Bisection Based Placement for the X Architecture

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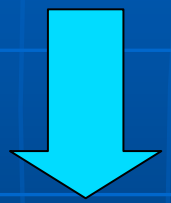
Introduction

- Design size have been increasing
- Process rule shrunk



- Length of wire is really important
  - Timing/Delay

Placement/Routing

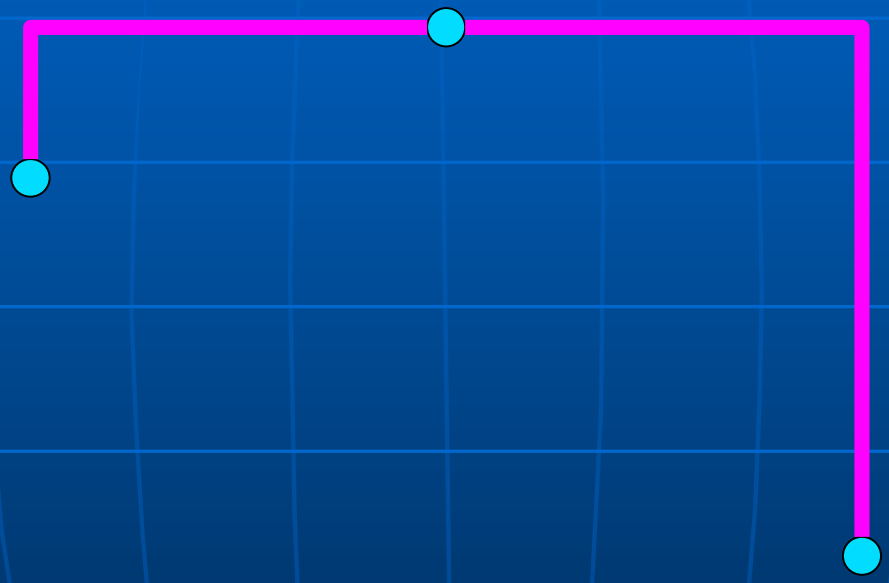
- For most of the history of integrated circuit design, wiring has been rectilinear; horizontal or vertical wires only.
  -- Manhattan Routing --
- Non-Manhattan wiring only inserted in some cases during detail routing.
- Placers have not been targeting non-Manhattan wire length

Non-Manhattan Routing Architectures

- Large scale use proposed in 2000 by Koh and Madden
- X-Architecture announced in 2001

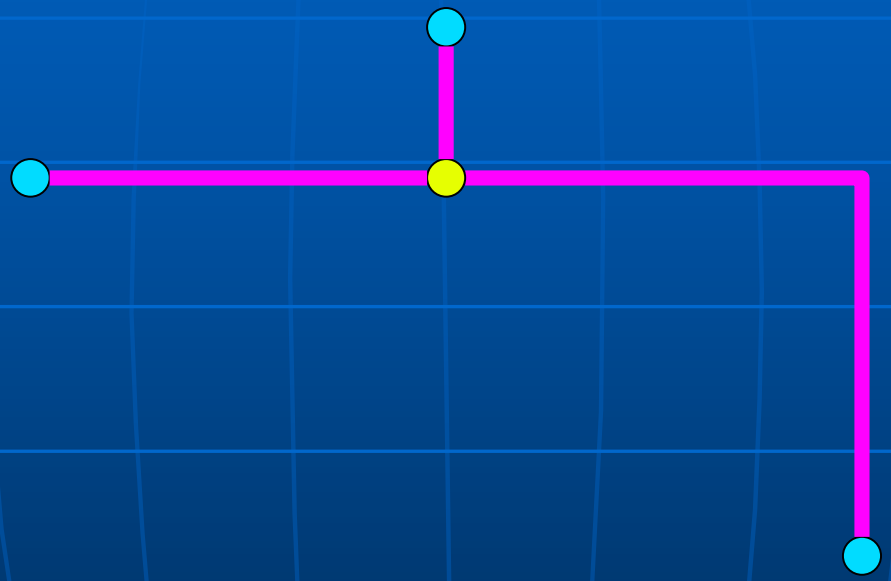
- Allow diagonal wire for routing in addition to vertical and horizontal routing

