Virtualizing Network

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Abstract. The challenge for the Telco is to find a viable technological and market perspective for escaping from the consolidation of current business. The paper argues that the virtualization and the creation of a platform for supporting a Virtual Continuum between real objects and their clones in the cloud can be a means to radically transform the present service paradigm. In order to achieve this goal the Telcos have to design, implement and deploy a new platform for future networks that enables the role of Service Enabler. The platform has to displace the consolidate client server paradigm addressing enabling distributed processing technologies like: software defined networking, overlay, and autonomic networking.

Keywords: Network of Networks; Virtualization; Overlay Networks; Self-Organization; Virtual Terminals; Virtual Environments, Virtual Continuum; Internet of/with Things.

1 Guessing the Future of Networks, Technologies and Markets

Technological evolution is difficult to predict but what is even more difficult to foresee is the market acceptance of possible technologies. However, the technological evolution of future networks seems to have taken some identifiable trajectories that, if accepted and pushed by the market, will lead to changes in the current communication environment.

Actually, technology trends for developing future networks are progressing at an impressive rate: processing is continuing to follow the Moore's curve and it is doubling in capability roughly every 18 months; storage capacity on a given chip is doubling every 12 months driving increases in connectivity demand for accessing to the network; optical bandwidth is doubling every 9 months – by increasing the capacity of a single wave length and by putting multiple wavelengths of light on a single fiber. Also technology adoption is constantly accelerating: for example the cell phone took less than 10 years to reach 25% of the US population, while the fixed telephone took over 30 years.

This technological evolution, from the standpoint of the Operators, will exacerbate even more the current consolidation of the market. In this section a few possible pictures of the future are sketched in order to figure out a possible global scenario in

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which Operators will operate in a ten years timeframe. A set of assumptions, that roughly can resemble to scenarios, are put forward and used to delineate possible situations in which the Operators could be acting in the future.

One major consequence of these technology trends is that networks will become more and more pervasive and dynamic, capable of interconnecting larger and larger numbers of nodes, IT resources, machines, smart things (e.g. consumer electronics devices) embedding communication capabilities. In the future, anything will be a network node. Actually, with the development of Internet of-with Things [1] in a few years there will be many billions of electronic devices connected with each other and to the Internet.

The paper argues that the virtualization and the creation of a platform for supporting a Virtual Continuum between real objects and their clones in the cloud can be a means to radically transform the present service paradigm. In order to achieve this goal the Telcos have to design, implement and deploy a new platform for future networks that enables the role of Service Enabler.

Far from being precise, scientific [2] or necessarily true, the primary use of this analysis is to identify and understand trends and circumstances that can have an impact on telecom approaches to market and technologies.

This evolution will have a deep impact from a socio-economic viewpoint, influencing economy development as a whole, public institutions, social relations, diffusion of information, privacy of citizens, etc. Moreover, it raises technical challenges and important socio-economic issues for stakeholders to consider: from simplifying such emerging complexity when managing future networks to identifying new business opportunities and models.

Connectivity picture. In the considered period, the trends towards higher (both fixed and wireless) bandwidth availability will substantially increase. From the point of view of fixed networks, fiber will reach a large part of homes and enterprises in many advanced countries, in addition new optical technologies [3] will provide to homes essentially unlimited bandwidth[1] with a very low cost per bit. In certain locations, the fiber deployments will not necessarily be led by Operators. Local administrations or governments agencies could have an important role in these infrastructure deployments. There could also be the case that the deployment is driven directly from user communities [5]. Availability of fixed bandwidth will also have an impact on mobile networks. Fibers deployments will foster and help in providing backhaul connectivity for next generation mobile networks, that, on the other side, will be able to provide to mobile users enough connectivity for executing complex multimedia services. LTE and its evolutions (e.g., LTE+) will be capable to deliver up to 100 Mbit/s in the downlink and 50 Mbit/s in the uplink if a 20 MHz is used (in a shared fashion). Sometimes mobile connectivity could be competing with fixed one also and so cannibalizing part of the fixed market (e.g., advanced ADSL like offering could be outplaced by mobile offering). Moreover, short range connectivity (e.g., 802.11ac) will also increase consistently offering to user a lot of bandwidth with very low costs. Terminals will also be able to act as routers and will dynamically create

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[1] Bandwidth consumption will be largely determined by video and multimedia services. With new technologies [4], the bandwidth available in the home will be sufficient to cover all the human needs and senses.

islands of connectivity that devices of the same user (or related people) could exploit for accessing to applications and functions.

This situation will likely have two major consequences: high bandwidth connectivity will be available everywhere (and often at a very low price); and the market will move towards flat rates also for mobile.

Personal Connectivity picture. One first hypothesis (derived also from the general connectivity picture, is that each user will be Always Best Connected (ABC). This ABC connectivity will be substantially different from what Operators were expecting, actually it will be provided in a transparent way (user always connected at the lower prices and best bandwidth), but the change of connectivity means and networks will be terminal and user based instead that network determined. This will be also supported by a strong integration (at the terminal level) between mobile and fixed networks (i.e., terminals will be able to adapt and to physically connect to different networks). Users will dynamically connect to smaller, more efficient and cheaper cell. Cognitive Radio [6] (terminals will adapt to the available frequencies and exploit free channels aiming at the optimization of communication) will exacerbate the situation from the Operators point of view, it will provide dynamic capabilities to highly evolved terminals that will exploit it in order to optimize the communication from the user point of view. The concept of ABC will likely have an impact also on the static relationships between customers and network providers leading to the possibility to rapidly change of Providers and even further to dynamic business models for connectivity. For example, the customer could dynamically negotiate with Network Provider for connectivity for a specific area and for a limited period of time, or to negotiate connectivity for a group of users or a community. The situation could be termed as a Telecommunication Supermarket [7], in which customers are not obliged to have a long lasting relationship with a provider, but they can dynamically choose for the best offering of the day.

(Personal) Data Picture

Importance of personal data [8] will be eventually recognized by final customers and consequently many current approaches to exploitation and profiling of customers will be hampered or made obsolete in favor or new methods that embrace the principle that personal data are owned by users. This will increase the level of privacy and control that users will exert on their data sets. A first consequence will be the seamless access to personal data (that thanks to the wide spreading of cloud based solutions will be more and more stored in the network). This will allow (under the direct control of the users and regulated by user defined contracts) the capability to dynamically create, aggregate and update personal data. The single user will be able to collect all its personal data, including any single transaction with other users or with services/applications or digital environments. User will have a sort of life-log including all the meaningful actions and information they produced or used. This will lead to a sort of transaction based world in which each single interaction between users and digital environments will be represented and sent to the user that will be able to store it in order to create a representation in the network of its behavior. This will imply the creation of new data types and sets strongly related (and deeply) representing the user, their preferences, and their behavior and interactions. These data sets will be used by "private" applications[2] that will help users to analyze their behavior and to improve their personal capabilities. Many interactions will take place in digital environments and consequently there will be a strong integration between real and virtual related data, making them indistinguishable and an integral part of the user characterization. Under the control of users, services related to social relationships will be transformed and will allow a better (and more meaningful) profiling of users. Services will became even more personal and intimate. Social sciences will be an important element in the definition of services and applications. Having such a deep representation and understanding of a user will also impact on the way Identity will be managed. Identity Management will make use of biometric techniques allowing a very strong association between the user, its associated devices and the surrounding environment. The user, however, could still assume different roles and identities according to its needs and wishes and also the digital environment in which he is operating (e.g., in a banking transaction, identity will be treated in much different way that in the access to a social network). Pseudonyms will be allowed and different levels of anonymity will be granted in a networked environment. The role of the SIMs will likely diminishing in favor of other (software based) mechanisms that will be able to relate the user to the specific environment and its played role and identity.

The Terminals Picture

Terminals will have a fundamental role under many perspectives. From a technical perspective, there will be an abundance of storage in mobile terminals (1TB in the terminal, toward infinite in the network). This will change the way services will be conceived and provided. For example, the equivalent of a current SD card could store all the movies produced during many years, so the video on demand service could access to the movie locally, while the authorization will be carried out by means of a network. The high processing capabilities in the terminals will allow to locally control the context. Context-awareness will mainly reside in terminals while the network will just support the availability of stored information. In addition, the capability to interoperate and adapt to the specific context will be, as said, embedded in terminals and for many situation it will be downloadable Over The Air (OTA). So terminals will highly adaptable to different situations, different environments and different technologies. Actually, the software embedded in the terminal will make more and more the device a personal service platform than a product. They will be personalized according to specific user needs and interests.

Pervasive Communication Picture. The flexibility of terminals, the availability of cheap connectivity will make possible the ubiquitous connectivity, i.e., users and machines will be constantly able to connect. This will push towards the rise of broad classes of communicating objects (smart object, beacons, smart materials, sensors, actuators, micro-machinery, etc). This will increase the number of personal data produced and to be managed by users. Ubiquity of connectivity will have the effect to stimulate the explosion of Augmented Reality and Internet of Things (IoT)

[2] i.e., applications that operate on and interpret personal data, but do not export these data outside of the user environment and control.

applications. With the development of the IoT, any object will be empowered with intelligence and with the capabilities to interconnect with any other object, machine and people anywhere, anytime. Several applications are envisioned today: from health to domotics, from energy management to security to types of digital enterprises. Whilst the IoT foresees billion of things potentially communicating with one another, the Internet with Things (IwT) foresees a growing number (in the hundreds of millions initially, to become hundreds of billion) of objects that will become accessible to human beings through the Internet. The IwT shares several technologies and architectures with the IoT although the "communications interface" should be adapted to meet human needs and the form factor of the object matters since the object is "visible" and its physical characteristics are a selling point, as important as its functionality. In the IoT the functionalities exposed are the ones designed by the producer of the "T"; in the IwT a significant number of functionalities will be mashed up by third parties.

