

Replication-based Fault-tolerance for Large-scale Graph Processing

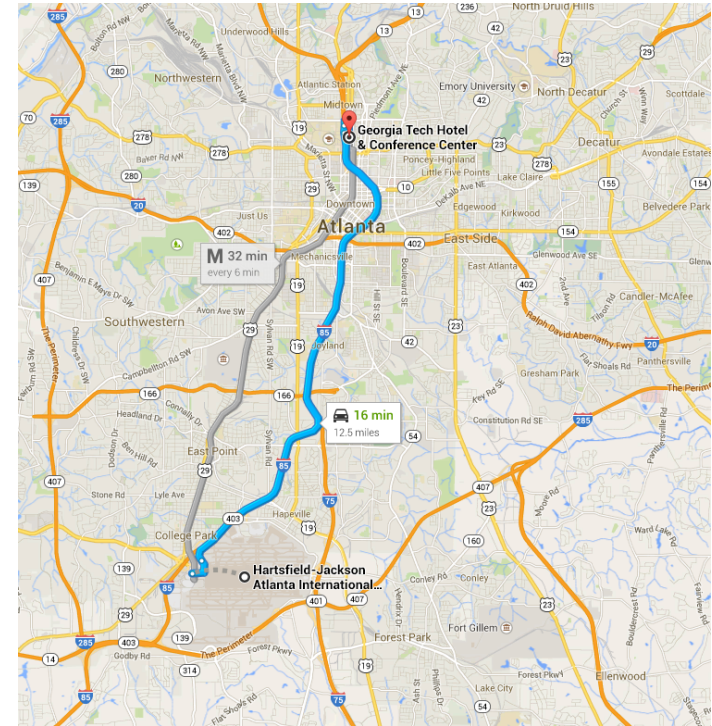
Rong Chen

joint work with Peng Wang, Kaiyuan Zhang,
Haibo Chen, Haibing Guan

Graph

- Useful information in graph
- Many applications
 - SSSP
 - Community Detection

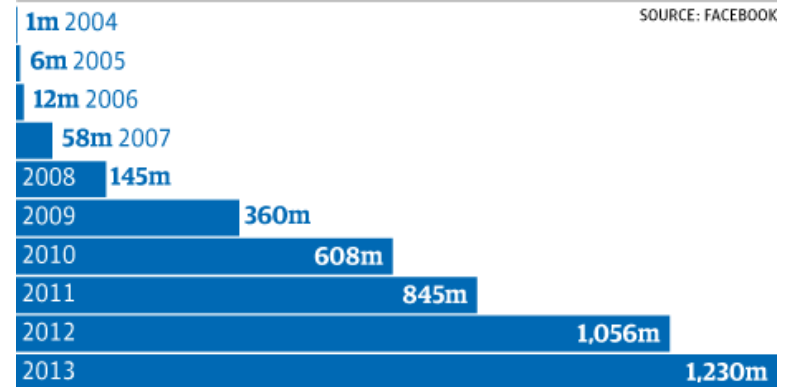
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Graph computing

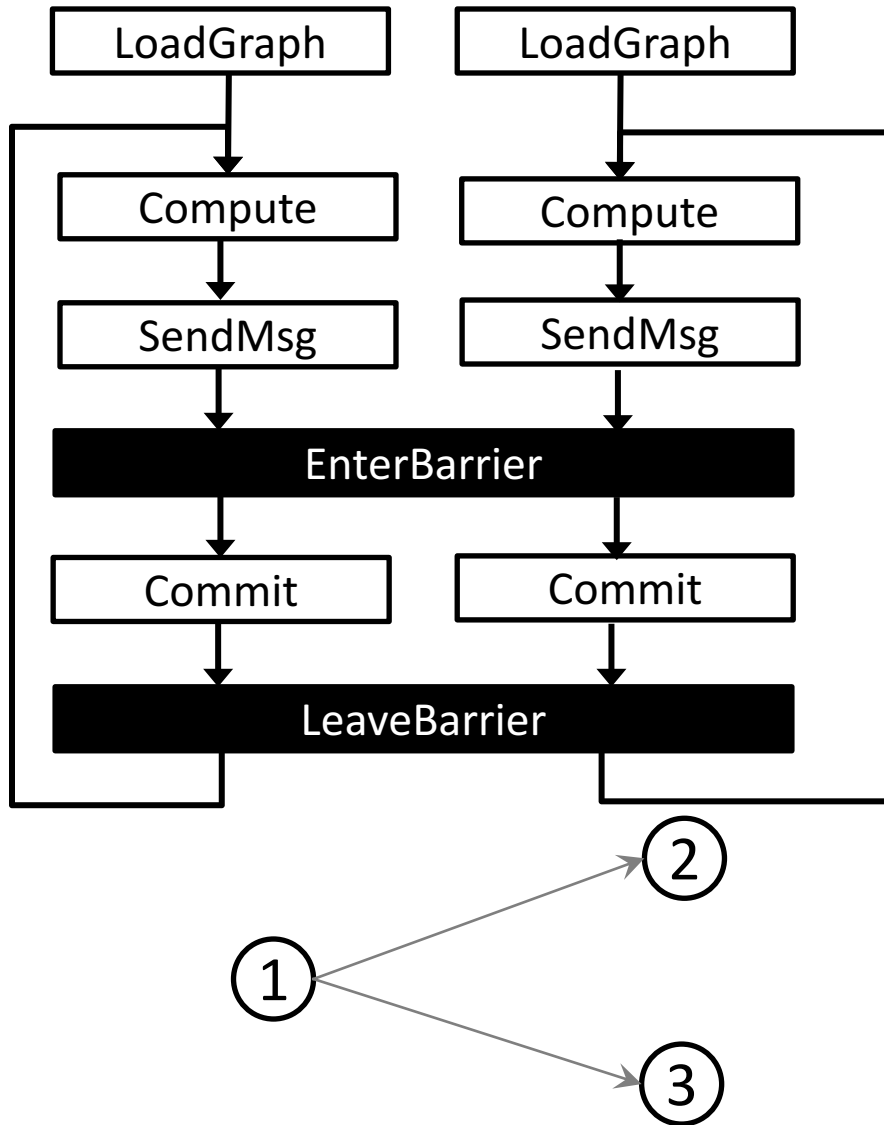
- Graphs are large
 - Require a lot of machines

Facebook monthly users



- Fault tolerance is important

How graph computing works



$$\text{PageRank: } R[i] = 0.15 + \sum_{j \in \text{Nbs}(i)} w_{ji} R[j]$$

PageRank(i)

// compute its own rank

total = 0

foreach (j in in_neighbors(i)) :

