Advances in Local Communications

Dr. Charles L. Jackson

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Executive Summary

Within the next few years, high-speed Internet access, together with complementary activities such as the widespread use of packet networks in the home and office, will change our views of what constitutes a telephone call or an access line. One consequence of the widespread use of packet technology on access lines will be a great reduction in the local carrier's ability to meter minutes of use of traffic or even to know how many simultaneous access connections the customer is using.

The fundamental change will be that many offices and residences will receive service over high-speed digital access lines carrying packets of data traffic. I am not discussing unproven technologies, but rather those that are available in the market today. For example, Sprint Canada described their ATM-based packet data network service saying,

> [ATM service] consolidates multiple communication streams into a single network . . . Supports diverse applications . . . . It's a versatile emerging technology that can support a variety of high-speed, high-bandwidth applications concurrently over a single network interface.

When a packet of data goes directly from customer premises to customer premises, neither Sprint Canada nor the access provider needs to know whether that packet is voice, video, or data. Further, if the customer is using reasonable privacy technology, the carriers will not be able to know.

Many manufacturers, including Nortel, FlowPoint, Lucent, NewBridge, and others, have recently announced products that can be used to connect a telephone to the Internet. The cable industry is developing equipment that allows telephone calls to flow over the data connections used for cable Internet services.

Industry today can affordably combine voice, computer data, video and any other form of information on a single packet-data connection. The likely changes in technology will improve the cost, ease of use, reliability, and other features of packet-based local access. Technological progress will also expand consumers' demand for packet-based local access by lowering the price and improving the performance of complementary

equipment such as computers, video equipment, home networking equipment, and digital telephone equipment.

The combination of low-cost networking and always-on Internet access will provide consumers with a host of useful options. The home and small office will need communications connections to the rest of the world that are always on and that can support multiple conversations or subconnections at the same time. Consumers will benefit from these new uses and will be willing to pay for them—especially if continuing technical progress brings the price down substantially. Both businesses and consumers will expand their use of data communications. Internet connections will become essential to most organizations (if they are not so already). Such Internet connections will need to be always available with little delay (always-on) and relatively fast (download simple graphics in a fraction of a second, complex graphics in a second or two).

Residential use of Internet services (a shorthand code for data communications uses) will expand greatly. The principal residential uses of the Internet for the next few years will be for email and for web applications such as shopping and gathering information. The Net is becoming our library, mall, and post office. As this happens, people who read, shop, or correspond have a greater and greater need for high-speed digital access.

High-speed digital connections based on packet-switching technology meet real needs of both consumers and businesses and are available today. The conditions are right for the rapid adoption of this approach to local telecommunications.

It seems reasonable that the organizations and people who benefit most from using these technologies will adopt them most rapidly. These are also the people who spend the most on telecommunications services and account for the lion's share of the usage. Consequently, their actions will have a disproportionate impact on the contribution flow.

The widespread use of high-speed packet access, often by the heaviest users of telecommunications services, will stress the current system of basing contribution on

minutes of use of switched traffic. The heavy users will have both the incentive and the means to avoid the contribution levy. Many will install equipment and systems that make the traditional measurement of minutes of use impossible in order to gain the other benefits of these new technologies—rather than out of a desire to game the contribution regime. From a practical point of view, the adoption of packetized access implies a great reduction in the ability to meter usage in units such as minutes of use or access lines.

Access providers will not be able to reliably distinguish between packets carrying voice, email, web content, or anything else. They will not be able to tell if one telephone is active in the home or if three are active. The old concepts of metering minutes of use or counting access lines will fade and disappear because they will not be feasible.

In this rapidly coming world, contribution should be based on practical measurements that can be made reliability and that cannot be easily manipulated by those who would game the system.

About the Author

Charles L. Jackson received his Ph.D. degree in electrical engineering from the Massachusetts Institute of Technology. Dr. Jackson is a member of the IEEE, the Internet Society, the American Mathematical Society, and Sigma Xi. He is an adjunct professor of electrical engineering at the George Washington University, where he has taught a graduate course in mobile communications. From 1982 to 1988, he was an adjunct professor at Duke University. He is a member of the U.S. Department of Commerce's Spectrum Planning and Policy Advisory Committee (SPAC) and of the Federal Communications Commission's Technological Advisory Committee (TAC). He has written for professional journals and the general press, with articles appearing in publications ranging from *The IEEE Transactions on Computers* to *Scientific American* to *The St. Petersburg Times*.

1 The Human Side of the New Technologies

Consider a typical family a few years from now, with two parents and a teenage child. The family has two computers, one for the parents and one for the student, and high-speed Internet access over a digital subscriber line. The computers are connected together and to the Internet using home networking technology.

It is eight in the evening. The teenager, Ann, decides that she needs a break from homework and uses the Microsoft Netmeeting software on her computer to join in a brief text chat with two of her friends, Leslie and Billy. Billy drops off the connection, and Ann and Leslie turn on their microphones and convert the text chat to a voice conversation.

Meanwhile, Dad is shopping on the Internet for a new pair of boots. He cannot find the boots he likes at the store's website, so he clicks on a button labeled **Speak to A Service Manager**, and a voice comes from the speakers of his computer saying, "How may I help you?" Dad describes the boots he wants, and the service manager replies that the store no longer carries that brand. Dad is disappointed but says, "Thanks," and then the voice connection is broken. Dad switches his browser to another store and continues looking for a new pair of his favorite boots.

