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Broadband Access

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Summary

The Internet continues to expand at an enormous rate, and the worldwide modem market will continue to be buoyed by this growth as the default solution for residential Internet access. Cable and xDSL modems will continue their strong movement into the residential marketplace.

The worldwide use of computers and new appliances that allow people to access the Internet from the comfort of their homes are the major driving forces behind the development and implementation of broadband technologies. The spread of broadband connections that provide lighting-fast Internet services is seen as a key factor in encouraging the proliferation of home networking technologies. Today, applications such as Internet access and high-speed remote access to storage media require more data capacity than traditional telecommunications services can provide. Replacing copper wiring with fiber optic cabling is one way of delivering this capacity to your home, but the associated technology is expensive.

Introduction

Over the last couple of years, the Internet has grown ubiquitous and today connects more than 400 million people. These consumers are demanding fast connectivity technologies to access the rich multimedia content that reside on the Web. The need for fast access to the Internet is pushing the demand for broadband access. Consumers are moving away from dialing-up using their phonelines towards new and improved connectivity platforms. Demand for high-speed Internet access solutions has fueled proliferation of a number of rival technologies. This white paper presents an overview of the key broadband technologies—DSL, cable, satellite, wireless, powerline, and ISDN technologies.

What is Broadband

Over the past few years, the Internet has become an inescapable part of our lives. It has been around in one form or another since the late sixties. In the last few years, it has caught the imagination of millions of people around the world with the number of people connecting to the Internet doubling every six months.

The Internet's best-known feature is the World Wide Web (the Web). The resources available on the Web can include text, graphics, video, audio, and animation. Unfortunately, many people that access the Web experience the frustration of endless waiting for information to download to their computers. You probably started accessing the Web with a 14.4K modem and then upgraded to 28.8K device. Nowadays we are seeing the mass deployment of 56K modems, which is still not enough to satisfy demands for speed. Everyone has come to believe that doubling analog modem speeds every year is no longer a feasible strategy. The days of impatiently waiting for Internet content are about to end with large companies like AT&T, Microsoft, America Online, Yahoo, and Cisco spending billions of dollars in bringing broadband delivery technologies to our homes.

Broadband is an industry term used to describe a communications link that has high bandwidth transmission capabilities. This high-speed communications link (higher than 128 Kbps) provides us with the conduit needed to access advanced services the Internet has to offer, such as rich multimedia content, video on demand, and private networking services. In addition to accessing rich Web content, broadband connections are always on, which means consumers do not have to go through a slow logging on process each time they access the Internet. With an always-on broadband connection, the Internet becomes an integral part of our lives and allows us to develop our own unique Internet experience. Broadband access provides the user with simultaneous up-link and down-link capabilities. As an example of high-speed access, a

3 Mbyte music (MP3) file takes 7.5 minutes using a 56K dial-up modem, three minutes using ISDN (144 Kbps), and 15 seconds using DSL or cable modem (1.5 Mbps).

Several rival technologies are competing to deliver broadband connections to consumer's homes. Xilinx believes that the bulk of these connections will be delivered by technologies based on cable, DSL, wireless local loop, satellite, powerline, or analog (dial-up) modem-based broadband delivery platforms.

Market Data

The adoption of broadband Internet access by many households has become a very powerful motivation to install home networks as multiple-PC households look to use this fast service on all PCs. According to IDC's residential broadband and telecommunications group, broadband access was installed in nearly 2.1 million U.S. households in 1999; and this number is expected to reach 21.2 million in 2003. Deutsche Banc Alex Brown forecasts that worldwide, the number of broadband subscribers will exceed 15 million users in 2001, and 40 million users by 2003.

Broadband Market Drivers

Some of the key market drivers for broadband access penetration are:

