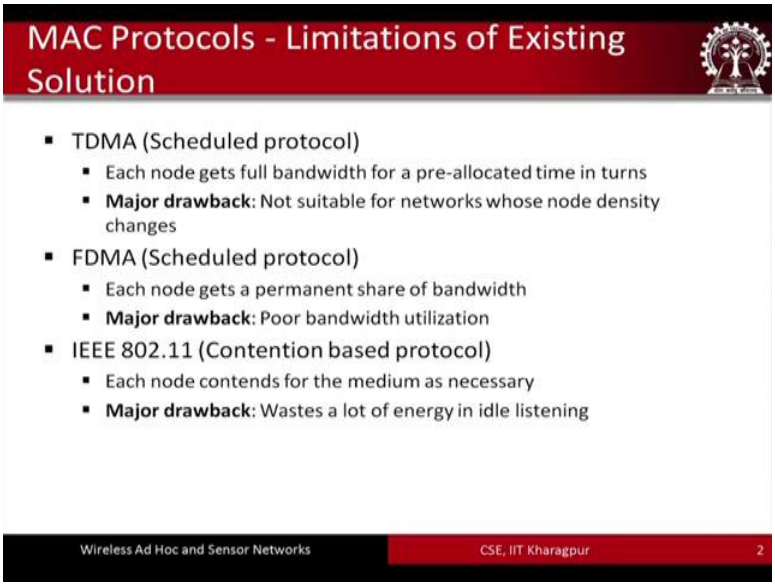
Wireless Ad Hoc and Sensor Networks
Prof. Sudip Misra
Department of Computer Science and Engineering
Indian Institute of Technology, Kharagpur

Lecture – 28
Medium Access Control in Wireless Sensor Networks- Part- II

In this lecture, we are going to continue our discussions of medium access control in sensor networks. As we have seen that sensor networks there are different variants of sensor networks, the traditional, contention based, solutions then the traditional scheduled based solutions and SMAC and the different variants of it are very popular medium access control schemes that are applicable for sensor networks.

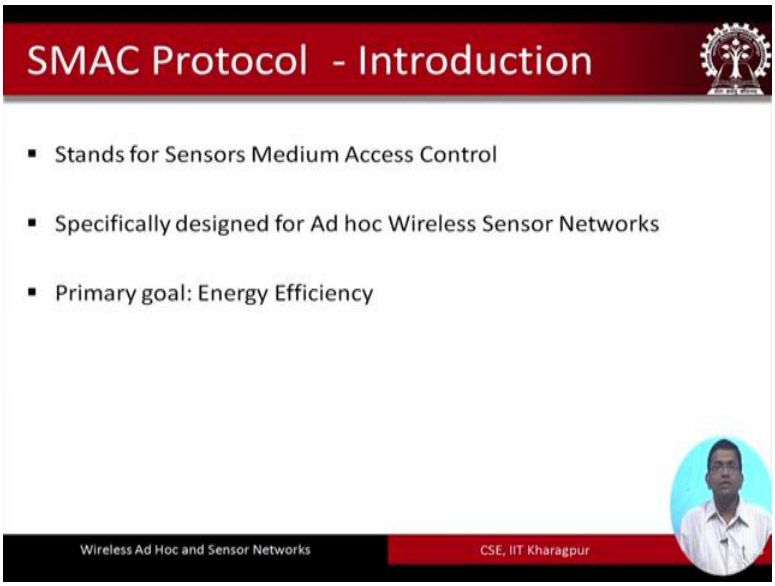
(Refer Slide Time: 00:47)



So, we have already seen this that we have scheduled based protocols like the TDMA and FDMA. In TDMA the different nodes they have some pre allotted time slots and these nodes they take turns as per the time slots to get access to the medium. In FDMA fixed schedules are given by the different nodes to get access to the medium in terms of specific frequencies or a share of bandwidth allocated to the different nodes.

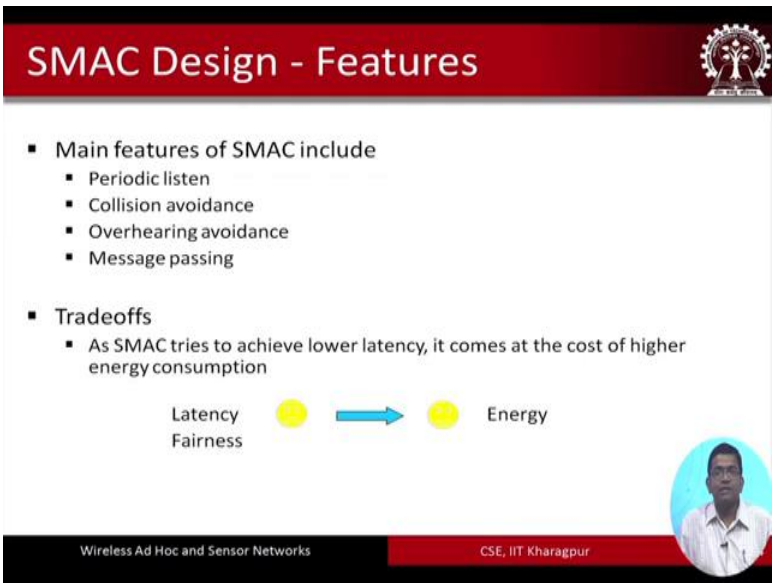
So, both of these approaches and the contention based approaches, they all have serious drawbacks including wastage of lot of energy in their application for use in sensor networks.

