Moscow Institute of Electronic Technology (Technical University)

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

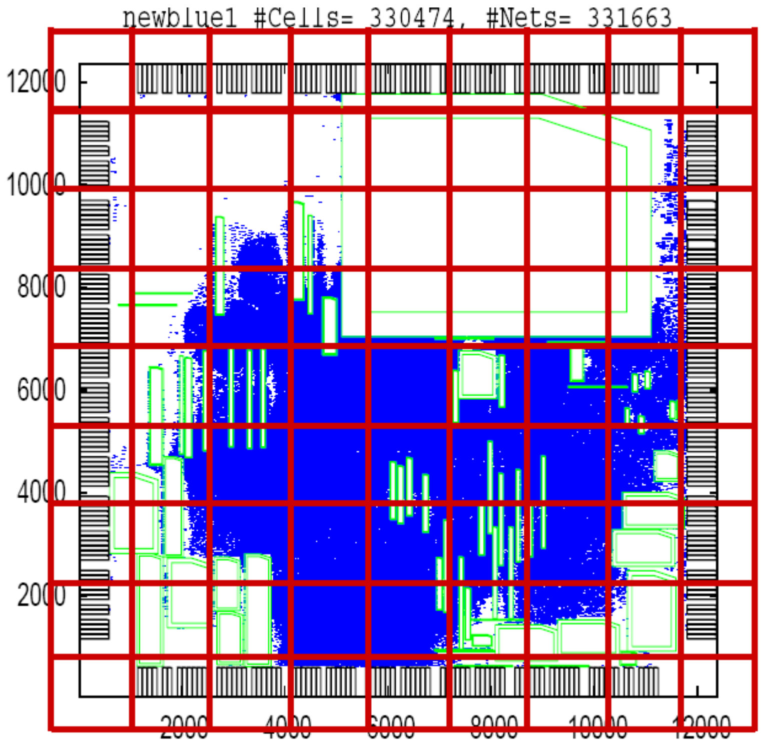
Issue:

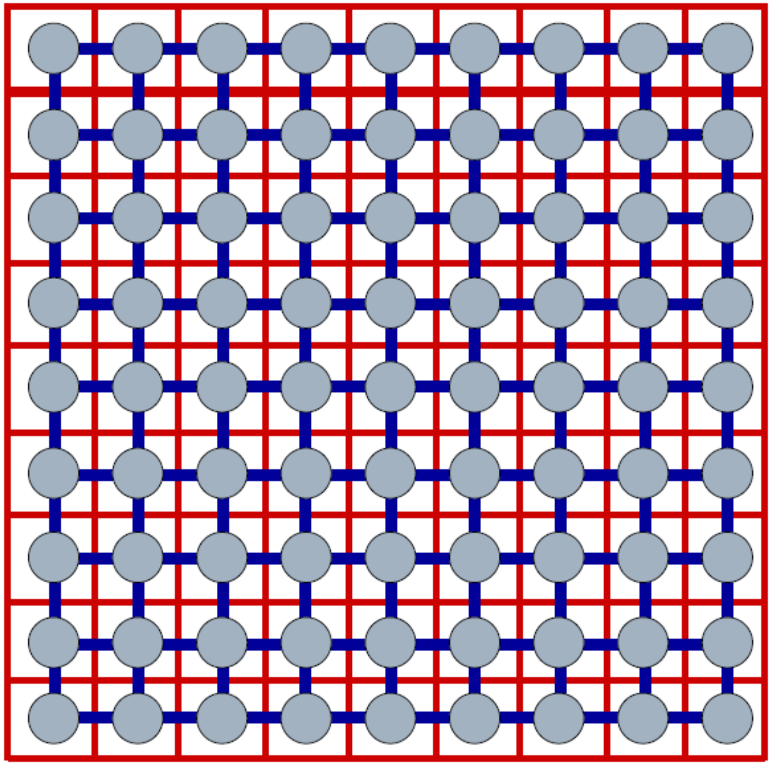
- What is a region?
- Model accuracy level?
- 2D or 3D?

What is Global Routing?

What is a Region?

