Studying the Adoption of 5G and Future Networks for Social Inclusion: An Innovation Systems Transitions Perspective for Networks-as-a-Service

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Abstract. This paper explores the adoption of 5G and future networks as a means of improving social inclusion. The paper outlines the cost dilemma associated with future networks (currently a barrier to the pervasive access required for social inclusion) and indicates that new business models and sector structure will need to be put forth. The authors posit that network as a service (NaaS) on shared spectrum is a viable and practical solution. Preliminary problem formulation research demonstrates that a transition to new sector structure will be met with strong resistance by incumbent mobile network operators as the sector at large have a vision of incremental change. To study how this transition will best be enabled, the phenomenon is viewed through the theoretical lens of Innovation Systems. Bergek and colleagues (2008) develop a means of examining Technology Innovation Systems (TIS) while (Geels, 2004) provides a tool to understand how innovation systems emerge and transition over time. Based on these two theories, a research framework is presented to guide future studies on this topic.

Keywords: Technology adoption · Social inclusion · 5G · Future networks · Neutral host

1 Introduction

1.1 Potential of Technology

The use, adoption, and proliferation of future networks, from 5G on is essential to propel and broaden economic prosperity and social wellbeing. While significant capital cost investment required for small cell networks is a well-documented barrier, the potential functionality of emerging technologies provides fertile ground for the development and implementation of new business models that increase the adoption potential and in turn improve mobile network coverage across previously isolated or disconnected rural regions.

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Access to the digital economy is now accepted as fundamental for economic development and regional resilience. Information and Communication Technology (ICT) and digital communications have been shown to enable economic development in both advanced nations [1] and developing contexts [2, 3]. For example, at the macroeconomic level, better broadband infrastructure is positively associated positively with a range of macroeconomic indicators, particularly GDP [4–6]. Previous estimation suggests that a 10% increase in mobile penetration contributes to increases in GDP per capita between 0.59 to 0.76% [7].

More locally, the rollout of fixed broadband infrastructure is associated with positive economic impacts [8, 9]. For example, firms which embrace digital connectivity are more productive [10, 11], more innovative [12], and better at expanding into new markets [3, 13, 14]. Areas with broadband access have lower unemployment rates [15], better regional economic productivity [16], and higher levels of social welfare [17]. In the United States, every 10-percentage point gain in broadband penetration annually (from 3G to 4G) has been estimated to generate more than 231,000 jobs, a ration expected to be replicated with future networks [18].

When taking a community-based perspective, studies show that strong rural connectivity is critical for economic growth in addition to educational development, social welfare supports, employment opportunities, and community engagement [2, 49]. Thus, the evidence unilaterally supports the future rollout of near-ubiquitous mobile network coverage as an important objective for economic stability, social inclusion, and regional resilience. Conversely, poor connectivity has negative implications for both business (affecting productivity) and society (reinforce socioeconomic divides) [19]. There is an obvious argument to strive for near-ubiquitous coverage in future rollout.

1.2 The Cost of Technology

While the benefits have been clearly articulated in the extant literature, the path to implementation and adoption are less clear. In short, telecommunications rollouts of previous generations have been limited due to infrastructure cost, this is concerning for future infrastructure-intense generations, given our current high-cost environment. Historically, due to economic and industry structures, telecommunications adoption has been sporadic. It has taken EU households ten years to grow internet access rates from 65% to 90% [20]. While coverage remains patchy and lacking ubiquity, during the last decade resources have continued to become increasingly constrained; European telecommunications operators have been experiencing declines in their revenues, mainly due to service price stagnation, regulatory constraints, and an increasing demand for investment in their infrastructures [21].

