Wireless Ad Hoc and Sensor Networks
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Lecture – 16
Opportunistic Mobile Networks- Part-II

So opportunistic mobile networks part 2. So, here we will continue with our discussions on enforcement of cooperation in opportunistic mobile networks, we discussed about the different mechanisms of enforcing cooperation the different types of schemes incentive based schemes then reputation based schemes and so on. So, we are going to continue from that point on.

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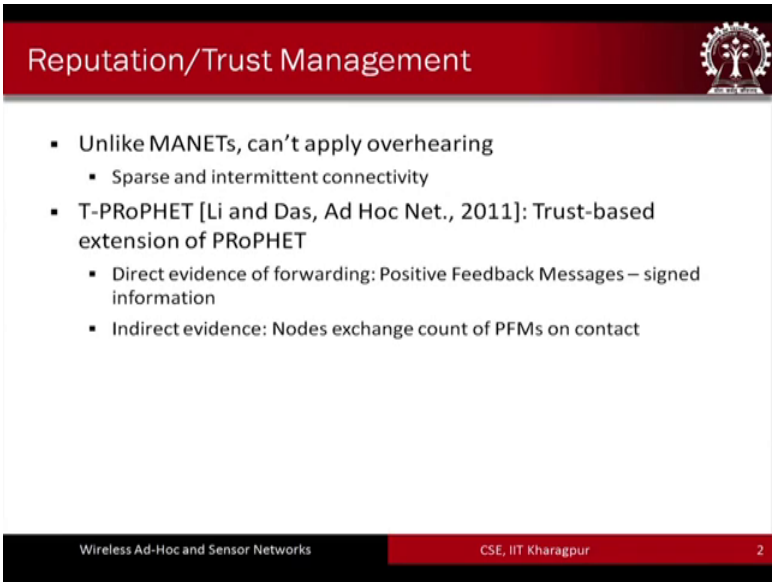

So, when we talk about reputation trust is also very important. So, that different nodes they would have to trust one another and the trust comes from reputation. So, the different nodes you know. So, one node can trust another node if that you know trustworthiness is more; that means, that the more probably has more reputation of message forwarding and so on.

So, but the problem is that these kind of mechanisms reputation based mechanisms trust based mechanisms. So, these kind of mechanisms have already been proposed for the MANETs as well. And that is something that we have seen earlier on in the course, but if we recall that the reputation based mechanisms which were proposed for MANETs the

underlying most of the underlying theories behind these schemes implementation of the schemes is that we are based on overhearing. So, overhearing means that the nodes you know. So, one node would be able to keep track of the reputation of the other nodes in the network in it is vicinity if it is able to overhear the communication that is going on between the different other nodes surrounding it, but because OMNs are sparse the connectivity between the nodes are sparse the different nodes are not very densely positioned. And there is intermittent connectivity between the nodes. So, that is the reason the schemes for reputation that are proposed for MANETs they are as such not usable in the case of OMNs. So, profit protocol we have already seen profit is a routing protocol a forwarding protocol and t prophet a trust based extension of prophet was proposed by Lee and Das and was published in the Ad-Hoc networks journal in 2011. And in this particular approach what they do. So, it is a basically trust based extension. So, trust has been incorporated in simple forwarding.

So feedback messages quality feedback messages FPMs. FPMs are used quality feedback messages are used as direct evidences of forwarding. So, basically direct evidences of forwarding means that not only that I get a feedback about forwarding from another node, but the another node would also have to endorse it. And they have to sign they all have to sign together and the signed one basically ensures that there is direct evidence that a particular message was forwarded it was indeed forwarded by that node indirect evidence indirect evidence. So, in terms of you know exchanging counts of this positive feedback messages on coming in contact with the other nodes.

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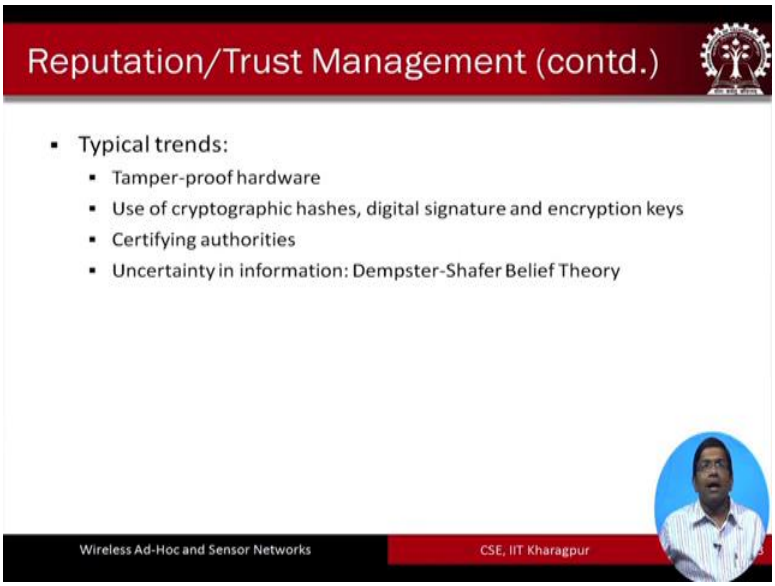

There are other trends as well for ensuring trust and reputation security in general. So, you know implementing tamper proof hardware use of cryptographic hashes digital signatures encryption keys all these traditional ways of encryption trust enforcement and so on. Damester Shafer theory for belief and trust and so on. So, all these things can also be adopted in this particular context by taking into consideration that the new challenges that are exhibited over here are taking into are taken into account.

