Wireless Ad Hoc and Sensor Networks
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Lecture – 05
Cooperation in Mobile Ad Hoc Networks-Part-II

Let us start with our discussions on Cooperation in MANETs. So, we saw that there are different mechanisms of offering incentives for cooperation in these networks. Primarily there are they are of two types: one is the virtual currency based systems, the other one is called the reputation based systems. So, first we are going to look at the virtual currency based systems.

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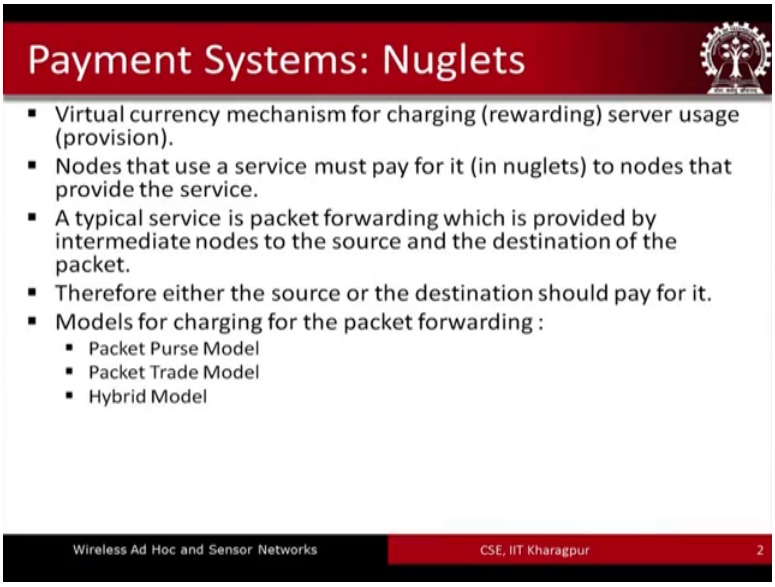

So, nuglets is one of these types of systems, where basically there is some kind of virtual currency mechanism that is used for charging or rewarding server usage or provisioning. That means, those nodes that user service will have to pay to the nodes in terms of this virtual currency is called Nuglets to the nodes that are providing the service. So, the service providers they are going to get paid, whereas the loops which require the service they will have to in turn pay for it.

So, this is very similar to what happens in a real marketplace. In a real marketplace when we go and we want to buy a commodity or we want a service, so what we do is that buyer will have to pay to the seller in terms of currency, so in terms of some money. And

a similar sort of thing we are trying to simulate in this sort of systems; the virtual currency based systems.

So, one of the typical services; so it can be any service you know. For any service that is offered by this provider this sort of mechanism can be implemented. So, a very simple kind of service could be the forwarding of the packets. Basically the node which is forwarding the packet it is going to pay the node; which is it is going to get paid by the node which is sending the packet to it. So, this is how this particular mechanism works.

And this payment is in the form of nuglets. Therefore, who pay? Whether the source pays or the destination pays; who pays for the service. So, depending on that there are two types of models that have been proposed: one is called the packet purse model PPM, the other one is called the packet trade model PTM. And in the recent times there has been another model which is called the hybrid model that has also been proposed which basically has a mix of flavor of the PPM as well as the PTM.

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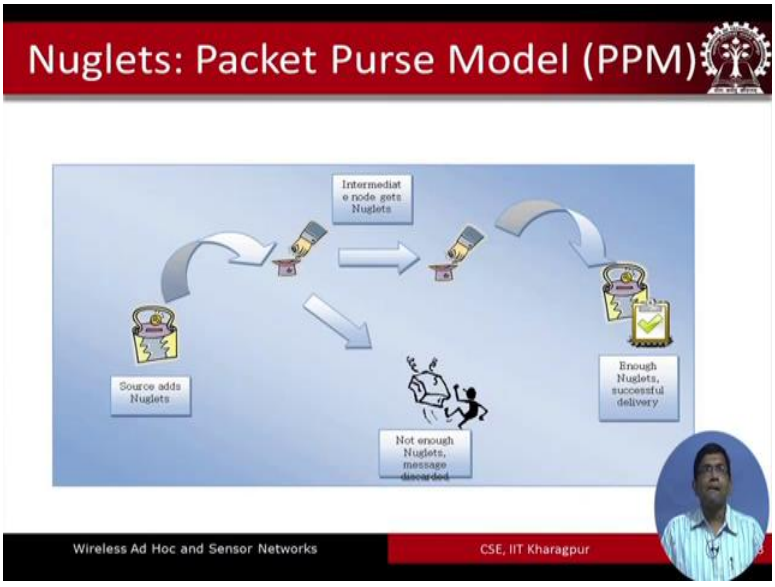

So, let us look at this particular figure to understand how the PPM model works. Let us say that we have a multi hop scenario, a network where there is a source node which wants to send some packet to the destination node. And it has to do it over a multi hop path involving two intermediate delay nodes as we can see in this particular figure.

So, basically what happens is along with the packet in the PPM model the source node adds these virtual currencies is called nuglets and would send it forward. The intermediate node receives the packet along with the nuglets, gives some nuglets and forwards it to the next hop neighbor, with the hope that the next stop neighbor would also do the same. And finally, the packet is going to be delivered to the intended destination node of the packet.

As we can see over here that if any of these intermediate nodes does not have the incentive of keeping some nuglets; that means, that if there is not enough nuglets that are left along with the packet, then that packet is going to be discarded by that particular node. So, it is it will not be forwarded further. So, the owners are on the source node to add enough nuglets so that to ensure that the packet will be eventually delivered to the intended destination node.

But as you can see that there are although if this model comes with some advantages there are some obvious disadvantages. For example, estimating one challenge or a disadvantage would be; estimating the what would be the enough number of nuglets that has to be added by the source node to ensure that all the intermediate nodes are going to keep some of them so that the there would be enough nuglets that will be still left when the packet finally arrives at the destination node. So, this is one thing. Second thing is; how many nuglets the intermediate nodes are going to keep, that is another challenge.

So, having coming up with a model to determine how many nuglets each of these intermediate nodes are going to keep and whether they are going to abide by that particular protocol that is set is also another challenge in adopting this kind of model. So, this is the PPM model.

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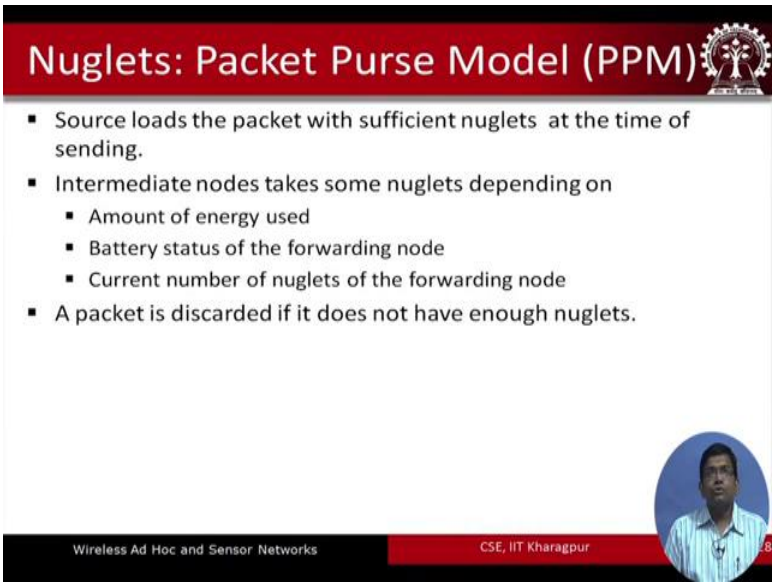

And let us now look at some of the other characteristics. So, the source node basically loads the packets with sufficient nuglets at the time of sending, as I just said. The intermediate node takes some nuglets depending on the amount of energy that it has used; the battery status of the forwarding node; the current number of nuglets of the forwarding node and so on and so forth.

And as we have seen a packet is discarded if it does not accompany enough number of accompany with enough number of nuglets. So, it has to the source node has to ensure that enough number of nuglets are added to the packet.

