Introduction to Internet of Things
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Lecture – 09
Connectivity Technologies- Part-1

So far what we have gone through and have understood what the different basic concepts that are involved in the networking aspects of IoT. So, we have gone through different protocols and these protocols include XMPP protocol, MQTT protocol, CoAP protocol cope and AMQP protocol. So, these are the different protocols that we have gone through so far and these protocols are primarily involved with service offerings.

So, they are at the higher level and now we are going to understand, we are going to go down and we are going to understand them more at the physical level. So, physical and partially are the link layer. At physical level and link layer level what are these different protocols; these protocol scan as whole offer connectivity to the different devices which can help in physical establishment of the network.

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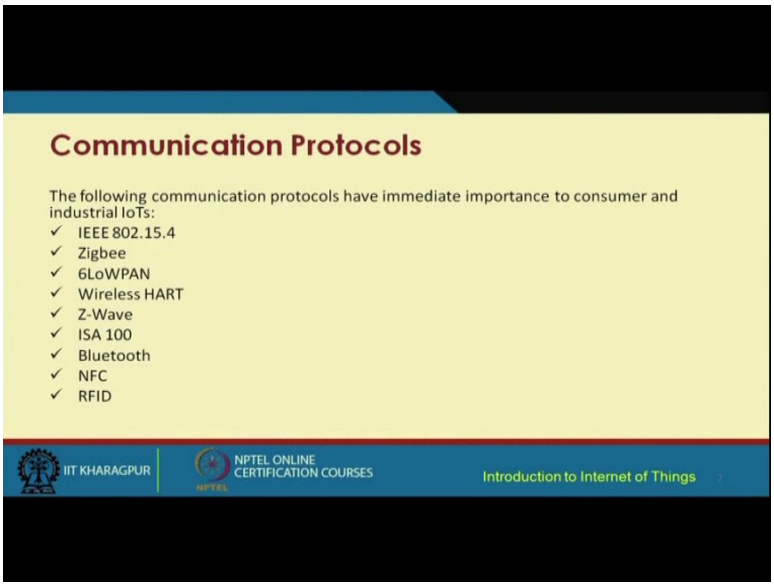

So, we are now going to go through some of these protocols. So, when we talk about these protocols, this can be used for both consumer IoTs and industrial IoT. So, consumer IoT means like smart home, then different applications of smart home, then for different serving, different applications for you know consumer devices, consumer based

systems and so on, then for industrial IoT it is like connecting different Machines, industrial Machines, manufacturing Machines and so on offering different connectivity's and smart intelligence on top of those devices and so on.

So, all these different protocols that are listed in front of us for example, this IEEE 802.4 which is a protocol as well as standard as well this can be used ZigBee is very much useful, 6 LoWPAN, wireless HART, Z-wave, ISA 100, Bluetooth NFC and RFID. So, we are going to go through most of these protocols in the subsequent lectures.

So, we will start with the first one which is the 802.15.54 which is IEEE standard and this basically is used for forming Wireless Personal Area Network.

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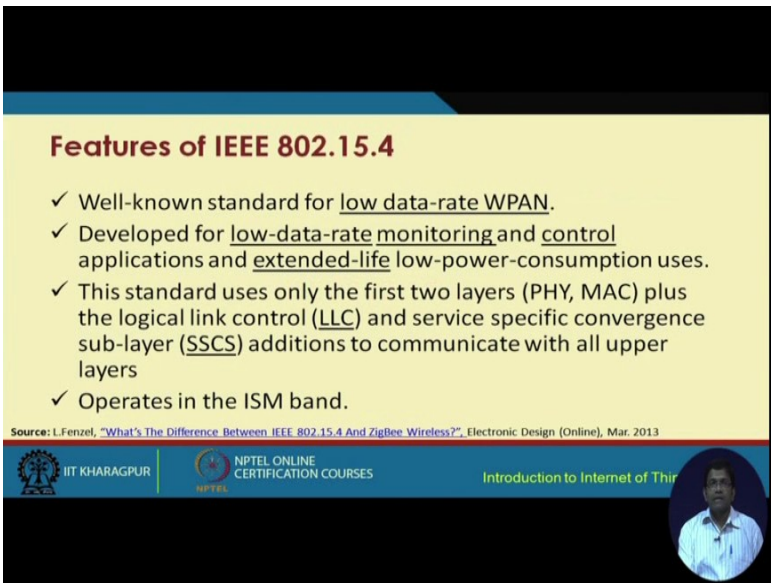

So, personal skill means like you know in the skill of person. So, personal area network are used for forming network at person skill. So, these are basically normally low data rate networks. So, these basically are developed for low data rate monitoring and control; so monitoring mean sensing low data, rate sensing, and then control maybe through actuation and so on and in the process offering because it is low data rate and is used for wireless personal area network.

These can help in offering extended life time to the networks extending the lifetime of the network because of the reduced power consumption. So, this standard uses two sub-layers, two layer sorry two layers. One is the physical layer and the other one is the MAC

layer plus the sub layers like logical link control, the SSCS which is the Service Specific Convergence Sub-layer, etcetera to communicate with the upper layers, but this particular standard it focuses on primarily two layers which is the physical and MAC.

So, physical MAC partly LLC and SSCS that is it about 802.15.4 as such. So, before we go any further I would like to remind you that in this case, the communication takes place in ISM band.

