Exploiting Bounded Staleness to Speed up Big Data Analytics

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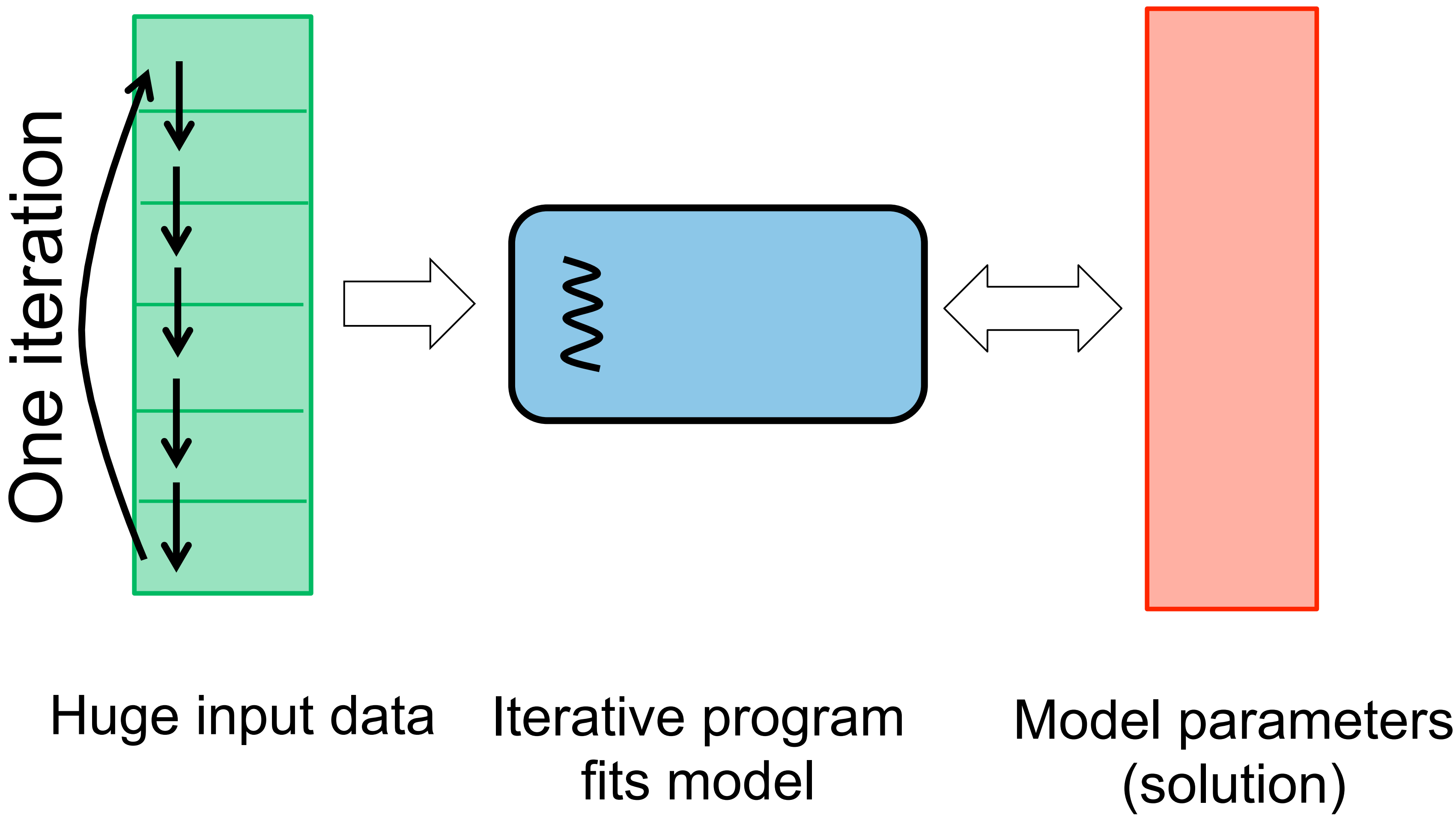
Big Data Analytics Overview