(Refer Slide Time: 01:38)



SMAC is something that we have seen is one of the first protocols that is specific to sensor networks that was proposed and we have seen that SMAC is good for use in sensor networks, there are different advantages of since you know the SMAC protocol and so this is you know something that is specifically designed for sensor networks by taking primarily the energy issue energy efficiency issue for these networks.

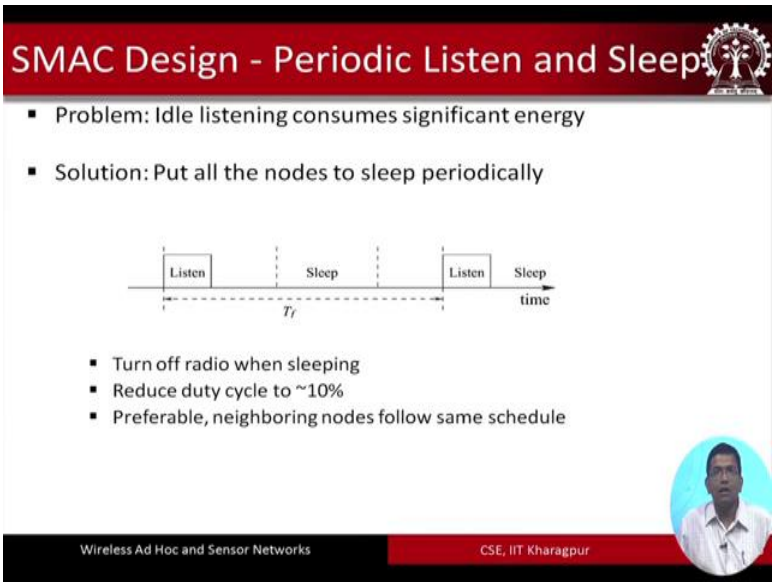
(Refer Slide Time: 02:09)



Here are some of the design features of SMAC, some of these are that SMAC takes into consideration the periodic listen not continuous idle listening. So, periodic listen

approach second thing is collision avoidance, SMAC avoids collisions in a great way overhearing avoidance also and message passing these are some of the main features of SMAC and we are going to look at these features in more details. In the next few minutes there are different tradeoffs in the use of SMAC, whereas, SMAC tries to achieve lower latency this particular protocol comes at higher cost due to energy consumption.

(Refer Slide Time: 03:01)



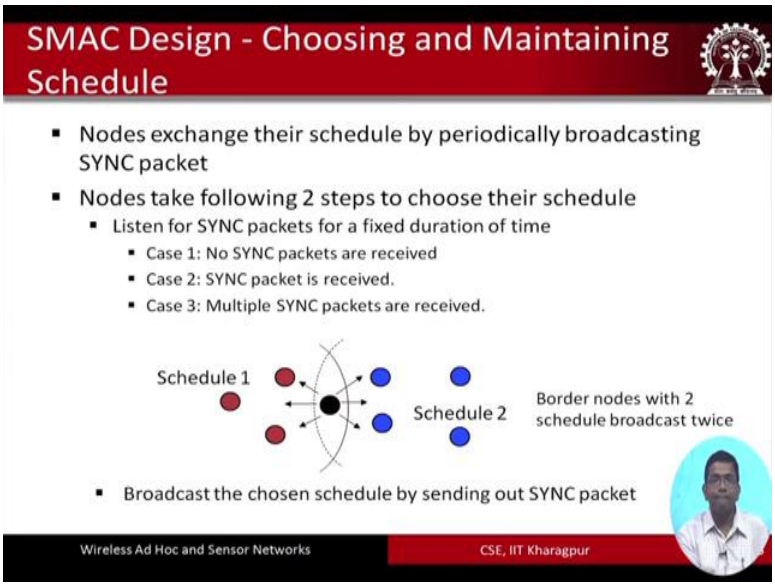
So, you know there is a trade off between latency and energy and fairness and energy consumption. So, SMAC design the integral to it is the concept of periodic listening and sleep. So, as we had seen in the previous lecture that one of the main endpoints in protocol design for MAC protocol design for sensor networks is that sensor networks are prone to idle listening and this process of idle listening consumes significant energy.

So, idle listening due to the idle listening and the excess consumption of energy this is something that is undesirable and what is proposed by SMAC is to put all the nodes to sleep periodically. So, this is what is going to look like if we look at what happens by the use of SMAC for sensor networks each of the nodes it is going to listen for a short duration of time and for a longer duration of time it is going to be put to the sleep state sleep mode and then it wakes up again listens for a short duration of time and goes to the sleep and so on and so forth.

