Wireless Ad Hoc and Sensor Networks

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Lecture – 21
Introduction: Wireless Sensor Network-Part-I

Introduction to wireless sensor networks part one. When the sensor networks as the name suggests are a class of networks where the nodes are sensor nodes, the nodes which sense which have the capability of sensing the physical phenomena that occur around them. These sensing can be of different types. A particular sensor node might be able to sense, temperature might be able to sense pressure they can sense if there is any object that is moving around them. Sensors can also sense colors can sense vibration occurring around can sense whether there is any sound around the sensors and so on.

Now, the sensor nodes have one of the components as a sensor and these sensor nodes collectively they form a network which is called the wireless sensor network. These wireless sensor networks are very popular currently and they have gained popularity since over a decade. Now sensor networks are very popular because of diverse types of applications they can be used for tracking an object in a particular terrain, they can be used for medical purposes for healthcare for space applications, for agriculture and so on and so forth. There are large number of different applications of wireless sensor networks. Wireless sensor networks are key to the formation of internet of things and internet of things and wireless sensor networks are very important components for building smart cities which have become very popular since the last few years.

In our country as well as abroad, we are going to look at some of the technical aspects of building wireless sensor networks. Initially it will start with the introduction. So, the first 2 lectures will cover the introduction to wireless sensor networks and thereafter we will gradually build upon and we will look at different other advanced concepts at another advanced concepts and techniques that have been designed for use in wireless sensor networks.

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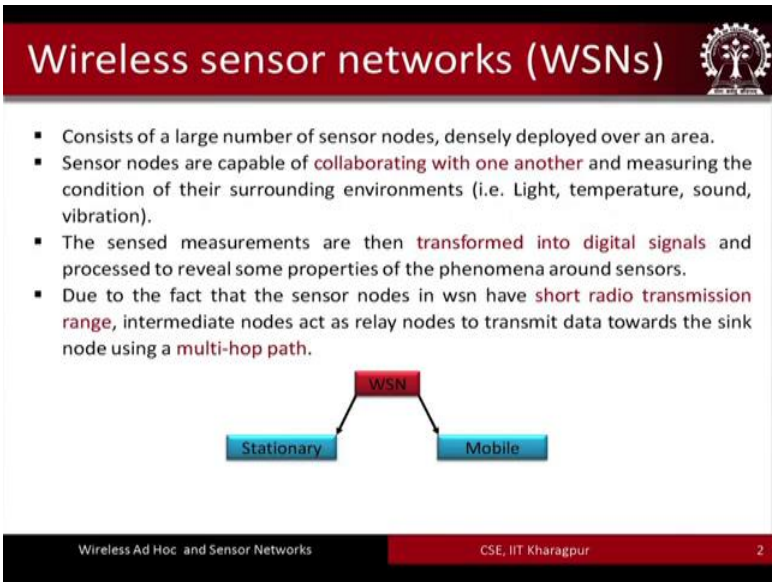

So, as I told you that a wireless sensor network basically consists of a collection of different sensor nodes. And these sensor nodes are typically not necessarily, but typically they are densely deployed in an area. So, the sensor nodes they basically communicate with one another the sensor nodes first of all they have the capability of sensing the physical phenomena that are occurring around them. For example, the examples of whatever I told you already like for instance.

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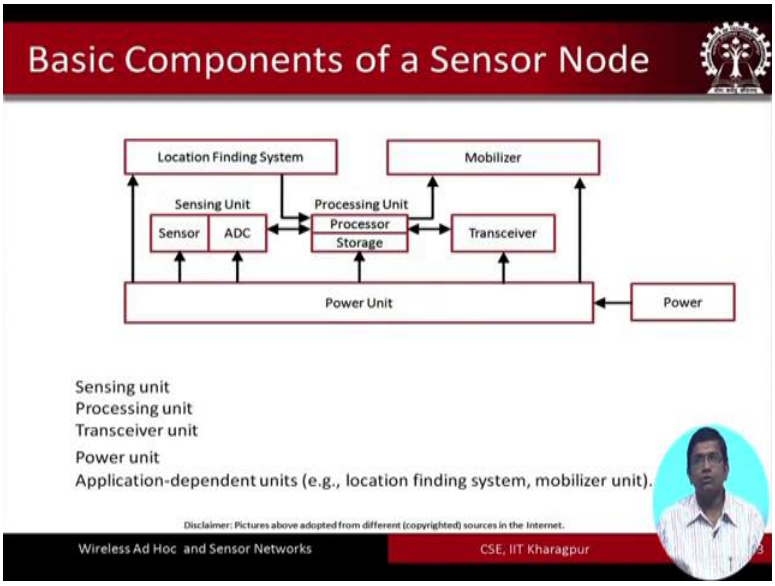

If there is a light sensor which is in the sensor node, then the sensors can sense the sensor node can sense light similarly temperature sound vibration and so on. So, like this actually there are different other types of sensing that can happen and the different types of sensors that can be embedded in a sensor node.

The sensor nodes they can collaborate with one another and collectively the sensed data that is the sensed data that are that are obtained from these using these sensor nodes they are transformed into digital signals to process the physical phenomena that are occurring around the sensor. And due to the fact that the sensor nodes have very short radio transmission range the intermediate nodes in this network act as relay nodes. So, what we essentially have is something similar to what we had observed in the case of ad hoc networks, a multihop kind of, a multihop kind of architecture and so basically what happens is the sensor nodes they sense the physical phenomena and the sensor nodes are very short transmission range short communication range, and because of which the data and this and this the sense data from one node through a multi hop path they are sent to the remote destination node.

And this remote destination node is termed in the sensor network literature as a sync node sometimes people often some people prefer to call the sync nodes as the base stations; however, keep in mind that there is distinction between sync node and a base station. A base station may or may not be a sensor node whereas, a sync node necessarily is a sensor node. So essentially if there is a computer or some kind of a data collecting device which is collect connected to a sync node then all the data from at the that are received at the sync node they could be stored in that particular computing device.

So, one question might have already arrived in your mind that why at all do we need the sensor networks, what is the use of the sensor networks. If it is about sensing sensors have been there since decades now. So, sensors have been there. So, what is new in sensor networks then? So the distinction between the standalone or individual sensors and the sensor network is that whereas, an individual sensor can sense the phenomena locally in a standalone fashion. In a sensor network you can deploy multiple such sensors and sensor nodes over a larger area in order to get an idea about what is occurring in that larger area.

So, basically to have bigger coverage bigger sensing coverage over a bigger area this is why the sensor nodes and the sensor networks become useful and that can be done. So, remote, if somebody wants to remotely monitor a particular area. So, sensor networks become very useful they come out to be very handy. Remotely in an unmanned fashion monitoring a particular region, sensor networks become handy. So, sensor networks can be classified broadly into 2 types. One is the stationary sensor networks. So, this is what most of the literature talks about in the sensor network community people talk about mostly sense stationary sensor networks. This is the classical form of sensor networks stationary sensor network means that all the nodes in the network in the sensor network are stationary; they do not move any of the nodes none of the nodes in the network moves.

