Wireless Ad Hoc and Sensor Networks
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Lecture – 01
Introduction: Wireless Ad Hoc Network- Part- I

Welcome to the course Wireless Ad Hoc and Sensor Networks. I am Sudip Misra. I am an associate professor in the department of computer science and engineering at IIT Kharagpur. So, today's lecture is the inaugural one, where we are going to cover some of the introductory things about wireless Ad Hoc networks. We are going to take an overview about the different concepts that, different technologies the corresponding protocols etcetera which are there and to enable the wireless Ad Hoc networks.

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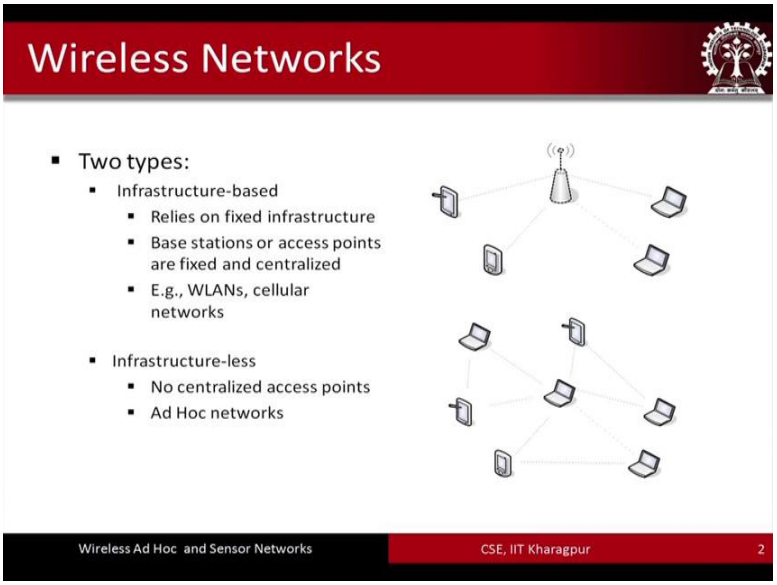

So, well is Ad Hoc networks are a class of wireless networks which are known as infrastructure less networks. So, wireless networks can be classified into 2 types one is called the infrastructure based networks, the other one is called the infrastructure less networks. The infrastructure based networks are those which rely on fixed infrastructure. So, that means, that they have some kind of equipments such as, base stations or access point which are fixed and centralized.

So, examples of infrastructure based networks are wireless local area networks, cellular networks and so on. Because, as we know that, wireless local area networks or cellular

networks they have devices known as access points or base stations. So, these access points or base stations they basically help in transmitting or routing the information that is sent from the individual nodes to the destination nodes.

On the contrary in the infrastructure less networks category, there is no centralized access point. So, as we can see in the figure on the bottom right hand corner we see that we have a collection of different nodes which can be laptops which can be tablets and so on and so there is no fixed entity like an access point or a base station. Unlike the topmost figure where there is and every node in such a case will have to communicate via that particular access point of the base station.

So, here we do not have such a thing in an infrastructure less network. So, the Ad Hoc networks that we talk about belong to the infrastructure less network category.

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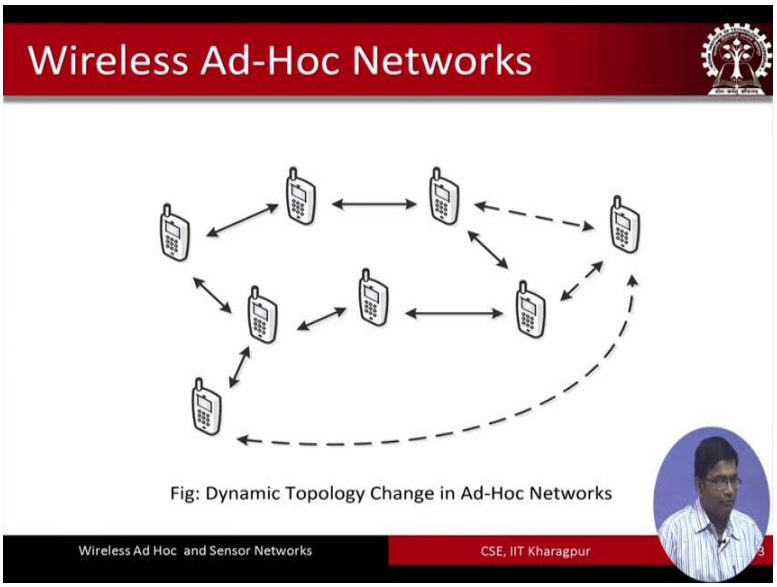

So, here is an example of an wireless of a wireless Ad Hoc network. So, as we can see over here in such a network, we have a collection of different wireless enabled nodes, which can communicate with one another and as we saw before that there is no base station or an access point. So, as we can see over here that, you know these nodes they can you know when they are in the proximity of each other, they can communicate with each other and they can form a topology these nodes they can move also and due to the mobility the topology of the networks they change over time.

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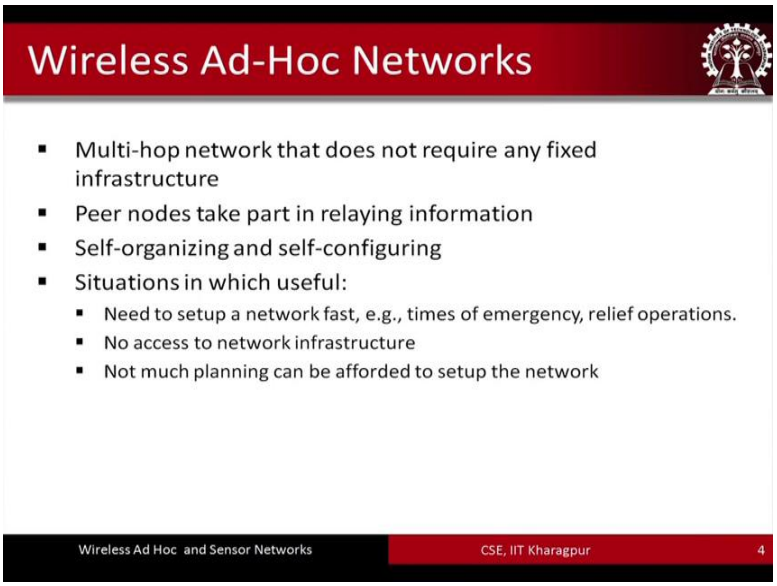

These networks they are also known as multi hop networks, because, they do not require any fixed infrastructure. So, what happens is, if a source node wants to communicate some information a a; that means, the source node wants to send some information to a destination node, it has to take help of the intermediate nodes in order to be able to send the data that it wants to send.

So, so basically the intermediate nodes they act as the peer nodes and these peer nodes they take part in relaying the information from the source node to the destination node. These networks are self organizing and they are self configuring. So, what is the meaning of self organizing and self configuring that we will see later and in these networks what happens is these networks, you know once you have the collection of different nodes and you put them together they would be able to form the network by themselves and you know the different nodes they would be able to start communicating.

So, the reason they are called multi hop is that, from the source node to the destination node, if the destination node is not within the direct transmission range of the source node then the source node will have to take help of some of the intermediate nodes in order to be able to send the data from it to the destination node. So, consequently what happens is it is not a single hop transmission from the source node to the destination node, but it goes through number of multi hop, you know number of intermediate nodes

consequently what we have is a multi hub structure; that means, the data that is transmitted goes through multiple hops from the sender to the intended destination node.