2D

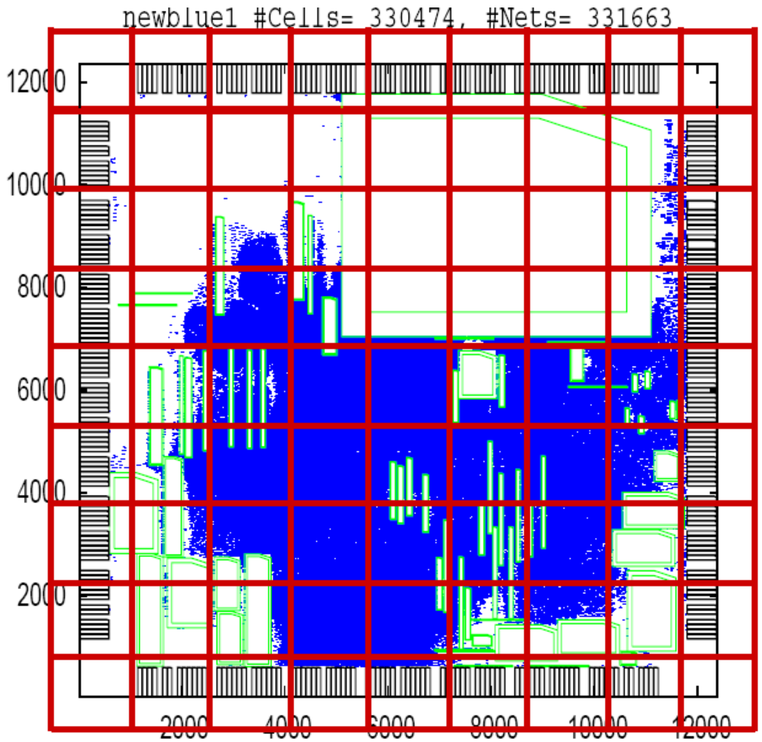


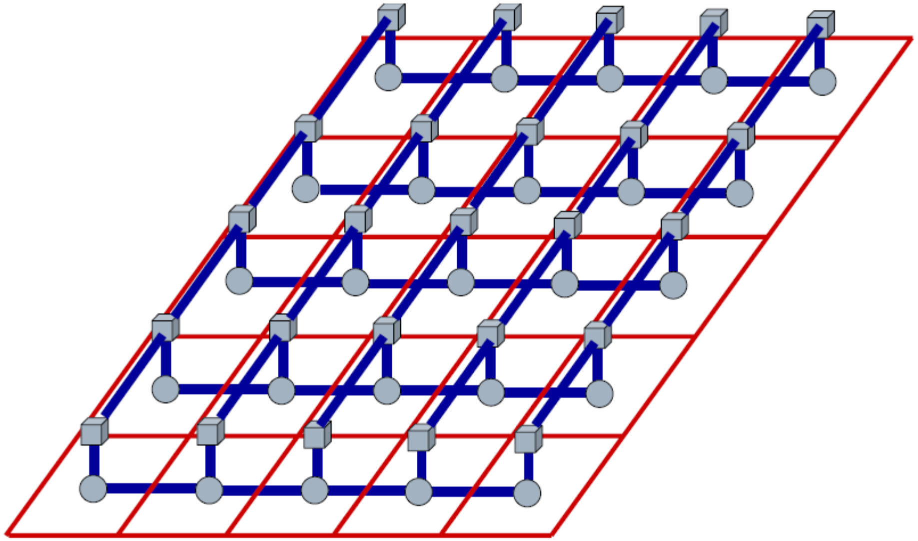


What is Global Routing?

What is a Region?

Or 3D?





What is Global Routing?

