"The Technology Revolution in Telecommunications"

C. David Decker, Vice President and Director of Research
GTE Laboratories Incorporated

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Massachusetts Institute of Technology

The following is an edited summary, not a complete transcript of the remarks made by the speaker.

David Decker: I'm going to talk today not just about what GTE is doing but about what I think is a fundamental dislocation in the industry I work in. Large as we are, we are a small player in a very large game that is evolving as we speak. A technology-led revolution is in progress. The communications, computer, and video entertainment industries are rapidly merging into one digital information movement and management industry, enabled and driven by technology. Technology has also driven regulatory change and has created the new competitive business environment in which these industries now operate.

The telecommunications industry is gradually subsuming the traditional telephone industry and also aspects of the computer information service industry and the video entertainment industry. These are being driven together primarily by a digital revolution going on in this country. This revolution in technology has regulatory effects. The fact that we have one common digital broadband infrastructure that can carry voice data, video images, etc., makes many of our historical regulatory distinctions obsolete.

We are moving to a market-driven structure in telecommunications. In the last 10 years we have had a regulatory-driven structure, in which inter-exchange carriers, local exchange carriers, cellular and cable TV providers all faced different regulations and were precluded from competing in each others' businesses. This is changing, at the federal level through the FCC, and also at the state level. We now have one industry developing where players from diverse backgrounds are going to compete to provide everything from information to communications to entertainment. It is not clear who is going to win and who is going to lose.

The transport and switching capabilities of traditional telecommunications businesses have merged with the intelligence inherent in computers and with the mobility of radio access to bring about what some people call the Information Age. It is important to understand that the transformations that have produced this Information Age, and which will drive it forward, are almost all technical. To look at a few arbitrary benchmarks of technical progress:

In 1987 the amount of computer power that you could buy for under $10,000 was 10 MIPs. By 1992 this figure was 70 MIPs. By 1997 it is expected to be around 300 MIPs. A second example of technical progress comes from looking at our ability to transmit data over local area networks. This rate has gone from 10 megabits per second in 1987 to 100 megabits per second in 1992. It is expected to go up to about one gigabit per second by 1997. With a gigabit per second connected to 300 MIPs, you get a completely different paradigm for computing and interacting with each other.

A third example of technical progress is the number of wireless channels per cellular sector. We have seen a change from a capacity of 60 channels with an analog system in 1987, to 200 TDMA (time division multiple access technology) in 1992. The number of channels is expected to rise to 1,500 CDMA (co-division multiple access) by 1997. In other words, as we go from analog to TDMA to CDMA over a period of a decade, the density of wireless voice channels per cell is going up by a factor of 250. This 1,500 channel figure estimated for 1997 will let us provide service to the same density of population that the wireline telephone industry reaches today. So again there is a new paradigm. The new wireless technology makes it possible to provide service to the same mass of people as traditional wireline technology.

A fourth example of tehcnical progress is the data rate to transmit a TV channel. This rate was 100 megabits per second in 1987 and went up to 1.5 to 3 megabits per second in 1992. It is expected to rise further to between .5 and 1 megabit per second in 1997. Finally, let's consider optical fiber, which is the backbone of our long-distance networks today. We have gone from being able to send 50 video channels per single optical fiber in 1987, to 200 channels in 1992. That number is expected to go to 5,000 channels in 1997. All these technical developments will alter the way people live and conduct business.

The pace of technical progress continues to accelerate, leading to a rapid convergence of the communications, computer, and video entertainment industries. Customers' needs will favor broadband solutions and mobility solutions that let you communicate wherever you are whenever you feel like it. Companies are faced with both challenges and opportunities in voice, data and video as competition emerges. Examples of the these challenges are: 1) the cable TV threat in the area of voice and data, 2) the threat from telephone companies to cable TV to provide video service, and 3) the wireless threat to wireline to provide voice, data and video. There will be an interesting war going on over the next few decades.

What do these technological changes mean? Technology is clearly changing society and jobs. John Hopfield of CalTech makes the accurate statement that "technology is never benign". Responsibilities that used to reside in people are being put into machines. This will severely affect — in fact, it has already begun to affect — the workforce. Many of the tasks that professionals take pride in doing are going be taken over by intelligent computer systems. Examples can be found in the areas of medical diagnosis, financial decision-making, secretarial and administrative assistance, customer service and network control.

This transformation is happening because of continued advances in four major technologies: 1) microelectronics, which provides cost-effective processing power, 2) software, which provides the network intelligence we can imbed in these systems, 3) photonics, which provides almost limitless information pipelines, and 4) radio access, which provides service mobility. The integration of these four technologies into cost-effective Information Age networks, products and services is the basis of the technological revolution and the basis of future business success.

In microelectronics, one important change has been the reduction in disk storage costs from $10,000 per million characters in 1960 to less than $10 in 1990. In general, there has been an explosion in cost-effective computer power. This explosion means greater capability, which we see for example in the replacement of mainframes and mini-computers with networks of personal computers. It also includes advances in information access. Examples here are movies stored on video servers for Video-on-Demand services, and rapid access to worldwide information via the Internet. Overall, we have seen a major decline in costs as we have gone up the learning curve in microelectronics.

In recent years, we have seen an explosion in data networking and interconnectivity. This is characterized most clearly by the Internet. The number of host computers — computer systems that connect directly to the Internet — has gone from 50,000 in July 1988 to 3,864,000 in October 1994. Since each host may connect to hundreds of PC's or other computers, this means the number of computers with Internet access is now in the tens of millions. This explosion in access is happening for a number of reasons: because computers are cheap and because the cost of connecting them is cheap. The economic advantages of the Internet are clear. The cost of sending one four-page copy from coast to coast is $2 if it is sent by voice, $1

if it is sent by fax, 60 cents by MCI Mail, but only a penny to five cents if it sent by the Internet. If four copies are sent, the cost increases for voice, fax and MCI Mail, but not for the Internet. In addition to its low cost, the Internet is also increasingly popular because it has user-friendly interfaces such as MOSAIC and Netscape which are becoming widely available.

Not only advances in microelectronics, but also advances in software technology are crucial to the future development of the industry we are discussing. This is because software is the dominant and fastest-growing cost segment for most telecommunications businesses. One area where software advances are going to be important is in object-oriented design and object-oriented systems, especially in terms of reducing the amount of code and reusing code and data objects across applications. A second area is in expert systems, where human expertise is being replicated by software. This is being done successfully, for example, in the telephone industry. Expert computer systems can be used to identify problems and take corrective action in a faster, more thorough and less costly way than the human experts they replace. A third area is in distributed systems technology, where client-server systems with standard interfaces allow improvement in performance and reliability. A final area where advances in software technology are crucial is in security and encryption technology.

