Impacts of New Technologies on Regulatory Regimes
Introductory comments

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Abstract: Traditional regulatory doctrine has been called into question by rapid technological change and convergence. With the migration to packet switched networks, the emergence of the internet protocol (IP) and the expansion of the mobile industry, regulators are encountering major challenges in responding to new innovations "just in time" by adjusting regulatory frameworks and legislation. The paper's objective is to discuss the foundations of such a new regulatory framework and stimulate debate on how to ensure successful ICT/telecommunications regulation in a world of technological convergence. The paper opens with a presentation of the main technological trends at stake within the core of the traditional regulatory regime. Major consequences on the ICT sector are subsequently analysed in the second section of the paper, with an emphasis on structural change that may affect the sector as a whole. Taking overall market structure into account, the third section offers indications of the probable implications of technology trends on the very roots of regulatory regimes. The conclusion tries to represent the challenges of the new regulatory paradigm by addressing the probable implications of technology trends on a specific regulatory issue, namely interconnection.

Key words: regulation, convergence, technologies.

Regulatory intervention in network industries (electricity, gas, water, railroad and telecommunications) is based on the theories of natural monopoly and market failure. Insofar as the industry is considered a "natural monopoly," introducing competition is neither privately profitable nor socially desirable, and regulatory intervention is required to ensure the sector's optimal performance. While this traditional principle has some universality, careful adjustments may be required when considering the specificities of the telecommunications sector. Compared to other industries, telecom networks are characterised by a dramatic technological change and face the rapid diffusion of new technologies. A core question is how effective regulatory policies could be developed in order to fully leverage the opportunities created by rapid technological changes. The purpose of this introductory paper is to initiate the development of an analytical framework.
and innovative content to explore issues related to new technologies and their impact on regulatory policies.

Traditional regulatory doctrine is thrown into question by rapid technological change and convergence. With the migration to packet switched networks, the emergence of the internet protocol (IP), and the expansion of the mobile industry, regulators are encountering major challenges in responding to new innovations "just in time" by adjusting regulatory frameworks and legislation. At a first glance, this emerging technological trend is likely to affect the main regulatory issues (interconnection, licensing, price regulation, spectrum management, numbering, security issues, and universal service obligations). Ultimately, the very boundaries and foundations of the overall regulatory paradigm are expected to be contested by this technological momentum.

The need for a new paradigm is even more meaningful in developing countries due to the opportunities to leapfrog technology and short-cut regulatory change. This new framework would ideally aim at facilitating the deployment of different technology options based on the establishment of an open, level playing field for all operators. The objective of this paper is to discuss the foundations of such a new regulatory framework, and to provoke a debate on how to ensure successful ICT/telecommunications regulation in a world of technological convergence. The paper begins with a presentation of the main technological trends at stake at the core of the traditional regulatory regime. Major consequences for the ICT sector are then analysed with an emphasis on structural change that may affect the sector as a whole. Considering overall market structure, the third section of the paper gives indications of the likely implications that technology trends may have on the very roots of regulatory regimes. Our conclusion tries to represent the challenges of the new regulatory paradigm by addressing the probable implications of trends in technology on a specific regulatory issue, namely interconnection.
Background

The rationale for regulation

Historically, the main objective of telecom regulation was to ensure the optimal performance of the POTS (Plain Old Telephone Services) network in terms of accessibility, affordability and QoS. This regulatory regime was based on the "natural monopoly" doctrine. In the context of an increasing return to scale (large fixed costs) and/or market failure, if there is a cost advantage for a single firm to produce all given vectors of output more cheaply than any combination of several firms (cost sub-additivity), then the monopoly is "natural" and the introduction of competition is conducive to inefficiencies, involving the need for regulation. Therefore, as far as the industry being considered a 'natural monopoly' is concerned, the introduction of competition duplicates costs and is therefore neither privately profitable nor socially desirable.