While the above events are taking place, Mom has been in the kitchen, talking with her sister on the traditional phone.

None of these activities requires any new technology. Microsoft's Netmeeting software comes preinstalled as part of Windows 98. Similar software is available for Macintosh and Linux computers. Nortel sells the software and equipment needed to place an Internet Voice Button on a website.[1] Vendors such as Intel and Cisco sell home networking hardware at relatively affordable prices.

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[1] For information on Nortel's Internet Voice Button product, see http://www.nortelnetworks.com/products/01/ivb/index.html.

How many telephone calls took place in the activities described above? How many minutes of use occurred? It depends upon what one chooses to call a telephone call or a minute of use. Mom's phone call used the traditional analog connection to the telephone company. The carrier was able to meter the destination of that call and to charge appropriately for it. Ann's conversation with her friend Leslie was digitized at her computer, put into packets, and sent over the digital transmission of the ADSL line. The voice stayed in packet form all the way to Leslie's computer where it was turned back into speech. The access carrier had no reasonable way to tell if the packets were voice, data, video, or a file transfer. Similarly, Dad's quick conversation with the store's service manager took place over an end-to-end packet connection. The access provider could not reasonably detect and meter that conversation either. Microsoft Netmeeting sends text, speech, and video out as packets.[2] Packets are packets. The access carrier does not know if they are voice, video, or data. The access provider cannot tell if the download is a homework assignment, a book, an audio broadcast of a hockey game, or a telephone call.

How many access lines were in use? The answer is one copper pair, but there were three separate voice conversations on that wire at one time. Of course, when Ann and Dad were talking over the Internet, web browsing from the home slowed down a little. How do the activities in this house relate to the old pattern of basing contribution on minutes of use? How heavy does the contribution have to be before Mom chooses to wait until a computer is free and then uses the computer to chat with her sister?

My goal in this report is to give the reader an understanding of the likely speed at which high-speed Internet access, together with complementary activities such as the widespread use of packet networks in the home and office, will change our views of what constitutes a telephone call or an access line. I also consider how the changes in technology will limit the local carrier's ability to meter minutes of use for telephone calls.

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[2] Microsoft Netmeeting includes a security option that, when used, prevents the access provider from observing the content of the packets.

To achieve that goal, I first provide glimpses of services or equipment available today that embody these technologies. Then, I provide an overview of the relevant technologies—and establish that the trends in the fundamental technologies strongly support the view that an increasingly large fraction of communications from offices and homes will be in the form of data packets, not analog speech. Next, I consider the human needs met by these systems, and I discuss the prospects for rapid adoption of the technologies based upon the consumer benefits they deliver. Finally, I go back to the inquiries above and address a few specific questions. What will telephone service mean? How feasible will it be for a carrier to meter minutes of use or count the number of voice access lines a customer is using? How likely is it that a significant fraction of traffic will move to these new technologies within a few years?

2 Some Quick Background

In interest of completeness, I describe the basics of packet communications and digital access services in this section. The reader who is familiar with these concepts will lose nothing by skipping immediately to section 3.

In the 1960s and 1970s, researchers around the world labored to develop technologies for communicating between computers.[3] One of the major developments in this effort was packet communications. The basic idea of packet communications is simple. All information to be transmitted is coded in digital form. The data for a particular destination are then broken up into smaller units, digital information specifying the origin and destination is put with the data, and the whole unit, called a packet, is passed on to the next computer in line. That computer looks at the address field—if the packet is not addressed to that computer, it passes the packet on towards the destination.

Packet communications can be compared to the postal service. Packets are like letters with an address on the outside and information on the inside. The postal worker takes an envelope out of the mailbox, examines the address, and routes it on towards the destination. The postal worker does not know if the envelope contains a payment, a greeting card, or a complaint about undelivered merchandise.

Packet communications offer several advantages including the ability to combine data from several sources or to several destinations on the same communications line similar to the way Canada Post can put letters from hundreds of people and organizations in Montreal onto an airplane headed to Vancouver. In telecommunications, this combining of packets from different sources is called multiplexing. Thus, a person with a dial-up connection to the Internet can begin downloading a file and then continue surfing the Web. The file data and the web surfing data are kept in separate packets, and the

[3] For background on packet technology at its history see *Internetworking Technology Overview* at http://www.cisco.com/univercd/cc/td/doc/cisintwk/ito_doc/index.htm and the Internet Society's history links at http://www.isoc.org/internet/history/.

communications software can sort them out and route the data to the correct destinations in the computer.

Packet communications technologies have been an enormous success. They are used today in the local area networks (LANs) found in most offices, in the Internet, and increasingly in access lines. Packet technology has evolved, and many different variations on the same basic principle have been implemented. Two of the most important implementations or versions of packet technologies are called the Internet Protocol (IP) and Asynchronous Transfer Mode (ATM). Packet transmission and the routing or switching of packets is more complex than the older technologies of circuit switching or dedicated point-to-point lines, but it has been widely adopted because of the efficiencies, including lower cost, that it delivers.

