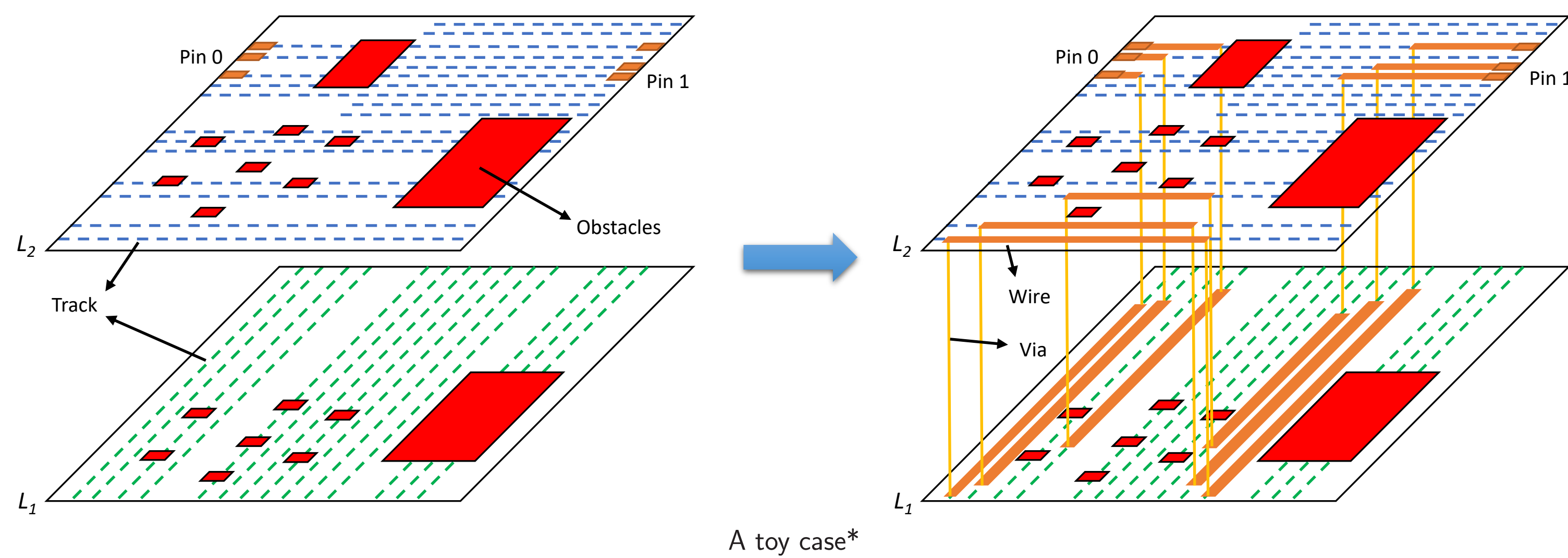




MARCH: MAze Routing Under a Concurrent and Hierarchical Scheme for Buses

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Key Challenges



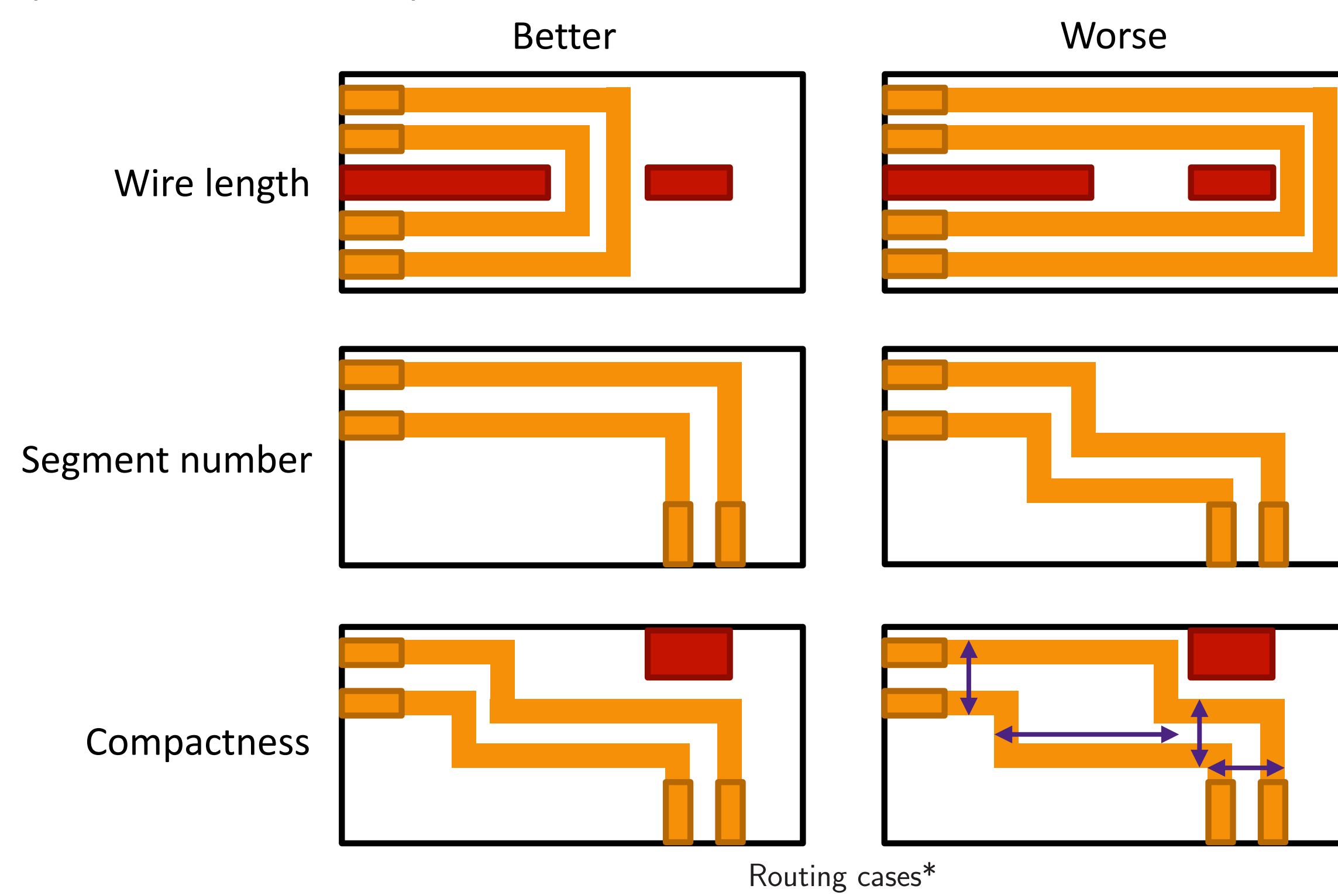
- Non-uniform and complex routing track configuration
- Need to route in between small obstacles
- Maintain the topology consistency for all the bits in the same bus

*This case comes from the slides "ICCAD 2018 CAD Contest Problem B Summary" (link: <http://iccad-contest.org/2018/>).

