Introduction to Internet of Things

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Lecture - 15
Sensor Networks – II

In the previous lecture we have already gone through some of the basic concepts of sensor networks. We have seen that by interconnecting the different nodes in the network, we can have an extended coverage of sensing and, that way we can also have emote real time distance monitoring of what is occurring around this physically deployed nodes in the network. We have also seen that there are different types of sensor networks. Stationary sensor networks, mobile sensor networks. And mobile sensor networks again can be of different types. One is aerial mobile sensor networks; that means, the mobile networks which move you know, sensor networks that move in the space we have terrestrial sensor networks. So, where the nodes they move on the surface of the earth. And we can have underwater sensor networks where the nodes basically move in the underwater area.

So, whatever be the sensor network, whether it is underwater terrestrial or aerial these nodes they basically have to cooperate with one another. In order for the network to function if the nodes do not cooperate they will not be able to function. So, how to promote cooperation? So, before that we need to understand the behavior of the different nodes in the network.

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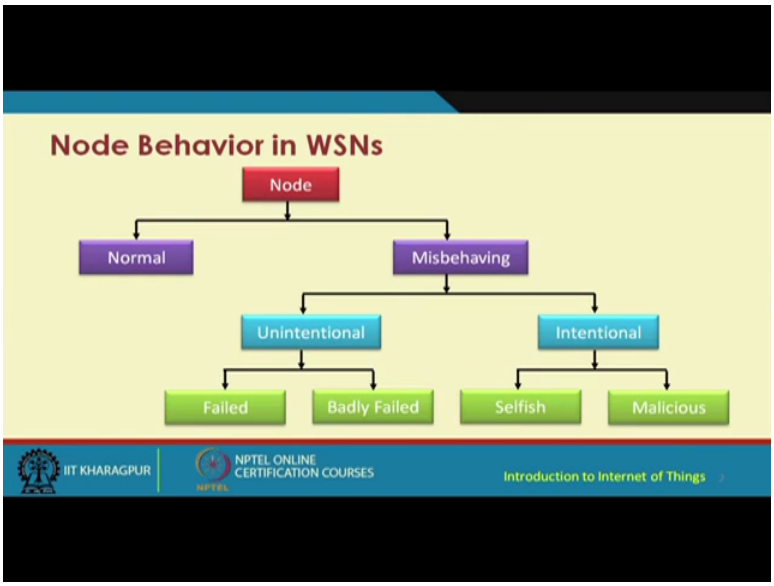

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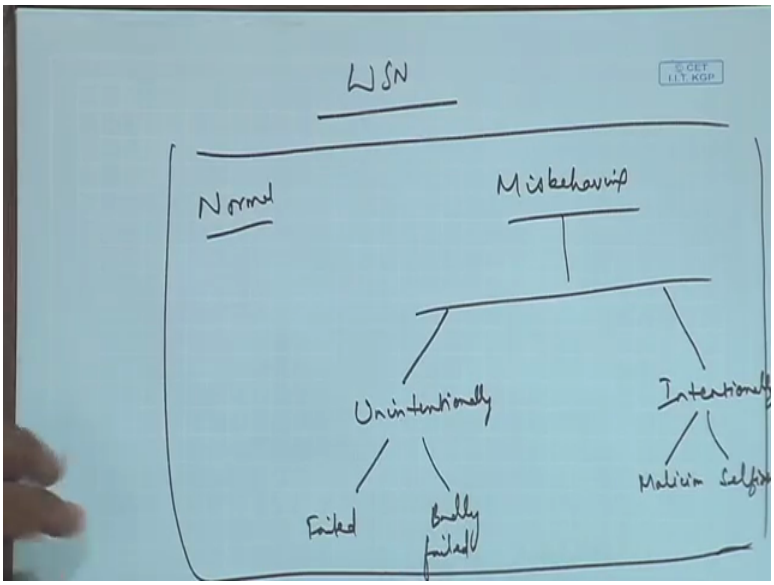

So, when we talk about sensor networks we have, we have nodes that would be behaving as they are supposed to behave. We can have nodes that would be misbehaving. So, we can have normal nodes we can have misbehaving nodes.

So, normal nodes we do not need to worry about they, you know as per the requirement the function the way they are supposed to function. Misbehaving nodes, this misbehavior can be of 2 types. One is that they misbehave unintentionally and the other one is where they misbehave intentionally you know intentionally they misbehave and unintentionally

means they do not do not want to misbehave as such, but you know unintentionally they end up on end up misbehaving.

So, in the intentional category we have 2 types. One is the malicious node and the other one is the selfish node. And in the unintentional category, we have the failed nodes and the badly failed nodes. So, these basically forms the taxonomy of behavior of nodes in a sensor network ok.

