Advanced IOT Applications

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Lecture – 19
Building blocks for autonomous vehicles - 2

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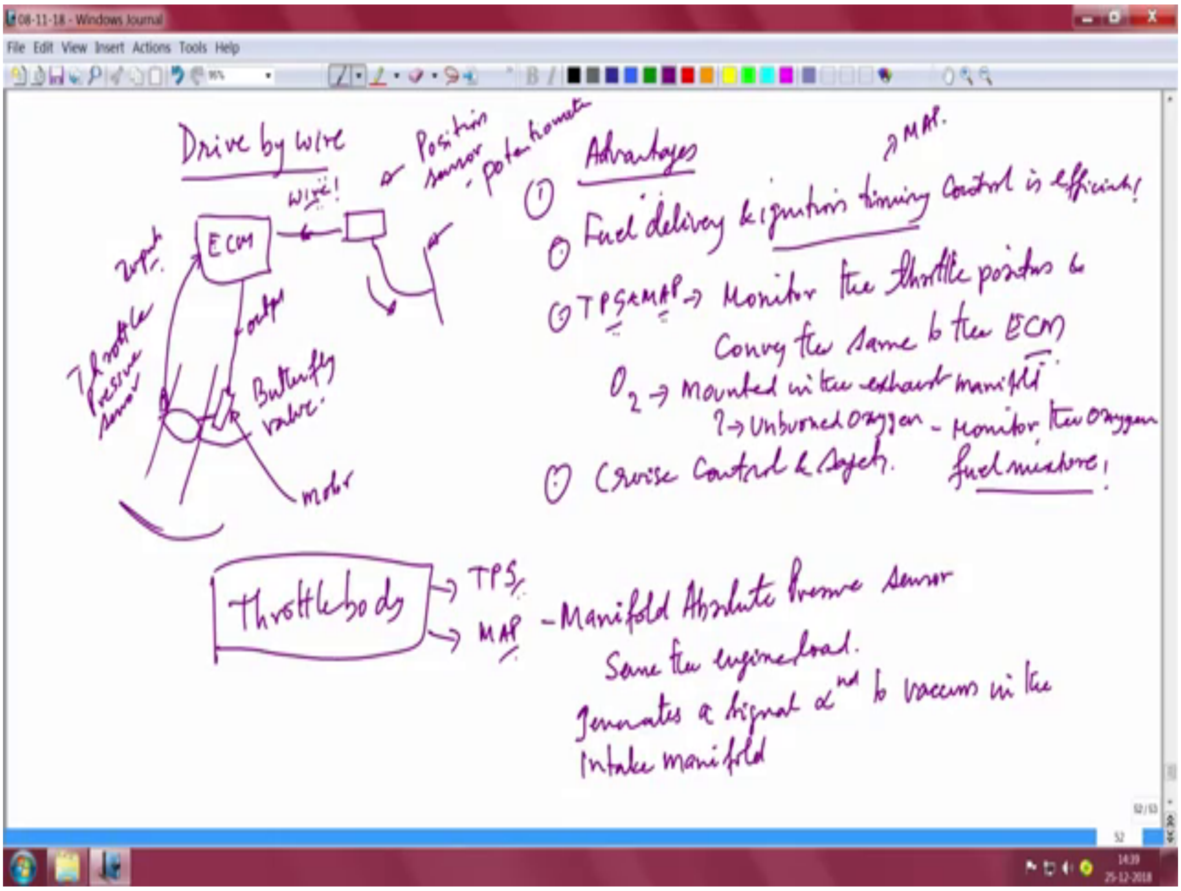

So, another sensor that you may be interested we to just complete the discussion on this, indeed is the oxygen sensor. Oxygen sensor actually mounted on the exhaust manifold. It will tell you how much of unburnt oxygen is there. So, this is important right? You want to monitor the oxygen levels to understand all about gazing the fuel mixture. So, you can say O2 is an output again; like throttle pressure sensor. So, there are other sensors you know they are called MAF sensor, Mass Air Flow which measures the amount of air flow that is going into the engine manifold, that is also there this MAF sensor.

