Chapter 1 Background

Overview

This user guide is intended to provide both instructions on installing cable modems and background on the high-speed data access phenomenon. This guide will offer this information in non-technical terms to the extent possible. Telecommunications technology is so full of acronyms and technical jargon that it is difficult, if not impossible, to express it in mainstream terms

This chapter focuses on the following.

- A brief review of the problems that created the need for new technology.
- How the industry is solving the problems.
- A look at the future of broadband communications.

The Next Level

According to the seers, the Internet has spawned a revolution that will forever change the way the world uses information. Yet a lot of folks—including countless millions who own personal computers, subscribe to AOL, and dial-up to buy books at amazon.com—are less impressed.

A major reason for this indifference is that dial-up access to the Internet can accommodate neither the tremendous increase in traffic volume that has recently occurred, nor the size and complexity of today's Web pages. Dial-up connections are too slow—at any conventional modem speed. Analog modem technology has reached its limit.

Now, technologists have improved access to the World Wide Web. Asynchronous Digital Subscriber Line (ADSL) and Cable modem technology represent the first generation of high-speed Internet access. The next level of high-speed technology is on the horizon, but major problems have to be solved before that level of performance is achieved. Preliminary reports of success with these problems strongly suggest, however, that great progress is being made.

About two years ago, TCI@home and Time Warner—two major Cable television companies—introduced Cable modem technology to its customers. Since then, demand has increased daily. Households across the country are beginning to recognize the benefits of always-on, no-wait, Internet access. Regional telephone companies around the nation are following suit with their versions of the ADSL technology.

Although the technologies deployed by the Cable and telephone companies are different, high-speed modems provide a common solution to the difficulties of crossing the "last mile".

The Last Mile

The last mile comprises twisted-pair copper wire and coax cable, suspended from telephone poles and buried beneath sidewalks. Copper wire is that part of the wiring infrastructure that poses the greatest problems. Billions of dollars have been spent upgrading much of the telephone and cable system with modern equipment, such as fiber optics, enhanced multiplexers, high-speed routers, and other sophisticated hardware, except the last mile.

Table 1 summarizes the various problems associated with the last mile. The terms PSTN and CATV are acronyms for the public switched telephone network and community antenna television, respectively and refer to the two different networks involved. Table 1 also shows that outmoded and corroded wiring limits speed because of bridge taps and loading coils, making high-speed connections difficult. Copper wiring must be completely replaced with fiber optic cable, but the job is capital intensive. It will take years for replacement to happen.

Table 1. Elements of the Last Mile

Network	PSTN	CATV
Transmission Media	Copper Twisted-Pair	Coaxial Cable
Systemic problems	Corroded wire Bridge taps [1] Loading coils [2]	One-way amplifiers
Physical limitations	Colossal size of wiring plant Attenuation [3] Crosstalk [4] Noise [5]	Colossal size of wiring plant Impulse Noise
Recent improvements	Upstream fiber optics High-speed routers and multiplexers	Hybrid Fiber Coax (HFC) Allows two-way traffic
Upgrade picture	Replacement runs in the billions. Industry regulation diminishes capacity to generate the funds over the short term.	Same

1 Employed in years past to extend the reach of telephone wire to new neighborhoods.

2 Employed in years past to amplify the telephone signal to extend its range.

3 Signal loss caused by the natural resistance of the copper wire.

4 Signal interference caused by the close proximity of other transmission wires.

5 Signal loss caused by electromagnetic interference.

What is Broadband?

Engineers coined the word *broadband* to distinguish it from voiceband. Voiceband occupies the bottom of the radio frequency spectrum, from 3 to 4,000 Hz (cycles per second). This is the level at which analog voice transmissions occur. Voiceband is also the frequency range that has flowed through copper telephone lines for the last 120 years.

Dial-up modem transmissions occupy this bandwidth. Broadband occupies the frequency spectrum immediately above voiceband, as shown in Table 2.

