Cut-Demand Based Routing Resource Allocation and Consolidation for Routability Enhancement

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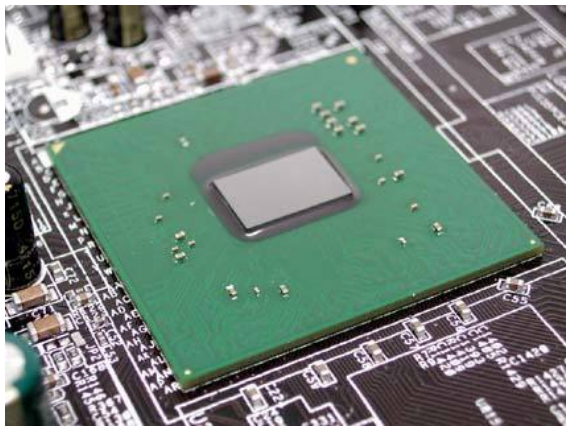
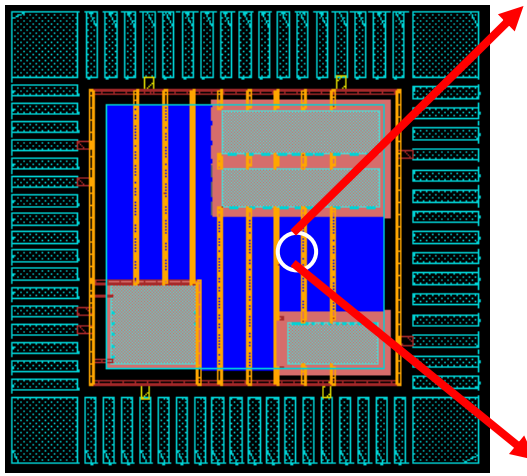
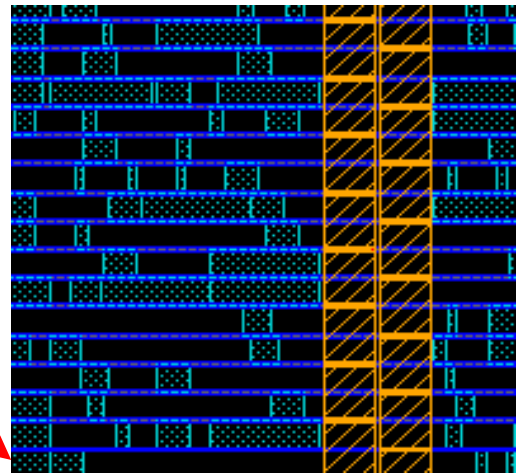
Our Contribution



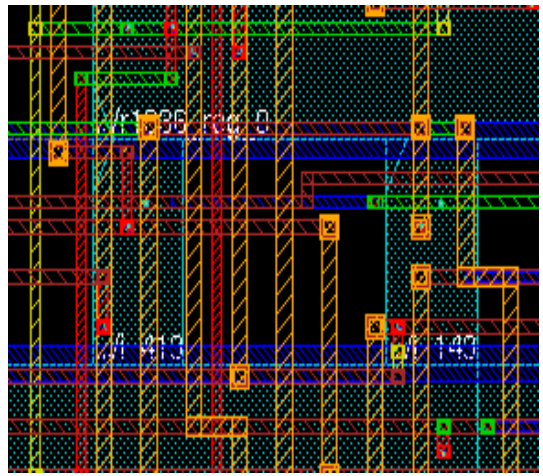
How to determine routing area and adjust placement for successful routing?



Floorplan



Placement



Routing

Outline

- Requirements for Successful Routing
- Cut-Demand
- Routing Area Decision
- Effective Resource Utilization
- Experimental Results

