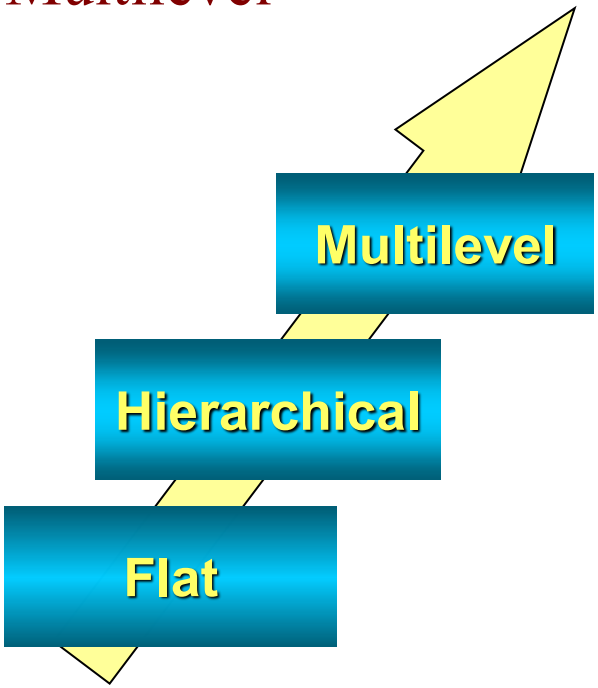
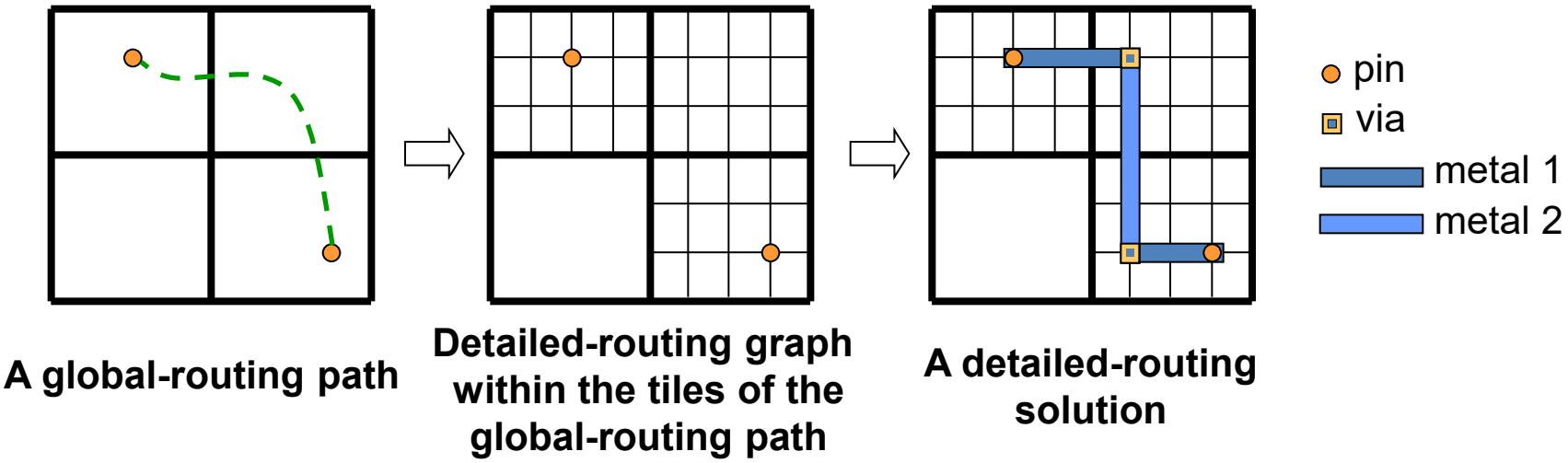
Routing Framework Evolution

- Billions of transistors may be fabricated in a single chip for nanometer technology.
- Need frameworks for very large-scale designs.
- Framework evolution for EDA tools:
  Flat ➔ Hierarchical ➔ Multilevel



Flat Routing Framework

- Global routing followed by detailed routing.
  - Maze searching, line searching, and/or A*-searching



- Drawback: hard to handle larger problems

Hierarchical Routing Framework

- The hierarchical approach recursively divides a routing region into a set of subregions and solve those subproblems independently.
- Drawbacks: lack the global information for the interaction among subregions.

