Introduction to Internet of Things
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Lecture - 36
Software - Defined IoT Networking - Part- II

So, now we are going to discuss about software defined networking and and its use in IoT. So, here we are going to talk about how SDN can help in improving mobile networks specifically.

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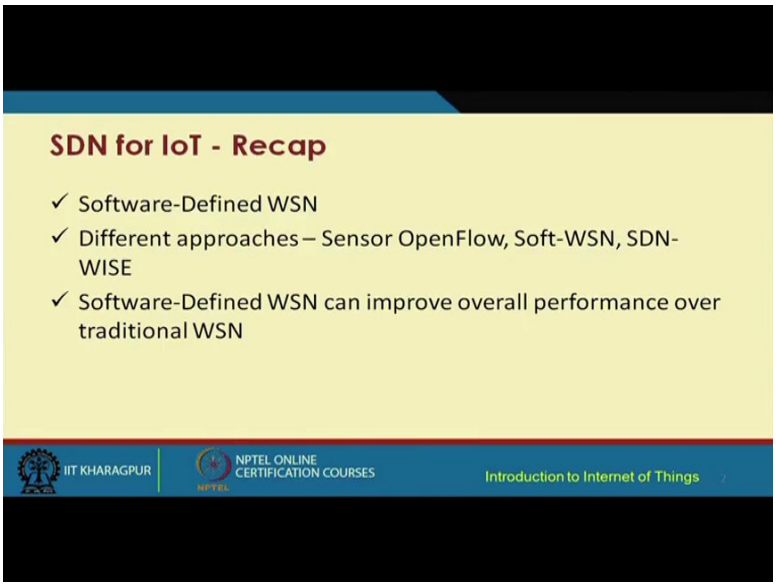

So, what we have already discussed in the first part of SDN for IoT lecture is that we have. So, a sensor networks and software defined networking can be used to improve the performance of sensor networks. So, we have different SDN approaches for WSN's and different approaches like Sensor OpenFlow, Soft-WSN, SDN-WISE are already available in the literature which can be used. Community can use it if they want to implement sensor you know SDN for WSN and we have also discussed about how software defined WSN can improve the overall performance of the network compared to the traditional WSN.

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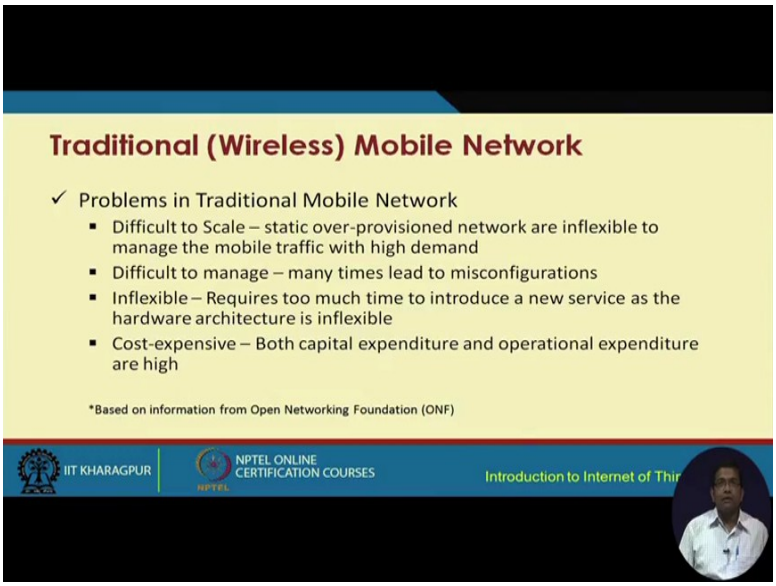

So, this is what we discussed earlier. Now, let us talk about the Traditional Mobile Wireless Networks. There are different problems in these Traditional Mobile Networks and these networks can be like Wi-Fi based networks. Mobile cellular networks or other mobile networks, the problems are with respect to scalability. So, you know what happens is each of these nodes in the networks if the nodes including the base stations access points etcetera, typically they are statically over provisioned you know. So, there is over provisioning in each of the nodes in these networks and they are inflexible to manage the mobile traffic with high demand.

They are difficult to manage many times. This leads to misconfigurations. They are inflexible and requires too much time to introduce a new service as a hardware architecture is inaccessible and they are cost expensive, both in capital expenditure and operational expenditure terms because both the capex as well as the opex are very expensive are very high.

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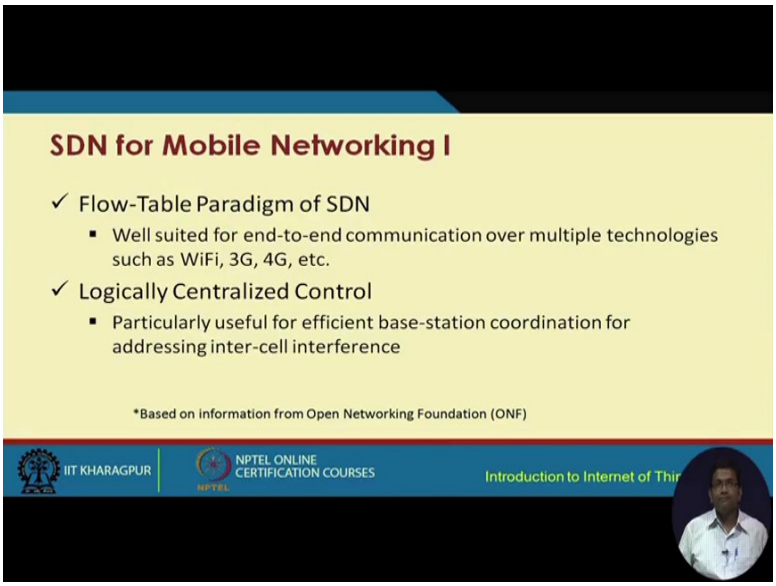

