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Abstract

In June 2004, the European Commission (EC) issued an "Information and Consultation Document" (European Commission 2004) that discussed how the Regulatory Framework of the European Union (EU) should be adapted to accommodate Voice over IP (VoIP) and invited relevant parties to comment on the Consultation Document. In our study, we use the responses of the different market parties to identify how incumbents seek to foreclose the market for VoIP telephony. From these responses we conclude that foreclosure is not only attempted by setting high prices for the use of infrastructure, but also by the strategic choice of infrastructure technology, which raises the cost of entry. We label the latter form of foreclosure "technological foreclosure" – as opposed to "market foreclosure". A simple modeling exercise shows that regulators seeking to avoid market foreclosure might trigger technological foreclosure. We argue that this has happened with the unbundling of the local loop in the EU, and that it might happen again with the transition to VoIP. We conclude that the current rights and obligations assigned to telecom companies effectively protect incumbents from competition by VoIP entrants. Moreover, the inaction of regulatory authorities when it comes to numbering and communication protocols is advantageous for incumbents and might obstruct the provision of new services in the future.

1 Introduction

The rising popularity of Voice over Internet Protocol (VoIP) not only challenges traditional telecommunications companies, but also puts National Regulatory Authorities (NRAs) to the test. NRAs have to modernize the regulation of the telecommunication sector and, at the same time, they have to ensure a smooth transition from the Public Switched Telephone Network (PSTN) to VoIP. Swift action is important because the potential gains from VoIP are large – and so are the vested interests of telecom operators.

Entry by VoIP providers is problematic for two reasons. First, the regulation of the telecom sector is designed specifically for the Plain Old Telephone System (POTS). A consequence is that it is not always clear what the rights and obligations of VoIP providers are. In addition, some of these obligations, such as in-line powering, do not make much sense and are very costly for VoIP providers to comply with. A second problem encountered by VoIP entrants is that interconnecting their networks with those of the incumbent telecom firms is difficult and costly. In this study we focus on the latter type of problem (although we sometimes also comment on the former).

In order to get a systematic overview of what barriers to entry are experienced by VoIP operators, we have conducted a systematic analysis of recommendations for the EU's telecommunication policy made by VoIP operators, telecom incumbents, Internet Service Providers (ISPs), and NRAs. These recommendations were given in response to the European Commission's (EC) Information and Consultation Document on VoIP (European Commission 2004). With the publication of this Document, the EC intended to stimulate the discussion about the regulatory treatment of VoIP in Europe. In the Document, the EC applied the EU Regulatory Framework ('EU Framework') to the provision of VoIP and characterized the rules guiding the general authorization of VoIP and the public policy requirements that might affect VoIP providers. These requirements are related to consumer protection and public safety, network interconnection and interoperability, as well as numbering.

We find that the strategies of the major participants offering or intending to offer VoIP widely differ. We identified three different strategies: new (alternative) VoIP providers, traditional telecommunication operators offering VoIP and (cable) multiple service operators (MSOs). Alternative VoIP providers have indicated that they will benefit from lower regulatory and market barriers to entry. They are opposed to public policy obligations on their VoIP offerings but at the same time in favor of keeping these obligations for traditional telecommunication operators. New VoIP providers consider the problem of interconnection between PSTN operators and VoIP providers as the central problem for their development.

Why does VoIP have the potential to cause structural change in the market for telephony? First, VoIP is cheaper than PSTN, has the potential to deliver a higher quality of service (QoS), and enables a wide range of new services. For these reasons it is likely that also major telecom operators will eventually switch to VoIP. Second, VoIP can be applied as a layer over the internet, which makes telephony independent from the physical infrastructure. In particular, VoIP enables telephony over DSL, Cable, and (W)LAN. Not only will this development increase competition for traditional telecom operators because other infrastructures, notably Cable, will also offer telephony services, traditional operators will also face competition on the local loop itself. This kind of competition comes in roughly two forms. First, VoIP can be delivered directly over the internet using a softphone (e.g. Skype) or via an adaptor

connected to the internet (e.g. Vonage). Second, ISPs can offer VoIP as a service parallel to an internet connection (e.g. Tiscali).

The four market structures implied in the discussion above are displayed in figure 1. The upper-left panel of the figure shows the traditional (European) structure of the telecom market. A formerly state-owned operator is in control of the local loop and provides POTS and nowadays often a DSL connection as well.[1] On top of POTS, carriers like Tele2 offer telephony by means of carrier preselect. The upper-right panel shows a scenario in which telephony becomes a fully layered service. The core-business of traditional incumbents then becomes the provision of a (wireline) infrastructure. The lower-left panel displays a scenario in which hardly anything changes – except for migration by incumbents from PSTN to VoIP. This situation might arise when government regulation effectively prevents the layered provision of telephony, or when incumbents are able to foreclose the telephony market, for example by keeping interconnectivity difficult and expensive. The panel at the bottom-right of the figure represents a situation in which ISPs bundle internet access

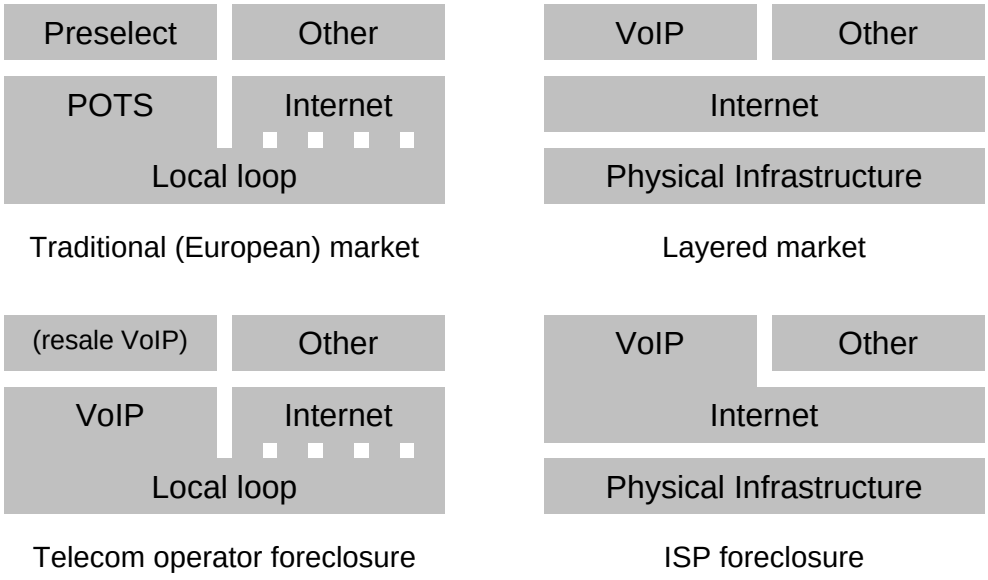

Figure 1 Scenarios for the structure of the market for telephony

with telephony. A possible advantage of this model over the layered model is that ISPs have greater control over the reliability and quality of the connection through specific Service Level Agreements (SLAs) with the infrastructure provider.

The layered model is probably the most desirable from the consumer's point of view. Although there currently are some drawbacks to this model, like the reliability of internet connections and the lack of access to emergency services, the layered model will arguably offer the best basis for the provision of new services in the future. However, the European experience with the unbundling of the local loop demonstrates that incumbent operators can successfully use their control over infrastructure to prevent competition in services based on that infrastructure. Widespread adoption of the layered model in Europe requires NRAs to be more effective and alert than they were during the unbundling of the local loop.

[1] The unbundling of the local loop has not been successful in Europe (see subsection 4.2)

We use a simple modeling framework to get an understanding of how the intervention of NRAs influences the behavior of incumbents. The approach followed by European NRAs during the unbundling of the local loop focused on regulating the prices charged by the traditional telecom operator for the use of infrastructure. Our modeling exercise shows that this type intervention of can have unanticipated effects on the incumbent's choice of infrastructure technology. If excessive prices for the use of infrastructure ("market foreclosure") are forbidden by the NRA, incumbents may choose to base their infrastructure on a technology that raises the cost of entry ("technological foreclosure"). This kind of behavior poses a dilemma for the NRA: technological foreclosure might be more harmful for consumers than market foreclosure if technological foreclosure leads to the adoption of an inferior infrastructure technology. We show that there NRAs might be able to simultaneously prevent market and technological foreclosure through strategically regulating the price of infrastructure use.

The next section will discuss how the technological differences between VoIP and POTS matter for the structure of the market for telephony. Section three contains the modeling exercise that demonstrates how intervention by NRAs can lead to technological foreclosure. The EC's policy initiatives towards VoIP are outlined in section four. Section five presents empirical evidence on the relevance of foreclosure in the case of VoIP. Additionally this section contains a summary of the European experience with the local loop unbundling.

2 The technological characteristics of VoIP

From a technological point of view, VoIP differs from POTS in four important respects: data transport, modular design, network architecture and signaling protocols, and numbering. Each of these four factors has the potential to alter the nature of the market for telephony significantly. Below, we provide a detailed description of the differences between VoIP and POTS and their implications for the telephony market.

2.1 Data transport

The first distinction between VoIP and POTS concerns the way in which (voice-)data are transported. VoIP departs from traditional telephony in that calls (or 'sessions') do not require a dedicated time slot on a wire. Instead, VoIP allows voice packets belonging to the same call to be sent over different routes through a network and at irregular time intervals. The absence of a need for fixed routes substantially reduces the complexity of extending a network (Frey and Zenner 2004 pp. 203-204). In addition, the absence of fixed timeslots implies that silences no longer have to be transmitted. These two features can make packet-based telephony substantially cheaper than circuit-based telephony.