Packet technology also makes the use of digital transmission on access lines flexible. Only a few years ago, high-speed digital access was used for dedicated corporate data networks and for multiplexed voice access from locations with a hundred or more telephone instruments. With the use of packet technology, the same access line can be used for voice, video, and various forms of data.

Improvements in digital transmission technology, known as digital subscriber line (DSL) technologies, now allow transmission over the local copper loop at high speeds, somewhere in the neighborhood of a million bits per second, at reasonable cost.

Consider a small business with a digital access line capable of carrying 768 thousand bits per second (kbps) to and from the Internet. Packet communications allows such a digital access line to be used for any service or bundle of services that can fit into 768 kbps. Thus, at 11:30 AM the line could be carrying 10 telephone calls, 5 web browsing sessions, and an email transmission, but at 1:30 PM it could be carrying 5 telephone calls and a video teleconference.

3 Current Availability of Big Pipes Delivering Multiple Services

Modern telecommunications networks have developed far beyond the expectations of many people. I recall a distinguished professor of electrical engineering telling me that consumers' data communications needs could not be satisfied until communications at 56 kbps was possible. It was not clear to us how communications at such high rates could ever be achieved. By then, it was well known (and I still have a book showing the calculations) that connections on dial-up lines were theoretically limited to a maximum data rate in the range of 10 to 20 kbps, but that practical systems would run slower. Of course, in those days only computer specialists had modems in their homes or offices. Today, close to a majority of households have computers with modems; consumers routinely use 56-kbps modems from the home. The growing popularity of cable modems and residential high-speed digital subscriber lines shows that many people find even 56 kbps limiting.

Future developments in our telecommunications networks will similarly outpace the imaginations of even experts. However, some of the steps forward are clearly apparent. The activities and offerings of firms today give a feel for the future. For example, Sprint Canada described their ATM-based packet data network service saying,

> [ATM service] consolidates multiple communication streams into a single network . . . Supports diverse applications. . . It's a versatile emerging technology that can support a variety of high-speed, high-bandwidth applications concurrently over a single network interface.[4]

In Figure 1 below, Sprint Canada compares the new ATM architecture with the old world of separate networks—showing three separate networks converging to a single network.

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[4] See Sprint Canada, *Asynchronous Transfer Mode—The Single Network Solution (ATM) Services*, ATM990515E, Sprint Canada Inc., 1999.

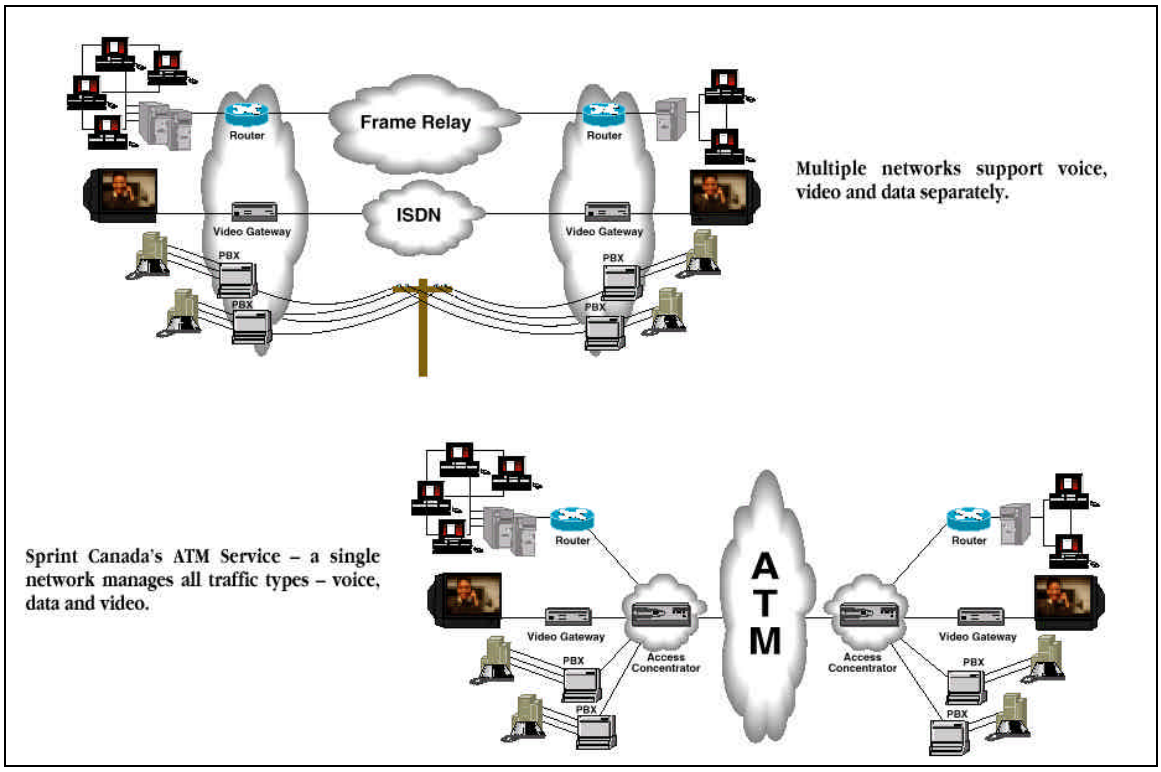

Figure 1. Sprint Canada's ATM Service Architecture.

