Wireless Ad Hoc and Sensor Networks
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Lecture – 30
Routing in Wireless Sensor Networks- Part-II

Now, we come to the second part of routing in sensor networks. Here, our focus will be on two classes of protocols. One is the location aware protocols; the localized protocols, where the locations of the different nodes are known somehow may be using a GPS or (Refer Time: 00:41) the other is the LEACH and other protocols, which are self organizing routing protocols. So, we are going to look at these two classes of routing protocols, in this particular lecture.

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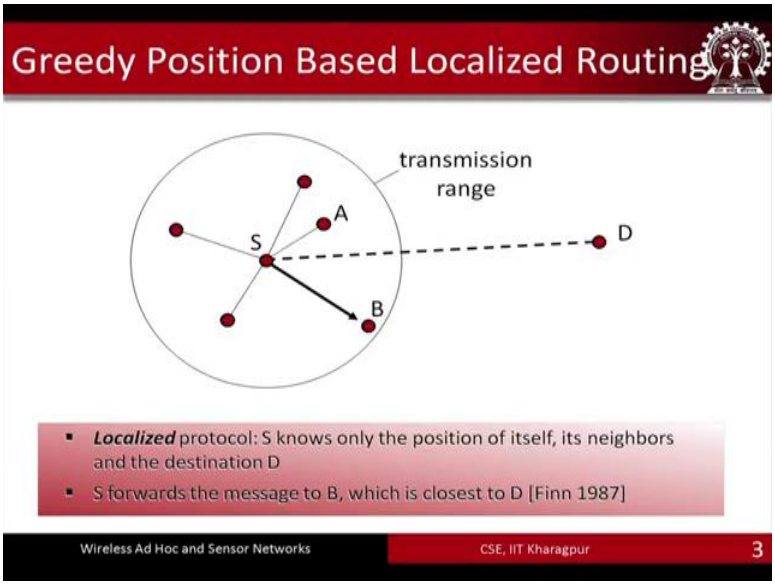

So, first let us look at greedy position based localized routing protocols. So, as you can see over here, in this diagram we see that we have a source node S and a destination node D. The transmission range of this source node is shown with the help of this unit disk graphs, with this circle. So, you know. So, so around this, inside this circle we have different other nodes like nodes A, B and the other nodes like this. So, if source node S has to send the data towards node D, it can either send it to A or to B or even these possibilities can follow, can also not be ruled out. But, it is more likely that it can be sent to A or to B because these are closer in different respects to node D.

So, we are going to talk about localized protocols, where the source node knows only the position of itself, its neighbors and the destination node D. So, it can, the source node because it knows the position of itself, A, B and D. It can decide which one has to be used; the A or the B to forward the message to. So, in this particular case it might so happen that instead of sending to node A, we find that node B is having a closer proximity to node D compared to A. This packet can be sent (Refer Time: 02:38) can up to, send a packet to node B because it is closer to node D.

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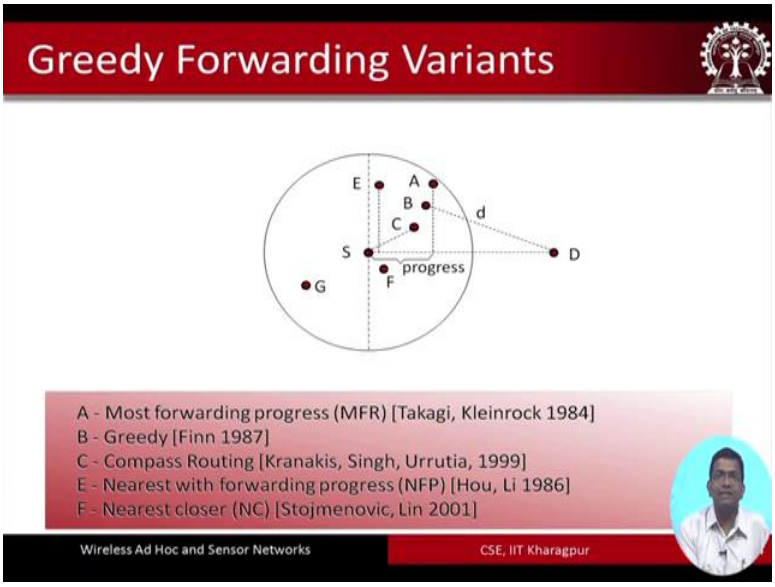

Let us look at other greedy forwarding variants as we can see over here. So, we have S, we have D, we have these other nodes like A, B, C, F, G, E, all of whose positions are also known, what they can be known. And, as before the position of S and D are also known. So, the possibility is now. And, how do we know the positions? As we have seen in the previous lecture that we can know because nowadays the sensor nodes can come equipped with GPS, which is very small cost. And, at the small; by investing the small cost, you know you can make things much more efficient. You can make the protocols much more efficient to function in these networks.

