Wireless Ad Hoc and Sensor Networks
Prof. Sudip Misra
Department of Computer Science and Engineering
Indian Institute of Technology, Kharagpur

Lecture- 27
Medium Access Control in Wireless Networks- Part- I

Our topic for today is medium access control for wireless sensor networks. So, in this topic will come to know about the different issues of medium access control for sensor networks the different challenges that are going to be phased you know when you try to implement the medium access medium access control solutions. And the different solutions that have been proposed to handle medium access in sensor networks. So, this lecture and the next one are basically dedicated to all these things that I just mentioned. So, when we talk about medium access control, it is about a common medium and in our case it is a wireless medium.

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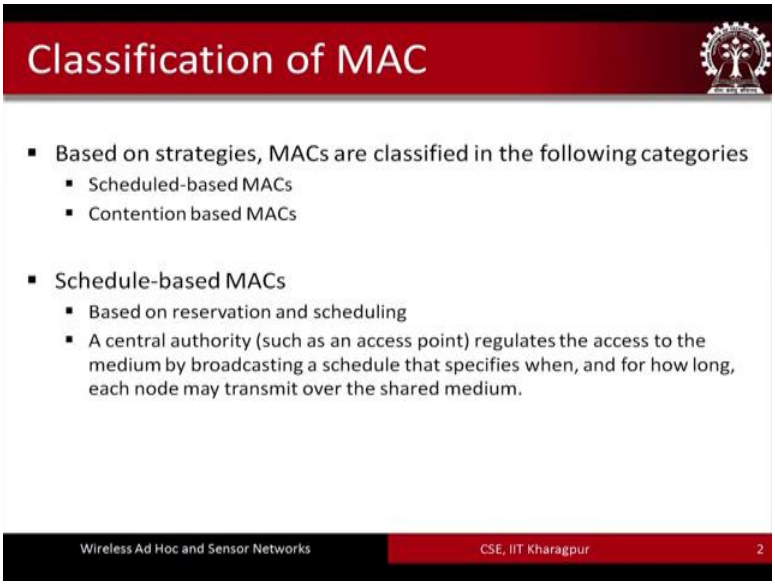

There are different sensor nodes that want to get access to the medium. And how do we enforce the discipline in the different nodes. So, that when the nodes they send the packets there is no collision either midway or at the receiver end.

So, there should not be any collision due to the fact that 2 or more nodes attempt to send data at the same time. So, how do you ensure that the different nodes, they send the data at different points of time. So, regarding that basically towards this particular approach.

In most of the wireless Ad-Hoc networks and definitely in the case of sensor networks as well, there are broadly 2 classes of medium access control solutions. One is schedule based fixed schedule based like in TDMA FDMA etcetera. And the other one is contention based like in the case of the CSMA class of protocol. So, these basically is also the same. It is also true an applicable for Ad-Hoc networks as well as we have seen before. So, same thing applies here, but we will see later on that either the fixed schedule based or the contention based protocols the ones that have been proposed traditionally they are not usable as such in an efficient manner in sensor networks.

So, why it is so and how it can be overcome? And what are the different solutions to overcome it these are the issues that we are going to look at in more depth. So, when we talk about schedule based protocols, there is some kind of reservation and scheduling of the different nodes to get access to the common medium. So, a basic way could be that there is a central authority like an access point which, basically regulates the access to the medium and the broadcasting schedule of the different nodes. So, which means that this particular entity the access point will give that will assign the different nodes which one to get access to the medium different time slots, for example, and each of these nodes they know the specific time slot, when they are going to attempt to transmit and they are going to refrain transmission in the slots that are not assigned to them by the by the access point.

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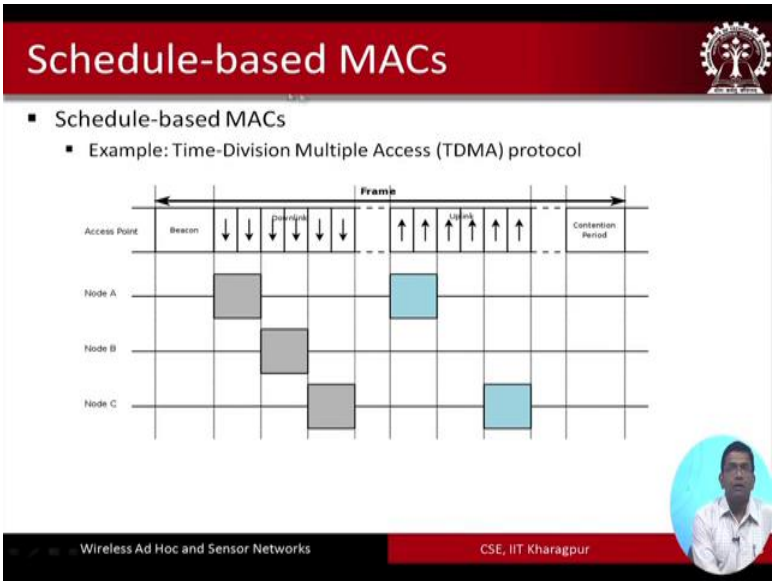

So, this is what the schedule based MAC protocols attempt to do. So, if we look at this particular diagram particular figure, what we see is we have an example of 3 nodes A B and C. They get their attempt to get access to the common medium. And as we can see over here for both the down leek link and the uplink, different time slots have been assigned to this different node.

So, for both downlink and uplink, there are different time slots that are assigned to these nodes individually. So, which means that these nodes they know when they have to transmit. And that way this class of MAC protocols they avoid the different nodes sending the packets they sending the frames at the same time and these frames leading to collision somewhere in between in the space. In the contention based protocols, these protocols as this name suggests they the different nodes that one to get access to the medium.