Then you have as I said oxygen sensor, there is temperature sensor, then there are speed sensor, there is an RPM sensor and so on. All of these sensors I can show you in terms of an engine ECU ok.

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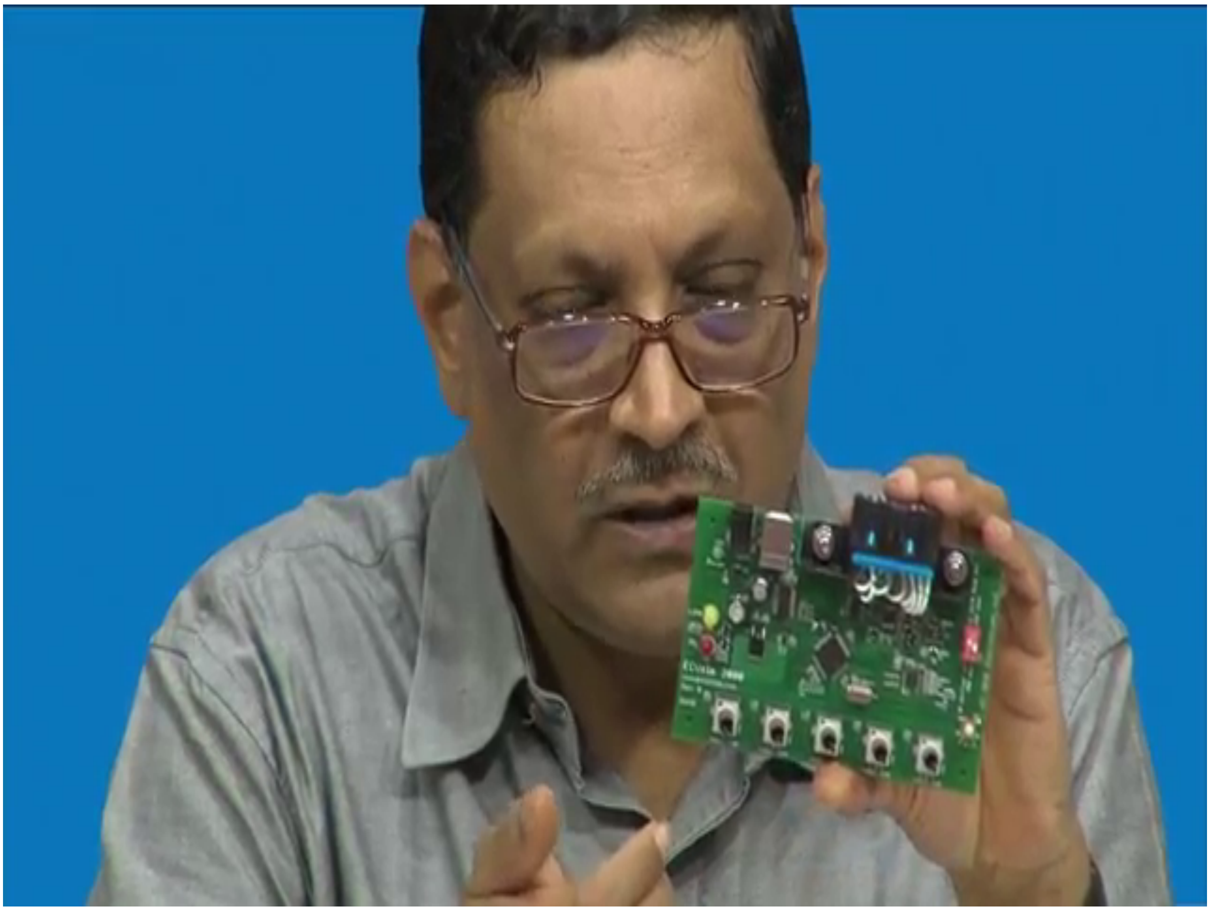

Here is an engine ECU, shown in the above picture. I drew this discussion only to tell you that this is what we want to do, we want to put this emulator simulator in action. each one of the knobs you see, there are 5 knobs. These 5 knobs correspond to different sensors as part of the engine ECU. It has essentially temperature, RPM, speed, oxygen and mass air flow.