Actually a sort of virtual continuum will be created between physical objects and their virtualization into the digital world. Actions in the digital world will have impacts and could modify the behavior of physical objects and progressively also their material Smart objects will respond to stimuli from the digital environments and will adapt in order to ease the usage and the experiences of people.

The pictures depicted so far have broad implications from a market point of view, some of them are briefly presented:

- Connectivity will be a commodity, in a world in which connectivity is always available and provided by different competing providers the users will always able to choose a convenient offering or proposition. The pure connectivity provider will compete with decreasing (and low) margins.
- Terminals are flexible and personal service platforms. Services will still be provided in a client server fashion (and for this reason data centers will be larger and larger), however their capability will be extremely useful to personalize the user experience and for balancing the functionalities that can have to be executed in the "cloud" with those that can be performed locally. In addition the availability of local environments able to provide storage, processing, networking and sensing capabilities will further modify the equation that all the intelligence has to be provided in the servers.
- Service personalization and adaptation will be pursued and provided in order to enable the user to have better and richer social relationships. Services will try to capture the essence of the specific people and help in providing and creating favorable environment for social interchange.

From a business perspective there will be many different business models based on supporting ecosystems. In certain cases, the ecosystem will see services as a means and not a goal, i.e., services will be provided for free because the ecosystem will find its revenue from other mechanisms than the selling of service features. Advertising will be still a major business model of such a type, but other business models will consolidate [9] or emerge. On the other side, programming and mashup technologies will be such that users will be more and more active in service provision/creation. On the other side, many industries that now focus on "products" will try to move the focus on services associated to that product. The “servitization” trend [10, 11] is of paramount importance for Operators that could help by means of network enablers and platforms in this transformation.

2 Lean vs. Smart, the Operators Dilemma

The global picture depicted in the previous section could be taken into consideration as a general context into which framing the future line of actions of typical Operators. A first point to observe is that complexity of the networks will drastically increase, above all at the edge (where almost “everthing” will become a node, e.g. Users’ devices, machines, sensors, actuators, etc). Currently the public networks are organized hierarchically with different segments of the network specializing for collecting and optimizing the flows at different aggregation points. Evolution of these networks is already moving towards an architectural simplification, through “flattering” of layers and reduction of segments; on the other hand, the edges of the infrastructure will see an increase of dynamicity and complexity (implying this several interworking issues). In other words, public networks’ architectural evolutions going towards simplification (especially through the deployment of “long” optical access) while edge networking is morphing to master complexity and to face the challenges of an environment composed by a sheer number of interacting devices capable to connect to different core networks.

One can easily imagine a scenario in the near future where virtual links are dynamically created and destroyed by applications and services to produce a very dense, interconnected environment of processing and storage resources, sensors, actuators, machines, etc. The edge will be the business arena of multiple Players (e.g. Network and Service Providers, Over-The –Top (OTT), Enterprises, etc.) interacting with each other as in a natural ecosystem, providing all sorts of services and data.

An interesting situation will likely occur: different networks will adapt each other in order to better fits the users requirements. This yields to the concept of a network of networks, i.e., a highly dynamic complex systems made out of many heterogeneous networks, systems and intelligent endpoints that cooperate and compete in order to achieve their goals pursing the satisfaction of customers’ requirements. Many customers can use this network of networks aiming at satisfying their specific communication (but also computing, storage and sensing) needs sometimes. Available resources (pertaining to different administrative domain) will try to optimize their behavior by adapting to customer requirements, but also pursuing a common “network or resource goal”.

If not mastered, such an increasing complexity will result in:

- Costly infrastructure difficult to install, manage and integrate;
- Lack of optimization of usage of resources;
- Lack of knowledge of the “network" as a whole and how it is globally and locally behaving in supporting customers’ requests.

Eventually, the edge of network infrastructures will be a sort of no man’s land (demilitarized zone) in which different sub-networks, nodes and devices will try opportunistically to get and (potentially) share connectivity, processing, storage and other functions. It is in this area that probably there is the major need for a cooperative optimization of resources. This can be achieved by means of self-organization leading to the concept of 0-Touch networks, i.e., networks that do not necessarily assume the human intervention for working, providing services, configuring and generally speaking support a number of management functionalities.

This evolution will require that the intelligence controlling network resources and their services will be implemented through sets of controllers (interacting with each other and properly orchestrated), embedding certain levels of automaticity (to ease human operation and mitigate mistakes) and decoupled from data forwarding and processing [12], [13].

Software Defined Networking (SDN) can be seen as a step in the direction of this network transformation. In SDN architecture, control and data planes are decoupled, and so network infrastructure is abstracted from business applications. This is expected to bring about greater programmability and the flexibility to build multiple networks (on the same physical infrastructure) offering multiple network services. Network services, for example, will include routing, multicast, security, access control, bandwidth management, traffic engineering, quality of service, processor and storage optimization, energy usage, and all forms of policy management, custom tailored to meet business objectives.

If an Operator aims at being a bit carrier or better a Lean Operator, it will avoid to provide functionalities, systems or resources coping with the edge complexity problem. The major goal of such an Operator will be the one of just providing the better connectivity towards the edge and to optimize by delayering the network and by using at the larger extend optical connectivity. The focus of a Lean Operator will be on Transport (prevalently at Level 1 and 2). This implies that such a Lean Operator will provide just a few basic transport services (maybe supporting virtual private networks and possibly some degrees of negotiable Quality of Service, QoS). The needed control platform will be designed in order to optimize (i.e., minimizing) the usage of transport resources and to provide a set of basic improved functionalities. The main goal is to reduce underutilization of resources and to increase the network capability (i.e., the bandwidth provided to the edge). An example of a simple infrastructure that could be of interest to a Lean Operator is represented in Fig. 1.

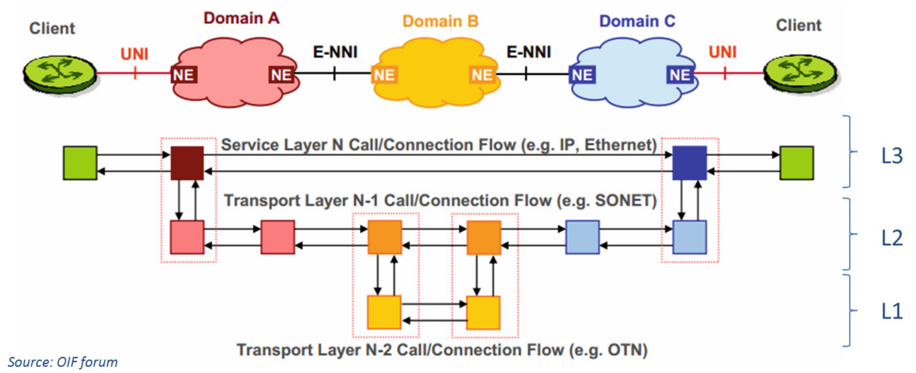

Fig. 1. A Lean Operator will try to keep all the traffic at level L1/L2 because operating at this level is less cost intensive that at L3 (mainly at the IP level). In this way the Lean Operator could optimize the transport at lower level and occasionally to deal with more consuming and possibly slower operation at higher layers.

"De-perimeterization" of Services

The current service offering of Operators are strongly tied to the network, Services are thought of, deployed, offered, and maintained in a strong synergy with a network. An operator very seldom will propose a service without a connectivity offering. Still services are thought as extending the value of the underlying network infrastructure. In addition, services are designed in order to replicate over and over the usual scheme of the network intelligence (i.e. services reside in the network and the edge terminals and servers are exploiting connectivity to provide and support their features). Apparently this approach has been rejected in favor of a client – server paradigm, but in reality the "interpretation" of this model is still related to the leverage of network functions.

On the contrary, the Internet has since a long time decoupled the (inter)network layer from the services. The Internet Protocol, i.e., the slim waist of the IP hourglass), is highly standardized and effectively implemented all over. In addition, http and html standardization has allowed the creation of a well-defined and easy to use environments for implementing services in a client – server fashion. The clear result of this separation is the possibility to transport bits and packet all over the world in a very effective way, and the possibility to access to services independently from the location and the networks used to forwards packets. This "de-perimeterization" of service allows the possibility for each small Web company in the world to effectively competing with major actors of the web. As a byproduct of this independency from the network, a web service can be reached from anywhere, and hence the "long tail" of web services is global. Vice versa, the strong tie between networks and service offering still carried out by Operators is confining Operators services to a smaller footprint essentially determined by the presence of the Operator's network. Even the biggest (mobile) Operator footprint is smaller than the potential footprint of a small web company. This has also an effect on the marginal costs of a global infrastructure and "software client" development. Operators can address well defined markets and their investment have to keep into account the deployment of a network, while web companies have a global reach and investments on networks are limited to those needed for connecting different data centers. Other costs are similar: the cost for put in place or extend the service delivery platforms (i.e., the Telco service layer versus Data Centre approach), the costs for developing software clients, the costs related to a management infrastructure. The main difference then is the reachable market that in the case of operators is limited by the presence of the network, while for Web companies is limited by the availability of an open Internet. For instance the case of Skype is illuminating. The Skype architecture is represented in Fig. 2.

