uSAP: An Ultra-Fast Stochastic Graph Partitioner

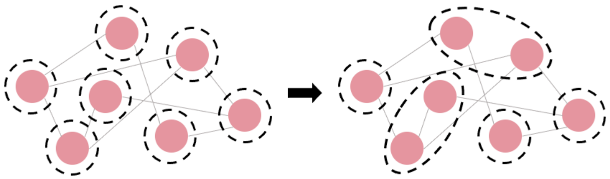
2023 MIT/IEEE/Amazon HPEC Graph Challenge

Chih-Chun Chang, Tsung-Wei Huang University of Wisconsin-Madison

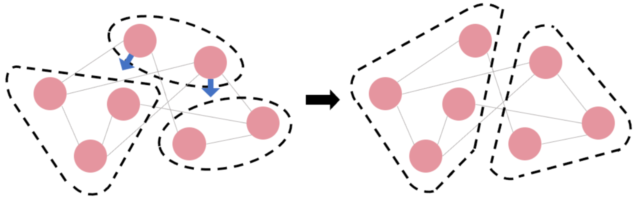
Challenges

- **Time-consuming** baseline sequential partitioner (PEIXOTO)

(1) Bottom-up block merging

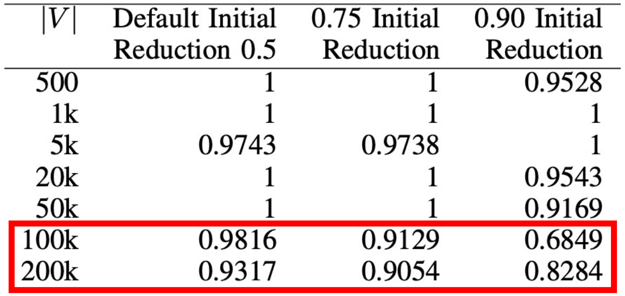


(2) Iterative MCMC nodal block assignment



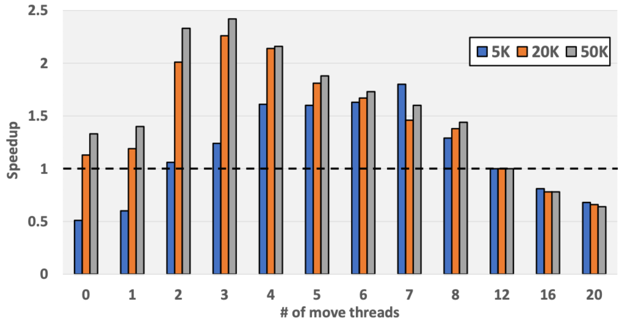
- **Improvable results** from 2021 Champion (FSBP)

(1) Aggressive initial merging



$\|V\|$	Default Initial Reduction 0.5	0.75 Initial Reduction	0.90 Initial Reduction
500	1	1	0.9528
1k	1	1	1
5k	0.9743	0.9738	1
20k	1	1	0.9543
50k	1	1	0.9169
100k	0.9816	0.9129	0.6849
200k	0.9317	0.9054	0.8284

(2) Parallelism control strategy



Recall decrease!

Not scalable!

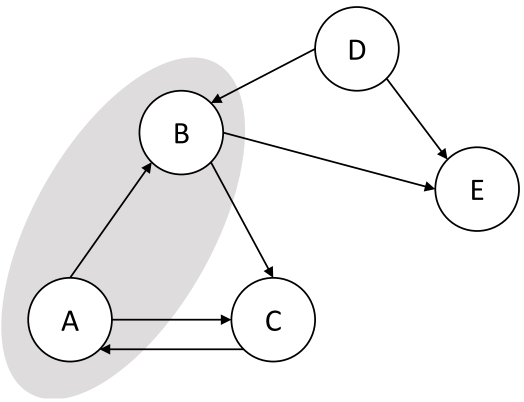
The figures are derived from FSBP paper.

