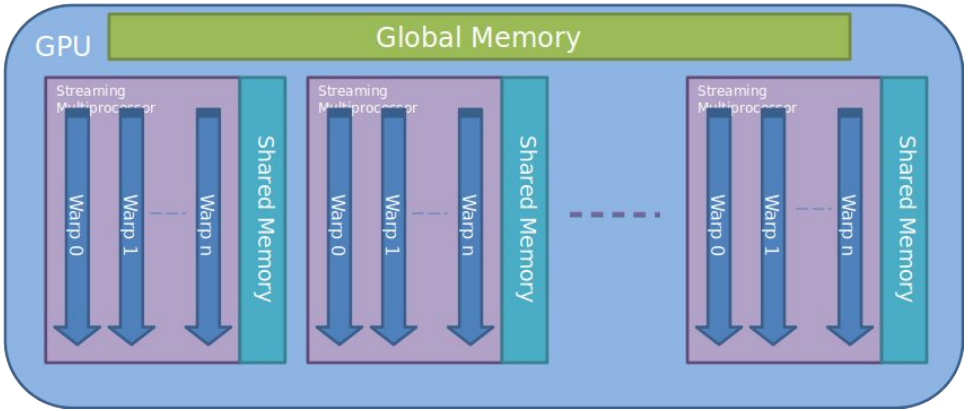
Optimizing Graph Algorithms for GPUs

By: Mayuresh Anand, Alon Albalak, Koa Sato

Graphical Processing Units

- **Composed of GPU cores**



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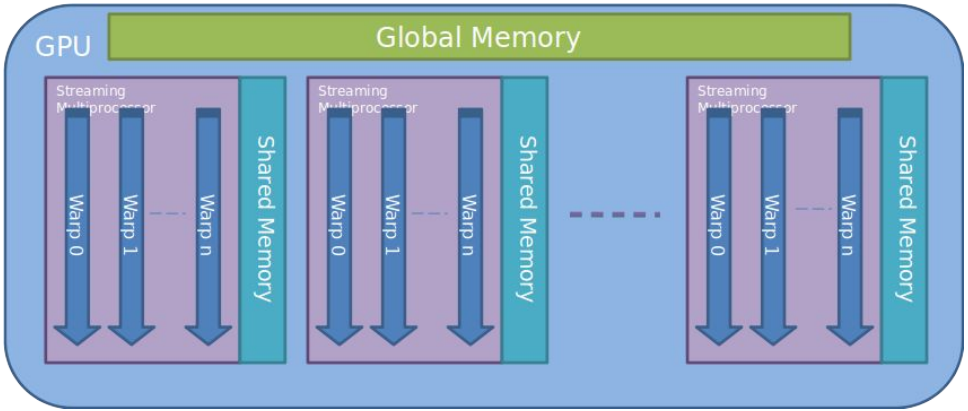

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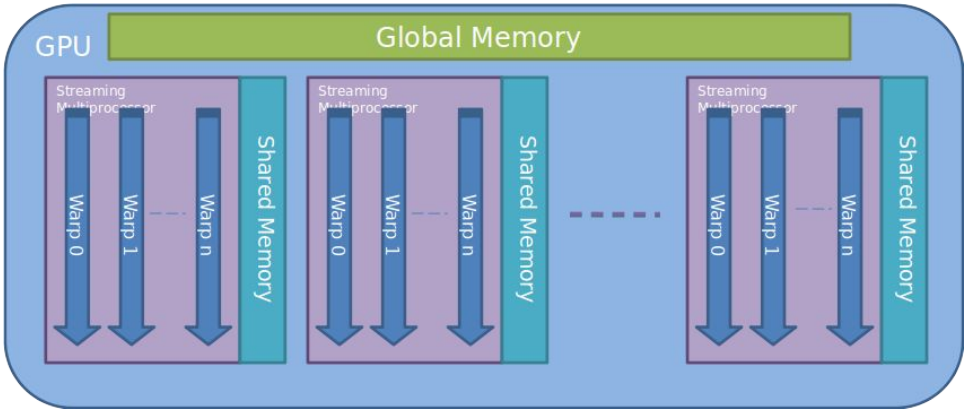
- **Threads are organized into warps, such that each warp executes an instruction in parallel**



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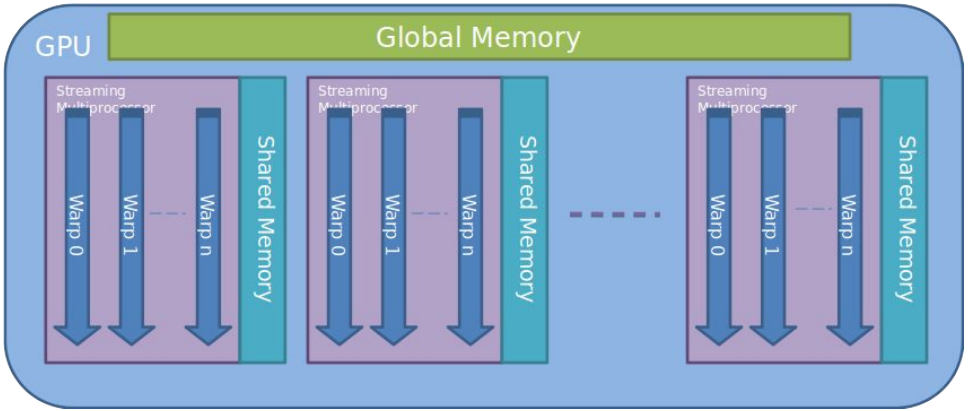
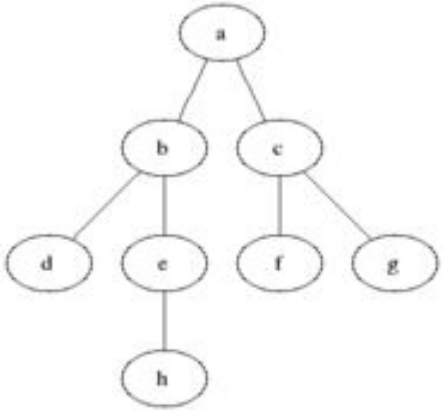
- **Most GPUs utilize single-instruction, multiple-threads paradigm**