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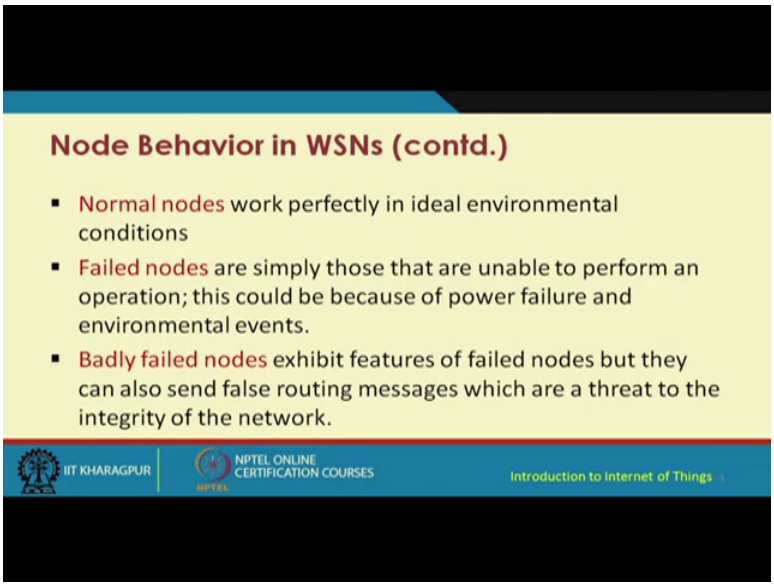

So going ahead we have normal nodes that work perfectly in an ideal environment condition. Failed nodes which are unable to perform the functions that they are supposed to perform maybe due to power failure, or maybe there is some hardware failure, or something of that sort. Badly failed nodes are like the failed nodes, but in addition they sent some false routing messages which basically hurts the integrity or the you know which becomes a threat to the overall integrity of the network. Selfish nodes are basically the ones which are unwilling to cooperate; they do not want to cooperate.

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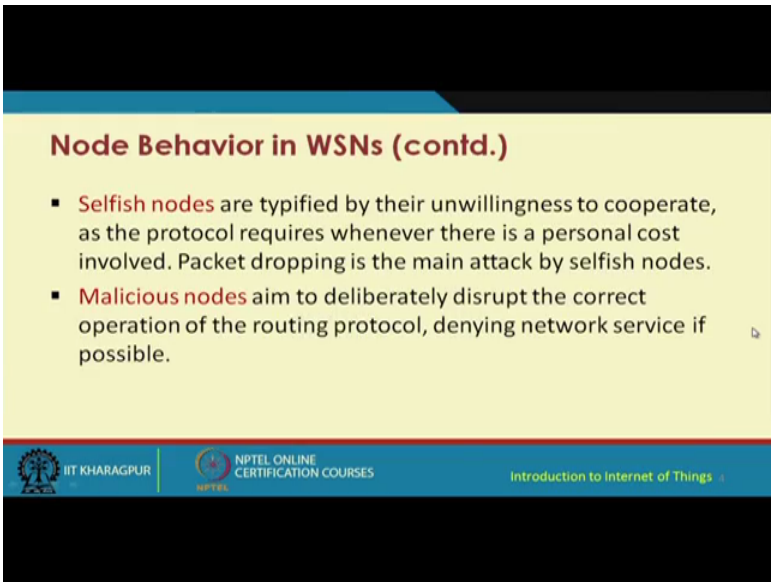

So, it is intentional misbehavior because, they do not want to cooperate because there is some personal cost that is involved. And packet dropping is one of the consequences of not willing to cooperate. So, if a node which is acting a selfish receives a packet. Instead of reeling it forward which it is supposed to do for successful operation of that particular network, it is going to drop the packet. And this is not desirable. And then we have the malicious nodes which are basically you know, which are like harmful nodes, which are a threat to the network, which want to successful deliberately disrupt the successful operation of the routing protocol or other protocols, and thereby they do not want to deliver the services that they are supposed to deliver.

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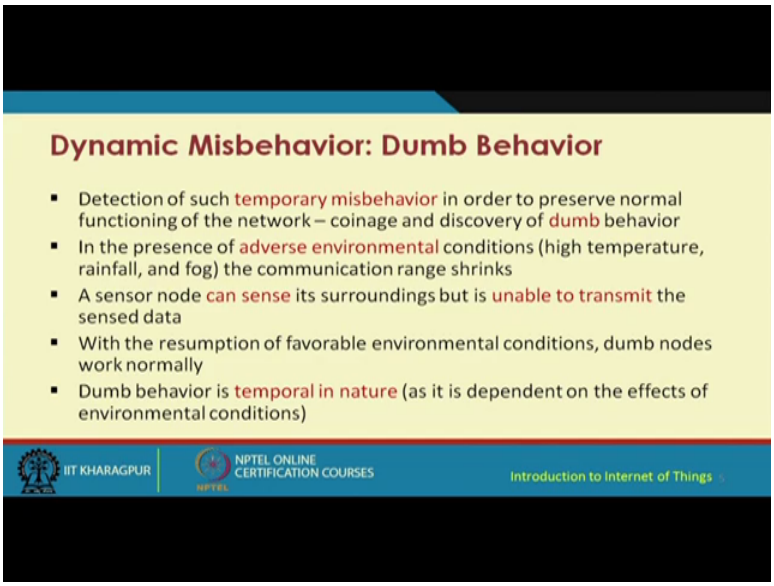

Another type of dumb load which was recently, very recently few years back only, developed or identified not developed, but identified by us in the SWAN lab, is the dumb behavior. And we are the ones who basically detected the existence of this kind of misbehaving node. This is an unintentional misbehavior. So, in this kind of misbehavior, unintentional misbehavior, what happens is these sort of miss behaviors pop up whenever there is some change in the environmental conditions. Maybe there is heavy rainfall, maybe there is heavy snowfall, maybe there is heavy fog and under those circumstances naturally as we know there is you know signal problems that are going to happen. So, a node is going to sense a sensor node is going to sense, but then it is not able to send it forward, it is not able to communicate. Because, of all these weather conditions or environmental conditions. So, that is the reason why the transceiver unit is not able to communicate at all. Or even if the signal strength goes down drastically. So, what happens is that there is no node in this facility.

