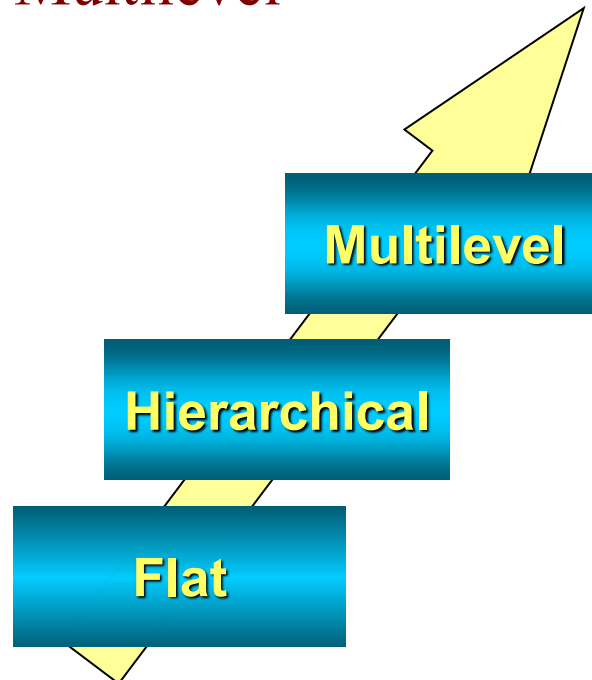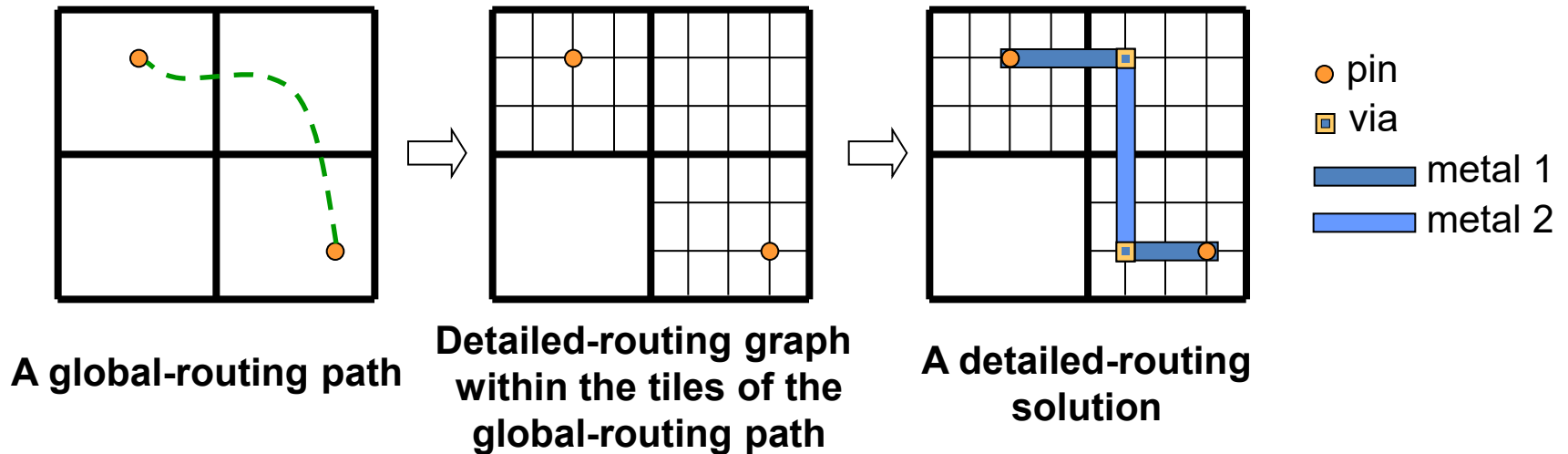# Routing Framework Evolution

