Introduction to Internet of Things
Prof. Sudip Misra
Department of Computer Science & Engineering
Indian Institute of Technology, Kharagpur

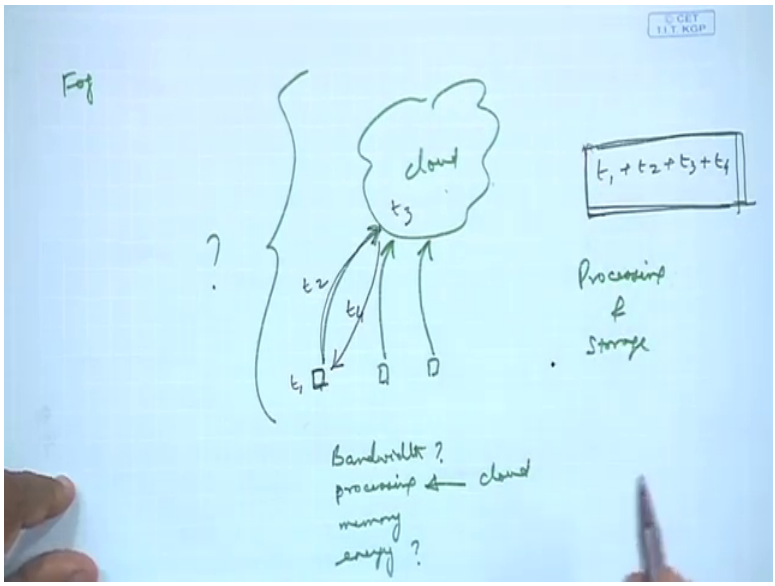
Lecture – 44
Fog Computing – I

In a previous lecture, we discussed about cloud computing and its importance in Internet of Things.

(Refer Slide Time: 00:23)

So, cloud is very important because you see that internet of things IoT devices; sensors, RFID devices and so many different types of devices, this sends so much of data and finally, those data have to be handled and that is the reason that a cloud came into picture; that all these data will be sent to the cloud for further processing and so on and so forth. Now, the main problem with cloud in internet of things environment is latency. So, what is meant by latency; I will explain to you before we go formally about discussing the concept of fog.

(Refer Slide Time: 01:14)



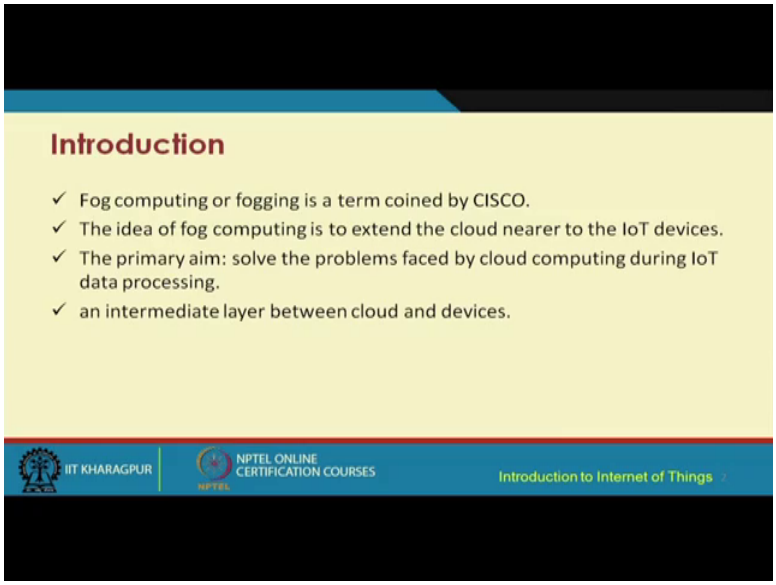
Let us say that we have a cloud and we have different IoT devices deployed. Now, what we have discussed when we were talking about cloud computing in the context of internet of things is that each of these devices, they send all these data to cloud; for further processing and storage. Now, that is a problem because you see this IoT environments, number one are constraint in different ways with respect to bandwidth, with respect to processing, with respect to memory, with respect to energy and so on so forth.

Now, this processing can be handled with the help of cloud, but what about the bandwidth, what about the energy consumption because what is going to happen in this sort of scenario of use of cloud in the IOT context is lot of data is going to float all around; over the network, lot of data through the internet are going to be sent to the cloud and that will unnecessarily consume the bandwidth and that will also consume unnecessarily the limited energy that is resident in all this devices and so on. So, we do not want to do that because communication consumes most of the energy.

So, we do not want unnecessary communications to take place and even if we do, we have to limit. Even if we have to communicate and that is required because in a network basically IOT is basically a network, so network communication is required, but how do we handle it efficiently this is what we are going to discuss in this particular lecture. So,

can we do something which is better than cloud? So, this is where fog comes into picture.