So, two things are important and this is this information has been adopted from the Open Network Foundation. So, two things are important when we want to adopt SDN for mobile networks. One is the flow table paradigm of SDN which is well suited for end to end communication over multiple technologies, such as Wi-Fi, 3G, 4G and so on so forth. The other one is the logically centralized control which is particularly useful for efficient base station, coordination for addressing intercellular interference. So, we are going to talk about each of these in slightly more detail in the next little while.

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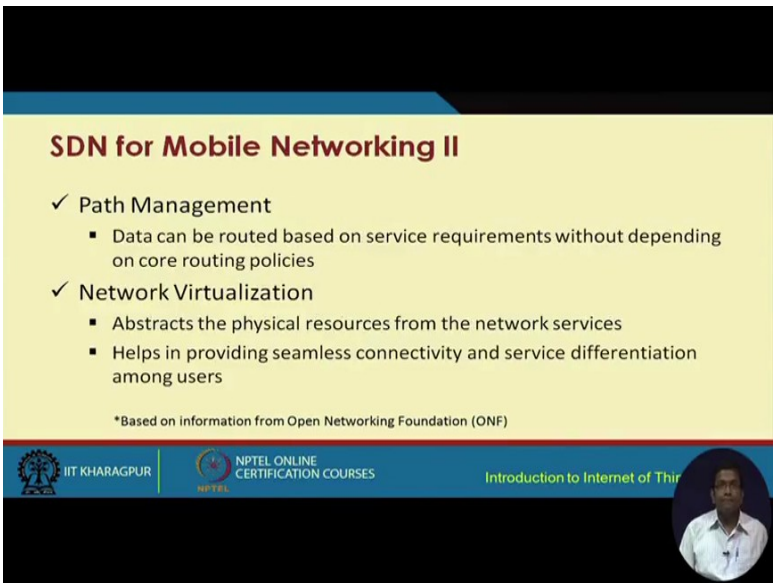

Other issues which are also important are path management which concerns basically data that can be routed based on service requirements without depending on the core routing policies and network virtualization which is about abstracting the physical resources from the network services. This helps in providing seamless connectivity and service differentiation among the users.

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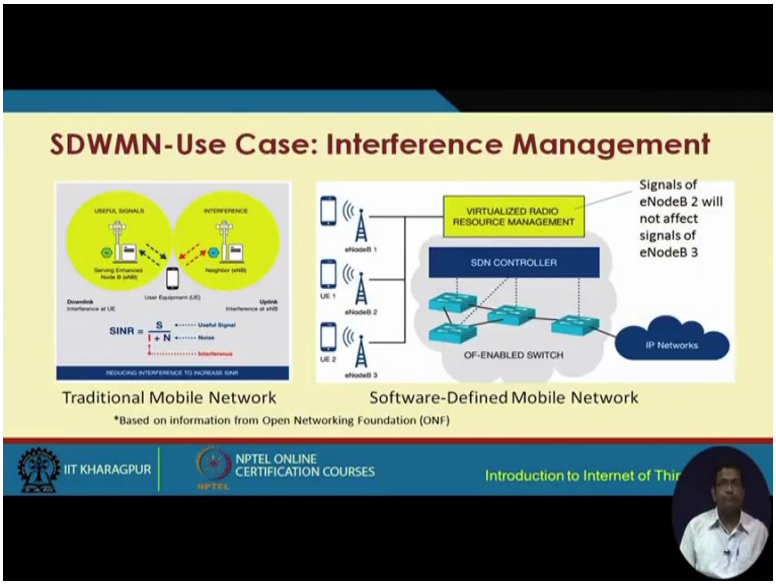

So, in a traditional mobile network, what happens is when a mobile equipment like this operates, it connects with a base station or an axis point for regular data. You know data back and forth between it and that access point and this particular node, it serves this particular access point, sorry this particular user equipment, but while it is doing so, it is also getting, it may also get affected by interference from another node. So, this red colored arrows basically shows the interference and the blue colored ones basically shows the regular data, transfer data communication.

So, there is this solution which is this SDWMN. It tries to address this particular problem of interference through the help of SDN. So, here what we see is the architecture of the software defined mobile network and as we can see over here, we have an SDN controller and the Virtualized Radio Resource Management Unit which basically takes care of interference with the problem of interference. So, this particular unit what it does is, it takes care of issues such as the signals of eNodeB 2 and the signal of eNodeB 3, they do not affect each other. That

means, the signal of eNodeB 2 will not affect the signal of eNodeB 3 affect means through interference affecting through interference.

So, this is made possible through this Virtualized Radio Resource Management Unit which has been proposed in this particular protocol or the solution which is SDWMN and with respect to mobile traffic management.

