Module
5

Broadcast Communication Networks

Lesson
6

High Speed LANs – CSMA/CD based

Specific Instructional Objectives

On completion, the student will be able to:

- Distinguish between switched versus shared LAN
- Explain the key features of Fast Ethernet
- Explain the key features of the Gigabit Ethernet

5.6.1 Introduction

In the preceding lesson we have seen that high speed LANs have emerged broadly into three types - *based on token passing, successors of Ethernet* and *based on switching technology*. we have discussed *FDDI* and its variations in the preceding lesson. In the second category we have the *fast Ethernet* and *Gigabit Ethernet*. In the third category we have *ATM*, *fiber channel* and the *Ether switches*. In this lesson we shall discuss the second and the third categories of LANs starting with successors of Ethernet.

5.6.2 Successors of Ethernet

On a regular Ethernet segment, all stations share the available bandwidth of 10 Mb/s. With the increase in traffic, the number of packet collisions goes up, lowering the overall throughput. In such a scenario, there are two basic approaches to increase the bandwidth.

One is to replace the Ethernet with a higher speed version of Ethernet. Use of Fast Ethernet operating at 100 Mb/s and Gigabit Ethernet operating at 1000 Mb/s belong to this category. This approach requires replacement of the old network interface cards (NICs) in each station by new ones.

The other approach is to use Ethernet switches (let us call it switched Ethernet approach) that use a high-speed internal bus to switch packets between multiple (8 to 32) cable segments and offer dedicated 10 Mb/s bandwidth on each segment/ports. In this approach, there is no need to replace the NICs; replacement of the hub by a switch serves the purpose. This approach is discussed in the following section.

5.6.2.1 Switched Ethernet

Switched Ethernet gives dedicated 10 Mb/s bandwidth on each of its ports. On each of the ports one can connect either a thick/thin segment or a computer.

In Ethernet (IEEE 802.3) the topology, though physically is star but logically is BUS, i.e. the collision domain of all the nodes in a LAN is common. In this situation only one station can send the frame. If more than one station sends the frame, there is a collision. A comparison between the two is shown in Fig. 5.6.1.

In Switched Ethernet, the collision domain is separated. The hub is replaced by a switch, which functions as a fast bridge. It can recognize the destination address of the received frame and can forward the frame to the port to which the destination station is connected. The other ports are not involved in the transmission process. The switch can receive another frame from another station at the same time and can route this frame to its own final destination. In this case, both the physical and logical topologies are star.

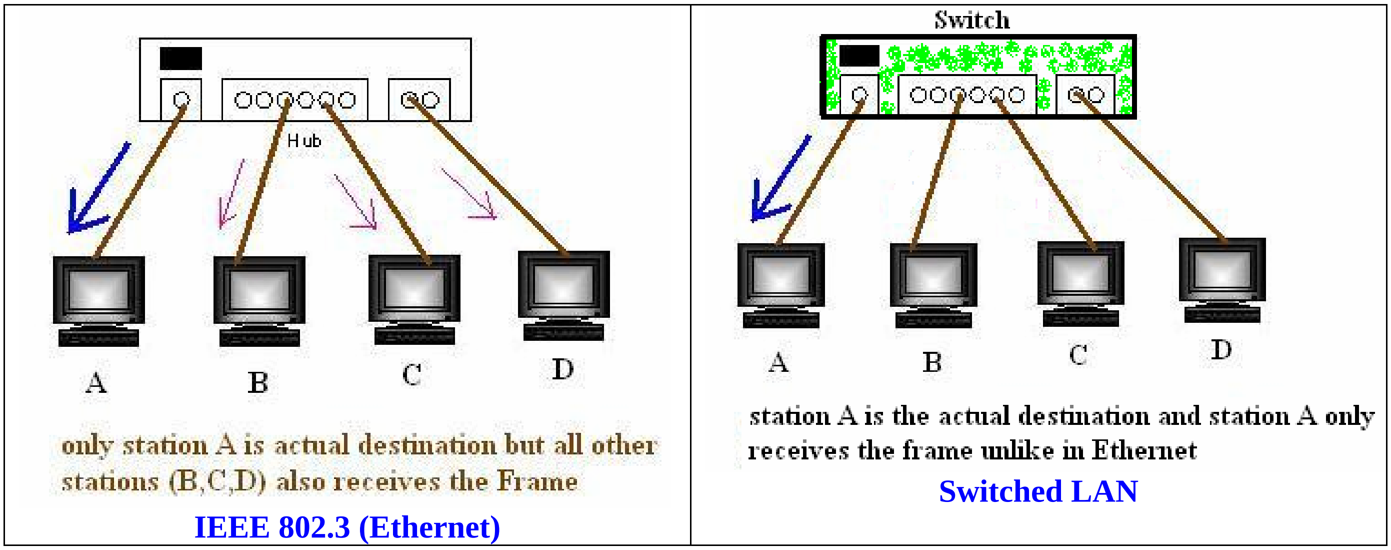

Figure 5.6.1 Difference Between 802.3 and Switched LAN

There are two possible forwarding techniques that can be used in the implementation of Ethernet switches: *store-and-forward* and *cut-through*. In the first case, the entire frame is captured at the incoming port, stored in the switch's memory, and after an address lookup to determine the LAN destination port, forwarded to the appropriate port. The lookup table is automatically built up. On the other hand, a cut-through switch begins to transmit the frame to the destination port as soon as it decodes the destination address from the frame header.

