Optical Wireless Communications for Beyond 5G Networks and IoT
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Lecture - 17
Part - 2
Power allocation in VLC based MIMO NOMA

Yeah so, now let us understand the DC channel gain in the optical wireless.

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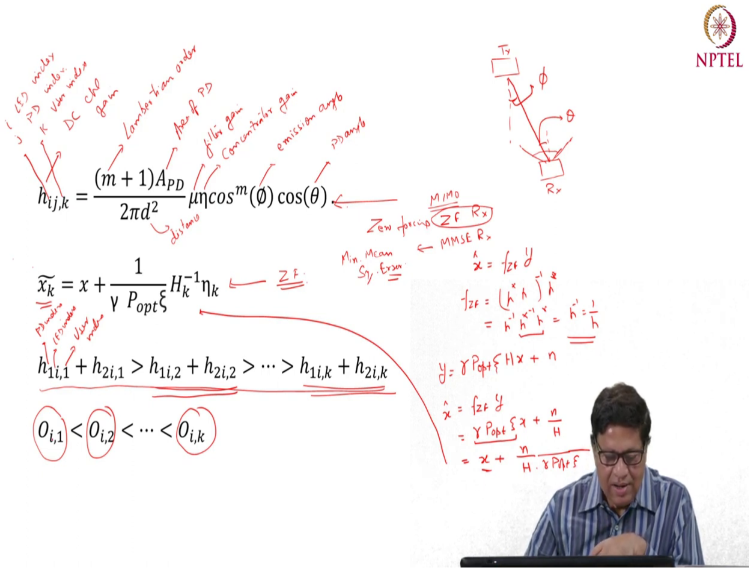

DC channel gain which is defined as h i j k where i is the LED index in our case there are two LEDs. So, i will have value 1 and 2, j is the PD index photo diode index again there are two photo diodes with each receiver. So, it will have value 1 and 2 and k is the user index.

So, h i j k is a DC channel gain between LED i and photo diode j for the user k and say 2 cross 2 matrix for each user and this is given by earlier classes we have read we have discussed this where m is the Lambertian order, it basically defines the radiation pattern of the LED Lambertian order. And this is the area of the photo diode and d is the distance between the ith LED and the jth receiver.

So, this is the distance and this mu is filter gain you might be using some filter either transmitter and this is the concentrator gain which is used rather receiver and phi is the emission angle and theta is the angle which the PD makes with the normal. So, this is P photo diode angle or let me illustrate this. So, this is your transmitter, this is say for your receiver and this is the LOS path.

So, this angle which the transmitter makes the LOS path makes with the normal is phi and the angle with the normal mix with the LOS path is theta and this is the FoV of the angle this whole thing is the FoV of the angle FOV of the device of the photo diode. So, h i g k h i j k that is a DC channel gain is written by this expression.

Now, remember when we were discussing about MIMO, we discussed about two types of receiver one was zero forcing receiver and the other was MMSE. So, this is zero forcing and this is a minimum mean square error. So, in this analysis we will use zero forcing because of simplicity. So, in zero forcing receiver if you recall the Y the estimated x which I am calling is x hat is given by zero forcing function into y y is the receiver and if you recall f z f was defined as pseudo inverse. So, it was defined as this.

So, this is h minus 1 minus this inverse will come here. Defined as this. So, this becomes h inverse h conjugate minus 1 into s conjugate which then this is 1. So, basically it gives you h inverse or is equal to 1 by h. So, this is the function which I have to used on y so, that you can get estimated output.

So, this is possible because we are using 2 cross 2 MIMO and the inverse exist because there are two LEDs and two photo diodes. So, f z f is defined as 1 by h. So, if I write my received power is y this is responsibility into received power P opt into modulation index into say channel matrix into x plus n.