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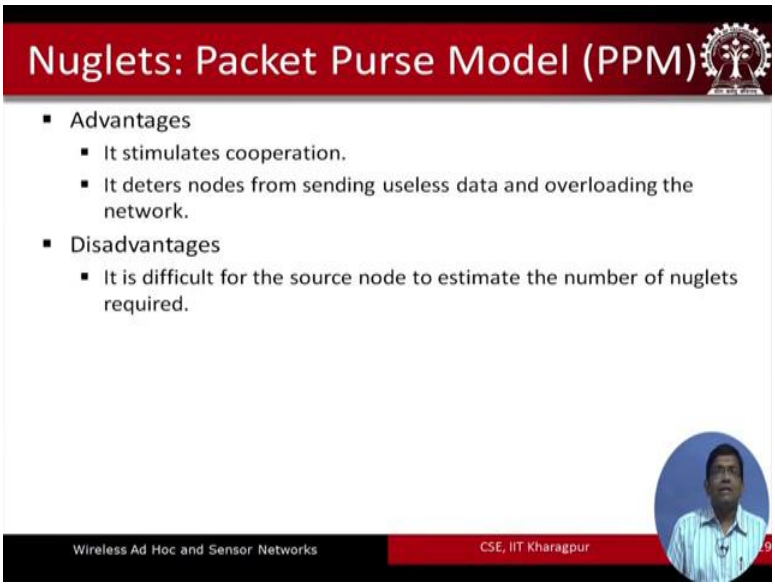

Advantages: it stimulates cooperation, it deters nodes from sending useless data and overloading the network; these are quite obvious. And disadvantage: I have already told you that it is difficult for the source node to estimate the number of nuglets that are required, because in that case the source node would have to know the number of hops the packet is going to take in order to get finally delivered at the intended destination node. And this particular information is typically not known to any source node a priori in an Ad-hoc network.

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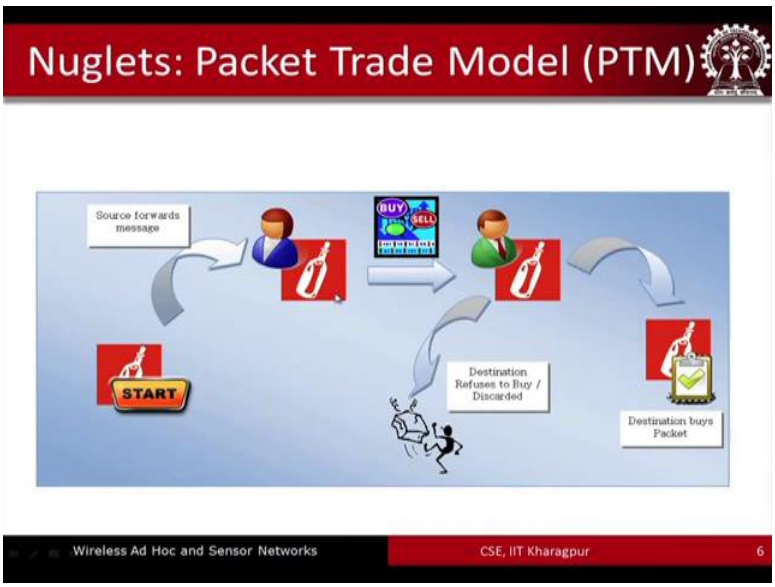

Now, the other model is the PTM model. In the PTM model we have a similar multi hop scenario, but instead of the source node thing; that means adding enough number of nuglets there is another kind of buying selling mechanism that is simulated between the intermediate nodes. There is some kind of a buy sell mechanism that is. So, basically in this PTM model what has to be ensured is that; the intended next hop neighbor or the destination node has to buy the packet from the previous upstream neighbor.

So obviously, in this model if the destination node refuses to buy the packet or an intermediate node in the chain refuses to buy the packet then the packet is going to be discarded, it is going to be dropped.

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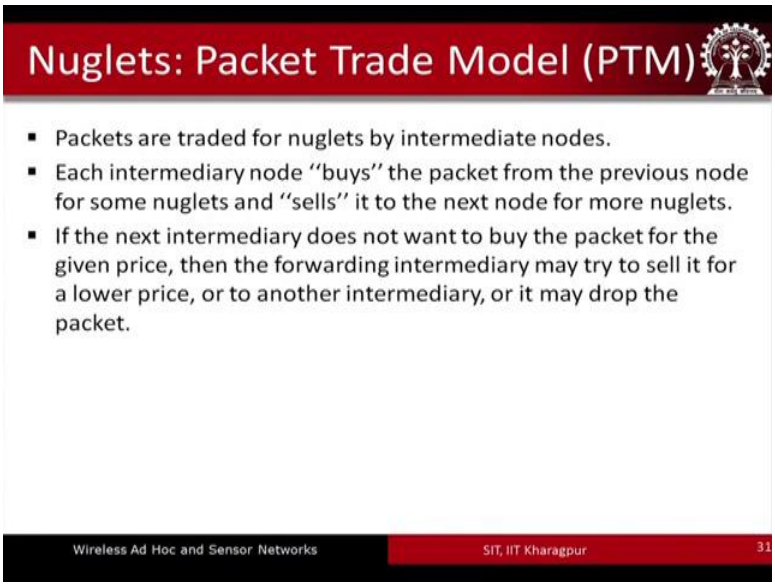

So, packets are traded for nuglets by the intermediate nodes. Each intermediate node "buys" the packet from the previous node for some nuglets and "sells" it to the next node for some nuglets. If the next intermediary node does not want to buy the packet for the given price, then the forwarding intermediary may try to sell it for a lower price, or to another intermediary, or it may drop the packet if there is no other option that is remaining with that particular node.

That means no one is willing to buy at the same price or a lower price. So, in that case there is no other option and the packet has to be dropped.

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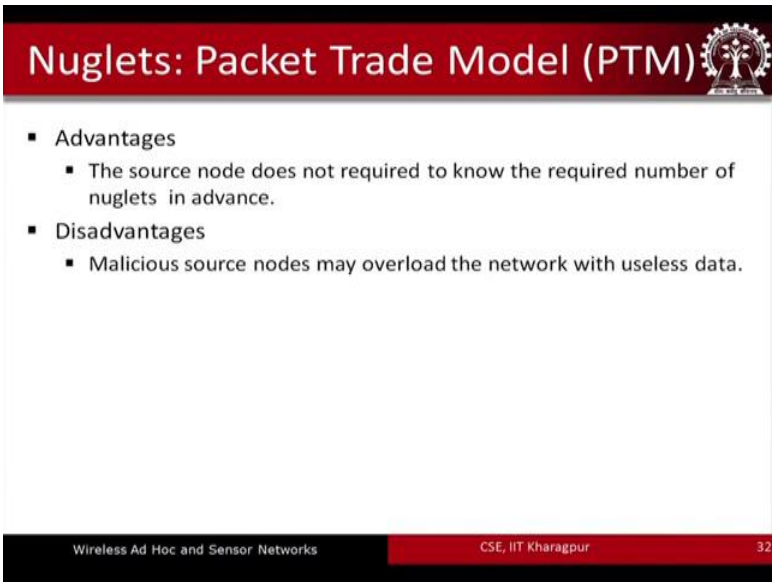

Advantageous: the source no does not require to know the number of required number of nuglets in advance. And disadvantages are: that the malicious source nodes may overload the network with useless data. So, this is quite obvious I and I do not think that I need to elaborate on this particular point of disadvantage.

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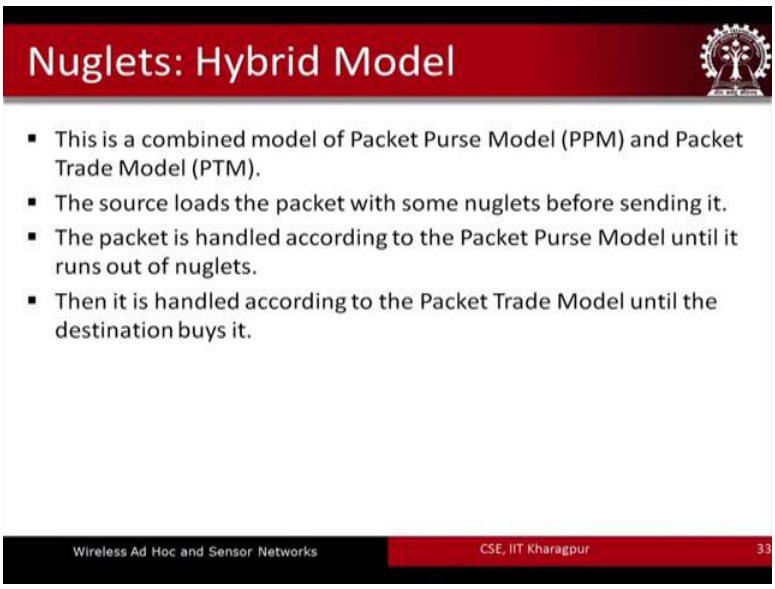

In the hybrid model the properties of PPM and PTM both are inherited. The source node here loads the packet with some nuglets before sending it like in the PPM model. The packet is handled according to the PPM until it runs out of nuglets. So, till that point you

know until the packet runs out of nuglets it will be PPM, then it is handled according to the PTM model that mean some other intermediate node or the destination will have to buy the packet from the previous neighbor which holds onto the packet.

