Routing

placement

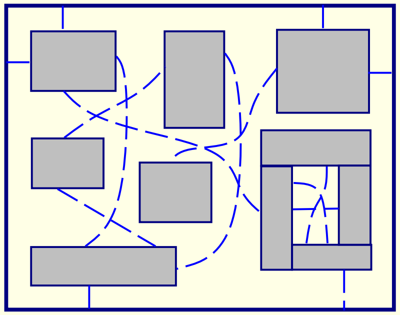
- Generates a "loose" route for each net.
- Assigns a list of routing regions to each net without specifying the actual layout of wires.

global routing

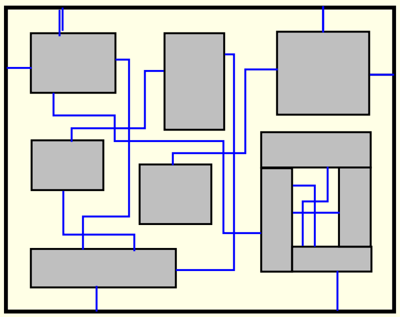
detailed routing

- Finds the actual geometric layout of each net within the assigned routing regions.

compaction



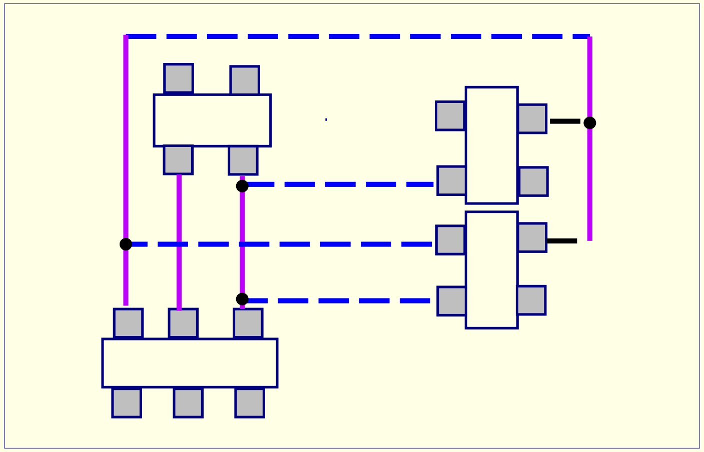
Global routing



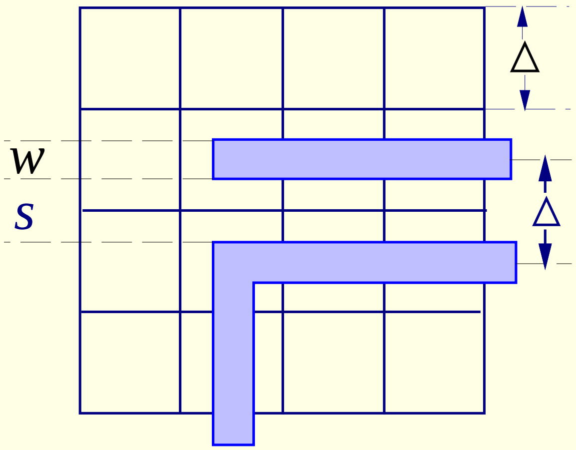
Detailed routing

Routing Constraints

- 100% routing completion + area minimization, under a set of constraints:
  - Placement constraint: usually based on fixed placement
  - Number of routing layers
  - Geometrical constraints: must satisfy design rules
  - Timing constraints (performance-driven routing): must satisfy delay constraints
  - Crosstalk?
  - Process variations?