- **Increasing popularity of the Internet:** Over the last couple of years the Internet has grown ubiquitous to a large number of consumers. Internet applications are increasingly involving voice, video, and data-in applications such as streaming video, web browsing (online shopping using high-resolution images), e-mail, MP3 files, voice over IP (VoIP), digitized photographs, and online gaming. These applications and the consumers are demanding high-speed Internet access from the comfort of their houses.
- **Increasing demand for high-speed access to the Internet:** Due to the problems incurred from using dial-up access services, an increasing number of Internet users are seeking Internet access services that provide much higher speeds. In order to avoid the "world wide wait," people are signing up for broadband delivery services that provide speeds many times faster than dial-up access.
- **Decreasing prices for broadband services:** As the prices for broadband services decrease the demand for these services will increase. The average monthly cost for a broadband service like DSL will cost you approximately $40. This is still significantly higher compared to dial-up access. The discounting of broadband DSL services through bundling services will enable them to compete more effectively with other types of Internet access services and will lead to a growth in revenues.
- **Growth in telecommuters and day extenders:** Due to the growth in telecommuting, there is an increasing number of people who work at home and need to gain high-speed access to the Internet much faster than those obtained through dial-up access. The telecommuters and day extenders are using technologies such as Virtual Private Networks (VPNs) to have the same access to work.
- **Home businesses:** A large number of small offices and home offices (SOHOs) are looking for high-speed Internet access for a few people in the office.
- **Home networking and the invasion of Information Appliances (IAs) and multiple PCs:** With the invasion of information appliances and the growth in the number of multiple PC households, the demands for faster Internet access have accelerated. Networking of information appliances and their Internet access requires high-speed and an always-on connection.
- **Increasing availability of multimedia and interactive applications requiring high-bandwidth capabilities:** As the number of multimedia and interactive applications that require high-bandwidth capabilities increases, the demand for broadband services will also grow. It is likely that the number of video-based applications over the Internet will grow substantially in the next several years and these will require a very fast means of accessing the Internet.

Technologies provide several broadband access to the home—cable, DSL, fixed wireless, satellite, powerlines, and ISDN. We discuss these technologies in more detail below.

Cable

Cable companies have taken the lead in supplying broadband connections to consumers. The first mover advantage of cable companies has made broadband services over a cabled network very popular, particularly for early adopters. Broadband services typically include telephony, interactive multimedia, high-speed Internet access, video-on-demand, and distance learning.

The types of services provided to consumers varies between cable companies. Becoming a service provider for multimedia services over cable is very much like becoming an ISP for the telecommunications industry. The issues and problems are very much alike, the key difference is the bandwidth available for providing service over cable being much greater, thus more applications can be supported. The network architecture deployed by cable companies to deliver broadband access connections is based on a network configuration of fiber-optic and coaxial cable, also known as hybrid fiber-coax (HFC).

Networks built using HFC technology have many characteristics that make it ideal for handling the next generation of communication services. Primarily, HFC networks can simultaneously transmit broadband analog and digital services. Additionally, HFC meets the expandable capacity and reliability requirements of new digital data services.

HFC's expandable capacity allows cable companies to add services incrementally without major changes to the overall network infrastructure. HFC is essentially a "pay as you go" architecture that matches infrastructure investment with new revenue streams, operational savings, and reliability enhancements. The HFC network architecture comprises of fiber transmitters, optical nodes, coaxial cables, and distribution hubs. The architecture of an HFC system required to deliver data services to a home network is illustrated in Figure 3.

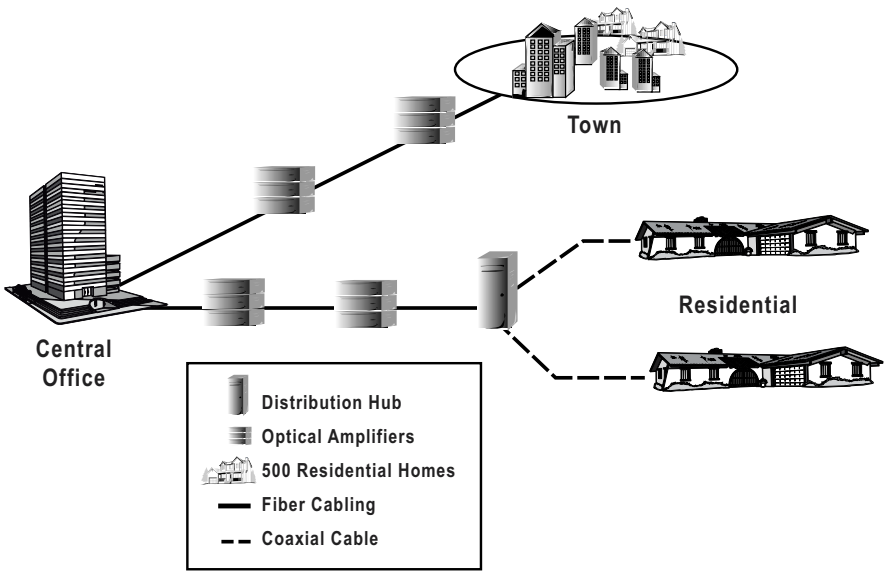

Figure 1: **Architecture of a Typical HFC Network**

From Figure 1, we can see that the signal is transmitted from the headend in a star-like fashion to the fiber nodes using fiber-optic feeders.

