**Wireless Ad Hoc and Sensor Networks**
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**Lecture - 08**
**Routing in MANETs- Part-I**

So, the topic that we are going to cover now is Routing in Mobile Ad Hoc Networks. And this topic is going to be covered in three parts: first what we are going to do is we are going to review some of the challenges that are posed by these network; the mobile Ad Hoc networks because of which the traditional routing algorithms for additional routing protocols and schemes that are already available for the internet are unusable in these environments.

So, thereafter we will look at few of the different specific challenges. Most of the challenges have to do with the multi hop nature of these networks, but there are few other challenges that are posed by the environment. The environment is a highly mobile environment, it is a decentralized environment, a distributed environment. There are lots of security concerns, there are the environment itself is lossy in nature, much more lossier compared to the other wireless networks

So, these are different challenges that are posed to routing in mobile Ad Hoc networks. So, routing in general as we already know from our basic knowledge of computer networks is a functionality of the network layer. So, network layer means layer three. So, the same thing happens. So, here also it is the same thing, same network layer problem in the case of mobile Ad Hoc networks in the same routing is a you know functionality of the layer three. And this is what you know we are going to review. So, what are the different specific functionalities, what are the challenges with respect to routing in these environments?

And thereafter, we will look at some of the solutions that have been proposed the different classes of solutions. And then a few examples we are going to go through and look at the different features of these examples, the features of the solutions that have been proposed for routing in the Ad Hoc networks

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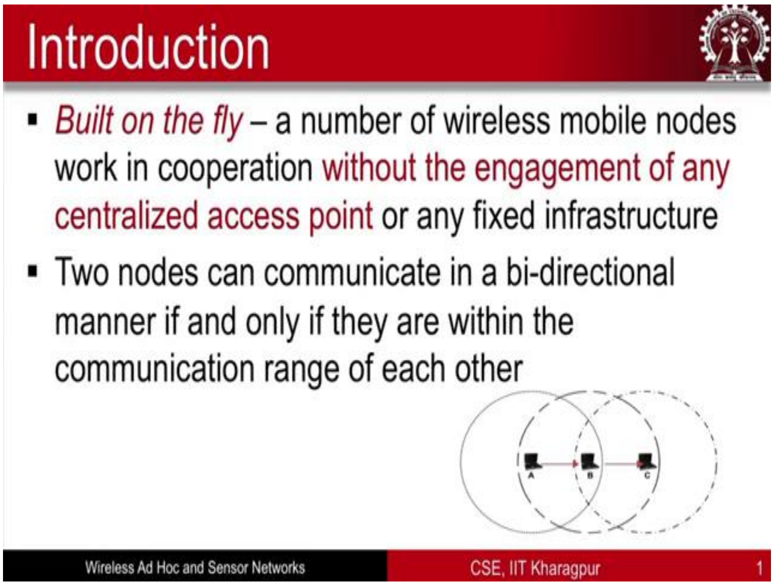


So, let us just recap some of these things that we already are familiar with by now. First thing is that these networks are built on the fly. That means, that you have a collection of different wireless nodes which basically cooperate the way they work is that these nodes they may not be able to talk to one another directly, but there are some intermediate nodes which cooperate with one another and they engage with each other. There is no centralized access point which can help coordinate all these different nodes. There is no fixed infrastructure and this is how these networks are built on the fly.

So, two nodes can communicate in these networks in a bi-directional manner only if they are within the communication range of each other. This is something that we already know and is quite intuitive as well. For instance, if we look at the figure in front of us so we have three nodes: nodes A B and C. So, as we can see from these figure nodes A and B are in the direct communication range of each other. And similarly B and C are also within the communication range of each other. Whereas, A and C are not. So, nodes A and C are not within the direct communication range of each other.

And how do we know that whether they are within the communication range of each other or not? This is basically if we look at in the figure, so surrounding node A we see a circle a dotted circle a dashed circle and this basically denotes the transmission range the communication range of node A. Similarly, for B and C also we can see the respective circles denoting, their respective communication ranges.

So, as we can see that in the case of node A within the circle of A basically the node B is positioned. Basically, what happens is this would mean that A and B are within the direct communication range of each other and they can communicate with each other. And, as I was telling you before so A and B are within the communication range of each other B and C are, but A and C are not. So, if A and C are not within the communication range of each other and A has to communicate with C then what A does is, A has to take help of node B in order to have the message that it wants to delivered to C delivered through it. That means, we will have to cooperate with node A in order for it to deliver its packet to node C.

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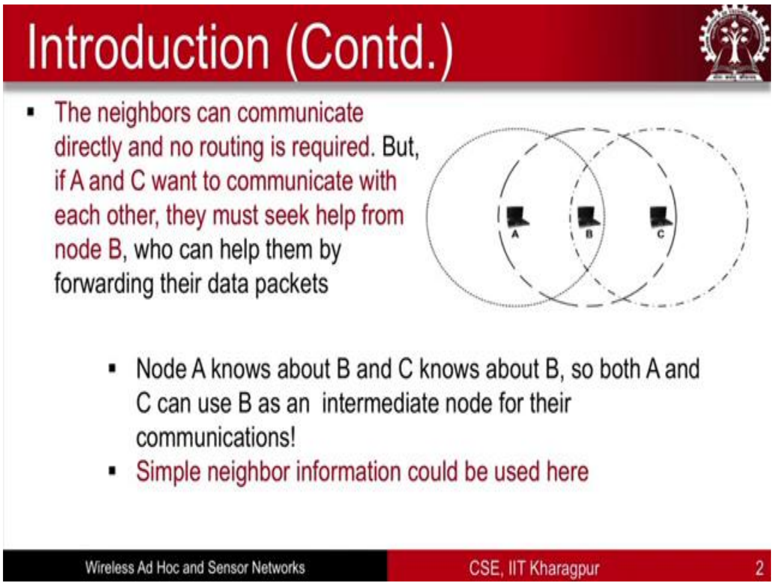


As we have the same that the neighbors can always communicate directly and there is no issues at all, and this is quite obvious. And we have also seen that A and C cannot talk to each other directly. So, there is a node B which in our particular case helps A and C to communicate. So, this node B will act as a forwarder of the data packet send by A to C. So, node A knows about B and C knows about B. So, both A and C can use B as an intermediate node for their simple communications.