I mentioned photonics as one of the four major technologies driving the information revolution. Photonics is the technology of carrying and processing information in the form of light photons instead of electrical current. Using fiber optics and semi-conductor lasers allows us to carry far more information than over traditional traditional metallic wire circuits. Other advantages of photonics are that fewer repeaters are needed to boost weak signals, that service quality is greatly increased, and that there is immunity to electrical interference. There is also typically less use of electrical power. For these reasons, since the early 1980's essentially the entire long-distance telephone network has converted to fiber optic cables.

Back in 1975, GTE was the first company to put in a fiber optic link carrying live telephone traffic. Today, due to advances in fiber transmission capacity, we are able to carry five or six times as much information over fiber optics as in the mid-1970's. And we are still using only a small fraction of the intrinsic bandwidth of that fiber. We have gone from fiber systems that carry 100 or so voice channels to systems that carry over 30,000 channels for hundreds of kilometers of amplification. This means that trunk bandwidth is becoming essentially free.

The fourth major technology I mentioned as critical to the information revolution is wireless access. Wireless access is evolving from the simple car telephone of 10 years ago to important new personal communication services. Through some of the new digital systems that are coming in, there is greatly increased wireless capacity sufficient to match the wired telephone. In Tampa, Florida, where GTE is both the cellular and the wireline carrier for the city, it would be technically possible to provide wireless access to the entire population through hand-held wireless telephones. If we are able to get enough people to sign up, it is possible to build very efficient systems. At high penetration levels, wireless technology is less costly compared to the wireline network. The cellular business is growing exponentially at about 40 percent per year. Wireless data will also be a major new business. It will facilitate such services as geographic information services, fleet tracking, and emergency 911. What makes this possible is the conversion of the wireless system from analog to digital and the greatly increased capacity of the forthcoming digital spread spectrum (CDMA) technologies.

What does the future hold from the standpoint of networks? I see future networks carrying a large volume of voice, data, image and video traffic simultaneously. All these things will be carried as digital bits on the same medium. If the regulators have their way, they will have four or five broadband pipes in everyone's home and six cellular carriers competing with each other. From a technological standpoint, however, this does not make sense; you really only need one (carrier). I also want to point out that the network architectures that are out there have been driven largely by traditional voice traffic. This is changing dramatically. Increasingly the architectures are being driven by data and video services. For most systems that carry video or large amounts of data, voice can go along almost for free.

The developing technologies I have been discussing will permit alternate ways of providing broadband services. They will also permit non-traditional competitors to enter high-end markets. The way the regulations work now, GTE and other local-exchange carriers have an obligation to provide telephone service to everyone, meaning ordinary citizens. But at the same time, we and other traditional players are facing growing competition in the high-end part of the business, where competitors like cable TV are stringing fiber optic cables up to businesses and universities. In a sense, we have our feet stuck in the concrete of the current regulations. We cannot do what technology permits us to do because of certain regulations. For example, telephone companies can offer video services or video dial tone — we can carry someone else's services to you — but we can not provide those services ourselves, because the FCC says so. This is why you hear so many people advocating for regulatory change and a level playing field.

To illustrate the type of challenges companies face today and into the future, I want to examine some of the technical options for broadband services (video and data) . There are at least six different ways of providing video to the home. These include satellite systems, enhanced cable TV, "wireless" cable TV, and optical fiber-to-the-curb. The cost of providing video services is largely a function of which technology is employed and the degree of penetration. The economics of the video service business depend on these factors, and alsoon the content of the offerings, on competition and on regulation. A company like GTE that wants to invest in video services needs to have a detailed understanding of the options from a technological standpoint, and also in terms of their projected evolution in performance and costs. Different technologies have varying cost versus service penetration behavior, and this behavior may change more over time for certain technologies than for others. Furthermore, the introduction of new technologies such as Asymmetric Digital Subscriber Line (ADSL) technology can potentially change provisioning and competition. This can make what seemed like the right decision a year ago into the completely wrong decision today. To make the most informed business decisions possible, it is essential that managers fully understand the capabilities and limitations, both present and future, of diverse competing technologies.

To conclude, the world of telecommunications has undergone a fundamental change in recent years and it continues to change. The financial and legal skills that served many industries well in the regulated past are no longer sufficient to ensure success in a deregulated, competitive new world. Rather, technical acumen is absolutely essential to prosper in the future. But not all companies who succeeded in the past will survive in their present forms in the future.

