Introduction to Internet of Things
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Lecture – 45
Fog Computing – II

So, now in this lecture, we are going to discuss in further detail about fog computing architecture. So, in the previous introductory lecture on fog computing, we have already seen the basics of fog the whole premise under which fog operates and also the advantages of using fog computing. So, that we have already seen the advantages of using fog computing over the traditional cloud computing and we have also seen that in IoT, it is essential to have a fog platform in addition to the cloud platform. So, I should remain you over here that it is not like a substitute; it is not like fog is a substitute of cloud so that we should not think that way. So, fog is something which is complementary it complements the cloud technology. So, we need both fog and cloud along with the IoT devices and the architecture along with the IoT architecture.

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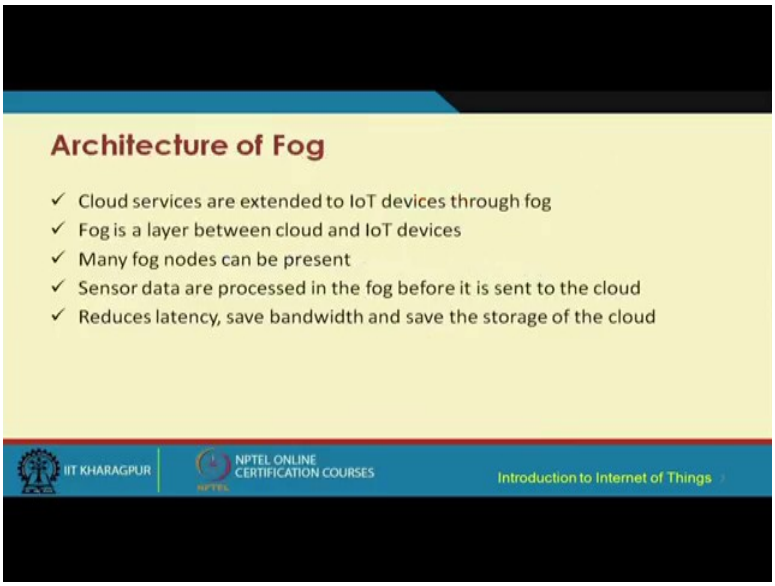

So, this is what we need. So, we need IoT devices the protocols the architectures plus fog plus cloud to have a complete platform for proper use. So, let us go through the details further. So, when we talk about the architecture of fog we have to keep in mind that the cloud services are extended to IoT services, IoT devices through fog. So, this is what is

happening. So, what is so essentially I should explain this thing in a little bit different way? So, essentially earlier what was happening is we have the cloud and we have the IoT devices; IoT devices sending the data to the cloud and then getting a response back or getting getting the data back from the cloud if it is required for further actuation of whatever details. So, this is the traditional way of dealing with IoT devices with only cloud.

Now, what we are saying over here is we need to have some capabilities of cloud being implemented closer to the IoT devices layer.

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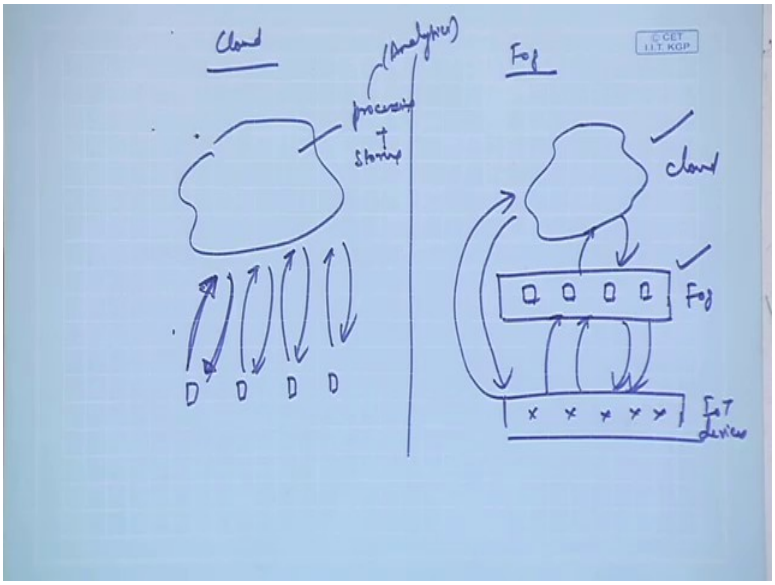

So, we want essentially something like this. So, traditionally we had cloud and now we are talking about fog architecture in the cloud architecture we have these different IoT devices and data being sent and response received either response or even the data can be fetched. So, this could represent even the data being fetched and. So, on and so forth, right and here the cloud would take care of processing of the data plus storing of the data. So, processing could even include things like running different analytics right.

So, this is the traditional model now the problem over here is that you know one very important problem is that the problem of latency; that means, that it takes. So, much of time for the data that is sensed by this IoT device to be uploaded to cloud doing some processing over there and then getting the response back. So, the overall over basically

this delays the whole process. So, in fog actually what we are saying is we still will have the cloud we will have the fog layer here.

So, this is cloud, this is fog very closer to this devices the IoT devices some are going to happen here and some of the processing and computation and getting some responses in the form of let us say triggers or actuation signals those would be sent to the cloud directly and some would be like in between in between means that like in some case we need to have computations only in that fog in some case you know some basic processing will be done in the fog and the rest would be sent to the cloud and in some case we can send directly to the cloud without having the intermediate fog.

So, we have 2 different comparable architectures of IoT one using cloud the other using fog and the essence is that in fog we are not saying that we will get rid of cloud this is you know we still have to go through a go by using cloud, but in addition we are going to introduce a fog layer. This fog layer is going to have something known as the fog nodes we are going to talk about these fog nodes shortly and here we are going to have these IoT devices. So, this is the whole crux of fog computing and the next few slides we are going to discuss in different ways the different aspects of fog.

So, essentially what we are doing is we are trying to bring the cloud surfaces in the form of processing storage closer to the IoT devices layer through the introduction of fog. So, as I said fog is a layer which is between the cloud and the IoT devices where many fog nodes may be present and the sensor data are processed in the fog before it is sent to the cloud and as I was telling you before that only those data where the data are time sensitive those would be processed in the fog there could be some other data which are not time sensitive. So, those would be better processed in the cloud itself.

