Future of Business and Finance

Nikhil Vadgama
Jiahua Xu
Paolo Tasca *Editors*

Enabling the Internet of Value

How Blockchain Connects Global Businesses

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Future of Business and Finance

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Foreword

It is easy to imagine one of humankind's earliest transfers of value happening over a campfire on a grassy plain or within a cave offering protection from the elements. One human passing food or clothing to another in exchange for something in kind.

For most of humanity's existence, transactions and the sharing of value were like this: payment delivered at the point of exchange; even long-distance transfers of money often involved the actual unit of value with coins or money crossing bodies of water via ocean liners or miles of the Old West on the backs of ponies. There's a reason treasure hunters invest huge sums of money to explore ancient shipwrecks as gold coins still lay at the bottom of the sea where they sank in transit.

For centuries, goods, information, and stores of value all travelled in the physical realm, conveyed by people from one destination to another. The advent of the telegram broke that cycle with information able to travel far ahead of individuals. Today, information can bounce electronically around the world in seconds, free to access, and share with no restrictions.

Unfortunately, stores of value "even when represented as ones and zeros on an electronic ledger" are still subject to outmoded rules of transfer. Unable to move freely, traditional value must stop and start between countries and currencies. Like the hare in its race against the tortoise, speed remains unrealised, instead traveling in fits and starts on its way to its final destination.

This current day, yet thoroughly unmodern, the mismatch between the speed of transit for information, goods, and value persists because today's payment systems were built for yesterday's companies. Today's companies like Amazon, Airbnb, and Uber need to make instant payments to customers, contractors, and small businesses around the world.

On its face, this is impossible because of the patchwork quilt of payment systems that cover the globe, each with distinct rules, processes, and currencies. To compensate, companies and providers must build bridges across these systems manned by payment teams that can sometimes grow to hundreds of employees. And to improve the speed of transactions, each bridge requires pools of money on either end in the local country's currency to create liquidity.

The end result is an enormous investment of cost and effort that is impossible for small companies or providers to match. This leaves the reality of instant value transfer over the world's antiquated money networks the domain of only the largest and wealthiest organisations; today's equivalents of the Medici family or other well-known financial brokers of the past.

However, a new reality for value is growing that has the potential to penetrate these walls and deliver a system of value that once again matches the speed at which goods and information can flow.

Blockchain technology allows for trust-minimised systems without central operators, breaking the monopoly of those able to straddle disparate payment networks by virtue of their size and wealth. Paired with digital assets designed for cross-border transactions, blockchain-based systems can deliver instant transfers of value anywhere in the world.

But we are not there yet. There are still missing pieces to the puzzle. Just as you require a specific address to send physical mail, a phone number to call someone, or an email address to send an email, so we all need unique digital wallet identifiers to send point to point value.

And the networks themselves still cannot work seamlessly in conjunction. Payment systems "whether traditional or blockchain based" have dozens of different methods of integration. We are still missing the Rosetta Stone for value the piece that will make it possible to unify all of these different networks.

In short, we do not yet have our Internet of Value. But we know we need it. And that is progress.

David Schwartz

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About the Editors

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Introduction to the Internet of Value

The term “Internet of Value” (IoV) has had many meanings ascribed to it. Part “Introduction to the Internet of Value” seeks to define this term, examining previous definitions and elucidating on what properties an IoV may have and provide an introduction to why the IoV is necessary.

Why is it important to define the term IoV? The blockchain and distributed ledger technology world have suffered from a lack of coherence in the common language used to describe properties in the field. By striving to create a better taxonomy and ontology, it is easier for stakeholders to communicate with more precise meaning-hopefully enabling faster progress and development.

Chapter “Defining the Internet of Value”, written by Horst Treiblmaier, begins by examining the development and evolution of the Internet and the rise of blockchain. It then moves on to the various definitions of the IoV, noting that blockchain is the commonality between all of them. A definition of the IoV is suggested as the “instant transfer of assets that can be expressed in monetary terms over the Internet between peers without the need for intermediaries”. The attributes of an effective IoV are described along with the potential enablers of its development. Finally, the chapter concludes with a high-level examination of the economic impact that the successful enablement of the IoV could have.

This chapter was reviewed by Paolo Tasca and Nikhil Vadgama.

Chapter “Internet of Value: A Risky Necessity”, written by Paolo Tasca, presents megatrends underpinning the IOV and discusses why the IoV is a risky necessity. This is an adapted reprint of Tasca (2020) Internet of Value: A Risky Necessity. Frontiers in Blockchain 3:39. Copyright ©2020 Tasca.[1]

Defining the Internet of Value

Horst Treiblmaier

1 From the Internet of Information towards the Internet of Value

The internet was conceived as a technology to enable communication via computers in the case of a partial network disruption, as might occur during a military conflict. It soon turned out that packet switching networks, in which data are flexibly routed via intermediary nodes, have numerous advantages over circuit switching, in which a dedicated communication channel is established prior to the start of a communication. The Transmission Control Protocol/Internet Protocol (TCP/IP) emerged as a protocol suite that includes four distinct layers, namely link (sometimes split into physical and data link layers), network, transport and application. Those layers implement the functionality which is specified in the 7-layer Open Systems Interconnection (OSI) model and form the basis of the modern Internet.

The Hypertext Transfer Protocol (HTTP) is part of the application layer and provides the foundation for the World Wide Web (WWW). Over the years, it has been proven to be a robust protocol capable of handling data requests. One of its significant shortcomings, however, is the fact that it is stateless. This refers to the fact that HTTP servers by default do not keep session information; each message sent is understood in isolation. A stateful protocol, in comparison, sees a single data packet as part of an overall communication. Simply put, such a protocol can answer questions such as "who is who?", "who owns what?" and "who has the right to do what?" (Voshmgir 2019).

Interestingly, the specification of HTTP includes a status code (402: "Payment required") which is reserved for future use and indicates that the necessity of mone-

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tary transfers was recognised early by the protocol's developers. However, for many years no technology existed to implement such a functionality.

It did not take long before the potential of the Internet for doing business was discovered. With the emergence of electronic commerce, the shortcomings of a stateless protocol soon became even more apparent. Sessions ("server-side cookies") and cookies were used to keep track of ongoing and previous communications. In the case of sessions, data are stored on the server in an encrypted form and enable secure communication. Cookies on the client side are stored by the web browser which sends them back to the server, creating a memory of previous events. Sessions and cookies enabled the WWW to become "stateful". This offered new opportunities for businesses and customers but also led to the emergence of powerful intermediaries which monitor and direct communication, transactions and gather vast amounts of data. The WWW has also turned into a platform for social exchange. A handful of dominating platforms have emerged due to network effects, which postulate that the value of a network increases with the number of its users.

Consequently, Internet users turned from consumers into producers of information through posting content online and simply surfing the WWW, leaving numerous traces of online behaviour behind. In addition, sessions and cookies made it possible to transfer payments through dedicated organisations, which not only monitor and potentially also control transactions but also charge fees for their services. This led to a situation in which a few powerful intermediaries emerged that are in charge of value transfer over the Internet. These organisations include credit card companies, which successfully transferred their business models from the real world into cyberspace, and new market entrants who tailored their business models to the Internet's capabilities. However, the full potential of the Internet did not materialise. In spite of the fact that modern networks allow for almost instant data transmission, in 2017 a typical international payment in the United States took 3-5 days to settle, had an error rate of over 5% and an average cost of USD 42. On a global basis, cross-border payments amounted to USD 180 trillion yearly, with a combined cost of more than USD 1.7 trillion (Ripple 2017).

The Bitcoin protocol, which was introduced in 2008 and implemented in 2009 by the pseudonymous author Satoshi Nakamoto, cleverly combined numerous existing technologies and, for the first time, solved the problem of online "double spending". Bitcoin is a decentralised network that achieves consensus without a pre-specified governance structure (see Chapter "Consensus: Proof of Work, Proof of Stake and Structural Alternatives"). In other words, one specific Bitcoin (or an arbitrary part thereof) can be owned by only one particular address at any specific point in time. Being a decentralised platform does not mean that Bitcoin lacks any form of governance, but rather that it does not depend on particular authorities in a rigid hierarchy. Instead, a consensus is reached between stakeholders such as developers, miners (mining pools) and validating nodes, all of whom can individually decide to enter or leave the system.

At its core, the Bitcoin protocol enables the transfer of a cryptocurrency. The value of a bitcoin is determined by the supply and demand of its users and is not backed by any other asset. The maintenance of the system is done by miners, who are incentivised by gaining cryptocurrency for the provision of computing power. Unlike existing payment systems, no central authority exists that determines costs, monitors transactions or restricts access.

Since Bitcoin's inception, it has not taken long for the identification of numerous use cases beyond cryptocurrencies and for the technology to gain widespread popularity. Numerous so-called Altcoins have emerged, modifying the source code of Bitcoin and adding additional functionality. Everything that can be mapped onto a digital asset can be transferred via a blockchain-based solution. On top of the Bitcoin blockchain, so-called coloured coins were used to represent real-world assets, but the limitations of Bitcoin's scripting language soon triggered the quest for more robust solutions. Consequently, blockchain platforms such as Ethereum were developed with the goal of increased flexibility through the availability of a fully-fledged programming language. Increasing amounts of functionalities were integrated into so-called tokens that can be easily transferred on the network and represent an asset. The term "tokenisation" thus refers to the transformation of asset rights into digital tokens that can be easily traded on secondary markets. In the offline world, this corresponds to the well-established financial practice of securitisation, by which different types of contractual debt or illiquid assets, such as mortgage or auto loans, are bundled and sold to third-party investors.

2 A definition of the "Internet of Value"

No clear definition yet exists for the IoV. At its core, it means that the Internet, a collection of protocols to transfer information in the form of bits and bytes over different physical media, can be used to transmit assets that can be expressed in monetary terms.

In the context of blockchain, the term "Internet of Value" was mainly popularised by Ripple, a technology company developing the distributed system, the XRP Ledger (Peduzzi et al. 2021), for settlement, currency exchange and remittance. Table 1 lists several definitions of the IoV as found in company reports and academic papers. The core feature of all definitions is the capability of blockchain to facilitate the exchange of digitised assets among peers.

The meaning of the term "value" has been fiercely debated among philosophers since the days of the ancient Greeks. A common distinction is made between intrinsic and extrinsic value, with the former, especially in a business context, often seen as the value that can be determined through fundamental analysis without referring to the actual market value. This distinction on value is not crucial for moving towards a definition of the IoV; rather the crucial point is that blockchain is capable of creating digital twins, which are digital representations of objects from the physical world, including human beings but mostly intangibles such as processes or systems. These digital twins can be expressed in monetary terms such that a certain value is assigned to them.

Blockchain technology facilitates the transfer of these digital representations with the help of asymmetric cryptography. By generating a pair of keys, one of which is

Table 1 Definition of the "Internet of Value"

[The Internet of Value is] a kind of trusted protocol that could, amongst other things, provide a notarial function for all transactions carried out on the web, automated and transparent for all	Hasse et al. (2016)
With the Internet of Value, a value transaction such as a foreign currency payment can happen instantly .... The Internet of Value will enable the exchange of any asset that is of value to someone, including stocks, votes, frequent flyer points, securities, intellectual property, music, scientific discoveries and more	Ripple (2017)
The Internet of Value refers to an online space in which individuals can instantly transfer value between each other, negating the need for a middleman and eliminating all third-party costs	Finance Monthly (2018)
[Internet of Value is a] platform of the next-generation Internet that enables various types of assets to be digitised and represented as digital values, and directly and securely exchanged using Blockchain	Truong et al. (2018)

public and the other one private, users can create certificates to prove the ownership of a digital asset. They can easily transfer them to other addresses instantaneously. The moment the transaction is validated by the network and written into the blockchain, control over the asset has shifted to the new owner. This validation process was previously done by third-party institutions such as banks. Here, banks are an intermediary facilitating the transfer of value. Other examples for intermediaries include brokers, agents or merchants. It is therefore likely that the role of existing intermediaries will change and new intermediaries will emerge, who will take over tasks such as identity verification or the quality assurance of physical property.

Notwithstanding the importance of these tasks and others that might emerge with the more widespread use of the technology, intermediaries are not needed for the actual transfer of digital assets. In summary, the IoV can be defined as follows:

The instant transfer of assets that can be expressed in monetary terms over the Internet between peers without the need for intermediaries.

A somehow related term is the "Internet of Things" which describes how the Internet is used as a medium for data exchange for objects in the physical world. Smart objects are computing devices equipped with positioning and communication technologies that communicate with each other over the Internet without the need for any human interference. The Internet of Things, therefore, refers to the communication of objects, whereas the IoV focuses on the addition of blockchain technology to create a layer for value transfer. The latter can be seen as an enabler for the former by enabling the interoperability and exchange of monetary assets without human interaction. The IoV can also enable micropayments, namely the transfer of small amounts of money that are only feasible in systems with low transaction costs.

3 Core Elements of the IoV

One of the first attempts to specify what the IoV is stems from the W3C Web Payments Interest Group (2015). In their manifesto, they first state that many value networks exist and always will do so, and that there are many ways to connect them. Furthermore, they identify several key attributes of the IoV such as the free movement of information, openness and availability for everyone, the existence of trust and security, the simultaneous occurrence of privacy and transparency, the absence of a single point of control, the application of open standards, and a simple and extensible underlying infrastructure.

They also refer to five core principles for open standards, as suggested by OpenStand, a movement to embrace principles for a modern paradigm of standards. These standards are respectful cooperation between standards organisations, adherence to the fundamental parameters of standards development, the collective empowerment to strive to develop standards that are chosen and defined based on technical merit, the availability of standards specifications and, finally, voluntary adoption by the standards market (IEEE Standards 2014).

Tapscott and Tapscott (2016) explicitly mentioned that the IoV requires stewardship at three different levels. First, each platform needs to be able to govern itself. Second, standards need to be developed on an application level. Thirdly, on the ecosystem level networks and advocacy groups need to conduct research and spread knowledge. Table 2 briefly summarises and explains these attributes.

In addition to the attributes in Tables 2, 3 identifies several enablers of an IoV. The digitalisation of value, namely the estimation of an asset's market valuation, is a prerequisite to creating an economy in which assets can be represented by their digital counterparts such as tokens. In addition, fundamental changes are required within organisations, which pertains both to business processes as well as organisational structures. Existing management tasks, many of which are auditing and control functions, will potentially be replaced by automated procedures controlled by algorithms. Decentralised applications and decentralised autonomous organisations (DAOs) allow for an unmediated exchange between objects, people and machines. The latter is enabled by machine-to-machine (M2M) technology or communication. The IoV thus provides the payment layer for all ongoing initiatives in this area.

Importantly, markets need to transform their methods and accept the fact that value is transferred via entries in decentralised databases. This not only pertains to activities related to business-to-business (B2B) but might involve all kinds of activities in which governmental institutions or private persons (e.g. as consumers) are involved. Finally, new and flexible legislation is required, providing a framework adjusted to rapidly changing environmental conditions.

Herzog (2019) summarises the mission of the IoV as follows: "to allow billions of people around the world to access an electronic wallet so that they can reclaim their financial freedom and exchange values without intermediaries". Although this statement has a special focus on private individuals, it is important to highlight that businesses and public organisations can equally make use of a digitised exchange of value.

Table 2 Key attributes of the Internet of Value (Tapscott and Tapscott 2016; W3C Web Payments Interest Group 2015)

Attribute	Explanation
Value moves as freely as information	Blockchain/DLT adds a new layer to the Internet, which solves the double-spending problem. The transfer of information thus corresponds to the transfer of value
Openness and accessibility	Blockchain/DLT allow the circle of users to be specified. In public blockchains, nobody is arbitrarily denied access to the Internet of Value
Trust and security	Trust in intermediaries is substituted by trust in technology. This includes trust in the underlying infrastructure, the protocol and network governance
The simultaneity of privacy and transparency	Blockchain/DLT-based solutions allow various degrees of anonymity. Concurrently, they enable real-time access to shared data
Not controlled by a single entity	Decentralisation and distribution of power are core features of blockchain/DLT
Open standards	The Internet of Value is built on OpenStand's five principles of modern standards
Simplicity and extensibility	The goals include an abstraction of key areas of complexity and the creation of a framework that supports existing systems while allowing for smooth transitions
Self-governing platforms	Platforms need to be self-sustained by developing their ecosystems, standards and use cases
Application-level standards	Standards on the application level established by consortia facilitate technology development and deployment
Networks and advocacy groups at the ecosystem level	On an ecosystem level, support is required to promote the technology and create awareness

Table 3 Enablers of the Internet of Value

Enabler	Explanation
Digitalisation of value	Processes to assess the market value of an asset and put it into a digital format
Organisational change	Organisations need to adapt their processes and structures
Market transformation	Markets need to enable and accept the digital transfer of value
Legislation	Government and supranational institutions must provide the legislative framework

4 Economic Impact

The addition of a stateful layer on top of the existing Internet protocol that enables the transfer of assets has significant economic repercussions pertaining to both governance issues as well as the overall structure of networks. The removal of intermediaries, in combination with increased information transparency, leads to a mitigation of the principal-agent problem. This pertains to situations where agents, who possess all relevant information, act in their own best interests rather than for those of the principals. The IoV helps to reduce this specific problem by applying smart contracts as well as by giving principals advanced options to monitor transactions. Similarly, increased transaction speed, as well as automation, will help to decrease transaction costs, namely all expenses related to making economic trades such as costs for search and information, negotiation, control and adjustment. From an organisational perspective, the IoV can help to create new forms of competitive advantage. Nevertheless, it might also disrupt existing organisational structures by automating complicated processes that previously demanded verification and confirmation at different hierarchical levels (Treiblmaier 2018).

5 Conclusions

The considerable potential of the IoV outlined above does not imply that its further evolution is straightforward and easy to predict. Many unresolved issues remain, which include topics such as privacy, especially when sensitive personal data are involved. When it comes to security, Blockchain/DLT technology has specific advantages over centralised database technologies as it does not offer a central point of attack. However, this does not mean that attack vectors on different levels do not exist. Targets for attack could be users' wallets but also the network, mining pools or smart contracts. In addition, the technology is still under development and predictions are hard to make regarding the technology itself and also where potential attack strategies are heading to.

A big unknown is the future adoption, both from organisations and end-users. In this regard, the usability of applications will play a decisive role and support at different levels will be crucial to promote blockchain technology in many different applications. Finally, it remains to be seen how incumbent companies, especially those who mainly function as intermediaries in the value chain, will react to changes in market structures and the emergence of novel business models which capitalise on the easy transfer of value.

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Author Biography

Horst Treiblmaier is a Professor in International Management at Modul University Vienna, Austria. He received a Ph.D. from WU Vienna and worked as a visiting professor at Purdue University, University of California, Los Angeles, and the University of British Columbia. His research focuses on the implications of blockchain technology.

Internet of Value: A Risky Necessity

Paolo Tasca

It is indisputable that a fundamental change is underway in the global economy. As ever, there are observable markers of a deep, structural transformation taking place. And as with earlier transformations, the Internet lies at its core. On the one hand, it is clear that the trend towards "digital" transformation, facilitated by the rapid development of the distributed ledger technology, is impacting not only information goods but also physical goods. It is gathering pace across a wide range of industry sectors, from personal banking to hospitality and the apparel industry, to name a few.

However, this alone does not fully capture the scale of the underlying structural shift from an industrial society based on material things to an information society populated by digital things and digital citizens interconnected in a new world of Internet of Value (IoV), where value is exchanged as freely and easily as information (OpenMarkets 2015).

In this chapter, I argue that the blooming of the Internet of Value is a necessary journey that we need to take in order to accommodate the unfolding of four long-term mega socio-techno trends: *datafication*, *dematerialisation*, *platformisation*, and *social and resources value* awareness. Unfortunately, as pictured in Fig. 1, this journey will not be without obstacles. *Systemic risk*, *governance risk*, *privacy risk*, and *social welfare risk* are four major sources of risk that we must mitigate in order to build an open, accessible, and secure Internet of Value for an equitable global economy.

This is a reprint of Tasca (2020) Internet of Value: A Risky Necessity. Frontiers in Blockchain 3:39.

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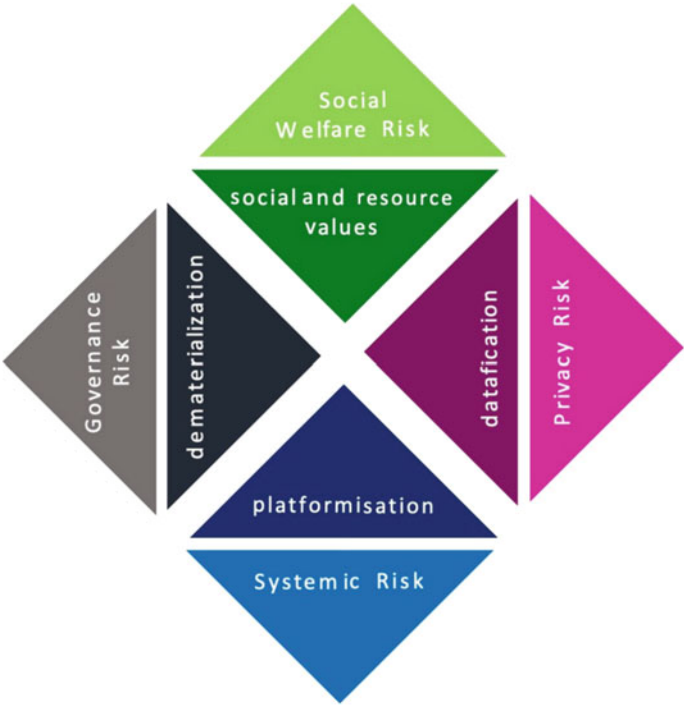

Fig. 1 Four megatrends underpinning the Internet of Value and four major sources of risk

1 The Internet of Value Driving Forces

I identify four key socio-techno trends underpinning the transition of our society to the Internet of Value. In this transition, the IoV emerges not as a goal but as a necessary infrastructure to enable these trends to unfold their potentialities fully.

The first trend is *datafication*.

Datafication is the transformation of social action into digitised information (Mayer-Schönberger and Cukier 2013).

In recent years, the amount of data available has increased at an unprecedented pace. In 2020, every person generated 1.7 MB in just a second, and Internet users as a whole generated about 2.5 EB of data each day (Po et al. 2020, 4–6). Regardless of whether we are aware of it or not, each of us every single day leaves our fingerprints in cyberspace. Every simple thing we do (from downloading a report, to ordering a pizza online, or to access the gym with our PIN) is potentially captured by someone and stored in servers somewhere in the cloud. This process of datafication is turning many aspects of our life into data, with value beyond their immediate utility. At one level, data that relate to our habits, routines, and other aspects of our lives have value in and of themselves by enabling consumers to interact with each other and the market in novel ways. According to World Economic Forum (WEF), we will produce more data in the next three years (2020–2022) than what we did in the last ten years (2010–2019) (Gast 2020).

Additionally, we are implanting Internet connectivity into our everyday environment—through smart devices we watch, wear, and interact with—as a way of generating ever-greater volumes of data for our consumption. This is the "Internet of Things" (or "IoT"), and it is estimated that by the end of 2020, the number of interconnected devices will exceed 50 billion; by 2022, 1 trillion networked sensors will be embedded in the world around us, with up to 45 trillion in 20 years.[1] An abundance of data enables new types of services to be tailored and delivered to consumers, whose needs, desires, and circumstances are—through the analysis of data—better understood than ever before.

Certainly, measuring the amount of data that we generate today and the number of interconnected devices is not an exact science.[2] However, what is important is the magnitude of this phenomenal trend that is turning many aspects of our lives into information as a new form of value. Through the process of datafication, information technology lets us measure, track, and exchange ever more types of value at ever-smaller increments. It is essential, therefore, to build an interconnected network of value exchange linking all of the things and all the individuals at the lowest possible transaction cost.

The second trend is *dematerialisation*.

When we talk about dematerialisation, we refer to the long-term process started a few decades ago of reduction in the material used in products. Dematerialisation is not only about digital goods but also physical goods. Physical goods have seen an increasing shift from tangible to intangible components. Soft things like intelligence are embedded in hard things, making physical goods increasingly behave more similarly to software.

Digital technology accelerates dematerialisation, boosting the migration from a production economy to an emerging service economy. As such, all spheres of the economy become redefined away from the conception of units of production—which underpinned our economic systems in past centuries—towards the more fluid concept of the exchange of value enabled by the IoV. A service economy is about value delivered. A service is an exchange of value—you do not get the product; you just get its function and the value that it delivers. As such, during this transition phase, the principle of "ownership of"—around which we built the capitalism markets—is put aside in favour of the more adequate principle of "access to." Indeed, ownership is casual, and a transaction occurs only once. Instead, a service economy is based on subscriptions to services characterised by an ongoing stream of data and transactions that are better supported if we get seamlessly ubiquitous access to the IoV.

The third trend is *platformisation*.

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[1] See, https://www.huffpost.com/entry/cisco-enterprises-are-leading-the-internetof-things_b_59a41fcee4b0a62d0987b0c6.

[2] See, for example, https://www.weforum.org/agenda/2019/04/how-much-data-isgenerated-each-day-cf4bddf29f/.

Platformisation is the establishment of digital platforms for various economic, governmental, and cultural activities (Poell et al. 2019, 1–2).

In recent years, we have witnessed the proliferation of technology-enabled platforms supported by computer and network-based information and communications technologies (ICT), which match both demand and supply of underutilised assets and allow everybody to be connected and disseminate/exchange information and value. Here, I refer to the third generation of platform business models: multisided marketplaces where a multitude of buyers and sellers meet and exchange any type of digital or digitised goods and value. Examples include data exchange platforms such as Dawex (dawex.com) and digital security marketplace such as Securitize (securitize.io). However, platformisation goes beyond digital goods and also includes idle physical goods, the utility of which can be exchanged among peers. Think about the emerging car-sharing platforms like Streetcar, ShareNow, and Zipcar or the platforms that allow households to let out their underutilised space like Airbnb and HomeAway.

This is a global marketplace of different types of interconnected platforms (platforms that depend on other platforms through mutually beneficial connections) that evolve in a Darwinian fashion by matching different needs and purposes. A growing component of our economy is occupied by platform business models that, for the amount of value generated, are gradually displacing linear business models.[3] In this "platformisation," consumers are closer to the producers, and in fact, consumers often act as producers or what the futurist Alvin Tafler called the "prosumers." Millions of consumers become prosumers. They exchange value in lateral networks at near-zero marginal costs. The difference between the linear business models and the platform is that the linear business models scale up by investing in internal resources and inventories. Instead, platform business models do not directly create and control inventory. They scale up by investing in their networks. The larger their network, the greater their value.

Platformisation fits well with the new consumers' habits of digital natives that are open to community sharing models from digital to physical goods. Thus, platformisation better interprets the needs of these people by creating a sort of "technological socialism," which elevates both the individual and the group at once.

The fourth trend is *social and resources value*.

Social and resources value quantifies the relative importance one places on the changes experienced in their lives, such as an increase in confidence or moving to a neighbourhood with a community park (Social Value UK 2020).

In the last centuries, capitalism has led to the erosion and loss of social and environmental capital in exchange for higher private profits. We have eroded the overall value of social and public goods (think about environmental pollution, for example) in favour of the value of private and personal goods. It is now recognised that this capitalist model is broken and that it cannot continue with the same principles as in the past. A growing number of people and companies are not willing anymore

[3] More than 60% of today's billion-dollar "unicorn" start-ups is composed of platform businesses (Cusumano et al. 2020).

to compromise social capital and natural resources for higher profits. This can be seen most clearly in the demand for assets tied in measurable ways to the quality of life. There is a growing awareness of their value, and people place a higher demand for quality of life, which of course engenders a broader spectrum of values beyond economic utility. Over the past decades, we have increasingly begun the process of tracking and accounting for different forms of value whether these are green bonds, social impact bonds, company loyalty schemes, carbon accounting (Richardson and Xu 2020), or a multiplicity of other forms. The IoV becomes, therefore, the infrastructure that allows us to smoothly exchange this growing number of different types of social and environmental values between companies and people.

We conclude by asserting that the IoV is the inevitable outcome of these four driving factors. At its core, the IoV is the information network that facilitates the transfer of value (often and increasingly) without the involvement or intermediation of a third party. It is exponentially characterised by hyperconnectivity. Almost by design, dematerialisation and platformisation require economic actors in ever more significant numbers to exchange data and value across networks. As in all markets, trust between participants is essential, and we would, therefore, expect that the IoV will emerge as interconnected networks of trust. Distributed Ledger Technologies (DLT) are a novel way of providing this trust, and other trust-providing technologies will likely emerge as the IoV takes shape in the next few years.

2 The Internet of Value Risks

The emergence of the IoV is not without risk. With the increasing economic importance and value of data come new trade-offs in respect of accountability, responsibility, ownership, privacy, and security. I identify four major sources of risks in the IoV-based economy.

The first risk is *systemic risk*.

Systemic risk refers to the risk of a failure of an entire system as opposed to the malfunction of individual parts (CFA Institute 2020).

Certainly, the systemic risk increases with the number of interdependencies between numerous and diverse networks of trust, which characterise the current globalised economy (Battiston et al. 2012). This is particularly true for financial networks where banks not only hold overlapping portfolios but also hold claims on each other's liabilities. In this setting, a bank's payoff not only depends on the bank's own financial condition but also on the financial conditions of the other banks to which it is interconnected. Thus, individual default risks are likely to be spread over the neighbours in the network (Tasca et al. 2017). For example, the UK interbank network was highly concentrated, exhibiting fat-tailed distributions of linkages and loan sizes at the time of the 2008–2009 global financial crisis (Saporta 2009). Consequently, the UK suffered a severe recession (Economic and Social Research Council 2015). Such network systems are characterised with tipping points, where shocks have a rippling effect, and a few failing nodes can cause the entire system to collapse (Gai and Kapadia 2019).

We do not have data to measure the systemic risk on the IoV because it is still in its infancy.[4] However, we can learn from other interconnected systems like the financial system, and we can derive some properties that can be used as a reference to measure the potential risks emerging in the IoV. History teaches us that increasing interconnection in complex financial systems is characterised by emergent properties that are not observable at the microlevel and higher fragility that can lead to cascading defaults and failures. Networks exhibit a trade-off between efficiency and robustness to attacks. The network topology, which is desirable for efficiency gains, does not generally match the one that is preferable in terms of robustness against attacks (Trajanovski et al. 2013).

Finally, when we talk about the IoV, we need to ask ourselves if the IoV would be considered a public good and if this public good would be managed by private entities that pursue private profits. In such a case, the IoV would be a private international network that would need—in case of disaster—to be backed by taxpayers because it would be too big to fail. Should we need to consider a public bailout of a privately managed system? These are the questions that we need to answer to properly design a stable, robust, and efficient IoV architecture. My recommendation is that the IoV architecture should wisely balance both the public and private interests.

The second risk is *governance risk*.

Governance risk is associated with accountability, responsibility, and ownership, which becomes critical for the viability and stability of the entire digital IoV ecosystem. Building a common understanding of rights and responsibilities, therefore, becomes essential.

Here, there exists a trade-off between private centralised governance models and public decentralised and anonymous governance models. Generally, private models are proposed by industry-grade network providers, while public governance models are familiar to open-source network systems. In the case of the IoV supported by distributed ledger technologies, private governance solutions are proposed by Hyperledger or the Ethereum Enterprise Alliance, to name a few.

Instead, decentralised public solutions are provided by Bitcoin, Tezos, and the like. Indeed, we observe that not only private governance models are centralised by design but also public models—that shall be decentralised—indeed tend to become centralised over time. For example, the top 5 mining ETH pools secure about 80% of the transactions in the ledger, 20% of ETH's core code was written by a single coder, 30% of Bitcoin's core code was written by a single coder, and 50% of all comments for Bitcoin Improvement Proposals (BIPs) come from the 0.3% of commenters. Given these dualities, we face a conundrum: either we let networks of trust be run by centralised but accountable trust providers or we keep direct "control" of our data

[4] For the Ethereum Enterprise Alliance, the criteria to join the BoD are not specified. You can join only classes B, C, and D. Class A is locked. In Hyperledger, the governing board adopts and maintains the rules. Members are chosen by Premier Members. This means that they must pay $250k/year plus the membership to the Linux Foundation, which costs either $500k/year or $100k/year.

via a synthetic-trust machine replication run by a small group of anonymous people who could easily go rogue (Tasca 2018).

When we talk about governance models of the IoV, we cannot avoid considering the risk arising from the lack of interoperability between different networks of trust that will need to exchange data and value between them. In particular, interoperability constitutes the point at which tensions emerge between three distinct intentions for blockchain technology as regulatory technology, business/economic infrastructure, and the model of social organisation. If "code is law," then the interoperability between blockchains is not a mere problem of standards; it is a problem of norms that should be addressed with reciprocal recognition between sovereign powers in their own space (Tasca and Piselli 2019).

The third risk is *social welfare risk*.

Social welfare risk concerns the decrease in the well-being of the entire society due to, e.g., growing inequality or inadequate supply of infrastructure vis-a-vis increasing demand.

While the promise of the IoV is transforming the global economic landscape by reducing search and transaction costs, which are particularly beneficial in emerging economies, how exactly those who are not fully connected to the Internet (still 3.37 billion as of 2020) would reap these benefits remains unclear. Therefore, to mitigate inequality and the social welfare risk, we need to expand the access to the Internet primarily in those areas where precisely the benefits of the IoV are expected to be most promising.

The fourth risk is *privacy risk*.

Private risk is associated with the uncontrolled disclosure of personal information (AICPA 2020).

This is the risk of being captured by the rhetoric of empowering people (advocacy and emancipation—see banking the unbanked) and the ability to trade seamlessly and be connected, where indeed the hidden intent is to feed capitalism with every aspect of every human experience (i.e., our data). This is the risk posed by the so-called surveillance capitalism (see Zuboff 2019). We cannot assume that the technology underpinning the IoV is isolated from the economy and society. Technology is always an expression of economic objectives that direct it into action.

We, therefore, propose a privacy-enabling electronic value exchange. There must be a plausible means by which an individual seeking to remit any digital/digitised assets or other value in the IoV can be assured, without the need for special technology, special dispensation, or third-party trust of any kind, that the metadata associated with the transaction, including time, location, counterparty, and other transaction details, would not be associated with any information that might be used to identify the individual. These privacy-enhancing technologies should be put in place to protect users from profiling and monitoring.

To conclude, I would say that it is romantic and simple to imagine a dystopian future and then ask the tech leaders to stop innovating and stop building the IoV architecture that will be necessary to shape our economy in the next decades.

It is, instead, much harder to promote those institutional and personal adjustments required in this complex and fast-changing world of liquid modernity where we find ourselves. I, therefore, invite all the operators and stakeholders who are building the new digital economy to work together to build an open, accessible, and secure IoV for an equitable global economy.

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How DLT Will Evolve in the Future

DLTs have changed in numerous ways since their inception in 2008. Few could have predicted the heights that Bitcoin has reached since then, followed by evolutions in the form of Ethereum, Hyperledger and Corda, to name but a few. What, then, can we expect from this technology in the coming years? Part "How DLT will evolve in the Future" focuses on how DLT may evolve in the future.

Chapter "Blockchains, DLTs and the Future of Payments" examines how DLT could transform payments and the benefits that could ensue. This is then followed by an examination of how DLT can facilitate machine-to-machine interactions and the transformative impacts of this. This chapter is written by Theodosis Mourouzis and Nikolas Markou.

Chapter "Consensus: Proof of Work, Proof of Stake and Structural Alternatives" examines the future of DLT from the perspective of the evolution of consensus mechanisms, discussing which new consensus mechanisms could replace proof of work. These include directed acyclic graphs, proof of stake and proof of burn. For those more mathematically inclined, this part also explores the dynamics of consensus mechanisms from a mathematical perspective. This chapter is written by Nicola Dimitri. This chapter was reviewed by Marcus Treacher.

Blockchains, DLTs and the Future of Payments

Theodosis Mourouzis and Nikolas Markou

1 DLT and Payments Transformation

Much of the hype around blockchain and Distributed Ledger Technology (DLT) has focused on its potential to change the financial services and banking industry fundamentally. Blockchain has promised to streamline financial transactions, reduce their cost and complexity, make the unbanked a viable new market and improve transparency and regulation.

Blockchain technology enables specific features such as

- Bi-directional messaging with settlement instructions in payment networks;
- Improved speed in payments, settlement in almost real-time and 100% digital;
- Transparency, end-to-end tracking of payments;
- Total cost and message details confirmed before initiation;
- Lower cost for cross-border transactions;
- Reduction in failed payments and costly interventions for error resolution;
- Full tracking of historical transactional data and lower probabilities of errors.

Figure 1 shows how cross-border payments operate today, highlighting the variety of issues that come to light based on the utilisation of a large number of siloed intermediaries.

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Fig. 1 Inefficiencies in today's international payments processes

Blockchain and DLT introduce a different logic for validation, settlement and record-keeping (Ibañez et al. 2021b). DLT offers the promising prospect of modernising payment services. This technological evolution has triggered changes in market demands, inviting financial services incumbents to innovate and enhance time and cost efficiencies. Many financial services and technology giants have already started collaborating to use blockchain to improve payments and the banking sector. Table 1 shows several blockchain projects from several different financial services entities.

The use of blockchain technology to resolve inefficiencies in payment and clearing and settlement methods (Karaindrou 2017) will give us a payment network fit for the modern era. The potential benefits of using DLT are as follows:

- **Lowering transaction costs**: currently, the average processing fee for a Bitcoin transaction is 0.04 cents (other blockchain networks have even lower fees than this) compared to more than 0.35 cents for a typical credit card transaction.
- **Replacing cumbersome back-office procedures with DLT**: in existing payment networks and infrastructure (regardless of whether the network is centralised or decentralised) recordkeeping is part of several bank–client relationships. Records are duplicated amongst multiple intermediaries, and are then reconciled through back-office procedures which introduce the risk of discrepancies or time lapses, leading to double-spending of the same asset. A DLT-based solution enables peer-to-peer sharing of data reconciled against a single version of the truth (Ibañez et al. 2021a).
- **Speed across the value chain**: reducing reconciliation procedures and enhancing data processing capabilities may lead to more transactions settling in real time.
- **Fraud detection capabilities**: deceiving payments or tampering with contracts is highly unlikely and too costly to garner profits. The existence of an immutable ledger makes the tracking of transactions in real time very efficient.
- **Automated contract tools**: DLT has the programmability to be coupled with self-executing applications via smart contract applications. Self-executing trans-

Table 1 Several blockchain and DLT initiatives from the financial services sector

Entity	Product type	Application
Mastercard	Blockchain-based API	Ability to send money over a blockchain and provenance of luxury goods
R3	Corda	Payments for instant transfers
Ripple	Native Blockchain	Exchange Network
SWIFT	As Proof of Concept	Reconcile their international accounts in real time, optimising their global liquidity
J. P. Morgan	Interbank Information Network	Blockchain payments network to respond to compliance and other payment delays
Libra Association	LibraCoin	P2P transfer of money using the underlying Libra coin
Bank of England	RS Coin	Bitcoin-like digital currency that works in a much more centralised way
IBM	IBM Blockchain World Wire	Clearance and settlement of cross-border payments
Mizuho Bank	J-Coin Pay	Digital currency platform acting as a bank

actions will minimise costs, maximise time efficiency and eliminate human error. Moreover, they will secure the enforceability of financial agreements stored on the ledger.

- **Better KYC and identity management**: cross-border transferable data about customers and real-time intelligence sharing eliminates the possibility of fraud.
- **Better identity management**: current identity management systems have many inherited privacy and security problems, especially for end-users. Blockchain and DLT may be the solution to these problems. Cryptography and other cryptographic primitives that preserve privacy, such as zero-knowledge proofs, bring the notion of self-sovereign identity (SSI). Entities that need to verify other users' information can do so without necessarily keeping track and storing their data.
- **Automated compliance and regulation**: automated compliance is beneficial for integration into organisations that process data such as banks and governments. Regulation can offer many benefits, which include lower time and cost requirements compared to manual controls. Compliance status and audit information can be accessed and checked within a single ledger, and in real time. Risk management decisions can be made based on real-time data. DLT can also reduce compliance fines, breaches and inaccurate reporting mistakes. Finally, DLT can, importantly, lead to continuously verifiable compliance requirements.

Major players in the payments, clearing services, settlement services and central banks are investing in DLT, envisaging high-tech, robust, secure, automatic, resilient and time-efficient payment systems. However, as the technology is still maturing, there are significant challenges for banks' global use of blockchain. These challenges are as follows:

- **Scalability**: blockchain has a global transaction limitation.
- **Privacy**: in the choice between public and shared ledger, privacy-preserving technologies such as ZK-SNARKs, MixNets and zero-knowledge proofs can be used to hide information regarding transactions, meaning possibilities for money laundering might arise.
- **Interoperability**: blockchain requires everyone to use a single ledger, and there is still no standard data schema or protocol for the many moving parts of a blockchain such as consensus and validation.
- **Regulation**: usage of digital assets for transaction purposes with an appropriate framework.

2 Towards Efficient and Automated M2M Transactions

The machine-to-machine (M2M) connections market is predicted to reach USD 27 billion by 2023, at a CAGR[1] of 4.6% from 2017 to 2023 (MarketsandMarkets™ 2017). According to the same report, "the number of M2M connections was 1.47 billion in 2016 and is estimated to reach 3 billion by 2023". The major drivers for growth are the massive adoption of the Internet in emerging economies, and the rapid developments in the Internet of Things (IoT) infrastructure.

The key concept behind IoT is a set of connected devices acting autonomously, communicating amongst themselves on a global scale and operating in an automated way, eliminating human intervention as much as possible. IoT is on a path to changing the way we live, and will have a significant impact on our daily activities. From homes that self-regulate temperature for our comfort to cities operating autonomously for efficiency and safety using smart technologies such as intelligent traffic lights and smart routing algorithms, the value of IoT appears to be endless. The future is here: many in-home devices are already connected to the Internet and help automate routine tasks.

However, there are still numerous challenges to be addressed before more extensive adoption can take place, such as interoperability issues, untrusted communication paths, data protection concerns and cybersecurity issues. A considerable problem is that of payment networks, as we would like to achieve complete automation and self-execution. This means that any monetary rewards or payments need to be in real time and not over two to three days (as is usually the case at the moment). Such

[1] CAGR—Compound Annual Growth Rate.

payments need to be of a minuscule cost, as they are going to be microtransactions for the majority of cases.

In 2017, according to analysts at Gartner, "there were an estimated 8.4 billion IoT devices. By 2020, that number could exceed 20 billion, and by 2030 there could be more than 500 billion". The impact of this revolution in connectivity extends far beyond just smartphones and private houses. IoT is about to be applied on a much larger industrial scale, to everything from fridges to farming to health care (Xu and Hoesch 2018), in a manner hardly imaginable.

IoT, in conjunction with blockchain technology, is expected to expand even further due to the capabilities of conducting automated and self-executing transactions. Smart contracts can encode conditions, agreements and constraints and automatically execute them when certain assumptions become valid.

Merging IoT and blockchain, we can create a secure, verifiable, transparent and immutable recording data method that "smart" machines could process in an automated, transparent and self-executing way. This network of interconnected devices will be able to interact with their environment and make decisions without any human intervention via the deployment of smart contracts.

Data-driven technologies such as machine learning (ML) and artificial intelligence (AI) can be deployed in parallel to create high accuracy predictions about conditions and constraints encoded into smart contracts. These technologies can also predict the "status" of the network and activities with very high accuracy. Predictive capabilities will enable the automation of procedures and proactiveness.

As a result of the exponential increase of IoT interconnected devices, M2M payment solutions are the next logical step (MarketsandMarkets™ 2017). When applied to M2M, AI and ML enable systems to communicate with each other and make their own autonomous choices (based either on hardcoded conditions or conditions predicted with very high accuracy by AI algorithms). Smart contracts will significantly reduce the costs of formalising, agreeing and enforcing contracts and making payments. Autonomous agents on the blockchain promise to eliminate agency and coordination costs and, perhaps, even lead to highly distributed enterprises with reduced or even no management.

Billions of IoT devices are connected worldwide, and it will not be long before almost all of our devices and technologies are connected through IoT protocols. M2M payments can include a multitude of scenarios, such as transactions based on customer behaviour without our knowledge, health and financial diagnostic tools and many others.

Blockchain is much more than a decentralised ledger, and can be considered a highly secure and trustworthy data bus. Participants in a blockchain network can trust the data transmitted through the blockchain, and transaction signing allows the source and integrity of the data to be verified. This means that we can be sure of where data comes from and that it has not been modified in transit. Blockchain and DLTs solve significant challenges in the data science life cycle, which include

- A lack of proper data governance;
- A lack of data definition and storage protocols: data are poorly defined, confusing the appropriate methodology for management. We thus miss many opportunities, as in many cases different data sources cannot be combined in a data analytics project;
- A lack of data security procedures resulting in corrupted or modified data;
- Too much data that is not useful stored in multiple sources under different schemata;
- Inconsistent data recorded using different procedures and protocols: inconsistency is a significant indicator that there is a data quality problem;
- Incorrect data recorded with no formal procedures;
- Poor data recovery capabilities.