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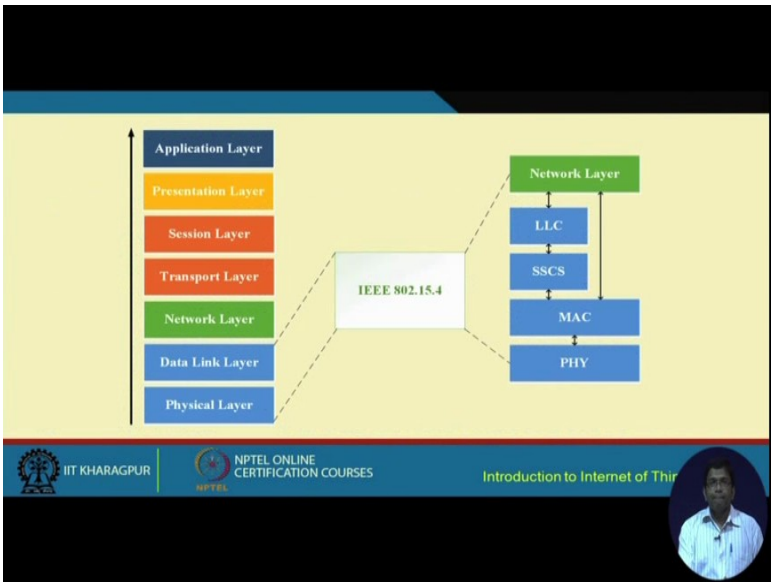

So, this is what I was explaining to you. So far this particular standard, this particular protocol defines specifications. This gives specifications for operating in the physical layer, MAC layer, SSCS and LLC sub-layers and how these are going to connect with the network layer, but the main focus is on the physical layer and the data link layer of the traditional OSI stack.

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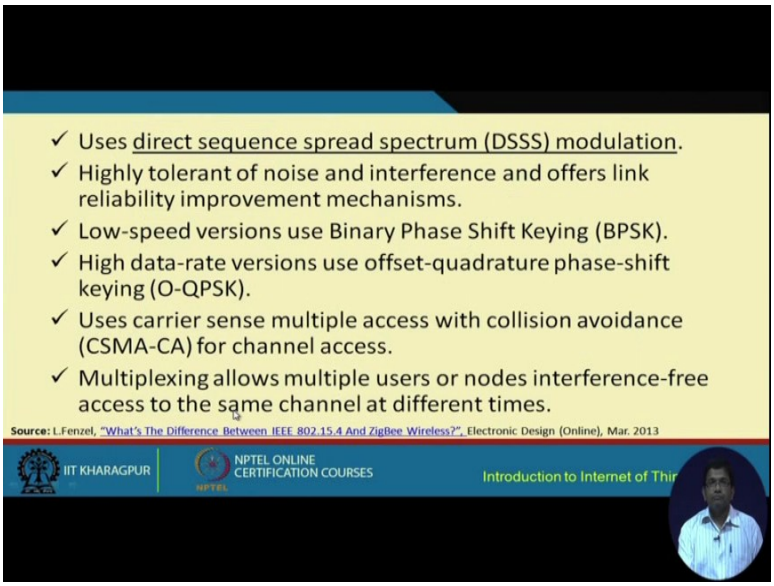

So, few features that we are going to just list over here and we are not going to go through them in detail because here I am assuming that I mean you have some basic background in networks and communication; if you have, you will be able to understand these a little better. However, if you do not have you know this is just for you to remember. We cannot go through the details of how these communication technologies, these different schemes, they work. So, this 802.15.4, it is based on the modulation schemes which is known as the DSSS which is Direct Sequence Spread Spectrum Technique. So, this is the modulation scheme that it uses DSSS modulation scheme.

So, these basically are highly tolerant of the noise and interference and offers link reliability improvement mechanisms. So, this particular standard is helpful in environments which are noise prone and have lot of interferences and in a presence of noise and interference, this particular standard can help in improving the reliability of the network.

So, it has two different variants, two different versions. The low speed version basically uses the BPSK and the high speed version uses what is known as the offset QPSK, O-QPSK and for MAC communication, it uses CSMA-CA for channel access. That means carrier senses multiple access and carrier sense multiple. CA stands for basically collision avoidance. So, carrier sense multiple access with collision avoidance is used for channel access and multiplexing basically allows multiple users of nodes to

communicate with one another in an interference free banner at different times over the same channel.

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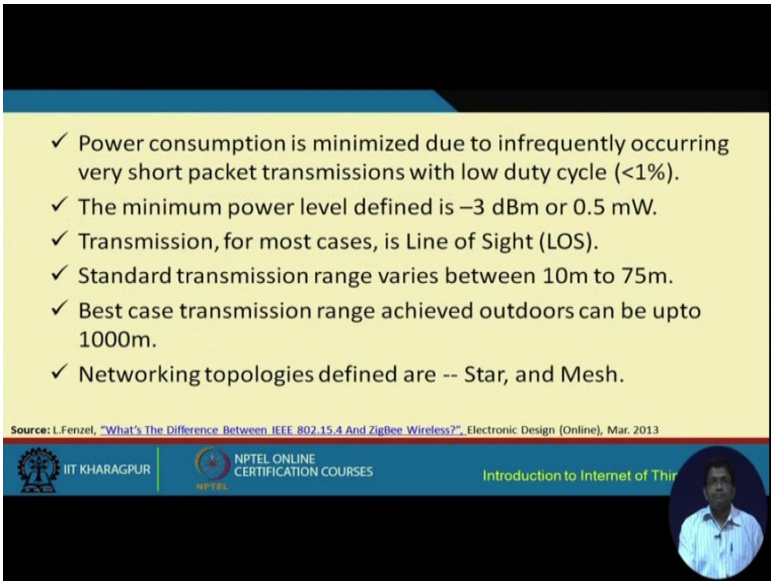

So, power consumption using this particular protocol is minimized due to the infrequently occurring very short transmissions with low duty cycle which is less than one percent. So, the minimum power level that is defined in this particular standard is minus 3 dBm or 0.5 microwatts. The transmission for most of these cases is line of sight transmission, however non-line of sight transmission is also possible, but you get better efficiency, better performance if line of sight communication is used.