Whereas in a mobile sensor network. It is essential that some or in the extreme case all the nodes in the network would move. So, that is the main distinction between a stationary sensor network and a mobile sensor network. There are multiple applications of mobile sensor networks mobile sensor networks are found in in oceans. So basically you know when some when you when we try to deploy sensor nodes on an ocean the nodes will be mobile due to the fact that there are ocean waves and currents.

So, such a network is going to be a mobile sensor network not only oceans in the terrestrial environments also sensors fitted to the different trucks and buses and cycles and so on which basically move on the road these because of the mobility of these vehicles the nodes they move and that is why we have a mobile sensor network that is how we have a mobile sensor networks similarly nowadays people are talking about aerial sensor networks and that is what we have covered in the UAV. So, when we talked about UAV networks in the lecture on UAV networks essentially, if these UAVs are fitted with different sensors then what we have are aerial sensor networks or UAV west sensor networks. So, these are the main 2 classifications we between the stationary sensor networks and mobile sensor networks.

So, a typical sensor node is sort of like a mini computing device, is sort of like a mini computing device which has some additional capabilities of sensing. A typical sensor node has a sensing unit because it is a sensor node it has a sensing unit it has a component which is a sensor which can sense certain physical phenomena according to the way they have been designed processing unit processing unit means the processor. So

we have the sensing unit we have a processing unit then there is the transceiver unit for communication purposes a power unit for powering up the node.

So, typically you know different types of batteries are used typically lithium ion batteries are used then there are other application dependent unit is that can also be there in addition to these core unit is. So, as you can see that whatever you find in a minicomputer a computer is nothing, but where there is processing capability. So, a processor is there in a computer and here as well right. So, in a sensor node as well last communications abilities are their last energy to power all of these things the sensor nodes holistically right. So, this is the typical architecture of a sensor node.

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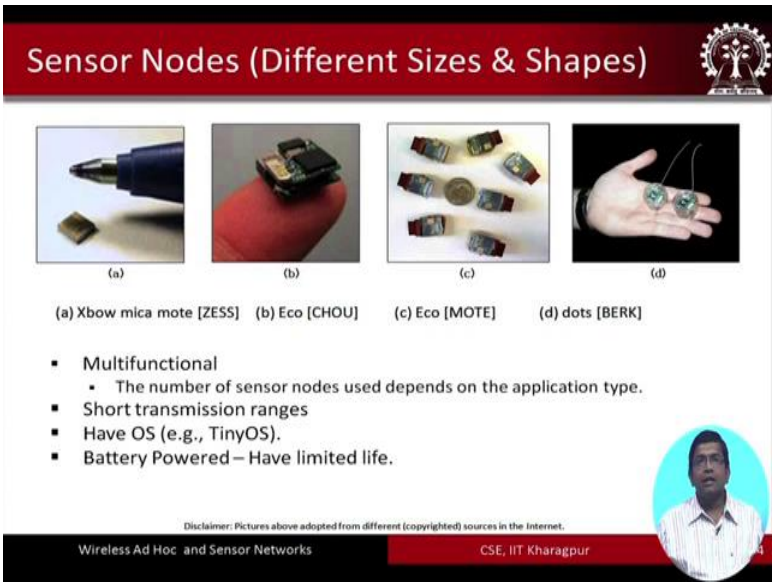

So, here are some pictures that have been taken from different sources detecting the sensor nodes. The sensor nodes are originally envisioned to be very small in size and they come in diverse shapes. So this you know we can by looking at these figures, we can see that the sensor nodes are typically comparable to the size of a fingertip, to the size of coins, or they are much smaller compared to the size of a pump, human pump, human head. And this is with this preference to you know a ballpoint pen. So, a tip of the ballpoint tip, you can from these references you can understand how small these sensors nodes are. Now that is regarding the size, regarding the shape the sensor nodes come in different shapes they could be circular spherical they could come in different other shapes rectangular square and so on.

The sensor nodes they are multi functional. So, depending on the type of sensor that is installed that is embedded in these nodes. They can sense different things. They have very short transmission ranges they have very short transmission ranges because of the again the limitations of the transceiver unit. Because of the size of the nodes again the capabilities of each of these components are also very limited. So, the sensor nodes like a computer they have an operating system.

Tiny OS is a very popular operating system that is used in the sensor nodes. And the sensor nodes are because they are very they are battery operated they are battery powered they have a very limited lifetime. And not only that they are battery powered, but the batteries that are used in this very small size sensor nodes you can imagine that the batteries are also very small in size, much smaller in size compared to these small sized sensor nodes. So, consequently due to the electric the electrochemical efficiency of the battery also depends on the size of the battery.

So, consequently the batteries also have very limited you know lifetime they have very limited lifetime. And because they have very limited lifetime what is very important is to ensure that whatever solution hardware software or whatever it is that is designed specifically for sensor networks, the solutions should be very much energy efficient this would be very much energy efficient. So, the algorithms that you design the protocols that you design the hardware that you design should be designed in such a way that energy consumption is very limited.

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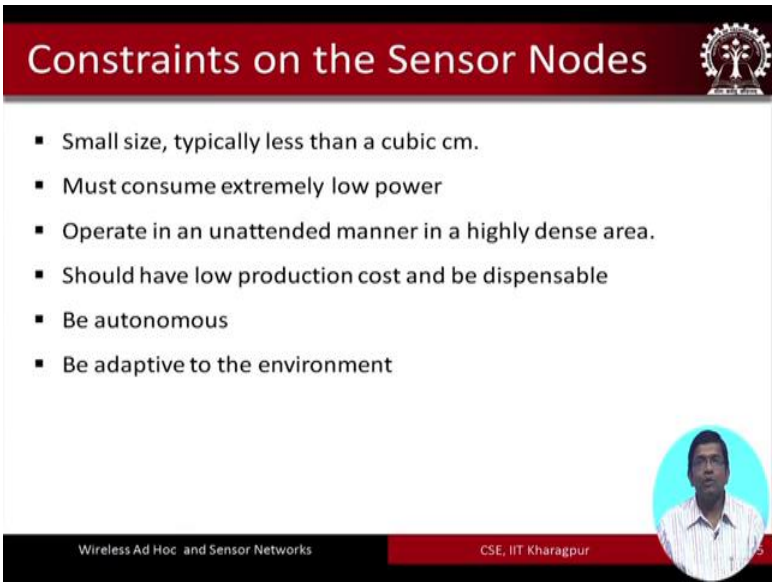

The sensor nodes are very small in size typically less than a cubic centimeter. They must consume extremely low power these are the things that we have already seen. And what makes sensor net networks interesting that is that these nodes the sensor nodes in the network operate in an unattended manner. They are designed to operate in an unattended manner in a highly dense area. They should have very low production cost and this should be dispensable, that is this is one of the reasons of you know is you know the sensor networks. So, basically to have very low cost sensor nodes.

