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On Industrial Automation and Control

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Topic Lecture – 49
The Fieldb Network - I
(Contd.)

So now having understood the connectivity the actual physical connectivity let us come to the OSI network architecture.

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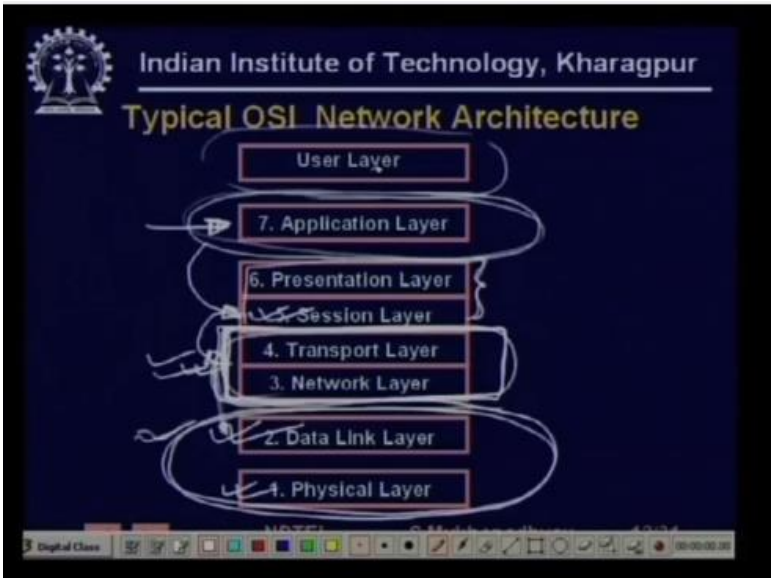

A typical a very generic general-purpose Network these are the general-purpose model and in the various special networks you have a you have some sort of an adaptation of these network architecture in all networks adapt this generic OSI network architecture in certain ways so in the

generic standard you have actually when over a network when we when one computer talks to them to another it need not know what is the network connectivity what is the address you just you know you very value when one person chats with another person over a long distance list sometimes over the globe.

So it is it is actually a virtual communication but actually physically these data or the text suppose which you are typing has to physically travel from your network across various communication channels and physically reach the other computer which may be thousands of miles away so this is achieved through a layer of protocols okay each protocol gives a service to the protocol above so that the protocol above and hide certain unnecessary details from the from the protocol above.

So this is the protocol above always sees it is own communication as across some across some virtual Channel and is freed from several you know technical details otherwise it would have been I mean absolutely impossible for us to do any communication over a network so the communication is actually goes is whole system is actually organizing layers and any message which is generated at a top layer will come down across the layers finally reach the communication channel and the electrical communication then it will travel across various you know nodes and then finally we will go up and reach the top layer of the destination process.

So you have typically you have physical layer which is actually the electrical layer where the actual electrical communication takes place modulation communication over any medium fiber-optic radio wire whatever data link layer is the next layer which actually provides increases the reliability of the electrical communication so here the data is not it is tilted as you know binary data packets are assembled error codes are attached so that during transmission if some data error occurs that can be detected these transport and network layers actually take care of the networking problems.

So firstly it does things like routing so if you want to transfer if you want if you are sending an email message from here to Japan from your say your host to whom you send where should it go so this kind of the this kind of routing information is routing is done by network layer then there

are sometimes you know they do you know things like congestion control so some particular channels may be may be down they may be choked so if data is not going through these channels they will they will there are the mechanisms by which people can do things like flow control.

So this network and transport layers actually take care of the network topology loading and network communication so once you have taken care of these from the session and presentation layers it appears as if you have a this is the physical communication this is the physical communication digital communication this is the network configuration and network performance ensuring so once you have these two layers these layers sitting on this and this actually see is some kind of a virtual session between two computers.

So it does not know it is completely oblivious of how through which path in the network this particular message is going so it does not know it just knows so it sets a session presentation layers are generally rudimentary that they are not very strong and it is the application layer which is application layers are configured for typical kinds of application like you know you want to have a remote terminal so you your want your PC to actually work as a terminal to a server which maybe elsewhere on the network.

So this is a remote terminal service there can be an email service right so these various kinds of common kinds of applications various kinds applicants TP service so file transfer so such things are is the particular details of these are actually handled by the application layer and the application layer once so then the application layer actually calls a session layer calls the session layer and says that you please set up a session for this particular application and then the session layer gives those it is session messages to the transporter network layer which decides how it will go and then they actually finally puts all the addresses etc…

And then finally these get to the data link layer and then they actually are transmitted in the medium the user layer not normally this user layer in this is OSI Network layer network architecture there are seven layer protocol which does not have the user layer because for general-purpose computing the user layer can be of enormous variety so therefore the user layer

is actually not specified but as we will see that in the particular case of industrial automation networks.

