Introduction to Internet of Things
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Lecture - 12
Connectivity Technologies – IV

Another very important protocol is Bluetooth this Bluetooth technology is heavily used for building IOT connectivity. We have already gone through zigbee we have also gone through different other allied technologies, such as 6 lowpan such as hart wireless hart RFID and also NFC. And this particular technology, Bluetooth is typically used for bit of different kind of applications, where it is required to form a personal area network, maybe to replace the wireless wired connectivity between the different devices wired connectivity, if you want to replace the cables between different devices Bluetooth can be used.

So, you move the cables have wireless connectivity between them that can be done with the help of Bluetooth and this is this protocol that we are going to discuss in this particular lecture.

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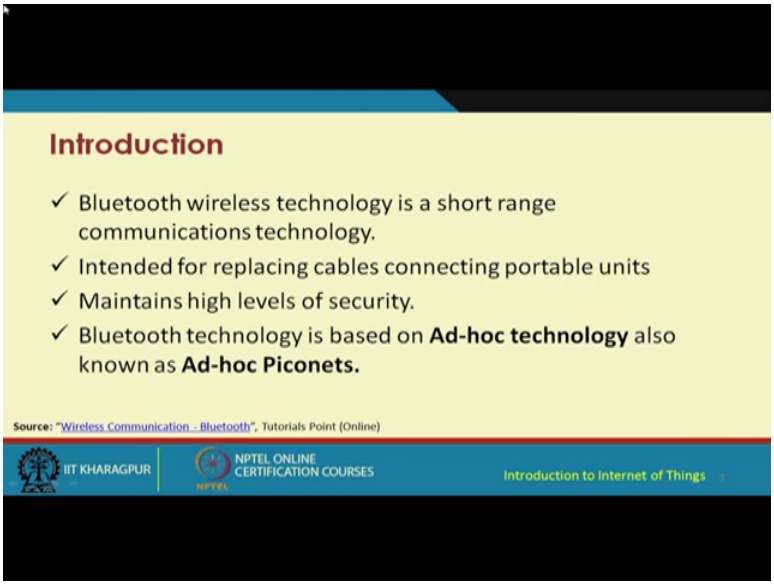

So, if we look at the Bluetooth technology, this is particularly used for short range communication. Personal area network for instance connecting different peripherals to a computer peripherals to a computer using Bluetooth is a very commonly used application

of Bluetooth the second could be to transfer data using Bluetooth between 2 mobile devices these mobile devices of course, need to have the Bluetooth radio to be supported, but if it is supported and now it is most of the mobile phones particularly the smartphones they are all enabled with Bluetooth.

So, you know one can transfer files music videos. So, on and so forth and this is something very common, that we do commonly we transfer files we transfer different things between 2 Bluetooth devices a very simple form of Bluetooth configuration where we have 2 Bluetooth devices a client and a server, and the data is transferred between these 2 devices, a very simple kind of configuration now in this particular course in this particular lecture we are going to go through all these different applications.

So, it is used Bluetooth is used for short range communication. And it is typically used for instances where it is required to replace the cable the existing cables have to be replaced. So, what is required is to have cable replacement protocols. And that is why as we will see shortly that we have an entirely different and entirely different protocol stack, which is basically proposed for using Bluetooth. Of course, it does match with the OSI layers TCPIP and OSI layers to a great extent, but then we have a completely different set of layers with different names in the Bluetooth architecture, and also we have separate protocols that are that function in each of these different layers.

So, we will go through it in a short while. So, Bluetooth one of the very good things about Bluetooth is security. Bluetooth basically ensures high level of security, and another very distinctive feature is that Bluetooth helps in forming Ad-hoc networks. So, concepts such as Ad-hoc technology Ad-hoc Piconets are basically commonly used in the case of Bluetooth.

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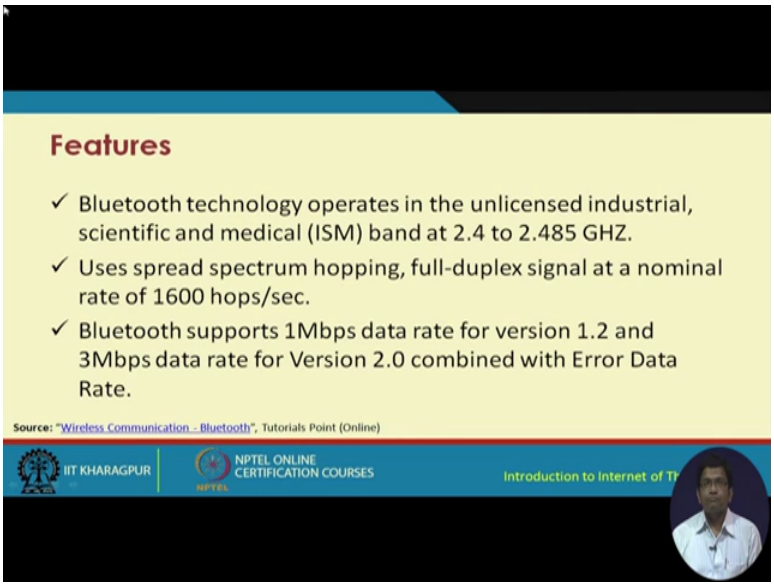

Bluetooth technology also like the previous ones like hart etcetera that we covered in the previous lectures operate in the ism band 2.4 gigahertz to 2.484 gigahertz, it uses spread spectrum hopping full duplex signal at a nominal rate of 1600 hops per second.

