Real-Time Systems

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Lecture No. # 32

Few Basic Issues in Real-Time Communications

Good morning. Let us get started, last class we were discussing some basic introduction to Real-Time Communications .We were contrasting it with traditional communication and then we were looking at its applications quality of service issues and so on.

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Today, we will continue from that point and we will look at few basic issues in real-time communications. So, this we were just started to discuss the last time about the traffic in a real-time network. And we were mentioning that we will find three main categories of real-time traffic: one is the CBR traffic at the Constant Bit Rate traffic which is the majority of the traffic in a real-time network and then we have Variable Bit Rate traffic and some Sporadic traffic which very rarely arise.

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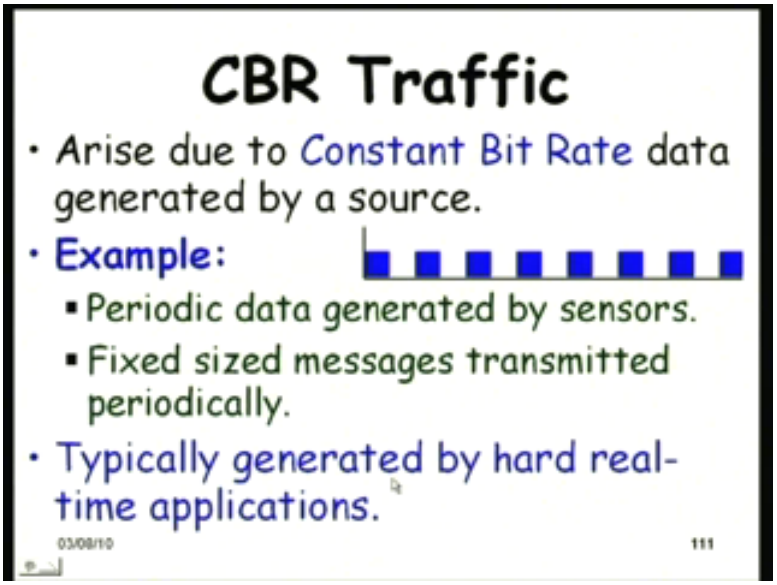

The constant bit rate data is generated by several types of sensors and also the commands to the actuators they are also in terms of constant bit rate. Overtime you see constant size data is being transmitted on the network.

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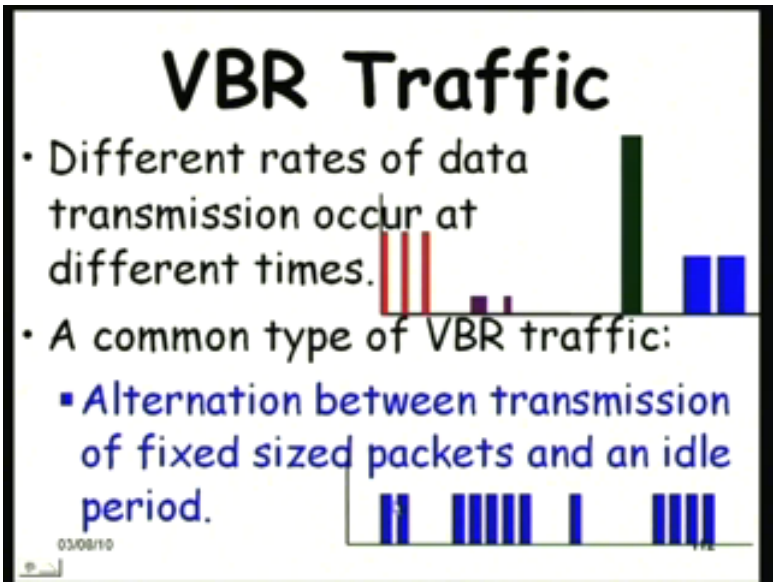

And then we were discussing about the variable bit rate traffic where the rate of data transmission or the size of data transmit generated by the source .I think that would be more appropriate the size of the data generated by the source varies at different times. So, at some time we have very small amount of data to be transmitted and some other

time we have large amount of data generated at the source needs to be transmitted. The common type of variable bit rate traffic encountered in a network is on-off traffic where there are fixed sized packets generated or nothing is generated. So, for some time there will be no data to transmit it will be idle period and sometime the data generated by the source is a constant size. This is the example where the data that is generated by the source is constant, but they arrive very randomly.

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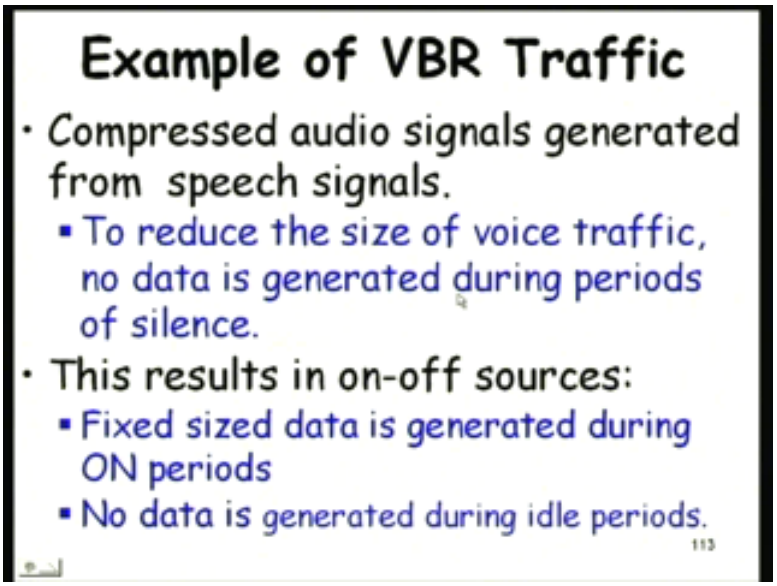

We were just started to discuss that last time about practical example of such traffic that is compressed audio signals. Typical traffic that is generated from a audio signal follows this pattern even video signal. Video signal will be slightly different to reduce the size of the voice traffic no data is generated when there are periods of silence and we were mentioning last time .That This is the one of the reason why packet-switched voice transmission is effective .No packets need to be transmitted when there are periods of silence. And it is surprising to know that when persons talk more than half the time it is silent. So, this result in on-off sources fixed sized data is generated during on period and no data generated during idle period, but if it was either a circuit switched or a point to point network then the entire bandwidth will be reserved for such traffic.

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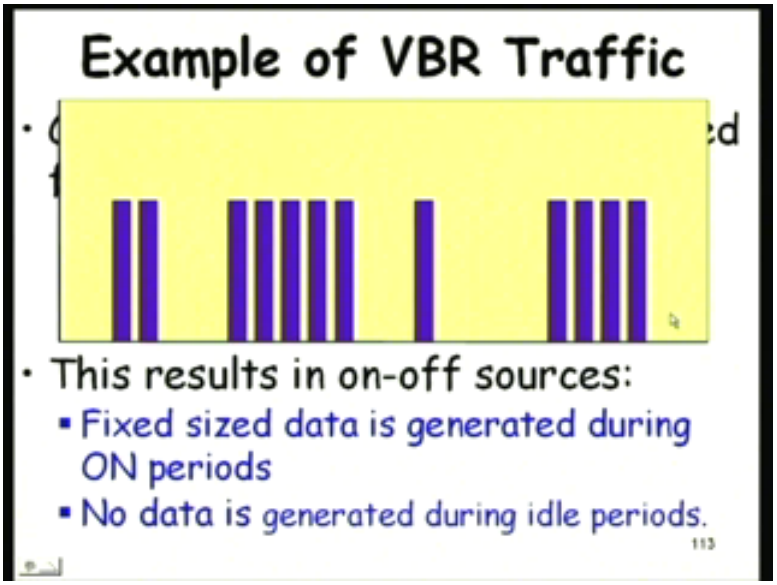

But here, the packet-switched network the VBR traffic can be efficiently handled and that is possibly the reason why we have VOIP etcetera becoming very popular and low cost .One of the advantages is that, no data is transmitted when there are periods of silence nothing to transmit no channel is held up for a communication . What do you think the other advantage general question? Why is the VOIP (( )) Bandwidth (( )) bandwidth requirement for transmission will be small. Why is that why bandwidth requirement is small?(( )) it can transmit more data over (( )) you do not have to transmit throughout you know continuously.

That is what we are saying that the channel is said when there are no data to transmit do not transmit that time the other people can transmit. So, it is one reason or there any other reasons .I mean just see that the cost of the telephony has just dropped drastically. One of the main reasons is this packet-switched transmission and VOIP costs nothing you know that. Only the cost for a broadband service or something.

So, just think of it, because it is not attend to our course really. Just think of it. There are many other reasons why the cost has come down. So, let us proceed a variable bit rate traffic fixed sized packets are generated or nothing is generated at all .This is one type of variable bit rate traffic. We were discussing a general concept of variable bit rate traffic where the size of the data was varying and that to they were generated a trend of times.

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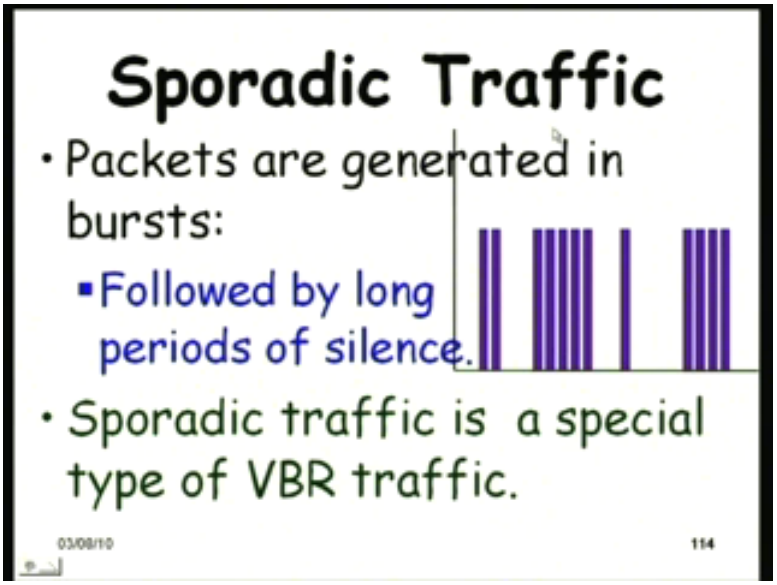

Another category of traffic you will find in the network is the sporadic traffic where packets are generated in bursts and then there are periods of silence.(( ))I think this diagram is bit inappropriate here. Actually we should have long periods of silence and the data size also should vary this diagram is inappropriate here. I think I will have another example here. That data the example there is not appropriate.