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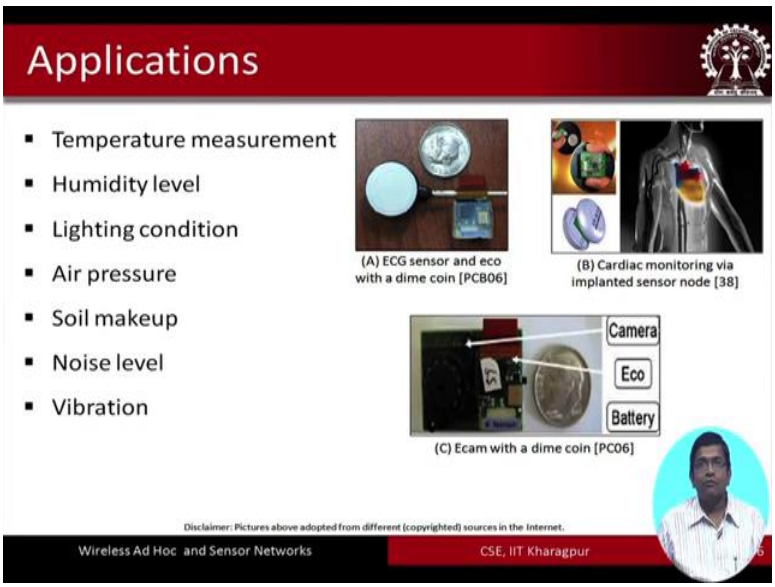

The nodes which can be which can be the nodes which can have low production cost low which can be fabricated in very at very low cost, and this would be. So, much low cost that you know if a particular node runs out off runs out off it is battery or if a node is damaged for one reason or another then once you have deployed these nodes you forget about them. So, their, they should be dispensable. And the way these networks are supposed to operate and the individual nodes in them is that they should be autonomous. This would be autonomous there should not be any human intervention human beings coming and doing things for these nodes that should not happen they should be able to run on their own. And this would be adaptive to the environment in which they operate. So, if there is any change in the environment the nodes should be able to strategize itself accordingly.

There are different applications of sensor networks. Here a few examples I have already named few examples at the beginning of this lecture. So, measurement of temperature measurement of humidity levels, lighting condition air pressure soil makeup noise level vibration and so on and so forth. These are not the only few applications to name. So, sensor networks can be used for agriculture, sensor networks can be used for health care and so on. So, here actually on the right hand side what we see are some healthcare applications of sensor nodes sensor networks. So, and later on in another lecture we will talk about how sensor networks can be used for health healthcare, where on a human body the sensor nodes can be deployed and the sensor nodes will be sensing different physiological functions and they are going to send the sensed information to the base station for further analysis.

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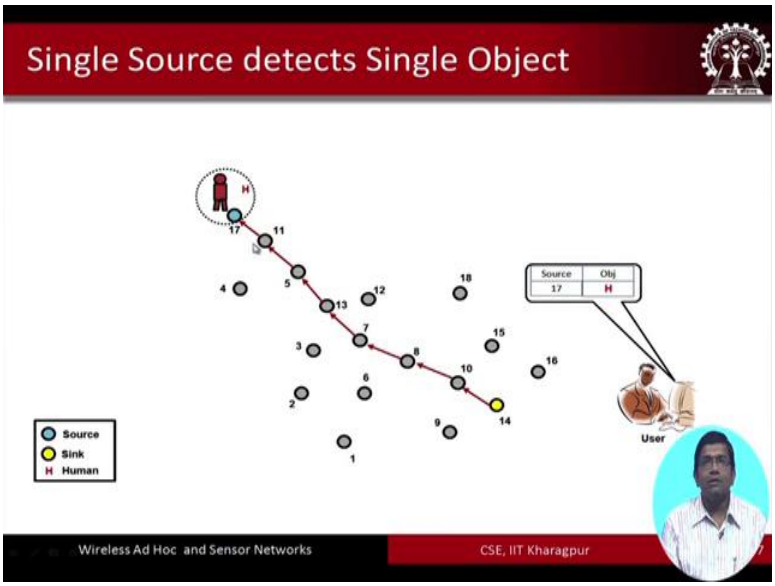

So, let us consider the figure in front of us, what we see over here is a source node and there are bunch of other different. So, sensor nodes, the source node as well as the sync node, the yellow colored sync node these are also concerned nodes like the other grey colored nodes, but additionally the. So, the sense the source node is the one source node is defined to be the sensor node, which basically senses a particular object or senses something. So, and the sensor node is going to sense and through a multihop path the sensed information is sent to the sync node.

Now as you can see that the arrows over here are shown in the reverse direction. So, I already told you that the sensed information flows from the source to the sync. On the contrary I have shown you in this figure that the links the arrows are in the opposite direction. So, this might occur to your mind that why is it shown in the opposite direction. The reason it is shown in the opposite direction is that these arrows basically does the communication between the sensor nodes in a sensor network can occur in 2 directions.

One, from the sensor node towards the sync, the other one from the sync towards the sensor nodes, what is shown over here is from the sync towards the sensor nodes, towards the source sensor node and the other sensor nodes. So, these basically represents the sending of it query. So, for instance more specifically, if I have to clarify this thing we have node number 14 we sense which sends a query a broadcast query maybe to all

the other nodes in the network saying that does any of the other sensor nodes see any human activity occurring around them. So, node17 in fact, see a human object responds by back by saying that it does. So, what is shown over here in that in this case is the direction of transmission or propagation of the query.