Solutions

- **Strongly Connected Components**-based initial block merging

$\Longrightarrow$ tries to find the blocks with more interactions to merge

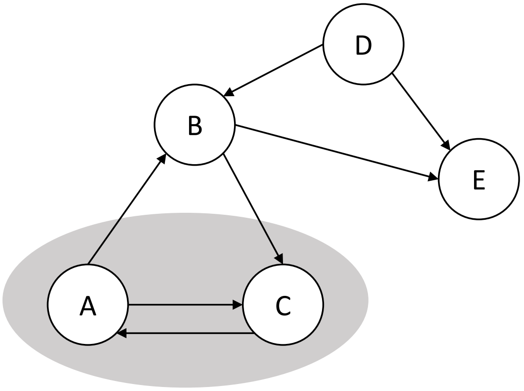
(1) Merge the block B



$$M_1^+ = \begin{array}{cc} \begin{matrix} A & B & C & D & E \end{matrix} & \\ \begin{pmatrix} 1 & 0 & 2 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 \end{pmatrix} & \begin{matrix} A \\ B \\ C \\ D \\ E \end{matrix} \end{array}$$

$\Longrightarrow \Delta E = 0.35$

(2) Merge the block C



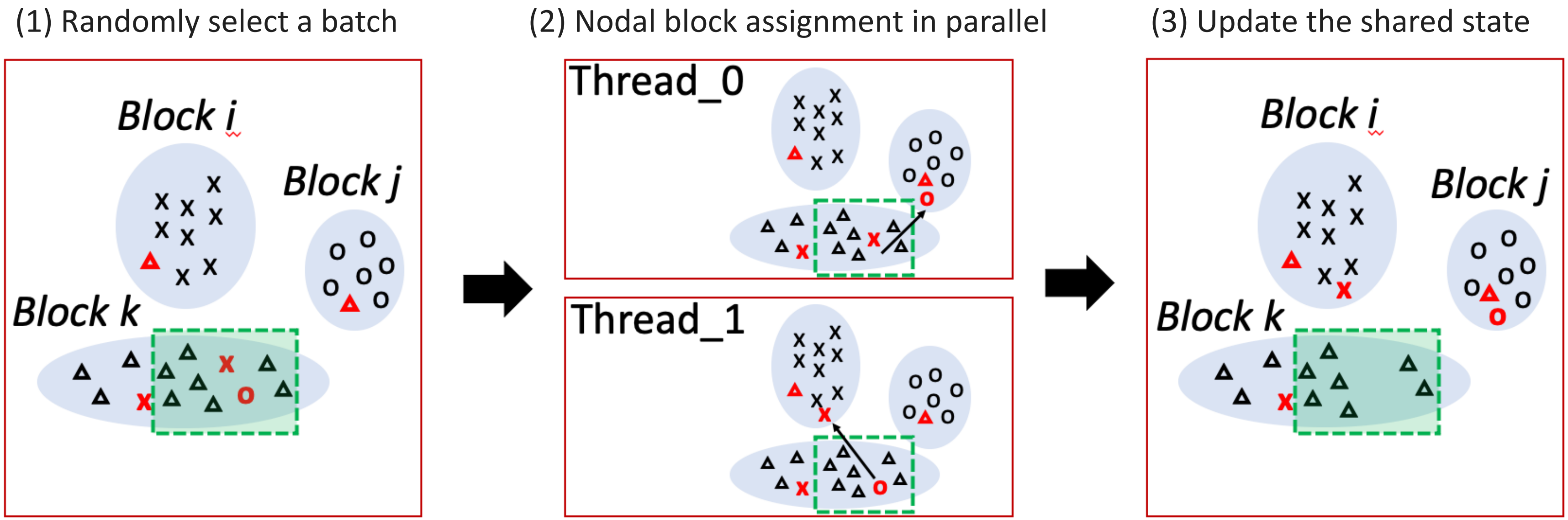
$$M_2^+ = \begin{array}{cc} \begin{matrix} A & B & C & D & E \end{matrix} & \\ \begin{pmatrix} 2 & 1 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 \end{pmatrix} & \begin{matrix} A \\ B \\ C \\ D \\ E \end{matrix} \end{array}$$

$\Longrightarrow \Delta E = -0.43$

We use a tunable threshold t_{SCC} to determine when to stop.

