NETHEADS VERSUS BELLHEADS

RESEARCH INTO EMERGING POLICY ISSUES IN THE DEVELOPMENT AND DEPLOYMENT OF INTERNET PROTOCOLS

FINAL REPORT

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FOREWORD

This report is a reconnaissance into emerging issues, and has been made as complete as possible within the resources available. Further comment by other experts can correct and clarify the inevitable errors.

As with any exploration, we have to keep reminding ourselves of what we already know, or reckoning the smaller events by means of the larger map. Two systems are in collision, the packet-routed signaling system called the Internet, and the circuit-switched telephone system. We shall look at what those terms mean, *circuit-switched* and *packet-routed*. We need to keep reminding ourselves of the simple and obvious features of the systems under examination in order to keep clearly before us the nature of the issues.

The simple and obvious features are deeply embedded in machines and the logical systems that control them. Before the Internet, we had no basis for considering the nature of the circuit-switched telephone network. It was the only thing, and how it worked was how communications systems had to work. How to compete with it was likewise limited to circuit-switched architectures and ideas. Most ideas of competition in telecommunications are still deeply influenced by the limitations of circuit switching, and in particular, the control system that runs the circuits and provides the features, which is called the SS7, or Signaling System 7.

The telephone system's business model is to charge for time and distance for calls, and for bandwidth. Services are defined by the owners of the network, not by users. Competition has been brought to bear on that system from other facilities-based providers, but the competition from the Internet is more radical. The important feature of the PSTN business model is this: even if all calling were flat rate, distance- and time-insensitive, one crucial feature would remain – the telephone company would define what services are offered. No else has the ability to define the nature of services offered over public telephone networks.

Given the current ideas about what unbundling consists of, other facilities-based competitors can only offer what the architecture of the PSTN allows. Competition is defined by the limits of the features that can be extracted from the SS7, and by the basic idea of leasing circuits operating in time-division multiplexing. Accordingly, our ideas of telecommunications competition are still influenced by the constraints of a legacy system. Thus, in our submission, the current conception of unbundling is actually a form of resale of basic components of this limited system rather than an ability to use networks in conformity with an Internet model.

It became clear as we explored the nature of the PSTN that, compared to the Internet, it is a one-trick pony: to borrow a term from computing, it has essentially one single application, the sale of channels multiplexed by time-divisions at 64 kilobits per second, and multiples thereof. In that limited environment, it is possible to offer quality of service guarantees, because, from a Nethead's perspective, there is only one application, which is bundled with transmission. The layered model of the Internet allows for many applications, each of which would have its own quality of service, and for transmission paths, which would also provide a quality of service independent of that provided in the applications.

A second major implication of the Nethead view is that the end-to-end Internet model promises to do away with the idea that anyone would have a monopoly in the definition of services. If the Internet open-architecture model prevails, a telephone company of the future will still be able to define services, but so will every other user of the communications system capable of writing good code. The challenge posed by the Internet model to the telephone system is much more than a change of pricing, or a change of service definitions. It promises a vast enlargement of who it is that is able to define what services will be. In short, the relevant remaining monopoly lies not in the possession of facilities, but in the exclusive ability to define services.

Some of these services will be inferior, from the point of view of a Bellhead. They will satisfy consumer wants, nevertheless. This is why Netheads do not treat quality of service as the be-all and end-all of what they get out of the Internet, any more than Microsoft, for instance, concerns itself whether your system enters a “general protection fault” and freezes.

A third major implication of the Internet model is that value is not created in the network, but at the edges, by users. This means that new applications, new value, can be created at the edge of the network, without the permission, control, or involvement of the network owner. And when network ownership is de-coupled from value creation, carriers derive no benefit from this new value beyond the new traffic it spawns. For this reason, the Bellheads will fight the Internet vision with all their strength.

Whether network architectures will evolve or be pushed towards a broader conception of who can define services is the key issue for the Next Generation Internet. Such a result might occur through the actions of government, mandating new forms of unbundling and interconnection with the PSTN, or it might come about from changed facts. Optical fiber planted in municipal rights of way will soon be used to avoid the last-mile local loop and bypass the PSTN altogether. This would herald a complete undermining of the ability of incumbents to impose restrictive network architectures.

It is therefore essential that those who regulate the telecommunications system and those who advise upon its structure be aware that the broadening of who may define services is at stake in the development of the next generation Internet.

1. THE CONFLICT IN DESIGN PHILOSOPHIES

1.1 THE CHALLENGE OF THE INTERNET TO THE PSTN

The emergence of the Internet is well measured by the proportion of data traffic to voice traffic on networks. Internet traffic is doubling very four months, whereas voice traffic, which is limited to the characteristics of people talking on telephones, grows by 6-9% annually. The result is that voice traffic will decline to less than 8% of total network traffic by 2004, and its relative decline will continue. Based on current levels of growth, the entire traffic on the PSTN may amount to less than one percent of the total before 2010[1].

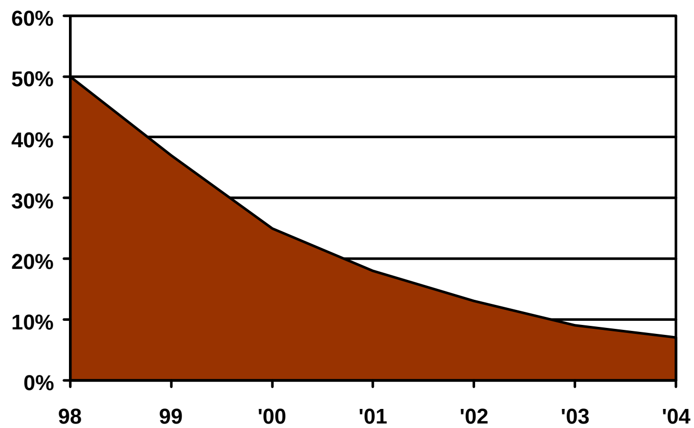


Figure 1: Data Traffic is Growing to Dominate all Public Network Traffic

(shaded = voice component of total PSTN traffic)[2]

Source: Next Generation Networks: A Practical View of Network Evolution", by Grant Lenahan, Executive Director, NGN Solutions, Bellcore, see Endnote 2

The telephone companies no longer have a choice to continue to build, operate and provision separate networks for data and voice. They are forced by competitive pressures to integrate them. And if these systems are to be integrated, or *converged*, a fundamental issue arises: which design philosophy is to prevail, the Internet's or the PSTN's?

The second large fact that needs to be adjusted to is the growing availability of bandwidth. While processing power doubles every 18 months, which is expressed in Gordon Moore's Law, bandwidth doubles every six months[3]. The much faster rate of growth in bandwidth argues for design philosophies that are predicated in abundant bandwidth, rather than elaborate protocols that conserve bandwidth. As we shall see in later sections of this report, large bandwidth, which is the same as high speeds, can be used for some applications such as telephony, as a substitute for architectures that rely on Quality of Service mechanisms in order to provide service guarantees.

As the Internet becomes the driver of the sea-change in how communications networks are structured, and therefore as the basic business of telephone companies, voice communication, is reduced to a side-show, it is timely to enquire into the means whereby the PSTN and the Internet are to be joined.

The object of this study is the connection of the PSTN to the Internet. The aim of this study is to reveal how various proposals–which are ultimately realized through software protocols – give advantages to incumbent telephone companies or to Internet service providers, and reflect different design philosophies of communications networks.

It is likely that, if optical fiber were brought to the home and business, this discussion would be obviated. In that scenario, there would be enough bandwidth for a multitude of service providers to reach the mass of end-users, and there would be no limitation based in the inadequacies of copper or coaxial cable to sustain Internet traffic, and therefore no capacity on the part of incumbents to impose a design philosophy based in legacy networks. For example, it would be conceivable for a LEC to run IP over ATM over a given colour and for an ISP to run IP over a different colour. As Bell/Canarie's engineers state:[4]

> It is conceivable that future Internet networks may be a seamless composite of transport protocols, each on their own dedicated wavelength.

The issues raised in this paper concerning the interfaces between the Internet and the PSTN are relevant because bandwidth is limited and we are going to be living with legacy systems for decades to come. If this premise is proven false, many of the issues raised in this report will disappear. Such would be the case if municipal rights of way are used to lay optical fiber extensively, so that the last-mile local loop ceases to be the bottleneck by which the PSTN exerts its power.

However, before that vision comes true, an entire system and design philosophy of communications will have to be overcome. This new system of communications does not involve setting up and tearing down circuits and obviates billing by the minute. How the current system proposes to defend itself from this vision, and perpetuate the old model, is the subject of this paper.

1.2 The Telephone Company Point of View

From a reading of the technical and policy papers proposed by the Bellhead side of the debate, it is clear that they conceive the Internet to be

- a threat to their business model, and
- missing a control component,
- on a path of *convergence* with the PSTN.

Their vision of the Internet is that it threatens the business model of the telephone companies by:

- Generating expenses without corresponding increases of revenue
- Raising the possibility that services will no longer be defined from within the capabilities of the PSTN.

The view from the telephone networks is represented by the opinions of those at Bellcore, the old AT&T Research, which has been recently renamed Telcordia Technologies. Telcordia is the authoritative repository of the PSTN point of view, which white papers from its employees tend to reflect.

Grant Lenahan, Executive Director of Next Generation Network Solutions at Telcordia, writes as follows:

> "Historically, the telecommunications industry has had two methods for dealing with the rise of data, which is predominantly packet, frame, or cell traffic. The first approach has been to carry data on the analog and TDM[1] networks designed and optimized for voice. Examples are DDS circuits, Internet access by modem, and dedicated 56k & T1/E1 lines. The second approach – growing more recently -- has been to build and operate separate, parallel networks for high capacity data traffic."

Citing developments in packet technologies and Moore's Law, he continues:

> "Given all these changes, it will make increasing commercial and economic sense to reverse the pattern of the past. In the future, when data is the dominant component of traffic demand, it will be more practical to carry voice over data networks, than to force-fit data into voice networks. And certainly it is not

[1] Time division multiplexing, which is the sharing of channels (spectrum) by splitting them into time slots. By contrast, the radio broadcasting system runs of frequency division multiplexing. Certain newer cellular phone systems work on code division multiplexing, which is a packetized system where spectrum can be shared, and signals received be deciphering the headers of packets that have appropriate addresses.

