Advanced IOT Applications

Dr. T V Prabhakar
Department of Electronic Systems Engineering
Indian Institute of Science, Bangalore

Lecture -17
Introduction to vehicle platooning

Let us now look at one more cutting edge example of intelligent transport system part of the upcoming an IOT application. And, that is related to vehicle platooning. Platooning has started assuming greater proportions particularly with the fact that the 5G is coming up in a big way. So, 5G technologies are going to be applied and likely one definite application area for 5G appears to be in platooning.

Question is what is platooning? And, what exactly goes behind in a platoon is something you are I am sure curious to know. And, let us go and lookup little bit to understand the theory in platooning. And, then also try and see if you can create a platoon in simulation software. So, that you can try platoon system and try out your own algorithms in front of your own computers or laptop. So, it is essentially to train you to understand: what are the newer things that are coming up in the area related to intelligent transportation systems.

I must tell you, before even start reading this module on intelligent transport, you go and look up YouTube videos. There are some outstanding practical examples of the proof of concept of platoon. I have seen that the there are companies, particularly these are motivated by European giants automotive giants. You have Scania which started talking about this, you have a platoon implementation by Mercedes, you have a platoon implementation by Volvo and so on.

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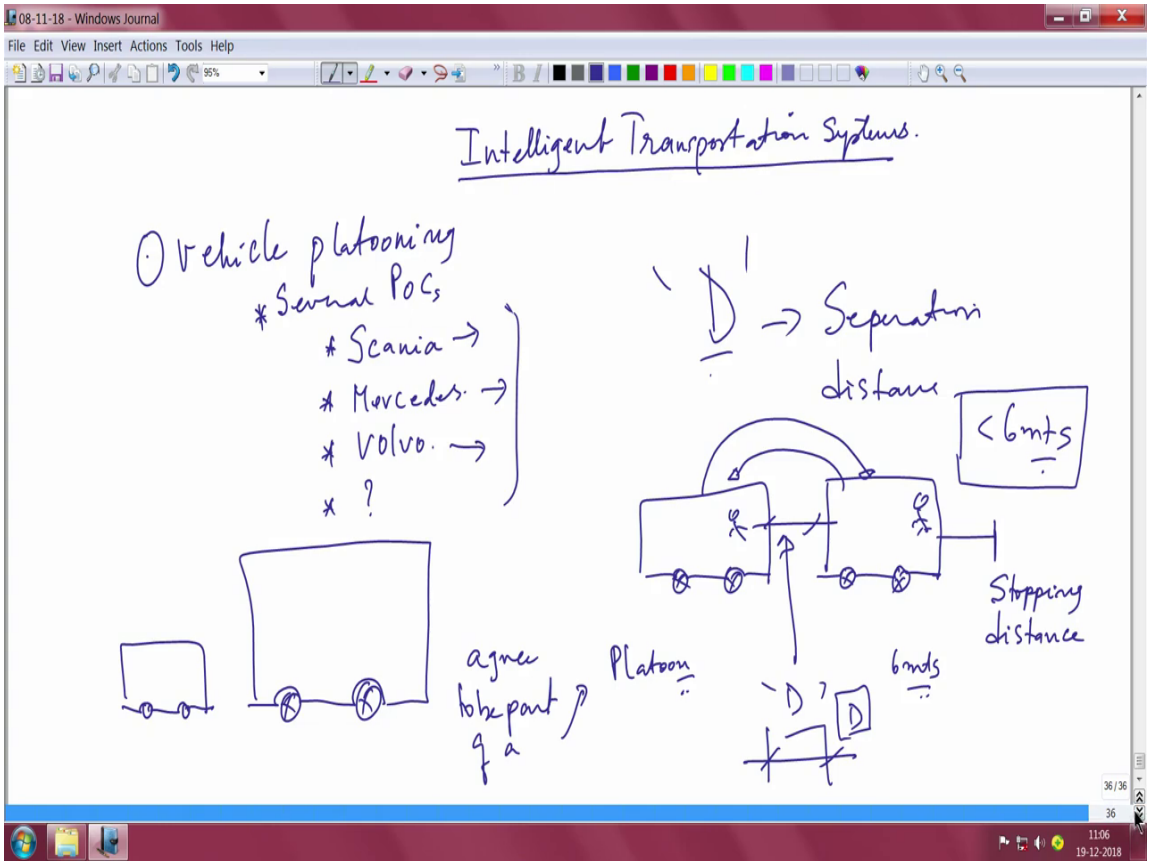

So, it is really a very exciting area and so I think it is important for you to understand the whole concept. So now, let us understand and ask ourselves in a very informal way what is this platoon all about? See platoon is nothing, but a collection of vehicles of the same type, preferably of the same type. If you are talking about trucks, you are talking about trucks of the same tonnage capability or loading capability; all of them on a highway. Most often platooning's we are talking about freeways or highways, where you are moving from one state to another state, or from one country and to another country and so on. A huge trucks, a big trucks which are carrying a lot of material from one side to the other, can essentially form a collection of vehicles.

The thing is if you are able to get these trucks to coordinate among themselves, collect them together in a logical fashion and, use communication infrastructure to communicate between these collection of vehicles, then you get some magic outputs. First thing is you will see that safety will improve, if provided your algorithms are right, your algorithms are working well and you will get safety as a very important consideration. Second thing is greenhouse gases; they will reduce tremendously, that is a second major advantage

you will get. Third one is if you platoon just look at the urban highway infrastructure both urban as well as the highway infrastructure roads are always crowded right. And, any amount or any wide broad is you know very soon gets choked in any good major upcoming city not good city, but upcoming city. Cities are never good to stay by the way you should stay in far of and little bit smaller towns and perhaps even villages to lead a good peaceful life.

So, the roads are always choked, but if you platoon you can get them logically together and pack a lot more vehicles on the freeway on the highway, which means utilisation of the infrastructure improves tremendously. So, these capabilities are something that you will get automatically. The fourth thing is fuel efficiency. The reason why that fuel improves is that when you logically pack them together into a platoon into the collection of vehicles into a one group, the air drag, that is offered to the complete system is much lower compared to the air drag that each vehicle would see right which means you are able to improve fuel efficiency or consuming less fuel.

Because, you are opposing air is much lesser and this can sort of be a big advantage for so, there are lot of benefits out there. And, you know greenhouse gases is a major challenge and if it reduces even by 5 to 7 percent for this platoon, from complete platoon as compared to individual, then you are doing already very good. Because, you know generation of electricity; energy is one sector where greenhouse gases seem to be contributing, transportation is contributing, agriculture is contributing, smart homes are contributing. All the sectors are major problem major sources of greenhouse gases. These are all sources essentially leading to a lot of greenhouse gases essentially trapping of light, that seem to create heating of the earth surface. So, in brief that is what it is and several gases are there. Methane is one of them, then nitrous oxide is another gas and so, many other pollutants are there, we can look at them in other if time permits in other modules.

So, these are the major advantages if you platoon them, but as a technologist what all do you require? And so, what are the things that you can implement in a IOT course. Why is IOT coming into this platooning area, because suppose you want to pack these vehicles closer you need very good sensors. You may need radar, you may need LiDAR, you may need camera sensors, all of them fusing the data from the sensors and somehow trying to

sort of keep the platoon going, keep the inter vehicle distance to a critical point such that the air drag is minimised and other benefits accrue because of the platoon.

So, the fact that all the sensors are by and large now part of IOT infrastructure. A course on IOT application, advanced IOT applications with platooning is a must also because the 5G connected vehicles module comes in a big way. So, that is another story. It is about V2X as they call vehicle to x; infrastructure, it could be vehicle to vehicle. So, all this is part of the major initiatives in 5G. So, now let us look at a set of small slide deck.

