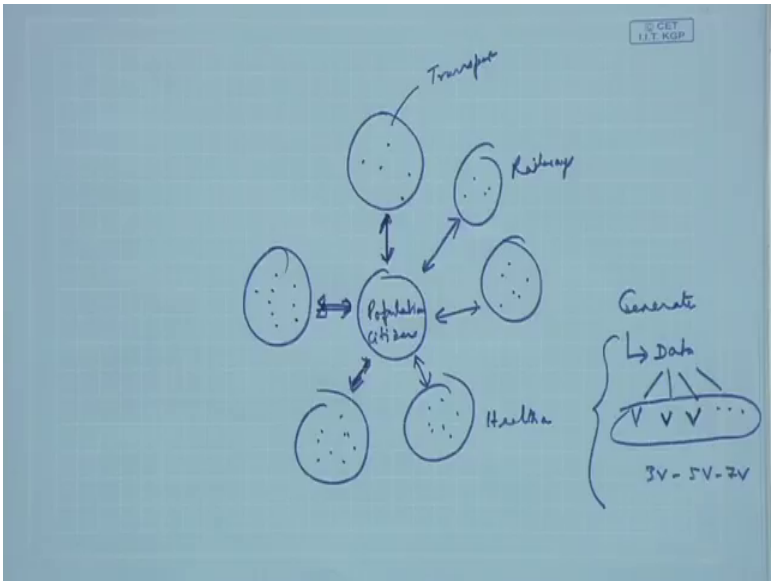
Introduction to Internet of Things
Prof. Sudip Misra
Department of Computer Science & Engineering
Indian Institute of Technology, Kharagpur

Lecture - 47
Smart Cities and Smart Homes-II

Now, we come to the second part of smart cities and smart homes. In part one, we spoke about the need for smart cities, the challenges in building smart cities, and few of the different issues with respect to building smart cities. So, in this particular lecture again we will be focusing on smart cities. And these again you know what ever we will be discussing on smart cities are also applicable for smart homes as well, but we will have you know a focus on smart of home in another lecture. But here we are going to discuss some of the technical issues behind enabling smart cities, some of the technical issues.

So, let us consider something before we go further. We have already seen that we have all these different components the transport, railways, schools and etcetera, etcetera.

(Refer Slide Time: 01:13)



And let us say in between we have this population, population means the citizens right. So, all of these things these different components, let us say this is transport. So, transport component has different sensors has different actuators. These, this is let us say railway, railways, all source has the same other components schools, hospitals, they all have different sensors, and different other IoT devices. Which generate, which generate

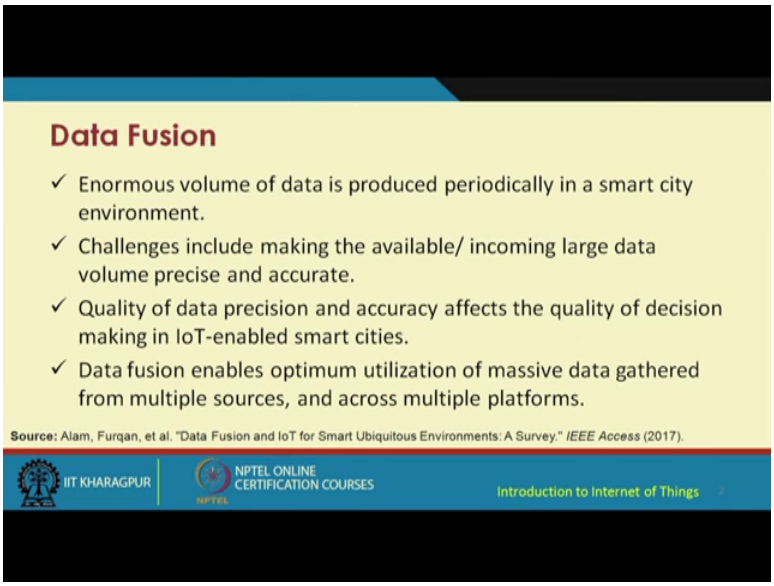
data, which generate and data. And this data has different you know characteristics with respect to volume this is gigantic, you know huge volumes of data, that each of these different components they are generating coming at high velocities, has different you know different types of data media data you know, multimedia data text data and so on and so on and so forth. They are at a these different characteristics of big 3 Vs to 5 Vs to 7 Vs, and this is something that we spoke about in a previous lecture already.

So, I not going to elaborate on these, but what is required is to do some good planning. So, what are you going to do with all this data? So, you know one possibility is that these data can be made available to the population, to the citizens. But making the data available just like that will not help. So, you have to do some processing. So, let us say that that processing is also done. Then you have to you have to fuse these data that are made available from these different sources, let us say transportation data and health care data sense from different points made available from these different locations, has to be this data have to be fused together in order to give better insight about different things in a smart city so that part is really challenging.

