Converged fixed and mobile broadband networks based on Next Generation Point of Presence

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Abstract: To achieve a joint optimization of fixed and mobile networks, we propose a new broadband network architecture organized around the innovative concept of Next Generation Point of Presence (NG-POP). NG-POP targets a disruptive evolution of the first aggregation node, also called Central Office (CO), or Local POP by opposition to more centralized POPs. It will allow both a better distribution of all essential functions of fixed and mobile networks (functional convergence) and a better mutualisation of fixed and mobile equipment and infrastructures (structural convergence). This paper presents the main ideas related to functional and structural convergence and illustrates the benefits expected from the underlying NG-POP concept for future converged fixed and mobile networks. The architectural concepts presented in this paper will be assessed in details in European large scale integrating project COMBO (COnvergence of fixed and Mobile BrOadband access/aggregation networks).

Keywords: NG-POP, fixed mobile convergence, access, aggregation, broadband network.

1. Introduction

In the next decade, an exponential growth of data traffic in fixed and mobile networks is expected. The major drivers for these developments are:

- Increasing number of internet-based services, such as community services and various kinds of interactive information and entertainment services - including bandwidth-hungry services such as High Definition or 3D video services (streaming, conferencing, etc.);

- Rapidly growing variety of devices, in particular mobile or portable devices such as smart phones, tablets or laptops;
- Intensified usage of any kind of online services, in particular by younger generations, independently of user's location with an "always on" model.

Today, customers can access services via fixed line networks or via mobile networks. Besides cable networks, fixed broadband networks in Europe are currently dominated by different flavours of ADSL technologies which provide up to 16 Mbit/s. FTTCurb with VDSL is state of the art with access speeds up to 50 Mbit/s. Fibre to the home networks (FTTH) are the next step and first deployments have been started. These networks enable data rate capacities of several hundred Mbit/s. In the mobile area, 2G and 3G networks are widely available and in some countries the deployment of LTE technology with data rates up to 100Mbit/s has been started.

Up to now, fixed and mobile broadband networks have been designed and evolved independently of each other, using different technologies and protocols, even with partly contradicting trends (e.g. centralization of fixed networks, decentralization of mobile networks). Currently, there is a complete functional separation of fixed line access/aggregation networks and mobile networks. Today Fixed Mobile Convergence (FMC) is thus mainly based on the service level with introduction of all IP services and IMS (IP Multimedia Subsystem), and operators have started to build a converged service control layer. In contrast, this paper focuses on the convergence of fixed and mobile broadband networks themselves. FMC networks will allow telecom operators to offer to their subscribers services that use wireline and wireless/cellular networks in a seamless way, unifying these two networks in a single network for all kinds of services.

Development of FMC network architectures is necessary, as the exponential growth of data traffic in fixed and mobile networks triggers significant network evolutions and deployment of new access technologies. For example, according to the FTTH Council Europe, 17 million households in the European Union will be connected to FTTH/B at the end of 2016 [1] and IDATE estimates that near 230 million FTTH/B subscribers will be connected worldwide at the end of 2016 whereas the number of LTE subscribers will exceed 900 million by the same time with 150 million only in Europe [2]; furthermore Cisco estimates that the number of devices connected to IP networks will grow from one networked device per capita in 2011 to three in 2016 [3]. In order to provide connectivity services to this number of subscribers with increasing traffic demands, telecom operators thus need to significantly invest in new generations of fixed and mobile network equipment, where an FMC approach can be essential to upgrade and operate a profitable network.

2. Motivations

New FMC network designs will need to progress to achieve a higher convergence and enable operators to offer the best service delivery. More specifically, the main challenges that telecom operators will have to face are the following:

1. Save costs: the overriding challenge associated with any type of network or traffic evolution is to save cost both in the network for operators and for end users, while maintaining adequate quality of service and experience;
2. Deal with increasing traffic and changing applications: traffic volume increase and end user applications are key issues to be understood for network dimensioning;
3. Adapt network structure: fixed line access network evolution may warrant access node consolidation through the use of longer reach and high capacity optics, reducing the

number of fixed access nodes. At the same time, the density of radio access networks will increase through the use of smaller cells, raising the number of radio access network elements whereas the number of mobile core nodes could also increase to allow a better distribution of key mobile networking functionalities;

4. Determine where to place the intelligence in the network: for example to support features such as handover mechanisms for nomadic use of cells within the network; handover between technology domains such as LTE, 3G and WiFi; and other more network support oriented features such as OAM (Operation, Administration and Maintenance), synchronization distribution or multicast support;
5. Enable multi-operator/multi-vendor environment: a converged network need to be open and support multiple operators as well as multi-vendor interoperability;
6. Allow seamless performance monitoring and management in shared networks: sharing of network resources requires common approaches to performance monitoring and performance management as well as defined network to network interfaces;
7. Reduce energy consumption: the reduction of energy consumption is a requirement to meet the increase in user traffic within the network.

