Wireless Ad-Hoc and Sensor Networks

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Lecture – 40
Real-life Deployment of WSN

In this lecture we are going to cover some real life deployment of sensor networks. In the previous lecture we had seen how to design a wireless sensor node the hardware designs the overall architecture, and the different important components how to using which a sensor node could be built. So, in this basically I am going to show you how those wireless sensor nodes that are built could be used to serve different applications. Actually we have used our swan sensor node that I had shown you in the during the lecture on hardware design.

So, that is swan sensor node we have used for multiple purposes for serving different applications ranging from agriculture healthcare so and so forth. So, here I have taken 2 examples from agricultural application, how we have used the swan sensor board swan sensor node and we have custom designed it for serving 2 specific agricultural applications the first one is basically for irrigation management and the second one for security of agricultural field. So, these are the 2 that I am going to briefly present to you for you to get a feeling of how the sensor nodes could be used for serving different applications.

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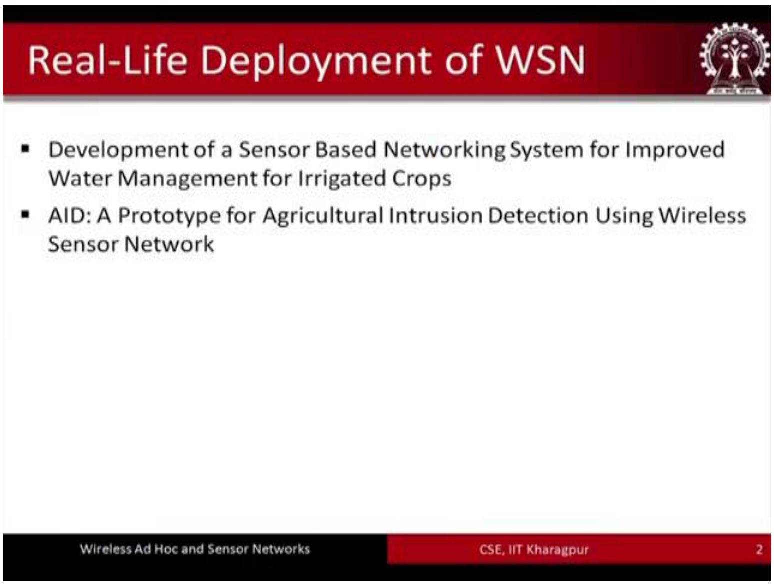

So, the first one as I said is the development of a sensor board sorry sensor node for improved water management for irrigated crops. And this particular solution is actually deployed in IIT Kharagpur in our experimental firm we have already deployed it is continuously you know it is this is functional this is operational and we are able to get data from the field. So, this is one application in agriculture the other application is basically for determining or monitoring if there are any intrusions into the agricultural field using a wireless sensor network.

So, basically as we know that particularly in our country we have different you know agricultural fields, where the agricultural produce in in the agriculture produce the are basically lost maybe due to humans you know stealing them or maybe due to cattles entering into the field and damaging the crops etcetera. So, it is very important to protect these fields from intrusions. So, we are how we are using our swan board swan node for addressing these application is what I am going to deeply expose you to.

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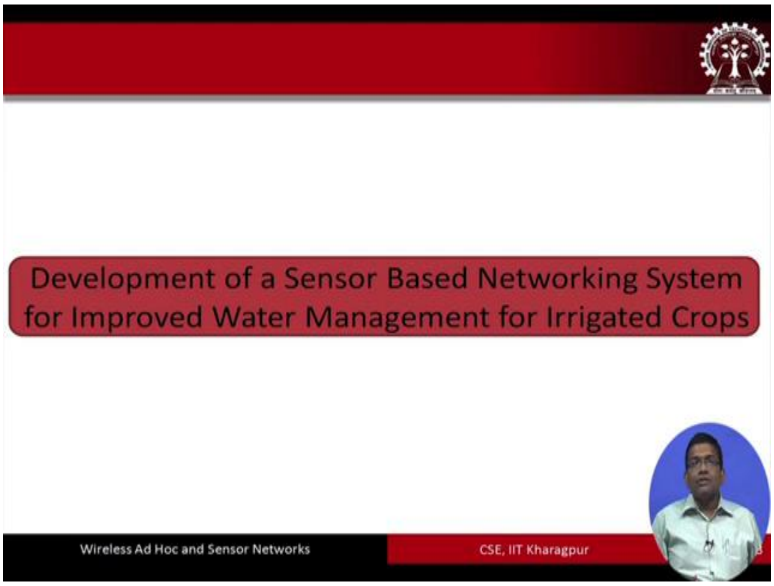

So, the first one is I promise to you is the sensor networking system using the swan board for improved water management for irrigated crops.

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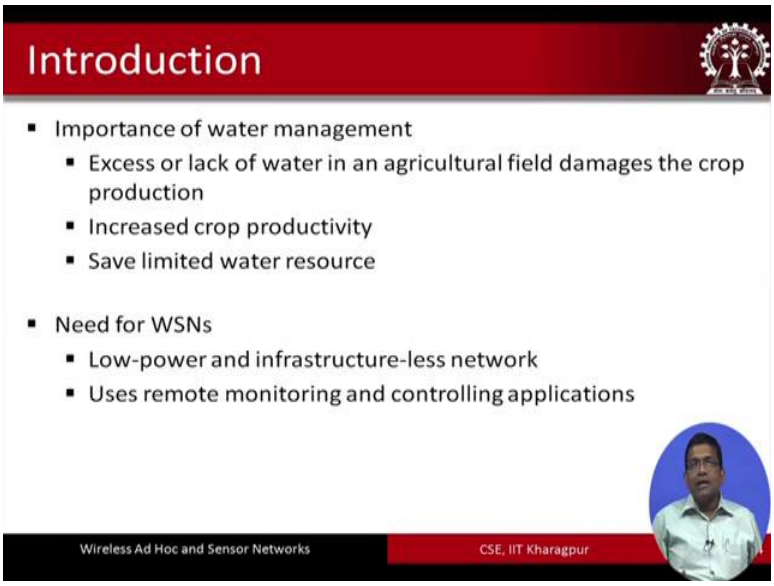

So, water is very important you know particularly you know when we are talking about use of water in agriculture water improves crop productivity, but at the same time it has to be you know the field has to be the crops have to be irrigated optimally. If you use too much of water the crops are going to die, but at the same time you know you cannot also have you know some optimal use of water because that will reduce the overall productivity, or even in the extreme cases the crops would die because of that and water use you know irrigation actually is very important particularly when we are talking about you know paddy crops for paddy crops you know, water is very important paddy crops you know basically survive on the basis of yield well as well as the survival of the paddy crops, is based on primarily how much is the water that is maintained in the fields you know it.

It cannot be too much it cannot be too less you know, what is the optimum one that has to be maintained in the field. So, we are we thought about how we can use sensor networks to basically enable the farmers to be able to get an idea about what is going on in the field the condition of water level in the field how much is the soil moisture in the field. And so also farmers would be able to remotely monitor the condition of their different feel that they own.

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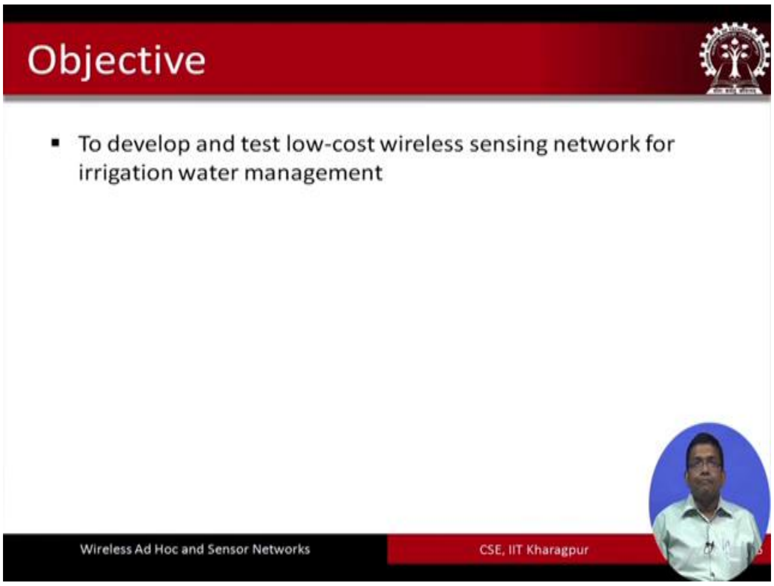

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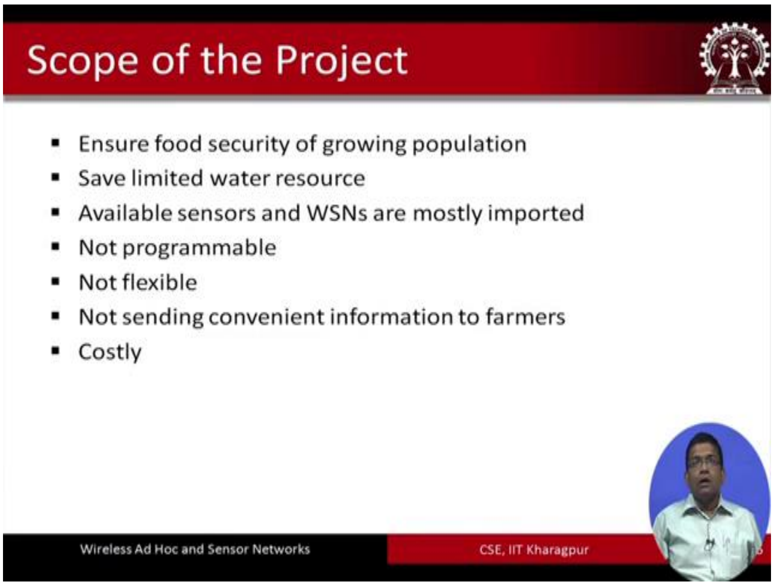

So, the overall objective of this project was to develop and test low cost wireless sensing networks for irrigation water management. So, you know we started with a few objectives we wanted to make a solution we wanted to come up with a sensor network solution, which would be flexible programmable would be convenient for farmers to use and at the same time this would not be too costly.