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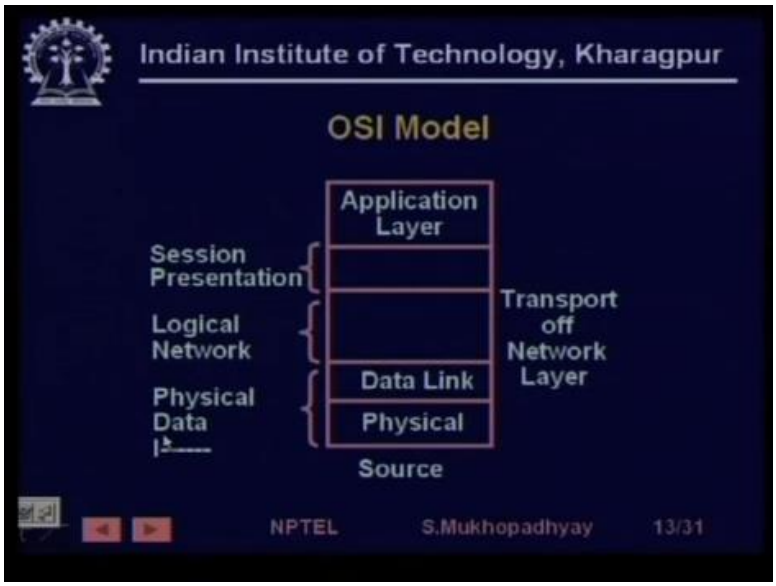

This is adapted right so what is done is we will skip these slides and see the field bus network.

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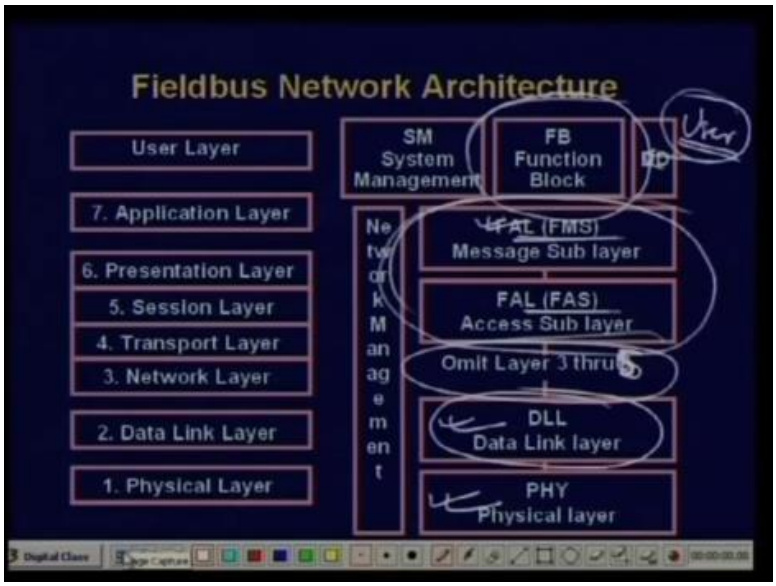

Architectures in the field bus network architecture there are there are certain differences so first difference is that the network in the factory is actually fixed it does not change second thing is that the what kind of message is that is the loading on the network how many messages are coming frequency of messages arising on the network are also more or less constant because you know all the time I mean once it is designed it is fixed it is not that new processes are being I mean large number of new processes can be suddenly generated because we know what kind of computations are actually going on in this in this network.

So therefore this you know this what I do mean to say is that the transport and network layer functionality is nearly removed so therefore it is good to remove the transporter network layer therefore the field bus network actually does not have actually has very rudimentary transport and network layer right so it has a physical layer it also has the data link layer which you know does also part of the little bit of it actually puts the addresses it actually ensures the that is who will transmit when say the medium access protocol etc…

For cyclic and a cyclic communication either is also had handled in the data link layer and this layer 3 through 6 that means session presentation and application are actually application is there

3 to 5 I would say physical data link network transport and session layers networks now 3 through 6 networks transport session and presentation these 4 layers are actually removed then on top of that you have an you have an application layer which application layer is so you have field bus application layer which is broken into2 sub layers.

One is called the field bus message sub layer the other is called the field bus access sub layer so using so the field bus access sub layer provides various kinds of addressing functionality and the field bus message sub layer actually configures the messages which are coming from the user layer so in contrast the field bus network proposes and a major user layer because here the computations are not of that much variety number one they are largely uniform there are all for process automation tasks and secondly because of the fact that you know it is necessary for easy configurability it is necessary that the.

So enormous flexibility is actually not needed so you can you can create various times of templates and you can you can create a separate layer within which it will be it will be easier for the for the application engineer for the process engineer to actually program his application so therefore an user layer is proposed so one layer is added and four layers are deleted so you have a this is the field bus protocol structure.

