VLSI Physical Design with Timing Analysis

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Lecture 45

Channel Routing Algorithms – II

Welcome to the course on VLSI Physical Design with Timing Analysis. In this lecture, we will discuss about channel and switch box routing. The content of this lecture includes channel routing algorithm such as dogleg routing. So, we discussed about one of the popular channel routing algorithm like left edge algorithm in the last lecture. In this lecture, we will discuss about another channel routing algorithm that is popularly known as dogleg routing algorithm. So, what is the most important feature of the dogleg routing algorithm is that it can route with less number of routing tracks when it is useful.

So, here it is useful when you have cycles in a vertical constraint graph. So, if you have basically cycles in the vertical constraint graph, the left edge algorithm is not useful. In that case, we introduce a concept called L-shape routing. We introduce a concept called L-shape routing or a dogleg routing.

So, here this algorithm basically improves the left edge algorithm by introducing a concept called net splitting. We will discuss about this net splitting in a minute in this lecture. So, what are the main advantages of this algorithm is that it elevates the conflicts. Basically, it removes the conflicts in the vertical constraint graph. So, whenever you have cycles in the vertical constraint graph, then that problem can be solved using this dogleg routing algorithm. And the second advantage is that it can route the nets with less number of routing tracks. So, let us take this small example here. So, you have A net here and B net here, then you have B net here and A net here. So, if I construct the vertical constraint graph for this one, it will look like this. So, you have A in the top, B in the bottom, then you have B in the top and A in the bottom.

So, it creates a cycle. So, these are the nodes and these are the edges. So, whenever there is a cycle, it is not possible to do the routing using left edge algorithm. So, what it was done here is that we basically split the nets into two nets. So, it is not like two different actual nets, it is a two piece of metals. Two piece of metal is used. So, if you can see here earlier, we can connect this B with this B. For example, we can connect this B with this B by this method. Let us say I will use this kind of routing. But the problem is that it will overlap with the net A.

So, this is not a correct routing. So, what we do, we cannot do this kind of routing because it will create a conflict with the net A. So, what we did here is that we divided the nets into two different parts. So, we divided the net into two different parts. This is one part, this is one part and this is another part.

So, what we have done is that and this is one more part. So, what we did here is that we split the nets. Then we use basically less number of tracks to route this one. So, now let us take an example how it is useful. So, here this cycle is created. This cycle is created and if I do the routing without the dogleg concept, so there are two things in this slide. One is called the, I will erase this one first. So, there are two concepts here. One is what it removes the conflicts. This is the first advantage.

We will discuss how it removes the conflicts and second one is how it is reducing the number of tracks. So, the first one is removing the conflict. So, it can remove the conflict using the dogleg approach. So, here what is happening is that we have a basically this is creating a cycle and whenever this creates a cycle, I cannot use basically same routing track for A and B together. So, if you can see here there is a conflict.

If I draw like this, it will create a conflict. If I draw like this, it will create a conflict. So, this is not allowed. So, what it was done is that we break the net into two separate parts. So, this is one part of the net. This is another part of the net and that was connected using the L-shape routing. That is connected using the L-shape routing. So, if you can see here, so this cycle problem is solved. So, this is a piece of metal, horizontal metal. This is a piece of horizontal metal and this was connected using a vertical metal here. Okay. So, but this routing is not allowed because it creates a conflict with, creates a short with the net A. So, this is how we can resolve the conflict. Then the second concept here is that number of track reduction. So, how I can reduce the number of track using dogleg. So, here what is the thing here is that the A and B are using the same horizontal track and it creates a conflict.