X Architecture



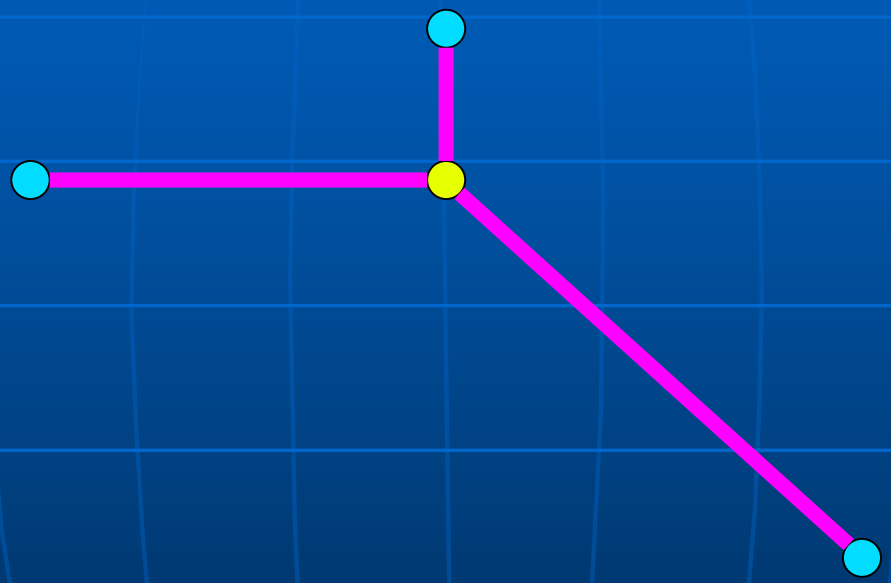
Rectilinear Minimum Spanning tree

X Architecture



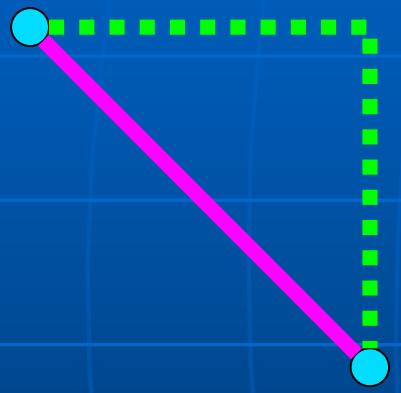
Rectiliner Steiner Tree

X Architecture



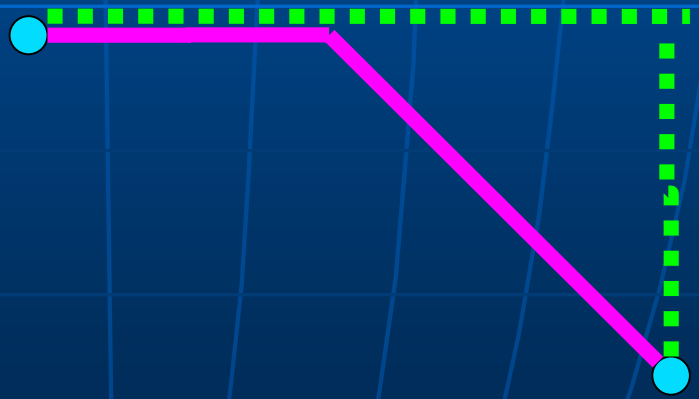
X Architecture Steiner Tree

Best, Worst, and Average (Random) Case



Best case

Worst case



Average

Motivation

- Adding diagonal wires should always help wire length
  - But by how much?
  - Is it worth the cost?
- On randomly placed points, we expect an average of 17% improvement
  - Applying X Architecture Steiner tree on real placements reduces only 8% of wirelength comparing with Rectilinear Steiner tree [Koh/Madden GLSVLSI'00]
  - Is it possible to improve on this?
  - Obtaining better wire lengths makes pursuing X routing more worthwhile

