Embedded Systems
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Lecture – 26
Networked Embedded Systems – III

Today, we shall look at wireless networks which are intended for usage in much smaller areas then 8 to 2.11 that we had discussed in the last class. We call such networks wireless PAN wireless personal area network.

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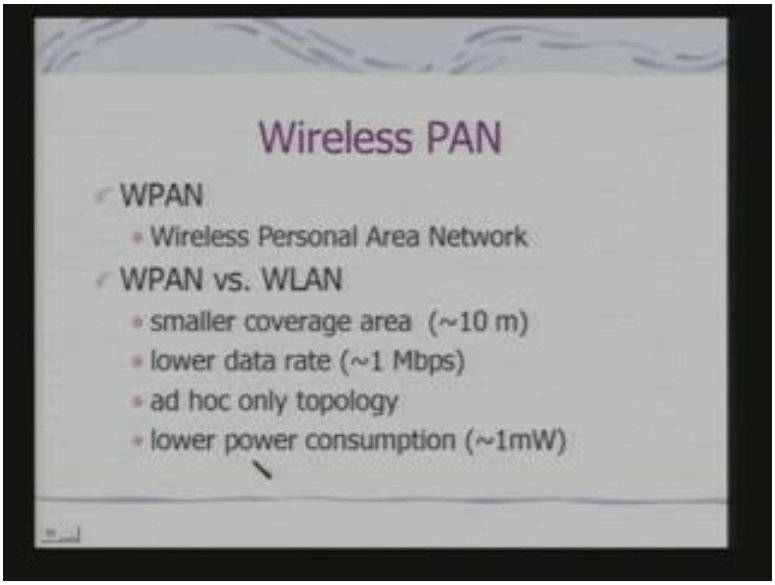

Now, what is the basic difference between wireless personal area network and wireless LAN? They are expected to have smaller coverage area lower data rates and ad hoc only topology in 8 to 2.11. We had distinguished between ad hoc as well as infra structure based wireless LAN. Infact, I can have a infrastructure base wireless LAN where I have an access point connecting to the backbone. Here, the primary objective is to set up ad hoc networks. And the more important thing this context is the lower power consumption. And that is also reason why would like to limit coverage over restricted area.

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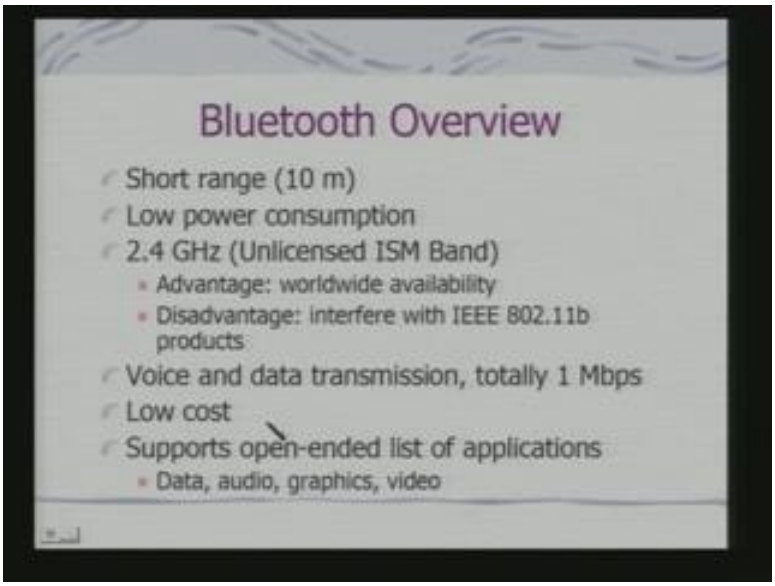

Bluetooth is currently and accepted IEEE standard for personal area network. It has got a short range, low power consumption, uses 2.4 Giga Hertz which is available which unlicensed band available is widely. But interface again with 8 to 2.11 b which also uses 2.4 Giga Hertz. It enables voice and data transmission at 1 Mbps rate and has got low cost. And it supports what we say open ended list of application in fact, lots of application concepts of develop around the Bluetooth specification.

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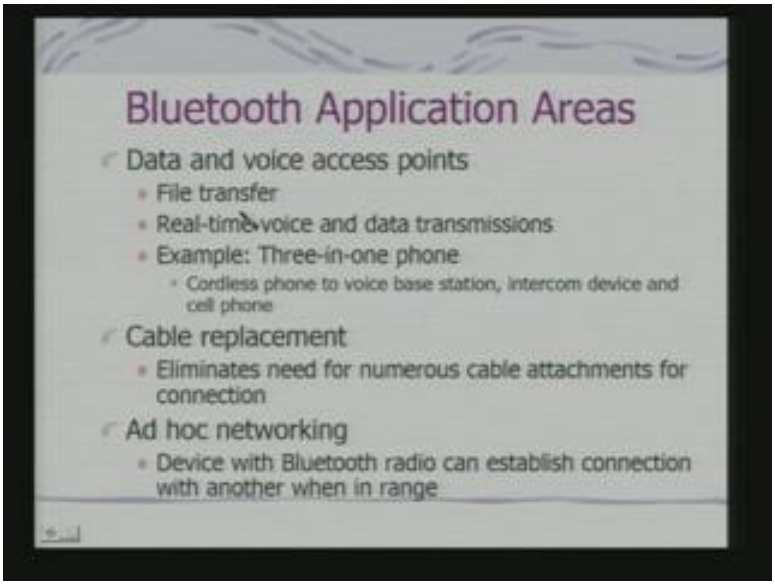

What the different application scenarios? We have the data and voice access points and through this access points you can have file transfer. You can have real time data as well as voice transmissions. So, example is 3 in 1 phone you can have a cordless phone to base station and intercom device as well as a cell phone. In fact, your hands free set for a cell phone can be connected via a Bluetooth link. The original objective with the Bluetooth was started was to replace cables variety of cable connections which are used for short range short distance connections whether they can be completely eliminated. And in fact, now, Bluetooth has grown beyond that very basic requirement. Also the ad hoc networking devices with Bluetooth radio can establish connection with another when in range. In fact, this gives a very interesting advantage that can be we are moving around. And you discover another Bluetooth enable device you can establish connection and an ad hoc network. The Bluetooth organization is based around to very basic concepts that of piconets and scatternets.

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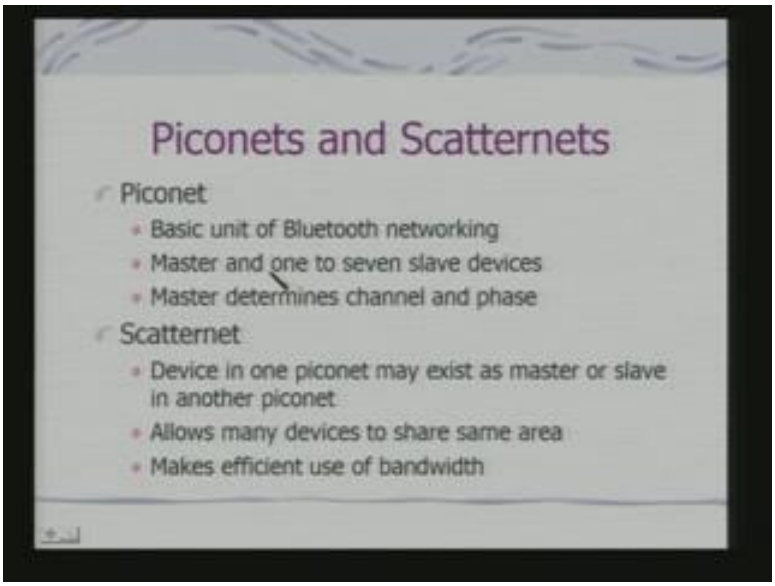

Piconets; in a way this cell which is the basic unit of Bluetooth networking. A piconet typically will have one master and 1 to 7 slave devices. If there are additional devices in the piconet they will not actively participating communication one the 7. The maximum of 7 slave devices can participate in communication with the master. So, each piconet has got 1 single master. Scatternet is the next higher level which consists of a set of piconets. Device is 1 piconet may exist as master or slave in another piconet and this allows many devices to share same area and makes efficient use of bandwidth.

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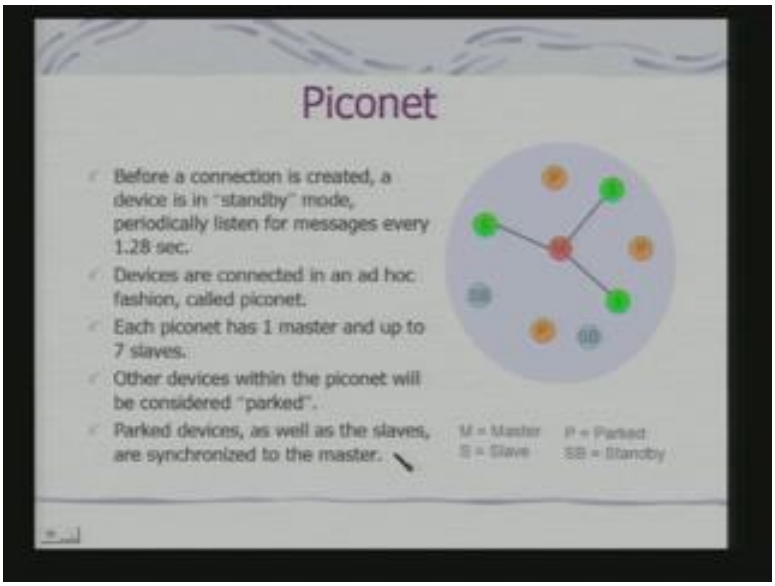

So, basically if you look in to it this is what would be the concept of a piconet. You have got this is master this is slave. Before a connection is created a device is in standby mode and it periodically listens for messages every 1 point to it seconds. And then devices are connected in an ad hoc fashion when there are other devices forming dynamically what is called a piconet. Each piconet has one master and up to 7 slaves. The nodes which are actually initiates the communication through negotiation typically takes over the role of the master. Other devices with in the piconet which are not slaving will be considered parked. This is the parked device with in the piconet. It is actually synchronized with respect to the piconet what is meant by synchronization will discuss later on. But it is not participating in data communication with the master. That is why we say that these node is in parked mode these are in stand by modes they are not actually in a way part of this piconet.

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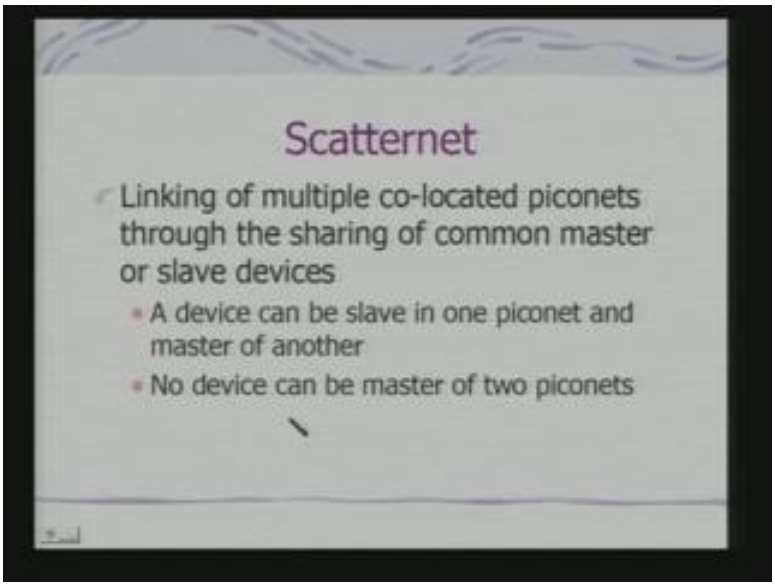

Parked devices as well as slaves as synchronized to the master then you have got scatternet. What is done in scatternet? Multiple co located piconets are linked up through sharing of the common master or slave devices. Master in one can be slave in another piconet. A device can be slave in 1 piconet and master of another. No device can be master of 2 such piconets.

