Routing Congestion Mitigation Techniques Targeting Dense Designs

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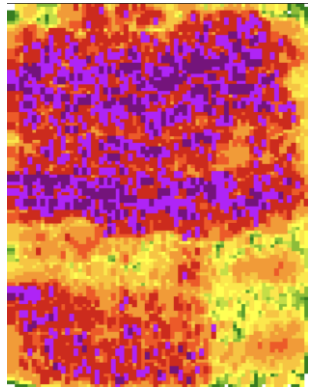
Motivation

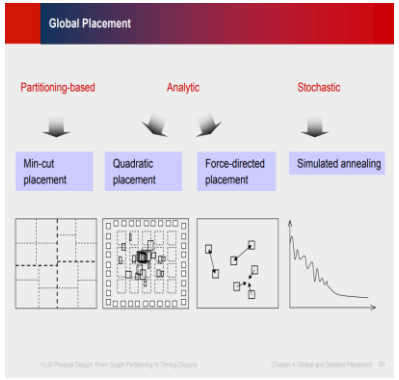
- Congestion plays a critical role in design closure for advanced technology nodes.
- Without reasonable congestion, it is impossible to route designs and maximize density/PPA.
- There are many challenges with managing congestion in dense designs that need to be overcome:

With dense designs and tightly packed cells, it is very hard to efficiently reduce the congestion with cell spreading techniques

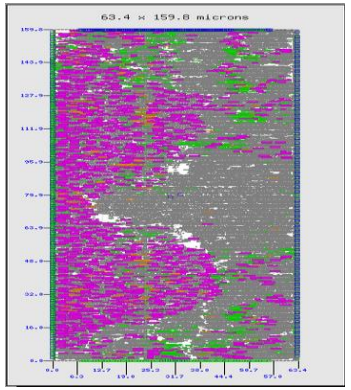


Congestion aware layer assignment can generally work well with the higher layers. But it is often hard to predict the congestion caused by the tight packed cells.

The space consumed by resizing and new buffers in the netlist topology directly impacts global placement and spreading algorithms (connectivity and topology matters).



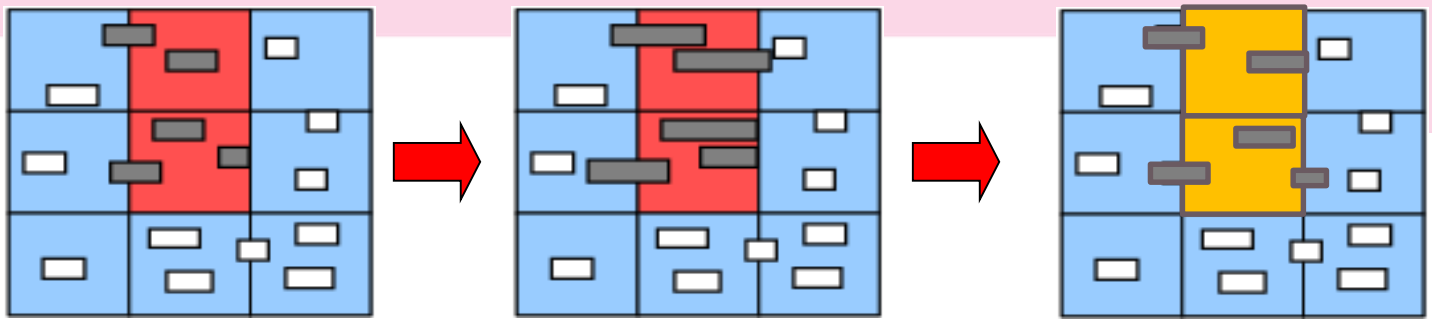
Most of the congestion mitigation techniques require high fidelity of global router congestion prediction



