Cloud Computing
Prof. Soumya Kanti Ghosh
Department of Computer Science and Engineering
Indian Institute of Technology, Kharagpur

Lecture – 34
Fog Computing – II

Hello. So, we will continue our discussion on cloud computing, rather we will continue our discussion on fog computing. So, what we have seen in the in our previous lecture or previous discussion on fog that there is a need of several application to instead of pushing all the data services and applications to the cloud instead whether you can do at a much lower level, right, there is some of the requirements are due to the bandwidth limitations like or reducing the bandwidth overload and in some of the things are real time applications, right, you need to do some real time applications which instead of pushing everything to the cloud getting the feedback process etcetera to end of the edge of the network may take much time, right.

So, in order to handle this, we need to push or there is a requirement of pushing some of this functionalities to the edge of the network or at intermediate level, right and also we have seen that all not all cases we require everything to be pushed into cloud, right, like specially applications like connected vehicles or you are that streetlight or traffic light management where it is more localized the phenomena is localized, right. So, it is more deal with the objects which are in nearby spaces.

So, it is no; there is not much requirement pushing all the data to the things. Again a with the with the huge prolification of sensors and for that matter IoTs, there is a huge volume of data generated where instead of sending the raw data to the cloud for processing, there we can do a pre processing or what we say some sort of a aggregation of the information and push it to the cloud for further processing. So, overall in looking all those things, there is a need to bring this data services application little down from the cloud what we say fogging or fog computing in some cases; also people say as a edge computing or having a distributed phenomena of the things.

There are few characteristics; what we have looked into of cloud which need to be served here also like scalability infinite scaling or scaling pay as you go model or metered services and that like making the infrastructure free type of situation of the things and

several other characteristics or cloud provide what was the median motivation of moving towards cloud need to be supported at by the fog also, right. So, that is that is the need of the things and is not like that all the a given a particular application a everything should be put on the edge of the things there may be we can do a partially at the at the cloud end and partially at the at intermediate or edge of the network, right.

So, this will bring different sort of challenges what we will try to look at in today's talk that what are the different type of things; what are the fog; fog devices are not so resource reach, right, like they are devices like intermediate routers or at time the sensing devices or the sync of that particular sensor deployment sync node of the versus deployment which is not actually. So, cool at the cloud not no whereas, as this was cool at the backend high resource cloud. So, there is a resource management comes in a big way of success of this type of a phenomena, right.

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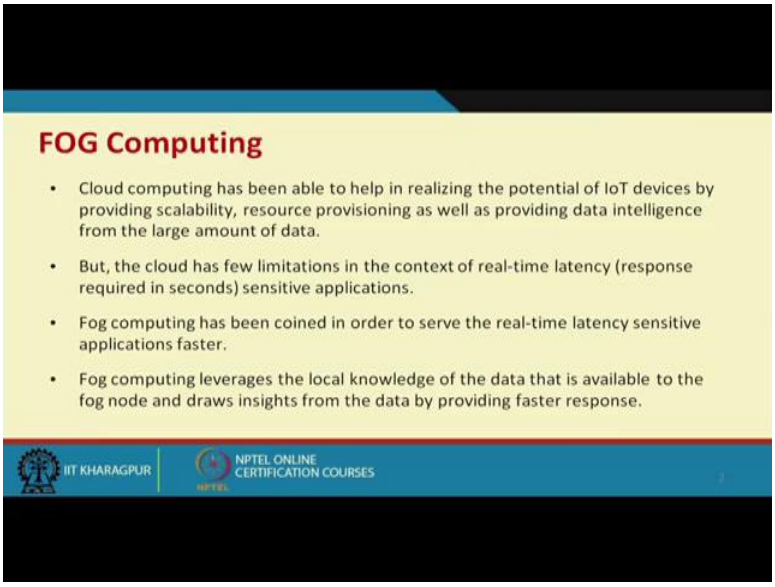

So, we will talk about fog computing. So, what we see that cloud computing has been able to help in realizing the potential of IoT devices or IoTs by providing scalable, scalability resource provisioning as well as providing data intelligence from the large amount of data. So, one is the scalability resource provisioning and the other end it can basically do some sort of a knowledge mining from the data right making data to from data to knowledge transformation sort of things, right that is at the backend, we are machine learning another type of algorithms which can run.

But the cloud has few limitations like specifically in the context of real time latency, right, response required in seconds or milliseconds or microseconds sensitive applications likes in case of its a application accident say; if there is a collision of the car and if there is this cars are intelligent car what we say that having which are regular ad hoc network or sort of things; if we need to push this policy and related information to the cloud, get it refined and find out the location etcetera in from the nearby cloud that maybe by that time, there may be few more or many more applicants a accident could have happened.

So, it could have been done in a very localized manner where instead of taking it to that that cloud and doing the processing I could have done at the localized manner impossible. So, this sort of real time applications; where this accident management or some other type of applications what we see that there can be a possible phenomenon doing that so, fog computing has been coined in order to serve real time latency sensitive applications faster, right, it has been coined to serve real time faster.

Fog computing leverages the local knowledge of the data that is available to the fog and draws insights from the data by providing faster applications. So, first of all is a order to serve real time latency or real time applications or which are time sensitive applications and also it as it leverages; the local knowledge of the data more at the local level available to the node and draws insight from the data by faster response, right. So, that is that exactly it tries to look at that fog sort of environment.