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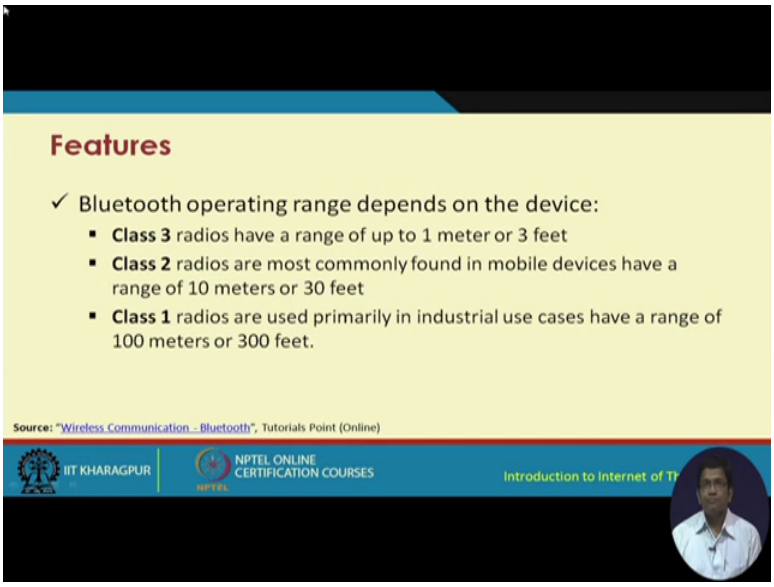

It supports one mbps data rate which is quite attractive short range high data rate communication is supported. In Bluetooth there are 3 types of radios that we will typically find and they all operate in different ways. We have the class one radios class 2 radios and class 3 radios. Class 3 radios have a range of up to 1 meter or 3 meters. Class

2 radios are most commonly found in mobile devices having a range of 10 meters or 30 feet and class one radios are used primarily in industrial use cases having a range of 100 meters or 300 feet.

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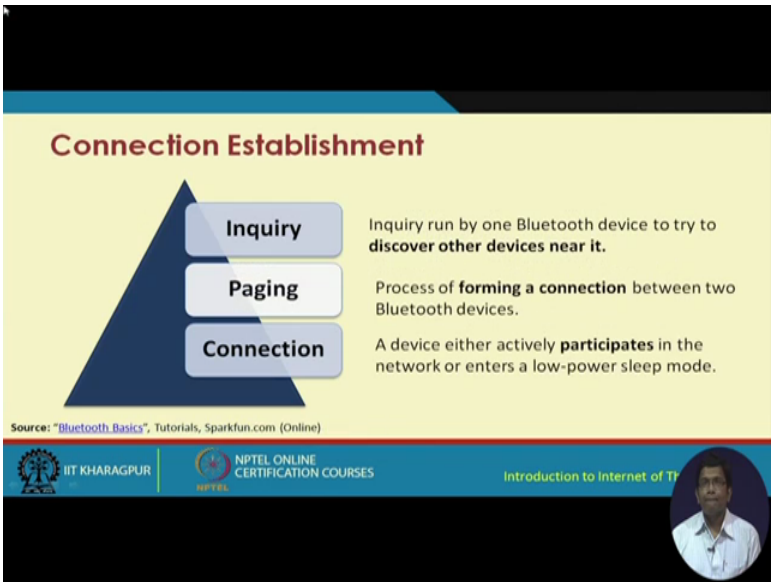

in terms of connection establishment using Bluetooth there are 3 different phases. The first one is the discovery or the inquiry phase. This next one is the paging phase, and the third one is the connection phase. So, basically for connection establishment there are only 3 phases in the inquiry phase, there is some kind of inquiry that runs from one Bluetooth device and that particular Bluetooth device basically what it does is it tries to discover other devices in it is vicinity.

So, this is, one Bluetooth device it is trying to explore what are the other devices in it is vicinity. So, this is basically this discovery phase or the inquiry phase very simple the next one, is the paging phase where some kind of connection is formed between 2 Bluetooth devices that want to talk to each other. E kind of connection is formed, and the third one is the connection phase where a device either actively participates in the network or enters a low power sleep mode.

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There are different modes of operation of Bluetooth devices, one is the active mode and this is the mode where the device basically is fully active fully functional in all different respects it actively transmit is data it actively receives data and so on and so forth. So, it is fully functional fully active the other 3 phases the sniff mode the hold mode and the park mode all these 3 different modes are basically power saving modes, and they default in very minute ways in very fine in different ways. In a sniff mode the device basically sleeps and only listens for transmission at a particular predetermined predefined interval.

In the hold mode, this is also a power saving mode where a device sleeps for a defined period and then returns back to the active mode. And in the park mode the slave will become inactive until the master tells it to wake back up. So, we have all these different 4 modes of operation of Bluetooth devices, the active mode fully functional, fully active, fully transmitting, fully receiving. And the other 3 modes the sniff mode hold mode and park mode are all essentially power saving modes of different types.