When a packet of data goes directly from customer premises to customer premises, neither Sprint Canada nor the access provider needs to know whether that packet is voice, video, or data. Further, if the customer is using reasonable privacy technology, the carriers will not be able to know.

Many manufacturers have recently announced products that can be used to connect a telephone to the Internet. FlowPoint, a manufacturer of equipment that interfaces both traditional telephone equipment and data communications equipment to a digital subscriber line using packet technologies, illustrates its vision in Figure **2** below.

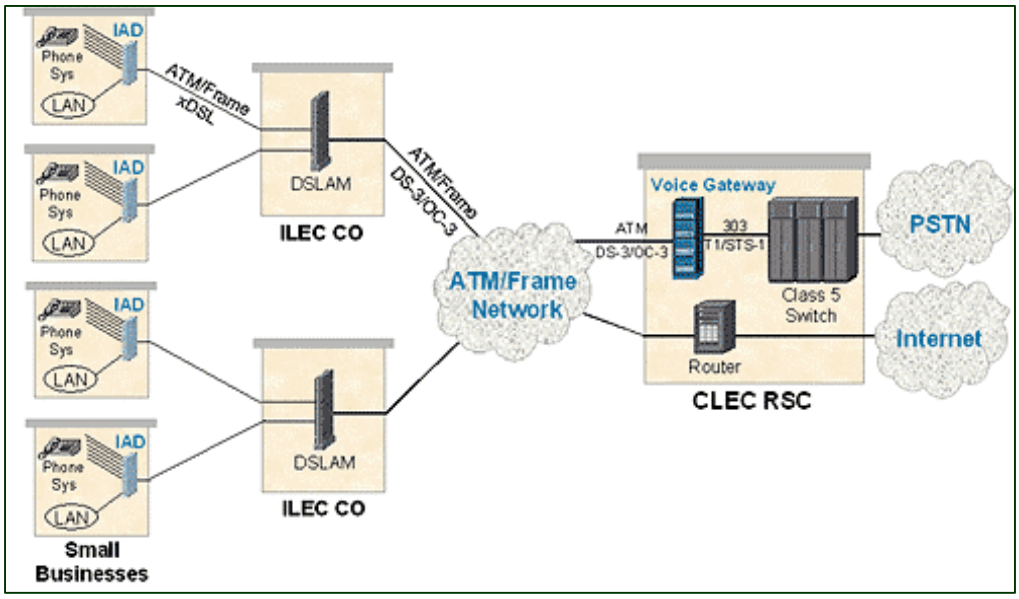

Figure 2. FlowPoint's 2200V.

Figure 2 illustrates the function of a product that is for sale today—FlowPoint's 2200V—it is not an illustration of a hypothetical future capability.[5]

A third example—Rogers Cablesystems reported at the end of the third quarter this year that it had added 25 thousand subscribers to its cable Internet access service for a total subscribership of 125 thousand.[6] This third quarter growth represents an equivalent annual growth rate of 100%. Consumers with Internet access over cable can run software such as Netmeeting or can use the cable version of devices like the FlowPoint 2200V to make telephone calls or to do video conferencing.

A fourth and final example—Newbridge already sells products supporting the big-pipe/multiple services model of communications services. I clipped the following text in Figure 3 from their promotional materials. I have marked in bold the text that is most relevant.

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[5] Other manufacturers provide similar equipment. See http://www.lucent.com/enterprise/sig/exchange/products/index.html or http://www1.nortelnetworks.com/dataprods/passport/html/passport4740.html.

[6] See http://www.rogers.com/rogers/investor/business/quarterly_reports/rci/rciq399.html.

The Newbridge SDSL solution offers managed services that were not practical in the past without costly direct fiber access.

Take Productivity to New Heights

To survive fierce competition while containing costs, **business subscribers are demanding technologies that provide high speed symmetric bandwidth and that support multiple communication services** (such as megabit access to the Internet, remote access to the corporate LAN and support for multiple telephone lines). This demand has led to the rise of SDSL technology.

Figure 3. Newbridge Promotional Materials.

Newbridge uses confusing industry jargon to make a simple point—business subscribers want the advantages of combining voice and data over low-cost packet networks.

I could go on, but my point should be clear from these examples. Industry today can affordably combine voice and computer on a single packet-data connection. What of the future? How will technology affect the cost and adoption of packetized local-access connections carrying multiple services?

Even without any analysis, it should be clear from the anecdotes and product descriptions above that, at least for some customers, high-capacity access lines carrying multiple services provide significant efficiency benefits that can be shared by consumers and suppliers. In the next two sections, I review expected changes in fundamental technologies and offer my views on how these changes will affect consumers' demand for communications services and the options available to carriers for providing such services.

4 Fundamental Technologies

The cost, ease of use, reliability, and other features of packet-based local access will improve with changes in technology. Technological progress will also affect consumers' demand for packet-based local access. Three technologies or building blocks lie at the heart of the local telecommunications—software, fiber optics, and integrated electronics. I consider each of these in turn.

4.1 Software

Embedded computers, controlled by software, allow us to build systems of immense complexity and to use standardized building blocks, such as microprocessor chips, for a wide variety of applications. Today, tiny computers are hidden inside radios, toys, automobile engines, thermostats, and microwave ovens. The use of software to define the function of equipment will continue and expand.