So, what we have basically is some kind of complementarity along with cloud by introduction of fog. So, what is the advantage number one reduction in latency, so the overall latency from the point the sensing is done till the point processing and storage and further response back is received at the source. So, that latency is reduced can be reduced significantly with the introduction of fog the second advantage is that because we are not flooding the entire network with all these different sensed packets we are sharing bandwidth and also we are saving storage at the cloud because not everything is sent to the cloud.

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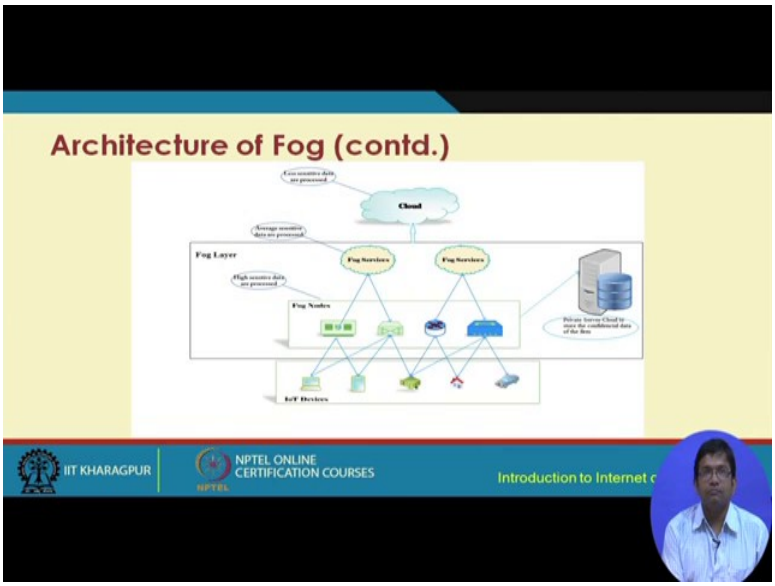

So, let us look at this figure; we have already gone through it from a different perspective in a different way. So, let us go through it. So, we have at the very bottom these IoT devices which are basically sort of like the physical layer of any network. We have these physical IoT devices over here then we have this fog layer this is the fog layer and then we have the cloud. So, IoT devices layer fog layer and the cloud this fog layer has these fog nodes which are sort of like virtual instances of the IoT devices these virtual instances are going to do are going to have better or improved processing capability improved storage capabilities and so on.

The fog layer I should mention over here has some transient storage capabilities transient storage. So, not like permanent storage. So, transient storage capabilities and permanent storage if required would be you know that kind of data would be sent to the cloud eventually. So, I should also mention over here another component that is very much important. So, the data that is fetched over here can we fetched from a private server or a cloud or the data can be basically pushed into these devices or this platform, the cloud platform the private cloud platform to store the confidential data of the farm former any organization which is basically adapting this technology.

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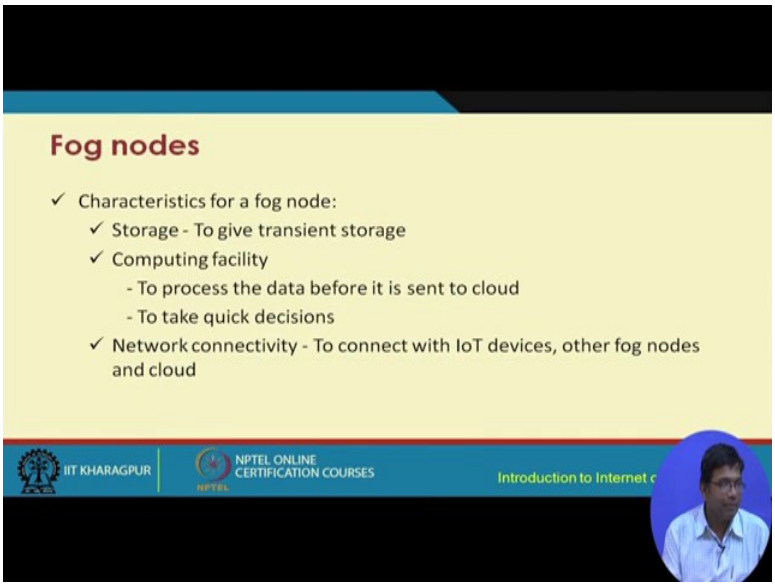

Now, the fog node that I just mentioned in the architecture in the previous slide has certain specific characteristics number one is storage. So, the storage over here is transient not permanent unlike in the case of cloud number 2 is the computing facility so which is about processing the data before it is sent to the cloud and that basically helps in reducing the time for taking decisions not taking decisions, but time for executing the decisions. So, quicker decision making and execution of the decisions because the processing is done close to the close to the IoT devices; that means, to the edge and that is why this reduction is going to happen compare to the traditional cloud.

Network connectivity is another characteristic of the fog node where the IoT devices basically connect with each other and other fog nodes and cloud the IoT devices in the IoT devices layer they also connect by other fog nodes and the cloud. So, they can either connect directly or by other fog nodes or by other cloud.

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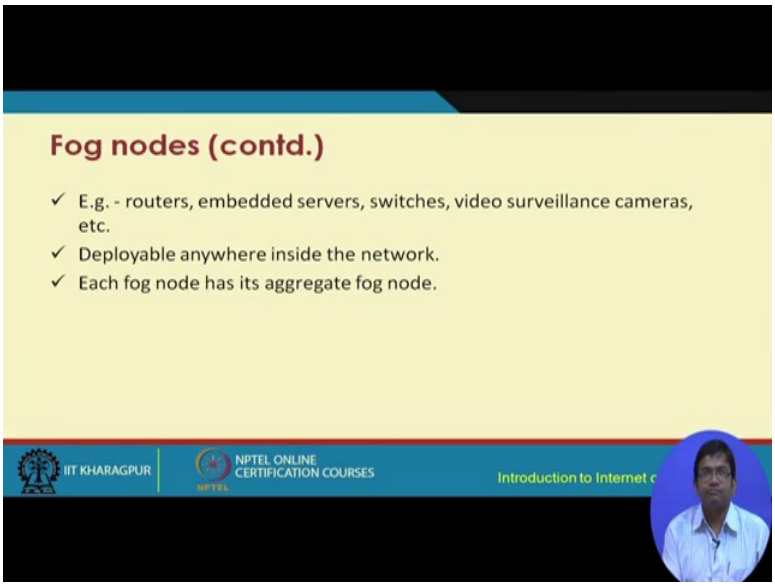

These fogs nodes could be instances of routers, embedded servers, switches, video surveillance cameras, etcetera, which are deployable anywhere inside the network and each fog node has its own aggregate fog node. So, this aggregate fog node concept; I will explain to you shortly.