Beth Rosenson, Rapporteur

Room E40-242A, MIT, Cambridge, MA 02139 (617) 253-0008 Fax (617) 253-7140

The Technology Revolution in Telecommunications

December 1, 1994

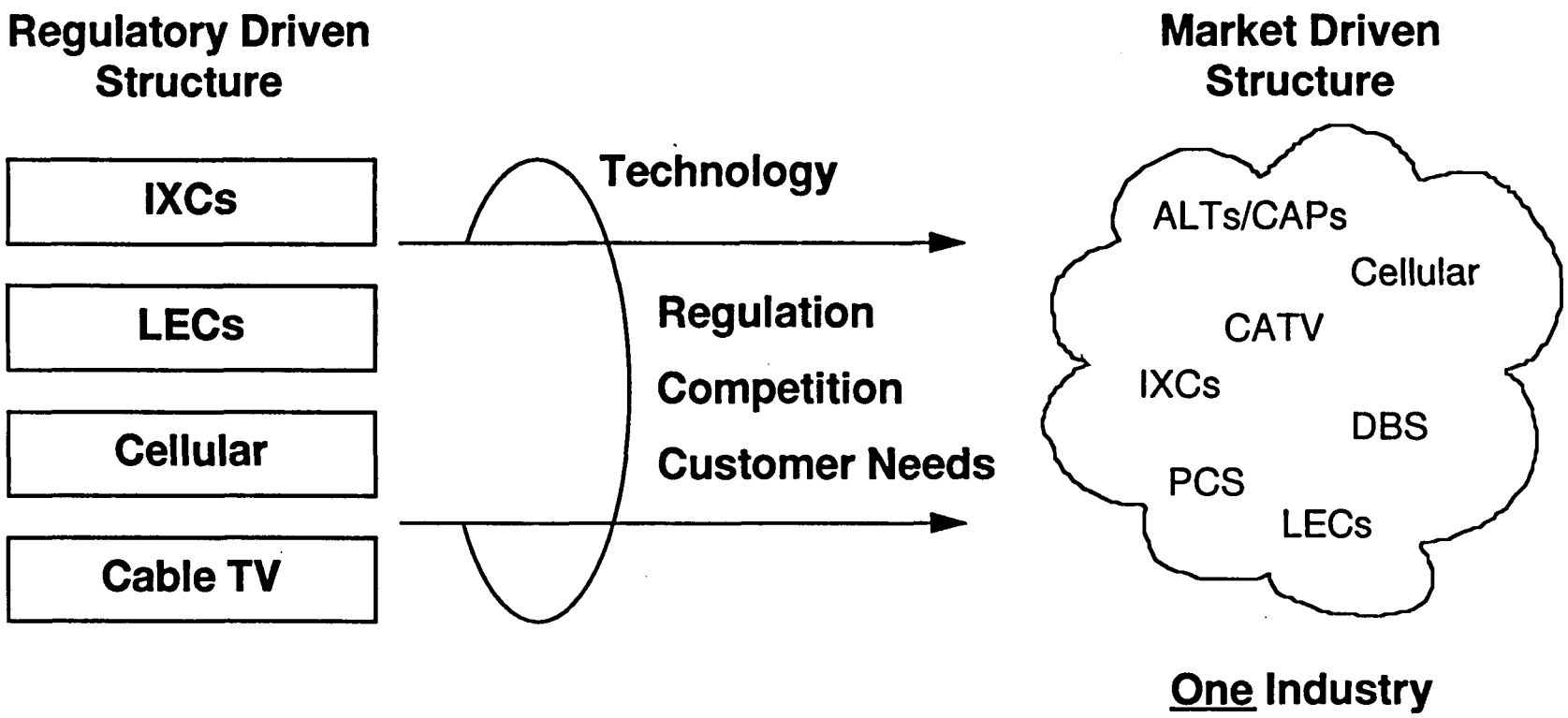
C. David Decker

GTE Laboratories Incorporated

A Technology-Led Revolution is in Progress

- The communications, computer, and video entertainment industries are rapidly merging into one digital Information Movement and Management industry, enabled and driven by technology.
- Technology has also driven regulatory change and created the new competitive business environment in which these industries now compete.
  - — Electrons and photons do not know whether they are regulated or not.
  - — Government Regulators do not want to stop regulating.

The Industry Is Evolving into a Market-Determined Structure



The 'Hype' is Over: The Information Age Has Finally Arrived

- The *transport* and *switching* capabilities of traditional telecommunications businesses have merged with the *intelligence* inherent in computers and the *mobility* of radio access to produce the Information Age.
- The Information Age: Information for the user
  - Where it is needed
  - When it is needed
  - In the forms most useful to the user: voice, data, video, images, graphics

The drivers for this transformation are all technical.

Technology Revolution Continues

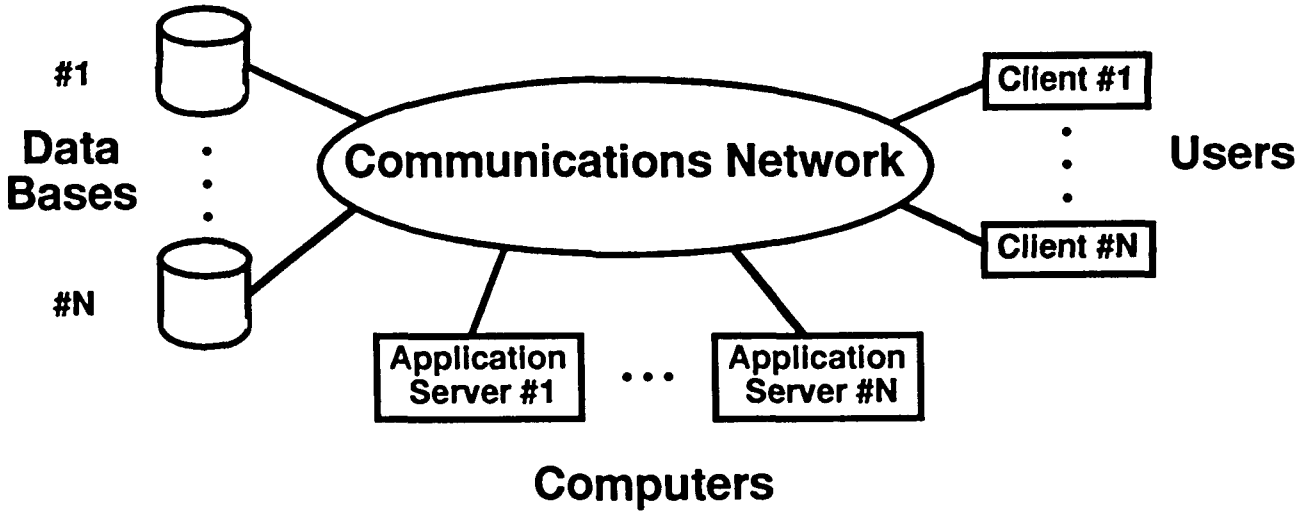
	1987	1992	1997
Computer Power for < $10K	10 MIPs	70 MIPs	300 MIPs
Local Area Network Data Rates	10 Mb/s	100 Mb/s	1 Gb/s
Wireless Channels per Cellular Sector	60 (Analog)	200 (TDMA)	1500 (CDMA)
Data Rate to Transmit a TV Channel	100 Mb/s	1.5 – 3 Mb/s	0.5 – 1 Mb/s
TV Channels per Single Optical Fiber	50	200	5000

These developments will alter the way people live and conduct business!

Future Networks as Distributed Computers

At *data rates* of 45 Mb/s, computers can communicate on the network at speeds equal to that of the internal data rates of a single computer. Distributed heterogeneous computation becomes a reality via *the network.*

The network *becomes* part of the computer!



Industry Convergence and Competition

- The pace of technical progress continues to accelerate, leading to a rapid convergence of the communications, computer, and video entertainment industries.
  - Customers' needs will favor Broadband and Mobility solutions.
- Companies are faced with both challenges and opportunities in voice, data, and video as competition emerges.
  - CATV threat to voice, data
  - Telco threat to CATV for video
  - Wireless threat to wireline for voice, data, and video

Technology is Changing Society and Jobs

"Technology is never purely benign" - John Hopfield (CalTech)

Responsibility is going to be invested more and more in computers.