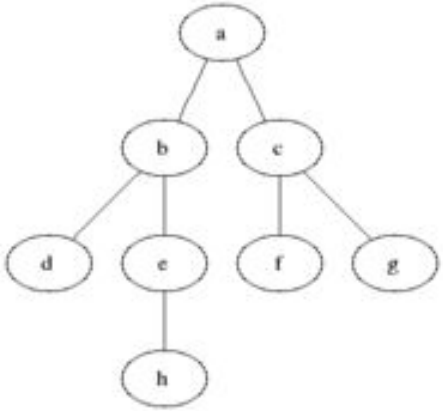
Graph Algorithms

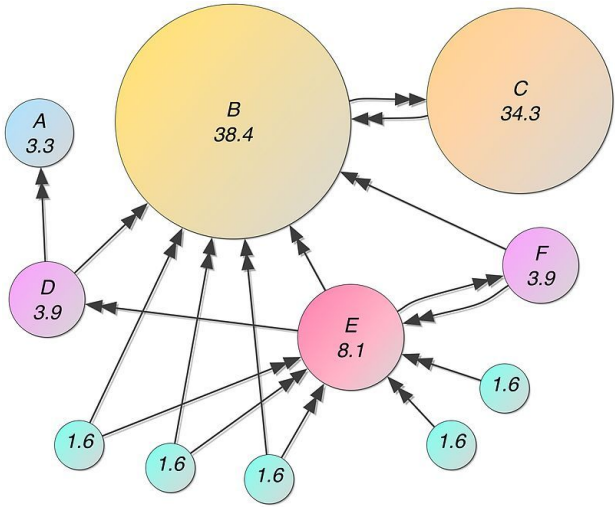
- **Breadth-first search**



Graph Algorithms

- Breadth-first search
- **PageRank**





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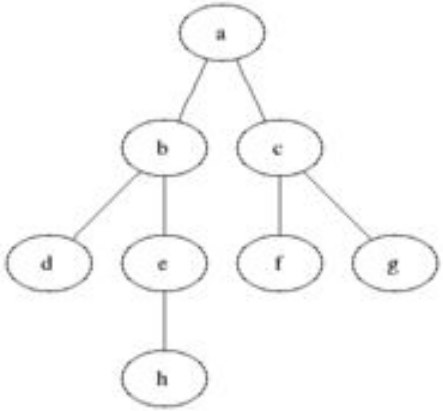

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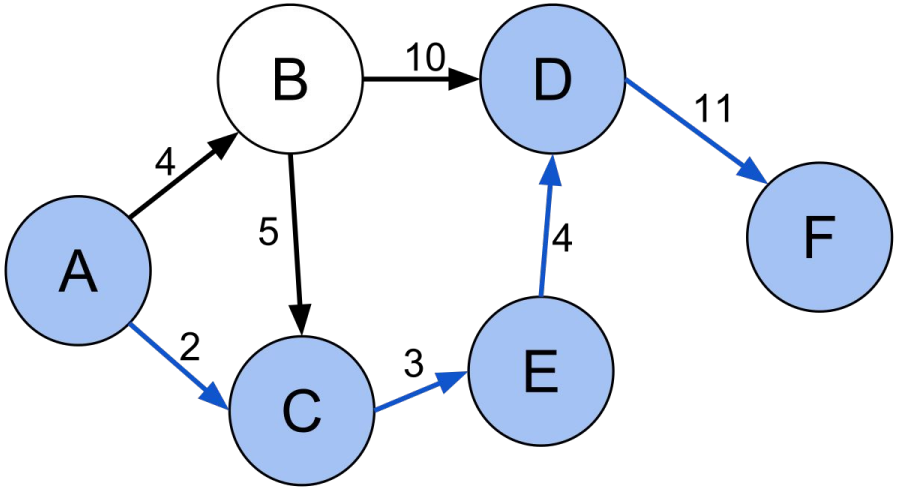
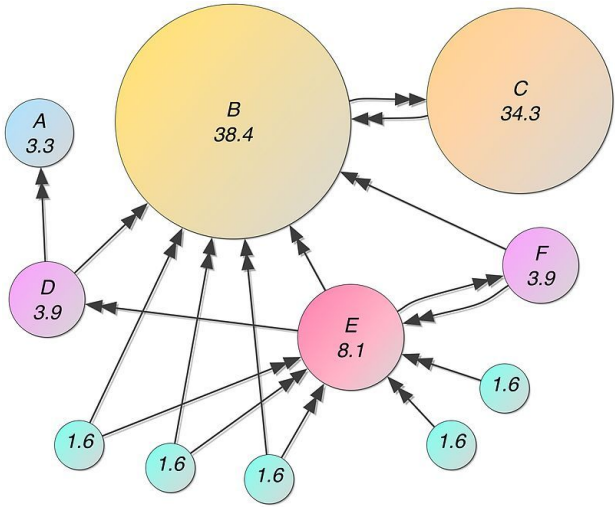
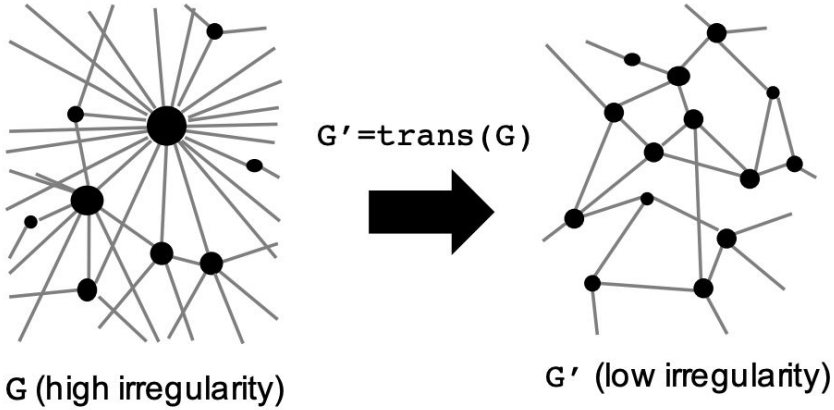
- **Single-source shortest path**