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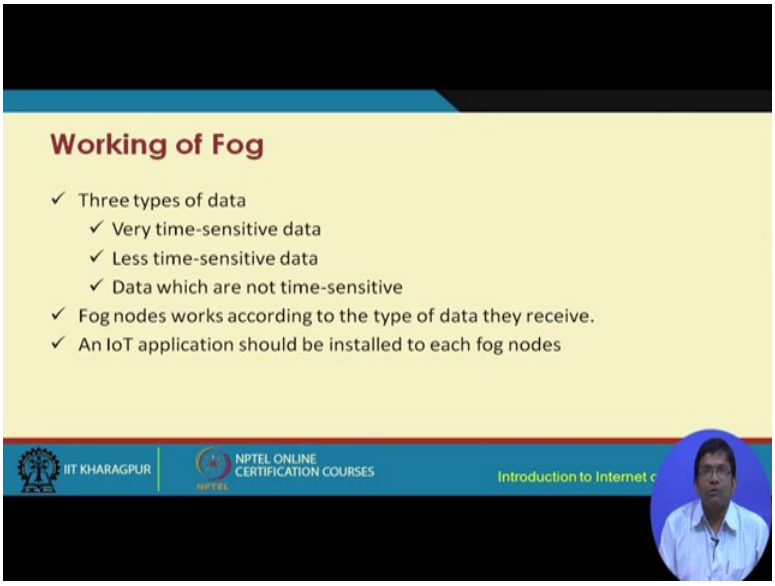

So, there are three types of data in any IoT application some data are very much time sensitive. So, we cannot really hold on to the data for too long. So, it has to be processed immediately and so on. So, for example, surveillance using cameras you know. So, it

does not make sense, if we are acquiring the data and after three four seconds or maybe you know after several minutes the decision about doing something at the ground is that information is sent to the IoT device maybe some actuation or something is sent to the IoT devices.

So, it is mean surveillance is such an application where basically time is very critical and we cannot delay to long less time sensitive data you know one is very time sensitive data like the surveillance applications less time sensitive data. For example, some non critical health care data is less time sensitive data and data of which are not time sensitive at all like you know the health care data, but which does not concerned the life or death of a patient sorry of a death of a patient not life, but death of a patient.

So, that kind of data is not time sensitive. So, fog nodes is work according to the type of data they that they receive and the IoT application should be installed in each fog node to handle this various types of data.

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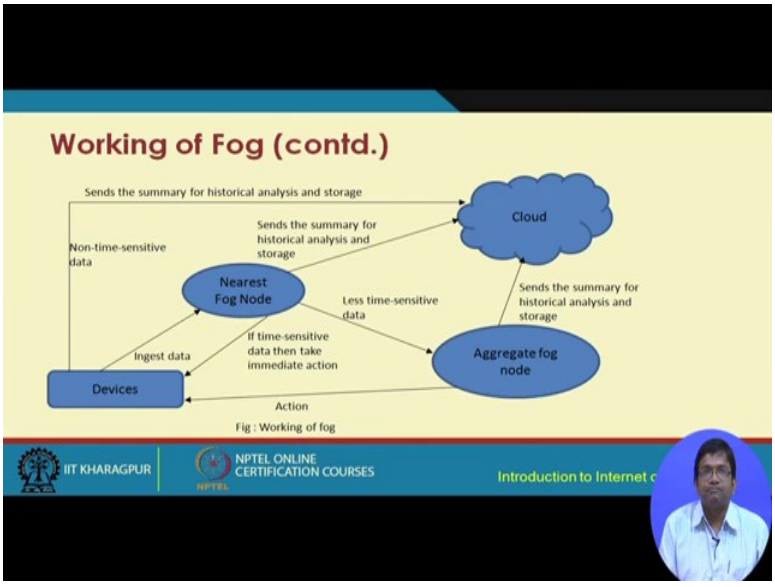

So, let us look at this particular diagram we have this IoT devices and these devices basically sent the data the data are ingested at the nearest fog node if it is time sensitive then some immediate action will be taken by the fog node and that result is going to be communicated to the IoT device the it sends the summary of the historical analysis and storage which are not very time sensitive to the cloud for longer term storage and processing.

Now, if it is a non time sensitive data then these devices send the summary for historical analysis and storage to the cloud because it is not time sensitive now in the previous scenario if the data is relative less time sensitive then it is aggregated at the fog node and that aggregated data is sent as summary for historical analysis and storage to the cloud and some action is performed on the IoT devices in the devices layer.

So, this is the whole idea behind fog. So, remember one thing that when we are talking about fog we are typically talking about low power resource constraint environments like IoT environments IoT environments directly with cloud not a good very not a very good solution as such. So, we need faster processing faster reactivity and so on. So, that is the reason we need some processing some storage capabilities at the age; that means, closer to the IoT devices. So, that is where fog comes as a benefit to this IoT technology.