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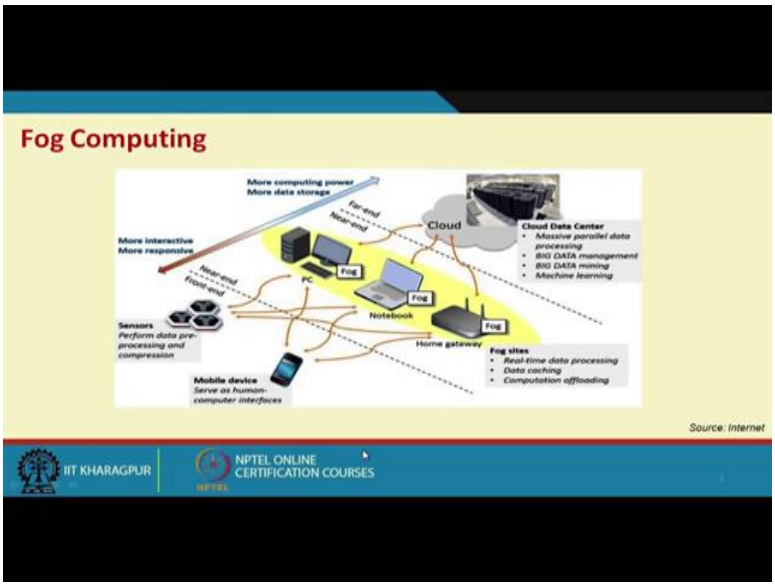

Now, this picture we have seen in the earlier our discussion on fog like we have one in cloud one in these sensors and mobile devices another; what we say contributing to were contributing to the data intermediate devices can constitute this fog, right.

So, this is this may not be specially installed for that right. So, we are having say routers or gateways some systems and other devices which are basically communicating to which are basically used for intermediate communication of the sensed data to the cloud, right. So, transmitting they are more as a some sort of a working as a store and forward from there why whether we can do store process forward and take some all locally right some of the things need to be forwarded at the other end for higher level of things or maybe aggregation over a over a larger geographical space when different sensors coming from the things nevertheless we can have a localized phenomena what we look at the using the data at the local level.

So, what we see that more computing power; more storage is at the end. So, the applications which are more computing intensive can be push to the other end whereas, more interactive or more responsive can be at the lower end. So, these are the 2 side of the things. So, intermediate; we have fog or even in some cases, these inter frontend devices can do some sort of a calculation and aggregate the data and same to the things.

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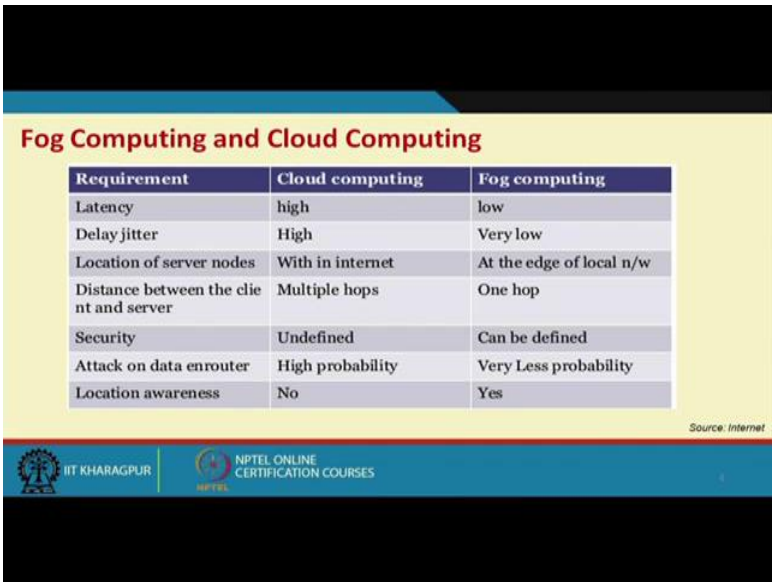

So, if you look at if we try to compare or compare and contrast between cloud and fog as we have discussed in earlier lecture that these are not competitive means in the sense they are not replacing one by another. So, what it is trying to do; it is mode of a; in a companion mode, right, some of the things which can be done better in cloud and should be done there and fog and they should do in a proper orchestration of the things a much requirement of the orchestration.

So, if we take a look at requirement of cloud and fog. So, if we say latency. So, is higher in cloud or lower in fog, right. So, latency is a higher delay jitter definitely the then say high are usually it is high and it is very low in the fog or low in the fog, location of server nodes within internet, right whereas, at the edge of the local network, right. So, where the server nodes are located in case of a cloud it is in the Internet, right you really do not know that where the services are given you talk about Amazon or Google or Microsoft or IBM or anything. So, sports or anything; so, what we do? We basically connect through their portal or link and we really as the individual do not know that where your application is being done; it is not like that that you cannot know; you can know, but nevertheless, they do on their resource management and provisioning and type of thing. So, that is what we say in the internet whereas, if you look at that fog type of scenario.

So, it is more on the edge in the local network like if I am doing say aggregation of the temperature sensing and taking a design of this particular room, with which is having say 10 odd sensors, then what I am doing is basically locally and I know that the server in this particular room is working for that things or the server which is serving for this particular room is working on the things, right at times that is useful because if you see some congestion or some problem in the things you can address the things at times there are other challenges, it may be a security loophole also because you know, if the temperature at being sensed by the servers and it is sending to things and if this particular lab or room in housing important other systems, then I can basically attack that server and say that do some manufacturing, right, even the temperature or means environmental sensing is giving some allowed, I say that everything is going on fine and at that type of thing.

So, there are downfall and type of things required and. Secondly, it needs to be resourceful to cater to the type of applications which I am trying to do. Distance between client and the server usually in case of cloud computing is multi hop, you are using this standard networking to go to the thing usually in case of a cloud, it is a one hop may in case of a fog, it is a one hop, right. So, they are at a one hop distance from the client to the server, right.