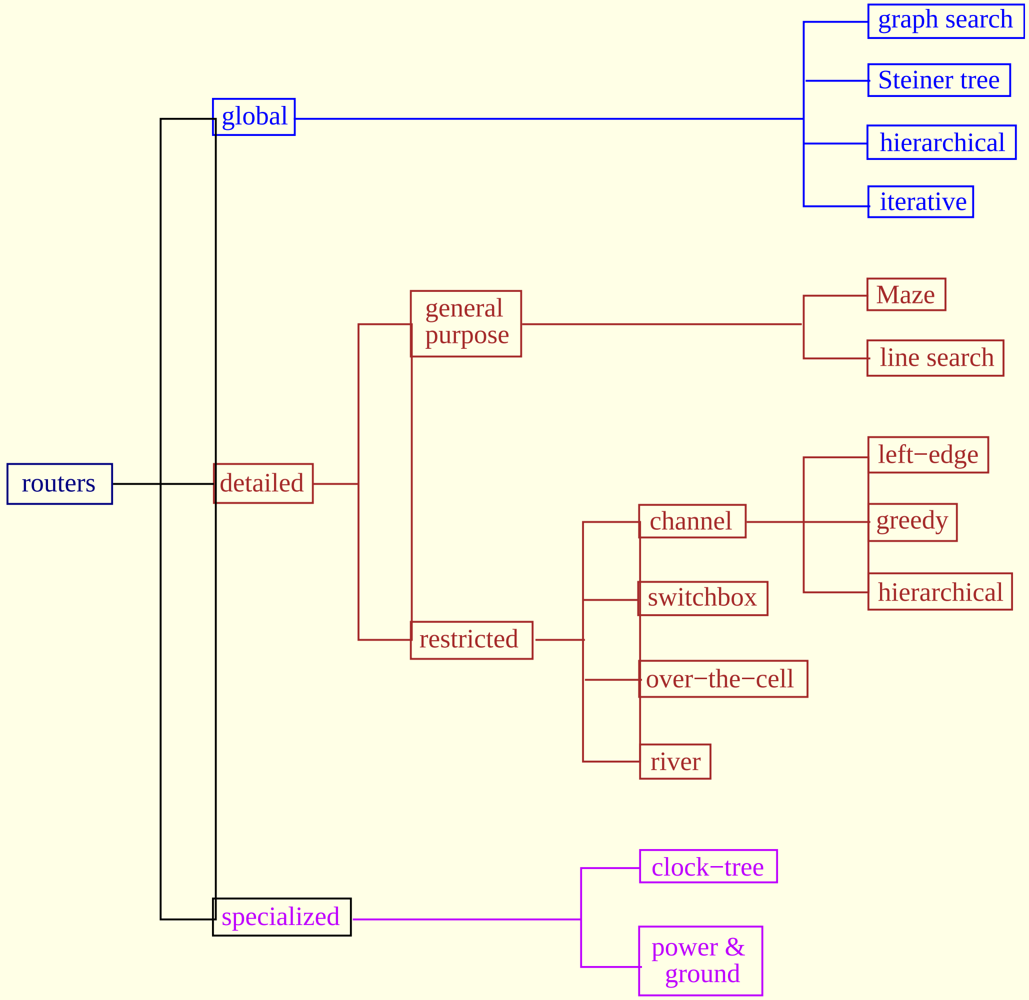


Two−layer routing



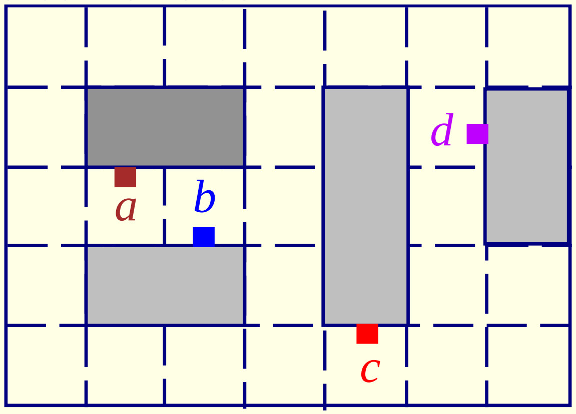
Geometrical constraint

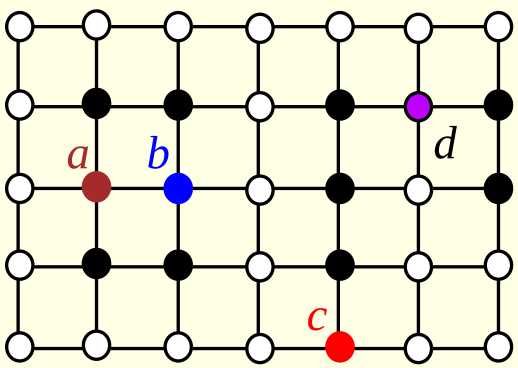
Classification of Routing



Graph Models for Global Routing: Grid Graph

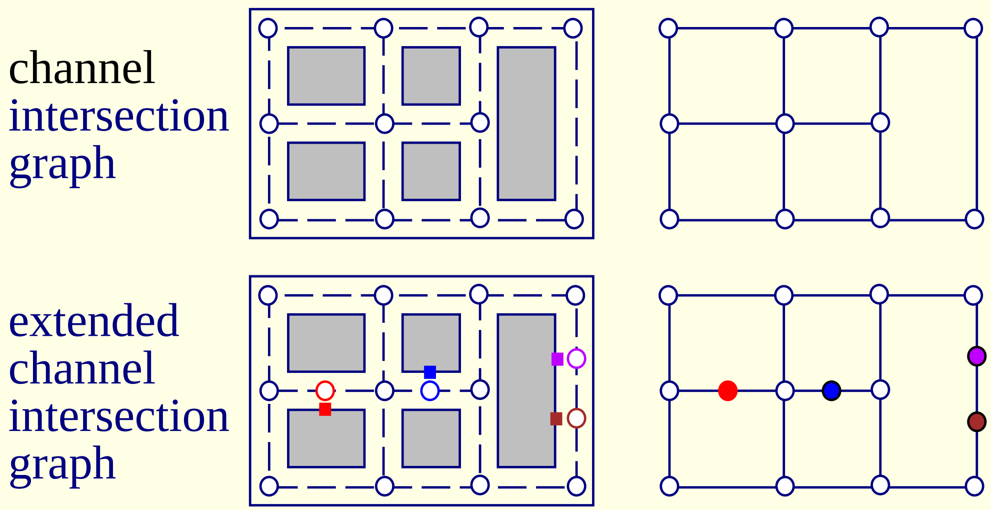
- Each cell is represented by a vertex.
- Two vertices are joined by an edge if the corresponding cells are adjacent to each other.