So, assuming that S, D and the other nodes, their positions are known. So, any of these nodes can be chosen. You know one possibility is to choose the node A because A has the most progress towards node D. It is the intended destination node. So, this one, this node A has the most forwarding progress. Most forwarding progress. Progress is defined

or it is determined by drawing the, though by taking the projection from node A on to S, onto the line connecting S and D, on to the line connecting S and D. So, this is how the most forwarding progress is obtained. Node B is an option because node B is closer to node T compared to our, all the other nodes that are in the vicinity of node S. So, this distance D can be used as a metric to determine that we can send to node B. So, this is a greedy approach that can be adopted as well.

We can send it; we mean, the node S. The node S can send to node C because the angle that C is tangle between line C S and S D is the least compared to the other possible angles that can be made between node S and the other nodes like A, B, E etcetera, etcetera. So, this is the least angle. Least angle theta formed by the straight lines intersecting at S, the straight line C S and D F intersecting at S. This particular angle is the least. So, this is what is adopted by compass routing.

Now, then what we have? We have the possibility of E, which can also be adopted. And, this E, basically unlike in the case of A, it has the, you know it has the least forwarding progress. And, which means that it is closest to S. So, one possibility is that you can opt for taking a node, which has the least progress to D and it is closest to S. So, you can choose to it. You can choose to send the packet to E from S or nearest closer. So, you know node F can be adopted because it is closest. It is closest among all the other nodes to the node S.

So, these are the different greedy algorithms that could be adopted by harnessing the position information that can be obtained through a GPS kind of mechanism. Position information of the nodes that can be harnessed through a GPS based mechanism.

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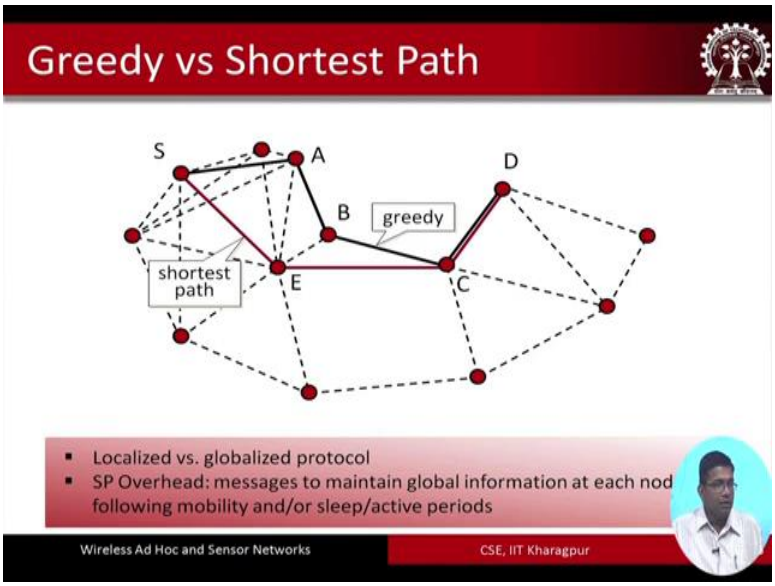

Now this, all these algorithms that we have seen, we had the greedy variants and the shortest path variant, which is the optimized with the least number of hops. So, you know S, E, C and D is the path with the least number of hops. So, this is the shortest path optimized algorithm, which can be adopted for routing between S and D. The other possibility is that the greedy approach that we had seen shortly few minutes back. If we adopt that node S, he is closest, sorry, node A is closest to D. So, node S will send to node A, and not to these nodes that I just showed to you. These nodes, it will not send to these nodes. But, it will send to A because A compared to these nodes that I had just mentioned, this node is closest to node D, which is the intended destination node.

So, similarly this approach can be followed all through. And, this path; by following this approach, the greedy approach, this path will be obtained for transmitting, for relaying the packet from S to D.

So, this is, this is a, there is a overhead, you know, when we talk about adoption of these algorithms, the shortest path algorithm. So, there is an overhead, and this overhead is mentioned. So, the messages to maintain the global information at each node following mobility and or sleep active period could be an overhead that cannot be ignored.