Solutions

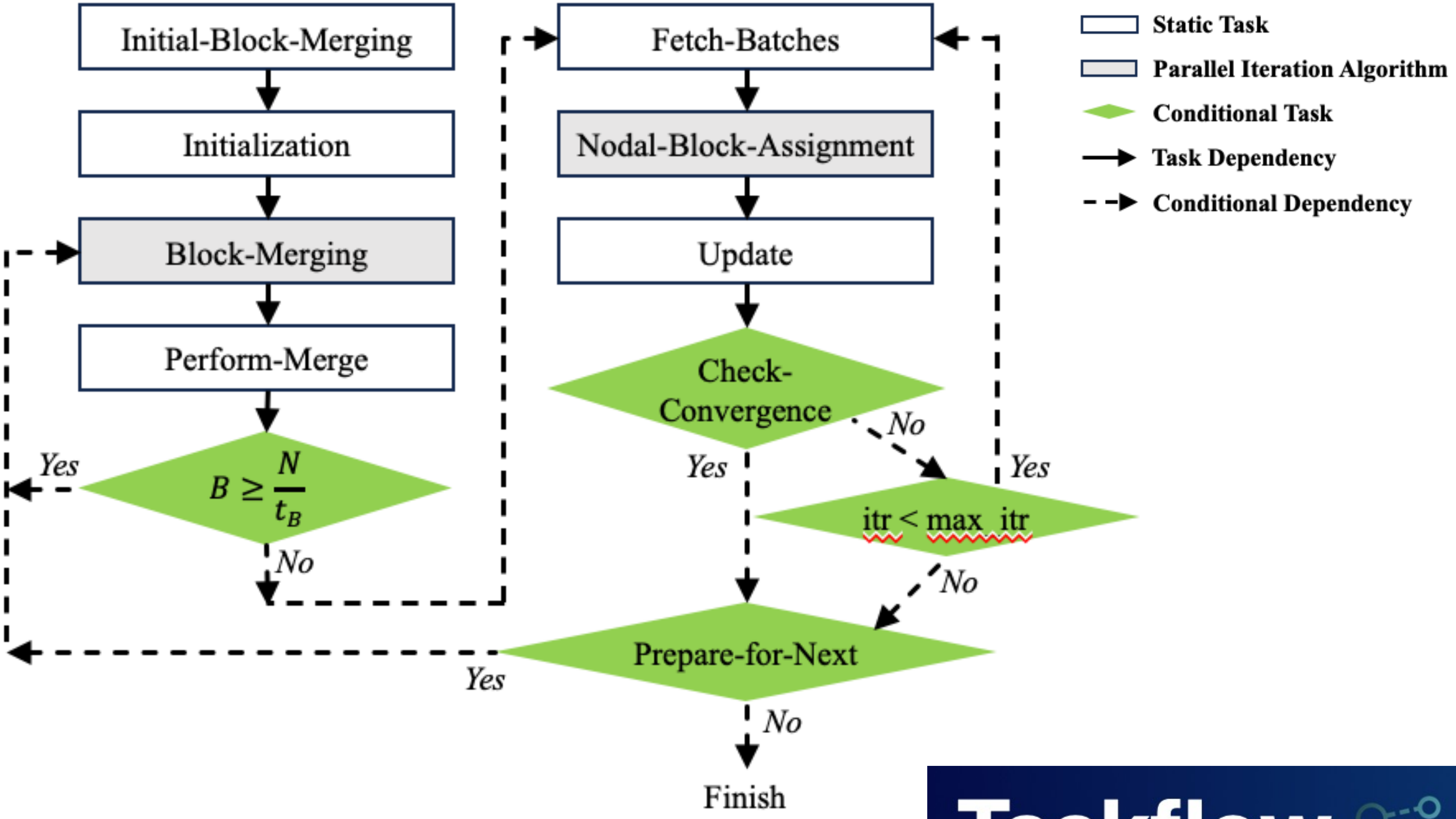
- **Batch Parallel** Nodal Block Assignment


(1) Randomly select a batch
(2) Nodal block assignment in parallel
(3) Update the shared state
Block i
Block j
Block k
Thread_0
Thread_1
Block i
Block j
Block k

The results of (2) are saved in a shared vector.