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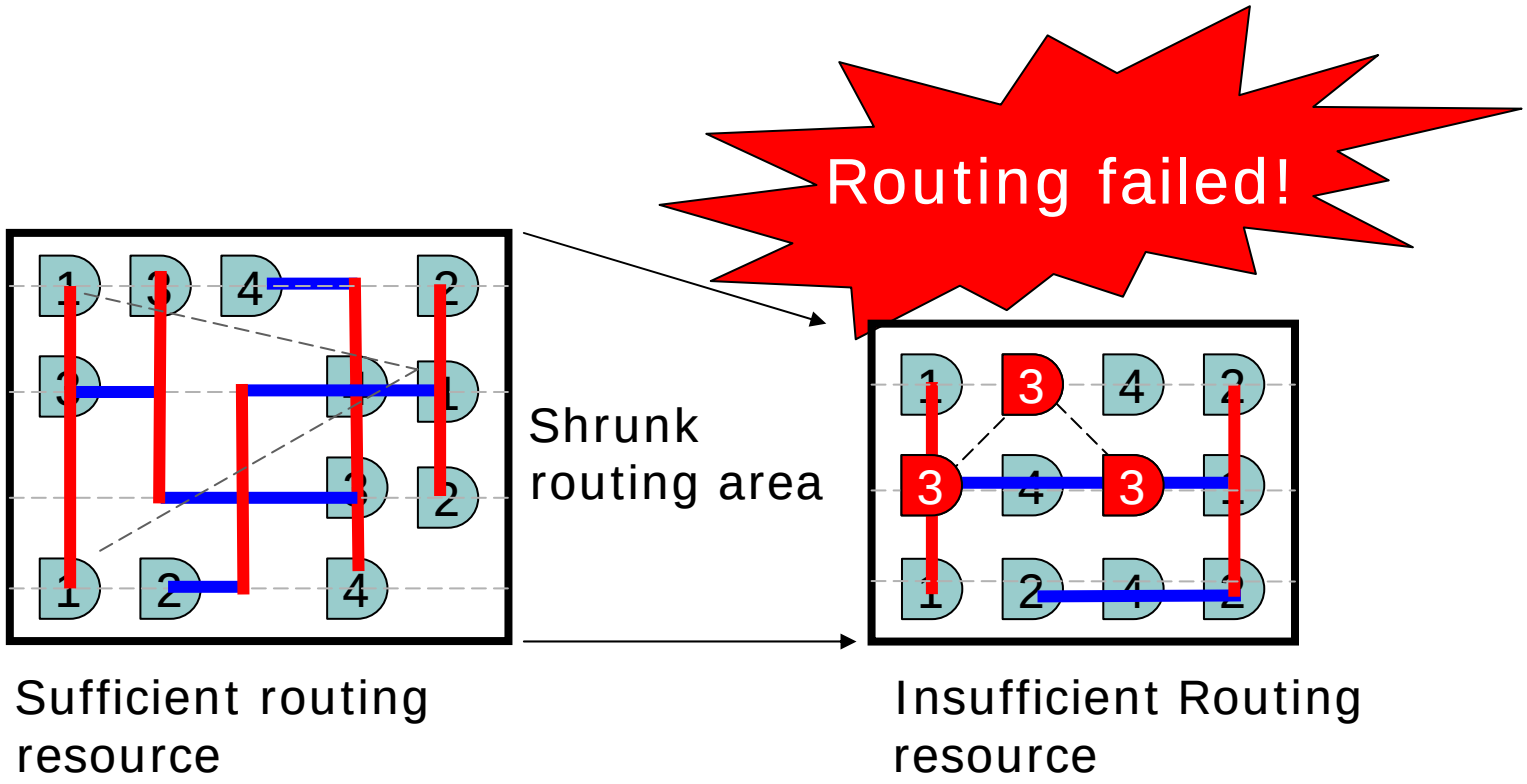
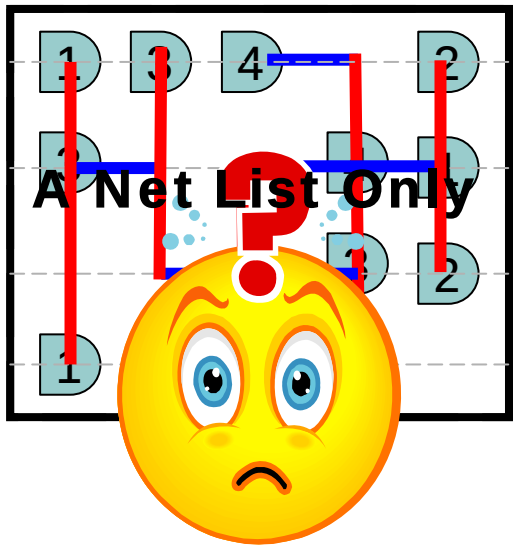
Successful Routing

- Sufficient Routing Resource



Resource Allocation in Floorplan

- How to allocate routing resource in floorplan stage

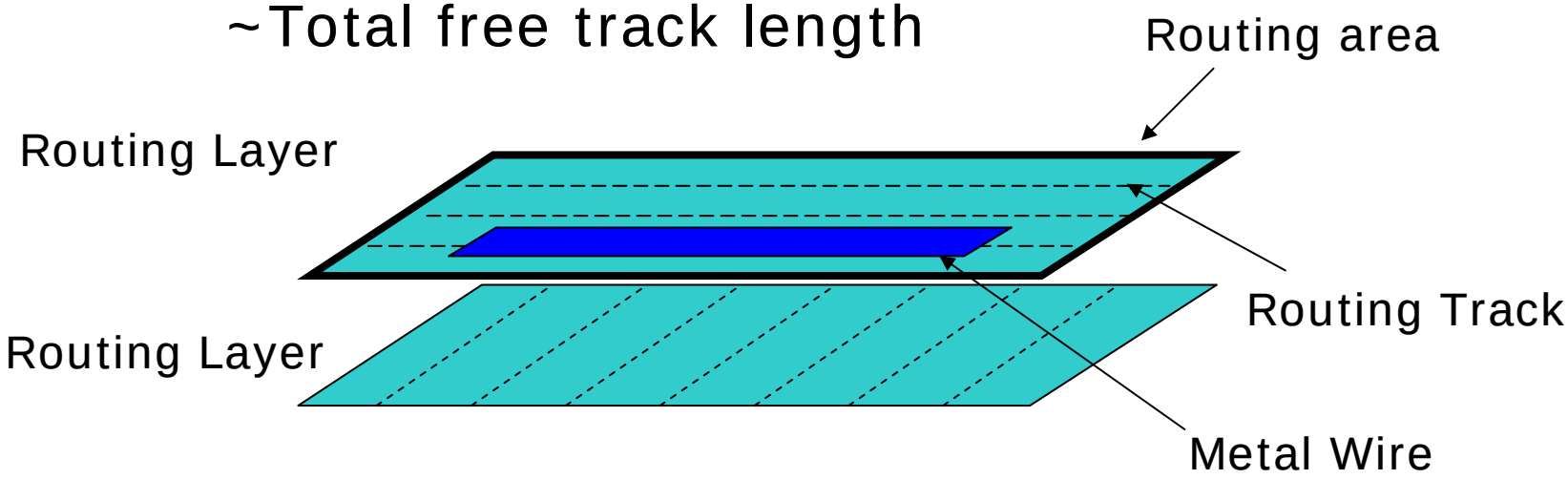


How much routing resources is required in detailed routing?