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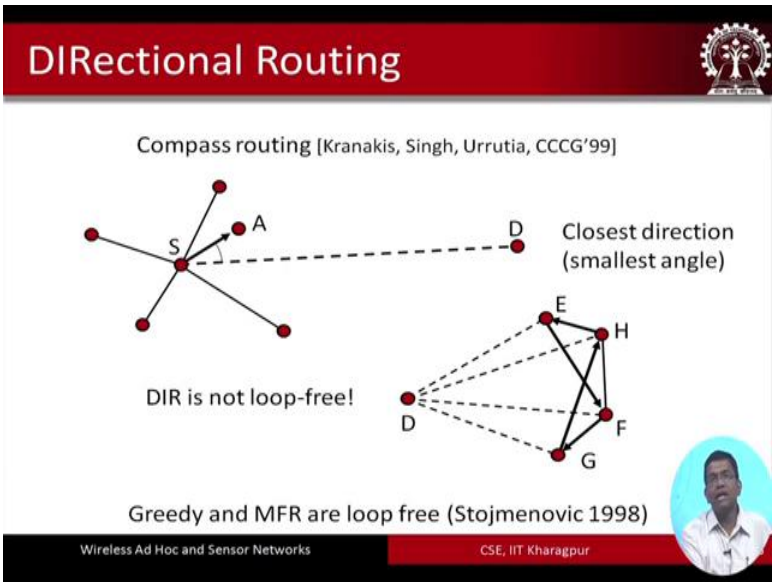

Compass routing is basically something where; as we have seen few minutes back that it uses the least angle to make the routing decisions, which node has to be sent to. So, you know S A makes the least angle with S D. So, you know this particular node is chosen and it has the closest direction. Compass routing basically determines which node has the closest direction; that means, the smallest angle with S D. Then, so this is the direction based routing. Then, you have the D. You know, another routing. So, it can be, you know, so another routing which is direction based as well. So, we will not look at those other types of directional based routing. But, the only thing that I would like to mention over here that it can be shown and it has been shown, in fact. That direction based routing is not loop free; that means, that loops are possible using direction based routing as shown in this particular figure.

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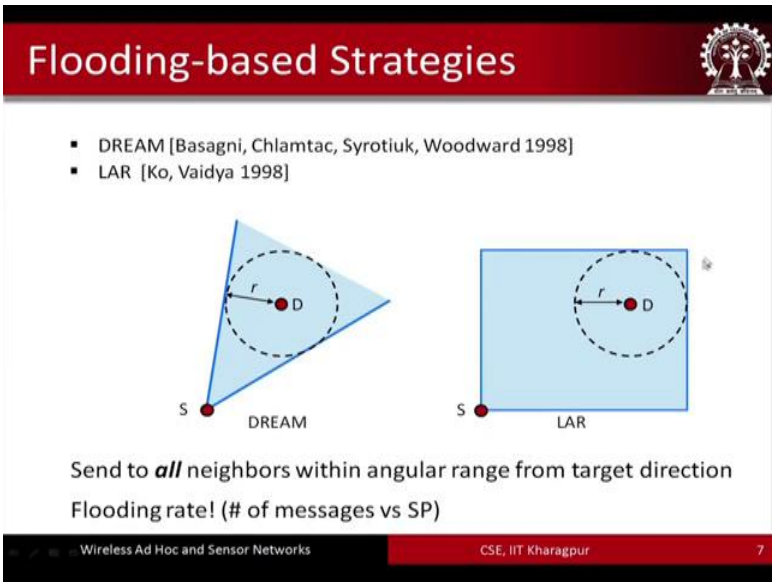

Flooding based strategies can also be adopted. So, in this particular example. So, DREAM and LAR are two algorithms, two protocols that follow flooding based strategies. So, here basically the approach is to send to all neighbors within an angular distance from the target direction. So, in this particular, I think to this, from this particular figure itself it is quite clear that an angle is made around the range of the intended destination node. And, all nodes that would fall within this particular angles are going to be flooded with the message. That is, you know that the source node S has an intense to send towards the destination node D.

The other approach is also quite similar. But, you know geometrically it looks little bit different. So, you have the source node, you have the intended destination nodes. Around the intended destination node, you have the range, and a rectangle could be formed in this particular manner. The source node as per this particular algorithm LAR, the source node would flood the packet to all nodes in this particular angular, in this particular rectangular region.

