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An Advanced Method of Routing Optimization with 3D Coupling Aware To Improve Timing

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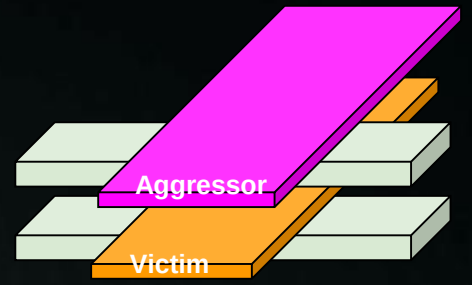
Motivation and Background

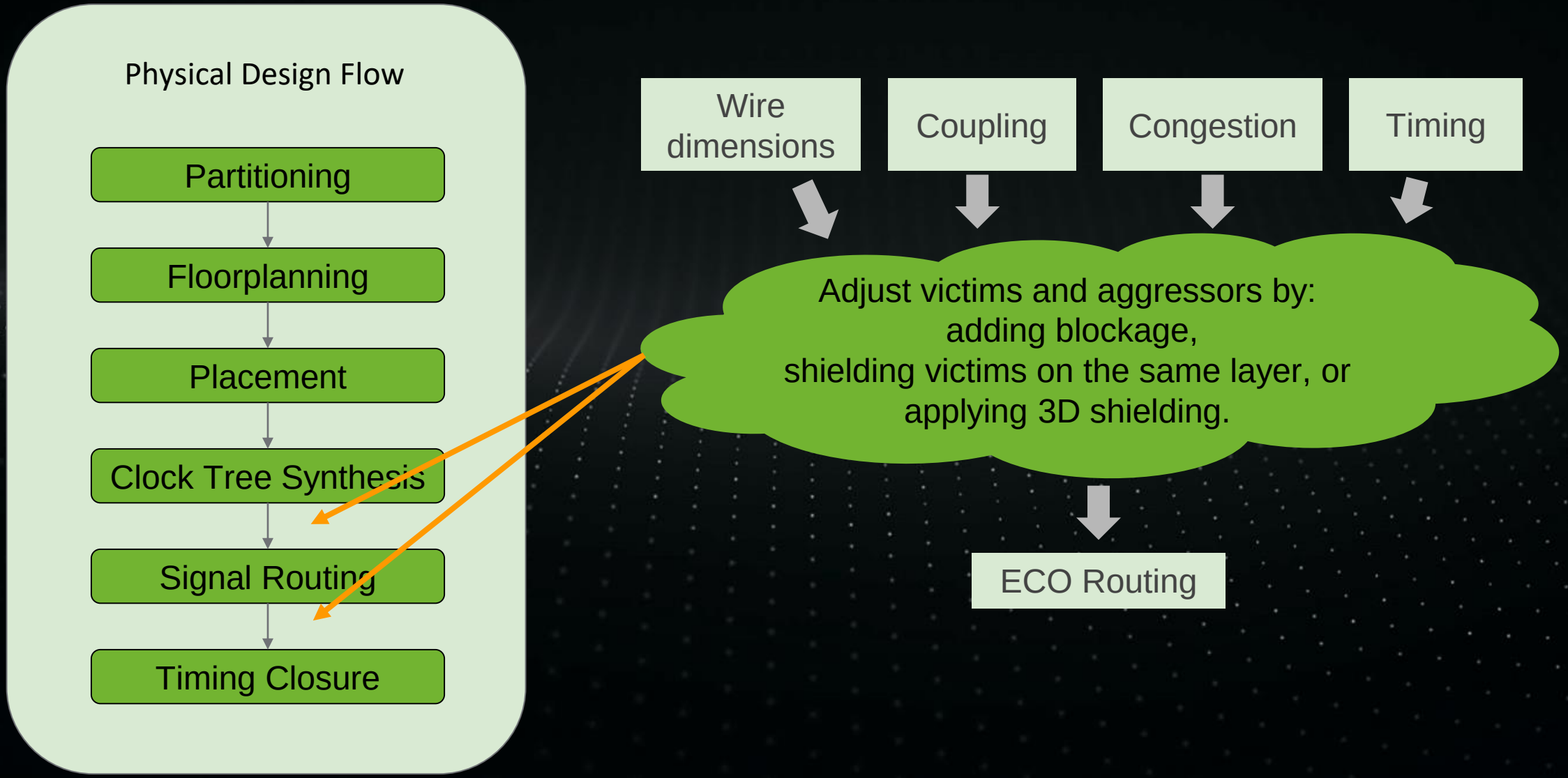
- Crosstalk caused by 3D coupling accumulates along a path.
  - Coupling on clock nets causes severe timing degradation.
  - Preroute timing estimation does not consider coupling.



