Wireless Ad Hoc and Sensor Networks
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Lecture – 17
Opportunistic Mobile Networks-Part-III

We now come to the third part of opportunistic mobile networks. So, here we will continue from what we had previously. So, we were discussing about exploration due to human mobility purposeful exploration and so on. So, these are the things that we discussed last in the second part of OMNs.

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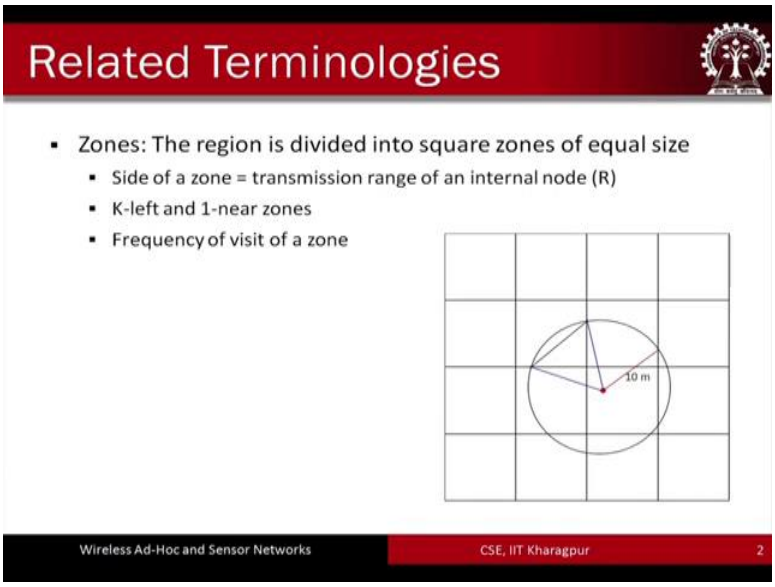

So, let us look at this particular figure. So, what we have over here is a region that has been segmented into different square like zones of equal size the side of the size of a zone is basically the side of a zone. So, these are the different zones right. So, it is the entire region has been segmented into different zones this square shaped zones and the side of the zone is equal to the transmission range of an internal node. And we call the concept of internal nodes and the external nodes that we discussed in the context of moons when in in the second part of the lectures. And so here also we talk about the concept of K-left zones and 1-near zone. So, let me just explain this to you first. So, for any zones we have number of zones over here. Let us consider this particular zones zone. So, one or other let me I think this is a better example. Let us consider this particular

zone. So, K-left zone. So, if k equal to 2 for example, then 2 left zones would be these 2 zones then we have another concept the 1-near zone.

So, for this particular zone the 1-near zones are this zone, this zone, this one, this one, this one, this one and this one and this one. So, we have around this all these zones which are 1-near zones. So, similarly you know. So, instead of 1-near one can go for 2 near and so on. And all these things can be extended further and there is another concept that is the frequency of visit of a zone. So, all these things these terminologies are going to be used in order to understand further about how these moons function.

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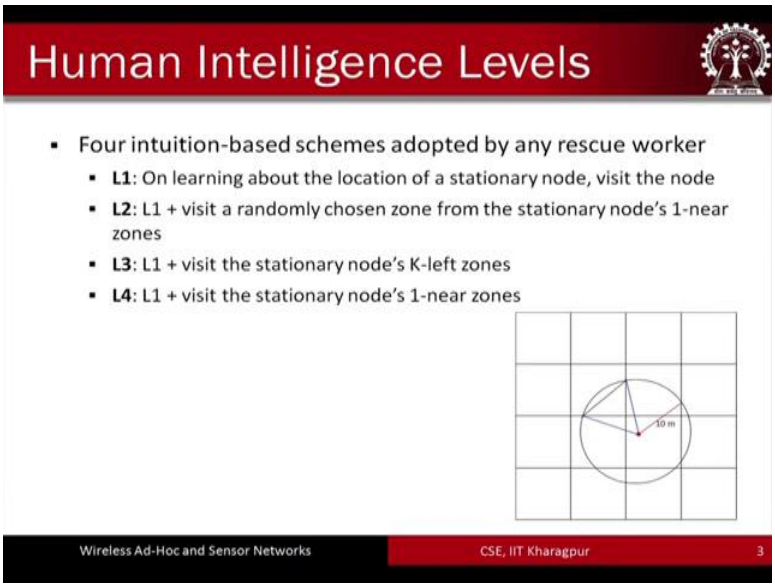

So, I already mentioned to you that in the case of moons human exploration is something that is very important. So, we have human beings who walk around maybe using t L w the truncated levy work model or any other model. Human beings who they move around not only that they move around, but they also apply their intelligence. So, there you know one can come up with different schemes of intelligence. So, we basically consider some basic forms of intelligence like the ones that we see over here. So, we use 4 different forms of intelligence L 1, L 2, L 3 and L 4. L 1 basically is on is that on learning about the location of a stationary node visiting that mode. So, that becomes the first scheme which can be used for you know rescuing a particular victim by a rescue worker. L 2 is another scheme that can be used for a similar purpose. So, which is basically that not only you perform as in L 1.

