Introduction to Internet of Things
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Lecture - 35
Software-Defined IoT Networking - Part- 1

Having understood software defined networking basic concepts through the previous two lectures, we are now going to see how SDN can be used in the context of internet of things the theme of this particular course. And as we will see that there is lot of opportunity and lot of problems number of problems that are facing internet of things can be addressed with the help of IoT with the help of SDN technology.

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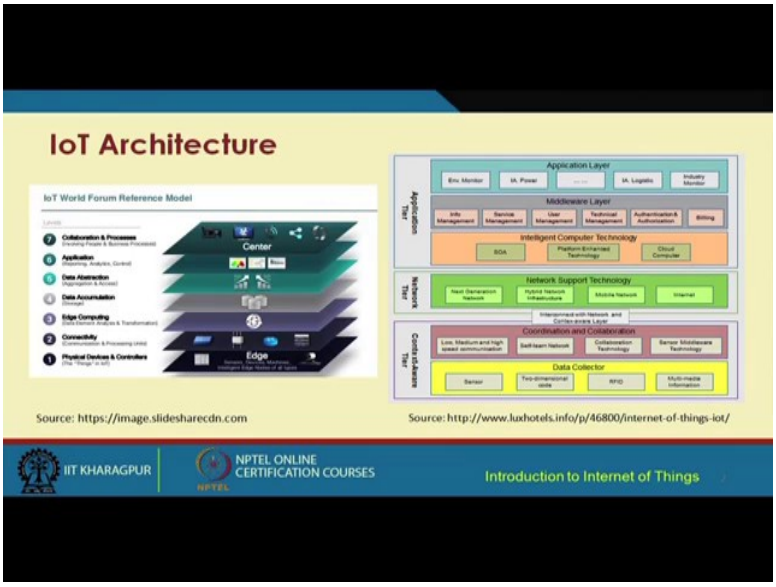

So, let us look at how SDN can be applied in making for making IoT efficient, so, if we look at the IoT architecture we have already seen the IoT architecture in different ways in the previous lectures. So, let us now look at from a different perspective. So, what we have as we can see here is the different layers in the reference model this is taken from the wall forum reference model and we have different layers. For example, the physical devices and controllers connectivity age computing data accumulation data abstraction application collaboration and processes and the right hand side figure shows a different view of IoT all together from a different viewpoint how IoT works.

So, we have this tiered segmentation of the IoT networks we have the context aware tier we have the network tier and we have the application tier and these different modules corresponding to each of these tiers are all given over here without. So, it is not required for us to understand each of this in further detail and with this particular background of IoT.

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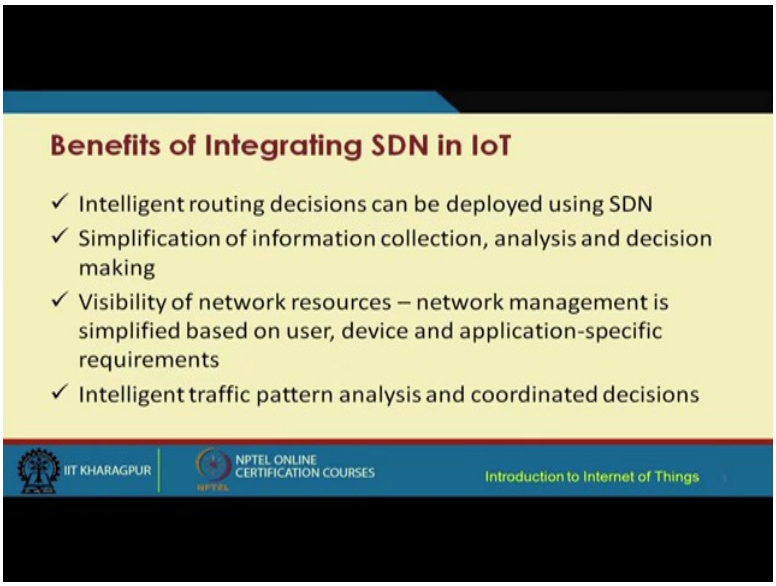

Let us now move ahead and see how SDN can benefit IoT. So, you know the integration of SDN to IoT. So, by doing integration of SDN to IoT one very important fundamental problem that can be solved is one can have intelligent routing decision making to be done to implemented in an SDN implemented IoT network.

The second thing is the information collection analysis decision making all of these can be simplified through the integration of SDN in IoT third is the visibility of network resources network management is simplified based on the user device the application specific requirements. So, this visibility of network resources and the simplification with respect to these criteria these aspects they can be done with the help of indication of SDN in IoT.

