ISPD 2008 Global Routing Contest

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Overview

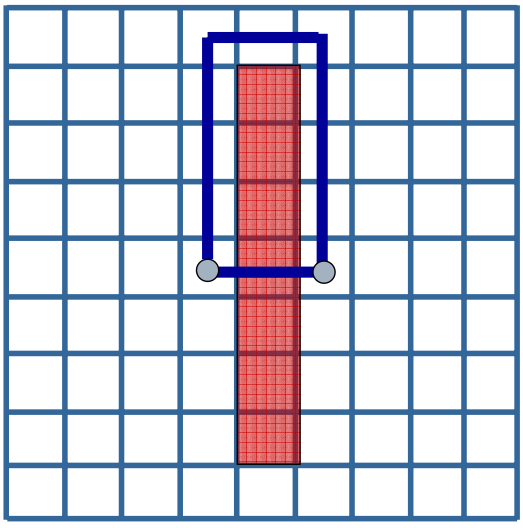
- Open contest primarily for academic community
- Totally 11 team registered initially
  - All academic teams
  - 4 teams from US, 7 teams from overseas
    - 1 team Hannover, Germery
    - 4 from Taiwan
    - 2 from Hong Kong
- 4 new participations
- 10 final entries
- Total 16 benchmarks
  - 8 from 2007 global routing contest “3D” benchmarks
  - 8 new global routing benchmarks are released
  - All derived from ISPD 2005/2006 placement benchmark solutions
- Quality metrics
  - Minimizing overflows
  - CPU-weighted total wirelength

New for 2008

- CPU time is restricted to 24 hours
  - Any run more than 24 hours => fail
- CPU-weighted total wirelength
- Parallel Algorithm is allowed (at most 4 CPU is allowed)
- Review our metrics from last year
  - G-cell size is good
  - After reviewing the data of several technology generations, we set via cost = 1 g-cell (the resistance ratio between via is slightly lower than one unit of wire in one g-cell). It was set to 3 last year.
- Thanks to our "Consultants"
  - Emails Discussions on the "best" metric
    - Patrick Groeneveld - Magma
    - Prashant Saxena – Synopsys
    - Jeffery Salowe - Cadence
    - Philip Chong – Cadence
    - Mustafa Ozdal – Intel
    - Gustavo Tellez - IBM
    - Stephen Quay - IBM
  - Good Metrics
    - Total overflow
    - Maximum overflow
    - # of nets with overflow
    - Average 20% worse congestion nets

Quality Metrics

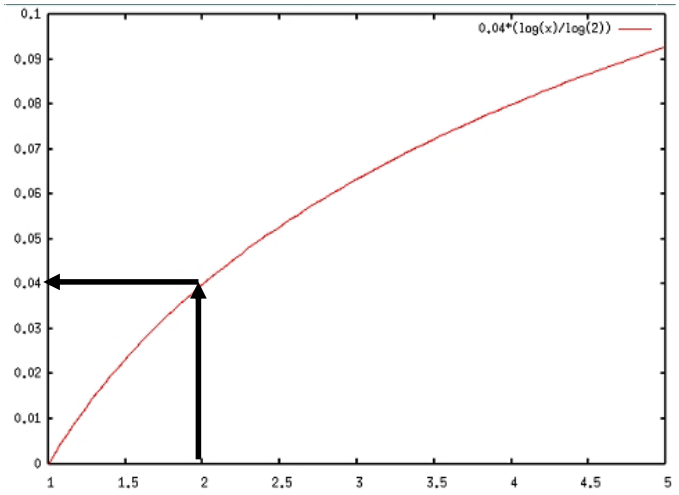
- Final quality metric
  - Minimum Σ Rank(circuit) wins the game
  - Rank per circuit is determined by
    - Minimum total overflows
    - Max overflow as the 1st tie breaker
    - Routed wire length as the 2nd tie breaker
- Routed wire length calculation considers via cost
  - One via connecting two consecutive metal layer = WL of one g-cell
  - CPU-weighted wirelength



Example from Mustafa Ozdal, Intel. Corp.

CPU-Weighted Wire Length Calculation

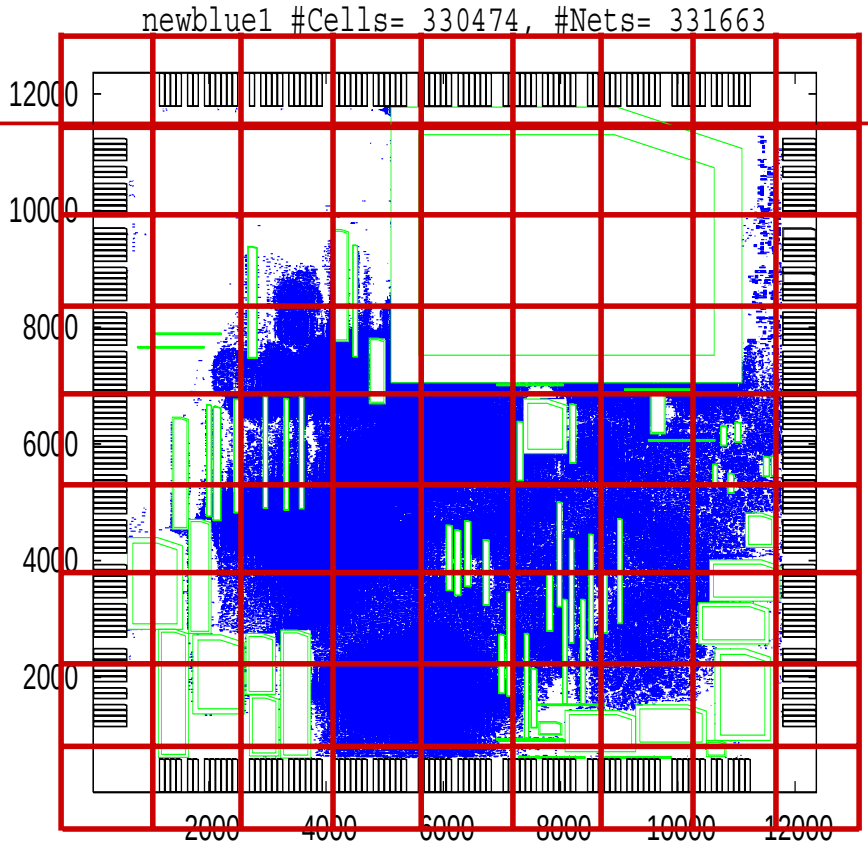
- 2nd tie-breaker
  - routed_wire_length * (1 + CPU_time_factor)
  - CPU_time_factor = 0.04 $\log_2$(router_cpu_time / median_cpu_time)
  - CPU_time_factor will range from -0.1 to 0.1
  - max 10% routed_wire_length advantage or disadvantage
  - if a router is 2x faster/slower, the router gets about 4% routed wire length advantage/disadvantage
- Similar to the one used in the ISPD 2006 Placement Contest



