Introduction to Internet of Things
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Lecture – 05
Basics of IoT Networking-Part-I

In this lecture and a subsequent few, we are going to go through some of the basics on the networking aspects of Internet of Things.

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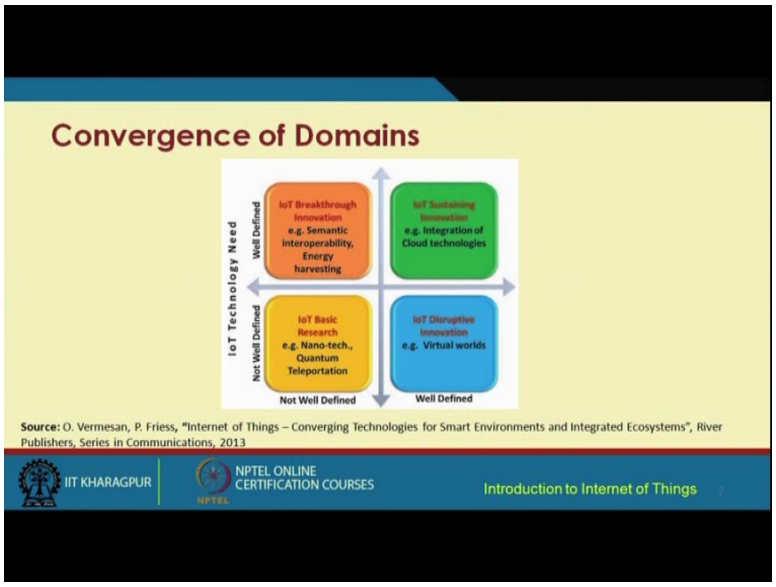

So, the first thing that we need to understand is that IoT has evolved a lot. So, starting from basic research, basic fundamental research and innovation, there has been different other types of innovation which are done through, which are disruptive, and some of the other innovations which are sustaining in nature. So, in terms of basic research, there has been a lot of research on the nanotechnology, the use of nanotechnology, the use of quantum teleportation. Quantum teleportation basically means that how the different information at the atomic level is sent from one point to another.

So, it is transported from one point to another at the atomic level and nanotechnology, it involves things like nano IoT, nano nodes, nano networking, nodes, nano sensor nodes and nano networks. That means, at the nanoscale forming a network which can be for different purposes, nano networks are used for different purposes in the human, inside the human body at the molecular level nano networks can be used. So, like this at the

nanoscale and for quantum communication, there has been lot of advertisements that has been done for involving basic innovations, basic research innovations.

So, this is one likewise for semantic interoperability. There has been lot of research on semantic in for interoperability. For example, let us see that a temperature sensor, it might be given the data as temp, another temperature sensor as temperature, another temperature sensor the third one. So, there has to be interoperability between all these different collisions, but they are all different to the same temperature, right. So, this is basically taken care of by things like semantic interoperability. There has been lot of research on this one, this particular aspect then energy harvesting. Again there has been lot of research, you know energy harvesting through different renewable sources such as wind energy, solar, etcetera. How these can harvest, you know how these deferent renewable sources from these how energy can be harvested to power the different nodes and IoT, these are very small powered you know small sized nodes with very limited power.

So, energy harvesting is very crucial. It plays a crucial role in the sustenance of these networks. So, there has been lot of work on this one also and this has been like you know these aspects for example, there has been lot of brick through innovation on these. Then, disruptive innovation for example virtual reality, augmented reality you know. So, these are all like you know involvement of these incorporation into the IoT network, there has been lot of research on this particular front and things like cloud big data, these are like sustaining technologies for IoT. Again there has been lot of work on these technologies as well.

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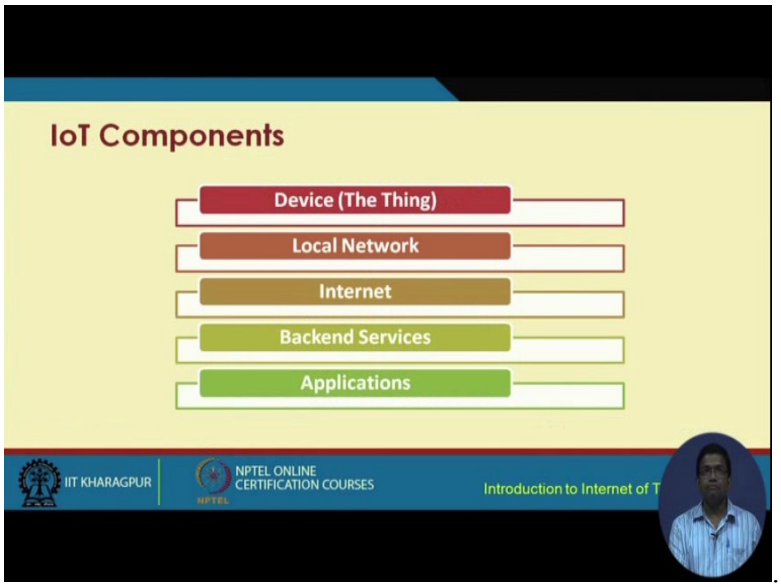

Now, when we talk about IoT, if we think about IoT, what we have? We have these different things which as I said in one of the previous lectures is these things are fitted. These are basically physical objects once again. So, these physical objects are fitted with different sensors and these sensors basically sense different physical phenomena that are occurring around them.