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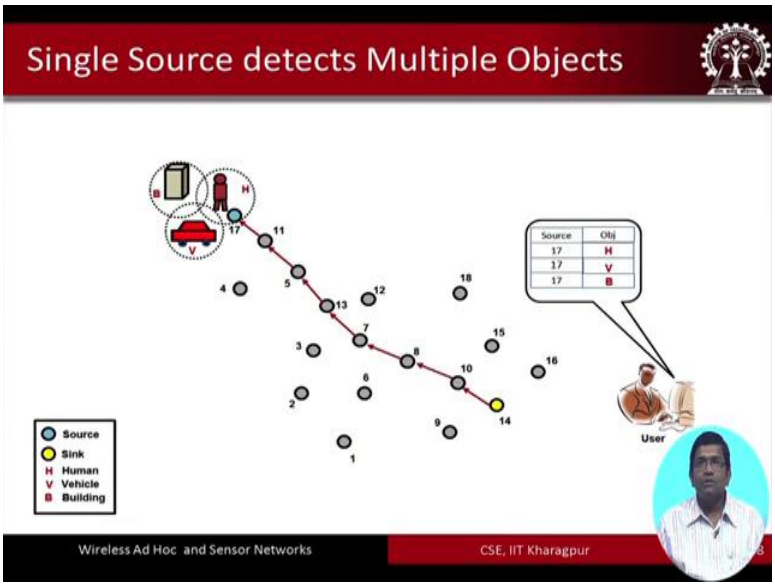

Now, let us complicate our scenario little further. So, in the earlier case we had a single object and a single source. A single source detecting a single object, now let us say that in addition to the human being like in the previous diagram we have 2 other different types of objects. We have a vehicle and we have a box let us say. So, now, in this particular case a box or a building or whatever it is you know, so 3 different types of objects, now, we have a single source detecting multiple objects.

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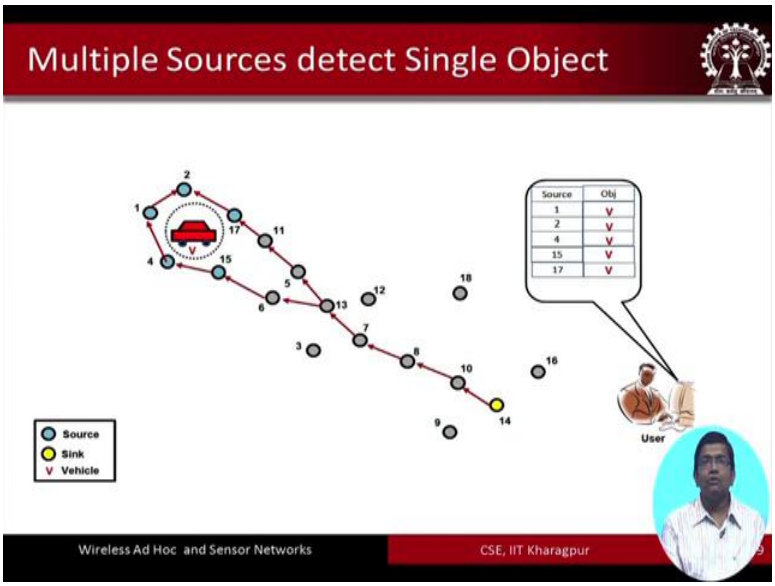

Now, we have the scenario of multiple sources multiple sources detecting a single object. So, we have nodes 1 2 4 15 and17 these blue colored nodes which have all together sensed the presence of a vehicle.

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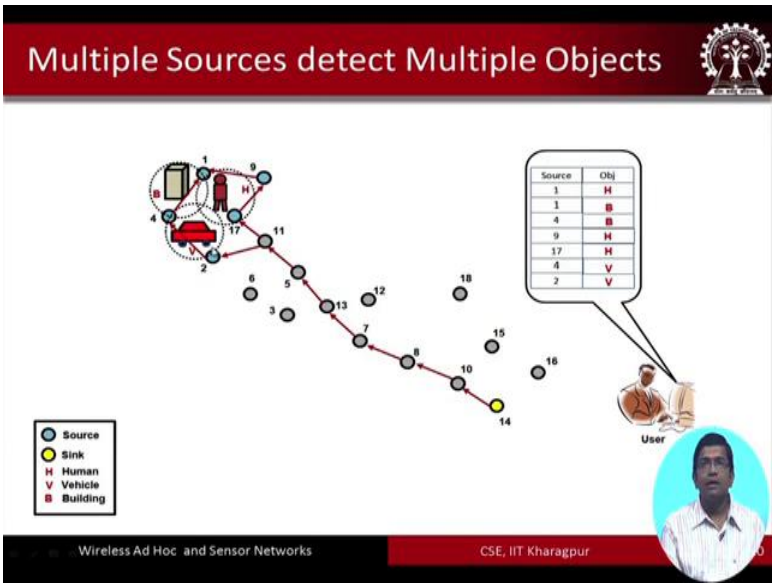

Another example of multiple sources detecting multiple objects, here you see that earlier also we had the case of multiple sources detecting, but it was a single object which was detected together by them, but here we have multiple sources and multiple objects

together. So, multiple sources detect multiple objects. So, this is what is depicted over here.

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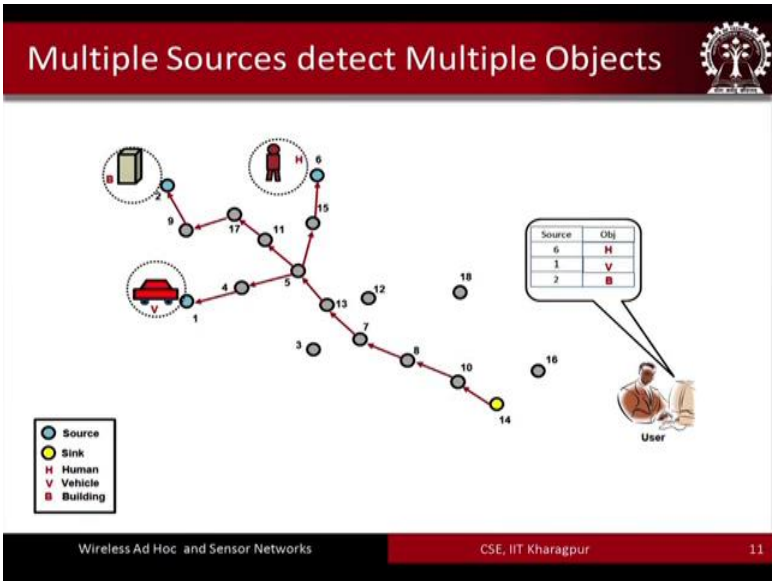

So, like in the previous case of multiple sources detecting multiple objects we can also have another situation another scenario of multiple sources detecting multiple objects. So, like unlike in the previous case where all the sources as well as the objects were co located over here, we do not have the sources and the objects the different sources and the objects co located. So, but still you know this is also a case of multiple sources detecting multiple objects. So, we have these different sources source node one detecting the vehicle source node 2 we detecting the building and source node 3 source node 6 which is detecting a human. So, we have these 3 different sources which are not co located which are far apart from each other and they detect 3 different objects.

