Data Communications
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Lecture # 02
Layered Architecture

Hello viewers, welcome to the second lecture of the lecture series on data communication. The topic of today's lecture is layered architecture obviously layered architecture for data communication.

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On completion of this lecture the students will be able to explain the concepts of layering, explain the basic principles of the layered architecture particularly of the OSI model, they will be also able to explain how information flows in a layered architecture and specify the functions of the seven layers of the OSI model.

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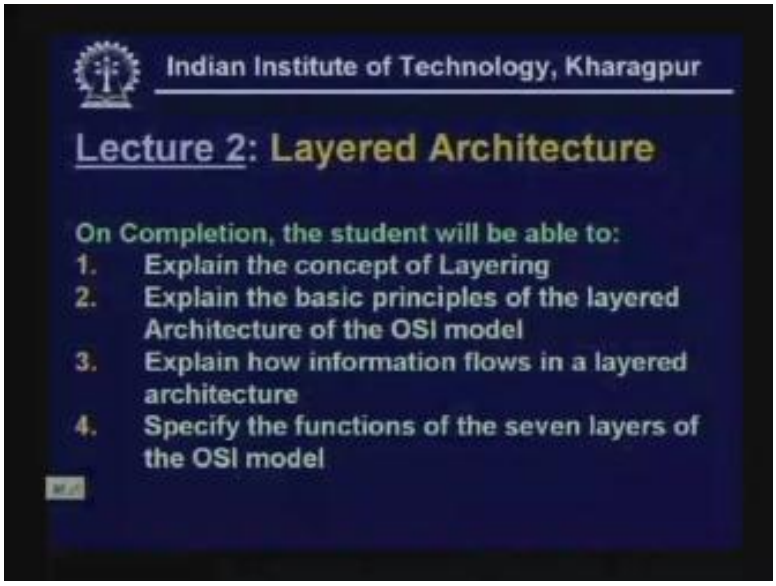

The outline of today's lecture is as listed here.

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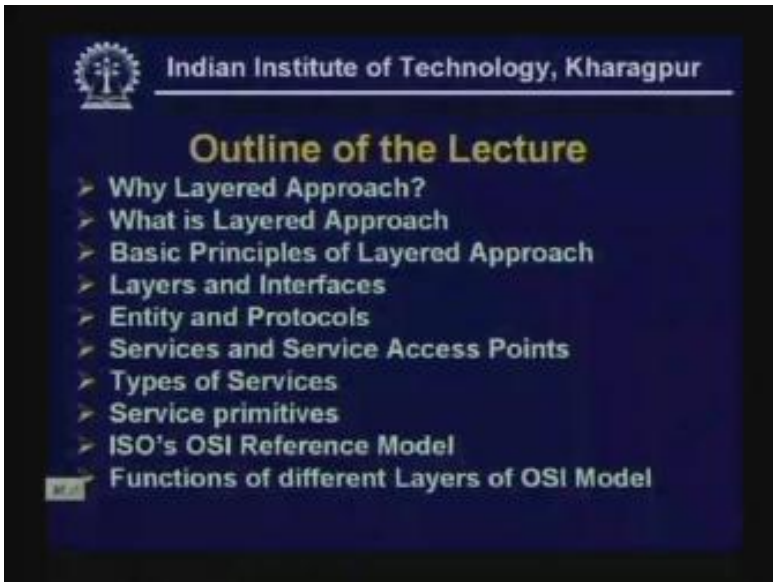

We shall first discuss why layered approach, what is layered approach, basic principles of layered approach, layers and interfaces, entity and protocols, services and Service Access Points, types of services, service primitives, ISO's OSI reference model ISO stands for International Standards Organization and OSI stands for Open System Interconnection and then we shall discuss functions of different layers of the OSI model.

First let us start with the basic concepts or why do we really need layered architecture. In the last lecture we have discussed the basic issues of data communication. There we have seen that data communication is a very complex process, it involves many issues, many functions and particularly when a user is trying to communicate with another user then the user must send in a particular form by following a set of rules so that he can communicate over an unreliable error prone communication system.

As we know the real world is not really ideal it has got noise and many things can happen like attenuation, distortion, noise these are the things that will be there so as a result the data we try to send will pass through the unreliable medium. So the user wants to perform reliable communication through the unreliable error flow medium and to do that it must follow a common set of rules for generating data.

And at the other end the receiver must follow the same common set of rules for interpreting the messages and unfortunately it has been found that the set of rules to be followed is very complex. It is so complex that it cannot be considered as a single entity, it is not possible to implement as a single entity in a monolithic form. Thus what is done in such circumstances is normally we follow a layered approach and this layered approach provides a viable process viable technique to deal with a complex problem.

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So not only in the case of data communication but layered approach is followed in many applications. In this particular case we shall follow the layered approach for data communication and we shall see it will involve a large number of functions. The large number of functions will be grouped or partitioned into hierarchical set of layers. Essentially this layered approach is nothing but a divide-and-conquer technique. What we do in a divide and conquer technique?

A particular problem or task is divided into a number of subtasks such that each subtask can be tackled easily.

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So let us see the basic issues or basic concepts of layered approach.

First point is as I said a complex problem is divided into a number of pieces of manageable and comprehensible size. Normally the data communication system is very complex. What we want is we want to divide it into pieces of manageable and comprehensible size such that each subtask or each piece can be understood easily.

We may consider it as a modular approach. We know that whenever we try to develop a software if the software is complex we try to divide it into a modular approach or structured modular approach, so what we do in that, we try to divide into modules then each module is developed independently. Hence that is precisely what we are trying to do here. So it may be considered as a structured modular approach.

One objective of this layered approach is that each module can be developed and tested independently. Why this is important?

Normally as we shall see a data communication system is not implemented by one person or complex application software is not developed by a single person but it is usually developed by a team of people. Similarly a data communication system is developed by a team of people having expertise in different areas. So here what we are doing is we are dividing into modules such that each module can be developed and tested independently. Whenever it is done when the development is performed by a team of people we can assign a particular module to a particular person then he can develop it and test it independently that is one of the basic principles of layered approach.

Then another basic principle is it allows easy enhancement and implementation of the functions of a particular layer without affecting other layers. That means as we assign a particular layer to a particular team member he will be able to enhance it, implement it independently. That means subsequently if some modification is needed, some correction is needed then that modification or enhancement can be performed independently without affecting other layers.

And whenever we shall be doing layering we have to follow some principles to do the layering, to do the partitioning. What is the first principle to be followed?

First principle is we have to use optimum number of layers. The number of layers into which the complex problem will be divided should not be too large, should not be too small.