Table 2. Broadband Frequency Spectrum

Frequency Range	Description	Purpose
3 kHz to 4 kHz	Voiceband	POTS [6]
25 kHz to 250 kHz	ADSL Bandwidth	Upstream
250 kHz to 1.4 MHz	ADSL Bandwidth	Downstream
5 MHz to 42 MHz	Cable Modem Bandwidth	Upstream
50 MHz to 550 MHz	Television Bandwidth	Analog Cable television
550 MHz to 750 MHz	Cable Modem Bandwidth	Downstream

6 Plain Old Telephone Signal

Networks

Two tin cans and a wire make a simple network. Without the wire, not much is accomplished. The wire makes the network. This is a principle we sometimes forget. So, in a discussion about networks, the transmission media that configures the network is central.

Copper wire carries electrical signals well. Fiber optic cable carries light pulse signals extremely well. They both carry encoded information, albeit at different rates of speed and efficiency. Both have their own physical characteristics, form the basis of the telephone system, and comprise a major portion of the Internet

Table 3 summarizes the four types of networks. For example, two or more computers sharing resources and connected by copper wire form a network. Local Area Networks (LAN) are examples of this kind of structure.

Two or more remote government or corporate locations, comprising hundreds of LANs and connected together by wires leased from Internet Service Providers (ISP), form a WAN (Wide Area Network).

An aggregation of networks connected to an infrastructure comprised of telephone wires, T1 (1.544Mbps) feeder lines, fiber-optic backbones, and a satellite or two, comprise the Internet.

Table 3. Network Composition

Networks	LAN	WAN	PSTN	Internet
Types	Ethernet	X.25 Frame Relay ATM	Circuit-Switching ATM	TCP/IP HTTP

Media	Unshielded Twisted-Pair Fiber-Optic Cable	Fiber-Optic Cable	Fiber-Optic Cable Copper Twisted-Pair	Fiber-Optic Cable Satellite Copper Twisted-Pair
Structure	Two or more PCs	Remote LANs	Switched telephone networks	Worldwide networks

ADSL and cable modems represent the culmination of efforts started by scientists ten years ago. However, to understand the significance of their achievement requires going back at least 30 years. How did modems get to this point? Where did ADSL and cable come from? What are the origins of these technologies?

Network History

In 1969, a group of scientists from the Advanced Research Project Agency (ARPA) connected four mainframes together and made them talk to one another. The four computers were located on the campuses of Stanford University, UCLA, UC Santa Barbara, and the University of Utah. This was the first Wide Area Network, comprised of dedicated telephone lines.

ARPA engineers designed the network as a test-bed for a fail-safe solution to be used in case of a nuclear attack. ARPA's mission was to create a technology that would maintain communications in the aftermath of a nuclear holocaust—so that retaliation would be possible. They succeeded, and the ARPANET grew apace.

Note It is interesting to observe that ARPA developed a communications technology, back in 1969, based on a network design that supported no centralized command structure. ARPA scientists feared that the Soviets would bomb a command center and break down communications. ARPA therefore developed a way to move data through an unstructured, chaotic network of transmissions lines and switches to ensure communications between two points, under any circumstances. Unknowingly, they lay the unique groundwork for the Internet.

ARPANET

In the mid-1970's, the ARPANET grew beyond its cold war model and bounded off in a new direction: research. The network first served as a means of sharing computer output between small groups of computer scientists. Then, in 1976, IT&T helped launch SATNET, the Atlantic Packet Satellite Network, linking the U.S. with European networks, making the world a much smaller place.

The 1980's saw exponential growth of the ARPNET that culminated in 1986 with the National Science Foundation creating NSFNET. NSFNET added supercomputers, routers, and fiber optic transmission lines to what would become the backbone of the nascent Internet.

In 1990, the government decommissioned the ARPNET. The NSFNET network then became the framework of the Internet. Later that year, the National Science Foundation opened the NSFNET to commercial use. And the rest as they say is history.

Video-on-Demand

When the NSFNET was turned over to commercial ventures, the telecommunications community recognized that the high-speed networks represented an unusual opportunity. Companies like Bellcore, Cablelabs, and Lucent were formed with the idea of developing products that would take advantage of the NSFNET windfall.