> economic to continue to build, operate and provision separate voice and data networks."

> "So, does this mean that data networks are the answer? Or that the Internet may truly subsume traditional telephone networks? Not really. There are at least two major challenges that those solutions don't address; (a) the continued demand for traditional voice communications, and (b) the need for high quality of service."

It will be seen that *Quality of Service* (QoS) is a key element of the telephone company point of view. From the Bellhead point of view, the concept of QoS has a complementary meaning, which extends to the experience of the end-user. For example, how quickly an end-user hears a ring after dialing a phone number is an element of the Quality of Service, as conceived by the phone company.

Comment on the Bellhead View

It is the authors' view that, in the PSTN, there is only one *application*, setting up or tearing down 64 kilobits channels. Since there is, in essence, only *one application* in the PSTN, it is impossible not to bundle service quality with transmission quality. End-user experience is a direct function of how well the PSTN performs this single application.

So what does QoS mean in an Internet environment, then? The difficulty with the concept of quality of service in an Internet is that it derives from ideas that really have no place there, like driving a 64,000 wagon train down the highway. For example, packet loss is not a degradation of service, it is rather a mechanism to make it possible for multiple applications to share the same finite bandwidth. On a highway, when there is more traffic than the road can handle, cars slow down and sometimes crashes happen. This is usually not a problem as cars simply route around the accident. By contrast, on railways, crashes and derailings are catastrophic.

If all we ever wanted to do was to talk on the telephone (one application), the PSTN would have remained fully adequate. However, as soon as computer to computer communications became important, the rigidities and expense of circuit switched voice networks became apparent. Since every projection of bandwidth requirements shows that data traffic will expand at a minimum of two orders of magnitude faster than voice, the assumptions of best effort engineering currently embedded in the Internet are likely to hold true indefinitely.

The Bellhead View, continued

This leads to the second major feature of the telephone company view of the world : *parity of services*.

> "The Next Generation Network (NGN) must offer parity – at least – in terms of voice quality, ease of dialing, and convenience features such as call waiting, Emergency 911, free phone ("800" service in the USA), and the myriad of capabilities offered by Centrex and PBXs that power most businesses today."
>
> "In summary so far, an NGN must meet the following characteristics:
>
> 1. One common network capable of handling data, voice and video communications
> 2. "Data friendly" or data-native packet (or cell) transport and switching infrastructure
> 3. Flexible services control elements to enable voice communications and support data and QoS in the future
> 4. Voice parity with the PSTN in terms of features and quality

> "Finally, a plurality of residential customers worldwide will not require advanced data and video services, or at least they will be unwilling or unable to pay the increased cost of high speed connectivity to their homes. Bellcore's research indicates that only between 10% and 30% of residential customers will be likely prospects for NGN services and NGN serving transmission architectures in the current planning timeframe."

> "Consequently, it will be essential for carriers to plan migration strategies to NGNs that protects their PSTN investments, re-uses as much of the PSTN infrastructure as is practical, enables seamless interoperability between PSTN and NGN services, and incrementally follows profitable demand for NGN services."

NETHEAD COMMENTARY

The assumption of this world view is that people will want what they have wanted in the past. Nothing could be further from the truth, if the example of personal computers is any guide. Who, for instance, would have wanted a web browser in 1994? Who would have paid for one? Yet the total reliance we now experience on products and services that did not exist even six years ago tells us something very important. Asking the customer what he wants and basing business decisions on what the leading customers want can be a fatal error in times of rapid technological innovation.[5]

As one former VP of Nortel told me in the course of this study, "the PSTN is a money machine. If the money machine is broken, you don't want to be caught with your wrench in it."

To review, the core of the concern of the telephone companies quite naturally is the recovery of their investments in the existing PSTN. The key issue for regulators and policy-makers is whether and to what extent design philosophies of the next-generation Internet should be rooted in existing PSTN ideas. This issue will be brought before government in the convergence of the PSTN with the Internet, in the form of interconnection policies and standards for internetworking.

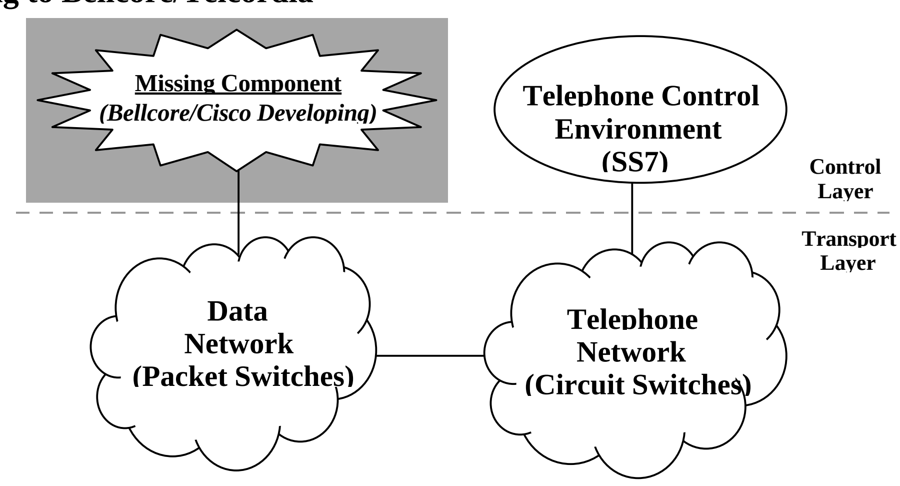
Two additional points are worth making. First, the telcos may already have fully recovered their investments, and their desire to "recover investments" may be no more than the desire to be paid a rent on obsolete equipment for a long time. Second, "convergence" is the term we apply to things we think of as being separate, whereas in fact, they are already united, and only backwards-looking ideas keep them apart.

1.3 The PSTN's Control System Described

Telcordia, formerly Bellcore, believes that an overall architecture for the integration of voice and data networks must be created and that new software products and control protocols must be developed and perfected. In order to understand the nature of the problem, we need to survey how the PSTN works, in comparison to the Internet. What is chiefly missing in the Internet, from the telephone company point of view, is a control system compatible to the Signaling System 7 (SS7) that underlies the PSTN

The following is taken from "The Secret Sauce of Convergence", by William Rabin of JP Morgan Securities Inc.[6]

Figure 2: The Missing Component for a Converged Voice/Data Environment, according to Bellcore/Telcordia



Source: "The Secret Sauce of Convergence: New Software Helps the Internet Find its Voice", J.P.Morgan Securities Inc., William D. Rabin , December 14, 1998, at

<http://www.telcordia.com/newsroom/knowledgebase/papers/jpmorgan_convergence.doc>

Today's telephone networks consist of two primary components: a "transport" layer that physically transports our voices back and forth and a "control" or "signalling" layer that insures that advanced features (such as call forwarding, call waiting, 800 numbers, etc.) are applied to the calls as appropriate. By contrast, what exists today in data networks is generally only the "transport" infrastructure, and there is no separate "control" layer. This missing element (according to Telcordia) is shown as the shaded area in **Figure 2**. The architecture under development by Telcordia and Cisco focuses primarily on creating a separate control infrastructure for telephony application on the data side of **Figure 2**. This helps integrate the voice and data transport layers and establishes a mechanism for providing advanced telephony services on data networks.

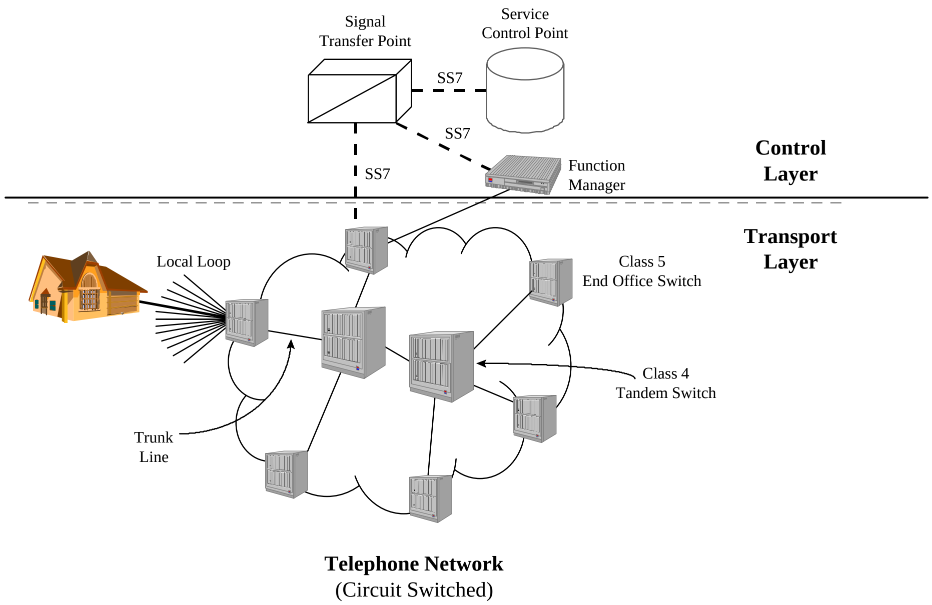
The architecture promoted by Telcordia and Cisco simply interfaces with the existing public switched telephone network (PSTN) and *does not propose to alter it in any way*.

The transport layer of the telephone network consists principally of Class 5 circuit switches (called "end office" switches) and Class 4 circuit switches (called "tandem" or "trunk" switches). These devices are housed throughout the country in buildings called "central offices," and these switches (along with the trunk lines connecting the switches) physically transport our voices from sender to receiver – typically in digital form.

Today's PSTN is pictured conceptually in **Figure 3** below. As a general rule of thumb, the trunk lines connecting switches within the core of the PSTN (i.e., within the cloud) are constructed from fiber optic cables, while the circuits connecting our homes to the nearest central office are made with copper wires. The connection from the PSTN to our homes is commonly referred to as the "last mile" or the "local loop." Because the 43 million tons of copper wire buried in the ground typically has not been refreshed in quite some time, the last mile of the telephone network has been called "the land time forgot."[7]

Figure 3: The Telephone Network

The Control Layer – SS7 Signaling



Source: JPMS.