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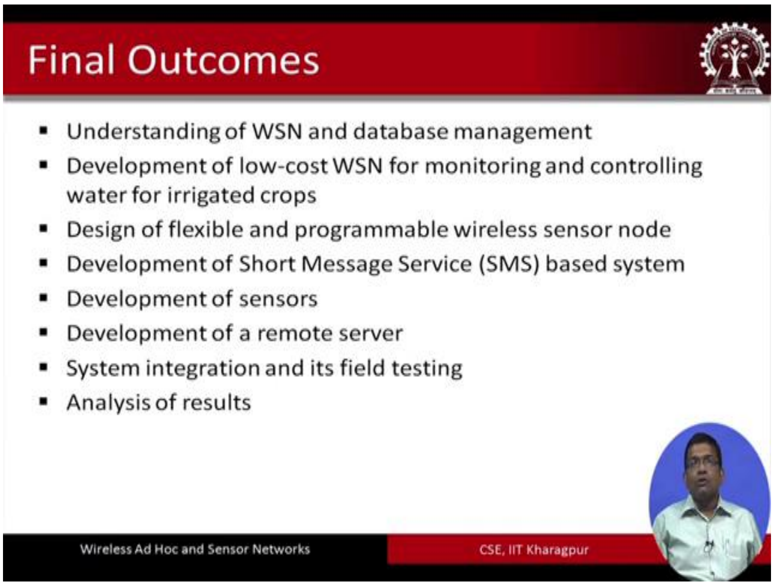

So, the final outcome is like this that we were able to develop a system which can monitor and control the water level of the irrigated crops in the field. And particularly we were targeting paddy crops in this, but you know. So, this kind of solutions can be scaled for use in other types of agricultural crops. The second is the design of a flexible and programmable wireless sensor node. Next one is the development of SMS based system because SMS is required because you know periodically the farmers need to get SMS in their mobile phones about the condition of the field you know how much is the water in the field, then how much is the soil moisture what is the temperature of the you know the environment where the crops are growing and so on.

Development of a remote server you know how the remote server basically will be tasked to do all the analytics you know run all the data you know analyze all the data that are being received, and system integration field testing analysis of the results these are all the different final outcomes of this project you know and overall with respect to the overall objectives.

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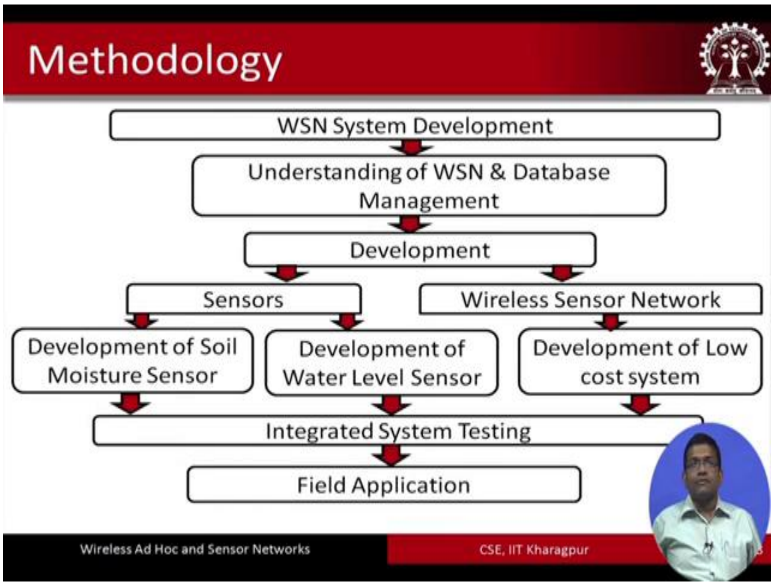

This is the overall methodology that was used from the wireless sensor system, understanding of the wireless sensor network and the database management. Then the development of the system you know with respect to the sensors that have to be used the specific sensors that have to be used in the sensor nodes connected to a sensor node. The wireless sensor network all together you know connecting the different sensor nodes with respect to the sensors you know soil moisture sensor development of the soil moisture sensor development of a water level sensor and with respect to the overall network development of the low cost network. And then overall integration into the into the overall embedded system that is being developed and testing it and finally, deploying it in the field. So, this is the overall chart of flow of tasks that we are conducted for developing the system for irrigation management for use in irrigation management in agricultural applications.

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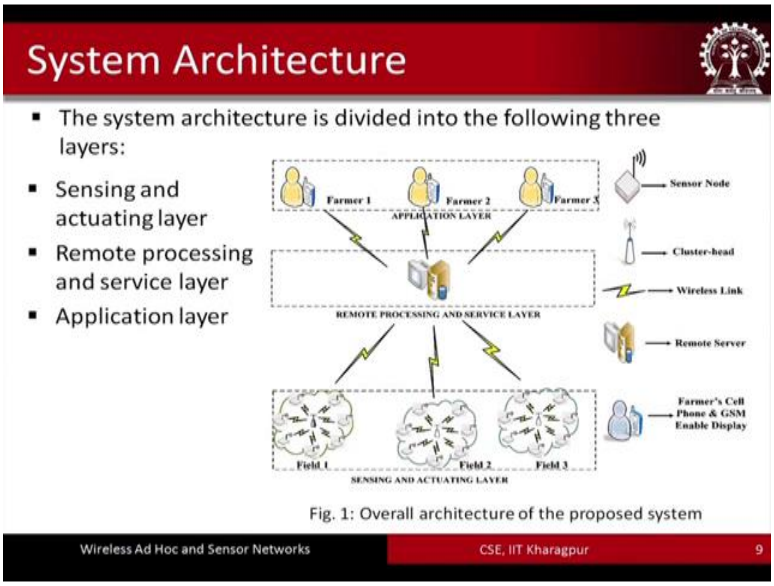

Here is overall system architecture and the very bottom layer we have the sensing and actuating sensing this is the bottom most layer. So, sensors actuators etcetera basically figure in this particular layer. Higher up we have the remote processing and surface layer, and which basically is concerned about you know about gathering all the data from the sensor remotely processing them and offering different services to the higher layer up and these services are going to be used in the application layers by the farmers who are equipped with different mobile phones over which they are going to get different alert messages.

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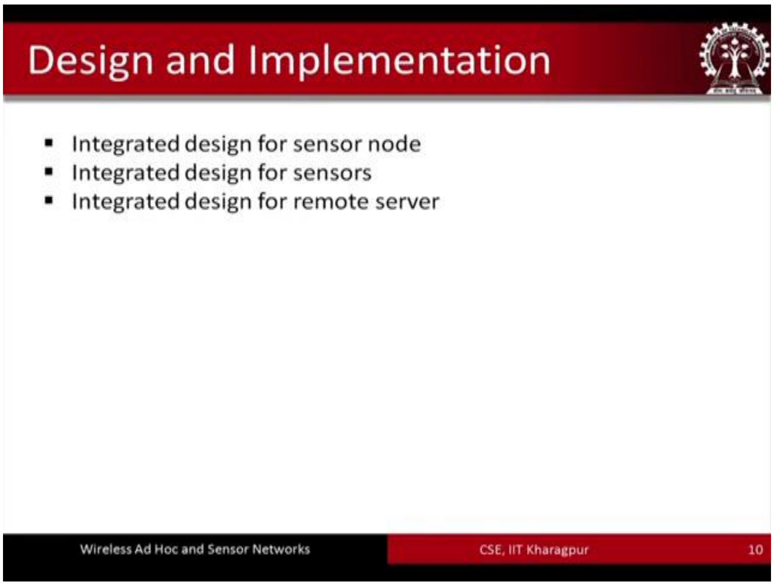

So, this particular job was focused on the development of the integrated sensor node the sensors and the remote server.

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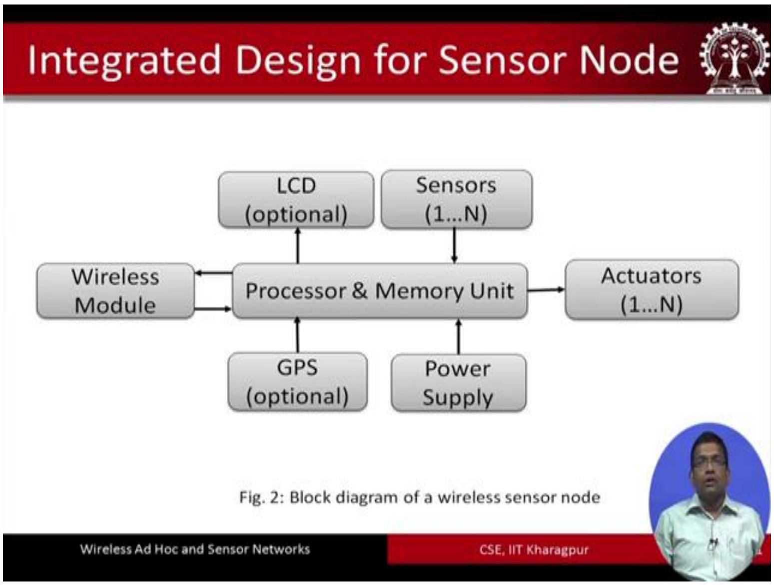

This is something this diagram, we have already seen when we were covering the hardware design of the sensor node in the previous lecture. And this is just a recap of the different components that are there are in the sensor node that we are going to use that we are going to develop for use in irrigation management.

