Introduction to Internet of Things
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Lecture - 11
Connectivity Technologies – III

For connectivity we have already gone through different technologies, which offer communication in IoT. Technologies such as zigbee, 6 low pan and the like. They are based on either they use either they are developed on top of 802.15.4 for instance the way zigbee has been developed. Or they use 802.15.4 standard the way 6 low pan does. Likewise there are other technologies which are sort of derived from or are based upon the IEEE802.15.4. Technologies such as hart and wireless HART, are 2 such technologies that we are going to cover in this particular lecture. So, HART the full form of, the full form of HART is highway addressable remote transducer protocol.

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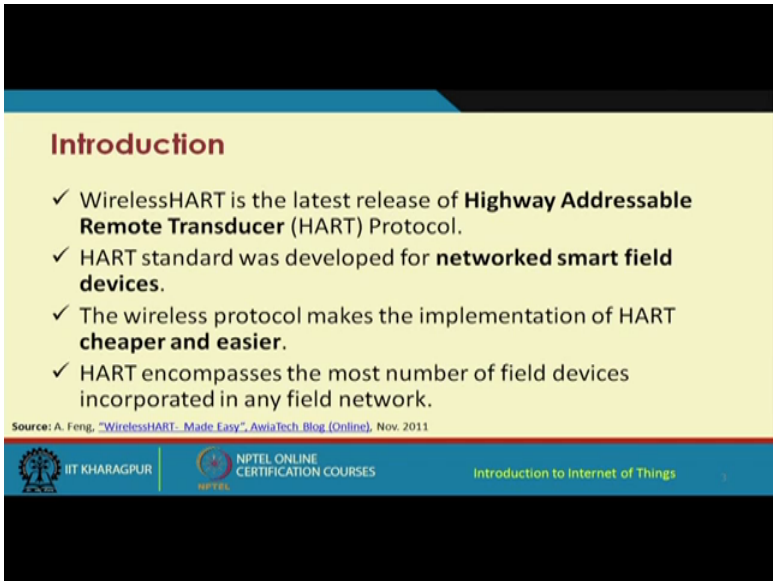

So, highway addressable remote transducer protocol HART and it is latest version which is a wireless version of it which is a wireless HART are 2 such technologies which are sort of derived from 802.15.4 standard. So, all these 802.15.4 standard based technologies and the protocols they are very useful for setting up IoT communication. The reason is that they enable short range you know, different data rate communication between low power devices as are found in IoT systems.

So, we will go through the HART and the wireless HART and the overview of it to understand how it functions and what are it is different features. So, the genesis of HART and wireless HART goes back to industrial IoT IIoT industrial IoT which is again one of the lectures that we are going to have in the future in this particular course. So, for many of these industrial applications such as industrial plants or vehicular networks connected vehicular etcetera. So, what is required is to set up some kind of is network between different field devices, to form a smart system a smart network. And this is what is required in IoT.

So, HART basically helps in the same way as zigbee does for establishing connectivity between different IoT devices. And the special the special focus of HART is on industrial applications. So, the HART protocol has been designed and is implemented in such a way so that it becomes cheaper and easier to implement in an IoT system. So, HART basically encompasses the most number of field devices incorporated in any IoT network..

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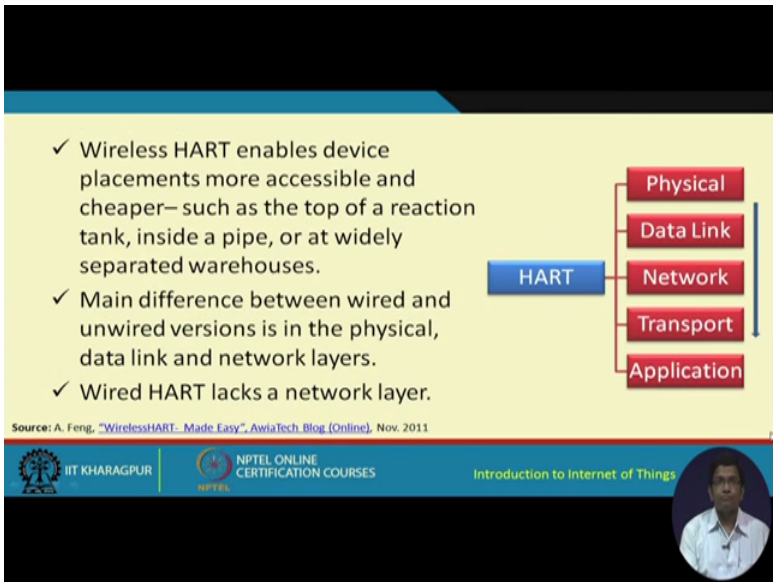

So, talking about HART and wireless HART it basically helps to, ensure accessibility of different devices. And the placement of such devices in such a way that it becomes cheaper to develop the overall system. The system becomes overall efficient and typically this protocol is implemented on top of a reaction tank inside a pipe or at widely

separated warehouses, to have connectivity between these different components or different parts of the warehouse or the reaction tank or the pipes etcetera.

