**Digital Protection of Power System**
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**Lecture 36**
**Introduction to IEC 61850-II**

Hello friends, so in the previous lecture we have discussed regarding the introduction of IEC 61850, so IEC 61850 is a protocol related to communication networks and systems for power utility automation and in this IEC 61850 we have discussed different parts.

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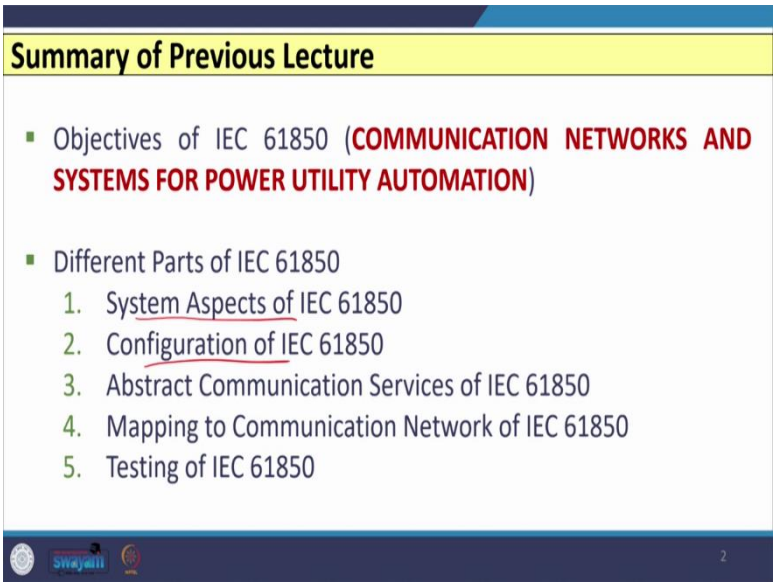


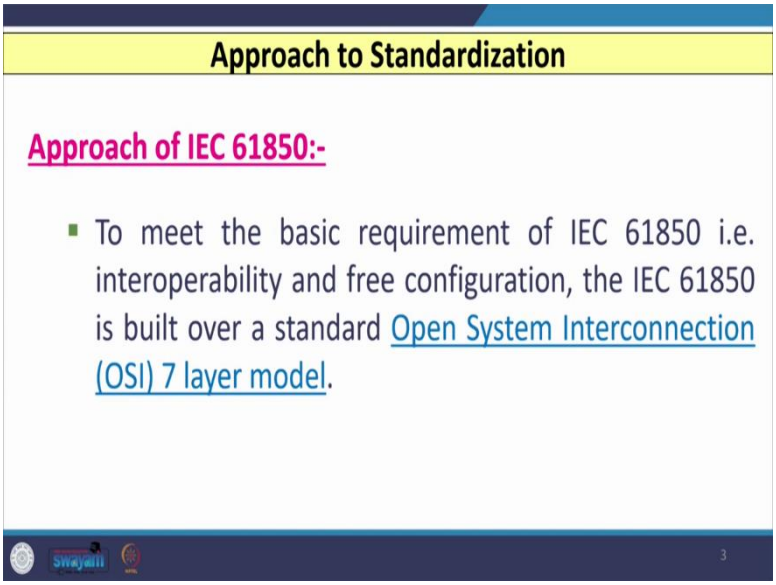


In this parts we have observed that there are basically 5 parts starting from system aspects of IEC 61850, configuration of IEC 61850, abstract communication services of IEC 61850 then mapping to communication network, and finally the conformance that is testing of IEC 61850,

and we have discussed that for each of these 5 parts there are several parts are also available say part 1, part 2, part 3 like that and we have discussed this thing in details in the earlier lecture Now, let us discuss first how we can go and approach with reference to the standardization.

So, initially in the previous lecture we have discussed the important objectives of IEC 61850 and we have discussed that interoperability, free configuration and long-term stability these are the three important objectives of IEC 61850 and if we wish to achieve these three objectives that is interoperability, free configuration and long term stability then IEC 61850 is built over a standard that is known as open system interconnection seven layer model. So, now let us discuss what OSI 7-layer model is and how it can be configured with the IEC 61850 objects and data models?

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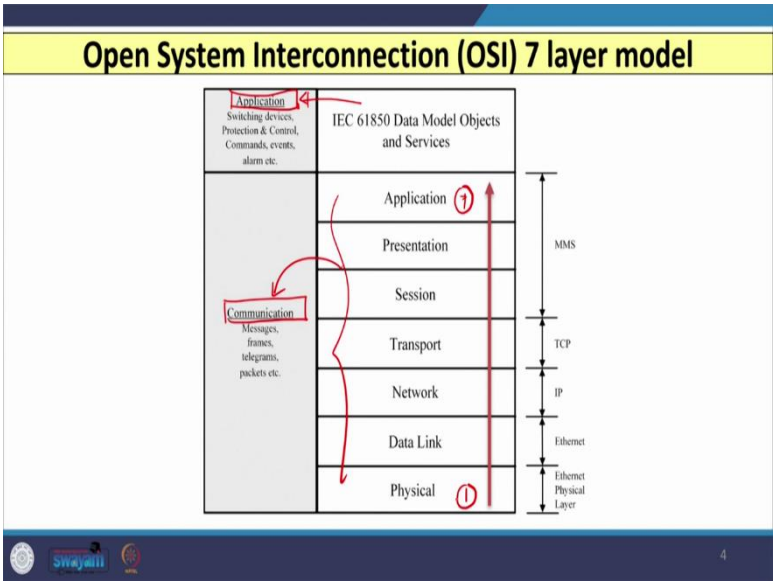


So, we can see that if we consider the basic layout or structure of OSI 7-layer model then this can be divided in two parts. The first part is related to the layer that is seven layers, it is related or meant for the communication purpose and this communication can be in the form of messages, it can be in the form of frames, telegrams or packets.

So, usually we know that when we are dealing with PMU, PMU will send the data in the form of the packets, so these 7 layers that are under the communication part are related to the messages, frames, telegrams, and packets. These 7 layer starts from the bottom that is the physical layer is the first one, and if you move ahead then these application layer is the seventh one.

The second part is related to the application purpose and this can be switching devices, it can be the protection and control applications, it can be the application related to the commands, events, alarm, etc. So, whatever the data model objects and services are available or there for IEC 61850 those are in application related issues, and all the 7 layers are under the communication related aspects.

So, we will discuss first these 7 layers starting with the bottom most layer that is the physical layer and then we will discuss the data model objects and services that is related to IEC 61850, so let us start our discussion with the physical layer. So, you can see in the layout (as shown in above slide) that physical layer is the first layer and in that I have mentioned that it is ethernet physical layer.

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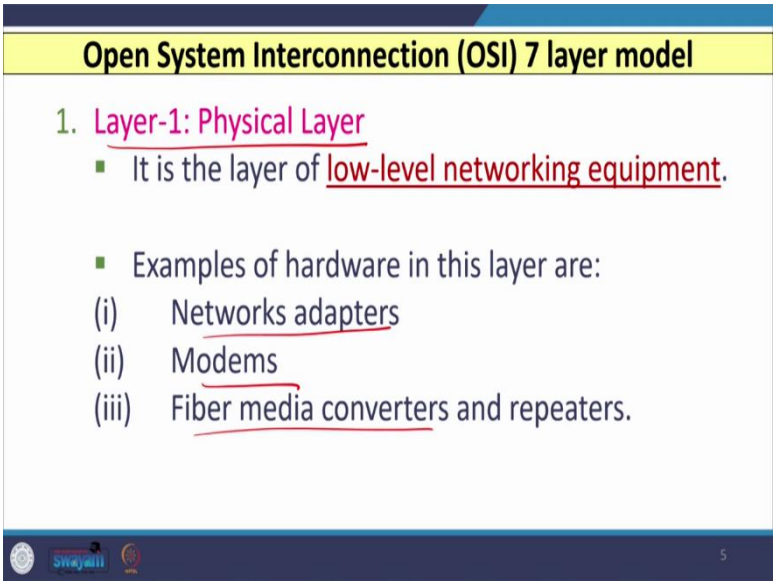


