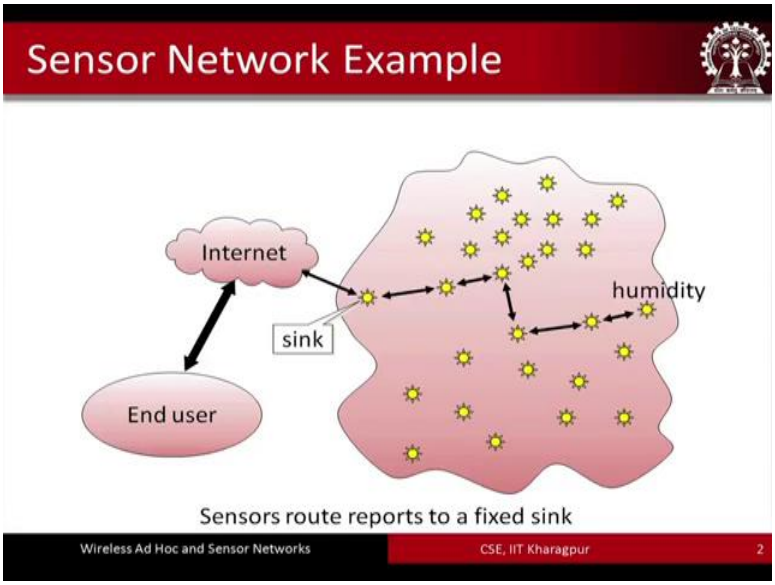
Wireless Ad Hoc and Sensor Networks
Prof. Sudip Misra
Department of Computer Science and Engineering
Indian Institute of Technology, Kharagpur

Lecture – 29
Routing in Wireless Sensor Networks- Part- I

Routing in sensor networks, this topic also we have divided into two parts. So, first we are going to go through some of the basics in terms of routing, the important concerns of routing in sensor networks, what are the different specificities that are there and then we will look at some of the protocols. Some of the sensor network specific routing protocols that have been proposed and the ones that are quite popular and popularly used in the community.

(Refer Slide Time: 00:52)

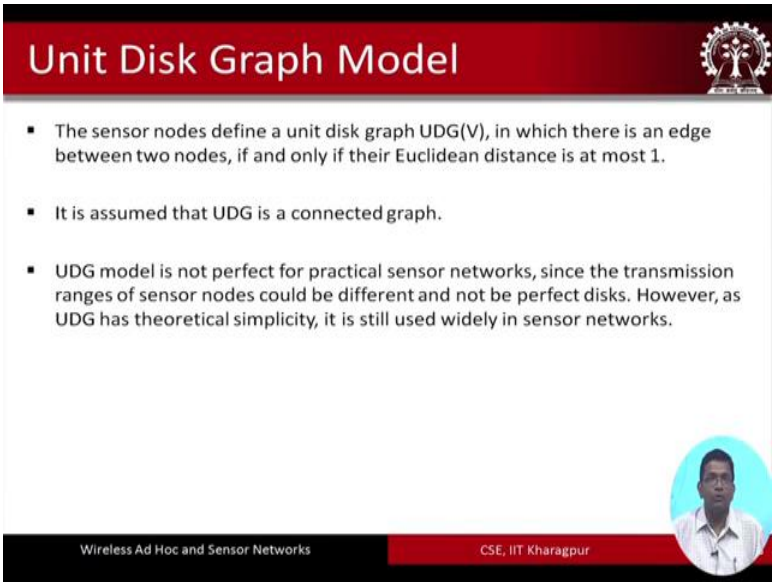


So, when we talk about sensor networks we have a scenario like this. So, what we have are different sensor nodes, different sensor nodes. May be you know in this particular example as we have seen that the sensor nodes. We are all sensing the humidity of the region. And, the humidity is sensed by the sensor nodes and through a multi hop path. The sensed data is sent to the sink node and, from the sink node that it are sent over the internet to the end user. See the common typical scenario of deployment of sensor networks.

So, what we see over here is we have a source node. And, through this multi hop path the data is sent to the sink node. So, the routing issue is that how do we know which path the sense data is to be sent through. So, one possibility is that it would be sent via the path that is shown over here to the sink node or the other possibilities could be maybe from here, it would have been sent here, then maybe here, then here, here, like this and so on. So, like this actually if we look at more carefully, there are different possibilities of sending the sensed information from the source node to the sink node.

So, how do we send, what should be the path, what should be the route, is what a routing protocol has to look into. So, this is what the different routing protocols for sensor networks, basically try to resolve that what should be the route through which the sensed data that is sensed by a particular source node is going to be sent to the destination node, the sink node.

(Refer Slide Time: 02:46)



So, we will look at different routing protocols that have been proposed for sensor networks. But, one thing I would like to inform to you that particularly in the case of routing and may you know and also it is applicable for other protocols that have been proposed for sensor networks is that it is generally assumed theoretically that the unit disk graph model is followed by these different networks.

