Accelerating Dynamic Graph Analytics on GPUs

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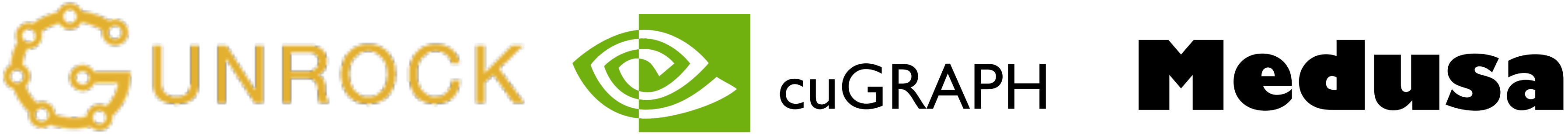
Presenter: Mo Sha
Aug 29th, 2018

Outline

- Introduction
- GPMA Dynamic Graph Processing
- GPMA+ Optimization
- Evaluation
- Conclusion

Introduction

GPU Accelerated Graph Analytics

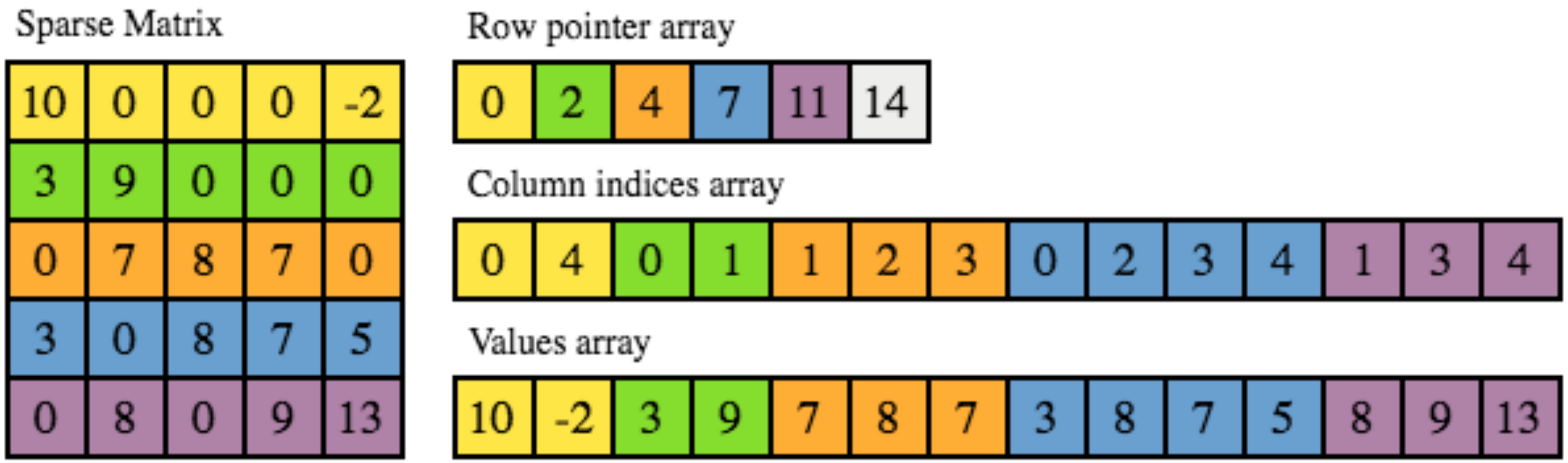


[1] https://gunrock.github.io
[2] https://developer.nvidia.com/nvgraph
[3] https://github.com/pymedusa/Medusa

Introduction

GPU Accelerated Graph Analytics

- Existing GPU Accelerated Graph Analytics focus on conducting graph primitives on static graphs.
- CSR(-like) graph format is widely used due to GPU computational architecture for better parallelism scheduling.



Sparse Matrix

10	0	0	0	-2
3	9	0	0	0
0	7	8	7	0
3	0	8	7	5
0	8	0	9	13

Row pointer array

0	2	4	7	11	14

Column indices array

0	4	0	1	1	2	3	0	2	3	4	1	3	4

Values array

10	-2	3	9	7	8	7	3	8	7	5	8	9	13

Introduction

GPU Accelerated Graph Analytics

- Existing GPU Accelerated Graph Analytics focus on conducting graph primitives on static graphs.
- CSR(-like) graph format is widely used due to GPU computational architecture for better parallelism scheduling.
- For evolving graphs, an entire rebuilding is required for each single update, which significantly limits the performance on evolving graphs.

Introduction

Dynamic Graph Format on GPUs requires …

- To support edge insertion, deletion, and edge value modification.
- To be compatible with existing GPU-based graph algorithms.
- An acceptable trade-off between update efficiency and the overhead introduced.

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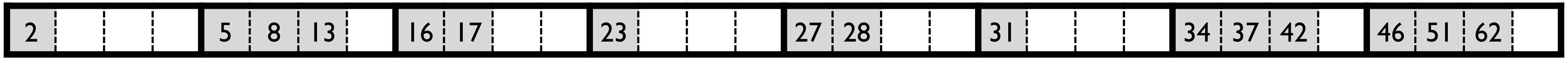
GPMA Dynamic Graph Processing

Introduce Packed Memory Array into GPU Graph Analytics

- Sort elements in a partially continuous fashion
- Leave gaps on each segment with a bounded ratio
- Self-balancing binary tree structure
- The amortized insertion complexity of PMA is proved to be $O(\log^2 N)$ in the worst case and $O(\log N)$ in the average case.

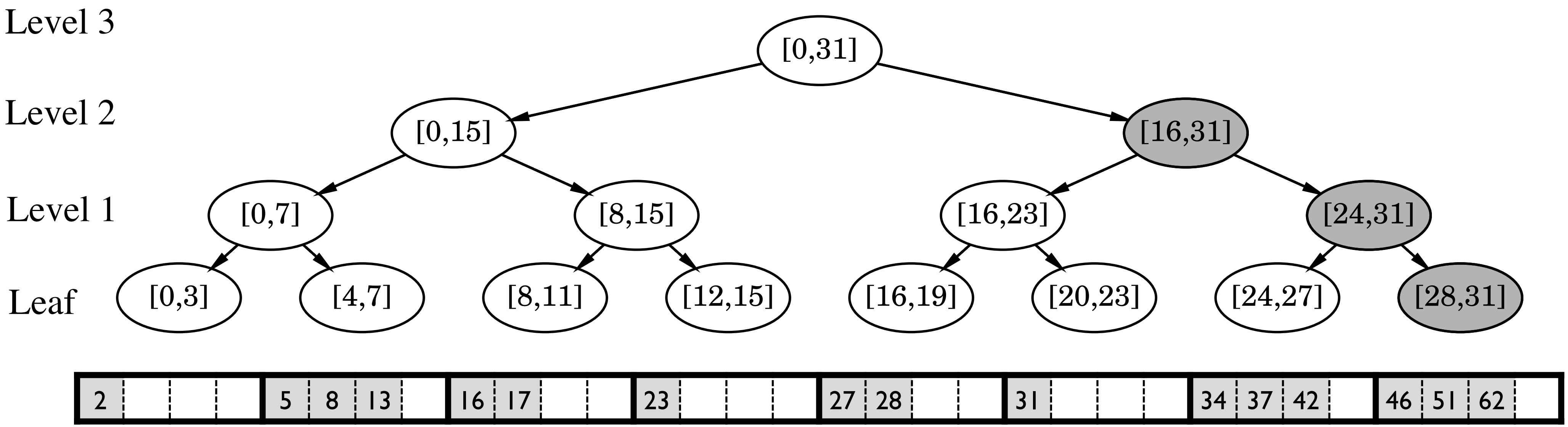


2				5	8	13		16	17			23				27	28			31				34	37	42		46	51	62	

[1] Bender, M. A., Demaine, E. D., & Farach-Colton, M. Cache-oblivious b-trees. SIAM J. Comput., 35(2):341–358, 2005.
[2] M. A. Bender and H. Hu. An adaptive packed-memory array. ACM Trans. Database Syst., 32(4), 2007.

GPMA Dynamic Graph Processing

	Leaf	Level 1	Level 2	Level 3
segment size	4	8	16	32
density lower bound ρ	0.08	0.19	0.29	0.40
density upper bound τ	0.92	0.88	0.84	0.80
min # of entries	1	2	4	8
max # of entries	3	6	12	24