The standard transmission range basically varies between 10 meters to 75 meters. 75 meters will particularly be obtained if it is used outdoors, but for indoor environments typically like 10 meters I would say above 30-40 meters and so on. So, the best case transmission that is received for outdoors can be even up to 1000 meter also in certain cases, but typically you know. So, that is a theoretical possibility, but typically you do not get that much of a transmission range even if it is outdoors that networking technologies that are supported are the star topology and the mesh topology.

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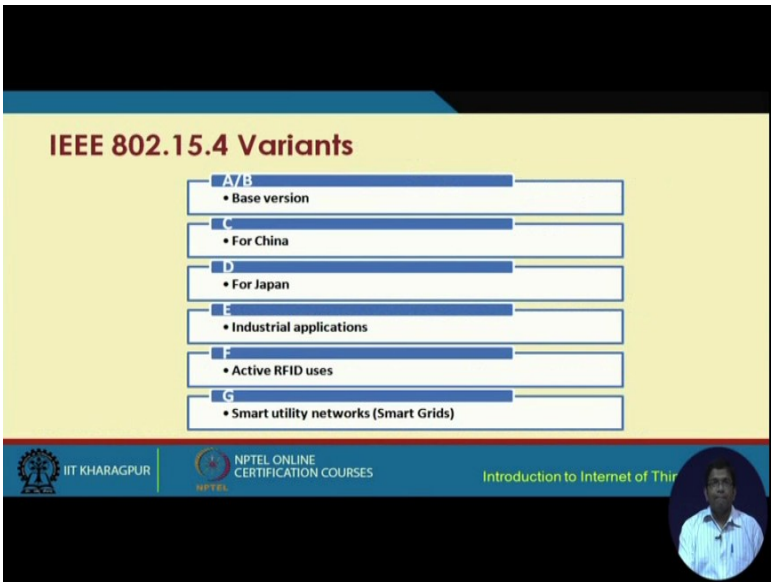

So, there are different variants of 802.15.4. So, within axel before we proceed further 802.15.4, the IEEE standard is useful for forming wireless personal area network. That means, small range low data rate, low power consuming networks, this can use the 802.15.4. Now, this basically has different variants, the base variants are a and b, but there are variants like the c variant which is used for China, the d for Japan, the e variant is used for Industrial applications, the f variant for active, RFID uses the g for smart utility networks such as smart grids.

So, these are the different variants of the 802.15.4 which are typically used for different purposes in different parts of the world.

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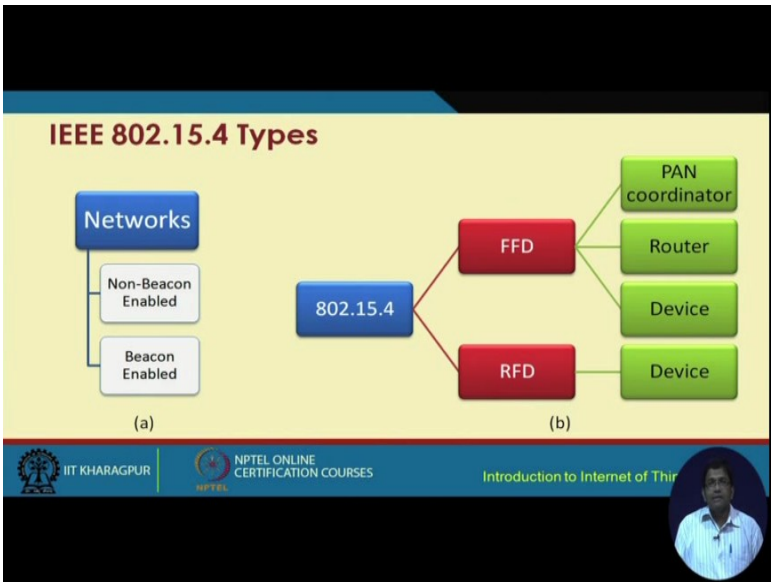

Now, 802.15.4 networks these networks can be classified into two types. The beacon enabled network and the other one is non-beacon enabled network. So, we will look at what is beacon enabled and non-beacon enabled shortly and also, these networks basically use different types of devices.

One is FFD which stands for Fully Functional Device and the other one is the Reduced Functional Device i.e. RFD. The fully functional devices include the PAN coordinator. That means, a personal area network coordinator, the router or the device, they can act as full functional device which can undertake all different types of functionalities, whereas the reduce functional device can only send something very similar.

So, they have reduced functional. If they cannot route, they cannot switch, they cannot send the packets, they cannot read a packets and so on. So, they can only do very simple things. These are the RFD's Reduced Function Devices.

