EE244: Design Technology for Integrated Circuits and Systems

Outline

Lecture 4.1

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

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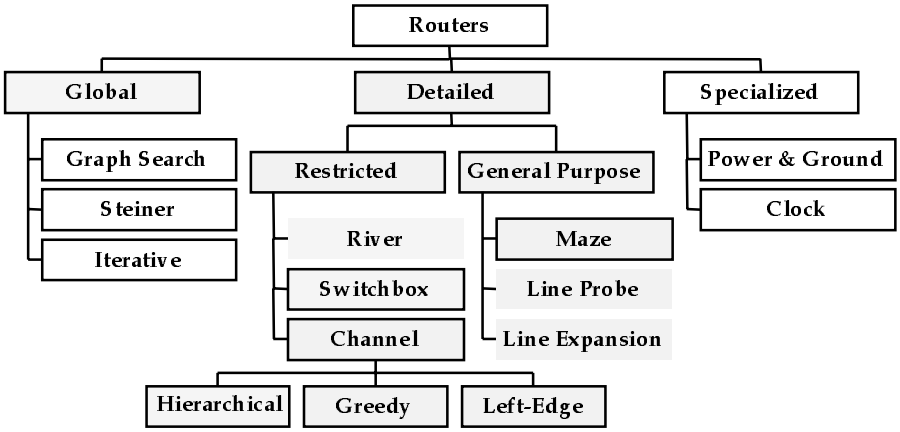
Taxonomy of VLSI Routers



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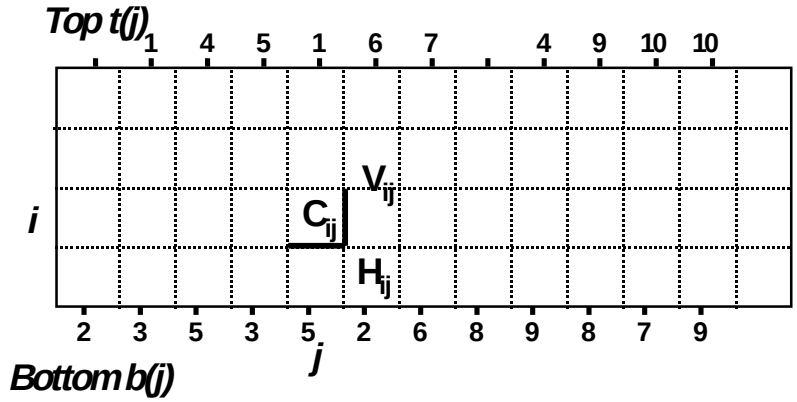
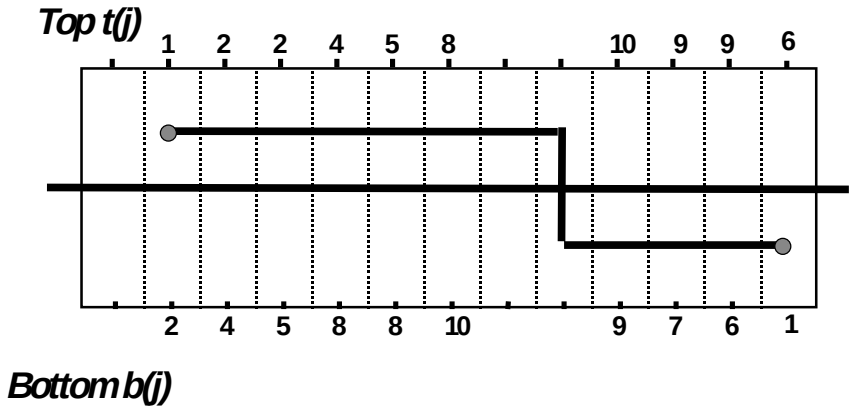
Hierarchical Routing

(Burstein & Pelavin)



C(i,j) rectilinear channel grid, i=1,2,…,m; j=1,2,…,n
$0 \le W(H_{ij}) \le 1$, $W(V_{kj})=0$, k=1,m, j=1,…,n