Routing Resource

- Routing area
  - Routing Layers
    - H/V routing Tracks
    - Metal Wires
- Routing Resource

  ~Total free track length

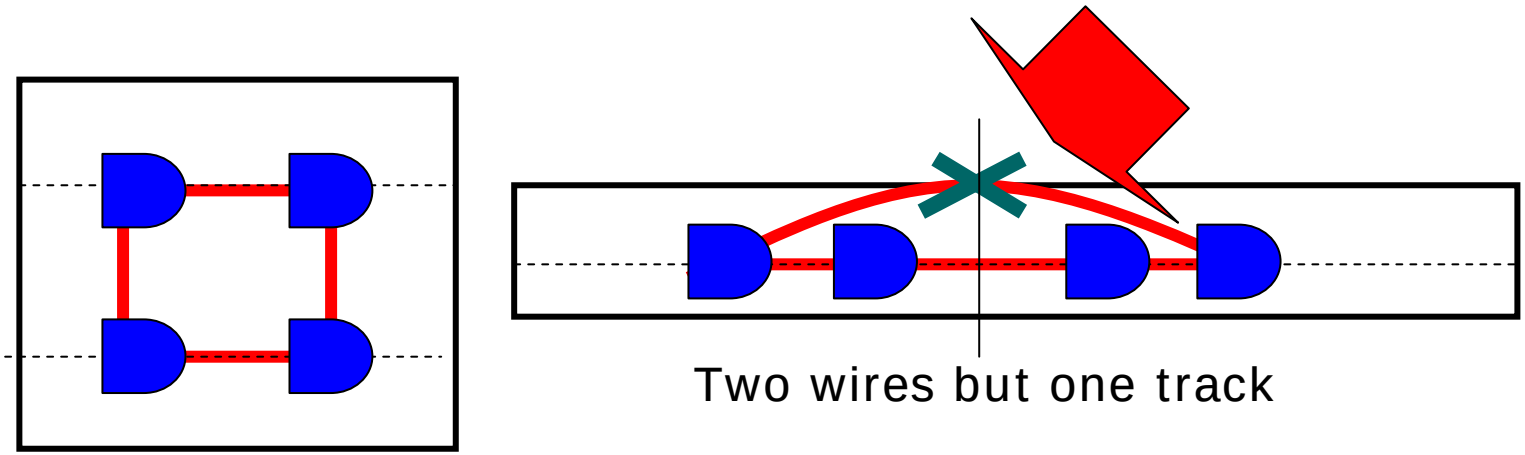


Previous Approach

- Target
  - total track length $\geqq$ total wire length
  - Total wire length prediction
    - Rent's rule based approach
    - Placement modeling based approach
  - Total track length
    - Decided by the routing area and a given process setting (e.g.: layer number)

Problem

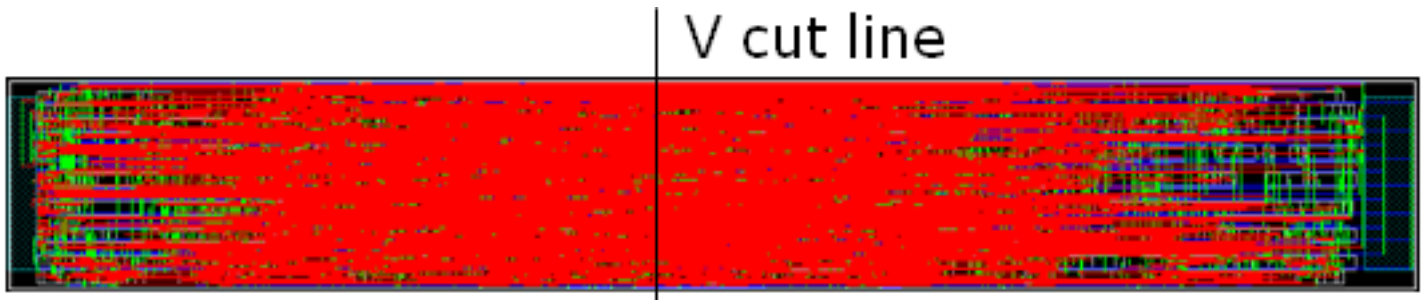
- Larger track length than wire length cannot guarantee successful routing



- Requirement:
  - #tracks on a cut line $\geqq$ #wires one a cut line

When Allocate Routing Resource..

- Satisfy the resource requirement on each cut line.
- Cut-demand
  - Required routing resources on a cut line



Outline

- Requirements for Successful Routing
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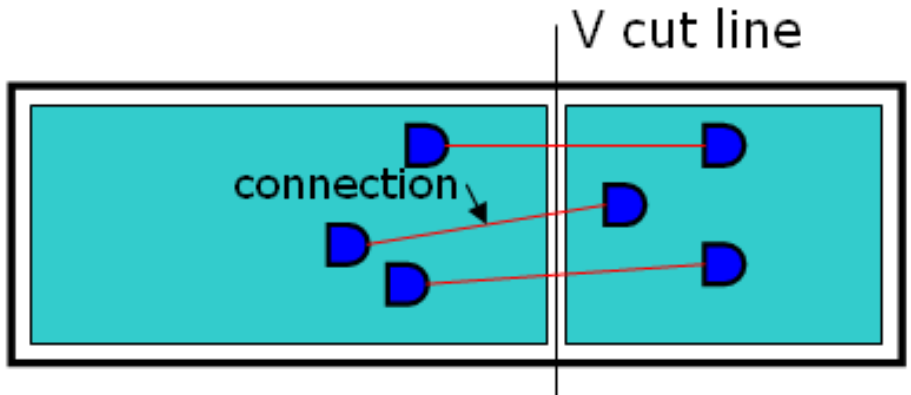
- Routing Area Decision
- Routing Resource Adjustment
- Experimental Results