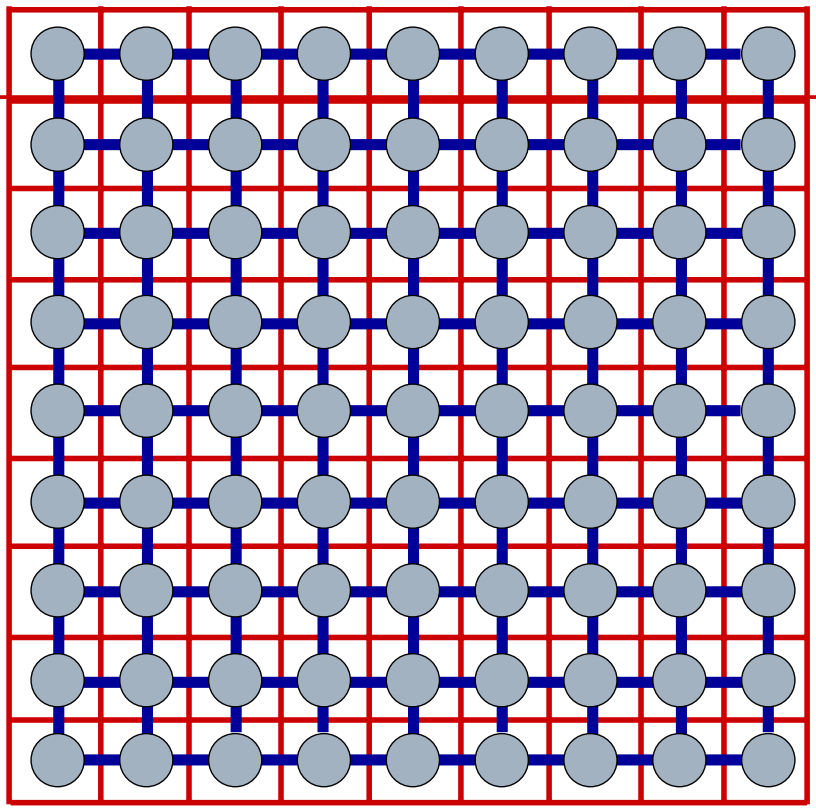
How Benchmarks were Generated

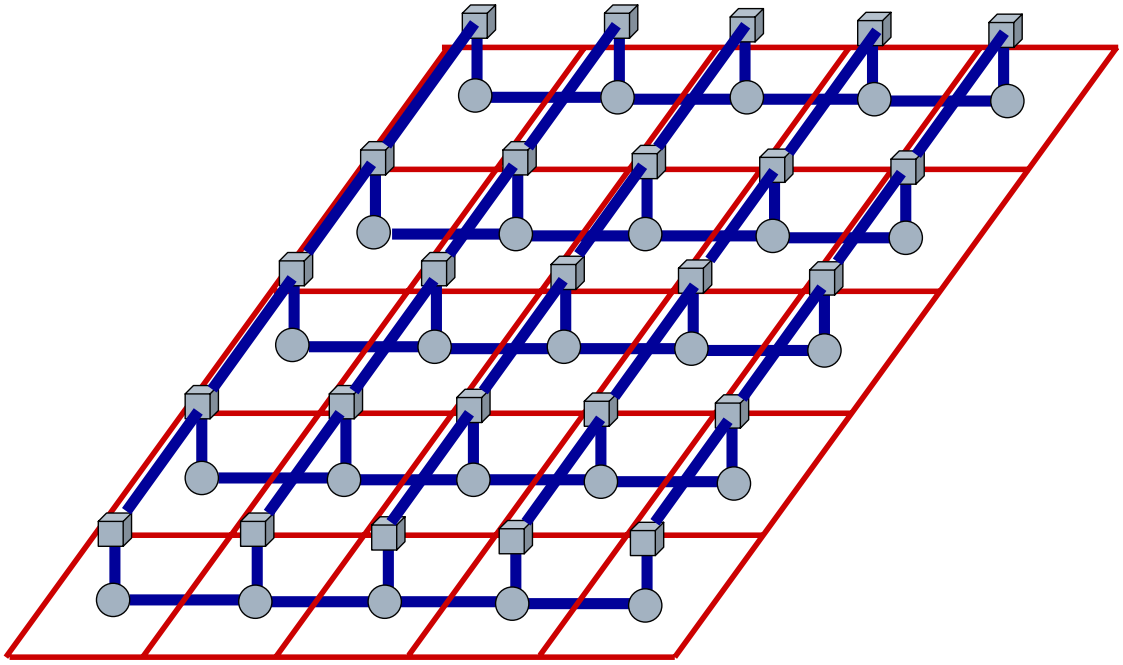
- For each ISPD 2005/2006 benchmark
  - adaptec1, adaptec2, adaptec3, adaptec4, adaptec5, newblue1, newblue2, newblue3 (2007)
  - bigblue1, bigblue2, bigblue3, bigblue4, newblue4, newblue5, newblue6, newblue7 (2008)

1. Pick Placement tools
   - Capo, mPL6, Dragon, APlace3, mFAR, NTUPlace3.0, FastPlace3.0, Kraftwerk
2. Pick density target
   - From 50% to 90%
3. Generate placement solution
4. Impose a tile structure
   - Basic routing resources are determined
5. Adjust routing resources



*Placement layout figure was generated by Capo Placer utility package.





Albrecht, C. TCAD 2001 paper on multicommodity flow based global routing algorithm.

