Wireless Ad Hoc and Sensor Networks
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Lecture – 33
Underwater Sensor Networks-Part-I

Underwater sensor networks; this particular topic will be covered in 4 part. So, this is the first part; part 1.

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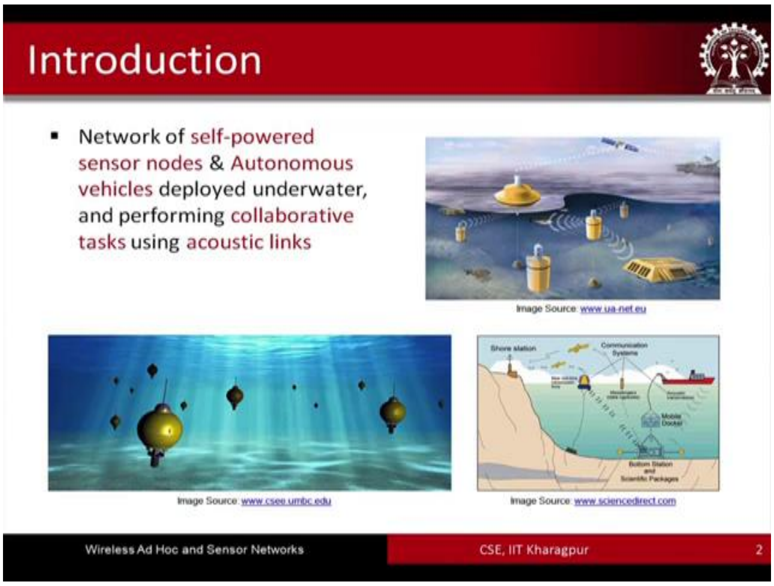

So, what is underwater sensor network? So, as this name suggest in that it is a sensor network which is submerged under water. So, these sensor networks basically operate under water like, under the surface of water. So, essentially what we have understood. So far in terms of terrestrial sensor network the same concept if we think of in an underwater environment and if we try to implement those concepts in such an environment then what will result is an underwater sensor network.

So, in an underwater sensor network, what we have are different types of nodes, these nodes are wireless nodes, but these are you know these nodes, they communicate with one another not through RF as in the case of a terrestrial sensor network, but using acoustic mode of communication. So, look at this particular underwater sensor network. So, we have these different nodes which are deployed at different depth and these nodes they can talk to one another using acoustic communication. So, one node would be sending acoustic communication signals to another node and so on and so forth and these networks you know these nodes let us assume that we are focusing on a particular node like this one and this node you know it is going to sense certain underwater phenomena around this particular node and similarly the other nodes are also going to the same and like as we have understood in the case of terrestrial sensor networks here also a multihop kind of mechanism is implemented and these nodes through a multihop path we are going to send the data to the surface station.

The surface station then essentially collects the data and then the data is analyzed to under to understand that what all phenomena are going on underneath the water surface and what is occurring around the water surface and so on. So, basically what we have in an underwater sensor network or UW essence is we have a network of self powered wireless sensor nodes which are autonomous and not only that these nodes are going to be the only once that are going to participate in this network even you can have autonomous vehicles like ROVs, AUVs, UUVs and so on which can also act as different other node and together these individual nodes the sensor nodes the ROVs, AUVs, etcetera and you know every everything together they will be communicating with each other and the sensed information is going to be finally, brought back to the surface sink through multihop path.

So, let us look at this particular picture over here what we have is over here we have you know the surface sinks the surface sinks on the surface can communicate through RF, but under the surface of water they are not going to communicate through RF, but through acoustic mode. So, acrostic node of communication and RF mode of communication together will be supported by each of these surface sink nodes. So, another pictorial view of these networks is shown over here. So, what we have is a source station then we have the surface sink nodes and we have these underwater nodes underwater sensor nodes or underwater other nodes a mobile ducker etcetera, etcetera. So, these nodes they will be able to communicate with each other and the data will be sent typically in real time to the surface sink stations like this one this one etcetera and they are finally, going to send the data to the shore station and for further analysis and so on.

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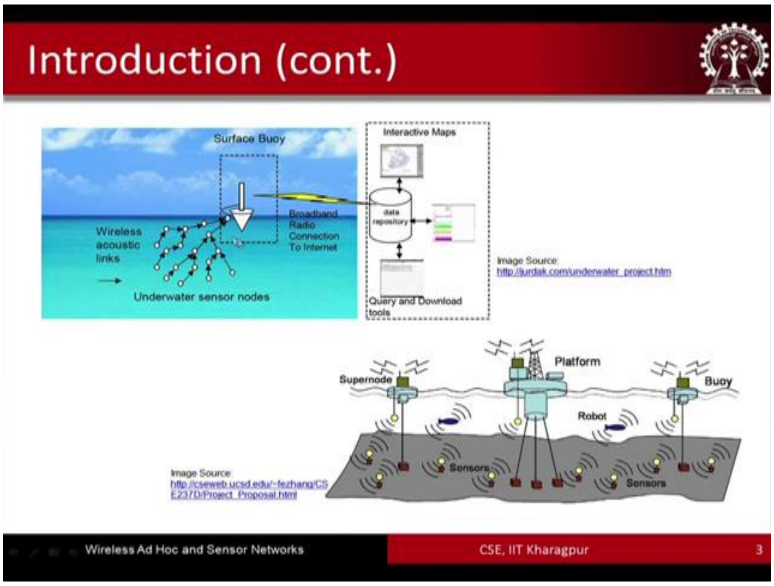

Another view of underwater sensor networks the topmost figure. So, what we have is you know this is something that we have already seen you know this kind of structure we have already seen in the acoustic sense sorry in terrestrial sensor networks where RF communication was used. So, exactly the same kind of structure is adopted in this environment as well underwater environment as well. So, the only difference is that acoustic mode of communication plus everything that happens is under water under the surface of water and the sink node is typically placed on the surface of the water and the sink node basically receives the data and for further analysis and so on.

Now, if we look at over here the de data are typically from the surface sinks will brought back brought using long range communication like GSM or you know other broadband communication mechanisms to the control center and at the control center the data are stored in different repositories where different queries can be run using different query tools and so on and different analytics will be produced.

So, here again another view of underwater sensor networks here what we see is these nodes you know. So, from the surface sink there are a couple of nodes which are basically streamed these are strings to these underwater sensor nodes from the surface sink. Similarly these nodes are also spring or they are tied; that means, they are words and in this particular case what we see is in this deployment around these word sensor nodes there are different other wireless sensor nodes which will be communicating through short range communication short range communication with this word sensor nodes and these word sensor nodes are going to send the data to the surface sink node.

