RoutePlacer: An End-to-End Routability-Aware Placer with Graph Neural Network

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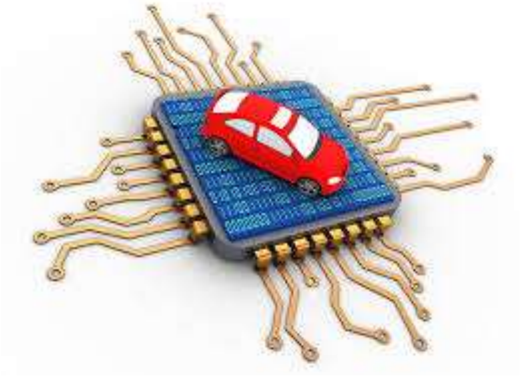
Deep Learning for EDA

Integrated circuits (ICs) are extensively used in modern electronic products like computers, smart-phones, and cars.





Due to the rapid growth in the scale of circuits, deep learning technologies have been widely exploited in Electronic Design Automation (EDA) to:

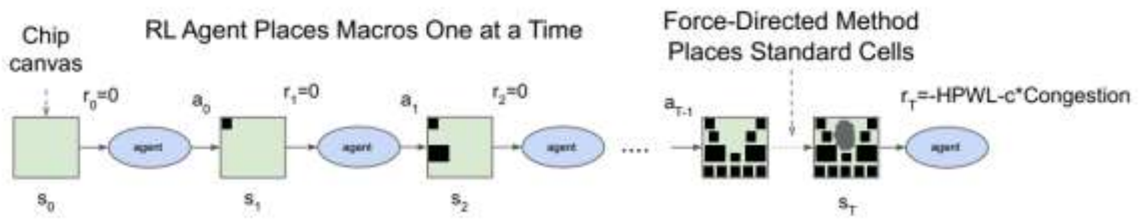
- speed up circuit design
- save labor costs