So, what we have essentially as we can see in this figure is we have a pattern of listen sleep listen sleep kind of cycle that is followed by each of these different nodes. So, these this as per the SMAC protocol this protocol suggests that it is required to turn off the node when the node goes to the sleep state and turning off, sorry not the node, but the radio, the turning off of the radio means that there is no communication that is going to take place. So, in the sleep state there is no communication that is going to take place because the radio is turned off and as we have also seen earlier in a previous lecture, when we were covering the introductory stuff we have seen that communication basically consumes the task of communication consumes the most energy among sensing communication and computation and so on and so forth.

So, basically this process of periodic listen sleep listen sleep kind of duty cycling reduces the energy consumption by at least ten percent in SMAC and it is preferable because the neighbouring nodes basically they all follow the same schedule and due to the this particular fact the you know this duty cycling and the discipline through the duty cycling approach it can be applied and thereby the energy consumption can be reduced at these different nodes.

(Refer Slide Time: 05:49)



So, how do we choose and maintain the schedule. So, what SMAC proposes is that the different nodes they would exchange their schedule by periodically broadcasting by periodically broadcasting, thus something called the sync packet the nodes take the

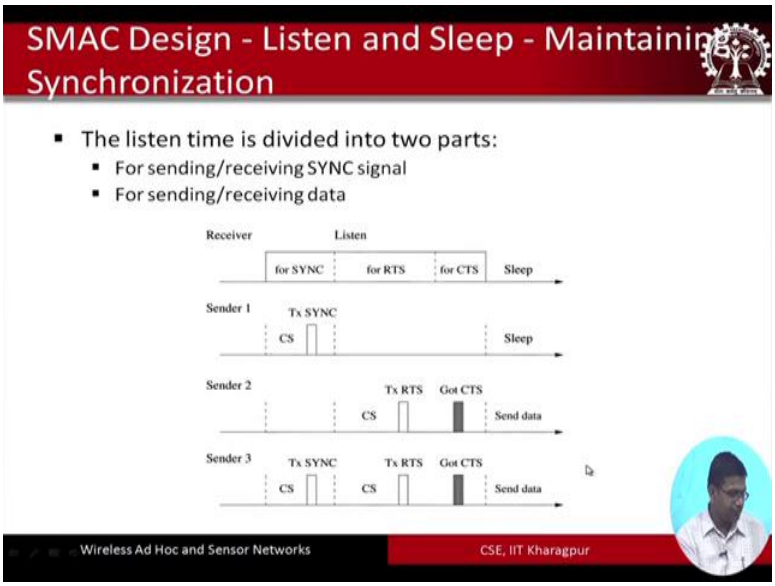
following 2 steps to choose their schedule. So, it will listen for the sync packets for a fixed duration of time there can be 3 cases when it is doing it. So, either there is no sync packet that is received or sync packets are received in the second case or multiple sync packets are received.

So, if we look at the overall you know the overall picture is like this that as we have seen before that in this particular SMAC protocol, it uses a virtual clustering kind of concept. So, in the virtual clustering concept we have different clusters and in these virtual clusters the different nodes they follow the same schedule.

So, we have in this particular diagram, we show that this these nodes they follow schedule one all these nodes this orange colour and the black colour nodes they follow schedule one and these nodes including this black coloured ones the blue and the black colour node nodes they follow the schedule 2. So, as we have seen and as we can infer that schedule one is followed by these nodes and in addition the black coloured node which is the border node and schedule 2 is followed by these blue nodes in and additionally this black coloured node.

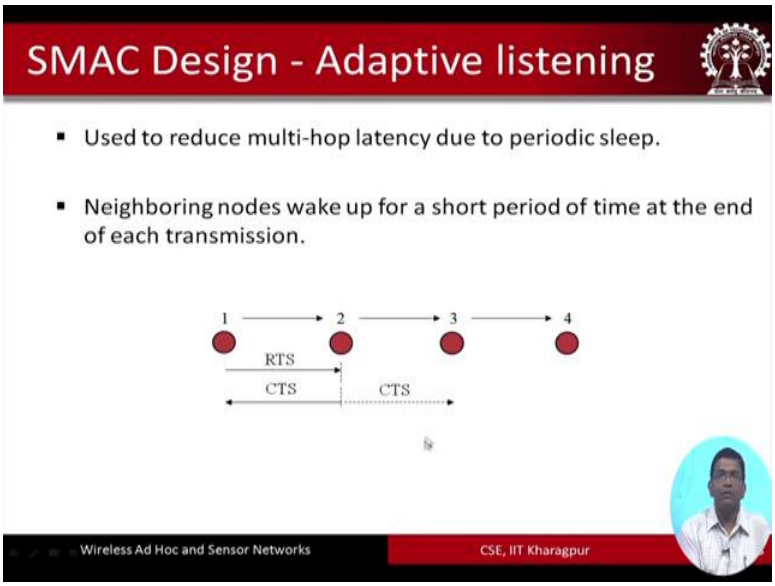
So, as we have seen that as we have seen that this border node basically follows both the schedules. So, and this border node initially let us say if the packet is sent from this virtual cluster it will initially follow schedule 2 and then if you once the packet reaches this particular the nodes in cluster you know it is going to follow the schedule one. So, this is how it works.