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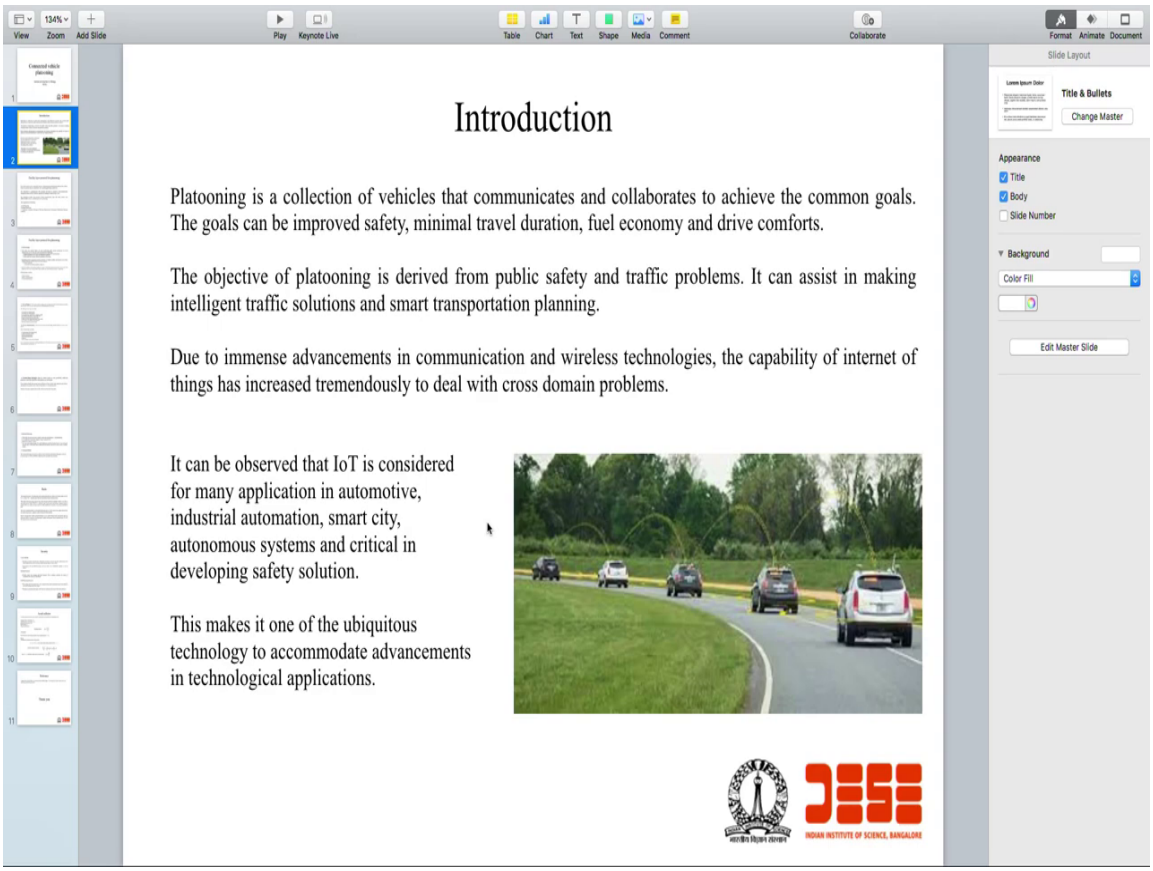

Now, there is a definition here as you can see. Platooning is a collection of vehicles I will not read everything you can read it at any point, but just to give you essentially it is a collection of vehicles there is communication, there is collaboration. And they have very common goals such as safety, minimal travel, fuel efficiency, your reduction of greenhouse gases, drive comforts and all of that right.

So, essentially it comes under intelligent or smart transportation planning and communication between vehicles in this platoon should happen through a wireless

technology, because you cannot tie these vehicles you have to put them logically together. So, wireless technology and therefore, 5G becomes a big candidate for trying out these platoon applications.

As you can see that, IOT is considered as a major push for supporting this intelligent transportation system application right. So, let us now look at that picture, it is a very interesting picture and lot of stories you can already build on this picture. There is a vehicle in the front, there is a car in the front and you can see the size of the ones that are behind. They are almost identical in sizes which means, when you say collection of vehicles they are all almost of the same type. You would not do a platoon of trucks and cars you perhaps do a platoon of trucks, you do a platoon of maybe SUV's and segments of that type of vehicles.

If you see the picture you see nice sort of a sprinkler picture from the first car to the second car. So, that essentially means there is some sort of logical connection grouping of all these vehicles and there is some sort of communication that seem to be happening between these vehicles. This is shown on a turning there is a curve there, which clearly indicates even if you have a platoon, that you need not assume that platoons are for highways and platoons are for roads which are absolutely straight. It can also be that highways have lot of turnings and this platoon continues to work even if there are turnings, and there are bends.

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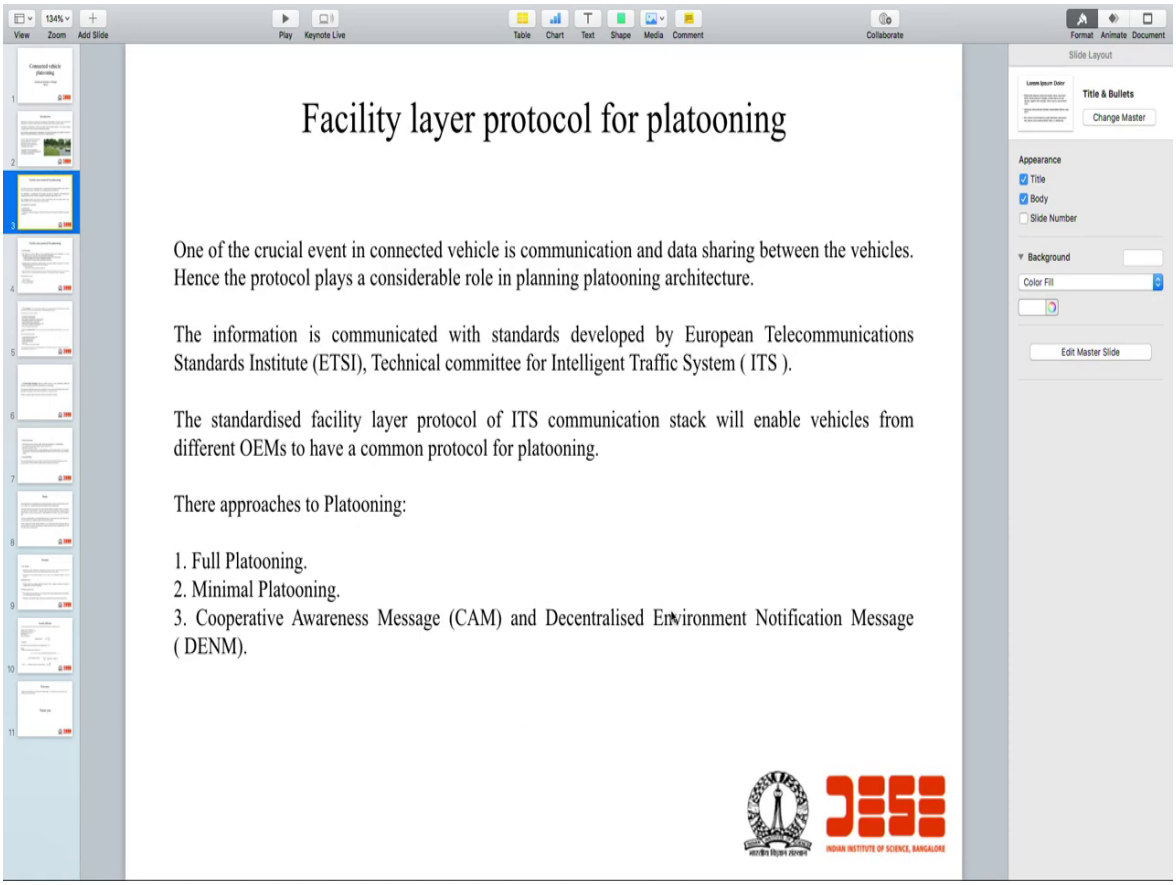

The big take away from this is there is a lot of effort from the European community particularly from ETSI, and the subcommittee working group there is the ITS intelligent traffic system subcommittee technical committee, looking at how to do standardization and so on. By and large you will see that platooning comes in two flavours; one is called full platooning and the other is called minimal platooning.

There is also a sort of platoon not necessarily a platoon, but indeed some sort of cooperative awareness messaging. Even, if you do not have a platoon you could be doing this awareness message and decentralized environment notification messages, which can be exchanged between vehicles from a safety perspective. So let us look at what a full platoon is.

