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THE INFORMATION HIGHWAY: THE CONVERGENCE OF TELECOMMUNICATIONS, BROADCAST DISTRIBUTION AND MICROPROCESSING

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The change is so fundamental it has been compared to ... the Industrial Revolution of the 18th and 19th centuries. But while that revolution took a century or more, this one is occurring in a matter of years. ... The infrastructure for this *new economy ... is the digitized, high-capacity, interactive communications and information networks that will carry the knowledge economy's primary product and factor of production – information. Our metaphor for this network of networks is the "Information Highway."*

Dr. David Johnston, Information Highway Advisory Council

INTRODUCTION

Telecommunications and cable television companies in Canada and elsewhere are undergoing a rapid transformation in the technologies they use and, consequently, in the services they can potentially deliver. No longer do these enterprises rely exclusively on copper wire or coaxial cable as their primary means of transmission; increasingly, they use fibre-optic cable, which carries information on a pulse of light, and wireless systems, which make use of the electromagnetic spectrum. The Internet, an intricate network of computer networks, and its amazing array of new software applications is also a revolutionary channel for the carriage of information that both complements and competes with the more traditional networks.

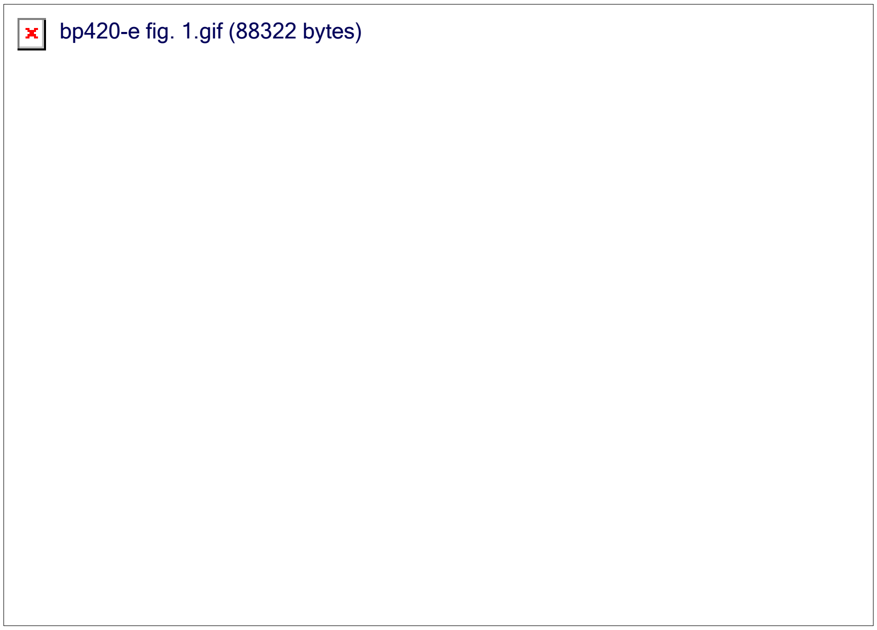
Together, these innovative technologies have immeasurably expanded the carrying capacity of their networks, which can now incorporate interactive two-way voice, video, data and graphics information forms, converted to and from the digital language of computers, to provide new services such as video-conferencing, video games, high-capacity data retrieval and processing, digital radio, video-on-demand (VOD) and much more.Formerly the preserve of, respectively, telephone, satellite and cable television companies, voice and data communications and audio and video entertainment services can now be provided over each other's transmission facilities. This dissolution of the conventional boundaries between telecommunications, cable television and micro-computer processing activities is paving the way for the convergence of information carriage services over what has been dubbed the "Information Highway."

This paper describes the innovations that foster this convergence of traditional communications services and those yet to be developed, highlighting their historical and economic significance for industrial policy.

THE WIRELINE NETWORKS: TELEGRAPHY, TELEPHONY AND CABLE TELEVISION (1)

Electrical communication by telegraph began in the mid-nineteenth century and marked the birth of the world's modern telecommunications systems. Telegraphy, from the Greek, meaning "writing at a distance," is a means of electrically transmitting encoded messages at the speed of light through a systematic opening and closing of electric circuits. The first such message, sent by Samuel Morse, the inventor of telegraphy, in 1844, between Washington, D.C., and Baltimore, Maryland, touched off society's foray into an era of experimentation with systems of instant communication at a distance. Consequently, it was not long after that telephony, from the Greek, meaning "distant voice," accomplished the same thing by encoding variations in sound waves (that is, changes in the density of air) into variations in electrical waves through vibrations of a diaphragm. The first telephone conversation (made by the telephone’s inventor, Alexander Graham Bell) took place in 1876 between Brantford and Paris, Ontario.

