Wireless Ad Hoc and Sensor Networks
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Lecture – 39
Hardware Design of Sensor Node

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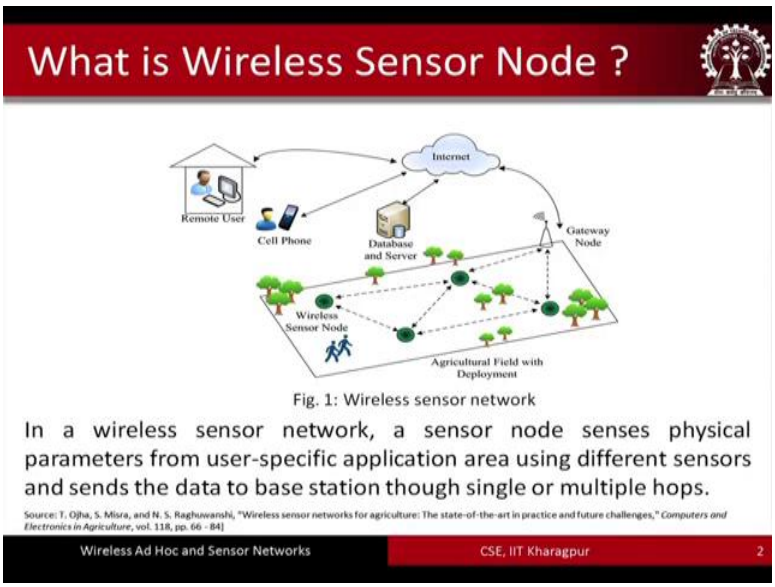

Hardware design of a sensor node; we have seen that a wireless sensor network consists of large number of sensor nodes. And then it is all about establishing wireless communication between these sensor nodes. So, that the data that is sensed by each of these sensor nodes could be transmitted through a multi hop path to the intended destination node the base station and so on. So, the main problem is how do you design a wireless sensor node. So, it can be designed in 2 different ways.

In fact, many different ways if we are talking about a regular wireless sensor node embedded system based wireless sensor node, this is what we are going to cover, now, but name spaced wireless sensor nodes could also be designed additionally, nano technology name spaced nano embedded name spaced technology could also be designed. So, mens at the micro electromechanical system and names is nano electromechanical system. So, both micro scale and nanoscale devices could also be designed, but we are not talking about the micro scale and a nanoscale devices, now we are talking about designing wireless sensor nodes at the normal skill which are little

bigger in size, but you know this is the first thing that one could do more easily without in the absence of existing technologies for mints fabrication or names fabrication.

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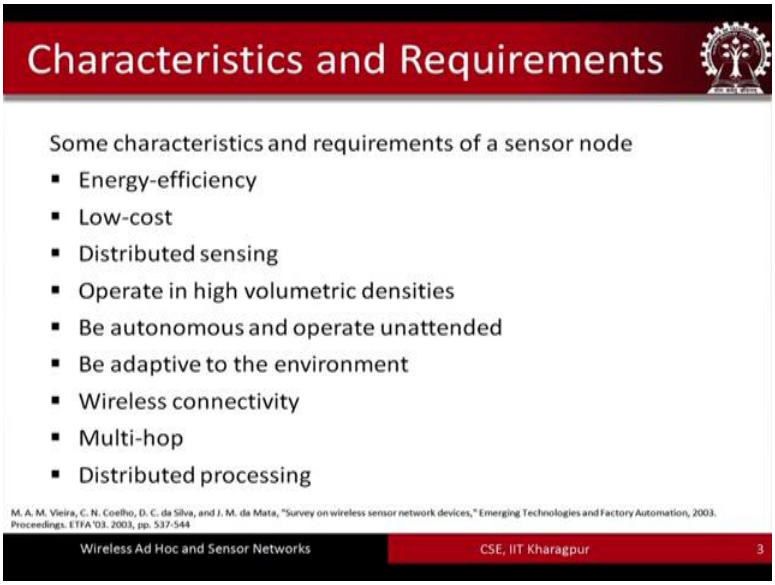

So, there are different characteristics and requirements of wireless sensor nodes they have to be energy efficient low cost distributed sensing should be supported, you know should be able to operate in high volumetric densities the autonomous and operate unattended, be adapted to the environment should support wireless connectivity multi hop communication and distributed processing like this. There are many requirements and characteristics of sensor node.

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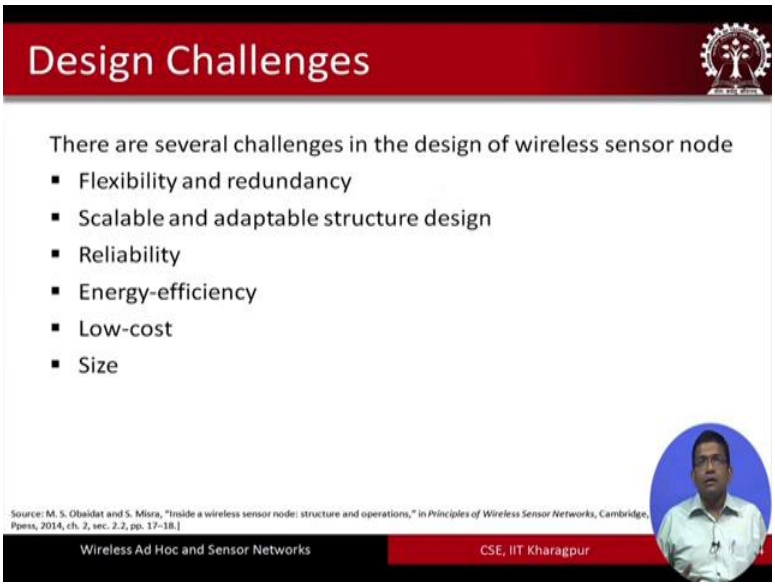

So, the main design challenge is to design how to design the sensor node in order to be inner to make it flexible and support redundancy redundant redundancy is a feature of sensor networks. So, how do you design a sensor node which would be able to take care of these attributes. Scalability and be able to adapt to the structural design. Be reliable the energy efficient low cost and the as much small in size as possible.

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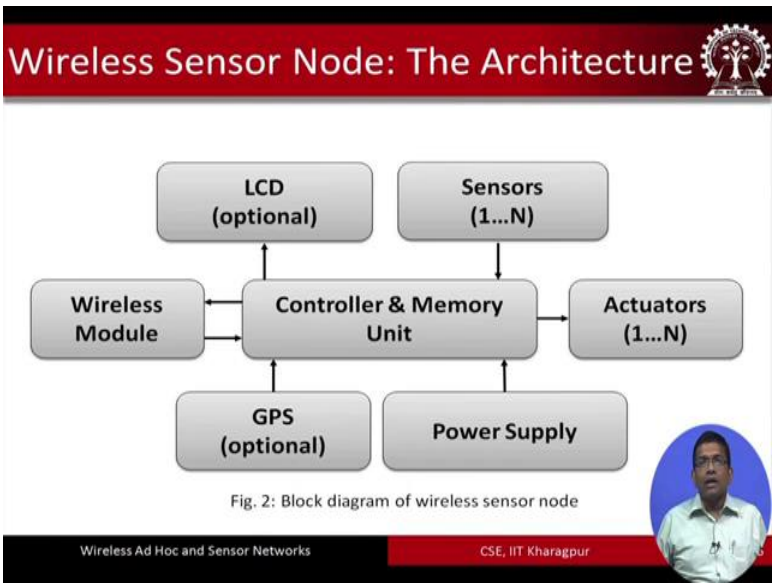

So, here is the overall architecture of a wireless sensor node. So, little later on during this lecture I am going to present to you a wireless sensor node that we have developed

ourselves in our lab at IIT Kharagpur. So, basically a wireless sensor node has couple of different units one at the core of a wireless sensor node is the controller and memory unit. So, the controller basically all the you know computations that are there. So, all the logics are implemented in the controller and also there is a memory unit then what is required is to communicate. So, for communication purpose you need a communication module and we are talking about wireless communication. So, it is a wireless module third is the sensors themselves.