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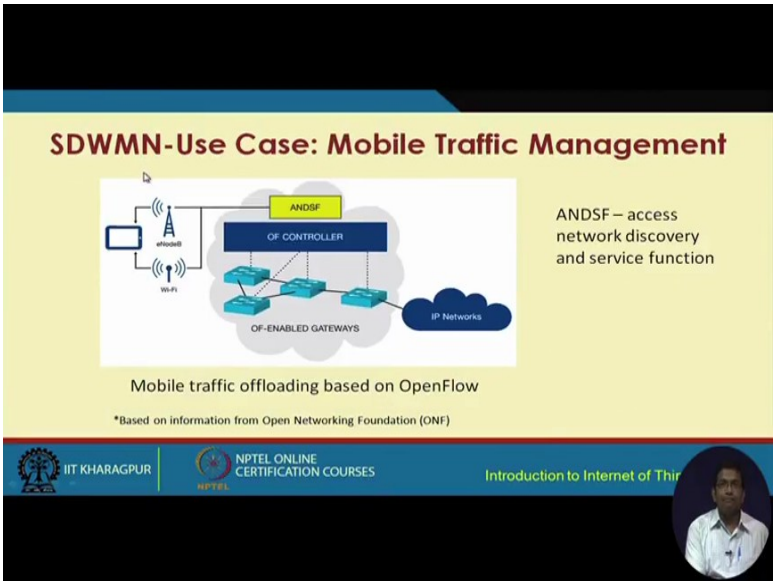

There is this unit which is the ANDSF, Access Network Discovery and Service Function Unit which basically takes care of it and this is done this way. So, we have the cellular as well as the Wi-Fi and the mobility. So, basically the what happens is when the user is moving, so the user can get first connected to the regular. You know Wi-Fi access point, then you know it might have better connectivity with the cellular network 3G, 4G and so on.

So, basically this particular solution basically takes care of it how to interoperate between these different different when the user is moving and is getting connected with you know and has different signals from different different devices from different networks, Wi-Fi network, 3G, 4G networks etcetera. How it is going to do this switching? So, the SDN basically comes to a rescue to solve this particular problem.

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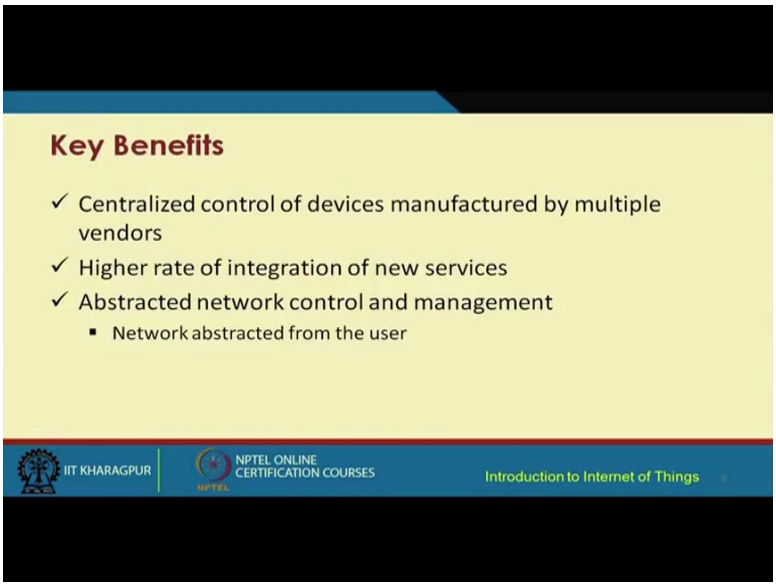

The key benefits of the solution is that centralized control of devices manufacture by multiple vendors is made possible. It is possible to have higher rate of integration of new services and abstracted network control and management is made possible through this particular solution with that option of SDN in these mobile networks.

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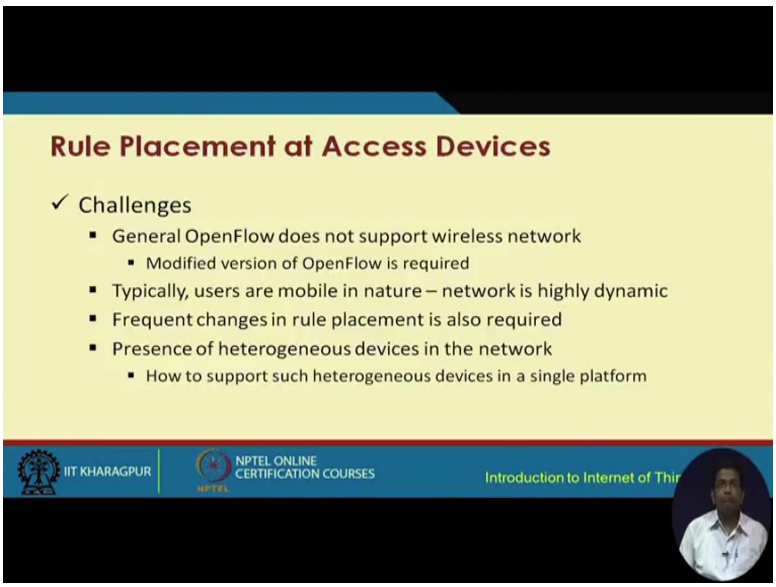

So, how so you know when we talk about SDN and in SDN based solution, it is about rules, flow rules and rule placement controller placement and so on. So, let us now look at how rule placement is made at the access devices in these networks. The challenges that are have to be

addressed are that number one, the general open flow does not support wireless network. So, you know because it is general open flow does not do that. Some kind of a modification of the existing open flow is required. Number two, typically the users are mobile in nature and the network is highly dynamic. Third challenge that has to be addressed with respect to rule placement in these networks is that the frequent changes in rule placement is required and the presence of heterogeneous devices in the network might is a reality in these scenarios.

