Hierarchical Routing Framework

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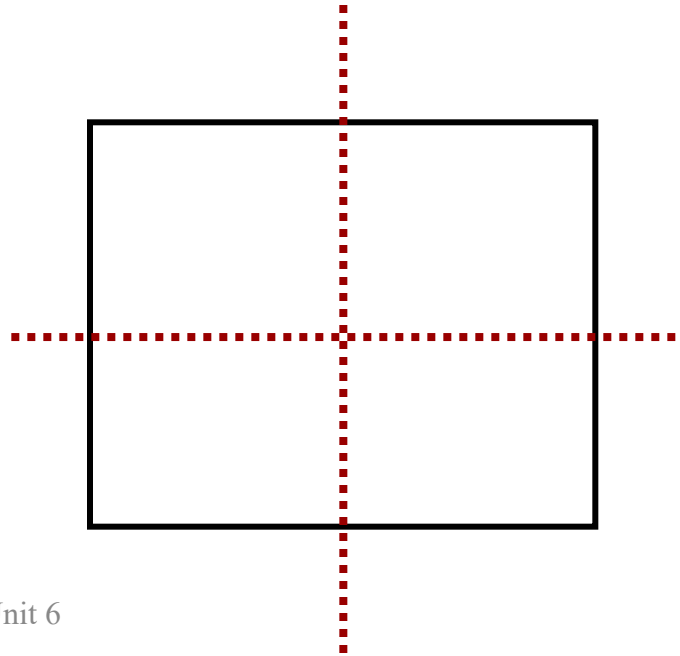

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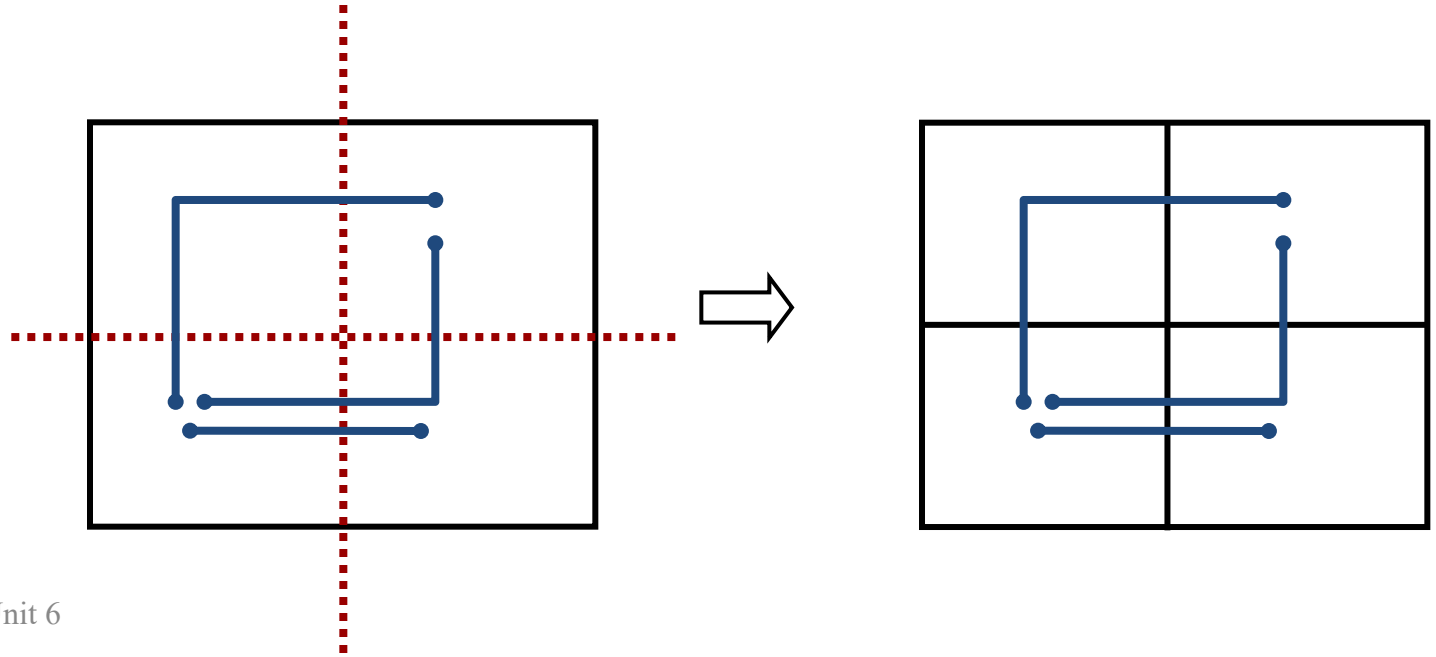