The proposed method to meet these targets is a joint optimization of fixed and mobile networks through a new access and aggregation network architecture organized around the concept of Next Generation Point of Presence (NG-POP).

3. Approaches to convergence of fixed and mobile broadband networks

"Convergence" is a trendy word, notably because it is seen as synonym for cost decrease and also because it corresponds to the behaviour of end users, who care for the service whatever the technology used (3GPP, WiFi, DSL, fibre…). Beyond the trend, convergence of fixed and mobile networks is a desirable though very complex target for network operators, because convergence supposes trade-offs so as to really benefit from moving different functions or pieces of equipment closer to each other. When several network domains taken separately are optimised on their own scope, it does not imply that the overall situation is better. It is certainly worth accepting only partial improvement of some domains, if this leads to a much better design for the overall scope. This is precisely our target: jointly designing and optimising the fixed and mobile networks as a whole, even if this leads to only partial improvements for the fixed network and the mobile network taken separately.

To achieve this joint design and optimization of fixed and mobile networks, we propose, as mentioned before, a new access / aggregation network architecture organized around the concept of Next Generation Point of Presence (NG-POP) (Figure 1). By NG-POP we designate the disruptive evolution of the first aggregation node, also called Central Office (CO), Local Exchange or Local POP by opposition to more centralized POPs. This first aggregation node plays a key role in telco networks because it is the mediation between downstream segments which are connecting customers (access networks) and upstream segments characterized by converged flows (core networks). Hence this aggregation level has to deal with several constraints: a wide variety of services and technologies, scalability issue, regulation duties, operational constraints, to mention a few.