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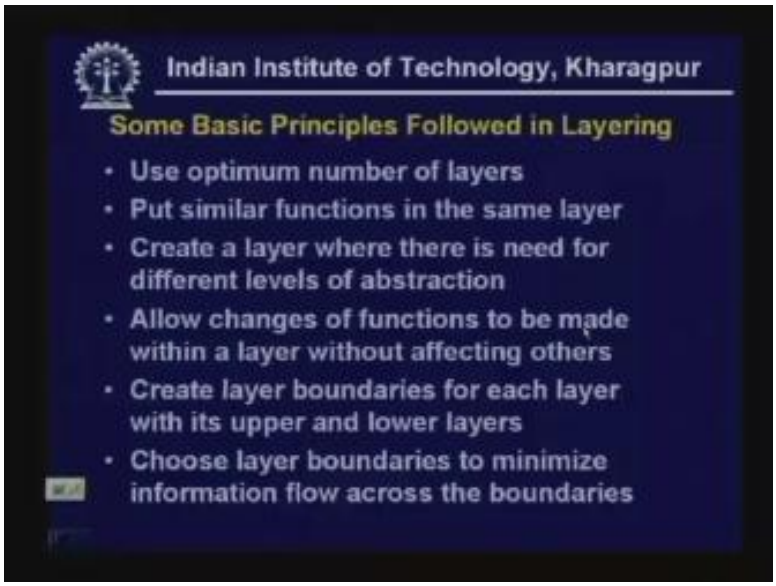

If it is too small suppose a complex problem is divided into two subtasks then what will happen is each subtask will remain again of high complexity. But what we want is we want to divide into some optimum number such that the subtask is not very difficult not very complex it is comprehensible, manageable and understandable. Then second principle that we have to follow is put similar functions in the same layer.

We shall see that in data communication functions some of the functions are similar, some of the functions are dissimilar. But we want to put similar functions into a particular layer and other functions can be put in another layer. This layering can be considered also from another view point from the level of abstraction. As we are performing a hierarchical set of layers we may consider that essentially you are dividing into different levels of abstraction. That means the top most layer has the highest level of abstraction and as we go down the layer it gets more and more refined, more and more defined and then at the lower most layer it becomes easy to implement.

That means higher layer will have higher level of abstraction and then the lower layers will have lower level of abstraction. And as I have already mentioned the partitioning should be done such that the changes of functions in a particular layer can be made within a layer without affecting other layers. Then as we shall see we have to create layer boundaries very judiciously.

Why it is necessary to create layer boundaries?
Because we shall say that the communication between layers will takes place through the layer boundaries. And if the layer boundaries are not judiciously defined then the communication may become a problem or communication information to be communicated will become a trouble. For example, we have to choose layer boundaries to minimize information flow across the boundaries. This is another objective or another principle to be followed while doing layering. Why it is necessary?

We are decomposing the data communication system into a number of layers. Now it is somewhat similar to multitasking or parallel tasking. A particular is divided into a number of parallel tasks or parallel processes. What we want in that situation is minimum inter-process communication.

Here also what we want is that the layer boundaries must be minimized in such a way we have to minimize the information flow across the boundaries. That means the two layers which will communicate with each other through these boundaries that information flow through these boundaries should be minimized.

Here as I was mentioning we have to create layers and also the interfaces between layers. Then in such a case we have to see that the system interconnection rules are modularized in terms of series of layers of functions say n layers. That means we shall divide the modules in the task into a number of n layers and each layer will contain a group of related functions and a layer below layer N and a layer above layer N are layer (n minus 1) and layer (n plus 1) respectively so we have to give names to the layers so that the top most layer will have the higher number and the lower most layer will have the number 1.

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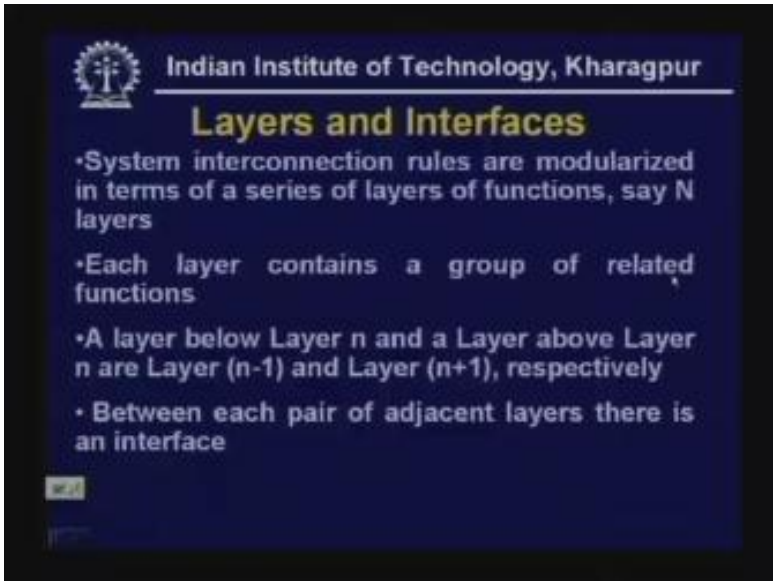

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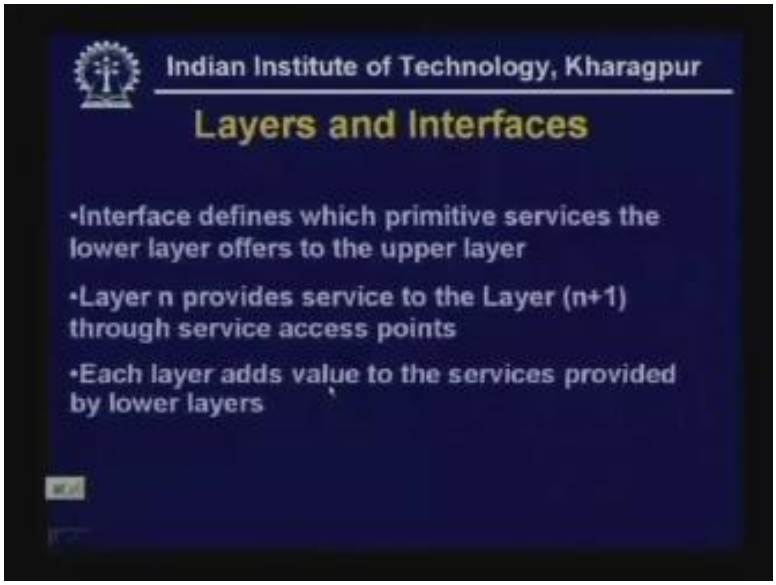

Then between each pair of adjacent layers there is an interface as I was telling and the interface will define which primitive services the lower layer offers to the other layer. As we shall see a lower layer will provide service to the upper layers. That means lower layer is a service provider and an upper layer is the service user and layer N provides service to the layer (n plus 1) through Service Access Points that means each layer will have a number of Service Access Points and through the Service Access Points layer end will provide services to layer (n plus 1).

