Current-Driven Wire Planning for Electromigration Avoidance in Analog Circuits

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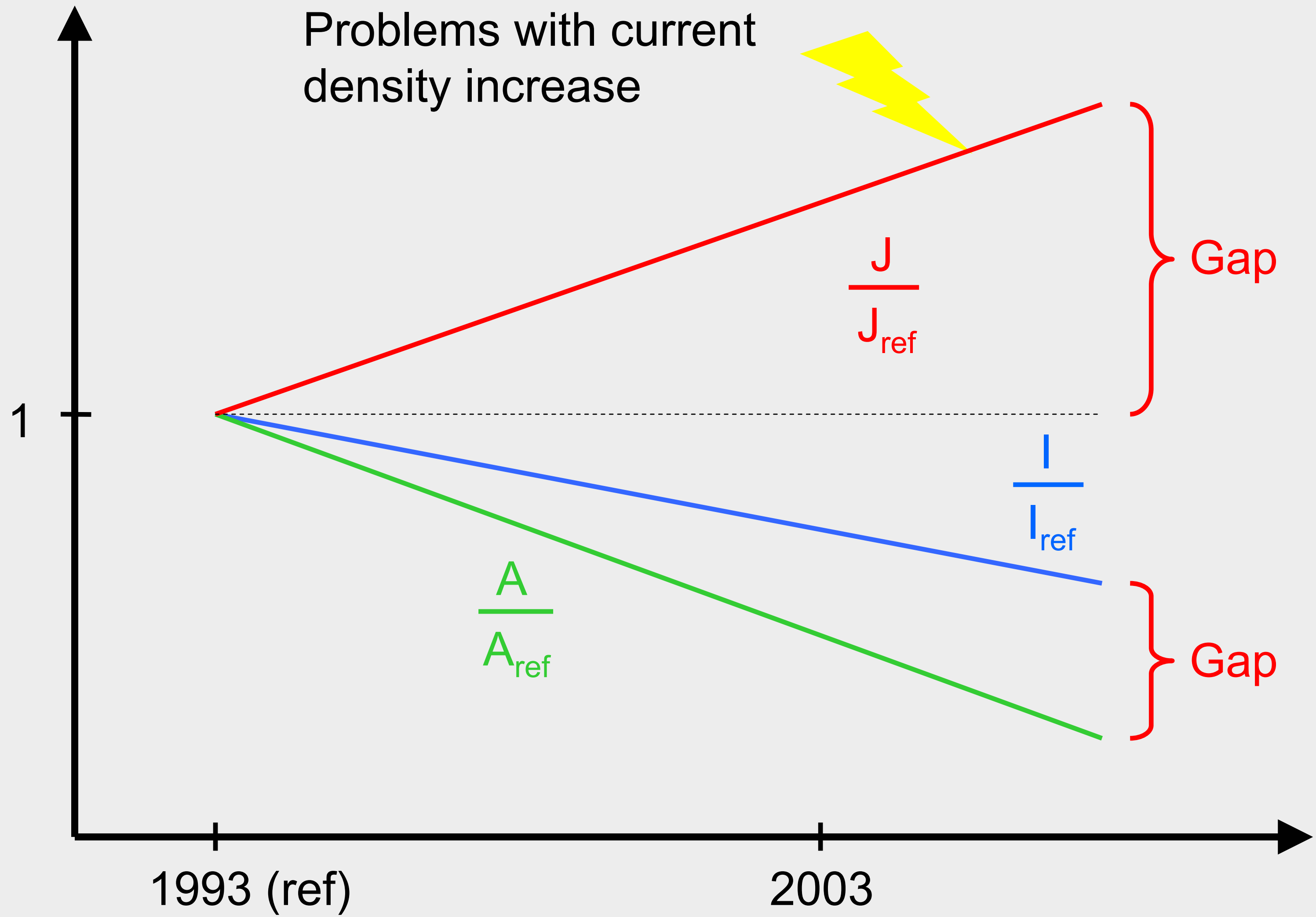
Motivation