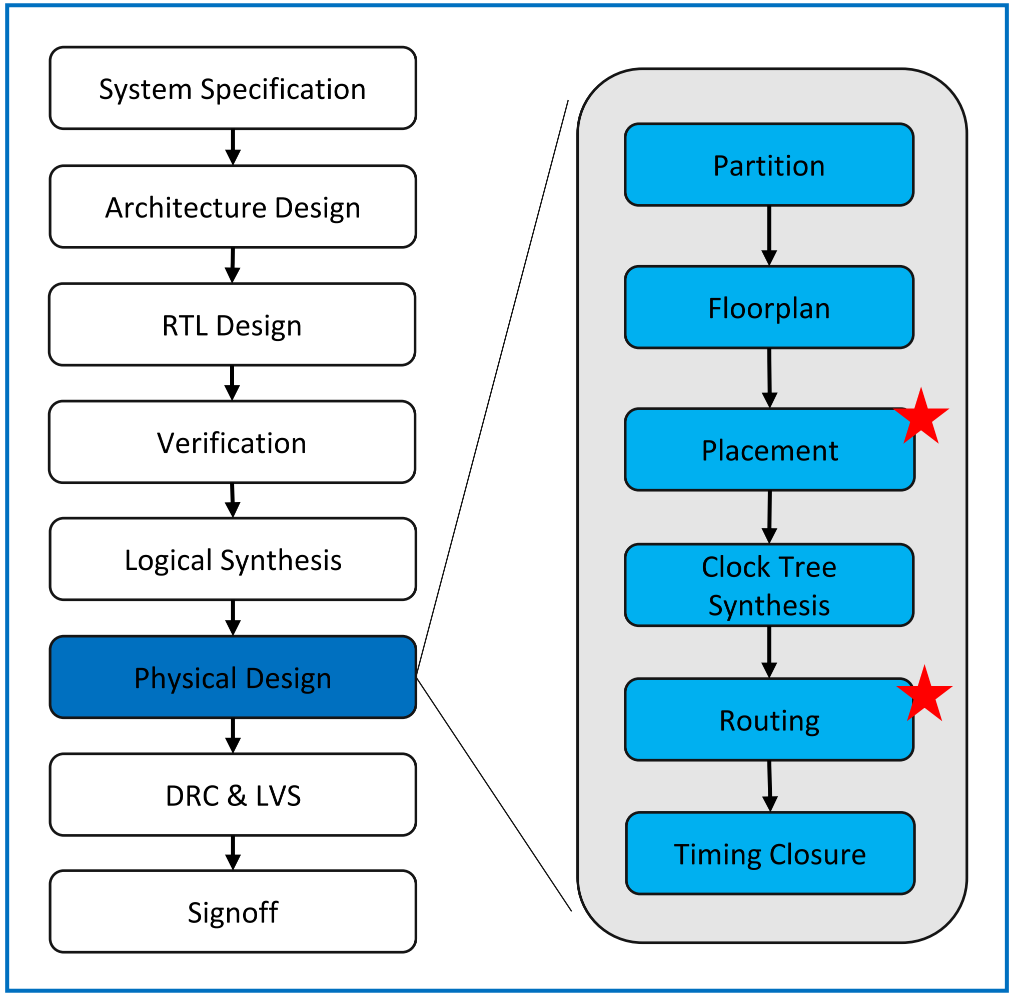
Routability-Aware Placement

Target of Placement

- Assign cell Position
- Optimizing Objective
  - Wirelength
- Satisfy Constraint
  - No Overlap

A graph placement methodology for fast chip design, A. Mirhoseini et.al, Nature, vol. 594, no. 7862, pp.207–212, 2021



