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One-for-All: An Unified Learning-based Framework for Efficient Cross-Corner Timing Signoff

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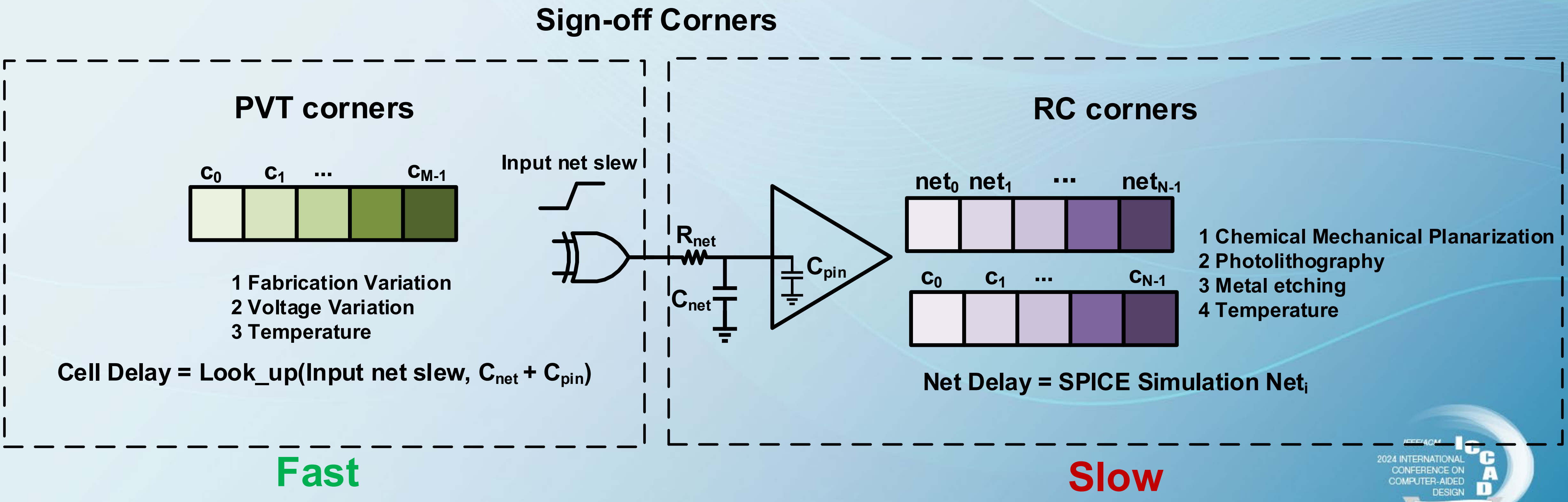
Challenges in Timing Signoff

- Hundreds of process corners.
- Lengthy ECO iterations.