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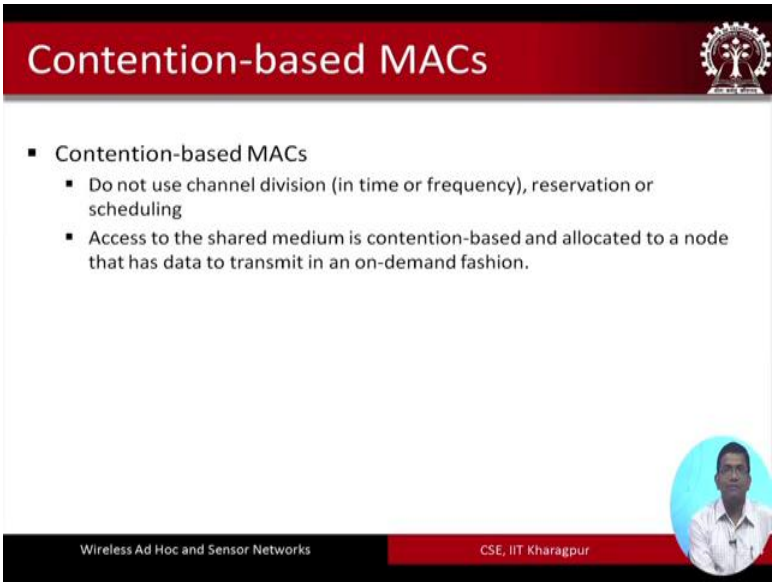

The shared medium they have to content for getting access to the medium, and they do not have any fixed you know time slots assigned to them like in the case of the scheduled based protocol. So, they do not even have a specific frequency assigned to them.

So, they will have to contend for getting access to the medium. And then they will be able to after they after a particular node has got access to the medium through the contention procedure, then only they will be able to send the data transmit the data in an on demand fashion.

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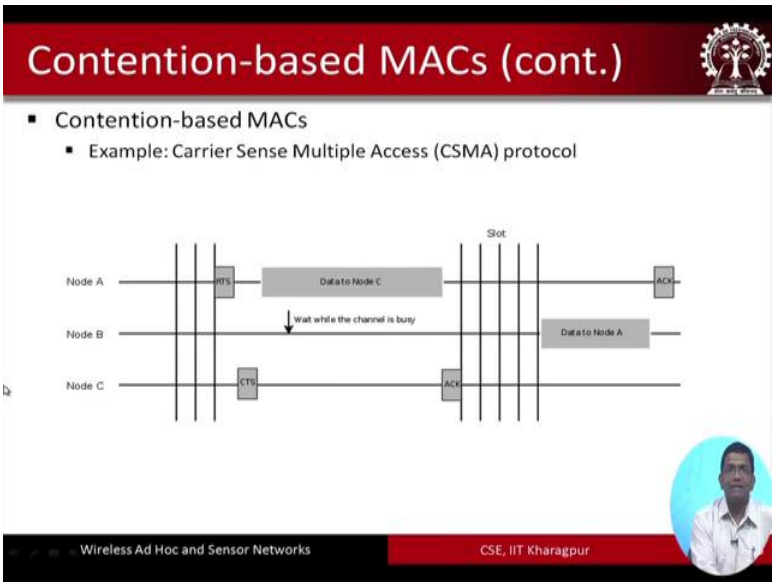

So, here is the diagram trying to explain how the contention based protocols belonging to the CSMA class of protocols function when used for this class of networks. So, here again we have an example of 3 nodes A B and C. So, as we can see that before data transmission can take place from node A which is trying to send the data to node C. So, A trying to send the data to node C, A first will have to contend for getting access to the medium. So, what it does is it will first send the RTS packet and we by now know what RTS means. Because this is the terminology that we have already seen in the Ad-Hoc network MAC protocols.

So, first an RTS the request to send frame will be sent. Then the node C which is the intended recipient will have to contain the confirmation back to node A in the form of CTS clear to send. Only after node A has received the CTS corresponding to the RTS that it had sent then only it can start the data transmission right. And corresponding to the data sent there are going to be acknowledgments that are going to be sent by the intended recipient node towards the sender; that means, in this case in this particular. Example C sends the acknowledgement towards A and as we can see over here node B which is basically in the neighborhood of nodes A and C, node C node B will have to wait until the channel is freed. So, when the node you know when it when node be says that there is an RTS city as being attempted between node A and c it will refrend transmission during this particular period.

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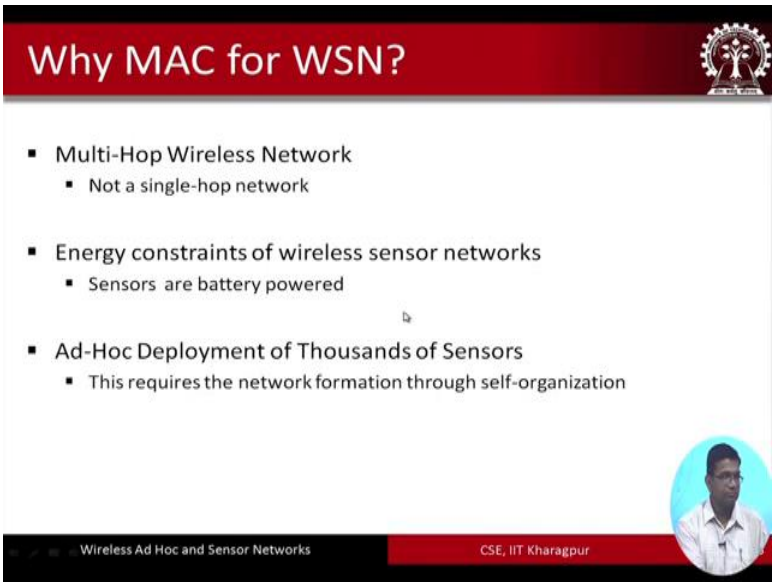

So, the question now, is that why cannot we use the traditional TDMA FDMA the schedule based protocol or the contention based protocols the CSMA class of protocols here as well. So, more specifically, we need to understand why do we need specific MAC protocols to be designed for wireless sensor networks. So, here are a few reasons why. So, first of all as we have seen during the introductory lecture on wireless sensor networks. So, the sensor networks have the multi hop pattern of communication between the different nodes. So, basically what it means is that the source node once it has sensed the data. It will be sending that sense data over a multi hop path cutting across different intermediate nodes in the route until the data is received by the sink node right.

So, what we have is a multi hop wireless network. So, as such you know you cannot use your traditional, you know the single hop based networks need to network MAC protocols like you know the traditional CSMA. Now we cannot use over here the ones that we could use let us say in our you know Wi-Fi wireless network or other infrastructure based networks we cannot use them over here because here we have a multi hop communication pattern number 1. Number 2 is that sensor networks as we have seen during the introduction are heavily constrained by different factors, energy is one of the principal limitations of these networks. So, in other words each of these nodes are severely energy constraint. So, corresponding to that you know all these traditional MAC protocols that were proposed for instance you know for Ad-Hoc networks or even other infrastructure based networks. We cannot use them over here because sensor

networks are much more energy constraint than the traditional Ad-Hoc network or even the other wireless networks like cellular or cellular networks or the Wi-Fi.