So, all of these are important parameters if you want to understand the engine and it’s functionality. If you want to look at how to use these sensors in a manner that they you can build autonomous systems, you have to understand the functions of each one of them. But, before we go on I must tell you see the ECU, It is a complete ECU system. You also see that there is a black connector which is called the OBD II, what OBD stands for is On Board Diagnostics version II it is called OBD II.

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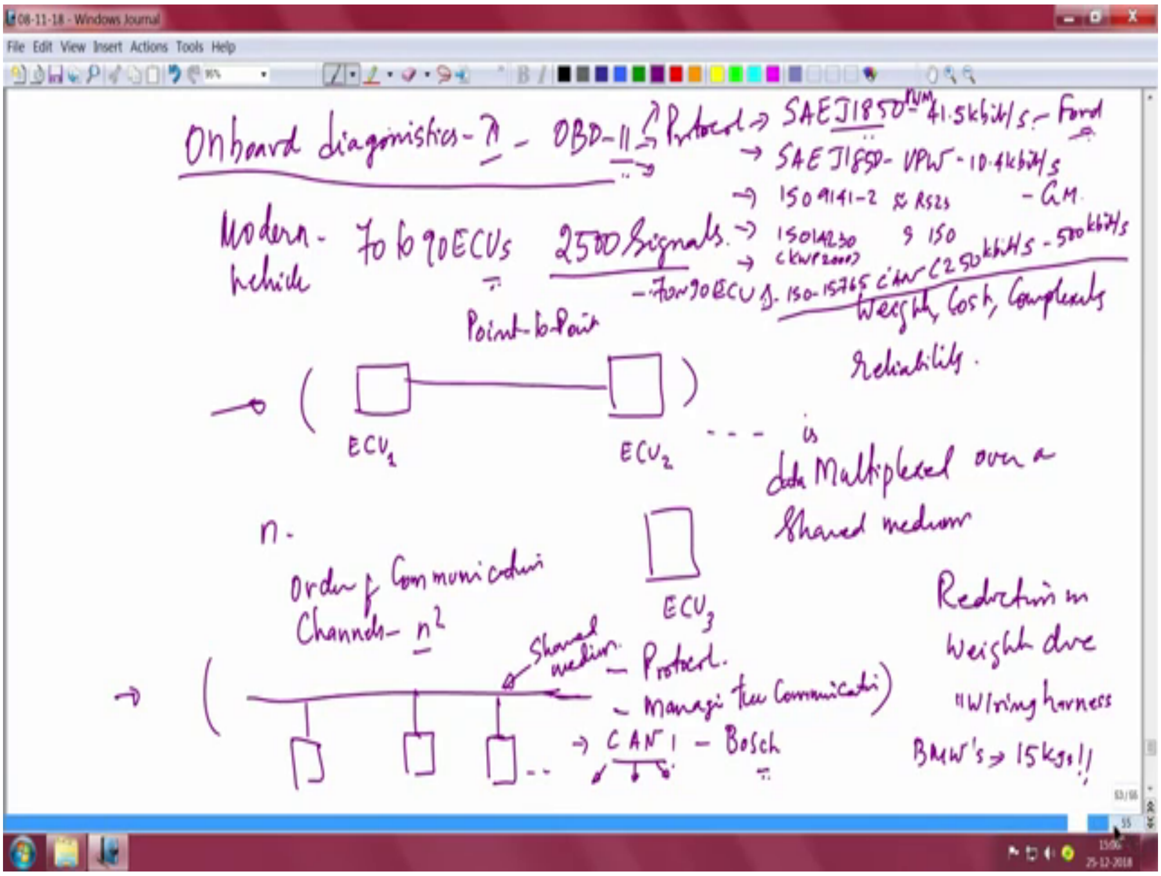
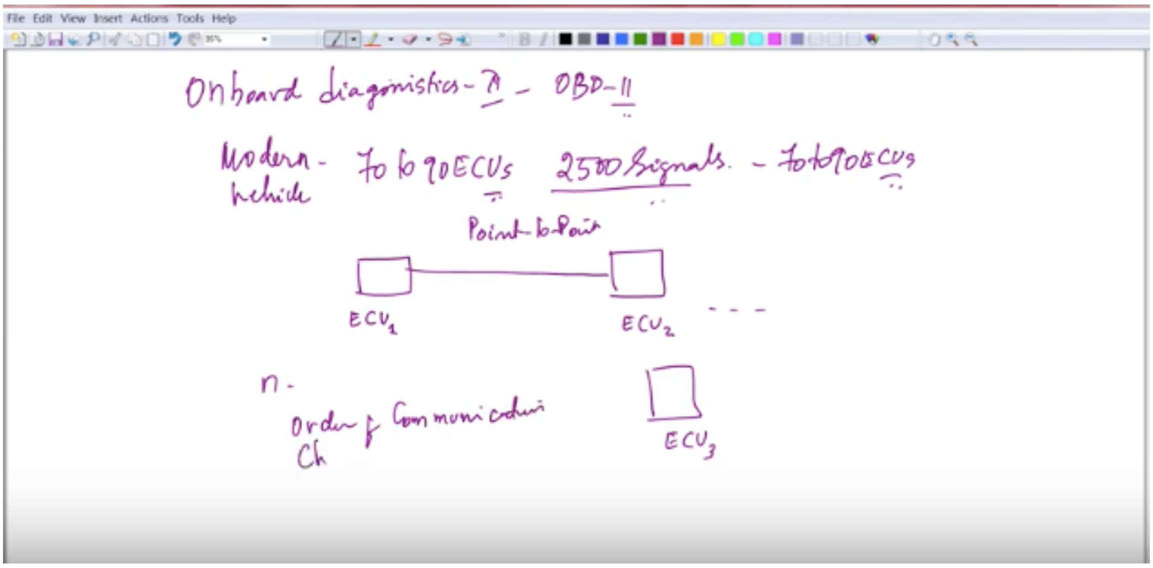