Proposed new methodologies

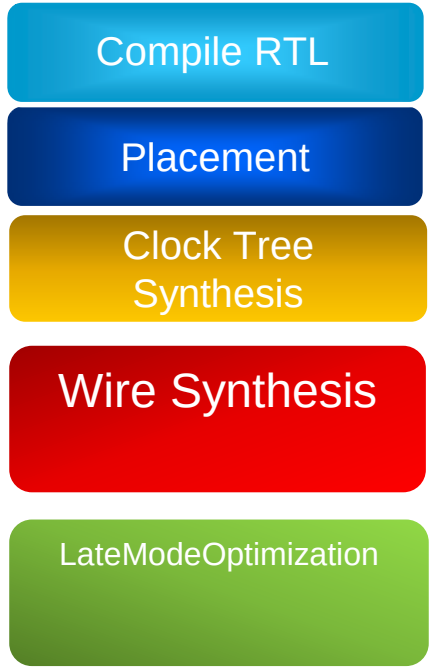
- CRISP^{+} (**Congestion reduction by iterated spreading during placement**)
- Core Polarity Inverter Removal
- Congestion reduction via the incremental router-based box movement

CRISP



*red represents higher congestion, orange represents less congestion

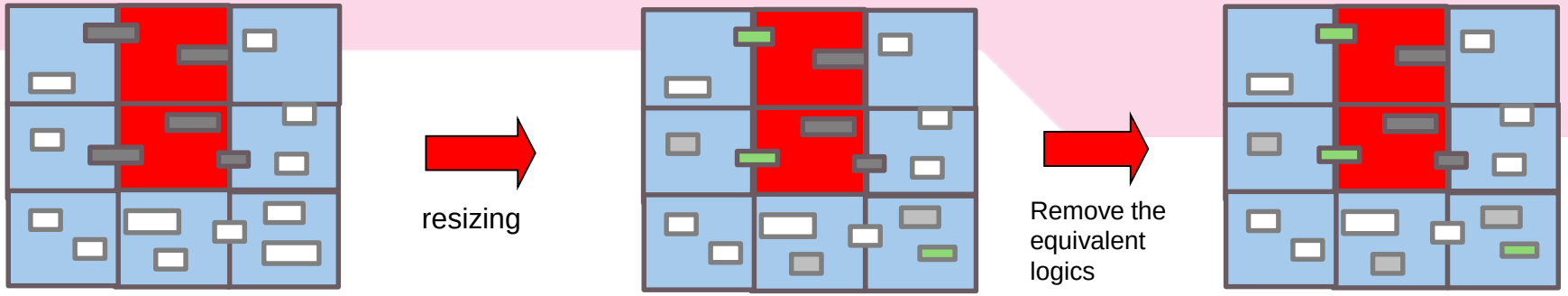
- Original [CRISP] Spreading method used for congestion mitigation
  - Temporarily inflate objects in estimated congested regions (creates overlaps)
  - legalize (spread) while minimizing displacement
  - finish by restoring objects back to original sizes



[CRISP] : **Congestion reduction by iterated spreading during placement, ICCAD'09, San Jose, CA, 2009.**

CRISP+

-----Spreading preceded by area-recovery is leading to more effective congestion mitigation!