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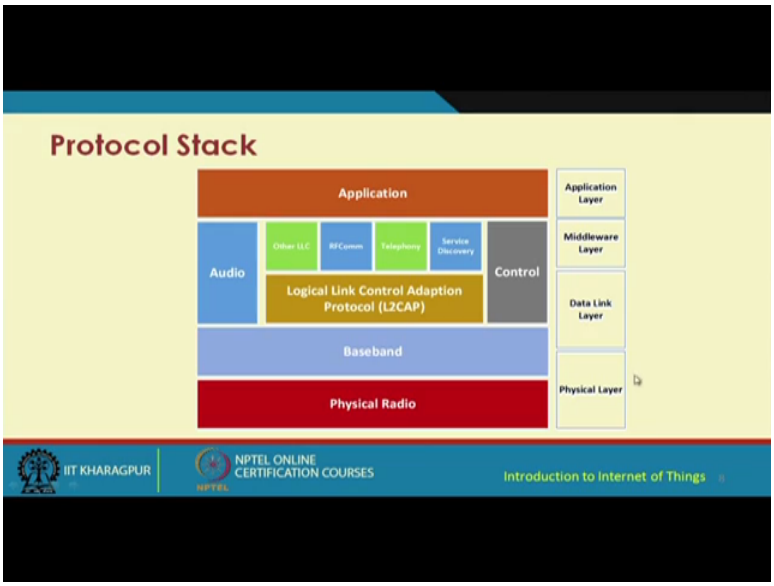

So, this is the protocol stack that I was talking to you about earlier. So, what we have the physical layer, then we have the baseband layer.

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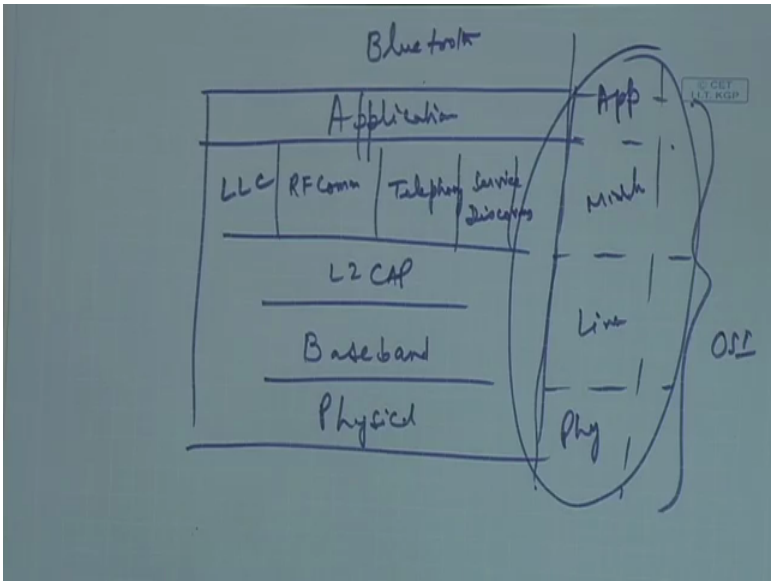

We have the L2 cap and then there are some different other layers and corresponding protocols that are supported in the top layers and then we have the application layer. So, these are the different layers in the Bluetooth protocols. I was telling you about cable replacement there are protocols such as RF comm protocols which will support

traditional telephony, protocols that will support service discovery, protocols that will support other link layer functionalities such as LLC.

So, these are the different functionalities that can be supported on top of this that the physical baseband L2 cap layers in Bluetooth. Now this basically can be mapped to the traditional OSI layers and so these are the OSI layers. So, here again you have the physical layer you have the link layer, you have the different middleware, you have the application layer. And the exact form of mapping is basically shown in this particular figure in the slide. So, this is how it maps ok.

So, we have physical radio layer or physical layer baseband layer L2 cap, and this you know LLC RF comm telephony service discovery and the application layer and this is how they map to the OSI traditional OSI layers.

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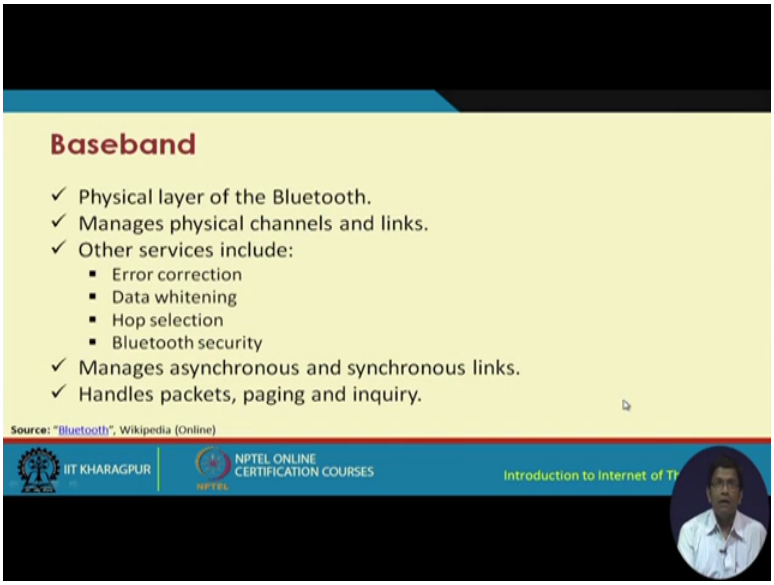

So, baseband layer or the physical the one that is above the physical here basically. So, physical is basically nothing, but the radio and you know we do not need to really understand baseband is the physical layer of Bluetooth it manages physical channels and links and different services such as error correction data whitening hop selection Bluetooth security we are not going through a details of it, it is not even required for you to know because you know if it is required, then really you know this is just you know we are just getting exposure to different protocols in this particular course.