The disadvantage of packet-based telephony is that it is vulnerable. As there's is no longer a fixed allocation of bandwidth for a session, there is no guarantee that voice packets arrive on time, arrive in the right order, or arrive at all. On a busy network, the queuing of packets is a source of delay unknown to circuit-based telephony. The variation in the interval at which packets arrive, or 'jitter', is another VoIP-specific source of delay. For these reasons, it has proven to be challenging for VoIP providers to achieve the same QoS as PSTN. Also the reliability of IP networks is does not come close to the reliability of traditional networks. The 99.999% of service availability of traditional telephony is much higher than the 94% availability of the best private data networks (Chong and Matthews 2004). Despite these

vulnerabilities, however, it is likely that further improvements in bandwidth and protocols will eventually cause the QoS of VoIP to exceed that of PSTN.

The difference in operating cost between circuit-based and packet-based technology will probably force even large telecom operators to migrate to VoIP. The potential of VoIP to provide a quality of service higher than POTS will only add to this incentive.

2.2 Modular design

The second aspect that distinguishes VoIP from POTS is layering. Being IP based, VoIP transport protocols[2] are part of the network-layer of the OSI reference model.[3] The advantage of layering is that for each layer protocols can be developed that function independently of the other layers, except for the layers directly below or above that layer. This means that VoIP protocols can be designed without having to take into account the characteristics of hardware. As a consequence, telecom operators using VoIP are less dependent on the manufacturers of installed hardware. The use of open standards not only stimulates competition between suppliers, but it also facilitates innovation e.g. through the entry of new firms.

Similarly, at the higher layers, software can be developed that functions independently from the exact VoIP protocol that is used. A significant implication of layering is that VoIP can be used for future software applications that might be very different from ordinary telephony. This contrasts sharply with POTS: adding even a trivial new service on a PSTN is complicated and expensive.

The modularity of VoIP makes it a potential threat for incumbent telecom operators. A VoIP service only requires a sufficiently fast and reliable connection to the internet, but the physical form of this connection is irrelevant for the service. In principle, people can continue to use a VoIP service when switching from, for example, ADSL-based to cable-based internet.

2.3 Network architecture and signaling protocols

A third difference between VoIP and POTS is that VoIP can be used in a variety of network architectures, while POTS needs a hierarchical network structure. In a PSTN, a hierarchy of switches takes care of assigning time-slots to a call. The state of the call is centrally registered in order to avoid maintaining empty slots.

Unlike POTS, VoIP does not require a hierarchically structured network for two reasons. First, VoIP packets do not require a unique timeslot in order to travel to their destination, so no hierarchy is required to set up a call. Second, the call-state only has to be known at the endpoints as inactive connections do not use up any bandwidth.

The architecture of a VoIP network is interdependent with the signaling protocol used for setting up and terminating calls.[4] The most important signaling

[2] A typical VoIP packet is based upon the (Reliable) User Datagram Protocol, or (R)UDP. UDP is less reliable than the Transmission Control Protocol (TCP/IP) as missing or damaged packages are not retransmitted under UDP. With real-time data, however, retransmission does not make sense as the retransmitted package will arrive too late to be of any use. On top of UDP, application data is encoded using the Real Time Transport Protocol (RTP). The actual voice data come after the RTP part of the package (Davidson and Peters 2000, pp. 181-183).

[3] OSI stands for Open Systems Interconnection model and was developed by the International Organization for Standardization (ISO). Its seven layers are physical, link, network, transport, session, presentation, and application.

[4] The protocols for setting up and terminating VoIP calls differ from the protocol used for PSTN.

protocols are H.323, Media Gateway Control Protocol (MGCP), and Session Initiation Protocol (SIP). The oldest and most widely used protocol is H.323, published by the International Telecommunication Union (ITU). An H.323 architecture usually involves gateways that connect to PSTNs or other networks and gatekeepers that manage traffic between gateways and H.323 enabled phones. In principle, all the intelligence needed for making a call resides in the endpoints: it is possible to connect one H.323 phone directly to another one without interference by a gatekeeper. Another way for connecting one phone to another is through proxy servers.

MGCP is a protocol developed by the Internet Engineering Task Force (IETF) that is used in a centralized VoIP network. The typical architecture of such a network involves a call agent that controls gateways and manages calls. The call agent uses MGCP to communicate with gateways. In this setup, gateways only transform TDM signals into packets and vice versa – all call management is performed by the call agent. A piece of modular software called 'softswitch', which is embedded in a call agent, allows the call agent to communicate directly with endpoints. These may use a variety of signaling protocols, such as SS7 (PSTN), H.323, or SIP (Durkin 2003). The obvious advantage of this architecture is its flexibility: MGCP enables a smooth transition from a TDM network to a VoIP network.

SIP is another protocol developed by the IETF. There is some resemblance between SIP and H.323. Like H.323, SIP can be used for direct connections between SIP enabled phones and for connections via proxy servers. Furthermore, as both protocols use RTP for data transport, their QoS characteristics are identical. The main distinction between the two protocols is that SIP is much simpler than H.323 (Zahariadis and Spanos 2004). Whereas SIP's design is highly modular and complements existing internet protocols, H.323 functions more as an umbrella for ITU standards.

The umbrella-approach not only makes H.323 a complex protocol, but it also prevents third-parties from developing new H.323-based applications: only ITU developed standards are incorporated in H.323 and some of these standards are proprietary. The modular design and open nature of SIP makes it much simpler for outsiders to develop extensions. In addition, SIP is a text-based protocol similar to HTTP while H.323 uses binary encoding.

Unlike MGCP, H.323 and SIP can be used not only on the networks of telecom carriers, but also on the internet. One important implication of this is that a separate telephone connection becomes redundant for users with broadband internet access. By using software-based phone, or softphones, people can make VoIP telephone calls over the internet. VoIP-to-VoIP calls of this nature are free in the sense that they do not require expenditure on top of the expenditure on the internet connection. Of course, the popularity of this type of telephony depends to a large extent on the possibility and cost of making a softphone call to a POTS telephone.

Of particular interest are Peer to Peer (P2P) softphones like Skype. P2P applications have the advantage that a connection between two endpoints does not require a central server. Only the user directory used often is centrally maintained.

Within a PSTN, signaling from one switch to another is done using the Signaling System 7 (SS7, or C7 in Europe). SS7 is an out-of-band signaling method, which means that data required for call management are transported as data-packets over a different wire than the TDM voice data are. Out-of-band signaling yields more reliable and faster data exchange than in-band signaling, because in-band signaling requires transmission of tones rather than data-packets. Out-of-band signaling does not makes sense when both voice and signaling data are transferred as packages, therefore VoIP signaling usually is in-band.

However, this is also changing. Skype, for example, uses a special protocol to maintain a distributed directory of users, such that calls can be made purely on a P2P basis without a centralized directory service.

VoIP can be based on a variety of network architectures and signaling protocols. Which architecture(s) and protocol(s) will eventually become the industry standards depends for a substantial part on the choices large telecom operators are currently making. In particular, incumbent operators might try to protect their market share by avoiding a decentralized SIP-based architecture.

2.4 Numbering

POTS numbers are centrally registered and conform to the ITU's E.164 numbering plan. An E.164 number can be called from any PSTN in the world. For VoIP, no numbering convention is accepted yet.

A VoIP call can only be set up if both endpoints know the IP address of the other endpoint. So in principle, the internet's Domain Name System (DNS) system functions as an elementary numbering plan for VoIP. This approach has some drawbacks. First, many internet connections use temporary IP addresses. ISPs often assign a random IP address whenever a customer connects to the internet. They do this in order to make more efficient use of the IP addresses they own. This problem can be overcome in two ways: VoIP users can get an email-like address (e.g. `bas.straathof@voipcorp.com`) from their VoIP provider or they can request an IP address specifically intended for VoIP. The benefit of the latter solution is that it enables number portability: it allows you change your VoIP provider without changing your address.

The ITU and the IETF are currently working on a system called ENUM, which couples E.164 telephone numbers to IP addresses using the DNS (Huston 2002). ENUM assigns a unique IP address to each telephone number. All these addresses will be part of the `e164.arpa` domain and will contain the telephone number in reverse order. For example, the E.164 number +31402472053 will be associated with the following IP address: `3.5.0.2.7.4.2.0.4.1.3.e164.arpa.` The reverse ordering facilitates a hierarchical administration of the `e164.arpa` address. For example, all digits before the last two are the responsibility of the country indicated by those last two digits (here The Netherlands).

An `e164.arpa` address not only connects an E.164 to a VoIP address, but also it can also connect to an email or web address.[5] This functionality allows the user to, for example, receive a short text message sent from a cellular phone by email.

The reasons why ENUM is not yet implemented are political rather than technical. The controversy is about who is going to populate the URIs (Huston 2002; Goth 2004). The original intention of ENUM was to give this authority to end-users (possibly through service providers). This version of ENUM is usually referred to as "User ENUM" or "Public ENUM". However, the telephone carriers, united in the ITU, wish to get exclusive control over the URIs – just like they control E.164. This version of ENUM is known as "Carrier ENUM" or "Infrastructure ENUM". Obviously, giving full control to incumbent telecom operators would not exactly increase competition in the telecom sector.