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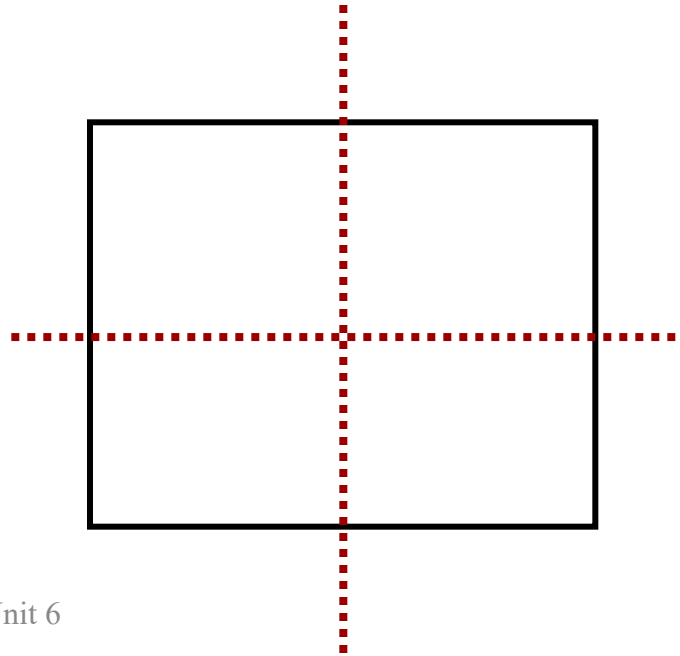

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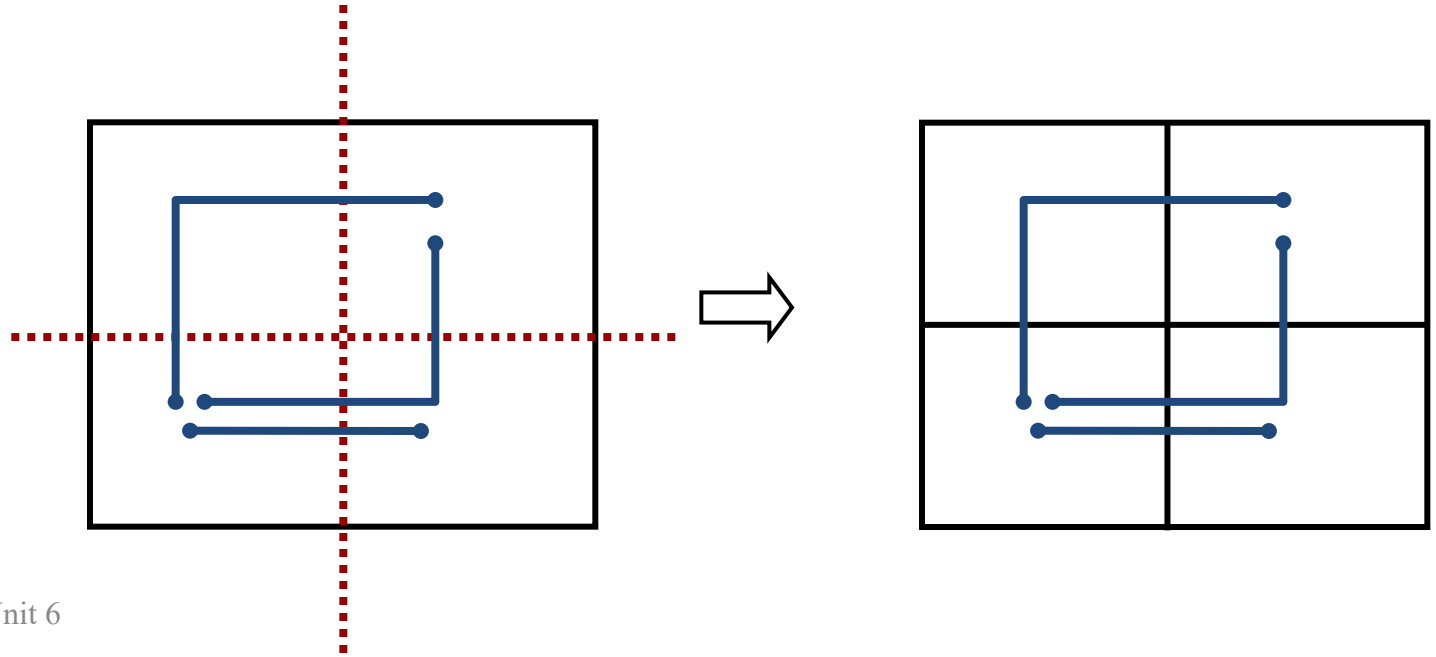