- 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



**A global-routing path**

**Detailed-routing graph within the tiles of the global-routing path**

**A detailed-routing solution**

- pin
- via
- metal 1
- metal 2

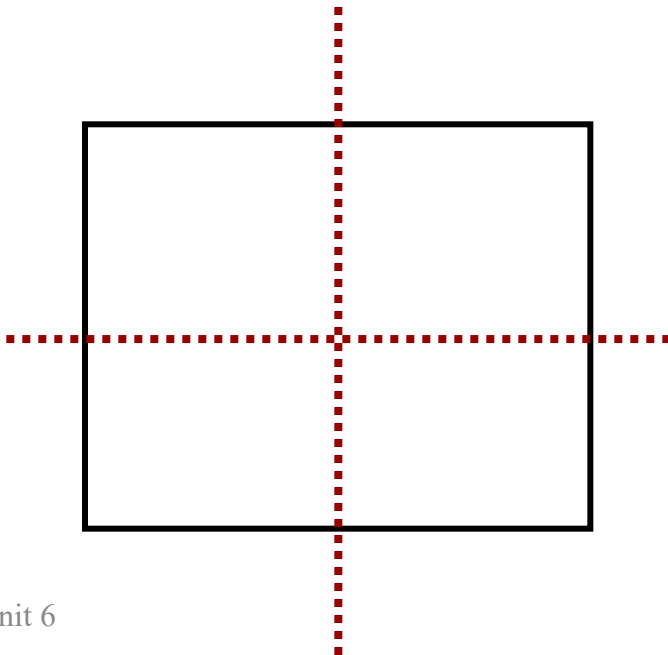- Drawback: hard to handle larger problems

# Hierarchical Routing Framework

- The hierarchical approach recursively divides a routing region into a set of subregions and solve those subproblems independently.

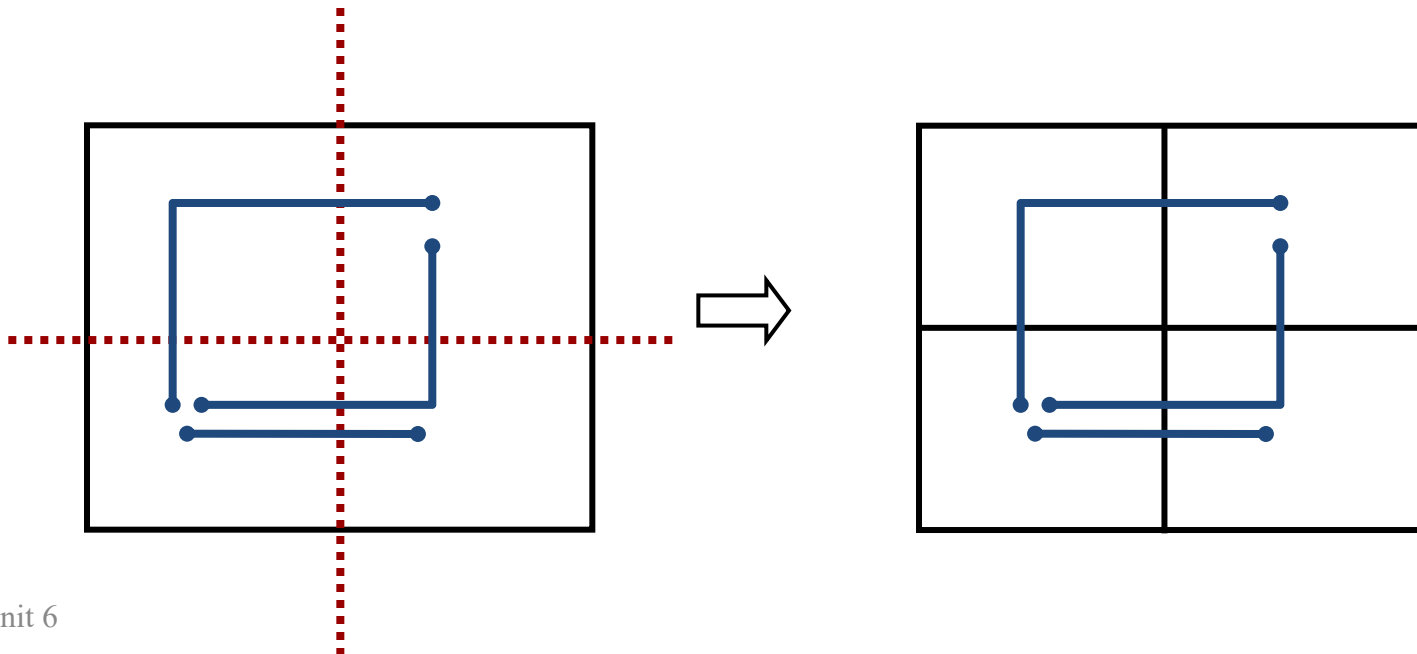- Drawbacks: lack the global information for the interaction among subregions.