So, it is not required to really dig into too much deep of each of these protocols we just have to be exposed and things like you know adding Gaussian noise. Or you know error correction etcetera. These are difficult these are basically you know the different functionalities data whitening you know with the help of white noise, you know Gaussian noise etcetera you know. So, these are the things that are basically supported in the baseband layer.

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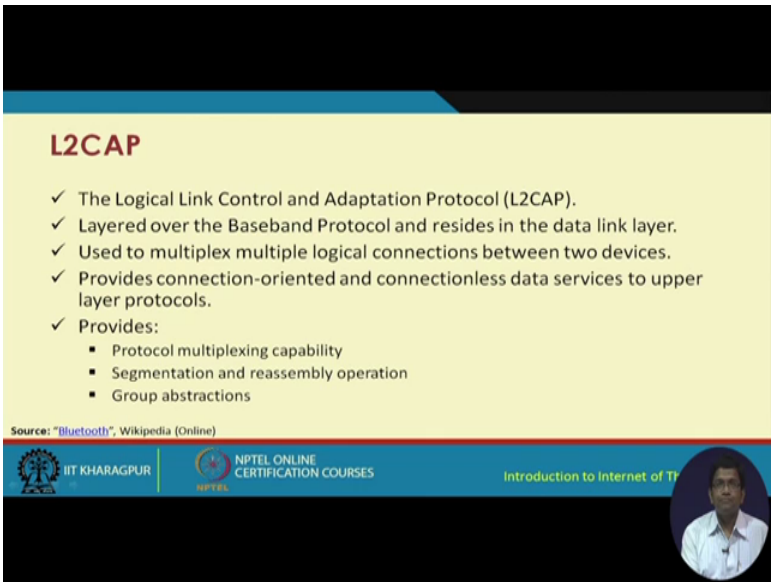

Then we have the L2 cap. And in the L2 cap which basically is on top of the baseband layer, functionalities such as multiplexing, multiple logical connections between 2 Bluetooth devices is functioned is made possible, in this using this particular layer.

So, this particular functionality is implemented in the L2, cap layer L2 cap provides connection oriented and connection less data services to upper layer protocols provides protocol multiplexing capability segmentation. So, because basically you know when you are sending a video for instance. So, it cannot be send to all at once right. So, it has to be segmented fragmented and segment wise it has to be transmitted and then area assembly also has to be done in a subsequently. So, segmentation and reassembly and group abstractions you know. So, together forming of the groups abstracting them and so similar kind of functionalities are all done at this higher up layer, which is the L2 cap layer.

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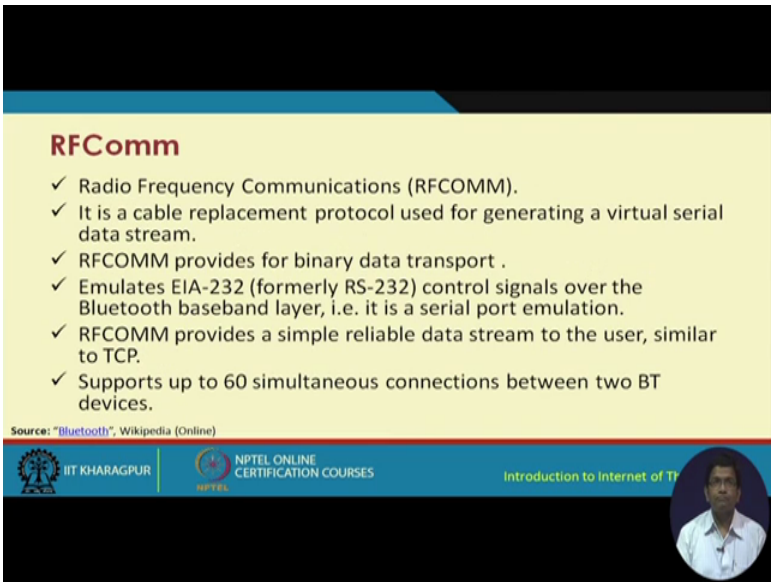

Then we have on top different protocols such as RF comm the full form is radio frequency communication protocol, which is basically a cable replacement protocol and the main purpose of RF comm or more specifically in you know. So, Bluetooth and more specifically RF comm is basically to replace the serial cables that are already. There that is to be traditionally used. So, use do away with the cables and introduce these protocols and that will basically make Bluetooth a cable replacement technology.

So, this RF comm it works as an emulation of the RS 232. And if you remember RS 232 are presently it is also known as EIA 232. RS 232 is basically you know it is a serial port communication protocol serial port communication protocol the traditional serial port communication protocol is RS 232. So, this RS 232 it is emulated, it is behaviors are emulated in this particular protocol the RF comm protocol, RF comm protocol it provides a simple reliable data stream to the user very similar to TCP and supports up to sixty simultaneous connections between 2 Bluetooth devices.