So, one thing is to deal with this kind of data, you know this big data that is coming in real time analyzing you know cleaning up processing, analyzing this kind of data in real time this is one thing. But in addition you have to fuse the data that are cross to (Refer Time: 04:15) that are coming from different sources, and that is a highly challenging issue. And like this there are different other issues in the building of smart cities, in the previous lecture we spoke about the overall idea the philosophy behind smart cities. But then you have to make it technically made possible, it is not like you know you connect few sensors and then, you know communication will be ZigBee Wi-Fi etcetera and then you make the data available no that data is going to be of limited use to the corresponding users of the stake holders so that is going to be of limited use.

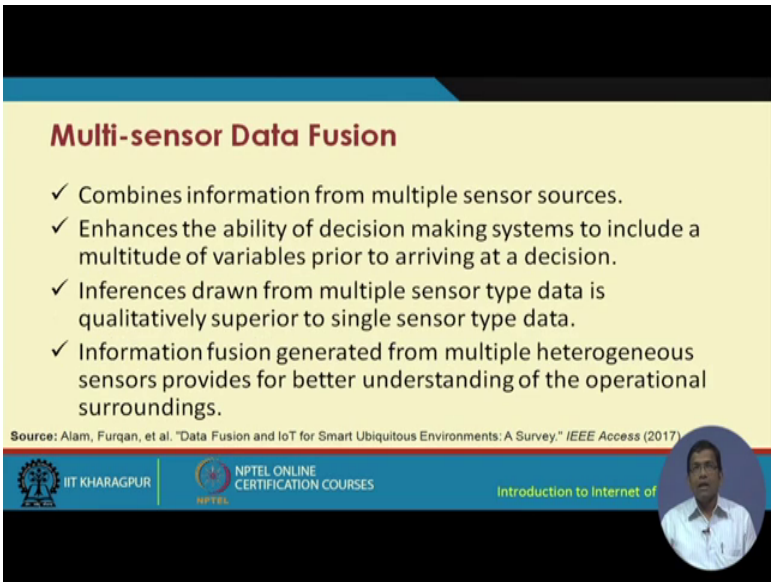
So, you have to you have to do some better job by fusing the data together, and then making that kind of fused data which has more in sight which will give more insight, you know that will be more useful.

(Refer Slide Time: 05:12)



So, let us look ahead and see what we have for us in data fusion. So, data fusion basically you know you are talking about in a smart city environment, we are talking about enormous volumes of data, that are produced periodically. And the challenges include making these particular type of data available. And so that the incoming larger data can make more sense can make more sense. And with the help of this data from these different sources, the large volumes of data from this different sources, different predictions, different analytics should be should be executed. So, the quality of data precession and the accuracy basically affects the quality of decision making, in this kind of IoT based smart city environments. So, data fusion basically enables optimum utilization of this massively collected data from different sources across different platforms.

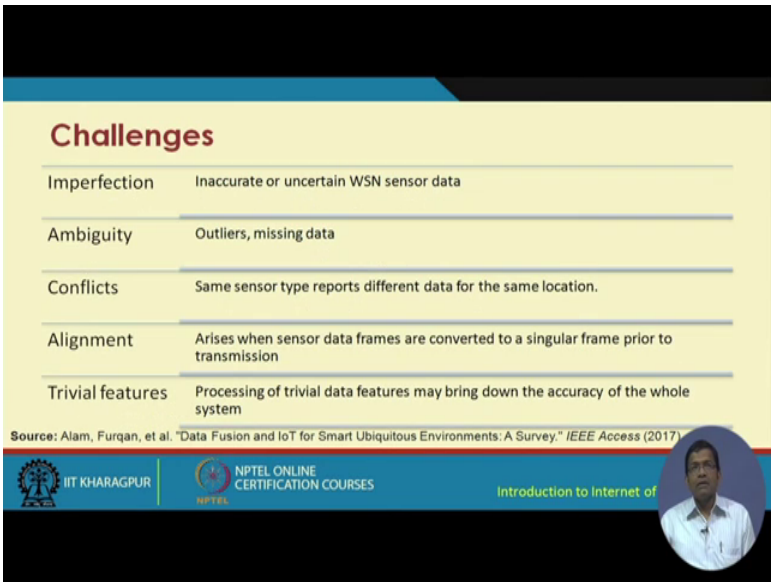
(Refer Slide Time: 06:18)



So, multi sensor data fusion is very important, which basically combines information from multiple sensor sources. It enhances the ability of the decision making system to include a multitude of variables prior to arriving at a decision, this is what I was telling you. So, it is not like clubbing 2 data together alone, but you considered the different you know different issues and considered the different variables that are affecting these systems, and you know taking all of these into account not just the sensor data taking all of these multitudes of you know, variables effecting the data and affecting the system together you come with you arrive at a decision, and make that decision made available not just decision, but may be different options and make that decision or the different options available to the users.

