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# Next Generation Network (NGN) Challenges on Access Networks

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**Abstract.** Telecom infrastructures are facing unprecedented challenges, with increasing demands on network capacity. With the increased demand for high-speed data services and the constant evolution of broadband access technologies, operators are faced with a number of issues when choosing the technology and building the network. Today, network operators are facing the challenge of how to expand the existing access network infrastructure into networks capable of satisfying the user's requirements. Thus, in this context, providers need to identify the technological solution that enables them to profitably serve customers and support future needs. However, the identification of the "best" solution is a difficult task.

**Keywords:** Access Networks; NGNs; Broadband Access Networks; Architecture; Techno-economic Model.

## 1 Introduction

The development of the information society is dependent on a universal broadband access network capable of reaching everybody. Broadband deployment is increasingly considered a key driver of economic development, productivity, job growth, and social advancement.

The rapid development of new-generation applications, such as high-definition television (HDTV), peer-to-peer (P2P) applications, video on demand, interactive games, e-learning, use of multiple personal computers (PCs) at home, and higher throughput requirements and communication demands make upgrading the access infrastructure a necessity. Ubiquitous broadband access requires a minimum bit rate that is sufficient to allow all citizens to benefit from these services. As a result, to run voice, data, video, and advanced Internet applications, residential users may soon need connections of more than 30 Mbps [1].

The needs of telecommunication networks with higher capacity are becoming a reality all over the world. However, the limitation of local access networks is the major bottleneck to providing broadband access [2]. It is recognized that there is a disparity between broadband availability in urban and rural areas. The pre-existing telecommunications infrastructure is generally poor and unevenly distributed in favor of urban centers [3]. In most rural areas, low population density and high deployment costs discourage private investments, creating a negative feedback of limited capacity, high prices, and low service demand. Building telecommunications networks in rural areas is costly. Further, in many cases, there is not a good commercial business case for rural deployments. Whereas established and competitive service providers already offer solutions for urban and suburban areas, there is little or no commitment to connect areas that include smaller towns and rural villages [4]. The deployment of access network broadband services on low-competition areas is characterized by low subscriber densities, longer loop lengths, lower duct availability, and consequently higher infrastructure cost compared to high-competition areas.

Service providers, network operators, and Internet access providers are faced with the challenge of providing higher capacity access to the end user and offering wider services. Consequently, new Internet infrastructure and technologies that are capable of providing high-speed and high-quality services are needed to accommodate multimedia applications with diverse quality of service (QoS) requirements. Until a few years ago, Internet access for residential users was almost exclusively provided via public switched telephone networks (PSTN) over the twisted copper pair. The new quadruple play services (i.e., voice, video, data, and mobility), which require high-speed broadband access, created new challenges for the modern broadband wireless/wired access networks [5]. The new services led to both the development of several different last-mile solutions to make the access network capable of supporting the requirements and a stronger integration of optical and wireless access networks.

## 2 Next-generation networks (NGNs)

The move toward next-generation networks (NGNs) has significant implications for the technical architecture and design of access network infrastructure, as well as the value chains and business models of electronic communications service provision [6]. This migration has begun to transform the telecommunication sector from distinct single-service markets into converging markets. NGNs allow consumers to choose between different access network technologies to access their service environment Sometimes, the NGN architecture will be limited to the developments of network architectures in the access network (local loop), referred to as the next-generation access network (NGAN).

NGANs are being deployed across the world with technologies such as fiber, copper-utilizing xDSL technologies, coaxial cable, powerline communications (PLC), wireless solutions, or hybrid deployment of these technologies. Wireless networks typically use a range of different technologies, including high-speed packet access (HSPA), HSPA+, worldwide interoperability for microwave access (WiMAX), and long-term evolution (LTE). Further, wireline networks are increasingly employing some form of fiber, such as fiber-to-the-home (FTTH) and fiber-to-the-curb/cabinet (FTTC). NGN access in a fixed network was initially a broadband access-based on the copper loops. However, many countries are developing projects to provide higher speed using fiber-based technology, such as very high-speed digital subscriber line (VDSL) or fiber-to-the-building/home (FTTB/H). For cable networks, it is of the case that the only voice service is Internet protocol (IP)-based, whereas for mobile networks, the migration to IP voice is more complex [7].

