PrIter: A Distributed Framework for Prioritized Iterative Computations

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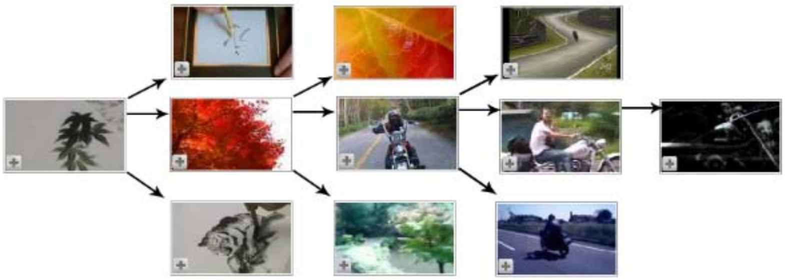
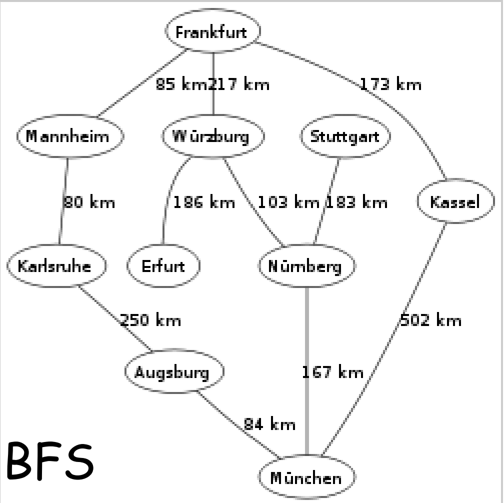
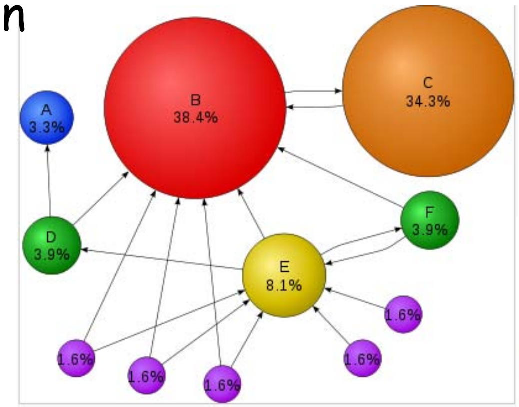
Iterative Computation is Everywhere