Once telecom markets were liberalized and no longer subject to monopoly conditions, external regulation became necessary as part of the separation between operations, policy making and regulation. The main areas of regulation were interconnection, universal access/service and the management of limited resources. Licensing has also been a major tool in most countries with the purpose of either limiting the number of operators and ensuring that operators abide by rules and regulations, or just keeping track of the number and kinds of operators or simply extracting a fee on operation.

This paradigm is currently challenged by technological change. The ICT sector has undergone some dramatic changes in recent years, triggered by the development of new technologies and the convergence of existing ones, leading to a merging of markets and services. These developments affect traditional regulatory strategies, raising questions of how to deal with growing pressure to adopt a converged regulatory regime and how to successfully realize the potential of alternative network infrastructures. Indeed, the evolution of ICT technologies has had a decisive impact on the components of current regulatory design, and is also creating the need for changes and redesign. As a result, regulators and policy makers are aiming to keep track of new technologies and be able to respond "just in time" by adjusting their frameworks and legislation. Moreover, regulators may take advantage of the unique situation created by technological change to
provide access to unserved areas and to leverage information and communications infrastructures as tools for economic growth and competitiveness.

The technological trend

The technological development of ICTs can be seen as a two-stage process.

In the first wave of technological change, three main developments (digitalization, computerization, and packet switched technologies) had a radical influence on the ICT landscape and the development and formation of different technologies/applications. The most fundamental precondition for the development of any other technological change is digitalization. It makes it possible to harness synergies throughout the whole value chain and consequently enables the expansion of resources in the access and core networks in a technical and cost efficient way. Computerization is another fundamental development and the role of computers has been vital in the development of infrastructures and the deployment of network nodes as a replacement for switches and as devices adding intelligence to network nodes. Lastly, packet switched technologies have played an important role in facilitating more effective use of available resources in different network infrastructures and enabling platforms for multi service delivery in the same network, and thus real convergence.

As far as the second wave of technological change is concerned, three different trends may be identified: the emergence of the Internet Protocol, new infrastructures and convergence.

The deployment of IP in virtually all infrastructures and services enables the fundamental separation between the transmission layer and the service and application layer below. The emergence of new infrastructures is identified as the second technological trend and may take different forms: new transport and network infrastructures in current legacy communication networks, a transport and network infrastructure in current legacy infrastructures, which are not designed for communication (like power line communication), and new physical infrastructures using wireless and wired technologies like WiFi/WiMAX, optical fiber, and hybrid optical & electrical infrastructures. The third technological trend, convergence, goes beyond the specific communication sectors and has a cross-sectoral impact. Digitalization, IP and advanced communication protocols/technologies
enable different services belonging to separate networks to come together. Convergence can be expressed as the ability of different network platforms to carry essentially similar kinds of services and the coming together of consumer devices such as the telephone, television and personal computer. It is therefore not just about technology, but about services, new ways of doing business and of interacting with society.

Three major consequences

Fundamentally, this two-stage technological development within the ICT industry has had three major consequences.

The end of the layered networks model

In the traditional model ICT networks were vertically integrated and mainly operated by the same entity. Infrastructures were organized based on a "Layered Network Model" composed of consecutive layers: duct and mast level, cable and antenna level, transmission level, network level and application level. The interface between layers was technically standardized by protocols and commercially agreed in service level agreements and other business and contract standardized commitments. For example, one player on the transport layer could rent fibre from several dark fibre providers to span its network and would need similar performance standards from each to simplify its offer to the service layer. Today these layers tend to be disintegrated at different levels. This very transformation from a vertically integrated system to more open platforms has a massive impact on the market for ICT services.

The decentralization of intelligence

Traditional telephony was a highly centralizing technology. The "intelligence" in the network was located centrally (in the functionalities of the switch) and usually controlled by one organization. In its historic form, largely "dumb" devices (telephones) were attached to the network and these had only a limited set of functions. By contrast, in the IP network no single entity controls anything but the most basic transport and relationships with other networks. The service-providing "intelligence" is deliberately designed out of
the network architecture: as a result, the network is "dumb" and intelligence is at the edge of the network. For example, a computer accessing the network has a far more complex range of service functionalities in its application programs and this is not solely related to its size. The decentralized "intelligence" in IP networks has consequently allowed strong growth in innovative services, content and applications in the developed world context.