This aforementioned decline is in the context of 3G and 4G capability and adoption; now the advent of 5G raises a different set of challenges. The need for densification in 5G and future networks will necessitate the installation of large amounts of small cell networks to meet future capacity demands. Small Cell deployment and operation tends to require costly backhaul and power facilities, this resource intensity is a key obstacle to their deployment [21–23]. The standard approach to date has resulted in each mobile network operator (MNO) in the market building their own dedicated network. This approach is fast becoming increasingly unviable, due to declining revenues, the escalating cost of delivery in rural areas [21], and resistance from local authorities to excessive street-based infrastructure [50]. It is estimated 5G will cost almost US $1 trillion to deploy over the next half decade. That enormous expense will be borne mostly by network operators, companies like AT&T, China Mobile, Deutsche Telekom, Vodafone, and dozens more around the world that provide cellular service to their customers [24].

1.3 The Solution

While these obstacles are real and immediate, there are characteristics of 5G, and other maturing technologies such as cloud, which lend themselves to new, more efficient, telecommunications business models. Primarily, these new business models are based on infrastructure (and possibly spectrum) sharing, titled neutral host. Secondly, virtualization of networks involves abstraction and sharing of resources among different parties. With virtualization, the overall cost of equipment and management can be significantly reduced due to the increased hardware utilization, decoupled functionalities from infrastructure, easier migration to newer services and products, and flexible management [25].

One obvious way to reduce costs, and thus potentially increase the pace of rollout, would be to build a single shared layer of small cells routing traffic of any provider – a neutral host [14]. This goes against business trends to date where a static approach has been dominant, i.e., squeezing out market efficiencies. The challenges and obstacles discussed above, in addition to the identification of a potential solution foreshadow a need for a more dynamic efficiency approach gaining long-term benefits from infrastructure-based market competition [26]. Yet MNOs are naturally taking a conservative approach to disrupting the dominant logic of their businesses and caution reigns supreme even if the proposed neutral host solution would open new growth opportunities [27], they are now becoming more open to the idea of market co-operation with competitors [28–30], including consolidating infrastructure duplication, in turn producing savings on capital and operational costs [31]. Apart from basic efficiencies, another advantage to having 'open' deployments of neutral small cells serving subscribers of any service provider is that this shared infrastructure approach would encourage market entry and improve the industry's competitive dynamics by making it easier for networks to get closer to a critical mass.

Beyond network cost efficiencies, a critical aspect of the 5G and future network is the ability to create customized network slices, i.e., logical network that provides specific network capabilities and features with logical isolation. Instances of virtual network resources and applications can be delivered to a new breed of cross-sector services tailored to specific customer needs with service level agreed (SLA) performance on demand. The flexibility offered by these technologies, mainly Software Defined Networking (SDN) and Network Function Virtualization (NFV) can be employed to develop virtual frameworks or network slices, including sets of logically segmented virtualized resources (such as compute, storage, and networks), shared within the same physical infrastructure [32]. Such flexibility in the infrastructure enables customization of the network slices in terms of resource placement, alignment to specific verticals, and more [48].

With virtualization, MNOs can attract greater numbers of customers from MNOs and SPs. For MNOs, since the network can be isolated into several slices, any upgrading and maintenance in one slice will not affect other running services. For SPs, leasing virtual networks enables them to "get rid of" the control of MNOs, so that customized and more flexible services can be provided more easily and the quality of service (QoS) can be enhanced as well. This also brings impressive revenues to MNOs, because SPs will need to pay more to the MNOs for use of their infrastructure and the clarity around roles and service provision in a neutral host network environment will reduce existing underlying arguments between MNOs and SPs around such issues [25].

Given these characteristics of neutral host and network-as-a-service, that strive to optimize the design and use of future networks we can posit that medium term network environments will be characterized by network-as-a-service on shared infrastructure. Our goal is to develop knowledge such that we can provide guidance on optimum network deployment and adoption paths with a view to maximizing the public good. Therefore, we define our research question as:

How can we create an enabling environment to support the rollout of 5G (and future) network-as-a-service shared infrastructure, in rural areas?