So, the main difference between HART and the wireless HART is in the physical data link and network layers. So, the wireless HART and the HART they are almost the same except that there are certain differences in these specific layers of physical data link and network, and we are going to go through them in a little bit more detail. So, we have to also keep in mind that wired HART basically does not have support for a network layer. So, looking at HART and the wireless HART what we have is a physical layer, data link layer, network layer, transport layer and application layer.

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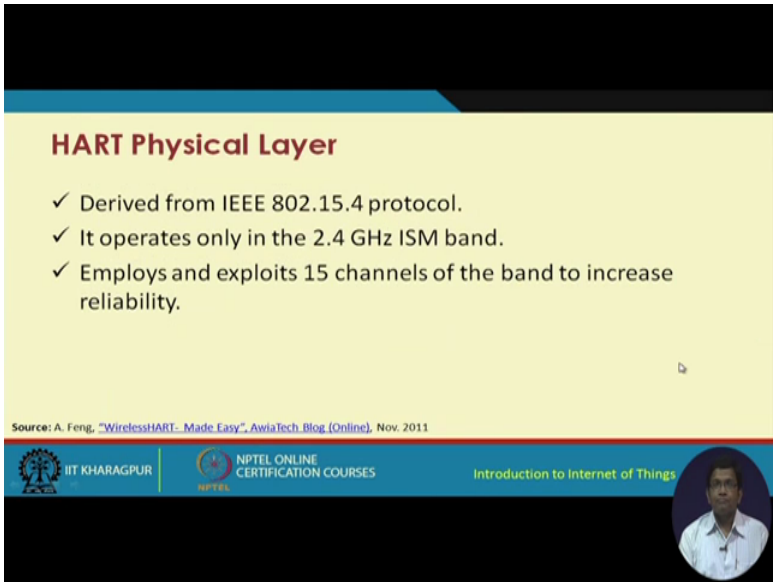

So, the physical layer as I said, is derived from the basic standard the most popular standard for IoT implementation the 802.15.4 IEEE standard. And this protocol the HART protocol functions in the ISM band, but more specifically the 24 gigahertz ISM band. It implies and exploit is 15 channels of the band in this particular ISM band to increase the reliability of the network. So, that is the physical layer with support for 802.15.4 derived reduced.

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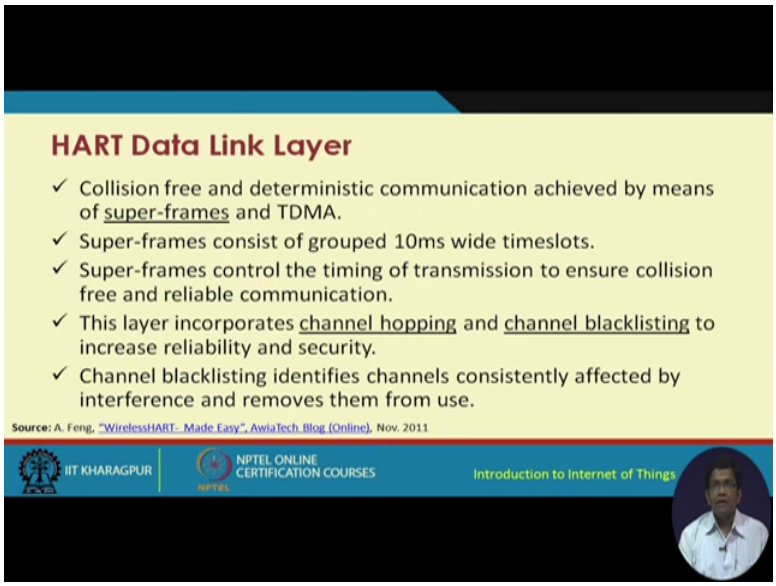

Then comes the data link layer. The data link layer has a concept of something known as the super frames. And the super frame basically helps in ensuring reliable communication, collusion free and deterministic communication between the different nodes of the network. And it is based on this particular layer it works using a TDMA like protocol, time division multiple access protocol where there are different time slots, when the different devices are able to communicate in those allotted time slots.