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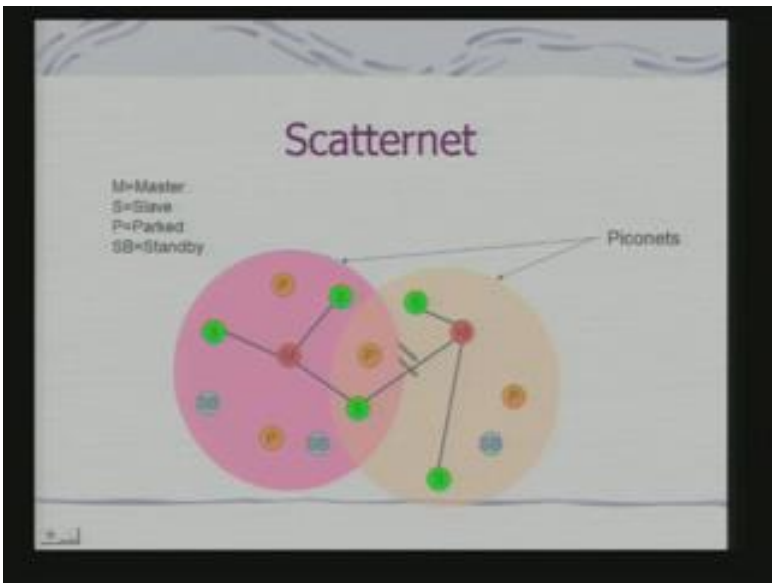

So, pictorially we look something like this. These are the two overlapping piconets. This is a slave which is common between the 2 piconets. These masters are distinct mode and

In fact, you can see that effectively I can establish communication between these slave nodes with these slave nodes. Because of this common slave connecting the 2 In fact, the common slave functions more like a bridge between the 2 piconets.

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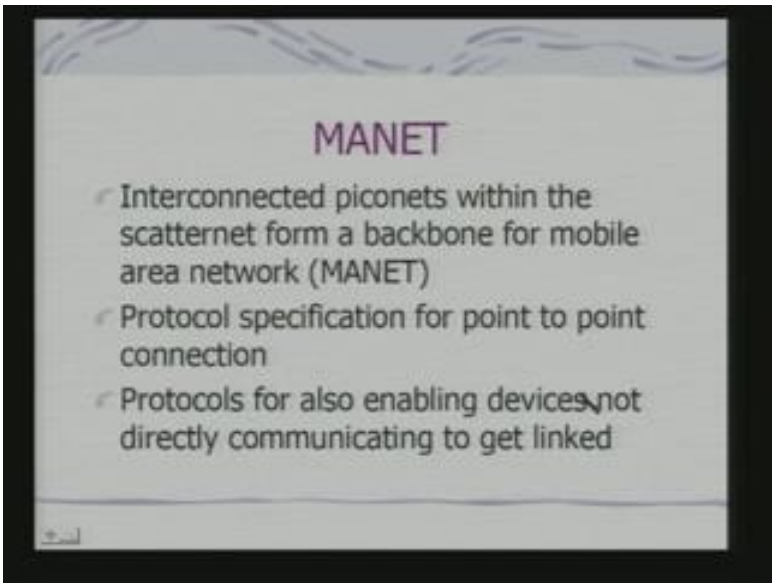

So, effectively what we get is interconnected piconets with in the scatternet form a backbone for mobile area network then you can actually complete network consisting of a set of piconets forming scatternets. So, you have got the nodes which may not even directly with each other, because keep in mind that ranges I said about 10 meters. So, there can be 2 nodes separated out they cannot communicate directly with each other. But through this provision of piconet and scatternet they can establish communication even though they do not have direct link. In fact, Bluetooth provides the protocol specification for point to point connection, as well as for a enabling devices not directly communicating to get link as well. In fact, these two aspects are taken care by Bluetooth and which goes in to creation of a mobile area network.

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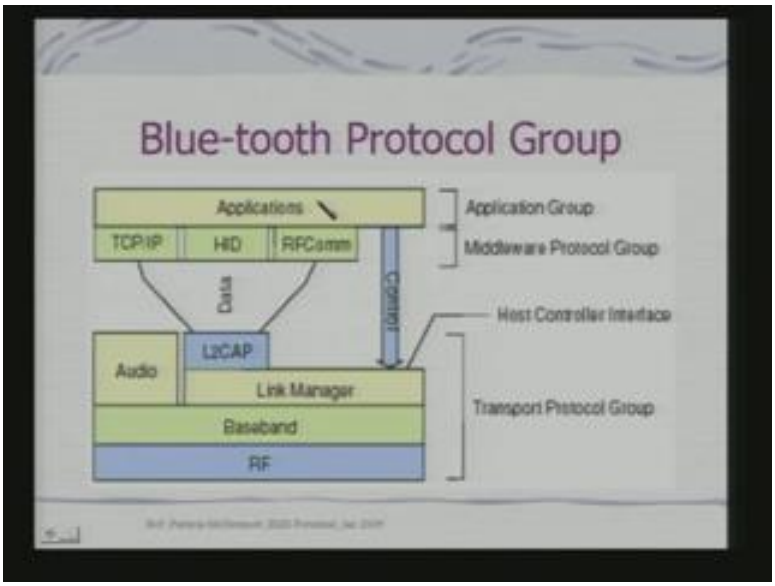

What is the protocol structure? Obviously, at the lowest level you have got a radio frequency communication. On top of that this is specification of the physical layer; on top of that you have got the base band .How the basic data is to be structured packetized communicated. You have got a link manager you have L2CAP shall discuss this later on. And on top of that this is basically what you called middle ware protocols for various applications. And this application sits on top of this middle ware protocol. And in fact, interestingly you will find there is a specific audio protocol as part of Bluetooth which enables audio transmission. So, these sits directly on top of your base band layer. So, it is not at an application level that audio is deliberate. And you have got through this control what we called host controller interface. In fact, host controller interface provides a mechanism for interfacing of a Bluetooth host with the corresponding application.

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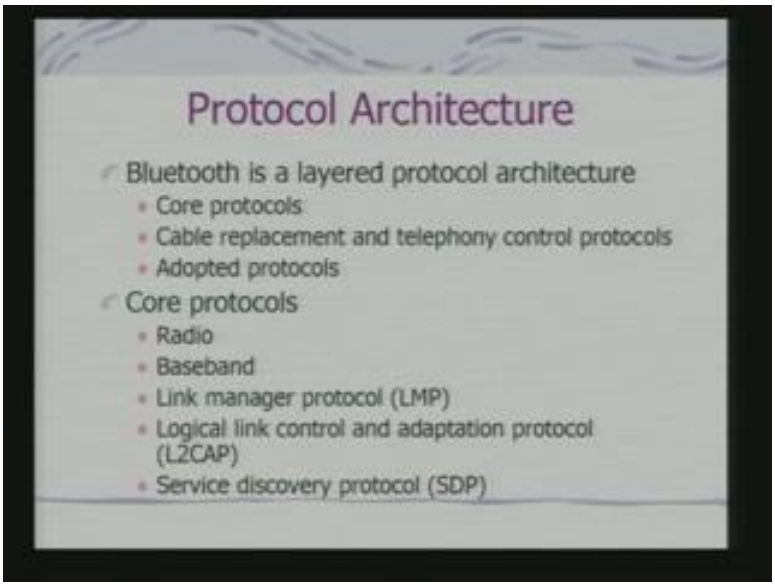

We shall not go in to details to these protocols, but let us try to understand these basic functionalities. In fact, we have seen from the diagram it is again a layer protocol architecture you have got core protocols, cable replacement and telephony control protocol and adopted protocols. In fact, we shall come to them later on.

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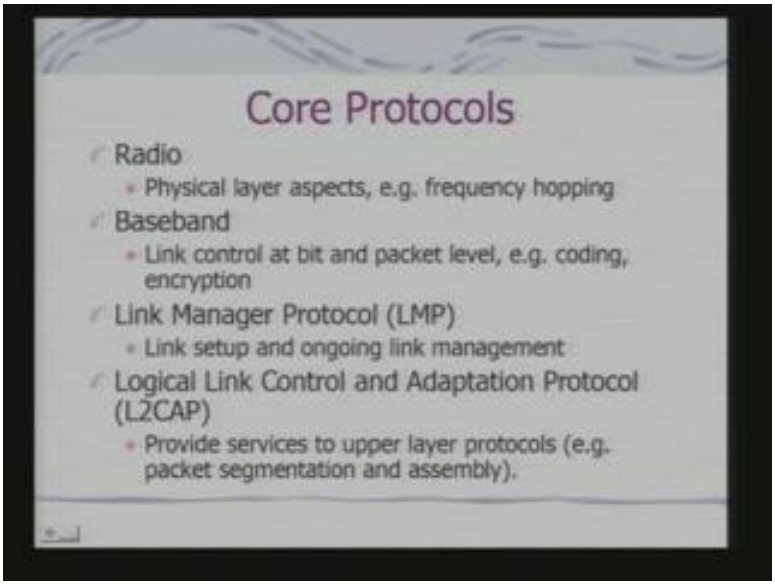

Core protocols are what? The radio, baseband, link manager, link control and adaptation protocol and as well as service discovery protocols. What the radio protocol is supposed to do? It has to provide for the basic communication. Bluetooth is based up on spect

spectrum as well as and inspect spectrum as required it uses frequency hopping. The base band it provides a link control at bit and packet level coding encryption that is packet sing issues. The link manager protocol sets up the link and manages the link. And logical link control and adaptation protocol provided services to upper layer protocol; that means the applications which provides a data that has to be segmented in to the packets again when you receiving the packet said to put together. So, this is the L2CAP protocol. And in fact, you can realize that once I have at a top layer I can have even implantation of TCP IP protocol which can go through your L2CAP. So, TCP IP in this case a middle group protocol.

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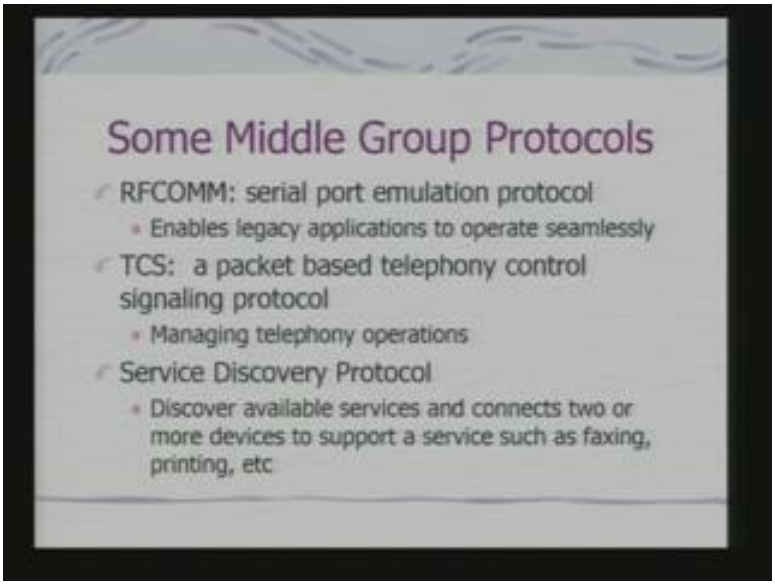

In fact, middle group protocol is a variety of firm. A simple if you remember that picture you have got RFCOMM which is the serial port emulation protocol. So, it enables legacy applications to operate seamlessly; that means, when we are having a serial port connectivity and I want to emulate the serial port connectivity over radio frequency I shall be using the RFCOMM protocol. In fact, you remember we talked about a telephony control protocol. So, say for example, if you consider that application where we said we have a telephone which can be moved around which is communicating with the base using your Bluetooth. So, I need a protocol to do this controlling we can have even a 3 telephone a telephone as well as the cell phone. And in such a case you need a telephony control signaling protocol.