2 Problem Formulation

In a classic engaged scholarship, problem formulation approach [33], when considering the problem of transitioning to a neutral host structure, the authors set out to engage industry and academic experts to "situate, ground, diagnose and infer the problem up close". 24 problem formulation interviews were held with: Irish based industry representatives (MNOs, telecoms hardware and systems, and infrastructure providers); academics; and the Irish regulator. These interviews were designed to extract opinions on the possibility of, and an adoption path to, a network-as-a-service on shared infrastructure solution for the Irish market.

2.1 Problem Formulation Findings

Currently two versions of neutral hosts were being piloted in UK and Irish cities. The most prominent model, offered by both infrastructure service providers and telecoms hardware systems providers, is a set of, up to four, small scale antennas enclosed within one package. This offers up to four MNOs the option of passive sharing base stations and backhaul connections. In essence, this model is the efficient bundling and use of infrastructure and cabling. There is no active sharing, with infrastructure management similar to current models. Therefore, incumbent business (or only incrementally different) models are envisaged when mainstream.

The less dominant neutral host model being offered is that of spectrum with small-cell infrastructure within confined geographical areas (e.g., campuses, commercial area). The dominant attitude of the MNOs operating in Ireland is to focus on a return of current assets. The backdrop to this attitude is the continuing decrease in return on invested capital (ROIC) which, in 2021, was 6.3% for Europe – barely higher than the cost of capital. This is before new investment in 5G. The dominant attitude of the three MNOs operating in Ireland is to focus on a return on current assets. The backdrop to this attitude is the continuing decrease in return on invested capital (ROIC) which, in 2021, was 6.3% for Europe – barely higher than the cost of capital. This is before new investment in 5G (McKinsey, 2023). Therefore, MNOs are working with a short-term focus the is rapidly becoming financially unviable, and this approach is becoming particularly less attractive in a high interest rate environment coupled with concerns of a recession or even stagflation. However as competitive strategic organization they are continuously scanning for opportunities, yet through a conservative aperture whereby any future investment will only be made with a high degree of certainty that a return can be extracted. This hesitancy and conservatism are particularly true in the case of potential small cell applications, where the marketplace is unknown. The reasoning is that MNOs will follow the market, i.e., they will invest when they are confident that a market does/will exist. At this point, collaboration is not a priority, yet consolidation is occurring as evidenced by the recent merger of Three and Vodafone in the UK. Reasons quoted for this are unknown in relation to guaranteeing customer service. With respect to the future, the attitude is that the market will evolve incrementally, and any vision of a future market structure looks broadly similar to the current market structure.

There has long been a move towards passive shared infrastructure. For cost efficiency reasons, MNOs have moved away from owning mast sites, and specialty site ownership/operations business have emerged. Their customers are the MNOs and, in the main, their view of the future is a strengthening of these relationships. Technology providers, in support of these trends, have begun to offer passive products. For example, Ericsson offer four miniature transceivers packaged in one box – a form of passive sharing.

Cities are actively reviewing the possibility of monetizing their city assets (lampposts, public buildings, etc.) as these become more important in higher frequency, small cell, urban applications (e.g., mobility and health). This aspiration is negated by the EU Commission's article 57 which defines the physical and technical characteristics of small cells and exempts them from any current or prior individual local authority planning permits. It also stipulates that, without impacting existing commercial agreements, deployments of small cells should not be subject to any fees or charges beyond the administrative charges.

3 Theoretical Perspectives

What is obvious from the interview content is that change is happening slowly and reactively. That is, advances are made when opportunities offer themselves in a reactive rather than a proactive manner. The status quo, in terms of power and power relationship is being maintained, evidenced by each stakeholders' behaviors which appear to be designed to strengthen their own position.

What is obvious from the interview content is that change is happening slowly and reactively. That is, advances are made when opportunities offer themselves in a reactive rather than a proactive manner. The status quo, in terms of power dynamics and power relationships is being maintained, evidenced by each stakeholders' behaviors which appear to be designed to strengthen their own position in isolation without exploring the combination power to be gleaned from collaboration.