And as we shall see each layer will add value to the services provided by lower layers. That means from the lower layer the services provided by layer N will be used by layer (n plus 1) to add value. Let me explain with more details with the help of a diagram

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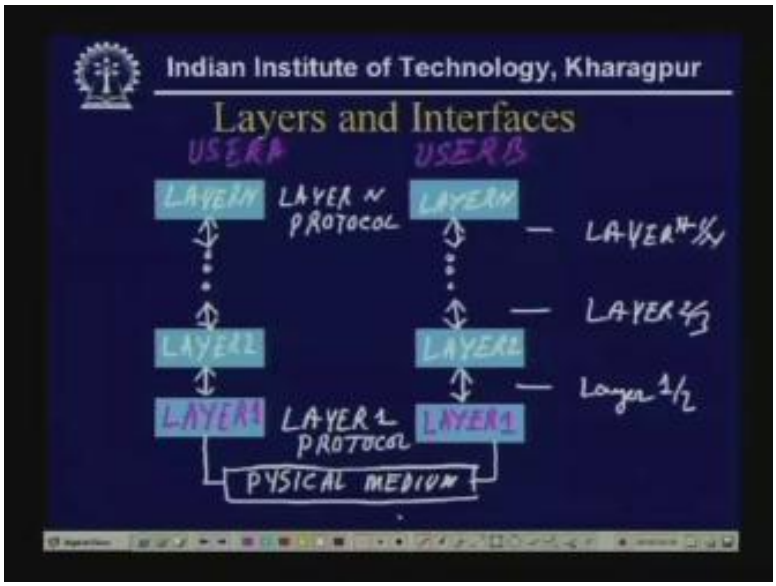

Here is layer N so this is layer 1 and this is layer 1 of another side so this is user A and this is user B and this is layer 2, this is layer 2, this is layer N and here is layer N. so we have grouped into n layers and as we can see there is layer boundary here or interface.

Layer 1 has an interface with layer 2 of this system, here also you have interface between layer 1 and layer 2 (Refer Slide Time: 17:52) then layer N has interface with layer (n minus 1), layer N has interfaced with layer (n minus 1), layer 2 has interfaced with layer three and layer 2 on this side also has interfaced with layer three. So here we have got n layers on two sides. Then here are the interface boundaries between layers. So this is the interface boundary between layer 1 and two, interface boundary between layer 2 and three and here is the interface boundary between layer (n minus 1) and n.

And as we shall see the communication takes place through a physical media, here is your physical media through which ultimately communication will take place and layer 1 will interface with the physical media and communication will take place in this manner. And each layer will have will have some protocols and this is known as layer N protocol. Later we will see in more detail about what we really mean by protocol and here we have layer 1 protocol.

So here I have drawn the diagram of two sides of a two system say here is user a here is user b as you can see the data communication system has got n layers here data communication system has n layers which are communicating with each other through a physical medium. This is the basic concepts of layers and interfaces.

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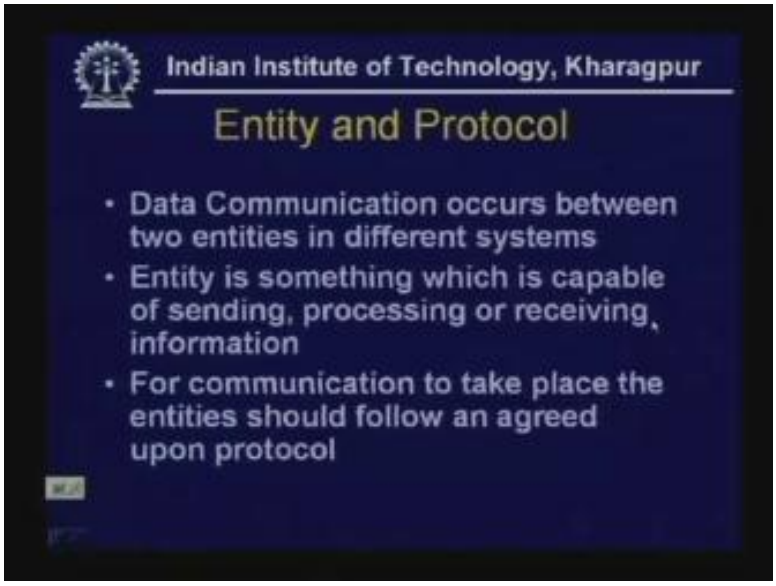

Data communication occurs between two entities in different systems. We have seen that the different layers are there and within each layer there are some entities and entities are responsible for communication. You may be asking what is an entity? Entity is essentially an active element. An entity is something which is capable of sending, processing or receiving information. An entity can be a piece of hardware, entity can be a piece of software or entity can be a piece of hardware software combination and these entities we will communicate, entity of layer n we will communicate with the entity of layer n of the other side so the entities will be communicating. These active elements within the layer are an entity and they are capable of sending, processing and receiving information. And for communication to take place the entities should follow an agreed upon protocol.

For example if two persons want to communicate they should use the same language. If one person is speaking in Bengali and another person is being is speaking in English cannot communicate with each other. They should follow some agreed upon rules which are known as protocol. So, for communication to take place the entities should follow an agreed upon protocol.

Here we have the details about the entity and protocol

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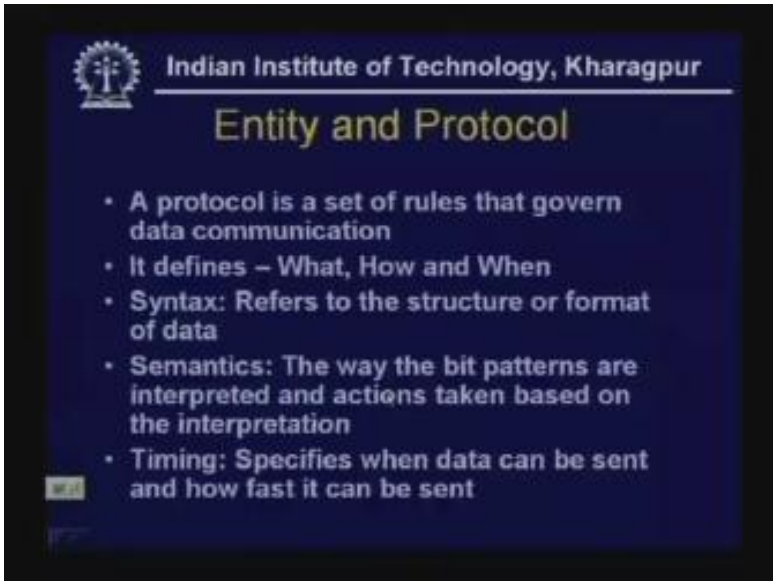

As I mentioned a protocol is a set of rules that govern data communication it defines what, how and when. So the protocol will define what to communicate, in what form the information is to be communicated, in what form it will go, will it be in the form of a bite, in the form of one kilobyte of packet or say one page of book so it will decide that and how it will be communicated. Also it will define when to communicate and for that purpose we have to define the syntax, semantics and timing.

Syntax will refer to the structure or format of the data. The data has to be properly formatted so that the other side can interpret it properly, then we have to follow also the semantic the way the bit patterns are interpreted and actions taken based on the interpretation. Semantics is nothing but some kind of grammar for example a language as a grammar, semantics is that kind of a grammar or the way the interpretation of data has to be done. So you have to define the syntax and semantics.

The timing is also very important for communication. It will specify when data can be sent and how fast it can be sent. As we shall go into the details we shall see that will be need for synchronization. That means when data is sent then the other side has to receive it from that point so that it receives correct data and also there will be some specific rate of communication. That means how fast it can be sent that has to be decided. So the rate of communication will be part of the timing.