Now, I know h h x into n and anticipated the estimated value is fzf zero forcing on in y. So, this will give me I will put the value of y here. So, this sorry put the value of y and also fz is equal to 1 by h. So, this gives me responsibility into P opt into xi x plus n. So, this will be n by H. So, just to normalize it I can divide by this is something constant I can divide this by this factor.

So, what I get is x plus n over H this will be this will come at the bottom into gamma P opt index. So, this is what I have written here. So, this anticipated for the kth user our estimated for the kth user is x plus 1 by gamma P opt xi gamma P opt xi into H inverse into n k this is the noise. So, this is n k.

So, this is the zero forcing receiver I have used here please refer to earlier classes for better understanding of zero forcing receiver. So, what I need to do now I need to find out the order of how I am going to define the order for successive interference cancellation. So, in this case there are two channel DC channel gains which are involved. So, I will be using the sum and the sum which is the maximum I will place them in this order.

So, basically this will give this will give this is for example, this is a user index. This is the LED index and this is the photo diode index, PD index. So, basically, I will see the DC channel gain on the user 1 coming from the LED i to both the receivers. Similarly, this is for the user 2, this is for the user k. So, I will find out an order and so, this is a decreasing order which I have fixed.

So, this becomes my order of successive interference calculation, alright. So, basically where I have the more channel gain that will be decoded first so on and so forth.

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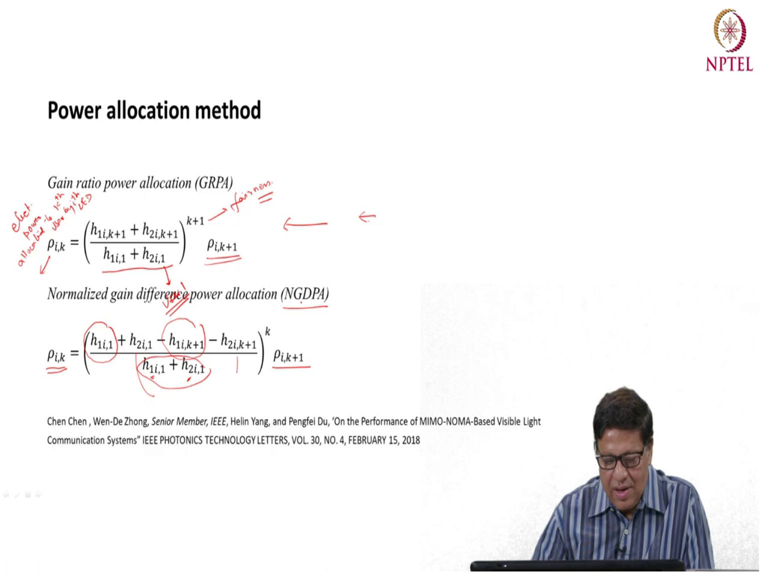

So, this is the order and how do I allocate the power to the LEDs? Because in NOMA allocation of the power is important. So, there are two methods which are used for allocating power. One is called as Gain Ratio Power Allocation or GRPA where so, this is the electrical power allocated to the kth user from the ith LED. This we had defined earlier.

So, electrical power allocated to kth user by ith LED or from ith LED. And this is to the k plus 1th user to the i and the ratio is actually this is with respect to the first user. So, you will find h 1 i 1 plus h 2 i 1. So, this is for the user 1. So, this is with respect to user 1 and here you have h 1 i for the kth k plus 1th user and similarly h 2 i for the k plus 1th user.

So, you take the ratio with respect to the user 1. So, that ratio and raised to the power k plus 1 in order to ensure fairness, this is to ensure fairness. So, if you allocate in this way power allocation to different users from the different LEDs which I am calling as GRPA. So, this is method say 1. The other method could be I take the difference of power allocation and normalize it.

So, this is as earlier electrical power allocated to the kth user by the ith LED. This is to the k plus 1th user by the ith LED and here I have taken the difference. So, you see this h 1 i 1 and subtracted with this and similarly this and this they are subtracted and this is with respect to the first user. Some of the DC channel gain of coming from the ith LED to different photo detectors, to different photo detectors as 1 and 2 and raise to power k.