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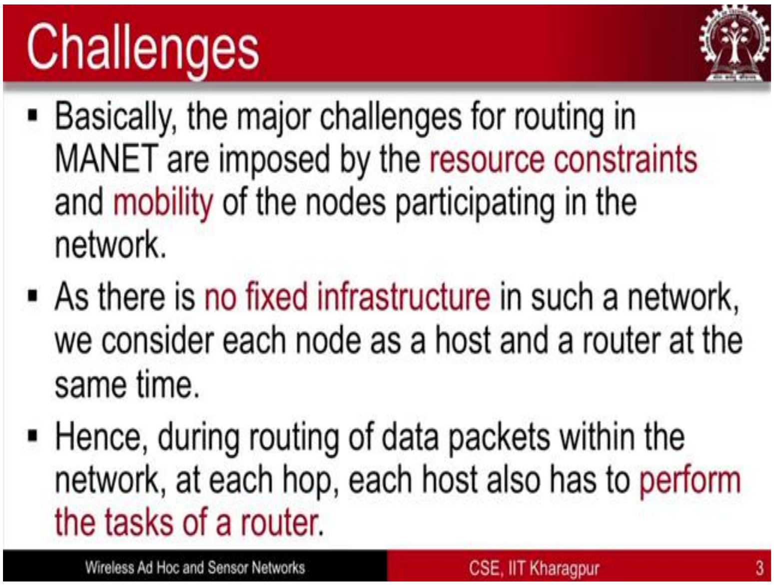


Now, the challenges with respect to routing in MANET are that first of all we have a heavily resource constraint mobile environment, the nodes are highly mobile, these nodes are highly resource constraints. It is not like another internet network where the nodes typically have much more capacity. These nodes themselves as we can recall from our basics, that these nodes are powered by batteries. And these batteries have very limited lifetime. So, consequently these nodes are very much energy constraint.

Similarly, there are other resources which are also constrained in these nodes. So, constraints with respect to the processor, capacity, and constraints with respect to the buffer capacity. So, like this actually there are many different issues, many different constraints that are posed to these networks. And these are some of the major challenges that are posed to routing as well.

So, as there is no fixed infrastructure in such a network; that means in MANET we consider each node as a host and a router at the same time. Hence during routing of data packets within the network and at each hop each host has to perform the task of a router. That means, that every node acts as a host as well as if required as a router a forwarder of the packets

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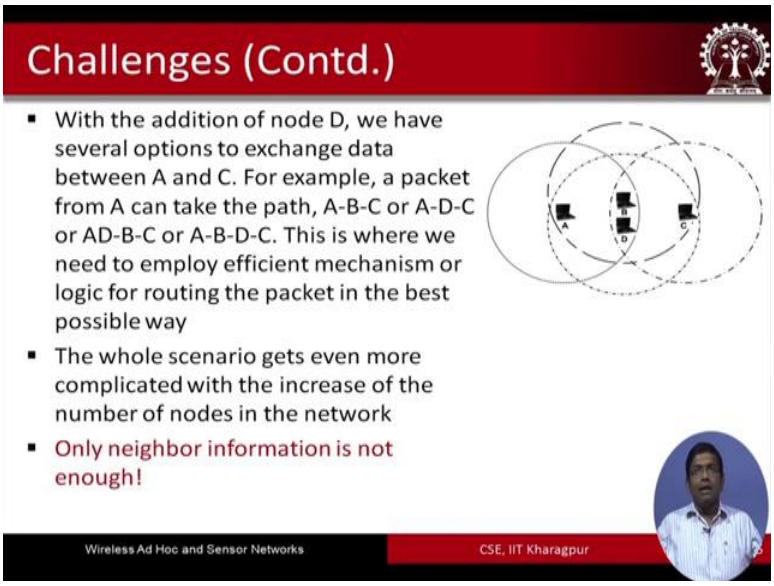


So, what we have seen so far is a scenario of three nodes A B and C. Now let us complicate the scenario little bit further by adding another node D. So, earlier we had seen that A and B are we in the communication range of each other, same goes for B and C. Now we have the node D and here A and D are within the communication range of each other. Similarly D and C are within the communication range of each other. Whereas, A and C like before or not. So, A has two choices to send the packet to C; either it can send it through node B or it can do it through node D, as we can see in the figure in front of us.

So, if you little bit look more closely we will be able to see that for node A to be able to send a packet to node C; it can either send it through the path A B C or A D C, or it can send as A D B and C or A B D and C. So, these are the four different possibilities that arises when we are adding just a fourth node to the existing scenario of three nodes. Just by doing the simple addition we are complicating the scenario. We have four different choices for node A to send it packet to node C. So either of these four choices have to be adopted. So, which one has to be adopted? Which of these four paths should be adopted in order for node A to be able to send it a packet to C?

Now, just imagine that when we are increasing the number of nodes even further, the situation is going to become worse. And is what is going to happen is that we are going to have many many more choices, exponentially large number of choices by increasing the number of nodes in the network. So, exponentially large numbers of paths are going to be you know increase the possibilities for a packet to traverse are going to increase. And that is between a pair of nodes, nodes A and C.