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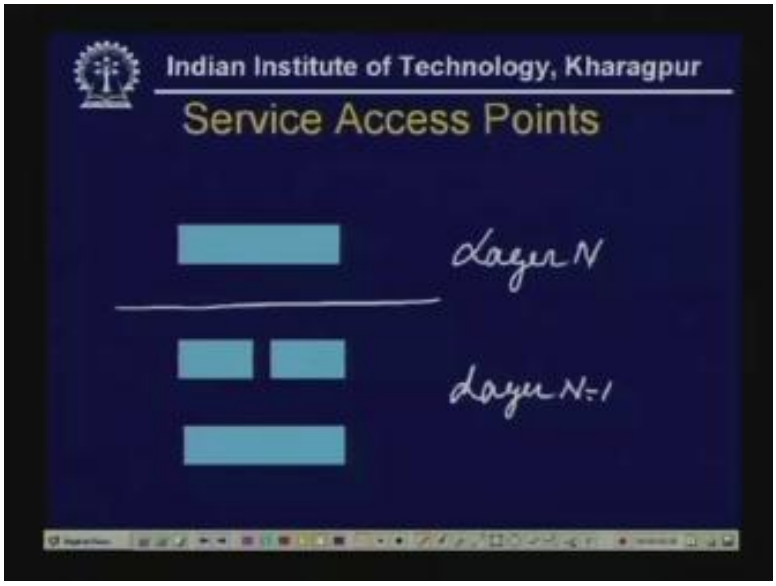

Let me explain how the layers communicate with each other through Service Access Points and for that purpose let us consider two adjacent layers. Here you have got two adjacent layers (Refer Slide Time: 24:27) say this is layer n and this is layer (n minus 1). So this is layer n and this is layer (n minus 1) and this is the interface between the two layers (Refer Slide Time: 25:00) and in these interface there is there is some Service Access Points, these are the Service Access Points SAP.

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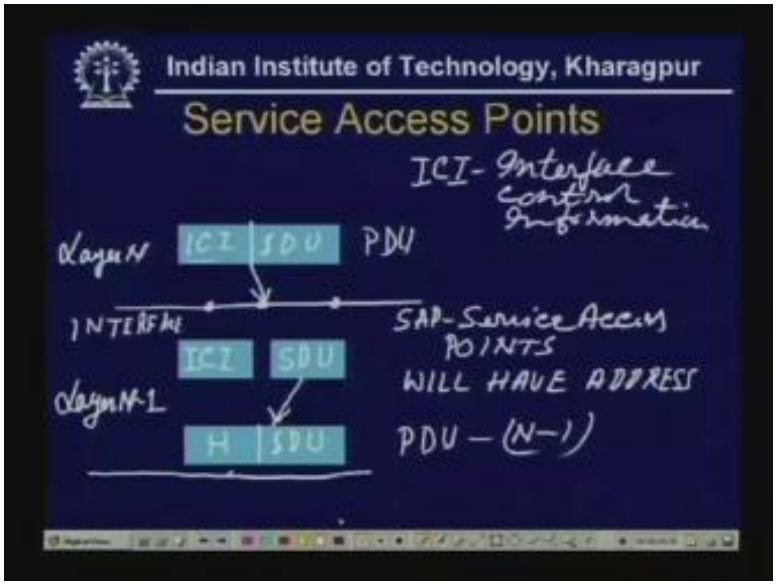

So, through these Service Access Points the layer N entities will get service from layer (n minus 1). So obviously the Service Access Points will have some address. Let us take an example for this.

Suppose we are using telephone system that socket of the telephone system is the Service Access Point of the telephone network. And as we know each socket corresponds to a telephone number and that is the address of that Service Access Point. So, if I want to use the telephone network for data communication my handset has to be connected to the socket and then I can get the services of the telephone system. So here it is somewhat like that, this is the service provider and this is the service user. And to get service from the service provider the layer N will send some data, it has got two parts; one is your Interface Data Unit IDU and the SDU Service Data Unit.

SDU stands for Service Data Unit and Interface Data Unit IDU and ICI is Interface Control Information. ICI actually is Interface Control Information and SDU is Service Data Unit for this and this is communicated to the Service Access Point and for communication to the lower layer.

So, interface control information is not really the data but it provides some control information to the lower layer. For example, whenever you are writing program in assembly language there is some assembly directive so that's the directive to the assembler for example ORG EGU DB these are the assembly directives. So these are not really the instruction but some directive to the assembler.

Here also we have somewhat similar to that the layer N will send this particular data called the PDU or Protocol Data Unit of this layer and this is communicated to the lower layer. And this lower layer will separate it out; ICI is separated out from the SDU Service Data Unit. Then the SDU can be divided into several parts. For example, here there is one part and it will be included that SDU will be included in that into another kind of Protocol Data Unit we call it Protocol Data Unit PDU and this layer (n minus 1) will add some header to it. So, after receiving this Protocol Data Unit from the N layer through the Service Access Point layer (n minus 1) will separate out the Interface Control Information, takeout the Service Data Unit put it in another Protocol Data Unit so this is essentially Protocol Data Unit corresponding to layer (N minus 1) which will add some header then again it may be sent to the next layer through Service Access Points. This is how the two adjacent layers layer N and layer (N minus 1) can communicate through Service Access Points and the unit of communication is Protocol Data Unit and that Protocol Data Unit is passed on through the interface to the lower layer which is interpreted with the help of the Interface Control Information. It takes out the Service Data Unit and again it makes another Protocol Data Unit by adding this Service Data Unit along with the header and that can be communicated with the next layer. So this is how the Service Access Point works.

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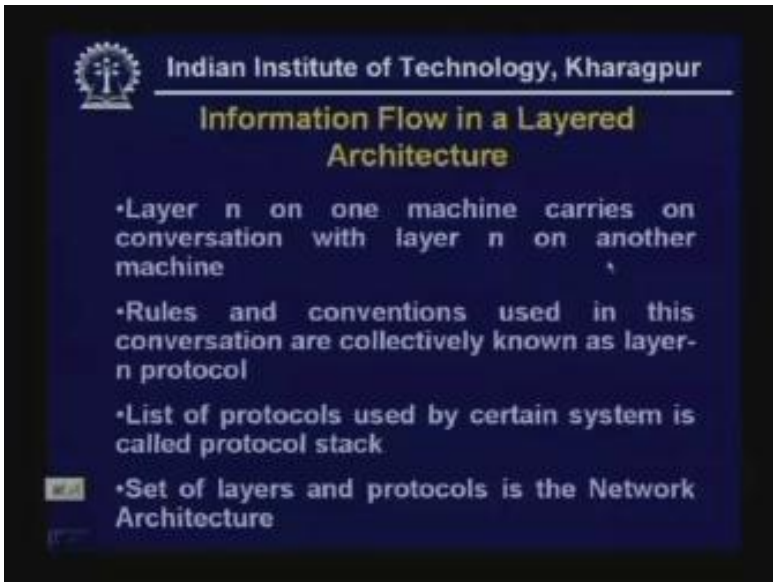

As we shall see layer N of one machine will carry on conversation with layer N of another machine. As I mentioned although we are using layering the entities of a particular layer of the same layer will communicate with each other and the rules and convention used in this conversations are collectively known as layer N protocol. And the list of protocols used by certain system is called protocol stack. So whenever the protocol is simple it can be written by a single protocol but sometimes we have to follow a set of protocols or a list of protocols and that entire thing is known as protocol stack. This is the protocol stack. And the set of layers and protocols in the network is the network architecture.