So, basically you know what happened at that last point, what it says the last challenge what it says is different types of heterogeneous devices having different configurations supporting different you know vendor specific solutions and protocols and so on exist in a realistic mobile based IoT network. So, how to support such heterogeneous devices in a single platform? So, these are the challenges that have to be worked upon in order to deal with the rule placement issue.

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So, there are different approaches or different solutions that have been proposed for it. Number one is ODIN, number two is Ubi-Flow and number three is Mobi-Flow. ODIN basically proposes the use of an agent. It is an agent based solution, agent based architecture.

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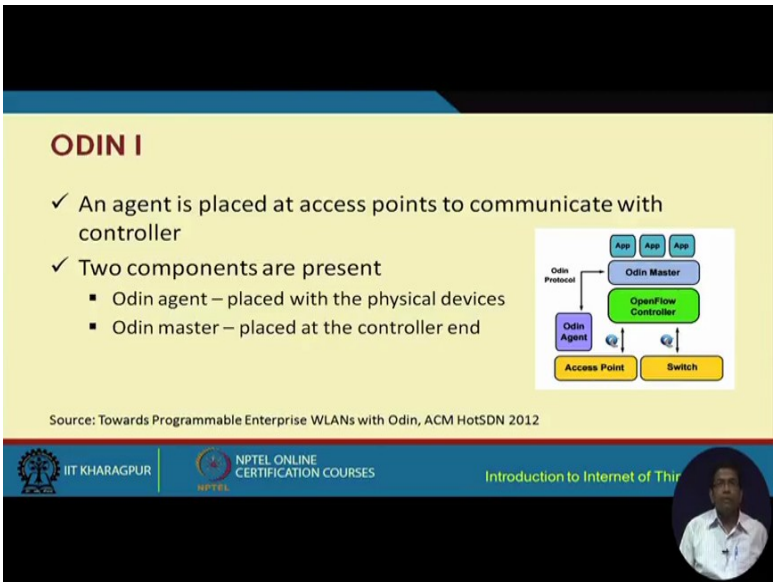

So, here an agent is placed at the access points to communicate with the controller. So, this is the ODIN agent and there is the ODIN master. So, we have the ODIN agent which is placed at the physical devices at the access point. For example, the ODIN master which is placed at the controller and now this is this hand shaking between the communication between the ODIN agent and the ODIN master that is taken care of by this ODIN protocol.

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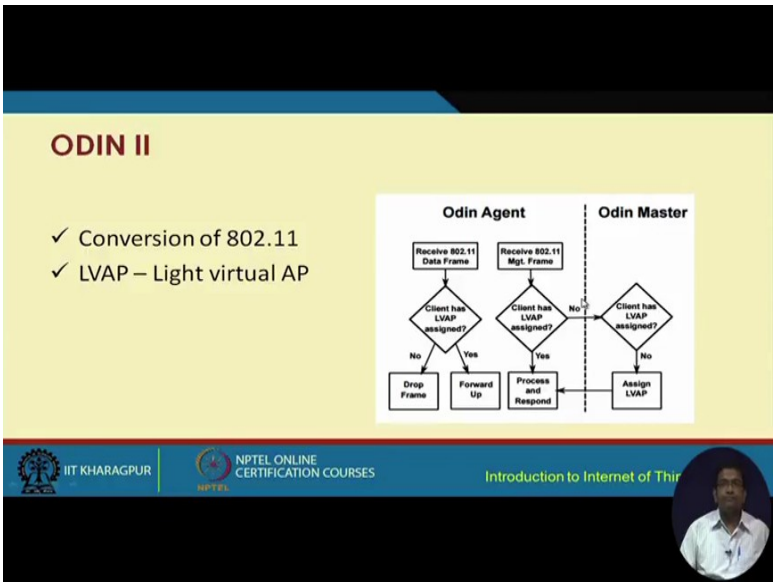

So, it uses the communication between the ODIN agent and the ODIN master. The corresponding flow diagram, the flowchart is shown over here. We do not need to understand

in detail, but it is given for those who might be interested to understand it nonetheless and so, basically it is a handshaking that goes on between this ODIN agent, add the access device and access point and the ODIN master at the controller that makes ODIN function.