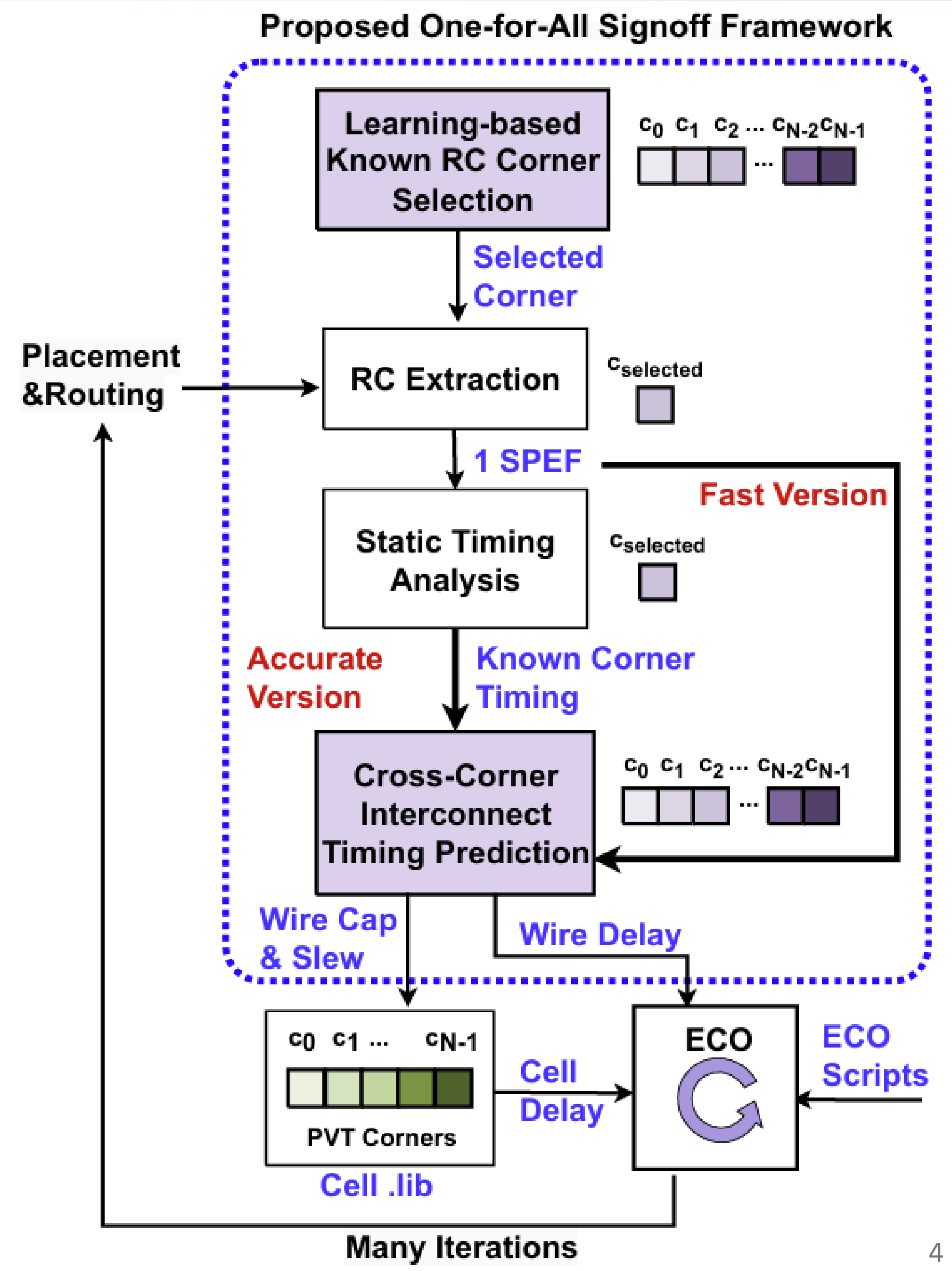


Problem Formulation

- Given the timing or only parasitic parameter for one selected ‘observed’ RC corner, estimate the interconnect timing for the remaining corners.
- Given few signed-off nets in all RC corners, classify the best corner as ‘observed’.