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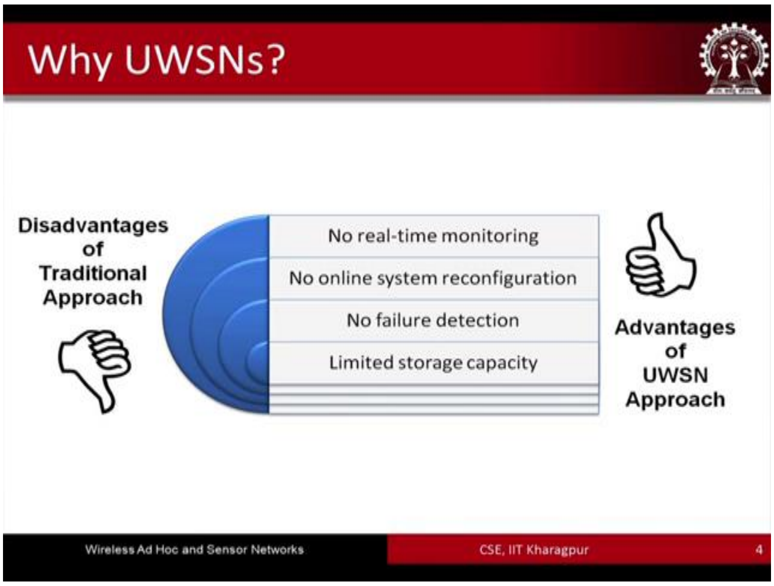

So, why do we need underwater sensor network? There are different advantages of underwater sensor networks. So, first of all real time monitoring is something that is very interesting that is very important. So, standalone sensor nodes which are dipped under water they you know they can record information that are occurring around them the standalone once, but you know they that is a traditional way in by how you know the traditional you know the sense sensor data are received from under underwater, but by doing that you know. So, by these only by recovering the these nodes which are which are sinking underwater recovering them on the surface shore then only the data can be obtained from them, but using underwater sensor networks one can do real time or monitoring of the region the or the or the or the oceanic column around which the these underwater sensor networks are deployed.

And there are different other advantages as well I am not going to go through them these are given in front of you, but there are other disadvantages also. So, these disadvantages we are not focusing over here, but what we see over here are the disadvantages of the traditional approach and you know how that is overcome by the u w s and approach.

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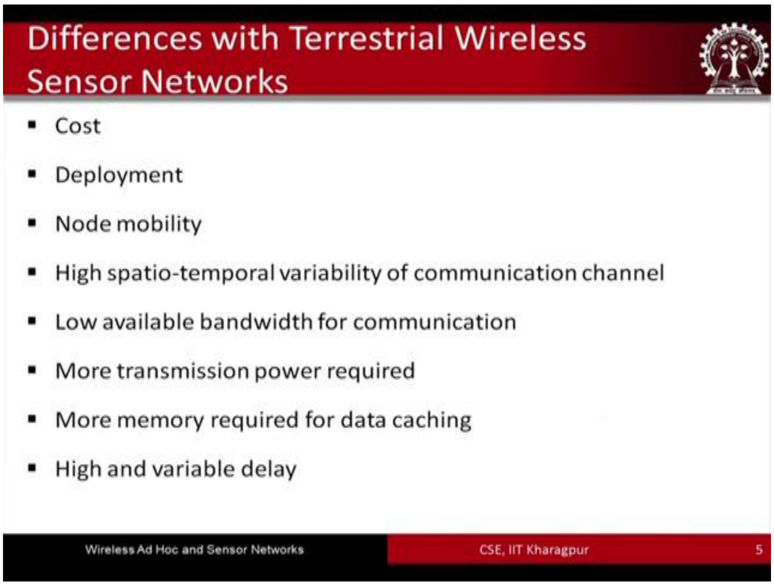

So, the differences between terrestrial wireless sensor networks and underwater sensor networks are like this. So, with respect to cost you know terrestrial sensor networks are much cheaper compared to the underwater sensor networks the underwater sensor node is very costly and underwater sensor network you know deployment is also much more difficult compared to terrestrial sensor network deployment node mobility; obviously, is very different. So, in the case of terrestrial sensor networks even if we are talking about mobile sensor networks they are also there can be active mobility which will be moving the nodes from one point to another. Really it is going to happen that physical phenomena like wind or something like that is going to move the nodes from one point to another, but in the case of underwater environment you know mobility of nodes due to underwater currents waves etcetera are very common phenomena.

So, node mobility is very different in the case of underwater sensor networks from the terrestrial sensor networks is in underwater communication environment in underwater channels basically there is high spacio temporal variability of these channels with time right. So, time and space there is high variability of these channels compared to the terrestrial environment.

Additionally the amount of bandwidth that is available for communication in underwater environments is much lower compared to the terrestrial environment and more transmission power is also required in the case of underwater sensor networks compared to the terrestrial once and also more memory is required for data caching because these nodes they are you know less powerful in terms of you know communication because of the medium in which they are communicating these underwater sensor node. So, you know lot of data caching requirement are there. So, there is more memory required for data caching and the amount of delay and the variability of delay is also quite high you know with underwater sensor nodes. So, basically from under the ocean column you know if a signal pulse is sent by a particular node for that pulse to reach to the surface sink that is going to take much longer duration then the similar distance in terrestrial environment.

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So, these now I am going to show you some of the pictures of different applications of underwater sensor networks underwater sensor networks can be used for ocean in ocean in monitoring ocean environment monitoring like coral reef monitoring and monitoring of you know different oil under water you know oil mineral resources under water can be used for ocean mapping underwater sensor networks.

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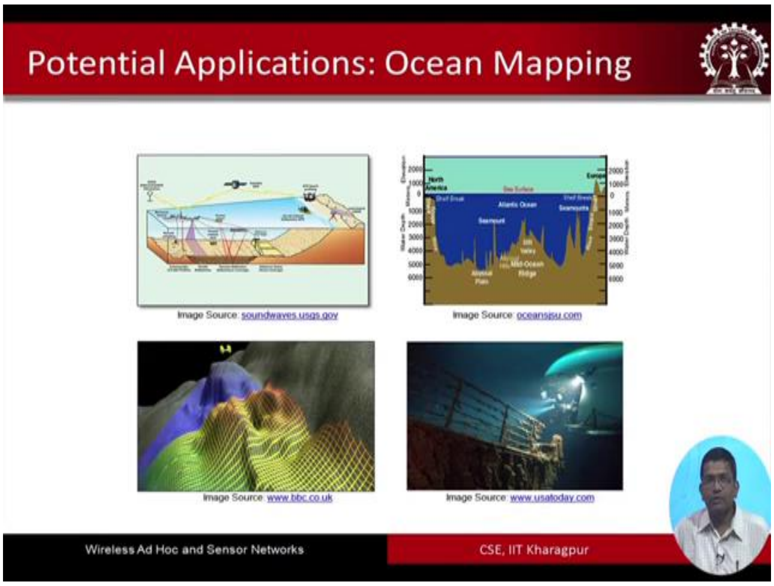

Typically you know they find a lot of used lot of applicability for ocean mapping ocean mapping means like you know how is the ocean column you know and how is the ocean floor you know typically as we know that the ocean floor is not generally flat at many most of the places underwater. So, there is lot of variability, there are lots of regions, mountains, etcetera under the surface of in the ocean floors.