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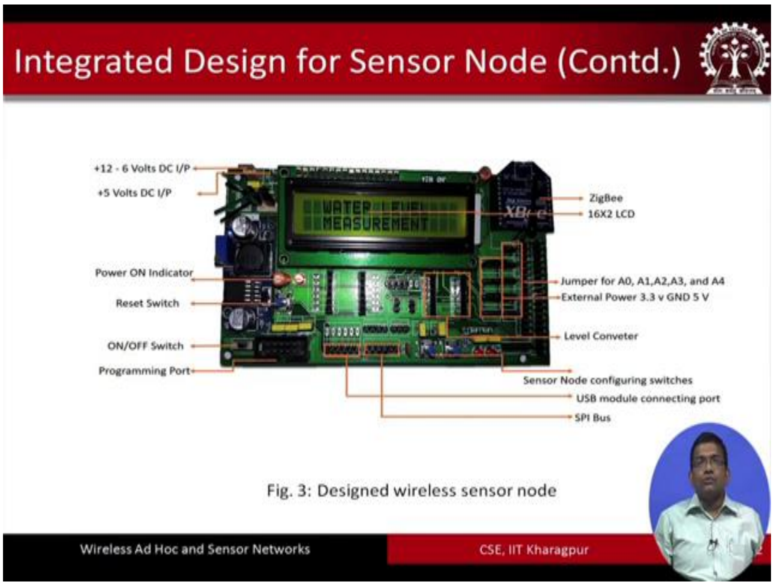

So, this is the actual sensor node that is used it is it looks similar to the swan board, the swan node, but you know the specific you know it has been specifically designed for use in irrigation management. So, it is not a general purpose solution that is used it is you know a general purpose to some extent, but then you have to customize it in order to serve the specific application requirements. So, this is what we have done we have custom designed we have customized the overall sensor node the general purpose sensor node and for making it useful for agricultural application.

And the different parts of it are shown over here, I just wanted to highlight few important once this is the ZigBee module that is used for sensor node to sensor node communication. Then you have this controller this controller the controller can be used you know for control functions; that means, computation etcetera. The controller is not attach attached over here in this particular figure, but you know the controller would be attached you know any micro controller like at mega 3 to 4 or something like that is could be used. These are the on off switches the programming port the reset switch reset switch can help in resetting the sensor node once it is switched on or off the entire node is reset from the start this is the power on indicator then you have these are the inputs the DC input then we have these are the level converters we have the sensor node configuring switches over here. And these are the different jumper and external power supply. So, these are the different components of this sensor node.

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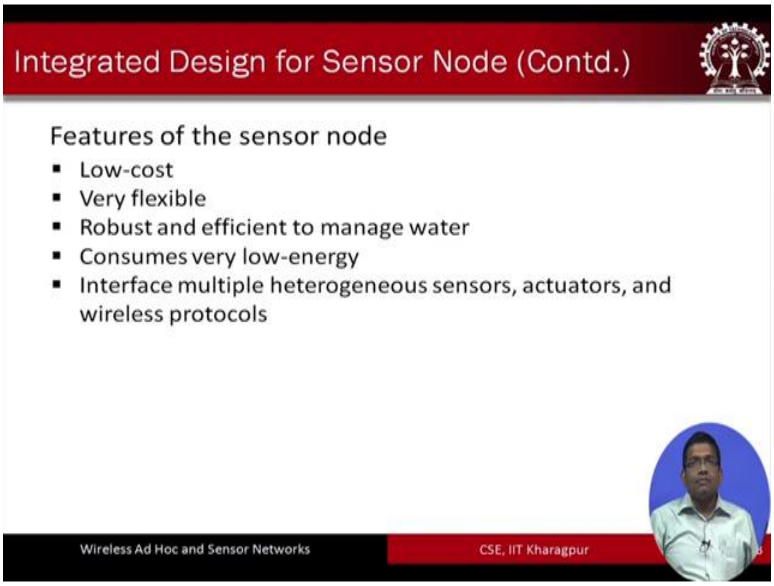

So, these sensor nodes that we have developed is low cost very flexible robust and efficient to manage water consumes very low energy, and interfaces with multiple heterogeneous sensors actuators and wireless protocol.

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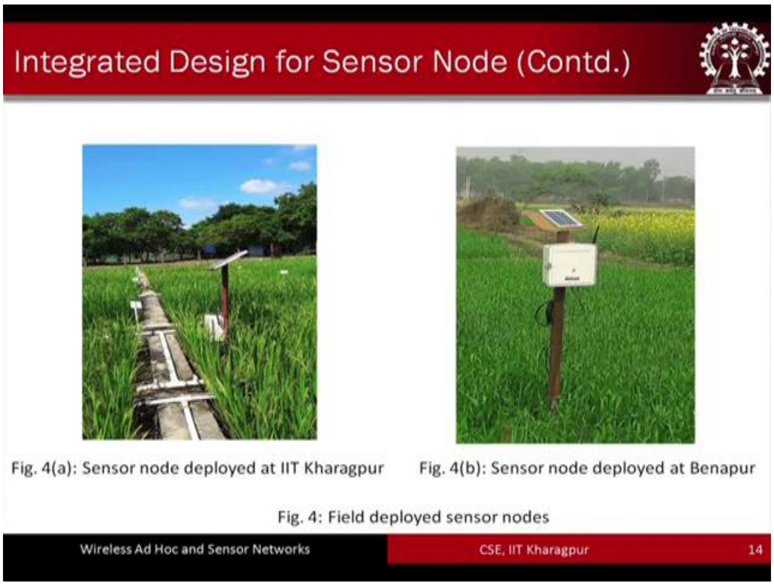

The sensor node has as I told you earlier that it has been deployed in our agricultural field in IIT Kharagpur. And so this known to basically as you can see you know it use the renewable source of energy to power it. So, we have used the solar panels for powering these sensor nodes, because you know typically in our country in the most of the agriculture fields still today you know does not have any continuous power supply. So, in a how we can use you know this sensor node in an autonomous fashion with respect to power supply by using energy harvesting features is what we thought about and so these nodes as we can see you know. So, these nodes not only they are powered by you know solar energy, but after the all these things processing is done you know with respect to the sensors, the sensors are basically dipped or put in the soil the water level sensors and the soil moisture sensor these are put under the soil and they send and all these computation etcetera are done in the swan node. And finally, through this antenna basically the data are sent long range we are using the GSM technology for sending the data they send data to the farmers in their mobile phones.

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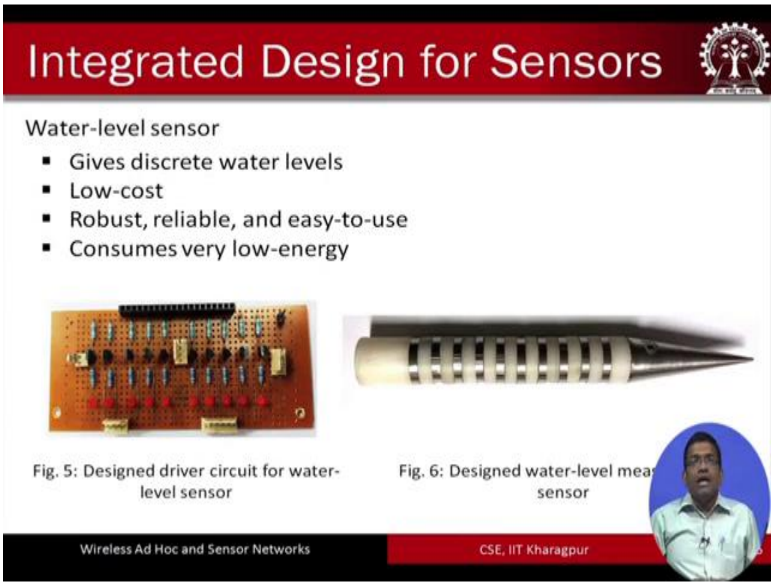

We have also designed some sensors ourselves. We did not took you will all the sensors our self. So, we for example, this is this is the water level sensor that we have designed our selves completely. It is completely designed in the house and the corresponding you know previous version of it, this is the later version of the water level sensor and this is the previous version of the water level sensor that was used and from this bed board, we are able to understand the driver circuitry for these water level sensors. So, this is a very simple design, but at the same time it is elegant, and it fit is it is very small in size. So, it fit is as a simple module that can be used very easily.

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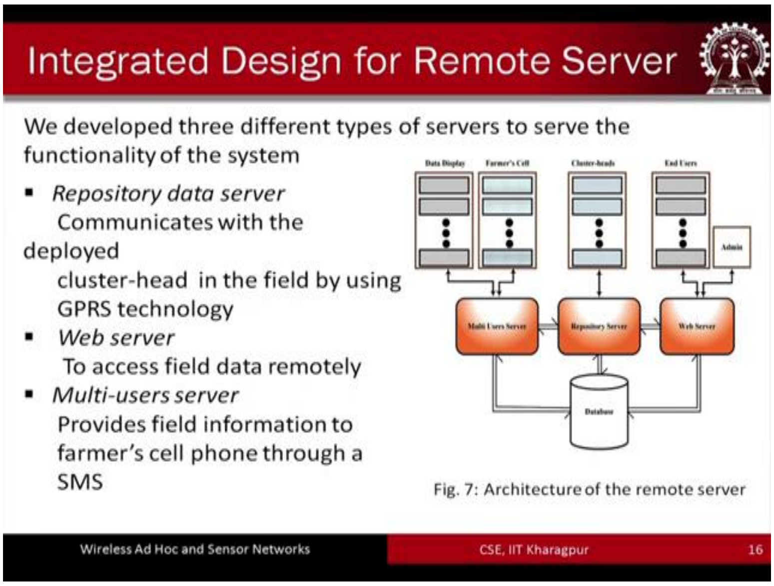

So, the server basically there are different types of servers, that have been used repository data sever basically communicates with the deployed cluster head in the field by using the GPRS technology. Web server is used to access the field data remotely and multi user server provides field information to former cell phone through a SMS facility.