In fact, TCS is a protocol at a middle layer which provides this application then the more interesting thing is the service discovery protocol. If you see your Bluetooth is basically an ad hoc protocol because if the devices come in contact the discover with each other. Now, this device can provide various kinds of services now, how do you understand the services being offered you need a protocol for service discovery. So, service discovery protocol discovers available services and it connects 2 or more devices such as fax machines printing etcetera .So, you can discover a printer it can discover a fax machine which is in the neighborhood. So, that is enable by the service discovery protocol.

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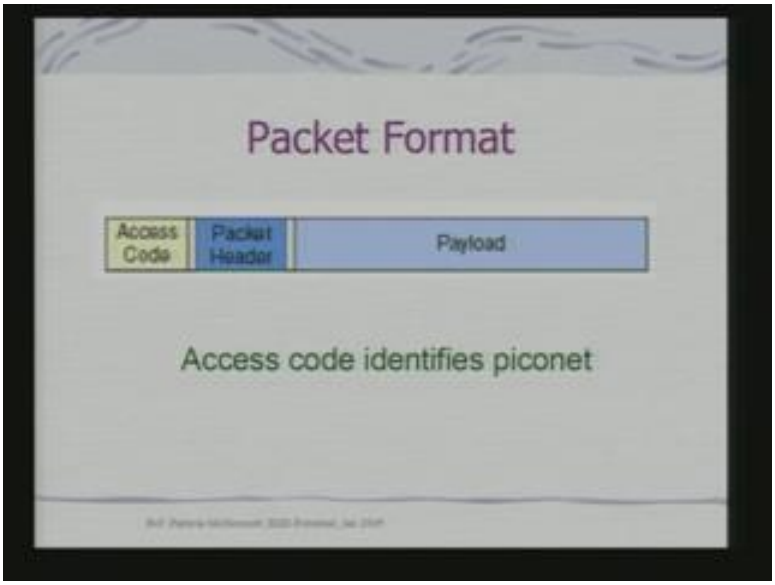

What is the packet format? Packet format is typically like this you have got an access code packet header and payload. The access code identifies the piconet, because they can be over lapping piconets forming a scatternets. So, I need to know whether this message is for a particular piconet or not. So, that is gets identified by the access code of the packet.

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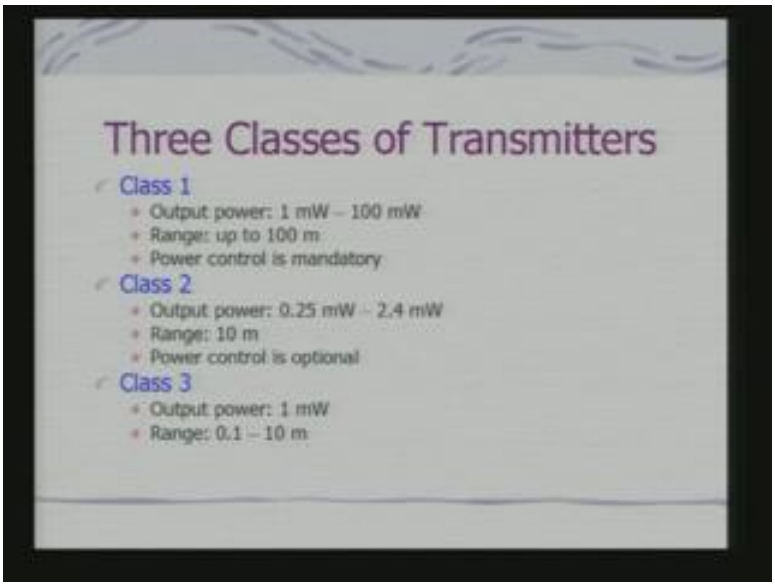

There are 3 classes of transmitters. In fact, you can see that 3 classes of transmitter is basically consume different amount of power and hence the ranges are also different. Typically it is the most commonly use is the ((refer time14:44)) range there are other 2 class 1 as well as 3 range of transmitters. So, the key aspect of the Bluetooth communication that is a physical layer part of it is frequency hopping what is frequency hopping mean and why is frequency hopping used? Obvious reason for frequency hopping is to provide resistance is interference.

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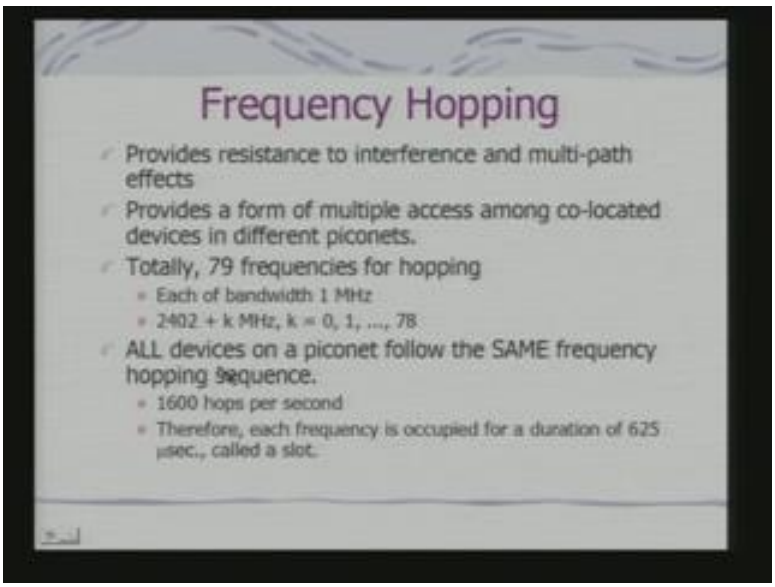

What is frequency hopping means that this transmitter's hope from 1 frequency band and narrow band that of frequencies to another narrow band frequencies over a time period in a particular fashion? Now, these make the system resistance to interference. As well as multi path effects what is the multi path effects? If it is a wireless protocol your data is actually getting reflected from the environmental objects and it will again come back. So, the data that is being received can come via multiple path and that can cause interference. And I need a mechanism by which I can minimize this interference. In fact, spread spectrum communication frequency hopping provides this capability. And that is the precise the reason why you will find the Bluetooth is using spread spectrum communication how it works?

So, it provides the form of multiple access among co located devices in different piconets. In fact, there is a total 79 frequency are used for hopping and each with of bandwidth 1 Mega Hertz. So, you start with 2402 Mega Hertz, because I say it is 2.4 Giga Hertz is the basic range and you have got this k bands which a k is shifted 0 to 78, because we are talking about 79 such bands and these frequencies are used for hopping. All devices in a piconet in follow the same frequency hopping sequence. And they use 1600 hopes per second when they are actually communicating. So, therefore each frequencies occupied for a duration of 625 Micro second which is called a slot. So, the communication is therefore, this kind of slot centric and the frequency hopping pattern is same with respect to a piconet.

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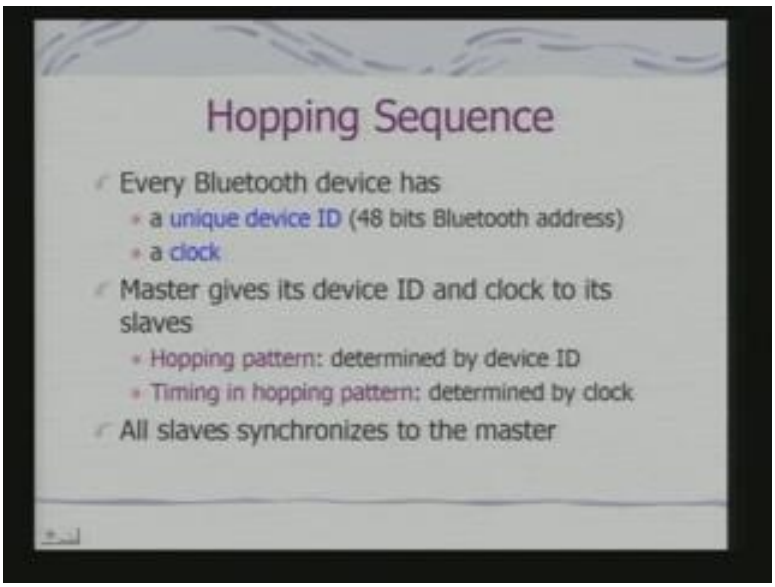

So, what is the hopping sequence? Every Bluetooth device has got a unique device ID. It is a 48 bits Bluetooth address and a clock. So, master gives its device ID and clock to its slave fine. So, the master determines the hopping pattern. So, since the master manages the piconet then a piconet has got a unique master. So, each piconet has got it own hopping pattern. And the timing in the hopping pattern is determined by the clock. All slaves therefore, synchronize to the master in fact, what does thus that implies? That implies the slaves cannot transmit in a random fashion. It can only transmit in synchronization with the master. And if you remember you talked about pack notes what are pack notes? Pack notes are not really transmitting, but they are still synchronizing with respect to the master. So, what can happen is a current slave note can be put to packs state and a current pack note can become a slave. And that is the basic advantage of having pack notes synchronized with respect to the master.

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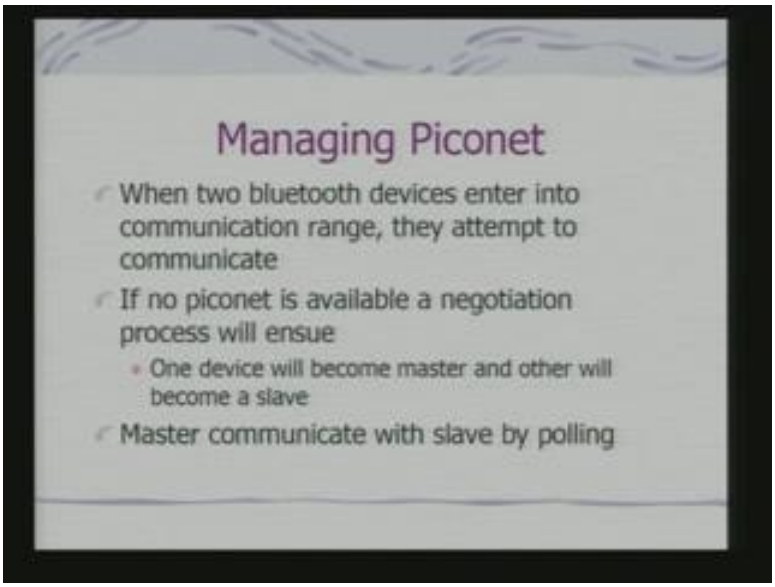

So, how do really manage the piconet therefore, so, when 2 Bluetooth devices enter in to a communication range they attempt to communicate. If no piconet is available you need to negotiate to set up the piconet. So, when you negotiate one device will become a master and other becomes a slave. Typically, the device which initiates communications becomes a master In fact, the whole protocols specification is there this negotiation, because if you remember we talked about the Bluetooth specification for a point to point communication. So, this is between one slave and one master if I negotiate are there are a set of slaves and a master or a set of notes communicating among each other they would

negotiate to have one identified as a master and master communicate with slave by poling. So, basically the poling takes place according to a specific rule the most common poling can be round robin. So, because 1 after another we go and I have the master therefore, implements around robin poling scheme. And this is what is known as time division duplex when a master is transmitting slave is receiving and cannot transmit and when the slave is asked for slave will transmit master receives.