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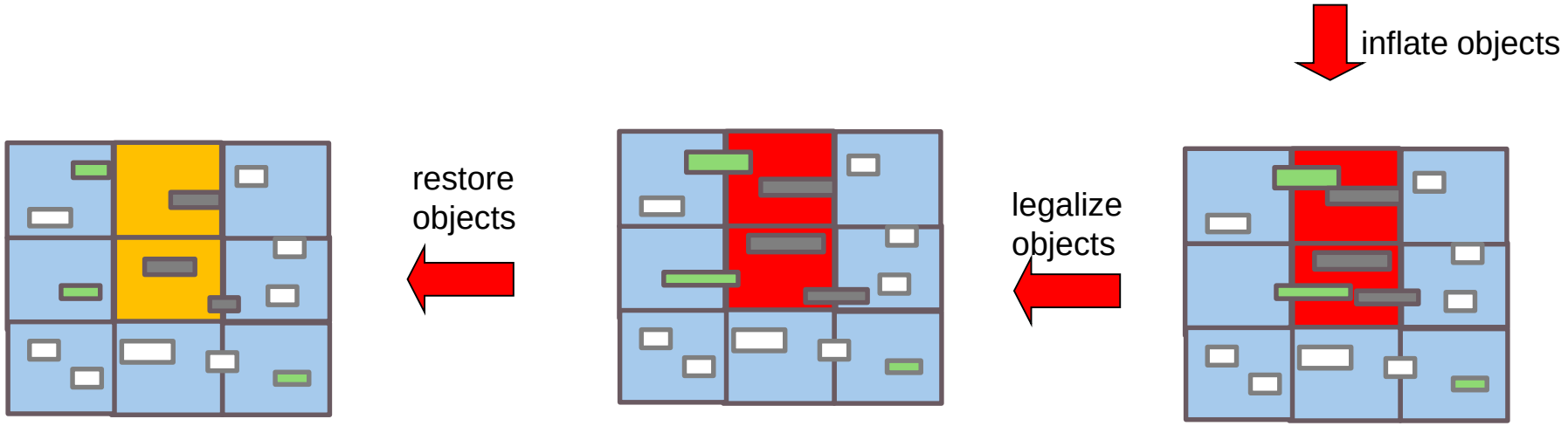
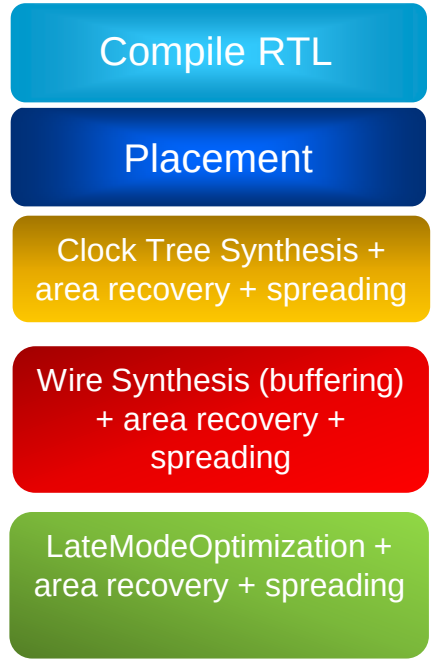
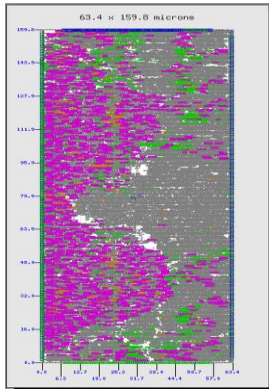


CRISP+

- Proposed [CRISP]/Spreading enhancements for dense designs :
  - Spreading preceded by area-recovery is leading to more effective congestion mitigation!
    - Aggressive area recovery creating free space (some of it) in congested regions
    - Remove the redundant equivalent net lists
    - Giving spreading more opportunities to smoothen the legalization process
  - Integrate Spreading more tightly inside post-Clock Tree Synthesis Timing Optimization flows
    - Periodic Spreading throughout Optimization flows to keep congestion under control
  - It showed significant congestion improvements compared to the original-CRISP method

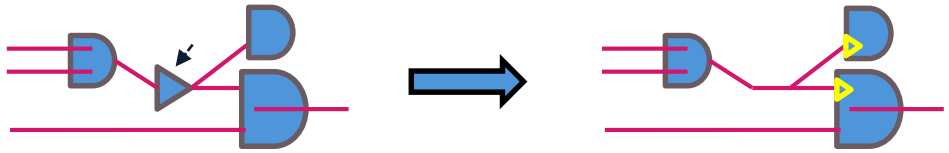


Core polarity inverter removal



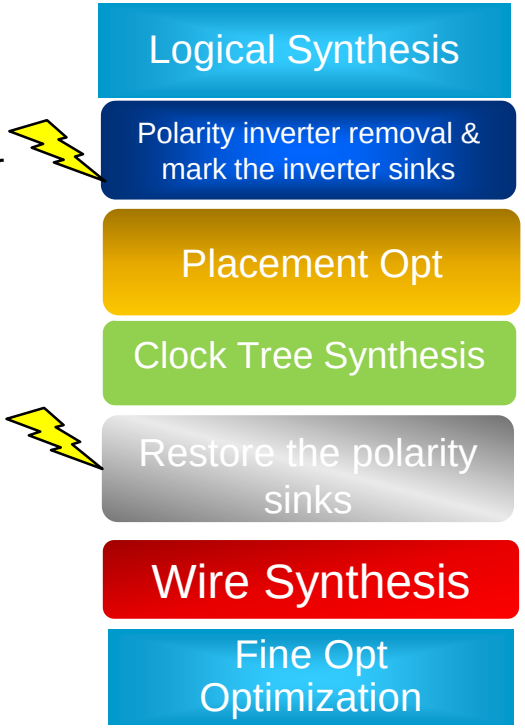
Temporarily removing individual inverters from the netlist for portions of the placement-driven synthesis flow which allows the placement to easily see the entire net, positive and negative sinks, and it ends with better wirelength.