Hierarchical Routing



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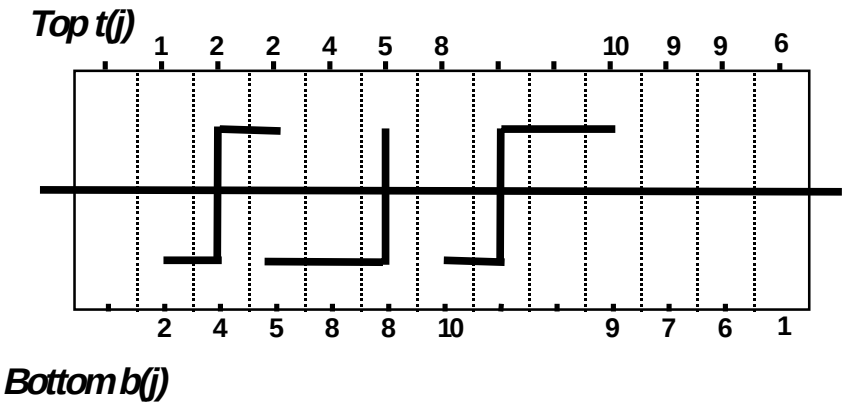
Hierarchical Routing



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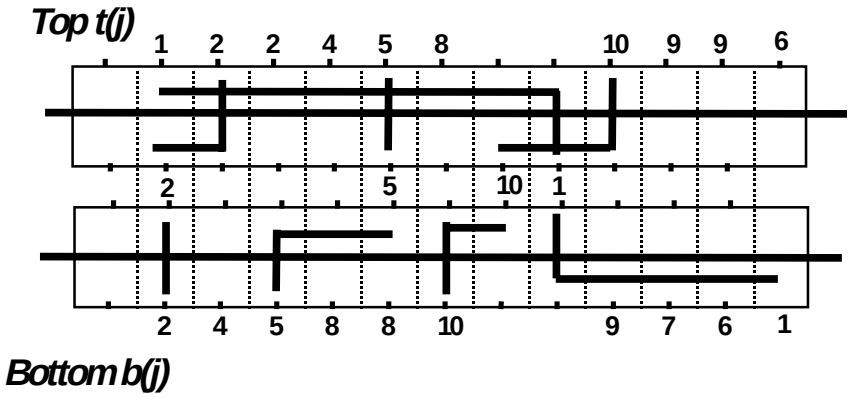
Hierarchical Routing



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Hierarchical Router

- **For any boundary B, let C(B) be the total number of routes crossing B.**
- **Route R_i is legal iff:**

$$C(B) \le W(B) \forall \text{boundaries, B}$$

$$C(V) + L(V) \le W(V) \ \forall \text{vertical boundaries, V}$$

$$\text{where } L(V) = \max(LL, RL)$$

$$LL = \text{no. routes in } G_{ij} \text{ but turning left before } V_{ij}$$

$$RL = \text{no. routes in } G_{ij} \text{ but turning right before } V_{ij}$$

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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_{1j}
- 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:**

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

- **Then define four structures as follows:**

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Wiring the (2-by-n) Grid

$T^1(k)$**: Is the minimum-cost tree which interconnects the cells:**

$$\{C(i,j) : (j \le k) \,\&\, (p(i,j) = true)\} \cup \{C(1,k)\}$$

$T^2(k)$**: Is the minimum-cost tree which interconnects the cells:**

$$\{C(i,j) : (j \le k) \,\&\, (p(i,j) = true)\} \cup \{C(2,k)\}$$

$T^3(k)$**: Is the minimum-cost tree which interconnects the cells:**

$$\{C(i,j) : (j \le k) \,\&\, (p(i,j) = true)\} \cup \{C(1,k), C(2,k)\}$$

$T^4(k)$**: Is the minimum-cost forest, containing two different trees:**

$T_1^4(k)$: uses cell $C(1,k)$ and $\{C(i,j) : (j \le k) \,\&\, (p(i,j) = true)\}$

$T_2^4(k)$: uses cell $C(2,k)$ and $\{C(i,j) : (j \le k) \,\&\, (p(i,j) = true)\}$