So, these sensor fitted things, sensors actuators and different other emirate devices, these are one component of the IoT, but these become different nodes in the network, these are the individual nodes in the network. So, then what we have is, these nodes they have to communicate with one another and the information that is sensed by one of these sensors fitted to these nodes, this information from the sensor and the other sensors, these are taken and are sent to the other sensor nodes, the destination nodes. So, how is that turn? First this information has to flow through the local network and then, if the destination, intended destination is outside this local network, then it is sent through the internet.

Typically if we are talking about an IoT which is basically internet based IoT, then basically it is going to flow through the internet or some other wide area network and finally, it is going to arrive at the intended destination node and may be there can be some at that point, actually there can be some analytic engine which is running on some backend server, those could be there and from that point from the decision, from these analytics, they can run on these servers decisions about actuation could be made.

So, what we see is from sensors to actuators through the local area network, the internet involving you know backend services analytics which includes again some you know high end processing at different servers and different complex algorithms, execution of different algorithms which are based on may be machine learning neural networks and so on and so forth. These are all required. So, basically you know what happens is we basically can conceive an IoT as a very complex system involving sensors, actuators, networks, local area, wide area internet and different servers, different algorithms, machine learning and so on, all executing together to make the system function as as one single entity. So, going back we have in this local network as you are saying then we have the internet, we have the backend services and finally, the applications that I have been served.

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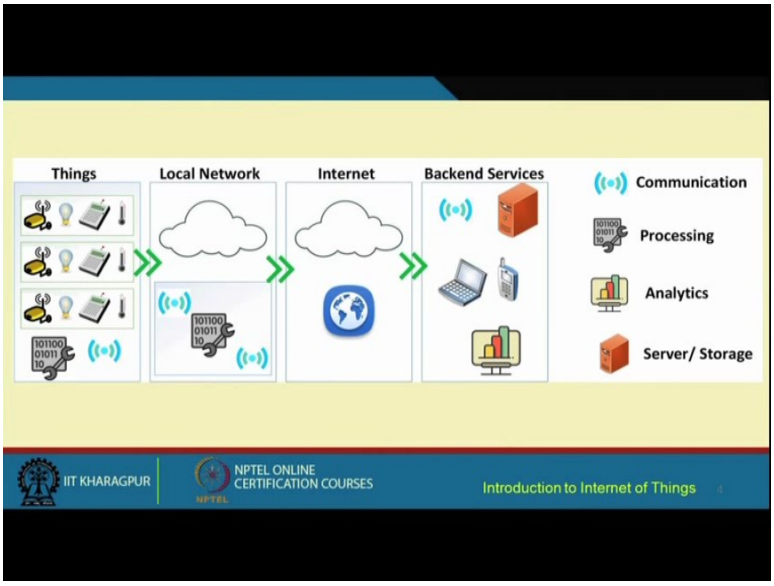

So, these are the different basic components of IoT. So, this is the scenario that I was referring to earlier. So, what we have we are these different things. These things could be like you know different physical objects which are fitted with different sensors. These things could be telephones, lightning systems, could be cameras, could be different other scanner, sensors like the temperature sensor and so on and these things are able to communicate with one another with the help of wireless technologies like Zigbee, Bluetooth, WiFi and so on. So, as you can see that this wireless basically helps these different devices to talk to one another and this information from these devices, they will go through a local network and from a local network, they will go through the internet to

you know these data are basically sent to the backend services involving different servers processors and so on and so forth. For running different analytics and then based on that different devices can be actuated you know may be a pump. This is an example that I gave earlier in a previous lecture basically for agricultural purposes. The use of IoT pump might be started might be actuated based on the data that is received from the sensor nodes and based on analytics are run at the different servers that are involved in the backend service processing.

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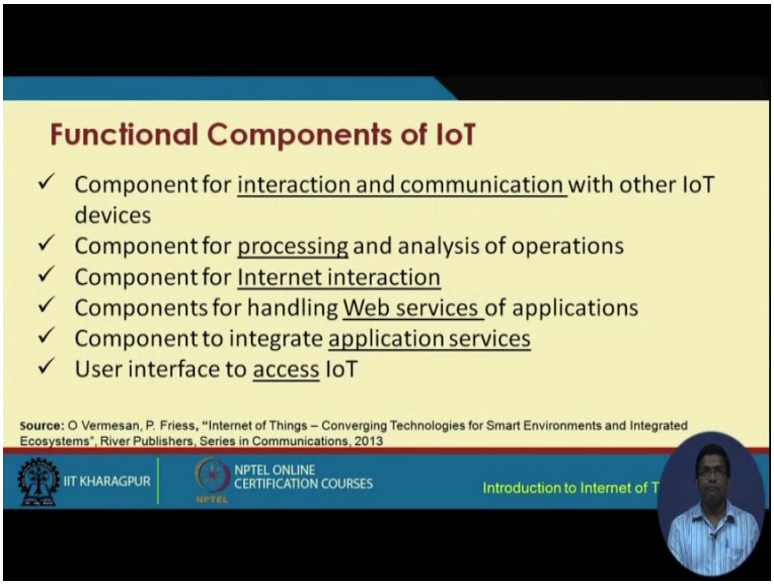