(Refer Slide Time: 03:46)



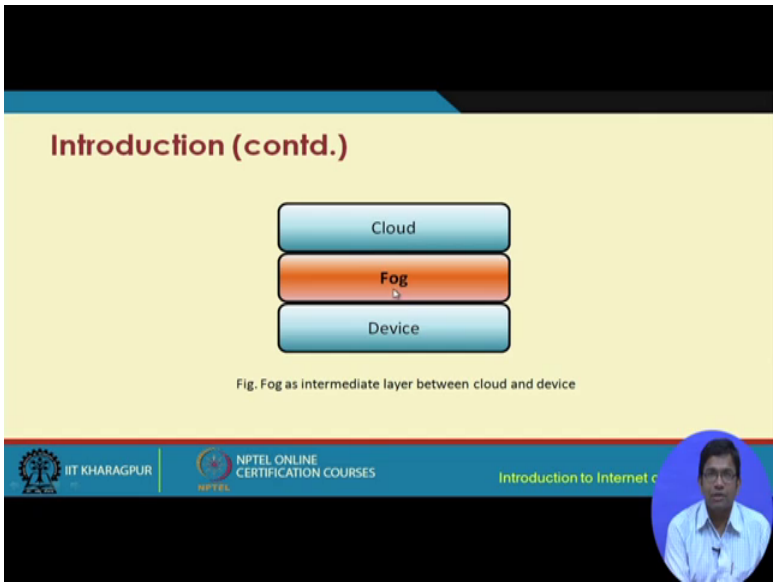
Fog was introduced by CISCO. So, it was sort of like an idea about how to being the cloud facilities close to the IoT devices because as we saw that we have all these data sent to the cloud you know that will not only take the bandwidth, limited bandwidth that is there in this kind of environment, but also that is going to take lot of time. So, in this particular case, the time that is required will be the time from when that event is sensed, that piece of data is sent to the cloud. So, this one let us say this is t 1, this is t 2, then the time for processing t3 and finally, that response will be sent back, so t 4 So, the response will be sent back for may be activation or something like that.

So, this basically becomes t 1 plus t 2 plus t 3 plus t 4. So, this is the total time that it takes until when the receiving device gets a signal about what to do and by such a time in most of the real life applications of IoT by this kind of time, you know most of you know the events, most of the unwanted events would take place. For example, if it is a surveillance application, maybe the intruder by this time because there is so much of latency that is involved, by this time the intruder might have already intruded into the territory or if it is a medical emergency scenario, by this kind of time it takes to send it to the cloud processing at getting a response back etcetera. So, even the real timelines is

going to be lost and because of this particular issue what is going to happen is, if it is medical emergency situation, the patient might die, right.

So, what is required is can we reduce the latency and this is what we are trying to do in fog computing. So, as I said that fog was basically proposed by CISCO and the whole idea is can we bring the cloud facilities, the attractiveness of cloud closer to the IoT device layer and the whole idea is to solve the problems that are faced by cloud computing for use of IoT for data processing. So, this is the whole objective of fog computing and the whole idea is also to reduce the delay that is incurred in sending the data from the sensor device to the cloud, from the cloud getting a response back and activating the particular device. So, can we reduce this particular time? So, this is the whole idea.

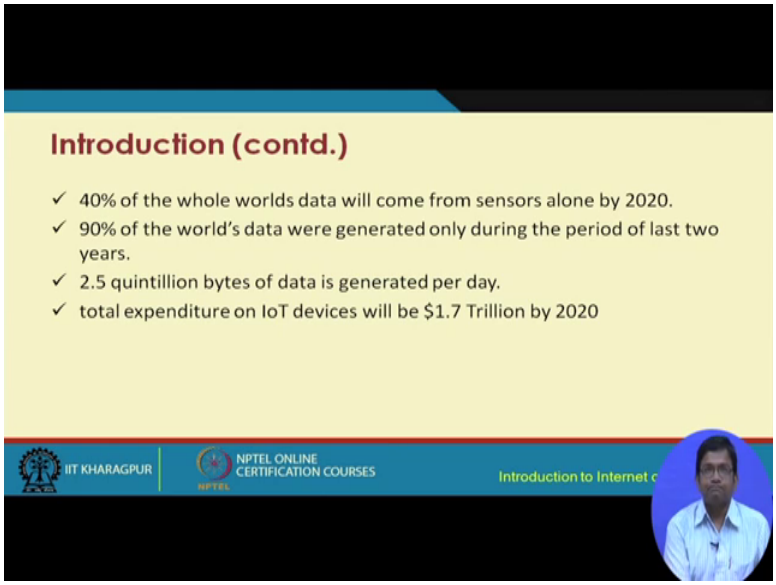
(Refer Slide Time: 06:51)



The whole premise under which the fog computing works, so conceptually what we have, we use to have IoT and cloud. You know this is the device layer where all these IoT devices, the physical devices operate and this is the cloud where all the data are sent for processing and storage. So, what fog is saying is, it is going to be sort of like a middleware or a middle layer rather where some of the computation, some of the processing, some of the storage at least transient storage is going to happen. Before the data that is sensed by these devices are sent to the cloud. Before it is sent to the cloud,

can we do some intermediate processing, intermediate storage for you know quicker decision making? This is the whole idea behind the use of a fog computing.

