Data Communication
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Lecture # 29
High Speed LANs

Hello and welcome to today's lecture on high speed local area networks.

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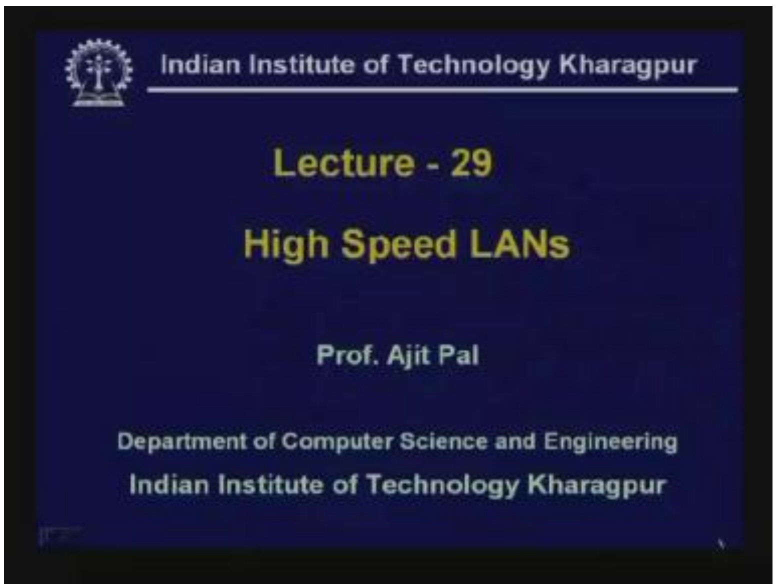

In the last lecture we have discussed the legacy LANS which have served the purpose for many years but unfortunately with the need increasing because of the application pool and technology push there has been need for high speed local area networks which is the topic of today's discussion. Here is the outline of this lecture:
High speed LAN categories
High speed LANs can be implemented based on token ring. Essentially it can be considered as extension of token ring which is known as FDDI.

High speed LANs based on successors of Ethernet, we shall discuss two technologies in detail, the Fast Ethernet and the Gigabit Ethernet and another alternative which is based on switching technology that has also led to high speed local area networks.

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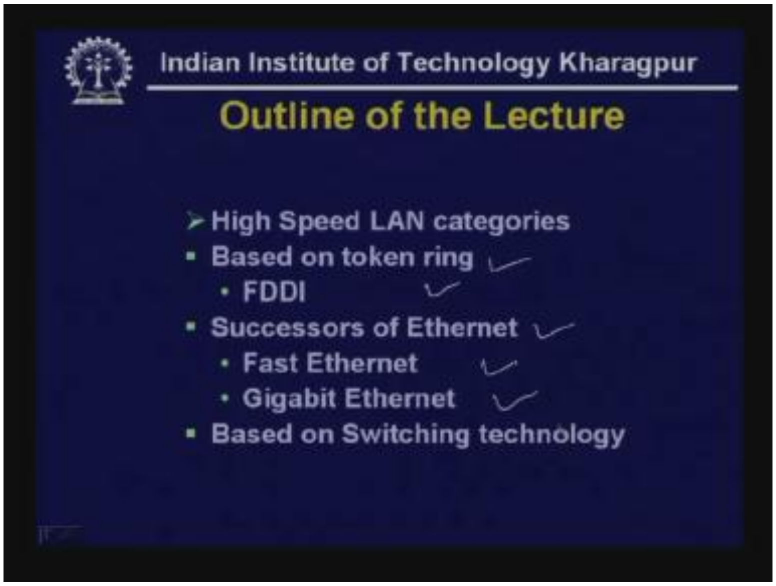

And on completion the students will be able to explain different categories of high speed LANs, distinguish FDDI from IEEE 802.5 token ring LAN. So although FDDI is based on token ring LAN there are many differences. The student will also explain how FDDI provides high reliability compared to IEEE 802.5 and then they will be able to explain or distinguish between switched versus shared LAN. They will be also able to explain key features of Fast Ethernet and also they will be able to explain the key features of Gigabit Ethernet.

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As I mentioned the LAN technologies of 70s the IEEE 802 committee's LANs 802.3, 802.4 and 802.5 can be considered as first generation local area networks. As we have seen their speed were in the range of ten to sixteen mega bits per second. But availability of powerful computers, this is your technological push, and emergence of new applications has created an urgent need for high speed LANs. Not only there is application pull but there is also technology push.

As I mentioned, because of the advancement of VLSI technology it is now possible to develop circuits which can offer it at a very high speed. Because of these two reasons now it is possible to have high speed local area networks.

As I mentioned in this lecture I shall consider essentially three different categories of LAN; one is successor of token ring which is essentially FDDI, second is successor of Ethernet which is one of the most popular LAN technologies then based on switching technologies. So these are the things which we shall discuss in this lecture.

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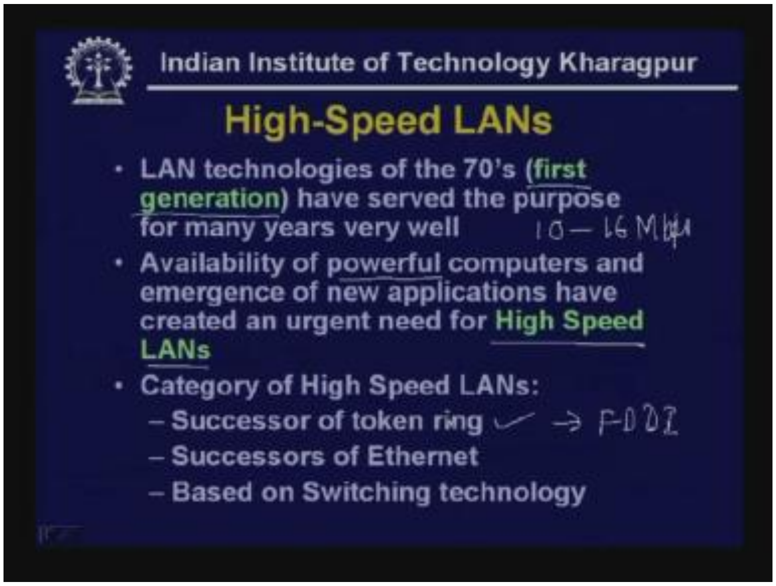

First let us focus on the FDDI which stands for Fiber Distributed Data Interface. It is based on token ring and this is supported by ANSI ISO LAN standard. As you can see there is a close relationship between ISO five layers and the FDDI layers.

As you can see the physical layer is divided into two sublayers. One is the physical layer medium defendant. As we shall see there are several mediums which can be used in FDDI such as optical fiber and twisted-pair so that there is a need for separate physical layer which is medium dependant so we call it PMD sublayer which decides the transmission parameters, connectors, cabling so this is the function of this sublayer. Then there is another sublayer which is a part of the physical layer that performs encoding, decoding, clocking, then the symbol set that is used (Refer Slide Time: 6:02) which is being done by the physical layer.

Also, there is a station management which encompasses both physical layer as well as data link layer which performs ring monitoring, ring management, connection management and also which performs the station management frames generated by this sublayer. And as you know medium access control performs the addressing, frame construction, token handling as discussed in the context of 802.5. Then the upper layers have been kept the same that is logical link control which is part of this data link layer.

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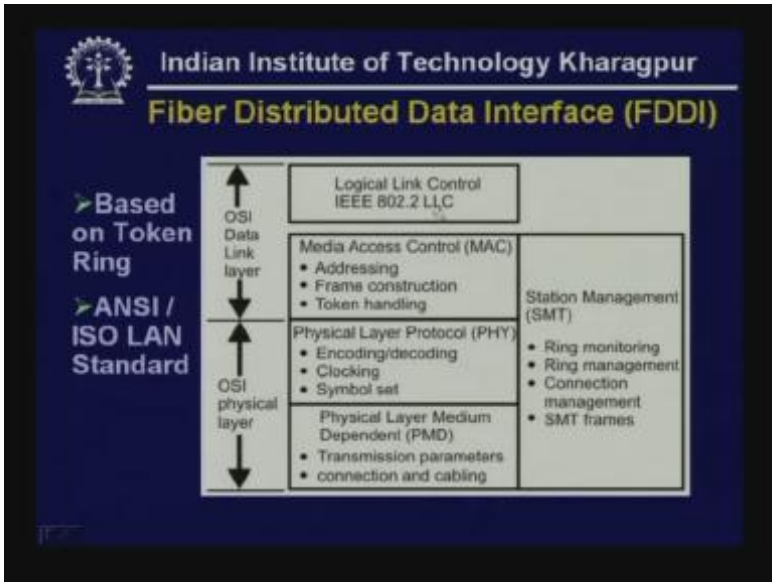

This sublayer acts as an interface with the higher layers of OSI layers that is network layer and other layers. So 802.3 LLC is identical to 802.3, 802.4 and 802.5.

Now let us have a look at the key features of FDDI.

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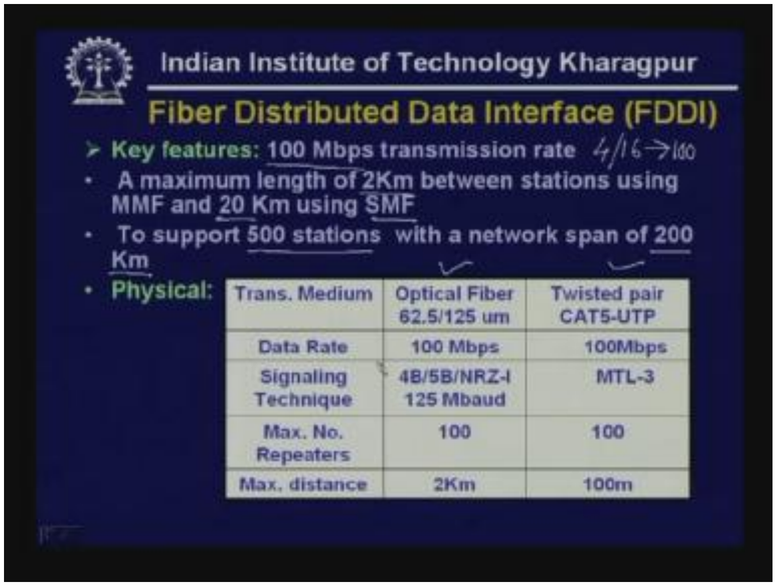

One of the important features is the data rate. As you can see the data rate has been increased from 16 megabits, 4 or 16 which was used in case of 802.5 that is token ring has been enhanced to 100 Mbps so this is almost an order or magnitude enhancement in speed. And it can support a maximum length of 2 Km between stations using multimode fiber and 20 km using single mode fiber.

