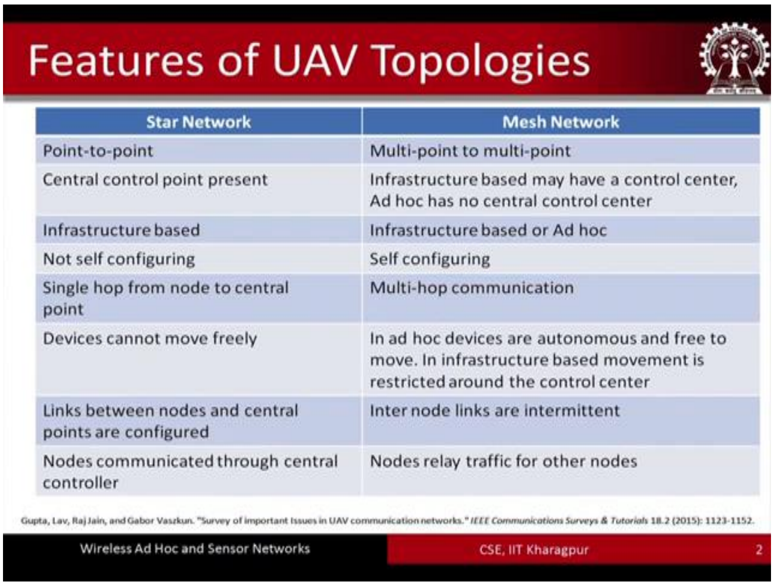
Wireless Ad-Hoc and Sensor Networks
Prof. Sudip Misra
Department of Computer Science and Engineering
Indian Institute of Technology, Kharagpur

Lecture – 19
UAV Networks: Part- II

In the first part of UAV networks, we had covered the basics of UAV networks we started with the physics behind these UAV networks. And the basic communications and topology topologies that are used while forming these networks. So, currently we are going to cover even further in depth of these networks in this particular part the second part of UAV networks.

(Refer Slide Time: 00:43)

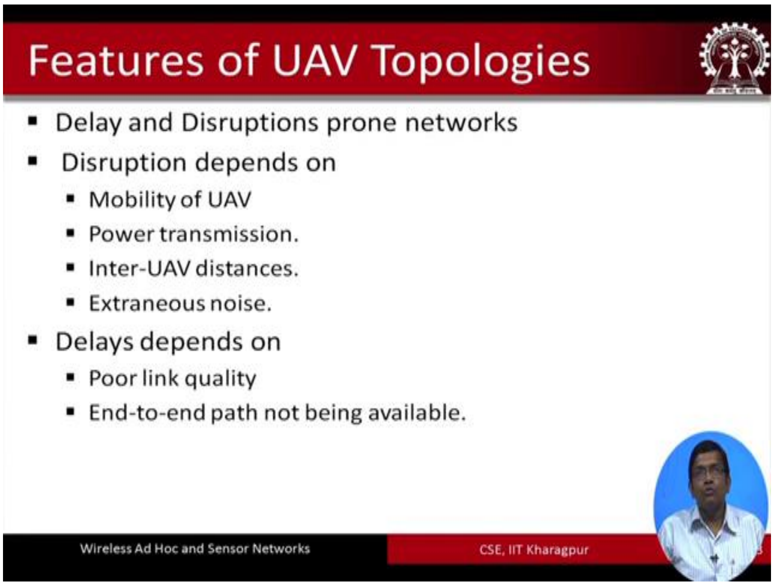


Star Network	Mesh Network
Point-to-point	Multi-point to multi-point
Central control point present	Infrastructure based may have a control center, Ad hoc has no central control center
Infrastructure based	Infrastructure based or Ad hoc
Not self configuring	Self configuring
Single hop from node to central point	Multi-hop communication
Devices cannot move freely	In ad hoc devices are autonomous and free to move. In infrastructure based movement is restricted around the control center
Links between nodes and central points are configured	Inter node links are intermittent
Nodes communicated through central controller	Nodes relay traffic for other nodes

So, what we are we are talking about are the 2 different topologies of UAV networks the star topology and the mesh topology. So, here is a comparison of these 2 different forms of topology we have already seen the pictures of these different topologies the star topology and the mesh topology. So, what we have is point to point connectivity in the star topology whereas, we have a multi point to multi point connectivity between the different nodes in the case of mesh topology. So, we have central control point that is present in a star topology. Whereas, in the case of mesh networks mesh topology we have infrastructure based which may have a control says center, or if there is Ad-Hoc part of the network that we are talking about it does not have any centralized control center. So, it is I said earlier as part of the previous part of the lectures on UAV networks. Either the infrastructure based communications may be used or an Ad-Hoc network communication may be used for these networks.