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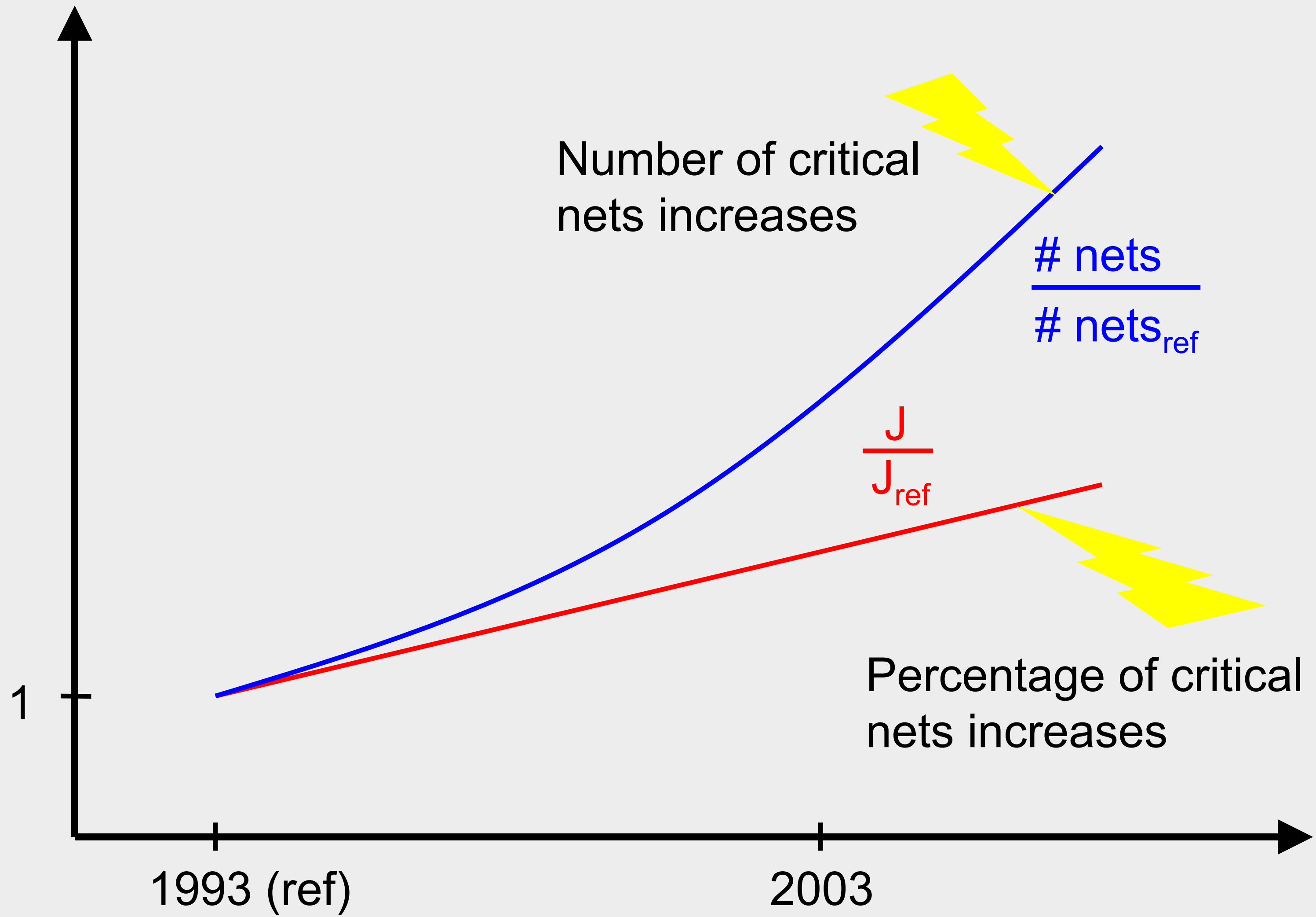
Motivation (cont.'d)