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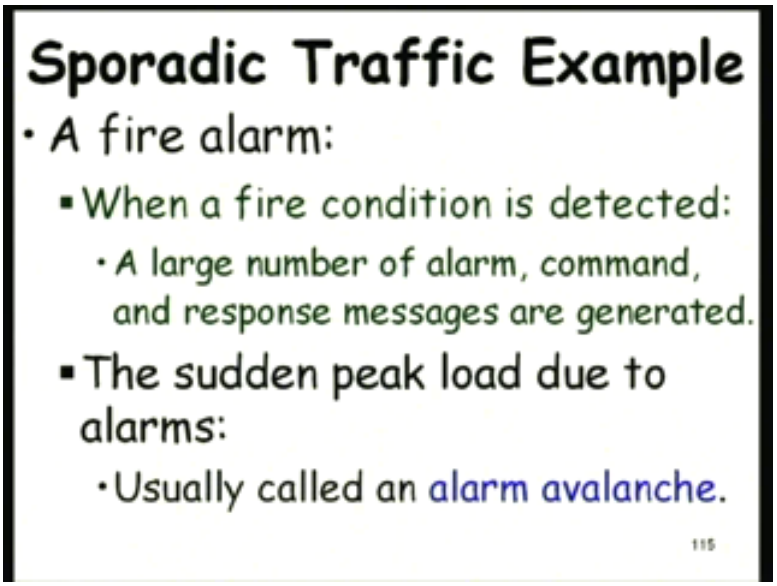

One example of a sporadic traffic is a fire alarm where very rarely a fire condition is detected, but once it is detected large number of alarm commands are sent out. There are response messages from these and may be action to be taken by sprinkler and so on. So,

suddenly there is a peak load suddenly the load increases due to alarms called an alarm avalanche.

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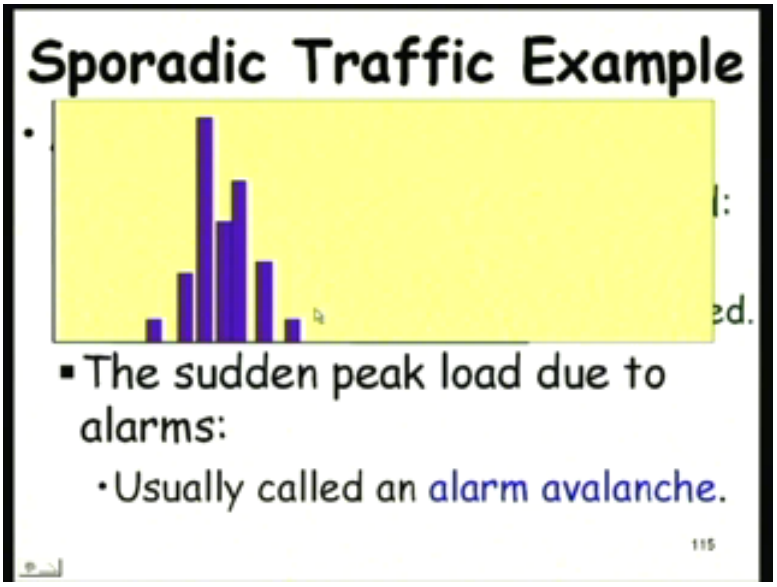

So, you would get a scenario like this. The suddenly there is periods of silence and suddenly you have burst of traffic occurring the alarm avalanche. This should be the appropriate example for a sporadic traffic and not the other one. That was by mistake got inserted there.

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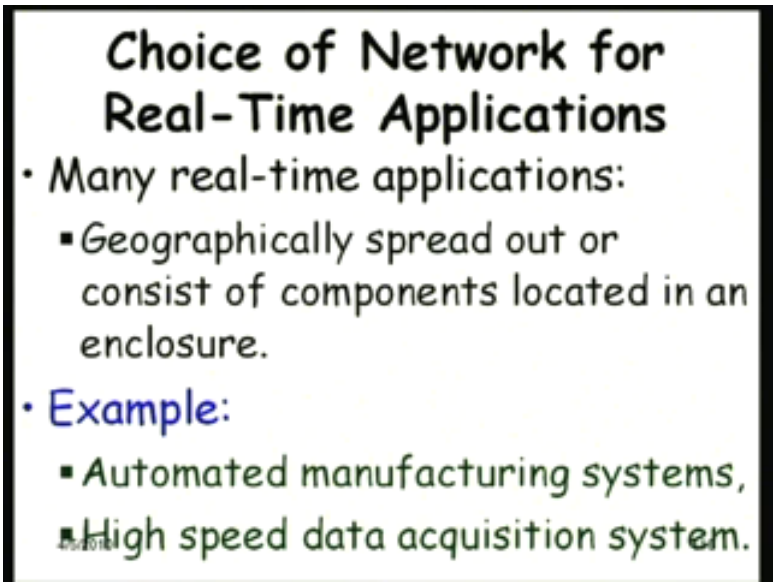

Now, let us see what are the choices of networks for real-time applications are(( )) sporadic traffic and the special case of variability (( )).Just sporadic traffic and the

variable bit rate traffic there are many similarities between them, but possibly what we can say is that ,for a sporadic traffic we are sure that once there is a burst another burst will not occur immediately whereas, a sporadic it can be even occurring throughout. I mean even the channel can be held up for the entire the maximum size that can be generated may be they can get generated continuously. But here for a sporadic it is a burst and once it occurs we know that it will not occur immediately. There is a difference minor difference between a sporadic and a variable bit rate traffic. As we were discussing to start with real-time applications are becoming spread out geographically, because the data sources are located at difference places or sensors are placed in different locations.

And also even when they are not geographically spread out they may be components which are located in an enclosure. For example, let us say car or a room that is automated or something. Even though they may not be geographically spread out, but there will be various components in an enclosure which need to communicate. There are two scenarios here that we will be addressing one is a geographically spread out another is there located almost the same enclosure different components communicate. There are many examples of such applications automated manufacturing systems we had discussed about these high speed data acquisition systems.

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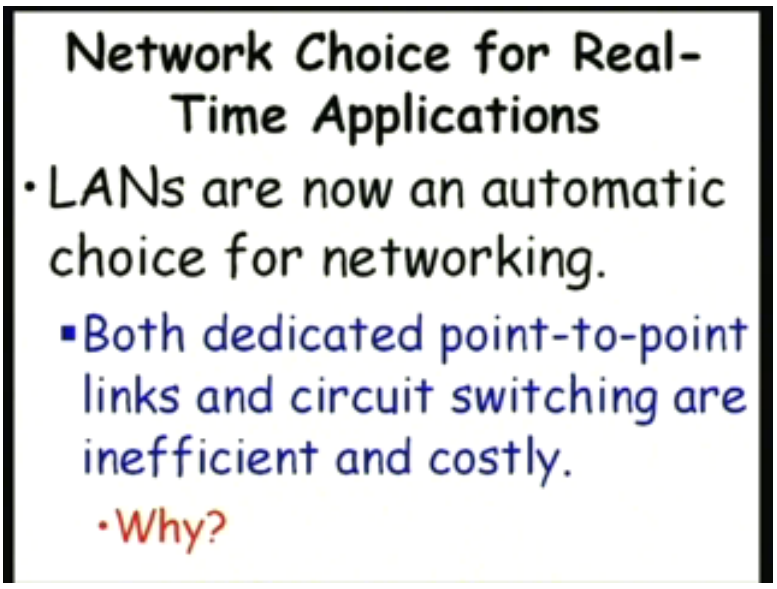

Now when they are not really spread out over a very large area which is normally the case they are spread over limited area Local Area Networks is an automatic choice for networking. In older times they are used to be point -to- point links and circuit switching these were popular when different components need to communicate use to have either connect them point to point or use circuit switching. They are inefficient and costly why is that. Why is point to point is is links and circuit switching inefficient and costly.(( ))

Exactly, there are many reasons if our point to point we will see that there are many disadvantages and even for a circuit switched whenever a connection is set up the entire bandwidth is reserved for it. I mean the allocated bandwidth even though it may not use that. So, it is inefficient.

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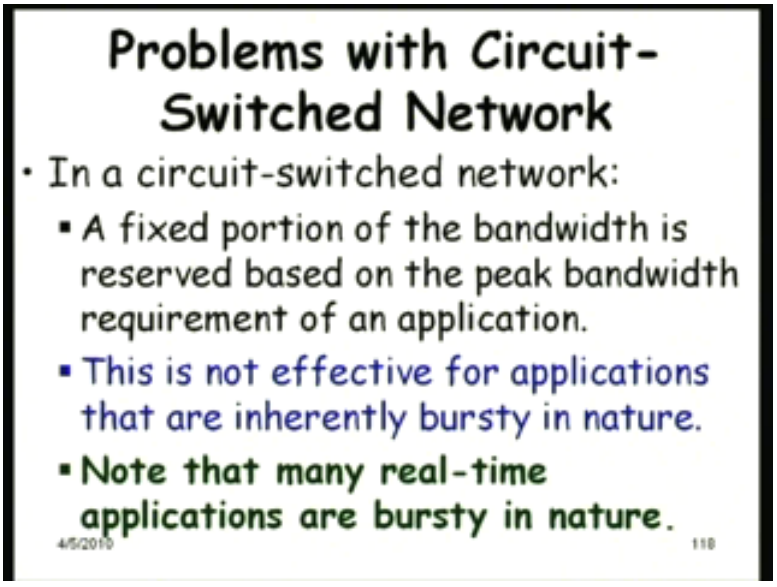

Let us see the problems with circuit switched network a fixed portion of bandwidth is reserved based on the peak demand and if the bandwidth requirement is constant then circuit switched network is All right, but that is rarely the case very rarely you will find that no the data is entirely constant.