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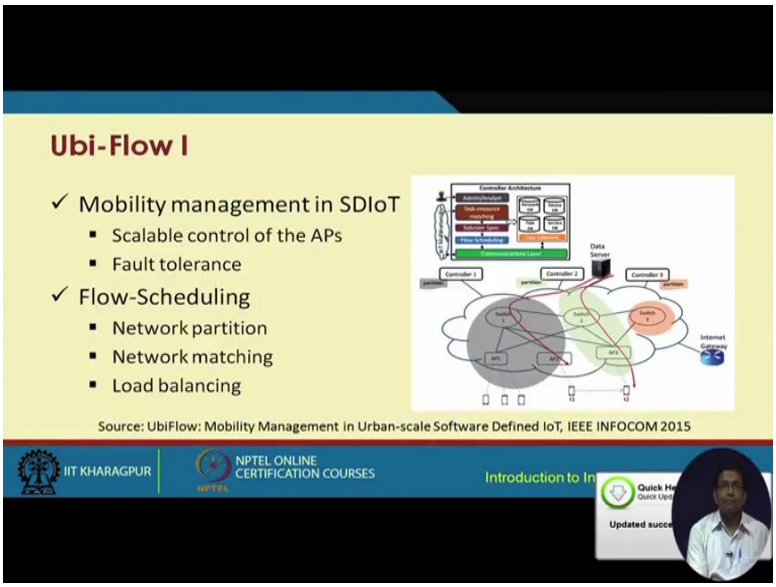

Now, let us look at the second solution, the Ubi-Flow solution which was published in infocom very recently in 2015 only, 2 years back.

So, here there are two main parts of the solution. One takes care of Mobility Management and the other one takes care of Flow Scheduling. Mobility management takes care of issues such as you know how to have scalable control of the access points issues, such as fault tolerance. That means, if some component goes down, then what happens you know how can the network still function and the other one is the flow scheduling which has three parts. First is partitioning this entire network into multiple partitions, no fragmenting this entire network into multiple partitions and over here we have shown those three partitions through three different color shades i.e. grey, light green and orange.

So, we have three different partitions shown over here network partitions and after this network partitioning has happened, then you know network matching has to be done. So, let us say that this particular mobile device receives a particular packet. So, then what it is going to do? It is going to perform, it is going to execute this network matching, network matching algorithm. What that network matching algorithm is going to do is, it is going to check that which of these network partitions should handle this particular packet.

So, then it will be sent to that particular partition for further handling and load balancing basically takes care of it you know. So, you know how the network matching and load balancing will be done together. So, the load balancing is going to take care of issues, such as that one partition should not get too much loaded while the other partition is under loaded and so on. So, this is what the load balancing is going to do.

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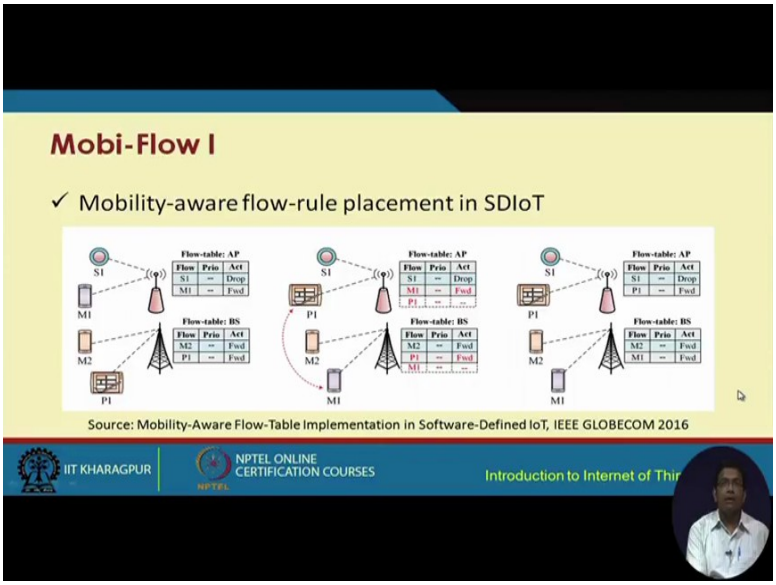

Now, let us look at the third solution that I was talking about the Mobi-Flow and this paper was published in IEEE Globecom, 2016 and this is the solution Mobi-Flow solution was proposed by us in the SWAN group and the mobility. So, Mobi-Flow basically gives a mobility aware flow, flow rule placement for mobile based IoT solutions, mobile place based IoT systems. So, let us look at these three scenarios over here. So, here we have different nodes S1 M1 connected to this particular access point. M2 and P1 connecting to another access point and their corresponding flow tables are shown here, the corresponding flows tables corresponding to this particular access point and this particular access point of the base station, the corresponding flow table is given over here. It is very easy to understand this part.

Now, let us see, let us say that the nodes M1 and P1 have interchanged their positions. Let us assume a very simple scenario, where M1 and P1 have interchanged their positions and the current situation looks like this. So, essentially you know what should happen is, we will have something like this. The another flow rule has to be added in the flow table

corresponding to this particular access point and the base station in this particular manner, but at the same time we also know that flow table spaces are very limited.

So, we cannot simply have these flow tables grow with the addition of these flow rules. So, you know what essentially has to be done is the scenario like this. So, how can we do it, this is what Mobi-Flow talks about.