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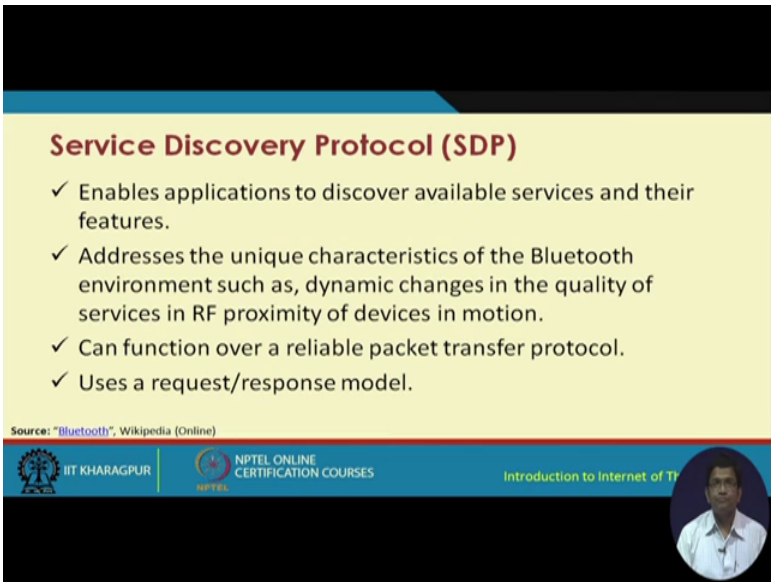

Then finally, we have the service discovery protocol and there are some telephony protocols etcetera, because which has to support the traditional telephony functions. So, we are not going through them service discovery protocol is very important because ultimately, we are going to use Bluetooth for offering different types of services to different applications. Some sort of service discovery has to happen. So, SDP enables the applications to discover available services and their features, and SDP addresses the unique characteristics of Bluetooth environment such as dynamic changes in the quality of services in RF proximity of devices in motion and can function over a reliable packet transfer protocol.

So, SDP it uses a service request response kind of model a request is sent a response is received back ok.

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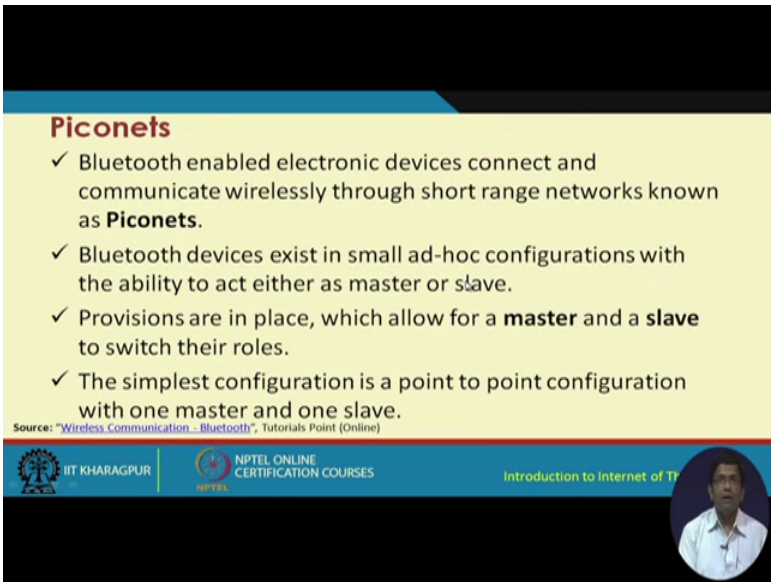

Now, a very important concept, I am going to explain to you which is very much important in order to understand Bluetooth. And this is known as the concept of piconets. Piconet is some sort of a unit you know unit form of network in Bluetooth, unit form of network what does it mean. So, we have let us look at this particular example. So, we are going to go through we have to understand how piconets work.

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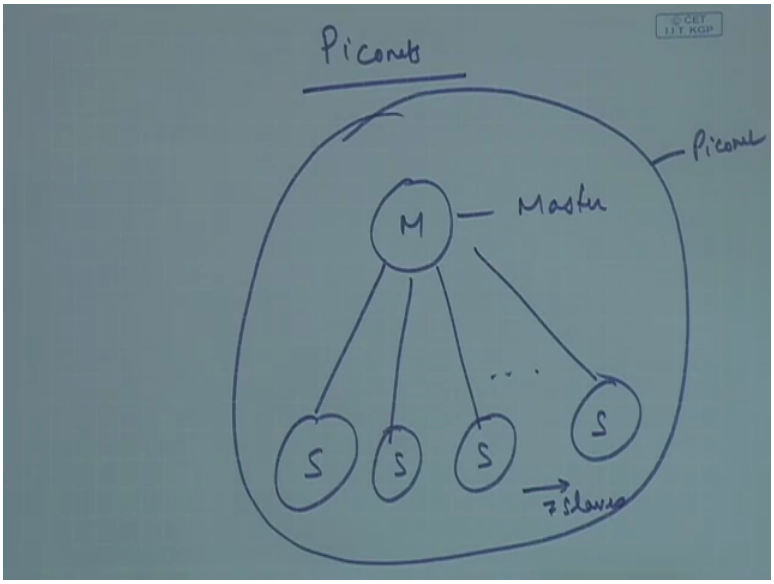

So, what we have is something known as the master. So, we have m Bluetooth node a Bluetooth device which will act as a master. And there can be different slave devices. So,

we have a master we have different slaves. So, this entire thing is a piconet. This is a piconet. And how many of in a particular unit; that means, in a particular piconet, in one piconet there can be only one master. Only one master and one or more slaves. How many up to how many 7 slaves, so 1 2 3 up to 7 slaves. So, there can be one master and one up to 7 slaves in a piconet.