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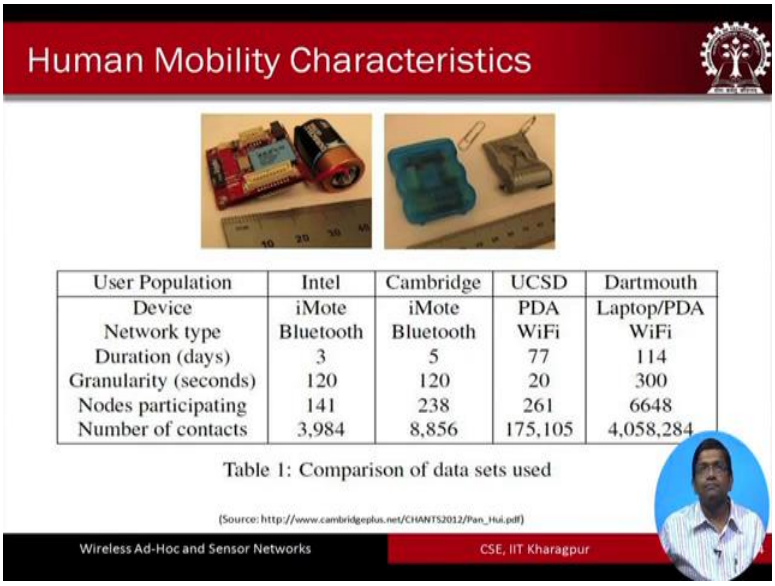

Now, let us come to another issue. So, in OMNs mobility is a very important thing and here we are talking about typically human mobility humans carry the nodes the nodes move due to the fact that the humans move right. So, basically there are different data sets on human mobility that are available. The intel data set the Cambridge data set the UCSD data set the Dartmouth data set and so on. And the corresponding properties are mentioned in this particular table the corresponding properties with respect to different criteria the device network type duration granularity node participating number of contacts all these different, with respect to different properties the different features of these data sets are mention.

So, why I am telling you about these data sets is these data sets are very important in understanding these data sets can be used in order to assess the performance of the different protocols that are proposed for use in these networks mobility is very important. So, con consequently the mobility traces are very important the position traces are very important how these different nodes under different circumstances have behaved in different past experiments that can be used to assess the performance of the pro protocols that are proposed for use OMNs.

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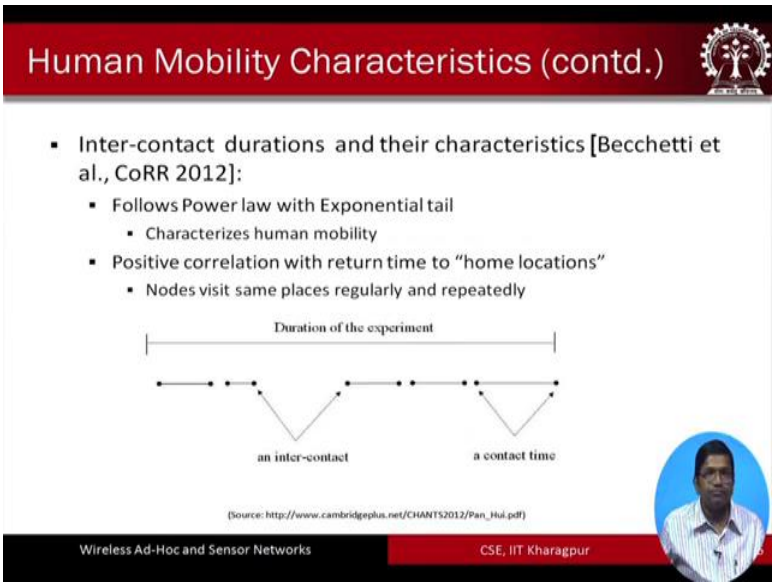

So, when we talk about mobility, there are 2 terms which are very important one is the inter contact time. So, basically let us say that the duration of an experiment is as shown in the figure over here this is the duration of an experiment. So, 2 nodes they might

initially come in contact. Then after some time they will again come in contact. Again after some duration of time they will again come in contact and so on and so forth. Until the end of the experiment. So, 2 terminologies in this context of human mobility are important.

One is called the contact time; that means, for how long when the 2 nodes are coming in contact how long they are going to stay in contact that is the contact time. And the inter contact time is that since the last time when they were in contact and the next time they are again in contact how much time has elapsed. So, it has been shown that these durations basically follow the power law with exponential trail. So basically what means what is meant is the node some nodes will be coming in contact with one another with each other more often than few other different other nodes. Some nodes more often than other nodes not only that another aspect also. So, the nodes basically visit the same places regularly and repeatedly.