- The occupied cells are represented as filled circles, whereas the others are as clear circles.





Graph Model: Channel Intersection Graph

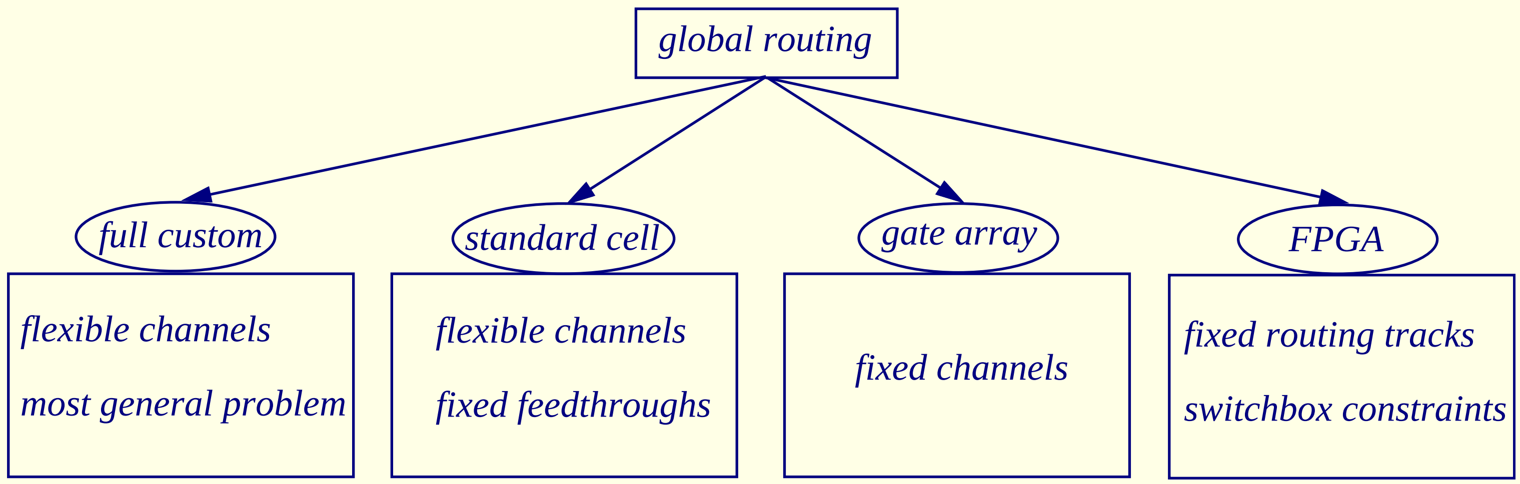
- Channels are represented as edges.
- Channel intersections are represented as vertices.
- Edge weight represents channel capacity.
- Extended channel intersection graph: terminals are also represented as vertices.