(Refer Slide Time: 08:18)



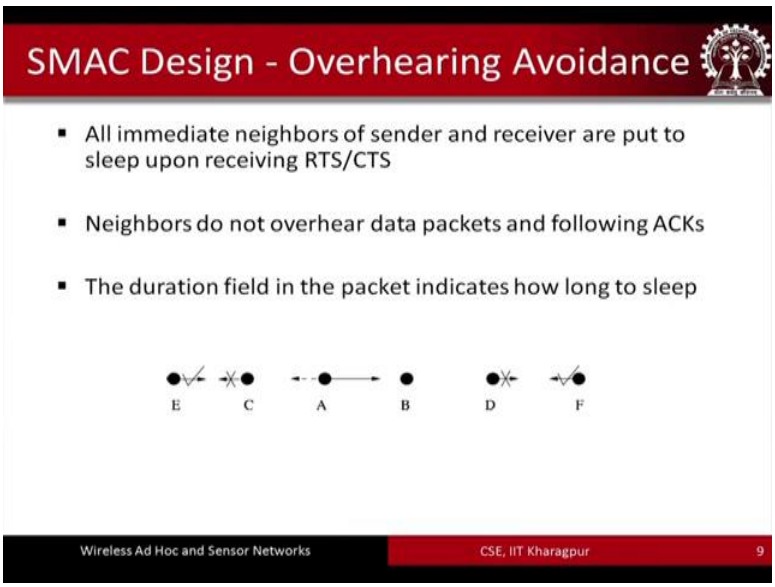
So, now how the synchronization between the listen and the sleep is maintained; so for this, we have to look at this diagram here we see that there are 3 senders sender 1, 2 and 3 and there is a receiver node and a fixed time slot is assigned for exchange of the sync packet and the exchange of the RTS, CTS. So, in this particular example we see that the sender one it sends it transmits first it is sends the senses the carrier and then it transmits a sync packet and then sender 2, it will you know it will first you know it will first carrier sense sees that there is no transmission. So, it will first send the RTS over here and gets the c t s back and then after that only it will keep on sending the data and the similar kind of approach is applied by sender 3 as well.

(Refer Slide Time: 09:27)



So, SMAC has a feature which is called the adaptive listening. So, this feature of adaptive listening is used to reduce the multi hop latency due to periodic sleep. So, here basically the neighbouring nodes wake up for a short duration of time at the end of each transmission. So, this is what is periodically is depicted in this figure. So, 1 to 2, there is an RTS that is sent a CTS is received back and that CTS; a copy of it is overheard by node 3, node 3 would then differ transmission and once it is complete it might opt to send packet to node 4 and so on all even to node 2.

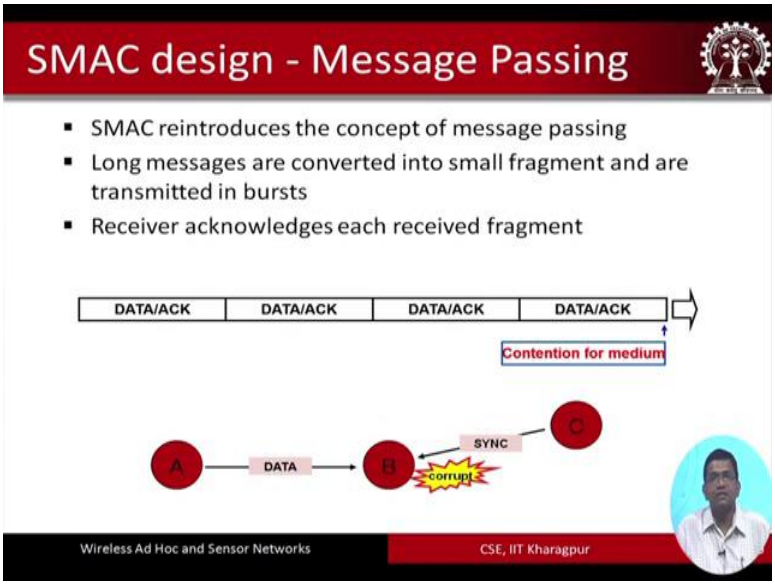
(Refer Slide Time: 10:02)



So, that was the other feature and then we have another feature which is called the overhearing avoidance and in overhearing avoidance as we can see the you know overhearing is something which is a very common problem in any wireless network and for sensor networks, it is a greater problem because we do not want energy unnecessary energy wastage due to overhearing and so we have to stop overhearing. So, as we can see in this particular figure we have a linear array of different nodes and in this particular example we have node A is sending a packet to node B and a copy of it as such will be hard by the neighbouring node C and similarly you know once the response is sent back from B, you know it will be overheard by that response will be overheard by node D.

So, as we can see over here node C and D would as such lose energy would waste 1 on energy due to overhearing of transmissions going on between A and B. So, what a SMAC suggests is that you stop this overhearing process of these neighbours. So, these neighbours will as such not over here the data packets and the following acknowledgements and that is how you know the energy wastage due to overhearing by the nodes C and D are going to be eliminated as per the SMAC design.