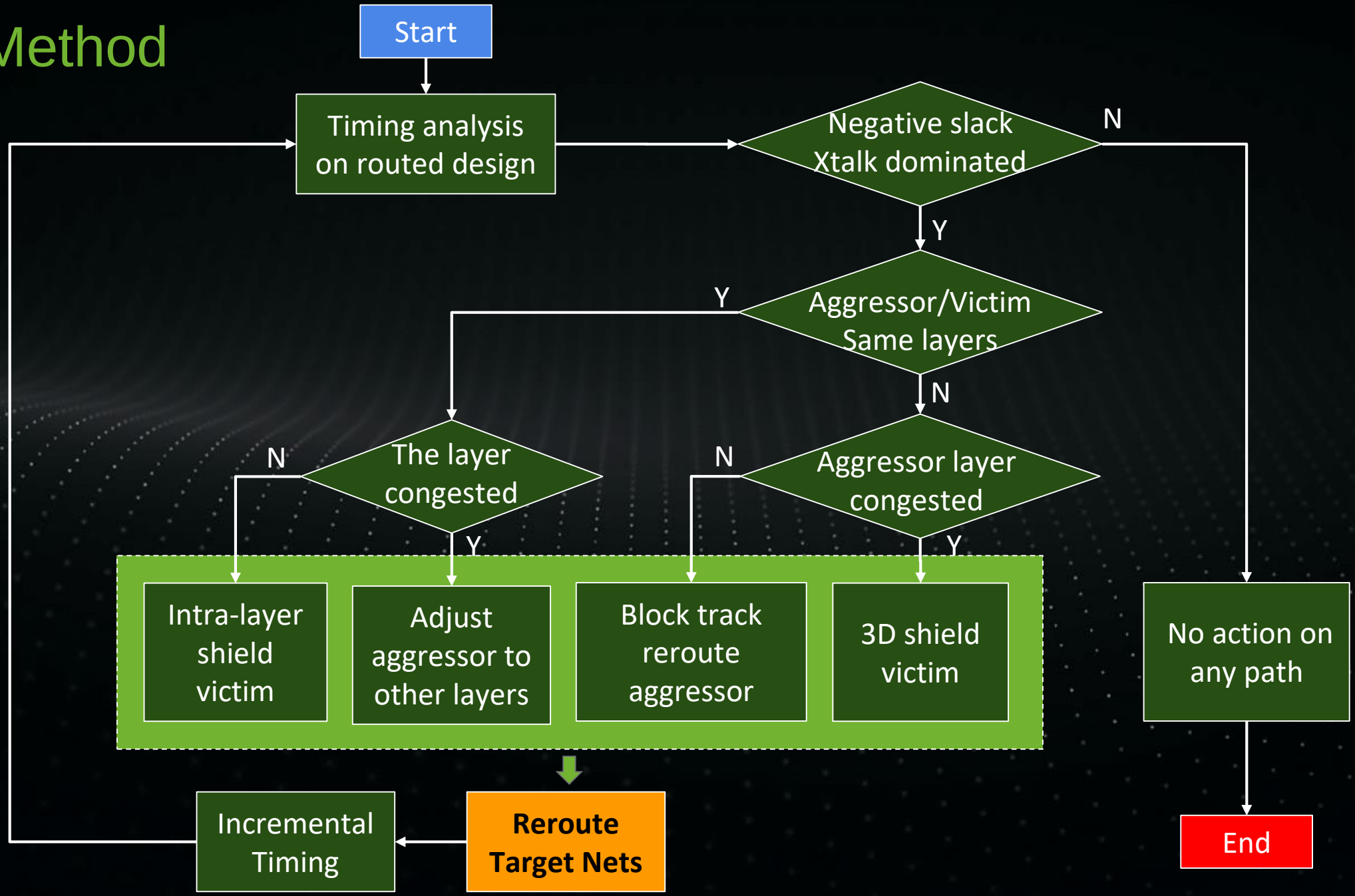
- Current EDA tools fix crosstalk by resizing or adding buffers which increases
  - power,
  - active area utilization, and
  - run time.