The divergence of infrastructure and services

Another significant market development is the separation of infrastructure and services. Formerly, infrastructure and service provision were integrated in individual companies. The same companies rolled out the infrastructures and supplied the relatively few services provided on these infrastructures (such as telephony). With digitalization, the technological potential for separating the different layers in the provision of communication services has increased. Moreover, this potential has increased further with packet switching technology. For example, the growth of e-Bay and Skype is the product of a lively market of providers in the service layer outside the vertically integrated domain of historic operators. The ongoing transition from large vertically integrated organizations (like incumbents and second national operators) to a small number of infrastructure providers feeding a mass of service-based companies is likely to mean that there will be a far greater number of horizontal players with trading between the different network layers in the market. Furthermore, whether due to market imperatives or regulatory pressures, significant numbers of historic operators are separating out their different operations into more or less free-standing subsidiaries.

Towards a new regulatory paradigm?

Regulation may be affected by technological developments in two different ways. Firstly, new technologies lead to the development of new services and modes of delivery unforeseen by existing regulation. Secondly, they affect the overall market structure and the level of competition by changing the conditions for supply or patterns of demands, which again affect the need for regulation.
Innovation and expansion capacity

To introduce the impact of overall technology trends on market and regulation, one may consider the development of new types of infrastructures and the increasing use of IP and other packet switching protocols. As they facilitate service convergence through the provision of common protocol, the two technology trends mentioned above imply competition between different types of players at the network level.

At the infrastructure level, the most important trend is the development of a new type of infrastructure. A growing number of infrastructures are available and the capacity of each of these infrastructures is increasing. The expansion of transmission capacities is related to technologies like: compression and the development of more efficient transmission protocols, modulation and coding of signals, software defined radio transmission and digital access technologies. For example, the impact of use of optical fibres is firstly related to a dramatic expansion in network capacity.

This tendency impacts service development (development of high bandwidth capacity services), and the cost structure of telecom networks. Furthermore, the use of optical material is impacting network convergence through capacity increases as optical telecom networks have the capacity to carry broadcasting services and optical broadcasting networks the capacity to carry telecom services, including broadband internet access. In addition to this use of optical fibres enables infrastructure sharing between telecom and electricity networks as power lines and optical fibres can be laid in the same ducts or even integrated in the same cables.

From the regulatory side, this new type of infrastructure is related to an increased spectrum range. Increased spectrum range is one of the key
drivers of the expansion of the transmission capacity in optical fibres, but is at least as important for growth in the capacity of wireless networks. It is, however, important to note that not all frequency resources are equally suited for the transmission of all applications. Therefore scarcity in certain frequency bands may persist, even if there are ample resources in other bands. The use of high frequencies eases the use of small cells in cellular networks. Capacity can therefore be increased, but the costs are also increased.

The increasing use of IP and other packet switching protocols IP/TCP is another element to be taken into consideration. For example, the dominance of IP as a transmission protocol increases interoperability between different services, as well as different service providers. This reduces barriers of entry, as it is easier to make a new service or new content available to a wide audience. Furthermore, through network intelligence, most functions including routing can be entirely separated from network operations. This enables a vertical separation of service provision from network provision.

Implications for overall market structure

Technology impacts the telecom market in many different ways. As pointed out above, new network technologies may be seen as process innovations, as they enable expansion of network capacity. On the other hand, expansion of capacity opens up the network for a wide range of new applications. For this reason, it is more meaningful to distinguish between different types of technology implications for market structure than different types of technologies. We will focus here on types of implications with an impact on the need for and design of regulations for the telecom market. These implications are horizontal integration and vertical separation.