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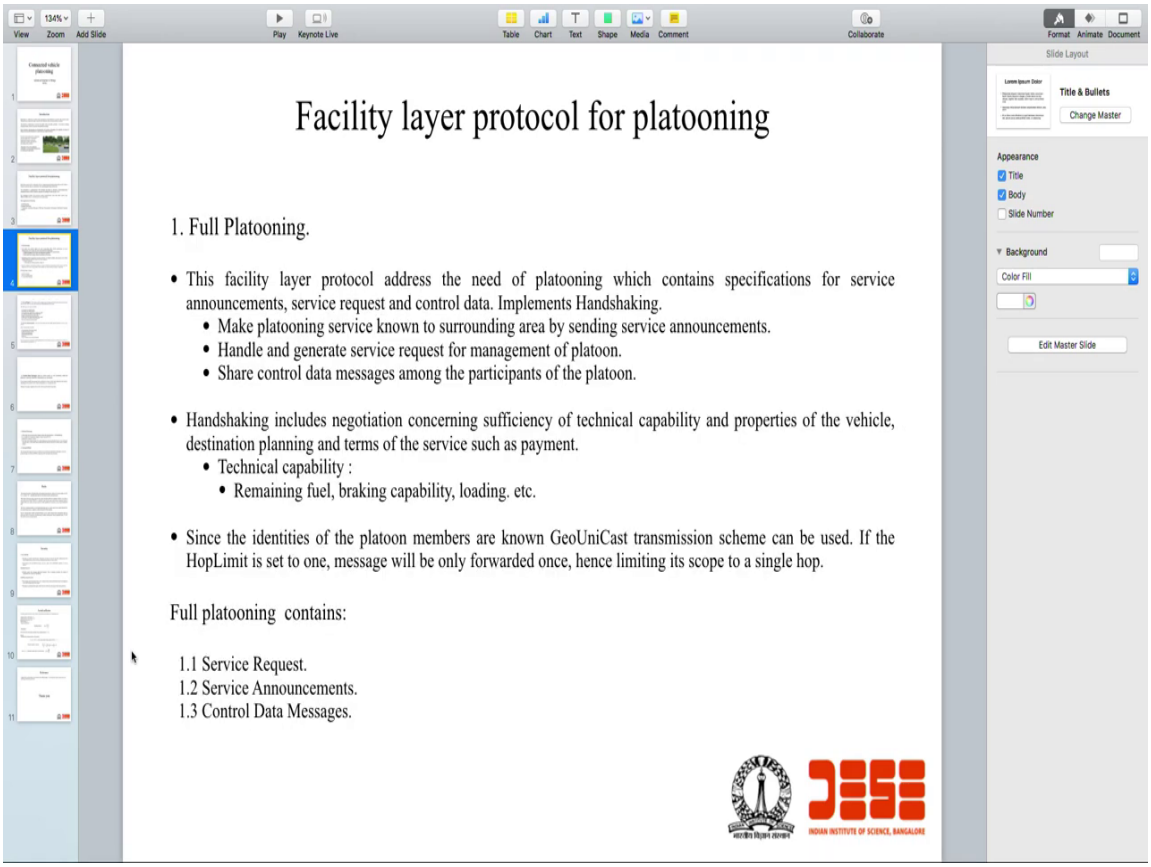

Platoon is like you have a driver. The driver is sitting and then there is a button if you look at the Mercedes video which I mentioned to you can see that, they press buttons. And, once you press the button then the platoon can start to form; that means, the driver the physical driver is the one who is initiating a platoon, which means there is still a human intervention as far as such a platoon is concerned.

But, why should we imagine things like that you can also say that, why should I know when to start a platoon. It should happen by all by itself if sees a similar vehicle truck, or a similar loading capacity or a tonnage capacity truck in front, and they have certain communication capability, they should simply be able to form a platoon by the way platoon is not just for 2 it is typically 3 4 and above, for 2 it does not make sense. So, I do not think you will see a platoon of less than 3. At least the videos I recall there are more than 3.

So, it should happen automatically, which means if you say full platooning system. Then you talk about automatic, you know message passing between trucks and vehicles and

then they are forming a platoon even without the awareness of the driver, driver is just driving and then suddenly there is a message says take your hands off we have formed a platoon. And, now we are going to move in a platoon. The driver is informed that he should take his hands off, that is one way and that is the full platoon.

The other way is the driver presses a button, the second thing minimal platoon is the driver presses the button initiates a platoon and then takes his hands off. So, these are two possibilities. Remember if you start imagining these two scenarios, in any case whether it is a full platoon, or whether it is a minimal platoon, lane changing and all or intersection all these things the platoons have to warn that drivers have to take care of the steering, they have to control the steering. There are many situations where the driver has to take control of the steering and has to guide the vehicle manually.

So, whether it is automatic or whether it is minimal, I think we are still at least I would say half a decade and above to see a full platoon without a driver, that is not going to happen at least in the next 7-8 year may be even a decade. But, it might ultimately happen because people are not interested in driving on a long highway, particularly if you take US, or Canada, or any of these places. So, the highway runs into thousands of miles. So, it is pretty difficult for humans to drive that kind of long distance and not get exhausted. So, the tiredness comes in.

If you look at full platoon facility there is a protocol for platooning, you make a platoon service known in surrounding area by sending service announcements. So, this is a nice sentence and we have a demo exactly I mean about this. So, make platooning service known to surrounding area by sending service announcements this is a minimum thing that you need to have.

Then handle and generate service request for management of platoon, then share control data messages among participants of the platoon, these are all important things. Then, there is handshaking which includes negotiation of concerning sufficiency of technical capability and properties of the vehicle and so on. If, you have vehicles which are of different in from, different segments you will have problems.

For example, if you take trucks they have a certain tonnage capability, and they have certain fuel that is there, and there is a certain braking capability that is provided. So, all this information should be passed on within the platoon. In a platoon essentially you will

have a leader and you will have followers. What should be the minimum distance between the leader and the follower? Again, I want you to go back and look at that YouTube video; it gives you tons of information in that small video clip. I recall that we are talking about platoons, which are formed in inter vehicle distance D.

Let us say D is the inter distance, I will call this D inter distance separation, separation distance between vehicles. You have a vehicle, and then there is another vehicle with inter distance, the D separation distance.

People are attempting under 6 meters something humanly not possible at all if you have a driver, you cannot brake at 6 meter. So, people are looking at less than 6 metres, but several video that you see they are even looking at 10 - 15 and 30 meters and up to about 50 meters. So, that is the point really that if you look at that video they will actually tell you that the inter separation is that, and you may have to inform vehicles have to talk to each other and say hey I can brake at 6 meters safely.

And, you may to announce back to say at what distance you will be able to brake. So, you will have to mention that back to the leader. Leader have to say the inter separation distance. You can also say that under any circumstance this D has to be maintained right, this is what you are you are looking the separation distance. And, you can also mention to the followers what is the stopping distance. Supposing you see an obstacle that, the moment you spot that obstacle it does not mean that you will apply brake immediately.

Because, that obstacle may simply pass off right it may be another moving object it may go away it may be far off and it may just vanish as you go closer. So, but you can always specify what is the stopping distance that you are going to look at, when you sort of decelerate. So, that is also specified and that is informed back to the other followers as well. So, that stopping distance is also an important. So, I will say stopping distance from an obstacle and also the separation distance between the vehicles. These are important parameters which you will have to look at. So, you can see it is quite logical.

So, several parameters have to be passed back and forth both directions to establish and say they all agree upon being part of a platoon. So, there may be a situations where I agree to be part of a platoon. So, this itself is not going to be simple. Therefore, you can now see the reason, the rationale; why you do not want to mixe small vehicles with large vehicles, you do not want to mix trucks with small vehicles. Because, they have different

capabilities it does not make sense to expect the same kind of a response from vehicles, but it might turn out that the little fellow in between may get sandwiched in very big vehicles. So, I will just go on a little further.