And the last one is intelligent traffic pattern analysis and coordinated decisions and I do not need to elaborate further on this, because this is quite self explanatory intelligent traffic pattern analysis and coordinated decision making through the controller right. So, we already know what a controller means and what it does. So, all these things can be done with the help of SDN. So, what is very important is intelligence you know more intelligence is proved into

the network and improving the efficiency of the network with the help of the SDN technology. So, IoT can also benefit from these advantages.

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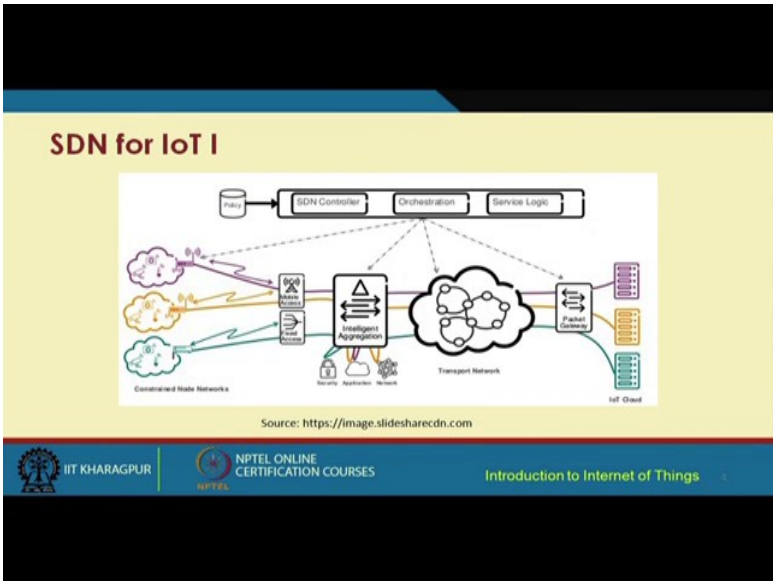

Now, if we look at this particular figure in front of us we have these different devices the IoT devices in different sub networks maybe and these devices through mobile axis or fixed axis channels this data from these devices they can be acquired and be transmitted to the data aggregator. Here all these data aggregation are going to be done of the data that is received from these different IoT devices. And then it passes through a transport network and from the transport network it goes to the different gateways and the packet segregation is going to be done using this.

So, this is basically the simplified view of an IoT network now what happens is when we want to integrate SDN what we are trying to do is we are going to use the SDN controller. So, what the SDN controller is going to do is it is going to control each of these different things different aspects and also it is you know it is going to improve the orchestration between the different devices between the different protocols that are running, etcetera, etcetera in this network and overall it is going to improve the service logic that is behind it. So, this is going to be improved.

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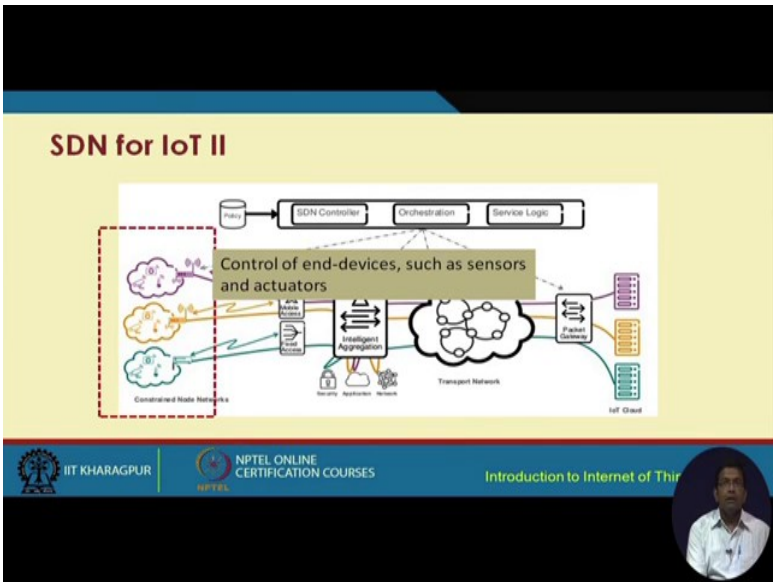

Now with the SDN with the implementation of the SDN the control of these n devices IoT devices which includes sensors actuators RF id tags and any other IoT device. So, you know the centralized control is made possible then here as we can see this part can take care of the rule placement, because we have these access devices over here the rule placement while considering issues like mobility etcetera and the heterogeneity of the n devices this can be implemented here.