So, here we need very lightweight MAC protocols to be supported by these networks number 1. Number 2, number 3 is that we have a scenario of Ad-Hoc deployment of thousands of sensors. So, thousands of sensors in a particular region these need these nodes once we are deployed they will have to self organize the network will have to be formed and so on and so forth. So, these requirements cannot be a such made by these traditional protocols the traditional MAC protocol like FDMA TDMA and CSMA. So, we need a new protocol for use for support of this particular feature.

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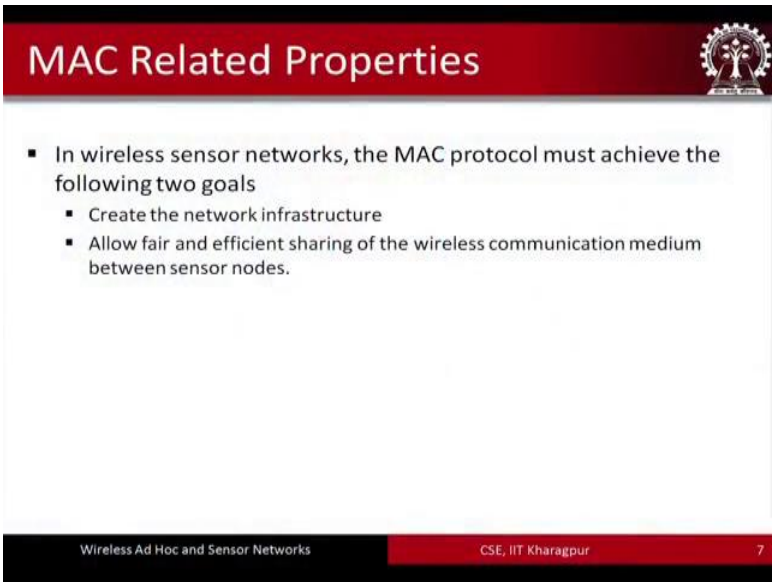

Number 4, is that there are different properties of sensor networks. And any MAC protocol that is designed for use in this in these environments. They must support they must achieve the following 2 goals. Number 1 is the creation of the network infrastructure. These networks will have to be once deployed they will have to form the network infrastructure the topology on their own and second is that these networks should allow fear and efficient sharing of the medium that is being shared by the sensor nodes.

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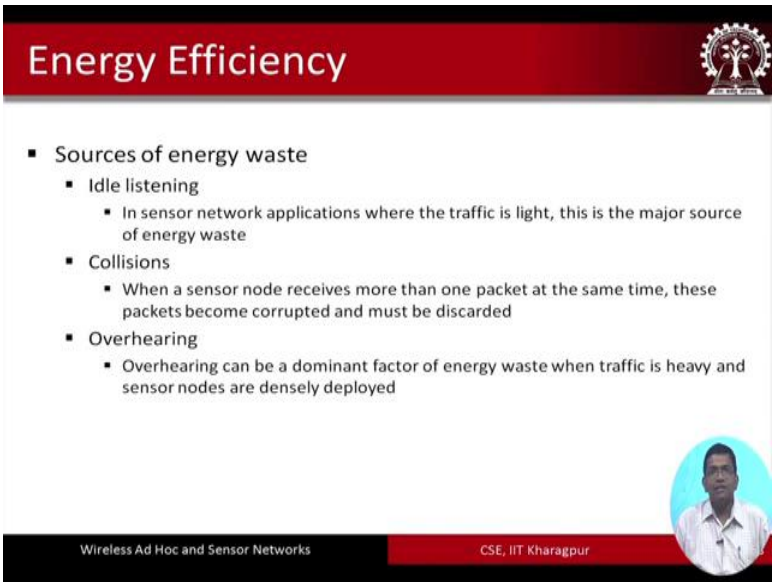

So, let us we have already seen that energy is a prime issue in this network. So, let us now look at it at further mode depth. So, when we look at the energy issue from sensor network perspective, the first thing that is very important is the problem of idle listening. So, in sensor network applications in particularly applications which have very light traffic, basically what happens is when you are deploying the different nodes in such kind of environment and if these nodes are continuously sensing. So, they are continuously listening, idly; that means, that as such there is no requirement there is no change in the event pattern or anything like that and still the sensor nodes they will have to sense the medium unnecessarily in spite of the fact that there is no additional information that is going to be associated with the sensed information.

So, this evidently is a major source of energy wasted. So, number 1 source of energy waste age is idle listening the second thing is collision. So, collisions are a very important concern in the case of sensor networks. The sensor networks in the particularly the pattern of data flow from the source node towards the sink node it is such a pattern which looks like the overall data flow pattern in these networks. From the source node to the sink node it looks like an inverted funnel like structure, and inverted funnel likes structure. Which means that the downstream nodes they are vulnerable to having the packet collided, because of the fact that multiple nodes from the upstream have sent the packet at the same time due to the fact again that there is some event that has occurred and together.

All these nodes that are in the vicinity they have sensed that particular event and together, they have reported their event to the next top neighbor and at the next top neighbor. There is a chance of collisions because both of them have reported or all of them rather have reported all of the nodes have reported the event at the same time. And; obviously, collisions would lead to packet corruption and the packets will have to be discarded. And that is the reason that collisions would lead to further you know energy wastage. And that is something that has to be aborted.

Overhearing is another dominant dominating factor of energy wastage. And this is particularly true when the traffic is heavy and the sensor nodes are densely deployed. Overhearing happens because of the fact that it is an open medium different nodes trying to communicate with the neighbors and in the process what happens is there are others who are not the intended recipients who are going to overhear, the transmissions and this is the reason that overhearing is going to lead to it is you know energy wastage unnecessarily. Other sources of energy wastage are protocol overhead.