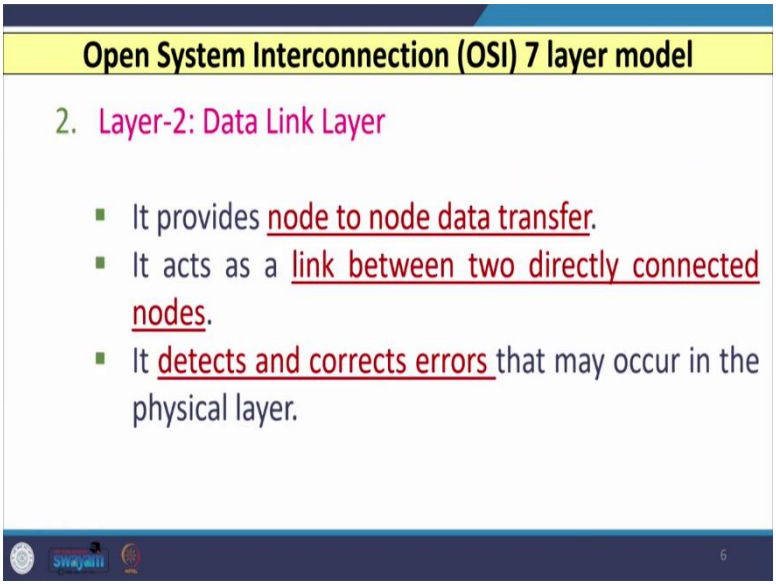

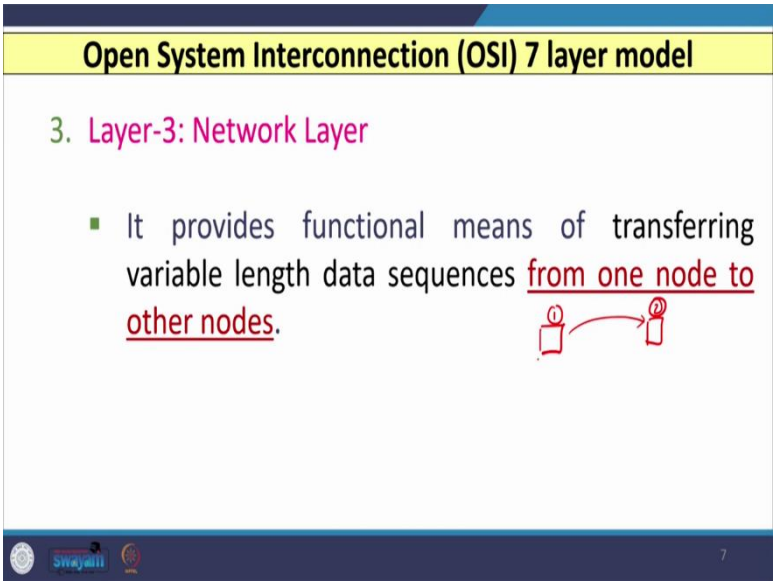


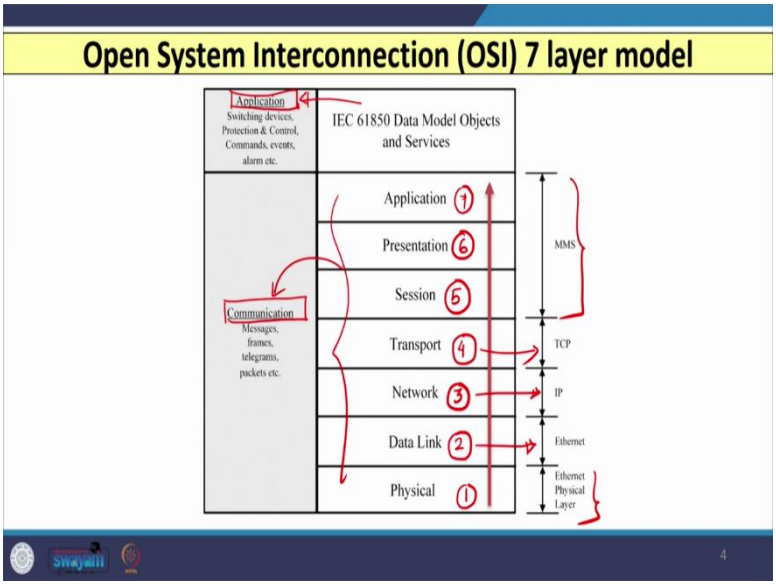


So, if we are talking about the layer 1 that is physical layer then it is the layer of low-level networking equipment. If we consider the example of hardware in this layer then these examples are network adapters then we have modems, and maybe we have fiber media converters and repeaters are the best examples of this physical layer and that is why you can see in the layer also I have mentioned ethernet physical layer, so it is a layer of low-level networking equipment.

Now, the second layer is known as data link layer, so data link layer is basically again I have mentioned that is it is again an ethernet layer. So, data link layer provides node to node data transfer, so it provides node to node data transfer and at the same time it will also act as a link between two directly connected nodes. It detects and at the same time also corrects the errors if any in the physical layer. So, if any errors are observed or available in the physical layer those are not corrected then that can be rectified by data link layer. So, it provides node to node

data transfer and it also acts as a link between two directly connected nodes, we will see what the function of nodes and all that.

The third layer is known as the network layer and as have mentioned it is related to the IP that is internet protocols. So, the third layer which is a network layer that provides functional means of transferring variable length data sequences from one node to another node. So, if you have let us say, the one node and if you have the other node and if you wish to transfer the data in the form of the sequences then this layer will serve for that purpose. So, from one node to another node it provides a functional means of transferring the variable data length sequences.

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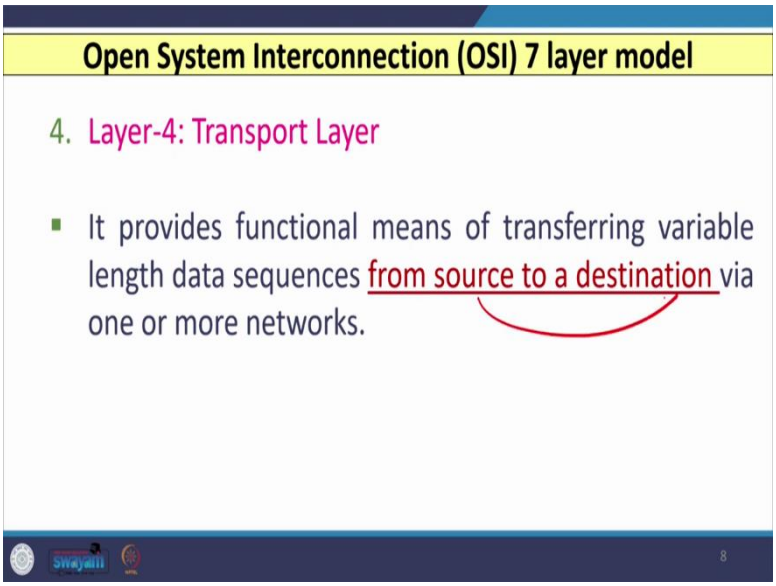


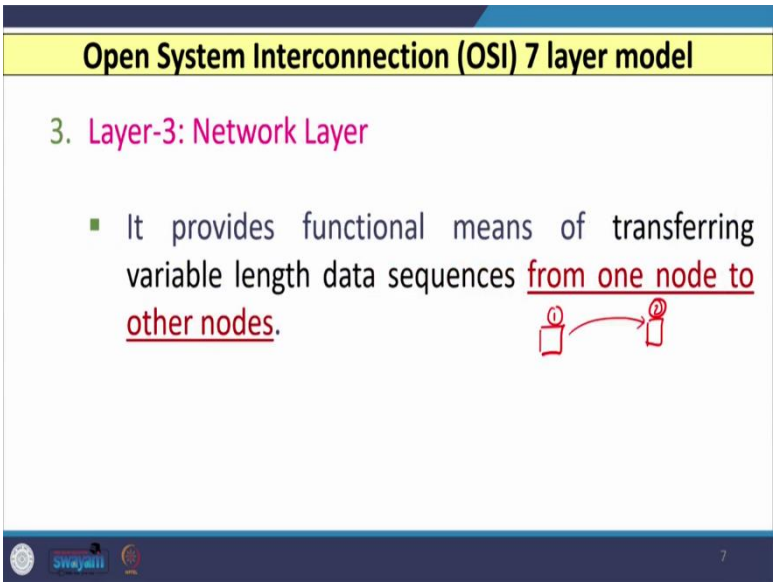

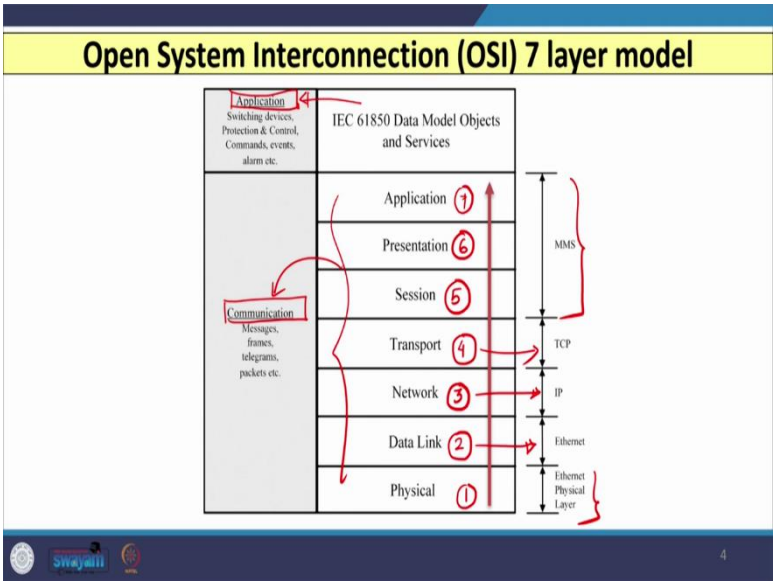


The fourth layer is the transport layer and it is also related to the transmission control protocol that is TCP. So, the transport layer provides again a functional means of transferring variable length data sequences from source to destination via one or more network. So, the earlier layer that is the network layer that will provides the functional means of transferring variable length data sequences from one node to other node.

Whereas the transport layer suffice the same function or serves for the same function, but again from source to the destination via one or more network. Then the fifth layer is known as the session layer and from this onwards that is fifth layer that is session layer, sixth layer that is presentation layer, and seventh layer that is the application layer, all are related to the MMS part that is the manufacturing message specification.