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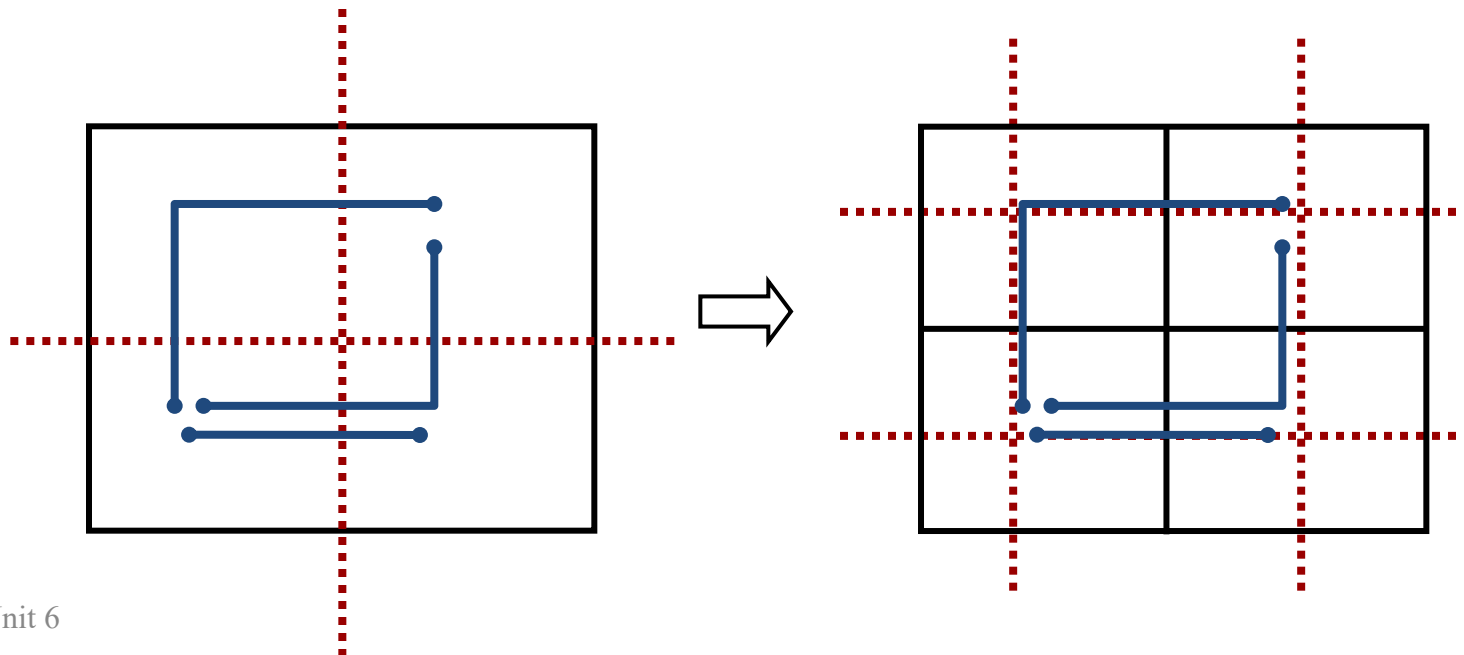- Drawbacks: lack the global information for the interaction among subregions.

