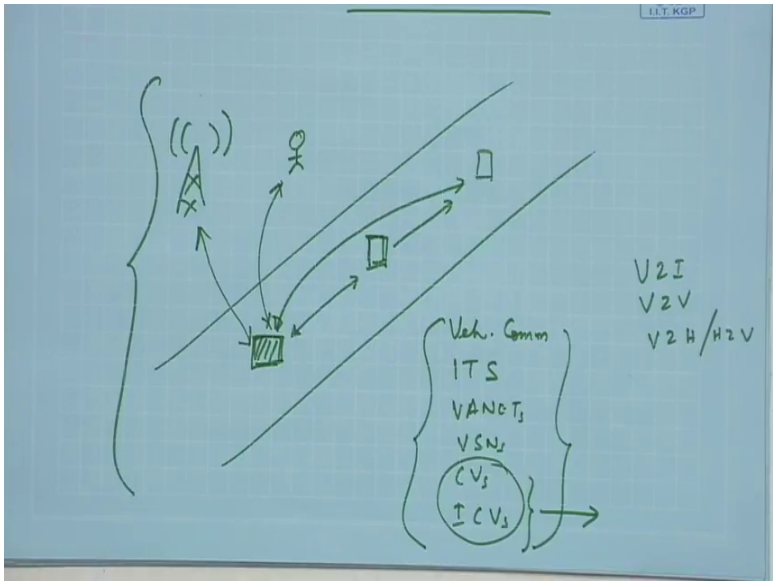
Introduction to Internet of Things
Prof. Sudip Misra
Department of Computer Science & Engineering
Indian Institute of Technology, Kharagpur

Lecture - 49
Connected Vehicles-I

Now, we start a new lecture which is on connected vehicles. So, connected vehicles has become very popular in the recent years. There is a lot of research that is going on building connected vehicles for good reasons, what are these different reasons? So, stand alone vehicles embedded with embedded with different sensors has been there since several years now if not decades. So, you know these standalone different vehicles you know we all are using different vehicles and these have different embedded sensors embedded systems and so on.

But in connected vehicles actually we are talking about how we can make communication between different vehicles possible. So, what kind of communications? Communication between a vehicle one vehicle with another vehicle. Communication between a vehicle and a pedestrian user or another user who is not there in the vehicle, and the roadside infrastructure or the existing infrastructure in a city. So, all of these different possibilities are there in a connected vehicle.

(Refer Slide Time: 01:37)

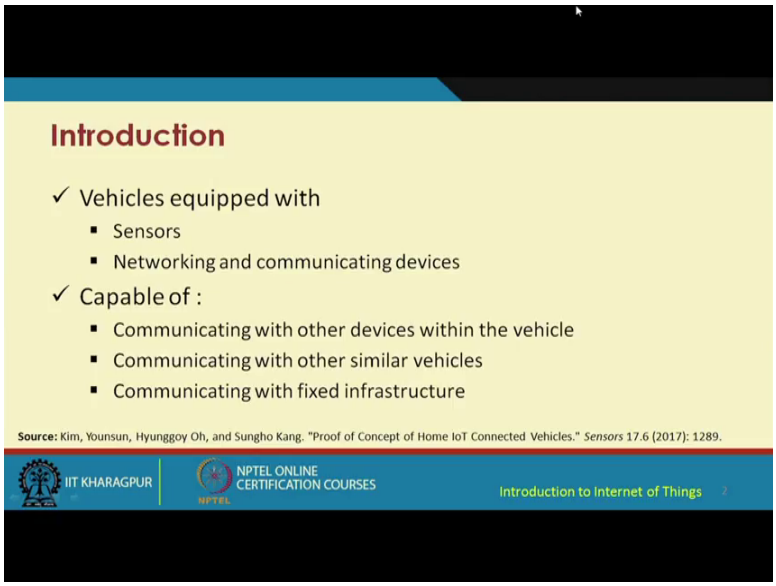


So, let us look at this particular example. So, let us say that we have. So, we are talking about a scenario to motivate why connected vehicle connected vehicles are required. So, let us say that we have these different vehicles on the road. So, in a every vehicle has it is own different sensors and it can even be feeded with more sensors more communication equipment and so on even further it can be done. So, if we talk about a single vehicle in a connected vehicle scenario these vehicle could be talking to the immediate next vehicle the neighbor vehicle. This vehicle could be talking to this one may be with the either directly or with the help of some intermediate vehicle which is there in it is neighborhood this vehicle could be talking to a roadside person you know.

So, this connection flow you know this communication flow might be possible or there could be these different existing communication infrastructure with which this information exchange may also happen. So, you can have V2I, V2V vehicle to infrastructure vehicle to vehicle communication, vehicle to human or even human to vehicle. And when we are talking about human we are talking about the humans who are not in the vehicle who are on the road side. So, all these things are made possible in the connected vehicles. And there is lot of; you know, if we look at the history there has been lot of you know, at least a decade or decade and a half there has been lot of research on vehicular communication and intelligent transportation systems, vehicular ad hoc networks, VANOTs vehicular sensor networks.

Then came this connected vehicles, then came the; you know intelligent connected vehicles. All of these you know in different forms have been around, but the different services this different service improvements that can be made possible in people are talking about in the context of connected vehicles and you know, and this intelligent connected vehicles.