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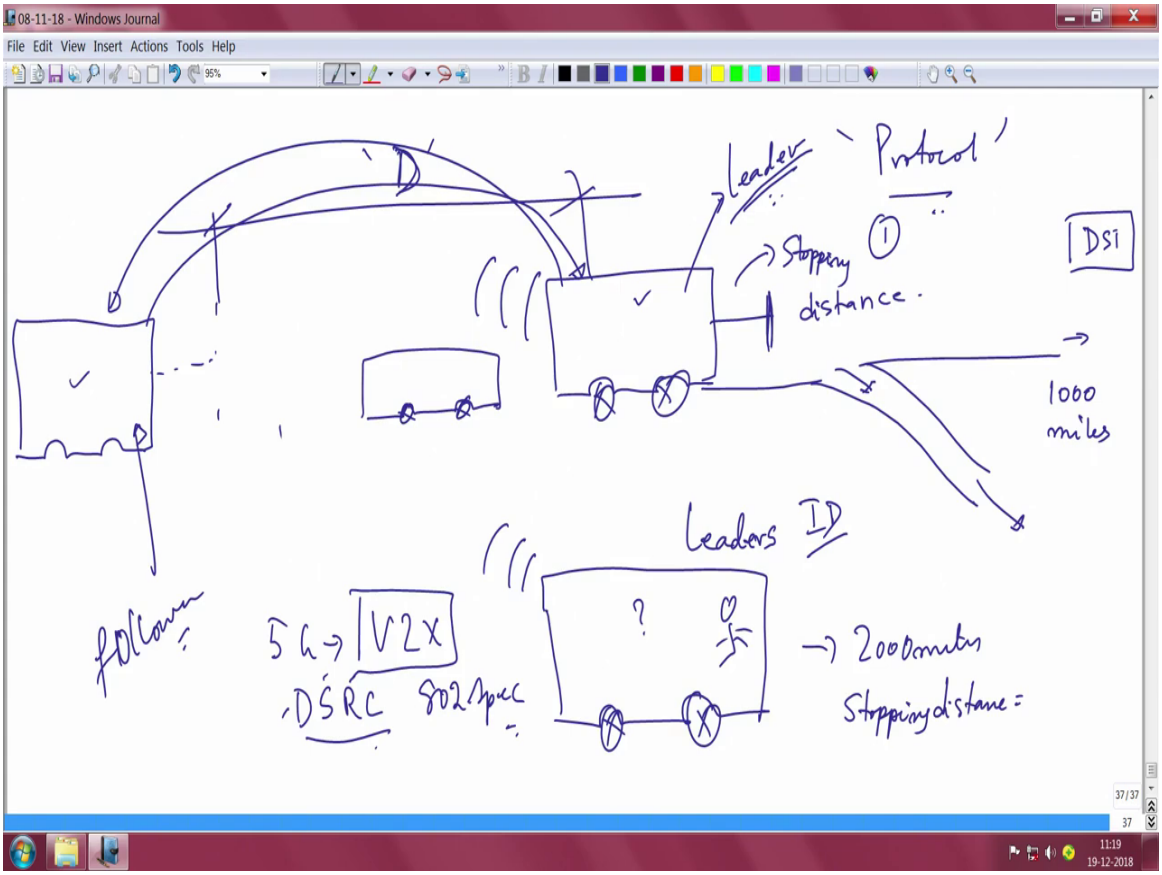

There were two vehicles which were originally a part of the platoon, rather they continue to be part of the platoon, but a vehicle from out came and came in the middle of these two. In which case this D has to go up right, this D has to move, because it becomes equivalent of a stopping distance.

So, therefore, what would happen in this case is the stopping distance is increased because the middle vehicle now becomes the obstacle for the followers. Therefore, the D has to increase. So, the D will have to go up. In other words the behind vehicle may get pushed back. The distance between vehicle increased. So, now, your new D actually adds also the separation distance also adds the stopping distance perhaps to maintain safety.

So, these kind of things have to happen, the capabilities have to be announced. So, you need a fantastic protocol, a good protocol to communicate from vehicle, to the other

vehicle and perhaps also exchange some information in both direction. If, there are followers behind, this information has to hop. The information communicated by leader hopped to the one behind follower and the follower in turn is communicating and so on and so forth. So, now, let us move on and see what are the minimum things, you need to do in order to get a platoon going. So, you essentially look at for full platoons 3 important things have to happen.

You talk about a making platoon service as I mentioned service known to surrounding area by sending out service announcements, handle and generate service requests, for management of platoon and share control data messages. So, full platoon means you have service requests, service announcements and control messages. So, let us look at each one of them.

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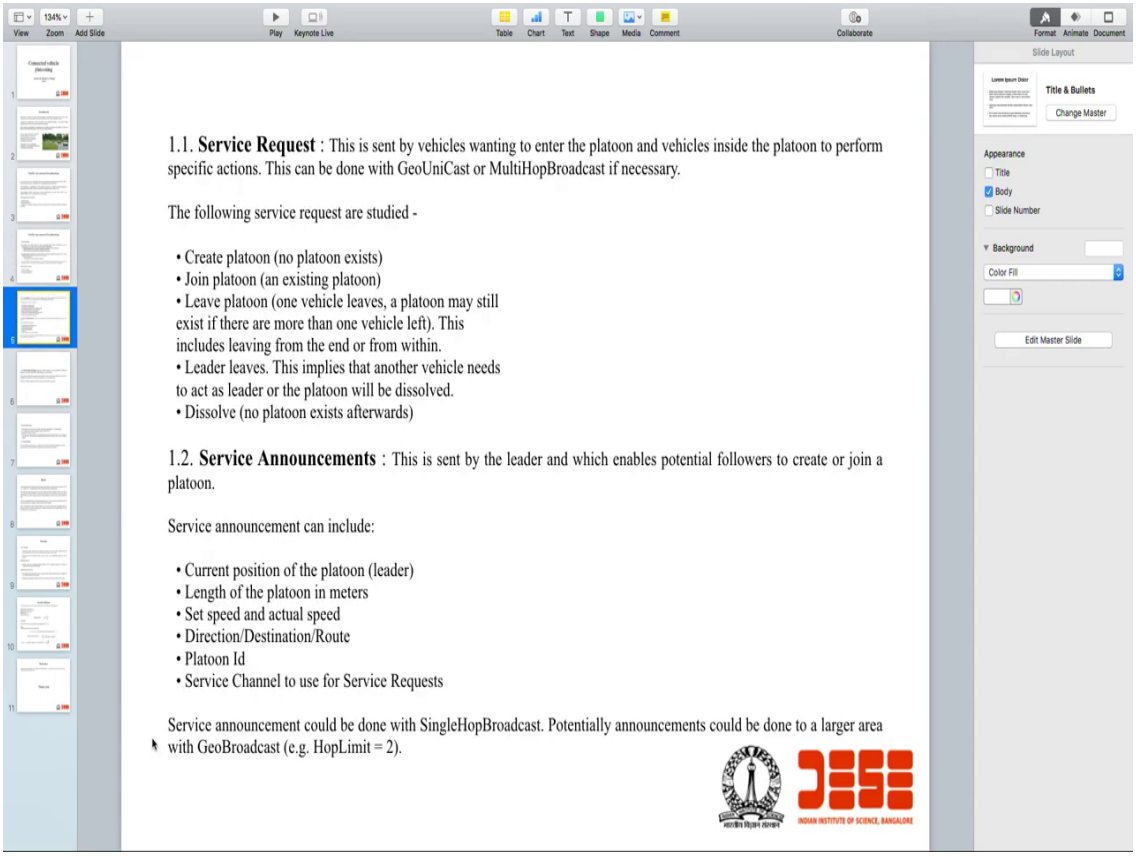
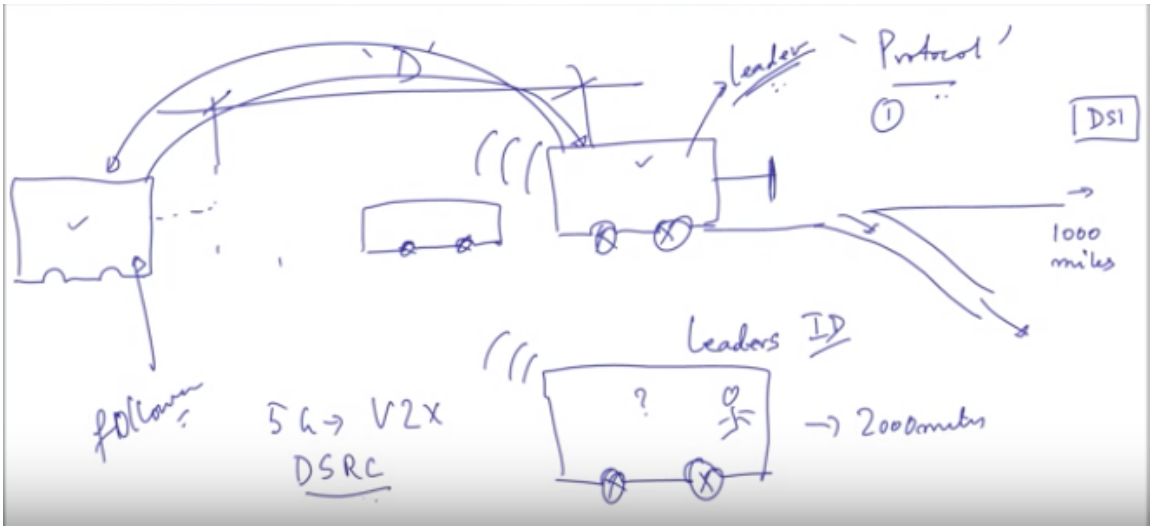