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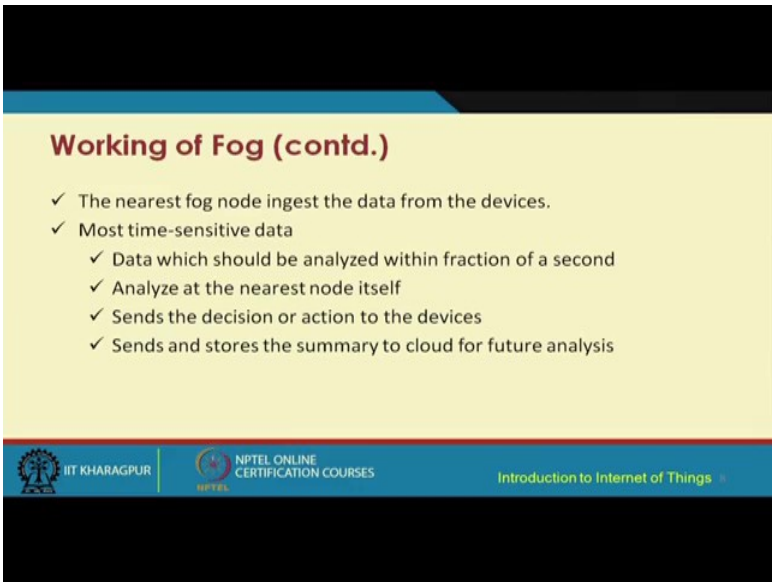

So, the nearest fog node basically ingests the data from the devices and the most time sensitive data are the data which should be analyzed within like fractions of a second and the analysis should be done nearest to the node itself and the decision about what has to be done after the analysis or the action that has to be taken based on the analysis is sent to the IoT devices like an actuator or something and a copy of it is sent and stored at the cloud for longer term storage and analysis for less time sensitive data the data of which can.

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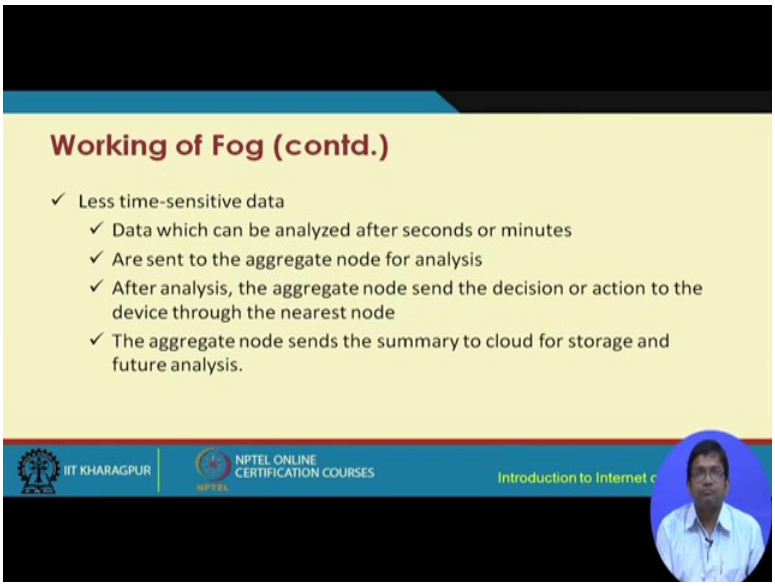

The less time sensitive data are the data which can be analyzed after seconds or minutes and they are send to the aggregate node the aggregate fog node for the analysis after analysis the aggregate node sends the decision or action to the device through the nearest node and the aggregate node sends.

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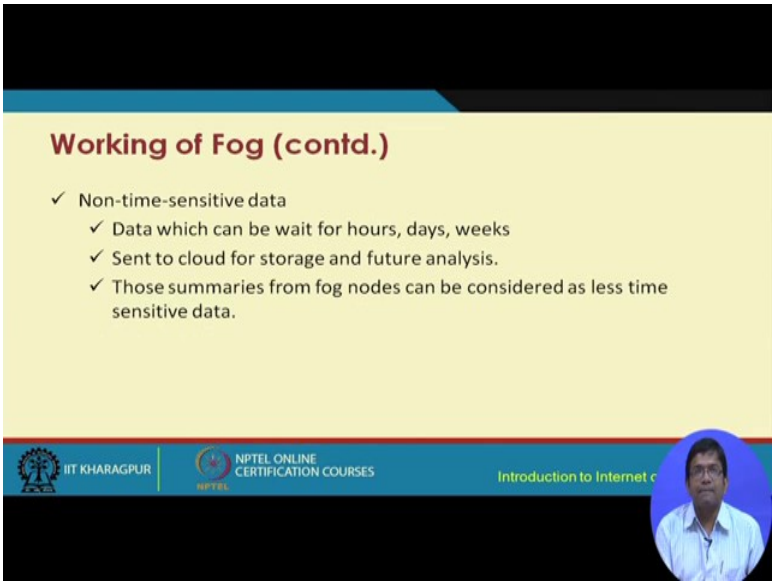

There is summary to cloud for storage and future analysis for non sense non time sensitive data which are basically data of which can wait for hours days weeks and. So, on these kind of data are sent directly to the cloud for storage and longer term analysis

future analysis and the summaries from the fog nodes can be considered as less time sensitive data or even some kind of data from the fog nodes from the IoT devices can also be directly stored in the cloud and those are the ones where time is not an issue at all.

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So, this is the summary of what action has to be taken at the fog node. So, analysis duration fraction of a second fog node closest to the devices does it seconds to minutes analysis duration the fog aggregate node does it and hours to weeks the cloud does IoT data storage duration is you know in the fog node this storage is transient it is in the order of hours or days for the aggregate nodes and months to years in the cloud for geographical coverage in a fog node what are closest to the devices the coverage is very local it is wider covered for the aggregate node the fog aggregate node and it is global for the cloud.