Solutions

- Task Graph Parallelism



Whether to perform nodal block assignment or not

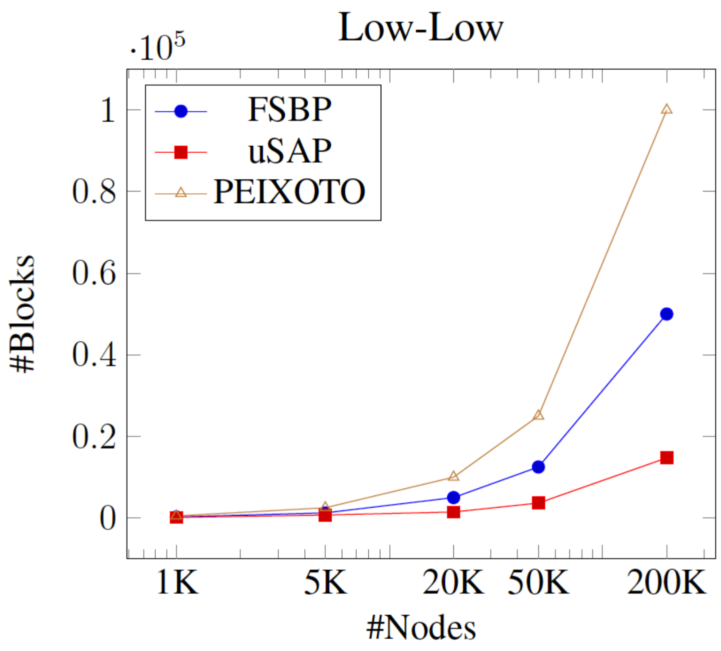
Experimental Setup

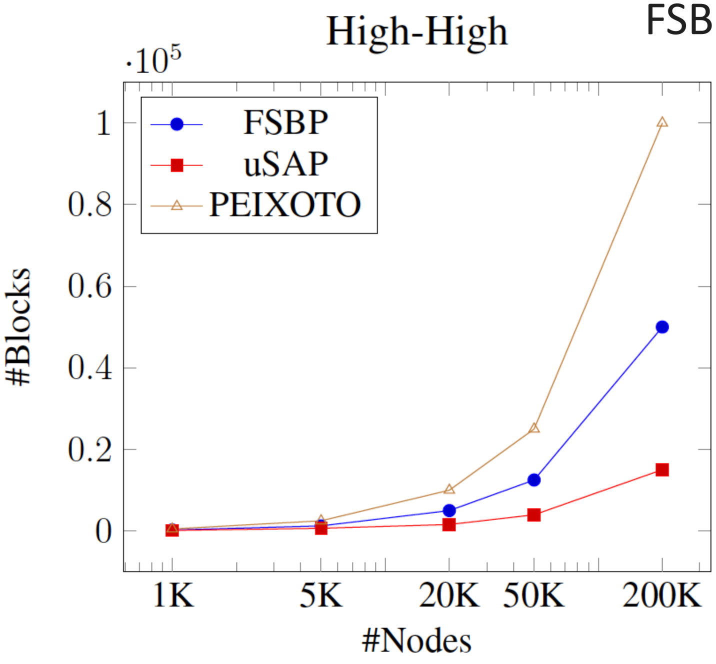
- **Baseline**
  - Sample code provided by Graph Challenge (PEIXOTO)
  - Faster Stochastic Block Partition (FSBP)
- **Dataset**
  - 2022 Streaming Graph Partition Dataset provided by Graph Challenge
- **Software**
  - Ubuntu Linux 5.15.0-58-generic x86_64 machine
  - GNU GCC-11.3.0 with C++17
- **Hardware**
  - 12-core Intel® Core$^{(TM)}$ i7-12700 processor
  - 32GB RAM