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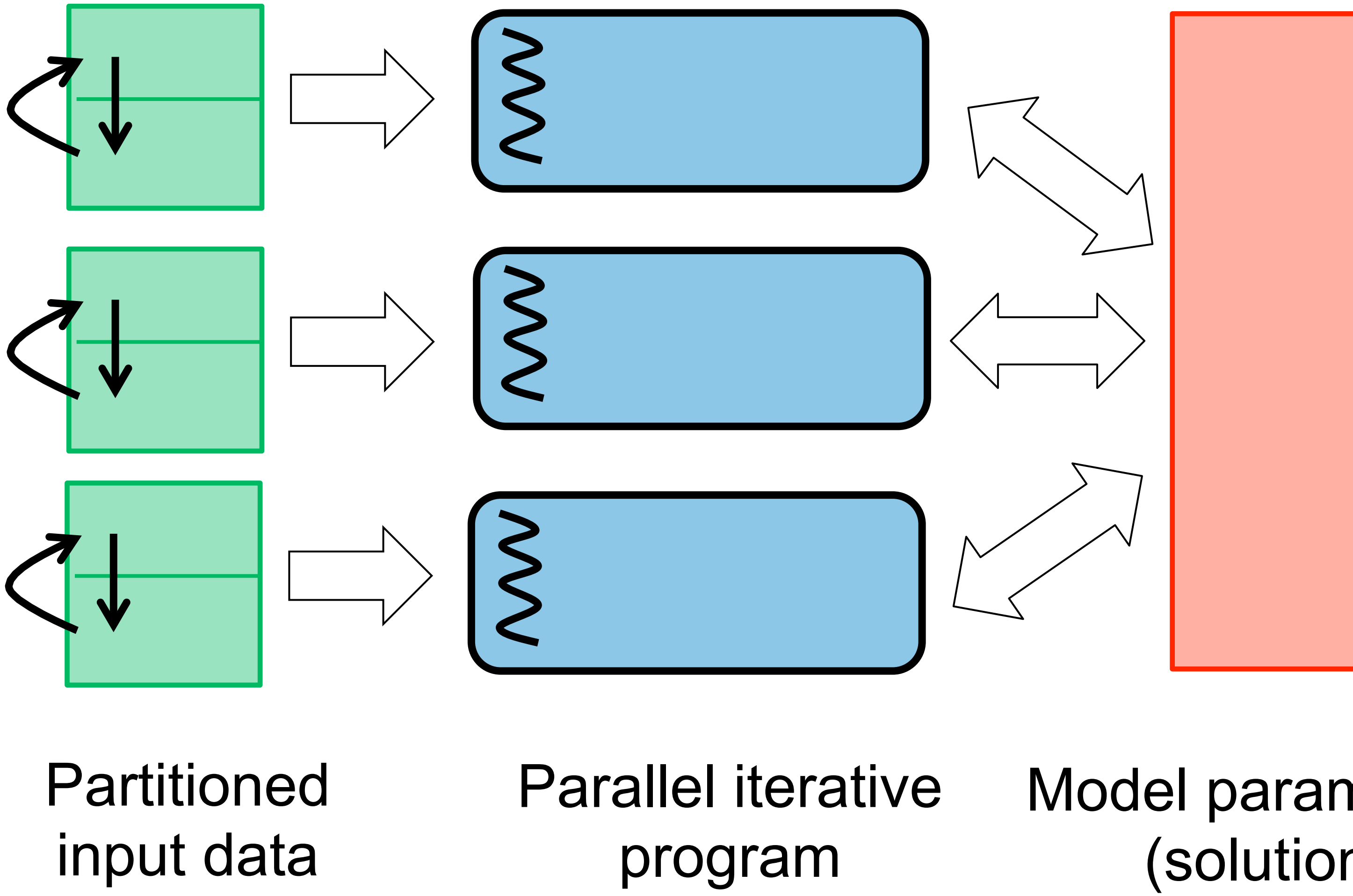