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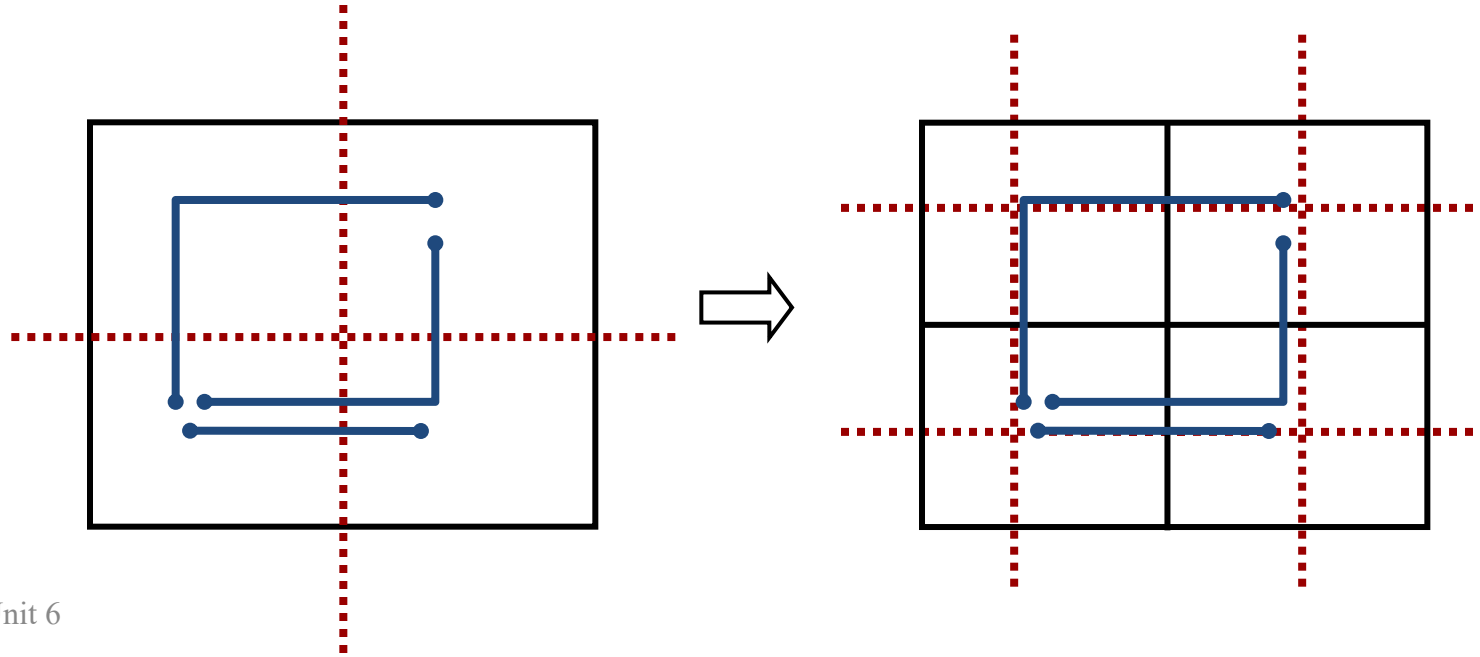

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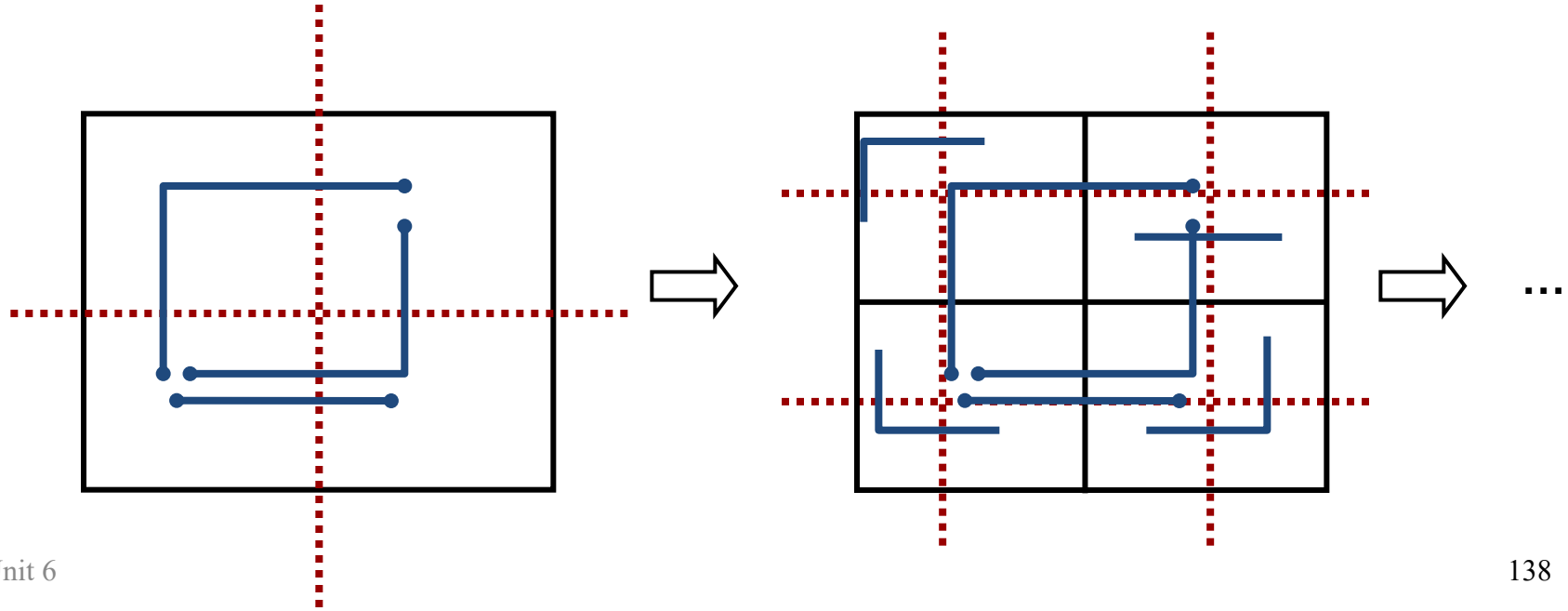