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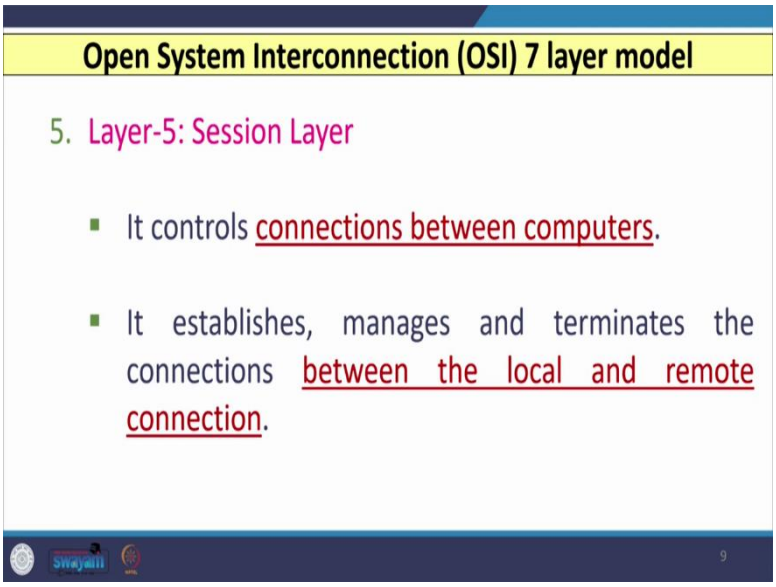


## Open System Interconnection (OSI) 7 layer model

6. Layer-6: Presentation Layer

- It transforms data into the level which is accepted by the application layer.



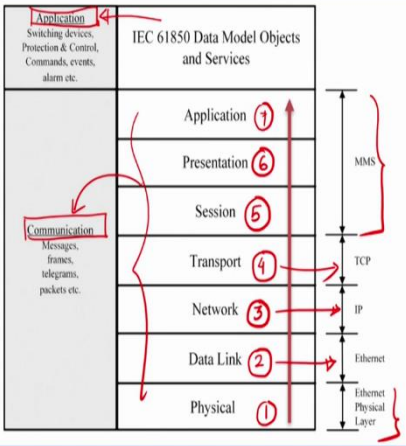
## Open System Interconnection (OSI) 7 layer model

7. Layer-7: Application Layer

- It interacts with software applications that implement a communicating component.



## Open System Interconnection (OSI) 7 layer model



So, if we talk about the session layer which is the fifth layer then it controls the connections between the computers. It also establishes, manages, and terminates the connections between the local and remote connection. So, if you wish to establish a connection between local and remote even if you wish to manage it or terminate the connections between local and remote then that is done by the fifth layer that is session layer. Then the next layer is known as the presentation layer, which is the sixth layer. This layer transforms data into the level which is accepted by the application layer.

So, basically it will act as an interpreter so that the one type of data that can be transformed to the data which is acceptable or understood by the application layer which is the top most layer that is the seventh layer, and the seventh layer that is known as the application layer it interacts with software applications that implement a communicating component.

So, it is going to again communicate with the several components which are there finally, so when we will see the detailed layout between this application and communication that is between the data model objects and services and this OSI 7-layer model then we will see that how application layer that can be communicated or through which how the information can be communicated with the higher levels.

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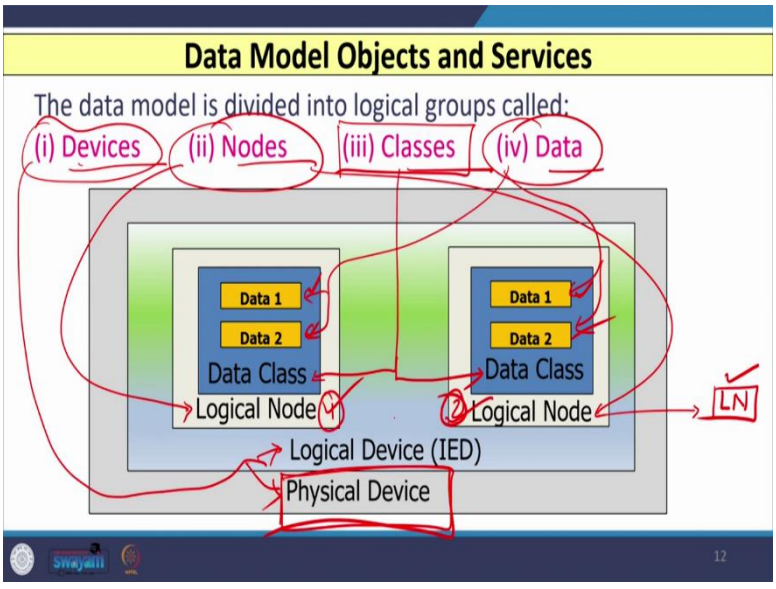

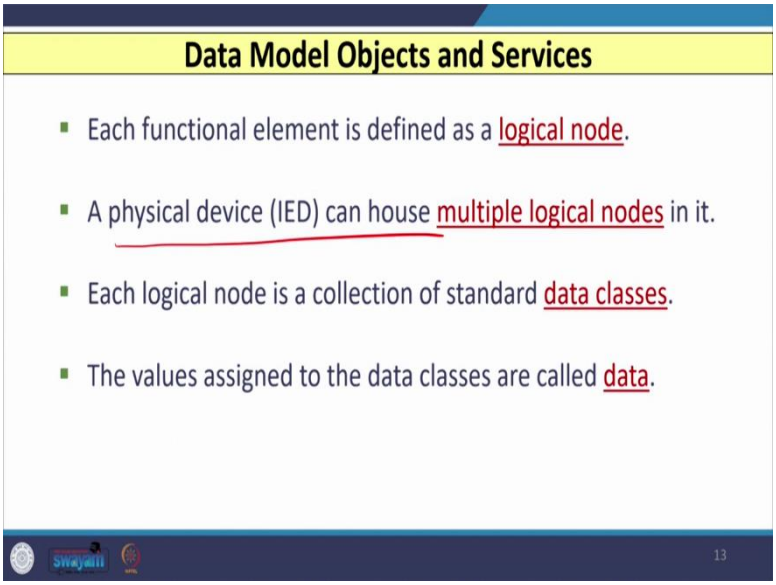


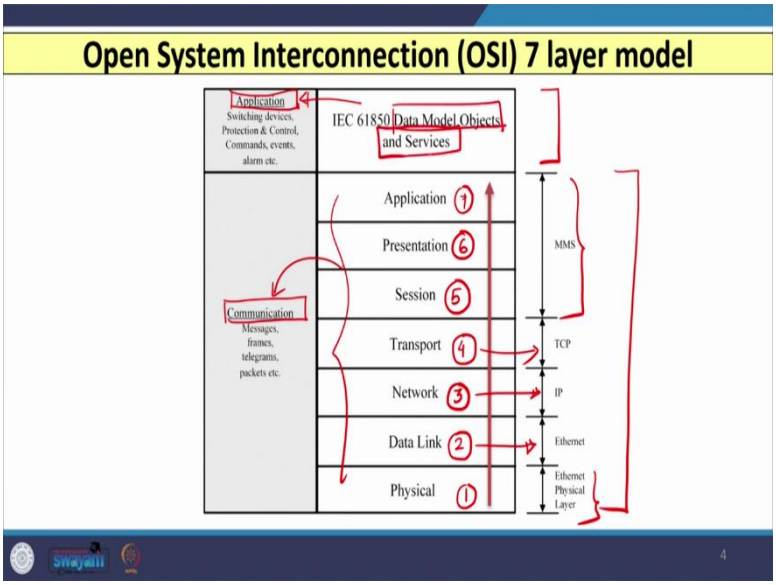


Now, with this background of OSI 7 layer model let us discuss the data model objects and services, so again if I go to the layout part then you can see that we have discussed this seven layers and what is the importance of each layer. Now, we want to discuss the data models objects and services part that is related to IEC 61850.

So, in this case when we consider the data model objects and services in IEC 61850 then it can be divided into logical groups and this logical group known by the devices, the nodes, the classes and the data. So, you can see that the first one that is the devices this part that comes here, so we have the physical device that is let us say whatever physical device we have PMU, IED, relay and then we have a logical device also, so devices that is available in the form of physical device or it is in the form of logical device.

Then we have the nodes, basically these nodes are known as the logical nodes, so the second part nodes that is available here in the form of the logical nodes and normally these logical nodes are denoted by the symbol LN, so LN that is nothing but the logical nodes. Then we have the several classes let us say these classes are nothing but the class of data.

So, you have the data class available here and in each data class it contains several data like the data 1, data 2, and so on. So, this point data that is nothing but these two things and similarly here also you have the data that is available in the data classes and this data classes are again part of logical nodes and different logical nodes are there in the physical devices.

Now, if I consider the logical nodes which is denoted by the symbol LN then each functional element is defined as a logical node. So, in any physical devices let us say IED, PMU it has many logical nodes, so any functional element that can be defined as a logical nodes. A physical device you can see this point that is known as let us say IED, it can be PMU, it can be PMU enabled relays, digital relays, anything, so a physical device can house multiple logical nodes. So, here you can see in this diagram (as shown in above slide) we have one physical device which contains two logical nodes, logical node one and logical node two, so it may have several logical nodes.