Security in case of a cloud computing 1; 1 argue is it is undefined; undefined in the sense that as the user and I do not have much control over the things, right. So, it is in that sense, it is undefined whereas, here it can be defined like you have a local things you may have some control over the thing. So, you use the may have some control over these particular devices or the organization can have control over the devices and can try to ensure some security like if I say the traffic light. So, of a particular city, then the traffic light management in that server of a particular zone is under the traffic authority of that city, right. So, they have a control had it been on the totally on the cloud. So, you do not know that what the data or applications are doing that is that is based on that service provider.

Attack on data enrooter; right. So, in the enroot data whether the attack in case of cloud if there are multiple hops. So, there is a chance of much become getting much compromised where in case of a fog, if it is a single hop, then as it is a single hop, then the getting compromised things are less, right. So, you have a little more control over the

thing location awareness in case of a cloud computing is minimal whereas, edge fog computing is location aware, it is primarily what we are doing is location aware type of things.

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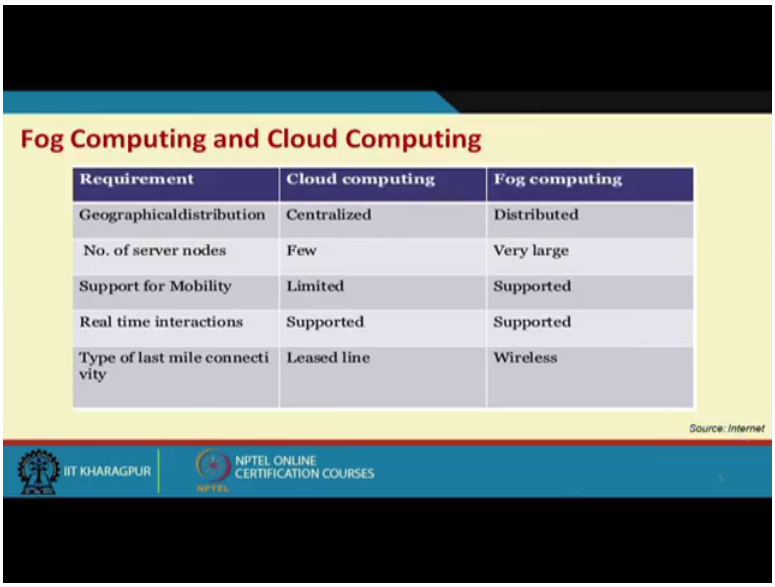

So, there are other things like geographical distribution in case of a cloud it is more of a centralized feeling. So, it is having a logically centralized things, in case of a fog it is distributed right number of server nodes in case of cloud are few because the that is at the clouding and usually servers are extremely resourceful though number of nodes required for the publications or type of things are very few in case of a fog; as it is edge as you go down the hierarchy, that the number of nodes increases much more. So, they are the very large number of urban nodes. Support for mobility in case of a cloud is limited right if you move from one or mobile application that it need to be switched etcetera to the different intermediate devices.

Now, it is carried by say one path once you move to the other path whereas, in case of a fog some sort of support is there in the mobility, because it takes a local deals and other things, right, it knows a priori things are that is where under which control and need to be transfer at a much lower level.

Real time applications real time interactions do supported by cloud and of course, it is supported by fog that is one of the major motivation to move towards fog computing scenarios type of last mile connectivity is usually disliked, right. So, or cable line in case

of a cloud, right whereas, in case of a fog is usually wireless, right that there is no hard and fast type of things, but these are you usual standard processes in reality, right.

So, there are pros and cons; it may so happen that as we are discussing fog. So, it is little bit more supportive towards the fog why it is there and, but nevertheless to both has importance and proper a synchronization orchestration between this fog and cloud should make the whole thing a reality.

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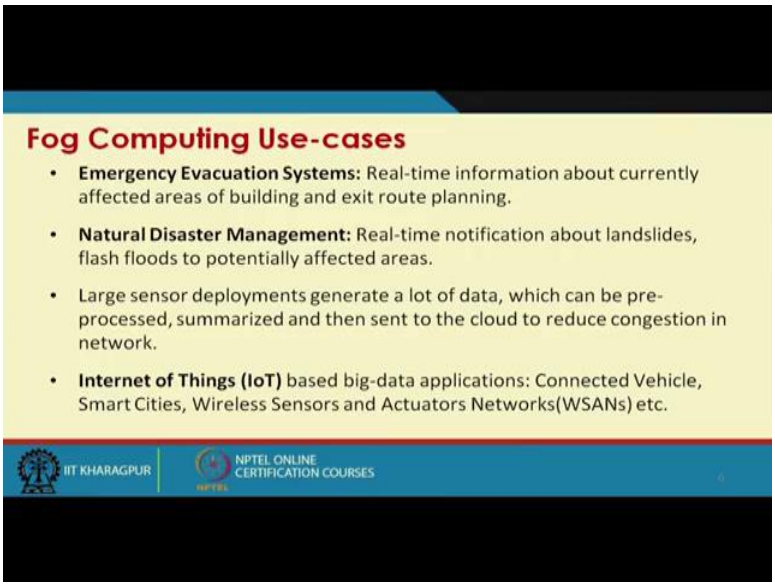

So, there are a several use cases, right or several scenarios where fogs are; fog will be very much applicable, one is that emergency evacuation system for any catastrophe or disaster real time information about currently affected areas or buildings and exit route planning etcetera. So, if it is a large building with several route paths for exit; if there is some catastrophe like fire or earthquake or something then the default paths may be getting locked right or may not be routable.

So, what you need to do? You need to do a based on that availability of the exit at every level or every individual rooms, etcetera, we need to path plan the path. So, we need to have it need to be dynamically replant or reroute it and where may be some local DSM is much more helpful natural disasters management. So, real time notification about landslides flash flood to potential affected area. So, that is one requirement. So, when we are having natural disaster management. So, real time notification things and there which are sometimes pretty localized for a particular region of interest where the things are

going on and may be useful way if we have this location aware information at a fog level.