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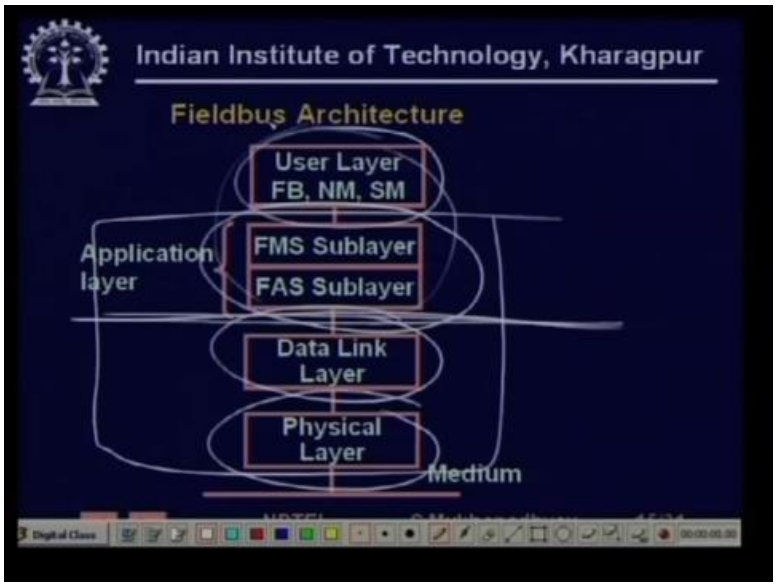

So you have finally the field bus architecture so you have the physical layer the data link layer and the application layer broken up into two parts and then you have the user and user layer which involves feed the function blocks which are you know abstract computing blocks which specify abstract communication let us say between analog input device and a process controller or a process controller and then analog output device.

So the it will just abstractly describe this in terms of function blocks and then the network communication through this I mean among this function blocks will be will be automatically realized by this part of the network right. So this is the field bus protocol in this lesson we will be mainly concentrating on the data link layer and the physical layer physical layer we have already discussed and in the next lecture we will be talking about the user layer and the field bus application layer.

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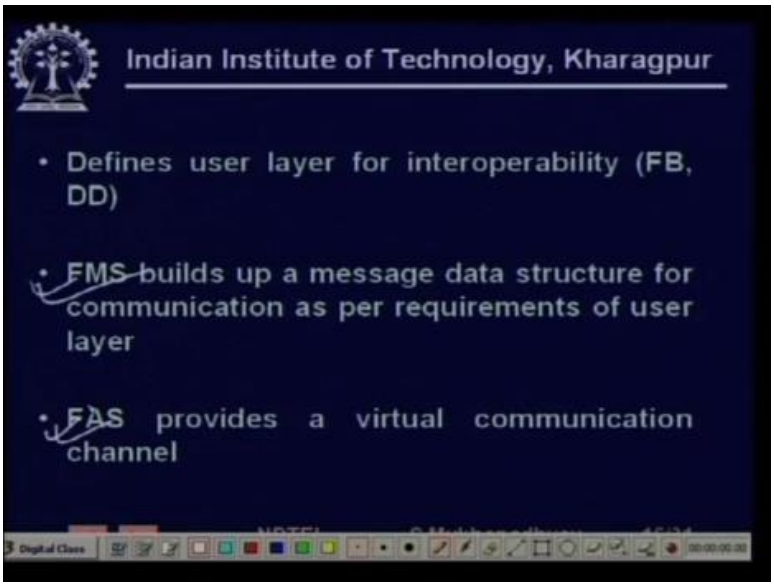

So the field bus as otherwise telling it defines user layer for interoperability so that you know every device so all the field bus devices are have to be of a certain have to be of a certain standard as far as software interfacing or data formats are concerned so those data formats have been already specified in the standard and any field bus device must comply with the standard so that they can be become immediately interoperable and these are defined in the user layer protocols the field bus message specification so the user layer just abstractly so may be there may be an analog input block simply in it is user layer it simply generates a value.

So this particular temperature signal has to go to the PID controller it says now for transmitting that to the PID controller this has to be actually made into a message and then a message has to be configured into a packet and then it has to be sent with after all the addressing etc…So the field bus message specification the field bus message specification builds up the message data structure for communication as per requirements and in fact there may be several function block processes within a device.

So all these devices frequently are generating data so they have to be put in the form of messages and then transmitted and then the field bus access sub layer once it gets the packet this is to be

transmitted then it then the field bus access sub layer adds you know addresses and the networking information such that this can actually reach another device on the bus you know each device has as a unique address and unless you since there is a shared medium unless you transmit your messages unless your messages contain addresses the device says we will not be able to understand whether of whether a particular data that you just seen.

Because everybody is actually listening on the same bus people are transmitting on the same bus and every device is actually listening on the same bus and picking up the data which is meant for it so the field bus access sub layer provides in this way by providing addresses provides a virtual communication channel so you know body the top layer should not need to worry about how this how each device is actually sensing and then picking up the data meant for it so it need not bother about that.

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The data link layer actually manages the communication protocol it takes care of the digital communication details error coding parity checking etc… and the physical layer provides a the electrical and medium dependent so if you have wire if you have RF then there has to be radio

transmission if you have fiber optics then there has the optical communication so all these details are handled by the physical layers and okay levels 3 to 6 are dropped for efficiency.