4.2 Fiber Optics

Fiber optic systems are one of the great success stories of the last two decades of communications technology. However, progress in fiber optics is far from over. Even if the technology were frozen in place, the investment in and deployment of fiber systems is far from the economic optimum. I expect that fiber optic systems will enhance local telecommunications in two primary ways. First, improved fiber systems will lower the cost and expand the capacity of the fiber infrastructure. Second, fiber will be built out closer to the subscriber—running to within a few blocks of many residences or into the basement of larger buildings. For some time to come, signals will be carried the last few hundred or few thousand feet by wire or wireless. Wire has the great advantages that it is already in place, has significant capacity over short distances, and can carry electrical power. Wireless has two advantages—in many locations, it can be put in place without significant construction effort, and it permits portable operation.

4.3 Integrated Electronics

By placing millions of transistors on a single chip, integrated electronics has permitted the building of systems of enormous complexity at low cost. Integrated electronics have progressed rapidly for the last three decades—following an empirical rule known as Moore's Law, which states that the industry will be able to cram twice as much capacity or capability onto a chip a year and a half from now than the industry can today. This law has been reasonably accurate for decades. Obviously, it cannot continue to hold forever. There are fundamental limits to how small electronic circuits can be built. The current literature indicates that we will probably be constrained by those limits within the next 10 to 15 years.[7] Another way to interpret this statement is that the experts are confident that progress in microelectronics will continue for several more years. And, of course, the systems being deployed today reflect the chip technology and designs of a few years ago. Consequently, I believe that there is still substantial margin for improvements in the electronics used in telecommunications.

Microelectronics affects two aspects of modern telecommunications. First, it allows us to build better networks. Modern modems, multiplexers, and switches all have microelectronics at their hearts. Second, it gives subscribers new options, such as low-cost computers, inexpensive video cameras, and facsimile machines that change the nature of subscriber needs. Without computers, consumers would not have the tools needed to download audio files over the Internet or to use software such as Microsoft Netmeeting.

Two important contributions of improved electronics in local telecommunications over the next decade will be to lower the cost of high-capacity transmission to the home and office and to lower the cost of combining multiple services onto a single transmission path. Expanded capacity in wired local telecommunications will come from digital transmission technologies that can send millions or tens of millions of bits per second over local copper connections combined with the extension of fiber optics closer to the

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[7] See the forward to the 1999 International Technology Roadmap for Semiconductors at http://www.semichips.org/.

subscriber premises. Expanded capacity in wireless is more problematic— it will depend upon access to the radio spectrum and the ability to install base stations as well as the capabilities delivered by the new technologies.

Improvements in these technologies will not only make high-speed digital access highly affordable but they will make available more effective complementary equipment for use by both organizations and individuals. The nature of the network will change. Consumer equipment will have greater capabilities, and control will shift towards the consumer. Many communications will be packet data from end-to-end, and the carrier will not know whether they are voice, video, data, or anything else.

5 Emerging Systems

The progress in the fundamental technologies permit improvements, such as lower cost or higher reliability, in the equipment used by service providers and consumers. In this section, I offer an overview of some of the evolutionary steps that will strongly influence the development of the local communications industry. I also identify the extent that these changes will encourage customers to use packet-based data communications for access.

5.1 Improved Customer Premises Equipment

Improvements in the equipment located on customer premises have had and will continue to have the largest impact on the structure of the communications network. It is the low cost and high performance of modern computers that has spurred the growth of the Internet. Many now forecast that the volume of data communications will soon surpass that of voice. In a similar fashion, facsimile machines rendered the old telex service obsolete.

5.1.1 Computers

Computers will continue to improve. Affordable disk storage will expand from a few gigabytes to hundreds of gigabytes. Processing speed and memory capacity will also increase—today's blazingly fast 500-MHz computers will be regarded as slowpokes. The fraction of homes having computers will grow—until computers become a universal appliance, one as common as a telephone or a television set. Many homes will have multiple computers.

5.1.2 Networking

Low-cost networking will be widely available and widely used. Today, essentially all large offices, most smaller offices, and a few residences use networks to connect computers together in order to allow for the shared use of resources such as printers and Internet connections. In September 1999, Intel introduced its AnyPoint home networking system, which uses home telephone wiring to carry data among computers at data rates

up one million bits per second (1 Mbps). Currently, the AnyPoint hardware and software required for a single computer sells for $US 49.[8]

Another low-cost route to networking in the home and office will be created by an initiative known as Bluetooth.[9] Bluetooth is a short-range radio system capable of substituting for cables for ranges of up to 30 meters. Bluetooth connections will be low cost, maybe $10 to $50 per connection, and will be built into many types of equipment. A second-generation version of Bluetooth will have substantially greater range—permitting it to be used for wireless networking inside a house or small office.

As promising as AnyPoint and Bluetooth are, some other product may come along that is better. But, clearly, technology has made networking affordable in the home and small office today.

5.1.3 Customer Premises Multiplexers

The boxes that connect consumer equipment to the telecommunications networks will become smarter and more capable. An important use of such equipment will be to provide the digitalization and packetization functions for existing telephones in the home.