So, we have seen that, in case of token ring the network span was very small and here the network span can be very large because of the longer lengths of the cables and it can support as many as five hundred stations and network span can be as big as 200 Km. so we see that it cannot be considered just a local area network, it encompasses a much larger area so you may consider it as some kind of a metropolitan area network. It can cover a very big campus.

Some of the features of the physical layer are mentioned here (Refer Slide Time: 8:23). There are two possible mediums which are supported; one is optical fiber. Here only the multi-mode fiber is shown but it is also possible to support single mode fiber for longer distance. Then the data rate in all the cases is 100 Mbps and signaling technique that is being used is different for the two cases. In case of optical fiber it uses two levels of encoding, four B by five B that is one of encoding and NRZ-I that is line encoding and block encoding both are being used here to generate data at the baud rate of 1.25 mega bits.

On the other hand, in case of twisted-pair, it generates MTL-3 encoding and maximum number of repeaters that can be used is 100 in both cases. And as I mentioned when multimode fiber is being used the distance that can be covered is 2 Km and for twisted-pair category 5 unshielded twisted-pair it can be 100 m.

now as I mentioned it uses 4-bit by 5-bit encoding and 5-bit code has no more than one leading 0and no more than two trailing zeros, this is necessary for clock recovery purposes and normally that it is line encoded by NRZ-1.

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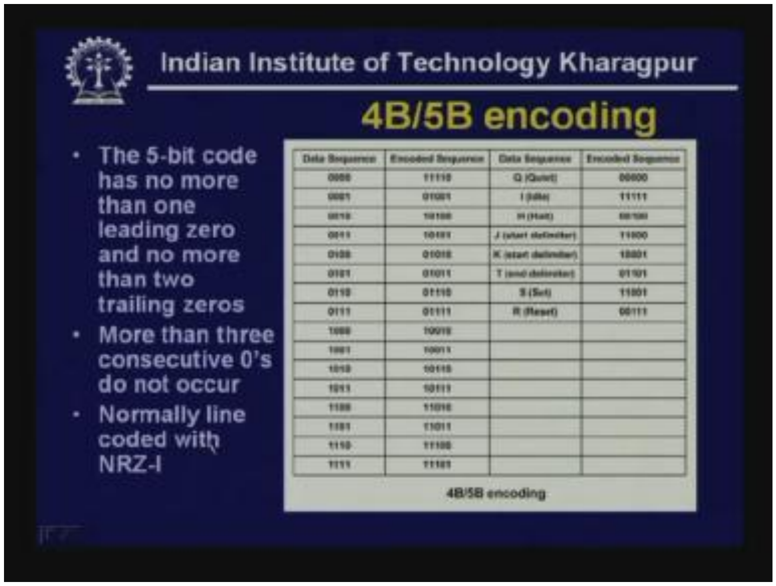

So this block encoding and line encoding these two are combined to have the encoding for FDDI. And this is the frame format (Refer Slide Time: 10:08) as you can see there is a preamble which can be 8 bytes minimum and it is followed by a start of frame delimiter that is 1 byte which specifies the start of the frame, then there is frame control of 1 byte which performs various control operations just like that 802.5 and then this is the destination address and this is the source address, this has the source address and destination address, it can be either 2 byte or 56 byte and data size should be greater than 0.

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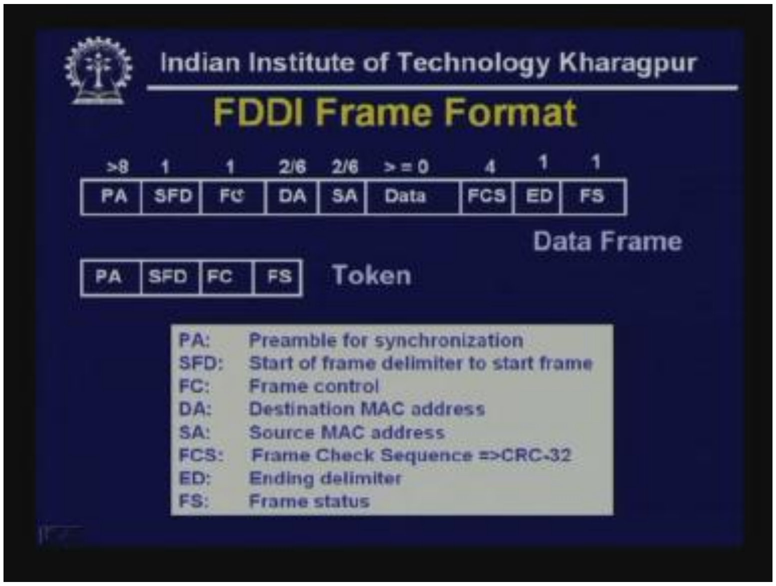

As such there is no limit but there is some maximum limit that is quite high. Then there is a frame check sequence, it is four byte, 32-bit cyclic redundancy code is being used and there is an ending delimiter of 1 byte and frame status as we have already discussed in the context of 802.5 is also used here. The token that is being used here has got a preamble that is used for synchronization, there is SFD which is the start of frame delimiter then frame control and frame status. So this frame status is appended. Hence, as you can see the token is much smaller compared to the data frame.

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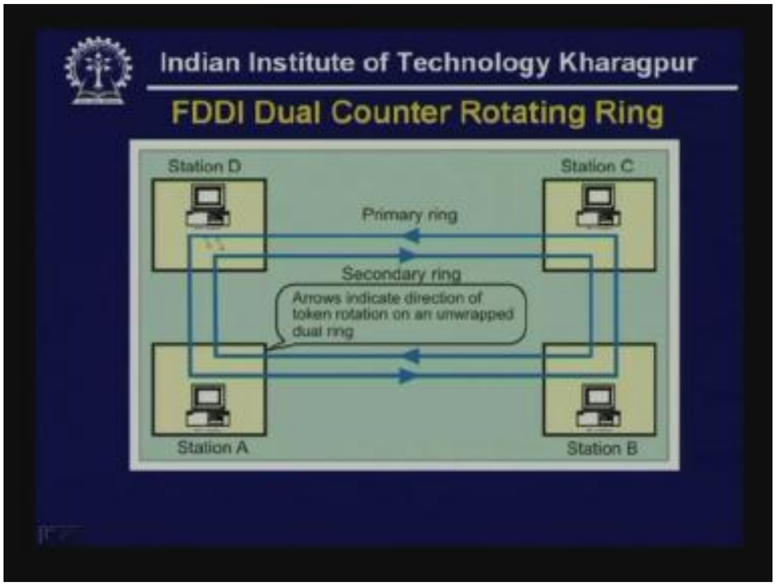

It uses a dual counter rotating ring for the purpose of reliability. In the case of 802.5 we have seen there is only one ring that rotates in the anticlockwise direction in this direction as shown. But here as you can see there are two rings, one is primary ring, another is secondary ring. So, the primary ring is normally in operation and secondary ring is essentially standby. So here as you can see the arrows are showing the direction, the primary ring rotates in the anticlockwise direction and secondary ring rotates in clockwise direction. So the packets or tokens can flow in this direction. That means there are two ports, two and two that is equal to four ports for each station which has to be connected and form a ring.

Now this dual counter rotating ring provides you high reliability. For example, whenever there is a break in fiber then some link has been disrupted then automatically the ring will wrap off in this manner so this station should be wrapped off and that faulty part of the fiber will be bypassed. This is how automatically it supports fault tolerance. that means it detects where the breakage has taken place then it does the repair and now as you can see here the ring is formed in this manner (Refer Slide Time: 13:12).

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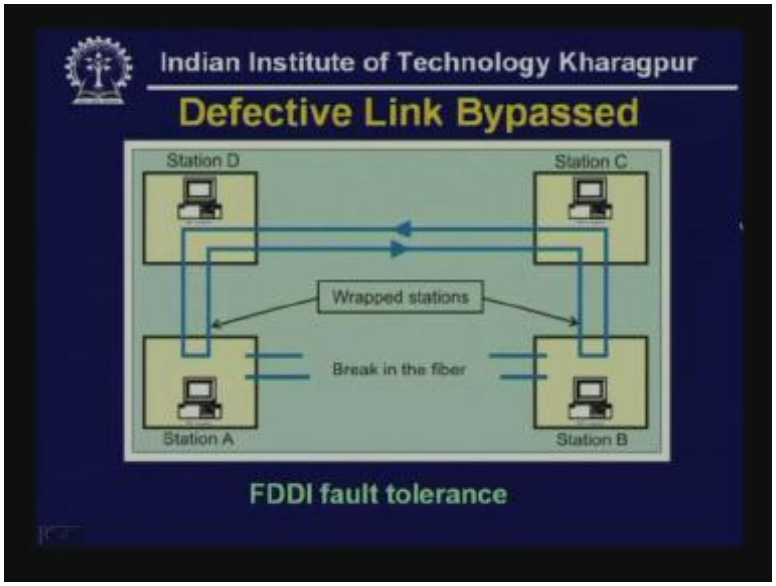

Therefore, by passing the fiber a ring is formed and it continues to offer it and it is transparent to the user so user will not know that this kind of failure has taken place. Similarly, if there is a station failure then the defective station can also wrapped off by wrapping up the two separate rings.

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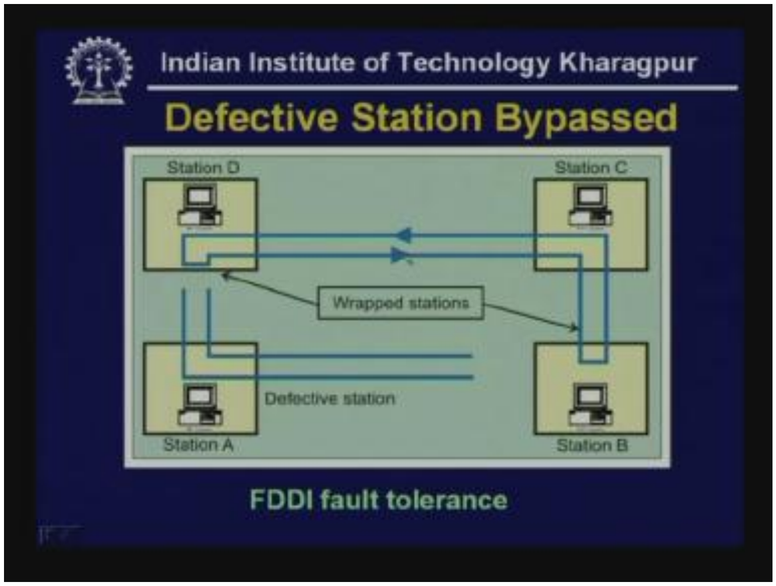

The secondary now becomes part of the active network so a ring is formed in this manner and this station can communicate with each other by using that token passing protocol and defective station is bypassed.