[5] For example, `3.5.0.2.7.4.2.0.4.1.3.e164.arpa` could refer to the following Universal Resource Identifiers (URIs): `sip:bas.straathof@voip.softphone.com`, `mailto:s.m.straathof@tm.tue.nl`, and `http://fp.tm.tue.nl/medewerk/s.m.straathof/`.

Another issue concerns the use of the `.arpa` domain, which is controlled by the US government. An alternative, more neutral, domain would be `.int`.

3 Technological foreclosure

The transition from circuit-based to packet-based telephony seems to be inevitable because of VoIP's scope for cost reduction and innovation, but as has been discussed in the previous section, the technological details are yet to be determined. However, the devil is in these details: companies that currently have control over the infrastructure are likely to influence which protocols and numbering systems will become the standards of VoIP in the future. By choosing standards that raise the cost of interconnection, incumbents in the 'upstream' infrastructure market can deter entry in the 'downstream' market for VoIP. Particular strategies that raise the cost of entry involve poor support of the SIP protocol and the establishment of carrier-ENUM. In this section we will present a simple modeling exercise that illustrates how the incumbents' choice of technology is influenced by how the NRA prices wholesale access to the local loop.

We label the phenomenon that a monopolist in an upstream market chooses the infrastructure technology in such a way that entry is deterred in the downstream market as 'technological foreclosure'.[6] Technological foreclosure occurs when market foreclosure is not possible or impractical. If the upstream monopolist has complete control over the downstream market, the monopolist will simply choose the most efficient (the "technically superior") technology and will restrict supply to competitors in the downstream market. When the monopolist has no full control over the downstream market, for example because of interference by the NRA, then the monopolist has an incentive to choose a technology in the upstream market that raises the cost of entry (or the cost of migration to the new technology) in the downstream market. If the NRA's actions are limited to setting a price ceiling for the intermediate good, then the NRA faces a trade-off: setting a low price ceiling (e.g. cost based) will trigger technological foreclosure, while setting a high price ceiling will lead to market foreclosure.

Technological foreclosure is closely related to technological tying (Gilbert and Riordan 2005). Technological tying occurs when the manufacturer of an essential component of a system designs this component in such a way that it will work better with the firm's own non-essential components than that it will work with non-essential components from competitors. Technological foreclosure differs from technological tying in that technological foreclosure does not require a degree of incompatibility between the infrastructure technology and the entrant's products. Both technological foreclosure and technological tying are examples of strategies in two-sided markets (Rochet and Tirole 2004).

The principle of the NRA's dilemma can be illustrated with a simple Cournot duopoly framework in which two firms compete by choosing output levels. Suppose firm *M* is a monopolist in the upstream market that competes with firm *E* in the downstream market. Both firms offer identical goods in the downstream market. For simplicity, assume that one intermediate is costlessly transformed into one final good. The cost of producing one intermediate good equals *k*. Without interference of the NRA, firm *M* will refuse to supply intermediate goods to firm *E*.[7] In order to prevent

[6] An overview of the literature on foreclosure in general is given by Rey and Tirole (2005).

[7] When the downstream market would be heterogenous, firm *M* could have an incentive for supplying firm *E* because it raises total demand for the intermediate product.

market foreclosure, the NRA will set a price ceiling *c*, such that firm *E* will enter the downstream market. The quantities sold on the downstream market are *x* and *y*, for firm *M* and firm *E*, respectively. Demand for the final good is implied by the price function:

$$p(x,y) = a - b(x+y) \tag{1}$$

The profit of firm *M*, π_M, consists of the revenue from the final goods market and the intermediate market, minus the cost of producing intermediate goods, and minus the fixed cost of migration to a new technology, *m*. The profit of firm *E* equals revenue from the final goods market, minus the amount spend on intermediates, and minus the cost of entry, *e*.

$$\begin{aligned} \pi_M &= p(x,y)x + cy - k(x+y) - m \\ \pi_E &= p(x,y)y - cy - e \end{aligned} \tag{2}$$

3.1 Regulated Cournot duopoly

Let us start with the case in which the regulator sets a price ceiling that allows the firm *E* to enter the market. The reaction functions of both firms are, as usual, obtained from the first order conditions for profit maximization. Note that *c* is exogenous to both firms.

$$\begin{aligned} x &= \frac{a-k}{2b} - \frac{1}{2}y \\ y &= \frac{a-c}{2b} - \frac{1}{2}x \end{aligned} \tag{3}$$

The quantities and price corresponding to the Cournot equilibrium are:

$$\begin{aligned} x &= \frac{a-2k+c}{3b} \\ y &= \frac{a-2c+k}{3b} \\ p &= \frac{1}{3}(a+k+c) \end{aligned} \tag{4}$$

From the equilibrium quantities and price, the Cournot profits can be derived.

$$\begin{aligned} \pi_M &= \frac{(a-5k+4c)(a-2k+c)}{9b} - \frac{(c-k)^2}{b} - m \\ \pi_E &= \frac{(a-2c+k)^2}{9b} - e \end{aligned} \tag{5}$$

3.2 Market foreclosure

The upstream monopolist can achieve foreclosure of the downstream market by reducing supply of the intermediate good. The price corresponding to the optimal

(from the monopolist's point of view) amount of the intermediate good results from an additional first-order condition.

$$\frac{\partial \pi_M}{\partial y} = \frac{\partial p}{\partial y} x + c - k = 0 \Rightarrow c = bx + k \tag{6}$$

Each additional unit of *y* costs *k* to produce and reduces revenue with *bx* because of the decline in the price, hence $c = bx + k$.

Insert this price into the reaction function of firm *E* and substitute for *x* using the reaction function of the other firm to get $y = 0$.[8] The corresponding output and profit of firm *M* are $x = (a-k)/2b$ and $\pi_M = (a-k)^2/4b - m$, respectively. With firm *M* having monopolized the downstream market, all innovation in the downstream market will have to come from this firm.

3.3 Technological foreclosure

Suppose the incumbent has the choice between two variants of a new upstream technology, *A* and *B*. The two technologies differ with respect to the opportunities they offer to entrants in the downstream market. Entrants can start producing final goods based on type *A* intermediates without high up-front investment. The cost of entry is much higher when the incumbent chooses technology *B*. One can think of technology *A* as having a highly modular design that is based on open standards, which makes it easy for entrants to develop a final good based upon intermediates of type *A*. The production of final goods based on technology *B* requires access to the (proprietary) standards of the incumbent, which makes it costly for an entrant to develop a final good.[9] The cost of entry when the incumbent has chosen *A* are e_A, the cost of entry for technology *B* are e_B, with $e_A < e_B$. Assume that the migration cost of the incumbent to technology *B* are higher than the migration cost associated with technology *A* ($m_A < m_B$), otherwise the incumbent would always choose *B*.

If the NRA is not expected to put a price ceiling on *c*, then firm *M* will choose technology *A* in order to save on migration cost. In this case, the incumbent prefers market foreclosure over technological foreclosure. When the NRA does interfere in the downstream market, it might become attractive for firm *M* to choose technology *B* if that would prevent the entry of firm *E*. Whether firm *E* will indeed enter the market depends on both the choice of technology by firm *M* and the price ceiling set by the NRA. The condition for entry is

$$\pi_E(T, c) = \frac{(a - 2c + k)^2}{9b} - e_T > 0, \quad T \in \{A, B\} \tag{7}$$

The highest price ceiling compatible with a duopoly can be found by solving the expression above for *c*.

$$c^E(T) = \frac{1}{2}\left(a + k - 3\sqrt{be_T}\right) \tag{8}$$

[8] As entry requires fixed cost of an amount *e*, a lower *c* will be sufficient to prevent entry.
[9] In the analysis below, we assume that firm *E* does not have to pay royalties to firm *M*.

Here, $c^E(T)$ is the highest intermediate price for which entry is profitable if firm *M* chooses technology *T*. The maximum price ceiling is lower for technology *B* than it is for technology *A*.

If the price ceiling is set such that firm *E* will enter only when firm *M* chooses technology *A*, then firm *M* might have an incentive to pick technology *B*. The higher cost of migration might be offset by the benefits of obtaining a monopoly. The exact condition is

$$\pi_M(B) - \pi_M(A,c) > 0 \tag{9}$$

The maximum price ceiling at which it is profitable for firm *M* to choose technology *B* can be found by substituting for both profit rates and solving for *c*.

$$c^{TF} = \frac{1}{26}\left(31k - 5a - 3\sqrt{13(a-k)^2 - 3(a+k)^2 - 52b(m_B - m_A)}\right) \tag{10}$$

If the price ceiling is higher than the threshold c^{TF}, then it is more attractive for firm *M* to have a duopoly with technology *A*, than to be a monopolist with technology *B*. Like with market foreclosure, all innovation in the downstream market will have to come from firm *M*, only now the scope for innovation is less because of an inferior upstream technology.

Technological foreclosure poses a dilemma for the NRA. If the NRA sets the price ceiling too high firm *E* will not enter the market, but when the NRA sets it too low firm *M* will choose technology *B*. There are two strategies the NRA can follow in order to simultaneously prevent both market foreclosure and technological foreclosure. The first strategy is to set a price ceiling that is high enough to discourage firm *M* from choosing technology *B*, while it is low enough for firm *E* to enter the market.

$$c^{TF} < c < c^E(A) \tag{11}$$

If it is possible to set *c* within this range, both market foreclosure and technological foreclosure can be prevented by the NRA. Although foreclosure might be prevented, this strategy is likely to be suboptimal as firm *M* still charges a high price for its intermediate products. This situation can therefore be described as partial market foreclosure. Firm *M* will be the most likely innovator in the downstream market because its profitability is higher.