Experimental Result

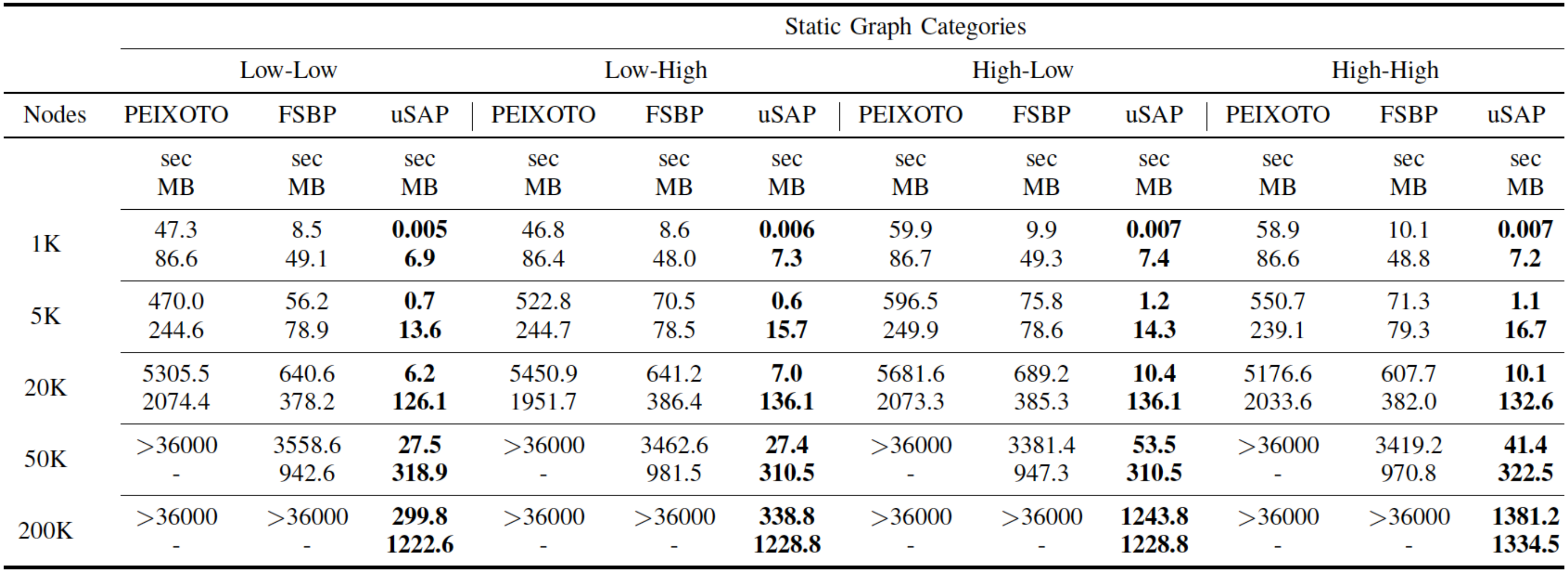
- Number of blocks after the initial block merging