So, because there is no node in this facility, essentially it is the effect is that it is not able to communicate, it is not able to delay, it is not able to send the sensed information to another node because, there is no such node. The range has shrunk; the range has decreased due to all these weather conditions. And we have coined the term dumb because, these nodes basically behave like sort of you know some sort of you know behavior of dumb persons who can hear, but who cannot speak out, a disability of these kind of differently abled persons, because of which they are not able to. They can they

can listen they can see everything, but they are not able to speak out and because of this kind of mimicking behavior with these kind of nodes the sensor nodes we term, these nodes this behavior as the dumb behavior.

Now, this dumb behavior is transient, it is temporary. Temporary means, that it will last only for the duration when the weather condition is bad. Now when the weather condition improves subsequently again the regular communication you know goes on. So, these sort of behavior, unlike the other types of misbehavior are only temporary in nature. And that is why this is known as a dumb behavior. Only dumb behavior unlike other kinds of misbehaviors intentional misbehaviors, these are very temporary in nature, and you know, they occur unintentionally. So, this is very important to understand. Now what is required is to detect this kind of misbehavior and then you know, offer connectivity this reestablishment.

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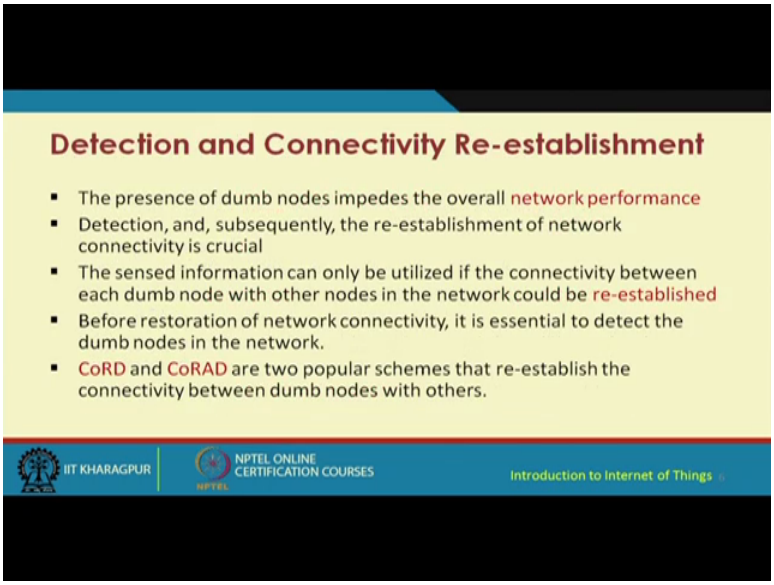

So, if this kind of see what happens is whenever this kind of behavior occurs in a sensor network. This kind of behavior will not occur typically in other types of networks. Because, sensor networks are typically deployed in hertz in the environmental conditions, in environments where the you know be all these physical things change quite fast quite rapidly and so on. So, since the networks are typical in for deployment in these kind of environments. So, what is required is to detect this kind of misbehavior happening in the network. Because, ultimately what happens, is the node which is not

able to communicate it is completely cut off from the other nodes in the network. So, then how will it how in the other nodes know that it is cut off? So, there has to be detected somehow. So, we worked on this particular issue of how to detect this kind of temporarily cut off nodes the dumb nodes and then, how to establish some kind of connectivity, even in the presence of dumb behavior. So, that the normal network functions keep on running until the weather conditions improve.

So, 2 protocols, cord and corad were proposed by us in the SWAN group. And these protocols are available for further.

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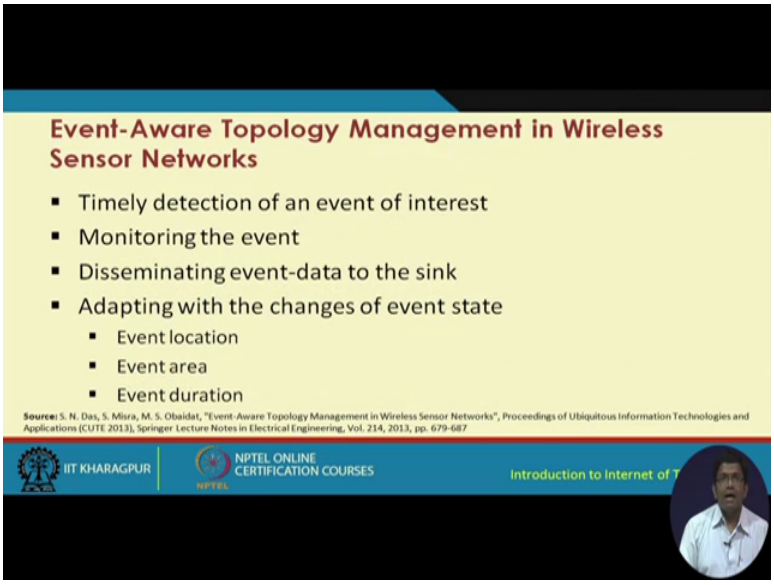

It is available in the internet for further reading. So, if you search with the cord and corad with few other suitable keywords you would be able to get access to these papers. So, these have been published in very prestigious venues like ACM transactions journal of systems and software of elsevier and so on.

Next, event aware topology management in wellness sensor networks, I also want it to give you a little bit of glimpse or flavor of this work. This also has been done by us in the SWAN lab. So, here basically you know we are talking about topology management. So, so topology management is primarily concerned about how to not only establish, but also how to manage the topology over time. How to keep the topology? How to keep the networks, the nodes in the network connected over time. So, that they cannot they can

continuously sense and disseminate the data through them to the sink and adapting to the changes of the event state, with respect to event location event area and event duration.