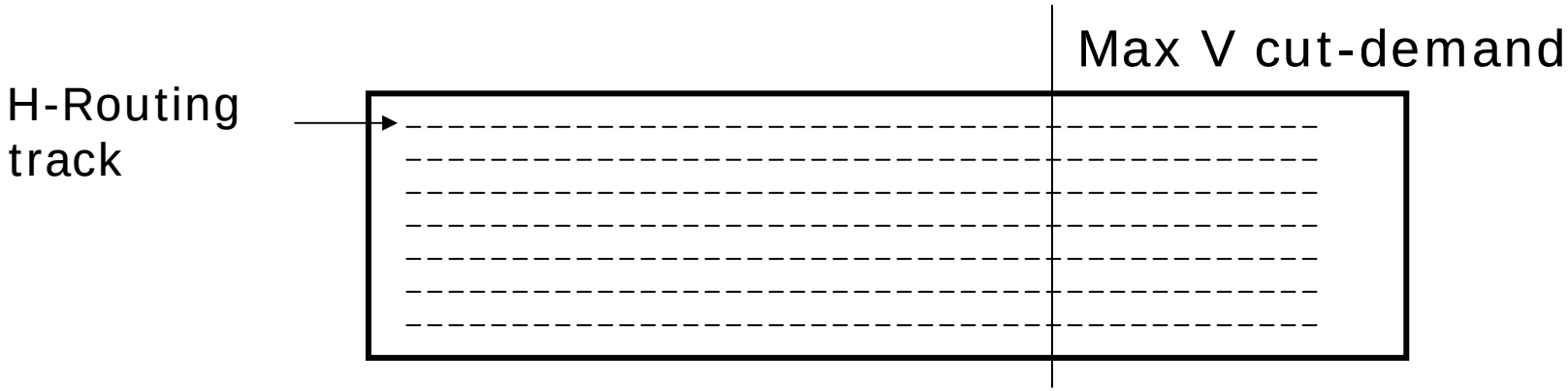
H/V Cut-Demands

- A cut line
  - A line to divided a design into two partitions.
- Cut-demand
  - The number of wires passing the cut line.
- H/V cut-demand
  - The cut-demand of a H- or V-cut line



When Allocate Routing Resource..

- To satisfy all H/V-cut demand
  - #H-routing tracks should be lager than the maximum V cut-demands.
  - #V-routing tracks should be lager than the maximum H cut-demands.



Our Idea

- To determine routing area to support sufficient routing tracks for maximum H/V cut-demands.

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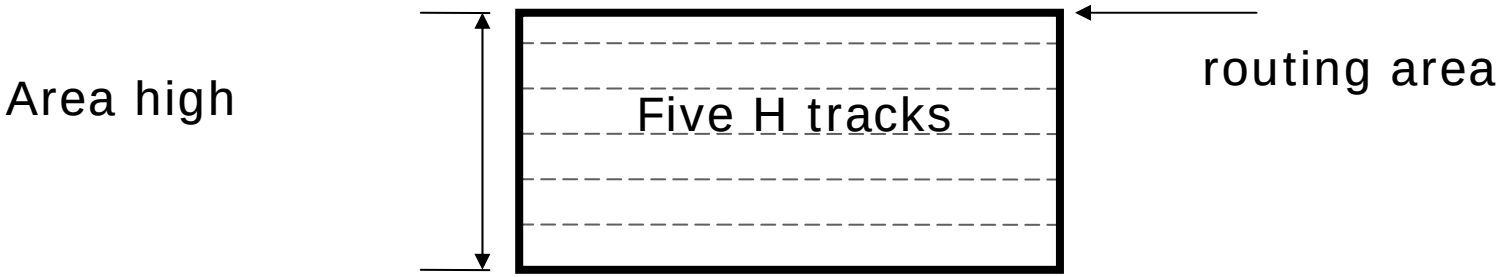
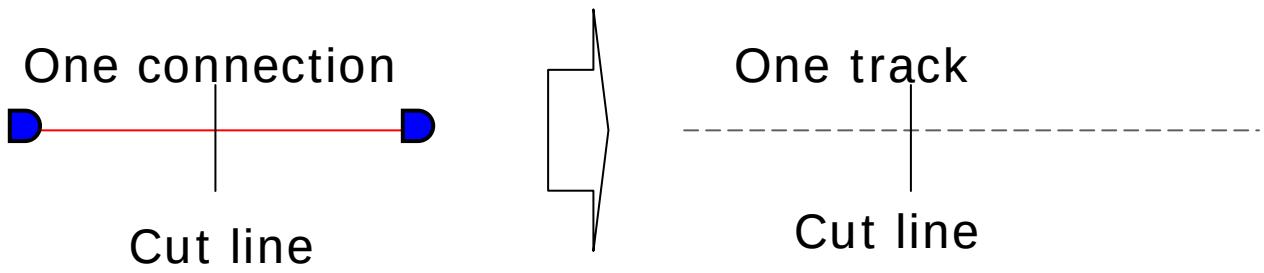
Routing Area

- Goal
  - have sufficient H/V routing tracks for max V/H cut-demand.
- Routing area (with given technology parameters)
  - Area height => #H tracks
  - Area width => #V tracks
  - Requirement
    - # H tracks ≧ max V cut-demand
    - # V tracks ≧ max H cut-demand



Maximum H/V Cut-Demands

- Maximum H/V cut-demand prediction
  - One track is needed to wire a connection



Maximum Cut Demand Prediction 1/3

- Rent's Rule
  - The format to predict the number of external pins of a design block.