The costs for the communication infrastructure are to a large extend externalized by Skype (and possibly put on the shoulders of Internet and Network Service Providers), i.e., the communication costs between any two end nodes in the Internet are paid for by the customers subscriptions, costs for communication interworking between an IP and a different network (skypein or skypeout) are paid by the customer. This allows Skype to have an interworking infrastructure between the IP and the public telecommunication networks. The service delivery platform comprises client nodes, supernodes and the Authentication infrastructure. Direct costs are essentially paid for the authentication and billing infrastructure, client nodes costs are those related to the development of the software client (there are no cost for skype in the usage of CPU and storage and connectivity of the client/customer), supernodes are often allocated for free or at a low price. The real infrastructural costs are related to the authentication and billing infrastructure (as well as the data center for downloading the skype client). It should be noted that the more skype clients are downloaded than the less their marginal costs are. The peer to peer network scalability has a positive effect on the costs of the client. This is a clear example of how virtualization of a network (the peer to peer network of skype) offers advantages in terms of scalability, global footprint and marginal costs.

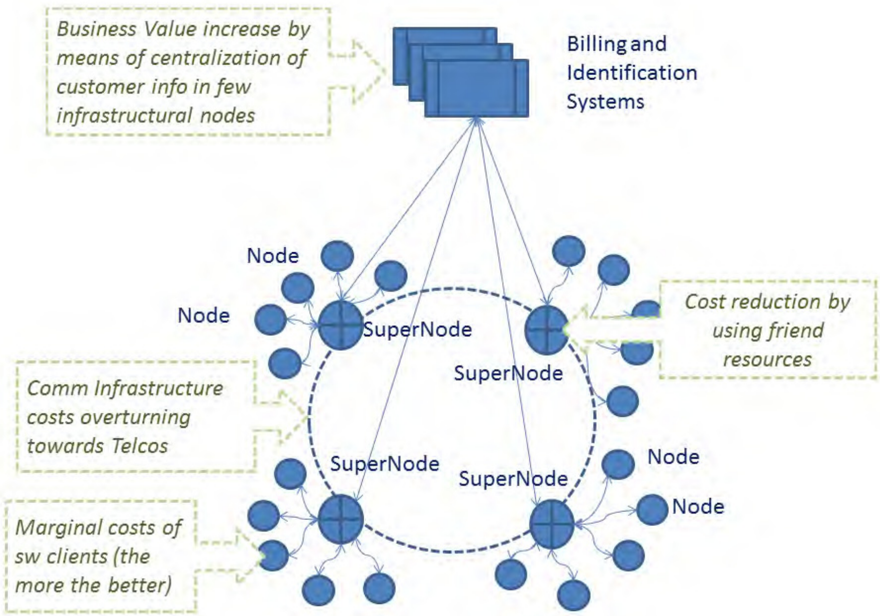

Fig. 2. Skype Architecture and some cost related considerations (derived from [14])

These considerations lead to a further requirement from the Operator's perspective: to support and seek for the "de-perimeterization" of services. Another related issue is the service delivery paradigm, Operators are lagging behind the web companies in infrastructures (e.g., cloud computing) and technologies (big data, real time web) and the technological gap is enlarging. Another issue should be considered here, many web companies are "technological" companies, i.e., they develop directly the technologies they need. Many web companies are in the forefront of technological innovation (e.g., twitter, google, amazon), while Operator, at the service layer, are at the most, best buyers.

Another consequence of the "de-perimeterization" of services is that web companies can use standardized technologies at the service layer, but still they can create walled garden and proprietary solutions. They do so by using http and xml derived means, while they create their own and proprietary environments and APIs. Operators instead are still seeking general consensus and interoperability between different networks and related service environments. Examples are RCS [15] or WAC [16]. Another consequence is that web companies can focus on how users interact with their services, while Operators need first to reach interoperability and then differentiation and personalization. The results are unmistakable: new interfaces and new modality of using services are a clear domain of web and it companies.

FON is an interesting example of how users can share resources and create a large scale communication community. FON is based on the possibility to create separate networks supported by the same WiFi access point. This dual network mechanism allows the access to the Internet by means of a FON based network. Another interesting example along the same line but even more socially oriented is Guifi [17]. They aim at the construction of a network of networks able to overcome the current limitations in connectivity and the digital gap in certain areas. They put together wireless connectivity as well as fibers in order to create a network infrastructure collectively managed. They are an officially recognized telecom operator in Spain. This approach could fit very well with the one named "home with tails" [5] which proposes the idea that single customers could be the owners of the fiber connecting the "last mile". This could create a different infrastructure based on the possibility to share optical connectivity within communities. Other interesting initiatives related to the concept of "network of networks" are Village Telco [18] and some military projects such as [19] or [20]. All these approaches together with other initiatives like Mantychore [21] are heading to the fact that networking resources can be put together and forming a network of network. This composite network can be virtualized (or in other words be "de-perimeterized") and it can be offering services to the connected people. Such a paradigm is a powerful one and it is able to lead to a radical transformation of the communication business and service delivery.

The de-perimeterization of Services leads also to the need to have means to recompose the fragmentation of the different resources and networks. Such a means could be a sort of network operating system whose major goals are: to provide an harmonized view on underlying network capabilities and to offer a framework for the execution of services (e.g., security, management, reusable functions). The relationship between real and virtualized resources has to be well designed because virtualized and overlay networks should have a link with the real resources otherwise physical resources' usage will not be optimized. This is happening in current peer to peer networks. So the relationship between real and virtual resources should be maintained and exploited in order to build a link between the network and the service layers. Approaches similar to ALTO [22] could be considered.

If a Lean Operator will try to keep all the traffic at level L1/L2 because operating at this level is less cost intensive that at L3 (mainly at the IP level), a Smart Operator will then be strongly involved in the definition, design, deployment and operation of such a network wide operating system. Its goal is the optimization of the available resources and the creation of a Virtual Continuum between real objects and their clones in the cloud can be a means to radically transform the present service paradigm. In order to achieve this goal the Telcos have to design, implement and deploy a new platform for future networks that enables the role of Service Enabler.

3 Choose a Strategy, Network Will Follow

In Future Networks, the role and the business goals of Operators will be extremely important in order to determine the network architecture. Three major business driven roles are sketched in Fig. 3 and briefly described here:

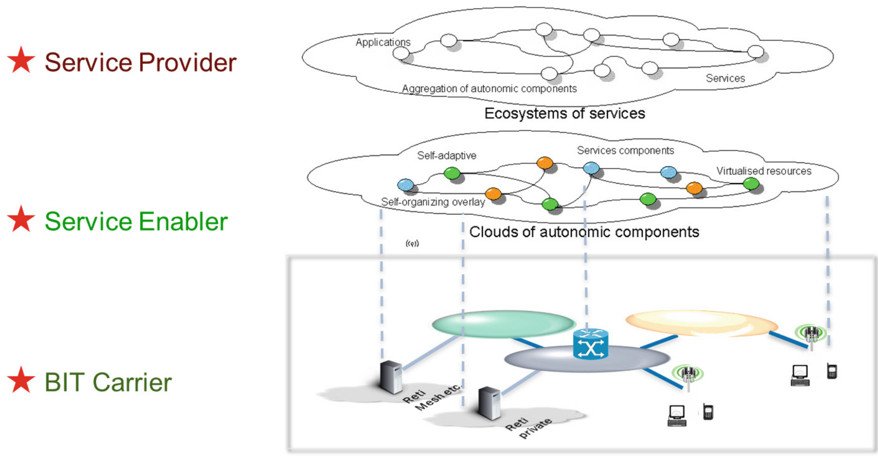

Fig. 3. Possible Roles for a Telco in Future Network Scenarios (e.g., Next Generation Networks)

- Bit carrier, in this role the Operator will focus on the most efficient and performing transport of bits. It will try to deliver and forwarding bits in the quickest and most economical way trying to move big chunks of data to the closest or more appropriate sink.
- Service enabler, it will focus on positioning its infrastructure as an enabler for the creation and development of data and information related services. It will put together controllers [23], functions and components that abstract the underlying network infrastructure, but do provide value to the final users as well as to Service providers and application developers. This architecture comprises reusable components that are able to self-organize themselves into reliable overlays that support the communication, processing, storage and sensing capabilities of the users. The Operator is not involved in the direct development of applications for the customers, it is instead enriching the platform services by developing platform components that can be re-used by service developers and service providers for creating new applications. These components are designed in such a way to optimize the usage of networked solutions. The Operators playing the Service Enabler role will be concerned with traffic optimization at several levels (L1/L2/L3) as well as the execution of functions at higher level (at the application layer of the ISO/OSI stack). At this level, openness, well defined platform services and components, and a wide set of established APIs are of the paramount importance because they are instrumental for application development and hence for attracting and nurturing a wide ecosystem of developers and service providers.
- Service Provider, it will organize its infrastructure in such a way to be able to rapidly manage the entire service and application lifecycle. The network and the Network operating system are the infrastructure/platform on top of which the operator will build and provide and deliver directly to customers (residential or business ones) its services and applications. Potentially this platform could be a walled garden to be used exclusively by the Operator or a set of other actors

under the strict control of the Telco. In this case all the functions from transport, to control, to generic platform services up to applications are rigidly under the control and scrutiny of the Operator that acts in such a way to compete also in vertical markets with specialized offering supported by the networked platform.

The networked infrastructure will deeply differ depending on the intended role played by the Operator.

