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# Chapter 1: Gigabit Ethernet

## Introduction

It has been observed that the development of networking technology for computer communication is directly related to other communication networks such as telephone, Television etc. The growth of the Internet for example is due to its availability to homes using telephone networks. Similarly all communication technologies thrive on the development of the physical medium technologies such as copper UTP wires, co-axial cables, Fiber optics, Satellite Technology. The various systems that are being discussed in this survey are the direct result of development in these physical medium technologies. With hardware becoming cheaper, the deployment of Internet has increased due to its ease of availability. Like any other utility, when Internet became easily available, it has now become indispensable. Today, with increasing multimedia applications, the requirement for higher bandwidth is growing enormously.

## 1.1 Development of Gigabit Ethernet:

Ethernet was originally conceived and developed by Xerox Corporation and was standardized and commercialized by the joint group DEC-Intel-Xerox (DIX). In parallel with DIX works, IEEE formed its 802 LAN standards, which was later classified as 802.3 (Ethernet), 802.4 (Token Bus) and 802.5 (Token Ring). Although all the LAN systems are technologically competent, Ethernet became and still is the most popular LAN technology. The primary reasons for this is that Ethernet is simple to implement as it does not have many features that Token Ring provides such as priority scheduling, ability to send large frames etc. Also with the development of structured wiring and LAN bridges, the deployment of Ethernet became very easy.

There is a constant changing relationship, over time, between computing and communication technologies. As the desktop network capacity increases, server and backbone network requirements also increase -and at a higher absolute level. With 10Mbps desktop connections, 100Mbps backbone and server connections are appropriate. Fast Ethernet (100Mbps) was developed to meet these requirements and was a huge success. However the combination of switching and Fast Ethernet held the potential to put even greater strain on network servers and campus backbones. With desktops moving from 10Mbps to 100Mbps connections, Gigabit Ethernet provides the required high-speed connection for the backbones.

## 1.2 Gigabit Technology Architecture

Gigabit operation is described as an evolution rather than a revolution in Ethernet technology. The gigabit Ethernet uses the same frame format and uses the same Multiple

access control protocol as the traditional Ethernet but provides some additional features such as full-duplex connections and support for multiple physical layers.

The Ethernet NIC comprises:

- A MAC entity or the Ethernet controller
- An Encoder/Decoder that converts data to/from the signals needed for transmission on the physical media
- A set of drivers and receivers such as electronic circuits or lasers as required by the physical media
- The physical medium used for communication.

### 1.3 MAC operation:

The Gigabit Ethernet MAC can operate in full-duplex as well as in half-duplex modes. Full duplex modes uses a star wired topology with every host using a dedicated medium connecting to the central LAN switch. Since this configuration completely avoids collision, no MAC protocol is required in Full-duplex mode and hence it is easy to implement.

The half-duplex mode has many more factors involved at gigabit rates. Half-duplex mode supports LANs using shared media and hence it requires CSMA/CD protocol for multiple access control. The use of this protocol requires that the minimum frame size be equal the delay-bandwidth product of the link for collisions to be detected.

The Ethernet frame format is shown below

Preamble	Destination Address	Source Address	Length /Type	Data	FCS
(8)	(6)	(6)	(2)	(46)	(4)

At 10Mbps with a frame size of 512 bits, the maximum propagation delay is 51.2 $\mu$ s. Depending on the cable type and the configuration of the repeaters the 10Mbps line can extend up to 2 to 3Km. With 100Mbps Fast Ethernet, the propagation delay has reduced to 5.12 $\mu$ s and hence the maximum network extent is up to 200m. This was acceptable as most of the LANs used were using twisted-pair wiring in a star-configuration to a hub in a wiring closet. However with Gigabit Ethernet, the maximum wire length would be limited to 20m, which is clearly inadequate.

Incorporating three modifications in the original standard provides the solution:

- 1) The 512-bit frame size and format is unchanged so as to provide interoperability with the existing networks and compatibility with existing drivers.
- 2) The MAC algorithm is modified to provide *carrier extension*, i.e. to increase the minimum length of a transmission without increasing the minimum length of the frame as seen by the higher layers. Thus the slot-Time reflects the longer round-trip delay of the network and has been set to 4096 bits.

3) The use of *frame bursting* mechanism to overcome the performance degradation caused by carrier extension. This allows the stations to send multiple 512-bit frames in one slot time without contending again for the channel.

As can be seen some significant changes have been made in the original Ethernet implementation to support half-duplex mode. The main reason of using half-duplex mode is that it Half-duplex (shared) LANs can use a repeater hub rather than a switching hub, thereby potentially saving some cost.

#### **1.4 Gigabit Ethernet Physical Layer:**

Gigabit Ethernet comprises two separate families of Physical Layer communication systems:

- 1) 1000BASE-X supports operation over multi-mode fiber, single mode fiber, and 150ohm balanced shielded twisted pair.
- 2) 1000BASE-T supports operation over Category-5 UTP.