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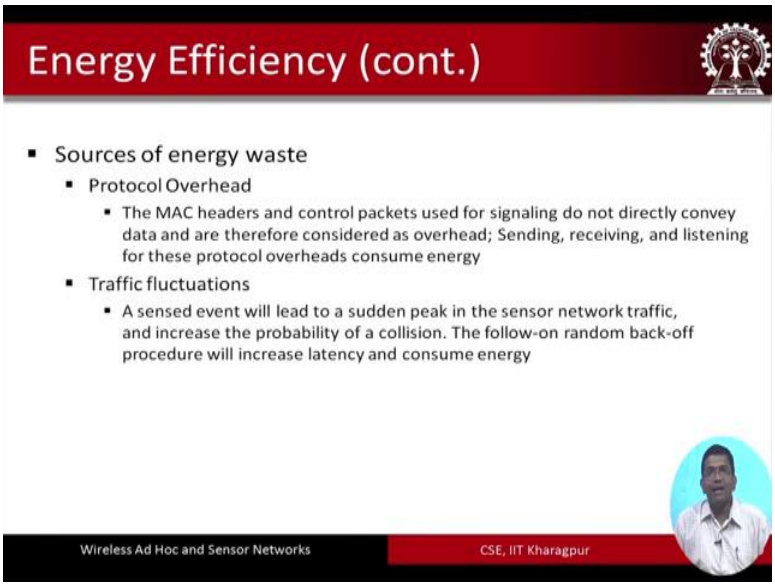

So, the MAC headers and the control packets that are used for signaling they basically do not directly contain the actual data that has to be that that carries the information. And therefore, they are the sources of overhead. So that basically leads to protocol overhead and additional unnecessary consumption of energy. Traffic fluctuation a sensor event will lead to sudden peak in the sensor network traffic and that fluctuation that up search

all of a sudden due to the event there is a sudden up search in the network traffic. And that basically this particular you know phenomenon it leads to unnecessarily increase in the probability of collision and that basically leads to energy wasted.

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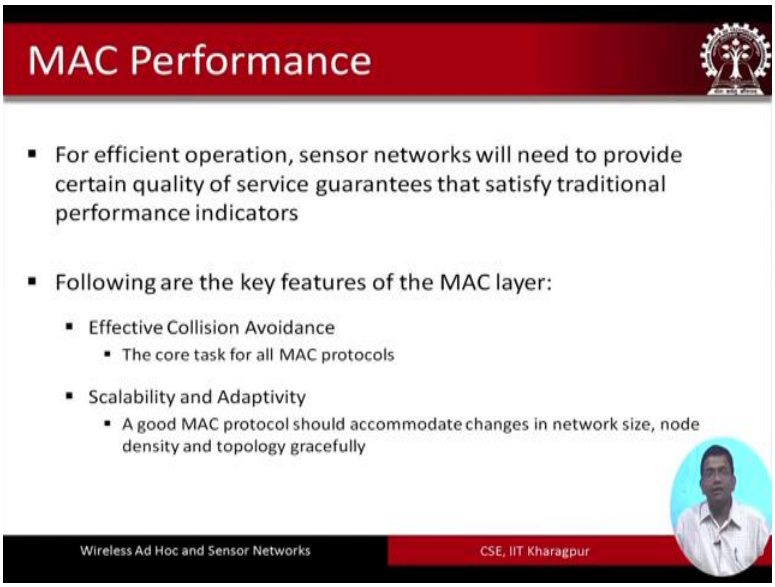

So, there are different issues with respect to MAC protocol design particularly from a performance point of view. There are certain quality of service parameters which have to be guaranteed quality of service factors, that have to be guaranteed and those factors should be satisfied by the sensor networks that are deployed. Additionally, there are different key features of the MAC layer that will also have to be taken into account for any design of MAC protocol for use in these networks. Number 1 is effective collision avoidance. This is a very important factor and it is a task of all MAC protocols that are designed for use not only in these networks, but for any kind of network. Number 2 scalability and adaptivity. Scalability as we have seen this term before on other occasions as well that when we were we are increasing the network size then how good the MAC protocol that we are designing will accommodate to the changes.

So, an additionally adaptivity to the density; that means, if the you know the sensor network becomes more dense gradually or at in some parts or throughout, then how the performance of that particular MAC protocol is going to be.

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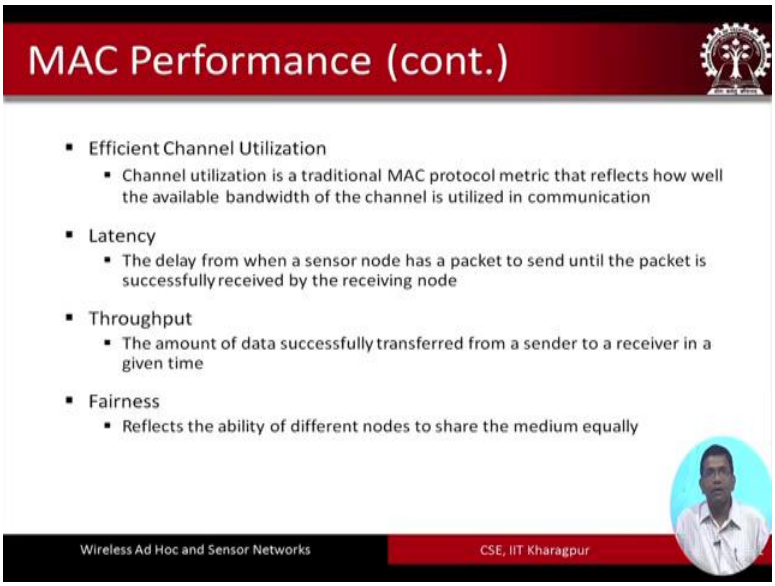

Efficient channel utilization is something that I do not need to elaborate. Similarly, latency throughput and fairness are issues that are also applicable to other MAC protocols that are designed for Ad-Hoc networks and other wireless networks. So, I am also not going to elaborate on these, but these are definitely different factors that have to be taken into account while designing a MAC protocols for sensor networks. And these are basically the determinants of performance of MAC in sensor networks.

