VLSI Physical Design with Timing Analysis

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Lecture 46

Switchbox and Over the cell routing

Welcome to the course on VLSI Physical Design with Timing Analysis. In this lecture, we will discuss about switch box and over the cell routing algorithms. The content of this lecture includes switch box routing and introduction to OTC routing and we will discuss about OTC methodology. Finally, we will discuss what are the challenges are there in detail routing in modern technology nodes. So, what is switch box routing? There are some terminology involved in this switch box routing. So, we will discuss that one first.

A switch box basically is defined as m plus 1 cross n plus 1 regions with 0 to m plus 1 columns and 0 to n plus 1 rows. And this 0th to m plus 1 columns are the left and right borders of the switch box. The 0th one and the m plus 1th columns are the left and right borders of the switch box. So, similarly the 0th row and n plus 1th row are the lower and upper borders of the switch box. We can see this one in a minute. Let us take this one. So, if you have a column, this is the 0th column. So, 0th column is nothing but your left border. So, 0th column corresponding to left border.

Then m plus 1th column is the right border. So, this one is your right border and this is your left border. Now this is related to columns. Now 0th row are the lower. Let us go to the, so this is the 0th row. So, this is the 0th row. So, that is your bottom. And similarly, this one is the n plus 1 row, which is basically your top boundary or the upper boundary. So, this is the upper boundary. Now it is very clear.

So, now we have basically first to mth columns. Others are first to mth columns are labeled with lowercase letter a and b like that. For example, if you can go here. So, we have discussed about 0th column and m plus 1 column already. Now other columns are denoted by the letters. So, this is the first column. This is the second column like this. So, those are the letters. Now we have first to nth tracks are labeled with numbers. So, first row to nth row are basically the tracks are denoted by numbers 1, 2, 3, 4.

So, this is the first row. So, this first row is the first track. Similarly, this is the second row. This is the second track like that. So, now what is the thing here is that I have 8 cross 7 switch box routing problem, in which I have m equal to 7 and n equals to 6 here.

So, you can see here n is 1, 2 like this till 6. So, that many tracks or rows are there. Similarly, I have a, b, c, d, e, f, g which is 7. So, you have basically n rows and m columns which is basically there. So, this left-hand side is one possible solution. This is one possible solution of the switch box routing problem. So, this left side is the problem and the right side is the solution. So, the left side is a switch box routing problem and right side is one of the solution. That might be many solutions are there. It is one of the possible solutions. Now we have to define some more terminology. In case of switch box your dimension and pin connections on the all side are fixed. The dimension are fixed and pin connection on all the four sides are already fixed. That is fixed. So, we are defining four vectors actually.

What are the four vectors? Basically, one is top, one is bottom, one is left, one is right. Four vectors are there. And switch box routing algorithms are usually derived from greedy channel routing algorithm. The switch box routing algorithms are normally based on the greedy channel routing algorithms. So, this is the switch box and this is the routing solution for this one. Here you have different blocks. Basically, blocks are there. This is b1, b2, b3 and this b4 and routing is there in all the four directions. So, for this problem statement we have a 8 cross 7 switch box routing problem and a possible solution is given. Here we are defining all the four vectors. What are the four vectors? I have one vector is top, second is bottom, third is left and the fourth one is the right. How these vectors are created? So, these vectors are created from the net IDs. So, if you can see in this one the top side what are the columns possible. You have basically 0 here, you have 0 here top side. Then the Dnet, basically there is no connection.

D means there is a Dnet is there. Similarly, you have Fnet like that all other nets are there in here. Now similarly I can do it for the bottom. Bottom is basically corresponds to this one 00GHBBH00GHBBH. Similarly in the left actually if you can see in the left side, this is the left side basically nets. The left side nets are it should be basically checked from the bottom actually A is basically this A like that the last 0 is this 0. Similarly, the right side this is for the right side. Now after this one what we can do is that this is one possible routing solution. Then this is the one of the possible routing solution for this switch box. But what is the procedure to do that this then we will discuss how we can do this switch box routing.