So, data fusion basically will help you in doing this. Inferences are drawn from multiple sensor type data and these are typically you know, qualitative the inferences are qualitative and you know, these basically are of more insight these are more insightful these are more meaning full than the single sensor type data. So, these putting these different types of it you know different types of data together and trying some kind of you know arriving at some kind of intelligent decision that is more insightful than the individual data. Information fusion generated from multiple heterogeneous sources provides for better understanding and understanding of the operational surroundings.

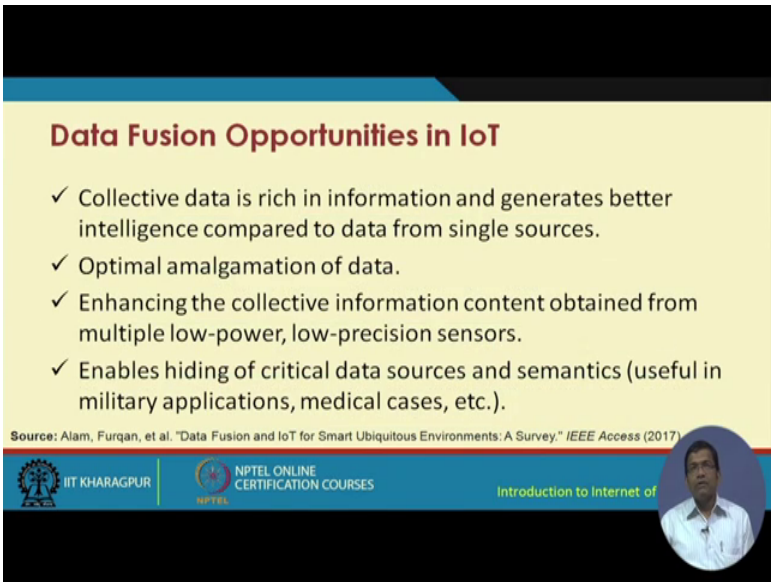
(Refer Slide Time: 08:05)



The challenges include, we are dealing with an environment where the data has lot of imperfection, imperfection due to inherent devices, devices like sensors etcetera, where there is lot of uncertainty around the environment there are lot of inaccuracies that can keep in. So, there is lot of inaccuracy uncertainty in the data and that basically leads to imperfections. Ambiguity is another we are talking about an environment where there are you know data that that are collected have lot of different outlets. Outlet means that there would be some data points which will be far away from the similar data points in the cluster. And there could be some missing data as well.

So, a ambiguity in the data can also creep. Similarity there can be conflicts in data that are connected from different sensors about the same thing, they might be conflicting they might be contradicting, alignment is like this that it arises when the sensor data frames are converted to a singular frame prior to transmission so that also has to be done, you know so that alignment you know into singular frame that is challenging. Different other trivial features for example, processing of trivial data features may bring down the accuracy of the whole system. And these are some of the challenges that have to be talked on when you are talking about data fusion in an IoT environment.

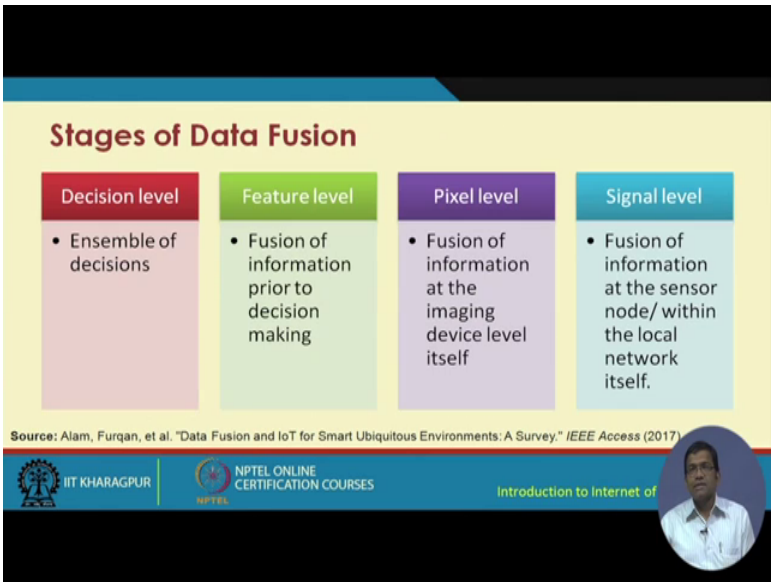
(Refer Slide Time: 09:38)



So, what are the opportunities? So, collective data is reaching information and it generates better intelligence better insight compared to the single source data from different individual sensors. So, putting these data together you know will make you to get better insight. So, you know what is the required is to optimally amalgate, optimally amalgate means that integrate optimally integrate the data, because you know the more and more you integrate you know it is possible to get more insight, but at the same time you know that also has to be done in real time to be you know, for that decision to be more meaning.