So, from 1996 onwards any vehicle that is manufactured particularly cars. There was a need for putting an on board diagnostics connector, which will give you data from all the ECU's which are there inside the vehicle.

Now, what are those ECU's, how many of these ECU's exist? Well a modern car; can have anywhere between 70 to 90 ECUs and this is a very important thing alright. So, which are carrying up to 2500 signals. You can regard what is a signal? To give you a feel of what a signal is you can imagine that input to ECM is a signal, you are giving a signal by a wire, you are giving another signal like out of ECM to butterfly valve, you are getting an input signal back to the ECM which are all signals.

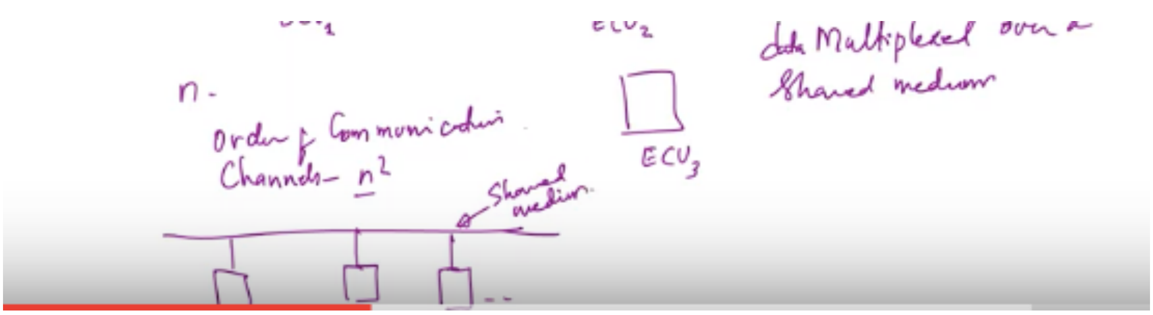
So, you can imagine the number of signals that are there in a modern car. The number of signals can be as high as 2500 signals, which are the exchange between 70 to 90 ECUs so, many signals and all that. So, you can imagine data that is exchange between point to point links, if you want to do between one ECU. ECU 1 and ECU 2.