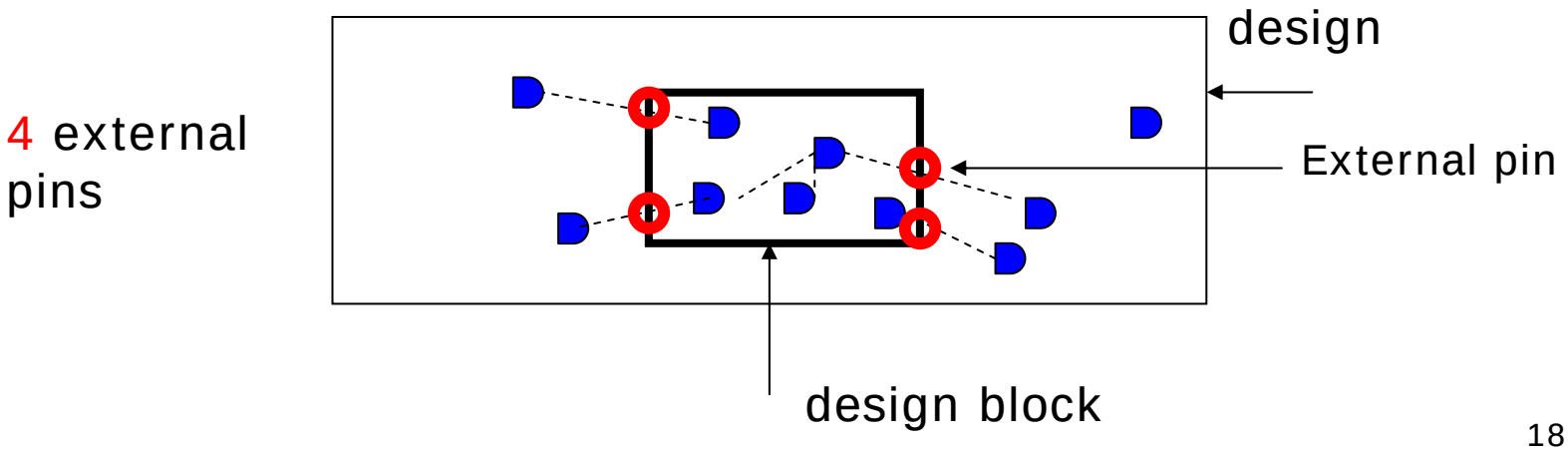
$$T = \lambda \cdot G^{p}$$

Rent's exponent

Gate count

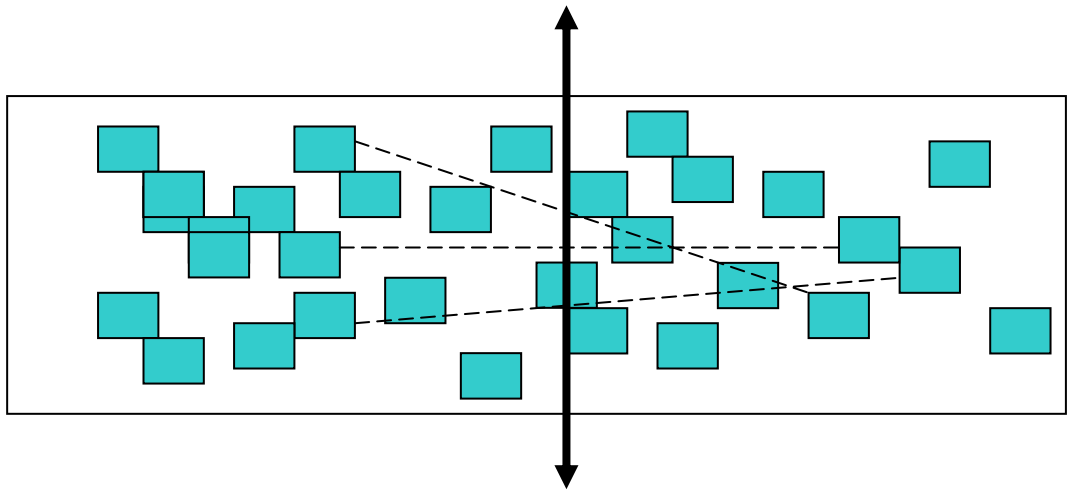
External pin count

average gate pin count



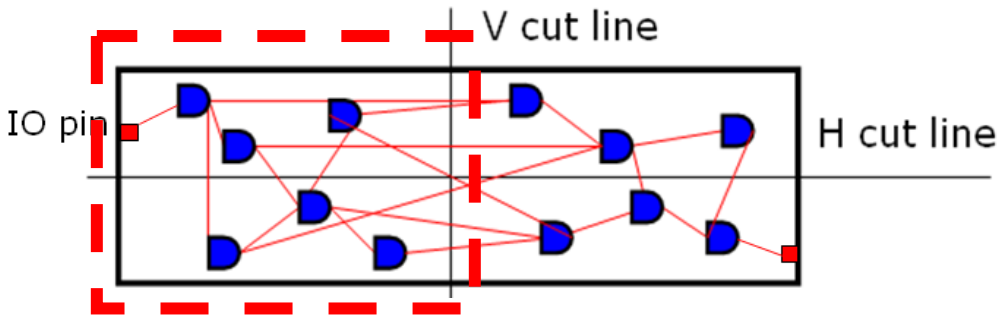
Maximum Cut Demand Prediction 2/3

- The maximum H/V cut-demand based on quick global placement (accurate)
- Do a quick global placement (no detail placement)
  - Calculate the maximum H/V cut-demands



Maximum Cut Demand Prediction 2/3

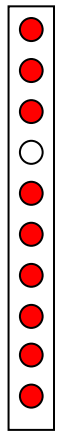
- The maximum H/V cut-demand based on Rent's rule (quick)
  - The maximum cut-demand is usually between two (nearly) equal-sized partitions
  - Max H cut demand = external pin count – IO pin.
    - Use Rent's rule to predict external pin count



Predict/Real = 6.8/7 wires.

Routing Area Decision 1/2

- In practice, routing tracks are not fully used.
  - Resource utilization rate
    - U_v = Max V cut-demand / num of H routing track.
    - U_H = Max H cut-demand / num of H routing track.



Routing Area Decision 1/2

- The minimum number of routing tracks satisfying H/V cut-demands.