1000BASE-X supports three types of optical fibers, 50- $\mu\text{m}$  multimode, 62.5 $\mu\text{m}$  multimode and 10 $\mu\text{m}$  single-mode and two different wavelength of laser drivers: Shortwave (850nm, designated 1000BASE-SX) and Longwave (1300nm designated 1000BASE-LX). The multimode fibers are inherently limited in distance and hence its applications are limited to intra-building connections. With Shortwave lasers, 62.5  $\mu\text{m}$  fiber can go up to 260m, and 50 $\mu\text{m}$  can go up to 525m. Higher distances can be achieved using Longwave lasers (550m for 62.5 $\mu\text{m}$ ), but at a higher cost. Single-mode fiber operation was first introduced by Gigabit Ethernet and is primarily used for campus backbone networks. Single-mode fiber (10 $\mu\text{m}$ ) operation requires Longwave laser and can go up to 3Km in full-duplex mode. Due to very high costs compared to multimode fibers, it makes little sense to use single-mode operation for half-duplex Gigabit Ethernet. Gigabit Ethernet was the first standard system to specify the use of laser optical drivers with multimode fiber. However the use of lasers give rise to an anomaly called the *Differential Mode Delay*, a timing distortion that can lead to excessive decoding errors. A short adapter cable is used in practice fix this problem.

The 1000BASE-X also supports operation over dual, 150ohm shielded twisted pair. These cables have a maximum useful length of 25m and hence are called 'short copper jumpers'. Its primary application is for connections between bridges, switches, routers, etc. within a single rack or closely placed equipment.

The various combinations of drivers and fibers thus result in different maximum usable lengths. Also in half-duplex mode the maximum length of a link is limited by the Ethernet MAC algorithm that requires the round-trip delay to be less than the slot-time. The Full-duplex links are limited only by the physical characteristics of the medium and the transceivers.

1000BASE-T ('T' for Twisted-pair) standard is being developed for bringing Gigabit Ethernet to the desktops. However there are a lot of difficulties in this task, primarily due to the transmission characteristics of UTP. Some of the problems are listed below:

- 1) The attenuation of UTP cables degrades rapidly with frequency in a non-linear manner.
- 2) UTP cables introduce high-levels of timing distortion for which compensation is required.
- 3) The EMI characteristics of UTP are much worse than that of shielded cable or optical fibers, thereby violating regulatory requirements.

### **1.5 Medium Independent Interface:**

The traditional 10Mbps Ethernet used an *Attachment Unit Interface* (AUI) that allowed medium independent Ethernet controllers to connect to medium specific transceivers. This was because the technologies used in the controller and the transceivers were fundamentally different. Controllers used primarily digital technologies and could be implemented using high-integration MOS processes. The transceivers on the other hand were primarily analog using ECL and discrete transistor technologies.

With the development of Fast Ethernet and the need for supporting 10Mbps as well as 100Mbps transceivers on different types of physical media, a completely new medium-independent interface was designed. This interface provided both a new physical connection mechanism as well as a different partitioning of the functions in the controller and the transceiver. The *Gigabit Medium Independent Interface* (GMII) is intended primarily as a logical interface than a physical one. Because of the very high clock rates, GMII is inappropriate as an externally exposed interface. It is used exclusively as a single IC or in IC-IC interface and does not support the use of any cables or connectors. The GMII uses a byte-wide data path that reduces the clock to 125 MHz and hence is practical to implement using CMOS technology. The GMII is a convenient abstraction for describing how controllers and transceivers interact; however it is less useful as a physical interface.

### **1.6 Gigabit Ethernet Hubs:**

Functionally, a 'Hub' is the common term used for repeater, switch and a router. A repeater is used for example, if a single server may not need a dedicated Gigabit Ethernet connection, a repeater allows a cluster of servers to share a Gigabit Ethernet switch port. The repeaters function as switch port multiplexers, or fan-out devices resulting in a switch with more station/server attachments than a port. The main disadvantage with using a repeater is that it requires the Gigabit Ethernet that supports shared LAN access using Half-duplex communication. This leads to significant loss of efficiency as the slot time is increased to 4096 bits while the maximum frame length is still 1518 bits. This causes a worst case collision overhead to 96%. This limitation is disregarded due to the fact that repeaters are much cheaper than Gigabit Ethernet switches that support Full-duplex communication and hence high efficiencies. The use of

switches is therefore limited to backbone applications where a high initial-cost-of-entry can be afforded.

The design of the switches for supporting gigabit speeds is also a challenge so not to make to switch the performance bottleneck. Three main design architectures are used for building switches- Shared memory, Shared bus and Cross-point switching.

1) **Shared Memory switches:** Uses a single common memory as the exchange mechanism for frames between ports. A 32-bit-wide memory bus with 60ns DRAM provides a usable capacity of about 300-350Mbps. Using faster and expensive SRAM, higher clock speeds and a wider memory bus could stretch the architecture. However even a 64-bit-wide memory with 66 MHz SRAM can support only one or two Gigabit Ethernet ports.