There are some steps are there. So, you have pin assignments are done on all the four sides. So, the pin assignments are done on all the four sides. Then basically this horizontal track, the horizontal track is automatically assigned to a pin on the left side. We will start from the left side like we do it in case of a channel routing algorithm.

We have a left edge algorithm is there which is a greedy algorithm. We follow the same concept. We assign the horizontal track to the each pin on the left side first automatically. Then we have basically jogs are used for the top and bottom pins. We can move to the top and bottom pin using the jogs.

As well as for the horizontal track connecting to the right most pin. We can use left side pin. The left side pin can be connected to three possible connections. One is it can go to top, it can go to bottom, it can go to right. So, we can introduce jogs in the routing such that we can connect to the any one of the pin connections. We will do one at a time. We have basically top, bottom, left and right is there and our goal is to route all the nets A to H within the switch box. How can you do the routing? So, we will consider one column at a time. The column A is basically is the first column, this column A. So, we are considering the column A. If you can see here, what we will do here? We will route all the metals, the horizontal metal first. So, this track is automatically assigned. Let us say here for A this is assigned, 0 means there is no connection, D means it is assigned, this is assigned, this is assigned. So, till this point it is done. Now whenever we are considering the column A that means that we are thinking how I can do the routing in this area, how I can route in this area, means in this area how this signal or the route should move. If you can see here, if your net A can move to track 2 because there is no route is there for the track 2.

So, it starts from the track 1 and move to the track 2 in this column A. So, this is the solution for column A only. This is the routing possible for column A till this point is column A. So, what I am doing here is that I am moving the A and this is jog is introduced. This is the jog actually introduced to move to track 2.

Similarly, if you can see here we have a pin D here in column B. So, what I do next I need to look for is the Dnet. So, it is going to the track 6. Dnet is going to the track 6. Similarly, then we do not have any possible basically since D is moved to track 6 we cannot have any routing possible for G and F unless only they have a horizontal track. So, F is assigned to track 4 and G is assigned to track 5. F is assigned to track 4 and G is assigned to track 5. And you have D is assigned to track 6 and A is assigned to track 2. So, this is the assignment for column A. Now we will move to the column B. So, in the column B we are allowed to do the routing in this area. So, basically if I can see here what is the next pin there. So, if you can see that my next pin 2 are there D and G. So, you can connect D to this side to do the connection and we can from G, I can move to track 1. I can go here till this point. So, I did in two color basically means that this green is horizontal metal this blue is basically vertical metal. Now what is happening is that after you do this then you have basically G and D is already over. So, here your G is assigned track 1 and D is already routed and your basically A net is running in track 2 then F is running in track 4 and your D is terminated there. D is not using any track.

So, D is basically connected to the top pin D. So, this is related to column B. Now I have a column C. In case of column C what is the solution? If you can see here my G

is also terminated. G and F are connected. G is connected to bottom pin and your F is connected to top pin. Now the third one is F is connected to the top pin G is connected to bottom pin. Then the third one is basically your A. A is moved to basically track 3. Now A is moving in the track 3 because we have a pin A in the track 3. Now this is the basically this is the thing done in this one. Then we will go for track D. Column D basically we have H in the both side so they will have a one vertical metal in the H which is extended and you have H this is column D where you have H is assigned to track 2 and A is assigned the track 3. Now after doing this you will go to track column E. You have basically another pin comes E is in track 5 and your basically A is in track 3 and your B is in new net. B is in a new net it is in track 1. So, now if you can see if you can draw like this you have two more columns are there.

So, now you have basically column F basically if you can see column F basically you have B is in track 1 and B is in the track 1 and you have H is in track 2. Then you have A in track 3, then you have 4 basically your E is in track 5 then fifth one is basically your basically C is in track 6. So, now if you can go to the next one your C is in track 6, this is basically column G. So, you have a track 1 B is in track 1 B is in track 1 then H is in track 2 then A is in track 3 then you have 4 which is basically the C net is in track 4 then you have 5 basically your E net is in track 5 then the sixth one is the C net which is in track 6. So, this is the assignment we do in the column G. After this your routing is done without any kind of conflict. So, if you can see here this is the final routing switch box routing and if you can see here you have two piece of metal here why this two piece of metal one solid line is horizontal metal and this dotted line is your vertical metal. So, because to avoid any kind of conflict so we use a preferred direction to the metal. So, if we follow this kind of approach we can do the routing in less time.