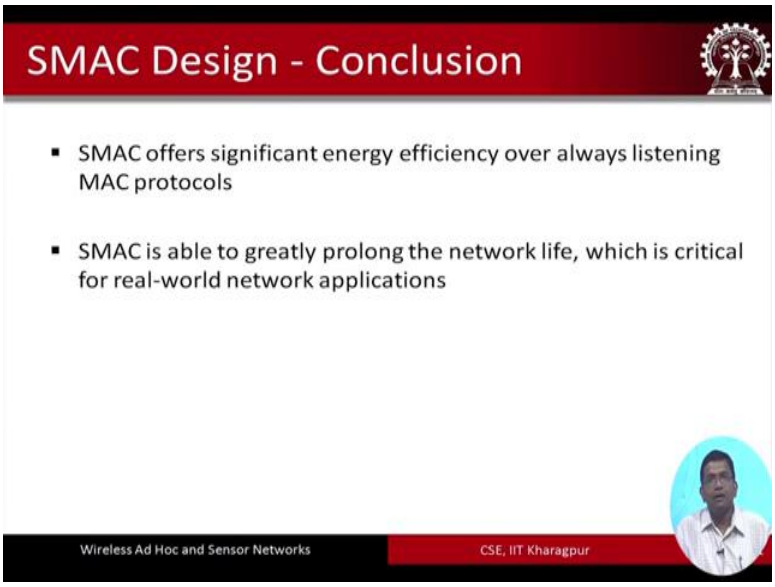
(Refer Slide Time: 11:43)



The other problem is taking care of message passing. So, here basically you know what happens is we have long data this long data are basically fragmented into different smaller data and the smaller data are sent and the corresponding acknowledgments are received in a contiguous fashion as shown in this particular figure. So, as we can see

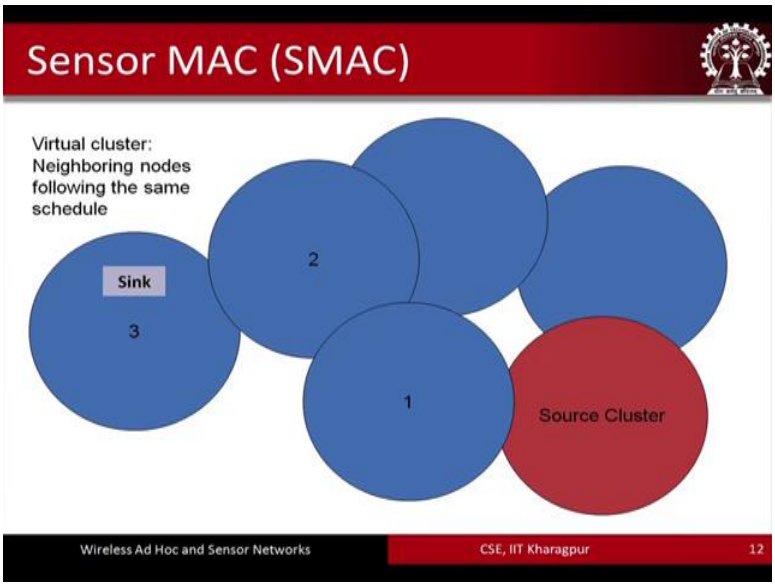
over here we have data sent from A to B, then once B has received, it could send the packet, but you know. So, there is at the same time in this particular example, we see that there is a sync packet that was sent by node C and that would lead to collision at node B between the packet that was the data packet that was sent by a and the sync packet that was sent by C and so we have at B's end, there would be collision due to which the packet that will be sent will be corrupt.

(Refer Slide Time: 12:45)



So, SMAC has we have seen basically cuts down on the energy consumption unnecessary energy consumption due to different factors such as idle listening and so on and so for overhearing idle listening and so on and so forth. And this was a problem with the other MAC protocol that we are proposed before the SMAC protocol and SMAC protocol consequently has been made more energy efficient and more usable by the sensor networks and SMAC is able to greatly prolong the network lifetime by cutting down on the energy consumption and the different nodes and this is a critical factor for any real world sensor network deployment.

(Refer Slide Time: 13:32)



