# HubRouter: Learning Global Routing via Hub Generation and Pin-hub Connection

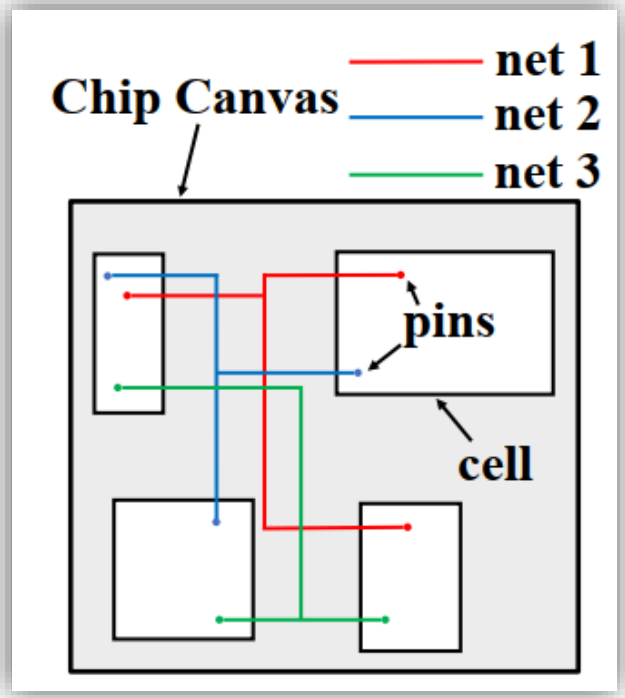
**Xingbo Du · Chonghua Wang · Ruizhe Zhong · Junchi Yan**

*Dept. of Computer Science and Engineering & MoE Key Lab of AI, Shanghai Jiao Tong University*