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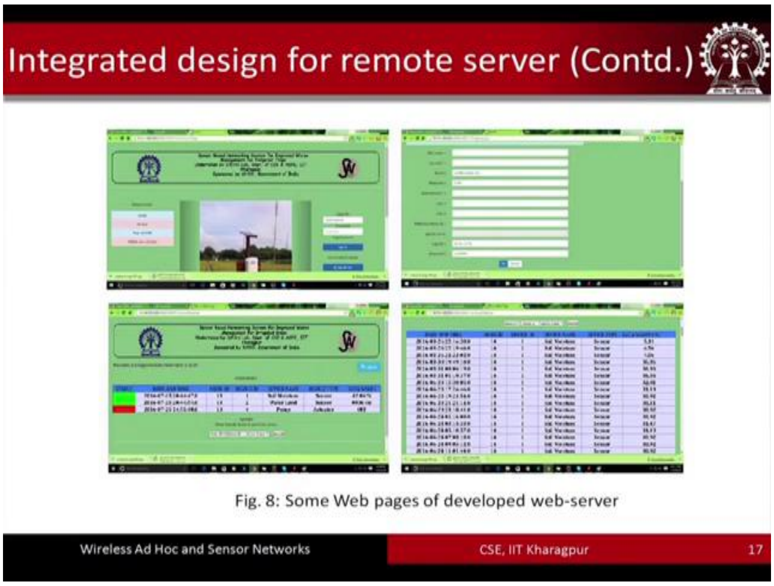

This is the user interface you know this is basically you know from the control station the interface, that one is going to see and the overall portal off. So, this is the portal the design of the portal. So, from anywhere in the world you know what is going on in my field agricultural field, I would be able to access that data from anywhere any part of the world through this portal. And here as you can see it is showing that which sensor node is up the green one indicates that the sensor node is up the red one shows that the sensor node is down. So, it is not functional. So, the health monitoring of the sensor nodes are also possible through this particular portal. And then we see that after we have performed some basic logging etcetera, we have registered ourselves we will be able to see the data in our screen. So, he is showing the data through the portal.

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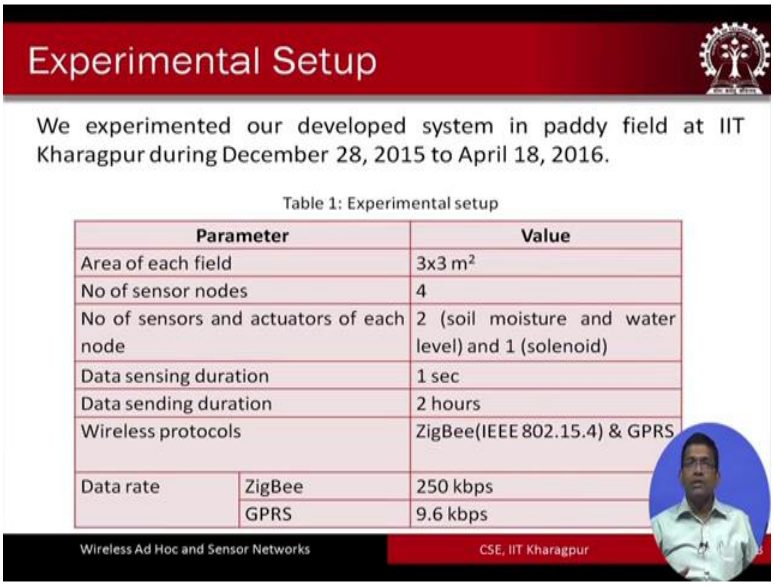

So, this is the experimental setup that was used by us for study in a paddy field in IIT Kharagpur. So, we have collected data between December 2008 2015 to April 18 2016, I am going to show you the data, but this is the experimental setup the area of each field was about roughly 3 cross 3 meter square the number of sensor nodes that were used to was 4, this is because you know we have very small figures. So, over here the reason is that we have experimental fields relatively small in size the actual fields are going to be bigger. And in fact, we have done those trials as well we have deployed our solution in much bigger fields in a village in the remote village from here about 20 kilometers from IIT Kharagpur. So, we have deployed there we have tried it out there in a bigger field as well.

So, ZigBee and GPRS. So, ZigBee for local communication and GPRS for long distance communication was used.

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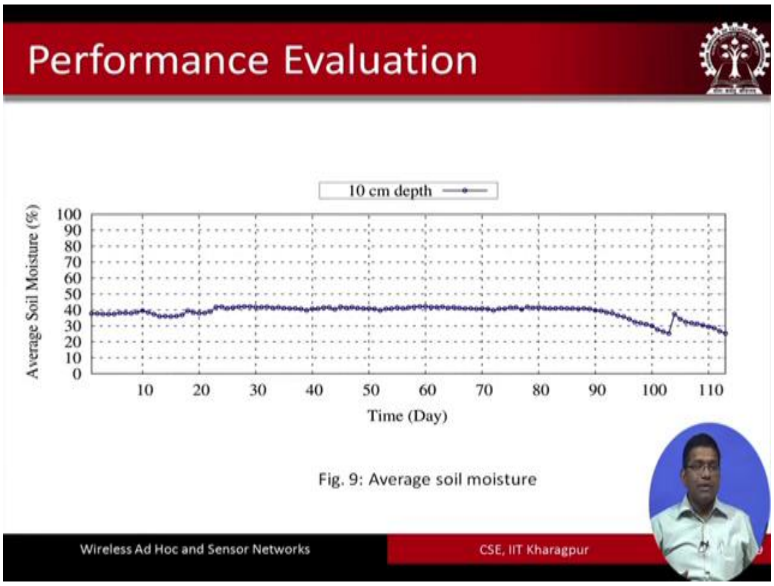

So, this is basically the data that we received during that period that I mentioned before between the 2015 to 2016 that data the average soil moisture data is plotted over here.

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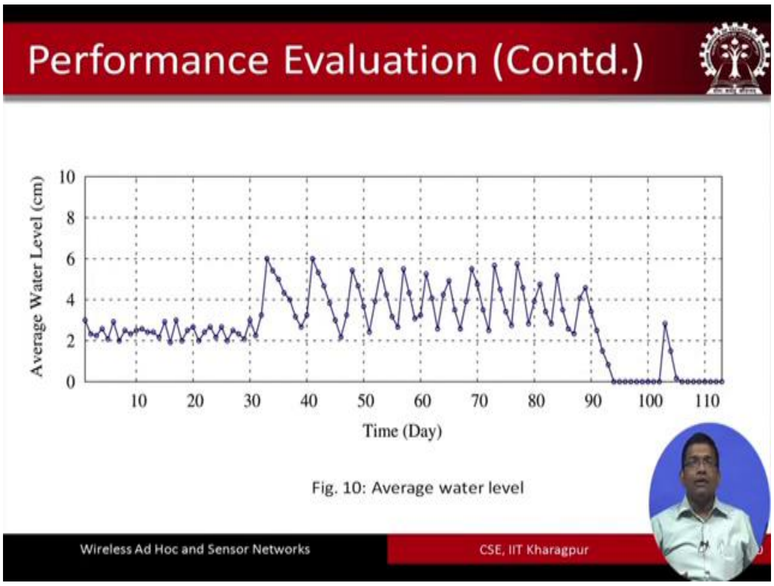

And the next one is basically the average water levels in the field over the time span that we mentioned before between December 2015 to April 2016.

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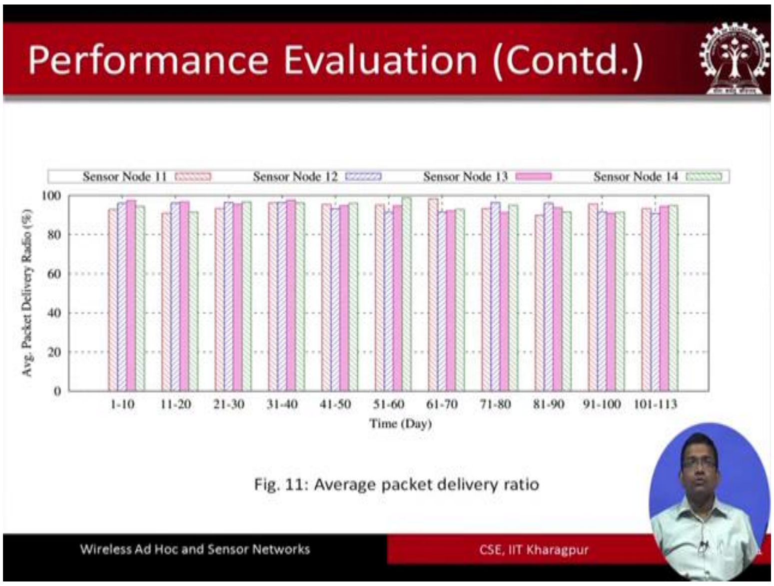

And this is the average packet delivery ratio by the different nodes the 4 nodes, that I mentioned node number 11 12 13 and 14 that you know the data that is sent the average packet deliver ratio is computed and it is plotted over here.

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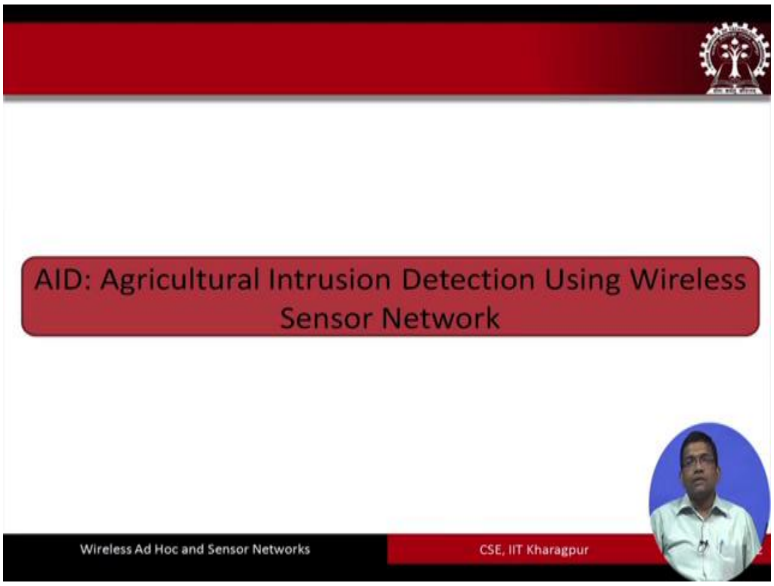

So, this was the first application the next application is basically a use of sensor network for automated remote intrusion detection and monitoring of agricultural field.