Second, the NRA can also prevent foreclosure by setting an extremely low or even negative value for *c*. A very low price ceiling might induce firm *E* to enter the market even when firm *M* chooses technology *B*. This happens when $c < c^E(B)$. As technological foreclosure does not work in this situation, firm *M* will always choose technology *A*. A refined variant of this strategy takes the form of a lower price ceiling for technology *B* than for technology *A*, enabling entry for both technologies without having to enforce an extremely low price ceiling in the latter case.[10]

The following table summarizes the strategies for the NRA. The first and second columns describe the policy by the NRA, the third column describes the

[10] Setting an extremely low price ceiling might have undesirable consequences. For example, firm *M* might be forced to lower the quality of the intermediate product.

technology chosen by the upstream monopolist, the fourth column indicates the type of foreclosure that arises. The fifth column gives a qualitative judgment of the kind of innovation that is likely to occur.

Table 1 Intervention Strategies NRA

Regulation	Condition	Technology	Foreclosure	Innovation
none	$c^E(A) < c$	*A*	market	by incumbent
high ceiling	$c^{TF} < c < c^E(A)$	*A*	partial market	primarily incumbent
low ceiling	$c^E(B) < c < c^{TF}$	*B*	technological	none
very low ceiling	$c < c^E(B)$	*A*	none	all parties
ceiling contingent on technology	$c < c^E(A)$ if A $c < c^E(B)$ if B	*A*	none	all parties

4 The New Regulatory Framework (NRF) and the Consultation Process on VoIP

4.1 The NRF for electronic communications

The New Regulatory Framework (NRF) consists of five different directives[11]. It has been based on the vision of the telecommunication sector in which different rights and obligations are assigned to different types of telecommunication services, in particular to Electronic Communication Service (ECS), Public Available Telephone Service (PATS), and Universal Service (US). For the definition of these three types of services are only two of major importance namely the Framework Directive (in particular Art. 2(c)) to describe ECS and US and the Universal Service Directive (in particular Art. 2(c)) to describe PATS and Art. 8, Art. 3.(2) and Art. 4(1) to characterize US. While ECS is only lightly regulated, the obligations and rights for providers of PATS and US are substantial.

Even if the NRF claimed to be "technologically neutral", the different Directives allowed for some leeway in the implementation of new technologies. Based on Art. 4(2) of the Universal Service Directive, providers of universal services have important advantage as that they are free to choose a particular technology as long as universal service obligations are met. This implies that suppliers of universal services could gain a strategic advantage over providers of ECS and PATS as the latter have to ensure compatibility with the technology used to by operators providing universal services.

The NRF does not explicitly deal with the strategic behavior of incumbent companies such as foreclosure but refers to the Competition Directive (2002/77/EC) and in particular to Article 82 (b) of the EC Treaty. The Directive states that exclusive

[11] These five directives are: the Framework Directive (2002/21/EC) and four specific directives, being the Authorisation Directive (2002/20/EC), the Access Directive (2002/19/EC), the Universal Service Directive (2002/22/EC) and the Privacy Directive (2002/58/EC). Furthermore, the Competition Directive (2002/77/EC) is applicable.

and special rights for the provision of telecommunication services and networks should not have the "effect of permitting a dominant undertaking to limit 'production, markets or technical development to the prejudice of consumers'". However, the Competition Directive also states that the Directive has to be adapted not only to the further opening of the telecommunication market, but also to recent technological developments in the market.

As the Competition Directive addresses different forms of strategic behavior ex post, ex-ante remedies are required in cases in which companies have significant market power (SMP). In these cases, ex ante remedies are proposed under the Access Directive and (in specific circumstances) under the Universal Service Directive. The concept of "emerging markets" has been introduced in the Framework Directive in order to propose a more flexible approach whereby no ex ante regulation should be imposed on companies with SMP.

4.2 The consultation process on VoIP within the NRF

The NRF did not refer to the potential of VoIP technologies and their expected effects on market structure. In order to overcome these shortcomings, the European Commission issued on 14 June 2004 an Information and Consultation Document that discusses how the regulatory framework should be adapted to accommodate VoIP. The Document has been aimed at describing the degree to which a provider of VoIP based services will face obligations under the NRF depending on the type of service offered. It makes a distinction between publicly available ECS and PATS whereby the latter has to operate with the rights and obligations that apply to a provider of publicly available telephone service. The Document characterizes two broad regulatory approaches with respect to problems emerging from the implementation of VoIP: the first approach is to impose traditional PSTN obligations on all new telephone-like services ('heavy regulation'); the second is ensure that consumers are fully informed and can make their own choices, while encouraging suppliers to find new technical solutions ('light regulation'). In Document the Commission follows the latter approach.

The Document, furthermore, distinguishes three major areas of concern: (1) consumer protection and public safety (such as integrity and availability of the network and emergency services); (2) Interconnection and interoperability; and (3) numbering including number portability requirements. Annex 1 refers to the public consultation about the Information and Consultation Document of the European Commission. In the public consultation. There have been 79 responses ranging from (non-)government institutions (4), regulatory agencies (10), new VoIP entrants, ISPs and connected industry associations (20), incumbent (mobile) operators and connected industry associations (25), cable operators (4) and (Inter-) national trade unions (4) (for an overview see Table 2). In the consultation process following the publication of the Information and Consultation Document, a number of concerns were raised by regulatory agencies, different market participants as well as consumer and trade union organizations.

Table 2 Responses to the Consultation Document of the EU

Respondent category	Number of responses
Alternative VoIP provider, ISP's and their industry associations	20
Incumbent (Mobile or Fixed) Telecommunication Operator and their industry associations	25
Cable MSO and their industry associations	4
National Regulatory Agency	11
Equipment Manufacturer and their industry associations	6
Trade Union Association	5
Consumer Organization	4
(Non-) governmental organizations	3
Software companies	1
Total	79

The common denominator has been that all participants in the discussion found the publication of the Consultation and Information Document useful and a way to stimulate the discussion on the implementation of VoIP technologies. There seems, furthermore, an overwhelming agreement that these technologies will have an important impact on the current and future market structure in telecommunications. However, there also is wide range of differences between the participants in the discussion.

The most diverse response came from the group of alternative VoIP providers, ISPs and their industry associations (“new entrants”). The common concern in this group has been about incumbent market parties leveraging their market power in existing markets to influence interconnection agreements, prevent interoperability and use numbering issues to retain or gain market power. There have been differences in opinions depending if they are ISP providing VoIP as a new service and new VoIP providers. This group also raised some concerns with respect to possible market foreclosure of incumbents as experienced by the introduction of high speed internet access and the local loop unbundling.

Within the group of incumbent (mobile or fixed) operators there have also been differences in their responses. They have been unified in asking for new VoIP entrants to receive the same obligations such as directory assistance as existing PSTN operators and have to guarantee similar network quality as the PSTN. They furthermore consider existing PSTN interconnection agreements also as appropriate for VoIP. However, contributions of participants differed with respect to whether (or not) VoIP should be perceived as a new regulatory challenge.

From the 32 European national regulatory agencies that are part of the European Regulators Group (ERG), 10 national regulatory agencies responded to the Document (see Appendix A). The NRA’s involved in the consultation process have been in favor of 'light regulation' approach proposed by the Commission and the principle of 'technology neutrality'. However, there have been differences across NRA's in their perception of problems facing the New Regulatory Framework with the emergence of VoIP technologies. In their responses, some regulatory agencies demonstrated that they did not expect major problems with respect to interconnection and interoperability as most issues in these areas have been covered by existing

regulation. For example, the Norwegian NRA expected no problems of interconnection for new VoIP providers. However, other NRAs actually expected difficulties in the area of interconnection as market participants would not be able to negotiate these agreements on their own. Or as the Dutch regulatory agency (OPTA) put it, the question could become who will pay for the gateway for interconnection. Some concerns from OPTA were also raised with respect to possible technical interoperability problems for new entrants. In order to solve problems of numbering, the UK regulatory agency described its experiences by providing a separate range of numbers and the Icelandic NRA characterized public ENUM as a solution to the problem of numbering.

Similar to the European Commission, NRA's did not consider market foreclosure as a possible issue in the introduction of VoIP even if the experience during the introduction of xDSL and local loop unbundling did show in different European countries that market foreclosure might persist (EAT 2005). Technological foreclosure was not mentioned by NRA's but new VoIP entrants have been critical about their experience during the introduction of xDSL and local loop unbundling and restrictions experienced during the testing of VoIP on incumbents networks.

5 Evidence on technological foreclosure

5.1 Recommendations by NRAs and market parties

The parties involved in the consultation process can be identified according to their possible migration and long-term strategies for VoIP. In their contributions, they describe expected obstacles in the process of implementing these strategies and recommendations for adapting the regulatory framework to the development of VoIP. The strategies of the major participants offering or intending to offer VoIP widely differ. We identified three different strategies: new (alternative) VoIP providers, traditional telecommunication operators offering VoIP and (cable) multiple service operators (MSOs).