But also you visit a randomly chosen zone from the stationary nodes 1-near zones. L 3 is L 1 plus visiting the stationary nodes K-left zones L 4 is L 1 plus visiting the stationary nodes 1-near zones. So, these are the 4 different schemes that can be adopted different human intelligence based schemes that can be adopted by a rescue worker to go around in search of different victims like this actually one can come up with different other schemes as well. So, it is not that these are the only 4 schemes. So, we had considered only 4 schemes, but this could be adopted by adopted and extended to different other schemes as well and this is what we are going to use in our study and see that how these schemes they compared with one another.

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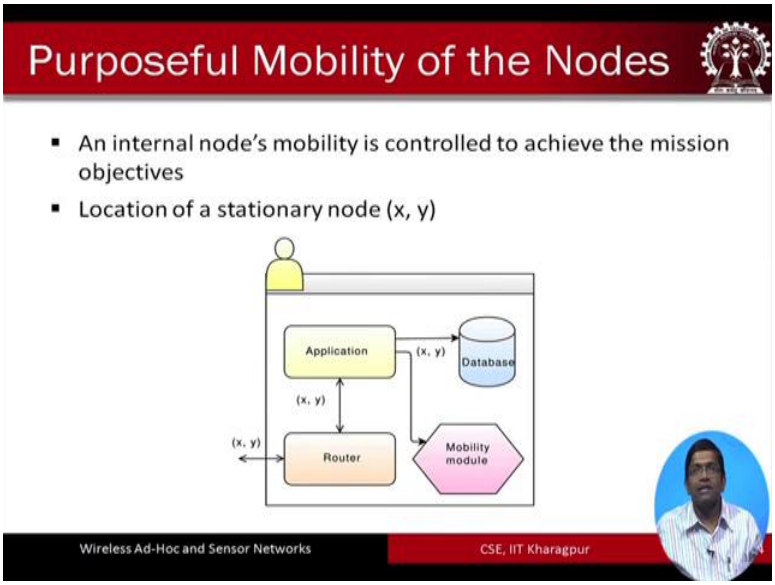

So, we already have seen that purposeful mobility is very important, and an internal nodes mobility is controlled in order to achieve the different mission objectives. So, that is where the purposeful mobility aspect of Rao and Kesidis that was supposed in TMC in 2004 has been adopted. So, and for a stationary node x, x y. So, this stationary node means it could be a victim it could be it could be the stationary node could be a relief camp or something like that which is relatively stable over time.

So, basically what happens is these values the locations of the stationary nodes they can be stored in the different you know databases and these locations can be shared with the other nodes through different applications. So, this is basically the structure of a particular moon node, and every moon node basically has this kind of architecture. So, it

has a database which stores the location of the different other nodes and that can be basically informed to the other nodes with which it is going to encounter.

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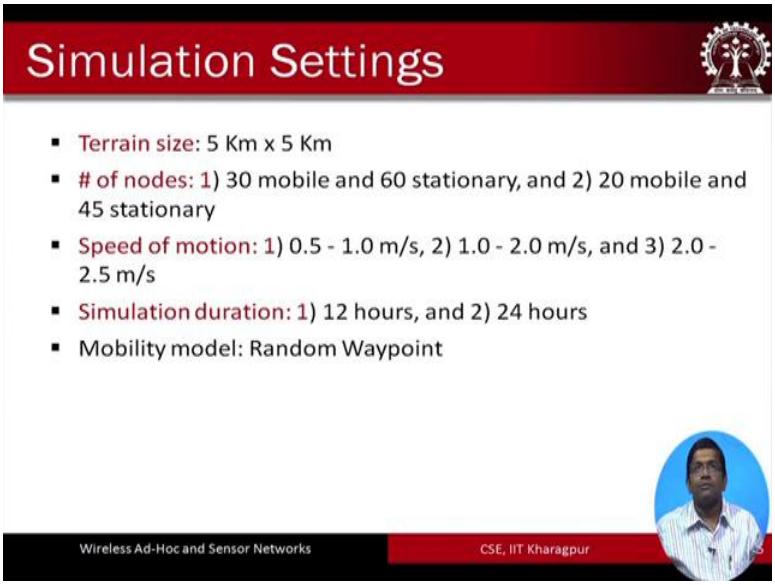

So, will just look at how these schemes they compare in terms of simulation based experiments that were performed L 1, L 2, L 3 and L 4. So, how they compare. So, you know. So, in our simulation we had used the one simulator. And we had simulated a terrain size of 5 kilometers by 5 kilometers. And where number of nodes that were used where you know 13. So, in one experiment 30 mobile nodes and 60 stationary nodes and in another experiment 20 mobile nodes and 45 stationary nodes and the speed of motions are also as shown and the simulation durations of 12 hours and 24 hours and the mobility model that was adopted was just a plain basic random waypoint mobility model.