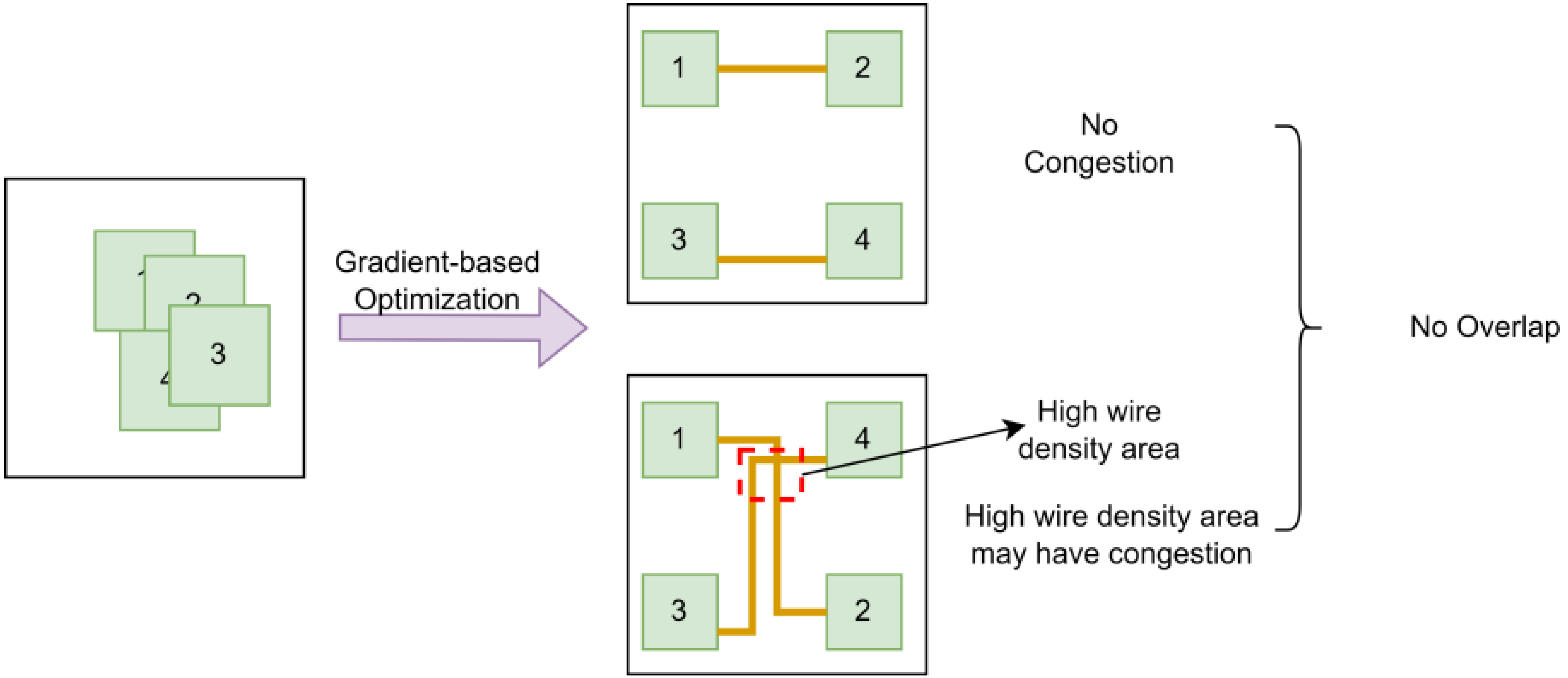


Chip Design Flow　　Auto Placement and Route (APR) Flow

Routability-Aware Placement

Challenges of Routability-Aware Placement

- <u>Optimize routability in placement</u>
- Model routability in objective function

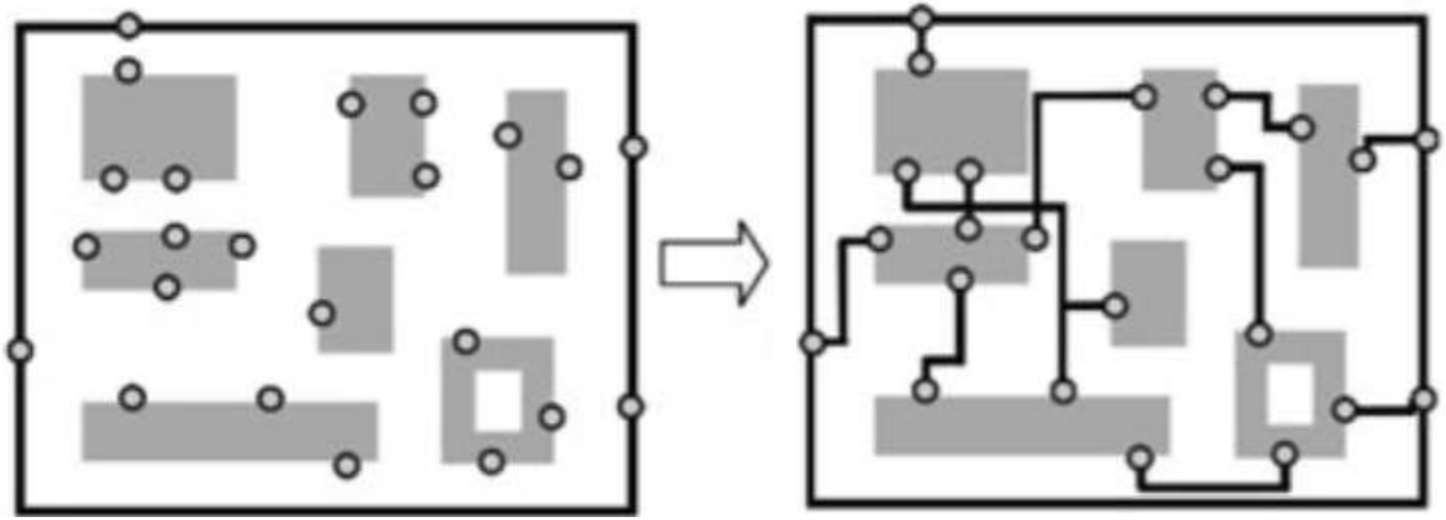


Routability-Aware Placement

Challenges of Routability-Aware Placement

- Optimize routability in placement
- Model routability in objective function

Routing is a **NP-hard problem**.