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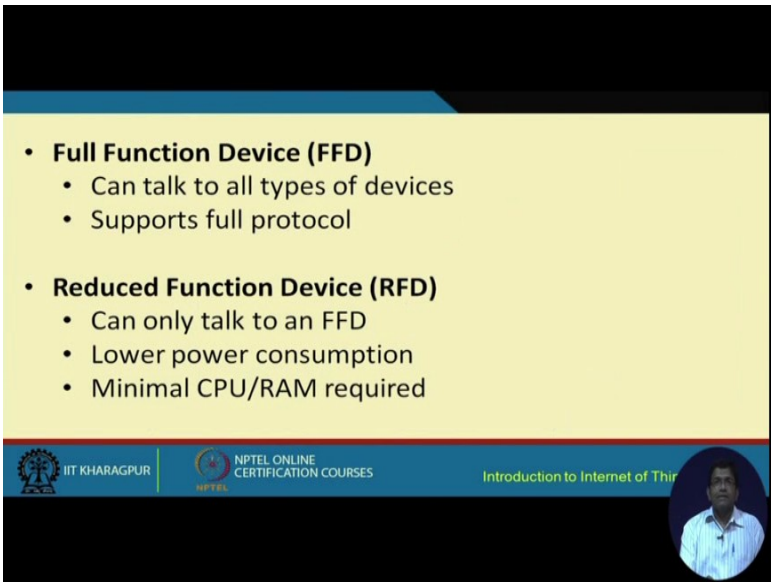

So, once again we have the fully functional device which can talk to all types of devices and can support full protocols. The reduced functional devices can only talk to a fully functional device and has lower power consumption and uses minimal CPU and RAM, so minimal processing and storage.

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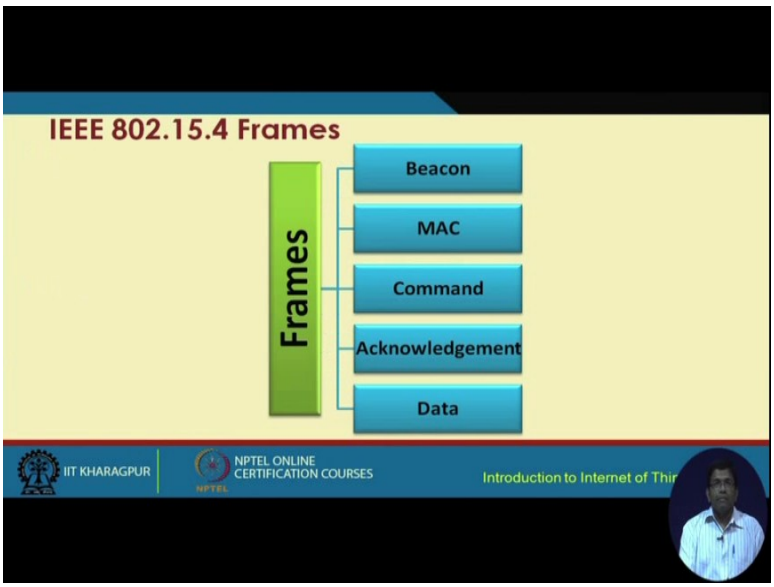

So, there are different frame formats, frame types that are defined for 802.15.4. So, there are typically five frames five frames that are defined for 802.15.4. So, we have the data

frame, the acknowledgement frame, the command frame, the MAC frame and the beacon frame. So, I do not need to elaborate further because these are quite obvious.

The command frame is used for things such as different control functions, such as associating a device with a PAN coordinator or disassociating a device or performing different other control functions. So, there are command frames and then, the MAC frames also do not need to elaborate further. This is standard and then, we have the beacon frames.

This beacon frames physically what they do is this pan coordinator at regular intervals of time, they basically sends these beacons which can basically advertise its present and the different devices that are able to get the signal. That means the beacon form that is broadcast by this particular PAN coordinator. These device they know that there is this pan coordinator which is present. So, this is basically enabled, this particular functionality is enabled with the help of this beacon frames.

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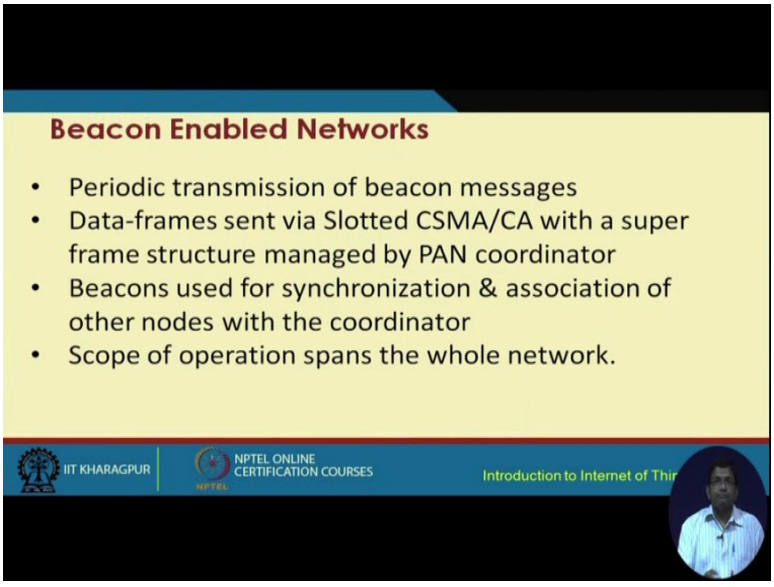

So, going back to the previous classification, we have seen that we have a beacon enabled network and the non-beacon enabled network. So, what is this beacon enabled network? So, in beacon enabled network basically periodically pan coordinator, it is going to send periodic transmissions of beacon messages. So, periodically beacon messages are going to be transmitted which are going to be received by different devices which one to get associated with the PAN and so on.