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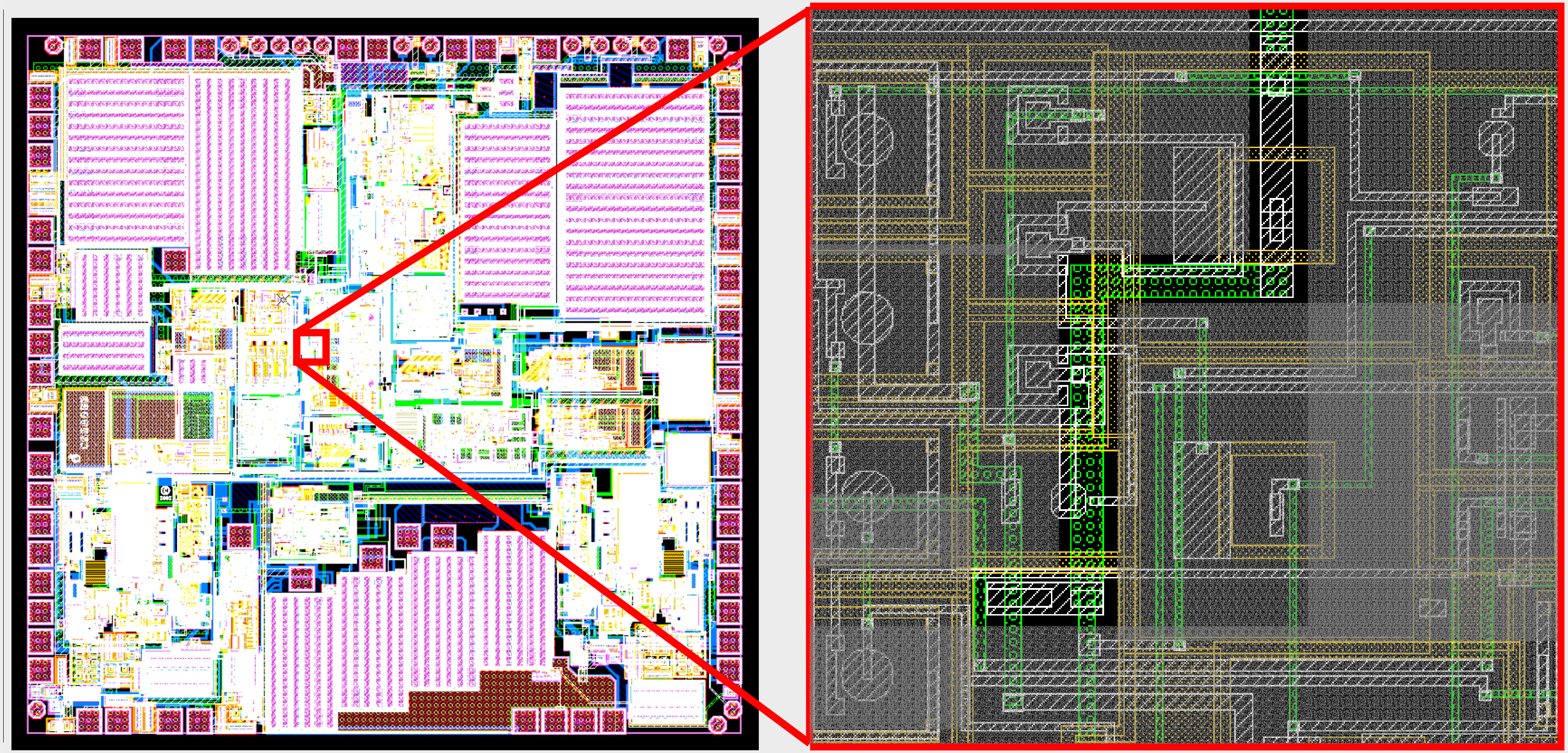
Current density critical nets exist in top level cells *and* block level cells



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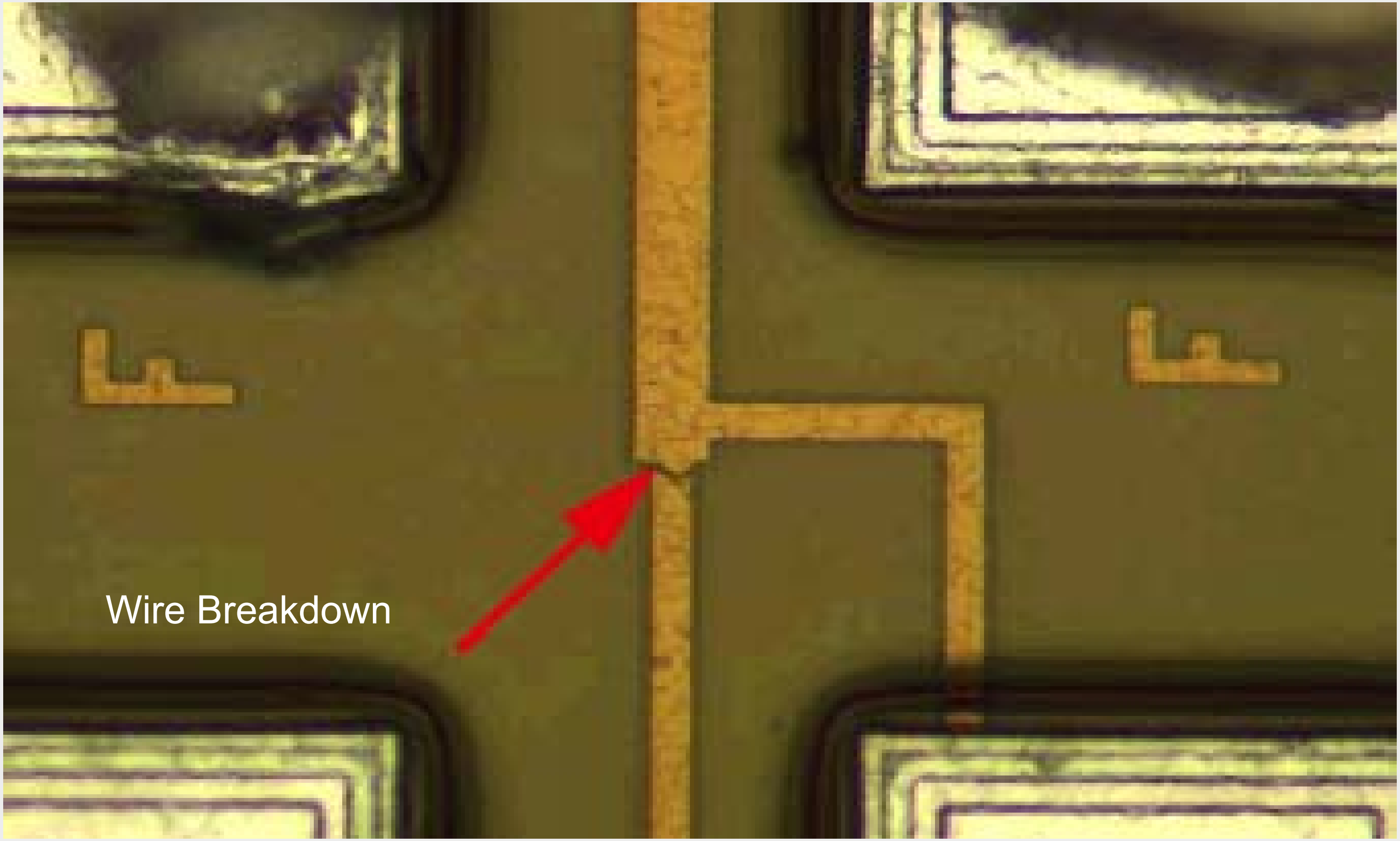
Physics of Electromigration