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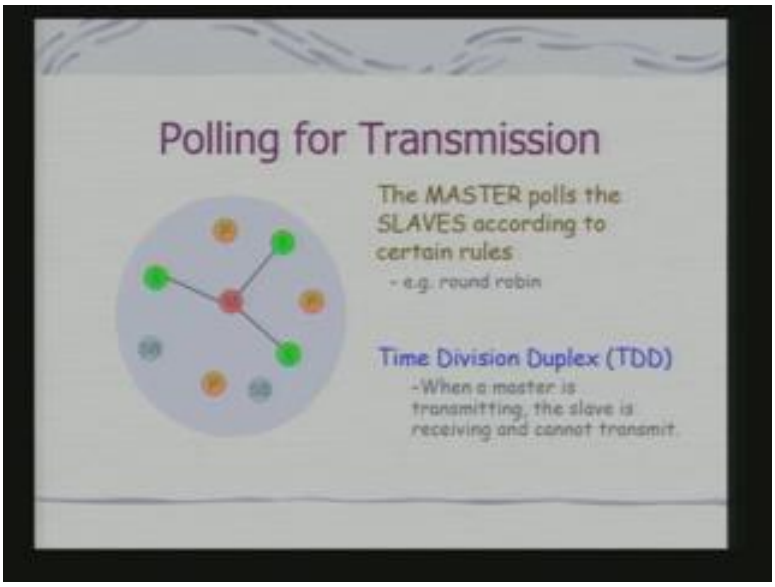

So, it is a time division duplex I hope you are understood why it is a duplex, because a typical time slot is provided for 1 way communication. But the link actually is a 2 way link fine. So, this is time is time division duplex and the master determines which slave will communicate. In fact, how does the poling takes place? Basically master sends the request to the slave and one slave receives the request in the next time slot slave will send its data.

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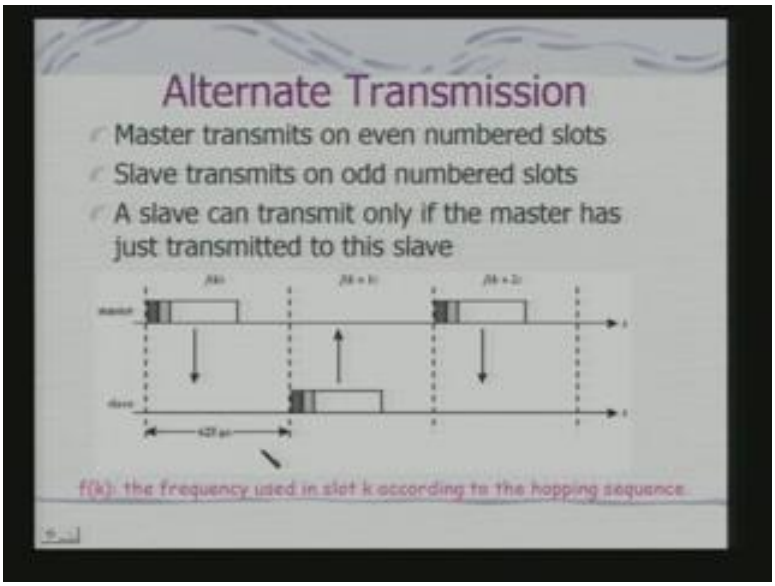

So, what we say that alternate transmission conceptually we are having alternate transmission. Master transmits may be on even number slots and slave transmits on odd numbered slots. A slave can transmit only if the master has just transmitted to this slave. A slave can transmit only if the master has just transmitted to the slave. This is basically the poling mechanism I said that communication takes place by poling. So, this is the poling mechanism. So, you can realize in this context you really cannot have a conflict, because there is only one master and you have the slaves and slaves are being provided with the slots.

And if you look it in to the diagram what is being shown is that that this master is a sending it here slave is sending it here and there is frequency hopping which is talking place. The frequency hopping is talking place because each frequency occupies the fixed time period. So, this is an illustration of what is meant by frequency hopping and the frequency hopping pattern is same for the piconet. So, you are master as well as the slave. So, as we have master with fk the slave at fk plus 1 and again mater goes in to fk plus 2. So, fk is the frequency used in slot k according to the hopping sequence peculiar to that of the piconet. Now, the physical links can be of two types; one is called synchronous connection oriented link.

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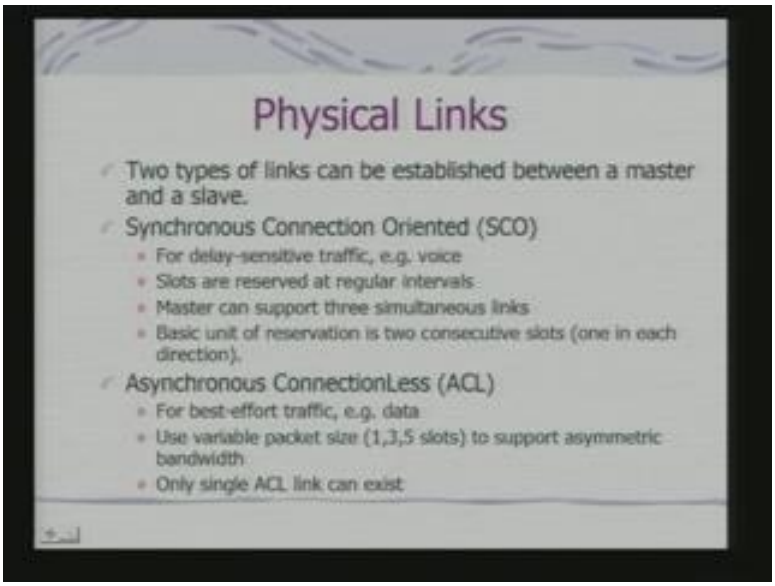

Another is asynchronous connection less link. Typically the voice is transmitted through a synchronous connection oriented link. In this case it is a time sensitive traffic. So, that means, we have discussed even in the last class the issue is related to time sensitive traffic. Because you got to have data packets arrives at fix delay or even if there is a variation of delay you need to know a need to know the bound of that delay. So, in this case slots are reserved at regular intervals if slots are reserved at regular intervals then what is guaranteed? The arrival of time sensitive packets at fixed intervals and so, you can have therefore, transfer of voice In fact, I told you that all your transfer support has been inherent to this protocol. So, that is why you have this definition of what is called synchronous connection oriented link.

In fact, master can support three such simultaneous link. And basic unit of reservation is to consecutive slots one in each direction. You can also understand the motivation for these you can actually have almost like a telephonic conversation over a Bluetooth link. The asynchronous connectionless link is for best effort traffic that is your data. And it can use variable packet size if the variable packet size means the slots that will be allocated for packet transfer to support a symmetric bandwidth requirement. And only a single ACL link can exist that it is a basic requirement. So the interesting feature is that this synchronous connection oriented link or asynchronous connectionless link how they are actually created? They are actually created if you look in to it the basic scheme is

what actually created by reservation of slots that is guaranteeing available of slots for delivery of time critical data.

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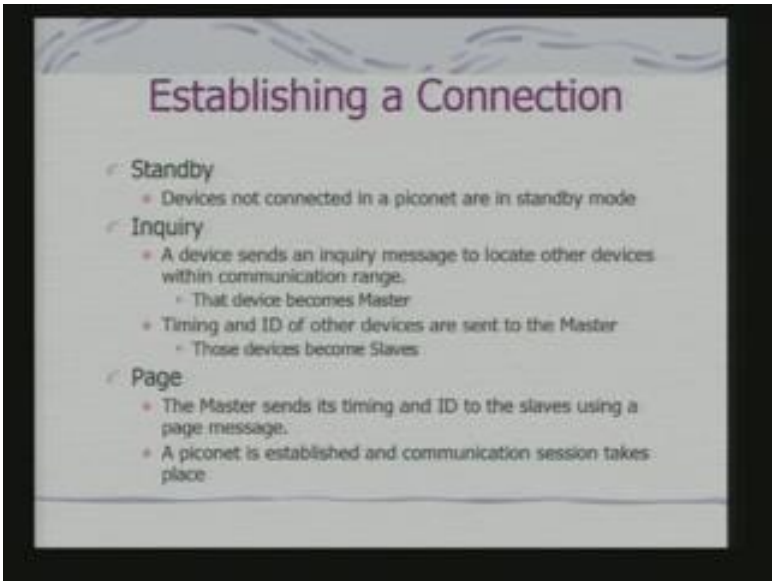

Now, how this whole process of connection establishment does takes place, because that is the basic key part of your Bluetooth protocol. Because you have got this Bluetooth is primarily as the ad hoc network. So, devices not connected in a piconet I have already told you are in a standby mode then you have got a inquiry mode. A device sends an inquiry message to locate other devices within communication range and that device becomes master. If the device is sending the enquiry message to discover other device then that device becomes a master. Timing an idea of other devices is sending to the master those devices become slaves.

This is also the page mode in a page mode master sends it timing and ID to the slaves using a page message. Now, the piconet assistance, because you know that master has to give its device ID to determine the frequency hopping pattern which characterizes a piconet. So, in a page mode the master sends it timing an ID to the slaves using a page message. And when it does that a piconet is established and communication session takes place. So, the basic things are initially nodes are in standby node there is an isolated node it will be typically in a standby node. Then it will initiate the inquiry discovers the other nodes assume the role of the master and then goes in to a page mode by which actually the piconet is set up.

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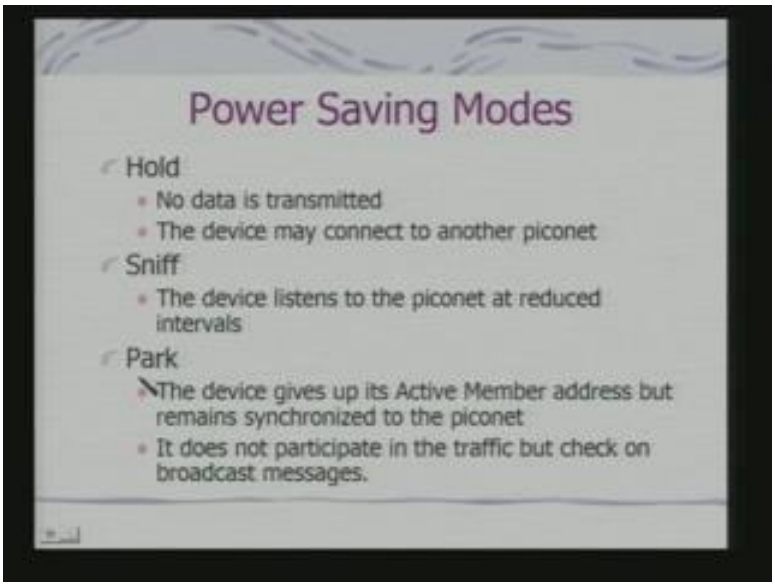

There also power saving modes, because power is an important aspect of these modes. So, these are Hold, Sniff and Park. Hold mode no data is transmitted and the device may connect to another piconet. So, currently it is on a hold it may decide to get connected to another piconet. Sniff is the device listens to the piconet at reduced intervals. And park the device gives up its active member address, because this active member address what there will be 7 active member that can be there in a piconet, but remains synchronized to the piconet. It does not participate in the traffic, but check on broadcast messages and that is the basic significance of the park you can realize that very easily a park mode can switched over slave mode.

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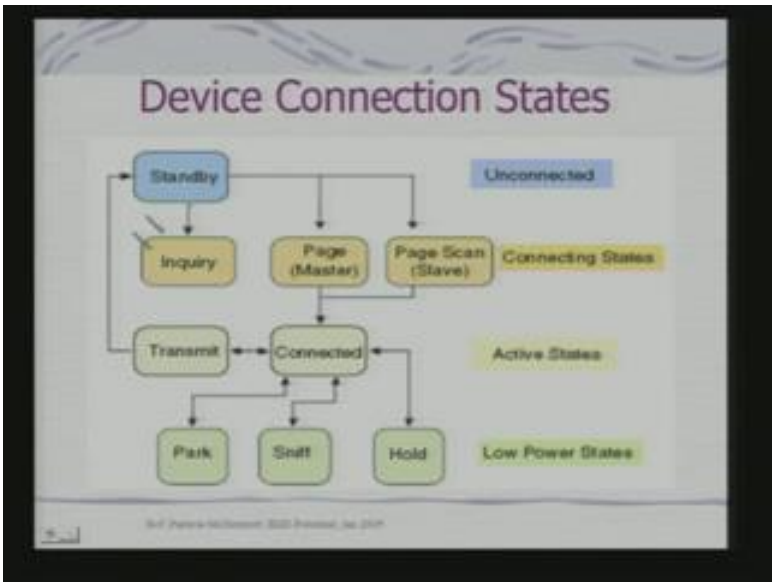

So, this is the state diagrams. So, of the state which in device is so, it is typically standby vso, the elegance are blue is unconnected. These are connecting stage then these are active stage and these are low power stage. So, from a standby mode you typically go in to an inquiry mode where you send inquiry message to discover other devices then there will be page mode for the master and page scan mode for the slaves. Scan mode means they are trying to process the message that has been provided by the master in a page mode and then they go in to a connected mode.