The slow rate of change may suggest that a difficulty in overcoming inertia is changing business models; there is a reticence to learn new knowledge; or possible strategic, cognitive, or resource lock-ins due to historical events or performance. From a theoretical perspective, all of these suggestions point to the notion of ‘history matters’, wherein these organizations have charted and set course on along a particular trajectory from which they are reluctant to change.

There are two possible broad perspectives based on level of analysis. That is, can we treat this as a system of independent organizations, or as a set interdependent actor. As independent organizations there are a myriad of theories that fit with ‘history maters.’ Vergne and Durand [34] identified many theoretical arguments that are based on the “notion” of history maters. The arguments that may apply to future network adoption include path dependency, absorptive capacity, institutional persistence, resource accumulation, structural inertia and imprinting.

Path dependency suggests that firms, based on a contingent event, develop self-enforcing behaviors, leading to lock-ins (e.g., [35–38]). Absorptive capacity is the ability of groups or organizations to take in knowledge [39]. Knowledge absorption is more likely, the similar the knowledge is to the organization’s current knowledge. Conversely, knowledge absorption is less when new knowledge is very different from the organization’s current knowledge. Institutional persistence asserts that socio-cognitive institutional patterns become sticky in an attempt to retain or gain resources, or to gain or retain control [40]. Resource accumulation, is derived from the resource-based view of the organization where unique capability, developed over time, is difficult to discard. Structural inertia suggests that organizations respond relatively slowly to the occurrence of threats and opportunities in their environments [41]. Finally, imprinting asserts that founding organizational characteristics, such as structure and social relations continue to influence the organization indefinitely [41].

From past literature, Vergne and Durand [34] identify the barriers to change, which lock-in or cause inertia, in three categories: cognition (metal maps and decisions making process); resource (sunk costs in operations and infrastructure); capability (knowledge and capability boundaries); and social relationships.

As a set of interdependent actors, a suitable perspective is the transitions of technology innovation systems. A technological system is defined as a network of agents interacting in a specific economic/industrial area under a particular institutional infrastructure or set of infrastructures and involved in the generation, diffusion, and utilization of technology. Technological innovation systems are defined in terms of knowledge/competence flows rather than flows of ordinary goods and services. They consist of dynamic knowledge and competence networks. In the presence of an entrepreneur and sufficient critical mass, such networks can be transformed into development blocks, i.e., synergistic clusters of firms and technologies within an industry or a group of industries [42]. Innovation Systems transition, that it, the change and evolution of innovations systems (such as the industry structure change in the adoption of a new technologically disruptive mobile network), is viewed in terms of overcoming history [45].

To critique innovation systems, we first need to be able to describe the system and its functions; followed by providing an understanding of how they emerge and evolve. From a systems level, different innovation systems can be assessed and compared with regard to the functions they fulfil [43, 44]. Functions are emergent properties of the interplay between actors and institutions. They can be assessed in order to derive policy recommendations, e.g., for supporting the development of a specific technology, such as a future network.

Bergek's et al. [43], focus was on technology innovations systems (TIS) and whose schema for analysis is depicted in Fig. 1. This is a seven-step process, starting with defining the TIS. The critical questions are: 1) the choice between knowledge field or product as a focusing device; (2) the choice between breadth and depth; and (3) the choice of spatial domain. The second step is to identify the structural components of the innovation systems. In the case of mobile telecoms, this can be ascertained through interviews.

Step 3 is the mapping of the functional pattern of the innovation system. This analysis aims at ascertaining to what extent the functions are currently filled in that TIS, i.e. to analyse how the TIS is behaving in terms of a set of key processes. Step 4 assesses the functionality and sets process goals. Initially the maturity of the innovation systems must be ascertained. This can be followed by comparing against other innovation systems to improve our understudying of how decisions are made. Step 5 ascertains the inducements and blocking mechanisms. In this, the cause and effect between inducements, such a policy, through functions and blocking mechanisms are articulated so that behaviour is better understood. Step 6 aims to develop modified policy that best enables a desired functional patter.