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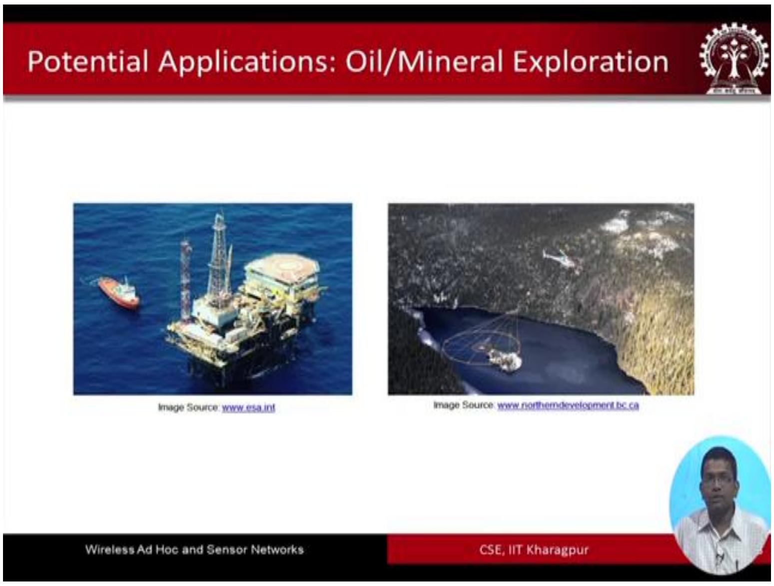

So, mapping of the ocean floors can also be performed using underwater sensor networks oil and mineral exploration is another thing that I already mentioned using underwater sensor networks this can be something that can be achieved.

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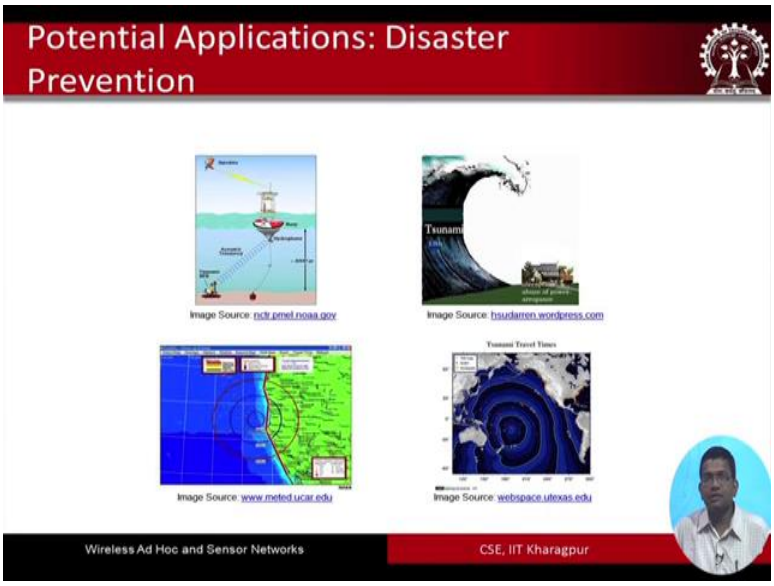

And the digester management tsunamis different tidal waves etcetera, etcetera you know prevention from those prevention of coastal areas from these natural disasters. So, you know prediction of tsunami is coming back prediction of the huge waves, tides, etcetera coming. So, those can be obtained through the deployment of underwater sensor network.

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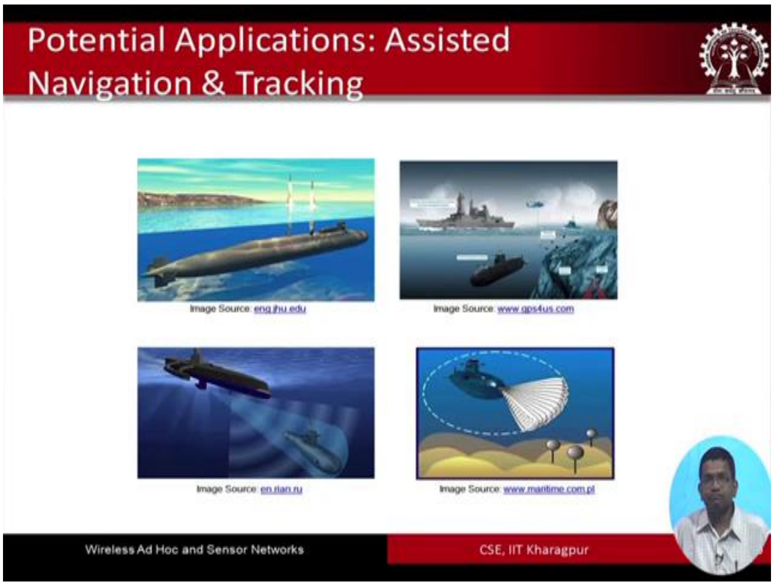

Another is assisted navigation and tracking you know. So, like you know a big sheep or a submarine it can help in you know in tracking different other you know different other activities underwater the same kind of thing can also be adopted even a submarine can be tracked and you know even a submarine can be assisted in its navigation using underwater sensor network.

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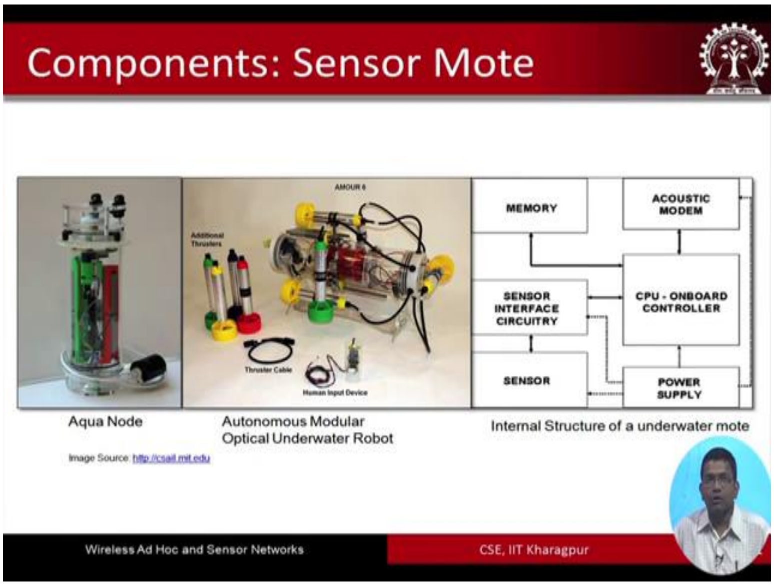