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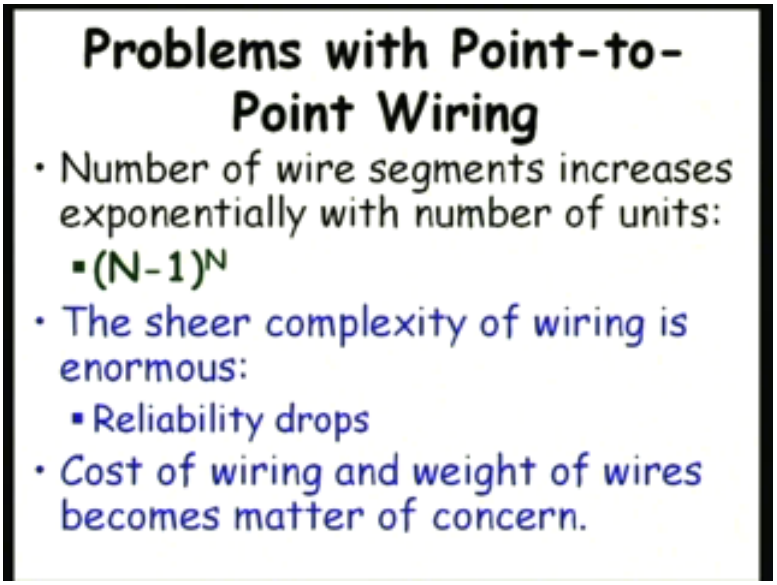

And many times the data is burst in nature .Similarly with point to point networking there are problems .The one of the main problem is that the number of wire segments increases exponentially with the number of units. If there are N units to be connected by point to point wiring the number of lines wire segments you will require is N minus one to the power N .Do you agree with this. Why is N minus 1 to the power N.(( )).

So, each component needs to be connected with a wire to N minus one other units and there are N such units. N minus one into N minus one N such multiplications which leads to N minus one to the power N number of wire just see it has reason exponentially and that to really really fast. And when the number of component increases that is complex systems has the systems are nowadays, the complexity of the wiring becomes enormous and naturally reliability drops. Somewhere has become loose wire is cut and it looks like a mess up wires and if somewhere there is a problem, it becomes very difficult to deduct which wire has snapped or is loose and not only that .It has low reliability and maintenance is a problem, but also the cost of wires is a matter of concern, but you put so many wires and connect them. Also the weight of these wires becomes very significant and we are talking of embedded applications and inside one enclosure. It becomes very difficult to continue with point to point wiring.

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In embedded applications one network type of network that evolved was the Controller Area Networks obtained or CAN which we will discuss briefly and then LANs are very popular and then of course, Internet there is an example of a wide area network is also.(()).We are discussing about bank transactions is not it. They will occur on internet or even you want to control some sensors on the internet from different places it is possible. So, internet is also is used heavily in setting of real-time communication.

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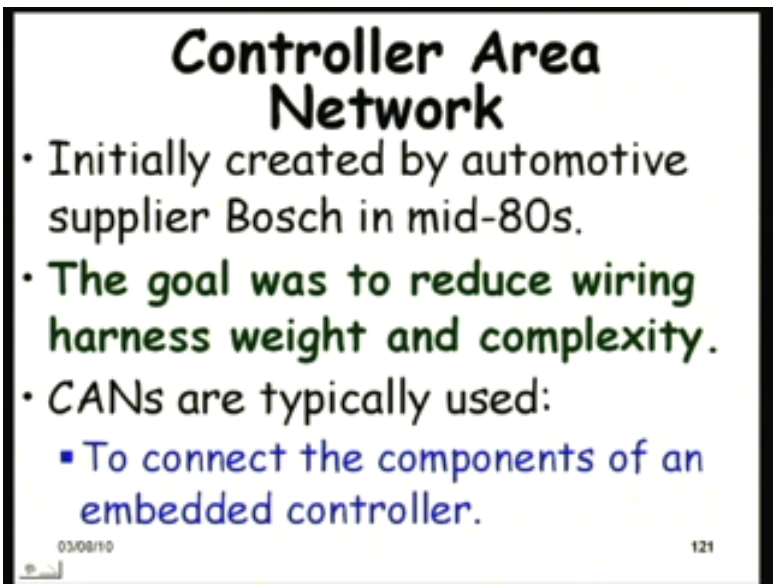

First let us look at the controller area network. Initially created by the automotive supplier Bosch a German manufacturer of automotive components in mid-80 about 25 years back. So, the goal was to reduce wiring harness weight and complexity. Wiring harness is the set of all the wires that have been used and as the number of components were increasing the manufacturers were observing that the weight is becoming enormous and the complexity of wiring is also becoming very bad resulting in low reliability as we are discussing just few minutes back. So, the CAN evolved and is heavily used to connect components of an embedded controller and nowadays not restricted to automotive segment alone used in various others places. For example, a ship or may be some embedded and (( )) UNIX and so on.

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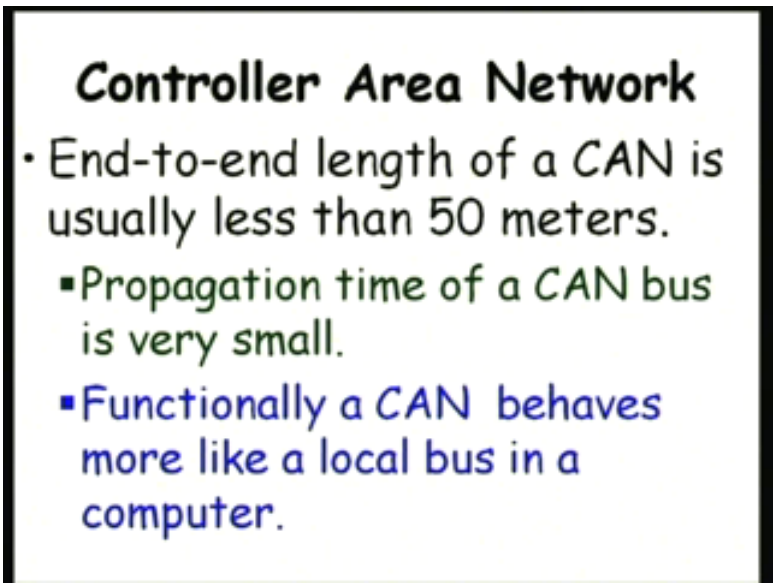

The end- to-end length of a CAN is less than fifty meters, because you know this work in small enclosures and as a result the propagation time of a Controller Area Network bus is very small. I think yesterday we were just mentioning that the propagation time of electromagnetic signals is one kilometer per five microseconds or something some data we are mentioning. For fifty meters the transmission time will be in nanoseconds. So, when the transmission time on the bus is nanoseconds, it is more like a local bus in a computer.

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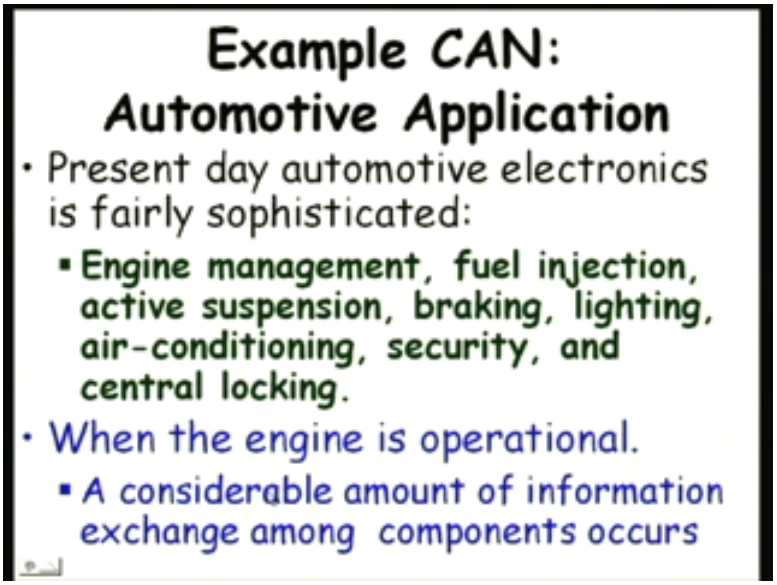

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Now let us just take and try to understand CAN through an example of an automotive application .The present day automotive electronics is sophisticated for example, a car on the road will have dozens of processors there called ECU Electronic Control Units. They control various aspects of a car. For example there may be electronic control units for engine management for fuel injection and these has become now compulsory for all cars to have automated fuel injection controlled by a processors .Active suspension, braking, lighting, air-conditioning, security air central locking all these are controlled by electronic components and which are need to communicate with each other and. they are interconnected using a CAN bus when the engine is operational lot of information is exchanged among these various ECU.

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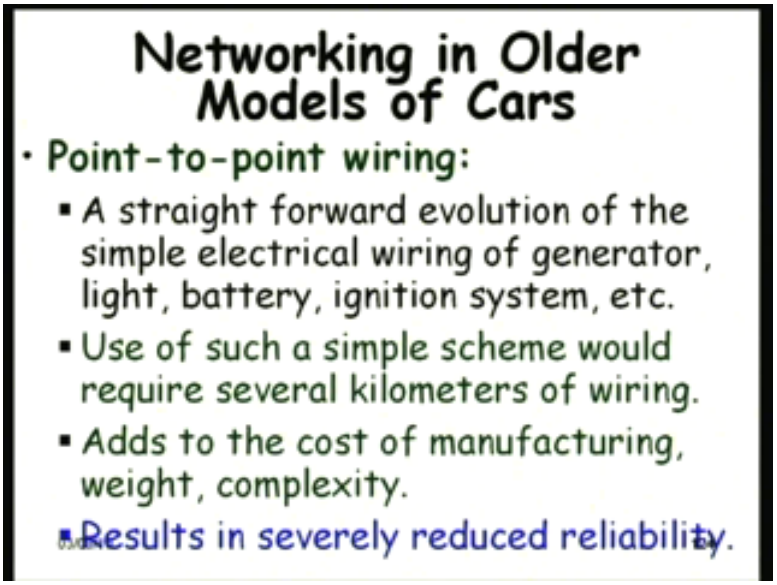

But in the older cars before let us say twenty twenty-five years back. There where electric components and there were some electronic components meters, but they were interconnected using point- to- point wiring. These was the evolution from the electrical wiring, generator light battery, ignition and so on. In the similar way the electronic components are also interconnected using a point- to- point wiring and. As the complexity of the cars number of electronic components increased the length of the wire was astounding even that time good models of cars you would need several kilometers of wiring. Adds to the cost of manufacturing the weight of the wires is significant just imagine one kilometer of wire how much it will complexity of wiring and not only that reduced reliability, because this different wire segments can become loose and can be cut.