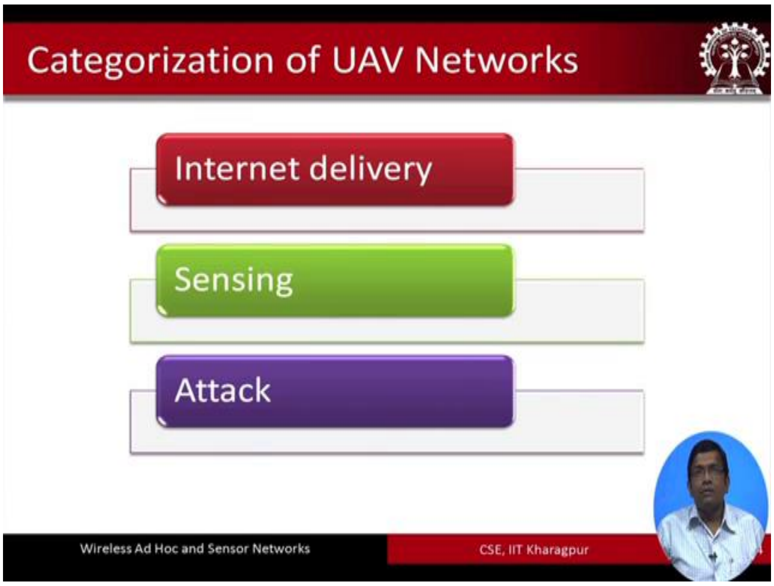
So, infrastructure based or infrastructure based and Ad-Hoc, then we have for you know the Ad-Hoc the start networks are not much self configuring. Whereas, in the case of mesh networks because of the overall reliability increase in the reliability of the different nodes in the presence of false as well these mesh networks can be self configuring self healing in fact, and self managing overall. So, there are other differences between these different types of topologies. I am not going to go through, but it is in front of you for you to go through and be able to appreciate.

(Refer Slide Time: 02:30)



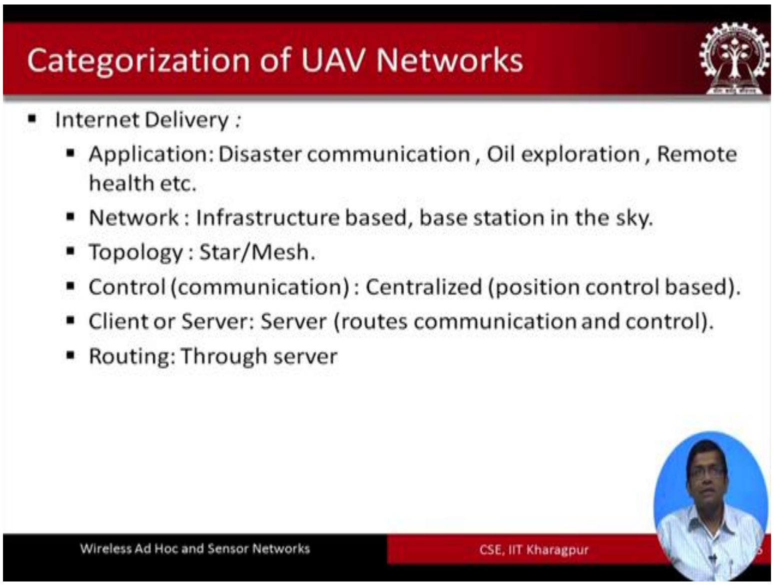
There are different features of UAV topologies these UAV topologies are very much prone to different types of disruptions. In fact, that is these are prone to different types of delays as well. The disruptions could be due to the mobility of the UAVs with respect to each other. The power transmission you know there might be failure in power transmission bit in inside a particular node. Or maybe that the inter UAV distances might have increased to the to the extent that they are not able to communicate with each other. And there could be other environmental or external noise that might also lead to disruption of communication between the different nodes in this network. Delays could be due to poor link quality which is quite common in these networks and due to end to end path not being available at all points in time.

(Refer Slide Time: 03:24)



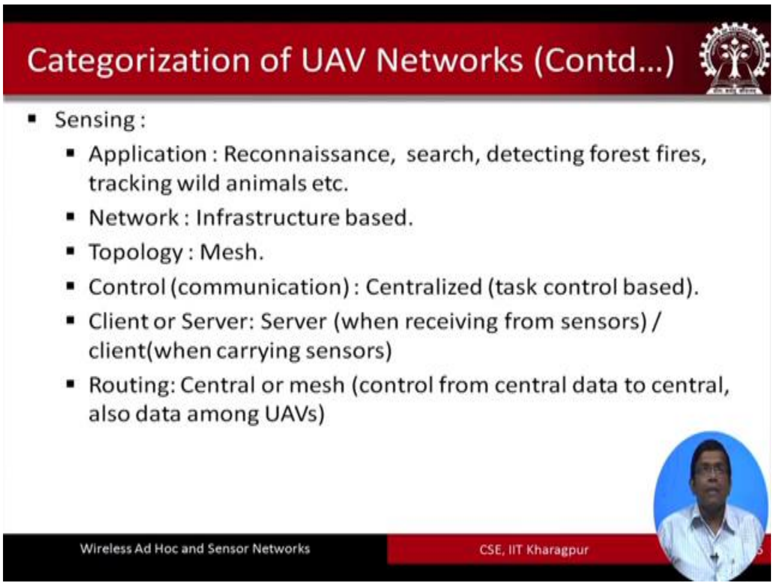
There are different categories of UAV networks. UAV networks can be categorized in terms of internet delivery the sensing or kind of attacks. So, we are going to go through each of them in a short file.