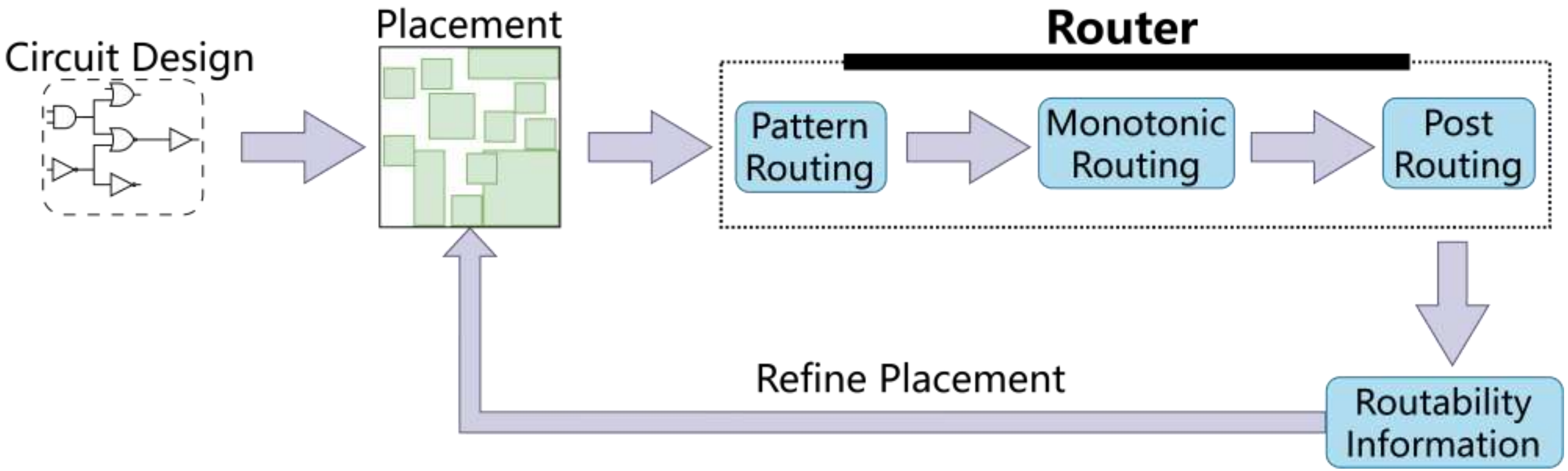
Routability-Aware Placement

Challenges of Routability-Aware Placement

- Optimize routability in placement
- Model routability in objective function

Existing methods are two-stages:

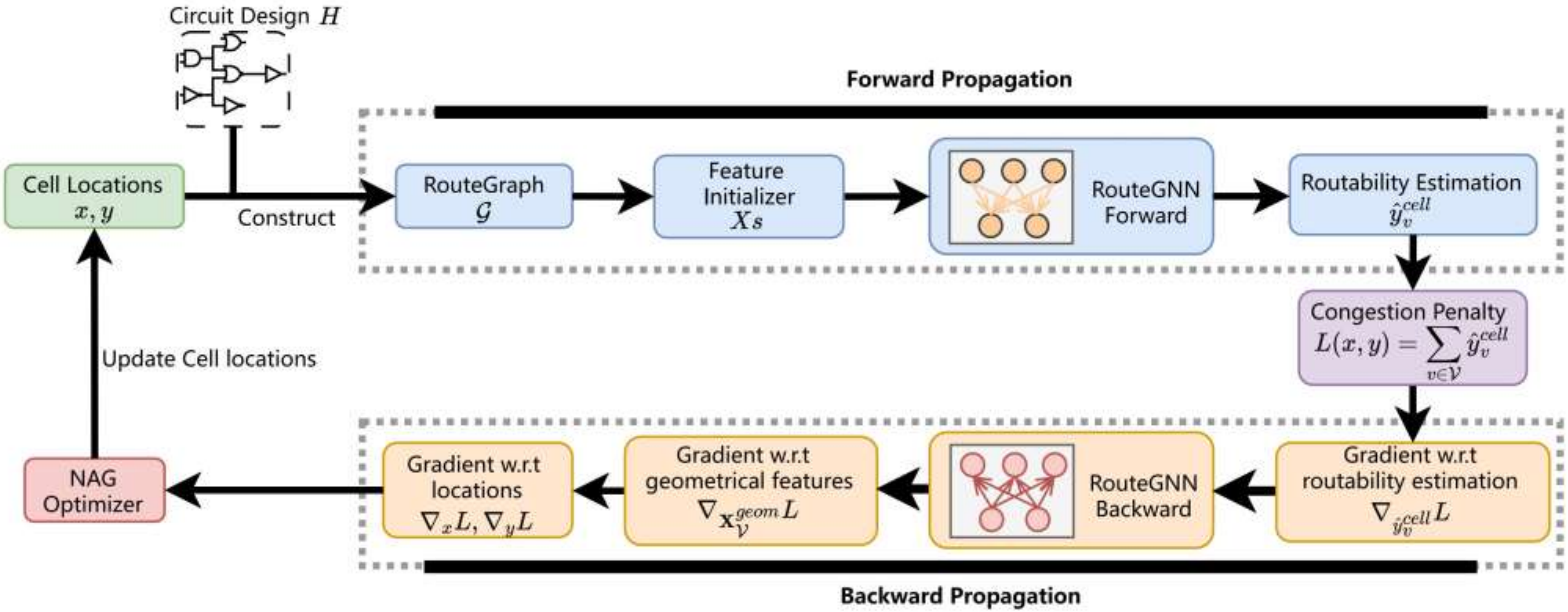
- Isolated stages
- Limited ability to jointly optimize routability metric