Hence, it has got a built-in reliability with the help of this dual counter rotating technique. Although the MAC protocol is closely rounded around 802.5 but there is one difference. As you have seen, in case of 802.5 a packet starts going and it goes around the ring and usually the bit length that means the time it takes to reach the transmitter that length is smaller than the transmission time of a particular packet. And as a consequence this particular station will receive the leading edge and then after receiving the leading edge it will consume it and then after the transmission of this frame is over it will start a packet. That means there is always some data on the ring. This means, after the transmission is over and this particular data packet is removed inside by the transmitter then a token is introduced in to the ring. So this is how it happens in case of normal token ring.

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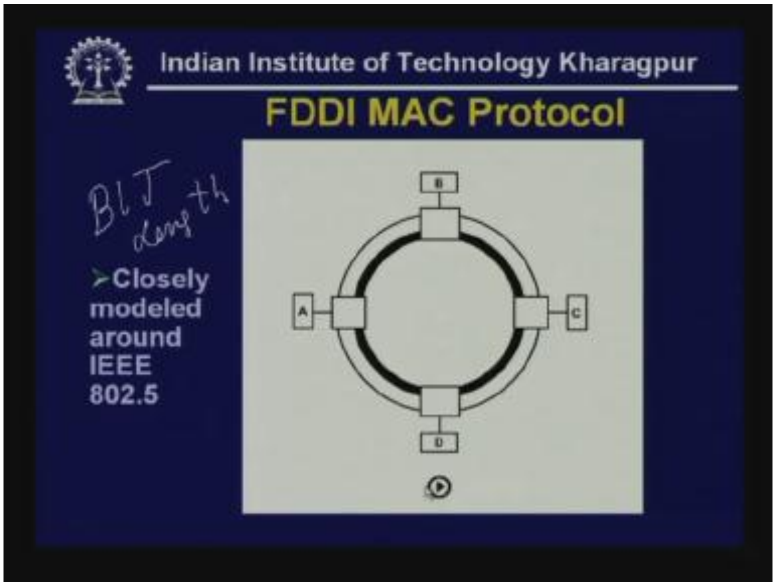

However, in case of FDDI there is a possibility that because of the very long length the bit length can be longer than the transmission time, that possibility is there because the transmission rate is high and also the length of the segment is high. If you are using single mode fiber it can be as long as 20 km so each of these segments can be 20 km.

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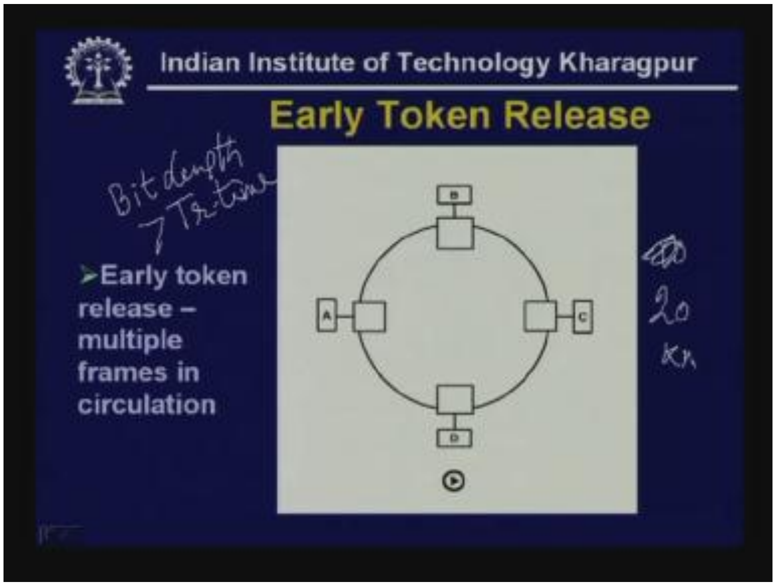

As a consequence whenever there is a big ring the bit length can be quite high. On the other hand, whenever you are transmitting at the rate of 100 Mbps the transmission time can be small. As a consequence there is a possibility that the leading edge will not reach the transmitter before the transmission is over. Thus in this particular case the transmission of a packet is started and it is already finished.

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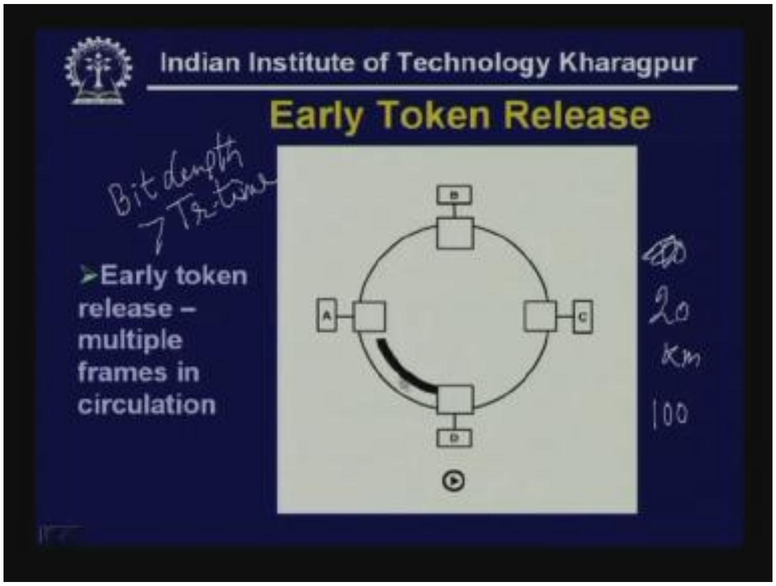

Now there is a possibility of introducing a token. So immediately after sending a packet a token can be introduced which is known as hourly token delay.

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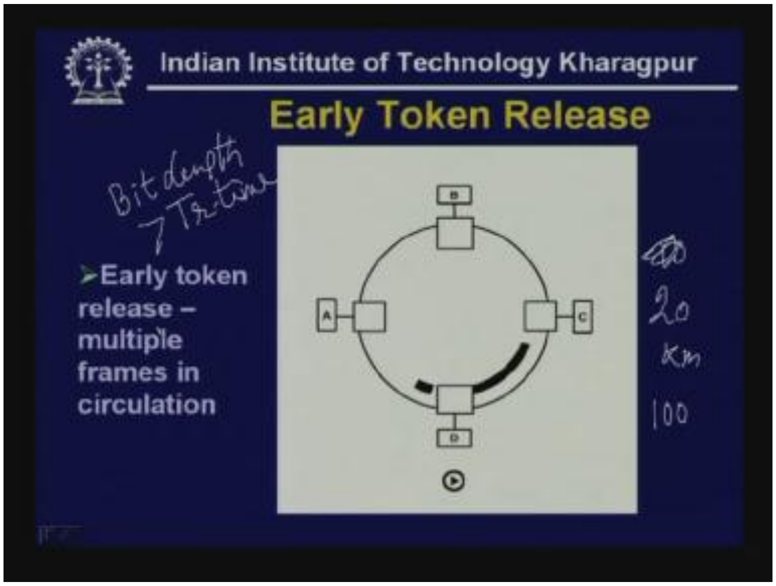

After this token is received by this station it can start sending a data. So you can see there is a possibility of having multiple frames in the ring simultaneously that is what is being supported by a FDDI. In FDDI there is an early token release that means immediately after the transmission of the frame a token is released and as a consequence multiple frames can be simultaneously present in the ring.

The MAC protocol is a time token protocol to support both synchronous and asynchronous traffic. So, in case of 802.5 that is your token ring network it is not a time token protocol but using this time token protocol this FDDI supports both synchronous and asynchronous traffic.

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There are three timers; one is known as Token Rotation Timer TRT, another is Token Holding Timer THT, another is Valid Transmission Timer VTR. These timers are used for the purpose of sending tokens and receiving packets. As you can see a station waits for a token, after a token is received it grabs the token then it sets the Time Rotation Timer equal to that TTRT that is essentially target token rotation time which is usually set by the network manager and which is larger than the total bit length that means propagation time of the ring then it resets the Time Rotation Timer so THT is set equal to this then it keeps on sending until this THT becomes 0. So this transmits packets until THT-0 and no packet is left. However, if no packet is sent then the token is released.

Now, as you can see the time is decided in this way. D max is the total propagation time of the ring and F max is the maximum time of a frame and this is the token transmission time and this is the allotment of synchronous traffic. That means each token is allocated a fraction of time for transmitting synchronous traffic and after transmitting synchronous traffic if there is any time left asynchronous traffic is sent and all these parameters are added together which must be less than this TTRT that is target token rotation time usually set by the network manager.

Hence, by using this kind of time token protocol the asynchronous and synchronous traffic is supported by FDDI. Now we move to some other Fast Ethernet or some other high speed LAN which is essentially based on successors of Ethernet.

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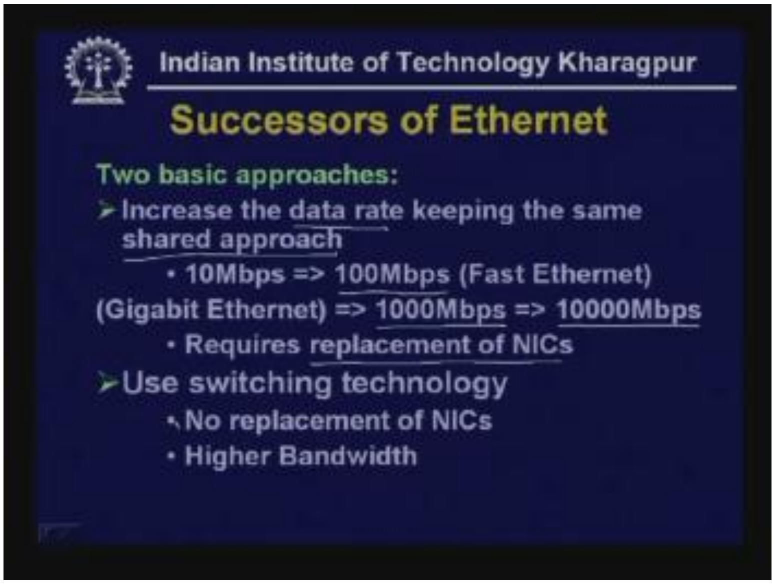

As I mentioned the successors of Ethernet uses two basic approaches. First approach is increase the data rate keeping the same shared approach. As you have seen in case of 802.3 that is your Ethernet based on CSMA/CD the shared bus was used for transmission or a hub was used which essentially acts as a some kind of shared multiport repeater with the help of which data transfer was done.

Now, using the shared approach speed can be increased from 10 Mbps to 100 Mbps Fast Ethernet and from Fast Ethernet 100 Mbps to Gigabit Ethernet 1000 Mbps and nowadays 10 GB network is also on the horizon that is 10 Gbps. That is also available. This is how the speed can be increased and this requires replacement of **network interface card.** So whenever you change the technology you go from Ethernet to Fast Ethernet or Fast Ethernet to Gigabit Ethernet there is a need for changing the network interface card.

