Shield Count Minimization in Congested Regions

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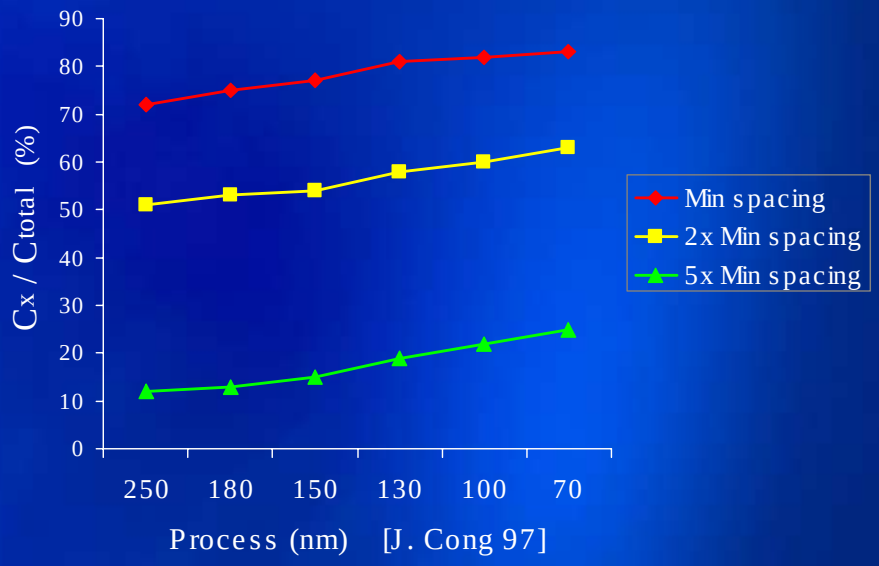
Motivation

- **Switching xcap worsening with process scaling**
  - Noise failures
  - Widened timing windows => convergence problems
- *Usual fix*: ***Shield all sensitive signals!***
- **# sensitive nets exploding**
  - Die-size impact (most designs wire-limited)
  - TTM impact if a block doesn't fit
    - Shield count known very late