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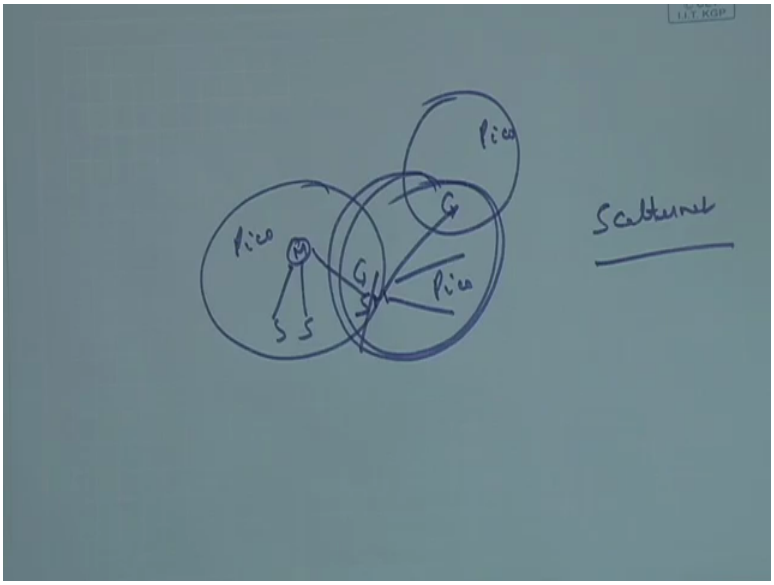

So, this piconet, we have one piconet. We have another piconet, we have another piconet. So, this is one piconet this is another piconet this is a third piconet. So, what we have are 3 different piconets and together all these piconets put together is known as scatternet. So, this is the concept of scatternet in a scatternet you have several piconets put together working together. And these piconets basically talk to each other via the gateway and this gateway nodes can be anything like you know. So, it might. So, happen that you have a master over here (Refer Time: 18:25) say that this is a master and then you have different slaves slave here, there can be another slave and this slave of this piconet can act as a master in this particular piconet.

So, you know the slave in one piconet can be a master in another piconet and then again it can have one or more slaves, and this is the way you know this chain continues and together we have the concept of piconets and scatter nets, so going back. So, we have Bluetooth enabled devices that connect and communicate wirelessly for short range communication, unit form of it unit network of it is the piconet. The Bluetooth devices

exist in small Ad-hoc configurations with the ability to act as either the master or the slave it provisions to have one master and one or up to 7 slaves in a particular piconet.

The simplest configuration is a point to point configuration, with one master and one slave and where we get it this is something, that we typically use a single master single slave kind of configuration is something that we use typically to exchange files to exchange videos to exchange images graphics and so on, between our mobile devices. So, when we are using our smartphones we turn on the smartphones to turn on the Bluetooth in our smartphones to of you know 2 devices. And then from one such device a image can be sent a file can be sent to another such device after the discovery or the initiation phase it can be sent, using this particular configuration.

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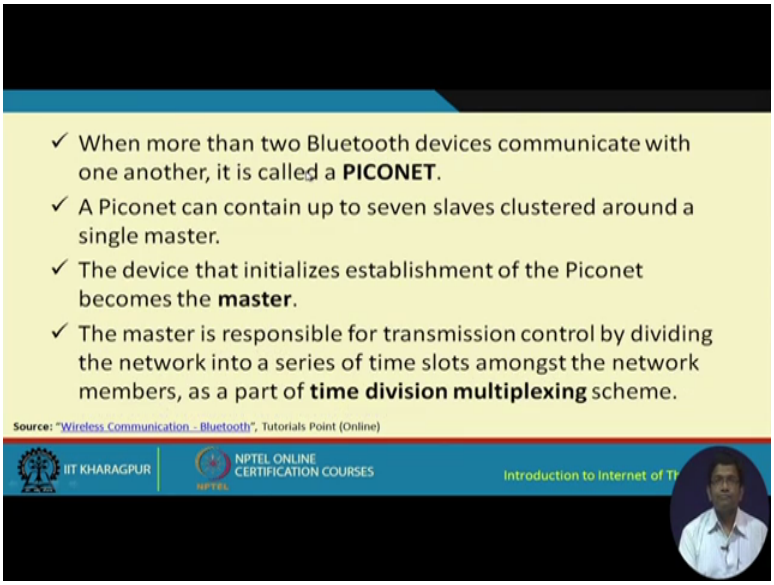

So, we have one master one slave kind of configuration. So, when more than 2 Bluetooth devices communicate with one another. It is called a piconet a piconet can contain up to 7 slaves clustered around a single master. The device that initializes establishment of the piconet becomes the master, and the master is responsible for transmission control by dividing the network into a series of time slots using TDMA. So, basically what happens is within a piconet we have a master and we have you know up to 7 slaves.