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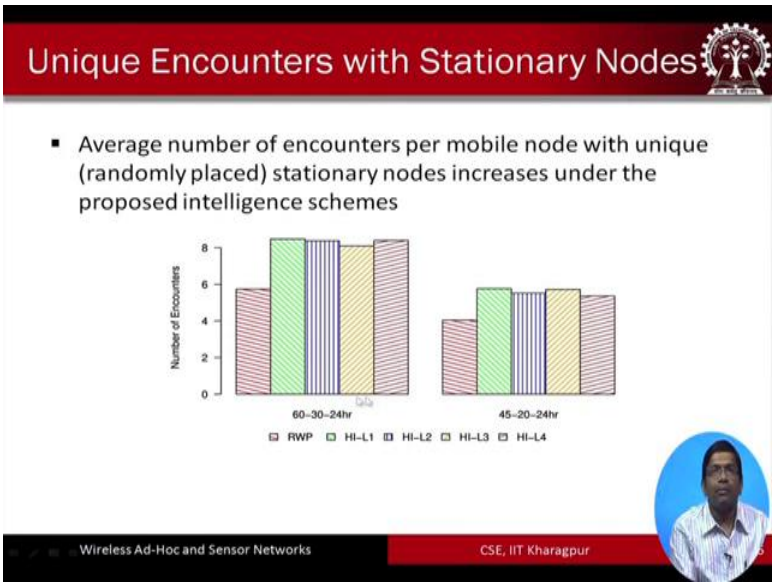

So, as we can see over here that compared to the random waypoint mobility model, the scheme's L 1, L 2, L 3 and L 4 these schemes they perform better in both the scenarios both the scenarios of 60, 30, 24 hours. So, 60 60 nodes 30 nodes. So, 60 is stationary nodes 30 mobile notes etcetera and 45 20 24 in both of these scenarios we are able to see that in terms of the number of encounters basically you know these schemes these intelligences based schemes L 1, L 2, L 3 and L 4 they perform better compared to RWP.

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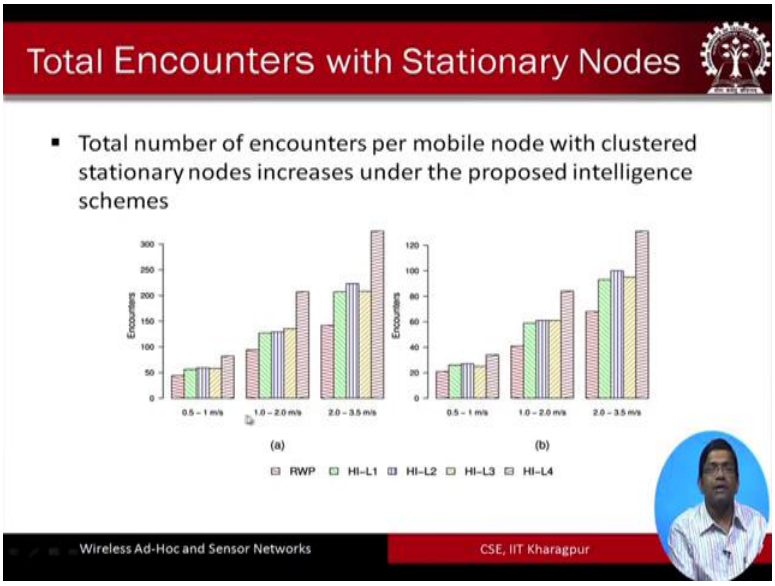

So, this is with respect to you know with respect to the different speeds the speeds of the mobile nodes and here also we see that the total number of encounters per mobile node with clustered stationary nodes increases under the intelligent schemes L 1, L 2, L 3 and L 4. So, this is you know these are the basically the different schemes and their comparison with the RWP; that means, the random waypoint mobility model.

So, the number of encounters as you can see are you get when you apply. So, in other words I mean what does it mean. So, this means that the number of encounters is more means that by adopting these intelligences based schemes one can these nodes they can come most frequently in contact with the stationary nodes the mobile nodes can come more frequently in in contact with the stationary nodes compared to the basic mobility model of a random waypoint. Actually in this particular paper the authors they did not consider the truncated levy walk human mobility model. So, that was not adopted. So, the basic the stochastic RWP which we have studied in the context of mobility models when we are talking about ad hoc networks or ad hoc networks mobility model.

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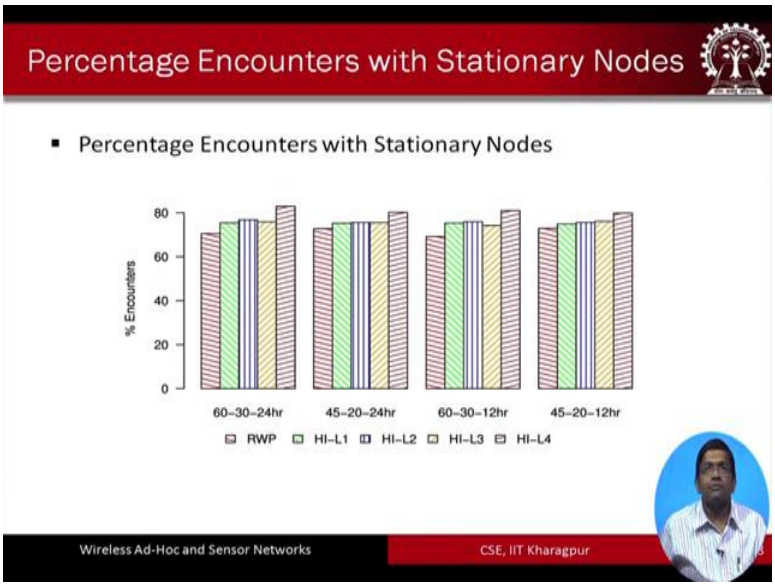

So, we have you already know about what is RWP. So, it was come you know it was compared with that RWP. So, in terms of the percentage encounters with the stationary nodes here also we find that although there is not too much of difference, but still percentage encounters with the stationary nodes in this particular context of adoption of L 1 L 2 L 3 and L 4 is better compared to the use of RWP, and I mean because the

legends are the same I do not need to explain this again, but distance for RWP and this for L 1 next one for L 2 L 3 and L 4 for the different scenarios 60 30 24 45 20 24 60 30 12 and 45 20 12.