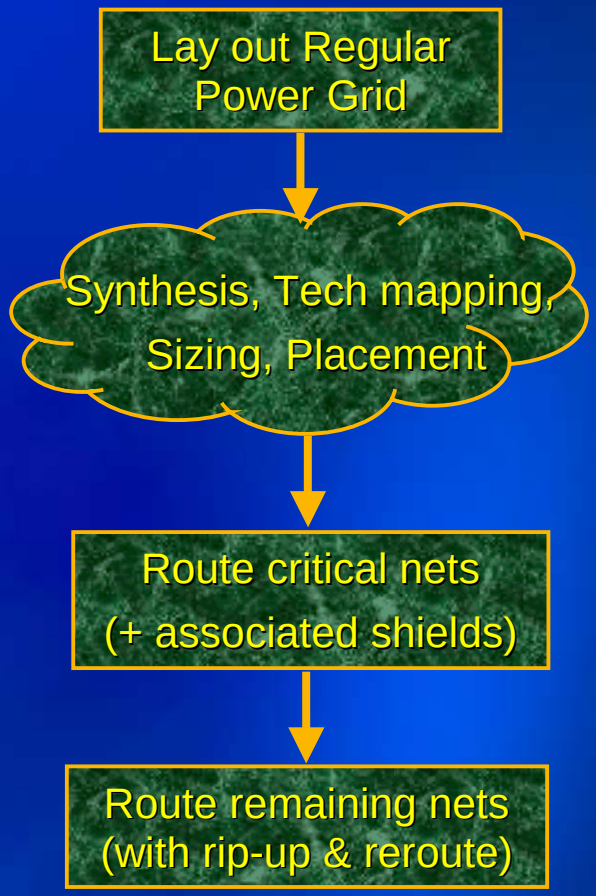
Traditional Routing Flows

The view from 30,000 feet…

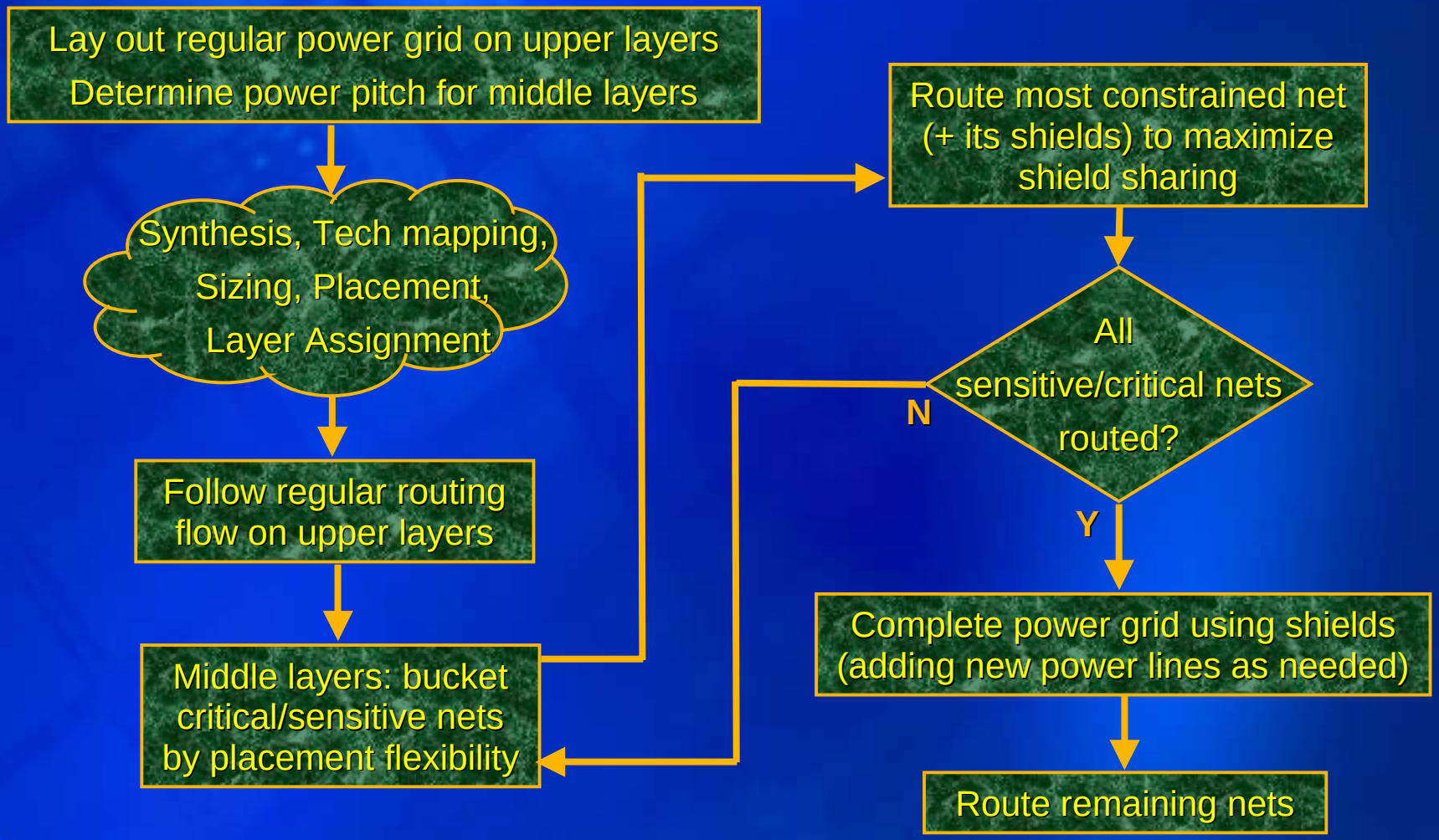
- **Pre-routed power grid not disturbed during signal routing**
- **Global routing assigns nets to GRCs**
- **Little effort at shield sharing**

Question these assumptions…

…but be very careful !