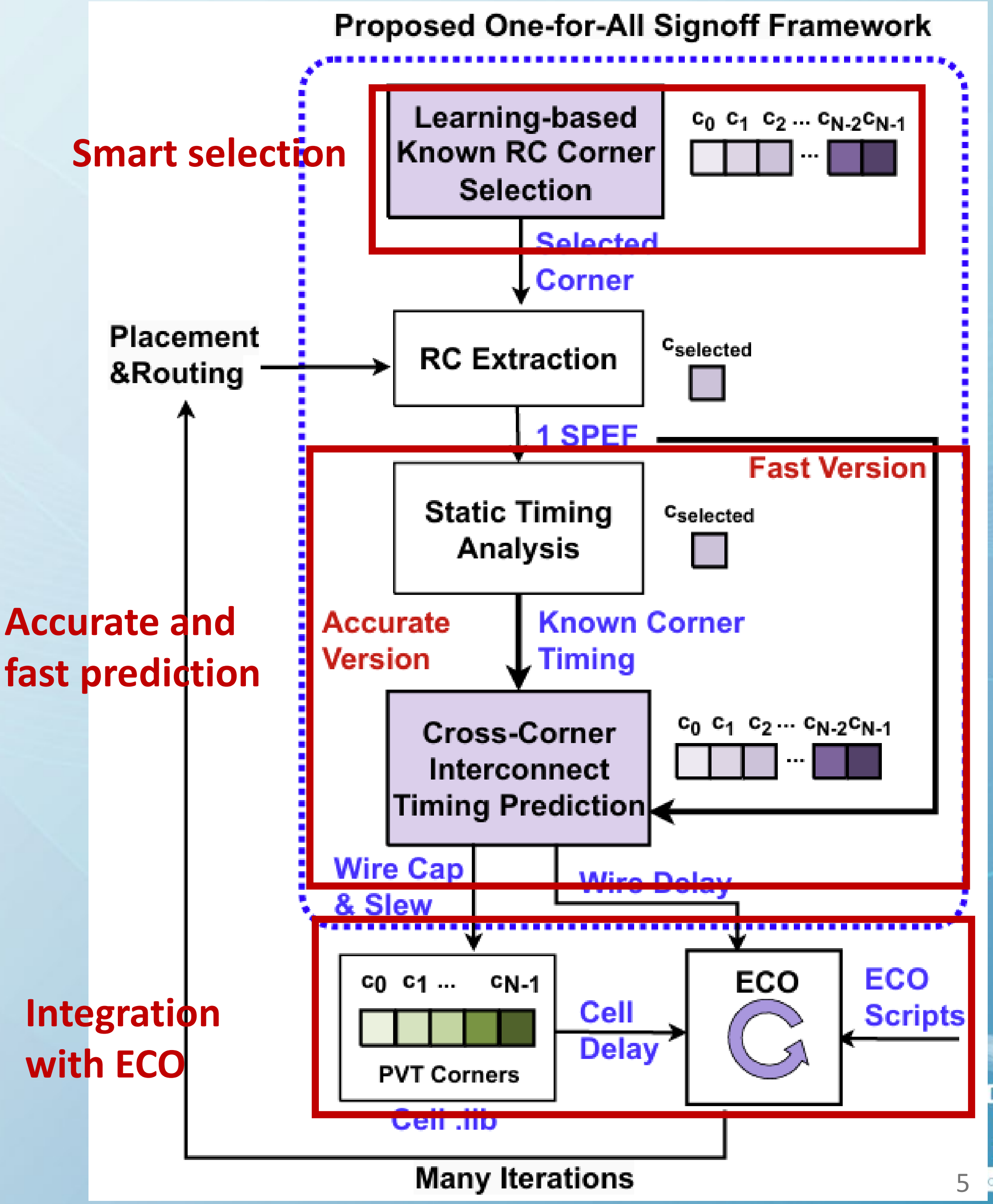
Proposed Framework

- A unified, **learning-based** approach.
- Utilizes a **single** known corner to predict timing across **all other corners**.



Key Contributions

- Precise and fast cross-corner timing predictions.
- Machine learning-based corner selection.
- Seamless integration with timing ECO processes.