In addition to the transport layer of the telephone network, **Figure 3** also depicts the control (or "signalling") layer of the PSTN. Unlike early signalling systems based on in-band tones, the control functions of SS7 are carried on an entirely different network than that used to carry the calls themselves. This SS7 network is a packet network that connects switches with Service Control Points, that contain databases (e.g., for number translation) and programs for acting upon the SS7 messages. They are switched through Signal Transfer Points, which are the packet switches (i.e. routers) for the SS7 network.

In other words, control activities and voice transmission are not carried out over the same path, or the same network for that matter.

A quick description of the components of the control layer follows:

- **SS7 Protocol –** This is the communications protocol utilized throughout the telephone control environment. SS7 is used for call setup (i.e., determining the path the call will take and establishing the circuit) and for accessing databases to obtain special handling instructions for advanced telephony services. Additionally, SS7 communicates network status information such as "trunk line 123 is being taken out of service." SS7 is an industry standard, bi-directional, full duplex protocol operating at either 56 Kbps or 64 Kbps. “Full duplex” means that communications take place in both directions simultaneously. Because SS7 is an industry-wide standard, calls can originate on one carrier’s network and terminate on another’s. SS7 signaling can be employed at any time during the call, not just at the beginning and end.

Comment: SS7 has been devised to control the redesigned PSTN for the digital age. Previously, the PSTN was controlled through in-band tones and other forms of primitive signalling. In contrast, the Internet has always been an all-digital network with shared data and signaling paths. TCP/IP is an end-to-end protocol and a peer-to-peer protocol. SS7 works as a peer-to-peer protocol among network control elements, but is only there to enable a master-slave relationship between machines that switch voice traffic and telephone network end-points. As such, SS7 is not an end-to-end protocol. There is no need for a “control layer”equivalent to SS7 in the Internet. The implications of this will be explored in this report.

- **Service Control Points (SCPs) –** These are the databases that contain programs that provide advanced telephony features such as call waiting, call forwarding, caller ID, 800 numbers, etc. Control-point software can operate on computer platforms ranging from Pentium-class PCs to high-end UNIX systems, and each Service Control Point can support calls from multiple end-office switches (i.e., from hundreds of Class 5 switches supporting millions of consumers). Because Service Control Points are so critical to the operation of the public telephone system, SCPs are typically deployed in pairs to provide backup.

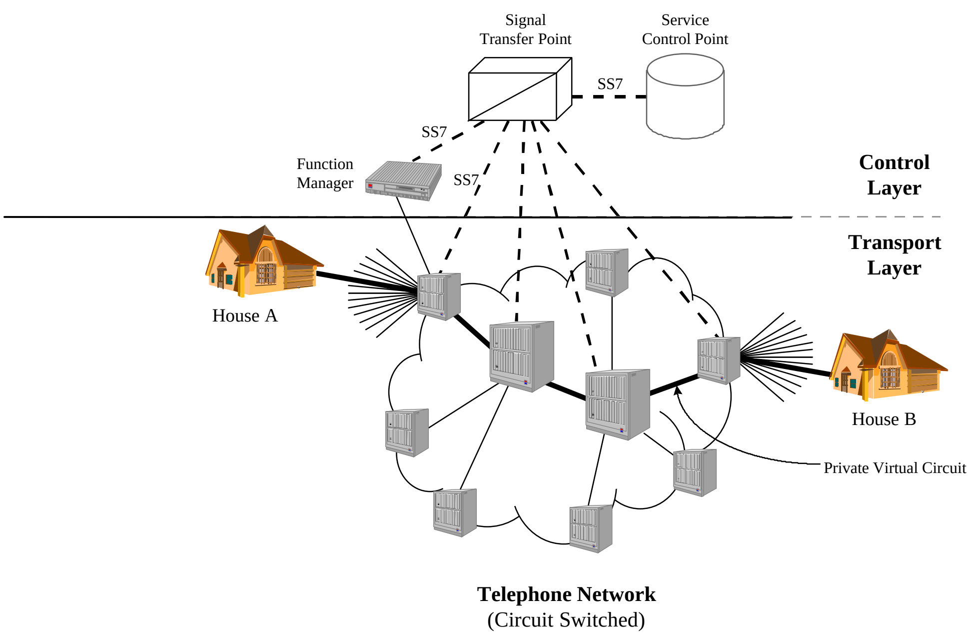
- **Signal Transfer Points (STPs) –** These are the “packet switches of the SS7 network”[8] that route control messages to the correct destinations. Each Service Control Point platform is linked to at least two of these Signal Transfer Points so that alternate paths are always available in case any single component fails.

- **Function Managers –** These devices (also called service nodes) are intelligent peripherals that provide services such as computerized voice and voice mail.

Figure 4 depicts how the signaling layer and transport layer operate together to provide advanced telephone services. In this example, person A picks up a telephone handset and dials person B’s number. This connects the sender to the edge office switch in a central office that in turn interrogates the database at the Service Control Point to see if there are any special instructions for this call. The message “how should I handle this call” from the Class 5 switch in the central office is routed to the proper database at the Service Control Point through the Signal Transfer Point. The SS7 control environment first checks to see if person B’s local line is busy. If it is, then the SS7 control environment interrogates the database to determine if additional handling instructions are on file. If the line is busy and no additional instructions have been given, then a recorded busy signal is played to the caller from the caller's local central office without a physical circuit ever having been established.

If person B's line is available, then the SS7 signaling system establishes the circuit from person A to person B through the network switches as shown. If there is no response from person B after a predetermined number of rings, the Function Manager may be activated by SS7 signaling to play a message to person A stating, "There is no answer yet. If you would like to leave a message for this person [for a fee that goes to the telecommunications service provider] just press the number 1 on your telephone." These sorts of advanced telephony features are designed to provide the maximum level of service to the caller *and the maximum fees to the service provider*.

Figure 4: Example of the Intelligent Network at work



Source: JPMS.

The telephone architecture described above is called "circuit switching." This approach dedicates physical resources (i.e., bandwidth and switch ports) to create a connection (i.e., a circuit) between sender and receiver that is fixed for the duration of the call. This circuit is "private" because no other people in the network are able to use any of the bandwidth allocated to this call. The circuit is "virtual" because although there is not a single physical wire running from the sender to the receiver, there seems to be.

Circuit switching was designed to optimize a key scarcity, the setting up of a call, so that it would only need to be done once per call. Originally, call setup used to be done by operators, then expensive electro-mechanical switches replaced the operators. Advances in electronics allowed these functions to be further performed by expensive computers. Now, call set-up resources are so abundant that a call can be set up millions of times a second, which is precisely what packet routing is, only for tiny packets instead of circuits.

1.4 THE INTELLIGENT NETWORK (IN)

One of the basic features of the circuit switched telephone system is that it is driven by intelligence in the network. The functions that may be added to the network are

a) defined by the owners of the network and

b) limited by the nature of the network,

which is engineered to provide 99.999% reliability (the five nines of reliability). In **figure 4** above, the creation of a virtual private circuit was illustrated. It could just as well have been an 800 number switching from one call centre in the eastern time zone to another in the Pacific time zone, or by giving the caller options as to how the call will be paid for.

The point of this discussion and figures above is to illustrate the extent to which the telephone company's value proposition is governed by the simple idea that services are added to the network's repertoire *exclusively* by the telephone company.

The second feature of the Intelligent Network is its design assumptions: that switching and bandwidth are expensive, and that they need to be conserved. To cite David Isenberg[9]:

> In those days, [the 1970's] computers, including those that controlled switching, were still considered expensive, scarce resources. When I worked in the nascent electronic toy industry in 1979, a single insight that eliminated six transistors paid my way. And the same factor – the need to save two expensive bytes of memory - laid the basis in this era for the Year 2000 Problem (stay tuned to the eleventh hour news for more on THIS story!). *(written in 1998 –TMD)*
>
> Now computer circuits are thousands of times cheaper. Moore's Law is what we call the ongoing improvement in computing cost and power. But in the 70s it was not generally known to be a `law' - to most telecommunications engineers (and to humanity in general), it has become the most game-changing wild card played in recent times.

Telephone networks have been designed for optimal use of scarce resources. The local exchange in your city, which handles the last four digits of your telephone number, theoretically could handle up to 10,000 telephones, e.g., with numbers 510-547-0000, 0001, 0002, et cetera through 510-547-9999. But the switching office is not designed to handle 10,000 simultaneous calls. It is designed to handle far fewer, maybe one tenth of that, based on the assumption that even in the busiest time of the day, only a fraction of its telephones will be active at any one time.

The network works as long as engineering assumptions (e.g., the length of a call, the number of call attempts, etc.) do not change. But let the assumptions change episodically (e.g., Rolling Stones tickets go on sale), or structurally (calls to Internet service providers last several times longer than voice calls), and the network hits its design limits - completing a call becomes a matter of try, try again.

What if network design were based on another assumption - that computation and bandwidth were cheap and plentiful?"

1.5 Next Generation Networks, Convergence of the PSTN with the Internet: The Clever Bellhead Vision

Isenberg's vision leads us to a fuller understanding of the Bellhead view of the issue, which is, how the Internet and the PSTN will *converge*. The first thing to notice is that, in the telephone company view, the two systems will converge, rather than that the design philosophy of one will prevail over the other. The assumption, frequently stated in the Telcordia papers, is that the investments in the PSTN are so huge that they cannot simply be discarded ("don't be near the caught with your wrench in the money machine").

Telcordia states the problem as follows[10]:

As companies plan to move into the new century, it becomes increasingly difficult to justify investment in separate voice and data networks. Whether the goal is to optimize existing networks to coexist with the new technologies, to transition networks, to meet the new market challenges by expanding network services, or to build a new network from the ground up, the strategy must align with the way that the increasing dominance of data services and the rapid investments in Internet Protocol (IP) technology are combining to accelerate convergence.

The issue of what to do about the Internet, and in particular, its troublesome features –traffic load, traffic characteristics, poor economics – is extensively discussed in a Telcordia white paper, “Architectural Solutions to Internet Congestion based on SS7 and Intelligent Network Capabilities”[11].