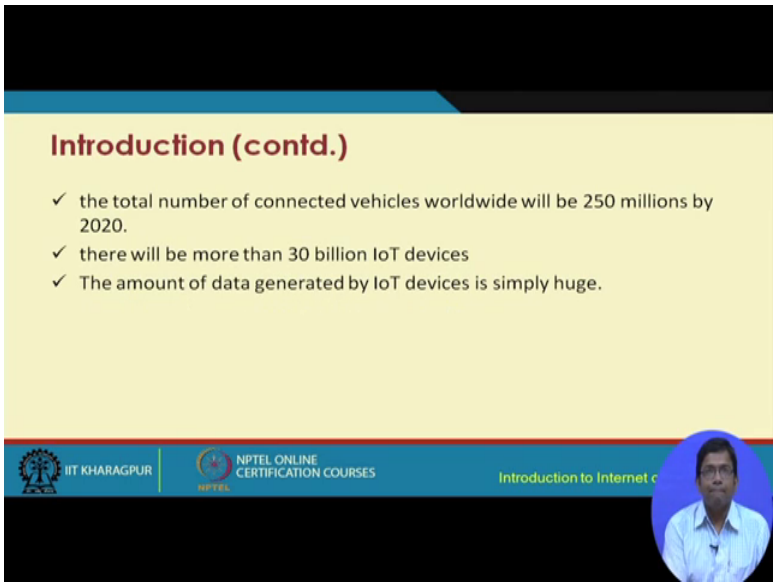
(Refer Slide Time: 07:41)



So, let us go back to some statistics which you know we also went through at the beginning of the course. So, we know that now it is because of all these different sensors etcetera, there is lot of data that is floating all around. So, it is estimated that by round 2020, 40 percent of the world's data will come from sensors and 90 percent of the world's data will be generated only during the period of last 2 years. So, 90 percent of world's data was generated only during the period of last 2 years.

So, you know it is also estimated that every day about 2.5 quintillion bytes of data is produced and the total expenditure on IoT devices will be about 1.7 trillion dollars by 2020. So, given all these different statistics, we now have to think about architecture of internet of things; where in we can use all these different devices in a scalable manner, such that the processing happens with large number of devices in a quicker manner and in an efficient manner.

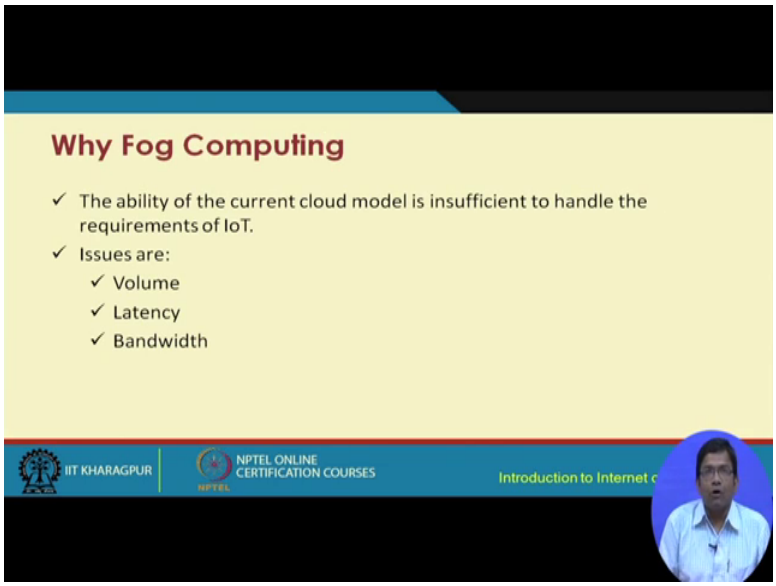
(Refer Slide Time: 09:03)



The total number of connected devices, sorry the total number of connected vehicles worldwide will be about 250 million by 2020 as per estimates and there will be more than 30 billion IOT devices again as per estimate.

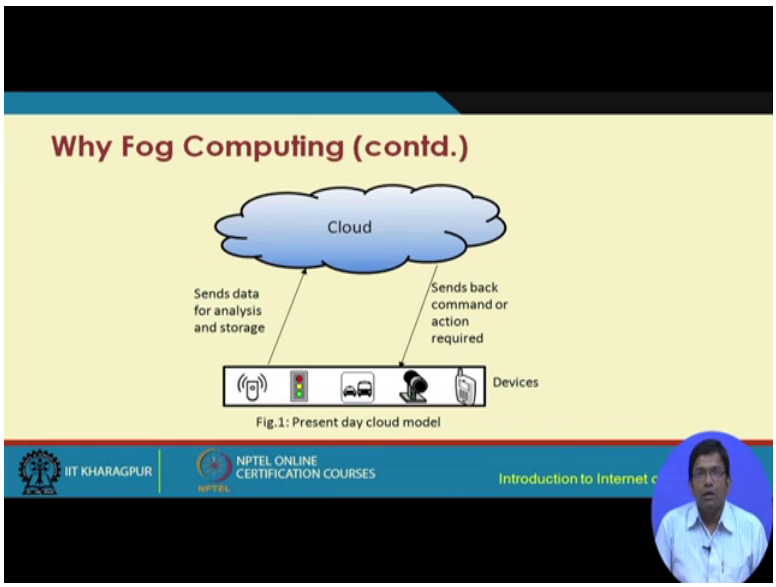
So, the amount of data that is going to be generated by these IOT devices is obviously quite huge. So, how do we handle this kind of huge data? I mean one way is basically to use all these big data analytics and so on, but even before that can we deduce the processing time of these data, can we do something from the network point of view and that is where we have to take help of fog.