As we know, no statistical argument can save lousy quality data, and blockchain is an intermediate step that guarantees the authenticity of data. This is known as GIGO (garbage-in, garbage-out) in computer science language. Blockchain enables us to solve all the above issues, as the data encoding, and data transfer protocols are hardcoded into the global public network. Data is written in the decentralised database after the approval of the whole network via hardcoded and transparent consensus algorithms. Thus, data quality is guaranteed, and hence the potential of AI and ML algorithms is much greater as the data is correct and trustworthy.

"Blockchain technologies, such as smart contracts, present a unique interface for M2M communication and provide a secure, append-only record that can be shared without trust and a central administrator" (Hanada et al. 2019). Smart contracts are considered to be a genuine game-changer for IoT applications.

Through encoded logic and constraints, it is possible to create agreements which will be executed when certain conditions and constraints are met. This is extremely useful for all kinds of scenarios, such as authorising payment when circumstances indicate that delivery of a service has been provided. Here, all interactions between a consumer and their connected devices (or indeed interconnected devices) are handled in a transparent, tamper-proof, immutable and frictionless way.

Furthermore, blockchain might come with a built-in cryptocurrency which can provide a method for participants to engage in economic transactions in an incentivised manner. Thus, the blockchain should provide the ideal backbone for connected IoT devices to securely exchange data and interact autonomously in an M2M economy.

For example, a smart contract can guarantee discounts on electricity bills or rewards via inbuilt tokens for a smart house appliance system that shows better performance in the consumption of underlying interconnected machines or the increased use of renewable energy. Below are a few examples of the applications of M2M connections by end-users (MarketsandMarkets™ 2017):

- **Health Care**: Many applications in this sector are expected to appear, such as patient monitoring systems, fall detectors, smart pill dispensers, telemedicine and many others. All of these devices will be interconnected and data will be streamed to doctors, enabling proactive measures as well. Blockchain can be used to ensure not only that data are released with the permission of the data owner, but also that the data quality (which is of great importance in this case) is guaranteed. M2M connections could potentially be utilised in hospitals to administer medications intravenously to patients whose vitals fall below a certain level.

- **Utilities**: Applications such as smart grids and smart meters. There are many blockchain applications; in this case, incentivisation can be built into the network so as to promote the use of more efficient machines, decreasing power consumption and increasing renewable energy use.
- **Automotive and Transportation**: Telematics, fleet tracking/monitoring, supply chain capabilities and sourcing capabilities.
- **Retail**: Intelligent vending machines, contactless checkout/PoS, digital signage and automated ordering. Better loyalty schemes can be built using blockchain technology, but the full tracking and sourcing of food life cycles will also be available and transparent. One of the most basic uses of M2M would be a vending machine which autonomously contacts its distribution company when its supplies have fallen below a certain point.
- **Consumer Electronics**: Smart TVs, smart appliances, smart refrigerators, smart washing machines, smart ovens and smart cooktops.
- **Security and Surveillance**: Commercial and residential security and remote surveillance with automated intelligence sharing.

Blockchain can significantly improve all the applications mentioned above, as its integration will guarantee transparency, self-execution and speed. It will provide a method for incentivising the desired actions into an ecosystem via tokenisation.

The widespread use of the Internet in the 1990s has changed the way we communicate forever. More than 30 years later, this technology, which initially seemed so foreign, has become an integral part of our daily lives. IoT, paired with blockchain technology, is laying the groundwork for the next step in the informational and technological evolution.

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Consensus: Proof of Work, Proof of Stake and Structural Alternatives

Nicola Dimitri

The blockchain version implemented by Bitcoin is based on a consensus mechanism called proof of work (PoW) (Narayanan et al. 2016; Antonopoulos 2017). That is, nodes wishing to confirm a block of transactions and receive the related reward must solve a cryptographic puzzle requiring computational power. Those trying to solve the problem, the so-called *miners*, compete with each other to *come first* in proposing the solution, and such competition has currently led to massive energy consumption by the Bitcoin community. The central intuition behind PoW is conceptually deep, though simple to understand. Nodes willing to compete to confirm blocks of transactions must spend resources to do so. In return, nodes have a strong incentive to keep the system evolving correctly, limiting malicious attacks on the system.

The incentive would be even stronger if the resources invested in *mining* were *sunk* costs, that is, expenditures entirely dedicated to that goal and with no utility for other goals. However, such meaningful expenditures are perceived by many as waste, as they support high energy consumption to solve puzzles with no immediate benefit for society as a whole.

However, because of these very high energy requests, as well as problems related to scalability and speed (Perez et al. 2020), concerns regarding the sustainability of blockchain models based on PoW have emerged in recent years. These have led to several alternative DLT models, differing in some elements from the blockchain frameworks inspired by Bitcoin.

To try solving or mitigating blockchain problems related to energy consumption, scalability, security and speed, an alternative class of DLT structures have emerged. One such structure is based on directed acyclic graphs (DAG). Latora et al. (2017)

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proposed DAG structures which appear in other contexts, such as citation networks (Goldberg et al. 2015) and are thought to represent a possible solution to blockchain-related problems. Unlike blockchains, with DAG, data are not stored in an ordered sequence of blocks, whereby each of them has limited capacity, but rather in a single block/ledger with no pre-specified capacity limit.

An interesting example of how data approval and storage work with DAG is the IOTA cryptocurrency. IOTA was founded in 2015, aiming to solve some of the problems that emerged with Bitcoin.

1 IOTA and Tangle

The first problem is related to energy consumption, which would be heavily reduced by eliminating the Bitcoin distinction between miners and users. Indeed, each node of IOTA's network *can be both a miner and a user*. There is virtually no energy expenditure for approving transactions in IOTA.

In IOTA, the sequence of blocks is replaced by the so-called Tangle (Popov 2018), which is the set of transactions executed in IOTA from the start. The term already conveys the idea that approved transactions are not organised in blocks. Indeed, the underlying structure of the Tangle is minimal and represents the underlying nature of the DAG in IOTA. This structure is given by a set of nodes and a set of directional links, each of them connecting one node to a pair of nodes.

Below, the interpretation of nodes and links in the *Tangle* is discussed. In the *Tangle*, each node in the network can be both a miner and a user. Consequently, unlike Bitcoin, no significant energy consumption is required to approve transactions. More specifically, transaction approval works as follows: except for the initial distribution of tokens, any new transaction wishing to join the Tangle, called a Tip, needs to approve a pair of transactions which already appear in the ledger.

Therefore, nodes in the *Tangle* represent transactions, whereas direct links connecting one node to two nodes represent approvals. However, when a *Tip* approves a transaction in the *Tangle*, it does not establish its definite validity. Together with other received approvals, it contributes to the validity of that transaction. Approving a transaction can be seen as analogous to voting for that transaction: the larger the number of obtained approvals, the more probable it is for a transaction to be valid and a definite part of the ledger.

As in Bitcoin, transactions have timestamps which describe the temporal evolution of the system. In the *Tangle*, however, a transaction timestamp is essential to understand the time evolution of the system (perhaps more than for Bitcoin), which is not organised in blocks.

The above description immediately clarifies why the *Tangle* has a minimal structure. Moreover, transaction approval does not require costly competition across miners. This makes IOTA suitable for small currency exchanges which, in Bitcoin, would offer low or no transaction fees for confirmation, which may delay or even prevent its insertion in a block.

As with other consensus mechanisms, the *Tangle* is not free from malfunctioning or malicious attacks. An example of a malfunction is when a *Tip* (a transaction in the *Tangle* that has not received approval yet) can remain without approval for a long period (even when a Tip contains no double-spending). A double-spending attack is also possible. This occurs when a transaction which contains IOTA units already spent in other transactions is approved. Strategically, this occurs through several small monetary transactions being performed deliberately by the attacker. These small transactions are valid and can correctly provide a sufficiently large number of acceptable approvals to an invalid transaction.

The above two examples illustrate that while DAG distributed ledgers such as IOTA can solve some of the problems related to blockchain systems inspired by Bitcoin, they are still prone to structural problems and malicious attacks.

2 Proof of Stake

A variety of consensus procedures have been proposed (Wang et al. 2019) to save on energy spending and speed up transactions in comparison to Bitcoin (Platt et al. 2021). This section discusses some of these alternatives to Proof of Work. The analysis of consensus procedures is essential because of the possible consequences for the correct functioning of systems, both in short and long periods.

Currently, the main alternative to PoW is proof of stake (PoS). In Bitcoin, blocks enclose confirmed transactions. The original idea (Bentov et al. 2014; Narayanan et al. 2016) underlying PoS was the following: a user is randomly selected by the system, with a probability that is proportional to his wallet *coinage*, to confirm the next block. The *coinage* of a currency unit is given by the number of blocks for which the unit has been unspent. The *coinage* of a wallet is given by the sum of the *coinage* of each unit in the wallet. For example, take a user who owns two currency units in his wallet. One has not been spent for three blocks and the other for four blocks. In this case, the wallet *coinage* is equal to seven. Once a unit is spent and transferred to another wallet, its *coinage* becomes zero, until it remains unspent in the new wallet for some blocks again.

PoS (BitFury Group 2015) was proposed initially in 2012 by the *Peercoin* cryptocurrency (Bentov et al. 2014) in a *hybrid* version where PoW was also present. Here, mining of a block was still based on solving a cryptographic puzzle by means of PoW; however, the difficulty was inversely proportional to the user's wallet *coinage*. Therefore, in this mixed PoW-PoS framework, a lack of computational power could be replaced by a high value of coinage, potentially saving energy consumption. Such a system can provide an incentive to spend currency units with a lower coinage first, and then those with a higher coinage. However, this behaviour may lead to infrequent transactions within the community, where individuals might be more interested in storing money (to increase the probability of getting additional units in the future) than exchanging it. Consequently, the blockchain system could end up becoming like a lottery, with currency units playing the role of lottery tickets.

More recently, further PoS versions have been proposed (Kiayias et al. 2017). *Coinage* has been eliminated in the PoS version adopted by *Blackcoin* (Vasin and Co 2014). Emerging platforms such as Algorand (Chen and Micali 2019), as well as more established platforms like Ethereum (Buterin and Griffith 2017), are thinking of using PoS as part of their consensus procedures.

Interestingly, the PoS version adopted by Algorand is reminiscent of the rotation criteria adopted in the Medieval Communal age. Here, political and administrative officials were periodically changed to prevent the emergence of dominant and autocratic positions. As we shall see, in Algorand rotation applies to proposers of blocks.

In Algorand, PoS operates by randomly selecting users to play a particular role. For example, users could be selected to propose a new block of transactions. Alternatively, they could be selected to be part of a committee which votes on some specific issue. This is PoS because users are randomly drawn with a probability that is positively related to the number of currency units they own. More specifically, if A is the total number of currency units in the system, called *Algo* in Algorand, and a is the number of units owned by a user, then $p = \frac{a}{A}$ is the probability that such a user would be selected to take a given role.

Those individuals with a higher stake are more likely to be selected and re-selected. Therefore, to prevent frequent re-selection as well as malicious activity against committee members, once a user has been chosen, he cannot be re-selected for the next few rounds. To discourage opportunistic behaviour and attacks against committee members, each member only knows whether or not they have been selected. This is possible through verifiable random functions (Micali et al. 1999).

The replacement of PoW with a consensus procedure based on PoS has been discussed within the Ethereum community since the start of the platform. The new consensus mechanism is called Casper and, like Algorand, it is based on the assumption that two-thirds of the users behave honestly. This assumption means that, if less than a third of users engage in adversarial behaviour, the system can keep functioning correctly. This is the byzantine fault tolerance threshold of the system.

Ethereum's proposed PoS also contains a feature on how to solve the *nothing at stake* issue, which may lead to malicious attacks. This issue could occur under PoS because, unlike under PoW, obtaining currency units is not expensive, and their duplication is costless. For this reason, the main elements of Casper (the final version of which is not complete) have been designed as follows. As in Bitcoin and Algorand, validated transactions are stored in a blockchain. However, unlike these platforms, to speed up and scale block validation, this is not performed block by block but periodically after a predefined number of blocks. Validation takes place at blocks called *checkpoints*. Any user with even a minimal amount of currency units can be a validator.

Validators can obtain some currency units if the block they propose is approved. However, to prevent the *nothing at stake* problem, a validator has to deposit a certain sum of currency units, which represents their *stake* in the system. PoS comes into play here. A validator can then cast a vote on which blocks to approve with their stake, over the total number of deposited units in the community. If the proposed block violates two specific Casper rules (inserted to avoid forks in the chain and double-spending), then the user's *stake* will be *slashed* and lost immediately upon detection of the attack.

Therefore, the deposit corresponds to the penalty imposed on attackers for adversarial behaviour. It is interesting to note that, when choosing the size of the deposit, a potential attacker faces a trade-off: the larger the stake, the higher the probability of approving a specific block (which contains a double-spending transaction), but the larger the penalty in the event their dishonest behaviour is discovered. Therefore, slashing deposits with Casper can effectively deter attacks to the Ethereum blockchain if attackers are detected in time.

The adoption of PoS drastically reduces electricity consumption when compared with PoW. However, consensus and monitoring procedures have to be effective in preventing more than one-third of the users from being able to attack the system.

Let us consider a simple numerical example to understand how Casper works. Suppose a user owns 100 *Ether* (the Ethereum currency). Moreover, assume they decide to build a deposit with $0 \leq d \leq 100$ of them. These d Ether are the user's *stake*. Furthermore, assume the whole community deposited a total of 1,000 Ether. When determining how large d should be, the user can think in terms of the following trade-off. Suppose they propose a block that contains a double-spending transaction and whose value corresponds to x Ether. Now suppose p is the probability of the block being detected once approved, and r is the reward obtained in case of a block approval. Furthermore, assume that D is the size of the deposit of the users who are expected to vote for that particular block. With these assumptions, the user's utility $U_a(d)$, in the event they attack, will be a random variable defined by

$$U_a(d) = \begin{cases} 100 + (x + r) & \text{with probability } (1 - p)\frac{(d+D)}{1000} \\ 100 & \text{with probability } 1 - \frac{(d+D)}{1000} \\ 100 - d & \text{with probability } p\frac{(d+D)}{1000} \end{cases}$$

and his expected utility will be defined by

$$EU_a(d) = 100 + \frac{(x + r)(1 - p)(d + D)}{1000} + \frac{(100 - d)p(d + D)}{1000} \tag{1}$$

Differentiating Eq. 1 with respect to d and equalising to zero provides the optimal value of the deposit d_a maximising Eq. 1, as defined by

$$\max\left(0, \min\left(d_a = \frac{(x + r)(1 - p)}{2p} - \frac{D}{2} + 50, 100\right)\right) \tag{2}$$

Interestingly, the value of Eq. 2 increases with x and decreases with D and p. Therefore, the value of d given by Eq. 2 is larger than 50, half of the available currency units, if

$$\frac{(x + r)}{D} > \frac{p}{(1 - p)} \tag{3}$$

that is if the ratio $\frac{(x+r)}{D}$ is larger than the odds ratio $\frac{p}{(1-p)}$. It is also interesting to observe that expression Eq. 1 clearly shows the trade-off faced by a user when choosing the deposit size. Indeed, the term $\frac{(100-d)p(d+D)}{1000}$ on the right-hand side of Eq. 1, being quadratic and concave in d, first increases and then decreases. Intuitively, this means that the utility maximising deposit typically should be neither too small nor too large.

If, instead, the user behaves honestly then his utility $U_h(d)$ will be equal to

$$U_h(d) = \begin{cases} 100 + r & \text{with probability } \frac{(d+D)}{1000} \\ 100 & \text{with probability } 1 - \frac{(d+D)}{1000} \end{cases}$$

and his expected utility will be

$$EU_h(d) = 100 + \frac{r(d + D)}{1000} \tag{4}$$

It follows that, as Eq. 4 is linear in d, it is maximised by $d_h = 100$, i.e. the entire available sum, hence the maximum size of the deposit. This observation is consistent with our intuition. Indeed, if the user is planning not to attack, then by depositing his entire available sum, he will maximise the probability of being selected to confirm the next block while running no risk of losses.

A user will consider attacking the system if, when replacing Eq. 2 and $d = 100$, respectively, in Eqs. 1 and 4 the former is larger than the latter. Note that if $d = 100$, then expression Eq. 1 becomes

$$EU_a(d = 100) = 100 + \frac{(x + r)(1 - p)(100 + D)}{1000}$$

which can be larger than Eq. 4 if $\frac{x}{r} > \frac{p}{1-p}$.

3 Proof of Burn

Proof of burn (PoB) is also another consensus protocol worth discussing. PoB is currently adopted by cryptocurrencies with limited capitalisation. The first and best known of these is Slimcoin (2014). The goal of PoB is analogous to PoS, to propose a consensus procedure solving the energy costs associated with PoW while simultaneously reducing the possibility of attacks. Like PoS, PoB is a consensus mechanism based on currency units held by users. However, unlike PoS, validation of a block and related reward are based on a *burnt* number of currency units by a user b. Operationally, burning some units means sending them to an address which nobody can use. Continuing with the previous example, if a user has 100 units in his wallet, then before validating the next block his utility level is a random variable defined by

$$U(b) = \begin{cases} 100 + r - b & \text{with probability } \frac{b}{1000} \\ 100 & \text{with probability } 1 - \frac{b}{1000} \end{cases}$$

and therefore

$$EU(b) = 100 + \frac{(r-b)b}{1000} \tag{5}$$

so that the optimal b_o is given by

$$b_o = \frac{r}{2} \tag{6}$$

That is, the optimal number of currency units to burn is half of the reward obtained by the user, in the event they are selected to validate the next block. Inserting Eq. 6 into Eq. 5, the expected utility becomes

$$EU\ (b_o) = 100 + \frac{r^2}{4000}$$

which implies that with PoB, the user's expected utility is larger than 100 and grows quadratically with the reward for block validation. If the above analysis is an acceptable description of what might happen with PoB, and if r is a relatively small reward, then b_o is also a small sum.

DLT is an area which is still rapidly evolving (see Chapter "Blockchains, DLTs and the Future of Payments"). The aforementioned discusses how DLT may develop from the perspective of consensus mechanisms, starting from Bitcoin's PoW and moving on to DAGs, PoS and PoB. By the time this section becomes available, it may already be partially obsolete. Nevertheless, it can hopefully still help readers navigate the fascinating area of DLT.

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Author Biography

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The Internet of Value and Financial Services

Many would agree that blockchain's biggest success to date is still its genesis creation. Bitcoin quietly made its mark in its early years with a cult following before becoming a phenomenon, and reaching prices near USD 20,000 at the end of 2017 and with a market capitalisation of over USD 300 billion, approximately the same as the GDP of Finland or the market capitalisation of JPMorgan (in 2020). Being able to replicate a decentralised payments network without any central authority is a feat few could have imagined this new technology achieving. Who would have ever thought as well that the price of Bitcoin would surpass USD 50,000 and achieve a market capitalisation of over USD 1 trillion in 2021?

However, many of the promises of Bitcoin as a payments network that could fuel the IoV have not been realised. Bitcoin, as the first iteration of blockchain networks, has its flaws. New technologies that are being created are thus seeking to build upon its foundations and create the economic value transfer layer for the Internet. In 2020 and 2021, we also see a new wave of innovation with DLT and financial services, in the form of the decentralised finance or DeFi movement.

In Part "The Internet of Value and Financial Services", how the IoV can impact the financial sector broadly, beyond payments, is explored, and on the lending and real estate sectors.

In Chapter "The New Internet of Value Financial Ecosystem", Hermann Elendner examines the new business models that have emerged from within the financial services sector due to the development of the IoV, concentrating on decentralised consensus. Elender breaks this down by examining new business models that will develop through a decentralised consensus-based on state, procedure, and agency. Mike Brookbanks reviewed this chapter.

In Chapter "From Banks to DeFi: The Evolution of the Lending Market", Jiahua Xu and Nikhil Vadgama explore the DeFi arena from the perspective of the lending markets. They discuss the importance of lending to our financial system, problems with our existing lending and borrowing markets and the emergence of new DeFi lending initiatives. They finish with a discussion on the future evolution of this sector. Matthias Bauer-Langgartner reviewed this chapter.

Finally, in Chapter "Real Estate and the Internet of Value", Alastair Moore, Niall Roche and Nikhil Vadgama look at the largest asset class in the world, real estate. They discuss how this often-overlooked sector is ripe for disruption with DLT and talk about general applications and advantages of adopting new technologies in the sector. They also describe a proof-of-concept undertaken by them and the United Kingdom Land Registry for a property transaction occurring on a DLT system. They end the chapter with a discussion on challenges for DLT adoption in the industry. Mark Venn reviewed this chapter.

The New Internet of Value Financial Ecosystem

Hermann Elendner

The IoV has extended digitisation from the realms of information and communication to now also encompass digital scarcity. This has allowed for the virtual representation of economic wealth and its easy and efficient transfer. Consequently, economic institutions and activities have rapidly shifted to near-instantaneous computer networks. The first functions to develop in the IoV, with blockchain technology, were payments and investments in the form of cryptocurrencies. Business cases quickly proceeded to securitise illiquid assets or usage rights, from file storage to real estate.

The IoV's close-to-frictionless mode of operation is proving superior to traditional marketplaces in terms of transaction costs, operating hours and ease of access. This has also led to a wave of disintermediation in the realms of innovation financing and private equity: startups are increasingly tokenising their products as a means to both raise funds and to target and influence their customer markets. Recently, the developments have bifurcated into, on the one hand, centralised service providers catering to blockchain ecosystems and, on the other, a strong push to build as much financial infrastructure as possible in a fully decentralised manner, true to the fundamental blockchain ideal, under the label of Decentralised Finance (DeFi).

1 A Tokenised World

"The tokenisation of everything" has become the central theme of a move to represent all "offline assets" by digital tokens that are transferable quickly and at low cost. Just as the Internet increased communication efficiency in existing enterprises, it also

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paved the way for numerous novel business models. DLT has also introduced transformational new business models: peer-to-peer structures with democratising effects that are uprooting monopolies or strong oligopolies from money (seigniorage) to investment, from trading to fundraising, and from logistics to supply-chain management. The IoV is also giving rise to entirely new forms of economic organisation, in particular Decentralised Autonomous Organisations (DAOs; Buterin 2014), which arise from new possibilities for governance combined with high-level automation. The common share traded publicly on a traditional stock exchange is being eclipsed as a means to structure both cash flows and control rights (Jensen 1989). Finally, even decisions that still need to be made by humans are indirectly affected by DLT mechanisms. Determining who is to be granted agency for each decision situation and to what degree, or optimising governance by mutually interdependent human–machine configurations, has become the most recent highly active field of research and development.

The new IoV business models in finance can thus be categorised into three successive generations of digitisation, based on the consensus provided by DLT. The first generation, classical blockchain and thus most cryptocurrencies, established a *decentralised consensus about state*. Most prominently, Bitcoin ensures a shared "truth" about how many coins are held by each address. The second generation introduced smart contracts and DAOs through *consensus about procedure*. Effectively, this began with Ethereum endowing all nodes with a common Turing-complete programming language. This generation allows smart contracts to be combined to create entire virtual organisations devoid of humans. Limitations of foresight that materialised in this generation ("The DAO") spurred the third generation, engineering a decentralised *consensus on agency*. Within this third generation, the governance structure is optimised to combine decisions made by computers, humans and by committees of any combination there of to run an organisation.

Importantly, the success of DLT has spurred a wave of re-thinking financial business models in general: prior to this, many had not yet fully taken advantage of digitisation per se. Clearly, efficiency gains should be exploited, and frequently serious innovative pressures have arisen from the disruption of the financial industry's status quo by digitisation alone. However, the fundamental innovation with the IoV has been *decentralisation* as introduced by the blockchain, now more generally by DLT (due to later non-blockchain-based protocols). In the next sections, new DLT-based business models in the financial-services world are discussed, broken down into the categories: decentralised consensus based on state, procedure and agency.

2 Decentralised Consensus Based on State

The first DLT was Bitcoin, proposed by Nakamoto (2008). Although at an immediate level Bitcoin represented the first cryptocurrency, the more abstract perspective is that it introduced a protocol aligning mathematical problems with economic incentives in a manner that ensured (provided the majority of participants remained honest)[1] eventual consensus regarding the "ownership"[2] of every token it generated. In short, the blockchain achieves two things simultaneously: first, it generates purely virtual units of economic value by achieving social scalability (Szabo 2017); second, it ensures agreement regarding the ownership of each unit (in terms of pseudonymous addresses).

At its core, the blockchain provides the functionality of a large lookup table which represents every token and who is entitled to send it[3] via their electronic signature. The key innovation was not the efficient data structure or low redundancy; rather, it was to get all participants to agree on the same attributions (despite wanting more tokens themselves). Furthermore, the key was to maintain this consistency across time despite frequent re-assignments (transfers), the non-synchronicity of computer networks, and prevalent desires to censor, duplicate or otherwise manipulate transactions.

2.1 Virtual Digital Tokens

Although it appears more demanding to build a technical system which not only achieves consensus about allocation changes but also generates purely virtual tokens with economic value, the opposite is in fact true. By relying only on self-generated virtual tokens, DLT avoids the problem of bridging the real/virtual divide. A purely virtual system can content itself with consistency and does not need to address truth. Once the blockchain achieves consensus about who is entitled to control a coin, this is sufficient to effectively establish ownership in the practical sense. A token that should represent some state in the physical world is encumbered by the additional problem that what the computer network may agree to could well fail to agree with reality.

It transpired that attributing value to virtual tokens was easier to achieve than attributing accurate virtual representations to real-world phenomena. Scarcity of virtual tokens is a necessary condition; in combination with an efficient method of

[1] For a discussion regarding whether the majority is required to be honest and altruistic, rationally selfish, or act in a Byzantine manner, see Ford and Böhme (2019).

[2] Ownership is under quotation marks as the technical system ensures no legal position but rather the technical possibility to "spend" the received balance, i.e. the exclusive capability to send received amounts to following beneficiaries.

[3] This analogy is not precise from a technical perspective, as bitcoins are highly divisible into 10^8 subunits named satoshis, and the Bitcoin protocol does not store a reference from satoshis to their owner (with the exception of block rewards) but rather a concatenation of transactions, so that "ownership" of an amount means control over a yet-unspent transaction amount; however, this setup achieves functionally the effect of an up-to-date lookup table, and many other cryptocurrencies actually implement data structures corresponding fairly closely to such a table.

transaction[4] and an initialisation scheme successful to onboard enough users,[5] it becomes sufficient.

2.1.1 Cryptocurrencies

The first blockchain business model was a payment system encompassing a monetary system with private seignoriage: Bitcoin, with its associated mining, quickly became a professional and competitive business with block rewards as a revenue source. As most cryptocurrencies are still based on PoW, and most other coins (e.g. PoS blockchains or DAGs) also provide incentives for verifiers, the business extends to the majority of coins.

Despite the ongoing debate regarding whether cryptocurrencies are money (Yermack 2015), innovations in DLT to establish payment systems are a strong business case. This includes the multitude of payment solutions working to bridge the cryptocurrency/fiat currency divide.

Due to the quick multiplication of coins available, another financial business case evolved from the early days of blockchain, involving crypto exchanges and marketplaces for trading cryptocurrencies against each other or against fiat money.

The large volatility of most cryptocurrencies' prices has led to a demand for so-called stablecoins, a young business case to provide low-volatility tokens, useful as units of account. However, as yet, no agreement exists about what exactly to stabilise, or how.

Strong activity in crypto exchanges led to what came about as auxiliary services and quickly developed into new business models: borrowing and lending (see Chapter "From Banks to DeFi: The Evolution of the Lending Market"), as well as margin trading.

In parallel, due to the large and growing numbers of crypto tokens and their return characteristics (Elendner et al. 2018), strong growth is expected to continue for business models of crypto-asset management, portfolio management including traditional and crypto assets, and other investment-management activities.

Particularly noteworthy is the strong emphasis on data-driven approaches: advanced analytics, in particular approaches based on artificial intelligence or machine learning, as well as on sentiment analysis (and thus frequently natural-language processing) play an important role in portfolio management with crypto assets.

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[4] Blockchain-based cryptocurrencies are efficient for transactions in certain circumstances (e.g. sending large values across continents and state and legal boundaries within minutes to a little-known recipient) and not so efficient in other circumstances (e.g. as fast as possible transfers and large numbers of transactions per second). The point for the argument here is that some useful use cases exist, so that the DLT generates some value as a transaction system.

[5] Various schemes (co-)exist, with time trends in their prevalence. After the initial approach of no initial balances with decentralised mining, airdrops, proofs of burn, the distribution of pre-mined coins, ICOs, and forks have also been successfully employed at various times.

2.1.2 Utility Tokens

In contrast with cryptocurrencies, characterised as virtual tokens without intrinsic functions other than transferability, utility tokens encode a claim to a service.

The increasing issuance of utility tokens has coincided with the growth of blockchain-based business models aiming to generate demand for the tokens. Commonly, they are sold early in a project's life cycle as a means of raising financing, possibly but not necessarily in an ICO. A classic example is filecoin (*filecoin.io*), a token to pay for storage on the InterPlanetary File System (IPFS), a blockchain-based network saving data in a distributed file system. While filecoins will trade on exchanges just like cryptocurrencies, the token is not meant to function as money or investment (although it may appreciate or depreciate); rather, it is designed to resemble a voucher for services provided.

This is the critical aspect of utility tokens: they are the major fully decentralised method of providing resources for decentralised applications (DApps).

An important aspect of utility tokens is that, as far as US regulation is concerned, a strong utility aspect should not render the token a security under the Howey test—and thus wide-ranging securities regulation is not applicable.

2.1.3 Security Tokens

The third class of static crypto tokens is security tokens. As the name suggests, they resemble shares in a joint-stock company. As the regulatory uncertainty regarding their status has by now been resolved in most developed jurisdictions, security tokens are now controlled under securities law. This means that a serious degree of effort and cost is required to issue them in a legally compliant way and, as such, their popularity has decreased significantly.

The one remaining business case where security tokens have been used is for fundraising if a utility token is deemed inappropriate or insufficient and the expected proceeds are sufficiently high to warrant the lengthy and expensive process, which may still be much cheaper than an IPO. An advantage of this is the possibility of structuring cash-flow rights in any manner. However, for complex structures where it is not only cash-flow or static voting rights that should be settled, governance tokens provide possibilities exceeding those of securities in financial markets.

2.2 Digital Representations of Offline Assets

As detailed earlier, "putting offline assets on the blockchain" creates a tension. On the one hand, representing offline assets on a blockchain requires a bridge of over the real/digital divide, which is difficult without a trusted third party. On the other hand, registries are an ideal use case for DLT due to their immutability.

2.2.1 Tokenisation with a Legal Basis

If an anchor outside the blockchain is embraced, the tokenisation is supported by a legal or contractual basis. A prime example is a land registry[6] introducing

[6] An example of a startup aiming to put real estate on a blockchain is *brickblock.io*.

near-instantaneous, counterparty-risk-free, notary-free and cheap transactions. Other property registers work in the same way. Prominent business cases include trading and settling traditional financial assets on DLT, as well as supply-chain management. A decentralised system can work in industry settings, where legal or competitive reasons prevent one player's control over the supply chain.

2.2.2 Tokenisation Based on Incentive Structures

The alternative to authority outside the DLT lies in incentive structures that ensure desired behaviour. Examples include identity and reputation systems, where participants cross-check each other, or verification systems, where they establish validity or attention tokens. As most of these use cases are non-financial, they fall outside the present focus.

3 Decentralised Consensus Based on Procedure

Although first-generation blockchains effectively provided a shared ledger of key/value pairs, a natural next step was to extend the consensus to include procedural stipulations. Ethereum (Buterin 2014) was the first to offer, with its Solidity, a Turing-complete programming language for code, which will be executed by all the nodes in the network on the Ethereum Virtual Machine (EVM). Effectively, this provides a method to write programs which then run on other people's computers without leaving to their discretion the integrity of execution. The distributed nature of the network ensures multiple independent verifications of the calculation, and the consensus algorithm ensures no single entity controls what is considered the output of the execution. Consensus based on procedure ultimately introduces "an un-ownable computer", programmable and usable by anyone. Many business models have sprung from this, most fundamentally in competition as an alternative DLT solution, but far more commonly in developing smart contracts and decentralised applications running on a major established platform such as Ethereum, Hyperledger, NEO or NEM.

3.1 Smart Contracts

Although the idea of smart contracts (Szabo 1997) pre-dates the blockchain by at least a decade,[7] Ethereum kickstarted the spread of smart contracts.

In a sense, "smart contract" is a misnomer, as arguably they are neither smart nor contracts. They do not constitute a contract in the legal sense, and they cannot react sensibly to unforeseen circumstances—in other words, they are just as smart as any computer program, or rather its programmers. The key distinction is that the

[7] Also, Bitcoin provides a Turing-incomplete script language enabling some smart contracts, for instance, multisignature accounts. See also *counterparty.io*, implementing a smart-contract protocol for Bitcoin.

code's execution is delegated to the blockchain, and therefore independent of any single entity. In this manner, smart contracts can incorporate information or actions available only in the future while remaining censorship-resistant and manipulation-proof.

The Ethereum whitepaper (Buterin 2014) classifies smart contracts into three categories: financial applications, semi-financial applications and non-financial applications.

Alternative meaningful classifications could well be proposed. For instance, a critical distinction occurs along the line delineating smart contracts that operate without a need for off-chain data from those meant to react to information outside the blockchain. Although, technically, such information must be brought on-chain, it raises a host of problems commonly referred to as the *oracle problem*—how to get an on-chain data representation of a state of nature that ideally is as trustless as the blockchain and truthful insofar as to describe the true state correctly.

The task of acting as an oracle that enters relevant data as a trustworthy, reliable and timely source onto blockchains has evolved into a business opportunity. In cases where data is generated by or otherwise under the control of a firm, the oracle problem becomes vacuous,[8] and a business case arises naturally.

For consistency, the following description of financial business models is structured in line with the Ethereum whitepaper classification (Buterin 2014).

3.1.1 Financial Applications

Given that the first and best-known usage of blockchain is cryptocurrency, it is unsurprising that business models within the IoV still skew towards financial applications. Moreover, the provision of decentralised services frequently (though not necessarily) calls for decentralised payment. Short of physical transfer (cash, gold, precious items) and the Hawala system, which are both unsuited for online business, DLT provides the only decentralised payment systems.

Token Systems, ERC-20 Among the most influential smart contracts is ERC-20,[9] which is used to generate new tokens on the Ethereum blockchain. As all fully decentralised business models in the IoV rely on digital tokens to generate revenue, while simultaneously not wanting to rely on a general-purpose cryptocurrency (if only for reasons of volatility alone; Yermack 2015), a standard procedure is to generate a dedicated token for the use of the service.

This is one of the most fundamental innovations in business models for the IoV: developing a token economy around custom-made tokens linked to the firm's ser-

[8] Unless the whole business were re-designed to not generate or control proprietary data in the first place.

[9] Technically, ERC-20 is a standard for Ethereum smart contracts; it also provides a template. The Ethereum Request for Comments (ERC) is part of the Ethereum Improvement Proposal (EIP). Since its introduction in 2015, ERC-20 has become the de facto standard for creating tokens on Ethereum. Due to technical deficiencies, it should be succeeded by ERC-777.

vices or activities.[10] Smart contracts open new possibilities beyond the creation of fungible payment or utility tokens. Customer retention programmes, promotions, data acquisition and user telemetry, complex pricing schemes including discriminatory pricing, reward schemes and demand shaping can, for better or worse, all be coordinated and incentivised by appropriate token design.

Fund Management Once economic value is stored in digital tokens rather than traditional account balances, numerous financial–industry functions can be automated via smart contracts. For instance, the trend towards passive fund management amounts to comparatively simple smart contracts for cryptocurrencies. One instance is the C20 token (*crypto20.com*), resembling an ETF for 20 major cryptocurrencies, yet in itself a token that can be acquired and held without middlemen.

In developed financial markets, the number of funds exceeds the number of stocks; moreover, smart contracts allow customers to interact close to real time at low costs (as no human labour is involved on the business side) with increased customisation and close-to-continuous adjustments. It appears a foregone conclusion that only a small fraction of business cases to be developed in this realm has materialised yet.

Saving and Investment In a domain where behavioural finance is documenting a host of human biases in decision-making, an increasing number of business models are being built around nudges meant to improve our financial results. Smart contracts effectively endow us with programmable wallets and accounts, possibly aiding in achieving savings goals and investment objectives, and have been used for retirement savings plans.

Financial Instruments and Derivatives So far, few projects have worked on matching the rich universe of derivative financial instruments on the IoV, yet this reluctance is fading fast—on both sides.

Online markets for digital derivatives of virtual tokens are implementing a growing number of predictable business models as they emulate traditional instruments.

Simultaneously, traditional financial markets are overcoming their reluctance to take up business opportunities from the crypto-economy. Starting with bitcoin futures trading on the CBOE in 2017,[11] traditional financial products are increasingly providing exposure to risks and rewards from the token economy. Recently, the first bitcoin-denominated bond was placed under UK regulation (William 2019), three sovereigns have voiced interest in issuing crypto-denominated government bonds (Esther 2019), and a major Spanish bank issued and settled a fiat-denominated bond on a public blockchain. Ethereum tokens represented the bond, and settlement was effected via another ERC-20 token tokenising cash in a custody account (Ian 2019).

[10] Precursors of the trend were visible in the gaming industry, where revenue streams of developers shifted towards larger fractions from in-game content sales. However, the early (the then-largest bitcoin exchange which failed in 2014, Mt. Gox, started trading cards from an online game and was actually named as a short form for "Magic: The Gathering Online eXchange") and ongoing (*wax.io* is building a blockchain-based marketplace to exchange video-game assets) links to the gaming industry must not distract from the seriousness of token economics.

[11] In the meantime, the CBOE has ceased trading XBT futures and ceded the market to the CME.

Insurance, Hedging and Betting Subject to the oracle problem described above but among the most promising use cases are conditional payments. Self-enforcing insurance contracts rely on a trusted information stream about the insured state (Cousaert et al. 2022). This is no different from standard insurance contracts. Insurance against fire or theft, for instance, relies on police documents to process claims, i.e. a trusted third party. The insurance company's business can be automated via smart contracts (see, e.g. Braun et al. 2020). For example, a French insurer is offering smart-contract-based insurance against flight delays or cancellations (*fizzy.axa*).[12]

Hedging needs can be covered with insurance or financial derivatives, but one use case stands out, namely stablecoins. The recent surge in interest in crypto tokens with stable economic value (Pernice et al. 2019) has led to a variety of approaches (most of which rely on oracles) and is driven by the role of stablecoins to bridge between conventional financial and crypto markets. This is the area with the most activity regarding new business models.

Finally, an active field are *prediction markets* (technically little distinct from betting markets, as long as the uncertainty is not self-generated; see, for example, *augur.net*). Their prominent role arises because odds ratios from bets are the closest to a decentralised solution to the oracle problem. As betting is costly, it prevents cheap talk, and as accuracy is profitable, it tends to incorporate all public information remarkably efficiently.

Financial Inclusion Importantly, crypto-only applications have the potential to increase financial inclusion. Put simply, in many developing regions, the prevalence of smartphones exceeds that of bank accounts.

3.1.2 Semi-financial Applications

This category captures smart contracts with both a financial and a noteworthy non-financial aspect to them. Examples include bounties for the fulfilment of pre-specified tasks, computing services, contracts for work and labour, and potentially even employment contracts.

3.1.3 Non-financial Applications

In a host of use cases, monetary consideration should not play a role. Examples include online voting, and censorship-resistant information provision, including identity and reputation systems, etc.

Naturally, non-financial applications often imply a for-profit business model. For example, reputation systems require that reputation cannot be bought. However, the operation of a reputation system generates sizable economic value, a part of which can be appropriated by the system operator. As the focus of this text is on financial applications, the broad range of such business cases is not considered further.

[12] Payments use standard current accounts, but technically operating such a business model as a crypto-only enterprise would be simpler.

3.2 DApps

Although smart contracts still rely on the user's interaction with the blockchain, the idea of decentralised applications (DApps) is to build interfaces for blockchain-based use cases that are as convenient as standard "apps", while simultaneously automating the processing to and from a DLT providing the (core) functionality.

Put simply, standard apps use application programming interfaces (APIs) to interact with a (central) database, whereas DApps use smart contracts to interact with the blockchain (or another DLT). Although a DApp may interact with any number of smart contracts, the point is that it includes both a front-end and back-end to provide a fully functional piece of software to users. At the same time, at least a part if not all of the program's logic and data is on a decentralised network.

Another major characteristic is that DApps are incentivised, usually by cryptographic tokens, to motivate network nodes to process them. Most are also open-source software. Given the explicit remuneration for the execution of the DApp, there is no need to hinder adoption by charging for software licenses; furthermore, the practise increases trustworthiness and reliability.

The main advantage of DApps therefore lies in the fact that nobody (not even the developers or the institution spearheading the DApp) has the power to manipulate the data or the processing of a deployed DApp.

Although almost any application could be implemented as a DApp,[13] in most instances the added effort in development and maintenance will not be worth it. In use cases where a trusted third party naturally exists or cannot be avoided,[14] there is little reason to decentralise the applications. However, in all cases where trust in a distributed network is preferable to the need to trust a powerful central authority, there is a use case for DApps.

Novel financial business cases abound in payment systems, insurance platforms, deposits, lending, fundraising and investment management.

3.3 DAOs

Decentralised autonomous organisations (DAOs) are the logical conclusion of the progression in blockchain applicability. If cryptocurrencies roll out their data (if only an allocation table), smart contracts roll out their computation (in addition to data, and possibly dependent on future information and actions) and DApps roll out all the use cases of an application, then DAOs roll out all the procedures of an entire business or organisation.

Although clearly this is not possible for all types of businesses, it constitutes a true paradigm shift in the cases where it is. If an entire organisation is implemented

[13] The only true technical restriction applies to systems with poor or inexistent connectivity.

[14] This is why the current trend of governments announcing their intention to put some of their online services on a blockchain is a curious phenomenon, as it is a rare occurrence for government offices to declare themselves non-trustworthy counterparties.

as code that runs on a blockchain, this utilises the unownable computer to generate an “unownable organisation”—not in the sense that there are no beneficiaries, who may well be specified in the smart contracts a DAO employs (resp. consists of), but in the sense that there is no human in control of the operations. Naturally, a DAO will only do what it has been programmed to do (and is hard to update). Nevertheless, its decentralised execution on a blockchain makes it impossible to change its procedures without it having provisions to that effect or without manipulating the entire blockchain.

A simple example of a DAO is that of a fund management DAO: a set of smart contracts that allow users to register an account and send crypto tokens to their account for which they are granted a share in the fund (in tokens), have the DAO trade to optimise its portfolio and allow owners to liquidate their holdings against a payout in cryptocurrency whenever they choose to. This is a simple set of business procedures that can all be implemented via smart contracts and outsourced to a blockchain. Therefore, the DAO becomes an enterprise with no employees and no managers—an organisation without people.

In principle, any business case requiring no physical intervention can be fully digitised in a DAO. After all, DAOs do not need to encode all future operations fully. Through their interaction with the blockchain, they can take inputs and decisions into the DAO, if it is set up to incorporate such future operations. For instance, “The DAO”[15] relied on curators to whitelist investment projects.

However, the legal status of DAOs is still unclear under virtually all jurisdictions, as is the question of how to deal with regulatory non-compliance. Such cases can arise even in the best-intentioned implementations, as updates to DAOs are non-trivial. Thus, any change in regulation involves the risk of a DAO continuing its operation unaltered when in fact the regulator has ruled that this must not happen.

Of course, provisions for updates can be implemented ahead of time as well as wind-down conditions; every responsibly set-up DAO includes these. However, the main purpose of blockchains is to hedge those who prefer an independent solution against central control—therefore all discussions around maximal control of blockchain-based business cases (no matter whether cryptocurrency, smart contracts or DAOs) are discussions about prohibiting blockchain technology, without explicitly mentioning so.

[15] The DAO. To understand the current reluctance with respect to DAOs, it is crucial to know about the first major DAO, literally called “The DAO”. It began in 2016 as the largest crowdfunding success (via token sale) in history, raising more than 100 million worth of euros in ether. It was implemented as a cryptocurrency venture-capital fund, with shareholders voting on which projects to fund, and subsequent funding and repayment effected in crypto tokens from and to the DAO. Due to a critical security bug in the implementation of the DAO, a third of the funds were drained by an attacker before a month had passed, and the DAO failed spectacularly, causing so much trouble that the Ethereum blockchain miners decided to coordinate a hard fork in order to mitigate the damage. Although this emergency measure has arguably worked for Ethereum, the enthusiasm for DAOs was appreciably impaired by the incident. It highlighted the difficulty of avoiding bugs in such complex pieces of software as DAOs tend to be, and the particularly risky situation of not being able to update a decentralised application quickly and consistently.

