VLSI Physical Design with Timing Analysis

Dr. Bishnu Prasad Das

Department of Electronics and Communication Engineering

Indian Institute of Technology, Roorkee

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Lecture 39

Single net routing (Rectilinear routing)

Welcome to the course on VLSI Physical Design with Timing Analysis. In this lecture, we will discuss about single net routing or rectilinear routing. So, the content of this lecture includes representation of the routing regions, then we will discuss about the global routing flow, then there is a procedure for we will define the RMST and RSMT, the rectilinear minimum spanning tree, rectilinear Steiner minimum tree. Then we will discuss about how to transform an initial RMST into a low cost RSMT and we will discuss about the Hanan grid. We will take an example to explain how a sequential Steiner tree can be constructed. So, first of all we will discuss about the representation of the routing regions.

So, we discuss about the routing regions it is divided into two types one is called uniform and non-uniform. In case of full custom design style we have non-uniform routing regions, in case of standard cell based design we have uniform routing regions. Now, we create a grid graph which is defined using two sets one V, E. So, since it is a graph, the graphs can be represented using V, E.

So, the V is basically the vertex or the nodes which is basically the small v is belongs to the capital V and which is represents the routing grid cells and the edges the set E basically it represents the connection of the grid cell pair. So, the routing regions are represented by the nodes. So, if you can see here we divided the total layout area or the chip area into different grids. So, it is a 5 cross 5 grid, but it is a 5 cross 5 grid and we have 25 nodes, we have 25 nodes. Then the these are the edges which is adjacent grids actually is connected with the edge adjacent routing regions are connected by a edge.

Then we have a channel connectivity graph. So, this is also, represents it is a graph we have two set one is V, E the V represents the channel, the node V represents the channel and the edges E represents the adjacency of the channel, adjacency of the channel. Adjacency means that we though on the channel which is connected to each other. So, if you can see here we have a channel 1 which is corresponds to this one. So, which is represented as a node and this is the node 1. Then we have node 2, this is the node 2 which is represented by the node 2. We have a this 1 and 2 are adjacent. So, that is why there was a edge between them. That is why we have a there is a edge between them. So, now we will look into the channel 1 the adjacent channel is basically node 4.

So, this is also, connected by edge connected by edge. So, if you can see here the same method is applicable for all the edges, same method is applicable for all the edges and which is basically then this is the channel connectivity graph G, channel connectivity graph G which has 9 nodes and all these are the edges. Now we have switch box connectivity graph which is also, defined using V, E and the V is basically one of the element of the switch box small v or the node v is one of the switch box and edge exists between two nodes if the corresponding switch box are opposite side of the same channel. The corresponding switch boxes are opposite side of the same channel. Let us take an example to see how we can create a switch box connectivity graph.

So, this is basically the graph here. This is a graph here. The same we can if you can see here. So, which are your switch boxes? So, we have this switch box is corresponds to this node. This switch box is corresponds to this node like this we can connect since the there is a path from this switch box are opposite with respect to each other. So, that is why there is a edge exists between 1 and 4. Similarly, created for all other switch boxes. So, now we will discuss about the global routing how we can do that what are the steps involved in global routing. So, the first step is basically the defining the routing regions. So, first step is defining the routing regions.

So, we have a layout area which is given to us which has placement of the blocks or placement of the standard cells all are defined the placement of the cells are given and the layout area is given. So, what we have to do? We have to create the routing regions. So, these routing regions are formed using this 2D, 3D channels, switch boxes and other region type like uniform, non-uniform routing regions. Then the regions and their capacity we need to define the graphs basically and their capacity and connections are represented by a graph. So, these regions are represented using some graph and their channel capacity will also, be encoded as a parameter in the nodes of the graph. Then what we have the step 2 is basically mapping the nets to the routing regions. So, we have another input to our routing algorithm is basically the net list how the signal can be routed. So, in this step 2 what we are doing is that each net of the design. So, the each net of the design is tentatively assigned one or the several routing regions it can have all possible routing regions it can be assigned So, as to connect to all the pins all of its pins. So, if you have a net then we can see what are the other all possibility that is there to connect to all of its pins.

Then what we have to do is that the routing capacity, timing and congestion all these information. So, the routing capacity and the timing and congestion all these needs to be provided for that path for that net. So, if these things will also, be provided. So, that will determine whether that path can be assigned to that net or not. So, whenever we are mapping the nets to a routing regions we will look into the capacity of the routing regions and the congestion in that routing regions if capacity is available and there is no congestion then that net will be assigned to that routing region.