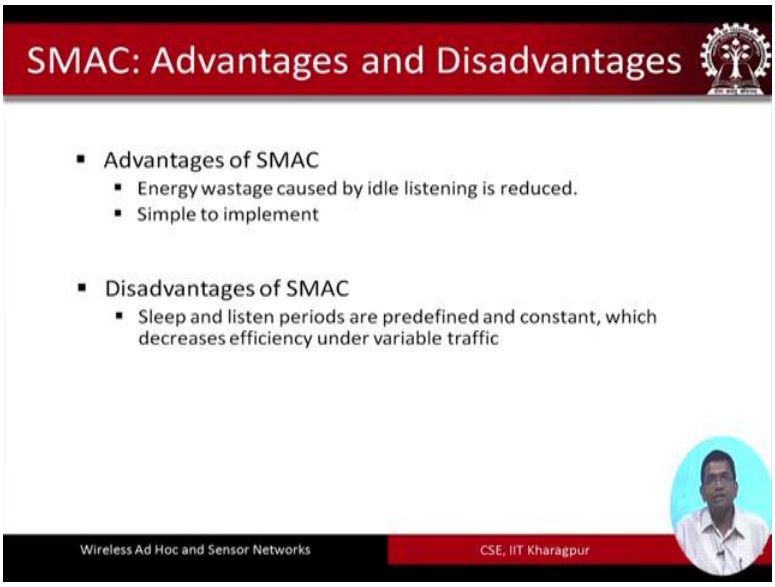
Now, let us look at this particular animation to make you to help you understand the working of SMAC protocol better. So, as we can see, in this particular figure, we have many different nodes that are deployed in a particular terrain and these nodes they you know. So, with these nodes using these nodes the different virtual clusters are formed and as we can see over here these virtual clusters they overlap as well which means that there could be different nodes which would be the bordering nodes between these different virtual clusters and so these bordering nodes they are going to sense the they are going to follow the schedules corresponding to each of the schedules that are followed by each of these clusters 2 and 3.

So, as we can see over here I will just show you the working of this animation from this how base MAC protocol works will be clear, but all you need to understand is we have different virtual clusters. In fact, we have different virtual overlapping clusters and there is a source cluster containing the source node and there is a sink cluster which contains the sink node and the source cluster it is going to sent the it is going to initiate sending the packet and the different nodes within it which are following the same schedule they are going to help in the process the packet will be transmitted to the virtual cluster one and from 1, it will go to 2 and then to 3 where the sink node is located.

So, let us now pay attention to how the animation works. So, I would particularly emphasize that please pay attention to the change in colours when I start the animation.

So, the source cluster basically sends the packet is now in 1 and then in 2 and finally, it arrives at 3 where the sink node is there. So, when the packet was there in a particular cluster the other nodes which were you know helping in this particular process they all were following the same schedule and then it was transferred to the border node to the next cluster and so on until the packet is received by the sink node in the sink cluster virtual cluster.

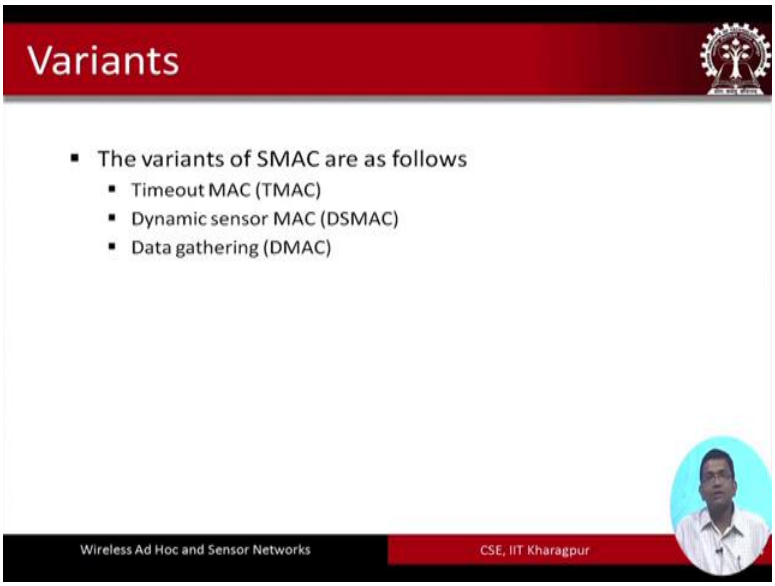
(Refer Slide Time: 16:08)



So, there are different advantages and disadvantages of the SMAC protocol the traditional the original SMAC protocol the SMAC advantage is that compared to the existing protocols MAC protocols for sensor networks SMAC is more energy efficient it reduces energy wastage caused by idle listening overhearing and many other different things that we are not there with as features with the other MAC protocols.

Another advantage is SMAC is a very elegant simple to implement protocol. So, it is basically ideally suited for use in sensor networks where ideally for sensor networks any solution that is proposed should be lightweight and simple. So, SMAC is a protocol which follows this particular design goal in terms of the disadvantages the sleep and listen periods in SMAC are predefined and constant and as we can see that any kind of fixed duty cycle kind of approach is not will not be efficient at all times particularly when the traffic is going to be variable and in the face of variable traffic basically any kind of fixed approach fixed duty cycling approach is unsuitable.