Just as general literacy lost central control over all written records and the printing press lost central control over all printed records, blockchains and in particular DAOs cast doubt on the possibility of achieving perfect central control over all computations and business cases that may be computed virtually. Of course, nothing precludes enforcement in the physical realm, as is still ongoing for written or printed material. However, just as central authority was hostile to general literacy and the printing press and often antagonised or even fought their progress, the same is visible today. A sense of lack of control (and possibly understanding) is driving significant regulatory efforts to stem the tide of decentralised computing.

The reality, however, is that in certain circumstances, when agency problems are acute or moral hazard is deemed a severe problem, decentralisation can effectively mitigate those problems and thus generate economic value. At the same time, flexibility and ease of updating business procedures have proven invaluable in many ways, providing a natural limit to the tendency to decentralise.

Despite regulatory uncertainty (to some degree still prevailing for tokens and smart contracts), it seems safe to predict that free societies will ultimately strike a balance between the need to prevent illicit activities and the gains from exploiting technological innovation. In this respect, DAOs pose in many ways the most consistent form of capitalising on blockchain or DLT.

Reinsurers Reinsurance companies are ideally suited to be run as completely automated enterprises. So far, the biggest roadblock appears to be the crypto/fiat divide. Although fiat transactions cannot be embedded in DAOs due to a lack of access to the standard financial system for entities without clear legal responsibilities, there is also no active insurance market denominated in crypto tokens only. However, the rise of stablecoins may quickly bridge this gap.

DEX Decentralised exchanges (Xu et al. 2022) are one of the business cases for DAOs which receive the most attention currently. The fact that most cryptocurrency trading occurs on centralised exchanges, requiring the currencies traded to be held in escrow,[16] has led to a push to decentralise the trading itself.

4 Decentralised Consensus Based on Agency

After consensus protocols about a shared state and those about a shared procedure (program execution), the highest form of decentralised consensus is about agency or governance. Although static security tokens can represent voting rights and thus define decision rights to some extent, consensus about agency denotes the significantly broader scope of both possibility and necessity for governance in a decentralised network: both on and of the blockchain.

[16] No stock exchange would take ownership of the shares traded there; yet such has been the case for almost all cryptocurrency trading until today.

4.1 Governance on the Blockchain

Three factors elevate the governance of a blockchain-based activity or organisation beyond the customary level. The first is the possibility of cheap and extensive record-keeping of extensive data sets that cannot be modified later. Such transparency (possibly only within the organisation) can resolve a host of agency problems (Yermack 2017). Second is the possibility to run internal markets within the organisation, based on crypto tokens. Third and most importantly, programmable tokens (via smart contracts) allow for complex designs of time-varying control rights, with decisions being relegated not only to code but also to human intervention depending on the designed mechanisms. This can allow for improved shareholder (or stakeholder) control while mitigating the amount of involvement required.

With regards to the first factor, business cases ranging from financial-claims trading and settlement to employee compensation are being implemented. The two further factors are under active research but are yet to see many commercial implementations.

4.2 Governance of the Blockchain

More attention has been paid to off-chain governance, i.e. the governance of the environment around blockchain-based applications. Since the DAO incident and the subsequent Ethereum hard fork, governance structures of the ecosystem of a blockchain have spawned research and debate.

Permissioned blockchains can rely on authority in cases of disputes regarding how a blockchain protocol should be changed. Permissionless chains have, so far, fallen back to informal governance by the persuasion of key developers, or to "voting by mining", a process that may tilt towards too many forks, as the decision to fork implies external effects.

Currently, most businesses active in this field focus on consulting services based on insights from mechanism design. However, several projects (including *tezos.com*, *decred.org* and *dfinity.org*) are pursuing the approach whereby governance of the chain should itself be put into the blockchain protocol. In any case, the importance of meta-governance will most likely spur progress in this field.

5 Conclusion

The IoV began when Satoshi Nakamoto solved the decade-old double-spending problem and introduced scarce and transactable, hence valuable, tokens to the Internet. What has been flippantly called "attaching a banknote to an e-mail" has revolutionised more than just payment systems. DLT has not only allowed decentralised systems to reach consensus on potentially controversial states of nature, but has evolved to engineer consensus about procedures (with smart contracts and ultimately DAOs) and even agency (enabling governance structures that we have only marginally started to utilise; see Chapter "Governance and Privacy Issues from the Internet of Value").

As the first use cases of blockchain technology were financial in nature, and as generating purely digital tokens of economic value is easier than getting real-world data aligned with their representation on a DLT, the business models we see in practice today are still heavily skewed in favour of financial applications. However, despite the conceptual difficulty of DLT and certain inherent inefficiencies limiting its applicability, many more non-financial business cases are becoming visible. Regardless of the current state of the volatile cryptocurrency prices, a factor that does affect the level of public interest, the digitisation of the economy and society at large is nonetheless progressing with increasing reliance on DLT.

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From Banks to DeFi: The Evolution of the Lending Market

Jiahua Xu and Nikhil Vadgama

Abstract

The Internet of Value (IoV) with its distributed ledger technology (DLT) underpinning has created new forms of lending markets. As an integral part of the decentralised finance (DeFi) ecosystem, lending protocols are gaining tremendous traction, holding an aggregate liquidity supply of over $40 billion at the time of writing. In this paper, we enumerate the challenges of traditional money markets led by banks and lending platforms and present advantageous characteristics of DeFi lending protocols that might help resolve deep-rooted issues in the conventional lending environment. With the examples of Maker, Compound and Aave, we describe in detail the mechanism of DeFi lending protocols. We discuss the persisting reliance of DeFi lending on the traditional financial system and conclude with the outlook of the lending market in the IoV era.

1 Introduction

Lending and credit have been an integral part of human society for thousands of years, with the first evidence of loans in human history taking place in Mesopotamia approximately 5,000 years ago (Freas 2018). Since then, lending markets have evolved to assume many different forms including consumer lending, student loans, mortgages, corporate debt and government bonds.

Fundamentally, lending is intricately related to the concept of trust and the promise of repayment. The act of lending is to lend money, to earn interest, and to be paid

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back. The term "credit" itself comes from the mid-sixteenth century French, meaning to believe and trust.

Lending has now become one of the most important financial activities in society. It fuels economic growth and cultivates forward-looking commercial activities. The size of the world's debt markets as of 2019 was estimated to be more than $255 trillion or nearly $32,500 for each of the world's 7.7 billion people, and more than three times the world's annual output (Jones 2019).

In recent times, technology's impact on lending markets has shown significant progress in solving many problems in relatively inefficient markets. For example, artificial intelligence and alternative data are making breakthroughs for financial inclusion through alternative credit scoring. This chapter focuses on how blockchain technology and its role in the Internet of Value are helping create more efficient lending markets. In particular, we address consumer, business and more recent crypto-asset lending, but the principles discussed can, of course, apply to the broader unsecured and secured lending markets (FCA 2021).

The rest of this chapter is structured as follows: in Sect. 2, we review conventional lending in society, fuelled by commercial banks as well as new marketplaces and lending businesses; in Sect. 3, we raise challenges currently faced in lending markets; in Sect. 4, we elaborate on new lending protocols in the decentralised finance (DeFi) space and argue how blockchain technology can empower lending markets for the age of the Internet of Value; in Sect. 5, we discuss DeFi lending protocols' status quo and their coevolution with centralised financial (CeFi) platforms; in Sect. 6, we conclude with an examination on how lending markets may evolve and transform in the future.

2 Lending in the Conventional Financial Market

Lending requirements of consumers and businesses are primarily met by two major types of organisations:

(i) banks,
(ii) new lending marketplaces and specialised companies.

In this section, we discuss the principal lending mechanics of these organisations.

2.1 Banks

In the lending market, banks hold a unique position as that of a "money creator" (Werner 2014). When providing a loan, a bank simultaneously extends its balance sheet by increasing its assets (loans receivable) and its liability (borrower's deposit) (Lindner 2013). The amount that commercial banks can lend is not as simple as a multiplier effect of the reserves they hold at the central bank; instead, it depends on various factors to do with market forces, risk, interest rates, borrower behaviour and regulatory policy. The majority of broad money in economies (with particular reference to the UK) are bank deposits, accounting for 97% of the total amount of money in circulation, created via loans (McLeay et al. 2014). Let us look at central banks and commercial banks in more detail below.

Central banks A new loan issued by a central bank can increase the central bank's outstanding money supply. Thus, a central bank is the "lender of last resort" as it is technically capable of issuing large-scale loans commonly used as a rescue plan to "bail out" commercial banks in a financial crisis. This practice has been occasionally employed since the global financial crisis of 2007–2009 in the form of Quantitative Easing (QE), where central bank reserves are created to purchase financial assets, mainly from non-bank financial companies (McLeay et al. 2014). Naturally, a central bank's excessive loan issuance inflates monetary supply, which potentially leads to currency depreciation. Bailout plans of this sort–where central banks "print" fresh money to ensure market liquidity–have historically received criticism as the action dilutes the money's value.

Commercial banks For commercial banks, newly created deposits through loan issuance can also be used as money in the sense that they can be accepted as a form of payment by non-banks. In effect, a deposit at a commercial bank represents the bank's promise to pay central bank money. Failure to collect a sufficient amount of outstanding loans as a result of, e.g. borrowers not being able to repay, thus induces a breach of promise on the part of the commercial bank, potentially resulting in bankruptcy and, more severely, mistrust in the overall banking system. This was precisely the story of the global financial crisis, where banks collapsed due to the high rate of default in the secondary mortgage market.

In summary, loans from banks (central or commercial) generate deposits, fundamentally different from the deposit-first operation of lending companies, which we discuss below.

2.2 Lending Companies and Marketplaces

Distinct from banks, ordinary lending companies function only as an intermediary of loanable funds; they cannot create forms of money. In other words, a lending company must absorb liquidity from lenders first in order to provide its borrowing clients' loans.

Indeed, it is mechanically feasible for lending companies to also operate as commercial banks: issuing a loan by creating a new deposit in the form of "promise to pay central bank money", in which case, deposits would not need to fully cover loans. Critically, however, the "promise" from lending companies—unlike commercial banks—cannot be used as legal tender. Consequently, borrowers would find it difficult to use this newly created deposit as a form of payment anywhere outside the lending platform. As Minsky (1986) put it: "everyone can make money; the problem is to get it accepted". Nevertheless, there are many other derivatives such as collateralised debt obligations (CDOs) that can be fungible in capital markets. It is also possible to transfer plain vanilla loans to those who might accept it as a substitute for fiat funds.

Generally speaking, there exist three mechanisms within non-bank lending.

Quote-driven market In a quote-driven market, the lending platform attracts both lenders and borrowers at the same time. Lenders on these types of platforms can be either institutional wealth managers or retail investors, as seen on UK-based Funding Circle and US-based LendingClub. The market trend has been that more and more institutional funding is being drawn to these platforms, and preferred by the platforms due to the economies of scale when dealing with larger investors (Ziegler et al. 2020). The borrowers are often individuals or small and medium enterprises, who apply for a loan by supplying relevant information such as loan principal required, borrowing period and credit history. While acting as an agent without taking any credit risk, a lending platform usually performs some degree of risk assessment of borrowers based on their profile to ensure the minimum quality of listed loans.[1] Rather than linking individual quotes from lenders and borrowers, most platforms nowadays pull funds and manage a diverse set of borrowers to better diversify risks for their pool of investors. Loans are fractionalised such that lenders can invest in a large number of these smaller loan chunks to reduce idiosyncratic risks, and can achieve exposure based on their risk appetite.

Order-driven exchange In an order-driven exchange platform, orders to borrow and lend with various price levels (in the form of, e.g. interest rate per annum) are cleared automatically through an order book. To address default risk, borrowers often need to provide sufficient collateral before placing an order. This mechanism is typically adopted for trading in global debt markets.

Over-the-counter An over-the-counter model refers to a purely bilateral lending model. Similar to how quote-driven markets operate, firstly a borrower submits a request to the platform enclosing personal information, credit history, etc. The platform then evaluates the request and assigns an interest rate suitable for the borrower's particular request and credibility. The request is subsequently posted on the platform where lenders can choose to fulfil individual requests. Peer-to-peer lending platforms, such as the China-based PPDai, adopt this model. Earlier, lending platforms typically engaged in this type of model before moving to a quote-driven market model.

3 Challenges with the Mainstream Lending Market

The current mainstream lending market, led by banking institutions, is fraught with issues.

Financial inclusion After the global financial crisis, more stringent lending rules and underwriting models were applied to banks. As a consequence, the threshold of credit

[1] https://www.fundingcircle.com/uk/resources/investors/team/meet-the-credit-assessment-team/.

rating was increased to lower the default risk. Clients with thin credit files, such as small and medium enterprises (SME) and retail borrowers (particularly immigrants and women) have become the most negatively impacted, facing increased difficulty to borrow from banks. The particular role that SMEs play in most major economies, especially developing economies, cannot be underestimated. Unfortunately, they are significantly affected by financial inclusion issues in lending, and lack access to alternative lending channels such as international capital markets. SMEs represent 90% of businesses and more than 50% of employment worldwide. The International Finance Corporation estimates that 65 million firms have unmet financing needs of $5.2 trillion each year.[2]

Passthrough issues Owing to the inefficiency of information flow and the tardiness in policy execution, government lending schemes often do not reach end clients fast enough. This was particularly evident during the Coronavirus pandemic, where commercial banks responsible for distributing loans to SMEs in the UK have not been efficiently passing them along (Barrett et al. 2020). The passthrough of changes in the interest rates were also delayed, resulting in a high lending rate in a low savings interest environment, which is detrimental to borrowers. For example, in the UK, the Bank of England's rate cuts are often not passed on to lower mortgage costs for borrowers (Singh 2020).

Intermediary cost Regulatory obstacles keep the barrier of entry for lending entities high, leading to an oligopoly market with imperfect competition. The centralisation of lending services enables high intermediary costs, and the resultant market friction further contributes to the inefficient usage of market liquidity, leading to the non-maximisation of utilitarian societal welfare. For example, in 2016, the UK government set out to challenge high street banks' oligopoly by encouraging the alternative lending sector's growth. To date, these new players have only managed to capture 20% of the market (Prill 2020).

Liquidity inefficiency The existing lending mechanisms in the mainstream lending market produces sub-optimal liquidity outcomes. Both the supply and demand sides of liquidity are crudely diverged into siloed submarkets based on factors such as the lending period, interest rate, credit rating, etc. even within the same lending platform. The oversupply of liquidity in one submarket cannot be promptly transferred to serve the demand from another submarket.

Subprime problems The challenges in securing a loan with a bank or any other major financial institutions leave many potential borrowers unserved. This prompts the rise of alternative lending entities, including peer-to-peer lending markets, that cater to the cohort unable to obtain financing from banks. Those lending entities typically charge borrowers a premium for securing funding, understanding that the borrowers have already been rejected by other sources and are left with no other options. Unfortunately, fraudulent activities and high default rates permeate these less strict lending markets, stifling their growth.

[2] https://www.worldbank.org/en/topic/smefinance.

Legacy infrastructure The dated information technology infrastructure used by mainstream lending entities is a crucial impediment to efficiency gains. Due to the lack of data exchange between financial institutions and the absence of a functional tracking system, clients' credit history is fragmented and opaque, exacerbating financial exclusion and fraud. Even with the entrance of new lending platforms with substantially lower operating costs (at levels half that of commercial banks), their ability to compete in this domain is outweighed by commercial banks' far cheaper funding costs (Deloitte UK 2016).

4 Paradigm Shift in Lending Enabled by the Internet of Value

New emerging technologies are improving the state of lending markets. In particular, blockchain technologies underpin the Internet of Value by creating a new economic layer of value exchange on top of the Internet. The rapid development on the Internet of Value is shifting the lending paradigm as new lending schemes enabled by decentralised finance, or DeFi in short (Werner et al. 2021), solve entrenched issues native to the current mainstream lending market. These new solutions present themselves in the form of protocols (Gudgeon et al. 2020), sets of rules determining how a lending market operates.

The DeFi market picked up momentum in 2020 and as of January 2021, the DeFi market's size, measured by the Total Value Locked, was estimated to be approximately \$44 billion.[3] DeFi projects include decentralised lending platforms, decentralised exchanges, derivatives, payments and assets.

4.1 Key Components of DeFi Lending Protocols

Despite their respective particularities, most DeFi lending protocols share two features:

(i) they deviate from existing subjective frameworks of centralised credit assessment to codified collateral evaluation;
(ii) they employ smart contracts to manage crypto-assets (Bartoletti et al. 2021).

A smart contract is a programme deployed on a distributed ledger, commonly the Ethereum blockchain, that can perform bookkeeping and calculations, receive and hold digital assets and execute transactions automatically when triggered by predefined events.

[3] https://defipulse.com.

Table 1 Overview of major DeFi lending protocols on Ethereum. Value locked refers to total balance of ETH and ERC-20 tokens held in lending pool contracts and is retrieved from https://defipulse.com/. Market cap refers fully diluted market cap of the governance token and is retrieved from https://etherscan.io/. Data are updated on 17 April 2021

Protocol	Value locked (billion USD)	IOU token	Governance token	Market cap (billion USD)
Maker	9.37	DAI	MKR	3.46
Compound	11.05	cTokens	COMP	5.77
Aave	6.41	aTokens	AAVE	7.27

Value locked Value locked originates from a users' deposits in a protocol's smart contract(s). The locked value forms a reserve to pay back depositors in redemption, and can also be used as collateral.

IOU token Lending protocols issue users IOU tokens against their deposits. Only those IOU tokens can be used to redeem deposits at a later stage, and they are also transferable and usually tradeable in exchanges.

Collateral A loan's collateral comprises the entirety or part of the borrower's deposit. The collateral value, together with the underlying asset's maximum loan-to-value ratio determines how much crypto-assets a user is allowed to borrow.

Liquidation The liquidable status of collateral is triggered automatically by a smart contract. When the loan-to-value ratio of a borrow position drops below a critical threshold—typically referred to as "liquidation threshold"—due to interest accrued or market movements, any network participant can compete to liquidate the collateral. The market price information of locked and borrowed assets are supplied to smart contracts through external data feeds providers called "price oracles".

Interest rate Borrowing and lending interest rates are computed and adjusted by smart contracts according to the supply-borrow dynamics, based on protocol-specific interest rate models.

Governance token Certain DeFi lending protocols distribute to users governance tokens that allow them to propose and vote on protocol changes, such as modification of interest rate models. Governance tokens are often used as a reward scheme to incentivise participation, from both borrowing and lending sides, in a protocol.

Table 1 displays the largest decentralised lending protocols by funds locked.

4.2 Major DeFi Lending Protocols

4.2.1 Maker

Maker protocol revolves around DAI, a stablecoin whose value is soft-pegged to the US dollar. Users who wish to borrow DAI must first lock collateral in a smart contract named the Maker collateral vault. The collateral can be ETH (the native coin on Ethereum) or certain ERC-20 tokens (digital assets on Ethereum). The collateral can constitute one single asset or multiple assets. The smart contract calculates the collateral value based on its quantity and its market price, where the market price is input through an oracle, i.e. an external data feed provider. The borrower can then request the smart contract to issue him some DAI amount below a predetermined threshold fraction of the collateral value. This threshold fraction determines when the collateral will liquidate. Borrowers are thus advised to request the issuing amount of DAI to be moderately below the threshold, such that the slight downward price movement of the collateral against DAI will not render the collateral available for liquidation.

There is no margin call with the Marker protocol. It is the borrower's responsibility to keep the borrow position overcollateralised by topping up collateral or repaying DAI in case of unfavourable price change. As soon as a borrower's loan-to-value ratio exceeds the liquidation threshold, any network participant is entitled to bid for the collateral by repaying part of the loan, thus liquidating the position.

To redeem the collateral from the vault, the borrower needs to repay their DAI loan and the loan interest, termed the "stability fee". The stability fee accrues over time. Its value is dynamically adjusted. When the stability fee is high, the borrower is incentivised to pay back some DAI, which is subsequently burned by the smart contract. Thus, this stability fee serves as a mechanism to steer the circulating supply of DAI, ensuring that the currency value does not deviate too much from its peg. There is no fixed loan period; DAI can be repaid partially or entirely at any time.

4.2.2 Compound

Users of the Compound protocol can supply and borrow ETH, as well as an array of ERC-20 tokens. Users who deposit crypto-assets into the protocol's smart contract will receive some cToken (e.g. cETH, cDAI) of an equivalent value, which can be used in exchange for the deposited asset plus interest in the future. A cToken is an interest-bearing token, whose exchange rate against the deposited asset increases over time (Leshner and Hayes 2019).

To borrow from the protocol, users first have to deposit funds, which are used as collateral for the borrow position. In that sense, a borrower must first and foremost also be a depositor. The Compound protocol computes and updates borrowing and lending interest rates for each asset automatically and continuously, based on the amount deposited and locked, as well as the amount borrowed.

The funds borrowed thus accrue interest in a time-variant manner. There is a maximum amount of funds that the user can borrow against his collateral. The market value of assets is determined through the protocol's price oracle. As both borrowed assets and collateralised assets experience price movements and accrue interest, the collateralisation ratio of a borrower's position changes continuously. Despite the absence of a fixed loan term, the borrower needs to ensure the overcollateralisation of his borrow position, such that the collateral does not become available to be liquidated by other network participants.

4.2.3 Aave

With the Aave protocol, formerly "ETHLend", liquidity suppliers deposit funds in a smart contract and receive the corresponding `aToken` (e.g. `aETH`, `aDAI`), representing a deposit certificate. An `aToken` is an interest-bearing token whose value is one-to-one pegged to the deposited asset. For example, if a user deposits 12 `ETH`, they will receive 12 `aETH` as proof of deposit. The balance of `aETH` automatically increases over time, mirroring the interest payment against the `ETH` deposit (Aave 2020). `aToken` holders can always redeem the underlying asset with a 1:1 exchange rate by sending `aToken` to the smart contract and receiving an equivalent amount of the underlying asset from the smart contract.

As with Compound, Aave users' borrow positions must be collateralised by their supplied funds and face liquidation risk once the position becomes undercollateralised. With Aave, borrowers can choose to use part of or the entirety of their deposited assets as collateral, and may switch between a variable interest rate and stable interest rate at any time.

Aave also supports "flash loans". Wolff (2018) introduced flash loans as a type of loan where a user borrows and repays funds within one transaction without collateral. Flash loans are often used to take arbitrage opportunities (see **Flash loan** 1), and to liquidate insufficiently collateralised borrow positions on lending protocols (see **Flash loan** 2).

Flash loan 1 Arbitrage

1: **Borrow** crypto-asset `XYZ`
2: **Sell** `XYZ` on exchange A at P_A
3: **Buy** `XYZ` on exchange B at P_B with $P_B < P_A$
4: **Repay** `XYZ`

Flash loan 2 Liquidation

1: **Borrow** x_1 crypto-asset `XYZ`
2: **Liquidate** a borrow position by paying x_1 `XYZ` to receive the collateral `ABC` with a bonus
3: **Swap** received `ABC` for x_2 `XYZ` with $x_2 > x_1$
4: **Repay** x_1 `XYZ`

Users themselves are responsible for customising each specific flash loan contract for a determined cycle of operations. A flash loan transaction is atomic: if the loan is not paid back, the entire transaction is reverted, while transaction fees still incur.

4.3 Current Use Cases

As of today, borrowers have been using DeFi lending protocols for two main purposes.

4.3.1 Earning Rewards

At the moment, the primary motivation for ordinary retail users of DeFi lending protocols has been to receive participation rewards in the form of, e.g. valuable, tradable governance tokens (see Sect. 4).

In the extreme, borrowers would repetitively

(i) borrow,
(ii) re-deposit borrowed funds as collateral,
(iii) borrow again;

As such, a "borrow spiral" is formed to maximise the amount of reward tokens that a user can receive (Cousaert et al. 2021).

4.3.2 Leveraged Trading

Leveraged trading is commonly seen among more sophisticated investors as well as institutional investors such as hedge funds. For example, an investor bullish about `ETH` may borrow, say, `DAI` to buy some `ETH`. In expectation of a price increase of `ETH`, investor would swap borrowed `DAI` for `ETH` on an exchange, hoping that the purchased `ETH` can be worth more `DAI` in the future to such an extent that it exceeds the loan amount and leaves the investor some profit.

Similar to the borrow spiral discussed above, an investor can repetitively

(i) borrow `DAI`,
(ii) swap `DAI` for `ETH`,
(iii) re-deposit `ETH` as collateral,
(iv) borrow more `DAI`.

As such, a "leveraging spiral" is formed (Perez et al. 2021) to maximise the investor's long exposure to a crypto-asset that is expected to appreciate.

4.4 Advantages of DeFi Lending Protocols

DeFi lending protocols exhibit apparent advantages over conventional lending schemes, broken down as follows:

Transparency Deployed on a public blockchain, the exact content of smart contracts according to each DeFi lending protocol is freely available and auditable. In addition, users' historical interactions with protocols and their lent and borrow positions are transparently recorded on the blockchain. Market information is public for everybody.

Democracy Absent a central authority, users vote on amendments of a protocol. In particular, governance tokens that are issued by many of these protocols to users give proportionate voting rights to those who have economic stakes in these platforms.

Liquidity Funds supplied to a lending protocol are pooled together and can be utilised efficiently. Thanks to smart contracts and blockchain, lending, borrowing and arbitraging can all be performed inexpensively and almost instantaneously. By guaranteeing IOU tokens' redeemability to fund suppliers, DeFi lending protocols also ensure full transferability and exchangeability of debt holdings.

Agility DeFi lending protocols can automatically update interest rates and ceaselessly reflect the latest supply-borrow balance of the market.

Trustlessness Lenders do not need to trust borrowers' solvency anymore, as ingeniously designed smart contracts enforce liquidation when default risk is present.

5 Discussion

5.1 Status Quo of DeFi Lending Protocols

The pace of innovation of DeFi lending protocols is astonishing, with new projects emerging and rapidly gaining attention. Nonetheless, the decentralised lending market is still in its infancy and at an experimental stage.

In particular, the growth of today's DeFi lending space is still mainly propelled by short-term oriented, "financialised" borrowing (see Sect. 4). Nevertheless, the development of the entire DeFi ecosystem coupled with the increasing adoption of crypto-assets will encourage more dominated genuine, utility-driven borrowing activities with DeFi lending protocols.

Given that everybody must "play by the code" in the decentralised environment, security requirements for protocols are exceptionally high. Unfortunately, there persist vulnerabilities and loopholes in smart contracts which attackers—rightfully albeit not righteously—exploit and profit from (Qin et al. 2021). In particular, malicious users are seen to abuse certain features of DeFi lending protocols to perform, e.g. flash-loans-funded price oracle attacks (Xu et al. 2022). The pseudonymous nature of blockchain, plus the absence of central authority, makes it challenging for attack victims to claim damage. As it stands, the community still resorts to regulations to deter malicious activities. In the long run, an improved protocol governance will lead to system resilience and a dependence on law enforcement external to the decentralised ecosystem will be reduced.

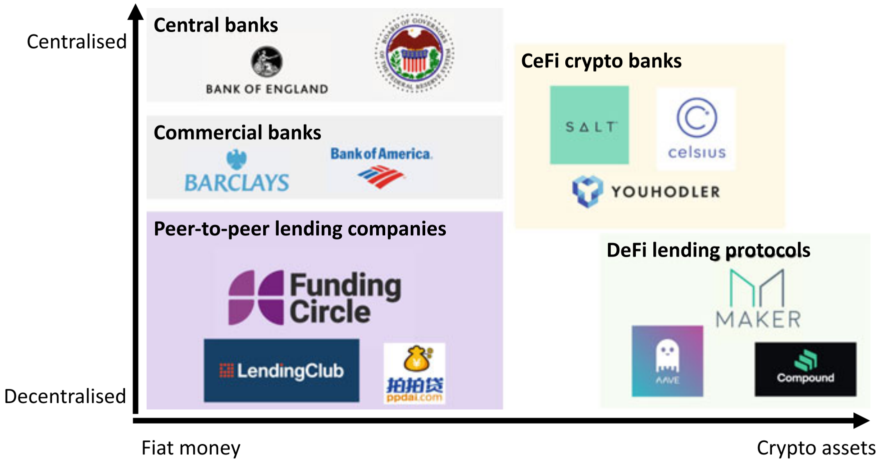

Fig. 1 Taxonomy of lending markets

5.2 Coevolution of DeFi and CeFi

DeFi still heavily relies on the long-established banking system. Notably, the value of crypto-assets on DeFi are still primarily gauged and acknowledged in fiat values. Among the most widely used crypto-assets are stablecoins (e.g. `DAI`), whose value is anchored to fiat currencies. As discussed at the beginning of this article, only central banks can, by definition, issue central bank money. DeFi's reliance on fiat denomination makes central banks irreplaceable, at least in the near future.

Centralised finance (CeFi) platforms for lending such as Salt, Celsius and YouHodler serve as bridges between the conventional monetary market and crypto-asset market. With those platforms, one can borrow fiat money directly (instead of fiat-pegged stablecoins), with their crypto holdings serving as collateral. Those platforms are operated by registered companies that act as counterparties to both their depositing and borrowing users. For that reason, those companies are also called crypto banks (see Fig. 1).

6 Outlook of the Lending Market—the Path to the Internet of Value

The emergence of the alternative finance sector focussed on lending has not led to the anticipated change and disruption to mainstream lending markets. The majority of these companies, reflected in the bottom-left part of Fig. 1, are yet to make a profit. While many have floated on international stock exchanges, their share prices have tumbled since their Initial Public Offerings (Sanborn 2019). Their problem has not only been the high costs of funding versus the incumbent commercial banks. Their technology advantage and abandonment of legacy infrastructure have not sufficed to outplay the competition. Furthermore, consolidation is occurring in the traditional part of the sector (Megaw 2020). Commercial banks are buying marketplace lenders who are in trouble and combining the latter's technological advantage with their own lower funding costs. Hopefully, this can only be good news for borrowers.

The Internet of Value, with a full spectrum of DeFi lending enabled, will mean that borrowers and lenders can seamlessly find yield and maximise their economic returns with whatever tokens and assets they wish to hold, without needing to go through any centralised intermediaries.

Expectably, the current DeFi markets' exceptional double-digit yields will fall, as it is unlikely that these yields will be sustainable. However, already they are beginning to attract interest from institutional players who have only invested in the traditional financial markets (Shen 2021). Although there are many more esoteric notions with blockchain technology powering the Internet of Value, such as asset tokenisation, the concept of yield is much more familiar to financial services professionals. Therefore, traditional financial services companies may seek to incorporate DeFi into their offerings sooner than expected.

As things stand, the traditional money market underpinned by central banks will not disappear. DeFi still faces regulatory and technology maturity issues, and it remains to be seen what will happen when these systems scale. However, with increased interest in Central Bank Digital Currency (CBDC) development, the conventional money market and DeFi will converge in the foreseeable future.

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Real Estate and the Internet of Value

Alastair Moore, Niall Roche and Nikhil Vadgama

1 Introduction

Real estate as an asset class is often overlooked as the largest in the world, greater than that of equities and debt securities and valued at over $250 trillion (Barnes 2018). Out of the global real estate market, residential real estate accounts for the largest share at approximately 80%. Although enormous in size, the impact of technology in general in the real estate sector has been limited. The main act of purchase and sale is still a predominantly manual and paper-based process. Land Registries have a limited degree of digitisation, and real estate markets are full of intermediaries and subject to high levels of fees, opacity and general slow turn-around times.

Technology is gradually coming to the real estate sector, with this burgeoning part of the sector called Proptech (Saïd Business School 2017). Included in this array of new technology is blockchain. Given the Internet of Value will enable value to move as smoothly as information over the Internet, indeed, the value in the world's largest asset class should be front and centre in this future (see Chapter "Blockchains, DLTs and the Future of Payments") (Ripple 2017).

This chapter sets out potential applications of Distributed Ledger Technology (DLT) systems in the real estate supply chains. In the first part of the chapter, we

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set out general technology applications for various use cases. In the second part of this chapter, we describe a proof-of-concept where a DLT system was used for the purposes of transacting a UK residential real estate title (conveyancing). This took place as part of the *Digital Street* project with the HM Land Registry (HMLR) in the UK. The project was intended to research and develop prototypes designed to make buying and selling a property more straightforward, quicker and cheaper through the innovative use of technology. The first trial of this approach for partial completion of the exchange process took place in March 2019 and forms part of the HMLR *Digital Streets* project. Finally, we conclude the chapter by discussing some of the strategic questions that require consideration before the technologies gain wider market adoption.

2 Applications of DLT in Real Estate

Land rights represent one of the most important economic assets for millions of people in the UK (Tuck and Zakout 2019). They are a critical source of livelihood and private market activity and are particularly important for the UK economy because of high levels of foreign direct investment (Fuerst et al. 2013).

Critical to the administration of land rights is the flow of information about assets and ownership. The process of sharing information between different parties to any transaction is central to conducting business. Therefore, improving the methodology or technology used to facilitate this information exchange may have advantages, not only to individual parties in terms of efficiency and cost savings but also to the entire market. For example, sharing information between parties to speed up transactions might enable the markets to clear faster, leading to higher volumes or more efficient price discovery. Alternatively, sharing data more efficiently between parties or aggregating it in new ways may facilitate the creation of new measures of counter-party risk and allow market participants to benefit from this new information (Stiglitz 2000). Some of these considerations are discussed in Sect. 4.

There are potentially many different applications of DLT within the real estate sector across different parts of the asset life cycle. In principle, some DLT systems might span the whole duration of the asset life cycle, but given the current fragmentation and different market segments, it is more likely that several systems span the lifecycle.

The construction industry has become increasingly litigious (Gerrard 2018) as projects have larger sums at stake and where contractors and subcontractors are forced to price their services more competitively. DLT has the potential to curb this current trend by creating a "Panopticon effect", where all parties' behaviour is moderated as they know that there is the possibility that their conduct will be properly observed at a later date.

Another broad trend to consider is that of the Internet of Things (IoT). The omnipresence of low-cost connected sensor networks is changing the way assets and buildings are instrumented and serviced. Through sensors and smart appliances, DLT systems could support the feasibility and reliability of IoT applications during both construction and management. A digital signature or "DNA" of a building could be created that persists across the entire life cycle of multiple owners, occupiers and service providers. IoT will be covered in more depth with respect to real estate and other sectors in other chapters in this book.

In describing the applications of DLT to the real estate sector, we consider the life cycle for real estate, namely starting with constructing, then transacting and finally managing real estate.

We briefly discuss different application areas in the following subsections before discussing residential conveyancing in detail in Sect. 3. However, an indication of the different parties and fragmentation of the existing transaction mechanisms in residential conveyancing are illustrated in Fig. 1, representing only a small section of the entire asset life cycle.

2.1 Building Information Management

Building Information Management (BIM) is utilised to track the various parts of a building as they are being constructed. BIM not only ensures that components are going in the right places but provides information on maintenance issues that may arise once the building is built. The utilisation of DLT here as a tool to track and audit the various parts of a building as it is being constructed can ensure a better reconciliation trail for any changes that are made to the model. Linking the various components of a building from their source to where they are utilised in the construction process provides a wealth of information ensuring the provenance of materials and parts of a building. Placing this information onto a DLT with clear governance and audit protocols allows for easy verification that a building has been constructed as expected and that various components have been checked, fitted and maintained as the design intended. Linking this information to the property title ensures that historical information is carried throughout the life cycle of the property. The utilisation of IoT sensors can facilitate automatic processes updating various features of a build. For example, one could use sensors to measure that building components have been maintained on time. Currently, BIM processes are seldom linked to asset registries and often are siloed away from other property information. A DLT system can help to ensure a common store of information for each property.

2.2 Construction Supply Chains

Supply chains often involve many manual processes and physical paper-based record keeping. Thus, the information about the supply and transport of goods from source to destination is often susceptible to human error, omission or at worse a laborious audit process. Indeed, it isn't easy in most supply chains to know for certain where goods are at any time. This is especially important for goods that have certain properties, such as temperature sensitivity. DLT utilised along a supply chain can ensure a single view of how components and supplies have moved from their

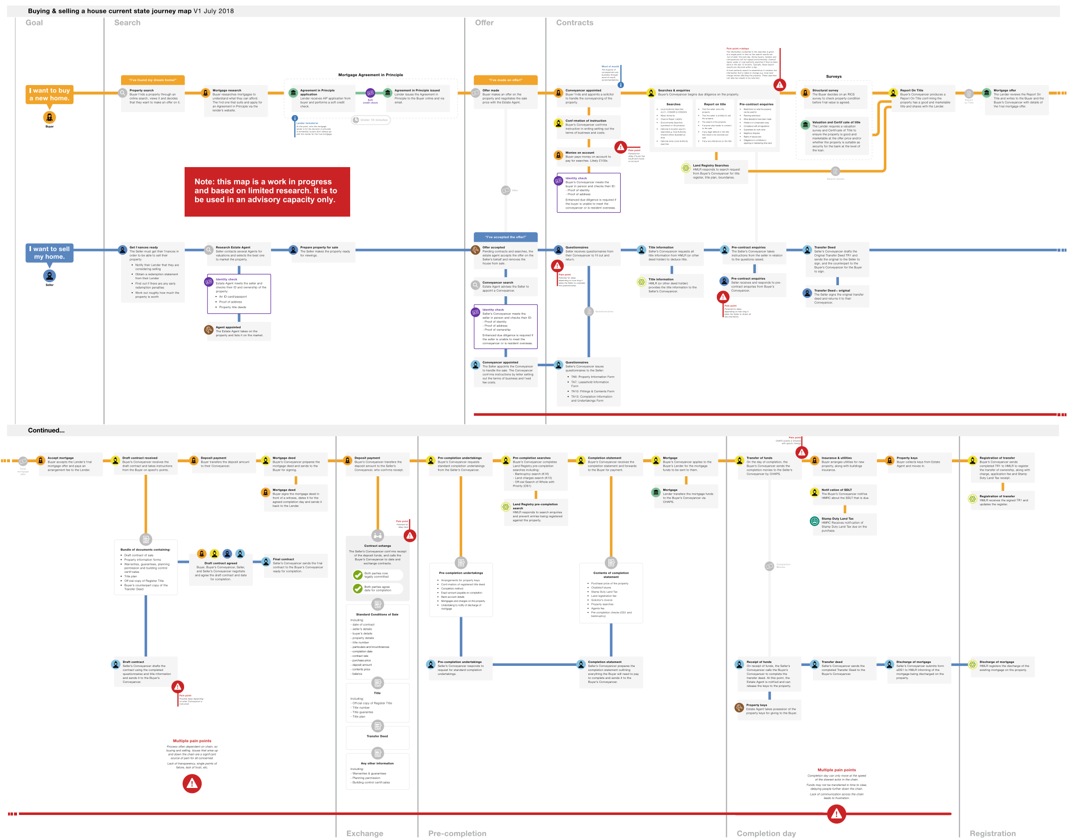

Fig. 1 Buy and sell user journey in conveyancing. Reprinted from HM Land Registry Digital Street Proof of Concept—Community Development Environment under the MIT License (c) 2018 Crown Copyright (HM Land Registry) from https://github.com/LandRegistry/digital-street-community-dev-env

source to their destination. Furthermore, the implementation of IoT sensors can help automate record-keeping processes. Smart contract technology can also be utilised for speeding up payments along a supply chain once contracted players complete obligations.

2.3 Title Creation

Linking all the pertinent material about the construction of a building to its title record can ensure the efficient storage of information about a building throughout its life cycle. An example of this could be linking all the planning, architecture, BIM and relevant supply chain information at the point of creating the title deed. Integration of various stakeholders in creating a title with HMLR would ensure a higher degree of data integrity for a property, making it increasingly useful when this information is required for property due diligence. A good example of this is the solution being developed by Lantmateriet, the Swedish land authority, which uses a digital blockchain-based solution to store digitised contracts for buying and selling properties (Lantmäteriet, Telia, SBAB, Landshypotek, Bank, ChromaWay, and Kairos Future 2017).

After construction and planning, the next stage is associated with the buying and selling of properties.

2.4 Property Search and Acquisition

The most common method of searching for available properties is searching property listings either held by brokers (agents) or placed on property portals (e.g., Rightmove[1] and Zoopla[2]). The information placed on portals or held by agents can be frequently inaccurate and lack standardisation. Furthermore, data about properties can be fragmented across several different platforms. The utilisation of DLT can directly link property information to its title, including all the relevant information on the building construction, maintenance and historical performance. Creating a distributed infrastructure would ensure that information is shared and accessible by various stakeholders and ensure more reliable information is available to all at a cheaper price point. This would reduce the cost of search and acquisition of real estate assets.

[1] https://www.rightmove.co.uk.
[2] https://www.zoopla.co.uk.

2.5 Due Diligence and Financial Evaluation

Due diligence processes during lease and property transactions are often based on paper records, are time-consuming and offline with many manual elements. Often documents still need to be exchanged via fax. By enabling property information to be consolidated and attached to a distributed asset registry, this information can easily be shared between different entities involved in any due diligence and financial evaluation processes. For instance, granting access to property information on an asset registry during a transaction due diligence process or when a financial loan is considered would enable these processes to be sped up significantly, and result in more transparency and fewer errors. An example of this is from the Bank of China which utilises a private blockchain to process 85% of all real estate appraisals in financial evaluation processes (Antonovici 2018). This has taken due diligence processes from days to seconds.

2.6 Real Estate Investing/Tokenisation

Real estate investing has historically been a non-fungible asset class. This has traditionally meant that one requires a lump sum of capital and a loan for the property's remaining portion. This creates a barrier to entry for those seeking to augment their portfolios with specific assets and exposure. There are also many intermediaries involved in a transaction that increase the costs associated with transactions. Portfolio investment is also available but is often confined to the commercial real estate domain, and portfolios are not specific or geographically specific. International real estate transactions in this domain are also challenging to facilitate. In short, for the average investor, it is hard to invest in a diversified real estate portfolio or specific assets. Tokenisation of real estate could be achieved by making real estate investments fungible. Utilising a token mechanism, or the concept of a digital share of a property that DLT underpins, would enable entities to trade parts of a property and create dynamic portfolios. This would also disintermediate many of the intermediaries involved with the real estate process as direct ownership of assets could be completed and logged on an asset registry, whereby all relevant information regarding a property would be available. In many respects, DLT enables an efficient mechanism to facilitate the transfer and clearing of real estate as a fungible asset, ultimately increasing asset utilisation. Smart contracts can also facilitate automatic payments and pass-through of income on property assets as well as provide voting facilities for any decisions that must be made regarding property maintenance. All of this must be supported by correct regulatory guidance as property investment in a fungible way is a regulated financial investment activity. There are several projects involved with tokenising real estate that includes Fluidity[3] and Consensys.[4]

2.7 Title Management

The digitisation of property records and the decentralisation of an asset registry would enable transparency, error reduction, reduced fraud and efficient transfer of assets between stakeholders. Land registries are digitised in some countries (not on DLT infrastructure); however, land titles are still paper-based in many countries (including the US). The utilisation of paper-based processes ultimately increases the scope for errors in title information, time for cross-validation of information and access to this same information. Once titles are placed on to a DLT, further relevant information regarding that property can be appended to it. Decentralising the asset registry to all the stakeholders involved in dealing with titles would enable lower-cost access and more transparent and higher integrity of information. Smart contracts could also be linked to the title to allow automatic processes to be enacted. This would enable asset transfer for buyers and sellers, verifying a transfer process or automated enforcement of certain conditions on loan payments on the property.

The final phase of the real estate life cycle is in real estate management.

2.8 Financing and Payment Systems

Smart contracts can be utilised to enable multiple processes involved with real estate management and transactions. On the transaction side, on successful conditions being met on due diligence, financial evaluation, verification of ownership and identity, smart contracts can enable the automatic transfer of a property title and initiation of payment from one party's bank account to another. Regarding other payment uses, a DLT-based system can enable automatic recording of lease payment information or tenant rental payments, which can serve as reputational and credit enhancement for various records for financial evaluation or due diligence. When considering cross-border payments, utilising certain token-based payment rails could be a way to streamline and reduce the cost of international payments when used in real estate transactions.

[3] https://www.fluidity.io.

[4] https://consensys.net/blog/enterprise-blockchain/how-350m-worth-of-real-estate-was-tokenized-on-ethereum/.

2.9 Property Management

Management of properties is highly complex, with multiple stakeholders involved, including tenants, vendors, property managers and landlords. Often many processes are offline or paper-based, and various stakeholders do not have software systems that integrate well. Utilising a decentralised database that enables read and write access across these stakeholders can lead to smart contracts facilitating automatic processes based on blockchain information.