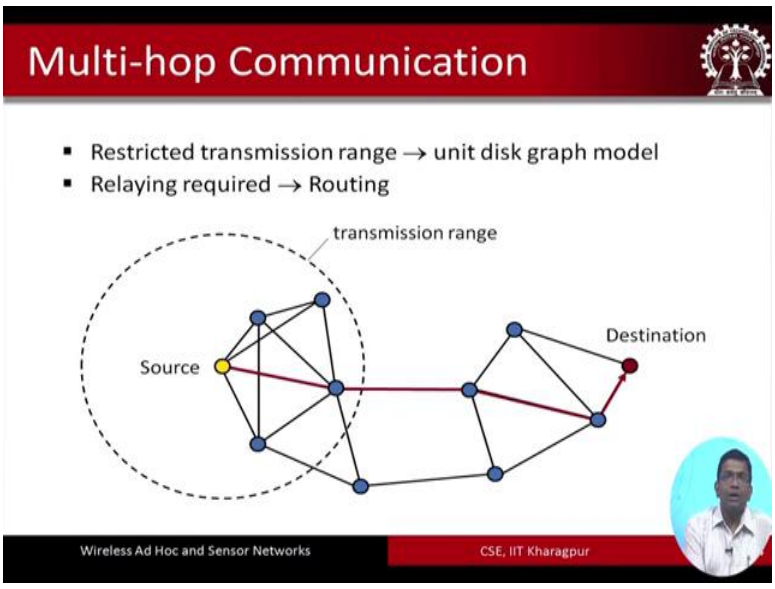
Now, mind you that this particular concept is a theoretical concept, which basically says that the sensor nodes would define a particular unit disk graphs around them; which

means that there would be, you know corresponding to every sensor node, there would be a circle, a unit radius circle around them, which corresponds to the communication range of that particular sensor node. And, it is a circle. So, this is a theoretical concept. And, it is a unit radius circle.

So as per this unit disk graph model, the sensor nodes define a unit disk graph UDG V, in which there is an edge between two nodes, if and only if their Euclidean distance is at most 1. And, I think I do not need to elaborate this because this is fairly simple and clear to understand. And, most of the theoretical literature on sensor networks and more specifically routing in sensor networks, assume that the UDG is a connected graph. And, this UDG model is good for use in theoretical, you know, solutions because that way we can have different solutions to be modelled much more easily. But, in practice actually the UDG model is not perfect and is not used and is not practical in most of the actual deployments of sensor networks.

And, in fact it might also so happen that the transmission ranges of the different sensor nodes might also be different. And, they may not all be the perfect disks due to environmental factors or different other (Refer Time: 05:19) I have; however, as UDG is a theoretically simple concept, it is still used widely in the sensor networks literature, particularly the theoretically oriented sensor network literature.

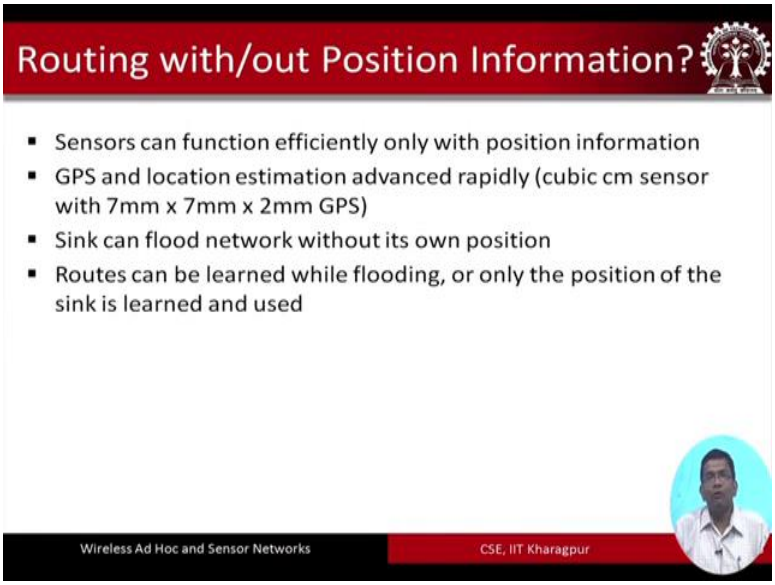
(Refer Slide Time: 05:33)



So, if we look at this particular figure, so what we have? We have a source node which has a transmission range like this. And within this transmission range, which is basically, which denotes the unit disk graph model. In fact, within this transmission range we have different other nodes like shown over here. And, from this source node through a multi hop path that sensed data can be sent to the intended destination node or maybe the sink node.

Now, the problem is like this that these intermediate nodes will have to relay the packet that each of them receive individually. So, what we have is that we have multiple options for sending the packet. One is basically shown using the red colour. This is one option. But, there were other options like this path, which could have also been adopted. Likewise, there are different other paths which could have been adopted as well. So, how do I know? How do I know that which path the source node which has sent the, sensed the data, through which path it is going to send the packet containing the sensed information? How do I know? So, basically a routing protocol will enforce; will basically determine and enforce that particular path.