Similarly, just imagine that every node can act as a source and it can act as a router as well. And similarly any node can also become a destination node. So, then the whole scenario for the entire network is going to become much more complicated. So, the routing protocols; so this is a case where routing has to come into picture. So, routing basically decides that which of the possible paths can be taken by the different packets between a source and destination. This definition is not something new for MANET, this is a definition for routing for other types of networks as well. The only thing that we have seen is we have multi hop scenario and the case of routing in this multi hop scenario becomes difficult becomes, challenging because of the reasons that we have already seen.

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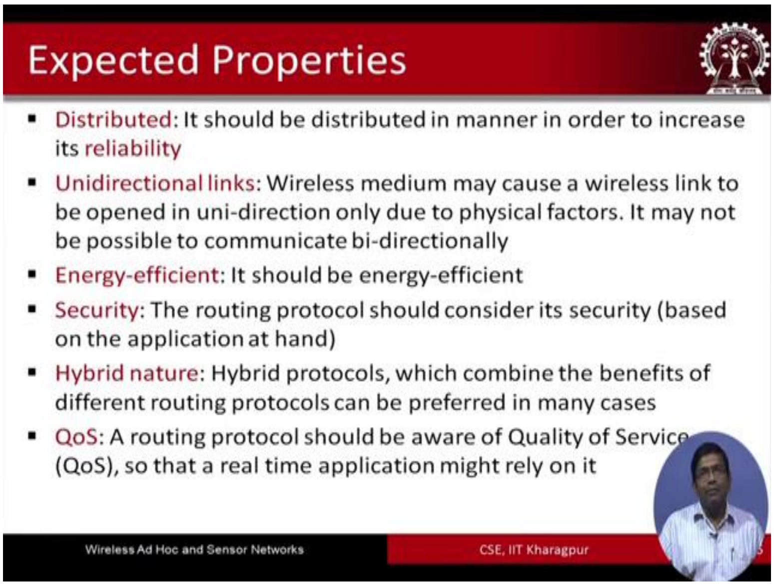


Now, there are multi hopping is one aspect, there are other aspects as well. So, let us look at it this whole problem from a more positive angle. So, let us try to keeping all the challenges in mind let us try to go through what are the properties that would be expected out of a routing protocol that is to be designed for MANETs. Let us look at it that way.

So, first of all we have a distributed environment. Obviously, the protocol that is going to be designed for it has to be distributed in nature, so it has to be distributed routing protocol. So, that is quite obvious. Second thing which is not very obvious is that the environment in which the nodes of MANETs operate, they are very error prone. So, there are different physical factors because of which the links can behave unidirectionally at different points of time instead of being bi-directional. So, this basically adds to the complexity gradually little bit further.

Now next thing is the energy efficiency. Obviously, as I told you before that energy is very crucial in these networks and the routing protocols that are proposed for these networks have to be energy efficient. Security is another thing, and this is something that we have gone through during the introductory part of the course. We have already seen that these networks are very much vulnerable to different types of security attacks. And consequently the routing protocols that are proposed should take that into account.

Hybrid nature of protocols because you know what happens is not a single solution would be able to offer solutions for different types of cases, and so what might happen is not a single solution, but a mixed of different types of solutions which inherently take care of the issues of different nature should be combined into a single protocol, a hybrid protocol and that can help in making routing efficient. So, hybrid nature of protocol is desirable.

And Quality of Service: so Quality of Service means for any network there is certain Quality of Service issues. Quality of Service issues with respect to the packet delivery guarantee, throughput bandwidth guarantees, delay, jitter, and so on. So, these are some of these Quality of Service guarantees that any network service providers should take into account. And the same thing when we think of applying; that means Quality of Service guarantees thinking of Quality of Service issues in a MANET the situation becomes difficult.

Because, first of all these networks are distributed they are mobile, they are error prone, there are security issues. And when you are talking about offering guarantees the scenario obviously becomes quite challenging.

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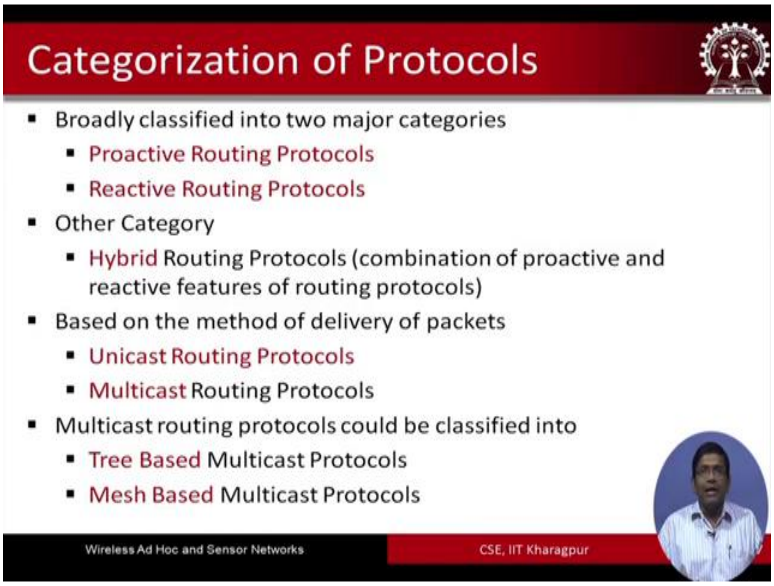


So, keeping security aside, there are different protocols that have been proposed routing protocols that had been proposed for use in MANETs. The reason I said security aside is that many of these base protocols that were proposed so far do not basically take security into account. But keep in mind that there are many other routing protocols more specifically which take security issues into account, so they are like secured routing protocols. So, for now we will not worry about the secure routing protocols, but the normal routing protocol.