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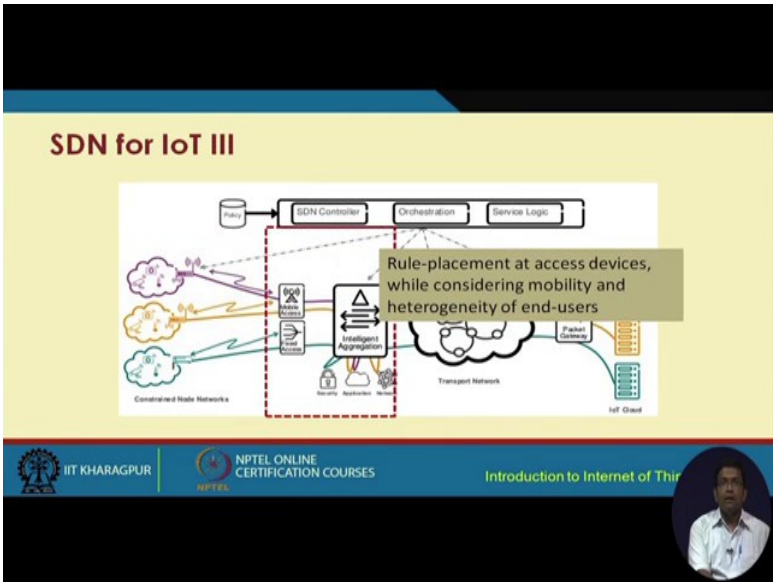

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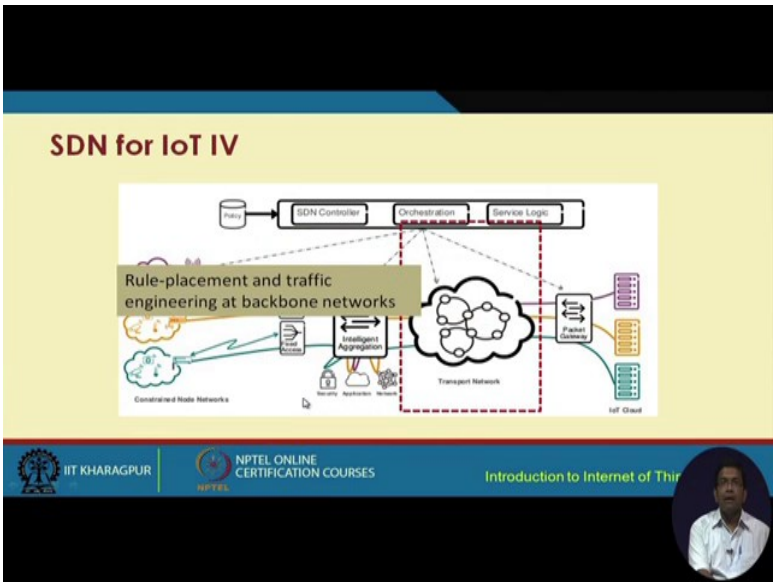

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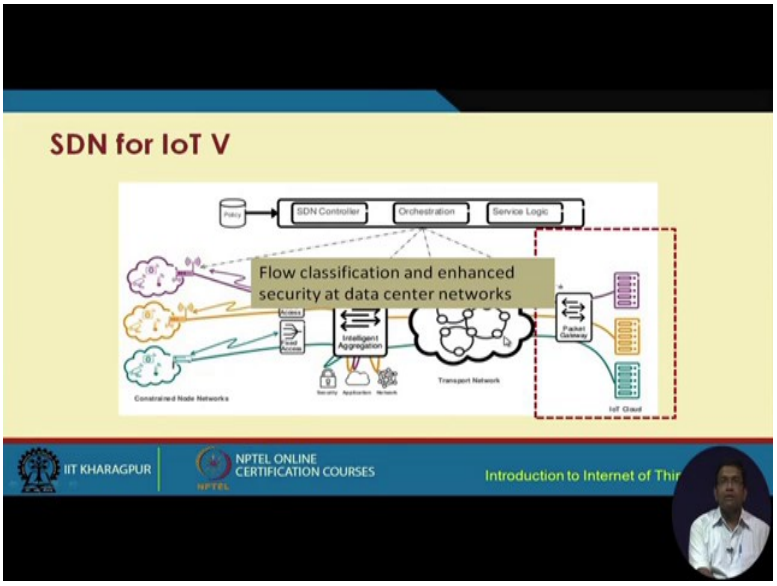

And the rule placement and traffic engineering and backbone networks can be taken care of at the transport network and flow classification and enhanced security are taken care of at the data center networks.