(Refer Slide Time: 04:30)



So, let us look at some of this basics which will help in building this connected vehicles. So, in connected vehicles we have the vehicles that are equipped with different sensors, networking and communication infrastructure different devices, or by you know intra vehicle communication. So, so remember 1 thing couple of things you know. So, what is going to happen is in a connected vehicles scenario number 1, it would be possible to communicate with the different devices inside a single vehicle number 1, number 2 is between different vehicles from a vehicle to the roadside infrastructure or a fixed infrastructure; that means, a non mobile infrastructure.

(Refer Slide Time: 05:17)

So, all these different types of communication are going to happen in a connected vehicles scenario. So, issues such as security privacies, scalability, reliability, quality of service and on top the lack of any singular global standard for connectivity, are some of the challenges that are facing the building of connected vehicles. So, if you are interested you know. So, this particular paper that is reference over here prove a concept of home IoT connected vehicles this paper you can go through this basically gives a good account of the different issues surrounding building of connected vehicles at present.

So, this is a recent paper that was published in 2017 in the sensors journal. So, the different challenges for example, security. Security is very important because you know. So, you are opening up with the help of wireless and with the help of these different vehicles plying all around in the city, yes you are opening up to lot of vulnerabilities at their your opening up you adding to the vulnerabilities and additionally privacy is also very important, because the vehicular data plying all across different people can get you know access to that data.

So, privacy of the data from different vehicles is very important, you know why privacy is important let us say, that if the data is leaked for one reason or another let us say that there is someone. So, I am driving and I am in a connected vehicle kind of environment, and from my vehicle the data is sent to another vehicle which is a trusted one by me. But in between the data is leaked and that data is made accessible to somebody else. So, in that case what is going to happen is the the intruder or the malicious person or the entity which gets access to this data which was not intended for it.

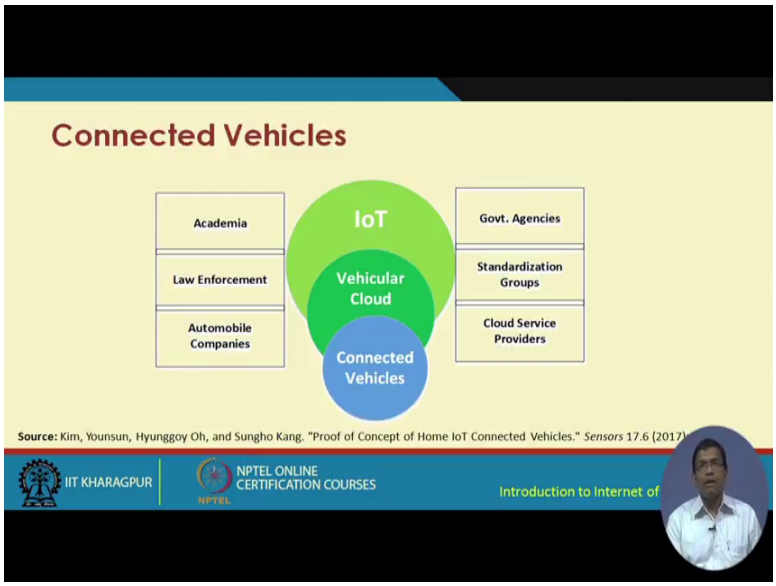
So, if that entity gets access to the data they will know that where I am going to for a for example, where this vehicle is going to, and that could be risky that could be even a security threat a safety threat. Because you know not only safety threat or security threat to the vehicle itself, but also to the people who are inside like for example, if I am the user of the car if I am the driver of the car, and if somebody gets access to this kind of information even my safety my security is also at risk.

Scalability is a huge challenge, you are talking about an environment where there is lot of mobility, large number of devices coming in going out of the cities and you have to have some kind of a registry about, who are the home users home vehicles who are which vehicles are the foreign vehicles, and some kind of pricings some kind of keeping

track of all these mobility etcetera, etcetera, yes. These are going to be there and at any time anybody from outside can be coming into the cities people can we know the vehicles can be going out of the city and you know it is a highly challenging scenario. So, lot of issues of scalability you know more vehicles being added large number of vehicles being added at in peak hours it will large number of vehicles could be added.

So, scalability issues are there upscale even downscaling also. You know if you think it will be deep you will be able to understand that downscaling issues are also there. Then you have the reliability issues with respect to the reliable communication being possible in this kind of environment quality of service lack of global standards.

(Refer Slide Time: 08:57)

