EE244: Design Technology for Integrated Circuits and Systems

Outline
Lecture 4.1

- Channel Routing
  - YACR
  - Hierarchical Routing
- Switchbox Routing
- River Routing
- Global Routing

Taxonomy of VLSI Routers
Hierarchical Routing
(Burstein & Pelavin)

\[ C_{ij} \] rectilinear channel grid, \( i=1,2,...,m; j=1,2,...,n \)
\( 0 \leq W(H_{ij}) \leq 1, W(V_{k})=0, k=1,m, j=1,...,n \)
Hierarchical Routing

Top t(j)

Bottom b(j)

Hierarchical Routing

Top t(j)

Bottom b(j)
Hierarchical Router

◆ For any boundary B, let C(B) be the total number of routes crossing B.
◆ Route $R_i$ is legal iff:
  
  $C(B) \leq W(B) \forall$ boundaries, B
  
  $C(V) + L(V) \leq W(V) \forall$ vertical boundaries, V
  
  where $L(V) = \max(LL, RL)$
  
  $LL$ = no. routes in $G_{ij}$ but turning left before $V_{ij}$
  
  $RL$ = no. routes in $G_{ij}$ but turning right before $V_{ij}$

Wiring the (2-by-n) Grid

◆ $P$ is a 2xn Boolean matrix, $p(i,j)$ true if net $N_p$ has a pin in $C(i,j)$
◆ $h_{ij}$ is the cost to be added if net cuts $H_{ij}$
◆ $v_{ij}$ is the cost to be added if net cuts $V_{kj}$
◆ Let l and r be the column numbers of the leftmost and rightmost pins of the net respectively:

$$l = \min\{k \mid p(1,k) \lor p(2,k) = true\}$$

◆ Then define four structures as follows:
Wiring the (2-by-n) Grid

\( T^1(k) : \text{Is the minimum-cost tree which interconnects the cells:} \\
\{C(i, j) : (j \leq k) \& (p(i, j) = \text{true})\} \cup \{C(1,k)\} \)

\( T^2(k) : \text{Is the minimum-cost tree which interconnects the cells:} \\
\{C(i, j) : (j \leq k) \& (p(i, j) = \text{true})\} \cup \{C(2,k)\} \)

\( T^3(k) : \text{Is the minimum-cost tree which interconnects the cells:} \\
\{C(i, j) : (j \leq k) \& (p(i, j) = \text{true})\} \cup \{C(1,k), C(2,k)\} \)

\( T^4(k) : \text{Is the minimum-cost forest, containing two different trees:} \\
T^4_1(k) : \text{uses cell } C(1, k) \text{ and } \{C(i, j) : (j \leq k) \& (p(i, j) = \text{true})\} \\
T^4_2(k) : \text{uses cell } C(2, k) \text{ and } \{C(i, j) : (j \leq k) \& (p(i, j) = \text{true})\} \)
Wiring the (2-by-n) Grid

- Computation of trees recursively:
  - Construct $T^i(k), i = 1, 2, 3, 4, l \leq k \leq r$
  - For $T^i(k + 1)$ simply compute extensions from each of the $T^i(k), i = 1, 2, 3, 4$ and pick the cheapest one.
- Claim routes a net in $O(n \log(m))$ time, for $n$ columns and $m$ tracks.
- Add vertical tracks to ends of channel as needed to meet capacity constraints
- Cannot handle cycles in VCG (what happens?)

Comparison on DDE$^1$

<table>
<thead>
<tr>
<th>Router</th>
<th>Tracks</th>
<th>Vias</th>
<th>Wire length</th>
</tr>
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<td>6526</td>
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<td>403</td>
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<td>YACR2</td>
<td>19</td>
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</tbody>
</table>

$^1$ Deutsch's Difficult Example, Density=19
Single-Layer Routing

- Single-Layer Routability Problem is NP-hard
- River Routing when all nets are two-terminal (e.g. busses, corners)

Single-Layer Routing problem

- Gas, Electricity, and Water problem
General River-Routing

- Two possible paths per net along boundary
- Path is alternating sequence of horizontal and vertical segments connecting two terminals of a net
- Consider starting terminals and ending terminals
- Assume every path counter-clockwise around boundary

```
T_1
P_1
P_2
T_2
```

General River-Routing

- Create circular list of all terminals ordered counterclockwise according to position on boundary

```
1s 2e 1e 3s 4e 5e 6e 7e 8e 8s 7s 6s
```
**Single-Layer Routing**

- Boundary-Packed Solution
- Flip corners to minimize wire length

**Global Routing**

- Provide guidance to detailed routing (why?)
- Objective function application-dependent
Global Routing

- Grid-Graph Model
- Checker-Board Graph (also use slicing structure)

Global Routing

- Channel Intersection Graph most common approach