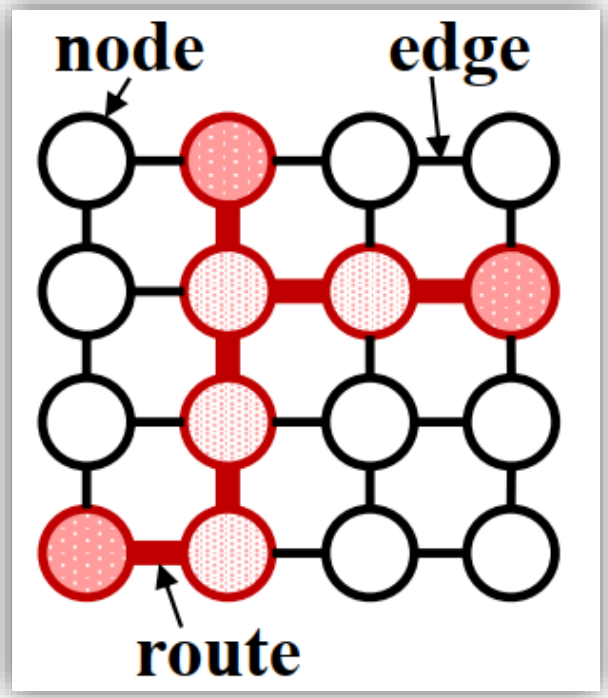
11/12/2023

# Introduction

## Global Routing



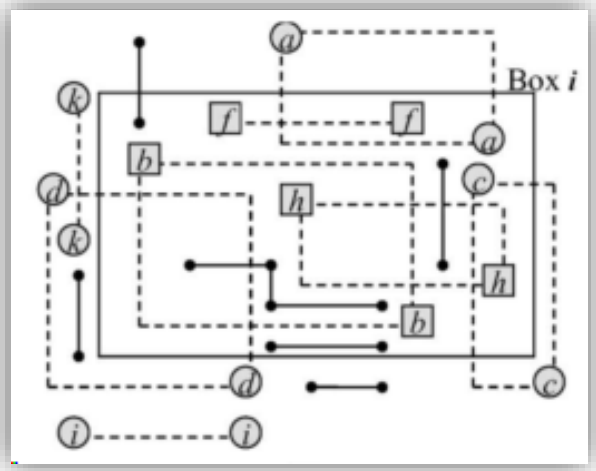

Chip Canvas and Netlist



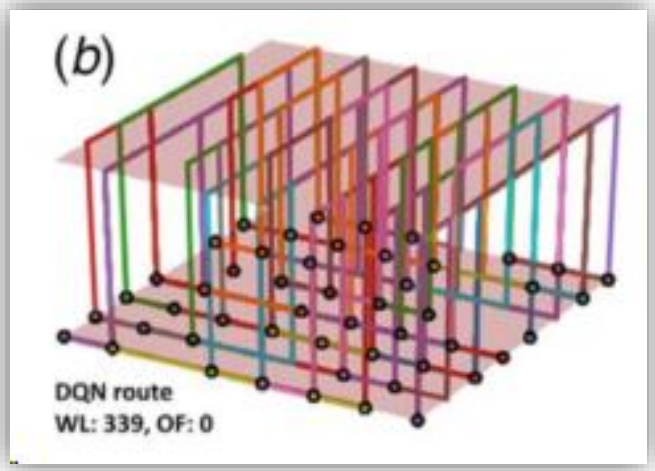

Grid Graph

# Introduction

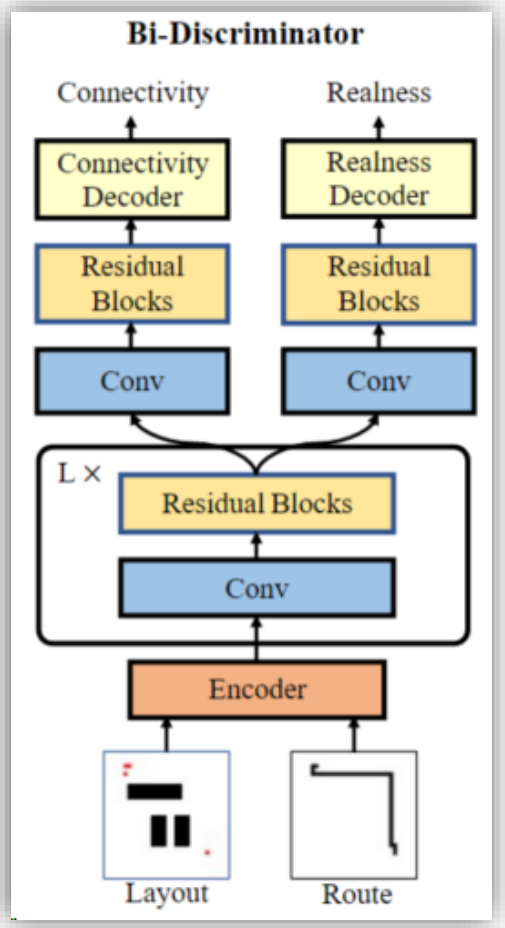
## Existing works




BoxRouter




DRL

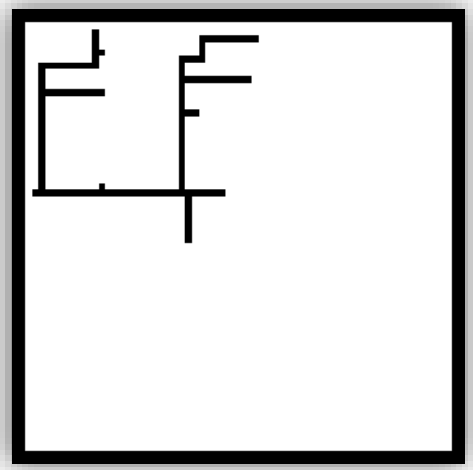



PRNet

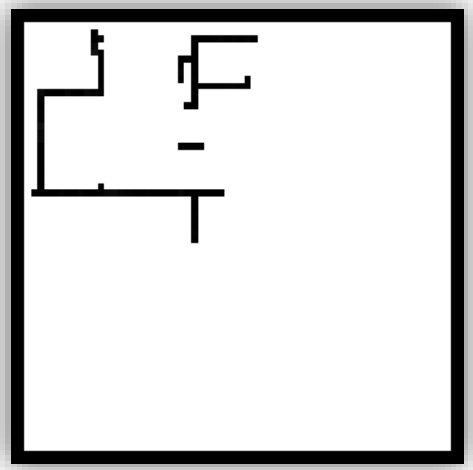
# Motivation

上海交通大學 SHANGHAI JIAO TONG UNIVERSITY

## the disconnectivity of PRNet



Original route



Generated route

| Metric | Case | PRNet (GAN) |
|---|---|---|
| Correctness Rate (%) | Route-small-4 | 0.806 |
| | Route-small | 0.334 |
| | Route-large-4 | 0.196 |
| | Route-large | 0.040 |

the disconnectivity proportion

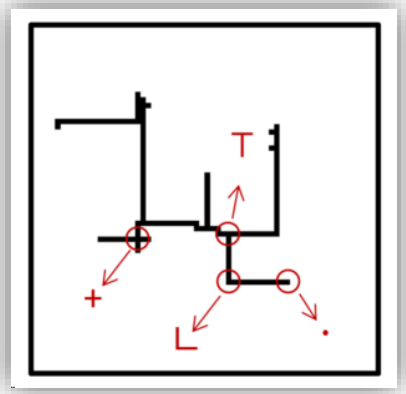
# Methodology

## Route and hubs

**Definition 1 (Hub).** *Given a one-channel image with $m \times n$ pixels, let $p_{ij}$ $(1 \le i \le m, 1 \le j \le n)$ denote the pixel in the $i$-th row and $j$-th column, whose value $r_{ij} = 1/0$ respectively represent routed/unrouted. Auxiliary denote $r_{0j} = r_{(m+1)j} = r_{i0} = r_{i(n+1)} = 0$, then the pixel $p_{ij}$ is a hub if and only if $r_{ij} = 1$ and it satisfies any of the following condition:*

(1) $+ : r_{(i-1)j} = r_{(i+1)j} = r_{i(j-1)} = r_{i(j+1)} = 1;$ (2) $\top : r_{(i-1)j} + r_{(i+1)j} + r_{i(j-1)} + r_{i(j+1)} = 3;$

(3) $\llcorner : r_{(i-1)j} + r_{(i+1)j} = 1$ and $r_{i(j-1)} + r_{i(j+1)} = 1;$ (4) $\cdot : r_{(i-1)j} + r_{(i+1)j} + r_{i(j-1)} + r_{i(j+1)} = 1.$