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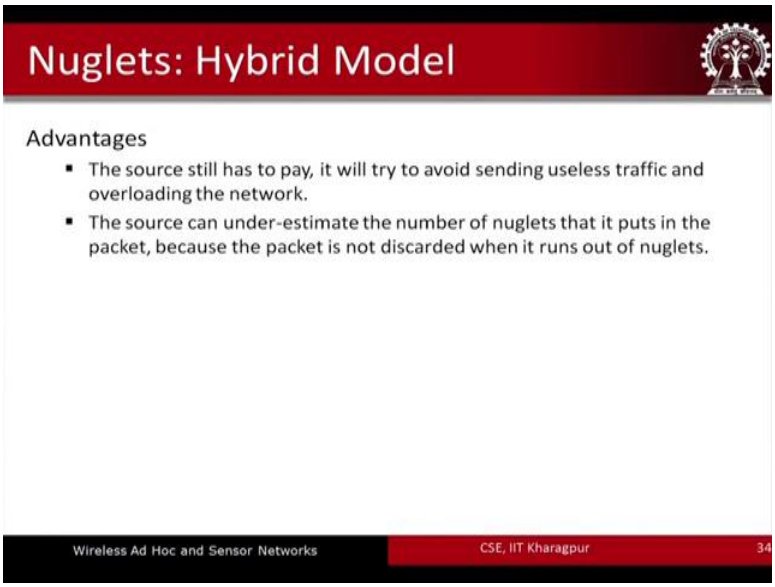

So, the advantage of this hybrid model is the source still has to pay, it will try to avoid sending useless traffic and overloading the network. And the source can underestimate the number of nuglets that it puts in the packet, because the packet is not discarded when it turns out of nuglets.

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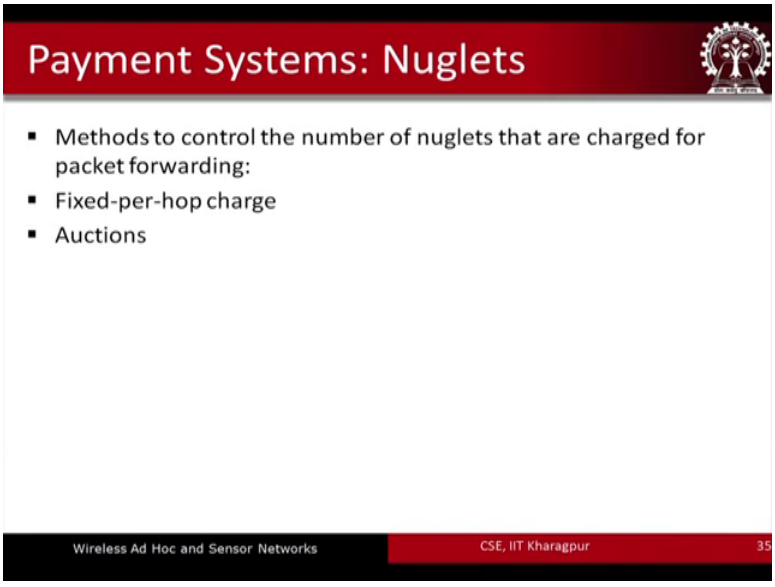

So, the way to control the number of nuglets that are charged for packet forwarding can be of two types: one is the fixed-per-hop charge; that means it is the fixed charging model, the other one is an option based model. In the same way as we encountered options in a real marketplace. So, it can be a fixed charge model or an option based model.

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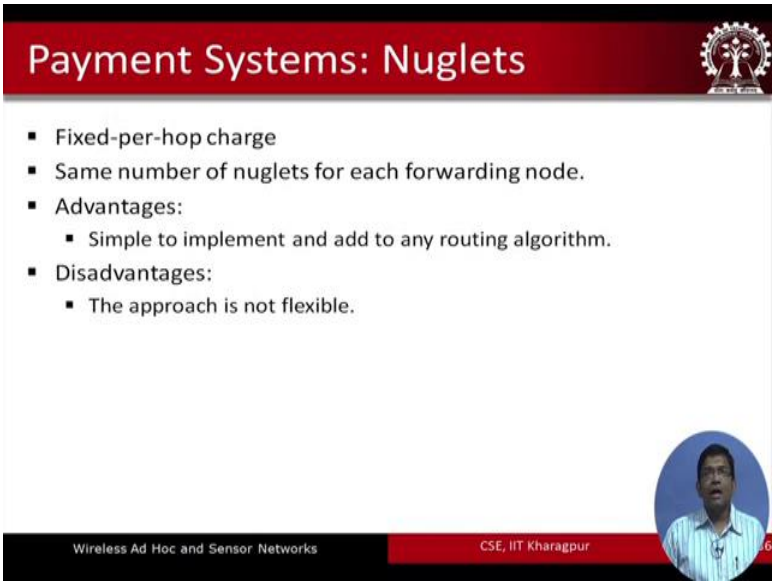

So, in a fixed-per- hop model charging model same number of nuglets are kept for each forwarding node. That means, every forwarding node would be keeping the same number of nuglets. The advantage of implementing such a fixed model is that it is simple to implement. Whereas, the disadvantage is that this approach is not very flexible.

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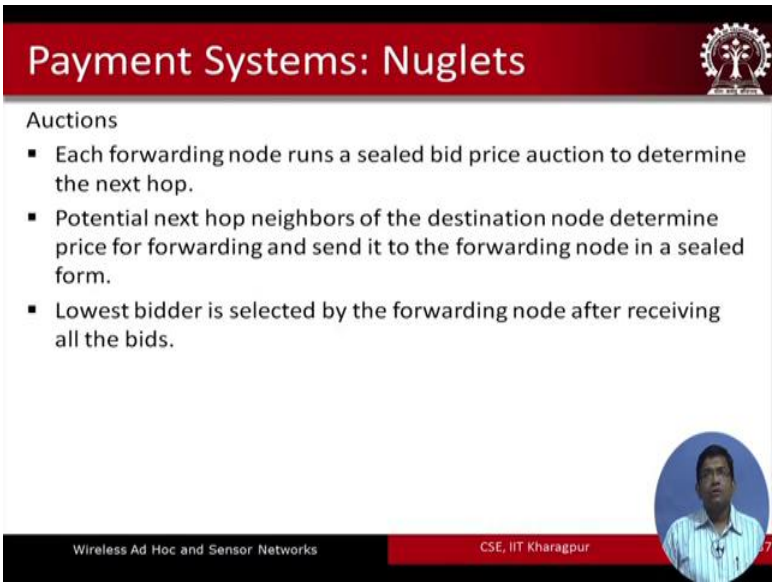

The auction based mechanism on the other hand use a sealed bid price oxygen mechanism to determine the next hop. So, among the possible next hop neighbors whoever bids the highest will be given the packet for forwarding it. So, the lowest bidder is selected by the forwarding node after receiving all the bids.

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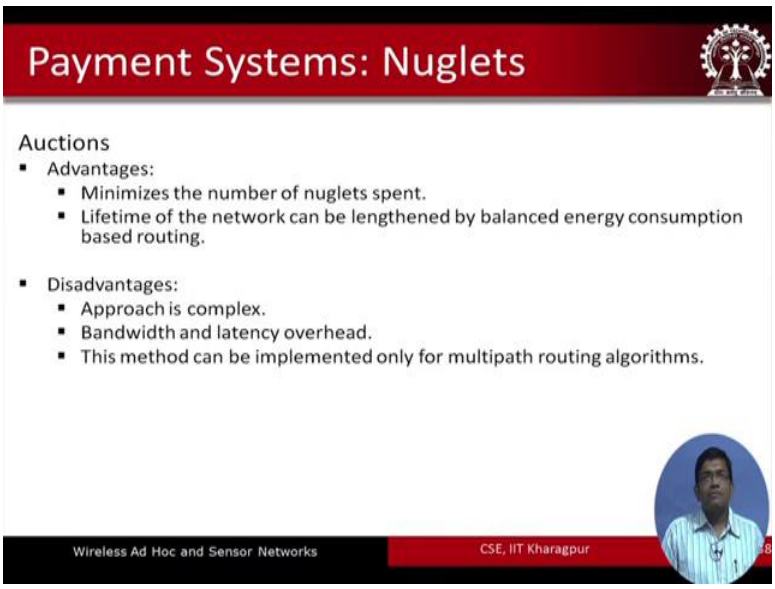

The advantages of auction based mechanism are minimizing the number of nuglets that are spent. And the second is lifetime of the network can be lengthened or it can be prolonged by balanced energy consumption based routing. In terms of the disadvantages,

this is not so simple to implement it is rather complex and there is a bandwidth and latency overhead. So, this method can be implemented only for multipath routing algorithms.