So, these networks are very useful in different situations. So, you know when it is like at different times of emergency or during relief operations. So, let us consider the different, you know different you know a few examples from the history. Let us say that when you know let us take the case of the September 11 incident that happened you know several years back. So, what happened is the entire infrastructure, in the building infrastructure as well as the network infrastructure that was there, it collapse the collapse due to the disaster and once the existing infrastructure collapses then it is very difficult for the rescuers the relief oper, pepole who are doing the relief operations to be able to communicate with one another. Because we know whatever was existing it does not, you know, it does not exist anymore.

So, what is required is that, in order to be able to efficiently, you know communicate between the different rescue workers and the different victims etcetera, you know what is required is to be able to have some kind of a mechanism by which the network can be set up very fast and. So, that communication can be restored. So, Ad Hoc networks come to be useful in such scenarios and because you know there is it is very easy to set up the network in such a scenario and also in cases like you know desert areas or remote areas, where there is no existing infrastructure in such a case also there is no existing network infrastructure in such cases also you know Ad Hoc networks come to be very useful.

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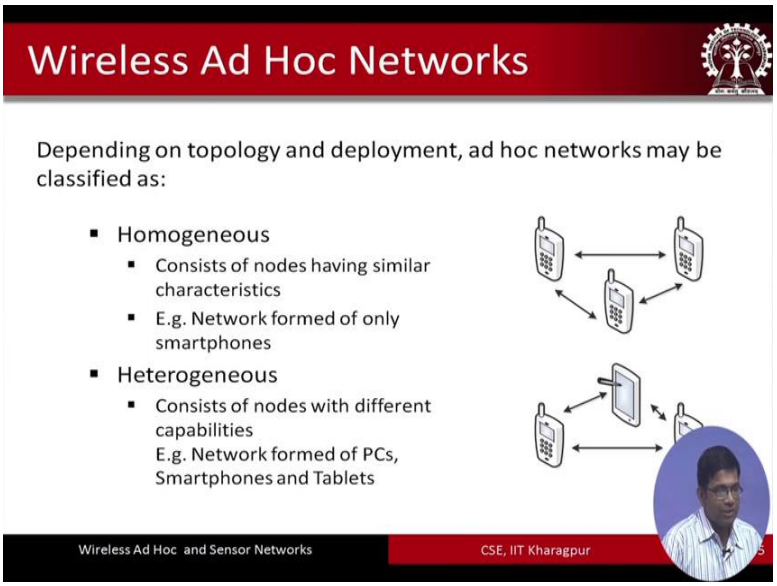

So, there is not much planning that can be afforded to set up this kind of network. So, that is why these networks prove to be very useful. So, the Ad Hoc networks, depending on the topology and deployment they can be classified into 2 types, 1 is called the homogeneous the other one is called the heterogeneous. In a homogeneous network as we can see on the, you know the topmost figure on the right hand side. What we have are different nodes in the network which have similar characteristics they have similar specifications and you know they are all very similar. So, an example of this kind of network is, a network formed of smartphones which have very similar specifications and capabilities. On the contrary we have heterogeneous Ad Hoc networks, where all the nodes may not be of the same type. They may not all have different, you know they may not all have the same or similar kind of specifications they may have different capabilities and so on.

An example could be a network that is formed of PCs, smartphones and tablets. So, the bottom most figure on the right hand side is an example of an heterogeneous wireless Ad Hoc network.

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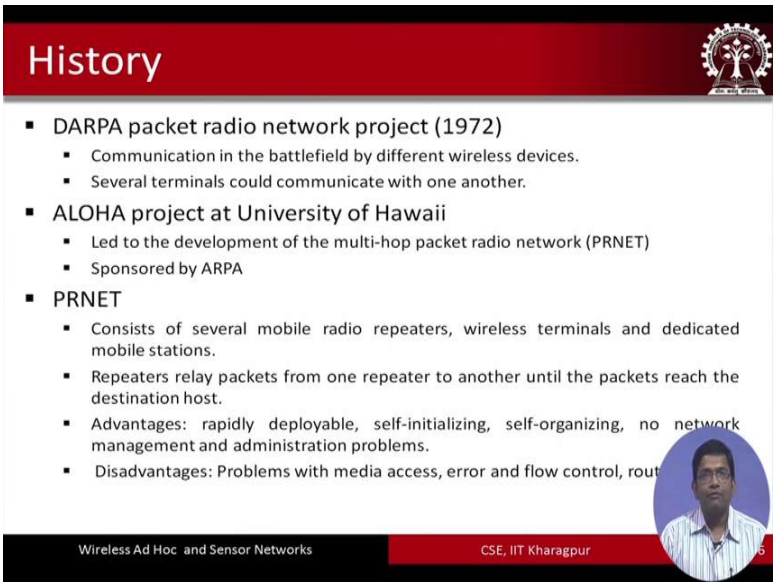

So, now let us look at little bit of history behind these Ad Hoc networks. The concept of Ad Hoc networks is not very new, it started in the 1970s, in the early 1970s with a DARPA project known as the packet radio network project, the PRNET project and the whole purpose of the whole objective of the project was to enable communication in a battle field between different wireless devices. So, that, different terminals could communicate with one another.

But the main problem those days in the 70s and so on, was that even though this concept proved to be useful and you know the project was successful because, you know it was demonstrated that such kind of mechanism could be you know deployed, but those days actually the devices used to be very bulky they were not very portable and so on and so forth. So, even though the packet radio network project was popular, finally, you know there was not much that was done since the 1970s.

In the 1980s and so on this packet radio network project again was relooked upon the reason is in the 80s late 80s and 90s. The wireless devices became very portable and consequently the concept that was demonstrated in the packet radio networks was, you know was becoming more beneficial for use in communication in different scenarios. Scenarios of disasters, relief operations and scenarios where there is no existing infrastructure and it is not very easy to set up network infrastructure because, nothing already exists and it is very hard to you know set up such a network.

So, the packet radio let us now look at the different characteristics of these packet radio networks that was proposed in the 70s the PRNETs, the packet radio networks basically consists of several mobile radio repeaters, wireless terminals and dedicated mobile stations these repeaters they relay packets from one repeater to another until the packets reach the intended destination host.

So the advantage of having such a network is that these networks are rapidly deployable. They are self initializing, self organizing and there is no such requirement of network management or administration problems. The disadvantages of these networks are many. For example, you know although it is very attractive to have this kind of network, but there are basic problems with respect to medium access. So, when you have several such nodes and there is no centralized coordinator or an access point, which can help the different node, nodes in to get access to the common medium. Medium access becomes medium access control becomes a huge problem.

Similarly, the traditional problems network problems of error control, flow control, routing and so on and so forth, including you know transport issues and so on. These become very challenging in these kind of networks and. In fact, without addressing these problems in the newer context of pr nets with the existing solutions, with the other kinds of wireless networks, the entire PRNET networks become very inefficient.

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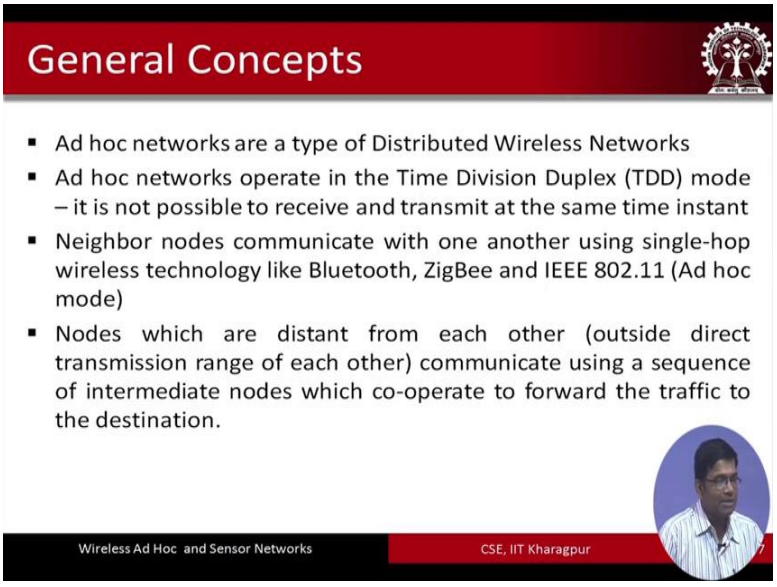

Let us now look at some of the general concepts in Ad Hoc networks. These networks, they belong to the broad category of wireless networks, all the distributed wireless networks. So, as this name suggests in these networks the different nodes, they are distributed in space and for the nodes to be able to communicate with one another. There has to be some kind of mechanism which will enable these nodes to be able to do.