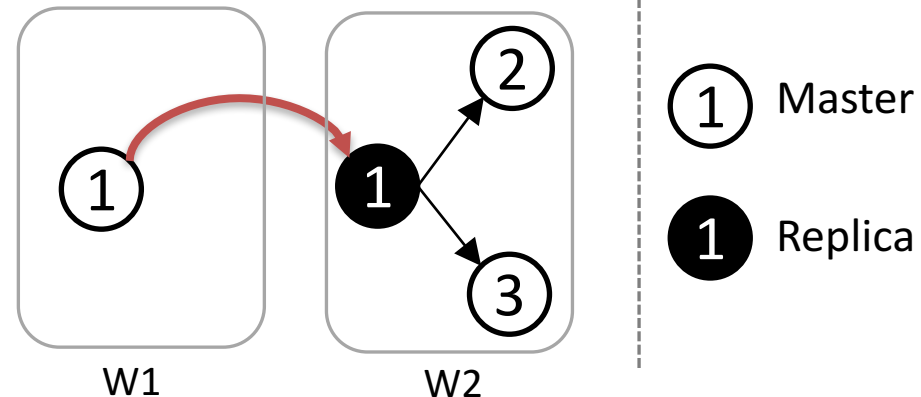
total = total + R[j] * w_{ji}

$R[i] = 0.15 + \text{total}$

// trigger neighbors to run again

if $R[i]$ not converged then

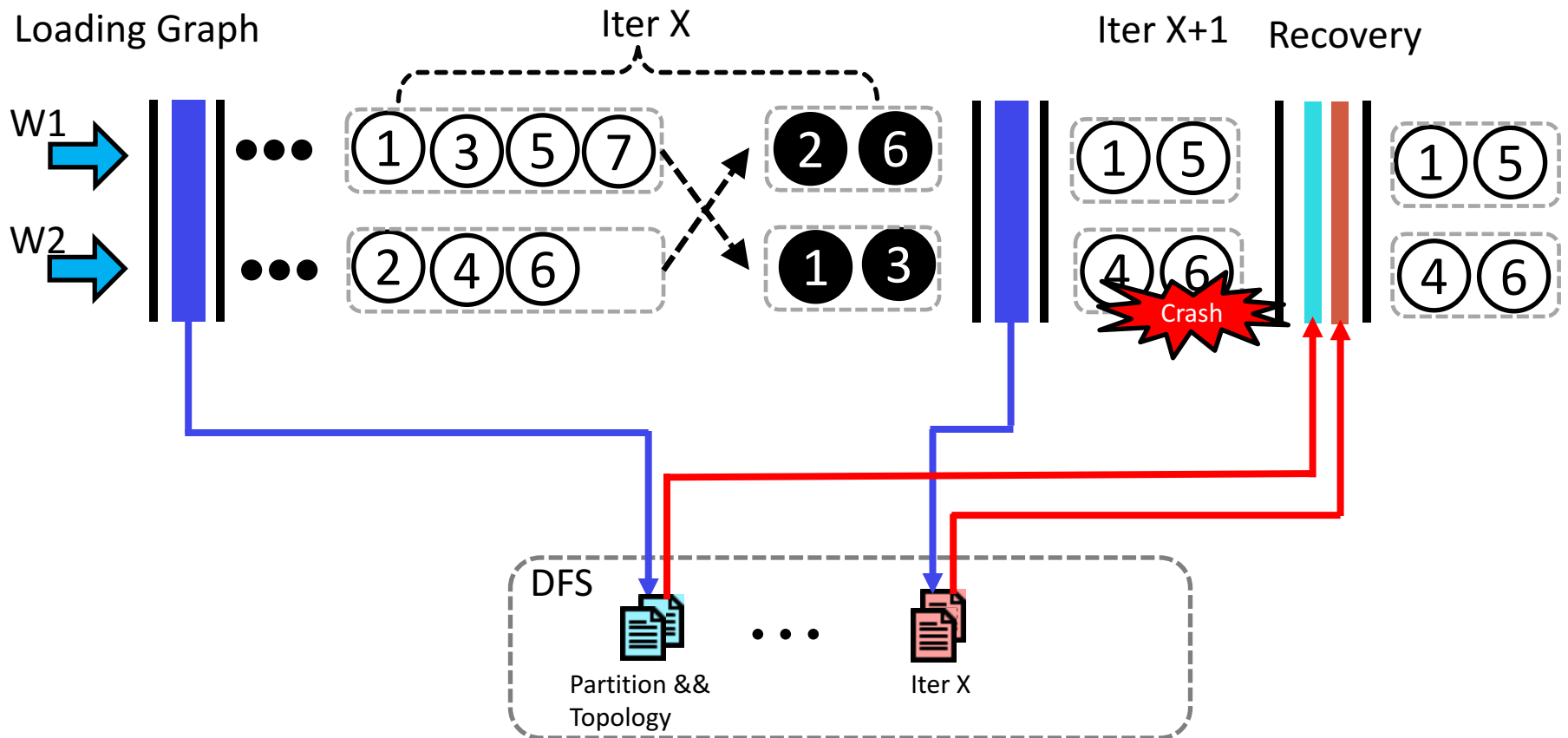
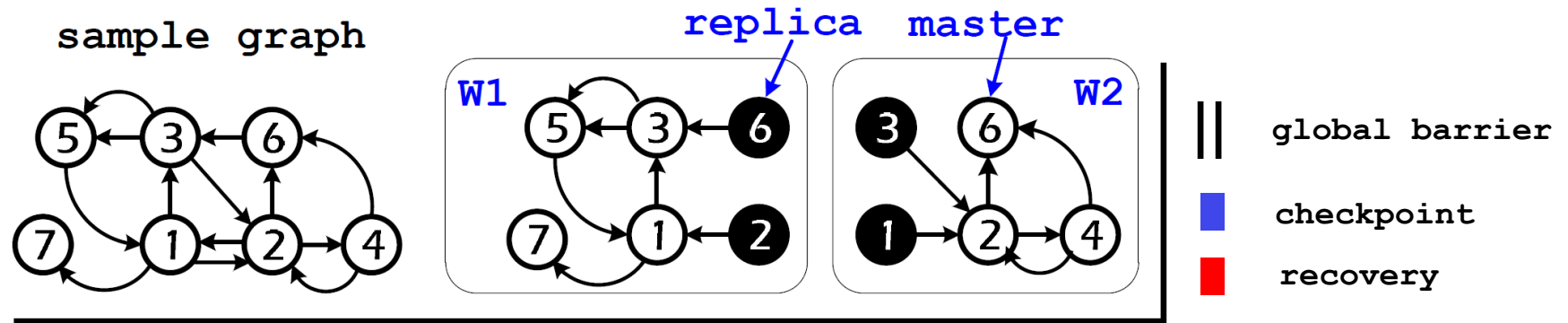
activate all neighbors



Related work about fault tolerance

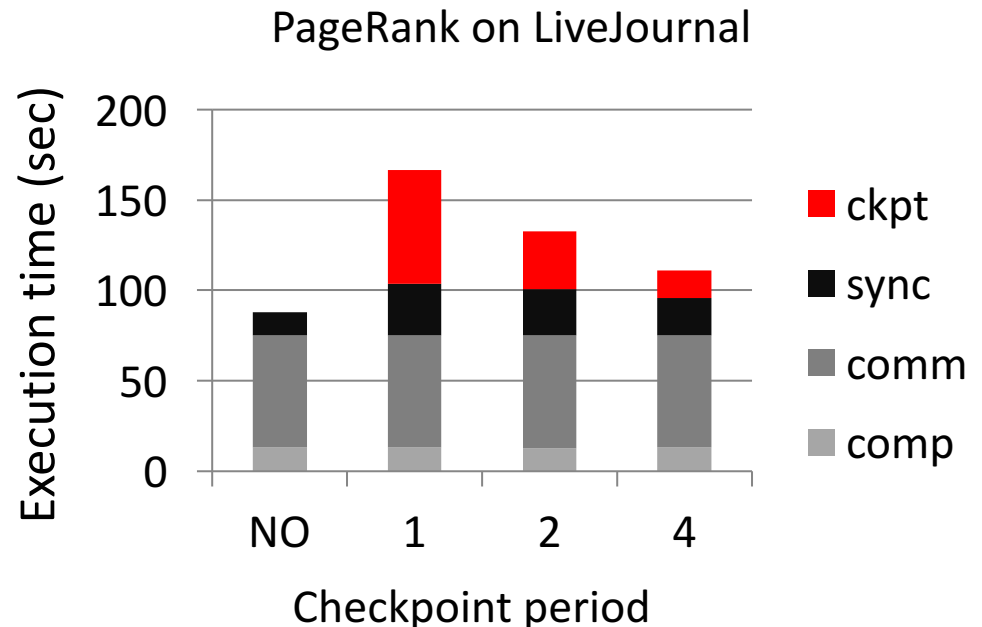
- Simple re-execution (MapReduce) 
 - Complex data dependency
- Coarse-grained FT (Spark) 
 - Fine-grained update on each vertex
- State-of-the-art fault tolerance for graph computing
 - Checkpoint
 - Trinity, PowerGraph, Pregel, etc.

How checkpoint works



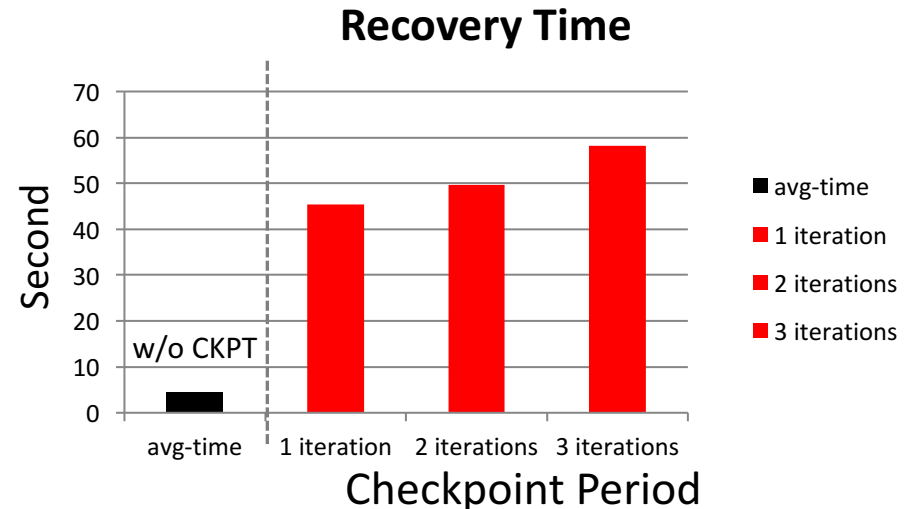
Problems of checkpoint

- Large execution overhead
 - Large amount of states to write
 - Synchronization overhead