Global-Routing Problem

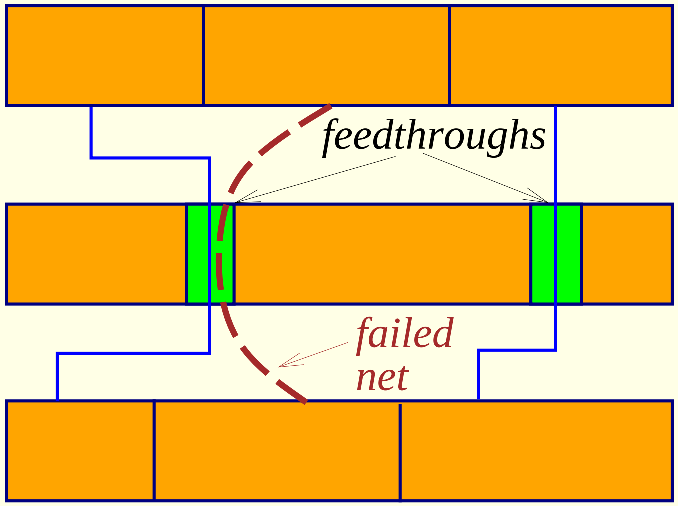
- Given a netlist N=$\{N_1, N_2, \ldots, N_n\}$, a routing graph $G = (V, E)$, find a Steiner tree T_i for each net N_i, $1 \leq i \leq n$, such that $U(e_j) \leq c(e_j)$, $\forall e_j \in E$ and $\sum_{i=1}^{n} L(T_i)$ is minimized,
  where
  - $c(e_j)$: capacity of edge e_j;
  - $x_{ij} = 1$ if e_j is in T_i; $x_{ij} = 0$ otherwise;
  - $U(e_j) = \sum_{i=1}^{n} x_{ij}$: # of wires that pass through the channel corresponding to edge e_j;
  - $L(T_i)$: total wirelength of Steiner tree T_i.
- For high-performance, the maximum wirelength ($\max_{i=1}^{n} L(T_i)$) is minimized (or the longest path between two points in T_i is minimized).

Global Routing in different Design Styles



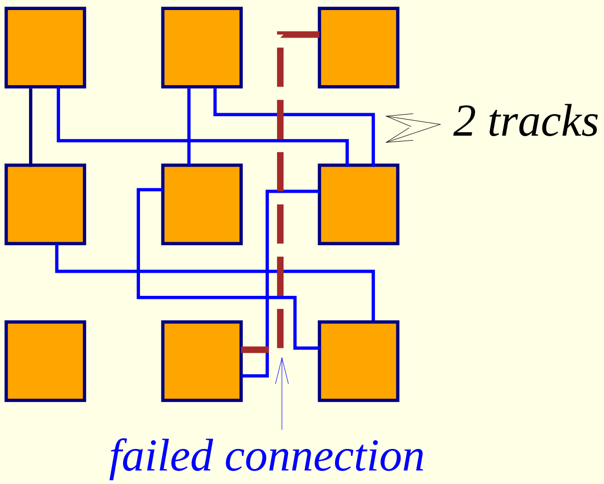
Global Routing in Standard Cell

- Objective
  - Minimize total channel height.
  - Assignment of **feedthrough**: Placement? Global routing?
- For high performance,
  - Minimize the maximum wire length.
  - Minimize the maximum path length.