Routing Resource (Edge Capacity) Adjustment

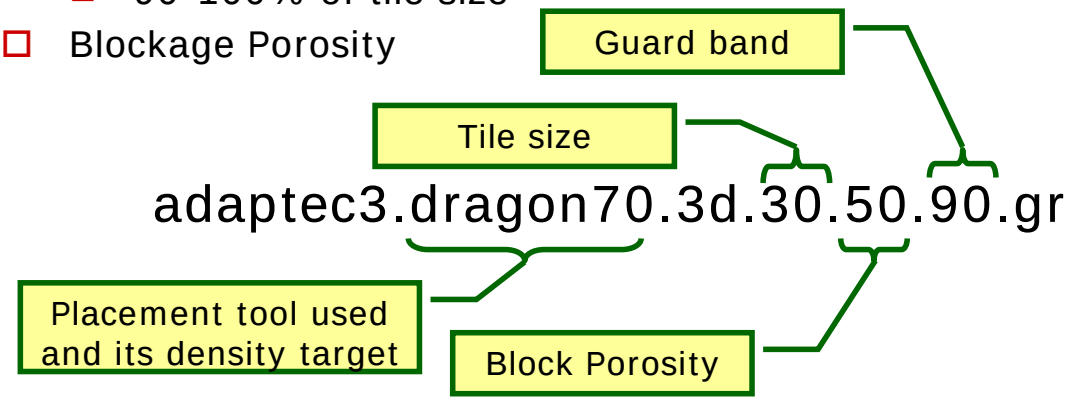
- Essentially determines the level of difficulty of benchmark
- Tile size
  - 30–50 wire tracks
- Limited usage in M1/M2 layer
  - 20% of available wire tracks
- Guard band
  - 90-100% of tile size
- Blockage Porosity

adaptec3.dragon70.3d.30.50.90.gr

ISPD Placement Benchmark Name

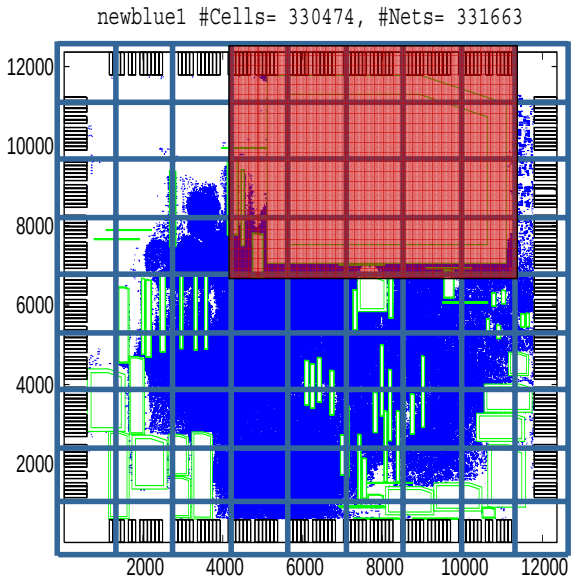
Edge Capacity Adjustment

- Tile size
  - 30–50 wire tracks
- Limited usage in M1/M2 layer
  - 20% of available wire tracks
- Guard band
  - 90-100% of tile size
- Blockage Porosity



More on Block Porosity

- Affects any tiles that sit on top of blockages
- Only affects M3/M4 metal layers



Overview of all 16 benchmarks

		Placement	Density	Tile	Tile	Guard	Macro	#Metal		Tile
	Circuit	Solution	Target	Dimension	Size	-band	Porosity	Layers	#Nets	HPWL
a1	adaptec1	Capo	70	324 x 324	35	90	50	6 (3/3)	176715	3000320
a2	adaptec2	mPL6	60	424 x 424	35	100	20	6 (3/3)	207972	2882254
a3	adaptec3	Dragon	70	774 x 779	30	90	50	6 (3/3)	368494	8619596
a4	adaptec4	APlace	60	774 x 779	30	90	50	6 (3/3)	401060	8175006
a5	adaptec5	mFAR	50	465 x 468	50	100	20	6 (3/3)	548073	8896706
b1	bigblue1*	Capo	60	227 x 227	50	100	10	6 (3/3)	196885	2986719
b2	bigblue2*	mPL6	60	468 x 471	40	60	60	6 (3/3)	428968	4049521
b3	bigblue3*	APlace	70	555 x 557	50	90	10	8 (4/4)	665629	7170444
b4	bigblue4*	FastPlace	70	403 x 405	80	80	20	8 (4/4)	1133535	10489255
n1	newblue1	NTUplace	80	399 x 399	30	90	50	6 (3/3)	270713	2079947
n2	newblue2	FastPlace	90	557 x 463	50	100	20	6 (3/3)	373790	4191219
n3	newblue3	KraftWerk	80	973 x 1256	40	90	50	6 (3/3)	442005	6998467
n4	newblue4*	mPL6	50	455 x 458	40	95	10	6 (3/3)	531292	7357235
n5	newblue5*	NTUplace	50	637 x 640	40	100	10	6 (3/3)	891920	12357104
n6	newblue6*	mFAR	80	463 x 464	60	100	10	6 (3/3)	835267	8823094
n7	newblue7*	KraftWerk	80	488 x 490	80	82	20	8 (4/4)	1647410	16284051

ISPD 2008 Global Routing Contest Winner

- ALL teams!!!!
- I truly think all teams should be the winner because…
  - Most results are better than last-year's best-results

	2007 BEST results				2008 median			Improvement from 2007		
	Overflow		Total WL		Overflow		Total WL	Overflow		Total WL
	Total	Max.	(e5)	Router	Total	Max.	(e5)	Total	Max.	(e5)
a1	0	0	59.52	MaizeRouter	0	0	56.52	na	na	5.05%
a2	0	0	55.99	MaizeRouter	0	0	53.08	na	na	5.20%
a3	0	0	136.27	MaizeRouter	0	0	133.43	na	na	2.09%
a4	0	0	124.72	MaizeRouter	0	0	122.59	na	na	1.71%
a5	0	0	170.14	BoxRouter	0	0	160.38	na	na	5.74%
n1	400	2	50.68	BoxRouter	44	2	48.98	89.00%	0.00%	3.35%
n2	0	0	77.55	MaizeRouter	0	0	76.86	na	na	0.89%
n3	32840	1058	113.86	MaizeRouter	33627	414	109.17	-2.40%	60.87%	4.12%

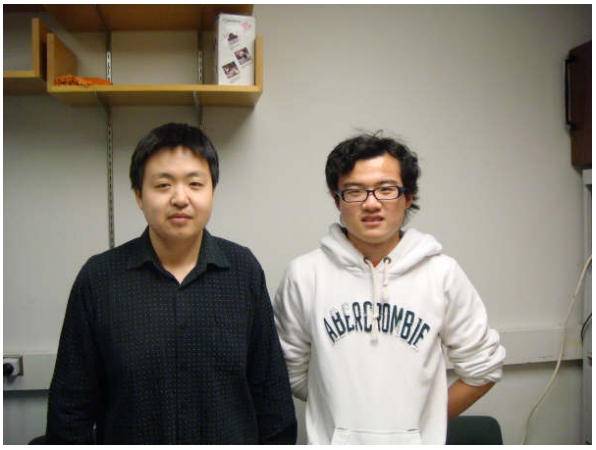
  - n1 is routable by a few routers
  - n3 is provably unroutable

