The ISPD-2011 Contest and Benchmark Suite

Natarajan Viswanathan, Charles J. Alpert,
Cliff Sze, Zhuo Li, Gi-Joon Nam, Jarrod A. Roy

IBM Corp., Austin, TX

Outline

- ☐ Overview of the ISPD-2011 Contest

- ☐ ISPD-2011 Benchmark Suite

- ☐ Contest Logistics

- ☐ Results

Acknowledgements

- ISPD-2011 steering committee and chairs

- Colleagues at IBM
  - Shyam Ramji, Bertram Bradley, Randy Darden and others…

- Academic global routing teams

- Contest participants

ISPD-2011 Contest

ISPD Contests: A Brief History

- ☐ ISPD-05 Placement Contest
  - ■ 8 industrial ASIC designs
  - ■ Evaluation metric:
    - ☐ HPWL

- ☐ ISPD-06 Placement Contest
  - ■ 8 more designs
  - ■ Evaluation metric:
    - ☐ HPWL
    - ☐ Density Overflow
    - ☐ Runtime

ISPD Contests: A Brief History

- ☐ ISPD-05/06 Placement Contests
  - ■ Advanced research in placement
  - ■ Coarse attempts to quantify routability
  - ■ Dearth of public global routing tools

- ☐ ISPD-07/08 Contests
  - ■ Spurred research in global routing
  - ■ Many high-quality global routers

The ISPD-2011 Contest

☐ Invited Talks…
- ■ Dr. C.-K. Cheng
  - ☐ Placement is a key step in physical synthesis
  - ☐ Need high-quality placement algorithms
- ■ Dr. Ren-Song Tsay
  - ☐ Place & Route cannot be completely independent
 - ☐ Look-ahead and feedback process

Routability-driven **Placement Contest**

In a Nutshell...

- ☐ Open contest, primarily for the academic community

- ☐ Benchmarks
  - ■ 8 industrial ASIC designs released by IBM Corp.

- ☐ New Benchmark Format
  - ■ Enable placement and routing

- ☐ Evaluation Metric
  - ■ Routability of the placement solution

- ☐ Evaluation Tool
 - ■ Real global router for congestion analysis
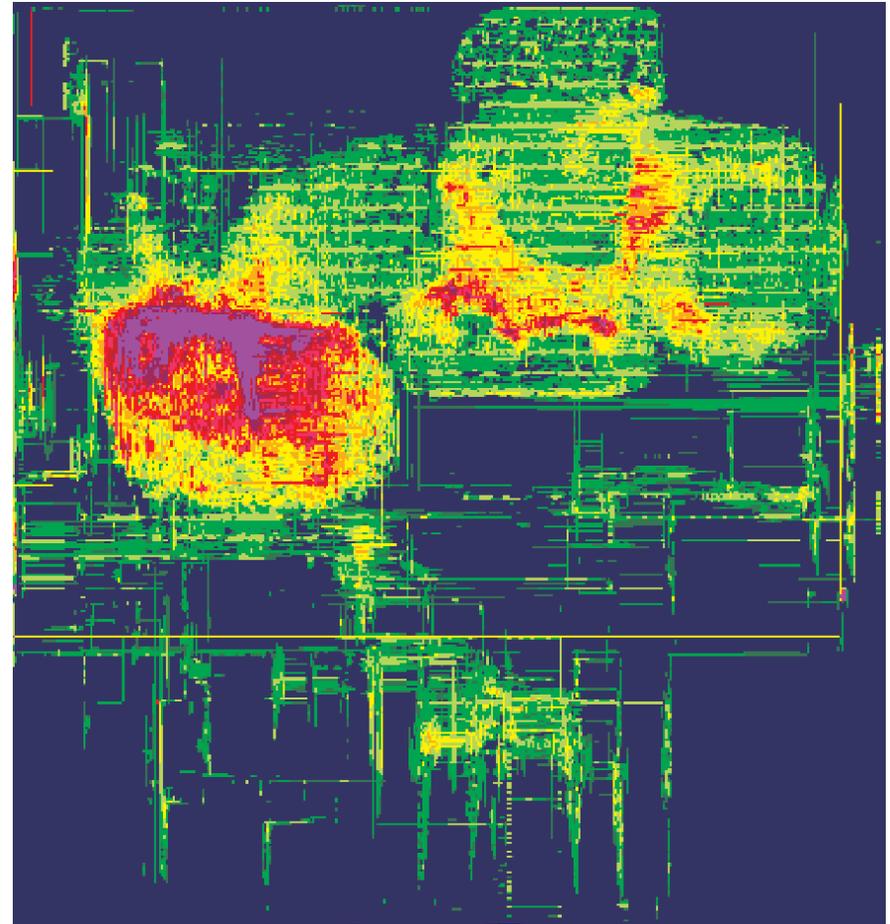
ISPD-2011 Benchmark Suite

Highlights

- ☐ Real industrial ASIC designs released by IBM Corp.