Multilevel Full-Chip Routing Framework

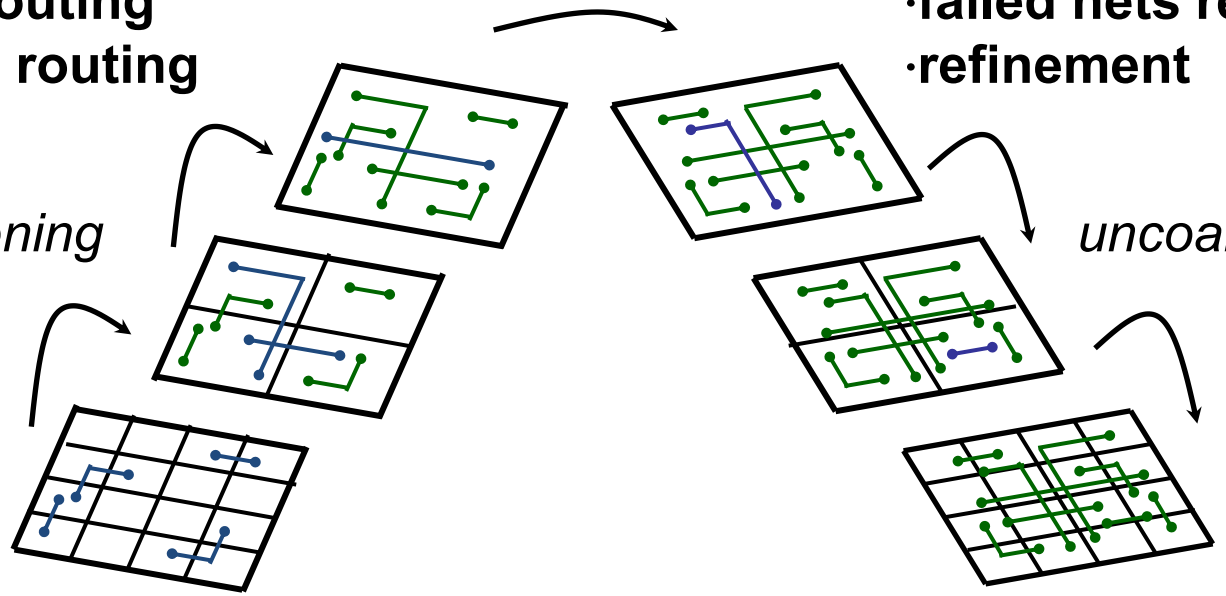
- Lin and Chang, "A novel framework for multilevel routing considering routability and performance," ICCAD-02 (TCAD-03).
- Multilevel framework: coarsening followed by uncoarsening.
- Coarsening (bottom-up) stage:
  - Constructs the net topology based on the minimum spanning tree.
  - Processes routing 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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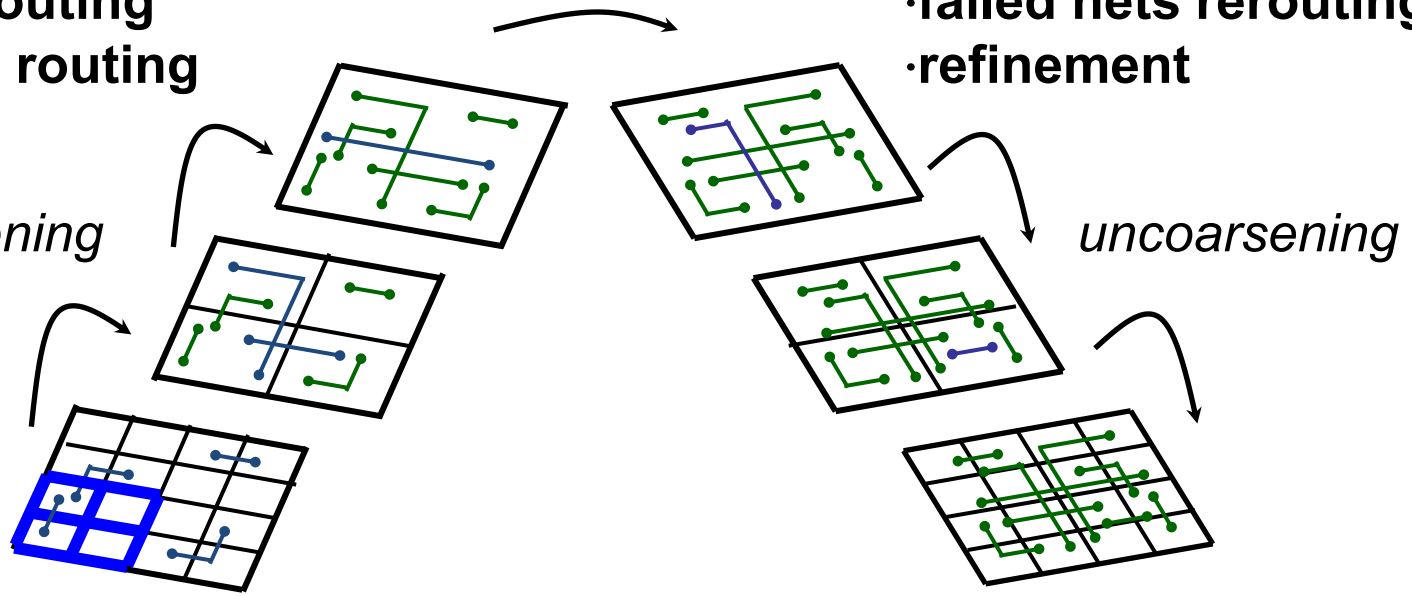