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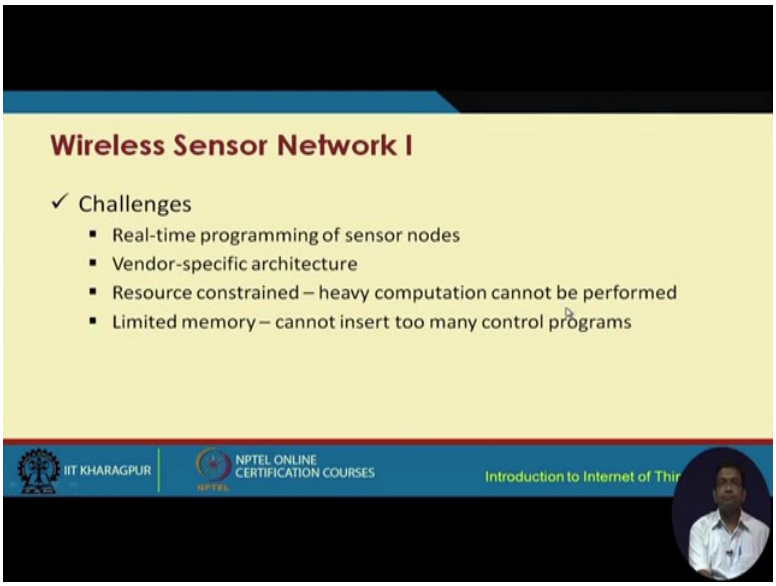

So, let us switch back our gear and let us look at one of the fundamental building blocks of IoT which is the sensor network. So, one of the challenge is in behind the working of the sensor network is real time programming of each of these sensor nodes is typically not feasible not at all feasible you know you cannot go and you know program the sensor nodes as such you know it is possible to program the sensor nodes, but you know real time programming of these sensor nodes is not possible. Then these sensor nodes and these corresponding networks they have they follow vendor specific architecture each of these nodes that are made by different vendors they have their own different architectures different layers implemented in them there is no one standard.

So, now the each of them they implement their own vendor specific architecture these nodes are resource constrained. So, you know the heavy computations that are often required cannot be performed at each of these nodes and additionally there is the resource limitation with respect to memory there is limited memory. So, we cannot insert too many control programs in these networks.

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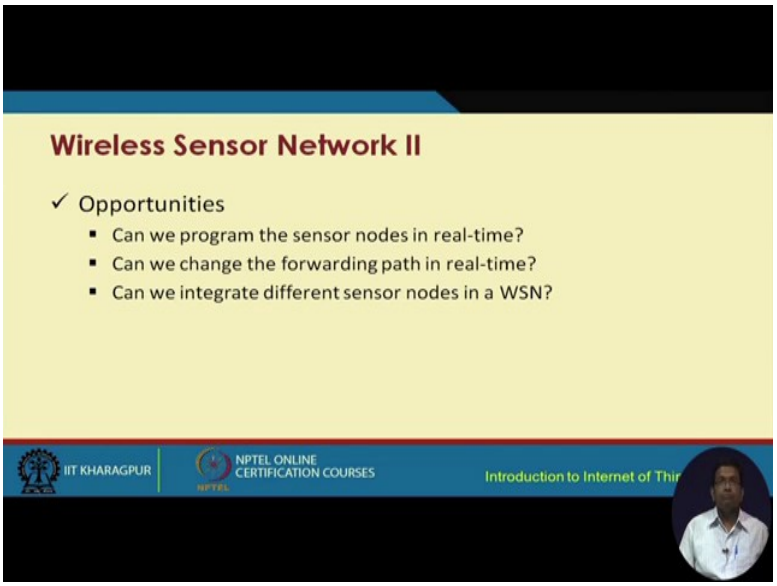

So, these challenges basically also gives us opportunities like can we program the sensor nodes in real time can we change the forwarding path in real time can we integrate the different sensor nodes in a sensor network.