Evaluation Rule

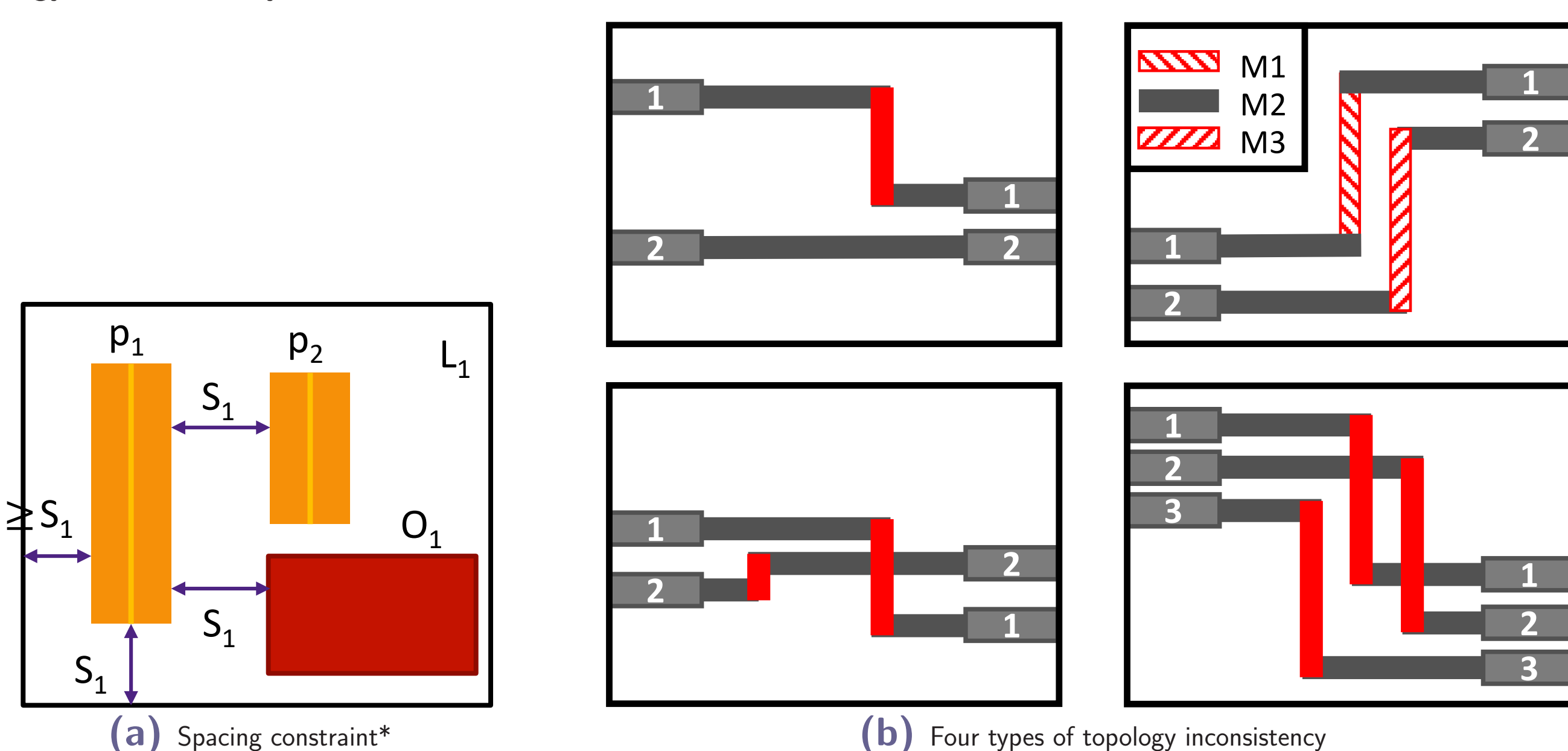
Routing Cost

- Wire length cost: shorter → better
- Segment cost: less → better
- Compactness cost: more compact → better



Penalty Cost

- Spacing violation penalty
- Routing failure penalty
 - Wire off-track
 - Track width violation
 - Bit open
- Topology inconsistency

