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
  - circuit.shapes
  - circuit.route

Original Files in Bookshelf format with some extensions

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 “Not in Image” 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

03/29/2011
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

<table>
<thead>
<tr>
<th></th>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grid</td>
<td>304 403 9</td>
<td>Grid size, can be modified to change the routing instance</td>
</tr>
<tr>
<td>VerticalCapacity</td>
<td>0 80 0 80 0 80 0 80 0 80</td>
<td>Can be modified to change the routing instance</td>
</tr>
<tr>
<td>HorizontalCapacity</td>
<td>0 0 80 0 80 0 80 0 80 0 80</td>
<td>Can be modified to change the routing instance</td>
</tr>
<tr>
<td>MinWireWidth</td>
<td>1 1 1 1 2 2 2 2 4 4</td>
<td>Routing instance (grid size, wire/via costs, etc.)</td>
</tr>
<tr>
<td>MinWireSpacing</td>
<td>1 1 1 1 2 2 2 2 4 4</td>
<td>Routing instance (grid size, wire/via costs, etc.)</td>
</tr>
<tr>
<td>ViaSpacing</td>
<td>0 0 0 0 0 0 0 0 0 0 0 0 0</td>
<td>Routing instance (grid size, wire/via costs, etc.)</td>
</tr>
<tr>
<td>GridOrigin</td>
<td>18 18</td>
<td>Routing instance (grid size, wire/via costs, etc.)</td>
</tr>
<tr>
<td>TileSize</td>
<td>40 40</td>
<td>Routing instance (grid size, wire/via costs, etc.)</td>
</tr>
<tr>
<td>BlockagePorosity</td>
<td>0</td>
<td>Routing instance (grid size, wire/via costs, etc.)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>NumNiTerminals</td>
<td>2</td>
<td>Number of terminals</td>
</tr>
<tr>
<td>p0</td>
<td>4</td>
<td>All pins belonging to p0/p1 are on layer 4 for routing</td>
</tr>
<tr>
<td>p1</td>
<td>4</td>
<td>All pins belonging to p0/p1 are on layer 4 for routing</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>NumBlockageNodes</td>
<td>2</td>
<td>Number of blockage nodes</td>
</tr>
<tr>
<td>o44</td>
<td>4 1 2 3 4</td>
<td>Block 4 metal layers within all the routing</td>
</tr>
<tr>
<td>o2407</td>
<td>4 1 2 3 4</td>
<td>Blocks that they overlap. These are layers 1 to 4.</td>
</tr>
<tr>
<td>Design</td>
<td>Total Nodes</td>
<td>Movable Nodes</td>
</tr>
<tr>
<td>-----------</td>
<td>-------------</td>
<td>---------------</td>
</tr>
<tr>
<td>superblue18</td>
<td>483452</td>
<td>442405</td>
</tr>
<tr>
<td>superblue4</td>
<td>600220</td>
<td>521466</td>
</tr>
<tr>
<td>superblue5</td>
<td>772457</td>
<td>677416</td>
</tr>
<tr>
<td>superblue1</td>
<td>847441</td>
<td>765102</td>
</tr>
<tr>
<td>superblue2</td>
<td>1014029</td>
<td>921273</td>
</tr>
<tr>
<td>superblue15</td>
<td>1123963</td>
<td>829614</td>
</tr>
<tr>
<td>superblue10</td>
<td>1129144</td>
<td>914921</td>
</tr>
<tr>
<td>superblue12</td>
<td>1293433</td>
<td>1278084</td>
</tr>
</tbody>
</table>
Floorplan Layouts

superblue18

superblue4

superblue5

superblue1
Floorplan Layouts

- superblue2
- superblue15
- superblue10
- superblue12
Contest Logistics
Timeline

- Nov 25, 2010: Release 1\textsuperscript{st} sample benchmark
- Dec 09, 2010: Release 2\textsuperscript{nd} sample benchmark
- Feb 07, 2011: Receive preliminary binaries from all teams
- Feb 11, 2011: Released “golden” router and evaluation script
- Feb 22, 2011: Released 3\textsuperscript{rd} and 4\textsuperscript{th} 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. **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**
   - National Tsing Hua University
Placement Teams

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
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:
    \[ \text{MAX}(0, (\text{Demand} - \text{Capacity})) \times (\text{Wire Width} + \text{Wire Spacing}) \]

- Total_Overflow = \( \sum \text{Edge_Overflow} \)
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
    - \(\text{TOF} \times (1 + \text{Runtime\_Factor})\)

- **Secondary Metric (tie breaker)**
  - Scaled Tile-to-tile Routed Wire Length
    - \(\text{R\_WL} \times (1 + \text{Runtime\_Factor})\)
Scoring Metric

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

<table>
<thead>
<tr>
<th>Rank</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>100</td>
</tr>
<tr>
<td>2</td>
<td>80</td>
</tr>
<tr>
<td>3</td>
<td>60</td>
</tr>
<tr>
<td>4</td>
<td>45</td>
</tr>
<tr>
<td>5</td>
<td>35</td>
</tr>
<tr>
<td>6</td>
<td>25</td>
</tr>
<tr>
<td>7</td>
<td>20</td>
</tr>
<tr>
<td>8</td>
<td>15</td>
</tr>
<tr>
<td>9</td>
<td>10</td>
</tr>
<tr>
<td>NS</td>
<td>-50</td>
</tr>
</tbody>
</table>