Store-and-forward approach provides a greater level of error detection because damaged frames are not forwarded to the destination port. But, it introduces longer delay of about 1.2 msec for forwarding a frame and suffers from the chance of loosing data due to reliance on buffer memory. The cut-through switches, on the other hand, has reduced latency but has higher switch cost.

The throughput can be further increased on switched Ethernet by using full-duplex technique, which uses separate wire pairs for transmitting and receiving. Thus a station can transmit and receive simultaneously, effectively doubling the throughput to 20 Mb/s on each port.

5.6.2.2 Fast Ethernet

The 802.u or the fast Ethernet, as it is commonly known, was approved by the IEEE 802 Committee in June 1995. It may not be considered as a new standard but an addendum to the existing 802.3 standard. The fast Ethernet uses the same frame format, same CSMA/CD protocol and same interface as the 802.3, but uses a data transfer rate of 100 Mb/s instead of 10 Mb/s. However, fast Ethernet is based entirely on 10-Base-T, because of its advantages (Although technically 10-BASE-5 or 10-BASE-2 can be used with shorter segment length).

Fortunately, the Ethernet is designed in such a way that the speed can be increased if collision domain is decreased. The only two changes made in the MAC layer are the data rate and the collision domain. The data rate is increased by a factor of 10 and collision domain is decreased by a factor of 10. To increase the data rate without changing the minimum size of the frame (576 bits or 76 bytes in IEEE 802.3), it is necessary to decrease the round-trip delay time. With the speed of 100Mbps the round-trip time reduce to 5.76 microseconds (576 bits/100 Mbps; which was 57.6 microsecond for 10Mbps Normal Ethernet). This means that the collision domain is decreased 10 fold from 2500 meters (in IEEE802.3) to 250 meters (fast Ethernet).

IEEE has designed two categories of Fast Ethernet: 100Base-X and 100Base-T4. 100Base-X uses two-wire interface between a hub and a station while 100Base-T4 uses four-wire interface. 100-Base-X itself is divided into two: 100Base-TX and 100base-FX as shown in Fig. 5.6.2.

100 BASE-T4:

This option is designed to avoid overwriting. It is used for half-duplex communication using four wire-pairs of the existing category 3 UTP cables, which are already available for telephone services in homes/offices. Two of four pairs are bi-directional; other two are unidirectional. This means that there are 3 pairs to be used for carrying data, in each direction (2 bi-directional and 1 uni-directional) as shown in Fig. 5.6.3. Because 100Mbps data cannot be handled by voice-grade UTP, this specification splits the 100 Mbps flow into three 33.66 Mbps flows.

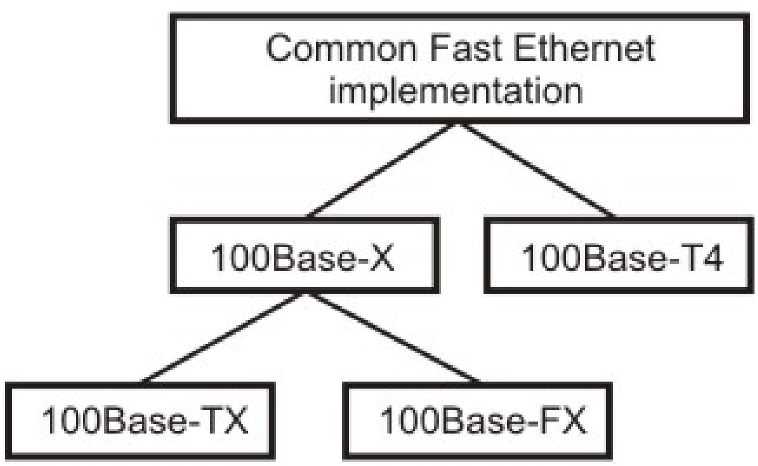

Figure 5.6.2 Fast Ethernet implementations

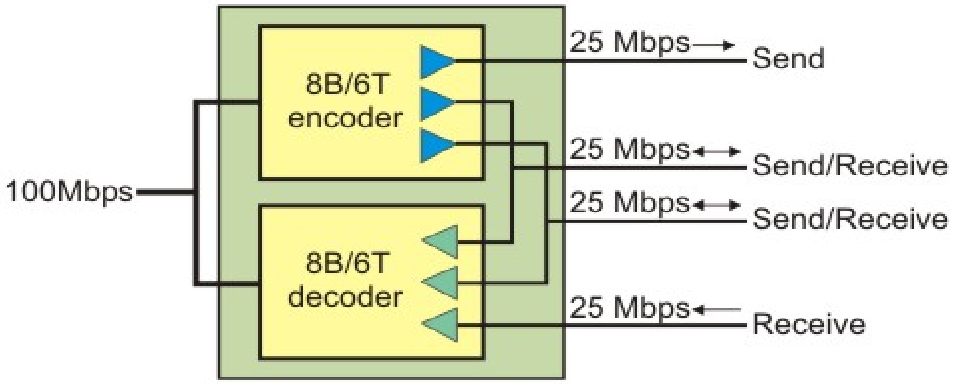

Figure 5.6.3 100Base-T4 implementation

100 BASE TX:

This option uses two pairs of category 5 UTP or two shielded twisted-pair (STP) cable to connect a station to hub as shown in Fig. 5.6.4. One pair is used to carry frames from the hub to the station and other to carry frames from station to hub. It uses 4B/5B encoding to handle 100 Mbps using NRZ-I signaling. The distance between station and hub should be less than 100 meters.