Each logical node is a collection of standard data classes, so you can see logical node 1 we have several data that is available in data class similarly in logical node 2 also we have data classes which contains several data and the values that is assigned to the data classes are known as the data. So, you can see here in data classes I have shown data 1, data 2 and so on, so this are nothing but the values assigned to the data classes and that is known as data.

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## Data Model Objects and Services

- Each control or automation function can be broken into a collection of different logical nodes.
- These logical nodes can be housed in a single IED or distributed among multiple IEDs.

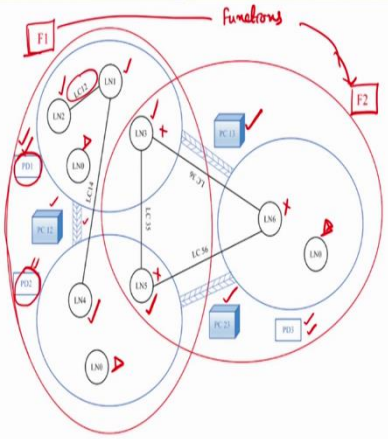


## Data Model Objects and Services

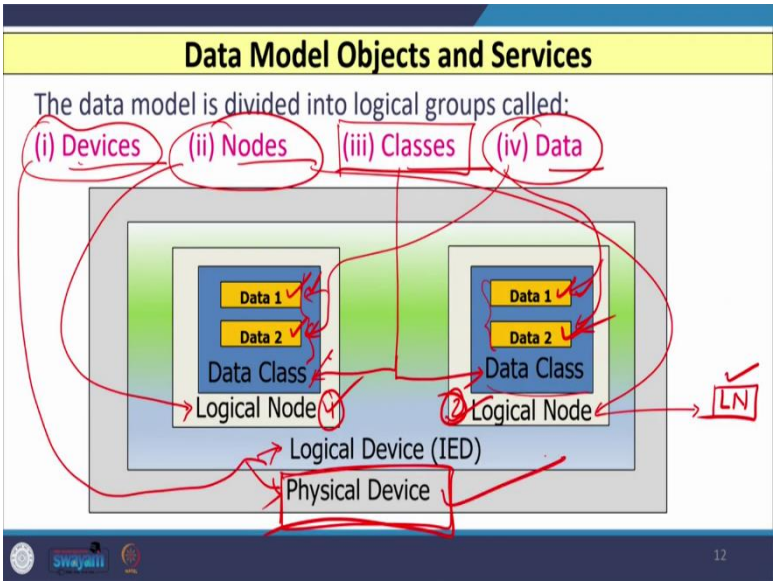
- All the logical nodes of a specific application are interconnected using logical connections.
- These logical connections can be over a single or multiple physical connections.



## Building Functions from Multiple Logical Nodes




- Two functions F1 and F2 are shown.
- F1 is split into five logical nodes whereas F2 is split into three logical nodes.
- These logical nodes are housed in three different physical devices (IEDs) i.e. PD1, PD2 and PD3.
- The logical node LN0 is the node through which identification of physical device is done.
- The logical connections between logical nodes are marked as LC and the physical connections between the physical devices are marked as PC.




Now, when we talk about the any function like control and automation function or protection function then that can be broken or divided into collection of different logical nodes. So, any function if I treat let us say protection function it has several logical nodes, if I have control function it has several logical nodes and so on. So, we can divide any function containing different logical nodes and these logical nodes are available in physical IED. These logical nodes can be housed in a single IED or these logical nodes can be distributed among several multiple IED's also.

So, you may found maybe in the diagram that one physical IED is there that contains let us say ten logical nodes and in some other case you may find that if you have three physical IED's then this three physical IED's you may have fifteen logical nodes and some of the logical nodes are shared by either between IED 1 and IED 2, between IED 2 and IED 3 and between IED 3 and IED 1 like that, this type of scenario is also possible. So, all the logical nodes we denote it by LN, of a specific application let us say protection application, control application or automation application is interconnected using some connections that is known as logical connections.

So, if I want to connect two logical nodes then it can be connected by the term known as logical connections and it is denoted by the symbol LC, so LC means a logical connection between two logical nodes. This logical connection can be either in a single IED or it can be a multiple physical connection that is also possible. Now, to understand this let us consider the building functions of multiple logical nodes, so here you can see I have shown one diagram and in this diagram you can see two functions I have shown and this functions are denoted by function one F1, and function two that is F2, so these two are nothing but the functions.

So, here I have shown two functions now function one F1 that is divided into 5 logical nodes, so in function one you can see (as shown in above slide) this red color I have shown the area or map of the function one and in that 5 logical nodes are available, you can see this is logical node one then you have logical node 2 then you have logical node 3, logical node 4, and logical node 5, so 5 logical nodes are available in function one.

Similarly, you can see (as shown in above slide) that in function two, 3 logical nodes are available one is this logical node 3, logical node 5 and logical node 6, so three logical nodes are available in function two. These logical nodes either 5 logical notes in function one and three logical nodes in function two they are located in different physical devices let us say for example, you can see that physical devices which I have shown earlier using this diagram you can see these physical devices which contain several logical nodes. So, here physical devices I have indicated by the symbol PD1, so it is physical device one let us say IED 1 and this IED 1 you can see I have shown with this blue circle so that contains four logical nodes LN1, LN2, LN0, and LN 3.

Similarly, physical device 2, PD 2 I have shown and this PD 2 is nothing but your physical device 2 or IED 2 that contains again the 3 logical nodes LN 0, LN 4, and LN 5. Similarly, I have another third physical device or IED 3 that contains 2 logical nodes LN 6 and LN 0. Now, if you observe this diagram (as shown in above slide) you can see that LN 0 is common for each physical device, so you find that LN 0 is there in PD 3, LN 0 is also there in PD 1, and LN 0 is also there in PD 2, in three blue circles you will find LN 0 that is a common logical node. So, this LN 0 is the node by using which we can identify the physical device name of a particular physical device or IED. So, if I wish to identify the name of particular IED then we can use this LN 0 node.

Now, you can see (as shown in above slide) that between two logical nodes let us say LN 1 and LN 2 it is connected by a logical connection the name given LC that is logical connection and as it is connected between 1 and 2, so the term LC12 is mentioned here. So, each logical node let us say LN 1 and LN 2 between two nodes we have a logical connection which is indicated by the symbol LC, so you have the connection between let us say 1 and 4, LC14, similarly you have a connection between LC36, LC35, LC56, and so on, so there are several connections are there between two nodes so data transfer can be there or possible in any direction between the two logical nodes.

Moreover you can see that (as shown in above) I have also shown a physical connection between two IED's, so you can see here for example PD 1 that is physical device 1 and PD 2 that is physical device 2, IED 1 and IED 2, I have shown this connection that is I have represented by PC 2, so it is physical connection between 1 and 2, where 1 indicates the physical device 1 and 2 indicates physical device 2. So, there is a physical connection existing between the two IED's or PD 1 and PD 2 in this case.

Similarly, physical connection is possible or existing between the IED 1 and IED 3 or physical device one and physical device three and similarly here also the physical connection is existing between the physical device 2 and physical device 3. Now, the question comes when any logical nodes let us say LN 1, LN 2 or LN 1 and LN 4 or LN 3 and 6 and 3 and 5 or 5 and 6, you can see the connection exist between these two nodes and it is again given by the logical connections.

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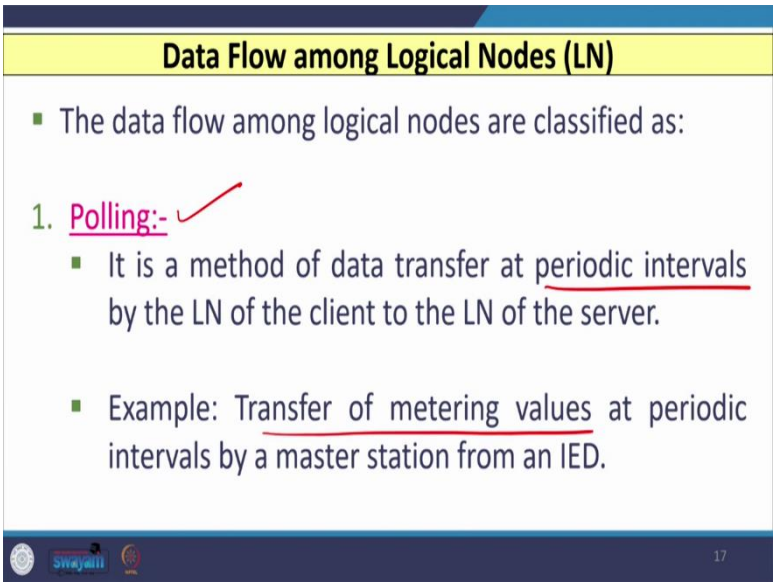

## Data Flow among Logical Nodes

1. Polling:-

- Advantages:-
  - The traffic on the network is fixed.
  - Data are achieved by multiple clients.
- Limitations:-
  - It is not able to provide data for time critical applications.
  - There are chances of data loss for events which occur between two consecutive polling.



## Data Flow among Logical Nodes

2. Unbuffered Reporting:-

- In this technique, a logical node available in the server sends data to one or multiple logical nodes.
- The server does not store the transmitted data.



## Data Flow among Logical Nodes

2. Unbuffered Reporting:-

- Advantages:-
  - This technique transfers data in a small period of time. Hence, it is used for time critical applications.
- Limitations:-
  - There are chances of loss of data for the event in case of temporary interruption of communication.