Proposed Routing Flow



Constraints on Proposed Flow

- **Must not compromise *early* analysis of power grid**
  - Upper layers: Wide power lines => can't be "extracted" from signal shields
  - Middle layers: Can model grid "virtually" using power pitch
- **Applicable to middle layers only**
  - Power grid here often fine-grained
  - Power line matching not essential across adj. blocks
    - Current between adj. blocks flows largely through upper layers even with matched grids
- **Use only in congested regions with many xcap-sensitive nets**

Shield Sharing Optimization

- **Order critical signals by placement flexibility, shield count**
  - Placement flexibility captures RC of vias near driver, detours
  - Update ordering dynamically during routing process
- **Route most constrained net first**
  - Maximize reuse of existing shields
- **One layer at a time**
- **Customize this meta-heuristic as needed**

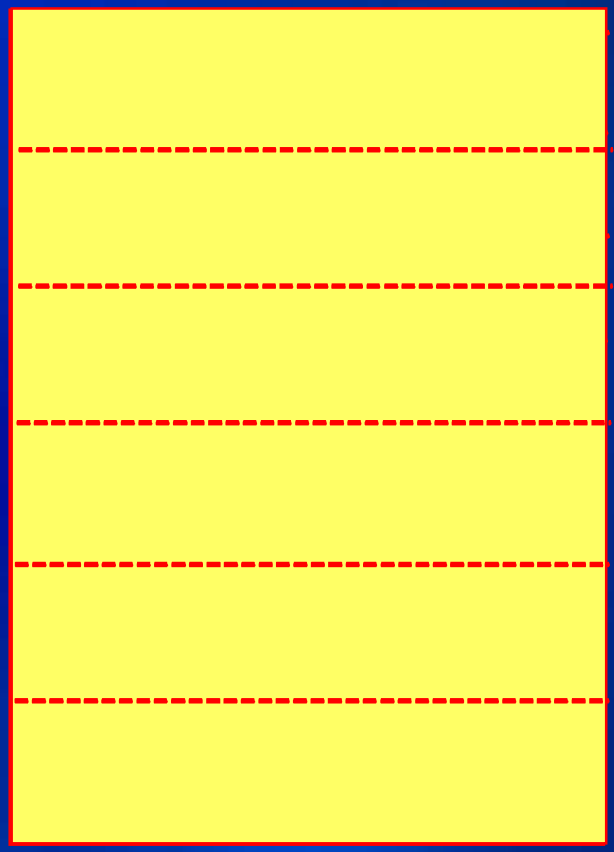
  Example coming up…

Shield Sharing Optimization

Applied within a domino synthesis system

- Library, routing methodology cause placement flexibilities to cluster around a few peaks