(Refer Slide Time: 09:46)



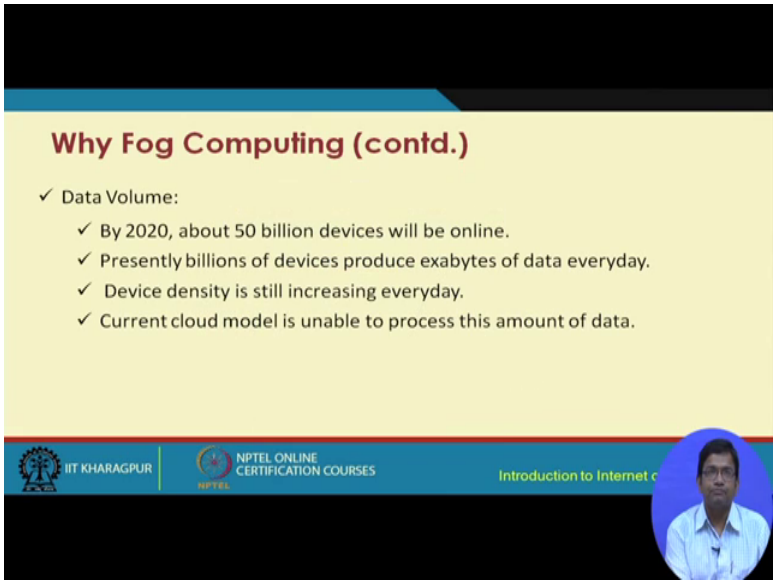
So, why do we need fog computing? It is because cloud has certain deficiencies. You know it is insufficient to handle the requirements of IoT. So, there are issues with volume of data that is produced by the IoT devices, the latency. That means, the time that it takes for a sensed data to go to the cloud and then come back, that duration is the latency and the bandwidth. Bandwidth means that you know how much data is going to I mean how much channel is going to be occupied because of this communication of all these data from the IoT devices.

(Refer Slide Time: 10:35)



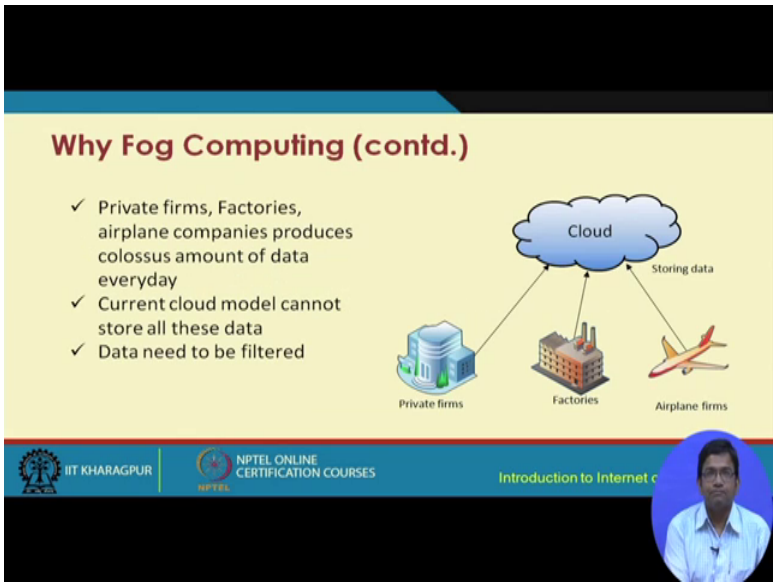
So, the fog computing architecture looks like this. So, we have all these IoT devices and we have the cloud. So, as I said traditionally we have to use these IoT devices to sense the physical phenomena occurring around them; send the data to the cloud and get an action or comment back. So, as we can see over here that this is the traditional cloud model. So, why we need fog computing because we want to reduce this particular time and typically, this cloud servers might be physically located even continents away means you know it is typical to have them in different cities and so on, but even continent away also. So, this physical limitation also introduces large latency in communication.

(Refer Slide Time: 11:39)



So, in terms of the data volume, it is estimated that by 2020, about 50 billion devices will be online and presently billions of devices produce exa bytes of data everyday and this is big data, right. So much of data is going to a produced every day, not only every day, but every second, every minute. Unusual volumes of data are going to be produced because of the introduction of internet of things. Exabyte means 10 to the power 18. So, you know we have giga byte, tera byte, beta byte, gita byte, exa byte, right. So, typically we use traditionally with giga bytes up data maximum, but now it is with you know internet of things and so on, it is very common to have tera bytes, gita bytes, exa bytes of data that is produced every day and to handle this kind of data volume. So, the device density is also increasing every day. So, the current cloud model is unable to process these amount of data.