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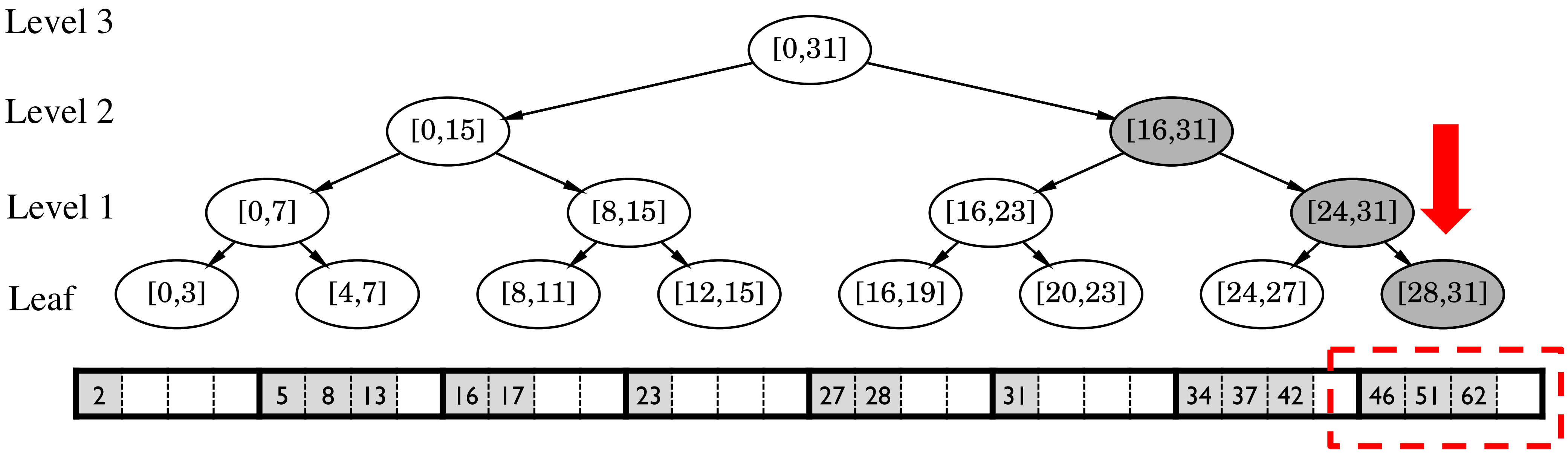

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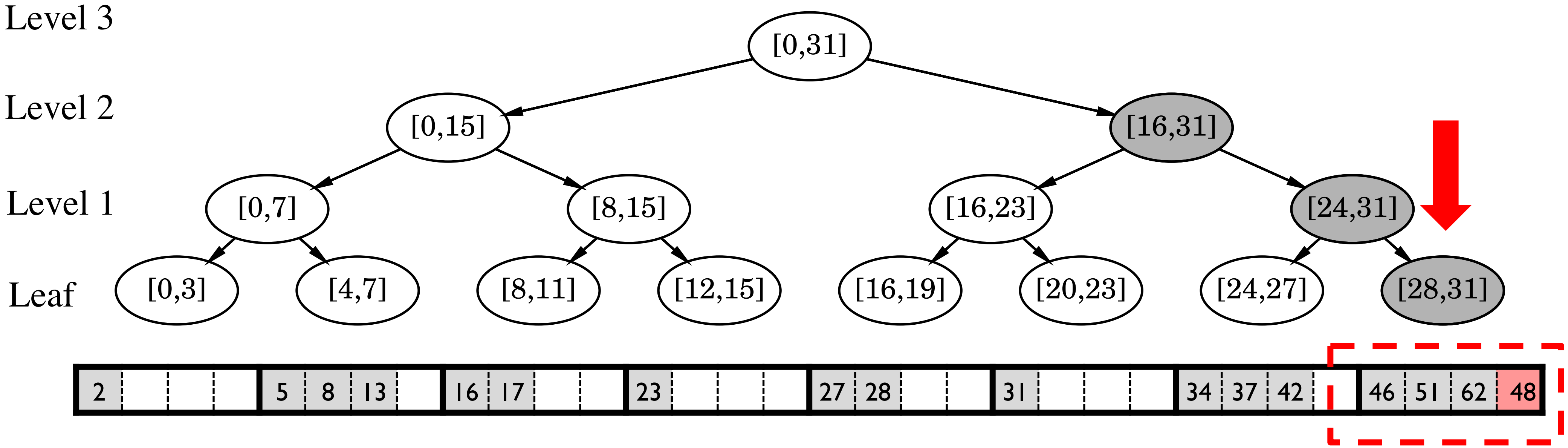

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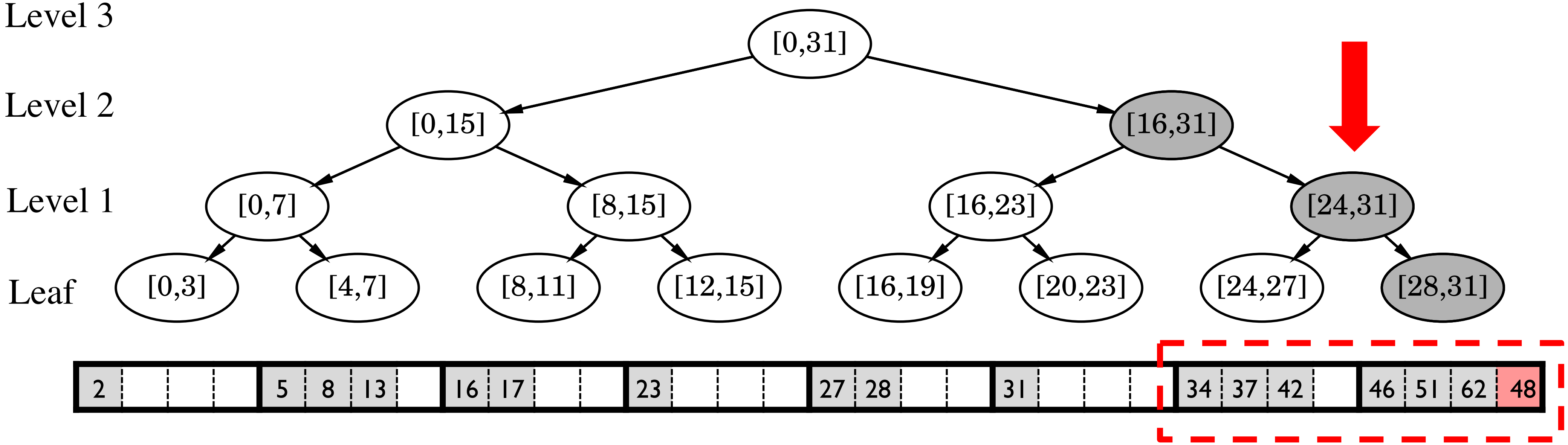

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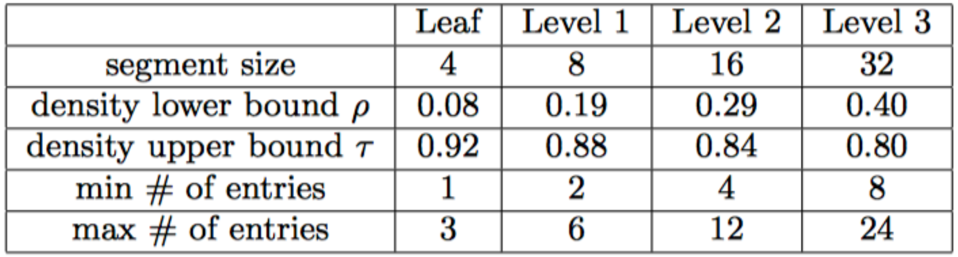

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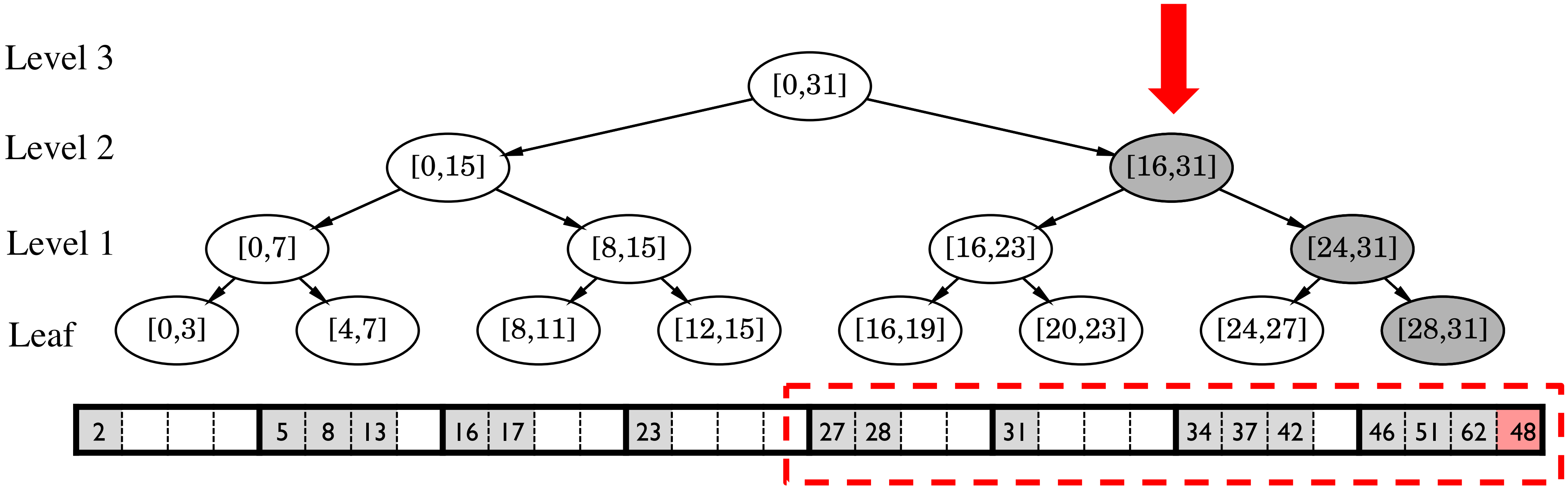