2) **Shared Bus Switches:** Uses a common bus as the exchange mechanism for frames between ports and the ports have their own memories for input and output queues. If the bus capacity was of the order of 2Gb/s (e.g. 64bit wide bus, with high clock freq.), a reasonable number of 100Mbps connections can be supported but not many Gigabit connections can be sustained.

3) **Crosspoint switches:** It provides transient "circuit" between ports by using electronic switching at nanosecond speeds. This architecture is much more scalable and hence suitable for Gigabit Ethernet switches.

Another important issue for smooth switching operation is flow control. If the load offered to the switch exceeds the forwarding capacity of the switch, then the input buffers will fill. A possible solution is to use what is called a *Buffered Distributor* to throttle the transmissions from any port that is exceeding some maximum threshold. This is called the PAUSE function for flow control and is used on full-duplex Ethernet. A device wishing to temporarily inhibit incoming data sends a PAUSE frame indicating the interval time to wait before sending the next frame. Note that previously all Ethernet transmitted by an interface were given by a higher layer protocol. With the implementation of flow control, the link interfaces need to generate and inspect PAUSE frames which in-turn asks for design changes of Ethernet interfaces.

## 1.7 Deployment Issues:

Currently Fast Ethernet is clearly a more cost-effective option relative to Gigabit Ethernet, also because of its presence in the industry for a few years. One advantage of Gigabit Ethernet is that it can operate over 3-Km links, however a number of vendors are now offering external transceivers that allow standard 100Mbps Ethernet interfaces to drive much longer distances than even Gigabit Ethernet. The added capacity of Gigabit Ethernet provides a measurable benefit only in applications that can completely utilize that capacity. Another major competitor to Gigabit Ethernet in the area of campus backbones is ATM technology. The advantages of ATM are the added capabilities beyond LAN such as low delay variance, QoS guarantee and integration of voice/video

and data at the Data Link layer. However ATM offers all these features at a much higher cost and implementation complexities as compared to Gigabit Ethernet. Also, the use of Ethernet (10Mbps, 100Mbps, 1000Mbps) allows much more seamless integration among desktop, workgroup and campus interconnections.

## **Chapter 2: XDSL**

### **2.1 Introduction to XDSL**

XDSL technology is a family of high-speed access technologies enables carry data on the ordinary telephone lines using intensive signal processing. XDSL was originally developed by Bell Communications Research to provide Video on Demand and interactive TV applications over twisted-pair wires. With the proliferation of the Internet and the ever-increasing demand for bandwidth, the technology is now being widely deployed as a broadband Internet access medium. The XDSL technology is completely different than the existing POTS technologies and therefore requires considerable processing power. The main advantage of this system is that there is an 'installed base' in the form of the subscriber lines. Most other broadband technologies require considerable time before even feasibility study can be done due to lack of infrastructure. The primary customers for these technologies are the SOHO (small office/Home office) group, which requires high bandwidth Internet connections and also connections to corporate LANs.

XDSL is a common term for the various Digital Subscriber Line (DSL) technologies available today, namely DSL, HDSL, SDSL, ADSL, VDSL and RDSL. The various DSL technologies differ from each other in data rate, operating distance, ratio between downstream and upstream speeds, as well as the applications they are designed for.

***Asymmetric Digital Subscriber Lines (ADSL):*** ADSL is characterized by different upstream and downstream traffic rates. Downstream data rates provided range from 1Mbps to 8Mbps. ADSL is geared to support applications such as Internet access, LAN bridging and VOD [1].

***High Bit Rate Digital Subscriber Lines (HDSL):*** HDSL technology provides symmetric rates of 768Kbps, 1.544 Mbps and 2.048 Mbps. HDSL modems are designed to run at fixed speeds and usually require two separate twisted pairs, both full duplex. HDSL uses 2B1Q modulation and cannot coexist on the same twisted pair with POTS. Typical applications of HDSL include access to the following systems: PBX network, cellular antenna stations, digital loop carrier systems, inter-exchange POPs, Internet servers and private data networks. [1]

**High Bit-rate Digital Subscriber Line 2 (HDSL2):** HDSL2 was designed to transport T1 signaling at 1.544 Mb/s over a single copper pair. HDSL2 uses overlapped phase Trellis-code interlocked spectrum (OPTIS).

**Rate Adaptive Digital Subscriber Line (RADSL):** RADSL is any rate adaptive xDSL modem, and uses Carrierless Amplitude and Phase modulation (CAP). The uplink rate depends on the downlink rate, which is a function of line conditions and signal to noise ratio (SNR).

**Symmetric Digital Subscriber Line (SDSL):** SDSL is a 2-wire implementation of HDSL. It supports T1/E1 on a single pair to a distance of 11,000 ft.

**Very High Speed Digital Subscriber Line (VDSL):** VDSL can run with both symmetric and asymmetric rates and can coexist with POTS on a twisted pair. The various rates being proposed are 26Mbps symmetric, 13 Mbps symmetric, 52 Mbps downstream and 6.4 Mbps upstream, 26 Mbps downstream and 3.2 Mbps upstream and finally 13Mbps downstream and 1.6 Mbps upstream. The disadvantage is that the maximum length is much lower than that of ADSL. [1] VDSL uses variable length optical fibers along with copper loops over the last few miles to provide the high bandwidth connection.