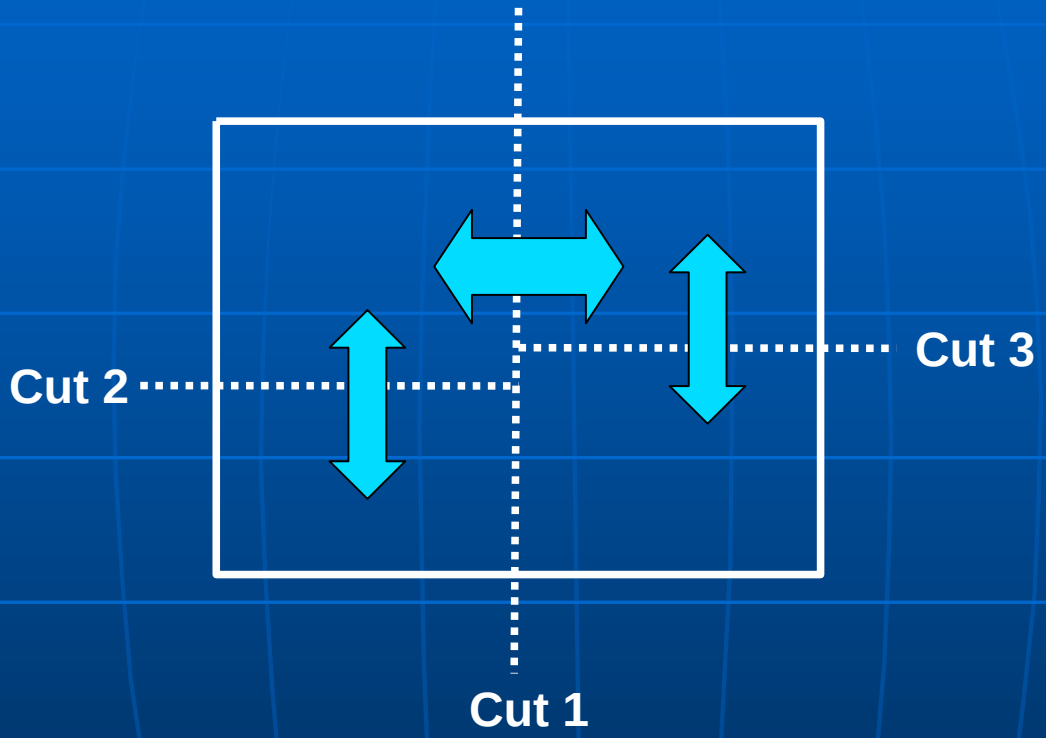
Objective

- Be *REALISTIC*
  - We want to be neither optimistic or pessimistic about non-Manhattan routing.
- Almost all placement tools have been tuned for rectilinear wirelength minimization
- Try tuning for non-Manhattan routing, so that we can evaluate the prospects

Evaluation of Patented Approach

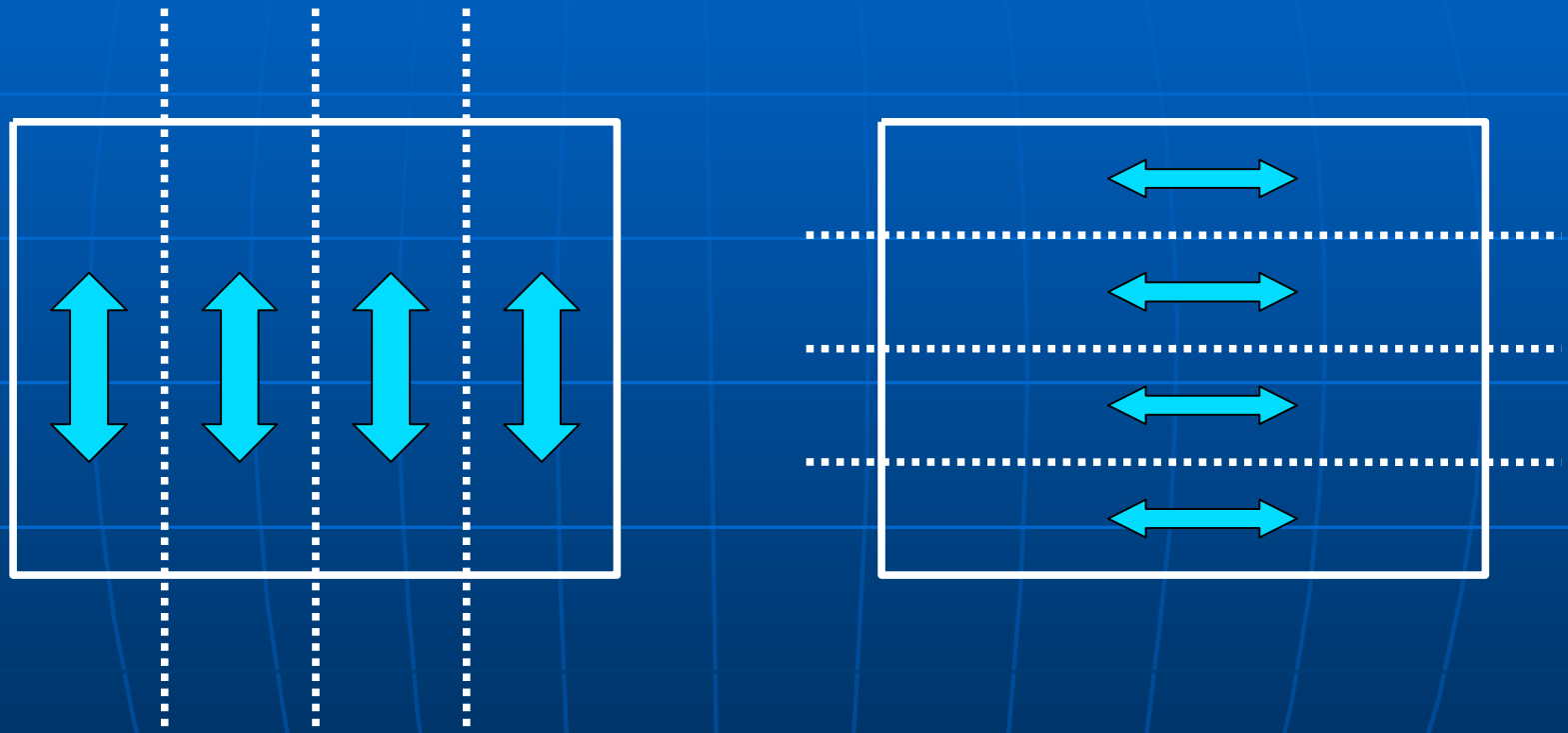
- Wire length gains have been limited by a lack of demand for diagonal wires
- Solution: orient cut lines in bisection to prefer diagonal arrangements [Teig&Ganley]