If you connect directly as shown above the ECU1 and ECU2 is a point to point link. You can have up to n ECU's as I said and each one establishing a point to point link.

You can also have ECU 3 intern establishing a connection to ECU 1 and a point to point link. So, one link is established another will not be there because they are all doing point to point. If, you want to do this if there are n ECU's, the order of communication channels will be the order of n square.

If n starts growing you will not be able to cope with the increasing ECUs, because you will have several issues of weight, cost, then you will have problems of complexity and you will also have problem of mainly reliability. You cannot do it this way, you cannot go on having point to point links and because reliability will get compromised, which essentially means that you will have to look at multiplexed communication over a shared medium, that is data multiplexed, data is multiplexed over a shared medium.



As shown in the figure you have a shared medium; you have ECU 1, you have ECU 2, you have ECU 3 and so on, connected over a shared medium. So, you go away from point to a shared medium, so that is a very important thing. And, once you have a shared medium you will need a protocol and a set of rules, which are to be exchanged, set of messages that are to be exchanged and rules for managing the communication.

All of this will be required, access to the bus, access to the channel, no access to the channel and so on and so forth. All of this means if you move away from the point to point connection to the kind of shared medium, you see the reduction in; you see a reduction in what specifically? the weight, reduction in weight, due to what the wiring harness. There is a mention that BMWs weight reduction, when it moved away from point to this kind of a shared medium protocol based system, it reduce the weight by 15 kgs which is whopping right?

So, all of this means, what is that famous protocol, which will allow you to choose on a shared medium well that leads you to CAN what else can it be, what else CAN it be it is indeed CAN and CAN was introduced by Bosch. And once people started looking at CAN which stands for controller area network. Wiring simplicity came in there was a very good possibility, that all of this is lead into autonomous driving again. Because, you are not isolating ECUs anymore they all talking to each other? They are all on the same shared medium, you are not talking of islands of ECUs, because you could not manage to connect them together, you just made them into islands. And those islands were just able to do amongst themselves which could never have moved towards autonomous driving, could not have.

So, this shared medium allows you that all the ECUs are now on one shared bus kind of and then that bus indeed is the CAN bus. It is moving towards autonomous driving. They allows you to do several things. Before, we move on to further parts of this module it is good to sort of understand OBD II protocol and the variants of them quite well. One of the first things that you will see when you read upon OBD II is SAE J-1850 there is an action called PWM. This gives you a data rate of 41.5 kilo bits per second standardized by ford, then there is another variant called SAE J-1850 VPW. This is Variable Pulse Width or something PWM means Pulse Width Modulation and VPW simply stands for variables pulse width it gives you lower data rate something like 10.4 kilobit per second.

And this is standardized by general motors. These are all giants have generated their own standards. Then is an ISO standard ISO 9141-2 is another standard, and this has asynchronous serial data rate of 10.4 again and it is somewhat similar to I would say very similar to RS232. So, there is this ISO-14230 KWP 2000, I will just write it in bracket. Then there is a very famous ISO standard and that I think you should recall you should keep in mind and that is ISO 15765.

And this is what I just discussed this is the CAN it gives you 250 kilo - bit per second. And it can also give you high speed CAN which can go up to 500 k-bits per second and this is the most popular. So, there are some voltage levels that the CAN specifies, what should pin 6 be, what is pin 14 and what is CAN H signal, what is it is voltage level, what is the minimum and the maximum? all that is specified as part of the ISO 15765. Therefore, it is important to know this and this as I mentioned to you was standardized the CAN protocol itself came out by was designed by Bosch.