- ☐ Information for placement and routing

- ☐ Design-density
  - ■ 28% - 60%

- ☐ Placement Blockages
  - ■ Fragmented image space

- ☐ Routing Blockages
  - ■ Detouring
  - ■ Capacity/Overflow calculation

- ☐ Varying metal width and spacing
  - ■ Layer assignment
  - ■ Capacity/Overflow calculation
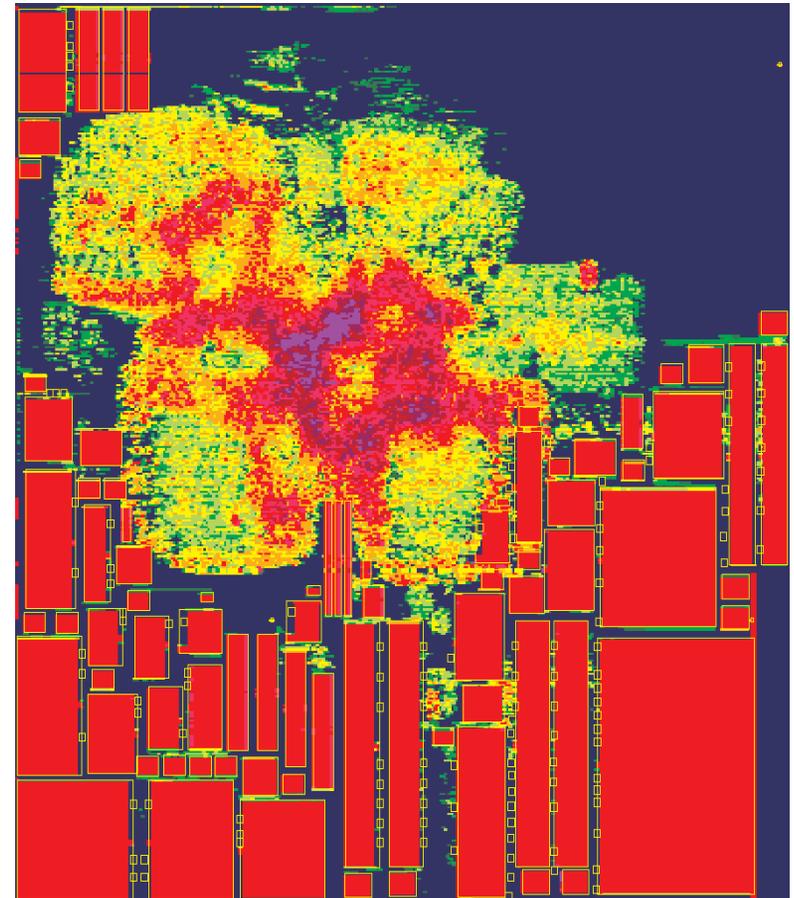
Benchmark Files

- ☐ Extend the Bookshelf format to handle routability-driven placement

- ☐ Benchmark files
  - ■ circuit.aux
  - ■ circuit.nodes
  - ■ circuit.nets
  - ■ circuit.wts
  - ■ circuit.pl
  - ■ circuit.scl

  Original Files in Bookshelf format with some extensions

  - ■ circuit.shapes
  - ■ circuit.route

  New Files with extensions for both placement and routing

Non-rectangular Fixed Objects

- ☐ Fraction of the fixed objects are not rectangular
- ☐ Affects placement density, routing capacity, etc.,
- ☐ Represented as:
  - ■ Enclosing rectangle (blue box)
  - ■ Set of rectangular component shapes (hatched red boxes)
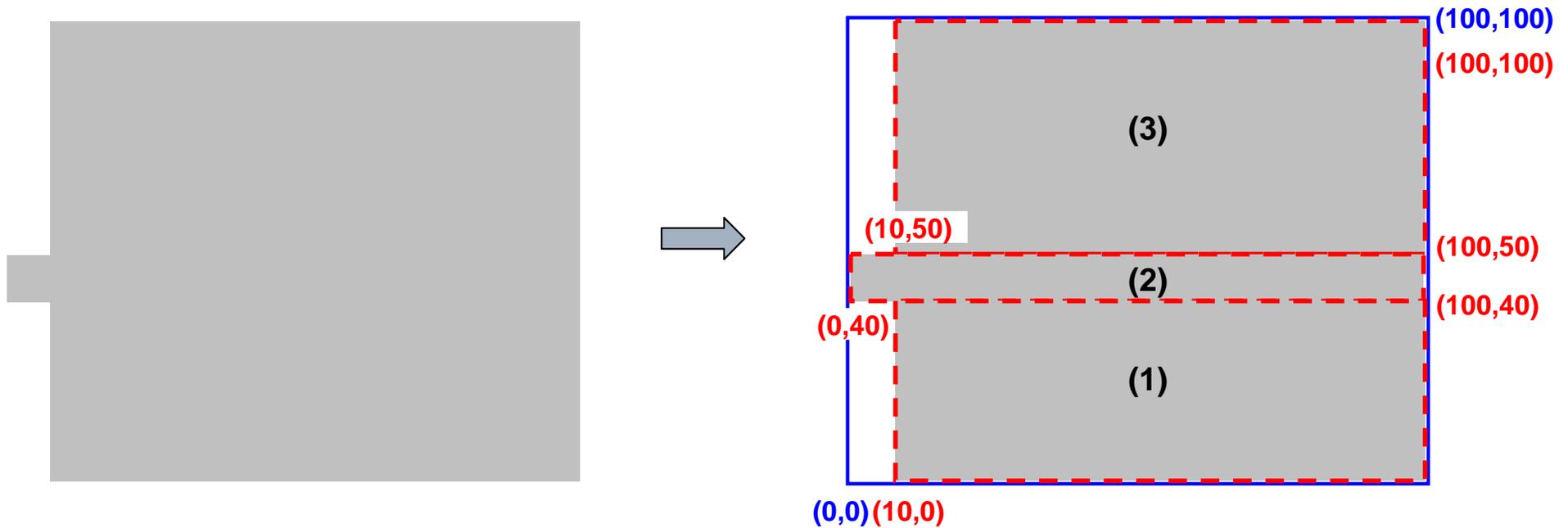
Terminal_NI Objects

- ☐ Fixed "**N**ot in **I**mage" objects
  - ■ RLM Pins
    - ☐ Fixed pins on metal layer(s) above the ones used within standard-cells for internal pins and/or routing
    - ☐ Corresponding objects are Terminal_NI objects
  - ■ Routing blockages
    - ☐ Same representation as other objects in the design