However, there is another alternative. Another alternative is used to use switching technology and this does not require any change of network interface card but using this switching technology you can achieve higher bandwidth than the standard 10 Mbps. How it can be achieved is explained here.

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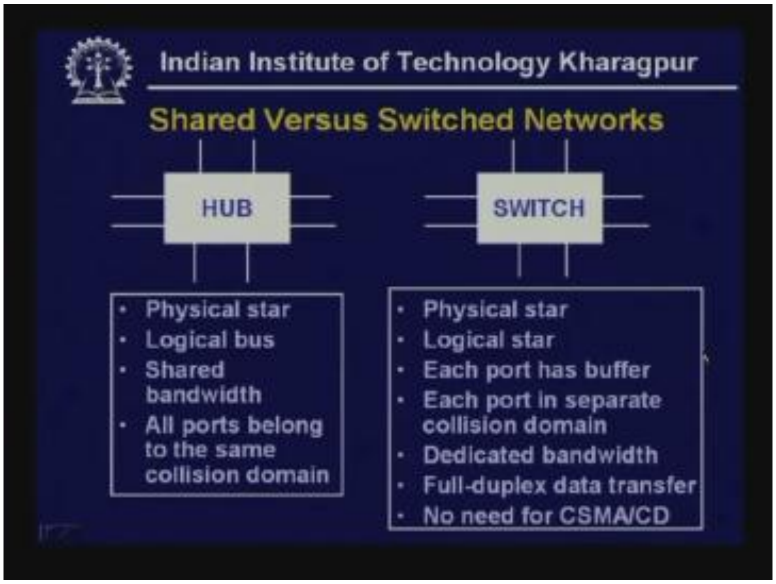

As you see here, this is the shared approach where you are using a hub so it is forming some kind of a physical star but logical bus. That means whatever signal is present here is also present on all the ports. That means on all the ports the signal is present so effectively you may consider it as a bus and all the ports are represented like this because same signal is being present on all the ports.

In other words it also shares the bandwidth. So here it is an 8-bit port, eight ports are there in this hub that means ten megabits per second is being shared by eight computers which can be connected to each of these links. So you can say the bandwidth is being shared and also we can say that all ports belong to the same collision domain. That means if two of this computers sends simultaneously, say, computer here and a computer here sends simultaneously then there is a collision. That means all codes belongs to the same collision domain and this is being overcome in this switched networks. Let us see how.

The switch is nothing but a fast bridge. We have already discussed about the function of a bridge. It functions not only as a physical star but also as a logical star, why, because if you connect a computer here and also connect another computer here then it becomes three computers or four computers, let's assume they are connected here so since it is a fast bridge this particular computer A can communicate with B and C can communicate with D simultaneously because each port has a buffer and a separate collision domain. That means the signal present here need not be present on all other ports. The signal present here is only transmitted to the computer where the destination station is connected and because of that each port has got separate collision domain, so collision domain here is separate. Earlier the entire ring was having the same collision domain but here the collision domains are restricted to each of these ports.

Also, each port has a dedicated bandwidth. that means if it is a 8-bit port essentially the bandwidth is eight megabits per second and another advantage of this switched approach is that whenever it is a hub we cannot full-duplex communication but here you can have full-duplex communication. Suppose A and B are having two pairs of wires then it can transmit as well as it can receive so both can transmit and receive simultaneously. So full-duplex communication is possible whenever you are using this switching technology.

Moreover, there is no need for CSMA/CD. The reason for that is since there is no shared medium there is no possibility for collision and as a consequence there is no need for CSMA/CD protocol for collision detection to get out of collision.

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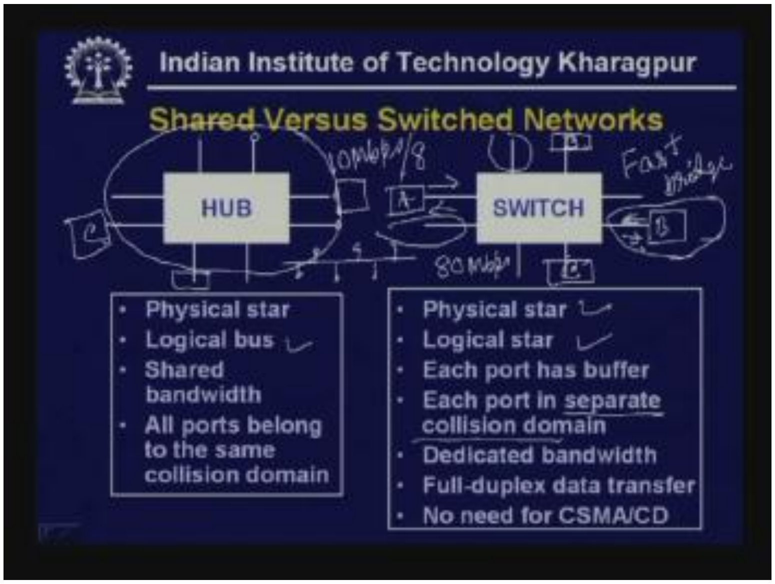

So here since they can communicate simultaneously among themselves the CSMA/CD function may not be needed. We know that in case of a switch ports are provided with buffer then switch maintains a directory with the address number and port number so based on the destination address the packet is forwarded to the particular port.

Each frame is forwarded after examining the address number and forwarded to the proper port number. Three possibilities exist in this particular case. The three possibilities are; in the first case it can be cut through. By cut through we mean, suppose this is the frame (Refer Slide Time: 26:14) then as we know there are starting delimiter and various other things then you have got a source address and destination address. Now, as soon as the destination address is available immediately it can be forwarded to the port without looking at the remaining part of the frame. This is known as cut through approach of forwarding.

However, whenever a frame is forwarded in this manner you cannot say that a frame is free from collision or from error. The reason for that is as you know for detecting collision it is necessary that the frame must be of 64 bytes but 64 bytes will be somewhere here so unless you receive 64 bytes you cannot give guarantee that the frame will not suffer in collision. That means you are forwarding a frame before receiving 64 bytes and as a result collision may not be detected so you may be sending a frame which will suffer collision.

Also, as you know the frame check sequence is present somewhere here near the end. So unless you receive the entire frame up to that part you cannot really detect collision, you cannot detect error. So whenever you receive up to 64 bytes then send and you can say that it is collision free. But in this case, frames are forwarded with error detection because you are not waiting till the end of the frame. However when you receive the entire frame buffer it, it detects error then if you find that it is error free only then forwards it which is known as fully buffered.

Therefore, depending on the three specific approaches it can be cut through, collision free and fully buffered. Obviously here the delay is minimum and in this case the delay is maximum.

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The reason is that you have to receive the entire frame, perform error checking then you can send it and this collision free has got some intermediate delays between minimum and maximum. In this case you have to receive after 64 bytes then forward it so these approaches are being used in case of switches, that is, whenever you are using the switching technique.

Now let us focus to the other approach. As I said the speed can be increased by increasing the speed of the data transfer rate. So, from 10 Mbps it can be enhanced to 100 Mbps. This is your Fast Ethernet.

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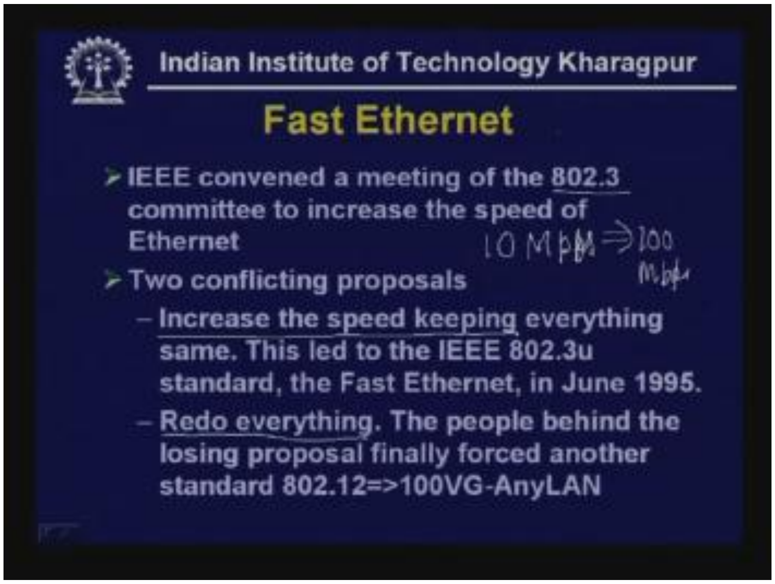

However, when the IEEE convened a meeting of the IEEE 802 committee to increase the speed of the Ethernet there were distinct proposals. Many people were not happy with their Ethernet because of the probabilistic nature of the transfer. As you know there can be unbounded delay, it is possible that a frame cannot be forwarded and cannot be transmitted, a particular frame may suffer many collisions so as a result it may not be sent to the destination.

Hence, to overcome this problem one group suggested redoing everything. However, another group suggested increasing the speed keeping everything the same and this led to standard IEEE 802.3u which is essentially the Fast Ethernet, it was proposed sometime in June 1995.

But another group suggested to simply discard the Ethernet scheme and propose a fully new standard which was known as 802.12 which is essentially 100 VG AnyLAN, data transfer rate is again 100 Mbps however it uses a completely different approach. Unfortunately this particular standard has not become popular. On the other hand, the Fast Ethernet has become popular because of the widespread deployment of Ethernet.

Let us look at the features of Fast Ethernet.

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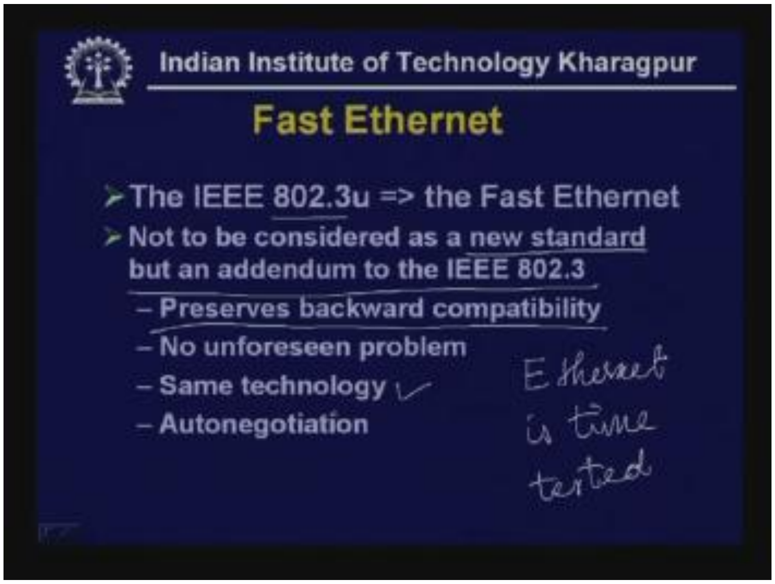

The IEEE 802.3u is the standard used for Fast Ethernet and it was not to be considered as a new standard but an addendum to IEEE 802.3. That means people considered it as an extension of IEEE 802.3 but not a new standard that means the frame format has been kept same, the minimum length and maximum length which is used in Ethernet has been kept the same so it preserves the backward compatibility. Since it preserves the backward compatibility and the Ethernet is already time tested there is no unforeseen problem and all the problems have been already sorted out so it uses the same technology at 802.3. However, some new features were added, one of them is autonegotiation.