You know whatever sensing has to be done the sensors has to be have to be attached to these sensor nodes that are developed. And then you have some kind of an energy unit which is going to power these nodes. So, we are talking about battery power sensor nodes. So, that we support and so on. Then you have the actuators you know. So, what after based on sensing you know, the actuation may have to be done.

So, the actuators have to be attached GPS is optional having an LCD screen maybe for debugging and so on. Is optional or displaying the messages these are optional things even the actuator is also an optional item right. So, based on sensing you know if actuation has to be done if the requirements of the application is such that actuation may not may need to be done then actuators may be required. So, this is the overall architecture of a sensor node.

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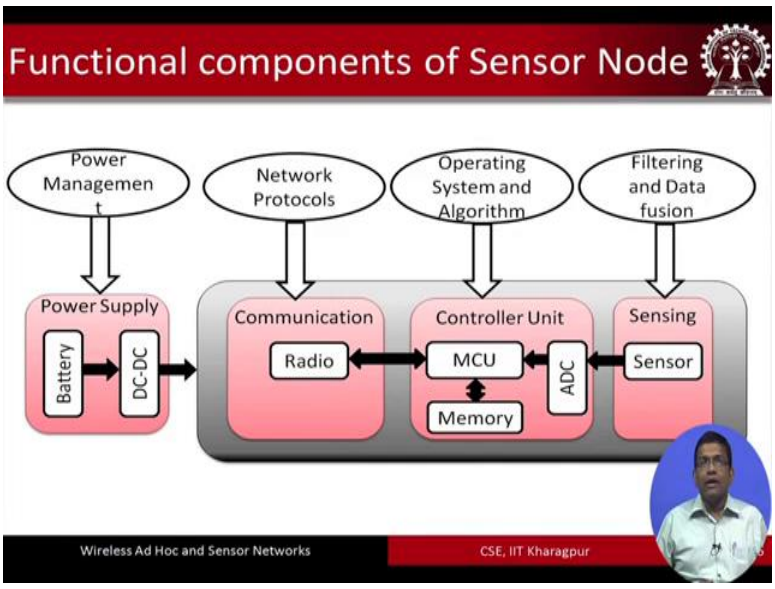

Now, if we talk about a wireless sensor node these are the different units. So, as we can see from here. So, first we have the power unit power unit for power management. Then we have the communication unit for communication purpose support of different radio network protocols. Then we have the controller unit like this which basically hosts the operating system and also executes the different algorithms.

And then for data handling and filtering fusion of data etcetera then you have the sensing unit like this. So, these are the main component functional components of a sensor node.

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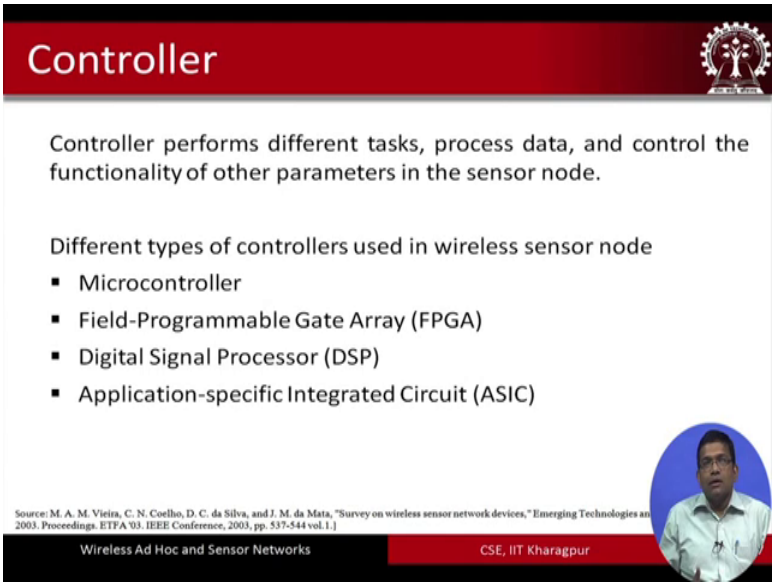

So, when we talk about the controller, controller is the main one of the core units of a sensor node. The controller basically is tasks to perform different processes execute different algorithms for control communication etcetera to know all different types of algorithms different logics you know and so on and so forth. So, all these things all kinds of computation are done and the controller. And there are different types of controllers that are used in a wireless sensor node. Microcontrollers are used then FPGA could be used to DSP based controllers could be used. ASIC based controllers could be used like this you know there are different types of controllers that could be used in a wireless sensor node.

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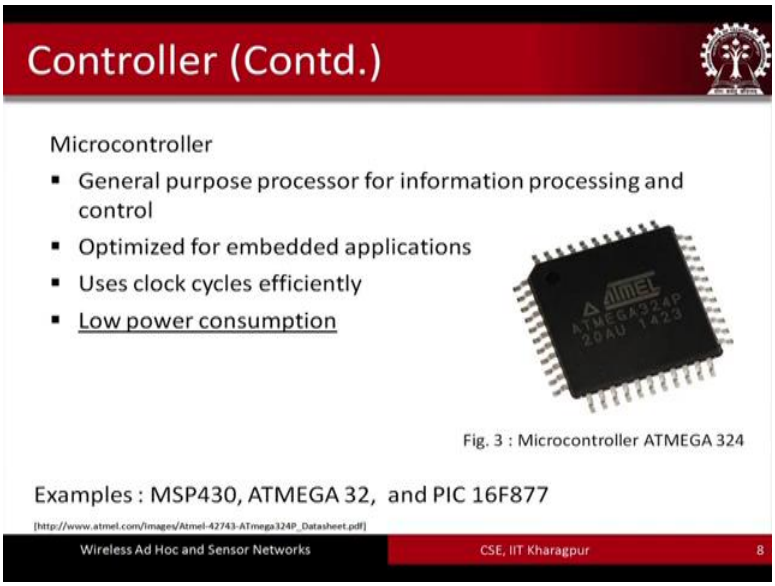

So, here where the picture that we see is that of a microcontroller called at mega 3 to 4 and this is a microcontroller which basically consumes very low power and uses the clock cycles very efficiently, and this is very attractive for use in embedded applications in general and ah.

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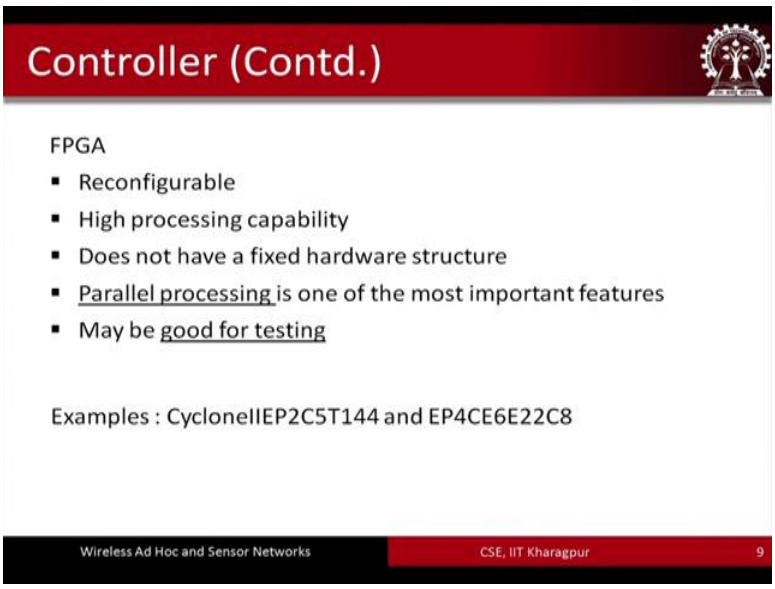

And sensor nodes in particular FPGA based controllers are also attractive particularly for parallel processing applications then.