So, the normal routing protocols for MANETs they can be broadly classified into two categories: one is the proactive routing protocols, the other one is the reactive routing protocol. So, we will go over each of these in a short file, but before that let me also tell you that there exists another category of routing protocols known as the highly routing protocols, which basically combine some of the features of the proactive and the reactive routing protocols. And they try to increase the efficiency of performance of these protocols.

So, this is one category of classification proactive, reactive, and hybrid; but there is another classification as well which is based on the delivery of packets. Based on the delivery of packets, the way the packets are delivered. The routing protocols can also be classified as unicast routing protocols or multicast routing protocols. Obviously, there is a broadcast routing protocol as well, but you know broadcasting is quite obvious so we will focus more on unicast routing protocols and multicast routing protocols. Unicast routing protocols is what we are going to go through one-by-one, but later on we will switch over gears and we will talk about multicast routing protocols towards the end of discussion of routing in MANETs.

So, routing protocols for multicasting; that means the multicast routing protocols can be classified into different types. We will go through the classifications one-by-one, but there are two very well known classifications of these protocols: one is called the tree based multicast routing protocols and the other one is the mesh based multicast routing protocols. So, tree based, mesh based, and there are a few other classifications of multicast routing. So, we will go over these different protocols when we go through multicasting in MANETs.

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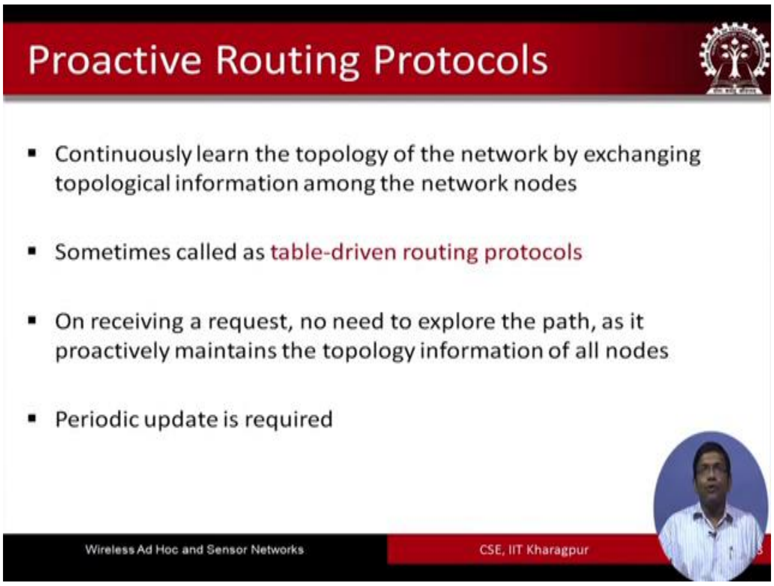


So, first let us look at what is meant by proactive routing protocols. In proactive routing protocols these protocols basically continuously learned the topology of the network by exchanging topological information among the different network nodes. These are also popularly known as table-driven or table based routing protocols. So, these protocols on receiving a request so they no need to explore the path any further, they will just look at their own table and they are going to find what is the path. And this table is updated proactively the table information. That means, that table contains what the routing information; that means that for a particular node the routing table is going to contain information such as that from this node to other nodes in the network what is the next hop that has to be taken.

And there are other things like sequence number, you know flags, etcetera, etcetera. So, which are additional information which are also stored in a routing table. So, these proactive routing protocols are quite similar, they have lot of similarity rather to the internet routing protocols that are already there such as OSPF or IP and so on.

So, these routing protocols need to ensure that proactively the tables that are stored in the different nodes of the network; table means the routing tables, they basically periodically update the content of the table. So, that has to be done proactively.

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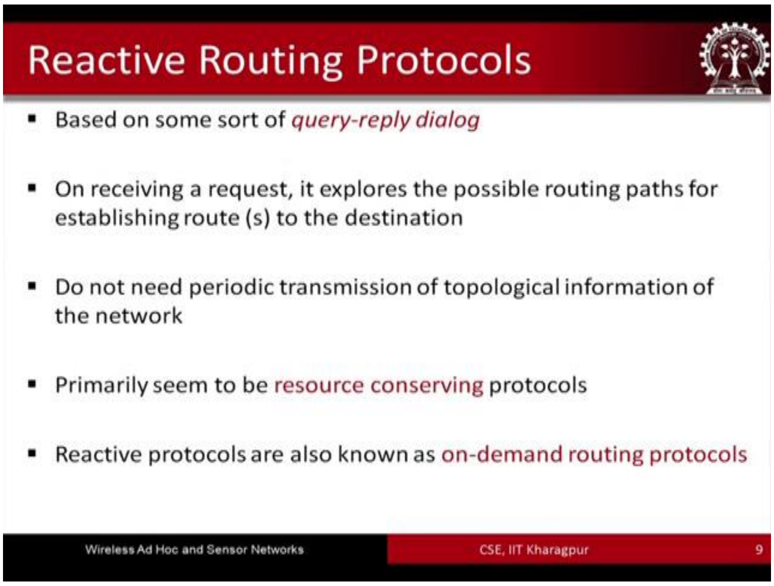


Reactive routing protocols on the other hand function through a query reply dialogue mechanism. Basically, you know on receiving a request these protocols export the possible routing paths for establishing routes to the destination. And they do not need periodic transmission of topological information of the network unlike in the case of proactive routing protocols. And these protocols, the reactive routing protocols on demand; that means, that whenever it is required they are going to explore they are going to discover the path to the intended destination and that information is going to be used for routing the packets further and later on if there is a request that comes in and you know that path is found to be useful it is going to be used otherwise again the path discovery is going to take place.