Migration strategies and long-term strategies

Alternative VoIP providers such as Vonage or Perceval have indicated that they will benefit from lower regulatory and market barriers to entry. Therefore they are opposed to public policy obligations on their VoIP offerings but at the same time in favor of keeping these obligations for traditional telecommunication operators. Their business models ranging from pure VoIP provision to multiple service offerings based on VoIP. The provision of VoIP by these companies will negatively be affected by strategic behavior of incumbent companies and might lead to their exit from the market.

For example, Vonage, a US based company offering VoIP as a nomadic service that can be accessed via broadband internet only, stated that company is currently unable to provide technically location information of user. Therefore they argued against imposition of public policy requirements in particular emergency services on ECS. The company argues in favor of number portability between ECS and PATS, as they consider this of critical importance to VoIP providers. Furthermore, they propose that access to geographic and non-geographic numbering resources is essential to VoIP providers as the Framework Directive does not distinguish between traditional telecommunication carriers and VoIP providers. They

furthermore argue that quality of service requirements should be imposed on provider of publicly available ECS.

Tiscali proposes that in-line powering of terminals should be characterized as a historic feature of the PSTN that is technically quasi infeasible and would increase unnecessarily increase costs. Furthermore, interconnection agreements will become in particular important in countries in which new number ranges are defined. There should be no differences in interconnection offers from mobile and fixed operators with respect to terminating calls that originate at VoIP-based service provider The AIIP (Association of Italian Internet Providers) has been straightforward in proposing that VoIP providers should not be classified as PATS.

In its response, the Belgian alternative access provider Perceval discusses in its response the threat of technological foreclosure as follows: "What if cable and phone operators with market power starts to use special software to identify third-party traffic on their broadband network? What if then they force VoIP providers to pay a surcharge (as a reaction to VoIP threat) or selectively block or slow down their traffic, or worse take discretely the opportunity to make counteroffers to consumers of the third party VoIP-provider." The company considers this as a current threat as the technology is already available.

For traditional telecommunication operators providing VoIP, such as KPN or Telefonica, the problem of VoIP implementation is rooted in their attempts to migrate from their fixed telephony network to an all IP network without cannibalizing existing service revenues and loosing customers while taking into account their existing legacy networks. As they are market parties with SMP they experience access obligations in regulated markets. Due to their access to the wholesale bottleneck facility, they can easily leverage their resources in this market to new emerging markets. They have been in favor of imposing equal public policy obligations on all new market parties offering VoIP.

TeliaSonera, for example, argues that the regulatory framework of the EU should remain technology neutral as the VoIP is still in its infancy. It suggest that the key distinction for PATS is if the service requires access to and from telephone numbers in the national numbering plan, otherwise (if there is just access to not from telephone numbers) the service should be defined as publicly available ECS. TeliaSonera is in favor of a regulatory approach that combines the traditional approach (PSTN obligations on all new telephone services) with a new approach (full information of consumers over service offerings). The company considers shared responsibility between network operator and VoIP provider for network integrity as reasonable. It furthermore argues that the issue of in-line powering needs reconsideration due to new developments in the market like cordless phones. Emergency services should be offered by new VoIP entrants.

There have been just a few responses from cable multiple service operators (MSOs). For example, Telenet, a Belgian cable MSO, suggested in its consultation document that a distinction should be made between ECS and PATS based on differences in service quality. VoIP entrants should be in a position to offer emergency services as they sign agreements with the underlying transport network operator.

Consumer protection and public safety

In order to guarantee consumer protection and public safety, there have been proposals in the consultation process to establish an Internet Registry Information System (IRIS) which can work as an alternative to SS7 network. To guarantee lawful interception it has been proposed that equipment manufacturers should agree on

common standards which can be coordinated via the European Telecommunication Standards Institute.

For new entrant companies the issue here has been that network integrity should be guaranteed by the company providing the infrastructure. Traditional telecommunication operators have been arguing in favor of sharing network integrity and obligations between network operator and service provider. MSO have suggested that networks should be characterized according to the quality of service provided. The issue here for NRA's has been whether (or not) the company providing VoIP also controls the infrastructure.

Interconnection and interoperability

New entrant companies have considered the problem of interconnection between PSTN operators and VoIP providers as the central problem for their development. As the IIP has argued that interconnection should be clearly established. Furthermore, there should be full interoperability and an opening of "proprietary protocols". Otherwise there is a threat that the dominant operator may delay or refuse to provide information necessary for interconnection. The experience of foreclosure of markets for high bandwidth access (in particular xDSL) has been taken as an example.

In contrast, incumbent telecommunication companies, like Telefonica and Telekom Austria, have proposed that Interconnection with VoIP providers should be agreed in a commercial environment and that interoperability is guaranteed in this environment Telekom Austria furthermore suggested that interconnection agreements between VoIP and PSTN have to rely on existing PSTN-PSTN agreements. With respect to interoperability, the company suggested that it should rely on minimum open and interoperable standards.

Numbering

New entrants are in favor in receiving geographical numbers. They expect that incumbent companies might discriminate against them by allocating new number ranges that indicate VoIP services. Incumbent telecommunication operators such as Telekom Austria have suggested that new numbering ranges should be developed for the use by new services such as VoIP as it enables users to recognize these services. It has furthermore been suggested that the European Commission should actually refrain from a general allocation of geographical numbers attributed to VoIP services.

In broadband markets, upstream access to the local loop (i.e. bottleneck facility) has been important for the roll-out of new broadband technologies. Unbundling of the local loop has been an important step of the European Union to provide equal access to this bottleneck facility for new entrants. However, local loop unbundling has not been as successful in stimulating competition as expected.

5.2 Local loop unbundling and foreclosure in European broadband access markets

Technological foreclosure is not unprecedented in the European telecommunication sector. The EC has experienced problems with foreclosure during the unbundling of the local loop (LLU)[12]. LLU proved to be difficult to accomplish as the former state-owned incumbents were (are) very reluctant to give entrants access to their copper

[12] A local loop is the pair of twisted copper wires that connects a customer's premises to the central office (telephone switch). LLU gives operators other than the incumbent access to the local loop.

wires. In addition, the inexperience and often sluggishness of EU Member States with regard to implementing enforcing regulation made LLU a cumbersome process.

From a technical point of view LLU can take place in three ways: direct access, bitstream access, and frequency sharing (Odling, Mayr et al. 2000). First, new operators may get direct access to the twisted pairs. In this case the operator can use the twisted pairs in any way permitted by the NRA. Direct access implies complete control of a local loop by a single operator. Direct access involves high fixed cost for entrant operators, but yields a relatively high degree of independence from the incumbent operator. A second type of LLU can be accomplished through bitstream access. With bitstream access the incumbent engages in the wholesale of DSL-connections to other operators, while it remains in full control of the physical infrastructure – including the local loop. In principle, bitstream access facilitates centralized network optimization, but the absence of competition in the physical layer of the network does not provide an incentive for innovation. Bitstream access is easily usable by entrants, but implies a lack of autonomy. Frequency sharing, the third type of LLU, allows several (usually two) operators to share a single pair of wires by subdividing the frequency spectrum. Frequency sharing requires a high degree of technical cooperation between the incumbent and the entrant. Unless the incumbent is willing or forced to cooperate fully, frequency sharing is not very attractive for the entrant. Both direct access and frequency sharing imply that the entrant needs to install equipment on or near the incumbent's premises. This is called 'collocation'. Naturally, collocation brings along technical problems and opportunities for the incumbent to frustrate entry.

The European Commission's interest in LLU dates from 1999. In the "Fifth Report on the Implementation of the Telecommunications Regulatory Package", the EC recommended the liberalization of the local loop to the Member States of the EU (European Commission 1999). Earlier reports by the EC emphasized that competition on the local loop had to be achieved through liberalization of cable networks.[13] Around 1999 some Member States (Austria, Denmark, Finland, Germany, and The Netherlands) were in the early stages of LLU. LLU became obligatory for incumbent operators in the EU from December 31st 2000 onwards under Regulation 2887/2000.[14] In particular, this Unbundling Regulation requires incumbents to offer interested parties direct access (or "full access") and frequency sharing ("shared access") against prices based on actual cost. The prices of LLU services together with technical conditions (for example related to collocation) must be made publicly available in the form of a reference offer. Incumbents are not allowed to discriminate between subsidiaries and competitors with regard to the prices and terms of LLU services. The Unbundling Regulation also states that incumbent operators cannot be required to "install entirely new local infrastructure" in order to make LLU possible. Implementation of the Unbundling Regulation at the national level is the responsibility of NRAs.

The "Seventh Report on the Implementation of the Telecommunications Regulatory Package" (European Commission 2001) assessed the implementation of the Unbundling Regulation in the Member States. The Seventh Report concluded that

[13] Cable networks have the disadvantage that they are designed for one-way transmission only: a cable connection consists of a single wire (instead of a pair of wires) and a cable network lacks a switching architecture, which makes connection speeds dependent on the number of users in the neighborhood.

[14] See European Parliament and Council (2000). The text of Regulation 2887/2000 was later adopted by the European Economic Area (EEA) under Joint Committee Decision 47/2001, which entered into force October 1st 2001.

the implementation of LLU had been “very disappointing”. In four Member States the incumbent had not published a reference offer for shared access, even though they were required to do this. More importantly, the number of unbundled lines still was a fraction of the total number of lines. At the time, direct access was the most significant and most rapidly growing form of LLU. LLU by means of frequency sharing and bitstream access was negligible in most Member States. As a consequence, the incumbents of seven Member States had been able to monopolize national DSL markets. The Seventh Report concluded that the failure of LLU was partly due to the complexity of implementing the Unbundling Regulation. Especially problems related to collocation and pricing proved difficult to solve, both for incumbents and NRAs. The report also blamed non-technical factors. The “reluctance or inability” of incumbents to provide access to the local loop against fair prices had not been counterbalanced by NRAs, whose supervision of cost accounting systems had been poor and whose dispute resolution procedures had been slow.