So, these super frames that we are talking about they are grouped into 10 millisecond wide time slots. And the super frames basically control the timing of transmission to ensure collision free and reliable communication. This layer the data link layer incorporates channel hopping and channel blacklisting to increase the reliability and security. How is it done? How is the reliability and security increased? Because there is channel hopping. So, you know what happens is, a transmission takes place in one of the channels then basically the transmission takes over in another channel at the next time instant. So, there is basically channel hopping. There is something similar to you know oh what happens in frequency hopping, frequency hopping spread spectrum. So, a similar kind of approach is adopted in this particular case as well.

So, because there is channel hopping at different time instance etcetera, that improves the security. You know and also improves the system from being hacked network from being hacked by different intruders or malicious agents. Channel blacklisting basically what it

does is it identifies the channels consistently affected by interference and removes them from use.

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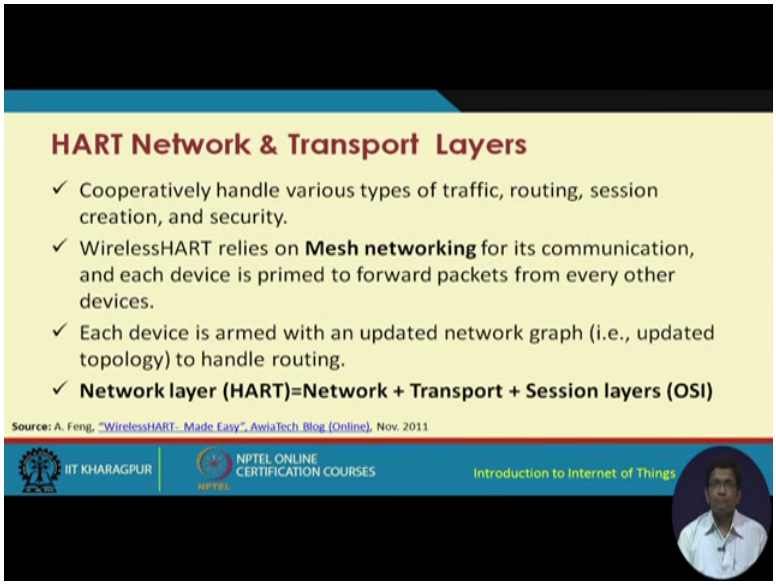

Now, looking at the network and transport layers after the physical and the data link layers. We see that these two layers they cooperatively handle various types of traffic, routing, session creation and security functions. Wireless HART is based on the mesh networking in communication.

So, a mesh network at the network layer is set up using wireless HART. And each device is primed at different time instants to forward packets for every other device. Each device in wireless HART is armed with an updated network graph; that means, the topology gets updated at subsequent time instants, and that way that particular topology is used to handle routing. So, the network layer in HART basically consists of the OSI network layer, the transport layer and the session layers, put them together and that is what is the network layer of the HART or wireless HART protocol.

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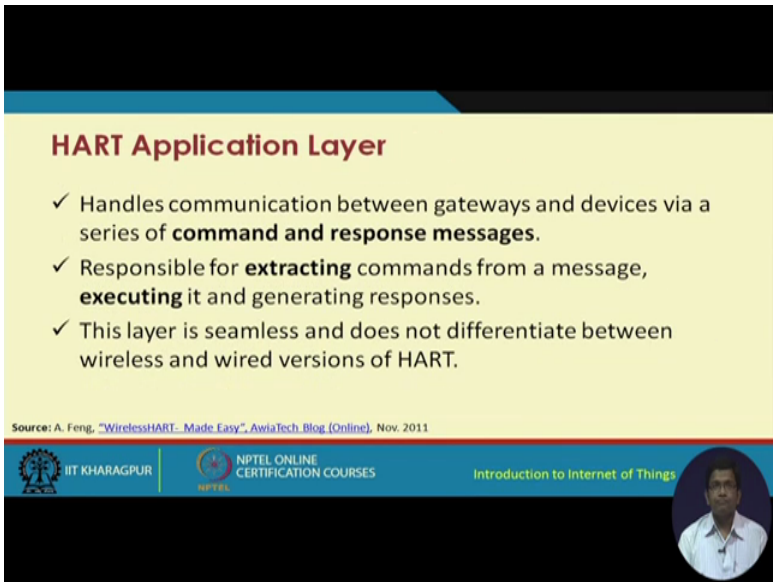

Application layer in HART handles communication between gateways and devices via a series of command and response messages. So, there are different command messages, response messages and a chain of such message flows take place to implement the application layer. This application layer is responsible for extracting commands from a message, executing it and generating responses. So, in extract the commands from the message, execute those commands and then respond to those commands. So, this layer is seamless and does not differentiate between the wireless and wired versions of HART.