Note: Headend is an industry term used to describe a service provider's main operations center.

The fiber node, in turn, distributes the signals over coaxial cable, amplifiers, and taps throughout the customer serving area. The size of the customer serving area varies and can range from 500 up to 2,000 home networks. HFC networks are two-way systems that are capable of communicating with a home network at speeds of 40 Mbps and greater. For cable companies, the combination of HFC with home networking technologies is expected to generate new streams of revenue.

Standards and Consortia

The digital revolution and the Internet are driving demand for broadband cable access to the home. Industry standards are crucial for the continued adoption of this type of broadband access technology. Some of the best-known international organizations that contribute to standardizing cable-based broadband connections include:

- EuroCableLabs (ECCA) or EuroDOCSIS in Europe
- DAVIC in Europe
- CableLabs in the United States

Market Restraints

The growth of cable modems in the market remains restrained because:

- **Limited availability of two-way HFC networks to residential customers:** Despite the fact that cable television services are now available to the majority of households, there are still delays in providing broadband cable services to all interested customers. Since this service is dependent upon a two-way means of communication, cable service providers must upgrade many of their networks. Many cable service providers operate over older networks, which only provide a one-way means of communications. Until, these networks are upgraded, the number of subscribers for broadband cable services will be limited.
- **Speed decrease due to shared nature of broadband cable services:** Broadband services delivered over cable operate in a manner that is similar to an Ethernet base local area network (LAN). As a result the subscribers who connect their in-home networks to cable-based broadband connections end up sharing the actual bandwidth available with other broadband subscribers. Consequently, some potential customers will be discouraged from signing up for this type of broadband service.
- **Relatively expensive cost of service:** The costs of service vary among different broadband cable service providers and are based upon whether or not a subscriber is already a customer of the cable TV operator.
- **Expensive cost of equipment purchase and installation:** In addition, relative to dial-up Internet access service, the cost of purchasing and installing a modem for accessing cable-based broadband services is expensive.
- **Competition from ADSL services:** With the increasing deployment and availability of ADSL services, many residential customers are refraining from purchasing broadband cable services.

Digital Subscriber Line (DSL)

Until a couple of years ago, the plain old telephone system (POTS) in conjunction with a standard modem offered us the most convenient means of accessing information on the Internet. Due to the explosive growth in the number of people connecting to the Internet using this system, it has become a less convenient system for accessing data. This is mainly because the existing telephone infrastructure was designed for voice signals only. It was never intended to carry digital information due to its sensitivity to external noise sources and attenuation losses over long distances. The demand on the system from a typical phone call is very different to the resources that are required to support a connection to the Internet.

Voice-optimized networks usually need to handle less than ten percent of their total number of possible users at any one time. One of the reasons for this is that the average duration of a voice call is between four and five minutes. In addition, as network usage follows well known patterns over time, resources can be allocated efficiently according to probabilistic models.

The patterns of typical data network usage are very different to those of a voice network. Firstly, users typically remain connected to the Internet for longer periods of time. Therefore, when you open a circuit to access the Internet, that circuit may remain open for a lot longer than one of your normal telephone conversations. During this time, the network resources for that circuit are unavailable for voice calls. (While a telephone call lasts on average three minutes, Internet

traffic lasts over three hours with no increased revenue for the telcos.) The increased level of Internet access combined with the very nature of this data traffic has prompted telecommunication companies and large carriers to deploy a new class of technology known as Digital Subscriber Lines (DSL).

DSL carries voice, video, and data at multi-megabit speeds over standard telephone wires. DSL services can achieve much higher bit rates than traditional analog modems. Depending on the exact type of DSL service being used, bit rates from about 1.5 Mbps to 51 Mbps can be achieved. The family of DSL services is collectively referred to as xDSL, where x refers to the different types of DSL technologies—ADSL, HDSL, SDSL, and VDSL.

Bellcore Laboratories in the United States developed the first xDSL service in the late 1980s. During this period, telecommunication companies were planning to compete directly with cable television providers for the video-on-demand (VoD) market. To do this, they needed a cost-effective way of making high-capacity connections to the homes of subscribers. Video-on-demand (the ability to download movies to the player using the Internet) is expected to generate large revenues for its providers.