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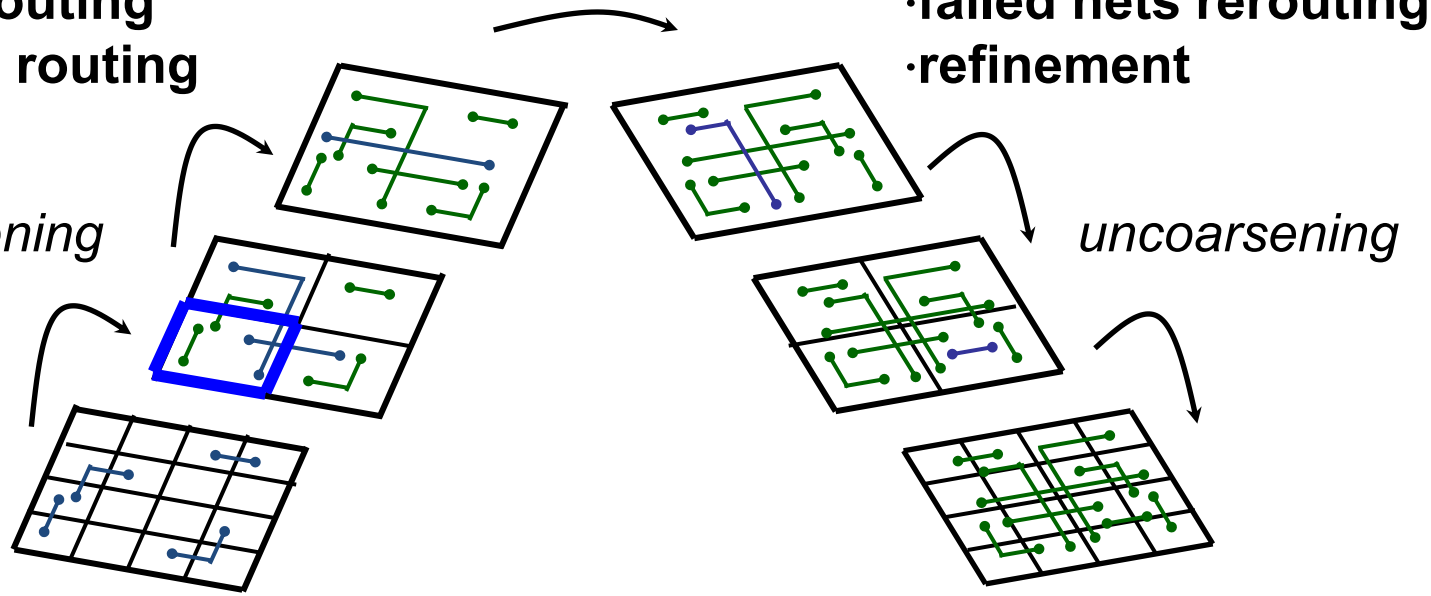