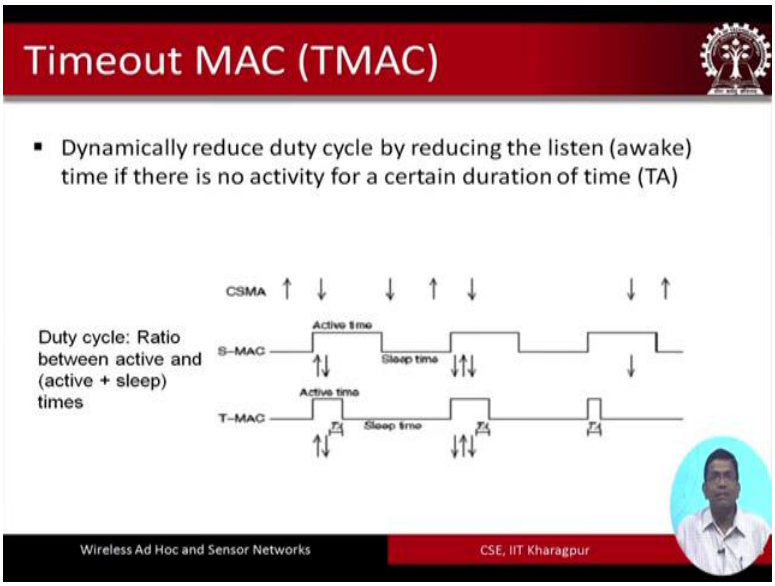
(Refer Slide Time: 17:25)



So, there are different variants of SMAC that we have proposed in order to overcome this particular disadvantage time timeout MAC, TMAC is one, second is DSMAC, the dynamic sensor MAC and a third is DMAC D; data gathering MAC, these are the names of few variants of SMAC that basically improve upon the performance of the original SMAC, but as we will; so I will just speak about them briefly. But one thing I would like to mention over here is that there are several other variants of SMAC that have been proposed which we do not mention over here, but this is for you to know that there are several other variants and improvements of SMAC protocols that exist in the literature.

So, but you know for the sake of simplicity we have avoided putting all these different protocols in this setup in this lecture.

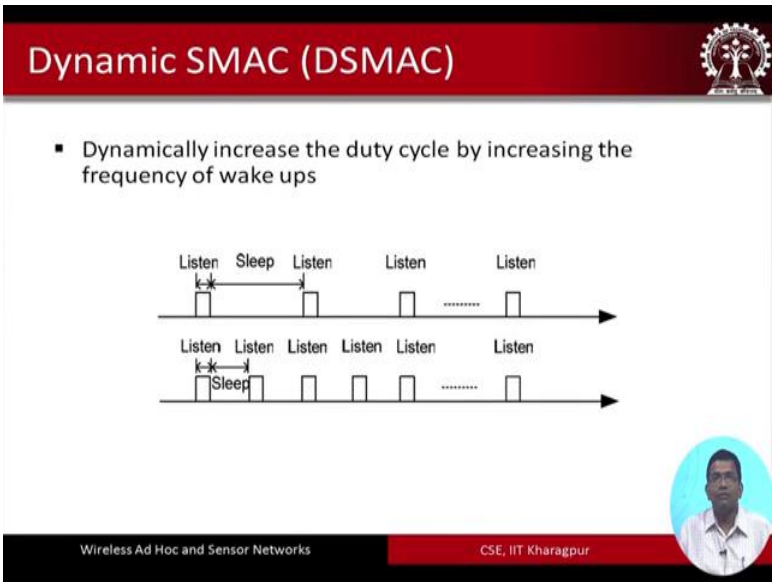
(Refer Slide Time: 18:29)



So, we have the timeout MAC and so what we have in the timeout MAC is that we have a variable duty cycle. So, this if we look at this particular figure if we look at this particular figure we have the SMAC which has a pattern like this which has a fixed duty cycle. So, fixed duty cycle means fixed you know active time sleeps sleep time then again the same active time sleep time and so on and so forth, we have a fixed duty cycle kind of approach that is followed by the SMAC protocol.

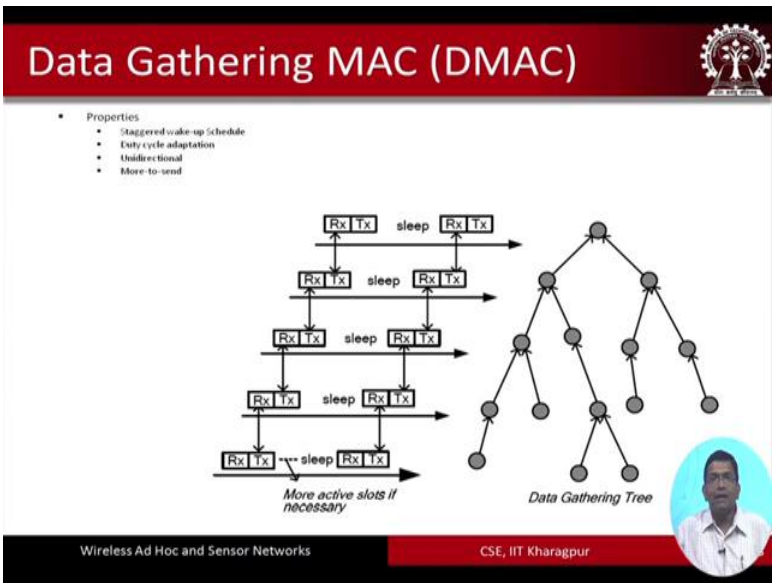
TMAC; in the case of TMAC as we can see compared to a SMAC the active period and the sleep periods have different durations overtime maybe you know adapting to adapting to the traffic conditions and so on. So, as we can see over here that here we have you know somewhat longer duration of active time then it is even longer the active duration is even longer here and it is shorter in this particular case. So, what we have is a variable duty cycling approach that is followed by the TMAC protocol compared to the fixed duty cycling approach that was proposed by the SMAC protocol.