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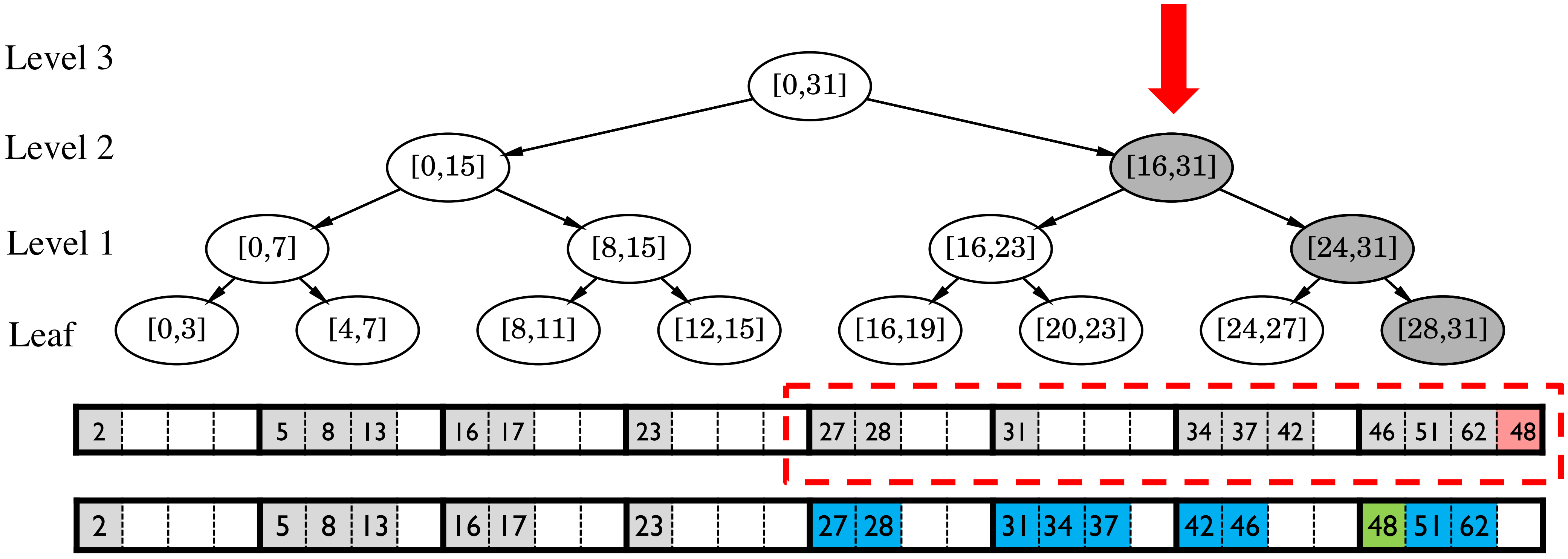

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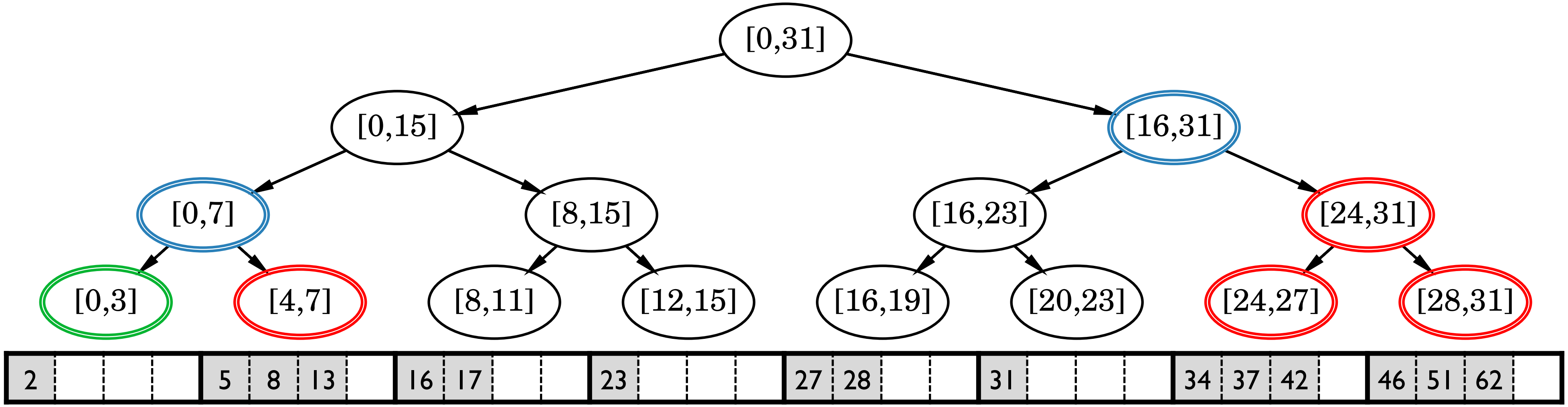

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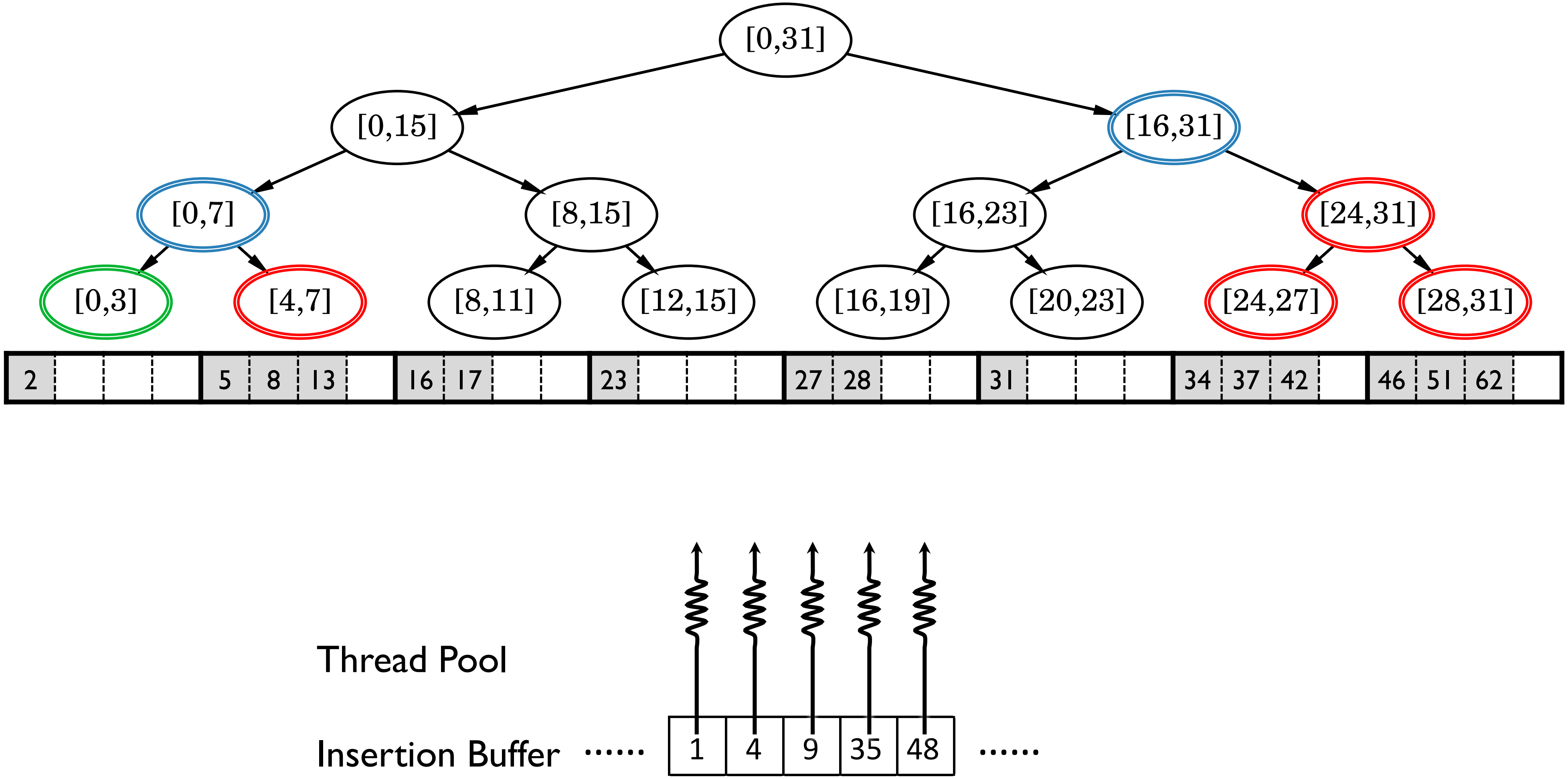