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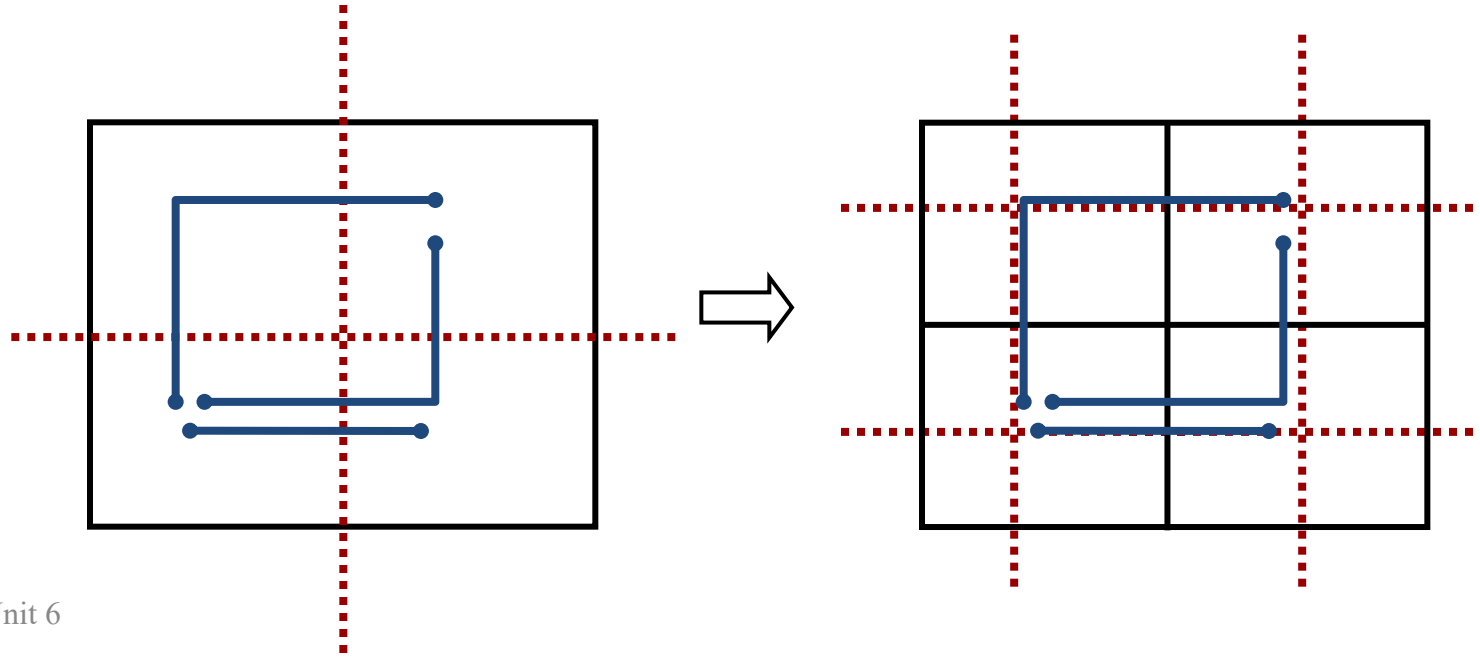

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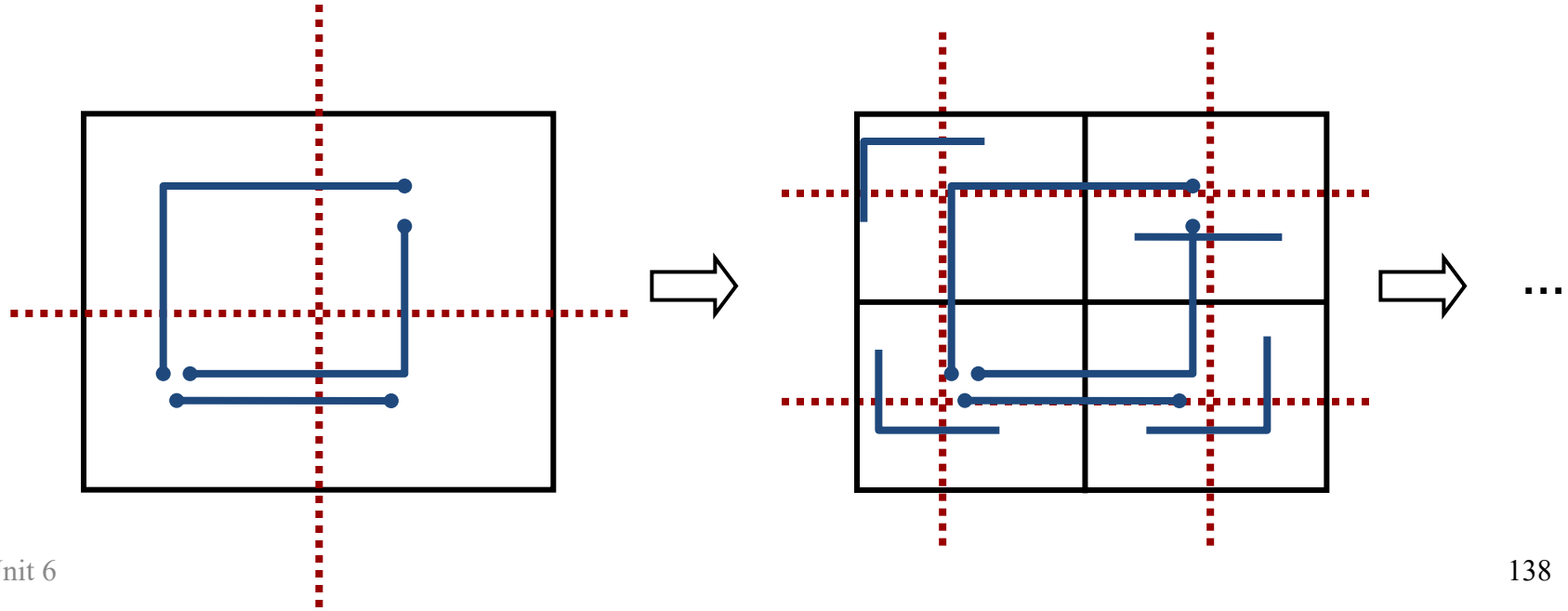