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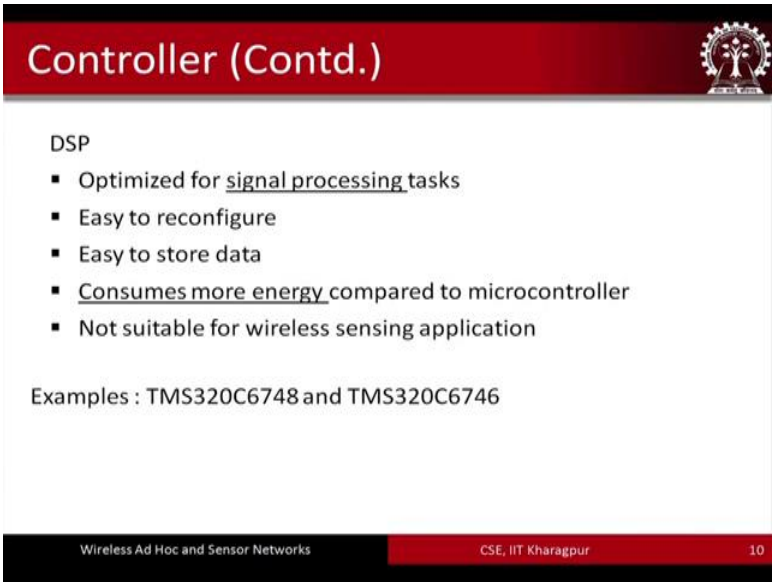

DSP based controllers are also there these are particularly attractive where signal processing tasks are quite heavy and; however, you know DSP based controllers they basically consume more energy compared to the microcontrollers.

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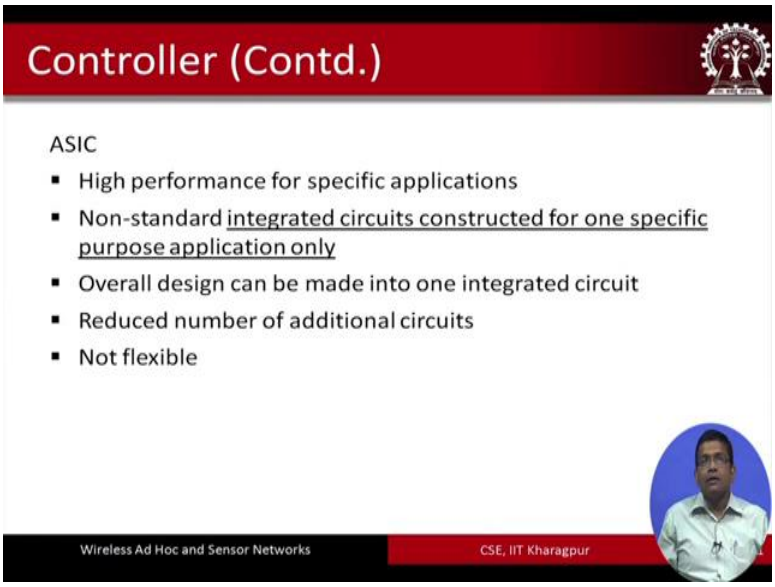

Basic base controllers are quite popular when a specific application is there which is targeted and for that actually asking this controller are more popular.

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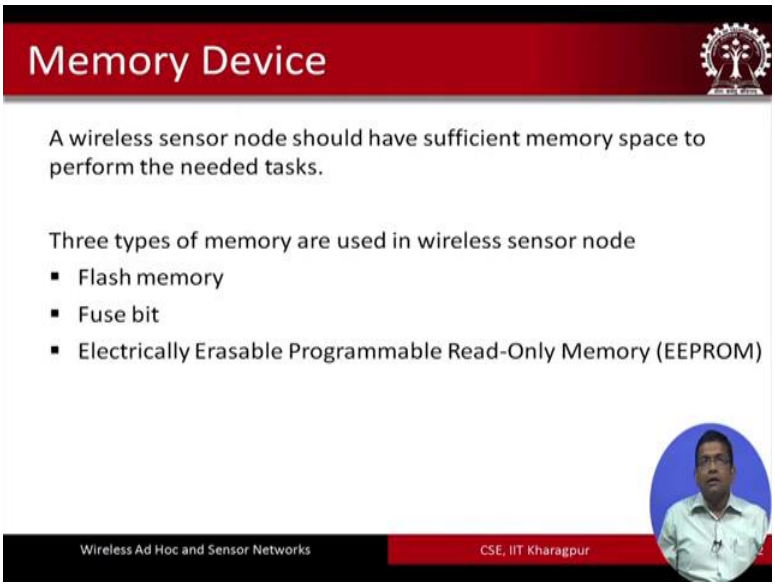

So, this is about the controllers then we have the memory device, the memory device which basically will store the data right. So these data have to be stored in the memory space. So, this device basically store state and there are different types of memory devices that can be used flash memory could be used fused bit memory could be used EEPROM based memories could be used.

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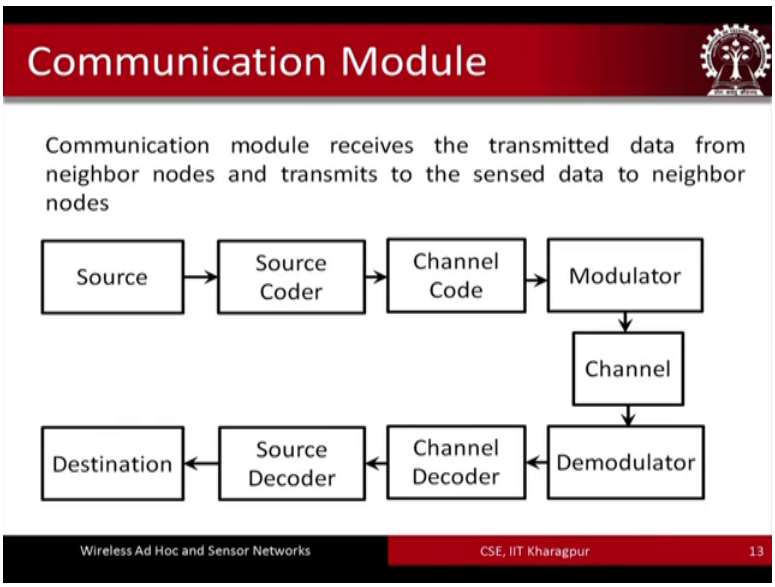

So, that is the memory unit and then you have the communication unit. So, for communication basically the data is received from the source node and then once it is

received you know it goes through the source coder, then the channel coding is performed modulation is performed goes to the channel you know at the destination and it is demodulated and then general decoding is performed source decoding is performed and the data is finally, delivered to the destination module destination node.

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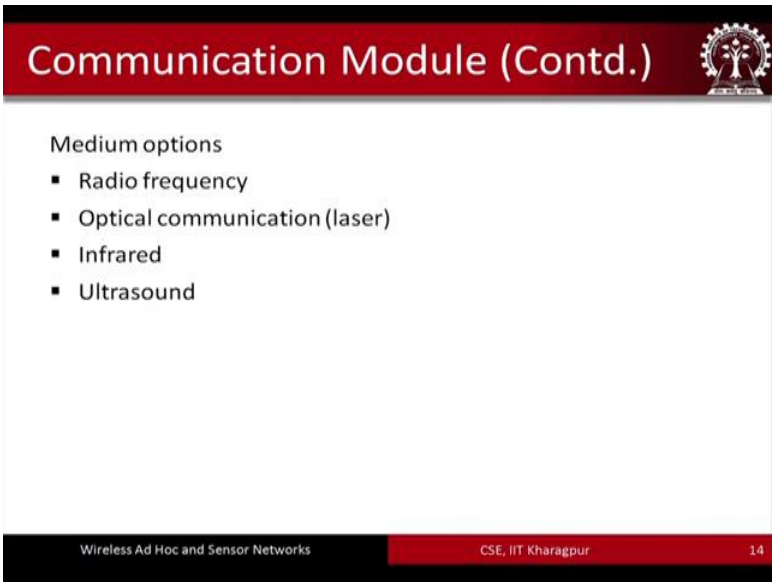

So, there are different mediums that can be used radio frequency you know RF medium can be used for communication. Optical communication could also be used then infrared would be used ultrasound could be all of these are different types of you know wireless medium that could be used for communication purpose between the different nodes you know wireless sensor network.