So, basically you know it could be that you know 2 nodes they come in contact every day regularly they come in contact when they are coming to the school; that means, the university or when they are going home and so on. And they regularly come in contact and as few other nodes they do not come in contact. So, much frequently at all.

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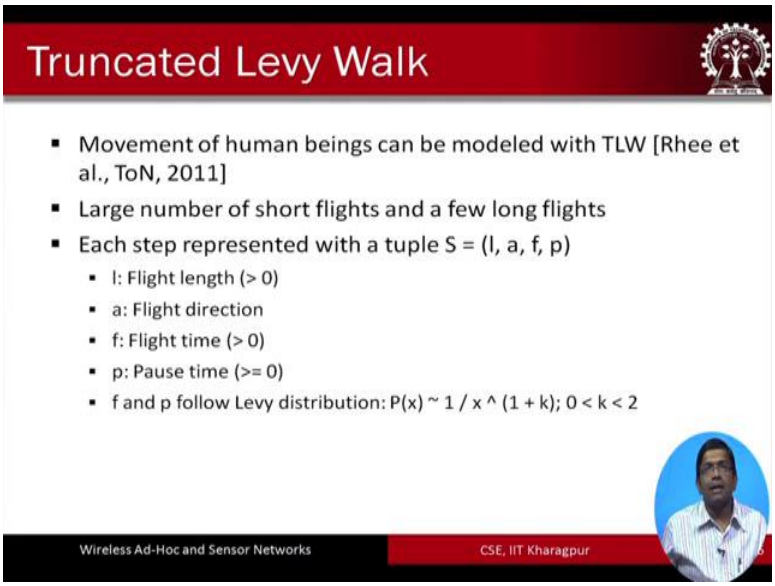

So, there are different mobility models that have been proposed to basically capture the behavior of how the humans move. So, one of these popular models is known as the

TLW models the truncated, levy dock levy walk truncated, levy walk model which was proposed by Rhee at el in the I triple E transactions on networking in 2011. So, this model as per this model, the model says that there are large number of short flights and a few long flights so; that means, that every human you know. So, they take large number of short flights and a few long flights.

So, I will just give you an example of this. So, basically typically what we do is, when we are in a university campus. We come to the university regularly we take short distances as we traverse short distances, within the campus we from the from our home to the university. From one department to another we are taking short flights. And that we do in large numbers compared to large flights long flights meaning that how often we are going out of station for example, how often we are going out of station. So leaving the campus we do not do to often. So, we do it only fewer times compared to traversing within the campus. So, this is just an example to you know. So, make this particular point clearer.

So, each step is represented with a tuple s which is a function of l a f and p l stands for the flight length, a is the flight direction, f is the flight time p is the balls time and f and p basically follow a probability distribution which is known as the levy distribution.

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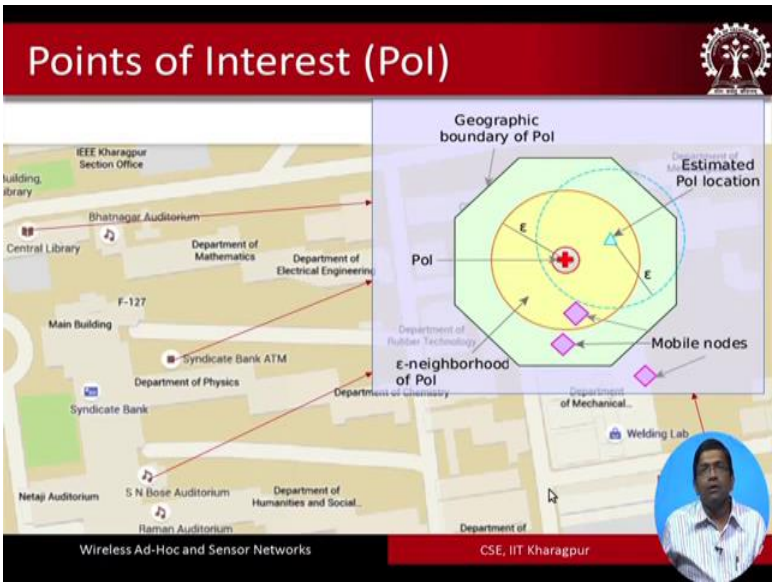

So, this is something that we worked on ourselves in this particular direction. We basically studied how calculated levy work can be extended for exploring different

points of interest in a particular city in a particular neighborhood. So, let us try to understand the figure that we see in front of us. So, this is just an example this is just a campus map of IIT Kharagpur. And as we can see over here there are different points of interest these points of interest could be maybe the location of a particular ATM the location of a particular auditorium and so on. So, as we can see in this particular grown up figure of a point of interest let us say that this is a point of interest. So, this is a point of interest and within a point of interest within the epsilon neighborhood of a point of interest, there could be one or mode more mobile nodes that can be located, or there can be different other points of interest that might also be located.