Now here is a on the on the left hand side what we see over see is basically and you know a pictorial view of underwater sensor node which is called the aqua node, a particular type of underwater sensor node which is called the aqua node and. So, basically these kind of nodes they can be used for connecting interconnecting and forming a underwater sensor network. So, in aqua node or any other underwater sensor node typically what happens is we have the similar kind of components as we also saw in the case of terrestrial sensor node we have; obviously, we have a sensor component we have sensor interface circuitry we have the CPU on board controller we have a power supply we have acoustic modem the only thing is that the modem over here is acoustic modem and; obviously, we have a memory unit as well.

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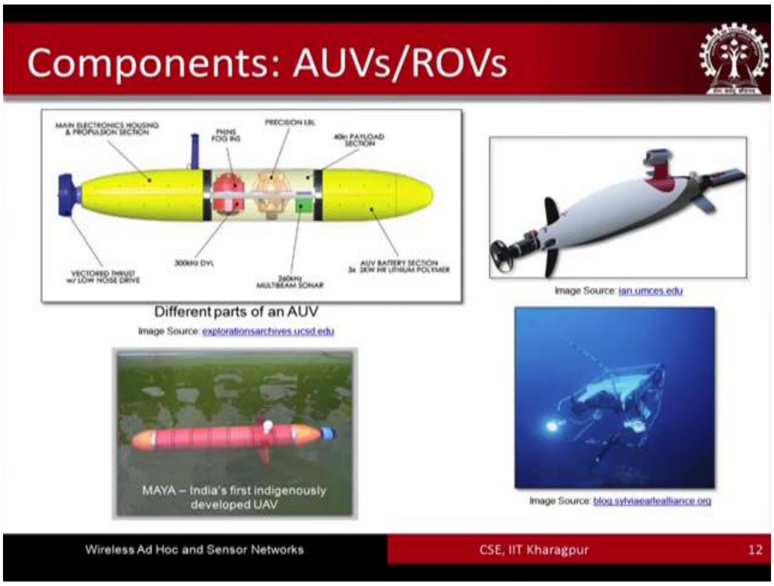

So, AUVs and ROVs autonomous underwater vehicles and remotely operated vehicles these are things which are also used in conjunction with UW essence. So, these are the pictures of autonomous underwater vehicles. So, these autonomous underwater vehicles can also act as data mules so which will collect the data from these different sensor nodes underwater sensor nodes and to being the data to a different point maybe surface of the surface of water or whatever.

So, like this you know they have different uses the AUVs scan be used along with underwater sensor networks typical underwater sensor networks to aid in different processes. So, in the top left figure what we see are the different components of AUV. So, I am not going to again explicitly mention each and every of one of them, but it is quite obvious you know while going through you can understand that what each of these components do.

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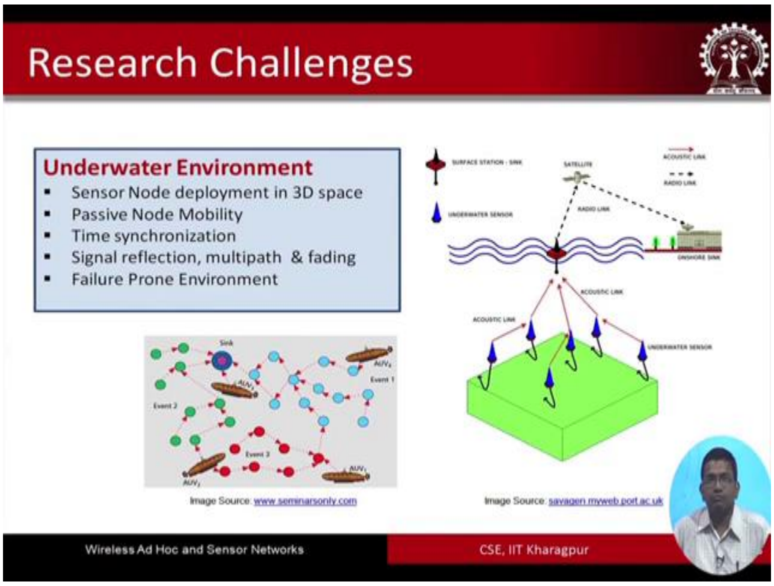

So, there are different research challenges in implementing underwater sensor networks the underwater environment itself is quite challenging. So, first of all unlike in the case of terrestrial sensor networks where typically we are talking about the deployment of the sensor nodes typically in a 2 Ds, 2 D kind of plane here in underwater environment we are talking about sensor node deployment in the 3 D space, 3 D space means what happens is starting from the very bottom. That means, the ocean bottom to the ocean surface throughout you are going to deploy the sensor nodes and these nodes which are deployed they have to maintain their position the x y z position on inside the ocean column.

So, you know even maintaining these positions the defined positions of the sensor nodes is very difficult because of the high degree of dynamism of the underwater ocean you know environment. So, these environments are typically you know very much chaotic there are lots of different types of underwater currents waves etcetera he which hit these nodes. So, these nodes are subjected to passing mobility because of these currents and waves hitting them these nodes can move from one point to another and so there is passive mode mobility time synchronization is another very interesting challenge. Time synchronization means that you know these nodes that are deployed at different places you know we have to be time synchronized otherwise you know the obvious problems of networking that we already are aware of those things are going to happen and how you are going to time synchronize these different nodes that is a very huge challenge there has to be a centralized clocking mechanism, but that centralized cocking mechanism cannot be implemented in these environments.

So, this one thing additionally there are physical phenomena such as fading multipath you know multipath make an multipath distortions signal reflection etcetera which also affect the signal quality for communication in this environment and these environments due to these high degrees of dynamism are prone to different types of failures and so on. So, these pictures that you see in front of you I do not need to explain them again. So, these are the concepts that I have explained in different ways earlier. So, sensor nodes can be deployed on the ocean bottom or they can be floating in the ocean column or they can be placed on the surface of the ocean column.

So, whatever be it these different nodes they will have to interconnect with one another to bring these sensed information to the surface for further analysis and so on.