## **2.2 DSL Technology:**

The existing telephone networks usually have a 24-gauge twisted pair copper wire, which has a bandwidth carrying capacity of 1MHz. The original infrastructure has been developed only for carrying voice signal only which has a spectrum from 300Hz to 3600Hz i.e. 3300Hz. This means that about 99.7 % of the available bandwidth is not being utilized. In a PSTN network, 30 voice signals are multiplexed, filtered and then sent over E1/T1 lines that have a maximum capacity of 2.048Mbps and 1.544 Mbps respectively. Thus the bottleneck lies at the exchange and not at the subscribers end. The line from the subscriber to exchange has a bandwidth of 1MHz and hence is under-utilized. The DSL technology utilizes the rest of the available spectrum for high-speed data transmission. The POTS signals and the data signals can be carried on the same copper wire (e.g. ADSL, ISDN) but are separated in the frequency bands they use. Both the data and the POTS signals are routed to their respective end terminals at the subscriber location and also to their respective switching equipment at the switching center, or the central office.

### **2.21 Challenges and Limitations of PSTN system:**

The following are some of the reasons of the existing PSTN systems being unsuitable for data transmission:

- 1) Signal Attenuation over copper wire is proportional to the distance as well as the signal frequency.
- 2) The signal to noise ratio is further reduced due to presence of white noise.
- 3) Presence of crosstalk between signals from two different lines. This may be tolerable for voice signals but is not tolerable for data transmission.
- 4) Radio Frequency Interference: The copper wires act as antennae for radio frequency signals in the air from sources such as AM radio and Ham radio. AM radio stations have a band from 560 KHz to 1600 KHz and hence the interference is predictable but ham radio signals are totally unpredictable and become a major source of interference for VDSL.
- 5) Impulse noise caused due to temporary electromagnetic interference.
- 6) Load coils present in long loops act as low-pass filters, thereby preventing the use of higher frequencies for data transmission.
- 7) The loops present in the existing PSTN networks are not always of uniform gauge which in turn changes the resistance of the wire.

## **2.22 Overcoming the challenges of the PSTN Access Network:**

DSL system uses the latest modem technologies along with some additional equipment to overcome the over mentioned problems and to make the telephone wires suitable to data transmissions. A DSL modem at the customer's end usually referred as the *Customer premise Equipment (CPE)* and that at the Local telephone office is called *DSL Access Multiplexer (DSLAM)*. The main functions of a modem are Line coding and modulation/demodulation. The modem designs vary according to the DSL technology being used. As an example, ADSL modems use Reed-Solomon FEC codes for error correction, two separate bands to provide echo cancellation and multi-dimensional trellis coding to improve the data-rate. DSL modems need to use pass-band line coding in order to separate the 0-4KHz voice band from the higher frequency data band. The two most popular modulation formats today are the Discrete Multitone Transmission and the Carrierless Amplitude Phase modulation. CAP is very closely related to the well-known Quadrature Amplitude Modulation (QAM). The only difference lies in the mixing of the two modulated signals. Most ADSL systems use DMT modulation while CAP is preferred for VDSL.

Also in ADSL since the POTS signals and the data-signals use the same copper wire, a device called splitter is used both at the CO and the customer premises. Splitter is a device that is attached to the phone line near where it enters the customer premise. The splitter forks the phone line: one branch hooks up to the original house telephone wiring and the other branch heads to the DSL modem. Besides splitting the phone line, the splitter acts as a low pass filter, allowing only 0-4kHz frequencies to pass to/from the phone and thus eliminating the 4kHz interference between phones and DSL modems.

Other approaches that are used are:

- 1) Receivers using digital filters with very tight tolerances and running on powerful DSPs can be used to recover the strongest signal despite very high attenuation loss and thus achieve high data rates.
- 2) The modulation format called Discrete Multitone Systems adapts well to line impairments such as bridged taps, crosstalk and radio frequency interference. DMT divides the spectrum above the voice frequency in up to 256 channels with 4KHz bandwidth each, often referred to as tones. The bits in each bin are individually modulated using Quadrature Amplitude Modulation to create the symbols. Each symbol can hold anywhere from zero to a maximum of 15bits/sec/Hz. This allows the transmission of up to 60Kbps per tone (15\*4KHz). In addition, a technique called bit swapping is used that allows ADSL to change the number of bits assigned to a particular sub-carrier. This tries to equalize the error-rate of each sub-carrier and maintain this over time by continually moving bits away from carriers with high error rates to those with low error rates. This technique allows for gradual changes in line conditions and achieves optimal performance at a given rate over time. [3]
- 3) VDSL signals are susceptible to Radio frequency interference such as from amateur radio. One technique to reduce interference is to use Power Spectral Density (PSD) Masks. PSD masks ensures that the power level of a signal transmitted at a particular frequency is low enough to minimize the possibility of interfering with another signal that may be transmitting at the same frequency.