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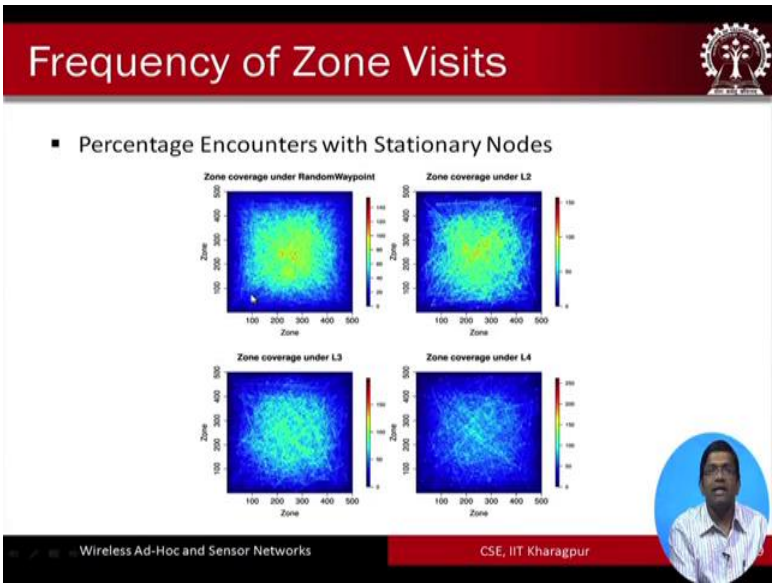

Another important observation was by adopting this schemes L 1, L 2, L 3 and L 4 we get better frequency of zone visit is compared to the use of RWP.

So, RWP basically as we can see from this heat map that here the tendency of the nodes is basically to come towards the center come towards the center. So, the center basically has more frequency of visit is of the nodes compared to the other schemes L 2, L 2 has little bit more flattered distribution of the nodes then L 3 is even better in terms of the flatness of the distribution of the nodes and L 4 looks even better. So, it has even better distribution of the nodes across the interactivity.

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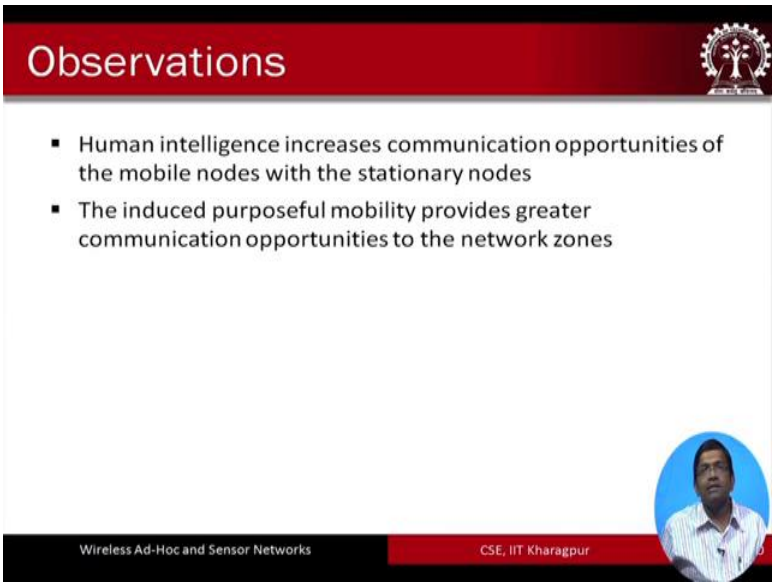

So, the observation is that the human intelligence basically increases communication opportunities of the mobile nodes with the stationary nodes see when intelligence means these schemes L 1, L 2, L 3 and L 4. So, this is what has been termed in the literature as human intelligence in this particular work. So, the 2 the induced the next observation is that, the induced purposeful mobility basically provides greater communication opportunities to the net zones. And this is basically not something that is specific to our work.

So, Rao and Kesidis had already observed it and they came up with their own solutions and own models towards that in line of that and we have simply adopted it and we have used it in this particular context.