Proposed Methodology

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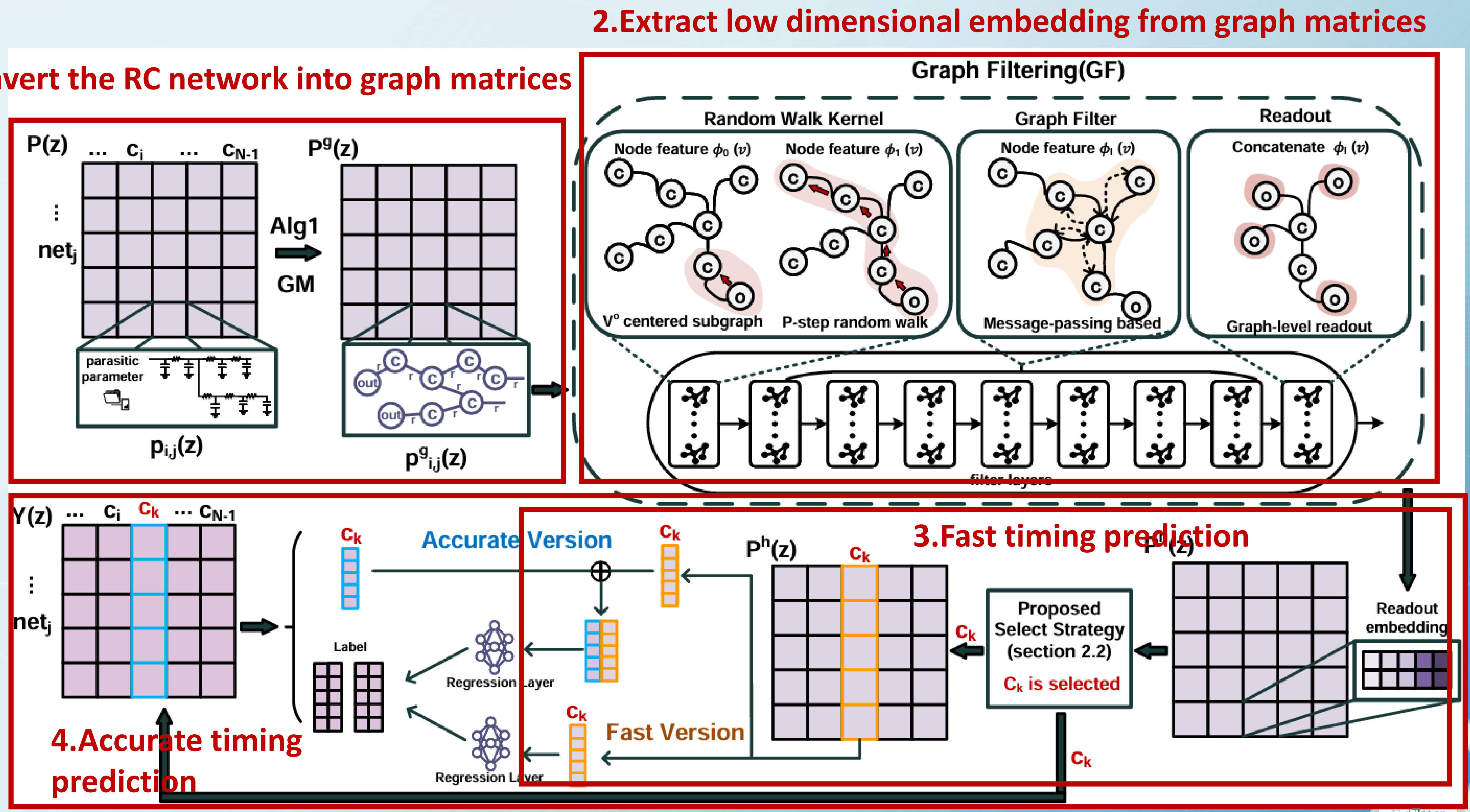
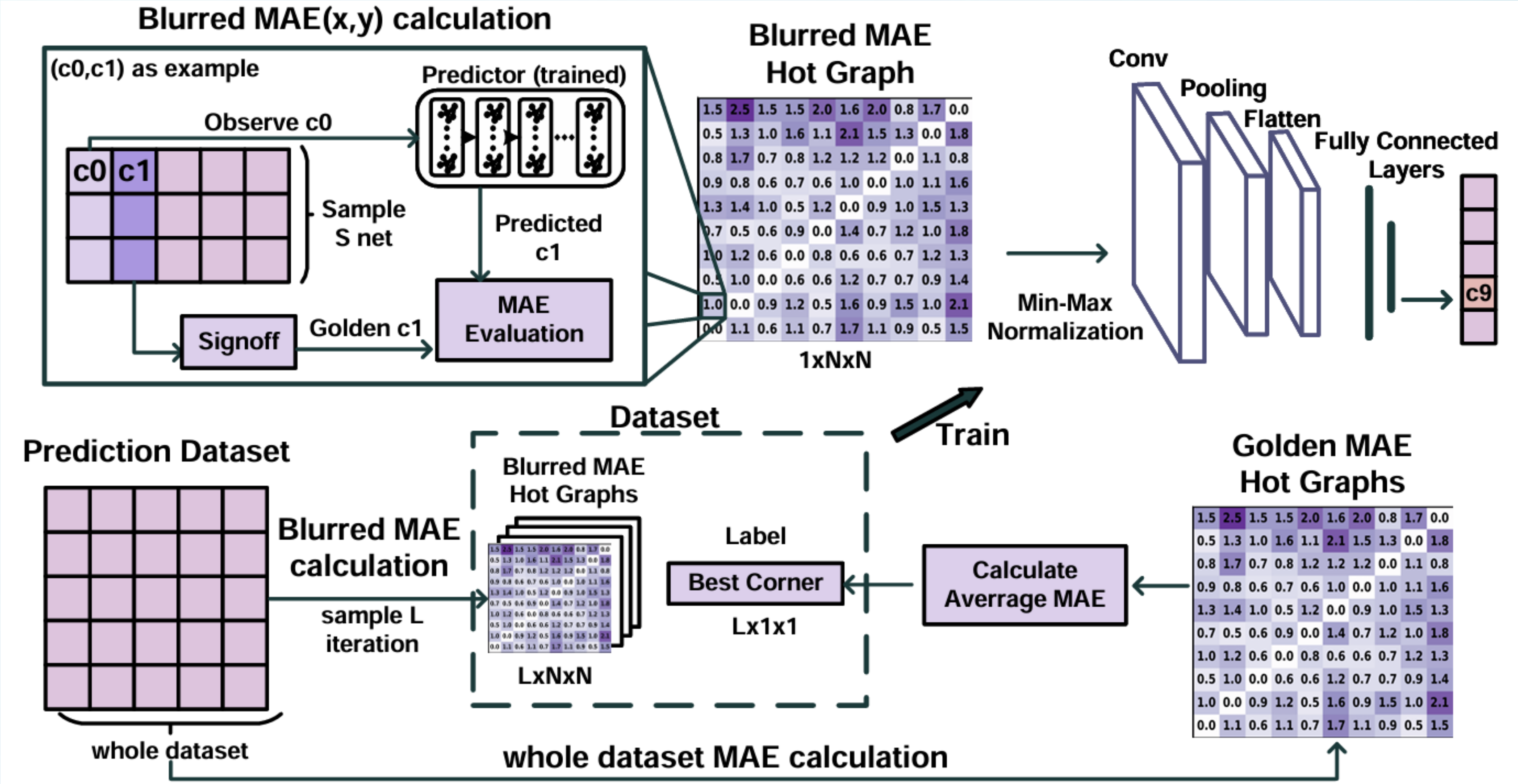
Cross-corner timing prediction module