(Refer Slide Time: 07:24)



Now, how do you perform routing? So, routing can be performed with and without position information. So, traditionally with a bare basics sensor node, what we can do is these nodes, they can discover who are their neighbours. Once they are deployed, deployed and they are turned on, so we can, you know we can enforce different

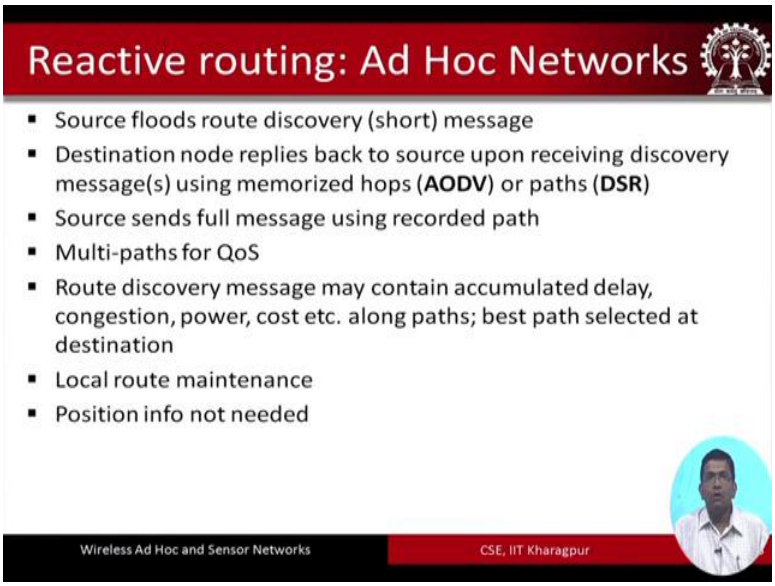
algorithms. We can basically have different algorithms which will make these sensor nodes to discover their neighbours.

So, through the discovery process, these nodes, they know who are there different neighbours. And that way, any sensor node which is acting like a source node can send the packet to the neighbours. And, from the neighbours further on until the packet which is the intended destination node. However, currently because of miniaturization because of namespace technology and very reduced cost of GPS technology and so on.

Now, it is the sensor nodes, at very low cost they can come equipped with GPS. And, if they are coming equipped to the GPS, it, you can get the exact geographic location of the deployment of each of these nodes at a very low cost. And that will help the sensor nodes to determine their respective positions. And that; you know that information can be harnessed, can be used by the different mac, different routing protocols for transmitting the packet from the source node to the destination node.

So, it has been shown that if the GPS information; the exact geographic position, location, information of these different nodes are known, then routing can be performed much more efficiently compared to, when, you know this position information is not known. But, at the same time it is not that you know we need only the GPS based ones or the, you know the ones without, you know some hardware does not come equipped with GPS, in which case you have to perform routing without the position information known apriori. And, in other cases, if the, in a position information through GPS is known, then routing can be performed even more efficiently. So, both of these classes of protocols are required.

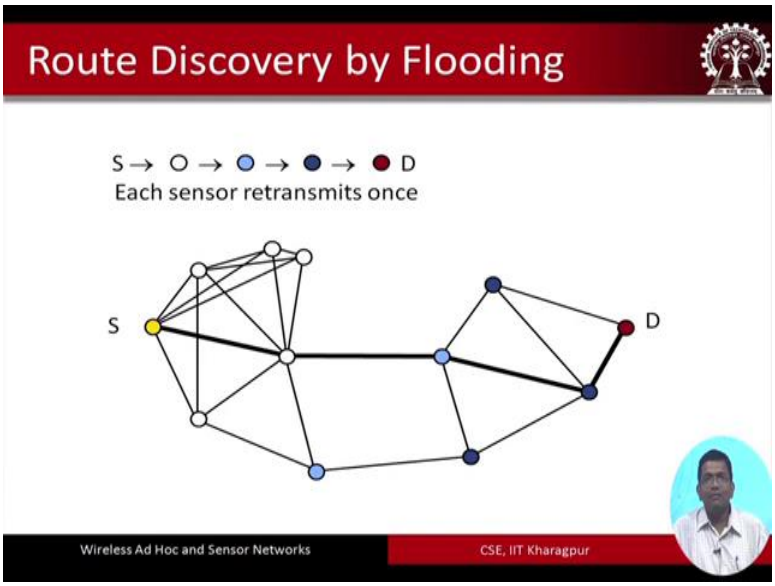
(Refer Slide Time: 10:00)



Now, as the kind of sensor networks that we talk about belong to the Ad Hoc networking category. So, we can use the AODV and the DSR protocols that were proposed, that are available for use of routing in Ad Hoc networks. And, we have already seen that when we discussed about routing in Ad Hoc networks. AODV, DSR are very popular routing protocols that are used in these networks. In fact, there are different implementations of sensor networks. The commercially available ones, which basically do not go for any sensor network specific protocol, but they just use the AODV or DSR protocols in their implementations. So, that is perfectly fine because you know AODV and or DSR will work in a multi hop, multi hop network. And, sensor network is a multi-hop network.