> Remove a few parts from a biological system, and it still functions: do the same with a computer, and New York City has no phone service.

The workforce will be severely affected.

> In 25 years, computers will have greater-than-present human intelligence for single tasks. Computers will take over many tasks professionals do and take great pride in:

Medical diagnosis	Secretarial assistance
Financial decision-making	Customer service
Legal opinion	Network control

Key Technologies

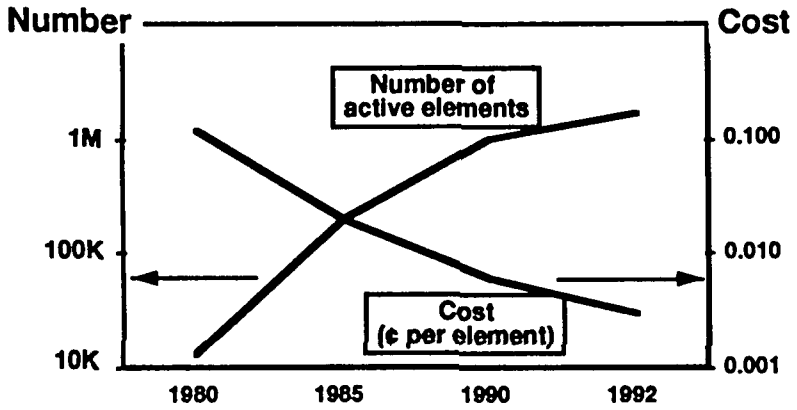
Telecommunications Businesses are Critically Dependent Upon Four Key Enabling Technologies

- **Microelectronics**
  - — **Providing cost-effective processing power**
- **Software**
  - — **Providing network intelligence**
- **Photonics**
  - — **Providing limitless information pipelines**
- **Radio Access**
  - — **Providing service mobility**

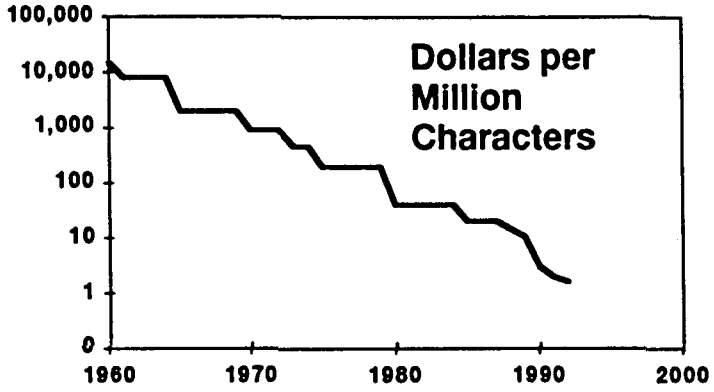
The *integration* of these four technologies into cost-effective Information Age Networks is the basis of future business success.

Microelectronics

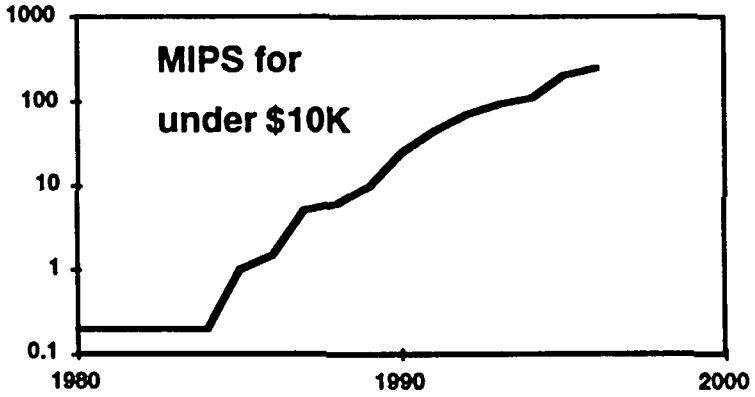
VLSI Complexity



Disk Storage Costs



Desktop Computers



Microelectronics

There has been an Explosion in Cost-Effective Computer Power

- **More capability**
  - — Mainframes and Mini computers being replaced by networks of Personal Computers
  - — Video transmission at 1.5 MB/s enabled by video compression (60:1)
  - — Cost-effective PCS handsets (CDMA chipsets)
  - — Portable Personal Digital Assistants
- **Information access and data storage**
  - — Movies stored on video servers for Video-on-Demand services
  - — Rapid access to worldwide information via the Internet
- **Lower Cost**
  - — Ubiquitous implementations

Microelectronics

- Price/performance ratio of PCs and workstations is causing an explosion in the use of these systems.
  - — 15 million PCs were purchased in U.S. in 1993.
- Data networking (LANs, WANs) and interconnectivity of networks are growing explosively.
- Computer interconnectivity is a major new business.
- An example: Internet, a network of networks. The start of the Information Superhighway.

	July 1988	July 1993	Oct 1994
Hosts (computers) on Internet	50,000	1,776,000	3,864,000

Why the Internet?

- **Economics**

Cost of Sending 4 Pages Coast-to-Coast		
	1 Copy	4 Copies
Voice	$2	$8
Fax	$1	$4
MCI Mail	$ .60	$2.40
Internet	$ .01-.05	$ .01-.05

- **Worldwide access**
  - — dave@gte.com
- **Friendly user interfaces (e.g., MOSAIC and Netscape) becoming available**
  - — Not just for nerds anymore

Software

Software is the Dominant and Fastest Growing Cost Segment for Most Telecommunications Businesses.