Then the step 3 the step 3 is basically assigning the cross points. So, in this phase what it was done is that routes are assigned to fixed locations. So, here we are assigning to the fixed locations here we are assigning to the fixed locations or cross points along the edges of the routing regions. So, here the routes are assigned to the fixed locations and our cross points such that we can do the routing. This approach can be scalable for the global and detail routing.

Since the routing regions are such that the routing regions can be handled independently in case of detailed routing. So, it enables scaling with respect to the global and detailed routing. Since the routing regions can be handled independently in case of detailed routing. So, now we will go into the rectilinear spanning tree. So, the spanning tree rectilinear spanning tree is the connects all the terminals basically.

So, it will connect all the terminals using only pin to pin connection that are composed of vertical and horizontal segment. So, we have to create a rectilinear spanning tree which connects the pin using two things one is the vertical segment and the second one is the horizontal segment. We have vertical segment and horizontal segment those are used to create the rectilinear spanning tree. The pin to pin connections can meet only at a pin. So, now after I we create the rectilinear spanning tree if the length of the total length of the segment used for creating the spanning tree is minimum then that tree is called a rectilinear minimum spanning tree.

So, what is the steps here? The first will assign the net using vertical and horizontal segment. Then we will check that whether that total length of the segment is minimum then that is called your rectilinear minimum spanning tree or RMST. Then we have another concept called rectilinear Steiner tree which connects. So, the rectilinear Steiner tree connects P pin locations. So, it connects the P pin location and possible some additional locations called Steiner points.

We will see this Steiner point in the future example the RST is a rectilinear Steiner minimum tree. If the total length of the net segment used to create the P pin net is minimum. So, there are multiple RSTs are possible, but one of them will be RSMT. So, which one is the RSMT? Where the total length of the vertical and the horizontal segments for all the P pins is minimum that one is called your RSMT or rectilinear

Steiner minimum tree. Some of the facts related to the RSMT which is called the rectilinear Steiner minimum tree, rectilinear Steiner minimum tree is given in this slide.

So, the RSMT for a P pin net has between 0 to P minus 2 Steiner points. So, it can maximum P minus 2 Steiner point minimum or minimum is that there might be no Steiner points. But so, what is the point here is that the degree of any terminal pin is basically can be 1, 2, 3, 4. So, the degree of a Steiner point is most important point is either 3 or 4. So, now, what we have to do is that this RSMT is always enclosed with a minimum bounding box of the net.

So, the total length of the LRSMT is at least half of the perimeter of the minimum bounding box. Length of the RSMT should be greater than equals to this half of the perimeter of the minimum bounding box of the net. So, let us take an rectilinear minimum spanning tree. So, this is the rectilinear minimum spanning tree, but we will create a RSMT from this starting point. So, in this case what is given to us we have given 3 pins P 1, P 2 and P 3.

So, 3 pins are given and what we are finding here is that low cost rectilinear Steiner minimum tree RSMT. So, how we can find it out? So, we have the minimum spanning tree given. So, this is the initial routing. Then the in the next stage what we will do we will create a L shape point L shape between the pin 1 and pin 2. So, we will create a L shape between the points with most overlap of the net segment. So, this is one pin and this is another pin we created a L shape here. So, this is my L shape. So, now we will create So, this is already there this other L shape is already there. Now what we will do we will connect this P 3 to P 2 using this net segment. So, using this net segment we will connect. So, now what will happen this point this point is my Steiner point. This point is my Steiner point degree of Steiner point is 3. So, this is my final RSMT. So, it is a rectilinear Steiner minimum tree. So, this first one is my RMST and the final one is my RSMT.

So, it creates a low cost RSMT the net cost will be minimum in this case. Now we will discuss about the Hanan grid. It was initially proposed by M Hanan in 1966 about this Hanan grid. So, what Hanan grid says that it consists of a line let us say we have a line x which is x p and y p that pass through each pin location x p and y p it will be x p comma y p. So, the only consider the only Steiner points located at the intersection of the vertical and horizontal line that pass through the terminal pins. So, if you can see here we have terminal pins are there these are the pins that need to be connected. So, we what we do we are finding the intersection lines. So, these are the intersection line which is basically this dotted lines are the intersection lines. This line, this lines all these lines are intersections lines. So, these intersection lines are basically connected whenever you connect them you will find some points what are those points this points.