Multifunction boxes that connect to terminals and computers on one side and to the Internet on the other side offer a significant opportunity for efficiency gains. One such piece of equipment is called the integrated access device (IAD)—a multiplexer that combines several signal sources for transmission over a local access connection. IADs are already on the market. A typical IAD might have four voice-line connections and a high-speed data connection—allowing a small office to connect its telephones, fax machines, and computer network to the larger communications world (the cloud) over a single high-capacity connection. IADs can be regarded as an evolutionary step beyond the digital loop carrier terminals local exchange carriers have deployed for years.

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[8] See http://shop.intel.answerexpress.com/store/intel.

[9] Bluetooth is named after King Harald Bluetooth who united Denmark and was an ancestor of William the Conqueror. For information on Bluetooth the radio system see www.bluetooth.com. For information on Bluetooth the Dane, see http://www.vikinger.dk/english.

Although the term *IAD* normally refers to special dedicated equipment, many personal computers have the processing capability needed to perform some of the functions of an IAD. Today's IADs are relatively expensive (several hundred dollars), making them cost effective for small organizations but still too costly for most residences.[10] Cost reductions over the next few years will make IADs affordable for residential applications as well.

IADs take speech signals, turn them into data packets, and multiplex those packets onto a high-speed data access line. This is quite unlike the way traditional telephone signals (typically analog voice) and high-speed digital signals share a digital subscriber line (DSL) today. In the DSL world, an analog telephone signal travels on the same copper pair with the high-speed digital signals from the subscriber location to the telephone company central office. At the central office, the analog telephone signal is separated from the high-speed data signal and then is sent on to the local switch in the usual fashion. In this case, the local exchange carrier can meter the analog telephone traffic generated by the consumer using the same technology that the carrier has used for many years. In contrast, if the customer sends a voice signal using the IAD, that voice looks like the other data packets coming from the customer location. If those voice packets are routed to equipment on the local carrier's network (e.g., an IP telephony gateway product), then the carrier can meter the customer's voice traffic at that point. But if those voice packets are addressed to another location, say another consumer's IAD in another province, then the local carrier cannot meter the voice usage on the access line—indeed the local carrier has no reasonable way to know that the packets are carrying voice.

The cable industry is also developing similar equipment—unfortunately they have chosen to use the term *multimedia terminal adapter* to describe the IAD concept. For some details on the cable industry work see the CableLabs web site for this effort—www.packetcable.com.

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[10] IADs may already be the most cost-effective way to provision additional lines to some locations.

5.2 Improved Transmission Pathways

The communications highways or pipes that connect offices and residences to the larger network will expand in capacity. These pipes will support high-speed web browsing, the delivery of audio and video services over the Internet, as well as multiple voice channels. As I observe below, the natural way to provide such connections is as a high-speed digital connection.

5.2.1 Fiber Optics

Fiber optic transmission systems will connect to most office buildings and many multiple dwelling units. Similarly, fiber will run from the carrier's central offices close to many detached residences—thereby shortening the distance signals must be carried by copper and permitting higher-speed transmission. In the case of the telephone industry, this development will be characterized as the combination of fiber to the neighborhood or fiber to the curb together with digital subscriber line technologies. A similar approach in the cable television industry is called hybrid fiber-coax (HFC).

5.2.2 Wireless

Wireless technologies will offer important alternatives for local communications. Below I describe likely improvements in wireless.

Existing mobile telephone systems will continue to expand. New technologies, sometimes called *third generation technologies*, will permit wireless phones to be used reasonably efficiently to read email or to browse the web. Such products are beginning to move to the market. For example, Cantel delivers email messages to some of their subscribers with digital telephones. Manufacturers are designing the follow-on products that will expand this market.

Satellite systems will also provide valuable alternatives, especially for locations that are too expensive to reach with fiber. Fixed radio systems, such as the Local Multipoint Communications Services, will offer high-speed Internet access.

By making Internet access available everywhere and available to people in motion, wireless systems will facilitate the widespread adoption of Internet technologies. This, in turn, will speed the use of high-speed digital packet access in homes and offices.

5.3 Impacts of the New Technologies

The availability of low-cost networking inside the home and small office and of multiplexed access to services will drive the development of a new approach to communications services. Customers will desire and purchase communications access options that give them always-on, high-capacity access to the Internet.[11] Such connections will be justified by their benefits for data networking. But, once in use they will offer efficient pathways to carry packets of voice and data that are carried over the traditional telephone network today.

The combination of low-cost networking and always-on Internet access will provide consumers will a host of useful options. Consider one simple example (I wrote this example just after the conversion back from daylight savings time). A clock or clock radio could have a built-in Bluetooth link and a processor smart enough to send an inquiry off to an authoritative time source. The clock would always have the right time (at least within a second or two) and would automatically adjust to daylight savings time changes. Obviously, networking in the home and high-speed Internet access cannot be economically justified by convenience in setting clocks. But, if the network and Internet access are in place, the marginal cost of putting such capability into clocks will be relatively low. The carrier will not know or care whether a packet comes from the consumer's wall clock, microwave oven, computer or telephone. Packets are packets.