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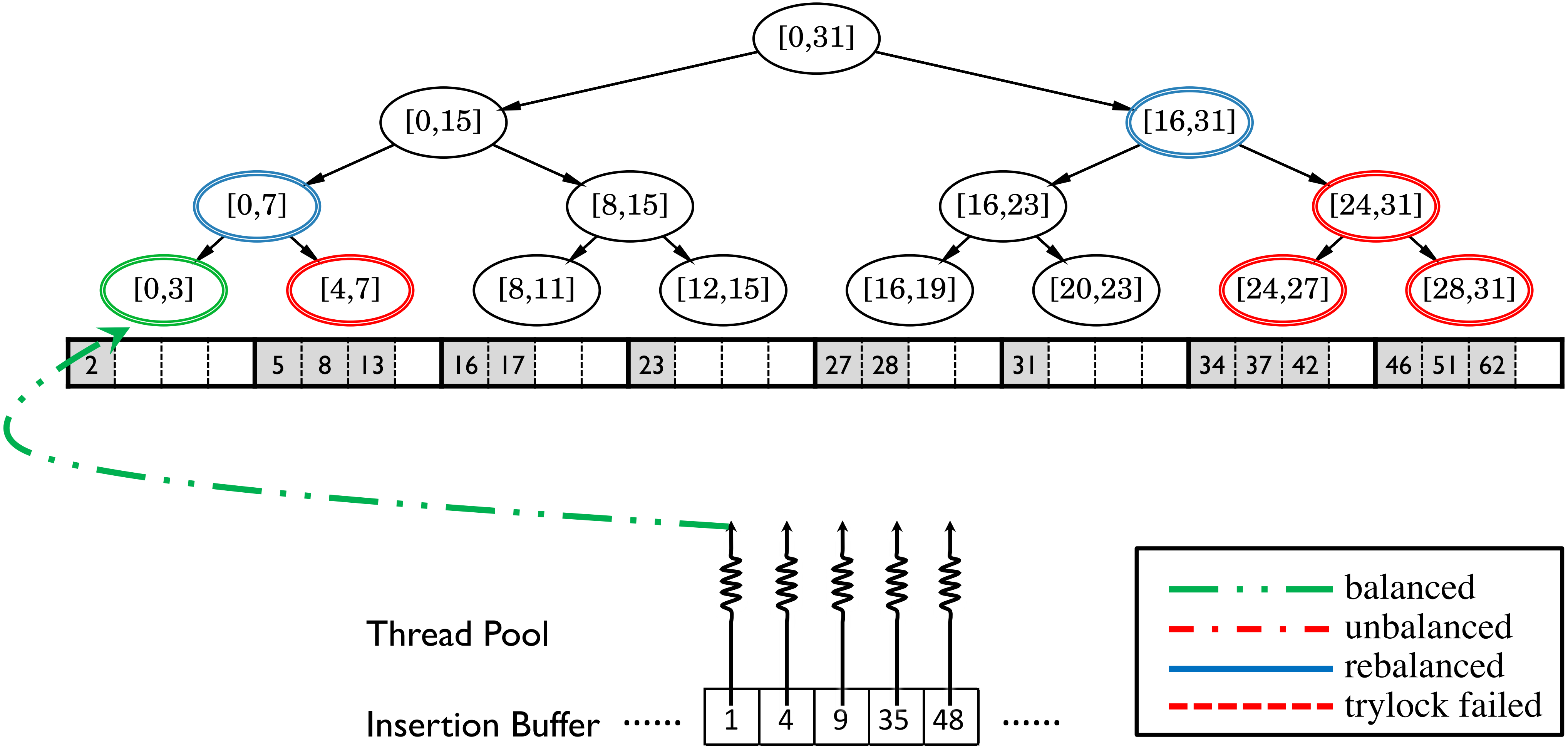
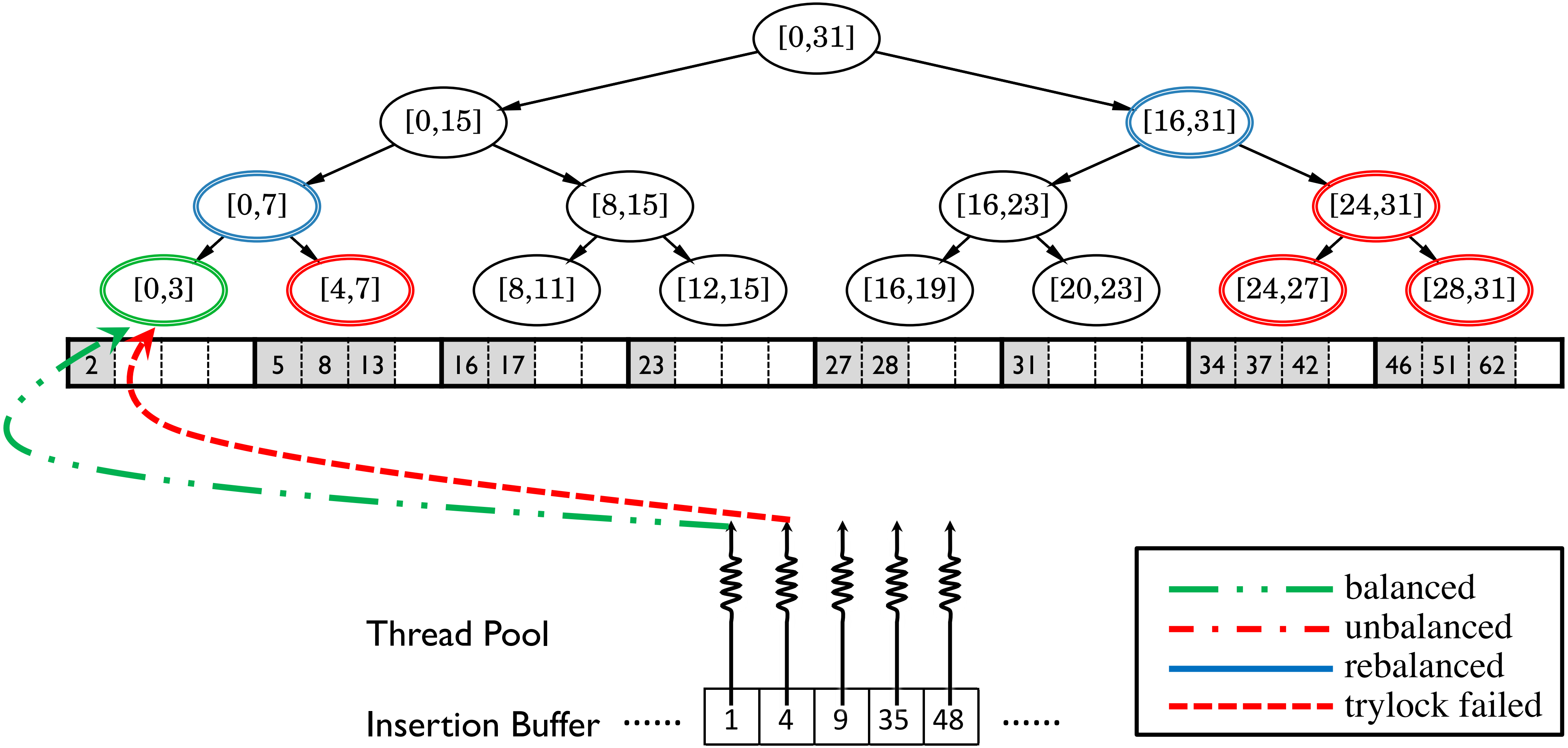


Thread Pool

Insertion Buffer

balanced
unbalanced
rebalanced
trylock failed

GPMA Dynamic Graph Processing



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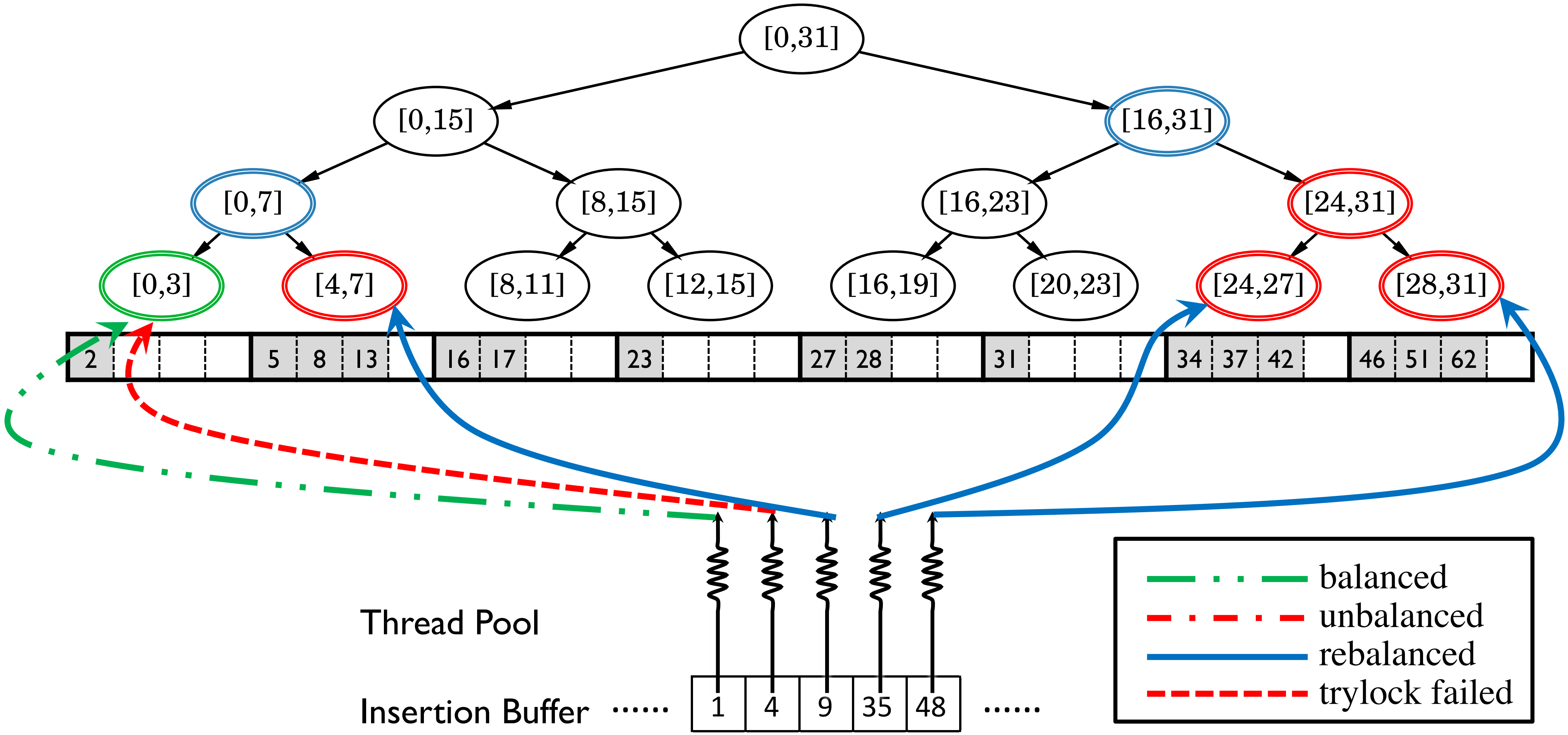