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So without going into the physical layer because that involves a lot of you know electronics basically and generally communication electronics so we do not want to get into that in this course so rather we look at the data link layer in the data link layer the features are.

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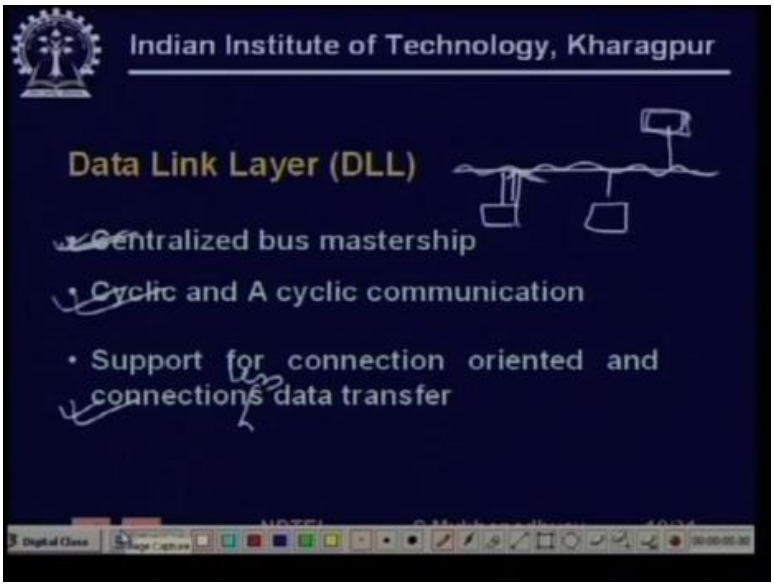

That you have centralized bus mastership this is very important to understand because the because you are having a ship bus on which everything is hanging right so if you talk if a particular device transmits on this bus there is signal existing everywhere on this connector so all the other devices can get it and it is very important that no two devices never transmit data on at the same time on the medium because then the data is going to be garbled so therefore has to be a there has to be a device which will decide who will speak at what time on the bus.

So this is achieved by what is known as bus mastership so the bus master distributes the right to transmit among the devices depending on their needs and depending on how you have configured it communication can be cyclic as well as cyclic that is some devices will every say one second they will send a packet so they require cyclic communication here are some may be a cyclic where which may be suddenly required may be due to some alarm condition or things like that.

So these two kinds of communication are supported by the data link layer and sometimes you have features for connection oriented as well as connection less data transfer this is

connectionless so you can have broadcast where you are not giving addresses or you can have a connection-oriented that if that is meant for only this node only right.

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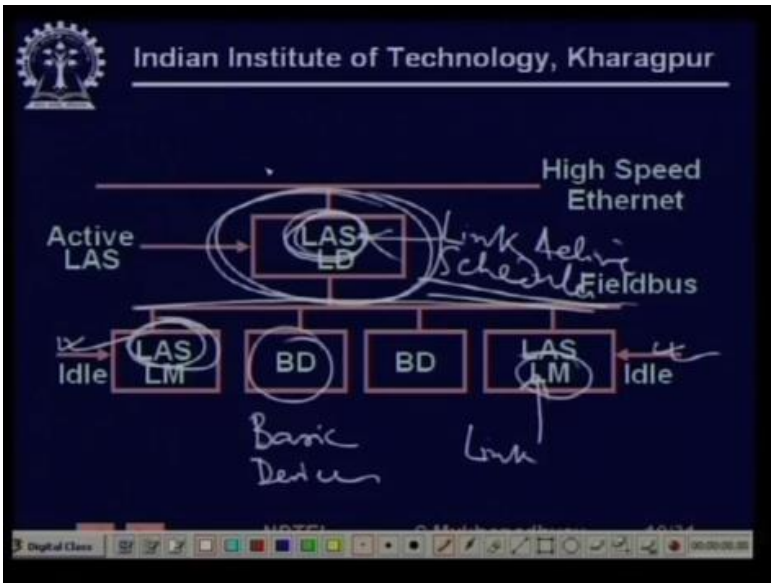

So this these are supported by the data link layer so pictorially it looks like this so on the bus this is a field bus there are various devices these are basic devices BD basic devices and these are linked masters so LM is a kind of device which is capable of becoming a link master and the and there is among the link masters there is a particular device which is called the active link active scheduler, so at this time these this is this link master can also become the link active scheduler but it is at this time ideal.

So these are ideal sometimes you provide more link masters because if but for some reason this link master fails then who will ensure the communication so there are some other link masters which are always kept in hot standby so that they will they can they can immediately takeover the communication and the control and coordination will continue this is very important right.