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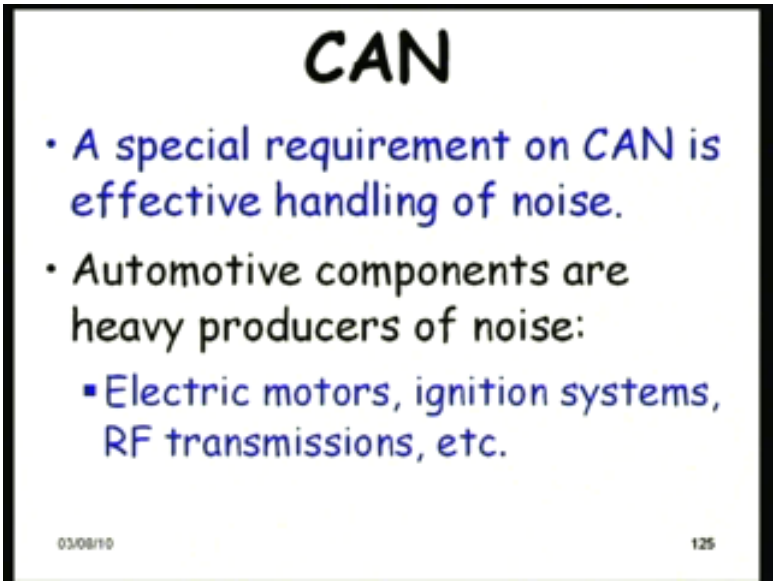

One of the special requirement at that time and CAN was handing of noise compare to the other types of buses .There is a special requirement of the CAN bus regarding noise ,because the automotive the origin was in the automotive segment and the automotive components are heavy producers of noise. For example wherever there is a motor there are sparks and large amount large noise is generated any motor you can easily make out by the noise it produces .You just take a reduce system there you can hear the noise that produces .Even the ignition system RF transmission all of them are heavy producers of noise.

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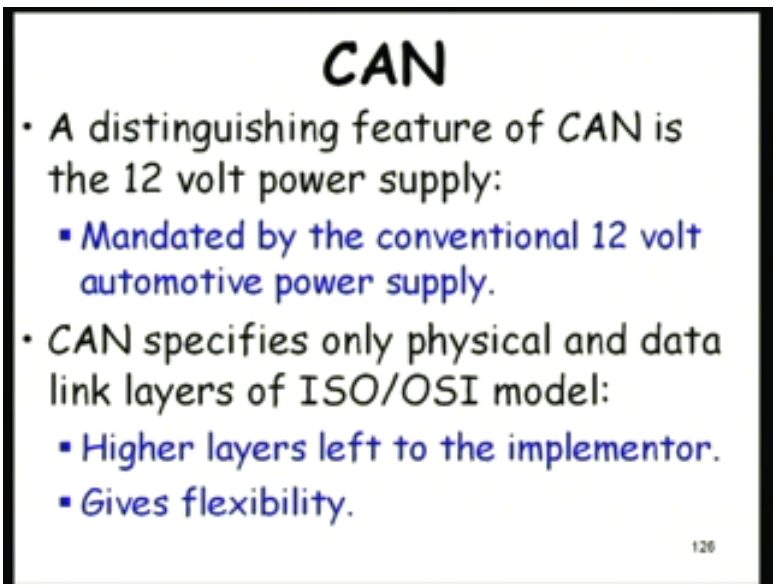

Another requirement was for it to operate at twelve volt power supply ,because all automotive vehicles operate at twelve volt supply and one thing that is important here is that it only its specifies the physical and data link layer and leaves the higher layers to the implementor gives flexibility.

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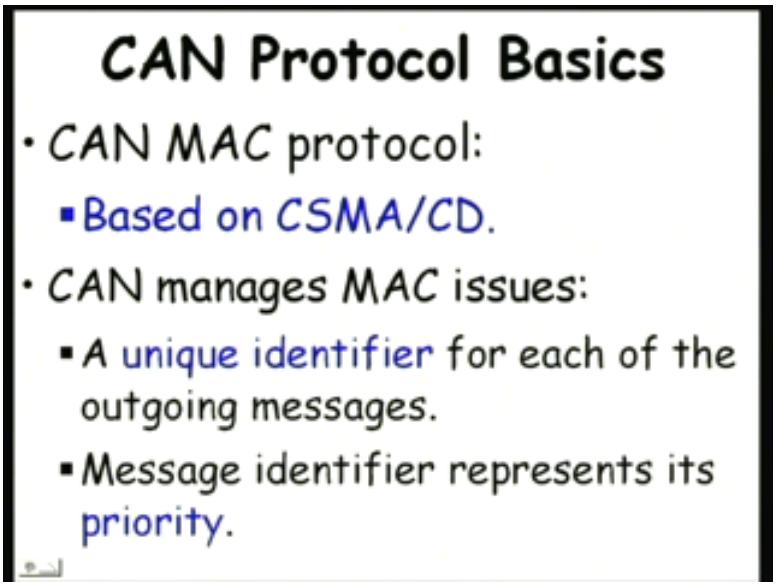

And the MAC protocol is that makes sense MAC protocol the Medium Access Control protocol is the CSMA/CD .CSMA/CD you know from a first course in networking. One implementation of the CSMA/CD is the Ethernet is very popular in traditional networking. CAN MAC is also CSMA/CD and here when CSMA/CD is used how does how do you assign priorities to different sources .Because you know there are some components whose messages need to be transmitted without delay.

Whereas, there are other source whose data can wait a little bit without much problem and collision CSMA/CD protocol an implementation of this in the ethernet .I mean we were just mentioning that it treats all the data sources as the same.So, how does this assign priorities to messages. So, what it does is each outgoing message is given a priority. The different sources basically they will have priorities assigned and these are unique. So, predefined priorities are assigned to sources.

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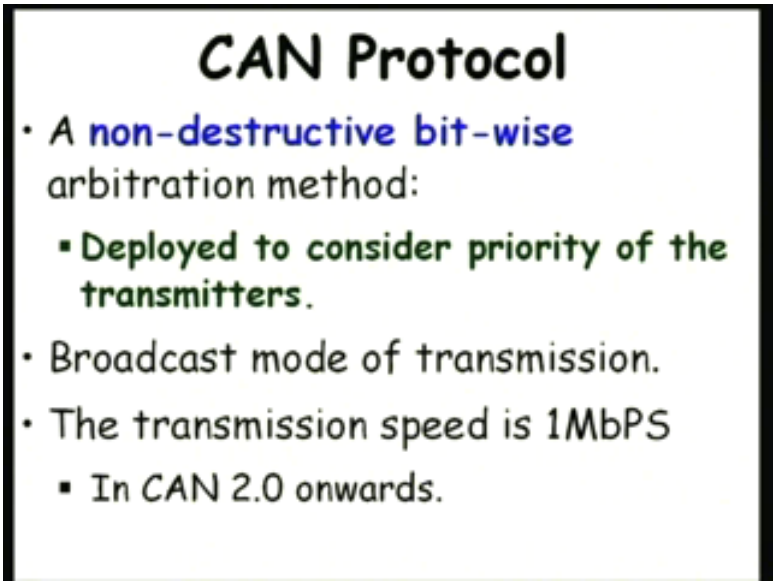

And when there are simultaneous transmission requests the protocol that is used here is called as a non-destructive bit-wise arbitration method .In collision based protocol like ethernet you know that when a collision occurs needs to be retransmitted is not it. They keep on trying after exponential back off. So, that is from a first level networking course you know that. But here it is a non-destructive bit-wise arbitration, because even when there are multiple sources trying to transmit. There is no necessity of a repeated transmission a non-destructive even though collision is detected need not be any retransmission let us see.

Non-destructive bit (( )).We will see what is meant by bit-wise .We will see that the unique IDs of the priorities of the sources .They are transmitted bit-wise and based on the priorities of different sources that are trying to send at the same time the examination of the bits leads to identifying which is the one that needs to transmit that the arbitration mechanism. So, let us look at this how it works. The priorities of the transmitters are considered in this the non-destructive bit wise arbitration and as is a CSMA/CD protocol it is a broadcast mode of transmission one Mega bits Per Second transmissions speed .I think later two point zero it has in the transmissions speed has increased to ten mega bits per second.

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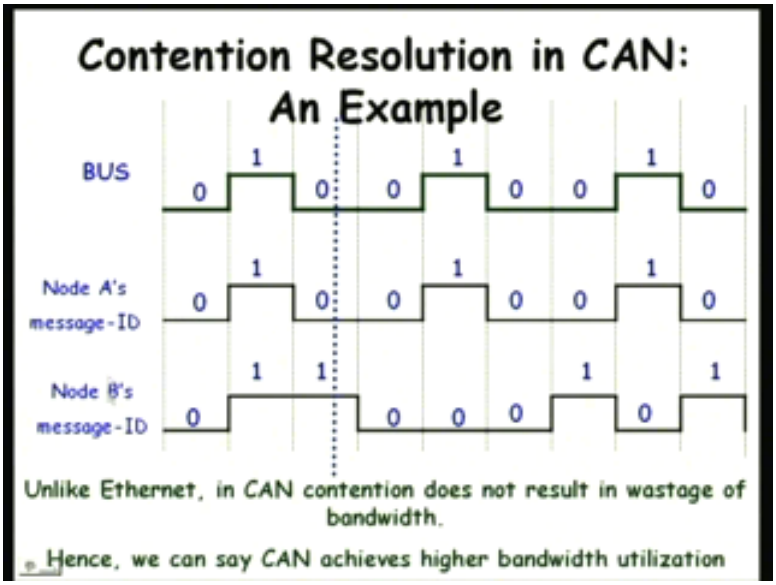

This is the basic mechanism which is use to resolve a contention just see here. There are two nodes and they transmit their ID at the start. Of course we are trying to explain it in a very simplified way it need not be that it always starts with a ID it may be some headers or something, but at certain point of time the IDs are transmitted and. These are 0 1 and let us say the resolution mechanism is that see this is one resolution mechanism that we are discussing their can be a dual of this I will just explain that. See here in once the ID is started to be transmitted see here Node B has put its zero here the most significant bit and this also has put zero here Node A and on the bus zero is transmitted and they can here that they have transmitted zero and zero is actually getting transmitted and now both A and B transmit one and they could here that one is also getting transmitted.

But at this point node A is transmitting zero and node B is transmitting one, but zero is getting transmitted. What it means is that a lower priority number priority one is higher priority than priority ten or priority twenty. But if it was the other way round that priority twenty is a higher priority than priority two or something .Then when a one is transmitted it will transmit one on the bus and once it hears that what it transmitted is different from what is actually what it shown on the bus is different .Then it will just drop out it will not transmit.