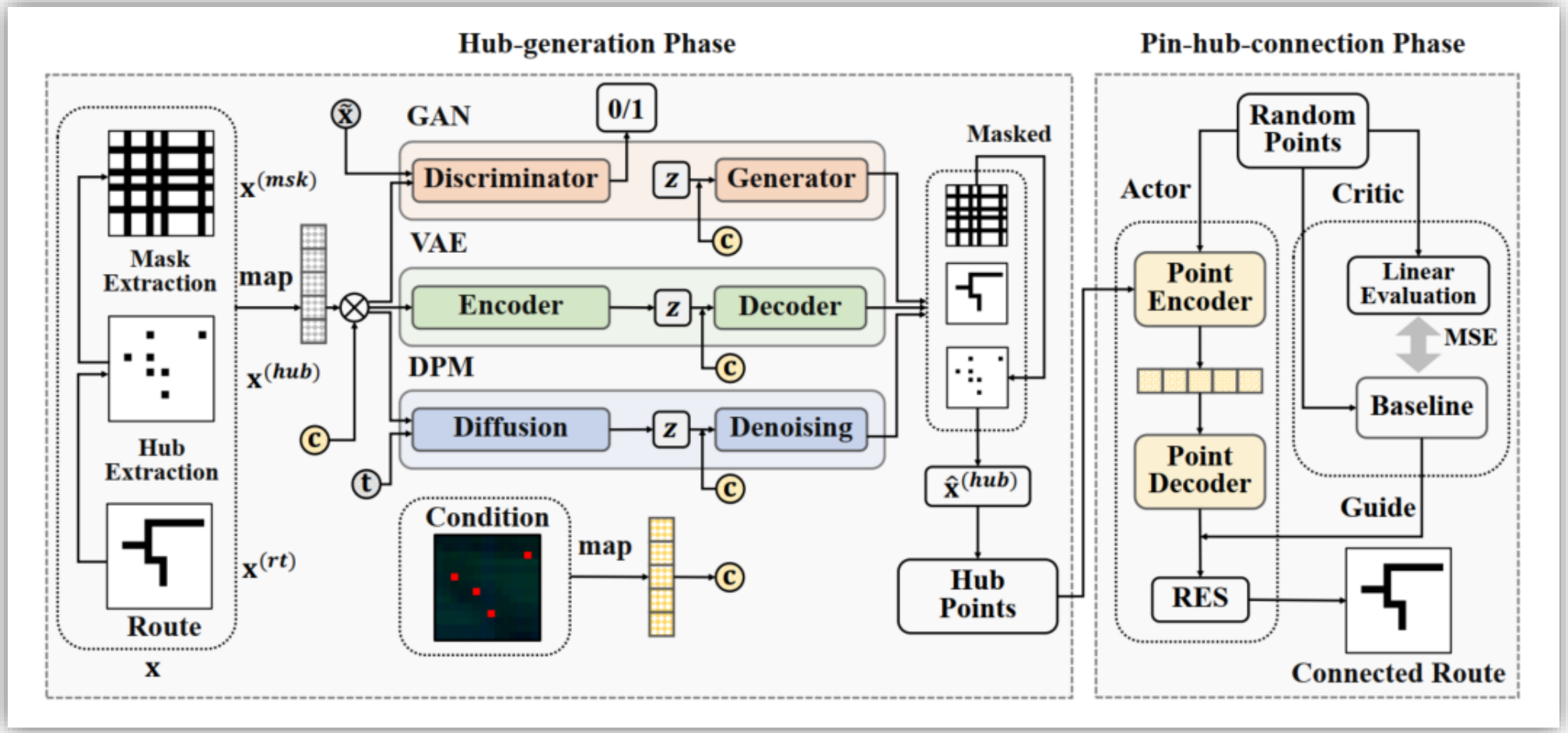



route

hubs

# Methodology

## Two-phase learning framework



# Experiments

上海交通大學 SHANGHAI JIAO TONG UNIVERSITY

## Correctness rate, wirelength rate, and generation time on ISPD-07

| Metric | Case | PRNet (GAN) | HubRouter (VAE) | HubRouter (DPM) | HubRouter (GAN) |
|---|---|---|---|---|---|
| **Correctness Rate (%)** | Route-small-4 | 0.806 | **1.000**$\pm$0.000 | **1.000**$\pm$0.000 | **1.000**$\pm$0.000 |
| | Route-small | 0.334 | **1.000**$\pm$0.000 | **1.000**$\pm$0.000 | **1.000**$\pm$0.000 |
| | Route-large-4 | 0.196 | **1.000**$\pm$0.000 | **1.000**$\pm$0.000 | **1.000**$\pm$0.000 |
| | Route-large | 0.040 | **1.000**$\pm$0.000 | **1.000**$\pm$0.000 | **1.000**$\pm$0.000 |
| **Wirelength Rate (%)** | Route-small-4 | **1.001** | 1.099$\pm$0.020 | 1.060$\pm$0.011 | 1.011$\pm$0.003 |
| | Route-small | 1.009 | 1.042$\pm$0.006 | 1.174$\pm$0.009 | **1.002**$\pm$0.001 |
| | Route-large-4 * | - | 1.122$\pm$0.039 | 1.100$\pm$0.021 | **1.005**$\pm$0.002 |
| | Route-large * | - | 1.041$\pm$0.014 | 1.242$\pm$0.021 | **1.001**$\pm$0.000 |
| **Generation Time (GPU Sec)** | Route-small-4 | 14.99 | **7.14**$\pm$0.19 | 673.21$\pm$5.08 | 7.16$\pm$0.05 |
| | Route-small | 18.51 | **7.70**$\pm$0.20 | 670.23$\pm$2.45 | 8.36$\pm$0.35 |
| | Route-large-4 | 19.47 | **7.24**$\pm$0.30 | 673.01$\pm$5.18 | 7.53$\pm$0.16 |
| | Route-large | 19.22 | 10.65$\pm$0.09 | 672.86$\pm$4.44 | **9.75**$\pm$0.35 |