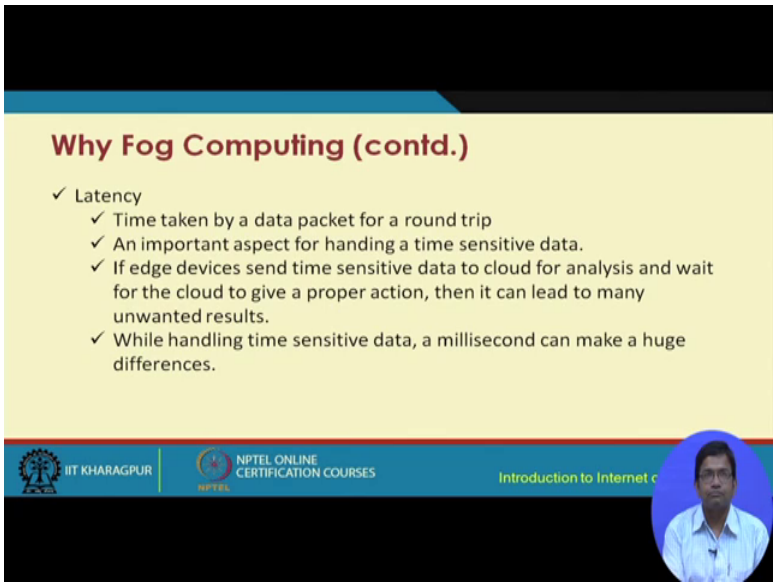
(Refer Slide Time: 12:55)



So, the private firms, factories, aero plane companies, they all produce huge volumes data every day. So, if you look at this particular figure, this will be clear. So, we are not talking about data produced by a single firm, we are talking about data that is produced by several firms you know and the different devices that are used in those firms i.e. the IOT devices, the embedded systems devices that are basically used in those firms. You know huge volumes of data are produced every day by a single firm and definitely large number of firms also produce large volumes of data factories. The same kind of thing factories also produces large volumes of data, aero plane companies. Airplanes themselves have lot of different types of sensors. They also produce large number of data. So, all these data would have to be sent to the cloud for further storage and processing.

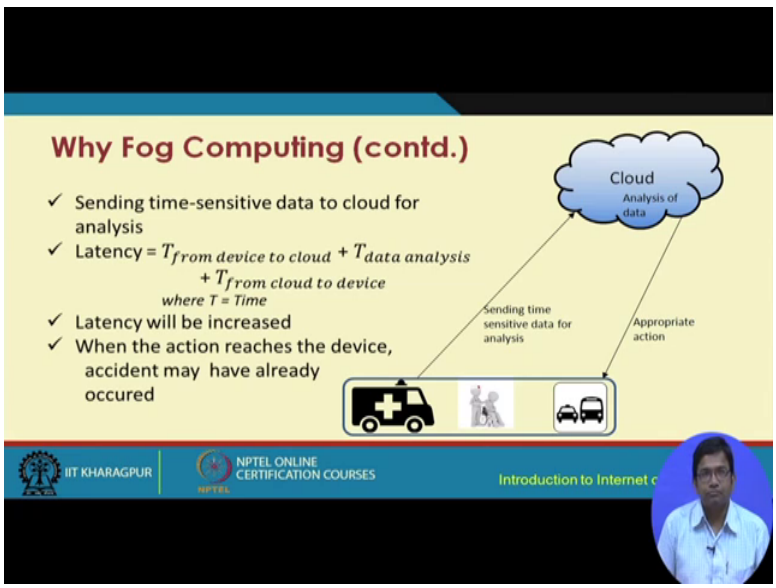
So, the current cloud model that we have already gone through in the previous lectures on cloud computing cannot basically store all these data. So, this data that is produced the raw form of data has to be filtered before the data is sent to the cloud., So, this has to be pre-processed, filtered before it is destined for storage and processing in the cloud.

(Refer Slide Time: 14:28)



In terms of latency, lot of time being taken by a data packet for a round trip and this is what I was explaining to you with the diagram that I showed at the outset. So, an important aspect for handling time sensitive data is basically to handle this issue of latency because if it is time sensitive, it is real time data. So, time is important and that is the reason why latency has to be handled with special interest. If the age devices sent time sensitive data to the cloud for analysis and wait for the cloud to give a prospered action, then it can lead to many wanted results. So, file handling time sensitive data a million second can make a huge difference.