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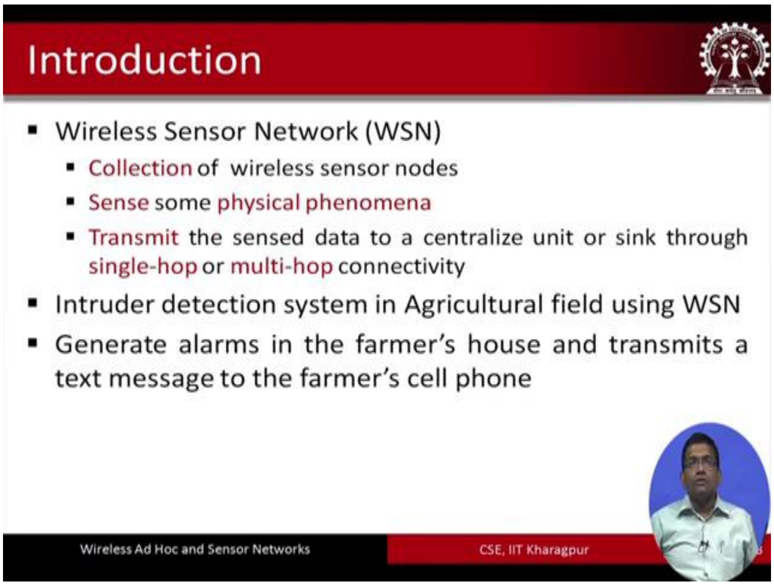

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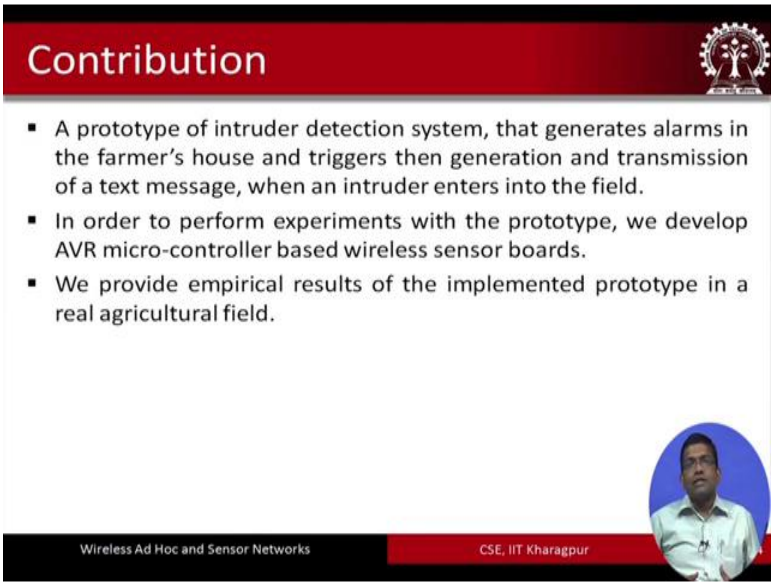

So, what we did over here is we develop the system that would be able to detect if there is any intruder the intruder could be a human the intruder could be cattels or anybody else who and once that is done then the farmers basically India mobile phones they would be able to get alarms in the mobile phones at their houses and so, that basically will help them to understand that there is some kind of intrders that has taken place in their field and then they can take corrective measures. So, we have in this we have used AVR micro controller. So, earlier we talked about a t mega, but here we have used the

AVR microcontroller and. So AVR is just a architecture and many micro controllers basically use this AVR architecture.

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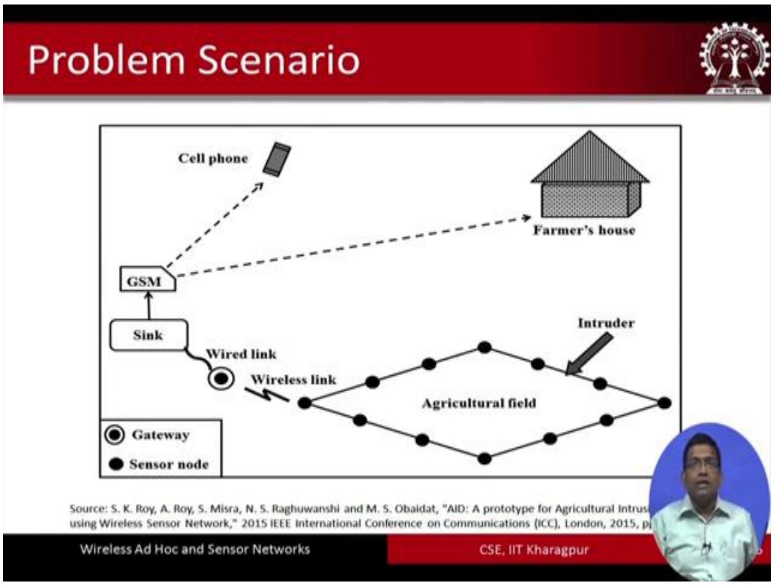

So, I will show you know the how the overall architecture of our solution looks like. So, let us say that this is the agricultural field and in the agricultural field, we have deployed these different sensor nodes in the periphery of the agricultural field, and these if there is an intruders these nodes, they will detect the intruder and through a multi hop path that data is going to come to the sink nodes, from the sink node it is going to go through over SMS to the cell phones of the farmers or their houses for generating different alerts, you know by which they would be able to know that something wrong has taken place. And the details of this particular the architecture and the corresponding solution can be obtained from this particular paper that was published by us IEEE, that was held in London in 2015.

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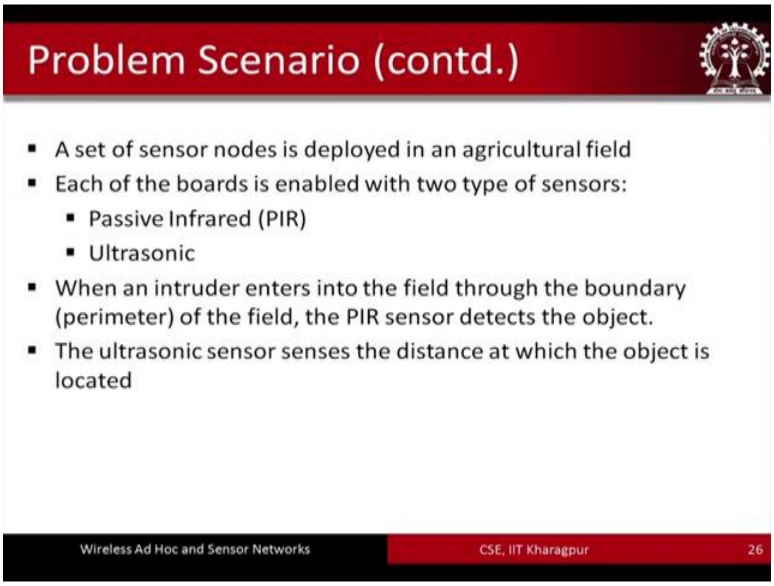

So, here what we have is a set of sensor nodes that are deployed in agricultural field. Each of these nodes they are enabled with 2 types of sensors one is the passive infrared sensor the PIR sensor and the other one is the ultrasonic sensor. So, when an intruder enters the field through the boundary of the field the PIR sensor detects the object the ultrasonic sensor then senses the distance at which the object is located.

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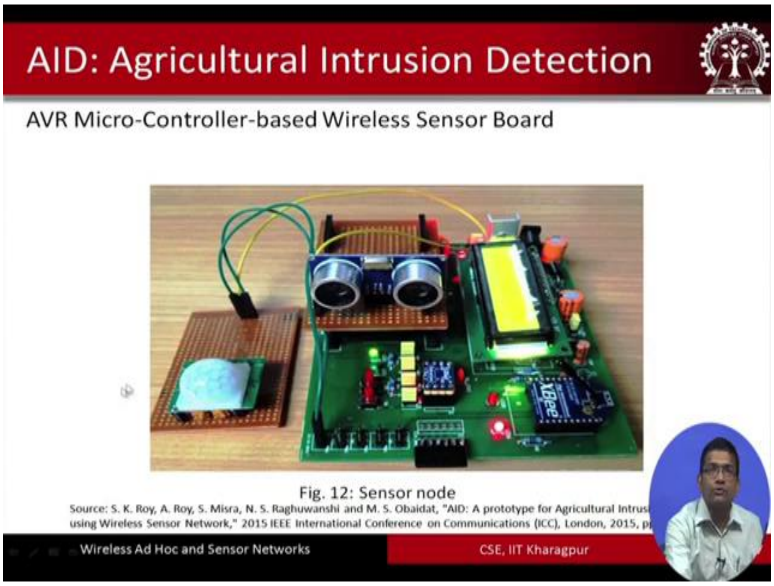

So, this is the overall you know this is how our system one node looks like. So, these are the 2 sensors that we have used. These are the proximity and this ultrasound sensor these are the 2 types of sensors that are used PIR and the ultrasound sensor.

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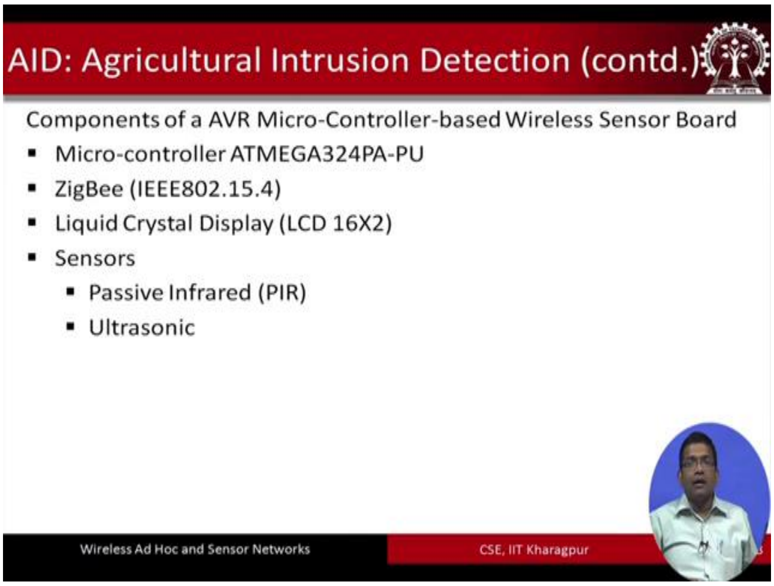

So as I said AVR based micro controller was used more specifically at ATMEGA324PA-PU ZigBee communication which is based on 802.15.4 standard or IEEE, LCD is there and the senses PIR and ultrasound ultrasonic sensors are used.