So, large sensor deployments generate a lot of data which can be preprocessed, summarized and then to send to the cloud to reduce congestion in the intermediate network. So, that is another requirement of fog, it may not be natural disasters management or natural disasters or hazard, but in other sense what we have that huge deployment of sensors that can have produce lot of data and it takes if you send the all the raw data to the cloud it takes a lot of bandwidth and lead to congestion.

So, which can be reduced by moving, pushing aggregated data and of course, the Internet of things, right based on big data applications like connected vehicle smart cities wireless sensor network, actuators, networks and those and its said the; so, these are all different-different; what we aspects of are the scenarios of internet things which again push lot of data and in the whole framework and all every time that you are; this may not be important like that maybe a local DSM is more important than taking a global DSM and type of things.

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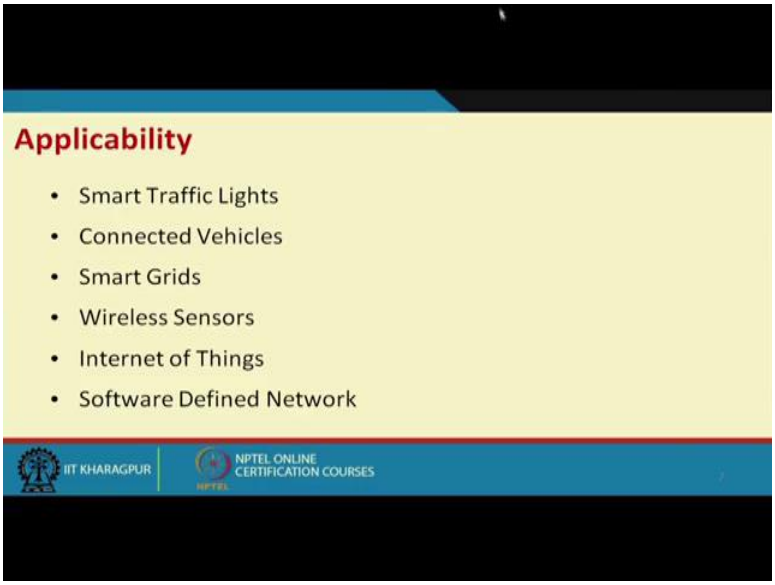

And if we look at the applicability, there are few here there are hundred more which can be there. So, smart traffic lighting maybe one application, connected vehicles, smart grids of course, sensor network, internet of things and software defined network. They provide this backbone of these applications to work on, all right.

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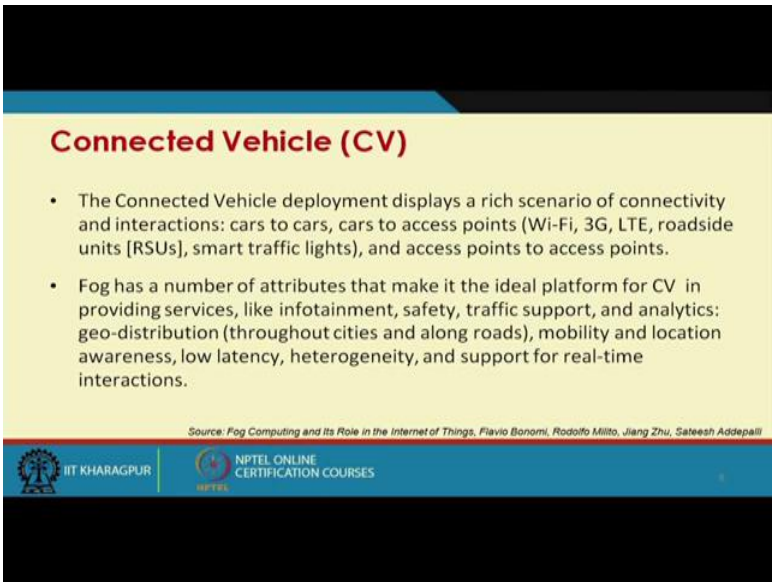

So, if we look at the connected vehicle deployment displays rich scenario of connectivity car to car; car to access points and type of things.

So, what we look at when we when we talk about vehicular infrastructure we have on the road different moving cars, right.

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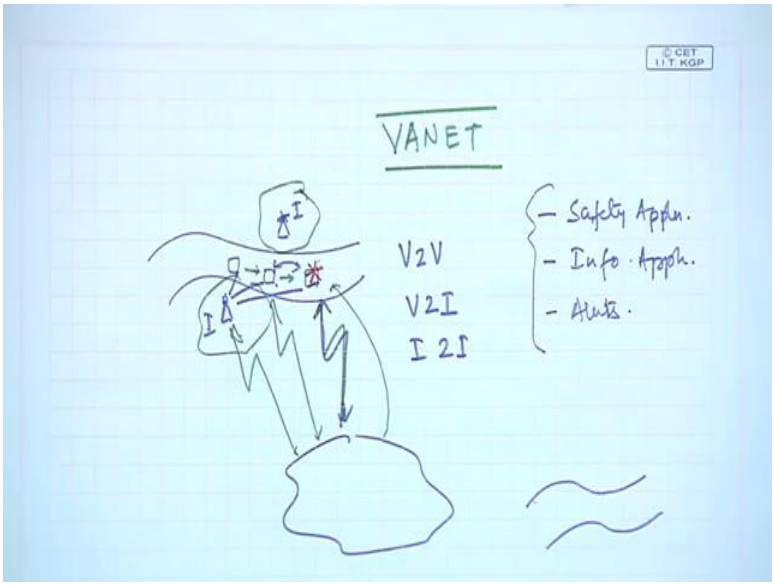

So, these are different vehicle and of course, different infrastructures. So, we have connectivity between this vehicle to vehicle or what we say V2V or V2I, I2I. So, these are different infrastructure which are hovering around and giving connectivity to these

different vehicles. So, this sort of things are different type of application one is safety related applications, another is say information on infotainment information related application and there are other things like Alerts and other type of things based on the title.