Then, the data frames are sent via slotted CSMA CA with a super frame structure that is managed by the PAN coordinator. The beacons are used for synchronization and association of other nodes with the coordinator and the scope of operation basically span the whole network.

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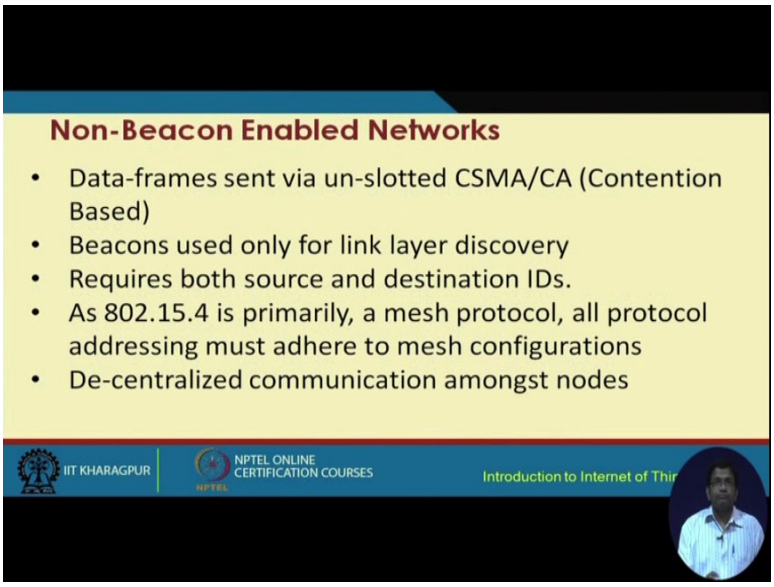

In the context of beacon enabled networks, in case of non-beacon enabled networks, the data frames are sent via un-slotted CSMS CA. The previous one for beacon enabled network, it was the slotted CSMA CA, but in the case of non-beacon enabled network, it is the un-slotted CSMS CA. The beacons are used only for link layer discovery and that means, whether there is any connectivity where is there is any link from one device to another and so on. So, beacon messages basically will help in the discovery of these different links from the PAN coordinator to the different devices and so on.

So, basically these network, this type of network that means the non beacon enabled network request both the source and the destination ids. So, as 802.15.4 is primary mesh protocol, it is primarily based on a mesh protocol. All the protocol addressing must adhere to the mesh configuration. So, this is basically in a excel how the 802.15.4 protocol functions and the different features of it.

We are now going to look at the ZigBee protocol which is heavily used for IoT applications for establishing connectivity between the different nodes and this ZigBee as we will see shortly is basically, it works on top of the 802.15.4 for extending this

functionalities to the different other layers. So, if you recall 802.15.4 is useful for establishing connections and function functionalities in the physical layer and the MAC layer. ZigBee basically will take these functionalities to the higher layers network and beyond network layer and beyond.

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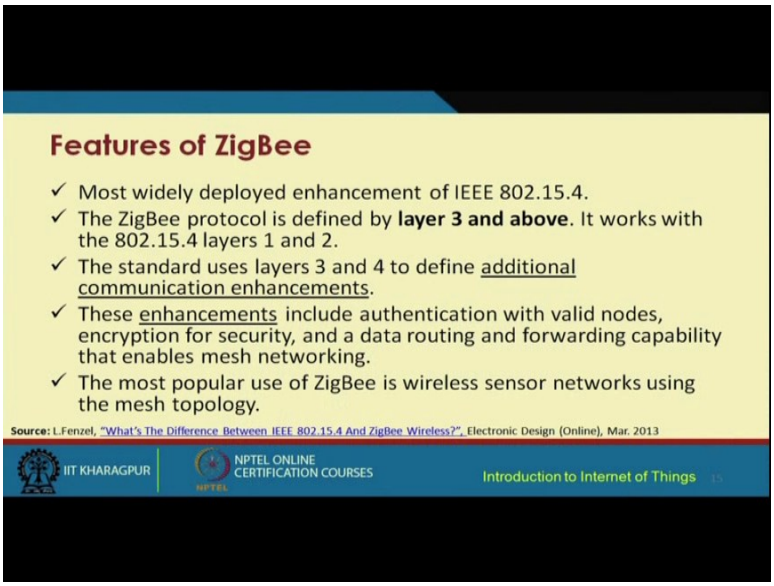

So, let us look at how ZigBee basically functions. So, ZigBee protocol is defined by the layer 3 and above. So, it works on top of layers 1 and 2 of 802.15.4 and extends to layer 3 and above and ZigBee basically works on top of 802.15.4. So, this is something that we have to understand and we have to remember that there is a difference between 802.15.4 and ZigBee.

This is what many people often confused. People think that ZigBee and 802.15.4 are one and the same, but it is not. So, ZigBee is definitely based on the 802.15.4, but it has its own distinct identity. So, the ZigBee basically uses layer 3 and layer 4 to define additional communication enhancements and these enhancements include authentication with valid nodes encryption for security and data routing and forwarding capability that enables mesh networking and ZigBee is typically used in wireless sensor network applications. It is heavily used in wireless sensor network applications, where mesh topologies are formed with the help of ZigBee.

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So, this is a diagraph diagram which basically shows the position of ZigBee with respect to 802.15.4. So, where is 802.15.4, it focus is mostly on the 5 and the MAC layers ZigBee takes it beyond MAC beyond network layer. So, network layer and the rest of the layers all the way up to the application layer basically this extension or the enhancement is made possible with the help of ZigBee over the 802.15.4 protocol.