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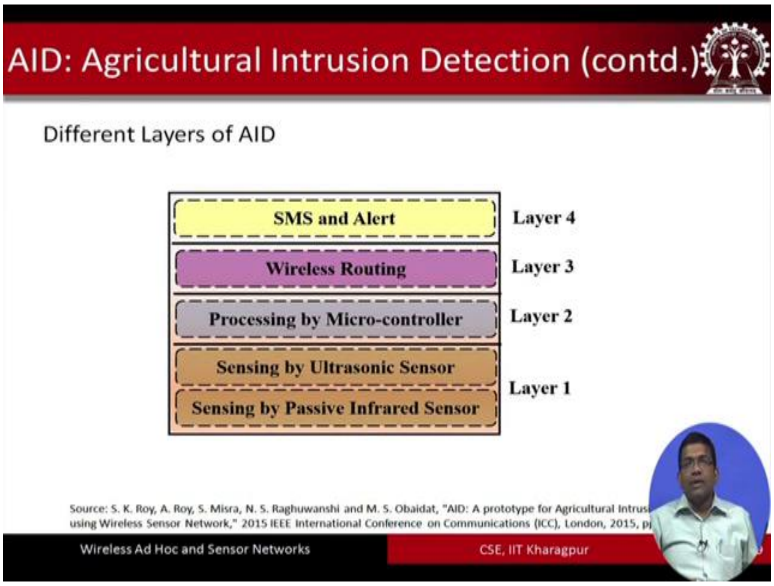

The different layers layer one basically is concerned about sensing by the ultrasonic sensor sense sensing by the PIR sensor and so on. Layer 2 is concerned about processing by the micro controller, layer 3 the wireless routing basically through a multi hop path the data that is sends has to be sent to the sink node. So, the PIR. So, so this particular layer the routing layer the layer 3 basically takes care of it and layer 4 is concerned about the applications that been sending the alert messages sending the SMS to the farmers mobile and so on.

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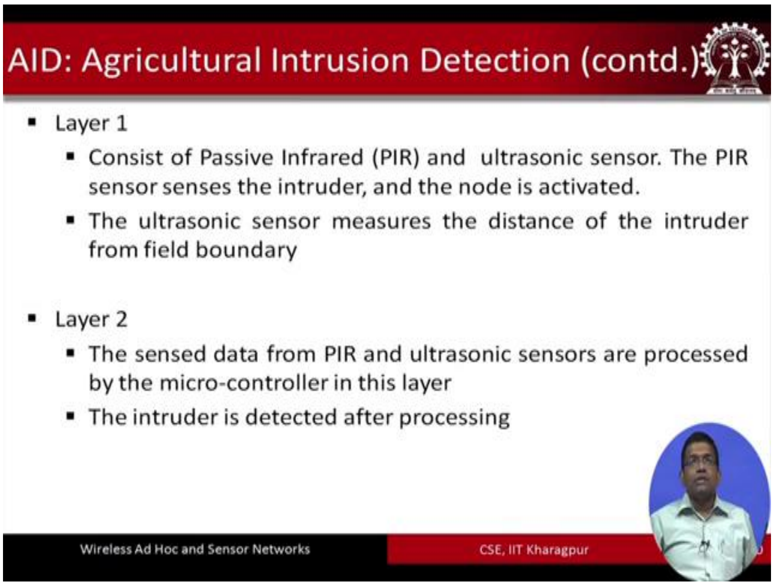

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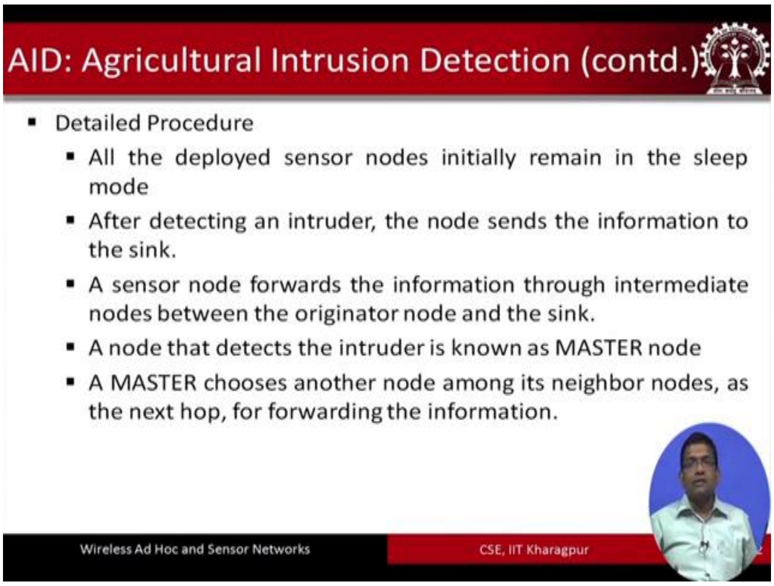

So, these are the different layer's layer one layer 2 layer 3 and layer 4. And so overall actually, what we have done is these sensor nodes they are all deployed initially and they remain in the sleep mode initially; that means, that the communication modules are in the sleep mode, means right sleep mode means that only they are able to sense, but they are not able to send the data out.

So, after detecting an intruder the sender the node since the information to the sink a sensor node forward the information through the intermediate nodes between the originating node and the sink. A node that detection intruder is called the master node, a master node chooses another node among it is neighbor nodes in next top node for forwarding the information.

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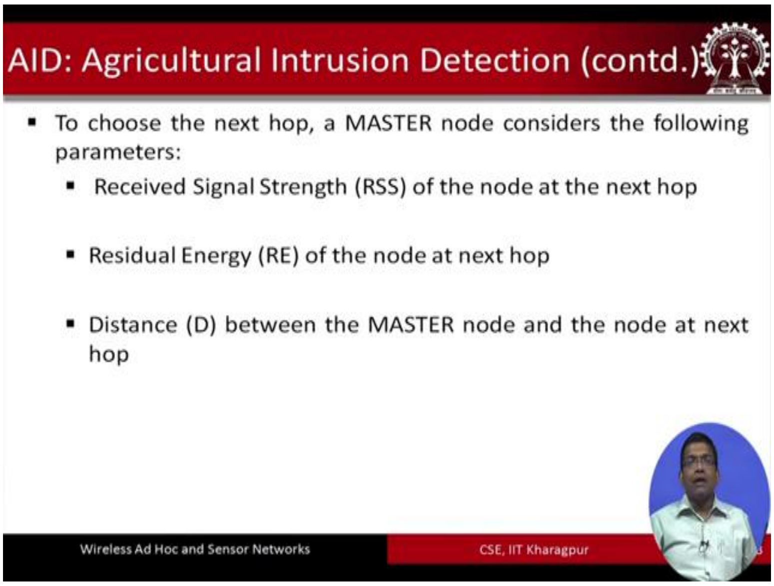

So, these are the different parameters that we have used and we have plotted. So, receive signals strength of the node then we have the residual energy of the node at the next hop and then we have the distance between the master node and the node and the next hop.

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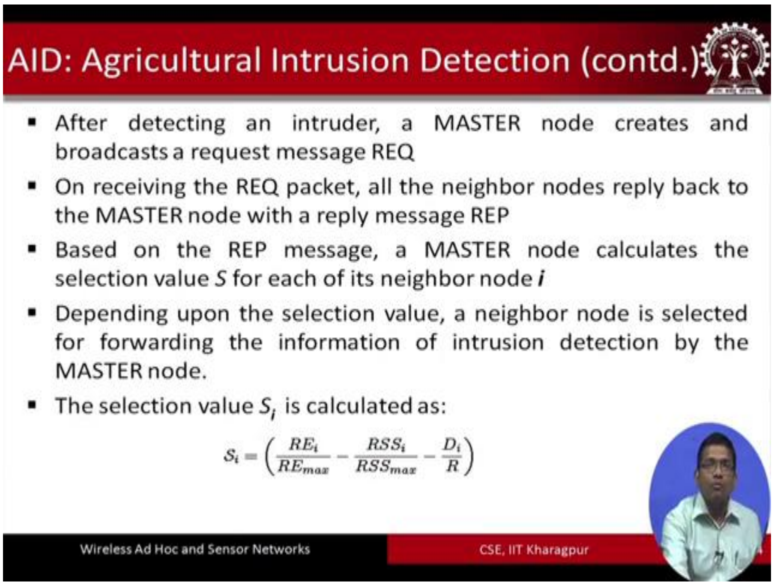

So, then we come up with a composite matric which is called the selection value based on these individual once we come up with a composite matric and this metric can be used to basically help identify whether there is any problem any intrusion that is taking place or not in the field.