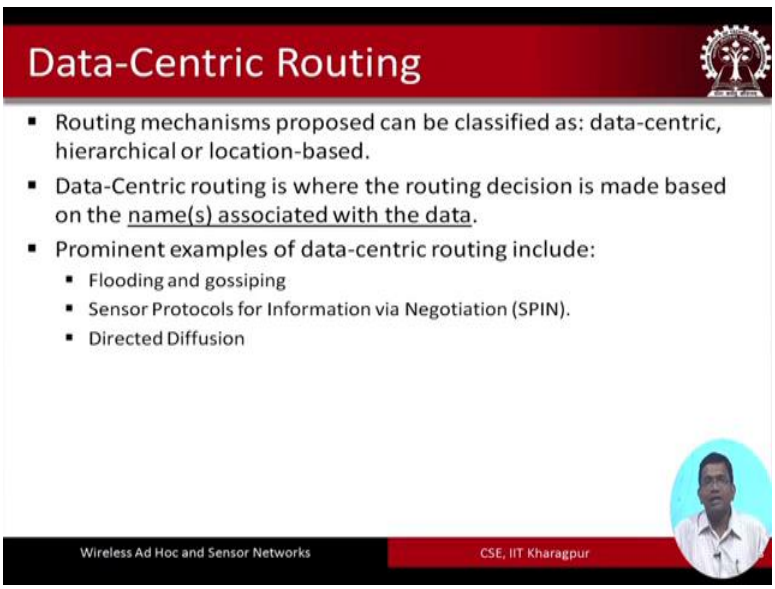
So, in these protocols the source node basically discovers the routes through short message exchanges. And then, consequently what happens is once the routes are discovered, the data can be sent through the discovered path. So, one possibility is that we can go for the, you know, by, go by adopting these Ad Hoc network routing protocols AODV, DSR or (Refer Time: 11:18).

(Refer Slide Time: 11:20)



The other possibility is that we can go for flooding based protocols. And, in flooding based protocols as we can see over here, the source node, it broadcasts the message to the neighbours. The neighbours are all going to have the copy of the packet. This neighbour will also have. And, it is then going to send to its neighbours and so on and so forth. Finally, you know a copy of the packet that was sent through this particular path is going to be reached over here. And because it is the shortest path over here, this path is going to be reinforced. And, all subsequent packets that are sent from the source node are going to be routed through this particular path.

(Refer Slide Time: 12:14)



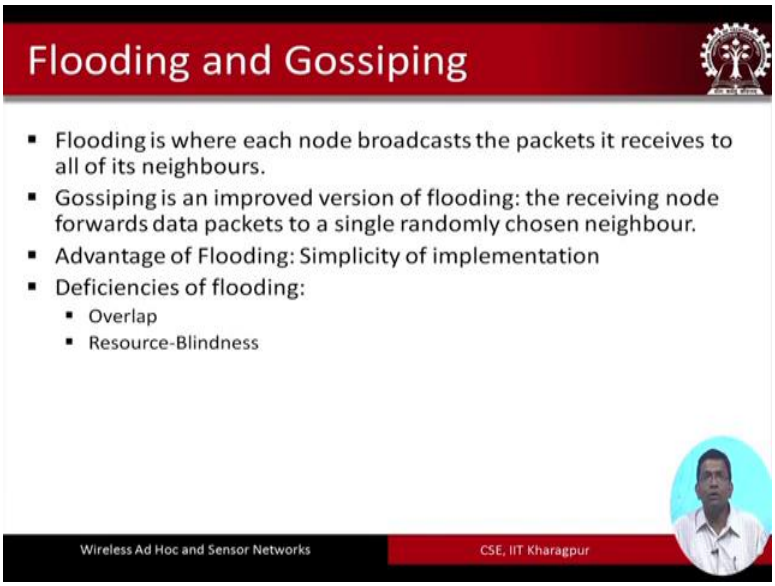
So, this is, you know, route discovery through a flooding based approach, which can be adopted in the sensor networks as well. But, can we do something better and more specific for sensor networks? Even the different constraints, energy constraints and the different features; for example, data centricity. So, can we harness those things? Can we propose routing protocols that will be more specific? (Refer Time: 12:39) to the more specific requirements of sensor networks. So, we have data centric routing protocols, which basically use the data centricity that is inherent to the sensor networks.

So, as we have seen that when we talk about sensor networks it is all about sensing data, sending data, handling data and so on, so it is all about data exchange between different nodes and so on and so forth. So, data-centric routing protocols, what they attempt to do is they attempt to harness the names that are associated with the data and use them for making the routing decisions. And, not actually go by having utilizing the specific addresses like the IP addresses associated to the different nodes.

So, if we did not have, in other words data centric routing protocols, what we need is some kind of addressing mechanism; which means that different nodes would have different specific addresses associated to them like an IP address or something of that sort. And, routing will be enabled by virtue of use of these addresses to identify how and where the data has to be sent from a specific point onwards. Data centricity, data centric routing protocols, on the other hand do not require the use of IP addresses or the like. And, what they say is we will exploit the use of names that are associated with the data and we will use them for making the routing decisions.

So, there are different prominent examples of data centric routing protocols. Flooding and gossiping are two popular ones. Likewise, we have the SPIN protocol, sensor protocols for information via negotiation, SPIN protocol and the directed diffusion DD protocol. SPIN, as we will see also has different variants of it; SPIN 1, SPIN 2, SPIN these, that, etcetera etcetera and so on. So, these are basically you know different improvements over the originally proposed SPIN protocol.