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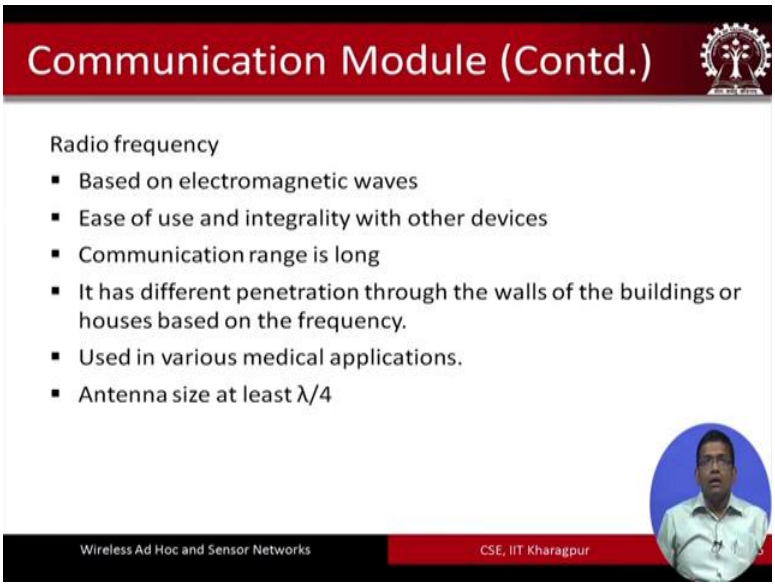

So, I am not going to go through this in detail, but this is there for you to go through if you do not have basic understanding about the different features of this media. So, first is the radio frequency medium video frequency based communication, where you know different electromagnetic waves are sent from the source to the intended recipient. And so there is some kind of antenna that has to be designed. So, these antennas are going to these antennas are going to send the RF signals from the source. And these RF signals are going to be received at the recipient where they have to be decoded and further demodulated etcetera in order to get meaning out of the information that is send.

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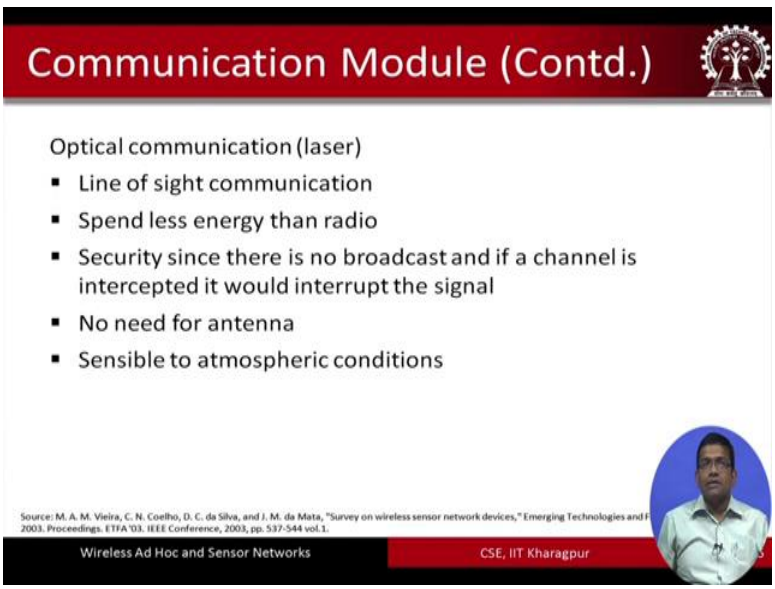

Optimal communication laser based line of sight communication it is basically more popular for line of sight based scenarios. And these basically spend less energy than radio communication, but at the same time as we have seen that you know wherever there is line of sight you know optical communication could be used, but not always another advantage is that there is no necessity for use of separate antennas for you know optical based communication.

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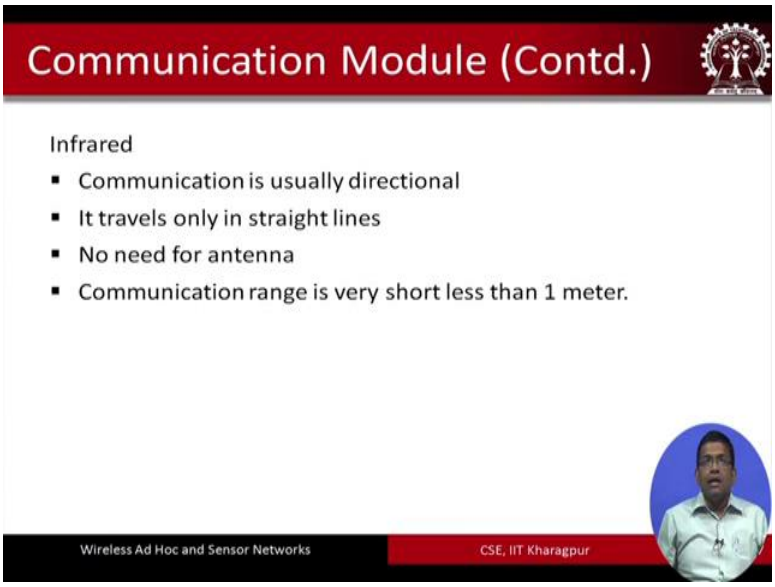

Infinity it is also very popular you know it is a communication that is directional in nature; that means, that it is travels in straight lines there is no need for antenna and the communication range is very short very short means less than a meter or so.

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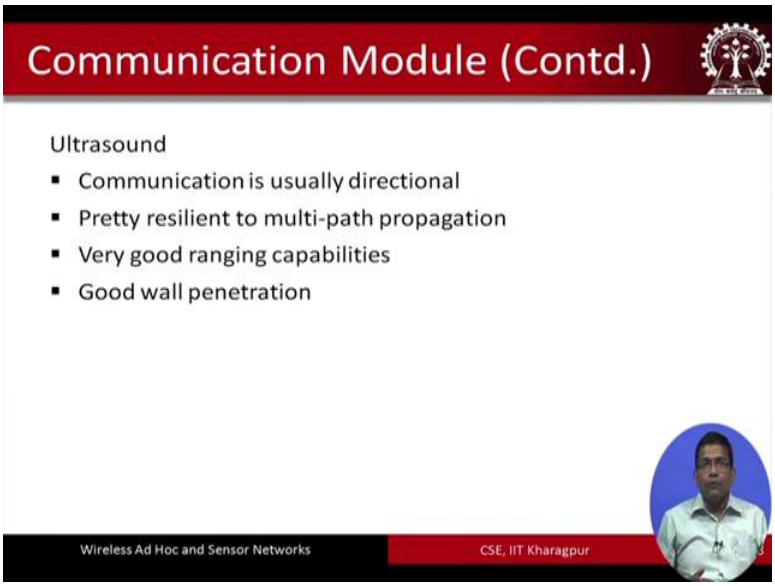

Ultrasound is also quite popular, you know particularly when you have medium in between the source and the destination; that means, that you know maybe a concrete wall or something like that ultrasound could be used because ultrasound.

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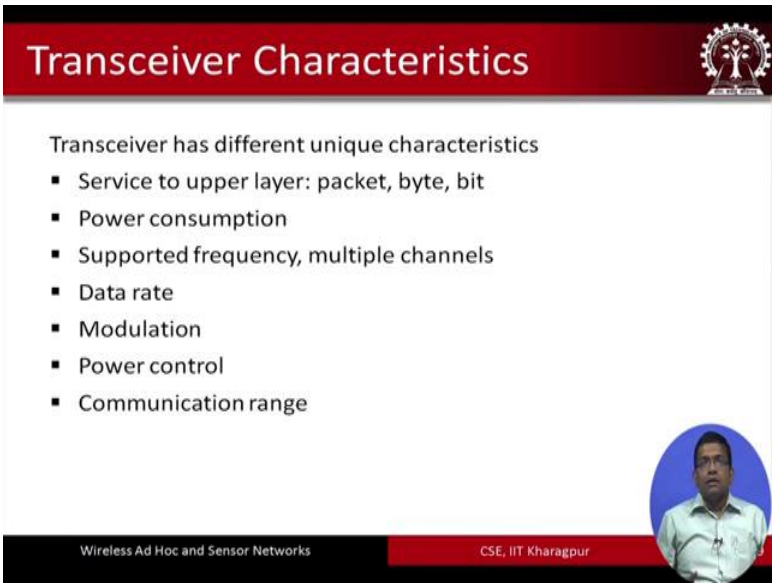

Basically penetrates the concrete walls as well the transceiver is the unit which takes care of the communication you know transmission and reception both. So the transceiver basically takes care of offering services to the upper layers by in the form of sending packets bytes bit is etcetera. So, the transceiver basically has different other

characteristics as well. You know lowering the power consumption because you normally charger transceivers basically consume lot of power they have quite power hungry. So, a good transceiver has to be designed which can consume less power for their use in sensor networks.

