Internet Access and Mobile Networks in Latin America

Technical Characteristics to Consider in Quality of Service (QoS)

September 2013

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1. INTRODUCTION

It is a fact that internet access service has become increasingly relevant, especially given the positive economic impact of broadband. Studies highlight that for every 10 percentage points of increased broadband penetration in Latin America and the Caribbean, GDP grows by 3.2%[1] and productivity by 2.6%.

There are several ways of accessing internet, through both telephone and cable fixed wireline networks, wireless and mobile devices, with or without utilizing Wi-Fi services. Each type has specific features which are naturally bound by the development, technology evolution and technical features of each type of access.

The benefits brought about by internet are numerous and undeniably valuable. They have enabled sudden and extreme decentralization of information and data, advantages for education, commerce and entertainment which has ultimately affected society's development. The industry expects governments and regulatory bodies to facilitate the necessary regulatory conditions and legal certainty to promote investment, appropriate deployment and timely technology adoption. By developing appropriate regulatory and governmental policies, specifically in the Latin America region, massive access to internet and content will be enhanced even further, thus reducing the digital divide.

The evolution of technologies and mobile networks has enabled a new form of internet access, simply called 'mobile internet'. Its use has become common in various urban centers and has proved to be a useful tool to reach the remote areas where access through other technologies is either unfeasible or difficult on account of the topology.

Despite this fact, certain sectors in different countries have put forth the need to set minimum value guarantees of internet indicators such as speeds or latencies, regardless of their access technology in order to improve users' 'Quality of Experience'. In the case of mobile networks as we shall discuss in this white paper, these regulatory initiatives do not recognize the existence of specific distinguishable network and access elements inherent to mobile access technology that are not inherent in other access technologies. Increased regulation of mobile broadband wireless is unnecessary, as policy makers must acknowledge that mobile wireless technologies encompass many different technical elements.

This white paper seeks to clarify what QoS means and how it relates to network performance and users. The paper then goes on to explain the different elements that make up a mobile internet access network, how these networks are configured and describes features of the elements and interface, mainly relative to the use of radio spectrum and the mobile nature. After defining the different components and limiting the sphere of discussion for 'quality of service', the paper discusses the intrinsic features of mobile technology that make it difficult to ensure minimum guarantees, the degree of control that mobile internet access providers have over them, and finally, the impacts that these impositions might have on internet adoption.

[1] A. Garcia-Zaballos and R. Lopez-Rivas, Governmental control on socio-economic impact of broadband in LAC countries, 2012

2. WHAT DOES QUALITY OF SERVICE (QOS) MEAN?

The ISO 8402 standard defines, clarifies and standardizes the terms referring to quality and defines it as the "*the totality of features and characteristics of a product or service that bears its ability to satisfy stated or implied needs*".

Generally speaking, when we say 'quality', we think about the service from the perspective of users, comprising of an end-to-end view. However, this view includes a collective effect of individual performances, such as the network, the terminal and customer service process performance. Given the above, there are many notions and standards that should be clarified in this ecosystem that are both subjective (user perceptions) and objective parameters.

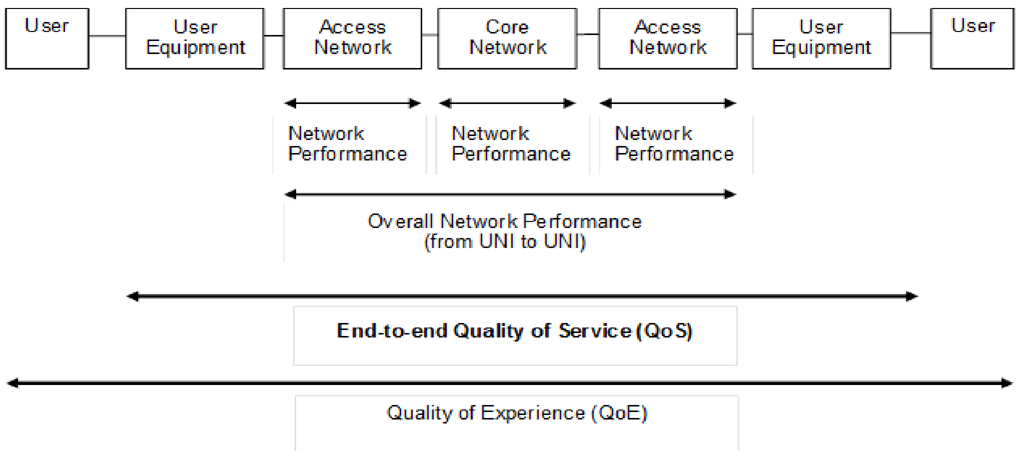

Figure 1. End-to-end Quality Experience.[2]

From the user's perspective, we refer to **Quality of Experience (QoE)**, as a **subjective** dimension of the service. This view varies according to each user as influenced by the environment, the terminal and QoS.

At a different analysis level and through its recommendation G.1000, the ITU explains that there are four different perspectives to analyze 'quality'—all the way from the perspective of the provider to the customer's. This is a comprehensive vision that helps conceptualize the two sides mentioned to QoS.

a) The quality standard expected by the customer when using a given service (their needs)

b) The quality standard that a customer claims to have experienced (perceived)

c) The quality standard that the service provider expects or declares to offer based on their network planning

[2] ITU-TE.800

d) The quality standard truly achieved and attained by the provider.

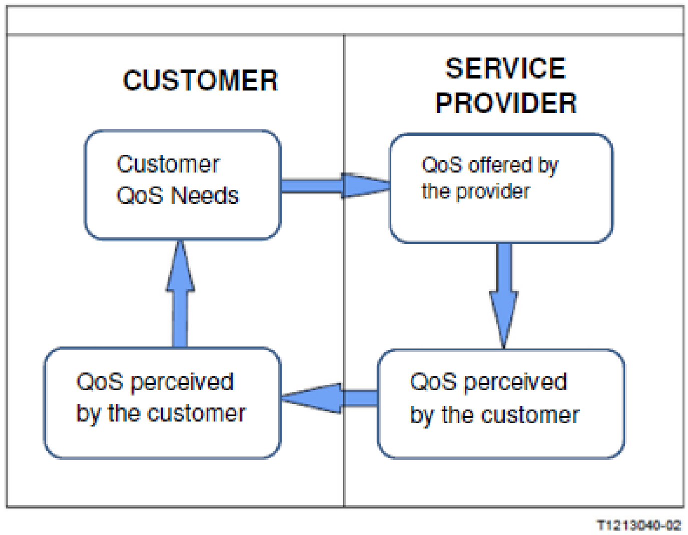

Figure 2. Four Perspectives on Quality as Defined by the ITU.

As we have already mentioned, an internet service provider (ISP) can only control the quality they ***expect*** to offer, which is determined based on design parameters and network features. Conversely, the quality standard achieved or attained is that which is assessed *ex post* after a given period of time and depends on specific elements over which the ISP does not have full control, such as behavioral and climatic aspects. This vision of the ITU includes all aspects impacting the quality offered and attained by the provider while acknowledging the perceptions and needs of the customer. Therefore, QoS includes all technical and non-technical aspects on the provider's side, such as processes, which are beyond the scope of this paper.

Focusing on the provider, the objective dimension of **Quality of Service** (QoS) may be understood and analyzed at different layers: terminal equipment, access network, core network and processes. There is an intrinsic relationship between Quality of Service and quality of network performance—two notions which are sometimes confused. The figure below shows the relationship between the two notions:

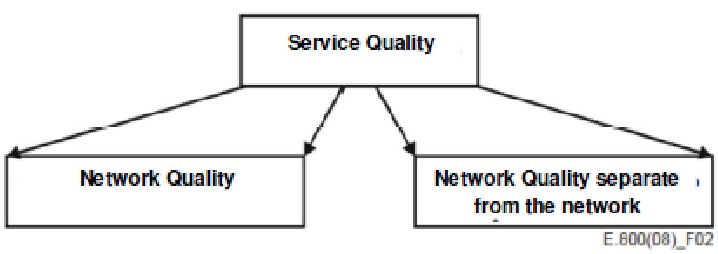

Figure 3. Relationship between Quality of Network Performance and Quality of Service.[3]

[3] E.800 (09/08)

The quality of network performance comprises technical parameters that are measured objectively and describe the performance of part of the network. These include: throughput rates, latency, variable delay, etc. On the other hand, network-independent factors comprise delivery time, processes and repair times among others. The relative weight these have on QoS depends on the nature of the service.

Considering the above, this white paper focuses on the quality of network performance that ISPs can manage (i.e. the quality they expect to offer on their network) which as we shall discuss later, is determined mainly by elements that depend on the access and core networks. The figure below illustrates the conceptual dimension discussed in this paper.