The first one we will do after we do the second one. The second one indeed is the service announcements. Now, let me draw your my your attention back to the picture. Anyone can be elected as a leader and the follower. If vehicle agrees to be part of the platoon. Now, what are the things that the leader has to do? The leader has to essentially make

available the current position of the platoon, length of the platoon in metres, that it wishes to manage, what should be the length that he looking at? Set speed and actual speed, direction and destination, route, platoon ID, service channel to use for service requests.

I will go into some details of each one of them, do not have to memorise any of these things, but you will have to just get an overall view of the following. See, I let me a put your attention back in back to this picture.



There is a leader, who is going in one direction. There are the road either curves or the road can go straight as well. So, let me draw a straight road now there a point if there are this going let us say some 1000 miles this will go in other direction. There is just no point in declaring to be a leader for a set of followers, but taking a deviation right near to curve is not going to help right, which means you seems to be a leader moment you take a right turn.

In other words all information about in what direction you are going is your DST, where in what direction you are going, what is your final destination, at what speed you propose to go, and passing all information that you can be a leader and announcing your service capability as a leader, all of this should be mentioned in the beginning. Imagine a situation where on the same highway there are multiple tracks, there can be one more vehicle. There can be one more vehicle running parallel, where it also making an announcement. A wireless link now is available, now which one should the follower go after? Now, that will depend on the parameters announced by the 2. So, called leader's. Let us say the leader says I am going 2000 miles which is indeed what the follower is

looking at. So the follower finds that if it attaches to the other leader, it can only follow for 1000 miles, but whereas, first leader says I am going 2000 miles in the direction of what this follower is planning to go.

How to distinguish between two leaders? You need a platoon ID. So, there is an ID. So, the ID is also part of what these leaders have to issue. So that is also part of all the service announcement. So, you can see and connect back here, current position of the platoon, length of the platoon, set speed, direction, platoon ID, and some channels for service requests right. Service requests means those are requests which are going to come from followers.

Now, what are the follower supposed to do go and look at 1.1. Create platoon; that means, it can say I want to be a part of a platoon. So, he says I am ready, I want to create a platoon, I want to be part of a platoon, if indeed there is a platoon I would like to join. So, the second one is saying I am ready to be part of a platoon, that is create platoon. I want to be part of a platoon, join platoon, I want to leave a platoon, because I think that the leader is not in the direction where I had planned originally, or I have special instructions by my whoever truck operator to take a different route so on and so forth. Or I have a problem with my vehicle and I would like to go by a lay by and stop there or do whatever.

So, there may be many reasons why you want to leave a platoon. And, then there is also things that leader leaves, the leader can also leave. This implies that another vehicle needs to act as a leader, that is real action of a leader is also part of the first bullet which is indeed the service request. Then, leaders, if the leader finds that there are no more followers, the leader may actually dissolve the complete platoon right.

So, in other words service requests that is sent by vehicles wanting to enter a platoon and vehicles inside the platoon to perform very specific actions. Now you have service announcements by leaders to enable potential followers, then there are service requests by followers and there is a provision to create and all that. How do you maintain the platoon? How do you ensure that if it is going over 1000 miles, you need to keep exchanging information let us look at how that happens?

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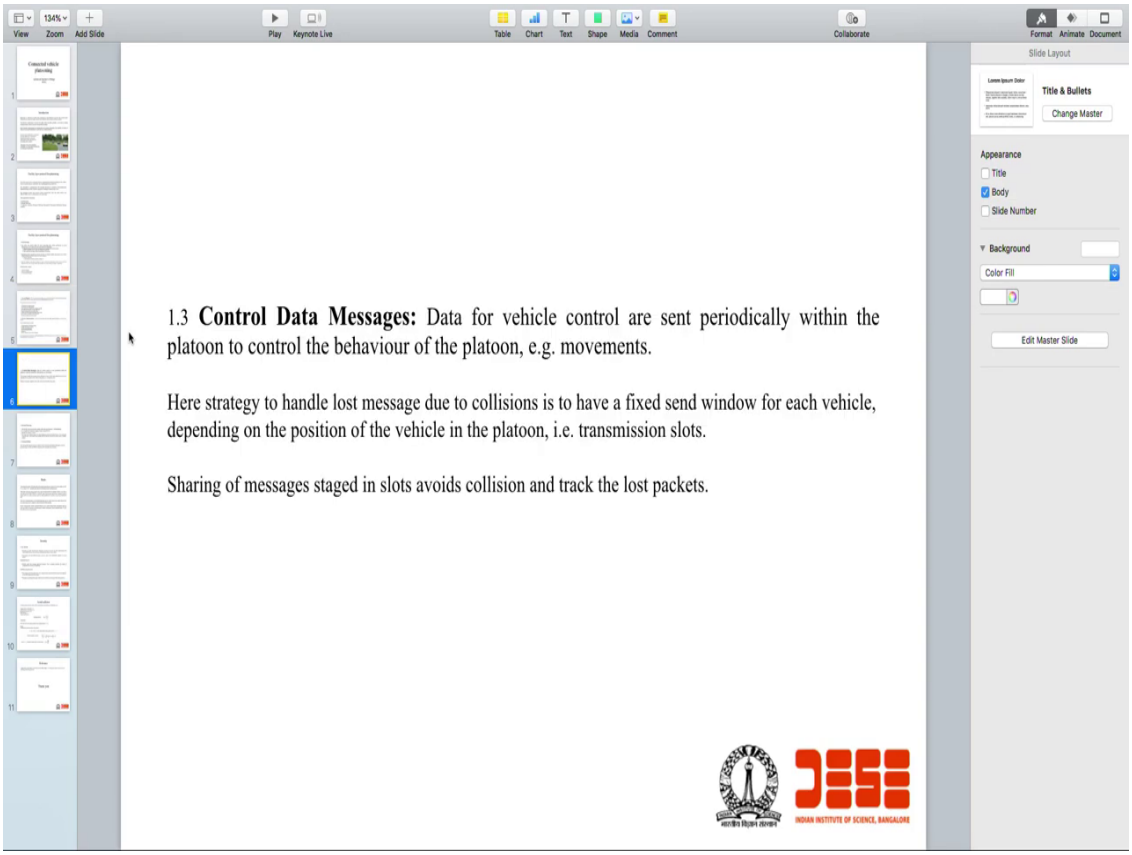

That is possible through what are known as control data messages, which are sent periodically to ensure that the platoon continues to behave, the same way the movements are same. And there are and there is a possible there is a provision to ensure, that no collision is possible between these vehicles and so on and so forth right. So, this is very important.