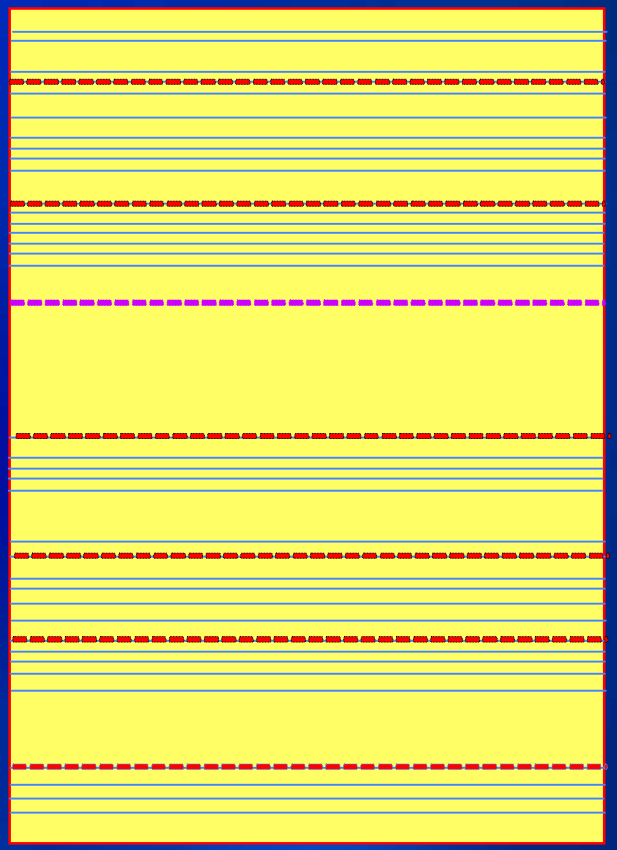
- **Discretize placement flexibilities into a small number of buckets**
- **Tile layout with min bucket size**
- **For current bucket & tile**,
  - place 2-shld nets and then 1-shld nets
- **Repeat tiling with next larger bucket, until all buckets done**



Adaptive Power Routing

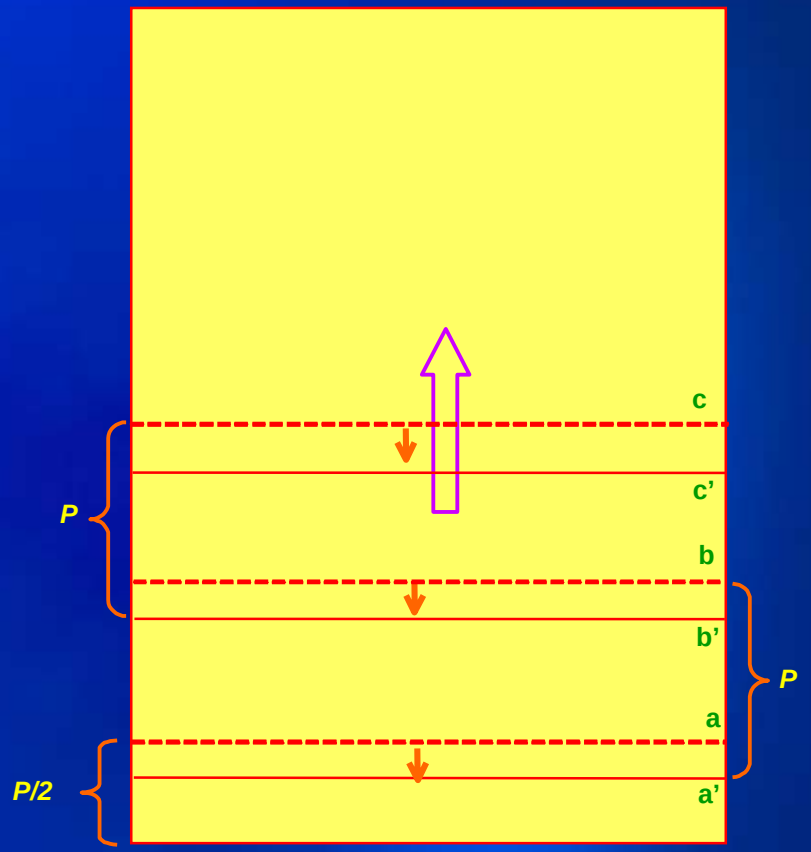
- **Extract power grid from existing shields**
- **Add new power lines only in shield-free regions**
- **Do adaptive power routing after sensitive signal routing**

- Flexibility in power grid => more shields double as part of grid than tracks in a prerouted grid that can double as shields



Adaptive Power Routing

- **Starting from “current” power line, search for “next” line**
  - Search backward from current track + P for first shield
  - If no shield found, repeat search for first vacant track
  - Set polarity of selected line
  - Reset “current” power line