So, this is what this particular work talks about. So, I am not going to, I am just going to give you little bit of idea about these works, but I am not going to go through each of them in detail. The corresponding reference is given for you are already use, if you are interested you know this paper you can please go through.

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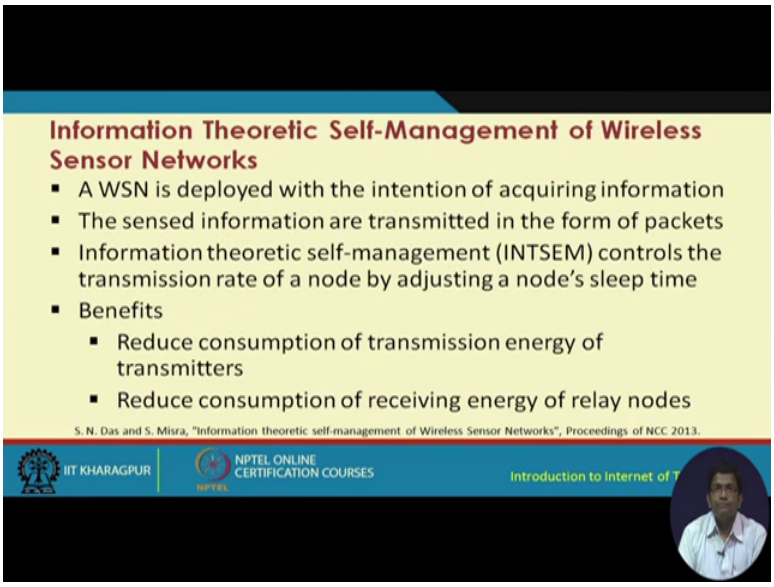

Another paper also done along with my student Shankar Nayayan Das, is this information theoretic self management of wireless sensor network. This is a fine work. Because you know, in sensor networks one of the problems is periodically the nodes this sense what is going on. Typically it is found that with respect to time it might so happen that the information content of this different sensed packets they do not change much. So, why do you want to unnecessarily overload the network by communicating those packets, where the information has not changed much?

So, what is required is at the source, detect how much the currently sensed packet, and the previously sensed one are correlated. And then through this measure, which where we are using advanced information theoretic concepts, we are identifying how much is the correlation between these sensed packets, and then send deciding upon which packet to send forward if they are sufficiently uncorrelated you sent the sensed packet, otherwise you drop it. You do not do anything further. Or queue it for sending it later, or

do something else. This is one possibility. Other possibility is that, in a sensor networks typically the nodes are densely deployed.

Now it might so happen that 2 or more different nodes they have sensed data, they have sensed data which are sufficiently correlated. Then the point is that all those 2 or 3 different nodes if they all have similar kind of information content, why do you all want to have those 3 packets to be sent forward to the sync? Because doing so will unnecessarily overload this highly constraint network. So, we have again used tools from information theory, to basically address this particular issue.

So, these ideas are very fundamental to sensor networks and we have addressed those, and I am trying to give you an exposure to all these different problems, so that you know that if you have to use sensor networks for IoT implementation what are the issues that have to be addressed for it. It is not like buying few IoT devices, few sensors, few different other devices and putting them all together we will have an IoT network. This is a common misconception, implementation deployment of IoT is heavily research intensive, it cannot be done in an ad hoc manner, you have to plan it properly and you have to design the protocols the design the algorithms, find out the different complications that are going to happen, and act accordingly.

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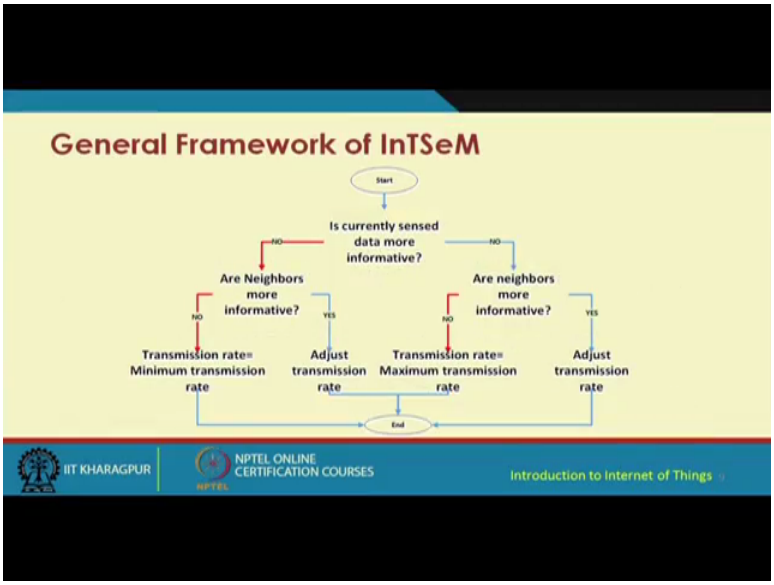

Going ahead we have, so I will skip it is there for you. This is part of the previous information theoretic approach that I mention and finding the correlation between the

different packets spatially as well as temporally. So, I am not going to go through it in detail, but it is available for you to go through in this particular slide.