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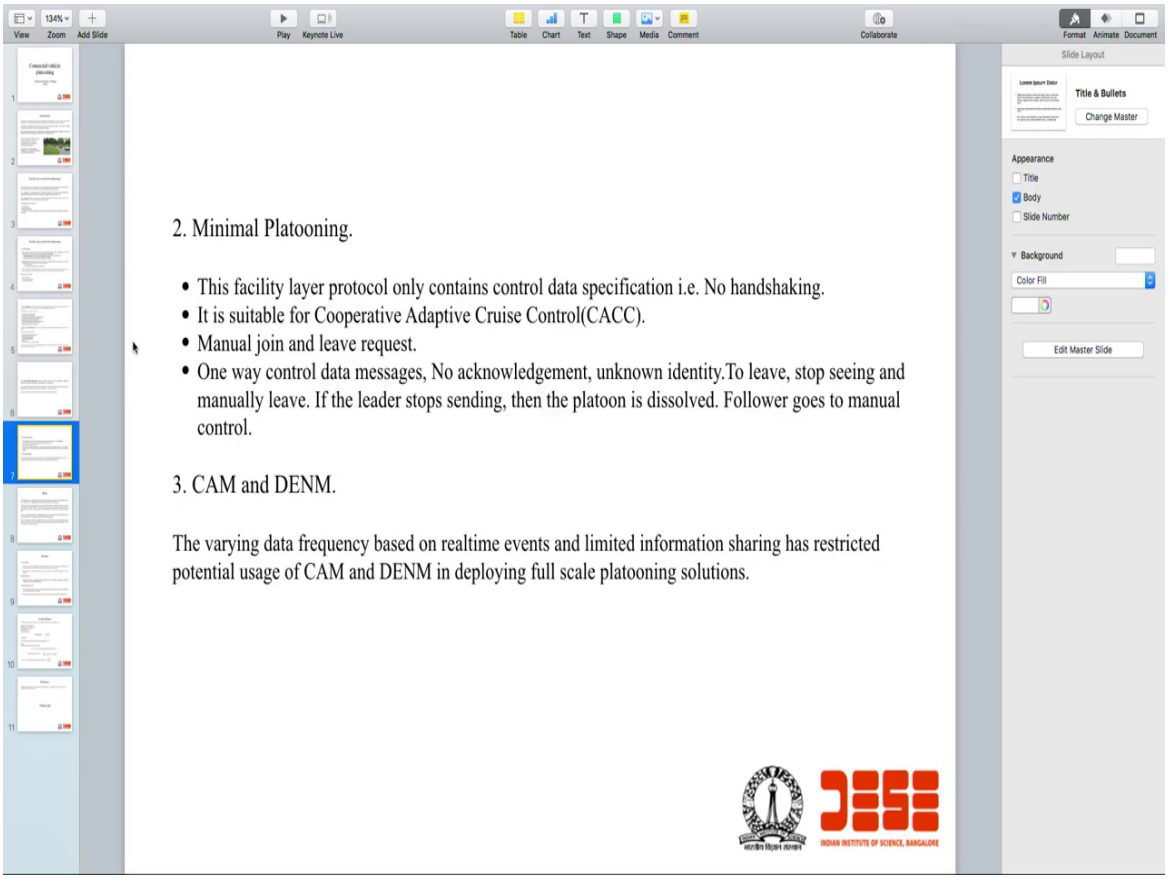

Now, let us look at a little bit of simple stuff I will skip minimal platooning because it is indeed, a subset of the full platoon. So, let us leave that and let us move on to the next slide.

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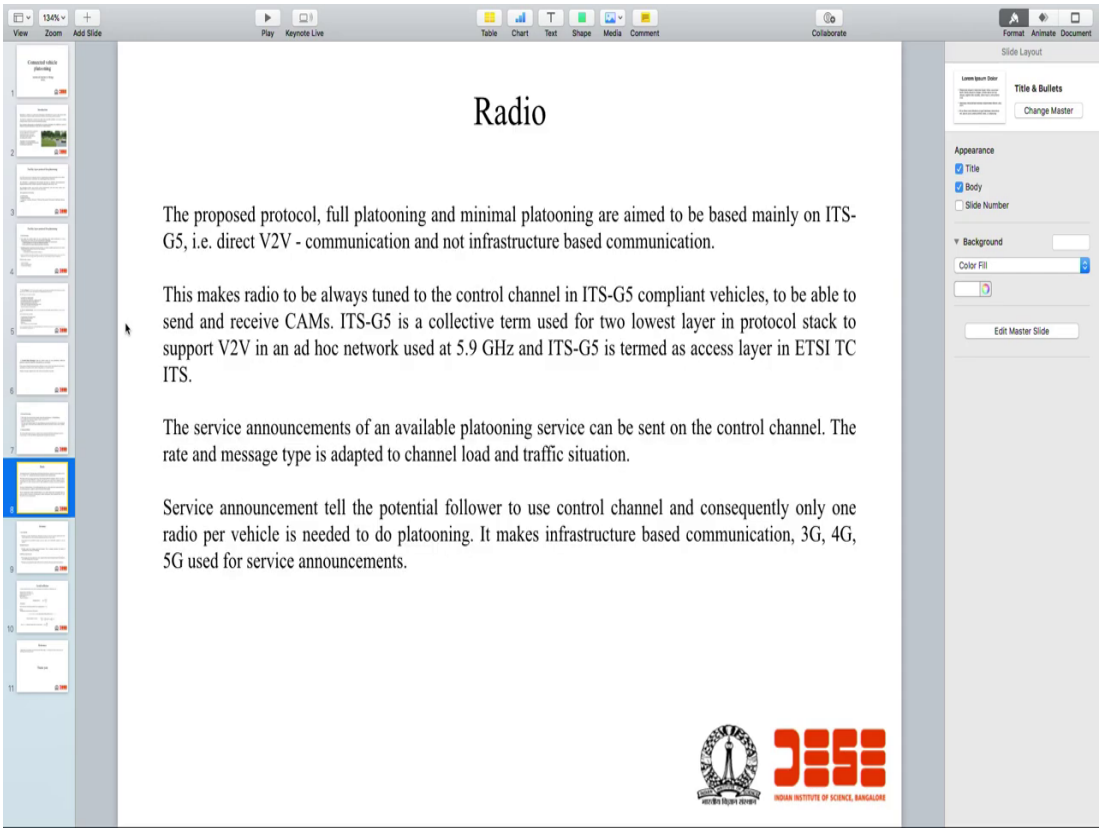

Radio is a interesting thing, this is for communication purposes. There is a radio as part of the wireless system. So, people have been talking about 5G wireless networks for the purpose of you know exchanging this information in the broad spectrum of V2X. And, DSRC is something that IEEE has also trying to standardise in the 802.1.1. This is called dynamic short range radio communication, there is an 802 specification for that. And so, please lookup the 802 spec for automotive applications particularly in the V2X framework.

So, ETSI two has been working on it and there are some proposals also from the ETSI group on trying to look at what is the good radio and what should be it is capabilities, how to support full platooning and minimal platooning and so on and so forth. So, let us move on to the next slide.

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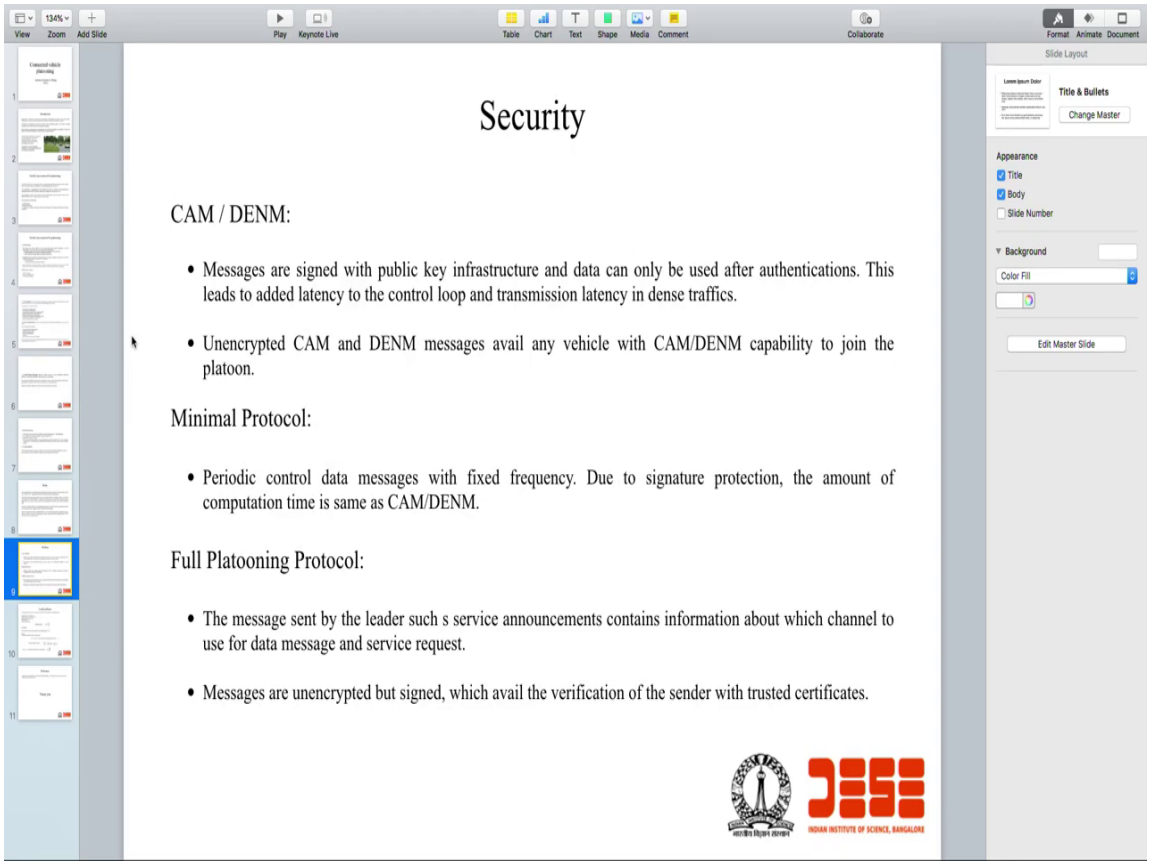