(Refer Slide Time: 03:44)



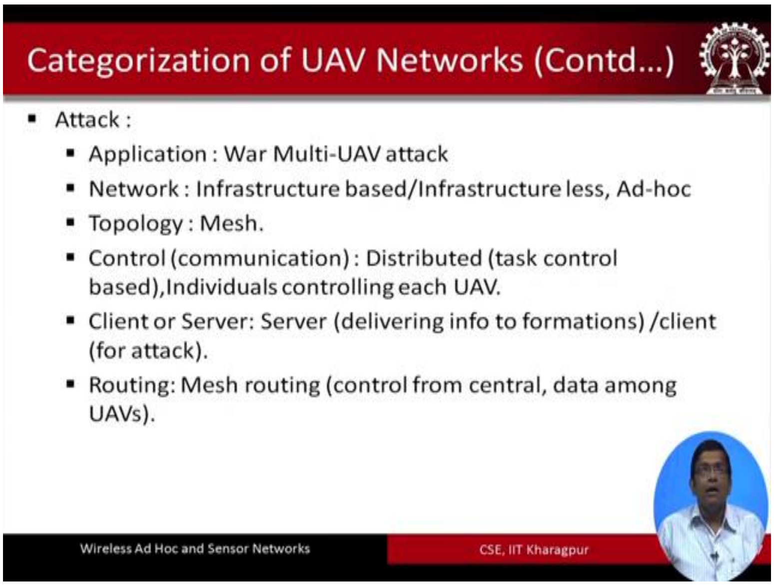
So, in terms of internet delivery there are different applications of disaster communication. So, communication you know networking in the case of disasters. Oil exploration remote health monitoring and so on. The topologies that can be used are the star topology or the mesh topology and both infrastructure based communications and where the base station is in the sky or even the Ad-Hoc form of communication might also be used for internet delivery, but typically it is an infrastructure based communication with the base station in the sky, that is the kind of topology that is used for internet delivery, then there is a centralized position control in the case of UAV networks for internet delivery and the server. So, here basically what we have is the client or server basically communicates the roots between the different nodes the communication that occurs between the different nodes, and they can these nodes can act as different servers and the routing is made through the servers.

(Refer Slide Time: 04:57)



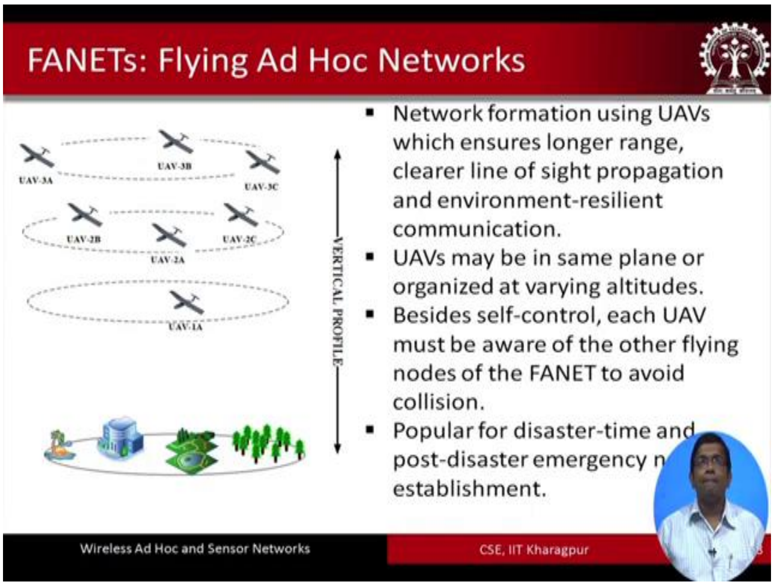
In terms of sensing applications such as reconnaissance of performing reconnaissance different search operations detecting forest fires tracking of wild animals etcetera for this basically you also need in addition to the UAVs to communicate with one another you also need them to be sensor enabled they can sense different things, and again the type of topology that is used here is the mesh topology. And the kind of control is the centralized control and the rout the kind of routing that is used is either a centralized one centralized routing or routing that is typically adopted in the case of mesh networks.

(Refer Slide Time: 05:42)



In terms of the attack which is the third category of UAV networks these type of network UAV networks can be used for what time scenarios, where it is required to have multiple UAVs perform some kind of an attack for you know war scenarios. So, the in type of network that is used could be infrastructure based or infrastructure less; that means, an Ad-Hoc network or and the topology that is used is a mesh topology and the routing consequently kind of routing that is used is the mesh routing.

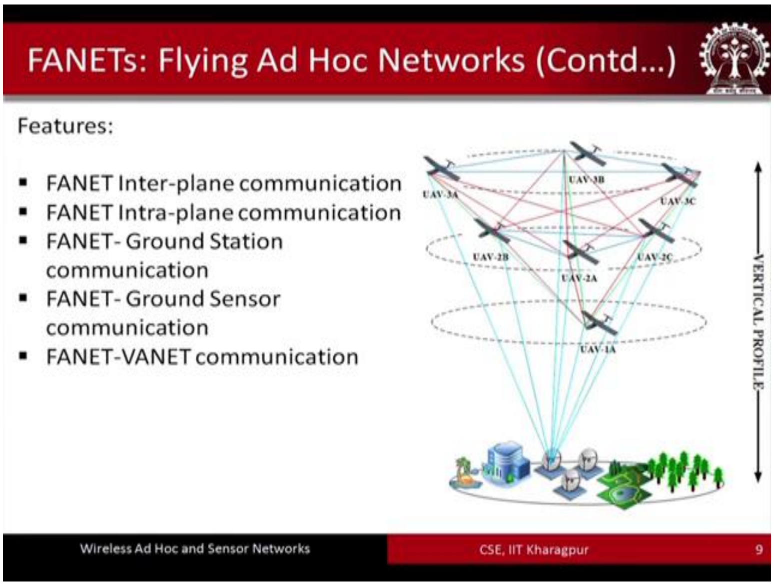
(Refer Slide Time: 06:22)



The Ad-Hoc networks that are formed using these UAVs or these flying devices. They can have different structures. So, here is a typical structure of Ad-Hoc networks formed using these aerial devices or the flying devices, which is called this type of structure or these type of network topologies are called FANETs. Flying Ad-Hoc networks is the full form of FANETs and as you can see over here this is the vertical profile of these of the FANETs.