Multilevel Full-Chip Routing Framework

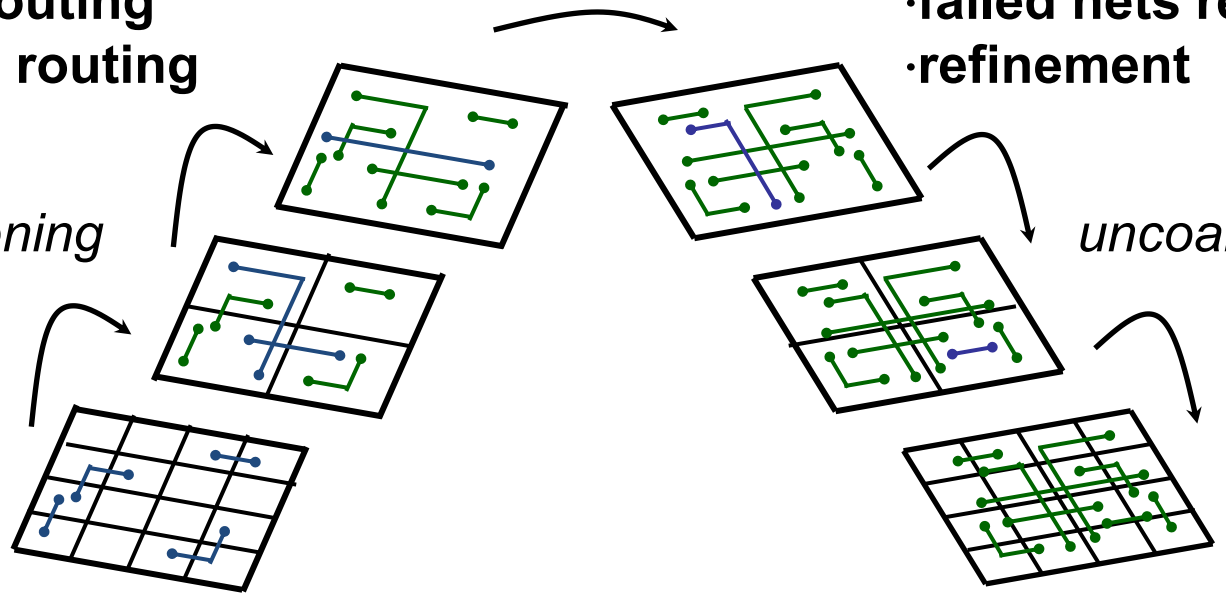
- Lin and Chang, "A novel framework for multilevel routing considering routability and performance," ICCAD-02 (TCAD-03).
- Multilevel framework: coarsening followed by uncoarsening.
- Coarsening (bottom-up) stage:
  - Constructs the net topology based on the minimum spanning tree.
  - Processes routing tiles one by one at each level, and only local nets (connections) are routed.
  - Applies two-stage routing of global routing followed by detailed routing.
  - Uses the L-shaped & Z-shaped pattern routing.
  - Performs resource estimation after detailed routing to guide the routing at the next level.
- Uncoarsening (top-down) stage
  - Completes the failed nets (connections) from the coarsening stage.
  - Uses a global and a detailed maze routers to refine the solution.

Λ-Shaped Multilevel Routing Framework

- - - - - To-be-routed net ——— Already-routed net

·**global routing**
·**detailed routing**

·**failed nets rerouting**
·**refinement**



Perform global pattern & detailed routing for local connections and then estimate routing congestion for the next level

Cost: congestion

Use maze routing to reroute failed connections and refine the solution

Cost: congestion + net length

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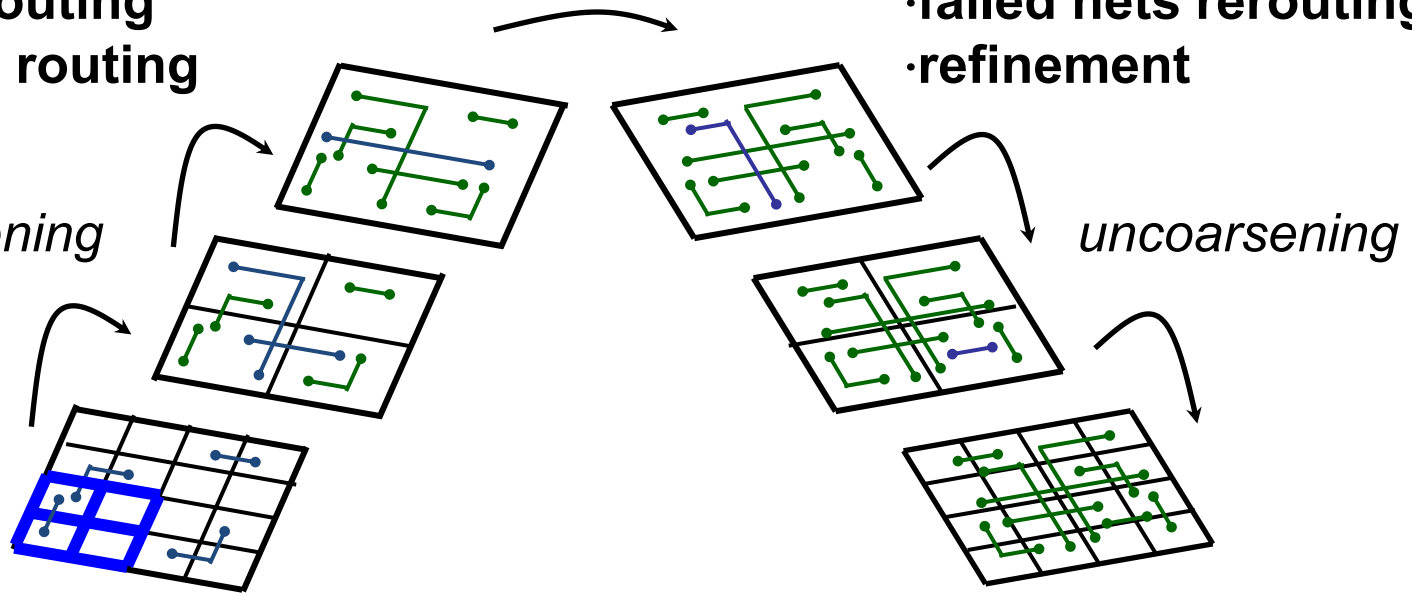