A study by Squire, Sanders & Dempsey (2002) offers more insight into the problems encountered by operators trying to get access to the local loop. The problems can be categorized into two groups: contractual and behavioral obstacles to entry. Starting with the first category, entrants report three kinds of issues: discrimination, excessive pricing, and predatory pricing. A majority of the incumbents are reported to provide more favorable terms to subsidiaries than they do to competitors. Besides charging higher prices, incumbents are also reported to discriminate with respect to delivery times, penalties, and restrictions. In the majority of cases the extent of discrimination appears to be unjustified. This holds especially for installation and collocation rates.

Excessive pricing is widespread in the EU. Entrants report that incumbents charge excessive monthly rentals and excessive fees for the installation and connection of new lines. Also widespread are administrative charges for services that are virtually costless. Probably the most notorious contractual obstacle is predatory pricing, in particular in the form of “price-squeeze”. A price-squeeze occurs when the incumbent operator reduces the margin between the wholesale price and the retail price of a service by setting a high wholesale price and/or by setting a low retail price. Operators trying to sell a retail service that they bought as a wholesale service from the incumbent will find it difficult, if not impossible, to survive when a price-squeeze is in effect. Examples of price-squeezes mentioned by entrants include small margins between wholesale ADSL prices and retail ADSL prices and small margins between wholesale direct access prices and wholesale ADSL prices (see also Wieland 2002).

Besides contractual obstacles to entry, also behavioral obstacles were reported. The most obvious type of behavioral obstacle is refusal to supply. Usually, a refusal of supply is motivated by technical problems (e.g. lack of collocation space) because an outright denial would be in direct violation of the Unbundling Regulation. Another type of behavioral obstacle is unjustifiable delay. For example, the time needed by an incumbent to provide a new unbundled line ranged between one week and several months depending on the Member State.

Unbundling of the local loop has not been successful in the European Union. Besides incumbent operators, also NRAs are to blame for this outcome. According to both the EC and entrant operators, the authority and capability of NRAs had been insufficient in most member states. Especially the expertise of NRAs in cost accounting systems and their slow dispute resolution procedures were regarded as problematic. Despite the EC’s effort to introduce competition in the European telecom

sector, incumbent operators succeeded in foreclosing entry in the DSL market, such that they became the dominant providers of DSL connections.

The LLU case demonstrates that incumbents used various strategies to foreclose entry. Foreclosure of entry through bitstream access appears to have been achieved by means of price-squeezes. The main strategy for direct access and frequency sharing seems to have been technological foreclosure. Both direct access and frequency sharing require a high degree of technical cooperation between the incumbent and the entrant. NRAs have not been able to enforce the cooperation of incumbent sufficiently. As a result, incumbents have been able to severely limit direct access and to prevent frequency sharing altogether.

The experience with the introduction of DSL services has shown in different European countries that incumbent companies have used foreclosure to extend their market power from wholesale markets into new emerging markets for DSL services. This lead to a situation in which the incumbent company became virtually the only company in the market and resulted in a low penetration of broadband access in some European countries. In the Netherlands, for example, the Dutch incumbent KPN acted strategically by means of refusal to access, legal appeals, and withholding of information, which enabled the company to gain 85 percent of the new emerging DSL market by 2003. Similar developments have been observed in other European countries (OPTA-EAT 2004).

6 Summary and Conclusions

Within the process of adapting the New Regulatory Framework to the development of VoIP, the Information and Consultation Document of European Commission has been aimed at proposing some regulatory certainty in the fast-moving markets for services based on VoIP. The Document has been based on an approach of light regulation whereby consumers should be fully informed in order to make their own choices, while encouraging suppliers to find new technical solutions. There has been some agreement within the consultation process that this 'light regulation' is appropriate due to the current state and the future potential of VoIP. Furthermore, some market participants have been in favor of abolishing "old" redundant regulation such as in-line powering and encouraging new regulation related to user ENUM. However, competition-related issues related to the introduction of VoIP have rarely been discussed by national regulatory agencies.

However, as the experience VoIP implementation has shown, competition-related issues have already come to the fore such as blocking testing possibilities offered to operators wishing to run VoIP based services over an incumbent's network. Different market parties indicated that there is the threat of technological foreclosure in particular related to interconnection, interoperability, and numbering. As there have been a number of more traditional issues in these areas such as hampering access and interconnection, new issues have emerged in particular related to proprietary standards and protocols used by incumbent companies. For example, the usage of relatively closed ITU-standards like H.323 (instead of open IETF standards like SIP). Concerns in this area have in particular been expressed by new alternative VoIP providers. As the Document did not explicitly focus on these issues, responses by NRAs have expressed some agreement that these issues will become important in the near future. In order to develop appropriate regulatory remedies, they have focused on issues surrounding the economics of interconnection (in particular pricing of gateways), the obstruction of new entrants by existing PSTN operators, possible interoperability issues in the domain above the IP-layer and numbering issues.

As we propose there is a threat of technological foreclosure, i.e. strategic behavior that is aimed at the implementation of inferior technologies in a way that restricts or hampers access to bottleneck facilities to entrant companies. This strategic behavior might have different forms – ranging from making bottleneck facilities incompatible with competitors products and technologies, engaging in technological tie-ins to refusal to unbundle. Technological foreclosure is different from market foreclosure as it treats the incumbent's choice of technology as endogenous. We show that there exist optimal pricing strategies for NRAs to avoid technological and market foreclosure by incumbents. Even if both forms of foreclosure are difficult to detect, there is a need to complement existing ex-ante regulation with a (dynamic) competition analysis to avoid technological (and market) foreclosure.

A Public Responses to EC Consultation Document

Nr	Abbreviation	Description	Country	PATS & USO	Consumer Protection & Public Safety	Interconnection and Interoperability	Numbering	Other issues to be addressed
National Regulatory Agency (NRA)								
1	Anacom	National Communications Authority	Portugal	Within public services VoIP, communication services accessible to the public (SCE) and telephone services accessible to the public (PATS)	PATS service providers obligations such as emergency services	Keep existing principles of interconnection, interoperability will be guaranteed	Problem of numbering	
2	ComReg	Regulatory agency	Ireland	Additional category if there is no direct access by service providers to E.164 numbers, PATS providers control over underlying infrastructure	PATS obligations towards emergency services do not extend to nomadic situations, concerns arise concerning emergency access for nomadic VoIP users (both ECS and PATS), but believe market developments will resolve this difficulty in time, not specific requirements for in-line powering of terminals , in favor of lighter regulation for access to emergency services from PATS	Technical interoperability problems are best left to the parties involved to resolve; indeed this approach is in line with the general thrust of responses to our recent VoIP consultation1 in respect of inter-operator and interconnection issues, which could be summarized as "Minimal intervention".	Geographic usage of geographic numbers by VoIP users must be carefully thought out and the Commission should hesitate to move further than its current policy of general encouragement in this matter.	
3	Minez & OPTA	Regulatory agency	Netherlands	'Substitution test' for telecommunication service if the service in question is a PATS service	Obligations and rights of VoIP operators should therefore not be different from the rights and obligations of PSTN operators.	Interconnection: The technical question should be answered by the operators involved but the economical question (who will pay for the gateway) could give rise to conflicts. Monitoring possible interoperability issues in the domain above the IP-layer.		Number Portability rights have been broadened such that next to PATS subscribers also ECS subscribers have the right to retain (to port) numbers (from either PATS or ECS provider)

Nr	Abbreviation	Description	Country	PATS & USO	Consumer Protection & Public Safety	Interconnection and Interoperability	Numbering	Other issues to be addressed
4	NITA	NRA	Denmark	PATS definition regarding originating and receiving calls through a number or numbers in a national or international telephone numbering plan does not fully complies with the aim of technological neutrality	Point of clarification: "fixed location" and "nomadic users"			
5	Norwegian PTA	NRA	Norway	a full set of obligations would apply to VoIP providers using ordinary telephone numbers		interconnection does not represent any problem for providers of VoIP providers Do not see any specific interoperability issues that would hamper the development of VoIP.	technology neutral approach to numbering	
6	OFCOM	NRA	UK	*Non-PATS* ECS. Legal basis for PATS definition?	The control over the underlying transport infrastructure need not be associated with ownership or direct control of the network, but could also take the form of indirect control arising out of an agreement with the provider of the underlying network		new non-geographic number range available (056) for Location Independent Electronic Communications Services	
7	ONE	NRA	Austria	Technology neutrality, VoIP provision in real time therefore similarity to voice telephony				
8	PTA Iceland	NRA	Iceland				ENUM should be further explained	