So, those are the information which will be there and in c there may be a overall cloud infrastructure where all could have communicated right and it takes a diesel and sends back information type of things now say there is a clash in this particular vehicle, right, if there is a clash then other vehicles which are approaching this vehicle now get information via this instead it could have been done locally, right, if I can set up a some sort of a fog around this sort of things, then I could have taken a local diesel because the accident here may not be nothing to do with some road going somewhere in some cities etcetera right or even in the same city some other part of the thing.

Now, here this type of connected vehicle phenomena or what we say a concept which is coming up or it is already they are VANET vehicular ad hoc network, right. So, to make it successful this fog maybe one of the applications, right. So, again smart city lighting as we see that if there is a traffic congestion etcetera that within the thing within that particular localized things sitting. So fog has a number of attributes that make idle platform for connected vehicle in providing services like infotainment safety traffic support and analytics like geo distribution, mobility, location awareness, low latency, heterogeneity and so and so forth. So, there is a lot of applications are there.

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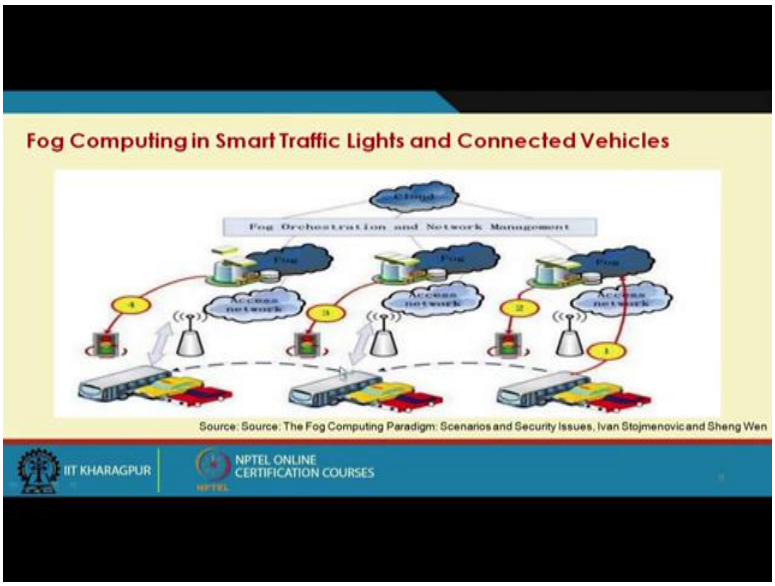

So, like what we see that there are different vehicles running at the backend. So, there are the access points or what we say that infrastructure along or sometimes known at road side unit or RSUs. So, these units are there; there are other traffic lights. So, based on this congestion etcetera this traffic light can be intelligent like it, it gives the timing for stop and go type of things may vary based on the congestion level. So, and at the backend we have that cloud which takes larger analytics problems which requires larger resources and we require a fog orchestration and network management layer which takes care of this synchronization or orchestration of the fog and also orchestration with the backend cloud.

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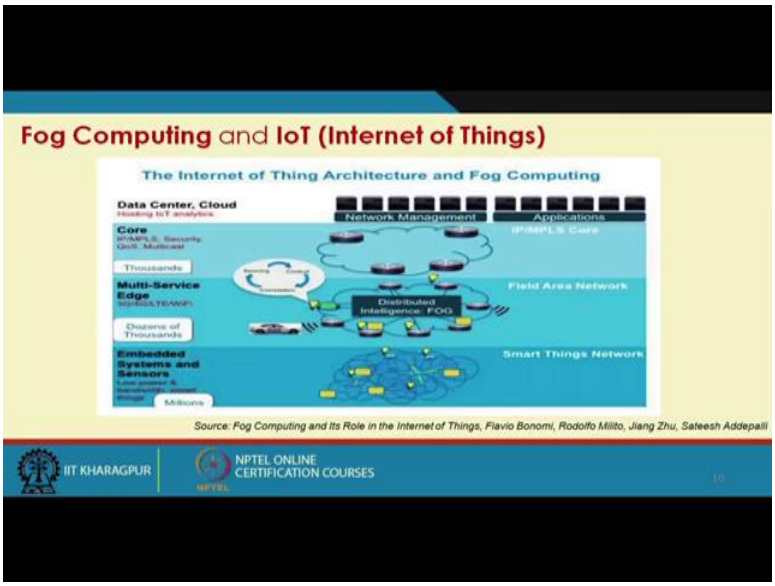

So, it is a system. So, what we try to see that this fog take a local decision whereas, large analytics can be pushed to the cloud environment, right. So, this is one of the scenarios there of course, if we look at a more of Internet of things. So, at the lower end we have embedded systems and sensors then multi service edge which takes the distributed in inclusions where fog can played a role and then we have a core network which is which is used to push the things at the upper cloud, right. So, this is in generic way of looking at the internet of things; where we see that a fog layer may help in reduce latency and providing better services.