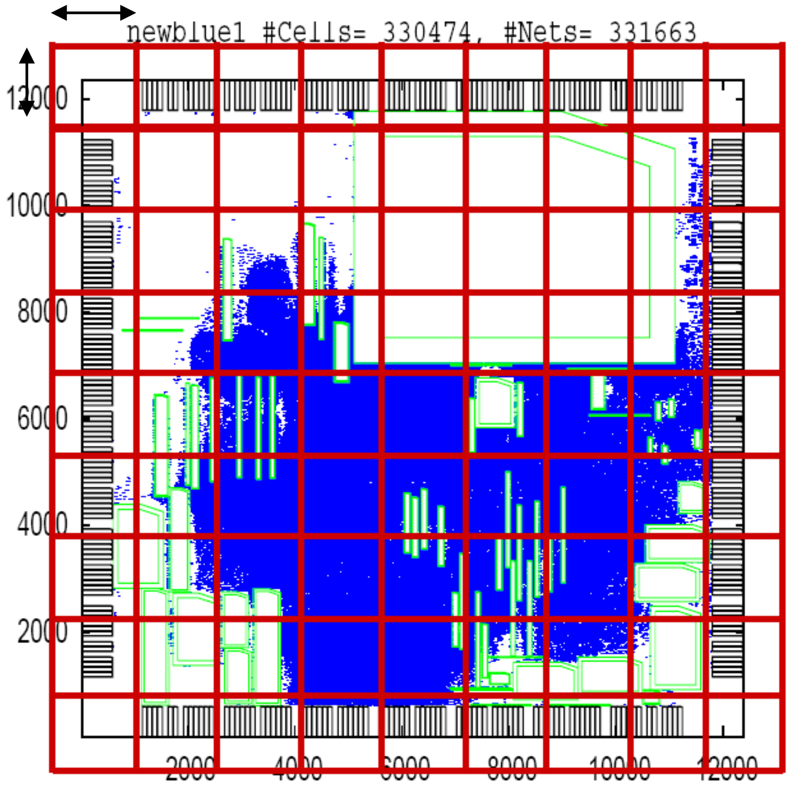
Model accuracy

Uniform Grid Step

N Tracks in Region

Around 30-50 Tracks

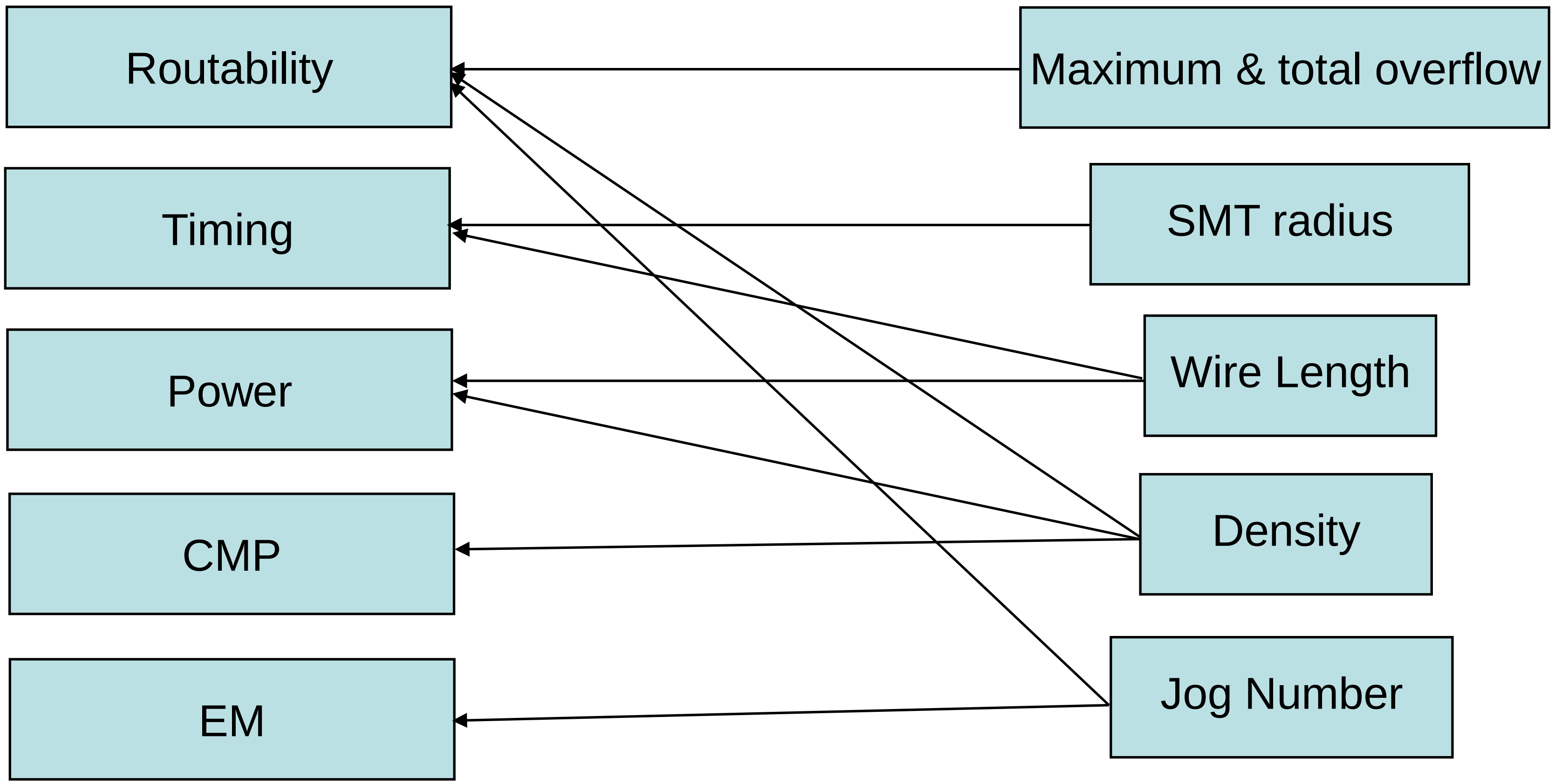
- *complexity*
- *accuracy*



What existing problems can be solved?

- Detail Route Quality (100% Routability)
- Timing / Power Optimization
- CMP (Chemical-Mechanical Polishing)
- EM (Electro Migration)
- Power Dissipation

Appropriate Metrics



ISSUE:

Native Multi-Objective Optimization

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

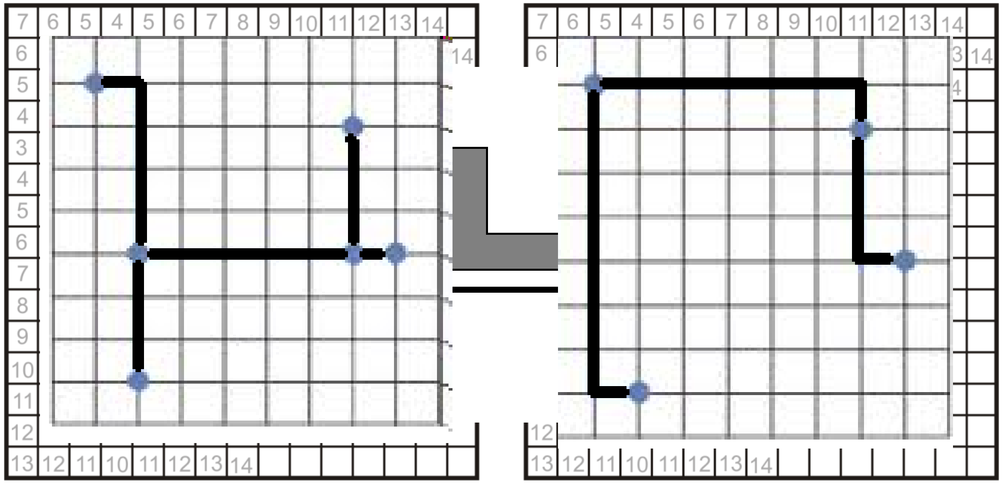
Multi-terminal

- 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.)

	Multi-pin					2-pin				Optimization		
Name	FLUTE	MST	Edge "Sliding"	MSMSMR	Maze	Maze	Pattern	Monotonic	A*-search	RRR	NCR	ILP
NTHU-Route	✓		✓	✓		✓	✓	✓		✓	✓	
NTUgr		✓		✓		✓		✓	✓	✓	✓	
FastRoute	✓		✓	✓		✓	✓	✓		✓		
BoxRouter	✓		✓	✓		✓	✓		✓		✓	✓
FGR		✓	✓	✓		✓			✓	✓	✓	
NCTU		✓				✓		✓		✓		
AMGR					✓	✓			✓	✓		
IGOR	✓					✓				✓		
Simple Router	✓					✓	✓			✓		
HSR	✓					✓	✓			✓		

Algorithms used in ISPD-2008

SMT algorithms genesis

1960s Exponential-time SMT!?!? MST is faster!

1970s Poor resources. MST-based RST construction.