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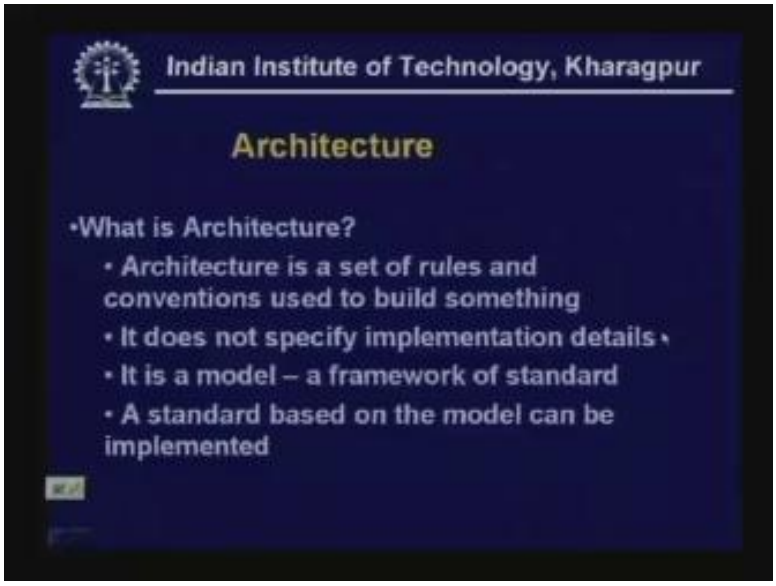

Our topic of lecture was network architecture but I did not define architecture. So here you see that the set of layers and protocols is the network architecture. And as I mentioned architecture is a set of rules and conventions that is used to build something.

Let me define more precisely what you really mean by architecture. It is a set of rules and conventions necessary for building something. it does not specify implementation details. For example, when we say Roman architecture or Gothic architecture we usually refer to some stylistic pattern of a building, it does not say how it has been implemented, those details are not known. Essentially it's a model and the model can be considered as a framework of standard and a standard based on model. Actually architecture will provide a framework of standard based on which something can be implemented.

As we shall see this network architecture will not really give you the implementation details. It will provide a framework of standard which can be used to implement something. Now as I mentioned the essentially different layers will interact with each other through the interface boundaries then the lower layer will provide service to its upper layer.

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Let us see the different types of services that are offered.

Services can be connection oriented or connection less. Connection oriented service is modeled after the telephone system. All of us know the telephone system. If we want to talk to somebody through a telephone system first of all you have to setup a link setup the connection. If you don't get connection because of some problem then no communication can take place. In other words no data transfer can be performed without setting a connection. Only after setting a connection data communication can be done so it is connection oriented.

Then connection less model is modeled after postal system. In a postal system we have seen if we want to send a letter to somebody we don't establish a connection with the receiver. We put the letter in an envelope, write down the address and then put that letter in letter box then from the letter box the postman collects it puts it in a bag sends it to the distance place there also another postman will open it and by looking at the address he will deliver it. So it can be connection oriented or connection less. Later on we shall have examples of the connection oriented and connection less services used in different applications.

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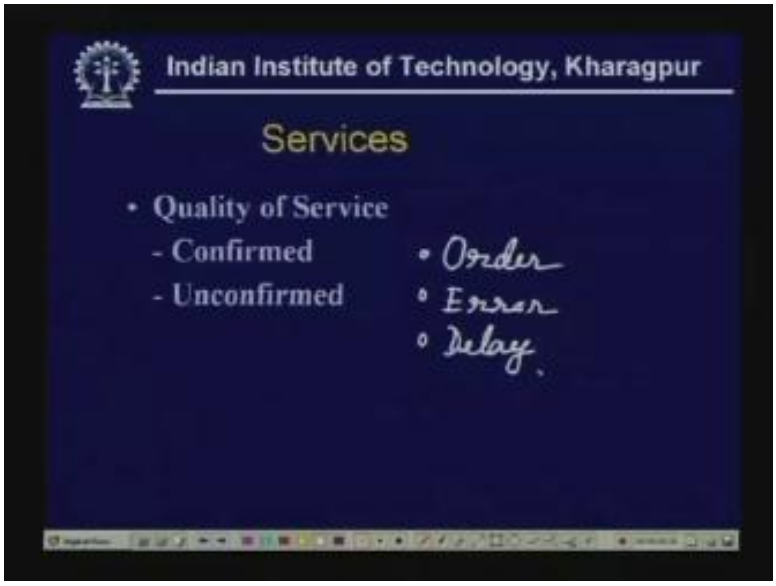

Then we can have some quality of service. Quality of service can be in different forms. One is confirmed service, another is unconfirmed service. For example we are sending a letter then after sending a letter if we want to know whether it has been delivered to the destination properly then it has to be confirmed service. Sometimes for example whenever we send a letter we send a letter we register an acknowledgement that means we have to use that acknowledgement card and after receiving that acknowledgement that particular packet or letter has been delivered to that destination. So in such a case we can call it confirmed service.

On the other hand normally we just post a letter and we assume that it will be delivered to the receiver. But there are situations when it is not done or there is some long delay. So that can happen in a unconfirmed service. And as we shall see a part of the quality of service may include order of delivery.

What do we really mean by order? Suppose we are sending three letters one after the other or say we are sending three volumes of a book one after the other then first we send volume I then we send volume II then we send volume III. It may so happen that at the other end it is not received in the same order it may be that volume III may be received first then volume I or volume II in such a case there may be some problem.

So sometimes it is necessary to maintain proper order of service. So order of service is important, the order in which things are delivered. Second is whether an error has occurred while sending the data. That means we have to find out whether any error occurred or did not occur. Then third issue which is part of the quality of service is the delay, how much delay that is occurring in delivering the thing. These are the various quality of services needed which are used as part of the service.

Let us take some example of services.

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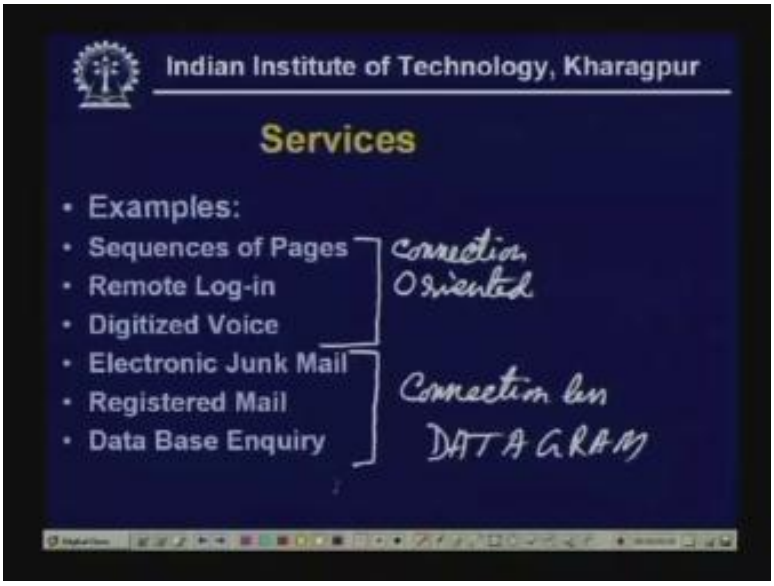

I have taken up six examples. First one is sequence of pages to be sent to another side, another example is remote login with which we are very much familiar with, third one is digitized voice. The first three can be considered as connection oriented and the next three are examples of connection less service.