So, when we have a connection exist that is known as logical connections between two logical nodes, the question comes how data transfer or data flow that is done between two logical nodes? So, let us see what are the different methods using which data flow among various logical nodes are possible.

So, there are several ways, the first way is known as the polling method. So, this method is a method of data transfer at regular periodic intervals between the logical node that is at the client and the logical node available at the server. So, between the two logical nodes one is at client, one is act as a server, if you wish to transfer the data then data flow can be possible at regular periodic intervals.

The example of this polling type of method or polling type of data transfer is transfer of metering values at periodic intervals by master station from the IED. So, when we want to transfer metering values when we want to acquire and transfer those values then polling method that can be used. However, polling method has several advantages and disadvantages, so let us see what the advantages of polling method are.

The first advantage is the traffic on this network is fixed, as we are transferring only metering values so there is no change in the traffic in the form of transfer of data, and the second is data are achieved by multiple clients so it is possible this type of metering data that can be shared with multiple clients.

However, polling method has several limitations also, the first limitation is it is not able to provide data for time critical applications like protection applications, which is very time critical when we want to initiate something, let us say breaker opening, and in that case this method is not able to provide data. However, whenever we use the polling method then there are fair chances of data loss particularly for those events which occur between the two-consecutive polling. So, the second type of method which is known as unbuffered reporting.

So, the name itself suggests that in this technique a logical node available in the server sends data to one or multiple logical nodes and this server does not store any transmitted data. So, this method does not store any data however, transfer of data between two logical nodes that is possible or maybe multiple logical nodes that is possible in this method.

This technique has an advantage in terms of the transfer of data in a small period of time that is its capability however, this method is used for time critical applications particularly for protection applications, because this technique transfer data in a small period of time so that is

why this method is widely used in case of time critical applications. However, the important limitation of this method is that the chances of loss of data particularly for those events in case of temporary interruption of communication services then in that case we cannot use unbuffered reporting method.

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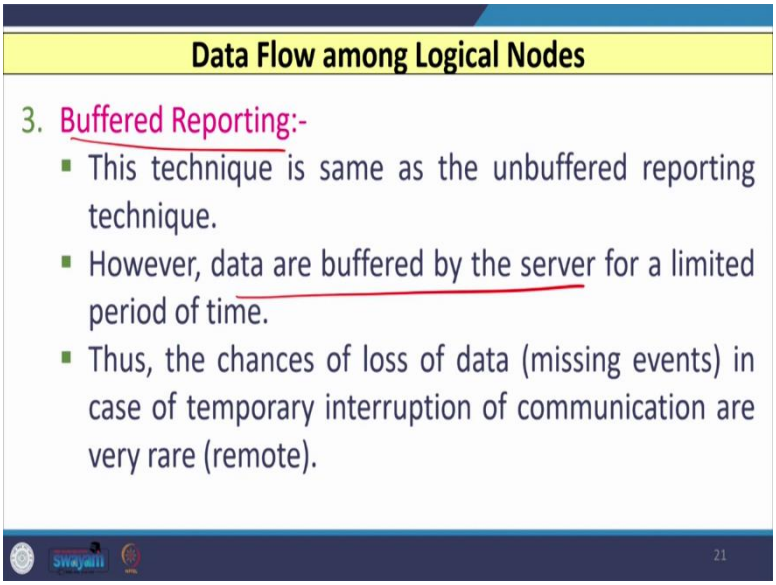


So, in that case we have to go for buffered reporting method, so this technique is same as the unbuffered that is previous one; the only difference is that the data that is buffered or stored by the server for a limited period of time. So, the chances of data particularly in case of any particular missing events when temporary interruption of communication takes place so that is very rare.

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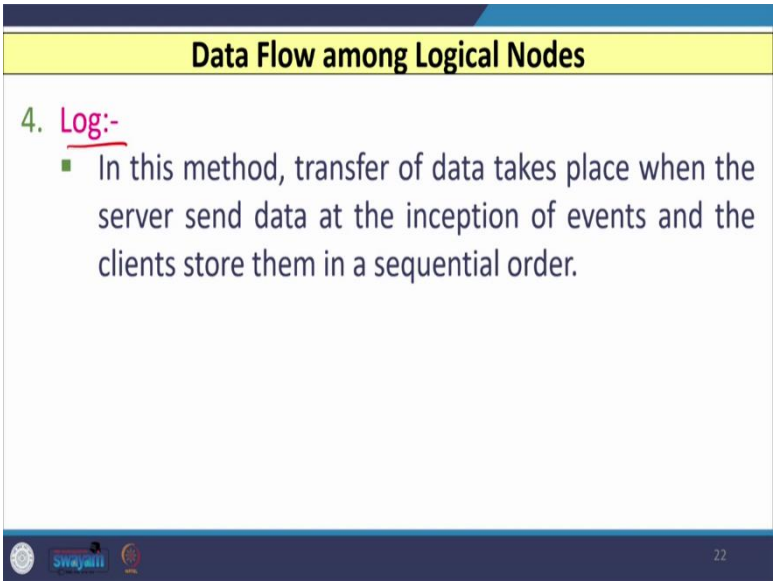


The fourth method is known as the log method, so in this method transfer of data takes place when the servers send data at the inception of events and the client store them in a sequential order. So, when server sends data because of some occurrence of some events then those data is available transferred and that is stored in the client in a particular sequential order.

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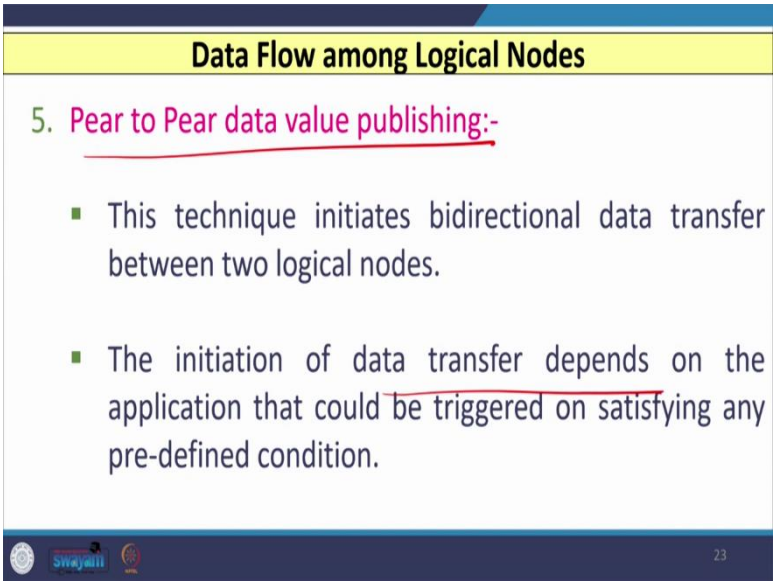


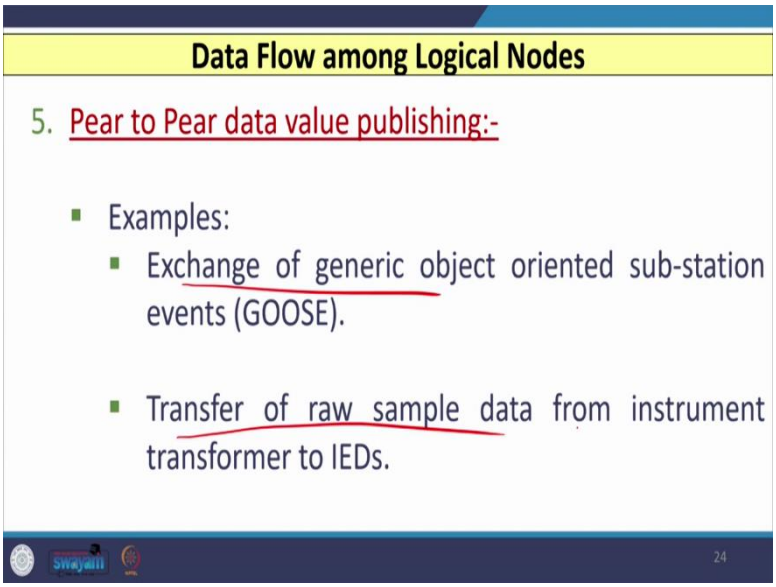


The fifth type of method is peer to peer data value publishing, so this type of technique initiates bi-directional data transfer between two logical nodes. So, initiation of data transfer depends on the application that could be triggered on satisfying a particular or predefined threshold condition.

So, whenever some condition is satisfied then some triggering is done and then this type of communication that is peer to peer data value publishing is carried out. The best example of peer to peer data value publishing is the exchange of information through GOOSE messages or events which is known as generic object-oriented substation events.

The second example is the transfer of raw data or raw sample data from any current transformer or CVTs that is known as instrument transformers to IED's or any PMU or any digital relays this is the second example of peer to peer data transfer.