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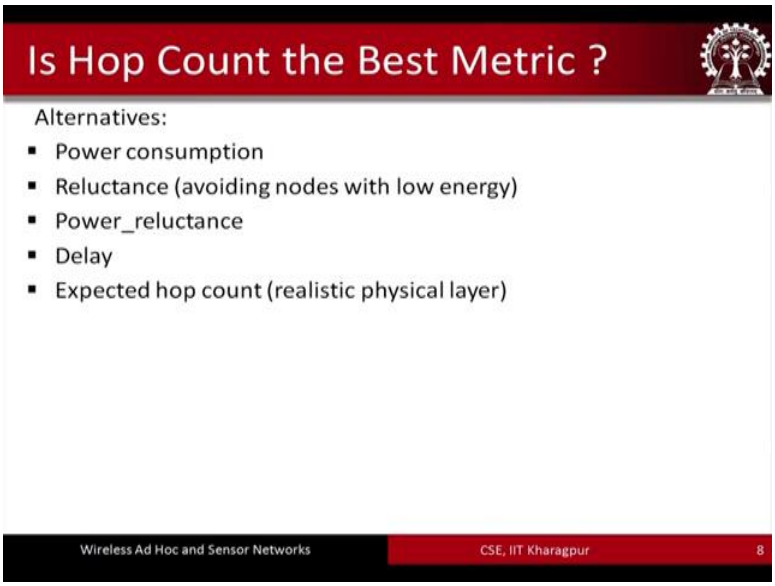

So, one question is that few minutes back we have seen that choosing the hop count to determine which path will be finally chosen. But, the question is that in sensor networks is hop count the best metric? As we had adopted hop count or hop count is adopted in as one of the best metrics for routing in the internet and so on in and many other wireless networks, as well. So, in this particular case also; that means, in this network sensor networks also is hop count the best metric? So, what are the other alternatives? Power consumption. We have already seen that sensor networks are have to be resource conserving. We have too much of limitation with respect to energy that can be consumed. So, power consumption, energy consumption, can it be used as a metric for determining the, you know, the path through which the packets servant to be sent.

Reluctance which means that avoiding nodes with low energy, delay, expected hop count and so on. So, all these are different alternatives that can be used as metrics for determining the path.

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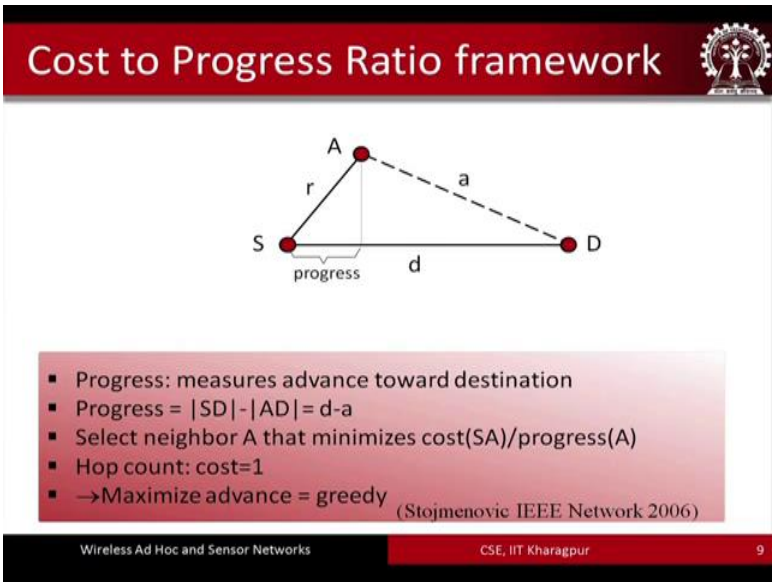

So, cost to progress ratio can also be used for determining for making the routing decision. So, let us say that we have a node A to which node S can send a packet. So, this particular, you know, so when we take the projection from A on to S D, this basically becomes the progress. So, progress basically, essentially means that it is the advance that is made by S through A towards node D. So, that progress can be used as a metric to make a routing decision.

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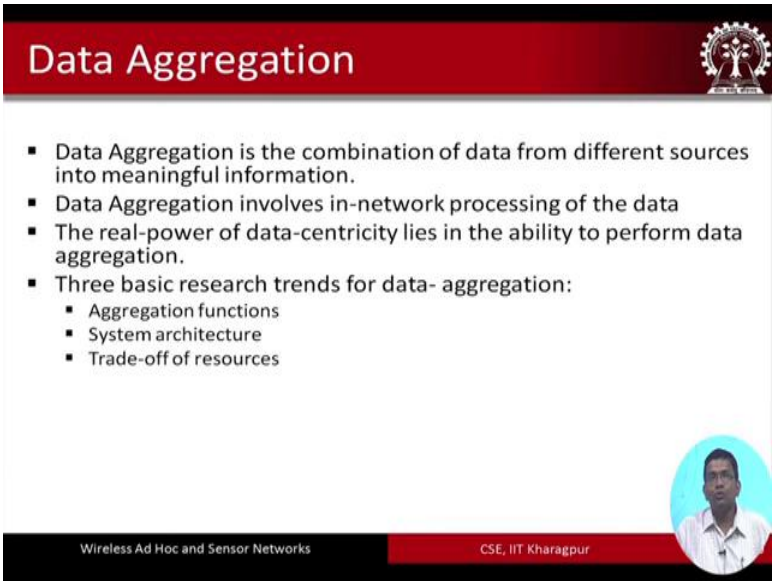