While most of Bell’s contemporaries were sceptical of his ideas (thinking them not based on sound engineering principles), history would prove them wrong; within a half century, the telephone supplanted the telegraph as the dominant mode of telecommunication. The obvious reasons for this was that the telephone encodes the message directly for transmission and is a more convenient and efficient two-way interactive communications system. Thus, because it required no specialized knowledge, the telephone, with its analogue signal, a method of coding the pitch of a sound according to its frequency or amplitude, was more popular than the telegraph, whose signal is based on a code comprising a series of dots and dashes.



Source: Ontario, Ministry of Economic Development and Trade, *Ontario Communications Handbook 1993*, p. 3.

The basic components of a telecommunications system include: a communica-tions terminal (i.e., telephone, teletypewriter, facsimile machine or computer); a "local loop" (i.e., wires, cables, poles and various equipment that connect the terminal to a local central office); switching equipment (located at the central office); large capacity trunk wires that connect the local central offices to a long-distance toll office; and transmission equipment that sends and receives signals over long distances (i.e., high capacity cables, microwave radio towers or satellites). These components must be compatible with each other (i.e., interconnectable and interoperable). Figure 1 provides a simple diagram of a modern fixed telephone system.

Although technically defined in Canadian law as a broadcast distribution undertaking, a cable television operator could equally be defined as a telecommunications carrier. When it was first developed in the 1950s, cable television was seen as a method of transmitting television programming that would supplement and improve over-the-air transmissions in rural areas. As it turned out, however, its success depended on broad acceptance as a means of improving and diversifying the entertainment available in urban areas. These systems have traditionally been one-way and passive at the receiving end, but could be modified to become two-way and interactive by the introduction of switching equipment to the distribution systems.

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Source: Ontario, Ministry of Economic Development and Trade, *Ontario Communications Handbook 1993*, Queen's Printer for Ontario, Toronto, 1993, p. 52.

A basic cable television system consists of: a "headend" (an array of antennas, microwave receivers and satellite dishes) that traps incoming signals and processes them to prevent them from interfering with each other; a cable (coaxial or optical fibre) that transmits these processed signals to the home; and a series of amplifiers that boost or rejuvenate the signals as their quality degrades with greater distances from the headend (fewer are needed when using fibre-optic cable). Figure 2 provides a simple diagram of a modern cable television system.

THE WIRELESS NETWORKS: MICROWAVES, RADIO AND SATELLITES

Wireless telecommunications systems, which include radio common carriers (i.e., one-paging and two-way mobile radio) and cellular carriers, have been operating since the 1980s. Cellular systems, which are mobile systems that operate over the local radio spectrum, are concentrated in urban centres and are connected to the wired telephone network. These technologies, therefore, both compete with and complement the wired telephone network. Figure 3 provides a simple diagram of a mobile cellular system; obviously, the more cells in the system, the more capacity the radio spectrum offers.

Forthcoming in this decade will be Personal Communications Services (PCS), a portable, mobile, digital, wireless communications system that works at lower power and higher frequencies than cellular, and therefore makes for a lighter and cheaper handset. It is not yet for use in fast-moving vehicles. PCS technology represents the next generation of wireless communications that will offer integrated services, including features such as call-waiting, call-display, call-forwarding, voice-mail and text display, and will be capable of facsimile and modem transmissions. Indeed:

> PCS will be a when-you-want, where-you-want and how-you-want telephone service. The notion of calling a place will be anachronistic. One will always call a person who will have a phone turned on and in hand, even though it might be switched to voice mail, call-forwarding on some other convenience tool.(2)