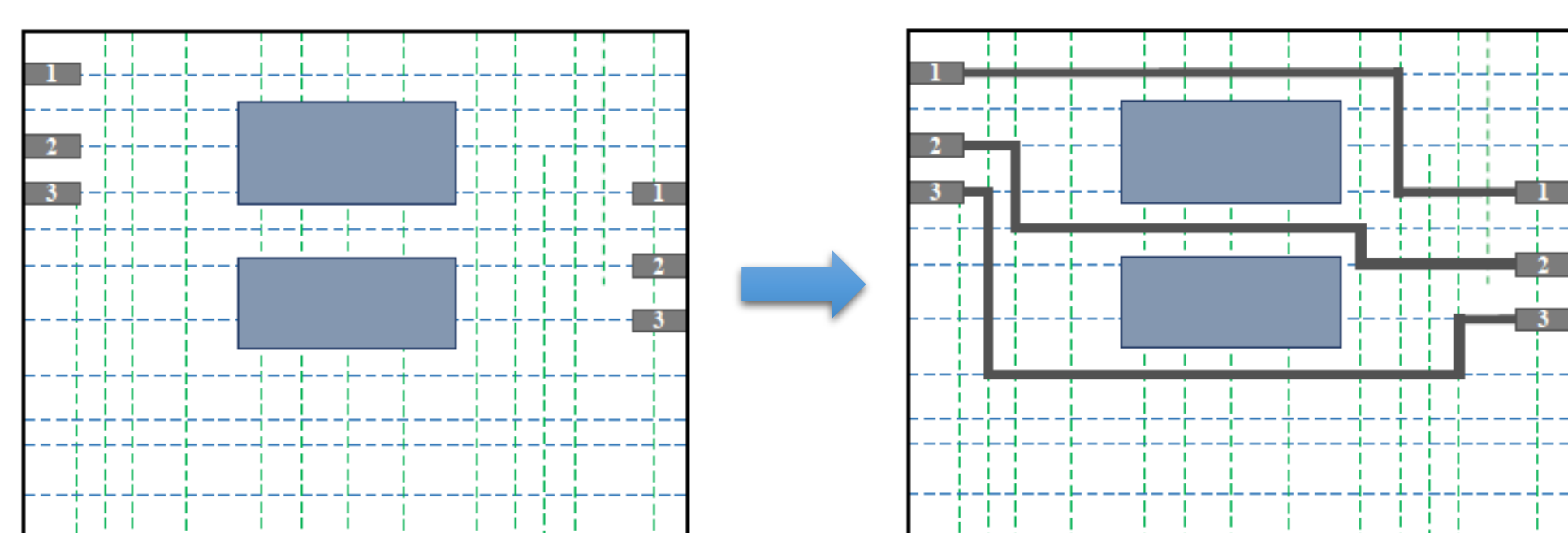


*These cases come from the slides "ICCAD 2018 CAD Contest Problem B Summary" (link: <http://iccad-contest.org/2018/>).

MARCH

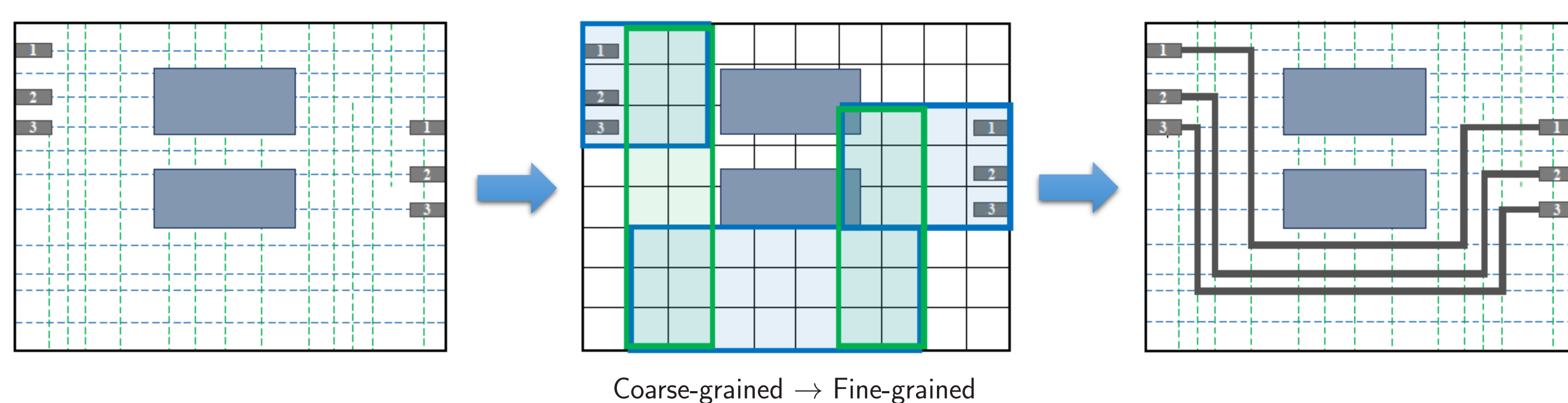
Counterexample: Routing Bit by Bit

- Advantage: traditional routing methods can be applied naturally.
- Disadvantage: topology consistency can hardly be maintained in a relatively complex routing environment.