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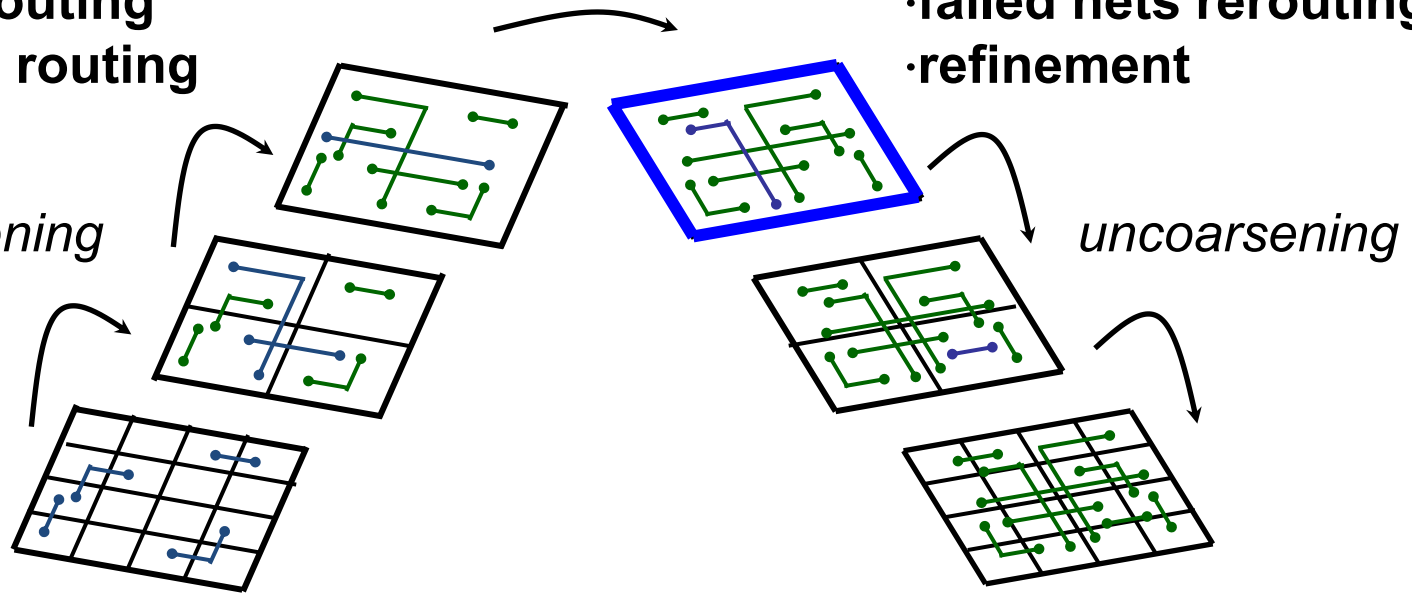

Perform global pattern & detailed routing for local connections and then estimate routing congestion for the next level

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A-Shaped Multilevel Routing Framework

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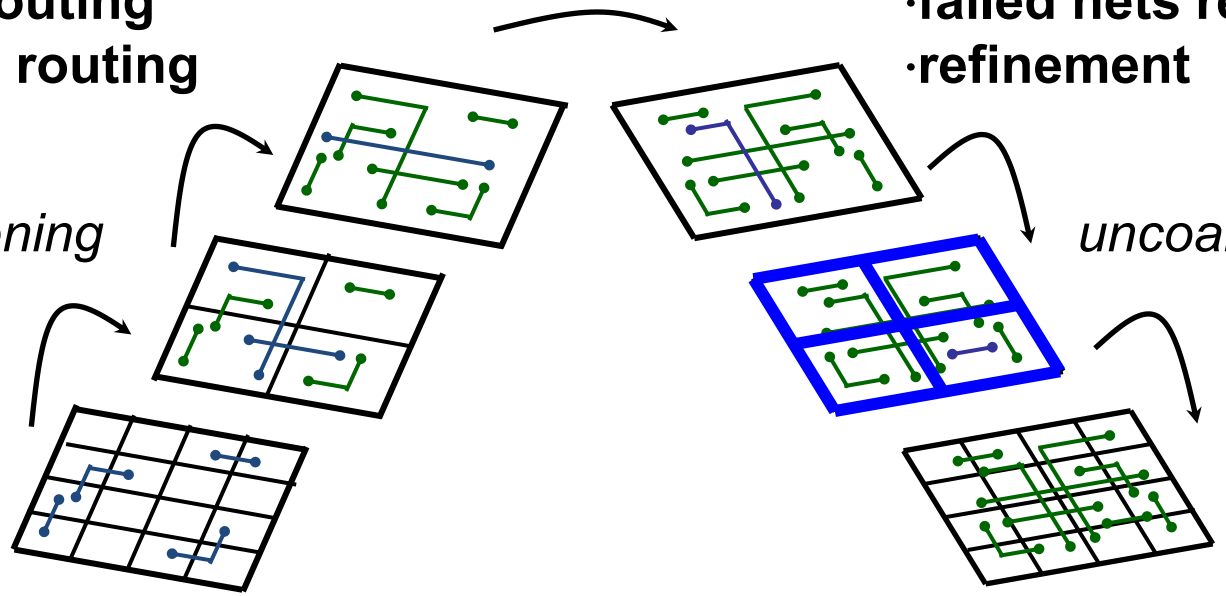

Perform global pattern & detailed routing for local connections and then estimate routing congestion for the next level