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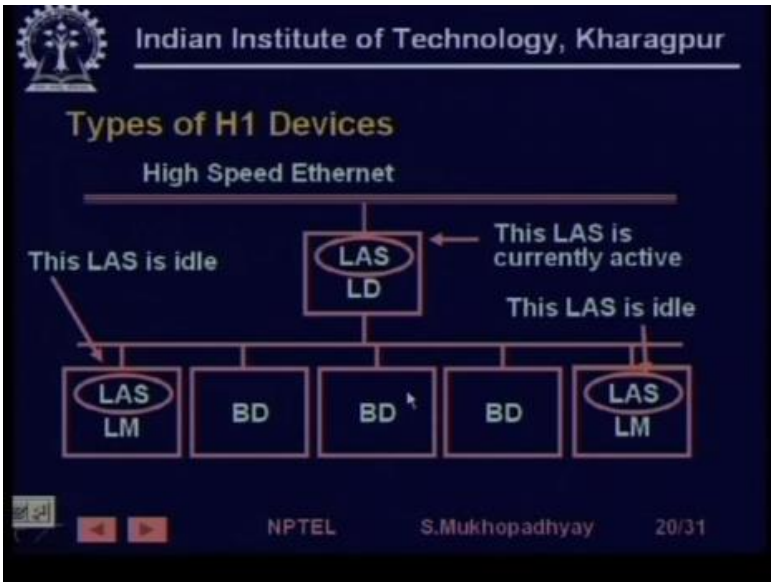

So exactly same diagram this is repeated so these are linked master and their basic devices are not capable of becoming link masters or link active schedulers while link masters are capable of becoming link active schedulers.

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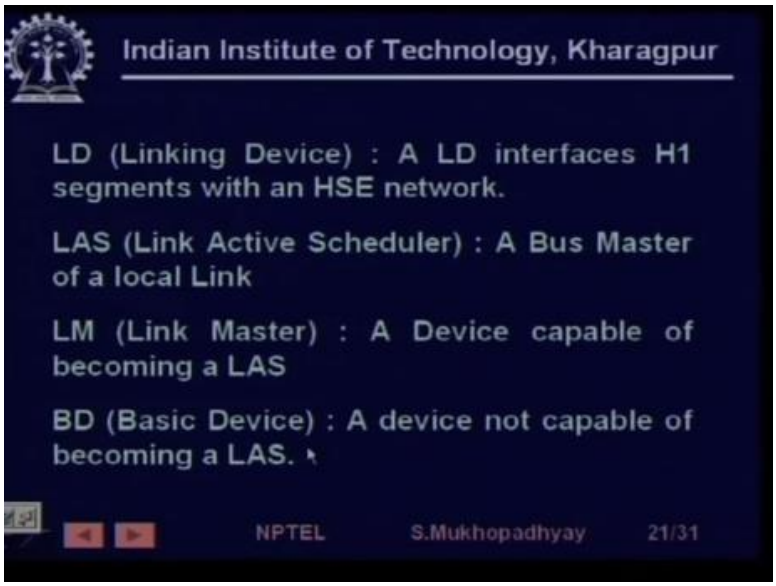

So LD is the linking device and LD interface with H1 segments with an HSE or and what HSE means link master that is what I said BD is basic device every device not capable of becoming a link.

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So link active scheduler is the is as I said it is a bus master which distributes right to transmit to all devices it is actually a functionality some software which may be present in several Link masters for fault tolerance and it is actually it actually does the scheduling of the various you know soft and hard real-time task so soft real-time communication tasks are those which also need to be finished in time but even if they are slightly delayed there is not so much of a problem but hard real-time tasks are those if you cannot finish those tasks those computing and communication tasks in time then the system may completely collapse right.

So it must for you in your scheduling you have to take care such that the hard real-time tasks are definitely finished within time so the link active scheduler also has to you know these you can always keep on as we said that there is easy configurability so you can add a device simply to the network and the link active scheduler also has to look for whether some new device has been connected and then has to configure them and then I have to take care of their communication needs.

So it also searches for added and remove devices similarly if your device is removed it has to take it off from its scheduling list.

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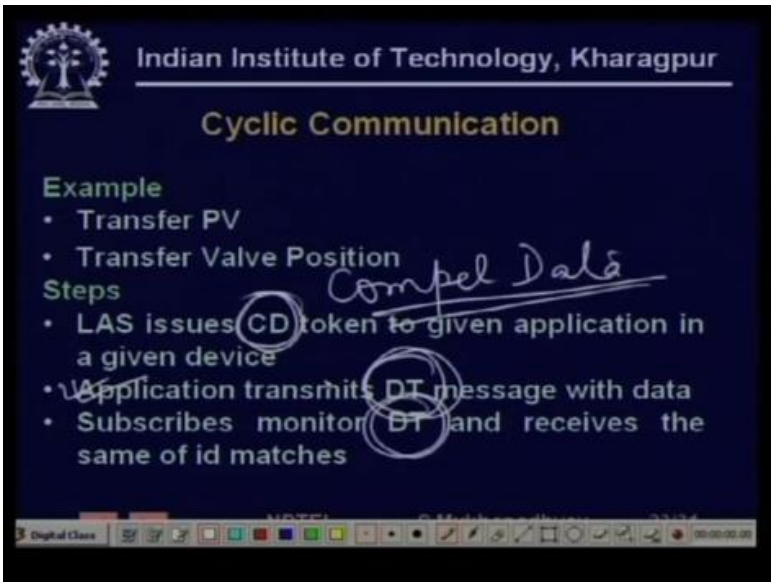