Sequence of pages, remote login and digitized voice are sent through connection oriented services. And whenever we send sequence of pages usually it is a reliable message stream. Whenever we are sending reliable message stream it is part of reliable service. Remote login is also reliable byte stream we are sending that is the service that we use and digitized voice is unreliable connection oriented service that we normally use, electronic junk mail is an unreliable datagram service that is connection less and another name of connection less service is datagram service then registered mail is essentially acknowledged datagram service as I explained earlier in details.

Whenever we do a database enquiry it is essentially the request replay service. So we have some examples of services provided in data communication systems. Whenever service is provided and particularly if it is connection oriented then there are some service primitives. One such service primitive is the connection request where a request is made with the help of the connect request in which one side of the system requests a connection to be established. Then with the help of signal the other side will indicate whether connection has been done, it will signal the called party that connection has been done.

Then we have the connection response used by the callee to accept or reject calls. That means the other side will have some indication. By having that indication the other side will respond and will say whether it wants to accept or reject calls then connect and tell the caller whether the call was accepted.

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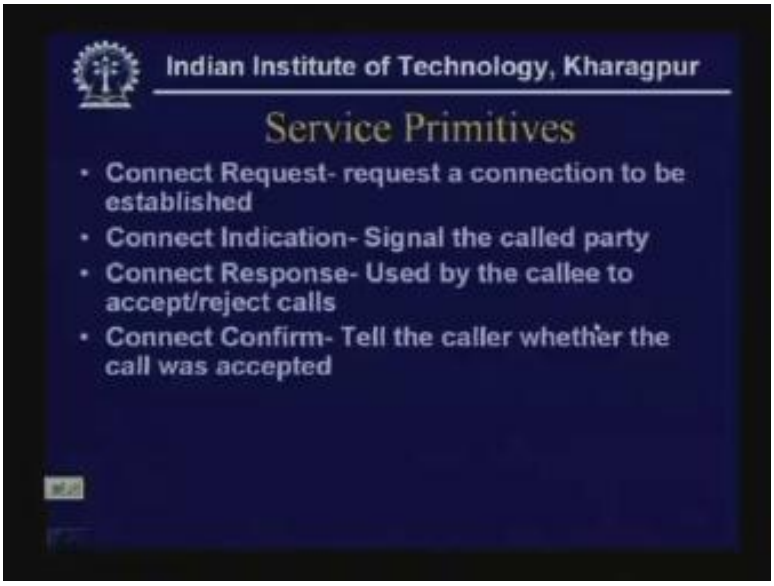

Then you have got data request, data indication, disconnect request and disconnect indication. These are the service primitives that have to be used in connection oriented service. Let me explain with the help of a time sequence diagram and show how it really occurs.

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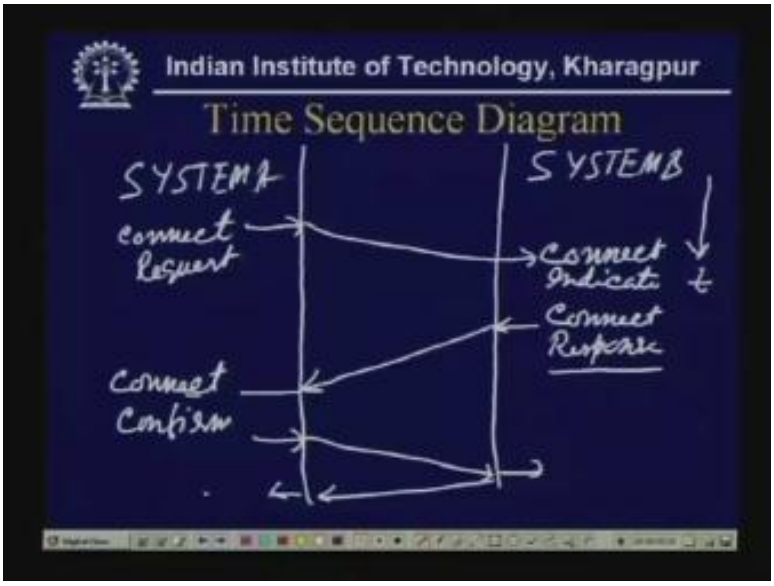

So this side is system A and this side is system B and here protocol actions are performed and obviously this is the service provider. So system A will make a request say connect request and in this direction you have got the time so after sometime the other side will get some indication so here we get connect indicate (Refer Slide Time: 44:20). Then this side the system B side will send the connect response and after some delay the other side will receive this connect confirm.

As an example you can consider the telephone system. for example if system A wants to communicate then it will dial the number and the other side will get the ringing tone that is the connect indicate and after hearing the ringing tone as connect indicate the user will respond by lifting the handset that is your connect response and the other side will get the information that connection has been confirmed. So once the system B side lifts the telephone this side will know that the telephone has been lifted and after that data exchange will take place in the same manner. That means data request will come from this side then it will have some data indication on the other side then the data response will come from this side to this side then it will have the data curve form and after the data communication is performed in this way then it will be disconnect request and disconnect confirm. So in this way in a sequence of time by using this protocol the communication will take place.

So we have discussed about the layering concept, we have discussed the concept of interface, the interface access points through which the communication takes place between two layers; we have also discussed some services and some service primitives.

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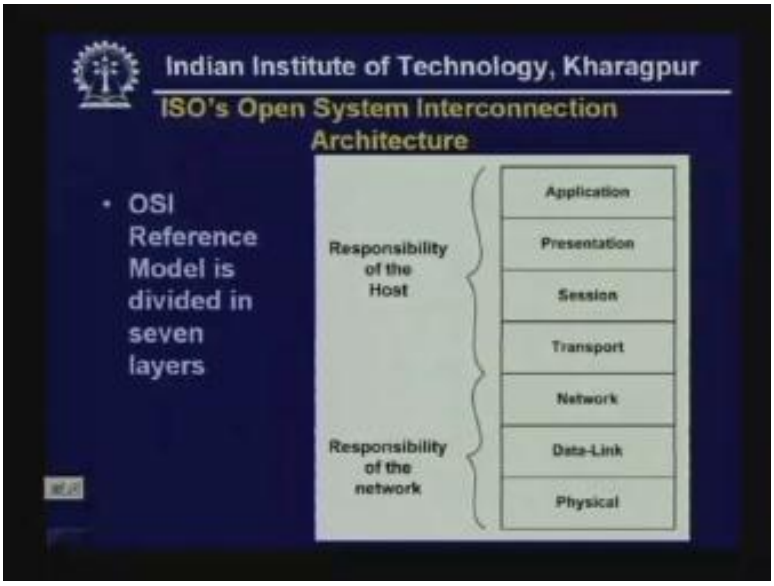

Let me explain layered architecture with the help of an example.

The most popular layered architecture that is followed in data communication is International Standards Organization's open system interconnection architecture, it is known as OSI reference model. As you can see it has got seven layers; physical layer, Data Link Layer, Network layer, transport layer, session layer, presentation layer and Application Layer. So we see it has got seven layers and out of these seven layers the lower three layers are the responsibility of the network and the upper layers are essentially the responsibility of the host or the computer. So here you see that with the help of these seven layers data communication is performed and most of the data communication systems follow this particular model.