And when they are connected they will be typically in a transmit mode when master and slaves will be normally in a transmit mode. If a slave knows out what it will go through? It will go to a hold state which is a low power state which is not really participating in the communication. It is go in to a sniff mode try to find out what is happening in the piconet it can also go to a part. But active master in the slave will be typically in a transmit mode. Next you have got the Bluetooth audio, because you have seen the Bluetooth audio sit directly on top of your base band. And we have already seen that how physical link provision is made for transmission of time critical data like audio data.

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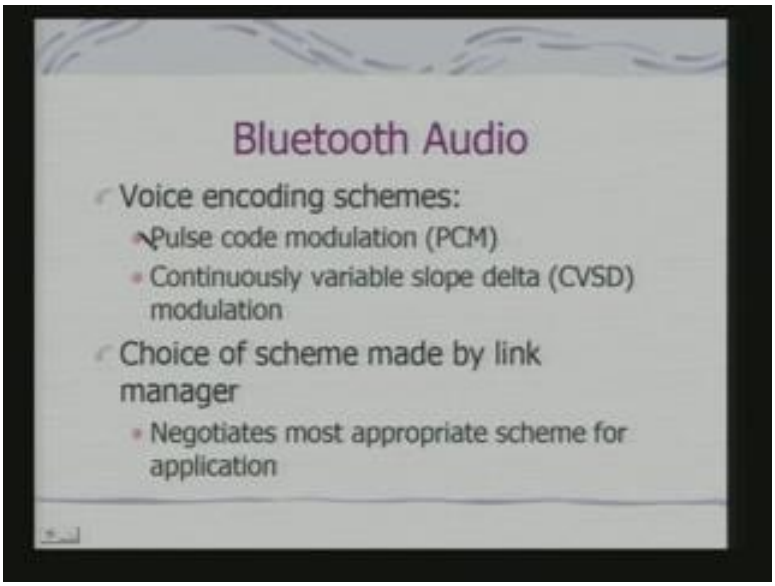

In fact, there are voice encoding schemes which are made as a part of your Bluetooth typically you can have PCM or continuously variable slope delta modulation. This is nothing but variation of the, your standard delta modulations. These are the two basic schemes which had been defined as part of Bluetooth protocol. And choice of the scheme is made by link manager. And negotiates most appropriate scheme for application; that means, what is the encoding scheme to be adopted that is negotiated by the link manager and accordingly the encoding scheme is adopted for transmission of voice data. Bluetooth link also provides security why security is important? The moment you have got the wireless link you can have any receiver so, you can set up an ad hoc network I can always come in to a room put in to a Bluetooth device get connected to the network. And then listen to the messages which I am not suppose to listen this is the basic thread in a wireless network fine. So, security is always a very critical issue in any kind of wireless ad hoc networking.

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So, the elements of these security I am discussing in the context of Bluetooth, but this is valid for various other wireless protocols as well. Authentication and encryption; authentication is verify claimed identity if you have a definite identity. Then only you can be accommodated in the piconet otherwise you may not be accommodated then there is encryptions so, use a key to encrypt the data. So, when if you are listening to that data if you do not have the key you cannot decode the data. So, associated with this could be a important problem of key management and usage, because key distribution to takes place.

Because this nodes to know the key for decoding a data. So, how safely the key has to be transfer that also becomes an issue. In fact, this are very basic issues with any kind of network security protocols. And they are also relevant in the context of Bluetooth more relevant in the context of Bluetooth, because it is an wireless channel any you can simply worked in with the Bluetooth enable device and since it is an ad hoc protocol the device may try to join the group and listen to the data which is not suppose to. Now, in with these kind of an ad hoc situation what is we are getting in to? We are getting in to a scenario where computers has gone outdoors.

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In fact, they started with the basic idea embedded systems computers going in to a variety of appliances. Now, actually we have the ability to kind of an ad hoc network mobile network that is your node joining from 1 piconet to another piconet setting up your mantel in terms of your scatternet you actually have ability to be mobile and still taken it. So, your computer in strictly has gone in to a outside world. And what you are trying to talk about now is the distributed computing in an outside physical world. Distributed computing classical is in terms of computers connected computers where not located in a physical world we are not moving around in a physical world. But now, you have the ability the computers embedded computers can move around. So, can move around in the car and still it is a connected through an ad hoc networking.

So, the whole idea here is cars can be collaborating for a safer and more fluid traffic. You do not bother about traffic signal you actually communicate have communication between the cars and you start communicating may be where you can come close together and you know which road to take on the basis of this communication. They can be distributed object tracking over a large geographical area. This is important for a variety of defense applications interestingly if you know the current controvers tracking the tiger in variety of tiger reserves. So, if you really have this kind of senses along with computers distributed in a forest area you have an automatic tracking this kind of wild animals in the habited. So, physically we are putting computers and you have the ability

to put computers in the external world and still stay connected. This list as to what is known as network sensing.

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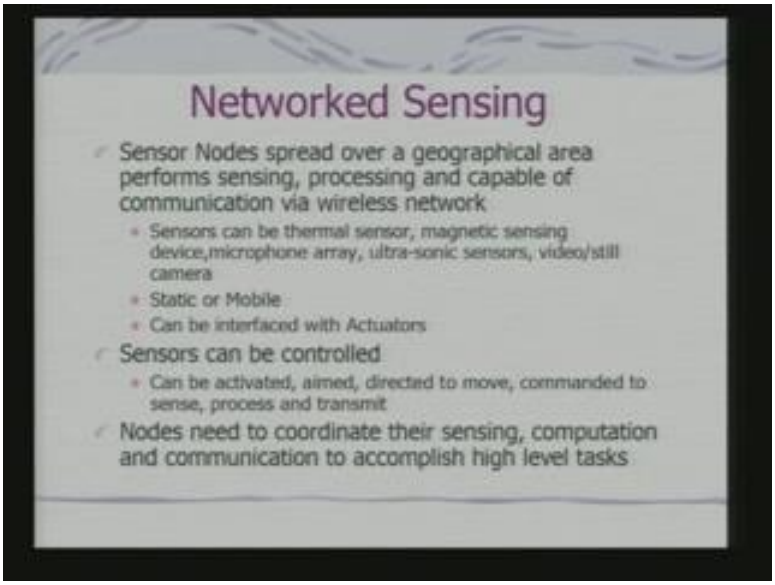

Because if you having computers all around what do you like to do? You like to do sensors sense information and communicated. So, you can have know sensor nodes spread over a geographical area which perform sensing, processing and capable of communication via this kind of wireless link. Sensors can be thermal sensor, magnetic sensor are variety of other sensors like microphone array ultrasonic sensors. The sensors can be static are even mobile can be interface to the actuators as well. So, since the interface the actuators the sensors you can control and take action influencing then environment.

The next interesting thing is sensors now can be controlled. So, sensors in a way I just not passive sensors you can have formally active sensors. So, sensors can be activated aimed directed to move commanded to sense process and transmit. So, it is not just a camera which is looking at me it is a passive sensor. So, now, you can make the camera active in the sense that it can be commanded to move around remotely. So, they can be various such sensors which can be activated aim directed or commanded over your wireless link. So, nodes need to coordinate their sensing communication as well as computation tasks to accomplish high level goals. So, that is what has now, become reality with these enabling technology that we have so far discussed.

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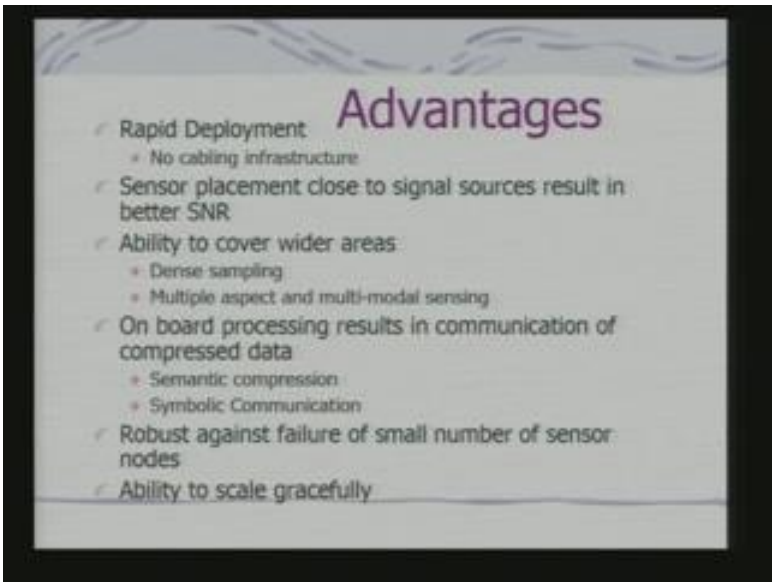

So, what is advantage of this kind of a scenario? You have got rapid deployment, no cabling infrastructure required sensor placement is close to signal sources results in better SNR, signal to noise ratio, because you are not transmitting the signal. So, environmental noise did not corrupt the data. Now, you have the ability to cover wider areas, you can have variety of sampling can I have dense sampling, because you can put sensors that every spot you can have multiple aspect and multimode results what is multimodal sensing? In you can put multiple sensors put in to 1 embedded system and you can have multi modality sensor and onboard processing, because if you now put in we have got embedded system.

So, if you put a processor so, what you we have talking about the movement we are talking about the wireless connectivity sensing be put in you are also putting a processor along with the sensor. So, effectively you can have process the data at the sensor itself and use low bandwidth communication link. And it will be robust again failure small number of sensor nodes, because you have already got an ad hoc protocol then there can be nodes discovered nodes can move out. But you may requires some special techniques to make the network self healing self organizing. And ability to scale gracefully, because if you look at you have got local net and local net connected over shared nodes. So, it can grow bigger without really protect in the constraint in the resources.

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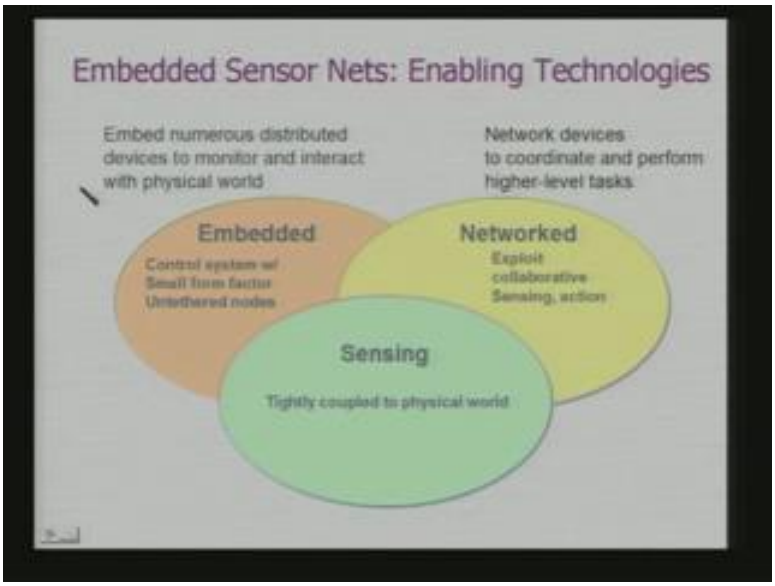

So, effectively what we have now, got is embedded sensor nets embedded numerous distributed devices to monitor and interact with the physical world. And the enabling technology was embedded system networking as well as the sensing schemes. In fact, the sensing scheme the most key issue is signal processing. Embedded system we have seen that how to have designs small compact devices their basic characteristics networking is in terms of protocol we have seen how the variety of protocols enables this kind of communication. But other task level application level then interesting thing is that network devices can coordinate and perform higher level tasks. So, there can be a distributed coordination.