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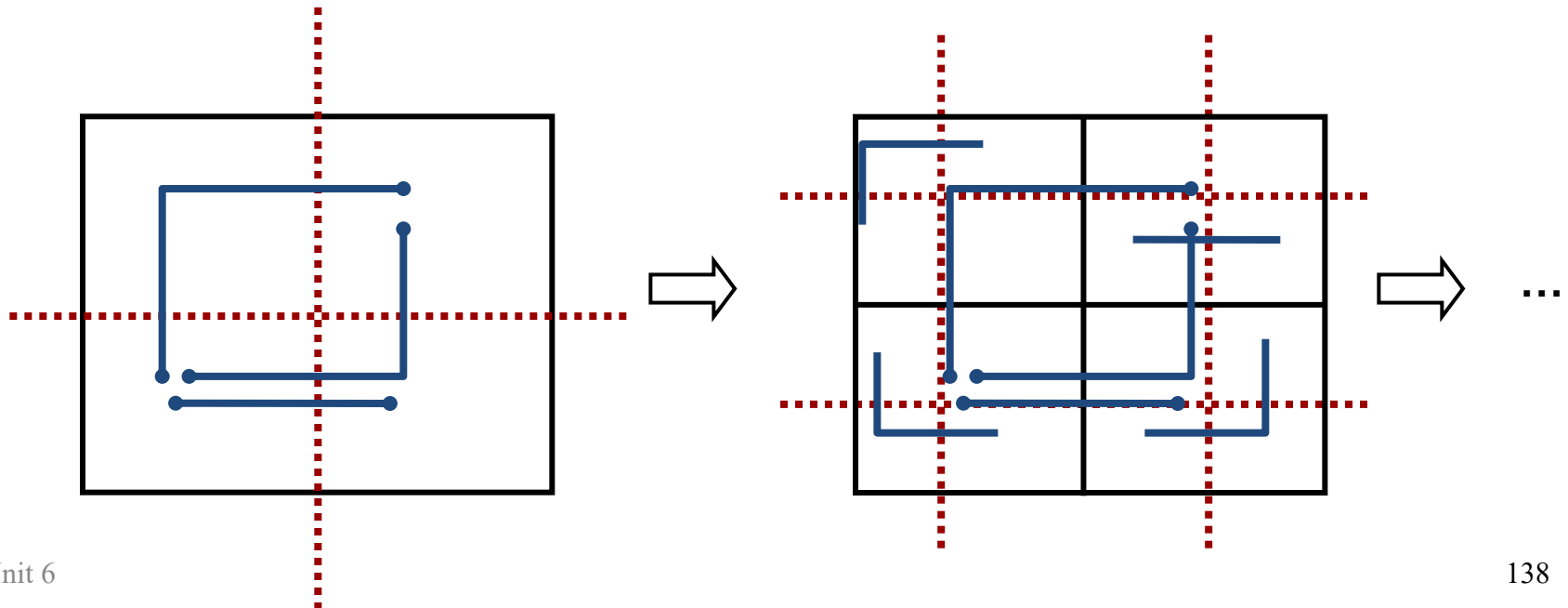- Drawbacks: lack the global information for the interaction among subregions.