Terminal_NI Objects

Placement Image
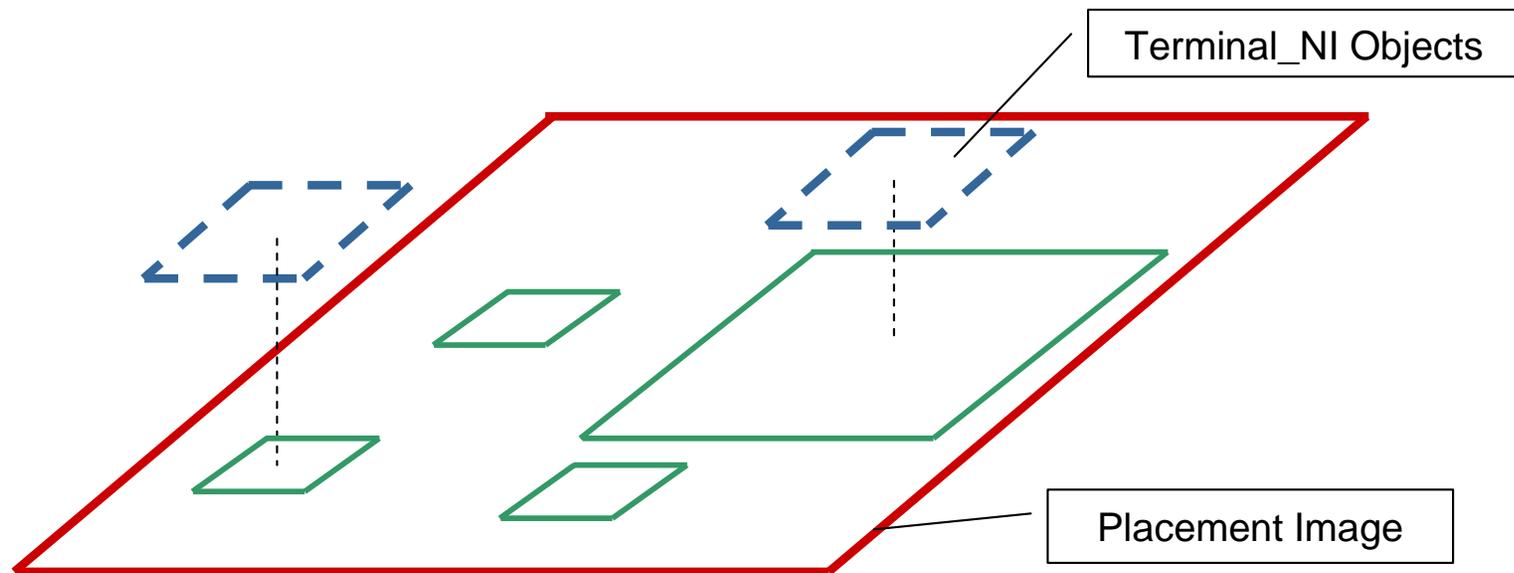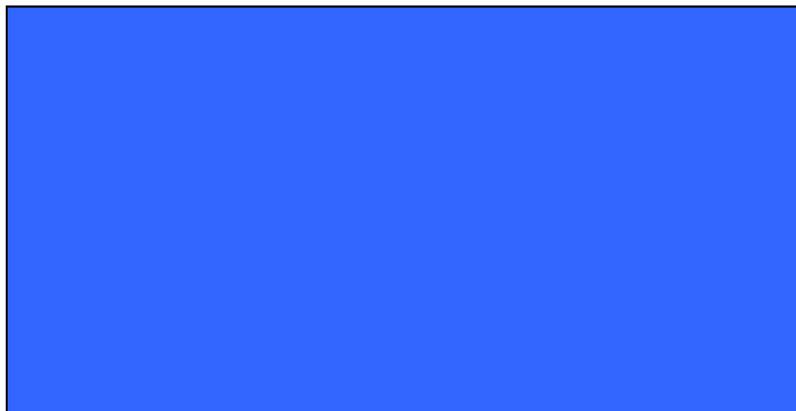
Metal Stack

- □ 9 metal layers

- □ M1-M4
  - ■ 1x width and spacing

- □ M5-M7
  - ■ 2x width and spacing

- □ M8-M9
  - ■ 4x width and spacing

Routing Information

```
route 1.0
# File header with version information, etc.,

Grid                 :  304  403  9          # Header section.
VerticalCapacity     :  0  80   0  80   0  80   0  80   0   # Can be modified
HorizontalCapacity   :  0   0  80   0  80   0  80   0  80   # to change the
MinWireWidth         :  1  1  1  1  2  2  2  4  4          # routing instance
MinWireSpacing       :  1  1  1  1  2  2  2  4  4          # (grid size,
ViaSpacing           :  0  0  0  0  0  0  0  0             # routing capacity,
GridOrigin           :  18  18                            # wire/via costs,
TileSize             :  40  40                            # etc.,)
BlockagePorosity     :  0
```

```
NumNiTerminals   :   2

  p0     4        # all the pins belonging to p0/p1 are on layer 4 for routing
  p1     4
```

```
NumBlockageNodes   :   2

   o44   4  1 2 3 4   # o44/o2407 block 4 metal layers within all the routing
 o2407   4  1 2 3 4   # tiles that they overlap. These are layers 1 to 4.
```

Statistics

| Design	Total Nodes	Movable Nodes	Terminal Nodes	Terminal_NI Nodes	Total Nets	Total Pins	Design Util.(%)	Design Den.(%)
superblue18	483452	442405	25063	15984	468918	1864306	67	47
superblue4	600220	521466	40550	38204	567607	1884008	70	44
superblue5	772457	677416	74365	20676	786999	2500306	77	37
superblue1	847441	765102	52627	29712	822744	2861188	69	35
superblue2	1014029	921273	59312	33444	990899	3228345	76	28
superblue15	1123963	829614	252053	42296	1080409	3816680	73	60
superblue10	1129144	914921	153595	60628	1085737	3665711	75	35
superblue12	1293433	1278084	8953	6396	1293436	4774069	56	44