DSL was created as a way of providing video-on-demand over copper wiring. However, this application was never fully developed and implemented properly. Although there are several types of DSL, the primary technology used for the home networking and consumer market is Asymmetric DSL (ADSL). It was designed for the local loop or last mile of copper from the Telephone Company's central office (CO) to a customer's home. It has many benefits for people who have in-home networks and are looking for a broadband connection to the Internet. Primarily, ADSL allows you to download data to a home network at speeds that are comparable with Ethernet standards.

Consumers that use DSL broadband have connection services up to 100 times faster than existing dial-up connections and over 25 times faster than ISDN. Secondly, the technology uses the existing phoneline network, so you can simultaneously use a telephone line for data transmission and voice calls.

Unlike a cabled TV environment, you will not experience the slow down or degradation of performance due to sharing of media. The ADSL equipment is relatively easy to install. Once your home network is connected to an ADSL broadband connection, you have the convenience of having an "always-on" access to the Internet. Typical ADSL broadband access links have downstream data transmission rates from 6 to 8 Mbps and upstream rates from 640 to 800 Kbps.

These factors are dependent on line length and the capabilities of the modem that is connected to your in-home network. As a rule of thumb, any home network within a range of three miles of the DSL service providers central office will receive a good reliable broadband connection. Data rates will start to degrade when the distance between your home and the central office is greater than three miles.

Apportioning the line bandwidth asymmetrically helps to achieve high data rates. An ADSL circuit has three different information channels:

1. A plain old telephone service channel
2. An upstream channel with a capacity of up to 1 Mbps
3. A downstream channel with a capacity of up to 8 Mbps

The frequency within the POTS channel is used for normal voice communications over a broadband connection. The second type of channel associated with an ADSL connection is the upstream channel. It is considerably smaller than its downstream channel and bit rates can range from 16 Kbps to 1 Mbps. Upstream rates can be set to be compatible with standard U.S. and European digital rate hierarchies.

The upstream channel is, in fact, a duplex channel, but is usually configured for upstream transmission only. This is why ADSL is called an *asymmetric* xDSL service. ADSL technology is ideal for a range of different interactive services. However, due to its asymmetric nature, it is not well suited to people who want to use their home networks for video conferencing purposes.

The downstream channel can be used to deliver Internet content and rich video-on-demand services to digital appliances connected to your in-home network at very high speeds.

ADSL Technologies and Standards

Making ADSL a reality requires the cooperation of a variety of industries and companies, along with the development of many new standards. A wide variety of international organizations have contributed to the standardization of ADSL over the past couple of years. The International Telecommunications Union (ITU) is one of the most prominent organizations promoting the standardization of DSL technology. Over the past couple of years, the ITU has put its weight behind two specific ADSL standards, G.dmt and G.Lite.

G.dmt ADSL technology uses existing phone lines between the central office and customer premises to provide always-on, high-speed Internet access at rates up to 8 Mbps downstream and up to 2 Mbps upstream. G.dmt was approved as an ITU standard in 1999.

While the G.dmt standard is quite popular with businesses, the G.Lite ADSL standard is more focussed on the consumer market. It provides data over existing phonelines at rates of up to 1.5 Mbps downstream and 512 Kbps upstream. Like G.dmt, G.Lite was also approved as an ITU standard in 1999. Because G.Lite offers high-speed, always-on Internet access at a low cost and with convenient installation, it will be the mass-market vehicle for unlocking the broadband market for DSL services.

G.Lite was specifically designed, from a technical standpoint, to eliminate the need for the DSL provider to send an engineer to the customer's premises. From a home networking perspective, G.Lite only requires the installation of a new modem to access the DSL broadband connection. The effort to introduce G.Lite is being spearheaded by an industry group called the Universal ADSL Working Group. Its charter is to support and expedite the development of a worldwide G.Lite standard.

The consumer DSL market is currently in a transitional phase common to emerging markets. To accelerate through this transitional period and enable a mass market for DSL broadband access connections, manufacturers are active in developing DSL products that comply with the G.Lite and G.dmt standards.

Fixed Wireless

The demand for bandwidth is growing at an explosive rate as more businesses and individuals seek faster access to increasingly complex content on the Internet. The worldwide Internet use is expected to climb from 142 million subscribers in 1998 to more than 500 million by 2003, according to IDC's research.