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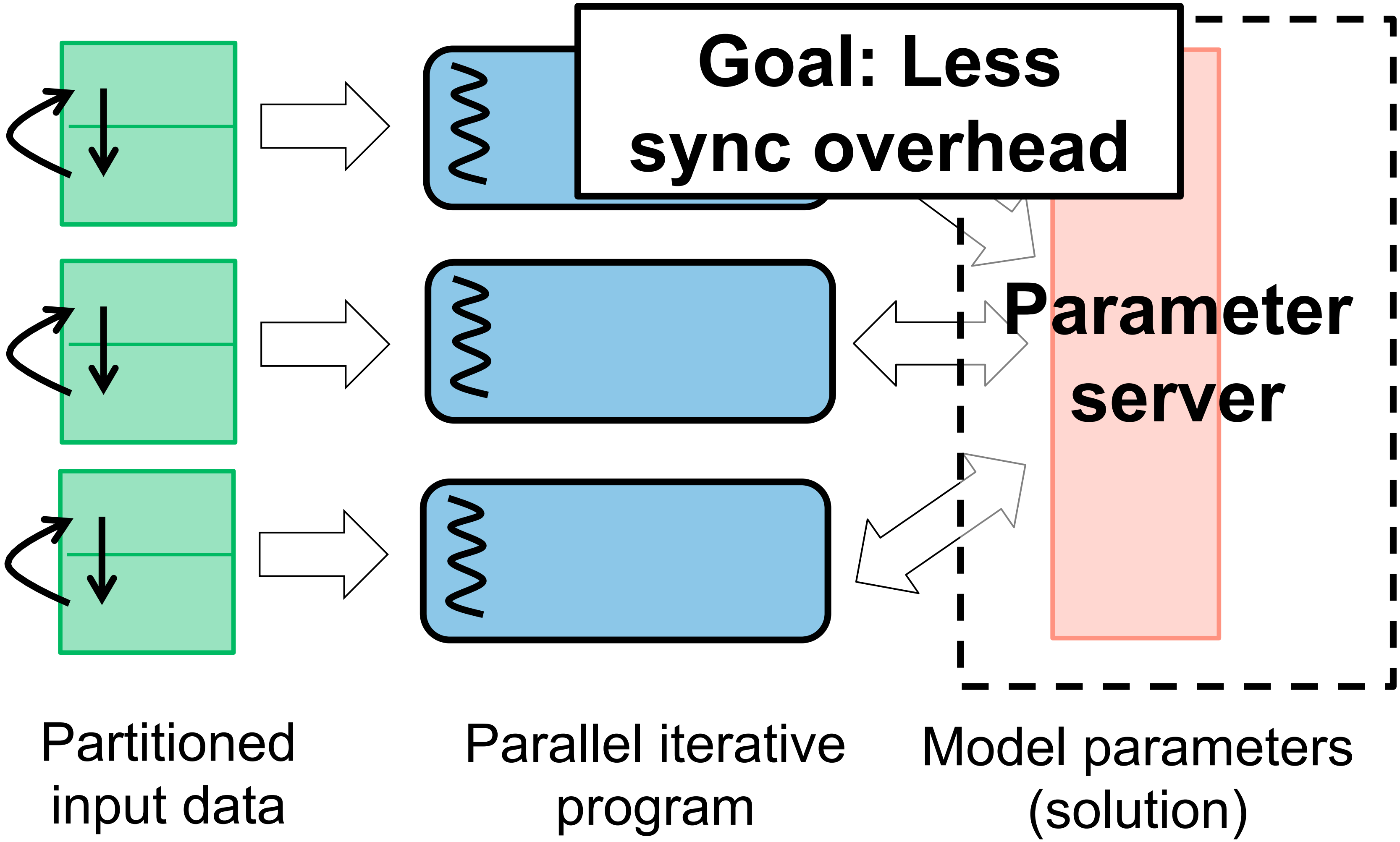