So, optimal amalgation of amalgamation of data, then enhancing the collective information content obtained from multiple low power low precision sensors. And enabling data fusion basically enables the hiding of critical data sources and the semantics.

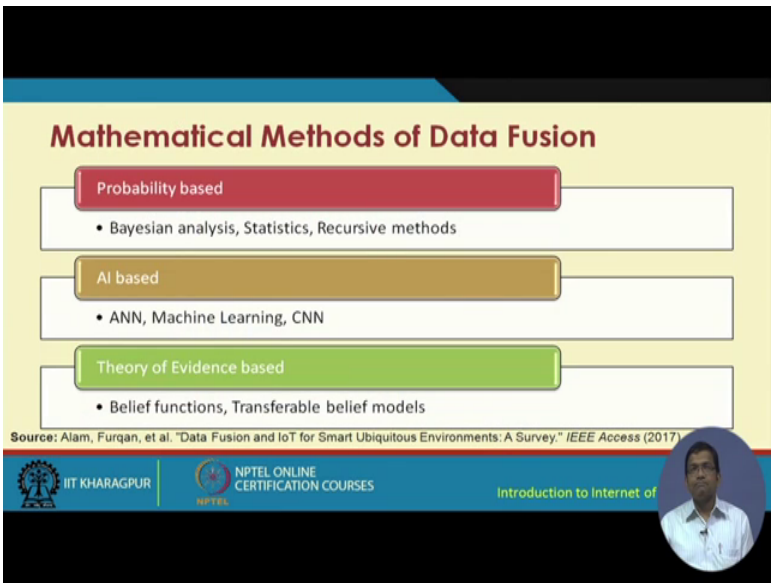
(Refer Slide Time: 10:43)



And that is useful for military applications for medical use cases. The different stages of data fusion include, decision level which is basically an you know talking about an ensemble coming up with an ensemble of decisions. Then feature level you know; that means, that the different features you know you fuse with respect to the different future features, at the feature level the integration is done the fusion is done.

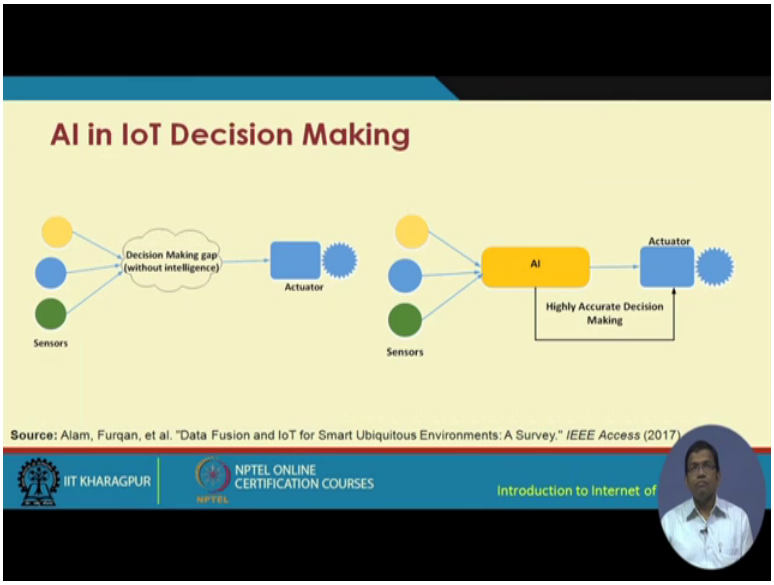
So, it is basically fusion of information prior to decision making. And pixel level is fusion of information at the imaging device level itself.

(Refer Slide Time: 11:28)



So, at the imaging devices that fusion is done in the device itself. And single level basically fusion of information at the sensor node or within the local area network itself. The mathematical methods of data fusion include using probability based schemes such as Bayesian analysis, statistics, recursive methods, EI based schemes such as artificial neural network, machine learning algorithms, deep neural networks, convolutional neural networks, theory of evidence based you know, evidence based schemes. For example, belief functions taking use of belief functions transferable belief models. So, these are the different mathematical methods that are used in order to come up with these intelligence from the different data that are you know that are secured from the different IoT devices.