So, irrespective of what is down underneath in the different bottom layers as I said, that there is certain difference between the HART and the wireless HART protocols at the network layer transport layer data link layer and the physical layer. In fact, as I said before pure HART the wired HART does not even have the network layer implemented. So, essentially the most of most of the difference comes in the other three layers which is basically the physical layer, the data link layer and the transport layer.

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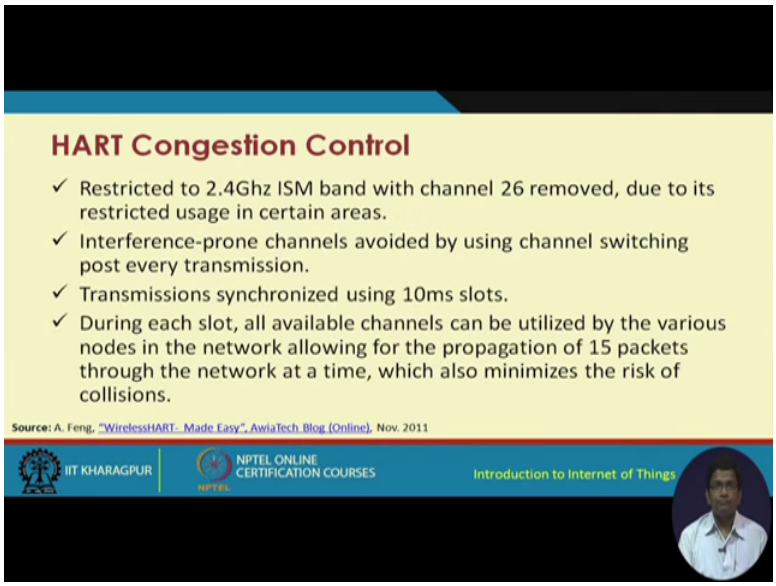

Now, one of the very important issues of use of HART or any such like protocol is how do you handle congestion. So, congestion is basically handled in different ways. So, we are talking about a 2.4GHz ISM band with channels with channel 26 removed from it.

So, there is no channel 26, due to the restricted use of this particular channel in certain areas. So, what we have is interference prone channels avoided by using channel switching post every transmission. The transmission is synchronized using 10 millisecond slots. During each such slot all available channels can be utilized by the various nodes in the network, allowing for the propagation of 15 packets through the network at a time, which also minimizes the risk of collisions. So, this is how congestion is controlled collisions are avoided and not avoided, but minimized and so on.

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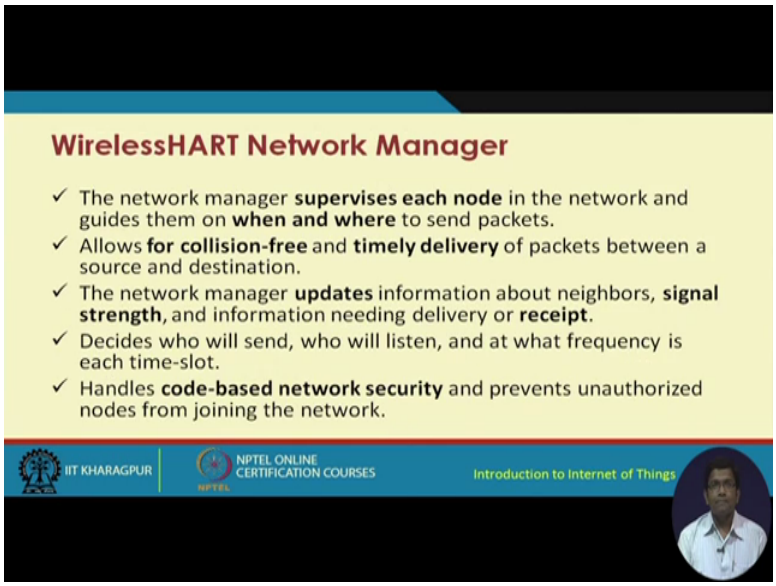

Wireless HART uses a something known as the network manager agent. The network manager agent supervises each node in the network and guides them when and where to send the packet. When to send the packet? And where what is the intended destination? So, this is what is the job of the network manager entity in the wireless HART. It allows for this network manager allows for collision free and timely deliver your packets between a source and the destination. The network manager updates the information about the neighbors the single strength and the information needing delivery of receipt. So, wireless HART basically uses something called known as the code based network security to prevent from unauthorized access or unauthorized attempts of different nodes from joining the network.