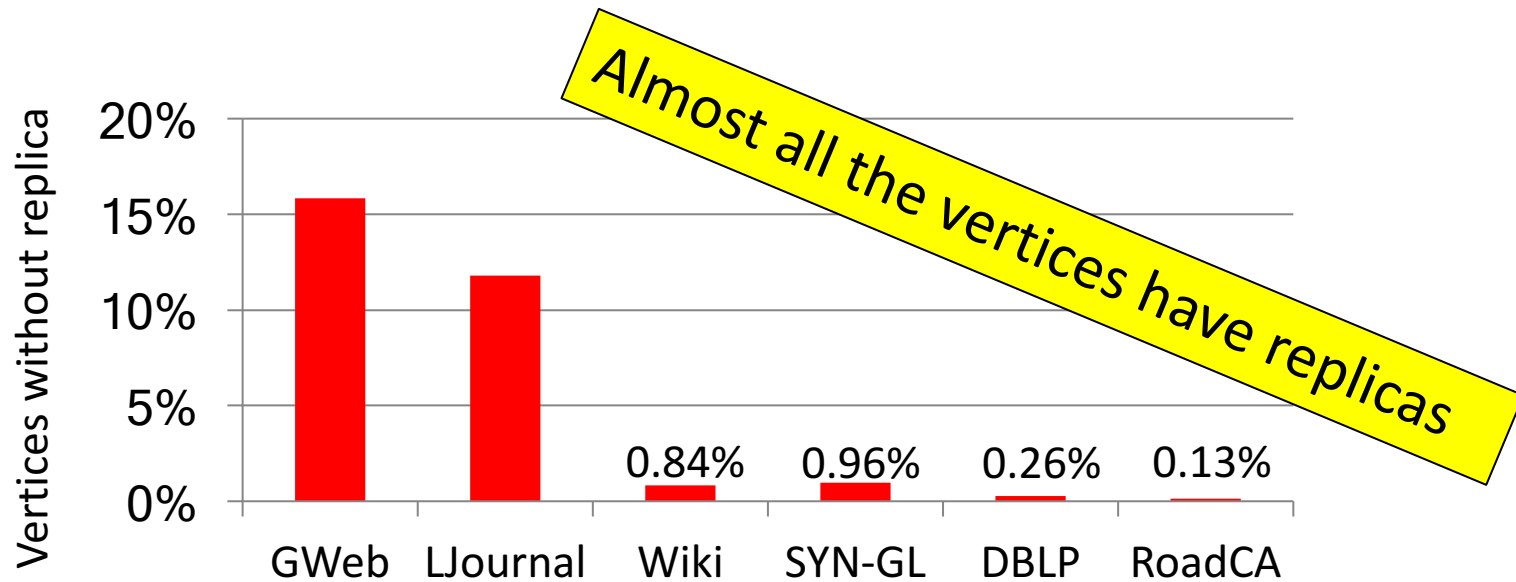
Problems of checkpoint

- Large overhead
- Slow recovery
 - A lot of I/O operations
 - Require standby node



Observation and motivation

- Reuse existing replicas to provide fault tolerance



- Reuse existing replicas → small overhead
- Replicas distributed in different machines → fast recovery

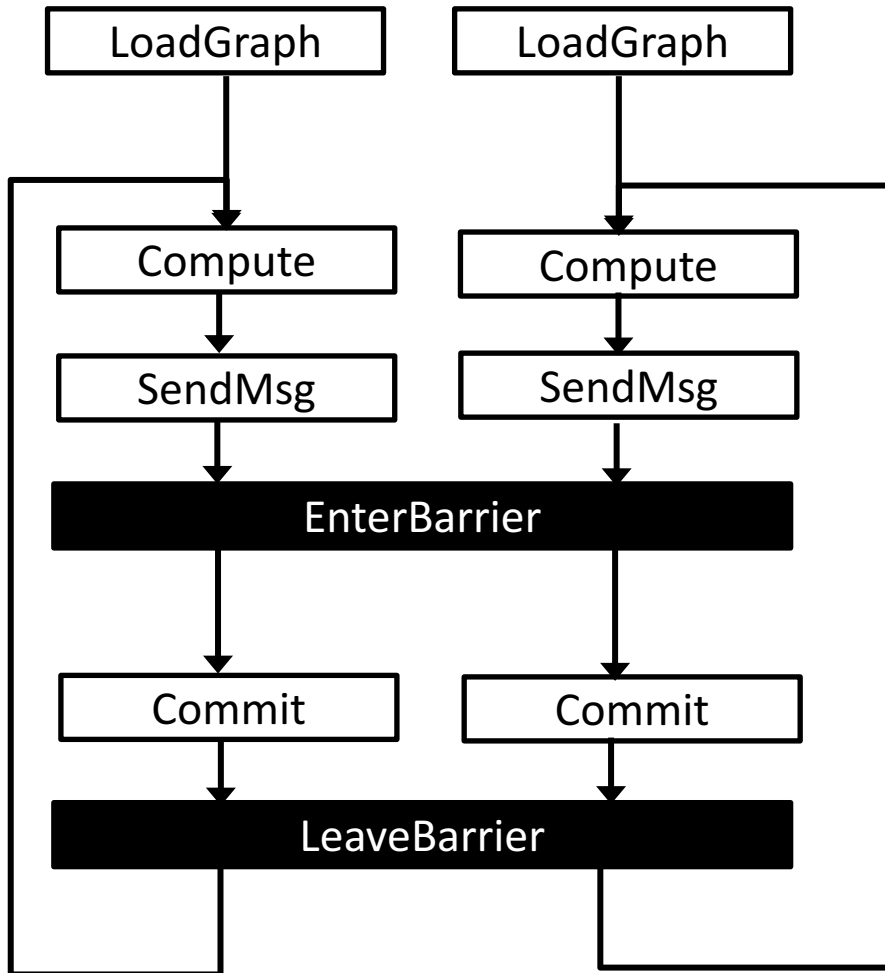
Contribution

- Imitator: a replication based fault tolerance system for graph processing
- Small overhead
 - Less than 5% for all cases
- Fast recovery
 - Up to 17.5 times faster than the checkpoint one