Nr	Abbreviation	Description	Country	PATS & USO	Consumer Protection & Public Safety	Interconnection and Interoperability	Numbering	Other issues to be addressed
9	RRT	NRA	Lithuania			Interconnection: Problem of caller line identification, when terminating traffic, routed over IP networks, in traditional telephone networks, especially when terminating in non-SMP operators' networks, because such traffic could be not accepted or different pricing from the general interconnection could be used.	Competition problems because of possible contradiction between territorially restricted use of geographic numbers (in case of open numbering plan) and nomadic VoIP users	
10	RTR	NRA	Austria	VoIP services that provide access to the PSTN, VoIP services enable voice communication only between Internet subscribers			Technology neutral regulation on geographic numbers	
Alternative VoIP providers and their Industry Associations								
1	AIIP	Association of Italian Internet Providers	Italy	VoIP providers are not PATS	Obligations not imposed on non-PATS providers	Should be clearly established (currently only implicit), IC with the technologies most appropriate, Full interoperability and opening of "proprietary protocols", Threat: Dominant operator may delay or refuse to provide information	VoIP providers to access (non-) geographical numbers	Exponential growth of video-call services
2	Albacom	Alternative carrier for provision of data transmission, voice and Internet services	Italy			Anticompetitive behavior can be expected from incumbent, offering lower quality , discrimination	PATS shall use geographic and non-geographic numbers	

Nr	Abbreviation	Description	Country	PATS & USO	Consumer Protection & Public Safety	Interconnection and Interoperability	Numbering	Other issues to be addressed
3	Colt Telecom	Alternative access provider	UK		- Obtaining appropriate access products, especially as regards the last mile, when trying to develop any-to-any services. This covers both the type of access products available at wholesale level, their price, the SLAs under which they are offered, the lead times, etc.; - Obtaining appropriate interconnection terms; - Obtaining appropriate termination rates for both fixed and mobile termination; - Numbering. - Obtaining effective migration solutions	- Current bundling/tying practices by incumbents in over half of the EU Member States consisting of linking an ADSL subscription to a PSTN subscription or linking an amount of free or cheaper minutes to the monthly PSTN subscription fee - high mobile termination rates, - not all of the used standards seem necessarily to be compatible - the applied tariffs and the volume of traffic incurred will be critical - situations where dominant market players will be able to leverage market power when negotiating IP-interconnection. - testing possibilities offered to operators wishing to run VoIP based services over the incumbent's network.	Numbers should reflect the characteristics of the service being provided, not the underlying technology.	
4	CompTel/Ascent	Alternative access carriers	US	VoIP operator that does not control infrastructure not PATS			Numbering used to discriminate by dominant party	
5	EuroISPA	European Internet Services Providers Association	Brussels	VoIP as PATS if substitute to traditional PSTN	VoIP exempted from obligations			

Nr	Abbreviation	Description	Country	PATS & USO	Consumer Protection & Public Safety	Interconnection and Interoperability	Numbering	Other issues to be addressed
6	ECTA	Industry association of Alternative Telecom operators	Brussels		The level of the emergency service obligation is large hurdle for market entrants that may need PATS status in order to benefit from inclusion in the Directory and for number portability, it makes it easier for incumbents to design VoIP services that consumers might consider substitutes for the PSTN that are not PATS	equitable and non-discriminatory interconnection between service providers. In particular, during the transition from circuit-switched to IP-based networks	ECS should be able to have access to both geographic and non-geographic numbers	whether increasing adoption of VoIP leads to increased net USO
7	Freenet.de	ISP	Germany	at the moment characteristics of telephone service for VoIP not applicable	Network integrity by provider controlling infrastructure			
8	ITSPA	Internet Telephony Service Providers Association	United Kingdom	Categories: • Connection Controlled Access Where VoIP services are provided by the network operator responsible for the connection. Operators of such services would include incumbents and cable operators. • Shared Connection Access Where VoIP services are supplied by an operator with high but not exclusive control over the transport layer infrastructure. An example of this would a service provided by an unbundled local loop operator. • Service Provider Access These services would be available primarily through a	Controller of the relevant infrastructure to ensure availability		Equal access to geographic and non-geographic numbering on a technology neutral basis	self-regulation is a viable model for VoIP services in EU Members states

Nr	Abbreviation	Description	Country	PATS & USO	Consumer Protection & Public Safety	Interconnection and Interoperability	Numbering	Other issues to be addressed
(cont.)				designated ISP • Access Independent Where a company provides VoIP services that are available from any Internet connection.				
9	Level3 Communications	Alternative operator	US	Issue of control over or ownership of the underlying transport infrastructure	clarification on "nomadic services"	Retain economic regulation in areas where there is persistent market power stemming from control over "last-mile transmission facilities", control over interconnection, and call termination,	Providers of VoIP services should not therefore be barred from obtaining geographic numbers on the basis that the service is nomadic	
10	Netzquadrat GmbH and Indigo Networks GmbH	VoIP providers	Germany		Emergency services are important for VoIP	Dominant position of DB Telekom in broadband access markets, bundling of telephony and broadband access		
11	Neuf Telecom	Telecom operator	France	control of infrastructure important	no inlinr powering of terminals	Interconnection offers with VoIP providers must be published		
12	ONI Telecom	New telecom operator	Portugal	Not only the principle of technological neutrality, but also the technical specificities of VoIP	in line powering of terminals not necessary	IP-IP interconnection will become an issue, need for SMP operators to publish a reference, Promoting the harmonization of standards	right to geographic and non-geographic numbers	
13	Perceval	Alternative access provider	Belgium	USO rights and obligations only to SMD operators	"control over" lowest layer of infrastructure, no obligation for in-line powering	Commission should promote initiatives for open source standard development and awarness in the domain of VoIP interconnection, interoperability and interprovider settlement standards	global naming and adressing system such as Intenet Domain Names System (DNS), VoIP over short term access to geographic numbers	No abuse of market power, cable and phone operators force VoIP providers to pay a surcharge (as a reaction to VoIP threat) or selectively block or slow down their traffic, or worse take discretely the opportunity to make counteroffers to consumers of the third party VoIP-provider

14	Pulver	Application Service provider	United States		peer to peer Internet communications no unnecessary government intrusion	Commission should ensure application service providers have reasonable access to last-mile facilities		Global IP alliance
15	Skype Technologies SA	VoIP provider	US	Imposing obligations on 'traditional' operators		Refuse to offer facilities such as technical interfaces		
16	Tele2	CPS provider				Greater focus on the competition problems experienced in the markets where new entrants' services are dependant on legacy networks and wholesale input from the fixed network		Suppress predatory pricing, margin squeeze and cross-subsidisation effects on telephone access:
17	Tiscali	Internet Service Provider	Italy	Agrees with PATS definition of its VoIP services	Underlying infrastructure has to be defined, in line powering historic	no differences in interconnection offers from mobile and fixed operators	Granting of geographic number ranges similar to PSTN	
18	VATM	Industry Association VAT services	Germany	VoIP PATS if calls to E.164 numbers	Joint development of options for e.g. emergency services	Access to wholesale market vital, bitstream access to wholesale markets	no discrimination by numbering	Threat of foreclosure as experienced with xDSL (and leased line markets), Risk of anti-competitive bundling

Nr	Abbreviation	Description	Country	PATS & USO	Consumer Protection & Public Safety	Interconnection and Interoperability	Numbering	Other issues to be addressed
19	Verisign	Provision of trusted infrastructure services	US	Appropriate balance between PATS and ECS	Emerging VoIP services different quality of service	Establishing a Internet Registry Information System (IRIS) as an alternative to SS7 network		
20	Vonage holdings corp	VoIP provider / New entrant	US	VoIP providers not same regulation as bottleneck services	Quality of service issues for third-party routing traffic		VoIP providers also access to number resources, Number portability critical	Storage of data in the US
Incumbent operators and their industry associations								
1	AFORS Télécom	Association of Telecom Operators	France	Minimum quality requirements for VoIP	Quality of service requirements for all parties	No imposition of interconnection requirements, market participants will be able to interoperate over the long term	New numbers part of existing numbering range	
2	ARCOR	Telecommunication carrier	Germany	VoIP is PATS if substitute, otherwise no technology neutrality		Only PATS providers E.164 numbers		Cooperation of market parties solve technical problems of VoIP
3	AT&T	Telecommunication carrier	USA	Disincentives arise from this distinction, Imposing traditional PSTN obligations on all market parties		Impede access to Internet content		
4	Bouygues Telecom	Mobile telecom operator	France	Distinction for VoIP between peer-to-peer, business and E.164	Asymmetric regulation not justified, minimum quality of service			
5	BREKO	Industry association (small) telecom operators	Germany	VoIP is PATS because it refers to public telephony	All market parties same obligations			
6	Cable and Wireless	Telecom Operator	UK		Preventing abuse by incumbents			
7	CEGETEL	(Mobile) Telecom Operator	France	Same obligations for VoIP operators as for PATS, quality of service requirements				
8	Deutsche Telecom	Telecom Operator	Germany	Further distinction between services which are publicly available and offer connection to the PSTN without using E164 numbers	not exempting VoIP providers from certain requirements in the field of consumer protection	Commercial negotiations of interconnection	no allocation of geographic numbers to VoiP providers	PATS also applies to GSM services Distinct market for VoIP due to nomadic character of VoiP

				regulatory bias as VoIP providers can decide whether to take PATS obligations PATS: service available to the public, for orginating and receiving national and international phone calls, through a number or numbers in a national aor international telephone numbering plan				
9	ETNO	European Telecom Network Operators Association	Brussels	On retail market where VoIP is offered as optional additional service to PSTN, not considered as traditional PSTN service	Network integrity should not fall only on the network provider	peering agreements exist (IP-IP interconnection) or market players have scenarios for PSTN-IP interconnection; market based solutions for gateways (interoperability)	National numbering conventions	
10	France Telecom	Telecom operator	France	Voip cannot replace PATS	Necessary to guarantee network integrity, Network integrity by party controlling the network			