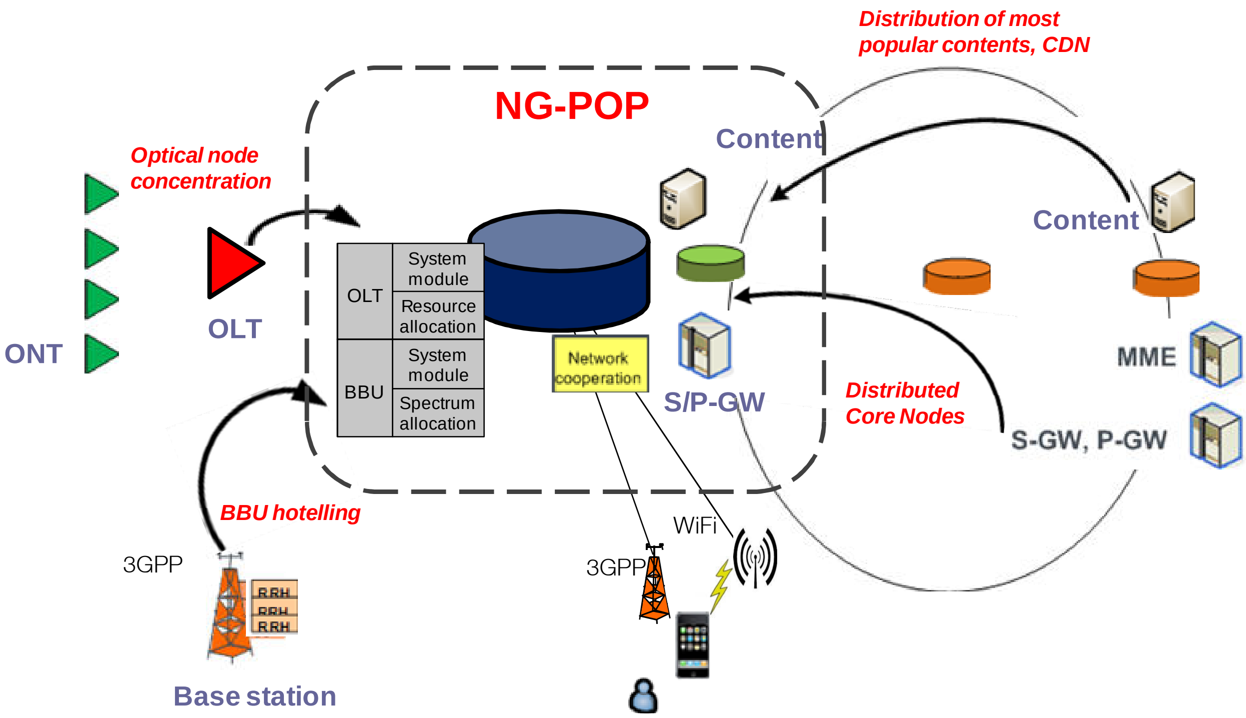

Figure 1: Next Generation Point of Presence (NG-POP) concept

The NG-POPs will be less distributed in the network than the traditional COs, thanks to optical node concentration: Local Exchanges, the local POPs of the copper network, are expected to consolidate to achieve a smaller number of Optical Access Nodes located further up in the network, thanks to the longer reach and higher capacity of FTTx networks compared with xDSL networks. As NG-POPs will be higher in the network than traditional COs, they will be able to host advanced functions of the mobile network such as Serving Gateways (S-GW) or Packet data network Gateways (P-GW). More generally, through this NG-POP concept, we aim at finding a better distribution of all essential functions, equipment and infrastructures of convergent networks. This will drastically reduce ICT infrastructure costs and energy consumption, whereas guaranteeing an optimal and seamless quality of experience for the end user. The overall NG-POP concept is illustrated in Figure 1. The arrows of the drawing indicate either shifts of some network functions to the NG-POP (e.g. content distribution, S/P-GWs), or even structural changes such as optical node concentration or Base Band Unit (BBU) hostelling. The ultimate NG-POP-based architectures will thus combine basically two important aspects of fixed / mobile network convergence:

- the convergence of fixed and mobile network functions, which we call functional convergence. The goal here is to better distribute the various functions of fixed and mobile networks by distinguishing those that should be more "centralised" from those that should be more "distributed";
- the convergence of fixed and mobile infrastructures and equipment, which we call structural convergence. The goal here is to share as much as possible the infrastructures (e.g. cables and civil engineering, cabinets, sites, buildings) and equipment of the fixed and mobile networks by envisaging, where possible and relevant, infrastructures and equipment that are shared between these two types of network.

3.1 Functional convergence

The convergence of fixed and mobile network functions will consist in implementing uniquely key functionalities of fixed and mobile networks, while ensuring openness of network interfaces, collaborations between various access technologies, a unified control plane, and in general a better distribution/localization of essential network functionalities. It will primarily impact the control plane of future networks through unified control mechanisms of fixed and mobile networks, but will also impact their data plane through streamlining of protocol stack and the objective of a better distribution of data flows in the converged network. Functional convergence will improve Quality of Service (QoS), Quality of Experience (QoE) and flexibility for the end user (e.g. coverage, accessibility, latency and usability). It will also improve the service attractiveness and the openness of infrastructures, thus fostering collaboration between service providers and network operators. As an example, functional convergence would allow a WiFi community service provider to implement fast handover for its customers between its WiFi platform and the 3GPP network of another operator, thanks to unified control of heterogeneous networks and technologies as well as homogenization at functional level of authentication and subscriber management.

As the wireless segment of FMC networks can be composed of access nodes using different technologies (WiFi, 3G or LTE/LTE-A) and different cell sizes (macrocells, microcells, picocells, femtocells), functional convergence will be needed to provide interconnection of all the components of these heterogeneous networks and technologies. Through a better localization and integration of functionalities, it should allow efficient network-level load balancing schemes by means of dynamic routing. Energy aspects have to be also taken into account in such kind of meshed base stations deployments to enable network sleeping tools when possible. Moreover, effective traffic offloading strategies by means of IP flow mobility in multi-access environment should be implemented to solve network capacity problems and to avoid congestion in the network. As an example, a FMC network would enable a better distribution and localization of EPC (Evolved Packet Core) [4] advanced functions such as P-GW to decrease the load of the mobile core network, as depicted on Figure 2.