Outline

- Execution flow
- Replication management
- Recovery
- Evaluation
- Conclusion

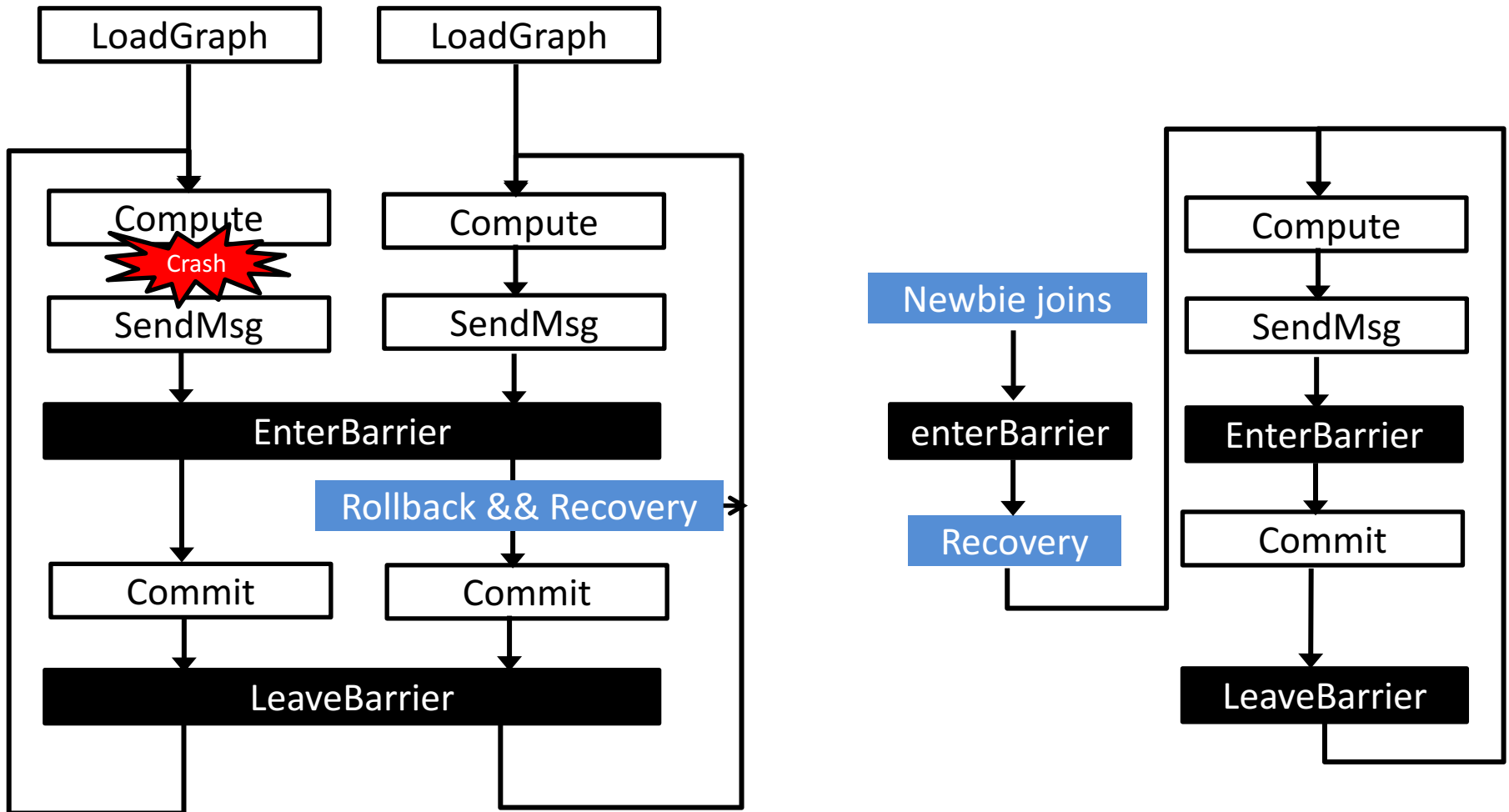
Normal execution flow



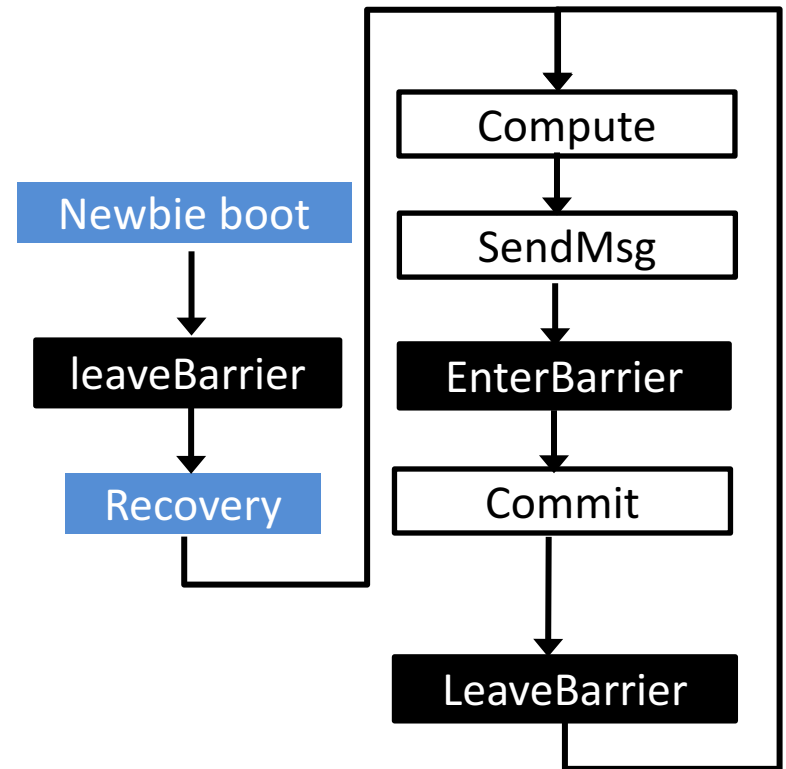
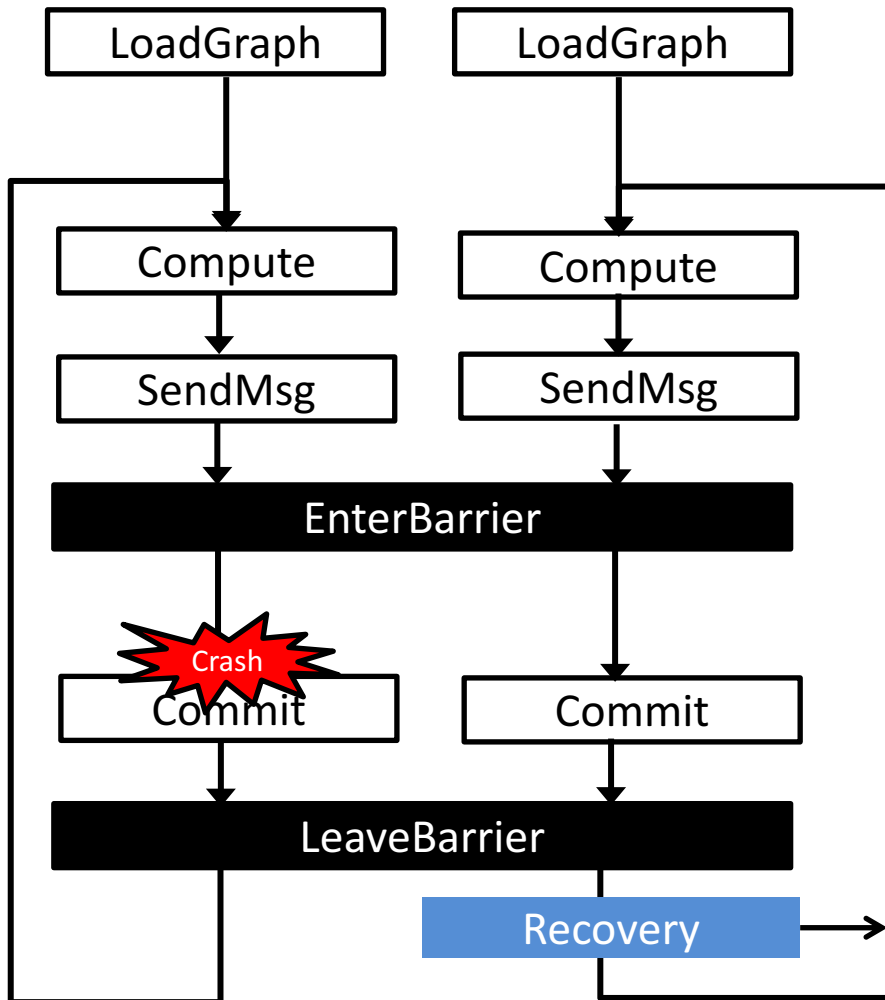
1. Adding FT support

2. Extending normal synchronization message

Failure before barrier

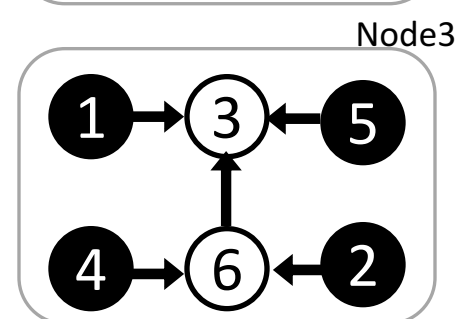
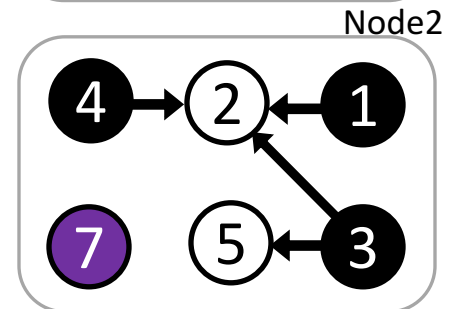
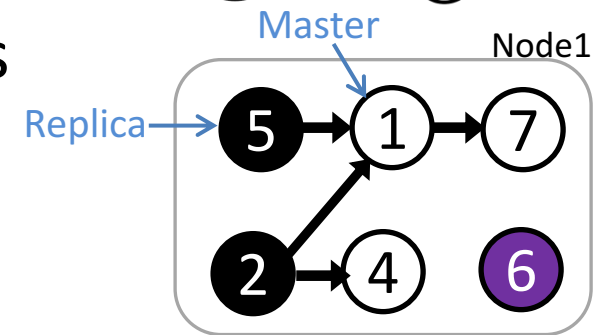
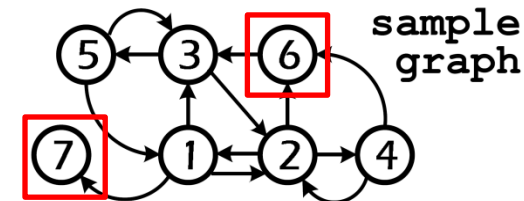


Failure during barrier



Management of replication

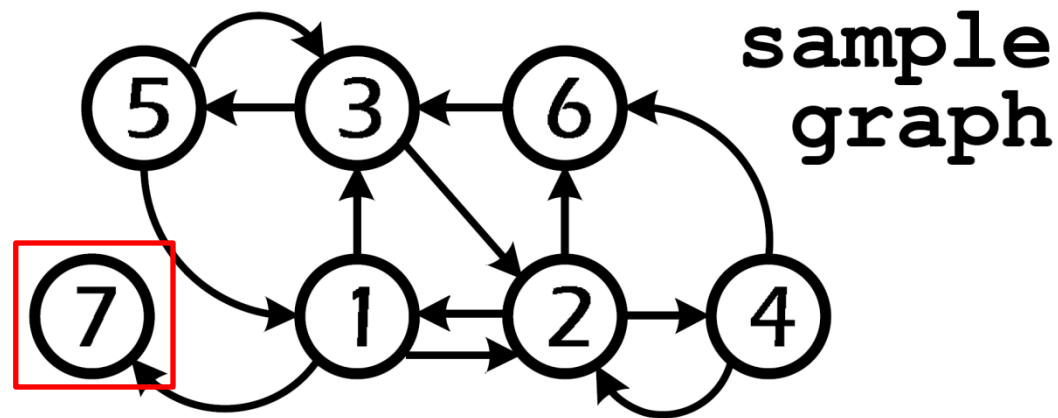
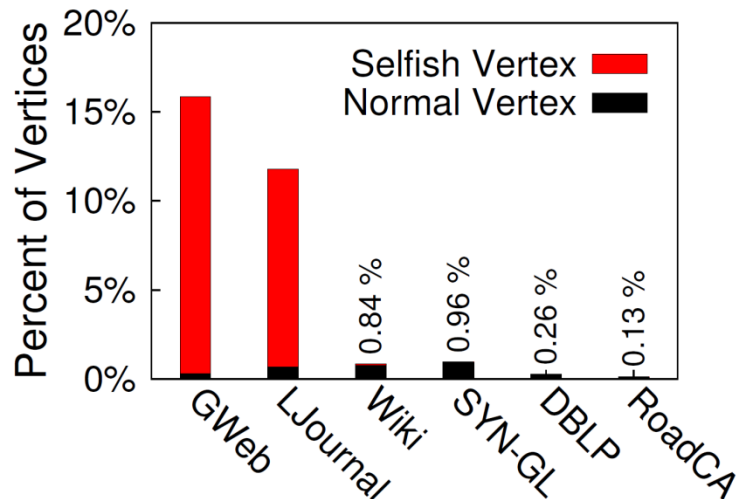
- Fault tolerance replicas
 - every vertex has at least f replicas to tolerate f failures
- Full state replica (mirror)
 - Existing replica lacks meta information
 - Such as replication location



