A New Approach to Multi-objective Global Routing for VLSI Layout

Gleb Zaglyadin
Outline

• Global Routing Problem
• Criteria and Metrics
• Existing Techniques
• SMT algorithms genesis
• Suggested approach
What is Global Routing?

Problem:
To define regions set for every net

Issue:
What is a region?
Model accuracy level?
2D or 3D?
What is Global Routing?

What is a Region?

2D
What is Global Routing?

What is a Region?

Or 3D?
What is Global Routing?

Model accuracy

Uniform Grid Step

N Tracks in Region

Around 30-50 Tracks

- complexity
- accuracy
What existing problems can be solved?

• Detail Route Quality (100% Routability)
• Timing / Power Optimization
• CMP (Chemical-Mechanical Polishing)
• EM (Electro Migration)
• Power Dissipation
ISSUE:
Native Multi-Objective Optimization

Appropriate Metrics

- Routability
- Timing
- Power
- CMP
- EM

Maximum & total overflow
SMT radius
Wire Length
Density
Jog Number
Global Routing Insides

- Model Setup
- Initial Solution
- Congestion Map
- Tree Optimization
- Layer Assignment
Existing techniques

Single net

2-terminal
- Maze routing
- Pattern routing
- Monotonic routing

Multi-terminal
- Steiner tree
- Spanning tree
- Decomposition
- Maze routing

Optimization Engines

- RRR
- 0-1 ILP
- MCF
- Ant colony

RRR – Rip-up and ReRoute
ILP – Integer Linear Programming
MCF – Multi-Commodity Flow
Existing techniques (cont.)

<table>
<thead>
<tr>
<th>Name</th>
<th>Multi-pin</th>
<th>2-pin</th>
<th>Optimization</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>FLUTE</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NTHU-Route</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>NTUgr</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>FastRoute</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>BoxRouter</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>FGR</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>NCTU</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>AMGR</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>IGOR</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Simple Router</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>HSR</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

Algorithms used in ISPD-2008
SMT algorithms genesis

1960s  Exponential-time SMT!?!? MST is faster!
1970s  Poor resources. MST-based RST construction.
1990s  MST-based RST is fast! Further wire length optimization. In search for SMT.
2000s  So much resources! Lookup table-based approach for minimum wire length.
2010s  So much criteria! Who needs minimum wire length? You to decide 😊
Multi-objective processing approaches

- Multi-component objective function
- Sequential optimization
- Iterative criteria priority adjustment (defining factors and order)

Conclusion:
Finding acceptable solution - very difficult problem
Suggested Approach Idea

1. Spanning Tree Set Generation
2. Spanning Tree Set Rectilinearization
3. RST Set Filtering
4. Optimization
Suggested approach (cont.)

RST Set Generating

Making MST

Setting Max Tree Cost Deviation

Searching Edges to Swap

Making Spanning trees on them

Rectilinearizing Spanning trees
Suggested approach (cont.)

**Steiner Tree Set Filtering**

\[ P(\mu_1, \mu_2) = \sum_{x} \sum_{y} \Delta D_{xy}^2 \]

\[ \Delta D_{xy} = D(x_1) - D(x_2) + D(y_1) - D(y_2), \]

To remove one of trees with \( P(\mu_1, \mu_2) < \text{const} \)
Choosing exact RSTs for each net

Problem Formulation:

Modified Kernighan-Lin algorithm is used

Tree swapping Gain:

\[ X(\mu_1, \mu_2) = \sum_x \sum_y \left( D_{xy}^{\mu_1} - D_{xy}^{\mu_2} - D_{xy}^{avg} \right)^2 \]
Suggested Approach Example

Cost: intersections number

Generated Trees

Locked  Locked  Locked
Conclusions

• Global Routing stage offers optimization possibilities almost for all major problems
• Global Router Must produce Routable solution
• Global Router Has to be Multi-objective
• Global Router Has to keep Wire Length in check