The Bit Carrier Infrastructure

An architecture supporting this role will be characterized by:

- An extreme focalization on the transport capabilities. The Operators will try to serve and fulfill connectivity requirements of its customers by putting in place an ubiquitous network (fixed and mobile, as well as low power wireless networks for machine communication). The deployment of fiber will be essential in order to create synergies between the fixed and mobile communications. Data will transit in the network in an optimized fashion, i.e., they will use minimal resources, they will be transported preferably by optical technologies (and at lower layer), usage of functions at L3 and up will be minimized and the major goal of such a bit pipe will be to deliver the chunks of data faster and in the shorter time possible to the data center where bits will be processed and transformed into data an information (generally outside of the domain of the Carrier). The network will be optimize for getting rid of bits as quickly as possible.
- A basic control infrastructure. Since revenue will be generated by bit transport, the control functionalities will focus on the best management of the infrastructure by to minimize the usage of valuable resources as well as the time for packet processing and delivery. The goal of the Operator will be to have the leanest infrastructure able to support the foreseen traffic. Network optimization will be of the greatest importance.
- A few basic service. The platform will still be able to provide a few services. They will be strictly related to the transport. Apart from billing and accounting of the network resources, the infrastructure could provide QoS related capabilities in order to allow service providers to adapt the allocated network infrastructure to the varying traffic conditions, some private virtual network functionalities in order to accommodate the need of companies for creating their own network infrastructure and to connect it to customers and employees. Mobility will still be a major service and probably the major revenue stream for the Carrier. It will be optimized and integrated with different access capabilities (from LTE and LTE+ to Wi-Fi and its evolutions to other techniques). Some interfaces and services will be offered in order to support the needs and requests of Virtual (Mobile) Operators that will create inter-regional or sovra-national virtual networks combining capabilities and capacity offered by carriers. Probably this type of carrier will also be proposing to customer the possibility to dynamically bid for connectivity when resources are under a certain threshold.

Fig. 4 represents a possible infrastructure for such a type of Operator.

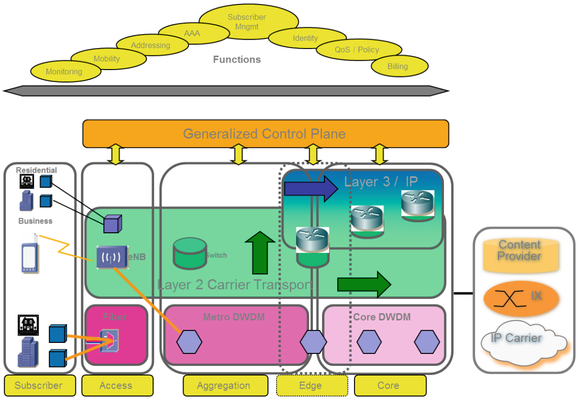

Fig. 4. A Possible Network Architecture supporting the Role of Bit Carrier

The Service Enabler Network

The network infrastructure needed to play the role of Service Enabler has to be radically different from the one of the Carrier. Three major differences must be emphasized: a) the communication focus moves from the lower layers (L1/L2) to upper layer L3 and UP (i.e., the network has to deal with IP and application player protocols), b) the network is not only based on communication resources, it has to integrate and offer processing, storage and sensing/actuating capabilities; 3) the focus moves from bits to data and information, the network has to provide means to gather, process and delivery to customers real time information. The networked infrastructure for playing the Service enabler role is represented in Fig. 5.

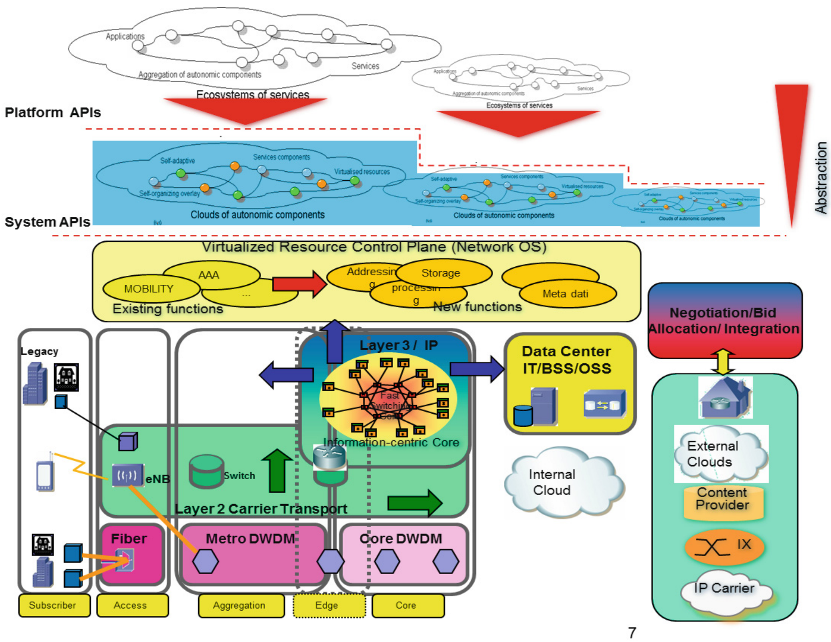

Fig. 5. A possible Network Architecture supporting the Role of Service Enabler

This platform is characterized by the fact that many of its functionalities and services can be abstracted and virtualized, they can be componentized and offered by means of API to the external world. Internally the resources will span a much larger intent that the simple communication capability: processing, storage and sensing/actuating will be integrated. The network will be open to extension and integration, i.e., external resources could be asked for and included in the entire infrastructure in order to allow the integration of customers network and systems into a common framework. For instance, banks and other financial entities that have a large system infrastructure will not move to the cloud, instead they will request for extensibility and integration (under their direct control) of networked capabilities. Virtualization and abstraction come to help. The Service Enabler will provide a set of virtualized capabilities that will extend the infrastructure of the financial institution. Also end user capabilities could be integrated and used in order to create complex computing and storage capabilities. For example a Nanodatacenter [24] could be dynamically built by integrating end user terminals into a virtualized data center. User could be remunerated for allowing the usage of their resources for a certain period of time. The integration relation is based on contract that can have a limited in time validity.

The platform should be able to accommodate also for smart objects, this pushes for introducing different communication paradigms that differ from the prevailing one (i.e., the client – server). The Service Enabler network should be able to provide a Complex Event Processing (CEP) engine capable of dispatching in real time events and commands to a multitude of smart objects as well as to derive usable information by analyzing event patterns. This real time event engine will be a sort of twitter of things where each smart thing will be able to send (and receive) events about its perception about the status of an environment, resources or system. Transactions, i.e., a set of events that describe the occurrence of a functionality, will became more and more important. Users will want to be informed of the final status of actions performed on their behalf from financial systems, or security related applications. Users will want to trace all the actions that they, or their terminals, or smart objects temporarily associated to the person are performing on behalf of the individual. These transaction will be able to represent the digital experience of users, and they need to be collected and passed to the users in real-time. A pubsub engine [25] seems to be a technical possibility to allow this transaction based digital world.

A representation of the twitter of things is provided in Fig. 6.

All these functions will be provided by means of componentized functions that will be instantiated as programmable entities of an overlay network. They will be resilient and self-organizing in order to allow the developers to focus on the functionalities of the service instead than coping with the complexity of the system organization. Each entity will provide specialized APIs in order to offer functions and programmability to the applications. Different levels of APIs will be requested in order to exploit different levels of abstraction that the Service Enabler network can support. The differentiation of API (represented in Fig. 5 as a ladder) are useful for allowing the service designer to choose the level of granularity and control on networked resources that the service needs.

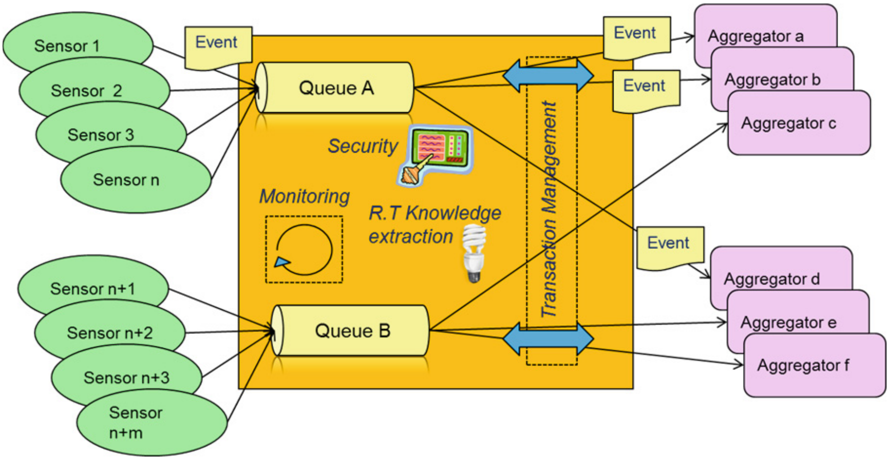

Fig. 6. A PubSub engine will be instrumental to support the passage from the Client – Server Internet to a Transactional Internet

The Service Provider Infrastructure

The Operator playing the role of Service Provider will opt for a different infrastructure. Its value is in the creation of applications, so all the platform will be customized at several levels (from the resource level to the upper layers) in such a way to take advantage by special feature and capabilities. The platform will lose

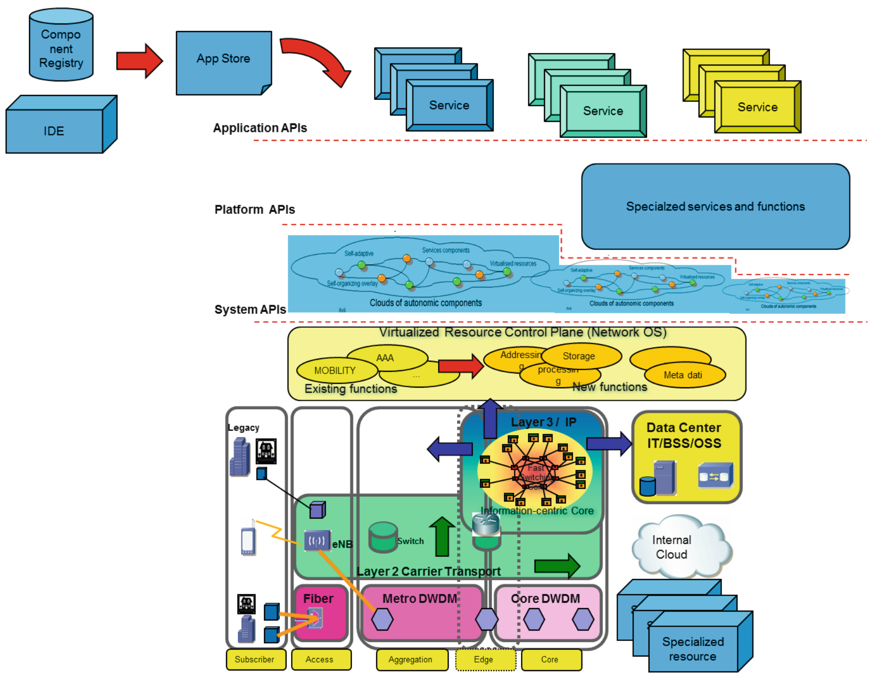

Fig. 7. A possible Network Architecture supporting the Role of Service Provider

generality and will be more and more targeted to the specific markets addressed by the Operator. The service and application creation will be highly standardized and a well defined registry of application will be introduced. This process of specialization will be further exacerbated by the need to support Application Stores.