- A method is proposed to eliminate crosstalk delay caused by coupling considering congestion, 3D effects, and wiring dimensions on different layers. This algorithm is effective after detailed clock or signal routing.

Coupling Mitigation Algorithm



The Method


Start
Timing analysis on routed design
Negative slack Xtalk dominated
N
Y
Aggressor/Victim Same layers
Y
N
The layer congested
N
Y
Aggressor layer congested
N
Y
Intra-layer shield victim
Adjust aggressor to other layers
Block track reroute aggressor
3D shield victim
No action on any path
Incremental Timing
Reroute Target Nets
End

Design Impact Handling

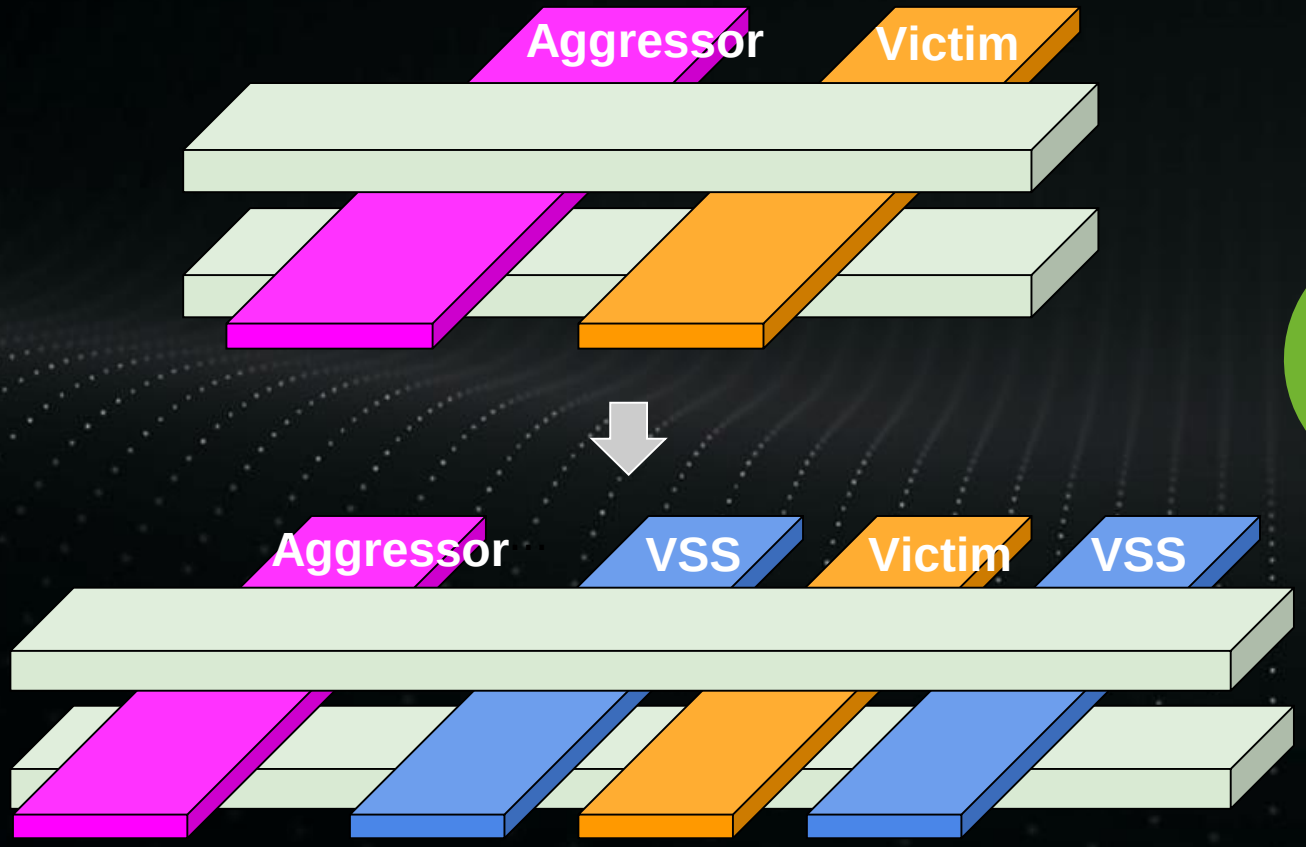
- User can control slack multiplier and crosstalk delay threshold to minimize impact to existing timing histogram.
  - Fix crosstalk if total crosstalk delay is larger than a ratio of total slack.
  - Fix crosstalk if crosstalk delay on single net is larger than a threshold.