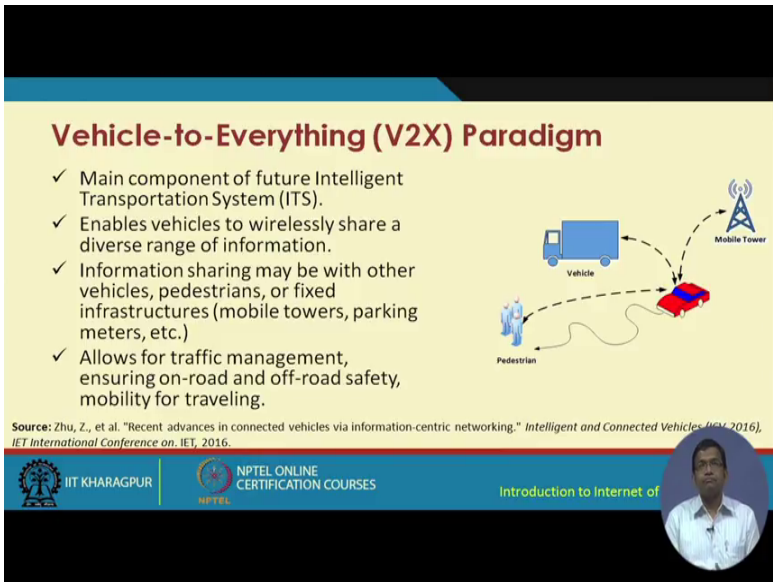


So, in a connected vehicle connected vehicles are very good as we have seen there are lot of different interesting use cases usefulness of connected vehicles then we have the vehicular cloud. In a vehicular cloud what is going to happen is these connected vehicles are going to send all these data these data are going to go to the cloud, from the cloud lot of you know analytics are going to be performed are you know the data the analytics data are going to made available to the respective stake holders and so on.

So, all these connected vehicles is part you can conceptualize connected vehicles in a as part of the vehicular cloud and vehicular cloud, and connected vehicles as part of the IoT. So, these are like enablers of internet of things. So, the different users and the stake holders of connected vehicles include academia, law enforcement bodies like police you

know judiciary etcetera law enforcement bodies, automobile companies, government agencies standardization groups cloud service providers. So, these are the different stakeholder's different actors of connected vehicles.

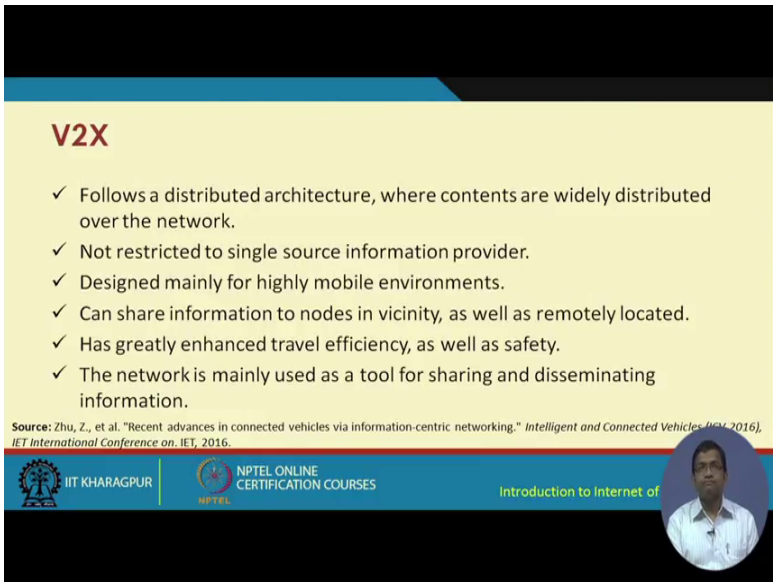
(Refer Slide Time: 10:08)



So, typically in a connected vehicle the most popular concept is the concept of vehicle to everything paradigm. So, V2X vehicle to everything V2X. So, V2X is basically part of the future it is intelligent transportation system, which enables vehicles to wirelessly share a diverse range of information, and the information sharing may be with other vehicles pedestrians or fixed infrastructures, such as mobile towers parking meters and so on. So, this is what at the very outset of this particular lecture I was also telling you that, this vehicle can communicate with the pedestrians on the way with the other vehicles on the road or with fixed infrastructures such as mobile towers or parking meters and so on.

So, this basically allows for graphic management ensuring on road and off road safety mobility for traveling and so on.

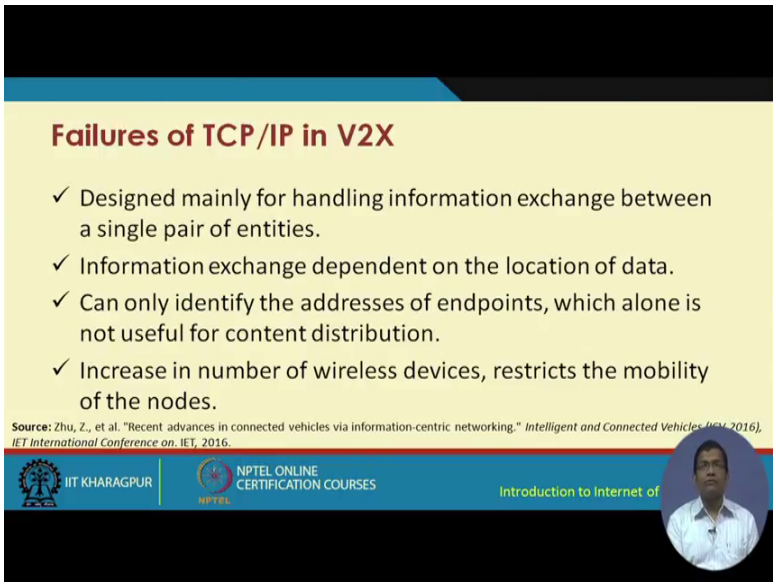
(Refer Slide Time: 11:20)



So, I do not need to elaborate on these, but this is quite evident and understandable the you know how this V2X is going to be useful. V2X basically follows a distributed architecture where the contents are widely distributed over the network. So, content based communication So, I will talk about that it is a content centric V2X basically uses content centric and not really the TCP/IP kind of you know information dissemination approach. It is not restricted to single source information provider it is designed mainly for highly mobile environments and vehicular environments are highly mobile environments. It is designed mainly for such kind of environments. The vehicles can share information to notes in the vicinity, as well as to remotely located notes.