Let me start with the functions of the lower most layer that is the physical layer.

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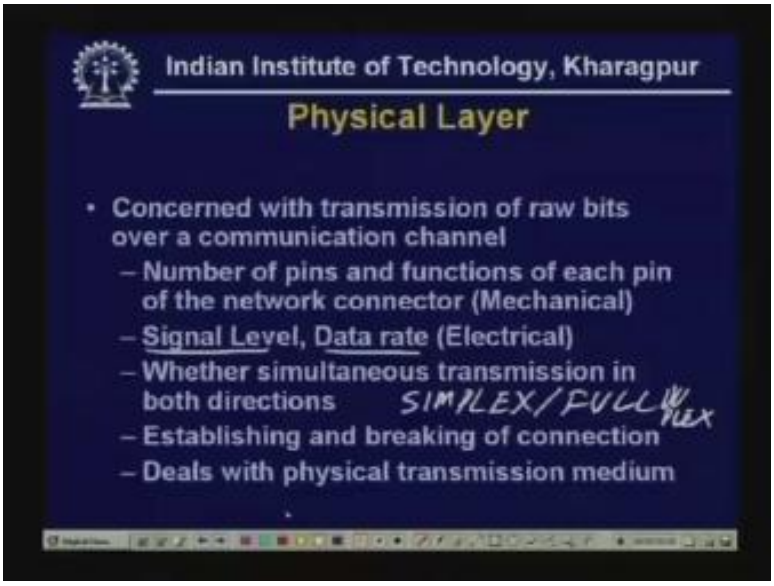

The physical layer is concerned with transmission of raw bits over a communication channel. As we have seen the physical layer is connected to the transmission medium. So this physical layer is concerned with the transmission of raw bits over a communication channel, it decides the mechanical interface that has to be performed between two systems. that means the connector what will be used, how many pins will it have, what is the length and so on and then it will have at the electrical part the signal levels, data rate and so on and then it will have functional procedural part and also it will decide whether simultaneous transmission is possible in both directions or not like simplex and so on. We shall discuss these in detail later; simplex or full duplex etc.

Then the lower layer also decides the establishing and breaking of connection. This is one of the functions of the physical layer and it deals with the physical transmission medium. That means what particular type of medium to be used, whether we shall be using a guided media like coaxial cable, optical fiber or we shall be using air unguided medium. So these are all decided as part of the physical layer.

With the help of a diagram let me explain how the physical layer will communicate.

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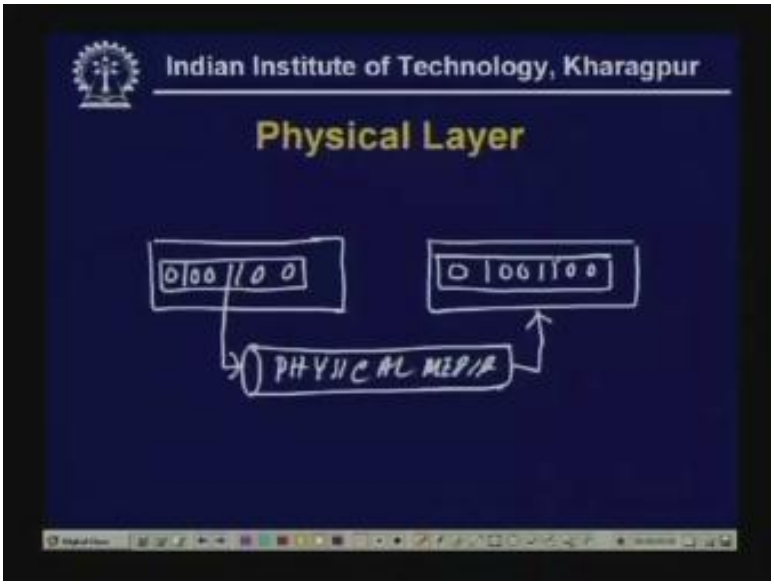

Suppose this is one side of the physical layer so here we have got one side. Suppose we are sending 01001100 then this particular data is a raw bit stream which is sent through a physical medium to the other side. The other side will receive the same thing so it will receiver 01001100 so this side will receive the data (Refer Slide Time: 51:01). So we can see here that these are the physical layers and these physical layers are communicating through a physical media and here is the raw bit stream. Then we have got the next layer that is your Data Link Layer.

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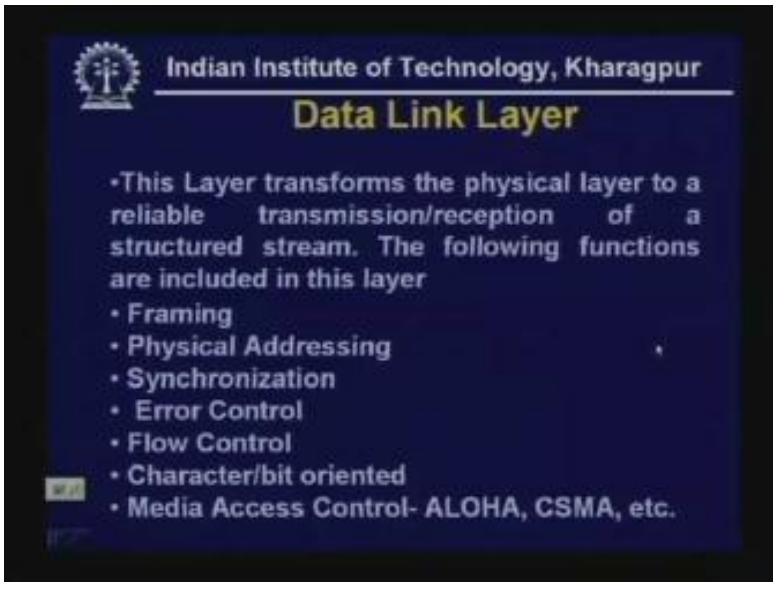

The functions of the Data Link Layer is that this layer transforms the physical layer to a reliable transmission and reception of structured stream. The raw stream is transformed into reliable transmission and reception of a structured stream and here are the functions performed: framing, physical addressing, synchronization, error control, flow control and also decides whether the transmission will be character oriented or bit oriented. And as we shall see whenever the communication is taking place to a multiple number of people then it will do Medium Access Control. That means a medium is shared by a large number of people. Then we have got network layer, these are the functions performed in a network layer.

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The network layer is responsible for source to destination delivery by establishing, maintaining and terminating connections and it will deal with logical addressing. As we shall see as part of the frame we have to put source at this destination address so you have to do some kind of framing and logical address will be part of that then it has to do routing because here it will go through a number of communication systems. There are examples of routing such as virtual circuits, datagram service etc. It will do assembly and disassembly of messages, messages may be assigned priorities and it may be necessary to do internetworking particularly in a heterogeneous network that will be the responsibility of the network layer.