> “Internet traffic creates a number of problems for the PSTN, but ultimately the most critical problem is that it upsets the PSTN’s established economics. Internet traffic increases the load on the PSTN resources, requiring the purchase and deployment of additional PSTN equipment, in order to carry the excess traffic. It follows that internet traffic increases costs experienced by network operators. In contrast, it results in little or no compensating revenue. Or, as in the case of second lines, the revenue is outweighed by the increased costs.” (at page 2)

The article proceeds to discuss five methods for off-loading Internet traffic from the PSTN. These strategies are divided into methods which offload the traffic before the first switch (pre-switch), or post-switch. The paper states that its principal contribution is to highlight the potential use of the SS7 and the IN (intelligent network) capabilities in any of the technical solutions proposed for the traffic problem caused by the Internet.[12]

The vision of the Next Generation Network held by the theorists of the telephone system is that it should, in general, be *like the PSTN* insofar as it would

- Endorse the PSTN’s definition of Quality of Service
- contain a control element

but that it would be *unlike the current PSTN* in that it would

- support video, voice and data on the same network
- be based on a packet-routed architecture.

1.6 The Next Generation Internet: The Nethead View

While the telephone company theorists acknowledge that we are heading to a world where packet switching will prevail, the missing element in a packet-switched environment is the *control element*, which the PSTN has in the parallel SS7 network (refer to **Figure 2**). From the point of view of the Netheads, the control element is antithetical to the basic architecture of the Internet.

The nethead view can be represented in two propositions, and we will spend the rest of the report explaining what they mean.

PROPOSITION #1

> Advances in communications represented by the Internet have made possible the existence of non-facility-based telecommunications providers, entirely different from resellers in the circuit switched world. They would provide new services built out of the physical apparatus of the telecommunications infrastructure, without being bound to existing service definitions imposed by incumbent network owners.

PROPOSITION #2

> Incumbents oppose this with all their power, because they are used to being the ones who define what services are. Through the development of proprietary signaling protocols, incumbent CATV operators and Local Exchange Carriers are preparing once again to force on their competitors, new network architectures and interfaces that will reduce the potential for competition made possible by the Internet's design philosophy.

Accordingly, the more that governments understand the nature of new networks and how they can be made more or less competitive, the better they can know whether and how to intervene in issues like standards (that is, protocols), interconnection, and unbundling.

So far Internet protocols have been developed well outside the purview of national governments. And it could be argued that the Internet developed precisely because it was outside the purview of international consensus based on legacy business models.

The exception is the ITU, which is a state-based organization. Only in the last year has the development of new Internet-based protocols become sufficiently important to be the subject of the ITU's attention[2].

It might be questioned whether governments had interests to defend here. The justification for taking an interest is that the future operation of networks may well determine how economies will function, and is therefore a matter of national importance. Governments are guardians of the marketplace, and they have legitimate interests in knowing how they work. *In a computer-mediated marketplace, interfaces between networks determine who may compete*. Protocols embody the ideas designed into these interfaces between networks.

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[2] Although H.323 could be considered by some people as a first, its was mainly about enabling ISDN videoconferencing to operate on IP networks, whereas the H.GCP effort recently undertaken by the Study Group 16 of the ITU-T has become the first all-out effort by the ITU-T to develop an IP-based protocol.

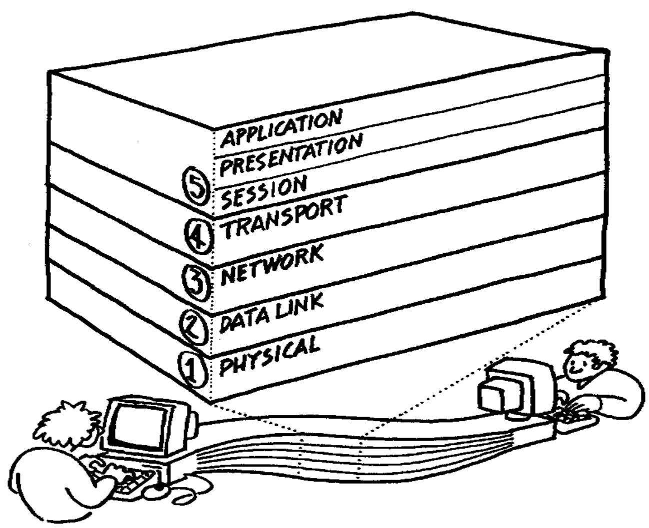
A precedent exists for intervention by government into the physical construction of switches in the PSTN era. When long distance calling was made competitive, governments mandated equal access so that dialing numbers was made the same for competitors and incumbents. This required expenditures by incumbents to change their switches to accomplish this. Intervention by governments in this case, if they were ever made, would concern the standards by which the PSTN is to interface with the Internet.

NON FACILITIES-BASED TELECOMMUNICATIONS PROVIDERS

The first proposition is that the Internet makes possible non-facilities based telecommunications providers. In order to understand this, we need to keep in mind the layered architecture of the Internet.

Figure 5

The Internet Works by Means of Layers of Protocol over a Physical Medium



The Open System Interconnection (OSI) 7-layer Network Model provides the most well-established method of looking at the underpinning of a data network architecture.

The layers can be remembered by the mnemonic: “All People Seem To Need Data Processing.” You will also note that the letters PSTN can represent the presentation, session, transport and network layers. By a curious coincidence, TCP/IP, the protocol of the Internet, functions at these four layers[3].

A non facilities-based telecommunications provider – as we define the term - develops services on top of an existing network. An example of a service overlaying an existing network is the World Wide Web, which floats on top of TCP/IP (the Internet). In the same way, the Internet overlays the PSTN (or any other physical medium).

The success of the Internet has demonstrated that two forms of telecommunications providers can co-exist in a symbiotic manner. The first provides the facilities, but does not define the services that are built out of those facilities. The second offers services over his preference of unbundled *network* or *data link* layers provided by the first.

Quoting David Isenberg:

> “IP terminates in a device at the customer's fingertips. Thus "endpoints" are no longer owned or controlled by telcos. This simple fact has profound consequences for how telcos do business. Because IP is an internetworking protocol, it makes differences between Networks irrelevant. So no matter how much intelligence a telco Network has, or how many cool features the telcos adds, in an all-IP Network, the only properties that matter are transport and connectivity. In an all-IP world, the network becomes the transport device for the Customer's application; much like a disk drive is the customer's storage Device. This means that new applications, new value, can be created at the edge of the network, without the permission, control, or involvement of the network owner. And when network ownership is de-coupled from value creation, telcos derive no benefit from this new value beyond the new traffic it spawns."

Definition

A non facilities-based telecommunications provider is one who offers services made possible by the unbundling of network and data link layers, the purpose of which is to redefine the characteristics of the underlying network.

In the current interconnection and unbundling regimes, it is not possible to buy or lease network elements unbundled according to the layers built in the protocols of the Internet. This is not surprizing, as the layered architecture of the Internet is scarcely known outside of network engineering circles. However, if communications systems are to reach their full potential, the layered model of the Internet must prevail. The means whereby the functionalities of the Internet will be made available to all, including telephone subscribers, is through a form of ‘unbundling’ appropriate to the architecture of the Internet. That means unbundling the *network* and *data link* layers of the PSTN.

[3] So you can think of TCP/IP replacing the PSTN.

In the light of what the Internet teaches us, this means that the ideas of unbundling in current Canadian telecommunications policy are inadequate, if not mistaken. It is our submission that the ideas of unbundling embedded in current policy really amount to no more than the resale of the parts of the PSTN. Even though people might think that they have successfully unbundled the PSTN, this is not the case. Why? The answer is that it is still not possible to purchase unbundled services according to the layers of the Internet. This state of affairs falls short of what unbundling *has to mean* in order to enable competition in an Internet era.

Treating the current wireline infrastructure (PSTN and coaxial networks as raw spectrum – as megahertz available for communications – is the necessary implication of this view. Interfaces will determine the services that may be extracted out of this spectrum. Until now these interfaces have been defined by concepts embedded in the limitations of the PSTN, in the case of telephony. The spectrum available in wires is fashioned and sold according to a monopoly's ideas of what can and should be provided, and this has meant charging by time and distance, using time division multiplexing.

For example, it is not possible to buy or lease spectrum that will reach a customer. This spectrum could be a colour in an optical fiber, or it could be a channel in a coaxial cable, or frequencies allocated for DSL service on copper at the level of raw Megahertz.

It will be objected that access to raw copper is available, and that this access to copper would solve the problem. It will be further objected that Competitive Local Exchange Carriers (CLEC's) have been allowed, and that these entities will provide an adequate framework for competition.

The business model of Competitive Local Exchange Carriers is premised on a competitor's ability to be allowed access to unbundled network elements owned by the incumbent local exchange carrier (copper loops, switches, distribution frames, databases and signaling networks). However, the CLEC value proposition is all-or-nothing: The CLEC gets the copper at inflated prices or resells the incumbent's services. The incumbent does not unbundle its spectrum, data link or network layers. Because from the Nethead point of view, LECs are not required to unbundle anything relevant to how communications must work in an Internet age, CLECs have only one real option, to replicate the business model of the existing Local Exchange Carrier. The opportunity to compete with the Local Exchange Carrier on its existing business model is not appealing, since the mandated resale prices for so-called unbundled network elements are, and will always be, higher than what the competitors will be able to sustain. In order to prevent CLECs from succeeding on their turf, the LECs have every incentive to inflate prices, to impose burdensome conditions on co-location requirements or to decline to unbundle according to the layers of the OSI model.

Finally, it is our view that the rise in popularity of the Internet has annihilated the sustainability of the CLEC business model. No one expects long-distance to subsidize local exchange services anymore. The most vibrant example of this has been the decision of the Canadian CATV operators to abandon their plans for competition based on the CLEC business models and to opt for Internet Protocol-based Telephony.[4]

The only way that a non facilities-based telecommunications service provider can offer services based on his selection of network and data link layers is by making possible a mechanism whereby he can specify the services he will require from the network. This new form of competition requires the ability of the competitor to be allowed to specify what he wants out of the network and data link layers. In contrast, the application layers, transport, network, data link, and physical layers[5] are currently bundled in telephone service offerings. This requires new gear in the PSTN, which the incumbents have no incentive to provide.

There are two distinct reasons for the limitations of what competitors are allowed to get out of the circuit switched phone network:

- People are not allowed to specify the services they can want out of the network and data link layers;
- In addition, the SS7 sets important limits to what can be specified in the current architecture of interconnection between the Internet and the PSTN.