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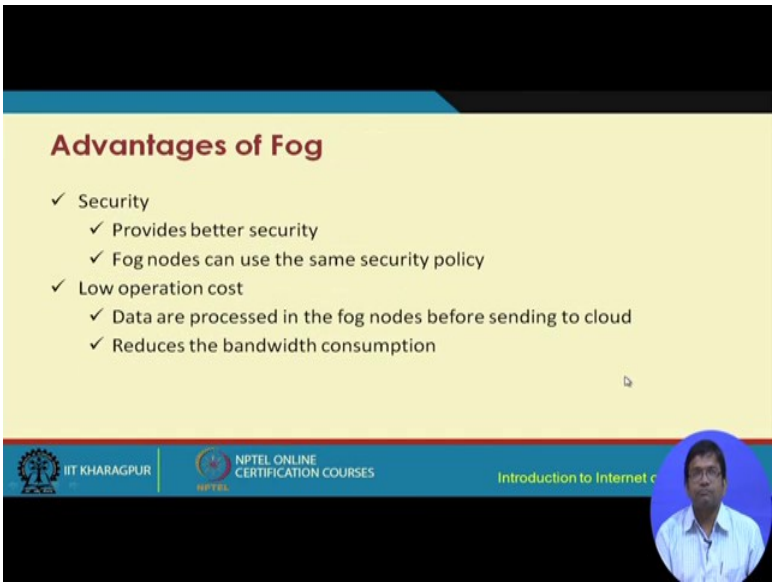

Advantages of fog security improved security faster processing low operation cost data are processed in the fog nodes before sending to the cloud. So, that way the bandwidth is also reduced bandwidth consumption is reduced and further the other important the most important I would think is that faster response time quickly the actions that are determine through the analysis can be executed in this kind of model that way the unwanted accidents.

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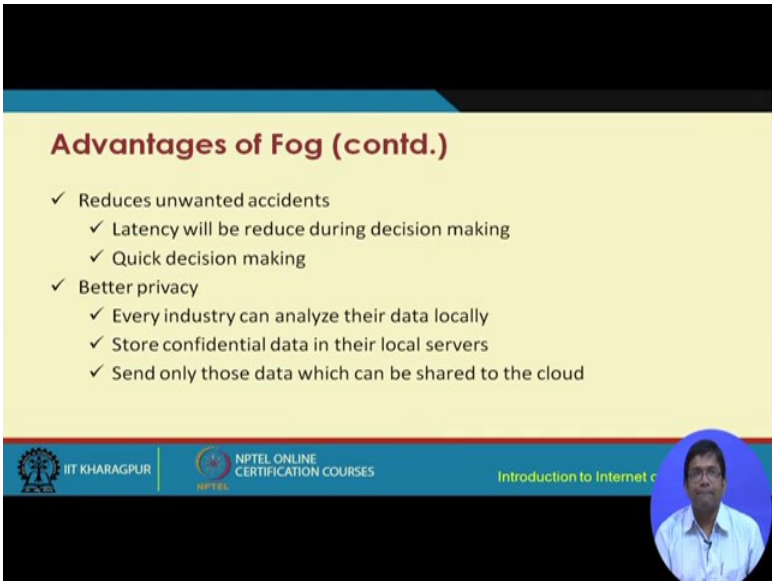

That are going to happen may be you know if the IoT devices are implemented in some safety critical platforms like you know industry; so, where there is industrial safety a prime concern.

So, in such case such a case it is required to process fast you now we cannot wait until it is sent to the distant cloud for processing storage etcetera, etcetera, we have to do it close to the point of sensing and that is where you know if you do that the processing time reduces quite significantly the decision making is becomes very fast and the unwanted accidents can be reduced in this particular using such a such an approach privacy every industry can analyze their own data locally and the confidential data in this fog approach can be stored locally in the local servers and only those data which can be shared with others which are not very confidential they can be sent to the cloud business agility also improves.

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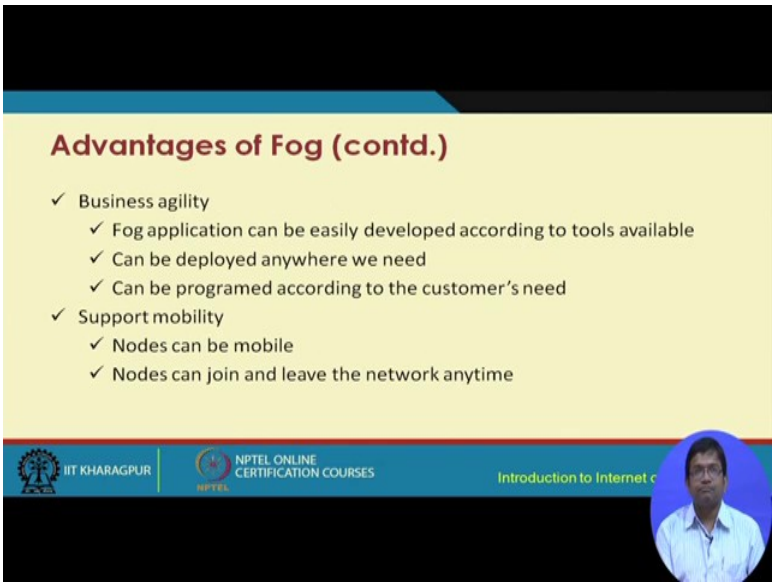

So, you know faster we can accept the customer's needs and those can be programmed very fast into the network and that way the costumers satisfaction can be improved supporting nobility here in this fog model the nodes can be mobile and the nodes can join and leave the network at any time a true feature of any pervasive computing system any ubiquitous mobile ubiquitous system.

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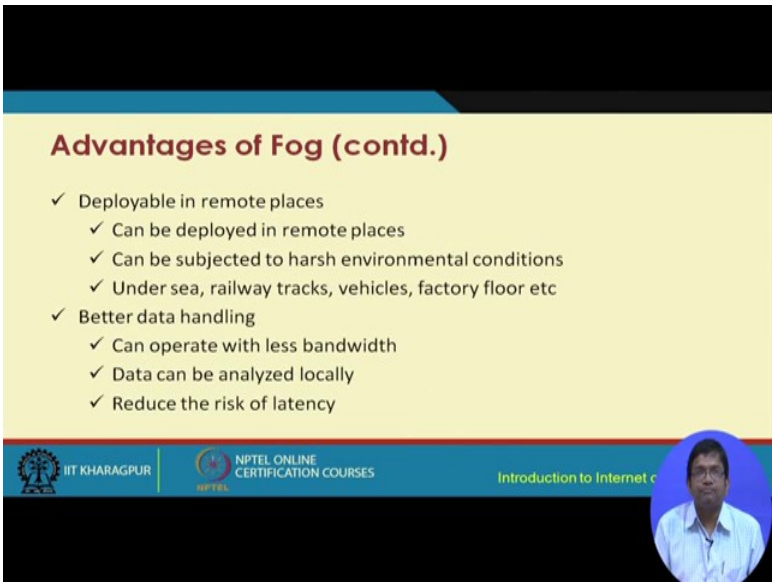

This solution the fog platforms can be deployed in a remote places and they can be subjected to harsh environmental conditions because typically this is what happens like environmental monitoring open environment you know different types of harsh environmental conditions snow fall rain fall hill storm etcetera, etcetera.