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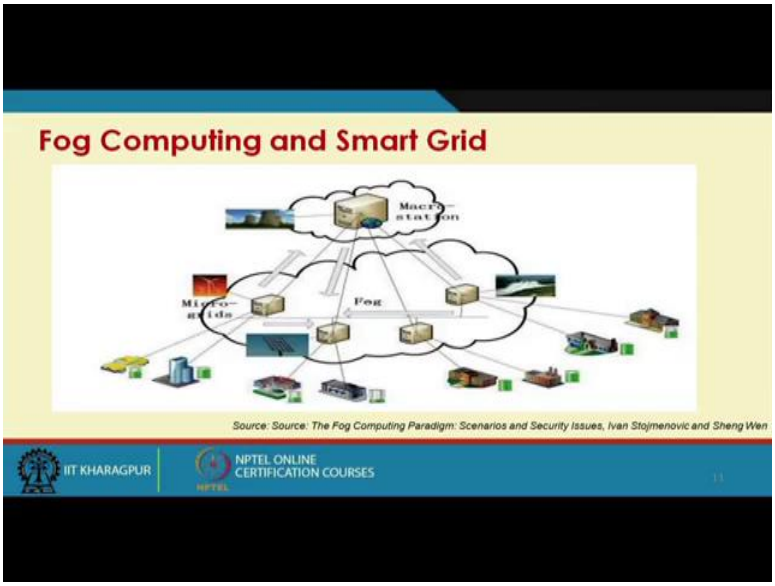

And though in our country may not be highly proliferated or it is not in a big way use, but it is going to come is that a smart grid, right. So, every home will have a smart meter and based on the based on utilization of the things at a from the from the home level to from at the house from unit of the house to as say region level and a largest state level the overall management can be done. So, I have a smart grid which not only give power to the homes and offices and installations also take a feedback and takes a call based on the things that how the power utilizations are there; it is connected to the power plant and the overall power management across the region across the country or across a larger geographical space can be managed by these sort of things.

So, here also fog plays a important role if I this if you are looking as a all things can be pushed into the cloud and take a call, right; however, suppose I consider IIT Kharagpur, if the homes are having smart meters then I could have taken a local decision that what is the overall utilization of the power and type of things and I send a aggregated information to the backend cloud, right. So, which takes a more takes of this aggregated information and take to analytics that over the over larger time span or over days months etcetera how things varies and take a call that what to provisioning of electricity based on the things.

So, this type of things are useful where we have that in devices or in consumer of electricity, then we have a fog infrastructure where micro bleeds and other things are there.

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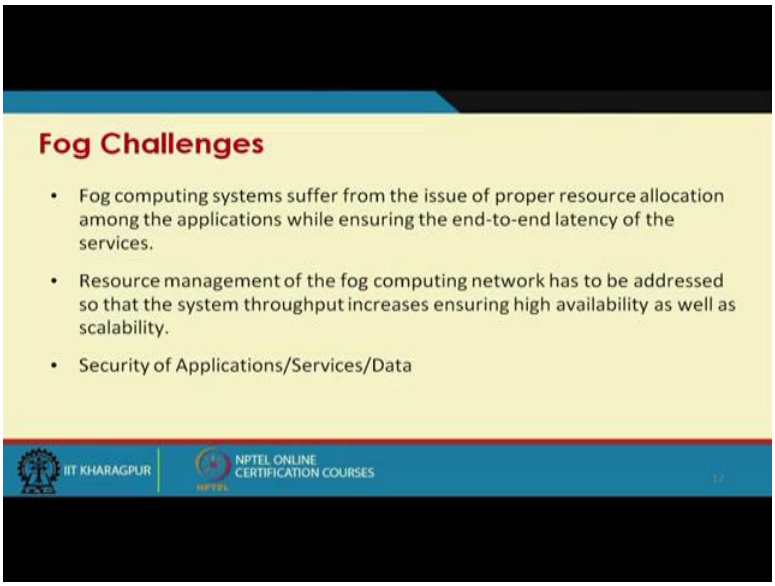

And then we have a micro station and push it to the larger in sort of a cloud environment and as we see that all; what we say lucrative or golden side of the form there are few definitely challenges or there are good amount of challenges in or to have a realization first of all these devices are not that resource full as cloud or cloud servers, etcetera.

So, that can give; what we say support to a minimize things. So, if it is such application is there which require much larger thing? So, you need to divide that biggest and accordingly, right. So, it may be among the fog devices some portion on these fog devices and some of the cloud and whenever we do this there is a lot of need of synchronization orchestration of the things, right because not only now the data are divided your application or the process is also divided. So, somewhere this aggregation of this data and processes need to be there. So, that is one of the challenges there are other challenges of the resource management in the fog itself like suppose if one of the fog device is overloaded whether I can migrate this application on the things whether I migrate this on the life like executing things can be migrated to the things.

So, these are serious challenges if we if we need to look at the things. So, let us see some of the things. So, fog computing system suffers from issue of proper resource allocation among applications while ensuring end to end latency of the services right. So, what we want to do that end to end latency and challenges are face resource management of the fog computing network has to be addressed so, that the system throughput increases

ensuring high availability as well as scalability. So, the basic phenomenon of the fog and finally, as these are distributed over different geographical space may be at with different authorities, then what about the security of this application and data and type of things whether that becomes a source for things; so, security aspects we discussed last lecture or last discussion on fog that this is a serious challenge.

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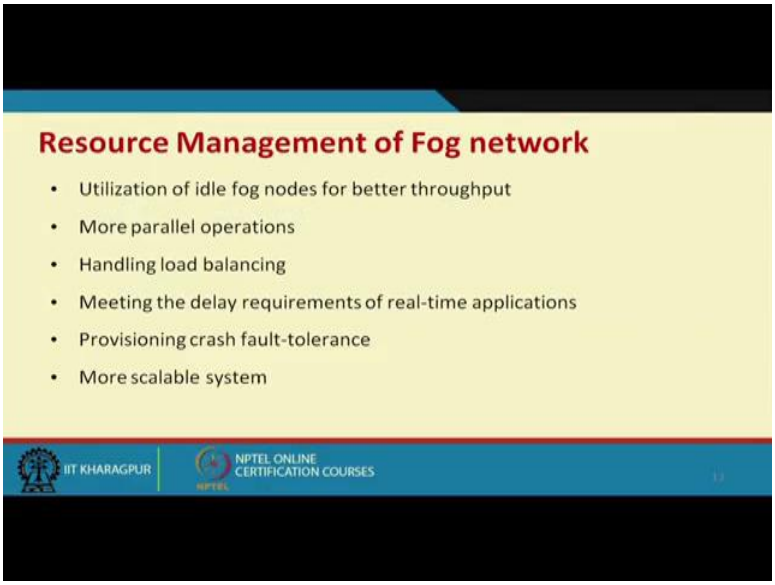