(Refer Slide Time: 19:44)



Another dynamic approach adaptive approach to the original SMAC is the DSMAC protocol where there is dynamic increase in the duty cycle by increasing the frequency of wake ups as shown in this particular figure. So, compared to having you know a fixed duty cycle where we have listen sleep listen sleep as in the case of SMAC, here what we have are more frequent listens and so on. So, as we can see over here we have variable duty cycling. In fact, in this particular example the duty cycle is increased by increasing the frequency of wake ups the frequency of listens over here.

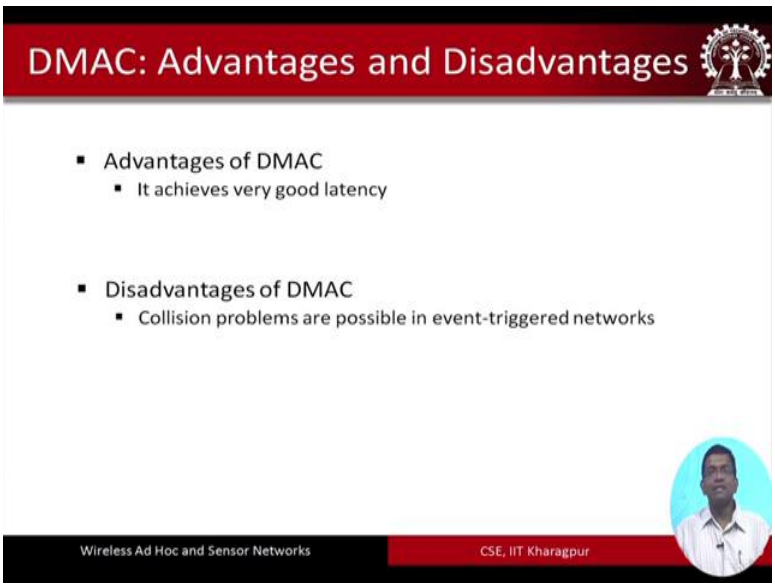
(Refer Slide Time: 20:42)



So, this is the comparison; comparison between SMAC and DSMAC and then we have the DMAC protocol; the data gathering MAC protocol which has a structure like this, it is a data gathering 3 kind of structure and this particular data gathering tree structure is harnessed to have a staggered wake up scheduling pattern of data transfer between these different nodes. So, as we can see over here these nodes the transmission schedules of these nodes are arranged in this particular way. So, we have this TX transmission you know synchronized with the received of these nodes in the in the second layer then second level then we have from over here this transmitted basically synchronized with this receipt and so on.

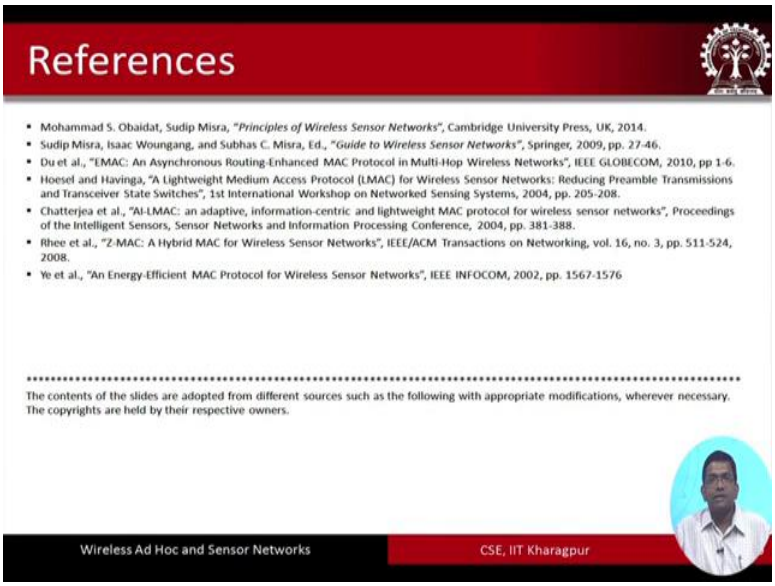
So, this is how over all the data is transmitted through the data gathering tree and underlying protocol in the medium access control follows this kind of schedule and this is why this is known as the staggered wake up schedule based MAC protocol; the DMAC protocol.

(Refer Slide Time: 21:56)



The advantages of DMAC is it achieves very good latency, but the disadvantage of DMAC is that collision problems are still possible because we have a particular structure the inverted under the tree like structure which is the event you know data gathering tree structure and that would lead to increased chances of collision.

(Refer Slide Time: 22:20)



So, here are the list of references once again for you to go through the individual protocols that we have discussed is the corresponding papers are mentioned over here.

So, with this we come to the end of the MAC protocols for sensor networks we have looked at in both of these lectures the previous part and this particular part we have looked at the issues surrounding the design of MAC protocols and how they can be overcome different MAC protocols that have been proposed for use in sensor networks.

Thank you.