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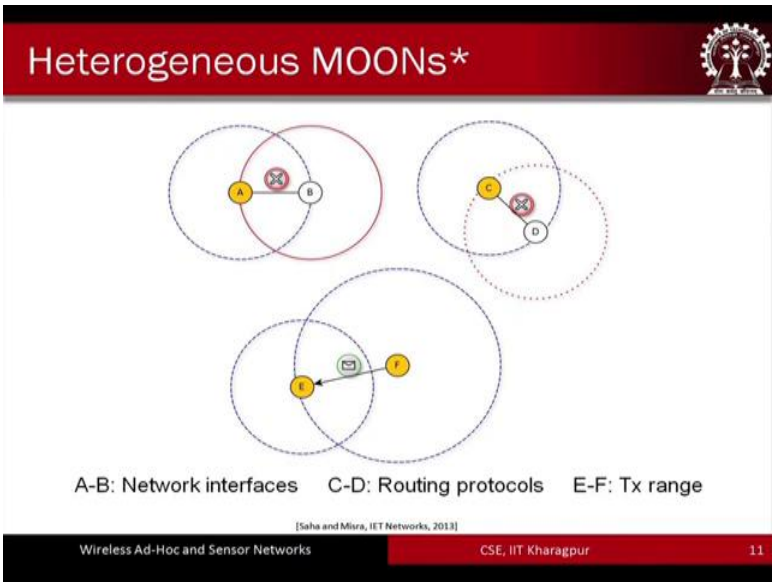

Now, another important issue is heterogeneity in moons. So, in moons basically the nodes they exhibit different types of heterogeneity. Heterogeneity with respect to the different network interfaces if different networking to So, A and B they have different network interfaces this is what is shown in this particular figure. C/ and d/, c/ is using a different routing protocol from d/, and they come in contact with each other. So, if they are using different routing protocol, how do they you know handshake with each other than this is an example where the transmission ranges are different. So, 2 different mobile nodes they have different specifications consequently their communication ranges could also be different right. So, this is again something that was studied by Saha and Misra; that means, in our group itself in our research group we have worked on this and this was published in the it networks in 2013. So, issues of heterogeneity in mobile opportunistic mobile networks. So, in terms of heterogeneity.

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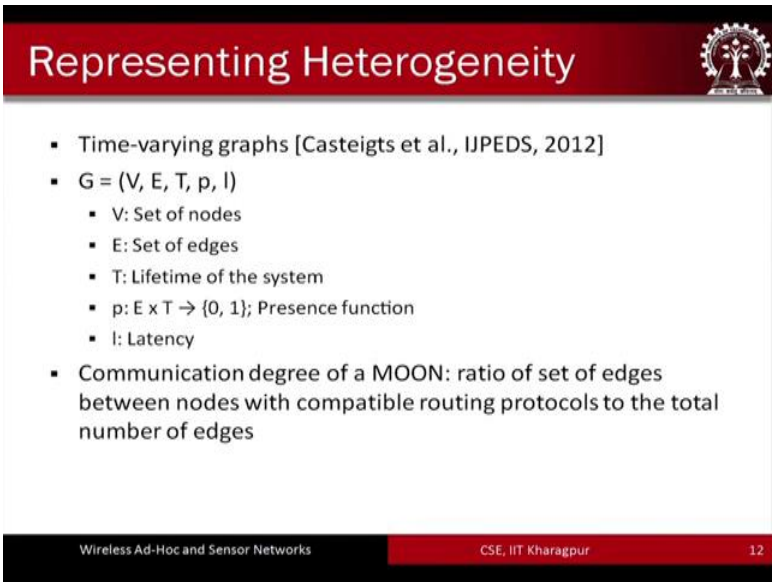

Basically, these are the things that have been studied representation of the different nodes set of nodes is represented as fee. So, these moons basically can be represented as time varying graphs, where each of these graphs have a set of nodes V a set of edges e, the time lifetime of the system T, then there is something called the presence function which is basically E cross T and which basically maps to E cross T, and then l which basically corresponds to the latency. So, the communication degree of a moon is defined this way that it is the ratio of the set of edges between the nodes with compatible routing protocols to the total number of edges.

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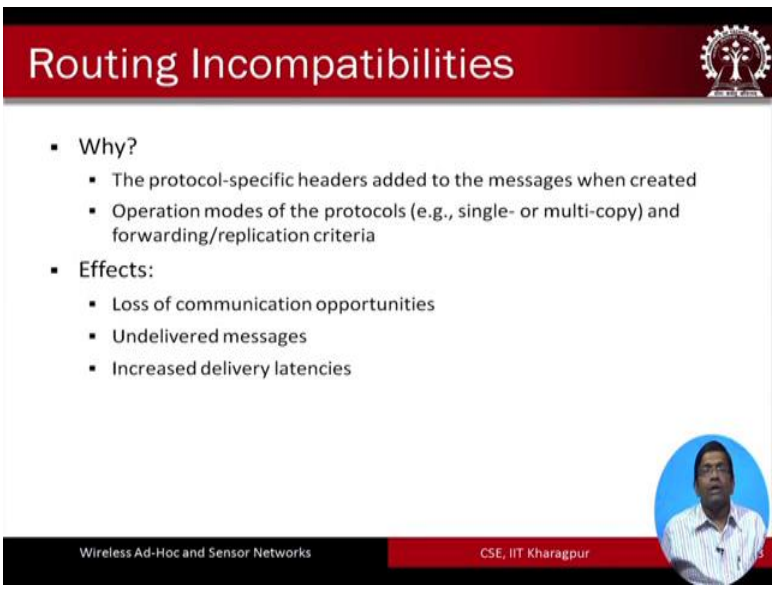

Routing incompatibilities. So, basically what happens is different protocols might be used by the different nodes in forwarding the messages right. So, consequently what happens is there are there are routing incompatibilities that might arise.