So, because there is no centralized entity, there is no centralized access point or a base station which can help in a centralized manner to be able to add these nodes in communicating with one another. These networks and the nodes in them they operate in the time division duplex mode. So, that means that, it is the you know it is the half duplex mode. So, that means, half duplex means that it is not possible to receive and transmit data at the same time instant. So, it is it is called the half duplex mode.

Having said that let me also tell you that this is what was existing, but currently there have been different works you know in the last you know decade or so. There have been different works which have considered solutions for full duplex networks. So, that means, it is possible in the present scenario, to be able to receive and transmit data between the source and the destination at the same time. So, in these networks the neighbor nodes they communicate with one another using single hop wireless technology. For example, Bluetooth could be used or ZigBee or the IEEE 802.11 which basically powers the Wi Fi as you know, but not 802.11 in the Wi Fi mode, but in the Ad Hoc mode. So, these are some of the names of different you know enabling technologies behind powering Ad Hoc networks.

The nodes which are distant from each other, that means, that the node which is not within the direct transmission range of a particular node. These 2 nodes can communicate with each other you hire the sequence of intermediate nodes. So, the intermediate nodes would have to cooperate and forward the traffic that they receive from the source node. So, that is why this is what I was also mentioning to you a while back this is why these networks are also known as multi hop networks.

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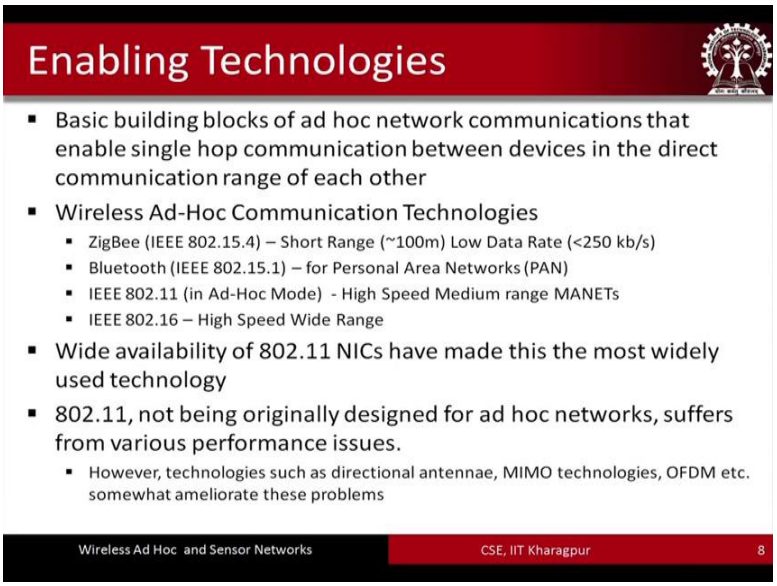

Now, let us look at once again,, the different enabling technologies that power these Ad Hoc networks and these form the basic building blocks for Ad Hoc network communication. So, these technologies include ZigBee, which is the you know which follows the standard I triple 802.15 point 4 which has hot transmission range, communication range up to approximately 100 meters ZigBee has; however, very low data rate which is less than approximately 250 kilo bits per second. The other technology that powers Ad Hoc networks is the Bluetooth, which basically confirms to the standard IEEE 802.15.1. Bluetooth is typically used for enabling personal area networks it is more commonly used for forming personal area networks. IEEE 802.11 in Ad Hoc mode is also used and this is particularly used where speed is an is an important requirement. When it is required to have different nodes communicate with each other and it is required to send data at very high speed because, as we have seen that, the speed in ZigBee is quite less.

So, 802.11 in Ad Hoc mode offers higher speed. The other one is IEEE 802.16 which has high speed, which offers high speed data communication and has wide range; that means, both the speed as well as the range are much higher in 802.16 compliant networks so; however, even if we have all these different types of communication technologies which can enable forming the Ad Hoc networks the 802.11 network interface cards as we know are very common. These are available in the different you know the smartphones that we

use or the laptops and so on. So, that is why for Ad Hoc networks typically the one of the most common commonly used standards is the 802 point IEEE 802.11.

However there are different performance issues of using IEEE 802.11 for Ad Hoc networks. So, we are not going to talk about those things here, we are going to keep our discussions at a very cursory level, but having said this we also need to keep in mind that even if 802.11 in the Ad Hoc mode has different performance limitations. There are currently different other technologies like use of directional antenna, MIMO technologies wave d m etcetera, etcetera, which can help in improving the performance of these networks.

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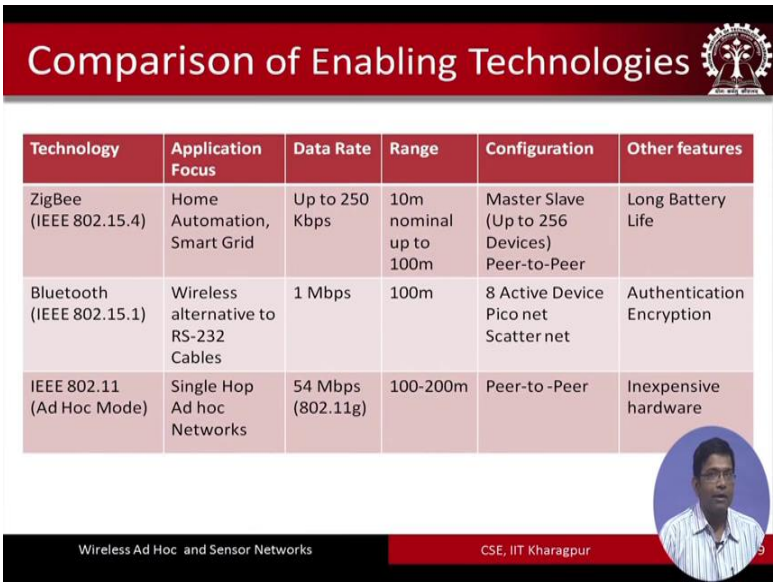

Here is a comparison of the different enabling technologies. So, this is these are the few that we talked about. So, far here we do not have comparison with 802.16 in this particular table, but a good fair comparison between 802.15.4 15.1 and 802.11 is shown in this particular table. So, if you look at application focus for it, for instance ZigBee is typically used for you know applications which are developed for home automations smart grid etcetera. On the other hand Bluetooth is more of like and like a wireless alternative to the r s 232 cables that traditionally were used and 802.11 in Ad Hoc mode is typically the full purpose is to form a wireless network in the Ad Hoc mode single hop wireless network in the Ad Hoc mode.

In terms of the data rate if we see 802.15.4; that means, ZigBee has very low data rate up to 250 k b p s you know this is something that we saw in the last slide also and Bluetooth on the other hand offers iterate of up to one M b p s which is; that means, significantly the return rate in Bluetooth is significantly higher compared to ZigBee and if we look at 802.11 the data rate goes up to 54 M b p s in terms of the transmission range, the communication range, ZigBee 10 meters to up to 100 meters Bluetooth 100 meters and 802.11 much longer than these 200 to 200 meters. So, we can get better ranges using Bluetooth and 802.11.