### 2.3 Deployment Issues:

**High customer investment:** ADSL modem costs hundreds of dollars.

**Wiring Line Qualifications:** Not all telephone lines are capable of passing the high frequencies used by DSL modems. There are also limits to the length of copper wire that DSL will work on. Therefore, a telephone line must be "qualified" before DSL can be installed on the line. The line qualification checks the length of the local loop, for the presence of loading coils, for the presence of excessive bridge taps, for local loops that are provisioned over DLC, and the general state of the line.

**Security risk:** An xDSL (or cable modem) connection to the Internet has a greater security risk than a plain old analog modem dialup connection. For one, the bandwidth is greater, allowing the possibility of more cracking to be done in the same period of time. More importantly, the connection is usually always on, which makes your hosts a much easier (and potentially more lucrative) target to find.

**Wire Length:** For the most common form of DSL (ADSL), you can't be more than about 17,500 feet from the DSLAM (head-end equipment).

**Splitters:** The problem with splitters is that it requires breaking and remaking some telephone wiring connections and perhaps even installing new wiring to the DSL modem. In many cases, this means a service call to the customer premise. To avoid this, various alternatives have been proposed. The Universal ADSL group is working on reduced speed DSL that is more immune to frequency interference and that probably uses only frequencies beyond human hearing. Rockwell has proposed something similar called CDSL (consumer DSL). Another solution, used by Netspeed equipment is to use "micro filters." Netspeed calls this "EZ-DSL." A micro filter is essentially a customer-installable low-pass filter with an RJ-11 jack on either end: the customer plugs the phone into one end and the plugs the other end into the wall jack. A micro filter is placed between each telecom device and the wall jack it plugs into, except for the DSL modem. [2]

## **Chapter 3: Cable Modem**

### **3.1 Introduction to Cable Modem:**

Internet connections in residential areas or to individual subscribers became so widespread because it used the normal telephone wires for data transfer and hence did not require additional wiring at the subscriber end. Cable modem technology also was also built up on the similar concept of utilizing the already existing infrastructure to provide broadband Internet access to individual subscribers. Traditional dial-up modem provide 56Kbps over the normal telephone wires, with Cable modem the access speeds are 2Mbps, which is almost 20 times faster. The major change required to the existing cable systems was that the existing cables TV signals were essentially broadcast and unidirectional and for using them for Internet access it needs to provide bi-directional data flow. As cost of optical fibers reduced, many cable operators started using Hybrid Fiber Coaxial cable (HFC) networks. Evolution to HFC is the first step needed to provide bi-directional communications paving the way for cable modem deployment.

An HFC network is a bi-directional shared-media system consisting of fiber trunks between the headend and the fiber nodes, and coaxial distribution. Compared with traditional tree-and-branch cable networks, HFC greatly reduces the number of amplifiers between the headend and the residence, thereby improving signal quality and improving reliability (amplifier failure is the leading source of service outage on CATV networks). [1]

Allocating different spectrum for upstream and downstream data ensures bi-directional data flow. A coaxial cable has a bandwidth of 450 MHz (50Mhz-500Mhz) and

provides 60 analog TV channels with 6MHz for each channel. A single channel of 6MHz can provide a data rate of 30Mbps using 64 QAM (Quadrature Amplitude Modulation Transmission) and a data rate of 43Mbps using 256 QAM. For Upstream communications, from cable modem to cable head end a narrower spectrum of 5MHz-42MHz is provided. This spectrum is more susceptible to interference from sources such as CB, amateur radio and home appliances. To reduce the effect of such interferences QPSK modulation is used, as it is more robust, however the data rate obtained is much lower (range from 500 Kbps to 10Mbps).

### **3.2 Cable Network Challenges:**

***Bi-directional Amplifiers:*** Modern HFC networks need bi-directional amplifiers for both upstream and downstream traffic. To accomplish this, back-to-back amplifiers with filters are arranged so that downstream signals are first filtered and then amplified. Similarly, the upstream signals will also be filtered and then amplified. The upstream path has an inherent disadvantage because of the branch and tree topology. During amplification of the upstream, the splitter outputs become its input. The splitter simply combines the incoming signals and noise, hence both are amplified. In the downstream direction, the signals passing through a splitter are attenuated on the splitter outputs, but the noise carried downstream is also attenuated. [1]

***Frequency Tuning:*** The cable modem is capable of using any one of the upstream and downstream frequencies. This allows the cable operators to change the allocated spectrum according to the changing traffic demand or the noise level, without user intervention.

***Multiple Access Control:*** Since cable modem technology essentially uses shared media, a MAC protocol has been defined for upstream traffic.