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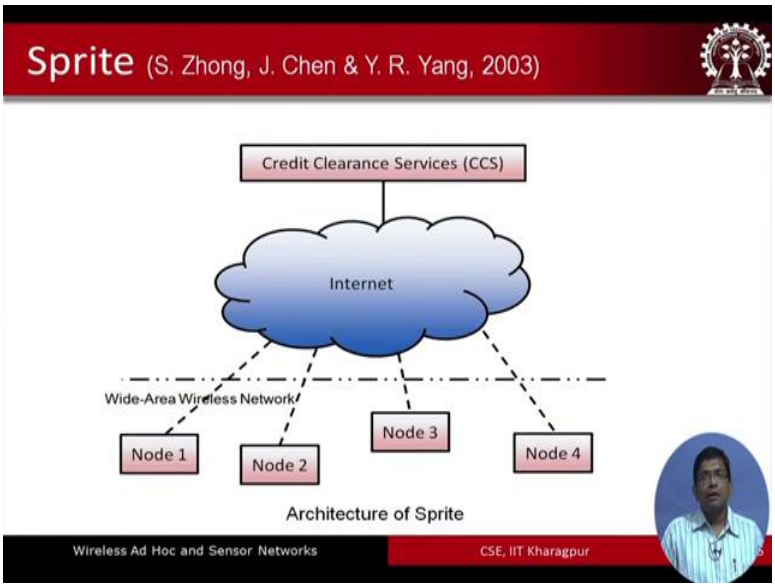

So, the other type of mechanism is called the Sprite. This is also a financial kind of mechanism, a currency based mechanism, but the way it operates is different from the way nuglets operates; nuglets base based mechanism operates. Here in sprite, what we see is an adoption of some kind of mechanism by which the credit card companies operate.

So we have, as we can see in this figure a scenario where there are large number of nodes, I mean a set of nodes in a wireless network let us say MANET. And these nodes they would connect in this particular model they have adopted this particular architecture, in the spite model this particular architecture is adopted. So, these nodes in the MANETs they would be connecting to some kind of great theorem service, a very similar kind of service as it appears in credit card cum credit card services in real credit card services. And these nodes are going to connect to the CCS via the internet.

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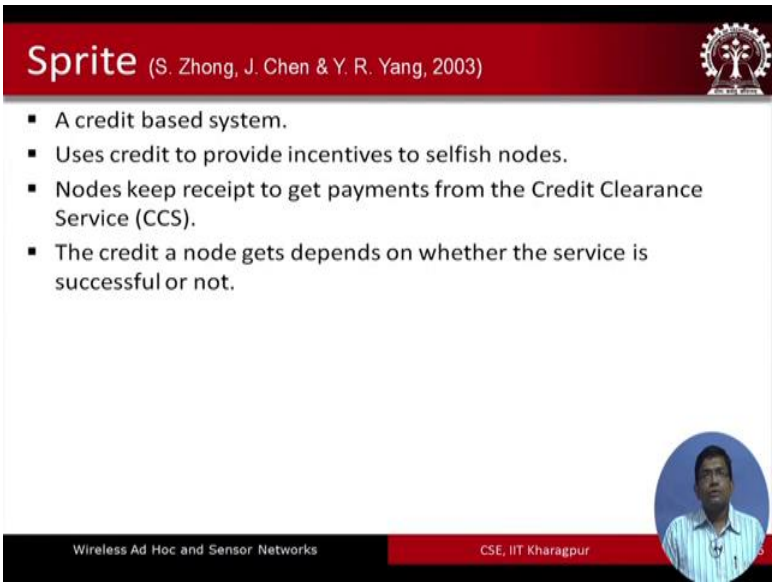

So, these systems use credit to provide incentive to the selfish nodes. These nodes keep receipt to get payments from the credit clearance services. The credit a node gets depends on whether the service is successful or not. So, these receipts are going to be kept by the different nodes and these are going to be in test from the CCS.

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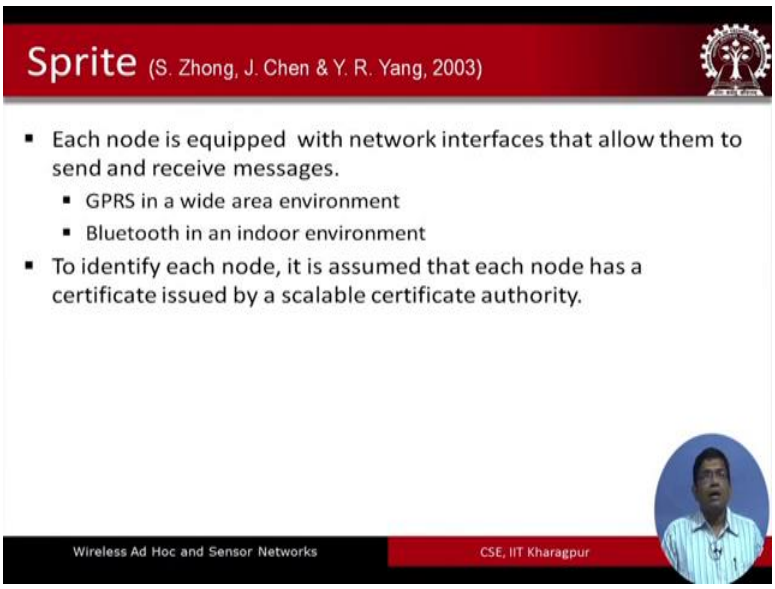

So, each node in sprite is equipped with network interfaces that allow them to send and receive message. And to identify each node it is assumed that each node has a certificate

issued by a scalable certificate authority. So, this is how it is securing this particular mechanism.

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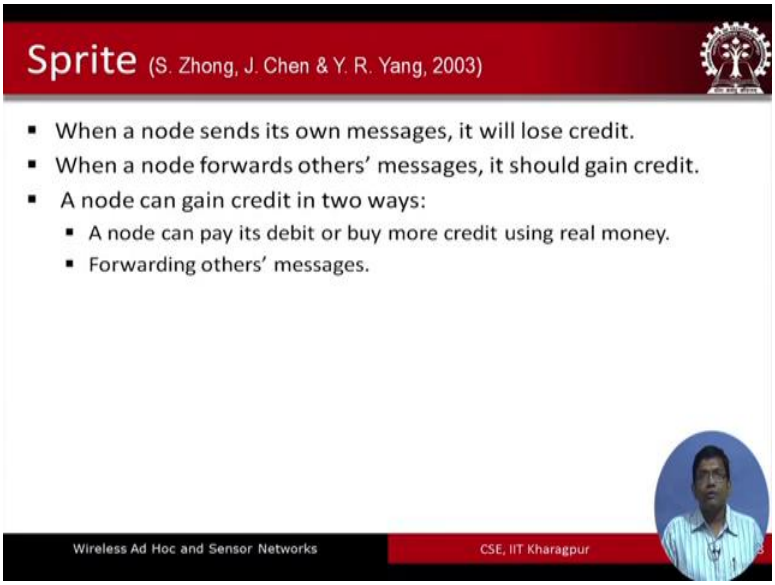

So, when a node sends its own messages it will lose credit. So, when you are sending you are doing it at the cost of your own credits. So, when a node forwards the others messages it is earning the credit. Very similar to what we had seen in the PPM model or the like another; PTM also very similar. A node can gain credit in two different ways: a node can pay its debit or buy more credit using real money.

So basically using real money also it can buy some credits, and by forwarding others messages. These are the two different ways in which a node can gain credit, it can buy credit it can get more credit from the system.