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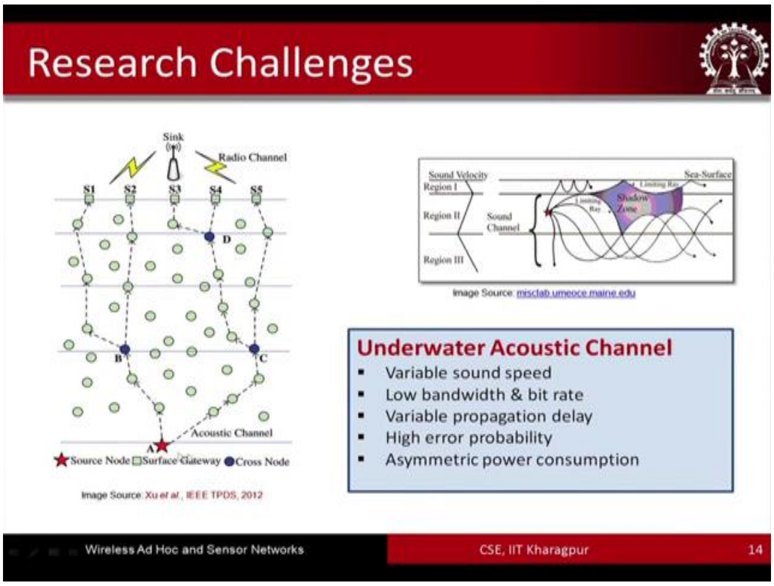

So, essentially what we have if we look at this particular picture is we have an acoustic environment acoustic channel and so, this particular source node in this example through multihop it is going to send the data that data through these different nodes are going to be brought to the surface sink nodes as shown over here and these are the surface gateways and these notes are termed as the crossroad. So, this is the overall implementation you know this is the overall topology of underwater sensor network this is what has to be implemented in practice and the acoustic channel if we talk about you know it is it has variable sound speed right. So, this sound speed at one point in the ocean column is not the same as another point in ocean column not only that it is not only vertical, but also lateral laterally also the sound speed where is a lot.

So, but you know if you if you go down the ocean column the variation is quite prominent. So, this is one thing the second is that low bandwidth and bit rate this is also another typical feature of these underwater environments variable propagation delay high error probability asymmetric power consumption asymmetric power consumption is also a very interesting feature that is typical of underwater sensor networks. So, this is one thing and another very interesting thing that we should also know about you know underwater environments is that there are things called shadow zones for any kind of a underwater communication, there you know shadow zones are typically present and shadow zones basically are the ones where through which these signals the webs the communication signals do not pass through those signals will not be able to penetrate through the shadow zones.

So, this is how the shadow jobs are created as shown pictorially and so, due to this shadow zone basically you know what happens is some of the communication is you know the overall communication is inefficient the overall the sum of the signals are typically not received on the surface the way they should be received and so on, because of the presence of the solutions the overall performance of these networks are typically affected due to the presence of shadow zones.

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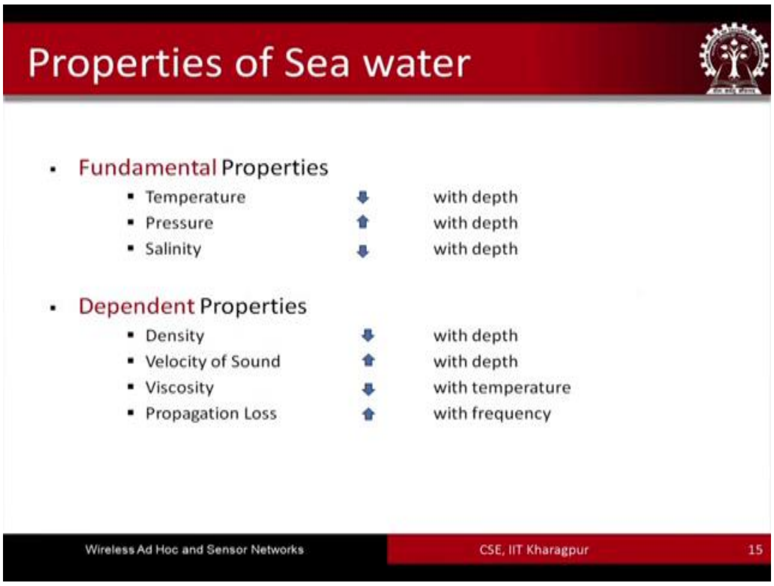

Some of the properties of you know of oceanic water sea water. So, if we talk about fundamental properties like temperature pressure and celerity. So, temperature with depth it goes down the more we go down deeper into the ocean the temperature basically goes down it becomes cooler and cooler the second is the pressure the pressure also the pressure basically increases as we go downwards in the ocean column because you know more you know more volume of water is going to be above. So, basically you know that leads to because there will be.

So, the more you go down there will be more water above you and that is why the pressure on the water pressure is higher the when one goes downward in the ocean column third is serenity basically reduces with depth this is another very fundamental property of the ocean of seawater. The second is the dependent properties density basically decreases with depth velocity of sound increases with depth viscosity goes down with temperatures in and proposition loss basically increases with frequency.

So, these are the different variations with depth temperature and frequency of the different properties of sea water ocean water.

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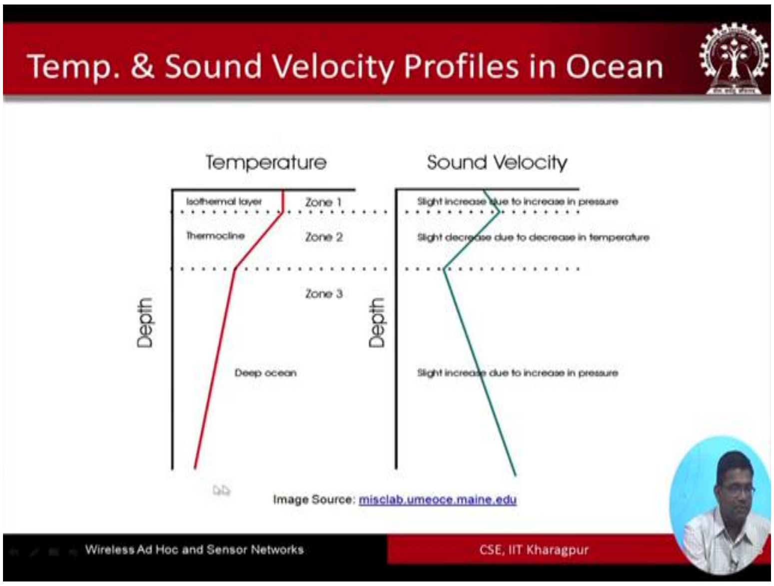

So, pictorially let us look at 2 of them one is the temperature variation with depth and the sound velocity variation. So, this is what we see; so, you when we talk about the oceanic column. So, it is basically typically it can be segmented into different layers or different zones. So, the first one is the isothermal layer then we have the thermo cline layer and then we have the deep ocean layer. So, these are the different zones.