Let me take a few minutes to introduce all teams

- I asked the teams to send me
  - Names, affiliation
  - Photos
  - And …. of course a brief description of their router

Team 1 – FastRoute 3.0

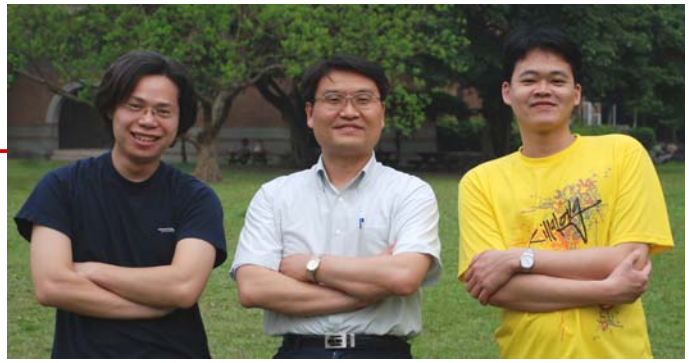
- Iowa State University VLSI CAD LAB
- Yanheng Zhang, Yue Xu
- Advisor: Dr. Chris Chu
- Description
  - 1. Initial Congestion Map Generation.
  - 2. Use FLUTE to generate initial RSMT.
  - 3. Generate Congestion Driven RSMT.
  - 4. Via guided Pattern Routing.
  - 5. Maze Routing until best overflow
  - 6. Layer Assignment
- Router uses at most 4 CPU



Team 2 – FGR

- University of Michigan
- Jarrod Roy
- Advisor: Dr. Igor Markov
- Description
  - 1) Decompose nets by Minimum Spanning Tree
  - 2) Initial routing and rip-up and reroute using an A*-driven maze router
  - 3) Rip-up and reroute using an A*-driven maze router and discrete lagrange multipliers
  - 4) Net topology reconfiguration during rip-up and reroute via epsilon-sharing
  - 5) Fast layer assignment
  - 6) full 3-D maze routing greedy cleanup to recover wirelength
- Router uses 1 CPU

Team 3 – NTUgr



- National Taiwan University
- Huang-Yu Chen, Chin-Hsiung Hsu
- Advisor: Dr. Yao-Wen Chang
- Description

  1. Prerouting with high-pin density analysis
  2. Initial iterative monotonic routing
  3. Enhanced iterative negotiation-based rip-up/rerouting
     (a) ultra-fast rerouting selection
     (b) parallel routing speed up
  4. Parallel layer assignment
- Router uses at most 4 CPU

Team 4 – NCTU

- National Chiao Tung University
- Wen-Hao Liu, Ke-Ren Dai
- Advisor: Yih-Lang Li
- Description
  - 1. Use minimum spanning tree to generate 2-pin connection for each net
  - 2. Use monotonic routing to get initial routing
  - 3. Do evolution-based rip-up and reroute with historical cost to get 2D global routing result
  - 4. Do layer assignment to complete 3D global routing
- Router uses 1 CPU

Team 5 – BoxRouter

- University of Texas - Austin
- Minsik Cho, Katrina Lu, Kun Yuan
- Advisor: Dr. David Pan
- Description
  - 1. Prerouting with flat routing.
  - 2. Use FLUTE2.5 for net decomposition.
  - 3. Initial routing and rerouting with maze routing. Use history-based method.
  - 4. Layer assignment, starting with nets with short WL/small number of pins.
- Router uses 1 CPU

Team 6 – NTHU-Route

- National Tsing Hua University, Taiwan
- Yen-Jung Chang, Yu-Ting Lee, Tsung-Hsien Lee
- Advisor: Dr. Ting-Chi Wang
- Description
  - 1. Project the design onto a plane.
  - 2. Decompose multi-pin nets by FLUTE.
  - 3. Route multi-pin nets with probabilistic L-shaped pattern routing to get initial congestion map.
  - 4. Change tree topologies of multi-pin nets with edge shifting.
  - 5. Route multi-pin with L-shaped pattern routing.
  - 6. Rip-up and reroute by congested region identification. The routing-techniques are monotonic routing and adaptive multi-source multi-sink maze routing.
  - 7. Repeat step 4. until one of the situation is satisfied:
    - overflow under a threshold.
    - iteration count reach the maximum iteration count limitation.
    - reduction of overflow is suspend too long.
    - some others...
  - 8. Refine the overflowed two-pin net by the same routing technique in step 4. but applied with different cost function.
  - 9. Layer assignment.
- Router uses 1 CPU

Team 7 – IMS GlObal Router (IGOR)

- Institute of Microelectronic Systems(IMS), Hannover, Germany
- Artur Quiring, Philipp Panitz, Ole Ohlendorf
- Description
  - 1. Use Flute2.5 to get a RSMT for each net
  - 2. Use the Steiner tree information and route each net with maze routing starting with smallest net.
  - 3. Rip up and reroute with maze routing, using different cost function then in step 2
  - - starting with longest route with overflow
  - - try to reroute the route with no overflow (edges with overflow are not considered)
  - - if not possible, try to reroute the route and accept new route if overflow is reduced (edges with overflow are considered)
- Router uses 1 CPU

Team 9 – HSR (Heuristically Statistical Router)

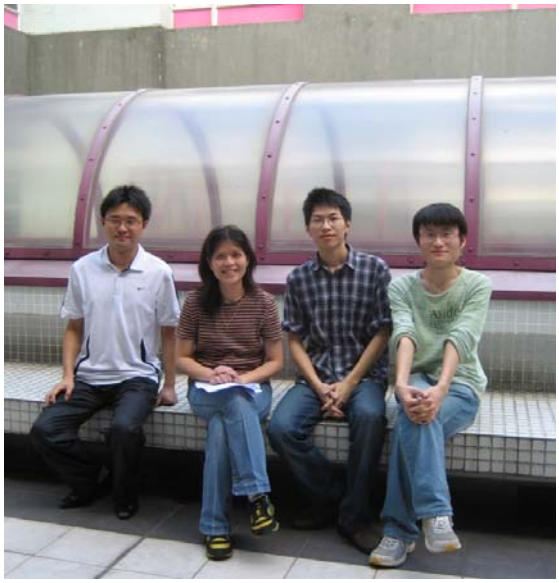
- Department of Electronics Engineering, National Chiao Tung University in Taiwan
- Sean Liu, Jerry Lee, Po-Cheng Pan, Ching-Yu Chin, Yi-Hung Chen
- Advisor: Dr. Hung-Ming Chen
- Description
  - 1. Sort each net according its density (standard deviation from pins).
  - 2. Invoke FLUTE2.5 to get a RSMT for each net
  - 3. for each net, perform quick 3D pattern route.
  - 4. Analyze the congestion and put overflow edges into an RRHeap.
  - 5. For each edges in RRHeap, reRoute it with overflow level 0.
  - 6. For each edges in RRHeap, reRoute it with overflow level -1.
  - 7. For each edges in RRHeap, reRoute it with overflow level INT_MIN.
- Router uses 1 CPU
- First time participation