With the limited availability of bandwidth from traditional telephone service providers and the worldwide deregulation of the telecommunications industry, a large market exists for fixed wireless broadband. Fixed wireless broadband is a relatively new service that is used by telecommunication companies to carry IP data from central locations on their networks to small low cost antennas that are mounted on their subscriber's roof. Access to the Internet at high speeds is among the primary advantages of broadband fixed wireless technology. It is capable of delivering speeds more than 100 times faster than those of traditional dial-up connections.

Wireless broadband is seen as an alternative to cable and DSL in suburban and rural markets. It is rapidly deployable, scalable, and has lower implementation costs than those of cable and DSL systems, which often require expensive infrastructure upgrades. Like DSL and cable, broadband fixed wireless is an "always-on" Internet-access technology that can meet the growing demand for rich multimedia and voice applications.

Technologies

Current deployments of fixed wireless broadband systems are based on a technology called multi-channel multi-point distribution system (MMDS). The basic components of an MMDS-based fixed wireless broadband system providing is shown in Figure 2.

At the customer's premises, a wireless modem converts the request for Internet data from the personal computer or connected network to a signal that is suitable for transmission over the MMDS network. This modem is connected to a transverter, which converts intermediate frequencies to radio frequencies and passes them to the antenna. The transverter is typically mounted on a customer's roof or on a mast to gain line-of-site visibility of the service provider's transmitter site. At the service provider's transmitter site, which is usually located on a top of a mountain or a tall building, another antenna is used to communicate with the wireless modems located in the customer's home. The transmission site then relays the request to the Internet Service Provider (ISP) facility**.** The ISP receives the request and retrieves data either from its servers or from the Internet over its own high-speed backbone connection. The ISP then returns the data via the MMDS network back to the computer or network located at the customers premises.

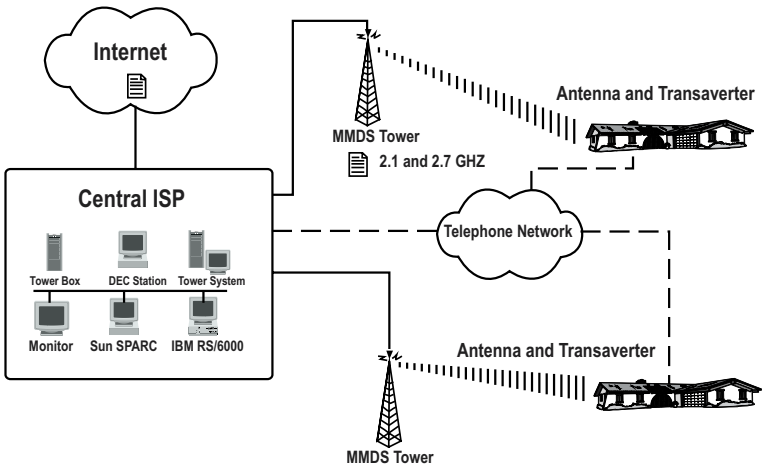

Figure 2: **MMDS Broadband Connectivity**

For many people who live in rural areas where it is cost-prohibitive for cable companies to build systems or for telephone companies to supply DSL service, fixed wireless broadband solutions will prove to be a very suitable alternative mechanism of accessing high-speed Internet services.

Satellite

Communication satellites are, in effect, orbiting microwave relay stations used to link two or more earth-based microwave stations. Communication satellite providers typically lease some or all of a satellite's channels to large corporations where they are used for long distance telephone traffic, private data networks, and distribution of television signals. The costs of leasing these huge communication pipes can be very expensive and are not suitable for the mass residential marketplace.

Consequently, a new suite of services was developed called a direct broadcast satellite (DBS) system that provides consumers with a range of high-speed Internet access services. A DBS system comprises of a mini dish that connects your in-home network to satellites located about 35,000 KM above the surface of the earth. These satellites have the ability to deliver multimedia data to your home network at speeds in excess of 45 Mbps. This speed can only be achieved when downloading content from the Internet to your in-home network. To upload or send information to the Internet, you need to use a slow telephone connection. You need a digital satellite modem to access this type of broadband platform.

Powerlines

For many years, power companies have had the ambition to use electrical distribution networks for communications and data transfer. The first patent on technology for sending signals over powerlines was in 1899. However, a realistic technology for providing high-speed, two-way communications has until recently been a dream of the utility companies. That dream is now

becoming a reality. The utilities' existing infrastructure of stout copper lines, long-distance cables, and in-house wiring has the potential to become a ubiquitous communications platform. Every electrical outlet in every building could become a port to the ultimate communications network.