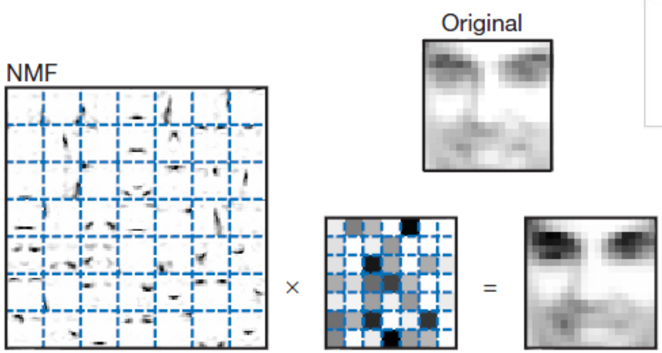
Youtube video suggestion



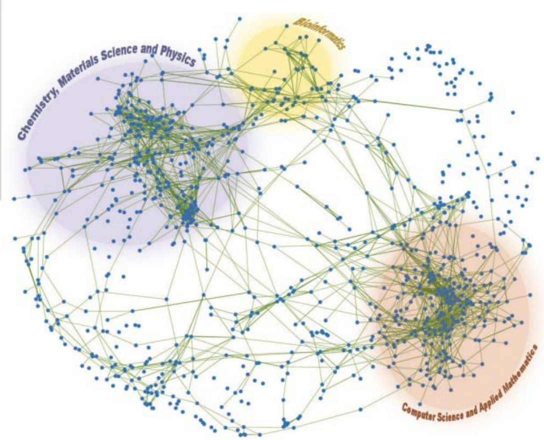
BFS



PageRank

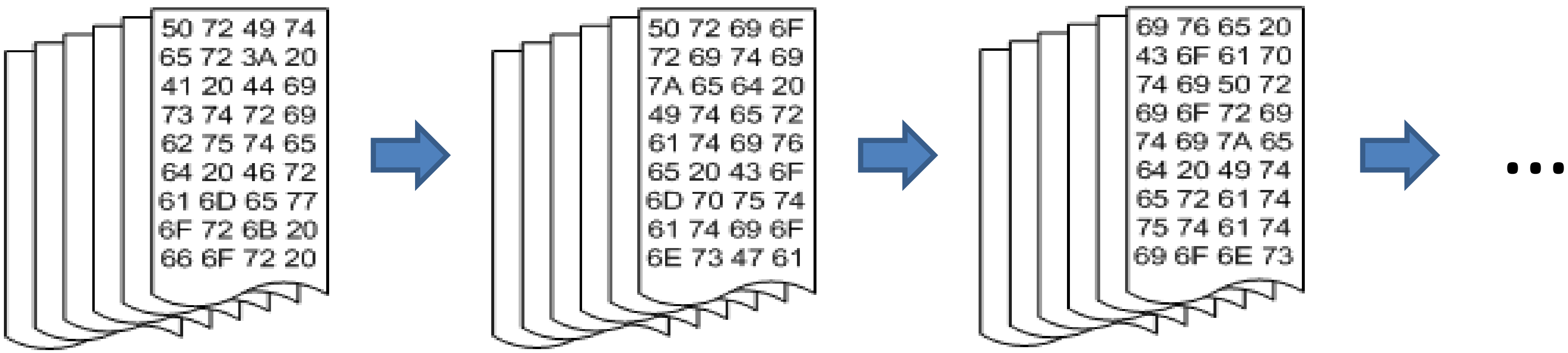


Pattern Recognition



Clustering

Large-Scale Iterative Computation



\+ Involve massive data sets

++ Process massive data iteratively

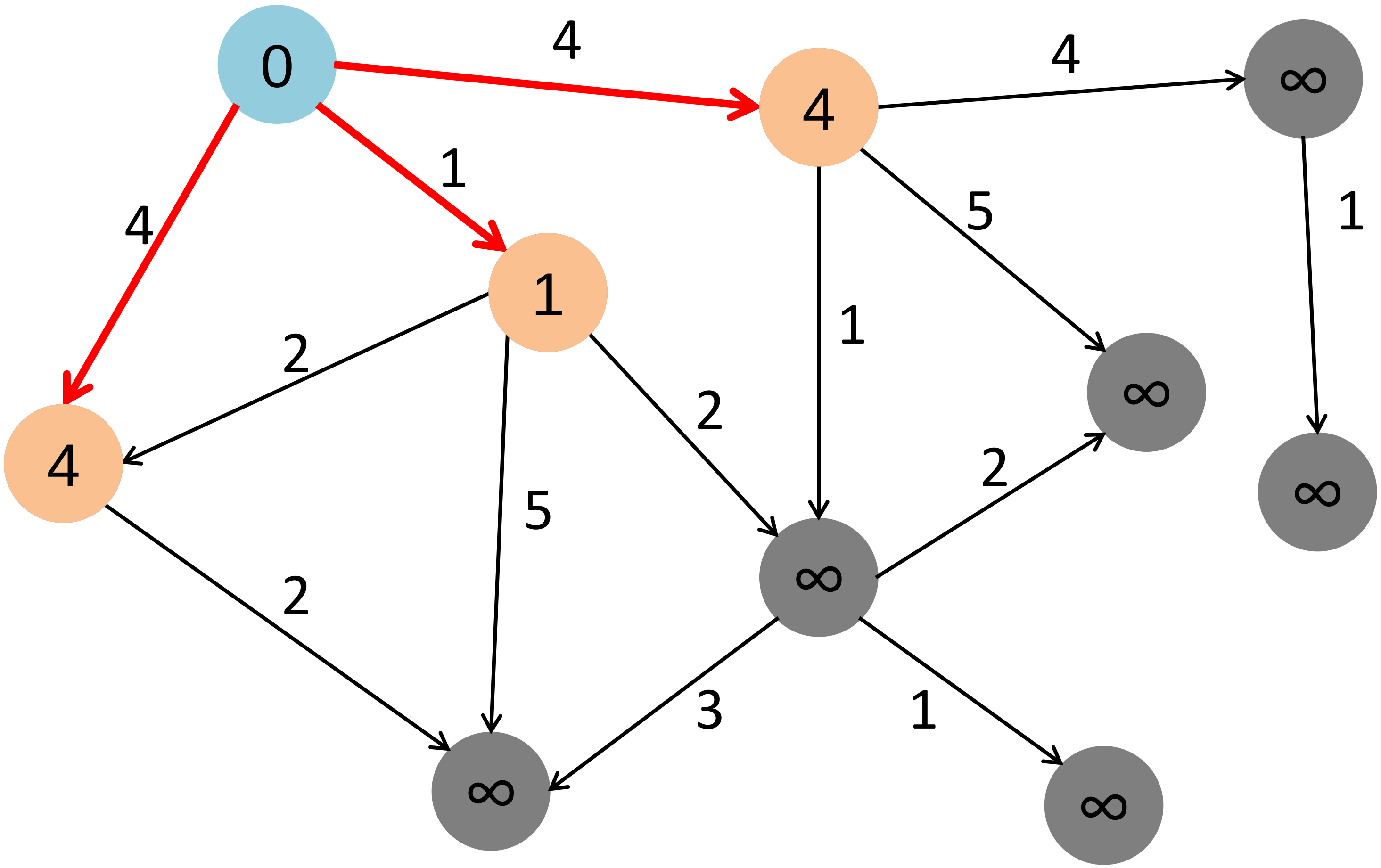
+++ Converge fast

Our Goal: a framework supporting iterative computation running in the cloud

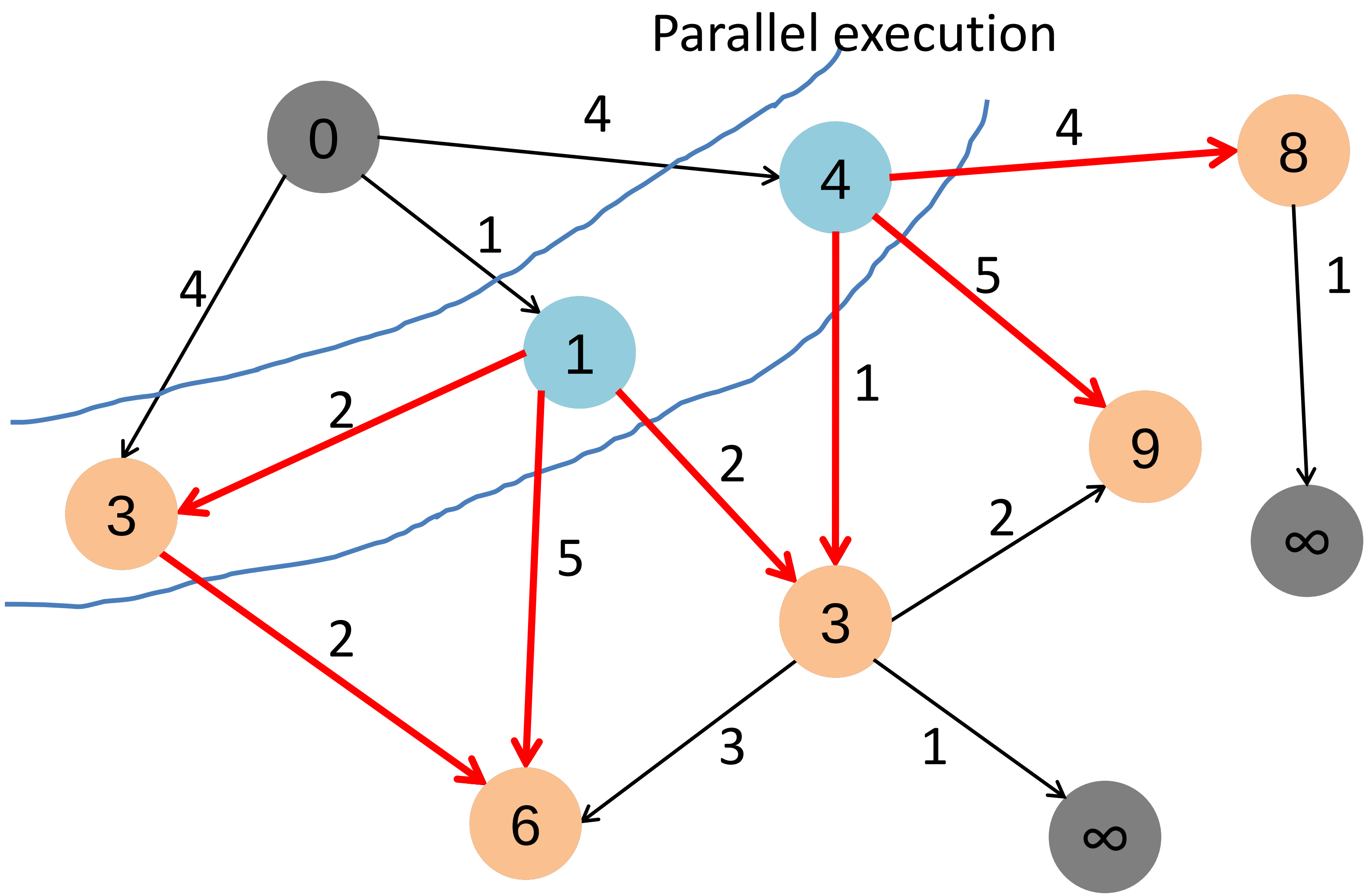
Outline

- Prioritized Iteration
- PrIter's Design & Implementation
- Evaluation
- Conclusions

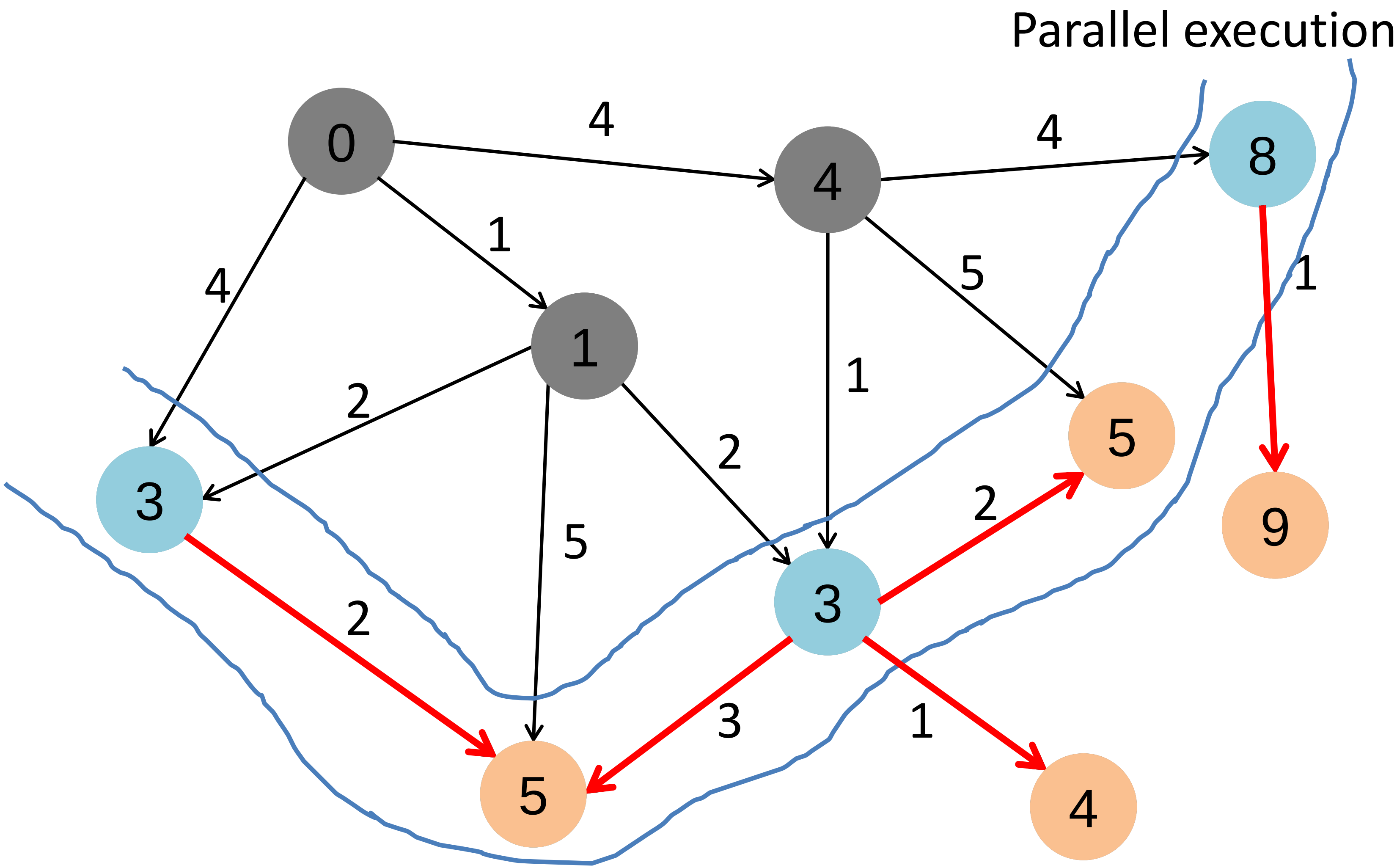
Parallel Parallel Single Source Shortest Path (SSSP): 1