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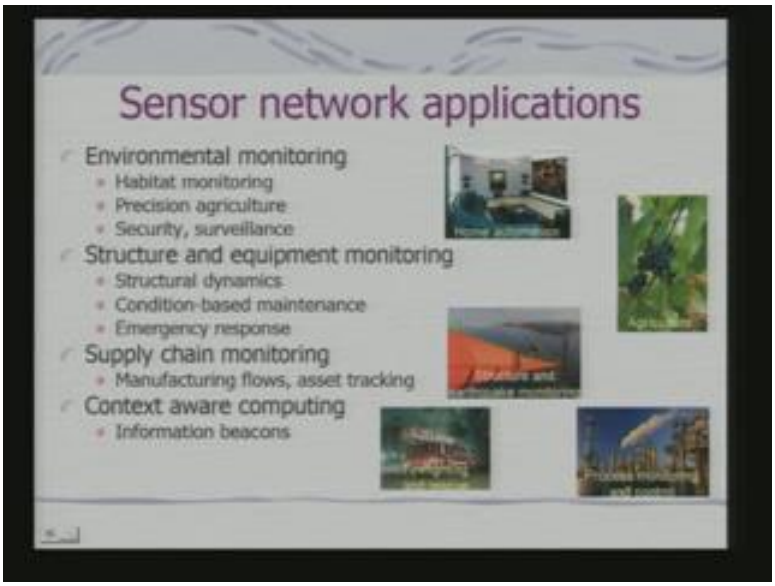

So, today, the imaging applications are many. There is home automation and In fact, it is related to your environmental monitoring, habit monitoring, precision agriculture, security, surveillance, a big housing complex you can have a surveillance using sensor nets with them embedded sensors distributed all around. You can have agricultural monitoring micro climate sensing you can have habitat monitoring. I give an example of tiger being tracked using a sensor network you can have water quality monitored. You can have may be alone the Jamuna you have the water flowing through and you want to monitor pollution levels. And you want to get an automatic data accusation that you can do through this kind of sensor nets then structure in equipment monitoring, because if there is an effect of earthquake you can monitor automatically generate the response.

So, you can have supply chain monitoring because your asset is moving around. And if you can track the assets; that means, any component or anything and you can find out whether you got enough store are not also you have got what is known as context aware computing. That means you can move in to a room the movement I move in to this room if I have some sensing device as well as transmitting device placed in my pocket lets a short pocket. So, the camera becomes on the recording becomes on automatically. So, a context have a system comes in. In fact, the whole area idea are a way sniff computing is built around this basic concept way sniff computing is what computing coming in to everyone.

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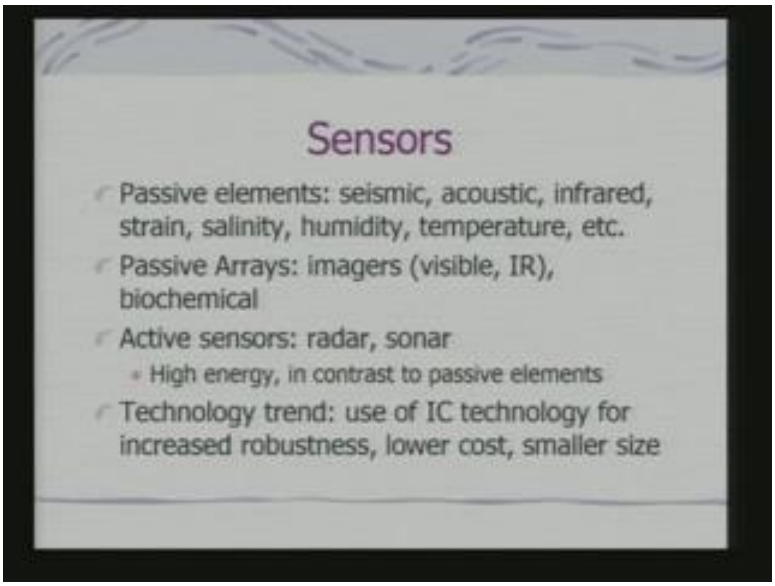

So, sensors can be a variety of sensors passive sensors, active sensors. Active sensors are those sensors which actually transmit some energy. And on the basis of transmitted energy it makes sensing of the external world. And the technology trend is make this sensors as small as possible.

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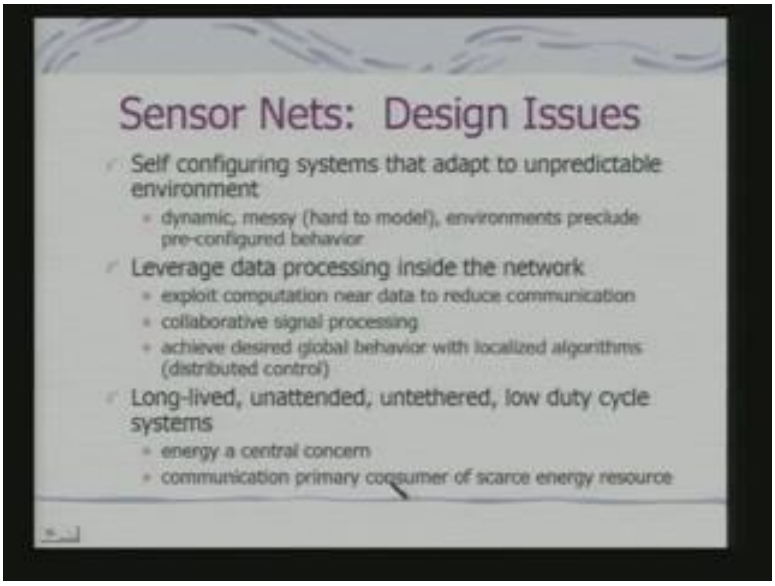

So, the, what are the design issue is that comes up in this kind of a sensor net? The basic issue is self configuration because you cannot physically reconfigure a system, because environment may change without your knowledge. The whole system should have the

ability to reconfigure on its own a node can fail arbitrarily. But a node failure should not make the failure of the entire network eminent. They should be an ability to self healing or even notification being generated for this failure of nodes. Then leverage data processing inside the network. So, exploit computation near data to reduce communication and these leads to what is called known as collaborative signal processing. Collaborative signal processing means there can be multiple nodes collaborating with each other for a signal processing tasks. And you have long lived, unattended, untethered, low duty cycles systems, because if you put a such a system in a forest you cannot visit regularly.

So, you got to design them as a robust and should be battery powered and battery expected to last for ears are together. So, energy becomes a central concern and what is very important is communication becomes a primary consumer of energy. Because you have seen you have got processors which have got very efficient energy characteristics and energy saving modes as well. But when you are communicating you have to transmit energy. So, you can understand that if I can do more processing at the node itself the need for communication would be less. So, there is this interesting a dual comes up it will communication and computation how much of computation is to be done how much of communication is to be done? So that you can optimize your energy usage. Next thing comes with the embedded control.

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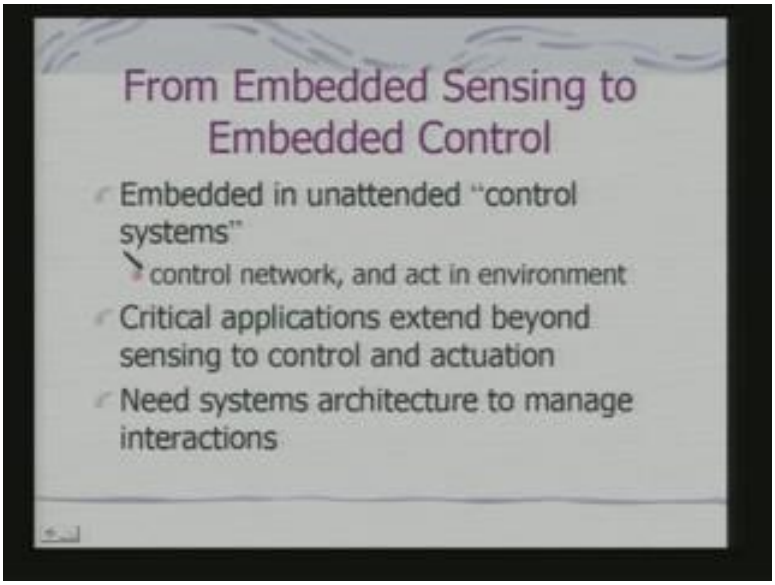

So, if node is embedded in unattended way so, it can have a control systems. So, effectively get a control network which active in environment. So, you need critical application which extends beyond sensing to control an actuation. So, In fact, you can thick in terms of a variety of controller actions which can be initiated through this process. In fact, a simple control action could be that a kind of a hypothetical slightly features tic. You have your traffic signals sitting inside your car at a traffic signal what happens? Your cars stop so, instead of having a traffic signal externally you can have a traffic signal inside the car itself. So, when moving through this sensing it realizes that you should stop now and that traffic signal automatically applies the breaks, because breaking control can be an embedded system we have already seen that as part of a can network. So, your traffic signal can initiate the break once it sensors that there are other cars in the vicinity trying to task. So, you can have a control mechanism built it to it. The basic idea of in network processing the point I was telling.

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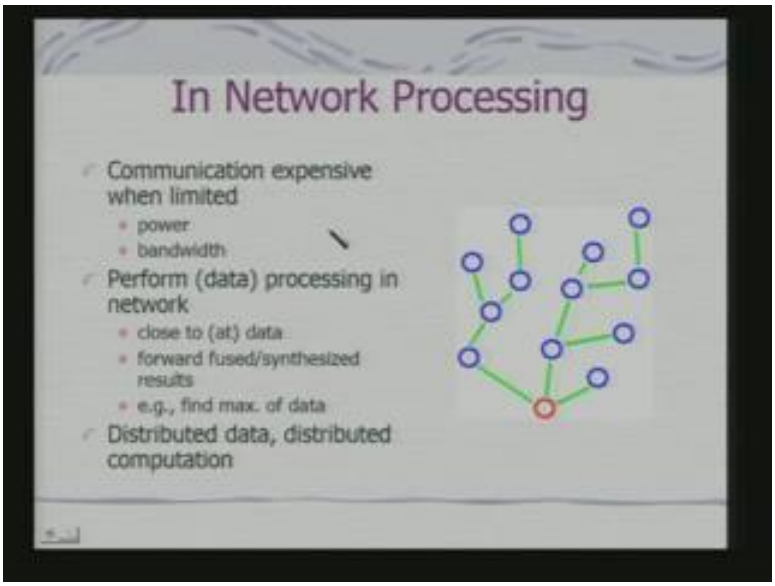

The communication is expensive when its limited power and bandwidth. So, perform data processing in network close at data and you are distributed data you have naturally a distributed communication. Now, these basically lead to known as a collaborative signal processing task. And this collaborating signal processing task takes place.