Satellite communications systems were pioneered in the 1960s by the U.S. National Aeronautical and Space Agency (NASA), which also assisted Canada in becoming the third nation to venture into space with the launching of the Allouette I satellite. Based on a 1945 proposal made by Arthur C. Clarke, Chairman of the British Interplanetary Space Society, a man-made earth satellite positioned in geo-stationary orbit (an altitude of about 36,000 kilometres) above the equator receives and transmits radio microwaves between distant locations on earth.(3) The satellite consists of: a number of repeaters or transponders (which provide a large capacity communications channel); a receiver for each transponder that is tuned to a frequency channel for uplinking signals from an earth station; a frequency shifter to lower the received signal to a downlink frequency; and a power amplifier to transmit the signal back to an earth station. Obviously, the more powerful the satellite's returning signal, the smaller and less costly need be the receiving equipment installed at the earth station. A Direct Broadcast Satellite (DBS), which provides Direct-to-Home (DTH) television and radio services, is specifically designed to minimize the cost and size of the receivers or satellite dishes and is placed over the equator to maximize its footprint and its potential consumer base.

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Source: Ontario, Ministry of Economic Development and Trade, *Ontario Communications Handbook 1993*, p. 17.

Table 1
Global Mobile Satellite Systems

Company	Major Investors	Launch	Funding	Terminal Costs	Satellites	Orbit
Teledesic	Craig McCaw, Bill Gates, Kinship Partners	2001	US$9.0B	n.a.	840	21 polar planes
Iridium	Motorola, BCE Inc., STET, Raytheon, UCI, Sprint	1998	US$4.7B	US$3,472-$4,167	66	6 polar planes
Project 21	Inmarsat	1999	US$3.5B	n.a.	n.a.	2 circular inclined planes
Globalstar	Alcatel, Vodafone, Dacom, Quallcomm, Hyundai, Loral, Deutsche Aerospace	1998	US$2.5B	US$694-$972	48	8 circular inclined planes
Odyssey	Teleglobe Inc., TRW	1998	US$2.1B	US$347-$417	12	3 polar planes
Ellipsat	Fairchild Space, Israeli Aircraft	1997	US$800M	US$556-$694	16	2 eliptical planes
Aries	Constellation Communications, Defense Systems	1997	US$417M	US$2,083	48	8 planes
Starsys	Starnet	1995	n.a.	US$104	24	n.a.
Orbcomm	Orbital Sciences, Teleglobe Inc.	1995	US$278M	US$278	26	inclined circular planes

Source: Communications Week International, 25 April 1994, in *Telecompetitiveness and the Wireless Sector: Competition Without Chaos*, p. 35; A. Michael Noll, "The Extraterrestrials are Coming," *Telecommunications Policy*, Vol. 20, No. 2, 1996, p. 79-82.

Finally, Global Mobile Satellite (GMS) services will also become available in the short to mid-term. Cellular services and PCS are based on the concept of frequency re-use within large metropolitan areas, along with frequency switching as a user moves from one cell to another. GMS services will provide an indirect link between subscribers via a series of integrated low- to mid-distance earth-orbiting satellites. The flight patterns of the satellites would range from 1,000 to 12,000 kilometres, depending on the compromise reached between the benefits of higher altitudes (i.e., greater coverage and therefore fewer satellites) and their costs (i.e., lower service quality related to a weaker signal, delay and echo). The services offered will range from voice, data, fax and video communications to position location, search and rescue, disaster management, environment monitoring and cargo tracking. It is not yet clear whether some of these services would directly compete with cellular services and PCS in urban areas or would complement these services to extend their use to remote, under-populated and poor regions of the world. Table 1 provides the most up-to-date information on the proposed GMS systems.

COMPUTERS AND THE DIGITAL REVOLUTION

As mentioned above, all telecommunications begin and end with the use of a terminal; in virtually all-new telecommunications systems, terminals have undergone signifi-cant change and improvement. Of course, the most prolific terminal innovation in the past 50 years has been the computer. In fact, most telecommunications experts compare the impact of the large-scale integrated circuit chip powering a computer to the impact of the Gutenberg movable-type printing press. Both in their day enabled low-cost re-production and processing of information on a scale never before imagined.(4)

From its original vacuum tube beginnings to mainframes, to minis, to micros, and to special-purpose chips, the computer has been a unique source of revolution in telecommunications. Initially, computers were stand-alone devices performing data-processing services and, at the beginning of the 1980s, their electronic memories were measured in the order of kilobyte (10^3) and megabyte (10^6) magnitudes. The rapid development of microelectronics brought with it, however, a host of intelligent terminals whose memory storage capacities could be measured in gigabytes (10^9) by the mid-1980s, in terabytes (1012) by the late 1980s, and in petrabytes (10^{15}) by the early 1990s.(5) Their memories were expanding exponentially, but their widespread usefulness was contingent on being tied together for the exchange and processing of their isolated databases, now made possible by means of their common digital language. Hence, the next problem in the evolution of the computer was simply one of communications and the solution was the computer software product.