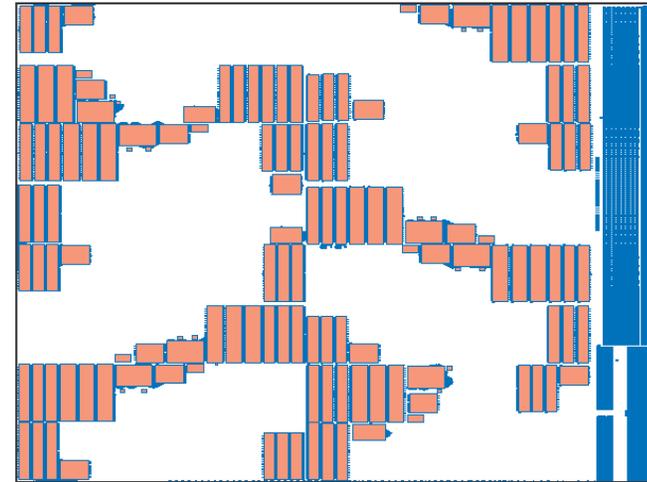# Floorplan Layouts
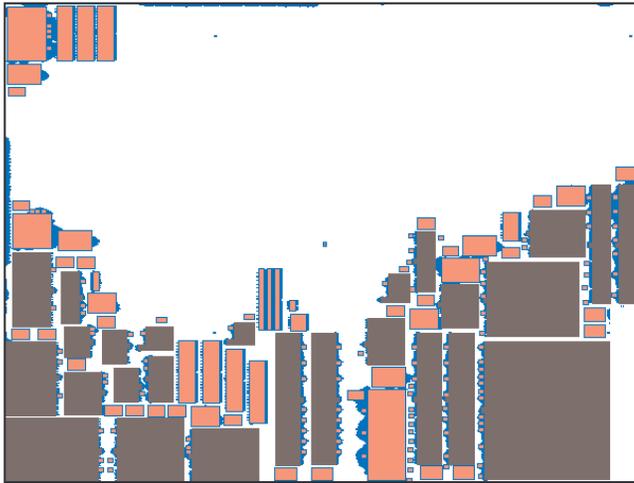
superblue18
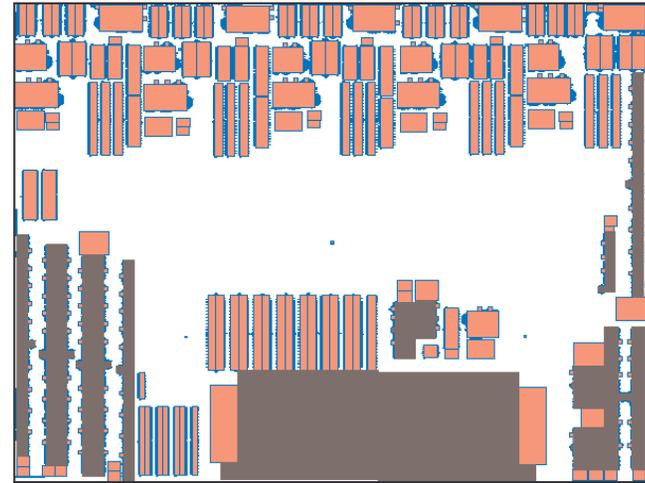
superblue4
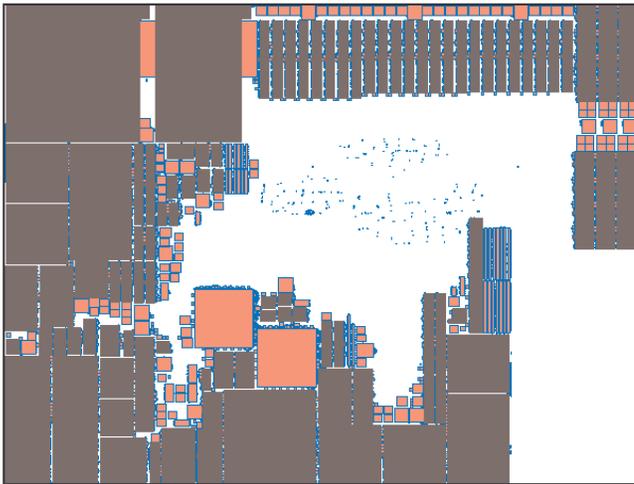
superblue5
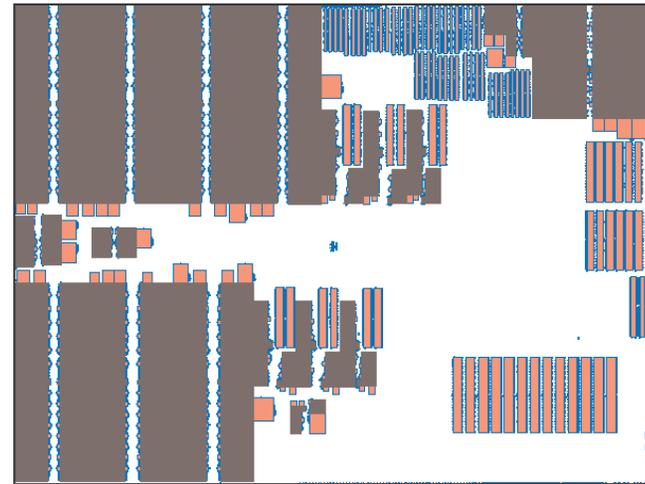
superblue1