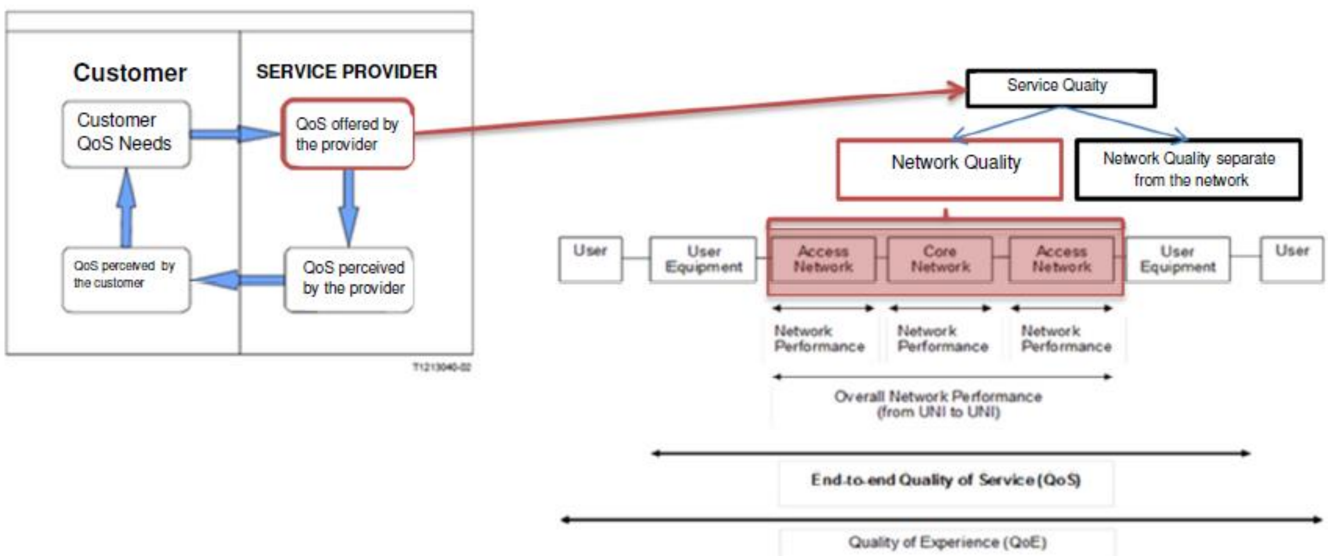

Figure 4. Sphere of Control of the Mobile Internet ISP.

This is essential for purposes of breaking down the discussion into perceived quality and quality actually delivered to customers. This brings into the discussion the different technical elements which determine network performance quality based on each network's technical features.

In terms of the perspective of QoS as offered by the ISP, this paper will provide technical elements to explain the challenges of setting parameters with objective standards, especially with regard to IP networks offering mobile access service, in particular to internet.

3. CONCEPTS AND PRINCIPLES OF MOBILE INTERNET ACCESS NETWORKS

Telecommunication networks consist of the information transport infrastructure. [4] To receive telecommunication service, users must use terminal equipment to obtain network access.

Every telecommunication service has unique features relative to backbone networks and terminals. For example, accessing either a fixed or mobile telephone network, the required terminal consists of a telephone device, while the network itself is made up of all the devices used to connect one user's telephone with another user's telephone between which information is exchanged. For mobile telephone service, the terminal consists of portable telephones with radio receiver and transmitter, an access network (base stations and network elements), a backbone network and other media to enable information exchange. The continuous technology evolution has enhanced mobile telephony access networks from providing voice services to data transmission services through an on-going evolution of 3G and 4G families of technologies, enabling the delivery of mobile internet service.

3.1. WHAT IS INTERNET?

Internet is a set of interconnected networks using the Internet Protocol (IP), which allows them to work as a single large virtual network[5] thanks to the use of a single public IP addressing field common to all users.

The GSMA defines internet as "*…a network made up of interconnected IP networks – data packet switching networks – owned by different operators. In the packet-switched networks, information – data, text, video, images or voice – is divided into data clusters of a predetermined size called "packets". These packets may follow different routes from source to destination and may experience different "disruptions" while traveling on the different network segments (for example, delay, packet loss, etc.).*

As a collection of different IP networks, the Internet offers a type of service known as "best effort". Therefore, the access operator cannot set aside resources for the "end-to-end" traffic of data packets in an internet connection."

Accessing the internet has contributed significantly to mobile data traffic. According to figures from Cisco[6], mobile data traffic grew by 70% in 2012 and reached 885 petabytes per month. This figure is 12 times the total internet traffic recorded in 2000. On the other hand, 4G technology connections created 19 times more traffic than an average mobile connection on a different technology. In addition, mobile data traffic is expected to grow 13 times from 2012 to 2017, at an annual compound rate of 66%, to reach 10 exabytes per month.

[4] This definition arises from International Telecommunications Union (ITU) recommendation ITU-T E.800 (09/2008).
[5] ITU-T Recommendation Y.101.
[6] Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update, 2012-2017 http://www.cisco.com/en/US/solutions/collateral/ns341/ns525/ns537/ns705/ns827/white_paper_c11-520862.pdf

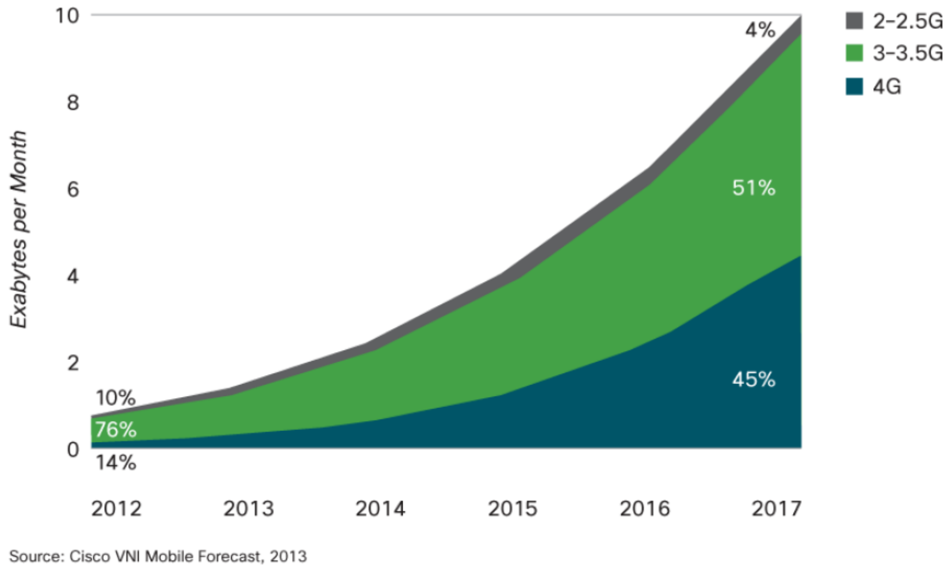

Figure 5. 4G Traffic Will Account for 10% of all Connections and 45% of the Traffic by 2017.

The sharp increase in the number of customers and hours of internet usage, in particular in mobile access services, has escalated the volume of data downloaded by users, which is reflected in significant increases of data traffic routed by the networks.

This unstoppable trend implies a considerable challenge for network operators, who should maintain the QoS of internet access services while they face investments in new network infrastructures, creating serious stresses on the economic sustainability of internet.

3.2 BASIC ELEMENTS OF INTERNET ACCESS NETWORKS ON MOBILE NETWORKS

The internet access service or Internet Connection is the log-on mechanism whereby a terminal (computer, smartphone, etc.) connects to the Internet, enabling access to internet service, email, the viewing of web pages on a browser and access to other services offered by this network.

There are several physical media for internet access, broadly known as access networks. Thus, the Internet may be accessed from a switched-line connection, fixed broadband (by coaxial cable, fiber optics cable or copper wire), Wi-Fi, satellite or mobile internet (equipped with 3G/4G/LTE technology).

Mobile telecommunication networks are those in which information is transmitted using portable user equipment (terminals) which have network access when located in the network's coverage area; this is the case with cellular technology and data (2G, 3G, 4G, LTE) networks. Although they have a few elements in common, mobile access networks grow separately from fixed networks, aimed at meeting the needs of users that require mobility and communication in a given area. To that end, they require the installation of base stations that cover a specific area and number of users. If more users or new areas need to be served, it is necessary to install new base stations to provide coverage or enhance the service provision capacity in areas of higher demand. These base stations make up the so-called "mobile access network", which differ from fixed networks and are the cause for mobile networks having their own conditioning factors in addition to the *best effort* IP network represented by internet.

Mobile networks are planned based on different elements which are intrinsic to a non-static network, such as users' behavioral patterns, since users change their location significantly over time and geographical / time / environmental (climatic) deviations may affect the customers' user experience. Therefore, the performance of mobile internet access networks depends both on network planning (elements controlled by the ISP) and on elements that the mobile network operator cannot control, such as timing concentration of users, climatic factors, obstacles to propagation, etc.. A second determining feature is that they are an access means whose resources are shared among the users connected to the base station both ways in the communication. For example, on loop networks, the use of access is exclusive to each customer.

3.2.1 SPECTRUM AND INFRASTRUCTURE

The main feature of mobile networks is their use of radio electrical waves as transmission support. These waves are characterized by their frequency and bandwidth. Radio electrical waves transmitted from a base station may not reach the mobile terminal due to obstructions along the way. The signal strength at the destination varies according to the location and moment in time, resulting in the likelihood of the signal not arriving in the conditions foreseen. In this regard, there are different issues that may affect the signal as it travels from the base station to the terminal and vice versa. This includes the fact that the network's neighboring stations may create interference to the signal and that the signal may be subject to industrial noise along the way, among other factors.

In addition, radio spectrum is a limited resource that has multiple applications or services to which it is internationally attributed. It needs to be carefully managed so that the use of one application does not interfere with another. For that reason, concessions for spectrum usage of the different radio services, such as mobile telephony, allocate spectrum blocks arranged at national or regional level.

A mobile base station which uses a portion of the spectrum has a radius that depends on factors such as base station output power and traffic in that location. It may range from a picocell of a few tens of meters to a macrocell of several kilometers. The frequencies available at the base station are shared by the users simultaneously.