Cross-corner timing prediction module

Corner Selection

- Selecting the most representative corner using minimal data.



Learning-based corner selection module

Experiments and Results

Setup and baseline

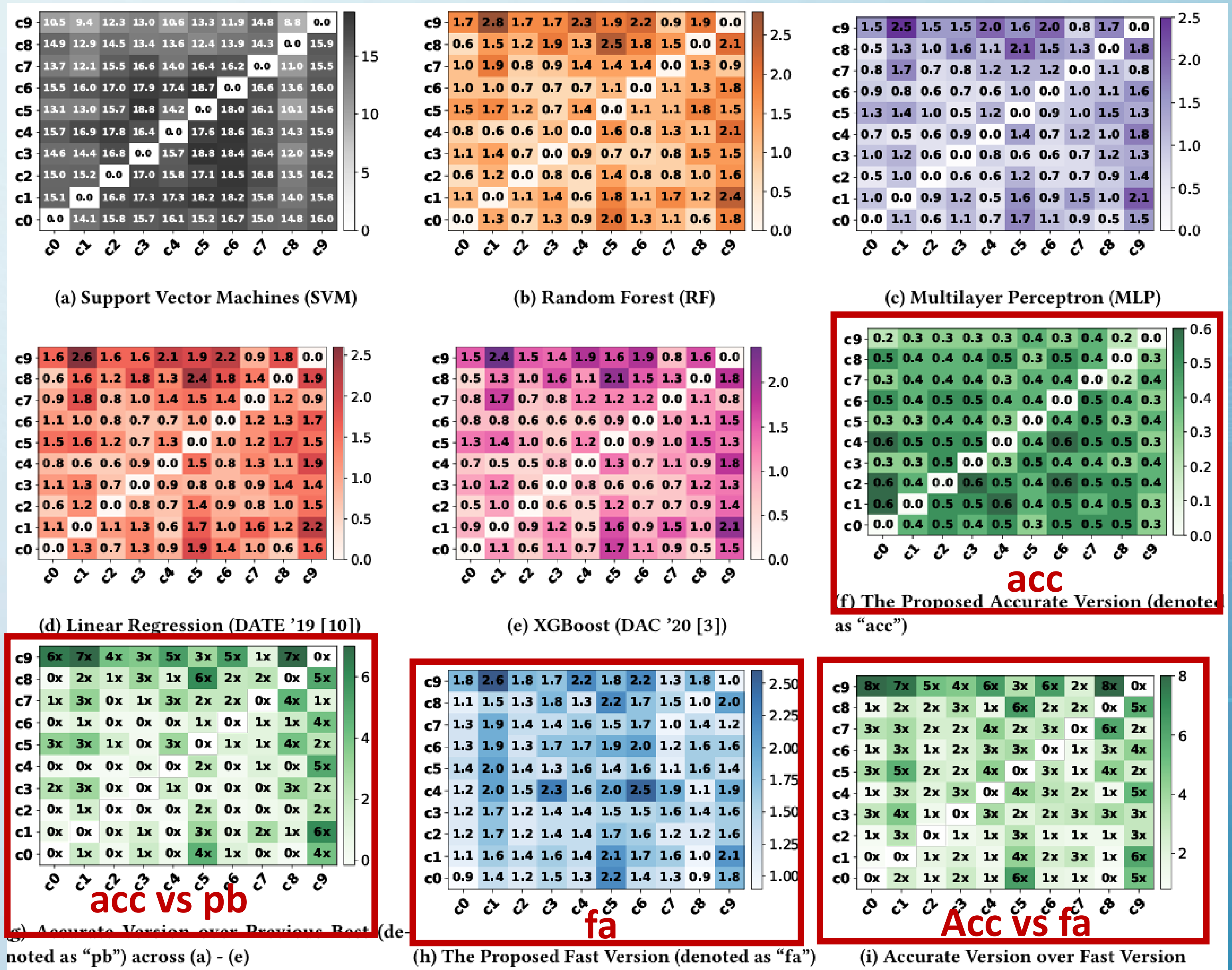
- Evaluation on industry-standard technology nodes (sub-10nm, 28nm).
- Representative benchmark.
- SOTA works and classical methods as baselines.
- Fast version denoted as **fa**, accurate version denoted as **acc**, previous best denoted as **pb**.