- User can control density and congestion limits to minimize impact to DRC.

Run Time of the Flow

- It requires minutes to figure out target nets.
- It takes hours to reroute target nets.
- Iteration count can be controlled by user.

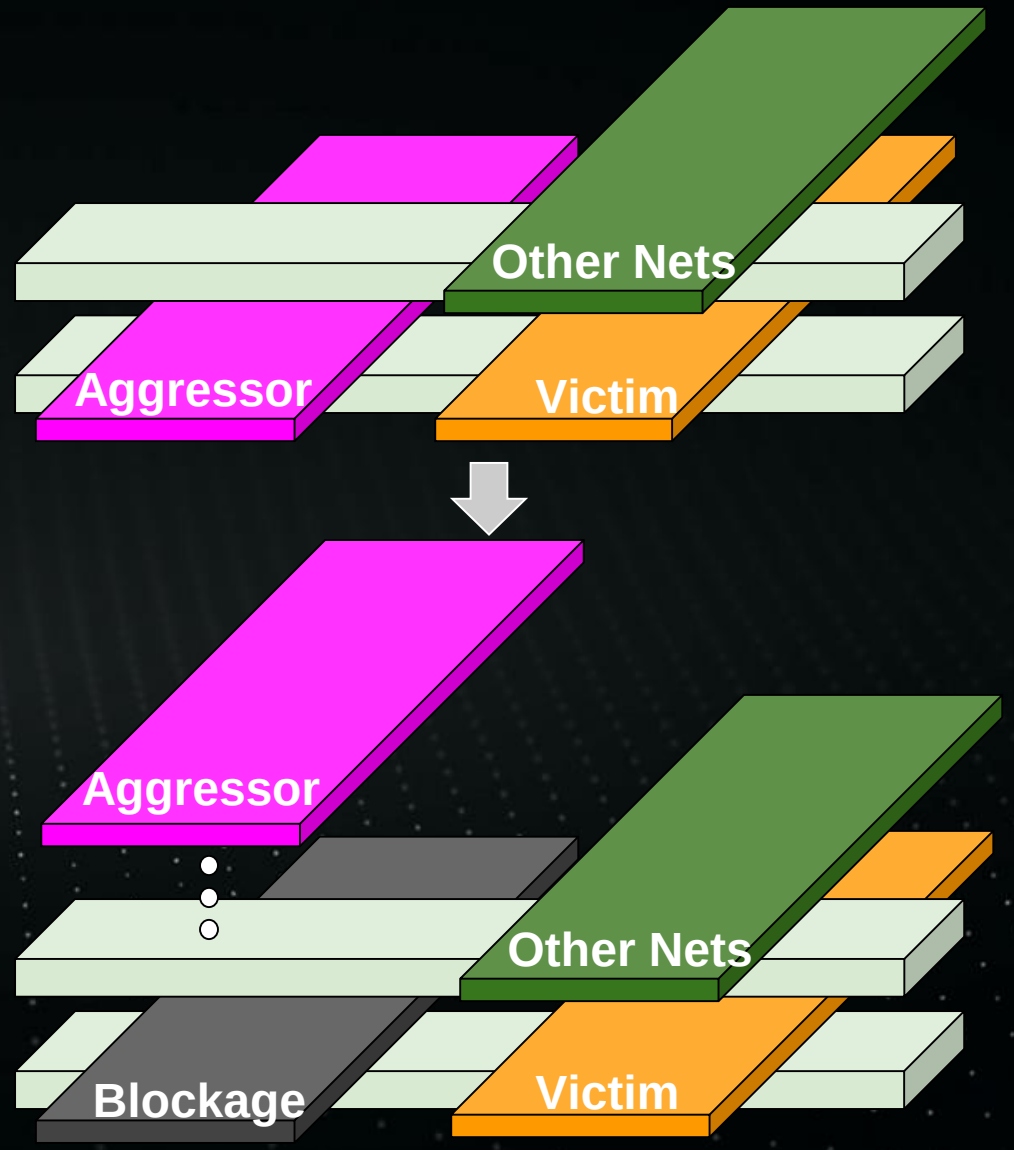