In addition, mobile networks have other components that may affect in particular the voice quality of service, such as the probability of failed terrestrial cellular handover when the user goes from one cell to another or changes sectors within a given cell. Unexpected interruption of calls is more frequent on mobile networks since mobility gives rise to signal strength fluctuations from location to location and, as a result, the user terminal may go through a low signal area where the communication is interrupted (as is the case inside elevators, for example).

On the other hand, in GSM technology, each cell can offer a limited number of radio channels, which can be overburdened by excessive communications resulting in blockage and preventing further communications from being routed. This situation is experienced when a large number of mobile users are located in the cell on specific massive events or as a result of massive concentration of mobile users moving in a city.

In relation to the above, in particular the technical features derived from shared use pose congestion issues in the network access. This forces operators to design specific traffic management steps for every situation during the network planning phase, such as setting a cap on the amount of information that can be received per month or reducing the throughput as from a given threshold regardless of the speed purchased by the customer.

Technologies such as GPRS, EDGE and HSPA were developed enabling higher throughputs in the mobile telecommunications band. For example, with HSPA+, peak theoretical speeds of up to 42 Mbps are achieved in the downlink and of 5 Mbps in the uplink by cell. However, this bandwidth must be shared by all the users that connect to that base station, so the actual throughput bandwidth is narrower when several users are on the same channel. The user's location in relation to the base station will also affect the throughput; the closer to the cell edge the user is, the worse the received signal is, resulting in reduced speeds. For example, with HSPA technologies, the throughput drops considerably whenever there are a significant number of users on the same cell.

On mobile networks, there is a clear inclination by operators toward LTE-Advanced technology, which seeks improvement in three areas—average and peak data throughput, spectral efficiency and latency in the user and control planes.

Adequate spectrum allocation is a pre-requisite for any operator wishing to be competitive in the mobile internet access market. To face the growing demand for data services, the ITU recommends the following allocations:

Market Setting	Spectum Requirement for RATG 1 (MHz)			Spectum Requirement for RATG 2 (MHz)			Total Spectrum Requirement (MHz)		
Year	**2010**	**2015**	**2020**	**2010**	**2015**	**2020**	**2010**	**2015**	**2020**
Higher market setting	840	880	880	0	420	840	840	1300	1720
Lower market setting	760	800	800	0	500	480	760	1300	1280

Table 1. ITU Recommended Spectrum Allocation for Deployment of IMT & IMT-Advanced Technologies.[7]

Thus, the ITU expects that for countries with mid-development levels, from 1720 MHz to 1280 MHz of spectral bandwidth, will be required by 2020 (including the spectrum which is already in use) to meet the demand for IMT-2000 (RATG 1) and IMT-Advanced (RATG 2) services, exceeding by far the current allocations in Latin America.

On the other hand, depending on the status of development of each market, in a scenario of growing population density and changing urban configurations and urban densification, more spectrum is required in addition to new infrastructure deployments. In addition, mobile devices and terminals are increasingly more complex, powerful and demanding.

3.2.2 MOBILE NETWORK TOPOLOGIES

Quality of service, including fast connectivity, is essential in IP internet service provision. The design of IP infrastructures is currently characterized by the high redundancy of all (largely scalable and reliable) components and the presence of multiple high capacity links.

Physically, the Internet is made up of routers interconnected by communication links. The simplest IP networks are made up of a few general purpose routers that are interconnected.

[7] ITU-R M. 2078

As networks become more complex with a larger number of elements, they should be structured in tiers or levels to ensure overall scalability, security, availability, etc. Elements are specialized in their applications, management and security become more relevant, physical location is a factor to be reckoned with and the capacity to manage high customer densities is critical.

The necessary network infrastructure to provide IP services may be broken down as follows:

- Access Network
- Core Network Backbone or trunking network, which includes the interconnection with other providers and internet outlet

Most ISPs also impose a physical structure on their networks organizing them in Points of Presence (POPs), which correspond to a physical location where a series of equipment are available, such as Access Nodes (base stations), Core Network and backbone routers among others.

The users' interconnection with the data network takes place at the level of these POPs. In mobile networks, these points of presence correspond to the telecommunications antennas and access systems which may adopt networks in different arrays as shown in the figure below.

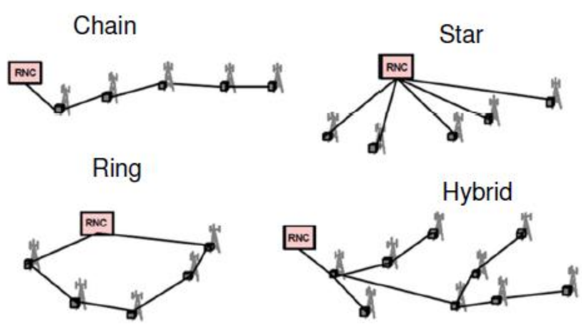

Figure 6. Access Network Topologies.

Generally speaking, we may distinguish three hierarchical levels of interconnection: the backbone (trunking), core network and access levels.

The figure below shows the overall basic architecture of a mobile network, made up of its essential components: user equipment and the access network and core network. All three include the mesh and backbone levels.

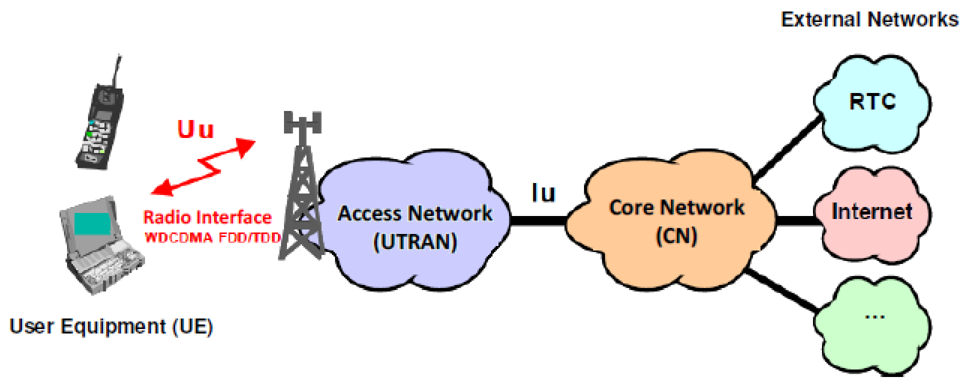

Figure 7. Mobile Network Topology.

Access Network: as indicated above, the user interconnections are made at the last level in the network, which corresponds to the immediate interface with the users' internet access terminals. This layer is responsible for providing network access to mobile devices. Its main components are:

Radio component:

- BTS (Base Transceiver Service): used for the device's access to 2G networks
- NodeB: Used for the device's access to HSPA networks
- eNodeB: Used for LTE network access

Controllers:

- BSC (Base Station Controller): responsible for controlling accesses coming from the BTS to route them on the 2G network
- RNC (Radio Network Controller): responsible for controlling accesses coming from nodes B and routing them on the 3G or 2G network.
- In LTE, the controller functionality is split between eNodeB and Core Network (Evolved Packet System).

Backhaul and Core Network: responsible for aggregating the traffic coming from access networks, adding user connections in the ISP's points of presence, interconnecting with other networks and traffic providers and with the rest of the network. Operators who also offer telephone access services and/or Internet Broadband access also through fixed accesses (copper pair, fiber, cable, etc.) share control and core switching elements to provide fixed and mobile services. Owing to the "all IP" evolution, the technical/economic relevance of a single network is increasing.

In addition, this layer is responsible for initiating, managing, controlling, charging and closing the mobile device's (terminal) session.

The Core consists of 2 parts: Circuit Switched (CS), used for voice; and data Packet Switched or PS, used for data.

The CS domain (for voice) is basically made up of the following equipment:

- MSC (Mobile Switching Center): responsible for managing UMG devices.
- UMG (Universal Media Gateway): it contains the resources for device connections and the PSTN (Public Service Telephone Network) or PLMN (Public Lan Mobile Network).
- HLR (Home Location Register): it manages the user database and is in charge of the services provided for users.

The PS domain (for data) is made up of:

- SGSN (Signaling GPRS Support Network): responsible for initiating the subscriber's data session.
- GGSN (Gateway GPRS Support Network): responsible for the connection with the service layer (Internet).

At the Core Network, there are also other pieces of equipment such as MME, SGW, PGW and HSS which have very similar features to PS equipment, but are used exclusively for LTE networks. This Core is called EPC (Evolved Packet Core) and the system which makes up the EPC and the LTE access (eNodeB) is called EPS (Evolved Packet System). LTE is all packet switched and does not have any circuit switched functionality; it does however provide interworking with legacy circuit switched technologies such as 2G and 3G

The figure below shows the types of mobile networks according to their technology (GSM, UMTS and LTE) and how the different elements relate to one another:

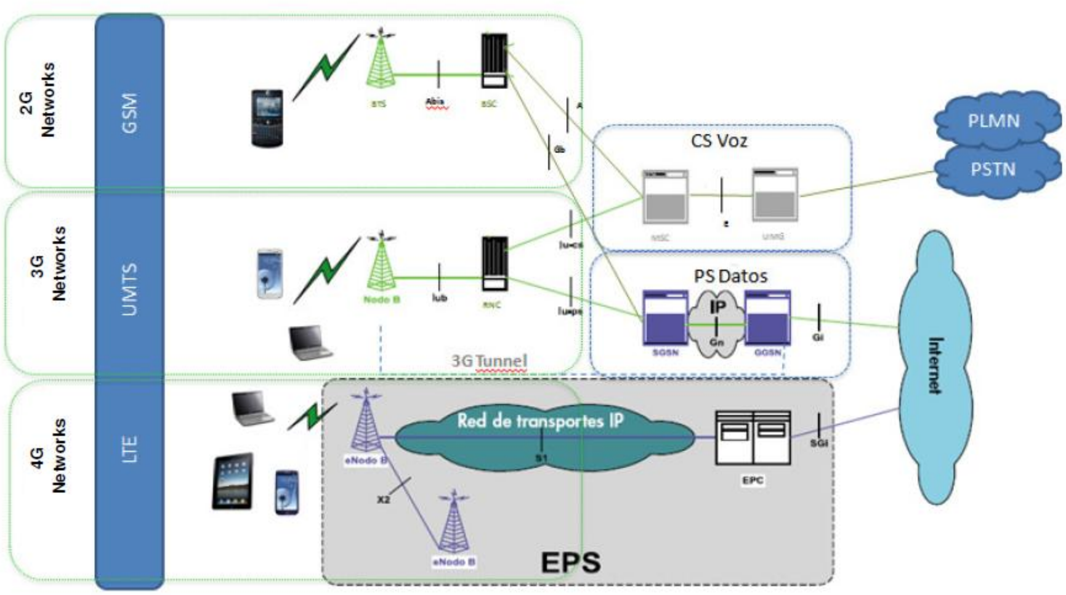

Figure 8. Mobile Access Networks by Technology.