As broadband access networks require considerable investments, before the investment decision is made it is important to compare the different technologies. The investment costs depend on the technology to be used, as well as on the demography of the service area and subscriber and throughput demand forecasts. The choice of a specific technology for NGAN can differ among countries, geographic areas, and operators. In recent years, there has been an increase in the number, coverage, and market share of "alternative" networks or operators, such as resellers, unbundling operators, cable network operators, operators using frequencies for WLL/WiMAX, or operators deploying optical fiber in the local loop [8]. This has resulted in differences in competitive conditions among geographic areas, which has led to increasing arguments (especially from incumbent operators) that geographical aspects should be recognized in market/competition analyses and regulatory decisions. There are several factors that might be responsible for this discrepancy [9]: state and age of the existing network infrastructure; length of the local loop; population density and structure of the housing market; distribution of the number of users and street cabinets for local exchange; level of intermodal competition in the market; willingness to pay for broadband services; and existence of ad hoc national government plans for broadband development.

## 3 NGN regulation

Broadband in the OECD is still dominated by DSL, but there is an obvious trend emerging to upgrade last-mile access networks to support the new services requirements [2]. To address these network requirements, many carriers in emerging markets must move from legacy platforms toward next-generation solutions with a combination of wireless and wireline technologies, such as WiMAX, IP-Ethernet, and new forms of DSL technology and fiber.

In the past, the residential wireline telephony access network was characterized by monopolistic bottlenecks. With the advent of NGNs, economists began to challenge this view, as convergence sparked the hope for infrastructure competition in the local loop [10]. It is recognized that regulation can inhibit investment on the part of incumbents [7]. In addition, most European regulators argue that a simple withdrawal of regulation is not the most appropriate solution, as it inhibits investments on the part of competitive entrants, which quantitatively are often just as significant as those made by incumbents. The change in regulation can also restrict consumer choice and inhibit competition. For example, when the incumbent operator simultaneously has a monopoly in the access network and activity in the retail market, price regulation is an important issue. Without it, the incumbent can use his or her power in the market to stop or impede the entrance of new operators in the retail market. However, if a regulatory authority rigidly controls the access price, it might reduce the incentive for the incumbent to make investments in the network. The regulatory authority should not increase uncertainties and must provide clear incentives and guidance for the investment required for deploying NGANs [11]. [12] argues that in the case of high Internet penetrations the competition policy could lead to maximum welfare with market price equal to marginal cost. However, for low-penetration markets the social welfare maximum is not achieved without subsidies to operators or customers.

Regulators should ensure that local loop unbundling (LLU) and sub-loop unbundling, bitstream, the transition to NGA, access to ducts and dark fiber, inside (building) wiring, collocation, and backhaul are defined in a transparent, efficient, and technologically neutral manner [8] (see Figure 1.1).

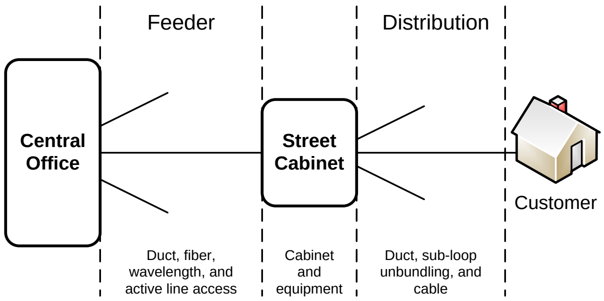


**Fig. 1.** Competition levels and locations

Although the cost of bandwidth in the active layer has reduced significantly (and continually) in recent years, the cost of civil works (such as digging and trenching) represents a major barrier for operators to deploy NGA infrastructure. Studies and deployments show that civil infrastructure is the largest proportion of the costs of fixed access deployment (up to 80%). Duct is a critical part of the next-generation access networks and its sharing would reduce or eliminate this capital cost and barrier to entry. However, duct access may need to be complemented by extra civil work to increase infrastructure capacity, the use of dark fiber (where available), or the use of conduits of alternative infrastructure providers. This also highlights that different and/or complementary regulatory tools may be required in different parts of the network [13].