Vertex: 5
Master: n2
Replicas: n1 | n3

Optimization: selfish vertices

- States of selfish vertices have no consumer
- Their states may only be decided by their neighbors
- Opt: get their states by re-computation

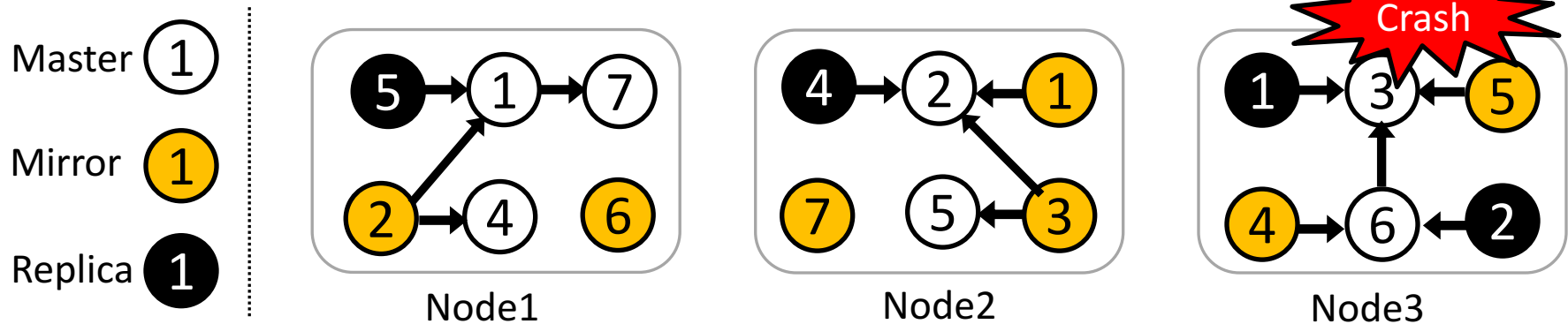


$$\text{PageRank: } R[i] = 0.15 + \sum_{j \in Nbs(i)} w_{ji} R[j]$$

How to recover

- Challenges
 - Parallel recovery
 - Consistent state after recovery

Problems of recovery



- Which vertices have crashed?
- How to recover without a central coordinator?

Rules:

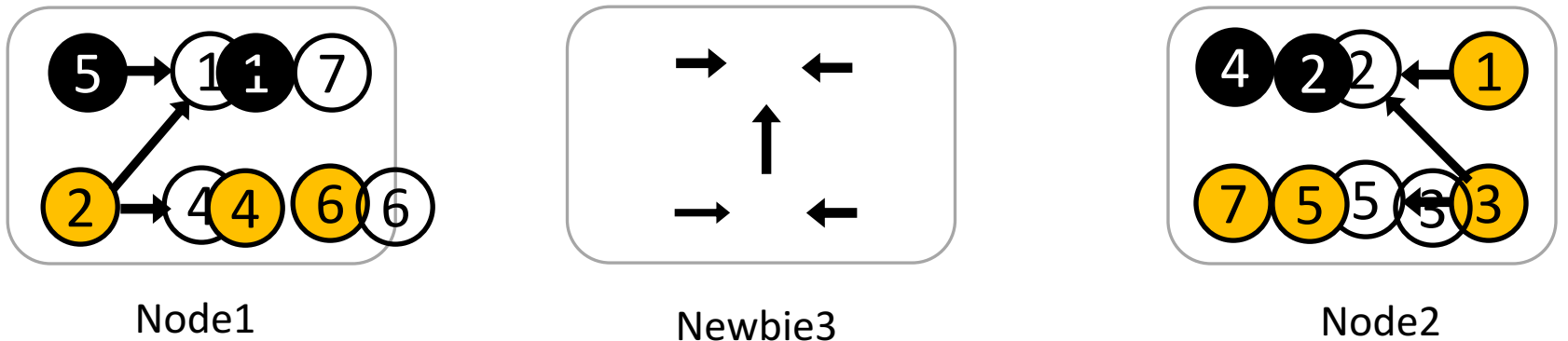
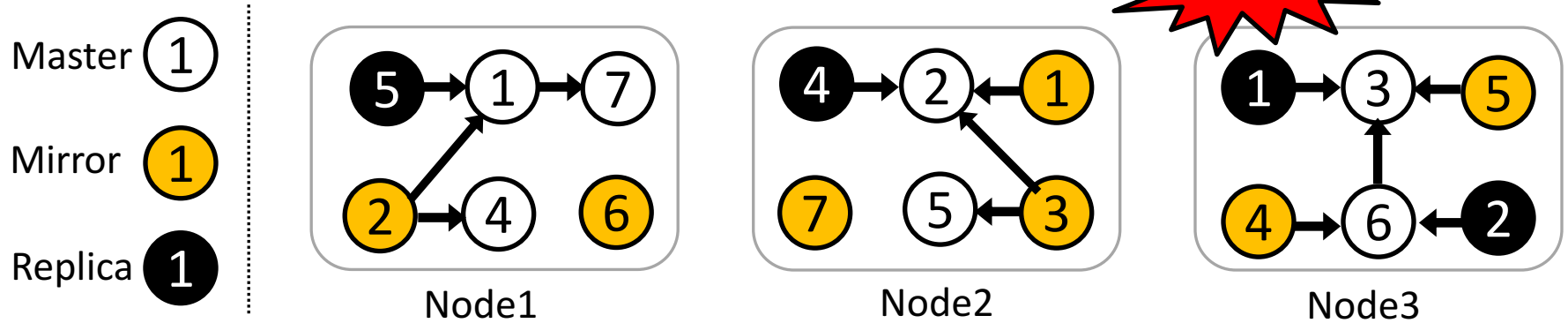
1. Master recovers replicas
2. If master crashed, mirror recovers master and replicas



Replication Location

Vertex 3:
Master: n3
Mirror: n2

Rebirth



Rule:

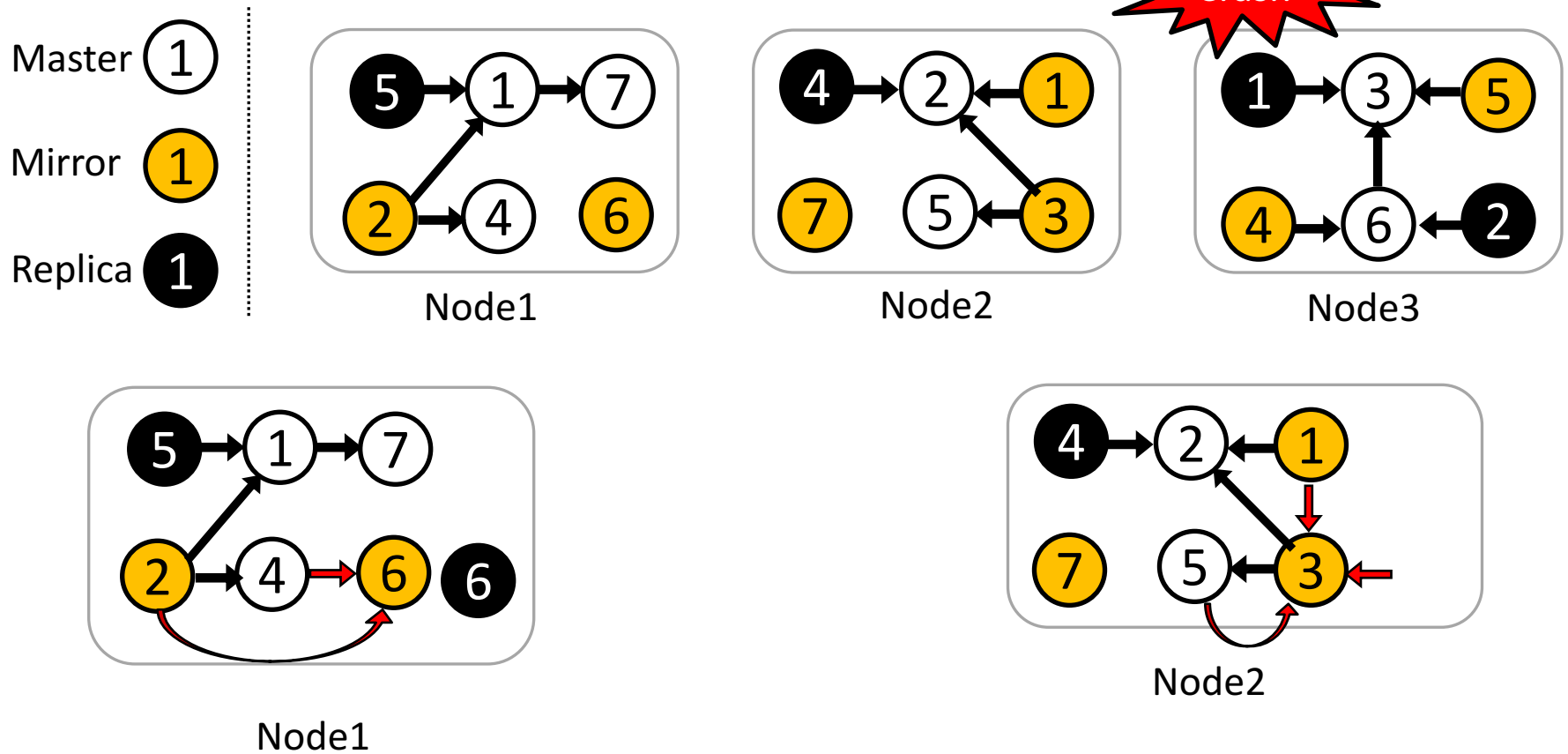
1. Master recovers replicas
2. If master crashed, mirror recovers master and replicas