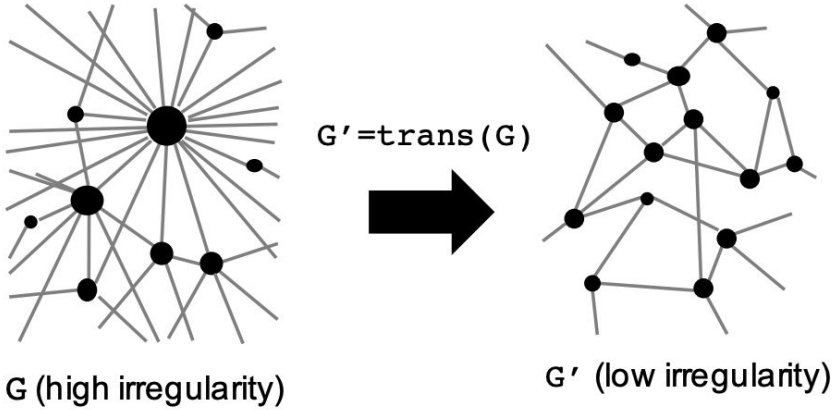


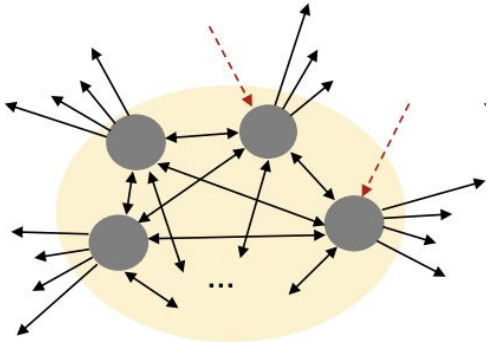
Graph Regularization



Graph Regularization

- Methods include transformations:
  - **Clique**





(a) $\mathcal{T}_{cliq}$

Graph Regularization

- Methods include transformations:
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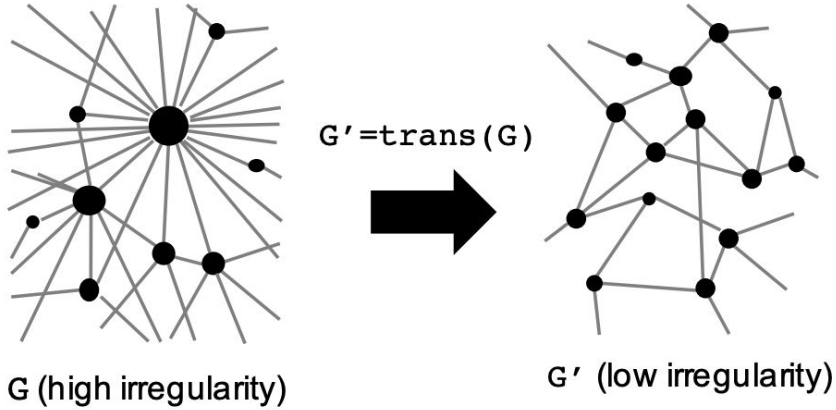
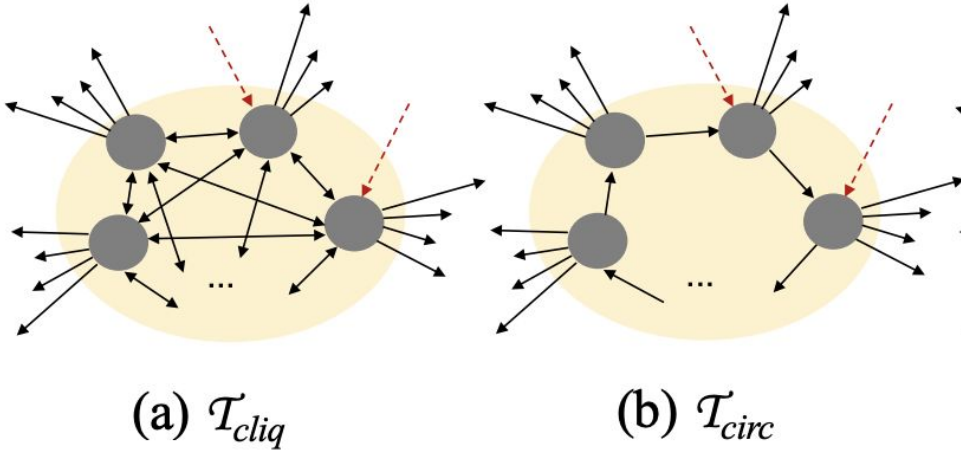
  - **Circular**





Graph Regularization

- Methods include transformations:
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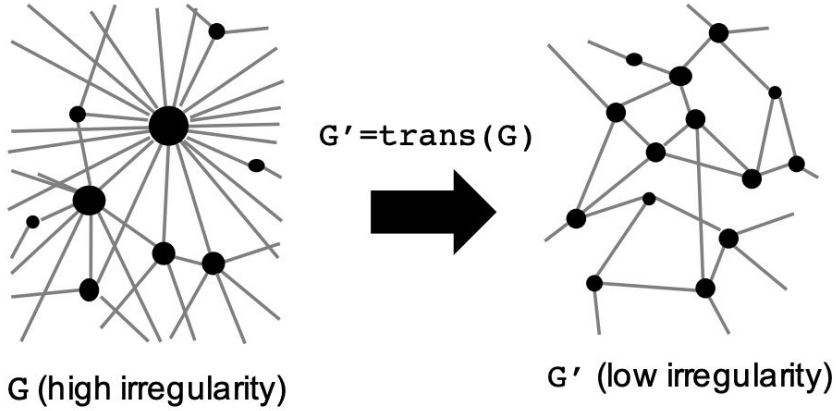
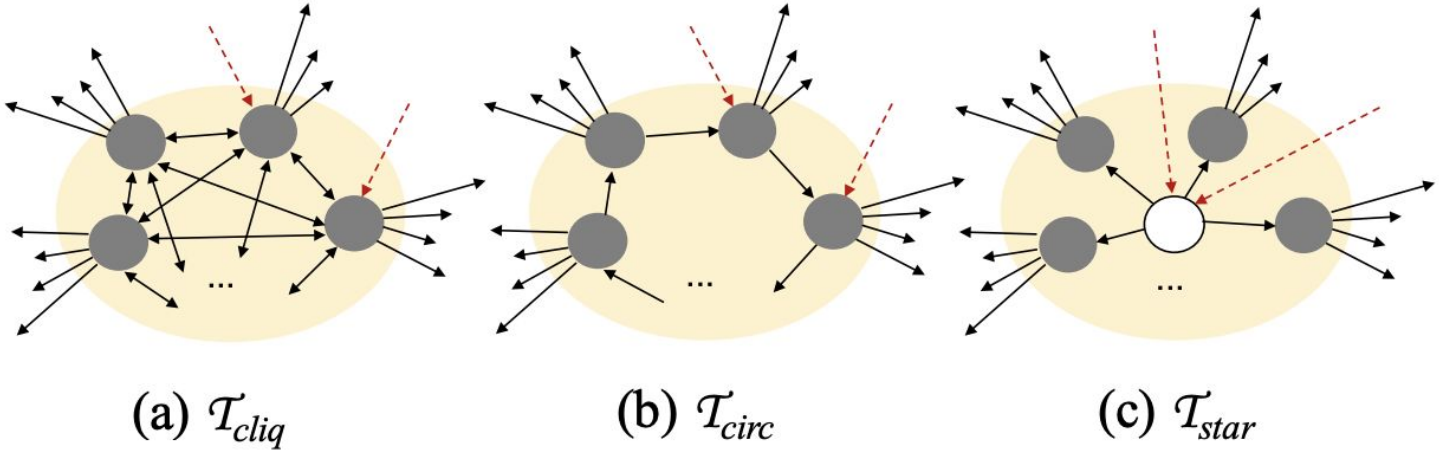
  - Circular
  - **Star**