RoutePlacer

We propose an **end-to-end** routability-driven placement framework

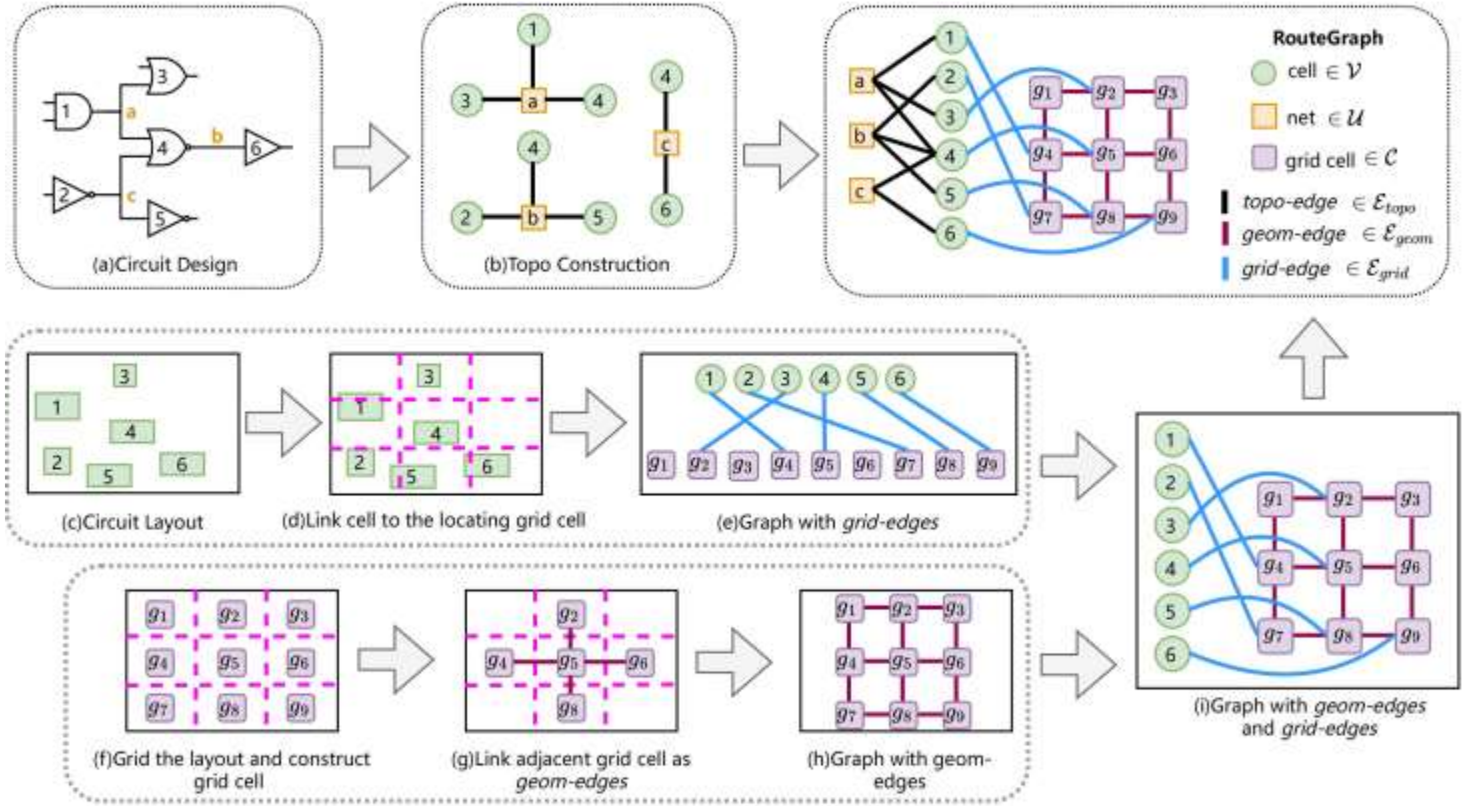
- Forward Propagation: RouteGNN to predict routability
- Backward Propagation: Integrate predicted routability into objective to enable end-to-end optimization