From a business perspective, functional convergence is getting more familiar to the Telco market and it is one of the most important targets. Large Telco operators which combine fixed and mobile networks are seeking functional convergence, because it will enable differentiated products and services to offer to the users, and they will then be able to provide their customers wider QoS and QoE, paying only one subscription. Mobile Virtual Network Operators are also interested by functional convergence so as to cut costs generated by traffic data paid to its wholesalers. For all these reasons, functional convergence is strongly expected in the incoming business models inside the Telco world.

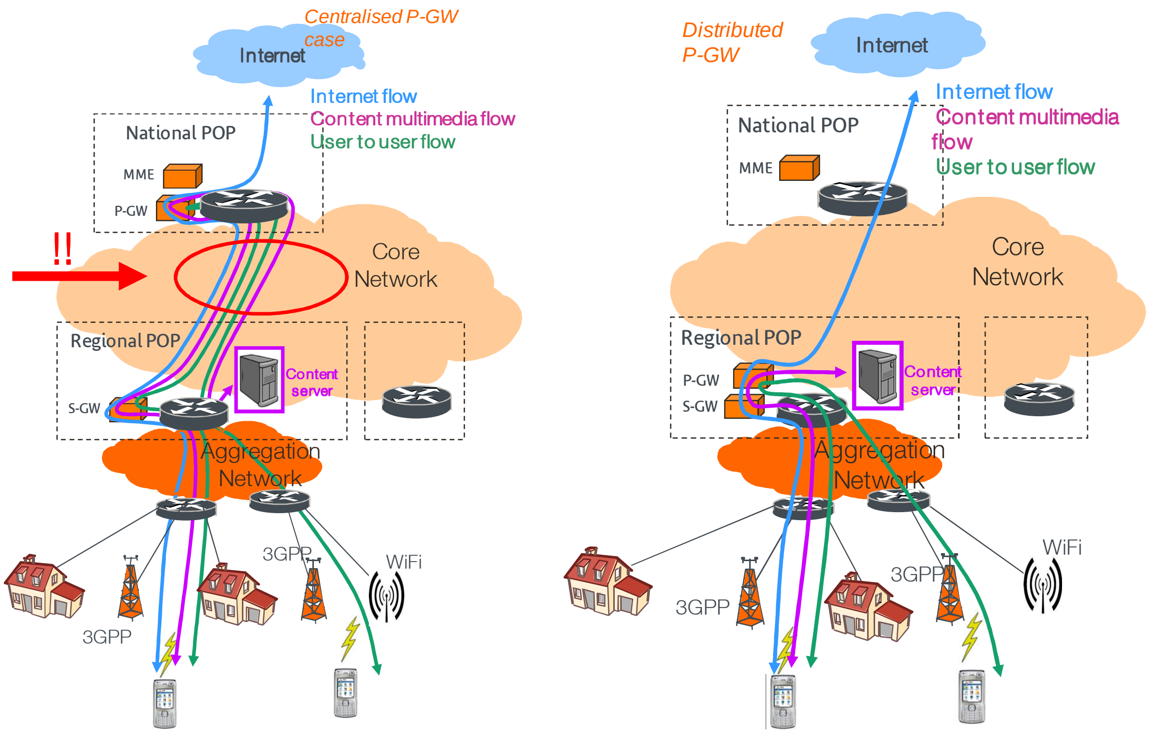

Figure 2: Example of functional convergence: (a) centralized P-GWs, (b) distribution of P-GW functionalities at regional level through functional convergence

3.2 Structural convergence

Structural convergence is defined as the mutualization of fixed and mobile access / aggregation network infrastructures and hardware (e.g. cable plants, cabinets, sites, equipment, buildings), as depicted schematically on Figure 3. This mutualization requires a deep understanding of both worlds and common network design targeting an ultimate integration of fixed and mobile networks.