(Refer Slide Time: 12:14)

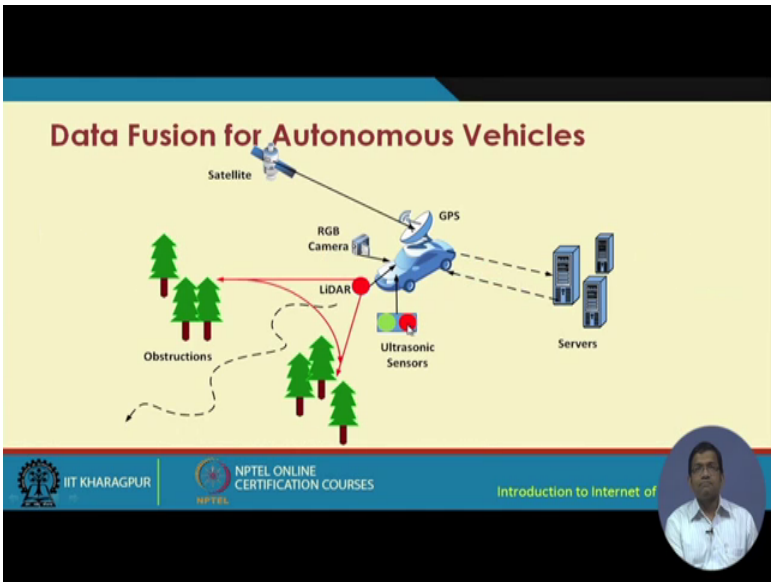


So, AI artificial intelligence comes as a big helper in enabling this. So, you know let us consider this particular figure. So, traditionally what happens is you have these different sensors and the sensor data has to be transmitted over the communication medium and has to be you know based on that some actuation is going to happen. But how that actuation is going to be made you know made possible, is it from one or 2 of these sensors in a based on these sensor value you are going to actuate, or can we do something better.

So, for betterness betterment what can be done is some kind of decision making has to be done with the help of intelligence by, by adding intelligence between these different

sensors and the actuators we can make things better make things improved. So, how is that made possible? With the help of artificial intelligence tools methods algorithms and so on.

(Refer Slide Time: 13:23)

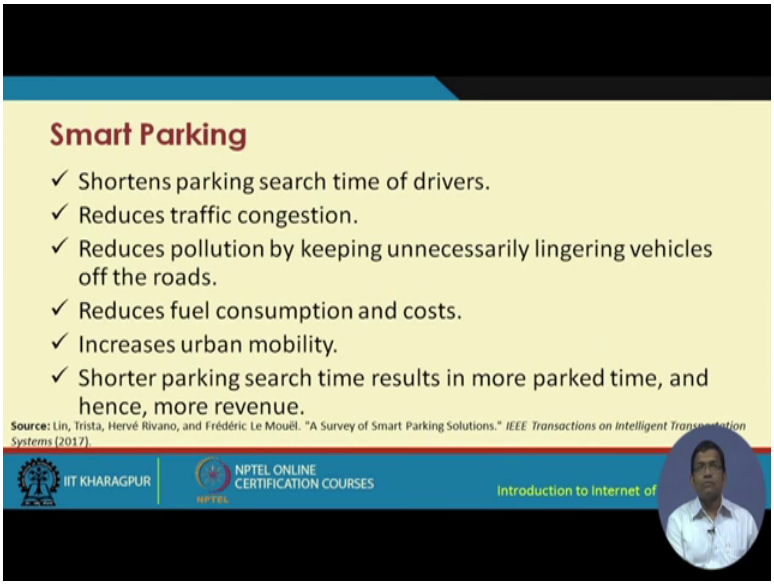


So, AI come as a rescuer over here, and what AI can do is it can make highly accurate decision making possible between the sensors and the actuators. So, let us consider the scenario of decision fusion for autonomous vehicles. So, for autonomous vehicles like autonomous cars etcetera, etcetera. They interact a lot with the environment you know, when there is a driver less car for instance. They need to take help of this different sensors they need to also communicate with you know the with the satellite with the GPS with the help of technologies such as you know LiDAR technology for obstruction you know, for getting a map of the obstructions ahead, or the ultrasonic sensors can help in even checking some different obstructions that are ahead of them in a small scale. LiDAR can give a bit bigger picture whereas; ultrasonic sensors can give a small scale picture of what is ahead of the autonomous vehicle.

So, autonomous cars you know they basically are collecting different data from different sources through different technologies like LiDAR sensor networks you know, from satellites through GPS and different cameras ahead of you know, in front of them. So, they all these different data of different types as you can see are connected and they are sent to the server. Now you know these data of different types you know, individually

they do not make much sense they are of limited help, but together can these data be fused together, so that the car the autonomous car can get some kind of decision making, about how it is going to proceed or whether it is going to turn left or right or what it is going to do. If it sees some pedestrians in front, then what it is going to do? Like this kind of thing is made possible with the help of data fusion data fusion technology. So, all these decision making through you know of the data that is connected from the different sources you know that is basically made possible with the help of data fusion.