Tigr - Transforming Irregular Graphs into more Regular ones

- **Claim that GPU-based graph algorithms suffer due to power law structure**

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  - **Altering the graph algorithms**

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- Previous works addressed the issue by:
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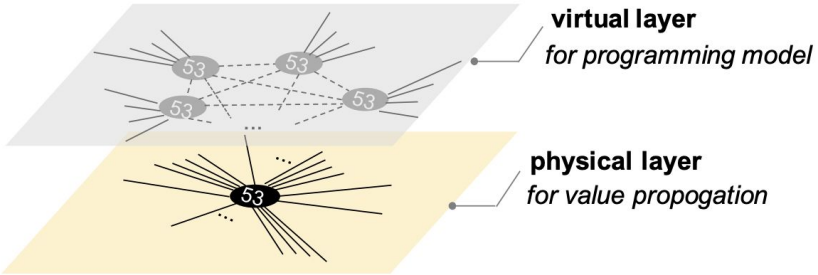
  - Altering the graph algorithms
- **Tigr targets the fundamental issue of irregularity by transforming the graph *virtually***



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CuSha

- **Use shards!!!**

https://dl.acm.org/doi/10.1145/2600212.2600227

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- Representing graph with shards has improved I/O performance for disk based graph processing

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CuSha

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- Representing graph with shards has improved I/O performance for disk based graph processing

- Shards allow contiguous placement of graph data required by a set of computation.

- G-Shards representation employs shard concept and modifies it appropriately for GPU.

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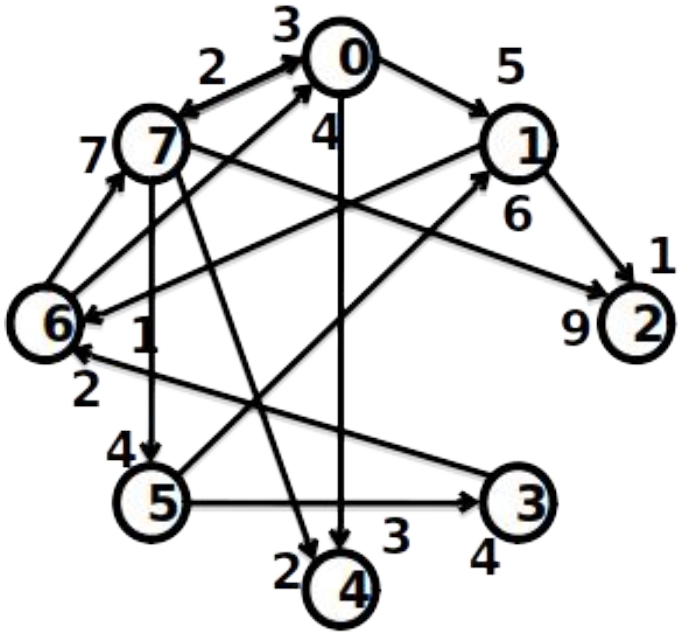
CuSha



Shard 0

SrcIndex	SrcValue	EdgeValue	DestIndex
0	x_0	5	1
1	x_1	1	2
5	x_5	6	1
5	x_5	4	3
6	x_6	4	0
7	x_7	3	0
7	x_7	9	2

Shard 1

SrcIndex	SrcValue	EdgeValue	DestIndex
0	x_0	3	4
0	x_0	2	7
1	x_1	1	6
3	x_3	2	6
6	x_6	7	7
7	x_7	2	4
7	x_7	4	5

VertexValues	x_0	x_1	x_2	x_3	x_4	x_5	x_6	x_7

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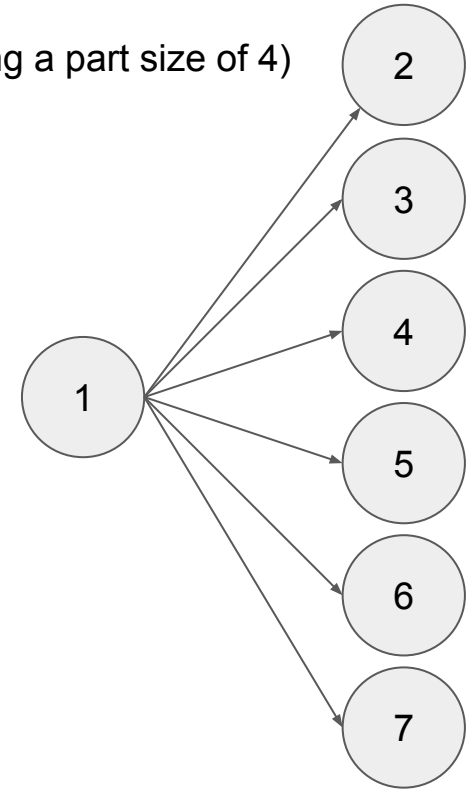
- We want to make graph algorithms run faster
- CUSHA uses G-shards to appropriately manage GPU resources
- What if we convert graph to more regularized one using an intermediate representation and input to CUSHA
- **This representation has lower out degree hence making it larger in size but regularized and efficient to process**

Hypothesis

- Can we achieve better performance from CuSha if we perform a physical graph transformation (UDT) that regularizes the graph before inputting it into CuSha?