FMC enables new mobile backhaul architectures that allow moving the mobile-traffic processing equipment, which takes place in the so called Base Band Unit (BBU), in a separated and possibly distant location at a central office that can be far from the antenna location, which is then reduced to a Remote Radio Head (RRH). BBU hostelling is only possible if fiber connects the base station (eNodeB) with the central office. The radio signal is then digitally transported over fiber (Digital Radio over Fiber, D-RoF) on the so-called fronthaul link. This becomes now possible thanks to the deployments of FTTH and LTE, and opens the way to the so-called Cloud RAN (Radio Access Networks) [5]. Structural convergence will further improve the use of the most costly part of fixed and mobile networks, and drastically decrease cost and energy consumption, thus improving also the return on investment of access and aggregation infrastructures: it will also allow central office consolidation of fixed networks to be performed in strong synergy with the development of mobile access infrastructures. FMC can thus target convergence of traditional PON (Passive Optical Network) access and dedicated wavelengths for mobile traffic fronthauling on a single fiber infrastructure, or even on a single equipment, ensuring also openness and flexibility for network operators and service providers, as illustrated on Figure 3.

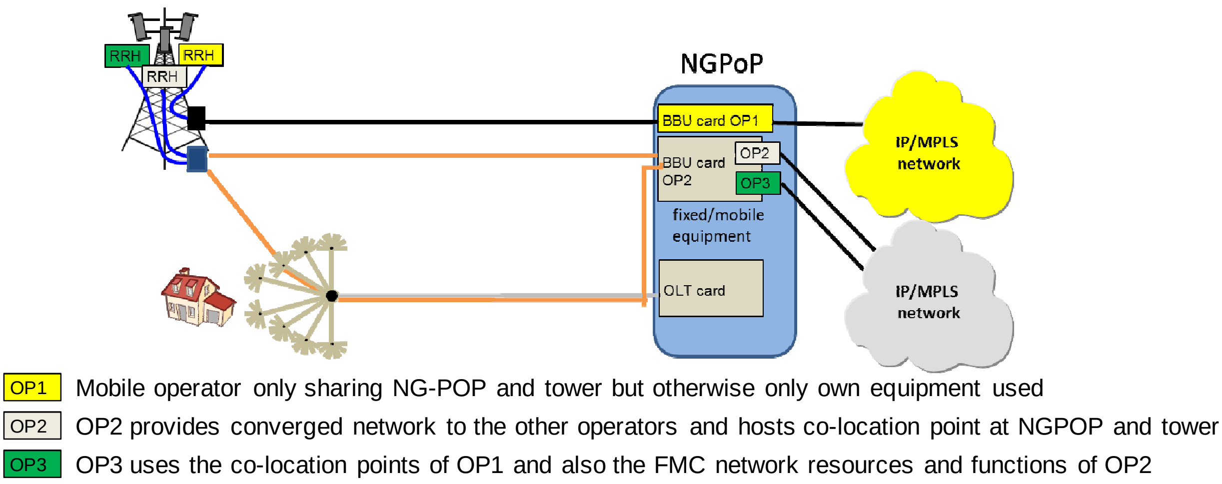

Figure 3: Convergence of fixed / mobile equipment and infrastructures towards NG-POP

4. Some enablers for functional and structural convergence

Functional convergence will benefit the customer by making the service independent of the access technology and the device, not through an additional service control layer but by using natively convergent technologies and protocols in the network domain. Functional convergence should also give the customer the best access to the network for a given service and in a transparent manner. Achieving functional convergence thus requires a thorough analysis of mapping between functions, equipment and infrastructures, so as to derive a better distribution of functions among the various pieces of equipment in fixed and mobile networks. Such improved mapping of functions has to rely on technological and architectural enablers such as:

- Unified control mechanisms of fixed and mobile networks;
- Advanced sleep modes involving both fixed and mobile equipment;
- Streamlining of protocol stack around IP and Ethernet technologies;
- Generalized 3D handover mechanisms combining horizontal handover (between cells), vertical handover (between access technologies, e.g. 3G, LTE, WiFi) and transversal handover (between operators);
- Advanced network-level offloading schemes involving both fixed and mobile networks;
- Openness of network interfaces;
- Harmonization of authentication and subscriber management.

Structural convergence is probably more complex to implement, as it involves sharing the infrastructures and equipment of fixed and mobile networks. In addition to the technical obstacles to overcome, it also requires evolutions in the business relations between mobile and fixed operators, and therefore developments in the regulatory framework. The path towards structural convergence will rely in particular on some technological and architectural enablers such as:

- Optical node concentration allowed by optical access technologies;
- Heterogeneous radio access networks combining small cells and macro cells;
- BBU hostelling with resource pooling, also called Cloud Radio Access Networks (Cloud-RAN);
- Mobile fronthaul technologies based on Digital Radio over Fibre (D-RoF) for the connection between BBU hotels and RRH at antenna locations;
- Multi-wavelength and multi-service optical access technologies.