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Then comes the transport layer. This transport layer is responsible for true end to end communication. In the previous one this network layer was not really concerned with end to end communication but here this transport layer is concerned with end to end communication. Particularly the quality of services required by the upper layer is provided by it, it will do port addressing which we shall discuss later on in detail. It may be necessary to multiplexing, multiplexes end user addresses onto network. It may be necessary to breakdown a packet into a number of packets and reassemble at the other side. So this segmentation and reassembly is done by this transport layer. Then we have the connection control which monitors the quality of services, end to end error detection and recovery, multiplexing, flow control these are the various functions performed in the network layer.

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Then comes the next layer which is the session layer. The session layer establishes connection and when the data transfer is complete it does the termination. So it performs dialogue management and as part of the dialogue management it will decide who will speak if you feel somebody will speak and how long they will speak. And as I mentioned the communication can be simplex, half-duplex or full-duplex which we shall discuss in detail later on.

Whenever the communication is taking place over a long distance there maybe failure. So, to recover from failure in a efficient manner some check point maybe done which is a part of the session layer. it will also do the token management. This is necessary when some critical operations are performed by one side. So the side which has the token will perform the critical operation and that management is done in the session layer.

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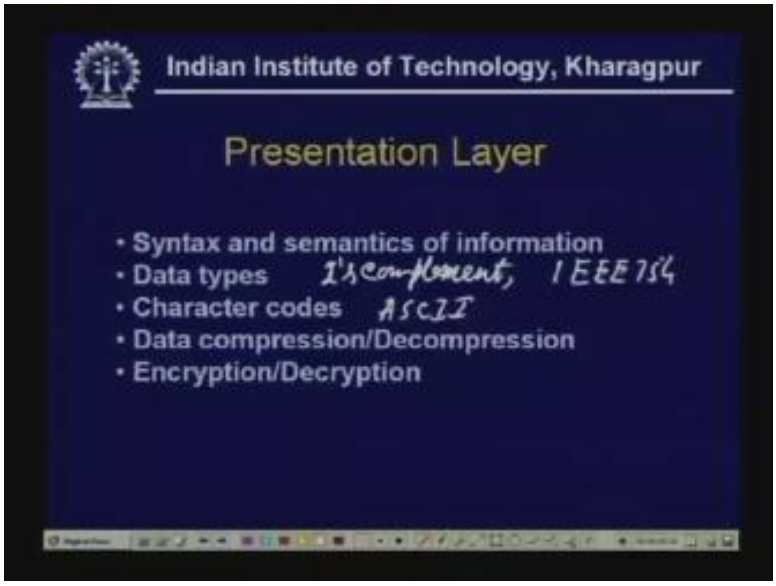

Then comes the presentation layer. The presentation layer is responsible for syntax and semantics of information. We have the data types, the type of data used, whether it is 2s complement number or whenever we are using floating point number we have to use IEEE 754. So what data types are supported is decided by this then the character codes like ASCII or something else is also decided. It will also decide about data compression at the other side, decompression like jpeg, mpeg compressions are also done which is part of this presentation layer. Sometimes for secured communication encryption and decryption has to be done and this is the function of this presentation layer. Finally comes the last layer that is your Application Layer.

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Application Layer is concerned with user applications and there are two types common application service elements, elements like login, password checks, or it can be specific application service elements like file transfer, access and management, job transfer and manipulation, electronic mail, videotex, teletex, telefax, message handling, document transfer etc are in within the Application Layer.

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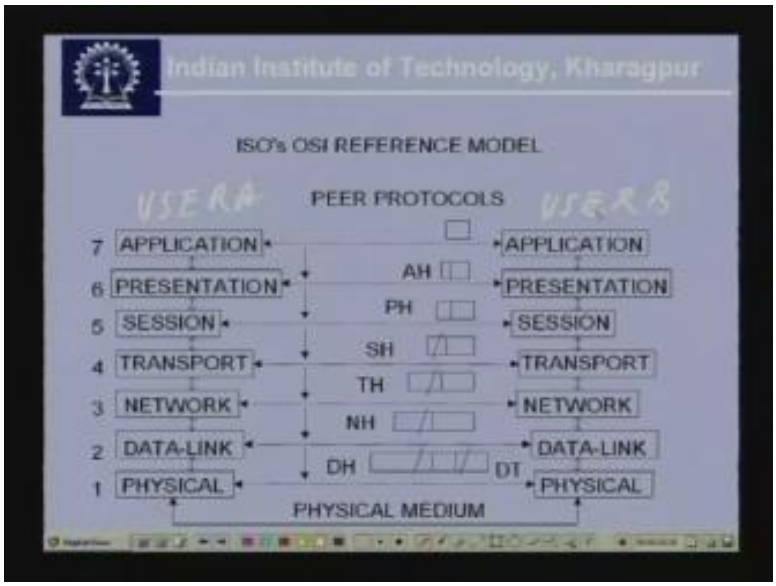

This diagram shows rather in a Gibbs in a nutshell the complete picture of communication.

here you see that from the Application Layer some data is coming in and then Application Layer puts a header to it and sends this to the presentation layer and the presentation layer in turn will put a header to it send it to the next layer that is the transport layer and the transport layer will put a header to it and send it to the network layer and the Network layer will put a header to it and send it to the Data Link Layer and the Data Link Layer will send it to the physical layer and physical layer will perform the communication. So here what is mentioned is how communication takes place. However, communication takes place between two users they are the peer protocols.

For example, here you have got the user A and here is user B. suppose they are sending email so this user A will send email and that it will go down through this channel and it will reach the user B. So essentially user A is communicating with user B and these are the layers which are used to pass the information to different layers so that it reaches the other side in proper form and it is interpreted properly. So before I conclude this lecture let me give you some review questions.

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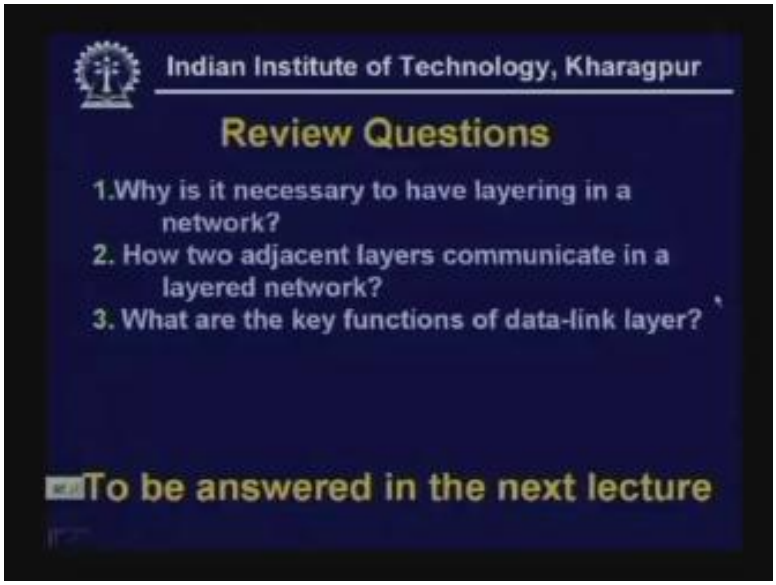

1. Why is it necessary to have layering in a network?
2. How two adjacent layers communicate in a layered network?
3. What are the key functions of Data Link Layer?

These questions will be answered in the next lecture, thank you.