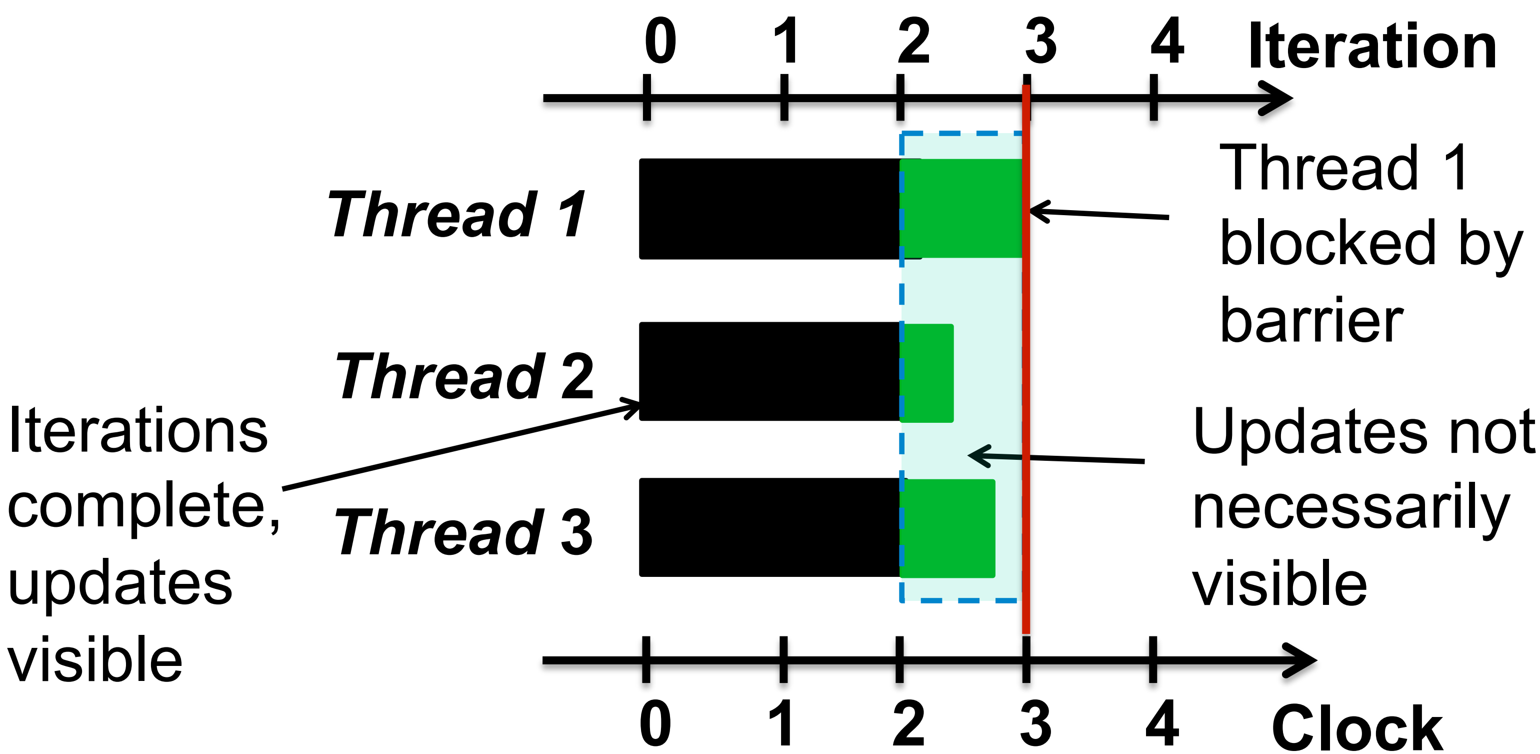
Outline

- Two novel synchronization approaches
  - Arbitrarily-sized Bulk Synchronous Parallel (A-BSP)
  - Stale Synchronous Parallel (SSP)
- LazyTable architecture overview
- Taste of experimental results

Bulk Synchronous Parallel

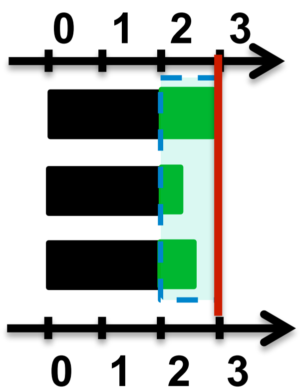
- A barrier every **clock** (a.k.a. epoch)
  - In ML apps, often one iteration over input data

Thread progress illustration:



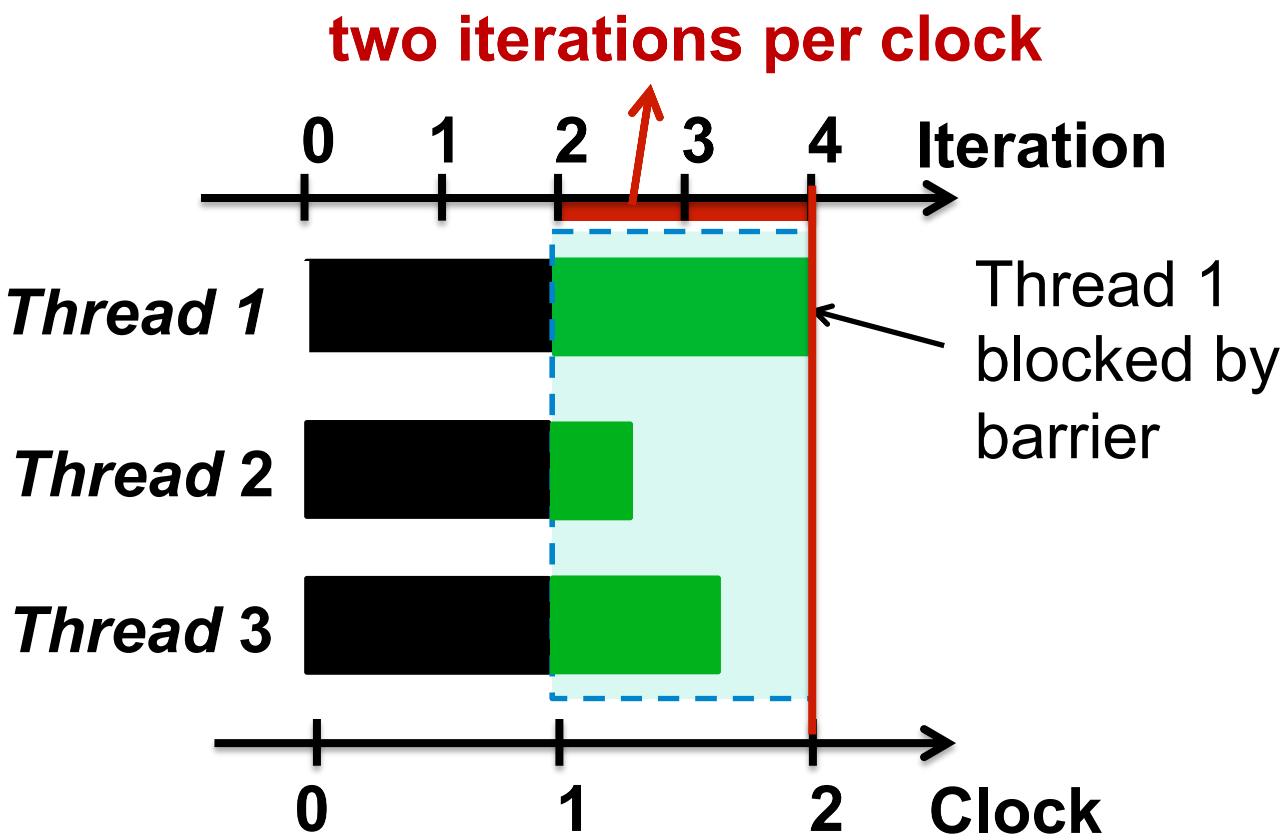
Data Staleness

- In BSP, threads can see "out-of-date" values
  - May not see others' updates right away
  - Convergent apps usually tolerate that
- Allowing more staleness for speed
  - Less synchronizing among threads
  - More using cached values
  - More delaying and batching of updates
- But, too much staleness hurts convergence
  - Important to have staleness bound
  - **Staleness should be tunable**



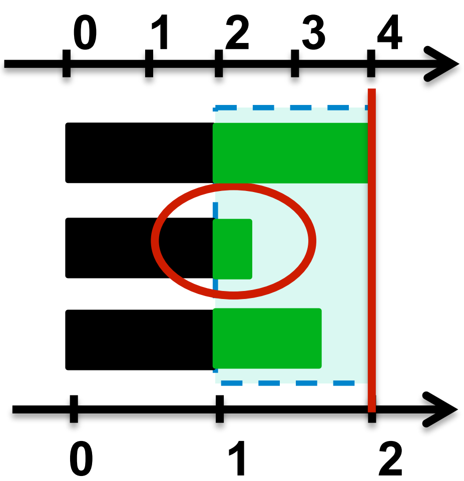
Arbitrarily-sized BSP (A-BSP)

- Work in each clock can be more than one iteration
  - Less synchronization overhead