For cyclic communication typically applicable in the case of control so you know transfer process variable or transfer valve position just an example so it continuously has to take the process variable compute the controls and then output to an output device so this goes on right so this is an example of cyclic communication so if there is cyclic communication what the link active healer does is that it issues a CD or compel data token to a particular device.

So once the compel data token is given this device to which this CD token was issued must respond with a data token right and then this is this it will send on the bus and then all the devices are actually all the time looking for the data so the device which needs the data token will actually will receive it and we will take it and then use it.

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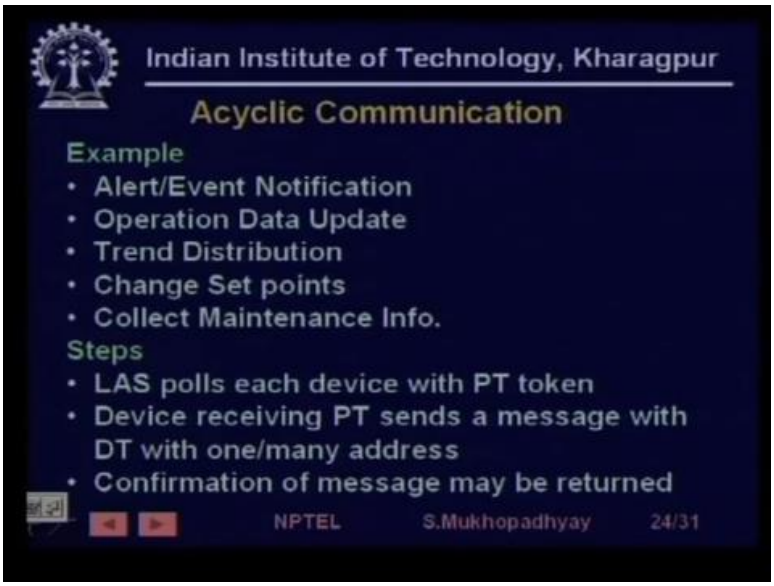

For acyclic communication a cyclic communication typically occurs when you have a lot of event notifications you have some operator data update sometimes you like to see some trends so you can ask for some trend data you can change set points or you can change give other kinds of commands to change operating modes collect maintenance information etc…

So these are these are not cyclic information's but demand-driven sometimes if they are invoke then that communication has to be obtained okay. For this the LAS polls each device with a with a with a PT token PT is the pass token so if you if a device has something to communicate it will take the pass token and then we will communicate if it does not have if it does not have anything to anything to communicate it will it will simply pass the token to the next device so whoever needs it will hold the token and then will transmit the data.

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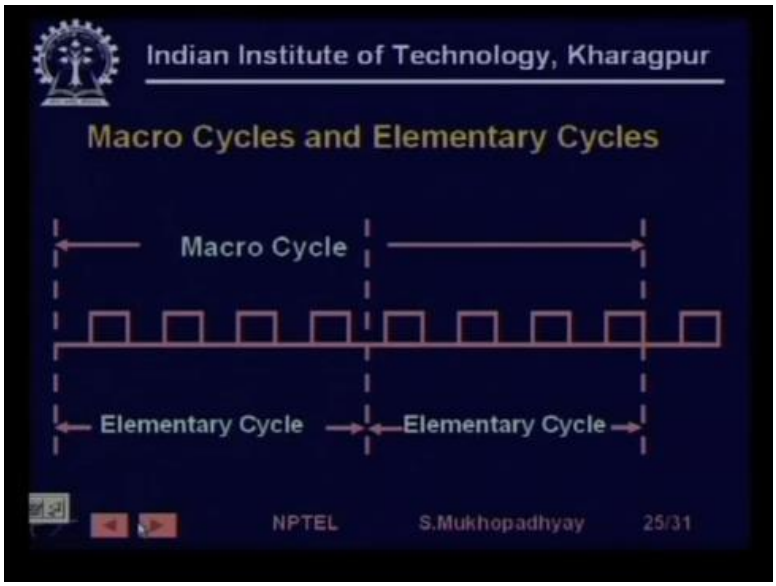

And the communication is actually organized overall into cycles called macro cycles and within each macro cycle so macro cycle is the basic cycle over which the over which the communication is periodic and then within macro cycles you have elementary cycles so an elementary cycle is decided by the fastest by the device which needs to communicate the fastest so you know if you have so let us let us see the next example we will understand it better.