1980s Performance and near-optimal RST!

iterated MST-based RST optimization.

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

Spanning Tree Set Generation

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Spanning Tree Set Rectilinearization

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RST Set Filtering

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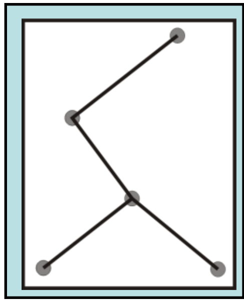
Optimization

Suggested approach (cont.)

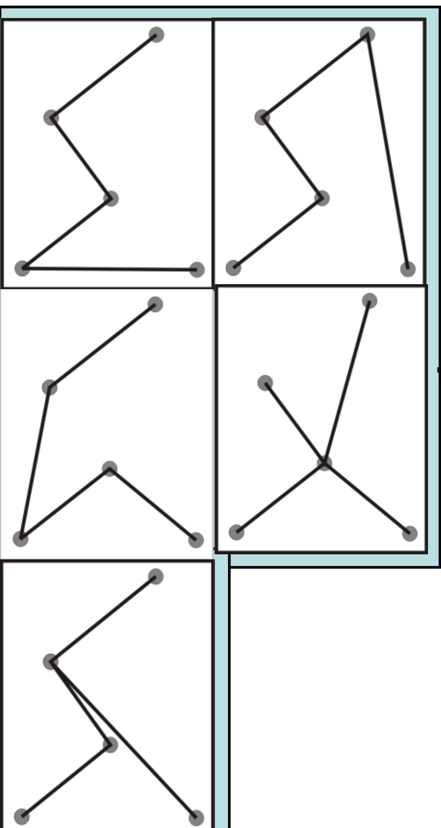
RST Set Generating



Making MST