- **Billing Systems**
- **Information Services**
- **Operational Support Systems**
- **Network Management and Control**
- **Customer Services**

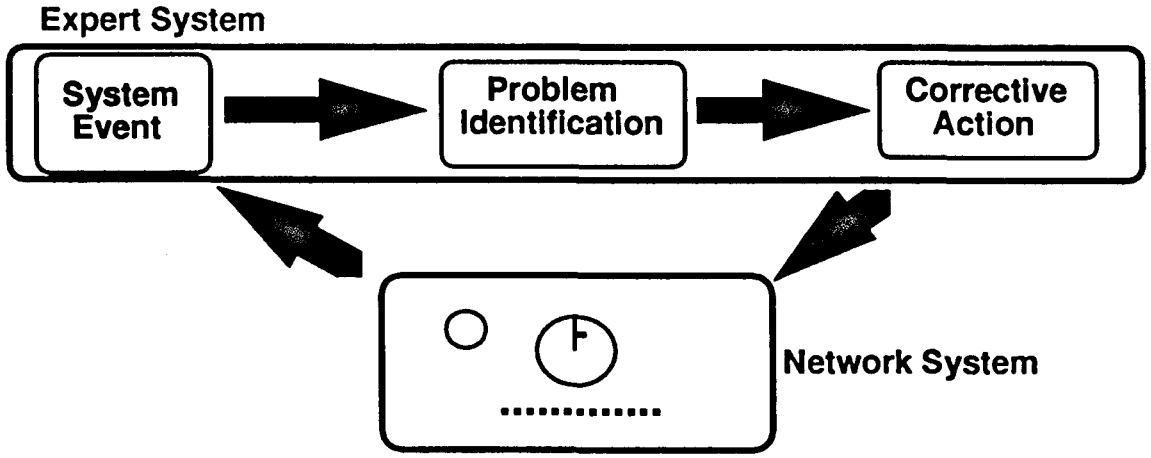
Software

Advances in Software Technology Are Crucial

- **Object-oriented design and systems**
  - — Significant reduction in amount of code
  - — Reuse of code/data objects across applications
- **Expert systems**
  - — Replicate human expertise in software
- **Distributed systems technology**
  - — Client-server systems with standard interfaces allow improvement in performance and reliability.
  - — Distributed database management systems provide a single logical view of physically distributed data.
- **Security/encryption technology**

Software

Expert Systems — Capture Best Human Expertise in a Computer Program



Expert Systems are faster, more thorough, and lower in cost than the human experts they replace.

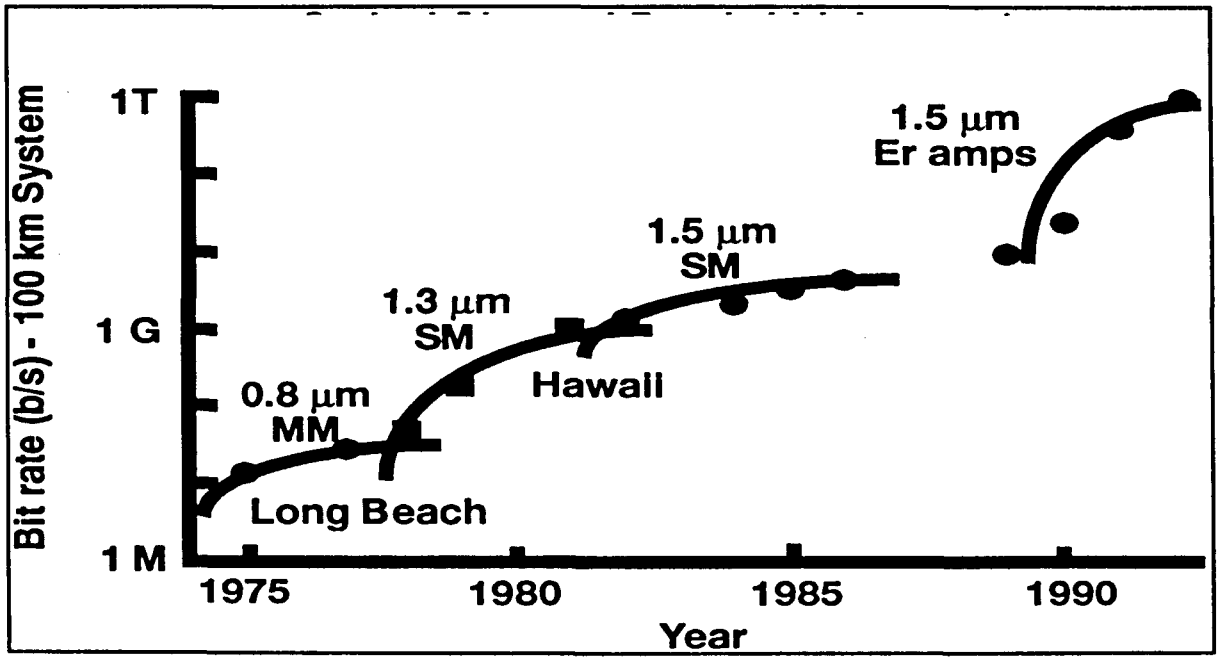
Photonics

Photonics is the technology of carrying and processing information in the form of light photons instead of electrical current.

- Enables far greater capacity via fiber optics
- Uses fewer repeaters to boost weak signals
- Increases service quality
- Increases network reliability
- Uses less electrical power
- Is immune to electrical interference

Photonics

Optical Channel Bandwidths Increasing



Still using only a fraction of intrinsic bandwidth of optical fiber!

Photonics

Fiber Transmission Capacity Has Changed Dramatically.

- Since 1974, five separate generations of fiber optic transmission systems have evolved.

Year	Fiber System	Capacity
1977	Multimode	160 Voice Circuits
1981	Long Wavelength	1500
1984	Single Mode	5000
1987	Single Mode	30,000
1992	Optically Amplified	30,000 + for long distances

Trunk bandwidth is becoming essentially free!