The argument about the limitations of the SS7 is secondary. As we have come to understand our proposals more clearly, it has become clear that the current architecture of interconnection is incompatible with an Internet-based vision.

The received ideas of how competition can occur to the incumbent telephone companies are co-location and unbundling. We have already discussed the limitations of the current ideas of unbundling, which amounted to the fact that they do not correspond with the layers of the Internet.

Next, since we are concerned how this unbundling could be accomplished, we became concerned about how the SS7 interferes with this possibility. As we shall demonstrate in our discussion of the SS7 signaling system of the PSTN, no matter how unbundled are the services that we may ever get out of the PSTN, all we will ever get is what the SS7 provides. Signaling System 7 is antique, it is fragile, it is closed, it is insecure, and it is at the core of the ability of the owners of the PSTN to define what services are. It is also at the core of their inability to provide the functions that are so easily incorporated into the Internet, such as number portability[13]. As we have previously stated, the essential monopoly of the telephone networks is the ability to define what services are.

[4] The very slow progress of CLEC's is a measure of how much regulatory expense is involved in competing against the incumbents on a PSTN model. How many more Metronets does Canada really expect ?

[5] The NDP, to carry on with mnemonics.

Ending the exclusive ability of the telephone companies to define services is achieved by allowing non-facilities based telecommunications service providers to define what they want to get out of the network and data link layers.

1.7 Some Basic Ideas to Work With

In order to explain what we mean, we are going to give a brief and we hope painless lesson in network architectures and ideas from communications engineering.

Certain concepts and definitions are key to understanding what follows in this report. *In the process of writing this document, we found ourselves providing a few supplemental definitions to established concepts.*

> *State*: State is the term used by engineers to describe a system's knowledge about itself.

For example, the PSTN is 'stateful'; it runs on a system which is cognizant of the amount of information within itself. The SS7 knows when a circuit is opened, and must know this, in order to set up and take down the circuits which allow a call. By contrast, the telephone handset has no 'state'.

The Internet runs on a system which is 'stateless'. It does not need knowledge of itself in order to run. Terminal devices determine whether packets have successfully arrived or whether some portions need to be resent. This function is not the responsibility of the routers that direct packets to their destinations.

As Bill St. Arnaud writes:

> "State" is one of the most costly attributes of any network. State requires that network elements and management systems maintain knowledge about a specific relationship or connection that has been established between elements across a network. Every time state is introduced into a network additional computing and network management resources must be brought to bear to keep track of number and quantity of different connections and also mechanisms for the initiation and termination of state on an individual connection.
>
> "The Internet at its most basic level is a "stateless" network. IP packets operate much like TV signals on a cable system in that they are unidirectional (unicast) and can be transmitted without a prior relationship being established between the sender and receiver. But one of the most powerful features of the Internet is a set of protocols called TCP packets that allows "state" to be established over an effectively stateless network.

“This is one of the fundamental reasons why the Internet is so successful today is that it can support both stateless and stateful relationships between network elements. This means that the network can be operated at very low cost and "state" only introduced where and when it is needed.” [14]

Proprietary: A proprietary protocol is meant to restrict communications across administrative domains, for example, between a cable outfit and the PSTN, or between two telephone carriers. It does not matter that a protocol is developed in an open process such as the Internet Engineering Task Force (the IETF); it will be proprietary if it limits communications in this way.

Protocol : The language spoken between computers to enable them to exchange information.
In addition

- Protocols also serve as a neutral ground between competitors.
- They provide mechanisms for ensuring backwards compatibility of services while driving the introduction of new services.

Services: Services are defined by the mechanisms with which they can be implemented; in the case of the PSTN, they are defined by the features of the SS7 and of the telephone switches controlled by the SS7. The range of services that can be offered are defined by the limitations built into the interfaces between systems or to the system itself.

Interfaces: Interfaces are defined as the boundaries between two systems that are interconnected. Limitations are built in the interfaces by restricting the expressiveness, or the semantics, of the protocol that is used for communications across the interfaces.

Intelligent network: The system that specifies what services are and can be.

Dumb network/stupid network: A network that does not define what ‘services’ are or can be.

In order to understand the ideas which will be set forth in this report, we also need to keep in mind the following categorization of relationships among machines.

Relationship	State		Example
Master-Slave	Master is completely 'stateful'	Slave is completely 'stateless'	Class 5 telephone switch to telephone
Server-Client	Server is not completely 'stateful'	Client is not completely 'stateless'	Web browser (client) assembles a web page from a server
Peer to Peer	State is shared		SS7 to SS7, computer to computer over TCP/IP

SS7: the SS7 is a control network for Time Division Multiplexing (TDM) switching characteristic of the PSTN.

In this report, we will divide the network notionally into two planes, the *call control* plane and the *media* plane. The SS7 works at the control plane. Voice and data communications occur at the media plane.

Call Agent: The call agent is a term for a certain control device for data networks that forms an essential part of the Clever Bellhead Vision of the Next Generation Network. The Call Agent is the "missing component" of **Figure 2**, above. The purpose of the call agent is to replicate the functions performed by the SS7 in the Class 5 switch on voice services in a packetized network.

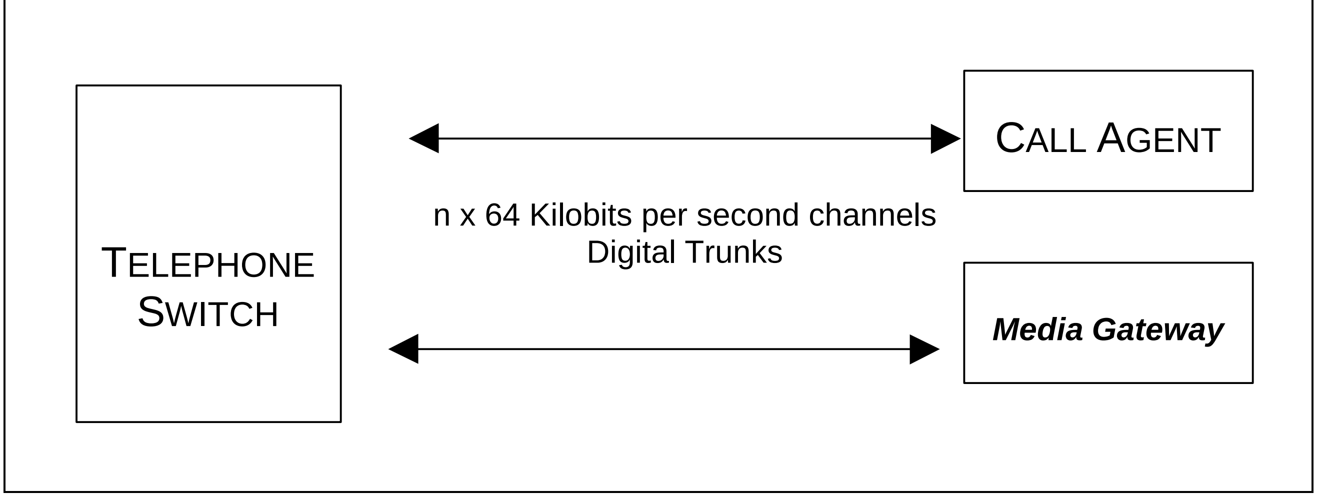
See Chart One "Relationship between a PSTN telephone switch and a Call Agent of a Next Generation Internet". The call agent is the technology that redefines the interfaces of the telephone switch by splitting apart the direct relationship between the SS7 and the voice channels found in a Class 5 switch.

Box 1 of Chart One illustrates how the PSTN is currently configured as a union of voice channel control links (the SS7) and voice channels (DSO's) in a Class 5 end-office switch. In the Next Generation Network- *the Bellhead vision* – the functions performed by the SS7 in relation to voice circuits are performed by the *call agent* in relation to data.

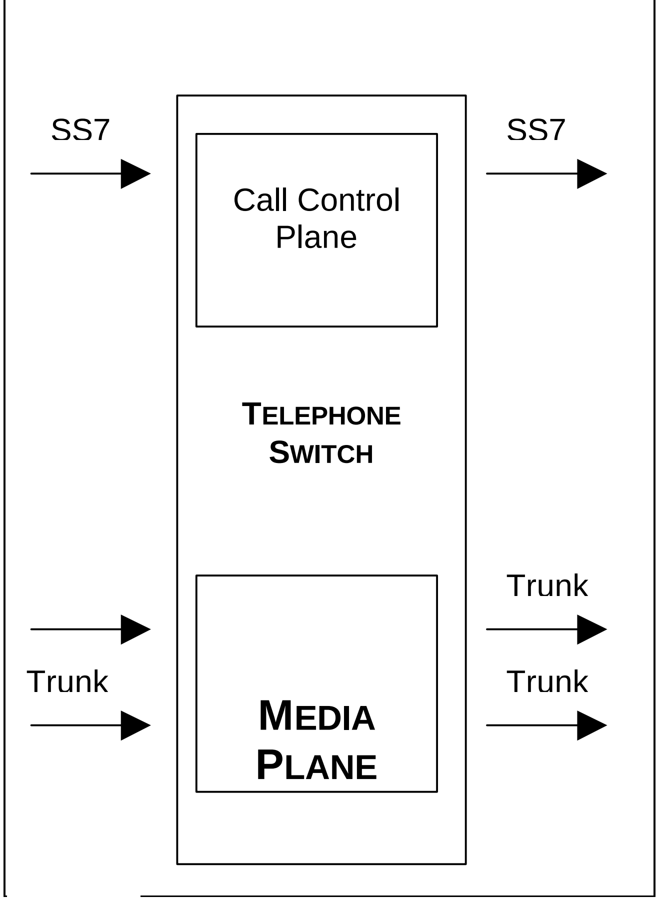
Box 2 of Chart One shows the union of the call control plane and the media or services plane in a voice telephone switch.

Box 3 of Chart One shows the *call agent* retaining control of services definitions in the development of Voice over Internet Protocol (VoIP) networks. The relationship of the *call agent* to the *media gateway* is a master-slave relationship.