(Refer Slide Time: 15:18)

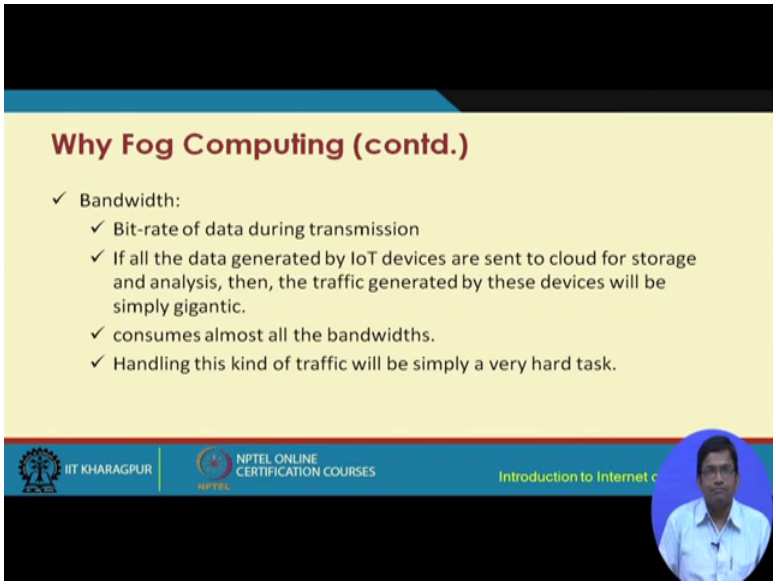


So, look at this particular figure over here. So, ambulances, then different buildings and different other you know different other devices and so on and cars and so on. So, they basically generate data which are time sensitive in nature. So, they basically generate; which are time sensitive in nature. So, that is the reason why they have to be processed pretty fast to be able to use the data in a meaning full manner.

So, they have to be paid processing pretty fast. So, ambulance for example will generate some data. So, the time that it takes the data to go from here to the cloud and come back, this can be represented with this you know this can be shown in the form of this kind of equation. So, latency equal to the time, it takes for the data to go from the device. That means the IoT device to the cloud plus the time for data analysis plus the time; it takes for the data to travel from the cloud to the device. So, latency will be increased and from the action reaches the device accident may have already occurred if it is an emergency situation or a connected vehicle situation.

So, this is the reason why fog computing is very important.

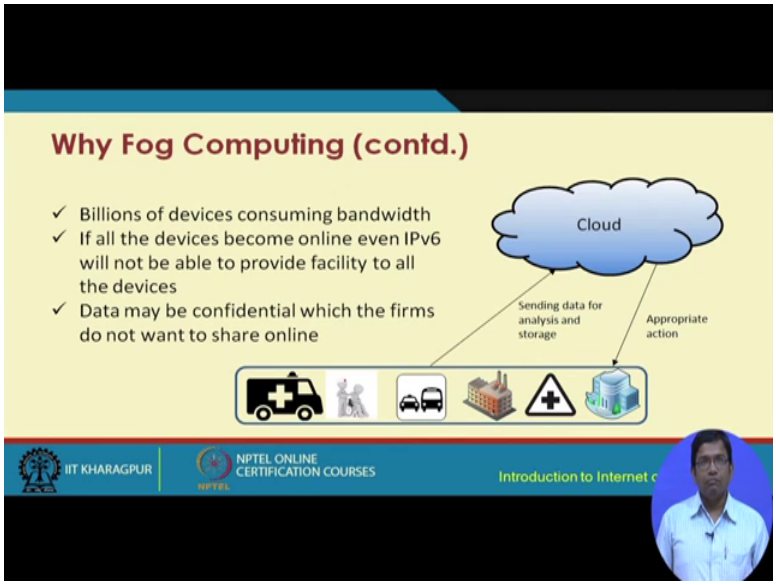
(Refer Slide Time: 16:45)



So, in terms of the bandwidth, the bit rate of the data; sorry in terms of the bandwidth, bandwidth is calculated as the bit rate of data during transmission. So, if all the data are generated by IoT devices and those data that are generated by these devices are sent to the cloud for storage and analysis, then the traffic generated by these devices will be simply gigantic.

So, these IoT devices are going to consume almost all the bandwidth because of this and handling this kind of traffic will be simply a very hard task.

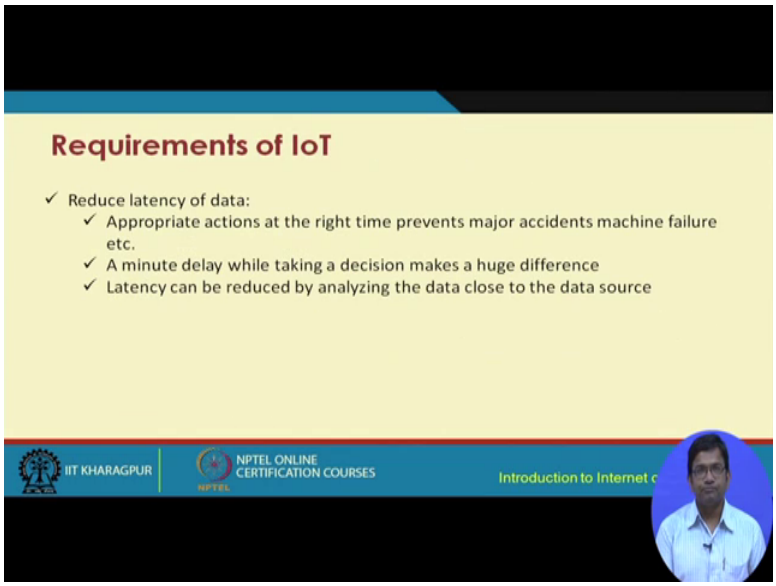
(Refer Slide Time: 17:27)



So, billions of devices consuming bandwidth if all the devices become online even IPv 6 or IP based technologies will not be able to handle the facility to provide the facility to all the devices and the data may be confidential which the firms do not want to share online. So, these are the different problems. One is the privacy of the data. This is of concern to the firms and the second is that you know dealing with these kinds of problems with IP based technologies like IPv 6 is a problem and also, the issue of having billions of devices consuming bandwidth.