So, the devices the fog technology as a whole will have to go through this kind of you know harsh environmental condition better data handling because you know less bandwidth will be consumed for handling the data can be analyzed locally.

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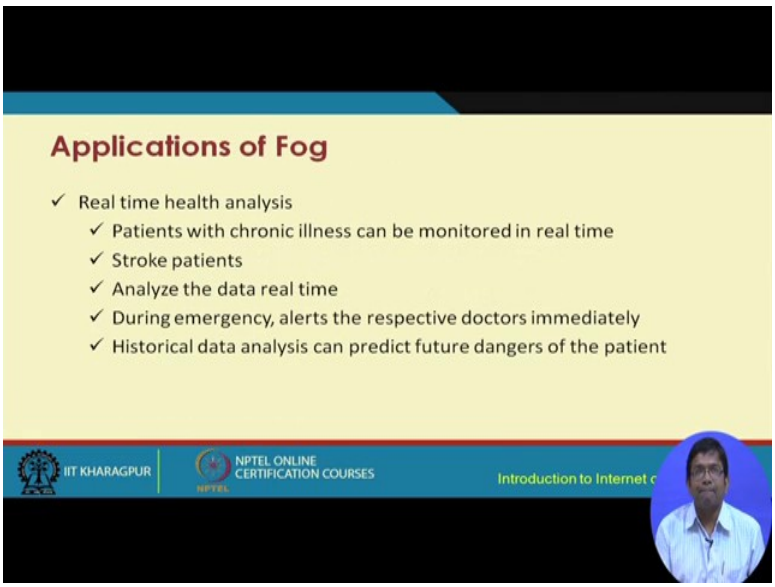

And that would reduce the risk of latency in terms of the applications of fog we can perform real time health analytics using fog technology where the patients with chronic illness can be monitored in real time patients you know undergoing stroke you know are any kind of medical emergency you know. So, this particular technology is basically good for use in such kind of situations.

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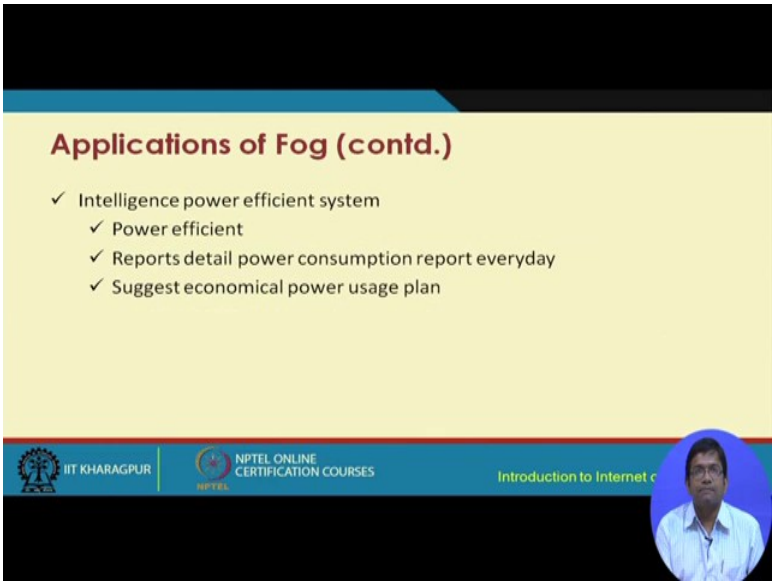

Intelligent powers intelligence power efficiency intelligence and power efficiency. So, fog is power efficient as we have seen before it reports the detailed power consumption report every day and suggest economical power usage plan a real time real monitoring is another application where the railway tracks in real time can be monitored on a day to day basis in an efficient manner. So, that is going to improve the overall safety and reliability of railway systems pipeline optimization.

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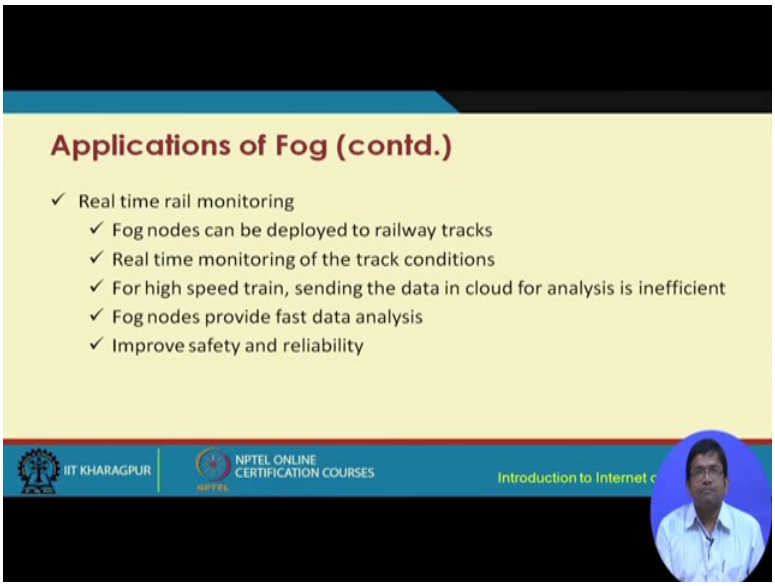