### 3.1 Segmented regulation

Segmented regulation has been identified as a regulatory framework that can potentially provide both incentives and controls for the deployment of NGNs [14]. OECD regulatory authorities have traditionally adopted a national geographic area focus when framing the geographic scope of telecommunications markets. However, with the increase in the number, coverage, and market share of “alternative” networks (or operators), different competitive conditions between geographic areas have occurred [8]. Based on results of market analyses, economists have suggested that differential regulation should be considered between geographic areas in which facility-based competition has developed and those in which it has not. Competition can be promoted at many levels and locations through contestability and innovation [15].

After the decision of several countries to implement geographic regulations, there has been increased interest in these questions. In the literature on the regulation of future access networks, the discussion on regulation and investment has taken center stage, given the pending infrastructure investments in many countries [16]. The geographically segmented regulation should aim not only at facilitating deregulation, but also at strengthening regulation in those regions where competition is viewed as ineffective. Then, segmented regulation can assist regulators in ensuring that the regulatory framework they apply is appropriately tailored to the competition situation [8]. Local decisions of a national regulator might lead to inefficiencies deriving from discrepancies between local and global cost-benefit evolutions. Segmented regulation may be helpful because it allows different solutions for the deployment of NGNs in urban and rural areas to evolve at different paces [14].

Figure 2 illustrates a scenario of the differences in competitive circumstances that may warrant geographically segmented regulation. There are geographical differences in conditions of competition, including the number of suppliers and market shares [17]. The deregulation of high-density areas might help to avoid the unnecessary protection of access-based competitors and strengthen incentives to invest in infrastructure. Further, maintaining regulation of low-density areas might promote competition with national offers because alternative operators are enabled to extend geographical coverage.

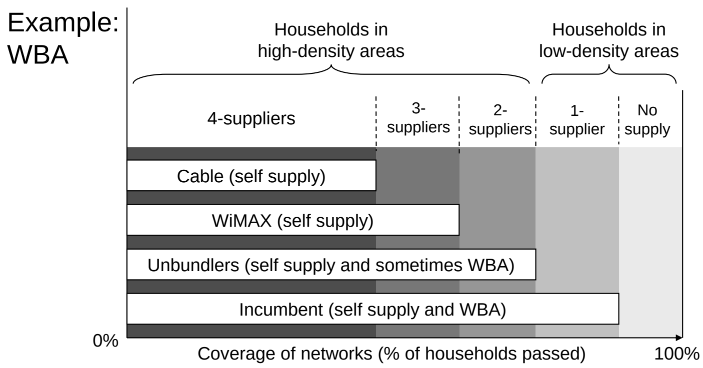


**Fig. 2.** Geographically segmented regulation [17]

### 3.2 Geographic differentiation

The analyses of several regulatory inquiries [15, 16, 18] on the national level show that access providers (usually the incumbent operators and former monopoly operators) are generally in favor of geographic differentiation. For example, a Spanish operator (Telefonica) argues that the geographical segmentation model can push investments and gradual deregulation, which permits to users enjoy the best possible scenario. The operator also defends the notion that differentiated regulation would prevent the increase of the digital divide. In Australia, Telstra argued that geographically segmented regulation will promote competition, giving service providers the appropriate incentives to use and extend alternative infrastructure, and will also promote competition by encouraging other carriers to offer wholesale local services.

For consumers, the impact of geographic differentiation is also important, given the often-repeated statements by politicians and regulators that policy and regulation are designed to be in the long-term interest of consumers [8]. For business users, the breakup of market analysis to the sub-national level is a source of significant alarm, especially with regard to wholesale broadband access services. For multinational business users, inconsistency of national regulations and the consequent inability to obtain seamless international network services without service quality, costs, and administrative disadvantages is already a serious problem.