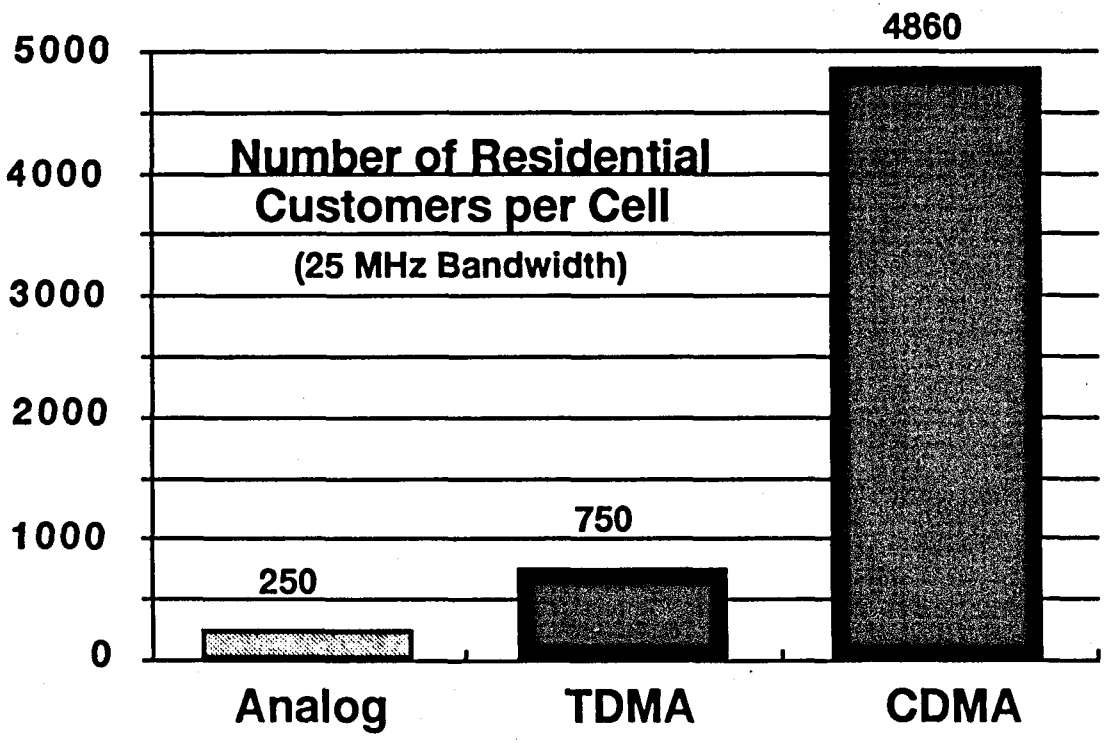
Wireless Access

Wireless Access is evolving from a simple car telephone with a limited number of subscribers to an important new system of personal communications and services.

- Greatly increased wireless capacity (sufficient to match the wired telephone) enabling true Personal Communications Systems and Wireless Data.
  - — CDMA allows one cellular carrier to provide dial tone to 100% of users, e.g., metro Tampa.
- At high penetration levels PCS is economically advantaged over the wireline network!
- Wireless Data should be a major new business.
- Geographic Information Systems will ride on Wireless Data.

Wireless Access

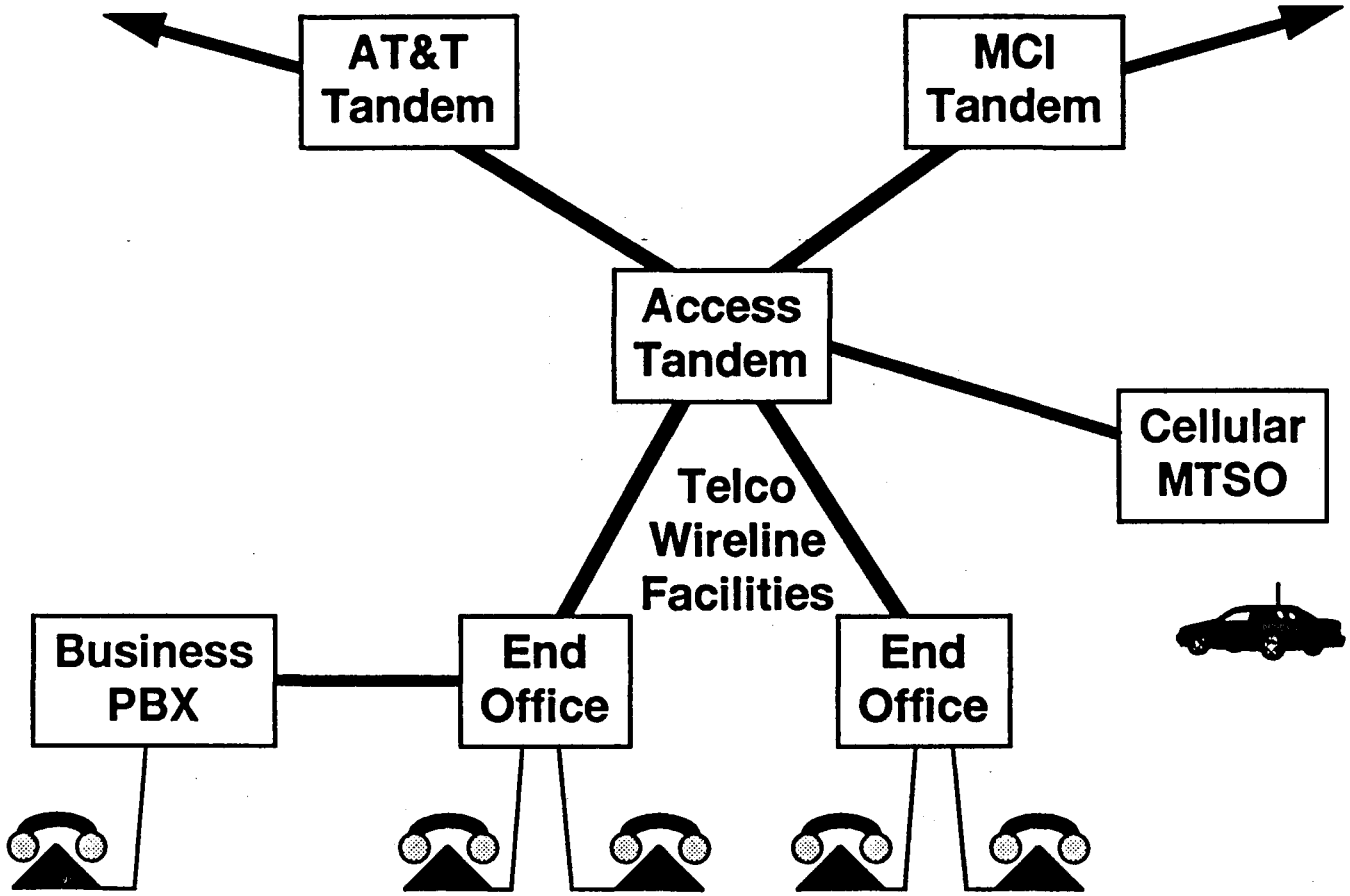
Traffic Capacity of Cellular Radio Technologies