So, in terms of the functional components of IoT, one of the very important things is basically interaction. Interaction not only with the physical environment by this different sensors but also interaction and communication with the different devices, that means, a different nodes in the IoT in the IoT network, then comes the processing. So, processing and analysis of the different functioning and the operations that taken place, so processing of that data, the processing of operations, so this is another component, the third functional component is basically the interaction typically with the internet and because you know at present most of the times, the most of the IoT implementations are still using the internet. So, it is all you know internet powered IoT implementations.

So, internet interaction is one of the very important components of building IoT. Then, we have the web services, web services machine to machine communication and so on. So, basically what is going to happen earlier most, when you talk about a web

technology, typically we are talking about human to machine communication, you know web service we are talking about you know some machine sending or some equipment basically sensing and sending that data to another machine for further processing or machine to machine communication is involved and offering different services. So, one machine offer some services to another machine and so on. So, this is basically you know this sort of thing in a IoT scenario is taken care of typically and then, we have the integration of different applications services and the user interface to access the IoT. That is another component.

So, there has to be a user interface, a human interface to access the IoT network or the IoT you know mega network.

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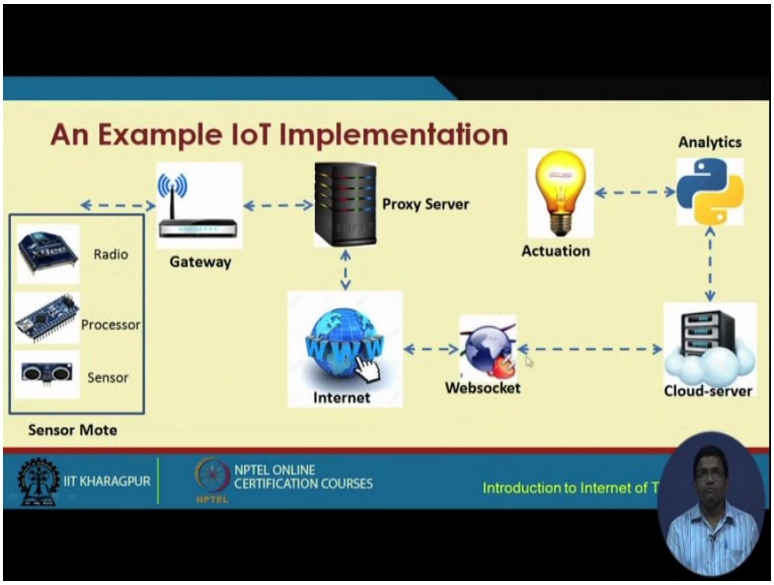

So, looking at this particular figure, I would like to try to clarify how the IoT implementation is typically done and it can be done to achieve different application needs. So, this is a figure which shows that we have different sensors, processors and radio. It refitted to each of these devices or the sensor nodes or the sensor motes or the IoT motes as you may want to call them. So, these motes, they talk to one another, but these different sensor nodes, they are basically within the jurisdiction or the domain of the gateway. So, the gateway is basically tasked to assign different locally unique addresses to these different nodes, to these different IoT nodes and the gateway basically takes care of the local addressing within that particular local area network. So, from the

that point, all the data can flow through a proxy server if internet access is required. So, it will go through the internet, then a web socket and from the web socket, it goes through a cloud server. That means, this is where lot of analytics and backend processing takes place and based on that the actuation based on the analytics and the infer ant says that and run from the sensed data actuation of different devices can take place.

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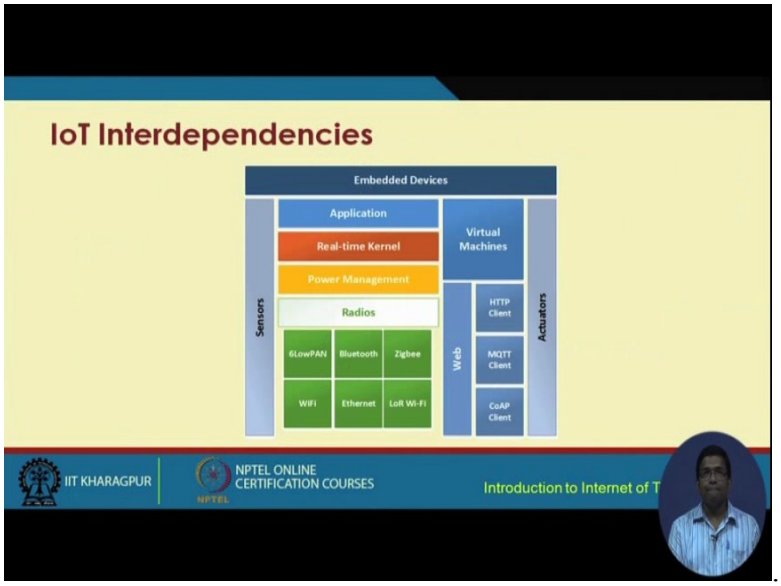

For example, lighting a particular lamp could be the actuation of that particular lamp. We have different interdependencies that are evolved in the implementation of IoT. So, if we look at IoT from another prospective or we have sensors, we have actuators and a bunch of other things that they are in between as shown in this particular figure. So, this is basically the entire spend of these different embedded devices.

