# Heuristic Power/Ground Network and Floorplan Co-design Method

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ASP-DAC 2008

# Outline

1. Motivation
2. Our Contribution
3. Our Approach
4. Experimental Results
5. Summary

# Outline

# Co-Design Power/Ground Network and Floorplan

- Simultaneous Adjusting of Floorplan and P/G Network
- Benefits of Co-Design of P/G and Floorplan
  - Fix the power supply problem at early stage.
  - Reduce the design iteration.
  - Improve power supply performance with reasonable floorplan tradeoff.

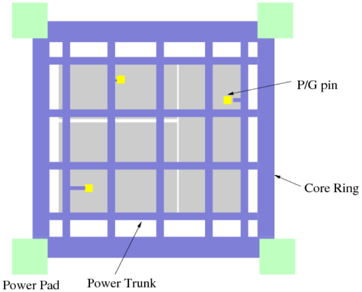


Figure: P/G model at floorplan stage.

# Essential Steps in Co-design of P/G network and Floorplan

1. Voltage Drop Estimation
   During thousands of iterations of the simulate annealing process in floorplanning, voltage drop should be calculated every time.
2. Adjust the Floorplan
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3. Optimize P/G Network Topology
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# Previous Work : Co-synthesis Algorithms of P/G network and Floorplan

- Floorplan and P/G Network Co-synthesis [1, 2]
  - Prescribed uniform mesh grid as P/G network.
  - Simulate annealing for floorplanning, considering the IR drop in cost function.
- Floorplanning and Decap Placement [3]

  Floorplanning algorithms to reduce the decoupling

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# Limitations of Previous Co-synthesis Algorithms

- Low Efficiency of IR Drop Estimation
  Due to thousands of iterations in the floorplanning process, the time used to build and simulate the P/G network in floorplan stage leads to a obvious time overhead
- Lack of Integration of P/G Network Optimization to Floorplanning
  Ignoring the irregular P/G topology could be a potential problem which could lead to miss of better design at early design stage.

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# Heuristic Floorplan and P/G Network Co-design Algorithm

1. Efficient IR Drop Estimation Method
   An analytic IR drop estimation method is proposed, which could speedup the IR drop assessment largely with tolerable inaccuracy.
2. Analytic IR Drop Estimation as Cost Function in SA Process
   Because of the efficiency of analytical IR drop estimation, evaluation of cost function in simulate annealing (SA) is largely reduced. Consequently, the time cost of the whole SA process could be reduced sufficiently.
3. Heuristic P/G Network Topology Optimization Algorithm
   A non-uniform mesh grid is built for the chosen floorplan to improve the power supply performance further more.

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# Basic Idea

- Virtual Metal Plane As Power Supply
  we introduce a “virtual metal plane” (VMP), which has the power supply function similar to a very dense mesh grid, serving as a *c*onceptual power supply.
- Analytical IR Drop Estimation As Cost Function in SA
  We obtain the analytical solution of equation of “VMP” and plug it into the cost function of SA. After the SA process done, we obtain a floorplan in favor of power supply.
- Heuristic P/G Network Optimization using “VMP”
  For the chosen floorplan, we optimize the P/G network according to the current distribution on VMP. i.e. Remove the regions of VMP where little current is conducted and form a non-uniform power supply mesh network.

# Principle of Virtual Metal Plane

- Similarity of VMP and Dense Mesh Grid

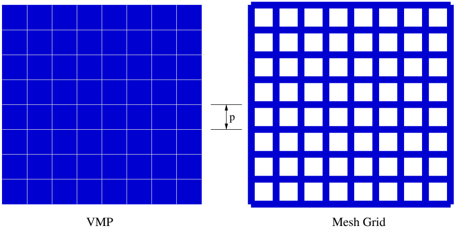


Figure: Virtual Metal Plane *VS.* Mesh Grid

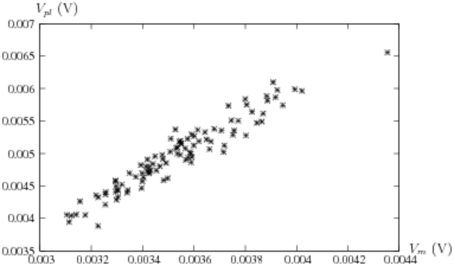


Figure: $V_{pl}$ *VS.* $V_m$

# Evaluate the power supply : Analytical IR Drop Estimation Using VMP

1. Estimate IR Drop by Solving the Equation of VMP
    1. Poisson equation of VMP

$$\Delta \cdot V(x,y) = \frac{I_0(x,y)}{\sigma} \quad (x,y) \in \Omega \qquad (1)$$