So, you know; how do we handle them together in a synergistic manner.

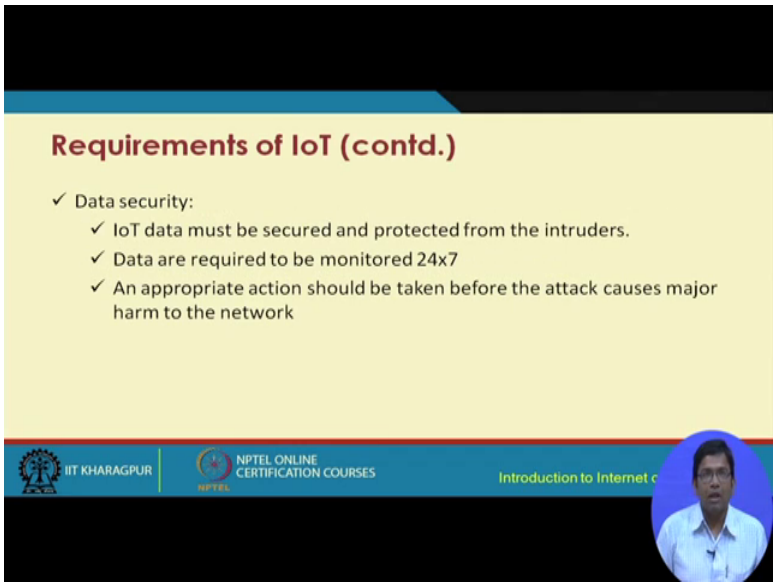
(Refer Slide Time: 18:20)



Reduced latency of data, appropriate action at the right time prevents major accidents, such as machine failure and so on. So, a minute delay while taking an action makes a huge difference and this is what I was explaining to you during the medical emergency scenario. A person might die if you know the decision making takes a lot of time compared to the time for sensing.

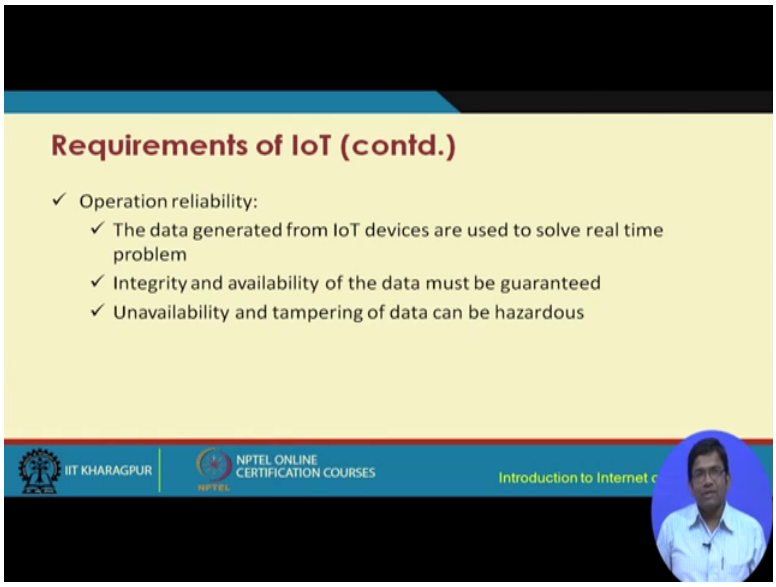
So, it has to be the time for decision making. That means, processing storage etcetera should be conformant with the time for sensing. So, the time it takes for sense is almost after something is sensed. Immediately thereafter it has to be disseminated and corresponding action also has to be taken in real time.

(Refer Slide Time: 19:13)



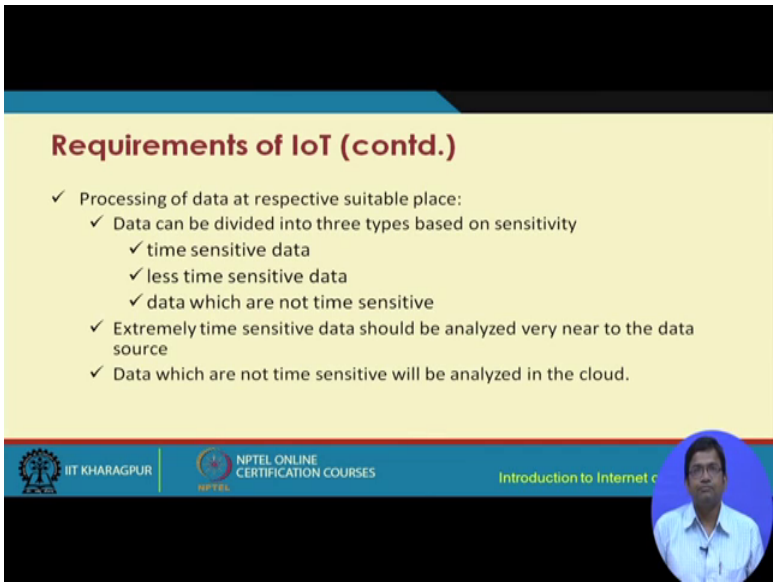
Data security, IOT data must be secured and protected from the intruders. Data is required to be monitored 24 7. An appropriate action should be taken before the attack causes major harm to the network and this is what I was explaining to you.