So, these might appear to a little bit cumbersome in the beginning, but we will go through few examples which will make the issues clearer. So, these reactive routing protocols are also by the way known as on demand routing protocols.

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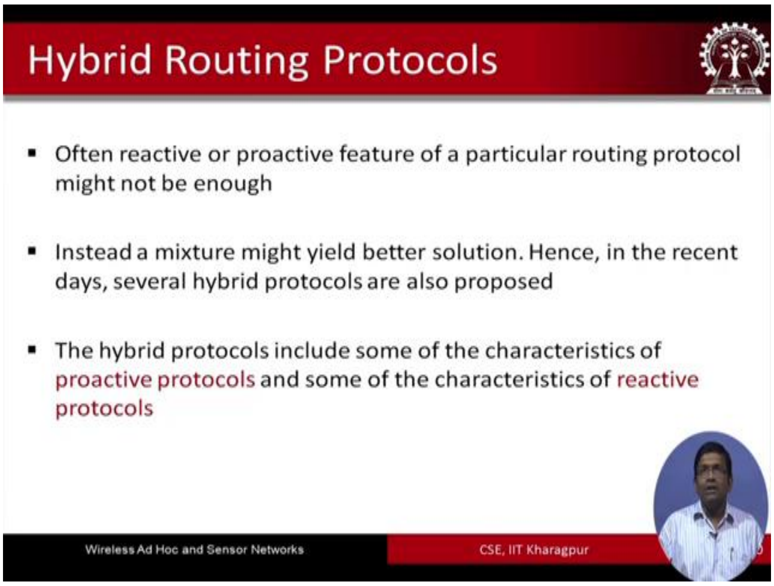


And I have already told you that combining the behaviours of some of the features of proactive routing protocols and some of the features or characteristics of reactive routing protocols we get a new class of routing protocols which is called the hybrid routing protocol. And these are expected to yield better performance, better solutions for routing under different circumstances.

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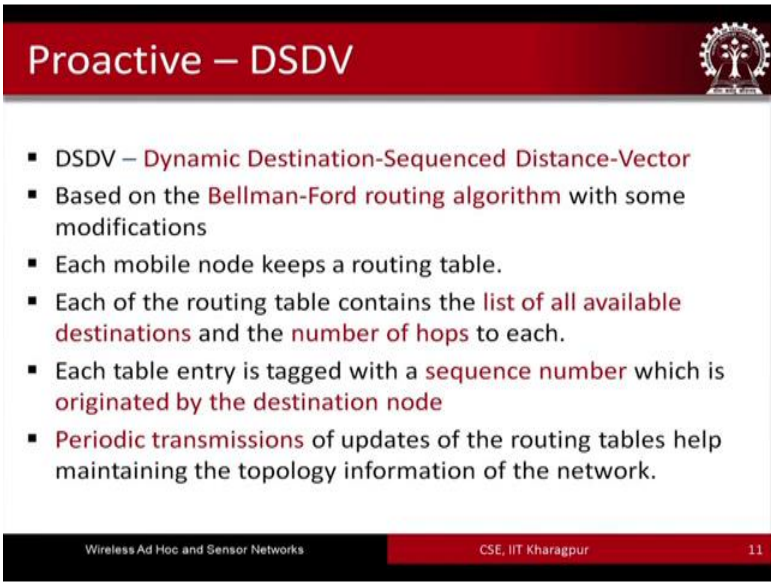


The first routing protocol that we are going to go through is the proactive is a proactive routing code protocol which is known as DSDV; the Dynamic Destination-Sequenced DistanceVector routing protocol. So, DSDV is the first protocol that we are going to go through. But keep in mind that whether it is DSDV all the other protocols that I am going to cover shortly and in the next few parts of routing in MANETs, we are not going to go through step-by-step of each of these routing protocols because that is not required. It is already there in the corresponding literature. And at the end of the slides you will be able to see the corresponding references that are available, where you can go through the protocols you know very closely one-by-one step-by-step you can go through. But here the whole idea is not to remember all these steps in so much of detail, but to understand that; what is the principle behind the working of each of these protocols?

So, DSDV is a very popular protocol. So, we will go through the corresponding features, the characteristics, the important characteristics highlighting the working of this protocol. As I told you that it is a proactive routing protocol. So, if it is a proactive routing protocol so there are tables which have to be maintained and it they have to be updated. That means, the contents of these tables have to be updated.

So, each of the routing tables of at the different nodes they contain the list of available destinations and the number of hops that are required to go to that particular destination. So, packets going to a particular destination through the different possible intermediate nodes how many hops are going to be taken. So, each table entry is tagged with something called a sequence number. We will go through what is meant by the sequence number later on. So, this sequence number basically ensures that the packets that arrive at a particular node they are not still. So they are basically time referenced, timestamp, so consequently the latest version of the packet that is received is going to be taken and the previous ones if they are received later on they are going to be discarded.

So, this is the sequence number. Periodic transmissions of the updates of the routing tables are made by maintaining the topology information of the network.