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What is Current-Driven Wire Planning ?

Layout Design	Constraints	Optimization Goals
Topology-driven	- Design rule correctness	- Min. net length - Max. percentage of finished nets - ...
⇓		
Performance-driven	- Design rule correctness + Performance	- Min. delay and skew - Min. number of buffers - ...
⇓		
Reliability-driven (Current-driven)	- Design rule correctness + Performance + Reliability	- Max. reliability - Max. manufacturability - Max. electromagnetic compatibility - ...

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What is Current-Driven Wire Planning ? (cont.'d)

- *Current flow* is our primary guidance parameter for wire planning
- Definition "Current-Driven Wire Planning":

  Current-driven wire planning is wire planning *controlled* by the current flow to be expected in various net segments.

- Optimization goal is to minimize the used routing area while ensuring interconnect reliability

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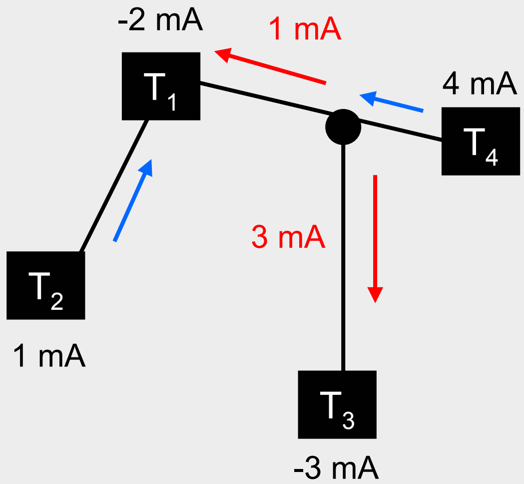
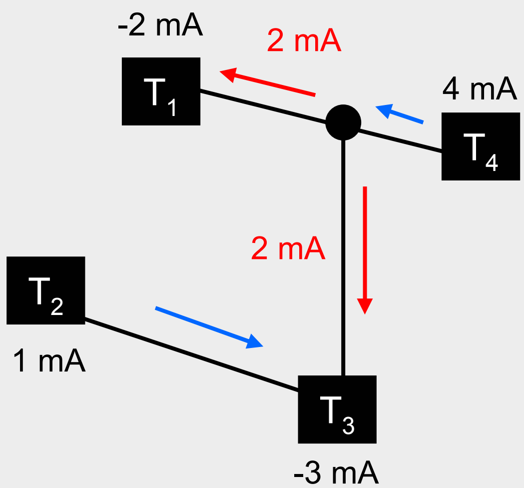
The Cyclic Nature of Current-Driven Wire Planning

... *Complete* Net Topology requires ...

Cyclic Conflict

... Current Flow in *all* Net Segments requires...