Team 10 – Simple Router

- Dept of Electronic & Information Engineering, Polytechnic University of Hong Kong
- Jingwei Lu
- Description
  - 1. Use FLUTE2.5 to get a RSMT for each net
  - 2. Compress 3D to 2D and construct a congestion map in terms of pattern routes.
  - 3. do pattern routing for each net and maze routing when some wire passes congested area.
  - 4. Remove extra Steiner points and segments when each net gets routed.
  - 5. Rip-up Reroute with three steps of different sequence: pattern route sequence, edge sorted by overflow and also each net sorted by overflow.
- Router uses 1 CPU
- First time participation

Team 11 – Amaze Global Router (AMGR)

- Dept of Computer Science and Engineering, Chinese University of Hong Kong
- Xiao Linfu, Li Liang, Qian Zaichen
- Advisor: Dr. Evan Young
- Description
  - 1. Use our fast multi-pin maze routing engine repetitively to generate a very good initial global routing solution.
  - 2. Rip-up and re-route with our engine.
  - 3. Do wire length minimization and bending reduction.
  - 4. Do layer assignment, starting with nets with larger number of pins and shorter lengths
- Router uses 1 CPU
- First time participation



Summary: Binary of routers

ID	Team Name	Binary name	CPU	size	other file 1	size	other file 2	size
1	FastRoute 3.0	FastRoute	4	418304	POST9.dat	6562490	POWV9.dat	2879334
2	FGR	FGR.exe	1	1382128				
3	NTUGR	NTUGR	4	1088443				
4	NCTU	dory	1	313094	LA	74479		
5	BoxRouter	br_ispd08.x.s	1	1228160	POST9.dat	6562490	POWV9.dat	2879334
6	NTHU-Route	nthuroute	1	1489864	POST9.dat	6562490	POWV9.dat	2879334
7	IGOR	main	1	138316	POST9.dat	6562490	POWV9.dat	2879334
9	HSR	GR	1	1204578	POST9.dat	6562490	POWV9.dat	2879334
10	simple router	simple_router	1	434384	POST9.dat	6562490	POWV9.dat	2879334
11	AMGR	CUHKrouter-new	1	46864				

New Benchmarks

- We adjust our new benchmarks such that the best open-source routers from 2007 produce small amount of overflow
- 5 out of 8 is routable by "median router"
- We look forward …
  - The 3 currently unroutable benchmarks will become routable within months

	2008 median			median router routable?	best router routable?
	Overflow		Total WL		
	Total	Max.	(e5)		
a1	0	0	56.52	O	O
a2	0	0	53.08	O	O
a3	0	0	133.43	O	O
a4	0	0	122.59	O	O
a5	0	0	160.38	O	O
b1	0	0	59.89	O	O
b2	0	0	96.46	O	O
b3	0	0	132.02	O	O
b4	389	4	237.22	X	X
n1	44	2	48.98	X	O
n2	0	0	76.86	O	O
n3	33627	414	109.17	X	X
n4	222	3	139.20	X	X
n5	0	0	238.00	O	O
n6	0	0	184.67	O	O
n7	1023	3	356.08	X	X

ISPD 2008 Global Routing Contest Winner

						2008			x	v		x	x			x	
	a1	a2	a3	a4	a5	b1	b2	b3	b4	n1	n2	n3	n4	n5	n6	n7	avgRank
A	1	1	3	1	1	1	2	1	1	1	2	2	2	1	1	1	1.38
B	3	3	2	3	3	3	5	4	2	2	3	1	1	4	3	3	2.81
C	2	2	1	2	2	2	7	3	3	6	1	3	6	3	2	4	3.06
D	4	4	4	4	4	4	1	2	6	5	4	4	4	2	4	2	3.63
E	5	6	6	5	6	6	3	5	5	3	5	5	7	5	5	5	5.13
F	7	5	5	6	5	7	6	6	4	4	6	6	3	6	6	6	5.50
G	6	7	7	7	7	5	4	7	7	7	7	7	5	7	7	7	6.50
H	8	8	8	8	8	8	8	8	8	8	9	9	8	8	8	8	8.13
I	9	10	9	9	9	9	10	9	9	10	8	9	9	9	9	9	9.13
J	10	9	9	10	10	10	9	9	9	9	10	8	10	9	9	9	9.31

- First time participating teams perform not as good
  - only have 2 weeks to try 8 new benchmarks