Researchers experimented for the first time with cable modems, hybrid-fiber coax cable (HFC), and laser transmitters for fiber optics. They started on a campaign that targeted the cable television customer as a natural market for *Video-on-Demand*. Video-on-Demand was an idea that envisioned first-run, full-length movies brought into the home over telephone and cable wires. The idea required modems that could handle digital signals and that could provide an interactive upstream channel (as opposed to the downstream channel that carried the movie) to control the presentation. Fast-forward, rewind, pause, and stop were commands that had to travel upstream to the movie server on the network.

Several years of development efforts came to naught, however. A range of technical and economic obstacles that emerged, not the least of which was the dramatic ascendance of the Internet.

The Solution

High-Speed Modems

Two types of high-speed modems are currently available: ADSL and Cable:
They are manufactured in two versions: internal and external.
The internal version is integrated typically onto an Ethernet adapter card, installed in a PCI expansion slot. The external version looks like a small set-top box and is connected to an external jack, mounted on an Ethernet adapter card, installed inside the computer chassis.

The modems represent two different technologies, yet both achieve the same result: they bring high-speed Internet access to the home over ordinary twisted-pair telephone wires, at speeds found only in corporate T1 (leased-line) environments.

To introduce their high-speed modems to the marketplace, manufacturers have agreed to open standards. This means that manufacturers work closely with standards committees to ensure that their products conform to the guidelines the committees proscribe. This approach accomplishes the following:

- Avoids proprietary products that have historically retarded industry growth.
- Follows a paradigm that works to the benefit of both consumer and manufacturer.
- Presents an image of consistency and integrity to the buying public.

Table 4. High-Speed Modem Specifications

Features	ADSL	Cable
Downstream data rate	Up to 8 Mbps	Up to 30 Mbps
Upstream data rate	Up to 1 Mbps	Up to 384 Kbps
Downstream frequency	250 kHz to 1.4 MHz	8 to 860 MHz
Upstream frequency	Up to 1.4 MHz	5 to 42 MHz
Security	DOCSIS 1.1 encryption standard	DOCSIS 1.1 encryption standard
Readiness	Always on	Always on
Deployment	Single wire to the home	Shared, as on a network
Upgrades from manufacturer	Downloaded	Downloaded
PC Interface	Ethernet	Ethernet
Protocol	PPP over ATM	PPP over Ethernet
Disadvantages		
Distance	Limited to 3 miles from Central Office. Performance declines with distance.	No more than 15 miles between the Head-End and the farthest subscriber. Network congestion slows performance
Noise		Upstream Noise
Deployment	POTS network. Upgrading the network is very expensive	CATV network Upgrading the network is very expensive

The Future

The challenges that confront the telecommunications industry today are many, but the end game is clear: Consumer demand for current broadband technology appears to be producing the revenues needed to proceed to the next level of technology. Future demand will usher in new products and data delivery systems that will pay for systems to bridge the last mile.

The End Game

Some of the products expected to create this excitement are still years away from being launched and represent a major risk for the companies spending billions of dollars now, hoping to find success in the future.

For example, in October 1999, Cisco Systems spent 7.3 billion dollars to purchase Cerent, a two-year old, fledgling company in Petaluma, California, that had never made a profit but had developed the technology needed to go to the next level. Three weeks later, right next door to Cerent, another small company, Optical Coatings Laboratory, Inc., accepted an offer of 2.3 billion dollars from JDS Uniphase for the technology that will help elevate fiber-optic transmission media to the terabit per second transmission level.

Tomorrow's technology depends on the following:

- A phased introduction of fiber optics into local wiring networks
- A gradual reduction of the distance between subscribers and telephone/cable distribution hubs.
- A revenue stream and marketing savvy that builds upon the success of each phase.

Table 5 summarizes the state of the market for broadband technology as it appears today and projects the path that broadband technology is likely to follow.

