CHARGING INFRASTRUCTURE

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Week-11

Lecture-53

Lec 53: DC Charging (CCS2)-IV

Hello everyone, welcome to lecture number 53 of this NPTEL lecture series on charging infrastructure. We will continue our discussion on the DC charging system using the CCS2 charger plug. So far, we have discussed the different charging sequences of the CCS2 charging system, and after that, we have seen the slack procedure which is used to logically connect the PLC modems of the EV and EVSE, which are actually making the physical connection. This is needed because, in cases where we have a charging station with multiple EVSEs and multiple EVs, one must ensure that the PLC modems of the EV and EVSE are connected to those that are physically connected. This means there should not be a case where the PLC modem of the EV is communicating with the PLC modem of another EVSE

rather than communicating with the PLC modem of the connected EVSE. This is ensured by performing the slack procedure, which measures the attenuation between the PLC modems. Those PLC modems with the least attenuation form a logical connection. Obviously, in a charging station where the EVSEs are placed at certain distances, the least attenuation will occur between those PLC modems that are very close to each other. These will be the PLC modems that are physically connected and placed near each other. This is why the slack procedure ensures that the correct PLC modems of the EV and EVSE are connected—those modems where the actual EV and EVSE are making a physical connection.

This is why slack procedures are needed, and they constitute the data link layer of the 7-layer OSI model, which we will explore in this lecture. Now, in this slack procedure, once it is completed and the PLC modems are logically connected, high-level communication can occur

between those modems. During charging between the DC EVSE and the EV, a lot of information needs to be shared between them. This information is shared using high-level communication, which is done using the seven OSI layers. Let us examine this. We have seen that the CCS2 high-level communication happens over PLC communication on the CP and PE lines, which are logically connected—meaning those modems that are logically connected. Once the PLC modems are logically connected, they are ready for high-level communication. In high-level communication, it is used to send or receive different charging parameters such as voltage, current, information like SOC, temperature, state of health, charging time, and other details shared when the DC EVSE is connected to the EV.

I mean, whenever CCS2 charging is taking place. Now, these messages Whatever is there between the EV and EVSE is exchanged using the seven OSI layers, which is the Open Systems Interconnection model or layer model, used to perform data transfer between two computers connected via a network. So, whenever two computers are connected to each other, they communicate following the seven OSI layer model. And each message shared between the EV and EVSE follows the OSI layers, which are nothing but a set of protocols. They follow the OSI layer model, starting with the physical connection and proceeding step by step up to the application or control application.

So, each message sent between the EV and EVSE follows this seven OSI layer model. So, let us first understand what the seven OSI layers are, because once we know them, it will be easier to understand how high-level communication takes place in the CCS2 charging system. Now, the seven OSI layers consist of seven layers, and each layer comprises some package of protocols needed to perform specific operations. So, these seven OSI layer models have seven layers, and each layer consists of certain protocol packages needed to perform specific operations to ensure successful communication between computers with different architectures or connected across different networks.

So, if you look at the seven OSI layers, which were standardized by ISO in 1984, they comprise seven layers, starting with the application layer. Again, here we are talking about the system that is actually transmitting the information. So, from the application layer, we have the second layer, which is the presentation layer. After the presentation layer, we have the session layer. After the session layer, we have the transport layer.

after the transport layer we have the network layer after the network layer we have the data link layer and after the data link layer we have the physical layer now as we have told that each layer is basically consists of several sets of protocols And those protocols is basically are being used to actually perform the specific functionality whenever the two computer systems are actually doing the communication. So whenever the two computer system does the communication, a lot of work needs to be done. and those work is being done following certain protocols in order to ensure the interpretability there those works are done following certain protocols and those protocols are packed together in different layers and those layers are mentioned over here so let us first understand in the simplest term whenever the two computers are getting connected how the data transfer has been taken place they could be having the different architecture that means different os or operating system, they could be connected in different networks, in different countries, in different regions.