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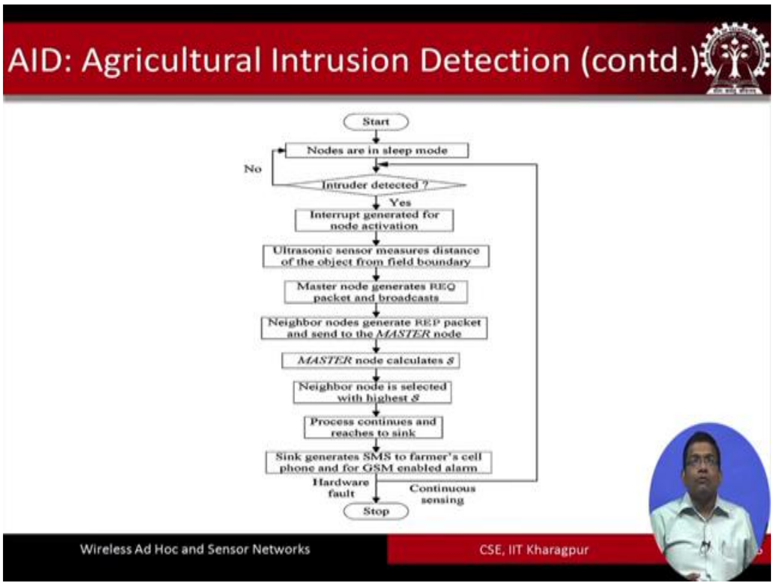

So, here is the overall flow chart in the in the in the interest of time and gravity, I am not going to go through these steps, but I think it is pretty much clear. So, if one follows this flow chart one would be able to understand quite easily that what are the different steps in the overall system.

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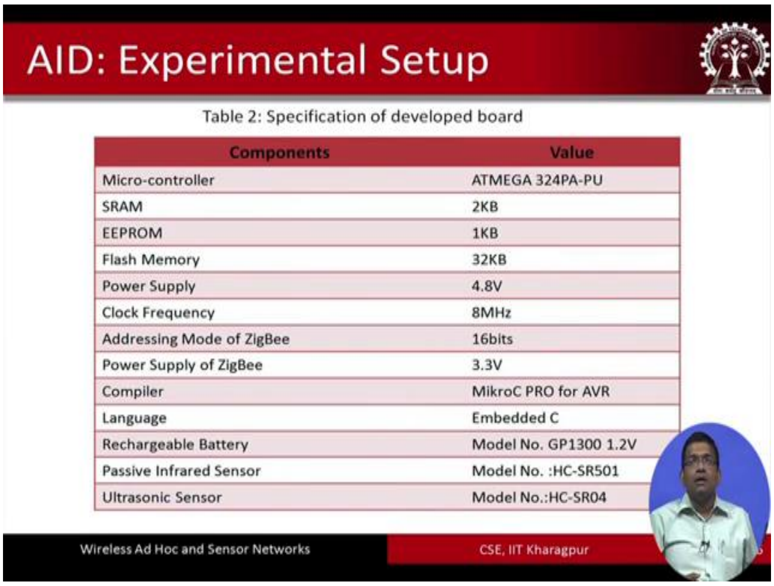

Here is the experimental setup. Micro controller ATMEGA324 was used SRAM is 2 kilobytes. So, as you can see that the SRAM is 2 kilobyte EEPROM is 1 kilobyte. So, as we can see that the memory is very less over here just a few kilobytes, and flash memory is high 32 kilobyte power supply 4.8 volts clock frequency 8 megahertz. ZigBee based communication is used then the batteries that are used are rechargeable the actual code with which this logic is written is based on embedded C language. And the ultrasonic sensor and the passive infrared sensors with their corresponding model numbers are mentioned in this table.

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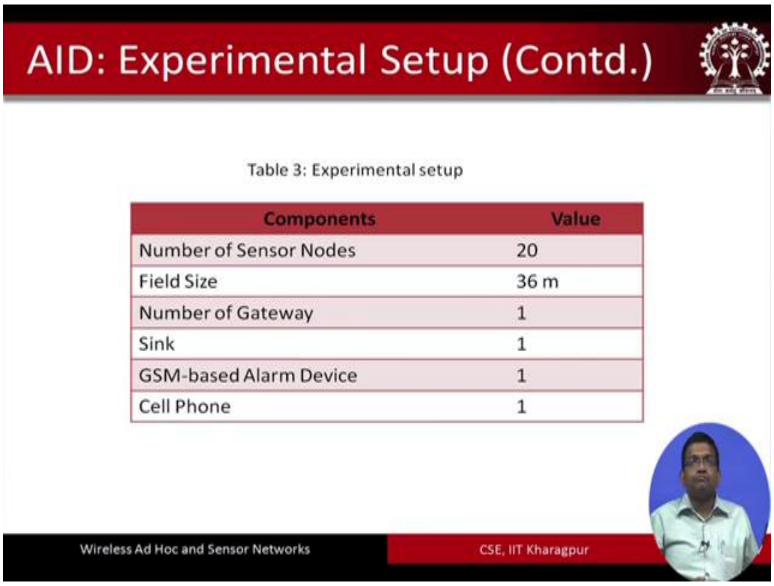

Some sensor nodes that were used are 20 numbers with the field size of 36 meters' perimeter this the overall 36 meter this the perimeter of the field and the number of gateways used was one sink node 1, GSM based alarm device that was used was one and the cell phone is only 1. So, this is the overall small scale setup that we have developed our self for particular purpose of intrusion detection in agriculture field.

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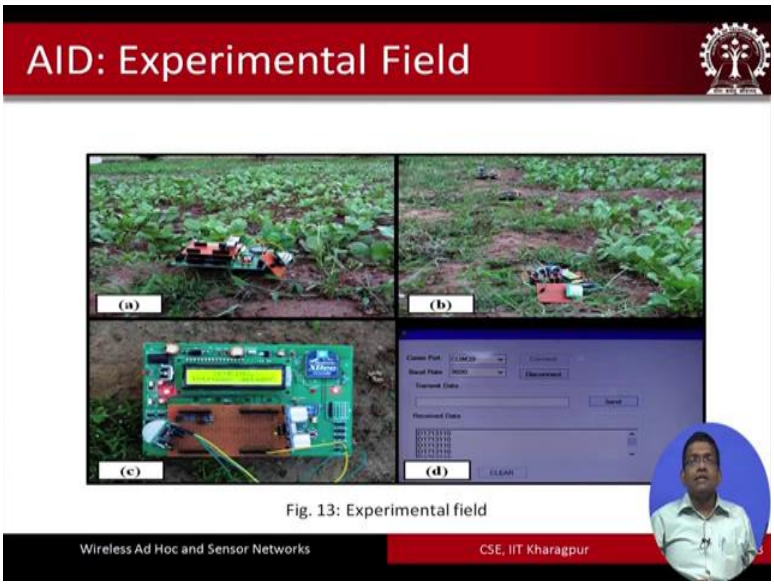

And this is this these pictures basically show you how the sensor network solution for this particular purpose of intrusion detection and monitoring named AID is deployed. So, this is this is in agricultural field, you know this is deployed around the periphery this is one node, but like this you know there are many other nodes around the periphery of these agricultural field.

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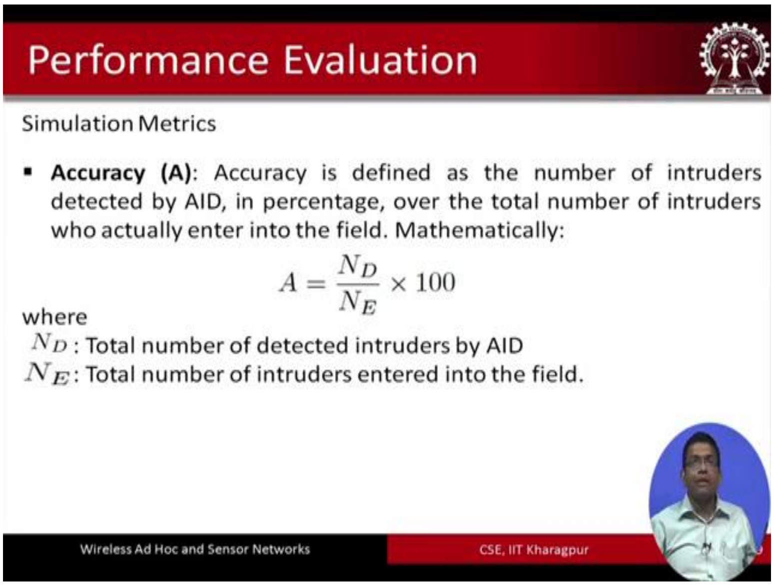

Different metrics were used accuracy which is defined as the number of intruders detected by the solution in percentage over the total number of intruders who actually entered the field this is one metric.

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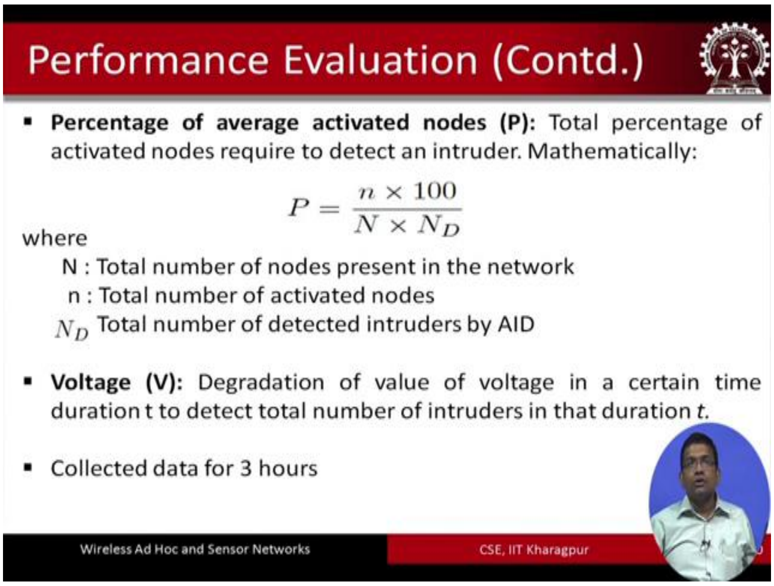

Percentage of average activated nodes which is the total percentage activated nodes required to detect an intruder voltage degradation of value of voltage in certain times time durations to detect the total number of intruders in that particular time duration, it is collected over a 3 hour period.