Scenario 1



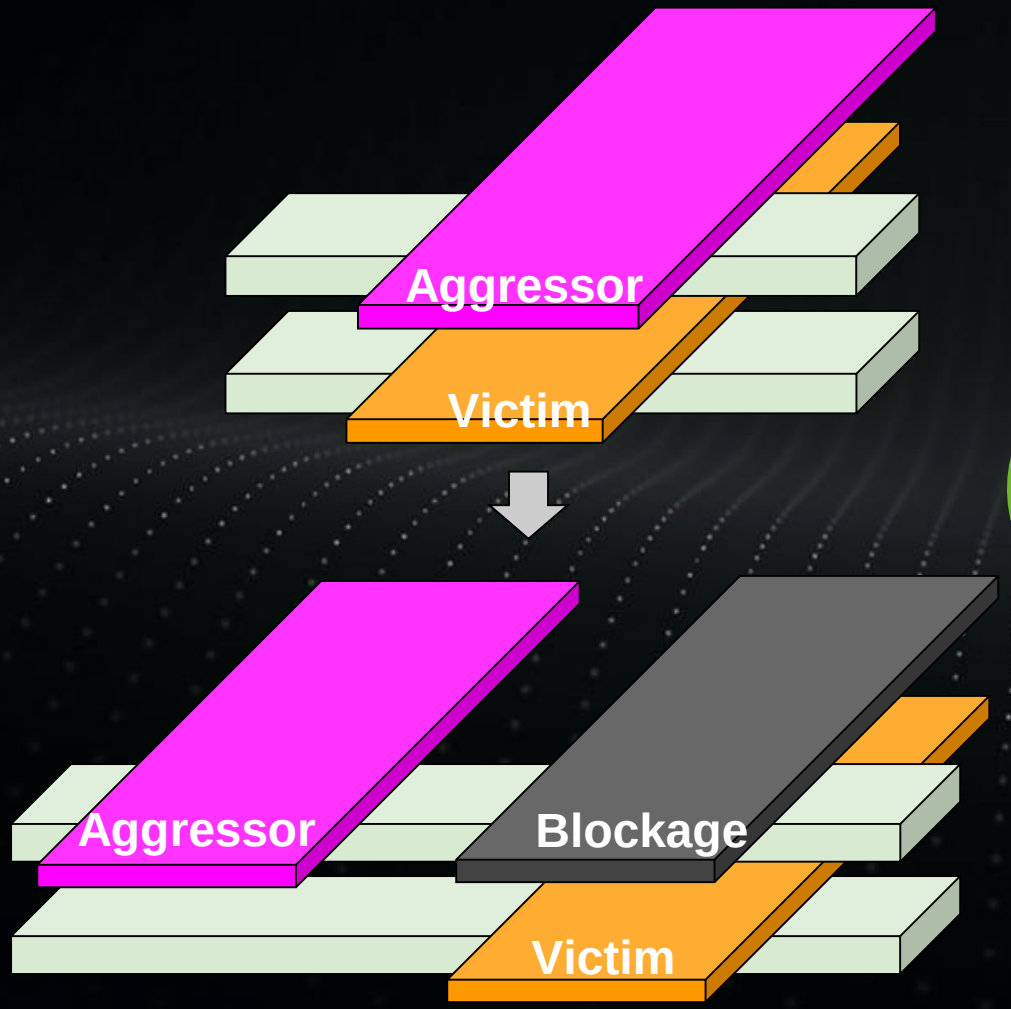
When the victim and the aggressor are on the same layer while the local congestion is **low**, ***intra-layer shielding will be created to the victim, and then the aggressor will be rerouted to a different location*****.**