So, these were the different other forms of routing. I will also talk about another class of routing. But, one thing that I would like to mention at this point is the issue of data aggregation. Data aggregation, the English meaning of it says it all. So, data aggregation is about aggregation of data, combination of data that are received from the different sources at a particular node. So, instead of sending all instances of the data that are received by a particular node from all its neighbors, a node could aggregate the data and it could send that summarized data for further processing, instead of flooding the network with so many packets and so on.

So, this will basically cut down on the number of packets that are flowing throughout. So, you know. So, how do you perform data aggregation? So, there are different approaches. So, one thing is that you adopt some data aggregation functions. For example, take an average. But, you cannot take average for each and every kind of data. You can take an average if you are, you know, if a particular node for instance receives from its neighbors, different temperature values, then it could adopt a simple average kind of aggregation function in order to take an average of all of them and then report it further to the next top neighbor.

But, such an approach cannot be adopted. Let us say if you are getting pixels of data from the neighbors, how can you take average of the different pixels that are received from the neighbors? So, it cannot be done. So, like this, actually there are different other complicated kind of sense data that can be received for which you know different advanced interesting aggregation functions can be designed. And, this is a very intense area of research. It has been a very intense area of research. Data aggregation is of interest because of these reasons, there are lots of research works that have been performed on data aggregation and different system architectures have been proposed to support data aggregation and so on. So, this is something that is of interest to sensor network’s researchers.

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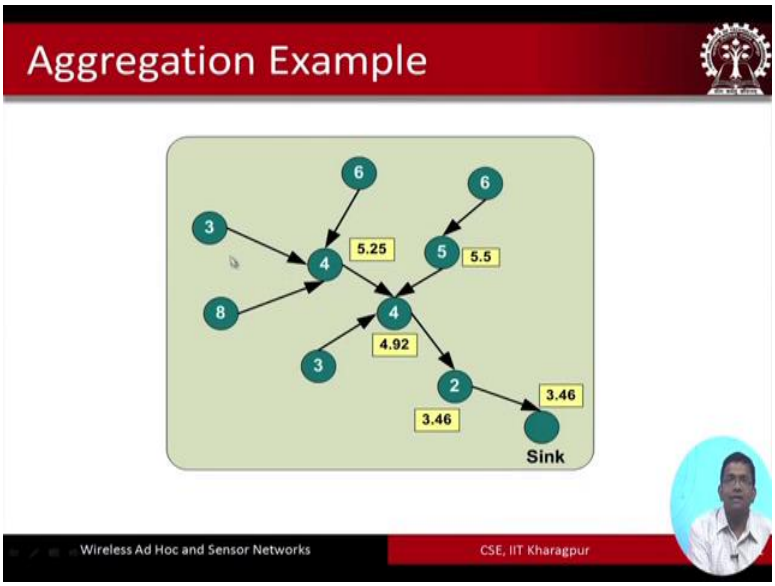

So, here is an example of the data aggregation. Let us say that a particular node has neighbors like 6, 3 and 4. And, these ID s can be used you know 6, 3 and 8. Sorry, 6, 3 and 8. And, these ID s could be representing the actual data that is sensed because these are numeric values. In over here, if we take the average of all of these, that average value of 5.24 could be reported to the next top neighbor. 4, 5.343 and 5, 5.24, 5.24, 5.25, 4, 5 and 3, their average could be taken. The average of 4.92 can be reported further and so on and so forth. So, this is how the aggregation function occurs. So, we have taken the simple aggregation function, the average. And, these average values are reported over here. And, those average values are finally though a multi hop path are sent to the sink node.