***Noise Suppression:*** A cable system may be viewed as giant antenna for various noises and impairments. This is especially true in the 5 to 42 MHz band of the RF spectrum. [1] The types of noise and their levels vary with time and region and hence it is difficult to make a safe estimate for design purpose. And to develop a system for handling the worst case scenario is not an optimal solution. The various noise sources are Hum modulation, Ingress noise, Thermal noise etc. The main approaches used for noise suppression are

- 1) Aligning the amplifiers properly in reverse directions
- 2) Ensuring the system is both mechanically and electrically sealed to prevent Ingress.
- 3) Reducing the channel bandwidth adds robustness to the system, since it reduces the group delay distortion and enables the use of higher order modulation schemes. This approach may not be economically feasible in some regions. [1]
- 4) A frequency agile cable modem (in a multi-tone carrier) is one method used to reduce (skip) noise impairments. The approach is to select only those carrier frequencies in the return path where noise is minimal

***Sharing the bandwidth:*** The upstream and downstream bandwidth is shared by the active data subscribers connected to a given cable network segment, typically 500 to 2,000 homes. Unlike circuit-switched telephone networks where a caller is allocated a dedicated connection, cable modem users do not occupy a fixed amount of bandwidth during their online session. Instead, they share the network with other active users and use the network's resources only when they actually send or receive data in quick bursts. So instead of 200 cable online users each being allocated 135 Kbps, they are able to grab all the bandwidth available during the millisecond they need to download their data packets -- up to many megabits per second. An individual cable modem subscriber may experience access speeds from 500 Kbps to 1.5 Mbps or more -- depending on the network architecture and traffic load.

Today when a number of broadband technologies are available it is argued that the shared bandwidth concept of cable modem technology is a bottle neck, however it has to be realized that the entire Internet is based on the concept of sharing resources. A much more likely bottleneck to the cable system connecting to the internet is the internet itself or even the ultimate web-site that is being requested. Recognizing that the Internet itself can slow things down, cable operators have created systems that cache popular Web sites closer to the user and that contain local sites of high interest. These sites reside on servers close to the subscriber and reduce dependence on access to the Internet. Such systems have been called walled gardens because they attempt to provide a large quantity of interesting Web pages to serve the subscriber's needs from just a local server.

***HFC Limitations:*** 1) Component failure in an amplifier in the distribution network can render an entire neighborhood out-of-service.  
2) Unlike Telecom systems that have their own power supplies, the Cable Systems depend on outside AC power supply. Failure of AC power supply may cause serious problems and by rendering entire region out of service.

### **3.3 Cable Modem Technology:**

The basic operation of a Cable modem is to transport high-speed digital data to and from the user to the cable network. Most cable modems are external devices that connect to a personal computer (PC) through a standard 10Base-T Ethernet card or Universal Serial Bus (USB) connection using a Category 5 cable. Data is transmitted between the cable modem and computer at 10 Mbps. Cable Modems are a combination of modem, tuner, bridge, encryptor, router, NIC, SNMP and hub.

A cable modem must be able to tune onto any one of the downstream 6 MHz bands to receive data from the headend. At the transmitting end, the cable modem must also be able to transmit at any of the downstream channels available. When a Cable modem joins a network it first listens to the downstream channels seeking entry to register its device. On receiving a strong signal it reads the subsystem frequency allocation layout and then requests the headend to acknowledge its registration.

The headend *Cable Modem Termination System (CMTS)* is an intelligent controller that communicates through these channels with *cable modems* located in subscriber homes on

one side and with the ISP on the other side. It thus acts as an interface between the ISP and the cable distribution network. The billing system is also incorporated at the CMTS.

To promote cable modem rollouts, as well as relieve technological confusion, CableLabs, an industry trade organization drafted a standard for cable modem products in 1996 called DOCSIS, which stands for Data Over Cable Service Interface Specification. The standard was developed to ensure that cable modem equipment built by a variety of manufacturers is compatible, as dial-up modems are.

### **3.4 Deployment Issues and proposed solutions:**

In order to provide open access, the cable operators are required to allow competitive ISP to utilize the cable networks. A major issue is to decide how to integrate, how many ISPs should be allowed to connect to one system and how to charge them for access. The CMTS has limited number of ports available that can be connected to the ISPs, however this prevents scalability as the CMTS equipment are very expensive and hence re-installations may not be affordable.

As the number of subscribers increase, the 6Mhz bandwidth will not be enough and hence to prevent traffic jams, the bandwidth has to be shared intelligently. One possible solution as mentioned in the DOCSIS release 1.1 is that of maintaining grades of services providing different QoS such as economy class, First class and business class. Subscribers with a real need for speed can get it on a reliable basis by paying a higher fee while those with more modest needs can pay a lower price.

One advantage with cable system is that it is scalable, i.e. if the demand increases very high then one more dedicated 6Mhz channel can be utilized for data communication. This however is not possible to implement in many cases, as it may not be acceptable by all the subscribers. A solution to this is modifying the distribution pattern of the system using *nodalization*. Nodalization is essentially the dividing up of the cable system into smaller cable systems, each with its own path to the cable headend. The neighborhood termination of that path is called a node. In effect, then, several cables, instead of a single cable, come out of the headend to serve the neighborhoods. Cable system nodes cater to anywhere from several thousand subscribers to just a few hundred. Putting in more nodes is costly, but the advantage of nodalization is that the same spectrum can be used differently at each node. A specific 6-MHz channel may carry cable modem bits to the users in one node while the same 6-MHz channel carries completely different cable modem bits to other users in an adjacent node. This has been called space-division multiplexing since it permits different messages to be carried, depending on the subscriber's spatial location.