Autonegotiation means network interface cards were provided with some additional functions. One is autonegotiation so it is backward compatible with Ethernet. That means with the help of this autonegotitation one can decide whether it will operate at ten megabits or at hundred megabits. That means a particular network interface card can support both ten as well as 100 megabits. That means Fast Ethernet switch can communicate with a computer which can operate at 10 and this can be operating at hundred. So you can see that this kind of incomptability is overcome by using this autonegotiation.

Also, it is provided multiple capabilities. It can transfer at 10 Mbps and also it can transfer at the rate of 100 Mbps. However, some changes are being made. Obviously the physical layer becomes little complicated so it added one additional sublayer known as reconciliation sublayer which essentially receives the data from upper layers and then transfers it to the medium independent interface in terms of 4 bits or and then the medium independent interface does the encoding and decoding.

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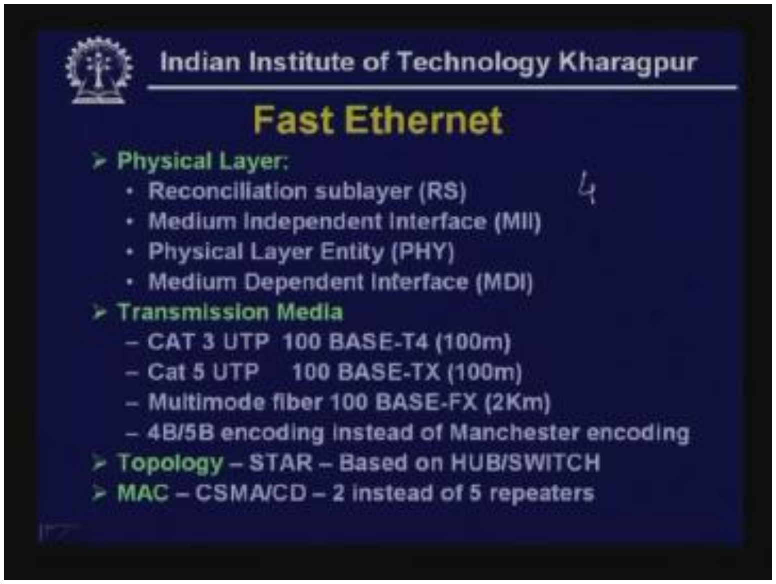

Then it has got a physical layer entity which is essentially in the medium independent layer that is being used in Ethernet then of course you have got medium dependent interface which essentially depends on the medium that is being used and here that the different mediums that is being supported by the Fast Ethernet. So it can use CAT 3 unshielded twisted-pair, CAT 5 unshielded twisted-pair and also it can use multimode fiber and so far as the topology is concerned it supports only hub or switch that means it does not support the bus technology which is used in Ethernet so it is essentially hub or switch based. Thus a hub or switch can have multiple ports and essentially it uses the star type of topology, it does not support the bus topology.

Then it uses CSMA/CD protocol. However, there is a need for minimum size of the frame or you have to reduce the size of the network so that the collision detection is ensured. As you know 64 bytes is used in case of Ethernet as the minimum size. So since it has retained the same size it had to reduce the number of repeaters so that using 64 bytes collision detection can be done only if two repeaters are being used in Fast Ethernet. Five repeaters used in Ethernet cannot be used in case of Fast Ethernet.

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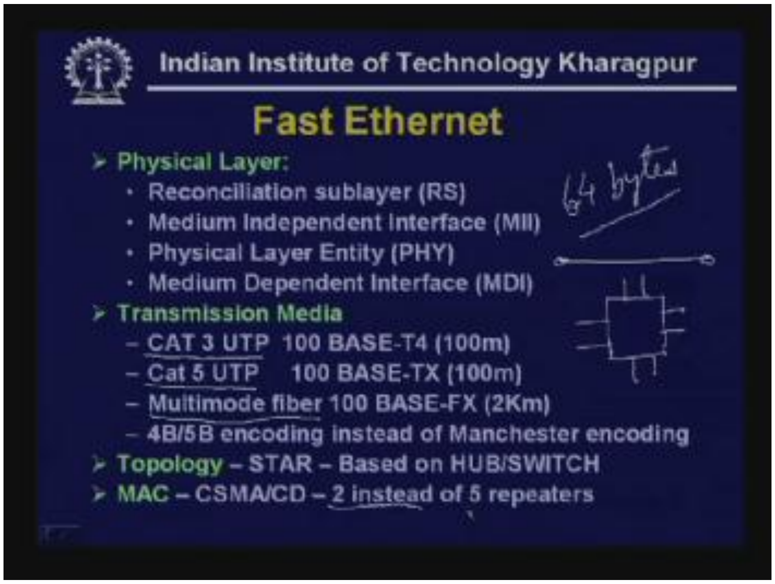

Here you can see various implementations of Fast Ethernet. There are two versions. One is a two wire and another is a four wire. So two wire version is mentioned as 100Base-X that means data transmission is baseband, the data transfer rate is 100 Mbps and the X stands for two wire communication.

On the other hand, there is 100BaseT-4 which is four wire communication. Let us see the four cases. First we shall consider the 100Base-TX, this is your 1000Base-TX (Refer Slide Time: 35:57) where that 4B by 5B block encoding is used. As you can see that reconciliation layer is supplying four bits at the rate of 25 Mbps, it is receiving it and converting it into 125 Mbps, this is the baud rate generated by the block encoder and then it is performing MLT 3 line encoder. The MLT 3 line encoder is essentially multiline transmission using three levels. So it uses plus 1, 0 and minus 1 levels and it is very similar to t inversion encoding.

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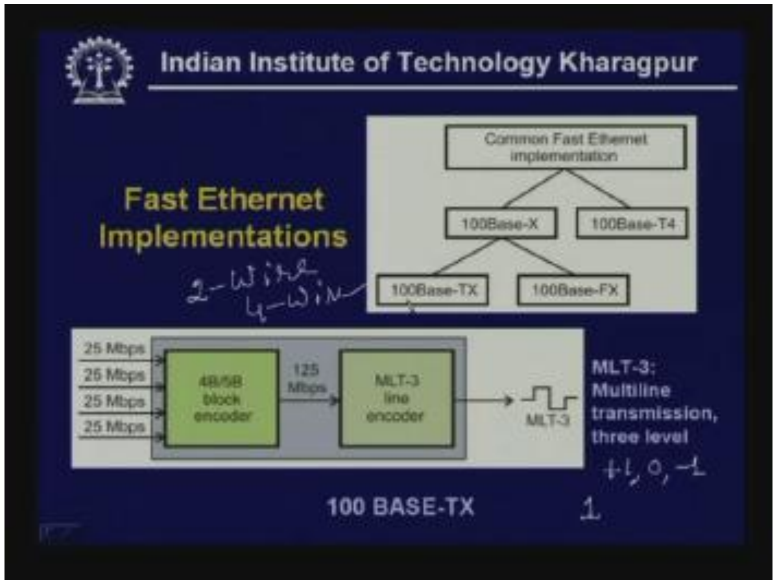

However, whenever 1 is encountered in the beginning of 1 it changes from plus 1 to 0 or 0 to minus 1 and so on. So it is very similar to that inversion encoding. However, there are three levels being used here in case of MLT three line encoder and this signal is being sent (Refer Slide Time: 37:12) in case of this 100Base-TX. The 100Base-TX uses CAT category 5 unshielded twisted-pair which can give a maximum length of 100 m.

On the other hand, hundred base FX where optical fiber is being used the NRZ-I inverse line encoding is used, the block encoding is same 4-bit by 5-bit encoding is being used so the baud rate is 125 Mbps. You may be asking, why Manchester encoding has not been used but instead of that four bit by five bit block encoding has been used. The reason for that is that if Manchester encoding is used the baud rate will be 200 Mbps so the cost of implementation will be very high. So to reduce the cost of implementation and to have lesser bandwidth this encoding is being done. However, by using this encoding it is possible to recover the clock, the clock synchronization is achieved as there is enough number of transitions in the signal.

In case of fiber optic medium instead of using MLT 3 encoding NRZ-I encoding is used as it is shown here so it has got two levels.

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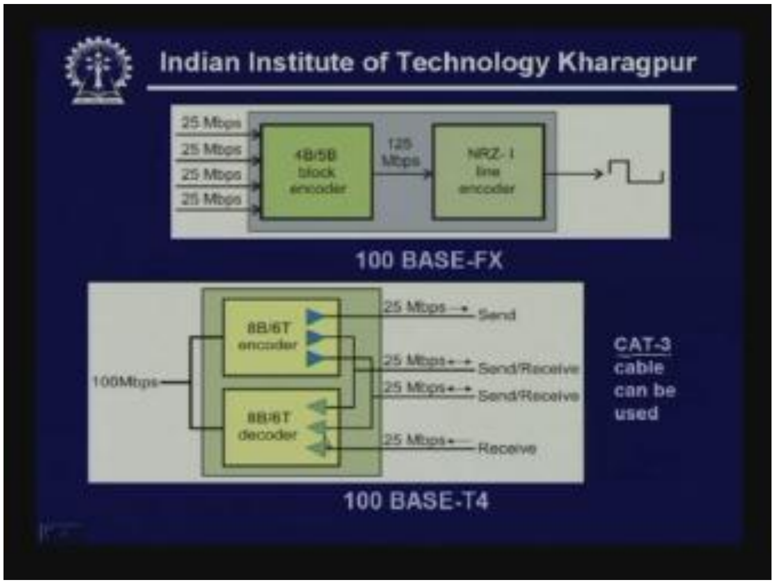

When you are using four wire you know there are many installations where category 5 is not present so Cat 3 cable is already present so if you want to utilize the existing cables then you can go for this 100BaseT-4. Here as you can see that 100 Mbps signal is converted, each eight bit is converted into six bit so eight bit by six bit encoding is being used and this is being sent where you will require four pairs of wires.