Routing Demand control by cut sequence



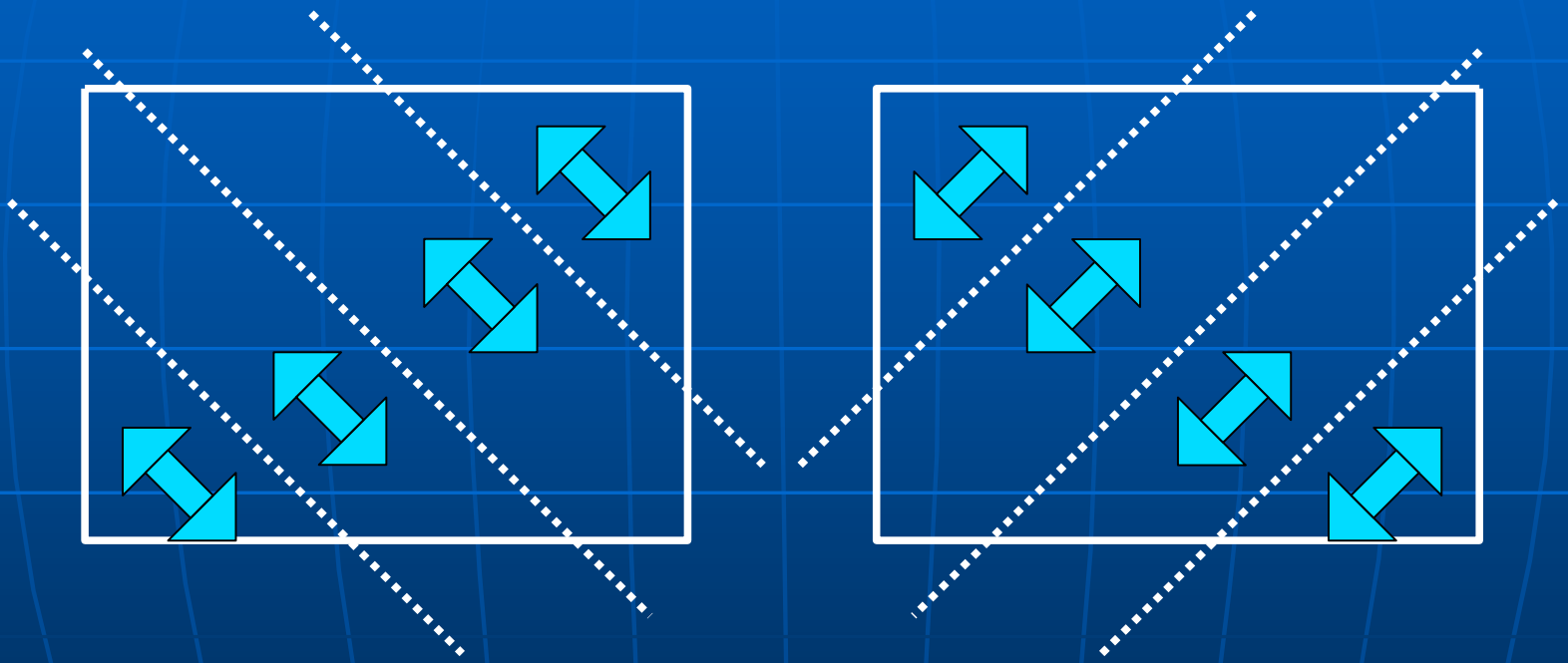
# of wire crossing on Cut1
< # of Cut 2 + # of Cut 3
In this case, vertical demand higher than horizontal demand

Routing Demand control by cut sequence



Cut sequence can be used to tune routing demand [Yildiz/Madden DAC'01]