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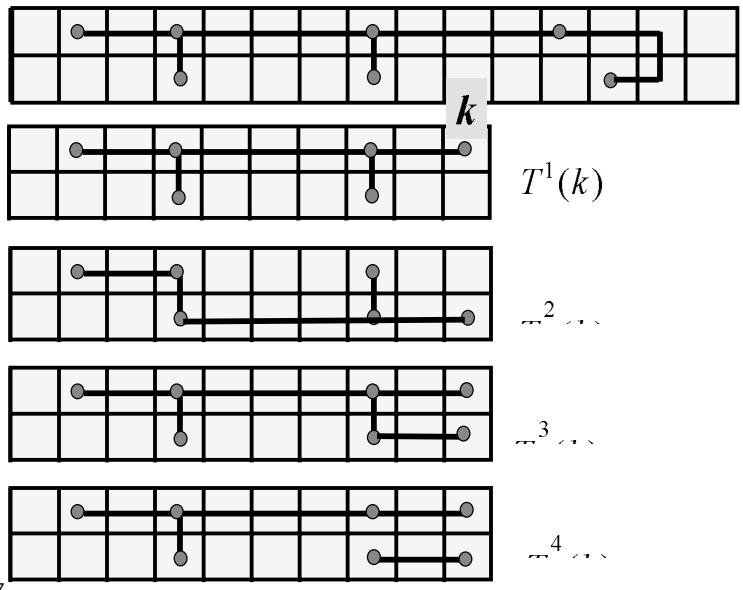
Wiring the (2-by-n) Grid



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Wiring the (2-by-n) Grid

- Computation of trees recursively:
  - Construct $T^i(k), i = 1,2,3,4, l \le k \le r$
  - For $T_j(k+1)$ 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?)

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Comparison on DDE[1]

Router	Tracks	Vias	Wire length
LEA	31	290	6526
Yoshimura-Kuh	20	403	5381
Greedy	20	329	5078
Hierarchical	19	336	5023
YACR2	19	287	5020

[1] Deutsch's Difficult Example, Density=19

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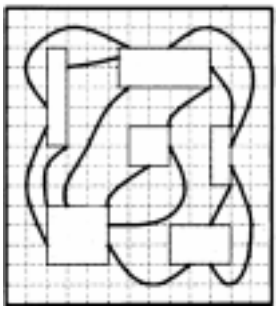
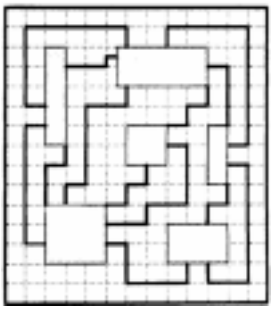
Single-Layer Routing

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





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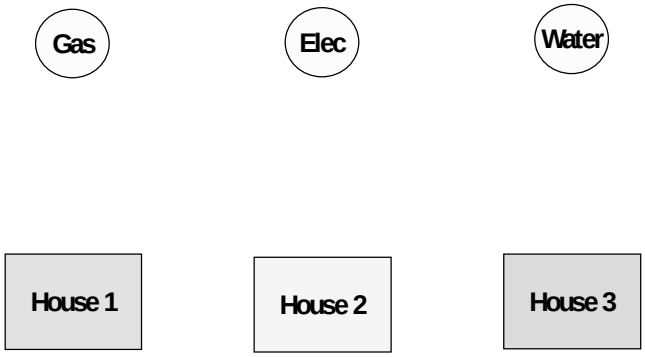
Single-Layer Routing problem

- **Gas, Electricity, and Water problem**



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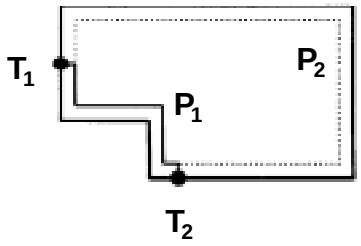
General River-Routing