Two Key Features of MARCH

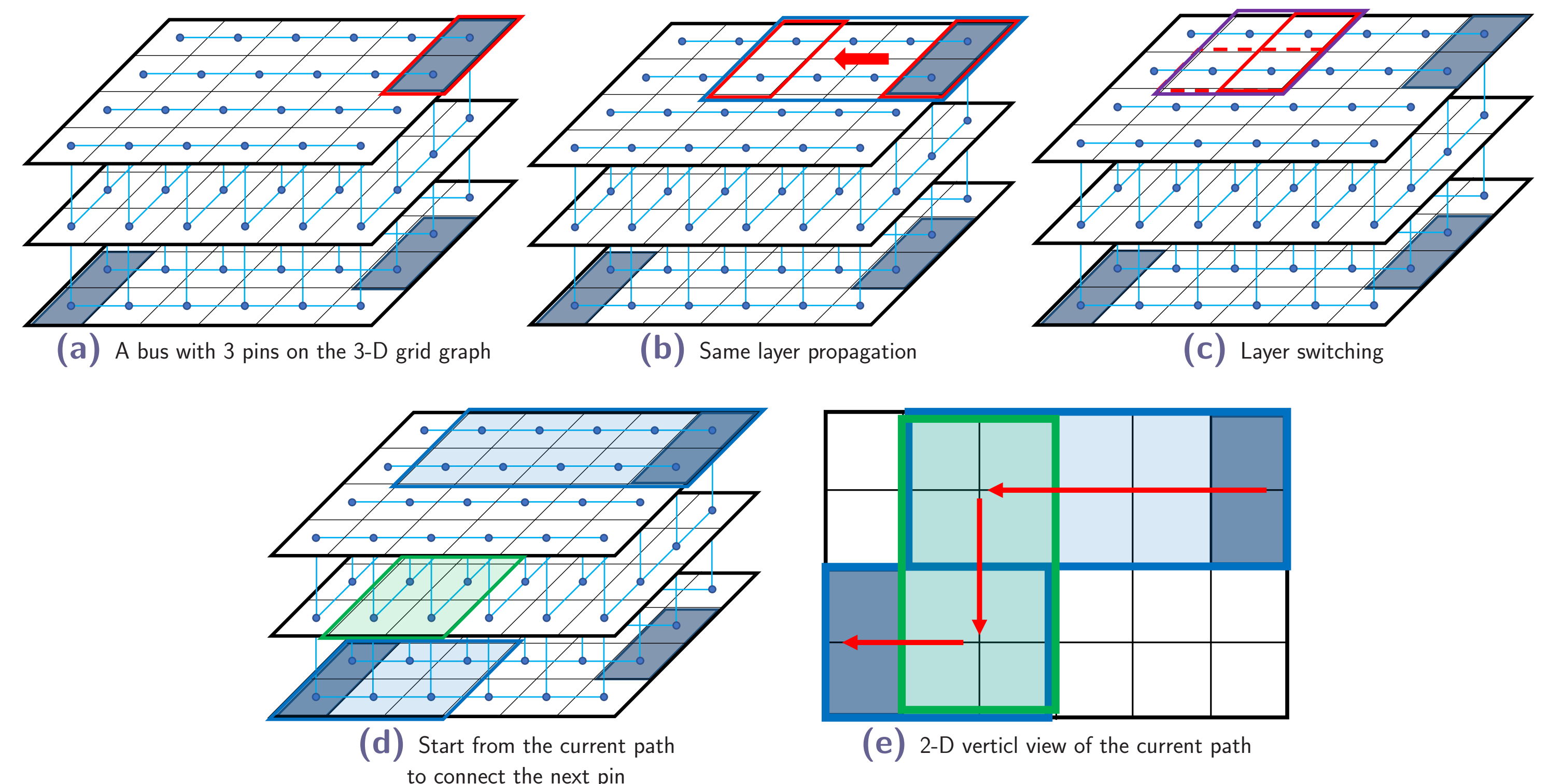
- Hierarchically → Efficiency
- Concurrently → Correct-by-construction