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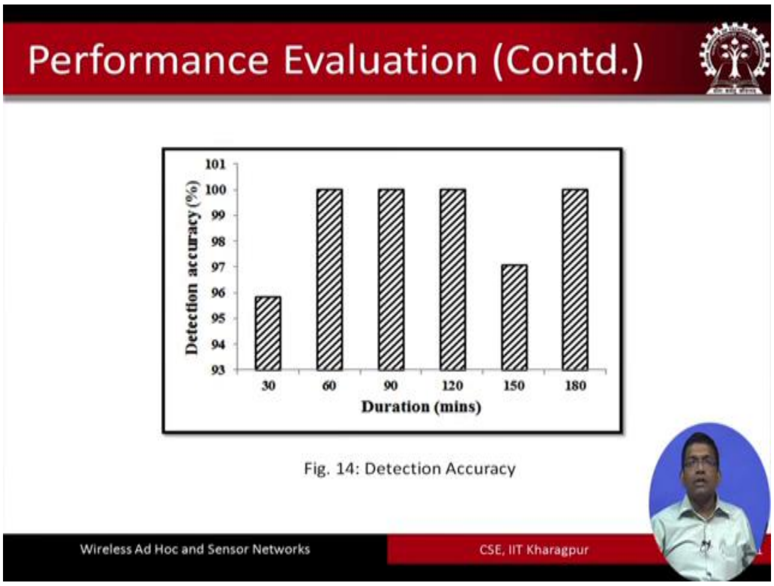

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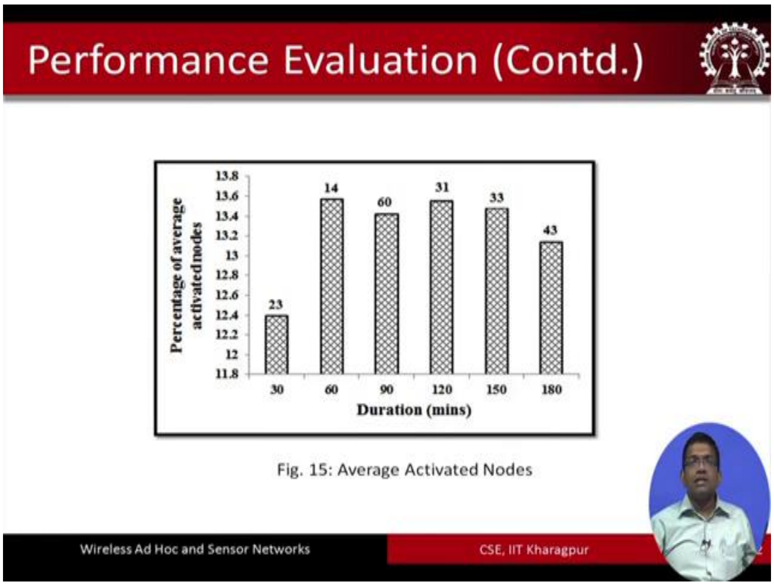

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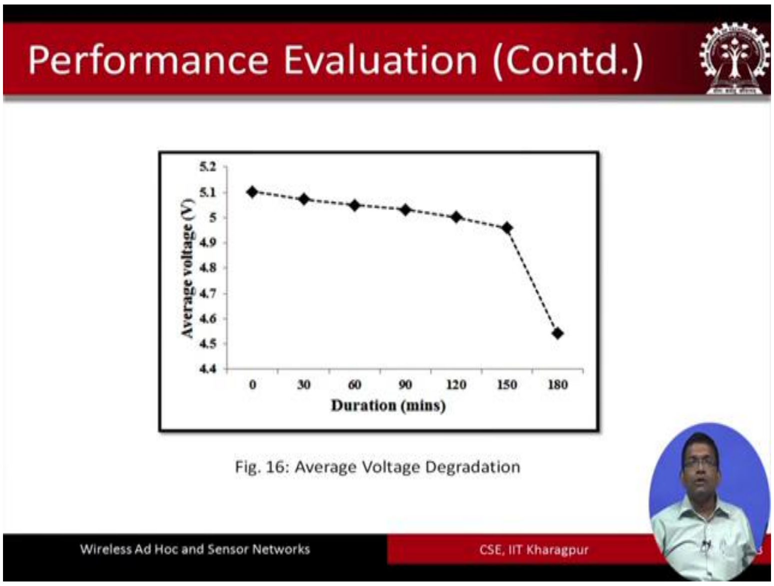

And these are plotted over here the detection accuracy is plotted with respect to time then the percentage or average activated nodes with respect to time is plotted. And also the average voltage voltage with respect to time is plotted.

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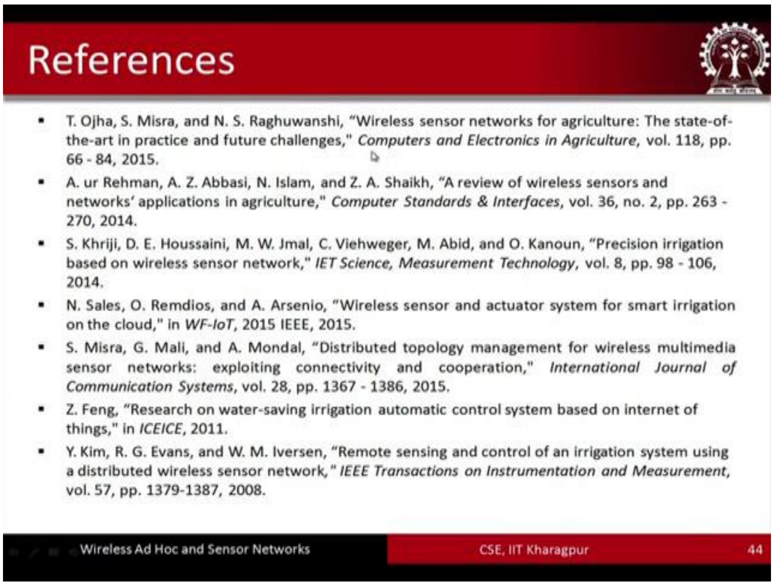

So, these are the different observations that we have obtained the different results that we have obtained by deploying aid in the agricultural field for protecting it from unwanted intrusions. So, basically the solution is useful for preventing loss of agricultural produce from the field either by humans or by animals and so on.

So, finally, these are some of the references. So, you know if you are particularly interested for sensor network applications in agriculture. We have a very good paper you know very popular paper wireless internet was for agriculture, which was published in the (Refer Time: 25:45) computers and electronics in agricultural channel. And this basically gives you a good overview or the good survey of how different people have come up with different applications of wireless sensor networks for agriculture.

So, like this not only agriculture for healthcare for different other applications as well since the networks could be used. And I would encourage you to go through different other applications as well more air sensor networks can be used different other applications, I have myself in all in our in my lab developed sensor network applications for use, in healthcare we have developed our own nodes which can be used for healthcare monitoring of different patients and so on.

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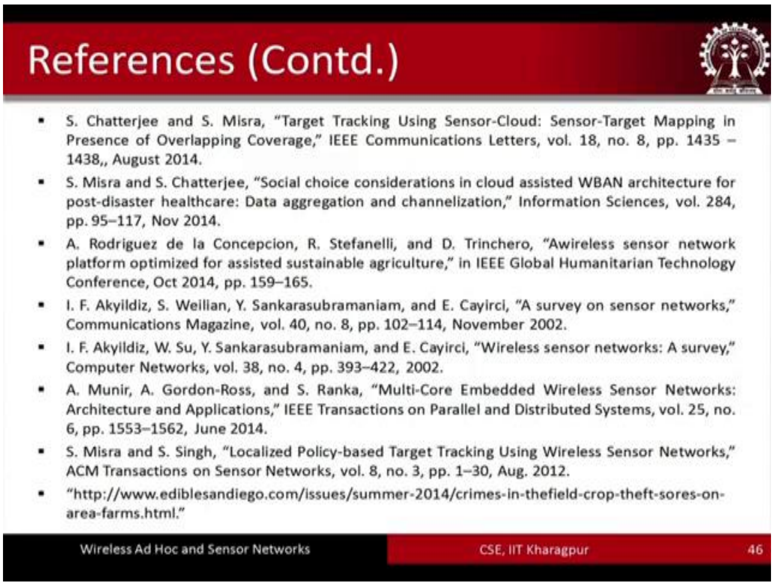

So, these are the few other differences. So, there are a number of references which you could go through and very interesting references some of them are basically authored by me.

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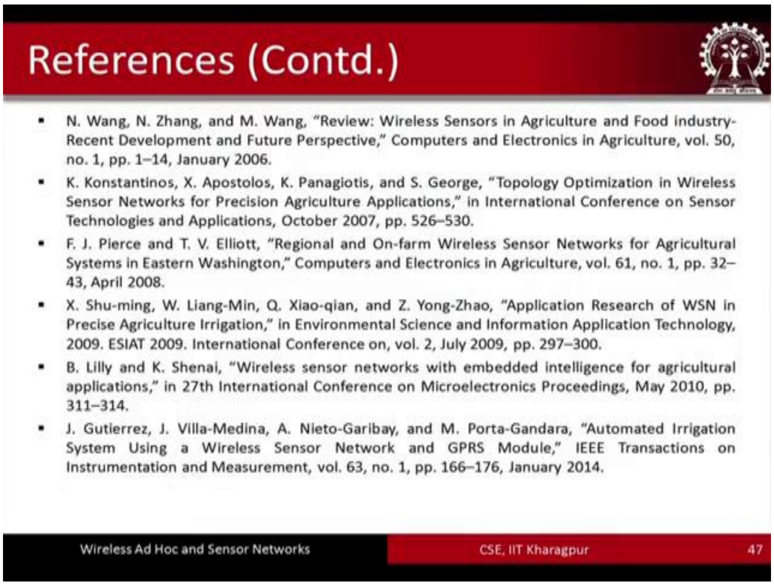

So, with this we come to the end of this lecture. And not only this lecture the end of this course you know all the modules that we have delivered for you. These have been you know we have been integrated in such a way. So, that you can understand the general concepts of mobile Ad-Hoc network sensor networks etcetera and finally, apply that knowledge in order to build an actual sensor network solution.

So, I hope that the course becomes very useful for you in the both for industry, use as well as for academic. So, those of you who are in the industry or those of you who are in the academics you know. So, I hope that this course will be of use to you for your own purposes.

Thank you.