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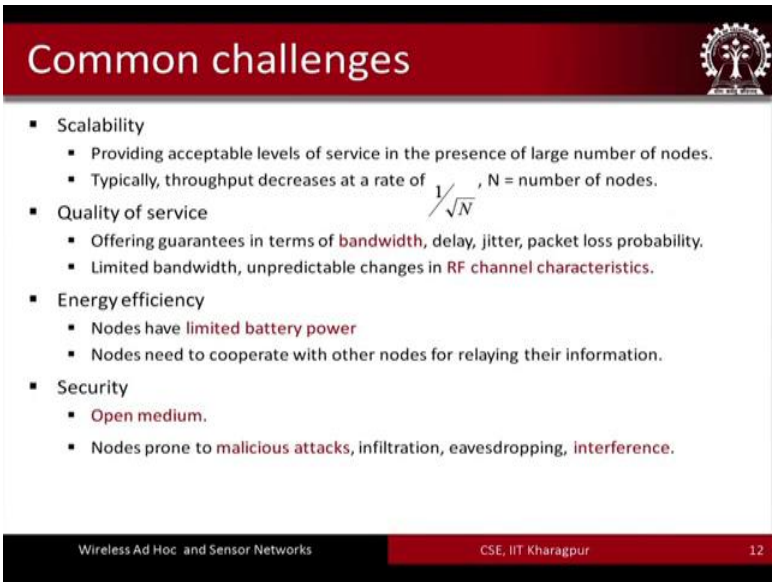

Now, let us look at some of the common challenges some of the common challenges behind implementing sensor network. The sensor networks that are to be designed and implemented, they suffer from some of the very prominent challenges, challenges with respect to scalability. For instance, scalability means that if you are increasing the number of nodes in the network how does the throughput perform. So, it has been typically shown that in a network if n is representing the number of nodes in the network, then the throughput decreases at the rate of one over square root of n. So, this is a very serious thing because from 2 nodes to 4 nodes for instance, if you increase n then the throughput basically goes down quite drastically, but at the same time we need to have large number of nodes to be deployed in a sensor network. So, how do we handle this?

Quality of service quality of service basically concerns offering guarantees in terms of bandwidth delay jitter packet loss probability these are some of the measures of quality of service. So, these are also known as quality of service parameters in networking. So, these quality of service parameters offering guarantees in terms of them for of for example, offering guarantees in terms of the bandwidth offering guarantees in terms of the delays etcetera these are important requirements of any network that is designed and deployed.

Now, the main problem with is with offering quality of service guarantees in these networks is that these networks have very limited bandwidth. And there are

unpredictable changes in the RF channel characteristics in these networks. In most of the cases due to the fact that these networks the nodes in these networks are deployed in environments which are quite chaotic in nature and due to that is not due to such a reason you know these networks the nodes the environment in which they operate, they have very chaotic general characteristics as well.

Energy is something that I have already told you these nodes are limit have very limited battery power the batteries in them are very small in size. So, the nodes need to cooperate with one another with the other nodes for relaying their information. So, these nodes not only have to perform their own regular tasks, but they also have to cooperate with the other nodes for relaying the other nodes information.

So, consequently energy is very crucial concerns in the networks these networks are have an open medium like other wireless networks and they are prone to different types of attacks. So, malicious attacks infiltration eavesdropping interference and so on and so forth, which make these networks very much vulnerable to these types of attacks and security consequently is a very important issue in these networks.

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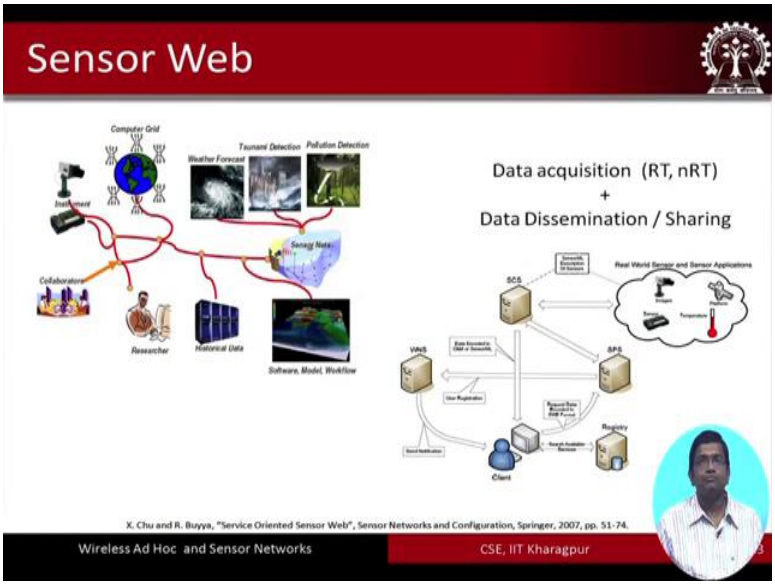

So, now let me show you few different types of different flavors of sensor network. One of the very one of the very prominent deployments of sensor networks is called the program prominent architectures of sensor networks is called the sensor web. In a sensor web as we can see over here that we have sensor different sensor networks we have

different other things, we have you know researchers, we have historical data, we have weather forecasts tsunami we have pollution detection etcetera. So, all these different data are basically sent to the web and probably to a computer read where the data can be processed further.

Data acquisition, in these networks there are 2, 2 phases the first phase is real time or non real time data acquisition and the other thing is after the data is acquired sending the data sharing the data with others; data dissemination. So, these are the 2 important steps or 2 important parts of these networks the sensor web networks.

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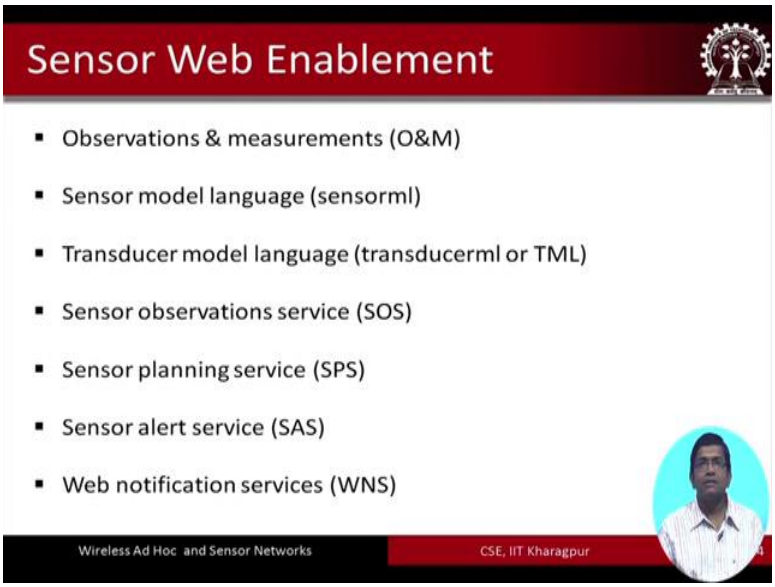

So, for enabling sensor webs there are different things that are used. One is there are different components of the sensor webs there are. So, all of these are different components. So, I am not going to read through all of them, but as you can see over here sensor modeling language. Sensor modeling language is a language that is used to model these sensor webs right. So, similarly you have a transducer modeling language transfusion ml you have the sensor observation service sensor planning service sensor alert service and so on. So, like this you know a bunch of different services modeling language languages and observations and management these are the different components of sensor webs.