So, how those things are being taken, let us discuss in brief because that will make us understand what are the protocols in each layer does and how they actually help in ensuring the successful communication between the two computers which are being connected together or which are being doing the data transfer with each other. So in 7 OSI layer, the first layer is nothing but our application layer. Now as the name suggests, the application layer will have some of the protocols which actually been used by the network applications. Network applications are those applications in the computer which actually uses internet to do the communications just like your web browser. I am taking a simplest example just like your web browser.

so the web browser uses certain sets of protocols to actually perform the user activity for example if you are searching certain website using required web address when you are doing the web surfing so network application will be using the protocols like http or https protocol so whenever one is doing web surfing you will do you know using http or https protocol Similarly, there could be the file transfer between the two systems which will be taken place and that file transfer need to be done using you know file FTP protocol which is file transfer protocol. So, this application layer consists of the protocols which will be used by the network applications to actually perform you know required user activity. So, consists of protocols. which is being used by the network application now what are those network application the computer application

which uses internet or other communications used by the network application to perform required user activity

So, for example, if the user is doing the web surfing, it's the HTTP and HTTPS protocol which is being followed. If the user is doing the file transfer between the two systems, then it's the FTP protocol which is being used. So, different network applications like web browser, your email applications. So, that is the actual purpose of the application. So, it's the user who will be interacting with the network application and network application will be

following certain protocol in order to understand what the user is doing. Now after the application layer comes the presentation layer So let's say once the user is doing web surfing or they have entered some of their data, those data will be in the form of your characters and numbers and those characters and numbers need to be converted into the form which is been understand by the computer or by the system which is actually be using those data. So presentation layer does basically three functionality which is translation, converts the user understanding language to the machine understanding language after the translation they will do the data compression where you know they compress the data in such a manner that because a lot of data need to be exchanged between the two systems so the data compression will help in doing the fast transmission of the data so data compression will be taking place removing the redundant informations

and then after the data compression it will be if the sender is doing it is the encryption just to ensure that the data is being presented to other layer or to other sets of protocol which is in a required manner so it will be encryption or on the receiver side it will be decryption which will be taking place now however to do perform this functionality there will be several protocols which will be used and those protocols will actually form the presentation layer as the name suggests it converts application layer data into the machine understandable form or presented the data in the machine understandable format and on the receiver side it is the vice versa that means it will represent the data in such a way that the user will be able to understand that data so it performs the three functionalities which is translation and data compression and encryption decryption that means presenting or representing the data into certain format which will be understandable by the machine in the transmitter side and on the receiver side it will be understandable by the user so that is the actually work of presentation after the presentation

layer you have the session layer now the session layer actually used to set up the session between the two systems so whenever the two computers are actually communicating with each other you have to first start the session between them then only one can do the data transfer so it is like the protocols in this layer will help to set up the session between the two systems over different networks and that's when the communication will be taken place so it basically does three particular functionality first is authentication that means for example if let's say if user is accessing his gmail so once it will enter the password try to reach the particular server has to authenticate that this is the correct user and that is coming under the authentication and once the authentication is been done it's the server which will decide to what level we should give the authorization so this is also been done been done using the protocol defined in the session layer itself

and then after the authorization it manages the session management so session management like it it keeps track of the files which is being transferred between server and the and the computer or the between the two computer system so it will also does that session management as well uh generally these three layers are you can say are done by the network application and then comes your next layer which is nothing but called as a transport layer So the user has entered the information using the application layer. Then it will represent in a certain form in the machine understandable format. Then the session is being created between the two systems where the communication has to be taking place. And then finally we enter into the transport layer where which does actually segmentation.

That means the data which are there is being divided into several segments. And then it will also take care of the flow control. and then the error control so in this thing what happens is that in the segmentation layer the data which is been there will be actually be broken into several segments so let's say this is segment 1 example segment 2 and segment 3 now in this segment what you have is along with the data you also have the sequence number and the port number so sequence number and the port number sequence number and the port number now the sequence number is been used in the receiver side it is been used to reassemble the segments to obtain the required data.