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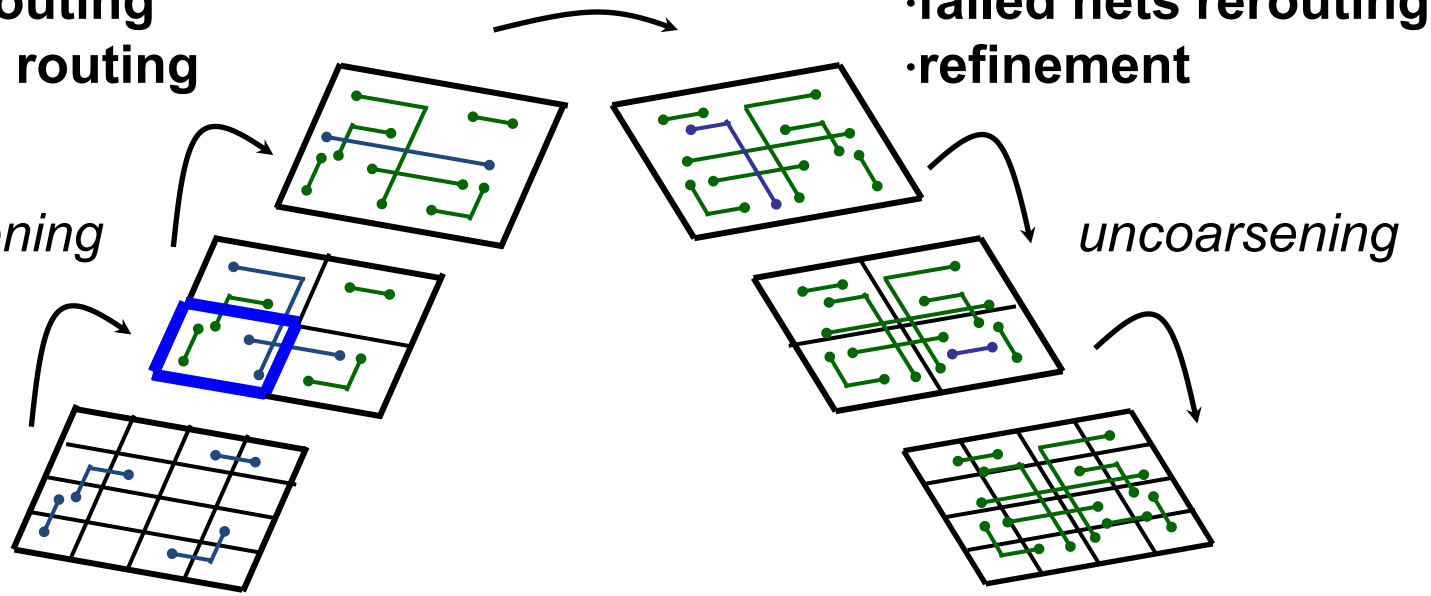

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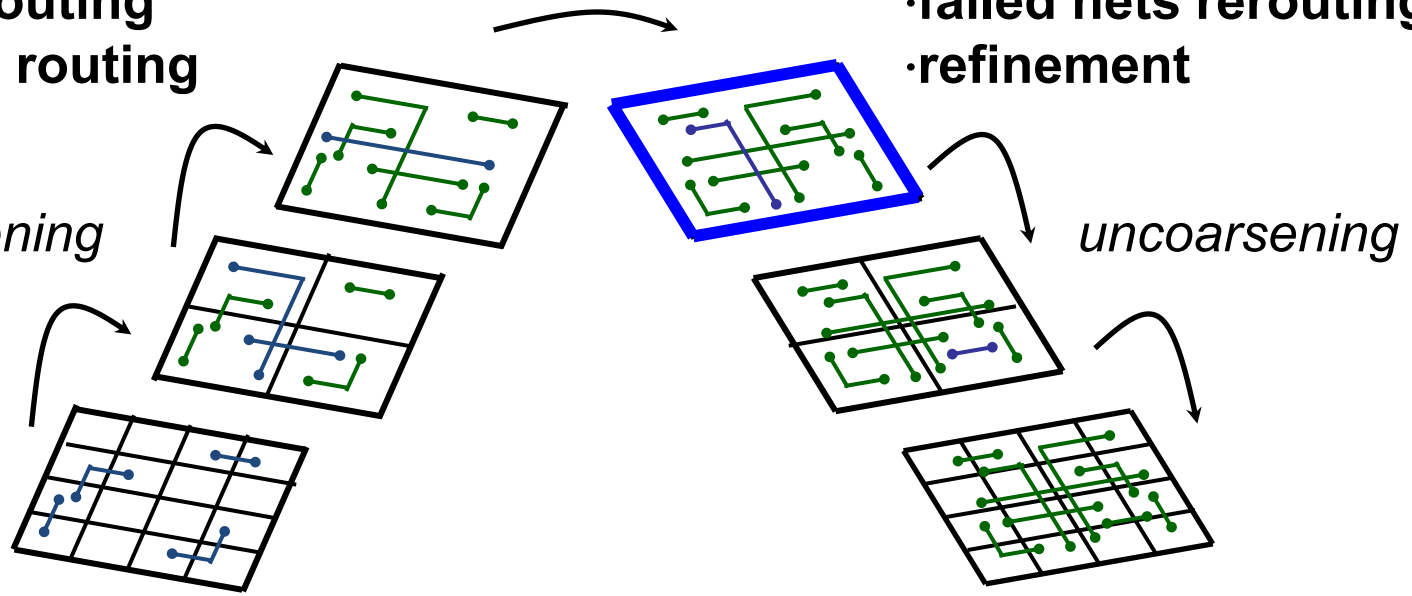