MARCH

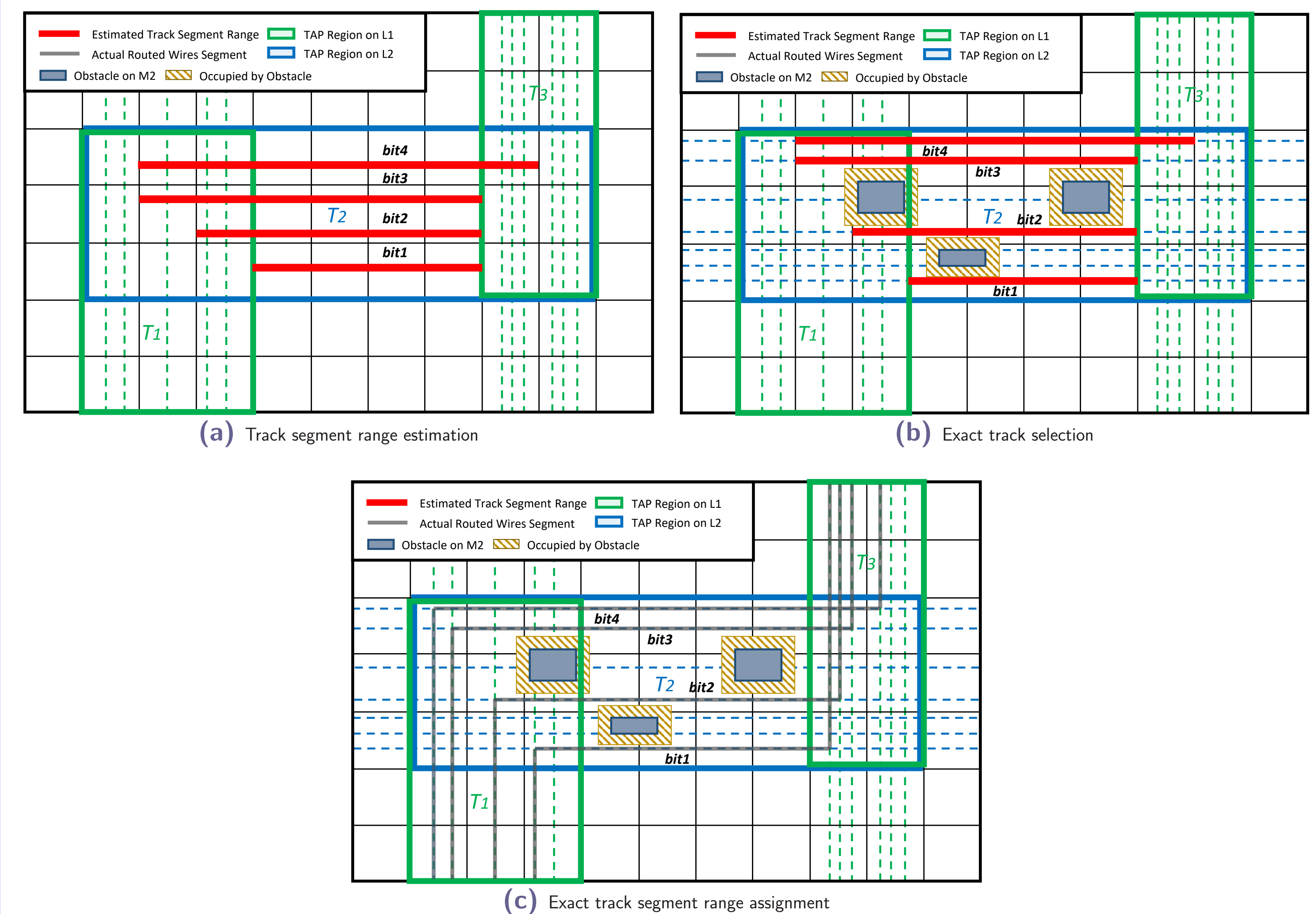
Topology-aware Path Planning (TAP)

- Same layer propagation
- Layer switching
- Build routing paths for multi-pin buses



Track Assignment for Bits (TAB)

- Track segment range estimation
- Exact track selection
- Exact track segment range assignment



Rip-up and Reroute Scheme (RR)

- Add history cost to the edge of the grid graph:
 - $h_{new} = \alpha \times n_{vio} + \beta \times h_{old}$ where n_{vio} is the number of spacing violations on the edge, and α and β are weights.
- Enlarge the *frontline* size of the bus by 1 on the layer where:
 - the number of spacing violations in a TAP region is larger than the bit number in 2 successive RR iterations.