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Previous Works

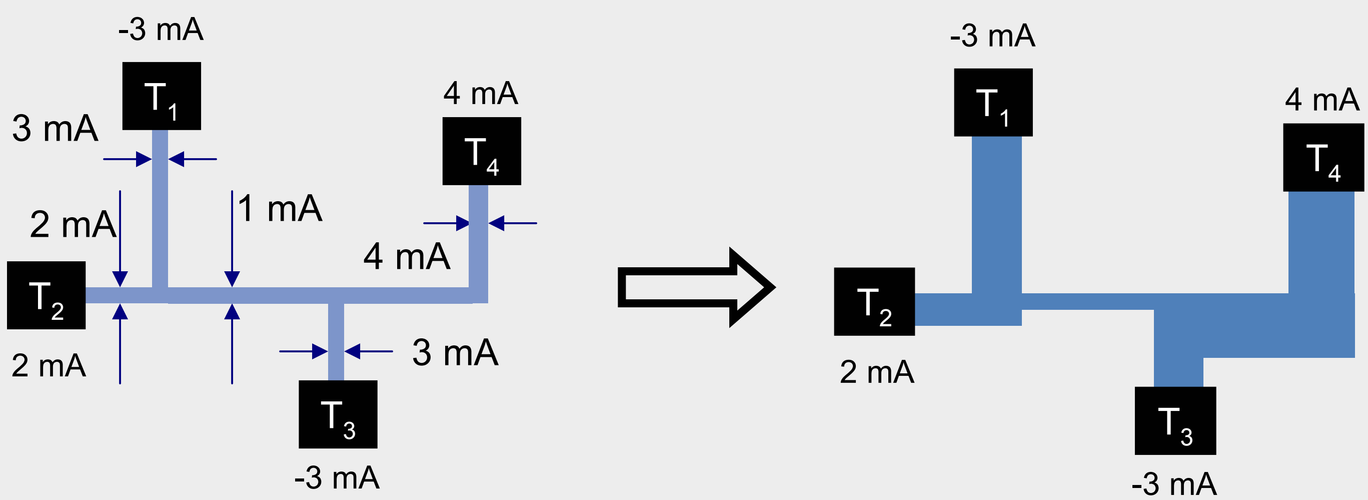
- Electromigration physics:
  [Black68], [D'Heurle71], [Black83]
- Wire width adjustment after routing (power routing):
  [Syed82], [Rothermel83], [Moulton83], [Haruyama87], [Chowdhury87], [Mitsuhashi92]
- Current-driven routing: Steiner point insertion
  [Adler00a], [Adler00b], [Lienig02]

Previous Solution: Wire Width Adjustment After Routing

Given: Layout topology of a routed net

Objective: Adjust wire and via cross-sections according to current flow in net segments

Algorithm:
1. Route net with arbitrary wire width(s)
2. Calculate all branch currents
3. Adjust cross section of wires and vias / via arrays



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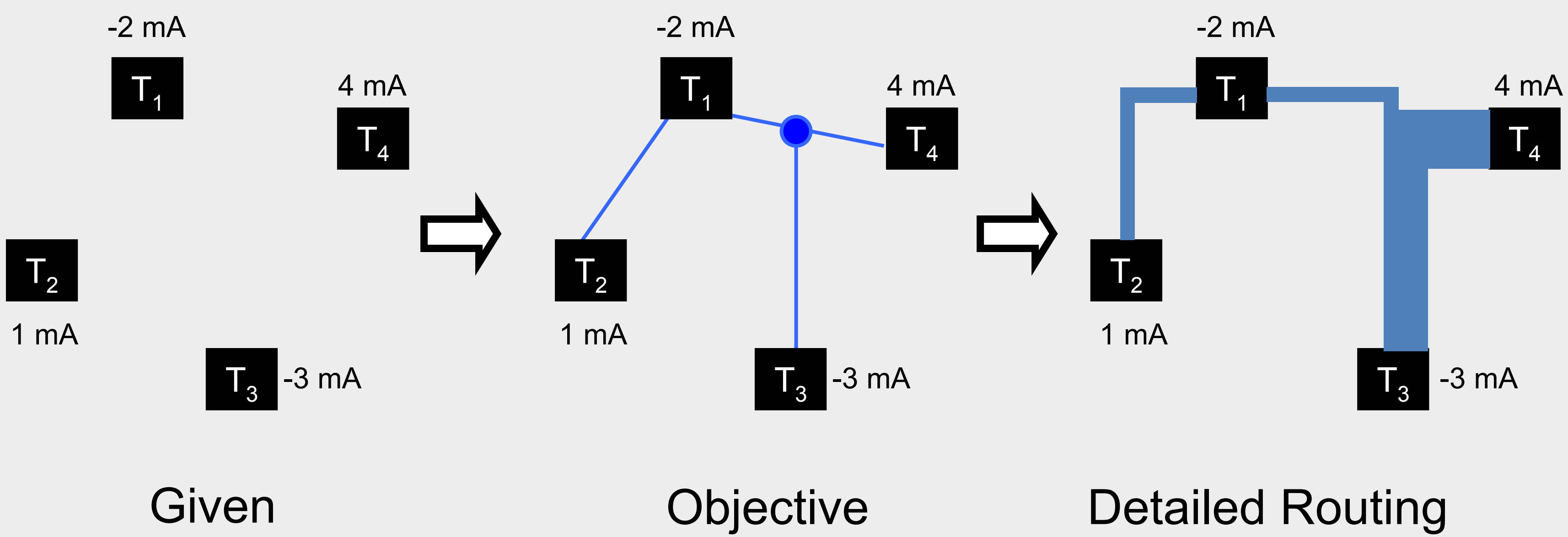
Our Solution: Current-Driven Wire Planning Prior to Routing