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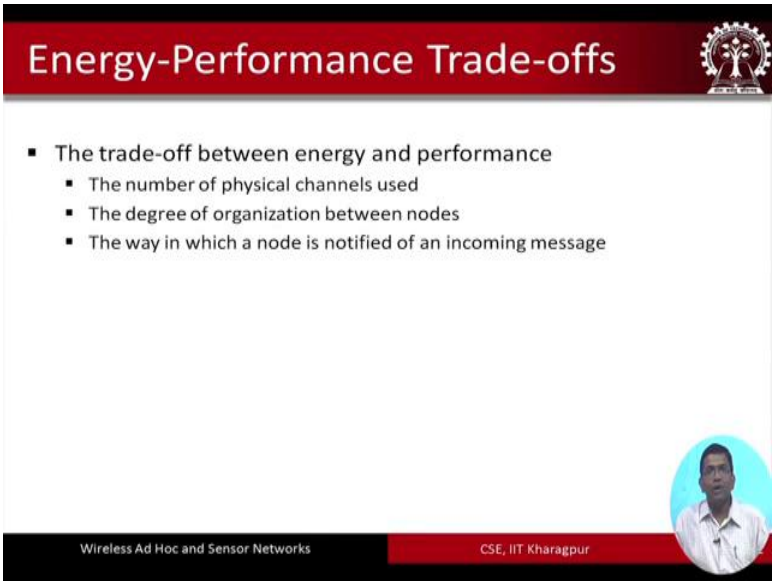

There are different tradeoffs between energy and performance with respect to the number of physical channels used, the degree of organization between the nodes and the way in which a node is notified of an incoming message.

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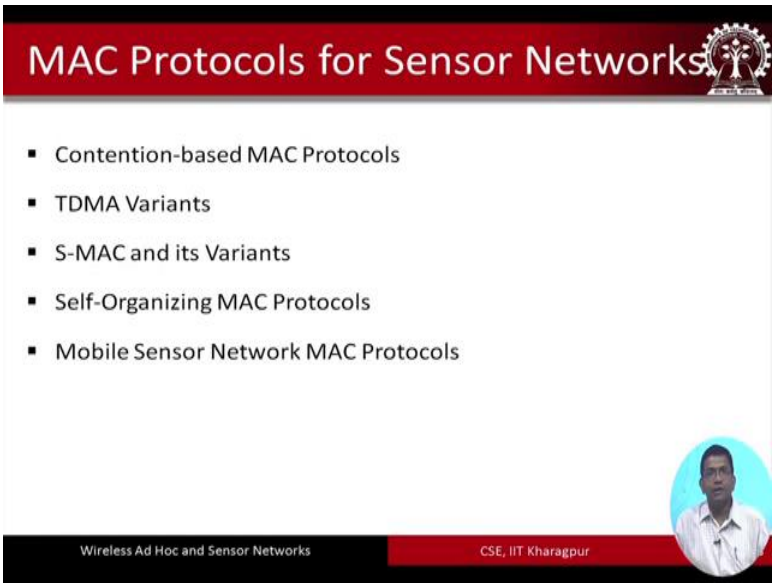

So, for sensor networks there are different MAC protocols that have been proposed so, far in the literature. And these can be classified into the following types the contention based MAC protocols TDMA variants SMAC, and it is variant SMAC is perhaps one of the most well known specific sensor networks specific MAC protocol that has been designed. And after SMAC because SMAC had different performance limitations. There were different variants of SMAC that were proposed later on. So, SMAC and it is variant variants are a very important class of MAC protocols that have been proposed for sensor networks and these MAC protocols I would say are the most important sensor networks specific MAC protocols that have been designed. So, far additionally there is another class MAC protocol which is the self organizing MAC protocols

So, all these 4 that we have discussed. So, far the contention based TDMA SMAC and experience and the self organizing MAC protocols. These are applicable primarily to the stationary wireless sensor networks and these as such are not applicable or usable rather in a mobile sensor network environment. So, additionally we have another class of MAC protocols which is the mobile sensor network MAC protocols that have been designed by different researchers and are available in the literature.

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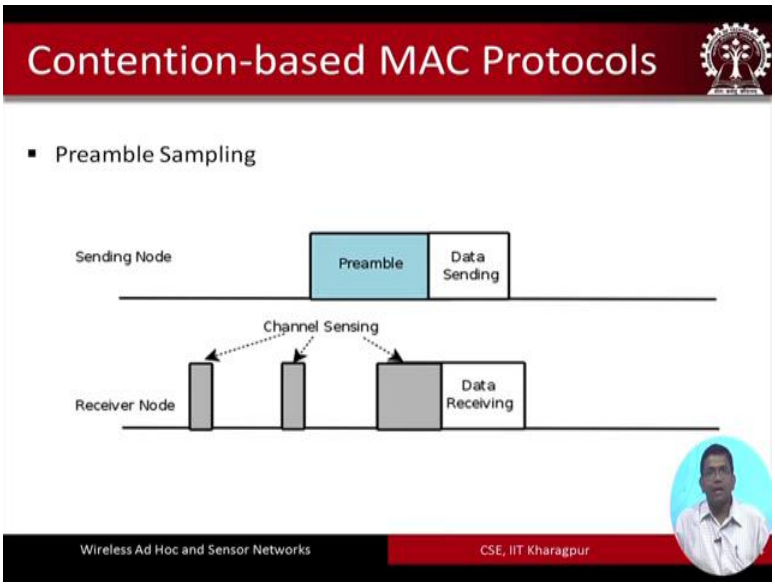

So, let us take some examples. The first well known contention based MAC protocols that have been designed for sensor networks are the preamble sampling and voice MAC protocol. These are very well known contention based sensor network MAC protocols. So, here as we can see over here in terms of preamble sampling there is a sending node and a receiving node.

So, what the sending node does is it keeps on sensing the channel, and what it means is it is trying to see that whether it can you know, it will sense the channel you know after longer durations of time. And then if it sees that there is a sender node which has which is trying to send a packet. And this packet has basically a preamble to it. Then you know what it is going to do is it is going to activate the sensing, and it will it will start sensing continuously that particular packet. So, consequently what will happen is once the preamble is detected then the data are going to be sent by the sending node and will be received by the receiving node.