However, electrical grids do the job they were designed to do, and they were not originally intended to transmit data. Inherent characteristics of power networks confounding communications efforts include: low impedance, no specific topology, multitudes of fuses and circuit breakers, and transformers which scrub encoded signals from the voltage wave. Despite these problems, the energy industry insists on seeking a way to use the power grid as a broadband communications platform. The major advantage to power networks is that they are ubiquitous, and the largest capital outlay for any communications network *is* the network.

Strengths and Weaknesses of Powerline Communications Technology

Powerline communications technology enjoys several important strengths. The electric power grid provides a perfect communications platform because it is the most extensive network in the world. Powerlines are almost everywhere in the world. Powerlines are extremely robust and most modern. Powerlines carry signals for long distances without requiring regeneration. Another advantage of using the powerlines is their near light speed propagation which makes them very powerful for fast delivery of video and audio data. Powerlines are capable of carrying enormous amounts of information and have a large capacity. There is no topology limitation for powerlines and any topology is workable. The main weakness of powerline communications is that it is still in the developmental stage pursued by a fragmented industry lacking standards.

Broadband Powerline Technology Providers

In an effort to commercialize the high-speed delivery of broadband content to millions of home networking users around the world, a number of large companies have developed proprietary technologies that allow utility companies to compete with existing broadband service providers. The following projects are considered to be some of the most advanced mechanisms for delivering data over powerline area networks.

- **Nortel and NorWeb:** In a joint effort, Nortel Networks and Norweb (subsidiary of United Utilities) are in the process of revealing a new technology that uses the electrical power grid for broadband access. It provides over 1.5 Mbps data access for home networking users. The technology uses radio frequencies (using cordless phone technology) on top of the mains electricity supply to deliver data. The technology uses a signaling scheme to separate data from electrical interference on the power line, allowing users to connect even if the power goes out. Customers need a network circuit card and communications software for their PCs to handle authentication, security, and subscriptions. Nortel's signaling scheme carries data between the local electricity substation and the home network. Substations are linked by fiber-optic to a central switch to provide access to the rest of the world.
- **Media Fusion:** Media Fusion is a technology company providing leading-edge research and communications system development and management using the powerline magnetic field as a platform. Media Fusion's basic communications infrastructure product provides voice, data, and video communications over the electrical grid at near light speed for

business and residential applications (see Figure 3).

Note: While designed for use in the U.S. market, this product can be easily adapted to comply with electrical and communications requirements in foreign countries.

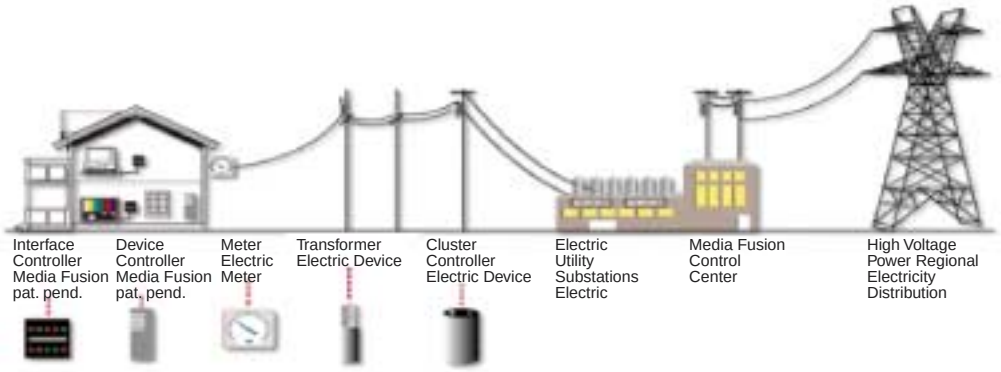

Figure 3: **Media Fusion's Powerline Platform**

Integrated Services Digital Network (ISDN)

ISDN is a technology that was originally defined in the mid-80s as a means of delivering integrated voice, data, and video services to consumers. ISDN involves the digitization of the telephone network through the use of a set of standard communication protocols. The growth of ISDN has been flattening within the past few years but it still may be a good solution where cable modem or DSL service is not available. Analysts indicate there are approximately two million ISDN lines deployed in the U.S. ISDN is a circuit switched technology. In circuit switching, a dedicated communications path is established between two stations. The process of establishing these dedicated paths is referred to as signaling and is carried out over special channels referred to as D (Delta) channels.