Broadband Networks

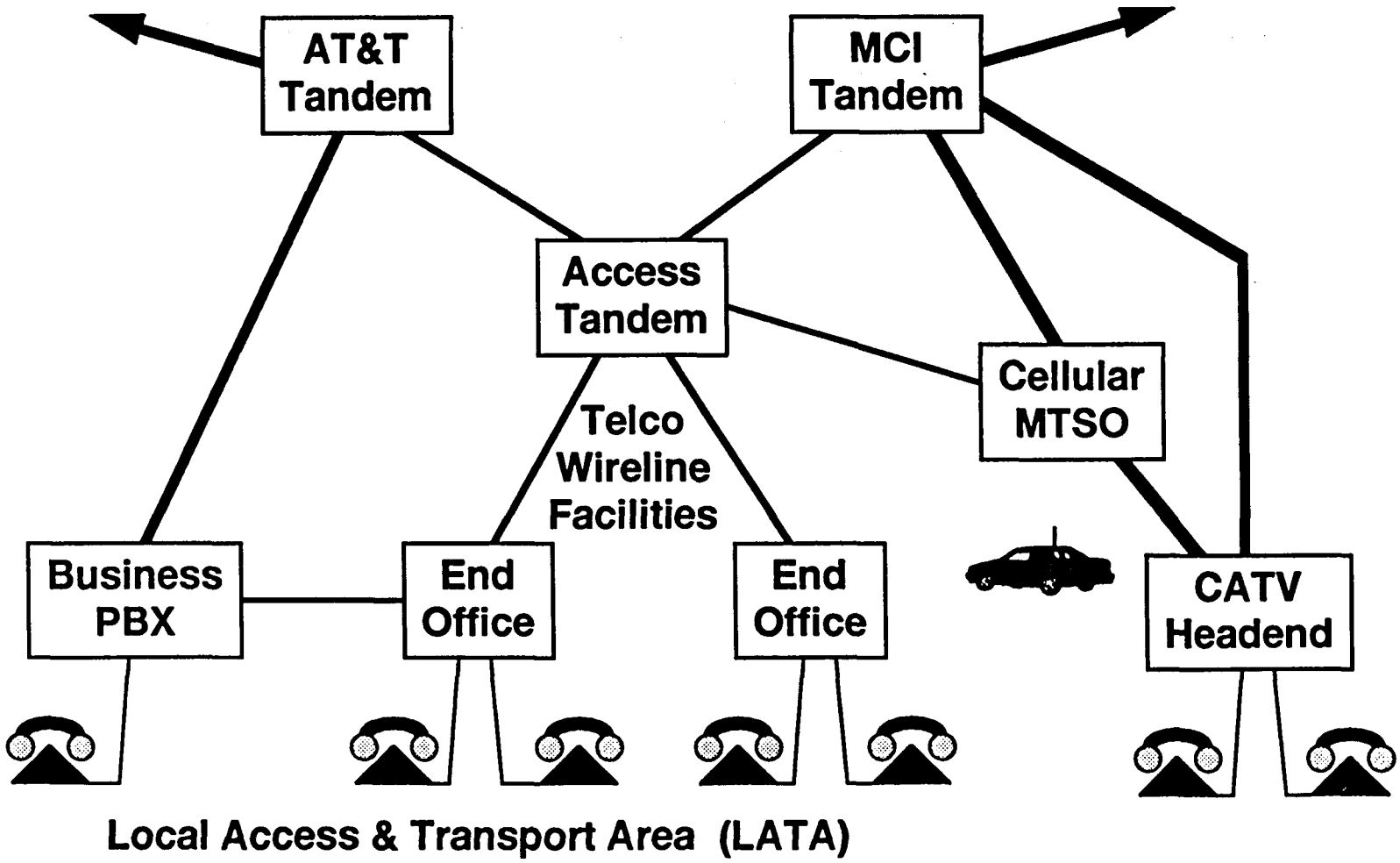
- Future networks will carry a large volume of voice, data, image, and video (TV) traffic simultaneously.
  - Multiple classes of service on the same medium.
- Network architecture will be driven by data and video services as opposed to traditional voice traffic.
- Available technologies will permit alternate ways of providing broadband services, and nontraditional competitors will seek to enter these high-end markets.

Networking - *The Good Old Days*



Local Access & Transport Area (LATA)