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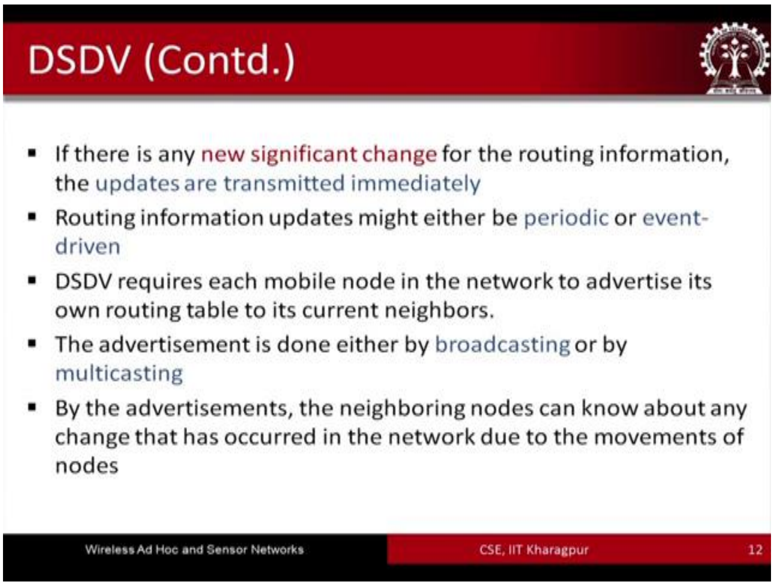


So, if there is any significant change for the routing information the updates are transmitted immediately. This is very important, because it is a proactive routing protocol and I have told you that what is the essence behind any proactive routing protocol DSDV being one also adopts the properties of proactiveness in routing. So, routing information updates might either be periodic or they can be event driven.

So, basically routing tables have to be updated; routing tables have to be updated because the information, the routes that might that were earlier valid may not be valid at a later point of time. Because in first of all we have a mobile network, second thing is that there are different other possibilities; possibilities because of different other environmental factors and so on, because of which the routes they change that information have to be propagated to the different tables.

So, DSDV requires each mobile node in the network to advertise its own routing table to its current neighbors. So, every node basically advertises to its neighbors that what is its routing table at different points of time. And so what is going to happen is quite obvious? So after you know certain deviations of time every node knows that who are the neighbors and how to reach the different other nodes in the network through the neighbors. So, this is what basically; a very simple a very very intuitive mechanism for routing has been adopted in DSDV.

So, this advertisement is done either by broadcasting or by multi casting. And by the advertisements then it the neighboring nodes can know about any change that has occurred in the network due to the movement of the nodes. So, this is quite obvious and I do not need to elaborate on this.

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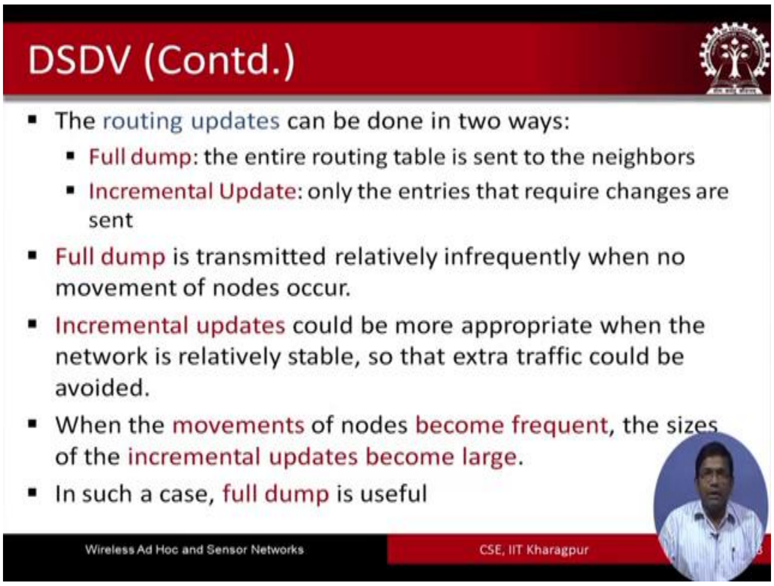


Now a very interesting feature: a very interesting thing that has to be kept in mind for using DSDV. So, how are these routing updates? It is all about routing updates. So, how are these routing updates done? It can be done DSDV suggests the authors of DSDV, the people who proposed the DSDV protocol they suggested that it can be done in either of the two ways.

So, one is called the full dump: full dump means that the entire routing table is sent to the neighbors. We have already seen that the DSDV talks about that every routing table every node basically shares it routing tables with its neighbors. So, how do you share it, either you periodically advertise your entire routing table to your neighbours so that they come to know about each and every content everything etcetera; so that is called the full dump. The other possibility is called the incremental dump and that is what is explained over here.

So, in incremental dump or incremental update rather. So, what you do is only that part which has changed is going to be propagated to the neighbors. So, only the entries that require changes are sent. And it is not like that full dump is always the best, better, incremental dump incremental update is better it is not like that. You know some cases you need to full dump in some other cases you need incremental dump. So, which one?

So, when the movements of the nodes become frequent the sizes of the incremental updates become large. So, consequently it is better to go for a full dumping in such cases. However, if the topology is ne not changing to fast then it might be a better option to go for full dump.

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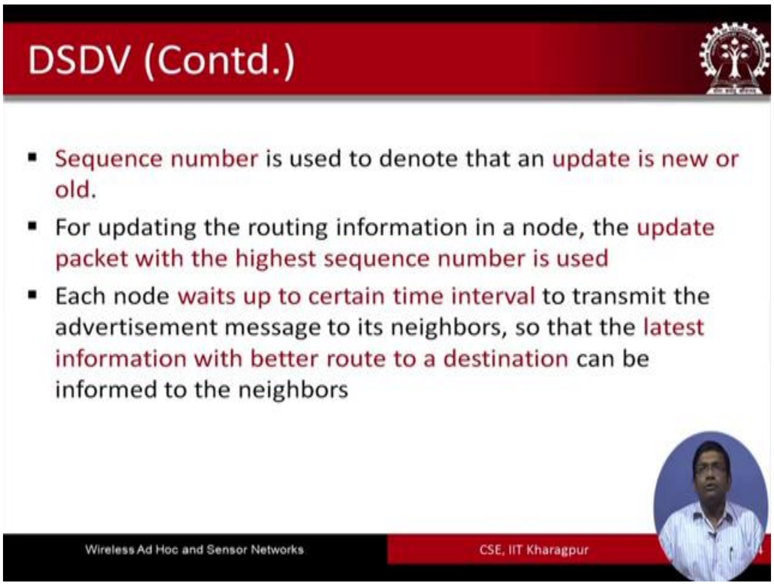


And sequence number is something that I have already told you. Sequence number is used to denote that an update is new or it is old. I mean when I am getting multiple copies of the same packet right. How do I know that whether it is the old packet, I mean whether it is the old one or a newer one how do I know? Then I mean the way it is handled is it has a sequence number which is basically time stamped.