Forward Propagation

RouteGNN takes RouteGraph as input which contains three types of edges:

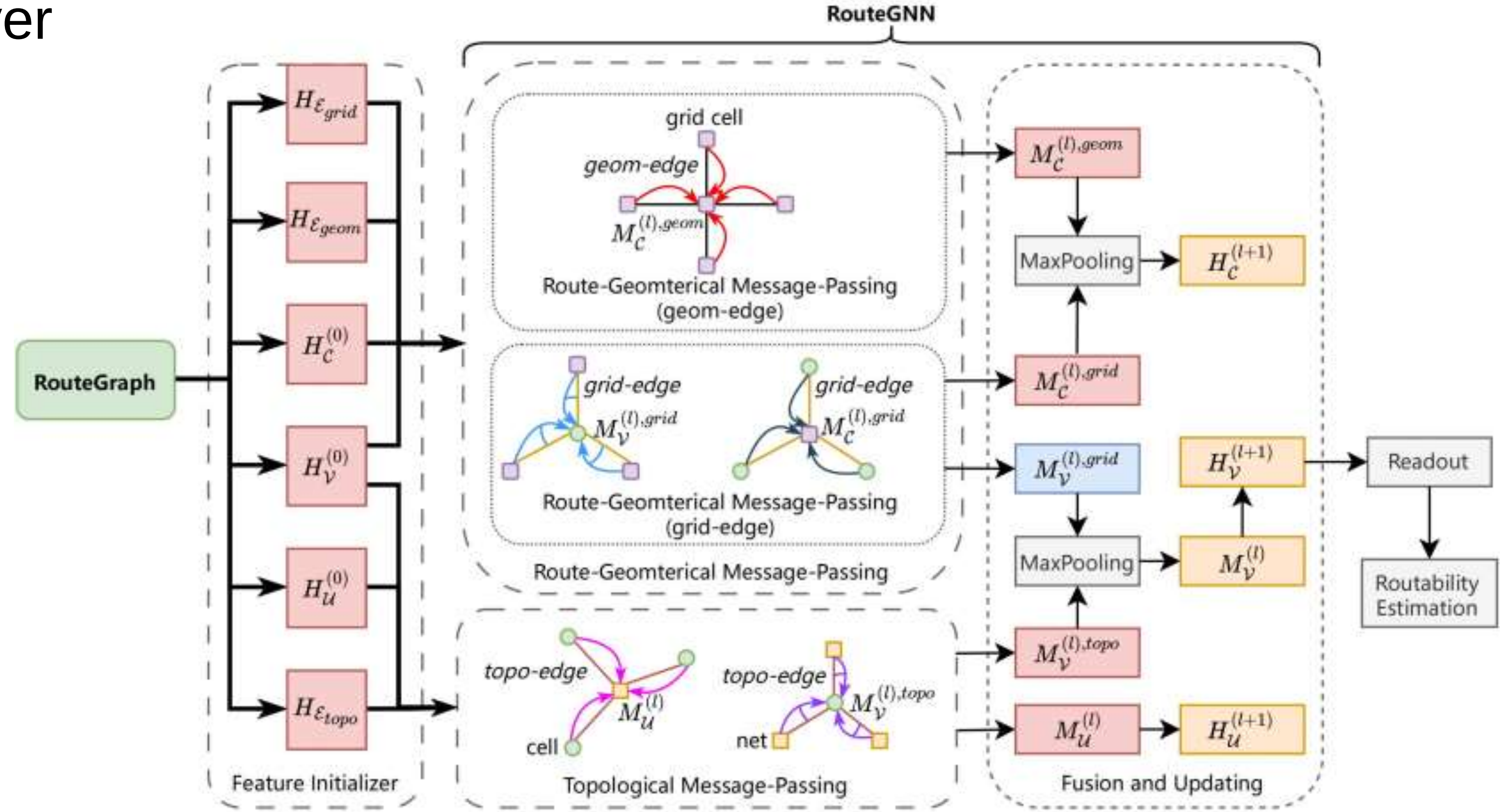
- Topo-edges: topological connections between cells and nets
- Geom-edges: geometrical adjacencies among grid cells
- Grid-edges: geometrical adjacencies between grid cells and cells