In short, the user equipment (terminals) access the network over the radio interface, while the access network is responsible for carrying user traffic (voice, data, mobile signaling, etc.) up to the Core Network. The Core Network contains the switching and transmission resources necessary to carry the communication to its destination.

Traffic concentration may take place over standalone auxiliary equipment or embedded equipment in the base stations.

3.3 ACCESS NETWORK ELEMENTS AND NETWORK PLANNING

3.3.1 SPECTRUM CHARACTERISTICS

There are several elements to consider when planning a network. The starting point is the amount of spectrum available, i.e. the number of MHz of spectrum and specific physical properties of the spectrum band (capacity, propagation, etc.).

In this regard, different spectrum bands have different physical properties. Thus, there are the so-called high bands and low bands.

There are several physical properties that differ between a high band and a low band. For network planning purposes, the most relevant are those related to **propagation (coverage), number of MHz and real estate penetration.**

In terms of propagation, there is a reverse ratio between frequency band and area covered under a constant model scenario, as shown in the following figure:

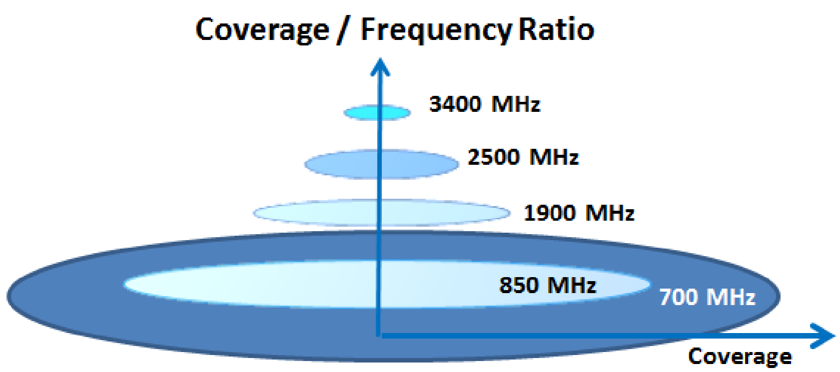

Figure 9. Frequency and Coverage.

The second important physical characteristic to consider is real estate penetration, which is commonly known as 'indoor' service. Low bands, such as 700 MHz,[8] are less liable to experiencing attenuation, diffraction and refraction phenomena in the passage through different materials, unlike the higher bands, which are more liable to disruptions. However, their use is conditioned by the development of an ecosystem for the band (e.g. terminals).

This has been proved empirically on the basis of measurements and simulations. By way of example, in the City of Ottawa measurements were made of losses (dB) from penetrations at different frequencies and buildings, where better results (smaller losses) were obtained at low bands.

[8] Communications Research Centre Canada, Ottawa. *Measurements of In-Building Signal Coverage and Building Penetration Loss in Downtown Ottawa at 700, 2500 and 4900 MHz.* October 2011.

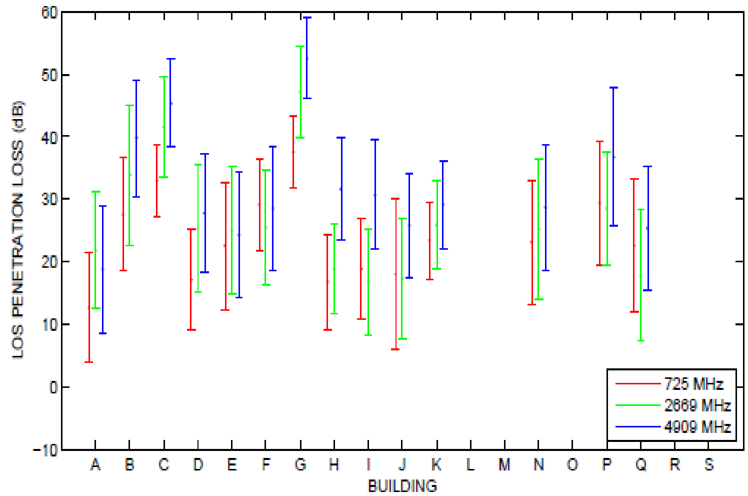

Figure 10. Average and Standard Deviation of Penetration Losses in 19 Buildings of the City of Ottawa.

The third characteristic is in relation to the amount of spectrum or size of the frequency block (MHz) available. It determines the capacity of hosting users and traffic. This factor is associated with potential demands by geographical area. Faced with higher demands of data flows, there should be growth either in terms of reusable frequencies or number of physical structures in the network.

3.3.2 BROADBAND AND THROUGHPUT

From the perspective over which ISPs have control, there are two notions that are widely used in telecommunications networks and frequently used interchangeably, although they should be differentiated. On the one hand, in a digital network, bandwidth is the amount of information or data that can theoretically be sent over a network connection in a given period based on the network design parameters. It can be understood as a nominal value. On the other hand, the throughput corresponds to the effective data transmission rate (data rate) achieved, so that the maximum theoretical throughput matches the bandwidth.

The bandwidth depends not only on the technology used and the amount of available spectrum but also on a trade-off between bandwidth and coverage. The higher the data speed requirement, the smaller the coverage area of the service. This implies a significant challenge for mobile network operators and a decision to be made for each business case.

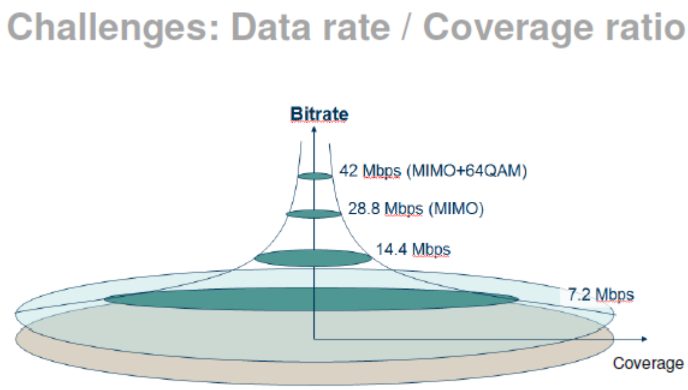

Figure 11. Data Rate / Coverage Ratio.

Now, from the perspective of quality of service as *perceived* by the user, the throughput or effective data rate achieved also depends on several elements:

- **Number of simultaneous** users where each one of them should receive the dedicated bandwidth required in their service.
- **The data transport 'route' chosen on the network.** Data packets travel on the networks from source to destination chosen based on the content that the user wishes to access. In addition, data packets not always follow the same route to download the same content: the paths that data packets may take are as diverse as satellites, telephone lines, submarine cables, etc. The dynamism inherent to such a network collection determines the route to be followed by each data packet at a given time.
- **Transport capacity.** HSPA evolution and LTE can support high data rates in the air interface, and the transport network or backhaul must have sufficient capacity to accommodate the data demand. If the transport network is under dimensioned users may not be able to achieve maximum speeds.
- **Data applications chosen by the user, which shall also have an impact on the service coverage.** Voice services have a broader coverage area than data. With heavier data applications (music streaming or video), operators will face different network planning requirements using heterogeneous networks combined with macro, micro, pico, small cells or WiFi. This is depicted graphically in the following figure:

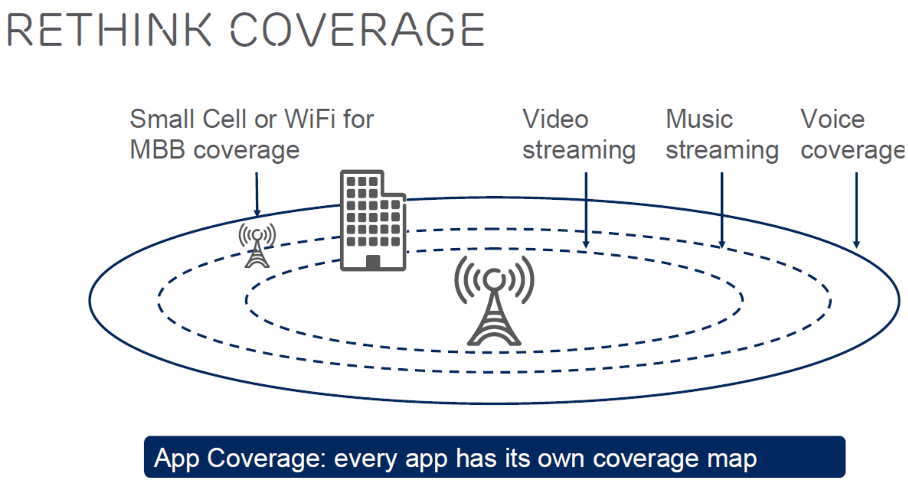

Figure 12. Coverage by Type of Applications.