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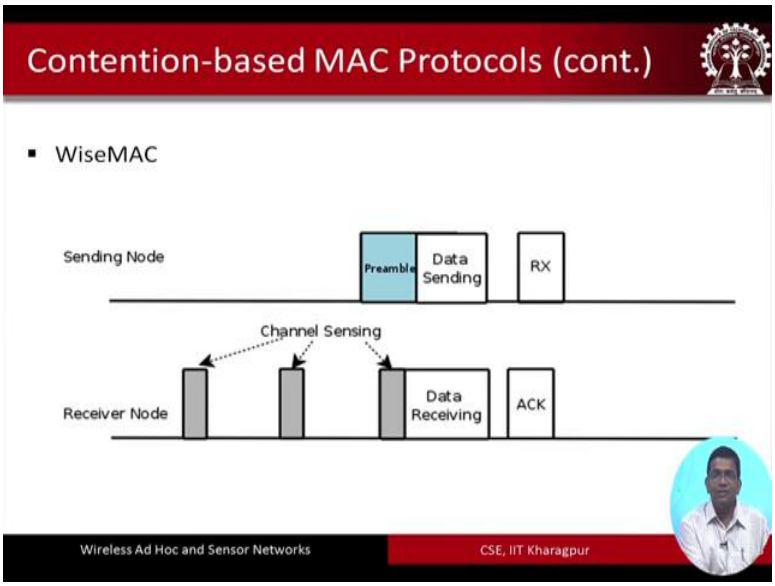

WiseMAC is also very similar to the preamble sampling approach addition in addition to what we have seen previously. Here we have not only the preamble and data sending data receiving kind of scenario, but also we have acknowledgements that are sent back by the receiver node corresponding to every data unit that is received by it from the sending node.

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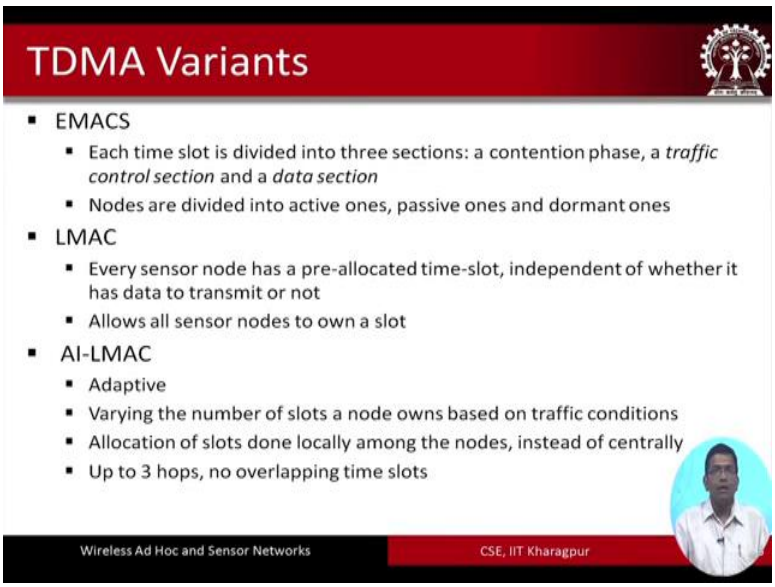

So, that were those were the contingent waste variants. TDMA based variants there are a number of them the EMACs is a well known protocol which is which is based on the

TDMA where each time slot is divided into 3 sections the contention section a traffic control section and a data section. Here the nodes are divided into the active ones passive ones and the dormant one. So, active and passive we already know by virtue of our basic knowledge of sensor networks dormant t is the term that we are listening for the first time.

So, dormant means that it is a more serious kind of you know slip state. So, serious kind of sleep state, means that most of the hardware circuitry in a dormant state are basically turned off. So, we have 3 states active passive and dormant in EMACs. LMAC is like a very simple kind of very you know simple kind of TDMA kind of protocol where basically sensor nodes own if you know specific slot in which they can transmit the data. And every sensor node has this slot independent of whether the data is there with it to transmit or not.

So, it is a you know it is a very b r basics TDMA kind of protocol AI-LMAC is basically an adaptive version of LMAC. Where this adaptivity is based on the traffic conditions. So, if the traffic conditions change basically, the different nodes that have already been already been allocated some time slots, that schedule is going to be changed dynamically based on this change in the traffic condition. So, this is the AI-LMAC.

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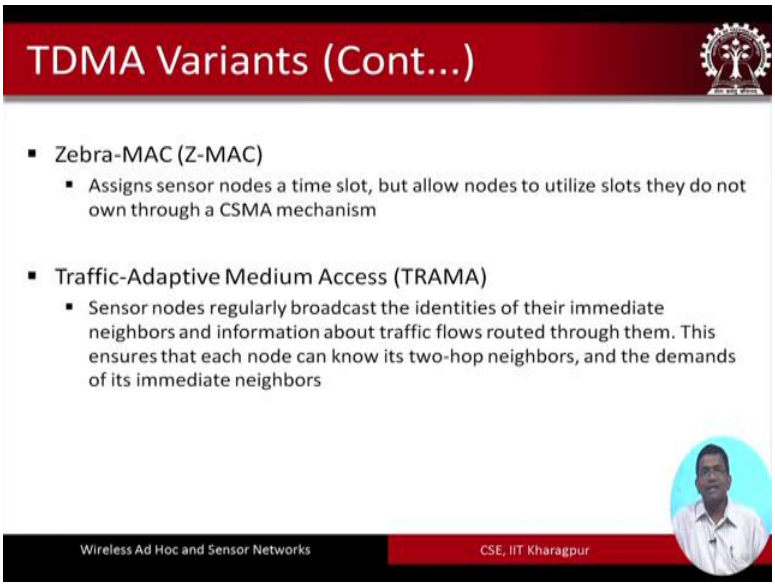

Then we have the Zebra-MAC the Z-MAC which assigns the sensor nodes a time slot as it is a TDMA variant, but additionally it allows the nodes to utilize the slots that it does

not own through a CSMA mechanism. And that is as you can understand from this description. This is probably the reason this zebra kind of approach is the reason why this is known as the zebra MAC. Additionally, we have the traffic adaptive medium access TRAMA protocol and particularly I am not going to go through it because this name says it all about how it works SMAC and it is variants.