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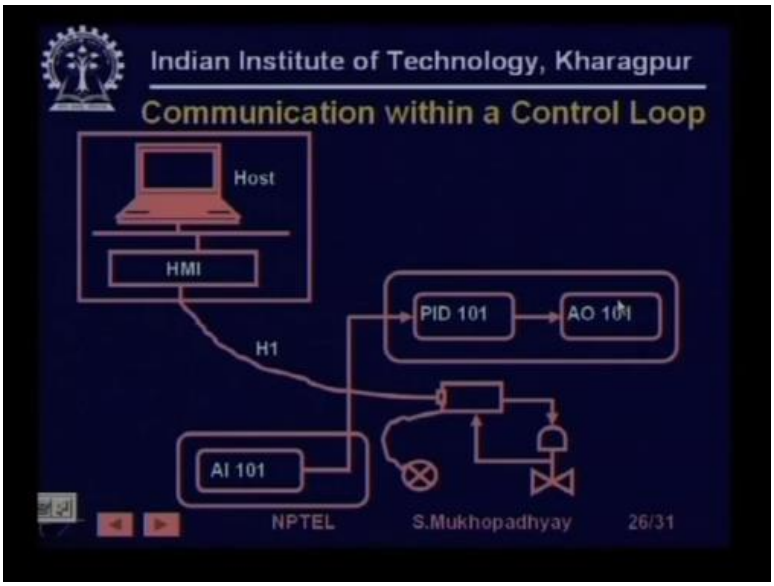

So for example to take this loop this is a PID loop with say an analog input PID and an analog output so these are you actually you know on different devices and the analog input so they are all on the network and the analog input this is a this is a functional block representation so virtually this AI must communicate with PID and then PID by must communicate with AO and they are actually physically different devices.

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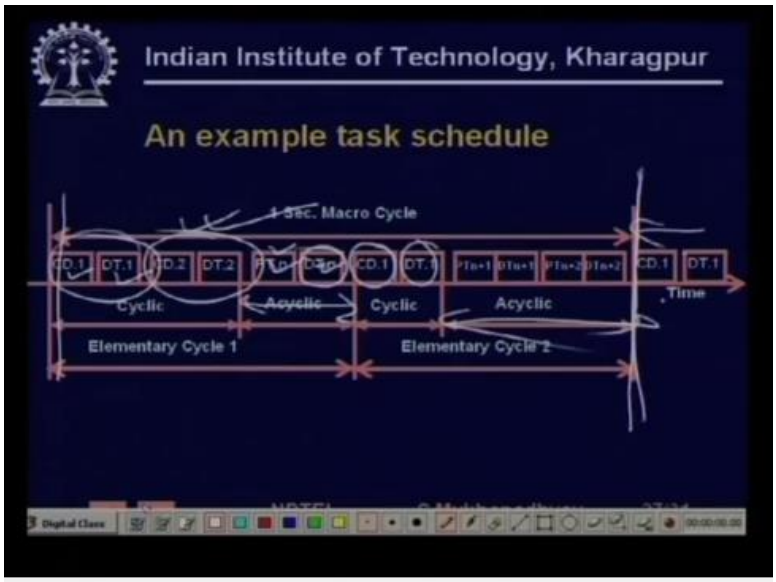

So in this case you see that suppose there are so this is an example you know of several devices so suppose it can very well happen that one device needs to talk two times in one second cyclic both are cyclic but another device who needs to talk only once so you see how it is organized so you have a you have a so the macro cycle is actually decided by the slowest device so since here the slowest device stocks needs to talk only every one second so therefore you have a one-second macro cycle on the other hand the elementary cycles are decided by the fastest device.

So in this case the fastest device needs to talk twice in a second so therefore in one micro cycle you have two elementary cycles so first time what happens is that CD 1 DT 1 so the first device talks then CD 2 DD 2 the second device talks and then some time is in this elementary cycle some time is kept free this time is kept for the for acyclic communication so if there is any a cyclic communication requirement then this PT n and DT n suppose this some NS device who needs to do some a cyclic communication so this PT will be passed and this and this DT will be transmitted .

Now in the next macro cycle you see that because CD1 and DT1 speaks it needs to talk twice in a second while CD 22 skipped because the second device does not need to speak twice in a

second and this whole time is actually utilized for a cyclic communication and then the next to a cyclic communication cycles go on and in the so now this micro psychic back to cycle ends and the second macro cycle begins so the first elementary cycle of the second macro cycle is here in which again CD1, CD2 and CD2 CD1 DT1 and CD to DT2 will take place. So this is the basic way in which the communication goes on here.