Now we will discuss about the over the shell routing. So, this over the shell routing is applicable for a process or the fabrication process where it supports multiple metal lines. For example for two layer process means having metal 1 and metal 2 we cannot do over the shell routing is not possible. So, in that case we need dedicated routing channels. This is one option. Then the second option is that where you have multiple metal lines multiple metal lines in process.

So, we have multiple metals are there M1 to let us say M5 or above. So, in that case we have basically over the shell routing is possible. So, that imply we do not need any kind of routing channel. So, when it is possible when the standard shell are placed back to back or without routing channel we can go for over the shell routing. And metal layers are usually presented by a coarse routing grid in the case of global routing cells.

Whenever you are doing the global routing these metal lines are placed in a coarse routing grid. But whenever you are going for a detailed routing then we have to assign the corresponding metal to a particular track. So, this is the example of standard shell placement without routing channels. Now if you can see here what is the concept here

is that your standard shell whatever you are doing usually they use only poly and metal one for internal routing. Why they do that? So, this poly and metal one is blocked over the standard cells. However higher level metals like metal 2 and metal 3 are not obstructed by the standard shell. And the router can take the liberty to route the signals with metal 2 and metal 3 that concept is called over the shell routing. So, if you can see here this is the basically the standard shell placement where you have metal 1 blockage is defined. Now you have pins in the metal 2 that can do the routing using the metals in metal 3 or metal 4.

So, this is the concept is called the over the shell routing. So, here basically nets are generally routed using standard tree and then by detailed routing. So, this is the main idea. So, whenever you are going for three layer routing so what we have is that you have metal 1 and metal 2 are the ports and metal 3 is used above the shell for routing. Metal 3 is used for the over the shell routing. So, this is a solution here what is happening here is that we have two blocks are there.

This is B1 and this is B2 and we have a channel. It is not standard cell routing actually it is basically you have two blocks and you have a channel and if you can see here your metal 1 is routed inside this block. So, you have metal 1 blockage is defined. Metal 1 blockage is defined for blocks B1 and B2. So, this is one of the important points. And second thing is that if you can see only metal 1 cannot route but metal 3 can route.

So, here if you can see this connection is through metal 3 above the shell. This connection is there in the metal 3 above the shell. So, this is called the over the shell routing in the block level where we have some channel is there in between where you can do the in between you can do metal 1 but over the shell you can do metal 3. And metal 2 is there in the pins metal 2 pins are there metal 2 pins are there like what it is mentioned here. So, now whenever you are doing this OTC routing it is performed in three steps. Select the net that will be routed outside the channel. We need to select the nets which needs to be routed outside the channel. Then we need to route those nets in the OTC area over the shell area. So, OTC area is basically this is let us say this is a shell above it is the OTC area. Then route the remaining nets within the channel. Other nets you can route within that channel. So, if you can see here you have basically three layer standard shells. Metal 3 layer is used both for horizontal and horizontal track inside the channel for the over the shell routing. If you can see this is metal 3 this piece of metal is metal 3. So, this is called over the shell routing for metal 3.

And inside the standard shell you have basically metal 2 is there. Basically, ports are shown in the metal 2. So, this will be routed using the metal 3. And the channel area can use this channel area can use either metal 1, metal 2 or metal 3. But over the shell only metal 3 is allowed. So, there are a lot of challenges in the routing in the modern technology nodes.

If you can see here in 130 nanometer we have six metal line each one of them having same width 1x width actually all of them are having 1x width. But if you can go to the 90 nanometer process till metal 5 this is 1x and B1 B2 is more than 1x or might be 2x. And in 65 you have 65 nanometer you have this is 1x this is more than 1x or 2x and this is 4x. So, similarly if you go to lower technology nodes you will have multiple metals and the higher level metals are wider to offer low resistance. And higher level metals are mostly used for supply routing to reduce the IR drop.

So, we discussed about the switch box routing and over the shell routing in this lecture. Thank you for your attention.