- Polarity Marking: before the virtual optimization/global placement step, the inverter trees are identified in the netlist and the polarity to the downstream sink from the root net is stored as an attribute.
- Polarity Removal: remove inverters from the netlist
- Restore the polarity sinks after clock tree synthesis. Any remaining pins with a polarity marking will be inspected for the correct polarity and restored by inserting an inverter or absorbing an inverter into sink or source.



inverter

Store polarity on downstream logic as necessary.



	Objects count	Final Congestion
Base	91251	94.06
new	86897	93.49

CRIRBM-
Congestion reduction via the incremental router-based box movement

- A novel incremental router-based box movement transform that moves gates from highly congested tiles to the less congested nearby tiles leading to significant congestion mitigation.
- Most of the congestion mitigation techniques focus on local congestion and pay less attention to the net connections.

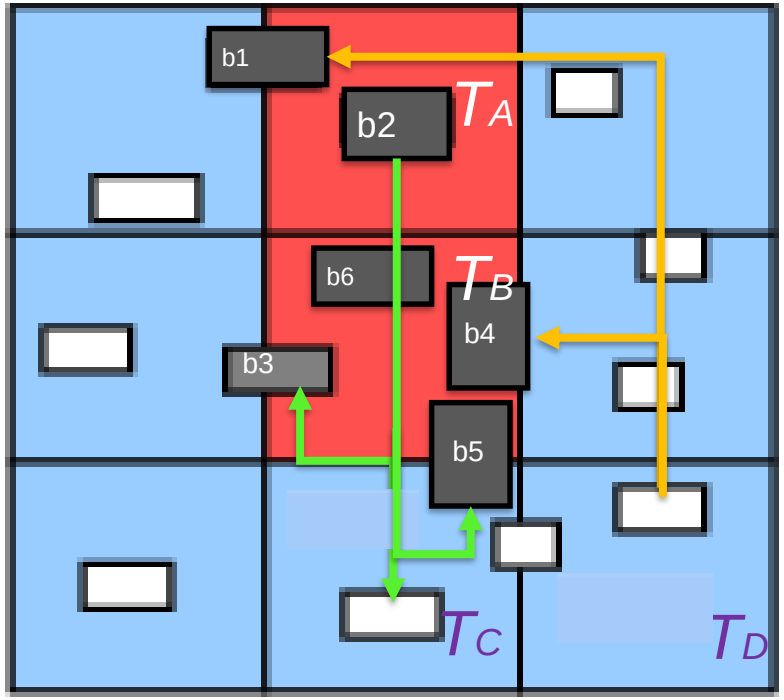


Fig. 1

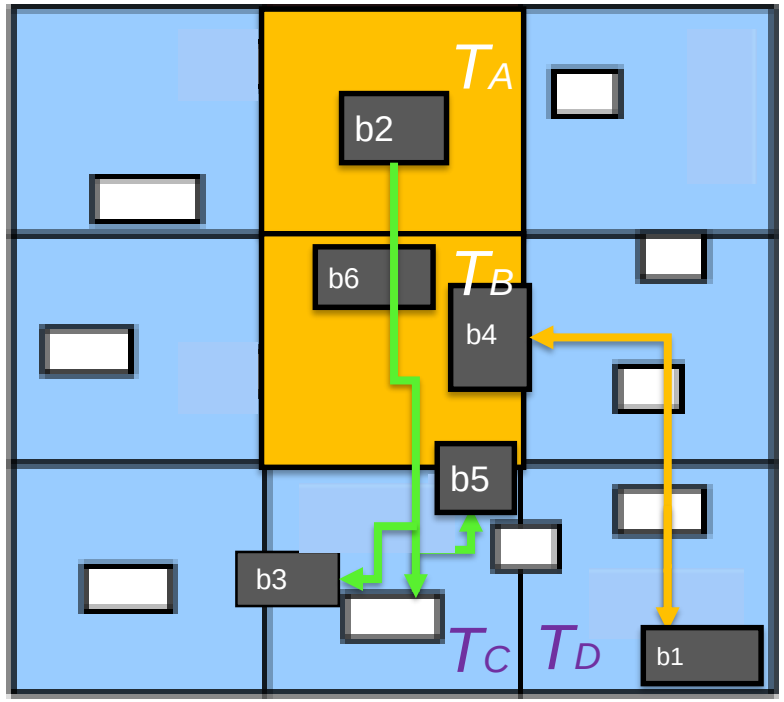
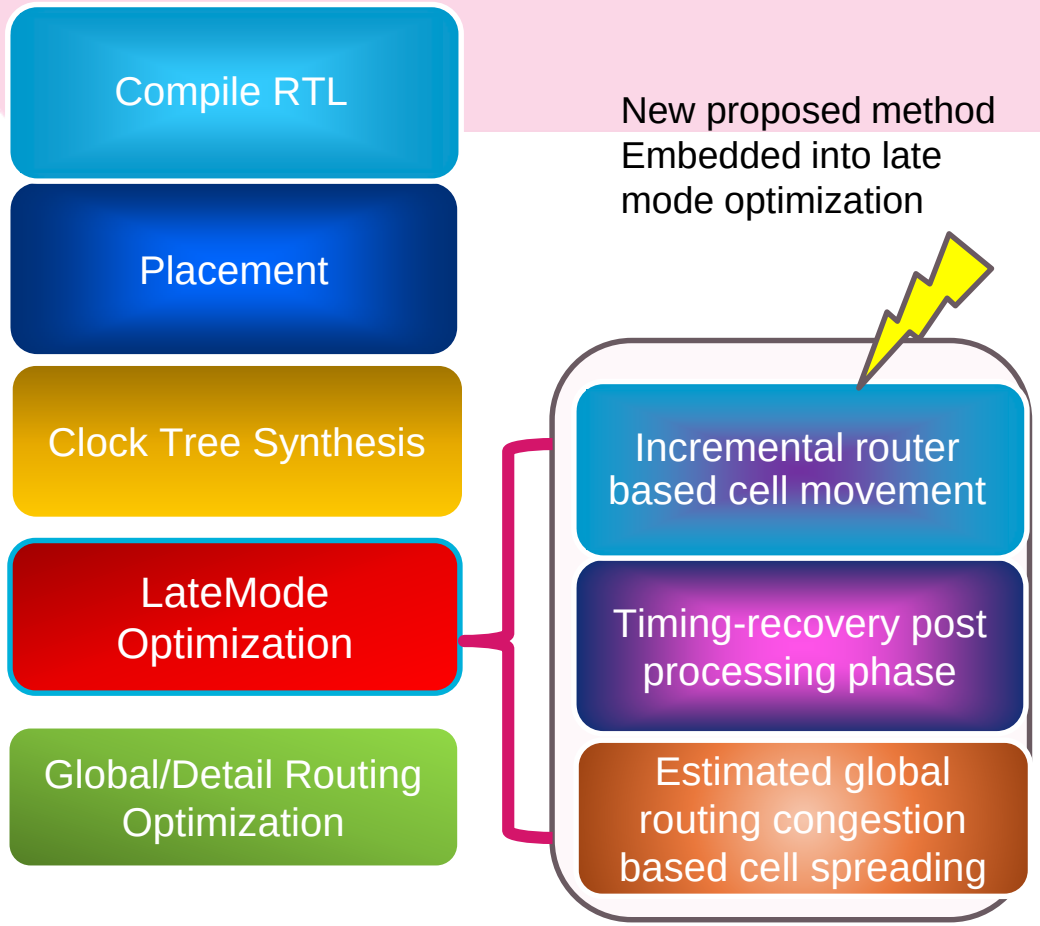