Scenario 2

When the victim and the aggressor are on the same layer while local congestion is **high**, ***the wiring track of the aggressor will be replaced by a blockage, and then the aggressor will be rerouted to a different location.***



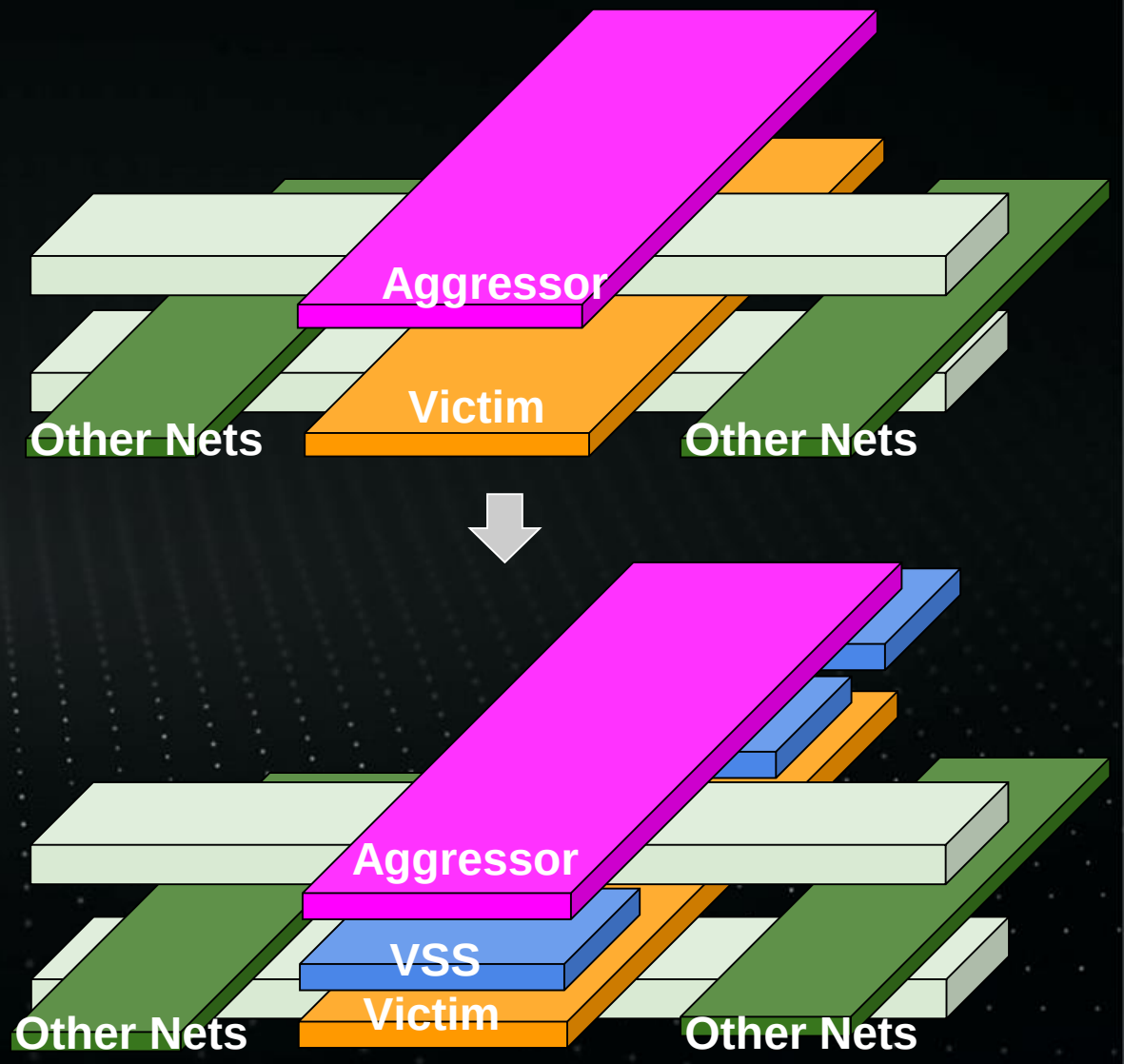
Scenario 3



When the victim and the aggressor are on different layers while local congestion is **low**, ***the wiring tracks of the victim will be replaced by blockages, and then the aggressor will be rerouted to another location not near the victim.***

Scenario 4

When the victim and the aggressor are on different layers while the local congestion is **high**, ***inter-layer shielding will be created between the aggressor and the victim nets***.



Programmable Algorithm

$$S = INT\left[min\left(\frac{\sum_{i=1}^{n} D(i)}{k * |Slack|}, 1\right)\right] * INT\left[min\left(\frac{D(i)}{D_{TH}}, 1\right)\right] * \left\{|L(j) - L(i)| + INT\left[min\left(\frac{C(j)}{C_T}, 1\right)\right] + 1\right\}$$

- 1st part is to determine whether the paths are crosstalk dominated (total crosstalk delay is greater than **k** ratio of the absolute value of slack).
- It could return 0,1

- 2nd part is to identify the victim net to be optimized where crosstalk delay is greater than the threshold value **D_{TH}**.
- It could return 0,1

- 3rd part is to calculate physical information for the coupled nets, considering congestion threshold **C_T**.
- It could return 1,2,3,4