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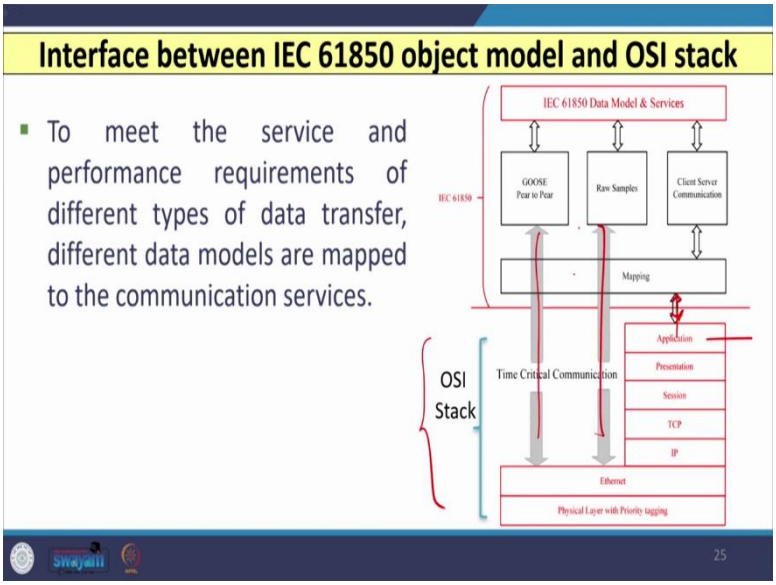


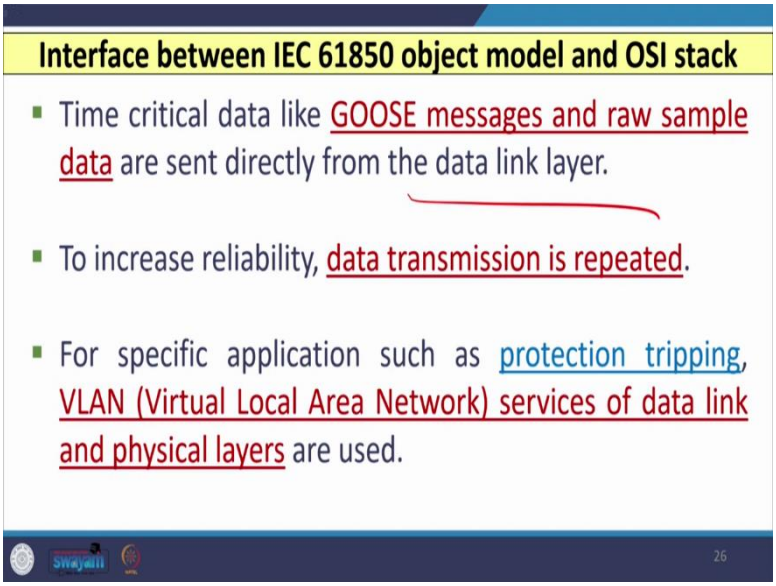


Now, let us see how the interface between IEC 61850 object model and the OSI 7-layer stack is possible. So, we have discussed that we have OSI stack which contains seven layers and the topmost layer is the application layer and you can see (as shown in above slide) that to meet the service and the performance requirement of different types of data transfer several data models are mapped to the communication services. So, you can see that if you want to transfer the data like metering data then you have to transfer like this through this application layer to the data models and services which come under IEC 61850.

However, in case of some time critical events like faults or some other cases the direct data transfer is also carried out from this ethernet layer directly to the GOOSE messages or row samples data, you can see here that I have shown here. So, as I told you time critical data like the generic object-oriented substation event messages and raw sample data are sent directly from data link layer to the IEC 61850 data models and services part. To increase the reliability data transmission is sometimes repeated and for specific applications such as protection tripping, virtual local area network services of data link and physical layers that can be used and these services are used by several utilities also.

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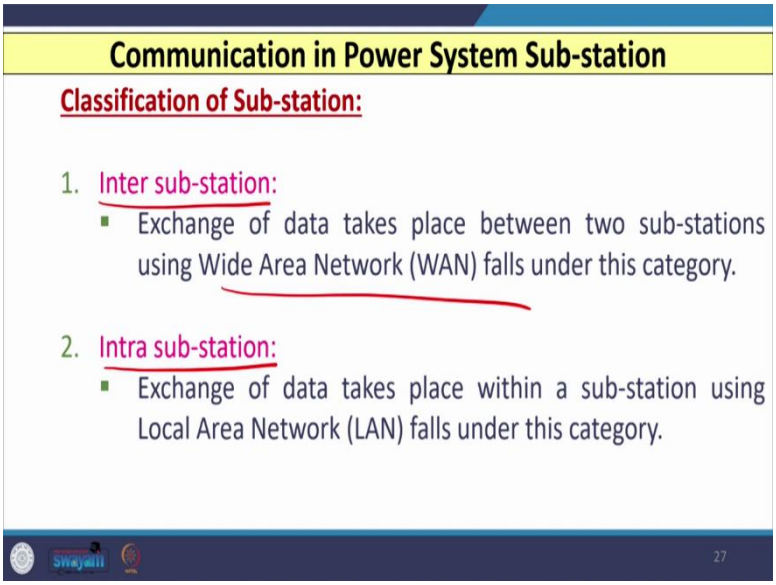


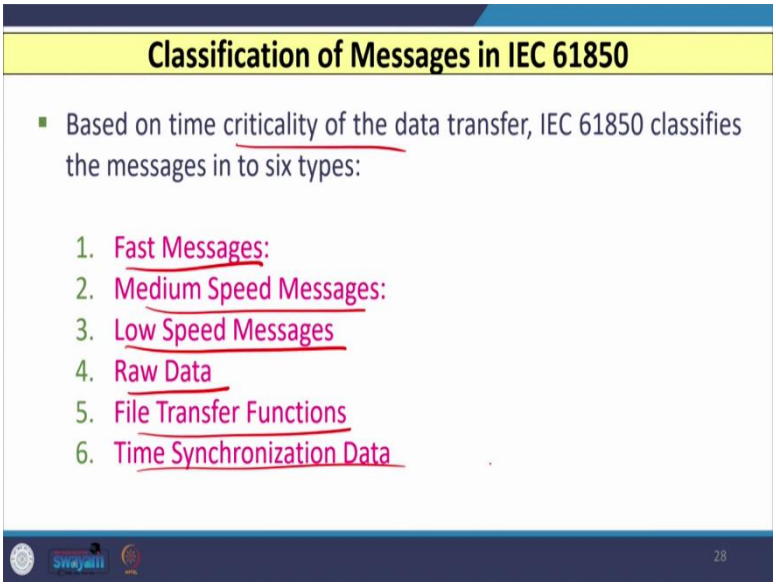


Now, with this background let us see how the communication is possible in different substations. So, we can classify the communication in the substation by two ways, the first is

known as inter substation communication. So, here in inter substation communication, exchange of data takes place between two substations and this can be done with the help of wide area network. The second type or category is the intra substation and here in intra substation exchange of data takes place within a substation using local area network.

Now, the question comes how the messages can be classified? So, whenever the communication is carried out with any of the methods starting from polling method or unbuffered or buffered or may be peer to peer communication then how the classification of messages that is possible?

So, classification of messages based on time criticality of the data transfer that can be done in 6 different categories and these are fast messages, we have medium speed messages, we have low speed messages, we have raw data, we have file transfer functions, and we have time synchronization data.

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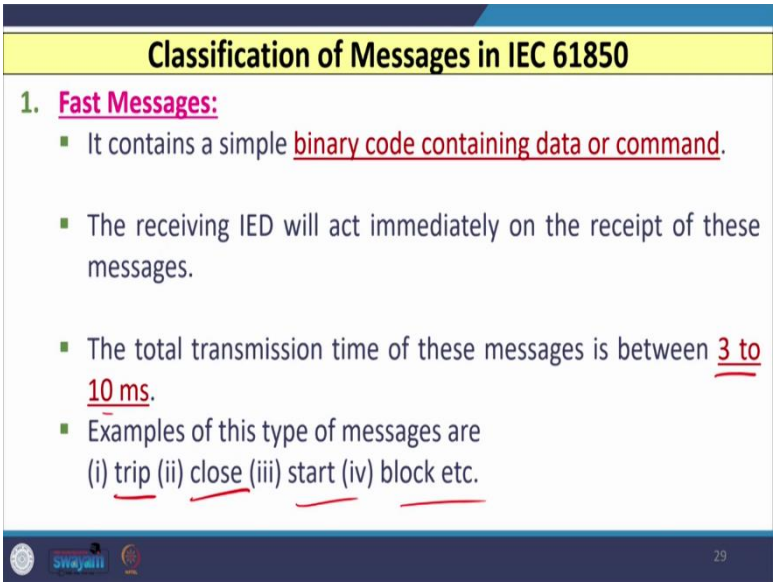


So, if I consider the fast messages then this type of messages contain a simple binary code containing the data or some command. The receiving IED will act immediately on the receipt of such type of fast messages and the total transmission time involved in this message is that is between 3 to 10 millisecond. The best example of this messages or first type of messages that is the trip signal we are sending, close command, start command or block command that is sent in case of inrush current in case of transformer, this all comes under fast messages.