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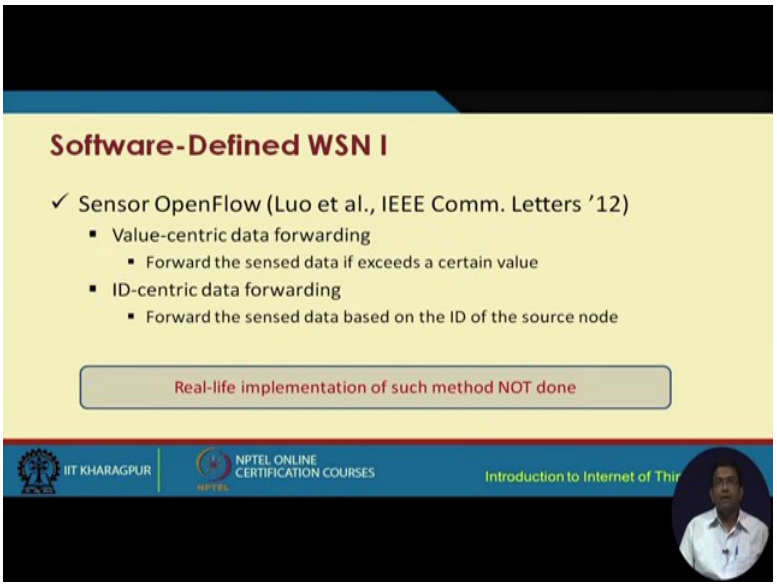

So, we have different solutions that have been proposed to take care of these challenges and opportunities that exist one of the recent works relatively recent works which was published in the IEEE communication letters in 2012 is the sensor open flow protocol. So, the sensor open flow protocol takes care of forwarding in two different ways one is the value centric

data forwarding the other one is the ID-centric data forwarding value centric. For example, if the sensor data exceeds a certain threshold value then the data is going to be forwarded other way the other way round is to adopt the ID-centric data forwarding. For example, the data will be forwarded based on the ID of the source node if it is coming from a particular source node with certain ID then it is going to be forwarded otherwise not.

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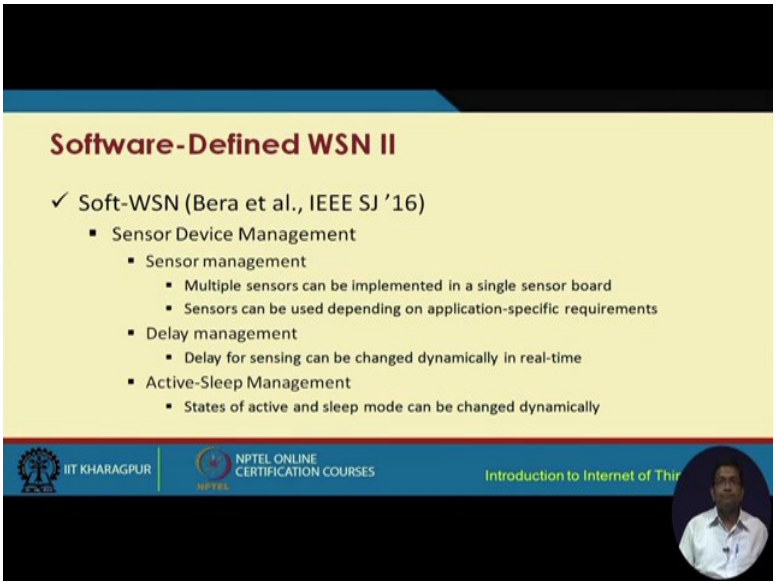

So, real life implementation of such a method is not yet available this is one of the limitations of these particular solutions Bera et al; that means, in our group this one group we have proposed the Soft-WSN protocol and it was published in the IEEE systems journal in 2016 here we have adopted different component solutions. So, we have the sensor device management which comprises of sensor management delay management and active sleep management I am not going to go through these in detail, but it is available and there is available for you in the slide and for further details it is there in the paper IEEE systems journal paper.