So, here you know V2X has greatly enhanced the travel efficiency, the safety, security and so on. The network in V2X is mainly used as a tool for sharing and dissemination of information. And that is not something very new because ultimately, what is going to happen is after this information is collected from these different sensors. If the dissemination has to happen with some communication medium and typically it is a wireless communication medium, where there is a network and the network basically helps in the dissemination of information.

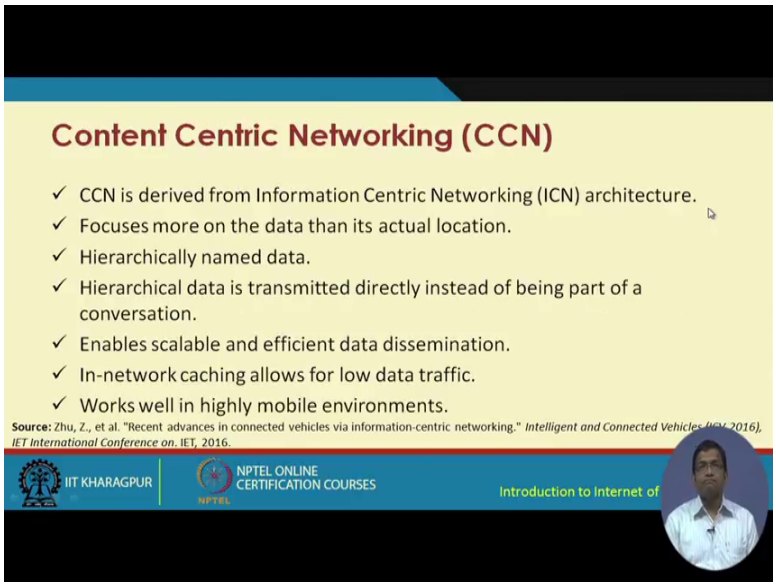
(Refer Slide Time: 12:30)



Now, what do we already have in terms of implementation of V2X. We already have our internet runs on TCP/IP. So, you know if we try to implement V2X on top of TCP/IP this is what is going to happen. So, you know it is going to fail, why? So, TCP/IP is designed mainly for handling information between single pair of entities. There is a source there is a destination you know and between these source and destination whether they are you know in direct range of each other or they are far apart, TCP/IP will have different solutions by which to send the data from one point to another.

So, the location the information exchange in TCP/IP is dependent on the location of data. So, you know there is a specific data base located at some place. So, from that point the data has to be fetched. So, from this particular data base in a particular server the data has to be fetched. So, this is like dependent on the location of the data can only identify TCP/IP can only identify the address of the endpoints which alone is not useful for content distribution, and that that content distribution is what is required in the cases of connected vehicles in V2X. And there is increase in the number of wireless devices which basically restricts the mobility of the different nodes.

(Refer Slide Time: 14:01)



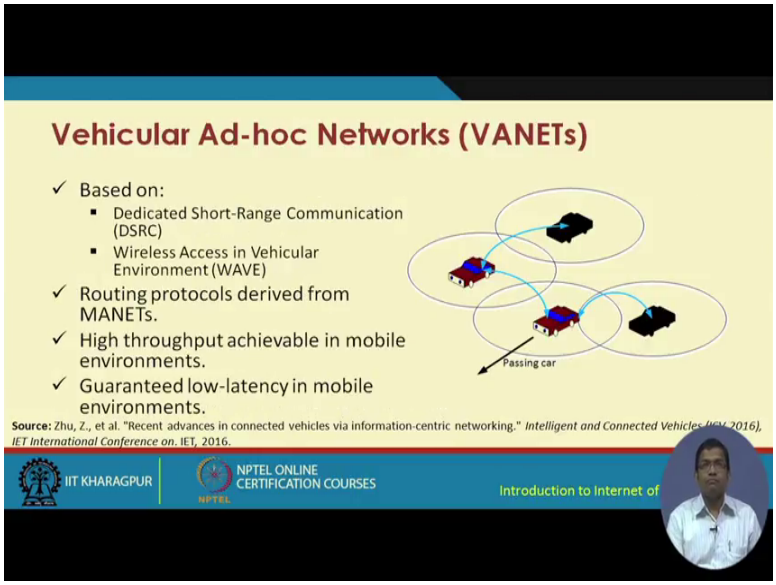
In content centric networking, you know it is basically conceptually has similarities to the popular information centric networking which focuses on the data than the actual location of the data. So, I need some data, I do not have to say that you know I have to get it from this particular database or this particular source, in content centric networking what is going to happen is, if I need access to a particular data I will be doing some kind of a broadcasting some kind of broadcasting of that particular requirement that query, and whoever has that data is going to send me the data. So, this is how the content centric networking contrast to TCP/IP functions.

So, we have hierarchically name data in content centric network. Hierarchically named data is something like x dot y dot z, you know this kind of hierarchy is followed. Something like you know my data would be something like mister dot sudeep dot age dot something. So, it is hierarchically named you know very similar I am giving you just an analogous example not the exact one. So, hierarchical data is transmitted directly instead of being part of the conversation. So, the conversation would be like the entire thing this dot this dot this dot this that becomes the entire conversation.