Fig. 2

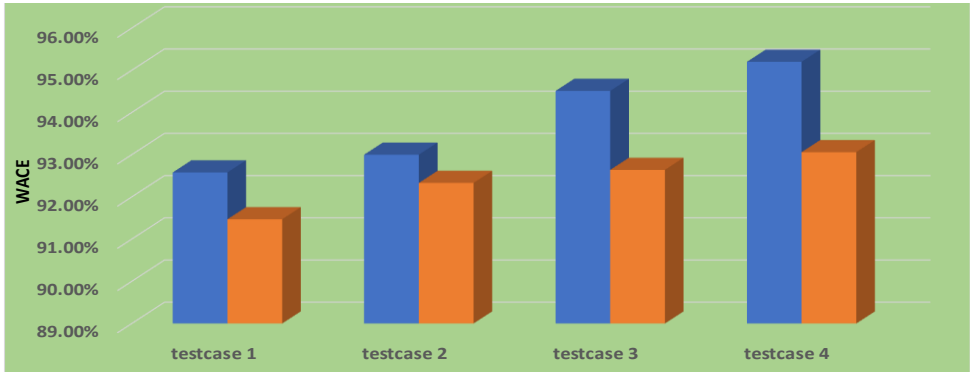
CRIRBM DETAILS

- A novel incremental estimated global-router-based box movement transform that moves gates from highly congested tiles to the less congested nearby tiles leading to significant congestion mitigation.
- It is paired with a timing-recovery post processing phase to reduce adverse timing impacts.
- In addition, the estimated global routing congestion-based cell movement method to mitigate congestion is more widely integrated into the late mode optimization steps.



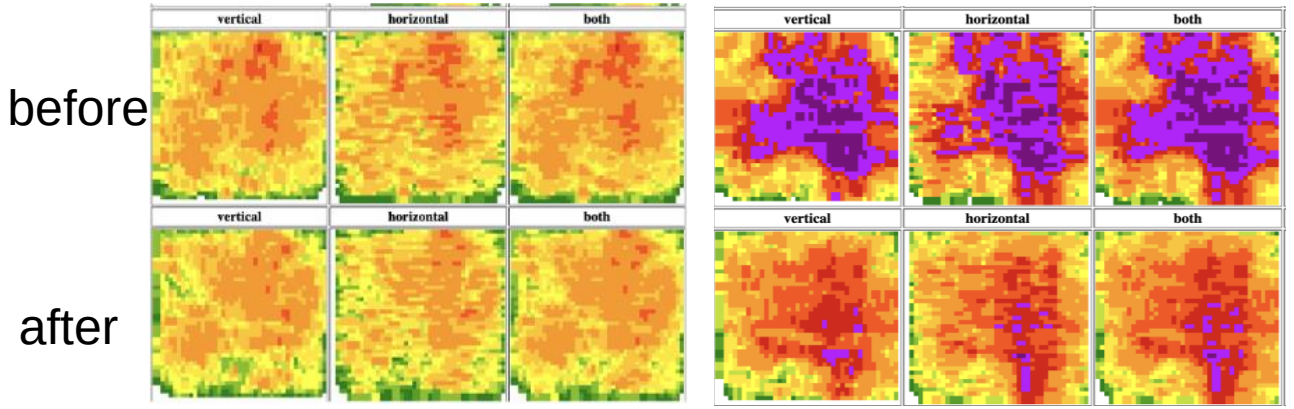
Full flow results / feedback

- Tests of new flow with all new features
  - 1%-3% of congestion relief



Blue color represents the existing flow result.
Orange color represents the result with the proposed methods

Congestion plot impact



customer1: With the new mode, "I do not see those 20k shorts”
customer2: The new mode has “the best QoR; we got congestion improved from 92% to 91% and power from 131 to 128”.
customer3: The new mode “greatly improved the congestion. The congestion of the testcase now in the 84% range” rather than 87%-90%.

1% congestion reduction has the big impact on the routablility

Summary

- Spreading preceded by area-recovery can reduce the object counts and improve the area utilization to have the better pin access and reduce the congestion simultaneously.
- Core polarity inverter removal also plays the very important role to let placement works better to minimize the wirelength.
- The novel incremental router-based box movement transform helps reduce the congestion hotspots.
- All above proposed methods turned several initially un-routable designs routable! We can get 1~3% congestion reduction for most of the testcases. 10% or more congestion reduction could be achieved for the most challenged testcases.