The systems software for a telecommunications switch, which today is really a specialized computer, provides the programming, coded in the binary digital language that directs its fundamental operations. Digital signalling is not new; in fact, the Morse code is a digital signal. A binary digital signal has two states: 1 or 0 – it’s on or it’s off – unlike an analogue signal, which can take on any number of values. Digital signals may be transmitted with or without a carrier wave. For transmissions without a carrier wave, there must be a direct electrical or optical contact at both ends. Thus, this is how the digital signals operate over Integrated Services Digital Network (ISDN) lines and fibre-optic cable. For transmissions over the radio spectrum or conventional telephone lines, a carrier wave, as shown in Figure 4, must be modulated/demodulated; hence the need for a modem.

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Source: United States Government Accounting Office, *Information Superhighway: Issues Affecting Development*, Appendix I, p. 47.

The two principal advantages of digital over analogue signals are the quantity and quality of information that can be transmitted. Since the amplitude of the digital wave is generally smaller than that of the analogue wave, the former takes up less space on the media or, alternatively, provides more "bandwidth" (i.e., a higher data transmission rate).(6) As well, an analogue wave is very susceptible to electrical interference, so the signal can become distorted to the point where it is no longer analogous to anything. With the use of periodic boosters, however, a digital signal should have absolutely no distortion whatsoever.(7)

Interestingly, the digital code is enjoying a renaissance of late because of the amazing receiving, storage and retrieval capacity of the computer. As indicated above, the telephone became more popular than the telegraph for personal communications because, since it freed the individual from having to remember the Morse digital code, it economized on the need for human knowledge. Now, however, the digital code is beginning to reassert its dominance in the form of the binary code (which follows arithmetical rules) primarily because the computer chip takes the place of the human brain in this memory task. Moreover, in this case, the digital code does not appear to favour one network over another, as was the case for telephony and telegraphy; rather, the code is dissolving the boundaries between the networks of telecommunications and broadcast distribution. Indeed:

> As technology evolves – and it is evolving at such a fast pace – issues such as is there a distinction between a broadcast signal and a telecom signal will become front and centre. Once you have digitized a signal, whether it is a telephone signal, a data signal or a broadcast signal, is irrelevant – a bit is a bit.(8)

THE CHANNELS: SWITCHES, MULTIPLEXERS AND DIGITAL VIDEO COMPRESSION

An important characteristic of any telecommunications network is its basic design. There are two general network types, depending on the aim: a switched architecture (usually a star-shaped configuration between the terminal and the closest node) that provides dedicated connections between the caller and the receiver; and a broadcast architecture (usually a "branch and tree" configuration) that provides mass communications to all destinations. Figures 1 and 2 show that the telephone networks (terrestrial or satellite) are in the first category, while cable television networks are in the second. These architectures are, however, based on the economic circumstances pre-dating digitization. In the United Kingdom, where cable television companies have been permitted to provide telephony since 1991, communications services are delivered by a "siamese" (copper twisted-pair wire and coaxial) cable over a network architecture known as "branch and bush." This configuration is a hybrid of the traditional telephone and cable television networks, where fibre-optic cable deployment is much more extensive because of the decreasing costs of cable relative to those of a switch. Since digitization and interactive services favour a switched network design, alternative switching methods are now discussed.

Telephone networks first used "circuit switches," where an end-to-end circuit is set up before a call begins. A fixed share of network resources is thus reserved for the duration of such a call, regardless of whether any communication is going on (see Figure 5). The primary advantage of this switching technique is that it is amenable to performance guarantees (for example, a guarantee that any delay will not exceed a certain time), and for providing detailed usage and accounting records. Its primary disadvantage is that resources are wasted during pauses in a conversation, which can be many.

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Source: United States Government Accounting Office, *Information Superhighway: Issues Affecting Development*, Appendix I, p. 50.