So, the sensors basically sense the data and that data is basically serving the application requirements and then, we have an operating system and a power management unit which basically you know does things like duty cycling of the sensors, how much the sensors you know how much time we are going to be active or how much time they are going to be in the sleep state, how to power them because these are very small sized you know, very resource staved sensors. So, basically the power unit in these sensor nodes, these are very small in size. So, basically consequently what happens is these embedded devices, they themselves are very resource staved.

So, we have a very power management unit which basically takes care of power management as a whole. How much power is required, for how long it is going to power, then what are the ways to harvest energy if at all it can be harvested and how much power consumption is going to take place at different points of time, can it be optimized different points of operation on and so on and so forth and as you can see over here, there after we have these different radios involving bluetooth, Zigbee, 6Low Pan, Wifi, Ethernet and low range basically wifi.

So, these are the different you know radios that can help in communicating the data that is sensed onward to other nodes. These basically different radio technologies can help for the communication purpose. So, alongside we also have things like virtual machines which takes care of the virtualization of the nodes, we have the web, we have you know different things like http client MQTT client, CoAP client. So, these are the once MQTT CoAP, we are going to talk next in the subsequent lectures. So, that will make our understanding clear, but these are like no different application level protocols that are used for functioning of these different IoT devices and finally comes the actuator verticals.

So, we have the sensors, we have different applications operating system, power management, radios, virtual machines web and then, we have these actuators all together which forms the embedded systems, the embedded devices.

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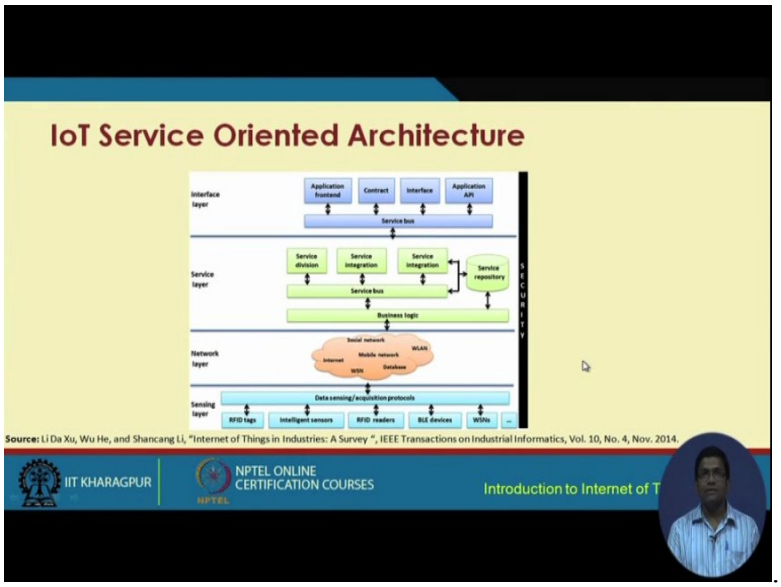

Now, let us look at the service orientation, the service oriented architecture of IoT. So, in the IoT if here what we have at these different layers, the sensing layer, the network layer, the service layer and the interface layer.

So, we have four different layers and as the name suggests, sensing layer basically takes care of sensing through different RFIF tags sensors and so on and so forth and then, data are sensed are acquired and so on are sent to the next layer higher up which is the network layer. The network layer basically serves sensor networks, social networks you know different other networks and data bases internet and so on. That is the network layer. Then, what we have? We have the service layer which deals mostly with the service delivery such as service, division service, integration service, repository service, logic by business logic and so on. So, all these different things that I involved with the offering of the services to support the business functions.

Then, we have the interface layer, we have the application frontend, we have a contract interface and application APIS. So, this becomes the interface layer and when we have the security issues which basically span all these different layer verticals, sorry layer horizontals.