So, this is the how the hierarchical data is organized. So, I do not need to really if I need to get access to a particular part of that hierarchical data, I do not need to access the entire conversation. I can simply pick up from that particular part. So, it enables scalable and efficient data dissemination in network caching allows for low data traffic, it works

well in highly mobile environments. So, in highly mobile environments you do not really need to keep track of the source the destination and the intermediate hops in between and how the data is going to float all around. So, you have a highly ad hoc kind of scenario and content centric networking, I basically the following this kind of philosophy that I just explained is very much useful.

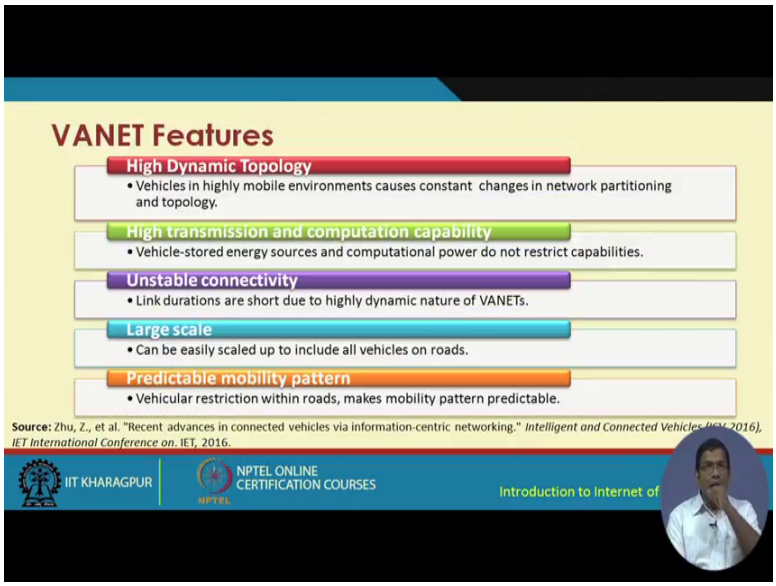
(Refer Slide Time: 16:17)



So, we are talking about vehicular ad hoc networks which is based on dedicated short range communication DSRC. And the wave protocol which is wireless access in vehicular environments the wave protocol.

So, these are the 2 you know very well known protocols that are used in vehicular ad hoc network, the DSRC protocol and the wave protocol. So, routing protocols are derived from the MANETs and, but here actually you have different types of characteristics than MANETs you know it is a derivation all these routing protocols for MANETs are basically derivations over from MANETs, but again they are different by taking the typical features of vehicular networks how the vehicles fly ply on the road on highways and so on are taking in account and how they communicate with the roadside infrastructure these are actually taken into account.

(Refer Slide Time: 17:24)



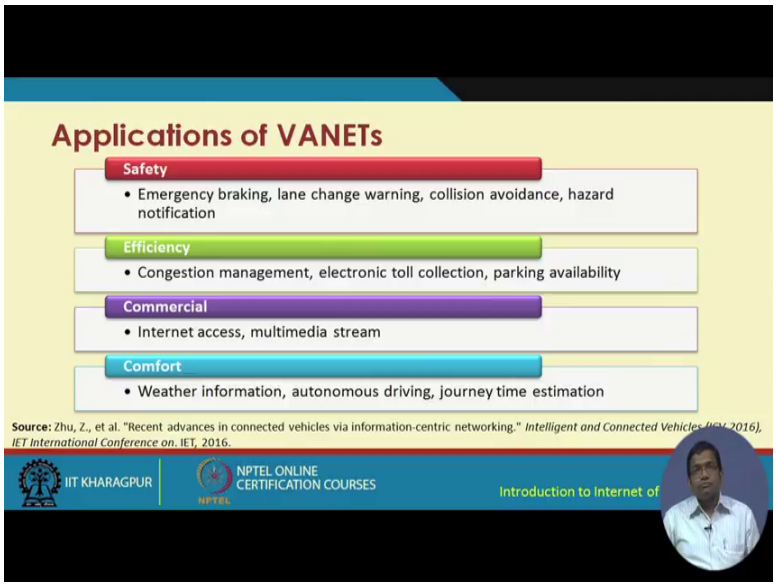
So, high through put is achievable in mobile environments using VANETs. And also low latency can be guaranteed in mobile environments in VANETs. VANET basically has different features. It has a highly dynamic topology, where the vehicle vehicles are highly mobile and they are changing their position. And the network topologies come continuously the brake and they make continuously. So, you have a highly dynamic breaking making kind of topology which is done continuously.

So, high transmission and computation capability the vehicles store energy sources sorry, the vehicles stored energy sources and the computational sources are used to draw power. And that basically is much higher compared to the stand alone IoT devices. And that is why there is no not much restriction there is not much of you know restriction on the energy source energy use and computational power and so on, because the vehicular you know energy sources and the computational energy sources in the vehicles these are quite high.

Unstable connectivity in VANETs link durations are short due to high dynamic feature of the these networks. These networks can be scaled up very easily to include different other vehicles on the road they can join these particular network without effecting the throughput in a very significant manner. The predictable mobility patterns can be can be achieved in these kind of networks because the vehicles are restricted within the roads you know how the road structure is and that basically restricts the mobility pattern also

and these mobility patterns are predictable in these kind of networks. In contrary in MANETs basically in mobile ad hoc networks the mobility is a big issue you do not know.