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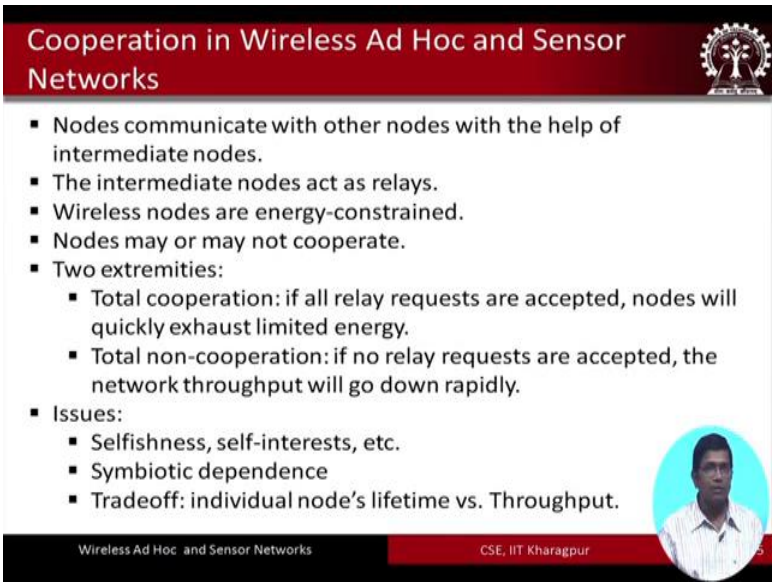

These sensor networks like the ad hoc networks have specific requirements, requirements in terms of cooperation. Cooperation of, by the intermediate nodes with cooperation of the intermediate nodes with the source and the destination nodes. The reason is that these are also multihop networks like the ad hoc networks the sensor networks are also multihop networks, and because of that you know thus the intermediate nodes they would have to cooperate, but at the same time these nodes these intermediate nodes are very much energy constrained.

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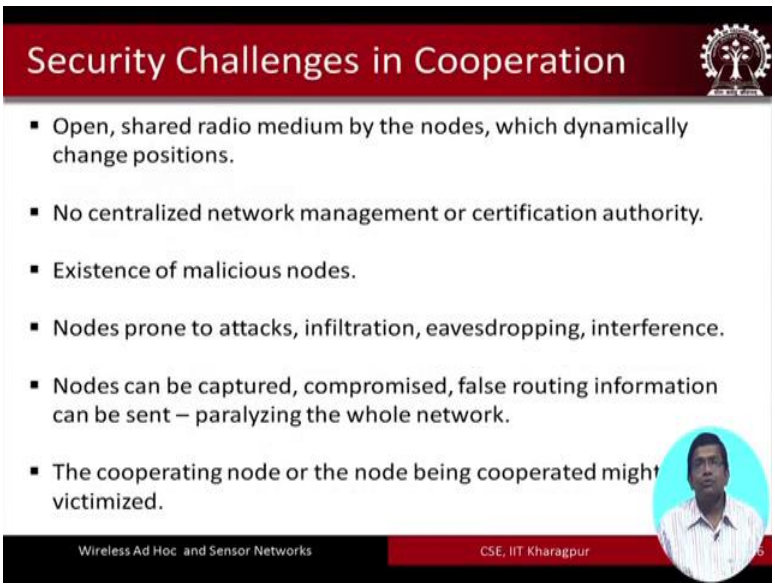

So, these nodes have a tendency not to cooperate. So, there are 2 estimatives 2 estimatives one is that we can have a case of total non cooperation. Or we can have the other extremity of total cooperation. So, in the case of total non cooperation none of the relay requests that a particular node receives is forwarded further. And so in the case of total cooperation all the relay request that a particular node receives will be forwarded further. So, neither total non cooperation nor total cooperation or ideal because of obvious reason. So, there are you know when we talk about cooperation issues of selfishness self interest symbiotic dependence etcetera becomes very important. There are security challenges in cooperation as well. So, we have, as we have seen that we have a resource constraint wireless open environment. So, where there is no centralized network management or certification authority and there are exist there is existence of malicious nodes.

These nodes are prone to attacks infiltration eavesdropping an interference they can be captured they can be compromised false routing information can be sent and so on and so forth all of which together can paralyze the whole network the cooperating node or the node being cooperated consequently might be victimized.

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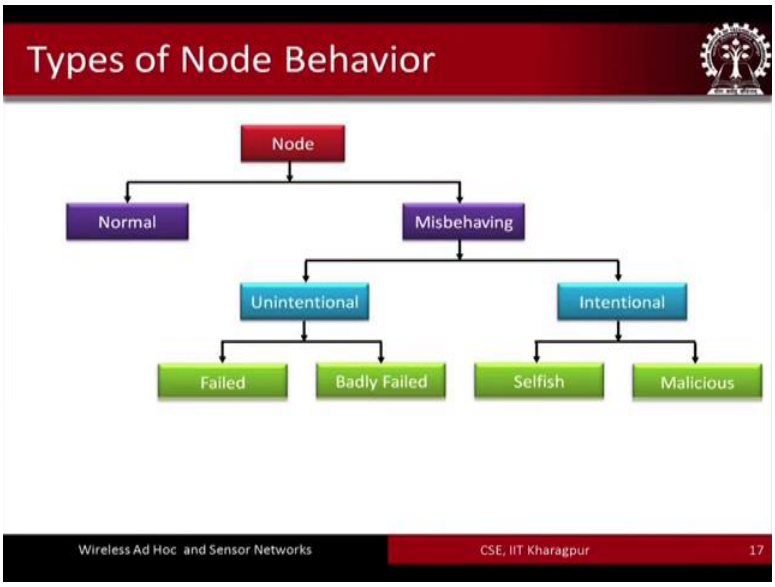

So, cooperation in such a scenario is not a very ideal thing, but at the same time cooperation has to happen, but being cooperative will make these nodes or the network vulnerable to different attacks. So, depending on the type of node behavior depending on

the type of node behaviors the nodes in these networks can be classified into 2 types normal and misbehaving. So, then within the misbehaving nodes, there are different types of miss misbehaving nodes normal nodes are the nodes which behave normally the way they are supposed to behave misbehaving nodes are the nodes which miss behave which do not follow the protocols that they are supposed to follow. So, they can further be classified in as unintentional misbehaviors or intentional misbehaviors. Under the unintentional category we have the fail nodes and the badly failed nodes in the intentional category we have the selfish nodes and the malicious nodes.