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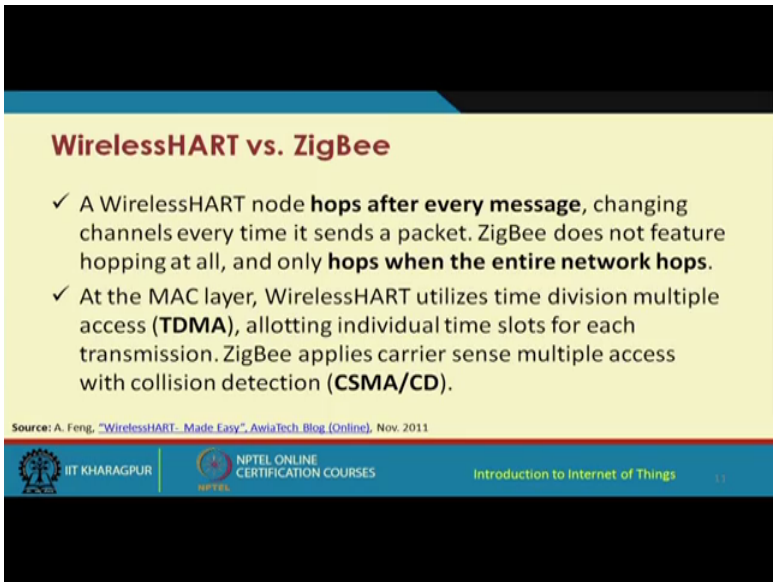

Now, as I in started at the very beginning, that these are all like you know protocols like zigbee or you know IPv6 or wireless HART. The IPv6 protocol has a little bit of different you know functionality from these protocols, but you know if you look at all these protocols, they are all meant for use in low power, low specification, resource constraint, bandwidth constraint, networks and this is where their usefulness in IoT comes into picture.

So, we now need to compare between for instance the popular zigbee protocol and the wireless HART. One thing is zigbee is primarily consumer based IoT. You know zigbee is primarily used for consumer based IoT whereas; HART is primarily used for industrial IoT applications, although nobody limits the use of either of these protocols for consumer or industrial application domains.

So, they can be used interchangeably, but primarily they are based on their implementations consumer iot, zigbee and industrial IoT HART and wellness HART. So, going back a wellness HART node basically hops after every message. And that as I said before improves the security of systems from being attacked or from unauthorized access to the network. Zigbee does not feature hopping at all on the contrary. And it only hops when the entire network hops. So, this is one of the primary points of difference between zigbee and wireless HART. Now at the mac layer wireless HART utilizes TDMA

allotting different time slots for each transmission on the other hand, zigbee is primarily based on the MAC protocol CSMA plus, so CSMA/CD or CSMA/CA.

So, CSMA class of protocols. So, zigbee is based on CSMA class of protocols contention based protocols. And TDMA is basically applied in the case of wireless HART.

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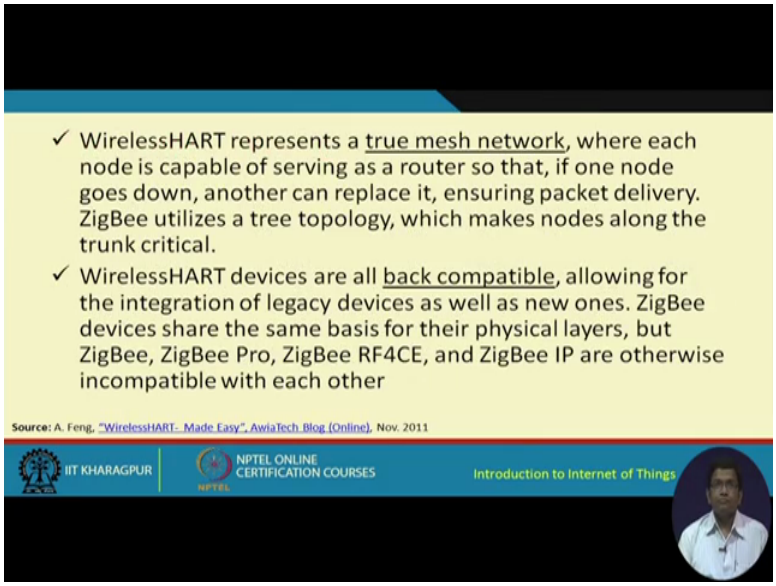

In wireless HART what is used is the mesh network topology where each node is capable of serving as a router. So, that if one node goes down another node can replace it. So, that basically in fact, this mesh networking topology improves the overall delivery reliability of packet delivery in the network. Zigbee use utilizes a tree topology which makes nodes along the trunk critical.