Benchmark

Process	Benchmark	#Cells	#Nets	#FFs
28nm	B19	13863	15394	1980
	PCI_BRIDGE	8518	9269	3337
	DES_PERT	1506	1634	192
	AES-128	5363	5432	935
	SALSA	11292	12749	1674
	OPENGFX	8220	8534	1584
sub-10nm	Industrial Design (confidential)	Over 1 million nets		

Accuracy comparison w/ prior works in sub-10 nm node

- X-coordinate represents the observed corner.
- Y-coordinate represents the predicted corner.



MAE(ps) heatmap compare with prior works

Comparison to previous best methods in sub-10 nm node

- At least 5 observed corners on average are required to achieve same accuracy as acc.
- Acc 62.6% accuracy improvement with pb.

The number of required corners to achieve same accuracy

	Proposed	Previous Best							
Known Corner	**#1**	**#1**	**#2**	**#3**	**#4**	**#5**	**#6**	**#7**	**# Minimum Required Corner**
c_0	**0.30**	1.62	0.83	0.5	0.38	0.40	0.39	**0.29**	7
c_1	**0.41**	1.36	0.62	0.47	0.50	0.50	0.53	**0.27**	7
c_2	**0.36**	1.06	0.64	0.52	0.51	0.53	0.38	**0.28**	7
c_3	**0.43**	0.88	0.60	0.60	0.61	**0.36**			5
c_4	**0.37**	1.12	0.62	0.63	**0.34**				4
c_5	**0.49**	0.92	0.74	0.50	**0.38**				4
c_6	**0.38**	0.89	0.63	0.41	**0.38**				4
c_7	**0.50**	0.83	0.77	0.71	0.76	**0.36**			5
c_8	**0.48**	1.18	0.93	0.76	**0.36**				4
c_9	**0.43**	1.02	0.77	**0.40**					3
Average									5

Summary of the predicted MAE(ps) (mean/min/max) of the unobserved corners

Benchmark		c_0	c_1	c_2	c_3	c_4	c_5	c_6	c_7	c_8	c_9
Industrial Design	**pb**	1.5/0.8/2.4	1.2/0.5/2.1	1.0/0.7/1.7	0.8/0.6/1.5	1.0/0.5/1.5	0.8/0.5/1.8	0.8/0.6/1.3	0.8/0.5/1.4	1.1/0.5/2.1	0.9/0.5/1.7
	fa	1.8/1.3/2.6	1.5/1.1/2.2	1.4/1.2/1.9	1.6/1.3/2.0	1.5/1.3/2.0	1.8/1.2/2.5	1.5/1.4/1.7	1.4/1.4/1.7	1.6/1.1/2.1	1.4/1.2/2.2
	acc	**0.3/0.2/0.4**	**0.4/0.3/0.5**	**0.3/0.2/0.4**	**0.4/0.3/0.5**	**0.3/0.3/0.5**	**0.4/0.3/0.6**	**0.3/0.3/0.5**	**0.5/0.4/0.6**	**0.4/0.3/0.6**	**0.4/0.3/0.5**

Comparison to previous best in 28 nm node

- Acc 95.3% accuracy improvement with pb, increase about 10s runtime on average.
- Fa achieves over a 2× speedup compared to acc, with 0.5 ps accuracy degradation on average.