Uniform-Degree Tree Transformation

(Using a part size of 4)



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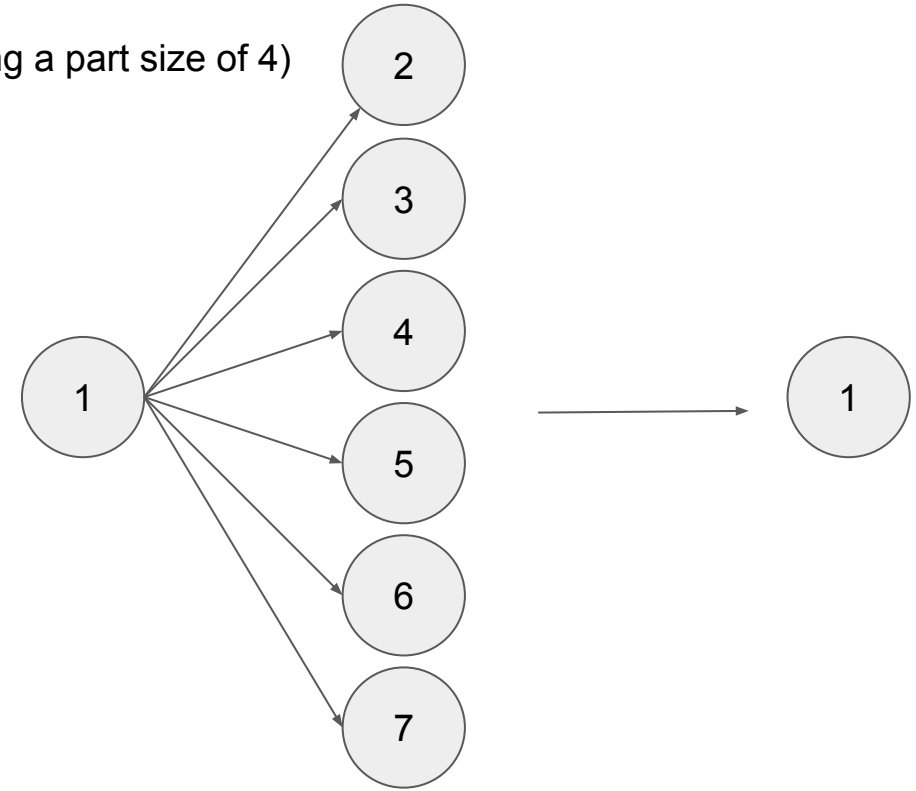

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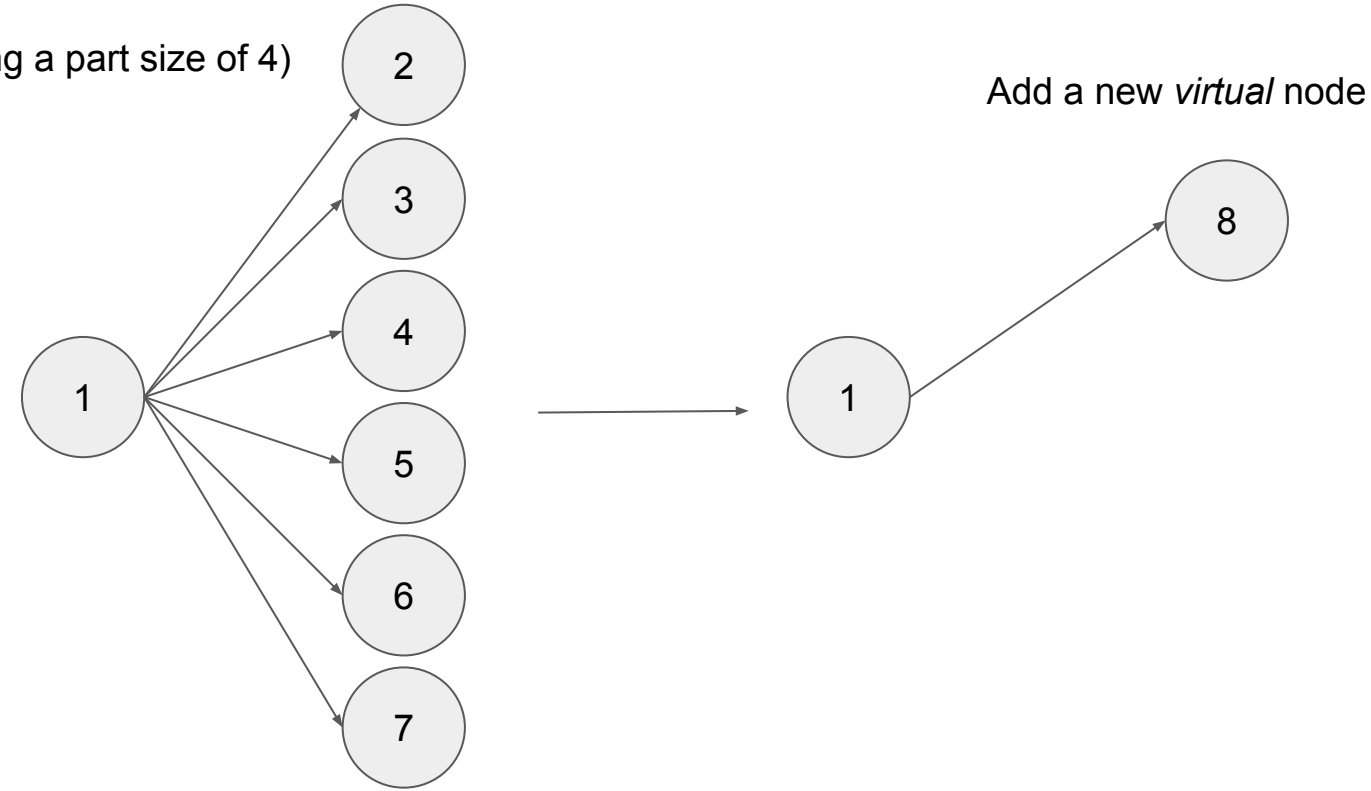