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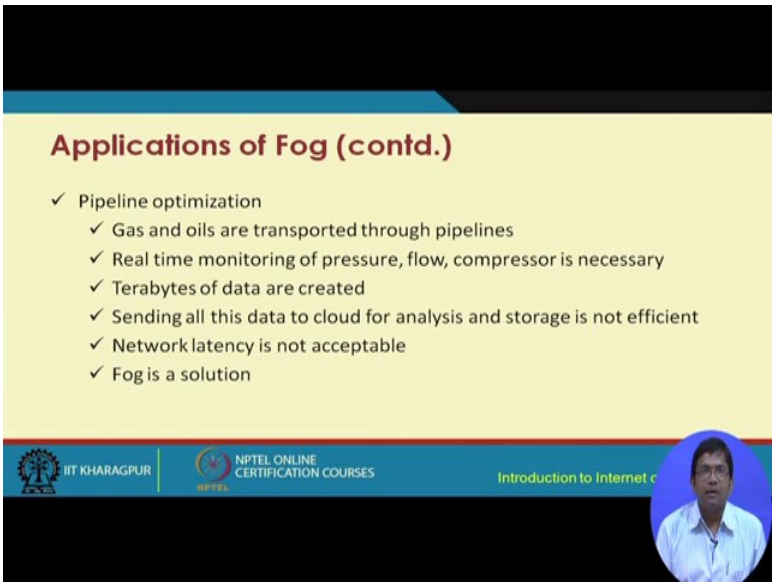

So, you know gas lines oil transportation lines are pretty common. So, real time monitoring of the pressure the flow the compressor you know compressor is necessary in such kind of gas pipeline systems.

So, Tera bytes of data are created and sending all these data to the cloud for analysis and storage is not sufficient and fog becomes a solution in such a scenario because latency to high latency is not very too much of high latency is not very acceptable in such cases

because there could be pipe leakages gas leakages and so on and that is not a very good thing to happen real time wind mill and turbine analysis wind direction.

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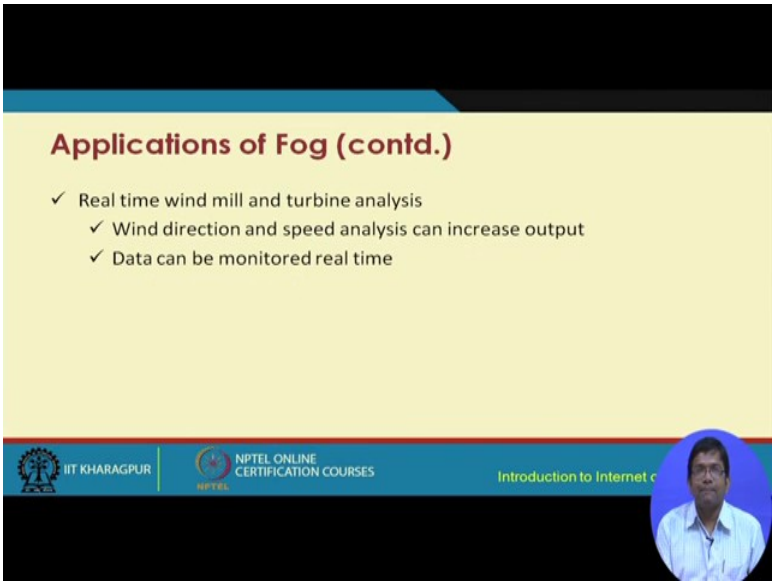

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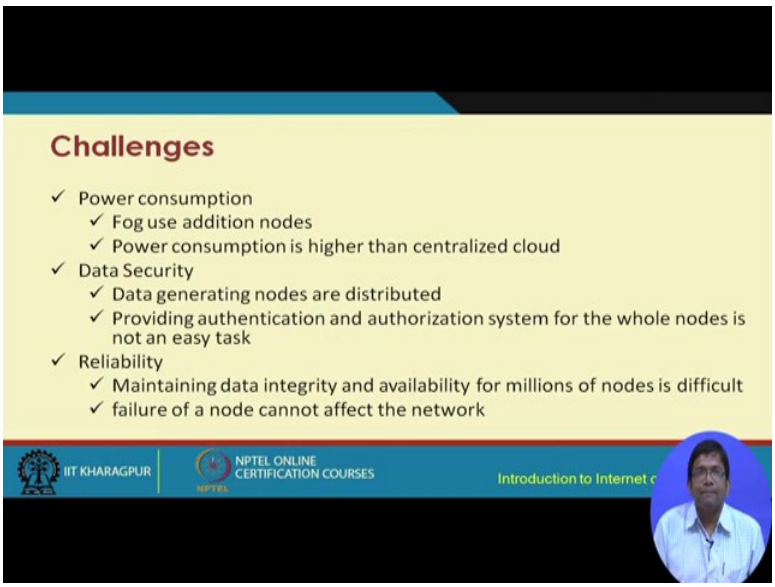

And speed analysis can increase the output data can be monitored in real time different challenges with respect to handling or consumption. So, additional nodes are used power consumption is higher than the centralized cloud and these are low power devices we are talking about and everything is done at the cloud. So, that is the reason why power

consumption has to be taken care of you know as a challenge in this kind of environment.

Data security; so, handling data security is a crucial challenge in fog platforms the data that are generated are distributed. So, it provides authentication and authorization system for the whole nodes and that has to be done for fog platforms which is not a very easy task in terms of reliability maintaining data integrity and availability for millions of nodes is difficult and the failure of a node cannot affect the network fault tolerance.

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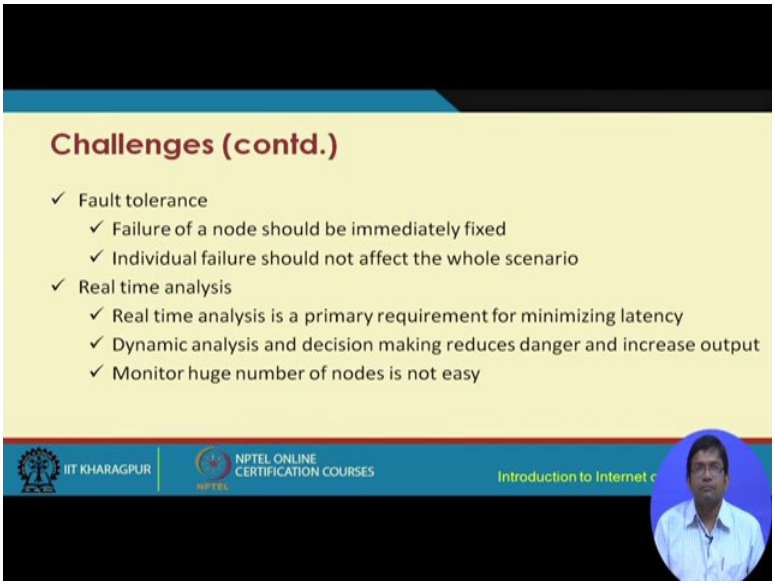

So, if there is some fault with a particular node and that should be immediately fixed and this fixation should happen ideally in an autonomous fashion. So, there should be autonomous fault tolerance fault detection also fault detection and tolerance and real time analysis real time analysis is a primary requirement for minimizing latency dynamic analysis and decision making reduces the danger and increases the through put.