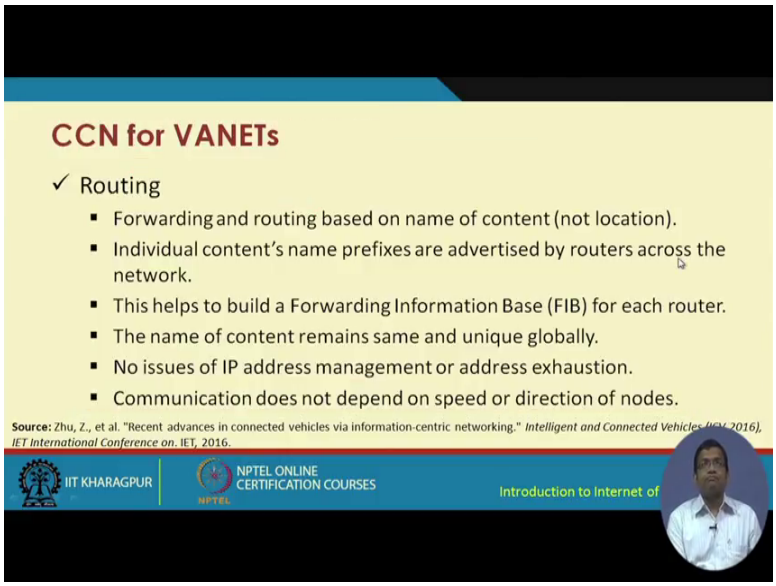
(Refer Slide Time: 19:17)



You know how the vehicles are going to move it is hard to predict the mobility of these different vehicles. Safety issues are there emergency breaking lenge sorry, lane change warning you know collision avoidance hazard notification these are the different safety applications of VANETs. Efficiency with respect to congestion management electronic toll collection parking availability these are again different attractive applications of VANETs.

Third type of applications are commercial applications for example, making a having internet access multimedia streaming all these possible on the road when you are on the road in the car in the vehicle. So, these are possible in VANETs, then different other comfort comforts with respect to getting whether information autonomous driving journey time estimation these are all made possible with the help of implementation of VANETs.

(Refer Slide Time: 20:05)

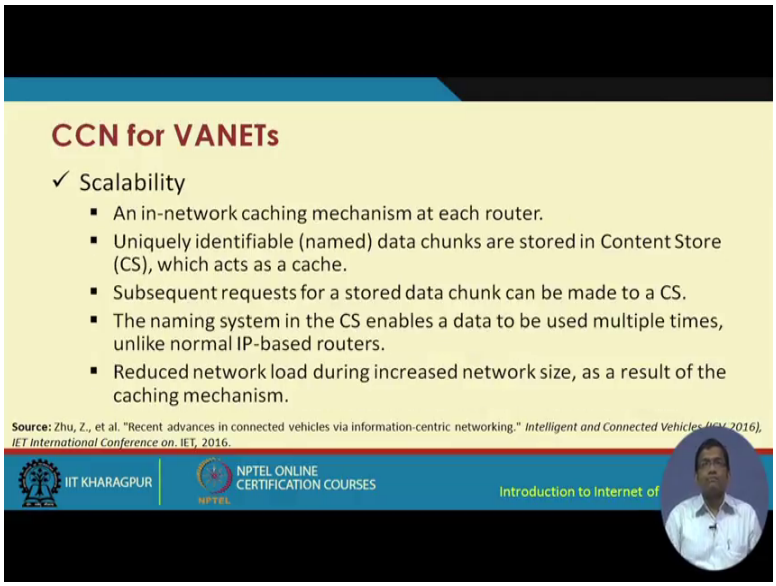


Then CCN the content centric networking that was telling you before, how it is implemented in VANETs?

So, some sort of routing is done, but this kind of routing is bit different. So, forwarding and routing is best here on name of the content not the location of the content. The name of the content is used for routing. The individual contents name prefixes are advertised by the routers across the network these helps to build a forwarding information base for each router. The name of the content remains the same and unique globally, and there is no issue of IP address management or address exhaustion. The communication does not depend on the speed or direction of the different nodes.

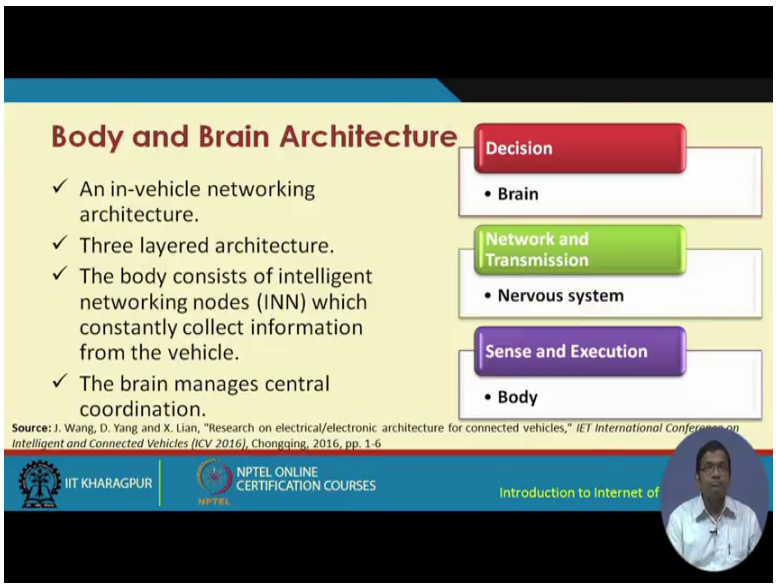
So, these are the different issues. So, the main thing that he have to has to be remembered is there is indeed the same way as we have routing tables in the case of TCP/IP based routing. Here we also have a very similar kind of thing which we have the forwarding information base at each of these different routers. But here the routing is done not on the basis of the location of the content, but on the basis of the name of the contents. So, where this and that name has to be unique. So, this is very important. If the name is not unique then this kind of routing cannot be done. So, in content centric routing the name also has to be unique in the network.