And what you see over here this particular geo geographic figure shows, sorry the geometric figure shows an example of a geographic boundary around the point of interest. So, with this understanding of the point of interest and the different other notations surrounding this particular concept we go ahead further.

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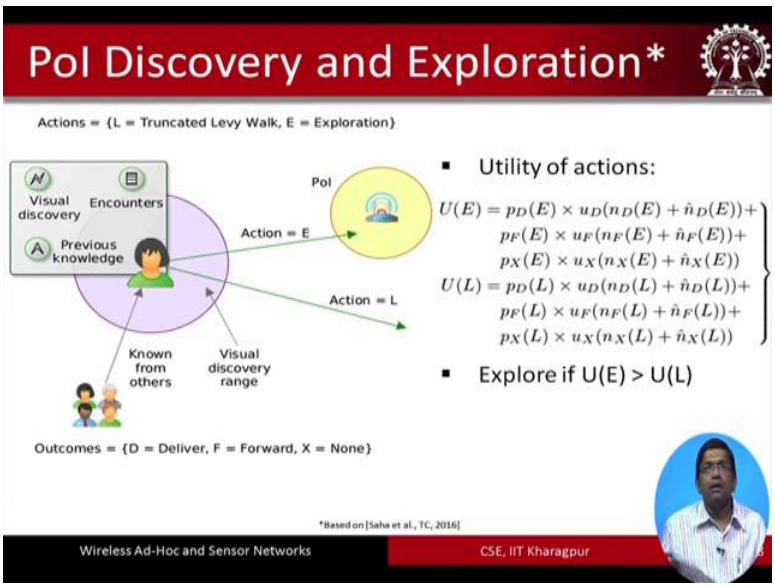

So, the point of interest typically has to be discovered and it has to be explored. And we are talking in in the context of OMNs opportunistic mobile networks. So, we all are carrying our mobile phones with us we are forming an opportunistic mobile network with the help of these mobile phones that we are carrying or more specifically pocket switch networks which is again a type of opportunistic mobile network there is in fact, I mean all those although these 2 have distinct identities, but there is lot of overlap in the

overall concept of OMNs and PSN's. So, let us assume that we are dealing with a type of OMN which is the PSN, now when a human being who is carrying a mobile phone is moving. So, there is every human being has moves and it explores the neighborhood in around it. So, that exploration can be in terms of the visual encounters.

So a particular node would be exploring a point of interest by taking any of these different actions. The action could be that it accidentally it encounters the points of interest. Or the action could be that it you know it does a particular type of walking it walks in a certain way and it discovers the point of interest, but the way it can discover would be different. It can encounter the point of interest which is which is sort of like an accidental encountering it maybe it has it visually sees visually discovers the point of interest. It visually discovers the point of interest. Or maybe it knows from previous knowledge it already has a previous knowledge about how to discover that point of interest how where and how to get that point of interest.

So, accordingly either what it can do either it can either it can take the levy walk model either it can take the truncated levy walk model, it can take that action or it can take the exploration truncated levy walk with exploration. So, it can explore using these mechanisms and then based on that the message that it had in it is mobile phone, it can be either delivered because if it is if that point of interest and the mobile phone in it is vicinity are is the actual internet destination or the message can be forwarded, to that node and with the hope that that node again will be forwarding it further or none of these basically none of these applies. So, one corresponding to that the utilities can be computed about you know how much is a total utility corresponding to the actions of exploitation and levy walk. So, I am not going to go through the concept of utility further because we are going to digress from the main understanding of the concepts. So, the overall utility will capture that if we take the simple truncated levy walk how much is the total benefit and if we take the exploration truncated levy walk with exploration how much is the total benefit. So; obviously, if the utility of exploration is more than the utility for in the truncated levy walk one would go for using truncated levy walk with exploration.

So, although I told you that I am not going to go through these in detail because you know. So, although it is given over here in the slide, but you know. So, we will we are going to drive digress from the main understanding of the concepts. So, if somebody is

interested it is available in our I triple e transactions paper that we have published in I triple e transactions on computers in 2016 and the full reference is given at the end of this presentation.

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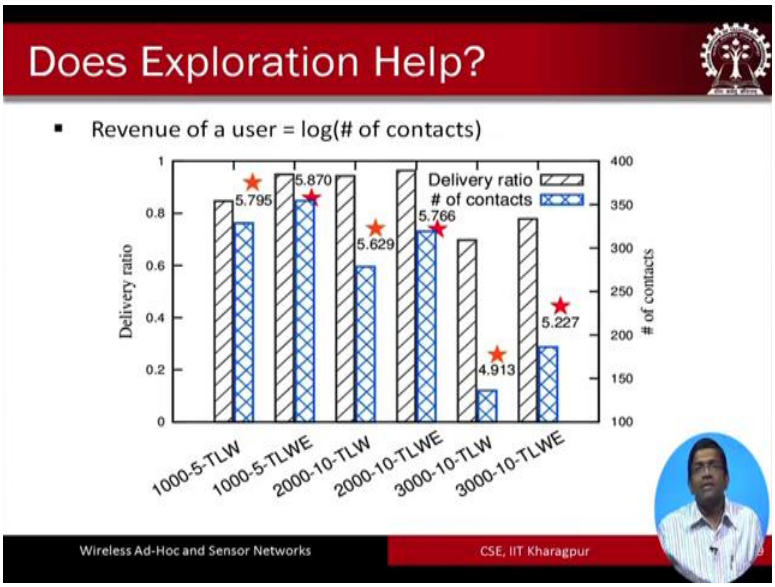