Rent/Leasing
Rental payment information can be stored and verified against the digital identity of a tenant and act as a store of creditworthiness and reputation. Similarly, contracts can be uploaded to a DLT record of a specific asset title and be signed digitally by both the landlord and the tenant. Contractual obligations, such as penalties or conditional clauses, could be enforced via automatic procedures enabled with smart contracts. Similarly, at the lease's termination, the smart contract could automatically return the tenant deposit if authorised by both the tenant and landlord. In the case of a dispute, a third party could arbitrate, referencing property information available on the blockchain to verify any claims.

Maintenance
Utilisation of BIM and architecture details placed on a DLT and linked to a property title enable automatic alerts when property inspections should be carried out and maintenance requirements. The utilisation of IoT sensors would also enable alerts to be created, as well as storage of historical information about various parts of a property's maintenance and upkeep. This information would be beneficial during transactions to determine the quality of an asset. Smart contracts could also automatically alert vendors to come and provide maintenance services for a building. Tenants could automatically upload maintenance requests to show issues with a property that cannot be held against them at the point of terminating a tenancy.

Energy
Energy ratings, usage and efficiency, can be tracked over time and appended to title information through the use of sensors that directly link to a DLT.

In this section, we have discussed some of the applications of blockchain and DLT to the broader real estate sector. The following section describes a proof-of-concept led by HMLR utilising blockchain and DLT for conveyancing.

3 The Digital Streets Application

Digital Street is an HMLR research and development project designed to make buying and selling property simpler, quicker and cheaper through the innovative use of technology (Farrant 2017). At the time of writing, the project explores the use of blockchain technology and smart contracts to bring greater transparency, speed and trust to property transactions.

The project has already created a digital register for a small selection of properties, which is a first step towards establishing a fully machine-readable register and able to be updated instantly.

The strategic aim of Digital Street is to give HMLR a space to break away from the constraints and current ways of thinking about the home buying process as it stands today. As set out in HMLR's business strategy (HM Land Registry 2017), the aim is to explore how we can use technology to revolutionise land registration and conveyancing.

3.1 Conveyancing

Conveyancing is the transfer of a legal title of real estate from one person or organisation to another. This also includes the granting of an encumbrance such as a mortgage or a lien. Typically there are two major phases to a conveyancing transaction. The first is the exchange of contracts (when equitable interests are created), and the second is completion (also called settlement, when legal title passes and equitable rights merge with the legal title). In England and Wales, conveyancing is usually done by a solicitor or a licensed conveyancer (it does not have to be, but is quite a labour intensive). If the transaction involves a mortgage, it's almost certain that the lender will insist that a solicitor is used for the conveyancing. Under English law, agreements are not legally binding until contracts are exchanged. This affords both the advantage of freedom before completion and the disadvantage of wasted time and expense in the event the deal does not complete.

A detailed (but simplified) user journey for both buyer and seller, and the interactions with various counter-parties, can be seen in Fig. 1. The normal practice is for the buyer to negotiate an agreed price with the seller, organise a survey and have the solicitor (or conveyancer) carry out their searches and pre-contract enquiries. The seller's solicitor or conveyancer will prepare the draft contract to be approved by the buyer's solicitor. The seller's solicitor will also collect and prepare property information to be provided to the buyer's solicitors, in line with the Law Society's National Protocol for domestic conveyancing. When undertaking property transactions, the conveyancer's role is to carry out due diligence by submitting queries—known as Conveyancing Searches—about the transacted property. These are designed to uncover factors the estate agent or surveyor may not know about, which could impact the buyer's enjoyment of the property. It takes on average 10–12 weeks to complete a conveyancing transaction, but while some transactions are quicker, many take longer. The timescale is determined by a host of factors: legal, personal, social and financial. During this period before the exchange of contracts (exchange being the point at which the transaction becomes legally binding), either party can pull out of the transaction at any time and for any reason, with no legal obligation to the other. This gives rise to a risk of gazumping and its converse, gazundering. Conveyancing is a component of the cost of moving home in the United Kingdom.

3.2 Current Limitations and Pain Points

As it stands currently, there are several problems with the conveyancing process. Conveyancing is labour-intensive and full of redundancy and duplication of effort. This results in a lengthy time for transactions to be processed and makes the process error-prone. In today's environment, where property transactions are often chain-dependent, errors in conveyancing in different parts of the transaction chain can compound delays. These delays are the result of several reasons, primarily around disparate technologies being utilised by the different stakeholders in the conveyancing process and little transparency in the process for both sides at any one time. In particular, at the points of exchange and competition, there is no way to verify what has occurred and understand where delays are in the chain. Both the buyer and the seller have their conveyancers and are siloed in the transaction process. There is no single point of truth to refer to with regards to the transaction process. Previous attempts to create solutions to address this have not been successful due to having to create replicating processes for all stakeholders.

This section focuses on a specific proof of concept completed by several parties on the completion of a residential property transaction on the blockchain. This proof of concept was led by HMLR and facilitated by Mishcon de Reya LLP, Shieldpay, Yoti, Natwest, My Home Move and HMRC. Before moving on, several of the participants mentioned above summarise what they see as the biggest problems with existing processes and infrastructure in conveyancing. Nick West, Chief Strategy Officer, Mishcon de Reya,[5] states that the technologies and systems currently used are disparate. Legacy systems cause delays in transaction times. Currently, there is no way for a seller or buyer to independently verify if exchange or completion has taken place or to understand where a delay is being caused in a chain. A number of the processes are undertaken manually, which makes transactions slow, time-consuming and frustrating.

Simon Charnock, Commercial Director of Yoti,[6] states that one of the biggest pain points in the property transaction process is the mix of methodologies used to identify and engage with buyers and sellers across each organisation that services the transaction. Estate agents, mortgage lenders, and conveyancing solicitors must identify the participants in a property transaction formally, yet their customers need to go through multiple identity verification processes to achieve this. Some of these processes involve insecure and easily defrauded practices such as posting documents, emailing document images and in-person document checks by untrained staff.

Geoff Dunnett, Legal Services Director of Shieldpay,[7] states that interoperability and sharing of data between systems is one of the biggest problems with conveyancing today. Each law firm, lender, estate agent, insurer, search provider, HM Revenue and Customs, and HMLR all have different systems that are not interconnected or

[5] https://www.mishcon.com.
[6] https://www.yoti.com.
[7] http://website.shieldpay.com.

interconnectable. To a certain extent, APIs are available, but this happens in silos on each side of the transaction. The Buy-side lawyer may well have excellent connections to the relevant stakeholders via API but no connection to what is happening on the Sell-side. There is no central point that allows all parties to a transaction to see the transaction's progress. Others have previously made attempts to join up the parties of property transactions on a single system, but these types of systems were not/have not been widely adopted because each party is required to re-enter information they have into a further system, and it requires buy-in from all stakeholders to be taken up.

Finally, Annie Birchall, Associate Product Manager, Digital Street at HMLR, states that through their research and engagement with the Digital Street community, they found that a lack of transparency and ID verification are two of the most significant pain points in the current buying and selling process. Buyers and sellers commonly complain that they don't know where they are in the process, while much of conveyancers' time is spent providing updates to their clients. ID checks can also take a long time and are often performed multiple times throughout the process.

3.3 DLT Solution

As part of the Digital Streets Initiative, a working prototype was built with a simplified number of transaction nodes on the DLT system. The overall architecture of the system is shown in Fig. 2.

There were two distinct stages to the creation of the prototype. Firstly, working with the community to learn and build prototypes internally, then working with the active participants to build the distributed network to perform a replica property transaction.

A first iteration of the CorDapp (Brown et al. 2016) was rapidly iterated that demonstrated a basic end-to-end automated property transaction. As shown in the initial Digital Street MVP Architecture model (Fig. 2), this distributed application was deployed across a private business network comprised of seven Corda nodes, all hosted within HMLR's cloud-based development environment.

Along with the CorDapp, other supporting applications were built and deployed, including Corda Remote Procedure Call clients and supporting applications to represent other party's systems and services. This initial proof-of-concept version was based on entirely fictional buyers, sellers, conveyancers and lenders, with minimal user interfaces, just enough to demonstrate the end-to-end flow. The conveyancing workflow can be seen in Fig. 3.

This initial version of the system contained states and contracts for land titles, charges and restrictions, agreements and payments. The automated flows updated the ledger to issue land title assets, remove and add charges and restrictions, draft and sign agreements, transfer ownership and calculate tax liability.

The tangible land title was represented as a digital asset so that the whole life cycle of the asset could be traced. In Corda, this type of asset is called a "LinearState", which represents an evolving asset that changes over time. We also modelled Agree-

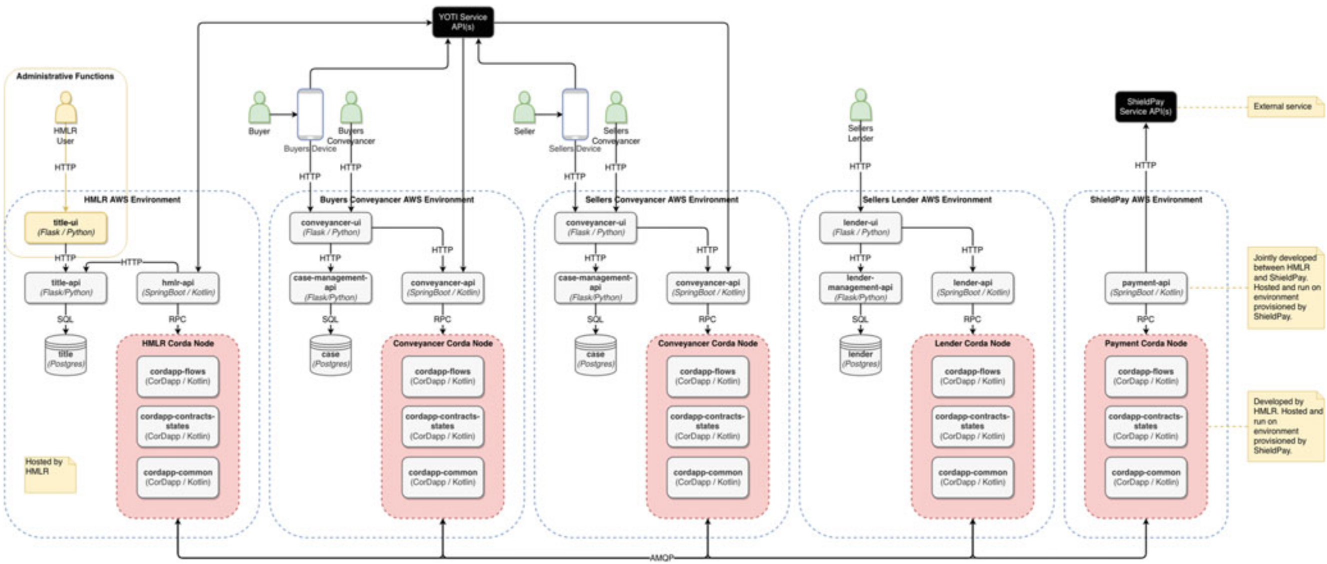

Fig. 2 Network model. This CorDapp implementation simplifies the conveyancing workflow initially to a five node network, but may in principle be extended to a greater number of counter-parties as necessary. Reprinted from HM Land Registry Digital Street Proof of Concept—Community Development Environment under the MIT License (c) 2018 Crown Copyright (HM Land Registry) from https://github.com/LandRegistry/digital-street-community-dev-env

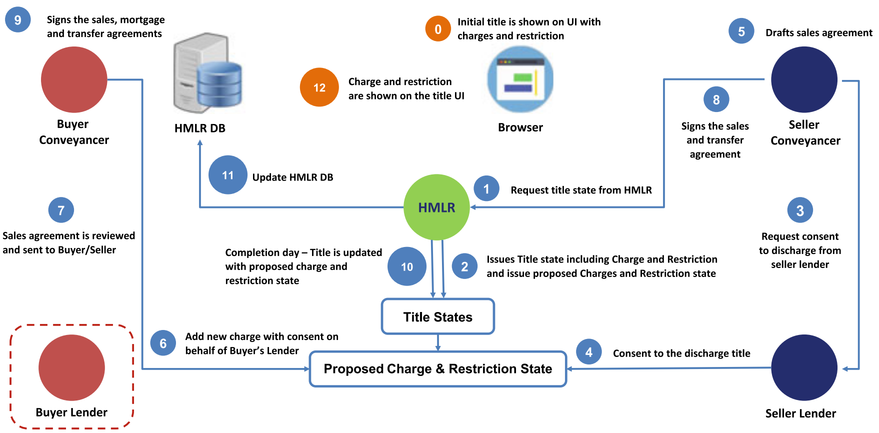

Fig. 3 Conveyancing workflow. Steps 1–11 for the completion of a sale. Reprinted from HM Land Registry Digital Street Proof of Concept—Community Development Environment under the MIT License (c) 2018 Crown Copyright (HM Land Registry) from https://github.com/LandRegistry/digital-street-community-dev-env

ments as linear states, which represented the sales agreement between buyer and seller and their conveyancers and evolved during the negotiation. This Agreement state is shared only with the required participants by leveraging Corda's need-to-know basis sharing mechanism.

3.4 Deployed Solution

The system's design and architecture described in the previous section were deployed and used for partial completion of a residential conveyancing transaction in the UK. The mirrored transaction chosen was the sale of a recently refurbished, semi-detached house in Gillingham that was completed on 6 March 2019. It had taken 22 weeks as opposed to the expected 6 weeks. The official digital transfer was on 23 March 2019 but completed on 2 April 2019 just after 18:00 UK time, due to problems.

In the mirror transaction, every participant ran a node on the network. The Cor-Dapp enabled real-time sharing of data that was made available to every authorised participant. This made it easier for transaction parties to see what was happening with the conveyance as each step was recorded on the ledger, providing a full immutable and undeniable history to all participants. Transactions were checked by all the participants involved, including a notary node, which ensured validity in the exchange and prevented "double spend". This entire conveyance process ran end to end in less than 10 min.

3.5 Successes and Benefits

Overall, the mirror transaction was a success and demonstrated that blockchain technology could enable speedier property transactions, more trust in the transaction, higher security levels and increased transparency for participants.

3.6 Moving from Proof of Concept to Deployment

In the following section, several of the organisations who took part in the proof of concept comment on what they see as the next steps for moving this proof of concept to deployment.

Nick West, Chief Strategy Officer, Mishcon de Reya, states that making the deployed technology fit with current processes and getting various actors to use it could be one of the biggest challenges going forward. There are numerous third-party stakeholders in a transaction, including clients, banks, conveyancers, agents, land registry, etc., and it requires full buy-in from all parties.

Geoff Dunnett, Legal Services Director of Shieldpay, states that being able to orchestrate a proof of value transaction with the organisations that are involved to date should be achievable and targeted. Shieldpay expects that sometime in the next 12 months, a DLT-based transaction will take place; whether that is entirely end to end or will still require certain legacy processes to complete registrations remains to be seen. Seeing wide adoption of such DLT systems stems partially from the need for HMLR to have the ability to service this (3–4 years) and for there to be a critical mass of law firms and lenders willing to participate (3–4 years). The barriers to adoption will be the resistance to change from key stakeholders, particularly from law firms and lenders. There will also need to be common standards and reliance on identity verification of underlying customers as well as actors on the DLT.

Finally, Annie Birchall, Associate Product Manager, Digital Street at HMLR, states that this kind of solution could be in the market in 2–5 years but depends on the industry's adoption of this technology. While the technology used in this proof of concept did prove capable of delivering some of the benefits mentioned, all of the organisations involved would need to enable the transformation of the conveyancing process. Alongside this collaboration, the work that HMLR is doing internally to increase the quality and improve the structure of our data as well as more robust ID processes needs to be in place before the technology could be adopted at its full potential.

There are some key barriers to this proof of concept moving towards a distributed, decentralised model:

- Standards—Interoperable standards have yet to emerge.
- Platform—HMLR would want to be able to support multiple platforms to enable the industry to interact with them. HMLR would need to investigate the platform/vendors that the industry might select.

- Data—HMLR cannot think about decentralising without digitising—HMLR currently has a Digital Register project looking at this.
- Authority—As the authoritative source of land and property ownership, HMLR has a challenge to use consensus-based technology. Using this technology a 51% attack on the network could change ownership of an asset which is an unacceptable risk, but it is in fact HMLR who is the only source of this data, underpinned by HMLR's indemnity fund.
- Identity—A more consistent and robust process for identity verification is needed in order for transactions to be fully digital.

This project represents an ongoing effort by HMLR to bring a range of emerging technologies to bear to modernise and redefine how traditional Land Registry and connected systems operate. If you want to find out more about the series of initiatives that are ongoing, please visit the Digital Streets' webpages.[8]

4 Challenges

DLT still faces several challenges in being adopted in a widespread manner within the real estate industry. Some of these factors are to do with the industry itself, some with the infancy of DLT and some with external factors. These factors include, but are not limited to,

4.1 Regulation

The real estate industry is highly regulated, particularly concerning property transactions and valuations. In the case of property investment from a tokenisation perspective, there remains a somewhat unclear regulatory guidance by many financial regulators about the exact ramifications of tokenisation of real estate or applications of DLT to create a fungible real estate transaction (Allen et al. 2020).

4.2 Interoperability

DLT is still in its infancy, and the technology is evolving. Research and development into new forms of DLT are ongoing and how it can interface with legacy infrastructure. In this sense, some may feel that until there is a stable form of interoperable technology, they should not adopt it (both forwards and backwards compatible). In doing so, there would be a risk of investing in the development and adoption of a technology that could become redundant quickly.

[8] https://hmlandregistry.blog.gov.uk/tag/digital-street/.

4.3 Coopetition Paradox

For DLTs to be effective, they require multiple stakeholders to work together, adopt and agree on a system's parameters. In a market where stakeholders are working together to facilitate processes for their mutual benefit, this is fine. But in a market where natural competitors must come together to share information on a common data level, "for example, brokers", then there occurs a paradox on how natural competitors should start to cooperate. There are two possible solutions to this, with one of particular relevance to the real estate sector. The first is that in the face of impending disintermediation, competitors realise that they can reduce the costs of information asymmetry by working together. In this scenario, although unit costs would decrease, the business volume would increase as asset utilisation increases. The second is that where there is a strong influencer who can essentially dictate to other stakeholders what they should be doing, for instance, HMLR, this can lead to the stakeholders in the ecosystem adopting a particular version of the technology.

4.4 Widespread Adoption

In general, the real estate industry's conservative nature and lack of technology adoption mean to kick start utilisation will be a somewhat slower process unless there is a mandate from an authoritative figure who wishes to embrace decentralisation. Several blockchain consortia aim to help improve the adoption of DLT in the real estate industry. These range from those that wish to impart education to the industry to those who wish to promote knowledge sharing and proof of concepts. An example of a consortium is the Construction Blockchain Consortium.[9]

5 Real Estate and the Internet of Value

In this chapter, we have discussed how blockchain technology could be applied generally to the real estate sector, looked at a specific proof-of-concept at the Land Registry in the United Kingdom, and discussed challenges to adoption.

The Internet of Value refers to blockchain empowering users through the communications layer of the Internet. As the Internet transformed how individuals and businesses communicated, blockchain seeks to change how information is verified, and networks are created. In the context of real estate, these two factors are vitally important. Recording information related to a building's facilities, maintenance and a tenant's rent and attaching that information to the building's title itself is an example of what can be achieved with better information verification. Along with this comes the benefits of reducing costs, more efficient processes and enriched data paving the way for new business models to be applied. Consider the example of the

[9] https://www.constructionblockchain.org.

conveyancing proof of concept discussed earlier—what would be possible once the purchase and sale of a building went from weeks and months to mere minutes? The possibilities are not currently known—but surely there will be many!

Besides the verification of information, we have the transformation of networks. Real estate is often considered an asset class out of the reach of many with significant barriers to entry, particularly for the young. The potential for tokenising real estate assets and enabling direct fractional participation rather than entirely owning gives a chance to many excluded from this market to access its returns. Moreover, the possibilities once again to think of new shared ownership, partial ownership and real estate access business models are endless.

Ultimately, as the largest asset class globally, real estate has surprisingly not seen the digital transformation in many other industries. Blockchain, along with many other emerging technologies, is making its mark on this sector right now. How quickly more than incremental shifts in the industry occur is dependent on how many existing participants will accept this new technology and where regulation will adapt to it. With the likes of HMLR and many other Land Registries around the world experimenting, it should be a case of when, and not if and sooner rather than later.

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The Internet of Value and Media

A premium is placed in the media and entertainment sectors on protecting and monetising intellectual property. Blockchain and DLT, with their properties of immutability, smart contracts and decentralisation, can provide a possible solution to transforming the sector concerning how content is created, protected and consumed.

The impact of DLT can extend far beyond this in the context of the IoV. In today's climate, where fake news is an issue with widespread implications, including the manipulation of democratic elections, the IoV can foster greater trust in the value ascribed to important information and ensure that individuals are not confined to their echo chambers. Part "The Internet of Value and Media" addresses how the IoV can transform the media sector.

Chapter "New Media Business Models to emerge from the Internet of Value" is written by Philippe Rixhon, who focuses on copyright and royalties related to media assets. It begins with an exploration of current and related legislation and then moves on to how the IoV can transform the industry. Importantly, it includes a discussion on the implementation of the applications of new business models and how to seize the new opportunities they present. Chapter "New Media Business Models to emerge from the Internet of Value" was reviewed by Nikhil Vadgama.

Chapter "Solving Challenges in the Media Sector with DLT" is written by Soichiro Takagi, who focuses on how the IoV can transform the broader media sector concerning general content creation. Chapter "Solving Challenges in the Media Sector with DLT" begins with a discussion of the main functions of media in society and how the Internet has changed the sector. It then moves on to the challenges faced by the modern media sector and, finally, how the IoV could solve these. Importantly, this chapter discusses issues related to how DLT could be used to improve the provenance of news media and combat fake news. Chapter "Solving Challenges in the Media Sector with DLT" was reviewed by Philippe Rixhon.

New Media Business Models to Emerge from the Internet of Value

Philippe Rixhon

Regarding media and entertainment, the Internet of Value (IoV) will help solve current problems and seize new opportunities.

The fair and efficient distribution of revenues in the digital age is challenging. The creative industries have left behind deterministic value chains and operate now on one stochastic value network where rights ownership and availability are uncertain. There are dynamic uncertainties around ownership—who owns what and when—and recent developments such as micro-licensing have led to dynamic uncertainties around availability. Rights ownership and availability will have to be determined in real-time to ensure effective licensing and accurate remuneration.

The IoV will be the backbone transfer network that secures contracts as well as digital media properties, and supports a wave of to-be-conceived applications which will enhance the lives of citizens, businesses and public authorities. The tokenisation of media assets will bring new opportunities to media and entertainment enterprises, such as secondary digital markets, protections of copies or new modes of fan engagement.

1 Background

The Internet is a formidable tool enabling participation in the cultural life of the community and enjoy the arts, but it is not up to speed in protecting the moral and

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material interests resulting from literary or artistic production. Things must and will change.

1.1 Business Imperative

Diminishing returns Although costs of reproduction and communication to the public are close to zero, the costs of licensing digital assets continue to increase.

For thousands of years, people have freely conveyed and translated works of others—either verbatim or with mild adaptation—until distribution became mechanical and then digital. Copyright is a child of the printing press; content business models are its grandchildren. The era of mechanical distribution was the *peak of copyright*, the theorised point in time when the maximum rate of return on content was reached, after which it seems to have entered terminal decline. This was the golden age when reproduction and distribution were costly but lasted only until the advent of digitalisation and the World Wide Web.

If (re)production and distribution are the flow of value from authors to consumers, then content licensing and royalty payment should be the counterflow of remuneration from consumers to authors. In the digital age, rights management is a complicated, imprecise, slow and expensive process. Advanced regulations and sophisticated business models are making it even more complicated, more imprecise, slower and more expensive. The creative industries are squeezed between the ever-decreasing costs of value flows and the ever-increasing costs of remuneration counterflows—an unsustainable situation. Policymakers are aware of the imbalance and want to fix it, but Web 2.0 is impotent to do so.

A stochastic value network The deployment of new web-based business models led to the emergence of a stochastic value network replacing deterministic value chains.

The American Music Modernization Act (MMA; Rice 2018) implies a straight value chain from songwriters and artists to recording companies, copyright owners, new mechanical licensing collectives and digital licensee coordinators, digital music providers and end-users. The latest European Directive on Copyright (European Union 2019) suggests a similar chain from authors and performers to rightsholders, management organisations, a variety of information society service providers, and several categories of end-users. However, the reality is very different. There is a mesh of relationships: any stakeholder can connect with any other directly. The end-user of today can be the author of tomorrow and vice versa; a digital music provider can also be a music producer. This is a value network enabled by interconnected networks using standardised communication protocols—the Internet. The participatory engagement of end-users—also facilitated by the Internet—will only amplify the intricacies of value generation.

The Open Music Initiative of the Berklee College of Music defined the minimum viable interoperability of an Application Programming Interface (API) (Berklee College of Music 2020) that could typically be used between a recording company and a digital music provider and applied to put the MMA into practice. However, so far this API conveys only static and straightforward metadata and does not mirror the complex, dynamic, fluid and transitional nature of the music industry. The MMA, therefore, will probably remain a temporary and limited solution.

A wicked problem at the edge Solving complex, dynamic, fluid and transitional Intellectual Property (IP) challenges in the media and entertainment sector—requires an independent multi-disciplinary approach.

The aforementioned problem can be characterised by the following six statements:

1. The very notion of copyright is a moving target.
2. The copyright problem can only have a temporary solution.
3. Tinkering with regulations makes matters only better or worse.
4. The copyright issue is a symptom of paradigm shifts.
5. Unrealistic policies have unforeseeable consequences.
6. Solving digital content remuneration is a unique process.

These six statements sound familiar: *Wicked* problems have no definitive formulation or solution; solutions to *wicked* problems are only better or worse; a *wicked* problem is the symptom of another problem; solutions to *wicked* problems have unforeseeable consequences; the process of solving a wicked problem is unique. Also described by Rittel and Webber (1973), wicked problem-solvers work in an area of tension between diverging interests, within which they must abstract their ideals. Copyright is a *wicked* problem; we will not solve it without making abstraction of the partisan interests of opposing lobby groups.

Since 1999, the world has become increasingly interconnected. In 2009, people interacted and shared ideas much faster, accessed an abundance of information, joined virtual and global communities and tried out new business models. Now, in 2019, society is at the *edge* (Shell 2016), a state expanding exponentially, scratching at problems with higher complexity, moving into unfamiliar social scenes, and addressing issues with a higher purpose. We can no longer solve the copyright challenge without considering artistic freedom, consumer privacy, children's security, energy consumption or democratic values. No single profession has all the answers.

1.2 Regulatory Imperative

Legal framework After numerous national patches, the century-old international Berne Convention remains the core regulation of the media and entertainment trade.

In 1450, Gutenberg was tinkering around with the printing press. Two and half centuries later, Queen Anne granted Royal Assent to the Copyright Act of 1710 (The Statutes of the Realm 1710). First, the technical disruptions of the printing press and phonograph prompted the businesses of publishing and recording. Then, authors requested the protection of their material and moral interests. What the Copyright Act did for commercial rights, the Berne Convention (Convention for the Protection of Literary and Artistic Works; WIPO 1986) did for moral rights such as author's attribution and work integrity. Policymakers regulate creative industries. Faced with the societal impacts of new distribution technologies, legislators balance citizens' freedoms of access with creators' rights to remuneration. Policy had always followed technology. That is, until 2016, when the European Commission proposed a directive on copyright that targets technologies, which are at best emerging. The paradigm has shifted: now, policy is preceding technology—uncharted territory (Rixhon 2018).

Now we must thread the needle. The moral rights of authors should be exercised according to the legislation of the Member States and the provisions of the Berne Convention, WIPO Copyright Treaty and Performances and Phonograms Treaty. Such moral rights remained outside the scope of the directive (European Parliament 2001) and are only mentioned in the directive (European Union 2019) to reiterate that they are the prerogative of the Member States. Moral rights do not have to be registered to exist, but copyrights—practically albeit not legally—ought to be registered somewhere to be remunerated.

Music Modernization Act The latest US legislation entails a database of works, reports of usage, as well as speedy and appropriate remunerations.

The Register of Copyright designates two not-for-profit entities, a Music Licensing Collective (MLC) on the side of copyright owners and a Digital Licensee Coordinator on the side of the Digital Music Providers, both monitored by qualified auditors. A Musical Works Database will be operated on one side, and Reports of Usage on the other side. At least now the collaboration between two stakeholder groups of one deterministic value chain of one content industry is regulated and will be organised.

Considering the multiple challenges around IP on the stochastic value network, the MMA is a modest but significant contribution. It closes loopholes, streamlines the collection and remittance of royalties, reduces legal uncertainty for digital music providers, and adopts the principles of fair market value. Composers, lyricists, performing artists and record companies should now receive fairer remunerations, and streaming companies should benefit from the efficiency of a blanket mechanical license and the security of reduced legal exposure. More importantly, the MMA draws a blueprint for stakeholder collaboration that can be adapted and used at various connections of the value network.

European directives on copyright The latest EU directive requires the identification and matching of works, rights and stakeholders, and the monitoring of usages and remunerations.

The directives on copyright contribute to the functioning of the Digital Single Market, provide for a high level of protection for rightsholders, facilitate the up-to-date clearance of rights, and create a framework in which the exploitation of works can take place.

According to the EU directive (European Union 2019) and its various exceptions, the payment of royalties for content communication to the public would require the:

- Identification of works, rights and stakeholders (authors, users and everybody in between)
- Matching of works and rights, works and stakeholders, rights and stakeholders
- Monitoring of usages of works and remunerations of rights
- Fulfilment of machine-readable contracts
- Protection of privacy and respecting of the Berne Convention

on the complex, dynamic, fluid and transitional value network, not only for music but also for films, press articles, etc.

The American MLC should launch operations on 1 January 2021; the European directive should be implemented on 6 June 2021. The American task is challenging but technically feasible; the European directive on copyright in the Digital Single Market is a letter of intent. At the technology level, no feasibility study has been conducted. At the business level, the stakeholder dialogue is still taking place. At the policy level, there is no Digital Single Market yet, but a group of 27 national jurisdictions. If, at least, the travails of the implementation conclude that a new approach is required to solve the wicked problem of copyright at the edge, then the time and effort spent will not have been wasted.

2 The IoV Promise to Media and Entertainment

To date, the IoV is still a research initiative, a work in progress. People who say it cannot be done should not interrupt those who are doing it. However, panacea marketers should not distract those genuinely searching for business solutions or opportunities. "The effectiveness and efficiency of innovation are directly related to the quality of the interactions between users and innovators during the whole innovation process" (Rixhon 2002). Accordingly, the following paragraphs are an attempt to connect users (new media business models) with innovators (emerging IoV).

2.1 Tokenisation of Media Assets

Standardisation Hierarchical tokens could be an effective and efficient solution to the need for standardised asset identification.

Everything that can be tokenised will eventually be tokenised—that is the foundation of the IoV. "Tokenisation increases the moneyness of an asset. Moneyness is the degree to which an asset approximates cash and thus is useful as a medium of exchange. An asset that can readily be converted into cash is similar to cash itself because it can be sold with little impact on its value and at low cost" (Tasca and Piselli 2019). Tokenisation, by increasing the liquidity of the media and entertainment market, may cause a rise in the velocity of exchanges, and in turn, on the general sector activity.

Because tokens have value and owners, one can deliver nearly any kind of solution with them. The hierarchical business tokens on EY's OpsChain (EY 2018b) can already represent assets and be used to exchange for sophisticated operational and financial services. Media assets are very complex; long-form musical films are perfect examples of their hierarchical complexity. Rightsholders will want to license such a film as a whole and each of its tracks individually. A vocalist on the second track might have already agreed on some exclusive usage of her recordings during a specific time window, and the songwriter of the penultimate track may want to block the performance of his composition in specific territories. Hierarchical tokens, by mirroring the complex structure of media assets, may help identify them and their subparts at an appropriate level of granularity.

Protection The non-duplicability of tokens and their incontrovertible relation with related digital assets could protect intellectual property in the digital sphere.

There was a time when the terms piracy and Digital Rights Management (DRM) were the buzzwords of the industry. Technological protection measures are access control technologies meant to restrict the use of copyrighted works. They tried to control the use, modification, and distribution of copyrighted works such as software and multimedia content, as well as systems within devices that enforce these policies (Office of the Privacy Commissioner of Canada 2006). This was not a success. First, it went against fair use policies and the right granted to consumers to make a few private copies. Second, it limited voluntarily the propagation of content only because the publishers could not monetise the copies. Recognising that DRM was counterproductive, content industries and policymakers introduced levies, a suboptimal blanket tax on the copying systems.

The IoV could change that. Indeed, it should not prevent copies, provided that each new copy is automatically monetizable; in this case, it should incentivise copying. Digital watermarks and digital fingerprints are tools to identify contents and trigger their protection, local enrichment or semi-automated monetisation. The breakthrough for automated monetizable propagation could come from the development of non-fungible tokens as shown by the CryptoKitties game. Non-fungible tokens represent something unique and are thus not interchangeable. They are used to create verifiable digital scarcity, user ownership, and the possibility of asset interoperability across multiple contexts in applications that require unique digital items. They are controlled by the user, instead of the publisher. This lets the assets be traded on third-party marketplaces without permission from the originator. Theoretically, a combination of content-based standard identifiers, non-fungible tokens and fungible sub-tokens could solve the challenge—notwithstanding the scalability question.

2.2 Smart Contracts

Simplification The automation of intercompany transactions could rely on templates and simplify the intricacies of current contracting.

It has been said that the music industry is a lawyers' affair and not an artists' business. There is some truth to this statement, and it does not only apply to the music industry. Most interactions among citizens, commercial or governmental organisations are subject to complicated rules and practices. Contractual effectiveness and efficiency will not come without simplification and trust.

Here, the IoV promise is called smart contracts. They are computer programmes, a bit like Excel macros, intended to facilitate, verify, or enforce the negotiation or performance of an agreement. Smart contracts allow the execution of credible, trackable and irreversible transactions without the involvement of intermediary third parties. They present a few challenges. Irreversibility might be a virtue in some applications, but not necessarily in all of them. That could be solved technically. Macros are formulaic standards that constraint the human propensity for exceptions. One could start by coding Creative Commons or similar standardised licences. They are non-revocable, so immutable macros would be an ideal means for recording the licensing information. When rightsholders register their works on a register using such a license, that license would be attached to the work for all times (De Filippi et al. 2016).

The biggest challenge is our relationship with the code and the expansion of algorithmic governance (see Chapter "The New Internet of Value Financial Ecosystem"). Twenty years ago, Lessig (2000): "Th[e] regulator is code – the software and hardware that make cyberspace as it is. This code, or architecture, sets the terms on which life in cyberspace is experienced". Two years ago, witnessing the advent of blockchain and machine learning, Hassan and De Filippi (2017) distinguished between legal rules, which stipulate what people shall or shall not do and technical rules which determine what people can or cannot do, eliminating the need for intermediary enforcement authorities. We are moving into unfamiliar social scenes.

Transparency Machine-readable-and-executable contracts could be fitted with real-time monitoring and comply with the most recent US and EU regulations.

Society is not ready to accept fully automated contracts—at least not yet. Contracts should be understandable. Can users understand coded macros encapsulated in black boxes? Can we understand coded laws whose rules evolve as information is gradually fed into the system? Most contracts are drafted by trusted people, governed by trusted laws and arbitrated by trusted courts. Can we trust machines?

On the other hand, how can we implement the new European directive efficiently on copyright without machine-readable-and-executable contracts? For the time being, we will rely on hybrid human–machine trust assurance, just like the way we board planes, which most of us do not understand, solely due to the trust we have in airline companies, plane manufacturers and civil aviation authorities, because we know that they understand them. In the same manner, the music industry is going into the MMA, reassured by the fact that the databases Musical Works and Reports of Usage is understood by the Register of Copyrights (a human organisation), systems engineers and qualified auditors.

Similarly, the smart contracts managing licensing agreements and royalty payments will be specified, coded, monitored and audited by teams including trusted lawyers and engineers. These specifications, coding, real-time monitoring and audits will be supported by computers, as is done in accounting.

2.3 Data Architectures

Distribution Previous attempts to centralise identification and metadata of media assets have failed. Keeping them distributed could succeed.

The Global Repertoire Database (GRD) aimed to create a central database to identify the owners, beneficiaries and administrators of lyrical and musical copyrights, enable licensees to find who controls the musical works they want to use, and facilitate efficient distribution of royalties (Cooke 2014). It failed for various reasons. *One*, global central database means a single *one* in the world. At first glance, it seems appropriate for *one* world wide web, but utterly utopian as *one* world government or monopoly would be. Other weaknesses included the deficient mirroring of the reality of the music industry, the necessity to handle *clean* data, and the lack of a performing dispute resolution mechanism.

One or many? As soon as we discard the concept of a single database, we should also abandon the idea of a few databanks and focus on interlinking a multitude of data repositories. This would come closer to the reality of human relationships and the nature of the Internet. It would also form a grid that is much more secure and resilient. Public domain or private property? Data are private assets that should be managed, controlled and protected by their owners. Therefore, a global repertoire ought to be based on a networked architecture of a multitude of private and proprietary data repositories.

The GRD failure was necessary to approach a solution. Lessons have been learned and applied. The Cube copyright platform developed by ICE Services in collaboration with Stage (ICE Services 2020) and the URights solution developed by SACEM in collaboration with IBM (Urights.net 2020) are—albeit via different methods—addressing the weaknesses mentioned above.

Governance Notwithstanding the remote possibility of trusted self-regulating systems, governance should remain a computer-aided human task for the foreseeable future.

Bill Rosenblatt, a globally recognised authority on technology issues on intellectual property in the digital age, recently wrote: "The MLC [. . .] is required to maintain a publicly accessible database of [mechanical rights] information and to accept data submissions in order to improve accuracy and currency. For rights databases, trust and governance are as important as efficiency; and blockchain technology has the potential to improve all of these areas if it can scale" (Rosenblatt 2019).

The developers are getting there. They may face the *blockchain trilemma*, "a term coined by Ethereum founder Vitalik Buterin that addresses the problem of how to develop a blockchain technology that offers scalability, decentralisation and security, without compromising either one" (Ometoruwa 2018). Attempts include Plasma, which can perform many complex operations by partially running them on a second layer on top of the consensus layer (Plasma 2019) or Hedera, based on directed acyclic graphs (Hedera Hashgraph 2020). Unproven technologies so far, but promising research. Developers are competing to reach mainstream adoption: watch this space.

The MLC is an experiment at computer-aided governance, bringing together recording companies, digital music providers, government, music publishers and songwriters' associations. It must be re-designated every five years. The technical solution will need to be re-designed too if its operator wants to leverage the DLT of the latest generation to improve trust in and governance of the rights and royalty system.

Integration The full benefit of smart contracts models would depend on their integration with regulatory compliance, tax and audit, and back-office infrastructure.

Typical issues faced by the media and entertainment industry include manual intercompany invoicing and payment procedures, the lack of materiality thresholds for intercompany allocations and journal entries, inconsistent global intercompany processes due to fragmented ownership, manual Excel and Word (yes!) modelling and calculations, and foreign currency exchange considerations. "Using smart contract functionality, an organisation can establish automated intercompany transaction processes. These contracts can have pre-developed processes, transaction thresholds and use "oracles" (e.g. Reuters to inform exchange rates) to reduce manual calculations (EY 2018b).

DLT will do for networks of enterprises and business ecosystems what ERP did for the single company: integrate information and process within and across enterprise boundaries. Using tokens and contracts will be the standard method by which companies transact with each other. However, that will require integrated solutions designed to solve multiple business problems with a solution based on a single distributed database, ensuring that data is stored consistently and only once, and supporting connections between processes and facilitating reporting across these processes. It will also require that DLT-based solutions shift from a separate parallel system towards integration with users' back offices and existing laws and regulations to ensure seamless business processes, convertibility, and audit controls.

3 Solving Problems

3.1 What It Will Take

Distributed ledger technologies To allow the permanent, immediate and transparent booking of licensing transactions in decentralised databases.

Distributed ledgers will allow media and entertainment enterprises to take advantage of single immutable records distributed across all nodes of a trusted rights network. Electronic markets for media assets will eliminate imbalanced transactions and discrepancies between different back-office systems, report accurately and timely, and improve compliance (Ibañez et al. 2021). The question is not if, but when.

Five developments will be necessary to transform DLT into a standard tool for enterprise interactions. Tokenisation, integration and a solution to the blockchain trilemma have been mentioned. We also need a shift from private blockchains used by corporations to public blockchains used by everybody, whereby the integration of both types could be the better approach. Private blockchains protect the privacy and security of their data. Participation requires an invitation, which itself is validated by a set of rules. Such blockchains are known as *permissioned* blockchains and are preferred for B2B transactions. Public blockchains are open networks that allow anyone to participate. These *permissionless* blockchains depend upon the number of users for their success, hence, they encourage participation through incentives. Today, they appear indispensable for B2C transactions. Furthermore, we need a transition from cryptocurrencies to fiat-backed *stablecoins* although, again, the integration of both types of money could be the better method, just like the incentivising compatibility of loyalty points and government-backed currencies.

Other necessary established or emerging technologies To translate real-life contracts into smart contracts and allow intelligent agents to recognise IP items and environments.

In the content industries, we love creating assets but dislike managing their metadata. We distinguish between rights data (identifiers, usages, rights, licenses and royalties), catalogue data (necessary to find an asset and for an asset to be found) and content data (enabling the enrichment of user experiences). Metadata in the media and entertainment industry are not yet ready for automated licensing. The use of identification standards is sporadic. Metadata structures differ significantly, are incomplete and contain errors. The poor quality of rights and catalogue metadata, and a century of failed attempts to standardise them, necessitate the development of intelligent metadata *ingestors*. These *ingestors* will rely on machine-trained pattern recognition and rule-based algorithms to digest non-standardised, incomplete and erroneous metadata and transform them into tokenised data subsets tradable through smart contracts.

We are the stewards of extraordinary catalogues but also of unmanageable numbers of agreements. They need to be translated into smart contracts. Here again, we will require need machine learning to support lawyers and engineers in their coding efforts.

We will also need digital object identifiers—tags or watermarks added to the media assets or digital fingerprints or content-based block hashes—to allow intelligent agents to recognise IP items and their contexts and maximise the chance of these agents triggering or fulfilling machine-executable agreements successfully. Finally, we will require considerable computer processing, storage, high-performance networks, and as little electrical power as possible (see Chapter "Consensus: Proof of Work, Proof of Stake and Structural Alternatives") to manage in near real-time the complex and dynamic rights associated with billions of daily transactions.

3.2 Where We Are

Are we at Kitty Hawk with the Wright brothers (1903) or in Dover with Louis Blériot (1909)?

Development trajectories are for engineers what hype cycles are for marketeers. Propelling planes with steam engines had been attempted, but powerplants with sufficiently high power-to-weight ratios were too difficult to build and abandoned. Combustion engines solved this problem, and humans could finally fly in the directions they wanted. Then came jet engines, a kind of second-generation powerplant. Finally, we connected airports with railway stations and highway interchanges and got a new worldwide transport grid. When it comes to the IoV and media and entertainment, we may be approaching Dover. For capacity, we will have to build Airbus 380s or Mriyas, for speed Concordes.

Imogen Heap "didn't expect to be able to develop a thing [. . . but thought if she] could just share an idea maybe someone would make something but, in the end, nobody was doing this thing" (Bitcoin Exchange Guide News Team 2018). Excited by the potential of issuing music on a blockchain, she released the song *Tiny Human* on Ethereum's public blockchain in October 2015. Heap found that decentralised technology could be leveraged as part of a sophisticated solution, but that on its own, it still had flaws. The bitcoin blockchain was not the answer (Mycelia for Music 2016). Recognising that music makers are the fabric of the music industry, Mycelia—Heap's team—is now developing *The Creative Passport*, a digital container aiming to hold verified profile information, acknowledgements, works, business relationships and payment mechanisms to help get music makers and their works linked and open for business. Using emergent DLT and featuring smart contracts, *The Creative Passport* plans to enable quick and easy direct payments and simplify collaboration from creativity to commercial partnerships (The Creative Passport 2020).

EY and Microsoft have joined forces to develop a rights and royalties solution for the gaming industry. Their embedded smart contracts are designed to enable accurate and real-time calculation of royalty positions, providing enhanced visibility for recording and reconciling royalty transactions. The underlying trust network is built using the Quorum blockchain protocol and implements confidentiality of agreements across entities. Xbox's game publishers, who are participating, get improved speed and visibility. They can generate daily accounting accruals and use timely data to improve their forecasting (EY 2018a).