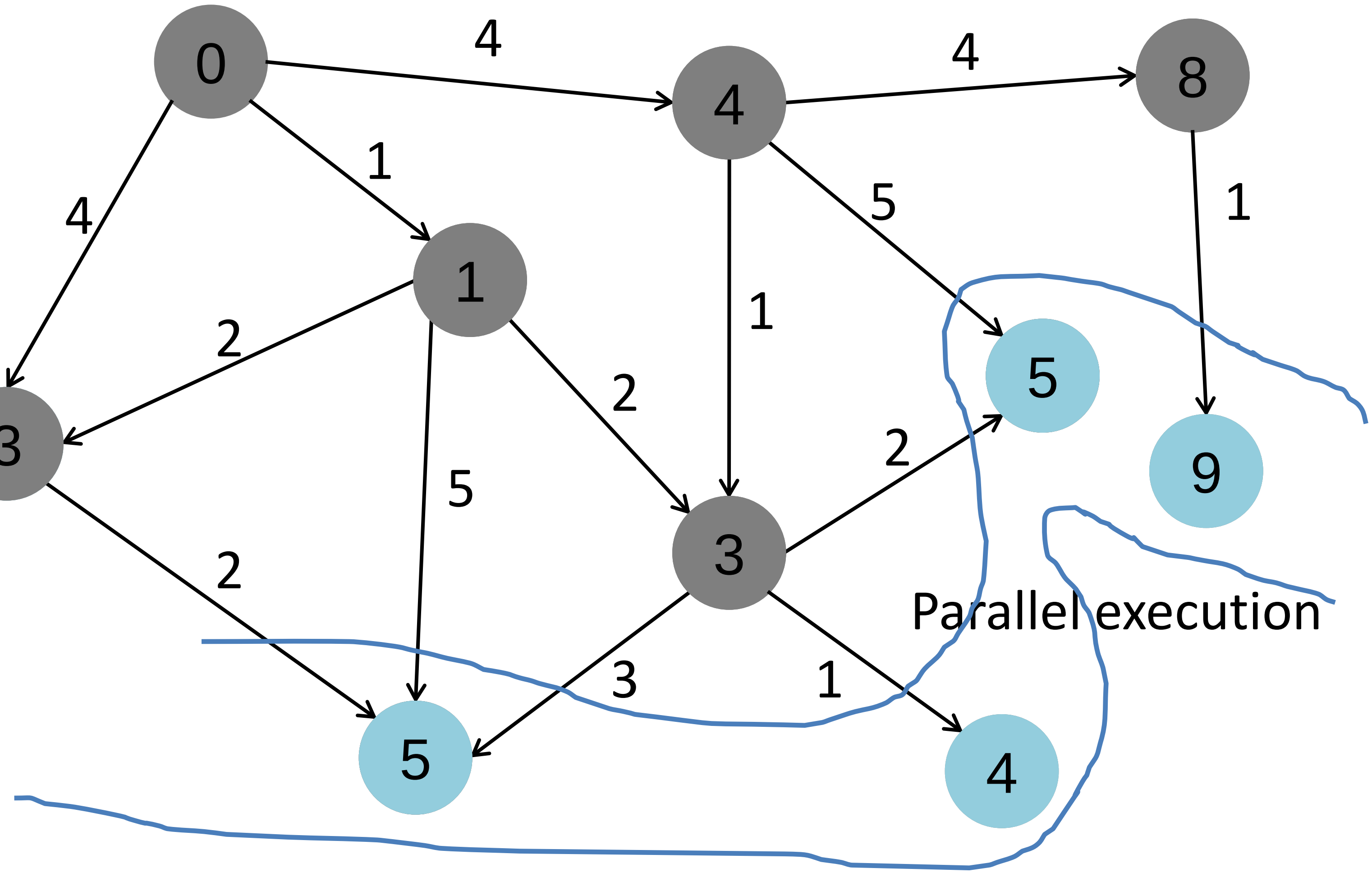
SSSP: 1+3



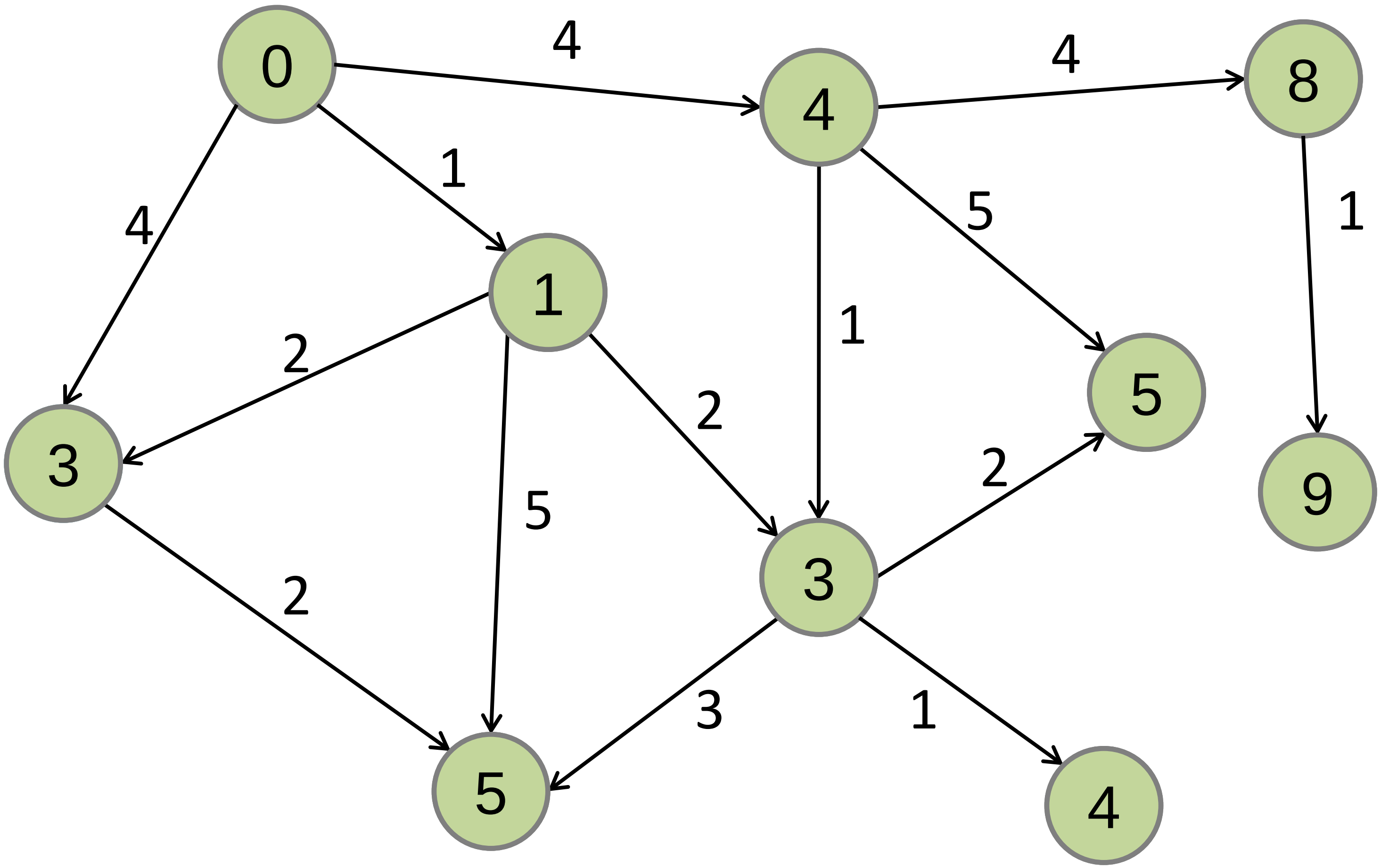
Parallel SSSP: 1+3+5



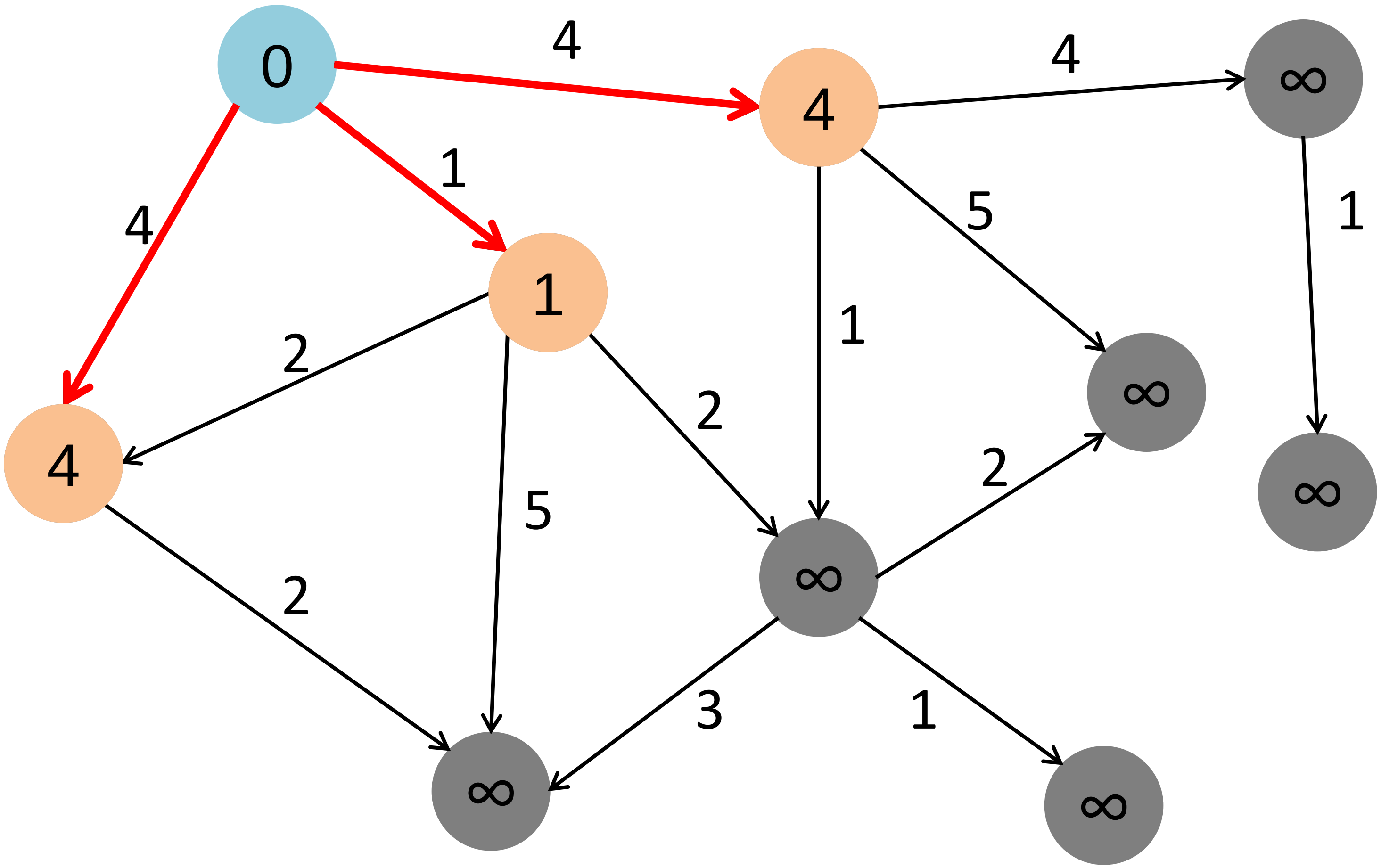
Parallel SSSP: 1+3+5+4



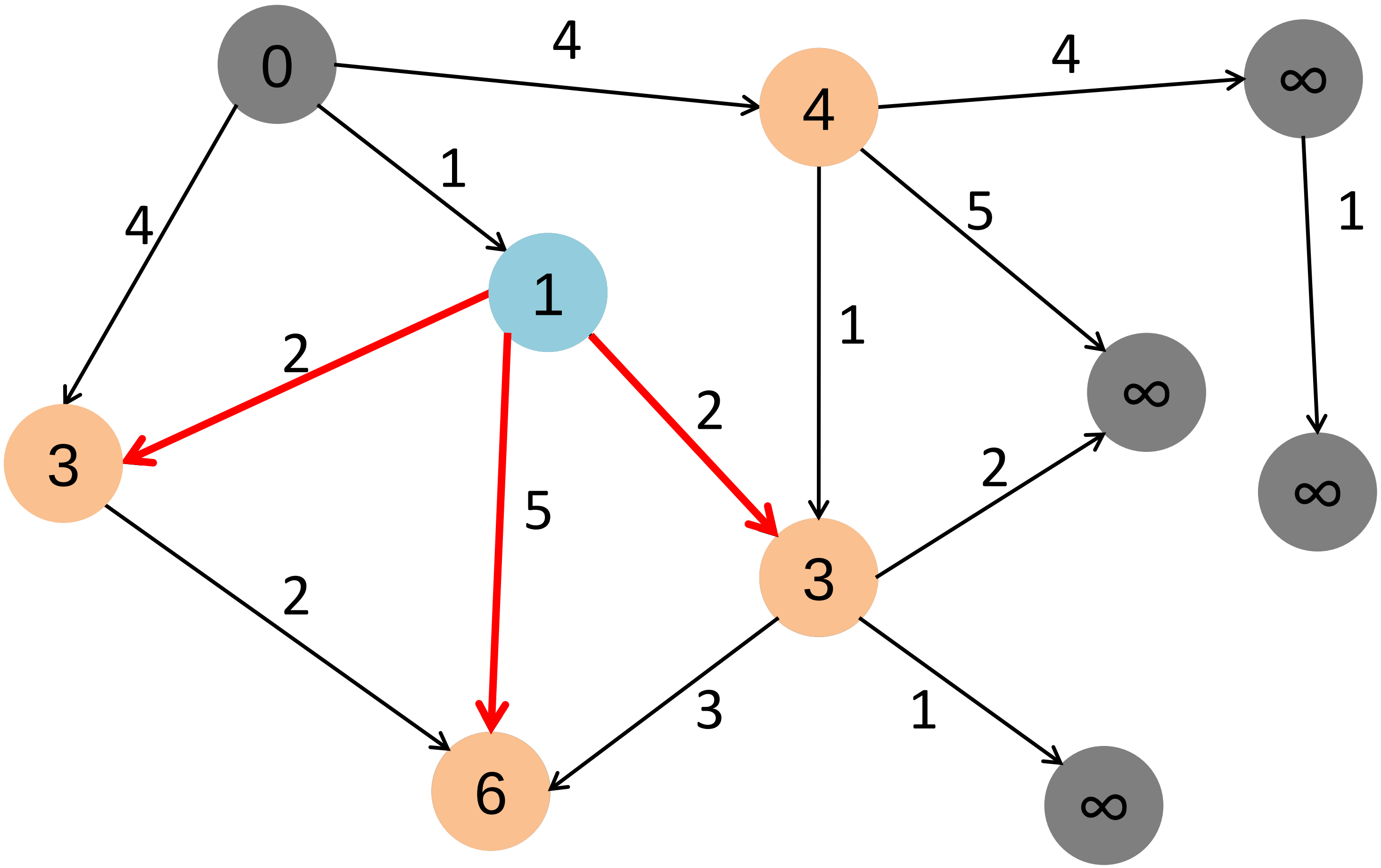
Parallel SSSP: 13 updates



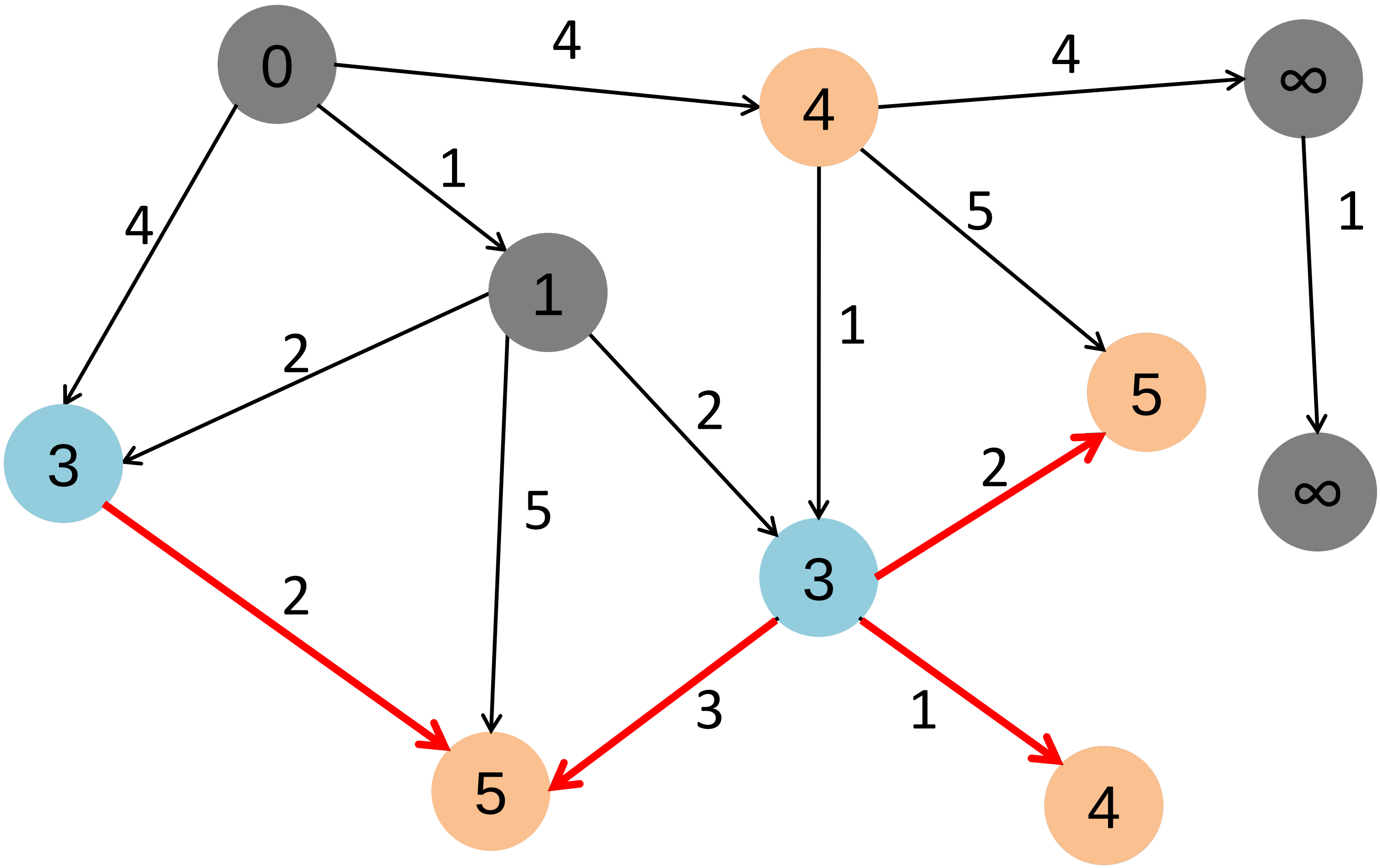
Prioritized SSSP: 1



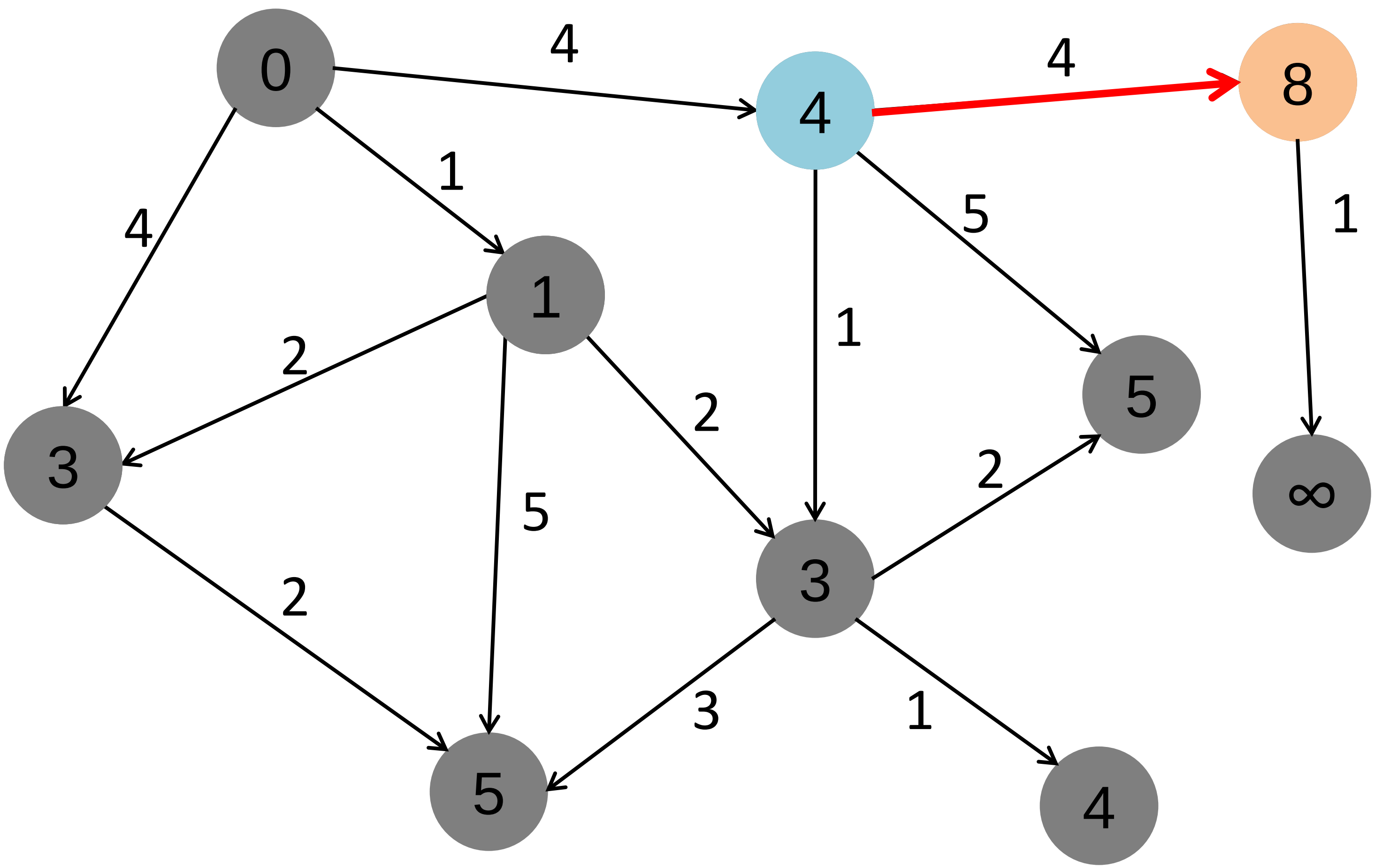
Prioritized SSSP: 1+1



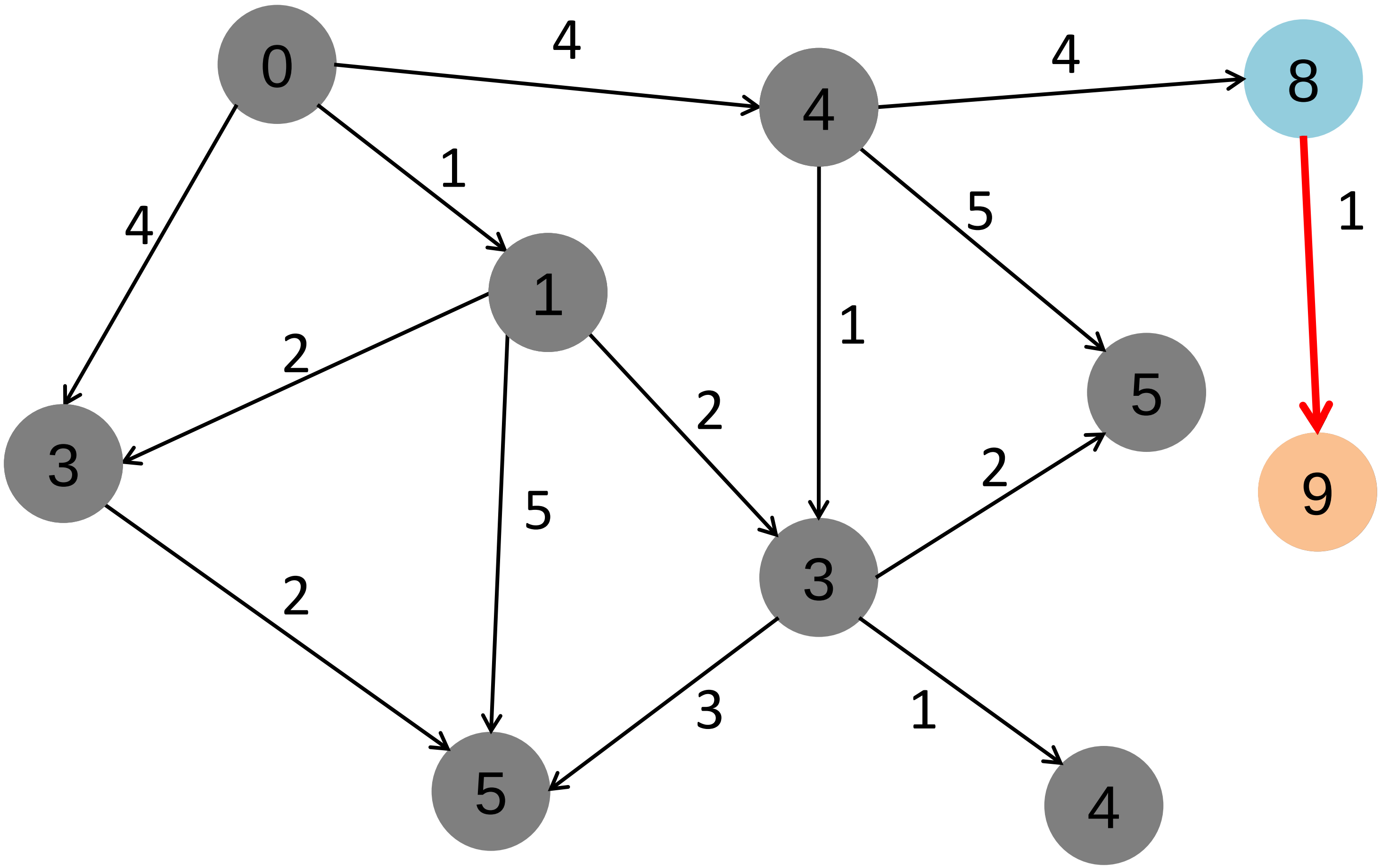