So, these are some of the important points of criteria, there are a few others with respect to configuration etcetera, etcetera, which we are not going to talk about now. So, in terms of the network functions.

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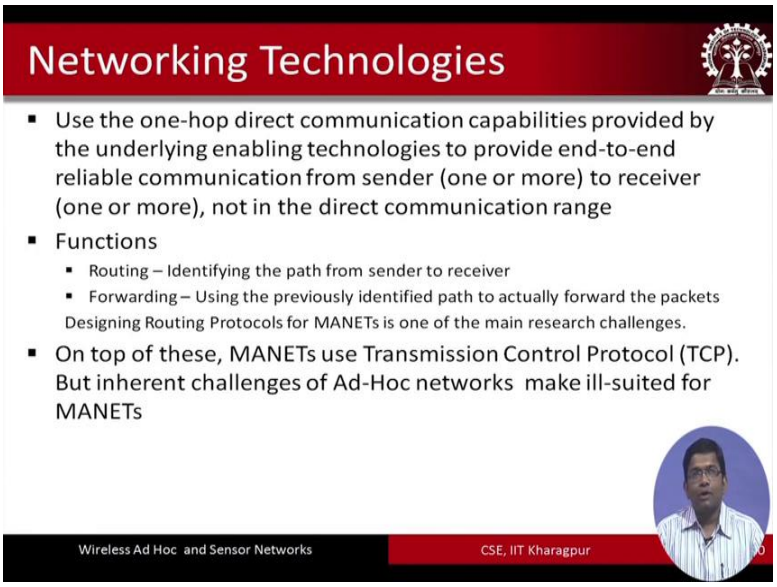

So, you know, what we know is if you have taken a basic course in networks as we know that there is a 7 layer or 5 layer architecture and the OSI architecture or the TCP IP architecture that is a typically used in the traditional networks. So, though those you know those network architectures can also be translated and they can be borrowed in forming the Ad Hoc networks as well.

The only difference is here we have to keep in mind that, we do not really have a single hop kind of network, but we have a multi hop kind of scenario and I have already explained to you what multi hop means. So, there are different functions of any network

whether it is Ad Hoc or not functions with respect to routing. Routing is a very important function right. So, routing means that from 1 point to another how to send the data what is the what are the different paths that are available or that can be made available for a packet to be sent from the sender to the receiver forwarding is bit different which is basically. So, 1 routing and forwarding they are closely linked.

So, routing basically takes care of you know determining the paths between the sender and receiver. Whereas, forwarding basically takes care of actually forwarding the packets between the intended source and destination nodes using the routes that are determined through routing. So, routing forwarding is one and. So, these are basically belonging to the layer which is known as the network layer below the network layer. So, routing and forwarding they sit on top of the data link layer and one of the main functionalities of the data link layer is basically medium access control. So, and we have seen some of the you know different issues. When we were talking about packet radio networks we have seen some of the limitations of using the traditional packet sorry traditional medium access control protocols in these kind of networks.

So, we have the link layer, we have the network layer routing and forwarding are important functionalities of the network layer and on top of these 2 layers what we have is the TCP; that means, the transport layer which basically takes care of transmission control. So, as we will see that there are different challenges of adopting TCP in Ad Hoc networks. So, we will see that bit later and later on in another lecture we will look at how you know TCP use of TCP leads to different performance challenges and we need a new class of transport layer protocols for use in Ad Hoc networks.

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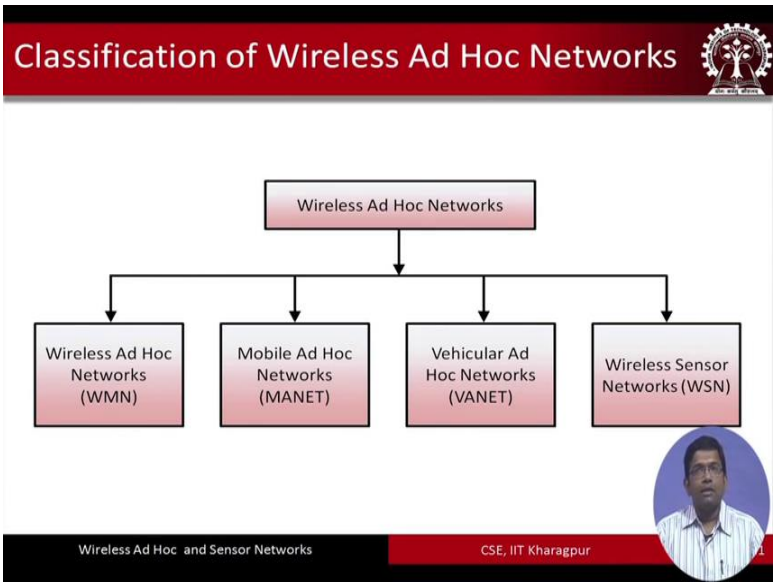

So, let us now move forward and see the different other aspects of wireless Ad Hoc networks. So, wireless this Ad Hoc networks is a broad class of networks and these wireless Ad Hoc networks they can be classified into different types. One is the pure wireless Ad Hoc networks where the different nodes are stationary, but they talk to one another in the Ad Hoc mode they communicate with one another in the Ad Hoc mode the second one is where some or all of the nodes in the Ad Hoc network are mobile. So, consequently these networks are known as the mobile Ad Hoc networks or MANET in short and then we have the vehicular Ad Hoc networks or VANET and in vehicular Ad Hoc networks it is an Ad Hoc network which is formed out of different vehicles moving on the road.

Then we have the wireless sensor networks and we are talking about the Ad Hoc wireless sensor networks. Where the sensor nodes they connect with one another in the Ad Hoc mode and an Ad Hoc you know sensor network is formed. So, let us now move ahead and look at these different types of Ad Hoc networks that we just spoke about.

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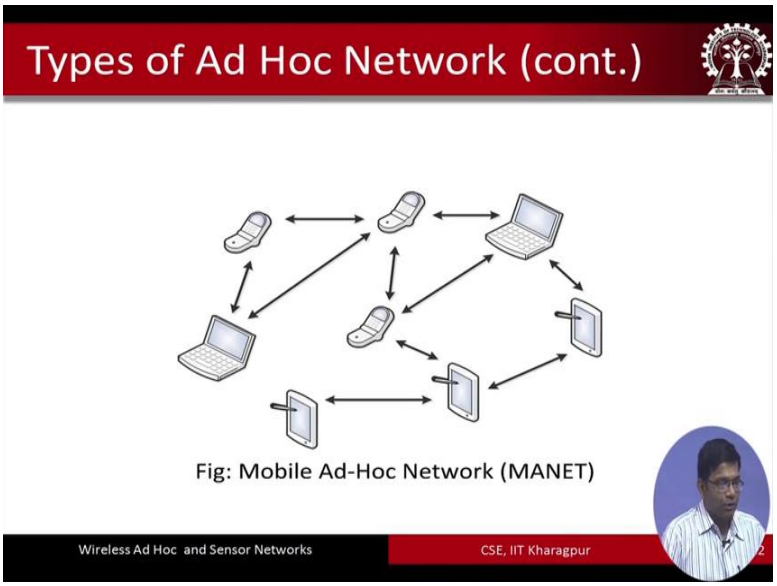

So, we have the mobile Ad Hoc networks as we can see in this particular figure. So, this is a heterogeneous Ad Hoc network and we have already seen what it means by a network being heterogeneous. So, in this particular case we have these different nodes which may or may not move.

So, some or all of the nodes in the network they move consequently these are known as mobile Ad Hoc networks.