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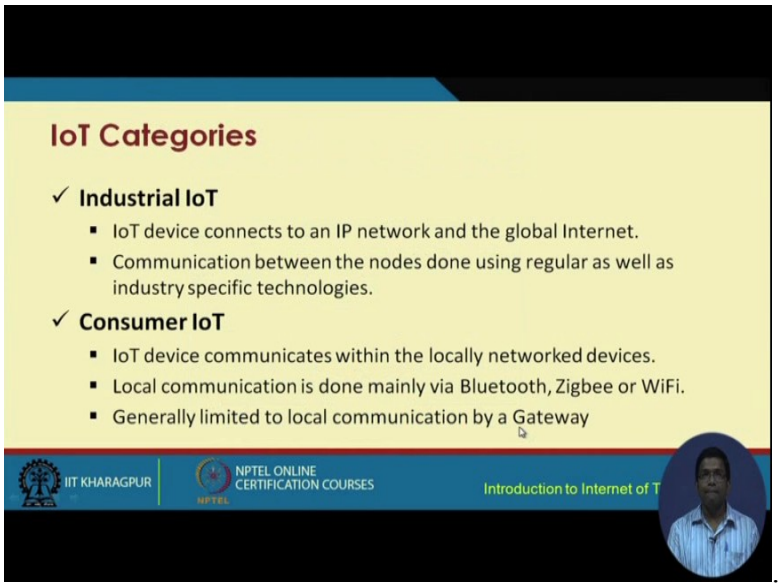

So, in terms of the categorization of IoT, it can be categorized into two. One is the consumer IoT which is what typically most of the people tempt to use and these are here, basically these different devices, they communicate with another through these local

networks and it can be you know find a further communication can also take place over the internet as well depending on the requirements either local or through the internet. Then, we have the local communication which is typically done via bluetooth, zigbee or wifi. So, basically this local communication is constraint within the bounds or within the domain of the IoT gateway. So, this is consumer IoT. Then, we have the industrial IoT which is basically quite similar to the consumer IoT, but the application interest is in the industrial sector.

So, we are talking about manufacturing industries with different machines, with these machines are fitted with different IoT devices and they together become the IoT device. They have different sensors and so on feature are there which can node as a whole can communicate with other machines and so on. So, this becomes the industrial IoT and basically, there are different communication that takes place between the different nodes as well as different industry specific technologies. Now, we talk about IoT gateways.

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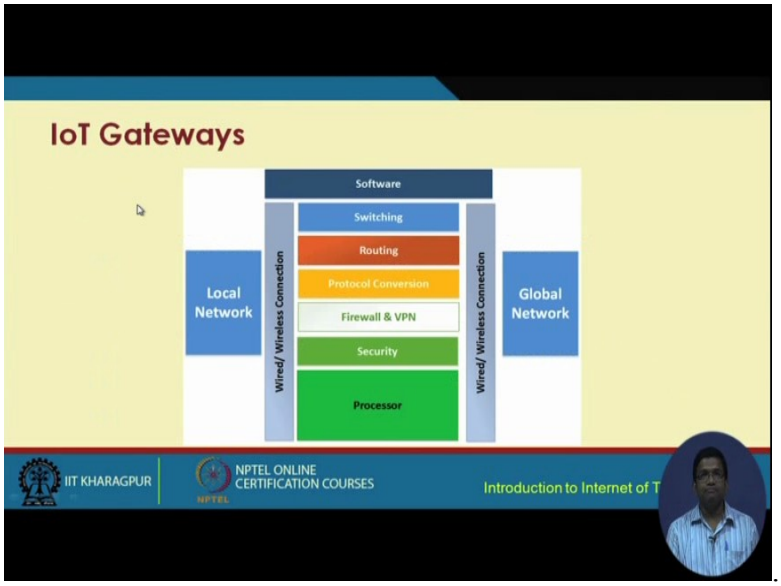

So, this is what I told you that in a local network, you have this locally unique addresses and that is they are within that local area network, IoT network.

So, these local addresses basically they take care of the addressing of the different nodes now. So, what are these gateways doing? So, the gateways basically take care of the addressing, but then in this is what the gateway structure looks like. So, this is what is here. So, we have the local network on one side of the gateway, we have the global

network on the other side of the gateway and this is where the gateway, this is how the gateway looks like. So, the gateway has and functions different tasks such as switching, routing, protocol conversion, firewall and VPN services, security as a whole and processing. So, this is what a gateway does and the gateway with the local network and the global network communicate via the wired or wireless channels and so on.

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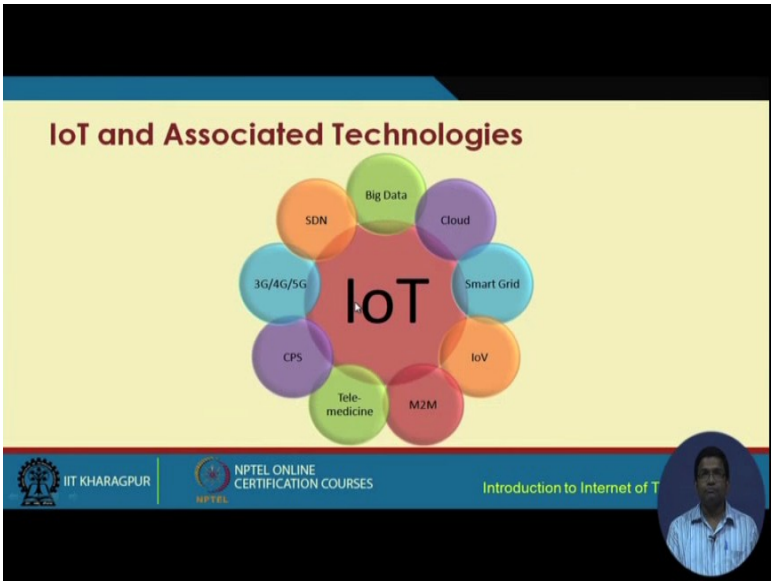