Prioritized SSSP: 1+1+2



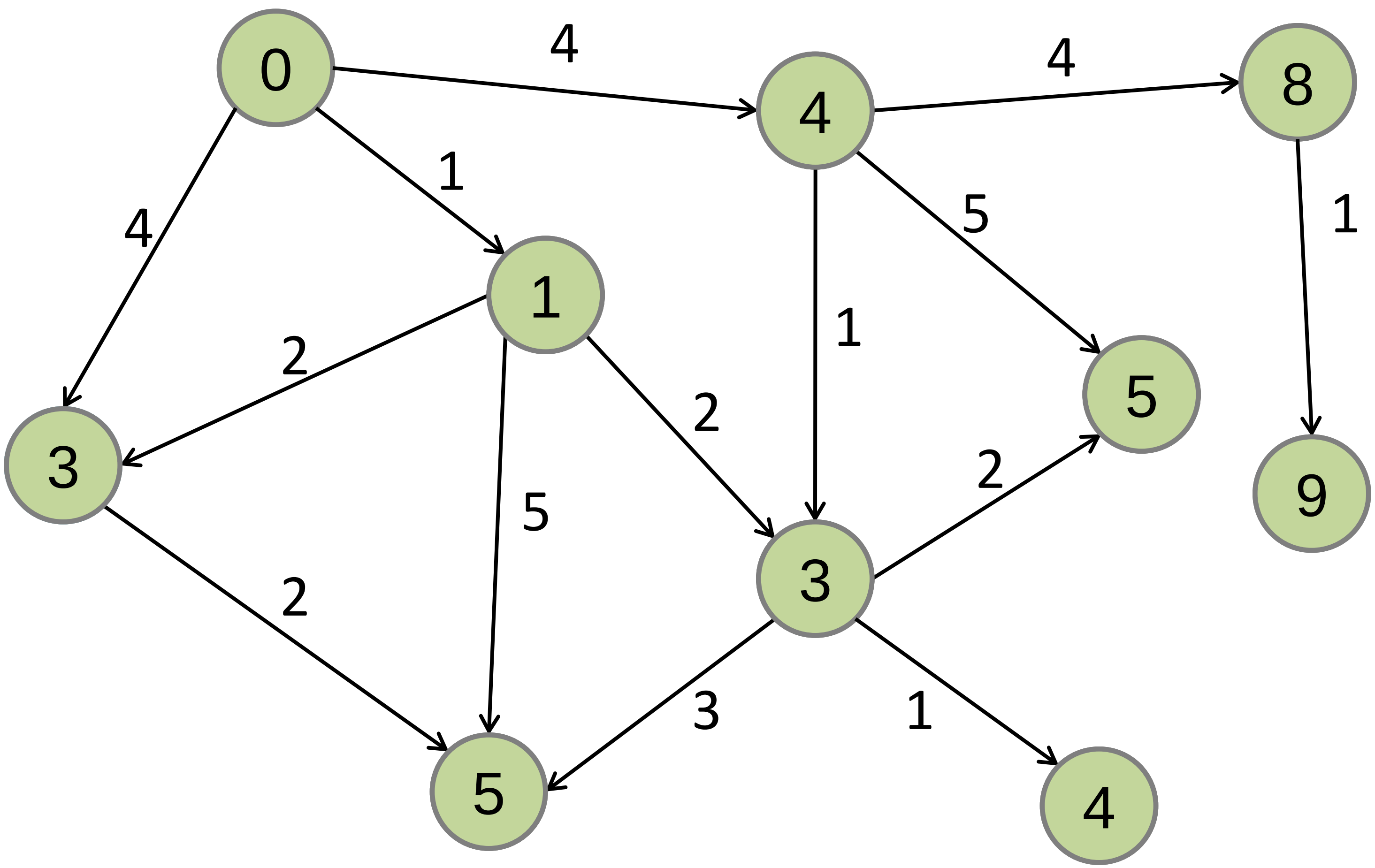
Prioritized SSSP: 1+1+2+1



Prioritized SSSP: 1+1+2+1+1



Prioritized SSSP: 7 updates



PageRank

$$R^{(k)} = dWR^{(k-1)} + (1-d)E$$

- *R* : size-n ranking vector (n)
- *W* : nxn matrix, W_{ij}=1/deg(j)
- *d* : damping factor (0<d<1, usually 0.8)
- *E* : size-n vector (1/n,1/n…,1/n)
- *k* : iteration number

Prioritized PageRank

- Priority is not that obvious as in SSSP

Incremental Update Function

$$R^{(k)} = dWR^{(k-1)} + (1-d)E$$

$$R^{(k)} = (1-d)E\sum_{l=0}^{k} d^l W^l + d^k W^k R^0$$

Incremental update function

$$R^{(i)} = R^{(i-1)} + \Delta R^{(i)} \quad , \quad \Delta R^{(i)} = dW\Delta R^{(i-1)}$$

$$R^{(0)} = 0 \qquad \Delta R^{(0)} = (1-d)E$$

Prioritized Incremental PageRank

$$R^{(i)} = R^{(i-1)} + \Delta R^{(i)}, \quad \Delta R^{(i)} = dW\Delta R^{(i-1)}$$