- On the other hand, in connection with the throughput in mobile services, the figure below shows the complexity in a mobile network since, as shown in the figure, different technologies may coexist within the same network and data management capacity varies considerably between technology types. Thus, when technology on a cell changes, there will be changes to the service levels, which was not the case when only voice service was provided.

- In addition to the change in technology, the change of cell **type** should also be considered, since upon changing from one cell to another, there must be an available channel on the adjacent cell and if, for example, the environment was a pico cell and there is a switch to a macro cell with a high speed data application, the user might perceive a degradation in the service.

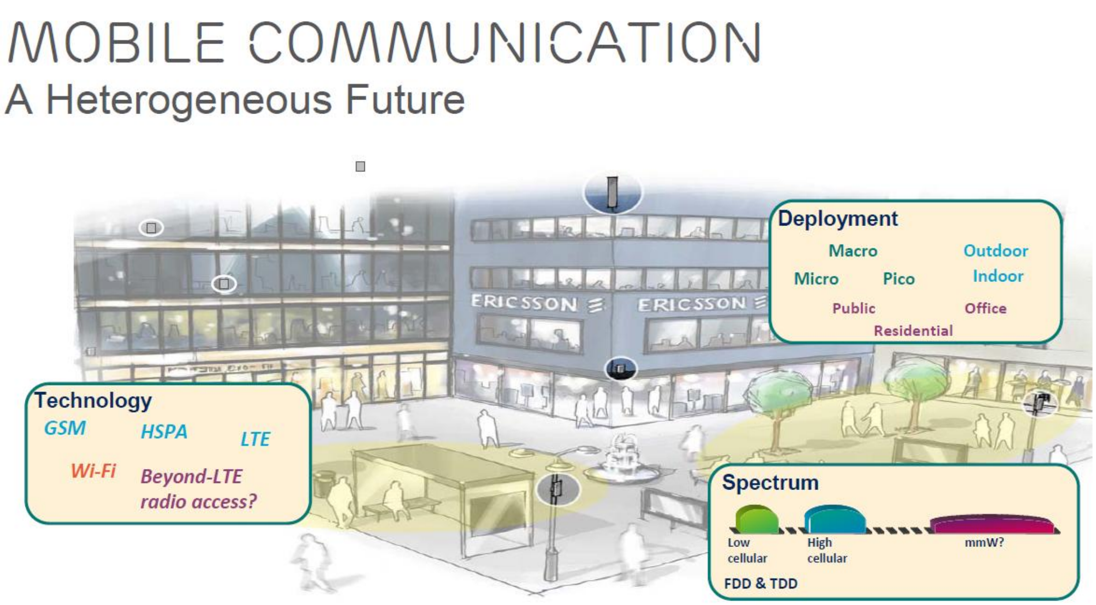

Figure 13. Heterogeneous Networks.

- If frequencies are changed, it will also affect service and it will be even more critical if there is not enough spectrum to manage the increasingly larger volume of data.

- Finally, the throughput will depend on the interference in the terminal-antenna interface, which becomes relevant in a mobile environment. When users are outdoors, it is not much of a problem. However, when users are inside a building, or elevator or subway, there are multiple cases of interference which are sometimes a challenge to control.

As was already explained, mobile networks face different variables and challenges. It is highly complex to keep a uniform network where certain parameters such as data rates or steady internet service access may be homogenized, which affect user perception and experience, especially when migrating from the data access network to other networks outside of the sphere of control of the first network, where there are also different factors that the first network cannot control.

3.4 ISP BOUNDARIES

Internet service providers have control only over a portion of the network between the end user and IP interconnection points connecting directly or indirectly through IP traffic operators with internet service and content providers. Using a very basic analogy, Internet Service Providers are responsible for appropriate operation of a portion of 'highway', not the entire highway, thus truck drivers may or may not use the most efficient highway, let alone make certain that the cargo (data) is delivered in good condition.

In providing internet access, there are several levels of networks involved. Many interconnected players and networks result in ISPs not having control over the end-to-end transport of data packets, i.e. from the ISP's server to the end user's terminal.

There are multiple access networks that connect to the rest of internet in a hierarchy of layers or levels of ISPs. To explain the capillarity and degree of aggregation of the networks involved in internet service provision from the interconnection's side we use the term 'tiers'.

There are several different ISP network tiers: Tier 1, Tier 2, Tier 3, etc. At the highest end of the hierarchy, there is a relatively small number of the so-called Tier 1 ISPs, defined as the networks capable of reaching any other network on the Internet without the need to purchase IP traffic. This tier corresponds to the networks that are closer to the internet backbone. Under Tier 1 ISPs, there are the lower level ISPs, such as Tier 2 and 3, which are connected to the Internet through one or more Tier 1 ISPs.

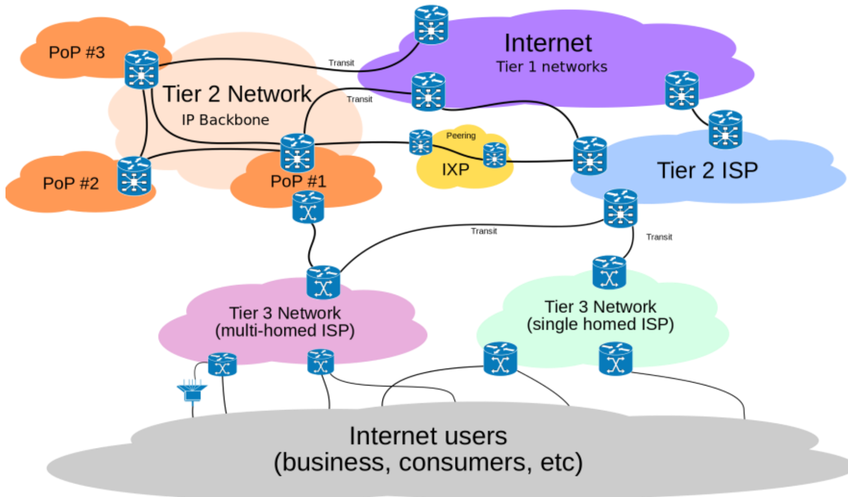

Figure 14. Interconnections between Different Tiers.[9]

As a result, the QoS and ensuing customer experience in accessing internet at a given time depends on the interaction among all the participants of the chain at that time.

By way of example, the following figures illustrate the connections offered by the highest tier providers. The most tangible example is that of submarine cable providers, who resell their services to Tier 3 internet providers.

[9] Source: Internet_Connectivity_Distribution&Core.svg. Author: Ludovic.ferre

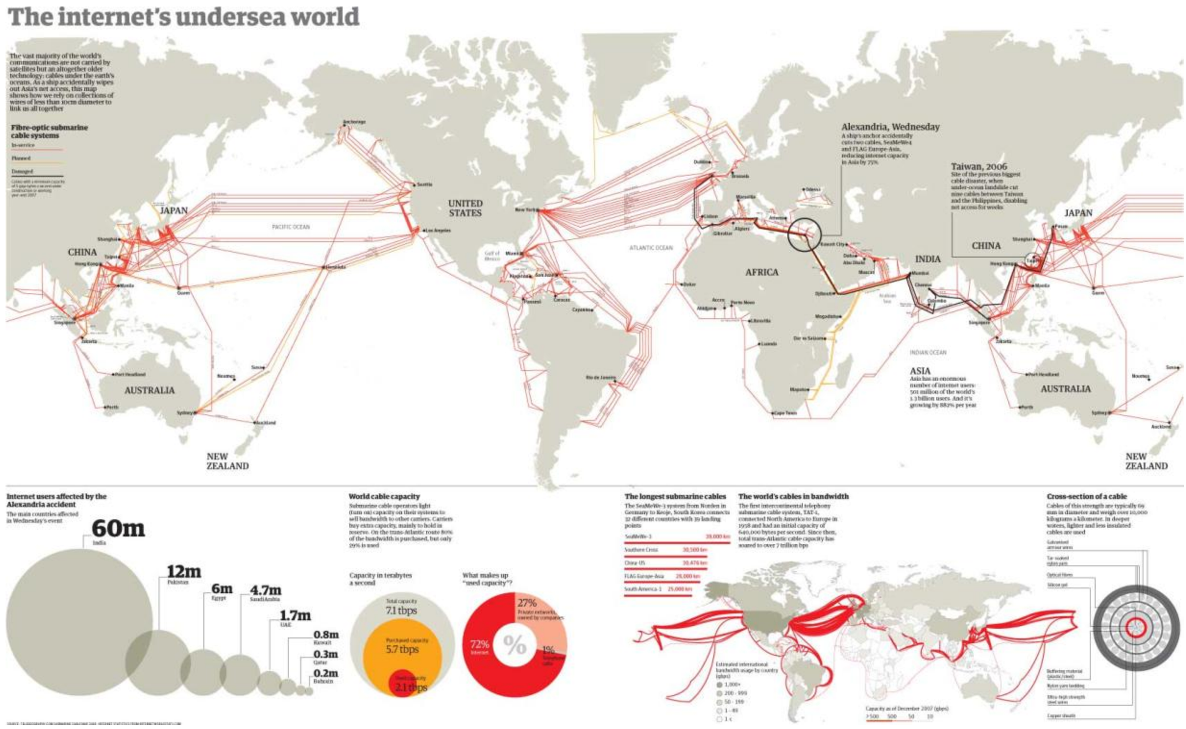

Figure 15. Examples of Tier 1.[10]

The figure above shows more density of this type of provider in the regions that have more demand and store larger volumes of content. The density between North America and Europe and between North America, Japan and China is noteworthy, in stark contrast with the situation relative to Africa.