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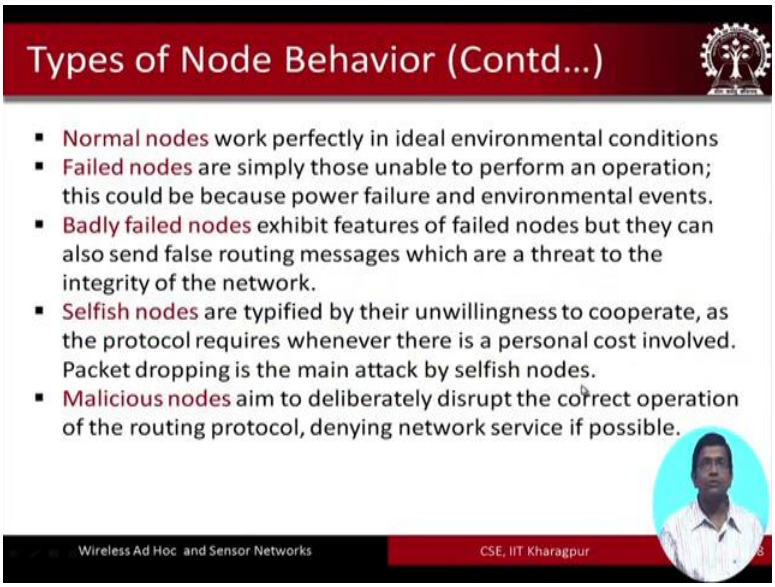

So, field notes are basically those which are unable to perform an operation. So, and these operations are the ones which we are supposed to perform. They are supposed to perform for example, certain they are. So, let us say that they are supposed to do some computations. So, they are not able to do that maybe because the node has run out of it is battery. So, or maybe there are some environmental issues due to which the node has failed to operate badly failed nodes are the ones which have not only the not which exhibit not only the properties of a failed node, but also additionally they can send false routing messages which are a threat to the integrity of the network.

Selfish nodes are typifies by their unwillingness to cooperate as the protocol requires whenever there is a personal cost that is involved. So, for example, a node might behave as selfish and instead of forwarding the packet that it receives it might drop the packet.

Malicious nodes basically on the contrary or I mean. So, they are not like the selfish nodes. So, in the in the case of the malicious nodes the deliberately these nodes they deliberately disrupts disrupt the correct operation of the routing protocols denying the network service if possible.

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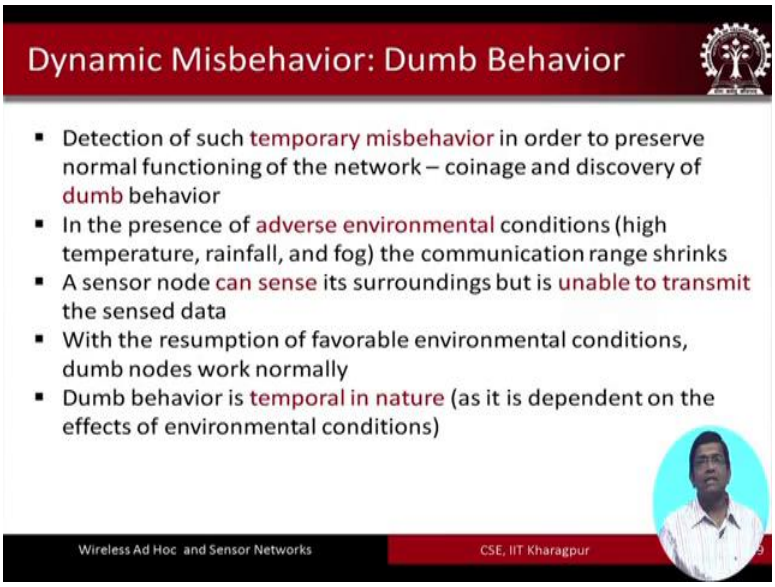

There is another type of node which is called the dumb node which basically has been proposed this kind of dumb behavior has been observed and they have been proposed by the researchers in the swan group IIT Kharagpur. So in the dumb behavior what happens is basically you know. So, let you know. So, what happens is you have the sensor nodes which are deployed in an open region and in these nodes they are they can get affected due to high temperature rainfall fog and other adverse environmental conditions.

So, because of that what happens? The communication range because of these environmental adverse conditions the communication range basically shrinks. And because the communication range shrinks and the sensor unit for the other hand can sense the way it is supposed to sense. So, these nodes they can sense, but they are not able to transmit the sensed data forward. So, with the resumption of the forwarded of the favorable environmental conditions the dumb nodes work temporary. So, dumb behavior is temporal in nature.

So, what it means is that at certain point in time the node may be able to behave the way it is supposed to behave, but at a later point of time at another point of time maybe due to

the occurrence of heavy rainfall or maybe due to heavy fog and so on the node is able to sense the way it is supposed to sense, but it is not able to communicate with the other node. So, whatever it has sensed it is not able to send it further send it forward. So, the node either has to buffers and then if the buffer is full the packet gets dropped.

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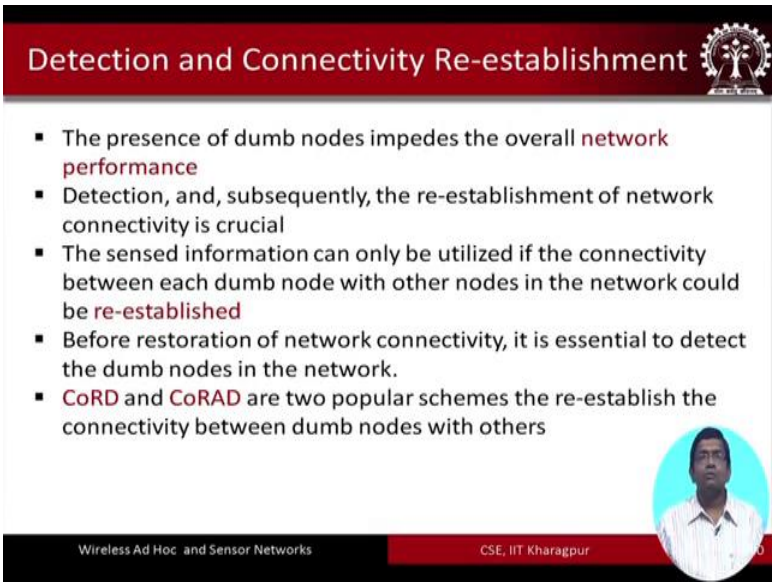

So, different issues are become very important, when we are thinking about dumb nodes. So, first of all one has to detect the presence of a dumb node detect the presence of or occurrence of dumb behavior among any of the nodes in the network. And then after that the nodes have to be identified and they have to you know and connectivity has to be reestablished around those dumb nodes by maybe isolating them and so on. So around these dumb nodes the connectivity establishment is the next thing, next important thing that should be done.