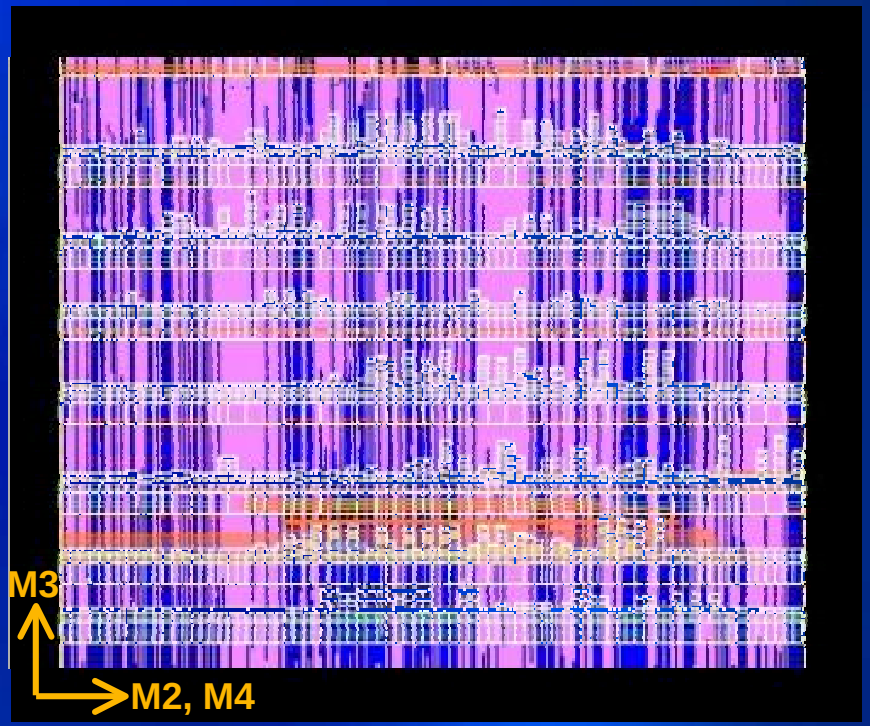


Optimality Properties

- ***Adaptive power routing uses fewest additional power lines to complete grid***
  - *for a given shield/signal net map and a given power pitch*
  - Induction based proof presented in paper…
- **Adaptive power routing runtime asymptotically optimal**
  - Linear in number of tracks
  - O(TP/p), T: # tracks, P: power pitch, p: routing pitch

Design Results

- **Tested on several domino blocks from a 0.18μ GHz μP**
- **One critical block taped out for hi vol product in ’99**
- **Custom quality shielding and routing in each case**
- *Taped-out block:* **prerouted grid + greedy shielding failed to fit**
  - Redesign would have impacted tapeout date
- **Valid operation on high volume product at >2GHz**



Design Results

- **Taped-out block: applied on M3**
- **1 M3 trunk per net, very tight net placement constraints**
- **363 signal nets, (38+30) preroutes (signal / power)**
- **Shielding requirements in final layout:**
  - 43 tracks: 1 shield
  - 62 tracks: 2 shields
- **Only 73 new shields added**
  - DWF (Khatri '99): 185 new lines
  - Prerouted grid + greedy shielding: ~140 new lines
- **Adaptive power routing: only 4 new power lines**
  - *A priori* grid: ~25 power lines
- ***Total* # track saving: 25% wrt DWF**

Summing Up

- **Addressed problem of routing in congested regions containing many xcap-sensitive signals**
- **Solution on algorithmic + methodological fronts:**
  - A new GR/DR abstraction for better xcap estimation
  - Sophisticated shield-sharing heuristics
  - Postpone power grid completion to after critical net routing
  - Extract power grid from shields
    - Add power lines only in shield-free areas
- **Proved optimality of adaptive power routing**
- **Validated on high volume μP silicon at >2GHz at 0.18μ**
  - Custom quality routing and shielding on critical block