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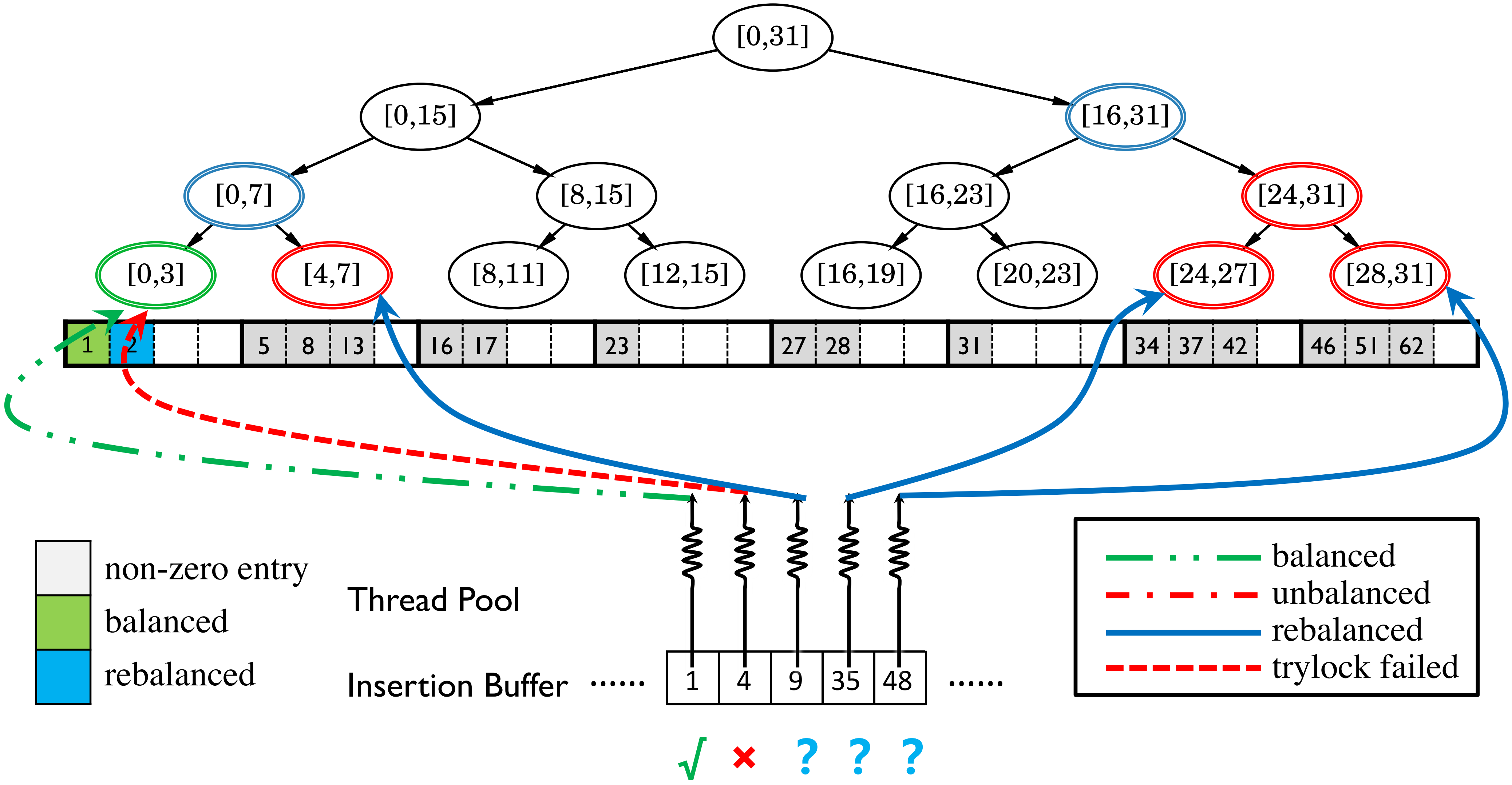

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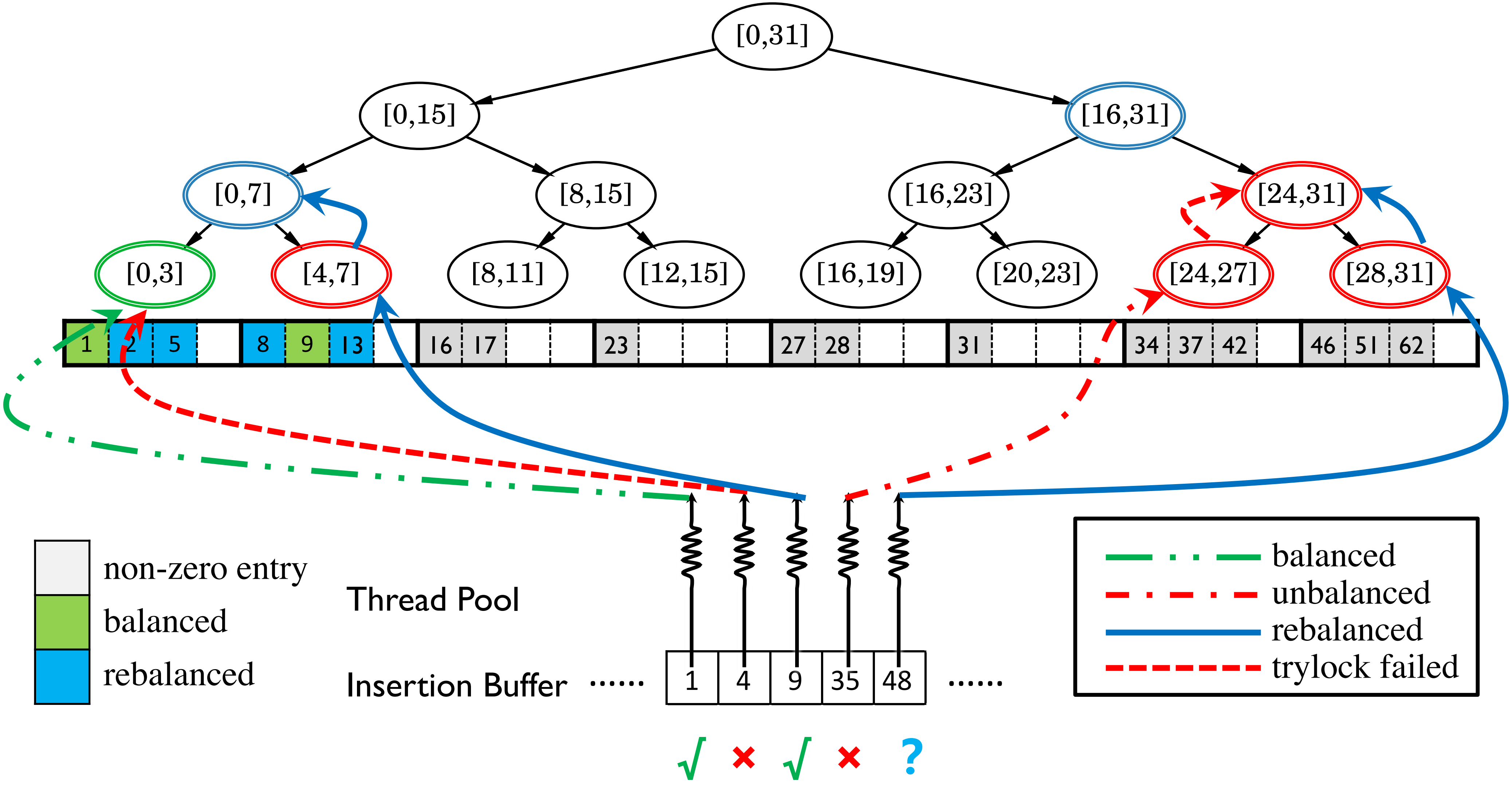