$BCs$ :

$$\begin{aligned} V(x,y) &= V_{dd}(x,y) \quad (x,y) \in \partial\Omega \\ \Omega &= \{(x,y) | 0 \leqslant x \leqslant a, 0 \leqslant y \leqslant b\} \qquad (2) \end{aligned}$$

    2. Solution of VMP equation (1)

$$V = \frac{4}{\sigma ab} \sum_{k=1}^{N_b} \sum_{i=1}^{\infty} \sum_{j=1}^{\infty} I_k \frac{\sin(p_i x)\sin(q_j y)\sin(p_i x_k)\sin(q_j y_k)}{p_i^2 + q_j^2}$$

# Choose the Best Floorplan : Floorplan and P/G Network Co-optimization

- IR Drop Aware Floorplanning Problem

$$\min_{s} \quad \lambda_1 A(s) + \lambda_2 W(s) + \lambda_3 R(s) \tag{3}$$
$$where \qquad \textstyle\sum_{i=1}^{3} \lambda_i = 1$$

And for a given floorplan $s$, the metal resource $R(s)$ is defined as follows:

$$\min_{w,p} \qquad \{R = \textstyle\sum l_i w_i\} \tag{4}$$
$$s.t. \quad V_{wst} \leq V_t, D_{max} \leq D_t$$

- Simulate Annealing to Solve Problem (3)

# Construct the P/G Network : Optimization of P/G Network Using VMP

- Heuristic Topology Optimization
  The basic idea of this topology optimization is to remove the regions where the current density is low. i.e. a mesh network is formed by removing the “useless” metal from the “virtual metal plane”.
- Current Density Distribution on VMP

$$
\begin{aligned}
I_{px}(y) &= \int_0^a \sigma \left| \frac{\partial V}{\partial x} \right| dx \\
I_{py}(x) &= \int_0^b \sigma \left| \frac{\partial V}{\partial y} \right| dy
\end{aligned}
\tag{5}
$$

where $V$ is defined by equation (2).

# Outline

# Experimental Results

| | Plain Floorplanner | | | | Uni-mesh Based Floorplanner | | | | Plane Based Floorplanner | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Module | Area ($mm^2$) | HPWL ($mm$) | $A_p$ ($mm^2$) | Time ($s$) | Area ($mm^2$) | HPWL ($mm$) | $\Delta A$ % | Time ($s$) | Area ($mm^2$) | HPWL ($mm$) | $\Delta A$ % | Time ($s$) |
| apte | 50.07 | 718.83 | 1.86 | 0.144 | 48.2 | 682.9 | -32.1% | 19.77 | 50.06 | 675.6 | -63.1% | 0.84 |
| hp | 9.55 | 191.4 | 1.08 | 0.424 | 11.66 | 199.3 | -40.4% | 30.47 | 11.59 | 162.5 | -41.6% | 3.24 |
| ami33 | 1.29 | 76.05 | 0.135 | 2.57 | 1.30 | 96.47 | -59.7% | 95.14 | 1.28 | 87.04 | -69.2% | 12.78 |
| ami49 | 39.60 | 1006 | 13.80 | 6.4 | 39.90 | 1282 | -65.1% | 138.97 | 40.30 | 1160 | -69.4% | 27.68 |
| xerox | 20.33 | 381.18 | 1.88 | 0.328 | 21.2 | 426.9 | -48.0% | 20.53 | 21.71 | 460.34 | -53.7% | 1.44 |

Table: Experiments on MCNC Benchmarks

# Outline

# Conclusion

- The Analytical VMP Approach
  We estimate the power supply capability efficiently. As a consequence, we speedup the cost function evaluation in floorplanning process.
- A Floorplan and P/G Network Co-optimization Method
  We find a promising floorplan which benefits the power supply integrity.
- A Heuristic P/G Design Method
  We carry out the fast P/G topology optimization with the given floorplan and the non-uniform mesh grid built by this method saves the routing resources of P/G network further more

# Thank you!
# Q&A

# For Further Reading I

C.-W. Liu and Y.-W. Chang
Floorplan and power/ground network co-synthesis for fast design convergence
*Proceedings of the 2006 international symposium on Physical design*, 86–93 2006.

S.-W. Wu and Y.-W. Chang
Efficient power/ground network analysis for power integrity-driven design methodology
*Proceedings of the 41st annual conference on Design automation*, 177–180 2004.

# For Further Reading II

S.-W. Wu and Y.-W. Chang
Power Supply Noise Aware Floorplanning and Decoupling Capacitance Placement
*Proceedings of the 2002 conference on Asia South Pacific design automation*, 489 2002.