(Refer Slide Time: 21:25)



Scalability and in networking caching mechanism at each outer is implemented, which uniquely identifies the named data chunks. And these data chunks are stored in something known as the content store which acts as a cash. Subsequent requests for a stored data chuck can be made to a content store. The naming system in the content store enables a data to be used multiple times unlike in the case of normal IP based routers as we discuss before. And the there is reduced network load during the increase network size as a result of the caching mechanism.

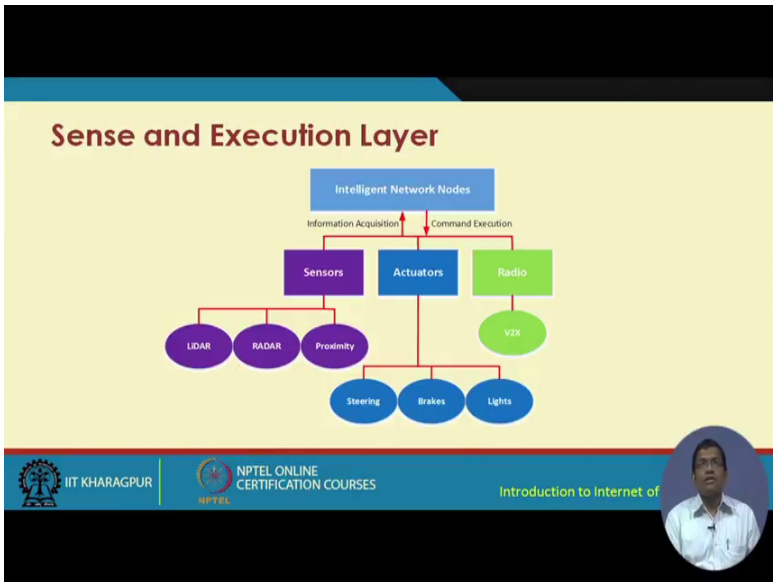
(Refer Slide Time: 22:00)



Now, will talk about a very interesting architecture which is called the body and brain architecture that has been proposed for the connected vehicles. So, it is an in vehicle networking architecture, which has very similar kind of you know architecture as the human body. As in the human body we have the body the code body having the skeleton the muscles the you know tissues the organs and this you know. So, that kind of structure, but on top you we also have the nervous system the brain etcetera and you know similar kind of thing is done in this case as well.

So, here we have a 3 layered architecture, there is that sense and execution layer then we have the network and transmission layer, and then we have the decision layer. So, the sense and execution layer is very similar to the body of a human body, the network and transmission layer is very similar to the nervous system of the human body. And the decision layer is very, very similar to the brain of the human body. So, there are 3 layers the body consists of intelligent networking nodes, which constantly collect information from the vehicle and the then the brain basically manages the central coordination.

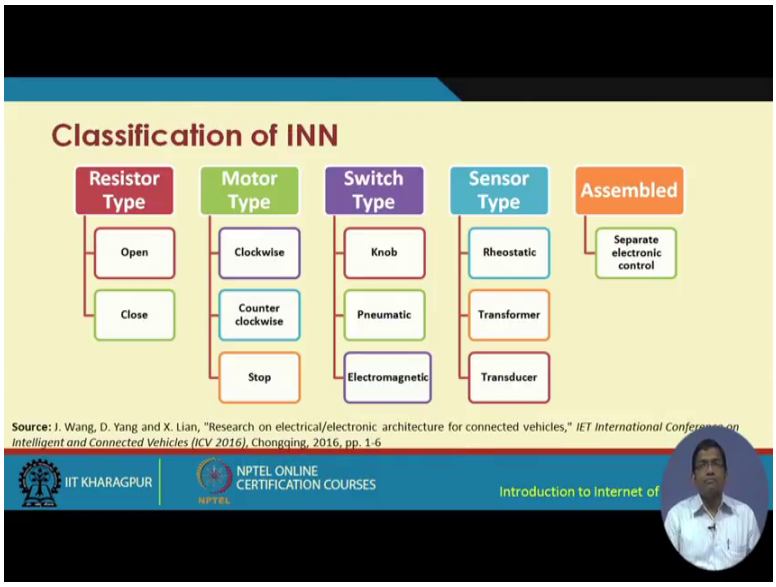
(Refer Slide Time: 23:13)



So, let us first look at the sense and execution layer. In the sense and execution layer we have these intelligent nodes. With the help of sensors actuators different radios the information is acquired with the help of different other devices like, LDAR, RADAR proximity sensors and different other sensors plus actuators such as steering brakes lights etcetera the information is acquired. And the commands are executed through the

through the actuators or through the different radio mechanisms. These are made available and this is how the sense and execution layer looks like in a connected vehicle scenario.