The arrays and capabilities of these submarine cables further determine the international bandwidth available in each country.

For Latin America, a strong dependency is evident on the route with the United States. According to statistics from TeleGeography Global Internet Map 2012[11], 85% of the broadband available for Latin America is on the route with the United States, while 14% is on intra-regional routes.

3.5 EXOGENOUS FACTORS

As has been mentioned before, one of the key considerations in understanding the determinants of quality of service of a mobile internet network is the fact that the internet is a *network of networks*, with access providers only controlling a portion of it.

Consequently, it should be noted that the end-to-end quality of service of a network will depend on the quality conditions offered by the operators who are part of the different segments involved in the communication. Thus, internet service providers are only responsible for quality on the segment they operate.

[10] Source: Internet_Connectivity_Distribution&Core.svg. Author: Ludovic.ferre
[11] http://global-internet-map-2012.telegeography.com

In addition, in the mere design or network buildup, there are variables to be regarded as having a behavior subject to compliance with service level agreements (SLAs) on IP interconnection topics and QoS management criteria of the third party internet operators and providers. These have a greater or lesser impact on the operation of a mobile internet access network and virtually cannot be controlled, thus affecting service levels.

This makes it difficult to control them. An appropriate balance should be sought in managing traffic relative to, most importantly, mitigating packet loss, congestion and latency.

The service conditions offered by mobile ISPs are directly linked to a series of technical conditions of wireless networks and show totally different conditions for each user or application supported on the network.

As explained earlier, on mobile networks network resources are shared and their measurable parameters are more varied depending, for example, on the network's planning and design or the amount and type of spectrum. Likewise, the network is subject to operation and quality patterns which in the first segment will depend on uncontrollable situations relative to **the number of users on the coverage radius** and their **mobility**, as well as these users' **consumption pattern**.

Cisco's figures reveal that only 1% of mobile data subscribers account for 16% of the total mobile traffic. It is expected that by 2017, there will be a coexistence/convergence of several devices dominated by smartphones that will lead consumption.

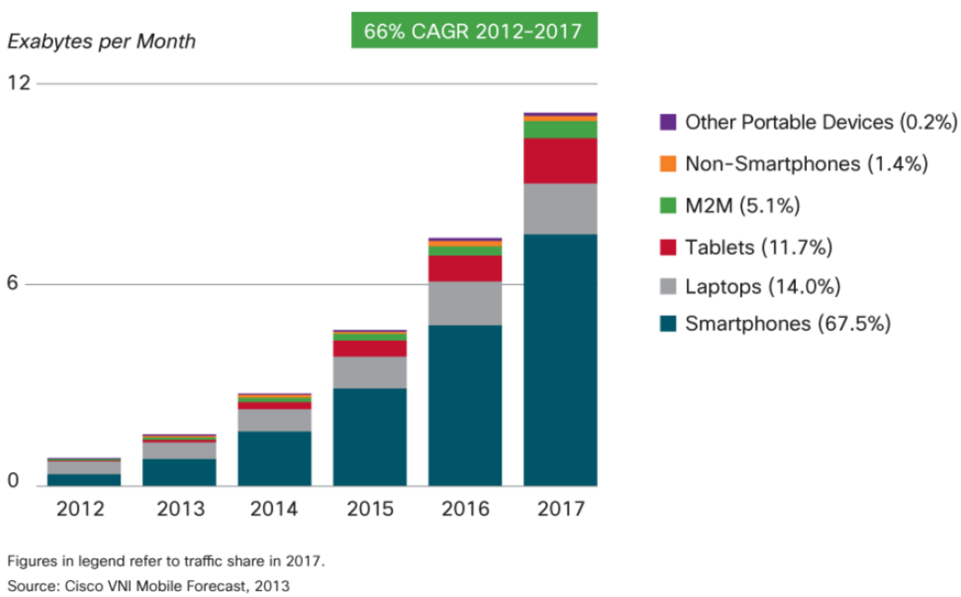

Figure 16. Smartphones will Lead Mobile Data Consumption.

Although these factors might be estimated and the network designed within given ranges of probability to support them, a situation of congestion of network resources would affect several of the users in the same cell; therefore, there is a greater likelihood of not being able to meet the demand nor provide certain service levels. From the perspective of the consumption pattern, it will affect the network by changing randomly according to the profile and geographic location of the customers. In terms of the number of users, this variable will change considerably from cell to cell, according to the moment in time, and will be influenced by the persons´ movements.

Mobility affects the data speed offered and since the concentration of customers on the network varies over time, it prompts events (i.e. traffic jams, demonstrations, etc.). This challenges the connection speed to users, creating excess demands of traffic flows. Likewise, the location of the customer relative to the base station may also make the radio conditions degrade if the user moves away from base stations. Even if the network has good base station density, there will be users to whom the quality of the connection will not be ensured because they will be on the cell edge, and therefore, under very unfavorable radio conditions.

Finally, it may be noted that there are other factors that coexist which cannot be controlled by the operators. These factors affect the correct operation of the network, ultimately influencing a user's perception of QoS. These are related to climatic factors (from areas of heavy rainfall or natural phenomena and disasters), the distances between the user's terminal and the base station (derived from the restrictions to antenna installation in certain places), changes in environmental topology, new buildings that block the signals and excess consumption (massive events or situations of national shock).

3.6 TERMINALS

Rather than being passive elements in internet service provision, mobile terminals have technical features and specifications that impact the customers' user experience. They encompass a wide range of shapes and features, such as smartphones and tablets, dongles, etc., each one capable of serving and meeting different user needs. They might also include new specialized terminals and devices (which provide music and Wi-Fi) and health monitors.

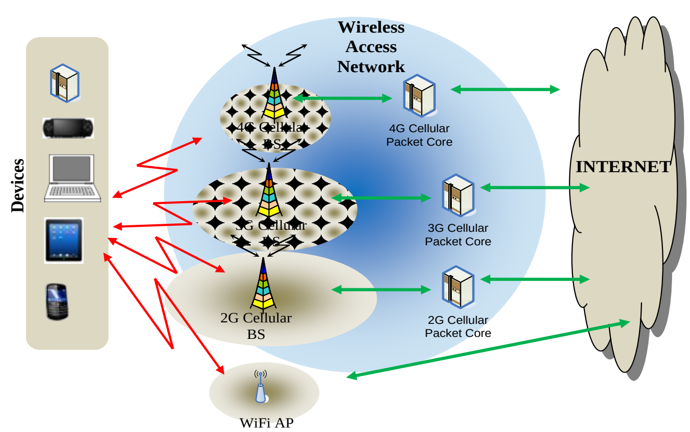

Figure 17. Devices and Radio Access Technologies to Enhance User Experience.

The user's QoE, as mentioned in Section 2 of this document, depends on several elements that also include the applications being used, the type of terminal and, mainly, the effectiveness of the terminal in communicating with the wireless access network and the network's capacity to maintain a consistent

QoS in the radio carriers, internet's capacity to connect the user and the provider, the provider's capacity to serve a content, etc.

3.6.1 CHOICE OF TERMINAL

Users are free to choose their terminal based on their own preferences, purchasing power, type of application, etc. The choice of device may also be based on the terminal cost relative to the associated service package. For example, a young student who cannot pay for a plan with a mobile company might prefer to use a portable music playback device capable of connecting to the internet via Wi-Fi; the student's main interest is listening to music and communicating with friends via instant communication applications when Wi-Fi access is on. Applications like the above have met the need for simple text messaging, which used to be the only low-cost means of communication with friends and family. The type of terminal over which you access mobile internet, its features and capabilities have a direct impact on the user's experience.

3.6.2 QUALITY OF COMMUNICATION EXPERIENCED BY THE USER

In the case of a mobile network, the quality of communication experienced by the user of the device depends on the (radio) access technology, conditions of the wireless channel, capacity of the device and capacity of the Base Stations. There are several performance aspects to consider such as the specific wireless access technology, the hardware of the device or terminal (receiver, antenna, etc.) and software capabilities that determine radio performance.

One of the main challenges for current and future devices is enhancing the radio interface for all the frequency bands allocated to the different service providers. The gains from the tuning components used in the radio interface vary along the total bandwidth allocated. Usually, the interface performance is enhanced based on the range of tuning, which depends on the ISP's frequency and operation band. This enhancement may vary across device makes and models and, therefore, it might account for a variation in the performance of different devices on the same operator network.

Moreover, there are other aspects in addition to radio performance that may affect the user's use experience on the network. For example, network array. Some services, such as VoIP, FTP, etc., may be downloaded by using different access technologies (voice on GSM, ftp on Wi-Fi) based on the ISP's provisioning policies.

Other aspects of the device's hardware and software different from the modem's configuration affect the user's experience. The size of the screen (display), the interface display and icons, the feature enabling switching between applications and battery duration, are a few important areas that impact on users' experience. How different applications are treated on the device; for example, email in contrast with web traffic, might also affect the experience.

These terminals are exposed to the same security vulnerabilities as PCs. Thus, the terminal's processing capacity, web browsing speed, etc. can be compromised by virus or other intrusions.