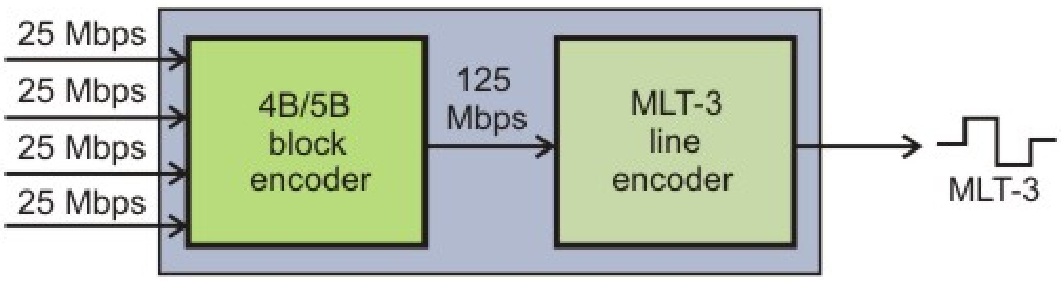

Figure 5.6.4 100Base-TX implementation

100 BASE FX:

This option uses two Fiber optic cables, one carry frames from station to hub and other from hub to station as shown in Fig. 5.6.5. The encoding is using 4B/5B and it uses NRZ-I signaling. The distance between station and hub should be less than 2000 meters.

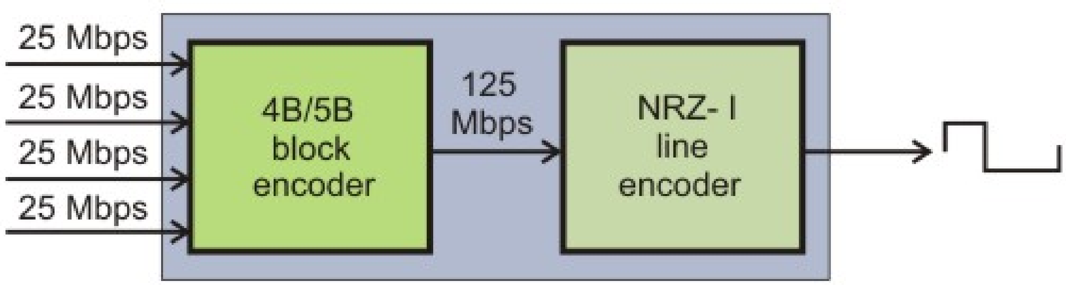

Figure 5.6.5 100Base-FX implementation

5.6.3 Gigabit Ethernet

5.6.3.1 Brief History and the IEEE 802.3z Task Force

As applications increased, the demand on the network, newer, high-speed protocols such as FDDI and ATM became available. However, in the last couple of years, Fast Ethernet has become the backbone of choice because it's simplicity and its reliance on Ethernet. The primary goal of Gigabit Ethernet is to build on that topology and knowledge base to build a higher-speed protocol without forcing customers to throw away existing networking equipment.

In March 1996, the IEEE 802.3 committee approved the 802.3z Gigabit Ethernet Standardization project. At that time as many as 54 companies expressed there intent to participate in the standardization project. The Gigabit Ethernet Alliance was formed in May 1996 by 11 companies. The Alliance represents a multi-vendor effort to provide open and inter-operable Gigabit Ethernet products. The objectives of the alliance are:

- Supporting extension of existing Ethernet and Fast Ethernet technology in response to demand for higher network bandwidth.
- Developing technical proposals for the inclusion in the standard
- Establishment of inter-operability test procedures and processes

5.6.3.2 Similarities and advances over Ethernet (IEEE 802.3)

As its name implies, Gigabit Ethernet - officially known as 802.3z - is the 1 Gb/s extension of the 802.3 standard already defined for 10 and 100 Mb/s service. Gigabit Ethernet builds on top of the Ethernet protocol, but increases speed tenfold over Fast Ethernet to 1000 Mbps, or 1 gigabit per second (Gbps). It retains the Carrier Sense Multiple Access/ Collision Detection (CSMA/CD) as the access method. It supports full duplex as well as half duplex modes of operation. Initially, single-mode and multi mode fiber and short-haul coaxial cable were supported. Standards for twisted pair cables were subsequently added. The standard uses physical signaling technology used in Fiber Channel to support Gigabit rates over optical fibers. Since Gigabit Ethernet significantly leverages on Ethernet, customers will be able to leverage their existing knowledge base to manage and maintain gigabit networks. Initially, Gigabit Ethernet was expected to be used as a backbone system in existing networks. It can be used to aggregate traffic between clients and "server farms", and for connecting Fast Ethernet switches. It can also be used for connecting workstations and servers for high-bandwidth applications such as medical imaging or CAD. But, gigabit Ethernet is not simply a straight Ethernet running at 1 Gb/s. In fact, the ways it differs from its predecessors may be more important than its similarities. Some of the important differences are highlighted below.