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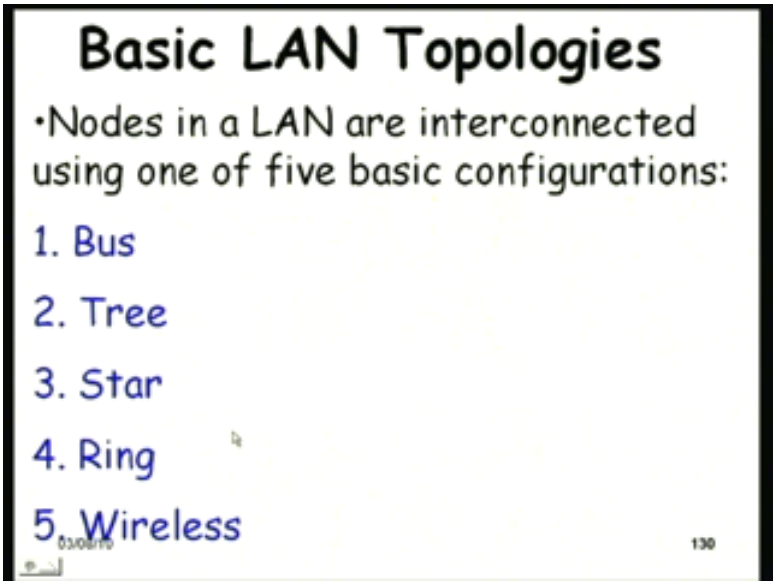

So, I think some other part of the example. I think forgot to give there, but that is the basic idea the(( )) .It will drop out it knows that a higher priority messages getting transmitted it will wait according to the CSMA/CD It will wait for certain time .Let the higher priority message pass through then it will sends in the channel and see whether it is idle and if it is idle it will again attempt to send and again this arbitration will takes place that whether there is a higher priority messages also waiting to be transmitted and it will get its chance to transmitted at sometime is that. (( )) Undue delay for some is it. See the way the components are designed in a automotive application or any other embedded application where time matters. These are designed conservatively assuming the taking the peak load into account.

And normally it would not happened that source never gets an opportunity to transmit what might happen is it gets delayed and the lowest priority messages will anyway messages logging which even if delayed by sometime does not matter. But there may be some technical (( )).That would depend on the design actually that would, if the design is not proper there can be problem. That (( )). That some critical message also can get delayed, but normally we will lot of simulation and so on would have gone before the parameters are fixed. That has to be taken care by the designer. Definitely.(( )).The critical messages not delayed that has to be taken care during the design period and we will just examine that theoretical analysis in the term of RMA or EDF similar to that would be difficult here .we will just identify the reasons.

So, theoretical analysis whether given the bandwidth and the protocol whether the constraints of all the sources will be met is difficult to analyze theoretically. We will identify the reasons and that will do later. Let us proceed with our basic discussion now. Now, the kind of LAN topologies that are used in a real-time application can be one of the following. We will see examples of this and as we proceed further may be after two lectures or something we will have a better idea about each of these topologies how they are getting used and what are the issues involved. One is of course, the bus which we are familiar with a first level networking course, Tree configuration, Star configuration, Ring configuration and Wireless. So, these five are extremely popular occur almost everywhere.

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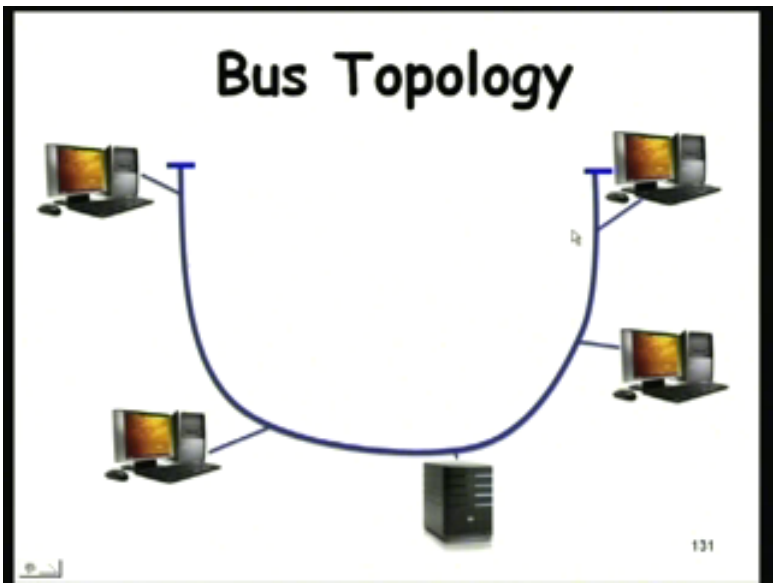

So let us check this out some properties of this. The bus topology as we know from a traditional networking course first level networking course is that there is a bus typically a coax cable and .Various types of computers attached to the bus and then it is the bus is terminated the terminators here in a coax cable.

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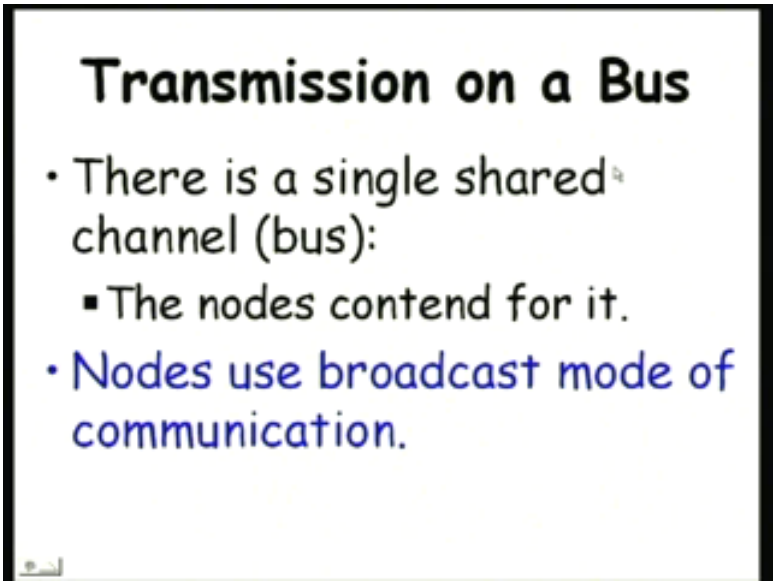

So, why there are terminators etcetera. All those are first level course let us not waste time on that. Since there is a single bus the nodes that are connected to it content for it and they use a broadcast mode of communication.

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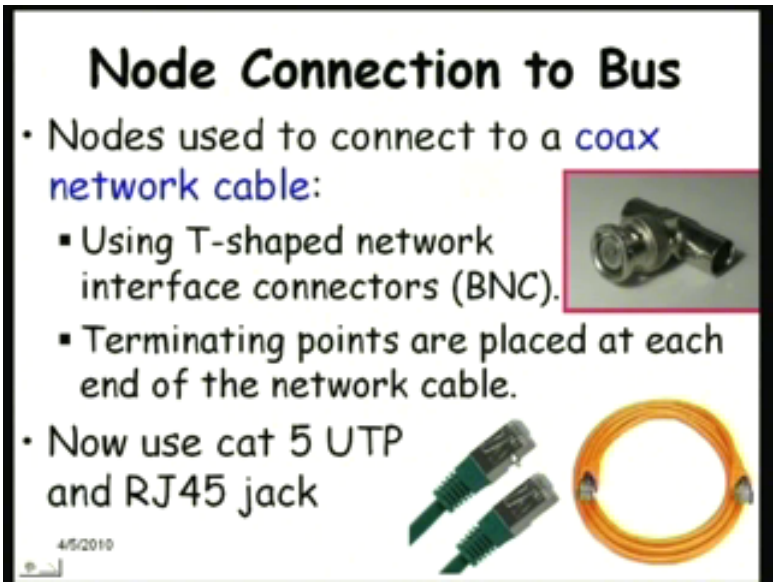

They used to be connected using a coax cable about fifteen years back .The older networks LAN you still find the your coax cables and then they were then computers were connected using T shaped interface connectors or the BNC cables. So, use to look something like this. Nowadays rarely in a LAN you find this and then terminating points are placed at each end of the network cable for load balancing, but now the scenario has changed no needs an coax cable and bus in the conventional sense is gone. Have you

seen in the lab? They are not there is not it. What is the reason why is it that the coax cable vanished.(( )).

Coax cable has excellent electrical characteristics compared to the kind of cable that you see today in the lab.(( ))The data rate was excellent on the coax cable you know in a coax cable you have metal insulator on a cable to prevent noise electrical noise cannot affect the signal, because there is sheathing a metal sheathing on the wire. It will be, I mean the signal character transmission characters are excellent noise is really low in those cables.(( )). Data transmission is very fast nowadays.(( )).You know data bit networks are there in the lab. I hope you.(( ))You are saying that attaching stations is difficult is it.

You have T sections available put T sections. I mean it is bit of work putting a T section and taking attaching a connection, but it can be done it is not that it is that difficult.(( ))How is that, I mean compare to what is a current networking. I mean what is the kind of cable there in the lab.(( )) It is UTP one advantage is the cost and the signal transmission is excellent here as we will see, because of varies reasons and at low cost not only that the configuration of the network has changed .It changed from a traditional bus to a star configuration you see in the lab ,see that all are connected in a star network and the cable was very difficult to manipulate bulky .

You cannot really you know bend it conveniently attach it on a wall or something, but these are.(( ))And not and another thing is reliability see if there is a brick then the entire network will be down, but here in a star network even if just one cable is broken is out then still it will operate satisfactorily. So, for those reasons the coax cable in the typical lab scenario has vanished replaced by universal twisted pair a cable appearing like this and R J 45 jacks which typically you handle in the lab and attaching the network connections.