So, how do you deal with such incompatibilities. So, basically protocol specific headers have to be added to the messages, when they are created and so this protocol specific headers basically make it difficult for these messages with different protocol headers for a protocol specification to talk to each other when they come in contact with each other. And the second thing is that the operation modes of the protocols for example, single. So, one protocol might be following a single copy routing another protocol might be following a multi copy routing and the differences in forwarding and application criteria could also be different and consequently there are different routing incompatibilities that might also arise. In terms of the effects what is going to happen because of using compatibilities there are the loss of communication opportunities there will be undelivered messages and there would be increased delivery latencies.

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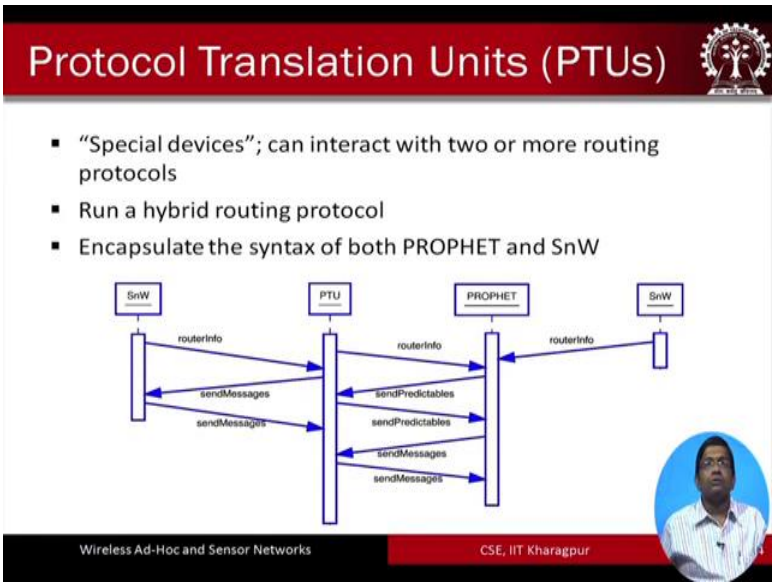

So, basically, this is something that we had proposed we propose the use of protocol translation unit is PTUs. So, you know let us say that 2 different protocols SnW and prophet 2 nodes following 2 different routing protocols SnW one using student eight the other one using prophet. So, in between we are introducing devices which will you know run this protocol translation unit.

And what is going to do is it, it is going to act as a translator between of the messages that are transferred or sent by the nodes from the different or the different nodes which want to communicate with each other. So, this will act like a middleware sitting in between these 2 different nodes acting as a translator of these different messages. So, that they can follow the messages sent by these different nodes following the different protocols.

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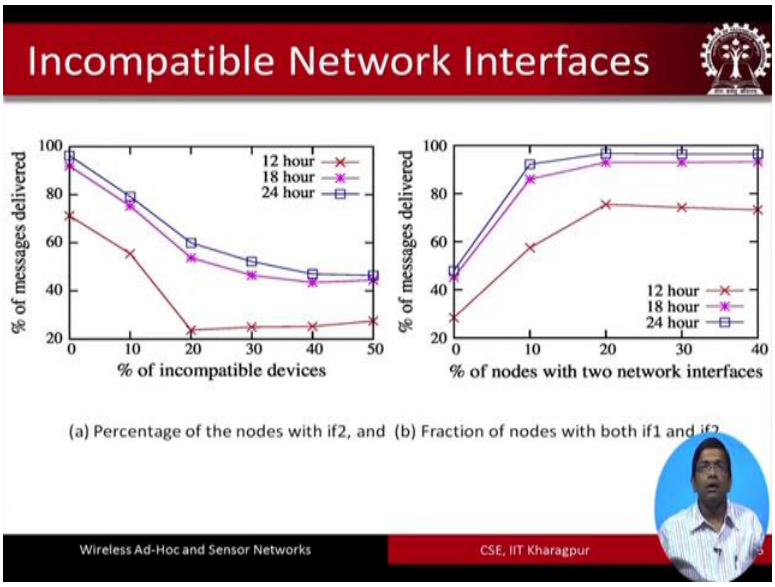

So, just in a nutshell this is something that is there in the corresponding paper, which is listed at the end of the slides. So, here basically what we observe is if we look carefully in terms of the percentage of messages delivered when one is using the protocol translator along with the regular scheme. So, the percentage of messages delivered basically increases. On the other hand, if it is not used then the trend is that as the number of as a number of all the percentage of incompatible devices increases, the percentages of percentage of messages delivered decreases. And it increases in this particular case. So, basically then the use of PTUs basically increases the chances of message delivery.