So, if you can draw like this, then my number of tracks will be reduced. However, this is not allowed. This routing for net B is not allowed as it will create a short in this location with the net A. To avoid that what it was done is that we divide the B net into two piece. What are the two piece actually? So, we have basically this is one piece of horizontal metal. This is another piece of horizontal metal. Okay. And so where is the conflict is there? There I am moving into the next track. Okay. So, here the conflict is there in this point. Okay. So, I move to the next track using the dogleg concept. So, here the number of track is basically if you can see here it is 1, here it is 2 and here it is 3. So, three tracks are used in this case. But if you go by this method where we are doing the net splitting, so here we have this is one track, this is another track. Okay. So, we are using two tracks. Okay. So, here this method will reduce the width of your channel also. Okay. And it do a very good routing. So, this is the beauty of this dogleg based routing algorithm. So, where we can do this kind of routing algorithm? It splits the P pin nets. Okay. So, P pin means that P greater any P number of pins are there where P is greater than 2, we can divide that net to P minus 1 segments, P minus 1 horizontal segments. So, we have let us say here if you can see B net is there, I splitted this B net into B1.

So, this is a single net. So, from here to here is a single net B. But what I did is that I divided that net into two parts, one is B1, one is B2. Okay. I divide or split the net into two parts B1 and B2. So, basically net splitting occur only in the column that contain a pin of the given net. So, where we do the net splitting? Where we have a pin is there, there only you can do the net splitting. Let us say here I have B pin is there. So, that is why net splitting happening at this point. Okay. Where the net splitting will happen? Where there is a pin is there in that column.

Okay. So, here there is a pin is there, B pin is there. So, that is the reason here we have did the net splitting. So, after the net splitting, what we are doing is that we are following the previous left edge algorithm, like the way we were doing the left edge algorithm earlier. So, this is the concept of net splitting. And we will look into an example here.

So, here if you can see, you have A and B is there. Okay. And both are using the same track. Okay. So, the same thing whatever I discussed in the previous slide. So, it was more basically how the procedure of the dogleg algorithm. So, there are two cases are there. This is approach 1. Then this is approach 2. Okay. So, in case of approach 1, we are not doing any kind of net splitting. So, what first we are doing? We are doing the vertical constraint graph without net splitting. So, this is the channel provided to me. Then I created my vertical constraint graph without net splitting. So, that results in my channel routing algorithm. And I end up with this kind of routing. So, where I am using first, second and third tracks. So, three tracks are used in the solution. The three tracks are used. In the second case, what we are doing? We did a net splitting.

So, we have a net or pin A. We have a pin A and the net B1. So, this is creating a vertical constraint because that may create a short at this location. So, A is above B1. So, B1 is connected by a directed arrow. Similarly, B2 is connected. B is above the C net. So, B2 and C cannot be in same track. A and B1 cannot be in the same track. So, what we did is that we use the B2 segment.

There is no conflict between A and B2. They are the parent nodes like we are doing it in the left edge algorithms. So, basically, so we can assign the A net here and B2 net here.

Now what we are doing? Then we do not have any conflict between B1 and C. So, the B1 and C can be assigned the same track. So, the B1 will come here and C will come here. So, what is the advantage of doing this is that number of tracks becomes in this case is one here, this is the first track and this is the second track. So, in this solution we are using two tracks. So, this is a procedure of using the dogleg routing algorithm. So, this is a procedure of dogleg routing algorithm. So, now we will discuss this dogleg left edge algorithm using one channel, using this example actually with an example it will be more clear. So, what is the main target is to how to route the nets A to D in the given channel. How many tracks are required? So, the first goal is that we do what we discussed earlier, we split the nets. So, what are the nets we will split? So, if you have any kind of conflict in that point you need to split the nets and whenever we split the nets there should be any pin corresponding to that column. For example, if you can see here you have a C net moving from this point till this point.

So, this is my C net. So, if I use the complete track then that cannot be accessible for the other nets. So, what I did is that I will check whether the pin is there in the vertical direction. So, there I will split the net. So, here if you can see I have a pin in this point so I split the net at this point. So, the C net is divided into C1 and C2 then we have basically one unit so it cannot be splitted. Similarly, D1 basically can be splitted into two parts because D1 is going from this point I will use a different color. So, D1 is going from this point to these two points. So, what is the intermediate points? There it will do the splitting. So, here it is splitting at this point. So, the D net is now become D1 and D2. So, then what we are doing by doing the net splitting is that we are reducing the constraint among the net and it will allow to re-sharing of the track. So, what is the advantage of doing the net splitting? It is reducing the conflict that is one thing and it allows the nets to use the same tracks. So, now we have C1 and D1. C1 and D1 is the VCG, Vertical Constraint Graph corresponding to this channel.