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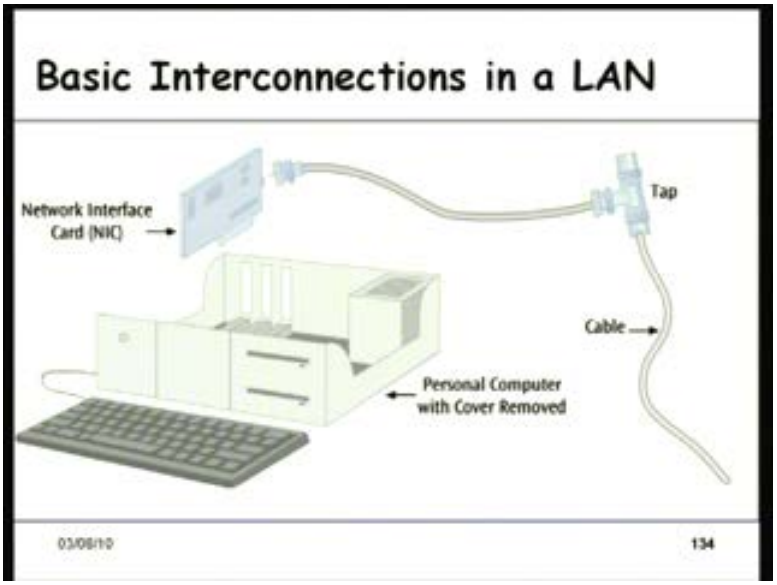

But let us spend few minutes, because these are also important as we proceed is how exactly. I mean how does the computer connect to a network cable and how does a computer let us say we know that at the physical address of a computer is unique. But how does that happen and what about the protocol issues how the protocol issues handled in a computer is. Anybody knows about that. How is a protocol network protocol implemented in a computer.(( ))This is the answer there is to be card like this which is to fit into the motherboard the NIC card Network Interface Card. It has a unique ID for the host .Basically each of the NIC has a ID which becomes the ID of the host and the low levels protocols are all coded in this.

They handle about the collision resolution arbitration sensing that bus all these are done by this here. Collide some (( ))You mean the ID is how the ID is coded.(( )) I D coded is just a I think forty two bit number binary number forty eight bit binary number it is there.(( )) The protocols are there we will just look at that. Use to be like this a special card use to get attached about fifteen years back, but now since every computer is networks see those days people many people did not network their computer they use to operates it is stand alone. But, nowadays it is rare to find somebody operating a computer stand alone and since it is a requirement for every computer every PC that is manufactured. This card is even built into the motherboard.(( ))

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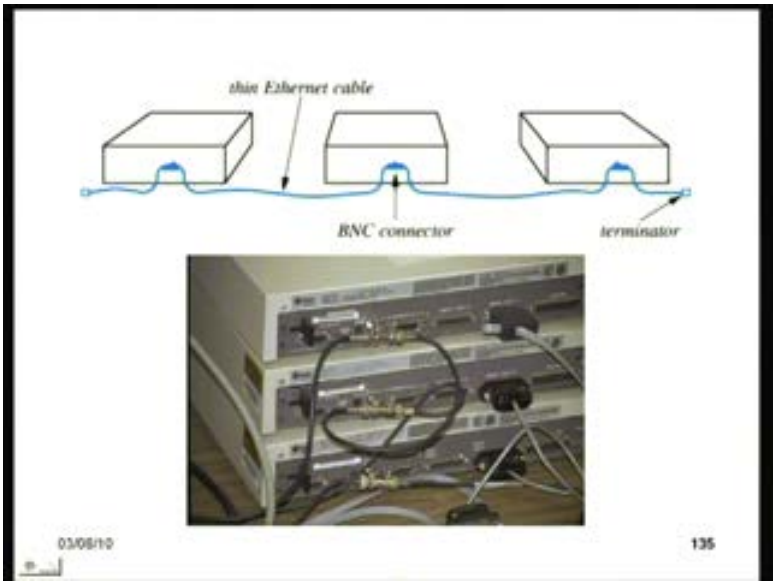

Again a very basic networking question let us not spend time on that. See the one is the physical address which is given by the its hard coded into the desktop or a computer, but there is another address the IP address which is given by the administrator. This address is bound to the IP address and there are address resolution protocols and so on. Please refresh the first level knowledge the physical address of a computer and its Internet Protocol address. They are very different addresses. The physical address is hard coded whereas; the Internet Protocol address is assigned. Use to appear like this that you have this coax cables T connectors and they are connected in the form of a bus, but nowadays that does not exist. Each of them is connected in a Star connection. So, what is at the center of the star?(( ))

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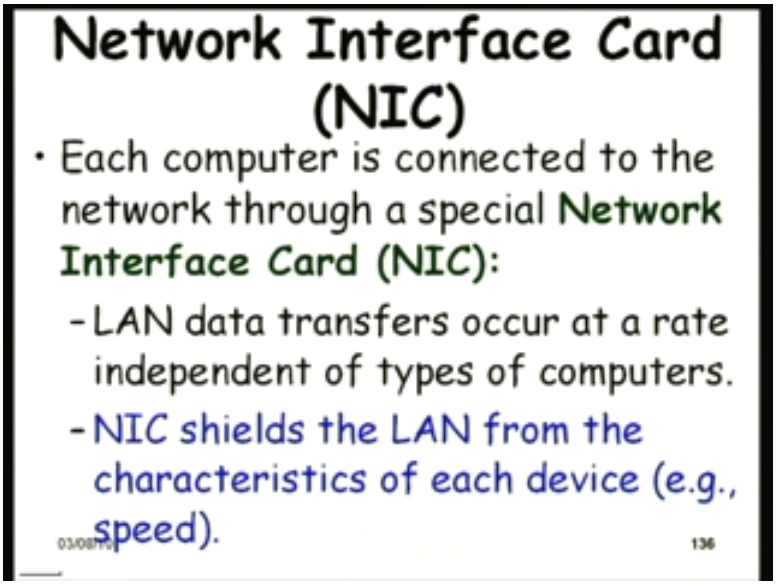

There will be a switch or a hub which is at the center of the star and the computers are connected in a star connection that is how every lab will look like .The Network Interface Card I think it is much more intuitive to talk in terms of a card rather than some component on the motherboard .The Network Interface Card it takes care of transferring data at a specific rate, because you know there is a LAN speed. When you talk of a giga bit LAN or a ten mega bits per second LAN. The data needs to be transferred at that rate irrespective of the processors speed or whether your computer you have a old computer, fast computer, slow computer or you have a new faster computer the data transmission and the network has to be at a standard speed determined by what kind of network you are using whether you are using a one giga bits per second ethernet or you are using a ten mega bits per second ethernet.

So, this is the card which takes care of that transfers data the rate independent of the whether the computer is a old slow computer it is a new fast computer or in other words the NIC it shields the LAN from the characteristics of the device .The device may be slow fast whatever, but the transmission occurs at the required rate.

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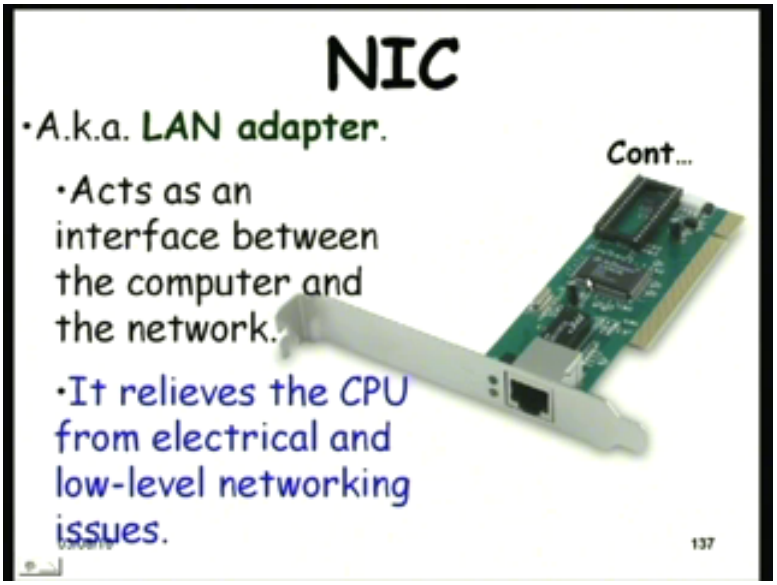

The NIC is also known as a LAN adopter .It relieves from the computer the CPU from the electrical and low level networking issues the protocol issues .They are all encoded in the NIC or the LAN adopter.(( )).Also known as A. k. a just written in the short form also known as a LAN adopter looks like this. This gets attach to the motherboard and here your R J 45 cable gets attached here and this is at the backside of the computer. See this chips here they would take care of the lower level protocol issues.

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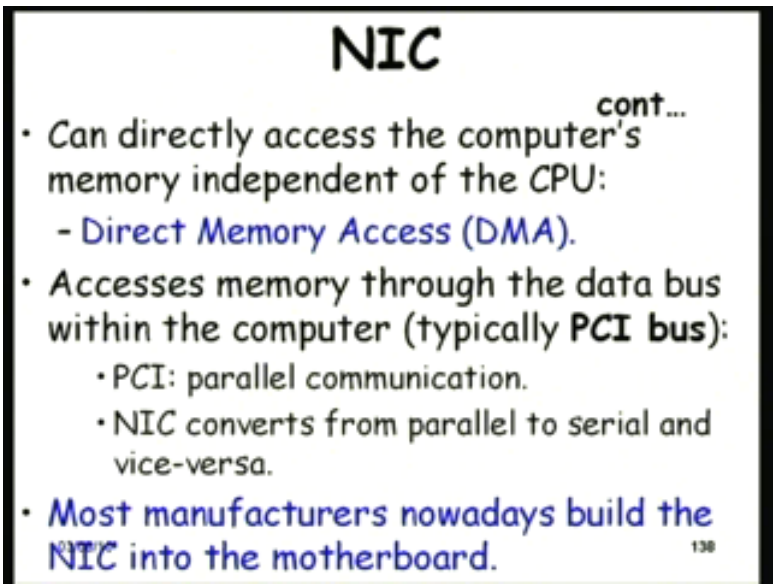

The NIC directly accesses the computer's memory and transfers data using DMA. Reads out data on to the network reads in data from the network using DMA and takes care of parallel to serial conversion, because it connects to the PCI bus inside the computer which is a parallel bus. This also another responsibility of the NIC in addition to taking the lower level protocol issues .It also uses DMA mode to transfer data and also convert data from serial to parallel and. Nowadays you would not find a card if you look for it, because they are built into the motherboard.