Note: A channel is a conduit through which information flows, usually a digital or analog signal comprising user data or network information.

Signaling results in the establishment of one or more 64 Kbps B (Bearer) channels between locations. Once established, these channels can be used for voice, data, or video. There are two main ISDN variants, Basic Rate ISDN (BRI), and Primary Rate ISDN (PRI).

Basic Rate ISDN services are targeted at home networks and small busineses. BRI service is delivered over a single twisted pair, the same wiring that is used to deliver Plain Old Telephone Service (POTS). It provides two B channels and one 16 Kbps D channel.

Primary Rate ISDN service is targeted at larger corporate customers. PRI service consists of 23 B channels in North America plus a single D channel running at 64 Kbps, yielding a total bit rate of 1.544 Mbps. In Europe, Australia, and other parts of the world, telecommunication companies provide 30 B channels and one 64 Kbps D channel. This gives a total interface rate of 2.048 Mbps.

Note: A PRI line requires two sets of twisted pair telephone lines.

The limited availability of DSL services has stimulated vendors to look for ways to provide DSL-like services using ISDN technology. While ISDN cannot compete with the bandwidth available from the newer DSL services, they have developed an approach that gives users the continuous availability that DSL provides—an always-on ISDN. It does this by using the D channel not just for signaling but also for forwarding IP traffic using the X.25 protocol. Since the D channel is always connected, this provides the subscriber with up to 16 Kbps of continuously available bandwidth. When the user traffic exceeds the bandwidth of the D channel, one or both of the B channels are connected. Taking advantage of this requires that always-on support is provided by the user's ISP, phone company, and the ISDN bridge or router that is used.

Standards and Consortia

The International Consultative Committee for Telegraph and Telephone (CCITT) initially developed ISDN standards and specifications. The CCITT was later replaced by the

International Telecommunication Union Telecommunication Standardization sector (ITU-T). The ITU-T is a subsidiary body of the United Nations. The ITU-T has defined ISDN as “a network evolved from the telephone network, that provides end-to-end digital connectivity to support a wide range of services”. These services provide for the transmission of both verbal and other types of communication. Users can access them using a limited set of standard multipurpose interfaces.

Xilinx ISDN Solutions

Figure 4 shows a generic ISDN modem and the role of various ASSPs, microprocessors, and memory devices. Spartan™-II FPGAs have several design wins in ISDN modems and they primarily function as the system interface to multiple ASSPs, systems controller, memory controller, and interfaces with different technologies such as Ethernet, RS-232, USB, and HomePNA.

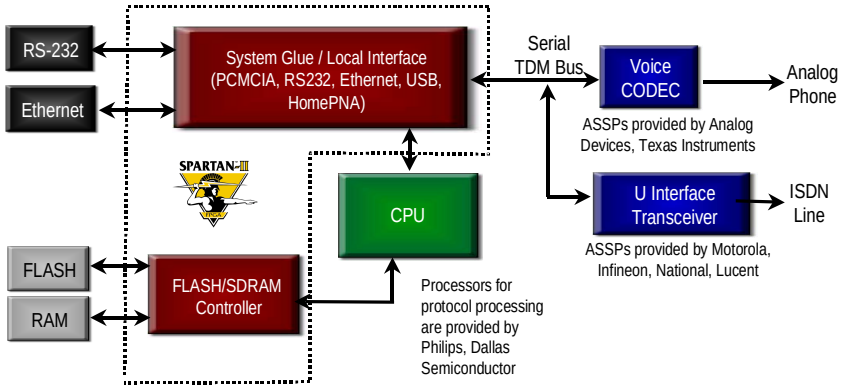

Figure 4: **ISDN Modem**

Analog (Dial-Up) Phonelines

While dial-up analog modems hardly qualify as broadband access, these modems are the most popular type of modems for providing Internet access.

Despite market enthusiasm for the many flavors of DSL, cable modems, and other residential broadband access approaches, the deployment of these alternative solutions continues to be gradual, sporadic, and regionalized. This means that for the foreseeable future, analog modems will still have an important role to play in enabling Internet connectivity.