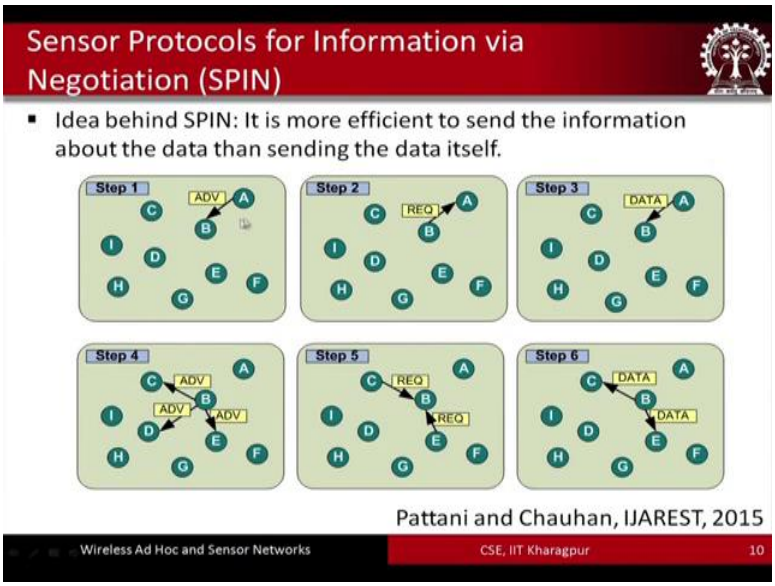
(Refer Slide Time: 15:04)



So, let us look at some of these protocols in more detail. Flooding and gossiping, I do not need to elaborate on them further. Flooding is a well-known concept of routing. Gossiping is you can construe gossiping as some kind of controlled version of flooding, where the receiving node forwards the data packets to a single randomly chosen neighbour; not to all the neighbours, as in the case of flooding. So, it is a controlled form of flooding.

But, there are different limitations of use of flooding or flooding based approaches like gossiping. There is overlap of data and flooding based approaches are resource blind. They will simply keep on forwarding data to the neighbours and so on, without taking into consideration that whether the nodes have sufficient resources available with them or not. So, this kind of solution are not very ideal for use in sensor network. So, we need something better.

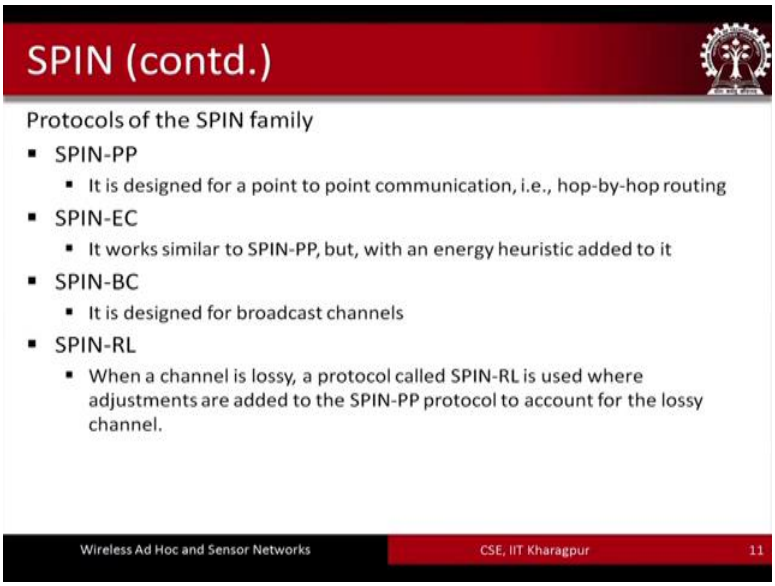
(Refer Slide Time: 16:01)



So, what is this better? So, SPIN protocol came to our rescue. So, in the SPIN protocol the idea is like this that we have a set of different nodes like the ones that are shown over here; A, B, C, D, etcetera till H. In this particular example, node A, for instance is the source node. It is the owner of the data at some point. Instead of sending the data to its neighbour B, what it will first do is it will first advertise saying something like that I have a data with some kind of metadata like this. Do you? I am advertising to all my neighbours. Node A advertises to all its neighbours. B is the neighbour in this particular case. So, the node B, if it is interested based on the metadata that is supplied by A, if it is interesting node B will then have to request the data from node A.

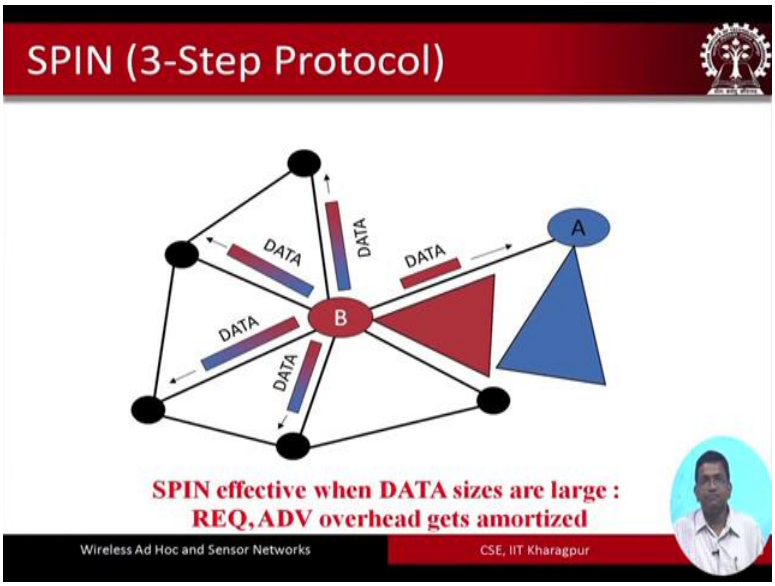
So, let us now go back and look at the slide. The particular figure, we see that in step 2, node B basically sends a request packet to node A. And then, only thereafter node A in step 3 will send the data to node B. In step 4, node B has the data through the above three steps. It is in position of the data. Then, what it will do is it will follow exactly the same procedure that was done by node A in step 1. It will also advertise the data it has in the form of advertisements to all its neighbours. So, node C, D and E received the advertisements in this example. So, in this particular case we see that both E and C, they request the data from B. So, B will send the data to both E and C as shown in this particular step.