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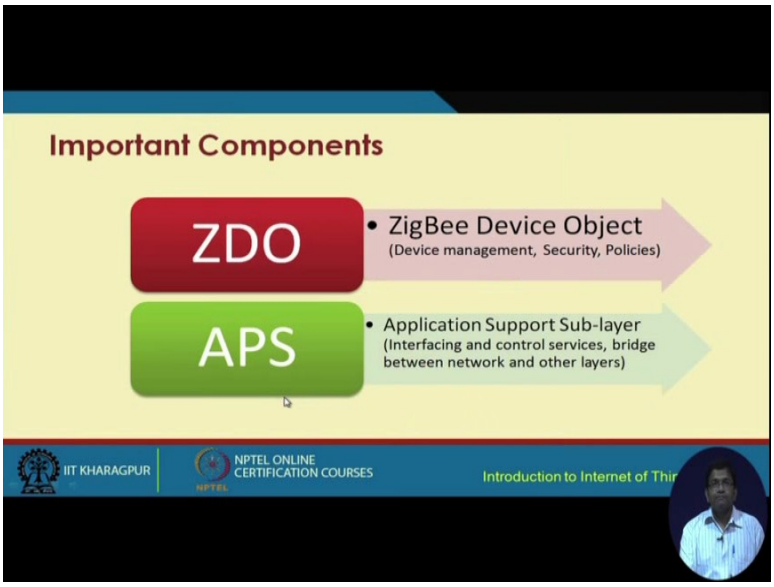

In ZigBee there are primarily two different components. The first one is known as ZDO which stands for ZigBee device object and it takes care of issues such as device

management, security provisioning policies and so on. So, these are the different functionalities of ZDO and that means the ZigBee device object component.

The second component is APS which stands for Application Support Sub-layer which takes care of services such as control services, interfacing bridging between network and other layers and so on. So, these are the two distinct components with separate functionalities as we have just gone through.

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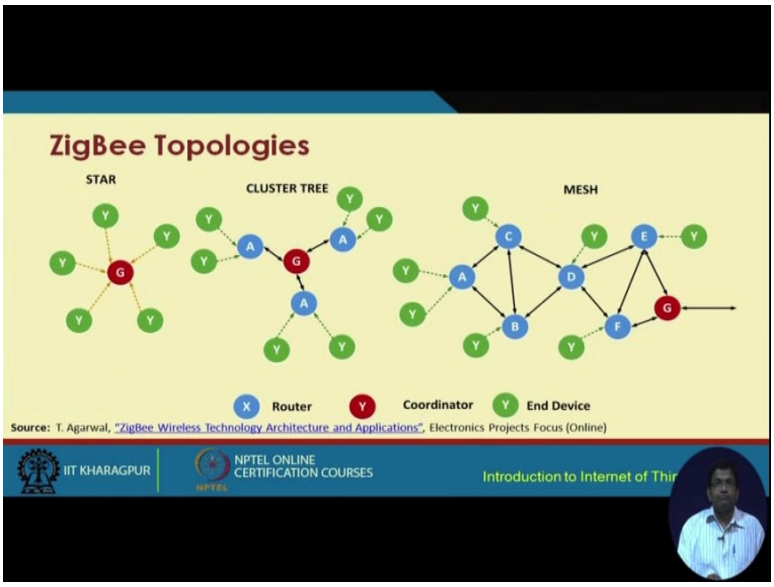

So, ZigBee basically supports star topology. So, this is the star topology that we see over here and we do not need to elaborate on this further. So, we have this controller node and we have these different age devices and these age devices, they form a star topology with the coordinator node. Sorry it is not the control; it is a coordinator node along with the coordinator.

Then, we have this coordinator node can be a gateway node also and this can be a simple local area network or local area network equivalent. Then, we have the cluster tree topology, where these are like different clusters that are formed with these different blue colored cluster head which basically in reality are things such as routers and hubs.

So, these will act as routers and these routers will form a tree like structure with the coordinator node. So, this is why this is known as the cluster tree topology and then, we have the mesh topology which is forming a mesh network with the help of these different

routers. These different routers, they form a mesh backbone kind of network and to each of these routers, these different devices are attached.

So, basically these green device are the end devices in this particular diagram and these green devices attached to these blue devices which basically denote the the routers and at the end of this mesh network on one end, we have this coding and then, node which acts as a gateway and from this point on it offers connectivity to the outside network such as the internet

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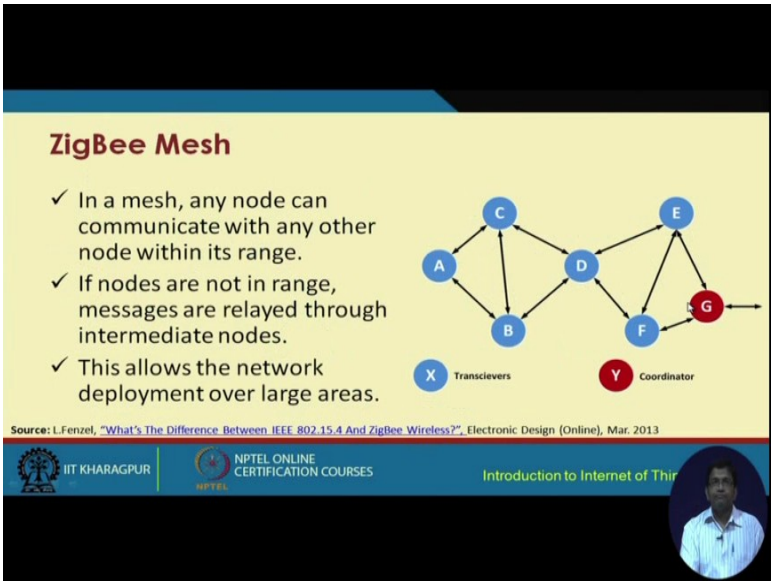

So, in a mesh any node can communicate with any other node within its range. So, this is the main advantage to offer faulty tolerance, reliability. Meshtopologies are very much useful. So, if the nodes are not in the range, messages are relayed through intermediate nodes. So, this allows the network deployment over large areas. So, using mesh topology you can extend the network to larger areas, you can span across larger area. So, this is possible with the help of the meshtopology.