⬜ non-zero entry

🟩 balanced

🟦 rebalanced

Thread Pool

Insertion Buffer ······ 1 | 4 | 9 | 35 | 48 ······

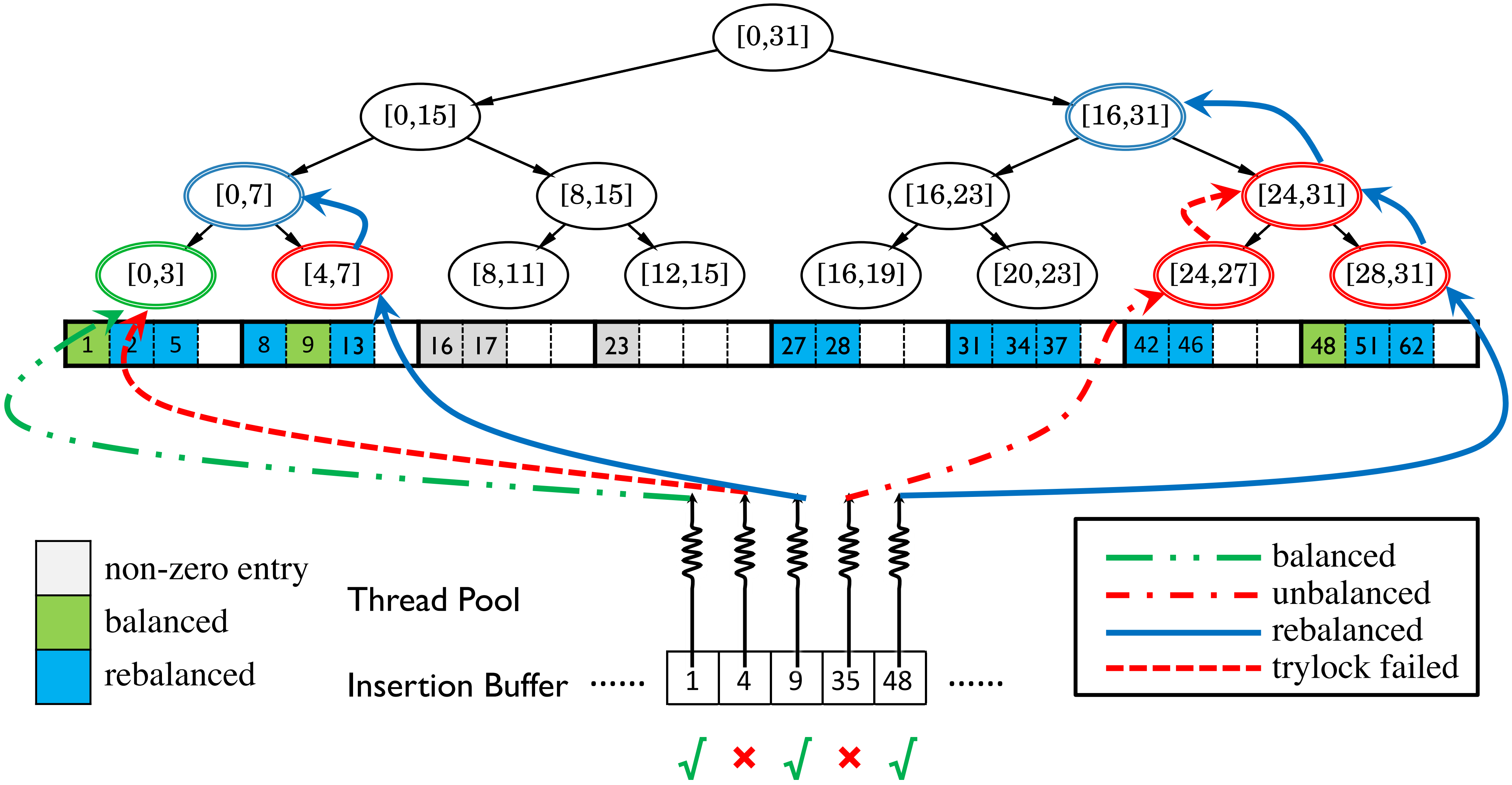
— · · — balanced

— · — unbalanced

—— rebalanced

- - - trylock failed

GPMA Dynamic Graph Processing



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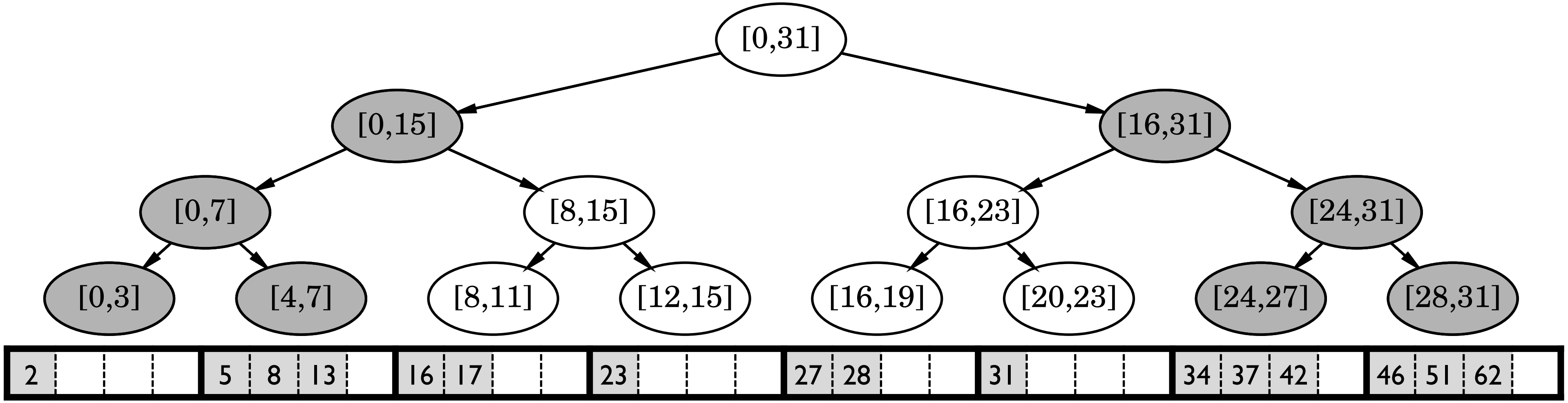
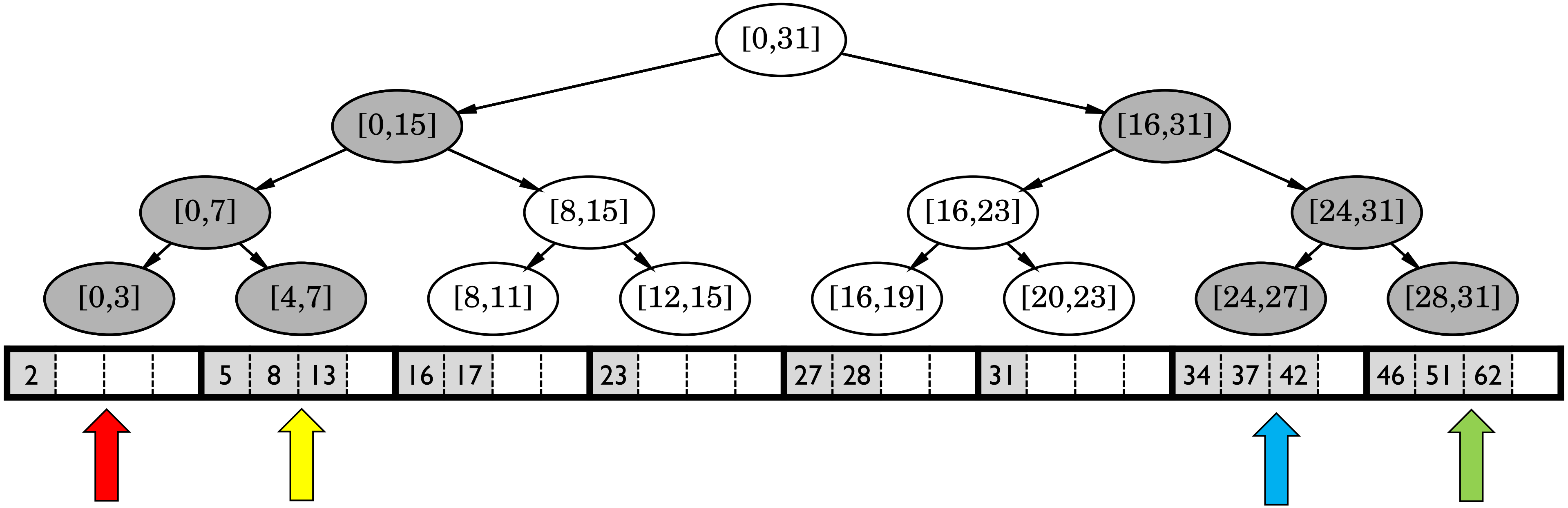
GPMA+ Optimization



Insertion Keys:

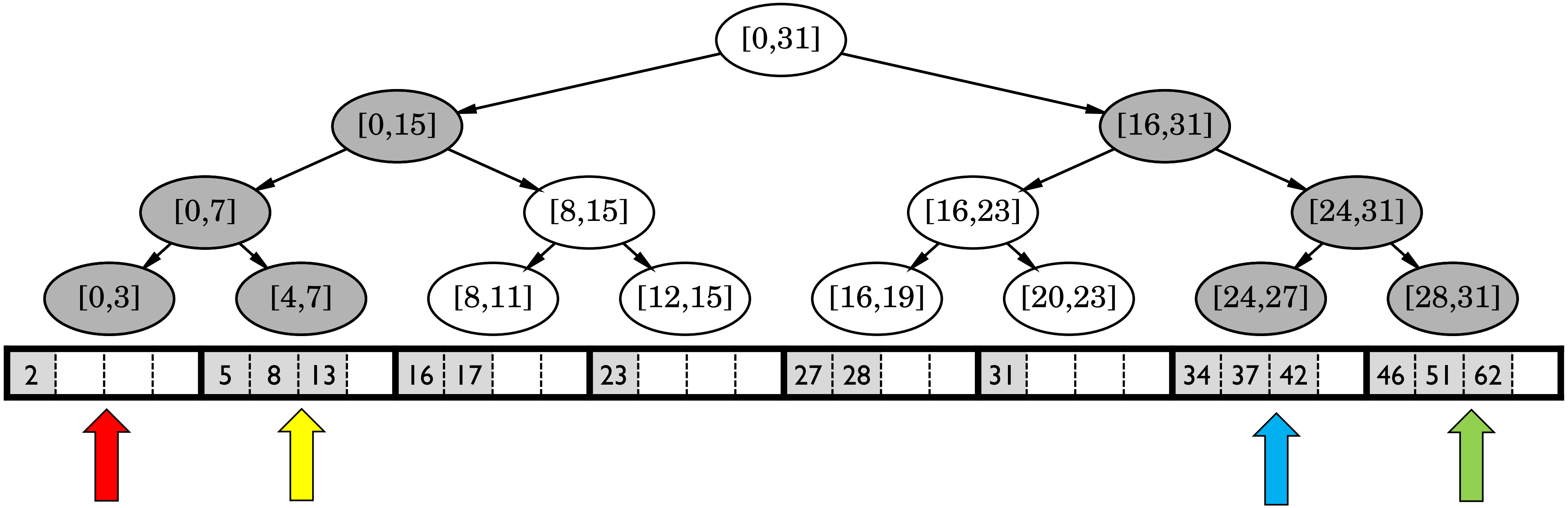
1	4	9	35	48

GPMA+ Optimization



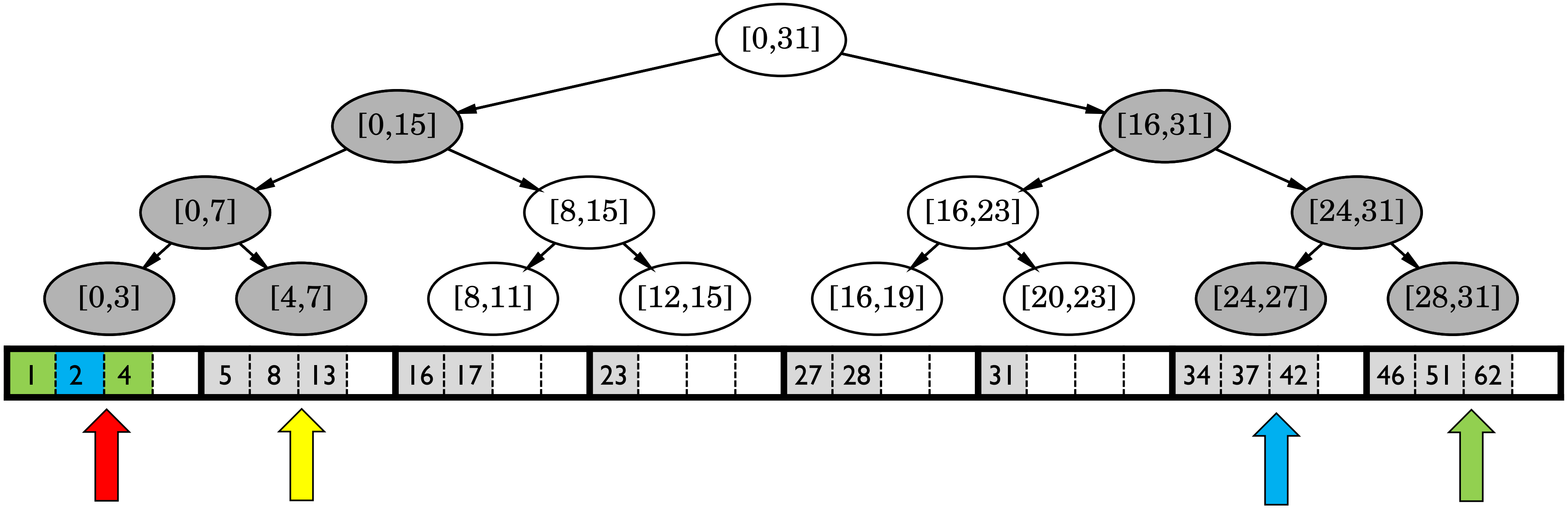
Insertion Keys:	1	4	9	35	48
Leaf Segments:	0	0	4	24	28

GPMA+ Optimization



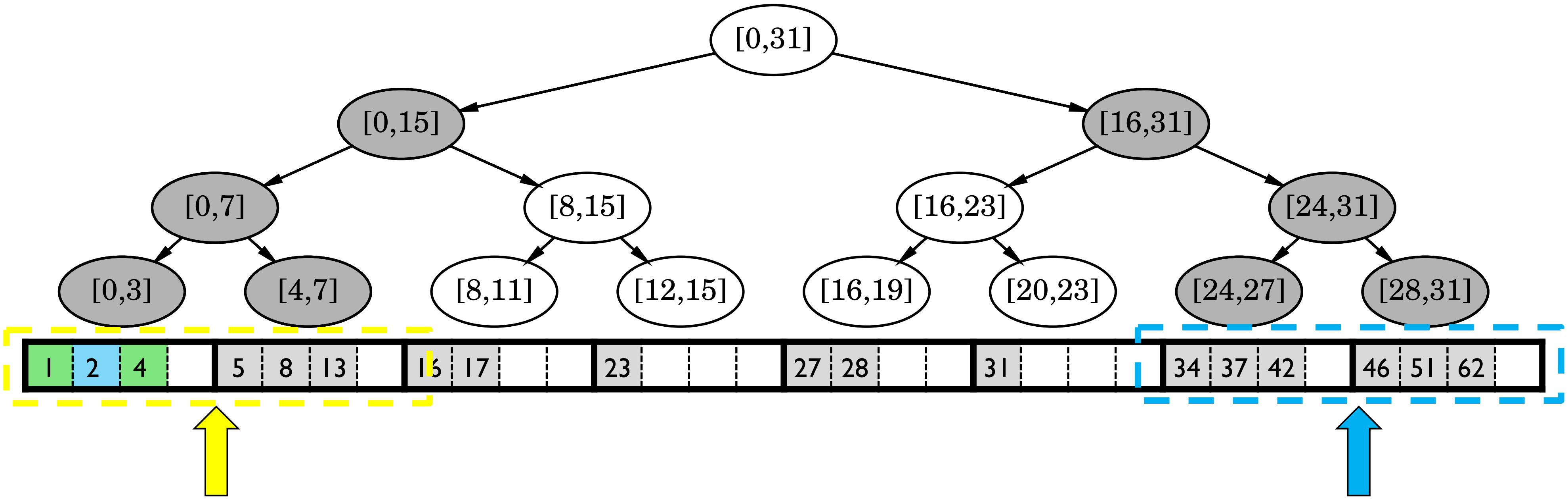
Insertion Keys:	1	4	9	35	48
Leaf Segments:	0	0	4	24	28
Update Segments:	0	4	24	28	
Update Offsets:	2	3	4	5	

GPMA+ Optimization



Insertion Keys:	1	4	9	35	48
Leaf Segments:	0	0	4	24	28
Update Segments:	0	4	24	28	
Update Offsets:	2	3	4	5	
Successful Flag:	Y	N	N	N	

GPMA+ Optimization



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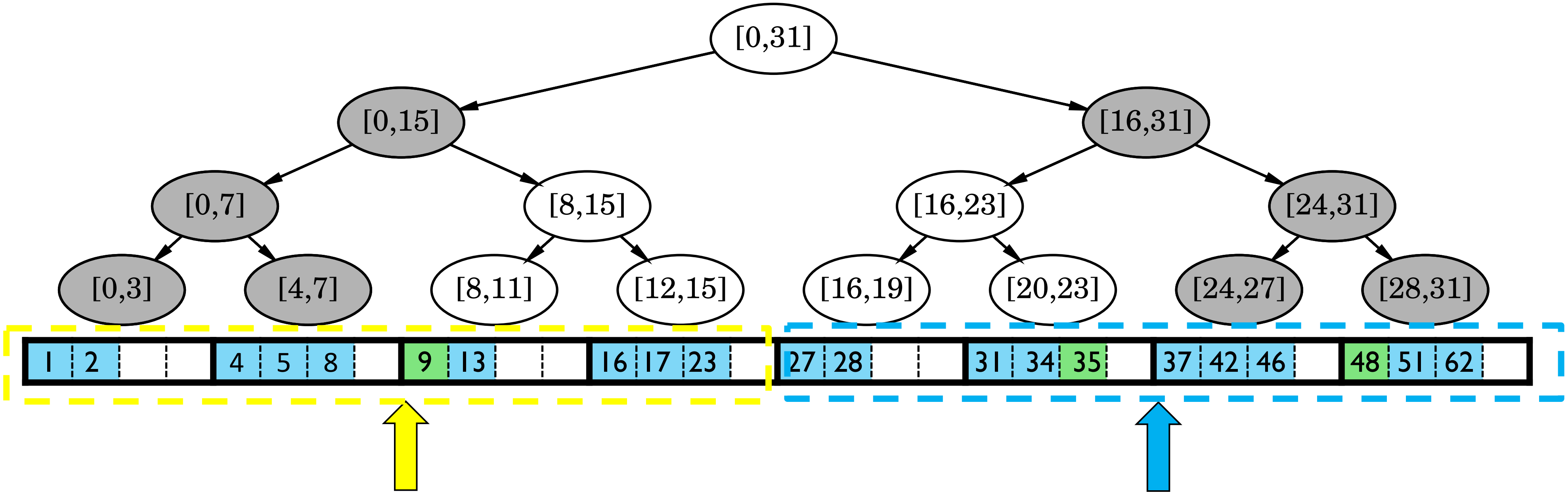
Leaf Segments:	0	0	4	24	28
Update Segments:	0	4	24	28	
Update Offsets:	2	3	4	5	
Successful Flag:	Y	N	N	N	

Insertion Keys:	9	35	48
Update Segments:	0	24	
Update Offsets:	1	3	
Successful Flag:	N	N	