So, this this could be one is based on some addition, the other is based on you know gain difference. So, using these two methods that is GRPA and NGDPA there can be other possibilities of power allocation. But if I take this kind of power allocation then then what I get is this kind of curve.

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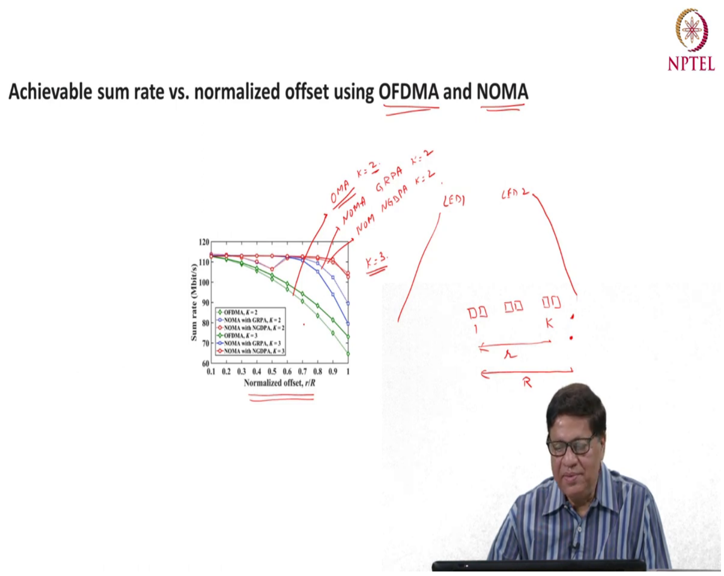

So, let us try to understand this. So, this is a achievable sum rate versus normalized offset using OFDMA and NOMA. So, this is r by R. So, when this value is 1; that means, that user is at the last location. You know remember we had this this as the system model LED 2 1 and we had user 1 here. This is a user 2, this is user K. So, with respect to this, this distance was r, small r and this has footprint say up to this point or say this point and so, this distance maximum distance will be capital R.

So, when r divide by R is equal to 1; that means, the user is at the extreme end. So, this is what it shows. So, basically it tells you the sum rate at different points in the room. So, if I use, if I have only two users for example, and so, OFDM, this is normal OFDM, this is not NOMA. So, this is shown by this.

So, this is the OMAth OMA for k is equal to 2. So, this is what you get the sum rate and if you use two types of power allocation method that is G R P A and normalized G T P A, one is the addition of the channel gains or there is a difference of channel gains for k is equal to 2. So, these are the respective curves you will get.

So, with NOMA is this, this is NOMA using algorithm G R P A, this is again k is equal to 2 and the third one is this dash line, this is NOMA, you are using the difference algorithm, normalize gain difference algorithm NGDPA and this is k is equal to 2. So, this performs slightly better than the GRP algorithm and definitely better than the normally OMA is equal to k is equal to 2.

So, same trend is there for k is equal to 3, when the users are 3. So, you have the same pattern. So, what we see here in NOMA using NGDPA its a power allocation strategy, we get the maximum sum rate possible inside the room. So, this we have analyzed MIMO NOMA system using VLC and this is you know much better as compared to OMA. So, which will meet some of the requirements of 5G and internet of things.