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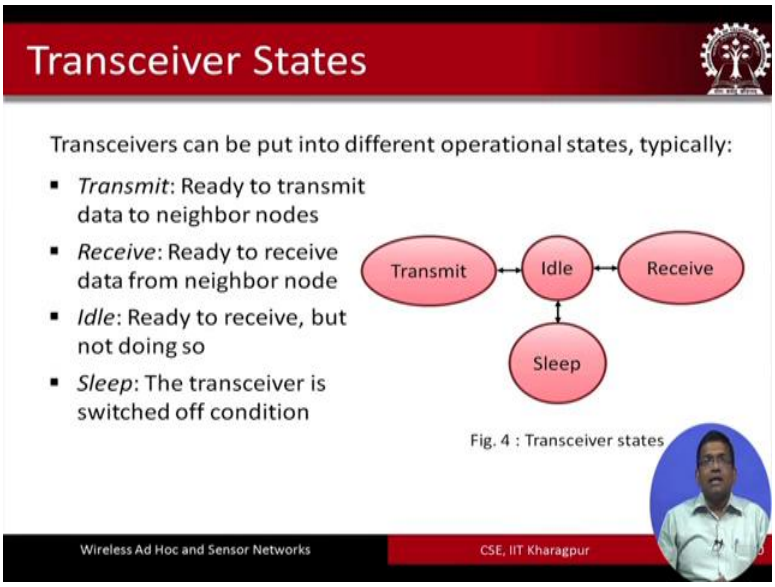

A transceiver basically can operate in these tips. We can see the 4 states in the slide in front of us. So, it can be in the idle state, it can be in the transmit state, receive state or the sleep state. So, transmit state is basically ready to transmit data to the neighbor nodes whenever the node is basically ready to transmit data to the neighbor nodes it is in the transmit state. Receive state in the node is ready to receive data from the neighbor nodes if the node is in the idle state it is ready to receive, but is actually not receiving the packets, actually not receiving the packets from other nodes. And sleep state is basically when the transceiver is switched off.

So, it is the sleep state the transceiver is switched off, but at the same time sensing is going on. So, sensing is going on if you know if this particular transceiver which is in the sleep state is attached to a particular sensor node sensing is going on, but the transceiver is in the sleep state.

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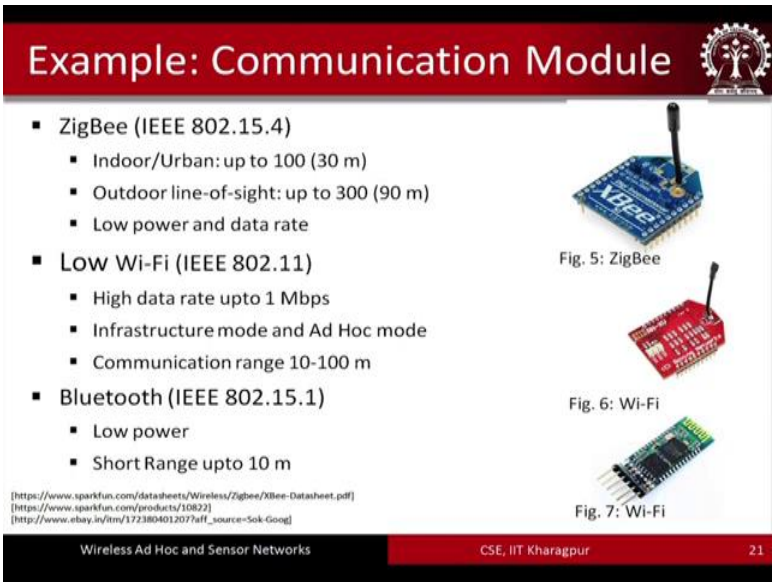

So, these are some examples of different communication modules that could be used in a sensor node. A ZigBee based communication could be used which is quite popular. In fact, ZigBee is popular for use in sensor nodes ah

So, ZigBee is based on the standard I triple E 802.15.4, which is basically good for indoor environments particularly where you know where there is requirement of low range low data rate and low power consumption and sensor network requirements sensor network applications basically have such kind of requirements the second is Wi-Fi. So, you know Wi-Fi offers longer range higher data rate, but at the same time consumes more power. And Bluetooth is good for you know forming wireless personal area networks you know and the transmission range is up to 10 meters and Bluetooth also consumes low power. And Bluetooth is based on the standard I triple E 802.15.1.

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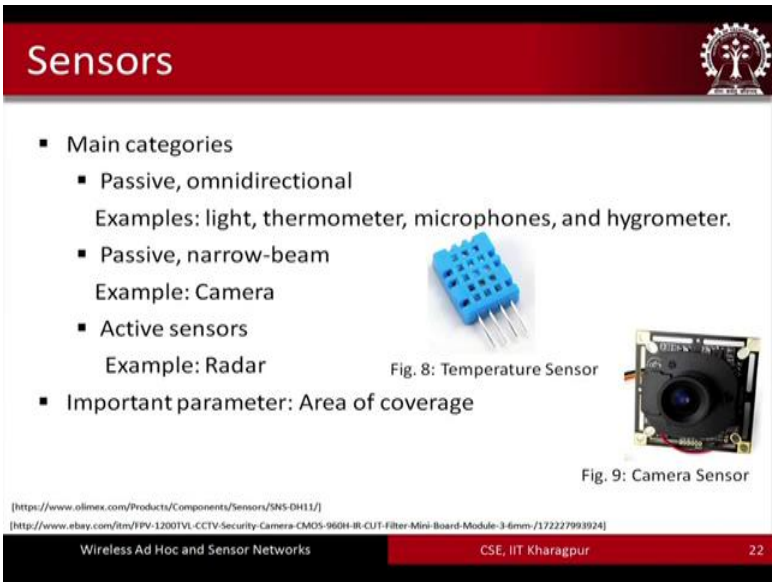

Different types of those were the communication you need communication modules different types of communication devices that would be used in the standards and so on. Now let us in a sensor node we have the sensors as well. So, the send different types of sensors based on the application could be used. You know sensors scalar in nature like vibration you know which can be measuring the vibration the temperature pressure and so on. Or sensors which are vector based. So, camera sensors are examples of vector based sensors. So, scalar sensors temperature vibration you know atmospheric pressure etcetera. And vector based they are basically camera sensors are an example of that. So, whatever be the type of sensor it is important to design sensors which can give maximum sensing range as much as possible typically you know the sensing range is quite low only a few meters and so on.

But what is important is to design the sensors and deploy them in such a way that the area or that is going to be monitored is going to be covered properly.

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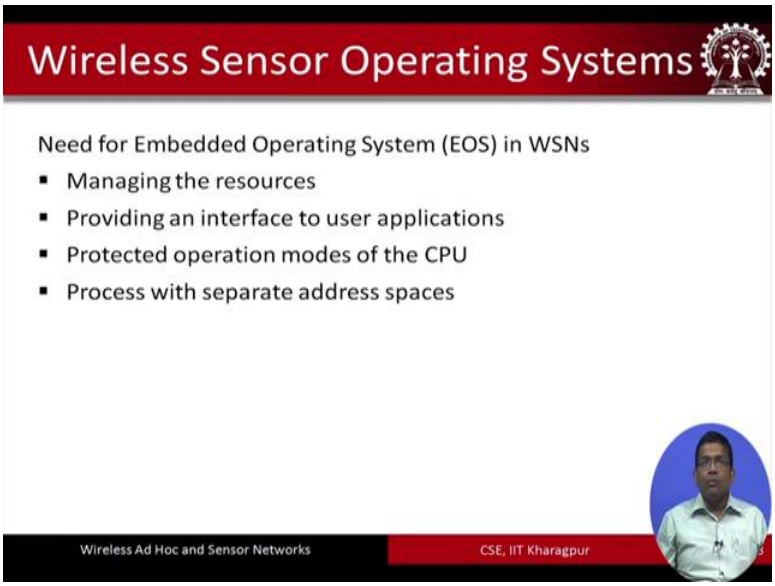

So, there are operating systems that are also used in the sensor nodes the embedded operating systems. And this is like the normal operating systems, but these operating systems the EOS the embedded operating systems are used for embedded devices.