So, all these dotted lines are basically intersection lines. So, these points are called your Hanan points. So, this point is called the Hanan points. So, now what we have to do is that So, the in order to connect those pins we have to connect the lines intersection lines. So, we connect this intersection line between this pin p 1 let us say this is p 1 and this is p 2 this is p 3 and this is p 4. So, we will connect this line first then we will drop a projection to that line. So, these are my these are my Stener points these are my Stener points. If you can see here the degree of that point is 3 degree of that point Stener point is 3. So, basically we will only consider the standard point that is located in the intersection of the vertical and horizontal line and that should pass through the terminal pins. So, one thing is that whenever we are considering the standard point it should be intersection of the vertical and horizontal lines and that should also, pass through the pins that should also, pass through the pins.

Now, we will discuss about the rectilinear routing. So, we have this different steps whatever we discussed basically we are defining the routing regions. So, these are the different routing regions. So, we have these are the grids actually these are all grids. So, we represented using the graph we represent the routing region using basically graphs then what we are doing we are defining the pins.

So, the pins are here these are the pins these are the pins. So, these pins need to be connected the pins are assigned to the grid cells. So, if you can see here this pin is assigned to this grid and this pin is assigned. So, this pin is assigned to this grid. Similarly, you can assign the pin assignment to the grid cells we are assigning the pins to the grid cells. So, now we will discuss about a sequential standard tree heuristic. So, we will discuss about how can you do a sequentially standard tree using if all the pins are given to me. So, what are my steps here? The first step is basically find the closest pin pair and construct a minimum bounding box. So, we will take the pins which are close to each other and create a minimum bounding box which will touch both the pins which will touch both the pins. Then the find the closest pair PMBB comma PC between any point PMBB on the PMBB and PC from the set of pins to consider.

Then we will create a PMBB the pin in the bounding box and the pin PC between from a set of pins to be considered next pin to be considered. Now, we will create a MPB for PMBB and PC. We have PMBB PC pair. Now, we will create another minimum bounding box including PMBB and PC the next pin. Then add a L shape line on the T on to the T deleting the other L shape. So, we will delete the other L shape. If the PMBB is a pin then add any L shape of the PMBB to the T. Then we will basically go to the step 2 until the set of pins to consider is empty. So, we will do this process for all the pins. So, now let us take an example.

It will be more clear with example. We have considered 7 pin P1 to P7. So, these are the location of the pins. So, these are the location of all the pins P1 to P7. Now, we will create a heuristic standard minimum tree using the sequential standard tree heuristics. So, we will create a minimum standard tree using the heuristic whatever we discussed just now. So, we will start with the first pin the pin 1 and pin 2. So, we will create a bounding box. So, this is the first bounding box. Then the second pin will consider is the 3. Second pin will consider is the 3. Then what we will do is that we will create a bounding box which will connect the PC with the first bounding box. We will create another bounding box which will connect the first bounding box with the second bounding box. So, if you can see this point then this point is your this point is your PMBB. So, this MBB is the minimum bounding box for the minimum bounding box. So, this P minimum bounding box if it is found out then we can say that this L shape will be deleted.

So, this L shape this L shape will be deleted like this. So, now we have basically another bounding box. So, this is the first bounding box, this is the second bounding box, now this is the third bounding box. So, the third bounding box will touch the second bounding box. Then you can see that the point where it is touching is the next Stener point. So, this is my second Stener point. So, whenever I am considering that one I have to delete this L shape. So, this L shape will be deleted. So, this L shape will be deleted. Now what will happen is that now I have basically this is a third and this is the fourth bounding box and third and fourth bounding box then what we have to do is that I need to delete this L shape. So, if I delete that L shape now I have this is the new routing then after that we will consider the all the other pins which is connecting to that bounding box.

So, if you can see here the 6 is connected to 5. So, now we have basically we can delete this one should be deleted. So, this one should be removed. So, this L shape should be removed. Now we have to create another bounding box. So, this the last bounding box we will see that if I go by this way it is not the right method because we have to do the signal routing two times it is changing the direction. So, this is not a good routing. So, we should delete those this type of routing. So, this will be deleted. Now I will have the final routing this one. So, whenever I am getting the final routing here if you can see here we have couple of standard points couple of standard points. So, what are those standard points? This is a standard point which is having degree 3 this is a standard point which is having degree 3.

So, this is also, a standard point. So, I have three standard points in this example and I have seven pins are connected using the minimum rectilinear standard minimum tree. So, this is the rectilinear standard minimum tree. So, in this lecture we discussed about the global routing and we discuss about two different approach one is called rectilinear minimum spanning tree and we discuss about rectilinear standard minimum tree. So, we discuss how we can convert the RMST to RSMT using the Hanon grid method.

Thank you for your attention. Thank you.