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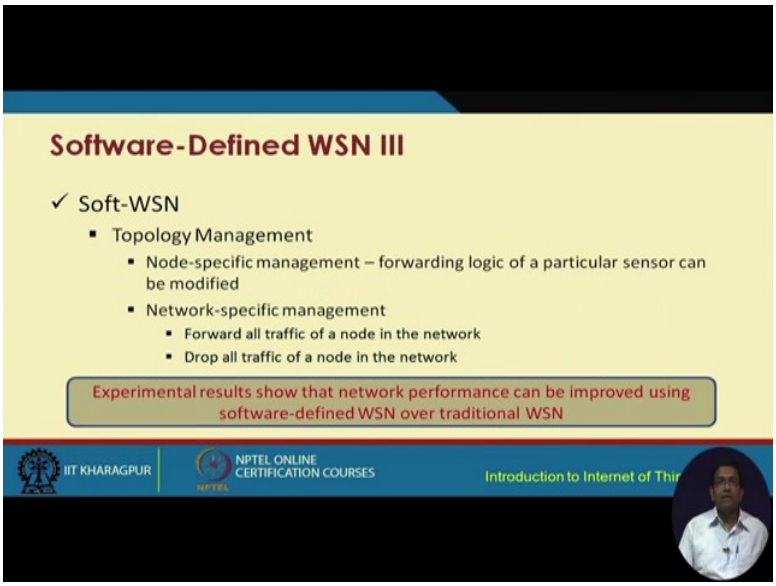

So, this is one major component the sensor device management and the other one is the topology management. So, topology management basically you know takes care of node specific management for forwarding of the data from their specific nodes and we have what we have done compared to the previous low et al's paper low et al's work which was published in IEEE communication letters in 2016 here we have performed experimental results you know here we have performed really real life experimentation. So, we have in this paper we have shown experimental results that show that the network performance can be improved using software defined WSN over traditional WSN.

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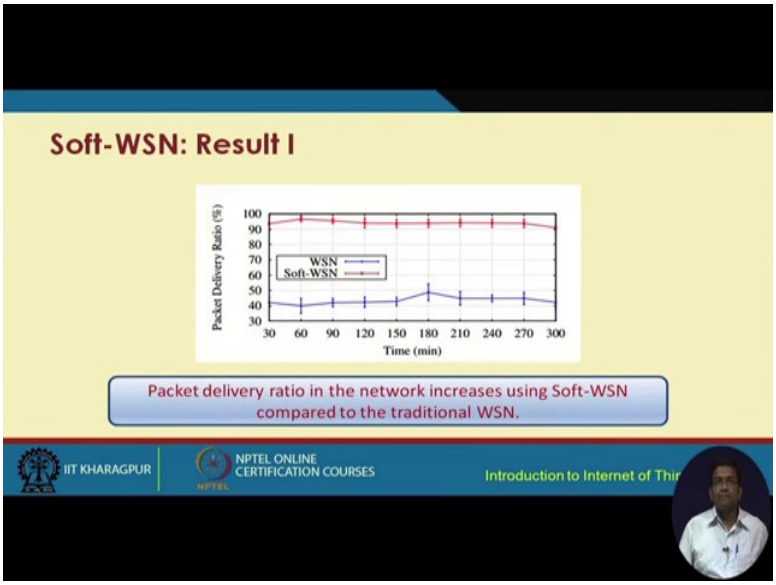

So, I will just present very briefly some of the results I have taken from that particular paper for example, with respect to the packet delivery ratio. So, this is the packet delivery ratio using soft WSN. That means the proposed solution and and the regular WSN where no protocol is implemented. So, it is a paired pone basic protocol that exists.

So, here that is the reason actually we have observed and that we are able to see much improved packet delivery ratio much improved packet delivery ratio using soft WSN. So, what we see is the packet delivery ratio in the network increases using soft WSN compared to the traditional WSN.

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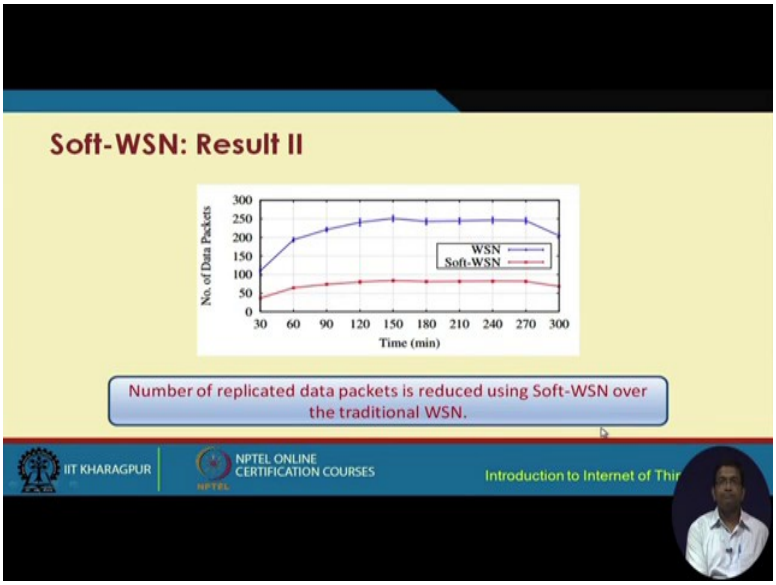

Here this plot shows the number of data packets that are forwarded and as we can see over here the soft WSN the number of data packets that are forwarded is much less compared to the number of packets in in a regular WSN.