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A-Shaped Multilevel Routing Framework

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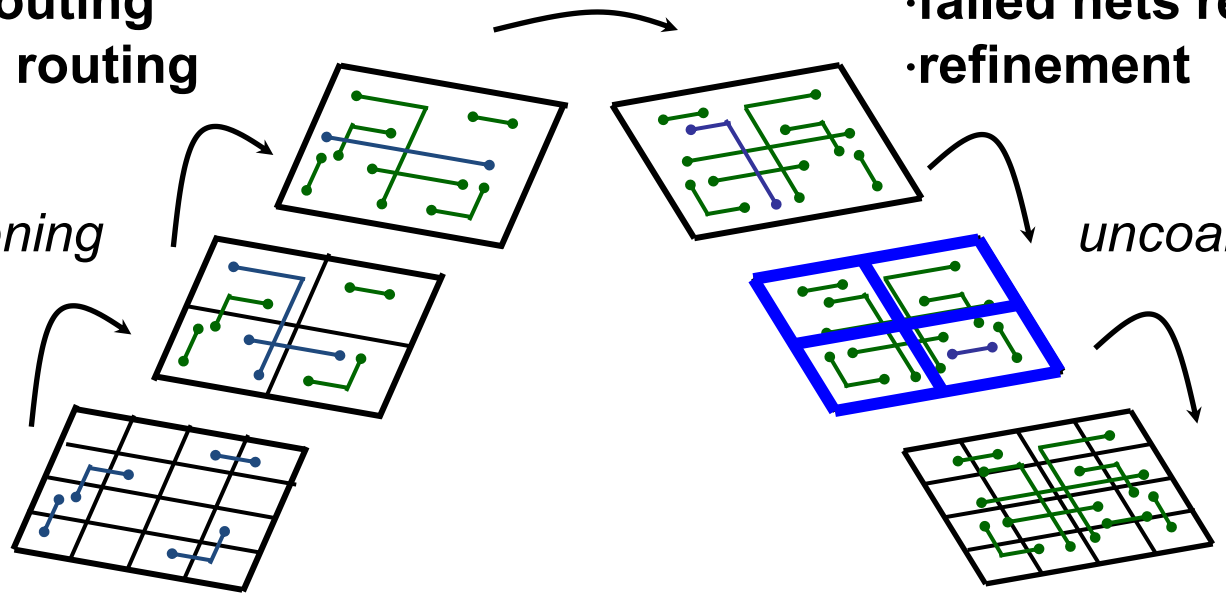

Perform global pattern & detailed routing for local connections and then estimate routing congestion for the next level

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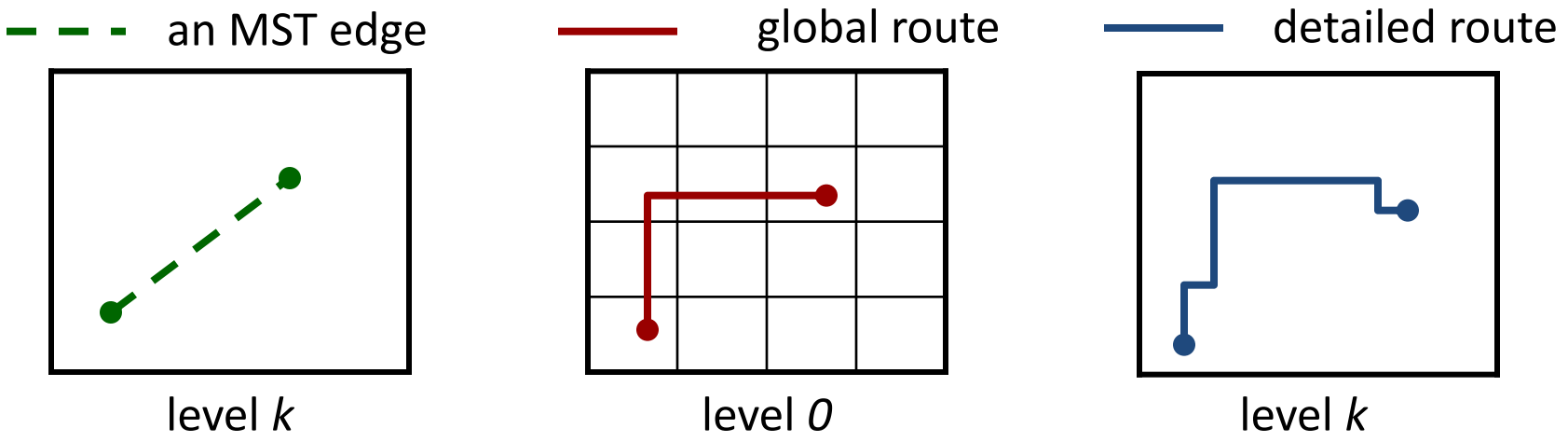
Use maze routing to reroute failed connections and refine the solution