Telephone networks have also adopted "packet switches," which are most suitable for computer-to-computer connections. Because computers usually communicate in bursts, a continuous link would be wasteful. A packet switch divides messages into packets of various sizes, each of which has a header that directs the packet to its destination through a network trunk line. There is no dedicated circuit; many different transmissions packets share the trunk line. Moreover, since these packets are jumbled and intermingled, the order of their arrival may bear no resemblance to the order in which they were dispatched. Packet switching thus requires sophisticated software that carries out complex routing and reassembly tasks (synchronization). Thus, packet switching uses network bandwidth more efficiently by economizing on scarce media capacity. Its main disadvantage is that problems may arise in transmitting voice and video traffic because the flow of information is not sufficiently predictable.

The Asynchronous Transfer Mode (ATM) has emerged as the optimal technique for overcoming the major deficiencies of both switching methods for transmitting all forms of information. It combines the benefits of circuit and packet switching by using packets of uniform size (48 bytes for data plus 5 bytes for the header). The ATM switch must simply read the connection identifiers in the headers of the 53-byte cells, which arrive one at a time, match this identifier to an output port, then route it to that port (see Figure 6).

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Source: United States Government Accounting Office, *Information Superhighway: Issues Affecting Development*, Appendix I, p. 51.

The information-carrying capacity of any transmission system is commonly referred to as bandwidth; to expand the bandwidth, digitization, digital video compression (DVC) and multiplexing are employed. More specifically, digitization and DVC expand capacity by creating more channels of traffic, while multiplexing allows more traffic to be carried per channel. Hence, coder/decoder (CODEC) machines or multiplexers permit many conversations to be transmitted over one cable without interfering with each other.

Consider a single picture on a television screen. Each picture frame requires the colour and intensity to be recorded on the tiny pixels that make up this screen. There are approximately 700 pixels per line, 576 lines per frame and 30 frames per second. (9) Thus, more than 12 million pixels of information are to be transmitted per second; this could be overwhelming for even a digital signal. DVC overcomes this potential information overload by making use of the fact that only a small portion of the information on a screen changes from one frame to the next; DVC only records the changing pixels. Depending on the standard used and the type of video, the amount of information can be thus reduced by a factor of up to 160. This explains why a fast-moving game of hockey viewed on TSN requires more bandwidth than Barney, the slow-moving dinosaur on PBS.

THE MEDIA: NETWORK CABLES AND THE RADIO SPECTRUM

All networks must have a physical medium in order to transmit signals. Conventional media include: copper wire, coaxial or fibre-optic cable and the radio spectrum; often a signal is sent over many different media. For example, a cellular phone call first travels over the radio spectrum, then over a copper wire or fibre-optic cable in the local exchange, then possibly back over the spectrum through a microwave or satellite link, and then on a copper wire to its final destination. The permutations of media used are becoming more numerous with time and innovation.

Conventional telephone service uses the copper twisted-pair wire in the local loop. Older exchanges that use a pulse dial can carry only an analogue signal; modern exchanges use touch-tone dialling, which can carry both analogue and digital signals. The copper wire medium offers the lowest bandwidth, carrying anywhere between 1 to 24 voice channels. It is possible to extend this narrow bandwidth by compression techniques, such as ISDN, which allows for the transmission of data, text, graphics and video without the need of a modem, and Asymmetric Digital Subscriber Line (ADSL) and High-rate Digital Subscriber Line (HDSL), which can provide VOD services over conventional telephone lines.

Coaxial cable is made up of a copper wire, surrounded by an insulator and copper shield; it is a broadband medium that can carry up to 1,000 voice channels at any time. A fibre-optic cable consists of very fine, transparent fibres of glass or plastic that direct the light on which a signal is superimposed; it can carry in excess of 30,000 voice channels or 150 high-quality video channels(10) and, because it is made of sand, the cable itself is cheap. Given current technology constraints, however, the cost of the opto-electronic equipment makes this medium economic only as a backbone of any telecommunications network. There will have to be significant cost reductions and greater demand for interactive services before it travels right to the home.

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Source: United Kingdom Parliamentary Office of Science and Technology, *Information 'Superhighway': The UK National Information Infrastructure*, London, May 1995, Annex 1, p. A4.

Finally, most modern telecommunications systems incorporate wireless interconnections at some phase in the communications link. Therefore, they use the electromagnetic spectrum as depicted in Figure 7. Telecommunications take place over the radio spectrum (from longwave to microwave segments). The radio spectrum has been used to transmit information since the invention of radio and television, but has now been harnessed for other purposes.