Floorplan Layouts
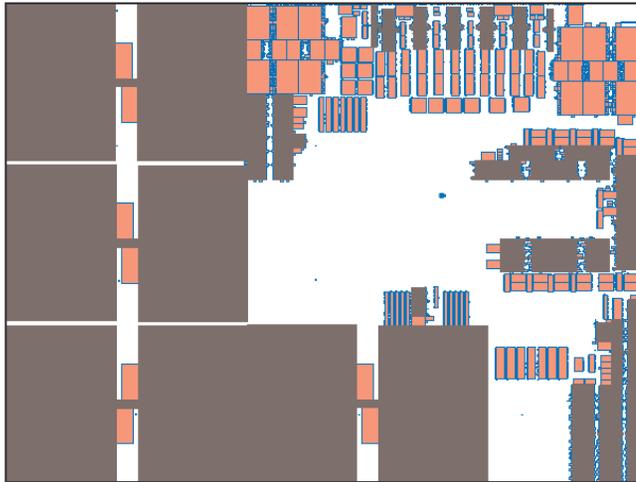
superblue2

superblue15
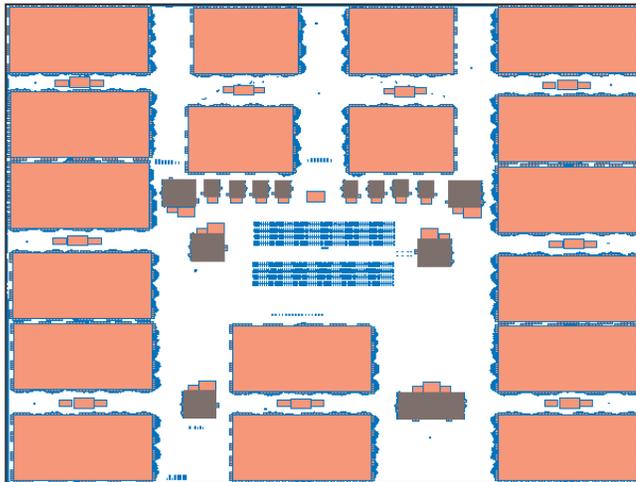
superblue10
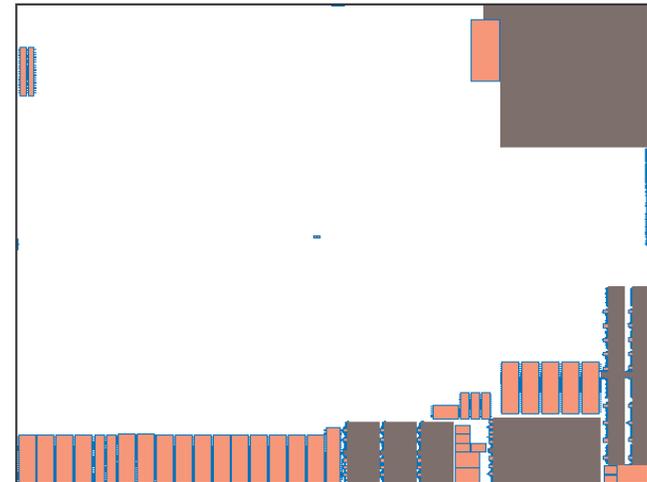
superblue12

Contest Logistics

Timeline

- [ ] Nov 25, 2010: Release 1st sample benchmark

- [ ] Dec 09, 2010: Release 2nd sample benchmark

- [ ] Feb 07, 2011: Receive preliminary binaries from all teams

- [ ] Feb 11, 2011: Released "golden" router and evaluation script

- [ ] Feb 22, 2011: Released 3rd and 4th sample benchmarks

- [ ] Mar 11, 2011: Receive final binaries from all teams

- [ ] Mar 12-27, 2011: Run final binaries on contest machine

- [ ] Mar 28, 2011: Announce Results and release "official" ISPD-2011 benchmark suite

Placement Teams (1)

1. **CPP**
   - ☐ Jui-Hung Hung, Tsu-Yun Hsueh, Moses Lee, Hsiang-Hui Yang, Tsung-Yen Chang, Yao-Kai Yeh
   - ☐ Chung Yuan Christian University

2. **NCKUplacer**
   - ☐ Chao-Jam Hsu, Cheng-En Lu, Po-Chia Chen, Chung-Lin Lee, J.-M. Lin
   - ☐ National Cheng Kung University

3. **NTHUplacer**
   - ☐ Hsiu-Yu Lai, Yuan-Kang Chuang, Hsueh-Ju Chou, Shao-Huan Wang, Tien-Yu Kuo and Yu-Yi Liang
   - ☐ National Tsing Hua University

Placement Teams (2)

4. **mPL11**
   - ☐ Jason Cong, Guojie Luo, Kalliopi Tsota, Bingjun Xiao
   - ☐ UCLA

5. **RADIANT**
   - ☐ Meng-Kai Hsu, Sheng Chou, Tzu-Hen Lin, Yao-Wen Chang
   - ☐ National Taiwan University

6. **Ripple**
   - ☐ Xu He, Tao Huang, Linfu Xiao, Haitong Tian, Guxin Cui, Evangeline F.Y. Young
   - ☐ Chinese University of Hong Kong

Placement Teams (3)

7. SC
- ☐ Sifei Wang, Xin Wu, Liu Liu, Haixia Yan, Qiang Zhou
- ☐ Tsinghua University

8. SimPLR
- ☐ Myung-Chul Kim, Dong-Jin Lee, Jin Hu, Igor Markov
- ☐ University of Michigan

9. VDAPlace
- ☐ Sean Liu, Ching-Yu Chin, Chun-Kai Wang, Po-Cheng Pan, Jerry Lee, Du-Hsung Tsai
- ☐ National Chiao Tung University

Evaluation Tool

☐ Use an actual global routing tool for congestion analysis

☐ Solicit global routing tools from academia

☐ Requirements
- Handle the new benchmark format
- Varying metal width and spacing across layers
- Reasonable runtime
- Moderate overflow reduction
- Stable