Forward Propagation

Multi-layer message-passing & fusing:

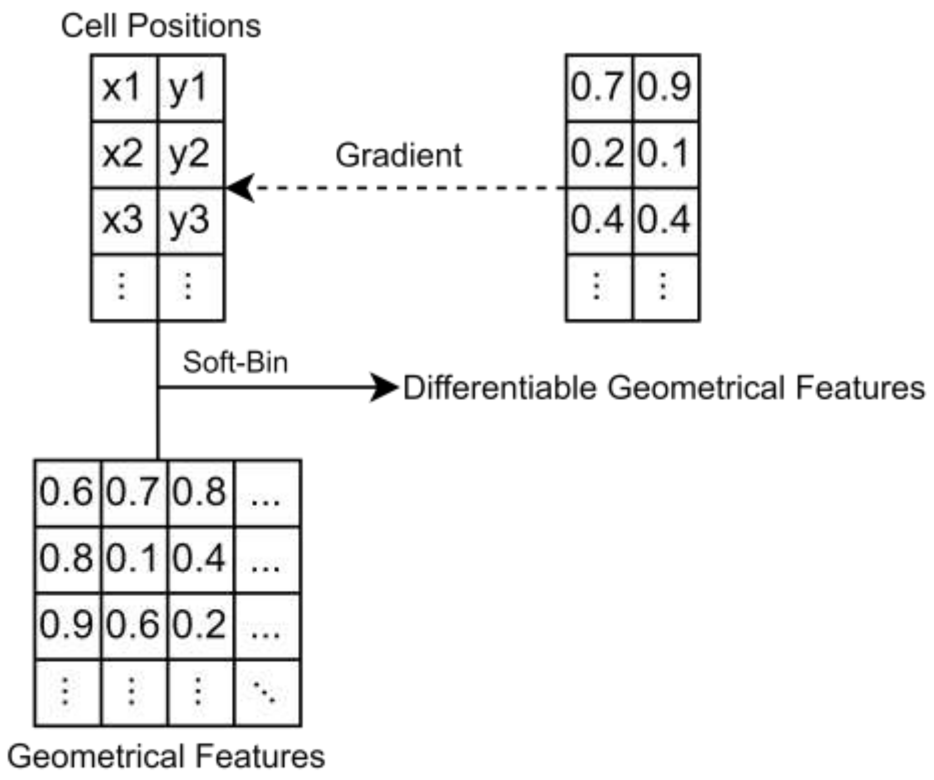
- Pass topological/route-geometrical message and fuse them at the end of each layer



Backward Propagation

Construct differentiable geometrical feature for backward

Current geometrical features(RUDY) are non-differentiable w.r.t. the cell positions



Experiments

Routing results on ISPD2011 benchmark:

- Our method can optimize routability across various circuits.

