Stability and Scalability in Global Routing

S. K. Han¹, K. Jeong¹, A. B. Kahng¹,² and J. Lu²

¹ECE Department, UC San Diego
²CSE Department, UC San Diego

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Outline

- Motivation
- Routing Estimation
- Experiments
- Conclusions
Motivation: Evaluation of Routability

- **Must avoid unroutable placement results**
  - Loop back to placement after routing fails == too expensive!

- **Routability determination during placement is critical but difficult**
  - Built-in congestion estimators in modern placers
Congestion Estimation During Placement

- Static, non-constructive
  - Fixed L-Z shape models
  - Equal-probability models
  - #bends-based probabilistic models
  - Testcase-independent models
    → too wide a gap between estimates and actual routing outcomes

- Constructive
  - Integrated global router (under the hood of placement tool)
  - Helps P&R convergence
    → global router must be high-quality and fast to serve in this role
This Work

- How good can a routing estimator be?

- One way to answer this question: How noisy or inherently unpredictable is the routing (or, router) that we’re trying to estimate?

- We experimentally assess “inherent unpredictability”:
  - Routing grid offset noise
  - Routing resource noise
  - Routing instance scaling

- We discover stability, scalability limits of global routers
Testbed (based on ISPD Global Routing Contest)

- Routing quality metrics
  - $TOF$ (total overflow)
  - $MOF$ (maximum $gedge$-overflow)
  - $WCI(A)$ (Worst congestion index)
  - $U(A)$ (Average net-score)

- ISPD-2008 Global Routing Benchmark Suite

- Four academic global routers
  - FastRoute-4.1
  - NTHU-2.0
  - FGR-1.2
  - NTUgr-1.1
Experiment 1: Offset Noise

- Estimation on stability to *grid-offset* noise
- Shift the origin of the gcell array horizontally and vertically
- Constraint on offset: all pins should be covered
Offset Noise Experimental Results

- **Total overflow (TOF)**
  - **FastRoute** vs. **NTHU**
  - Graph shows variations with offset, indicating performance differences.

- **Max overflow (MOF)**
  - **FastRoute** vs. **NTHU**
  - Graph shows peaks and troughs with offset, highlighting overflow behavior.

- **WCI(100)**
  - **FastRoute** vs. **NTHU**
  - Graph displays WCI values across different offsets, showing fluctuations.

- **U(20)**
  - **FastRoute** vs. **NTHU**
  - Graph illustrates U values with offset, emphasizing stability or variability.

These graphs provide a comprehensive view of the experimental results under varying offset conditions.
Experiment 2: Resource Noise

- Add $d$ units to both blockage and capacity to all the edges.
- Effective capacity of every edge is unchanged.
- Global routing problem should not be different, from router viewpoint.
Resource Noise Experimental Results

- **Total overflow (TOF)**
  - **FastRoute**, **NTHU**, **NTUgr**, **FGR**

- **Resource noise ( = d)**

- **Maximum overflow (MOF)**
  - **FastRoute**, **NTHU**, **NTUgr**, **FGR**

- **WC(100)**
  - **FastRoute**, **NTHU**

- **U(20)**
  - **FastRoute**, **NTHU**
Experiment 3: Instance Scaling

- Simple scaling of X1 benchmark $\rightarrow$ X2 benchmark
  - Duplicate all pins and nets of the original benchmark
  - Double the capacity and blockages of gedges

- Twice the X1 solution cost is an upper bound on the optimum X2 solution cost
Instance Scaling Experimental Results

- Total overflow (TOF)
- Max overflow (MOF)
- WCI (100)
- U (20)

Graphs showing scaling factors for different tools and methods.
Conclusions

- Study stability and scalability of four global routers

- All four routers show room for improvement

- Possible reasons leading to instability
  - Testcase-specific parameter tuning
    - Knobs tuning on one benchmark may lose its advantage on others
  - Over-reduction of congestion (reflects ISPD contest metric)
    - Unnecessary detours and over-sensitivity
    - Routability estimation allows moderate congestion (WL within 10% extension)
  - Unstable metrics
    - \( TOF, MOF, WCI(100), U(20) \) all vary significantly over different gcell definitions
    - New metrics with better stability are needed to facilitate future work
THANK YOU
References


References

Problem Formulation

- Routing grid modeling
- Decomposition of design area
- Mapping of rectangles into $g$cells (global cells)
- Other parameters
  - $g$edges (global edges), $g$edge capacity, $g$edge overflow