## 4 NGNs challenges

To deliver the new services to end customers, a large variety of access network technologies and architectures are available for operators to include both narrowband and broadband technologies with and without wires. The selection of the best solution requires an understanding of the technical possibilities and limitations of the different alternatives, as well as an understanding of the costs resulting from building and operating the networks. Therefore, the use of cost models for measuring the costs of providing telecommunications services has become commonplace [9].

The advent of NGNs creates new challenges for network operators, service providers and regulators. When network operators want to make investment decisions, they must consider the present utilization and emerging innovative uses of the Internet services (such as P2P applications, video downloads, next generations of videoconferencing, interactive video and television, collaborative gaming, and network-based backups) that lead users to adopt bandwidth intensive behaviors, which imposes additional costs on network operators.

Business modeling is broadly used by operators and regulatory authorities. Operators, existent or new entrants, use models for strategic planning, project analysis and selection, etc. The existent operators (e.g. incumbents) can use business modeling to study tariffs, analyze the cost of services, analyze competition, analyze of alternative technology strategies, business case evaluation, definition of the rollout strategy, appraising alternative investment opportunities and determining economically appropriate cost floors. To new entrants, these models give important information in the deployment of network infrastructures. For example, a cost model, with a series of calculations based on a certain costing methodology, provides the costs that a firm incurs to provide different services using different technologies.

One of the most important roles of any regulatory authority (NRA) is to impose cost oriented pricing to operators with significant market power - regulators require good cost models for the purpose of establishing the prices of regulated telecommunications services. However, without a detailed understanding of the costs of delivering services, regulators cannot impose appropriate rates for either retail or wholesale services [19]. In addition, regulators need the information produced in cost models to define strategies and policies [20].

Cost models deliver several benefits to operators and regulatory bodies. However, [19] contended that a new, accurate, and more flexible cost model for the new multi-service NGN networks are needed. More than ever, not being able to understand the cost drivers and model the costs of an NGN network leads to significant risk for both regulators and network operators. The current models are not adequate when faced with the challenge of delivering a range of new and complex services over a radically different network infrastructure.

### 4.1 Methodologies for telecommunications modeling and simulation

Several cost methodologies can be adopted by network operators, service providers, and regulators. For example, [20, 21] identified several alternatives for performing telecommunications modeling and simulation: (a) economic models that are used for analyzing dynamics within the telecommunications market; (b) engineering cost models that are used to sum up the capital expenditure (CAPEX) for each network element (e.g., the long-run incremental cost model (LRIC)); (c) techno-economic models that are designed to evaluate deployment scenarios and to support the selection of optimal technology and deployment time; and (d) game-theoretic models that can be used to capture non-cooperative interactions between operators, such as exploring entry strategies and how market outcomes are affected by competition or regulation.

In dynamic and competitive markets, including telecommunications, firms base their decisions on the relationship between prices and forward-looking (or long-run) economic costs - costs that would be incurred if a new service were provided. Forward-looking economic cost computer models might enable regulatory authorities to estimate the forward-looking cost of network facilities and services. In the United States, the Federal Communications Commission (FCC) uses these methodologies as a basis for determining universal service support levels, cost-based access charges, and pricing for interconnection and unbundled network elements [9].

The LRIC methodology is often used by NRAs to determine the cost-orientation of regulated operators and set pricing levels for wholesale services. However, it is also a valuable tool for determining the cost of a single service, whereas a network typically provides multiple services. The European regulatory framework recommends the use of the LRIC standard for controlling dominant operator interconnection rates, which should be cost-oriented [22]. There are two main sub-methodologies for the LRIC. The total service long-run incremental cost (TSLRIC) type considers each service as a cost increment factor. This framework was first developed in the late 1970s and early 1980s to deal with issues surrounding the application of common cost concepts in firms producing more than one product or service [23]. The cost estimate developed using a TSLRIC framework shows the cost a firm would avoid in the long run if it no longer provided the service, holding all of its other production activity constant.

The total element long-run incremental cost (TELRIC) type is based on network elements. It allows the economies of scale achieved by different network elements to be distributed among services in relation to the intensity of use that each service makes of the element. Also assures that the cost allocated to a service is related to its use to the network with respect to the rest of services [22]. If market (or regulated) prices in a competitive framework exceed long-run economic costs, new providers will be attracted to the market; this entrance would be efficient. On the other hand, if prices fall short of economic costs, no new competitor will have an incentive to enter the market. In addition, some incumbent firms may decide to leave.