So, basically the question that we attempted in this particular work to understand is whether exploration; that means, truncated levy walk with exploration, whether that is more beneficial compare to that regular truncated levy walk by which humans typically move, following which humans typically move although I mean. So, human mobility is a very complex issue. So, truncated levy walk basically approximates the actual human mobility, but still you know. So, that is the best model that is available.

So, far and So, if we look at some of these comparisons between the truncated levy walk, then truncated levy walk with exploration for different scenarios like this. We find that let us just see look at the first 2 for the first 2 fist histograms that we have in front of us. So, we find that truncated levy walk with exploitation performs better generally comp with respect to the delivery ratio. So, overall the delivery ratio is more and also in terms of the number of contacts with the other nodes. So, finding another node another mobile node to which the node can deliver a message, or it can expect the message to be forwarded from that node and give it give the message to it. So, that basically using the truncated levy walk with exploration that basically gives better performance. And the

similar kind of thing similar kind of phenomenon is also observed in the other scenarios like this.

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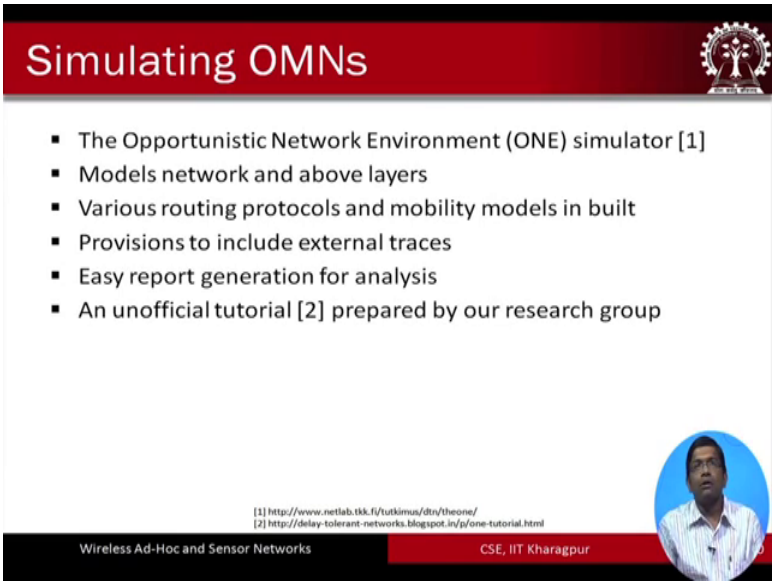

Now, most of the works on use of OMNs have been done through simulations, there is a large volume of work which use simulations. So one of the pop very popular simulator simulators for simulating OMNs is the one simulator and you are encouraged to go through this particular tutorial, the URL is given over here. And this particular tutorial will give you an understanding about you know how to use the one simulator if you are working or if you are interested to simulate the opportunistic mobile networks.

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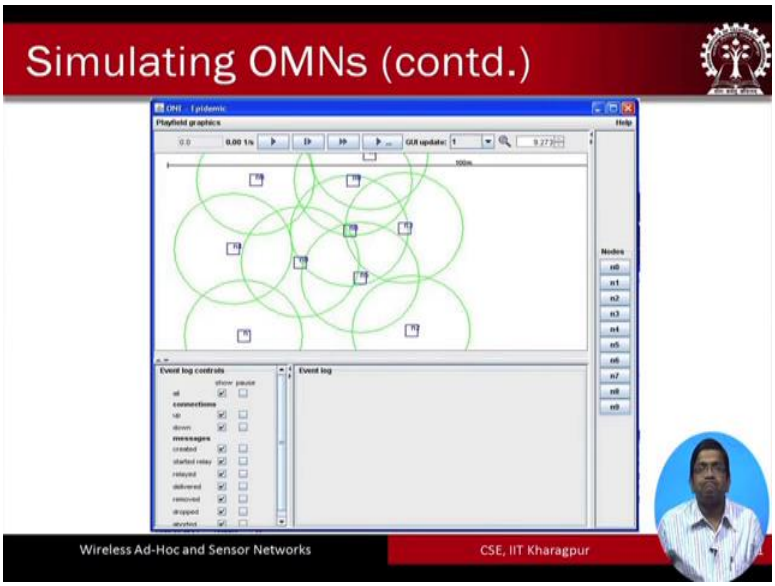

So, let us look at one of the basic graphical interfaces of OMNs. So, this is what the graphical interfaces of one simulators. So, this is one of the interfaces of the one simulator. So, what we see over here are the different mobile nodes and the corresponding range the communication range these are basically depicted in this particular. So one can set the different parameters write different pieces of code and can simulate OMNs using this particular simulator the one simulator.