ISPD 2008 Global Routing Contest Winner

- With CPU-weighted TWL
- With TWL instead of CPU-weighted TWL

	a1	a2	a3	a4	a5	b1	b2	b3	b4	n1	n2	n3	n4	n5	n6	n7	avgRank
A	1	1	3	1	1	1	2	1	1	1	2	2	2	1	1	1	1.38
B	***3***	***3***	***2***	***3***	***3***	***3***	***5***	***4***	***2***	***2***	***3***	***1***	***1***	***4***	***3***	***3***	***2.81***
C	***2***	***2***	***1***	***2***	***2***	***2***	***7***	***3***	***3***	***6***	***1***	***3***	***6***	***3***	***2***	***4***	***3.06***
D	***4***	***4***	***4***	***4***	***4***	***4***	***1***	***2***	***6***	***5***	***4***	***4***	***4***	***2***	***4***	***2***	***3.63***
E	***5***	***6***	***6***	***5***	***6***	***6***	***3***	***5***	***5***	***3***	***5***	***5***	***7***	***5***	***5***	***5***	***5.13***
F	7	5	5	6	5	7	6	6	4	4	6	6	3	6	6	6	5.50
G	6	7	7	7	7	5	4	7	7	7	7	7	5	7	7	7	6.50
H	8	8	8	8	8	8	8	8	8	8	9	9	8	8	8	8	8.13
I	9	10	9	9	9	9	10	9	9	10	8	9	9	9	9	9	9.13
J	10	9	9	10	10	10	9	9	9	9	10	8	10	9	9	9	9.31
	a1	a2	a3	a4	a5	b1	b2	b3	b4	n1	n2	n3	n4	n5	n6	n7	avgRank
A	1	1	1	2	1	1	2	1	1	1	1	2	2	1	1	1	1.25
D	***2***	***3***	***3***	***3***	***3***	***2***	***1***	***2***	***6***	***5***	***4***	***4***	***4***	***2***	***2***	***2***	***3.00***
E	***3***	***2***	***2***	***1***	***2***	***3***	***3***	***4***	***5***	***3***	***3***	***5***	***7***	***3***	***3***	***5***	***3.38***
B	***5***	***6***	***5***	***6***	***4***	***4***	***5***	***6***	***2***	***2***	***6***	***1***	***1***	***6***	***5***	***3***	***4.19***
C	***4***	***5***	***4***	***4***	***6***	***5***	***7***	***3***	***3***	***6***	***5***	***3***	***6***	***5***	***6***	***4***	***4.75***
F	6	4	6	5	5	6	6	5	4	4	2	6	3	4	4	6	4.75
G	7	7	7	7	7	7	4	7	7	7	7	7	5	7	7	7	6.69
H	8	8	8	8	8	8	8	8	8	8	9	9	8	8	8	8	8.13
I	9	10	9	9	9	9	10	9	9	10	8	9	9	9	9	9	9.13
J	10	9	9	10	10	10	9	9	9	9	10	8	10	9	9	9	9.31

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NTHU-route
NTUgr
FastRoute 3.0
BoxRouter
FGR
AMGR

	a1	a2	a3	a4	a5	b1	b2	b3	b4	n1	n2	n3	n4	n5	n6	n7	avgRank
						2008			x	v		x	x			x	
A	**1**	**1**	**3**	**1**	**1**	**1**	**2**	**1**	**1**	**1**	**2**	**2**	**2**	**1**	**1**	**1**	**1.38**
B	**3**	**3**	**2**	**3**	**3**	**3**	**5**	**4**	**2**	**2**	**3**	**1**	**1**	**4**	**3**	**3**	**2.81**
C	**2**	**2**	**1**	**2**	**2**	**2**	**7**	**3**	**3**	**6**	**1**	**3**	**6**	**3**	**2**	**4**	**3.06**
D	**4**	**4**	**4**	**4**	**4**	**4**	**1**	**2**	**6**	**5**	**4**	**4**	**4**	**2**	**4**	**2**	**3.63**
E	**5**	**6**	**6**	**5**	**6**	**6**	**3**	**5**	**5**	**3**	**5**	**5**	**7**	**5**	**5**	**5**	**5.13**
F	**7**	**5**	**5**	**6**	**5**	**7**	**6**	**6**	**4**	**4**	**6**	**6**	**3**	**6**	**6**	**6**	**5.50**
G	**6**	**7**	**7**	**7**	**7**	**5**	**4**	**7**	**7**	**7**	**7**	**7**	**5**	**7**	**7**	**7**	**6.50**
H	**8**	**8**	**8**	**8**	**8**	**8**	**8**	**8**	**8**	**8**	**9**	**9**	**8**	**8**	**8**	**8**	**8.13**
I	**9**	**10**	**9**	**9**	**9**	**9**	**10**	**9**	**9**	**10**	**8**	**9**	**9**	**9**	**9**	**9**	**9.13**
J	**10**	**9**	**9**	**10**	**10**	**10**	**9**	**9**	**9**	**9**	**10**	**8**	**10**	**9**	**9**	**9**	**9.31**

How does 2008-best compare to 2007-best

	2007 BEST results				2008 BEST results				Improvement from 2007		
	Overflow		Total WL		Overflow		Total WL		Overflow		Total WL
	Total	Max.	(e5)	Router	Total	Max.	(e5)	Router	Total	Max.	(e5)
a1	0	0	59.52	MaizeRouter	0	0	53.50	NTHU-route	na	na	10.12%
a2	0	0	55.99	MaizeRouter	0	0	52.31	NTHU-route	na	na	6.57%
a3	0	0	136.27	MaizeRouter	0	0	121.66	NTHU-route	na	na	10.72%
a4	0	0	124.72	MaizeRouter	0	0	121.73	FGR	na	na	2.40%
a5	0	0	170.14	BoxRouter	0	0	155.55	NTHU-route	na	na	8.57%
n1	400	2	50.68	BoxRouter	0	0	46.53	NTHU-route	WOW	WOW	8.19%
n2	0	0	77.55	MaizeRouter	0	0	75.71	NTHU-route	na	na	2.37%
n3	32840	1058	113.86	MaizeRouter	31454	204	106.49	NTHU-route	4.22%	80.72%	6.47%

Summary

- Academic routers show great improvements
- A good set of global routing benchmarks
  - Overflow minimization
  - Routed wire length minimization, CPU-weighted
- Future directions?
  - What is a good/fast way to evaluate global routing?
    - Information inside a g-cell is ignored
- Look forward to next global/detailed routing contest
  - Open to any suggestions/feedbacks
- http://www.ispd.cc/rcontest

ISPD 2008 Global Routing Contest Detailed Results

Overall Rankings

							2008										2008			
										x	v		x	x			x	
		a1	a2	a3	a4	a5	b1	b2	b3	b4	n1	n2	n3	n4	n5	n6	n7	avgRank
NTHU-Route	A	1	1	3	1	1	1	2	1	1	1	2	2	2	1	1	1	1.38
NTUgr	B	3	3	2	3	3	3	5	4	2	2	3	1	1	4	3	3	2.81
FastRoute 3.0	C	2	2	1	2	2	2	7	3	3	6	1	3	6	3	2	4	3.06
BoxRouter	D	4	4	4	4	4	4	1	2	6	5	4	4	4	2	4	2	3.63
FGR	E	5	6	6	5	6	6	3	5	5	3	5	5	7	5	5	5	5.13
NCTU	F	7	5	5	6	5	7	6	6	4	4	6	6	3	6	6	6	5.50
AMGR	G	6	7	7	7	7	5	4	7	7	7	7	7	5	7	7	7	6.50
IGOR	H	8	8	8	8	8	8	8	8	8	8	9	9	8	8	8	8	8.13
Simple Router	I	9	10	9	9	9	9	10	9	9	10	8	9	9	9	9	9	9.13
HSR	J	10	9	9	10	10	10	9	9	9	9	10	8	10	9	9	9	9.31