4 Seizing Opportunities

4.1 Metered Consumption and Micropayments

Limitations of subscription and ad-based models Subscriptions are limited by consumer wallet size and eclectic consumption behaviour; the productivity of ad-based streaming remains to be proven.

There are basically four business models for distributing audio, video and other media content over the Internet:

- Free of charge—typically used by public services such as state-owned media outlets like ZDF/ARTE in Germany or the BBC in the United Kingdom.
- Subscriptions—grant users access to a service, typically to listen or watch until they unsubscribe. They can listen or watch with no limits. The best example of such a business model is Netflix.
- Transactions—usually this does not involve users signing up for the service or create a user profile. Instead, they pay based on the content they listen to or watch. This relates to movies and is also used for series, sports and events. iTunes is an example of a transaction-based service.

- Advertisement—free for users, whereby they log in and stream music or videos in return for spending time watching ads. YouTube is the best example of such an ad-based service.

Many content distributors opt for a mix of business models, for example, subscriptions and advertisement as done by Spotify and YouTube, or hybrid forms such as *freemium*, where teasers can be accessed free of charge but premium content is behind a paywall, as practised by most online newspapers and magazines.

Free of charge is intrinsically problematic, and there is a wallet-limit to the number of subscriptions an eclectic adult can take, while the younger generations are reluctant to pay for anything in advance. Finally, ad-based models are awkward; their rightsholders' remunerations cumbersome, their exploitation of users' data restricted and their effectiveness circumvented by ad-blockers.

Metered pay-as-you-go Real-time micropayment is the "natural" way ahead, but bundles would still be allowed, and consumer privacy and security must be respected.

Transaction-based business models offer the fairer, most flexible and preferred remuneration process. They are widely used by gas, water, electricity, telephone and broadband providers, in transport (train tickets and highway tolls), and by financial institutions. They rely on (smart) metres, are easy to use (contactless smart cards), offer discount mechanisms (prepaid amounts and data packages), and can be bundled, monitored, reported and audited.

In media and entertainment, not only do the transactions involve tiny amounts of money, but these minuscule sums must often be split among many rightsholders according to complex and dynamic rules, whereas the cost of the transaction process must remain affordable. Combining the functionality of tokenised assets and smart contracts should open the door to speedy and affordable micropayments.

There have been two exemplary related developments. First, Lightning is a decentralised network using smart contract functionality to enable instant payments across a network of participants. It is meant to allow instantaneous payments, work across blockchains, and be scalable and low cost (Lightning Network 2020). Meanwhile, AdEx is a trust-minimised solution for digital advertising that aims to reduce ad fraud, improve ad budgets and protect user privacy. The platform connects publishers and advertisers without intermediaries on a decentralised exchange and provides both parties with real-time reporting. AdEx payment channels solution allows micropayments for each ad impression—a unique benefit for advertisers and publishers (AdEx Network 2020).

4.2 Creativity, Consumption and Granularity

Track-based licensing The granularity of licensed digital assets is increasing, typically from a concert to a song to a musical phrase, from a text to a title, from a film to a picture.

Keeping track of all the music used in films or on television shows is a formidable task that requires vast and systematically updated computer databases which log the music composed for past and new productions. Cue sheets are used to make this immense task feasible. Without them, it would be impossible for composers and publishers to be compensated for their work. An accurately filled out cue sheet is a log of all the music used in a production. If there is more than one composer for an individual piece of music, or if the writer and publisher split their royalties on anything other than a 50/50 basis, this must also be indicated on the cue sheet, as these are important factors in payment calculations. With the increase in independent producers and streaming operators, the filing of accurate cue sheets has become even more crucial to track the use of music (BMI 2020) and remunerate all the rightsholders of one film or one TV show.

Now that hierarchical tokens, trusted networks, smart contracts and micropayments are in sight, granular, track-based licensing will—perhaps soon—be significantly facilitated. This will allow the licensing of one track of a film or even of one part of one track of a film for the purpose of streaming it as it is or remixing it. A world of new monetisation possibilities is opening.

Micro-licensing Real-time micropayments could support micro-licensing based on time, territory, channel or use.

What is valid for the granularity of the media asset is also true for the granularity of the usage of that asset. Time, territory, channel and use can be split. The granularity of usage parameters will enable flexible and dynamic business models, increase revenues and amplify collaborations. Smart-contract-automated real-time micropayments are a condition, the uncertainty around rights availability a consequence.

A crucial prerequisite for short-lived and granular content transactions is the ability to address and identify content quickly. However, the press and other industries dealing with digital content do not even have standard identifiers, e.g. there is no widely adopted, standardised identifier for images. The overhead and costs of manually assigning and tracking identifiers for them would be prohibitive. Auto-generated identifiers created algorithmically from the content itself could be one solution (ISCC 2020).

"With the advent of DLT, the IoV is moving towards a trusted network of peer-to-peer transactions. In a multi-sided ecosystem, anybody may have a legitimate interest in generating or looking up an identifier for some digital content. In an increasingly heterogeneous media environment, open and accessible standard identifiers that are specifically designed to manage small and sometimes transient pieces of digital media content will be essential for transactions" (ISCC 2020). They will replace proprietary identification systems and provide a socio-politically acceptable implementation of Article 17 of the EU directive 2019/790.

4.3 A Secondary Market for Media Assets

Peer-to-peer exchanges of pre-owned media assets Prices in the primary market are usually set beforehand, whereas prices in the secondary market will be determined by the economic equilibrium between supply and demand.

An ambitious *theoretical* promise is based on a modest premise: it should be possible to extrapolate fintech uses of blockchain to media and entertainment. In 2019, a nominal share is a digital file, and so is a song or a film. What applies to nominal shares might apply to .mp3 or .mp4. A company issues shares: the copy of a share is not a share and has no value. An author issues media assets: the copy of a media asset is not an asset and has no value.

A nominal share changes holder through a blockchain transaction. The blockchain transaction is immediately and transparently recorded into the shareholder register, a distributed ledger. The shareholder registrar knows who is holding the nominal shares and how they came to their holders. A media asset changes holder through a blockchain transaction. The blockchain transaction is immediately and transparently recorded into the fan register, a distributed ledger. The fan registrar knows who is holding the media assets and how they came to their holders.

First, the stock market sets the current price of a share; then, it exchanges that share. First, the secondary market for media assets sets the current price of a media asset; then, it exchanges that media asset.

4.4 Next-Generation Engagement

Token-based direct interaction Just as the issuer of nominal shares must be able to contact a shareholder, the issuer of media assets will be able to interact directly with the asset holders.

Companies issuing nominal shares must conduct corporate actions. They must invite their shareholders to general assemblies, send them reports and proxies and collect their votes. Equally, artists publishing media assets should be able to engage fans. They should invite them to concerts, send them news and alerts, sell them merchandise in context and facilitate their participation.

A media asset changes hand only against payment while the asset register is updated. Issues of media assets can be limited or unlimited. Current readers and players can read and play blockchain media assets, and existing online shops can sell blockchain media assets.

The previous paragraphs are a *theory*. They outline what could soon be technically feasible without yet considering business sustainability or societal frameworks. Typically, the concepts of privacy which apply to *nominal* shares are not the same as the principles of privacy which apply to the consumption of media and entertainment. The European General Data Protection Regulation (GDPR) that came into force in May 2018 is a case in point; the reconciliation of GDPR and DLT an object of research (for further information see Finck 2018). A new method for managing online identities, consent, privacy and the right to be forgotten will be necessary to implement the above-mentioned theory in practice.

Collaborative Creation Distributed ledger technologies will not only mediate the contact between authors and consumers but will also support their active collaboration.

In media and entertainment, fan engagement grows step-by-step. Publishers—

1. Present high-quality content on various media;
2. Adapt same idea or content to various media;
3. Enable customers to follow content from one medium to the next;
4. Empower customers to discover content, and engage in different media;
5. Enhance customers' lives by triggering their active collaboration.

Customers' loyalty and willingness to pay are directly related to real value—their engagement with content. Artists and producers have four aces in their sleeves. First, they can enrich and offer additional context, thrilling stories, virtual reality and useful services. Second, they can interact and let customers play games, exchange among themselves, and connect with artists and productions. Third, they can embed promotions and transactions into video players, sell in context, ease the buyer experience, offer augmented exposure to sponsors, and generate valuable audience data. Finally, they can add even more value by personalising and presenting relevant content across all touchpoints, tailored in real-time according to customers' profiles, momentary situations and predictions.

Distributed ledger technologies and blockchain will be instrumental to build trusted exchanges of digital content against remuneration. What TCP/IP did for the transfer of information, blockchain will do for the transfer of value. Access and remuneration will be synchronised. The promise of Article 27 of the Universal Declaration of Human Rights will be realised; what Web 2.0 did for the access to culture and media (United Nations 1958), Web 3.0 will do for the remuneration of artists and authors (United Nations 1958). The IoV will have a radical impact on all aspects of media and entertainment from creation to collaboration, distribution and remuneration. Value creation, measurement and exchange will remain the core of our industry.

Harnessing the IoV will be its most critical success factor.

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Solving Challenges in the Media Sector with DLT

Soichiro Takagi

Abstract

Throughout history, media is a field that has been affected by technological development. Since the 1990s, the Internet has been the main driver of influence, profoundly affecting how people create, transmit and share information worldwide, consequently changing the structure of the media sector. Although digital technologies are transforming the media sector, various challenges are arising as seen in fake news and echo chamber. This chapter explores how distributed ledger technology (DLT) and blockchain technologies can contribute to solving new challenges in the media sector. This is worth exploring because the central advantages of blockchain/DLT are related to trust, and the new challenges in the media sector are mainly related to the lack of trust. This chapter provides a framework to show the benefits of using blockchain/DLT and discusses how those benefits can solve the challenges in the media sector.

1 The Changing Structure of the Media Sector

1.1 Media and Distributed Ledger Technologies

Throughout history, media is a field that has been affected drastically by technological development. The letterpress technology invented by Gutenberg in the fifteenth-century transformed how religious ideas are transmitted. The invention of the radio and television enabled information to be transferred among people instantly. Since the 1990s, the Internet has been the main driver of influence, profoundly affecting how people create, transmit, and share information worldwide, and consequently

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changing the structure of the media sector. Using the Internet, people can create and share information with a far more extensive range of audiences on a global scale. Anyone, not only professionals in the media sector, can exchange their views and opinions on social and political issues across distant locations and national borders.

Although digital technologies are transforming the media sector, new challenges are arising. For example, "fake news", which aims to disseminate false information based on a specific self-interest, has become a social problem. The flow of information is curated by platform services such as social networking services, but people are not fully informed as to how that curation is conducted. Although the Internet has offered a broad range of opportunities to harness the potential of people to create, transmit and share information, new challenges are also arising in the media sector.

In this context, this part explores how DLT and blockchain technologies can contribute to solving new challenges in the media sector. This is worth exploring because the central advantages of blockchain/DLT are related to "trust", and the new challenges in the media sector are mainly related to the lack of trust, as demonstrated by the following sections.

The next part is structured as follows. The remainder of this introductory section clarifies the main values of media in modern society and demonstrates how the Internet is changing the structure of the media sector. Section 2 presents and discusses the challenges caused by the Internet revolution. In Sect. 3, the benefits of using blockchain/DLT in general are summarised by using a framework. Section 4 discusses how the benefits of using blockchain/DLT can solve challenges in the media sector. Section 5 concludes the discussion.

1.2 The Value of Media in Modern Society

When people refer to "media", it has two meanings depending on the context. The first is "medium" of information, which supports conveying information from person to person. This has taken the form of materials and methods such as stone, paper, radio, and television, which have worked as a medium of exchanging information. The other is the role of "mediation" of information, which is the activity of collecting, transmitting, and sharing information, usually curating and editing the information to fit social demands and the interest of audiences.

Whether it is a professional media service or an amateur journalist, the valuable functions of media can be presented as

1. Conveying information.
2. Curating information.
3. Presenting discussion points.
4. Providing a public space for discussion.

The first is conveying information, which is the transmission of information from one place to another, including the creation of content to describe facts. This can be observed in various situations such as political activity, disasters, and news about local retailers.

The second is curating information, which is the selection of information that should be delivered to audiences. Curation is affected by a variety of factors, such as the constraints on resources (e.g., newspaper space), the writers' interest, the interests of society, and potentially the interests of sponsors and advertisers.

The third is structuring discussion points, which is the editorial function that suggests how the information should be interpreted and what should be discussed by audiences. This is done partly through the curation of the information and partly by editorial comment and articles.

As an extension of offering discussion points, the fourth is providing a public space for discussion so that people can communicate and discuss social topics to deepen their understanding and occasionally build consensus on the direction of action. This is related to the concept of the "public sphere"; that is, the place where public opinion is formed (Habermas 1991).

From the first to the fourth valuable functions of media, the tasks become more complicated and include normative interventions. In other words, they shift from focusing on the simplest form of media as the transmitter of information to becoming a subjective activist in society, as seen with journalism.

1.3 Macro-Level Changes in Key Attributes of Media

In the last 20 years, the emergence of the Internet has dramatically impacted the media sector. Table 1 shows the change in key attributes of media at a macro-level, comparing newspaper, radio/TV, and the Internet. The flow of information has shifted from "One to N (a number of people)" to "N to N". This shift reflects a change in key resource constraints to disseminate information.

Table 1 Changes in key attributes of media

	Newspapers	Radio/TV	Internet
Flow of information	One to N	One to N	N to N
Producer of information	Professionals	Professionals	Anyone with an Internet connection
Key resources	Paper, Printing machinery, Distribution capacity	Radio wave license, Broadcasting facilities	Internet connection, Devices
Reach of information	Limited to logistical boundaries	Limited to radio wave boundaries	Limited to Internet connections

In the newspaper age, papers, printing machinery, and distribution capacity played important roles as key resource constraints. Radio/TV also requires similar resources such as radio wave licenses and broadcasting facilities. However, in the Internet age,

Table 2 Key providers of media values on the Internet

	Web-news	Blogs	Social networking services
Conveying information	Professional media person	Anyone	Anyone
Curating information	Professional media person	Not curated	Platform services
Presenting discussion points	Professional media person	Not provided	Autonomously structured, influenced by platform curation
Providing public space for discussion	Professional media person	Not provided	Autonomously provided, influenced by platform curation

all that is needed is an Internet connection and low-cost devices to disseminate information, such that a vast number of people have begun creating and publishing information.

However, the reach of information has also expanded drastically alongside technological development. The logistics of physical papers have limited newspapers; content of Radio/TV has been transmitted to the extent of the reach of radio waves. However, information on the Internet can be transmitted globally as long as audiences are connected to it (although language differences are working partly as practical barriers to information flow). Consequently, the role of collecting and disseminating information has been drastically expanded from only a limited number of professionals to a wide range of participants, including ordinary citizens. The amount of information circulating in society has also exploded.

1.4 Key Providers of Media Value on the Internet

When we examine more closely who is playing essential roles in the valuable media functions mentioned above on the Internet, we can analyse them according to the different tools they use, as shown in Table 2.

In web-news media, the four valuable functions of media are provided by professionals of the media sector. This has not changed substantially since traditional media such as newspapers and televisions. However, blogs can already be written by anyone who has an Internet connection. The written blogs are posted without curation, and usually no one officially takes the role of structuring discussion points or offering a public space for discussion aside from individual authors' opinions. Thus, audiences have to search for information which matches their interests from a vast number of blogs online.

Emerging social media platforms such as Twitter and Facebook were designed to solve the curation problem by managing information based on the social connections of users. Curation by Internet search engines, such as Google, has also become more important, as the amount of information has exploded, making it difficult for people to find what they are looking for without assistance. Therefore, important functions of media are provided increasingly by platform services such as Google, Facebook, and Twitter. Regarding presenting discussion points and providing public spaces for discussion, it is generally autonomously provided by users but greatly influenced by the curation of platforms, as platforms control what information is presented to each user.

One of the problems in platform-centred media is that the curation by platforms is conducted by "black box" algorithms, which include various variables such as users' preferences and social networks. It is difficult to audit the algorithms and compare personalised outcomes. This issue raises concerns over trust in new media compared to traditional media.

The emergence of the Internet has made citizens major players in the media sector, and the distinction between producer and consumer of information has become vague. Anybody can collect, produce, and disseminate information and opinions on a global scale and at a low cost. This has caused an "explosion" of information, making it difficult for audiences to find important information. Platforms such as social media were introduced to solve the problem by curating information based on social networks, but several problems arose, as illustrated in the next section.

2 Key Challenges in the Modern Media Sector

As more information is created and published not only by professionals but also by the general public, the variety and quantity of information have been widely enriched in society. Moreover, it is the person who knows the topic best who can provide the most valuable information. For example, reviews by actual users of washing machines and refrigerators are sometimes more valuable than reviews by professionals who have not actually used the appliances in their daily lives. However, the impact of the Internet on the media sector has also raised several challenges, as shown below.

2.1 Fake News

Fake news has become a social problem due to the ability of anyone to publish and disseminate information through websites, weblogs, and social media. Fake news can be defined as the intentional dissemination of false information with a certain purpose. It is sometimes based on a political goal or interest, or simply aims to cause confusion in society. Fake news occurs because there are no mechanisms to check the quality of information at the origin, and by people's intrinsic willingness to disseminate information, which is amplified when the information is surprising.

2.2 Disruption of the Professional Media Sector

As people spend more time on social media consuming information generated by other users, advertisement expenditure has been shifting from traditional media to Internet platforms. Google's advertisement revenue reached USD 95.4 billion in 2018 compared to all US newspapers earning USD 16.5 billion (Fox 2019). However, web services and social media companies such as Google or Facebook only convey information on their platforms. They do not bear the same responsibility for writing, editing, and checking the information accuracy as the traditional media sector. As the traditional media sector declines, it could become difficult to maintain jobs for such professional editors and journalists.

2.3 Echo Chamber

As a result of expanded sources of information online and social media's curation prioritising "click" rates, people tend to be exposed only to views similar to their own. This phenomenon is called "Echo chamber" or "Filter bubble" (Pariser 2011). This is caused by various web services from search engines, web-news to social media platforms as soon as they personalise content based on users' preferences and past activities. Consequently, people are wrongly inclined to feel as if all others think as they do.

2.4 Online Advertisement Fraud

As mentioned earlier, advertisement expenditure is shifting from traditional media to Internet services. However, Internet advertisement is facing another problem: ad fraud ("Ad Fraud"; Wikipedia, 2020). This occurs when the number of advertisement exposures to audiences is manipulated and reported to advertisers, who then must pay excessive fees for ads. In other cases, online advertisement is not displayed at all for viewers but hidden behind a website and counted as if they were actually viewed by audiences. It is estimated that ad fraud will reach USD 50 billion by 2025 (Shields 2016). This is a consequence of the difficulty of tracing activities online, compared to newspaper adverts, which can easily be checked by advertisers through printed papers.

Several challenges are arising as the media sector changes. The common and essential factor behind the challenges is the lack of trust caused by the explosion of the number of players creating and disseminating information. The central topic of this chapter is how these challenges can be solved by blockchain/DLT; therefore, the next section explores the benefits and advantages of using the technology.

3 Benefits of Blockchain/DLT and General Use Cases

There are several benefits of using the blockchain instead of conventional relational database management systems (RDBMS). In this chapter, the benefits are summarised according to three attributes: anti-tampering, value circulation, and traceability.

3.1 Anti-tampering

Conventional information systems protect information from being tampered with by building firewalls and via strict user-authentication techniques. However, blockchain/DLT can protect information from manipulation by linking data from its origin to its latest status and by auditing the data in transparent settings. In other words, blockchain/DLT can ensure the integrity of data even if the information is shared with a number of anonymous users.

Through this attribute, enterprises can reduce the costs of securing data against tampering. This means that protecting the integrity of data is no longer a core function of some organisations, and its role can be delegated to the blockchain network.

A typical use case of anti-tampering is the storage of educational records, as practised by the University of Nicosia (2015) and the Massachusetts Institute of Technology (MIT 2020). They store the key information of the education certificate (typically a hash value of certificate) in the Bitcoin blockchain, thus ensuring that the digital certificate is genuine and not counterfeited.

3.2 Value Circulation

Most blockchain/DLT platforms provide a function to build a linkage between value and specific entities, such as Bitcoin and Bitcoin owners. Given that blockchain/DLT does not depend on the trust of specific organisations or authorities, blockchain/DLT enables everyone to create a system to manage value. These systems can capture, record, and symbolise various types of value and transfer this value across diverse stakeholders. Typical usages are cryptocurrencies such as Bitcoin, but many types of value, such as electricity and land ownership, can be managed with blockchain/DLT. This attribute also works to create various incentive mechanisms driven by the issuance of tokens.

Various examples using this attribute can be observed. For example, Ant Financial provides a blockchain-based inter-exchange system between mobile payment services. They constructed a blockchain-based system to connect Alipay and GCash in the Philippines, so that users of each service can send money across different mobile payment platforms. In another example, Earn.com integrates Application Programming Interfaces to micro-payments and enables the value of small data to be captured and makes them tradable between anonymous stakeholders. As an extension of embedding payments in M2M transactions, electricity is also a significant field using blockchain/DLT. Digital Grid, a Japan-based electricity technology company, is providing an ecosystem in which houses and buildings can exchange solar-powered electricity by using blockchain, which manages the flow of electricity and coordinates market transactions of electricity (DIGITAL GRID Corporation 2020).

3.3 Traceability

The trust in the integrity of information in blockchain/DLT is ensured by the logical linkage of transaction data from their origin to their present state. This historical management of transactions enables us to trace back how information originated and was transferred across stakeholders.

For example, Everledger traces how the ownership of diamonds is transferred across many owners, and Walmart is using blockchain/DLT to trace the transactions of foods to ensure that the products they sell are genuine and safe. On the other hand, the UK government conducted a trial using cryptocurrency technology for welfare payments to check that the assistance is provided as intended by legislation. In another instance, Startbahn created a system which manages the trade of artworks, so that the original creators can obtain a certain portion of the value generated in the secondary market.

As evidenced above, the benefits of using blockchain/DLT can be summarised in trust-related three attributes, and cases utilising these attributes are observed in various sectors. The next section discusses how these benefits can be applied to the challenges in the media sector.

4 Solutions for the Media Sector

As observed in Sect. 2, many challenges in the media sector are related to a lack of trust, therefore these challenges could be solved by blockchain/DLT-based solutions. The following argument discusses how blockchain/DLT can solve the key challenges introduced in Sect. 2, considering the benefits of blockchain/DLT as shown in Sect. 3.

Against fake news, the central approach is to minimise the incentives to disseminate false information and motivate people to share only truthful information. As truthful information has a certain value for society, "value circulation" approaches can be used. Typically, tokenisation can be considered, such as seen in its primitive form in Bitcoin, where token issuance motivates people to contribute to maintaining the trust of information in Bitcoin payments. Examples of this approach are observed in Steemit[1] and ALIS,[2] which issue and use tokens to incentivise people to create and share information highly valued by others. However, it is worth noting that incentivisation by token issuance should be carefully analysed and designed to assure that its value formation is sustainable. Another method is to store a complete record of information history by using anti-tampering, and traceability approaches so that one can trace back how fake news is disseminated. However, this should also be carefully considered in order to avoid sacrificing privacy and the right to free speech.

The second issue was the disruption of the professional media sector. A traceability approach could be used to securely store and share how much each article is

[1] Steemit - https://steemit.com/.
[2] ALIS - https://alismedia.jp/.

viewed and valued by others, to ensure the author of the information is appropriately compensated. It is also possible to include evaluation mechanisms by audiences. It is a particularly reliable solution where platforms are earning excessive rent and writers are not appropriately compensated.

As demonstrated in Sect. 1 that analyses the important role of platforms as curators of information, the key to the solution for the Echo chamber problem is the behaviour of the platform providers. The focus should be on enhancing the trust in and transparency of the algorithms curating information for users for the audiences to understand and check how information is selected and displayed to each user. The anti-tampering attribute could be used to store the curating algorithm and compare the results of curation across different users.

Lastly, online advertisement fraud can be solved via two approaches: anti-tampering and value circulation. With anti-tampering, displayed ads or their identifiers can be stored from users' web browsers into blockchain/DLT, and the payment of advertisers can be based on the stored information. This approach depends on the functionality of web browsers but can reduce the risk of manipulated records of advertisement. On the other hand, as an example of the value circulation approach, Hakuhodo, a Japanese advertising agency, is creating a solution which converts digital advertisements into digital assets so that users can proactively collect digital ads rather than passively view displayed ads. In this case, collected digital ads can be used, for example, discount coupons for products of the advertisers (HAKUHODO 2019).

These are examples of approaches for solving challenges in the modern media sector; other solutions can be envisaged considering the three benefits of using blockchain/DLT.

5 Conclusion

As observed in this chapter, the media sector is in the middle of a transformation driven by the Internet revolution. As technology has empowered people to create, collect, and disseminate information, the media sector is facing a different ecosystem involving a proactive public rather than simply media professionals. Alongside this transformation, there is the challenge of making the media space trustable and accountable.

Key advantages of using blockchain/DLT are related to enhancing trust, such as seen in anti-tampering, value circulation, and traceability. Therefore, blockchain/DLT can contribute to solving the challenges. However, it should also be noted that blockchain/DLT is only one of the components of societal ecosystems, and that it alone cannot fully solve the problems. The challenges in the media sector relate to a wide range of social elements such as mediation, incentive, evaluation, industry, and occupation. Trust in twenty-first-century media should therefore be reinforced via the full combination of business, legal and technological solutions.

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The Internet of Value and E-Commerce

E-commerce has changed significantly since new business models were introduced at its beginnings. Few would have predicted that a company that was one of the first to sell books online would become the largest marketplace in the world.

The Internet revolutionised e-commerce and empowered consumers with more choice, better deals and the ability to order products with a few clicks of a button. With these benefits, however, have also come negative consequences. Consumers' data is being exploited. Consumers are also wasting more in our linear economy where new products are consigned to the garbage pile after being use for a limited time. This is causing greater pressure on the Earth's limited resources.

Part "The Internet of Value and E-Commerce" focuses on how the IoV powered by blockchain can lead to the next level of empowerment for consumers, whilst mitigating some of the negative consequences in the arena of e-commerce.

Chapter "The Internet of Value in Consumer Markets" is written by Peter Bambridge and Chris Wyper. They focus on how the IoV can address e-commerce business models in the areas of loyalty, direct to consumer, servitisation, sustainability, data and self-sovereign identity. All these areas have a direct impact on the evolving role of e-commerce business models and how these will affect consumer markets.

Chapter "Marketplaces and the Internet of Value" focuses on the importance of e-commerce marketplaces and how the properties of trust, transparency and immutable data, which are brought forth by blockchain, can lead to a fully functioning decentralised marketplace. This chapter is written by Antony Welfare.

Finally, Chapter "The Internet of Value and the Circular Economy", written by Geri Cupi, focuses on how the IoV can empower new business models in e-commerce focussed on the circular economy. This chapter includes case studies on the fashion industry before moving on to discuss the importance of non-fungible tokens empowering new business models.

This part was reviewed by Stylianos Kampakis.

The Internet of Value in Consumer Markets

Peter Bambridge and Chris Wyper

1 Introduction

The core principle of the Internet of Value (IoV) is the fast and easy transference of value between two parties, cutting out middlemen or eliminating third party costs in the process. In the e-commerce world, the transference of value occurs when consumers "pay" for the products they are "buying". Credit card and online payment systems such as PayPal are the most common methods for transferring value, certainly in a consumer world. However, these systems still rely on a go-between to complete the transfer.

Most e-commerce platforms today still rely on these traditional forms of payment, but some e-commerce platforms are beginning to accept cryptocurrency as payment, e.g. Shopify. Although much has been written about cryptocurrency, it is not yet widely adopted across e-commerce as a medium for payment; however, cryptocurrency represents an opportunity to facilitate the quick transference of value.

This is easily understood when one considers cross-border settlement transactions that are currently both slow and relatively costly. The role of technologies such as blockchain in disintermediating such processes is well recognised and opens the door to quicker and more cost-effective processes. There is a wide range of digital transactions where Distributed Ledger Technology (DLT) can facilitate such value exchange, from loyalty points to shares and from music to art.

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Although value is often expressed in monetary terms (assets, stocks, products, etc.) it can also relate to the social or consumer value that customers receive when buying products or services. In this case, value is transferred via things such as time saved, feel-good customer factor or reducing environmental impact. These may be less tangible than the transfer of money, but in today's world, they are no less important.

No matter whether we are discussing monetary, social or customer value, the two core issues that must be addressed are *trust* and *transparency*.

Traditional e-commerce payment methods have a level of surety; if a customer uses a valid credit card, the seller will get paid, and in return, the customer trusts that they will get the goods they have paid for. The supporting banking system provides a level of support, albeit not infallible. In addition, consumers today want validation and greater awareness of a product's authenticity, manufacture and lifecycle.

According to Tapscott and Tapscott (2018), the IoV is fundamentally enabled by blockchain. Consequently, when considering new e-commerce business models enabled by the IoV, we must examine the impact blockchain has on providing sufficient trust and transparency to enable a quick transfer for value, whether monetary, social or perceived customer value. Across retail and consumer Goods Industries, collectively known as consumer markets, the areas that we see as emerging include: loyalty, direct to consumer, servitisation, sustainability and the areas of data and self-sovereign identity. Each of these areas is considered below in turn.

2 Loyalty

Loyalty programmes have been around for a long time in industries such as retail, hotels, airlines and credit cards. These programmes are all designed to try to build customer loyalty by rewarding the right behaviour. Establishing loyal customers has always been important given the frequency of repeat business and average basket size; driving repeat business is critical. Most of these programmes have been focused on the interests of the company by geography and have been engineered to retain the "value" in the rewards to only be consumable within their own business.

Some companies have found that running such loyalty programmes can be expensive and with questionable returns. In challenging economic times, it is easy to lower the level of rewards, but that can lead to a significant drop in engagement.

What is really needed is a more cost-effective model to run loyalty programmes and allow the currency of the reward to be utilised across brands/companies/channels/geographies. This is where blockchain can help enable a new generation of loyalty programmes.

Blockchain is well suited to holding secure information about transactions that generate rewards and providing a platform to allow rewards to be spent only once. Combined with the management of identity, this can then become a valuable source of insight and marketing opportunities.

Blockchain could be used to simply keep track of virtual points, or to manage tokens as the reward currency. By overcoming the complexity of traditional loyalty schemes and driving higher engagement and redemption rates while reducing costs per transaction, blockchain can be used to establish a new approach to loyalty programmes.

Most consumers are members of many different loyalty programmes (the average is over seven schemes per consumer in the US); carrying multiple loyalty cards is a nuisance and does little to encourage engagement. Having blockchain-based loyalty tokens that are interoperable across loyalty schemes would significantly affect this. This approach can also address the problem of points expiring over time and enhance the overall customer experience by increasing flexibility.

Smaller organisations are not excluded from such opportunities to engage in blockchain-enabled loyalty programmes, as costs are reduced. For businesses running such schemes, fewer people would be required to run the system and monitor the liabilities. Online sites can use such reward schemes to drive repeat business and increase total customer value. Offering such a loyalty scheme for customers across multiple companies provides increased exposure through network effects. An excellent example of this is qiibee,[1] which lets companies create loyalty coins on a blockchain.

3 Direct to Consumer

Although there are similarities between the Direct to Consumer (D2C) and Business to Consumer (B2C) model, the key (simplistic) distinction is that in D2C, the manufacturer is selling their products directly to the end customer without the need for retailer intermediaries. In reality, however, the lines are blurred between manufacturers and retailers, but for simplicity, we focus here on the pure D2C model, manufacturers selling to consumers via e-commerce channels.

Indeed, the evolution of e-commerce coupled with disruptive technologies has given rise to a myriad of new entrants selling everything from mattresses, razors, wine, groceries and fashion alongside the large, traditional consumer organisations such as Unilever or P&G. Products are sold to consumers either on a company's e-commerce site or via a storefront on online marketplaces such as Amazon, eBay or Alibaba.

For consumer organisations, D2C offers a range of benefits such as retaining more profit (no retailer middleman), access to customer data, a greater degree of product personalisation and more scope for testing new products. However, D2C companies still face a range of challenges that mirror B2C models—namely, transaction fees, cost of returns and the complexity associated with running different models.

Blockchain offers the potential to change D2C e-commerce business models, driving value for customers and retailers in several ways:

[1] Qiibee—https://qiibee.com/.

- By leveraging cryptocurrency as a method of payment, which can reduce operational fees for sellers and, in return, lead to lower prices for consumers.
- By redefining loyalty programmes from point to token-based, to unlock the value held in legacy loyalty programmes. Blockchain offers a more affordable way to store and use rewards which in turn can reinforce brand loyalty, leading to increased sales and customer satisfaction.
- By ensuring a greater degree of trust and transparency than in a traditional D2C model by providing verifiable evidence of product provenance and authenticity. This reduces the risk of counterfeiting and also provides evidence of product composition to ensure product safety and quality, driving brand equity. Value, in this case, is driven based on the assurance that the product is what it says it is and also that customers are not put at risk.
- By creating a digital footprint of product warranties via blockchain that reduces administrative overhead and also supports effective and targeted product recall. Value, in this case, is the time saved by both the seller and buyer as well as the minimisation of the costs associated with the recall process by targeting only affected products.
- By simplifying and connecting across the supply chain to reduce administrative costs and save time associated with bureaucracy as products move from suppliers, through manufacturing to consumers. Smart contracts can be leveraged to redefine e-commerce supply chains to speed up processes, reduce costs and ensure continuity of supply.

Blockchain presents a number of opportunities to enhance and open up new ways of doing business online. At the core, value is derived from reducing the number of links in the chain and, in doing so, driving down costs that aid customers and buyers. Ultimately, increasing trust and transparency across the supply chain is critical to ensure the deliverance of viable D2C models, and blockchain has the capability to help redefine how these supply chains work and, in turn, open up different ways of selling in a D2C model.

4 Servitisation

Servitisation is the process of turning a conventional consumer product into a product-as-a-service. In the consumer world, there are many examples from meal-kit subscriptions to product replenishment, and from clothing subscription services to product rental. None of these ideas are new, but with e-commerce, the models have been given a new injection of life and, more importantly, the ability to do things differently. Blockchain and DLT have the opportunity to enhance these models further by focussing on trust and transparency to underpin and quicken the transference of value in the IoV.

To illustrate this, take the example of online high fashion rental business models. This is fundamentally a B2C model whereby customers can either rent single items for a designated period or sign up for a subscription service which gives them a certain number of items in a given period. In this case, the value is transferred for a limited time until it shifts back to the buyer. Given the relatively low barriers to entry, consumers are also increasingly able to connect and rent directly with other consumers (C2C), thereby deriving an income from their assets, namely their clothes.

In most cases, these models follow the standard e-commerce approach, namely “find products”, “add to basket” and then “pay” via credit card or online payment methods such as PayPal before the products are shipped to the customer. Along the way, banking intermediaries take fees for processing the transaction, and there is an inevitable delay in terms of value being transferred between buyer and seller.

Although some measures are in place already to prevent fraud, the risk still exists that a seller may rent an expensive item for a fraction of the retail cost and never see the product again. Of course, the flip side of that argument is that customers trust the product they are renting is indeed genuine, either in terms of the brand name or how the product is manufactured (e.g. there is no leather or fur, or it is made from sustainable cotton, etc.)—in other words, the product is as advertised!

Trust and transparency are at the heart of driving new or emerging business models and blockchain, as a fundamental enabler delivering the IoV, is critical in making this happen. There are several ways this could occur:

1. **Building verifiable customer records.** Blockchain could be used to hold a verifiable customer record that could be shared across platforms. This could reduce the additional vetting processes some sellers take before allowing customers onto their platform, or it could provide evidence. For customers, it potentially opens up new sellers in different markets, increasing the range of products that could potentially be accessed. Add to this the use of cryptocurrency as a payment mechanism, and sellers have an increased level of trust or, to put it another way, the level of uncertainty decreases.
2. **Building verifiable supplier records.** For customers, transacting with sellers is also based on trust, hence blockchain holding verifiable supplier records reduces the uncertainty that you are engaging with a supplier that isn’t reputable or buying products which are not what they appear to be. For larger B2C organisations, this may be less of an issue, but if you are a consumer renting your clothes from another consumer, having verifiability helps to alleviate potential trust issues. For sellers, it potentially opens up new customers in different markets by providing a level of transparency and verifiability to you—that you can be trusted.
   Verifiability, in this case, is about the surety of the transaction: reducing the uncertainty that I am going to be paid as a seller, and that I will receive my product as a buyer, and then as a seller that I will have my products returned.
3. **Providing product transparency and traceability.** Blockchain can also help to extend this model by providing additional information about the product. This could range from provenance (where was it made?), authenticity (is it real?) and product composition (does it have leather, real fur, additives used, etc.?). Customers are placing increasing emphasis on the non-monetary value they receive from companies they interact with. Having visibility regarding where and how products are made helps align with their personal values and worldview.

Blockchain, coupled with virtual currencies, can be used to enhance and extend the current rental e-commerce model, whether B2C or C2C. Value transference can occur on several levels, for example:

- The use of cryptocurrencies to eliminate middleman involved in facilitating transactions between buyers and vendors
- Increasing rental model scope and reach, thereby reducing the impact on the environment by making fewer clothes and supporting the broader aims of the circular economy, in effect creating a transfer of social value in the form of less waste and lower consumption of resources.
- Improving customer perceived value, in this case transferring time back! As one customer indicated, she didn't have to spend time shopping....she did it to "make her life easier at work".
- Creating a basis of confidence and trust between parties that have not previously dealt with each other.

As we increasingly move from an ownership to a rental model, and products as a service, the IoV can help scale existing models by connecting buyers and sellers on a truly global level, whereby individuals can compete with much larger companies, potentially simplifying and reducing the cost of doing business.

5 Sustainability

Sustainability is all about the ability to maintain existence, whether that is through reuse, recycling or reduction in consumption. The environmental footprint that an enterprise generates is a growing area of concern for consumers, brands, manufacturers and retailers; in fact, for the entire supply chain.

Sustainability covers multiple dimensions including social, environmental and economic performance. In the Unilever Sustainable Living Plan, the core belief is that business growth should not be at the expense of people and the planet. In Marks and Spencer, Plan A (because there is no Plan B) is about building a sustainable future by being a business that enables our customers to have a positive impact on well-being, communities and the planet in everything that they do. These examples are being followed with interest by many in the industry. The question is, can emerging technologies such as blockchain be adopted to help deliver such benefits and illustrate the improvements being made?

Blockchain has a vital role to play in enabling sustainability in many areas (see e.g. Richardson and Xu 2020), including the following:

- Tracking materials in garment construction
- Reducing waste in production processes
- Reducing water consumption in production
- Tracking carbon footprint
- Tracing plastic usage across the supply chain

- Enabling the circular economy
- Combating counterfeit goods
- Providing product provenance and authenticity

For enterprises, all these areas can contribute towards a strengthened sustainability proposition through improved efficiency, and the reduction of waste, packaging, materials and water consumption while lowering the carbon footprint. By also taking steps to address product authenticity, share provenance information and reduce counterfeit goods, enterprises can evolve the perception that consumers have of their brand and their business. Increasingly, consumers are looking for products that align with their beliefs and lifestyle while also addressing their needs for convenience, reliability and safety (see also Chapter "The Internet of Value and the Circular Economy").

This therefore poses the next question: How can blockchain and IoT help enable solutions to facilitate addressing the needs in each of these areas? There are multiple layers involved in answering this question, including providing the following:

- An immutable audit trail of events over time that can show the history of product movement throughout the supply chain, enabling product traceability/transparency and influence the shopper's buying decisions
- Certification of product provenance and product authenticity
- A platform for recording the recycling of products/packaging, and reducing the overall usage of plastics
- A platform to manage the tokenised incentivisation to help influence consumer behaviours and buying decisions cost-effectively
- A platform for a new generation of loyalty systems to incentivise the right behaviour.

If we think about value in an environmental sense, the social value of using fewer resources and being more efficient may be more critical to the planet than the commercial value. A great implementation of this concept is Poseidon,[2] which uses blockchain to track carbon footprint.

6 Data

Consumer industries have never been short on data, but e-commerce is a business model founded on data. Much has been written about the use of machine learning and AI to identify patterns, make recommendations or even use digital assistants as part of the e-commerce customer journey. Of course, all of this relies on and generates huge volumes of data. Many, if not all, of the emerging e-commerce business models, such as subscription or new rental models, rely on the use of AI to learn, adapt and

[2] Poseidon—https://poseidon.eco/.

refine the products offered as part of the service. In doing so, retailers learn more about their customers, targeting them with more relevant products in the hope of driving more sales.

The use of technologies such as AI is helping to drive customer value in the form of time saved. In applying AI and machine learning to customer and product data (size, style, fit, colour, etc.) retailers can deliver the right products tailored for customers without the customers themselves having to spend time shopping or returning unsuitable clothes.

Technologies such as Blockchain have essentially risen to prominence, much like AI or machine learning, because of the importance that is now placed on data across every corner of commerce. Blockchain and AI use data in different ways, but the combination of the two could potentially extend or create new e-commerce models. If companies or even individuals can use data that is currently out of their reach, either for regulatory or competitive reasons, they could drive deeper customer insights, better align supply and demand or even open up new avenues for engaging with customers.

To achieve this democratisation of intelligence, blockchain can be used to control access to protected data, permitting data scientists to run their algorithms without exposing any of the underlying information. In this case, e-commerce companies could earn revenue from renting out their data or "open-source" innovation to highlight new insights or opportunities to enhance the e-commerce offering. Leveraging blockchain to act as the security layer minimises the level of trust required between different parties and can stimulate a new era of openness, innovation and data sharing.

The rise of e-commerce has led to customers freely handing over their personal information to retailers with very little thought about how it is used. The same is also true for retailers, large and small, who use marketplace platforms such as Amazon or Alibaba to sell their products, although in reality it is a case of "accept the terms or else you can't use the platform"! Building on the security theme discussed above, blockchain represents an opportunity to restore the control of data to the "rightful owner":

- **Customers**: building e-commerce platforms on top of blockchain offers enhanced security and privacy with no central power owning the data. Customers are free to use or sell the data to e-commerce companies if they wish. In this case, the customer behavioural data has a value that was mostly given away by the customer. Nevertheless, by leveraging blockchain value transference can occur, depending on what the customer values in return!
- **Retailers**: Using an e-commerce marketplace usually means that access to customer behavioural data is dependent on the marketplace provider—the retailer does not own it!

Blockchain offers the promise of restoring ownership into the hands of the retailers, thereby reducing the cost of acquiring the data and driving more equitable competition.

Furthermore, blockchain can drive the advancement of e-commerce business models by opening up access to valuable data sources in different ways and by providing the security backbone to ensure trust between parties. Value can be created not just by selling data but also by encouraging innovation without breaching data protection or impacting competitive advantage.

7 Self-sovereign Identity

As there appears to be some confusion regarding the meaning and role of self-sovereign identity (SSI), it makes sense to begin with a simple definition before examining the key role that SSI plays in enabling many of the aspects of the IoV.

SSI is a model used to manage identities in a digital world, whereby businesses and individuals can control their personal information, where it is held and how it is used. Identity is no longer just a passport issued by the government.

Storing SSI on a blockchain, and sharing that information when required, disintermediates the traditional role of third parties in trust validation and provides self-sovereign control. This personal information can then be used to identify participants in transactions. Decentralised digital identity is not new; the concept has been around since the 1970s—what is relatively new is the potential use of blockchain to help facilitate it.

SSI can be a key enabler of new model approaches in the area of e-commerce. By taking control of their SSI, businesses and individuals can control what information they chose to share and with whom they chose to share it. This is a key part of establishing trust.

SSI provides the efficient control of private information, rather than having the owner hand over all their data, knowingly or otherwise, to third parties who may then use it for their purposes or even sell it on to others. The reality online is that if you are not paying for a service then you are the product, and you are paying for it with your data (such as on the major social media platforms).

The burden of managing personal data passes to the individual, who then also has to consider its security.

The evolving framework of regulatory models, such as the EU's GDPR, the US Privacy Act and Federal/State laws, are establishing compliance requirements that must also not be overlooked.

For further information about the evolution of identity, please refer to Allen (2016), whose work includes the famous "Ten principles of Self-sovereign Identity".

Regarding the IoV, identity is key if transactions are to be trusted.

- In loyalty, being able to identify the individual and build their profile uniquely is foundational. The use of marketing techniques to drive the behaviour of consumers incentivised by loyalty hinges on recognising the consumer and what segments they belong to.
- In direct to consumer, the individual becomes the direct channel for the product or service, so again their identity is critical. Building a history of transactions and subscriptions rapidly becomes a valuable source of insight.