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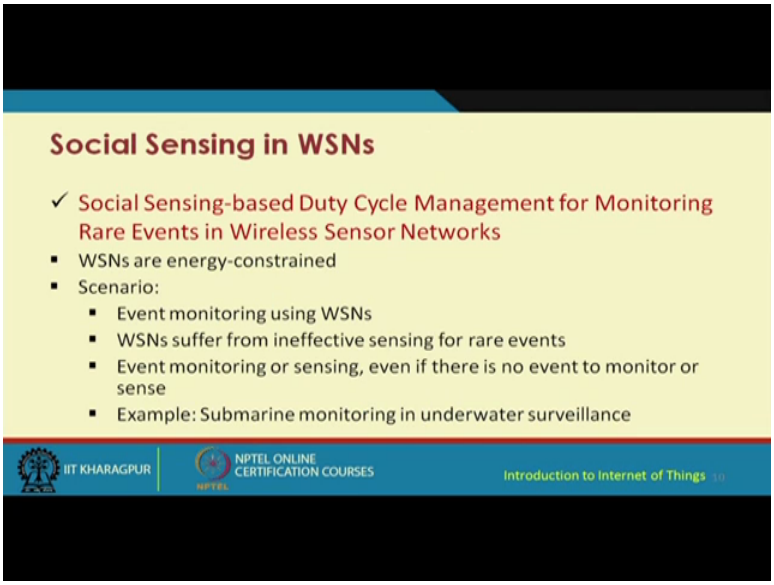

Another very important thing is social sensing. Social networks like twitter, facebook, etcetera, these are quite popular. At the same time sensor networks are also quite popular, but sensor networks duty cycling is very important because, of these low powered nodes. So, low powered nodes mostly have to be kept in a dormant or a sleep mode, and they have to be woken up periodically. Now when do you wake up, do you wake them up after a certain interval of time? Or is there a better way of waking them up?

So, we basically studied this issue, and we have seen that if the social sensor networks are hooked up to the sensor networks sorry social networks over the internet then, we can exploit, we can exploit the information flow in these social networks to identify whether the sensing interval can be increased or decreased. May be that based on some you know cracking of the twitter data, there is a straight to the national security. So, the sensor networks that are deployed in the coast, in the water, for naval defense or for aerial defense etcetera, their duty cycle can be increased accordingly. So, can be put in more alert, but for rare events you do not need to improve the duty you know increase the duty cycles so often. You can keep them in a low duty cycle environment.

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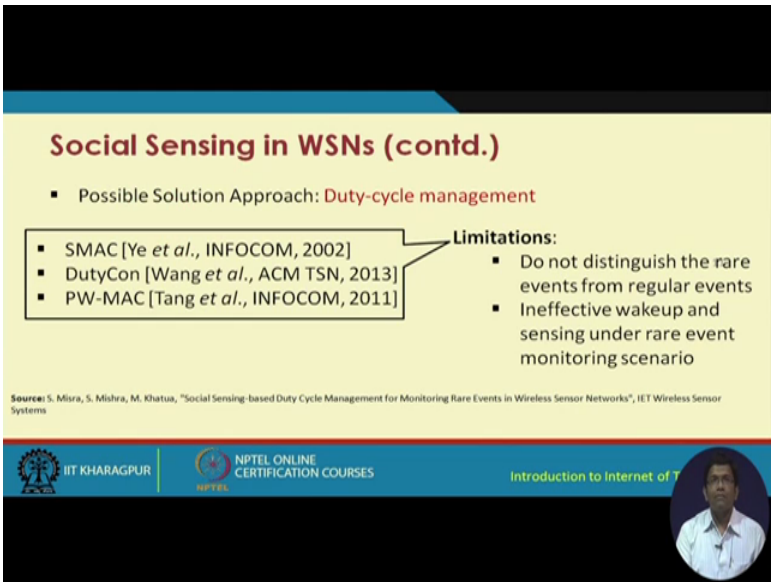

So, this is what this third work basically talks about and the source of this literature is also given over here. So, you can if you are interested you may go through this particular. But to understand, how social networks and sensor networks can be integrate together in order to improve the performance of the sensor networks.

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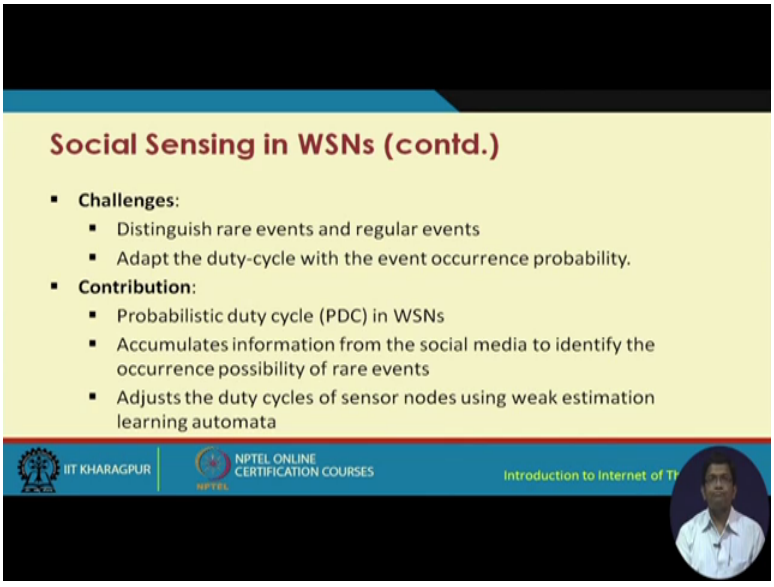

There are different challenges with social sensing. Distinguishing rare events and regular events, adapting to the duty cycle with the event or occurrence probability and what we have done is probabilistically we determine how the duty cycle is going to be managed.