However, the analog modem market continues to struggle despite the increasing volume of sales. This is due to several negative trends such as eroding margins in all segments and a significant decline in shipments for these devices. At the retail level, prices have fallen significantly, and in many cases, modems can be purchased for less than $20.

The overall analog modem market can be categorized in three distinct segments:

- **Branded modems**: In this category, the customer buys the product as a specific entity. Branded modems may be sold individually or in multipacks through a variety of channels, with the majority finding their way into the retail channel.
- **PC OEM modems**: These modems are shipped directly to PC manufacturers, and are then preinstalled in the PC itself.
- **PC card modems**: With this form factor, the modem is designed to fit into slots typically found in laptops that conform to the PCMCIA standard. The emerging mini-PCI form factor is also included in this category.

Some popular market trends include:

- On a worldwide basis, Internet and PC growth continues to sustain the analog modem market growth.
- The worldwide availability, ease-of-use, and low cost of analog modems are unmatched by any other technology and will remain so throughout the forecast period. Even if a

consumer will be using an alternative access technology, consumer PCs will continue to incorporate analog modems.

- Volume sales will continue to increase even as margins continue to decline.
- Gradual market erosion will continue as new technologies such as xDSL, cable modems, and ISDN enter marketing channels achieve market acceptance (thus surpassing the modem in mind share), and are increasingly deployed.

IDC predicts that the worldwide analog modem shipments will increase from 76 million units in 2000 to over 115 million units in 2003. While faster access continues to grow at a much faster rate, even by 2002, analog modems will continue to account for over two-thirds of the total modem shipments.

The modem is designed to operate with any dial-up phone worldwide. These modems support high-speed analog data, voice, and fax operation. The integrated modem is host controlled, thus reducing the overall chip count and the need for a separate microcontroller.

The 56K/V.90 modems offer data speeds up to 56 Kbps. It takes advantage of the PSTN which is primarily digital, except for the client modem to the central office local loop. The modem is ideal for remote access applications such as ISP, online service, or corporate site. The v.34 modem provides up stream data speeds up to 33.6 Kbps, providing error correction and data compression.

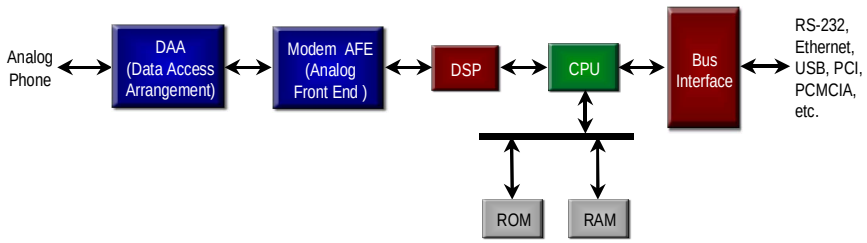

Figure 5: **Analog Modem**

Figure 5 shows a generic analog modem and the role of Spartan-II FPGAs in these systems. Spartan-II FPGAs provide the system and bus interface to technologies such as RS-232, PCMCIA, PCI, UART, USB, and Ethernet.

Conclusion

Therefore, the focus over the past few years has been on deploying new technologies on existing network infrastructures. Consequently, the telecommunication companies developed a technology called DSL, which transforms ordinary phonelines into high-speed digital lines for ultra-fast Internet access. The family of DSL technologies range from ADSL to VDSL (very high-rate DSL). This section provided an overview of two members of this family that have emerged as the types of DSL services most in demand for home network users—G.dmt and G.Lite.

Cable and satellite companies have also done a great job in marketing their networks as an infrastructure that can provide home networking users with a variety of broadband Internet services. The new era of digital TV presents these network service providers with an opportunity to deliver profitable Internet centric services. Cable companies are able to offer Internet access service to users of home networks at a much higher rate than traditional and specialized Internet Service Providers. Wireless operators are also looking at ways of using MMDS technologies to boost data rates between our homes and the Internet.

In addition to the cable, wireless cable, and telecommunication service providers, the satellite companies are also capable of providing home networking users with a powerful broadband platform for accessing the Internet. Power companies are also exploring the possibility of using their electrical power grids to carry telephone, radio, video, Internet, and multimedia data to any destination at near light-speed. Although cable, DSL, satellite, and powerline technologies are

on the edge of mass-market deployment, ISDN still remains the most widely deployed digital broadband service in the world.

Revision History

The following table shows the revision history for this document.

Date	Version	Revision
03/21/01	1.0	Initial Xilinx release.