However, to reduce the cost of implementation it uses four pairs of wires and as you can see there are two 25 megabit ports; one is exclusively sent or transmit, another is exclusively received and two ports are bidirectional send and receive. So, these two are used for collision detection purposes. On the other hand here (Refer Slide Time: 39:43) you can use both transmit and receive. So, by using four pairs you can transmit at the rate of 100 Mbps and you can use category 3 cable.

Therefore, these are the three different types of physical media that is being supported by Fast Ethernet. In 1995 Ethernet captured 86% of the total market that means Fast Ethernet became very popular and as a result there was a need for enhancing this technology. You may be asking why this Ethernet became so popular. First the Ethernet was proposed then Fast Ethernet was proposed, both were compatible they can be used simultaneously and the result for their success was high reliability which is even today, availability of management and troubleshooting tools, it is highly scalable, you can very easily expand the network, cost of implementation gradually reduced and switch cost per-port reduced continuously with time.

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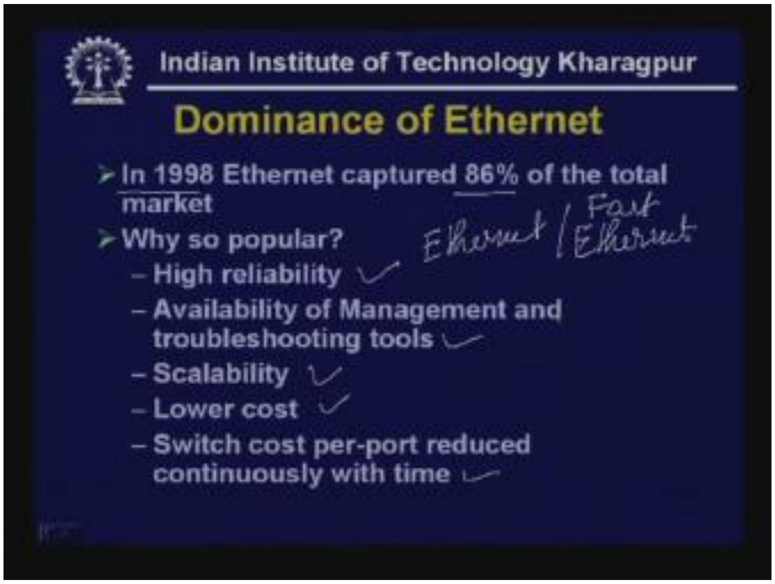

That means because of the widespread deployment the cost of implementation become very small in case of Ethernet and as a result FDDI and ATM which were used in the intermediate period gradually faced out taken over by Fast Ethernet technology. So FDDI and ATM which can be considered as second generation high speed local area networks were gradually replaced by Ethernet.

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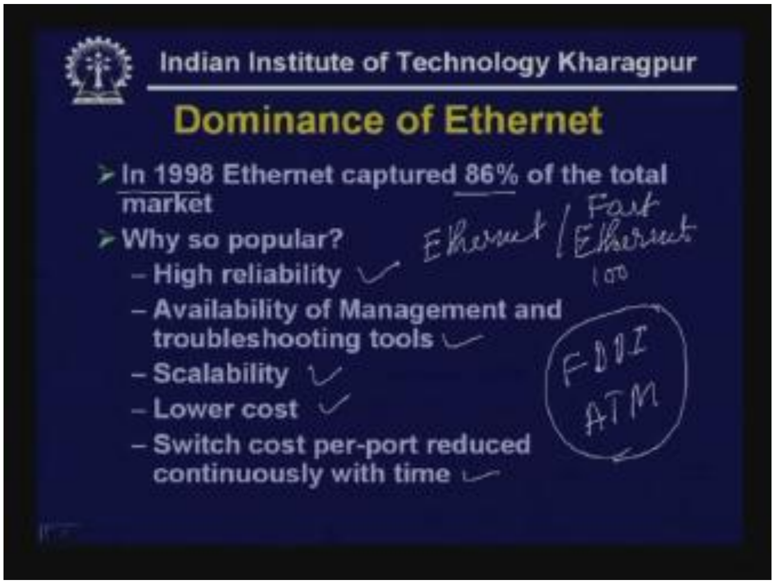

However, 100 Mbps were not found to be adequate so a new standard was developed which is essentially known as Gigabit Ethernet. The key objectives of this Gigabit Ethernet were higher speed network at the backbone level which can support data rate of

1000 Mbps. So, to retain backward compatibility again the frame format were kept same minimum and maximum frame sizes and also it allows both half-duplex as well as full-duplex operation. Normally full-duplex operation is used. However, to maintain backward compatibility half-duplex is also supported. So it uses CSMA/CD with at least one repeater with collision domain diameter of 200 m.

In case of Ethernet the number of repeaters were 5, in Fast Ethernet it was reduced to two and in case of Gigabit Ethernet it has been reduced to only 1 so that the collision detection is possible. It uses only star wired topology that means no bus topology is supported here, it is again based on hub or switch and multiple ports are provided on this hub or switch.

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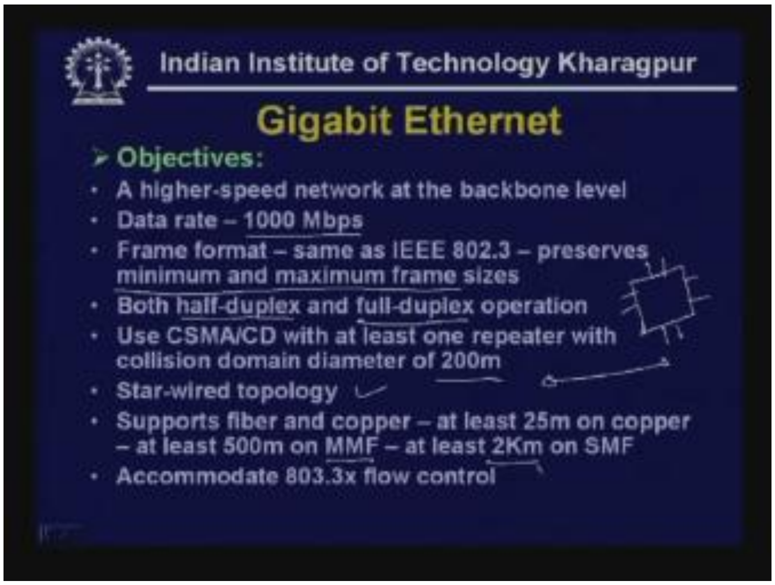

It supports fiber as well as copper, at least 25 m on copper and at least 500 m on multimode fiber and at least 2 km on single mode fiber. And also it has added some features which are not present in Ethernet or Fast Ethernet known as flow control. These are the functional elements of the Gigabit Ethernet technology. So, as you can see the physical layer has got several alternatives several layers medium access control MAC layer, full-duplex or half-duplex, gigabit media independent layer then there are other functionalities which are performed, it reduces 8-bit by 10-bit encode decode whenever it is in that two wire transmission. On the other hand, whenever it uses four wire transmission then it is 1000BaseT and encoding decoding is different.

In thousand base LX it uses long web optical fiber and in thousand base SX it uses short wave optical fiber and thousand base CX it uses shielded balanced copper 120 ohm balanced copper and in 1000BaseT it uses category 5 UTP so it supports four different transmission medium and the standards are referred to as 802.3z physical layer for these cases and in case of this thousand base T it is referred to as 802.3b physical layer.

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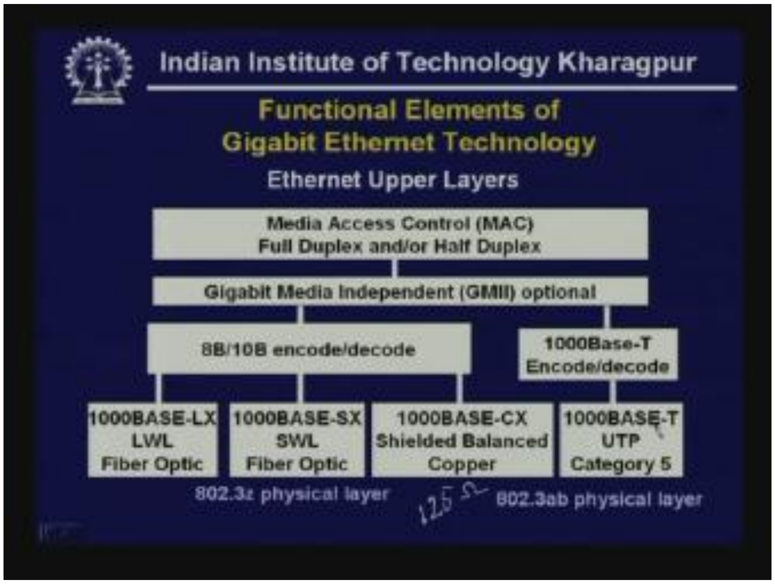

Now, to provide more flexibility one important functionality known as Gigabit Ethernet interface carrier has been introduced by the developers of Gigabit Ethernet and this GBIC Gigabit Ethernet Interface Carrier allows network managers to configure each port on a port by port basis. That means you can use 1000Base-CX on one port, 1000Base-T on another port, 1000Base-SX on another port and 1000Base-LX on another port supporting different types of LANs using different types of optical fiber and laser. As you can see here the thousand base SX uses 780 nanometer laser and 1000Base-LX uses 1300 nanometer laser.

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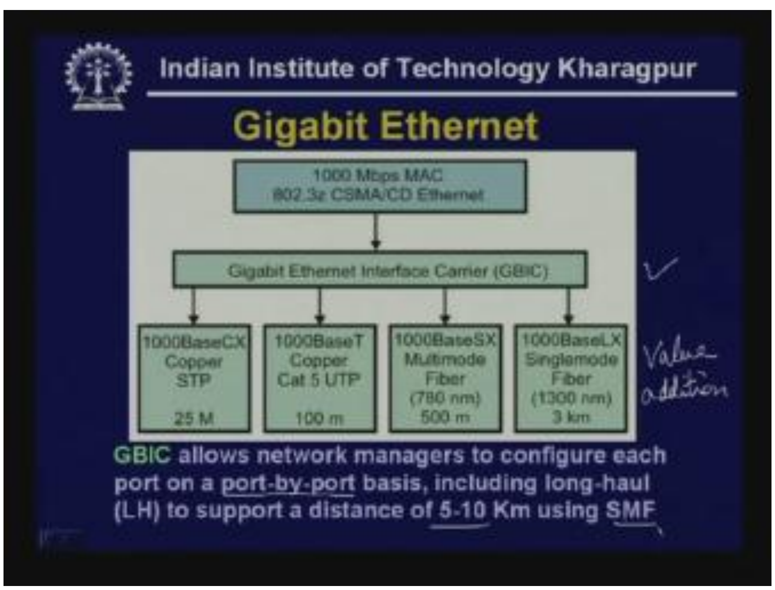

In addition to that there is some value addition. This value addition is done by providing another standard, another medium that is long haul LH medium that supports a distance up to five to ten kilometer by using single mode fiber. Therefore, even by sending data at the rate of 10 Mbps you can send up to a distance, that is, you can send up to 5 to 10 Km so this is definitely a very big advantage of Gigabit Ethernet network.