So, as we can see from this particular figure what we have are different UAVs flying in different layers in different levels. So, what we have is one UAV in one altitude, these 3 UAVs flying in the same plane in a different altitude and these 3 UAVs in another plane higher up in another altitude. So, we have together a flying Ad-Hoc network and so what could happen is these UAVs in a particular plane they should be able to communicate with each other. And the same thing happens in the different other layers as well and also between these different layers they should be able to communicate with each other.

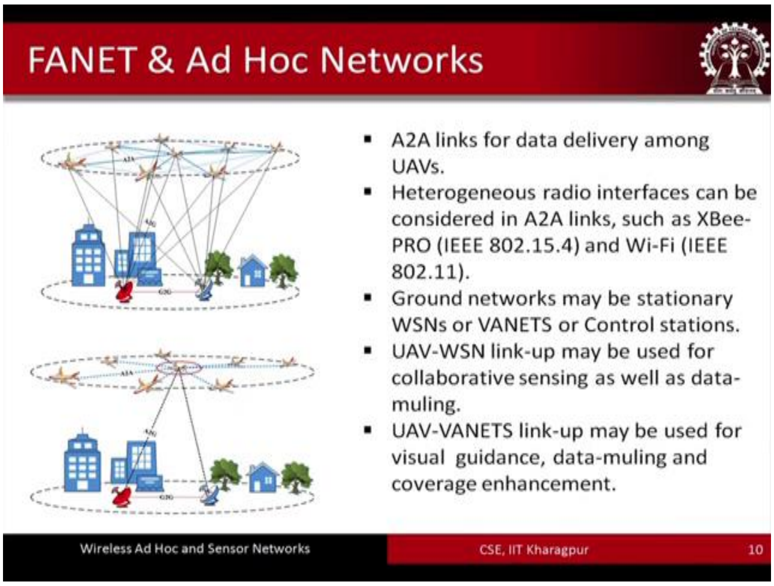
(Refer Slide Time: 07:46)



There are different features of these flying Ad-Hoc networks. So, these features are basically dependent on the type of communication that is taking place. And is something that I have already spoken a short file back. So, in with the ground station basically these UAVs in the different planes, they can connect with the ground station in this manner. And so between in a particular layer these UAVs can also talk to each other and the UAVs can also talk to each other we across different planes like in this particular example. So, this UAV in this plane is able to talk to this particular UAV in another plane and so on. So, across different planes also these UAVs can do perform different types of communication.

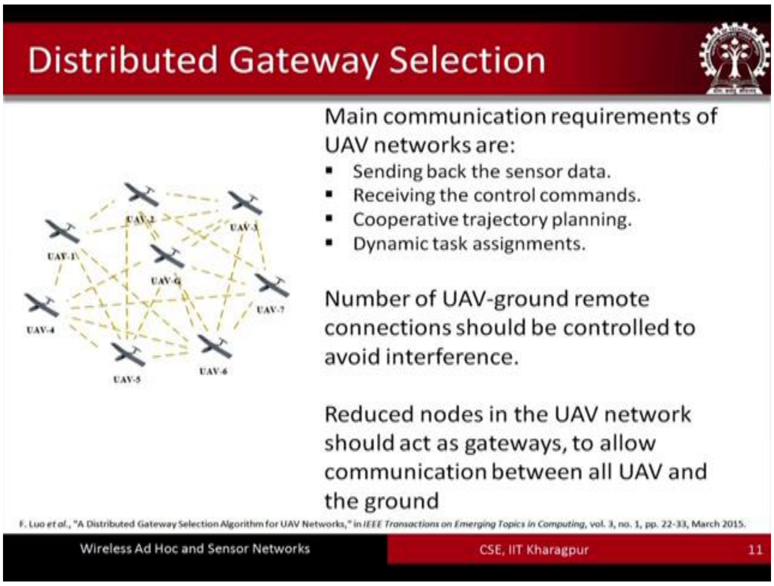
So, in a FANET we have inter plane communication; that means, across planes inter plane communication we have inter plane communication; that means, within a particular plane the different UAVs that are there they should be able to communicate with each other and we also have communication from the ground stations to the different UAVs in different planes. So, FANETs ground station communication ground sensor communication and VANET communication, communication means that within in. So, there is a vehicular Ad-Hoc network on the ground and from that vehicular network the different nodes should be able in that particular, vehicular network not only this should be able to communicate with one another the different vehicles should be able to communicate with one another, but also they should be able to communicate with the UAVs which are flying. So, this is the overall idea of formation of FANETs.