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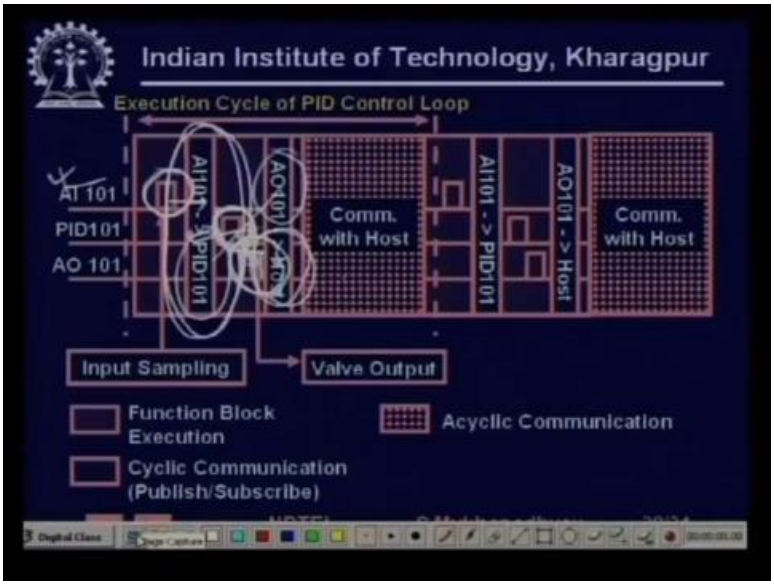

So for example see in that in that communication loop things are serialized also so first in this communication loop what happens is that first the AI 101 to PID 101 takes place so the analog input gives feedback to the PID controller then the PID controller PID controller now the PID controller as we had seen in the previous diagram that the PID controller and the analog output devices where on the same physical device so there is no need for communication so this PID controller giving value to AO is there is no need for communication but this analog output may also we may also have to be transmitted to the host.

Or some operator station which wants to see what kind of outputs are going to the plant so for that you need a communication so that is so at this point of time so they hear the analog input process computes input samples and then a communication is scheduled after this

communication ends the PID data has got the result so it will compute and then the PID will directly give and then the AI block will compute this does not require any communication because the PID and the AO block are on the same physical device no communication is required and then the AO block will communicate on the network with the host right. So this is the way the this PID loop computation and communication will go on.

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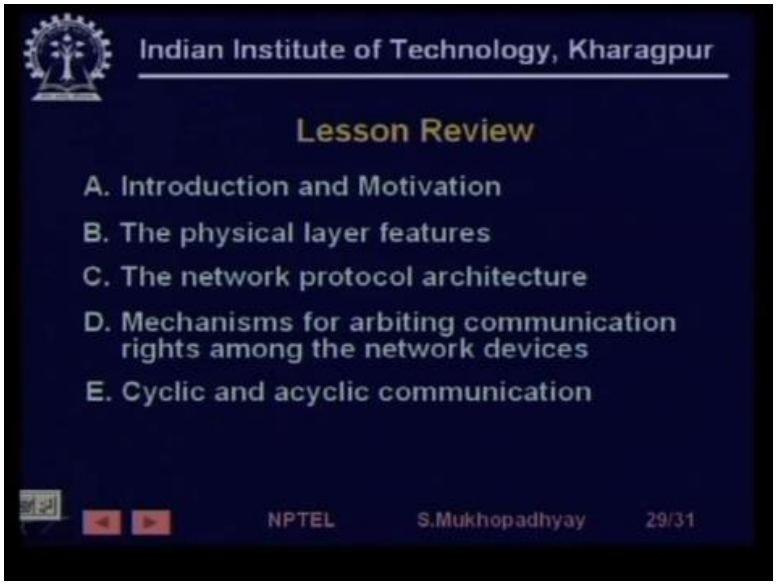

So this brings us to the end of the lesson so let us renew it so in this lesson we have seen the basic introduction and motivation of having a network so obviously here I would like to make a comment that obviously there are advantages of having a network over you know a simple analog or point-to-point digital communication system but one has to remember that the investments required for the field bus network all kinds of software the smart field bus devices all these things I mean the application domain must be large enough and must require enough quality and enough that is the cost of setting up this field but bus network must be justified.

So even if it is you know quite elaborate and gives lot of functionality but one should have need for that functionality and using that functionality I mean revenue should be should be returned so that is the this is we have this is another comment so introduction and motivation then we have

seen the physical layer features and we have seen that how these are connected how these are to be connected and how using repeaters and then detail communication you can have very large networks and you can have wiring advantages and you can have very reliable data communication.

Then we have seen the network protocol architecture and we have seen that it is basically some kind of an adaptation for the special purpose of plant wide control of the OSI layers and we have seen the what are the layers existing in the in the field pass architecture then we have seen the mechanisms for orbiting communication rights among the network devices so how cyclic and acyclic communication goes on by and how centralized bus master issues tokens to particular devices which take them and then transmit data.

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So this brings us to the last thing points to ponder some questions so for what kind of application is the network such as field bus justified right so I raise this point immediately so you can think of some application where this will be justified why our network and transport layer is absent in the field bus network this also has been discussed which communication mode constitutes the dominant traffic cyclic or acyclic so you can think of the various process automation tasks and

then decide which is mentioned two advantages of distributed control over centralized control so with this I would like to conclude today.

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Thank you very much.