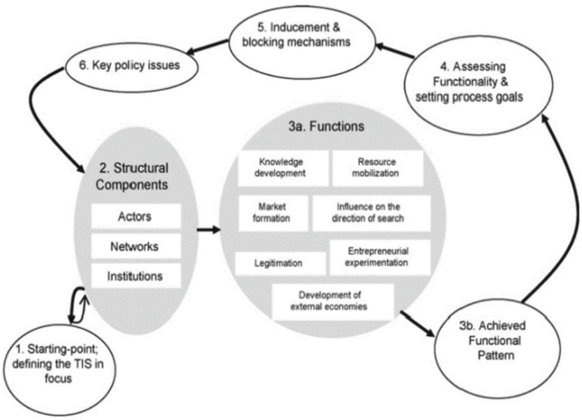

Fig. 1. The Scheme of Analysis *(Bergek et al., 2008, adapted from Oltander and Perez Vico, 2005)*

Authors, such as Geels [45] have identified large technology systems (LTS) as a separate unit of analysis. LTS refer to a particular kind of technology involving infrastructures, e.g., electricity networks and telephone systems, internet. The assertion it that among the components of a LTS are physical artifacts (such as network infrastructure), but also organizations (e.g., manufacturing firms, investment banks, research and development laboratories), natural resources, scientific elements, legislative artifacts (e.g., laws) and university teaching programs [47]. Geels [45] asserts that literature on technological transitions (TT) has elaborated the concepts of socio-technical regimes, niches and landscapes, which form the basis of a so-called multi-level framework to study the transformation of regimes. The multi-level framework conceives technological transitions as interactive processes of change at the micro-level of niches and the meso-level of socio-technical regimes both embedded in a broader landscape of factors at the macro-level (e.g., [46]) as depicted in Fig. 2.

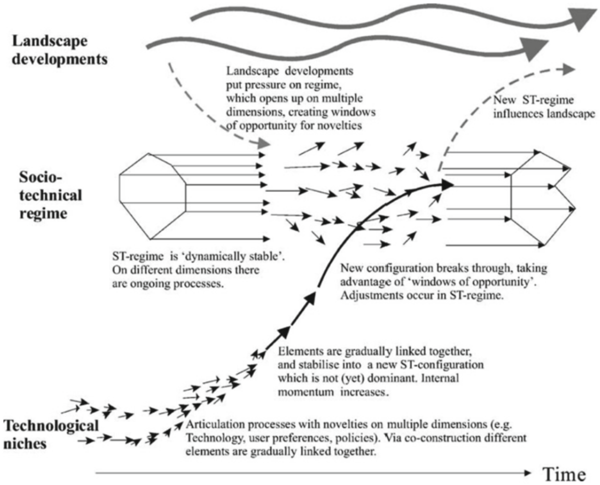

Fig. 2. The Scheme of Analysis *(Bergek et al., 2008)*

Radical innovation niches, such as 5G, provide space for learning processes, e.g. about technical specifications, user preferences, and public policies. Niches allow a deviation from the rules in the existing regime. Rules in technological niches are less articulated and clear-cut. There may be uncertainty about technical design rules and search heuristics, and niches provide space to learn about them. The work in niches is often geared to the problems of existing regimes (hence the arrows in Fig. 1). Niche-actors hope that the promising novelties are eventually used in the regime or even replace it. Technology niches interact with the sociotechnical regime and can be viewed from seven perspectives: technology, user practices and application domains (markets), symbolic meaning of technology, infrastructure, industry structure, policy and techno-scientific knowledge. The last layer, landscape, refers to aspects of the wider exogenous environment. Landscapes are beyond the direct influence of actors, and cannot be changed at will.