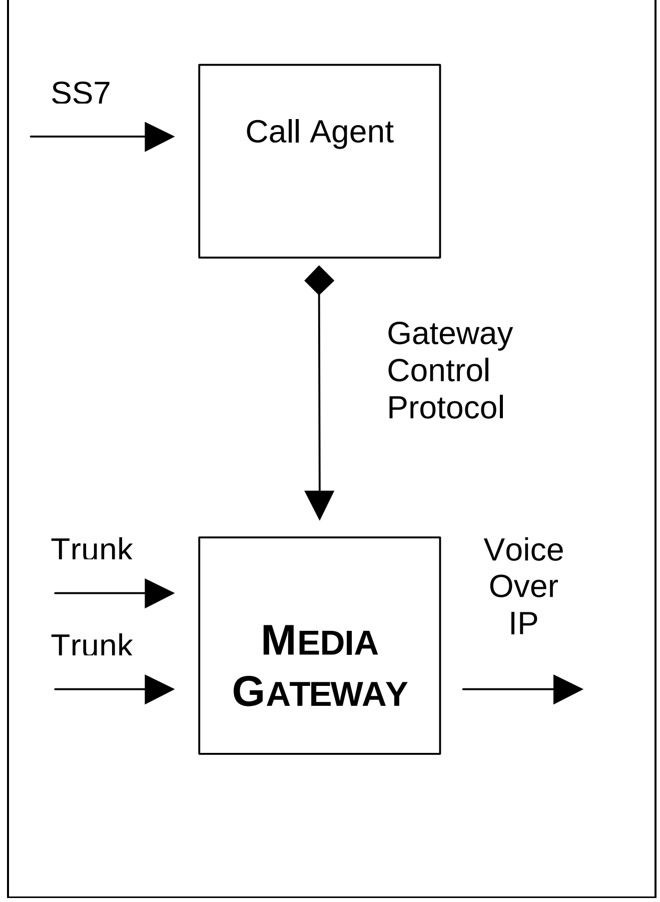
Chart 1 – Relationship between a PSTN telephone switch and a Call Agent of a Next Generation Network



2 - PSTN



3 – Next Generation Networks



PROPOSITION #2

The proposition was stated thus:

> Through the development of proprietary signaling protocols, incumbent CATV operators and Local Exchange Carriers are preparing to force on their competitors new network architectures and interfaces that will reduce the potential for competition made possible by the Internet's design philosophy.

It will be seen from Chart One that the *call agent* is the proposed device for achieving the second proposition, that is, to frustrate the Nethead vision. This would be done in two ways:

- By removing the logic from the telephone switch and placing it in the call agent, and
- By not specifying the interfaces between call agents that would be open to competitors.

1.8 INTERNET TELEPHONY VERSUS IP TELEPHONY

Since most of what we are relating is a debate between two visions for the future of the Internet, it is useful to lay out the concepts and attributes associated with each design philosophy.

IP TELEPHONY (THE BELLHEAD VISION OF TELEPHONY)

- Works from the existing business model of telephone calls – time x distance x bandwidth = revenues;
- Relies on international settlements to allocate revenues between carriers;
- Relies on contribution and subsidies to achieve universal services;
- The network ends in the call agent, just as it used to end in the Class 5 switch;
- The protocols it operates upon are proprietary, and not end-to-end (E2E) in the sense that Microsoft uses a proprietary code;
- All 'state' is kept away from the end-user's device;
- Provides Quality of Service assurances;
- IP Telephony is a subset of *Next Generation Networks*, but, in view of its master-slave design philosophy, services continue to be defined from the centre of the network.

INTERNET TELEPHONY (THE NETHEAD VIEW OF TELEPHONY)

- Works from a new business model: always on, the world is a large free calling area;

- Telephony is fully integrated into a portfolio of Internet services;
- The network ends in the end-user's device;
- The end-user can define services;
- Protocols are end-to-end, and open. Linux is the example of an open code. TCP/IP is an example of an end-to-end protocol;
- Substitutes speed (bandwidth) for Quality of Service (QoS) and provides best efforts service;
- Internet Telephony is a part of *Next Generation Internet Services*, whose nature will be as various and unpredictable as was the addition and overlay of the World Wide Web on top of the Internet.

  "The most significant distinction between the various Internet Telephony applications is the question of how much PSTN is in the network".[15]

CANARIE'S CA*NET 3

Canada has an existing high-speed Internet backbone in the form of Canarie's Ca*netII and other private backbones operated by UUNet and other large ISP backbone providers. The model under development at Canarie is the CA*net3, a very high-speed backbone network. The distinctions between the two generations of Internet backbone illustrate many of the points that have been presented so far, that the voice-based model is being superseded by a model built from the ground up on IP-based ideas: speed, simplicity of protocols, reduction of layers, end-to-end and peer-to-peer architecture. Canarie explains important aspects of CA*net 3 in its Frequently Asked Questions:[16]

> **5. What is the difference between CA*net II and CANARIE's CA*net 3?**
>
> The two networks have different, but not incompatible, architectures. Similar to American high speed Internet2 systems, CA*net II operates on top of two electrical layers (ATM and SONET) which then rides over light. Taking technology in a new direction, CA*net 3 is designed to run directly over light, eliminating the two extra layers and significantly increasing speed as well as efficiency. Built alongside the backbone system of 10 regional points of presence that link research networks across Canada to each other - as well as to the United States, Europe and Asia - CANARIE's CA*net 3 is eventually expected to replace the existing CA*net II. Until then, CA*net II will run parallel to the new system until the network is robust and stable.
>
> **6. What sets the CA*net 3 apart from other high performance systems?**
>
> The search for faster transmission speeds propels the world market into Canada's historical areas of strength in high-speed telecommunications. Most Internet systems are built for voice and are based on a three-layered network: ATM (Asynchronous Transfer Mode) which rides on top of SONET which, in turn,

rides on top of the optic fibre. In the United States, Internet2 and the National Science Foundation funded vBNS (very large broadband network services) provided by MCI, plan to use a high-speed Internet, which will use high-speed SONET facilities and IP-over-SONET routers. As early as October 1998, the CANARIE and Bell Canada consortium will take telecommunication technology a generation beyond what is being built in the United States. In another world first, Canadians will have a telecommunications network built for the Internet first, and voice second. A generation ahead of Abilene and vBNS, CA*net 3 eliminates the reliance on traditional voice infrastructure. Instead, it will put the Internet directly over light, allowing it to operate at much higher speeds. The difference is dramatic. The Abilene project predicts it can deliver the entire contents of the Library of Congress in one minute - a task CANARIE's CA*net 3 could perform in a mere second.

There are three points that can be deduced from the above description. The first is that the evolution of networks towards faster speeds involves the elimination of protocol layers derived from voice communications and quality of service considerations. In the CA*net3 plan, Internet Protocol will ride directly on light, eliminating two complex protocols for voice services, ATM (Asynchronous Transfer Mode) and SONET. The reduction of layers lowers costs by eliminating the engineers who sustain these layers as well as the associated amplifiers and repeaters which sustain SONET and ATM.[17]

The second point we may infer from the decision to base the next generation Canarie on IP: it will be ‘stateless’, because TCP/IP is a protocol that maintains no knowledge of the state of the system, and that it will have open interfaces, again, since IP is an open, end-to-end system.

The third point is an obvious corollary from the use of optical fiber. Nothing else will suffice to carry the traffic loads that are expected.

1.9 WHAT IS AT STAKE

The existence of ISPs poses a problem for local exchange carriers. The Internet is an overlay on the PSTN, in the same fashion that it would be an overlay on any physical transmission medium. The PSTN portion of total communications will inevitably decline. New sources of revenue must be found. Some observers believe that incumbent telephone carriers have the means and incentives to take over the customer base of the ISPs.

One knowledgeable observer and expert in PSTN/Internet integration is Fred Seigneur.[18] He writes:

“For over one hundred years the central office (CO) with its subtended copper lines has defined the reference architecture by which subscribers access the public switched network (PSN).

> Today's digital central office switch is like the mainframe computer of the 70's: a centralized, proprietary architecture, no longer suited to the service demands of the Information Age.”

But the issue is far greater than the health or disappearance of a particular service industry.

The issue concerns the ability of people to enjoy the benefits of a communications network where power is delivered to the end user to define the services that the network will provide.

This involves the redefinition of the interface between the fundamentally different PSTN and the Internet. That interface is a *gateway*.

In effect, providers of Next Generation Internet Services want the legacy PSTN to do very little. They want the PSTN to tell them to which IP address a signal should be sent so that a caller from the Internet can reach a PSTN subscriber.

2. PROTOCOLS

2.1 CHARACTERISTICS

Protocols were previously defined as:

Protocol: The language spoken between computers to enable them to exchange information.

In addition

- Protocols also serve as a neutral ground between competitors.
- They provide mechanisms for ensuring backwards compatibility of devices while driving the introduction of new services.

Protocols are also the means of expressing binary information through one of several encodings:

- ASCII
- Binary aligned
- ASN.1

ASCII characters are the ones we are familiar with from keyboards. They are readable and therefore cheap to debug. HTTP, the Hyper Text Transfer Protocol used for the transport of Web data on the Internet, is encoded in ASCII..

Binary aligned encodes the instructions by means of the number and the order of the bits. The order of bits designates the functions to be performed, the value of the bit designates how the function is to be performed. TCP/IP is a binary aligned protocol.

ASN.1 is the Abstract Symbolic Notation 1 and encodes the data according to one of many rules, such as BER (ASN.1 Basic Encoding Rules) and PER (Packed Encoding Rules).. It is the most complex encoding. ANS.1 requires encoders and decoders on each end to send, read, debug and manipulate the data inside a protocol which uses ASN.1 It was conceived by the Bellheads, and its encoding is predicated on the scarcity of bandwidth, for the same reason as ZIP files conserve bandwidth in email.

Other encodings exist, but they will not be dealt with further here.

2.2 HOW PROTOCOLS ARE DESIGNED

Protocols take their place and have their meaning from the network architectures or design philosophies that they are designed to serve. Accordingly it proved impossible to consider protocols in this report until the design philosophies of the Internet and the PSTN were discussed.

Protocols are forms of programming and are therefore the products of rational design. Generically they are the product of a three step process:

1. The requirements of the protocol are determined (what must it do?)
2. The most appropriate semantics are found (what is the meaning of the messages? What is the number of the messages back and forth between computers that is expected to complete the transaction?).
3. The most appropriate encoding is chosen.