Routing Demand control by cut sequence

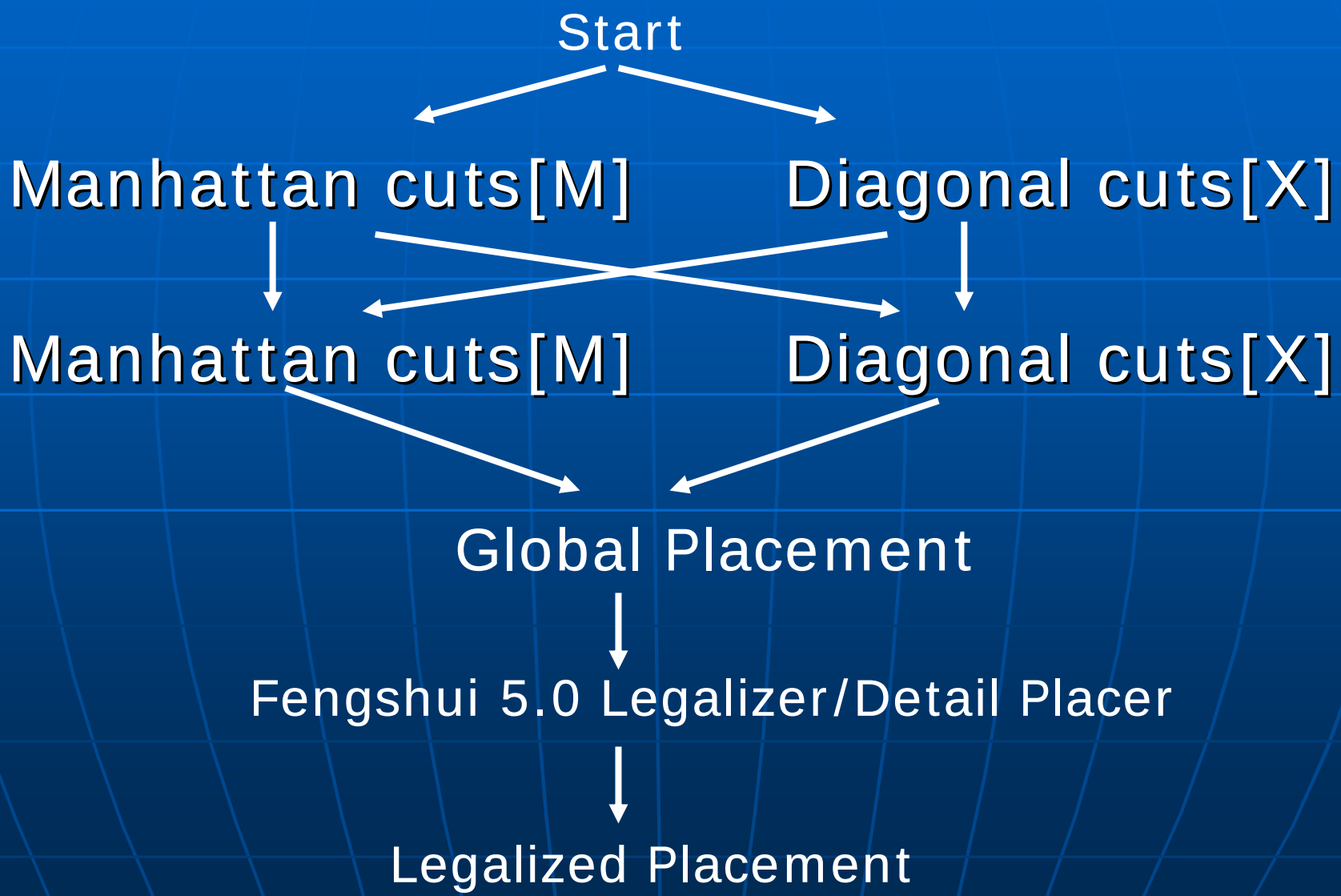


Fractional cut

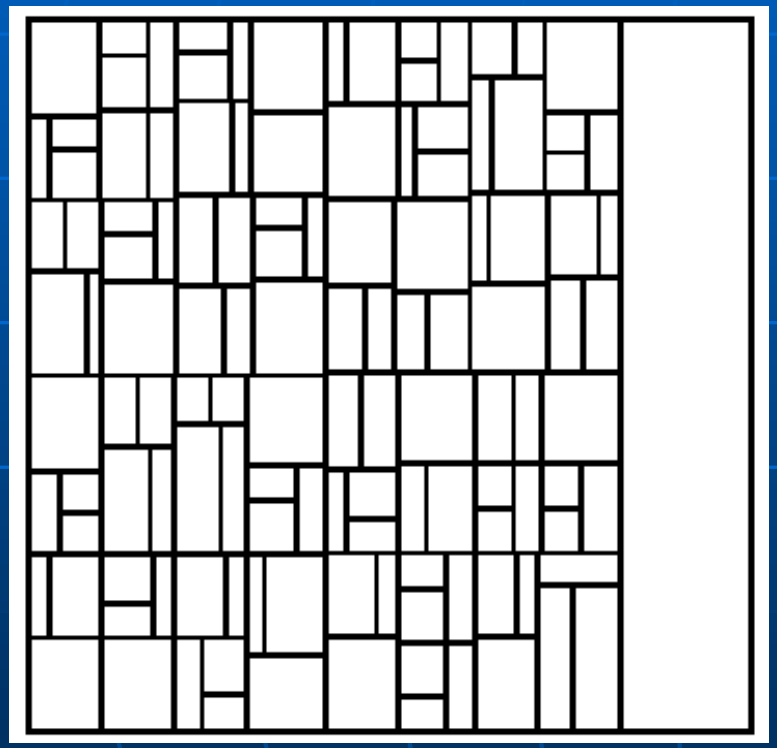
- Traditional Bi-section based placer does not allow to cut the region freely – you must cut region on the standard row line -
- Fengshui 2.0 introduced fractional cut[Agnihotri+ ICCAD'03]
  - You can cut region freely