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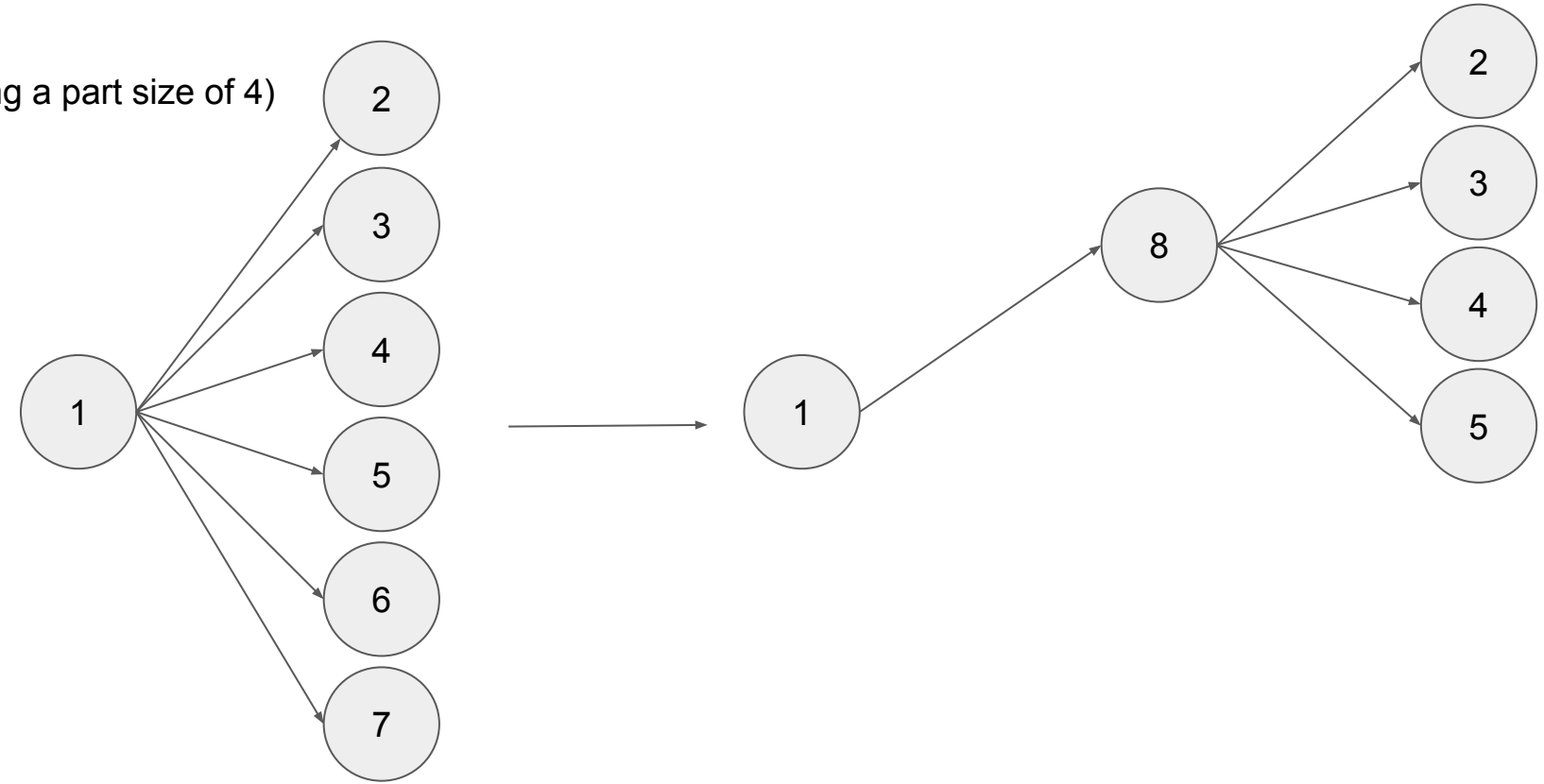

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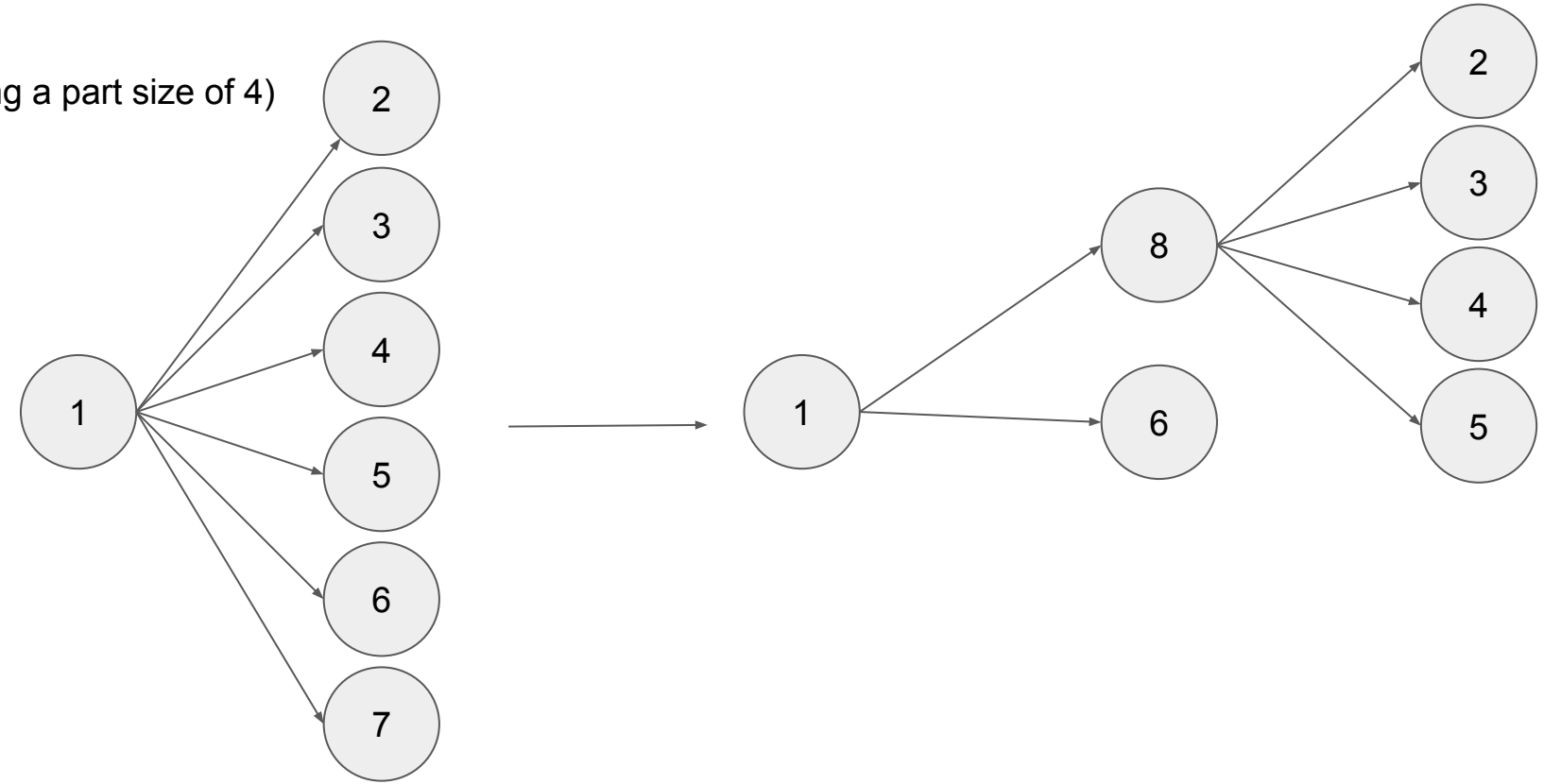