a1

- -- : cannot finish in 24 hours, or router crashes

router	TOF	MOF	TWL	CPU/s	CPUW-TWL	CPU-factor	rank
NTHU-Route	0	0	5349595	475	4962279	-0.072	1
NTUgr	0	0	5609515	293	5048564	-0.100	3
FastRoute 3.0	0	0	5554101	105	4998691	-0.100	2
BoxRouter	0	0	5380627	1227	5285899	-0.018	4
FGR	0	0	5405141	2102	5477954	0.013	5
NCTU	0	0	5693690	2274	5796210	0.018	7
AMGR	0	0	5813658	1209	5706498	-0.018	6
IGOR	0	0	11309822	34112	12440804	0.100	8
Simple Router	2974	12	7495873	6863	8108653	0.082	9
HSR	671842	216	7988073	11203	8786880	0.100	10

a2

- -- : cannot finish in 24 hours, or router crashes

router	TOF	MOF	TWL	CPU/s	CPUW-TWL	CPU-factor	rank
NTHU-Route	0	0	5230979	104	4707881	-0.100	1
NTUgr	0	0	5337541	73	4803787	-0.100	3
FastRoute 3.0	0	0	5307805	25	4777025	-0.100	2
BoxRouter	0	0	5271806	162	4857235	-0.079	4
FGR	0	0	5255902	855	5347743	0.017	6
NCTU	0	0	5274884	632	5274884	0.000	5
AMGR	0	0	5558821	1585	5853963	0.053	7
IGOR	824	6	11425731	52005	12568304	0.100	8
Simple Router	--	--	--	--	--	--	10
HSR	274474	100	7564757	22208	8321233	0.100	9

a3

- -- : cannot finish in 24 hours, or router crashes

router	TOF	MOF	TWL	CPU/s	CPUW-TWL	CPU-factor	rank
NTHU-Route	0	0	13111262	481	12126960	-0.075	3
NTUgr	0	0	13355806	309	12020225	-0.100	2
FastRoute 3.0	0	0	13330495	101	11997446	-0.100	1
BoxRouter	0	0	13179058	1635	13119867	-0.004	4
FGR	0	0	13173349	3327	13654190	0.037	6
NCTU	0	0	13397630	1900	13453456	0.004	5
AMGR	0	0	14061475	3779	14678128	0.044	7
IGOR	0	0	26543118	41933	29197430	0.100	8
Simple Router	--	--	--	--	--	--	9
HSR	--	--	--	--	--	--	9

a4

- -- : cannot finish in 24 hours, or router crashes

router	TOF	MOF	TWL	CPU/s	CPUW-TWL	CPU-factor	rank
NTHU-Route	0	0	12172692	135	10955423	-0.100	1
NTUgr	0	0	12259485	104	11033537	-0.100	3
FastRoute 3.0	0	0	12222909	33	11000618	-0.100	2
BoxRouter	0	0	12211779	403	11618867	-0.049	4
FGR	0	0	12166776	996	12210400	0.004	5
NCTU	0	0	12257582	876	12210719	-0.004	6
AMGR	0	0	12790383	2756	13587555	0.062	7
IGOR	0	0	20857198	7132	22942918	0.100	8
Simple Router	22	4	18329297	68823	20162227	0.100	9
HSR	145016	54	16675078	75094	18342586	0.100	10

a5

- -- : cannot finish in 24 hours, or router crashes

router	TOF	MOF	TWL	CPU/s	CPUW-TWL	CPU-factor	rank
NTHU-Route	0	0	15555389	1030	14186746	-0.088	1
NTUgr	0	0	15929290	1058	14552331	-0.086	3
FastRoute 3.0	0	0	16085928	284	14477335	-0.100	2
BoxRouter	0	0	15685923	1889	14854998	-0.053	4
FGR	0	0	15661544	6584	15960349	0.019	6
NCTU	0	0	15989791	3881	15807146	-0.011	5
AMGR	0	0	16557585	5580	16715394	0.010	7
IGOR	5964	12	29942773	85057	32937050	0.100	8
Simple Router	7714	14	22297896	52503	24527686	0.100	9
HSR	1713562	194	22189684	63597	24408652	0.100	10

b1

- -- : cannot finish in 24 hours, or router crashes

router	TOF	MOF	TWL	CPU/s	CPUW-TWL	CPU-factor	rank
NTHU-Route	0	0	5631048	586	5138273	-0.088	1
NTUgr	0	0	5784460	839	5398117	-0.067	3
FastRoute 3.0	0	0	5830862	232	5247776	-0.100	2
BoxRouter	0	0	5698086	1147	5420102	-0.049	4
FGR	0	0	5733109	4194	5882474	0.026	6
NCTU	0	0	6146808	6704	6473331	0.053	7
AMGR	0	0	6153326	1141	5851493	-0.049	5
IGOR	2232	6	10859508	45795	11945459	0.100	8
Simple Router	14092	14	7791304	4494	8025354	0.030	9
HSR	866118	168	8116300	5432	8448900	0.041	10

b2

- -- : cannot finish in 24 hours, or router crashes

router	TOF	MOF	TWL	CPU/s	CPUW-TWL	CPU-factor	rank
NTHU-Route	0	0	9059102	594	8153192	-0.100	2
NTUgr	0	0	9718446	15862	9777096	0.006	5
FastRoute 3.0	142	4	9820174	673	8838157	-0.100	7
BoxRouter	0	0	9042719	2346	8138447	-0.100	1
FGR	0	0	9142997	14287	9142997	0.000	3
NCTU	24	2	9004580	22927	9250349	0.027	6
AMGR	0	0	9646199	13287	9605806	-0.004	4
IGOR	2680	6	15695449	44227	16718933	0.065	8
Simple Router	--	--	--	--	--	--	10
HSR	1207512	104	14044578	85484	15449036	0.100	9

b3

- -- : cannot finish in 24 hours, or router crashes

router	TOF	MOF	TWL	CPU/s	CPUW-TWL	CPU-factor	rank
NTHU-Route	0	0	13075301	259	11767771	-0.100	1
NTUgr	0	0	13573270	296	12215943	-0.100	4
FastRoute 3.0	0	0	13165477	187	11848929	-0.100	3
BoxRouter	0	0	13133112	380	11819801	-0.100	2
FGR	0	0	13200687	5256	13675523	0.036	5
NCTU	0	0	13204201	10955	14238785	0.078	6
AMGR	0	0	13710765	6343	14352683	0.047	7
IGOR	1706	8	28927224	85113	31819946	0.100	8
Simple Router	--	--	--	--	--	--	9
HSR	--	--	--	--	--	--	9