Problem of (A-)BSP: Stragglers

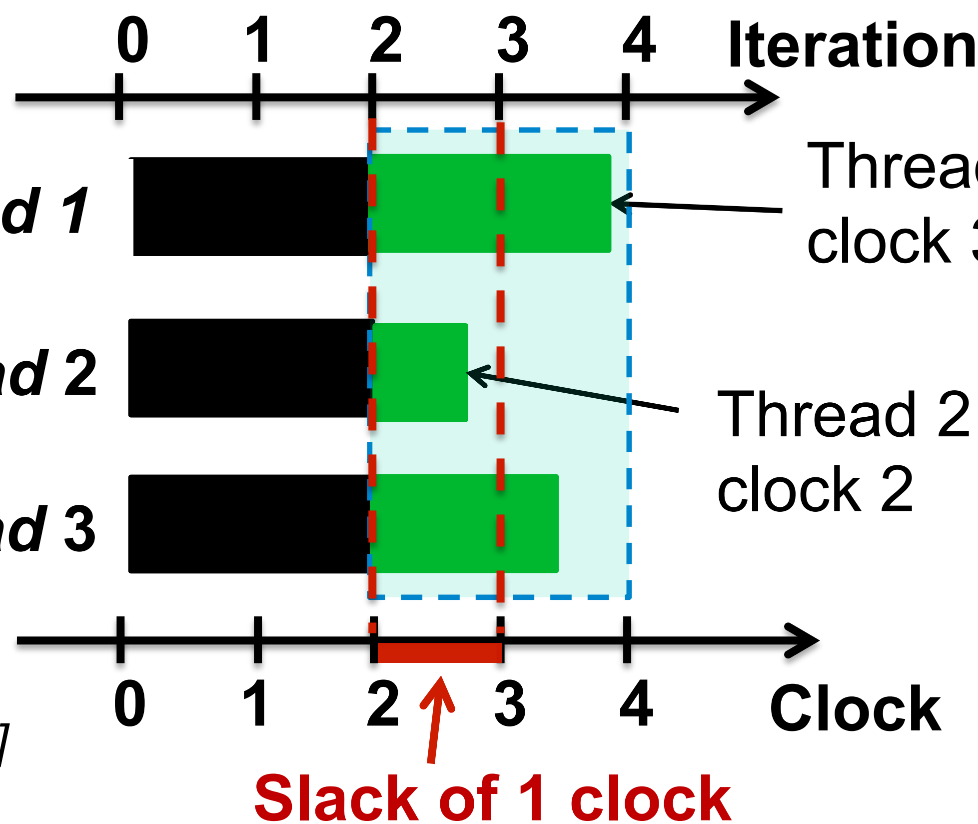
- A-BSP still has the straggler problem
  - A slow thread will slow down all
  - Stragglers are common in large systems



- Many reasons for stragglers
  - Hardware: lost packets, SSD cleaning, disk resets
  - Software: garbage collection, virtualization
  - Algorithmic: calculating objectives and stopping conditions

Stale Synchronous Parallel (SSP)

- Threads are allowed to be **slack** clocks ahead of the slowest thread

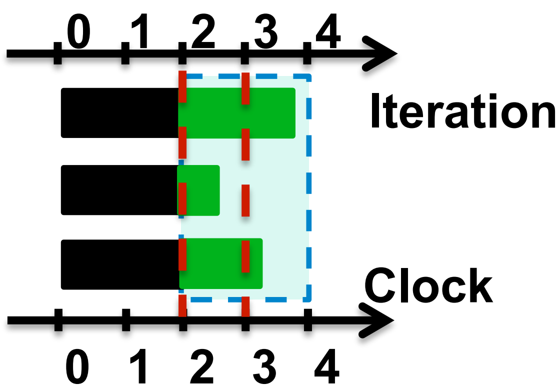


[HotOS'13, NIPS'13]

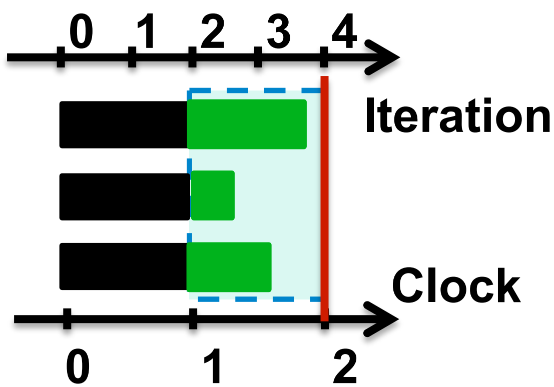
Two Dimensional Config. Space

- Iters-per-clock and slack are both tunable
  - A-BSP is SSP with a slack of zero
  - Every SSP config. has an A-BSP counterpart with the same data staleness bound