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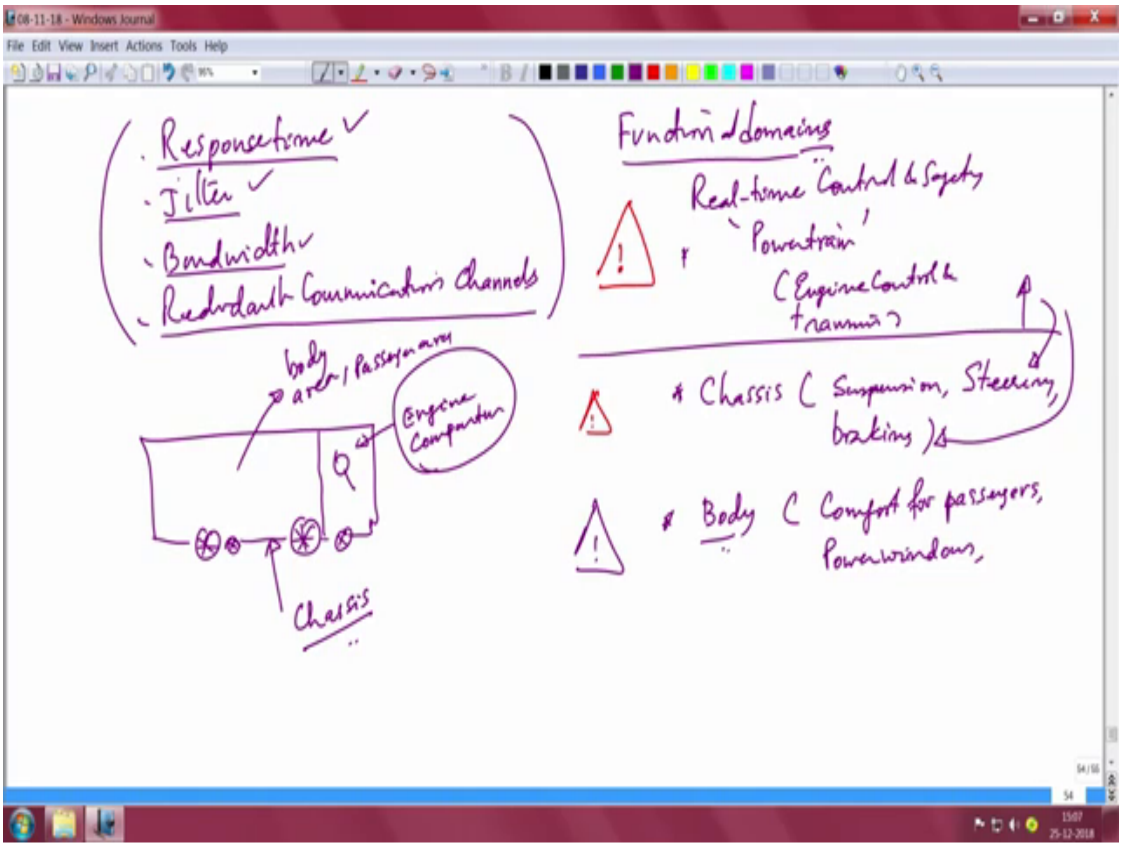
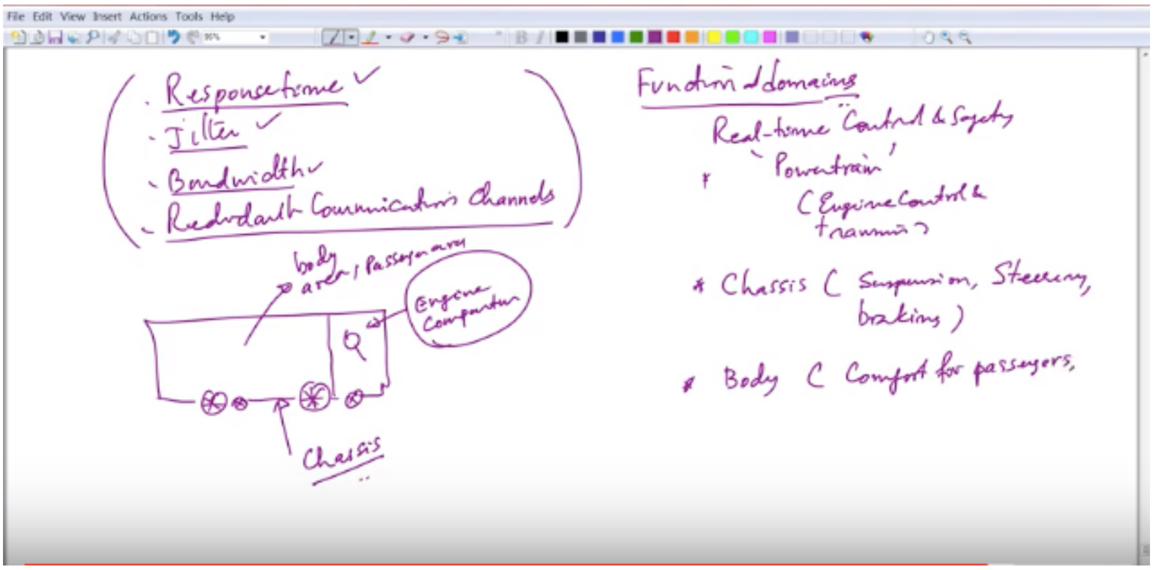