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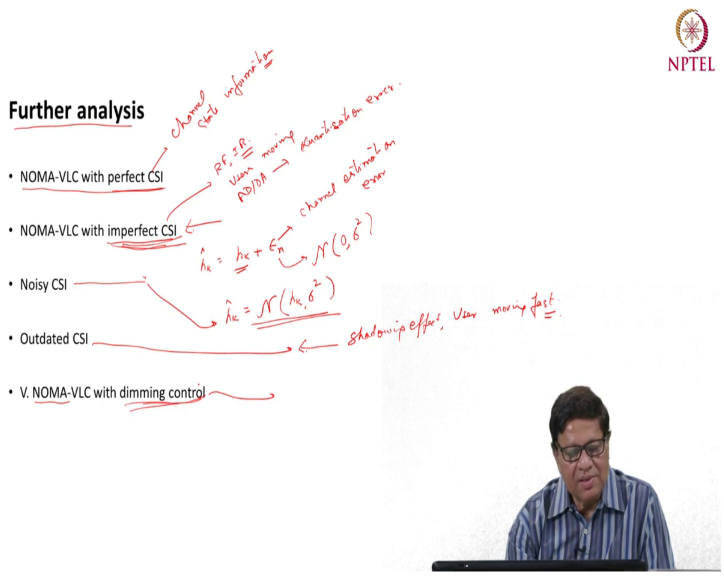

There are further analysis which one can do because if you see the NOMA-VLC assumes you know one analysis which you can do is using perfect channel state information, this is channel state because you require channel state for successive because you have to find out the order. So, you have to correctly measure the channel state information or DC channel gain, channel state information.

So, one can do analysis with perfect CSI, but in practically it is never a the estimation of the channel is never perfect, there are imperfections, there are errors. So, one should do analysis with you know imperfect CSI and this could be because you are for channel estimation you are sending some pilot signals and that can be in the form of RF or IR.

So, this may introduce some sort of impairment or the users may be moving, users moving, the channel CSI will change or DC channel will change and when you are finding out the channel you are doing some analog to digital or digital to analog conversion. So, there will be some sort of quantization error. So, these are the things which will make your channel estimation not very accurate.

So, while doing the analysis one should consider these effects which is what I mean by NOMA VLC within perfect CSI. Another issue could be you know the CSI could be noisy, the estimated DC channel gain for kth user for example, will be some h k which is the actual value plus some channel estimation error.

This is a channel because there may be some noise present and this will result into some estimated value which is different from the actual value. So, this is channel estimation error and so, this has a normal distribution with 0 mean and some variance. So, when I estimate h k so, this will be something like this the distribution will be h k into some variance.

So, this becomes under noisy conditions the estimated value will be something like this. So, this also one should take into account while doing the you know defining the ordering or calculating the channel gain. There can be a issue with outdated CSI. Suppose the user is moving very fast and whatever information you have got for the channel it is no longer valid because the user has moved from to a different location or there is some sort of shadowing effect has happened.

So, sometimes you will get a CSI or channel state information which is outdated which is not current. So, this should also be taken into account and this basically comes from the fact that shadowing effect or user moving fast. The other issue would be VNOMA VLC with dimming control.

So, variable NOMA VLC with dimming control. Now, as we have seen earlier when you are using optical wireless communication or visible light communication inside the room you should be able to see the performance or you should be able to maintain the performance under dimming condition also. So, the system should work in dimming condition also.

So, when you know you dim the light basically you are reducing the power. So, one has to while doing NOMA specifically when you are doing power domain NOMA this becomes very important the dimming becomes very important. So, this is another area where you know still lot of work is to be done where you are able to use NOMA under dimming conditions.

So, this is another challenging area. So, these are the some of the few challenging area which are still being worked on and so, to get the correct estimation one has to consider all these environments. So, we will stop the discussion of NOMA and VLC now and we will now take some other applications of optical wireless communication system and the next application which we intend to take is coexistence of Li-Fi and Wi-Fi and then we will also have one application which is vehicular to vehicular communication.

So, these are the two things which we will cover as part of the application and these things are also covered as a simulation exercise towards the end of the course wherein there are about there are five simulation exercises basically dealing with indoor communication dealing with different modulation for example, OFDM and all and Li-Fi, Wi-Fi coexistence application.

And underwater simulation or simulation exercise and also typical vehicular to vehicular you know communication using visible light. So, these are the few simulation exercises which will take up offer we have discussed the theory part of it.

Thank you.