(Refer Slide Time: 09:31)



So, FANETs do compare with Ad-Hoc networks. In fact, FANETs and Ad-Hoc networks they can be integrated together as well. So, here is an example the first figure what we see is we have different A2A; that means, air to air links like this, then we have air to ground links like this and then we have ground to ground links like this. So, this is one type of architecture of these flying Ad-Hoc networks. And so it is another architecture of you know this is more like a mesh like architecture over here, and this is more like a star kind of architecture that is used here, where the ground devices they are able to communicate through direct link with the centralized coordinator in this particular, in this particular case. In this particular layer, this is this is acting like the coordinator in this particular layer which can help coordinate the communication between these different nodes UAV nodes in this in this plane.

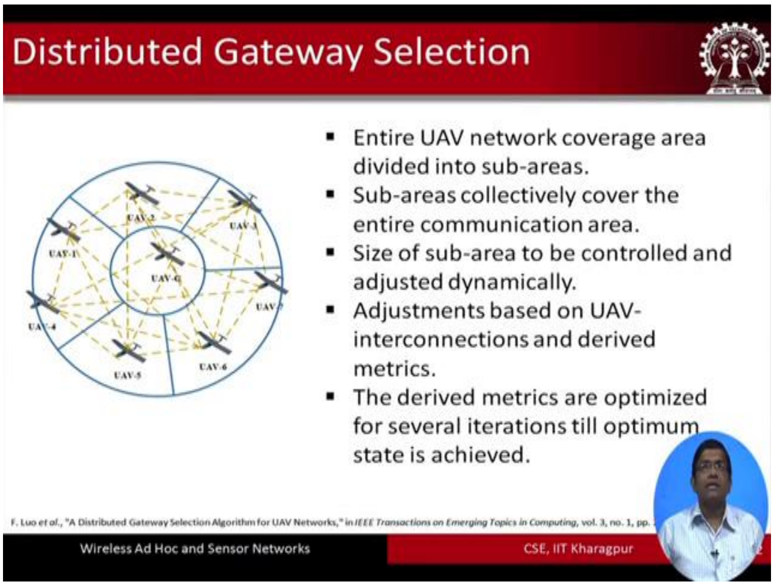
(Refer Slide Time: 10:41)



So, distributed gateway selection is a very important problem. So, they there is you know. So, if we look up look at a UAV network like this if we are talking about this. So, what is very important is to select the gateways. So, the main communication requirements of UAV networks are sending back the sensor data to the ground receiving the control commands cooperative trajectory planning and dynamic task assignment. And the number of UAV ground remote connections should be controlled to avoid interference then the less number of such kind of connection connections between the UAVs and the ground; that means, A2G kind of communication the lesser the number of such kind of communication or the connections we have the lesser these networks are prone to interference

So, the reduced nodes in this UAV network should act as gateways to allow communication between all UAVs on the ground.

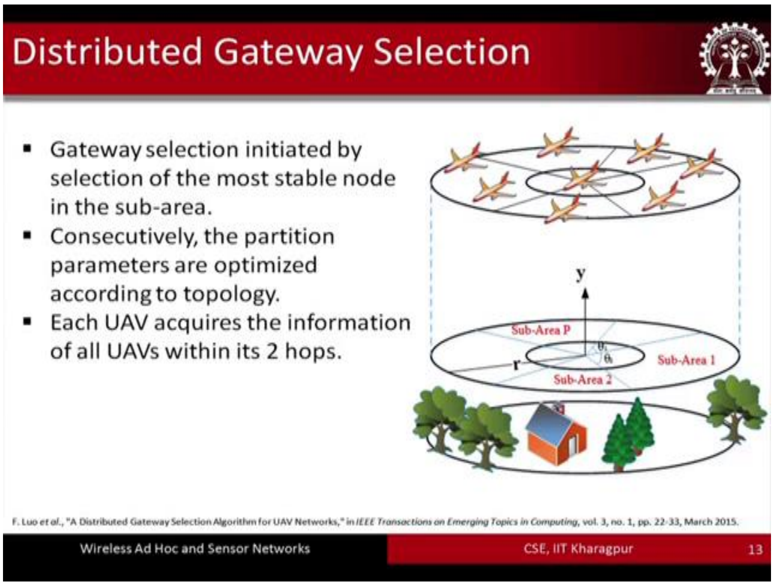
(Refer Slide Time: 11:40)



All UAVs and the ground sorry. So, these UAV networks you know they have to a formed they are deployed in such a way that they have to cover a particular area. So, if we look at the figure in front of us, what we see is a figure like in the case of the previous slide. So, here we have different UAVs in a particular plane. And these UAVs together they will have to accomplish a particular mission maybe a reconnaissance or something like that where they have to go and cover a particular area. So, that particular area could be divided into different sub areas as shown over here.