PEIXOTO: 50%
FSBP: 75%



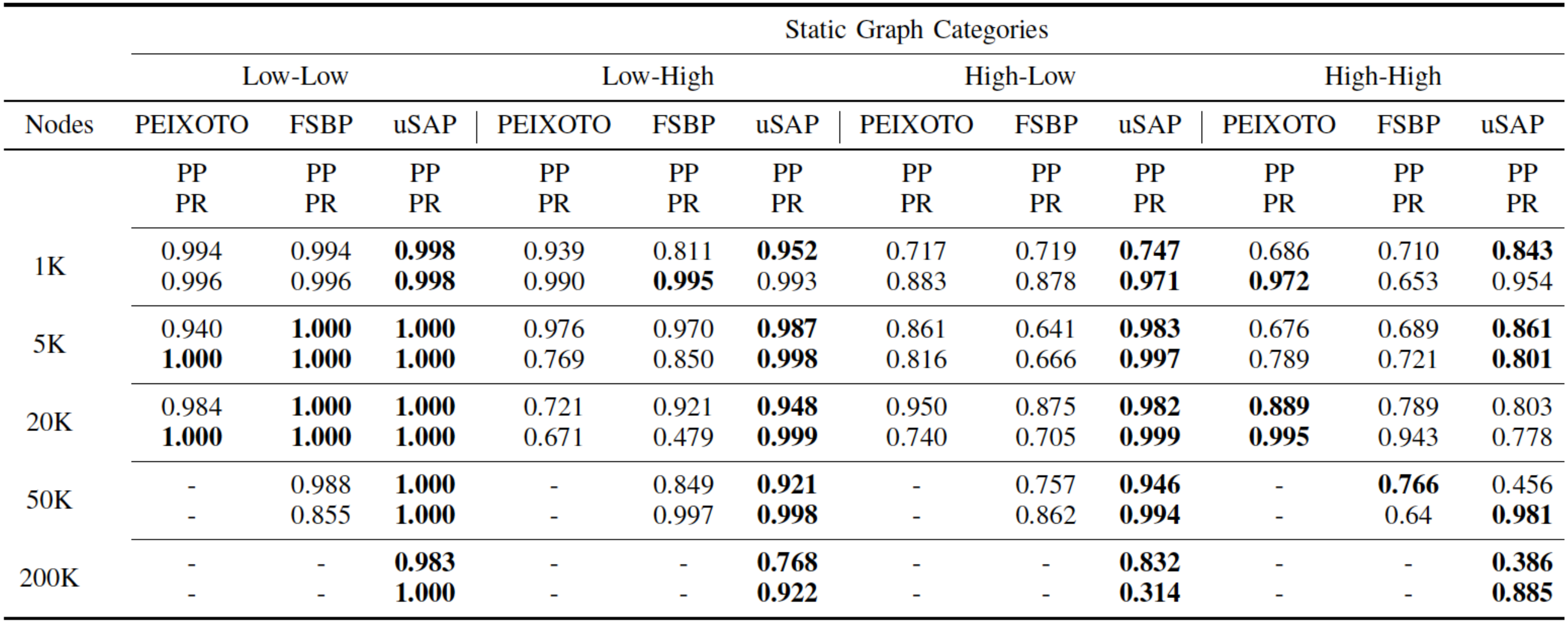


Overall Runtime



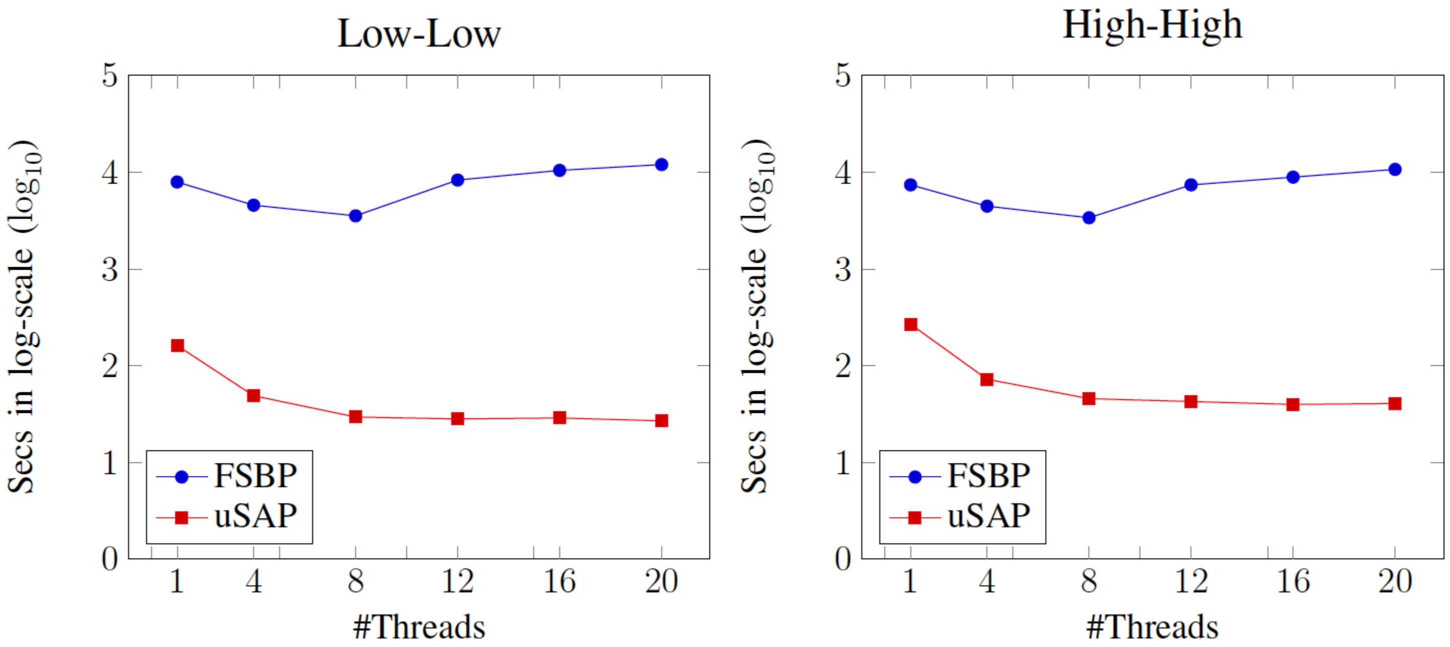
	Static Graph Categories											
	Low-Low			Low-High			High-Low			High-High		
Nodes	PEIXOTO	FSBP	uSAP	PEIXOTO	FSBP	uSAP	PEIXOTO	FSBP	uSAP	PEIXOTO	FSBP	uSAP
	sec MB	sec MB	sec MB	sec MB	sec MB	sec MB	sec MB	sec MB	sec MB	sec MB	sec MB	sec MB
1K	47.3 86.6	8.5 49.1	**0.005** **6.9**	46.8 86.4	8.6 48.0	**0.006** **7.3**	59.9 86.7	9.9 49.3	**0.007** **7.4**	58.9 86.6	10.1 48.8	**0.007** **7.2**
5K	470.0 244.6	56.2 78.9	**0.7** **13.6**	522.8 244.7	70.5 78.5	**0.6** **15.7**	596.5 249.9	75.8 78.6	**1.2** **14.3**	550.7 239.1	71.3 79.3	**1.1** **16.7**
20K	5305.5 2074.4	640.6 378.2	**6.2** **126.1**	5450.9 1951.7	641.2 386.4	**7.0** **136.1**	5681.6 2073.3	689.2 385.3	**10.4** **136.1**	5176.6 2033.6	607.7 382.0	**10.1** **132.6**
50K	>36000 -	3558.6 942.6	**27.5** **318.9**	>36000 -	3462.6 981.5	**27.4** **310.5**	>36000 -	3381.4 947.3	**53.5** **310.5**	>36000 -	3419.2 970.8	**41.4** **322.5**
200K	>36000 -	>36000 -	**299.8** **1222.6**	>36000 -	>36000 -	**338.8** **1228.8**	>36000 -	>36000 -	**1243.8** **1228.8**	>36000 -	>36000 -	**1381.2** **1334.5**