New innovations have blurred the boundaries of the telecom sector. A wide range of new telecom service products have been created. Some of these products incorporate service elements from other sectors (such as IT or broadcasting). At the same time, digitalisation and the expansion of network capacities enable network convergence, namely the transmission of IT, telecom and broadcasting services on the same networks. The moving boundaries between telecom and relates sectors are best illustrated when one considers the layered network model outlined above.

Horizontal integration involves convergence between two or more of the different branches of the sector (IT, telecoms, broadcasting and other
Convergence, on the other hand, can take place in one or more of the three levels in the value chain (content/services, transport/software and equipment/hardware). The digitalization of voice and other communication services means that it is now possible to handle many different services on the same network (network convergence). Examples of these services include: cable telephony, internet via cable, IPTV, VoIP, triple play and 3G broadcasting. These trends do not imply the immediate unification of these different markets. Different services will continue to be transmitted on a number of competing networks using different technology platforms (wired and wireless). However, each type of network will have its own comparative advantages in providing particular services in a particular environment. Although a unified pure optical network providing all sorts of communication services may be the optimum solution in the long run, this will not materialize in the immediate future, particularly not in low and middle income countries.

The competition between network types will be shaped by the availability of existing network structures, as well as demographic factors such as customer density and the demand for particular services. It is a regulatory challenge to ensure fair competition without favouring particular technologies. If not properly designed, regulation can skew competition between different networks.

The vertical structure of telecom markets has undergone considerable changes since the 1980s. Previously, the telecom sector was dominated by national or regional monopolies controlling all levels of the value chain and with close ties to the national equipment industry. In some countries operators even produced parts of their own equipment. Since then the market has become much more disintegrated, and different levels in the value chain may be controlled by different companies. One reason for this is that use of digital transmission technologies and of the IP protocol has made it easier to separate the various functions. It has become easier to separate network and service provision. This enables the development of a market structure with a vertical separation of network operators and service providers, as seen in the internet market. This has created a market structure with different levels of competition within different market segments, and a supply structure with a wide range of companies representing different degrees of vertical integration. The first category only includes incumbent operators, as they are the only players with a fully developed fixed access network. The second category includes companies supplementing their own infrastructure by leasing raw infrastructure facilities from others. This enables them to maintain full control over all network functions. They may, however, also outsource part of their transmission by
use of switched interconnection to other networks. Mobile virtual network operators (MVNOs) belong to this category. Another possibility is to act only as a service provider and let another telecom company be responsible for all network operations. In this way some of the most important barriers to entry found in the telecom market are avoided. The last category includes companies from other public utility sectors with their own network facilities such as railway and electricity network companies. Such companies may wish to profit from their access to infrastructure without engaging in all segments of the value chain in an entirely new business area.

One of the major aspects of vertical separation is that it becomes possible to provide services without local presence. This implies that services like VoIP may be provided by companies that are outside the jurisdiction of the national regulator.

**Impacts on cost structure**

Although telecom networks were seen as natural monopolies with a limited scope for competition a few decades ago, it has become feasible to establish competition in most segments of the telecom market. The natural monopoly doctrine is largely based on cost concepts such as cost-subadditivity, increasing return to scale and economies of scope. New innovations have not only made substantial cost savings possible, they have also impacted the cost profile for telecom networks. From a market regulation perspective, the impact of new technologies on cost structure is important. In order to address this question, a rapid overview of the economics of the various network technologies at stake is given below.

To establish a copper based network demands substantial long term investments, particularly in the access network. Here the major cost driver is total cable length, which again depends on the number of connections and the density of customers. Therefore it can cost five times as much to connect customers in rural areas as in metropolitan areas. A major part of the costs are related to the laying of cables underground. Here substantial savings can be obtained by using ducts that can be used for several cables. The digging costs are highly dependent on the geo-type of the site. It should be noted that digging costs per kilometre are often much higher in metropolitan areas than on open land.