Global Routing in Gate Array

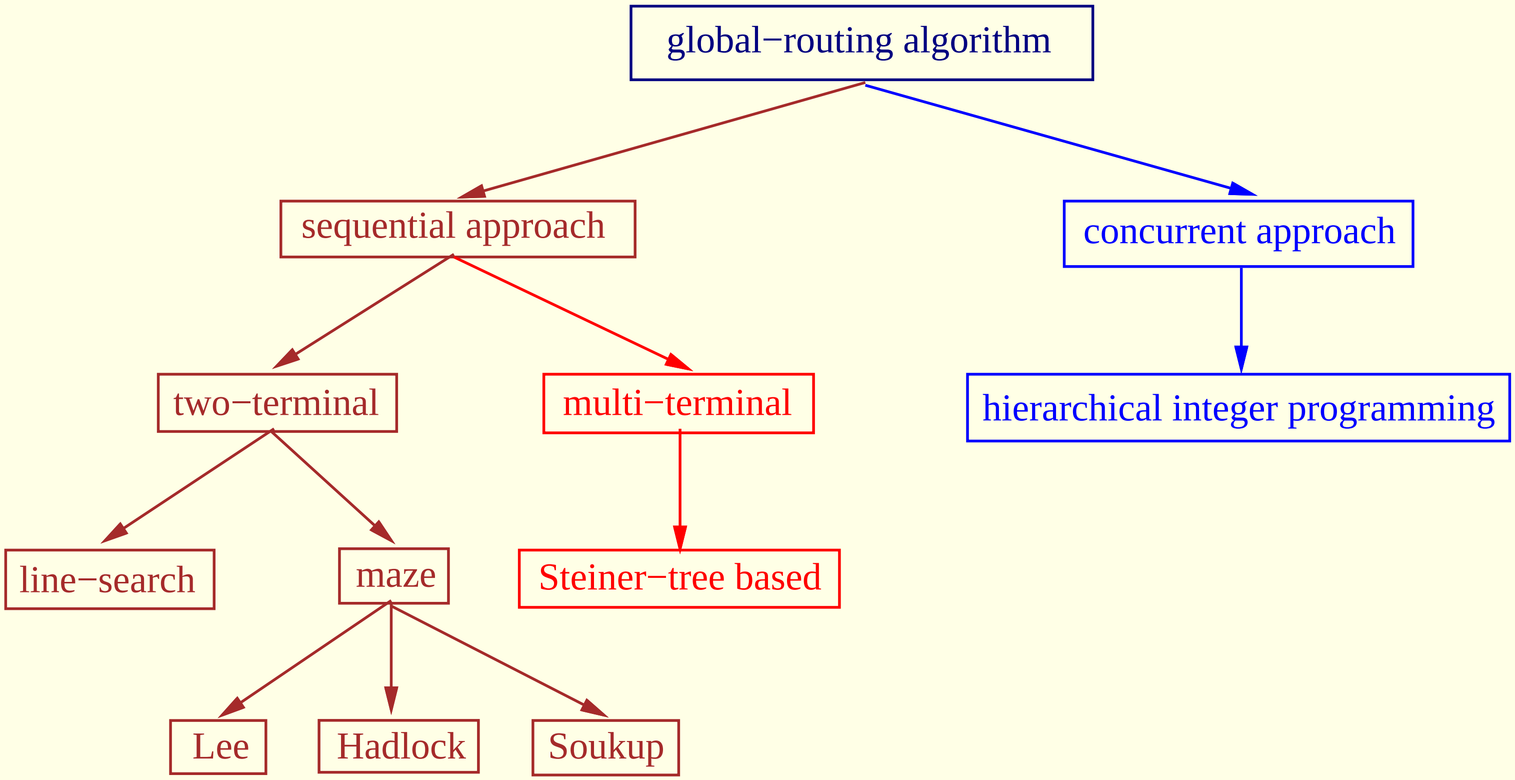
- Objective
  - **Guarantee 100% routability.**
- For high performance,
  - Minimize the maximum wire length.
  - Minimize the maximum path length.



Each channel has a capacity of 2 tracks.

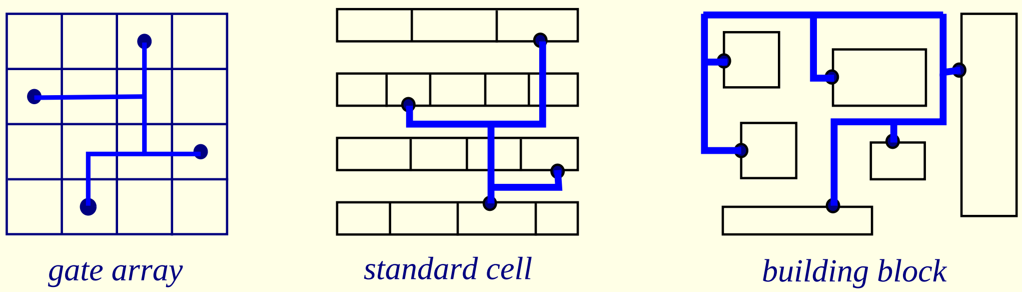
Classification of Global-Routing Algorithm

- **Sequential approach:** Assigns priority to nets; routes one net at a time based on its priority (net ordering?).
- **Concurrent approach:** All nets are considered at the same time (complexity?)