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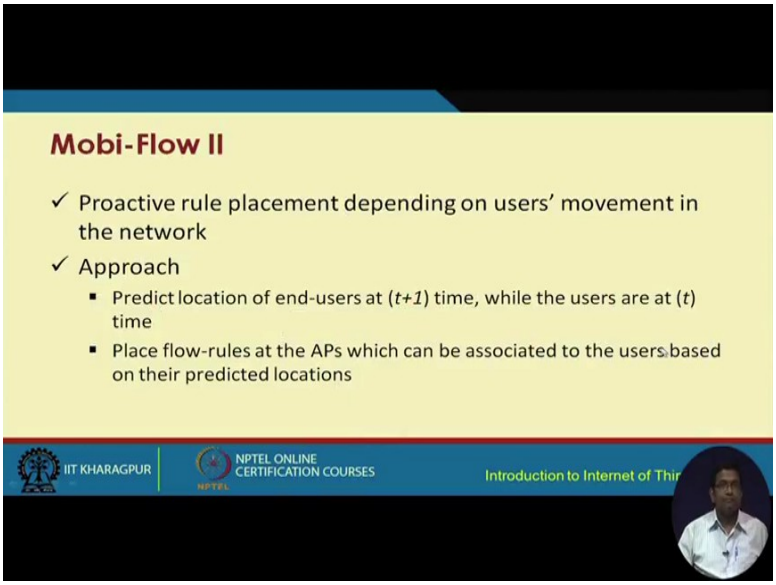

So, Mobi-Flow gives a proactive rule placement scheme depending on the users movement in the network and when we talk about such a scheme, you know what is very important to have some kind of prediction of the location of the end users at the next time instant give you the data of how the user was moving till a particular time instant.

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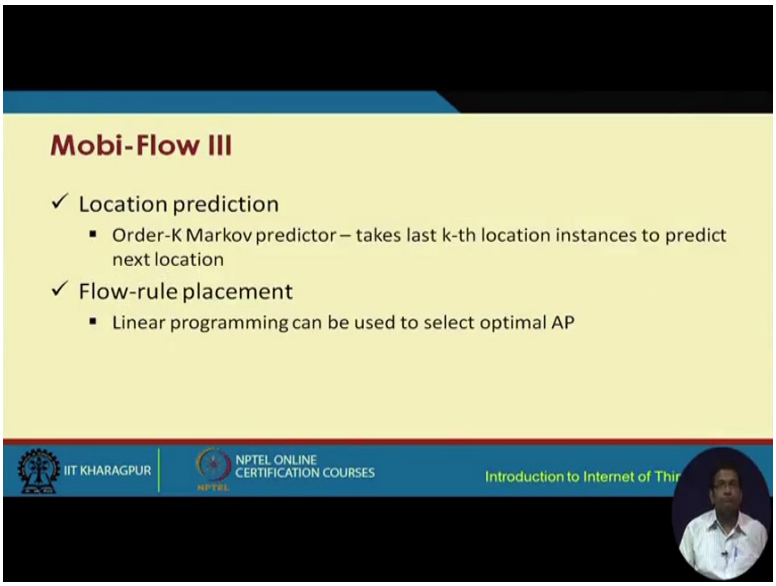

And then, placing the flow rules at the access points which can be associated to the users based on the predicted locations, location prediction, this is done in Mobi-Flow using something known as the Order-K Markov Predictor which basically takes the last k th location instances to predict the next location and the flow rule placement which basically is a linear programming based solution that is used to select which access point is going to be the optimal one.

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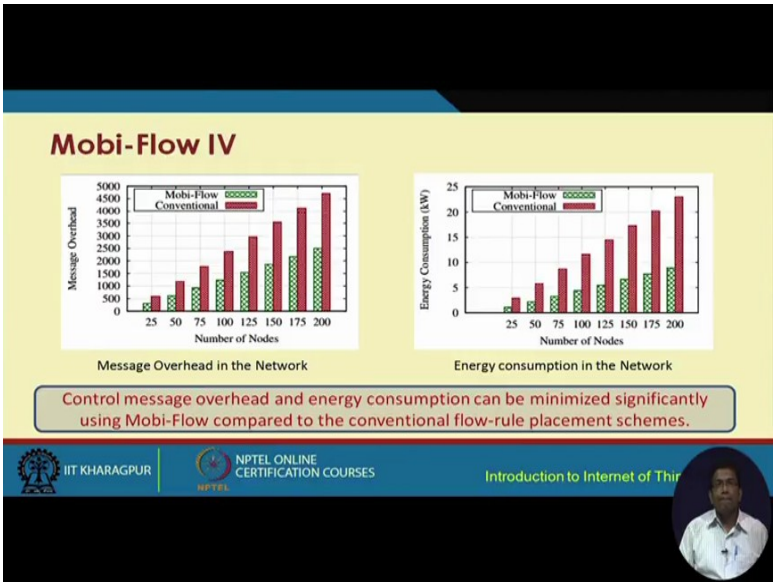

So, for further details the difference of Mobi-Flow was given in 2016 Globecom paper and if somebody wants to have more insight about how Mobi-Flow works, so one needs to go through that particular paper, but I would like to summarize by giving a a summary of the results of comparison between Mobi-Flow and the conventional solution.

So, what we have is with respect to message overhead and energy consumption, Mobi-Flow performs better compared to the conventional network, conventional solution and this is quite evident from these two plots. So, control message overhead and energy consumption can be minimized significantly using Mobi-Flow compared to the conventional rule placement schemes.