Measure convergence speed by $||R^{(i)}||_1$, monotonously increasing to $||R^{(\infty)}||_1 = 1$

$$||R^{(i)}||_1 = ||R^{(i-1)}||_1 + ||\Delta R^{(i)}||_1$$

Suppose in each iteration, update
of $\Delta R^{(i-1)}$, that is all the other e

$$||\Delta R^{(i-1)}||_1 = \Delta R^{(i-1)}(j)$$

$$||\Delta R^{(i)}||_1 = ||dW\Delta R^{(i-1)}||_1 = d\Delta R^{(i-1)}(j)$$

W is column normalized matrix $||w_j||_1 = 1$

Priority is given to la

Theoretical Results

- Incremental PageRank converges to the same vector as PageRank
- Prioritized Incremental PageRank
  - Converges to the same vector as PageRank
  - Converges faster than Incremental PageRank
- Same can be proved for many other iterative comptation
  - Personalized PageRank
  - Katz Measure Computation
  - Label Propagation such as Adsorption
  - Single Source Shortest Path

Existing Frameworks

- MapReduce, Dryad
- Support Iterative Computation in the cloud
  - HaLoop (VLDB ‘10)
  - Spark (HotCloud ‘10)
  - Piccolo (OSDI ‘10)
  - Pregel (SIGMOD ‘10)
  - Twistter (MapReduce ‘10)
  - CIEL (NSDI ‘11)
  - iMapReduce (DataCloud ‘11)
- GraphLab
  - Multicore enviroment

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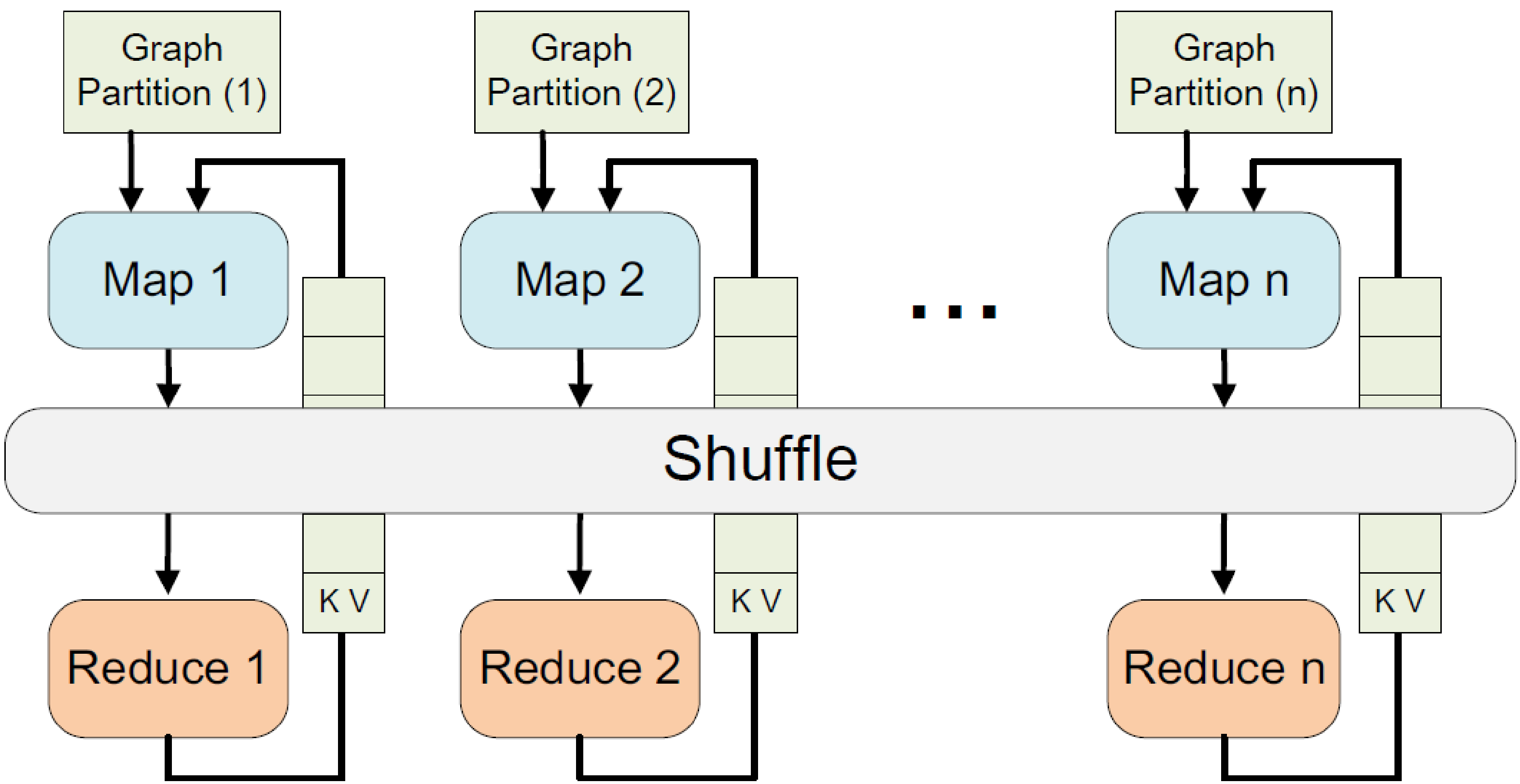
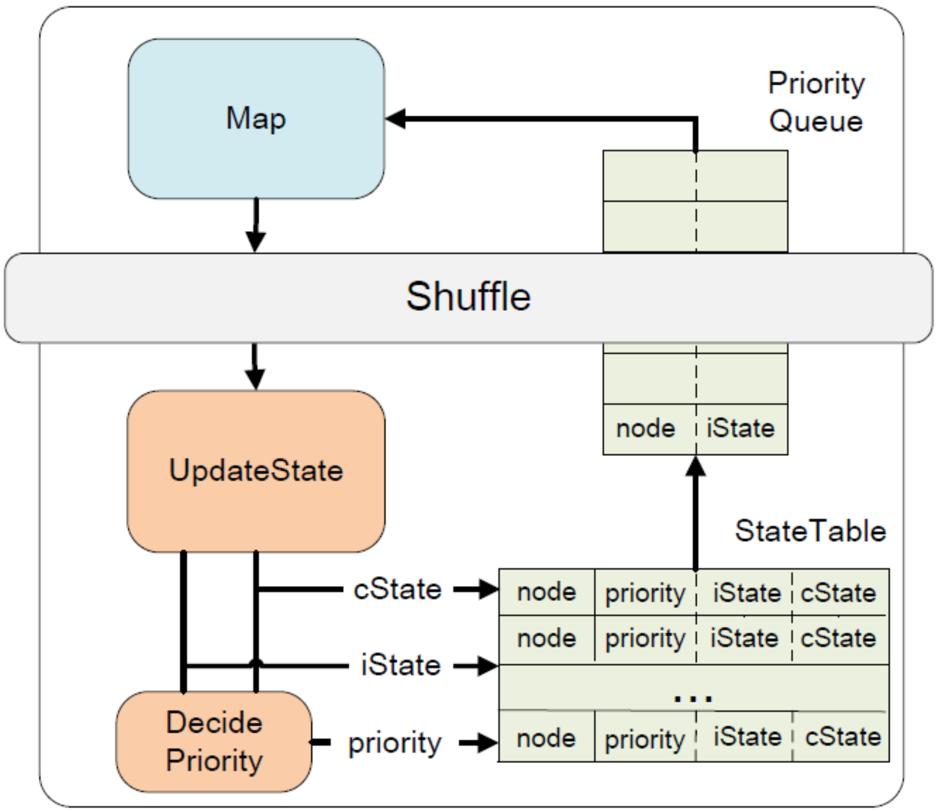
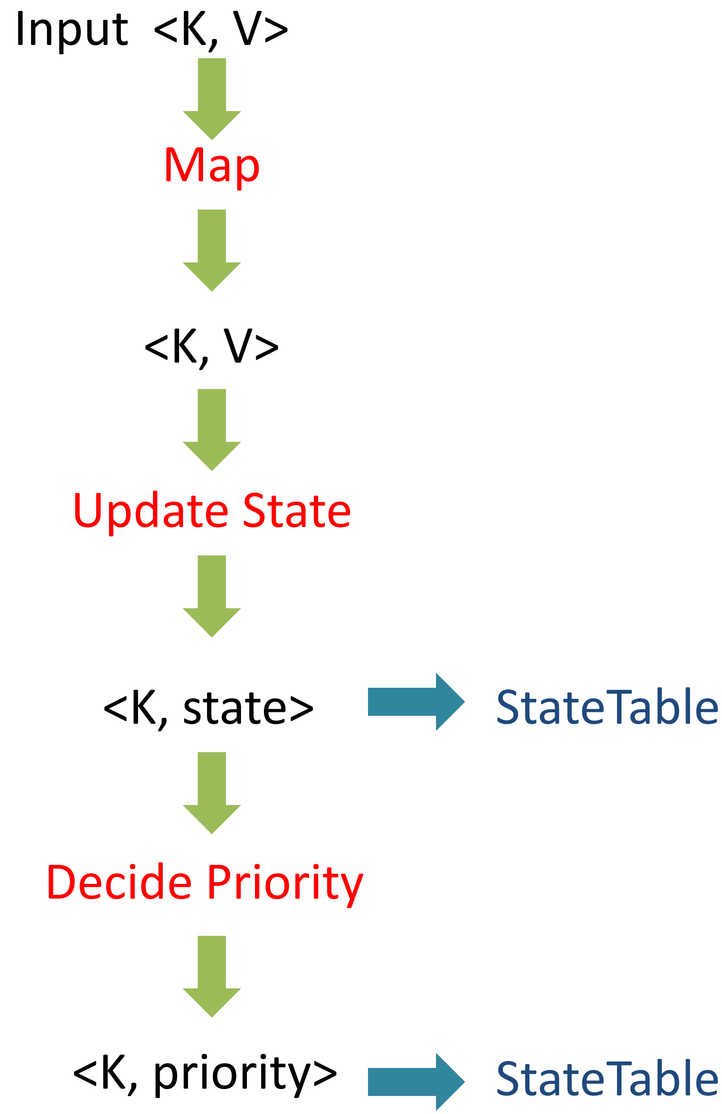
Iterative Processing