So, we accumulate information from the social media to identify the occurrence possibility of rare events, and adjust the duty cycles of sensor nodes using some learning, machine learning approach.

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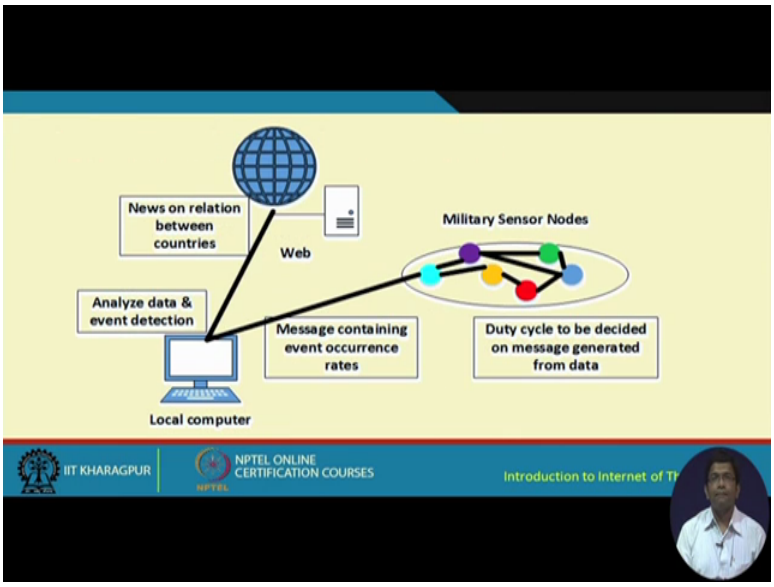

Again, so in this particular figure we see that let us say that this is a military sensor network, how this duty cycle is going to be changed over time of this, based on the data that is received from the web from social media.

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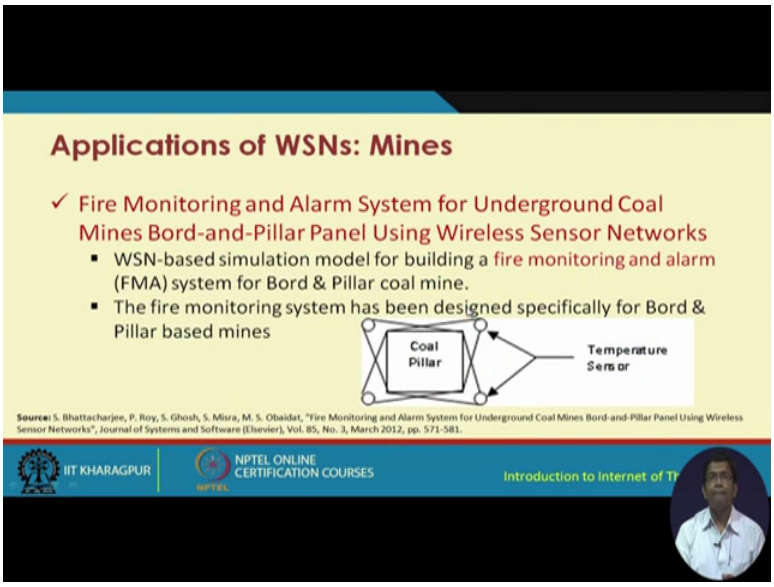

Sensor networks can be used for a diverse range of applications, for agriculture space applications, mining and health care and so on and so forth.

Here is an application of sensor network it for mines. In our country coal mining is very important. And one of the ways of coal mining is basically the bord and pillar coal mining. Bord, bord. Bord and pillar coal mining. So, in the bord and pillar coal mining, what happens is there are some columns these pillars, that are that are basically that is the way the structure of mining is done coal mining is done. Now in modern pillar coal mining So, what we are saying is will be putting different sensors so as to ensure that whenever there is a possibility of fire taking place, it will get automatically detected and it will alert the respective persons, and if indeed fire takes place then, to you know through the actuators to release water pulps in pipes and so on and so forth.

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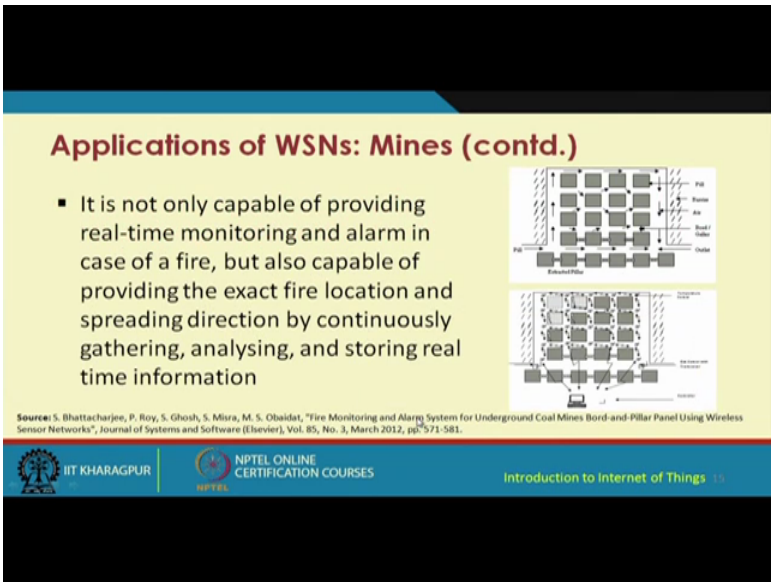

So, this particular paper whose source is given over here, basically talks about how to do it. So, these are the different columns the pillars and, these are the bord and the gallery. These are the different bords and the gallery and, this is how the sensors are going to replace, the temperature sensor, the gas sensors, and so on. These are all going to be placed and where the actuators are going to replace. These are all shown over here in this particular.