Problems of Rebirth

- Standby machine
- A single newbie machine

Migrate tasks to surviving machines

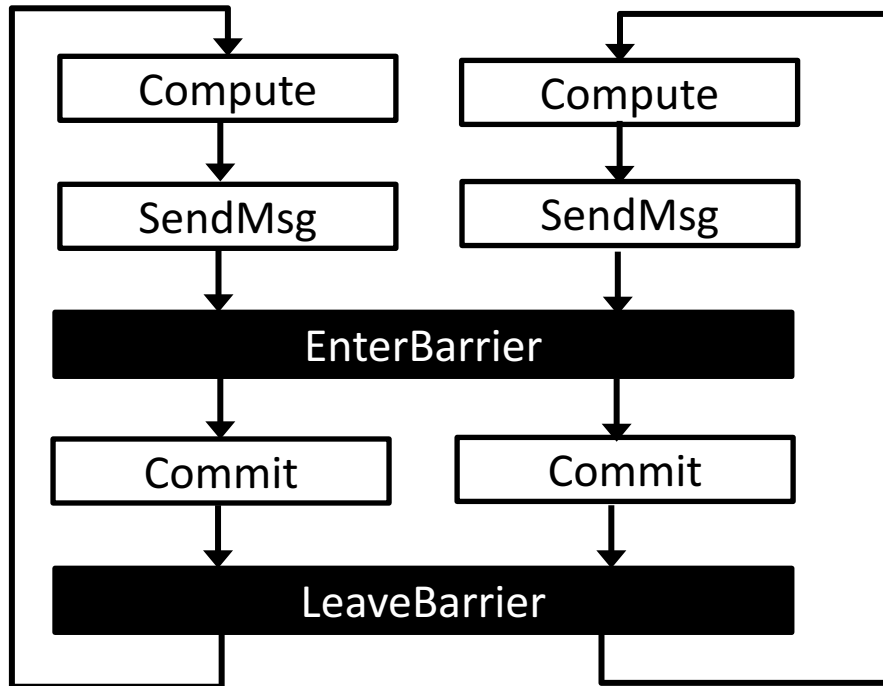
Migration



Procedure:

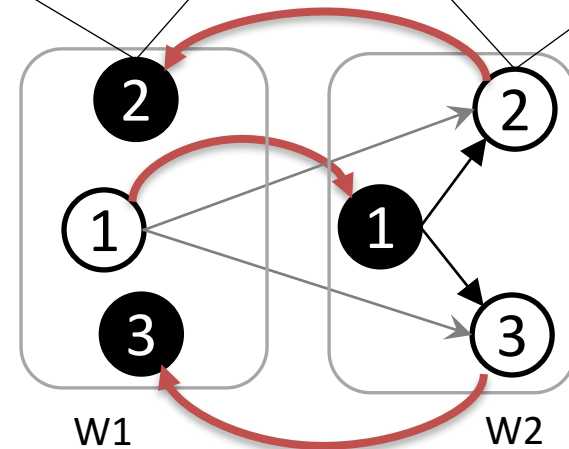
1. Mirrors upgrade to masters and broadcast
2. Reload missing graph structure and reconstruct

Inconsistency after recovery

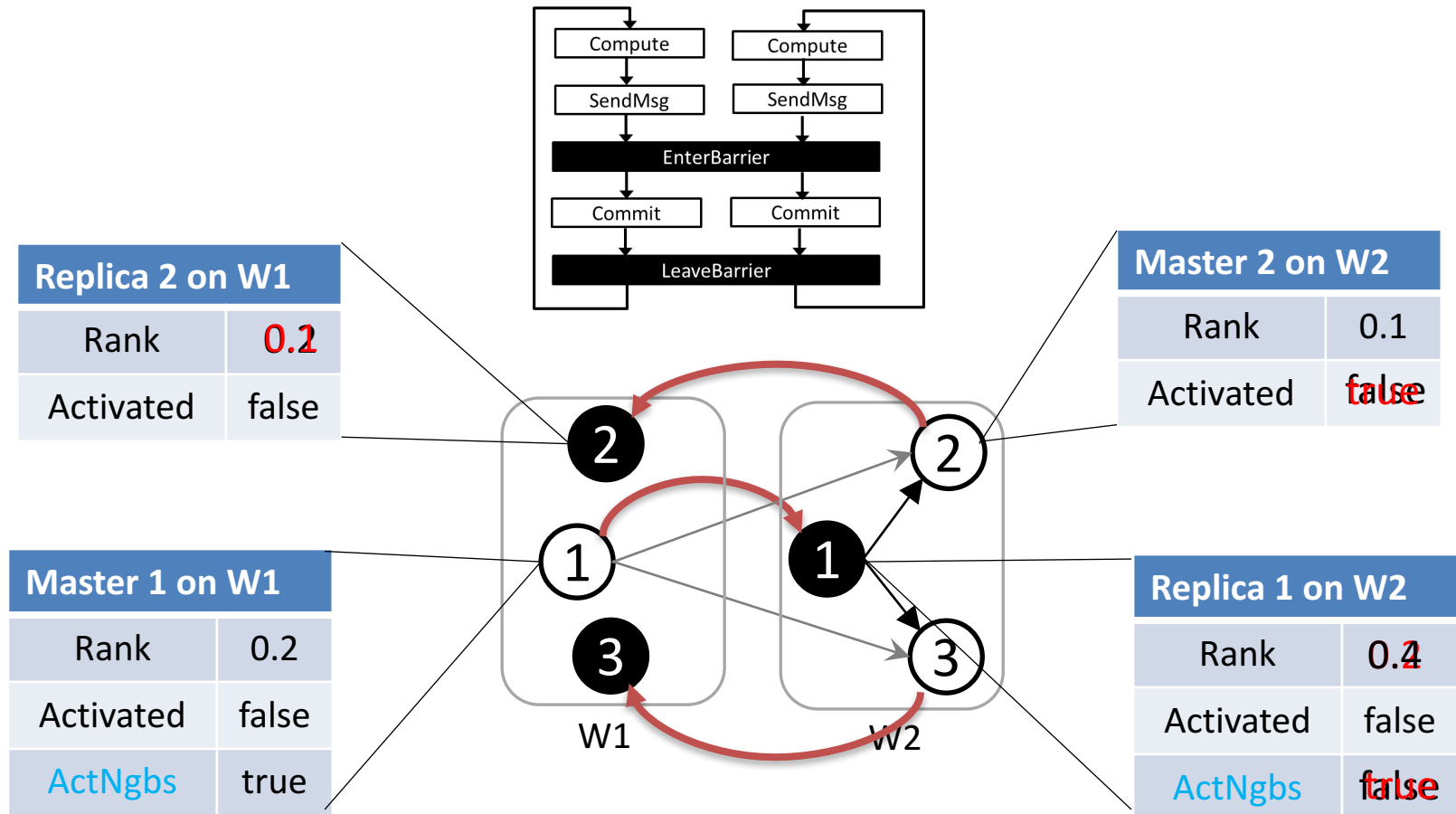


Replica 2 on W1	
Rank	0.2
Activated	false

Master 2 on W2	
Rank	0.1
Activated	false



Replay Activation



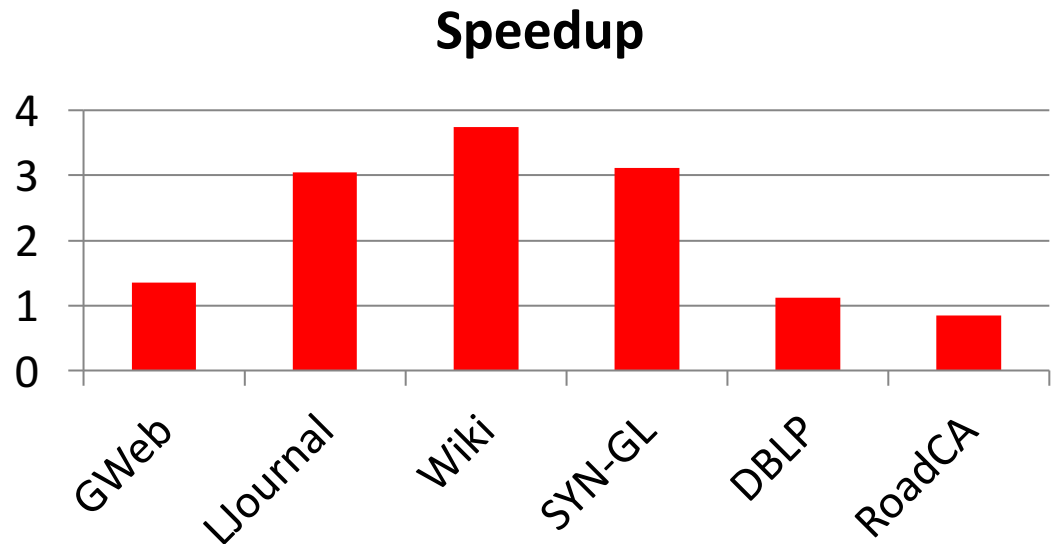
Evaluation

- 50 VMs (10G memory 4cores)
- HDFS (3 Replications)
- Applications

Application	Graph	Vertices	Edge
PageRank	GWeb	0.87M	5.11M
	LJournal	4.85M	70.0M
	Wiki	5.72M	130.1M
ALS	SYN-GL	0.11M	2.7M
CD	DBLP	0.32M	1.05M
SSSP	RoadCA	1.97M	5.53M