(i) The cabling requirement of gigabit Ethernet is very different. The technology is based on fiber optic cable. Multi-mode fiber is able to transmit at gigabit rate to at least 580 meters and with single-mode runs exceeding 3 km. Fiber optic cabling is costly. In order to reduce the cost of cabling, the 802.3z working group also proposed the use of twisted-pair or cable or coaxial cable for distances up to 30 meters.

(ii) Gigabit Ethernet also relies on a modified MAC layer. At gigabit speed, two stations 200 meters apart will not detect a collision, when both simultaneously send 64-byte frames. This inability to detect collision leads to network instability. A mechanism known as *carrier extension* has been proposed for frames shorter than 512 bytes. The number of repeater hops is also restricted to only one in place of two for 100 Base-T.

(iii) Flow Control is a major concern in gigabit Ethernet because of buffer overflow and junked frames in heavily loaded condition. The solution proposed by IEEE subcommittee is the 802.3x. The X-on/X-off protocol works over any full-duplex Ethernet, fast Ethernet or gigabit Ethernet link. When a switch buffer is close to capacity, the receiving device signals the sending station and tells it to stop transmitting until the buffer becomes empty.

(iv) Finally, one important feature, which Ethernet technology lacks, is the Quality of Service (QoS). The gigabit Ethernet is a connectionless technology that transmits variable length frames. As such, it simply cannot guarantee that the real-time packets get the preferential treatment they require. The IEEE subcommittee developed two specifications that will help Ethernet provide the required QoS. 802.lq tags traffic for VLANs and for prioritization. 802.lp is a signaling scheme that lets end station request priority and allows switches to pass these requests along the path.

The gigabit Ethernet comes into its own as an internetworking switch link (ISL) that aggregates 10-and100-Mb/s feeds from the desktops and servers. Presently, gigabit Ethernet is already matured with a large installation base as a backbone network technology.

5.6.3.3 Gigabit Ethernet Protocol Architecture

In order to accelerate speeds from 100 Mbps Fast Ethernet up to 1 Gbps, several changes were required to be made to the physical interface. It was decided that Gigabit Ethernet will look identical to Ethernet from the data link layer upward. The challenges involved in accelerating to 1 Gbps have been resolved by merging two technologies together: IEEE 802.3 Ethernet and ANSI X3T11 FiberChannel as shown in Fig. 5.6.6.