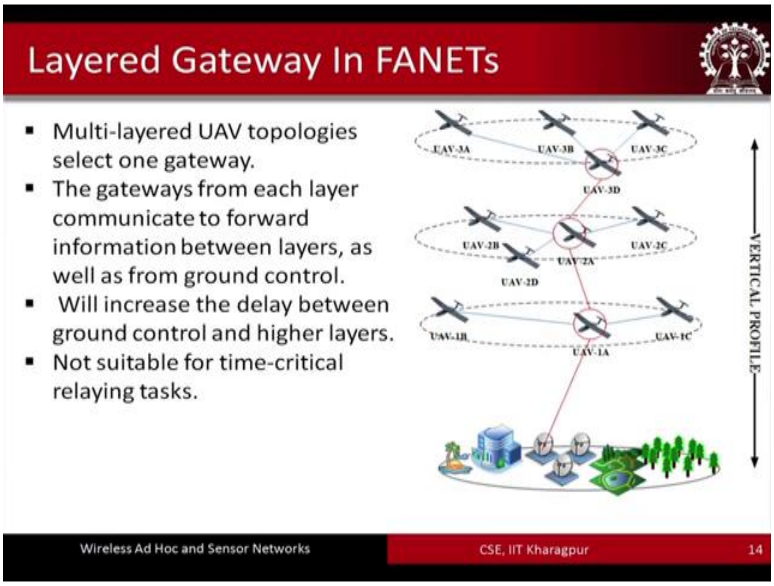
So, what we have this is one sub area, this is another sub area, this is another sub area and so on and so forth. We this entire UAV area is divided into different sub areas. So, these sub areas collectively cover the entire communication area. The size of a sub area to be controlled is to be controlled and adjusted dynamically. Because the network topology is also quite like to likely to change quite fast in this network. So, it is very important not to have a fixed zone, but to change these zones or the sub areas dynamically and control them. So, these adjustments are based on UAV interconnections and derived metrics the derived metrics are optimized for several iterations till optimum state is achieved.

(Refer Slide Time: 13:06)



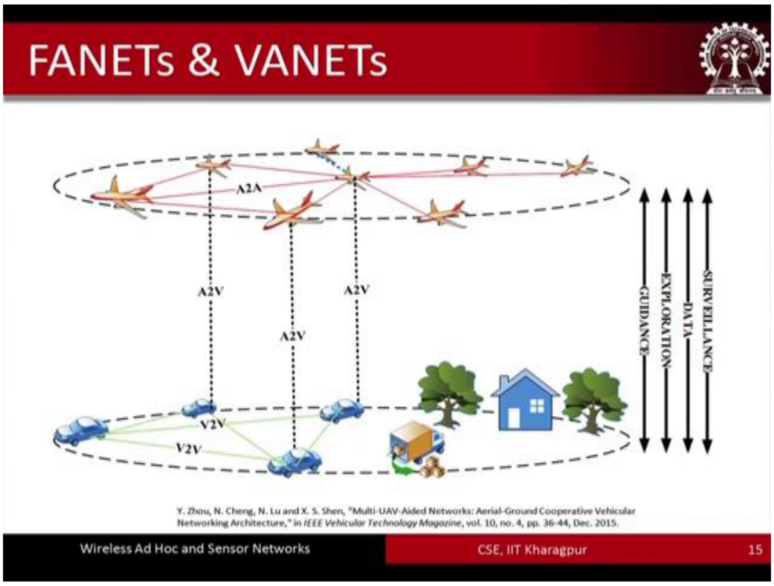
So, how is the gateway selected, to the gateway selection is initiated by the selection of the most stable node in the sub area. So, we have different sub areas as shown over here. So, we have different sub areas and this is how it is shown over here. So, we have sub area 1 sub area 2 and their projections on the plane. So, we have these projections we have sub area 1 2 3 4 5 and so on and so forth, and in each sub area what happens is the most stable node in that particular sub area is identified and selected. And that particular node is identified as the gateway node. And consecutively the partition parameters are optimized according to the particular topology and each UAV acquires the information of all UAVs within hit it is 2 hop neighbors.

(Refer Slide Time: 14:02)



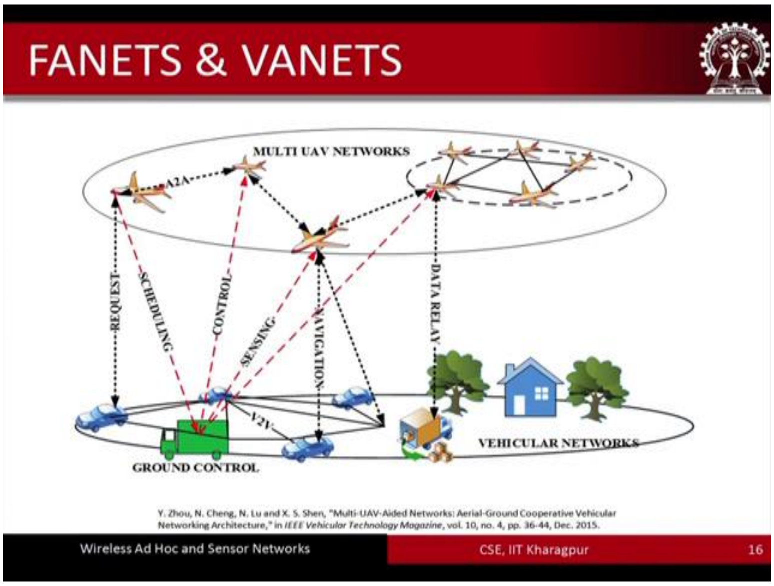
This is the layered structure of deployment of these UAV networks or the FANETs. So, what we have over here are these different nodes that are deployed in different planes. So, as we can see over here these nodes which are marked with a red colored circles. They are identified as the gateway nodes. And these gateway nodes they can help the gateway known in the different planes they can help connect with the other gateway nodes in the different other planes. So, the gateways from each layer communicate to forward information between the layers as well as the ground control. And that will increase the delay between the ground control and the higher layers, and this type of architecture is not very suitable for time critical applications, because that these basically increase the overall delay of the network, although there is greater coverage and improved connectivity, but it is at the cost of increased let me see as well.