- In phase one, ADSL and CATV networks expand to gradually eclipse dialup modems and Basic Rate ISDN that represent yesterday's technology. This initial phase of development, deployed over existing telephone or CATV lines, offers data transfer rates of 1.5 Mbps. 1.5 Mbps is sufficient to attract consumers to the Internet and telecommuters to corporate LAN access.
- In phase two, ADSL and CATV continue as the incumbent technologies, gaining speed on improvements in fiber-optic multiplexing, hub deployment, and cable network design.
- In phase three and four, step change improvements enhance upstream and downstream performance. Very high data-rate Digital Subscriber Line (VDSL) emerges as the probable technology to replace ADSL. Fiber to the Neighborhood (FTTN) and then Fiber to the Curb (FTTC) are two infrastructure changes that must accompany VDSL to establish fiber optics as the dominant transmission media.
- In phase five, Fiber to the Home (FTTH) becomes a reality, enabling multi-gigabit per second transmission rates.

Table 5. The Future of Broadband

Time Frame	Development Stage	Technology	Downstream Rate of Speed	Upstream Rate of Speed
	Narrowband Networks			
Yesterday's Technology	Dialup Modems	PSTN	56 Kbps	33.6 Kbps
	Basic Rate ISDN	ISDN	128 Kbps	128 Kbps
	Broadband Networks			
Today's Technology	Phase 1 Broadband	ADSL	1.5 Mbps	384 Kbps

		CATV	1 Mbps - 10 Mbps	.1 Kbps - 1.2 Mbps
Tomorrow's Technology	Phase 2 Broadband	ADSL CATV	6 Mbps - 9 Mbps	.4 Kbps - 1.2 Mbps
Fiber to the Neighborhood	Phase 3 Broadband	FTTN/ ADSL	26 Mbps	3 Mbps
Fiber to the Curb	Phase 4 Broadband	FTTC/ ADSL	52 Mbps	6 Mbps
Fiber to the Home	Phase 5 Broadband	FTTH/ VDSL	.2 M bps - 10 Gbps	.2 Mbps - 10 Gbps

Emerging Markets

Telecommunications engineers face a difficult challenge in the coming years, but marketers are likely to face an even more daunting task. Marketing executives must define and project markets for broadband applications that are not even in existence today. The accuracy of their projections will bear heavily upon the funding of the many hardware projects that must be implemented.

As outlined in Table 5, the current markets for broadband are limited to 1.5 Mbps. The markets include the Internet, full-screen teleconferencing, access to corporate LANs (at less than optimal speed), and other markets that are being developed. The market for pre-digitized movies, for example, suffers less from inadequate network speed than it does from the current dearth of economical storage capacity for the movies and the memory buffers required to ensure smooth delivery.

The picture will get more complicated as markets for real-time activities emerge. For example, digital coverage of live news events will require a doubling of transmission speed to transmit a satisfactory picture. Coverage of live sporting events will require a doubling of that figure to capture rapid motion. Finally, HDTV (High Definition Television) will demand at least FTTN bandwidth to fulfill its dream.

Industry experts predict conservatively that these markets will materialize over a period of about fifteen years, depending on the following:

- How fast regional telephone and cable television companies can attract subscribers and generate the funds.
- How long market prices continue their downward spiral.
- How many new and unexpected technologies the industry can develop to trim time to market.

Table 6. Markets for Broadband

Markets	Applications	Transmission Speed Requirements
Entertainment	Pre-digitized movies	1.5 Mbps

	High-Speed Internet Access	1.5 Mbps
	Pre-digitized video	3.0 Mbps
	Video-On-Demand	3.0 Mbps
	Gambling	3.0 Mbps
	Digital Museums	3.0 Mbps
	Live Digital Video	3.0 Mbps
	Live Sports	6.0 Mbps
	HDTV (High Definition Television)	19.0 Mbps
Professional	Telecommuter Access to Corporate LANs	1.5 Mbps
	Full-Screen Teleconferencing	1.5 Mbps
	Tele-Medicine	1.5 Mbps

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