- Sum up the scores across all designs

Highest Total Score Wins the Contest

03/29/2011
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

<table>
<thead>
<tr>
<th></th>
<th>superblue18</th>
<th>superblue4</th>
<th>superblue15</th>
<th>superblue12</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>superblue18</td>
<td>52498</td>
<td>159584</td>
<td>171184</td>
<td>2272764</td>
<td>320</td>
</tr>
<tr>
<td>superblue4</td>
<td>72426</td>
<td>443324</td>
<td>345284</td>
<td>514614</td>
<td>285</td>
</tr>
<tr>
<td>superblue15</td>
<td>514886</td>
<td>118850</td>
<td>143350</td>
<td>542786</td>
<td>325</td>
</tr>
<tr>
<td>superblue12</td>
<td>470266</td>
<td>256632</td>
<td>767310</td>
<td>3147446</td>
<td>210</td>
</tr>
<tr>
<td>SC</td>
<td>22293862</td>
<td>18791758</td>
<td>24048238</td>
<td>26966722</td>
<td></td>
</tr>
<tr>
<td>VDAPlace</td>
<td>115403542</td>
<td>14864648</td>
<td>29909636</td>
<td>44023638</td>
<td></td>
</tr>
<tr>
<td>NTHUplacer</td>
<td>163461970</td>
<td>262357510</td>
<td>NS</td>
<td>487025748</td>
<td></td>
</tr>
<tr>
<td>NCKUplacer</td>
<td>131891096</td>
<td>68856096</td>
<td>179519490</td>
<td>737031204</td>
<td></td>
</tr>
<tr>
<td>CPP</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td></td>
</tr>
</tbody>
</table>

03/29/2011
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

<table>
<thead>
<tr>
<th></th>
<th>mPL11</th>
<th>SimPLR</th>
<th>Ripple</th>
<th>RADIANT</th>
</tr>
</thead>
<tbody>
<tr>
<td>super blue 18</td>
<td>52498</td>
<td>72426</td>
<td>514886</td>
<td>470266</td>
</tr>
<tr>
<td>super blue 4</td>
<td>159584</td>
<td>443324</td>
<td>118850</td>
<td>256632</td>
</tr>
<tr>
<td>super blue 15</td>
<td>171184</td>
<td>345284</td>
<td>143580</td>
<td>767310</td>
</tr>
<tr>
<td>super blue 12</td>
<td>2272764</td>
<td>514614</td>
<td>542786</td>
<td>3147446</td>
</tr>
<tr>
<td>super blue 5</td>
<td>499582</td>
<td>223944</td>
<td>176902</td>
<td>765852</td>
</tr>
<tr>
<td>super blue 10</td>
<td>1159416</td>
<td>1311688</td>
<td>1010058</td>
<td>616424</td>
</tr>
<tr>
<td>super blue 1</td>
<td>89176</td>
<td>78</td>
<td>816</td>
<td>170314</td>
</tr>
<tr>
<td>super blue 2</td>
<td>1849664</td>
<td>2138796</td>
<td>1128906</td>
<td>1453774</td>
</tr>
</tbody>
</table>
# Runtime (sec)

<table>
<thead>
<tr>
<th></th>
<th>super blue 18</th>
<th>super blue 4</th>
<th>super blue 15</th>
<th>super blue 12</th>
<th>super blue 5</th>
<th>super blue 10</th>
<th>super blue 1</th>
<th>super blue 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>mPL11</td>
<td>2413</td>
<td>2560</td>
<td>5138</td>
<td>6971</td>
<td>3818</td>
<td>5046</td>
<td>3573</td>
<td>4318</td>
</tr>
<tr>
<td>SimPLR</td>
<td>2791</td>
<td>3083</td>
<td>7697</td>
<td>10046</td>
<td>5649</td>
<td>12989</td>
<td>5686</td>
<td>7913</td>
</tr>
<tr>
<td>Ripple</td>
<td>11226</td>
<td>7631</td>
<td>17831</td>
<td>21390</td>
<td>10885</td>
<td>22319</td>
<td>9915</td>
<td>16887</td>
</tr>
<tr>
<td>RADIANT</td>
<td>3718</td>
<td>3019</td>
<td>12580</td>
<td>19089</td>
<td>6170</td>
<td>12873</td>
<td>6895</td>
<td>8611</td>
</tr>
</tbody>
</table>
# Scaled_Overflow

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

\[ \text{Scaled\_Overflow} = \text{TOF} \times (1 + \text{Runtime\_Factor}) \]

03/29/2011
## Final Score

<table>
<thead>
<tr>
<th></th>
<th>super blue 18</th>
<th>super blue 4</th>
<th>super blue 15</th>
<th>super blue 12</th>
<th>super blue 5</th>
<th>super blue 10</th>
<th>super blue 1</th>
<th>super blue 2</th>
<th>Total Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>mPL11</td>
<td>100</td>
<td>80</td>
<td>80</td>
<td>60</td>
<td>60</td>
<td>60</td>
<td>60</td>
<td>60</td>
<td>560</td>
</tr>
<tr>
<td>SimPLR</td>
<td>80</td>
<td>45</td>
<td>60</td>
<td>100</td>
<td>80</td>
<td>45</td>
<td>100</td>
<td>45</td>
<td>555</td>
</tr>
<tr>
<td>Ripple</td>
<td>45</td>
<td>100</td>
<td>100</td>
<td>80</td>
<td>100</td>
<td>80</td>
<td>80</td>
<td>100</td>
<td>685</td>
</tr>
<tr>
<td>RADIANT</td>
<td>60</td>
<td>60</td>
<td>45</td>
<td>45</td>
<td>45</td>
<td>100</td>
<td>45</td>
<td>80</td>
<td>480</td>
</tr>
</tbody>
</table>
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