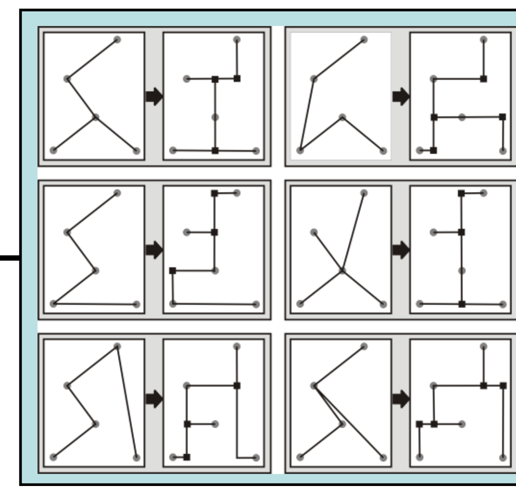
Setting Max Tree Cost Deviation

Searching Edges to Swap



Making Spanning trees on them

Rectilinearizing Spanning trees

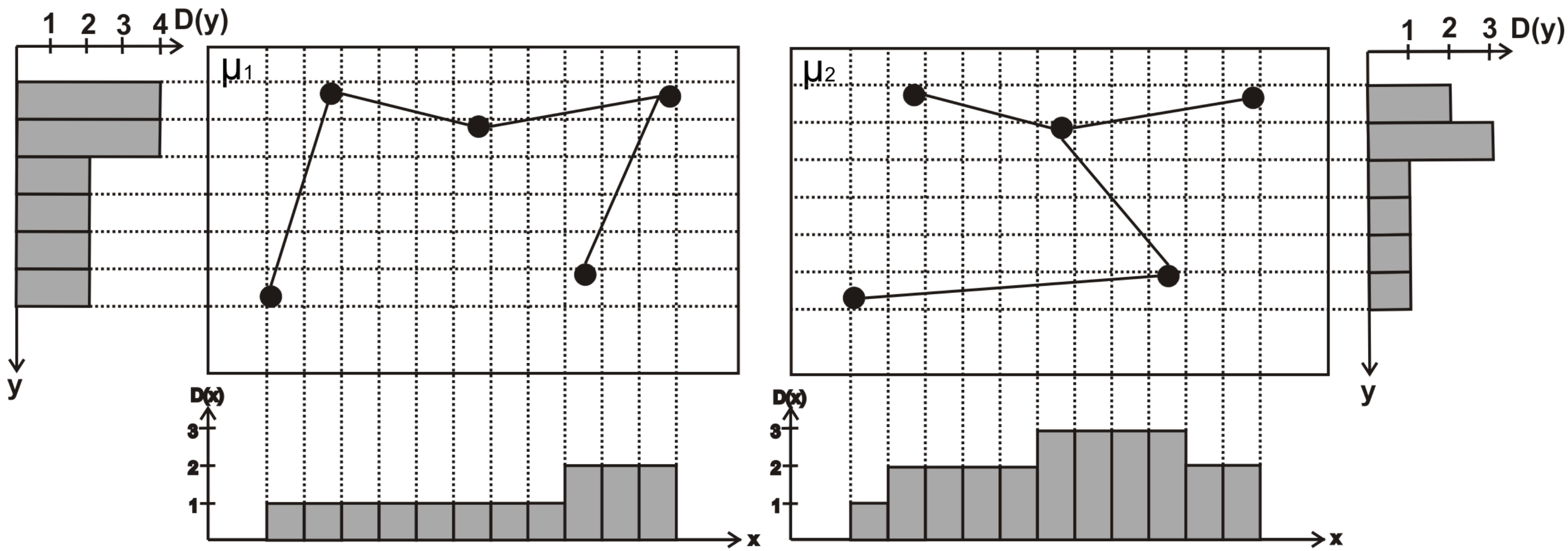


Suggested approach (cont.)

Steiner Tree Set Filtering

$$\mathrm{P}(\mu_1, \mu_2) = \sum_x \sum_y \Delta D_{xy}^{\;2}$$

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



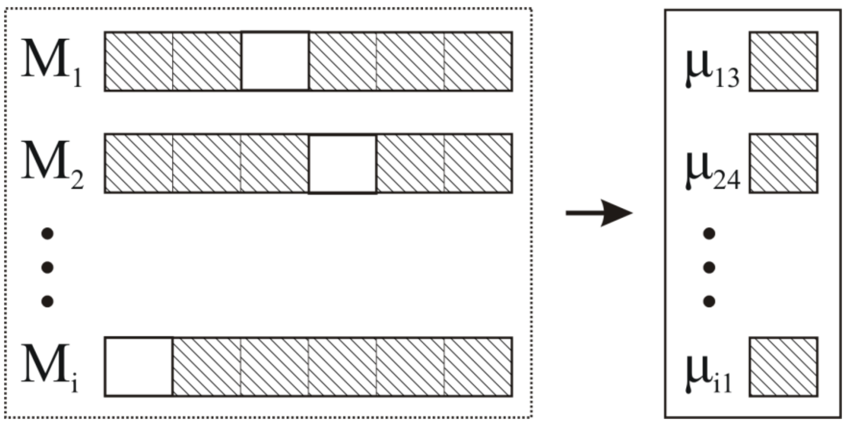
P(μ1,μ2)=355

To remove one of trees with $\mathrm{P}(\mu_1, \mu_2) < const$

Suggested approach (cont.)