Cable TV networks are established to provide broadcasting services. The total costs for a cable TV network are somewhat lower than for a copper-
based telecom network. The costs for an upgrade in order to provide data services are comparable with those for upgrading telecom networks to xDSL. However, the share of fixed costs is lower.

Due to their very high capacity optical fibres have first been installed in the core network. This has reduced the costs of long distance communication to less than 1% of the former costs per traffic unit. This has implied that the costs of fixed network services are concentrated in the local loop and convergence between the costs of local and long distance communication. It follows that the installation of an optical fibre network involves substantial long term fixed costs and that there are very high levels of economies of scale and scope. However, the costs of end equipment are largely variable, as the costs of transmitters converters etc. depend on bandwidth capacity.

The cost of establishing a new wireless network are considerably lower than for a fixed network, as the costly last mile can be completely bypassed. 2G networks in particular have proved to be a cost effective viable alternative for provision of telephony. The establishment of 3G networks is, however, much more costly, particularly in low density areas, as maximum cell size is much smaller than for 2G services. In high density areas the costs per bit may, in some cases, be even lower than in 2G networks. The major cost driver for 2G and 3G networks is geographical coverage. When density of use increases a certain point, usage becomes the major cost driver, and the fixed costs constitute a lower share of the total costs than for fixed networks. The lifetime of the investment is also shorter.

A Wi-Fi network can be set up at very low cost and demands no long term investments. Wi-Fi is often seen as an alternative to 3G as it offers higher bandwidth capacity at lower costs. At present the limited range of coverage implies that Wi-Fi can not be used as a substitute for the entire local loop in rural areas. The WiMAX standard provides similar functionality as Wi-Fi, but with a much higher range. In contrast to Wi-Fi, WiMAX uses licensed frequency resources in some cases, which may add to the costs, and also make it more difficult for small local operators to use this technology.
Conclusion: an example of regulatory challenge

An implicit idea of this paper is that, to understand technological implications on the level of regulatory issues, their impact on regulatory foundations must first be analysed (see figure below). This calls for a transversal analysis, with an emphasis on the principles embedded in regulations and underpinning them, to understand their probable consequences on well-known regulatory areas such as licensing, universal access and interconnection.

Why interconnection (still) matters

In enabling the creation of new alternative communication networks, new technologies confirm interconnection as an important tool for the facilitation of competition in both services and facilities. Convergence and the increasing importance of packet switched services are bound to affect the kind of interconnection products developed. These products include new network products in both the access and the core network.

They also raise challenging issues: what interconnection service products are relevant for the provision of voice telephony (including mobile, fixed and VoIP), internet access, broadcasting services etc.? What interconnection products will become relevant in next generation networks (for example, constant bitrate, variable bitrate and available bitrate)?

Another issue related to the 'disconnect' between infrastructures and services is the changing environment for interconnection. Interconnection basically depends on two main questions: standards and the incentives for operators to interconnect (including the regulatory obligations on operators).

The standardization question (see below) has partly become more transparent with the layered structures of communication networks and partly more complicated because of the abundance of standards for the different layers. The question of interconnection regulation becomes more diversified with the many different forms of interconnection agreements regarding the different layers in the communications processes.

As a consequence, switched interconnection of voice telephony and the related charging mechanisms will, de facto, become less important.
As phone calls will only be one out of a number of different types of communication services in a packet switched network, the core issue will be interconnection between unbundled network elements and exchange of data in an IP network, rather than mediation of voice calls between different networks. Moreover, the current regulatory framework for interconnection focuses on interconnection of telecom networks, while for instant broadcasting networks are either unregulated or subject to different types of regulation. Convergence implies that harmonisation is necessary in order to achieve technology neutral regulation.

**Should regulation be cost-based?**

As mentioned earlier, the change in technology from circuit-switched to IP-based networks affects the cost of providing and running networks. Consequently, regulators must be aware of new cost structures. They will need, if they don't consider moving to something like capacity-based interconnection rules, to revise the figures they determine (and the basis of their determinations) to take into account the change in the nature of the networks.