Fig. 7 represent a possible architecture for a Service Provider.

4 Focus on the Service Enabler Network

In order to play the role of Service Enabler, a set of conditions should be met the Telco. First a clear business model should be implemented that gives value to the Telcos as well as to a broad ecosystem; second a set of technologies and mechanisms should be mature for a wide deployment and extensive usage; third a viable architecture should be designed and implemented in such a way to enable the role and the related ecosystem by mixing and match the needed technologies; forth (and mainly important) a set of valuable services and applications should be enabled and made possible by the architecture. The lack of one of the conditions, or a bad “execution” of one of them, can hinder the success of the entire approach. In the following these fourth conditions are further discussed and analyzed.

A New Business Model for the Telcos

There are many expectations about the forthcoming Internet of Things. It should provide an environment in which objects can collaborate and help humans in many aspects of their day life. Applications are foreseen in many vertical fields ranging from e-health and well-being, to smart cities and, from smart home environments to complex digital organizations [26]; from smart automotive to smart transportation. All these interesting (form the technological and business points of view) scenarios are characterized by fragmentation and verticalization, i.e., the solutions are designed and developed in a silos fashion without a common effort for deriving a supporting platform. For instance the smart home environment is highly characterized by the fragmentation of “small” vertical solutions (e.g., for alarms, for power consumption management, for domotics, and the like). They have to be integrated in a case by case fashion and this introduces complexity and reduces the reuse of solutions. In addition, the end users percept the market and the opportunity as highly complicated and devoted to specialized people. All these circumstances are slowing down the development of the market. A possible solution is the emergence of Brokers for Internet of Things. These are actors that can offer a platform for the collections and management of user data as well as the capability to subsidize the user or the use of wireless sensor network and the ability to drive the market towards common standards and solutions. The approach proposed here for a Telco is based on a few concepts:

- The possibility to represent in the cloud (i.e., in a distributed and open platform) a clone representation of real world objects and to open up a set of APIs for controlling them or interact with them;
- The possibility to represent non only sensors or actuators, but also other real world objects and concepts (e.g., a place, a product, etc.);

- The possibility to transform a product and an object into a service by means of its virtualization and representation in the cloud.

This is a relevant step forward from the internet of Things to the Internet with Things in which possibly all the objects and many "concepts" can be virtualized, represented and "programmed" in the Internet by means of open interfaces. Fig. 8 depicts the Internet with Things and a few of its characteristics.

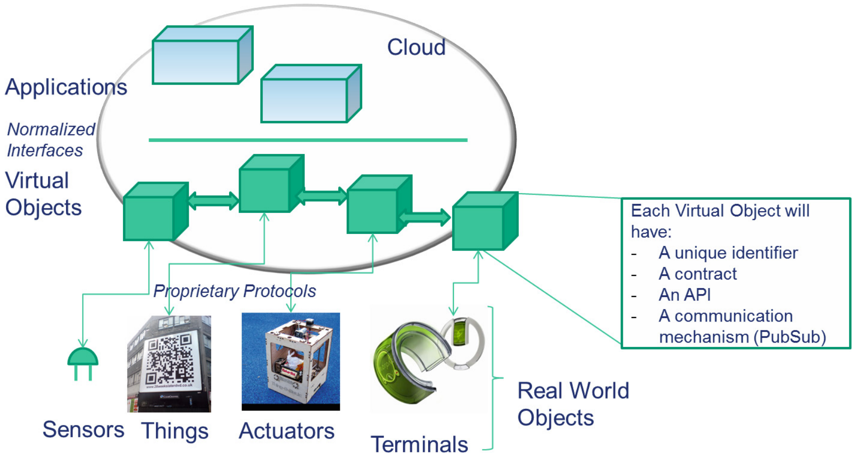

Fig. 8. Towards the Internet with Things

This approach will leverage the concept of *servitization*, i.e., the capability to leverage a product and make it a services. For example, a dishwasher can be just lent to the user and it will pay for each washing cycle, or the service provider can suggest what cleaning products to buy, and many other similar patterns.

Sometimes the servitization works better with the so called Network Effect, i.e., the increase of value of a product or service depending on the number of people that use it. Internet with Things works well either with or without the network effect. For small services that needs very specific applications, the virtualization can produce good effects in terms of sharing of the underlying infrastructure and means for programming it, For more general services, the Internet with Things can leverage the social effects of virtualized objects and creating large communities that share services, virtual objects and especially data generated by them. For instance, wireless sensor networks for the home environment could collect various data about the usage of resources, these data can be neutralized and be shared within a community in order to determine virtuous behavior in the usage of valuable resources such as energy, gas and the like. People sharing these data could engage in a sort of competition aiming at reducing their carbon footprint.

The value proposition of the Telco in this approach is differentiated: it relies on an extended communication capabilities:

- The connection between a real object and a virtualized one is based on Always Best Connected communications, i.e., the communication infrastructure (the object itself and the network of networks) will strive to provide a reliable link offering the maximum capability possible depending on the context of use of the resource.

- The platform provides a set of functions and means for exerting the expected behavior of the virtual object, e.g., processing, storage and communication capabilities (e.g., PubSub engine, data store). In addition it provides means and functions for controlling, managing and monitoring the virtual objects (e.g., the object repository for brokering of objects and resources).
- A set of Application Programming Interfaces, APIs, for allowing high level of programmability of virtual objects and platform functions/objects. APIs are fundamental for service construction and allow to programmers the capability to create new services and applications. Programmers can create general solutions as well as vertical ones that are tailored for specific markets and businesses.
- Generic services and applications can be created on top of at least two different levels of APIs: virtual Object APIs for directly control the virtualized instance of a real object, and higher level APIs for benefiting of all the rich functionalities offered by the platform. These API are used by developers (Internally and externally to the Telco) for creating services. In this respect, the servitization capabilities can leverage a number of innovative applications.
- A set of already developed and tested applications by a large ecosystem (here the network effect can have its greater effect).

Fig. 9 represents the value proposition with respect to the architecture.

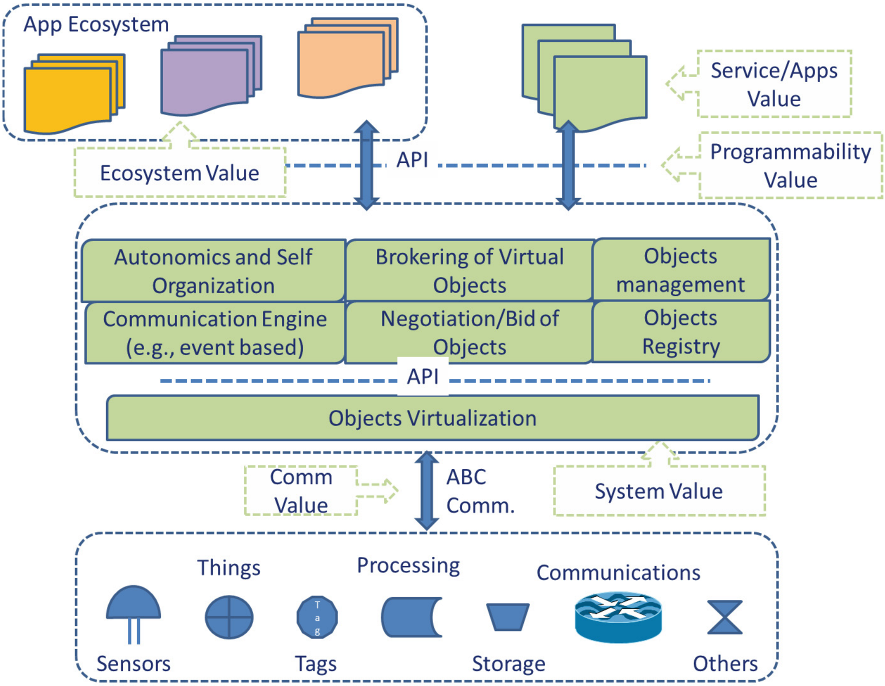

Fig. 9. Some valuable features of a Service Enabler Platform

It is worth to consider the difference of this approach respect to the traditional attitude of Telcos. In a traditional business proposition, the Telco was trying to create a full offering by acting a number of different roles in the value chain of a service (from infrastructure, to platform up to service provider). This was done by leveraging the network and its capabilities. In this approach, the Telco will focus mainly on the role of Platform Providers and will act in order to collect and integrate different infrastructures (processing, storage and communications) as well as to allow different service development capabilities. For certain services, the approach still allows the Telco to play the full set of roles (i.e., the service provider) or to focus on the communication infrastructure (connectivity provider). This flexibility will guarantee the possibility to choose the best role depending on the service proposition.