- In servitisation, the use of verifiable customer records and supplier records are inherently based upon unique identity. To allow access to the information on transparency and traceability need to be managed, so again this is dependent on secure identity.
- In sustainability, identity is essential because rewarding the right behaviours requires clear identification.
- In data, unique identification of the individual and the organisation are critical elements of the underlying data infrastructure used to collate and analyse this data into information.

Identity is vital to the security of information and ensuring accurate and attributable information.

8 Conclusion

The IoV may be a relatively new concept which is continuing to evolve, but it is clear that it is here to stay. Emerging technologies such as blockchain have a critical role to play in enabling this exchange of value.

Although there are multiple blockchain platforms on the market today, this will change going forward through consolidations, failures and technology breakthroughs. In consumer markets, the winning platforms will be the ones that effectively address the areas of loyalty, direct to consumer, servitisation, sustainability, data and self-sovereign identity. All these areas have a direct impact on the evolving role of e-commerce business models.

By briefly addressing each of these critical areas, this article has attempted to bring some clarity to the evolving role of the IoV and how it is already starting to change the world of both the consumer and the entire consumer market.

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Marketplaces and the Internet of Value

Antony Welfare

Marketplaces are one of the oldest business models in our civilisation—we have been bartering and exchanging goods for centuries. With the advent of the IoV, together with blockchain technology, we can now use this to power the next revolution—we can now trade anywhere, anytime and with anyone using a trusted, peer-to-peer marketplace.

1 Blockchain Powering the New Marketplace Model

With blockchain technology powering marketplaces, we will develop a transformational method for all citizens, businesses and governments to do business together on trusted, peer-to-peer marketplaces. With its trust, transparency and immutable characteristics, blockchain technology will allow a seller and a buyer to connect without any "middleman."

This is where we see a dichotomy. On the one hand, a marketplace built on blockchain technology can facilitate direct network creation by removing intermediaries. But the other side of the equation is that, the marketplaces today are owned and run by globally complex and complicated organisations, span country boundaries, offer millions of product choices, and require effective management and administration to enable an efficient and controlled exchange of goods. A significant trait of the current global marketplaces is that, they offer excellent customer service to match the customers' expectations set by the current retail marketplace leaders.

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This said, there are many areas to look at when building a trusted, peer-to-peer marketplace: customer service, delivery, marketing, product quality, returns, and packaging, to name but a few. This is where the challenges will lie—how do we build decentralised marketplaces that will compete with the current operators?

Numerous blockchain-based marketplaces will exist (and some, mentioned later in this chapter, are already operating). One question remains: will these marketplaces become global giants and serve customers with extensive product ranges? This will undoubtedly be a challenging goal to attain.

2 Mega Marketplaces Today

There are currently several global giant marketplaces who dwarf other retail businesses in size and scale. Take Amazon,[1] for example, at the point of writing this chapter, the value of the company was around $1.6 trillion. This makes Amazon around five times bigger than Walmart[2] and over 60% larger than the other top ten retailers' combined value as of August 2020 (Johnston, 2020). Alibaba[3] is another who is valued at around $700 billion currently,[4] and who dwarfs other retail companies in their markets by a large margin.

Uber,[5] Airbnb[6] and other service marketplaces are strong, but the 2020 Covid-19 pandemic challenged their business models. We will see how they survive, but they have already challenged the taxi and travel accommodation industries' established business models.

Let us explore Amazon and Alibaba's marketplace models further and see how they operate and what makes them powerful. Amazon is the best known online marketplace in the western world; Alibaba, in the eastern world. Both have similar models and modus operandi—they want to take every customer, retain them for their long-term future value and entice them to use their services as often as possible.

They are pure retail killers with one goal: to be the only place for customers to shop, and they have five distinct advantages. These are:

1. **Customer service**: A marketplace which offers a one-stop-shop for customers to buy any product they want, easily and with one interface. They sell almost anything on their marketplace, meaning customers can use them instead of shopping at many different retailers and brand websites. This convenience, together with many other features, enables them to keep customers returning.
2. **Ultimate convenience**: The ultimate convenience to buy all your different products and add them to your basket. These can all be purchased in one transaction

[1] https://www.amazon.co.uk/.
[2] https://www.walmart.com/.
[3] https://www.alibaba.com/.
[4] As of September 2020.
[5] https://www.uber.com/.
[6] https://www.airbnb.co.uk/.

and delivered in one go. There is no fuss. No need to worry about credit card details, and a customer only needs to wait for one delivery, which is often the next day or even the same day.

3. **Scale**: These marketplaces have significant scale and cross borders and languages. For example, Amazon has an integrated European delivery network, enabling customers to buy quickly and simply from anywhere around the world. Alibaba and their TMall subsidiary, allow sellers who do not know Mandarin or even trade in China, to open an online store and trade with the vast Chinese market and other countries in Asia.
4. **Online only and technology literate**: This is a critical factor and something which enables them to grow exponentially, without the burdens of physical retail assets. They can also subsidise their business's growth via sales in their ancillary technology service offerings (e.g. Amazon Web Services). This is a critical difference and a symptom of the inflated technology boom we are experiencing in 2020. Their valuations are based more on the subscription-style model (i.e. Amazon Prime) versus making money on products' margins. Their marketplace business is subsidised by their web services and cloud hosting services. This is where they "rent out" their global computing infrastructure to other companies for a monthly fee.
5. **"Taxless trading"**: Most marketplaces are so big and global that they can "manage their tax liability" globally. Much literature on this exists in the public domain and will not be repeated here. Still, the relevance here is that the competitive "field" is not "levelled" between the current business model of a marketplace and a traditional retailer. Often a marketplace pays less taxes, whilst a retailer pays more, thus making less profit, less able to invest and ultimately less able to compete with the marketplaces.

Marketplaces have become a major part of the retail landscape. Their online market share can be anywhere up to 90% in some countries and accounting for around 10–30% of total e-commerce retail sales.

In summary, Amazon and Alibaba operate with two critical principles. Provide incredible customer service and offer extensive product ranges. These are critical to these marketplaces' success and difficult to achieve with a decentralised blockchain-based market.

A more likely path for growth will see smaller blockchain-based marketplaces grow, focusing on a particular product or range. As these develop, over time, these could merge and expand into a global marketplace.

3 Marketplace for Everything Built Using Blockchain Technology

For a marketplace built with blockchain technology, there are both significant challenges and an unlimited range of options. The current marketplace landscape includes (remembering that services and products are included in the marketplaces sector)

Amazon, eBay, Alibaba, Uber and Airbnb; all marketplace giants who can be challenged by a marketplace using blockchain technology.

In March 2020, a blog was posted by Ericsson titled “Can we put our trust in a decentralised marketplace?”. Within it, there is an excellent explanation of the differences of a centralised and decentralised marketplace. It states that, the three ways that a provider can provide services are through a centralised marketplace, no marketplace, or a decentralised marketplace (Robert 2020).

The blog states that “Business rules” are the driver of a decentralised marketplace, and these will be covered next.

The significant challenges to creating a thriving blockchain-based marketplace also exist for current centralised marketplaces around implementing these business rules. These are:

1. **Customer service**—how do you service the buyers and customers of your marketplace, especially when it comes to delivery and returns? How do you ensure the products are correct?
2. **Marketing the products and services**—how do you find buyers for products and services? Both Amazon and Alibaba spend millions of dollars advertising their services and building a massive following when they enter a new country. Likewise, Uber and Airbnb also spend millions of dollars advertising their services, especially using social media.
3. **Seller onboarding and sales order management**—how do you attract the best sellers and products/services to your marketplace? How do you make sure they are genuine? How do you manage the order process across millions of sellers and buyers?
4. **Product/Service quality**—the most critical part of a marketplace is that the product or service is of the correct origin and quality as described on the marketplace to ensure the sellers get the products and services they expected.

With these four factors and more, blockchain technology can be leveraged with its properties of trust, transparency and immutable data to help solve these challenges.

A Trusted, peer-to-peer Marketplace can surpass a traditional marketplace in the following ways:

- **Item**—currently, trust in transaction fulfilment is placed in the marketplace’s centralised corporate owner. These marketplaces use a rating system for sellers and products to monitor what is correct and what is not, but do the ratings on these marketplaces reflect buyers’ true satisfaction? With a blockchain-based marketplace, you will use a ratings system and loyalty programme to ensure the marketplace “self regulates”. This is very different from the current rating systems, in that, with blockchain, these ratings and reviews will be decentralised and less likely to be manipulated. There is no central authority able to control reviews, which means there will be more genuine reviews. The self-regulation will mean that bad actors are seen (via poor ratings), and new buyers will not trade with them in the future.

- **Transparency**—the transparency of the quality of products and services and the ratings and reviews customers give are critical on a marketplace. Many existing marketplaces only offer very limited checks (if at all) on the quality of a product or service sold. As a result, buyers may find that the product is not what they thought it was and as it was described. With a blockchain-based marketplace, you will see transparently if a product is not as described; it will receive a poor rating that is immutable and cannot be deleted.
- **Product provenance**—we can also use product provenance blockchain solutions to ensure the product and service is what it says it is. By tracking the raw materials, through the manufacturing process, the constituents of a finished item can be written to a blockchain, giving a full history of the products' makeup and origins.
- **Product certification**—using a blockchain solution for certifying the origins of the items. Many solutions will help track products and certify them, which can easily be implemented into a blockchain-based marketplace. For example, trackgood.io and symbolplatform.com[7] offer a technology solution for certification and tracking of goods for sellers: "Trackgood enables brands to build transparency in their supply chain with ease and share their impact with consumers with confidence. Authenticity and trust are backed by Symbol blockchain technology."[8]
- **Immutable data**—without transparency, you must place your trust in the hands of a centralised marketplace provider concerning the data uploaded and altered by a particular product or services seller. With immutable data, all data and transactions have an audit trail, and version history is evident. Any negative feedback or the records of poor-quality products and returns, for instance, are recorded for posterity.
- **Big data or "Value"**—as awareness from users about how centralised marketplaces sell their data grows, the opportunity for blockchain marketplaces as an alternative that places control of a user's data back in their hands will emerge. One particular model that would appeal to users is getting "paid" to share their data and, based on that data, obtaining better and more tailored recommendations on vendors' products and service offers.

These six factors will enable a trusted, peer-to-peer marketplace to thrive when underpinned by blockchain technology. By successfully leveraging these six factors, the challenges to creating blockchain-based marketplaces that have wide-ranging products and services can be overcome.

[7] https://blog.nem.io/empowering-transparency-and-sustainability-in-supply-chain-through-symbol-blockchain/.
[8] https://trackgood.io/.

4 Are Decentralised Marketplaces Realistic?

What is the reality of decentralised trusted, peer-to-peer marketplaces and will this become a mainstream future business model? Blockchain technology has three advantages that it can offer over current marketplaces (trust, transparency and immutability). But for new business models to be empowered and become a reality, some centralised remnants of existing marketplace business models will need to be dealt with or retained to do with marketing, seller onboarding and customer service.

The benefits can be achieved by implementing blockchain technology, where the parties involved should work on a consensus agreement for the “central” processes that must occur. The main idea here is that the “consensus mechanism” replaces the centralised authority/owner. Many consensus mechanisms will allow the marketplace users to work together, make decisions and grow the marketplace. For more information on consensus mechanisms, see Welfare (2019).

5 Consensus Mechanism for a Trusted, Peer-to-Peer Marketplace—POS+

In Chapter “Consensus: Proof of Work, Proof of Stake and Structural Alternatives”, there is an analysis of the different consensus mechanisms that help manage and maintain blockchain ecosystems. An interesting consensus mechanism for a blockchain-based marketplace could be Proof of stake + (POS+). This is described in the symbol platform article by NEM Group (n.d.): “Symbol uses a Proof of Stake Plus (POS+) system, which adds a few weighting factors on top of Proof of Stake to incentivise a healthier economic system. For example, POS+ gives an advantage to accounts that have many recent transactions in order to encourage network usage.” The POS+ mechanism is used to drive the Symbol platform blockchain and the NEM Blockchain, which both use the power of the ecosystem to maintain the integrity of the blockchain.

If we used POS+ for a marketplace, it would give the power to the people who use the marketplace the most, both buyers and sellers. It would offer rewards to those “nodes” aka users of the marketplace, with loyalty or financial token rewards for maintaining the network.

This would mean that the “more you buy” or the “more you sell” the stronger your reputation and your rewards. The bigger you get, the more rewards you share, but also the more responsible you become to maintain and manage the marketplace for the benefits of all users.

How would this work in practice? In the Symbol platform documentation (2020), they show the example of how their native token (XYM) can be used to incentivise the network. If the marketplace users all host a node, they will become harvesters and eligible for a reward when transactions are verified. There is also the “sink account” for each block verified, which could reward all the users for their reviews and ratings.

This is a fascinating way to manage a marketplace built using blockchain technology and rewards the most active users with the highest rewards, but ensures they still run the marketplace with integrity and trust.

6 How a Trusted, Peer-to-Peer Product Marketplace Can Replace Amazon or Alibaba

Let us explore how a trusted, peer-to-peer marketplace would work taking on Amazon and Alibaba's current models.

The current model that most of these marketplaces use is as follows:

1. Sellers list products on the centralised system.
2. These items are then marketed by the centralised owner using digital marketing and social media.
3. Buyers buy the products via auction or a fixed price and pay at the checkout for all the products, irrespective of which seller they are bought from.
4. The products are then delivered to the customer dependent on their requirements.

With a trusted, peer-to-peer blockchain-based marketplace, the model would instead operate as:

1. A group of entities/people form the blockchain marketplace team—this could be a group of companies wishing to trade a certain type of product or service.
2. The team agrees on the principles around consensus—this is the complex part, where the group of different entities will need to agree how they trade together. Utilising a POS+ consensus mechanism would automatically support a healthier and efficient ecosystem.
3. Next, the team needs to agree on the business rules such as operations, customer service, administration, etc. Here lessons learnt from the best practices of current marketplaces should be observed and incorporated.
4. Sellers then list their products using the agreed consensus mechanism, to ensure the products are correct and verified.
5. The buyers enter the marketplace and buy the product, adding the products to a marketplace basket.
6. Payment is made via a token, cryptocurrency or fiat currency depending on the requirements and regulations.
7. The seller(s) dispatches the product(s), and the buyer confirms the arrival of the goods.
8. The buyer and seller then "rate" both the service and the actual product quality—if you have implemented this on the OS+ Symbol blockchain platform, you will be able to use the native tokens to reward the buyers and sellers for this activity.

The difference, and significant advantage with a blockchain-based trusted, peer-to-peer marketplace, is the vetting of a service provider at the start of the process to ensure their products and services are as they state they will be provided. Information about the seller and customer feedback of their products could be leveraged and automated by smart contracts.

7 OpenBazaar: A Decentralised Marketplace

OpenBazaar[9] is a retail marketplace that uses Bitcoin as its principle currency for payment. It operates without restrictions or fees. Businesses and individuals are free to trade with each other without any third party or intermediary involved. OpenBazaar presents an alternative to today's centralised marketplaces that charge fees to list and sell products.

OpenBazaar connects users directly through the use of a peer-to-peer network. Data across the network is distributed across nodes instead of being stored on a central database. OpenBazaar is open-source software, over which nobody has control. Every user can contribute to the network, and no company or organisation is in charge of its operations. Every user of OpenBazaar has control of their retail store and private data.

The customer experience that OpenBazaar provides is practical, albeit the platform is not aesthetically appealing. Nevertheless, it is a working and successful example of a blockchain-powered marketplace.

8 Conclusion

When building a trusted, peer-to-peer marketplace, blockchain as a technology can empower new business models that place trust, transparency and immutable data at their core.

If we utilise the correct consensus mechanism for the marketplace (e.g. POS+) and a set of business rules and agreements agreed to upfront by the marketplace's founders. These can be automated using smart contracts, enabling a very efficient, effective and self-regulating marketplace for both buyers and sellers.

The world of marketplaces is globally significant, and any new marketplace will have to compete with the notable giants that exist today. This is a realistic prospect, and with blockchain technology as the enabler, we will see many decentralised peer-to-peer marketplaces.

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[9] https://openbazaar.org.

Author Biography

Antony Welfare has over 25 years experience in Retail and Consumer tech, followed by 6 years (and counting) in Blockchain Tech and is a leading expert in the Commercial Blockchain space. He has practical experience working with leading global organisations in developing strategies and implementing enterprise and business blockchain solutions. As former Innovation Strategy Director at Oracle Corporation, he developed their Go To Market strategy for blockchain apps in the EMEA region. He also served as Managing Director of DXC Technology, a global technology consultancy, where he led their blockchain practice, delivering over 50 projects and building a global team. In 2018, Antony co-founded the Retail Blockchain Consortium alongside UCL Centre for Blockchain Technologies, Oracle and MonoChain, to drive blockchain adoption across the retail value chain. Antony is the author of *Commercializing Blockchain: Strategic Applications in the Real World*, which was published in 2019 by Wiley. This book comprises research and findings from thirteen global experts in blockchain, as well his own significant experience in the blockchain space.

The Internet of Value and the Circular Economy

Geri Cupi

1 Introduction to the Circular Economy

Sustainability is increasingly becoming recognised as a crucial agenda for policymakers to consider and for companies to integrate into their strategies. The term sustainability originates from the French verb "soutenir": "to hold up or support" (Brown et al. 1987). In practical application, this involves utilising Earth's finite resources efficiently and responsibly with consideration of resource supply for the following decades.

2 A Primer on the Circular Economy

The current linear economy exploits resources at the expense of future generations. Raw materials are utilised in goods and service production, and then disposed of despite still retaining economic value. Switching to a circular economy minimises our resource expenditure through optimising production to be most lean and implementing processes to utilise materials post-consumption. Circular economy minimises natural resource expenditure in the short run to retain a larger total amount of natural resources in the long term.

The circular economy concept has been steadily growing in popularity amongst scholars since the 1970s, alongside the mnemonic of the 3Rs: *Reducing* materials and waste; *Reusing* products; and *Recycling* materials (Kirchherr et al. 2017). The circular economy has regenerative and restorative design at its core so that products and services can be traded cyclically.

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In the years following the industrial revolution, the number of consumed products per capita has drastically increased; with the average lifespan and usage of products declining. Consumers have grown more impatient and less resourceful with purchases, leading to a large excess of waste and a strain on the planet's resource abundance. This waste will often be burned or left to pile in landfills, causing additional negative externalities to the environment. The circular economic growth approach mitigates pollution impacts, protects finite resources, and can lead to greater employment opportunities and innovation incentives (Ellen MacArthur Foundation 2015).

While lowering resource usage may be interpreted to hinder the economy, McKinsey[1] projects that the circular economy may cause a 3% boost to Europe's resource productivity levels by 2020. This would create cost savings of EUR 600 billion a year, and lead to EUR 8 trillion more in other economic benefits. Additionally, another 100,000 jobs could be created by 2025. As the circular economy requires innovations to progress past linear value chains, it will incentivise interdisciplinary collaboration between designers, manufacturers, and recyclers to find sustainable business solutions.

According to the Ellen MacArthur Foundation (2015), if the construction, food, and mobility sectors implement circular economy practices, it could reduce carbon dioxide emissions by 48% in 2030 and a decline of 83% by 2050. This would involve minimising fossil fuel dependence, optimising usage scenarios for transport, and eradicating fertiliser use across operations.

3 How the Internet of Value and E-Commerce Can Help

We need a collective societal shift away from current "throw-away" culture to a society that views waste as a valuable resource; utilising it to derive maximum output and minimise environmental damage.

3.1 The Three Pillars of the Circular Economy

3.1.1 Reduce

Sustainable production reduces the amount of materials and resources required for consumption. Additionally, aiding customers to take more considered action—such as in supporting sustainability-driven companies and foregoing the purchase of counterfeited goods—can lead to lower resource depletion on the whole.

Companies are increasingly being pressured to ensure their production practices are transparent and traceable. Blockchain enables the provenance of an item, which is beneficial in tackling counterfeits. According to the OECD and EUIPO (2016), counterfeiting is worth nearly 0.5 trillion dollars worldwide. Typically, it involves deceptive counterfeiting, where consumers believe they are purchasing an authentic

[1] https://www.mckinsey.com.

item. Alongside the economic loss, many human lives are lost due to counterfeiting each year (Hirschler 2017). If provenance is known, customers can make better-informed decisions and divert expenditure from the counterfeit market. Secondly, provenance shows fair work practices and respect for workers' rights, as buyers can confidently know that an item is supplied and manufactured from ethically sound sources. Third, it allows for the discarded waste from goods production to be traced. Excess materials such as the USD 100 billion wasted in clothing per annum is monitored using blockchain, mobilising the trade of excess materials between producers (see also Chapter "The Internet of Value in Consumer Markets").

3.1.2 Reuse

Blockchain can incentivise the reuse of items. For instance, MonoChain[2] offers a blockchain solution that provides a certificate of ownership to a consumer, allowing them to track their item's life cycle and ownership right from the beginning of production. This instils confidence in buyers and sellers through ensuring information symmetry on luxury goods. Similarly, owners may be given a financial incentive to extend their product's or service's lifespans by acquiring tokens to reward prolonged use.

3.1.3 Recycle

At present, recycling companies spend millions per year, manually inspecting items to ensure non-recyclables are disposed of. Utilising IoV to ensure better provenance and item tracking can lead to massive cost and time savings. To incentivise better recycling practices for both organisations and consumers, the number of correctly recycled items per person may be rewarded through financial rewards such as tokens.

4 Circular Economy for the Fashion Industry

Fashion is one of the most resource-intensive industries. The carbon footprint of 1 tonne of clothes generates approximately 23.2 tonnes of carbon dioxide; consumes 1060 m3 of water; and produces 1.7 tonnes of waste annually (Wrap 2017). The problem extends into the industry's waste issue, as 80% of waste is incinerated or landfilled. These practices lead to soil acidification. The widespread use of synthetic textiles also releases toxic microplastics into our oceans, harming aquatic creatures and makes its way into the human food chain. Fashion's drastic environmental impacts in combination make 8.1% of global climate impacts across non-renewable energy use, freshwater use, human health, Greenhouse Gas (GHG) emissions, and ecosystem pollution (Quantis 2017). These externalities are projected to worsen by 2030, with GHG emissions and waste both expected to increase by around 68% to

[2] https://www.monochain.org/.

2.8 billion and 147 million tons/year respectively (Global Fashion Agenda and The Boston Consulting Group 2017).

Roughly 21 billion tonnes of textiles are sent to landfill yearly. Fashion's projected carbon dioxide emissions are expected to reach nearly 2.8 billion tonnes per year by 2030. This is equivalent to approximately 230 million passenger vehicles being driven for a year on average.

Resale can change this if each item has multiple owners over its lifespan, the demand for new clothes decreases. Research by Ipsos MORI shows that more than half of us own clothing that no longer fits us; 10% hang on to unworn favourites, and 36% of us keep pieces that feel outdated or out of fashion. For example, the UK's water, carbon, and waste footprints could be decreased by 4%, 3%, and 1% per tonne of clothing respectively if there was a 10% increase in second-hand sales (Wrap 2017). With waste being a growing issue, the circular economy solution will likely gain traction, and the need for provenance of the product will become more evident.

A notable trend in the fashion industry is the growth of the second-hand market, valued at USD 24 billion in 2018 and projected to grow at 1.5 times the size of fast fashion within the next decade. 72% of second-hand shoppers have shifted from traditional retail towards used items, and 90% of senior retail executives recognise and show interest in resale to advance their corporate efforts towards circular fashion by 2020 (Global Fashion Agenda and The Boston Consulting Group 2017).

5 MonoChain as an Example of a Circular Economy Fashion Company

MonoChain offers a ledger based on blockchain technology which shows who has owned the product/been a licensee and enables producers, sellers, and buyers to validate the authenticity of a product. MonoChain uses blockchain to objectively record verifiable details regarding when and where products and raw materials are utilised.

Through the implementation of this blockchain solution, fashion companies can far extend the monetisation of their product to include the value-added service of reduced risk of counterfeit fraud and facilitating the resale of the product at the end of the customer's use to bring value to a new user.

MonoChain is a B2B partner for global fashion companies, providing them with the opportunity to extend their customer relationship and lifetime value. MonoChain can transform the secondary market by mobilising the onward sale of authentic fashion items, providing much-needed protection for buyers and sellers.

What is the process for MonoChain implementation? When a user buys an item, they receive a Certificate of Ownership, a non-fungible token (NFT). They are then able to enter this into their MonoChain wallet. When completed, the user can receive offers to sell the item in real time. When selling to a buyer, the item is first moderated. The NFT and money are held in separate wallets, and this is enabled using a multsig escrow and Ricardian contract. If the item is authentic, the NFT and the product move to the buyer. The seller will then receive their payment. Each time the item's ownership changes, it is recorded in a private blockchain (Hyperledger Sawtooth). MonoChain has plans to move to a public blockchain in the future to include information on item provenance, materials, and other relevant information.

This solution will create beneficial impacts for the environment by allowing easy tracking of the sources of materials used in production. It will also increase the utilisation rate and decrease the disposal of clothes after minimal use. Third, it will allow easy recycling through automated sorting of clothing based on textile components.

5.1 Non-Fungible Tokens

An NFT is a tool to secure uniqueness and identity. It enables certificates, real estate data, physical assets, and personal identities to be stored on the blockchain.

Fungible refers to goods which can be substituted for other (equal number of) units of the same commodity. It is an essential attribute to any currency, and fungible tokens include Bitcoin, Ether, EOS, XRP, or any ERC20 tokens. NFTs are unique as they differentiate from one another despite common attributes. They standardise ownership of an asset category, but those assets do not have the same market value.

In 2017, the ERC 721 standard was established that enabled NFTs to be created on Ethereum and lead to the possibility of creating digital collectables on blockchain. NFTs enable digital scarcity without relying on central authorities. Information on NFTs on the Ethereum blockchain is publicly available, transparent, and immutable. In our centralised world, companies have tried to create scarcity through limited

Table 1 Differences between fungible and non-fungible tokens

Fungible tokens	Non-Fungible tokens
Interchangeable Tokens of the same type can be exchanged for any other, and they all have the same value. For example, two cash bills or notes of the same monetary value can be exchanged without any difference to the holder	**Non-interchangeable** One NFT cannot be replaced with another NFT, even though they may have the same value and be of the same type. For example, you could not exchange your identity card for someone else's identity card, even though they are documents of the same type
Identical All tokens are the same and have the same specification.	**Unique** Every NFT is unique, even though they may be from the same type or class. No two NFTs are identical
Divisible Tokens can be split or divided into smaller units, and each equivalent unit is worth the same as another. An example would be exchanging cash bills or notes for coins	**Non-divisible** NFTs cannot be split or divided into smaller units. Each NFT is one complete unit only
Ethereum Standard used: ERC-20 This standard enables the issuance of tokens on the Ethereum Blockchain	**Ethereum Standard used: ERC-721** This standard enables the issuance of NFT on the Ethereum Blockchain

editions, runs, and sale time. Cryptokitties exemplify how a blockchain-based token can create scarcity and how a digital asset can have value (Table 1).

5.1.1 NFT Example: Cryptokitties

Cryptokitties are an example of an NFT on Ethereum, which took the blockchain world by storm in 2017. They are collectable assets that are unique and stored in wallets on the Ethereum blockchain. One can buy, sell, and even breed digital cats (each cat's digital genetic material is stored on the blockchain). At the height of interest in Cryptokitties, some were selling for USD 300,000, with the number of transactions slowing down the entire Ethereum network. Their sales hit over USD 12 million just three months after their launch in 2017.

5.1.2 General Use Cases

There is a range of use cases for NFT, which can be found in Table 2.

Table 2 General use cases for NFTs

Use case	Description
Collectables	Collectable cards (e.g., baseball and Pokemon cards), autographed football shirts, stamps, or any other collectable imaginable can have their digital counterparts collected and tracked. An example of this is Opensea
Tickets	Each ticket issued has its own NFT and means the ticket is unique and ownership more easily verifiable. Upgraded was creating ticket NFTs and was recently acquired by Ticketmaster. The GET Protocol also supports ticketing solutions on a blockchain
Art	The Art industry faces issues with forgery, frauds, and scams concerning the provenance of items. NFTs can tack ownership on an immutable ledger. Verisart and Artory are two companies that are operating within this sector
Identity	NFT could be used to represent characteristics as they relate to someone's ID. For example, you could have an NFT for your driving license or passport. Whenever you need to interact and share information related to your identity, you can show ownership of the NFT. Examples include Sovrin and uPort
Licensing	NFTs can be used for software licensing. A novel use case of NFTs here is the enablement of trading software licenses. If users no longer want to subscribe to a software service, they could sell the NFT to another user who wants the license. The license can turn into an asset for the user. An example of this is license.rocks
Real estate	Proof of ownership of real estate can be streamlined with NFTs. Access to building and facilities can also be facilitated by having access to a token. Examples include Meridio and Real Blocks

6 Conclusion

The IoV allows tokenising real-world goods, which is beneficial from an investment perspective and an access perspective. NFTs could provide the basis for a new blockchain-powered economy on the IoV and lead to a more sustainable world powered by the circular economy.

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Geri Cupi was listed as a Forbes 30 under 30 for Retail and E-commerce in 2020. He is currently CEO of Twig, a new generation financial services app that allows customers to release instant cash from goods they no longer need or want in a seamless, reliable and secure way while fuelling the circular economy. He is also the co-founder of MonoChain, a blockchain-based platform powering re-commerce and product provenance solutions for the brand and retailer ecosystem.

Internet of Things and Oracles

The number of Internet of Things (IoT) endpoints is expected to reach an installed base of 25.1 billion units by 2021, having experienced a 32% growth rate over the preceding five years. As ever more devices become connected, IoT devices are becoming a daily and soon integral part of our lives. This boom in connected devices can enable brand new business models to be developed.

IoT devices themselves are vitally important in the blockchain ecosystem. Blockchains and smart contracts that are written on top of them require trusted information to be inputted to execute in a way that is fair between contracted parties. This information is usually provided by an oracle, which in many cases is an IoT device.

Part “Internet of Things and Oracles” explores the topic of how creating a strong and trusted oracle ecosystem and with IoT devices can fuel and support a vibrant IoV.

Chapter “The Internet of Value and Internet of Things” is written by Rajan Kashyap, who focuses on discussing new business models that can emerge from the IoV when IoT devices are used. Using the Business Model Canvas, different types of emerging business models powered by IoT and the IoV are discussed, including customer to customer, customer to machine and machine to machine. Some use cases of IoT and blockchain follow. Finally, the chapter concludes with a brief analysis of how IoT is intertwining with other emerging technologies, including AI and 5G.

Chapter “Oracles and Internet of Things in the Internet of Value” focuses on the importance of oracles and how IoT devices could be used for this purpose in a blockchain ecosystem. The chapter looks at applications of oracle systems in the real estate and insurance industries and how these systems could alleviate some of the difficulties faced during the Covid-19 pandemic by businesses. This chapter is written by Niall Roche and Alastair Moore.

This part was reviewed by Stylianos Kampakis.

The Internet of Value and Internet of Things

Rajan Kashyap

1 Internet of Things and Related Business Models

With IoT came the proliferation of sensors for light, sound, vibration and temperature; sensors for everything imaginable. The data from these sensors became extremely helpful in tracking, measuring, controlling and monitoring remotely. This capability led to the introduction of many new business models and innovation in existing business models. Some of the prominent IoT-based business models include (Chaabane 2017):

- **Product-as-a-service:** the customer does not buy the product, but rents/leases it from either the manufacturer or a third party. The responsibility of maintaining the equipment lies with the equipment owner (i.e. the manufacturer or the mediator). IoT played a prominent role in this model, as the remote monitoring of equipment became simpler, and acceptance of this model increased. The healthcare industry is a big adopter of this model (see Chapter "Blockchains, DLTs and the Future of Payments"), as healthcare equipment is expensive and requires proactive maintenance.
- **Performance-as-a-product:** the ownership of equipment is necessary or desired, but the performance of the machine can still be outsourced with this model. For example, the cost of maintenance of jet engines in aircraft can be extremely expensive and might have a significant impact on the business. In this event, the business owner would like the experts (manufacturers) to be responsible for the performance of the machine. Most jet engine manufacturers offer some sort of

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care package for which they guarantee the performance of the engine by remotely managing and monitoring it and performing maintenance.

The IoT has also enabled a variety of new methods for doing business and has found a good niche in the sharing economy with the following applications:

- **Revenue Sharing:** through new services provided to end-customers. One such example is bag tracking services provided by airlines. A passenger's bag will be tagged with a sensor provided by an airline partner, and this service can be purchased for an additional fee. The revenue generated is shared between the airline and the tag provider.
- **Cost-saving Sharing:** it is hard for businesses or individuals to keep tracking the usage of a commodity. In this model, a third party can monitor and regulate the usage with the help of IoT sensors and help save on costs of usage. The savings are shared between the business/individual and the service provider.
- **Product/Asset Sharing:** whereby a big asset like a car can be shared among multiple users who only pay for the usage of the asset. This model is very similar to the product as a service model, but in this case, the asset is used by multiple users.

2 Inefficiencies in Current IoT Business Models

Almost all business models that depend on IoT have significant inefficiencies, leading to a higher costs to the consumer/end-user. The primary reason for these inadequacies is the presence of a human intermediary. Although the intermediaries are an overhead, they are necessary to ensure privacy, integrity and trust in the transactions.

The presence of intermediaries leads to the unwillingness of the consumer to share sensitive data (e.g. personal health data). Although IoT sensors can collect a wide variety of data, the availability of that data to unlock its full potential is very limited. Even though current IoT business models are successful, there is significant value yet to be unlocked.

3 How the IoV and Blockchain Can Help

Blockchain technology is facilitating peer-to-peer contractual behaviour without any third party required to "certify" IoT transactions. It answers the challenges of scalability, single point of failure, trust, record-keeping, time stamping, privacy, trust and reliability in an extremely consistent manner (Satish143 2017).

Blockchain/DLT can ensure integrity and privacy without the need for any intermediary. The technology can bring trust in a system, encouraging people to share sensitive information, as well as enabling two machines to work together and fully trust the data, as it is written on a tamper-proof ledger. This can enable unhindered transactions across the ecosystem without ever being mediated by a third party, resulting in various new business models.

The blockchain-IoT integration approach brings countless new opportunities, such as (Alam 2019):

- **Building Trust:** because of the security features among the various connected devices; only verified devices can communicate in the network and every block of the transaction will first be verified by miners and then can enter the blockchain.
- **Savings in Costs and Time:** this approach reduces the cost because it communicates directly eliminating intermediary and third-party nodes. It provides direct communication, thus reducing the time taken in transactions from days to seconds.
- **Security and Privacy:** by facilitating secure access to data. Blockchains are not designed to store large amounts of data, but they can provide "control points" to monitor data access.
- **Creating the right incentive structure:** to share IoT/cross-sectional data which can have the most disruptive impact across different industries. Blockchain (and tokenisation) can be used to solve the "how and why sharing data" dilemma. Once data is shared, it can be more easily validated, authenticated and secured (Corea 2018).

4 The IoT/Blockchain Business Model Canvas and Industry Applications

Osterwalder and Pigneur (2010) proposed the "Business Model Canvas", providing nine building blocks, as shown in Table 1.

Table 1 shows how cross-border payments operate today, highlighting the variety of issues that come to light based on the utilisation of a large number of siloed intermediaries.

Based on work by Liu (2018), three different general business models for IoT-Blockchain and their application to key industries can be created (using the Business Model Canvas) that could showcase how these industries could be disrupted by new business models.

1. **C2C (Customer to Customer):** This model can enable transactions between two customers directly without the need of a third party, as trust is established by the network. For example, the owner of a self-driving car can earn extra money by renting it out to anyone who needs it. Normally, the owner of the vehicle is unsure of the renter's driving capabilities and does not trust the other person. However, in the case of self-driving cars applied to a blockchain-based solution, the owner of the vehicle can be far more confident about renting the car to a stranger as there is an existing shared record of his driving performance. This is shown in Table 2.
2. **C2M (Consumer to Machine):** Customers can interact directly with machines and upgrade their features with digital payments, as shown in Table 3.

Table 1 Business model canvas: nine business model building blocks (Osterwalder and Pigneur 2010)

Key partners	Key activities	Value proposition	Customer relationships	Customer segments
Who are your key partners? Who are your key suppliers? Which key resources are we acquiring from our key partners? Which key activities do our key partners perform?	Which key activities do our value propositions require? Our distribution channels? Customer relationships? Revenue streams?	What value do we deliver to our customers? Which of our customer's problems are we helping to solve? What bundles of products and services are we offering to each customer segment? Which customer needs are we satisfying?	Which type of relationship does each of our customer segments expect us to establish and maintain with them? Which ones have we established? How are they integrated with the rest of our business model? How costly are they?	For whom are we creating value? Who are our most important customers?
	Key resources		**Channels**	
	What key resources do our value propositions require? Our distribution channels? Customer relationships? Revenue streams?		Through which channels do our customers want to be reached? How are we reaching them now? How are our channels integrated? Which ones work best? Which ones are most cost efficient? How are they integrating them with customer routines?	

Cost structure	Revenue streams
What are the most important costs inherent to our business model?	For what value are our customers really willing to pay?
Which key resources are the most expensive?	For what do they currently pay?
Which key activities are the most expensive?	How are they currently paying?
	How much would they prefer to pay?
	How much does each revenue stream contribute to overall revenues?

Table 2 C2C (customer to customer) business model canvas—self-driving cars

Key partners	Key activities	Value proposition	Customer relationships	Customer segments
Self-Driving Car Companies Blockchain Platform Investors Self-driving car owners	Dapp Development Maintenance and updated	Cash Free Taxi Service Secured Transaction Record Chance to earn additional money with spare resources Wider Scope of digital currency New method to freelance	Automated service Co-create Value	Self-Driving Car Owners Passengers
	Key Resources		**Channels**	
	Venture Capital Software R&D		Dapp Social Media Marketing	
Cost structure			**Revenue streams**	
Software Development Salaries Marketing			Advertisement Value-added Services Acquisition	

Table 3 C2M (consumer to machine) business model canvas—upgrade the equipment

Key Partners	**Key Activities**	**Value Proposition**	**Customer Relationships**	**Customer Segments**
Equipment Manufacturer	Pluggable Feature Development	Incremental revenue for Manufacturer	Automated service	Equipment owners
Blockchain Platform	Payment processing	Pay-as-you-go upgrades for customer	Co-create value	Third party providers
Digital Payments Provider	**Key Activities**		**Channels**	
Customer	Software R&D		Equipment interface	
Cost structure			**Revenue streams**	
Feature Development Marketing			Value-added Services	

Table 4 M2M (machine to machine) business model canvas—automated supply chain

Key partners	**Key activities**	**Value proposition**	**Customer relationships**	**Customer segments**
Equipment Manufacturer Blockchain Platform Digital Payments Provider	Machine to machine interaction development Payment processing	Incremental revenue Increased process efficiency	Automated service Co-create value	Equipment owners Third party providers
	Key activities		**Channels**	
	Software R&D		Equipment to equipment interaction	
Cost Structure			**Revenue Streams**	
Feature Development Marketing			Value-added Services	

3. **M2M (Machine to Machine):** Machines talking to each other can reduce supply chain delays and create revenue for the manufactures/producers (see Chapter "Blockchains, DLTs and the Future of Payments"). For example, the truck in the yard can talk to warehouse autonomous fork-lifts regarding its presence on the loading gate. All the interfaces on the supply chain can be automated using a machine to machine interface. This can be seen in Table 4.

With these three Canvas/Models, we can examine how these can be applied to specific industries, as in Table 5, where the examples tell us more about what model fits what business and what the main dynamics are.

5 Blockchain Projects Utilising IoT

Many blockchain projects utilise IoT to facilitate business processes in nearly every sector imaginable. This section examines examples of companies utilising blockchain and IoT and with what use cases.

IOTA is one example of a cryptocurrency for the IoT industry. The main feature is the tangle, a DAG for storing transactions (Popov 2018). The tangle can be considered the next evolutionary step of the blockchain, offering features required to establish a machine to machine micropayment system. Other authors in this book elucidate on the tangle (see Chapter "Consensus: Proof of Work, Proof of Stake and Structural Alternatives") consensus mechanism.

IOTA states that its technology is being used in several different areas including mobility and automotive, global trade and supply chains, industrial IoT, EHealth, smart cities, customs and border management and digital identity. A few more of these will now be examined in detail to see how IoT is enabled with IOTA.

Table 5 Models applied to specific industries

Industry	Application/product	Model
Automotive	Pre-paid direct hire of autonomous vehicle Self-parking and automatic updates On-demand features upgrade	C2M, C2C, M2M
Healthcare	Personal medical records monetisation Personalised pre-emptive healthcare services	C2M, C2C
Retail	P2P transactions without an intermediary such as eBay	C2C
Logistics	Consumer to machine interaction	C2M, M2M
Smart homes	Lifestyle data monetisation Automatic product ordering and payments	C2M, C2C, M2M
Insurance	Pre-usage based insurance Automatic claims settlement Personalised medical insurance plans	M2M, C2M
Manufacturing	Personalised manufacturing	M2M

Within the Smart Cities area, IOTA could be used to gather information from IoT sensors from people and objects within the city. This could then be reported to both residents and authorities. IOTA is involved in Project Alvarium (Yarger 2019) alongside Dell Technologies and the Linux Foundation. This project is creating an open-source technology stack with multiple stakeholders working together and enabling large scale complex integrations. This can form the technology stack that systems in smart cities are built on top of. Within the eHealth arena, IOTA has been used by SmartOptz, allowing patients to monitor their own healthcare data and share it with others (SmartOptz PLT 2020). IOTA has also been used by Pact[1] to facilitate the sharing of healthcare data among institutions and patients via an API that interfaces with the Tangle. Finally, turning to the mobility and automotive industry, IOTA is being utilised by Jaguar and Land Rover, where cars are being created with built-in wallets enabling them to make and receive payments for selling data, paying for parking and tolls.

As well as IOTA, there are several other projects that utilise blockchain and IoT. Modum[2] is a blockchain company that is creating trusted digital ecosystems for sensitive goods and digitalising supply chains. With reference to IoT, Modum produces MODsense devices that can be used to track items in a supply chain that interface

[1] PACT Care BV—https://pact.care/.
[2] Modum.io AG—https://modum.io/.

with their blockchain solutions. The MODsense One device monitors temperature and is particularly suitable for pharmaceutical supply chains (Modum.io AG 2020).

OriginTrail[3] is another example of a blockchain company that is creating an ecosystem dedicated to making global supply chains converge. One particular use case for IoT devices is in smart farming. Here, OriginTrail is protecting data from Kakaxi's[4] IoT farming devices, fostering consumer trust in the provenance of their food. Kakaxi's IoT devices integrate cameras and climate-monitoring devices, collecting data such as temperature, humidity, day-length and rainfall (OriginTrail 2020).

6 A Final Remark on AI and 5G

5G: Low latency is one of the key requirements of most of the use cases with IoT. Current 4G networks are unable to cope with the volume and speed required for these use cases to work. Consequently, IoT implementation is limited within controlled environments, barring a few implementations such as autonomous cars. 5G is expected to provide a network speed of 100 gbps, which is almost 20 times faster than 4G networks. The upgraded speed and capacity will enable use cases which are currently not prevalent.

Artificial Intelligence (AI): M2M communication is increasingly going to be independent of any intervention, requiring machines to become intelligent. AI will play a key role in machine decision-making.

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Oracles and Internet of Things in the Internet of Value

Niall Roche and Alastair Moore

1 Introduction

In this chapter, we discuss the importance of trusted information entering into blockchain systems provided by oracles. Whether these are human inputted manual signals, or automatic machine updates from Internet of Things (IoT) devices, updating records is at the heart of any blockchain-based system. Smart contracts that depend on external data rely on these devices to function correctly. For these blockchain systems to be trusted, the source of any information entering must be accurate and reliable. If smart contracts automatically execute based on questionable externally inputted data, this can have severe monetary and, possibly, legal issues. In the context of the Internet of Value (IoV), if blockchain is empowering this, then the veracity of the information on the IoV will only be as good as the quality of oracles present.

This chapter is structured as follows. First, there is a general discussion on what oracles are and why they are vital to any functioning blockchain ecosystem. Next, we look at how oracles are used in blockchain applications in the real estate and insurance industries, focusing on how oracles could help provide more resilience, trust and efficiency to legal contracts. Finally, we end this chapter with a discussion on Oracles and security.

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2 Oraclised Data

Ensuring that smart contracts (or any automated legal agreement) are trusted requires that external data (possibly coming from many providers) that provide inputs into these contracts are valid. Typically, in a trustless DLT system, an external provider of truth is referred to as an *oracle*. The oracle concept has been discussed in relation to several blockchain solutions, including Andresen (2014).