A Contest within the Contest…

- Five academic global routing teams
  - coalesCgrip
    - Hamid Shojaei and Azadeh Davoodi, University of Wisconsin
  - NTHU-Route
    - Hsueh-Ju Chou, Hsiu-Yu Lai, Yuan-Kang Chuang and Ting-Chi Wang, National Tsing Hua University
  - FGR
    - Jin Hu and Igor Markov, University of Michigan
  - FastRoute
    - Yanheng Zhang and Chris Chu, Iowa State University
  - BoxRoute
    - Jhih-Rong Gao and David Pan, University of Texas

Qualifying the Routers

- ☐ Release two designs in the new benchmark format

- ☐ Iterative testing on multiple placement instances

- ☐ Comparison with our internal congestion analyzer

- ☐ Mini-placement contest
  - ■ 5 placements with varying congestion
    (as evaluated by our internal tool)
  - ■ Test the stability of the routers
  - ■ Do all routers rank them identically?

- ☐ After two months, 3 teams remained
  - ■ coalesCgrip, NTHU-Route, FGR

ISPD-2011: Golden Router

- **coalesCgrip**
  - Hamid Shojaei and Azadeh Davoodi
  - University of Wisconsin, Madison

- Satisfied all requirements:
  - New benchmark format
  - Varying metal width/spacing across layers
  - Very stable
  - Reasonable runtime

Evaluation Metric

☐ Total Overflow (TOF) of the routing solution
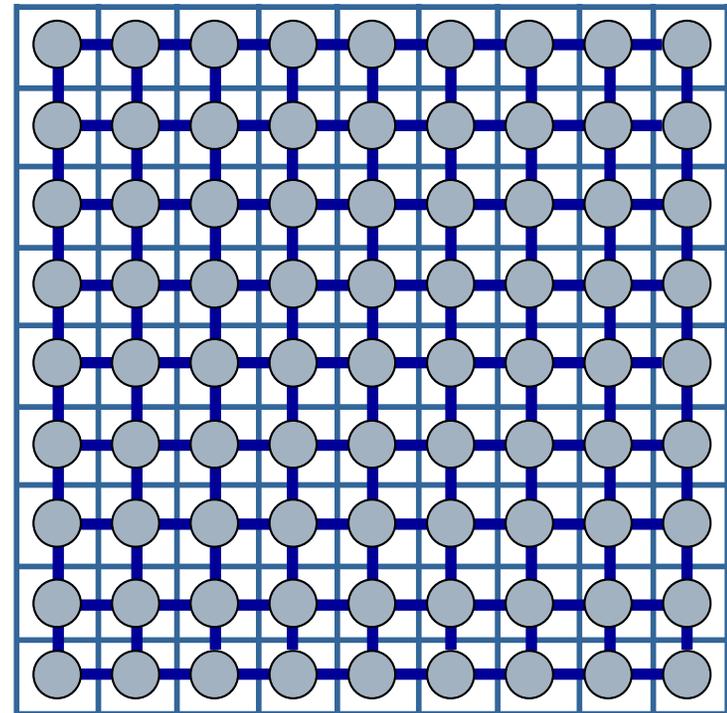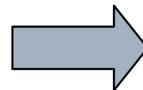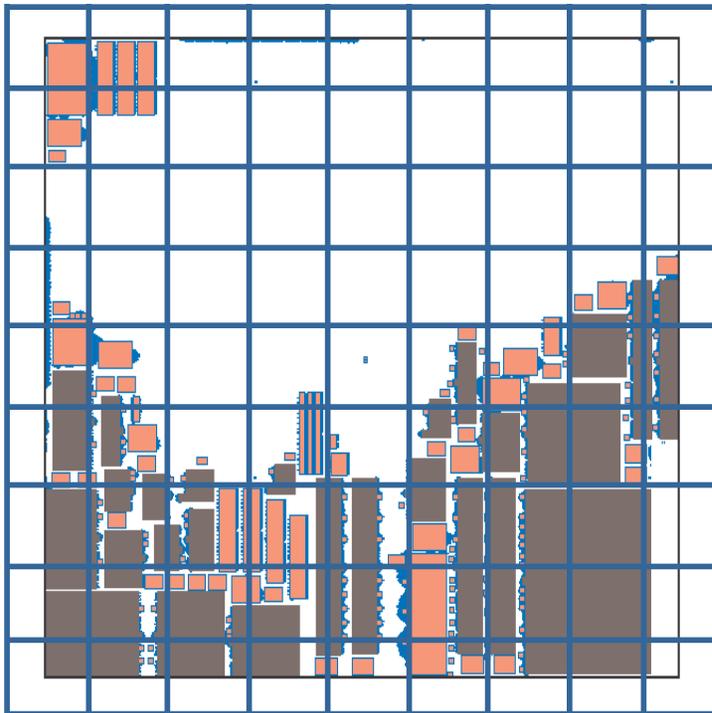
Total Overflow

☐ For a tile edge on a particular layer

- Capacity: Max allowed number of tracks
- Demand: Actual routing demand in tracks
- Edge_Overflow:

MAX(0, (Demand-Capacity)) × (Wire_Width+Wire_Spacing)