Now let us look at the encoding techniques that are being used in Gigabit Ethernet.

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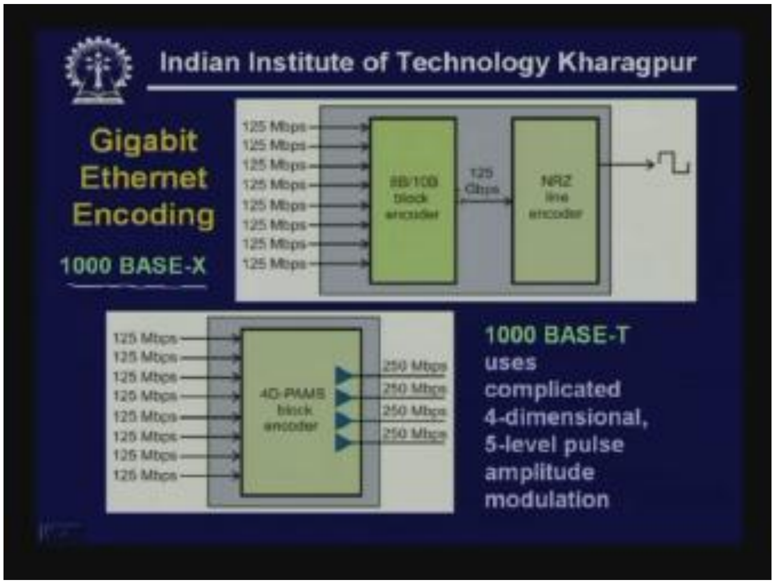

So you can see here this thousand base X as I was telling which uses two pair wire networking either copper or optical fiber receives 8-bit from that reconciliation layer then it performs 8-bit to 10-bit block encoding so that synchronization is possible. Here the data rate you get is 12.5 Gbps so there is (( )) decimal point and this is the baud rate and it uses energy at line encoding to send data on the optical fiber or copper whatever it may be.

On the other hand, when this four wire cabling is being used that uses category 5 cable as you have seen, the Cat 5 UTP. In that particular case, a very complicated encoding technique is used known as, 4D four dimensional five level pulse amplitude modulation. That means it receives the eight bits from the reconciliation layer at the rate of 125 Mbps then this complicated encoding is done to transmit data on four wires and it can support up to 25 m. So up to 25 m this four wire cabling can be done for short distances. Otherwise we can use shielded twisted here which can also use 25 m that is 10000Base-CX or you can use optical fiber to support up to 100 m or 500 m or 3 km or it can be 5 to 10 Km.

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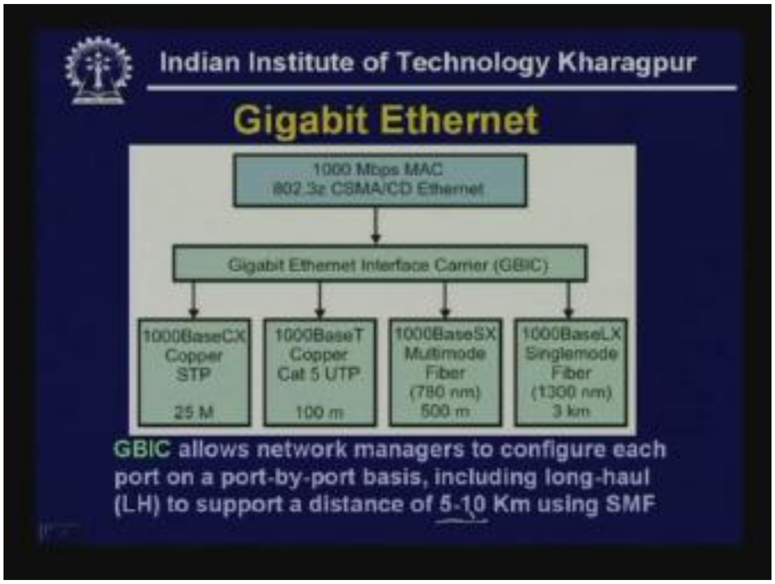

These are the key features of Gigabit Ethernet. It is not simply Ethernet running on 1000 Mbps so it is not just the extension of speed it has added many more features. First of all it has to do carrier extension.

As I mentioned that although it uses a sixty four bytes of minimum packet size that is not enough for detecting collision when you are transmitting at the rate of 10 Mbps. in such a case you have to use 500 bytes. However, the frame can be of sixty four bytes and carrier is extended to five hundred twelve bytes to achieve two hundred meter collision domain keeping the minimum frame size as sixty four bytes.

And also another feature has been added which is known as frame bursting. After the slot time it allows additional frame transmission because it is sending at a fast rate. Once a token has been grabbed, instead of sending just one frame at a time it can keep on sending multiple frames after the slot time is over. Then it can use buffer distribution, all incoming frames are buffered in first in first out order which is another feature added and also it does flow control using X-ON X-OFF protocol which is not present in Fast Ethernet or Ethernet.

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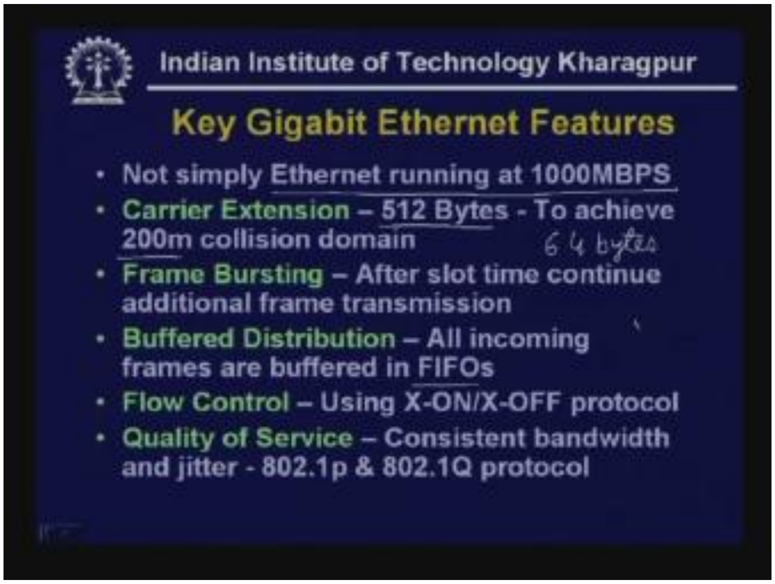

Since it is using full-duplex communication this X-ON X-OFF protocol can be supported. For example, this is the X-ON X-OFF protocol.

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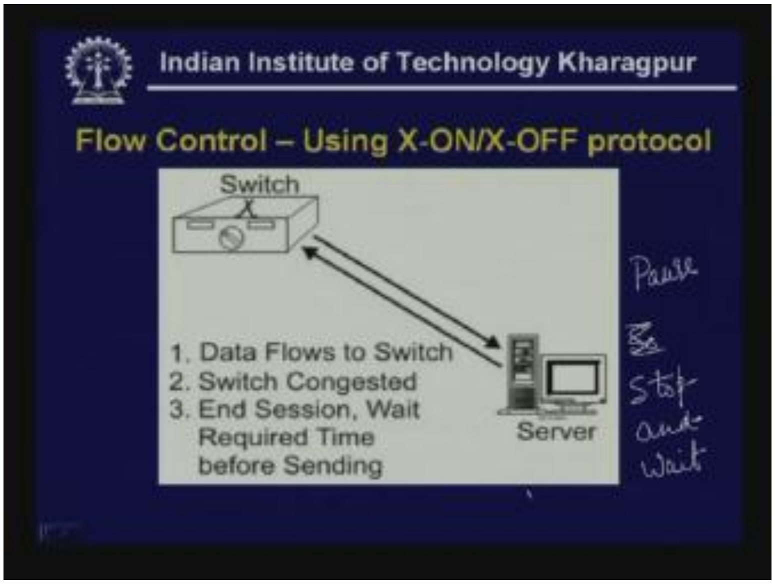

So this is the switch and this is the server. Suppose the server is sending data at a very high speed the data is going to the switch then unfortunately the switch is not able to transfer the data that means it is buffering the packets but the other stations which are connected to it are not able to receive at that rate so the switch is getting congested so in the reverse direction it will send a false frame and after receiving that false frame the server will end session and wait required amount of time before sending. It is somewhat like stop-and-wait protocol that is being used for flow control. The same is being implemented by using this full-duplex line which is known as X-ON X-OFF protocol.

Moreover, in Ethernet and Fast Ethernet there is no quality of service. the reason for that is because of the CSMA/CD protocol it is probabilistic, there can be unbounded delay, there can be loss of frame which cannot be accepted in many applications particularly in real-time applications so quality of service has been added to this standard in case of Gigabit Ethernet to support consistent bandwidth and jitter and the standards are named as 802.1p and 802.1q. By following these standards the quality of service is maintained by Gigabit Ethernet so that the Gigabit Ethernet can support real-time traffic like voice and video which cannot be supported by Ethernet.

What are the typical applications of Gigabit Ethernet?
These are the areas where Gigabit Ethernet can be used. We can upgrade switch to switch links. For example, you have got two switches which are Fast Ethernet switches, these two can be linked with the help of a Gigabit Ethernet switch and these are known as uplink ports. With the help of these uplink ports which are provided as Gigabit Ethernet port you can do these kinds of links as shown here.

Upgrading switch to server links: for server which can transmit at a high rate you can have Gigabit Ethernet network interface card and then link it to a gigabit port of the switch. This is where Gigabit Ethernet can be used.

Upgrading the switched Fast Ethernet backbone: Suppose this switch (Refer Slide Time: 53:25) was earlier a Fast Ethernet switch it can be replaced by a Gigabit Ethernet switch which will form as a backbone network.

Upgrade a shared FDDI backbone: As I said FDDI is more or less an outdated concept now, not being used in practice so this can be replaced by Gigabit Ethernet switches.