Some potential uses of oracles as outlined in Beniiche (2020) and De Filippi and Hassan (2018) include:

1. Applications that need a good source of randomness, e.g. in determining the winner in a game of chance such as Ellis (2017), Chen et al. (2018) and Ocean Protocol Foundation and Ltd. (2020)
2. Connecting to data feeds from a third party conveying the latest currency conversion rates and for sports and financial markets prediction markets such as Wager (2017), Hivemind (formerly TruthCoin) (Sztorc 2015), Gnosis (2021), PDFS (Guarnizo and Szalachowski 2018) and Augur (2021)
3. Networked to devices such as temperature sensors for certain types of agriculture and supply chain contracts such as Team (2018)
4. As outlined in the insurance section of parametric insurance agreements in de Pedro et al. (2017)

2.1 Oracle and Trust

Many DLT solutions function as closed-systems. Here trust is provided by the security of the underlying architecture and consensus mechanisms or what is often referred to as *trust by computation* (Antonopoulos 2017) providing *trustless trust* (Hoffman 2014; Werbach 2018b).

Whilst trust is provided at a peer-to-peer level, it is restricted to accessing on-chain data and communicating with peer nodes. As described in Egberts (2017), certain types of blockchain systems and applications that include smart contracts and DAOs[1] need "exit-points" of interaction with the outside world. These exit-points can be facilitated using oracles to record information from the physical world (Werbach 2018b). The external information can come from sources such as sensors and IoT devices Team (2018), as well as from trusted data providers, including humans.

The high-level process for off-chain data retrieval and validation of third party supplied data is outlined in Fig. 1. Validation of the data retrieved can be achieved by using approaches such as TLSNotary Szalachowski (2014) and this is an approach used by oracle platforms such as Provable.xzy (formerly Oraclize) (Provable 2019) and Zhang et al. (2016) now part of Ellis (2017). A comprehensive comparison of

[1] https://en.wikipedia.org/wiki/Decentralized_autonomous_organization.

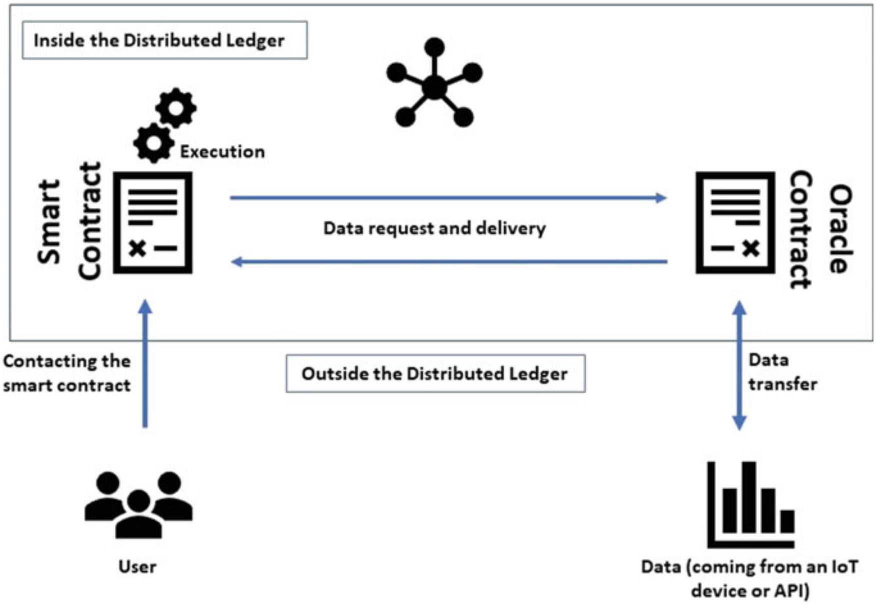

Fig. 1 Automated oracle structure

oracle platforms and the various technology approaches used to ensure trust in each platform can be found in Al-Breiki et al. (2020).

Oracles such as Buterin (2014) and Jason Teutsch (2017) are protocols and decentralised networks of records where participants who submit results that are closest to the median of all submitted results and detect errors are rewarded. Trust is achieved by the number of validators involved and their economic incentives to provide a truthful and accurate response. These incentives are derived from Schelling (1960) and based on Nash Equilibrium with oracles that are found to provide inaccurate answers having less influence on future aggregation processes.

Egberts (2017) proposes to use oracles to achieve *Verifiable off-chain Computation*. Ensuring the integrity of the output is crucial for trust to be preserved in the system:

> *Computational integrity implies that a reported response o of a computation C is correct with respect to a request i and dataset S such that $o = C(S)$, ensuring that a prover P correctly reports the output rather than a more favorable output to the prover* (Ocean Protocol Foundation and Ltd. 2020).

To achieve integrity, oracles generally perform their computation by executing in what is claimed to be a sandboxed environment. In some cases, these are a type of Trusted Execution Environment (TEE) (Sabt et al. 2015) to ensure that the results are not compromised (Stefan Thomas 2018; Provable 2019; Ocean Protocol Foundation and Ltd. 2020; Ellis 2017). One approach outlined by the Enterprise Ethereum

Alliance[2] for secure off-chain compute (Sanjay Bakshi Yevgeniy Yarmosh 2020) involves using Intel's Software Guard Extensions (SGX).[3] These are a set of extensions to the Intel architecture that aim to provide integrity and confidentiality guarantees for security sensitive computation (Costan and Devadas 2016). A number of vulnerabilities have been identified with SGX as illustrated in Chen et al. (2019), Kiriansky and Waldspurger (2018) and Aldaya et al. (2019). Another TTE, ARM's TrustZone[4] is also supported by Ellis (2017) but also has vulnerabilities (Makkaveev Slava 2019; Cerdeira et al. 2020). Team (2018) have been working on their own hardware implementation of a TEE (IoTex 2019). There have also been issues with oracles and exploits and this topic remains an active research area. Further discussion around comparisons of oracle approaches and vulnerabilities can be found in Beniiche (2020), Al-Breiki et al. (2020), Thevenard (2019) and Davis Joshua (2019).

3 Oracles in Real Estate

Oracles can play an important role in a DLT-enabled real estate solution by adding trusted external data sources into the system. As outlined by Pitman et al. (2020), the success of solutions involving oracles aggregating real-world data from distributed data depends on their adoption and traction in the smart contracts' ecosystem. For this to occur, there needs to be trust in who the oracles are and their accountability. For oracles to play their part and provide sustainable, accurate information, there should be a sufficient financial incentive or other motivation such as reputation or regulatory-mandated.

This section will look at several different application areas of oracles in the real estate sector. Beginning with blockchain and property valuation, we will look at trading real estate data and then move on to generally discuss how legal agreements could be made more efficient with the use of DLT and oracles, and particularly how this could have been useful during the Covid-19 pandemic.

3.1 Oracle Applications to Real Estate Appraisal and Data

The Bank of China (Hong Kong) was reported to have applied blockchain to 85% of its real estate appraisal (Antonovici 2018). Jones Lang LaSalle Incorporated (JLL) also used blockchain in 2018 for Spanish commercial real estate valuation seeing benefits of a reduction in time to receive a property valuation report from a week to three days (Pitman et al. 2020).

As property appraisal requires several different data points to create an accurate valuation, oracles can be used as part of the process by verifying the generated data

[2] https://entethalliance.org.
[3] https://software.intel.com/content/www/us/en/develop/topics/software-guard-extensions.html.
[4] https://developer.arm.com/ip-products/security-ip/trustzone.

sources. Data can come from several sources, from human-generated surveys to image data captured from aerial drones[5] and low Earth Orbit (EO) satellites. The use of blockchain data structures to validate EO data and metadata (data acquisition time/date, etc.) provenance is outlined in Agency and European Space Agency (2019) as a way to provide a trusted source of data in the event of a dispute.

Machine Learning algorithms, as outlined in Law et al. (2018), can be shown to help house price predictions using image data from individual properties and amenities in the local area. Multiple data sources and models in an ensemble approach can create more accurate pricing models. The valuation models components themselves and the data that they were trained on could also be traded on Machine Learning Marketplaces like Ocean Protocol[6] or Singularity.net,[7] opening up new data-sharing opportunities and revenue opportunities.

Real estate listing providers also provide an important source of real estate data, with rich information on sale and rent properties. Blockchain could also serve as a monetisation tool for property listing data captured by these providers. An example of an attempt to create a blockchain-based Multiple Listing Service (MLS) was Rex MLS (Smart Evander 2016).

Other examples of data that may be beneficial to the valuation process could be provided by oracles including:

- Energy Performance Certificates (EPCs)[8] or other equivalent building ESG-related rating
- survey documents such as condition reports and home buyer reports
- searches related to a property including Local Authority and Environmental (such as Water Searches submitted), rejected and approved planning applications and permits for work with Local Authorities
- proof of repair and service, (e.g. boiler etc.) carried out by authorised tradespeople and with authorised parts.

Oracles can also provide an opportunity for the trading of real estate data. Taking property search data as an example, efficiencies could be made with a marketplace of existing search results. This would provide a level of cost recovery for users who paid for the original search. Some validation of these results would be needed, and some of the searches will be specific to the individual property, whilst others will be at a more general level of locality and can be of benefit for others undertaking similar searches. Where the search results are still needed to be undertaken for individual properties, the overall wisdom of the crowd of recent and local search results can provide some market intelligence, such as the likelihood for the buyer to experience issues with the property (which the buyer could then factor into the price they are willing to pay).

[5] https://www.camflyfilms.co.uk/, https://marwoodsurveyors.com/drone-services/.
[6] https://oceanprotocol.com.
[7] https://singularity.net.
[8] https://ec.europa.eu/energy/en/topics/energy-efficiency/buildings/certificates-and-inspections.

3.2 Oracle Applications to Real Estate Legal Contracts

Oracles could also play a role in creating more efficient legal contracts in the real estate sector. As an example of a legal agreement driven by oraclised data sources, let's take the penalty payment for not adhering to the completion date in a real estate transaction in the UK. This penalty is determined by the UK Law Society (The Law Society 2018). The current system requires making a phone call for historical rates with the actual rate itself published by the Law Society fixed 4% above the Barclays base rate.[9] This type of data that feeds into contracts could be something that can easily be done automatically with an oracle approach. The authors have discussed these types of proposals with the UK Law Society as a potential route forward to increase innovation, transparency and improve efficiencies. The authors have demonstrated this work as part of the Real Estate Working Group of the Accord Project[10] and developed it as part of the Digital Streets initiative[11] (further elucidated below).

The authors outlined an approach (UCL CBT 2020) that builds on the oracle concept by proposing a set of components that collect, aggregate and validate data from disparate sources, then packaging it in an agreed scheme that allows it to be used in a Lexicon outlined in a range of automated contracts. The proposal and initial prototype component development addressed the COVID-19 breakout and subsequent lockdowns and other restrictions for businesses to have a degree of certainty in their legal agreements. The proposed approach provides flexibility in the deployment of these components in existing oracle platforms, proving transparency and an audit trail of data as it is sourced, processed, delivered and consumed. A high-level overview of the proposed approach is shown in Fig. 2.

The COVID-19 pandemic[12] has caused widespread uncertainty for people and small businesses, who feel the financial impact of the pandemic due to supply chain issues, government restrictions, reduced customer footfall and spending power. It is difficult for parties to agree on the details of contracts in this environment of uncertainty. This uncertainty could come in the form of unpredictable new government policy, a new intervention measure introduced to counter changes in infection and transmission rate or general economic unpredictability.

Legal agreements are, in many cases, not well equipped to respond to changing restrictions and legislation. Simple examples of parameterised contracts might reference only a single source of data, as in the earlier example of a late penalty in a real estate contract (for example, a specified bank's base interest rate). In general, contracting clauses are not responsive or revised once memorialised. Real estate and construction were identified as key sectors that could benefit from this research.

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[9] https://www.lawsociety.org.uk/support-services/help-for-solicitors/practice-advice-service/q-and-as/how-do-you-calculate-interest-rates-for-late-completion-/.

[10] https://accordproject.org.

[11] https://hmlandregistry.blog.gov.uk/tag/digital-street/.

[12] https://en.wikipedia.org/wiki/COVID-19_pandemic.

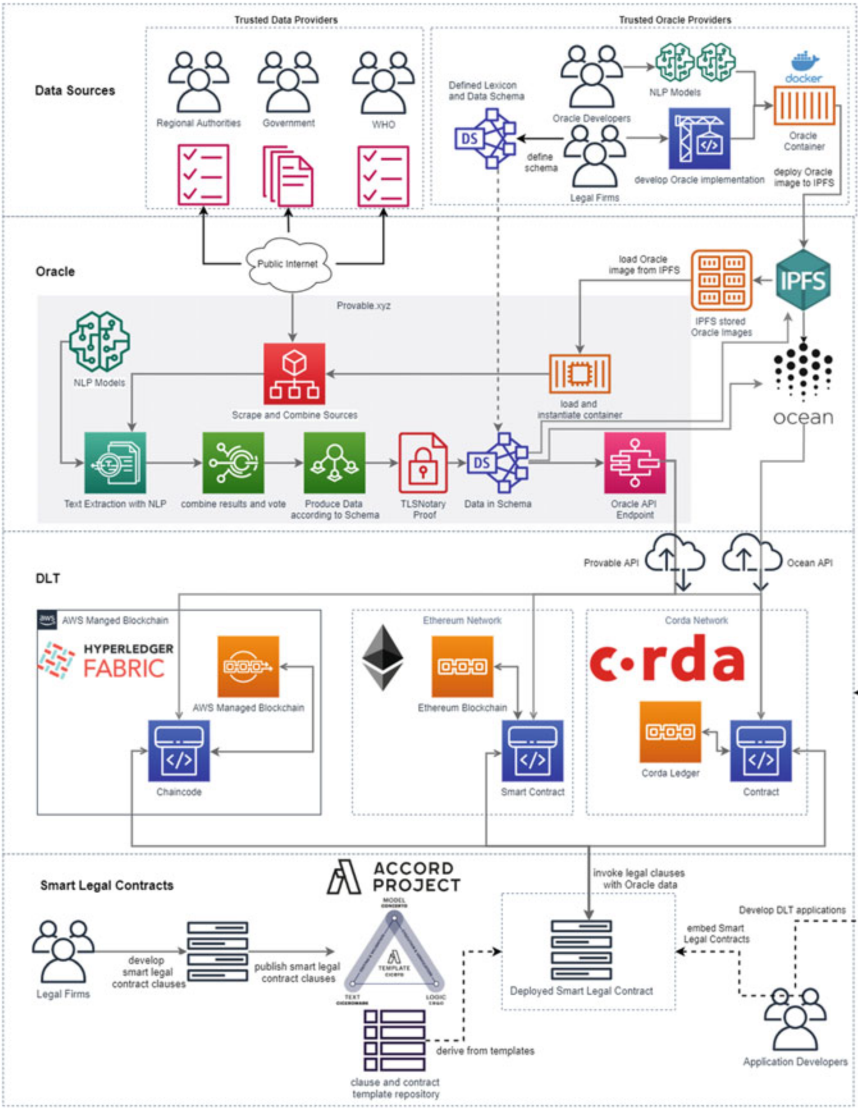

Fig. 2 Oraclised data schema responsive legal agreement

An example of this complexity can be seen during the initial response to the COVID-19 pandemic when the UK government updated legislation to restrict residential property purchasing activities. The UK Law Society guidance (The Law Society 2021) temporarily adjusted the liabilities and penalties related to property purchases (The Law Society 2020). Within this legislation, an important event was when the government would lift restrictions. In light of this, real estate contracts were revised with clauses referring to these restrictions and what should occur within a period of 30 days after restrictions were lifted.

Real estate legal agreements could have been written to use an oracle to monitor the official date that restrictions were eased in a particular region or tier of infection. Additional changes made to standard house purchase contracts following the initial period of uncertainty were a relaxation of a number of the penalties for parties unable to meet their obligations due to the pandemic. Where previously there was a penalty for breach by either party, many of these would not apply whilst the pandemic was a factor in the breach. This makes the standard house agreement far more complex to automate due to the number of permutations added by the pandemic and the degree to which the pandemic could be considered a factor. Figure 3 illustrates this process's additional complexity using a contract diagram the authors propose.

In general, there is a need for reliable information that can be used to guide and govern contractual obligations and performance to mitigate risk in the real estate sector. Examples include tenancy agreements, insurance contracts and business interruption (BI) insurance. There are also many instances where these contracts are not clear and comprehensive under pandemic situations. Adopting local and regional restrictions that adapt based on local infection rates and risk factors means that contracts need to be adaptive to their environment. To be effective, these contracts need to have a trusted source of data, an agreed data schema and a legal lexicon that can add clarity to legal agreements. Combining these elements can lead to a fair and transparent set of legal agreements that can add clarity to an uncertain future.

The authors propose an integrated approach to improving the current approach by

1. Defining a universal standard of legal lexicon that will help provide increased levels of guidance and clarity in interpreting contracts in a fast-changing environment.
2. Building an open source set of data standards to govern crises related reporting. This could include a regional number of deaths, infections, beds used by hospitals or transmission rates, in addition to government restrictions on certain types of businesses.
3. Creating a method to reduce interpretation issues with contracts affected by a crisis such as a pandemic. Automation of aspects of legal agreements, using smart contracts, can improve their ability to be adaptive and dynamically adjust obligations in the agreement based on information from a trusted third party.

These concepts are united into a cohesive set of elements that can form a trusted set of data sources that are collected, aggregated and verified. Then, they are made

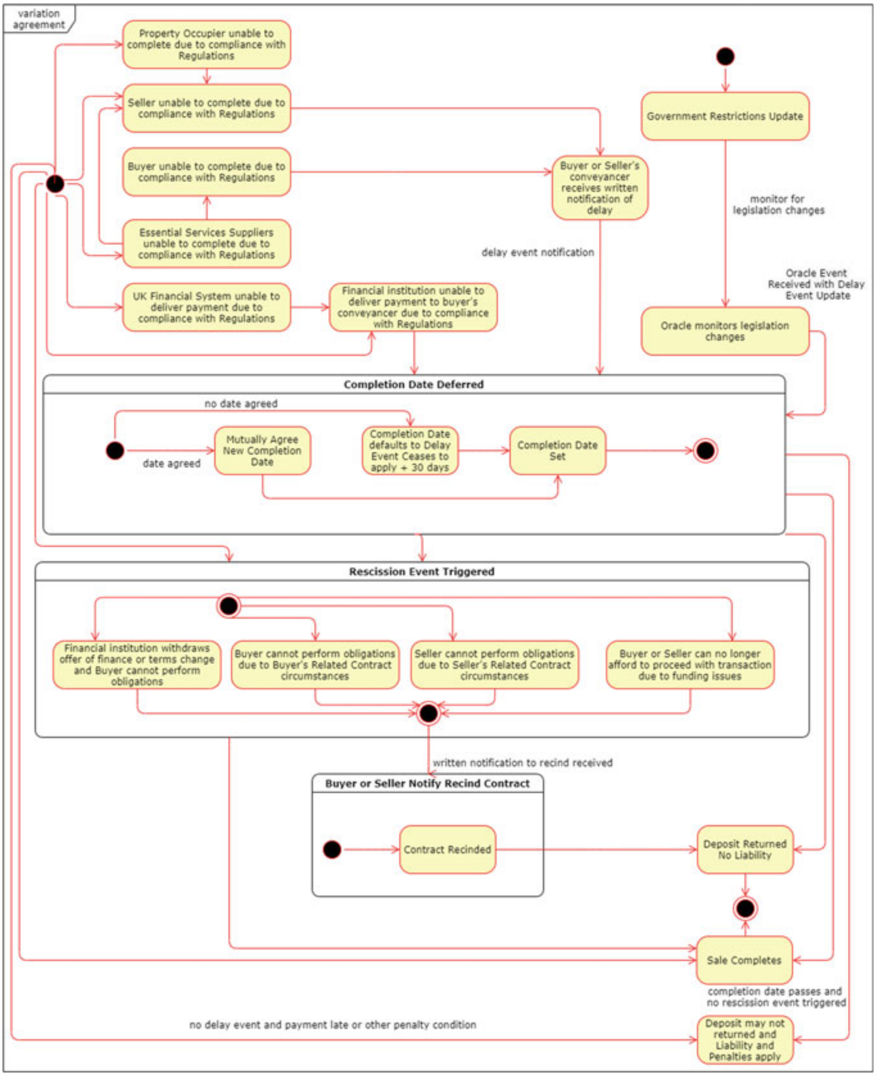

Fig. 3 COVID-19 responsive real estate contract diagram

available on distributed platforms such as IPFS[13] and published into data trust models such as Ocean Protocol.[14] The authors' approach aims to source data from multiple trusted sources and make this available for a range of potential data consumers, including smart contracts.

[13] https://ipfs.io.

[14] https://oceanprotocol.com.

A platform such as Ocean Protocol is useful for sourcing data and algorithms to process the data, such as NLP models to extract data into a standard schema for use by contracts. The current implementation developed uses the Provable (2019) platform. Still, the authors intend to explore other options such as Chainlink,[15] and algorithms that run inside Ocean Protocol or SingularityNET[16] to act as a trusted source. Another promising approach avenue, though currently at an early stage of development, is API3.[17]

These contracts can run on a range of permissioned and permission-less DLT systems. An implementation for Hyperledger Fabric[18] is available, with Ethereum[19] planned to follow. A sample legal smart contract has been developed using the Open Source Accord Project.[20] The sample pandemic policy contract that can use data returned from the initial oracle and the DLT code is listed in public repositories.[21]

The use of data derived from non-human sources such as from sensors and data capture devices is further explored in the next section by looking at the wider benefits and opportunities for data gathered from IoT and shared via an oracle. A particular emphasis is on using data sources to deal with extreme events such as extreme weather conditions and pandemics and the impact on insurance.

4 Oracles and IoT Applications to Insurance

4.1 Oracles Applications to Insurance During Covid-19

As estimated by OECD (2020a), the financial impact from the Covid-19 pandemic on GDP ranges from 20% to 25% in many major advanced economies. In the UK alone, GDP fell by 20.4% in April 2020 (Scruton 2020). The long-term impact of the pandemic and the resultant economic downturn is likely to have ongoing financial repercussions for years to come.

The pandemic has had an economic impact due to factors such as:

1. Government enforced closures, or limited trading ability, such as restaurants only able to open for take away or delivery
2. Limitations on concurrent customer occupancy, where allowed
3. Reduced customer footfall due to travel restrictions
4. Consumer confidence issues and unwillingness to go outside
5. Lack of consumer spending due to furloughing
6. Ongoing economic uncertainty

[15] https://chain.link.
[16] https://singularitynet.io.
[17] https://api3.org.
[18] https://www.hyperledger.org/use/fabric.
[19] https://ethereum.org.
[20] http://accordproject.org.
[21] https://github.com/niallroche/covidhack-legalsmartcontract.

7. Supply chain and fulfilment issues

The economic impact on businesses has also been compounded by a lack of clarity in contractual arrangements between parties such as suppliers, landlords, customers and insurers, leading to ongoing risks for businesses.

In particular, the insurance industry has been slow to respond to the fallout of COVID-19 with several high profile news reports (OECD 2020b) and legal challenges (Axling 2020; Gangcuangco 2020) being taken against insurance companies that are not paying compensation, despite indications that their policies consider pandemics (Ross 2020). A lack of clarity from regulators and government has worsened the situation. Although some insurers were found to be liable for the losses (Barton 2021), there is still ambiguity in contractual commitments (ABI 2020).

On 5 March 2020, the UK Government added COVID-19 to the list of "notifiable diseases" under the Health Protection (Notification) Regulations 2010.[22] According to the Department of Health and Social Care, this was to help companies seek compensation through their insurance policies for losses arising as a result of the pandemic.

However, despite this declaration, there are ongoing issues. One issue with many agreements, such as insurance policies, are references to compensation not being applied when a force majeure event occurs. In English law, there is no agreed meaning or legal doctrine of force majeure, which is why it is always so heavily debated (Martin Cherry 2020).

Aside from insurance issues, the impact has had several secondary effects, for example, government-mandated, enforced business closures or restrictions. Another example is the reduction of operating capabilities and consumer demand. The economic impact on businesses influences their ability to make rental payments and other obligations. Whilst government schemes, such as business rate freezing and staff furlough schemes, may help, the reality is that many businesses will struggle to make rental payments.

Many existing rental agreements do not take these types of considerations into account. Given the complexity of business closures, partial closures, local infection rates and restrictions, there is a need for flexibility in repayment arrangements to reflect the reality of the impacts these businesses are facing. A dynamic lease agreement that considers local restrictions by adjusting payment arrangements by updating rental amounts, payback duration or freezing repayments during closure periods, or moving to a percentage of turnover model could be considered with a sufficiently agile and accurate set of data points and smart clauses.

[22] https://www.gov.uk/guidance/notifiable-diseases-and-causative-organisms-how-to-report#list-of-notifiable-diseases.

4.2 IoT as Oracles in Insurance

The construct mentioned previously already exists; for example, there are parametric flood insurance policies[23] : during a flood, if the water level rises above a certain threshold and hits a sensor, the insurance policy becomes effective and pays compensation. Although not wholly automatic yet, before a payout, there is still a degree of due diligence to be performed; these policies represent a positive move forward in the industry towards automatic detection and settlement.

There is a natural fit with these automated processes and DLT-based solutions processing data generated by IoT sensors (see also Chapter "The Internet of Value and Internet of Things"). As outlined in Werbach (2018a), there are three elements that need to be trusted in a transaction: the counterparty, the intermediary and the dispute resolution mechanism. DLT can be used for all three. Emerging decentralised solutions (Naik et al. 2019; Cousaert et al. 2022) include Etherisc (Mussenbrock and Karpischek 2017) and NexusMutual (Karp and Melbardis 2021). They provide automatic compensation for flight delays, flood damage, hurricane and crop damage according to weather reports and satellite imagery from decentralised geospatial data providers such as FlyingCarpet[24] and potentially Earth Observation (Agency and European Space Agency 2019). Etherisc has already made a payout to farmers in Sri Lanka when extreme weather conditions occurred (Evans 2019). Decentralised dispute resolution is also maturing with approaches like Kleros[25] and Mattereum (Mattereum 2020), amongst others.

Another example where external events impact on contractual events can trigger insurance payouts is the Weather Ledger project,[26] which is part of the Digital Catapult Field Labs (Lesaege et al. 2019). This project is attempting to solve an issue in the construction sector where delays due to rain on the construction site can lead to disputes between contracting parties. The approach uses IoT-enabled local weather sensors installed on the construction site. These sensors are much more reliable than online sources of weather data that may not be accurate enough to provide sufficient data granularity at a local level. Construction contracts specify a particular series of clauses related to ten-year storms and a specific minimum amount of wind or rainfall to justify a delay.

The Weather Ledger proof of concept determines the local weather conditions using IoT sensor data. This data is either communicated over mobile networks if available, or via LoRaWAN[27] or satellites, allowing the sensor data to be delivered to an oracle platform such as Provable.[28] The oraclised data is then fed to a legal

[23] https://floodflash.co.
[24] https://www.flyingcarpet.network.
[25] https://kleros.io/whitepaper_en.pdf.
[26] https://www.digicatapult.org.uk/for-large-businesses/collaborative-research-and-development/the-weather-ledger.
[27] https://lora-alliance.org.
[28] https://provable.xyz.

smart contract platform such as the Accord Project to provide data to a parametric contract implementation.

A similar oraclised proof of concept[29] smart legal contract looking at weather-related claims in the solar power generation industry was developed to trigger claims when there were more than ten days of "adverse" weather per quarter.

Automated parametric insurance contracts need to have suitable data sources with sufficient levels of reliability and trust. This provides a business opportunity to have a network of independent data providers. These providers should be capable of supplying reliable and impartial sources of data with sufficient levels of traceability and transparency to ensure the integrity of the data.

The GSMA produced a report outlining several use cases for DLT in IoT (GSMA 2018). Whilst there are many uses for the capture, storage and security of IoT data, one of the key areas of opportunity is unlocking the value of the data captured. Oraclised data sources can be as diverse as information feeds coming from web pages, sporting, political and news events and financial data. They are also increasingly including data from IoT devices capturing climate-related data and increasingly imagery from satellite or low earth orbit, or even drone-captured imagery. As an example of unlocking this value, the imagery data gathered from these types of IoT devices can be used for DLT-enabled carbon credit trading (Mandaroux et al. 2021) as a verified source of data around tree plantations and other carbon offset projects. The use of IoT and DLT in the area of climate change has been explored in more depth in Climate-KIC (2018), Mandaroux et al. (2021) and Andoni et al. (2019).

The variety and veracity of these data sources can unlock hidden value in a range of domains that can benefit from efficient contract automation. The overall cost and efficiency savings can be passed on by contracting parties to the data providers, ensuring the legal agreement's integrity and leading to new business opportunities.

One of the concerns of using IoT data is the performance impact of DLT to process the volume and velocity of IoT data on-chain (GSMA 2018). Approaches taken by Hedera Hashgraph[30] and network approaches specifically designed for these types of use cases such as IOTA[31] may provide some options for addressing these performance considerations.

The architectures evolving for processing IoT data include those with a distributed approach. Data processing is moving closer to the source of the data due to the decreasing computational cost on devices and the increasing power of edge-side computing (Agbo et al. 2019; Giang et al. 2015). The roll-out of 5G technologies and low power networks such as NB IoT,[32] LTE-M[33] and LoRaWAN[34] means that IoT devices can typically support high bandwidth or massive numbers of connected

[29] https://docsend.com/view/xe6xds9.

[30] https://www.hedera.com.

[31] https://www.iota.org.

[32] https://www.gsma.com/iot/narrow-band-internet-of-things-nb-iot/.

[33] https://www.gsma.com/iot/long-term-evolution-machine-type-communication-lte-mtc-cat-m1/.

[34] https://lora-alliance.org.

devices to send large amounts of captured data for central processing. The capabilities of Mobile Edge Computing[35] allow for complex processing at the point of capture and pre-processing or aggregation before sending to a central server or cloud services.

The ability to run DLT nodes on these clients, in addition to Machine Learning models, such as image classifiers, provides new opportunities for a data and model economy. DLT-enabled IoT and gateway devices that gather data and share proof of capture into a oraclised immutable data store, when combined with trusted data verifiers, can enable executable contracts that execute within multiple layers of the network architecture.

As an example, data analysis running on an edge device such as a Raspberry Pi or a smart camera[36] can execute Computer Vision or Machine Learning image processing algorithms. These algorithms could identify objects and then transmit these objects' count instead of needing an entire video feed to be sent for analysis. A practical example of this could be to measure footfall, which Hoxton Analytics[37] has created to provide proof of customers arriving in a shop or retail environment. This could be useful in a real estate/retail contract when charges are based on footfall, occupancy levels or other factors that a smart camera could determine.

Data sharing marketplaces such as Ocean[38] can be used for storing and exchanging both raw and processed data and ML models. This data and these models could be purchased to augment data analysis. Ocean provides a new type of marketplace for verified data sources, where one use case could be for contract processing in insurance claim verification and automated triggering. Captured data could also be traded and used as a basis for DLT-enabled online dispute resolution using platforms such as Jur.[39]

5 Oracle Reliability and Trust

Security in a DLT network and the smart contracts that execute within it is dependent on the underlying network and smart contract code auditing. A major weak point of the system may be the external data provider's accuracy and reliability, as the smart contract logic will automatically operate based on its data. Multiple sources of data should be available to ensure the accuracy and trustworthiness of any data used. If a bad actor with a financial or other interest provides incorrect data, having multiple providers and an appropriate strategy for resolving differences in received values is necessary. Strategies may include voting, potentially with a weighting towards more reliable providers, and a round-robin approach, where the values from multiple oracles will be used over time (at the risk of a malicious or inaccurate oracle being

[35] https://www.etsi.org/technologies/multi-access-edge-computing.
[36] https://aws.amazon.com/deeplens/.
[37] https://www.hoxtonanalytics.com.
[38] https://oceanprotocol.com.
[39] https://jur.io.

used occasionally). A reputation score for oracle sources may help ensure trust in the validity of these sources and, if available, could be used to weigh the votes.

6 Conclusion

This chapter discussed how oracles could play a role as providers of verified data from trusted providers in various areas and provide data to improve transparency and increased efficiencies.

Focusing on the real estate sector, we looked at use cases featuring data. These use cases include how data used in pricing models could create new value streams and enable some disruption to an industry that has gained from a lack of transparency and barriers to data. Already, aspects of this can be seen in action with various new platforms and solutions in the market.

We also discussed how smart contracts could be used in a pandemic situation and how IoT could facilitate more efficient insurance provision. Given ongoing uncertainty, and the likelihood of future pandemics and related events, many smart contracts applications will require oraclised data sources. Examples of this include, parametric pandemic insurance linked to business interruption schemes or rental and lease agreements. The approach elucidated earlier on utilising Oracles and IoT has application in the construction sector and tracking climate-related events such as storms and significant events such as floods and earthquakes. Benefits in cost savings from automation and increased accuracy of processing payment calculations and a shared audit trail of contract parameters, inputs and claims obligations can lower overall administrative cost from manually managing policies and thereby increase certainty.

Ultimately, successful blockchain adoption in many industries requires a complete ecosystem of providers to perform various roles: from infrastructure providers to exchanges and, importantly, oracles. The Internet of Value can only thrive on connecting global businesses should the blockchain ecosystem be functional in its entirety - and oracles will play a vital role in providing trusted data.

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Internet of Value and Systemic Risk

Systemic risk refers to the risk of a failure of an entire system as opposed to the malfunction of individual parts. Certainly, systemic risk increases with the number of interdependencies between numerous and diverse networks of trust, which characterise IoV. This may create a high level of network interdependency. We do not have data to measure the systemic risk of the IoV, because it is still in its infancy.

However, we can learn from other interconnected systems such as the financial system, and we can derive some properties that can be used as a reference to measure the potential risks emerging on the IoV. History teaches us that increasing interconnection in complex financial systems is characterised by emergent properties that are not observable at the micro-level, and higher fragility that can lead to cascading defaults and failures. Networks exhibit a trade-off between efficiency and robustness to attacks. The network topology, which is desirable for efficiency gains, does not generally match the preferred one in terms of robustness against attacks.

Part "Internet of Value and Systemic Risk" focuses on the emerging systemic risks associated with the IoV. Chapter "Structure, Robustness and Efficiency of Networked Systems" is written by Fabio Caccioli and focuses on the structure, robustness and efficiency of networked systems. Chapter "Potential Sources of Internet of Value Systemic Risk" is written by Josep Lluis de la Rosa Esteva and discusses risks focused on the IoV.

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Structure, Robustness and Efficiency of Networked Systems

Fabio Caccioli

1 Introduction

The development of blockchain and distributed ledger technologies (DLTs) aims to transform economic interactions by facilitating the method by which value is stored and transferred between individuals. This is achieved through the emergence of peer-to-peer systems, where users directly interact with one another rather than through intermediaries, thus reducing the cost associated with their transactions (Ibañez et al. 2021).

Users will contribute to the development and maintenance of such platforms, which should, therefore, emerge with no requirements for central planning, apart from some engagement rules that define the collective decision-making process.

Such engagement rules must provide the correct structure of incentives for the system to correctly develop as a distributed system where all users are equal. This is non-trivial, as networked systems that develop over time in a self-organised manner with no central planning tend to become more centralised and witness the emergence of special users on which interactions tend to concentrate.

The emergence of special users occurs because of a simple self-reinforcing mechanism: if a user is more important than others, other users will tend to interact with that user, thus making it more important (Yule 1925; Simon 1955; Price 1976; Barabási and Albert 1999).

From the perspective of the system as a whole, there are benefits and risks associated with the emergence of special users: their existence can facilitate the propagation of information and overall efficiency of the system. This, however, comes at the expenses of the increased fragility of the system to attacks targeted to the special

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users. This implies the existence of trade-offs between efficiency and robustness that must be accounted for when designing a networked system.

The study of networks, a very active field of research in complexity science since the 90s, provides a useful insight concerning these mechanisms and trade-offs. This chapter reviews—in an idiosyncratic manner and without a claim to completeness—some lessons that have been learned in relation to the stability and efficiency of complex networks, and its attempts to derive some insights for Internet of Value (IoV) networks. The interested reader can refer to the following references for comprehensive reviews on complex networks (Albert and Barabási 2002; Caldarelli 2007; Barrat et al. 2008; Dorogovtsev et al. 2008; Newman 2010).

2 Random Networks

Networks are a mathematical abstraction used to represent systems composed of many units that interact in pairs. The mathematical representation of a network is given in terms of a set of nodes (representing the units) and links that connect nodes (representing interactions).

The typical question asked when studying a network concerns the relationship between the structure of the network and its function. We want to find general relationships that are independent of the fine-grained details of the network at hand, in order to draw conclusions that are valid for a class of networks rather than a specific realisation, which may, for instance, be affected by noise. To this end, different classes of random networks have been introduced in the literature (Albert and Barabási 2002; Caldarelli 2007; Barrat et al. 2008; Dorogovtsev et al. 2008; Newman 2010). For each class, some specific features are (statistically) fixed, the rest being as random as possible. This allows us to understand the effect on the system of those features that are being fixed.

The most famous class of random networks are Erdős–Rényi networks (Erdös and Rényi 1959). An Erdős–Rényi network with N nodes can be constructed by considering all possible pairs of nodes and drawing a link between each pair with probability p. The parameter p controls the level of connectivity of the network: each node will on average be connected to $< k >= p(N-1)$ other nodes. The number of neighbours of a node is called its degree. A network's degree distribution is the distribution of degrees across its nodes. We see in the following that the degree distribution strongly affects the property of random networks.

In the limit of large networks ($N \gg 1$), the degree distribution of Erdős–Rényi random networks is a Poisson distribution with average $< k >$. For this type of distribution, the probability of observing a node with a degree much farther from the average degree decays quickly, so that Erdős–Rényi networks are typically used to describe systems where all nodes have similar connectivity.

Also in a regular lattice (like for instance two-dimensional grid), nodes have similar connectivities (in fact they have the same degree). Erdős–Rényi networks are, however, quite different from a regular lattice because the average distance between nodes is much smaller: In a regular d-dimensional lattice, the average distance between nodes grows as N^d, whereas on Erdős–Rényi networks it grows only as $\ln N$. This means that Erdős–Rényi networks, at odds with regular lattices, are quite compact objects: it is possible to navigate between nodes quickly, and this remains true as we increase the size of the network.

Because random networks appear to be easy to navigate, and because all nodes of an Erdős–Rényi network have similar importance (when measured in terms of connectivity), we can consider Erdős–Rényi networks as prototypical examples of distributed networks.

Although very useful from a theoretical perspective, the analysis of many real networked systems (technological, biological, social) makes it clear that Erdős–Rényi networks are, however, not a good model to describe the connectivity of real networks. In fact, the latter tend to be characterised by heterogeneous distributions of degrees, with a few nodes acting as highly connected hubs among a majority of less connected nodes. There are many more differences between real networks and random networks; here we focus for simplicity on the degree distribution, as this can be linked to the centralisation of the network.

The configuration model is a way to generalise Erdős–Rényi networks to networks with any degree distribution. Rather than just fixing the average degree, as in Erdős–Rényi networks, we now fix the entire degree distribution $P(k)$. A network of the configuration model can be generated as follows: First, we assign to each node i several half links k_i drawn from the probability distribution $P(k)$. Then, we randomly match half links to form links between pairs of nodes. In this way, it is possible to generate networks with any given degree of distribution.

To mimic the connectivity pattern of real networks, the class of scale-free random networks has, in particular, been considered in the literature (Albert and Barabási 2002). These networks are characterised by a power-law distribution of degrees $P(k) \sim k^{-\gamma}$. When the exponent γ satisfies $2 < \gamma \leq 3$, the variance of the degree distribution diverges, which makes it apparent that the fluctuations of degrees across nodes are large. The existence of hubs in scale-free networks facilitates the navigability of the network, as they can act as shortcuts to move from one node to another. In fact, the typical distance between nodes in such networks scales as $\ln(\ln N)$ (Cohen and Havlin 2003), even more slowly than for Erdős–Rényi networks.

Given the inequality in terms of nodes' degrees that characterises scale-free networks, they are considered in the following as examples of effectively-centralised systems (a purely centralised system would be represented by a star network, with the provider of the service at the centre, and all users connected to it. In a scale-free network, there is no single central node, yet most of the activity is concentrated on a few nodes).

3 Large-Scale Connectivity of Random Networks

Intuitively, we would expect a networked system to be able to perform its function if it is "well connected", that is if it is possible to reach a sizable fraction of nodes from any other node. This is, for instance, the case if the network is supposed to enable the transfer of information between its parts.

This intuition can be formalised in mathematical terms through the concept of a giant component. A component of a network is a set of nodes that are all connected between them, in the sense that it is possible to reach any node of the set starting from any other node in the set following a path of links. If we consider the largest component of a network, we can say that there is a giant component if the number of nodes N_{LC} of the largest component scales with the size of the network N as $N_{LC} \sim N$.

Apart from the mathematical details, the existence of a giant component signals the fact that a sizable fraction of nodes belongs to the same component, which we take as a proxy that the network can perform its function (for instance, it means that information could travel among a relatively large set of nodes). In the absence of a giant component, the network is just a collection of components that are very small compared to the total number of nodes and are disconnected between them. Therefore, the network is not well-formed, and it does not display any large-scale coherence.

For a network generated through the configuration model, it is possible to derive the following condition for the emergence of a giant component (Molloy and Reed 1995):

$$\frac{\langle k(k-1)\rangle}{\langle k\rangle} > 1 \quad (1)$$

where $\langle \cdots \rangle$ denotes an average over the degree distribution of the network. The equation above can be specialised to the case of Erdős–Rényi and scale-free networks. For Erdős–Rényi networks, the condition reduces to $\langle k\rangle > 1$, which means that if the average degree is larger than one, the network displays a giant component. Note that this implies that the giant component appears already for sparse networks (in a network of N nodes, there can be up to $N(N-1)/2$. A network is said to be dense if the number of links scales with the number of nodes N as $O(N^2)$: If the number of nodes doubles, the number of links quadruples. A sparse network is, instead, one for which the number of links scales instead as $O(N)$: If the number of nodes doubles, the number of links also doubles).

For an Erdős–Rényi network there are then two regimes: If $\langle k\rangle < 1$ there is no giant component, whereas if $\langle k\rangle > 1$ there is a giant component and the network in the abstraction under consideration, can perform its function.

For a scale-free network with $2 < \gamma \leq 3$, the situation is quite different: the second moment of the degree distribution diverges, which implies that the condition for the existence of a giant component is always satisfied. The intuition behind this behaviour is that the presence of hubs facilitates the connectivity of the network, which is always able to perform its function.

Given that we are taking Erdős–Rényi and scale-free random networks as toy models of decentralised and centralised systems, the lesson we gain from this analysis is that, whereas it may be easier for centralised systems to function, decentralised systems can also operate well in the sparse regime, provided a sufficient number of links is present. Thus, IoV system designers would need to account for these network properties.

4 Robustness of Random Networks

So far, this chapter has discussed what happens when pairs of nodes are randomly connected and asked the question of under what conditions a giant component emerges in the network. The opposite problem is now considered: given a network with a giant component, how many nodes should be removed for the giant component to disappear. This exercise is useful to understand how robust a network with respect to the failure of its nodes is.

The answer to this question depends on the protocol used to remove the network nodes. If nodes are removed randomly with uniform probability, scale-free networks are more robust than Erdős–Rényi networks. If nodes are removed starting with the most connected ones, Erdős–Rényi networks are more robust than scale-free ones. The reason for this behaviour—often referred to as robust-yet-fragile behaviour—is simple: whereas in Erdős–Rényi networks nodes have similar degrees, scale-free networks are characterised by the presence of few hubs—which facilitate the connectivity between different parts of the network—and many "poorly" connected nodes. In that configuration, to break the network, hubs must be removed. However, if nodes are removed randomly with uniform probability, it is not likely that the hubs will be removed, because they are few and, with higher probability, a poorly connected node will be selected for removal. However, if the removal protocol favours the removal of highly connected nodes, then by removing a few selected nodes (the hubs), it is very easy to break scale-free networks (Cohen et al. 2001).

This intuition is extremely important for IoV systems. This confirms that a distributed network will perform worse than centralised ones in the case of random failures of nodes, whereas they will be better off in the case of targeted attacks aimed at breaking the system.

5 Spreading Processes of Random Networks

So far, the structural properties of networks have been considered. However, how does the structure of the network affect the outcome of dynamic processes that take place on the network? This question is useful to understand, for instance, how information spreads on networks.