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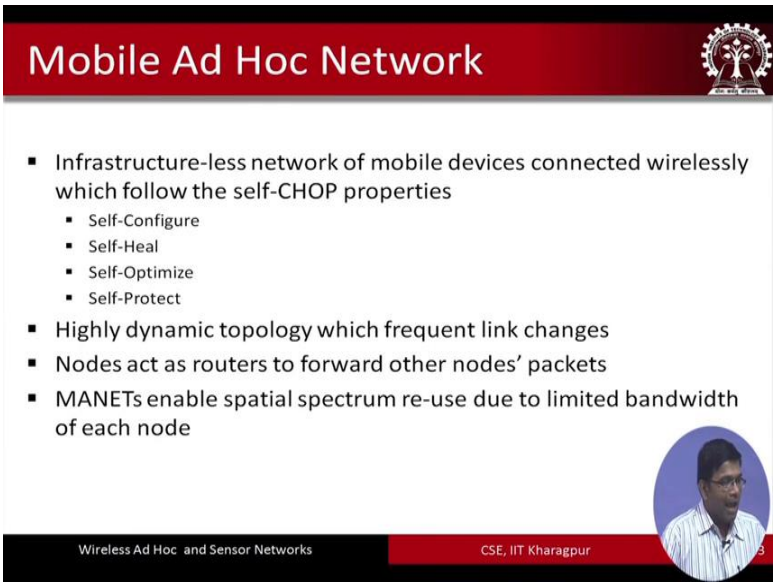

These mobile Ad Hoc networks have different properties which are known as the self chop properties and we will talk about the self chop properties in one of the next lectures. So, chop stands for C stands for 1 figure H for heal O for optimize and P for protect. So, we have self configure self heal, self optimize and self protect properties which basically characterize these networks. That means the mobile Ad hoc networks and in mobile Ad Hoc networks due to the mobility there are frequent link changes and consequently we have a very dynamic kind of environment where the topology changes quite fast ok.

So, the nodes in these networks they act as routers to forward other nodes packets as in any Ad Hoc network as in any multi hoc network and the spectrum is basically used and they are used due to the fact that the bandwidth that is shared by the different nodes is very limited.

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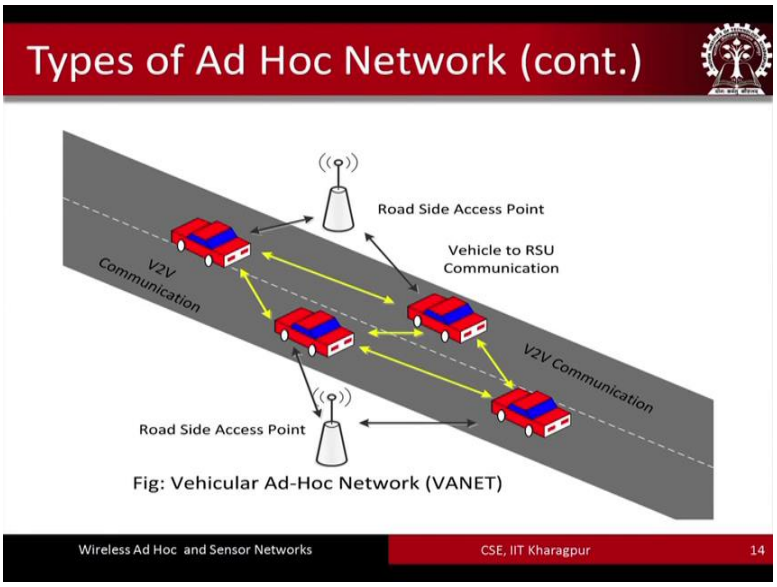

Let us now look at the other category of Ad Hoc network, which is known as the vehicular Ad Hoc network. In regular Ad Hoc networks what we have is an Ad Hoc network is formed by different vehicles which are moving on the road.

So, what we have as we can see in this particular figure is we have on the road we have different vehicles, who want to communicate with one another and each of these vehicles they have something an electronic equipment, electronic circuitry which is known as the OBU the on board unit and these on board units in each of these vehicles they have the capability to talk to something known as the road side access point RSU s road side units

road side access point. So, these are like access points that we know in Wi Fi and these access points are basically installed in the road side.

So, these vehicles they can talk to one another and you know as we can see in this particular figure we have the double sided, you know double headed, yellow colored arrows which basically signified at there is communication that can take place between the different vehicles and the black colored ones which basically say that you know which basically denote that you know these vehicles they can talk to the road side units. So, we have 2 types of communications one between the vehicles and the other one between the vehicle and the road side units ok.

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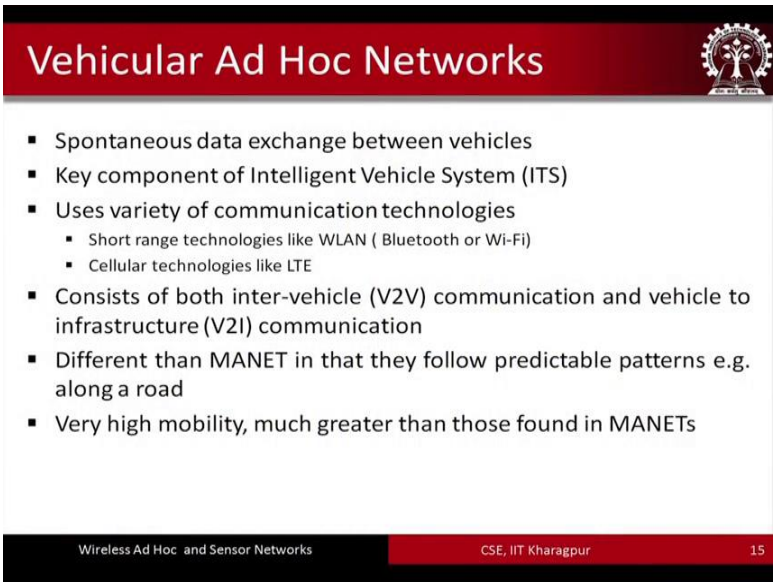

So, these vehicular Ad Hoc networks are very useful because they can help in spontaneous data exchange data transmission between these different vehicles. So, that the vehicles they can talk to one another and there is a good reason for that you know. So, you know vehicular Ad Hoc networks they offer different, in though they have different applications with respect to things like you know informing. Let us say that when one is traveling on the highway and it is found out you know the vehicle observes that there is some kind of accident that has taken place immediately the vehicles that are following this particular vehicle they can be informed about this particular you know accident.

So, this is one, the other thing is with respect to you know different comforts that can be offered to the drivers of the vehicles you know they can be offer different services when they are driving and so on. So, communication between them is very important. So, there are 2 types of communication that are typically considered in the vehicular Ad Hoc networks. So, one is known as the inter vehicle communication which is the vehicle to vehicle communication V2V and the other one is between the vehicle and the road side infrastructure which is the V2I communication. So, V2V between the vehicles themselves and the other communication is V2I vehicle to infrastructure these vehicular Ad Hoc networks although they might look very similar to the mobile Ad Hoc networks they are. In fact, bit different because here, the traffic patterns the communication traffic patterns are fairly predictable unlike in the case of a mobile Ad Hoc network. Where the traffic meter patterns may not be predictable and here the other difference is that in vehicular Ad Hoc network the nodes are much more mobile, they are much more mobile than in the case of the nodes in a typical MANET these 2 are very important differences between a MANET and a VANET.