So, now let us see before you understand anything with respect to the different ECUs, you will have to look at the following parameters, or following I would say metrics to understand what should be the ECUs responsibility? specific to a given part in the vehicle. One of the things is response time, the other is jitter, bandwidth and redundant communication channel. See all this is coming now slowly into our domain, because we have now decided to go in with the protocol isn't it?

So, if you come to a protocol, you have to look at what does the protocol that will tell you from any communication networks book that these are important parameters moment you going for a protocol. So, again all this is leading to very interesting things happening in the automotive world, essentially, the CAN protocol has to give you certain responses, should be within certain jitter for different functions of the vehicle. So, what are these functions and how do we divide them? So, typically you will want to divide a vehicle, let me draw a picture of a vehicle, it is my famous picture which I keep drawing.



So, you can divide the system into 3 parts, where there is an engine compartment, then there is the place where people sit and this is I would say cabin area or passenger area, and then there is this chassis area. On which the complete engine is mounted ,also on the chassis, then the seats and other things are also laid out on top of them inside to build a cabin around the chassis.

So, you can see that response time, jitter, bandwidth, redundant communication channels all this that any protocol will have to provide, will largely depend on where and what ECU you are referring to. Are you referring to an ECU of the engine compartment, engine related, cabin related and chassis related?

So, you can divide them into broadly several functional domains. So, I will put down the functional domains. Now, what this functional domains are why do you need them, because you need you have different features for them and you have different constraints. Now, if you look at real time control and safety. You will be talking about the vehicles powertrain, which is nothing but engine control and transmission related real time control and safety right.

Next will be the chassis which I showed you above, next will be the chassis, when you say chassis you are talking about suspensions, you are talking about steering, you are talking about braking. All of this will become another domain.

The third one will be body or cabin body area or passenger area, body which implements comforts, comfort for whom? Comfort for passengers. This all what you currently have can be part of this body for example, music in the vehicle then Bluetooth connectivity from your phone is some people have this wireless Bluetooth devices which is another functionality.

And if you open the door there is a light, when you want to get of you need some light on where you are likely to put your foot. So, there is the door lamp and then there is a ceiling lamp. All these are part of body comfort for passengers, then you have power windows. All of that then lamps, LED lighting, music, entertainment, all of that and then of course, the boot space switch that is you press the switch the boot opens up and so, that you can pull out your luggage and all that.

So, that function and all of that is part of body. So, it is not at all important if something fails here, but these too you cannot afford right. I would still put real time control and safety power train is absolutely critical followed by of course braking, steering and suspension which are equally critical and also important., So why Realtime is in big red? is because it is the one that will perhaps command the chassis part. So, the big red will command the smaller red.

So, if engine; somehow the command should come from real time control part to the chassis part. So, that braking is there or steering is there, so, it should not fail here at all. Most of what we do in the autonomous driving space, different algorithms and all that perhaps will come in real time control, which will then link to all these parts steering breaking and all that. So, indeed everything is centred around the real time control the big one. So, these are the 3 domains you can say and each one of these systems like powertrain chassis or body have different response times from the network jitter requirements, bandwidth and whether you need a redundant communication channel or not will have to be considered in the case of the first two.