MAE(ps) of each unobserved corners in 28 nm

Benchmark		c_0	c_1	c_2	c_3	c_4	c_5	c_6	c_7	c_8	c_9	**Run Time (s)** [1]
B19	**pb**	0.122	0.133	0.162	0.169	0.105	0.110	0.151	0.162	0.111	0.116	161
	fa	0.464	0.483	0.529	0.540	0.457	0.466	0.552	0.548	0.501	0.519	**53**
	acc	**0.005**	**0.005**	**0.005**	**0.006**	**0.005**	**0.005**	**0.006**	**0.006**	**0.005**	**0.006**	172
PCI_BRIDGE	**pb**	0.240	0.268	0.258	0.269	0.185	0.197	0.254	0.261	0.192	0.190	115
	fa	0.801	0.860	0.857	0.860	0.752	0.811	0.869	0.865	0.810	0.827	**50**
	acc	**0.011**	**0.011**	**0.011**	**0.011**	**0.011**	**0.011**	**0.012**	**0.012**	**0.011**	**0.011**	126
DES_PERT	**pb**	0.088	0.084	0.107	0.094	0.078	0.078	0.108	0.088	0.063	0.067	59
	fa	0.450	0.459	0.625	0.600	0.425	0.508	0.572	0.600	0.499	0.517	**42**
	acc	**0.011**	**0.012**	**0.012**	**0.013**	**0.011**	**0.012**	**0.013**	**0.013**	**0.013**	**0.012**	69
AES-128	**pb**	0.240	0.268	0.258	0.269	0.185	0.197	0.254	0.261	0.192	0.190	96
	fa	0.802	0.854	0.891	0.920	0.818	0.839	0.930	0.927	0.854	0.876	**47**
	acc	**0.009**	**0.010**	**0.010**	**0.010**	**0.009**	**0.009**	**0.010**	**0.010**	**0.010**	**0.010**	107
SALSA	**pb**	0.341	0.391	0.407	0.442	0.287	0.289	0.388	0.419	0.273	0.281	150
	fa	1.436	1.475	1.502	1.560	1.397	1.455	1.569	1.610	1.467	1.518	**54**
	acc	**0.012**	**0.012**	**0.012**	**0.012**	**0.012**	**0.012**	**0.012**	**0.013**	**0.012**	**0.012**	161
OPENGFX	**pb**	0.147	0.162	0.205	0.220	0.135	0.135	0.218	0.223	0.135	0.138	123
	fa	0.620	0.646	0.682	0.706	0.609	0.647	0.692	0.723	0.650	0.671	**49**
	acc	**0.007**	**0.007**	**0.007**	**0.008**	**0.007**	**0.007**	**0.008**	**0.008**	**0.007**	**0.007**	134

Runtime Improvement and corner selection accuracy

- Fa over 2× speedup acc in delay prediction.
- Acc 10× acceleration of ECO processes.
- In small sample size (200), the test accuracy surpasses 70%.

Runtime(s) for two ECO iterations (in 28nm).

	Iteration #1			Iteration #2		
Benchmark	**fa**	**acc**	**Traditional ECO**	**fa**	**acc**	**Traditional ECO**
B19	53	169	1574	53	172	1608
PCI_BRIDGE	70	147	1354	50	126	1154
DES_PERT	43	79	697	42	69	588
AES-128	42	112	1009	47	107	962
SALSA	53	127	1582	54	161	1502
OPENGFX	50	100	1285	49	134	1228
Average	**51.83**	**122.33**	**1250.17**	**49.17**	**128.17**	**1173.67**

Know corner selection accuracy with respect to the sample size (in28nm)

Sample Size	Training Accuracy	Test Accuracy
100	0.663	0.611
200	0.805	0.744
500	0.771	0.767
Mixed	0.814	0.8

Conclusion

- Learning-based cross-corner timing signoff frame work is proposed.
- Only one RC corner timing or just parasitic parameter is enough to predict interconnect timing in all corners.
- ‘Observed’ corner smart selecting strategy, enhance the framework’s adaptability.
- Integrated in ECO flow, the proposed framework accelerates each iteration substantially by over 10×.

Q&A

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