Given: Net terminals with currents

Objective: Obtain a list of net segments with an optimized current flow

Task: Determine a list of global connections and global Steiner points in order to achieve an optimized current flow



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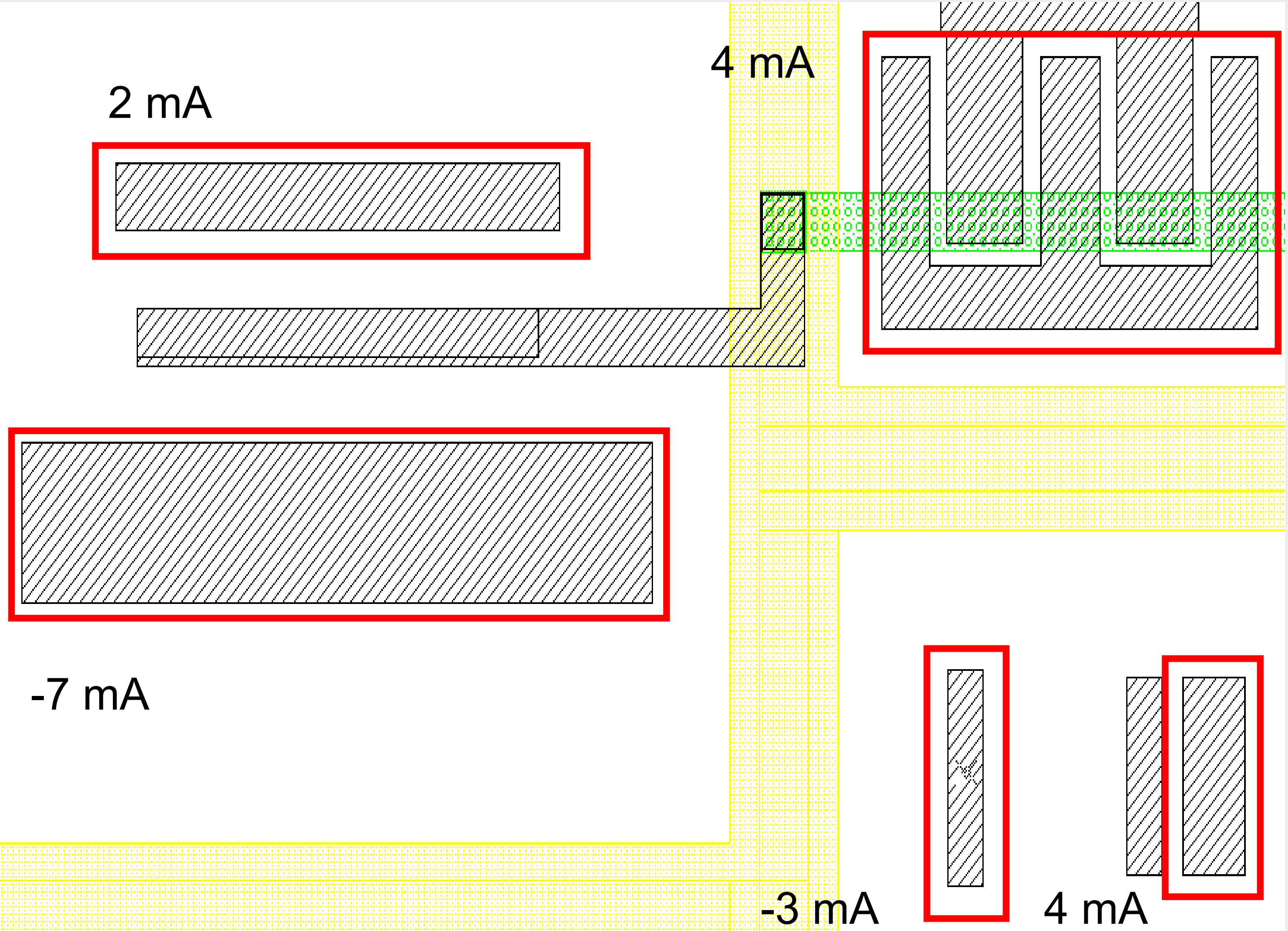
Our Algorithm