So, what the master does is it will have to divide the time that is allotted into different slots. And we will have to distribute those slots among the slave nodes in that piconet

and the master will have to ensure that periodically, this thing is done and is distributed to the different slaves in it is piconet. So, this is the job of the master in a piconet.

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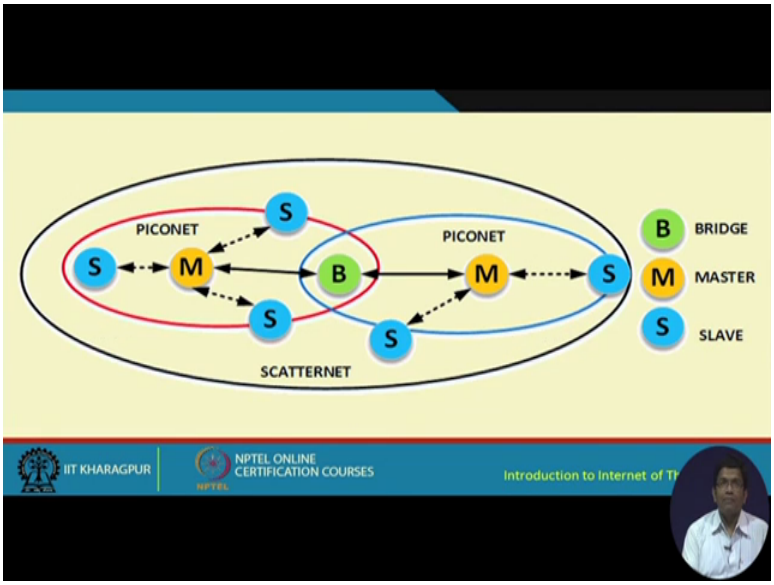

So, this is the diagram showing the configuration of piconet and scatter net. So, we have within a piconets, we here what we see we have a scatter net consisting of 2 piconets this is one piconet, this is another piconet. And we see that there is a master and there are 3 slaves rather 4 slaves and this slave is acting as a bridge between these 2 piconets, and these are again 3 different slaves for this particular piconet.

And here as you can see over here we have distinct masters in each of these piconets, it is not like the same master. In fact, what we could have had is this bridge which is a slave for this piconet would have also been configured in such a way, that it would act as a master for this piconet this is also possible.

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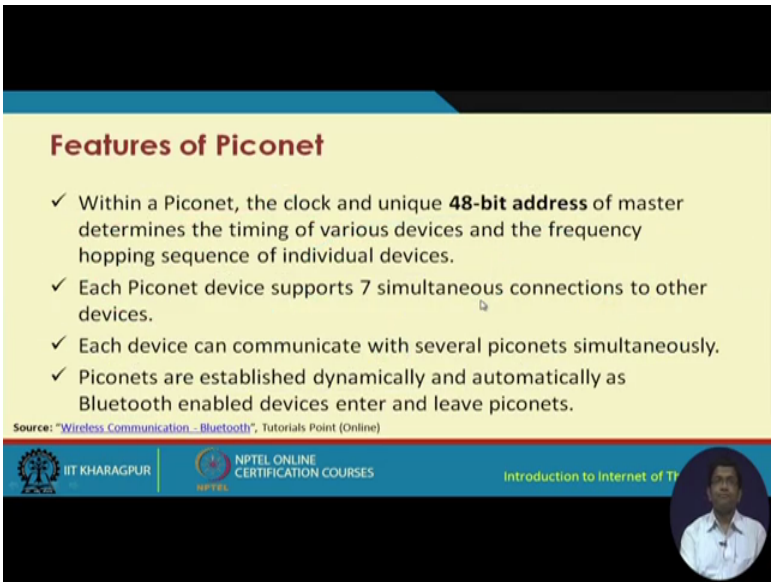

So, the master of the slave they use the 42 bit addressing. So, this is the addressing scheme that is used each piconet device will support 7 simultaneous connections to other devices each device can communicate with several piconets simultaneously. And piconets can establish dynamically and automatically as Bluetooth enabled devices enter and leave piconets.

So, they can basically configure self configure, they can change you know devices can not the Bluetooth devices can get into a piconet can go out of the piconet dynamically. And the topology changes accordingly. So, all these things are featured in a piconet.

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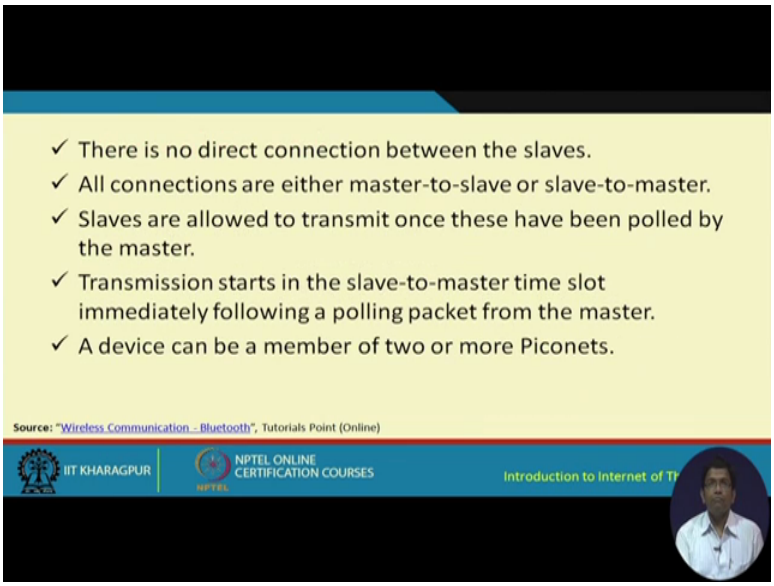