Today services such as DirecTV and Tivo use connections to the telephone network to support metering/billing, service authorization, database downloads, and so forth. Such

[11] By high-speed, I mean speeds in the range from a few hundred thousand to a few million bits per second. These rates are high capacity today and have the capacity to carry several voice signals and support web browsing at the same time. Ten years from now, these speeds will be ordinary, not high capacity.

telephone connections have the advantage of working in almost every home but provide only limited capacity. In addition, consumers face the difficulty of running a telephone line to the location of the television set. Extension of the Internet to appliances in the home would enhance the operation of such equipment.

To recapitulate, improvements in underlying technologies are expanding both the supply of and demand for advanced communications capabilities. Technology already on the shelf or proven in the lab and capable of being manufactured today but not yet in the market will greatly expand consumer options. Local networking will spread from larger offices to smaller offices and residences. In the beginning, the principal devices networked in the home will be computers and computer equipment such as printers, cameras, and scanners. But once networks are in place in the home, and especially when these networks are connected to the larger Internet, putting other devices in the home onto the home network will enhance performance.

The home and small office will need communications connections to the rest of the world that are always on and that can support multiple conversations or subconnections at the same time. Packet communications, such as are provided by the IP architecture and ATM, can support such multiple connections. Two people can browse the web at the same time over an IP or ATM connection. An access line using these protocols can be shared by voice and data. IP and ATM have the scalability, capacity, and low cost needed to make them become almost omnipresent. Only if something significantly better comes along will they not dominate network architectures for the next several decades.

Some important implications of these developments are clear. Although customers will purchase digital connections primarily to provide a connection to the Internet, many subscribers—located in big offices, small offices, and residences—will send most or all of their voice traffic over the high-speed packet connections. These developments will benefit consumers, but they will make some old assumptions, such as the assumption that a telephone consumer has a single voice-grade access line, obsolete. In fact, neither access lines nor minutes of use will be measurable in the way they are today.

6 Expanded Use of Communications

The new technologies are creating opportunities for people to do old tasks better or to do new things that were impossible before. Some of these things are in a sense routine, but still important. Consider a woman in a small town who falls and injures her arm late at night. The town is too small to justify the expense of having a radiologist present at the hospital at all times. Using a high-speed data connection, the local hospital can relay an X-ray image of the injured arm to a radiologist at home or perhaps at a hospital in a larger city. In such a case, the high-speed data communications reduce the injured party's wait for treatment.

Consumers will benefit from these new applications, will be willing to pay for them, and will use them. Both business and residential consumers will expand their use of data communications. Internet connections will become essential to most organizations (if they are not so already). Such Internet connections will need to be always available with little delay (always-on) and relatively fast (download simple graphics in a fraction of a second, complex graphics in a second or two). For example, the opening page of the Government of Canada website, www.gc.ca, contains an image of a map of Canada. That map takes several seconds to download over a dial-up connection, an annoying lag, but downloads almost instantly (1/5 second) over high-speed local access such as an ADSL link.

Residential use of Internet services (a shorthand code for data communications uses) will expand greatly. The principal residential uses of the Internet for the next few years will be for email and for web applications such as shopping and gathering information.

6.1 Email

In Canada, email has reached the point where the network is so valuable that most office workers must have access. Similarly, a large fraction of residential consumers have access to email, and its value is growing each day. Currently, 20 to 40% of households

have access to the Internet.[12] The Calgary Minor Soccer Association's (CMSA) web page lists email addresses for 5 of the 8 directors of the association. The social nature of email is becoming more like that of telephone access. For a substantial fraction of the population, it is now part of basic communications, not a frill. Many of us are in the situation in which others depend upon our access to email. Email grew slowly for a long time. In the beginning (1970 or so), Internet email connected the computer science community—all the academics and many in industry. Email spread in academia, especially in the natural sciences, and somewhat more slowly in business. But, a few years ago, it crossed a threshold and has begun to grow very rapidly. There is a well-developed theory of network externalities that explains why network growth can explode once a certain critical mass of users is reached. A few years ago, relatively few people had email, so the value to many of having email was low. Now, many people in Canada have email, e.g., a majority of the board of the CMSA, and therefore everyone finds it more valuable to have email. This process of positive feedback will continue and expand.

6.2 Web Applications

The World Wide Web is a wonderful source of general information. For example, the easiest way to get information on the University of British Columbia (UBC) is to point one's web browser at www.ubc.ca. An application to UBC can be filed electronically at www.pas.bc.ca. CRTC documents are available at www.crtc.gc.ca. Similarly, one can find news, local youth sports league scores, weather, and traffic conditions on the Web.

The Web can also be a source of entertainment. A fan can listen to Senators hockey games at http://www.broadcast.com/sports/hockey/nhl/senators. Such audio programming only requires a relatively modest 6.5 kbps of capacity. Today's Internet also permits the delivery of relatively low-quality video. In the future we will be able to get broadcast quality or even DVD quality video over the Internet. (The DirecTV service is digital with a data rate of about 3 to 5 Mbps. DVDs, which deliver better-than-

[12] http://www.crtc.gc.ca/ENG/NEWS/RELEASES/1999/I990517e2.htm

broadcast-quality picture and sound, run at about 10 Mbps, and high-definition (advanced television) requires about 20 Mbps. Thus, an ADSL link to the residence can carry one or perhaps two broadcast-quality video signals. Improved video compression technologies may increase the number of video signals that can be delivered at the same time over an ADSL link.