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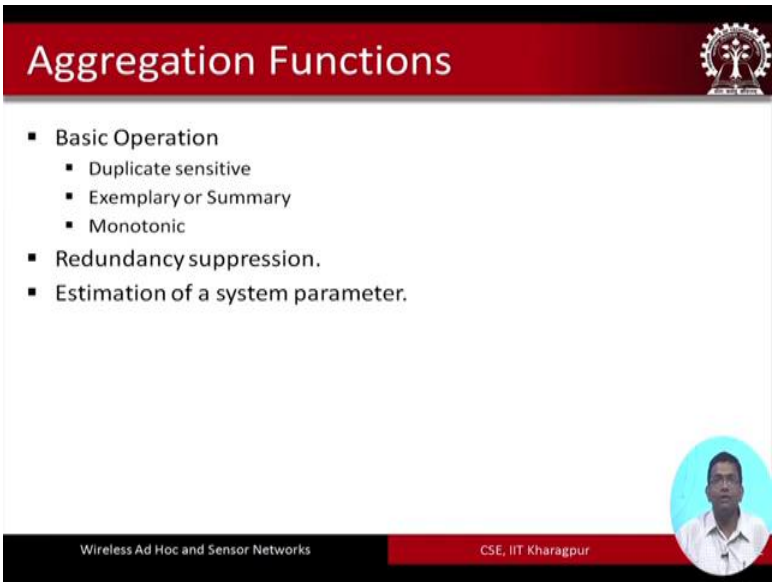

So, these are the different types of aggregation functions that can be adopted. So, we are not going to talk about them further.

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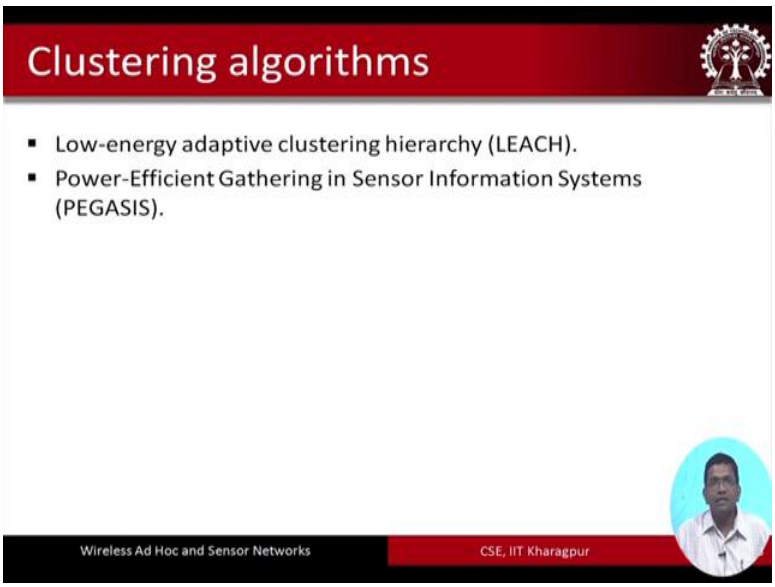

But, one thing finally I would like to mention is we have already seen data-centric routing protocols for sensor networks. We have seen localized, you know, routing protocols which basically exploit location information; specific location information: latitude, longitude, for instance and so on. So, similarly there is a, there is another class

of routing protocols, which is called the cluster based routing protocols. LEACH and PEGASIS are two well-known cluster based routing protocol.

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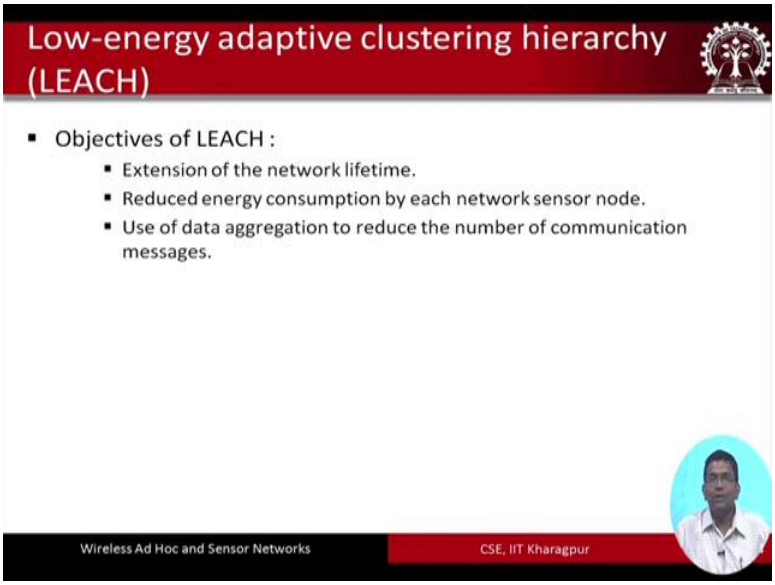

So, one thing that has to be kept in mind is we have already seen LEACH protocol, when we were talking about topology management and when we were talking about MAC protocol as well. LEACH is actually not a routing protocol as such. LEACH basically is a protocol, which basically cuts through, you know, medium access routing and so on. So, topology management and so on. So, it is basically a multifunction protocol. So, the objectives of LEACH are basically to improve the network lifetime to reduce energy consumption by the different nodes and use data aggregation to reduce the number of communication measures, sorry, communication messages.