(Refer Slide Time: 15:26)



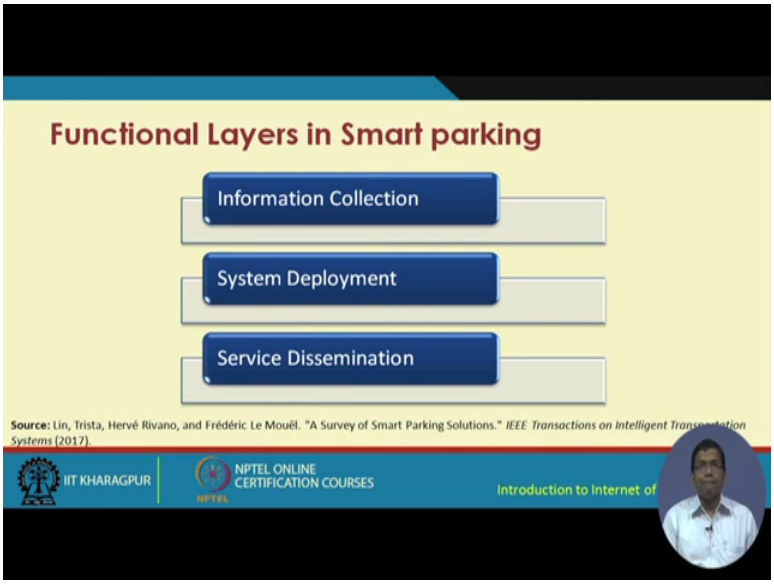
Smart parking, I already spoke about smart parking in a in the previous lecture, but let us dig into this smart parking little bit further. Smart parking is very much an important component now a days we have smart parking solutions in different cities already started to be deployed. So, in a smart parking environment what happens is, you know the user knows ahead of actually going to that particular spot, that which of the spots in the cities have free parking spots right. Which of these different parking lots have free parking spots. And then accordingly the driver can make a decision about where to go and park the car.

So, smart parking basically shortens the parking search parking search time of the drivers. So, basically you know searching for the different parking lots that search time would be reduced will be shortened and you know it the parking is going to be made efficient. It reduces the traffic congestion, reduces the pollution by keeping unnecessarily

lingering vehicles off the road. So, you know So, what would happen is in a smart way you know where to go and where to park that way it is not going to happen that you are in a queue waiting for your parking your engine is on you are polluting the environment.

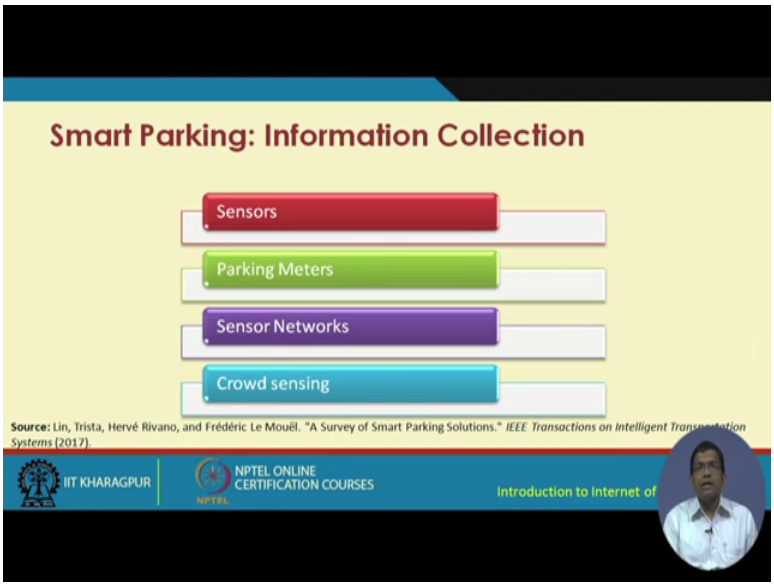
So, in a smart parking basically also helps in reducing pollution unnecessarily in a city. It reduces the fuel consumption and costs as well and these are all actually interlinked, so that you know fuel consumption more fuel consumption more pollution. More costs are involved you know so, like this these are all interlinked. Increases the urban mobility and the shorter parkings search time results in more parked time and hence more revenue.

(Refer Slide Time: 17:10)



So, in a smart parking scenario we are talking about you know information collection, system deployment, rather I would start with the system deployment system is deployed information is collected, and the surfaces are disseminated to the end users.

(Refer Slide Time: 17:28)



So, these are the different functional layers of smart parking. In terms of information collection information is collected from the sensors the individual sensors in the car in the parking lot, there are different parking meters the sensors are networked together. So, you have the sensor network, and also the crowd sensing, crowd sensing basically is from the crowd the from the different sensors in the mobile force in the smart phones for instance you are able to collect the different data, and these data will help in decision making.