Cost: congestion + net length

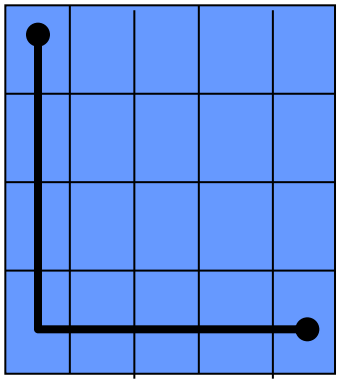
Coarsening Stage

- Build MSTs for all nets and decompose them into two-pin connections.
- Route **local nets (connections)** from level 0.
  - Two-stage routing (global + detailed routing) for a local net.

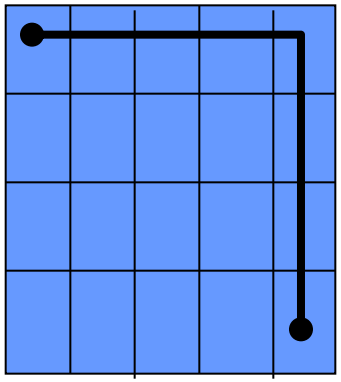


Global Routing

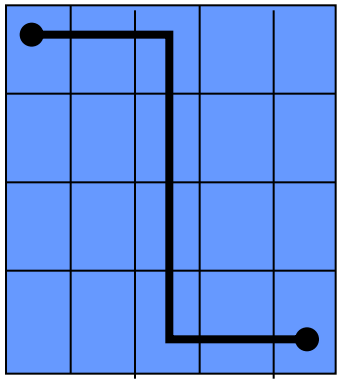
- Apply pattern routing for global routing
  - Use L-shaped and Z-shaped connections to route nets.
  - Has lower time complexity than maze routing.



Lower L-Shaped connection



Upper L-Shaped connection



Z-Shaped connection

Cost Function in Global Pattern Routing

$G_i = (V_i, E_i)$: multilevel routing graph at level i.

Define $R_e = \{e \in E_i \mid e \text{ is the edge chosen to route}\}$

Then

$$\text{cost}(R_e) = \sum_{e \in E} C_e,$$

where C_e is the congestion of edge e

and

$$C_e = \frac{1}{2^{(p_e - d_e)}},$$

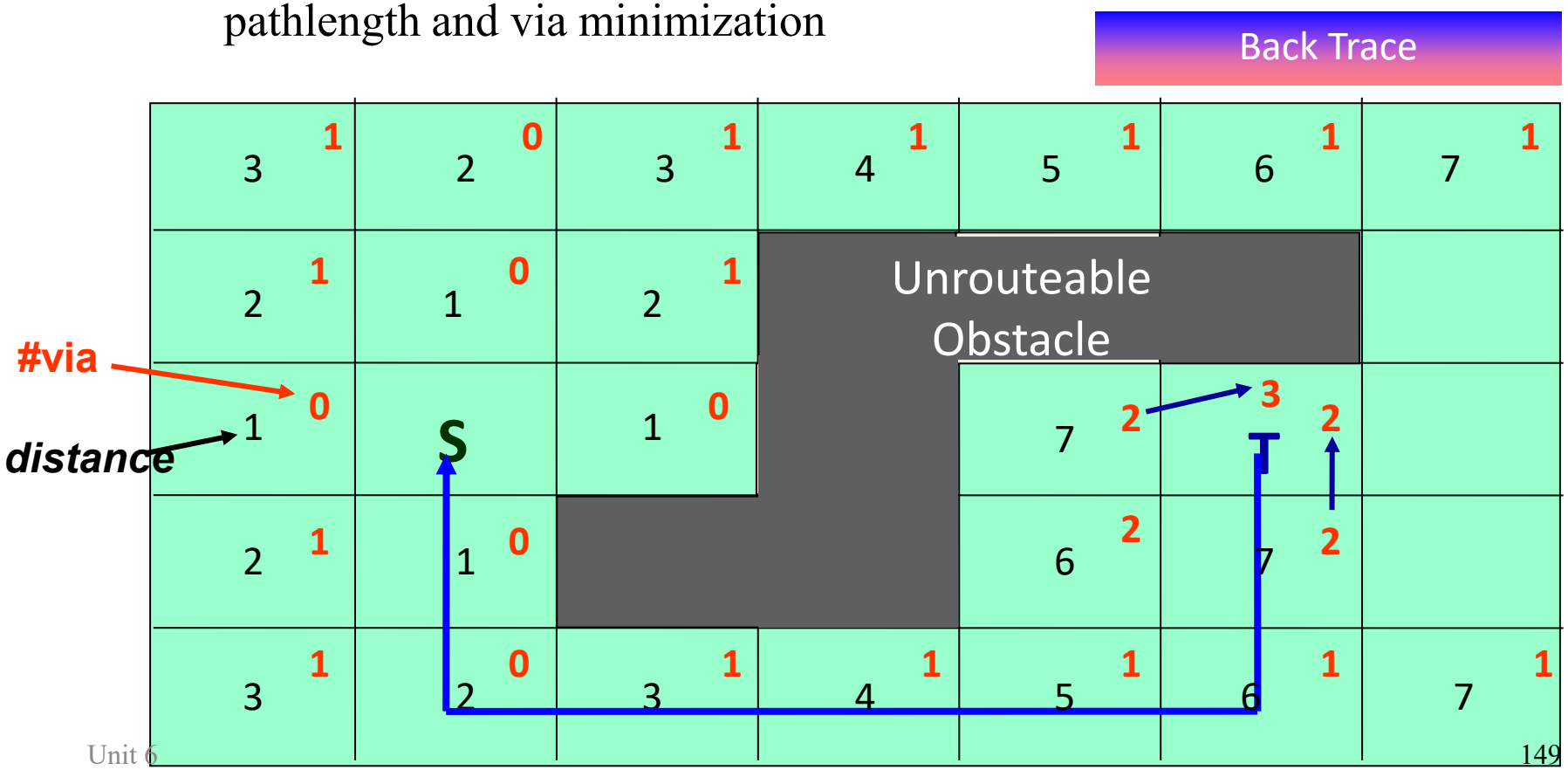
where p_e and d_e are the capacity and density associated with e, respectively.