Again, the degree of distribution of the network can strongly affect the outcome of dynamical processes taking place on networks. A typical example of this can be observed, for instance, in epidemic spreading models. Consider, for instance, the SIS model, where each node can be susceptible or infected. The dynamic is very simple: At rate α, each infected node infects its susceptible neighbours, whereas at rate β, each infected node becomes susceptible (i.e. it recovers, but it does not become immune). In this spreading process, the question raised is of whether, in the stationary regime, the fraction of infected nodes can be larger than zero. By solving the model, it is possible to find a condition for this to occur (Pastor-Satorras and Vespignani 2001)

$$\frac{\alpha \langle k^2 \rangle}{\beta \langle k \rangle} > 1 \tag{2}$$

This condition depends on the moments of the degree distribution, and it defines the so-called epidemic threshold, which discriminates between a regime where no infected nodes remain in the system and a regime where a finite fraction of nodes remain infected. The epidemic threshold is equal to $\langle k \rangle / \langle k^2 \rangle$ if $\alpha/\beta < \langle k \rangle / \langle k^2 \rangle$ there is no epidemic, otherwise there is. The epidemic threshold crucially depends on the moments of the degree of distribution. In particular, we see that—at odds with the case of Erdős–Rényi networks where the two regimes exist—for a scale-free network, it goes to zero, meaning that a finite fraction of the population will always be infected as long as the transmission rate α is larger than zero (Pastor-Satorras and Vespignani 2001; Barrat et al. 2008). Again, this is due to the presence of hubs that facilitate the spreading of the infection.

Epidemic spreading models cannot be directly used to model the propagation of information in networked systems, as the propagation mechanism is context dependent. For instance, uninformed individuals may require multiple exposures to informed individuals to acquire the information, or informed individuals may decide to stop spreading the information if enough of their neighbours are already informed (Daley and Kendall 1964; Daley and Gani 1999; Barrat et al. 2008). Therefore, results concerning the efficiency of different networks may depend on the specific mechanism at hand. For instance, in the case whereby informed nodes stop propagating information if enough of their neighbours are informed, the presence of hubs may reduce the capability of the information to reach the entire network, should these stop propagating the information.

A real case application of epidemic spreading models to distributed systems is the study of forks in the blockchain, which may impact IoV systems. In this case, nodes represent miners who validate transactions and spend computational power to form new blocks to be added to the blockchain. The mining process can be modelled as a Poisson process on each node, whereby a new block is discovered at a given rate. When a new block is found by a node, this is broadcasted at a given rate to its neighbours, who, in turn, broadcast the new block to their neighbours and start mining on the new block, and so on. This propagation process can be modelled as an SIS model with $\beta = 0$ (Decker et al. 2013), i.e. infected nodes (nodes that have been informed about the new block) never recover from the infection. A blockchain fork occurs whenever the new block does not reach the whole network before an alternative block is found by an uninformed node. The probability of a fork increases with the number of nodes in the network, which may lead to scalability problems.

In this context, the efficiency of the system can be, for instance, measured in terms of the probability of reaching the majority of the network before a fork occurs. A comparison between Erdős–Rényi and scale-free networks shows that the latter scale better (Caccioli et al. 2016).

6 Conclusion

The comparison between Erdős–Rényi and scale-free networks discussed above provides some ideas concerning the robustness and efficiency of IoV networked systems. The main points that emerge are the following:

- In Erdős–Rényi random networks, nodes are homogeneous in terms of their degree, whereas in scale-free networks, nodes are unequal because links concentrate on a few hubs. We can use these models as abstract examples of distributed systems and effectively-centralised systems.
- From a structural perspective, scale-free networks tend to be more efficient: They are more compact, and the presence of hubs make it easy to navigate through them.
- This increased efficiency comes at the expense of a high fragility to targeted attacks: if a few hubs are shut down, the system breaks and will fail to perform its function.

More centralised systems, where special nodes serve as hubs, appear to be more efficient. This is, perhaps, the reason why many real networks that have no central planning (such as the Internet, cryptocurrency open networks or social networks) spontaneously evolved towards a structure that can be better approximated by scale-free networks than Erdős–Rényi networks. See Tasca (2015) for the centralisation of the Bitcoin network.

The reason for this tendency can intuitively be understood by the desire of nodes to establish connections with important nodes to facilitate their access to the system. This is at the basis of the celebrated Barabasi-Albert model of scale-free networks, which explains how a scale-free network may be the result of individual nodes' decisions. The decision-making process they use in their model is simple: As new nodes come to the network, they need to connect to already existing nodes. The choice of their neighbours is random, but with a bias such that the probability of connecting to a node increases with the degree of that node. This preferential attachment, rich-get-richer rule leads to a self-reinforcing mechanism by which the more connected a node is, the newer connections it tends to attract. This eventually leads to the emergence of hubs in the system and consequently power-law distributions of degree. This implies the existence of special nodes on which most of the activity in the network concentrates.

The same special nodes that improve efficiency, however, make the system vulnerable to attacks. Once the special nodes are identified, it is sufficient to focus on them to take the system down, so that the most efficient network structures are not necessarily the most robust to attacks. This represents a potential trade-off between efficiency and robustness to attacks, which is of paramount importance for IoV systems: the network topology which is desirable for efficiency gains does not generally match the one that is preferable in terms of robustness against attacks.

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Potential Sources of Internet of Value Systemic Risk

Josep Lluis de la Rosa Esteva

With the continuous development of the IoV, the lack of interoperability between networks of trust can become an important source of systemic risk.

Indeed, the main problem that the blockchain technology faces at the moment for the sake of the IoV is the lack of interoperability and the obstacles faced in building a second and third layer network.

There are thousands of distributed ledgers out there today, and they perform or improve several functions. Each ledger is working separately like a local area network (LAN) of the 1970s that did not communicate with others around it; closed off because there is no adoption as yet of industry-wide standardisation of protocols. If they could all interoperate, then moving several digital assets and converting from one to another could be fast, cheap and more secure, especially as there would no longer be a need to rely on risky centralised exchanges.

Even if the current financial system started adopting distributed ledgers on a large scale, with each institution using its own private or public ledger, not all of the challenges faced by today's siloed systems would be solvable. Paradoxically, in this scenario, the situation with cross-border and inter-bank transactions might remain the same, as it would require time-consuming processes for value to move from one ledger to another.[1]

Thus, interoperability is a must, and its lack is a potential source of systemic risk. This is of paramount importance, especially in the current expansion phase where the IoV's new business models come up to erase long-standing barriers and enable

[1]See Xu et al. (2021), Dubovitskaya et al. (2021) for critical analyses on existing cross-ledger transaction protocols.

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the democratisation of finance and property by empowering its users to transact instantly not only across borders, but also across currencies while closing cultural and socioeconomic gaps.

The reasons for the lack of interoperability between ledgers are many; not only the lack of agreed standard protocols to make it possible, but the fact that every ledger has different goals when it comes to how data and the digital assets are handled. They are also built using different distributed ledger technologies, languages, protocols and consensus mechanisms. For more insights about the blockchain interoperability issue, we refer the readers to Tasca and Piselli (2019).

The lack of interoperability—driven by the diversity of missions and technological proposals for ledgers—is not the only source of systemic risk envisaged here. In addition, the lack of scalability of these new network technologies could worsen the risks of assets and value, in general, being lost in endless sidechains.

Sidechains, state channels and payment channels are off-chain solutions to specialise the validation of transactions in subsets of nodes. An off-chain transaction is the movement of value outside of the main ledger, despite being very likely registered in a local or minor ledger validated by subsets of nodes from the main net, which, in turn, tend to be trusted parties among each other and work out in a permissioned minor ledger (Back et al. 2014).

Subsequently, only a "summary" of this minor ledger is uploaded on the main ledger in any form that is eventually validated by the main net. Risk is again at the core of this specialisation. If this is the technology which will be used for a hyperconnected IoV, we may expect that from time to time, tokens might get trapped in these new siloes or take the wrong direction in the network, and therefore, their value might fade according to their distance to the main net and the number of summary hops required to get the greatest level of confirmation.

To summarise, considering the current growing trend of open communities along with all types of permissioned ledgers, and the developments of side-channels for speeding up consensus for those who transact at high volume or demand higher privacy or speed, the lack of scalability and interoperability are major risks.

Of course, the network structure also plays an important role, especially if we consider networks of networks—see coloured coin applications (Bitcoin Wiki 2020) for example. This source of systemic risk is of paramount importance, as numerous new initiatives are proposing services backed by collateral in whatever asset that is tokenised (i.e. lending, factoring, insurance, guarantees of service, creative industries and more). The trend of collateralising the risk of digital currencies or any of the new digital assets may lead to systemic risk.

The crypto-collateralised stablecoins, conceived as a workable, truly decentralised approach to stabilise prices, they are not that stable (Perez et al. 2021). The same might occur with crypto-collateralised loans, which are paid by smart contracts collateralised by cryptocurrencies (see Chapter "From Banks to DeFi: The Evolution of the Lending Market"). For example, *"when you want to take a Dai loan from MakerDAO, you freeze some Ether in MakerDAO as a guarantee that you will repay your loan. As the US mortgage market collapse of the 2000s has shown, Collateral is an unstable asset whose price may decrease significantly"* (Heydari 2018). Under these assumptions, the stablecoins' smart contracts might demand several times more collateral than the original value of the loan.

The phenomena of the IoV presents an interesting avenue to the application of tokenisation to new business models that may lead to systemic risk. The IoV facilitates value moving as quickly and as easily as information does. As value is something that is up to a society to determine, there is practically no limit to what can be exchanged over the Internet with value for individuals or institutions. According to Heydari (2018), already in 2018, cryptocurrencies had attracted 5% of gold market customers to reach a USD 400 billion market size, and since then, stablecoins with all type of collateral, and above all with Bitcoin, have greatly grown, with a peek in mid-2020.

Therefore, another source of systemic risk may come precisely from the nature of digital assets used as collateral. Tokenisation and collateralisation might create new types of much more complex asset interdependencies, and the collapse of even a small asset used as collateral could trigger the domino effect of a failure cascade.

The value of some collateral might fade by their lack of usage, trust, lost in a minor ledger, and indeed because they are poorly preserved. Finally, the preservation of collateral value over time must be considered. The preservation of value tackles the problem of value loss through time and exchanges (de la Rosa 2020). Through time, the accumulation of errors that occur when updates and migration into new technologies take place tend to erode the usability and integrity of digital assets. Thus, their value may reflect this situation and suffer a devaluation, as they would not be ready for any value transaction as the receiver will not receive the assets at their full integrity in the form and time that is required. Similarly, the accumulation of errors in the transmission of value to inappropriate receivers impacts the value that goes on erosion. The two factors, obsolescence and bad exchanges multiply, accelerating the decrease in the value of digital assets.

Thus, the development of techniques that look after the curation and integrity of digital assets along with their proper ownership management across all exchanges is all about the preservation of value, as an ultimate safeguard to avoid systemic risks triggered by a failure to preserve the value of digital assets.

The value preservation will be enormous as I also foresee massive migration of value onto DLT, a sort of Value Deluge, that requires fine value preservation of digital assets to avoid Value Blackouts which would amplify systemic risks. A Value Blackout would harm collateral and undermine the long term storage of value of digital assets.

To conclude, there has been a discussion of some potential sources of systemic risk to the emergence of the IoV. However, it is difficult if not impossible to be exhaustive regarding all possible sources. Indeed, the recent 2007–2008 financial crisis showed that with increasing connectedness comes increasing complexity, which is understood as greater interdependence. Any increasingly complex system is also characterised by higher unpredictability and speed, and presents emergent properties not observable at the micro level, leading to higher fragility. For further discussion on economic complexity, please see Sahdev (2016).

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Josep Lluis de la Rosa Esteva focuses on research on DLT and its applications to intelligent agents, virtual currencies and digital preservation. Notable blockchain projects he has been associated with are licens3d.com, venushina.org, welicense.io and reciclos.cat. He is also a professor at the University of Girona, a visiting professor at ETH Zurich and a research associate of the UCL CBT.

Governance and Privacy Issues from the Internet of Value

The IoV is a functional layer on top of the Internet that enables decentralised digital economies and value transfer. The IoV allows value to be exchanged as quickly and fluidly as information is today.

Providing a distributed network with the so-called trustless trust, where users trust the system output without having to trust each other, serves as an ideal architecture for the realisation of the IoV. Blockchain challenges centralised, top-down decision-making setups through radical transparency and smart contracts composed of auto-enforceable code.

Deemed as home to money without banks, companies without managers and countries without politicians, blockchain can transform our incumbent systems. But blockchain solutions are still nascent and face problems, particularly with on-chain governance that is often misaligned with privacy rules and regulations. Part "Governance and Privacy Issues from the Internet of Value" explores some of these issues.

Chapter "Governance and Privacy Issues from the Internet of Value" considers the challenges and risks arising from the IoV on governance and privacy that are apparent with the transfer of trust and risk. It further considers the current governance and privacy issues with the development of new digital services such as blockchain that underpin the IoV, and how these issues need to be addressed. This chapter is written by Mike Brookbanks.

This part was created with the support of Danielle Mendes Thame Denny and reviewed by Alexandra Sims.

Governance and Privacy Issues from the Internet of Value

Mike Brookbanks

1 Introduction

Within the current supply chain, the trust between producer to consumer associated with the transfer of value is based on legal contract and established relationships—through and with central counterparties (Banks, Agents Regulators, Government Departments, etc.). Blockchain creates a value web of relationships (Cartwright and Oliver 2000; Block et al. 2008) between all participants/entities (including the producer and consumer). New collaborations between entities are becoming established, which shift and threaten the "established" governance frameworks.

Aligned with this is a level of "governance" and "privacy" that is developing "bottom-up" within blockchain technology as auto-enforceable code and smart contracts. This is being built with new organisational entities such as the DAO.[1] New enterprise-level governance and privacy frameworks/models and standards, therefore, need to be developed to address the changing trust/risk models between consumers and suppliers.

There is a considerable gap between on-chain developments and the enterprise level of governance and privacy required by governments and regulators; for example, how are the data privacy requirements set out in GDPR[2] to be addressed "on chain"?

[1]The DAO was a digital decentralised autonomous organisation, and a form of investor-directed venture capital fund. The DAO had an objective to provide a new decentralised business model for organising both commercial and non-profit (Shermin 2017).

[2]The General Data Protection Regulation 2016/679 is a regulation in EU law on data protection and privacy for all individual citizens of the European Union and the European Economic Area. It also addresses the transfer of personal data outside the EU and EEA areas (European Parliament and the Council 2016).

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Although the existing literature provides several models on technology governance, its role and how it interrelates with corporate/business strategy and the delivery of technology to the business (Wu et al. 2015), the current view is that technology governance still does not address the particular requirements of changing business models within the IoV; it remains disconnected from corporate/business strategy (Valentine and Stewart 2013).

In parallel, there is also a developing body of work creating the underlying standards for blockchain: ISO/TC 307 with working groups focusing on both privacy and governance within the Blockchain. These new standards focus on the technology and do not address the broader socio-economic issues of the IoV. New frameworks are required to address both the IOV's distributed/collaborative governance and privacy. With the implementation of digital services, there will need to be a degree of flexible adaptation of the business models and governance within the IoV to address the disruption driven by technology change.

2 Governmental/Regulatory Governance

To date, many of the digital services within the IoV have been developed based on financial services and technology companies such as Hyperledger, Ethereum, R3 (Corda) and Facebook (Libra). The development of these services is now being established across industry, government, manufacturing and retail, whereby supply chains are being both enabled and disrupted by blockchain-based digital services (Maull et al. 2017).

It is clear that technology companies continue to promote the development of these innovative digital services between consumers and suppliers with scant regard for the manner in which the trust/risk dynamic will shift as the value chain changes and new intermediaries are introduced (see Chapter "Marketplaces and The Internet of Value"). This presents governments and country regulators with a problem of governance and privacy. Their aim is to promote the introduction of innovative digital services (Holmes 2017):

- to improve trust (Nienaber et al. 2014) and inclusion (CPTM 2016);
- as a way of resolving longstanding economic problems, improving financial inclusion (CSJ 2016);
- to address change in the political economy (Cohn 2016) to create new markets.

Although they have to ensure the problems of the past are not repeated, they also have to ensure that risk within the market/value chain between consumers and suppliers is not increased, and that trust and privacy between participants are maintained. The challenge is that the social, economic, cultural, ethical, legal, governance and risk models that govern the introduction of innovative digital services are nascent (Walport 2016; CPTM 2016; Adams et al. 2017). None of the prime movers within the technology companies and financial services companies have a history of responsible innovation. Governments and regulators need to promote the development of innovative digital services and markets as part of the IoV while ensuring that innovation is responsible and governed (Stirling 2016; Valentine and Stewart 2013), and that privacy and risk are managed (Chiu 2016; Walch 2015). The Bank of England recently announced policy and rules of engagement for Facebook's Libra (Reuters 2019) which demonstrate how the creation of this blockchain-based payment system should be regulated by the standard banking rules.

Unfortunately, the standard banking rules are not aligned with the changing digital economy which encompasses more than just finance. Therefore, country policymakers, governments and regulators also need to consider how blockchain would change the existing governance frameworks and regulations, to cover the socio-economic aspects alongside the ledgal, process and technical standards. It should be noted that supervising a blockchain and DLT "network" is more complex than supervising central market infrastructures. Nodes on the same network might be established in different geographies/jurisdictions and subject to local privacy and governance requirements (CPTM 2016). The IoV will operate globally, so governance and privacy need to consider these challenges in the development of their regulations and standards.

The IoV will reduce barriers to entry, introducing a borderless economy which will impact commercial and individual privacy[3] : "the ability of any one legal entity to protect the privacy of its citizens through public policy". The actions of public and private organisations that operate outside its borders within the IoV will, therefore, need to consider privacy and its legislation as a key requirement (Catalini and Gans 2016). In a commercial context, privacy entails the protection and appropriate use of the personal information of customers, and the meeting of expectations of customers about its use (Pearson 2012). What is appropriate will depend on the applicable local laws and individuals' expectations about the collection.

One way of thinking about privacy is "the appropriate use of personal information under the circumstances" (Swire and Bermann 2007). Today, large technology companies and financial institutions have wide and historic data about persons, their identities and transactions. Private data has become valuable information to feed artificial intelligence for new commercial models (Akgiray 2019). These new technologies are straining the traditional legal frameworks of privacy. Today, people willingly and freely supply their private information until they lose control of their privacy.[4] As more information is recorded and made accessible, it becomes easier

[3] There are various forms of privacy, ranging from "the right to be left alone", "control of information about ourselves" (Westin 1968), "the rights and obligations of individuals and organisations with respect to the collection, use, disclosure, and retention of personally identifiable information," AICPA and CICA (2009) focus on the harms that arise from privacy violations (Solove 2006) and contextual integrity (Nissenbaum 2004).

[4] Privacy differs from security, in that it relates to handling mechanisms for personal information, although security is one element of that. Security mechanisms, however, focus on the provision of protection mechanisms that include authentication, access controls, availability, confidentiality, integrity, retention, storage, backup, incident response and recovery. Privacy relates to personal information only, whereas security and confidentiality can relate to all information.

for people to be judged on the basis of their past actions. The privacy problem is now more complicated with a global profile. The enforceability of information privacy laws can be undermined if organisations are able to escape country-specific regulatory responsibilities by transmitting those data to other jurisdictions for analysis (Pearson 2012).

Although privacy is regarded as a "human right in Europe, in America, it has been traditionally viewed more in terms of avoiding harm to people in specific situations." The collection and processing of personal information are subject to different regulations in many countries around the world (Pearson 2012).

Most countries' privacy laws were created before the Internet. Gaps thus exist between the guidance that regulations provide and decisions that organisations need to make about the collection and use of information (Pearson 2012). Organisations processing personal data must ensure that their operations comply with applicable privacy regulations, as well as with consumer expectations, but this can be very challenging. In a "borderless world", created through the IoV, public policies to protect personal privacy are inextricably interdependent (Bennet and Raab 2006).

New privacy risks are emerging, and the capacity to cause consumer harm has increased dramatically (Pearson 2012). Companies must find ways to demonstrate responsible practices to integrate ethics, values and new forms of risk assessment within their organisation. While privacy supports the establishment and maintenance of trust between service providers and users, it is universally accepted as best practice that such privacy mechanisms should be built in as early as possible into a system's lifecycle (Pearson 2012).

Legal issues, such as the legality and enforceability of the records kept on the blockchain, also need to be carefully considered. Differences in laws across countries may interfere with a wide deployment of the IoV across complex multi-country supply chains.

Therefore, governments and regulators must collaborate and consider how the legal, process and technical standards will need to change and adapt concerning associated standards and governance.

Common standards (legal and technical) are required to ensure that the IoV does not add another layer of complexity in the markets between suppliers and consumers. Indeed, although blockchain should, in principle, enhance the traceability of transactions—and hence, transparency—the encryption of the information could make it harder to disentangle and process it, at least in the short term (CPTM 2016). This would effectively render supervisory work more challenging. Blockchain and DLT standards and governance need to be introduced in each country to control/manage the adoption, both within the country and between countries. From a common standard view, ISO 307 is developing a governance/regulatory technology standard. Within countries, regulators need to consider the developing standard-based frameworks to govern the interactions between participants, both "permissioned" and "non-permissioned". These rules would need to address many potentially complex issues. Examples include the liabilities of the respective participants in the event of, for example, fraud and error, correction mechanisms and penalties in the event of rule infringement, the intellectual property attached to the technology, or the territoriality of the law likely to apply to the network (CPTM 2016).

3 Corporate/Technology Governance

Neither standard approaches of corporate social responsibility nor responsible innovation (Blok and Lemmens 2015; Stilgoe et al. 2013) cover the momentum building behind the development of innovative digital services within the IoV. Operational/technology governance and the responsible management of innovation, within corporations and industry, is also at the early stage of development (Blok and Lemmens 2015) in terms of the disruptive nature of digital channels and technologies. Valentine and Stewart (2013) stated that boards of directors, who have the ultimate legal responsibility for the strategic future, performance and conformance of their organisation, have both ethical and fiduciary care responsibilities to be competent to govern technology. Although industry and government have developed the precautionary principle, especially in their drive to manage the governance of technology (Stirling 2016), this also fails to address the specific nature of disruptive digital technologies (Blockchain, AI, Big Data) on business. There is clearly a need to control the development of online digital-based services and markets by ensuring responsible innovation (Stilgoe et al. 2013) and technology governance (Stirling 2016) and how risk is managed (Chiu 2016).

The research into technology governance needs to be focused on using digital technologies and innovation responsibly, so that it is developed to promote creativity and opportunities that are socially desirable and undertaken in the public interest (EPSRC 2017). Gordon (2012) highlighted the missing link between Information Technology (IT) governance and the strategic alignment of boards within different industries. As Gordon (2012) concluded, there is no significant relationship between IT strategic alignment and levels of IT governance structure and federal IT governance structure. To be effective, technology governance should support three main objectives: "(a) regulatory and legal compliance, (b) operational excellence and (c) optimal risk management" (Robinson 2005). What has changed since this study is the adoption by business and industry of new disruptive digital technologies, which will have a significant impact on the overall corporate governance for boards of directors. Alongside improved trust one of blockchain's biggest promises is the elimination of some or all intermediaries (Maull et al. 2017). There has been little discussion of this view of corporate governance in relation to IoV and the blockchain as a disruptive digital technology. It is interesting to map the basic purposes of corporate governance against the basic properties of blockchain technology against the key areas of corporate governance, as seen in Table 1.

Table 1 Properties of corporate governance against properties of blockchain

Areas of corporate governance	Properties of blockchain
Transparency	Shared distributed ledgers
Accountability	Irreversibility of records
Responsibility	Peer-to-peer communication
Fairness	Smart contracts

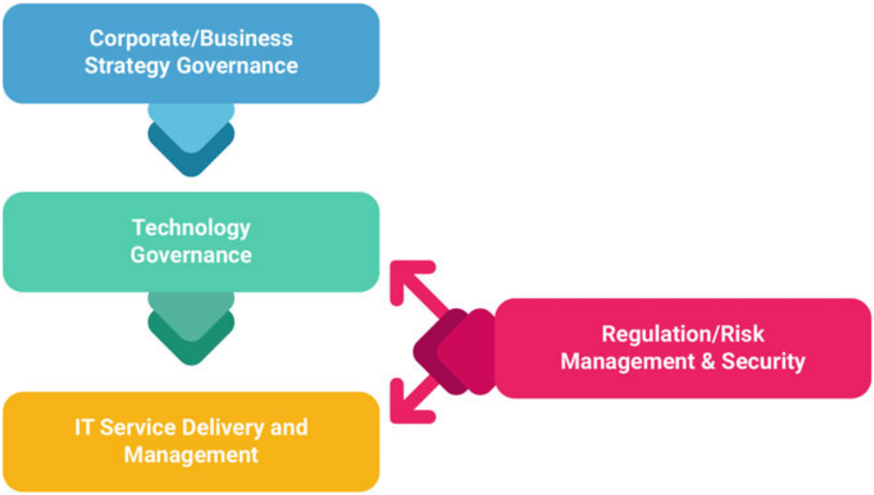

Fig. 1 How various strategy, governance and risk management areas relate to IT

Furthermore, Valentine and Stewart (2013) called for boards to step up to their technology governance responsibilities and link to their key measures of share price, revenue and profit, through reputational risk. As stated by Aula (2010), reputational risk is a top concern for many boards, as the current impacts of product failure are immediately reported in social media which, while affecting the share price, also has an impact on the consumer/supplier trust relationship. "The loss of reputation affects competitiveness, local positioning, the trust and loyalty of stakeholders, media relations, and the legitimacy of operations, even the licence to exist... leading European managers to consider reputation risk to be the primary threat to business operations and the market value of their organisations" (Aula 2010, p. 44). The conduct of the company, the associated operational risk and trust in the company are all the responsibility of the board in the drive to strengthen corporate governance (Child and Rodrigues 2004). Clearly, technology governance and the link between risk and trust is a developing and a necessary area of research, especially in financial services, where there is the unstoppable drive to adopt new technology to try to gain market advantage.

Technology governance detailed within literature can be viewed from diverse perspectives, but again the focus is on supporting standard delivery models and supply chains. It does not address the emergent IoV and the disruption this will have on trust, risk and established supply chain relationships. Technology governance should be considered as part of the overall governance within a business, linked to the corporate/business strategy and the actual delivery of technology (IT) that supports the business, as shown in Fig. 1.

There are several views of technology governance from the literature; Peterson (2004) examined technology governance as organisational capacity exercised by the board, executive management and IT management. Meanwhile, Weill and Ross (2004) went so far as "requiring senior levels to specify decision rights and an accountability framework to encourage desirable behaviour in the use of technology". This view of technology governance in this context is primarily concerned with IT project selection and prioritisation issues and how the authority for resources and the responsibility for IT are shared between business partners, IT management and service providers (Weill and Ross 2004, 2005).

Weill and Ross (2004) stated that "technology governance consists of the decision rights, incentives and the accountability framework to encourage desirable behaviour. This includes the foundational mechanisms in the form of the leadership and organisational structures and processes that ensure that the organisation's technology sustains and extends the organisation's strategies and objectives". What is missing in this definition is the context, in that the technology governance needs to integrate with the business strategy and delivery requirements. Van Grembergen et al. (2004) posited that technology governance includes "the combination of leadership, structures and processes' and it will achieve the fusion of business and IT".

All these views are required to ensure that IT sustains and extends the organisation's strategies and objectives (IT Governance Institute 2003). In this manner, technology governance has become an important integral part of corporate governance (Ko and Fink 2010). Technology governance within a business should focus on the organisational alignment, integration and relationships. It is apparent that benefits arise when technology and business activities are aligned, so that they both share the objective of achieving organisational goals (Gordon 2012). In terms of business, technology provides the means to integrate organisational activities by eliminating duplication and bottlenecks. The activity of governance itself improves the understanding, and hence the working relationship, between technology and the rest of the business. Consequently, benefits can be readily identified, such as returns in the form of increased revenue/profits, and the balance struck between value creation (risk-taking) and security (risk managing). However, what is apparent is that the various detailed concepts of technology governance are still evolving, mainly because of "the specialisation and disconnectedness between globally-dispersed IT governance interested communities" (Peterson 2004, p. 41) which are appearing with the IoV.

There are several bodies that have developed IT technology governance best practice frameworks, including:

- the IT Service Management Forum (ItSMF 2020),
- the Information Systems Audit and Control Association (ISACA) and Information Technology Governance Institute (ITGI).

The most widely adopted frameworks according to Stafford (2003) are COBIT (Control Objectives for Information and Related Technology), ITILw (Information Technology Infrastructure Library) and ISO17799: 2000 (International Standards Organisation). To implement technology governance effectively, mechanisms are required to ensure there is integration between "mission, strategy, values, norms and culture, and to promote desirable IT behaviours and governance outcomes" (Weill and Ross 2004). The technology governance mechanisms are frequently indicative of an organisation's (both IT and business) capability (Karimi et al. 2000; Bradley et al. 2012) and performance. Technology governance is critically important, as it is seen to have a substantial impact on return on investment in IT. In fact, Weill and Ross (2004, pp. 3–4) argued that "effective IT governance is the single most important predictor of the value an organisation generates from IT". It is evident that "strategic alignment can be achieved by implementing well-designed technology governance mechanisms" (Weill and Ross 2005). As noted by Huang et al. (2010) "well-designed and orchestrated IT governance mechanisms are expected to produce technology-related decisions, actions and assets that are more tightly aligned with an organisation's strategic and tactical intentions".

In summary, the governance of technology, including IT, is still developing. There are a number of differing approaches/frameworks that are being interpreted by enterprises to meet their organisational goals. It is clear that the new business models within the IoV need to be considered with developing new governance frameworks that at least link governance mechanisms, strategic alignment and organisational performance (Wu et al. 2015). The collaborations between entities within the development of the IoV challenge the normal models.

There is a body of work detailing governance and privacy with established frameworks for the delivery of technology, these are outdated and do not address the changing trust and risk challenges of the IoV (nor the underlying digital technologies). This governance and privacy gap has been recognised within the new digital technologies and developments, and collaborations between parties are attempting to address the gap.

More formal research is required "top-down" as the current "bottom-up" approach does not address the regulatory and control requirements from the business. New businesses and business models developing within the IoV and the blockchain economy will be constrained when outmoded governance is introduced (Reuters 2019) that stifles innovation.

4 Practical Development of Governance and Privacy with the IoV

Blockchain, the innovation that underpins the IoV, determines that the network of participants is open, and where permissionless participants do not need to know or trust each other to interact. On a blockchain, transactions are verified and recorded by the connected nodes through cryptographic algorithms. In permissionless public blockchains (Zheng et al. 2018), there is no human intervention, nor central point of control. If nodes are unreliable or malicious, the blockchain is able to verify the transactions and protect the underlying distributed ledger through the cryptographic algorithms—consensus mechanisms "proof of work and the developing proof of stake" which makes human intervention or controlling authority theoretically unnecessary (Van Rijmenam et al. 2017).

The decentralised trust or trust-by-computation and its importance can hardly be overstated: indeed, it represents "a shift from trusting people to trusting math" (Antonopoulos 2017), with applicability that "goes far beyond the creation of decentralised digital currencies" (Atzori 2015). With the recent development of new digital platforms, products and services have become increasingly unbundled, bringing producers and consumers closer to each other.

Historically, within a supply chain, the terms of service have always dictated that one or more trusted third party/organisations are present. The IoV, public blockchains and smart contracts can disintermediate these third parties, introducing new methods of coordinating activities such as task allocation, coordination and supervision of participants that are geographically distributed, without the necessity of a centrally managed organisation (Maull et al. 2017).

The blockchain, underpinning the IoV with a distributed configuration, can produce an acceptable solution for privacy. However, full "privacy control" is, as yet, far from being realised. On a public blockchain, users have "pseudonymous" identities, and hence their real-world identities are largely protected via private key cryptography (Van Rijmenam et al. 2017). However, details of transactions are still fully transparent because the distributed ledgers are shared by all. Users can adopt "privacy-enhancing techniques (e.g. use a new address for each transaction and obfuscate their transactions by mixing them with others), rely on an intermediary (e.g. a digital wallet provider) or use a system that separates basic information about a transaction (e.g. its existence and timestamp) from more sensitive attributes" (Van Rijmenam et al. 2017).

In addition, sensitive information could be stored on a "private blockchain (or database) and immutably linked to the public blockchain entry using a digital fingerprint" (Athey et al. 2016, 2017). As an active area of research new protocols are being developed to mask transaction data. These protocols aim to offer anonymity to users through zero-knowledge cryptography and implement different degrees of access to transaction information. Despite the fact it might not always be possible to achieve perfect masking or obfuscation might (Barak et al. 2001), it is clear that different blockchain implementation will also be able to compete in terms of the privacy level they provide to their users (either at the protocol level or through a trusted intermediary). When combined with privacy-enhancing measures, this can solve the trade-off "between users' desire for customised product experiences and the need to protect their private information" (De Filippi et al. 2016).

What is apparent is that governance and privacy do need to be established in a "management blockchain" where smart contracts are formed from the governance and privacy rules. The "management blockchain" is then linked to participant technologies and provides the required "control function".

5 Collaborative Governance of the IoV

Many of the practical developments to date for the IoV and blockchain have been collaborative, requiring cooperation among multiple participants. Governance of these collaborative organisations is critical to the success of these projects. Many enterprise blockchain solutions will be implemented by a "consortium" of enterprises, building one or more applications on top of a "blockchain platform", such as we.trade and Voltron in trade finance (Rutter 2017).

Established organisations, corporations and central governments have also been using the concept of Fintech (Chiu 2016; Puschmann 2017) as incubator technology functions within their organisation to lever new technology, innovation and deliver new solutions that will affect a change in the culture, internal trust, business model, the market and supply chain. Although this is an attempt to change the way they manage and govern the development of technology, some innovators are embarking on deploying new technologies without a clear vision or link through strategic alignment to the business model, technology governance or risk.

Blockchain and DLT are relatively base technologies which, when developed with toolboxes (e.g. Hyperledger Fabric) can see their functionality easily extended. Research has shown (Rutter 2017) that the current approaches to the development of blockchain technologies typically consider a relatively small business problem, e.g. the provenance of a single good—wine, diamonds, spinach or a micropayment between counterparties. The developed solution is then progressed by the consortium through the iterative development of the business problem, which is then extended to new areas, adding in complexities of the supply chain and then developing the technology. Therefore, the governance of the technology should follow this iterative cycle, developing as complexity is added.

The overall governance of the consortium will be as important to enterprises as "blockchain platform" governance. Consortium level governance "permeates" through all aspects of the blockchain, and governance is an integral component of a sustainable network (Arun et al. 2019).

When the requirements for governance within the enterprise are considered as detailed earlier, combined with the position of the IoV to change the trust/risk and value models, it is clear the IoV does require a more sophisticated governance and privacy model.

The contributors within the collaboration for the IoV are typically today to be a mix of industry practitioners, government/regulators and academic scholars. Technology governance and privacy of the IoV could be based on the principles to ensure that all participants and stakeholders in the ecosystem are represented, and focus on and address the following issues: implementation of the business model, determination of intellectual property ownership and how to manage funds to support the blockchain project. These principles will need to be expanded to address the vertical and horizontal gaps in governance that are seen within the developing IoV. While, typically, most blockchain consortia will be governed through traditional entities, an alternative is a "contractual joint venture" in which all the rights and obligations are managed through a collaborative approach, with an overarching contract. In this model, the participants have "joint liability" for funding. While decision-making can also be difficult, the collaboration needs to be closely managed as the approval of all members may be required to act.

The Reducing Friction in Trade—Wine programme (Holmes 2020) is an example of consortia governance and it includes companies from the wine industry, service providers to these companies (for example, freight forwarders in logistics blockchain project consortia), academic institutions, non-profit institutions, software developers and users of the blockchain project. The Reducing Friction in Trade—Wine programme consortium is driven through a mix of collaboration and governance both business, and technology between the various stakeholders. Privacy of data and access controls are built in to the underlying blockchain technology. A programme board has been established across UK Government, Industry and Academia representing the major stakeholders in the Reducing Friction in Trade—Wine programme. Holmes (2020) headed by the author as the Programme Lead.

6 A Way Forward

Today, standard governance and privacy frameworks are mostly organisationally bound, and they are not orientated to support developing digital technologies and the distributed nature of the IoV. It is also established (Valentine and Stewart 2013) that there is a disconnect between technology and corporate governance and the risk/regulatory standards and the technology delivery processes (Wu et al. 2015). There are gaps between business strategies, corporate governance operations, risk management, technology governance and delivery within an organisation—vertical integration is missing for digital technologies. Most developments were made in the 1990s and 2000s, and they are not aligned to the drivers of this decade.

With the introduction of IoV, more horizontal integration gaps appear, as each stakeholder has a different set of strategies, processes, organisations and drivers. The IoV is developing new trust, value and risk business models across stakeholders from different organisations. Therefore, the development of new frameworks needs to take place, which address the changing decision rights, accountability and incentives, communication and organisational constructs. These must meet the multi-stakeholder distributed nature of this new world.

There is no single framework that addresses the vertical gaps within an organisation and the horizontal nature of the distributed business models established through the IoV.

Clearly, there are new building blocks being created that could support the framework:

- Organisational—with collaborative governance developing cross organisation,
- Technology standards for technology governance and privacy—as standards ISO 307,
- Current business governance mechanisms that have been established within an organisation (which are often disconnected today).

The process to develop the new governance and privacy frameworks is not established—one that considers the new business models within the IoV and iteratively uses components from the building block to continually develop the governance mechanism. The implementation of governance is not a one-off task; technology governance and privacy frameworks need to adapt, as the business models within the IoV develop continually. Leaving governance to the technical developments and embedding it "on-chain" poses risks for the stakeholders, consumers and suppliers within the IoV.

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Author Biography

Mike Brookbanks has over 25 years' experience determining how business challenges are addressed through technology innovation as an enterprise architect. His recent focus has been the application of DLT/Blockchain & AI, its governance and responsible innovation. He represents the BSI on ISO307. He is managing a programme with the UK Government and researching how DLT/blockchain can reduce friction in international trade.

Executive Summary

A.1 The Internet of Value

Five decades ago, the birth of the Internet revolutionised the way information is produced and shared. Prior to that, people resorted to disconnected channels, such as direct person-to-person communication or postal, telegraph and telephone (PTT) services, to transmit information. Through its communication protocol, the Internet makes information easily and immediately accessible across the globe, irrespective of physical location or users' native language. Today, the Internet has become the pathway for people to create, store, retrieve, curate and exchange any sort of data.

Despite the advancement in the exchange and transmission of information, the exchange and transmission of "money"—or, in a broader sense, "value"—continue to be siloed. Our long-standing, traditional banking system fundamentally controls monetary activities. Although payment gateways such as Paypal and Stripe allow people to conduct certain types of monetary transactions inexpensively on the Internet, it remains a challenge to conduct all the types of transactions people and firms need. This is particularly so for those transactions involving substantial amounts and underprivileged users from unbanked regions.

Eleven years ago, blockchain technology emerged, changing the fragmented nature of our monetary system. The technology gives control over value flows to value holders by eliminating conventionally trusted intermediaries such as banks and escrows, and by allowing all participants of the value network to contribute to the operations of the network. Peer-to-peer transactions surpassing regional and economic infrastructure restrictions become possible.

More recently, the advent of smart contracts has led to further efficiency enhancements of the value network on the blockchain. A smart contract ensures that value transactions automatically occur following pre-programmed rules without human intervention. In tandem with the Internet of Things (IoT) technology, smart contracts enable machine-to-machine value transactions on blockchains. As such, value

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can be created, stored, retrieved, curated and exchanged swiftly and cheaply within the blockchain ecosystem just like information, forming the Internet of Value (IoV).

A.1.1 The Motivation for This Book

Late 2017 witnessed a tulipmania-like craze for blockchain due to the skyrocketing price of cryptocurrencies and the high expected return of Initial Coin Offerings (ICO). However, the enthusiasm quickly waned when investors realised the pervading scams and frauds associated with ICOs. The overall price level of cryptocurrencies plummeted subsequently, and the reputation of the companies in the blockchain sector suffered. The mantra "we have a new technology, now we need to find the problem" was not fulfilled.

Unfortunately, conventional wisdom still equates blockchain with cryptocurrency and fails to see a wide range of uses for the technology beyond this. To date, cryptocurrency trading is mostly speculative, resulting in high price volatility and scepticism about the underlying technology.

Against this background, the University College London Centre for Blockchain Technologies (UCL CBT) put together a team of industry and academic experts to work together for six months to provide a variety of perspectives on:

- The massive potential of the technology that can drive the establishment of the IoV;
- Blockchain's component pieces that enable the IoV, including smart contracts, cryptography and various consensus mechanisms;
- Specific protocols that propel the development of the IoV such as XRP and IOTA.

A.1.2 Key Takeaways

The most important key takeaways from this book are summarised below (see the corresponding chapters for the original research articles).

- **The IoV can be defined as the instant transfer of assets expressible in monetary terms over the Internet between peers without need for intermediaries.** The IoV can grow in the new distributed ledgers paradigm, where digital assets, namely digital representations of claims on material or immaterial assets from the physical world, remain unique. At the same time, their ownership and usage licenses are being exchanged, sent, copied and updated without a trusted central authority. [Introduction to the Internet of Value]
- **The mission of the IoV is to exchange any amount of value as quickly and fluidly as information is exchanged today.** Value creation, measurement and exchange will remain at the core of human society, and harnessing the IoV will be its most critical success factor. [The Internet of Value and Media]

- **The IoV forms a Value Web of relationships that remove the silos of existing data structures and networks.** The IoV reduces barriers to entry, introducing a borderless economy. [The Internet of Value and Media]
- **The IoV is fundamentally enabled by blockchain.** Ensuring trust and transparency, blockchain allows new e-commerce business models to achieve quick transfers of value, whether monetary, social or perceived customer value. Across retail and consumer goods industries, collectively known as consumer markets, the areas subject to potential disruption include Loyalty, Direct to Consumer, Servitisation, Sustainability and the areas of Data and Self-sovereign Identity. [The Internet of Value and E-Commerce]
- **Merging the IoT with blockchain technology enables more efficient machine-to-machine transactions, further enhancing the IoV.** As such, data can be logged in a verifiable, encrypted and tamper-proof fashion, and can be processed by self-executing machines. The network of interconnected devices will be able to interact with their environment and make decisions without any human intervention via the deployment of smart contracts. [How DLT Will Evolve in the Future]
- **Advancements in artificial intelligence and 5G drive the evolvement of the IoT.** The emergence of 5G will ensure low network latency, one of the critical requirements of most of the use cases with IoT. The development of artificial intelligence will play a key role in automating complex decision-making processes. [Internet of Things and Oracles]
- **The removal of intermediaries in combination with increased information transparency leads to a mitigation of the so-called principal–agent problem**, whereby agents possess all relevant information and act in their own best interests rather than in those of the principals. The IoV helps to reduce this specific problem through the use of smart contracts, as well as by giving principals new possibilities to monitor transactions. [Introduction to the Internet of Value]
- **New IoV businesses can take the form of decentralised autonomous organisations (DAOs) through an optimised governance structure that incorporates decisions made by both computers and humans.** The technological innovation inevitably unlocks new ways of doing business in finance that result in the realisation of one big aim: cost saving. By leveraging these new technologies, most of the legacy costs, including labour overhead and costs incurred due to human errors that financial institutions bear in their balance sheets, can be cut to the bone. [The Internet of Value and Financial Services]
- **Everything that can be tokenised will eventually be tokenised—this is the foundation of the IoV.** Tokenisation increases an asset's moneyness, i.e. the degree to which an asset approximates cash and can thus be used as a medium of exchange. An asset in its tokenised form can be exchanged with little impact on its value and at low cost. [The Internet of Value and Media]
- **Through reliance on purely virtual tokens, DLT sidesteps the complications of bridging the real/virtual divide:** A purely virtual system can address "truth" through self-containing consistency. Once the distributed ledger achieves consensus about who is entitled to control a tokenised asset, this is sufficient to effectively

establish ownership in the practical sense. [The Internet of Value and Financial Services]

- **Global central banks could cooperate to reap the benefits of recent technological advances.** Early examples of synthetic central bank digital currency (sCBDC) will drive more central banks to reactively follow suit and launch their versions in partnership, either with each other or with private actors, despite the current low appetite for global economic cooperation. To cater to the new trend and remain competitive, centralised digital currency issuers will likely provide new on-ramping options and exchange pairs with decentralised cryptocurrencies, leading to their true mass adoption. The proliferation of new forms of money may act as a bridge and educational tool for the mainstream public to transition from legacy systems to a new tokenised economy. [The Internet of Value and Financial Services]
- **In a distributed network, a trade-off between efficiency and robustness to attacks must be made.** The increased efficiency through the establishment of special nodes serving as hubs comes at the expense of high fragility to targeted attacks: If a few hubs are identified by attackers or shut down, the system breaks and will fail to perform its function. [Internet of Value and Systemic Risk]
- **Although the transparent and open transmission of data on blockchain imposes privacy concerns, new protocols are being developed to protect personal and confidential information effectively.** Through zero-knowledge cryptography, transaction data can be obfuscated, and varying degrees of access to information can be implemented. [Governance and Privacy Issues from the Internet of Value]