So basically what happens is for updating the routing information in a node the update packet with the highest sequence number is used; highest sequence number means it is the most current packet. So, current most current packet means that it has the latest information. And this latest information will give a better route to the destination. This is the whole idea of maintaining the sequence number in these routing tables.

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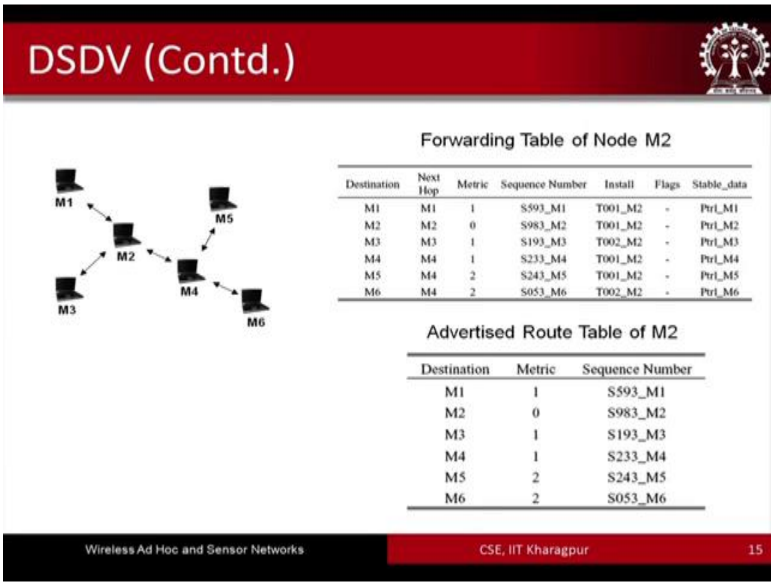


| Destination | Next Hop | Metric | Sequence Number | Install | Flags | Stable_data |
|---|---|---|---|---|---|---|
| M1 | M1 | 1 | S593_M1 | T001_M2 | - | Ptrl_M1 |
| M2 | M2 | 0 | S983_M2 | T001_M2 | - | Ptrl_M2 |
| M3 | M3 | 1 | S193_M3 | T002_M2 | - | Ptrl_M3 |
| M4 | M4 | 1 | S233_M4 | T001_M2 | - | Ptrl_M4 |
| M5 | M4 | 2 | S243_M5 | T001_M2 | - | Ptrl_M5 |
| M6 | M4 | 2 | S053_M6 | T002_M2 | - | Ptrl_M6 |

| Destination | Metric | Sequence Number |
|---|---|---|
| M1 | 1 | S593_M1 |
| M2 | 0 | S983_M2 |
| M3 | 1 | S193_M3 |
| M4 | 1 | S233_M4 |
| M5 | 2 | S243_M5 |
| M6 | 2 | S053_M6 |

Similarly, let now let us look at this particular figure. We have a scenario of how many nodes; 6 nodes, so M 1 through M 6. Now let us consider that we initially have a topology like shown in this figure. And let us focus on the forwarding table of node M 2.

As you can see over here node M 2 has direct neighbors M 1, M 3, and M 4. So, basically if M 2 has to send something to M 5 it should send to M 4 and expecting that M 4 will forward it to M 5. So, this is how these entries are made. So, the first three; let us just focus on the first three columns of this routing tables, the forwarding table for node M 2.

So, from node M 2 to M 1 the next hop is going to be M 1, the next hop is going to be M 1. And matrix means the number of hops, how many hops? One hop. Now, from node M 2 to M 2 the next hop is going to be M 2, same node. And number of hops is 0. So, from M 2 to M 3 next hop is M 3 number of hops is 1; M 2 to M 4 next hop is M 4 number of hops is 1; M 2 to M 5 next hop is M 4 number of hops is 2; M 2 to M 6 num next hop is

M 4 number of hops that are required is 2. So, this is basically derived based on this particular topology.

Now let us look at a scenario, because we are dealing with MANETs. So, it might so happen that the node moves let us assume a very simple scenario where the node M 3 moves to a new position as we have just seen. So, M 3 basically changes its position and it has now connected let us say with M 6; that means that they are using the transmission ranges of each other.

Now, let us look at what is going to happen to the forwarding table of node M 2. So, what happens as you can see over here is that from M 2 to M 3 earlier it was 1 hop and the next hop node was node M 3 alone. Now in this present scenario as we can see the updated information will show you; that from M 3, sorry from M 2 to node M 3 the next hop so if you have from M 2 to node M 3 if you want to send the packet then the next hop is M 4 not M 3 like before, and the number of hops is how many 1, 2 and 3. So, this becomes the revised routing table.

In this particular case because it is a very simple change probably we will go for an incremental update, not a full dump. Full dump would be more valid like if all the different nodes are moving etcetera and you know instead of so many incremental updates you just update, you share the entire table with your neighbors.