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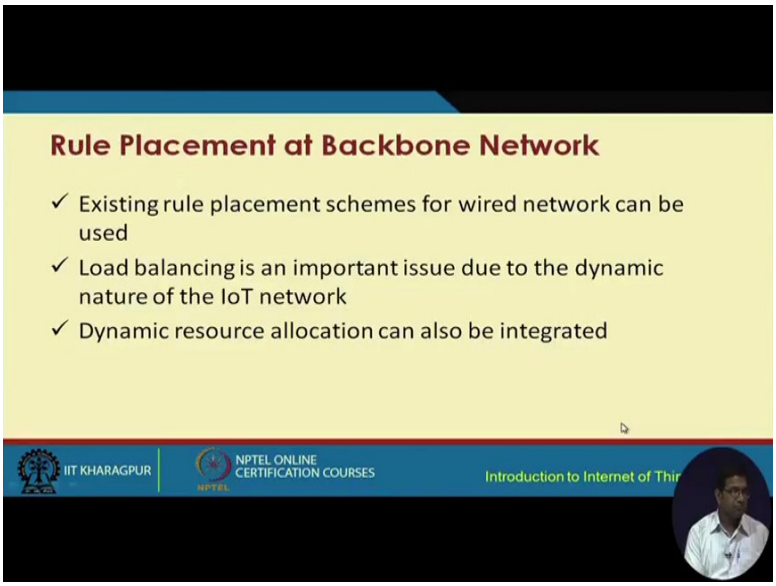

So, next we have to take care of how to perform rule placement at the backbone network. So, the existing rule placement schemes for wired networks can be used over here because most of the backbone networks are have a topology and the structure. The overall architecture is similar to that which exists for wired networks.

So, we can use the existing rule placement schemes for wired networks over here as well for the backbone network of IoT and the load balancing is an important issue due to the dynamic nature of the IoT network. So, dynamic resource allocation can also be integrated.

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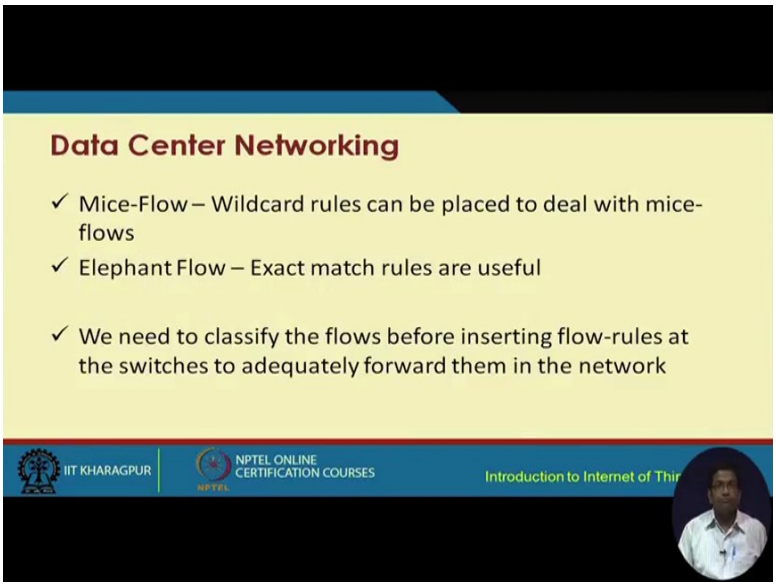

So, another very important thing that we have to remember in this particular context is the Data Center Networking. So, there are two types of flows that occur in Data Center Networks. So, Data Center Networks basically you know here we are talking about implementation of data center networks with the help of SDN.

So, typically two different solutions of adoption of SDN are in data center networks. So, here we have typically two types of flows that are observed. One is the Mice-Flow which are basically you know small flows and the other one is Elephant-Flow which is basically you know large scale flows where big volumes of data are coming, big sized data are coming and so on and small flows, Mice-Flows where small sized data are coming. So, here what is suggested is for the Mice-Flow wildcard rules can be placed to deal with these flows, the wildcard rules and for the Elephant-Flows what is required is to have exact match of the rules.

So, we need to classify the flows before inserting the flow rules at the switches to adequately forward them in the network. So, if it is an elephant flow, you know we have to have exact match. If it is a Mice-Flow, we will go for a wildcard match. Anomaly detection can also be performed in IoT network using SDN or open flow.

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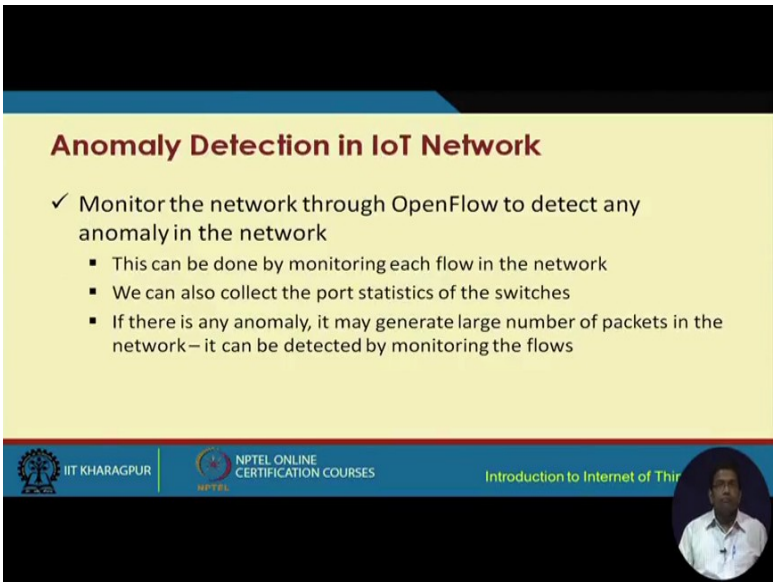