- Diagonal cut is possible

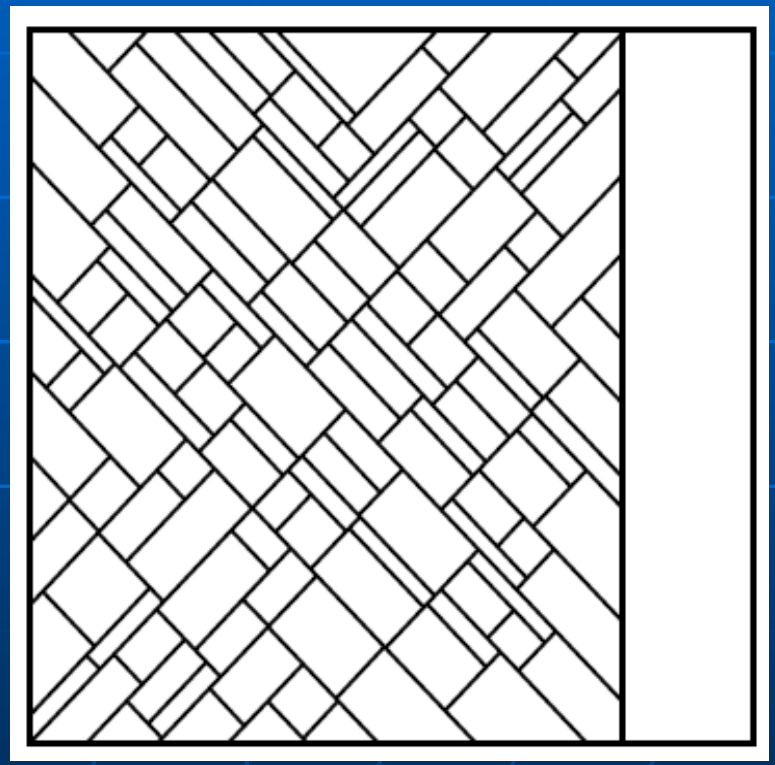
Flow of our tool
-- XPlace --



Global placement cutline

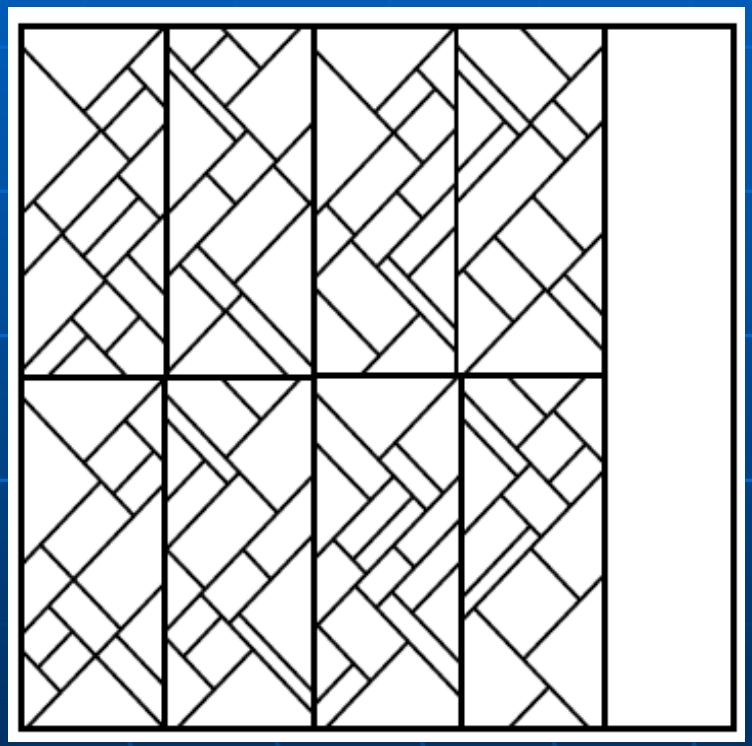


M Placement

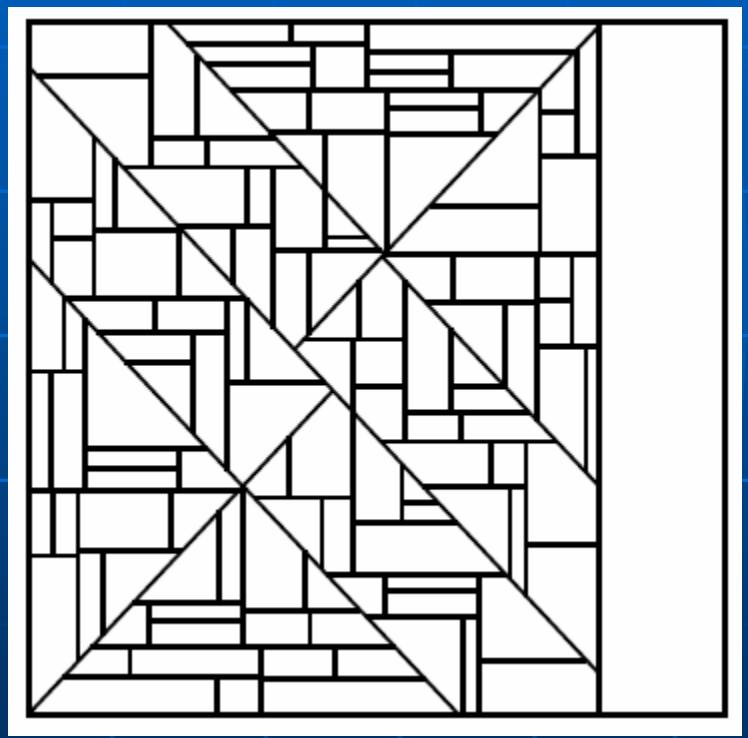


X Placement

Global placement cutline



M+X Placement



X+M Placement

Experimental Result - Manhattan Cuts -

	XPlace [M]	KraftWerk	Capo8.6	Dragon 2.23	Feng shui 2.0	mPL 2.0
Ibm01	0.52	0.70	0.55	0.58	0.52	0.64
Ibm02	1.53	2.15	1.59	1.58	1.47	1.61
Ibm07	3.39	5.12	3.70	3.59	3.30	4.07
Ibm08	3.73	4.66	3.84	3.82	3.66	4.25
Ibm09	3.10	4.26	3.22	3.20	3.01	3.81
Ibm10	5.76	7.61	6.15	6.02	5.67	6.61
Ibm11	4.60	5.80	4.85	4.72	4.59	5.96
Ibm12	8.04	10.41	8.58	8.58	7.75	9.44

*Manhattan Half-Perimeter Wirelength

*Our placements are densely packed

*feng shui 5.1's legalizer and detail placer is uesed

- Results of Manhattan cut sequences are competitive with other tool

Experimental Result
- Non-Manhattan Cuts-

	M	X	M+X	X+M	Feng shui 2.0
Ibm01	0.52	0.67	0.65	0.59	0.52