### **3.5 Future Developments:**

The DOCSIS has developed standards for VoIP (Voice over IP) enabled modems. Such a CPE has a powerful IP-enabled gateway installed at the users end that uses a

protocol called SGCP to carry voice packets along with data packets. With the large bandwidth available with cable modem technology, the focus of the Cable industry is now shifting to Cable Telephony and applications using extensive multimedia. Examples of such applications include

1. Video Conferencing: Runs over IP and allows users to communicate live using streaming video and audio.
2. Facsimile using IP over private networks or over the Internet.
3. Web casting: Is generally used for wide distribution of information such as news to clients without explicit requests from the clients. This is called PUSH technology.
4. Multicasting is the automatic transmission of files or streaming audio and video to pre-selected multiple users.
5. Virtual Private Networks: Is a closed LAN on top of the Internet.
6. Home monitoring/ Security: The cable network can be used to monitor homes for fires, break-ins, and medical emergencies.

## **Chapter 4: DirecPC System**

### **4.1 DirecPC Satellite System:**

DirecPC is a product from Hughes Network systems that offers a high-speed Internet connection using a satellite link, providing download Internet access speeds up to 400kbps. The main advantage of this technology as compared to other broadband access technologies is that it has wide coverage with just one installation. In remote or rural areas where cables and DSL lines are not easily provided, satellite service is readily available. There are currently five GEO satellites being used for DirecPC. They are: G11, Galaxy 3R,G4R, SatMex 5, & GE 1.

### **4.2 Satellite Communication Technology and Issues:**

Satellites use the SHF (Super High frequency 3000MHz to 30,000MHz) for communication. This band consists of microwave frequencies and travel along the Line of Sight (LOS) between the Earth and the Satellite. Satellites were introduced commercially in 1965, and were used primarily as a repeater in space. Till 1980s, satellites were used mainly in point-to-point links creating a worldwide telephone network. After early 1990s Satellites were used more and more in a point-to-multipoint connectivity, also called broadcast, in which there is a single uplink station and using the

satellite repeater, continuous stream of signal can be transmitted to all receiving points in the coverage area. This was used for transmitting television signals nationwide. If each receive terminal is given transmit capability, then the broadcast network is turned into a multipoint interactive. Such a network is required for using the satellite link as a part of the Internet. There are certain issues associated with using satellites in computer communication as discussed below.

**Link latency:** The inherent problem with a GEO link is the large latency due to the distance and the noisy nature of the channel. The latency is about 0.5 sec, which becomes a problem for a network using TCP/IP connections. TCP uses a mechanism called slow start to discover the channel throughput capacity upon initial connection set up. In this mechanism, TCP sends a packet and waits for its response, if it receives the response, it doubles its sending window. With 0.5 sec delay, the initial setup time will be unacceptably large. To overcome this delay, TCP connections are terminated and re-originated at both ends of the satellite links. Over the satellite link, a new protocol is used that is both transparent to TCP/IP and optimized for the satellite environment and which does not use Slow Start. Since the service provider controls the link and schedules capacity, the throughput for a TCP connection is known prior to transmission and no discovery process is required. The data is sent at a predetermined rate over the link without any round-trip delays. [5] This mechanism is called TCP spoofing and is implemented in DirecPC systems.

**Reliability:** Since Satellite Communication provides single-hop connectivity, 100 % back up is needed for all equipment in case of failure. Total satellite failures (including launch failure and on-orbit failure) require contingency plans to be predesigned. A common cause of communication outage is RFI problem rather than hardware failure and satellite operators need to be well equipped to identify and resolve this problem. Generally RFI is restricted to one frequency and therefore the users can be reassigned to different frequencies till RFI is removed.

**Error correction:** Computer communication generally uses ARQ (Automatic Repeat Request) schemes to ensure data integrity. In this scheme, if the received data is found to be erroneous, the data is retransmitted. However in satellite links, due to the high latency, ARQ schemes may cause the sending to halt for up to 2 seconds and hence is not appropriate. The Satellite systems therefore use Forward Error Correction (FEC) schemes that correct the error at the receiving end instead of asking for retransmission. The acknowledgement that the sending end expects is sent before the distant receiving end receives the data. This ensures continuous data transfer. To achieve this functionality the satellite system needs a special type of equipment called Delay Compensation Unit (DCU). Another solution for this problem is to use Selective retransmission for only the erroneous packets.

**Traffic Dependency:** Satellite links provides a Constant Bit Rate (CBR) type of service which is more suitable for traffic such as voice or video; intermittent traffic such as electronic mail are much less beneficial under CBR.