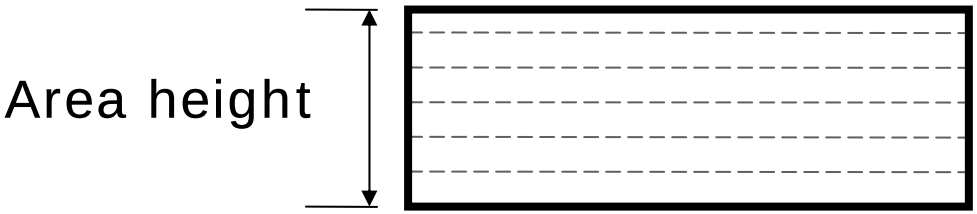
Distance between neighboring tracks

The max V cut-demand

$$\text{min - height} = \left\lceil \frac{D_v}{U_v L_h} \cdot w \right\rceil,$$

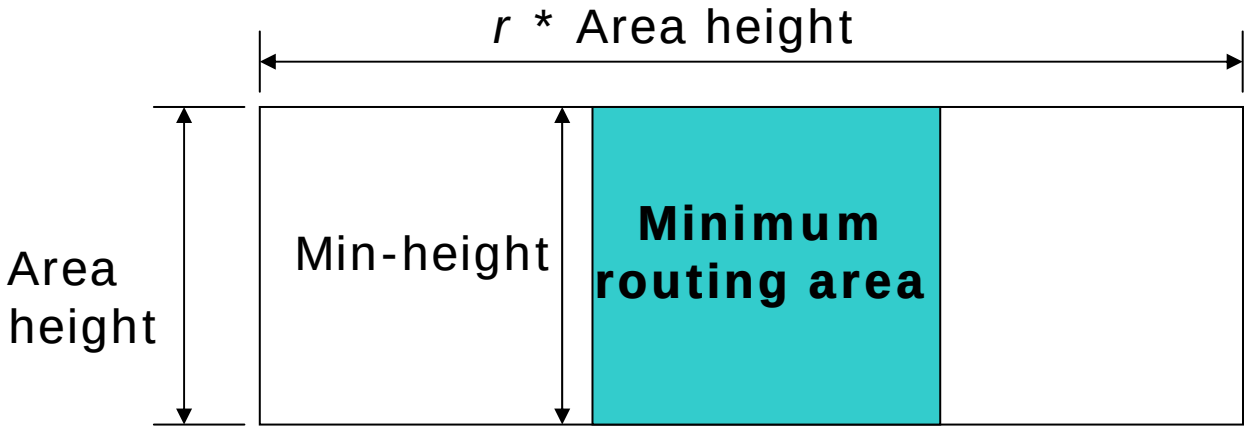
The # required H-tracks

Number of free layers with H tracks



Routing Area Decision 2/2

- With a given aspect ratio, *r*, the routing area is the minimum one which encloses the rectangular of minimum routing area.



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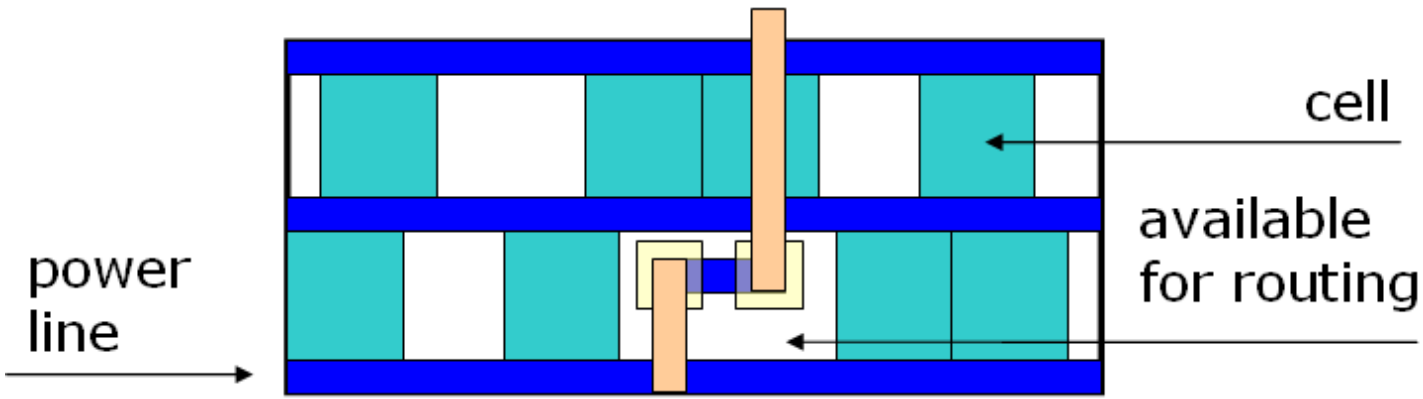
Effective Resource Utilization

- A method to adjust metal-1 routing resource in placement.
  - effective resource utilization.

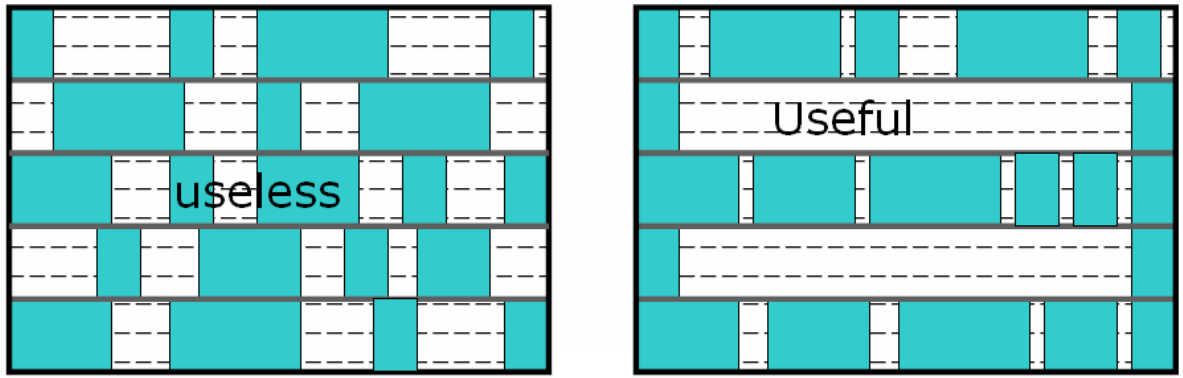
“Useless” Routing Resource

- Small routing areas in metal-1 are rarely used.
  - Create a wire on a small routing area, two extra via are required.