Experimental Results

Detailed Results of MARCH on IC/CAD 2018 Benchmarks

| | Characteristics | | | | Metric Weights | | | | | MARCH Scores | | | | | | | |
|--------|-----------------|---------|-----------|-----------|----------------|-----------|-----------|-------------|------------|--------------|-----------|-----------|-------------|-------------|------------|-------------|----------|
| | bus no. | net no. | layer no. | track no. | w_{wire} | w_{seg} | w_{com} | w_{space} | w_{fail} | C_{wire} | C_{seg} | C_{com} | C_{route} | N_{space} | N_{fail} | C_{total} | Time (s) |
| beta1 | 34 | 1260 | 3 | 49209 | 5 | 1 | 5 | 8 | 2000 | 34 | 34 | 112 | 765 | 0 | 0 | 765 | 50 |
| beta2 | 26 | 1262 | 3 | 49209 | 5 | 1 | 5 | 8 | 2000 | 26 | 26 | 85 | 578 | 0 | 0 | 578 | 9 |
| beta3 | 60 | 665 | 3 | 22732 | 12 | 1 | 4 | 8 | 2000 | 72 | 62 | 253 | 1942 | 0 | 0 | 1942 | 72 |
| beta4 | 62 | 698 | 3 | 22732 | 12 | 1 | 4 | 8 | 2000 | 76 | 71 | 294 | 2165 | 0 | 0 | 2165 | 39 |
| beta5 | 6 | 1964 | 4 | 54150 | 8 | 1 | 5 | 8 | 2000 | 6 | 6 | 13 | 118 | 231 | 0 | 1966 | 12 |
| final1 | 18 | 1032 | 3 | 81226 | 10 | 1 | 5 | 10 | 2000 | 18 | 22 | 30 | 356 | 84 | 0 | 1196 | 352 |
| final2 | 70 | 1285 | 3 | 14209 | 10 | 1 | 5 | 10 | 2000 | 70 | 81 | 259 | 2071 | 148 | 0 | 3551 | 199 |
| final3 | 47 | 852 | 4 | 21379 | 10 | 1 | 5 | 10 | 2000 | 47 | 51 | 558 | 3313 | 15 | 0 | 3463 | 133 |

$$* C_{wire} = \sum_{bus} b C_{wire}^b, C_{seg} = \sum_{bus} b C_{seg}^b, C_{com} = \sum_{bus} b C_{com}^b$$

Compared with the winners of IC/CAD 2018 contest*

- Reduce spacing violations greatly
- Avoid any routing failure
- Have competitive routing costs
- Have a much shorter runtime

| | First Place | | | | Second Place | | | | Third Place | | | | MARCH | | | | | | | |
|------------|-------------|-------------|------------|-------------|--------------|-------------|-------------|------------|-------------|----------|-------------|-------------|------------|-------------|----------|-------------|-------------|------------|-------------|------------|
| | C_{route} | C_{space} | C_{fail} | C_{total} | Time (s) | C_{route} | C_{space} | C_{fail} | C_{total} | Time (s) | C_{route} | C_{space} | C_{fail} | C_{total} | Time (s) | C_{route} | C_{space} | C_{fail} | C_{total} | Time (s) |
| beta1 | 689 | 280 | 0 | 969 | 3600 | 701 | 5096 | 0 | 5797 | - | 641 | 8744 | 4000 | 13385 | - | 765 | 0 | 0 | 765 | 50 |
| beta2 | 515 | 760 | 0 | 1275 | 3600 | 563 | 4904 | 0 | 5467 | - | 484 | 9472 | 2000 | 11956 | - | 578 | 0 | 0 | 578 | 9 |
| beta3 | 1936 | 0 | 0 | 1936 | 71 | 2024 | 0 | 0 | 2024 | - | 1999 | 1928 | 0 | 3927 | - | 1942 | 0 | 0 | 1942 | 72 |
| beta4 | 2192 | 0 | 0 | 2192 | 64 | 2271 | 0 | 0 | 2271 | - | 2250 | 1048 | 0 | 3298 | - | 2165 | 0 | 0 | 2165 | 39 |
| beta5 | 119 | 1848 | 0 | 1967 | 3600 | 95 | 616 | 2000 | 2711 | - | 98 | 1216 | 2000 | 3314 | - | 118 | 1848 | 0 | 1966 | 12 |
| final1 | 327 | 830 | 2000 | 3157 | 3317 | 367 | 2750 | 2000 | 5117 | - | 252 | 0 | 10000 | 10252 | - | 356 | 840 | 0 | 1196 | 352 |
| final2 | 1824 | 4500 | 8000 | 14324 | 3600 | 1890 | 2990 | 8000 | 12880 | - | 1976 | 6910 | 0 | 8886 | - | 2071 | 1480 | 0 | 3551 | 199 |
| final3 | 2966 | 490 | 10000 | 13456 | 3600 | 2678 | 300 | 2000 | 4978 | - | 4238 | 20 | 24000 | 28258 | - | 3313 | 150 | 0 | 3463 | 133 |
| Avg. Ratio | 2.130 | | | | 105.45 | 3.731 | | | | 7.832 | | | | 1.000 | | | | 1.000 | | |

*The scores of top 3 teams of IC/CAD 2018 contest are provided by the contest organizer. A binary is also obtained from the first place to get its runtime information.