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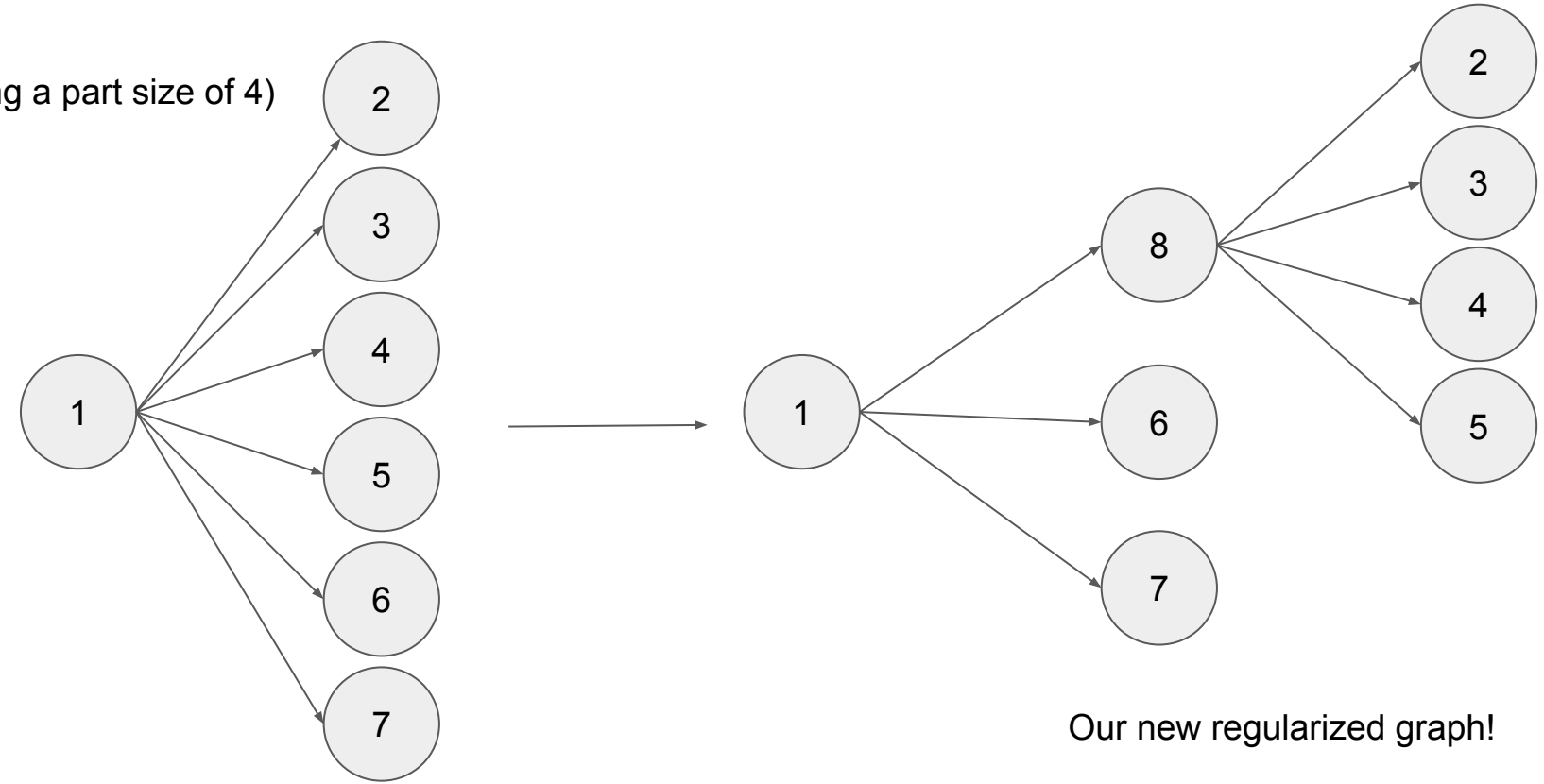

Our new regularized graph!

MACHINE CONFIGURATION

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Datasets

- Pokec social network[1]
  - 1632803 vertices, 30622564 edges
- Higgs twitter[2]
  - 456627 vertices, 14855842 edges
- Amazon product co-purchasing network[3]
  - 403394 vertices, 3387388 edges

1 - https://snap.stanford.edu/data/soc-Pokec.html
2 - https://snap.stanford.edu/data/higgs-twitter.html
3 - https://snap.stanford.edu/data/amazon0601.html