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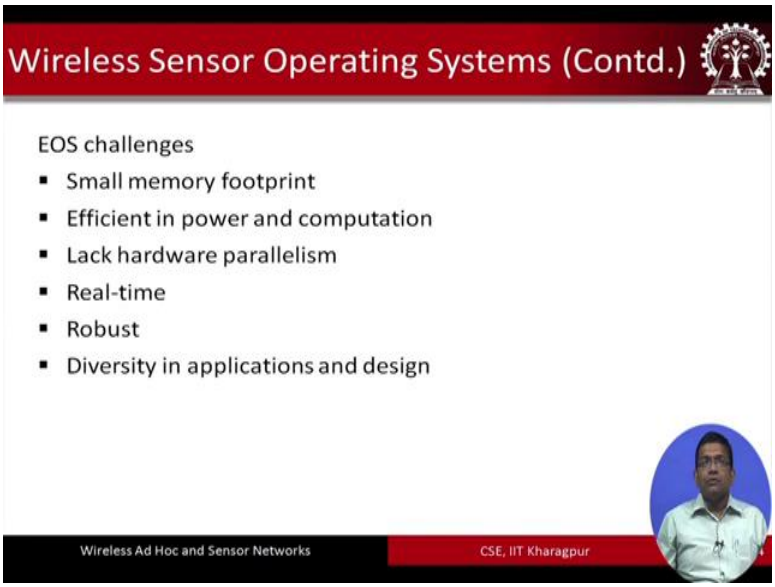

Like wireless sensor nodes and these embedded wireless sensor devices they have small memory footprint they are efficient in power as well as computation power consumption. And computation there you know basically support typical embedded applications are real time in nature. So, they support to real time applications they are robust and they

support divers different types of applications with and become in in different types of designs.

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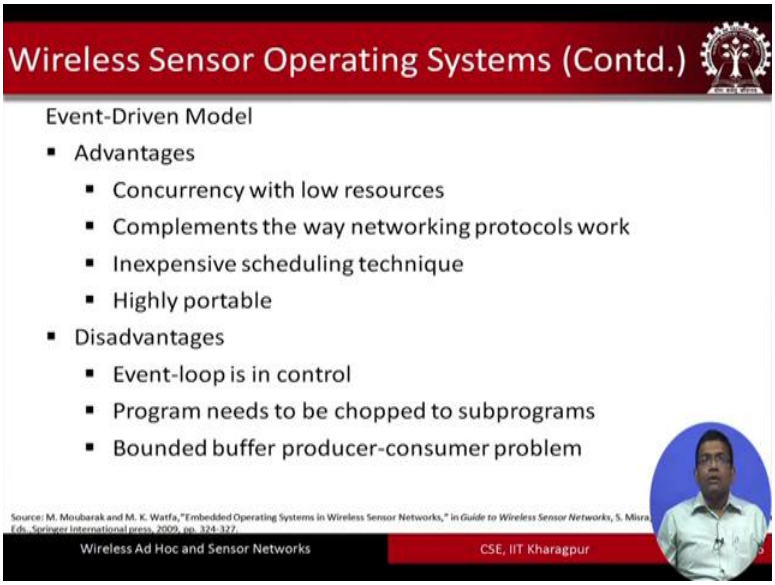

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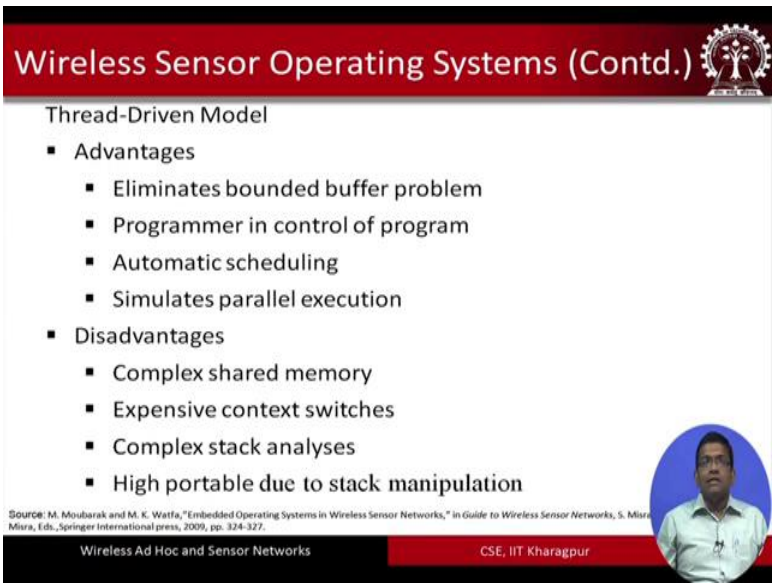

So, these embedded operating systems could be based on event driven model thread given model, and each of these they have their own advantages and disadvantages which I am not going through.

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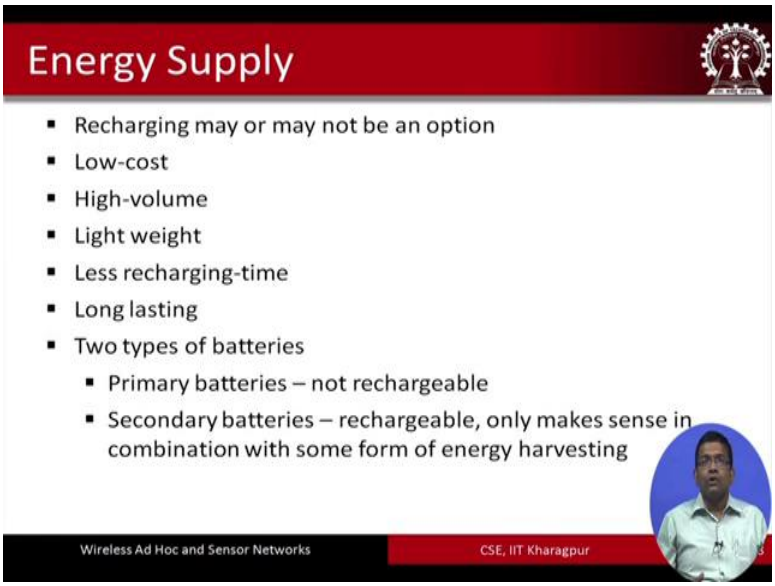

But it is there for you to go through and have a feel of it. So, everything fine. So, we have a communication unit we have a sensing unit and so on., But then you know something has to power these nodes. So, we had computation done using the controller communication using the transceiver unit. And then then we have the memory unit which stores the data temporarily and so on. So, but overall this node has to be powered with some kind of batteries. Typically, so these batteries you know it is good if these batteries are rechargeable batteries; however, it is not necessary that the batteries have to be rechargeable.

So, basically you know the primary batteries are not rechargeable batteries, but secondary batteries are rechargeable. And particularly you know if there is a requirement of an application which is a requirement of energy harvesting. So, maybe from solar or maybe from wind or something like that then these secondary batteries are required because they are rechargeable. And once the energy is repeated energy can be harvested from the environment and energy can be you know restored in those batteries. So, energy supplies you know it has to be low cost high volume lightweight and with less recharging time and long lasting for making them useful for use in sensor network applications.