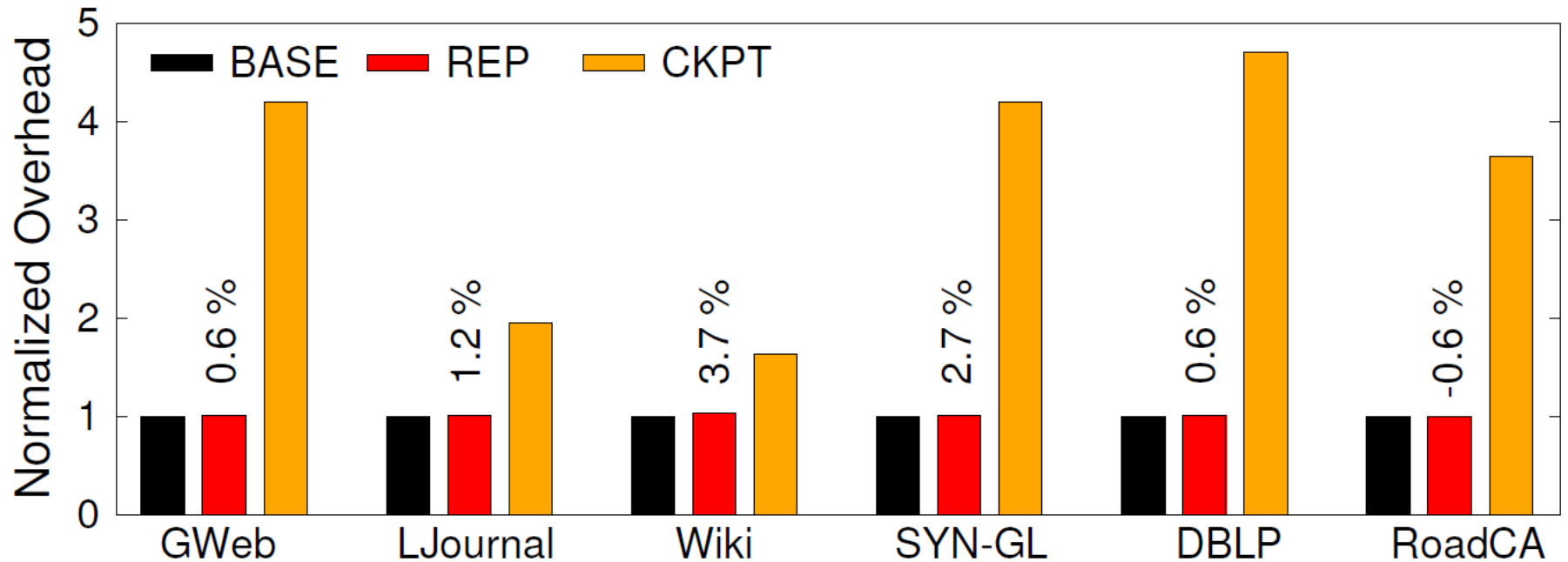
Speedup over Hama

- Imitator is based on Hama, a open source clone of Pregel
 - Replication for dynamic computing [*Distributed Graphlab, VLDB'12*]



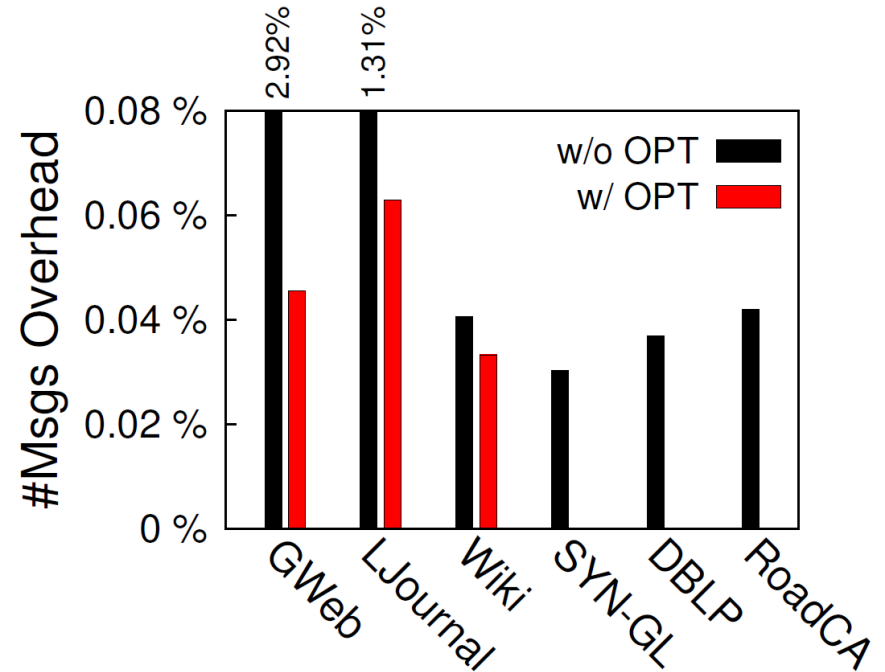
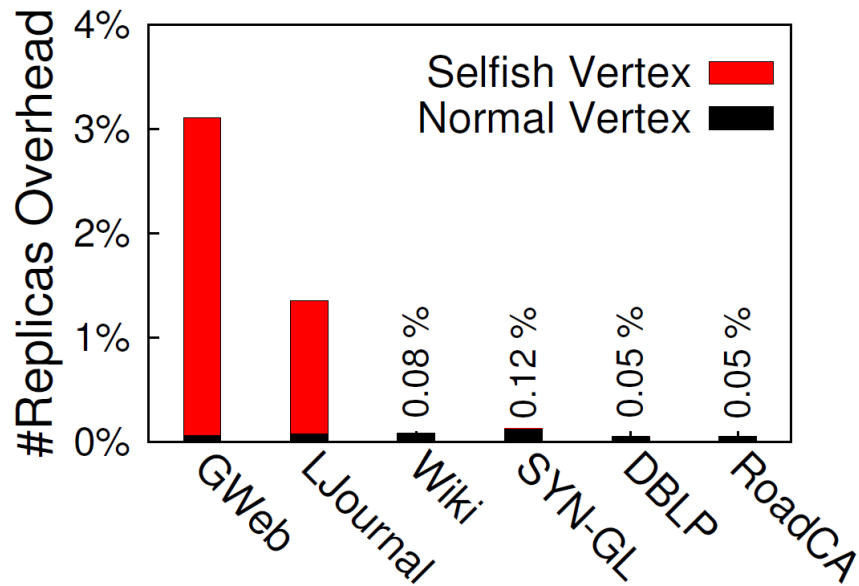
- Evaluated systems
 - Baseline: Imitator without fault tolerance
 - REP: Baseline + Replication based FT
 - CKPT: Baseline + Checkpoint based FT