So, here you know it is required to monitor the network through open flow to detect any anomaly in the network which can be done by monitoring each flow in the network. It is also possible to collect different port statistics at the different switches and thereby from these statistics, you know anomaly detection techniques can be implemented and different anomalies can be found out.

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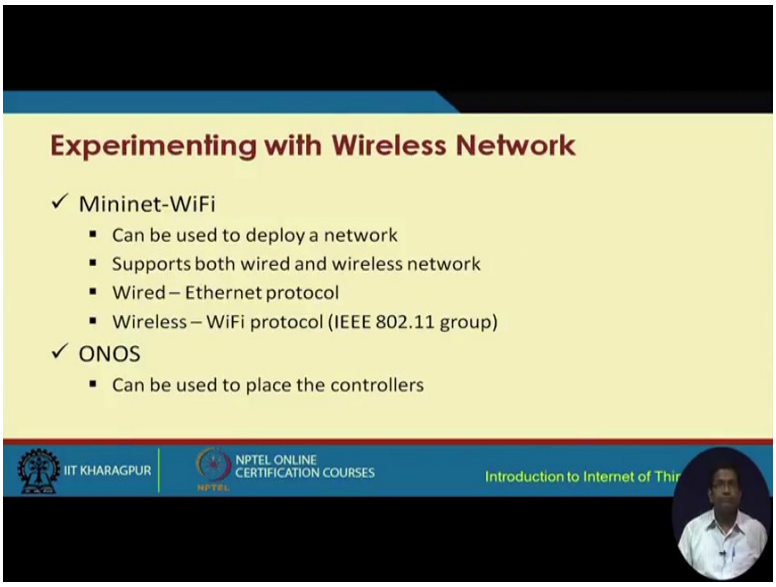

Now, what is required is to experiment with these wireless networks. So, what are the different platform that are available? So, Mininet traditionally did not have any wireless

support, but recently there is this Mininet-WiFi that is available which can be used to deploy a network support. Mininet-WiFi can help support both wired and wireless network. Wired implements the Ethernet protocol and Wireless implements 802.11 class of protocols. So, this is one platform that is available. Mininet-WiFi, the other one is the ONOS platform which can be used to place the controllers. ONOS basically helps in placement of the controller.

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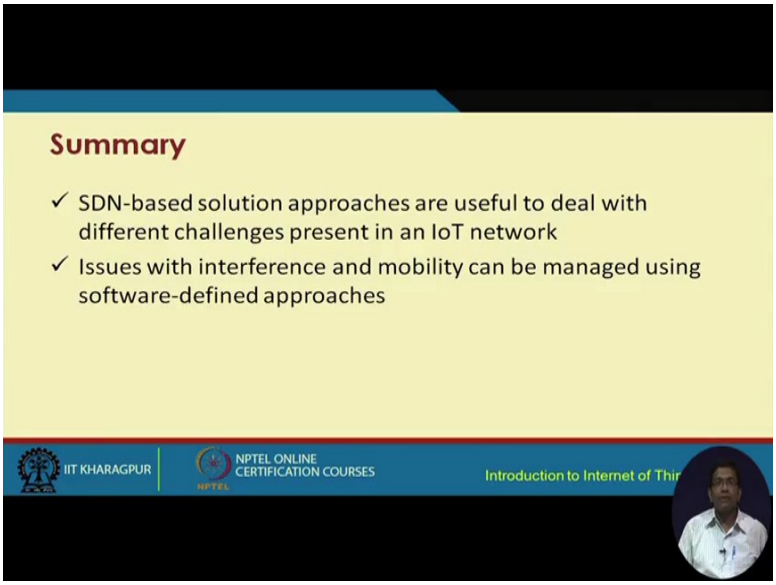

So, it helps to solve the controller placement problem. So, again to sum up SDN based solutions are useful to deal with different challenges present in an IoT network and in the first part of it, we talked about IoT in the context of sensor networks and small power, you know small devices, small IoT devices and in the second part, we talked about IoT in the context of mobile networks, mobile devices and so on and we have talked about three different solutions. One is the Ubi-Flow, Mobi-Flow and ODIN. These are the three different solutions that are available recently to support SDN for mobile IoT networks.

So, there are different issues of interference and mobility management which have to be taken care of in these SDN based approaches to SDN based approaches to IoT. So, interference is a very common thing, a very important problem that has to be addressed so and mobility as well because mobility is something that occurs in any IoT network and particularly the mobile based IoT networks.

So, with this we come to an end and we will stop here for the, we have understood that how SDN can be used for implementing IoT networks and making the IoT networks much more efficient.

Thank you.