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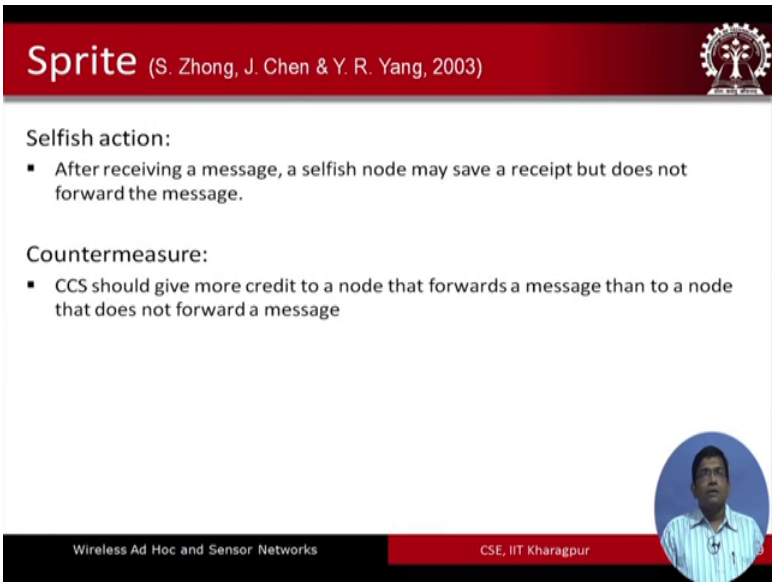

So, selfishness is something that is typical in sprite. So, after receiving a message a selfish node may save a receipt and would not forward the message. So, this is something that can still happen and sprite is vulnerable to that. The countermeasures to you know tackle this kind of selfish behavior would be that the CCS; that means the credit clearing service should give more credit to a node that forwards the message then to a node that does not forward the message.

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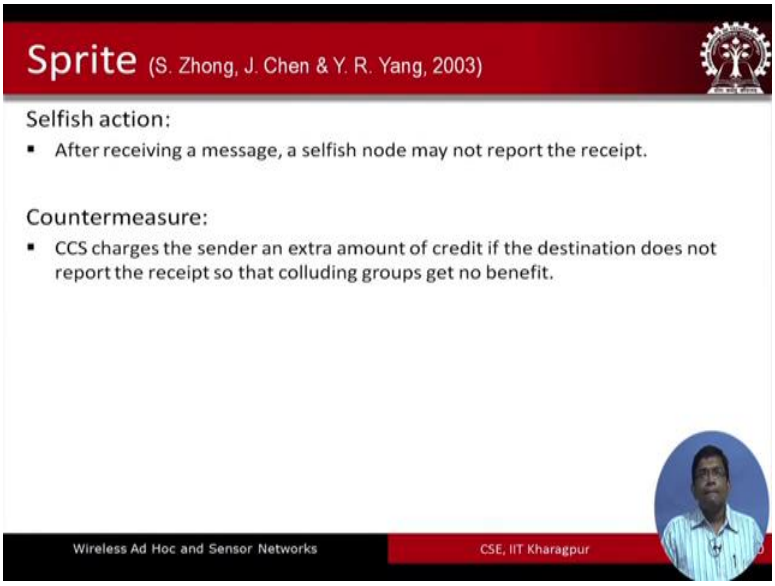

So, the other selfish action could be that after receiving message a selfish node may not report the receipt. And the countermeasure for this would be the CCS charges the sender and extra amount of credit if the destination does not report the receipt so that the colluding groups get no benefit.

So, this is quite obvious countermeasure to counter this kind of selfish action. So, these are the two different types of selfish actions that can occur and these countermeasures are also mentioned.

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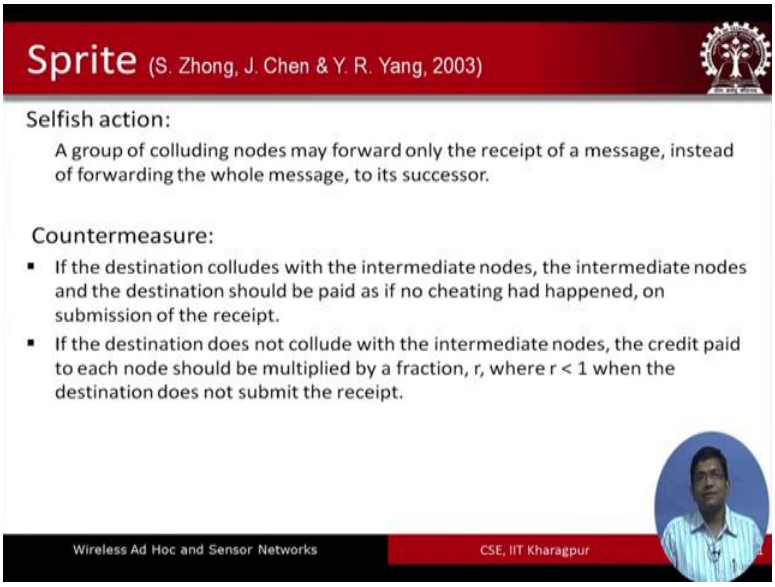

Another one is that in sprite a group of colluding nodes may forward only the receipt of the message instead of forwarding the whole message to its successor, you see. And the corresponding countermeasure is mentioned over here. So, here actually what would happen is if the destination colludes with the intermediate nodes: the intermediate nodes and the destination should be paid as if no cheating had happened and no submission of on submission sorry, on submission of the receipt.

So, let me repeat: that if the destination colludes with the intermediate nodes the intermediate nodes and the destination should be paid as if no cheating had happened on submission of the receipt. If the destination does not collude with the intermediate nodes, the credit paid to each nodes should be multiplied by a fraction r, where r is less than 1 when the destination does not submit the receipt.

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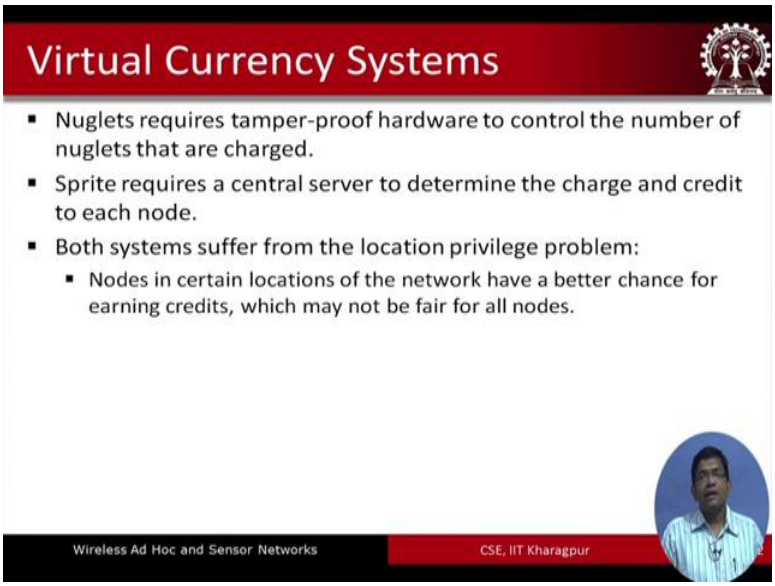

So, this is a countermeasure against the third kind of selfish action that can be adopted by any of the nodes in sprite. So, these are the three different ways in which a node can behave selfishly even when adopting sprite.

So, let us look at the virtual currency systems as a whole. So, nuglets based mechanism basically you know its attractive, but the disadvantage is that adoption of such a mechanism would require implementing some kind of tamper-proof hardware to control the number of nuglets that are charged. Sprite in particular requires the central server to determine the charge and credit to each node. So, both of these systems whether it is the PPM PTM, that means nuglet based system or the sprite have two different types of advantages.

Additionally, both of these systems they suffer from something well known as the location privilege problem Which means that the nodes in certain locations of the network have a better chance of earning credits, which may not be fair for all the nodes in the network. So, certain nodes get privileged over other nodes due to their location in the network.

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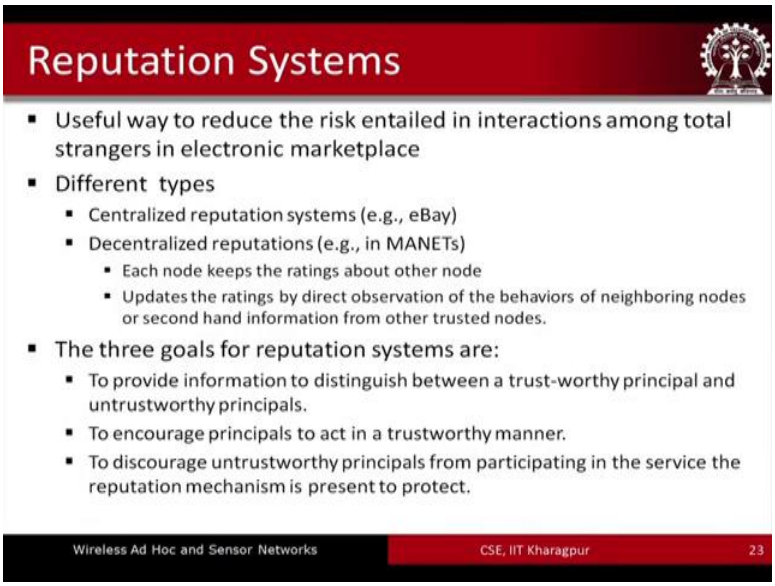

On the contrary there is this whole separate class of systems for countering misbehavior, which is called the reputation based systems, which have been proposed. Which again does not suffer from some of these disadvantages that we have seen, but they have their own set of advantages other set of advantages and disadvantages.