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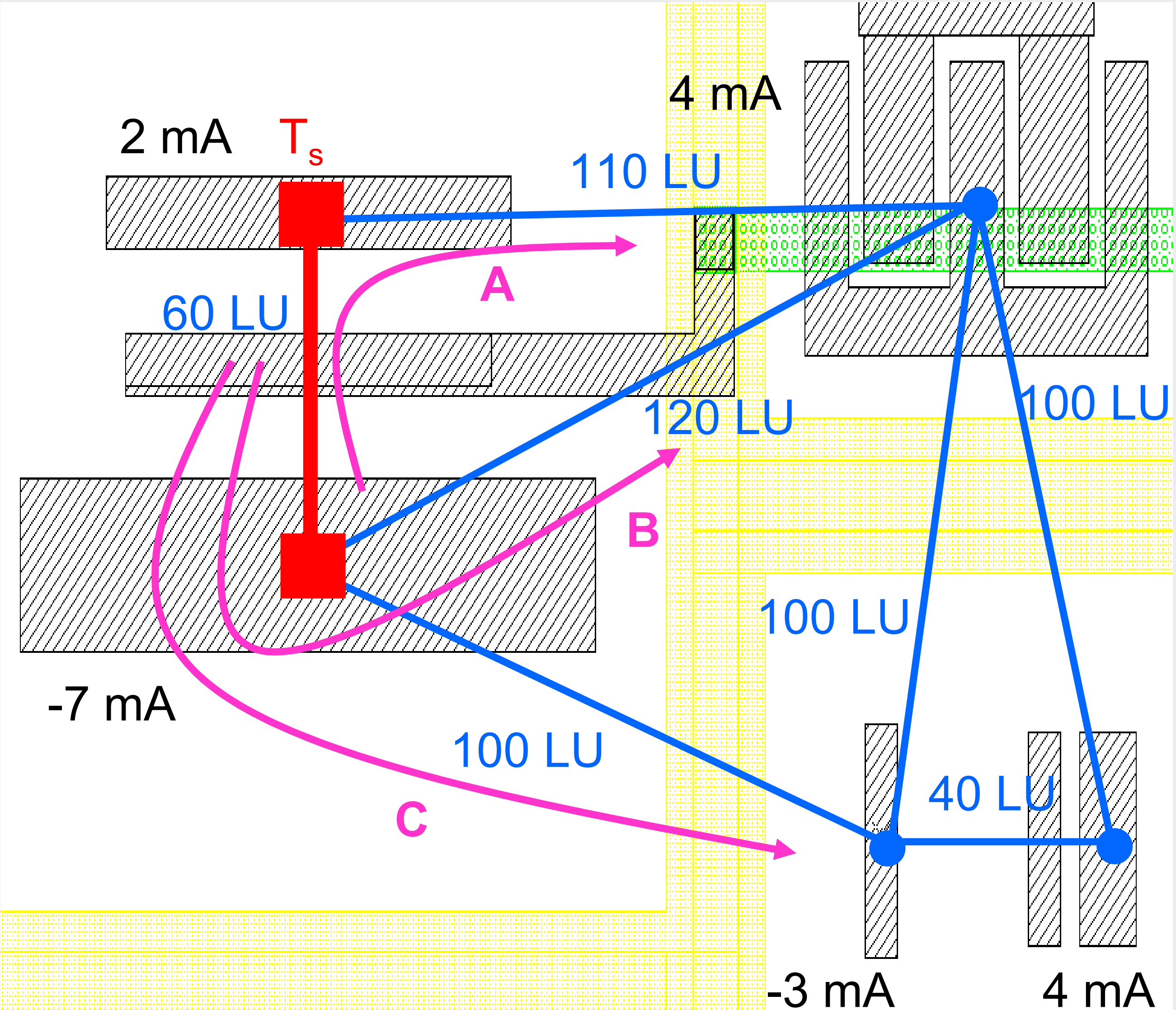
Our Algorithm (cont.'d)



1. Create mesh graph
2. Choose start terminal T_s
3. Get shortest edge for T_s
4. Calculate CCA for active edge:
   A: 970 LU^2
   B: 720 LU^2
   C: 620 LU^2