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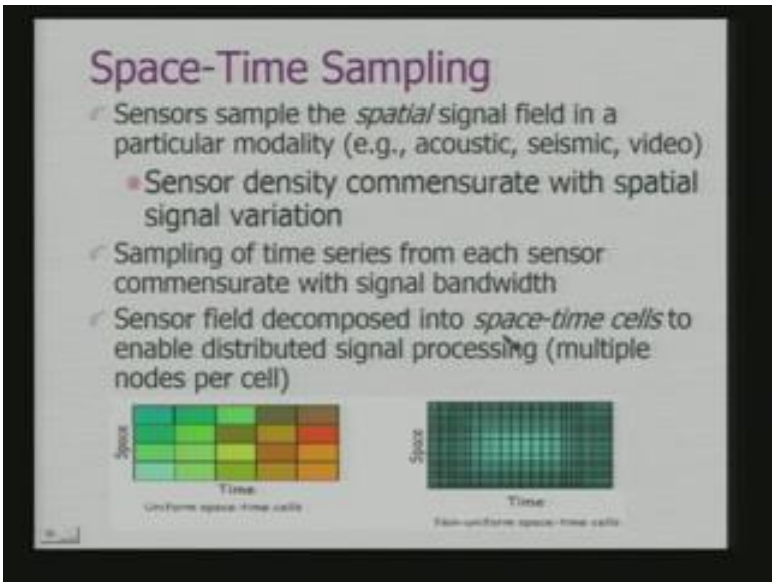

Over space overtime; this is interesting you should note this very carefully, because, now the signal processing problem in the context takes slightly differentially we talk about sampling of a signal over time domain. Now, when a phenomena is distributed over a geographical space and you are putting the nodes a different points what you are doing? You are doing a special sampling as well as temporal sampling. So, you have doing a space temporal sampling of the signal fine and each sample can now, be processed at different nodes, because you are physically sampling the space by putting nodes different locations.

So, that the sample individual sample over time gets processed at different nodes. And if you have to get the pick picture out of such a network you need to have all this nodes collaborating together. So, that leads as to the concept of what is called collaborative signal processing node. So, sampling at of time series from each sensor is commensurate with the signal bandwidth. And sensor field is decomposed in to space time cells to enable distributed signal processing in a collaborative fashion. I can have a uniform sampling I can have a non uniform sampling of the space time.

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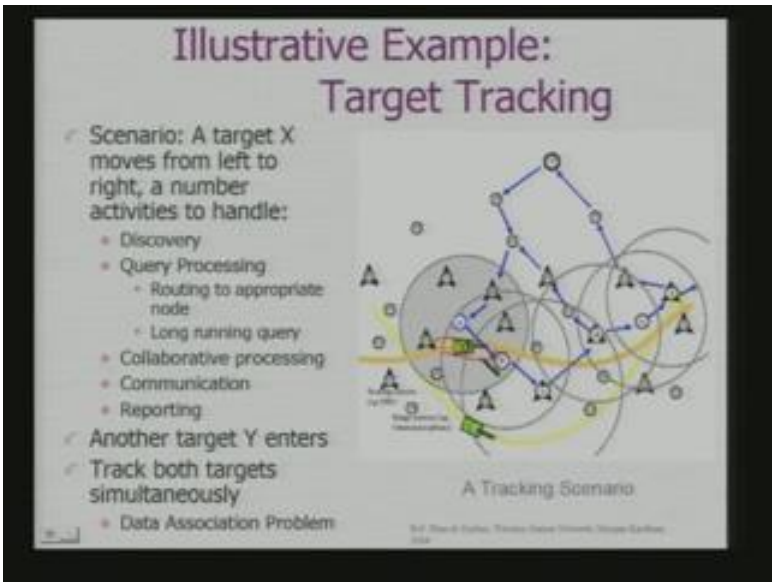

These are simple example that of the target tracking. I can track a target tracking using a variety of sensors. So, you see that there are various nodes and the sensors which are connected here. And let us look at a scenario. A target x moves from left to right and there are number of activities to handle fine. So, this is your target first target which is moving along this path. And this are all nodes and these nodes not always communicating with each other the blue arrows shows you that when depending on the need the communication is set up. So, first is the discovery of the target. The discovery of the target can be by this node A and there can be a query injected in to the network by the user from here. Query could be what is the target? There can be long term query which are there in a network itself being processed. Now, the query processing require what the routing of the query to the appropriate node, because the query has been posted by some node at some point and when there is a long run query it requires data accumulation for servicing the long run query then comes a collaborative process, because this node A has got some information and now this object is moving along.

So, node B has to be allotted to gather information about this node. So, this is the basic collaborative processing just consider that you have got multiple cameras and there is a person moving around and you want to keep track keep image of that person using multiple cameras. But this cameras are not taking images blindly they are taking images when they have been activated. So, another target why I enter so, here you need to track both the targets. So, you have to have a time sharing. So, all the issues of time shear

concurrent systems becomes relevant with respect to the nodes that we are dealing with also there is a problem of data association the data that is being sensed I need to know that data belongs to which object. So, that is the data association problem. So, this is the very typical example of what we called collaborative signal processing problem and here I have basically sample space with various sensors. This sensors could be passive I had sensors could be in this case example is passive sensors as well as your only directional sound sensors ultra sound sensors.

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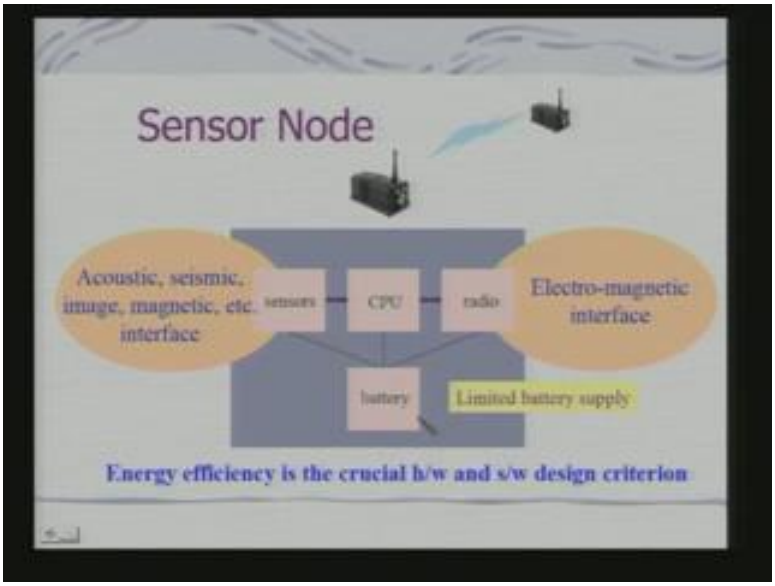

So, sensor known therefore would have sensors CPU are radio for RF communication and a battery, the battery is of limited supply. So, energy efficient is crucial for hardware and software design.

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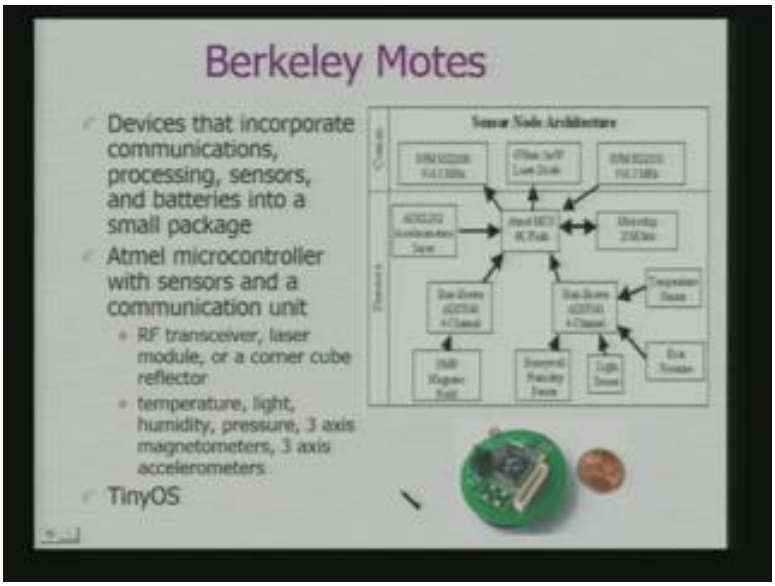

And let us take look at some simple examples of such nodes the Berkeley motes which are the most famous this kind of sensor motes there motes, because it says the device that incorporate communications processing sensing and batteries in to a small package. This Berkeley mote is built around Atmel micro controller with sensors and a communication unit. Communication unit could be an RF radio frequency could be a laser module or could be corner cube reflector. So, this are for optical communication then it can have temperature light humidity pressure magnetometer accelerometer sensors. So, if you see the basic frame work is this is your communication architecture and this path is you Atmel which is a micro controller. And to which you have got multiple channels of analog to digital converter to which your sensors that are actually linked. And this Atmel micro controller manages the hold show, but; obviously, you need a OS to run here and In fact, this Berkeley came up with the ways called TinyOS.

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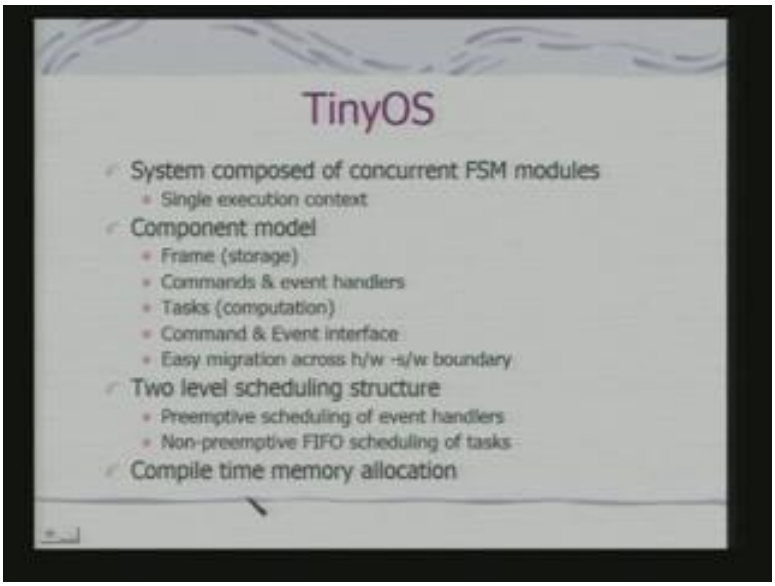

In fact, TinyOS the interesting feature of the TinyOS is that it is a small OS. In fact, the whole idea is that OS is being provided as a set of components and your application which use this component and you compile OS as well as application together you have a high level language specification. So, when you compile it together your application along with OS gets compiled in to a source code which gets loaded in to the actual mote. In fact, it uses actually non preemptive scheduling, because there is a task queue tasks are put on the task queue. And then they are scheduled for execution when the task queue is empty what happens? The node goes in to energy saving node. This tasks typically run to completion when this task is preempted whenever there is a interrupt, because there is a so, many sensors whenever there is the interrupt this tasks are preempted. This interrupts are refer to as events. So, each interrupt correspond to what is called an event context called an even context.

So, this is the basic event interface which is defined by a given context and when a even context means what and interrupts service to features of small duration and they would do some small work and again it would go back to the tasks. Task is not interrupted for servicing another tasks. In fact, the whole OS is model as a collection of concurrent FSA module with a single execution context. The most interesting feature of it at why this way the whole model has been built, because you want to minimize the complexity involved. The other interesting thing is that it is a compile time memory allocation there is no provision for dynamic memory allocation. The memory allocation is done

completely in the compile time cannot really have allot kind of a thing when you are developing an application in timing space, because that would change your memory requirements in run time and it require an overhead for heap management. So, that part is completely eliminated in TinyOS this another hardware example this is I want it to show.