As the name suggests reputations systems are basically where the reputation of the behavior of the different nodes are kept track off, and based on the reputations that are tracked and based on that the routing decisions are made. So, reputation systems can be classified into two types: one is the centralized reputation systems, very similar to what we see in systems like the eBay or Flipkart and so on, where basically the reputation of the buyers and the sellers are kept track of in a centralized manner. That means, there is one or more servers who keep track of the reputation of the buyers and sellers in a centralized fashion.

Decentralized reputations are basically typical in MANETs, where each node keeps the ratings of other nodes in the networks. And based on this particular activity they update the ratings by direct observation of the behaviors of neighboring nodes or secondhand information from other trusted nodes. Either through direct observation of the behaviors of the neighboring nodes or from secondhand information from other trusted nodes. This is how the decentralized reputation mechanisms which are typically adopted in MANETs works.

The three goals of reputation systems are: to provide information to distinguish between a trustworthy principal and untrustworthy principles, to encourage principals to act in a trustworthy manner, to discourage untrustworthy principals from participating in the service the reputation mechanism is present to protect. So, these are three important objectives of reputation based systems.

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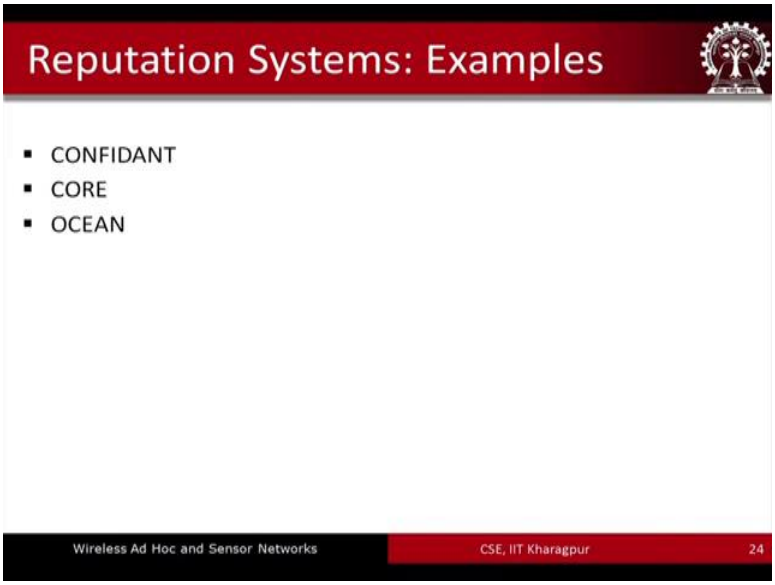

Specific examples of protocols belonging to this class of systems are: confident, core and ocean. All of these three are basically acronyms, the corresponding full forms are not given over here, but these are well known by this particular acronym names; confident, core and ocean.

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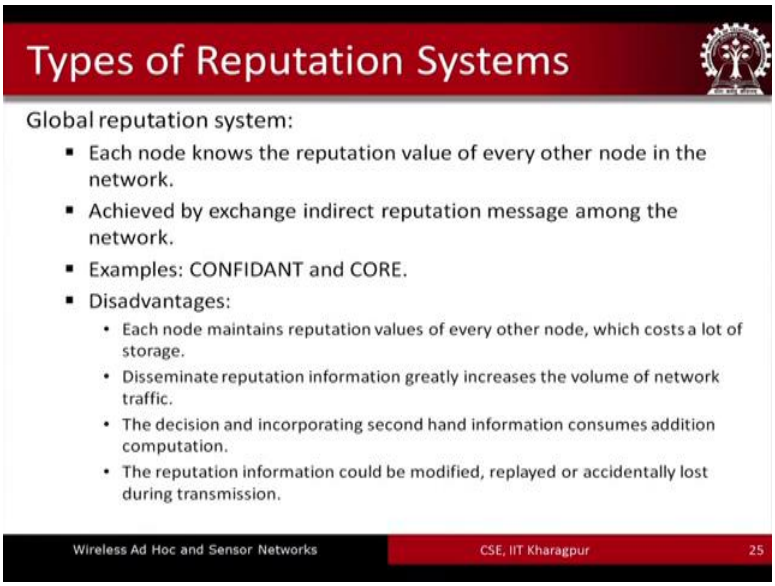

So, the reputation systems can be of two types: in the global reputation system, where basically each node knows the reputation value of every other node in the network. And this can be achieved by exchange of indirect reputation message among the different nodes in the network. Confident and force specifically belong to this particular category. There are several disadvantages also of adopting a global reputation system. First is that each node maintains a reputation values of every other node, and that is not a very good thing because it would cost a lot of storage and that is not very ideal in MANETs which are already is resource (Refer Time: 22:19). Second disadvantage is: disseminating reputation information greatly increases the volume of network traffic, too much of network traffic you know.

So, these are control packets kind of right. So, these reputation information, these are not carrying the actual data the actual traffic that has the data. So, this additional volume of traffic is unwanted, but at the same time if you have to adopt these mechanisms you know you have to increase the traffic with this kind of additional information. The decision and incorporating secondhand information consumes additional computation. And the reputation information could be modified replayed or accidentally lost during transmission.

These are the four different distinct disadvantages of this class of reputation systems.

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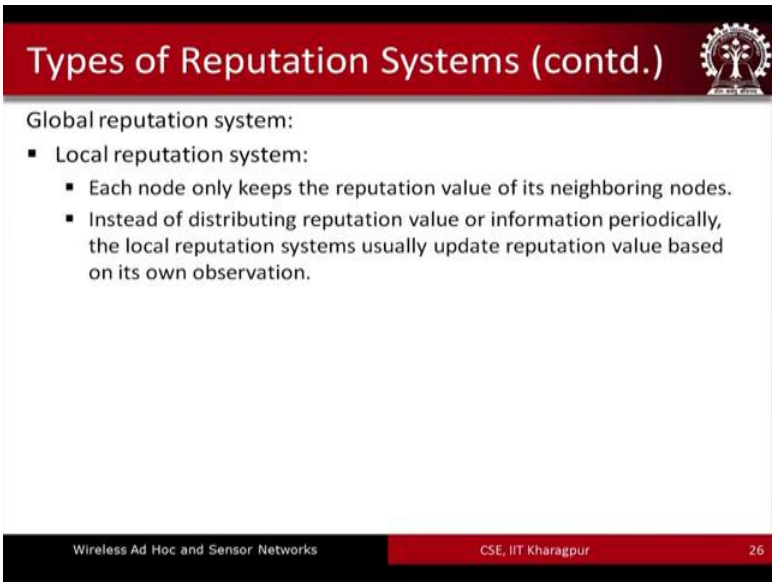

In the local reputation system basically: each node only keeps the reputation value of its neighbor nodes. So, unlike in the previous case where we have seen that each node knows the reputation value of every node in the network, here each node only keeps track of the reputation value of only its neighboring nodes. And instead of distributing the reputation value or information periodically the local reputation systems usually update the reputation value based on its own observation.

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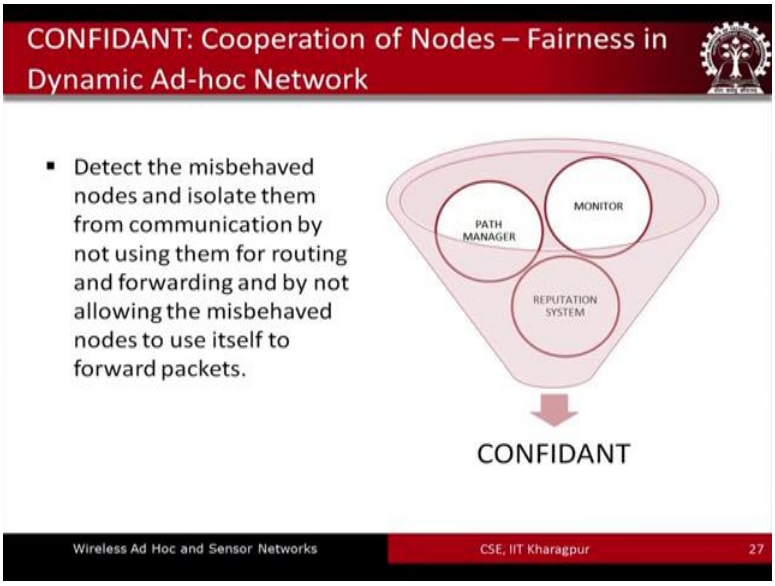

So, I told you that confident basically is a kind of protocol that belongs to the global reputation system category. So, in confident the full form of which is cooperation of nodes fairness in dynamic Ad-hoc networks. In confident what is done is one detects the confident basically detects the misbehaving nodes and it isolates them from communication, but by not using them for routing and forwarding and by not allowing the misbehave nodes to use itself to forward packets.