Normal execution overhead

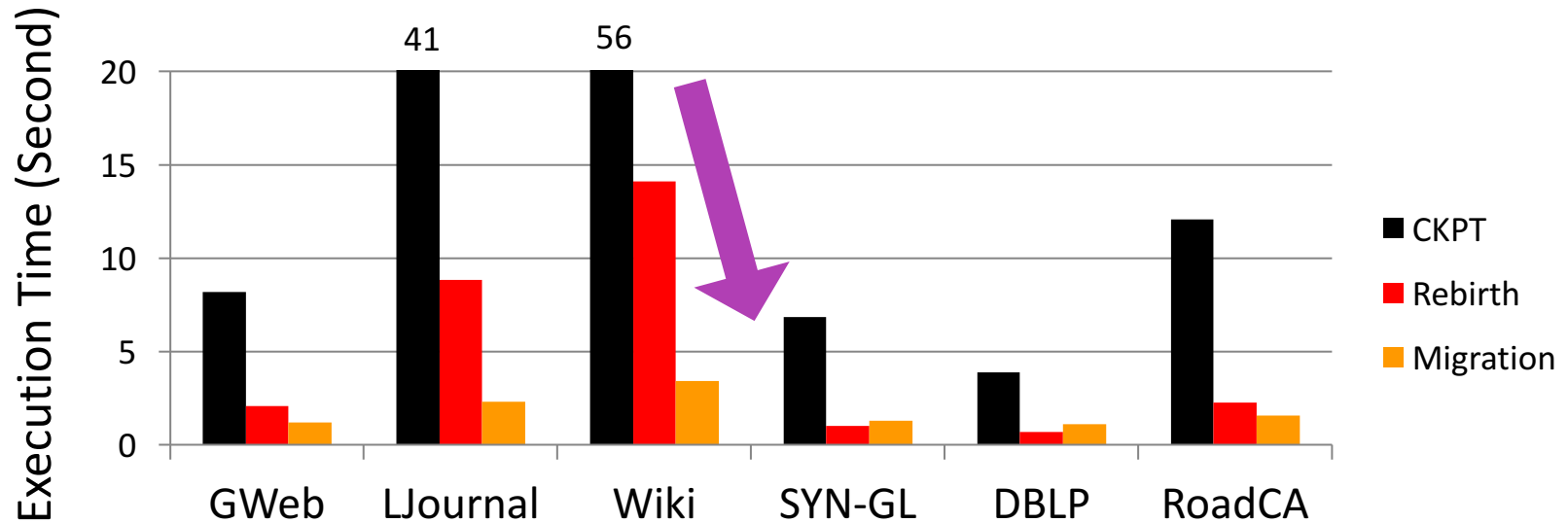


Replication has negligible execution overhead

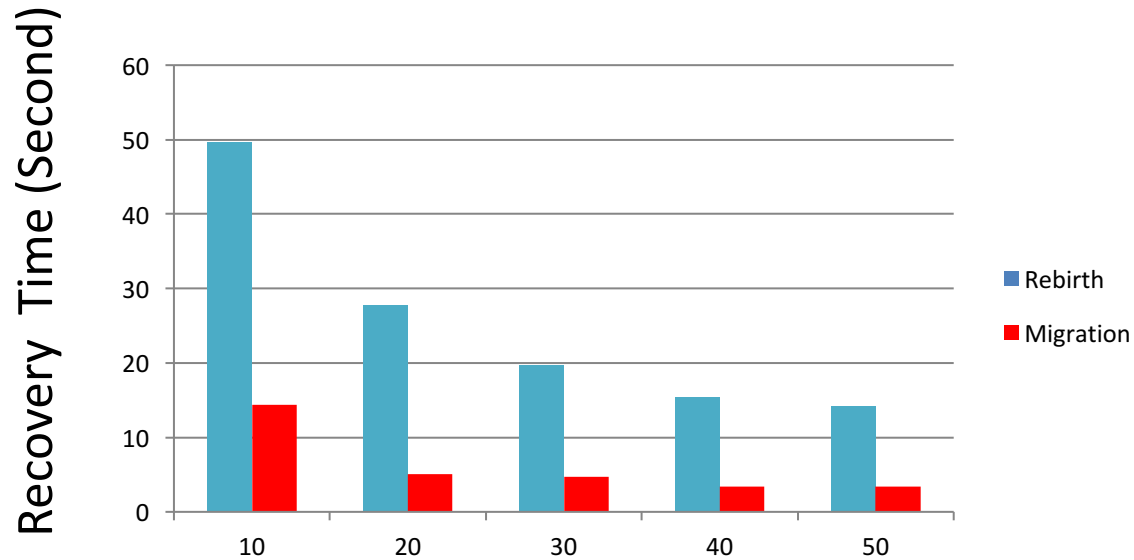
Communication Overhead



Performance of recovery



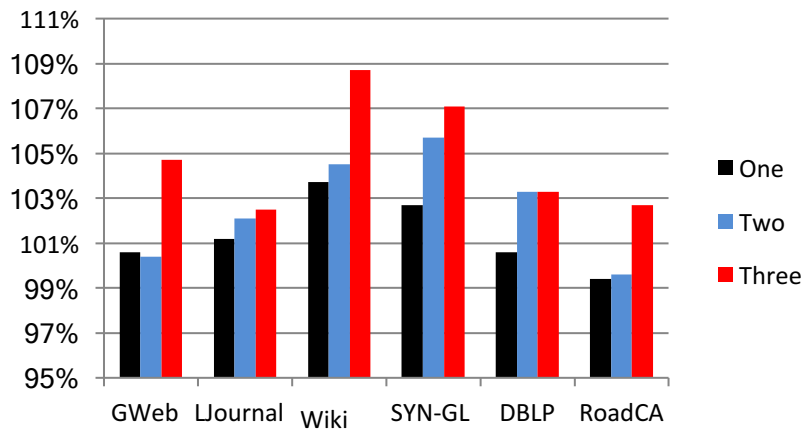
Recovery Scalability



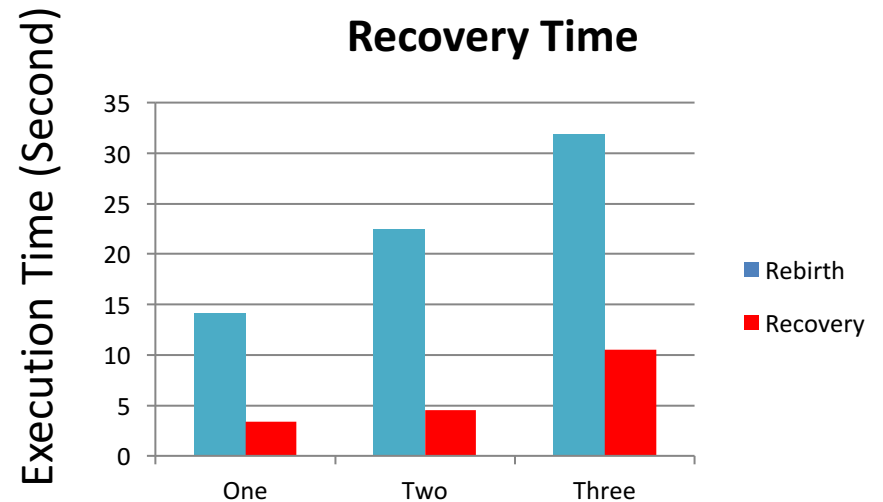
The more machines, the faster the recovery

Simultaneous failure

Overhead

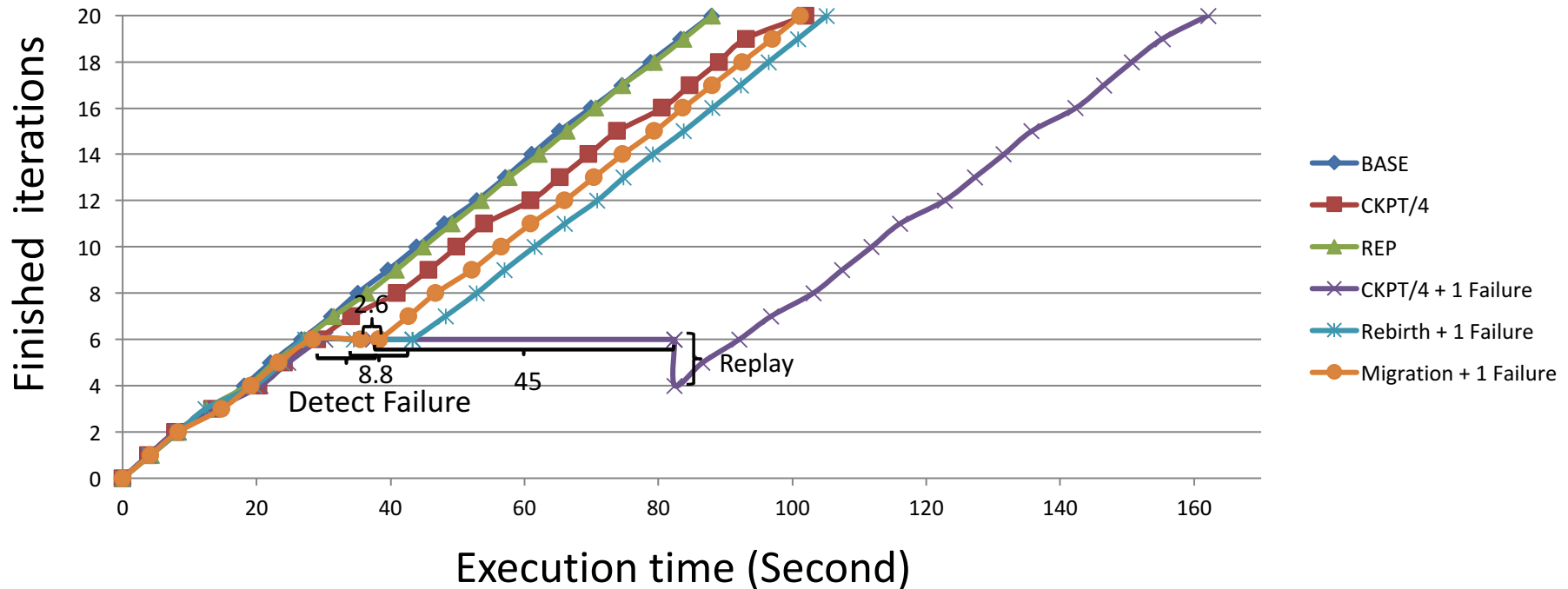


Recovery Time



Add more replicas to tolerate more than 1 machines simultaneous failure

Case study



- Application: PageRank on the dataset of LiveJournal
- A checkpoint for every 4 iterations
- A Failure is injected between the 6th iteration and the 7th iteration

Conclusion

- Imitator: a graph engine which supports fault tolerance
- Imitator's execution overhead is negligible because it leverages existing replicas
- Imitator's recovery is fast because of its parallel recovery approach

Backup

Memory Consumption

Config	Max Cap(GB)	Max Usage(GB)	Young/Full GC	
			Number	Time (Sec))
w/o FT	3.85	2.76	40/15	13.7/13.4
FT/1	5.05	3.70	50/29	19.9/21.7
FT/2	6.24	4.51	55/29	23.6/26.1
FT/3	6.99	4.91	58/30	25.7/29.7

Partition Impact