Security, as you know is a very important part of the platoon you must be looking at leader announcements that contain information about which channel to use. And, the service requests; they are all messages which have to be encrypted, they should be a verification on the sender with trusted certificates. And in the full security system gets blown when we talk about the fact that platooning's have to be maintained.

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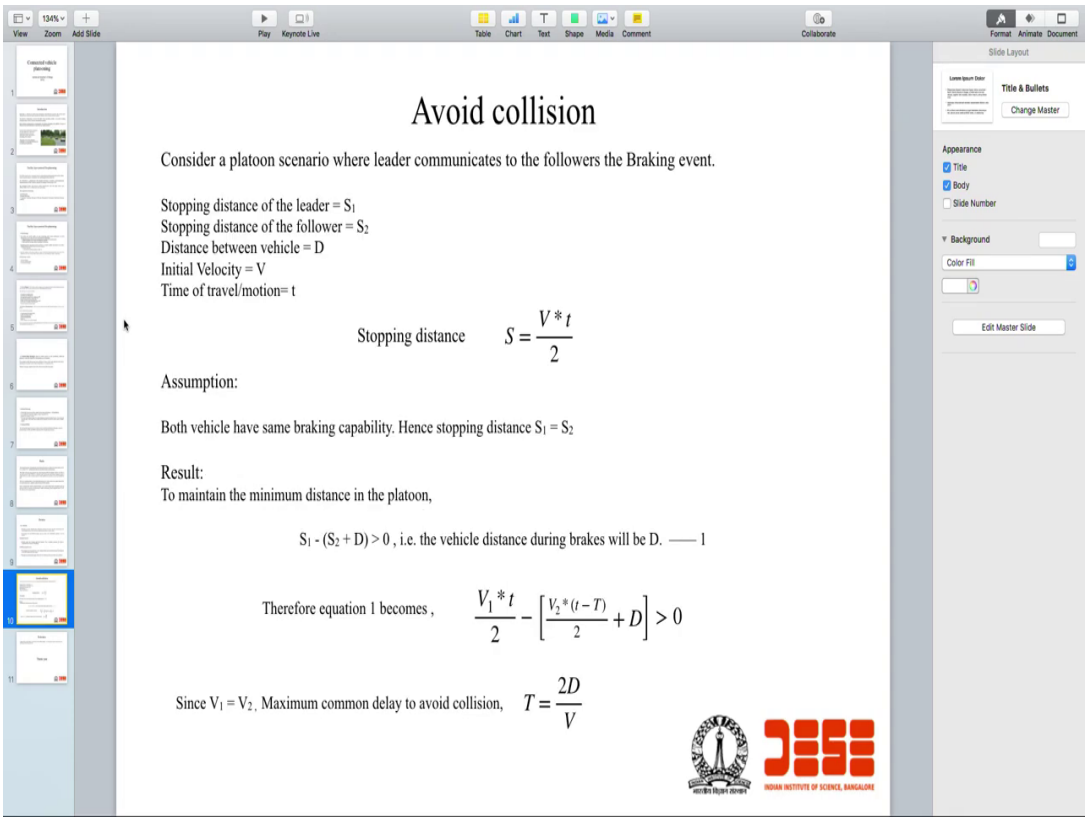

So, this slide is a very interesting slide, it just gives you a very simple idea of what I was discussing. And, let me draw your attention to this picture here, we mentioned about the D, which is the separation distance. We also spoke about the stopping distance, that is when it sees an obstacle it is going to be a stopping distance. So now, how does everything connect from simple laws of physics which we know from kinematics.

So, one of the things that you can do is you can calculate this stopping distance easily. You can calculate the stopping distance by applying one of the third motion law. So, stopping distance you can apply using the third law of motion, which indeed is S = (V*T)/2. S is the stopping distance which you can see and so that is a very simple thing. What is V? V is indeed the initial velocity of the vehicle, it is moving and time of travel or motion is “t” and then S is simply the stopping distance.

So, when you say S is the stopping distance, you are talking about leaders stopping distance which is S1, and you are also talking about the follower stopping distance which is S2. You expect S1 and S 2 to be the same because that is the reason why they are

under a platoon. They have the same capabilities. So, therefore, S1 is equal to S2; you can see that the braking capabilities are the same. And therefore, S1 is equal to S2 you have to ensure that this is actually a very critical part because only then you can be talking about vehicles of the same type being part of a platoon.

Now, in order to maintain the minimum distance, D separation distance which I spoke to you about, you had to ensure that S1-(S2+D) that minimum separation distance is actually greater than 0, that is the vehicle distance during braking will continue to remain as the distance D. That is even after it stops dead halts the leader and the follower the distance is maintained to be whatever, that a less than 10 meters or equal to 10 meters or whatever we discussed as part of the minimum distance between, so that continues to be maintained. So, the D will be there.

So, if you keep that in mind and apply the stopping distance criteria, because S1 = S 2 you do simple substitution and simplify. You will find that the delay to avoid collision ;T = 2D/V , V is the velocity of the vehicles. So, that is a very simple calculation again it came from that nice paper that we found.

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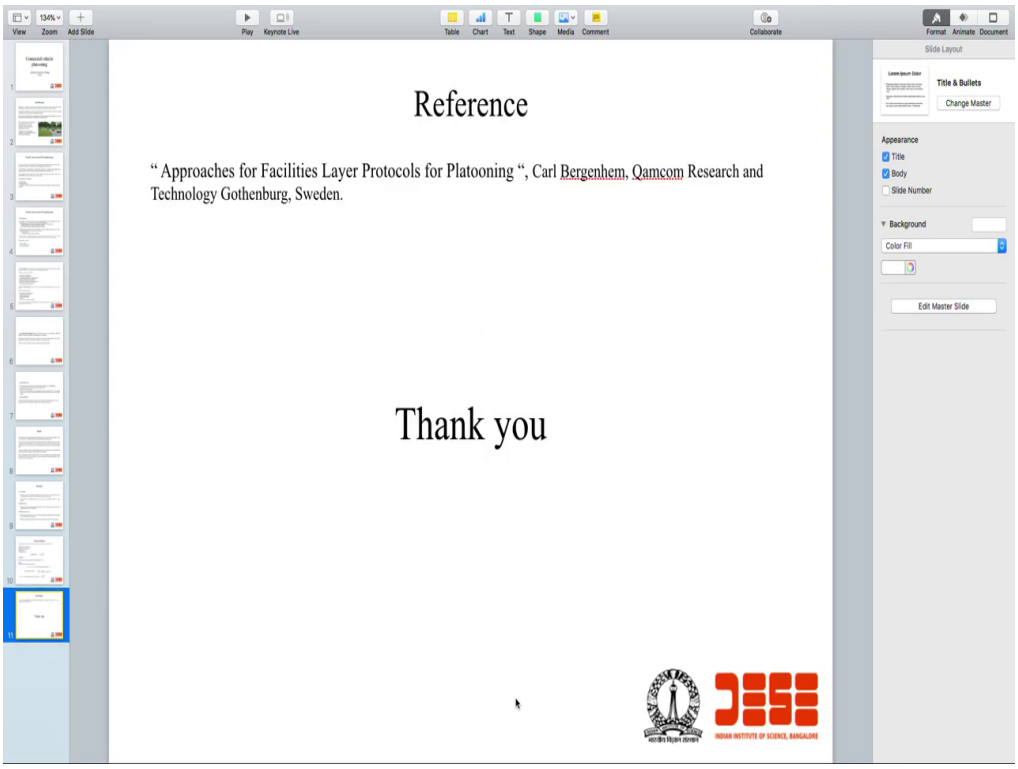

And therefore, you could definitely look up that paper and the paper is given here. “Approaches for facilities layer protocols for platooning” and you can refer to this paper hopefully you will be able to find it on the web without much difficulty.