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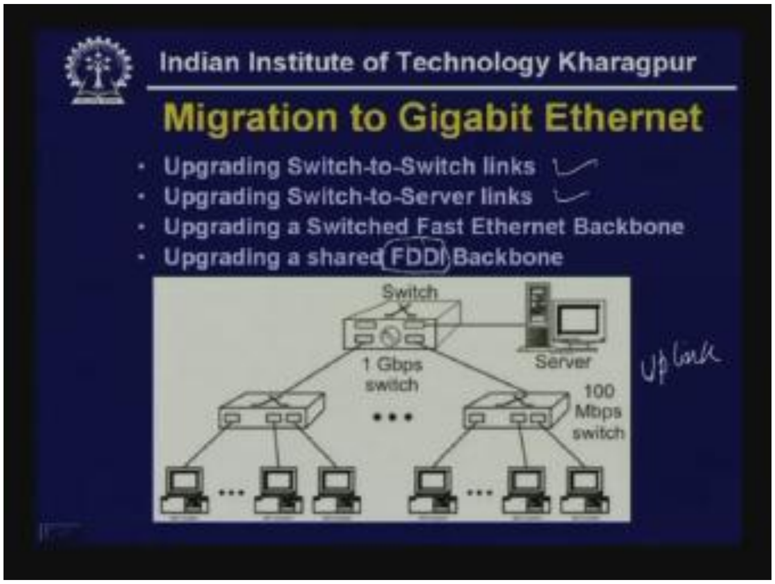

These are the typical applications where Gigabit Ethernet can be used and migrated in the Fast Ethernet network or FDDI network. Now it is time to give you the review questions.

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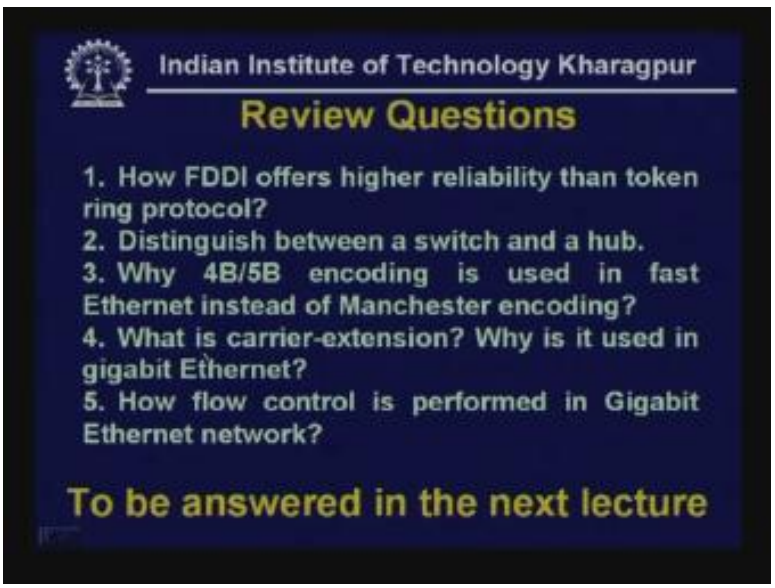

1) How FDDI offers high reliability than token ring protocol?
2) Distinguish between a switch and a hub.
3) Why 4B by 5B encoding is used in Fast Ethernet instead of Manchester encoding?
4) Why what is carrier extension? Why is it is used in Gigabit Ethernet?
5) How flow control is performed in Gigabit Ethernet network?
Here are the answers to the questions of lecture minus 28

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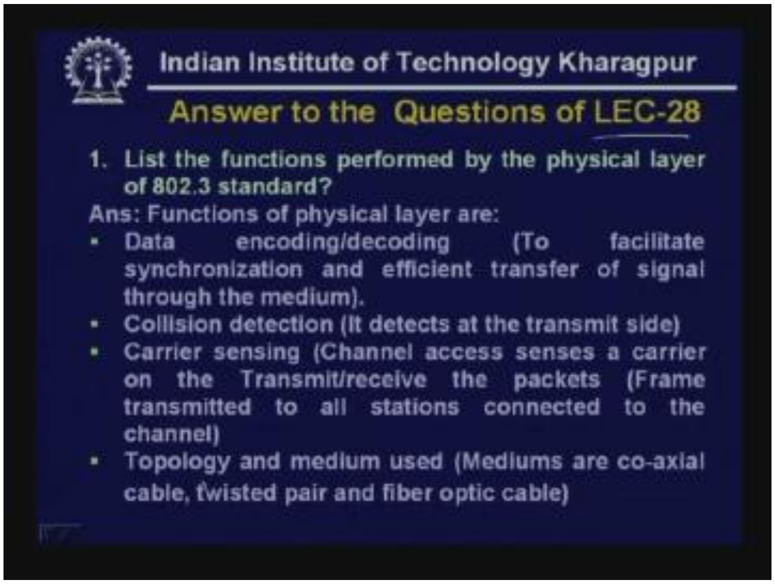

1) List the functions performed by the physical layer of 802.3 standard?
Functions of the physical layer are:

- Data encoding and encoding to facilitate synchronization and efficient transfer of signal through the medium
- Collision detection
- carrier sensing and
- It also decides the topology and medium to be used, this is the function of the physical layer.

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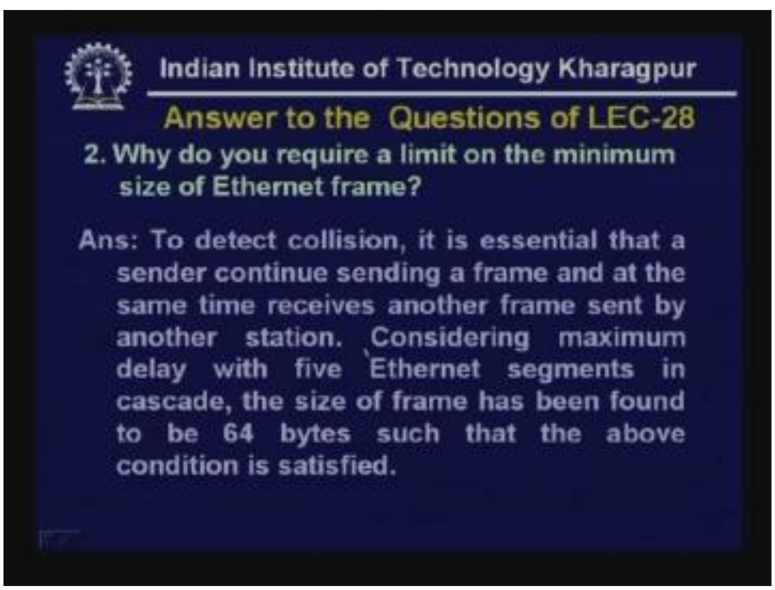

2) Why do you require a limit on the minimum size of Ethernet Frame?
As I mentioned, to detect collision it is essential that a sender continues sending a frame at the same time receives another frame sent by another station, that's how collision is detected. So, considering maximum delay with five Ethernet segments in cascade the size of frame has been found to be 64 bytes such that the above condition is satisfied.

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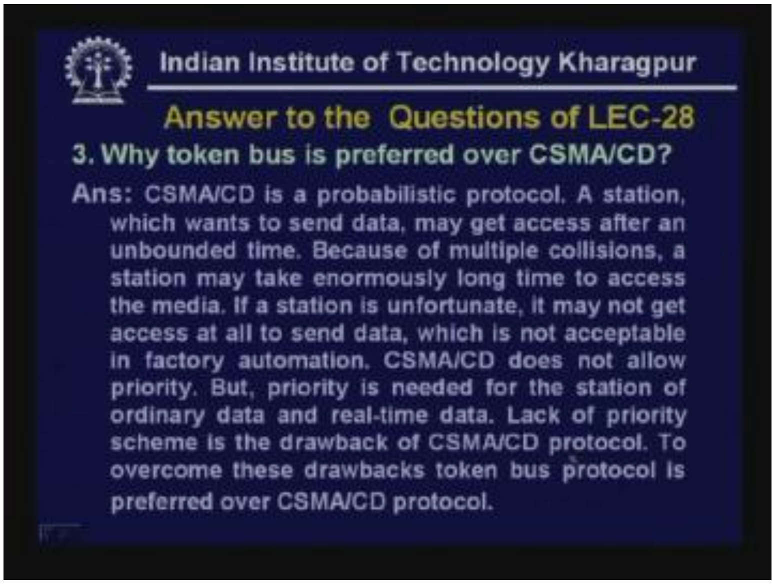

3) Why token bus is preferred over CSMA/CD?
CSMA/CD is a probabilistic protocol. A station which wants to send data may get access after an unbounded time. Because of the multiple collisions a station may take enormous time to access the media. If a station is unfortunate it may not get access at all to send data which is not acceptable in factory automation. So CSMA/CD does not allow priority. But priority is needed for the station so that ordinary data and real-time data can be transmitted. So, lack of priority scheme is the drawback of CSMA/CD protocol. So to overcome these drawbacks token bus protocol is preferred over CSMA/CD protocol but not always.

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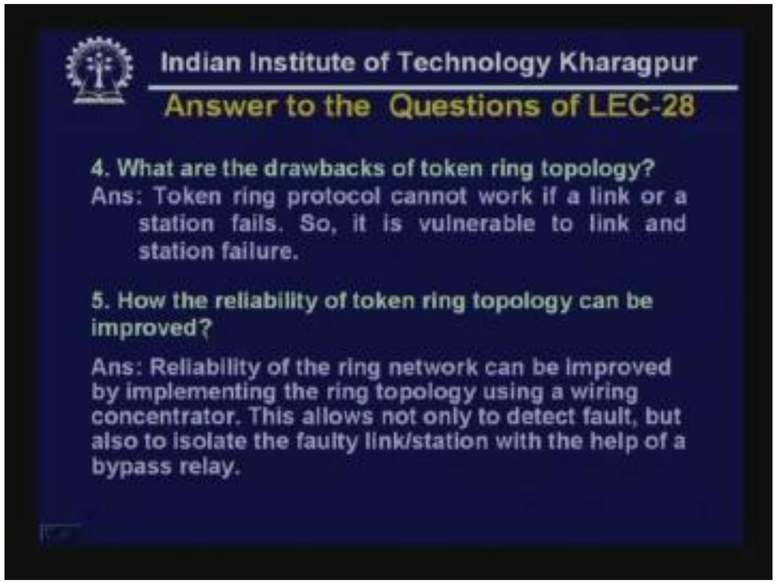

4) What are the drawbacks of token ring topology?
Token ring protocol cannot work if a link or a station fails. There is no built in reliability added provided in token ring so it is vulnerable to link and station failures. This is being overcome in FDDI.

5) How the reliability of token ring topology can be improved?
Reliability of ring topology can be improved by implementing the ring topology using a wiring concentrator as you have seen and this allows not only detecting fault but also isolating the fault link or station with the help of a bypass relay.

So here are the answers of the questions given in lecture - 28 and with this we conclude our discussion on high speed local area networks and this lecture we have discussed FDDI, Fast Ethernet, Gigabit Ethernet and also the concept of switched local area networks. In the next lecture we shall discuss the wireless LAN, thank you.