As an example in the case of the Internet Protocol,

1. The header must contain the source address and the destination;
2. How to signal which of the TCP or UDP protocols to use; and
3. Binary aligned encoding was chosen.

2.3 Forums for the Development of Protocols

The main organizations that are actively defining the protocols and the architectures of the telecommunications networks are:

1. ITU, the International Telecommunications Union, http://www.itu.int
2. IETF, the Internet Engineering Task Force, http://www.ietf.org
3. ETSI, the European Telecommunications Standards Institute, http://www.etsi.fr
4. Cablelabs, the research arm of the North American CATV industry, http://www.cablelabs.org

1. The activities of the ITU, formerly the CCITT, is an old body dating the earliest stages of international coordination of telecommunications standardization, when the industry was a relatively coherent group of government sanctioned monopoly telcos. The ITU study groups, which participate in the developments of IP telephony, are Study Groups number 8, 11 and 16. To the eyes of IETF members, the ITU-T has a reputation of developing protocols in secret and to standardize the solutions well before they are known to interoperate.

2. The Internet Engineering Task Force (IETF) is a large open international community of network designers, operators, vendors, and researchers concerned with the evolution of the Internet architecture and the smooth operation of the Internet. It is open to any interested individual.

The actual technical work of the IETF is done in its working groups, which are organized by topic into several areas (e.g., routing, transport, security, etc.). Much of the work is handled via mailing lists. The IETF holds meetings three times per year.

Although dating to the first days of the Internet, the IETF has enjoyed significant attendance only during the last ten years. The apparent openness of the IETF disguises the fact that it is a strict meritocracy. Ideas are vetted by peers in the most thorough fashion. The IETF has been described as a social innovation, possibly for the manner of its operations, possibly for the fact that it has never been associated with governments or monopolies. It works on what is called rough consensus and running code, which is to say that final agreement on every detail is not required before a protocol is launched, and that protocols are made as compatible as possible with existing elements of the Internet. The IETF has a tendency to develop simple protocols for well-defined applications.

Started by the same academics who devised the Internet, its membership has been steadily added to by representatives of business.

3. The pertinent activities of ETSI are principally done in the Telecommunications and Internet Protocol Harmonization Over Networks project (TIPHON) of ETSI, http://www.etsi.org/tiphon. The participants in ETSI Tiphon are meeting in this body to complete the activities started in the ITU-T. The attendees of ETSI Tiphon is pretty much the same than the attendance to the ITU-T.

4. The incumbent cable TV operators of Canada and the United States are driving the activities of Cable Labs. More specifically, the activities of Cablelabs are being done under the umbrella of the PacketCable project, http://www.packetcable.com. The activities of Cablelabs are known to be contentious in the industry, as for example, Cablelabs members are known to deliberately disallow the participation from the telephone companies in the advancements of digital television. All activities of Cablelabs are done under Non-Disclosure Agreements and cannot be revealed until completed.

Since the first network elements that need to be developed for Next Generation Networks are gateways to the legacy networks, virtually every telecommunications standardization body have begun developing *gateway control protocols*. Presently, most of the activity seems to be concentrated around IP Telephony, and is aimed at reaching industry consensus on adequate mechanisms to bridge the legacy PSTN with the Internet.

However, gateway protocols will need to be extended for other applications than telephony, notably multimedia conferencing, radio and television applications.

A partial taxonomy of protocols

Gateway Control Protocols are concerned with the interface between legacy networks (cable and the PSTN) with the Internet.

- On behalf of a *call agent*, for instance, it would enquire whether a gateway has a channel available for a person to make a call from the Internet to through to the PSTN.
- It would validate a personal identification number for making long distance calls, for instance.

Session Control Protocols are concerned with the management of the *session* (see figure 5). They seek to find compatible media between terminals. They handle personal mobility in telephone calls.

Telephony Signalling Transport Protocols are useful when the Internet is interposed between two PSTN's. They provide a mechanism for tunneling information across next-generation networks information that is only relevant for legacy equipment.

2.4 A Case Study in the Development of Protocols

There is an expression that Internet time is happening faster than clock time. The following case study supports the view that protocols are developing and mutating like viruses.

SGCP – Simple Gateway Control Protocol

Sometime back in June 1998, Christian Huitema, a prominent Nethead now working for Bellcore/Telcordia proposed SGCP to replicate the behaviour of the PSTN on the Internet by mimicking the behaviour of the Class 5 switch. Accordingly, this was a master-slave protocol.

IPDC – Internet Protocol Device Control

By August 1998, Level 3, a new IP-based telecom carrier, proposed improvements to SGCP and relabelled it. Critics disliked the closed process whereby it was created.

MGCP – Media Gateway Control Protocol

Sometime in September/October of 1998, MGCP is put forward. It is a relatively stable 6 month old proposition. It is intended to handle video as well as telephony. It is based on ASCII encoding and would be relatively simple to implement.

MDCP – MEDIA DEVICE CONTROL PROTOCOL

November 1998 – Lucent makes slightly different proposals at the ITU for a gateway control protocol for video.

MEGACO –MEDIA GATEWAY CONTROL PROTOCOL.

November 1998 -The IETF creates its own working group for multi-media gateway control protocols. the IETF MEGACO working group is presently gathering consensus on the requirements of a gateway control protocol which is probably going to be limited to telephony-only applications in its first inception.

The points to note in this recital of events are that

- Gateway protocols will determine what services may be extracted from the PSTN by way of the Internet, and are therefore of crucial interest for Next Generation Internets, and;
- Philosophical differences between the IETF and the ITU and its derivative bodies will persist.

A CLASSIFICATION OF PROTOCOLS

	Peer to peer	**Master-slave**
Not end to end	SS7	MEGACO, MDCP, MGCP,SGCP
End to end	H.323 SIP	A null set

What is the significance of this proliferation of proposals? In the opinion of François Ménard:

> "The current proposals for device control protocols (IPDC, SGCP, MGCP, MDCP) have not demonstrated the ability of these protocols to be used across service provider administrative domains. This means in practice, that these protocols would never be used between two different Internet Service Providers and that these protocols could be used by the telcos to gain back vertical control, forcing proprietary interfaces on the parties wishing to compete against them.
>
> Such protocols would require the development of new interfaces that would have to be unbundled. These interfaces could cause the same amount of prejudice that

> SS7 imposes, and furthermore will require years of deliberations, finally to end up with a slightly improved SS7, but never getting out of the paradigm that services are defined by the telcos. Logic says that the *Next Generation Network* is an internal restructuring of the PSTN, and that call agents would only have to talk to call agents within a single service provider**,** relying on SS7 for communications across service providers."

2.5 Another Study in Protocols: IETF versus ITU / H.223 versus SIP

The interoperability of IP with the PSTN is determined by the functions embedded in the *gateways* between them.

Two protocols for the handling of multi-media communications across IP networks are under development in the IETF and in the ITU. The IETF candidate is SIP, for Session Initiation Protocol, and the ITU's favourite is H.223. The principal corporate backer of SIP is MCI Communications, while others also participate. H.223 is backed by a more numerous and powerful contingent including Microsoft and Lucent. A master's thesis compared them[19], and the criteria they used are important for understanding what one would want to look for in protocols:

Extensibility: Extensibility denotes the ability of the protocol to sustain added features over time as new applications are developed.

Scalability: Scalability denotes the ability of the protocol to sustain ever increasing volumes of traffic without congesting or breaking down. One of the features that allows for scalability is the absence of a requirement for 'state' in the routers that handle the traffic.

Services: Services denote the ability of the protocol to accomplish various functions.

In this particular case, the SIP protocol was found to be simpler, more extensible, and more scalable, though opinion differed as to whether it provided the same set of services as H.223, these being assigned in SIP's case to other protocols.

A report from CMP Net[20] "Bellheads versus Netheads" describes the fight between the IETF and the ITU over these protocols as follows:

> Critics of H.323 say that standard is too oriented to the old circuit-switching model (it uses a phone number addressing scheme instead of IP addresses) and too expensive to implement (the codecs specified as part of the standard are proprietary and require licensing fees). Engineers at MCI Communications Corp. have been among the most critical of H.323. "H.323 breaks the model of having

> one network for all services," says Henry Sinnreich, member of the executive staff working on Internet development at MCI. "We already have a phone network, and we already have the Internet. Now we have to build an H.323 network that does everything differently."
>
> Ultimately, the IETF has more than a technology battle on its hands as it tries to sway the public network establishment. "I don't think the IETF will ever carry the weight that the ITU does," says Aberdeen Group's Taylor. The ITU has a long, rich history of specifying standards all the way down to the physical interfaces, Taylor says. The 'Netheads don't have the muddy work boots and helmets," he adds. "They're just dealing with Layer 3 and above."

Whether the last comment proves fatuous or insightful remains to be seen.

3. COMPETITION IN A NEXT GENERATION INTERNET

We have observed in the course of the last 18 months the growing conviction on the part of all players in the networking game that the PSTN as we have known it is going to be significantly less important, tending to insignificance relative to the volume of data traffic, and that networks based on IP will prevail. Corporate takeovers of packet-router makers by makers of circuit-switches, such as that of Bay Networks by Nortel, speak louder than any consultant's report that the jig is up for circuit-switching. The stark graphic in **figure 1** shows the expected decline.

Protocols and ideas based in voice circuit switching, such a ATM and SONET, are being squeezed out, as next generation networks are predicated on IP directly over glass fiber.

For the telephone companies, their power to generate revenues has derived from a business model that charges for duration, time of day and distance of voice calls, as well as for bandwidth, and more importantly, reposes in the hands of the owners of the network the exclusive ability to define services. For example, the frequently heard "let Bell notify you if this line becomes available in the next half hour. A 35 cent charge will apply", shows the Intelligent Network at work for the shareholders. Note also that this new service feature cannot be disabled at the request of the end-user.

The Internet potentially changes this situation by allowing people at the periphery of the network to define the services they will extract from it. Granted not everyone has the capacity to do this but it suffices that some are able to do this. The invention of the World Wide Web, which drove the expansion of what was an otherwise obscure signalling system called the Internet, is the classic example of what is meant by people at the edge having the ability to create new services. Hypertext, URL's, web browsers, search engines, filters – all these would have been simply inconceivable in a network running on the internal controls of the proprietary, complex and fragile SS7.