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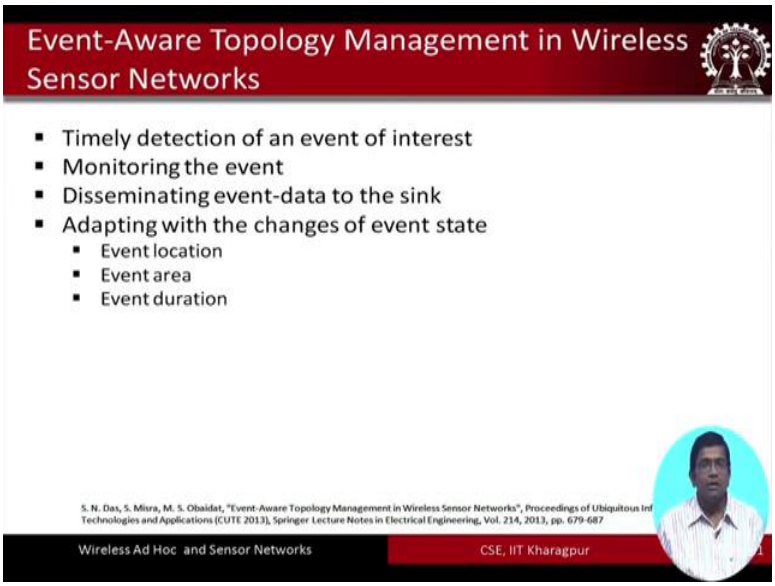

So, there are different schemes that have been proposed cord and cord are 2 popular schemes that have been proposed to reestablish connectivity between dumb nodes and other nodes.

So, few other things are very important in the context of sensor networks will cover, topology management in a later lecture. And so in topology management there are different issues. So, in our group we have worked on event aware topology management. So, depending on the location of an event depending on the area the span of the event and the durations over which the event is occurring, the topology management can become important. So, topology management means that first of all the topology has to be discovered and thereafter the topology has to be tracked and it has to be managed.

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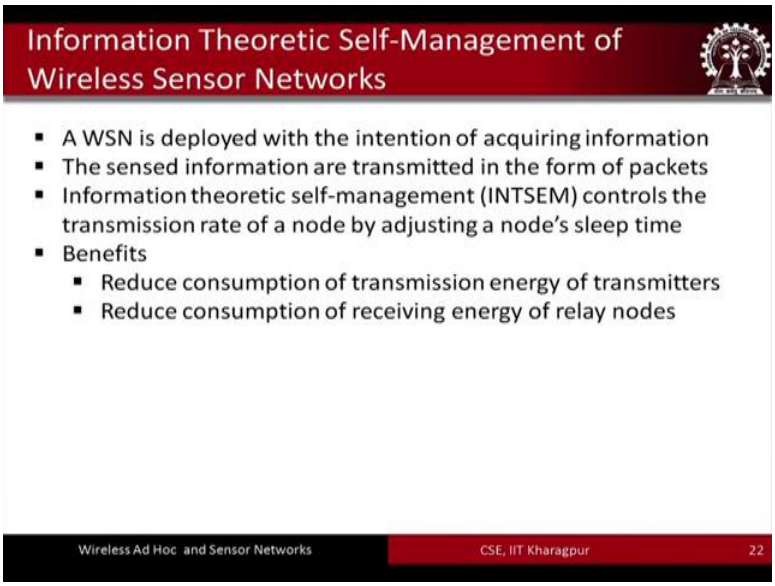

So, this is important. So, this will cover later and the next thing is the self management of the wireless sensor networks. The wireless sensor networks as we have already seen they have they are supposed to self organize themselves they are supposed to self manage themselves, and that is quite obvious and this these comes with lots of be benefit is, but at the same time you know. So, what happens is these sensor networks you know. So, this kind of self management comes out to be challenging. So, the reason the reason is that there is lot of.

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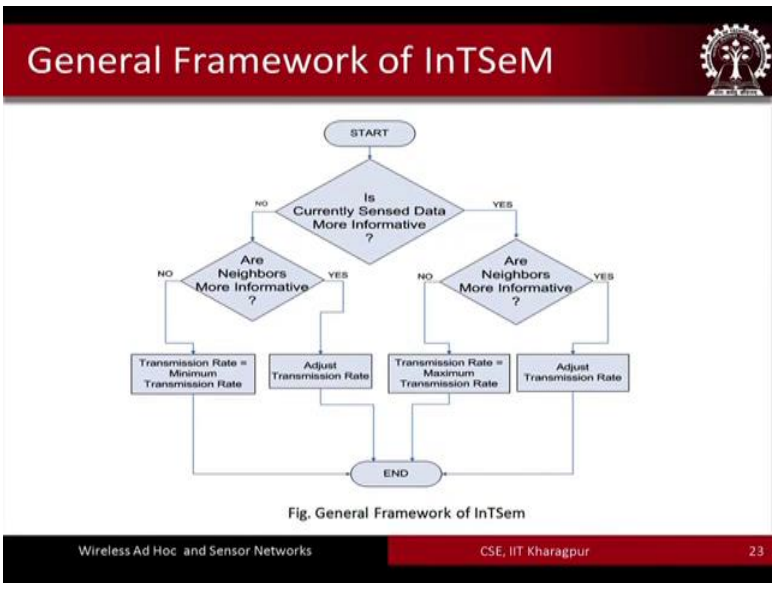

So, one of the things actually one of the things that we have done is that we try to identify that how we can make this thing efficient how we can make the self management efficient.

So, for this actually we have proposed a particular framework called the instem framework where we try to identify whether this currently sensed data is more informative compared to the data that was earlier received. So, if it is more informative are there more neighbors this are the neighbors more informative and so on, and if it is not. So, if the currently sense data is not more informative then are the neighbors more informative and so on. So, like this you know. So, this is the recentry this is an framework about how to execute this particular self management scheme.

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So, with this we come to an end this is the list of references like before we have listed all the different papers and books that can be consulted for understanding the basics of sensor networks not only the basics. Actually all of that the different aspects of sensor networks that we will also be covering in the later course, these books will come out to very handy.

So, let me just give you a few highlights. So, this paper basically talks about this paper talks about self organizing sensor network in the presence of dumb notes. So, similarly this paper also does the same and then the sensor web material on sensor web is available in this particular paper and so on. So, there are 2 books that I should mention one book is

these are the 2 books that actually have been published by me on sensor networks. So, one book is a very recent book by obaidat myself and this book is titled principles of wireless sensor networks. It was published in 2015 in Cambridge by Cambridge university space. So, this book is very important and the other book is guide to wireless sensor networks published by Springer and so these 2 books are very much useful resources for understanding sensor networks that the basics of sensor networks plus also the advanced topics in sensor networks.

Thank you.