SJTU

# Experiments

上海交通大學 SHANGHAI JIAO TONG UNIVERSITY

## Wirelength and inference time on ISPD-98

| Metric | Model | IBM01 | IBM02 | IBM03 | IBM04 | IBM05 | IBM06 | GRL-8 | GRL-16 |
|---|---|---|---|---|---|---|---|---|---|
| WL | Labyrinth [24] | 75909 | 201286 | 187345 | 195856 | 420581 | 341618 | 2376 | 8204 |
| | Boxrouter [8] | 63687 | 172304 | 147463 | 169033 | **410614** | 280477 | 2328 | 7991 |
| | DQN [30] | OOT | OOT | OOT | OOT | OOT | OOT | 2434 | 8356 |
| | PRNet [6] | 61950 | 172802 | 152037 | 170493 | 420274 | 287777 | 2497 | 8172 |
| | HR-VAE | 64703±1498 | 176492±6830 | 159968±3281 | 179895±5274 | 434942±2916 | 300448±5560 | 2415±33 | 8584±244 |
| | HR-DPM | 66446±1586 | 190588±2337 | 168454±2486 | 183696±1736 | 475820±5516 | 316700±2843 | **2285**±7 | **7746**±29 |
| | HR-GAN | **61056**±151 | **167545**±236 | **147050**±208 | **164298**±326 | 411857±472 | **278198**±423 | 2306±8 | 7768±30 |
| Time (Sec) | Labyrinth [24] | **6.47** | 10.14 | 12.07 | 36.81 | **7.54** | 18.43 | **< 1 second** | **< 1 second** |
| | Boxrouter [8] | 7.01 | 12.91 | 11.74 | 41.76 | 13.45 | 29.17 | **< 1 second** | **< 1 second** |
| | DQN [30] | OOT | OOT | OOT | OOT | OOT | OOT | > 1 day | > 1 day |
| | PRNet [6] | 254.31 | 585.23 | 523.34 | 573.19 | 1606.00 | 1227.31 | 11.54 | 28.25 |
| | HR-VAE | 9.66±0.08 | **9.69**±0.04 | **10.19**±0.06 | **12.93**±0.07 | 14.58±0.00 | **17.28**±0.16 | 5.83±0.01 | 5.88±0.02 |
| | HR-DPM | 1796.09±38.68 | 2772.29±16.83 | 2936.52±21.23 | 3865.21±25.07 | 4369.47±22.56 | 4965.08±121.46 | 37.00±2.58 | 53.90±2.85 |
| | HR-GAN | 41.02±0.51 | 46.58±0.56 | 52.04±2.35 | 67.31±3.51 | 72.28±3.72 | 88.02±4.45 | 6.31±0.20 | 6.38±0.04 |

SJTU

# Limitation



- The two-phase scheme is not end-to-end under a joint training scheme;
- The supervised module for hub generation depends on large amount of training data;
- The further decrease on overflow needs a reroute process;
- Finally, it would also be compelling to integrate the learning-based methods of logic synthesis, with routing methodologies, including those presented in this work. This would allow for a data-driven approach to the chip design pipeline.


上海交通大學

SHANGHAI JIAO TONG UNIVERSITY

# Thank you