Wireless HART devices are all backwards compatible and that basically allows for the integration of legacy devices as well as the new one. So, this is one of the very important and attractive features behind using wireless HART because, you do not have to totally forget the legacy and the contemporary systems, because it is backwards compatible you can use wireless HART in conjunction to the legacy systems and protocols. Zigbee devices share the same basis for their physical layers, but zigbee zigbee pro zigbee RF4CE and zigbee IP or otherwise incompatible with each other. So, this is also a very attractive or important difference between zigbee and wireless HART

Another very important technology is NFC and this NFC technology as you will see shortly has lot of similarities with the RFID. RFID are also based on something known as magnetic induction. Magnetic induction between the card reader; that means, the RFID card reader and the RFID tag RFID card. And in the case of NFC as well we will see that there is a similarity of this sort.

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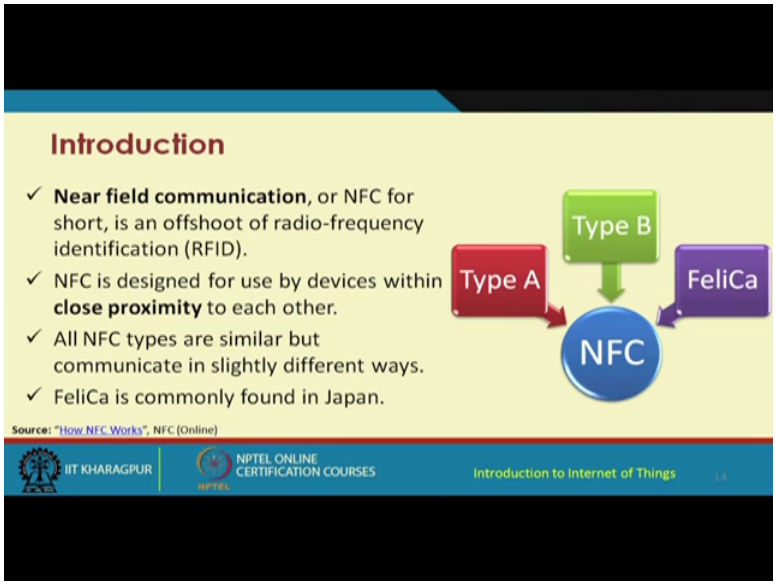

So, NFC one the full form of NFC is near field communication. And this is basically as I said, is very similar to the RFID technology and this is something the RFID technology is something that we have discussed previously in a previous lecture.

So, NFC is designed for use by devices within the close proximity to each other. All NFC types are similar, but communicate in different ways, a very allied NFC technology, which is known as the FeliCa is commonly found and is used mostly in Japan. The contemporary ones type A and type B NFCs are used in the rest part of the world.

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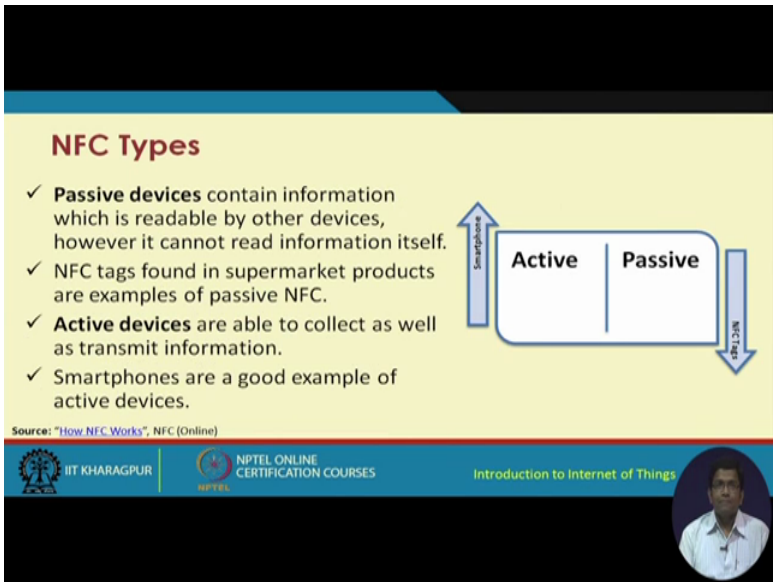

There are different primarily 2 types of NFC devices. One is the passive device, and the other one is the active device. Passive devices are more common than the active devices. Active devices are typically implemented in smartphones and so on.

So, you have an NFC support along with your smartphone in which are basically you know these NFCs that are implemented in the smartphones are basically active collectors of of information, and they are also active transceivers, you know rather transmitters of the information. So, we have active devices. An example as I as I just said is the use of NFC in you know active NFCs in smartphones. And all the passive devices are typically used in NFC tags and so on. And these are very similar to the RFID tags and very similar kind of technology which is based on magnetic induction. These RFC tags sorry these NFC tags, they contain information which is readable by other devices; however, it cannot read information it itself and these NFCs like in the case of RFIDs are typically used and are implemented in supermarkets.