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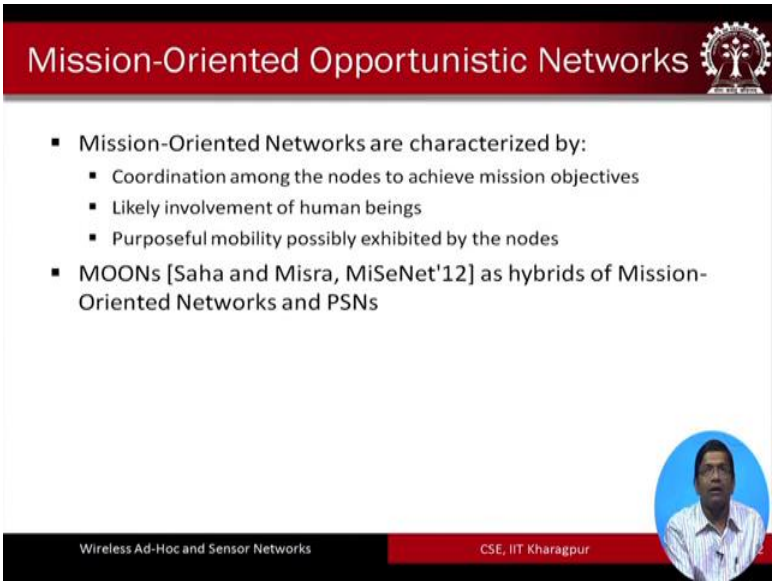

So, a type of opportunistic mobile network is the mission oriented opportunistic mobile network. And more specifically there is something called the moon's mobile mission oriented mobile opportunistic networks. It is something that we have worked on extensively and we are among the very few people worldwide who have done work on mission oriented opportunistic mobile networks. So, basically in mission oriented opportunistic mobile networks there is likely involvement of the human beings also. So, basically humans are also kept in the loop.

So, human beings also become the act as the different nodes in this networks in addition to the other nodes like a laptop a tablet or basically a mobile phone a smart phone. Additionally, there is another aspect also of moons which is the purposeful mobility. And the it moves basically what we have observed is and we have what are the way we have characterized moons is that these moons basically they exhibit properties of purposeful mobility of the different nodes. So, purposeful mobility. So, the nodes basically with a certain purpose we are going to move from one point to another. So, this is another very distinct identity that is given to the moon's compared to the other forms of OMNs.

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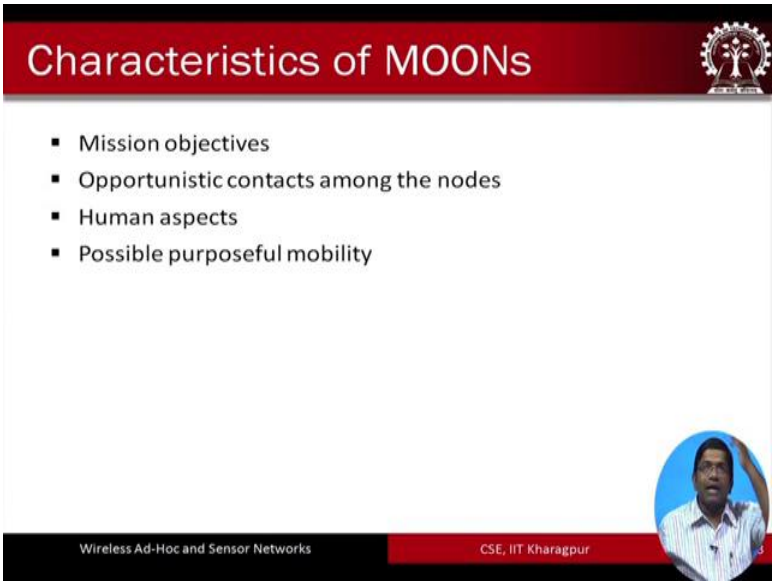

So, these are some of the characteristics of moon's the moons have specific mission objectives. The mission objectives some of the examples could be post disaster relief operation that is that is one mission objective. So, a moon could be set up with a mission

objective of post disaster relief operation opportunistic another characteristic is opportunistic contacts among the different nodes.

So, this is quite common like in the case of OMNs human aspects is very important in the case of moons. So, humans in the loop. So, humans can also become different nodes. So, if I receive a message after that I may not be sending it to another mobile phone directly, from me I can send to another human being or from here my you know I can see another node and I can give it, I can you know I can speak and I can deliver the message that I have received from another mobile node I can speak and I can deliver it forward to the other nodes. So, the and there is possibility of purposeful mobility as I already mentioned.