A representation of the new ecosystem is given in Fig. 10.

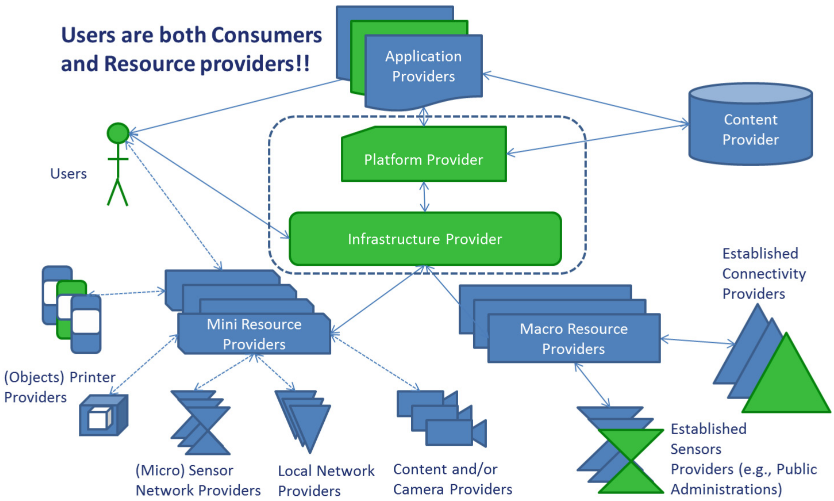

Fig. 10. The Ecosystem envisaged for the Service Enabler Platform

One of the major differences is the role of the user: it is not only a customer, it can be a provider of resources and be a partner of the Telco. The platform in fact is built also by putting together and integrating resources pertaining to different administrative domains (and end users will have a key role in this). One requirement of the platform is to be able to easily and dynamically integrate resources, systems and networks of other actors in such a way to cooperate in the creation of a synergic network of networks.

Virtualization for the Service Enabler Platform

Service Enablers' networks will therefore rely more and more on highly-developed software, which will accelerate the pace of innovation as it has done in the computing and storage domains.

Virtualization [27] technology, introduced by IBM in 1973, became very popular with systems like the hypervisor Xen and VMware. These systems have been widely used to enhance isolation, mobility, dynamic reconfiguration and fault tolerance of IT systems. The concept of virtualization has been migrated to networks.

Of course, network virtualization already exists in virtual private networks (VPN) which generally use the multi-protocol label switching (MPLS) technology, operating on the link level layer. Another form of virtualization is to segment the physical local area networks into virtual local area networks (VLAN). An overlay network is yet another form of network virtualization which is typically implemented in the application layer (Fig. 11), though various implementations at lower layers of the network stack do exist.

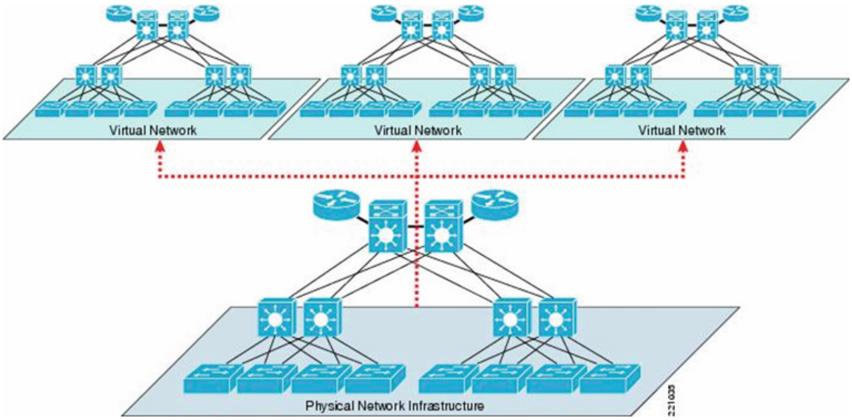

Fig. 11. Network Virtualization
(Source: http://www.cisco.com/en/US/docs/solutions/Enterprise/Network_Virtualization/PathIsol.html)

Nevertheless current concept of network virtualization is based on the idea of introducing in network equipment hypervisors (as formerly used for virtualizing IT resources). An hypervisor, also called a virtual machine manager, is a program that allows multiple operating systems to share a single hardware host. Each operating system appears to have the host's processor, memory, and other resources all to itself. However, the hypervisor is actually controlling the host processor and resources, allocating what is needed to each operating system in turn and making sure that the guest operating systems (called virtual machines) cannot disrupt each other.

For example, the principle of a virtual router is that one physical router is divided into several virtual routers residing inside virtual machines.

Network virtualization is a powerful technique as it provides flexibility, promotes diversity, promises security and increased manageability: by allowing multiple heterogeneous network architectures to cohabit on a shared physical substrate, network virtualization is a diversifying attribute of the future networks. Network virtualization allows achieving multiple advantages: for example, the crash, or the misuse, of a virtual resource is confined in a virtual network (e.g., by applying fault recovery policies enforced by self-healing capabilities) and it has no impact on other virtual networks; it is possible to put in place, in each virtual network, specific logics and policies (e.g. to optimize the usage of allocated resources according to SLA).

This evolution will require new management approaches capable of operating, in an integrated way, both real and virtual network resources. A way to implement this operational intelligence is based on decoupling data processing-forwarding from sets of controllers (interacting with each other and properly orchestrated), embedding certain levels of automaticity (to ease human operation and mitigate mistakes).

Software Defined Networking (SDN) [28] which can be seen as a step in the direction of this network transformation. In particular, in SDN architecture, network control and data planes are decoupled, so that network infrastructure is abstracted from business applications (see Fig. 12). This is expected to bring programmability and flexibility to build multiple networks (on the same physical infrastructure) offering multiple network services. Network services, for example, will include routing, multicast, security, access control, bandwidth management, traffic engineering, quality of service, processor and storage optimization, energy usage, and all forms of policy management, custom tailored to meet business objectives.

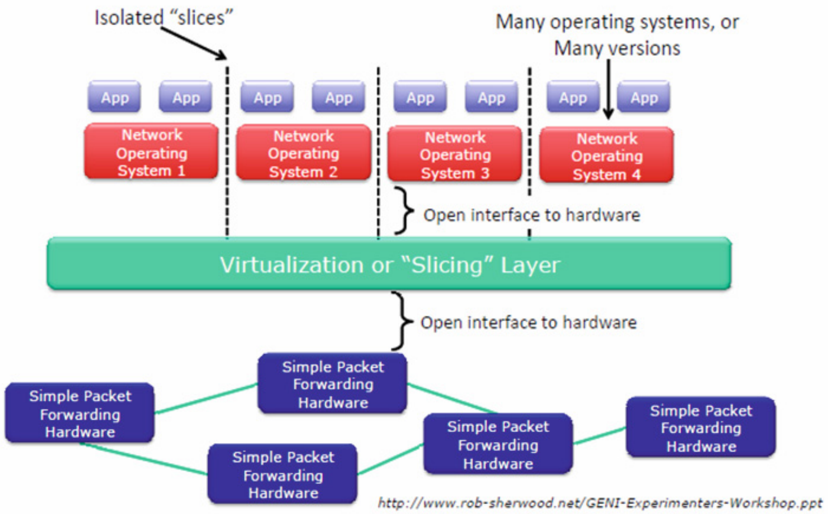

Fig. 12. Decoupling network control and data planes to abstract network infrastructure from business applications [28]

This network transformation should also pay attention to open-source initiatives aiming at providing "network connectivity as a service". For example OpenStack is an open source cloud project developing two technologies: OpenStack Compute and OpenStack Object Storage. OpenStack Compute is the internal fabric of the cloud creating and managing large groups of virtual private servers. OpenStack Object Storage is software for creating redundant, scalable object storage using clusters of commodity servers to store terabytes or even petabytes of data. Interestingly, Quantum is project of OpenStack looking to provide "network connectivity as a service" between interface devices managed by other OpenStack services. In other words, Quantum is an application-level abstraction of networking: it requires additional software (in the form of a plug-in) and it can talk to SDN via an API. Fig. 13 represents a possible integration between the two solutions.

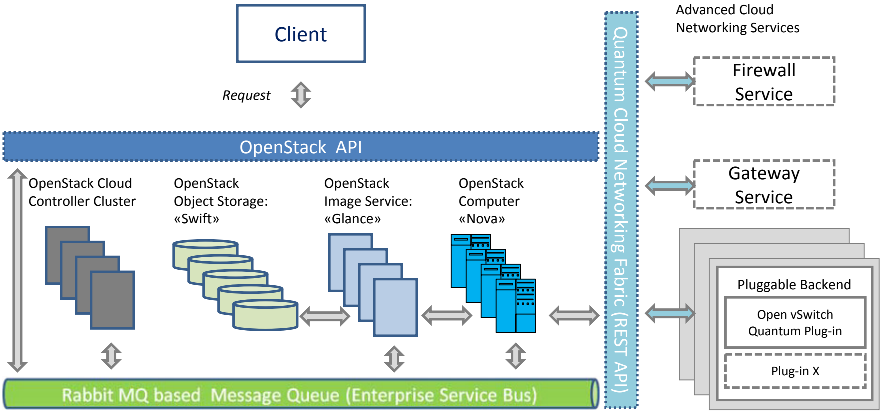

Fig. 13. Integration of OpenStack and Quantum

Eventually future network of networks will look like a complex environment (e.g. ecosystem) of resources and associated controllers in a continuous and dynamic game of cooperation and competition. As known, complex systems exhibit properties (e.g. self-organization) that emerge from the interaction of their parts and which cannot be predicted from the properties of the single parts: this will make the architectural design and the Operations particularly challenging.