Detailed Routing

- Via minimization
  - Modify the maze router to minimize the number of bends.
- Local refinement
  - Apply general maze routing to improve the detailed routing results.
- Resource estimation
  - Update the edge weights of the routing graph after detailed routing.

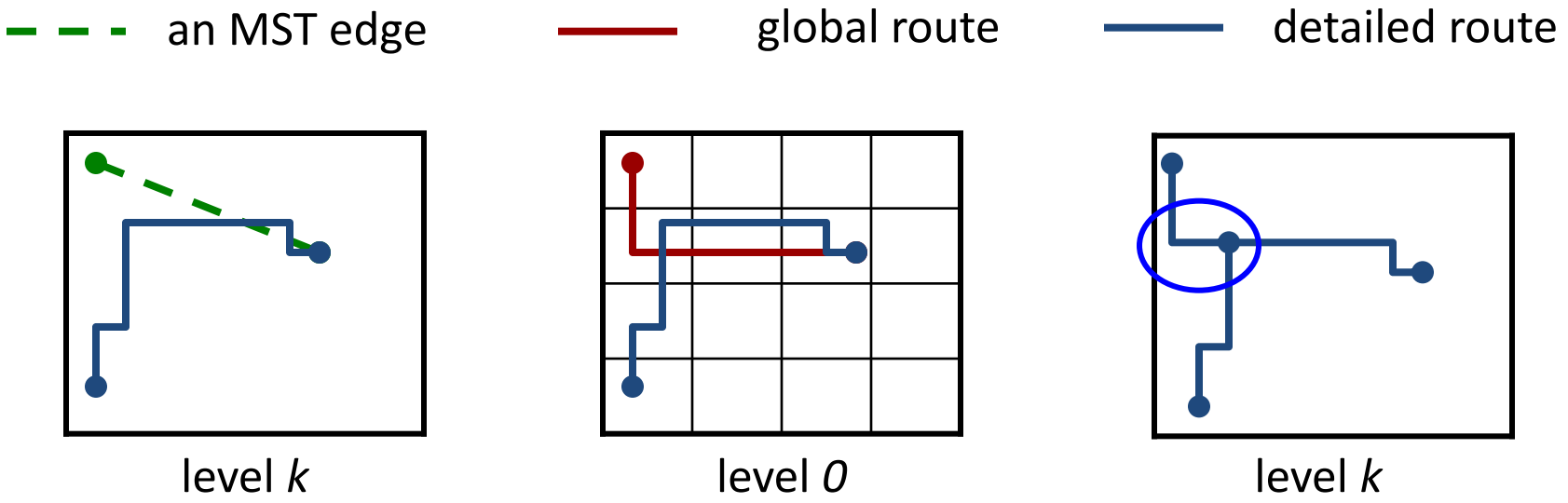
Via Minimization

- Simultaneous pathlength and via minimization (SPVM)
  - perform modified maze routing that simultaneously considers the pathlength and via minimization



Local Refinement

- Local refinement improves detailed routing results by merging two connections which are decomposed from the same net.



Resource Estimation

- Global routing cost is the summation of congestions of all routed edges.
- Define the congestion, C_e, of an edge e by