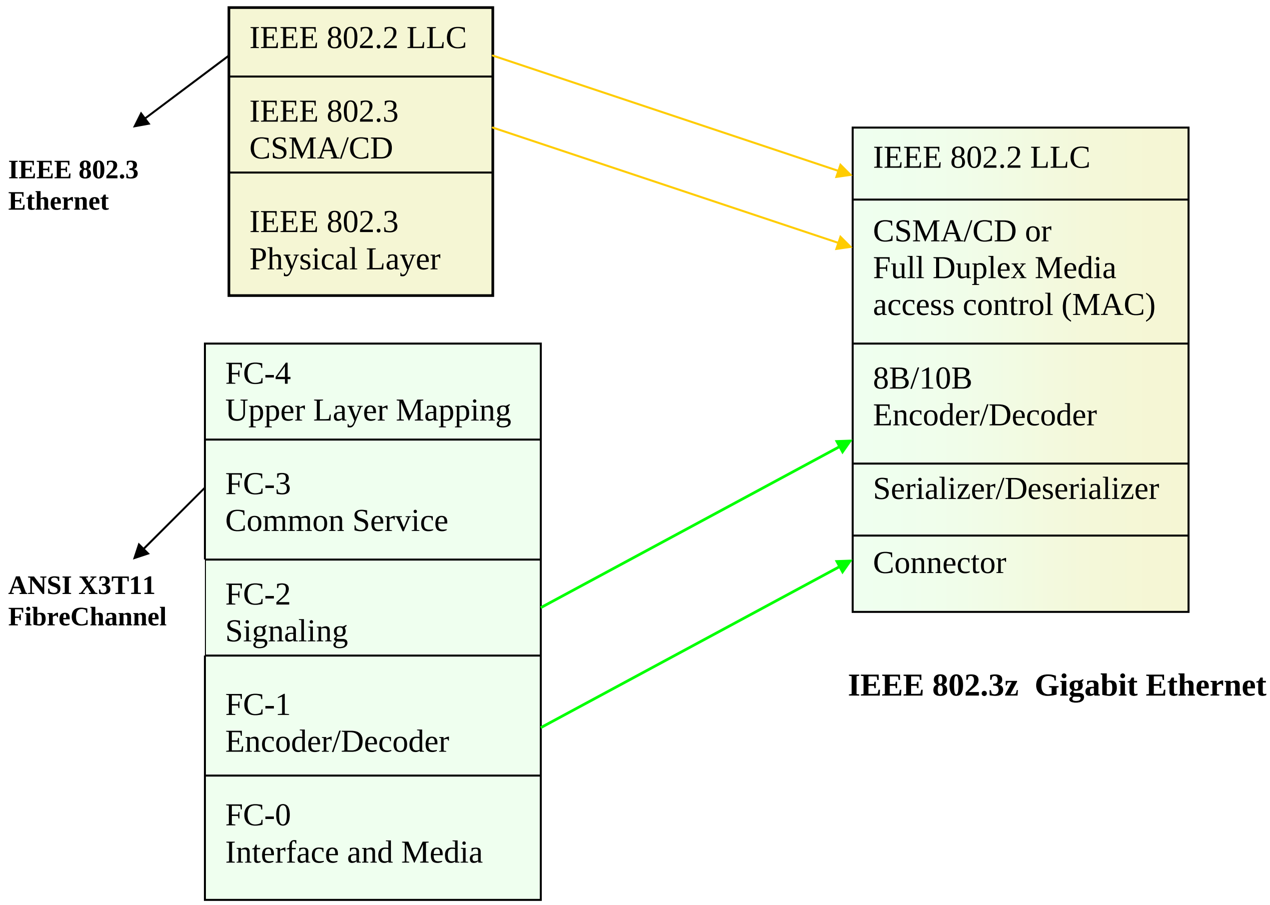

Figure 5.6.6 Gigabit Ethernet Architecture -1

5.6.3.4 GMII (Gigabit Media Independent Interface)

The various layers of the Gigabit Ethernet protocol architecture are shown in Fig. 5.6.7. The GMII is the interface between the MAC layer and the Physical layer. It allows any physical layer to be used with the MAC layer. It is an extension of the MII (Media Independent Interface) used in Fast Ethernet. It uses the same management interface as MII. It supports 10, 100 and 1000 Mbps data rates. It provides separate 8-bit wide receive and transmit data paths, so it can support both full duplex as well as half duplex operation.

The GMII provides 2 media status signals: one indicates presence of the carrier, and the other indicates absence of collision. The Reconciliation Sublayer (RS) maps these signals to Physical Signaling (PLS) primitives understood by the existing MAC sublayer. With the GMII, it is possible to connect various media types such as shielded and unshielded twisted pair, and single-mode and multi mode optical fiber, while using the same MAC controller.

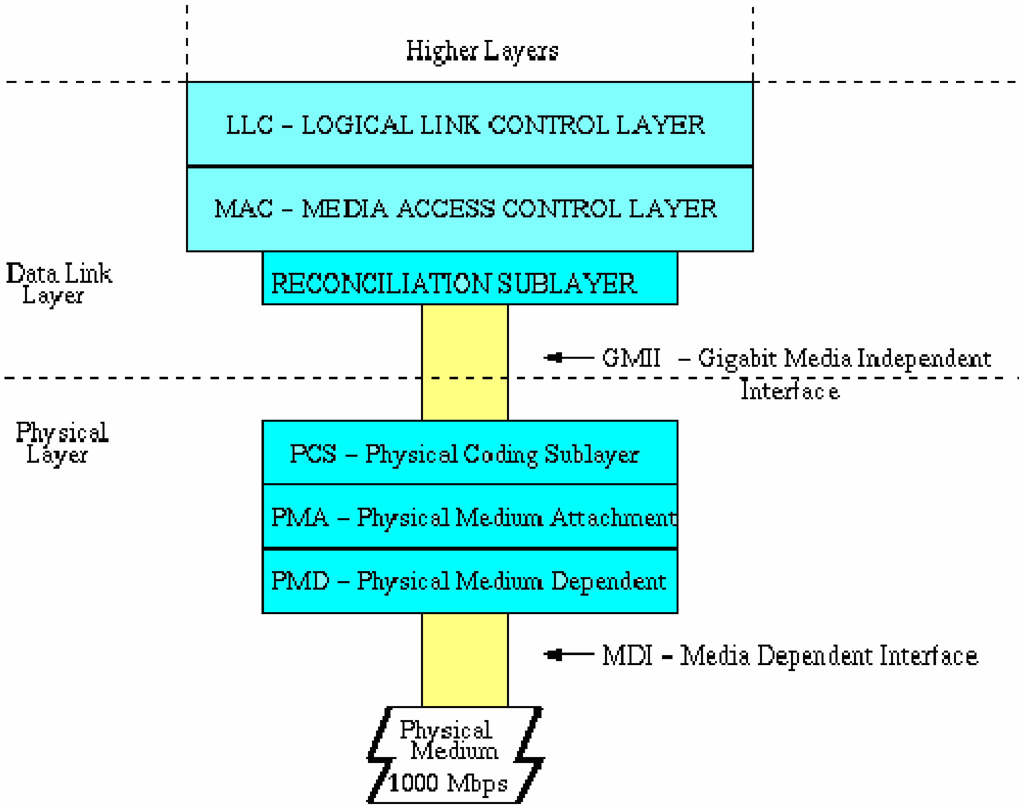

Figure 5.6.7 Gigabit Ethernet Architecture-2

- **PCS (Physical Coding Sublayer)**

  This is the GMII sublayer, which provides a uniform interface to the Reconciliation layer for all physical media. It uses 8B/10B coding like Fiber Channel. In this type of coding, groups of 8 bits are represented by 10 bit "code groups". Some code groups represent 8-bit data symbols. Others are control symbols. The extension symbols used in Carrier Extension are an example of control symbols. Carrier Sense and Collision Detect indications are generated by this sublayer. It also manages the auto-negotiation process by which the NIC (Network Interface) communicates with the network to determine the network speed (10,100 or 1000 Mbps) and mode of operation (half-duplex or full-duplex).