3.6.3 TYPES OF APPLICATIONS

Applications play a very relevant role in the next generation of data packet services. Some of these are maintained by sending regular (data) messages that are not visible to the user and that may have a significant impact on the performance of the network and the user's terminal.

Both the radio access and the backhaul supporting all mobile communication services are affected by these requirements. While some users predominantly use applications that take up significant bandwidth (i.e. video applications), others only use applications that take up small amounts of bandwidth (i.e. email). Some access technologies, such as GSM, are enhanced for certain types of applications, such as voice calls. Access technologies are constantly being improved and new releases and standards have been adopted to meet the needs of the new applications.

4. ELEMENTS TO BE CONSIDERED RELATIVE TO THE QOS ACCESS TO MOBILE INTERNET

With the emergence of new services and improved device capabilities, internet traffic from mobile devices and the demand for data have been growing at an unprecedented pace, experiencing almost exponential increases. Likewise, the use of mobile internet converges over many elements as people become used to having better coverage and internet access wherever they go.

These growing volumes of data and the users' increased demand should be managed appropriately by mobile networks. An efficient radio access technology is essential to achieve this. Currently, there are several mobile broadband technologies available, such as HSPA, HSPA+ and LTE.

As described, the number of LTE network deployments is constantly increasing. These new networks usually call for integration with GSM/GPRS and EDGE and UMTS/HSPA and HSPA+ technologies and may include both the new deployments and overlays of existing networks or changed provider solutions.

The second half of 2012 saw a fast growth of LTE connections, mainly from smartphones in countries like Japan, South Korea and the United States. It is estimated that LTE subscriptions reached 100 million over the past year and will reach 1.6 billion by the end of 2018. Nevertheless, it is also expected that over the same period there is a growth in UMTS/HSPA subscriptions, from 1 billion to 4.4 billion. In this regard, there will be around 3 times more subscriptions to this technology than LTE by 2018.

For this reason, regardless of whether mobile operators achieve access to spectrum for LTE in the short term, they further face the challenge of ensuring availability and good operation of the UMTS/HSPA networks with the purpose of also responding to the growing number of smartphones without LTE support and other devices. Even if LTE networks are being deployed, operators need their HSPA/HSPA+ networks to provide a comparable quality experience when users move beyond LTE's coverage area.

As demand grows, mobile internet access services are exerting huge pressure on the amount of spectrum available. Operators must identify new ways of using spectrum more efficiently over their GSM, HSPA/HSPA+ and LTE technology networks.

At the same time, the fast adoption of smartphones and the intensive use in some cases of internet application signaling / control – a factor beyond network operators' control -- has significantly increased the amount of network signaling, creating massive volumes of data and multiplying the number of network incidents. It is for this reason that network performance measurements and their interpretation should be harmonized and adapted to the complex nature of current networks to ensure network performance is met according to the operator's goals. The way in which a device behaves on a network may change when a new model is introduced. Software updates may also alter the way an application works, while the steady flow of new applications to the market affects the way in which KPIs are interpreted.

In addition to these trends, new features and services are constantly being introduced, which implies that the test methods and measurements could most likely not be kept up to speed to ensure that users' experience continues being measured accurately. Additional subscription services, as will be the case with Voice over LTE (VoLTE) and high definition Video on Demand (VoD), could become standard services offered over LTE broadband networks. Many operators could voluntarily use transparent methods to report important information to users and allow them to make informed decisions. Voluntary Indicators published by operators could possibly be simple enough to be understood by customers. Thus, for various reasons described throughout this white paper, measurement, performance or QoS information by operators should not be required by regulators. The hierarchical architecture defined in the cellular network topology and, in particular, ISPs' (which are interconnected with other ISPs), implies that end-to-end quality of service is supported by the service levels provided by all the players involved.

To provide an appropriate mobile internet access experience, networks need enough capacity and coverage to enable the delivery of the growing amount of data at low latency. One possible approach, among others, is to deploy heterogeneous networks or self-organized networks (SON). To prepare networks to route the traffic flow, operators face having to improve and densify the existing mobile access networks and add small cells in an optimal manner. How, when and where said networks will migrate will be determined by their mobile access services and their existing networks, as well as by market expansion or technical and economic considerations.

Therefore, it should be noted that there is no single solution applicable for all cases and, thus, enough flexibility is required to ensure customer expectations are met in a profitable framework, with efficient spectrum usage and ensuring the network's safe operation into the future.

Whether operators are expanding their 3G network to new coverage areas or as a future complement of LTE deployments, there are a number of key challenges which should be considered for both cases from the public policy perspective:

- The shared goal by regulators and operators of having broad WCDMA / HSPA coverage efficiently deployed to ensure the viability of operators providing the service.
- Successful management of a very high number of smartphones, characterized by a mix of voice and data traffic with demand peaks.
- Ensuring a free and open marketplace without heightened regulation on the mobile wireless industry; whereas regulatory policy allows the free marketplace and customers to choose the winners and losers based on their experiences.

In view of the above, the industry's regulatory policy authorities should consider that operators face the need to ensure that their current networks have the right coverage, capacity, performance and business cases to keep up with the fast growth of mobile internet, IT usage and expectations. No mandatory regulations about QoS or performance indicators should be made by governments or regulators. The customers will decide the winners and losers in the free and open marketplace and the regulators should allow decisions to be made by subscribers own choosing.

As already indicated, in a first approach, the ISP providing mobile network access who is closest to the user bases its service levels on the parameters defined in the access and core networks (mesh network and trunking network), the access network being the network section which typically faces the most serious limitations to bandwidth and capacity.

A strict treatment of the issue calls for considering multiple factors, including:

- The traffic load to be supported at each interface, considering the different contributions (user traffic, signaling, management, header overload, etc.)
- Source traffic parameters (peak rate, medium rate, activity factor, etc.)
- QoS requirements (tolerance to loss and delay) associated to each type of service (see Figure 12).
- Traffic management policies (admission control, traffic prioritization, congestion control)

To derive maximum value from the radio spectrum, operators will further need solutions from flexible base station deployment strategies that enable ideal placement of radio sites. **Operators will need to consider alternatives for site placement by cooperating with new partners such as municipalities, retailers and external agencies, rather than the traditional agreements that were reached with land owners and tower approval committees.** In metropolitan areas, supplementing the already dense macro networks with additional small cells at street level will call for the use of small antennas in such a way that the equipment is almost invisible. This leads to the need for regulators to ensure appropriate articulation of these new solutions at no barriers and with requirements commensurate with the size of the efforts, since deploying a significant number of small base stations changes the rollout economics of mobile networks. The need to move seamlessly across one wireless access technology to another to maintain maximum coverage, capacity and use of resources, calls for effective work between macro and small cells, as well as between radio access technologies.

4.1 BARRIERS TO THE DEPLOYMENT OF INFRASTRUCTURE AND QOS

The growing demand for higher capacities and competitive prowess in the marketplace leads the different mobile internet access providers to constantly expand their networks in order to meet the higher demands.

Mobile internet access providers expand their networks either to increase their geographical coverage and thus serve new customers, or to increase their capacity by installing more base stations and reuse the available spectrum. The amount of spectrum is a relevant competitive advantage. Its scarcity forces additional investments in sites and antennas.

As rightly explained in 4G Americas' 2012 white paper ***Mobile Broadband Acceleration in the Americas***, "Among the several challenges faced by mobile operators we can point out: 1. The data tsunami has made it more evident that huge investments are required to deploy new mobile infrastructure (**placement of new sites** and setup of radio communication stations or BTS) to meet the demand as well as **the need to have more spectrum and capacity available**, 2. Both national and local regulations relative to the **granting of permits and authorizations** required to operate the necessary infrastructure, and 3. The population's concern (**social alarm**) about electromagnetic emissions from antennas is making it difficult for operators to deploy infrastructure since they cannot find appropriate locations for the new sites, resulting in uncovered areas, as well as the need to find environmental solutions with minimum visual impact."

Local urban regulations have a direct impact on the dynamism of the mobile access network, this being precisely the section of the network which poses the main challenges in terms of performance and service levels.

In all cases, it is essential for the necessary conditions to be met for the deployment of infrastructure that enables appropriate delivery of internet user experience.

4.2 THE NEED FOR A SHARED FRAMEWORK

Traditionally, KPIs (a set of key performance indicators) have been used to ensure that the networks' performance objectives are met. Managing the complexity of KPIs is quite difficult in a single-technology environment. In an ecosystem that encompasses all technologies (2G, 3G and 4G); the degree of difficulty is considerably higher, so the reliability of the KPI should not be guaranteed as a true reflection of the user's actual experience.

There are as many ways of measuring network performance and operation as there are equipment and infrastructure providers. Just like the metric system was introduced to compare weights and distances based on similar scales across international borders, today's mobile industry needs a shared framework to check network performance so that by publishing these measurements, users may take informed decisions to fit their needs.

Some of the main characteristics of such a shared framework include:

- Establishing the measurement 'object':
  - ITU (International Telecommunications Union) and ETSI (European Telecommunications Standards Institute) recommendations on performance reports
  - Selecting a significant yet manageable number of key high-level indicators built on many lower level performance indicators
  - Including only KPIs relevant to users' experience

- Defining a measurement protocol, seeking the involvement of the industry:
  - Specifying how and where each KPI must be measured
  - Using terminals available in the market with the configuration of standard network parameters as part of the measurement protocol to be designed including operator involvement
  - Focus on checking that it matches operator priorities and is applicable in strategically selected areas

In terms of international quality of service standards applicable to telecommunications services, we may mention the work of international or regional organizations like the International Telecommunications Union (ITU) or the European Telecommunications Standards Institute (ETSI).