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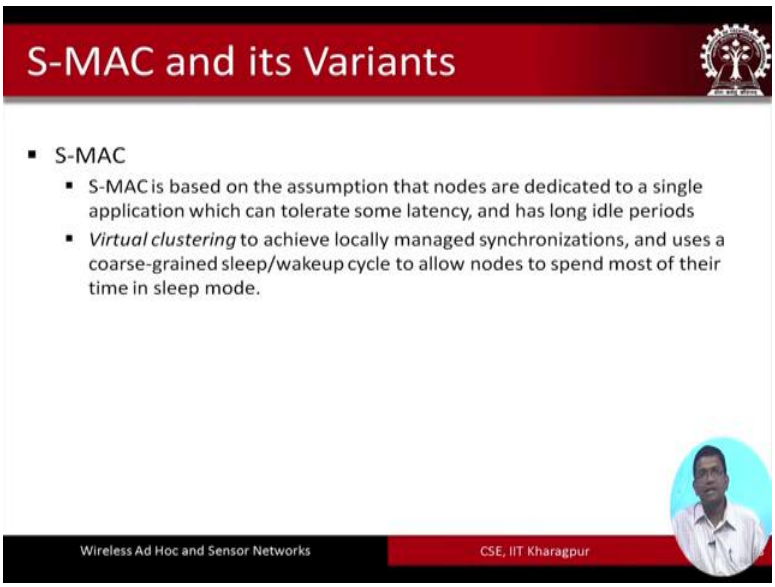

So, the first thing is s max SMAC as I told you is perhaps one of the primitive most primitive sensor networks specific MAC protocols protocol that was designed. And the SMAC protocol basically works on the basis of the concept of virtual clustering. And this virtual clustering is achieved look is performed to achieve locally managed synchronizations. So, which means that the different virtual clusters are formed on the basis of the nodes member nodes in a cluster performing the same or following the same kind of time schedule. So, they are time synchronized all the nodes in a virtual cluster or time synchronized more or less. So, they all essentially will then follow a coarse gained sleep wake up cycle to allow the nodes to spend most of their time in the sleep mode.

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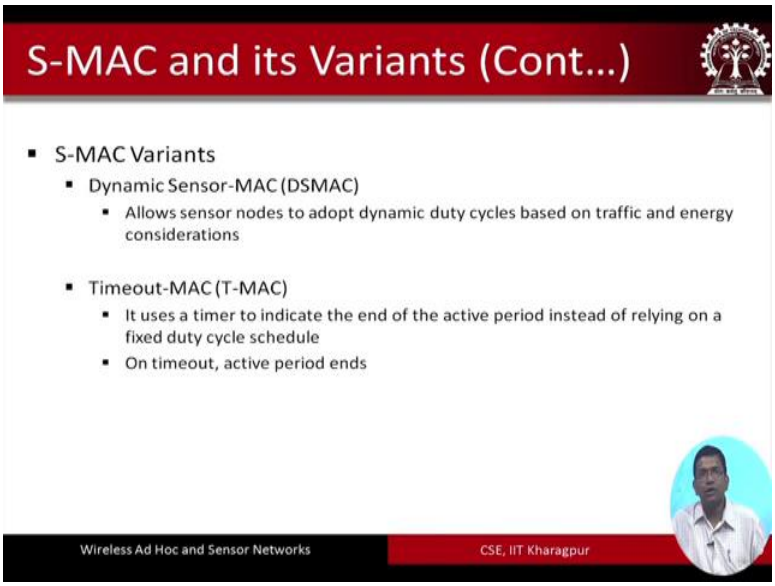

There are different variants of the SMAC protocol. As we have seen that the SMAC the traditional the most primitive the first SMAC protocol that was proposed uses a fixed duty cycle pattern.

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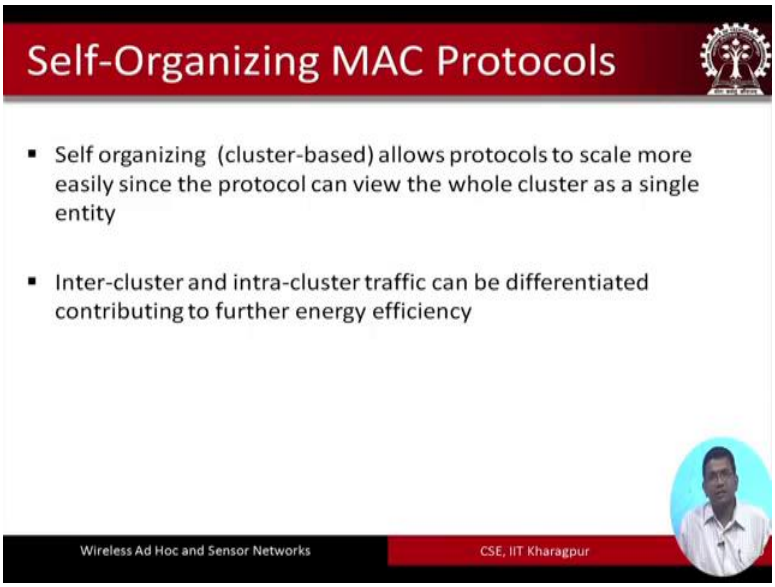

So, there are other protocols the d SMAC the T-MAC and so on. And so far there are many others which were proposed by incorporating adaptivity dynamism to this scheduling process. And these are the protocols that we will look at in more detail in the next lecture. Additionally, we have the self organizing MAC protocols, which allow the

you know these protocols they allow the nodes to scale more easily since the protocol can view the whole cluster as a single entity. And in these we have the inter cluster and inter cluster traffic that can be differentiated. So, basically traffic within and outside the cluster they can be differentiated contributing to further energy efficiency.

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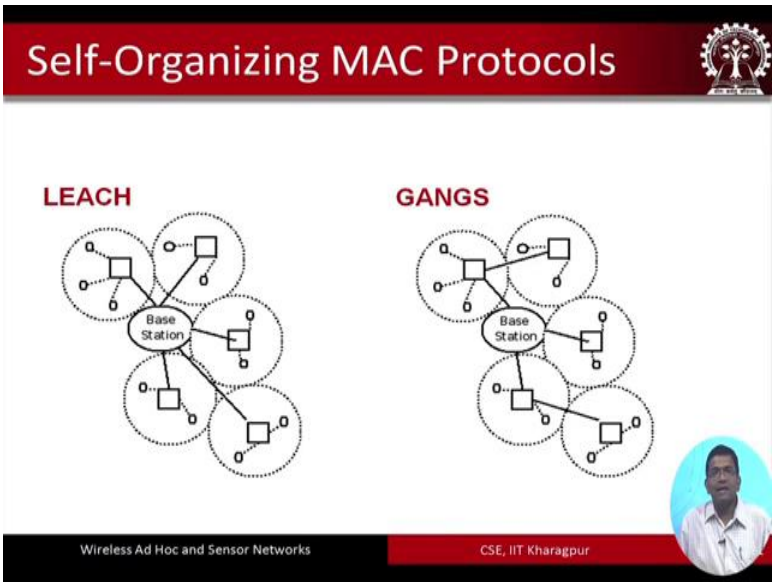

So, there are 2 examples that I have shown over here the leach protocol and the gangs protocol which belonging which belongs to the self organizing MAC class of protocols. And as we can see in in the case of both of these self organizing protocols, they are based on the cluster clustering approach.