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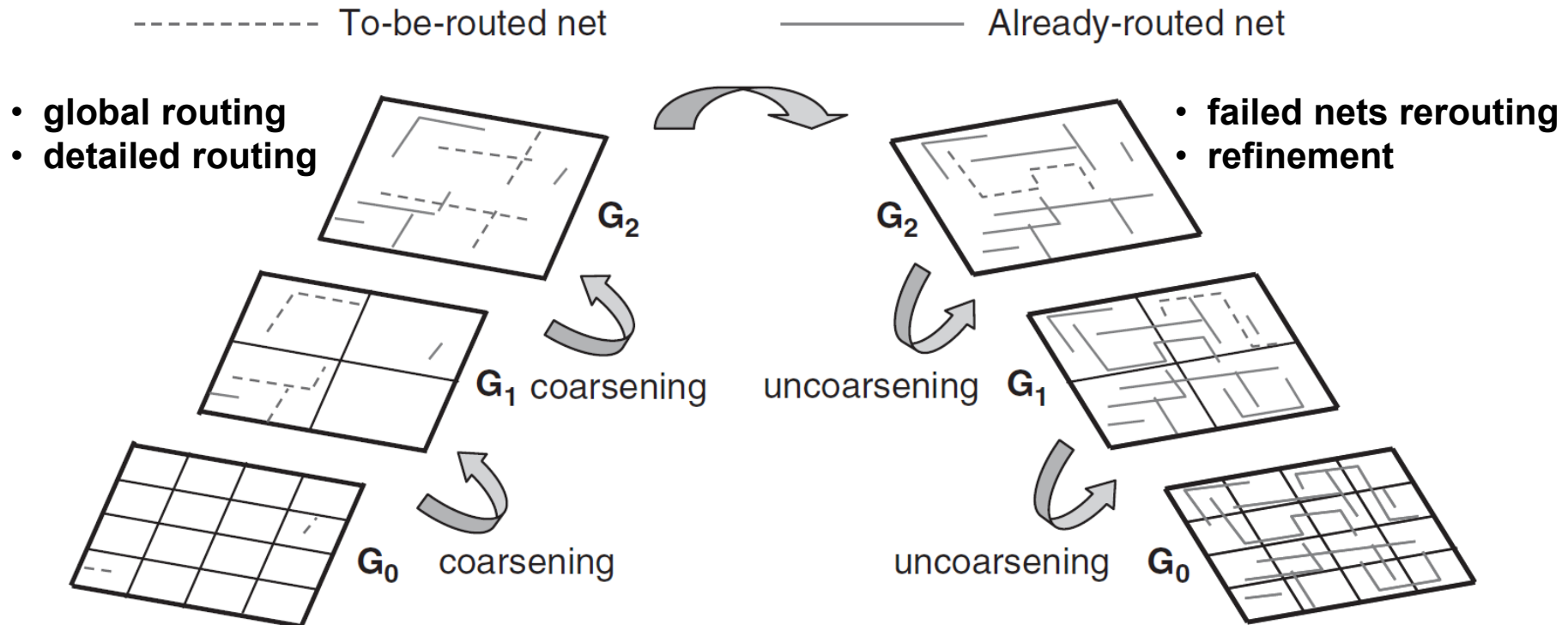
# Hierarchical Routing Framework

- 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.

# 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**

$G_2$

$G_1$ coarsening    uncoarsening    $G_1$

$G_0$ coarsening    uncoarsening    $G_0$

$G_2$

- **failed nets rerouting**
- **refinement**

Perform global pattern & detailed routing for local connections and then estimate routing congestion for the next level
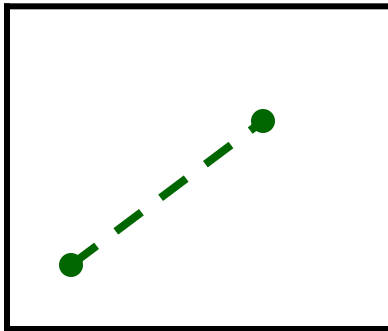
Use maze routing to reroute failed connections and refine the solution

Cost: congestion

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.
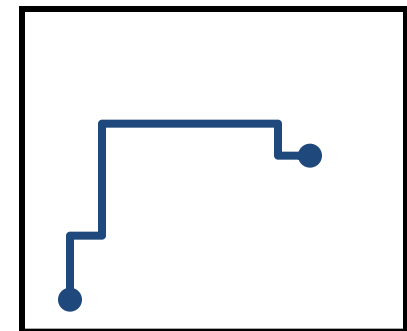