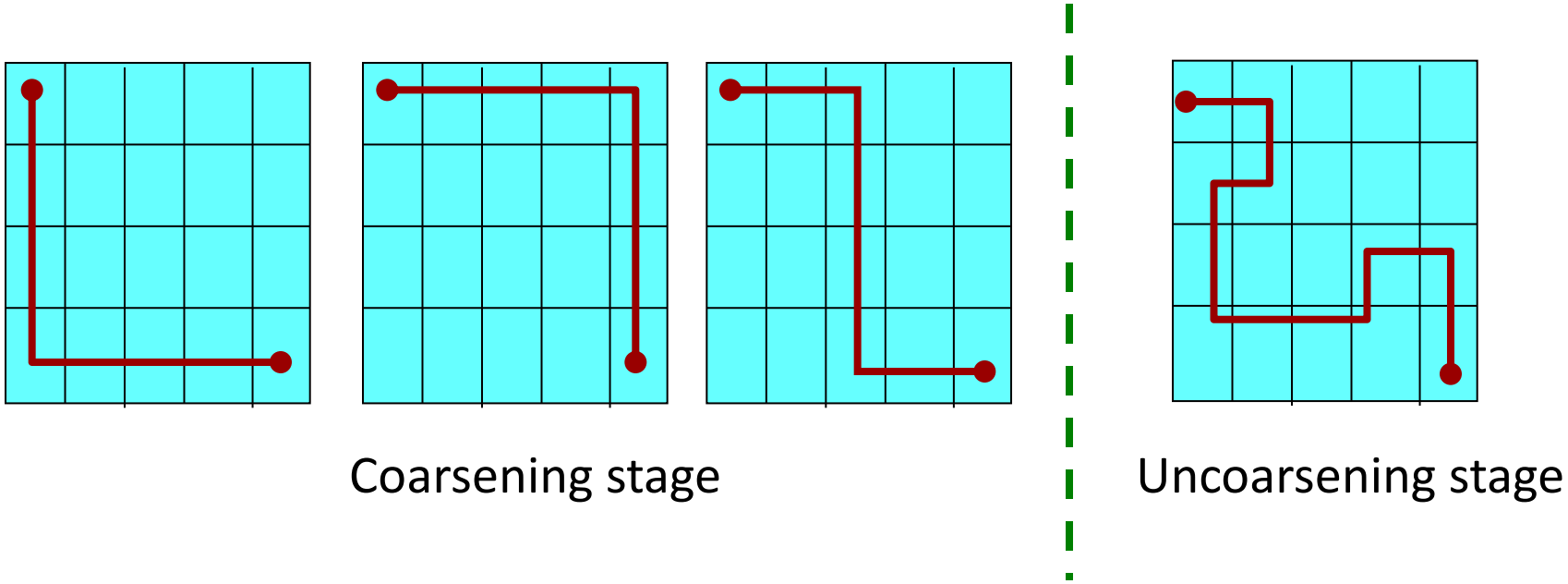
$$C_e = \frac{1}{2^{(p_e - d_e)}},$$

where p_e and d_e are the capacity and density, respectively.

- Update the congestion of routed edges to guide the subsequent global routing.

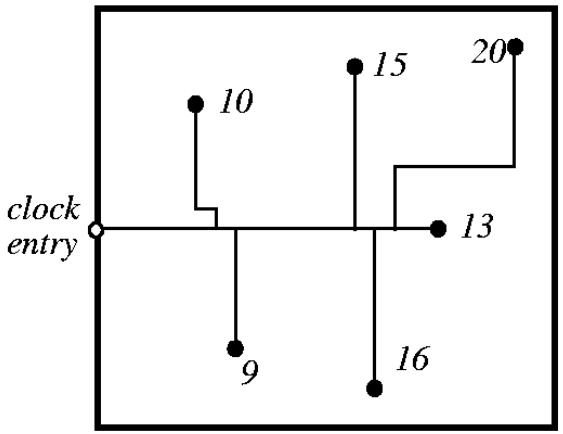
Uncoarsening Global Routing

- Use maze routing.
- Iterative refinement of a failed net is stopped when a route is found or several tries have been made.

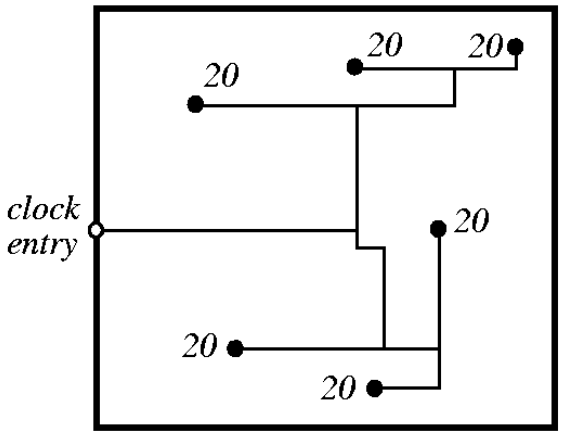


Clock Routing

- **Clock skew** is defined as the difference in the minimum and the maximum arrival time of the clock.



clock skew = 20 − 9 =11



clock skew = 0

- Route clock nets such that
  - Clock signals arrive simultaneously
  - Clock delay is minimized

    * Other issues: total wirelength, power consumption.

Clock Routing Problem

- Given the routing plane and a set of points $P=\{p_1,p_2,\ldots,p_n\}$ within the plane and clock entry point p_0 on the boundary of the plane, the **Clock Routing Problem (CRP)** is to interconnect each $p_i \in P$ such that $\max_{i,j\in P}|t(0,i)-t(0,j)|$ (skew) and $\max_{i\in P} t(0,i)$ (delay) are both minimized.
- Pathlength-based approaches
  - H-tree: Dhar, Franklin & Wang, *ICCD,* 1984.
  - Methods of means & medians (MMM): Jackson, Srinivasan & Kuh, *DAC*, 1990.
  - Geometric matching: Kahng, Cong & Robins, *IEEE TCAD*, 1993.
- RC-delay based approaches:
  - Exact zero skew: Tasy, *ICCAD*, 1991.
  - Deferred merge embedding (DME) algorithm: Boese & Kahng, ASICON-92; Chao, Hsu & Ho, DAC-92; Edahiro, NEC R&D, 1991.