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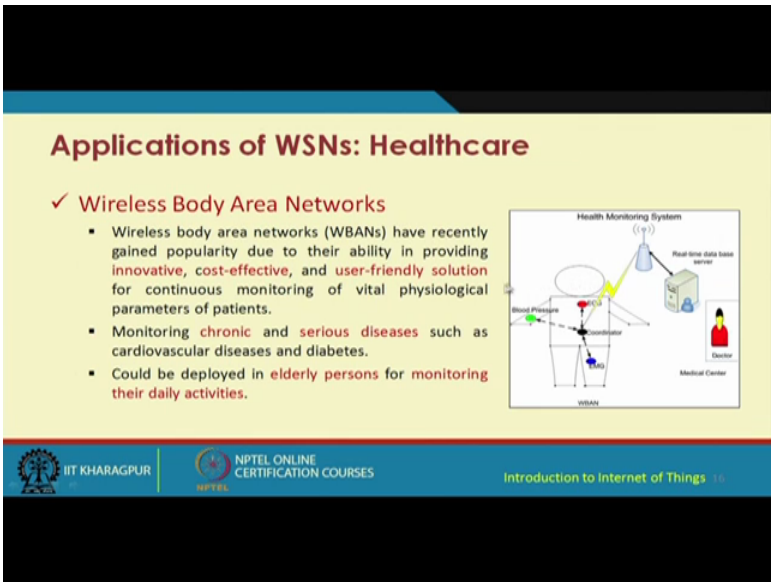

Now, the other work is healthcare, the other application domain is healthcare. In healthcare what happens is the humans are fitted with different physiological monitoring sensors. Sensors that will monitor physiological conditions with respect to body temperature, blood pressure, you know oxygen saturation in the blood, you know cardio cardiac functionality, a functioning and so on and so forth.

So, when these sensors are all put together on the human body, they can all sense about that physiological functioning of that particular patient, and sends you know send that sensed data to a local unit on the human body, typically mobile phone kind of device, which is technically known as the LPU the local processing unit. So, this becomes the LPU the coordinator. So, all these sensors we will be sending the sensed information to this particular coordinator, and this becomes, this unit because something known as the w ban, or wireless body area network. And from here the data is sent to the you know, through the internet, to the server for doctors to understand remotely the condition of the patient.

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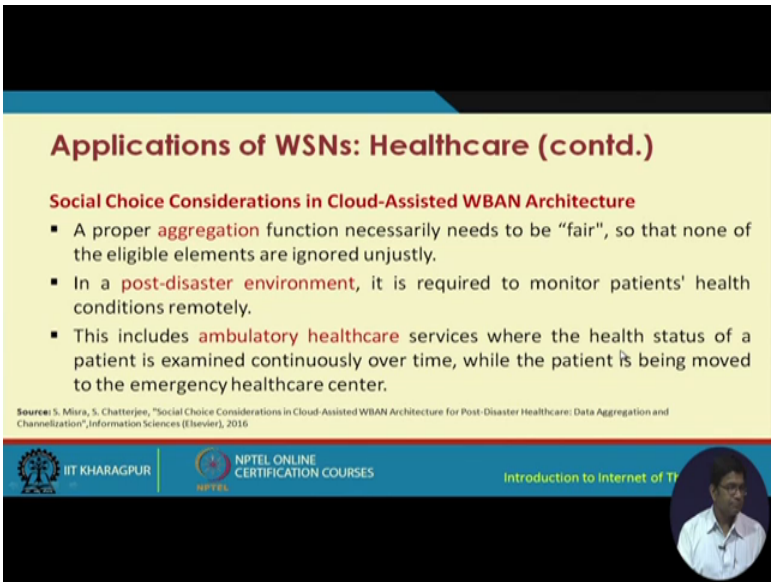

A very important and an attractive concept, is the concept of cloud assisted sensor network. Specifically in this particular paper we have talked about social choice considerations in cloud assisted wireless body area network architecture, for post disaster healthcare.

So, concept of social choice theory of economics has been used in order to in order to impart fairness to the different nodes in the network, in a cloud assistant w ban scenario. W ban is a sensor network a physiological monitoring sensor network. And all this data in a w ban cloud is going to go to the cloud end. The physiological data are going to go to the cloud end. Now the question is that, how do we ensure fairness among the different nodes in the network? For that we have used the social choice theory for improving it.

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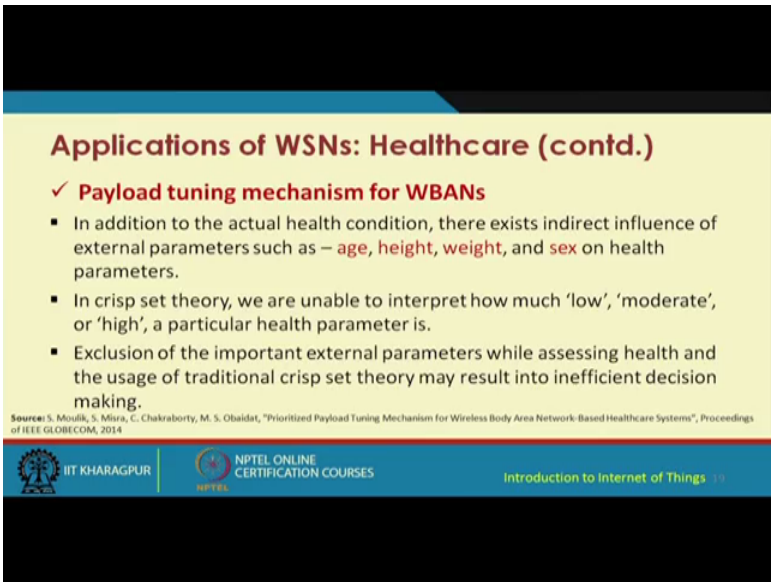

A very important work that was done again in the SWAN lab is the work that is sited over here. Prioritized payload tuning mechanism for wireless body area based healthcare system. This was published in IEEE globe com in 2014.