(Refer Slide Time: 18:05)



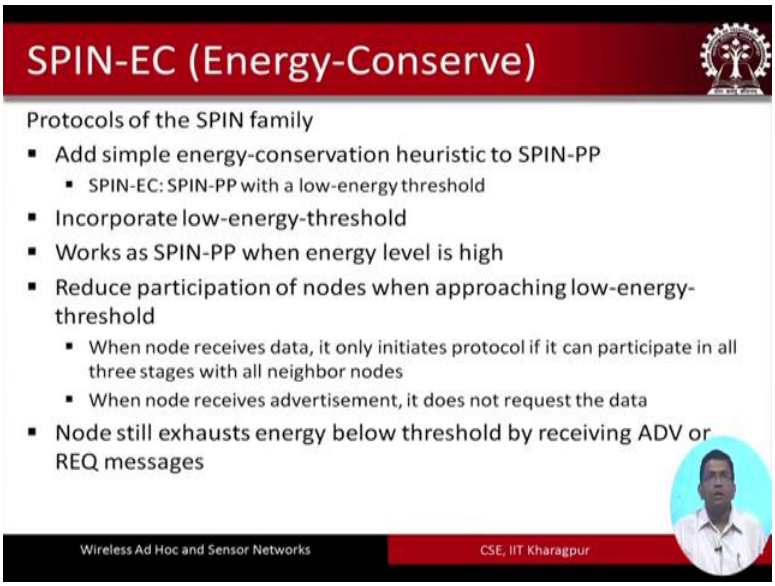
So, SPIN basically is a very simple and elegant protocol. The original SPIN. And, there are different other protocols that have been proposed, which belongs to this class of protocols, the SPIN class of protocols, SPIN-PP, SPIN-EC, SPIN-BC, SPIN-RL and so on and so forth. There are so many different other spin protocols that have been proposed, which basically follow more or less the SPIN concept of routing. So, I am not going to go through them here in further detail. It is for you to go, you know, understand. I mean understand means like you know you can just go through this different protocols. So, it is quite, you know different features of these different SPIN class of protocols are given over here. And, they are very simple to understand.

(Refer Slide Time: 18:56)



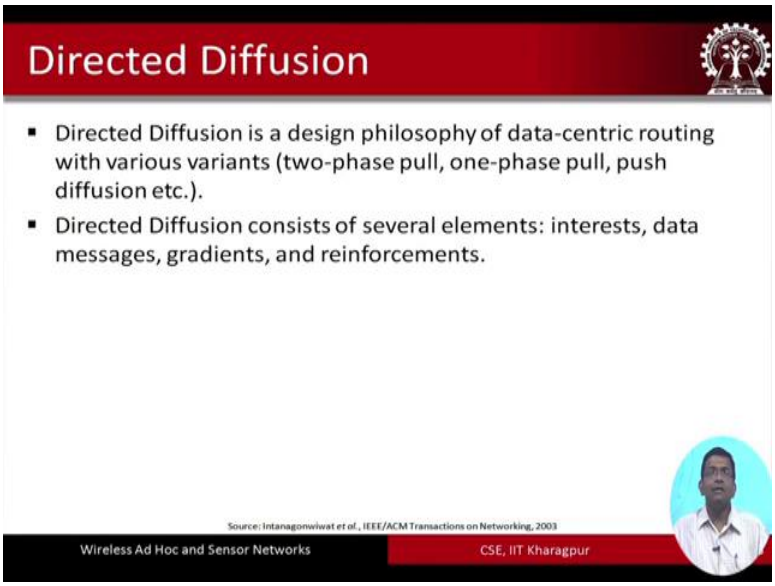
So, let me now take the help of an animation in order to understand this three step approach of SPIN that we have looked two slides back. So, let us go through it once again. So, node A basically what it will first do? It will send an advertisement to all its neighbours. Node B, in this particular case is a recipient of this advertisement. So, then node B, it sends a specific request to node A for getting the packet from A, node B receives the packet, the data, actual data. Then, what node B does is it will send again the advertisement to all its neighbours. So, all these nodes that we can see over here, all these nodes are the recipients of this advertisement. So, they are going to send the request whoever requests, will send the request to node B. So, this is how it works. And finally, the and after this advertisement request, data exchange as the packet exchange, the actual data will be sent by node B to all the requestors of that particular data for which the advertisement was made.