So, how the temperature varies with depth when one holds down the isothermal then thermo cline and the deep ocean are shown through this particular plot then the second plot basically shows how the sound philosophy changes when one goes down in the ocean column. So, initially there is a slight increase due to increasing the pressure then there is slight decrease due to decrease in temperature because of what increase and decrease of the velocity. So, slight increase of the velocity due to the increasing the pressure then there is slight decrease in the velocity due to the decrease in the temperature and there is slight increase they are after due to increase in pressure. So, this is how the sound philosophy basically varies with depth.

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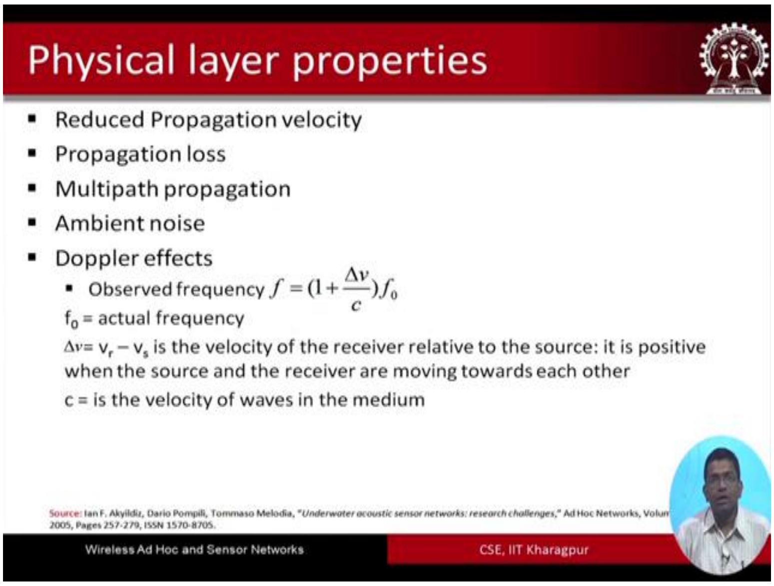

So, when we talk about the physical layer in communication for underwater and. So, there are different things that happen. So, one of the things one of the properties is of. So, if we think about the propagation the sound wave propagation the velocity of sound wave propagation that basically significantly gets reduced this is number one. The second thing is there is lot of propagation loss in underwater channel those web propagation loss signal propagation loss there is quite significant amount of loss in the underwater environment. Third is multipath propagation there is a lot of multipath when distortions etcetera you know which basically affect these physical layer of these communications environments underwater communication environments. There is lot of ambient noise ambient noise due to maybe mammals you know and different other you know water currents and so on etcetera there is a lot of ambient noise in underwater environment Doppler Effect.

So, Doppler Effect is very interesting because you know we are here talking about sound sources; that means, sound mode of communication acoustic mode of communication and as we know that when the nodes move when house sources move it might. So, happen that Doppler Effect might be observed and if you if we recall from our plus to physics. So, the Doppler you know the object frequency you know through Doppler Effect F equal to one plus delta v by c times f 0 where f 0 is the actual frequency. So, you see that the actual frequency is no longer there and it is changed it you know it basically increases.

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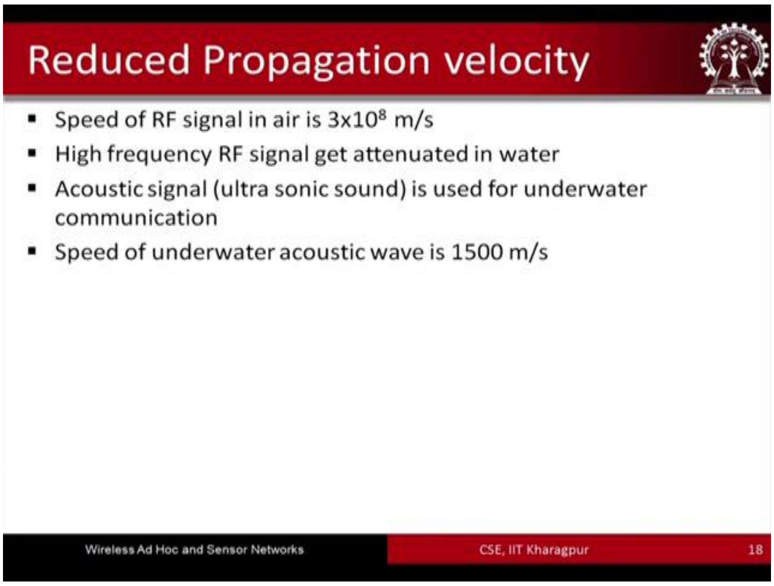

So, there are other properties of the signal velocity. So, for RF in here you know it is 3 into 10 to the power 8 meters per second the speed the high frequency RF signal gets eliminated in the water acoustic signal is used for underwater communication and the speed of underwater acoustic waves is 1.5 kilometers per second. So, 1500 meters per second this is the speed of underwater signals underwater wave acoustic waves.

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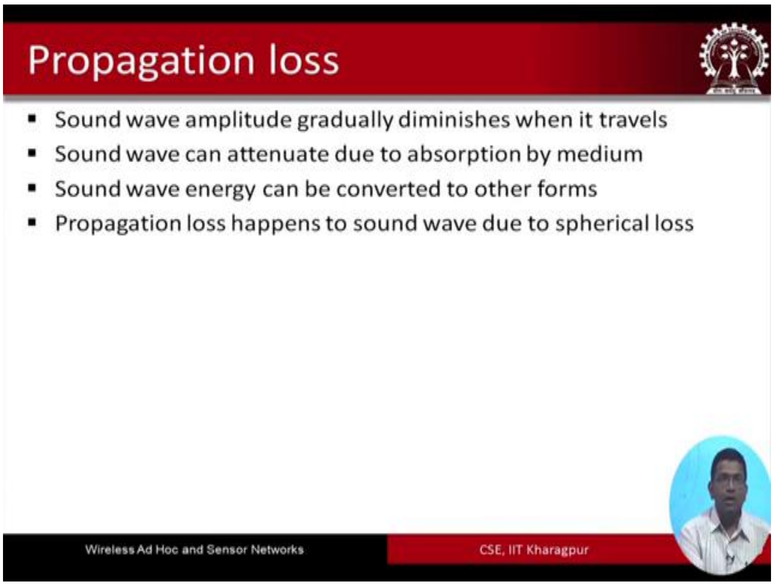

There is lot of propositions loss there is not a propagation loss the sound waves amplitude basically diminishes quite fast then the second thing is the sound waves gets attenuated due to absorption by the medium. Third is that the sound wave energy can be converted to other forms and the propagation loss happens to sound waves due to spherical loss.