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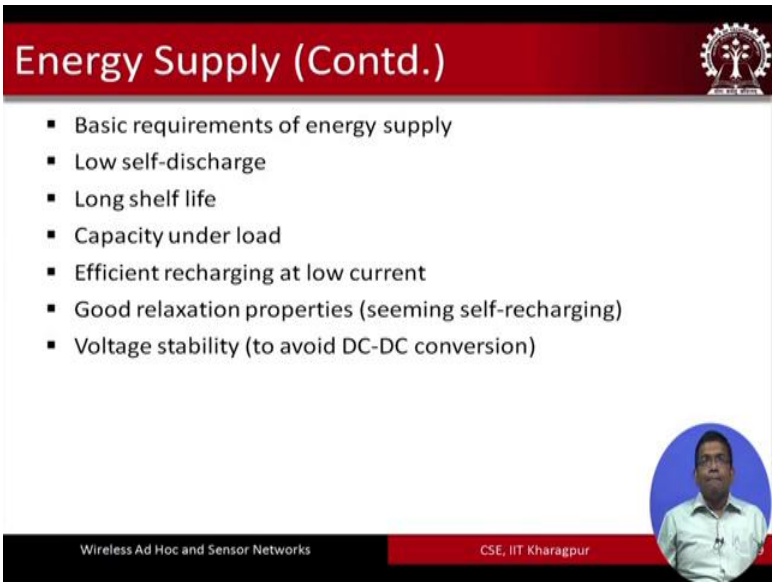

So, these sensor energy supplies sensor node energy supplies they should also have low self discharge rate. Because self discharge is something that we are already familiar with; so basically you know when you have a battery which is full recharged you leave then nothing it is going to discharge out of it is battery on it is own. So, these batteries that are going to be used for powering the sensor nodes. This should have low self discharge rate this should have long shelf life. And you know they should support different types of voltages different voltage requirements.

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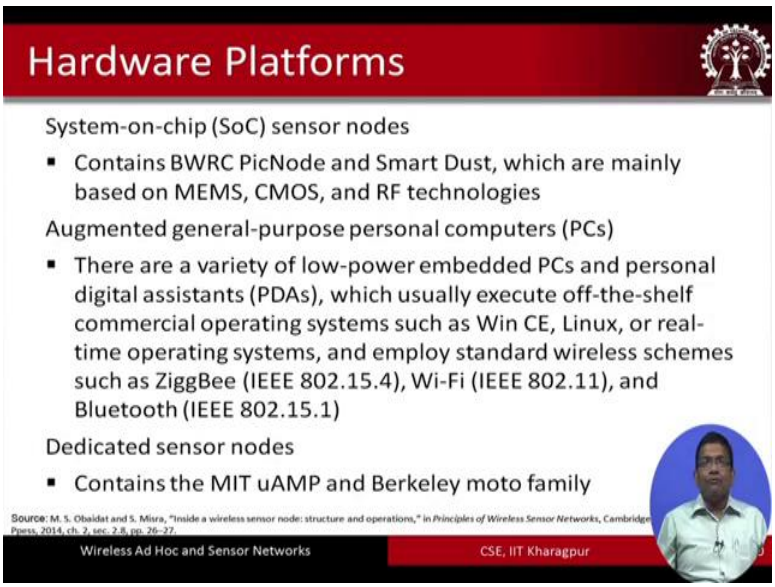

Different types of hardware platforms are possible for use you know typically system on chip SOC sensor nodes are possible augmented general purpose personal computers PCs are possible dedicated sensor nodes could also be developed. And the corresponding examples belonging to each of these hardware platform categories are medicine over here just in the interest of time.

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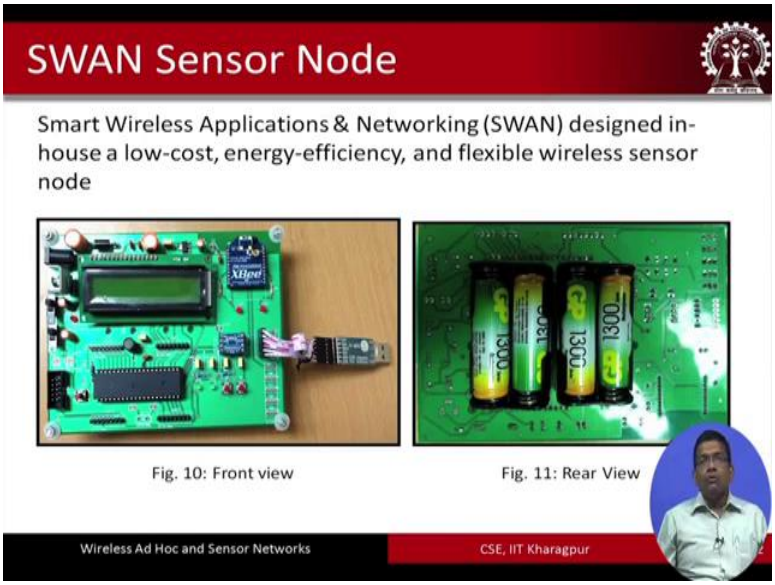

I am not going to mention each of them individually. So, these are the different types of sensor nodes as I said now I will give you an example of a sensor node that we have developed in our lab in our lab the swell lab at IIT Kharagpur. So, the swell lab basically has designed this sensor node. So, let me just point out using the mouse the different parts of sensor nodes, this is the sensor node and we have already seen that a sent sensor node needs to do certain computations right. So, these computations can be done with the help of this controller. This controller can help in performing different computations. Then we have seen that some kind of transceiver units used. So, by the way this controller that we have used is the at mega controller. And we have a communication unit for sending the sense data, and over here it is shown that we are using the ZigBee communication unit, but it does not have to be ZigBee you know one could use other types of communication units based or maybe Wi-Fi or you know even GSM based communication and so on. So, it depends on the application the nature of the requirements and so on. What type of communication units going to be used, for sensor to sensor node the sensor node communication typically ZigBee is good, but from sensor

node directly to a base station some long range communication such as Wi-Fi or you know GSM is better? So, this is basically the USB charging or even in the USB not necessarily for charging, but USB device which can be connected to a computer for may be transferring the data, from the node to the computer or from the computer to the to the node. This is basically the programmer that would be used you know once you have written the code.

And microcontroller code it has to be burned into the microcontroller right. So, for that the programmer comes handy. So, programmer basically will help in burning the code that is written in your PC into the microcontroller. Then we have over here we have this is the display unit which is an optional thing, but it is good to have if you are if you want to show something, if you want to display if your node has to display certain messages for users to understand what is going on. Or even for debugging purposes the display units good useful.

And then you have all these power units this is the which you know this is the charging point for batteries to be recharged. So, the power basically the power input can be made from here. And these are the on and off you know switch, a switches we can be used for switching on and off the sensor node. And this is on the other side you know this is showing the rechargeable batteries that are used. So, you I mean these are the batteries that we have used for our general purpose sensor nodes, but you know one could use different other batteries a small size battery depending on the requirement for which the sensor node is fabricated.

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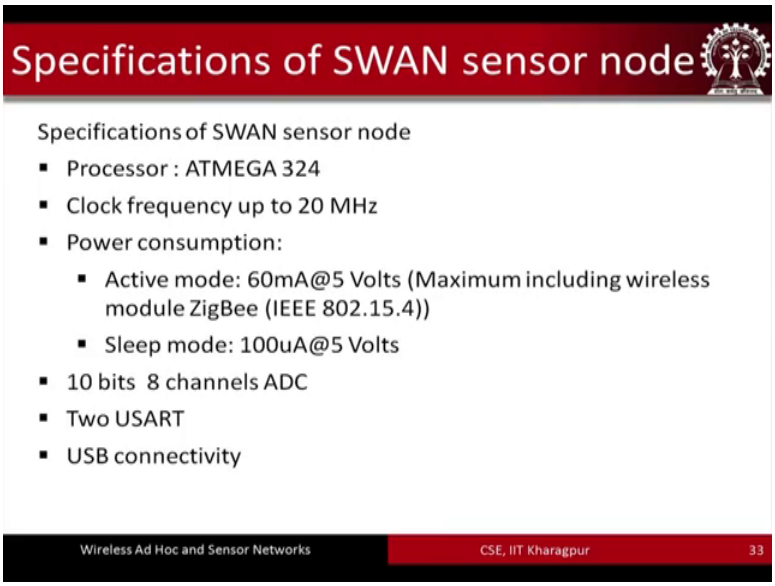

So, this is the general specifications of the sensor node that we have developed at mega 3 to 4 processor is used. Then the clock frequency is up to 20 megahertz power consumption in the active mode is 60 milli amperes at 5 volts input. And in the sleep mode it is 100 micro ampere at 5 volts input. Then in bit is 8 channel ADC is used analog to digital converter and 2 USART and USB connectivity. These are the different specific specifications of the sensor node that I have just shows you the one that we have developed in our lab here are few other specifications.