So that's why the sequence number are being added to each segments and the port number indicates to which network application it should be routed to. So that has the port number

information. Then after that, you know, once the segmentation has been done, this layer is also responsible for ensuring that when the two systems are actually getting connected and they're doing the communication with each other, they must do the communication at the same rate. For example, let's say this is a sender. and this is a receiver for example let's say sender could be your computer and receiver could be the server which is visiting at some network at a very far place so whenever the sender is sending the messages to receiver let's say sender could able to send with one mbps of data however the receiver can able to accept 10 mbps of data so now obviously there is a mismatch between the communication

between data rates so that's when the message will be sent to receiver to change your 10 mbps receiving rate to 1 mbps receiving rate and that's when the flow control is been ensured so that's when the loss of data can be avoided Similarly, the other way around could also be done. Let us say if the sender is sending with 10 Mbps. However, the receiver could able to receive only 1 Mbps. Then the sender will be asked to actually reduce its sending rate to 1 Mbps such that the data rate is being insured.

and then finally at last we have error control which actually includes mechanism for error checking and retransmission of lost data so thus the transport layer contains protocols which provides fast reliable error check data transmission again we are not going too much in detail so we are just keeping briefly to understand how this layers works so this layer is having this particular protocol which will doing this three functionality all together After this layer comes the next layer which is nothing but our network layer. In the network layer it particularly does the logical addressing, routing and path determining. In case of logical addressing which will be done in this layer I mean following a certain protocol like IPv6 or IPv4 depending upon which protocol is been followed. So here it will be done IP addressing then masking which is been done like to ensure to which network it should be connected to.

so that's what the masking is been done so in this case along with this one also has to ensure the routing so the masking and ip addressing will actually ensure that to which network the data to is to be routed to and then after routing is been done it's the part determination because let's say if you wanted to do communication with some server which is sitting in some different region so the message has to be sent by different networks maybe Let's say you are sending a message from your home Wi-Fi, it will go to the router, from the router it goes into the other network,

maybe to different countries, maybe to different region to reach to that particular server. Now, during that thing, there could be many paths which it could follow. So, this particular network level determines shortest path to be taken, again following certain protocols. Now, in this case, the most important thing is the IP addressing, logical addressing which has been done.

So, in this case, since the data which has been there, which has been segmented in the transport layer will then be sent, these segments will then be sent, let us say this is a data segment, will then be sent to the network layer and in the network layer, the the IP addresses will be appended with you know IP address of sender and IP address of receiver so IP address of sender and IP address of receiver now this IP address is important because this IP address will now determine to which network it should connect to and it will also determine in the network to which computer you should connect to because in the particular network there could be several computers which are being connected for example let's say in your assume you are staying in some big colony and in colony you have hundreds of homes in each home has one computer so the ip address will determine that you have to connect to that colony network and in that network it will determine to which computer should be connected to. The segment which you have obtained from the transport layer will then be augmented with the IP addresses of the sender and receiver and that will form the IP packet.

So, from the data it is been converted into segments, from the segments it is been converted into IP packets And then this IP packet will comprises of the segment which is again some portion or some small part of the data with the IP address of the sender and IP address of the receiver. And then this particular thing will be actually routed and that routing is being understood by once the masking is been defined where the masking defines to which network it should connect to which will be defined by this routing. So, after the network layer Once you obtain the IP packets, it will be then sent to the data link layer.

Now we have done the logical addressing because logical addressing will define to which network it should connect to, how it should be routed to and different masking has been defined. Now after this thing, they will also define the physical addressing. So there are two type of addressing. One is logical addressing. Another one is the physical addressing.

and this physical addressing is been done by the data link layer and it also controls how the data is been placed and or taken from the from the physical medium what I mean by that is the first and foremost thing is physical addressing now you take any system which has to be connected to the network so that particular system will have the network interface card and that particular network interface card has the physical addressing called as the mac addressing called as the mac which is media access control address now this address is the unique address which will be given to each network interface card which is been placed in your device which will be connected to the your network for example your mobile has one mac address your computer which is being connected to network has one mac address which has been there in the network interface card and this mac address is basically the physical address it is very unique number and once the network interface card is being incorporated in your system that mac address card will now be the mac address of the system in which it is being incorporated now this mac address is nothing but it's a It is a 12 digit alphanumeric number