IP telephony for example, has dramatic impacts by reducing the costs of providing voice telephony services. Technology is steadily decreasing the cost of networks, while the costs of billing and customer service may be falling more slowly. This creates strong downward pressure on retail prices. As a result, POTS operators may be obliged to undertake unanticipated write-offs of the value of their existing assets. In African countries, this issue may be relevant, as many new entrants are already IP-centric (i.e. use IP in their core backbone networks), as opposed to incumbents that are only starting to move away from their legacy systems and upgrade to IP-based backbones.

**Should regulation be sector specific?**

The question of sector specific and/or general competition regulation is related to two intertwined issues – firstly, the market implications of technology convergence, and secondly, the development of the telecom markets towards more 'normal' market conditions. The reason that they are intertwined is that convergence – insofar as it opens up telecom markets to increasing competition, provides new modes of access and eases the
restrictions on radio frequency usage – will contribute to a 'normalization' of the telecoms area.

The present sector specific regulation in telecoms was implemented in connection with the liberalization process in the area. The main fields of sector specific regulation are universal service/access, interconnection and the regulation of limited resources (radio frequencies, rights of way and numbers). Although this may not have been generally agreed from the beginning, a main goal of sector specific regulations has been to reach a stage in market developments in the area, where special regulation can be lifted. This applies to interconnection when it is clear that unregulated market mechanisms are able to see to the optimal spread of access technologies in the specific markets and where, at least, the asymmetric parts can be disbanded once it can be determined that there is sufficient competition between different providers. An open question remains, however, whether interconnection regulation of the relations between equal sized operators must continue or whether network effects will automatically lead operators towards interconnection. It finally applies to the regulation of limited resources if new technological solutions will partly solve the scarcity issues. However, as there always will be some kind of exclusivity aspect to these questions, some kind of regulation (or self-regulation) will always be necessary.

Technology neutrality and standardization

Technology neutrality is a prescription for avoiding (too much) public intervention in the choice of technology solutions in markets. It has become a basic guidepost for regulatory intervention around the world. Technology neutrality is partly based on technology convergence, as similar services can be supplied on different technology platforms, and as regulations should seek to promote competition between different technology solutions, instead of 'picking a winner'. However, the prescription for technology neutrality goes beyond technology convergence, as it is based on a more profound policy of limiting public intervention in the directions of technology development. The idea is that market mechanisms are better at making these choices, and that the risks of 'wrong' technology choices by the public sector are substantial.

Technology-neutrality is still considered as a fairly good regulatory principle in a converged environment. Neutrality ensures a fair and predictable regulatory regime, flexible enough to embrace technological
changes and market developments. The question of how to adopt a technology-neutral interconnection regime, in a context where IP-based networks are becoming the main voice traffic carriers, is of growing importance for regulators. The spread of IP telephony raises dramatic interconnection payments issues. In a classic direct regime interconnection payments are possible because of the regulatory requirement of cooperation between origin, transit and termination operators. In a VoIP context, levying different levels of interconnection charges may simply not be possible for terminating operators due to the use of virtual numbers and the difficulty of locating the origin of calls.

Standardization activities have changed immensely since liberalization started in the telecoms sector. The focus has shifted from network aspects towards application and service issues. With growing convergence between telecoms and IT, securing interoperability between applications and services is a key task. This does not mean forcing private companies and citizens to use specific standards, but there can be important public assignments in promoting the use of standards and specifically open standards in and between public organizations, thus also influencing the use of standards not only between public institutions and citizens and private enterprises, but also among citizens and private enterprises. These kinds of standardization activities at a national level, specifically on the application and service levels, should not seek to restrain the use of new standards. The aim should be to facilitate the interoperability between different applications and services. The approach should be open to the introduction of new standards and to promote the use of open standards. The standardization activities should thus be seen as facilitation activities for market development.