So, all these data taking together and fusion of these data will help in decision making.

(Refer Slide Time: 18:03).

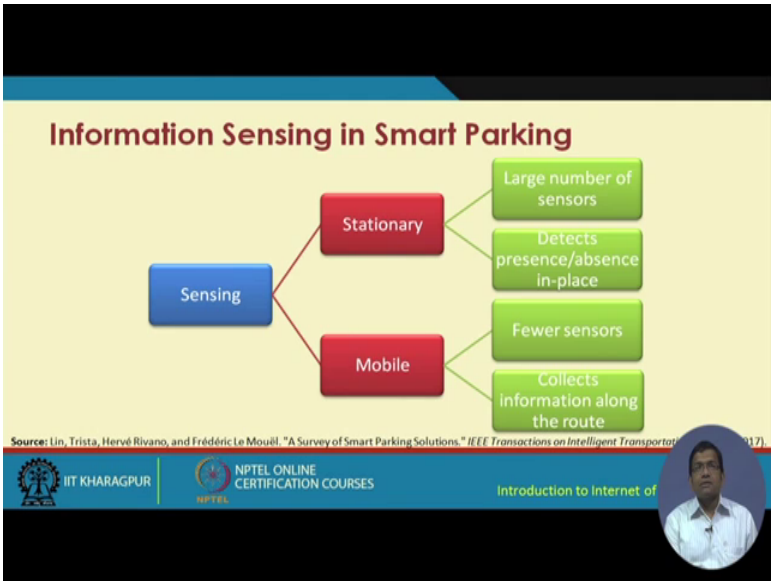
Then we have the system deployment with respect to the software system that has to be developed, the information management of the data, the E-parking you know guidance system that will help in guiding the vehicle, about where to go how to go and you know and parking the car there then the data analytics over all.

(Refer Slide Time: 18:28)

So, these are the different system level deployment issues in smart parking. Service dissemination with respect to dynamic pricing, strategizing, infrastructure based information infrastructure free information.

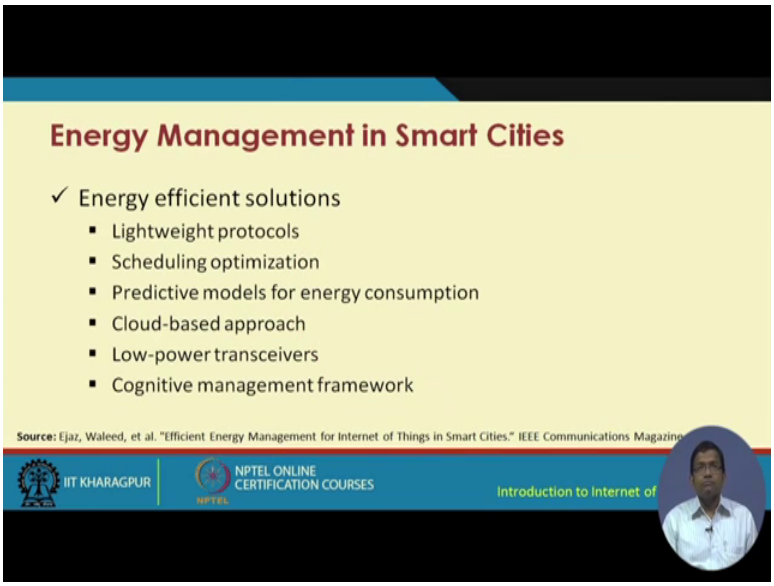
So, infrastructure based and infrastructure free. So, infrastructure free from the different sensors you know these are not connected to the regular infrastructure like Wi-Fi etcetera, etcetera. This is infrastructure free infrastructure based means like from the regular internet infrastructure from the regular city communication infrastructure like Wi-Fi and you know like 3G, 4G you know, the cellular networks. So, on these are all like the infrastructure based, and then infrastructure free is what I just told you with the help of sensors ad hoc networks formed out of these different mobile device of different users etcetera. Then parking choice and vehicular activities these all contribute to the building of services required for smart parking.

(Refer Slide Time: 19:22).