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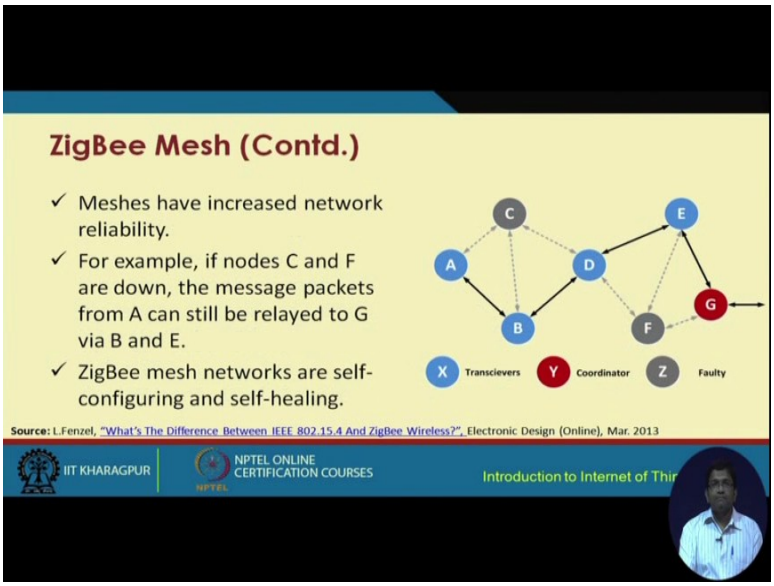

So, the meshes have increased network reliability. For example, if nodes C and F are down in this particular scenario, so let us say that initially we had this kind of a mesh. Now, if the nodes C and F, these routers are down for one reason or another, the messages can still go from A to Z using this particular path because an alternative path was possible to have in because it is a mesh network.

Now, the ZigBee mesh networks are self-configuring and self-healing. Self-healing is quite obvious because if there is some link failure or node failure or something, it is possible to have other alternative routes and yes they can configure on their own, they can form the network on their own. So, this is the advantage of the ZigBee mesh network.

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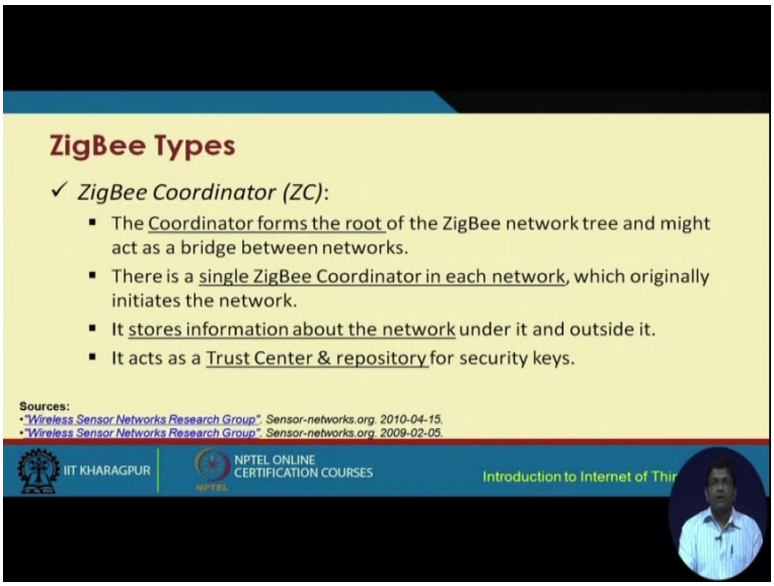

So, in ZigBee there are different entities. The first one is the ZigBee coordinator, ZC. The ZigBee in the coordinator basically forms the root of the ZigBee network.

So, the entire network or the network tree has a route and these routes are known as the ZigBee coordinator and form this coordinator. So, first of all there is a single coordinator and from this coordinator, there is single hop connectivity to the end devices. So, this coordinator basically stores information about the network which is under it and which is outside it.

So, basically you know it is sort of buffers some of this information that I received from these end devices and stores with it for certain time. It buffer for some certain time. So, it also acts as a trust center and repository for the security keys.