(Refer Slide Time: 15:09)



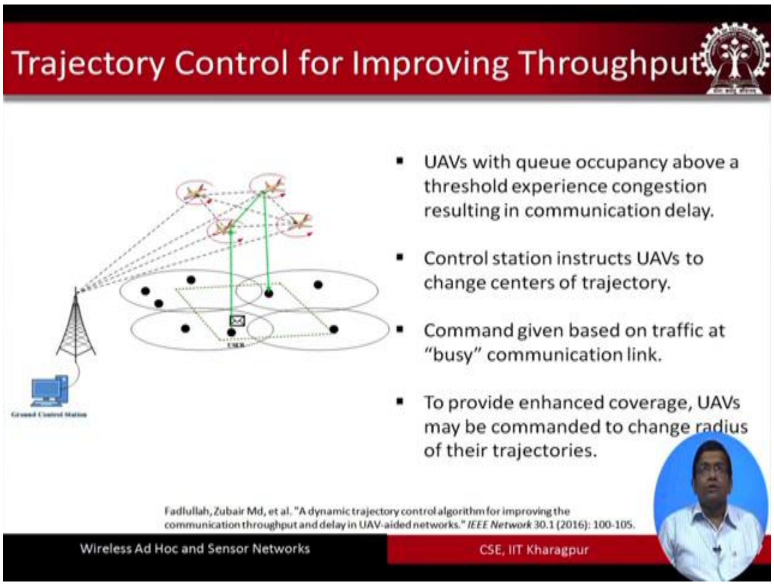
So, when we talk about MANETs, we are talking about vehicles, which vehicles and different nodes the human beings or whatever carrying different mobile phones. So, we have VANETs, MANETs on the ground. So, then if you are talking about VANETs these VANETs can communicate the VANETs node can communicate with the UAV node and so we can have different links. So, not only we have V2V links as in the case of VANETs, but also we can have A2V hillings; that means, air to vehicle links. So, we have air to vehicle links.

(Refer Slide Time: 15:47)



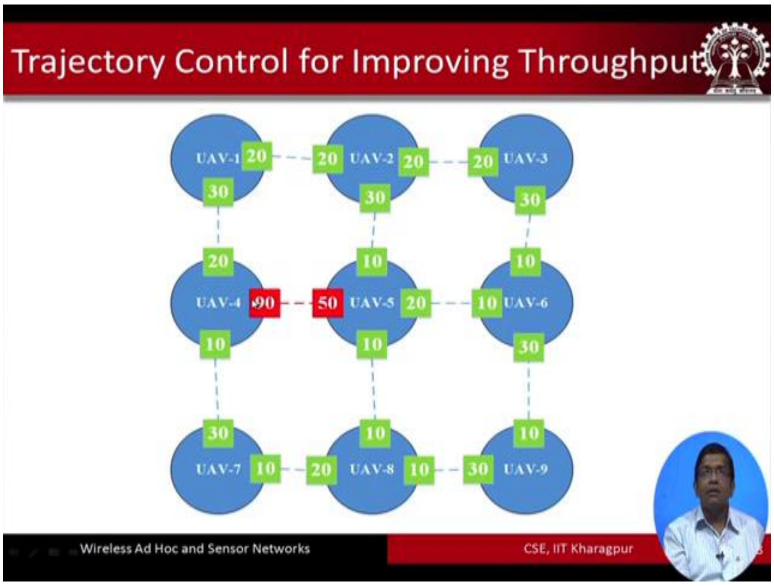
So, we have you know we have ground control. We have a ground control. We have vehicle to vehicle communication in the on the ground and then with the multi UAVs on the air, there is control there is you know scheduling, there is different other requests sensing navigation etcetera, different types of information exchanges that can go on between the different nodes in the air and from the air to the ground and on the ground as well.

(Refer Slide Time: 16:23)



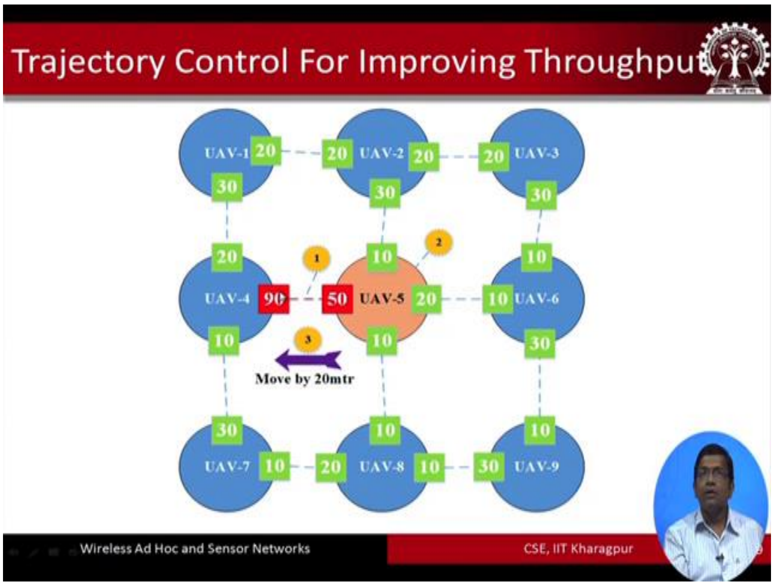
So, these nodes they are moving, their trajectories have to be controlled. And if we are talking about a swarm of these UAVs then their control has to be different depending on type of you know swarming behavior that is desired. UAVs with queue occupancy above a particular threshold they are likely to experience the collision resulting in communication delay the control station instructs the UAVs to change the centers of the trajectories. And the command is given based on the traffic at the busy communication link. So, these are these are some of the very fundamental things about communication about trajectory control in the case of these networks.