Ibm02	1.53	1.83	1.81	1.67	1.47
Ibm07	3.39	4.18	4.17	3.74	3.30
Ibm08	3.73	4.78	4.77	4.10	3.66
Ibm09	3.10	3.90	3.85	3.74	3.01
Ibm10	5.76	7.48	7.26	6.31	5.67
Ibm11	4.60	5.61	5.48	5.04	4.59
Ibm12	8.04	9.79	9.48	8.67	7.75

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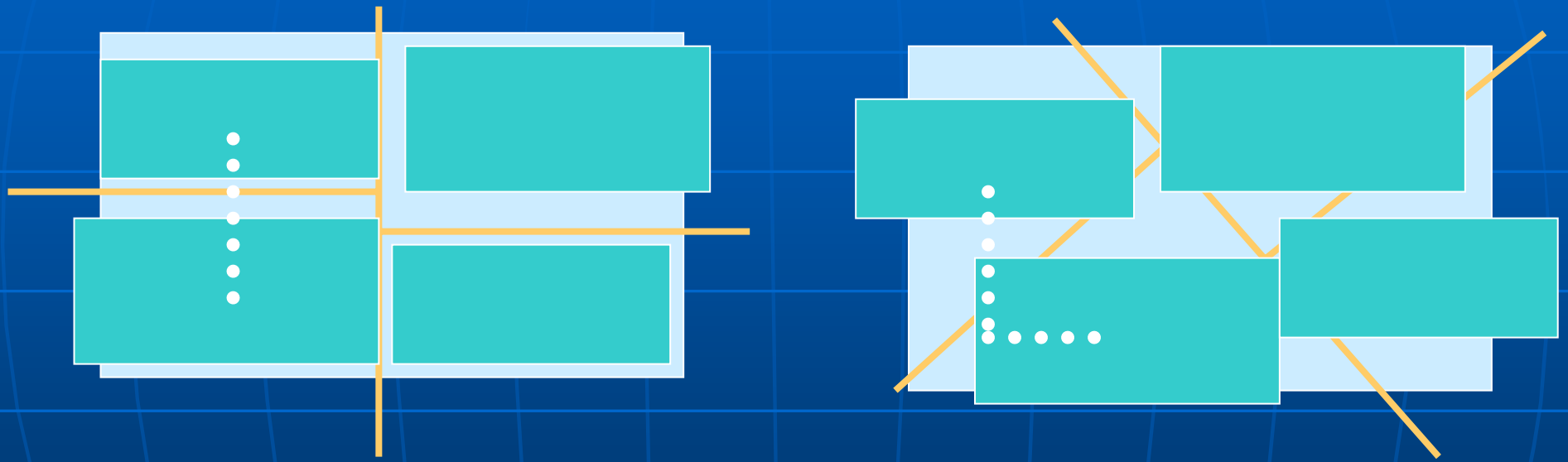
Half-Perimeter



Comparing Half-Perimeter, Diagonal cut is worse than Manhattan cut

Experimental Result
- Non-Manhattan Steiner Tree Lengths -

Benchmark		Global Placement							
		Manhattan Steiner				X Steiner			
		M	X	M+X	X+M	M	X	M+X	X+M
ibm01		0.62	0.74	0.74	0.67	0.57	0.57	0.63	0.65
ibm02		1.82	2.04	2.05	1.92	1.68	1.73	1.8	1.7
ibm07		3.79	4.5	4.56	4.1	3.48	3.73	3.94	3.57
ibm08		4.46	5.41	5.48	4.77	4.09	4.5	4.73	4.18
ibm09		3.55	4.23	4.24	3.86	3.24	3.48	3.65	3.34
ibm10		6.54	8.09	7.97	7	5.96	6.68	6.87	6.08
ibm11		5.05	5.95	5.85	5.44	4.62	4.89	5.03	4.72
ibm12		9.07	10.6	10.4	9.57	8.28	8.77	8.95	8.36
avg.		1	1.19	1.18	1.07	0.92	0.98	1.02	0.93