and it is been embedded in your network interface card let's say if you are having our EVSE which will also have the network interface card that network interface card will have the MAC address and that is a physical address it will not going to get changed in the entire lifetime or until that network interface card is there in that EVSE the IP address can change because the EVSE may be connected to different networks maybe EV can be going to different charging stations and will be connected to different networks so the IP address may change but the MAC addresses will remain be the same for EV and similarly for EVSE it will be fixed MAC address it is not gonna change and every EV and EVSE will have its own unique MAC addresses so in this particular layer the IP packet which will receive which has the IP addresses of sender and the receiver. After this IP packet, you will generate actually frames. So, in the frames, you have IP address and that will be appended with MAC address 1, MAC address 2, which is MAC address of sender and MAC address of

receiver or mac address of sender or you can say that mac address of sender or source and mac address receiver or destination similarly here also sender or source receiving receiver or destination so that mac address will be there and this will actually along with this frame There will be some thing will be added at the tail part of this frame, which actually nothing but the things related to error control. And this particular setup, this entire particular setup is called as

the frames. So from the data it goes to segment in transport layer from the segment goes to IP packet in the network layer from the IP packet it goes to the frames in the data link layer which has the MAC addresses of the source and the destination is been appended along with some error control codes which will be added at the tail side. So this is the main functionality of data linker which will defining the physical addressing to this IP packet.

along with this this data link layer will also control how the data is been placed or taken from the physical media so physical medium if you talk about here media access if i am talking about media access this media i am talking about is the physical media which is actually is the physical media which is nothing but optical fiber is one or one physical media the copper wire is one another physical media Air is another physical media where the Wi-Fi communication will be taken place so these are the different physical media and this data has to be placed in the physical media to actually being transported to the destination through that physical media so how this will be added because let's say more than one computer is been accessing the same media so one has to ensure that particular data is not getting corrupted one after the other they will be accessing that particular media so that will also be ensured by the protocol mentioned in the data link layer However, in EV and EVSC, since there are only two nodes whenever the EV and EVSC are connected, so the main important functionality of this layer will be defining this physical addressing and ensuring that the two PLC modems are properly connected. Or you can say at this point only, we have the physical logical connection which is being set up.

Then after that comes the last layer which is called as the physical layer. Now as the name suggests, it contains all the protocols which will be used to define how the data has been pushed into the physical media. what will be the voltage levels what will be the frequency different parameters of the physical media will be defined in this you know which are being packaged in this particular layer so in this physical layer so from the data we converted into segments from the segmented after augmentation of the IP addresses of source and destination we get the IP packet from the IP packet we will add the MAC addresses of the sender and receiver that will actually form the frames and after the frames it will be converted into bits of information which will be in the terms of 0 1 1 in some fraction it will be there so that will be the bits of information which will be logic level 0 1 0 1 0 1 the frames will be in the form of bits that bits will be converted into signals that logic levels will be converted into signals and then will be sent to the

physical media so here in this case we have several signals for example in case of air we have radio signals so this layer will define what will be the frequency range the strength of signals signal to noise ratio different things will be defined in case of this is the wi-fi communication we are talking about in case of physical copper wire

copper wire or you can say LAN in case of that we have the electrical signals that means in the form of voltage and the current in terms of that in case of optical fiber it will be the light which will be light signal which will be present so over the physical media the signals will be sent and that signals will be representation of the bits which is obtained from the frames And that signals will be sent over the physical media. So, this physical layer will consist of the protocol which will define that particular information related to that physical layer. So, this is the case in the sender side. On the receiver side, if we take the receiver side, this is the sender side.

on the receiver side the same thing will happen in the reverse manner signals is being sent on the other side the signals is being received it will be then converted into bits of information from the bit of information it will be converted into frames using the data link layer protocol from the frames it will be converted into the packets ip packets using the network layer protocols from the packet it will be converted into segments the segments will be extracted using the transport layer protocol and then the segments will be reassembled together using the transport layer protocol and it will be converted into the real data in the machine understandable format and then it will be converted into the user understandable data in label data in the presentation layer and then it will be presented in front of the receiver. So, the same thing is doing in the reverse manner on the receiver side that means it goes from the physical layer to the data link layer to the network layer to the transport layer Then from the transport layer, you have the session layer and then session layer will be converted into the understandable data, you know, user understandable data format using the presentation layer and then it will be shown to the user using the application layer protocols.