There is no direct connection between the slaves all connections are either through the master to slave or slave to master mode slaves are allowed to transmit. Once these have been polled by the master transmission starts in the slave to master timeslot immediately following a polling packet from the master and the device can be member of 2 or more piconets, and this is something that I explained earlier as well.

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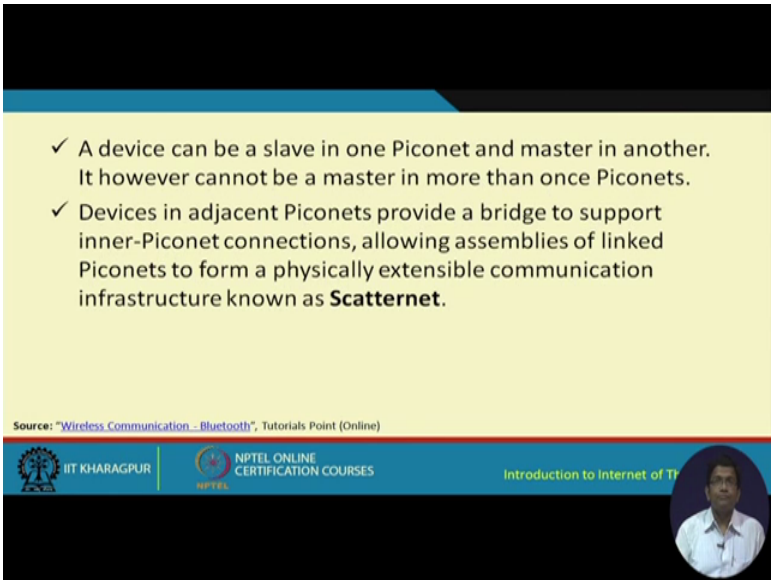

In one piconet that that particular device can be a slave in another piconet, it can even act as a master and together you put all these piconets and what you get is a physically extended infrastructure comprising of several piconets known as the scatternet.

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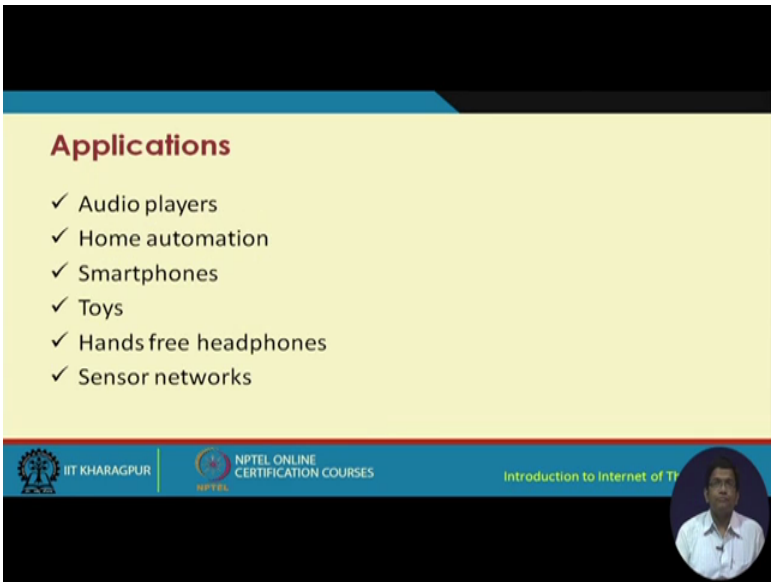

Applications of Bluetooth are quite common. Audio players, home automation systems, smartphones, toys, hands free headphones, sensor networks they all are users of Bluetooth. So, the Bluetooth is a very important technology, that we have just covered and it is quite heavily used for building IOT systems. Zigbee, hart Bluetooth, NFC RFID these are all like different technologies that can be used for establishing connectivity between different nodes for building up IOT.

They all have their different distinct features and we have already seen that in the previous lecture we have seen that how hart wireless hart and zigbee differ from each other. And now it is also quite evident how Bluetooth differs from zigbee. So, for Bluetooth, we can have high data rate communication compared to no data rate in the case of zigbee, but zigbee is consumes much lower power compared to Bluetooth. So, there are pros and cons depending on the application. In fact, what can also happen is we could be using all of these technologies together in parallel, and we can have a Bluetooth working with zigbee, zigbee working with hart etcetera and so all these things are possible.

Zigbee primarily consumer IOT hart wireless hart primarily industrial IOT, but it does not even matter you can even put all of them together for maybe industrial IOT or on the other hand consumer IOT. So, this can also be done. So, these are that all these powerful technologies that can be used for building IOT systems.

Thank you.