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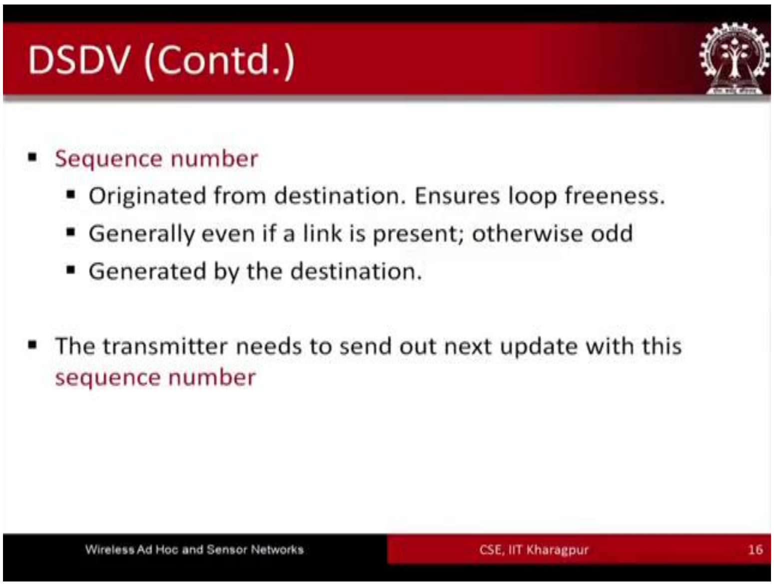

So, sequence number; I have already told you a couple of times. It is originated from the destination for ensuring loop freeness. And this number is generally even if a link is present; otherwise it is odd. The transmitter needs to send out the next update with this sequence number. So, the sequence number is basic sent along with the update.

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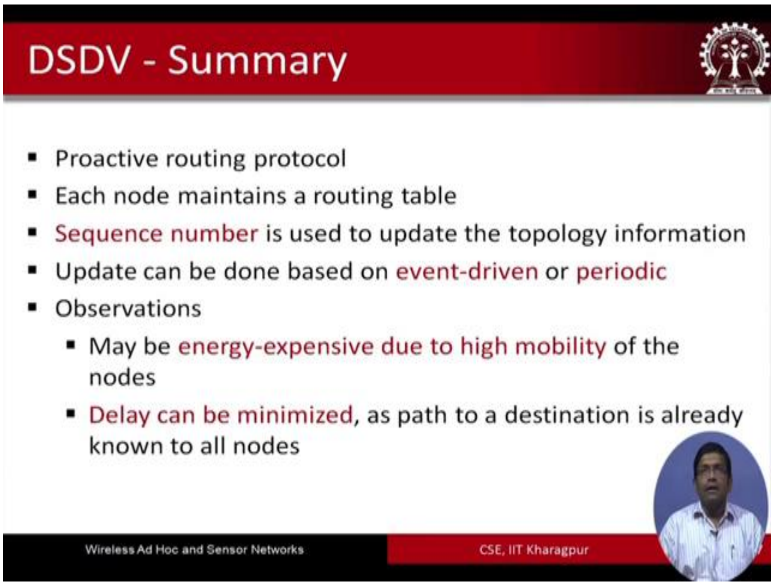


So, in some we have already gone through the different important features of the proactive routing protocol DSDV, where each node maintains a routing update. There is a sequence number that is stored in the routing tables which is used to update the topology information. And the update can be done based on event-drivenness; in an event-driven manner or in a periodic manner. And we have few observations.

So, if we have a scenario where the nodes are highly mobile, so it might be more energy expensive to adopt DSDV. And delay can be minimized using DSDV as a path to the destination is already known to all the nodes. On the other hand as we will see later on that if we are adopting instead of DSDV a proactive routing protocol if we are adopting a reactive routing protocol then delay becomes even more crucial delay becomes even more crucial because you know typically a reactive routing protocol does not in many cases. I mean it is not necessary. So, if it is rather if it is not able to find if a packet has come and the packets destination is known and in the route cache it is not already found using a reactive routing protocol, when using a router reactive routing, but is not already found how to reach the destination node.

So, what happens is these reactive routing protocols will start a discovery process and using that discovery process basically the roots are discovered, you send a request out, the destination response back and the path gets confirmed. So, this entire process as we can see basically increases the delay propagation delay of the packet. That means, the delay using these reactive routing protocols becomes more compared to DSDV and many other or rather all other proactive routing protocols.

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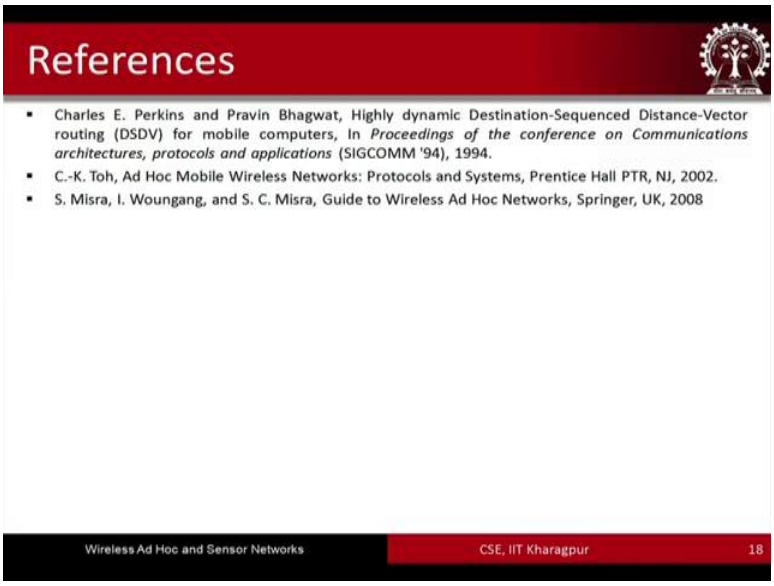


So, these are the references. So, I do not need to elaborate this, but you know DSDV and the first reference will help, the next two are the books that we have already been referring to in the other lectures of this course.

Thank you.