This is how the actual communication will be taking place between the two systems connected over different networks. if we take one example assume we have you know let's say computer 1 which is been connected via wire to the network 1 and through the network 1 it will be connected to let's say network 2 using the satellite link it will be connected here through the wire and from the network 2 it will be connected to assume using the Wi-Fi link it will be connected

to the computer too so here what we have is we have our frame in the frame we have ip packet and in the ip packet we have the mac addresses at the header and tail which will be some error correction code it will be sent through the let's say this is the router to the router both routers are there in this router the IP packet will be extracted and again the new H1 and T1 will be I mean S2 and tail has been added now in this H1 is nothing but MAC of C1 because that is the sender and destination is MAC of N1 and here it will be MAC of you know MAC of N1 and receiver will be MAC of N2

however the IP will not gonna change on this router at network 2 we will again extract the IP packet from the IP packet your H3 and then unit T3 will be added where H3 comprises of MAC of sender which is N2 and here it is MAC of C2 and in this place again it will be extracted IP will be extracted And once the IP will be extracted from this one, the segment will be extracted and from this one, different segmenters will be added to actually form the data and which is being shown to the user. So this is how the MAC addresses and the logical addressing is being used to send the different data between the two computers connected at different networks over the different channels. now in case of ccs2 if we see let us define our ccs2 this thing where we have physical layer we have data link layer we have network layer again this is layer one we can say layer 2 layer 3 from the network layer we have our transport layer same as our this thing layer 4 transport to session which is layer 5 session to presentation and presentation to application

Now, this is layer 6 and layer 7 since we told you that it consists of several protocols. All these things will be defined in ISO 15118-1 and ISO 15118-2 standards. All these things will be technical descriptions of the protocols, different requirements of different layers, general information, and all those things will be incorporated in ISO 15118. However, some cases are there which are up to this one. So, this is defined in ISO 15118-1, which consists of general information and different general requirements, and then the physical and data link layer if we take the physical and data link layer.

For the physical and data link layer, what we have is we have defined the information in the 15118-3 standard, where this protocol has been defined for layer 1 and layer 2. From this layer to the top layer, we have defined in ISO 15118-2, where it carries all the information. Technical information of those layers; however, individual layers are actually derived, which is included in

ISO 15118. It is derived from different protocols. For example, the network layer protocol will be defined by Internet Protocol (IP) or ICMP, which is nothing but Internet Control Message Protocol. And then, you know, if we talk about the transport layer, the transport layer will be following the standard like UDP, User Datagram Protocol. Again, I am not going into those protocols.

And it will also have the TCP protocol, which is nothing but Transmission Control Protocol. Different protocols will be defined, which will be derived from these protocols and be included in ISO 15118-2. Then, the session layer will actually be having, you know, vehicle-to-grid session layer protocol, and the presentation layer will consist of, you know, XML or EXI. Based protocol where the data is being represented using the Extended Markup Language or the Efficient Extensible Markup Language. So, we can say XML, which is Extensible Markup Language, and EXI is Efficient XML Interchange. This is the way by which the data has been represented in this presentation layer following this protocol. And then, finally, the application layer, which has the protocol like V2G application layer, then you have SDP protocol, where SDP is nothing but SECC Supply Equipment Communication Controller Discovery Protocol.

So, those protocols will be defined in the different OSI layer models of the CCS2. I mean they are included in the ISO 15118-2, but they are derived from these particular protocols. So, let us see one by one how the high-level communication in the case of CCS2 takes place using these seven OSI layers. Now, let us see the first layer, which is the physical layer. So, in the physical layer, the initial condition—that means the condition before the protocol corresponding to this layer is implemented—is that the protective earth and control pilot lines are connected, meaning the charger plug is plugged in, the PWM of 3 to 7 percent is initiated onto the control pilot and the protective earth, meaning the charging stage is in the B2 state.