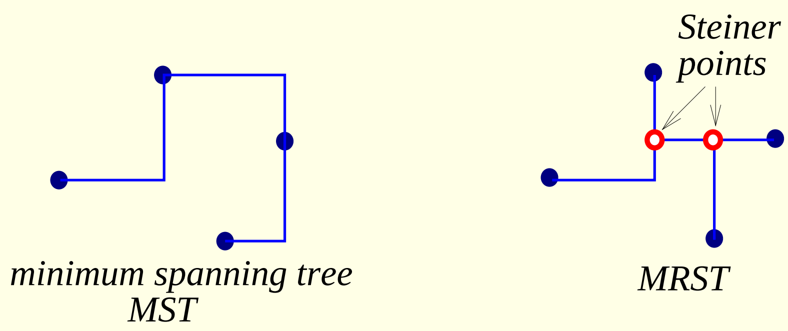


The Routing-Tree Problem

- **Problem:** Given a set of pins of a net, interconnect the pins by a "routing tree."

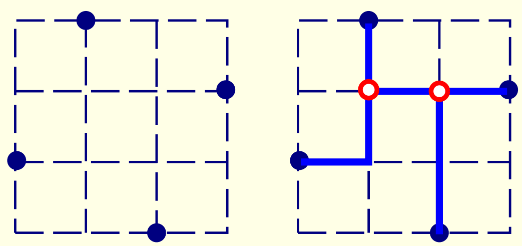


- **Minimum Rectilinear Steiner Tree (MRST) Problem:** Given n points in the plane, find a minimum-length tree of rectilinear edges which connects the points.
- $MRST(P) = MST(P \cup S)$, where P and S are the sets of original points and Steiner points, respectively.

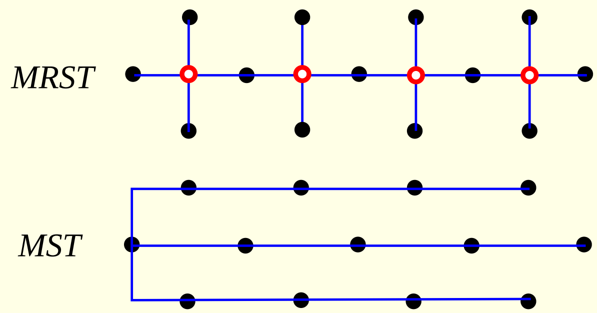


Theoretic Results for the MRST Problem

- **Hanan's Thm:** There exists an MRST with all Steiner points (set S) chosen from the intersection points of horizontal and vertical lines drawn points of P.
  - Hanan, "On Steiner's problem with rectilinear distance," SIAM J. Applied Math., 1966.
- **Hwang's Theorem:** For any point set P, $\frac{Cost(MST(P))}{Cost(MRST(P))} \leq \frac{3}{2}$.
  - Hwang, "On Steiner minimal tree with rectilinear distance," SIAM J. Applied Math., 1976.
- Best existing approximation algorithm: Performance bound $\frac{61}{48}$ by Foessmeier et al.
  - Foessmeier et al, "Fast approximation algorithm for the rectilinear Steiner problem," Wilhelm Schickard-Institut für Informatik, TR WSI-93-14, 93.
  - Zelikovsky, "An $\frac{11}{6}$ approximation algorithm for the network Steiner problem," Algorithmica., 1993.



Hanan grid



Cost(MST)/Cost(MRST) −> 3/2

A Simple Performance Bound

- Easy to show that $\frac{Cost(MST(P))}{Cost(MRST(P))} \leq 2$.
- Given any MRST T on point set P with Steiner point set S, construct a spanning tree T' on P as follows:
  1. Select any point in T as a root.
  2. Perform a depth-first traversal on the rooted tree T.
  3. Construct T' based on the traversal.