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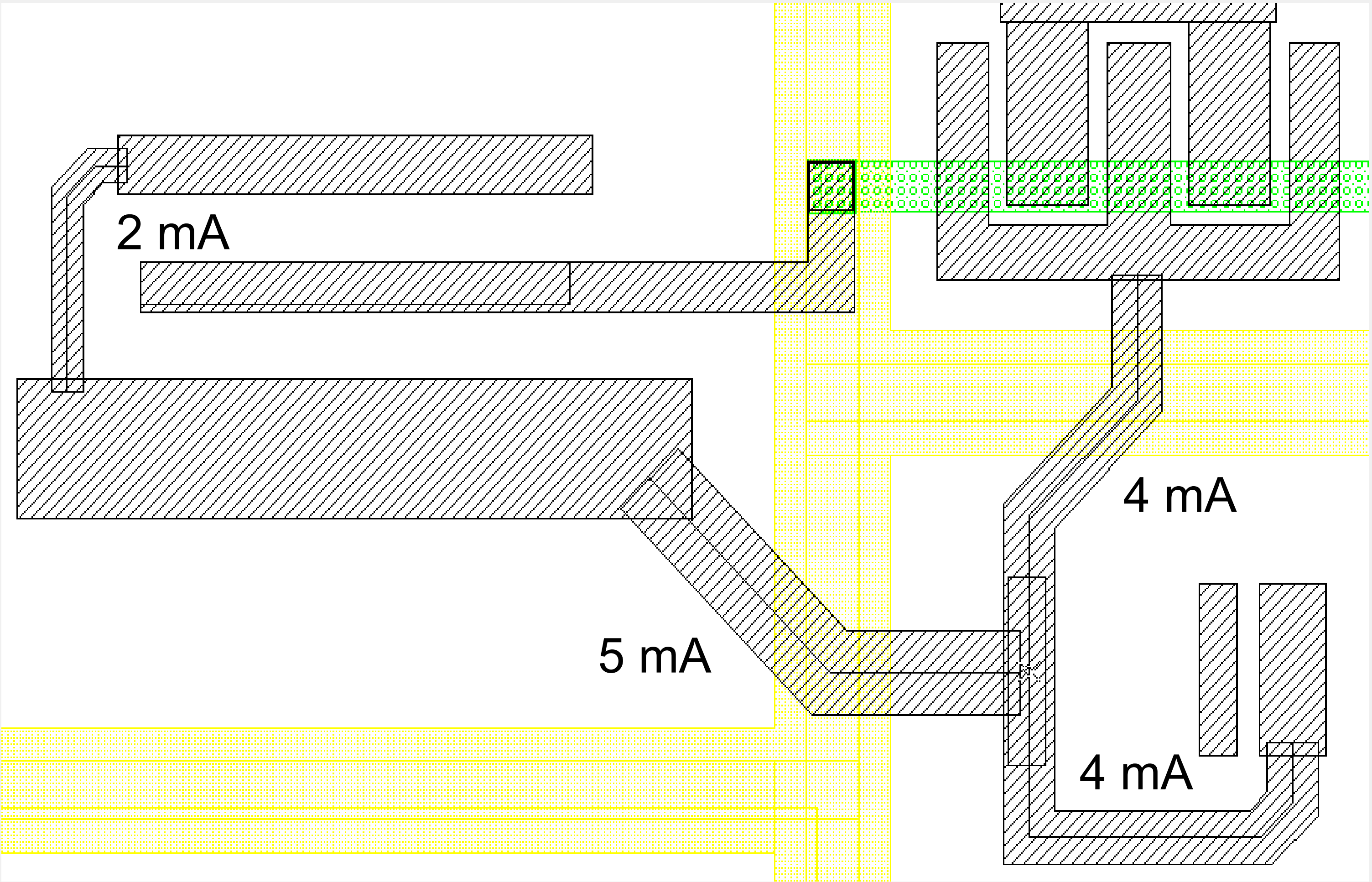
Our Algorithm

Detailed Routing Result



Results

Cells	Method	Wire Area (μm^2) *	Vias	Routing Area (%) **	Routing Time (min)
supply	**Our approach**	**50,220**	**145**	**100**	**3**
	Manually	51,440	138	102.6	≈ 125
	Steiner tree	n/a	149	102.0	22
	Terminal tree	n/a	148	102.2	4
wala	**Our approach**	**76,337**	**136**	**100**	**3.5**
	Manually	76,340	130	100.3	≈ 150
	Steiner tree	n/a	142	103.0	8
	Terminal tree	n/a	139	104.0	5
imux	**Our approach**	**78,880**	**178**	**100**	**4.5**
	Manually	80,320	178	103.4	≈ 180
	Steiner tree	n/a	198	103.8	9
	Terminal tree	n/a	193	103.9	5
receiver	**Our approach**	**54,604**	**180**	**100**	**6**
	Manually	58,380	178	102.5	≈ 185
	Steiner tree	n/a	199	102.0	13
	Terminal tree	n/a	197	102.8	7
dcdriver	**Our approach**	**102,275**	**455**	**100**	**14**
	Manually	108,880	460	104.1	≈ 240
	Steiner tree	n/a ***	n/a ***	n/a ***	n/a ***
	Terminal tree	n/a	483	106.0	20

* *Wire Area = Current connection area (CCA) of all wires according to Equation (6)*

** *Routing Area = Die area used for routing*

*** *Not applicable due to memory and run time limitations*

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Conclusion

- Presented new and effective method for current characterization
- Presented new strategy for fast current-driven wire planning based on segment allocation and hence, current calculation, *prior* to detailed routing
- Industrial usage showed very promising results *and* some important practical issues (e.g. inhomogeneous current flow, via array sizing, etc.)
- In future, reliability-related constraints (such as current strengths) must become an integral part of place/route/verification tools in order to fulfill reliability constraints

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