Note that many different enablers could be relevant for the overall target of functional and structural convergence, and the lists given above are just preliminary. As an example of key enablers for structural convergence, BBU hostelling and D-RoF-based mobile fronthauling are illustrated on Figure 4 below and further described in [6]. These techniques will allow a centralized set of BBUs with resource pooling to be shared among a large number of RRHs located at different antenna sites. They are paving the way to the Cloud RAN concept and could also eventually enable the sharing of fibre access infrastructures or even shared fixed and mobile equipment at the NG-POP.

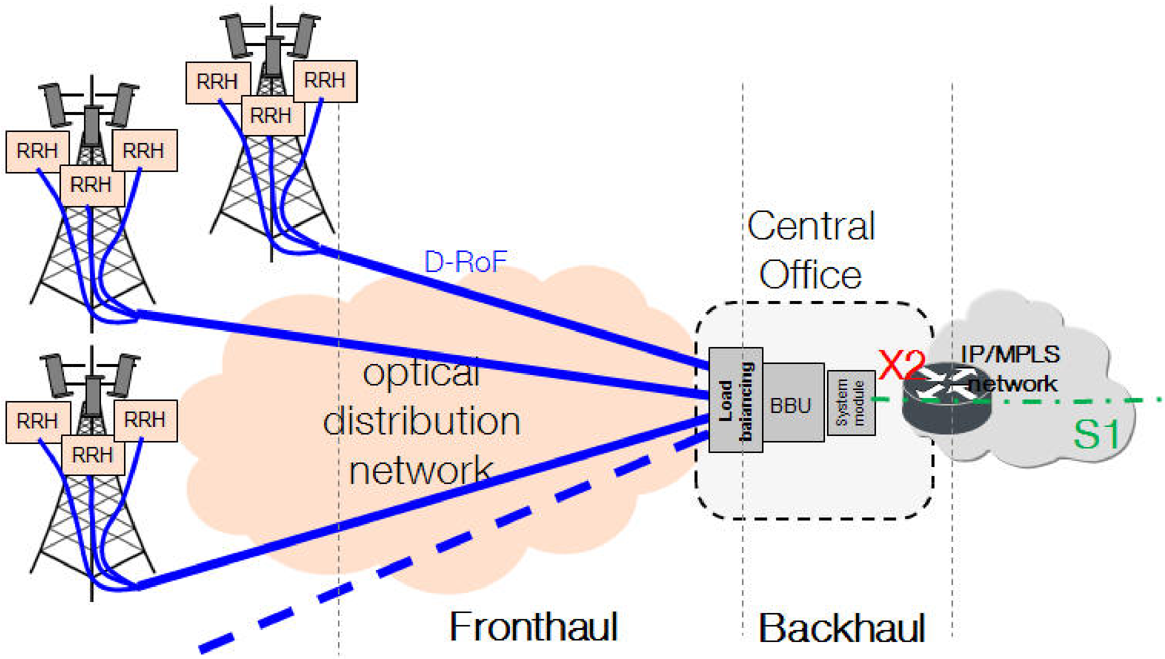

Figure 4: Some key enablers of structural convergence: BBU hostelling with resource pooling (C-RAN) and D-RoF-based mobile fronthauling.

5. Conclusions

Tremendous changes in fixed and mobile networks are required to enable the Gigabit society, leading to enormous investments in network infrastructures. In the past, fixed and mobile networks have been designed and evolved independently. Today, standardization work and bodies dealing with fixed and mobile networks are still separate, and Fixed Mobile Convergence (FMC) is mainly implemented at service level with introduction of all IP services and IMS, allowing a converged service control layer. In contrast, the Next Generation Point of Presence concept will allow the convergence of fixed and mobile networks themselves, by combining, on the one hand, an optimal and seamless quality of experience for the end user and, on the other hand, streamlining and sharing of fixed and mobile network infrastructures and equipment, which will ensure increased performance, reduced cost and reduced energy consumption. This will lead to a better distribution of all essential functions, equipment and infrastructures of convergent networks.

Acknowledgements

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