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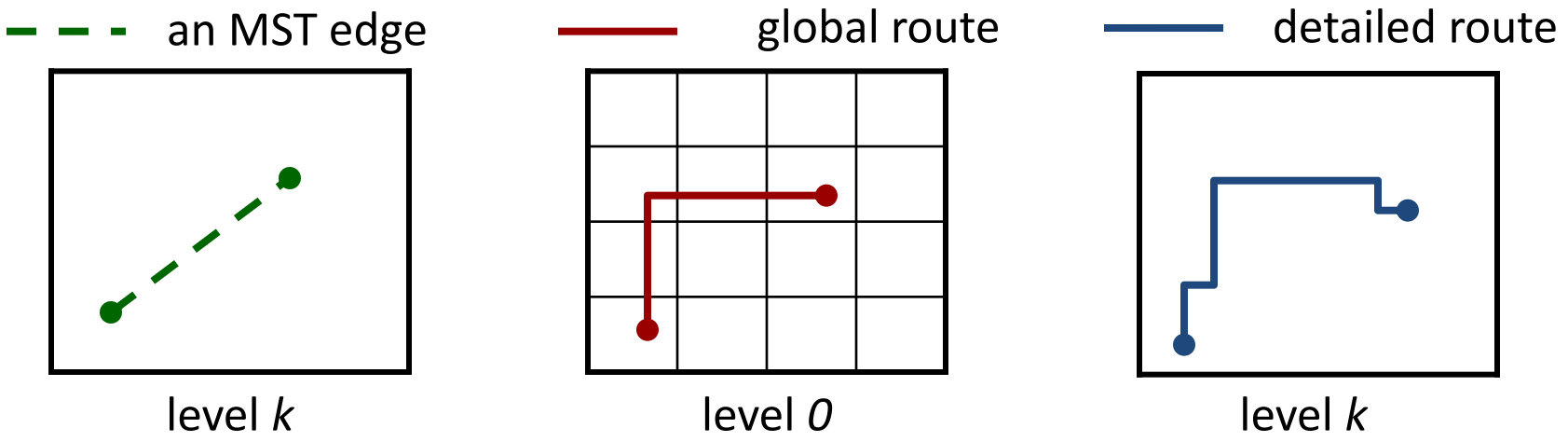
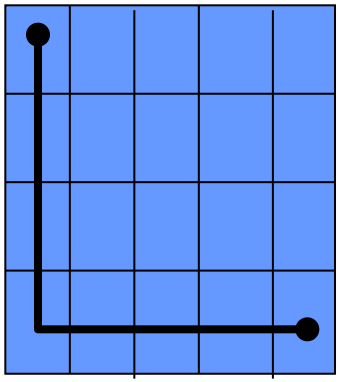
Coarsening Stage

- 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.

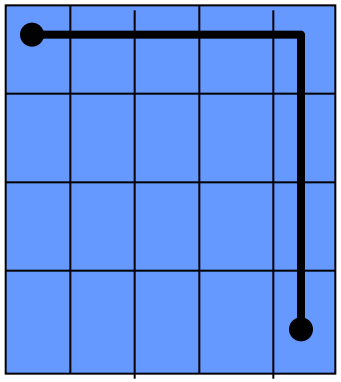


Global Routing

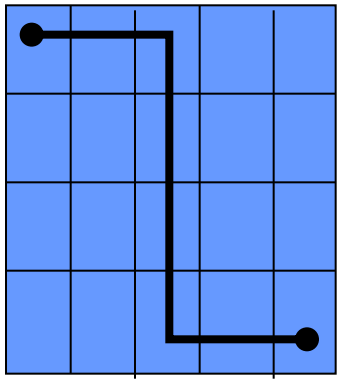
- Apply pattern routing for global routing
  - Use L-shaped and Z-shaped connections to route nets.
  - Has lower time complexity than maze routing.