Table 1: Comparsion results on ISPD2011.

Netlist	#cell	#nets	TOF↓		MOF↓		H-CR↓		V-CR↓		WL($\times 10^6 um$)↓	
			RoutePlacer	DREAMPlace	RoutePlacer	DREAMPlace	RoutePlacer	DREAMPlace	RoutePlacer	DREAMPlace	RoutePlacer	DREAMPlace
superblue1	848K	823K	**72380**	74694	**16**	20	0.22	0.22	**0.19**	0.20	**12.90**	12.91
superblue2	1014K	991K	**709172**	895270	46	**40**	0.54	**0.51**	**0.26**	0.31	**25.19**	25.29
superblue4	600K	568K	**114232**	119732	**36**	44	**0.45**	0.53	**0.21**	0.25	**9.18**	9.19
superblue5	773K	787K	**348976**	363260	**32**	34	0.43	0.43	0.26	**0.24**	**15.31**	15.36
superblue10	1129K	1086K	**142986**	251602	20	20	0.29	**0.28**	**0.15**	0.16	**24.10**	24.33
superblue12	1293K	1293K	**2112070**	2201282	**104**	112	**1.13**	1.22	0.59	**0.55**	**15.47**	15.56
superblue15	1124K	1080K	**115962**	116112	16	16	**0.25**	0.26	0.13	0.13	**14.51**	14.52
superblue18	484K	469K	**100336**	104162	16	16	**0.25**	0.27	0.19	**0.18**	**8.65**	8.67
Average ratio			1.00	1.15	1.00	1.06	1.00	1.04	1.00	1.04	1.00	1.01

Experiments

Routing results on ISPD2011 benchmark with additionally implemented cell inflation methods:

- RoutePlacer can be extended to traditional two-stage pipelines.
- Incorporating RouteGNN into two-stage methods can yield improved routability-aware placers

Table 2: Comparsion results on ISPD2011. RoutePlacer and DREAMPlace additionally implement cell inflation methods.

Netlist	#cell	#nets	TOF↓		MOF↓		H-CR↓		V-CR↓		WL($\times 10^6 um$)↓	
			RoutePlacer	DREAMPlace	RoutePlacer	DREAMPlace	RoutePlacer	DREAMPlace	RoutePlacer	DREAMPlace	RoutePlacer	DREAMPlace
superblue1	848K	823K	**4612**	5340	36	**16**	**0.14**	0.19	0.32	**0.19**	13.72	**12.97**
superblue2	1014K	991K	**45338**	64464	**12**	16	0.19	**0.14**	**0.14**	0.18	26.23	**25.40**
superblue4	600K	568K	**6632**	7242	8	8	0.18	**0.13**	0.13	0.13	9.79	**9.35**
superblue5	773K	787K	**36726**	108106	**18**	26	**0.23**	0.35	0.19	0.19	17.09	**16.47**
superblue10	1129K	1086K	**44116**	45158	12	12	**0.20**	0.21	0.13	0.13	24.91	**24.66**
superblue12	1293K	1293K	**26296542**	28714180	**184**	456	1.39	**1.34**	**1.12**	1.83	**39.67**	41.89
superblue15	1124K	1080K	**15904**	41430	8	8	**0.18**	0.19	0.09	0.09	**15.07**	15.30
superblue18	484K	469K	91388	**22412**	18	**16**	0.27	**0.20**	0.19	0.16	**8.98**	9.21
Average ratio			1.00	1.45	1.00	1.20	1.00	1.02	1.00	1.04	1.00	0.99

Thank you