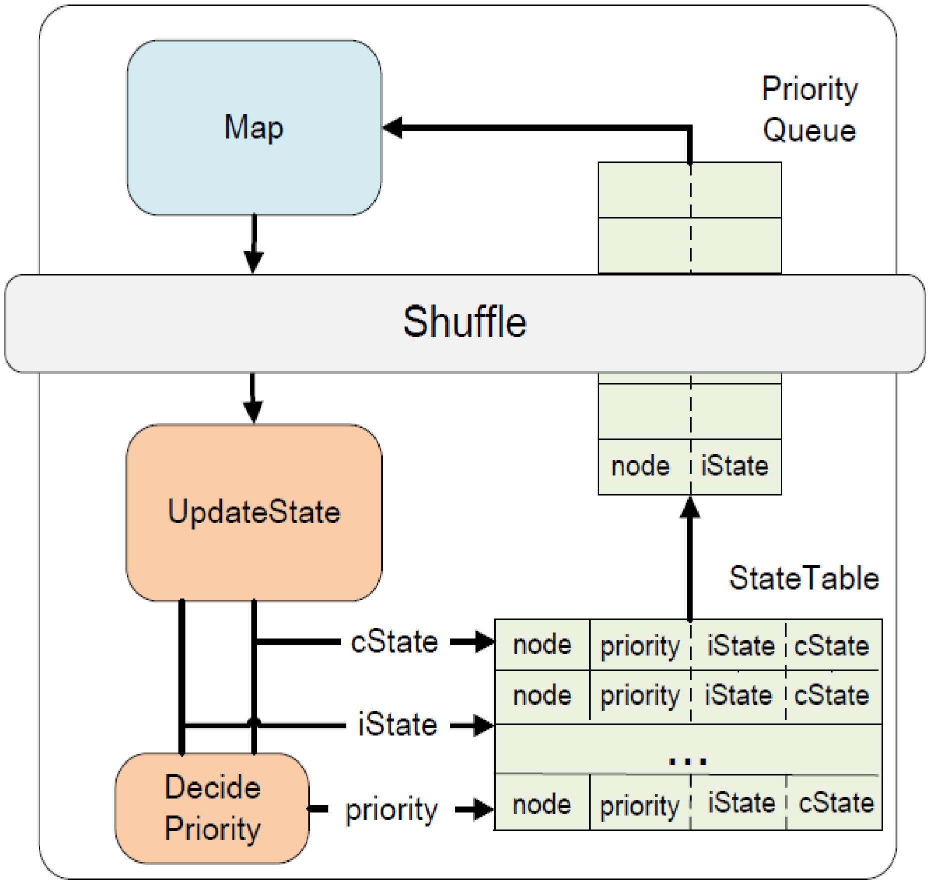


Update StateTable





Extract PriorityQueue



- Extract <K,V>s that have higher priority
  - Sampling method to retrieve a threshold
  - A single pass of StateTable
  - Priority larger than threshold, enqueue

Optimal Queue Size

$$q^* = \sqrt{\frac{\beta \cdot N \cdot T_{ovhd}}{\alpha \cdot T_{proc}}}$$

- Use the default value
- Set a value based on N

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Experiment Cluster

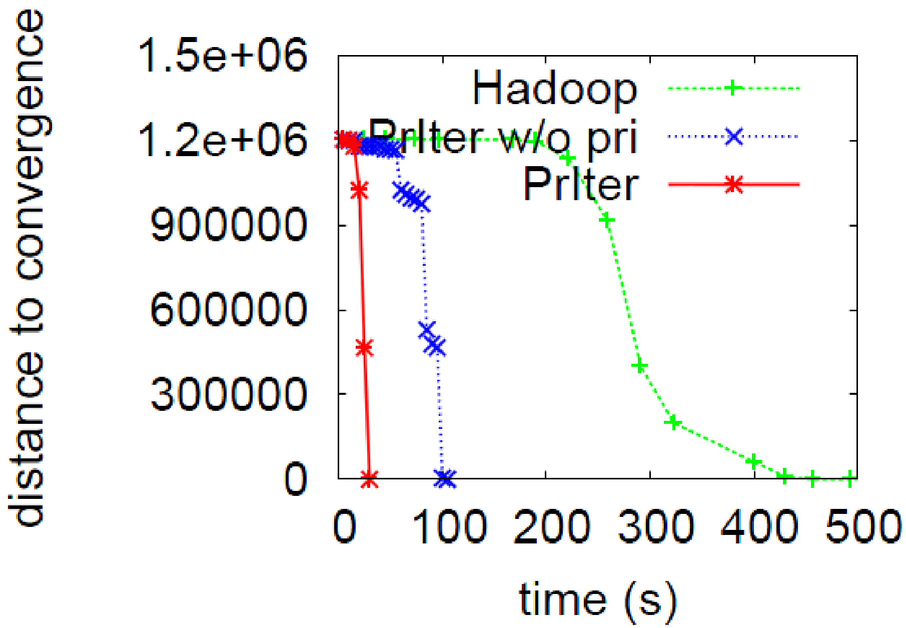
- 4-node local cluster
  - E8200 dual-core 2.66GHz CPU, 3GB of RAM, and 160GB storage
- Amazon EC2 cloud
  - 100 medium instances

Data Sets

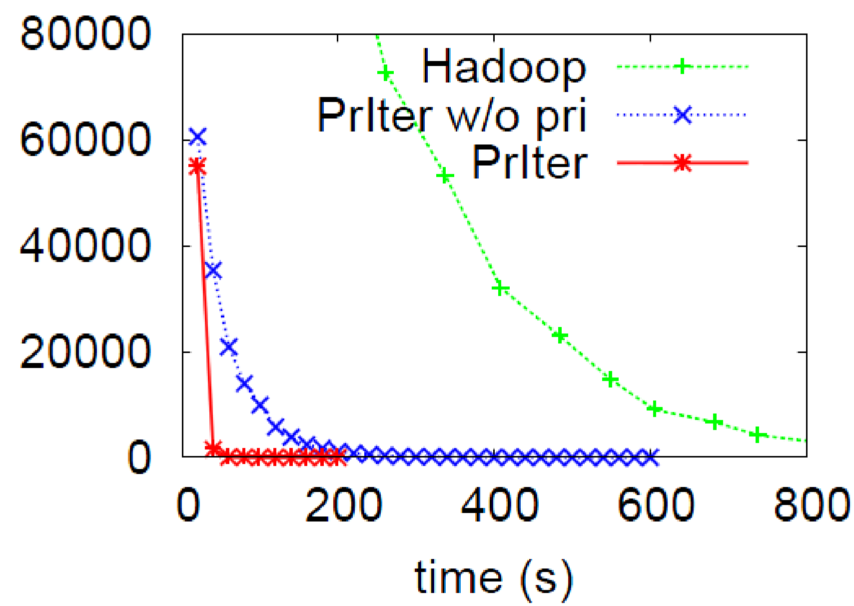
Table 1: Data Sets Summary

Algorithm	Graph	Nodes	Edges
SSSP	Facebook	1,204,004	20,492,148
	LiveJournal	4,847,571	68,993,773
	roadCA	1,965,206	5,533,214
PageRank	Berk-Stan	685,231	7,600,595
	Google	875,713	5,105,039
	Notredame	325,729	1,497,134
	Synth_WEB	100,000,000	1,216,907,427
Adsorption	Facebook	1,204,004	20,492,148
	Youtube	311,805	1,761,812
	Amazon	403,394	3,387,388
ConnComp	Amazon	403,394	3,387,388
	Wiki-talk	2,394,385	5,021,410
	LiveJournal	4,847,571	68,993,773

Convergence Speed (Local Cluster)

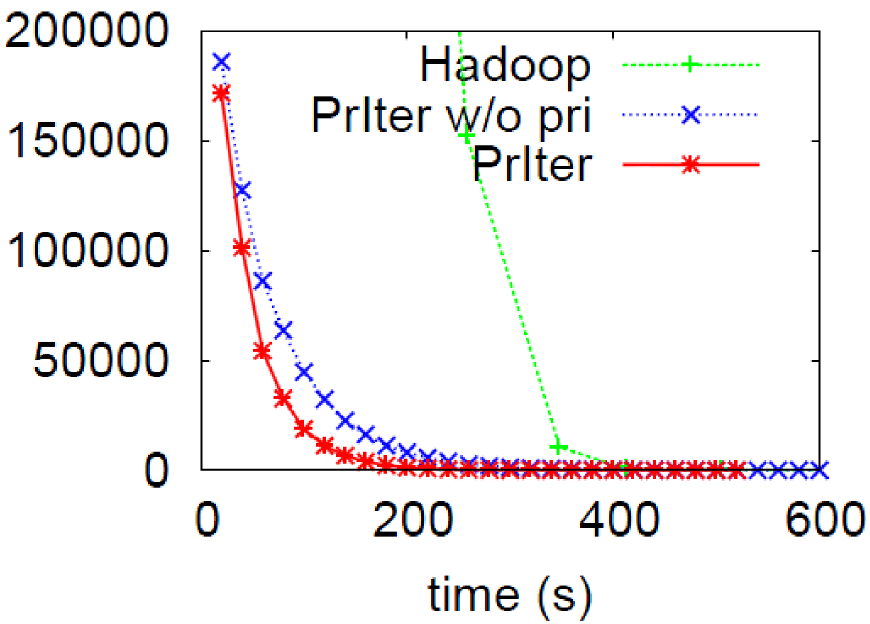


SSSP (Facebook)