Choosing exact RSTs for each net

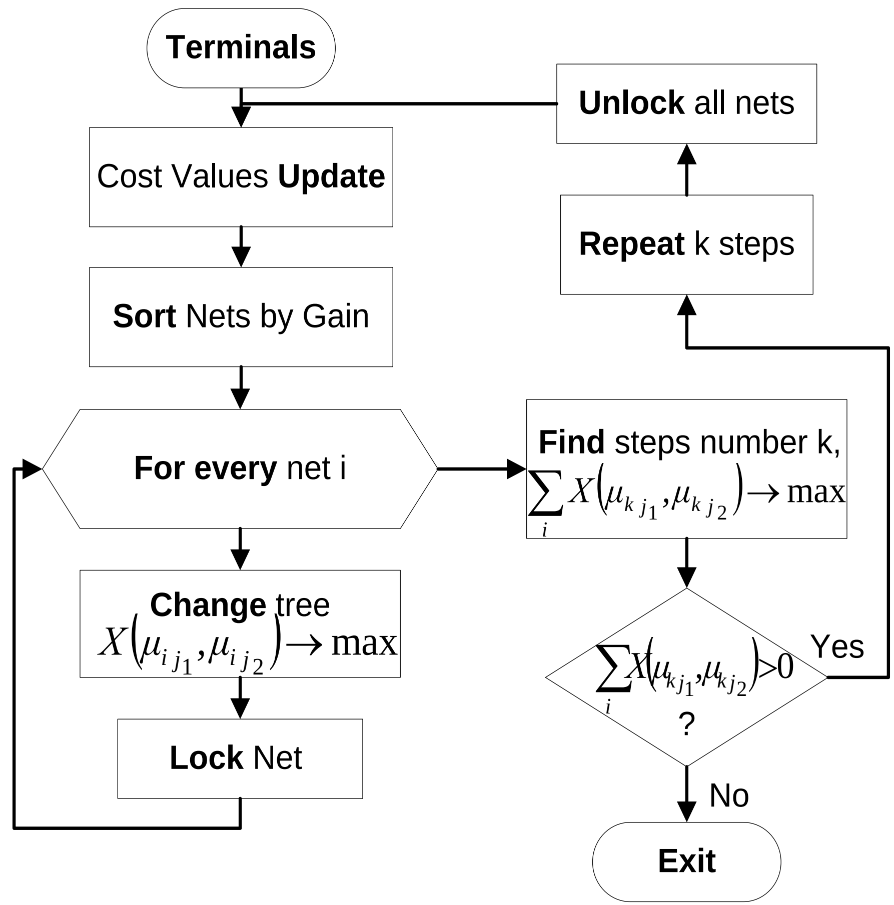
Problem Formulation:



Tree swapping Gain:

$$X(\mu_1,\mu_2)=\sum_x\sum_y\left(D_{xy}^{\mu 1}-D_{xy}^{\mu 2}-D_{xy}^{avg}\right)^2$$

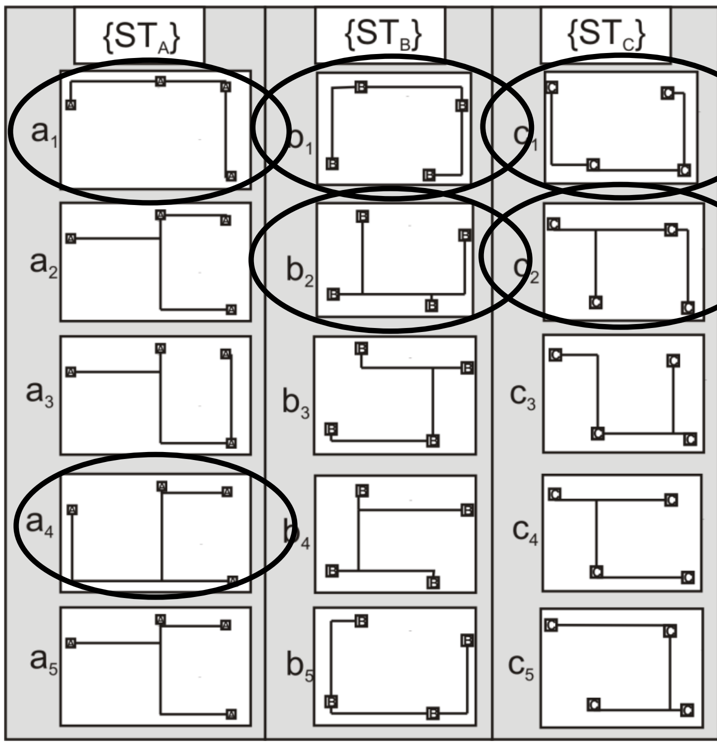
Modified Kernighan-Lin algorithm is used



Suggested Approach Example

Cost: intersections number

Generated Trees



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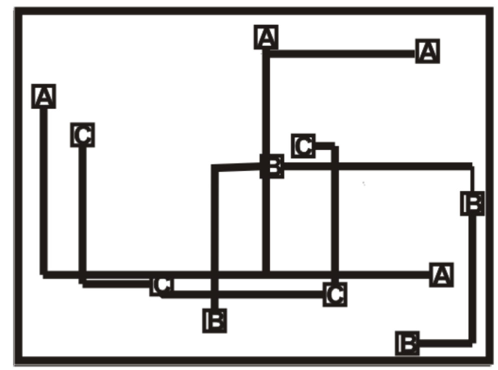

Conclusions

- 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