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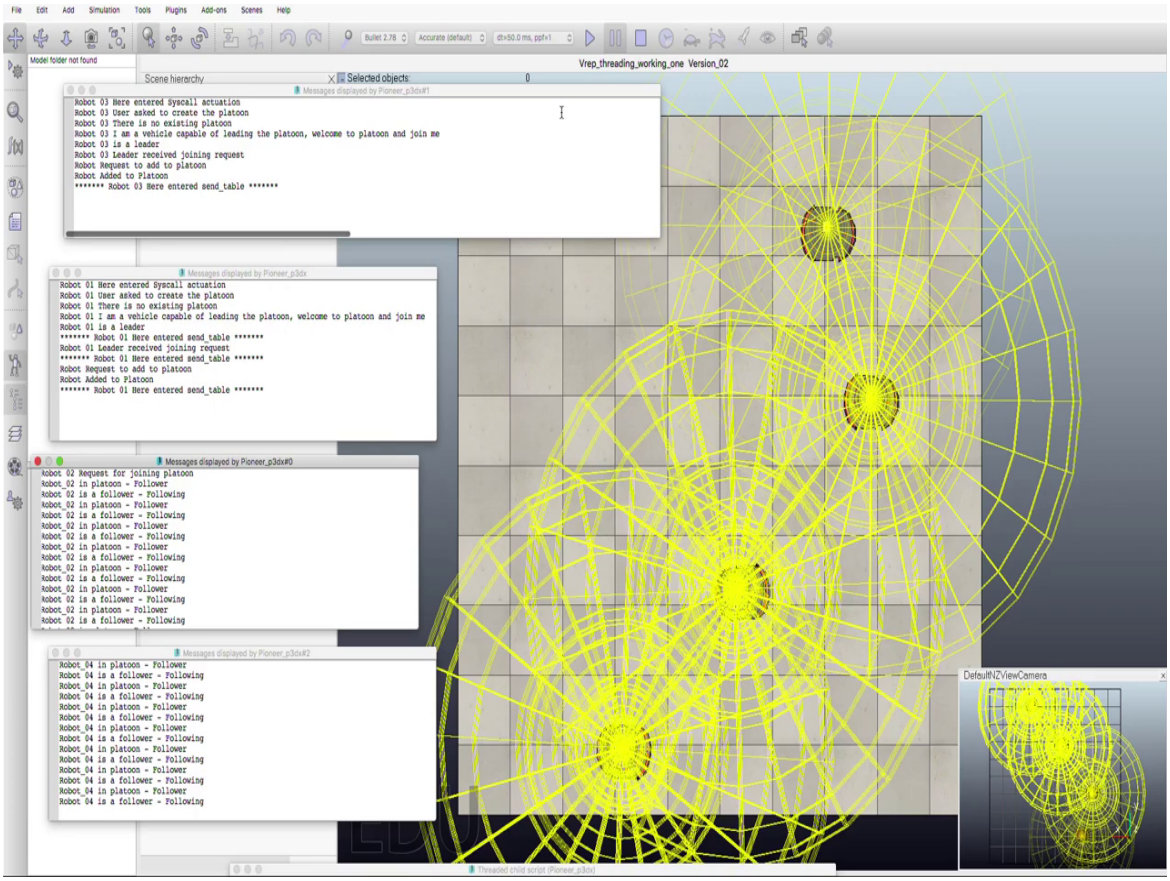
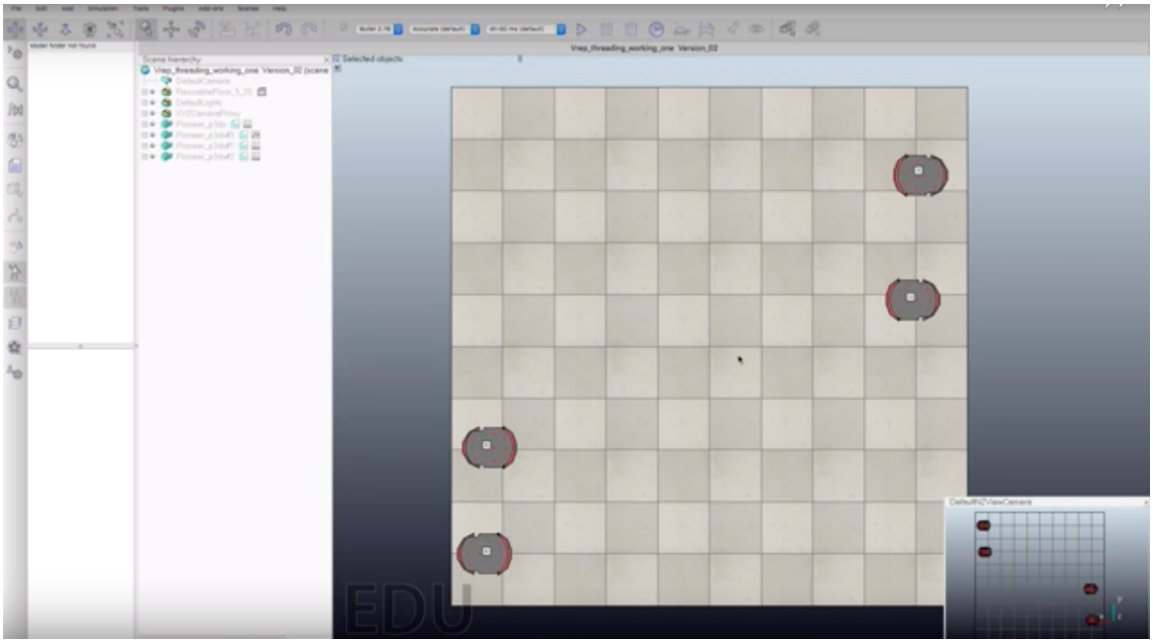


So, this is overview of a platoon and now let us move on to see how to do this simple platoon example in the V_rep. So, the demo is very simple essentially we will show you creation of a platoon to begin with, there is no existing platoon. So, you have to create a platoon and then there are vehicles which wants to join this platoon. And then of course, when you talk about creation of a platoon if there is no platoon. The guy who announces first indeed becomes the leader. Because, there is no platoon and if he is a leader he will have to do some very special things like what we discussed, service announcements have to be done. And, what does that contain, position, lengths, speed, direction, platoon ID service channels all that will have to be done specially by the leaders.

So, we will start with a demonstration using Vrep. This Vrep is something that you have done even previously part of this course. So, we will continue to use Vrep and give you some capability.



Let us turn our attention to this screen, the extreme right are 2 vehicles and extreme left there are 2 vehicles. Now, that means, basically there are 2 platoons. So, they will have different platoon ids. And, they expect vehicles to join their respective platoons. And, you can see that on the extreme left one and the extreme right one are shown in the for the purpose that the vehicles are crossing each other the directions are different.

So, you expect on the left extreme those two part of a platoon, and the right side one those two being part of a platoon because they are in different directions right. So, let us start the demo

Refer: https://www.youtube.com/watch?v=yVPxbPXlnio – 41:06

Before you start you will see something interesting, that there is no platoon therefore, what should happen create a platoon should happen and then you get a leader and then the leader will make an announcement. You can see this they have broadcasting, we have broadcasting and you realize suddenly that 2 IDs have been announced and then there are 2 platoon and then the followers out there.

So, maybe you should try this when you find this code, but I will read out what is out there it says, there is no existing platoon, You can try this messages, you can read up the paper you can look up the you tube videos I mentioned to you from Scania, from Mercedes, from Volvo and get an nice idea of what exactly is happening in this world of platooning. The message continues to go as long as the leader exists and the platoon exists the follower continues to give out a messages. So, this intern this essentially conveys our idea of platooning.

Thank you very much.