☐ Total_Overflow = $\sum$ Edge_Overflow

Runtime Factor

- Encourage placer efficiency
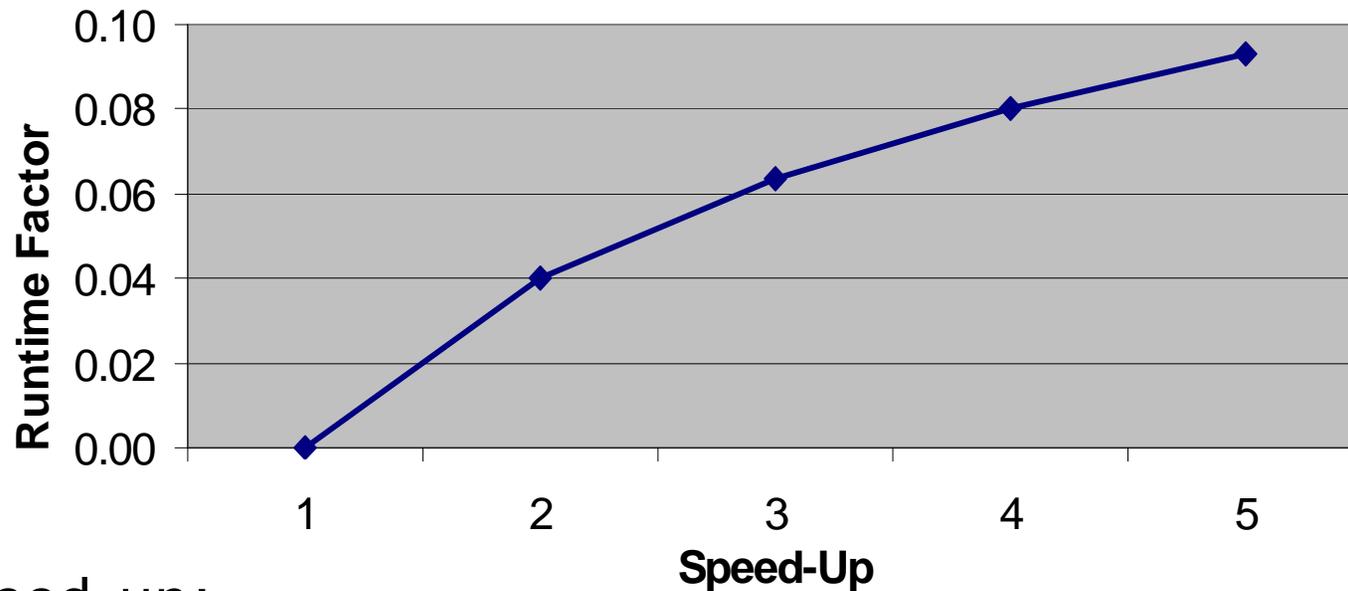
- Speed-up:
Placer_Wall_TIME / Median_Wall_Time

- ±4% overflow advantage for a 2X speed-up/slow-down

- Maximum factor is set to 10%

Final Quality Metrics

□ Primary Metric
- Scaled Total Overflow
  = TOF × (1 + Runtime_Factor)

□ Secondary Metric (tie breaker)
- Scaled Tile-to-tile Routed Wire Length
  = R_WL × (1 + Runtime_Factor)

Scoring Metric

- ☐ Rank the teams for each design
- ☐ Assign a score for each rank

Rank	Score
1	100
2	80
3	60
4	45
5	35
6	25
7	20
8	15
9	10
NS	-50
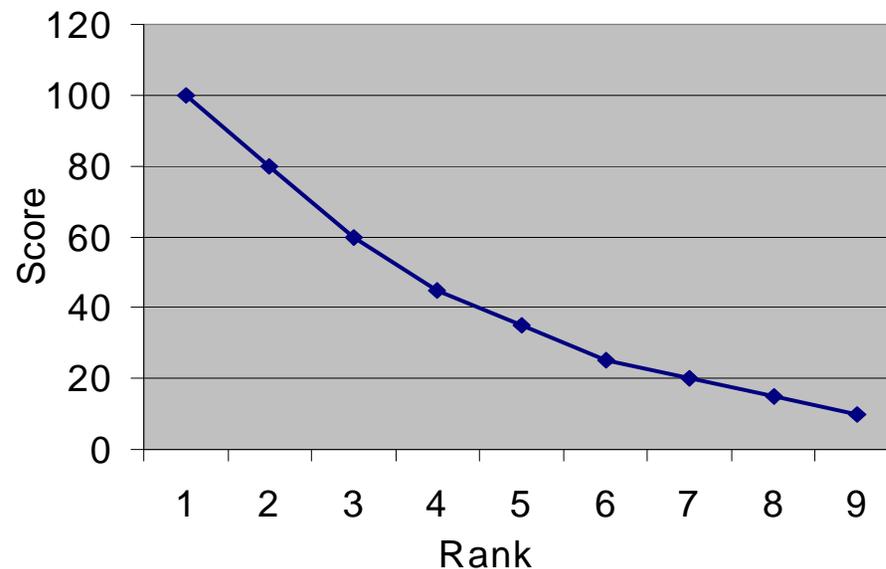
- ☐ Sum up the scores across all designs

Highest Total Score Wins the Contest

Contest Flow

```
┌─────────────────────┐
│   Contest Placer    │
└─────────────────────┘
          │
          ▼
┌─────────────────────┐
│   Golden Router     │
└─────────────────────┘
          │
          ▼
┌─────────────────────┐
│      Measure        │
│   Total Overflow    │
└─────────────────────┘
```
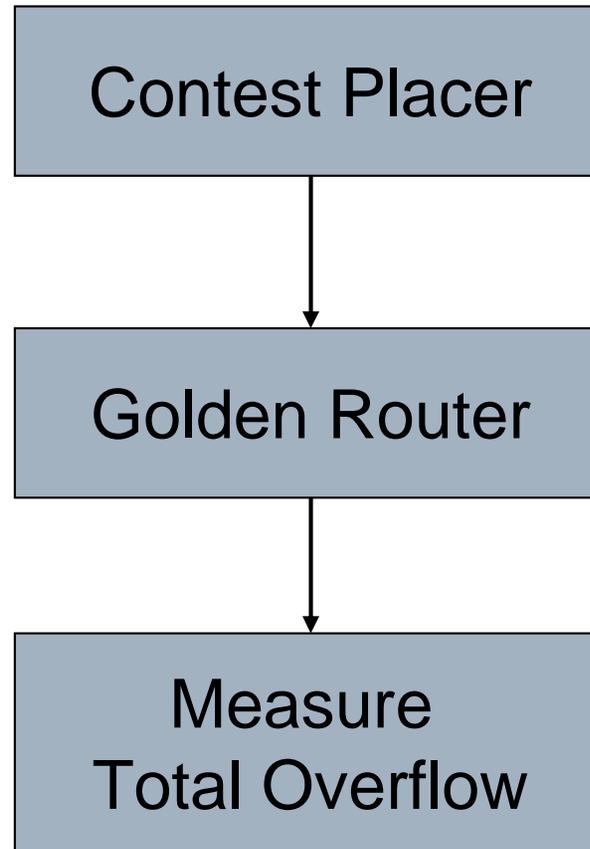
ISPD-2011 Contest Results