So, resource management in fog network; so, has different aspect they utilization of idle fog nodes for better throughput whether there is possible there is some of the fog nodes and it is basically skewed some nodes are more loaded than others more parallel operations how to generate more parallel operations handling load balancing meeting the delay requirements of real time applications, right. So, if you have real time applications; how it can be provisions properly provisioning crash fault tolerant and type of things, right. So, like I can say that if the fog node goes down what will happen to those applications and data and which are running on that fog nodes how to handle those how to migrate those data whether I require a prior in application that even if goes down the other will take up and all those things require a resource management and incurs cost and so and so forth.

More scalable systems; so, at the scalability is our core of the whole thing right scalability is one of the major aspects of cloud we service fog computing; so, how to have better scalable systems.

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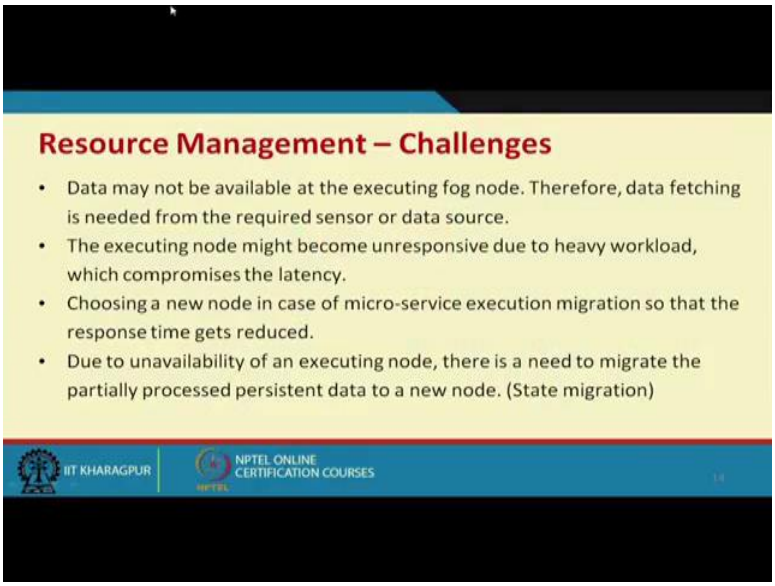

So, they are if we look at little more nitty-gritty data may not be available at the executing fog node. So, the application is there the node may not be there therefore, data fetching is needed from the required sensor or data source. So, that is a phase cyclist their executing node might become unresponsive due to heavy workload which compromises of the latency there may be a issue choosing a new node in case of a micro service execution migration.

So, that the response time gets reduced even if I have a way of migration if I am a micro service is running on a particular node or a smaller or cut down version of the service or chopped service or a partition service is running if I am if even if I am able to migrate that I see that this node is going down; what should be where I should migrate how to find a node at a thing.

So, some algorithms would run and type of things and some sort of managements would come into play due to a unavailability of executing node there is a need to migrate partially processed persistent data to a new node. So, it is half-cup thing need to be migrated. So, that is another need final result has to be transferred to the client or actuator within less amount of time in order in doing.

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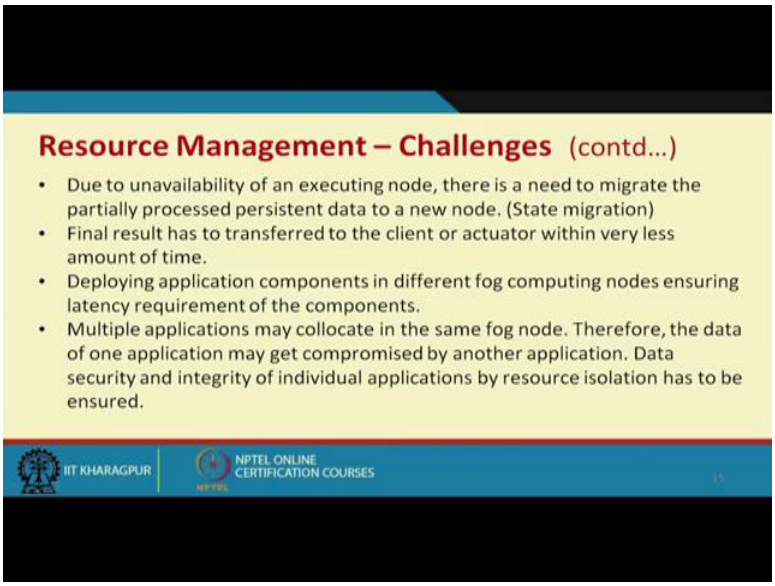

So, I should not lose out on the time deploying an application components in different fog nodes ensuring latency requirements of the components multiple applications may collocate in the same fog node, right, therefore, the data of one application may get compromised by the other.

So, it may happen that number of application more than one application in the same data security and integrity of individual application and resource application has to be ensured, right. So, what we look at the multi tenancy problem in the cloud that sort of problem can be there in the fog and fog gives less resource.