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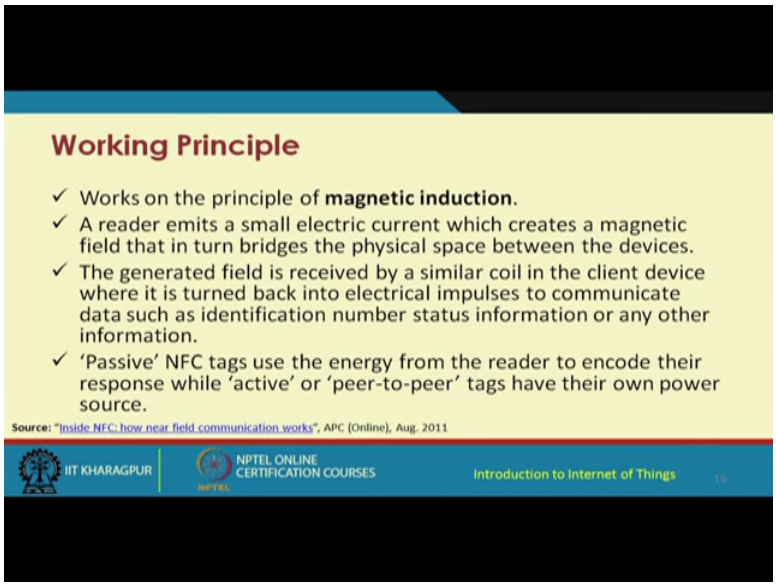

So, as I was just saying in a short while back, NFCs are based on the physical principle the scientific principle behind the functioning of NFCs is the concept of magnetic induction.

So, here basically there is a NFC reader, which emit is a small electric current which creates a magnetic field, which in turn bridges the physical space between the devices. So, you bring the NFC reader close to the NFC device there is a magnetic induction that basically goes on between these two entities and that is how the information that is encoded in these NFC tags are transmitted, are sent to the NFC reader. The reader basically emits a small electric current which creates a magnetic field that in turn bridges the physical space between the devices, this is what I will just saying short while back.

The generated field this magnetic field is received by a similar coil in the client device, where it is turned back into electrical impulses to communicate data such as identification number status information status information or any other information. NFC tags are used in the case of supermarkets and similar kind of libraries etcetera. They use the energy from the reader to encode their response while the active or peer to peer tags have their own power source.

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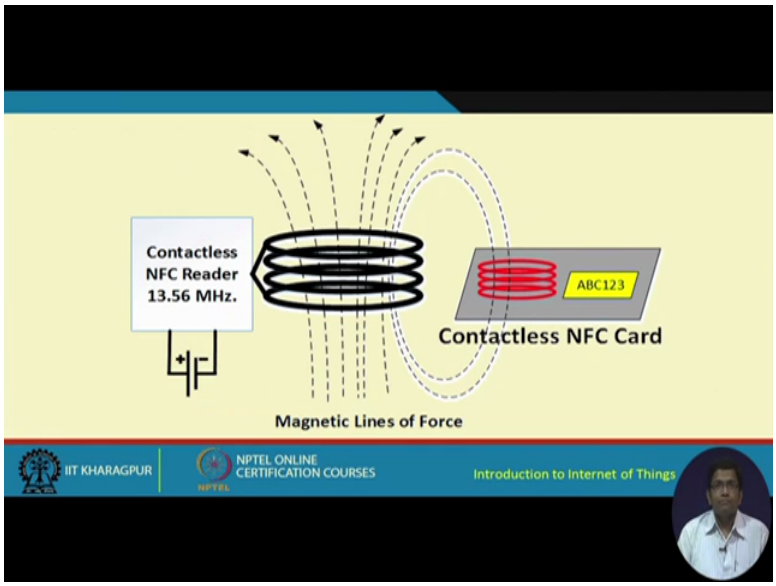

So, in this particular figure this particular physical or scientific principle that I just mentioned is shown over here. So, what we have pictorially as it is shown what we have is the NFC card

So, this has some magnetic coil kind of and then we have this NFC reader, through which current is passed. So, a magnetic field is generated and that is how the information transfer between these two entities the card as well as the card reader takes place.