So, the data packet means the replicated data packets. So, I should mention this over here the number of replicated data packets. So, replicated data packets not the number of regular data packets, but the replicated data means this soft WSN basically reduces the number of replications of data packets over the traditional WSN.

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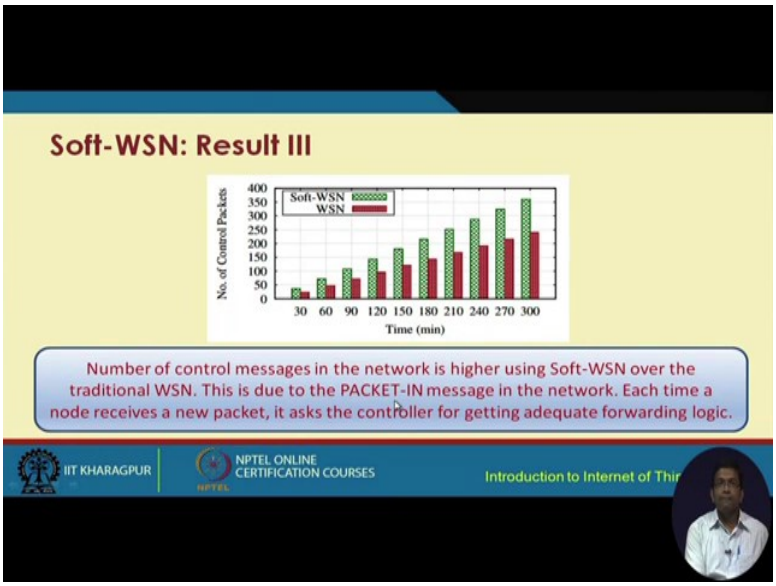

The third result basically shows the number of control packets that are forwarded the number of control packets in the network is higher using this proposed protocol the soft WSN protocol. That means, our protocol over the traditional WSN this is due to that the packet in messages in the network are less each time a node receives a new packet it asks the controller for getting adequate forwarding logic and that is why the number of control messages in the network gets reduced.

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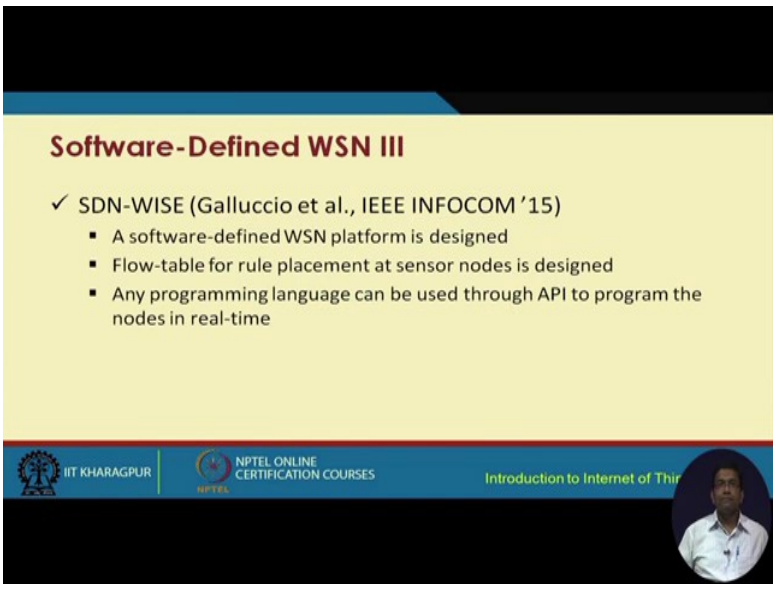

The other solution which has integrated SDN into sensor networks is the SDN-WISE and it was published in the IEEE INFOCOM conference in 2015. So, here it is a SDN you know software defined some WSN platform SDN why is basically proposes a software defined WSN sensor network platform where the flow table for rule placement is is available at the sensor nodes it was designed how the flow table is going to look like and any programming language can be used through API to program the nodes in real time in SDN-WISE.