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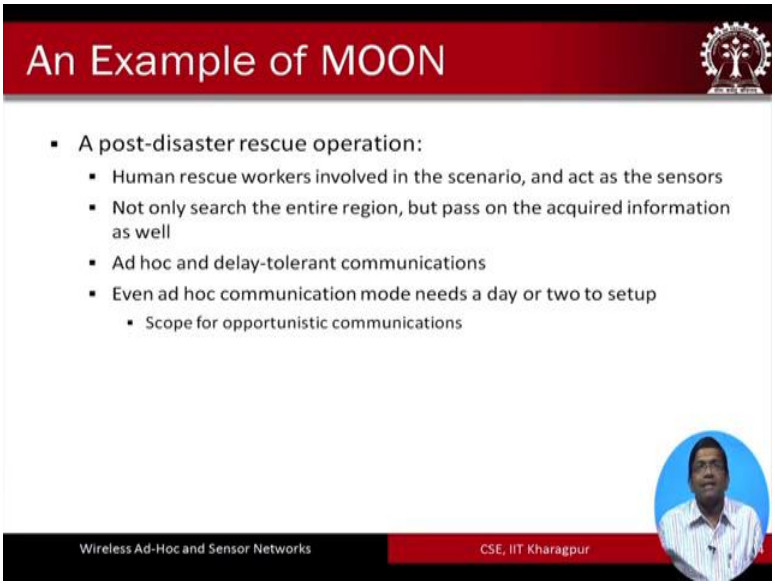

So, an example of mobile mission oriented opportunistic mobile network is a post disaster rescue operation where human rescue workers are involved in the scenario and they act as different sensors. So, the senses mean they have their own mobile phones plus they also have their own sensors. So, they use their own senses their sensing capability every human being has their own sensing capability, and based on that they act as the different sensors. So for example, you know. Something a human being a rescue worker when they are moving around, they use their own sensing capability and to in order to understand that whether it is possible to find a victim around a particular you know site of disaster or not.

So, post disaster. So, human rescue workers not only search the entire region, but they pass on the acquired information as well and Ad-Hoc. And d delay tolerant based communications are conducted in this kind of rescue operations and even Ad-Hoc communication mode needs a day or 2 to set up. And that is why opportunistic mobile communication become even more important for use in these post disaster recurs operational scenarios.

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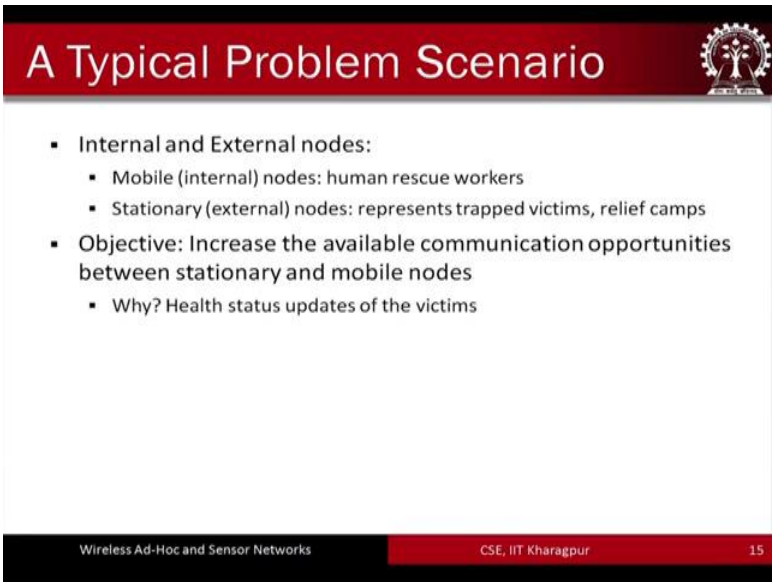

So, in in a typical you know post disaster you know scenario, there can be 2 types of nodes. Nodes which represent basically the trapped victims the relief camps and so on. Which basically are relatively stationary and these in our work we have in our paper in the literature, these have been termed as the external nodes. And on the contrary there are human rescue workers who basically you know act as the mobile nodes, because they move around these stationary nodes and they have been termed as the internal nodes.

So, the overall objective is to increase they available communication opportunities between these stationary and mobile nodes.

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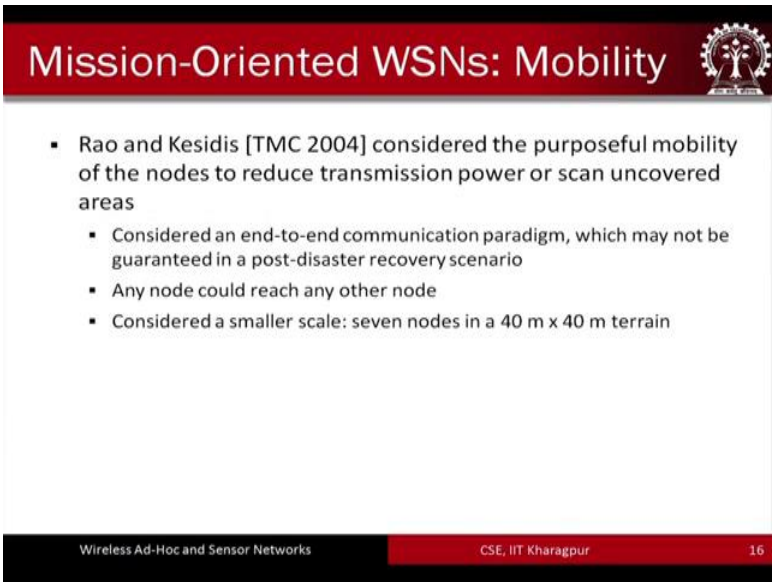

So, Rao and Kesidis in an in the paper which was published in the I triple e transactions on mobile computing in 2004 considered that purposeful mobility of the nodes can happen in order to reduce the transmission power or scan the uncovered areas, purposeful mobility may be you know there is some uncovered area we which has to be explored and that is why purposefully a particular node might move to that particular location.