Architecture

The Service Enabler Platform (a network of networks) will strongly depend on:

- the virtualization of resources (communication, processing, storage, sensing);
- the cooperative orchestration of single or subsystems' resources;
- the introduction of self-organization capabilities in order to achieve an autonomic, cognitive [12] behavior of applications and resources (the highly dynamic and unpredictable behavior of a network of networks requires the real-time adaptation to different contexts);he introduction of different (from client server) paradigms for the cooperation of distributed (virtual) objects.

Overlay networking is a real distributed processing paradigm and it fits properly in this dynamic environment. The combination of these technologies will lead to a programmable networked environment such as the one represented in Fig. 14.

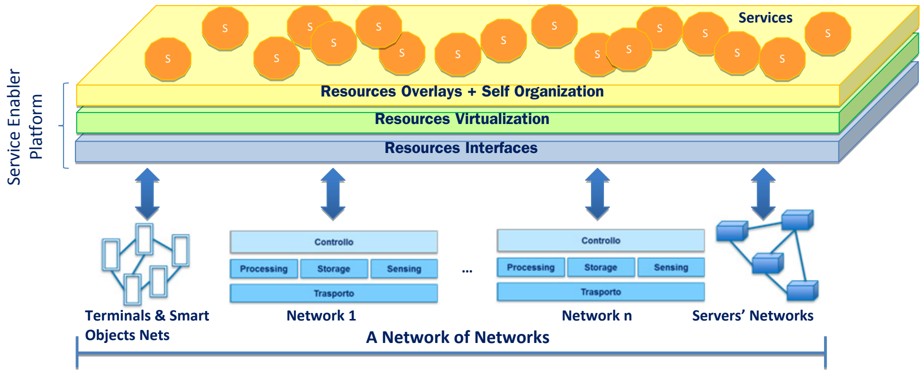

Fig. 14. A Service Enabling Environment and its basic principles and layering

The Service Enabler platform is a sort of Network Operating System, that, through the representation and virtualization of networked resources spanning across many subsystems and different administrative domains, will allow applications to negotiate for "virtualized" and autonomic resources, to allocate them, to control and program their functionalities according to the specific needs and requirements. The upper layer is made out of overlay network that comprises basic resources. These basic resources can be extended or can be integrated with new specialized ones in order to allow for the provision and offering of many services. It is important to stress out the role of end-users terminals and networks. They provide to the entire network a set of capabilities and the possibility to the entire network to rapidly grow (similarly to peer to peer networks in which end users contribute to the resources of the system that can scale up).

A broader view of the architecture is given in Fig. 15.

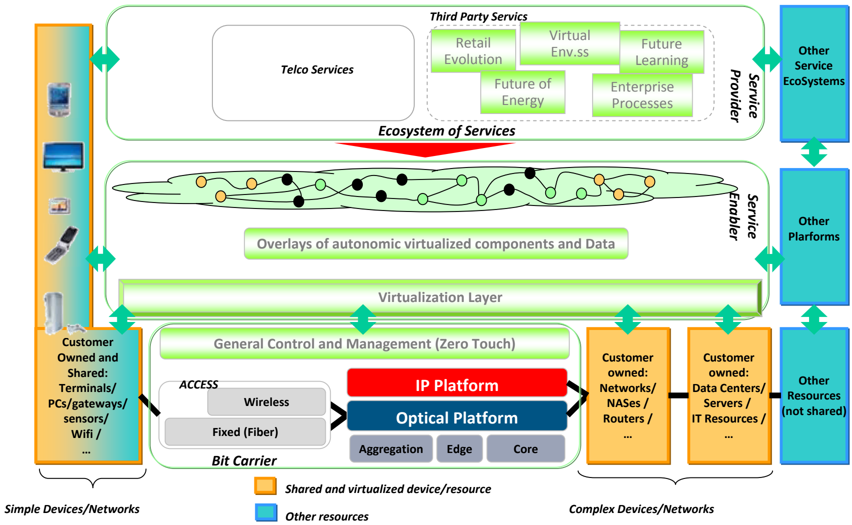

Fig. 15. A Service Enabler Platform

This platform could be considered as a sort of blueprint that an innovative Telco can progressively implement, deploy and improve according to the technical and market evolution. The need to integrate the Telco platform with external ones is of paramount importance, because it is the key to exceed the offering of the web companies. The integration and openness is a key differentiator as well as the ability to integrate several networks in such a way to "de-perimeterize" the communication and processing infrastructure.

Virtual Continuum as a Service

One of the many scenarios enabled by the Service Enabler Platform is related to the virtualization of terminals. Users are already using more terminals per person, and in the future this trend could increase because more smart objects will be dynamically associated to the single user. The virtualization capabilities promised by the Service Enable Platform promise to nurture an very valuable service portfolio related to terminal virtualization.

The Virtual Terminal

The concept of virtualization of mobile phones is getting more interest worldwide. There are already some initiatives related to the definition of Virtual Terminals and Virtual Environments. For instance the Clone Cloud project within Intel Research Center in Berkeley aims at "clone the entire set of data and applications from the smart-phone onto the cloud and selectively execute some operations on the clones, reintegrating the results back into the smart-phone". Also NTT is working on a Virtual Terminal with the idea of offloading many time consuming processing tasks from the terminal into the network.

The concept behind these projects is very simple: to integrate data and execution environments of the terminal into the cloud, i.e., to provide a functional extension of the terminal capabilities into the cloud (see Fig. 16).

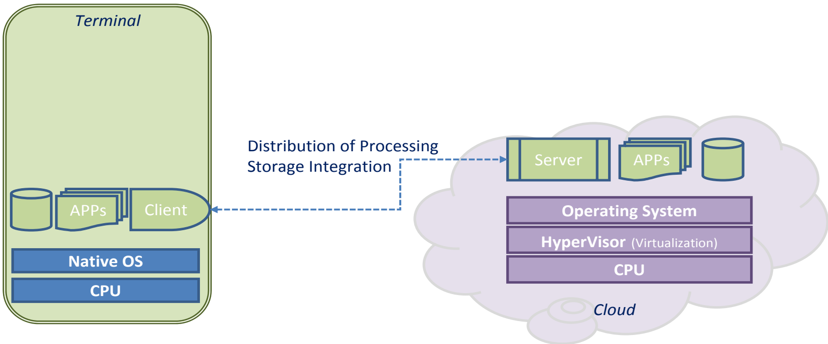

Fig. 16. An Example of virtualization of a Terminal in the Cloud

These initiatives try to complement the capabilities of smartphones with those of the cloud. The typical functions can be the computation off-load or the synchronization of data between different clones (e.g., like silk of amazon [28]). These are important functions that in the short – medium term can have market relevance. They can increase the capabilities of simple terminals (e.g., those of plain vanilla 2G terminals) or to extend the battery life of power demanding terminals. The service could offer a continuous presence of the customer in the network (e.g., in the social networks) and the ability to aggregate around the Virtual Terminals the many specific terminals used by the single customer.

Operators have a clear idea of the real social network of the customers. Actually the entire set of call and message related information does clearly define the social network of customers. Many services can be created exploiting this knowledge of the customer (exceeding those enabled by the address book: e.g., the Skydeck service was building the social network of the customer by storing all the messages sent and received as well as the records of all the calls).

Some Examples

Moving the SIMs into the Virtual Terminal. A user could map one or more physical terminals onto a (subscribed) virtual terminal in order to synchronize them or to extend their capabilities. The user decides how to deal with communications and processing services, however the different terminals can create a sort of mesh network and can partition information and computational tasks among them. See Fig. 17.

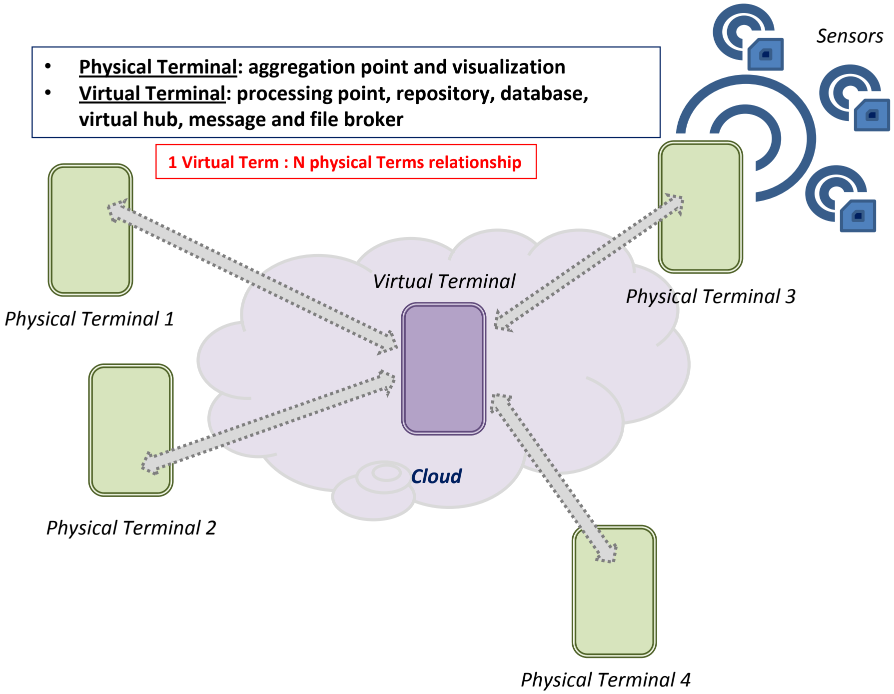

Fig. 17. A 1-to-n mapping between n real terminals and one virtual clone

Another situation is depicted in Fig. 18: a user has many virtual terminal subscriptions and it associate the unique physical terminal to all it virtual images in order to integrate all the services into a single end-point.