What we are saying about protocols is essentially quite simple. The interfaces between the legacy system, the PSTN, and the new system, the Internet, or IP-based networks, will define what we will be able extract from the PSTN in the future. What services people will be able to extract from the telephone system of the future – even without a PC – will be very much greater under certain scenarios of network interfaces than in others.

A system based on a proprietary control architecture, the SS7, and a master-slave relationship between that system and the traffic flowing through switches, has obvious difficulties accommodating a connectionless peer-to-peer architecture with no controls, no 'state'. This has been evidenced by the 'Bellhead' ideas presented at the beginning of the report. The Internet is thought to be missing a 'control element' analogous to the SS7, which we identified as the *call agent.*

Various proposals for protocols were looked at. Many were found also to embody concepts that potentially allow the PSTN to retain control of the interfaces and continue the business model whereby the PSTN determines the services to be extracted from the system.

At this point two distinct possibilities are open. The first is that policymakers and regulators will be aware that network architectures for the future are being decided now, outside their cognizance. Consequently they will decide to take an interest in next generation Internets and develop expertise to relate the proposals by various sides to policy implications, including competition policy. Hopefully, they would concern themselves with seeing that interfaces to the PSTN are made open and consistent with the open and dynamic signalling system that the Internet represents.

There is no evidence however, from the history of Canadian telecommunications regulation, that a purely regulatory approach to opening up the system to competition will be swift or effective. Recall that this is not competition of like services, but a radical redesign of network architectures and a change of business models. There are several reasons for this doubt. Even with the best will in the world, the Nethead vision will face a tough uphill climb owing to the relative strength of telecommunications providers, compared to computer makers and Internet service providers. The Bellhead vision can and will be defended ably by the power of incumbency.

The second possibility, and one which bears watching and encouragement, is that the 'last-mile' problem will be evaded by the ability of municipalities to offer rights of way, either by themselves or by allowing others to lay fiber. Various users would be able to light up their own colours or sections of the fiber. This model has been outlined recently in Bill St. Arnaud's "Gigabit Internet to the Home".[21] This would be competitive pressure in the real world. The examples that will be set by new service providers using municipal common fiber will show what can be accomplished when there is no legacy PSTN to block progress or extract tolls.

To conclude with Bill St.Arnaud:

> “In these past deployments industry was granted an exclusive monopoly in exchange for a commitment to provide ubiquitous service to all communities throughout the country. A Gigabit Internet to the Home network, however, is premised on competitive equal access and will require the defining of a new set of relationships between industry and government.”

Putting it in other words, the Next Generation Internet will be one where all service providers will be able to light a colour of the ubiquitous fiber for their own purposes, using their own business models, on a common infrastructure. By common infrastructure we mean that end-to-end IP-based communication will have dissolved the significance of different ownership of different last-mile bottlenecks. If this model prevails it will not be possible to parlay public service obligations, such as universal service, into commercial privileges. This involves either a revised idea of what interconnection means, one which is consistent with the Internet, or the deployment of a new network, an IP freeway rather than a circuit-switched railroad.

SOURCES

Many papers and sources contributed to this document. The authors are grateful to the following for their insights, courtesy and time.

Fred Seigneur, telecommunications network consultant, http://www.sonetech.com/
“All people should be able to write software to control the PSTN”.

Bob Frankston, IP evangelist, http://www.frankston.com/
“What is fundamentally at stake, is that IP commoditizes communications”.

A recently retired Nortel VP, who shall remain anonymous.
“ISP’s don’t own the last mile or the means to communicate with other sites, They have an application – that’s all. They are the mercy of the owners of that [last-mile] infrastructure”

Bill St. Arnaud, Director, New Networks, Canarie, *bill@canarie.ca*

François Ménard

François Ménard started his career as one of the first ISPs in the province of Quebec. He then sold his company to join Mediatrix as a product specialist. During his five-year stay at Mediatrix he became a lead architect in the development of several voice over IP products, developed many contacts in this emerging industry and was invited as a speaker at various industry conferences. He was also active in the development of Internet Telephony through many working groups of the IETF, the TIPHON project of ETSI, and the PacketCable effort of Cablelabs. His representation of Mediatrix at the MIT Internet Telephony Consortium spearheaded his passion for Internet economics and policy. He his known to be an advocate of Internet Telephony as fully integrated with the other services of the Internet and a proponent of the Session Initiation Protocol. His vision for Internet Telephony was also featured in two issues of the Cook Report on Internet. He has recently become a professional consultant in the area of Next Generation Internet Services.

David Isenberg

David Isenberg is a former employee of AT&T Bell Laboratories, now a telecom industry analyst, who gained fame as author of "Rise of the Stupid Network". David contributed valuable, indeed, essential insights to the preparation and editing of this paper. He is found at www.isen.com, isen@isen.com, 1-908-[654]-0772.

Telcordia Technologies:
"Our role in the history of telecommunications includes:

- Leading the industry in setting standards through our Generic Requirements and COMMON LANGUAGE products
- Providing critical technologies such as SONET, ATM, DSC, and SS7, that are the underpinning of today's networks
- Developing the core software that allows U.S. telecommunications companies to handle more than 150 million service orders annually and to manage almost 200 billion calls at extraordinarily high levels of reliability.
- Developing the software that handles every 800 / 888 call in the U.S.
- Working with over 500 companies in 55 countries to incorporate our software into their network systems.

We believe that we will play a similar role in the rapidly approaching transformation of carrier networks from circuit based architecture to a packet based architecture. Telcordia is currently the clear leader in the development of the network software and associated services that will allow IP networks to operate efficiently on a large scale and to seamlessly interconnect both with the existing Public Switched Telephone Network (PSTN) and the new IP based networks."

Articles

CANARIE

"Architectural and Engineering Issues for Building an Optical Internet", September 22, 1998, draft, by Ting Wo Chung, John Coulter, Jeff Fitchett, Sam Mokbel and Bill St.Arnaud, <http://www.canet2.net/archeng/architectural>

"Gigabit Internet to Every Canadian Home by 2005"
Bill St. Arnaud, <www.canet2.net/archeng/home.html>

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"Next Generation Networks: A Practical View of Network Evolution", by Grant Lenahan, Executive Director, NGN Solutions, Bellcore (renamed Telcordia Technologies) http://www.telcordia.com/newsroom/knowledgebase/index.html

Telcordia Technologies – Communications at a Crossroads
http://www.telcordia.com/aboutus/vision/changingcommunications.html

"The Secret Sauce of Convergence" by William D.Rabin, J.P.Morgan Securities
<http://www.telcordia.com/newsroom/knowledgebase/>

"Architectural Solutions to Internet Congestion based on SS7 and Intelligent Network Capabilities" at http://www.telcordia.com/aboutus/vision/changingcommunications.html

"A Practical View of Network Evolution", Grant Lenahan, at
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<http://www.cs.columbia.edu/~hgs/sip/papers.html>

"A SIP of IP Telephony", Fredrik Fingal and Patrik Gustavsson
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"The Impact of Settlement Issues on Business Evolution in the Internet" Sanford Marble, Bellcore
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Endnotes

[1] See or hear the speech of John Sidgmore, Chairman of UUNet at <http://www.uu.net/lang.en/events/sidgmore-keynote-nwio98/>
[2] Source: "Next Generation Networks: A Practical View of Network Evolution", by Grant Lenahan, Executive Director, NGN Solutions, Bellcore (renamed Telcordia Technologies) http://www.telcordia.com/newsroom/knowledgebase/index.html
[3] "Architectural and Engineering Issues for Building an Optical Internet", September 22, 1998, draft, by Ting Wo Chung, John Coulter, Jeff Fitchett, Sam Mokbel and Bill St.Arnaud, at page 6,

section 71.1 “High Density Wave Division Multiplexing,” <http://www.canet2.net/archeng/architectural

[4]Ibid, at page5, section 71.1 “High Density Wave Division Multiplexing,” <http://www.canet2.net/archeng/architectural

[5] *The Innovator’s Dilemma*, by Clayton M. Christensen, Harvard Business School Press, ISBN 0-87584-585-1. Christensen shows how leading companies consistently fail to deal well with disruptive technologies, of which the Internet is surely the foremost example, because they do all the regular things well. They ask their leading-edge customers, “do you want this product?” Naturally the customers have no clue why they would want a web browser, for instance, before they have even conceived of what it could be, or how they could use it. Who would buy a telephone for $1,000? Who would buy an *inferior* telephone for $1,000? Yet your computer is that inferior telephone. “It is simply impossible to predict with any useful degree of precision howdisruptive products will be used or how large their markets will be.” (at p. 158)

[7] *Data Communications*, February 1998.

[8] <http://www.webproforum.com/bell-atlantic2/topic04.html.>

[9] The Rise of the Stupid Network, by David Isenberg, at< http://www.hyperorg.com/misc/stupidnet.html>. Isenberg’s home page is at <www.isen.com>

[10] <http://www.telcordia.com/aboutus/vision/nextgeneration.html>

[11] by http://www.telcordia.com/aboutus/vision/changingcommunications.html

[12] at page 11 of the article, refer to note 7.

[13] To change your email address in a computer, you enter a few new pieces of information into your email software. Any computer thus modified will receive your email at a new or different physical address. That is the equivalent of local number portability. Those acquainted with the enormous difficulties engendered by trying to get local number portability out of the PSTN would do well to contemplate how trivial the problem is in a net-based architecture, where the intelligence resides at the edge.

[14] Gigabit Internet to Every Canadian Home by 2005”, Bill St. Arnaud, www.canet2.net/archeng/home.html

[15] “A Taxonomy of Internet Telephony Applications”, David D. Clark, Internet Telephony Consortium, MIT, ddc@lcs.mit.edu

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[18] http://www.sonetech.com/~fred/resume1pg.html

[19] “A SIP of IP-telephony”, by Frederik Fingal and Patrik Gustavsson, 10 February 1999. Found at http://www.cs.columbia.edu/~hgs/sip. The website belongs to Henning Schulzrinne of Columbia University. He is a major source of ideas within the IETF and protocol development generally.

[20] < http://www.teledotcom.com/0598/features/tdc0598cover1_side1.html >

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