So, the gang s and the leech they look similar as we can see because these are the clusters that are formed by these protocols. And the cluster heads in this protocols they are going to act like the leaders in these clusters. And this is how these protocols are going to work, but there is a difference between although seemingly visually the leach protocol and the gang protocols they appear to be similar. If we look bit closely we will see that in the case of leach the base stations or the cluster heads they have direct connectivity one hop connectivity to the base stations; however, in the case of gangs we see that these cluster hit is may not have one hop connectivity to the base station. So, as in this particular case there is multi hop connectivity from this cluster hit to the base station.

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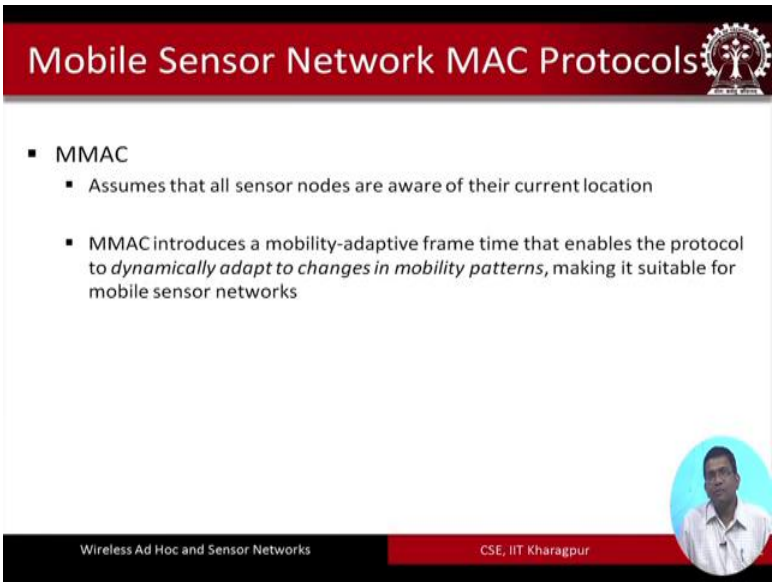

So, those were the self organizing class of protocol. And finally, we have another class of MAC protocols which is called the mobile sensor network MAC protocols which are basically designed to be working with the mobile sensor networks. So, MMAC is an example of the mobile sensor network MAC protocols which assumes that all the sensor nodes are aware of their current location. So, MMAC introduces a mobility adaptive frame time concept that enables the protocol to dynamically adapt to the changes in mobility patterns making it suitable for the mobile sensor network.

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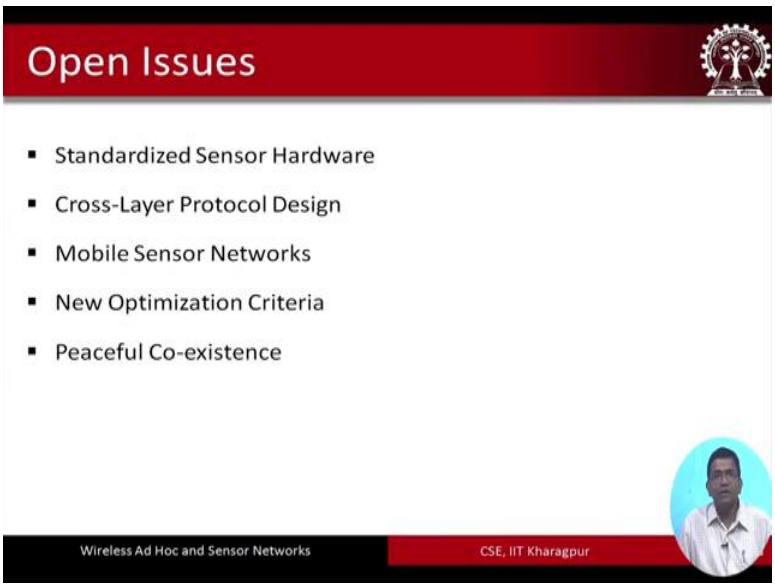

Here are a few open issues in terms of MAC protocol solutions for sensor networks. We do not yet have a standardized sensor hardware. We do not have cross layer protocol design.

So, cross layering can improve the performance of MAC protocols and for mobile sensor networks which are very common nowadays many of these protocols that I discussed initially accept the MMAC, and similar other protocols are unusable for mobile environment. So, we need more mobile sensor network MAC protocol and different optimization criteria will have to be considered and so on and so forth these are some of the open issues.

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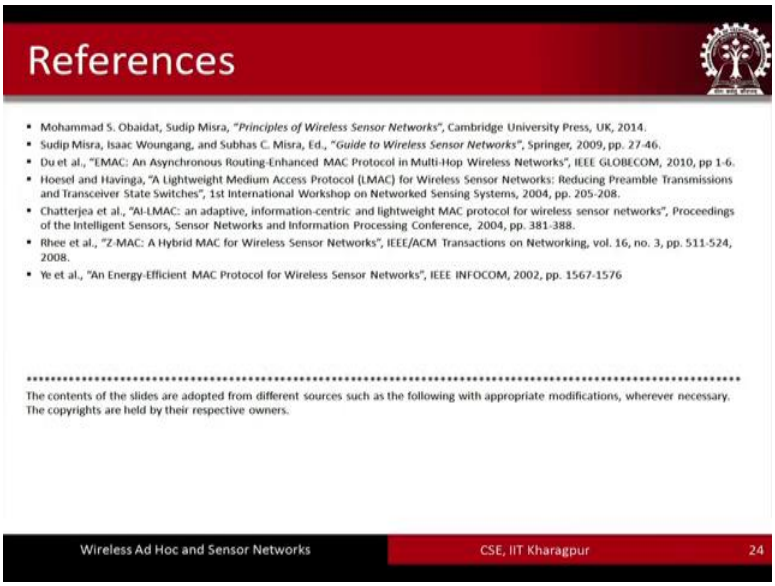

And finally, as before as we do for every lecture here we have listed all the references that are relevant for understanding the different protocols and the different concepts that we have covered in this particular lecture.

Thank you.