Networking - *Competitive Alternatives*

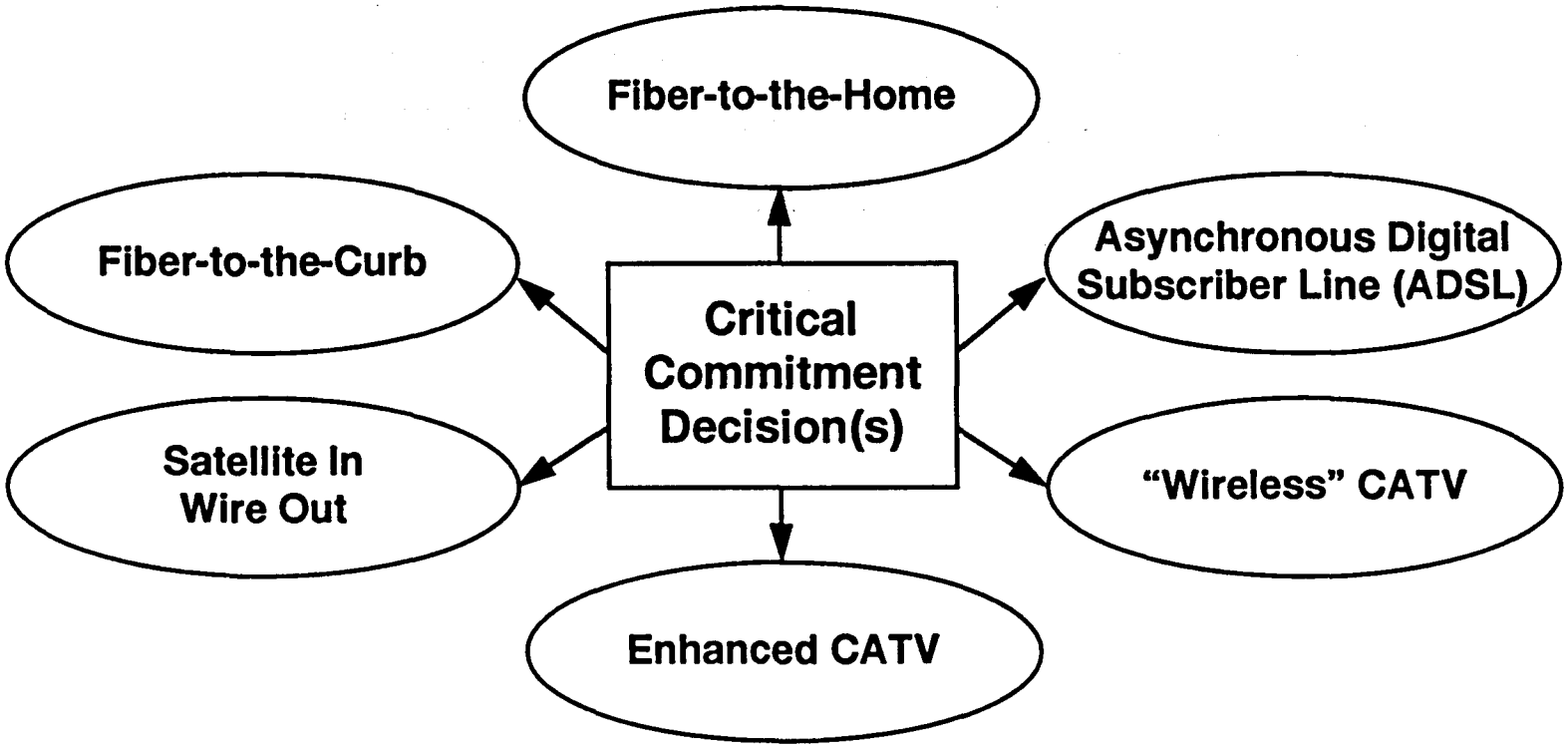


Broadband Economics

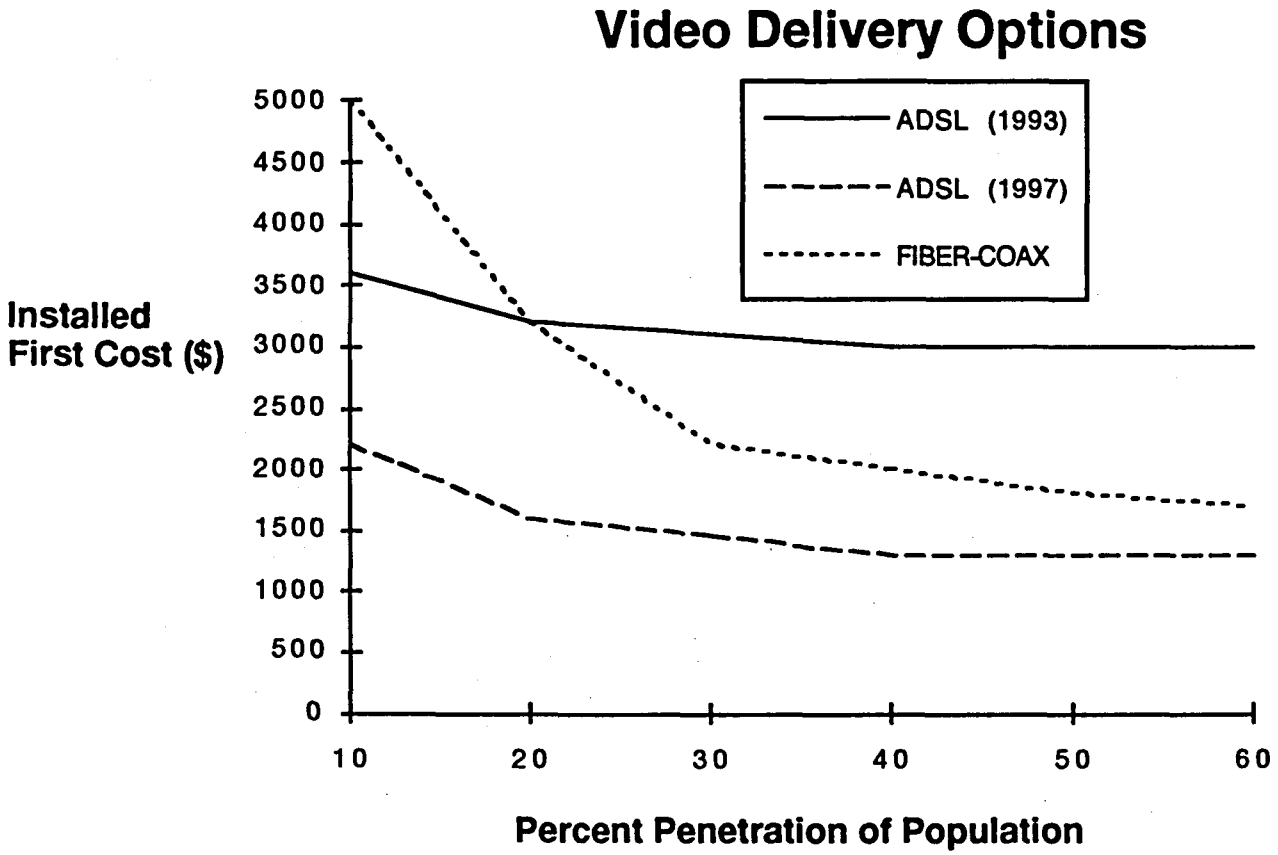
- The cost of provisioning broadband services (Video, Data) is a function of
  - — the technology employed,
  - — the degree of penetration of service acceptance, and
  - — the degree of synergy with imbedded plant.
- The economics of the business depend on these factors as well as content of offerings, service pricing, competition, and regulation

We will today examine some technical options for Broadband to illustrate the challengescompanies face.

Video Options



Illustrative Broadband Economics



Choice of Technology depends upon projections of service penetration as well as projected life-cycle cost reductions.

Business Decisions and Technology

- A detailed understanding of Technology options -- as well as their projected evolution in performance and costs -- is essential to making proper business decisions in telecom's newly competitive world.
- Different technologies have differing cost vs. service penetration behavior, and some of these may change more over time than others.
- Introduction of new technology (such as ADSL) can potentially change provisioning and competition.
- It is therefore essential that managers fully understand the capabilities and limitations of diverse competing technologies.

Technology Progression

- **Significant advances have occurred where the four key technologies have been integrated to provide enhanced systems capabilities.**
  - **Asymmetric Digital Subscriber Line (ADSL) technology carrying compressed video over twisted pair copper wiring (up to 4 video channels to home)**
  - **Cable Loop Carrier Systems providing 480 channels of voice and data over 25MHz of cable TV bandwidth**
  - **Personal Communications Systems (PCS) that may be able to compete with wireline telephony on the basis of cost as well as on their desirable mobility features.**

Conclusions

- The world of Telecommunications has fundamentally changed.
- The financial and legal skills that served so well in the regulated past are not sufficient to ensure success in a deregulated, competitive new world.
- Technical acumen is absolutely essential to prosper in the future.
- Not all companies who succeeded in the past will survive in their present forms into the future.

This is an exciting time to be in the telecommunications industry!