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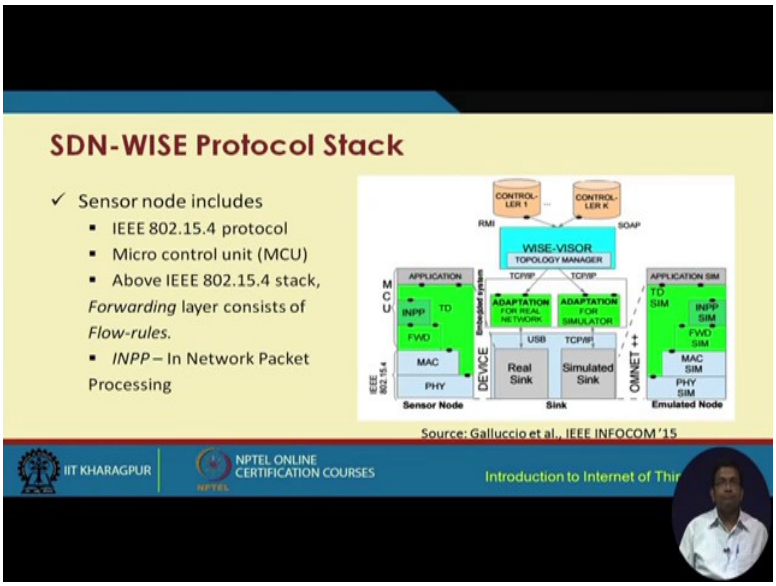

Very briefly I want to show you the schematic of how SDN-WISE works I do not want to you know discuss this solution in detail, but I just wanted to show you the overall architecture of SDN-WISE. So, what we have are the sensor nodes we have the sink. And we have the emulated nodes and so, as we can see over here we have in the sink we have the real sink and their simulated sink. And these are the different layers the forwarding layer over here and the different other regular layers and how they talk to each other.

So, this part is the emulated part and this part is the real part and this one the sink basically has to both the components the real sink as well as the simulated sink. So, these sensor nodes basically they have they run the 802.15.4 protocol in their work SDN-WISE there is a microcontroller unit and there is a 802.15.4 stack on top of which SDN-WISE basically functions right. And then we have the INPP which is the in network packet progressing processing layer.

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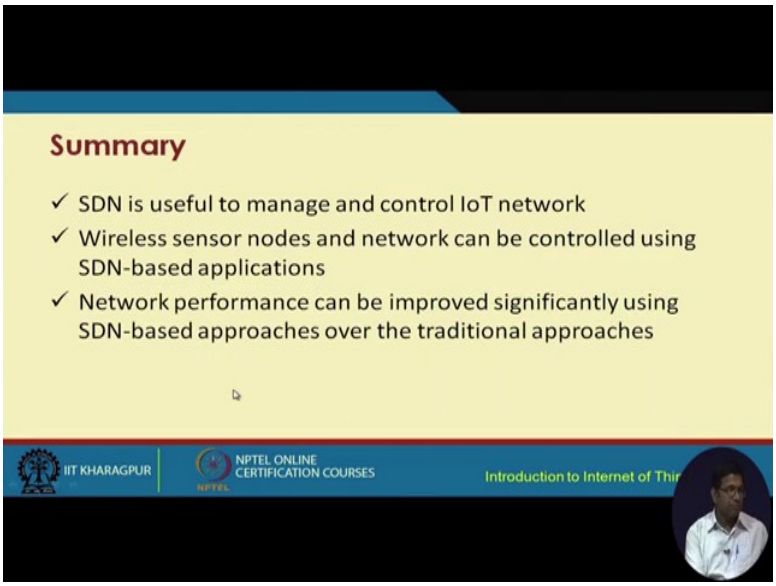

So, in summary we have looked at how SDN is useful to manage and control the IoT network wireless sensor nodes. And network can be controlled using SDN based applications, network performance can be improved significantly using SDN based approaches over the traditional sensor network approaches and we have also seen that there are different protocols.

The latest one that we have seen is the SDN-WISE we have also looked at the soft WSN protocol that was in fact, proposed by us. And we had experimented with real hardware real IoT hardware real sensor network hardware and before that there is there was another solution that was proposed by Low et al and was published in the IEEE communication letters in 2012.

So, basically these are the three main protocols that are available currently there are few other solutions also that might that are also available, but these are the prominent ones and. So, this is basically the state of the art with respect to the implementation of SDN for sensor network.

In the next part of the lecture we are going to talk about how IoT devices like mobile devices can exploit the use of SDN to make them efficient. With this we come to an end.