GPMA+ Optimization



Insertion Keys:	1	4	9	35	48
Leaf Segments:	0	0	4	24	28
Update Segments:	0	4	24	28	
Update Offsets:	2	3	4	5	
Successful Flag:	Y	N	N	N	

Insertion Keys:	9	35	48
Update Segments:	0	24	
Update Offsets:	1	3	
Successful Flag:	N	N	

Insertion Keys:	9	35	48
Update Segments:	0	16	
Update Offsets:	1	3	
Successful Flag:	Y	Y	

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Evaluation

Datasets

	|V|	|E|
Reddit	2.61M	34.4M
Pokec	1.6M	30.6M
Graph500	1M	200M
Random	1M	200M

Specification

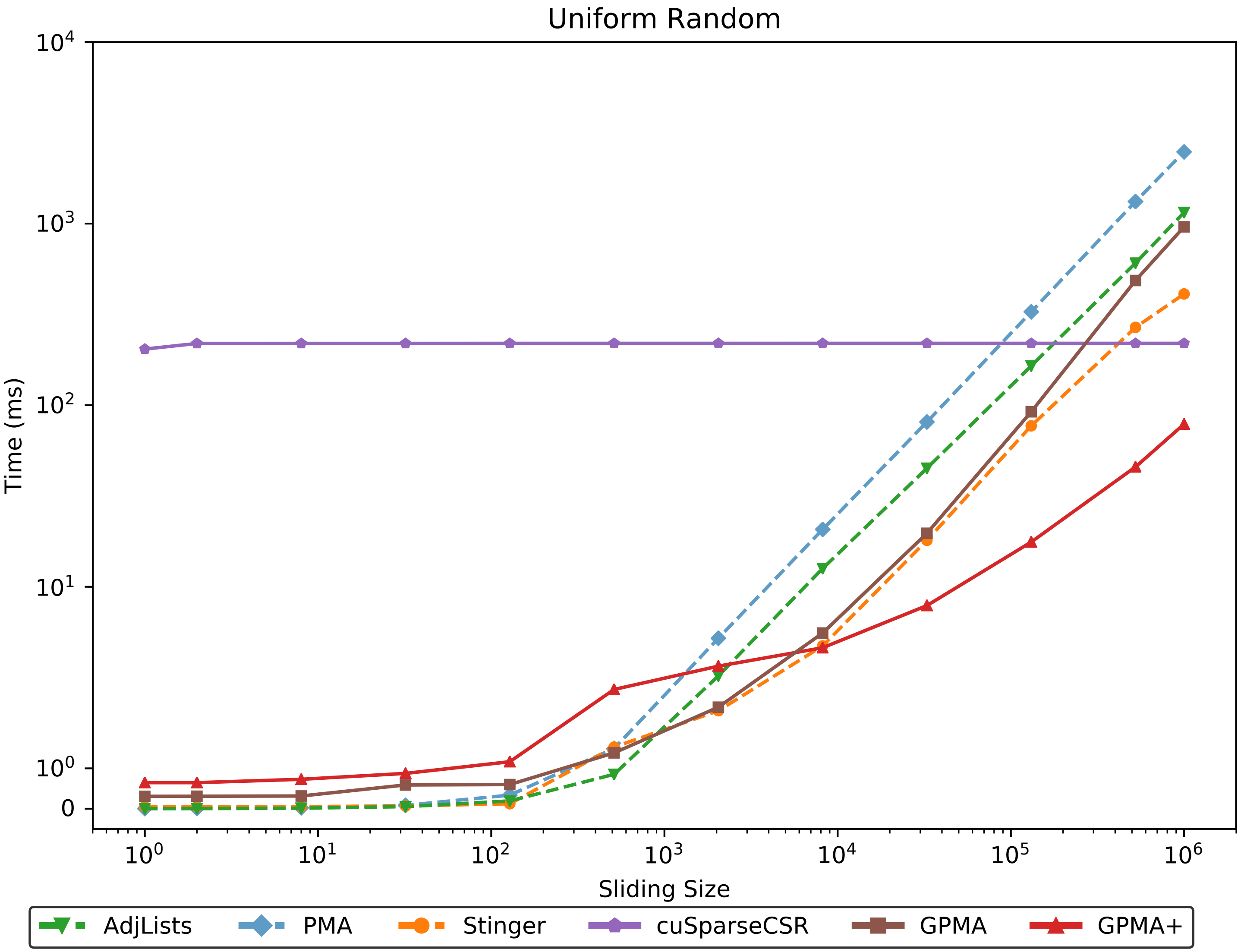
- CPU-based
  4-way Intel(R) Xeon(R) CPU E7-4820 v3
  40-cores, 1.90GHz
  128GB memory
- GPU-based
  Intel(R) Core i7-5820k
  6-cores, 3.30GHz
  64GB memory
  Nvidia GeForce Titan X 12GB

Baselines

	Container	BFS	Connect Component	PageRank
CPU Approaches	AdjLists	Standard Single Thread Algorithms		
	PMA			
	Stinger	Stinger built-in Parallel Algorithms		
GPU Approaches	cuSparseCSR	D. Merrill et al.	J. Soman et al.	CUSP SpMV
	GPMA+			

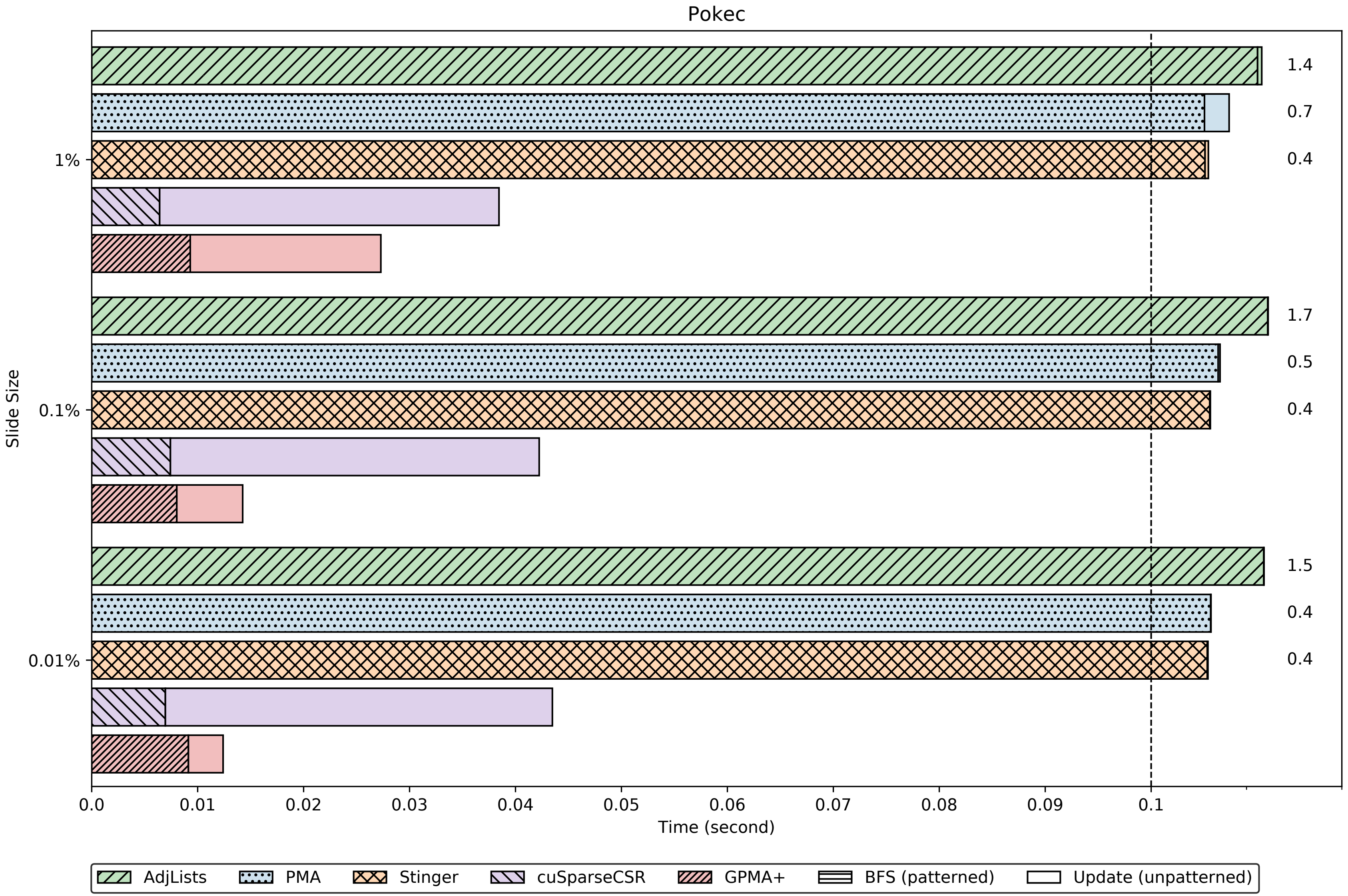
Evaluation

Insertion



Evaluation

BFS



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Conclusion

I. *We introduce a framework for GPU dynamic graph analytics and propose, the first of its kind, a GPU dynamic graph storage scheme to pave the way for real-time dynamic graph analytics on GPUs.*

II. *We devise two GPU-oriented parallel algorithms: GPMA and GPMA+, to support efficient updates against high-speed graph streams.*

III. *We conduct extensive experiments to show the performance superiority of GPMA and GPMA+.*

Thank you!

Open Source: https://github.com/desert0616/gpma_bfs_demo