The major point is that a TT occurs as the outcome of linkages between developments at multiple levels. Radical innovations break out of the niche-level when ongoing processes at the levels of regime and landscape create a 'window of opportunity.' These windows may be created by tensions in the socio-tech regime or by shifts in the landscape which put pressure on the regime. TTs are about the linking of multiple technologies. TTs do not only involve technology and market shares but also changes on wider dimensions such as regulation, infrastructure, symbolic meaning, industrial networks (represented by the increased density of arrows). Once established, a new sociotechnical regime may contribute to changes on the landscape level. With respect to change, socio-technical systems, rules and social groups provide stability through different mechanisms. For a transition to happen, it is these concepts that must be considered:

Socio-technical systems, in particular the artefacts and material networks, have a certain 'hardness', which makes them difficult to change. Once certain material structures or technical systems, such as market structure, they are not easily abandoned.

Rules include: 1) Cognitive rules that direct us to look in particular directions and not in others. This can make us 'blind'. Competencies, skills, knowledge also represent a kind of 'cognitive capital' with sunk investments; 2) Normative rules: built on social and organizational networks that have been stabilized by mutual role perceptions and expectations of proper behavior. For example, in some relationships, it is not seen as 'proper' to raise certain issues; and 3) Regulative and formal rules, which are established systems stabilized by legally binding contracts. Contracts, technical standards, or rules for government subsidies are examples.

Social groups are actors and organizations embedded in interdependent networks and mutual dependencies which contribute to stability. Once networks have formed, they represent a kind of 'organizational capital', i.e., knowing who to call upon (trust). In organization studies it has been found that organizations are resistant to major changes, because they develop "webs of interdependent relationships with buyers, suppliers, and financial backers and patterns of culture, norms and ideology".

4 Building a Research Framework

The development of a research framework is the operationalization of the described theories (Fig. 3). We use the Bergek's et al. [43] scheme of analysis to describe the innovation systems, i.e., the current structure, policy and motivations of mobile telecoms operations.

Along with the different elements, as per Bergek et al. [43], this will describe both the Socio-Tech systems (the artefacts and material networks, that have a certain 'hardness', that are difficult to change) and the Social Groups (actors and organizations embedded in interdependent networks and mutual dependencies which contribute to stability).

With this done, the focus can then be on understanding the coordination of the innovation system. That is understanding the cognitive, normative, and regulative rules that MNOs, infrastructure providers, and technology providers adhere to.

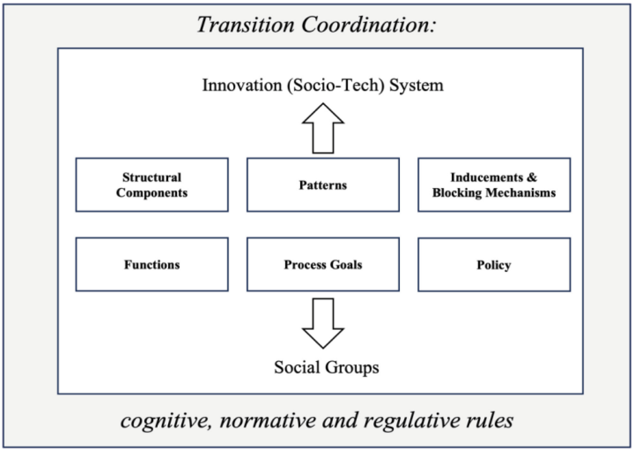

Fig. 3. Research Framework

4.1 A Path to a Methodology

This paper is intended to: a) describe the significant issues associated with the adoption of 5g and future networks for social inclusion; and b) present a theoretical foundation from which to investigate. These are the first two phases of the classic engaged scholarship process [33]. The next phases are Research Design and Problem Solving. In this case the Research Design should be examined through the use of a process model – an event-driven explanation of the temporal order and sequence in which a discrete set of events occur based on a story or historical narrative. The intent is to understand history, so that recommendations (to enable the management of mobile networks through network-as-a-service on shared infrastructure,), can be developed with a high degree of confidence of their efficacy.

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