The value of all the three parts multiplied together is used to choose the best strategy (1 of 5) for the routing optimization

Implementation Example -- Post-route Timing Iterations

Iteration	Total crosstalk delta delay of victim clock nets (ps)	Setup violation number	Setup WNS (ps)
n-2	55.737	4256	-1100
n-1	33.283	1428	-163.689
n	57.577	21709	-175.807
n+1	8.487	786	-127.222

Xtalk Fix

- **14nm Chip**
  - During timing closure, new setup violations were introduced by increased crosstalk delay from iteration n-1 to n. The crosstalk delta delay came from aggressors located on different layers.
  - Scenario 3 was dominant -- aggressors on different layers, low congestion. k=0.3, D_{TH}=1ps, C_T=0.1.
  - Lower coupling reduced variation on clock paths, and setup fails were reduced in iteration n+1.
  - In subsequent iterations, no unexpected new setup violations popped up.

Summary

- **The method** may be used after detailed clock or signal routing, considering both timing and physical information to calculate a scenario for shielding victims and rerouting aggressors.

- The proposal costs only very limited runtime increase.

- **The advantages of this method are as follows:**
  - Different coupling scenarios, including 3D coupling, are considered.
  - The reroute method minimizes impact to timing, congestion, power and utilization.
  - It reduces timing-closure iterations.

- **Engineering implementation:**
  - These techniques may be integrated with current EDA tools.

Thank You

Q & A