So, first we will find the S of each of the column. So, S of each of the column we will find it out. This is the first step then we will create the vertical constraint graph corresponding to this channel. So, then once it is done then what we will do? We will take that VCG and do the routing. So, net splitting is already done. So, what we are doing here is that we are using the C1, D1 and A has no parents.

So, which one is the left one that should be used first. So, there are possible nets should be used is C1, D1 and A. So, what is written here? So, then why I am using C1 because it is the leftmost one. If you can see this is the leftmost one. So, that is why I am taking the C1 first and assigning it to the track 1. So, then what is the remaining nets are there? So, what are the remaining nets are there then we will look into that.

So, of the remaining nets only net A does not have any conflict. So, if you can go back to that diagram, so C1 and D1 has a conflict at this point. So, the C1 and D1 cannot be placed in the same track. So, C1 and D1 have conflict. So, it cannot be placed in same track. So, they cannot be placed in same track. Now what we will do? Then there is a net is there A which has no conflict with C1. So, C1 and A can be placed in the track 1. C1 and A are routed in track 1. So, this is the basically conclusion from this slide and what you have to do since they are routed they should be removed from the vertical constant graph. So, this is the next thing. So, this is also cannot be routed.

Now next will be we have this is the vertical constant graph. So, what are the nets available to us is now we have D1, C2, D2. D1 is the no parent, C2 and D2. D1, C2, D2 has no parents. So, this is the conclusion from the first slide. So, now we will go and see how this C1 and A is routed in track 1 in the final routing stage. If you can see your C1, this is the C1 actually, this piece of metal is C1 and this is A is routed in track 1, this is the track 1. So, this is from the first steps of the algorithm or first iteration of the algorithm. Next, we will go to the track 2 assignments. Now we will look into how what are the nets will be assigned to the track 2.

So, we will first look into the nets which has no parents. So, the nets which are the parents are D1, C2, D2. So, we will consider those nets. Then we will look into which one is the leftmost one. So, leftmost one is your D1. So, first priority will give into the D1 which is the leftmost one. And if you can go and see this one D1 is the leftmost one. So, that will be used the track 2. Now D1, C2, D2. D1, C2, D2. D1, C2 has a conflict and D2 has no conflict. So, what is that D2 does not have a conflict with the D1 because both are the same nets. So, therefore D2 can be used in the same track. So, D1 and D2 can be assigned in the same track. So, this D2 since conclusion is that D1 and D2 are routed in track 2.

So, D1, D2 are routed in the track 2 because there is no conflict. But C2 is not routed as it has a conflict with D1. So, C1 has a conflict with D1 because they are in the same metals are same lines are shared. So, it cannot be routed. So, now if you can go to the track 2 in the final layout D2 is used. So, this is your D1 and this is your D2. So, it is using track 2. Now we have the after you remove the D1 and D2 from the VCG then we have nets B and C2 are left out. So, the B and C2 are the nets which will be we will look into it. So, the which is the leftmost one B or C2 will go back to the B and C2 which is leftmost one B is the leftmost one. And is there a conflict between B and C2? I will use a different color. So, the B and C2 leftmost one is B and is there a conflict between B and C2 if I place both of them in the same track will it create a short? No.

So, B and C2 can be placed in the same track that is track number 3. So, the conclusion is that B and C2 are routed in track number 3. So, this is the conclusion from this slide. So, B and C2 is removed from the VCG. So, there is no more elements in the vertical constraint graph. So, if you can see here this is your B this piece of metal is your basically B and this piece of metal is basically C2. This piece of metal is basically C2. After you do these assignments then you can merge the vertical connect C1 should be connected to C2, D1 should be connected to D2 like that and this is the final routing after using the dogleg routing algorithm.

So, in this lecture we discussed about the dogleg channel routing algorithm. It is very useful in reducing the number of tracks in the channel routing and it also used for removing the conflict arises due to the cycles. Thank you for your attention.

Thank you very much.