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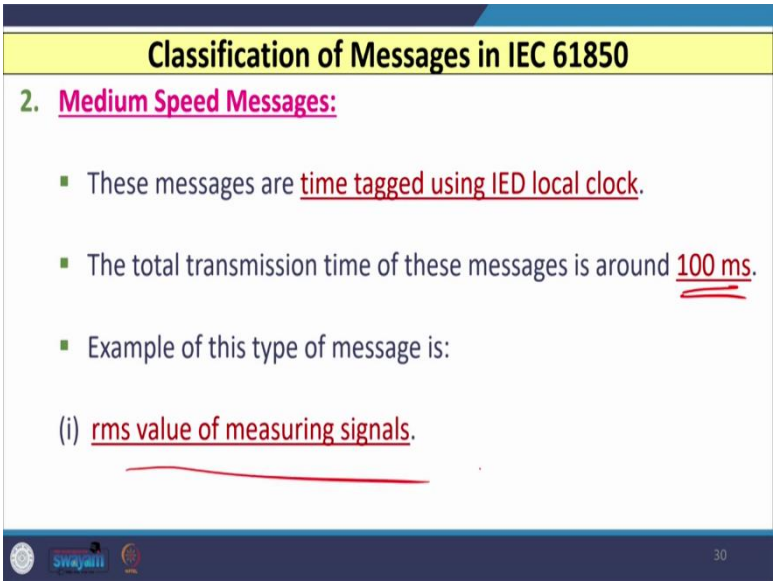


The second type of message is that is known as medium speed messages and this message are time tagged using IED local clock. So, the total transmission time in this case is around, 100 millisecond and the best example of this type of message is rms value of measuring signals.

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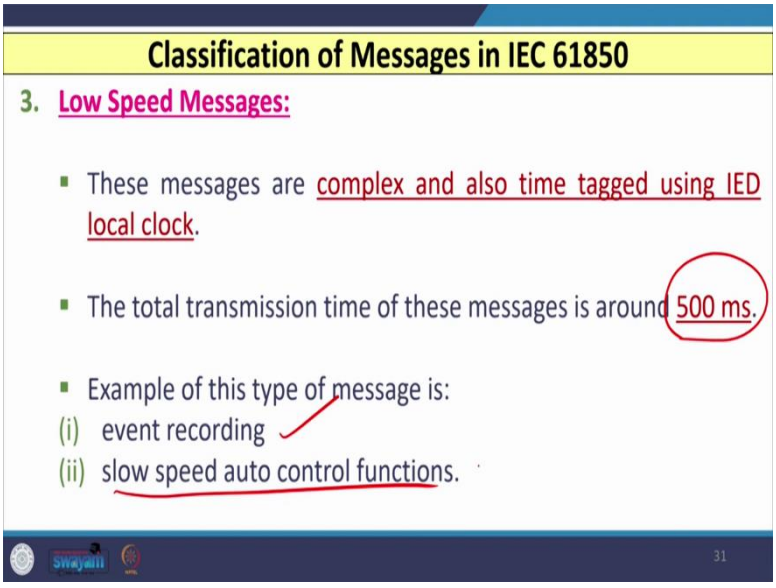


The third type of message is that is known as low speed messages, so these messages are complex and these are also time tagged using IED local clock. The total transmission time of this message is that is of the order of 500 millisecond and the several examples of low speed type of messages that is event recording or slow speed auto control functions, this are the best examples of low speed messages.

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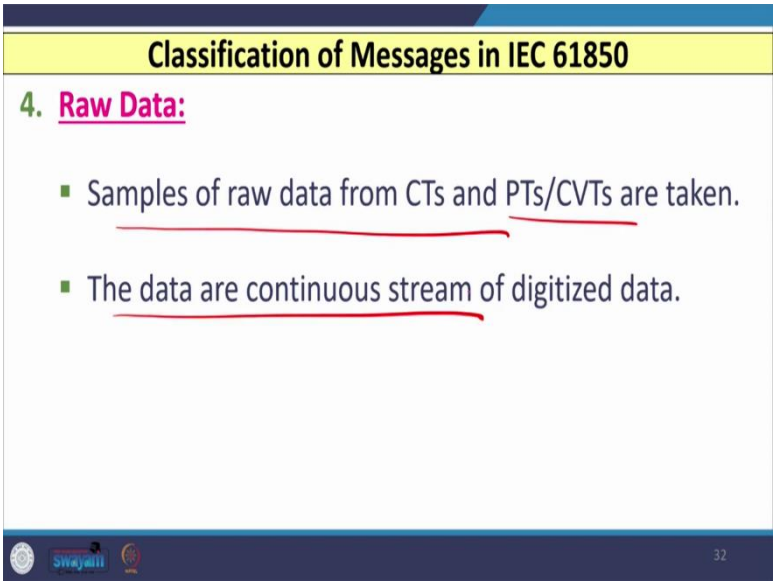


The fourth one is the raw data, so samples of raw data from current transformers, CT secondary or potential transformers or capacity voltage transformer secondary are taken; this data are in the form of continuous stream and these are digitized data, so this are nothing but the raw data.

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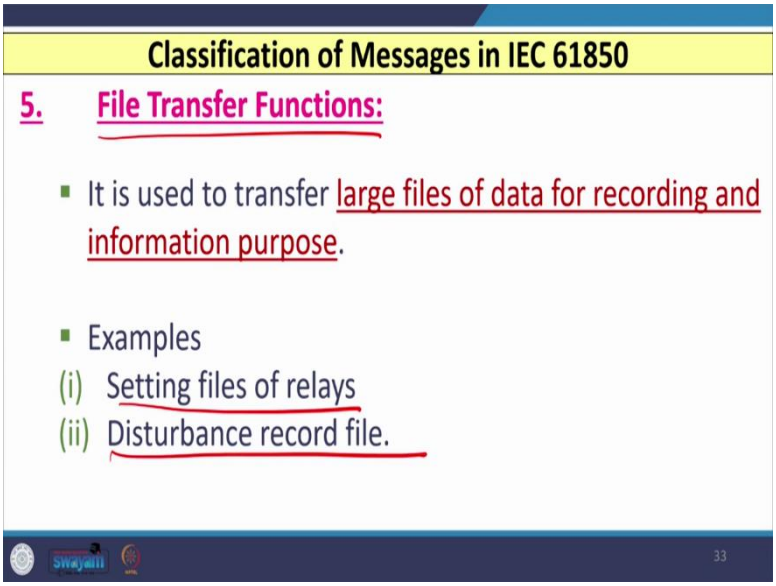


The fifth type of message is the file transfer functions, so this type of message is used to transfer large files of data let us say for recording or information purpose and the example of file transfer messages or functions are let us say, you want to transfer the setting files of the relays, let us say what is the over current relays are there, what is the plug setting and time dial setting of this relays, disturbance record file those are also there, so when such files are transferred then this type of functions are used.

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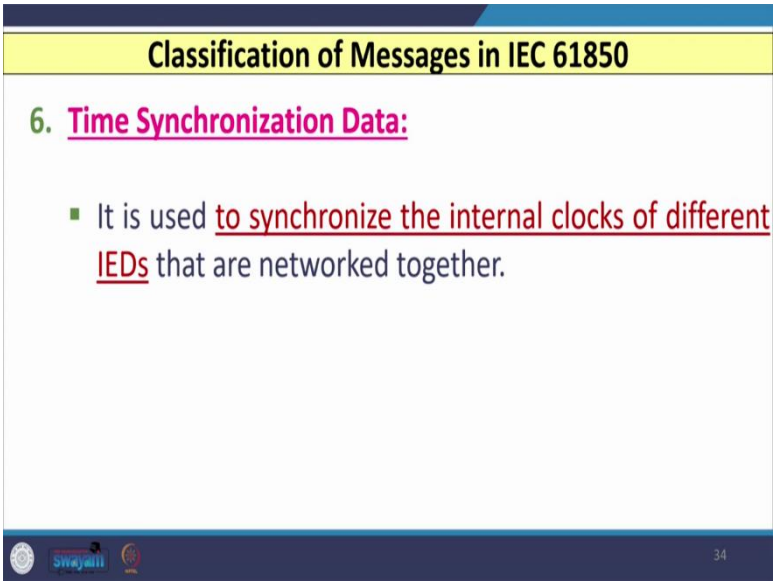


The sixth type is the time synchronization data, so it is used to synchronize the internal clocks of different IED's that are networked together when we have multiple IED's available in a particular substation then to synchronize the internal clocks of each IED's time synchronization data this type of messages that is used.

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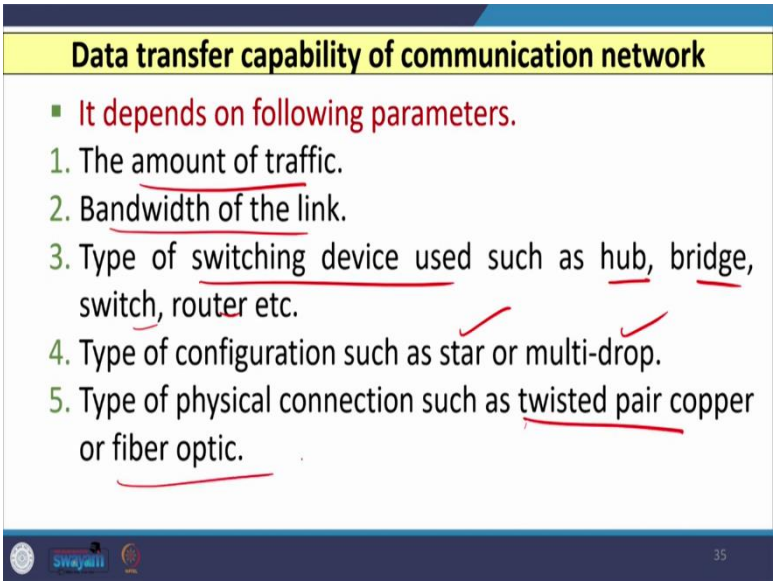


Now, the question is the data transfer capability in a communication network, so data transfer capability of a communication network depends on several parameters and some of the important parameters are the amount of traffic, we have what is the bandwidth of the link or medium, what are the types of switching device used, for example the hub, bridge, switch, and router, what are the type of configuration we are using, let us say star configuration or multi

drop configuration or what are the type of physical connection we are using, whether we are using twisted pair copper or fiber optic, so based on that also the data transfer capability depends. So, these are the few important parameters which we need to consider when we talk about the data transfer capability of any communication medium or network.