Phase 1: Released Designs

☐ Reduce maximum H(V) capacity values

☐ Run all placers on 4 released designs

☐ Run the golden router on the placement solutions

☐ Get Total Overflow of the routing solution

Total Overflow on Public Designs

	superblue18	superblue4	superblue15	superblue12	Score
	52498	159584	171184	2272764	320
	72426	443324	345284	514614	285
	514886	118850	143580	542786	325
	470266	256632	767310	3147446	210
SC	22293862	18791758	24048238	26966722	
VDAPlace	115403542	14864648	29909636	44023638	
NTHUplacer	163461970	262357510	NS	487025748	
NCKUplacer	131891096	68856096	179519490	737031204	
CPP	NS	NS	NS	NS	

Top Four Teams (Alphabetic Order)

- ☐ **mPL11**
  - ◼ Jason Cong, Guojie Luo, Kalliopi Tsota, Bingjun Xiao
  - ◼ University of California, Los Angeles
- ☐ **RADIANT**
  - ◼ Meng-Kai Hsu, Sheng Chou, Tzu-Hen Lin, Yao-Wen Chang
  - ◼ National Taiwan University
- ☐ **Ripple**
  - ◼ Xu He, Tao Huang, Linfu Xiao, Haitong Tian, Guxin Cui, Evangeline F.Y. Young
  - ◼ Chinese University of Hong Kong
- ☐ **SimPLR**
  - ◼ Myung-Chul Kim, Dong-Jin Lee, Jin Hu, Igor Markov
  - ◼ University of Michigan

Phase 2: All Designs

- ☐ Run top 4 placers on all designs
  - ■ 4 released
  - ■ 4 "hidden"

- ☐ Run the golden router on the placement solutions

- ☐ Rank the placers for each design

- ☐ Assign a score for each rank

- ☐ Sum up the scores across all designs

Consider Only Total Overflow

	super blue 18	super blue 4	super blue 15	super blue 12	super blue 5	super blue 10	super blue 1	super blue 2
mPL11	**52498**	159584	171184	2272764	499582	1159416	89176	1849664
SimPLR	72426	443324	345284	**514614**	223944	1311688	**78**	2138796
Ripple	514886	**118850**	**143580**	542786	**176902**	1010058	816	**1128906**
RADIANT	470266	256632	767310	3147446	765852	**616424**	170314	1453774

Runtime (sec)

	super blue 18	super blue 4	super blue 15	super blue 12	super blue 5	super blue 10	super blue 1	super blue 2
mPL11	**2413**	**2560**	**5138**	**6971**	**3818**	**5046**	**3573**	**4318**
SimPLR	2791	3083	7697	10046	5649	12989	5686	7913
Ripple	11226	7631	17831	21390	10885	22319	9915	16887
RADIANT	3718	3019	12580	19089	6170	12873	6895	8611

Scaled_Overflow

	super blue 18	super blue 4	super blue 15	super blue 12	super blue 5	super blue 10	super blue 1	super blue 2
mPL11	**51591**	157968	164469	2176093	486986	1096454	86265	1780403
SimPLR	71783	443591	339793	**503577**	223360	1312027	**78**	2133469
Ripple	551672	**125138**	**148258**	554817	**183137**	1041872	837	**1175478**
RADIANT	473875	256476	776862	3196538	767755	**616264**	171215	1457245

Scaled_Overflow = TOF × (1+Runtime_Factor)

Final Score

	super blue 18	super blue 4	super blue 15	super blue 12	super blue 5	super blue 10	super blue 1	super blue 2	Total Score
mPL11	100	80	80	60	60	60	60	60	**560**
SimPLR	80	45	60	100	80	45	100	45	**555**
Ripple	45	100	100	80	100	80	80	100	**685**
RADIANT	60	60	45	45	45	100	45	80	**480**

Conclusions

☐ New benchmarks to enable placement and routing

☐ Reflect complexities of modern ASIC designs
   - Placement blockages
   - Routing blockages
   - More metal layers
   - Varying metal width and spacing across layers

☐ Standardized framework to evaluate placement algorithms
   - Metrics
   - Congestion Analysis Tool

**Hope this effort will lead to interesting developments
in the area of routability-driven placement**

Final Results

- ☐ **3rd Place**
  - ■ **SimPLR**
    - ☐ Myung-Chul Kim, Dong-Jin Lee, Jin Hu, Igor Markov
    - ☐ University of Michigan

- ☐ **2nd Place**
  - ■ **mPL11**
    - ☐ Jason Cong, Guojie Luo, Kalliopi Tsota, Bingjun Xiao
    - ☐ University of California, Los Angeles

- ☐ **1st Place**
  - ■ **Ripple**
    - ☐ Xu He, Tao Huang, Linfu Xiao, Haitong Tian, Guxin Cui, Evangeline F.Y. Young
    - ☐ Chinese University of Hong Kong