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

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

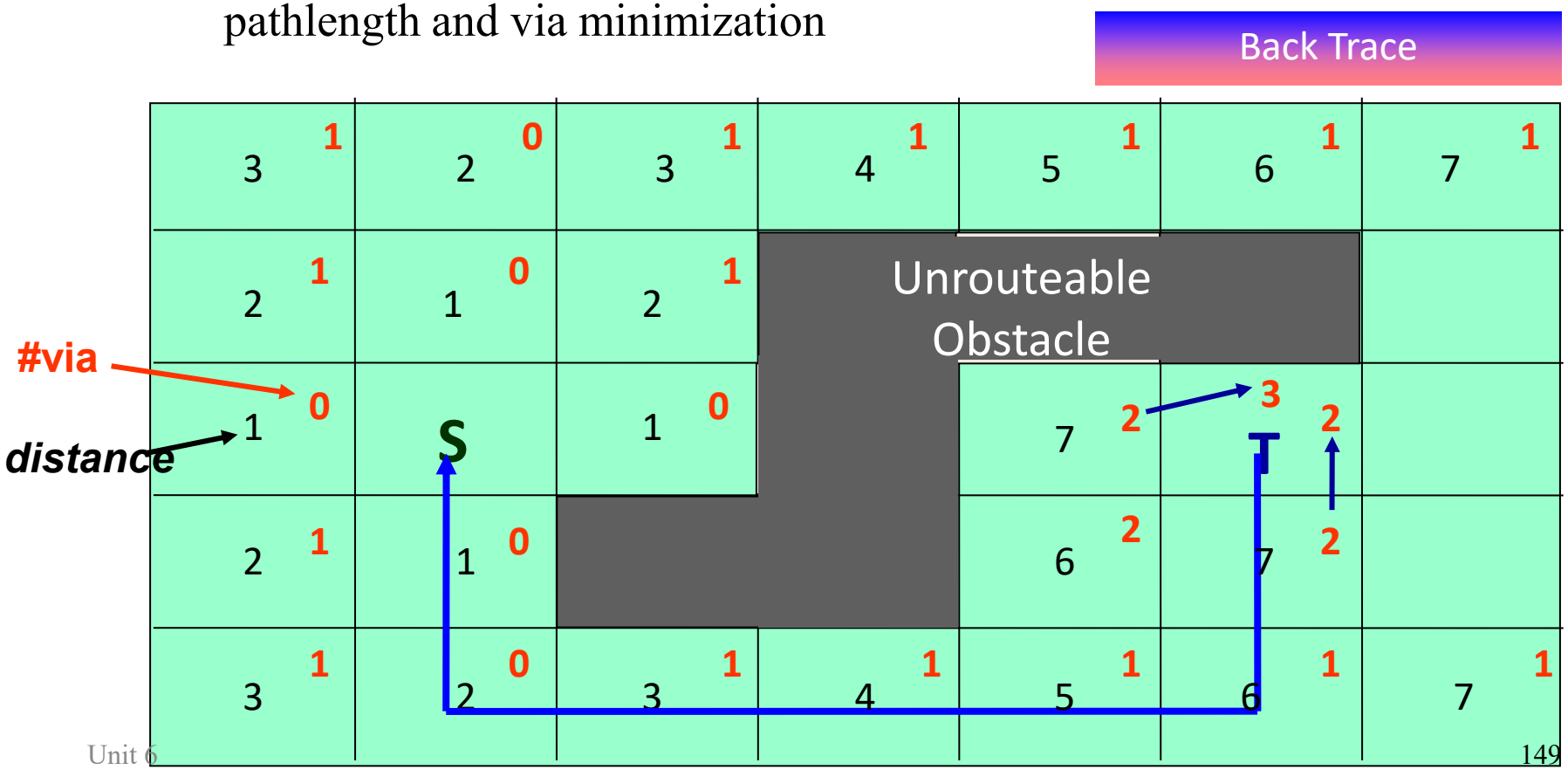
where p_e and d_e are the capacity and density associated with e, respectively.

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.

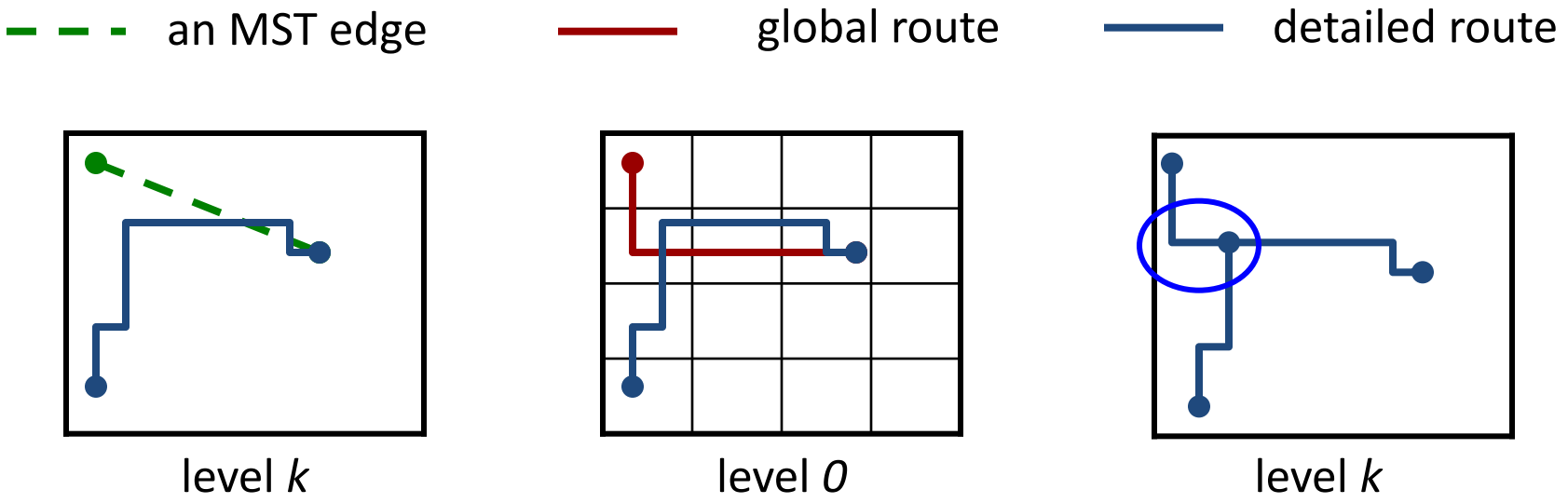
Via Minimization

- 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.