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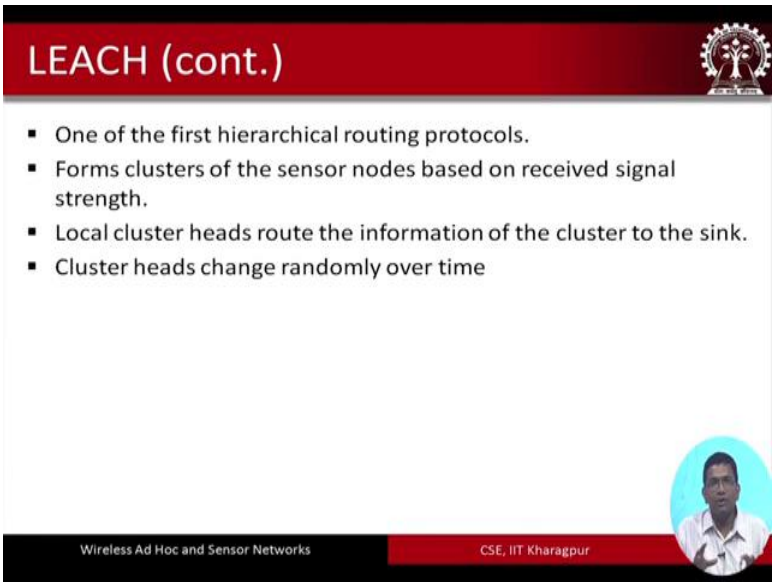

So, it is one of the first hierarchical routing protocol which means that different clusters are formed using different sensor nodes based on certain metrics. Maybe, the received signal strength. And, the local cluster heads route the information of the cluster to the sink. And, the cluster heads basically change randomly over time. And, one thing that we had seen in when we were discussing LEACH on other occasions, each is that the cluster heads in LEACH are assumed to have, assumed to maintain one hop connectivity to the base station.

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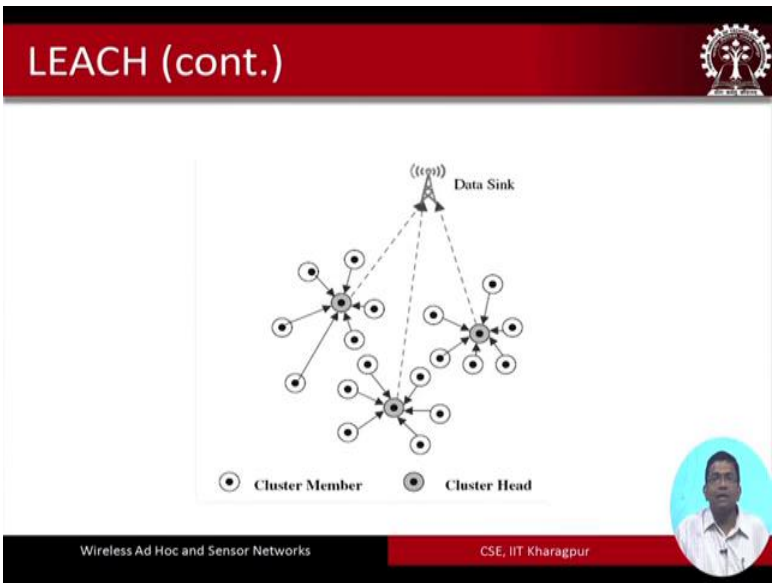

As we can see in this particular figure. So, we have different clusters that are formed like this. And, there is a cluster head. The cluster head is responsible for aggregating the data that is reported by the cluster members. And that aggregated data is finally sent to the sink node through one hop connectivity like this.