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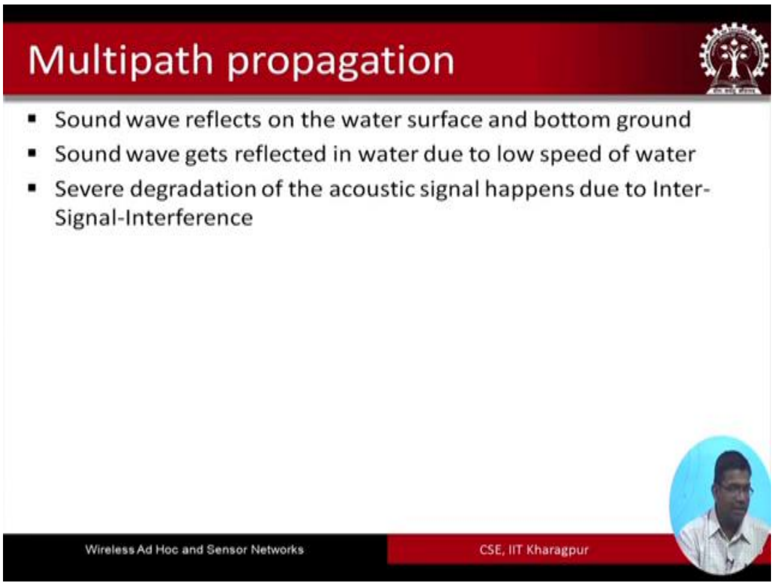

Multipath if its multiple phenomena are quite prominent as I said before in underwater environments this occurs you to the reflection of these waves sound waves on the water surface and ocean bottom and so on, the sound waves they get reflected in the water due to the low speed of water and also the variable speed of water at the different layers they are also the reflection of the sound waves can occur. So, all of these you know lead to multipath effect and these basically will lead to overall the severe degradation of the acoustic signal strength.

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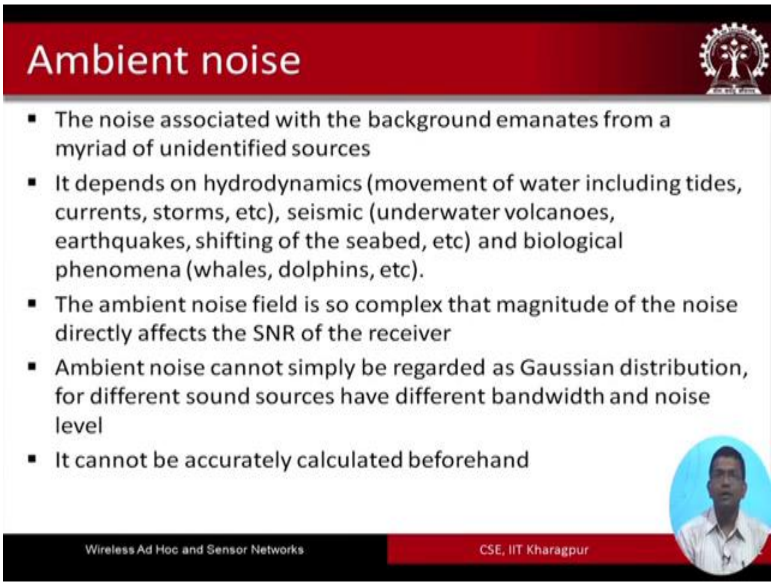

Ambient noise; noise associated due to the background or the surrounding environment due to hydro dynamics; that means, the movement of water including tides current storms etcetera vise seismic activities may be underwater volcanoes earthquakes shifting of the seabed biological phenomena maybe you know noises that are made by the mammals like under you know the oceanic mammals marine mammals like whales dolphins etcetera the ambient noise field is. So, complex that magnitude of the noise directly affects the SNR of the receivers. So, this is something very serious issue and which should be taken care of when dealing with underwater communication.

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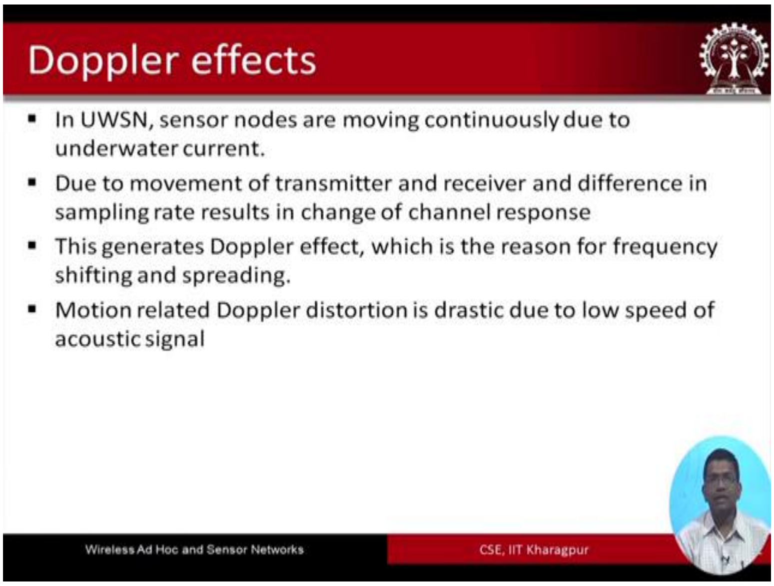

Doppler Effect is something that I have already mentioned what we have the transmitter and the receivers they basically move continuously and these are sound sources. So, consequently due to the movement or mobility of the sound sources Doppler Effect comes in the picture. So, this is something that has to be taken care of you know Doppler Effect has to be taken care of while dealing with underwater communication.

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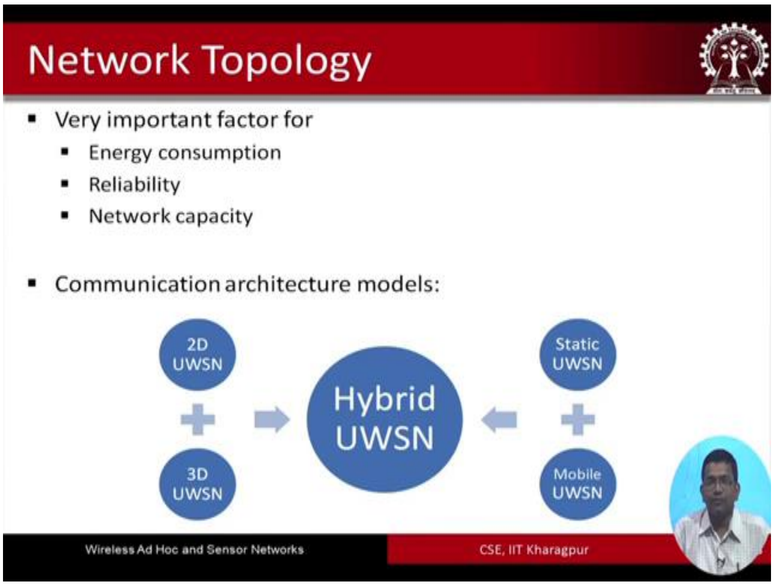

So, the second the next thing is basically there are different models for building underwater you know underwater sensor networks there are 2 D models there are 3 D models there are hybrid models which are basically combination of 2 D and 3 D models. So, I am going to talk about these in the next lecture and there are static underwater sensor network models plus under you know mobile underwater sensor network mod models and hybrid of these 2 these are the different types of different you know underwater sensor network models that are available.