THE INTERNET

The Internet is a worldwide network of computer networks using the common Transmission Control Protocol/Internet Protocol (TCP/IP) as their link. This loosely organized system of interconnected computer networks initially served the research and education community; however, the types of users have grown with new service applications. Current estimates put the number of host computers at approximately five million worldwide, made up of an estimated 30 million users in more than 70 countries.(11)

The Internet was formed in the 1960s out of the efforts of the U.S. Department of Defense’s Advanced Research Projects Administration (ARPA) to build a link with universities and its high-tech defence contractors. The decentralized computer network (ARPANET) was designed so that it would remain functional even if parts of it were damaged by a nuclear attack. It spread to include the wider academic community in the 1980s when the U.S. National Science Foundation formed NSFNET by connecting its supercomputers to ARPANET. In the early 1990s, special software, such as the hypertext index on the World Wide Web ("WWW"), and the packet-switching equipment that allowed users to send sound and video information (over its fibre-optic cable backbone) were added to the routine downloading of files for which the network had until then been used; this popularized the Internet not only in academic groups but in the community at large, and primarily with young people. A 1995 survey indicates that American commercial clients account for 27% of the total host computers on the Internet; educational clients, 24%; government, 4%; military, 4%; organizations, 3%; networks, 3%; and others, mainly non-American host computers, 35%.(12) Information retrieval programs, such as gopher and the WWW, account for 38% of all traffic; file transfers, 37%; and e-mail, 16%.(13)

Most Internet traffic flows across the backbone networks owned by a few Network Service Providers (e.g., *i*Star Internet Inc., Sympatico Inc., MCI Communications Corporation, Sprint Corporation, America On-line Inc., etc.) which have "peering" agreements whereby they pass on packets to each other free of charge. The Internet leases lines from the phone companies, but sometimes provides a connectionless link through packet switching. In this case, there is no end-to-end set-up; each packet is sent by the host computer, according to a route-finding algorithm, to another computer (a "router"), then to another router, and so on until it arrives at its destination, where the packets are reassembled. Packets making up one conversation may take more than one route to this destination. Thus, the connectionless network economizes on router memory and connection setup time and makes good economic sense when lines are cheaper than switches.

bp420-e fig.8.gif (106209 bytes)

Source: TeleGeography, Inc., *TeleGeography 1995: Global Communications Traffic Statistics & Commentary*, p. 54.

Users, whether individuals or corporations, have accounts with the providers or access the Internet indirectly through an on-line service (e.g., CompuServe) or a reseller that offers customers software, a connection and/or content (see Figure 8). The Internet was first funded primarily by subsidies from government and its agencies, but these have been phased-out as commercial fees are expected to take over funding completely. This funding re-organization should further permit the Internet to develop into an efficient commercial business. Organizations usually pay a connection fee based on bandwidth required, while users pay nothing but their time. Access providers to the Internet generally charge individuals monthly fees (e.g., from $10-$30) that provide a given number of hours of service (e.g., five to 200 hours per month) plus incremental charges for additional hours of service ($0.25-1.50 per hour). User fees have been contemplated and eventually will be implemented – likely on a priority rather than a per unit of time basis – when congestion has become a significant problem.(14)

INDUSTRY CONVERGENCE AND THE INFORMATION HIGHWAY

The Information Highway has been described as a "network of networks," providing electronic connections to advanced communications and information services.(15) This infrastructure promises to bring voice, text, data, graphics and video forms of information from a vast array of knowledge-based services (including education, entertainment, banking and commerce) to link homes, businesses, governments, schools, libraries and other institutions across the world. The technologies that are the driving force behind these developments are also simultaneously dissolving the traditional boundaries between the different communications networks. Indeed:

> [T] echnological progress in the rapidly changing information economy is undermining all previous assumptions about specializing in communications delivery. Telephone companies can modify their land-based networks to offer standard broadcast television services and interactive broadband services. Cable firms can move two-way, interactive video as well as offer voice and data communications. And other types of wireless or spectrum-based systems can offer any or all of these services.(16)

The resultant convergence of technologies and services is thus sparking our social and economic evolution (some claim revolution) to an information-based society.(17)

The so-called network of networks is often compared to a real highway. Table 2 provides a description of the Information Highway and its asphalt equivalent according to their network levels, with examples. It includes the types of content transmitted, the services/applications, the channels and the media.