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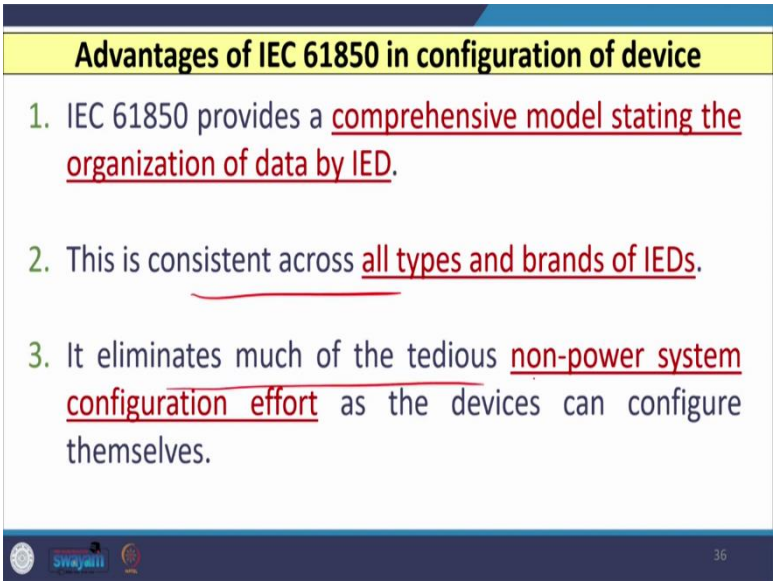


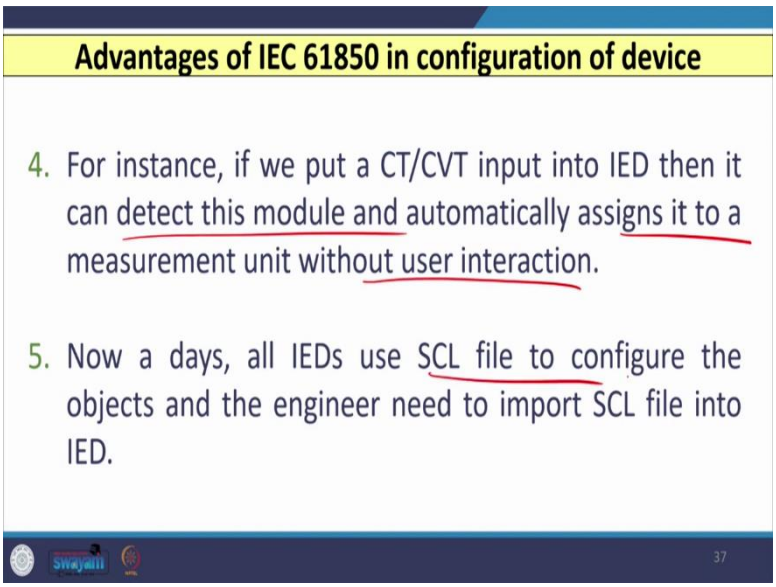


Now, if we consider the advantages of IEC 61850 in a configuration of a particular device then this is particularly in the prospective of utility then the IEC 61850 provides comprehensive model stating the organization of data by IED. So, this will provide a comprehensive model in which the different IED's are there and particular IED the data are organized in a particular sequential manner. This is consistent across all types and brands of IED, so this is nothing but the interoperability objective of IEC 61850.

This also eliminates much of the tedious non-power system configuration effort as the devices can configure themselves. For example, if we put CT or CVT input to the IED then we have to connect it and then it can detect this module and automatically assigns to a measurement unit without any user interaction. So, no user interaction is required and nowadays in all IED's what you have to do is you have to simply configure the objects and the engineer needs only they have to import the SCL file into the IED. So, if this file is imported into the IED then it can be automatically configured.

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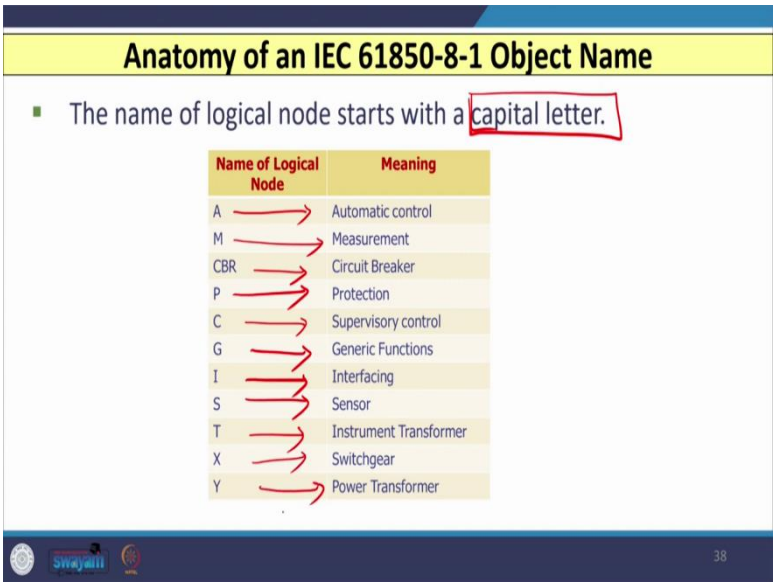


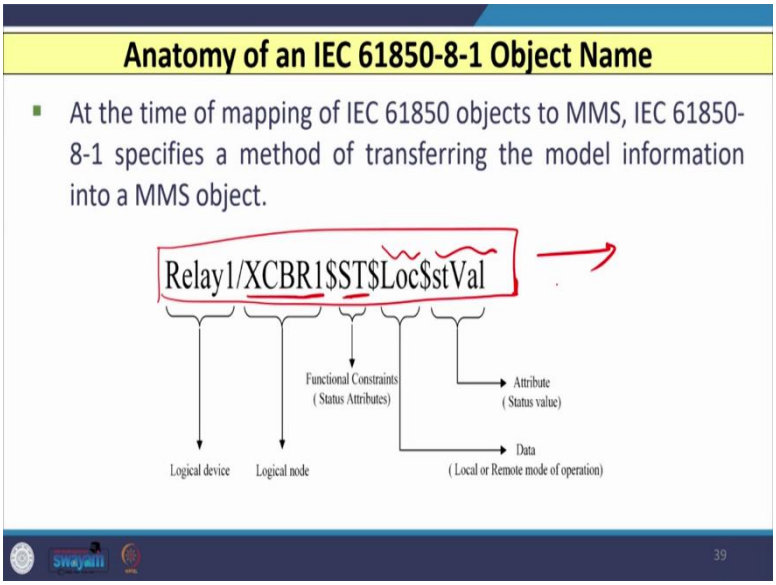


Now, the last but very important point is what is the anatomy of the object name that is given in IEC 61850-8-1? So, the name of the logical nodes normally starts with the capital letter, so this chart will tell you what is the name of logical node and what is the meaning. Let us say if

we give the name A then the meaning is automatic control so this logical node is meant for automatic control functions. If I give M as a name to the logical node then it is meant that it is for measurement purpose. The CBR name of the logical node that is meant for circuit breaker, P name given to logical node meant for protection purpose.

Similarly, C is for supervisory control, G that is for generic functions, I that is for interfacing, S for sensor, the T for instrument transformer, X for switch gear and Y that is for power transformer. So, if I just write down what is the script to define the anatomy of the object name then at the time of the mapping of IEC 61850 objects to the MMS that is the manufacturing message specification then IEC 61850-8-1 specifies the method of transferring the model information into the MMS object and this is done by this way.

So, here you can see (as shown in above slide) that the first I have mentioned the relay one, so that is your logical device and then I have given the name to this logical node that is XCBR1, so you can see that CBR is meant for circuit breaker and X is meant for switchgear, so it is for switchgear circuit breaker name let us say number one then the dollar sign and then ST that indicates the functional constraints or the status attributes then again dollar sign and then the Loc that is the data which is local or remote mode of operation, then again dollar sign and then st value that is the status value or attribute. So, this is how we can just define the logical nodes and logical devices with specific value those are fixed.

So, here in this lecture we started our discussion with the logical nodes and then we have discussed the seven layers of OSI and then we have discussed the data models and the objects and then we have discussed the different methods to communicate the logical nodes that is one logical node with the other logical node and then we have seen that what is the important of several messages starting from fast messages to low speed messages and file transfer functions and so on.

At last we have discussed the anatomy of the IEC 61850-1 that is the object name and in this we have discussed that using a specific format we can define the logical device, we can give the logical node and then several status attributes data and the attributes are there that is given to this object name, so thank you very much.