Initiated onto the control pilot and the protective earth, meaning the charging stage is in the B2 state. And on both sides—that means on the EV and EVSE—we have HomePlug Green PHY-compatible-based modems, and the protocol corresponding to this physical layer actually performs the function of stabilizing the physical link on the protective earth and control pilot lines to the opposite side. Opposite side means, for the EV, it will be the EVSE, and for the EVSE, it will be the EV. So, the protocol corresponding to this particular layer ensures the physical link. To be made between the EV and EVSE, and the result of this is that the PLC modem on either

side—that means on the EV and the EVSE side—is ready for communication with a stabilized frequency band of 2 MHz to 28 MHz. Now, this particular layer ensures the start of the physical connection to provide the data transfer between the EV and EVSE. Now, in this case, the data transfer is bidirectional, meaning the data can be initiated from the EV to the EVSE or from the EVSE to the EV.

And the protocols which are there actually define the physical properties of the physical media. That means the wires which are connected between the control pilot and the protective earth on either side. And those properties are such as the voltage levels and the frequency band. Now comes layer 2, which is the data link layer. Before coming to the data link layer, the precondition—or you can say the initial condition—is nothing but that the physical layer is properly stabilized, meaning the physical layer protocol is successfully implemented. Then, in this particular layer, the configuration of PLC nodes will take place. So, PLC nodes means you know you have the EV and EVSE nodes, which will take place. One of the important things which takes place in this particular layer is that the signal level attenuation characterization procedure is done, and after the signal level attenuation characterization procedure, the logical connection is set up between the two PLC modems. Logical connection means the PLC modems can now communicate with each other, so the outcome of this will be the stabilization of the communication link.

That means the logical connection of the PLC modems has been done following the protocols which are included in the data link layer. So, this layer ensures an error-free transfer of data frames from one node to another node over the physical media, and this particular layer is responsible for performing the slack procedure. All the information related to the slack procedure is defined in the protocol which is included in the data link layer. Then comes the network layer. Before coming to the network layer, the initial condition will be that the data link layer protocols have been successfully implemented. The protocol in this particular layer will actually be responsible for implementing Internet Protocol version 6 to assign the IP addressing, or you can say the protocol present in this particular layer is responsible for doing the logical addressing, or you can say IP addressing. And it ensures unique addresses among the nodes which are communicating with each other.

That means unique addresses to the PLC modem of EV, PLC modem of EVSE, the supply equipment, communication controller—all those things can be defined with unique IP addresses. And in this particular case, the IP addressing of the nodes is done using the SLAAC procedure, or you can say SLAC procedure. At the same time, the protocol in this particular layer actually implements ICMPv6 to send the error messages, which is nothing but the Internet Control Message Protocol. That means when the error messages are sent, they are sent using the Internet Control Message Protocol version 6, and when the normal messages are sent, they are sent using the IPv6 Internet Protocol standard. The outcome of this will be that all the nodes responsible for communication obtain valid IP addresses. Now, this is the important thing because that will define the logical addressing of the different nodes—that means the IP addressing of the different nodes. Here, the nodes mean all the controllers which are doing communication in the EV as well as in the EVAC. So all those nodes which are there—you also have the supply equipment communication controller, you also have the EV communication controller—so all those things should also retrieve or achieve the valid IP addresses. And then, finally, what this particular layer does is it actually controls the routing of connections.

It decides the path for the data which it should take—that means it actually defines the logical addressing, and once the logical addressing has been defined, it will also define what the path determination of the data should be to reach from the source to the destination. So that is what the protocols in this particular layer do. We have seen the three OSI layers, and we have understood different OSI layers. Then we are just seeing what these three OSI layers do particularly in the case of high-level communication of the CCS2—how these layers actually perform the particular tasks that we have defined over here. And we will continue our further discussion on different layers. In the next lecture, thank you very much for your patience in listening to this lecture, and we will see you in the next lecture following our further discussions.