So, they basically considered an end to end communication paradigm, which may not be which may not be guaranteed in a post disaster recovery scenario, any node in their work could reach any other node and they consider a small scale network of 7 nodes in a 40 meter by 40 meter terrain. So, this is although we got the idea in our work by with Bberusaha and myself, whether we have although we have got the idea of purposeful mobility from this particular from this particular paper, but we have adopted it in the context of mission oriented opportunistic networks the mission of the moons and we have tried to improve the performance of mobility the performance of these networks overall by using this particular concept.

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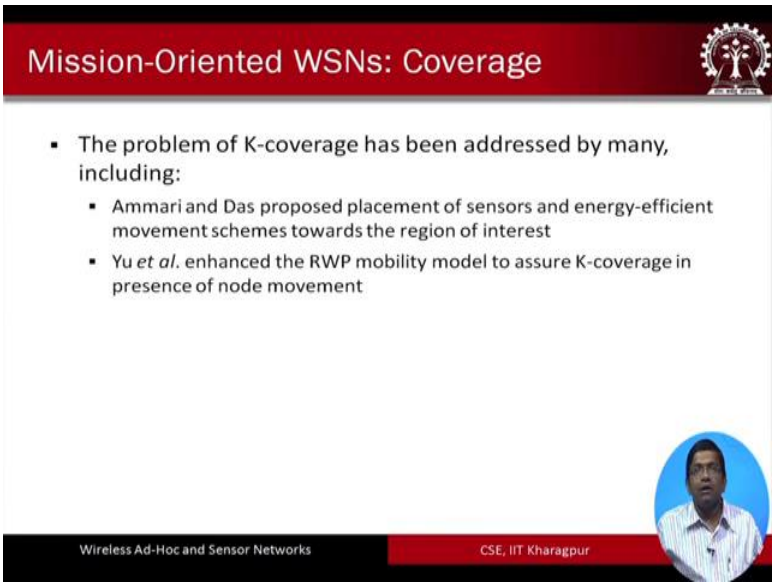

So, another concept that is that was also used in moons, but has been adopted from another paper is by is a concept of K-coverage. So, K-coverage means that any point in a particular region will be covered by k number of different nodes covered, means either it can be communication coverage; that means, it is being covered you know it is within the communication range of k different nodes or it can be a sensing coverage signifying that it is within the sensing range of k different nodes. So, this work was done by Ammari and Das first and then later on followed by Yu et al.

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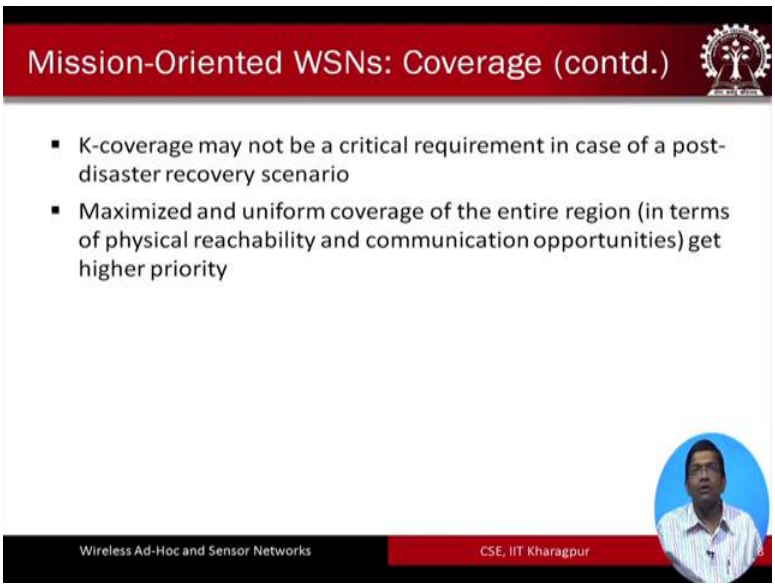

So, K-coverage is not a very (Refer Time: 26:47) requirement in our case of post disaster recovery scenarios. And here basically we maximized. So, rather in our case the maximized and uniform coverage of the entire region gets the higher priority, because we are dealing with post disaster rescue operations, we are trying to use moons for post disaster rescue operations for that particular purpose.

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So, with this we come to the end of the second part of opportunistic mobile networks. And then we are going to go through the third part after this.

Thank you.