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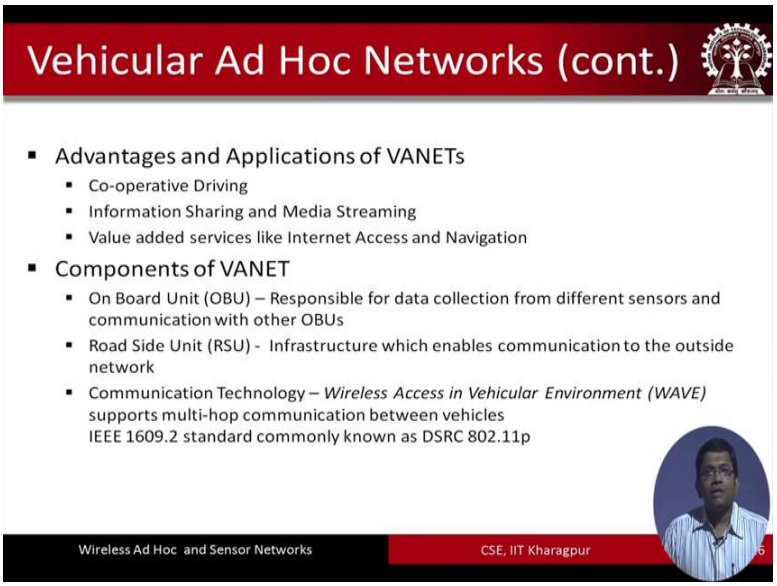

So, there are different I was telling you about the different advantages and applications of vehicular Ad Hoc networks, cooperative driving is one information sharing is another medias medium streaming value added services like internet access navigation and so on. So, there are broadly 3 different components of VANET onboard unit which is responsible for, data collection from different sensors and communication with other on

board units of other vehicles road side unit the you know RSUs which basically offers infrastructure which enable communication to the outside network. That means, from the VANET to the outside network to the internet or GSM etcetera etcetera and the communication technology itself which helps these you know these units to be able to talk to each other. So, there are different standards that have been proposed I triple 16090.2 is a standard that is typically used for powering the vehicular Ad Hoc networks.

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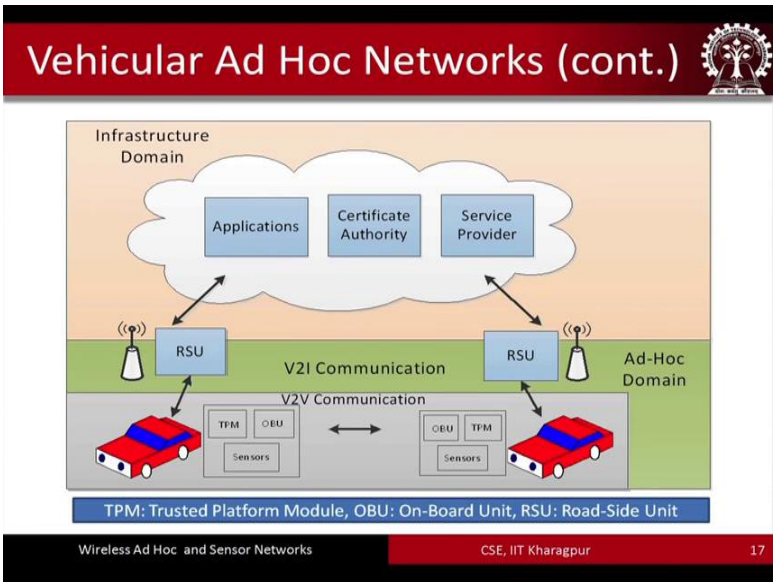

So, here is a diagram of the overall order of vehicular Ad Hoc networks. So, as we can see that, we have vehicles in one layer and each of these vehicles as you can see have the electronic circuitry the OBU then the trusted you know module which is known as the trusted platform module TPU. You know that for module and the vehicles also have different sensors which collect different information from the vehicle from you know the behavior of the driver and so on and so forth.

Different other things the sensors they collect the information about and these information are then through V2V communication these can be shared between the different vehicles and also from a vehicle to the RSUs these information can be sent to the internet, where you know you have you know different applications that are running and so on. So, the service provider would get access to these data from these different vehicles and so on right. So, and these you know and the data can be domain to get information about the different aspects of how the you know the vehicles how they are

communicating you know what are the different issues that are going on when they are on the road and so on and so forth.

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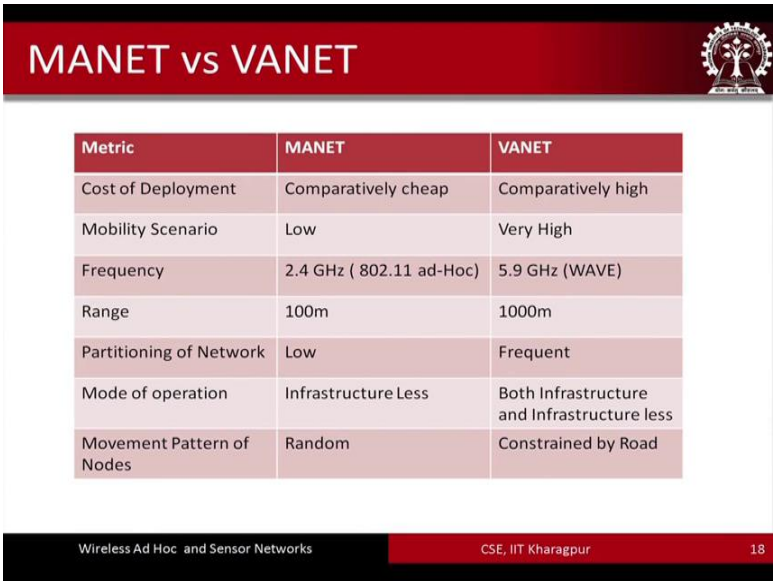

So, here is again a comparison between mobile Ad Hoc networks and vehicular Ad Hoc networks in terms of cost of deployment VANETS are highly expensive to deploy compared to MANETS in terms of the mobility. The MANETS have low mobility whereas, vehicular Ad Hoc networks have high mobility because, the vehicles them themselves are different quite fast and consequently the nodes they are moving quite fast. So, they have very high mobility. Then frequency you know MANETS typically the operator in the 2.4 gigahertz range whereas, VANETS in the 5.9 gigahertz sorry were in the 2.4 gigahertz band whereas, VANETS in the 5.9 gigahertz band range of MANETS is up to around hundred meters whereas, in VANETS it is around thousand meters; that means, in a kilometer or so in the kilometer range.

So, you know in terms of the network partitioning MANETS also get partitioned the networks get partitioned quite a bit, but in VANETS actually due to the huge mobility the partitioning is much more. Mode of operation yeah infrastructure less in MANET whereas, in VANETS it can be both infrastructure less as well as infrastructure based; so these are some of the important, you know comparison I know important aspects and how the MANETS and VANET they compared with each other.

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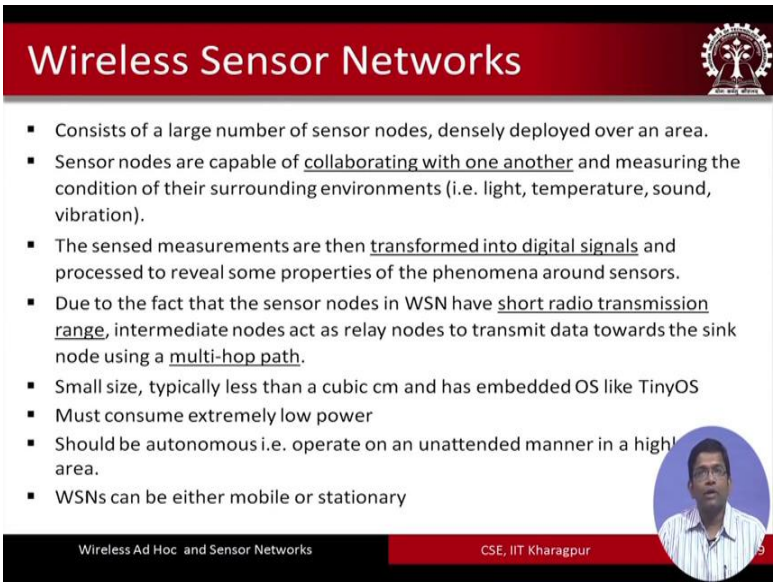

The other category of Ad Hoc networks is the wireless sensor networks, you know where basically you know these nodes themselves have different sensors onboard and. So, consequently these nodes they will be able to sense the different phenomena physical phenomena that are occurring around them and you know. So, from the sensed information the sensed information through a multi hop paths are sent to something known as the base station and you know. So, from the base station you know remotely you know the different phenomena that are occurring around the sensors. That are deployed on the in the field they can be monitored.