Table 2
The Information Highway
Network Levels, Highway Equivalent and Examples

Network Level	Examples	Highway Equivalent
Content	Conversations Messages Programming Databases	Content
Services/Applications	Telephone Service Video Service Electronic Mail Internet	Trucks Containers
Channels	Analogue Voice Circuits DS-O, T1 Circuits Cable Channels	Lanes
Media	Fibre-optic Cable Coaxial Cable Twisted-copper pair	Roads

Source: Elizabeth Angus and Duncan McKie, *Canada's Information Highway: Services, Access and Affordability*, Industry Canada, Ottawa, May 1994, p. 29.

Most of the physical components of this Information Highway are already commercially available; in fact, the investment in infrastructure needed for its eventual creation will likely be forthcoming within the next decade. Most Canadians have access to computers, fax machines, "smart" telephones, cable television, video cassette recorders (VCRs) automatic banking machines, video shopping networks and, increasingly, the Internet. What remains is to make these electronic machines inter-operable. While substantial network interconnection is in place, such as in the case of computers and wired and wireless telephony, most networks still act independently; that is, most communications originate and terminate on the same network. Indeed:

> There currently exist in Canada a large number of communication networks that consumers and businesses rely upon for the exchange of voice, data and video communications. ... Each of these networks has particular strengths and is capable of carrying some but not all types of communications. Long distance competitors ... have extensive long distance networks but do not, in general, have the local facilities to terminate and originate much of their traffic. Telephone company networks provide ubiquitous switched capacity but do not have broadband connections to most subscribers. Cable networks have broadband subscriber connections but have limited switching capability. Wireless networks currently face a number of capacity limitations.(18)

While this may be so for today, one must keep in mind the potential of current communications networks:

> [A] ll the companies involved in the convergence or collision of previously distinct communications sectors were involved in some form of electronic access to their customers. Most had a protected customer base. ... However, as we all know, this situation has begun to change rapidly, at least from the standpoint of technology. Cable companies will be able to provide voice, video and broadband data services such as the Internet and video on demand. The same holds for the telephone companies.(19)

Hence, the Information Highway promises a much greater degree of interconnection and interoperability than is currently available; some claim it promises ubiquity. Given these expectations, it is simply a matter of time until the right technology becomes commercially viable and modifications are made to the current networks.

Figure 9

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Source: Charles Sirois and Claude E. Forget, *The Medium and the Muse: Culture, Telecommunications and the Information Highway*, Institute for Research on Public Policy, Ottawa, 1995.

Ubiquity would probably require changes in the industrial structure of telecommunications and broadcast distribution sectors, as modelled in Figures 9 and 10. Figure 9 presents the *status quo*, regulated-monopoly market structure of the Information Highway, while Figure 10 depicts an idealistic, competitive and seamless marketplace model with three tiers. The first, innermost tier comprises end-use consumers who are equipped with multi-purpose terminal equipment (yet to be developed). They obtain multimedia services of all types from the service providers that make up the middle tier. These service providers are retailers; they obtain content, such as video entertainment and high-capacity data services, from the input suppliers and telecommunications services from the telco-cableco-satellite companies that make up the outer layer – the infrastructure of this last tier is made up of inter-connected elements of copper, coaxial, fibre and radio-based technologies.

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Source: Charles Sirois and Claude E. Forget, *The Medium and the Muse: Culture, Telecommunications and the Information Highway*, Institute for Research on Public Policy, Ottawa, 1995.

An important service feature favouring expanded use of the Information Highway is its user friendliness. The next generations of computer software must be so simple that a computer can become an essential household appliance, with household acceptance rates in the high 90% range, like those for telephones, televisions, and VCRs.

Until recently, it appeared that the best candidate for an Information Highway network for most North American cities would be based on a terrestrial architecture known as "fibre-to-the-pedestal," using fibre-optic distribution to a set of remote interfaces from which a coaxial cable would be extended to the consumer. Each remote would have served an estimated 500 customers at a cost of about US$1,000 per customer, with a 50% subscriber penetration rate.(20) This cost may not be competitive, given new developments within the past year.

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Source: Salvatore Salamone, "Higher Data Speeds Coming for Plain Phone Lines," *Byte*, January 1996, p. 30.