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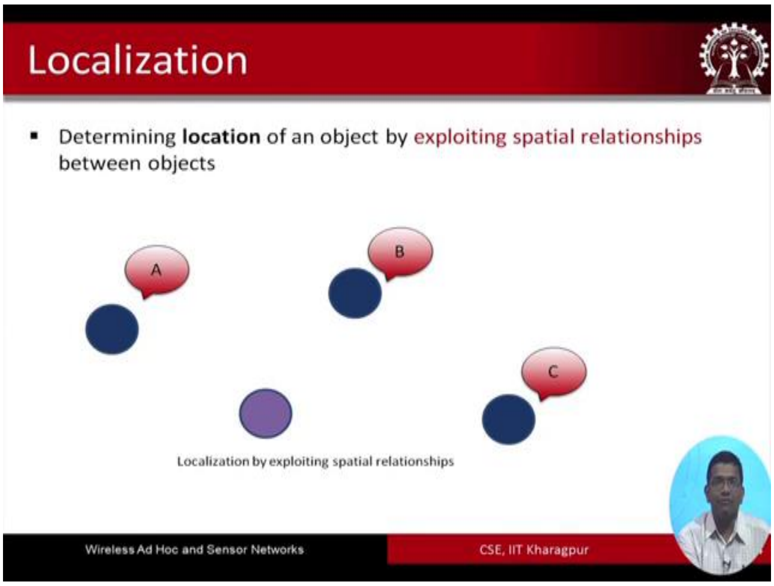

Localization is a very important issue nucleation talks about determining the location of the particular object by exploiting the special relationships between the different objects. So, if we know the location of the difference nodes you know in a particular terrain. So, with respect to as a function of those locations can be determine the location of an unknown node. So, this is how it looks let us say that we have 4 nodes; 1, 2, 3, 4. So, these are the 4; 1, 2, 3 and 4. So, the blue color nodes are the ones which have the locations node and let us assume that this particular node that is no its location we have to find the location of this particular node. So, this is how we have. So, we have nodes A B and C whose location are known and then. So, we have to find the location of this particular node as a function of the locations of nodes A, B and C, this is the whole idea behind the problem of localization in sensor networks.

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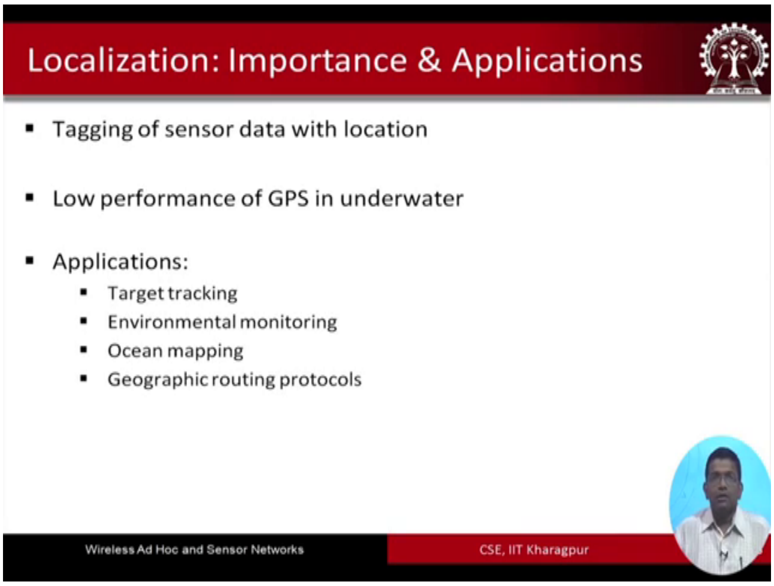

So,. So, the whole idea is why do you want to localize these sensor nodes why do you want to tag the sensor nodes with their corresponding locations why do you want to know the locations because you know it is important to find out where each of these nodes are and because that way the sensor data that is being sent by each of these nodes you can tag the location information along with. So, that at the base station where the sensor data are retrieved. So, they are basically one can infer that where form the sensor data has come from which particular sensor node and where it was at a particular instant of time. So, this basically that is why the location localization you know comes in handy.

Localization basically has different applications target tracking is one environmental monitoring is second ocean mapping is third and you know also localization you know looking at lowing the locations of the different nodes that basically is used to make routing protocol sufficient the geographic routing protocol basically hardness the locations of the different nodes in the network.

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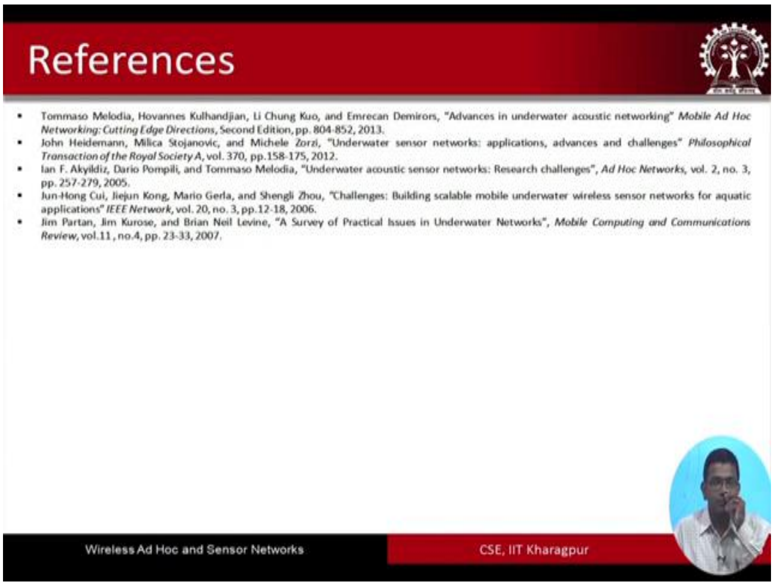

So, these are some of the important to references additionally you know you know there is a good treatment of underwater sensor networks in the book principles of underwater sensor networks which is authored by Vydath and Misra and has been published in the Cambridge university press.

Thank you.