So, here basically we are using fuzzy logic, in order to improve the tuning of payload in a w ban. So, conditions you know in addition to healthcare conditions, there exist different other external parameters such as age height, weight, gender of the patient and so on. So, all these also have to be taken into consideration.

So, those are you know those can be you know, those can be modeled better with the help of fuzzy logic, fuzzy theory, fuzzy set theory, rather than using crisp set theory. And so, what we had we have done is using the fuzzy based concepts, we have you know taken all these things into consideration and have tried to improve the payload tuning of that particular network.

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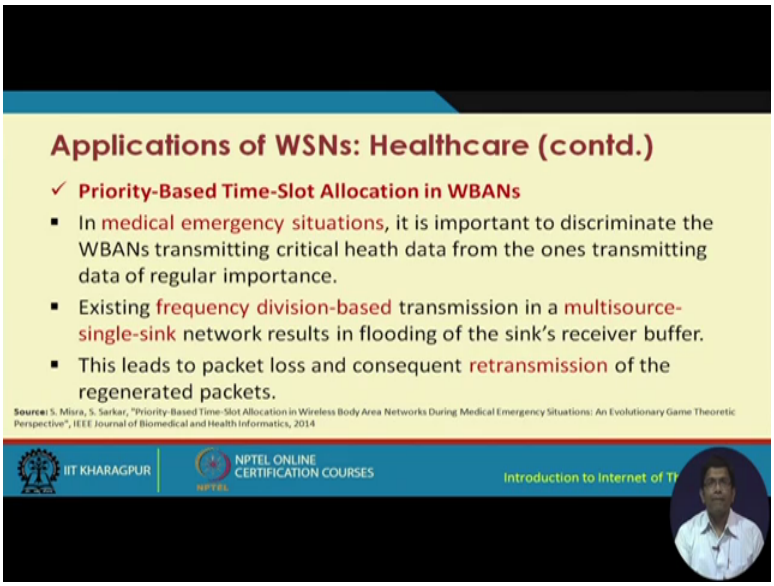

Another important thing that also has to be taken into consideration when we are talking about healthcare sensor networks is, that particularly during emergencies you know, what happens is let us see that after a post disaster environment, in a post disaster environment. So, so what happens if there are so many casualties? So, many victims and so on and so forth. So, and at the same time we have very limited medical resources be doctors, nurses, paramedics and so on. We have very limited.

So, they all have to be taken care of now if we are using sensor networks. You know deploying different sensors on the human body you know of the patients victims and so on and so forth, then what also has to be done is that, certain patients might require urgent attention, more urgent attention compared to certain other patients. So, that differentiation has to happen. Otherwise what might happen, is some patient who is at the point of maybe collapsing or dying he does not get helped whereas, somebody else who is not so critical get more attention. So, that fairness has to happen, that priority has to be given and this particular paper which was published in the IEEE JB JBHI IEEE journal of biomedical and health informatics basically talks about it.

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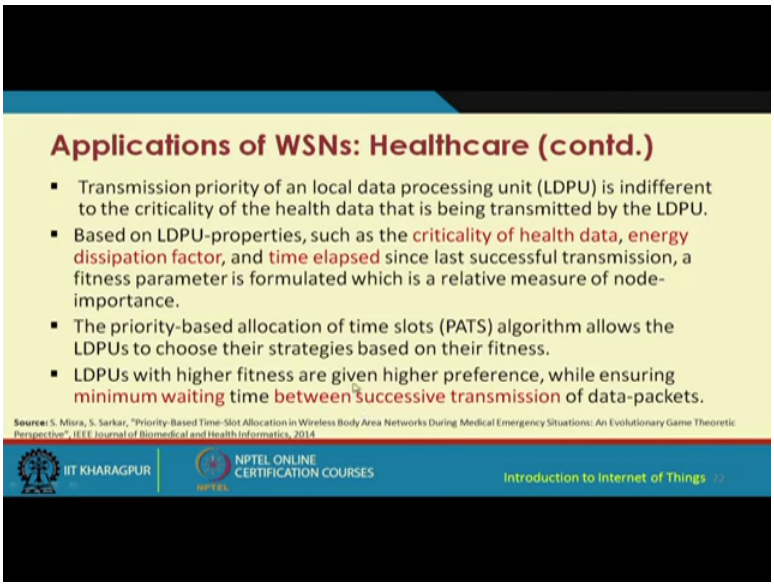

So, we have in this particular lecture gone through different flavors of research works, and applications of sensor networks. We have seen that how sensor networks can be used for the broader context of internet of things, deployment of sensor networks to achieve the objectives of internet of things. This is what we have gone through in this particular lecture. We have seen that there a there are lot of applications and we have also seen that there are lots of research issues. Some of the research issues and their flavors is what you have been exposed to in this particular lecture.

Thank you.