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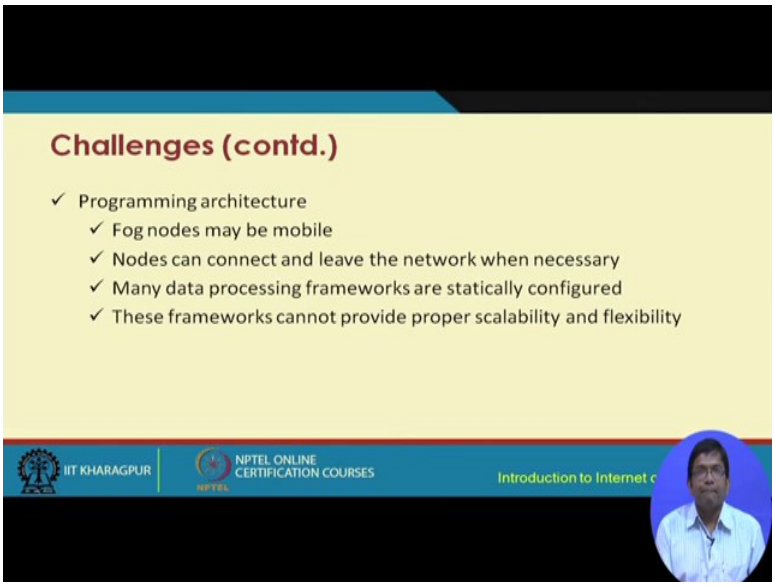

In terms of the programming architecture fog nodes may be mobile nodes can connect and leave the network whenever necessary and many data processing frameworks are statistically configured these frameworks cannot provide proper scalability.

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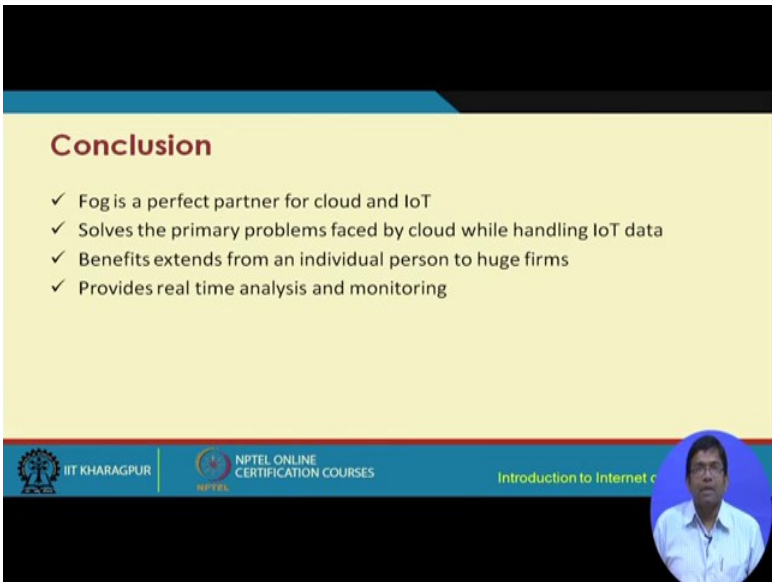

And flexibility in conclusion fog is a perfect partner for cloud and IoT. It can sit in between IoT and cloud to help IoT in the different functions that it has to perform it solves the primary problem that is faced by cloud with handling IoT data; it reduces it

reduces the latency overall and that is one of the I would say that it is one of the most important benefits of the use of the fog technology.

The third is it benefits the benefits extends from an individual person to huge farms and. So, basically you know. So, this is a scalable architecture. So, it is not like only a few people who would be using it. So, the benefits can be extended to huge farms through the use of fog technology and this fog technology basically provides a real time analysis and monitoring.

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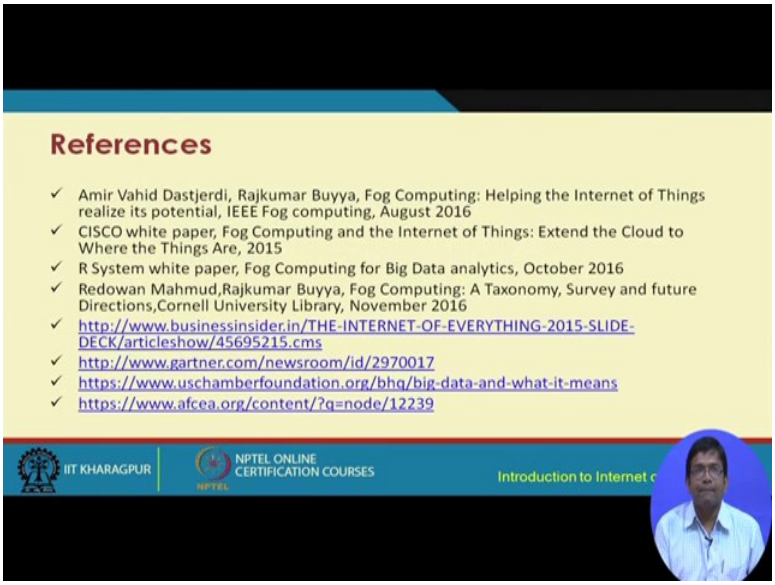

So, these are some of the references for you to go through further and if you are interested to understand fog and some of this contents have been taken from these references and the other references that have been mentioned at the bottom of the slides in the in this particular lecture.

Thank you.