The techno-economic model enables network managers to evaluate the benefits of innovative technological developments in the context of global economics of the business of telecommunication services. Using a given set of input parameters, this methodology calculates several results, such as cost and revenue, and performs risk and sensitivity analyses that support the management of network operators to elaborate adequate strategic guidelines for the medium-term planning of the network and service evolutions. It is normally implemented in spreadsheets, such as Excel. Moreover, it is useful for comparing the CAPEX of broadband access technologies.

An engineering-economic model starts with an engineering model of the underlying network (physical local exchange network) followed by an economic model that calculates the costs of the projected network. The design of the engineering model usually follows the procedure used in the planning of a realistic network, which involves the choice of system architecture, equipment planning, service and capacity prediction, and infrastructure planning.

Once the costing methodology is chosen, the model can be designed under two main network modeling approaches (see next table): top-down (based on financial accounting) and bottom-up (based on traffic demand). However, it is common to see models that result from the combination of both approaches. Hybrid models combine the advantages of bottom-up and top-down models and, consequently, provide a high-quality standard [24].

**Table 1.** Top-down and bottom-up modeling approaches main characteristics

| Top-down approach | Bottom-up approach |
| --- | --- |
| Uses the existing network as a starting point from which an attempt is made to find the most accurate mapping of cost centers, costed units of output, and activity-based allocations [24]. The top-down model uses data from the operator accounts to calculate the costs of particular services.<br>The bottom-up approach involves the development of an engineering-economic model to calculate the costs of particular network elements and in turn particular services. | The bottom-up modeling approach represents an efficient cost structure, objective and based on available information.<br>Bottom up cost models are an attempt to determine analytically which network components are necessary to efficiently satisfy a given demand. So, using the traffic demands, it identifies the required network elements to provide the different services.<br>Based on engineering and economic principles, each service is related to the network elements quantities required for producing it and the corresponding cost. |

However, the described models for telecommunication analysis do not consider the influence of factors, such as competition, policy, and regulation. Therefore, in this context, game-theoretic models have successfully been used to analyze market dynamics in telecommunications (infrastructure competition). They can also be employed to analyze competition between firms to find a dominant strategy for each player or an equilibrium with which all players are content [21]. Game-theory models are concerned with the analysis of optimal decision making in competitive situations, although it is important to note that game theory does not predict the outcome of competition [21, 25]. Instead, it is a set of mathematical expressions used as a language for logical behavior. Given presumptions about the conducts of players, game theory maps the available strategies of each player in the game. To determine the likely outcome, game theory uses the concept of Nash equilibrium.

As seen above, the complexity of business modeling requires the use of software tools for manipulation with input and output parameters, modeling relationships, and calculating results. [26] define a business model as a framework for creating economic, social, and/or other forms of value. However, the term "business model" is used for a broad range of informal and formal descriptions to represent core aspects of a business, including purpose, offerings, strategies, infrastructure, organizational structures, trading practices, and operational processes and policies. Because of its simplicity, Microsoft Excel is frequently used as a general-purpose tool for business modeling, but it is not a good option in cases where more complex techno-economic interactions must be modeled.

## 5 Conclusions

As seen in the previous paragraphs, in order to meet the emerging demands for broadband services, adequate telecommunication access network designs are crucial for network operators, service providers, and equipment vendors. With the high number of technical candidates and design options for developing access networks, it is necessary to perform calculations to identify cost-efficient combinations of technologies, functionalities, and network structures. In addition, other issues, such as regulatory and competitive aspects, should be considered.

However, competition in telecommunications is more complex than in many other industries because of the nature of communications networks. A correct construction of a techno-economic model permits the minimization of errors in the network development phase and calculation of results, allowing for an evolutionary development of the network solution. The detailed modeling, including offered services, serving area, equipment, operational cost processes, revenues, and other related techno-economic elements, assures a significant conformity between techno-economic models and real deployment.

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