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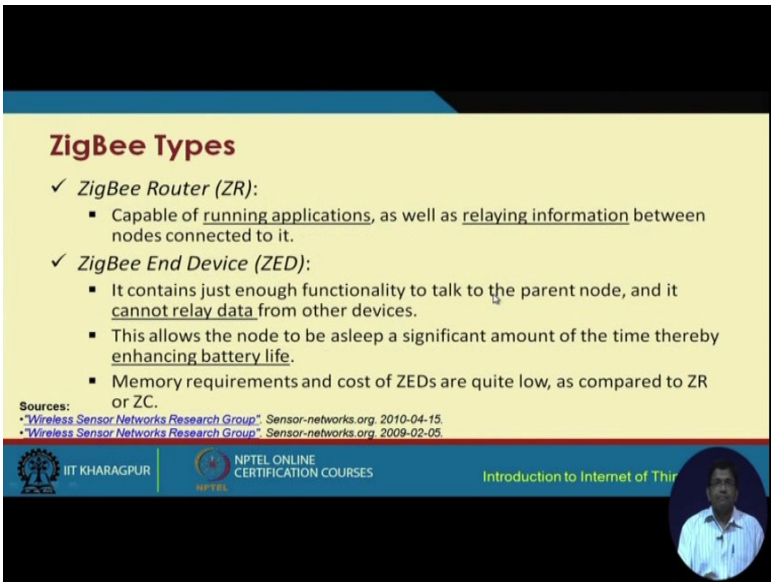

Then comes the ZigBee router which is capable of running applications as well as relaying information between the different nodes that are connected to it and then, we have the end device which contains just enough functionality to talk to the parent node and it cannot relay data from other devices. So, it has reduced functionality. So, it is a reduced functionality device.

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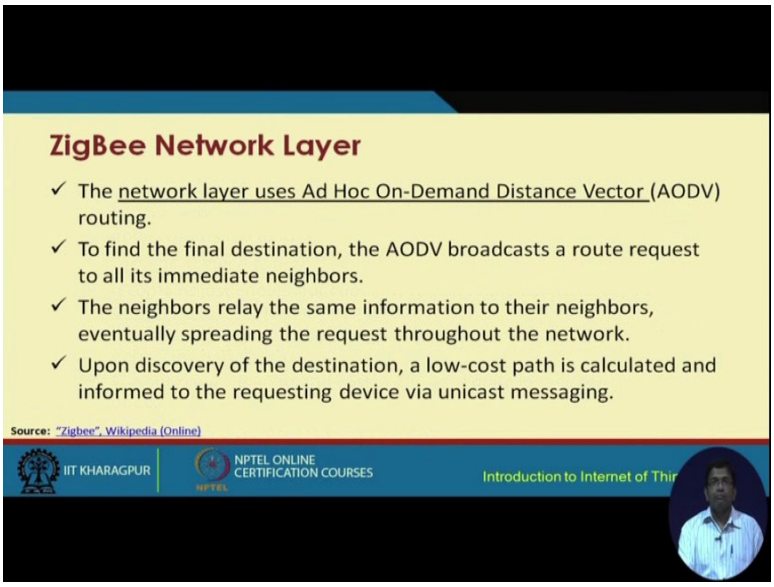

Now, ZigBee also incorporates a network layer. So, this network layer uses the ad hoc on demand distance vector routing protocol which is the AODV protocol and it is been

popular in the case of ad-hoc networks. It is used mostly in the ad hoc networks for as a routing protocol that operates in the network layer and it used to find the final destination. So, how it can be found? AODV basically this particular protocol, it broadcasts a route message to all its intermediate neighbors.

These neighbors basically they relay the same information to their neighbors intern and eventually this message space across throughout the network. Upon discovering of destination, a low cost path is calculated and is informed to the requesting device via the unicast messaging. So, this is how this particular protocol functions.

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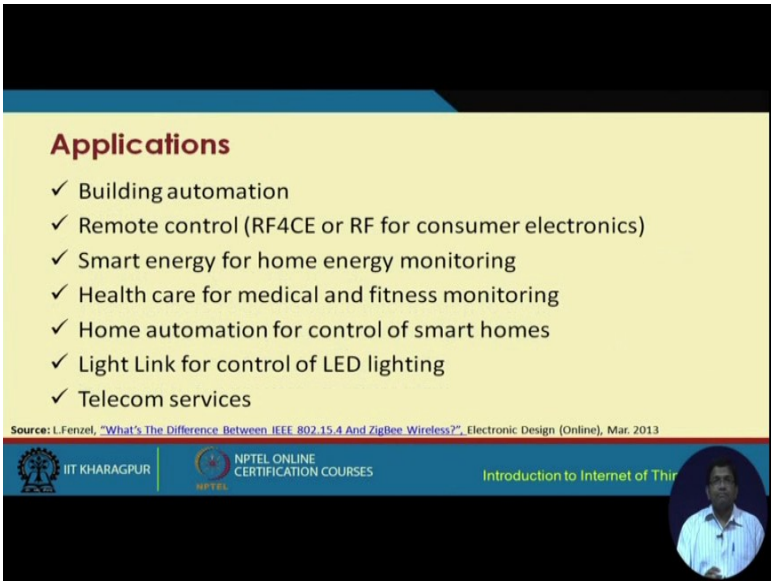

So, ZigBee has different applications and it can be used for building automation smart homes, smart health care, telecom services, offering link connectivity to led lighting systems, then smart energy for home, energy monitoring, building automation. I think I have already mentioned remote control and so on so forth.

These are the different applications where this ZigBee protocol can be used. So, we come to an end of this. So, we have discussed two very important protocols IEEE 802.15.4 and the ZigBee protocol in this particular lecture. We have seen that where as the 802.15.4 it is primarily restricted to the physical and the MAC layers ZigBee basically extends it or enhances its functionality beyond network layer and all the way up to application layer.

So, ZigBee basically uses the protocol AODV for routing purposes and it is one of the very popular protocols that is used for sensor networking applications particularly using the mesh topology and we have all seen that there are different types of topologies are there i.e. star topology, cluster tree topology, mesh topology and so on. Mesh topology is particularly useful when there is higher reliability that is required from the network deployment for the application for which it is being used.

Thank you.