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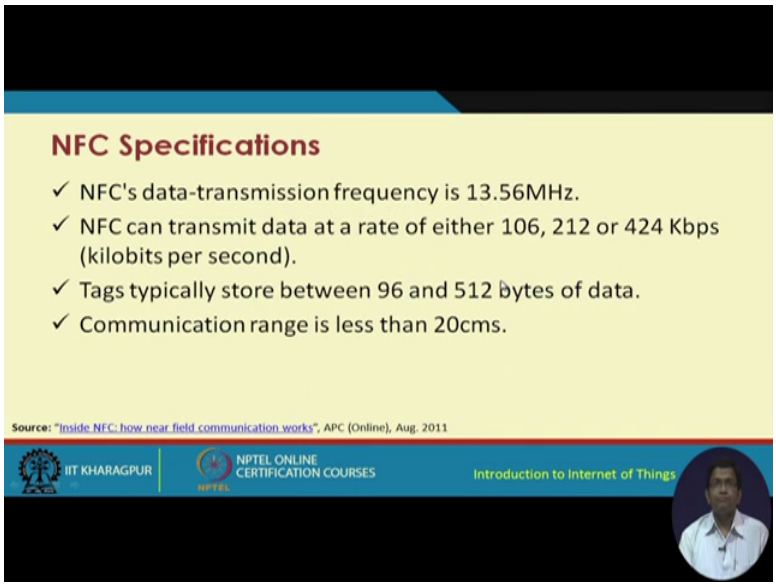

The NFC specification, NFCs data transmission frequency is 13.56 sorry megahertz. NFC can transmit data at the rate of either 106, 212 or 424 Kbps. That is typically stored between 96 and 512 bytes of data, and the communication range is less than 20 centimeters.

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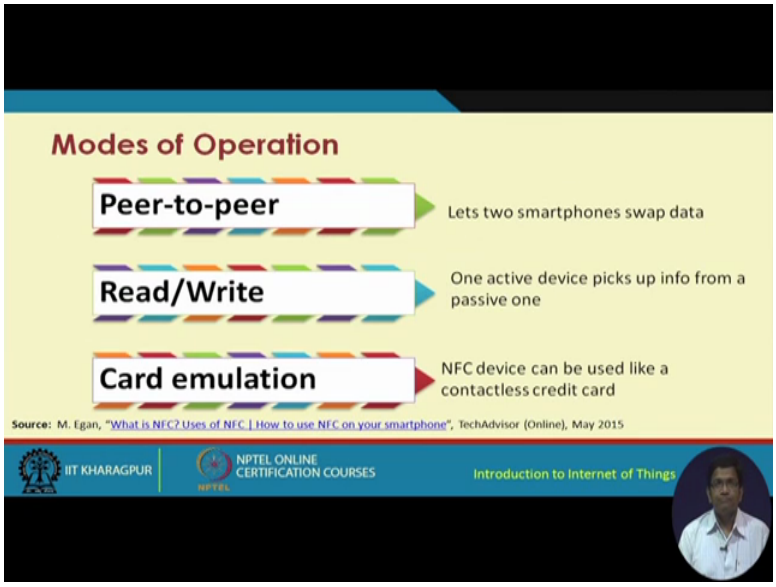

There are primarily three modes of operation of NFC. The first is the peer to peer mode. The second is the read write mode, and the third is the card emulation mode. In the peer to peer mode two smartphones they can for example, swap data between themselves and this is this particular mode which helps these 2 smartphones to be able to exchange the data between themselves. The read write mode, here one active device picks up information from a passive one.

So, active device from passive device picking up information is an example of read write mode of operation. And card emulation, the NFC device can be used like a contactless credit card. So, in credit cards also and very similar to the way it is done. So, in credit cards also you know these kind of things are implemented the RFCs are implemented. So, that what you have is payment through these NFA enabled credit cards. So, there is a contactless credit card. So, these NFC basically makes it contactless the functioning of NFC basically makes it contactless.

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So, we have three modes of operation the peer to peer mode, the read write mode and the card emulation mode. So, I already mentioned about payments using smartphones, parcel tracking, information tags in posters and advertisements, computer game synchronized toys, low power home automation systems these are all different examples of NFC applications. NFC reader the card and the NFC reader being used for all these different types of applications is something that makes NFC very useful and effective for IoT applications.

So, to conclude what we have gone through are primarily two protocols the HART and it is wireless variant the wireless HART, and NFC, which is the near field communication. In HART and wireless HART basically there are the layers physical layer, the data link layer, network layer, transport layer and application layer. HART the wired HART basically does not have it does not have the network layer. Wireless HART does and, wireless HART basically works on top of the IEEE 802.15.4 or rather to be more precise and correct, wireless HART works as a derived protocol from the 802.15.4.

It is derived from 802.15.4 because it has different features that I have been suggested in 802.15.4 and is implemented over here, in HART and wireless HART rather. Whereas, in NFC basically works very similar to RFIDs, and you have an NFC reader and a NFC card and there is magnetic coupling that you know magnetic induction that helps these two entities to transfer information between them, to read information let us say from the

card to the reader, so these are all very attractive technologies that can be used for implementing internet of things.

Thank you.