### **4.3 Satellite Communication Advantages:**

1. Satellite communications can cover a large area and is independent of the bridged distance within its coverage area. It is therefore very economic for serving large areas or for worldwide communication.
2. Satellite communication is basically of broadcast nature and hence they inherently set up networks in star topology. Therefore satellites are useful for direct communication with a large number of fixed and mobile users.
3. Satellite networks can be setup in a relatively short time and have a flexible architecture.
4. Satellite systems uses a wide Frequency spectrum, e.g., For the C and Ku bands, the available spectrum is of the order of 1Ghz each. The bandwidth available to the users can be multiplied by using several frequency reuse techniques.
5. Satellite communications become very important and even indispensable in areas of poor or fragmented terrestrial data communications such as ocean shipping lines, desert land, etc.
6. Satellite systems use microwave frequencies that have more predictable behavior than any other radio transmission system.
7. Advantage of satellite communication is end-to-end transmission through a single hop, which overcomes multi-router network drawbacks such as lost packet and congestion. Also Satellite links are an ideal environment for IP multicast and selective Acknowledgement schemes.

### **4.4 DirecPC System:**

DirecPC system is based on GEO satellites that are orbiting at a distance of 22,800 Km from the earth. The satellite acts an intelligent transponder (receive and transmit) in the space. At the customers end, a DirecPC service system requires a 21-inch Satellite-dish antenna connected using a co-axial cable to a internal PCI card modem or an External USB modem connected to the users computer. The antenna operates over frequencies from 11.7-12.2GHz (Ku band), and is linearly polarized. It uses a non-penetrating roof mount and is rated to withstand winds up to 125 mph.

For the upstream traffic until recently, DirecPC connections had to use the normal telephone lines using dial-up connections. A user request is sent using the modem to the Internet via the users ISP. The ISP points to the Information Handling Services (IHS) Web Hosting center and makes the request. The requested site is then sent to Hughes Network Satellite System and is beamed to the Satellite. The Satellite then beams the data back to the user Satellite dish and it is then transported to the user's computer. This type of connectivity is only suitable for low to moderate end users.

DirecPC is now offering a Satellite upload channel providing 128Kbps rate for directly transmitting user data to the satellite. DirecPC uses a Indoor Transmit Unit (ITU) to send data to DirecPC satellite which in turn sends it to the DirecPC Network Operations Center (NOC). The NOC forwards the request to the Internet where the data is forwarded to the final destination. Data sent to the user is transmitted to the satellite by

the NOC. The receive channel to the DirecPC Indoor Receive Unit (IRU) is a DVB (Digital Video Broadcast) transport stream which contains Multiprotocol encapsulated DirecPC IP traffic operating at the rates up to 45Mbps. The data is decoded and then presented on the user's computer. [2]

The satellite technology is quite well tested as far as reception and transmission of digital signals is concerned, the main problem with employing this technology for broadband Internet access is to make the various Internet protocols work on a satellite link such that it provides seamless integration with the existing Internet. There are certain issues that are hindering the widespread acceptance of DirecPC system. These issues are discussed below

#### **4.5 Issues in the deployment of DirecPC system**

- 1) DirecPC has drivers available for only Windows system. Unix, Linux, MAC users cannot use DirecPC systems.
- 2) DirecPC assigns to you static IP address, while ISP uses dynamic allocation of IP addresses. Some ISPs, for security reasons, may limit some features to those users having dynamically assigned IP addresses from the ISPs own pool of addresses and those services may not be available for DirecPC users.
- 3) Software compatibility issues
- 4) During a heavy storm the signal may freeze off and on or, at worst, be completely blocked. While it's rare for the signal to become completely blocked, severe weather often reduces incoming satellite signal strength. Reductions in strength below 90 often result in reduced online speeds.

#### **4.6 Future Developments:**

Like all other broadband technologies, the DirecPC system is also concentrating on Multimedia applications for the future. Hughes has a new project called *Spaceway* that will provide bandwidth-on-demand: the ability to transmit and receive data, video, voice, audio, and multimedia where you want it, when you need it. Once the geosynchronous orbit Spaceway system is operating, the next phase of Hughes' global broadband plans is to introduce a complementary nongeosynchronous system. This system will have satellites operating in lower earth orbits and will expand the network capability to offer additional interactive broadband multimedia communications services in high traffic markets. [7]

## **Summary:**

All the above technologies discussed above promise high-speed access and huge bandwidth. Every technology has its advantages and disadvantages- Gigabit Ethernet has a big competition from existing Fast Ethernet and ATM for backbone networks. The DSL system cannot use the existing telephone wires after all, although it started with the idea of using the present infrastructure. However if installations are not a problem then it provides high-speed reliable service irrespective of the distance. The Cable modem system also became popular as 70% houses in North America are connected to the Cable network. The cable modem service is therefore cheaper than ADSL, but it still has issues of bandwidth sharing and security. The satellite system has its advantages as being ideal for IP multicasting but it is currently not available for all platforms. Also, the two-way satellite connection, that does not need dialup connection for upstream is yet to penetrate the market. Another important issue is to get standards for equipment supporting these technologies so that all the vendors have compatible products. Different forums and work groups are emerging for developing various standards for specific technologies. All these technologies work on different physical mediums and use different equipment and standards, but are a part of the common Internet and hence it is necessary to provide interoperability between different technologies and provide seamless integration.

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