EXPERIMENTATION

- **Computation time for UDT-CuSha on BFS and SSSP**

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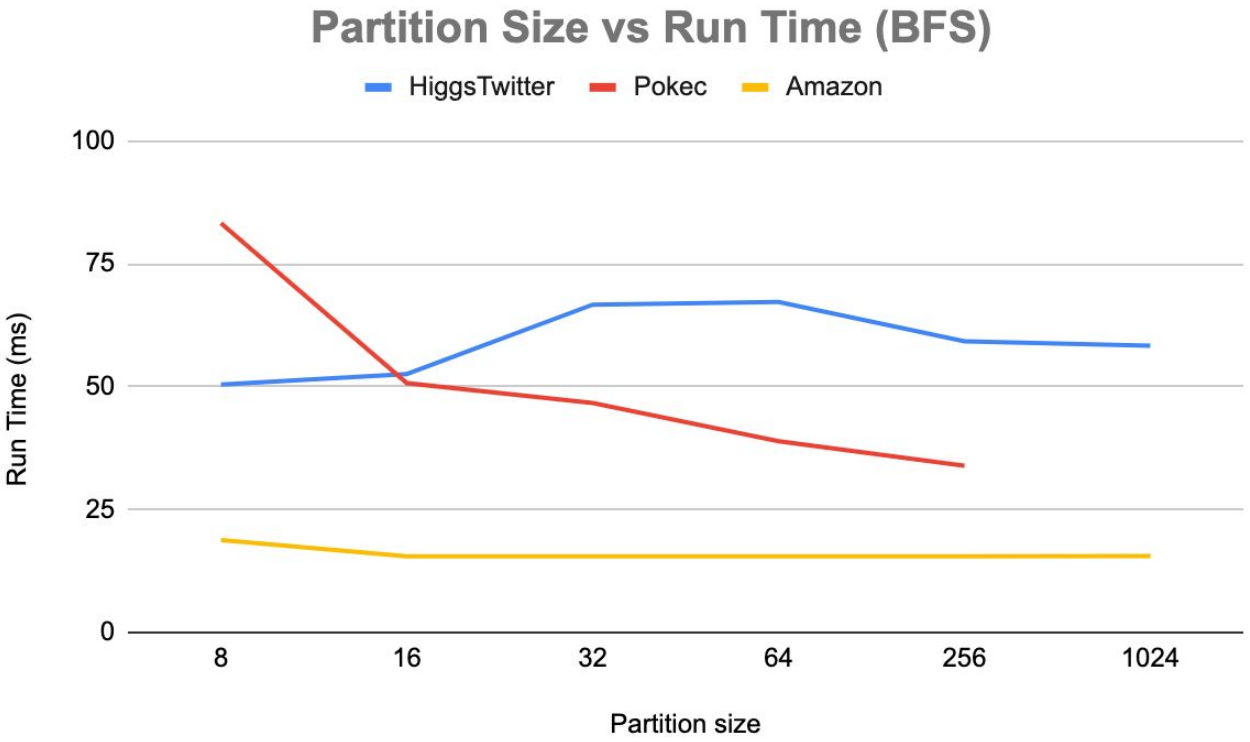
- **Comparison with baseline (Tigr-V+ and CuSha)**

Experimentation Results



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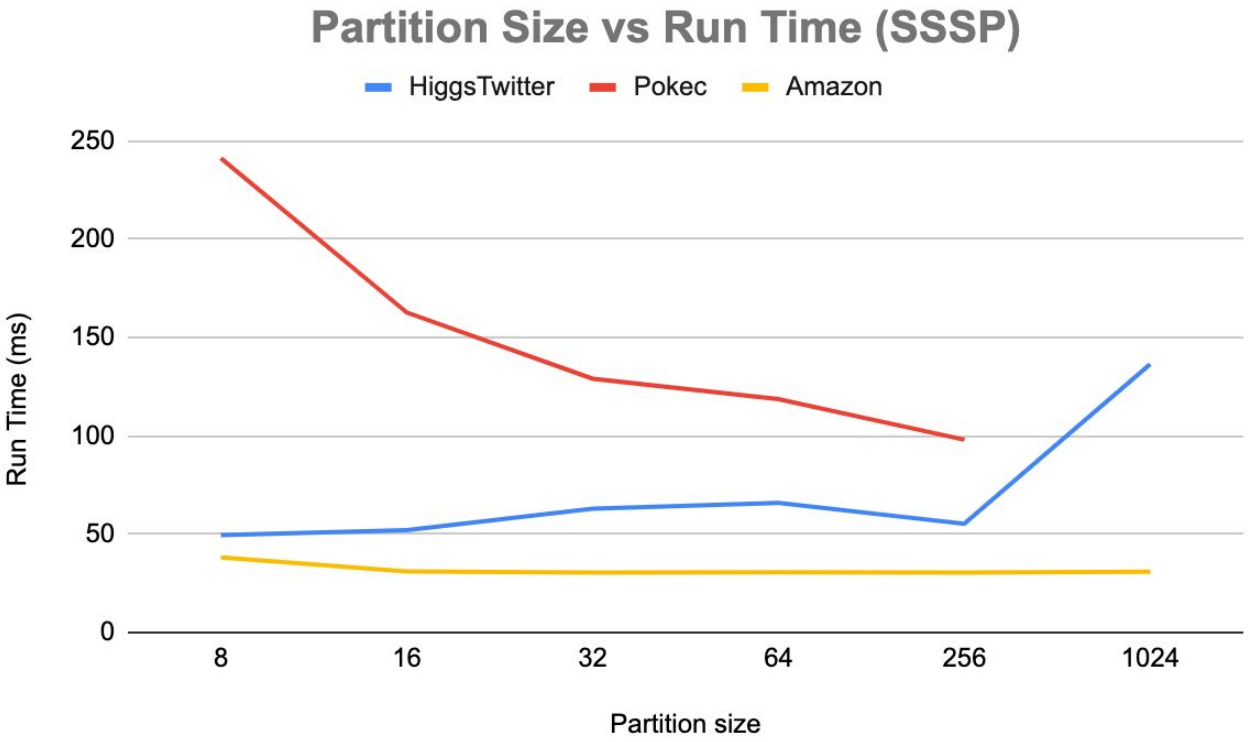

Comparisons with Baselines

Twitter	UDT-CuSha	UDT-CuSha	UDT-CuSha	UDT-CuSha	UDT-CuSha	UDT-CuSha	CuSha	Tigr
Part Size	8	16	32	64	256	1024	N/A	8
Time (ms)	**49.4730**	**52.0758**	**62.9978**	**65.9644**	**55.3284**	136.479	132.789	6.7826

Amazon	UDT-CuSha	UDT-CuSha	UDT-CuSha	UDT-CuSha	UDT-CuSha	UDT-CuSha	CuSha	Tigr
Part Size	8	16	32	64	256	1024	N/A	8
Time (ms)	38.1308	30.966	**30.4466**	30.5708	**30.4798**	30.8584	30.5586	7.182

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  - **As part_size increases, performance on Higgs decreases, performance on Amazon**
  - **Similar size graphs, however:**
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- **Trade-off between increased number of nodes and regularization**

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- UDT transformation is useful, but only for graphs with high irregularity
- Analysis of graph prior to execution of algorithms is very important
  - A graph that has small maximum outgoing edges will not benefit from UDT
- **Try adjusting virtual warp size in CuSha algorithm to match part size**

QUESTIONS?