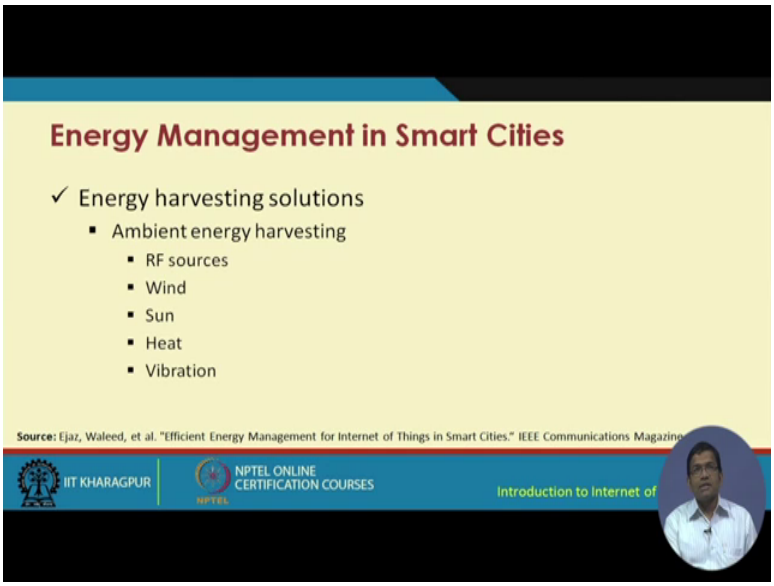
In terms of information sensing in smart parking, the sensing can be done from stationary sensors or from mobile sensors. Stationary sensors like you know if you are collecting the data from stationary sensors you need large number of sensors to be deployed at different points, which will detect the presence or absence of different vehicles or from mobile sensors where fewer sensors would be required compared to the case of stationary sensors, and these mobile sensors the fewer mobile sensors would collect information along the root when they go by.

(Refer Slide Time: 20:00)



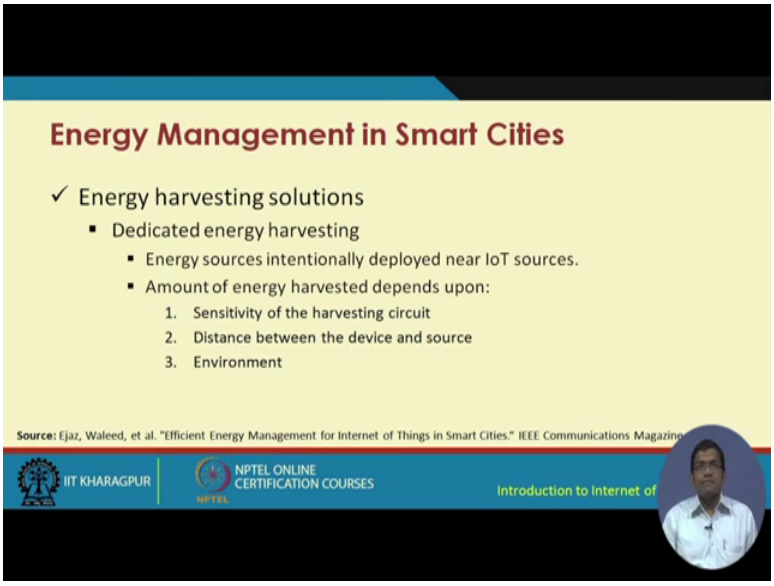
Energy management in smart cities you need energy solutions. So, energy efficient solutions it is required to light weight the protocols because you are dealing with a highly resource constraint environment, and at the same time energy consumption has to be reduced for you know reasons of greenness environment and so on. So, lightweight protocols are required, it is required to schedule the optimization of you know optimization of energy consumption. And then predicting models for energy consumption is another important thing. Then you have the cloud based approach, low power conceivers, cognitive management framework these are the different energy efficient solutions for energy management in smart cities.

(Refer Slide Time: 20:47)



Energy harvesting solutions would include technique help of these you know harnessing energy from these renewable sources of energy, such as sun, wind, heat, vibration RF sources. Now a day's people are talking about harvesting energy from radio frequencies as well. So, from RF sources harvesting energy from sun wind heat vibration and like this. So many different types of you know sources of energy ambient sources of energy are there, and how you can harness the energy from all of these different sources.

(Refer Slide Time: 21:24)



Energy harvesting solutions would include dedicated energy harvesting by the deploying different you know different sources like solar panels, etcetera; you know deployed pre deployed. Energy sources are intentionally deployed near the IoT sources to power these IoT devices for example, in our agricultural field, closer to the sensor node very close to the sensor node, we have these solar panels. And these panel solar panels basically power the sensor nodes that we have deployed in our agricultural field and these sensor nodes are basically deploy you know, were developed in the swan lab of our institute. So, the distance between the device and the source, the sensitivity of the harvesting circuit and the environment these basically are contributors to determining the amount of energy that is harvested.

So, with this we come to an end of the second part of the lecture on smart cities. Here we have mostly covered issues such as, how to handle the data that is received from this different sources. We can try to make inferencing with the help of these standalone sensor data that are received the separate individual data that are received. Or is it possible to do better, you know it is possible to do better by fusing the data from the different sources together with the help of intelligence and so on. So, this is the end of the smart cities part 2. The next in the next part we are going to talk about few other different issues of building these smart environments and there the focus will be on smart homes.

Thank you.