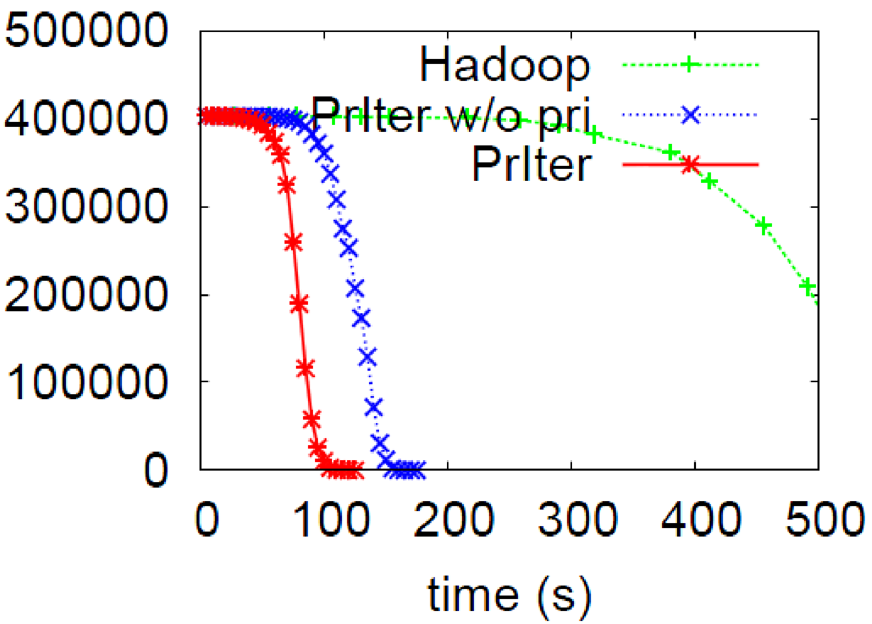


PageRank (BerkStan)

Convergence Speed (Local Cluster)



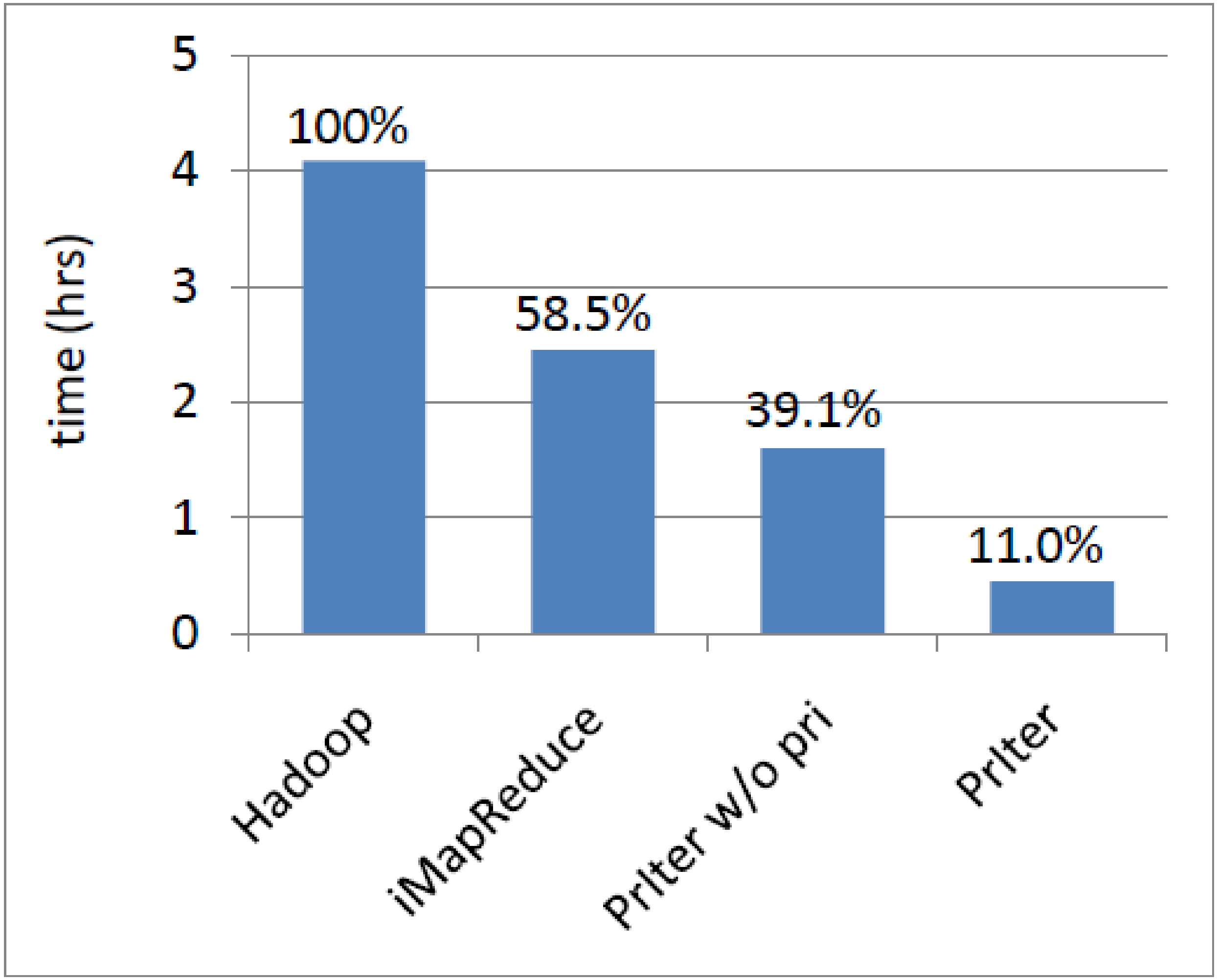
Adsorption (Facebook)



Connected Components (Amazon)

Convergence Time (EC2)

Pagerank

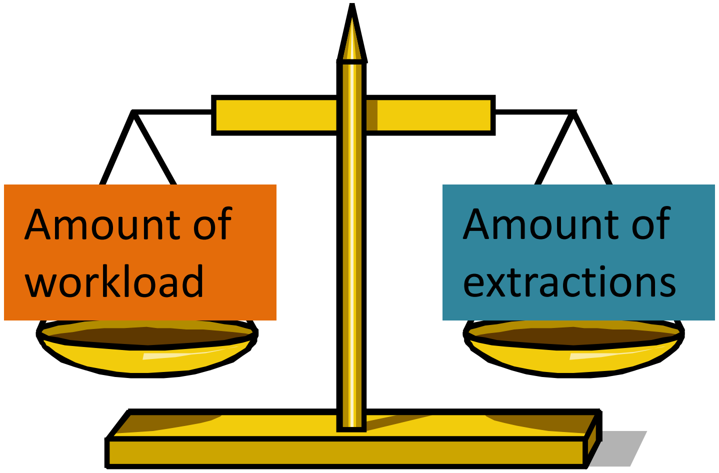


Conclusions

- Proven effectiveness of prioritized iterative computation
  - Converge faster
  - Derive the same converged result
- PrIter
  - Distributed framework that supports prioritized iteration
  - Reduces expensive data access by performing more effective update first
  - Achieve up to 50x speedup comparing to Hadoop
  - MapReduce like API
- Our source code is available at

  http://code.google.com/p/priter/

Optimal Queue Size



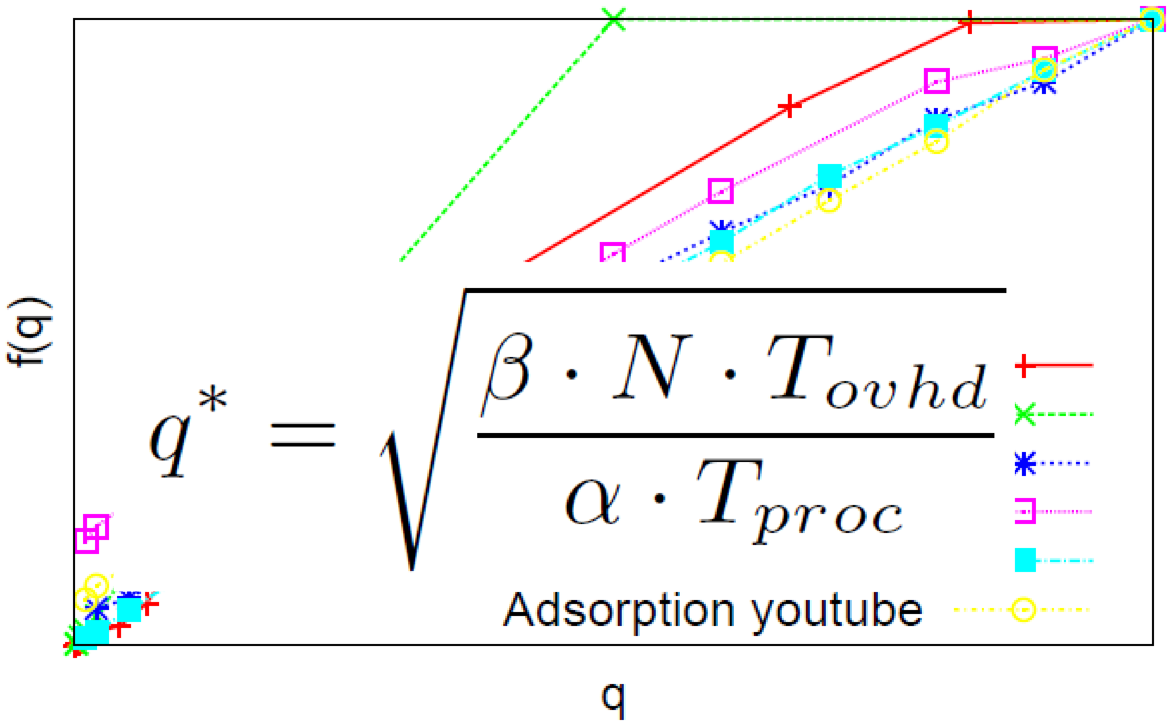
- The optimal case: update the most prioritized node
  - Need a pass of StateTable (overhead)
  - NOT practical
- The other extreme case: update all nodes in StateTable
  - NOT prioritized iteration
- Less updates (less workload) need more frequent queue extractions
- An optimal queue size that balances these two

Optimal Queue Size

$$\min_{q}\left\{ f(q) \cdot T_{proc} + \frac{f(q)}{q} \cdot N \cdot T_{ovhd} \right\}$$

- q: queue size
- f(q): total updates needed
- f(q)/q: number of queue extractions
- N: StateTable size
- T_{proc}: processing time for a node
- T_{ovhd}: scanning time for table entry

Optimal Queue Size



$$q^* = \sqrt{\frac{\beta \cdot N \cdot T_{ovhd}}{\alpha \cdot T_{proc}}}$$

- Online estimation
- Set a default value based on N