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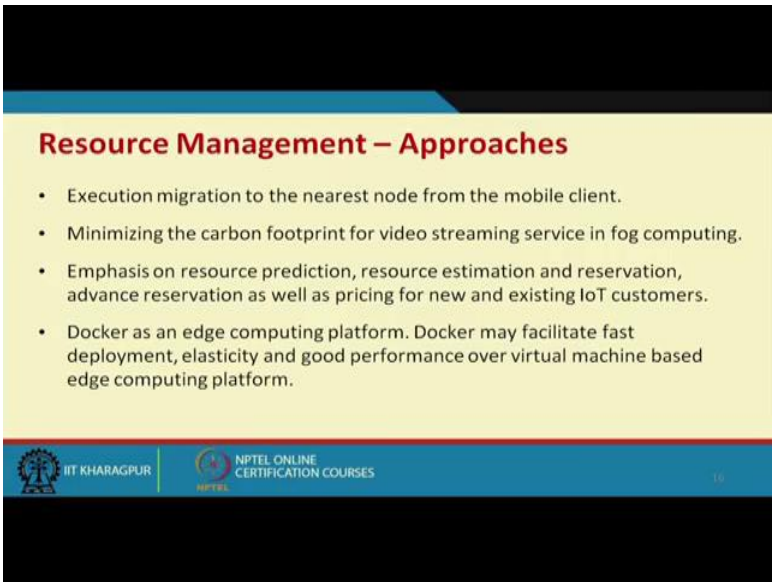

So, that may the problem may be more escalated and there are several approaches people try to follow like executing migration on the nearest node which is available or to the thing. So, the nearest node which is free may not be the most suitable, but the available node type of things minimizing carbon footprint or video thing my major objective is that to reduce that energy or carbon footprint emphasis on resource prediction whether I can have a the approaches, prediction, resource estimation, reservation, advanced reservation as well as pricing of the new IoT application; so, that we can do a priori estimation of the things.

There is another service which we say Docker as an edge computing platform to deploying Docker may facilitate fast deployment elasticity good performance.

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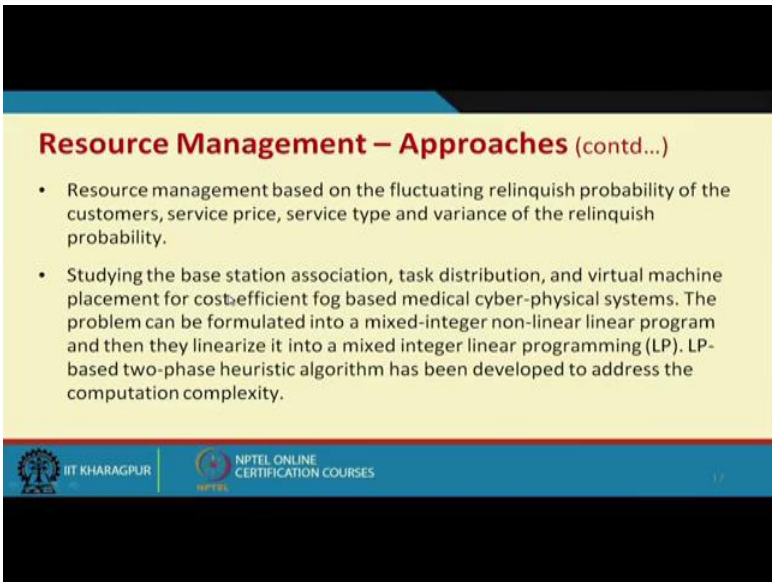

So, resource there are resource management based on fluctuating relinquished probability of the customer research prices etcetera people follow that there are other things like studying the base station association tasks distribution virtual machine placement and so an for and formulating a LP formulation to optimize the thing applying heuristics algorithm to a approach that problem.

So, these are the different type of approaches which people are trying to do and you can see; these are there are lot of research motivation here, right; there are lot of research going on and those who are interested; this is a field where which can be looked into or you can work on those type of aspects this is a ongoing another upcoming area to look at.

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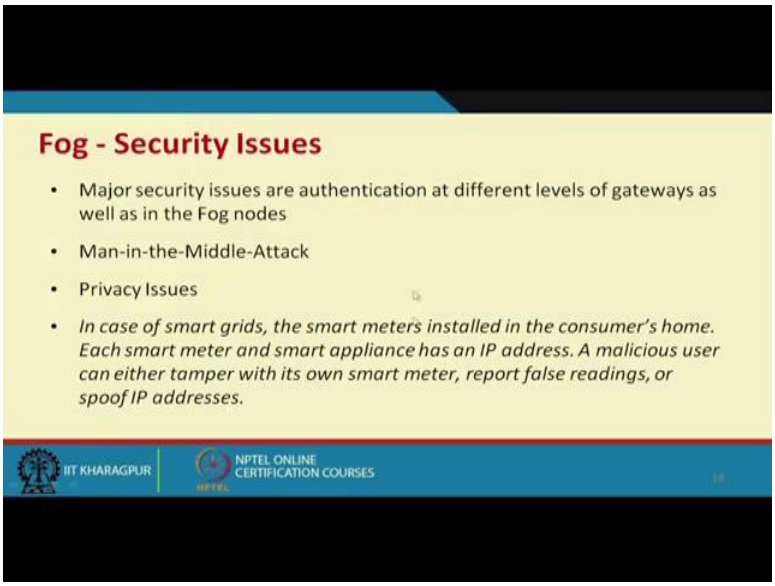

And security issues already we have discussed I am not repeating that. So, security what we try to emphasize here security is also a major challenge right because low resource you cannot run say resource pool or what we say resource hungry security applications what we say which or security measures which are resource hungry. So, you need to be need to be appropriately sized to this fog type of fog devices to run on.

So, security is also a major issue it is not only that the data I can be compromised the fog is devices may be a platform to simulate to simulate or launch attacks right. So, because it is distributed now things are distributed less control over this centralized cloud and the ISP. So, there is a there is a chance of this being exploited. So, need to be looked into things are there how secured or how robust this fog devices are also a major challenge, people are working on with this we let us stop today.

So, what we discussed that that the importance of fog, amalgamation of the fog and cloud that it is not like that a through throughout one of the technology are things are there rather proper synchronization and orchestration between them is a is the real way to have a successful implementation of this framework.

Thank you.