So, here in confidant we have three different components: first of all the monitor, the second is the reputation system, and the third is the path manager. So, three different components that basically is there in confident. So, monitor basically what it does is it is like the watchdog. So, it keeps an eye on the behavior of the different other nodes in the network.

Reputation system basically bids based on the behavior it is going to assign some reputation values to these different nodes. And the path manager what it does is based on the reputation values that are maintained by the different nodes it is going to calculate that which paths comprising of which nodes would lead to higher reliability of delivery of packets.

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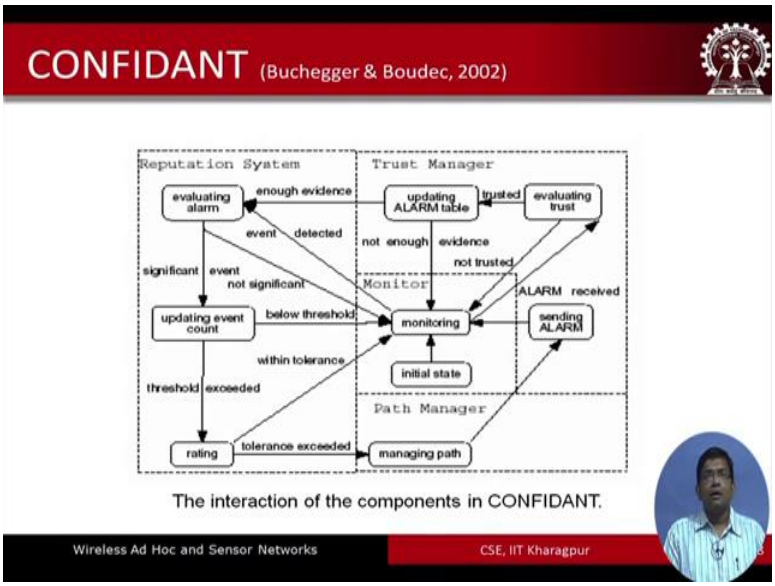

So, this is the block diagram for the rather it is a state diagram, like it is not a block diagram so it is a state diagram. And here as we can see that there are different states and the corresponding; so to conditioned from the different states you know corresponding

you know activation messages that state transitions that are going to happen to transition from one state to another.

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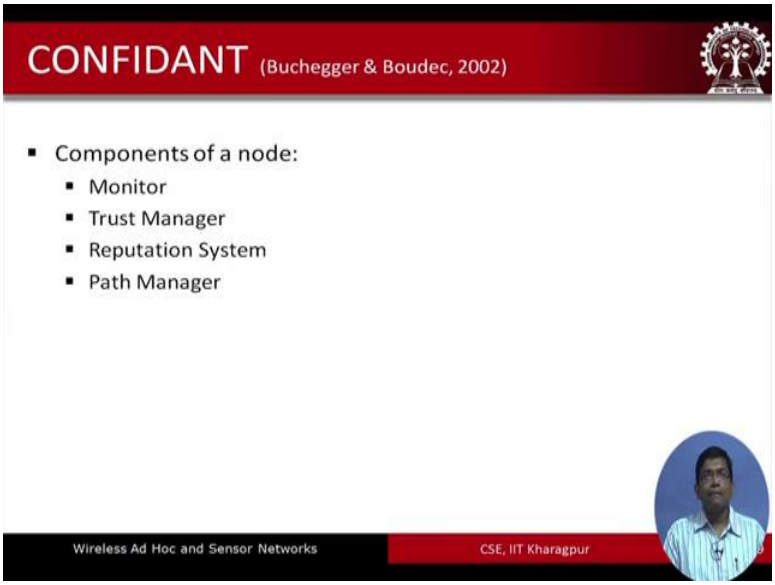

So, these are the components of a node when implementing confident: monitored, trust manager, reputation system, and path manager.

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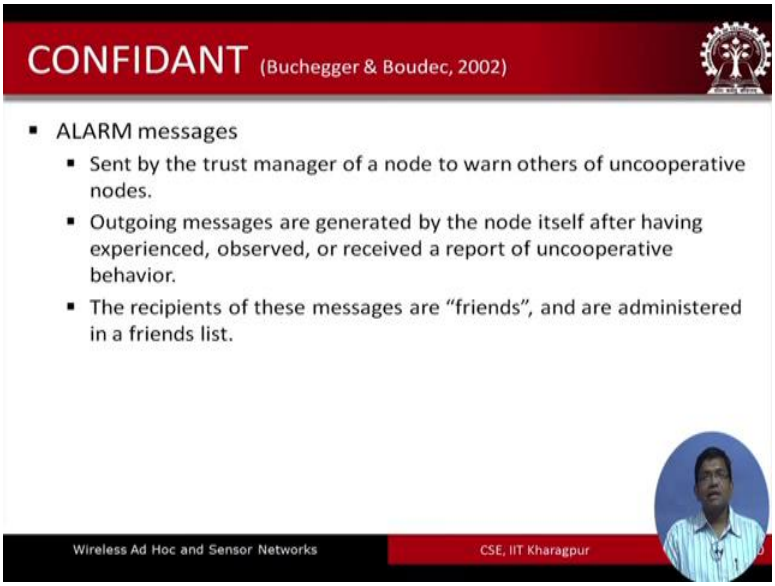

Confident uses alarm messages which are sent by the trust manager of a node to warn others of uncooperative nodes. The outgoing messages are generated by the node itself

after having experienced, observed or received the report of uncooperative behavior. And the recipients of these messages are friends and are administered in a friends list.

Basically, in essence what it is trying to do is it is going to send to its own friends a node; to its own friends it is going to send some kind of an alarm or a warning message saying that there are few other nodes which are uncooperative nodes, and these nodes should be aware of those nodes.

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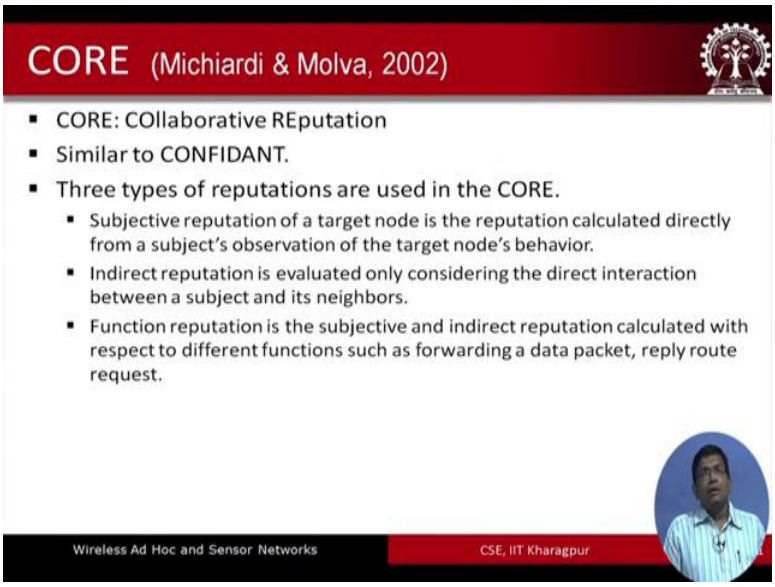

Another mechanism which was proposed around the same time as confidant is called the CORE. The full form of which is Collaborative Reputation. And it also operates in a similar manner to confidant. Here basically three types of reputations are used: first in the subjective reputation. So, this is basically the reputation of a target node which is calculated directly from a subject's observation of the target nodes behavior; indirect reputation which is evaluated only by considering the direct interaction between a subject and its neighbors; and a third is function reputation which is the subjective and indirect reputation which is calculated with respect to different functions such as forwarding editor packet, reply route request, and so on.