- **PMA (Physical Medium Attachment)**

  This sublayer provides a medium-independent means for the PCS to support various serial bit-oriented physical media. This layer serializes code groups for transmission and deserializes bits received from the medium into code groups.

- **PMD (Physical Medium Dependent)**

  This sublayer maps the physical medium to the PCS. This layer defines the physical layer signalling used for various media. The **MDI (Medium Dependent Interface)**, which is a part of PMD, is the actual physical layer interface. This layer defines the actual physical attachment, such as connectors, for different media types divided into three sub layers: PCS, PMA and PMD.

5.6.3.5 Media Access Control Layer

Gigabit Ethernet has been designed to adhere to the standard Ethernet frame format. This setup maintains compatibility with the installed base of Ethernet and Fast Ethernet products, requiring no frame translation. Gigabit Ethernet maintains the minimum and maximum frame sizes of Ethernet. Since, Gigabit Ethernet is 10 times faster than Fast Ethernet, to maintain the same slot size, maximum cable length would have to be reduced to about 10 meters, which is not very useful. Instead, Gigabit Ethernet uses a bigger slot size of 512 bytes (In Ethernet, the slot size is 64 bytes, the minimum frame length). To maintain compatibility with Ethernet, the minimum frame size is not increased, but the "carrier event" is extended. If the frame is shorter than 512 bytes, then it is padded with extension symbols. These are special symbols, which cannot occur in the payload. This process is called *Carrier Extension*

- **Carrier Extension**

Gigabit Ethernet should be inter-operable with existing 802.3 networks. Carrier Extension is a way of maintaining 802.3 minimum and maximum frame sizes with meaningful cabling distances.

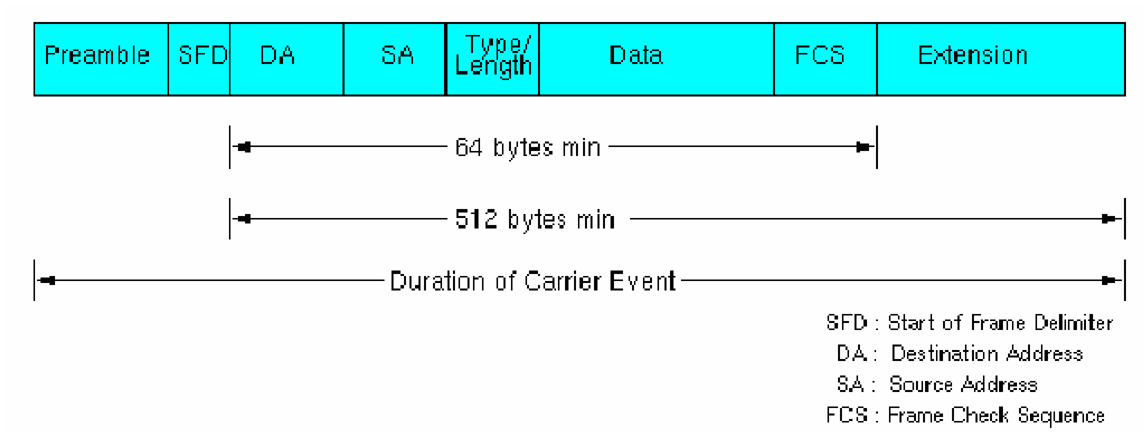

Figure 5.6.8 Ethernet Frame Format With Carrier Extension

For carrier extended frames, the non-data extension symbols are included in the "collision window", that is, the entire extended frame is considered for collision and dropped. However, the Frame Check Sequence (FCS) is calculated only on the original (without extension symbols) frame. The extension symbols are removed before the FCS is checked by the receiver. So the LLC (Logical Link Control) layer is not even aware of the carrier extension. Figure 5.6.8 shows the Ethernet frame format when Carrier Extension is used.

- **Packet Bursting**

Carrier Extension is a simple solution, but it wastes bandwidth. Up to 448 padding bytes may be sent for small packets. This results in lower throughput. In fact, for a large number of small packets, the throughput is only marginally better than Fast Ethernet.

Packet Bursting is an extension of Carrier Extension. Packet Bursting is "Carrier Extension plus a burst of packets". When a station has a number of packets to transmit, the first packet is padded to the slot time if necessary using carrier extension. Subsequent packets are transmitted back to back, with the minimum Inter-packet gap (IPG) until a burst timer (of 1500 bytes) expires. Packet Bursting substantially increases the throughput. Figure 5.6.9 shows how Packet Bursting works.