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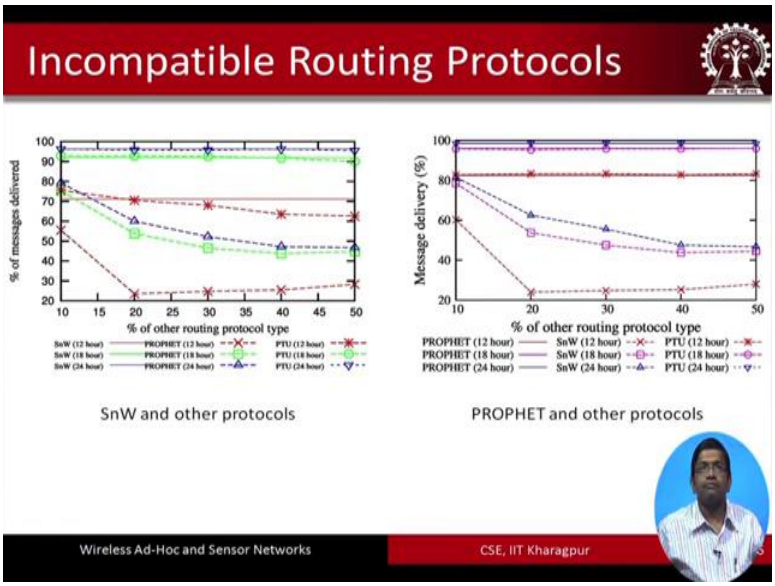

Now, here basically what is compared is again with respect to percentage of messages delivered, but how the different routing protocols they perform. So, comparison between the pure prophet between pure prophet and SnW and SnW and PTU. So, under different scenarios 12 power you know of running profit 12 power of running SnW 12 power of using the PTU best scheme and so protocol translator unit being used and so on. So, what we find over here.

If we look closely at these plots we find that the PTU best schemes they perform better compared to the pure SnW and your prophet.

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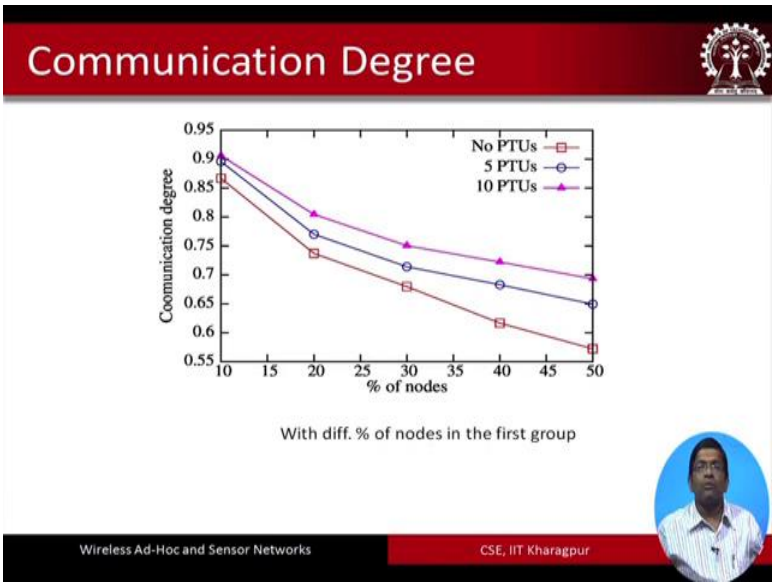

So, this is with respect to the communication degree which was already you know which was already defined earlier you know a few minutes back. So, we what we see over here is as a percentage of nodes increases, the communication degree basically goes down and with respect to the different for all the different schemes where there is no PTUs used where 5 PTUs are used and where there are 10 PTUs and that are used. So, what we see is that more number of PTUs are used then the communication degree in general is better compared to 5 PTUs used and 10 PTUs used.

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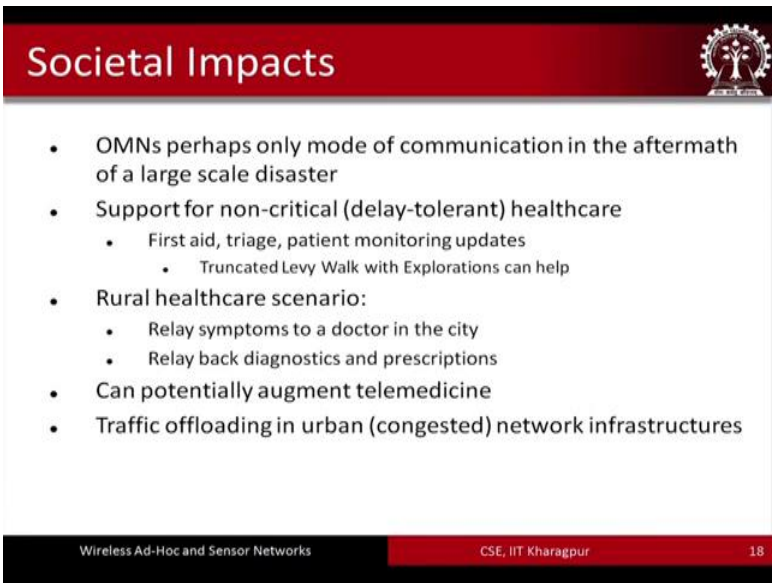

Societal impacts are very important OMNs are one of the prime reasons of use of OMNs is to serve different social needs. So, OMNs perhaps are only are the only mode of communication after a large scale disaster. Because ad hoc networks are better, but not as much as in the better than pure wireless networks like you know Wi-Fi or cellular networks, but you know OMNs are even better than the ad hoc networks. So, and also in the case of also in the case of rural healthcare scenarios in rural healthcare basically what happens is you know.