These wireless sensor networks they can be classified into 2 categories one is the mobile category the other one is the stationary category. So, they can be either stationary or they can be mobile typically when we talk about wireless sensor networks we are talking about stationary Ad Hoc sensor networks whereas, when we are talking about mobile sensor networks typically the nodes are mobile and we are still talking about Ad Hoc network, but you know having nodes which are mobile.

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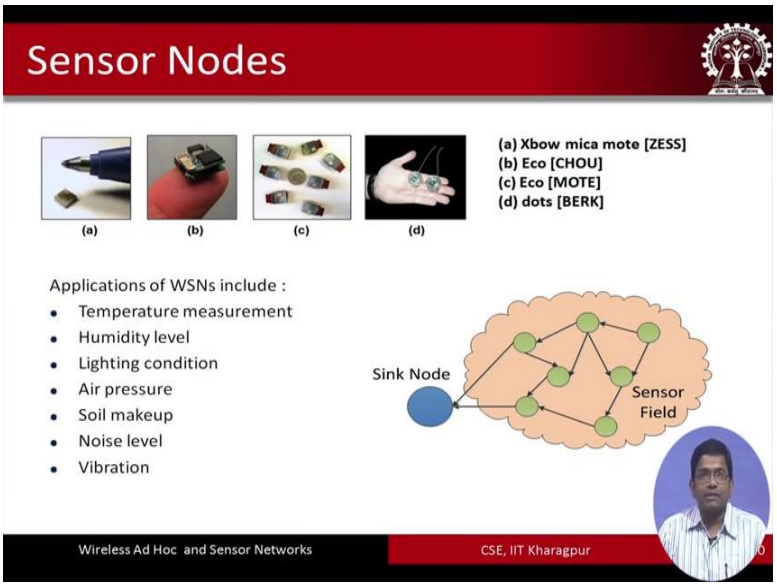

So, here is an example of different types of sensor nodes. The sensor nodes typically or theoretically they are very small in size you know not just theoretically I mean. In fact, as you can see in this particular figure, there are different sensors which are very small in size different you know different points such as the fingertip or the pump you know the you know the pump surface as you can see these nodes they are very small in size and they are very small they are comparable to the fingertips size of the fingertip or a comparable to the size of the coin or they are comparable to the size of your pump and they have different applications they are used, yeah for different types of applications temperature measurement humidity level measurement lighting condition measurements air pressure soil makeup noise level measurement vibration so on and so forth.

There are actually several different types of applications of you know sensor networks.

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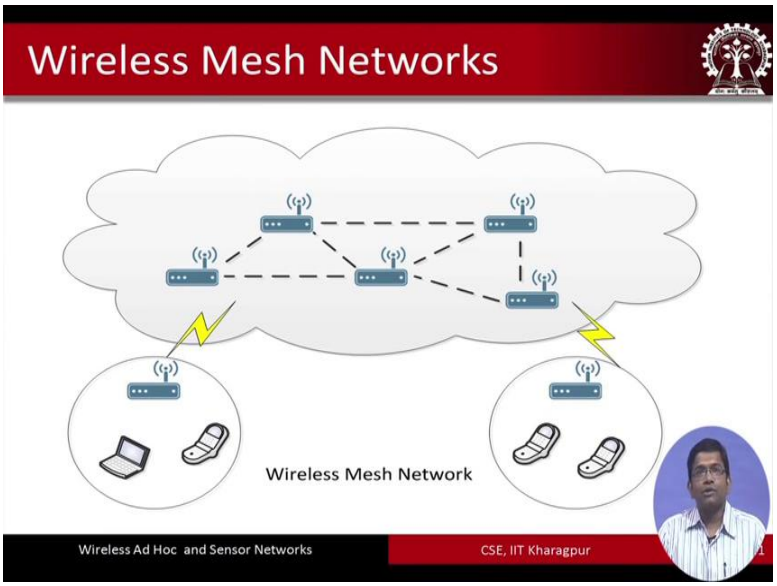

The other category is the wireless mesh network in the wireless mesh networks what happens is it is somewhat like the mobile Ad Hoc networks, but in the backbone, we have a backbone of access points which are connected in a mesh like fashion and as you probably are, already aware there is there that a mesh apology you know is useful to increase the reliability of transmission in a network.

So, for example, if one of the links breaks in a mesh network, so there are there it is likely that there are other links which can help in sending the packets from one point to another. So, we have wireless mesh networks.

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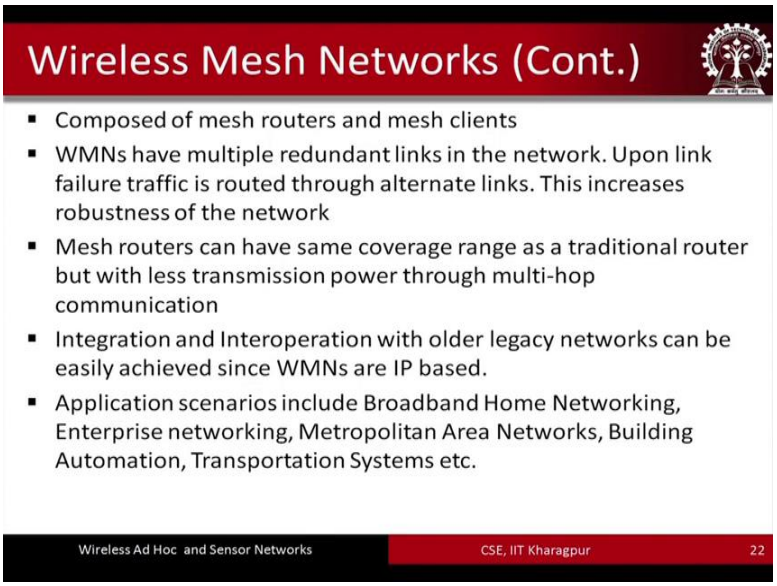

So, as you as I told you that, we have mesh routers and mesh clients typically, these mesh routers they would be configured in a you know in a mesh like configuration which helps in improving the reliability of the networks and reliability of communication between the different nodes in the network they also have different types of application scenarios, broadband, home networking enterprise networking, metropolitan area networking, building automation transportation and so on and so forth.

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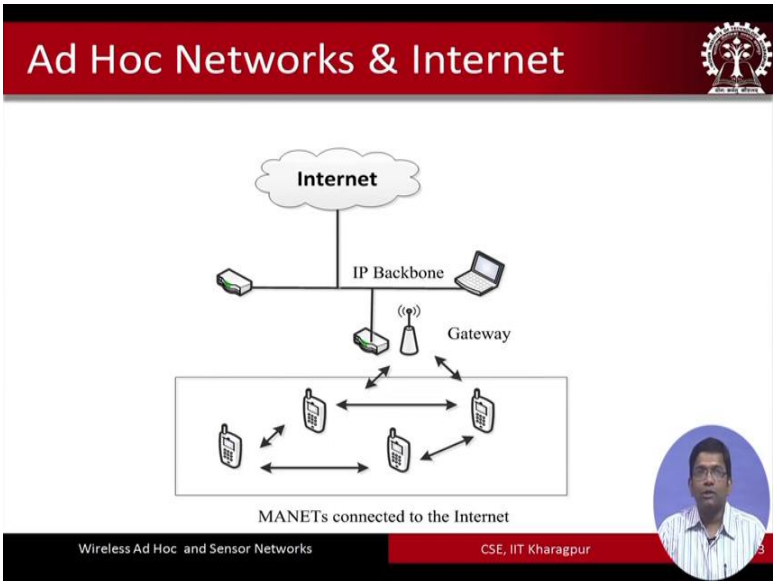

Here is an example of Ad Hoc networks is connected to the internet. Ad Hoc networks may or may not be connected to the internet this is an example of Ad Hoc network which is connected via an IP backbone to the internet.