“Useful” Routing Tracks

- Our method
  - Use placement blockages to create useful M1 routing tracks.
  - long routing tracks on metal-1.



1. Two placement blockages are created.
2. Four “useful” routing tracks are created.

Algorithm Flow

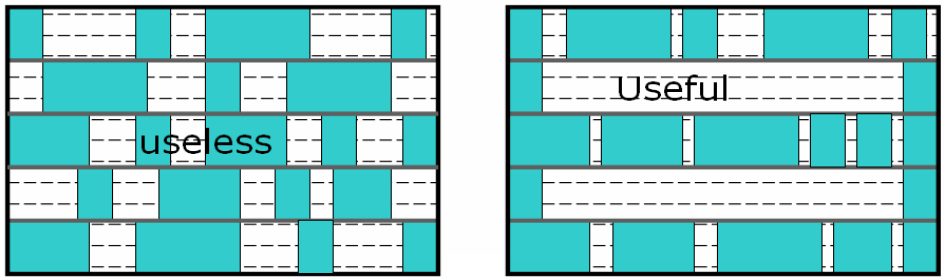
Input: An un-placed design

num-blk /* placement blockage num */.

util-rate /* resource utilization rate. */

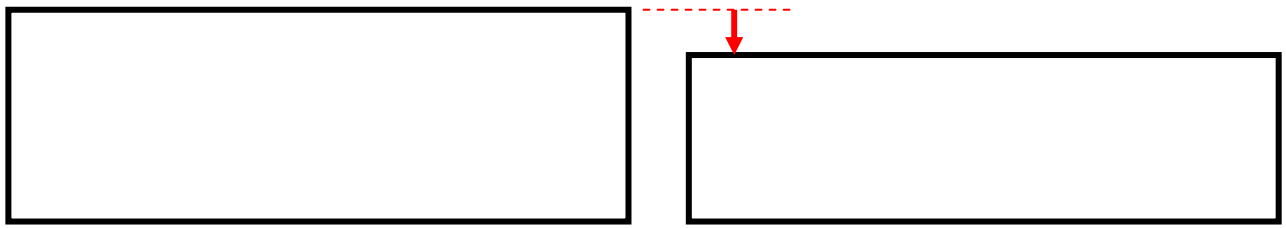
Output: A placed design

1. free-area = design area · util-rate– total cell area;
2. Determine the rectangular a placement blockage
3. Uniformly create num-blk placement blockages.
4. Call a placer to place cells.



Routing Area Shrinking

- With increasing of “useful” routing tracks, the routing area can be shrunk.



Upper Bound

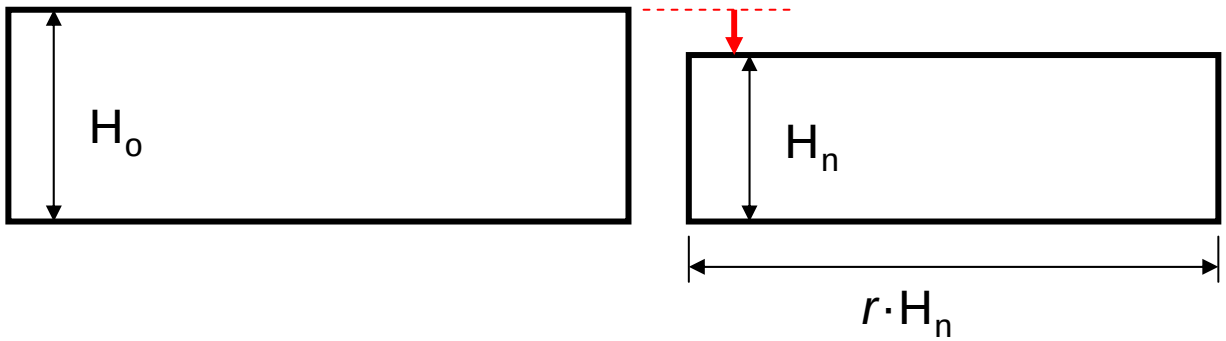
- A design is routable if it has enough H tracks.

Total cell size

$$\#\,\mathrm{H}\text{-tracks} = L_h \cdot \frac{H_o}{w} = L_h \cdot \frac{H_n}{w} + \frac{H_n^2 \cdot r - A}{w \cdot H_n \cdot r},$$

H Layers

Track pitch



Outline

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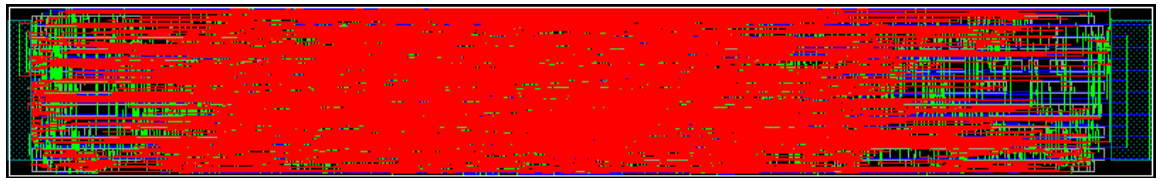
Experimental Results

- Test cases
  - Five congested test cases with large aspect ratio.
  - We focus on allocating sufficient H routing tracks.