Benchmark		Legalized Placement							
		Manhattan Steiner				X Steiner			
		M	X	M+X	X+M	M	X	M+X	X+M
ibm01		0.62	0.75	0.72	0.64	0.57	0.62	0.63	0.57
ibm02		1.82	1.98	2.01	1.86	1.67	1.72	1.77	1.68
ibm07		3.79	4.37	4.48	3.96	3.47	3.71	3.88	3.54
ibm08		4.44	5.26	5.39	4.62	4.07	4.47	4.68	4.14
ibm09		3.55	4.1	4.17	3.73	3.23	3.46	3.6	3.31
ibm10		6.54	7.87	7.85	6.79	5.93	6.66	6.79	6.02
ibm11		5.05	5.77	5.74	5.26	4.6	4.87	4.96	4.67
ibm12		9.07	10.3	10.3	9.34	8.25	8.74	8.87	8.31
avg.		1	1.15	1.16	1.04	0.91	0.98	1.01	0.93

Interpretation of Results

	M Steiner	X Steiner	Improvement
M	1.00	0.92	0.08
X	1.19	0.98	0.18
M+X	1.18	1.02	0.14
X+M	1.07	0.93	0.13

- M Placement takes an advantage of X Steiner tree as reported by [Koh/Madden]
- X Placement prefer more diagonal wires
- X+M seems a possibility
  - Long diagonal wires at the top layer, short Manhattan wires at the lower layers.

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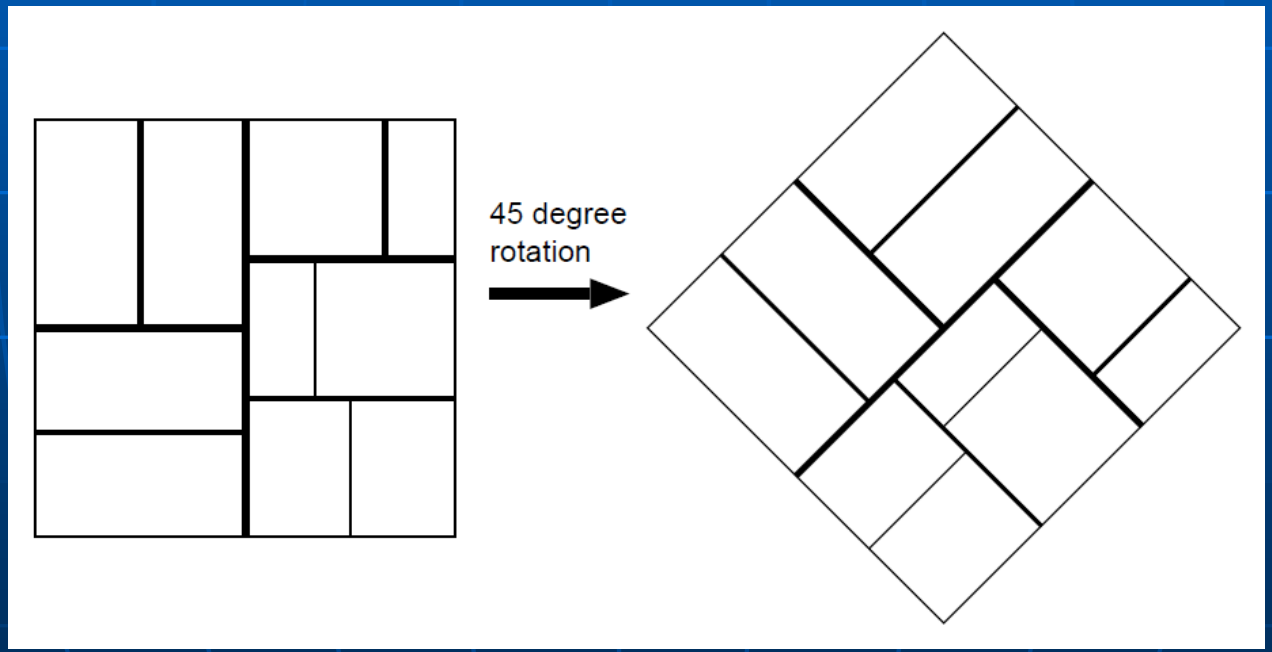
45 Degree Rotation

Manhattan Placement + Manhattan Steiner

vs.

X Placement + X Steiner



At best, no wire length change for X routing.

Manhattan routing at a severe disadvantage.

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Conclusions

- Diagonal cut lines did not help
  - They put Manhattan routing at a disadvantage, rather than making X routing more effective
- Wire length improvements still in the 8% range for X routing
  - X has a disadvantage because of more complicated routing, and layer restrictions
- Further improvements are still possible
  - For example: upcoming ISPD paper from NTU group!

Thank you