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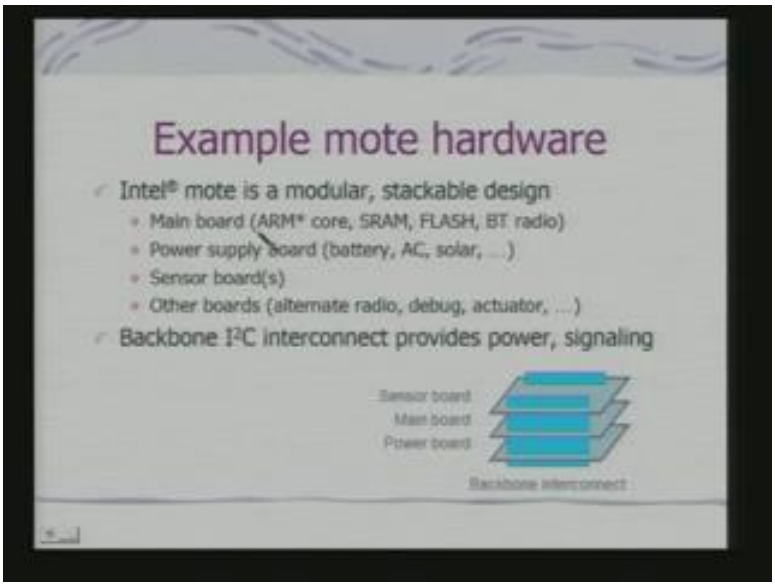

Because you got a high level processor like arm which we are already studied and it is mote coming from Intel family. So, it is a back backbone I2C interconnects provides power and signaling. So, you got a sensor board main board and power board and use them to connect via I2C configuration I2C bus we have already discussed.

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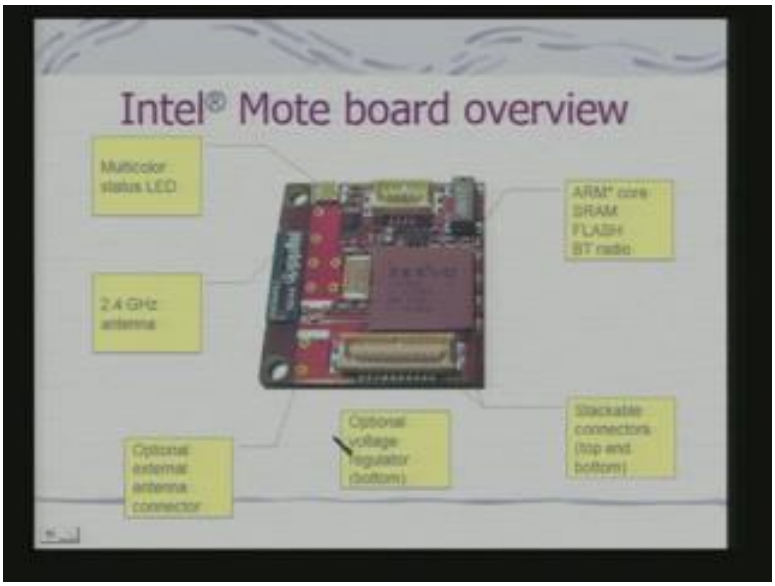

They also have this antenna and this arm code with a flash and BT radio basically it implements provide.

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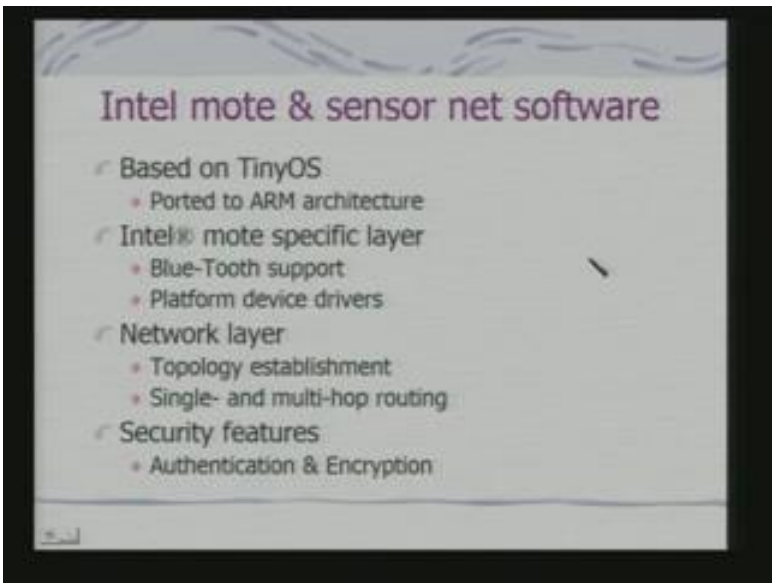

So, Bluetooth and the OS is again the TinyOS and provides all the features of Bluetooth management.

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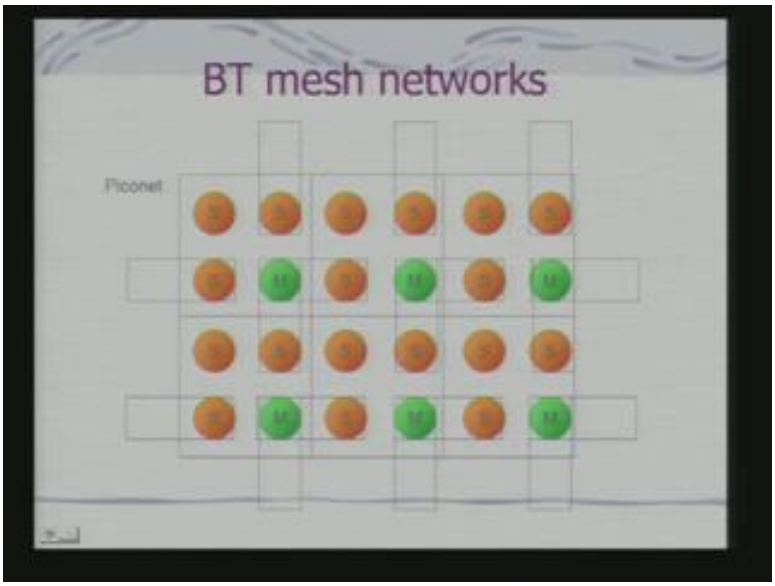

So, you can see how this motes can be used setting of the network. So, we have studied already Bluetooth. So, let us see I can have this nodes. So, effectively what you generate? You generate a piconet so, it is a fixed configuration you are tilling the space you are tilling the space and putting this nodes a piconet mate is set up. Then you have got multiple set up piconet and this piconet now gets connected. So, setting up your scatternet and the complete communication frame work so, this way I can have the connectivity to other nets. So, net can go on so, it is a tile.

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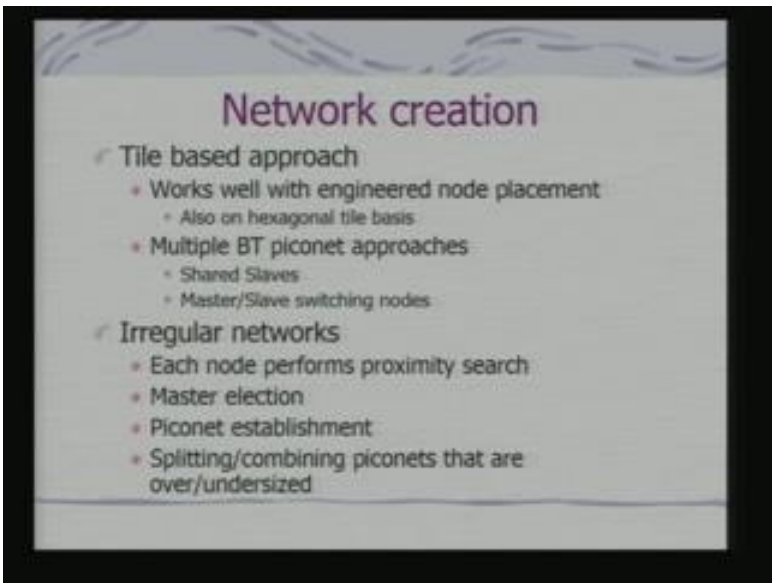

So, it is a network creation the tile based approach which is the very basic fix configuration. You can also have a irregular network where each node performance proximity searches which is basically your enquiry. And then you do a master election and set up the piconet. So, it is a basic negotiation and ad hoc which can be built.

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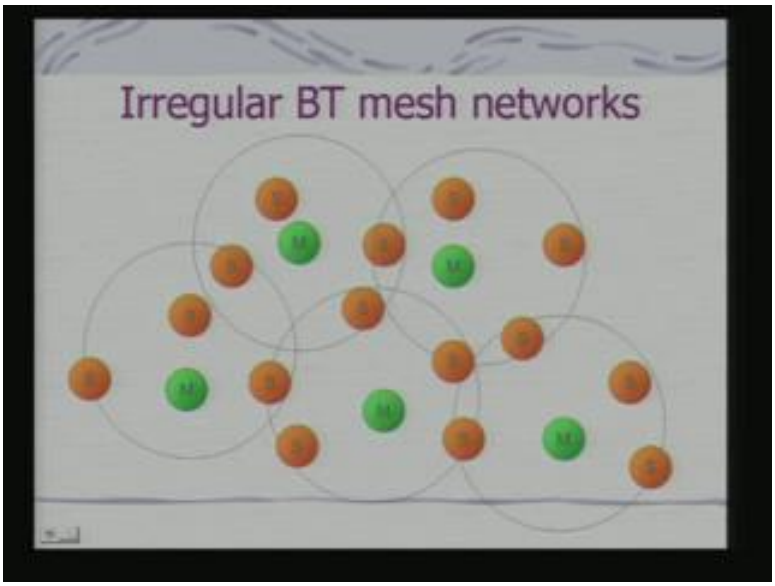

So, effectively I have this kind of node which is irregularly distributed. They start communication through enquiry. So, 1 gets selected as a master and then others become slave and you basically set up the piconet. And this can be done at over local over lapping intervals setting of the scatternet. So, basically you can see that using the Intel node, because it has got inherent support of Bluetooth in the software itself top of your tiny over. As well as the hardware support for Bluetooth communication you can use this kind of sensor node in an ad hoc fashion over Bluetooth network.

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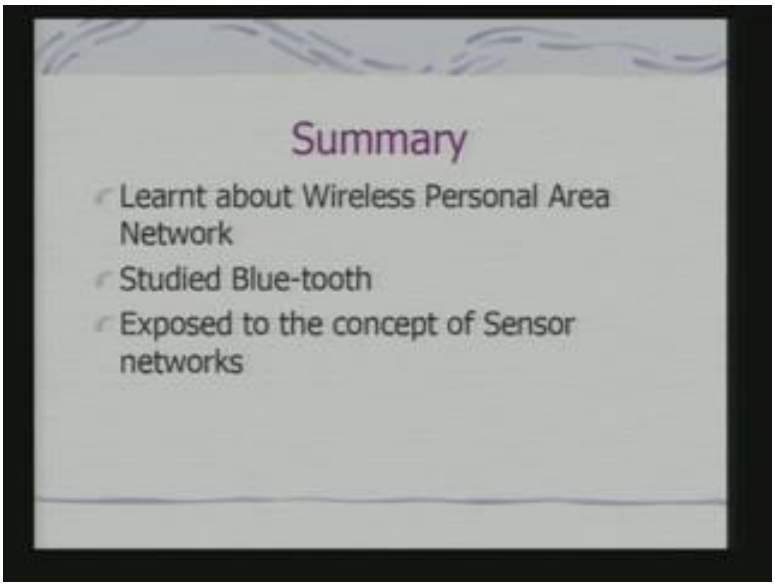

So, we have learned about today wireless personal area network studied Bluetooth and got exposed to the concept of sensor networks. And we have seen how using Bluetooth we can set up a very simple sensor networks. But there would be more interesting and sophisticated algorithm sensor nets for a which are energy conscious and as well as application conscious and their issues related to design of such a network basic applications. So, that is what we shall look at in the next lecture any questions? So, see when a see the basically establish a connection here. So, at slot is allocated. So, when a slave goes in to a kind of a hold mode the master would know that it is not, no longer participating in the communication. So, any of the other node which is in the park node and park mode can now, switch in to a slave if the master then the piconet itself. So, the basic idea is the piconet is set up with the master in place. So, until and analysis all of them agrees to hand off the piconet will no long where exists the master really does not over.