Pairwise Precision and Recall



	Static Graph Categories											
	Low-Low			Low-High			High-Low			High-High		
Nodes	PEIXOTO	FSBP	uSAP	PEIXOTO	FSBP	uSAP	PEIXOTO	FSBP	uSAP	PEIXOTO	FSBP	uSAP
	PP PR	PP PR	PP PR	PP PR	PP PR	PP PR	PP PR	PP PR	PP PR	PP PR	PP PR	PP PR
1K	0.994 0.996	0.994 0.996	**0.998** **0.998**	0.939 0.990	0.811 **0.995**	**0.952** 0.993	0.717 0.883	0.719 0.878	**0.747** **0.971**	0.686 **0.972**	0.710 0.653	**0.843** 0.954
5K	0.940 **1.000**	**1.000** **1.000**	**1.000** **1.000**	0.976 0.769	0.970 0.850	**0.987** **0.998**	0.861 0.816	0.641 0.666	**0.983** **0.997**	0.676 0.789	0.689 0.721	**0.861** **0.801**
20K	0.984 **1.000**	**1.000** **1.000**	**1.000** **1.000**	0.721 0.671	0.921 0.479	**0.948** **0.999**	0.950 0.740	0.875 0.705	**0.982** **0.999**	**0.889** **0.995**	0.789 0.943	0.803 0.778
50K	- -	0.988 0.855	**1.000** **1.000**	- -	0.849 0.997	**0.921** **0.998**	- -	0.757 0.862	**0.946** **0.994**	- -	**0.766** 0.64	0.456 **0.981**
200K	- -	- -	**0.983** **1.000**	- -	- -	**0.768** **0.922**	- -	- -	**0.832** **0.314**	- -	- -	**0.386** **0.885**

Scalability



Contribution

- SCC-based Initial block merging
- Dynamic batch parallel nodal block assignment
- Task graph parallelism

Thank you!

uSAP: An Ultra-Fast Stochastic Graph Partitioner

https://github.com/gary30404/uSAP.git

Chih-Chun Chang, Tsung-Wei Huang University of Wisconsin-Madison