Electronic commerce is exploding. It seems that every day a new firm announces a web site where one can buy or sell almost any item. Amazon.com, the Internet bookseller, may be the best known, but there are literally thousands of such firms.

The Net is becoming our library, mall, and post office. As this happens people, who read, shop, or correspond have an increasing need for high-speed digital access. Technology push, demand pull, and network externality (critical mass) effects will cause a relatively rapid transition to this new regime.

6.3 Application Service Providers

One consequence of the new technologies has been the growth of a new industry—the application service providers (ASPs). Several firms are now providing computer services over the Internet—one of the pioneers in the business was FutureLink of Alberta. The business model is simple; the supplier runs the software on their computers and takes care of software installation, maintenance, and making backups. The user only runs simple software on his or her computer, perhaps a web browser, and uses that simple software, together with a local area network and a connection to the Internet, to use the application, say a specialized accounting program. The user's computers are easy to install and maintain.

ASPs simplify the world for their customers. The ASP's customers do not need to learn how to install or maintain the complex software packages they use. The degree of success of the ASP industry is not yet clear. Note that this industry depends upon high-speed data services and requires that those services be reliable. The more successful the

ASPs, the greater will be the demand for high-speed data and for multiplexed connections from offices to the Internet.

6.4 Conclusions

High-speed digital connections based on packet switching technology meet real needs of both consumers and businesses. Some of these uses are minor but convenient, such as permitting wall clocks to automatically adjust to daylight savings time. Other uses will lead to substantial efficiency gains. I believe that the conditions are right both in Canada and in most of the industrialized world for the rapid adoption of this approach to local telecommunications.

7 Implications for Telecommunication Carriers

It seems reasonable that the organizations and people who benefit most from using them will adopt these technologies most rapidly. Such organizations will shift relatively rapidly to packet access. These are also the people who spend the most on services and account for the lion's share of the usage. Consequently, their actions will have a disproportionate impact on the contribution flow.

7.1 Demand

Carriers will face a challenging mix of demand. Some customers will be satisfied with traditional services—others will find that the new services are essential to their business survival or are of great benefit in their personal lives. Carriers will have to deploy high-speed digital services to meet the needs of these customers. Extensive use of high-speed packet access services by many customers appears likely to occur soon.

Such widespread use, which will often be by the heaviest users of telecommunications services, will stress the current system of basing contribution on minutes of use of switched traffic. Such heavy users will have both the incentive and the means to avoid the contribution levy. Many of these heavy users will install equipment and systems that make the traditional measurement of minutes of use impossible in order to gain the other benefits of these new technologies—rather than out of a desire to game the contribution regime. Carriers will have to face the consequences of a world where customer usage cannot be measured in units of minutes and lines.

7.2 Implications for Metering Usage

The use of high-speed digital packet services, such as ATM or IP, for local access will make it increasingly hard for the access service provider to detect phone calls and phone-call-like communications. Consider a home where one person is using Netmeeting to make a telephone call while, at the same time, the rest of the family is listening to a basketball game over the Internet and the home web server is running. How will the

access service provider be able to distinguish between listening to the telephone call and listening to the basketball game?

If the access provider also provides the telephone service, then the access provider can meter telephone use at the point where it converts packets into more traditional telephone calls. However, digital networks will give consumers alternatives that permit them to avoid metering. If contribution is allocated or assessed per minute of certain types of traffic, then consumers and suppliers will have an economic incentive to take steps that cause traffic to be classified as something else.

Of course, there are countermeasures. For example, one could (at least in theory) require that all software that is capable of putting voice and other designated traffic into packets be designed to meter and to report all use to a central authority. Software could be registered and the use of unregistered computer software by consumers prohibited. Of course, this would be a foolish policy which would handicap Canada's economy, would be politically infeasible, and would be difficult to enforce—it would require a regime more like that of East Germany before the fall of the Berlin Wall than that of Canada.

From a practical point of view, the adoption of packetized access implies a great reduction in the ability to meter usage in units such as minutes of use or voice access lines.

8 Conclusions

The vast changes we have seen in telecommunications over the last two decades—wireless growing from nothing to one wireless telephone for every third person in Canada, the Internet growing from a research system with a few hundred computers to a widely used system with tens of millions of computers connected, computers in most offices and many homes, hundreds of channels of satellite television, and wireless remote controls for the TV set—foreshadow the enormous changes yet to come. The details of these changes are unclear, but the general outline is dimly visible.

Consider the example of family use of a high-speed access link that I used to open this report. That example illustrated people using these technologies to meet their everyday needs. They were chatting with family and friends and shopping for shoes. The new technology made these acts easier and more convenient. Of course, for some people the benefits will be much greater. Email is a boon to the deaf; the web a godsend to many who are confined to their homes.

One highly likely change is the widespread use of efficient, high-speed packet access along with the growth of pervasive networking inside both organizations and residences. In such an environment, the current practice of basing contribution on measurements of the minutes of use appears increasingly problematic.

Access providers will not be able to distinguish between packets carrying information that used to go over a telephone connection and those carrying email or web content. Access providers will not be able to tell if one telephone is active in the home or three are active. The old concepts of metering minutes of use or counting access lines will fade and disappear.

In this rapidly coming world, contribution should be based on practical measurements that can be made reliability and that cannot be easily manipulated by those seeking to lower their bills.