b4

- -- : cannot finish in 24 hours, or router crashes

router	TOF	MOF	TWL	CPU/s	CPUW-TWL	CPU-factor	rank
NTHU-Route	182	2	23075825	7533	20788825	-0.099	1
NTUgr	188	8	24281795	24785	23544085	-0.030	2
FastRoute 3.0	206	2	24344416	2480	21909974	-0.100	3
BoxRouter	472	4	23156271	52644	23459407	0.013	6
FGR	414	4	23162928	85513	24114597	0.041	5
NCTU	364	2	22697006	31275	22312076	-0.017	4
AMGR	656	4	24698274	72421	25476181	0.031	7
IGOR	10102	26	43403139	85091	45174003	0.041	8
Simple Router	--	--	--	--	--	--	9
HSR	--	--	--	--	--	--	9

n1

- -- : cannot finish in 24 hours, or router crashes

router	TOF	MOF	TWL	CPU/s	CPUW-TWL	CPU-factor	rank
NTHU-Route	0	0	4652916	306	4187624	-0.100	1
NTUgr	6	2	5032685	69021	5070766	0.008	2
FastRoute 3.0	76	2	4898128	772	4408315	-0.100	6
BoxRouter	44	2	4694504	74488	4750677	0.012	5
FGR	8	2	4682710	84737	4773578	0.019	3
NCTU	30	2	4595493	16675	4253556	-0.074	4
AMGR	112	2	5040263	72086	5091039	0.010	7
IGOR	2498	6	9409745	60539	9409745	0.000	8
Simple Router	--	--	--	--	--	--	10
HSR	258496	58	7107317	20416	6661499	-0.063	9

n2

- -- : cannot finish in 24 hours, or router crashes

router	TOF	MOF	TWL	CPU/s	CPUW-TWL	CPU-factor	rank
NTHU-Route	0	0	7571354	67	6863619	-0.093	2
NTUgr	0	0	7747520	31	6972768	-0.100	3
FastRoute 3.0	0	0	7625150	18	6862635	-0.100	1
BoxRouter	0	0	7594436	109	7096327	-0.066	4
FGR	0	0	7588737	259	7470967	-0.016	5
NCTU	0	0	7578450	419	7671042	0.012	6
AMGR	0	0	8055326	664	8367355	0.039	7
IGOR	0	0	14186747	1870	15583956	0.098	9
Simple Router	0	0	11186020	23155	12304622	0.100	8
HSR	100080	34	11608837	16643	12769721	0.100	10

n3

- -- : cannot finish in 24 hours, or router crashes

router	TOF	MOF	TWL	CPU/s	CPUW-TWL	CPU-factor	rank
NTHU-Route	31454	204	10649470	7746	9584523	-0.100	2
NTUgr	31106	432	17968738	48563	17584317	-0.021	1
FastRoute 3.0	31650	734	10926015	1892	9833414	-0.100	3
BoxRouter	32404	828	10907887	82615	11008981	0.009	4
FGR	34850	396	10555856	85640	10675593	0.011	5
NCTU	35310	206	10622537	65912	10582527	-0.004	6
AMGR	37828	186	11396687	74803	11436982	0.004	7
IGOR	--	--	--	--	--	--	9
Simple Router	--	--	--	--	--	--	9
HSR	1165162	2180	13944019	85561	14101446	0.011	8

n4

- -- : cannot finish in 24 hours, or router crashes

router	TOF	MOF	TWL	CPU/s	CPUW-TWL	CPU-factor	rank
NTHU-Route	152	2	12989866	4023	11690879	-0.100	2
NTUgr	142	2	14378346	67087	14367521	-0.001	1
FastRoute 3.0	226	4	13572072	596	12214865	-0.100	6
BoxRouter	200	4	12947326	78225	13052341	0.008	4
FGR	262	2	12959353	85220	13128517	0.013	7
NCTU	162	2	12842299	58302	12728614	-0.009	3
AMGR	218	2	14267375	72241	14317575	0.004	5
IGOR	7742	14	23735598	85048	24042662	0.013	8
Simple Router	8260	26	18332861	26747	17346202	-0.054	9
HSR	881026	242	18327002	68849	18340623	0.001	10

n5

- -- : cannot finish in 24 hours, or router crashes

router	TOF	MOF	TWL	CPU/s	CPUW-TWL	CPU-factor	rank
NTHU-Route	0	0	23166430	854	20849787	-0.100	1
NTUgr	0	0	24577706	1679	22811988	-0.072	4
FastRoute 3.0	0	0	24119456	330	21707510	-0.100	3
BoxRouter	0	0	23294032	1700	21636760	-0.071	2
FGR	0	0	23295876	9963	24015967	0.031	5
NCTU	0	0	23480222	15542	24808532	0.057	6
AMGR	0	0	24640594	15062	25989940	0.055	7
IGOR	18762	22	40645334	85083	44709867	0.100	8
Simple Router	--	--	--	--	--	--	9
HSR	--	--	--	--	--	--	9

n6

- -- : cannot finish in 24 hours, or router crashes

router	TOF	MOF	TWL	CPU/s	CPUW-TWL	CPU-factor	rank
NTHU-Route	0	0	17695878	818	16093031	-0.091	1
NTUgr	0	0	18555976	935	17017946	-0.083	3
FastRoute 3.0	0	0	18659522	242	16793570	-0.100	2
BoxRouter	0	0	17975468	1785	17156317	-0.046	4
FGR	0	0	18030096	6194	18503078	0.026	5
NCTU	0	0	18377894	6078	18839950	0.025	6
AMGR	0	0	19049367	6980	19680418	0.033	7
IGOR	10836	16	32184209	85072	35402630	0.100	8
Simple Router	--	--	--	--	--	--	9
HSR	--	--	--	--	--	--	9

n7

- -- : cannot finish in 24 hours, or router crashes

router	TOF	MOF	TWL	CPU/s	CPUW-TWL	CPU-factor	rank
NTHU-Route	68	2	35357343	8433	31821609	-0.100	1
NTUgr	310	2	37222081	86732	37427060	0.006	3
FastRoute 3.0	588	6	35859311	11391	32273380	-0.100	4
BoxRouter	208	2	35120201	84743	35266586	0.004	2
FGR	1458	4	35023501	86068	35200840	0.005	5
NCTU	3094	2	34367258	56929	33721528	-0.019	6
AMGR	3582	4	37825580	72933	37655638	-0.004	7
IGOR	25940	14	68922133	85152	69228559	0.004	8
Simple Router	--	--	--	--	--	--	9
HSR	--	--	--	--	--	--	9