(Refer Slide Time: 17:13)



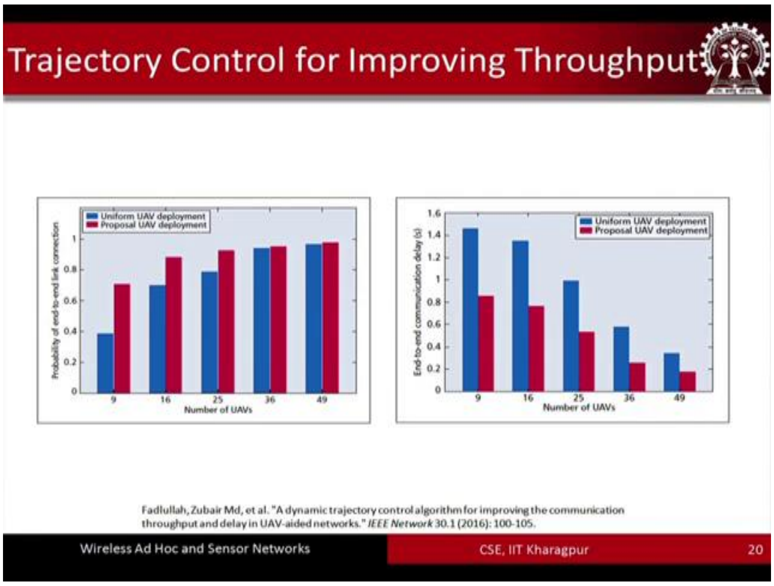
So, as you can see over here in this particular case we have different UAVs, a planner few of these UAVs deployed. So, as you can see these are basically this figure they basically show that how many packets can be cued at the different interfaces of these UAVs when a structure like this a topology like this is deployed. So, what we can see over here is through this interface like you know the buffer occupancy of this interface is 90. So, if the buffer occupancy of this interface is 90 then what can be done is this particular UAV which has lesser buffer occupancy. This can move from this particular position and come closer to this particular UAV, and can help this particular UAV which already has you know it is buffer capacity full to be to able to communicate with the rest of the nodes in this network.

(Refer Slide Time: 18:11)



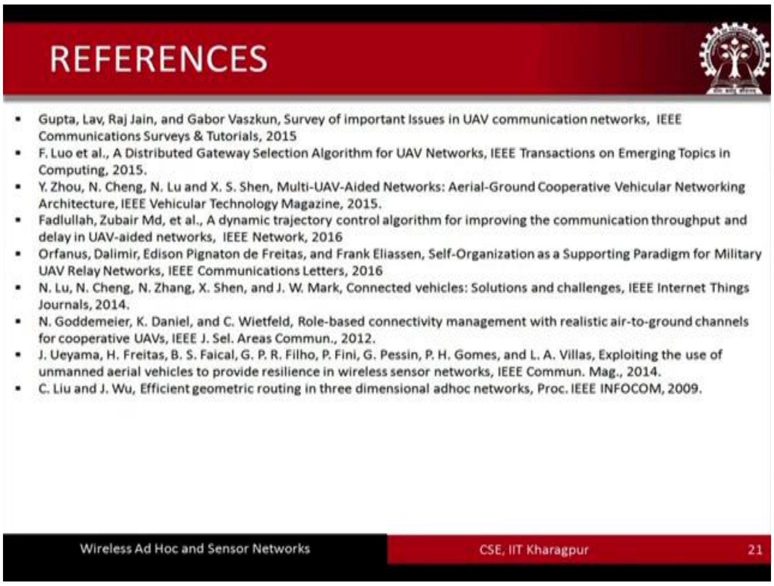
And that will improve the overall throughput because lesser number of packets are going to be deployed. So, what we can see over here is this particular UAV it moves about 20 meters or. So, this is just an example of course, about 20 meters of. So, it moves in towards the direction of this particular UAV. So, that after movement after moving over here this particular UAV can help this one overloaded UAV, UAV with you know increase buffer occupancy to be able to route packets from this UAV to the other nodes.

(Refer Slide Time: 18:43)



This is just an example a comparison of how you know this is taken from this particular reference. That is given over here in this slide. So, what we see is how to you know trajectory control how the throughput can be increased in the case of UAV networks. So, in terms of comparison of the uniform UAV deployment, and the proposed UAV deployment we see that overall the performance of the proposed UAV deployment is improved compared to the uniform UAV deployment. So, this is proposed means proposed by the authors of this paper. So, this is what they proposed and they have shown that the trajectory control the weight is shown helps one to achieve improved throughput improved efficiency compared to the having a pure uniform UAV deployment in a particular region.

(Refer Slide Time: 19:44)



And again these are the references for that can be used to understand these concepts that we have covered in a short while in detail.

Thank you.