ADSL technology now in the early stages of development promises ubiquitous access to the Internet, VOD and video-conferencing over conventional telephone lines through an architecture known as "fibre-to-the-curb" (see Figure 11), at an estimated cost of $500 per customer. Unlike HDSL, which supports equal transmission rates upstream and downstream of about 1.5 to 2 Mbps to the user, ASDL delivers much more bandwidth downstream than upstream. Using digital signal processing and multiplexing techniques, ASDL can deliver between 9 and 10 Mbps of data over copper wire lines with the installation of transceivers at both the customer's premises and the telco's local office. This technology will become competitive with cableco modems that offer 10 Mbps of data, but which tend to suffer from quality degradation as the number of users increases. Furthermore, it is estimated that the next generation of ADSL will provide 25 or 51 Mbps over shorter distances;(21) thus, incremental investments in fibre-optic cable extending closer to the curb of the home could be made as demand warranted.

While it is useful to think of the electronic network of networks as an Information Highway, the road metaphor is too restrictive. It misleads people into believing that some huge uniform "Information Pipe" might develop. The broader concept of an "Information Transport Network" may be more useful. This reminds us that goods and people travel by train, plane and boat on rail, in the air and over water, as well as by car and truck over a road network. Moreover, the different modes of transportation specialize in the cargo they haul, depending on distance, terrain, timeliness, convenience, the bulkiness of the cargo and the probability of obtaining a back-haul shipment. In the same way, an electronic network of networks comprising varied media and network specialization (based on such factors as reliability, timeliness, security and capacity offered) could also emerge. The digital revolution, which today appears to be stimulating a convergence of technologies and services in telecommunications, may also be stimulating possibilities for divergence of technologies and services that may not become apparent until much later.(22)

Thus, it is possible, but by no means certain, that "fibre-to-the-pedestal," "fibre-to-the-curb" and the radio spectrum networks will co-exist.

> There are at least two new jokers in the deck, representing a major departure from the capabilities of wired networks. The first of these technologies is the advent of direct broadcast satellites, or DBS, and the second is wireless personal communications systems, PCS. They are mentioned in the current context simply because both technologies provide yet another type of electronic access to customers, and both will be in a position, sooner rather than later, if the pundits are to be believed, to provide many, if not most, of the new services now provided by telephone and cable companies. (23)

Indeed, some experts have claimed that a telecommunications network set up from scratch today would comprise only wireless technologies. The introduction of this wireless "wild card" has made it almost impossible to formulate government policy for preserving and enhancing the underlying framework of the electronic information carriage sector, given the present state of technologies and knowledge. This suggests that federal policy-makers ought to be careful to ensure that their decision-making and program delivery are technology-neutral.

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(1) This section relies heavily on the contributions of Robert E. Babe to *The Canadian Encyclopedia*, p. 2123-26.

(2) Robert Simmonds, Clearnet Communications Inc., Senate of Canada, *Proceedings of the Standing Senate Committee on Transport and Communications*, First Session, Thirty-Fifth Parliament 1994-95, Issue No. 33, 24 November 1995, p. 6.

(3) Robert E. Babe, *Telecommunications in Canada*, University of Toronto Press, Toronto, 1990, p. 219-221.

(4) Industry Canada, *Communications for the Twenty-First Century*: *Media and Messages in the Information Age*, Ottawa, 1992, p. 25.

(5) Anthony M. Rutkowski, "*The ITU at the Cusp of Change*," Telecommunications Policy, August 1991, p. 286.

(6) Data transmission rates are usually measured in bits per second (bps). For example, an ISDN line has a bandwidth of 64,000 bits per second, or 64 kbps, and high-definition television has a bandwidth of about 140-560 million bits per second, or 140-560 Mbps.

(7) The corners of a digital signal wave are not always perfectly square, making for the possibility of error. Redundancy checks have been built into the data stream to detect and correct such errors.

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(12) The Economist (1995), Survey, p. 2.

(13) MacKie-Mason and Varian (1994), p. 76.

(14) The marginal cost of an additional hour of service over the Internet is virtually zero. The user fees contemplated would be set only to reflect the congestion costs. There are a variety of ways to design such a user fee (see *Telecommunications Policy*, Vol. 20, No. 2, 1996); for example, a user could include a priority code in the header of each information packet that would activate an additional charge to the sender

and/or receiver only when there was congestion on that area of the Internet.

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(21) Salvatore Salamone, "Higher Data Speeds Coming for Plain Phone Lines," Byte, January 1996, p. 30.

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(23) Côté-O’Hara (1995), p. 6.