Nr	Abbreviation	Description	Country	PATS & USO	Consumer Protection & Public Safety	Interconnection and Interoperability	Numbering	Other issues to be addressed
11	GSM Europe	Industry association mobile operators	Brussels		Issue of control difficult to discover	no specific new requirements for interconnection agreements, interoperability driven by market	different numbering schemes are possible (geogrpahic, dedicated)	
12	KPN	Telecom operator	Netherlands	Uniform treatment of VoIP providers, VoIP services are multimedia services used in a nomadic way		Interconnection and interoperabilty has to be adapted to VoIP	Dedicated numbering ranges	
13	Matav	Telecom operator	Hungary	PATS categorizationn based on service characteristics not provider characteristics	Major issue is control or ownership over infrastructure	Market player should develop interconnection and interoperability agreements	Geographic numbers should be reserved	
14	NetCologne	Telecom operator	Germany		Emergency services for all VoIP providers			
15	Portugal Telecom	Incumbent operator	Portugal		"visited"networks operator should be obliged to grant full access and location functionalities			
16	SFR	Telecom operator	France					
17	STPT	Industry association Telecom operators	Spain					
18	Telecom Italia	Incumbent telecom operator	Italy	Some obligations only refer to PATS such as directories, operators assistance, non geographic numbers				
19	Telefonica	Incumbent telecom operator	Spain	Different classification SCE / STDP	Similar burden on service providers	Interconnection with VoIP providers should be agreed in a commercial environment, interoperability is guaranteed	Assign an assigned number range for VoIP	
20	Telekom Austria	Incumbent Telecom operator	Austria	Agrees with distinction PATS / Non-PATS	Network integrity not only infrastructure provider, Users should be informed if emergency calls cannot be routed	Interconnection between VoIP and PSTN have to rely on existing PSTN-PSTN agreements, minimum open and interoperable standards		New numbering ranges should be developed for the use by new services
21	Telekomunikacja Polska	Incumbent telecom operator	Poland	Any VoIP provider subject to PATS	Network integrity should be provided by network and service	VoIP provider should show in contract if they provide emergency services/ caller ID		

					provider			
22	Teliasonera	Incumbent telecom operator	Sweden	PATS if calls are to and from public telephone network, PATS at fixed locations and all PATS, if calls to but not from public network ECS	not all PSTN obligations are imposed on VoIP		Use of geographic numbers both for fixed and nomadic users	
23	TI Denmark	Telecom industry association	Denmark	Calls routed via softswitch outside scope of ECS, if calls to PSTN than ECS			New requirements for numbering (e.g. different national numbers)	

Nr	Abbreviation	Description	Country	PATS & USO	Consumer Protection & Public Safety	Interconnection and Interoperability	Numbering	Other issues to be addressed
23	UKCTA	Industry association of telecom companies competing against BT	UK	Agrees on classification PATS, ECS	"Control "of infrastructure has further to be defined, in line powering questionable	No abuses of interconnection expected	Number allocation forward-thinking	
24	VAT	Industry Association (Alternative) telecom operators	Germany	Technologically neutral approach, PSTN requirements for all VoIP providers	Equal legal requirements			
25	Vodafone	Mobile operator	UK	VoIP offering PATS same obligations, but in new way		Symmetric interconnection agreements		
Cable operators and their industry associations								
1	ECCA	Industry association of European Cable Companies	Brussels	Difference in regulatory intervention between similar PATS would only be justified if an SMP position is observed.				
2	ONO	MSO	Spain					
3	TDC	Cable MSO	Denmark	PATS-like VoIP should be harmonized in Europe		Current PSTN regulations not transferred to VoIP	Assign different range of numbers	
4	Telenet	Cable MSO	Belgium	Difference between ECS and PATS should be on quality of service	Emergency numbers can be provided by VoIP providers due to contracts with transport infrastructure providers		Numbering an issue that has to take pace with technological developments	
Equipment manufacturers								
1	Avaya	Equipment manufacturer	Belgium			Requiring access to (enhanced) emergency services from all market parties, agreement on common set of standards		Prominence to the needs of people with disabilities
2	CISCO Systems	Equipment provider	Belgium	VoIP which are genuinely new, VoIP do not meet all aspects of PATS, VoIP meet all aspects of PATS, VoIP meeting all aspects of PATS and fall under USO	Depending on different categories USO requirements differ	No ex ante regulation necessary for interconnection, Interoperability voluntary	Numbers are not scarce resources	Role of ENUM
3	EICTA	Industry association computer electronics			in-line powering of terminals out of date.	problems if VoIP interconnection being specified in accordance with legacy PSTN standards as multiple		

Nr	Abbreviation	Description	Country	PATS & USO	Consumer Protection & Public Safety	Interconnection and Interoperability	Numbering	Other issues to be addressed
(cont.)						conversions between IP and legacy Time Division Multiplexing (TDM) would severely affect quality and break the conveyance of advanced functionalities		
4	Intrado	Equipment manufacturer	UK		service with a "look and feel" of public services must provide emergency services			
5	Lucent Technologies	Telecom manufacturer	United States		In-line powering relict from PSTN era	Interconnection and interoperabilty key factors	Non-geographic numbers might become important for VoIP	
6	Motorola	Telecom equipment manufacturer	United States		Advice of users of the implications of extended loss of mains power supply	Direct IP-IP interconnection increasing importance, Market forces will solve interoperability problem	Own personal numbers	
(Inter-) National trade union organization								
1	Connect UK	Communication Workers Union	UK	VoIP should contribute to USO				
2	CWU	Communication Workers Union	UK	VoIP should contribute to USO				
3	Danish Metal Workers Union	Trade Union	Denmark		Consumers must be made aware of the limitation of VoIP in relation to power failures and emergency; There must be access to alarm call	Access to VoIP (Broadband) at a fair price; Operators shall guarantee a reasonable quality; Consumers shall have the possibility of number portability; The structure of rates must be transparent (No hidden rates)	There must be a special series of numbers reserved for VoIP	
4	Intellect	Trade union organization	UK					
5	UNI Telecom	Global Trade Union	Switzerland	Accept classification, but all VoIP services regulated	Limited competition in uneconomic areas, US maintained for VoIP			
(non-) Governmental Organizations								
1	Autorites Francaises	Government	France	PATS it can be useful to specify that it includes at the same time services whose		Technological neutrality reaffirmed by the new regulatory framework involves	Technological neutrality	

				suppliers have the direct control of the infrastructures and other services whose suppliers do not have it.		that all the provisions concerned with the interconnection must apply fully to networks IP, as well as to other networks		

Nr	Abbreviation	Description	Country	PATS & USO	Consumer Protection & Public Safety	Interconnection and Interoperability	Numbering	Other issues to be addressed
2	Bundesrepublik Deutschland	Government	Germany					Link between ENUM en E 164 numbers, Integration of E. 164 number plan and IP
3	VNO-NCW	Employers Organization	Netherlands	Technology neutrality for limited time period only, VoIP as PATS same obligations	Definition of "control" of network not clear		European number range (+388) available for nomadic VoIP	
4	Wirtschaftskammer Österreich	Governmental organization	Austria	Principle of technology neutrality				
(Inter-) National User organization								
1	ANEC	European Association for the Coordination of Consumer Representation in Standardization	Belgium		Information on network quality should be measurable	Role of de facto standards in interoperability		
2	INTUG	User organization	Belgium	It is essential to have clear criteria by which an operator is designated or certifies itself as being PATS or not	Incumbent has to guarantee access to emergency services, otherwise violation of the non-discriminatory principle.		creation of new number ranges has a problematic history	
3	Telecom e.V.	Industry Association Large Telecom Users	Germany	Principle of technological neutrality				
Software companies								
1	Microsoft	Software company	United States	Narrower VoIP definition: IP-based technology that is used to convey real-time voice communications.				EU Member State regulators should adopt a harmonized approach to the regulation of VoIP.

B List of acronyms and terms used

Acronym	Description
ARPA	Address and Routing Parameter Area
DNS	Domain Name System
E.164	International numbering plan for public telephone systems in which each assigned number contains a country code (CC), a national destination code (NDC), and a subscriber number (SN).
EC	European Commission
ECS	Electronic Communication Service
ENUM	Electronic NUMbering
EU	European Union
ERG	European Regulators Group
IETF	Internet Engineering Task Force
IRIS	Internet Registry Information System
ISP	Internet Service Provider
ITU	International Telecommunication Union
H.323	ITU multimedia signaling protocol
LLU	Local Loop Unbundling
MGCP	Media Gateway Control Protocol
MSO	Multiple Service Operators
NRA	National Regulatory Authority
NRF	New Regulatory Framework
P2P	Peer to Peer
PATS	Public Available Telephone Service
PCM	Pulse Code Modulation
POTS	Plain Old Telephone Service
PSTN	Public Switched Telephone Network
QoS	Quality of Service
SLA	Service Level Agreement
SMP	Significant Market Power
SIP	Session Initiation Protocol
softphone	Software-based telephone
SS7	Signaling System 7 (C7 in Europe)
TDM	Time Division Multiplexing
URI	Universal Resource Identifier
US	Universal Service
VoIP	Voice over Internet Protocol
VoDSL	Voice over Digital Subscriber Line
W(LAN)	(Wireless) Local Area Network

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