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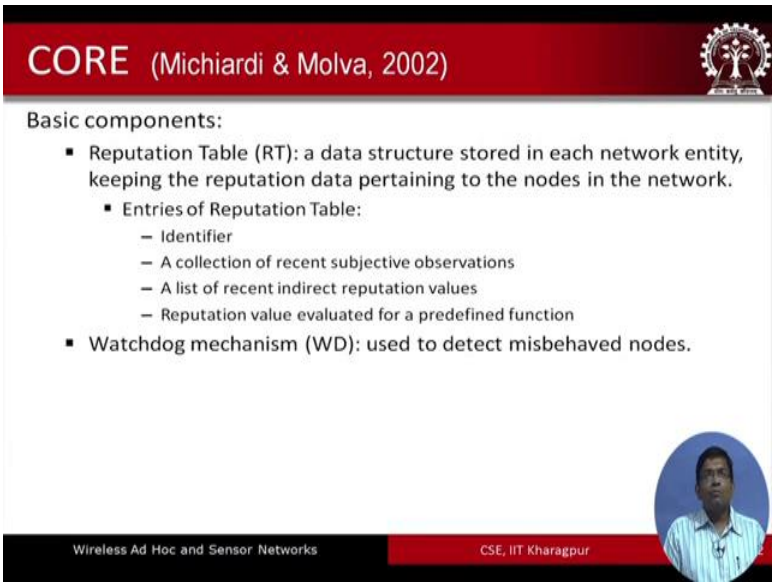

The basic components of CORE are very similar to that of in principle they are very similar to that of the components of confident. So, here we have the reputation table the first component and the watchdog mechanism. I am not going to explain these once more, because you know the whole concept is quite similar to that of the similar kind of component apparel components that we have seen in the case of confidant.

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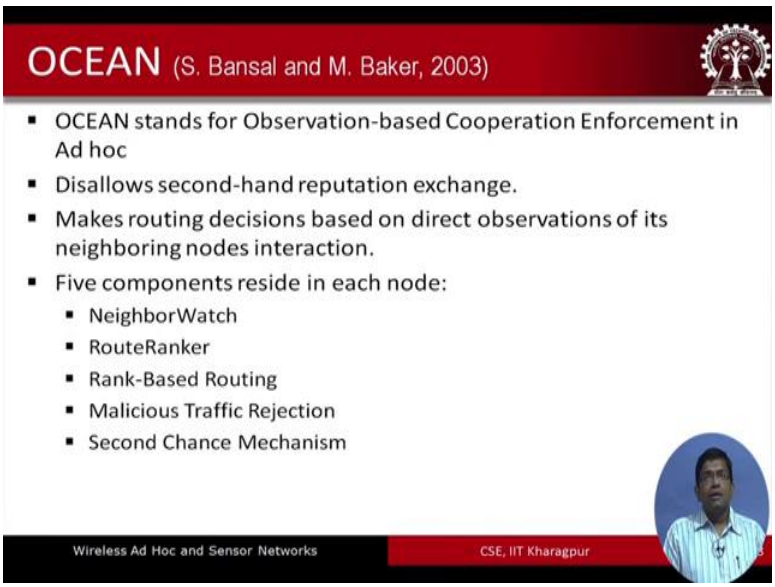

OCEAN basically is another kind of reputation based mechanism. The full form of OCEAN basically is Observation-based Cooperation Enforcement in Ad-hoc networks.

OCEAN basically this allows second hand reputation exchange, it makes routing relations based on the direct observations of its neighboring nodes through interactions. And in OCEAN again a different set of components are resident in each of the nodes.

So, the first one is the neighbor watch, the second is the router anchor, the third is the rank based routing, the fourth is malicious traffic rejection, and the fifth is second chance mechanism.

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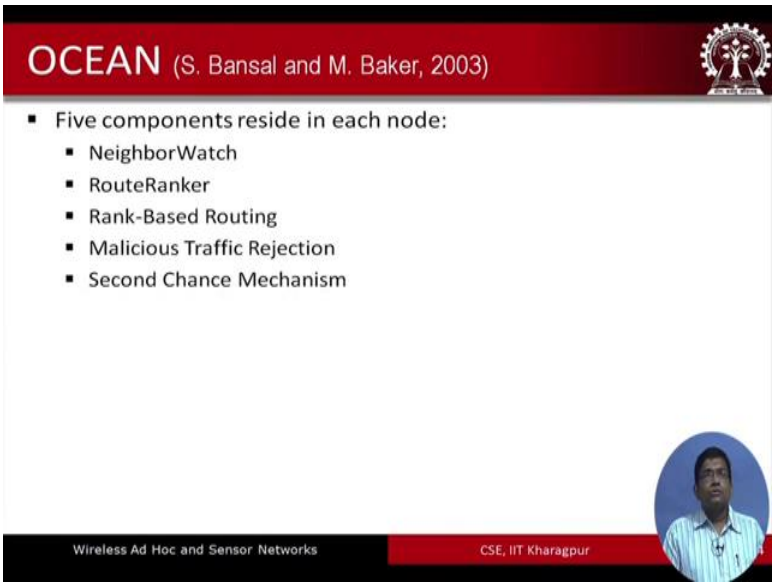

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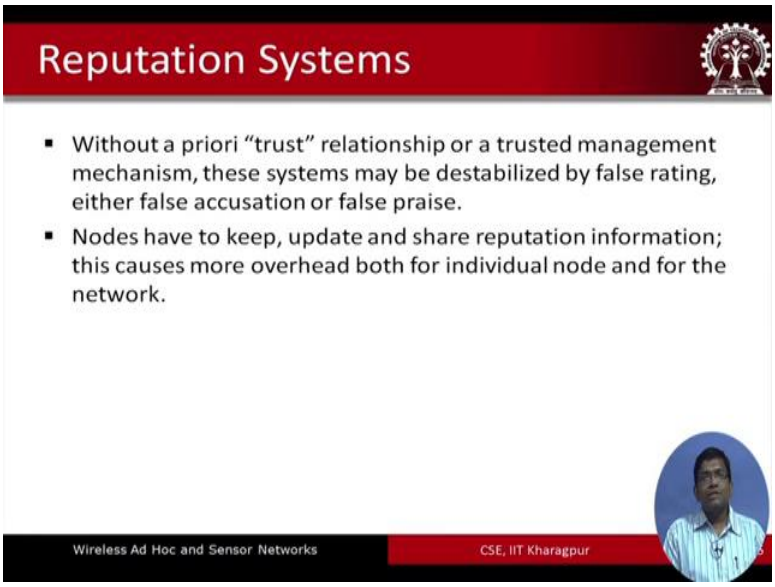

So, these are the different reputation based mechanisms that have been, there are very popular in the literature; so confident CORE and ocean. But reputation based mechanisms although they are very attractive they basically have work under certain assumptions; assumptions of trust for example. That you are trusting your neighbors or particularly you know if you are exchanging secondhand information; if you are handling secondhand information indirectly you are trusting the other nodes in the network.

So, without a priori trust relationship or a trusted management mechanism these systems may be destabilized by false rating, either false accusation or false praise. This is a very serious limitation of use of reputation based systems. So, the nodes have to keep update and share routing information which basically causes more overhead for individual notes and for the network. This is another serious limitation of adoption of irritation based systems.

So, with this we come to an end of the whole topic of cooperation in MANETs. And we have already seen in this particular module that there are different ways in which cooperation can be enforced in MANETs, because cooperation is a very important thing in these networks. It is very important to ensure that the intermediate nodes they cooperate with all other nodes that particularly the source and destination nodes if we are talking about routing specifically or for any other services that a network offers.

So, the cooperation between the different nodes is very important. And there are good reasons which are attributed to the different limitations the resource limitations of these networks due to which cooperation between the different nodes may not happen as desired. So, in order to promote cooperation what happens is there are different mechanisms that have been proposed to virtual currency based mechanisms, packet purse model, packet trade model; these are examples belonging to this particular category. Sprite is another one which is bid different from the PPM and PTM. But again sprite also belongs to the virtual currency mechanisms.

So, these are the three. And then we talked about the reputation based mechanisms where you know application of the different nodes either locally or globally is kept track of by the different nodes in the network. And that information is shared with the different nodes for helping them determine which intermediate nodes have to be adopted for

sending a packet from a source node from one of the from each of the source nodes to the intended destination nodes.

So, for belonging to this reputation based system category we have confidant, CORE and OCEAN. And we have also seen that confidant and CORE they suffer from the location privilege problem. That means, that if some of these nodes they occur in some part of the network, these nodes they get privileged from the services compared to the other nodes in the network. So, their location basically helps them to get privileged. So, with this we come to an end of the entire topic of Cooperation in Ad-hoc Networks.

Thank you.