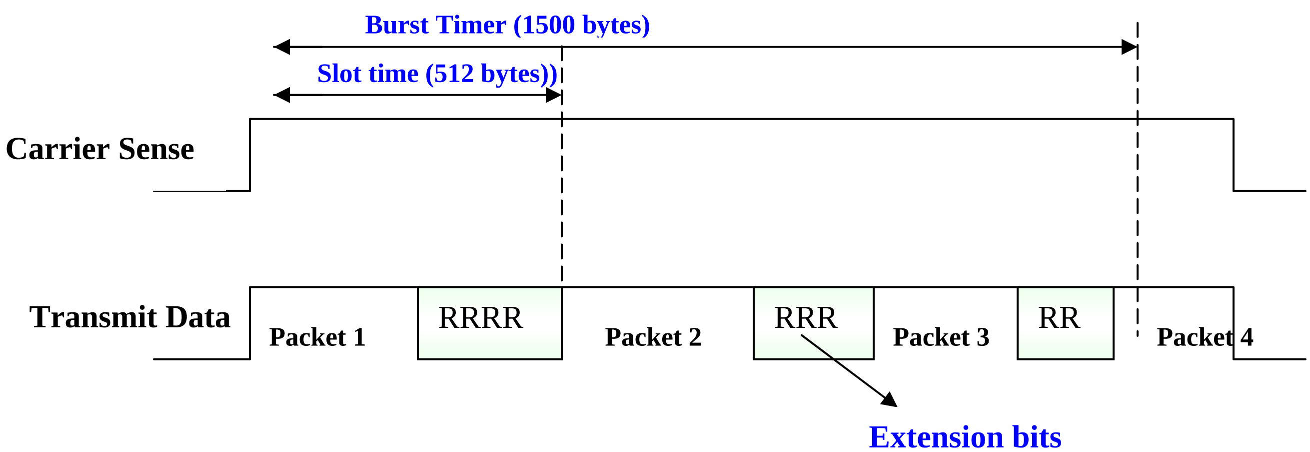

Figure 5.6.9 Packet Bursting

GBIC: Gigabit Ethernet Interface Carrier allows network managers to configure each port on a port-by-port basis, including long-haul (LH) to support a distance of 5-10 Km using SMF as shown in Fig. 5.6.10.

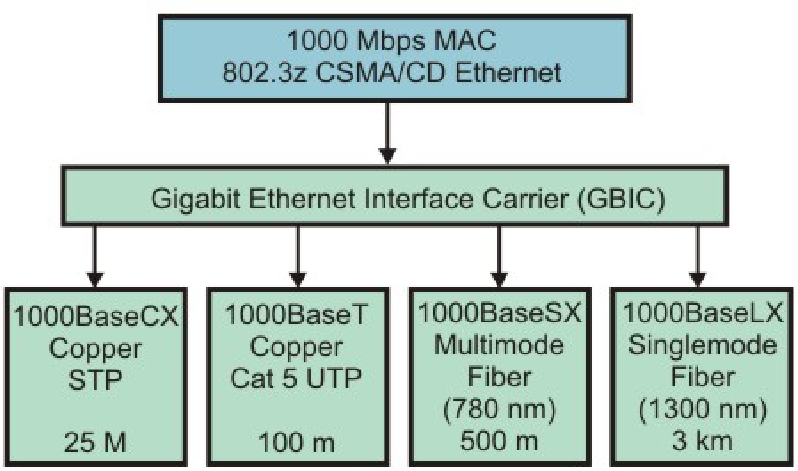

Figure 5.6.10 GBIC architecture

Migration to Gigabit Ethernet

Possible migration approaches to Gigabit Ethernet network from existing Fast Ethernet or Ethernet network is given below:

- Upgrading Switch-to-Switch links
- Upgrading Switch-to-Server links
- Upgrading a Switched Fast Ethernet Backbone
- Upgrading a shared FDDI Backbone

This illustrated with the help of Fig. 5.6.11.

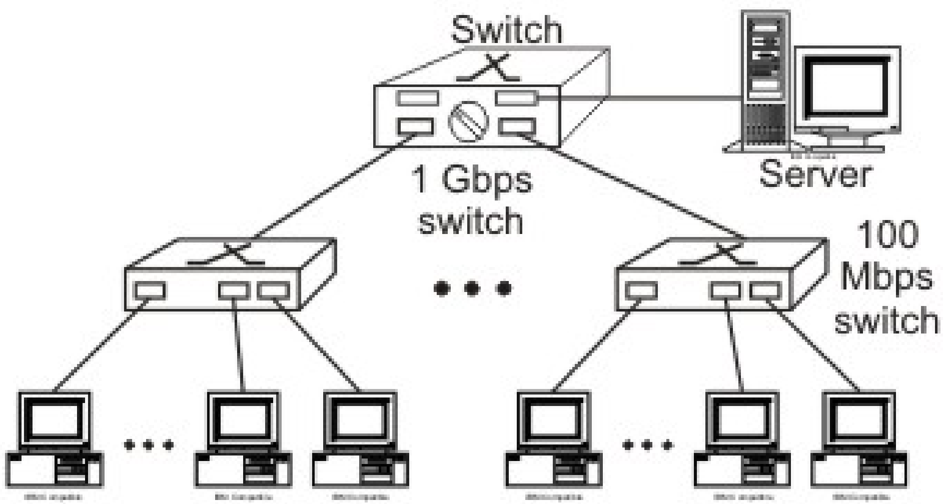

Figure 5.6.11 Migration to Gigabit Ethernet Backbone network

Fill In The Blanks:

1. Switched Ethernet gives dedicated 10 Mb/s bandwidth on __________ of its ports.
2. In Ethernet (IEEE 802.3) the topology, though physically is _________ but logically is BUS. i.e. the collision domain of all the nodes in a LAN is _________.
3. In Switched Ethernet, collision domain is separated. Hub is replaced by a ________.
4. There are two techniques used in the implementation of Ethernet switches: _____________ and ________
5. IEEE has designed two categories of Fast Ethernet: ____________ and __________.
6. 100-Base-X itself is divided into two: __________ and __________
7. The Gigabit Ethernet Alliance was formed in ___________ by ______ companies.