So, there is lack of connectivity between the different nodes. So, basically when the villagers they come in contact with the doctors in the city only after several hours; that means, that maybe you know once in a day a particular villager will be coming in contact with the doctors and then you know the entire day will pass the next day will pass and again the chances of getting in connectivity with a particular doctor by a villager would happen.

So, basically you know. So, these networks are again you know they basically perform they exhibit the properties of moons, if I exhibit properties of OMNs in general. So, in the in case of you know, o m n, OMNs basically exhibit lot of use they have lot of advantages of being used in the case of post rescue operations rural health care and so on. And so forth. There are different other societal you know societal applications where these networks can be used.

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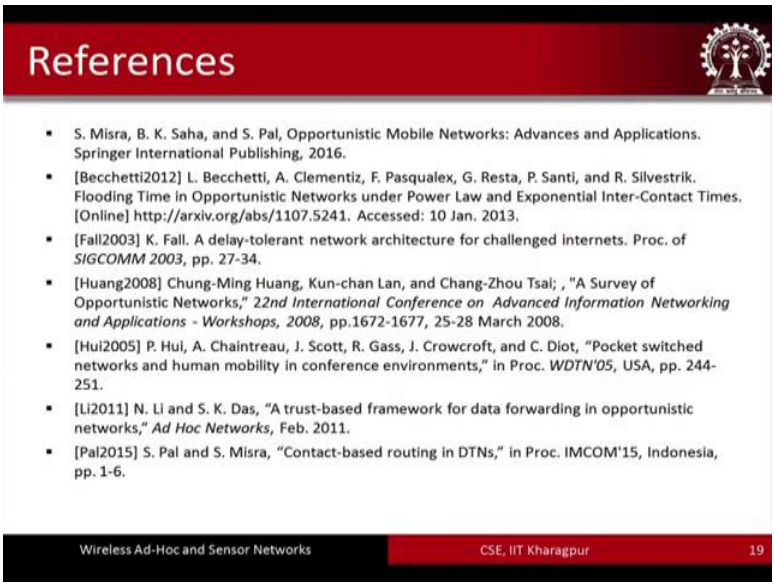

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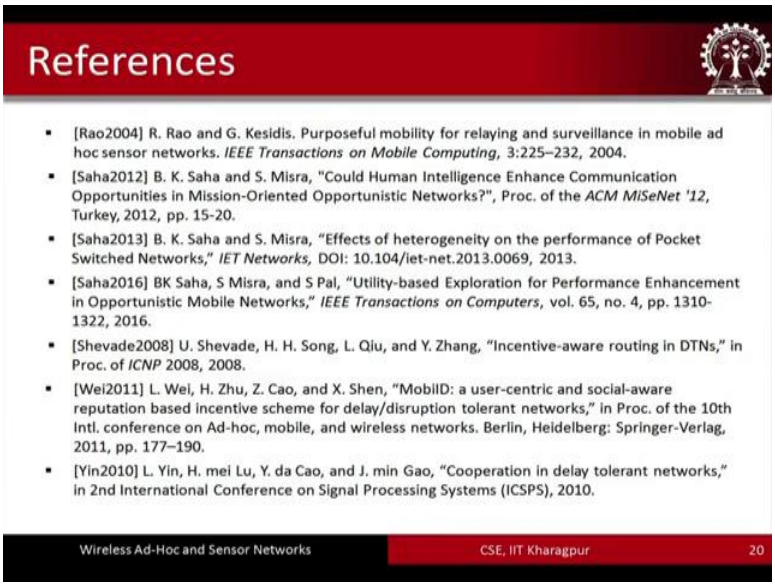

So, with this we come to an end. So, these are the different references all the references are listed over here. So, one thing I would like to mention over here is we have covered the topic of opportunistic mobile networks in 3 parts part 1 part 2 and part 3. So, not that the audience should note that the students should note that not that all the parts are going to have all the references, but all the references can be obtained by looking at the references at the end of each of these 3 parts to all the 3 parts taken together and the reference is taken together one would be able to get the references.

So, another thing that I would like to mention at this point is opportunistic mobile networks is a little bit more advanced topic and that is. So basically what happens is because it is an advanced topic it is more likely to be of interest to audience who are in the P.G level the research scholar and so on. And, but at the same time because here actually what we have done in these lectures as you have seen that we have given lot of research lot of concepts which can be used for the research and so on.

So, this is this is a very important very hot topic currently because of the reasons that you have seen it can be used for different societal applications it can be used for solving different problems in the society and so on. Rural health care or you know posterior relief operations and so on. So, there is likewise there are actually many other different applications of OMNs and the last thing, that I would like to mention is that many of these references that you will see you must have also noted actually when I was covering

the different concepts, is I was referring to our own works the reason is that many of the works that have been done on OMNs worldwide have actually been done by us, but; obviously, there are other groups research groups worldwide which are also very active in OMNs, but we have also done a lot of work on OMNs which we consider as very you know significant very much fundamental and these happen published in very reputed journals and conferences.

So, that is the reason actually we were referring to this because these are fundamental in nature and that is what I wanted the student to learn and I am sure that this particular lecture will be of interest to students who are more who have more research orientation like the P.G students like the research scholars and so on.

Thank you.