(Refer Slide Time: 20:21)



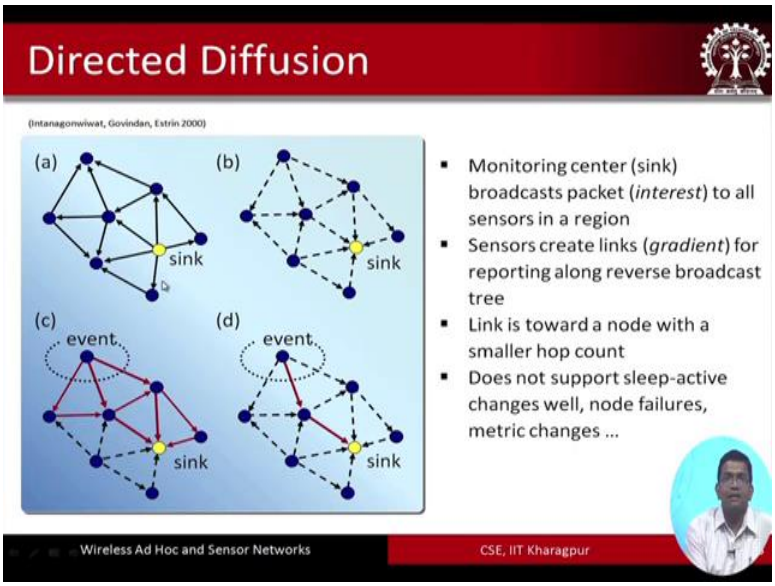
So, the SPIN-EC protocol is a very popular specific protocol. Energy Conserving SPIN protocol, which basically as this name suggests, it adds simple energy conservation heuristic to the SPIN, basic SPIN protocol. And the SPIN-PP protocols, which is basically a low energy, you know, SPIN protocol. So, it incorporates the low energy threshold and it works as a SPIN protocol PP, which is again a very basic SPIN protocol, where energy level is very high. So, you know. So, in essence actually I do not need to elaborate on this further. But, as you can understand the SPIN-EC protocol is a very energy conserving protocol, which tries to minimize to the extent possible the energy consumption of the difference nodes that use this particular protocol for routing.

(Refer Slide Time: 21:24)



Now, the other class of protocol is the directed diffusion. Directed diffusion, like SPIN and the SPIN class of protocols is also a data-centric routing protocol. So, the design philosophy is that you use the data centricity in different ways to get different variants, the two phase pull, one phase pull, push diffusion and so on. So, data centricity again is harnessed over here in order to route the packets. So, there are different. You know, so whether you are using this approach or the other, in general the DD approach consists of the following steps. First one is the interests propagation, second is message forwarding, third is gradient formation and fourth is reinforcement. So, these are the four steps primarily that are adopted by the DD protocol.

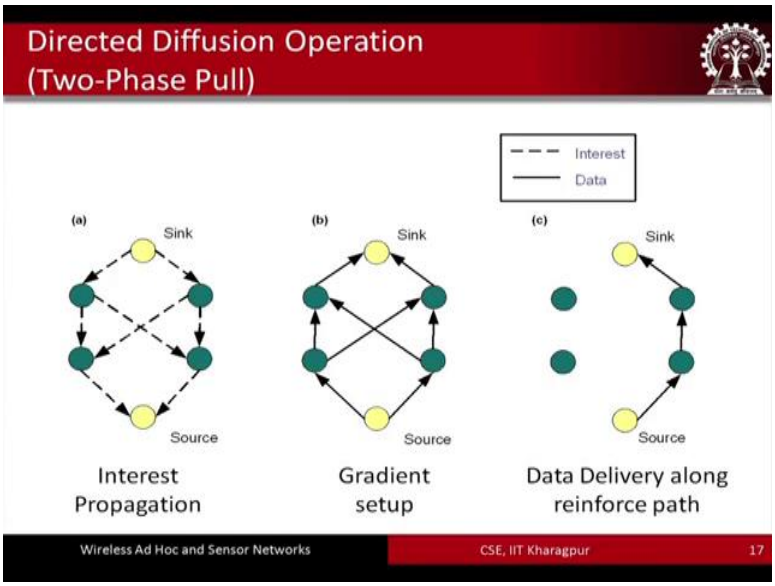
(Refer Slide Time: 22:23)



So, as we can see over here, we have an example. We have a sink node and we have A node which can act as a sink, act as a source. The sink node basically propagates, it broadcasts and interest message to all the sensors in its region. The sensors create links that are gradients for reporting along the reverse direction as shown in figure b. Along the reverse direction, as you can see that the gradients are attempted to be created.

Finally, through this, these two steps, the link is created towards a node with a smaller hop count. So, finally what we have is if the event has occurred in, you know, around this particular node, this node is going to report along these paths. And finally, along the different paths that are shown over here, finally this least hop count 1 is chosen and the event will be continuously reported from this node towards the sink node. So, I hope that you can understand this approach. It is a very simple and elegant approach, a very popular approach, a very popular protocol. Directed diffusion is a very popular protocol like the SPIN family of routing protocols.