- 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



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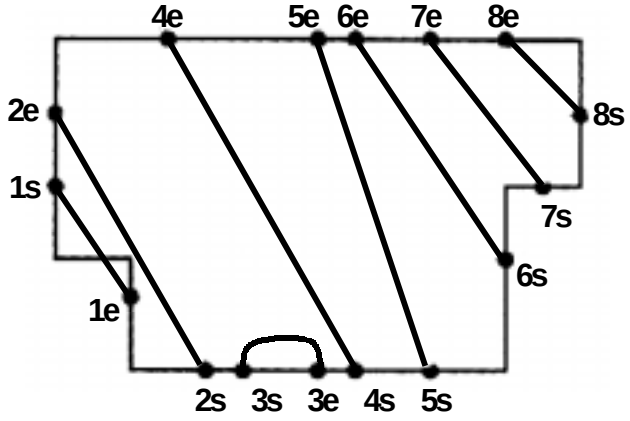
General River-Routing

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



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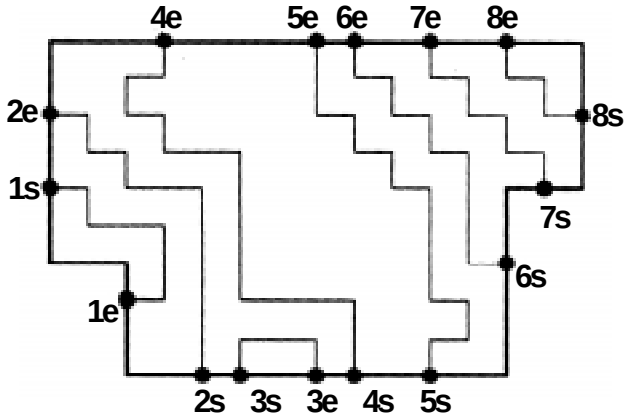
Single-Layer Routing

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



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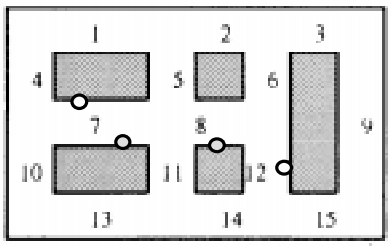
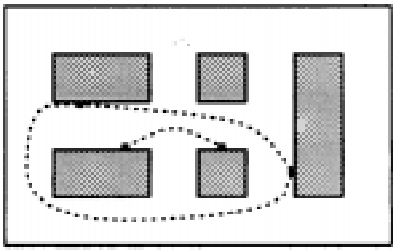
Global Routing

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





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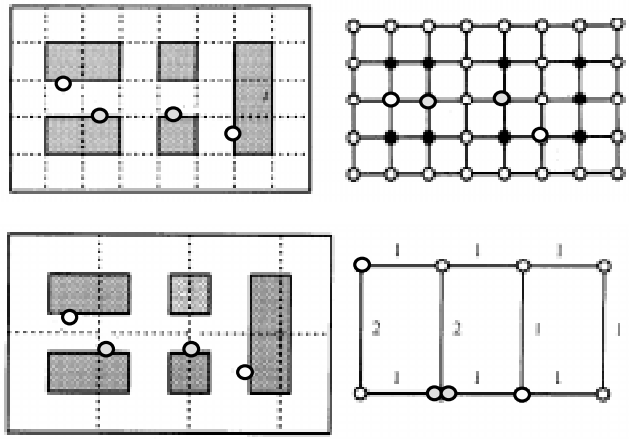
Global Routing

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



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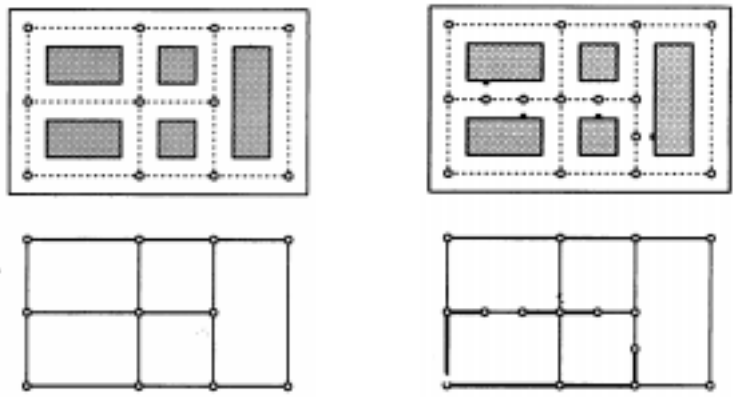
Global Routing

- **Channel Intersection Graph most common approach**



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