(Refer Slide Time: 19:26)



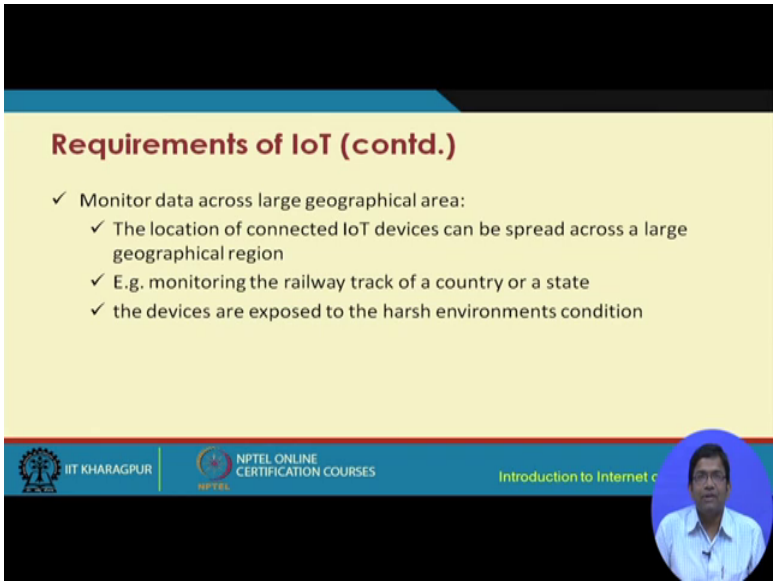
The operationals reliability, the data that is generated from the IOT devices are used to solve real time problems. The problems of integrity and availability of data must be guaranteed and unavailability and tampering of the data can be hazardous.

(Refer Slide Time: 19:45)



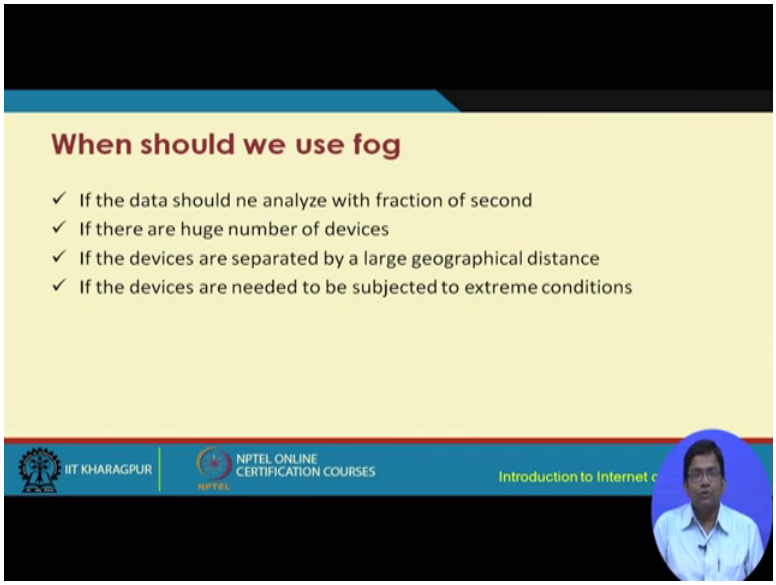
Processing of data at the respective suitable places, data can be divided into three types based on the sensitivity. One is time sensitive data, second is the less time sensitive data, and third is data which are not time sensitive at all. So, this kind of filtering has to happen with respect to the sensitivity of data. So, extremely time sensitive data should be analyzed very near to the data source and data which are not time sensitive will be analyzed in the cloud.

(Refer Slide Time: 20:22)



So, time sensitive data closer to the devices, non-time sensitive data send it to the cloud, monitor data across large geographical areas, the location of the connected IoT devices can be spread across a large geographical area. Examples, monitoring the railway track of a country or a state, the devices are exposed to the harsh environmental conditions additionally as well.

(Refer Slide Time: 20:48)



So, when should we use fog? If the data should be analyzed within a fraction a minute, fraction of a second, if there is huge number of devices in the network, if the devices are separated by large geographical distance or if the devices are needed to be subjected to extreme conditions.

(Refer Slide Time: 21:13)

So, with this we come to an end of first part of lecture on Fog Computing. In this lecture, we have understood what fog is, the genesis of fog computing and also, about how fog computing can help in building internet of things systems. We have also in the process gone through some limitations of the use of IoT.