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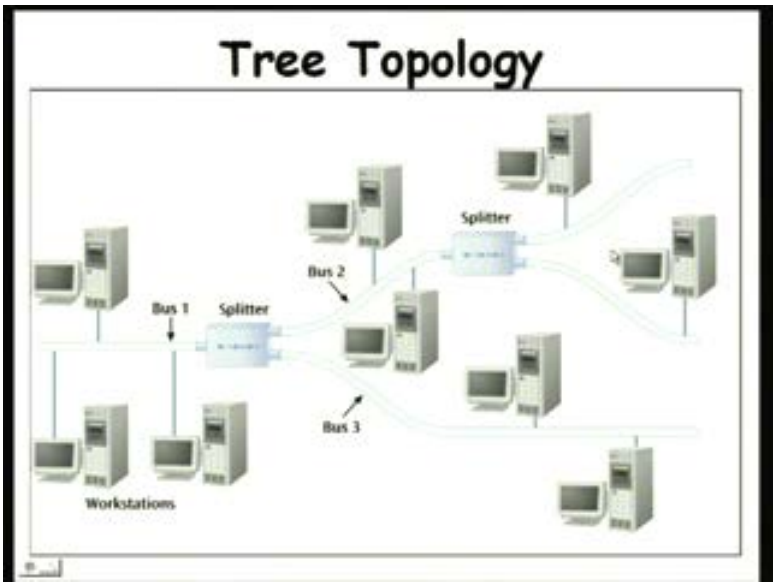

The tree topology is also popular when you have splitters and the different busses get arranged in the form of a tree.

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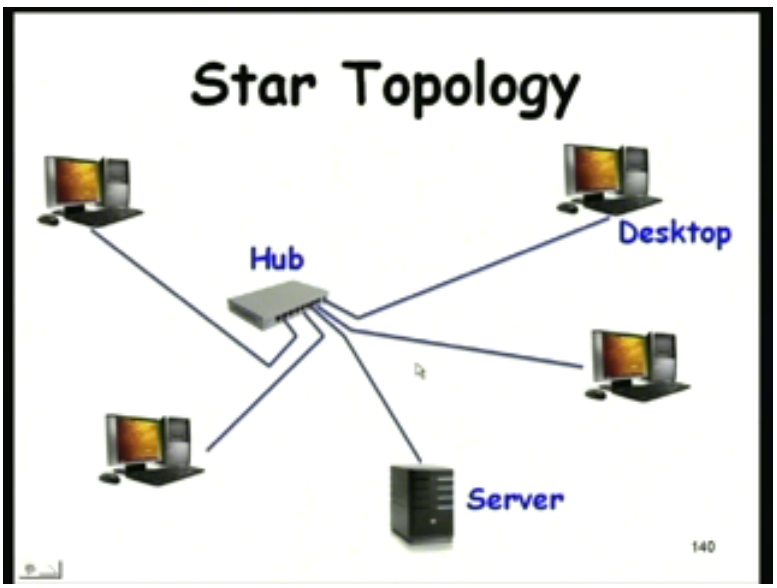

The star topology as we were saying is become presents almost everywhere every lab every LAN that you see around as a star topology at the center may be as hub to which the different computers are attached.

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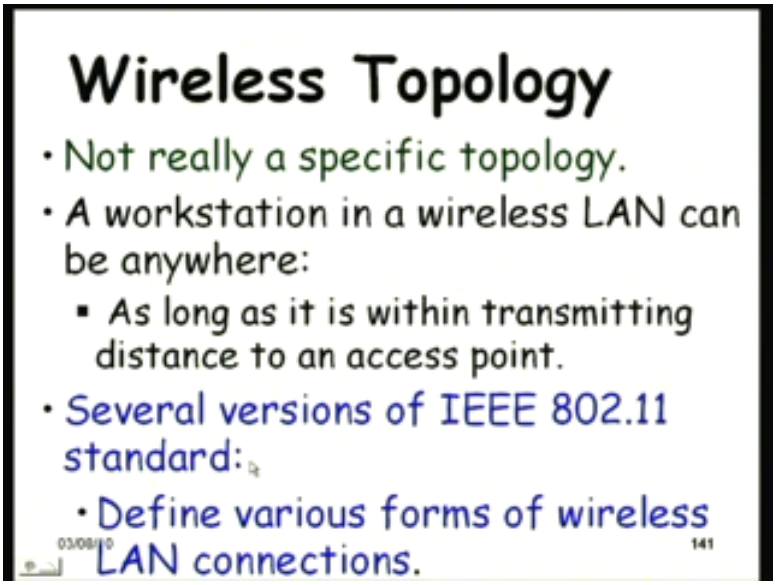

The wireless even though we said a topology is not really at does not denote a specific topology because these are free to move, nodes are free to move and they can take any step is not it, but still it is I think from a classification point of view .We can consider wireless also as a topology and there are several versions of I EEE 802.11standard which define various forms of wireless LAN connections.

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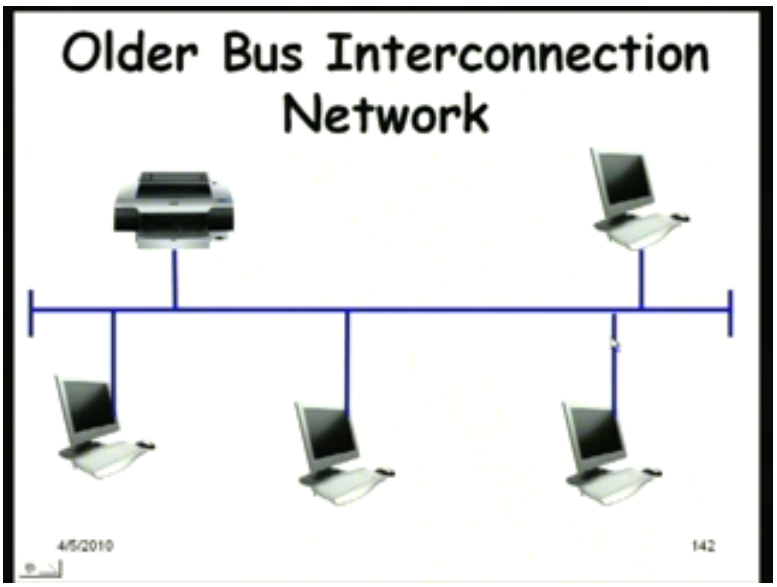

May be as we proceed slightly more in our discussion on using the wireless for real-time communications we will discuss these issues. The older networks use to appear like this there is a bus and the computers are attached on that.

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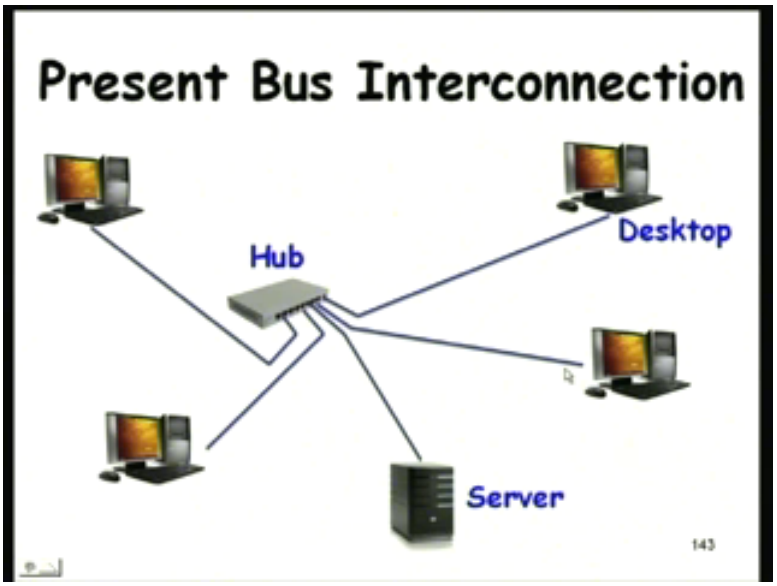

And the present one looks like this .We had seen that it is much more reliable it is cost effective the twisted pair costs very less one- tenth of the cost or may be one- twentieth of the cost of what the coax cables use to cost and easily manipulated.

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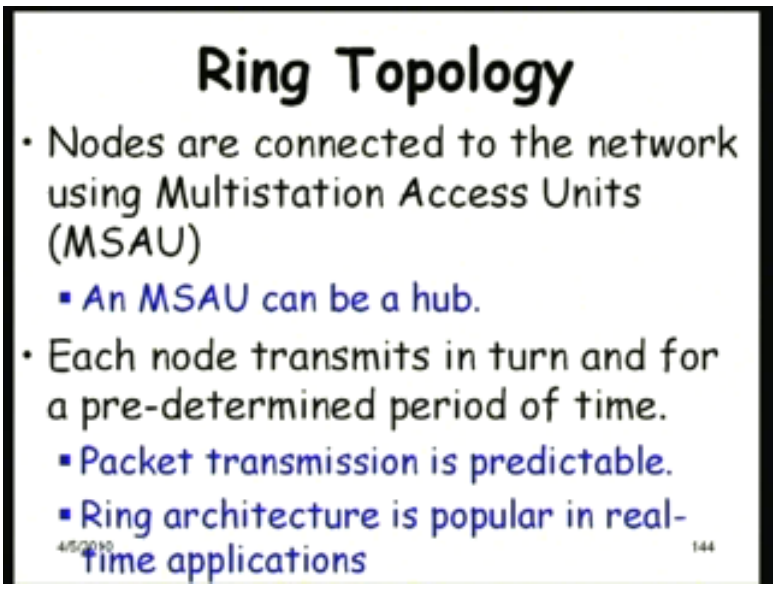

You can set up a network in less than few hundred I mean five hundred rupees you have small set of computers using the hub costs some two hundred rupees or something three hundred rupees and then the wires cost almost nothing you can setup a LAN even in your hostel rooms. Another one which is very popular in real-time applications is the ring topology. So, then computers are connected in the form of a ring and the individual computers are connected to the ring through a Multistation Access Unit or MSAU. MSAU would can also be a hub we will just see the diagram. In the ring topology the nodes transmit in turn for a pre-determined period of time. Because they take turns and also transmit for a pre-determined period of time, therefore when something needs to be transmitted you know exactly how long it will take I mean in the worst case.

Depending on when the data has arrived to the time the data would be the transmission would be complete it is very easy to compute the time it will take is not it ,because you would compute how much time each one will transmit and it is in which number among all these. So, depending on how many are there before it and for how much they will transmit you can find out when it will get it is turn and for how long it will transmit and based on that you can find out the transmission time predictably. So, that is one of the main reasons why the ring topology is popular, but as we will see that the ring topology as its problems .We will identify the problems let us proceed, because of its characteristic that transmission time is predictable you can compute a bound on the transmission time its popular real-time applications.