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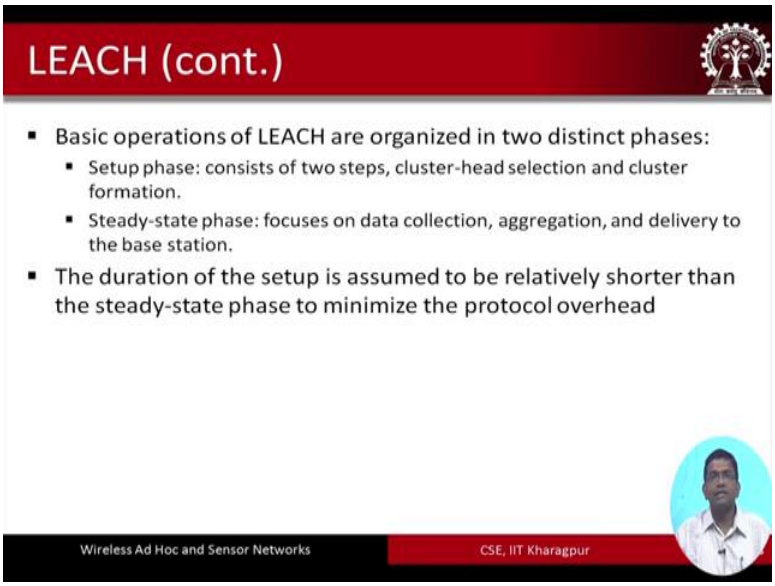

So, the basic operations of LEACH are organized in two distinct phases. Setup phase, which consists of two steps: Cluster head selection and cluster formation. And, the steady-state phase which focuses on the data aggregation, data collection and delivery to the base station.

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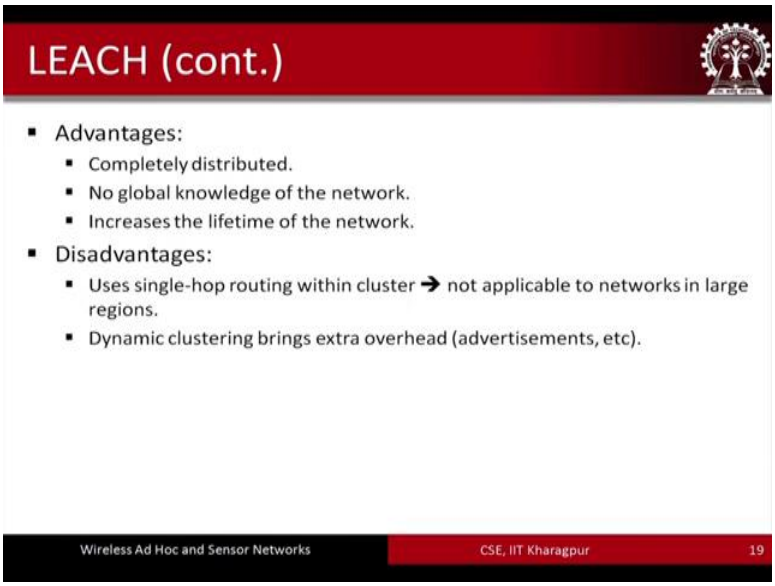

Advantages are that leach is a completely distributed protocol, where there is no global requirement, where there is no requirement of global knowledge of the entire network at. And, it increases the lifetime of the network.

The disadvantages are that it uses single hop routing within a cluster, and is not applicable to networks in large regions. And, dynamic clustering approach that is adopted by LEACH, basically it invites additional overhead in terms of the advertisements that are sent out to the different neighbors, etcetera, etcetera. So, this additional overhead leads to additional energy consumption, and which is undesirable for sensor networks. So, these were the limitations of use of LEACH protocol.

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So, here again we have the list of references of different routing protocols that we have covered in the previous lecture and this one. And, you are encouraged to go through these literature, which have been readily made available to you, in order to understand these protocol in further detail, if you want to.

So with this, we finally come to the end of this entire topic of routing. In sensor networks, routing is an important function of any network, sensor networks as well. But, the main problem that we have seen is in routing the main problem is sensor networks have specific requirements. And, designing routing protocols to meet those requirements is a challenge. We came up with different classes of routing protocols. We have seen SPIN class, class of protocols, data–centric, direct diffusion protocol, which belongs to the data-centric routing protocols.

We have seen location aware routing protocols like the ones that we have seen today. They may far most forwarding progress routing and greedy routing and so on, shortest path routing and so on. So, these are location aware routing protocols, where the nodes are aware of the locations; where their locations and the locations of the other nodes in their vicinity. And finally, we have looked at the cluster based routing protocols. LEACH is a cluster based routing protocol. And, also the issue of data aggregation and how aggregation is performed. Their issue of designing different aggregation functions is a challenge in data aggregation in sensor networks. How do you design different

innovative functions? It aggregation functions is of interest to the sensor network community, and is a challenge that different people are trying to work on sensor networks.

So, with this, I think we have summarized the entire coverage of routing in sensor networks. So with this I think the essence of routing and the different important issues have already been covered by me. So, I hope that you have understood lessons and the different solutions that are out there.

Thank you.