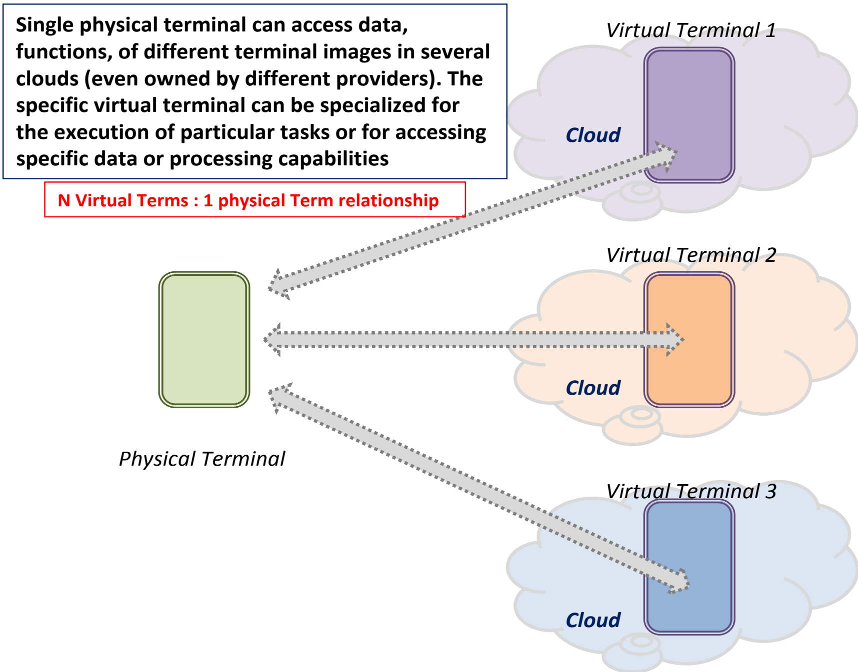

Fig. 18. An n-to-1 mapping between a physical terminal and n virtual clones

My Trip Scenario. A person can create a virtual object called "my trip" that represents all the needed information related to a travel. This object is created in the virtual environment. This object comprises the set of information, data, and alerts needed to make the trip easier or more rewarding for the user. The user first visit virtually by means of a street view, the destination. S/he bookmarks some points of interest with alerts. All the booking and tickets are aggregated to the virtual object "my trip" (aggregation of information). At the check-in the user has just to share with the clerk a pointer to the ticket and gets in return another object (the check-in object) to associate with the "my trip" object. At the destination the user can start wandering and can ask the navigation support to "my trip" and can get also some useful information about monuments, restaurant and the like. This instance of "my trip" (plus some addition location information) can be stored in the system. Old information can be used to recall the user of things done or seen in that place.

The Virtual Continuum: A Definition

The concept of virtual terminal is just a first step: it should be gradually extended to encompass and integrate other physical objects. Virtualization in the network of physical objects aims at the creation of a "virtual continuum" between the real and virtual environments. There will be a constant entanglement between real objects and their representations in the network. Events, actions, data on a physical object will be represented in the virtual world and vice versa.

The Virtual Continuum will enable the exploitation of the Service Enabler Platform. It will be enriched and personalized with a huge set of applications and services that largely exceeds the portfolio of communication related services supported by current and future communication platforms. The opportunities related to virtual environments and the related platform can be also a means to change or shape new markets like Augmented Reality, Internet with Things, Ambient Intelligence / Context Awareness, Social Media, Entertainment, Micro and Distributed production and the like.

There is the need to design and develop a set of APIs and functionalities that virtualize the Terminal (an open and licensable physical and logical architecture of the terminal). The agreement between many Telcos could be important to ensure a significant market for application developers.

The virtualization of terminals and objects straightforwardly leads to the aggregation/integration of clusters of objects and consequently to the ability to virtualize entire real environments. An environment can be a living room or a house, but also a store or a shopping center, a business or a hospital, a whole global telecommunications network or a distributed data center. The concept of virtual environment is important because it allows a Telco to build global offers independently from the direct control of resources (more often owned by others) or networks. This feature should be well understood and analyzed because it is the key to the “de-perimeterization” of services and the ability to create a “network of networks” (e.g., integrating the specific Telco owned network with those of other Telcos or enterprises networks) or “overlay networks” that span over other networks. Overlaying capabilities will be a means to provide a global coverage of services and virtual environments (a sort of roaming feature) and to introduce the concept of resource brokering.

A virtual environment is a software feature that allows customers to use features tailored to their specific needs. The allocation and adaptation is mediated/optimized considering the customer’s needs and the possible allocation and exploitation of existing local physical resources. In addition, the functionality of virtual environment allows third parties to develop services that may be provided regardless of the actual availability of specific local resources by means of an intelligent use of remote and virtualized resources. A Virtual Environment will gather different resources pertaining to different domains and will integrate them in a dynamic infrastructure. Virtual environments will be designed and operated like complex systems capable of self-organizing. Fig. 19 represents the problem domain addressed by the Virtual Environment and Virtual Continuum concepts.

The concept of virtual environment can support future enterprises’ needs by seamlessly integrating different technologies like cloud computing, virtualization and composition of networks, sensors and actuators. A business operates in its own environment, made out of its resources (physical, logistical, intellectual, contract).

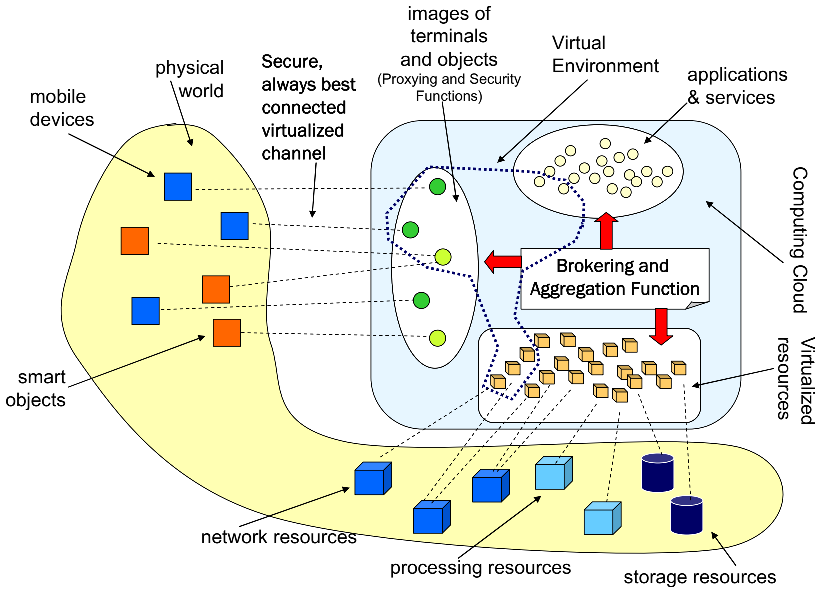

Fig. 19. A Virtual Environment as supported by the Service Enabler Platform

In the coming years, the businesses will tend to transform their organizational structure moving from rigid and hierarchical structures (e.g., organizational or functional units) to open environments in which resources and processes are not directly controlled and they can even reside outside the enterprise perimeter. New flexible organizational models need to be supported by the ICT infrastructure. They will be characterized by a loose coupling of dynamically associated heterogeneous resources pertaining to different domains; their integration and aggregation will be so dynamic that human intervention for configuring the environment is not possible. Virtualization and autonomic networking will be used in order to support the self-organization of the environment according to self-CHOP features.

5 Conclusions

In the future context draft by the Service Enabler Platform proposition, a Telco can leverage its traditional assets like: management skills of complex systems, the offer of multi-channel communications, identity management of users, integration with (and within) various business sectors and institutions and its global value within the national and international relationship system, and disrupt the market (currently dominated by the service offering of the web companies) making new compelling service offering within an open environment. The proposition and the related architecture leverage the role and the resources of users, giving them a central role in the entire approach.

Moreover, adopting this approach does not implies to disregard existing business models, instead it means to build a new compelling offering that shifts the focus from physical point to point connectivity to a higher meaning of “connectivity”: customers’ needs are to be supported by the creation of secure and flexible communication environments made out of virtualized resources that dynamically adapt to the context of usage in order to meet customers' needs at the best. In a sense, for businesses it is a move from simple integrated communication offering to the next step of communications: the integration of cloud computing, storage, communications and sensing/actuators; while for the mass market it is the move from the "access gateway" or the set-top-box to the next level of communications made out of the integration of content, data, information, social relationships (i.e., a move towards an information centric networking).

Why Enter This New Course

Part of the value will be in the deep knowledge of the customers and its data. This knowledge can be monetized in terms of security services (e.g., to protect privacy and data ownership) or in term of profiling seen as a service to the user), controlled by the user (the profiled data will be used according to the allowed and agreed mechanisms negotiated with the users).

The virtualization allows the Telco to leverage its assets (connectivity and management) for entering into new businesses that have the potential to transform the current processes and business models: from virtual reality to the Internet with Things.

The real interest for moving in this direction is twofold: on one side the possibility of a repositioning and re-appropriation / sharing of the value that terminals and smart objects will continue to build, and on the other side the possibility to reposition the Telco infrastructure as a global platform and an enabler of services. Taken together, these aspects can slow down and possibly reverse the fall in revenues and importance of the traditional business of Telcos.

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