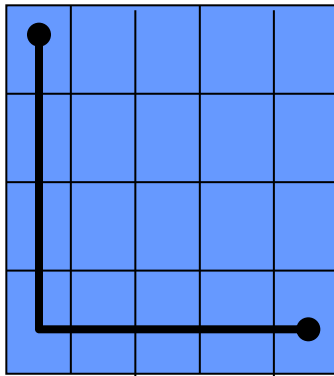- - - an MST edge       ⸻ global route       ⸻ detailed route
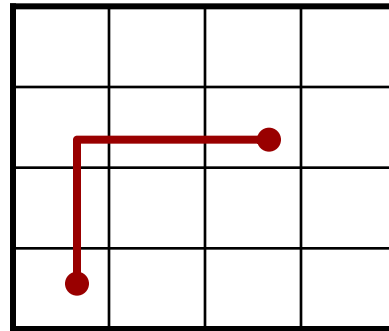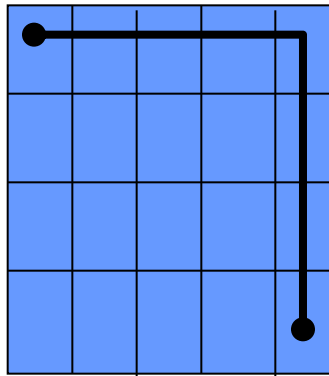
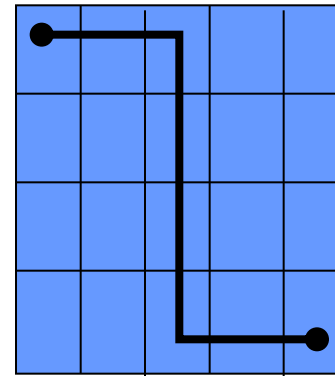level *k*       level *0*       level *k*

# 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 $R_e = \{e \in E_i \mid e$ 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.
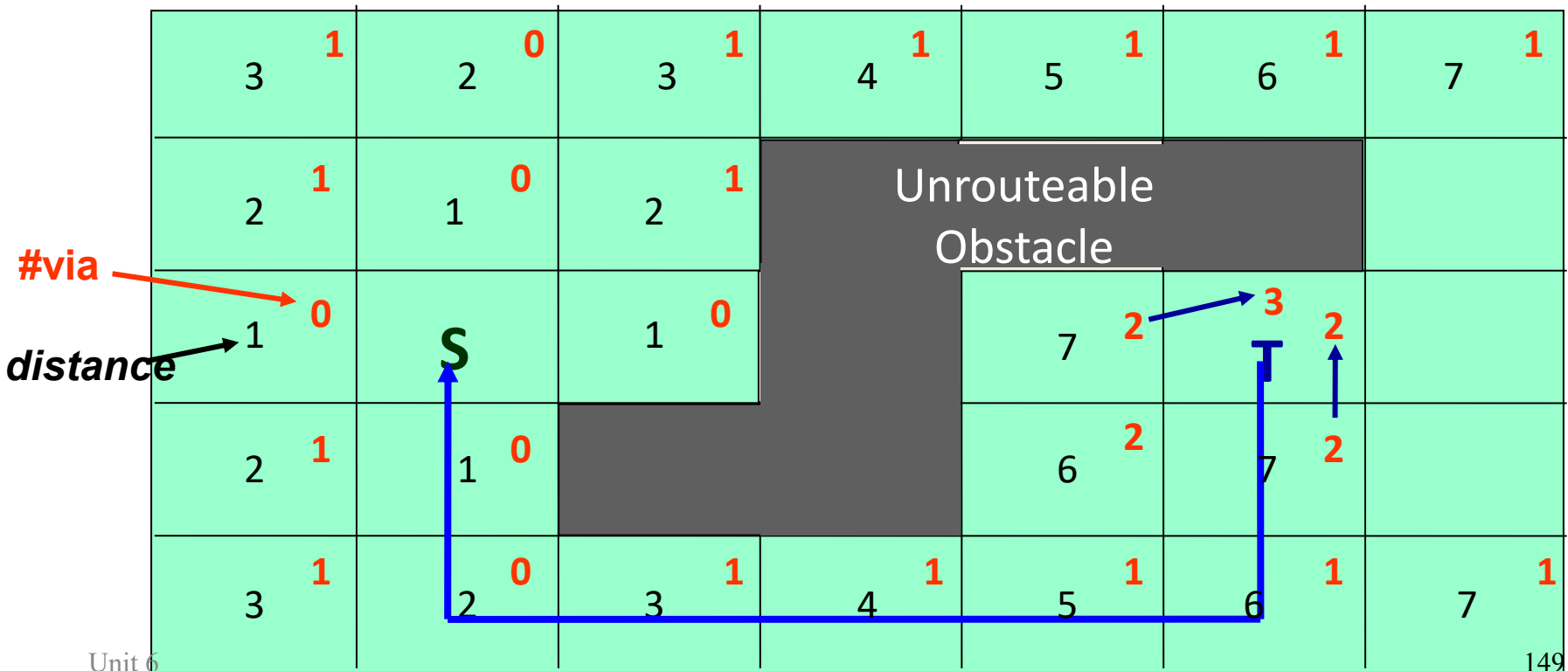
# Detailed Routing