ITU

As a specialized body of the United Nations, the ITU studies the technical aspects and issues recommendations for global standardization on a non-binding basis. The body defines how communications networks should work to ensure their interoperability and enable service provision.

Within the ITU-T, Study Committee 12 is charged with studying issues relative to QoS. ITU-T E.800 Recommendations provide a series of common usage terms in the study, pursuing the complex task of representing the interests of all the stakeholders of the telecommunication services market (including users, service providers, manufacturers and regulators).

Currently, the Study Committee is working on a new Recommendation on mobile QoS covering mobile network service aspects: TD 53 (GEN/12): E.MQoS (Draft New Recommendation on Mobile QoS). This Project seeks to summarize the basic issues and parameters of QoS from the user's perspective and include some equipment measurement features.

ETSI

In the case of ETSI, this body is also responsible for reviewing standards applicable to QoS. ETSI is a global standards developer for information and communications technologies. This institute is recognized by the European Union as a Standards organization. Currently, its recommendations are adopted in the fixed and mobile industries worldwide, and its work is compatible with ITU recommendations. Both organizations usually take into consideration the mutual work published earlier with a view to harmonizing the conditions under which telecommunication services are provided in a given sphere.

This organization further encompasses QoS issues. It has a series of recommendations called ETSI TS 102 250 aimed at implementing and documenting a measurement system of quality parameters for internet access service from mobile networks.

All of these standards and working groups aim at establishing a series of technical indicators that should later be analyzed and enshrined in a measurement protocol based on the industry's input according to each country's needs and reality.

Owing to the characteristics of mobile networks discussed in the previous sections, authorities should promote a transparent approach toward users by establishing a balanced number of indicators that are relevant in consumers' decision-making. One example of the above can be found in the United Kingdom, where mobile operators signed a Good Practices[12] agreement to promote informed marketing toward users.

4.3 QOS DEBATE IN MOBILE INTERNET ACCESS

Despite the previous considerations on quality, in some countries certain sectors have pointed out the need to regulate internet access service quality and in some cases even establish minimum guarantees of internet indicator values (such as speeds or latencies) regardless of the access technology by applying the principles. This does not recognize the existence of factors such as mobile network design

[12] http://www.mobilebroadbandgroup.com/documents/mbg_mobile_broadband_gpp_010609.pdf

engineering, technology limitations, ISP scope and boundaries, user behavior and other external factors that are impossible to control by internet access provider operators.

As explained in this paper, these ultimate requirements of quality are incompatible with the mere nature of a best effort type of internet service, let alone mobile access service, and could raise an additional and artificial barrier that might in the long run affect the innovation experienced by the internet and the timely adoption of new technologies and services.

It is a fact that mobile telecommunications networks have evolved from providing voice as the only service to providing a wide range of information internet-based data services.

The advent of mobile access networks has brought along a conceptual break between the design and engineering features that make the mobile access network distinct and the recognition that the internet is a combination of *best effort* IP networks on which access providers have a limited field of action restricted to their portion of the value chain.

Some national authorities have understood that mobile networks have features intrinsic to their wireless nature that make them difficult to adjust to specific conditions. These features differentiate them from other internet access networks. Such is the case with the notion of Traffic Management, which is broadly accepted in the mobile industry as a necessary tool to ensure efficient use of shared resources (i.e. spectrum) and operational efficiency is necessary for all users to avoid service degradation.

Imposing a given QoS creates its own significant risk of harming consumers, since (as indicated above) it could harmonize competitive points among operators and reduce the possibility for innovation. Consequently, a minimum quality of service represents a potentially significant danger for consumers in general by imposing higher costs that fail to guarantee better user experience while requiring additional operator investment in regulatory smart counter equipment without real return.

Thus, regulatory authorities should not impose regulatory burdens on operators when considering QoS or performance factors. Any guidelines should be only voluntary provisions for operators. It is the customers that will make informed decisions as to which operator best meets their needs and, at the same time, it is these decisions that push the operators to differentiate their offerings effectively. The forces of the free marketplace by subscribers should decide the market winners and losers.

It is important not to overlook the potential damage to competition that might result from imposing QoS requirements. Not only would it mean completely ignoring certain competitive points, such as the market for innovative products beyond the minimum accuracy criteria necessary, but it would also significantly reduce the parameters subject to regulation. As if effectively dictating a specific set of services, competitors might compete only on these parameters since they would inevitably be raised in terms of importance. On the other hand, there is considerable risk that the specific tariff structure developed around the set of QoS requirements would stagnate, only evolving with the changes in regulated quality of service parameters.

Any mandate should further recognize that some network users may want the QoS called *"best effort"* if provided at a proportionally lower price point. For example, some customers may require internet connectivity to access services that demand less network resources, like instant messaging, but also need this network connectivity at very low cost to be economically viable. The minimum QoS requirements might therefore have the undesirable consequence of preventing these devices and applications from entering the market, significantly slowing the growth pace of the internet mobile access market.

Additionally, there would be significant difficulty in overseeing compliance especially relative to internet access service on mobile networks given that the actual level of service provided for a connection depends on a wide range of factors. As indicated earlier, the ISP with whom a user signs a consumption agreement is only the final stage in the connection with the services/content to which said customer seeks access. The level of service offered through the ISP depends on the service provided by the ISP, but is not determined by it.

For mobile networks, the QoS experienced by the customer depends on the number of multiple users and their position on the cell and signal strength. In addition, the device used by the customer (and the size of the screen where data must be delivered) have a substantial impact on the user experience. Configuring a minimum QoS on mobile networks seems particularly problematic. Consequently, any QoS requirement would have a very limited repercussion unless its operation is guaranteed simultaneously from end-to-end and by all the players in the supply chain.

So many variables are at stake on a mobile broadband access network that it is not possible to ensure a sufficiently high level of QoS over a minimum threshold. The investment in the mobile network capacity is unequal and the location of bottlenecks may be unpredictable or temporary (i.e. music festivals, sporting events, etc.). A government role of investing on a network would result in an entire underutilized network with oversized capacity, diverting funds from the other network investments and, even despite all of the above, subject to all the access network variables that determine the customer's use experience.

Requiring operators to invest inefficiently might also prove counterproductive considering many regulator functions. Finally, it is necessary to stress that investment funds are not unlimited. If the regulation increased minimum effective levels of network investment, it would be equivalent to raising entry barriers. Ultimately, it is up to the market and consumers' demand to determine the most appropriate allocation of the finite investment resources.

5. CONCLUSIONS

As a user consumes more data from the Internet anytime and anywhere using, mobile wireless access, the need for QoS becomes more relevant. Unfortunately, it has recently been observed that QoS has been placed on some countries' media and political agendas. With mobile broadband access intrinsic conditions and particularities, government regulatory QoS burdens should not be imposed on wireless operators. To fully understand the policy issues, it is necessary to distinguish between *perceived quality* and the *quality actually delivered* to the customers by introducing the various technical elements which determine the quality of network operation based on each network's technical features.

Delivery of internet access service is only possible through the interconnection of countless networks. Each portion must be controlled by different operators and providers; therefore, the internet should be understood as a combination of 'best effort' networks.

The operational quality of a mobile network depends on several variables inherent to mobile networks such as coverage, shared use of network elements, physical characteristics and access interface properties (radio spectrum). Different elements exogenous to the network are also added, such as climatic factors, array of the topology of the propagation media (urban or rural), user behavior and their mobility and consumption pattern, among others.

Mobile networks develop complex topologies which makes each of them unique. On a single network there might be various technologies coexisting which will affect the data management capacity. Thus, when there is a change of cells, there is a change of technologies; service levels will change. This was not a viable concern when only voice service was delivered in the past. In addition to the change of technologies, the change of cell type should also be considered upon switching from one cell to another. An available channel must be found in the adjacent cell; for example, with the switch from a picocell environment to a macro cell with a high speed data application, the user may perceive a degradation of service.

The quality of user experience depends on the number of users with different use profiles and their location within cell and signal strength. In addition to the terminal, the screen size, device hardware and the quality of each network makes up their internet connection. Internet services and applications use network resources without having the features of the access network in most cases. Applications and continuous software developments push the networks increasingly to the limit, prompting more improvements on providers' networks.

Configuring a minimum QoS on mobile networks seems particularly problematic and bureaucratic with no value added to the consumer or operator. Consequently, any QoS requirement would have limited repercussions unless its operation was simultaneously guaranteed from end-to-end and by all the players in the supply chain, (which is currently not feasible in a best effort internet scenario).

Free market economics are currently taking place as the internet access market continues to be highly competitive. As in any competitive market, the quality of services is a differentiator and an attribute whereby consumers' decisions force effective market competition.

The quality requirements enforced by external market agents, characterized in this case as the regulators, are not inclined to increase efficiency levels nor translate them into social welfare or the users' benefit. Since they fail to match or create compatibility with mobile service conditions, they become a negative externality. This may contribute to the artificial raise in some indicators and creation of additional costs for operators in the near term future. It also may affect more relevant performance indicators, such as coverage, capacity and technology evolution, which will have no impact on the customers' short-term experience, but will on the long-term.

When quality requirements do not match the nature of an IP network, let alone mobile wireless access service, additional and artificial bureaucratic burden may cause a long term effect on the innovation of internet and the timely adoption of new technologies and services.

Given the evidence mentioned above, establishing a series of QoS requirements could be inappropriate. Imposing QoS could further result in a net damage to end users, since it would reduce the potential for innovation and it would harm competition.

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