Cases	*#inst*	*#net*	*#layer*	*A.R.*
U1	1,234	1,333	5	0.2
C1	834	902	3	7.8
C2	1,558	1,775	3	7.8
C3	6,747	6,934	3	4.8
C4	143,616	82,078	5	4.1

Cut-Demand Prediction

- GP approach provides more accurate results.
- The prediction errors
  - Rent: less than 21%, average 11%
  - GP: less than 8%, average 5%

Cases	Rent	GP	#max V cut-demand
U1	252	243	241
C1	111	109	101
C2	174	176	166
C3	409	335	338
C4	2,908	3,128	3,098

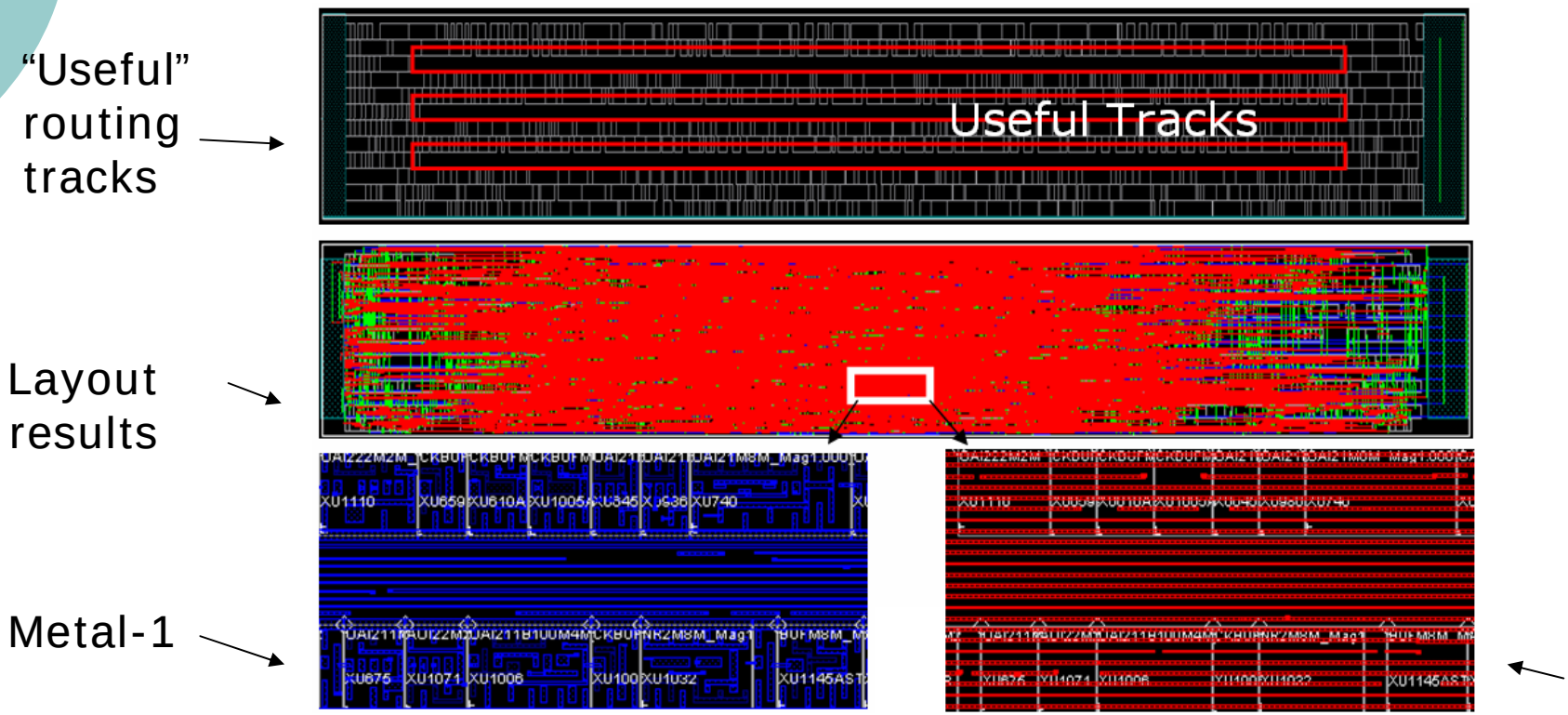
Routing Resource Consolidation 1/3

- **5.3 times Faster**
- Better layout
  - Less via count and sort wire length

	Original P&R results			Our Result		
Case	*time(s)*	*W.L.(mm)*	*#via(x100)*	*time(s)*	*W.L.(mm)*	*#via(x100)*
U1	603	169	130	67	164	127
C1	19,223	152	90	825	142	86
C2	236	22	114	62	22	113
C3	2,737	174	516	2,058	163	487
C4	81,640	10,083	8246	38,876	9,789	8,084
Ratio	**5.3**	1.03	1.02	1	1	1

Routing Resource Consolidation 2/3

- The routing result of C2.



Routing Resource Consolidation 2/3

- Routing area reduction
  - reduced 2%~15%

Case	*Shrink*	*Time(s)*	*Len(mm)*	*#via(x100)*
U1-S	8%	573	162	130
C1-S	10%	8566	145	88
C2-S	**15%**	**909**	**20**	**113**
C3-S	10%	11054	161	495
C4-S	2%	45845	9790	8089

Conclusion

- We should allocate enough routing resources for H/V cut-demands.
- Resource allocation and consolidation approaches are proposed.
  - Routing area decision. (cut-demand prediction)
  - Effective resource utilization. (routing resource consolidation)
    - 5.3 times run-time faster.
    - Routing area is reduced by 2~15%.

- Q&A

SoC Cases

Routing Resource Consolidation for All Aspect ratio