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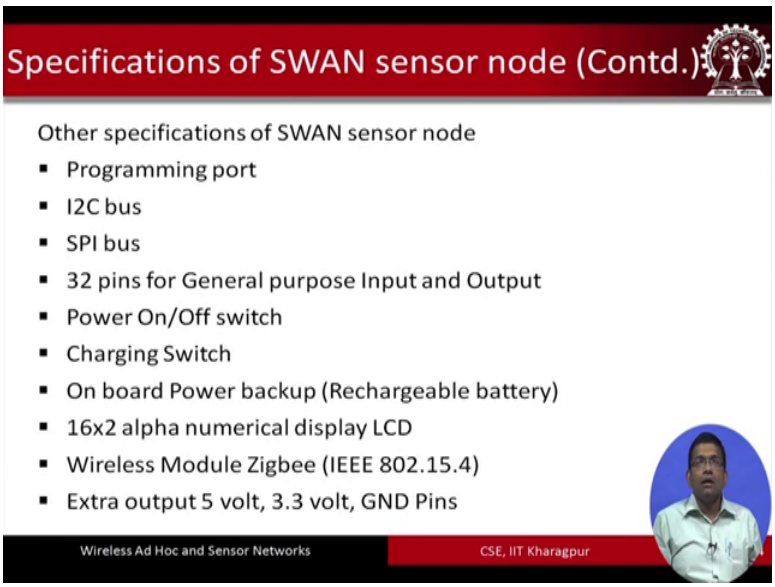

So, I am not going to go through them individually, but it is there for you to just read and try to have a feel of the nature of the sensor node that we have developed.

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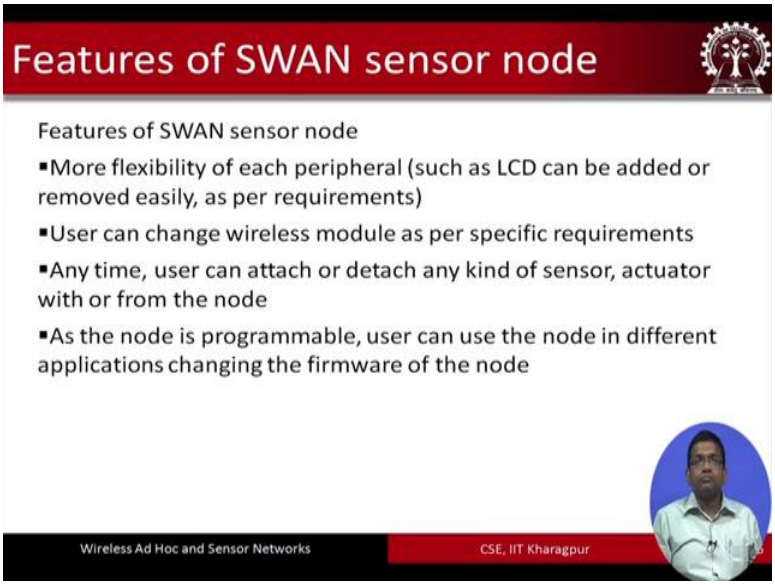

And these are the different features of these swan sensors node. It is flexible you know supporting debugging etcetera you know users can also be able to see the messages you know what is going on and so on. Users can change the wireless module as per the specific requirement. So, it is flexible in that sense you just can change the wireless module you know instead of ZigBee you take the ZigBee output maybe GSM in GSM module in or Wi-Fi module in. So, that way you know and without affecting the rest of the board right. So, you take it out and put it in the other module that you want. So, it is flexible in that scene any time, the user can attach or detach any kind of sensor actuator with or from the node as the node is programmable users can use the node in different applications.

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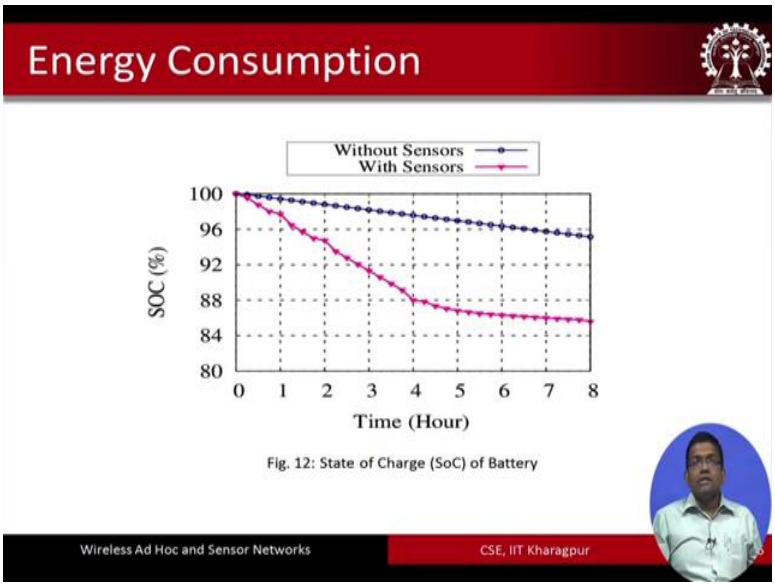

Changing the firmware of the node. So, just by changing the firmware of the node this node you know as a whole can be used for something different applications. So, these are the state of charge in the battery using this one node. So, you no need to explain we can without sensors how the charge you know degrades over time is shown in this particular plot.

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So, here are some references that could be useful for you. So, you know in the book principles of wireless sensor networks authored by Obaidat and Misra. Here you will

find a chapter which is titled inside a wireless sensor nodes structural operations from where you can understand some of these concepts that I have covered today.

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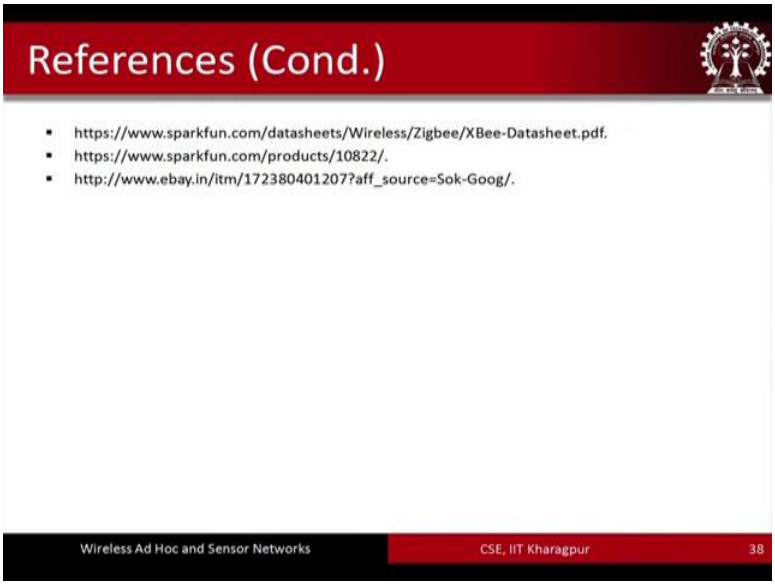

So, here a few other references, even you know from where you can purchase these individual electronic components for that actually these sites are useful. You can purchase the individual electronic components have your own circuit design about how to integrate them in the form of an embedded device. And then you know it is all about the production of the device from that point on. So, this is quite not. So, difficult you know these sensor nodes are not.

So, difficult to make, but at the same time you know it is not very trivial as well. So, basically you know once you have some general idea from the lecture today, you know you can start building a sensor node of your own, by purchasing these different electronic components from the sites and I have just shown you in the differences. So, I hope that you have got some good understanding about how to make a wireless sensor node and the different components of it. How to make a wireless sensor node, actually we have not talked about circuit design etcetera, but you know we have a patent filed from where you can get an idea about how to what would be the circuit design for our particular sensor node or if you can get in touch with us. So, with this we come to an end of this module on hardware design of wireless sensor node.

Thank you.