So, this is how the IoT gateways function different associated technologies of IoT involving big data, cloud, smart grid, internet of vehicles. That means, you know different vehicles on the road are fitted with different IoT devices which can communicate with one another and different intelligence about the route traffic conditions, about the offering different road side services can make possible with the help of internet of vehicles. Then, we have the machine to machine communication where one machine talks to another without any human intervention.

We have telemedicine offering you know offering health care services to the demote hospitals, demote health care centers and so on. CPS server physical systems, we have 3G, 4G, 5G, we have sdn and so on. So, these are the different associated technologies which together make IoT which together are used to deliver IoT solutions.

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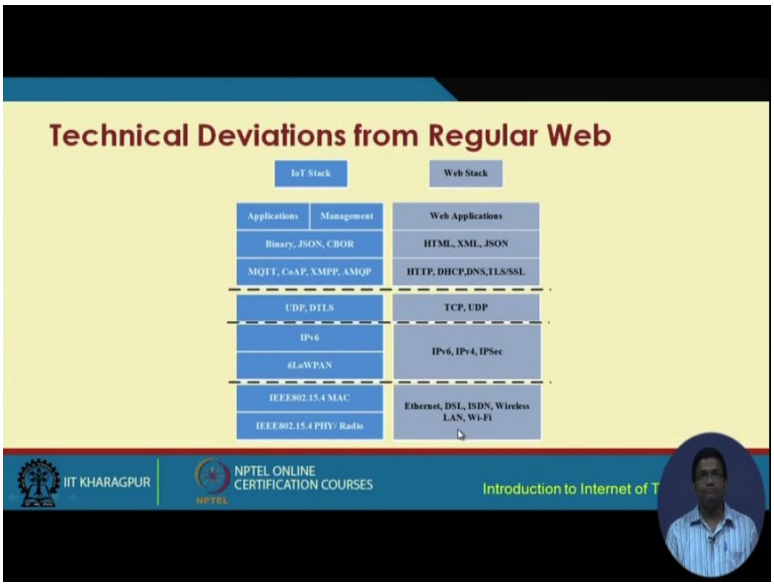

Now, you know if we try to make a side by side comparison between the IoT stack and web stack, we will see that more or less the application layers remain the same for both IoT as well as the web. So, conceptually these application layers, these different layers, communication layers and application layers that communication layers remaining the same between IoT and web, but what is different is that we have a new set of protocols that are used over here. So, the new set of protocols and additionally in IoT, unlike in the case of web things such as different types of management, management of the network, management of the power, management of different other resources, these are all additionally taken care of in the IoT node in the IoT stack which is not available in the case of the web and this is very much required because you know in the case of IoT, we are talking about heavily resource constraint nodes and this heavily resource constraint nodes basically required management, network management in terms of energy, in terms of processing, in terms of data and so on so forth.

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So, there are different key technologies that basically help IoT survive. We have the future internet knowledge aggregatio obtained through data assignation, data collection processing and analysis. Then, we have different standards, we have sensor networks, we have communication, we have cloud computing, we have discovery services, nanoelectronics embedded systems, software system integration and last, but not the least what is this over here on top is the security on privacy issues. So, security on privacy issues are per amount in IoT because there are heavy concerns because you know we are dealing with resource constraint nodes with communication constraints, bandwidth constraints, processing constraints, energy constraints and so on. So, these nodes become very much valuable to different type of attacks, different types of security breaches and also because IoT systems are very much detailed intensive, there is lot of information that frozen through the network as a consequence of which the privacy of the individuals of the organizations might be at stake. So, security and privacy and trust also which is not mentioned over here, these are very much important to power IoT technologies. There are different types of challenges, securities, scalability, energy efficiency, bandwidth management, interfacing interoperability.

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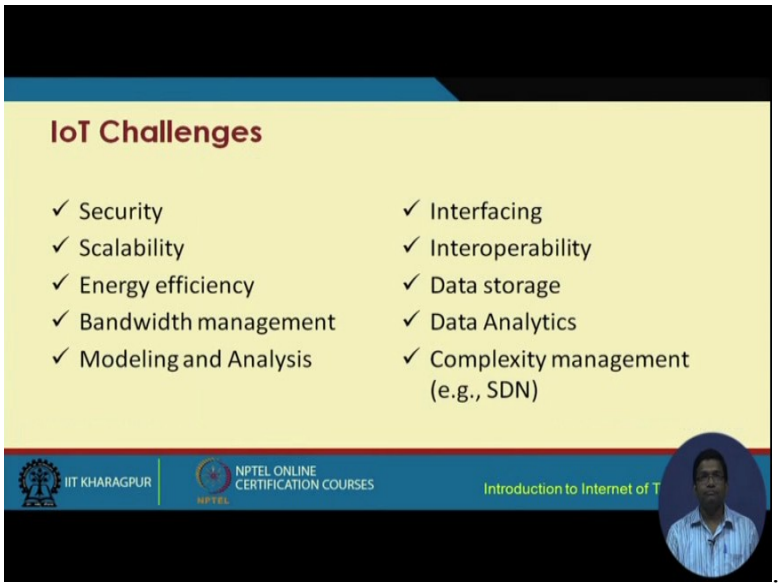

