Compaction

Squeeze layout to reduce chip area
Helps eliminate inefficiencies caused by other steps

Partitioning
Floorplanning
Placement
Global Routing
Detailed Routing
Compaction
Compaction Example

Minimize channel height. Minimum 3λ spacing, 3λ wide metal, 7λ wide vias
Compaction Process

1D vs. 2D compaction
2D too complex – compact vertically, then horizontally, then repeat

Use design rules to set constraints
Minimum separation
Connectivity & minimum wire width
Constraint Graph

Represent rectangles by their edge(s)

Fixed dimension block requiring one edge

Variable dimension block requiring two edges
Constraint Graph (cont.)

Represent constraints in a directed graph.
Edge weights represent minimum separation.

Minimum Separation

\[ \begin{align*}
\text{A} & \quad \text{B} \\
\geq 6 & \\
\end{align*} \]

\[ \begin{align*}
B & \geq A + 6 \\
\end{align*} \]

Exact Separation

\[ \begin{align*}
\text{C} & \quad \text{D} \\
8 & \\
E + 2 & = F + 20 \\
E & = F + 18 \\
\end{align*} \]

\[ \begin{align*}
D & = C + 8 \\
D & \geq C + 8 \\
C & \geq D - 8 \\
\end{align*} \]

Overlap

\[ \begin{align*}
\text{E} & \quad \text{F} \\
2 & \\
\end{align*} \]

\[ \begin{align*}
F + 18 & \geq E \geq F \\
F & \geq E - 18 \\
E & \geq F \\
\end{align*} \]
Constraint Graph Generation: Shadow Propagation

Move to the right, finding other objects
Add nodes L (leftmost) and R (rightmost) to designate sides.
Longest-Path in Acyclic Graphs

Label L with longest path 0
While nodes not all labeled
Find node with no unlabeled predecessors
Label node with longest path, based on predecessor labels
Longest-Path in Cyclic Graphs

Cycle types:
- Zero weight cycles
- Negative weight cycles
- Positive weight cycles

B = A + 8

C - 10 ≤ D
D - 10 ≤ C
D ≤ C + 10

C is within 10 of D

A → B
B → A

C → D
D → C

E → F
F → E

H → I
I → H

G → E
E → F

New offer

\( E + 2 \leq F \)
\( F + 4 \leq E \)
\( F \leq E - 4 \)

\( E + 2 \leq F \leq E - 4 \)
Longest-Path: Liao-Wang

Identify backward edges
Do until convergence, $|V|$ times maximum
  Run DAG (directed acyclic graph) longest path on forward edges
  Propagate information across backward edges
If it fails to converge there is a positive-weight cycle
Longest-Path: Bellman-Ford

Wavefront = L
While wavefront not empty, but for a maximum of |V| iterations
  For all neighbors of wavefront nodes
    If path to neighbor is longer than any prior path to that node
      Add neighbor to new_wavefront
  Wavefront = new_wavefront
If it fails to converge there is a positive-weight cycle.
Critical Path Analysis

Go from left to right finding leftmost position for each node
Go from right to left finding rightmost position for each node
Place cells within their range of freedom

  Longest path (the constraining path) in the graph has fixed nodes

Options:
1.) Leftmost
2.) Rightmost
3.) Middle of range
4.) Force-directed within range

Note: Leftmost or rightmost densely packs – may make 2nd pass harder.
Critical Path Analysis Example
Example

Example using left/top position. Do horizontal compaction.
Fixed sized metal blocks, 3 lambda separation required

L = 0
A = 0
E, D, C = 6
F = 15
G = 21
R = 241
Example (cont.)

Vertical compaction on previously compacted layout (use top positioning)

\[ T = 0 \]
\[ A, E, G = 0 \]
\[ D, F = 10 \]
\[ C = 18 \]
\[ B = 23 \]
Example (cont.)

Continue iterating: Horizontal

A
3x16

D
3x5

C
6x5

E
8x7

F
3x3

G
3x12

L = 0
A = 0

\& \therefore \frac{P_C}{E} = 6

F = 12

G = 18

R = 21
Example (cont.)

Final result

A 3x16

D 3x5

E 8x7

C 6x5

F 3x3

G 3x12