8. The GMII is the interface between the ________ layer and the ___________ layer.
9. ________, a sublayer of GMII provides a medium-independent means for the PCS to support various serial bit-oriented physical media.
10. *Packet Bursting* is an extension of ______________. Packet Bursting is "Carrier Extension plus a ____________".

Solutions...

1. each
2. star, common
3. switch
4. *store-and-forward, cut-through*
5. 100Base-X, 100Base-T4
6. 100Base-TX, 100base-FX.
7. May 1996, 11
8. MAC, Physical
9. PMA (Physical Medium Attachment)
10. Carrier Extension, burst of packets

Short Questions:

Q-1. Explain the basic difference between IEEE 802.3 and switched Ethernet, as far as implementation is concerned.
Ans: In Ethernet (IEEE 802.3) the topology, though physically is start but logically is BUS. i.e. the collision domain of all the nodes in a LAN is common. In this situation only one frame can send the frame, if more than one station sends the frame, there is a collision.

In Switched Ethernet, this collision domain is separated. Hub is replaced by a switch, a device that can recognize the destination address and can route the frame to the port to which the destination station is connected, the rest of the media is not involved in the transmission process. The switch can receive another frame from another station at the same time and can route this frame to its own final destination.

Q-2. Explain the two techniques for implementing Ethernet switches.
Ans: There are two techniques used in the implementation of Ethernet switches: *store-and-forward* and *cut-through*. In the first case, the entire frame is captured at the incoming port, stored in the switch's memory, and after an address lookup to determine the LAN destination port, forwarded to the appropriate port. The lookup table is automatically built up. On the other hand, a cut-through switch begins to transmit the frame to the destination port as soon as it decodes the destination address from the frame header.
Store-and-forward approach provides a greater level of error detection because damaged frames are not forwarded to the destination port. But, it introduces longer delay of about 1.2 msec for forwarding a frame and suffers from the chance of loosing data due to

reliance on buffer memory. The cut-through switches, on the other hand, has reduced latency but has higher switch cost.

Q-3. What are the different categories of Fast Ethernet?
Ans: IEEE has designed two categories of Fast Ethernet: 100Base-X and 100Base-T4.
100Base-X uses two cables between hub and the station while 100Base-T4 uses four.
100-Base-X itself is divided into two: 100Base-TX and 100base-FX.

* *100 BASE-T4*: This option is designed to avoid overwriting. It is used for half-duplex communication using four wire-pairs of the existing category 3 UTP cable, which is already available for telephone services in homes/offices. Two of four pairs are bi-directional; other two are unidirectional. This means that there are 3 pairs to be used for carrying data, in each direction (2 bi-directional and 1 uni-directional). Because 100Mbps data cannot be handled by voice-grade UTP, this specification splits the 100 Mbps flow into three 33.66Mbps flow.

**100 BASE TX*: This option uses two category 5 UTP or two shielded (STP) cable to connect a station to hub. One pair is used to carry frames from the hub to the station and other to carry frames from station to hub. Encoding is 4B/5B to handle 100 Mbps; signaling is NRZ-I. The distance between station and hub should be less than 100 meters.

**100 BASE FX*: This option uses two Fiber optic cables, one carry frames from station to hub and other from hub to station. The encoding is 4B/5B and signaling in NRZ-I. the distance between station and hub should be less than 2000 meters.

Q-4. What are the Objectives of The Gigabit Ethernet Alliance?
Ans: The objectives of the alliance are:

- supporting extension of existing Ethernet and Fast Ethernet technology in response to demand for higher network bandwidth.
- developing technical proposals for the inclusion in the standard
- establishment of inter-operability test procedures and processes

Q-5. Explain GMII (Gigabit Media Independent Interface) in brief.
Ans: The GMII is the interface between the MAC layer and the Physical layer. It allows any physical layer to be used with the MAC layer. It is an extension of the MII (Media Independent Interface) used in Fast Ethernet. It uses the same management interface as MII. It supports 10, 100 and 1000 Mbps data rates. It provides separate 8-bit wide receive and transmit data paths, so it can support both full-duplex as well as half-duplex operation.

The GMII provides 2 media status signals: one indicates presence of the carrier, and the other indicates absence of collision. With the GMII, it is possible to connect various media types such as shielded and unshielded twisted pair, and single-mode and multi mode optical fiber, while using the same MAC controller. It has three sub-layers namely: PCS (Physical Coding Sublayer), PMA (Physical Medium Attachment) and PMD (Physical Medium Dependent)