So, when we are talking about interfacing, it is typically we are referring to device interfacing. So, different you know one device talking to another device may be these devices do not belong to the same vendor, they are not running the same stack, they are not following the same standard and so on. So, then comes consequently then comes the interoperability issue. How to make these devices talk to one another? How different protocols, the different devices, the different algorithms, they are going to hand shake with one another? So, like this, this is another challenge which is typical of IoT implementations and then, we have data storage and analytics and complexity management with tools such as SDN. So, SDN basically helps in addressing the complexity of systems by decupling the control plane from the detect plane of the networks, different considerations and they are for building IoT. One is that will have a straight network architecture which can be used by different IoT implementations.

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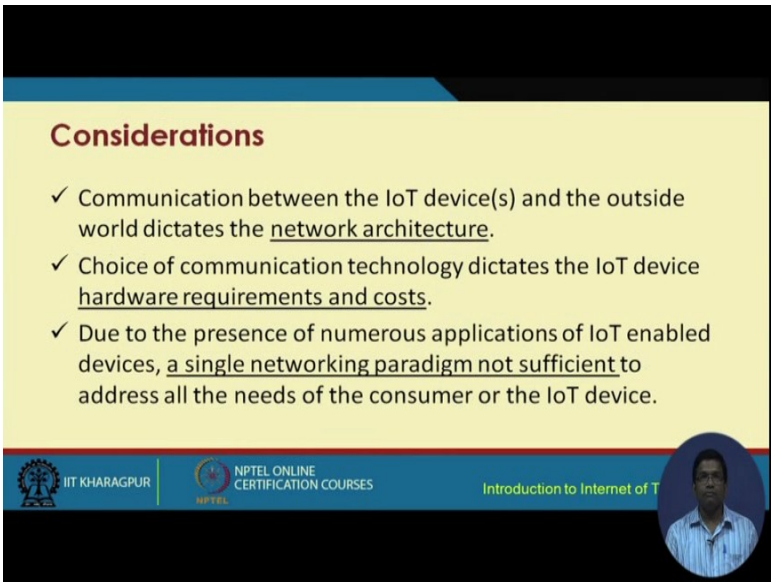

So, there has to be governing network architecture. Number two, hardware requirements and cost are important you know what type of communication hardware are going to be used and different devices in the costs that are involved and due to the presence of numerous applications of IoT enabled devices, a single networking platform may not be sufficient to address the needs of the consumer or the IoT device.

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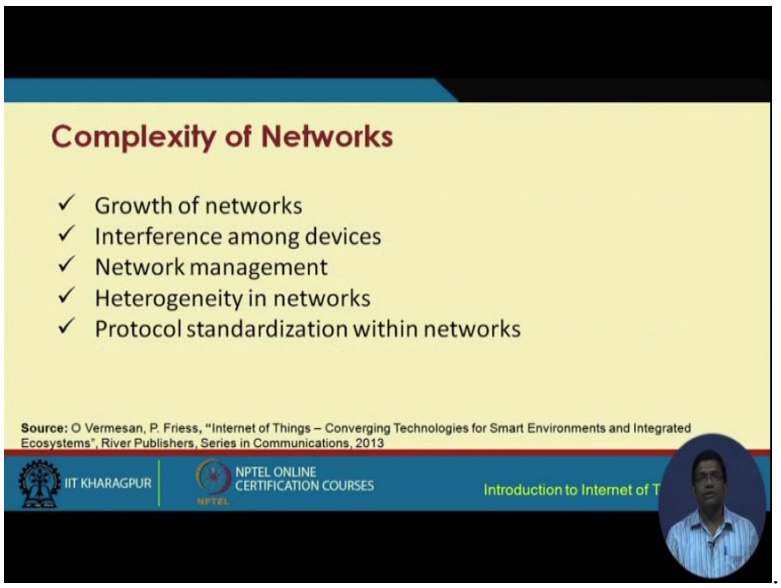

So, this is another. The third consideration that has to be taken into account while building the IoT systems, then we have the complexity of the networks. Uou know if the

number of nodes in the network increases, then whether in the solution because if the system is going to be you know sustainable whether it can be scaled up or not, then we have interference among the different devices. This is very much vital in any network. Interference is a crucial issue and particularly IoT networks involve lot of large number of typically densely deployed nodes and these nodes as you know typically wireless power by wifi or bluetooth or zigbee and so on.