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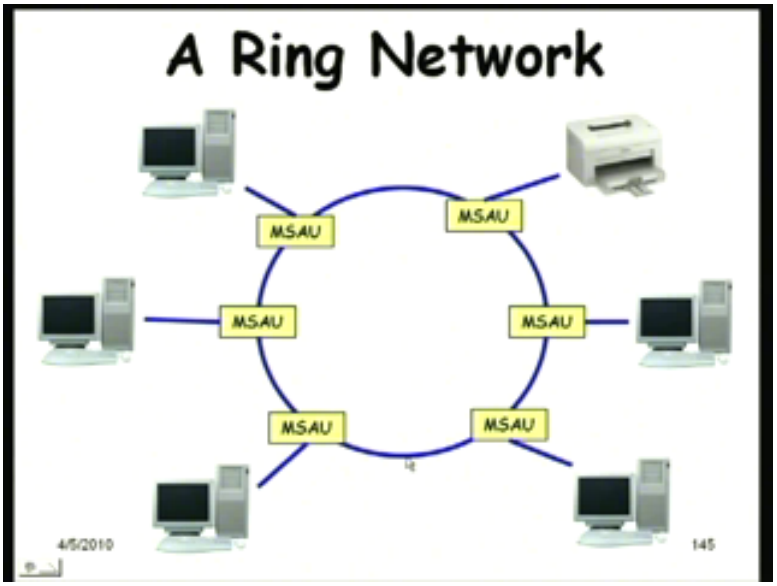

Look like this computers connected on a ring through which can be hubs where several problems with the ring architecture .One is that any break in the ring can bring the whole network down.

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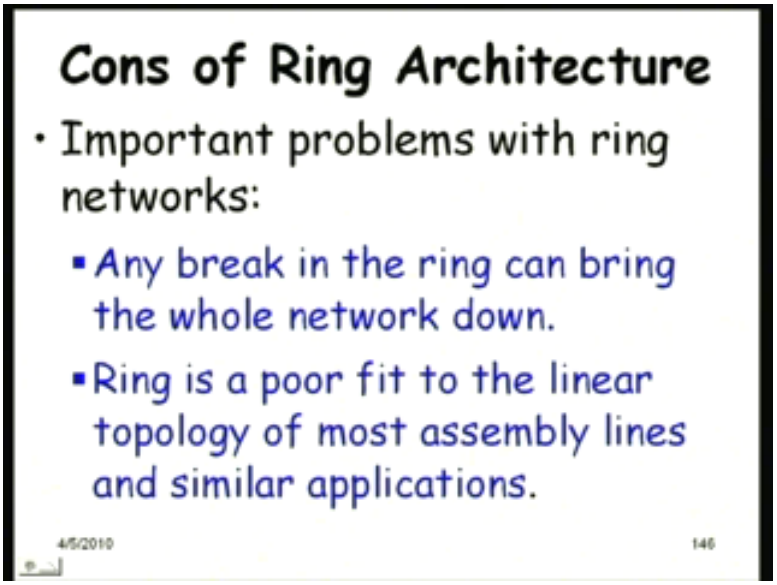

One major problem reliability issue. The other difficulty in using the ring architecture in real-time embedded application is that is a poor fit to the linear topology in most of the assembly line and similar applications.

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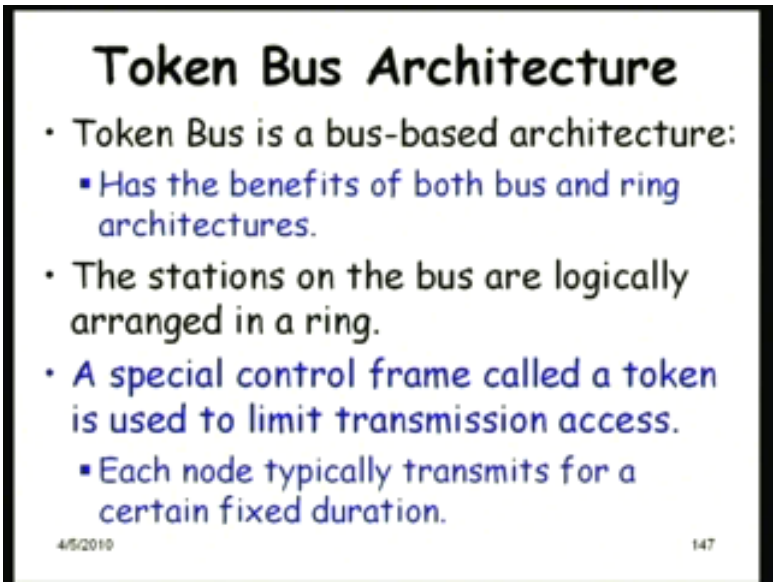

So, naturally desire in the form of a bus or something rather than in a ring .Of course you can have a token bus architecture where we have similar protocol like a ring, but we use the bus as the topology .It has benefits of both the bus and the ring architecture. The stations are logically arranged in a ring and token is passed and as long as a station or a computer holds the token it can transmit data. So, the arbitration mechanism is taken care through a token, because at any time only once station will be holding a token and once a station gets the token it starts to transmit. But there are durations assigned for each node for how long they can transmit once they get token after that time even if they have data to transmit they have to give the token to the next node.

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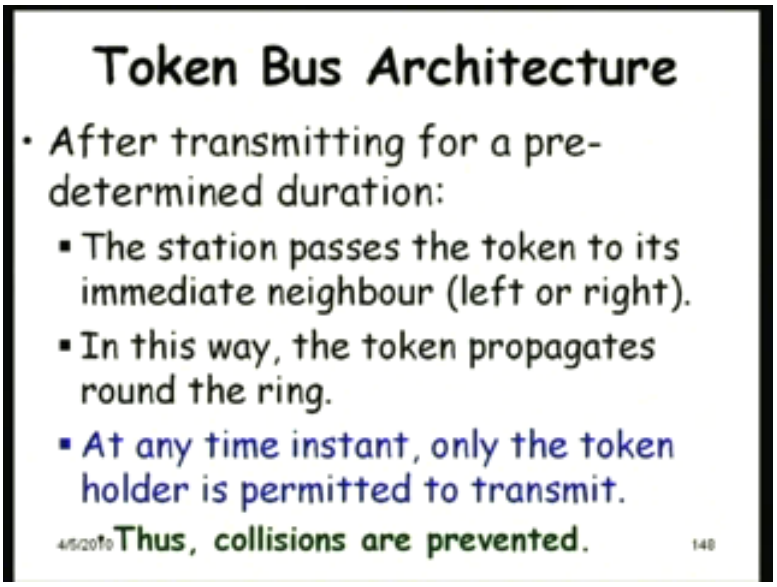

After transmitting its duration assign duration it needs to pass the token to the neighbor and a token propagates around the ring and. At any instant only one token only there is one token holder who can transmit.

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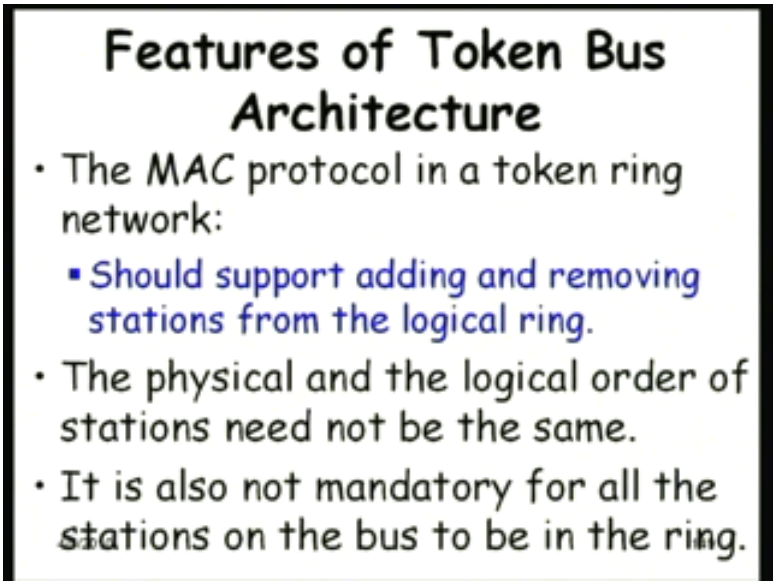

So, arbitration mechanism is simple collisions are prevented and of course, we should have protocols per how to add and remove stations in a token bus architecture or in the logical ring. Because they are may be stations which are part of the ring sometime and they might get excluded in some other time. The other thing is that the physical and logical order of the stations may not be the same and also all the stations on the bus need not be under ring. Is just an.(( ))

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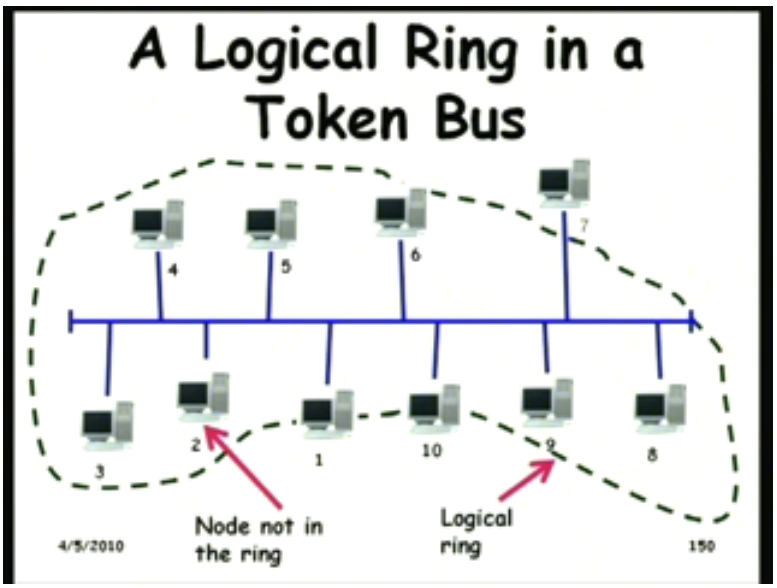

I will just show you with an example that even though there are many computers attach to a bus all of them may not be on a ring. Just see here this is not included in the ring there in the bus. So, How then how wills that (( )).See the it does not participate in communicating with this using the token bus architecture.(( )).Exactly.(( ))Why not in a token bus there can be on a single bus multiple rings can adjust. Let us not complicate the issue .Let us just understand the basic concept of a token bus, because who will is discuss its use in real-time application the protocols that are used. We will do some performance computation for this in what applications it can be used for what it cannot be and we will discuss little later on. So, we will just stop here and we will continue with few more basic issues before we start with the protocols for real-time communications which is suitable for which application.

Thank you.