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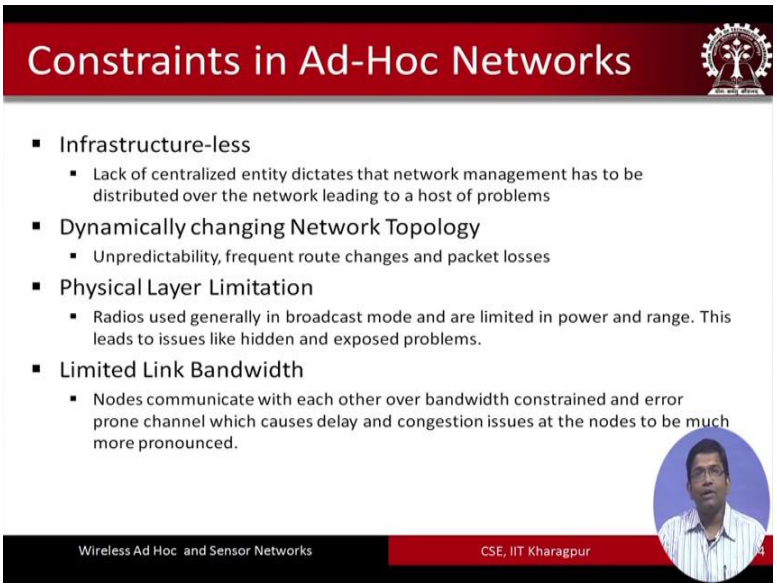

There are different constraints in Ad Hoc networks they are infrastructure less. So, there is a lack of you know centralized, you know entity which basically in other types of networks these centralized network entities they dictate that it work management functions and they control the different other nodes in the network. They have dynamically changing network topology and which can be very unpredictable, where you know in these topologies because the nodes are moving quite fast and the network topology is changing quite fast.

There are routes which are determined between 2 different nodes they change quite frequently and consequently there could be different packet losses that can also arise due to the frequent changes in the network topology. There are different other limitations with respect to the physical layer and also we have to keep in mind that the bandwidth in these type of networks are very very limited. So, you know whatever communication protocols are designed for these networks they all have to keep this particular constraint in particular in mind while designing these networks.

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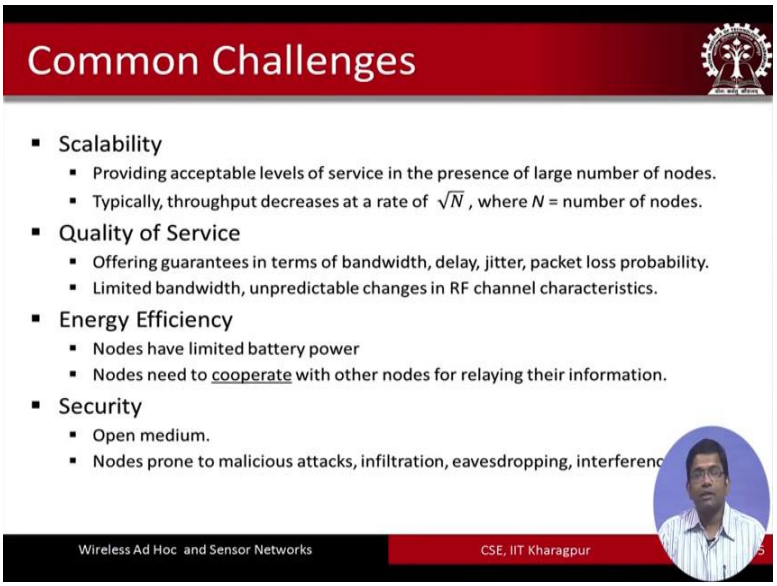

There are other challenges in designing these networks. Challenges with respect to the scalability means that when you are increasing the number of nodes in the network basically you know what happens is in Ad Hoc networks the scale will the through put of these networks they decrease, it decreases quite fast and. So, that it will typically decrease at the rate of you know one over square root of n where n is n denotes the number of nodes in the network quality of surface implies that offering guarantees in terms of bandwidth delay jitter packet loss probability and so on.

So, because in these networks, are these networks operate in very unpredictable environments. That means, environments where there are unpredictable changes in r f channel characteristics and these environments are very low bandwidth. So, offering guarantees with respect to this particular u s criteria are is a very challenging problem. Energy efficiency is another these nodes are battery powered, these batteries have very limited you know limited energy stored in them and at the same time these nodes not only they have to perform their own functions they also have to cooperate with other nodes for relaying their information and security is another issue.

So, what we have is a open wireless medium where the nodes are prone to malicious attacks infiltration eavesdropping interference and so on and at the same time not only that it is a open medium like in any other wireless network, but also there is no centralized entity which can help in taking care of you know different you know or

implementing different or you know security algorithms such as the traditional security algorithms for you know public key infrastructure e k I you know you know and so on and so forth.

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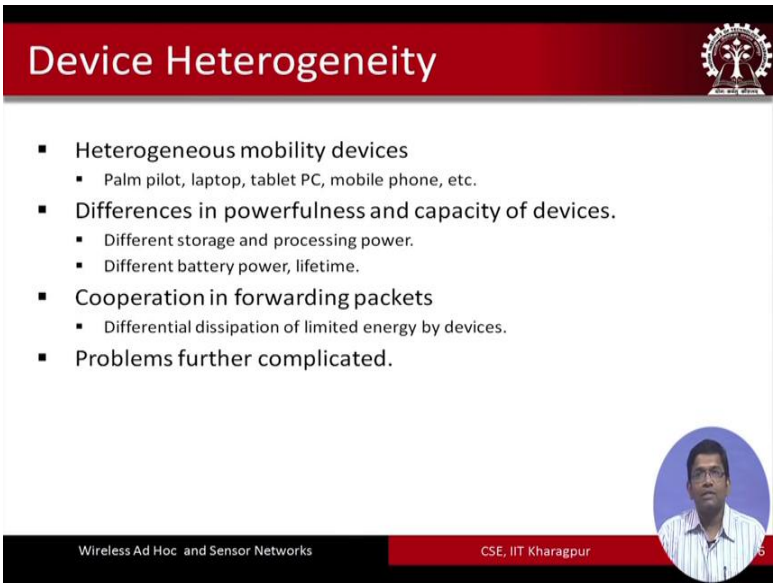

So, those things implementing them in an Ad Hoc network would be very challenging heterogeneity of devices is another. I have already spooked about device heterogeneity in a typical you know Ad Hoc network 1 can expect there would be different types of devices laptops p d a is I am plum pilots mobile phones all trying to communicate with one another which is not very common in other types of wireless networks.

So, this with this we come to the end of this particular module and. So, what we have seen is Ad Hoc networks are very useful they are very you know they are very important, but the, but at the same time you know designing an Ad Hoc network and deploying an Ad Hoc network is very challenging and we have also seen that there are different types of Ad Hoc networks and the challenges in each of these different types of Ad Hoc networks is also you know different. So, the challenges in implementing or deploying and a mobile Ad Hoc network are different from the challenges that are involved in deploying a wireless mesh network, a wireless sensor network or a vehicular Ad Hoc network. So, with this we come to an end of this particular module.

Thank you.