So, interference between these different communication between these different nodes that at the corresponding radios and so on is possible. So, how do you handle it? Network management as a whole as I was telling in earlier involving you know energy management, involving computation management, involving communication management, involving service management and infrastructure management and so on. So, network management as a whole then heterogeneity in the networks. Heterogeneity in terms of the devices standards the protocols, the algorithms and so on.

So, how do you handle because IoT devices unlike traditional internet, IoT networks come in different, you know come from different vendors, different devices coming from different vendors, different devices using different algorithms, these different protocols being used and so on. So, all these basically invite dealing with the issue of heterogeneity and lot of heterogeneity is involved. So, how heterogeneity is taken care of and protocol organization and standardization within the network, how the different protocols can be standardized, so that a device running one protocol can talk to another device and so on.

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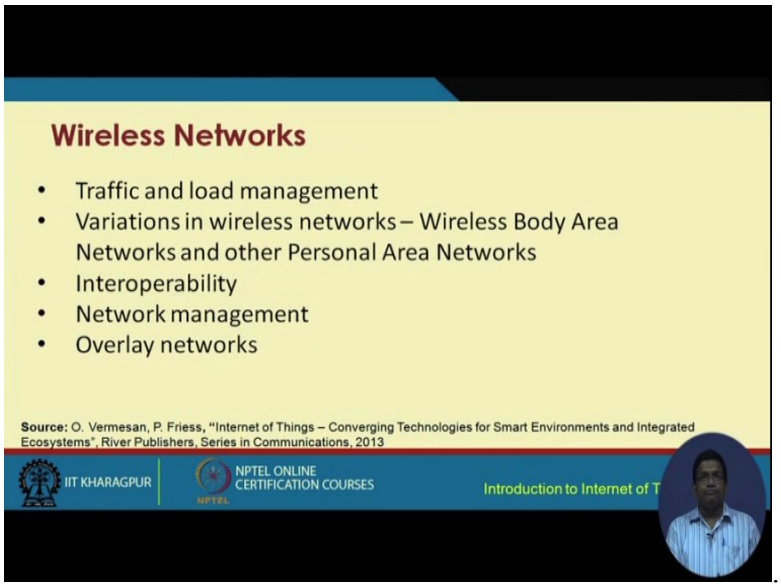

The different wireless networks are used issues such as traffic management, load management, then variations in the different wireless network forms for example, wireless personal area network, W turn versus wireless body area network, interoperability which I have already mentioned just a while back, then network management and overlay network. So, basically you know the overlay network takes care of some kind of a virtualization of the physical devices on you know and one type of this physical virtual devices and the networks and overlay is created, this is basically the overlay network.

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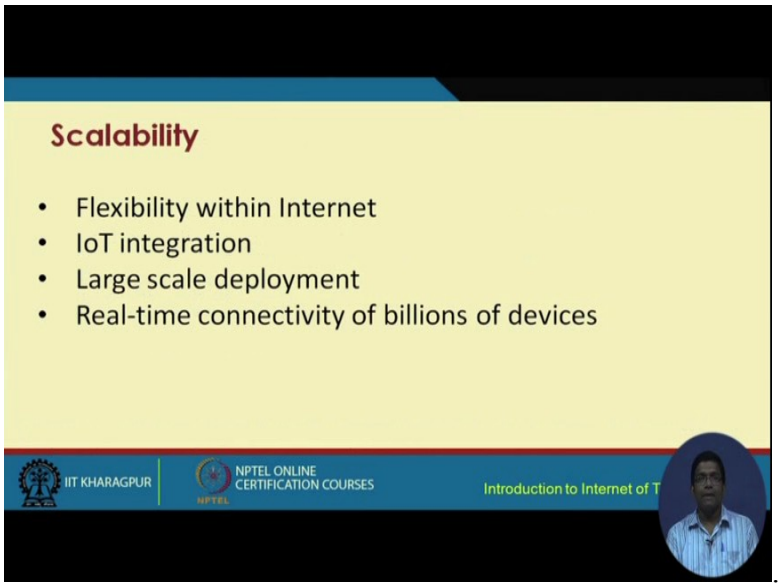

Scalability is involving flexibility within the internet. Then, integration of different IoT devices, there are many manufactured using different standards may be in using different you know vender specific protocols. So, IoT integration is a very complex issue which basically dictates the scalability of the system, large scale deployment issues and real time connectivity of billion centurions of devices.

With this we come to an end of this lecture on the basics of IoT networking, but this is just a first part. We are going to cover many other issues involving the networking aspects of IoT in the subsequent lectures and from there, we can understand from this subsequent lectures, we can understand how forming an IoT is very complex, what are the different protocols, individual protocols that are how they are, may not be a single isolated or a single thread head. Let us say one protocol for IoT as a whole, but there all these individual protocols settled there. So, how that can be taken care of and for how can architecture be sent up between these different IoT devices manufactured by different vendors. So, like this actually there are different complexities that I have involved. So, we have really talked about that in the subsequent lectures.

Thank you.