(Refer Slide Time: 23:48)

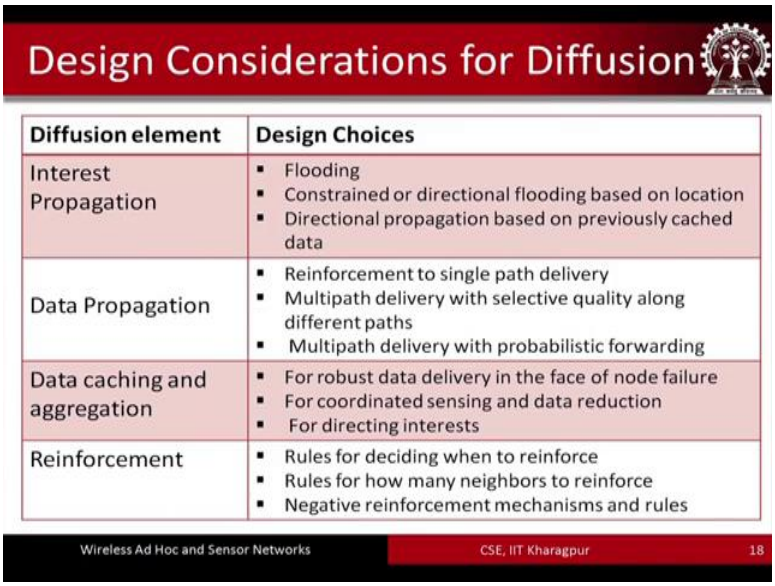


So, let us look at this particular figure, which basically clarifies how the two phase pull, you know approach of directed operation, directed diffusion in a functions. So, first as we have seen before is the interest propagation. So, sink basically floats to all its neighbours and interest, it broadcasts an interest message which will be propagated all through until it comes to a, to a node which is the source node. So, source node is the one which will respond by saying that let us say that you know let me take one specific example to make this part to particular point clearer.

Let us say that the sink can propagate and interest by sending a message, which says that can any of these nodes sense a particular object? So, then you know this will be broadcasting and it will be propagated all through. And, let us say that this particular, this yellow coloured node acts as a source node because you know it is, indeed senses a particular object. And then, what it will do is it will respond back along the differs path. So, this is the gradient setup phase.

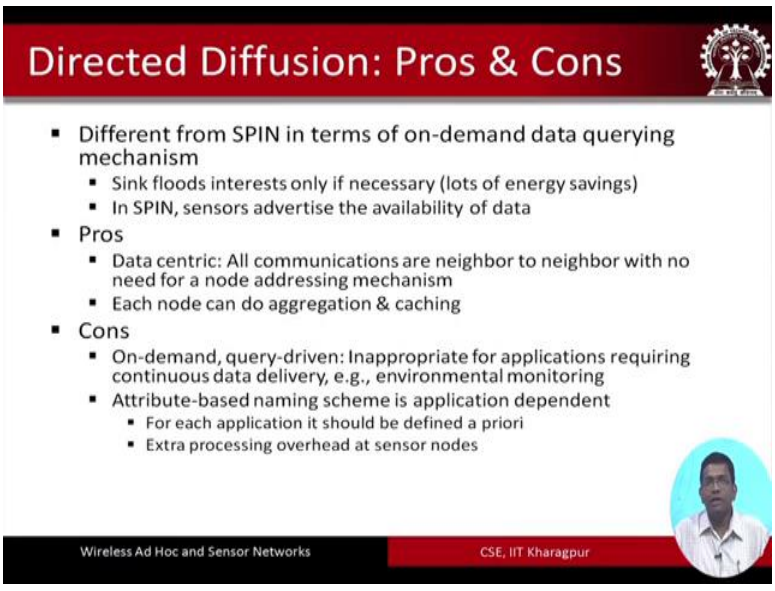
And finally, so along all these different paths, this interest is, this gradient messages are going to be forwarded. And finally, the least hop count 1 will be reinforced as a path through which the data are going to be continuously sent from this source node to the sink node.

(Refer Slide Time: 25:32)



So, there are different design considerations for directed diffusion with respect to the interest propagation, data propagation, caching and aggregation, reinforcement and so on and so forth. And, these are for you to go through. So, you know it is quite simple to understand. So, I am, I do not need to elaborate on this particular slide.

(Refer Slide Time: 25:52)



So, there are different advantages and disadvantages of directed diffusion. Although, it is a data-centric routing protocol where you do not really need to have any kind of IP addressing or similar kind of addressing approach to be adopted for routing but, there are

different, you know, advantages of it. But, there are different disadvantage, advantages as well.

So, one of the disadvantages is that on-demand, very different. So, this approach is inappropriate for applications that require continuous data delivery. So, example, environmental monitoring, this is one disadvantage. Second disadvantage is that it is an attribute based naming scheme and is application dependent. For each application it should be defined what that application is about, apriori. And, extra processing overhead at the different sensor nodes are required by adopting this particular approach.

(Refer Slide Time: 26:57)

So, here is the list of references as usual. So, directed diffusion, the original paper and, the paper that talks about it in more detail is available here. Similarly, the other protocols like SPIN class of protocols and their corresponding references are also given in this particular slide.

So, with this we come to an end of the first module, the first part of routing in sensor networks. As we will see in the second part that there are many other interesting approaches to routing in sensor networks and, using which you can make routing much more efficient. So, this is what basically we are going to look at in the next part, the second part of routing in sensor networks.

Thank you.