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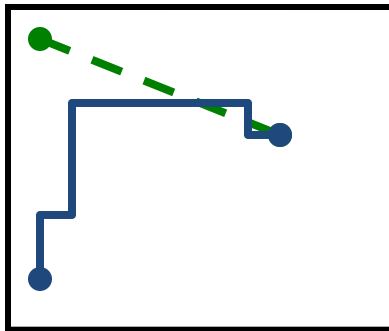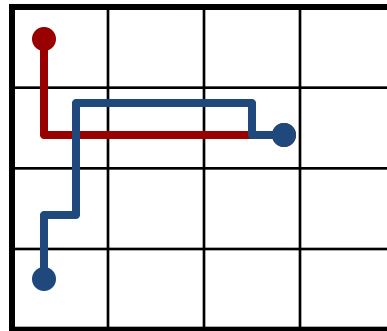  - perform modified maze routing that simultaneously considers the pathlength and via minimization

# Local Refinement

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

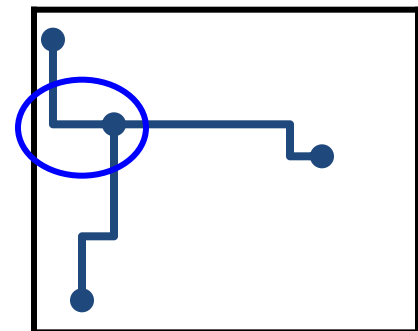- - - an MST edge ——— global route ——— detailed route



level *k*            level *0*            level *k*

# Resource Estimation

- Global routing cost is the summation of congestions of all routed edges.

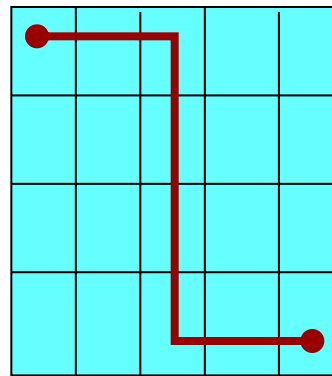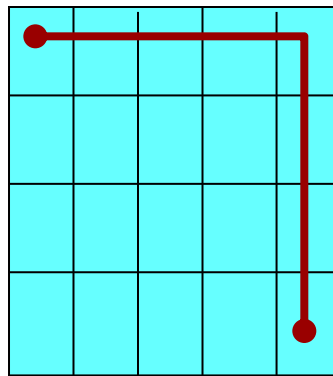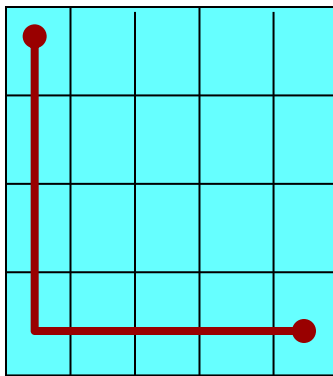- Define the congestion, $C_e$, of an edge $e$ by

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

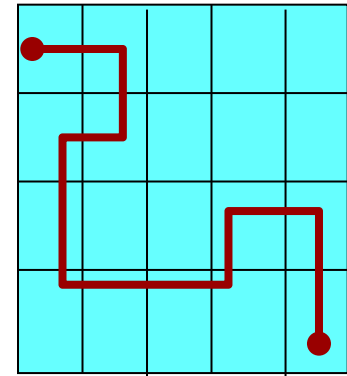  where $p_e$ and $d_e$ are the capacity and density, respectively.

- 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.



Coarsening stage

Uncoarsening stage