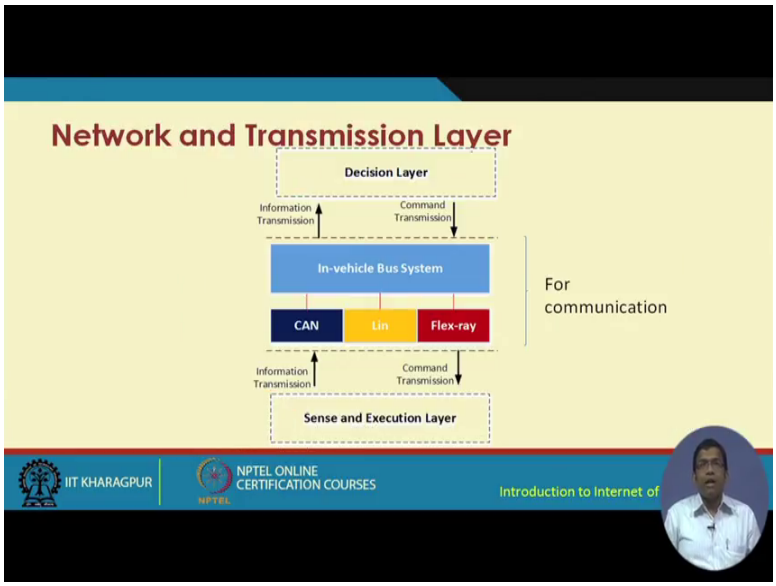
(Refer Slide Time: 23:54)



The intelligent networking nodes which has intelligence with implemented with the help of software you know different software. There are there are different types of nodes, one is the registered type nodes which can be opened or closed. There is a motor type nodes which basically are you know the motors can be moving clock wise counter clockwise or the motor can be stopped.

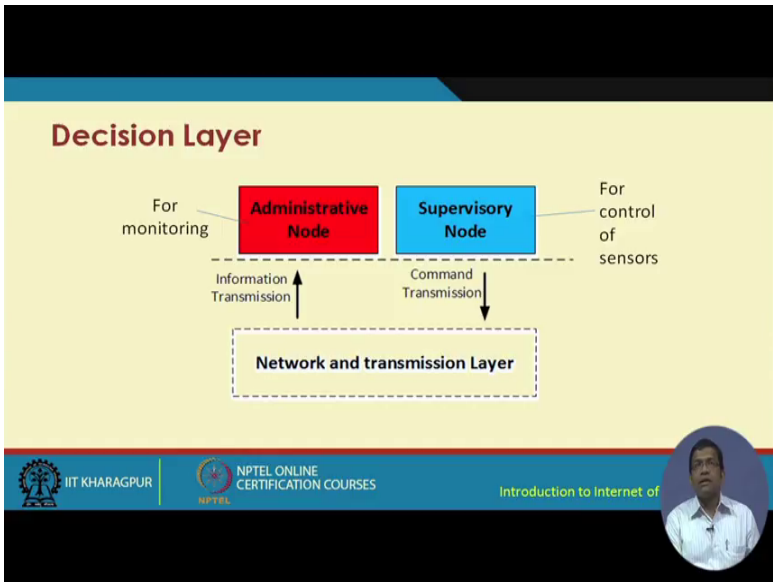
Switch type nodes switches can be of different types in a intelligent net node in a intelligent vehicle, a it could be the switches could be a nob. A pneumatic switch or an electromagnetic switch the sensors could be rheostatic switch rheostatic sensors rheostats we already know what a rheostat is. So, rheostatic sensors or transformers or transducers or they could be assembled nodes comprising of different separate electronic controls.

(Refer Slide Time: 24:45)



The network and transmission layer looks like this. So, you know this is basically you know this network and transmission layer, and as this name suggest we have for communication this is used primarily for communication. The sense and execution layer on the very bottom and on the top we have the decision layer and in between we have this communication in communication layer. Where there is a in vehicle bus system bus means that it is a collection of ware. So, we have the in bus in vehicle you know bus system and there are different you know proprietary and to open source components for communications. So, all these together will comprise the network and transmission layer which is used for communication. And that basically sit is in between the sensing and execution layer and the decision layer that we talk about now.

(Refer Slide Time: 25:31)



In the decision layer which sit is on top of the network and transmission layer. The information is transmitted for monitoring to the administrative node and for control of the sensor nodes the supervisory node basically sends the command to the network and the transmission layer, for further sending to the actuators underneath. So, with this we come to an end of this particular lecture of connected vehicles. We have talked about the first part of the connected vehicles the different issues with connected vehicles why connected vehicles are very important, and the different associated terminologies for example, vehicular communication we also spoke about different other allied terms such as vehicular ad hoc networks vehicular sensor networks.

Then intelligent vehicular systems then internet sorry, connected vehicles and intelligent connected vehicles ICVs; so, these are the different things that we spoke about in the next lecture we will talk about few other different issues with connected vehicles, and how those issues can be resolved.

Thank you.