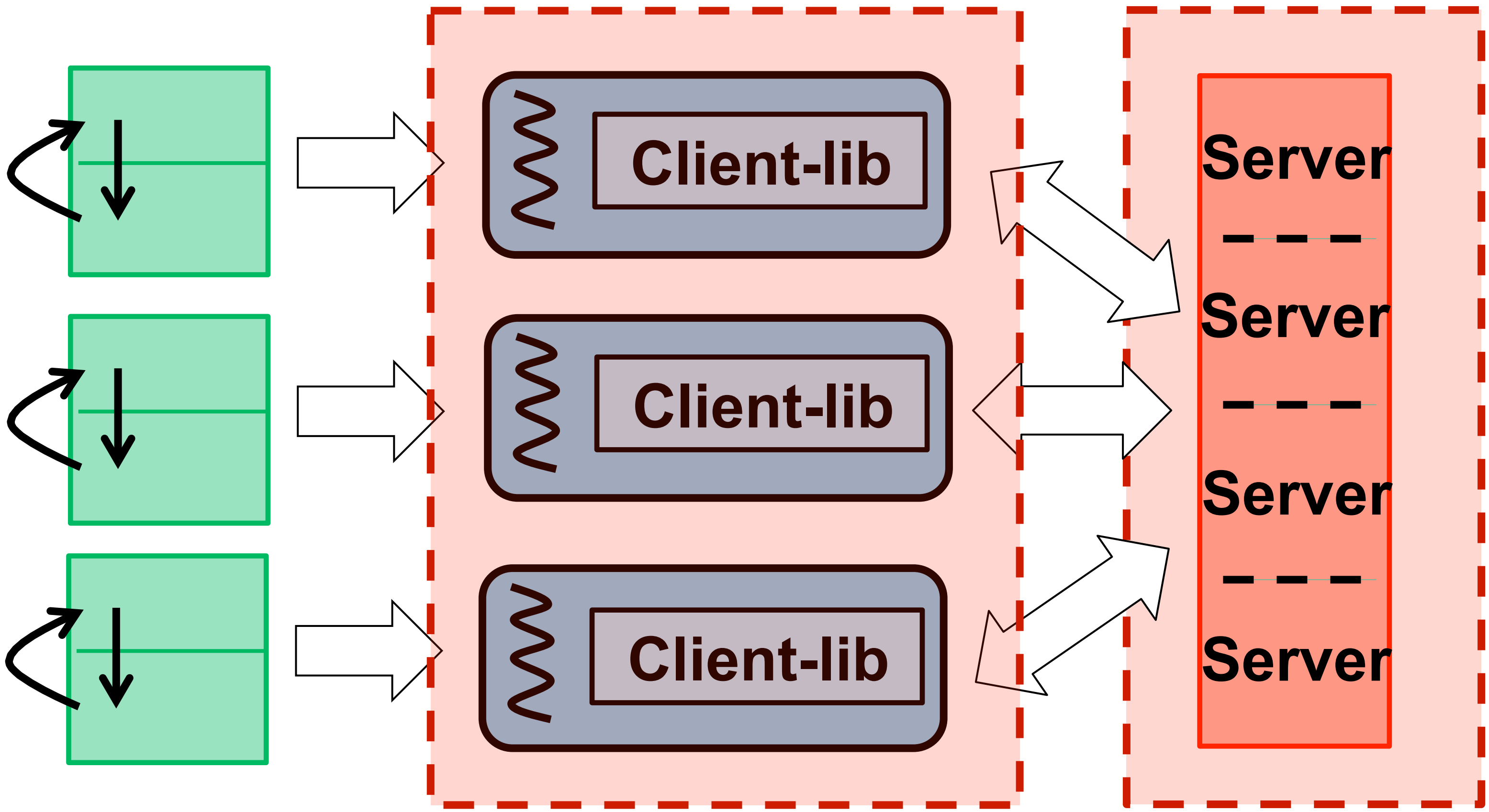
SSP (iters-per-clock=1, slack=1):



A-BSP (iters-per-clock=2, slack=0):



LazyTable Architecture

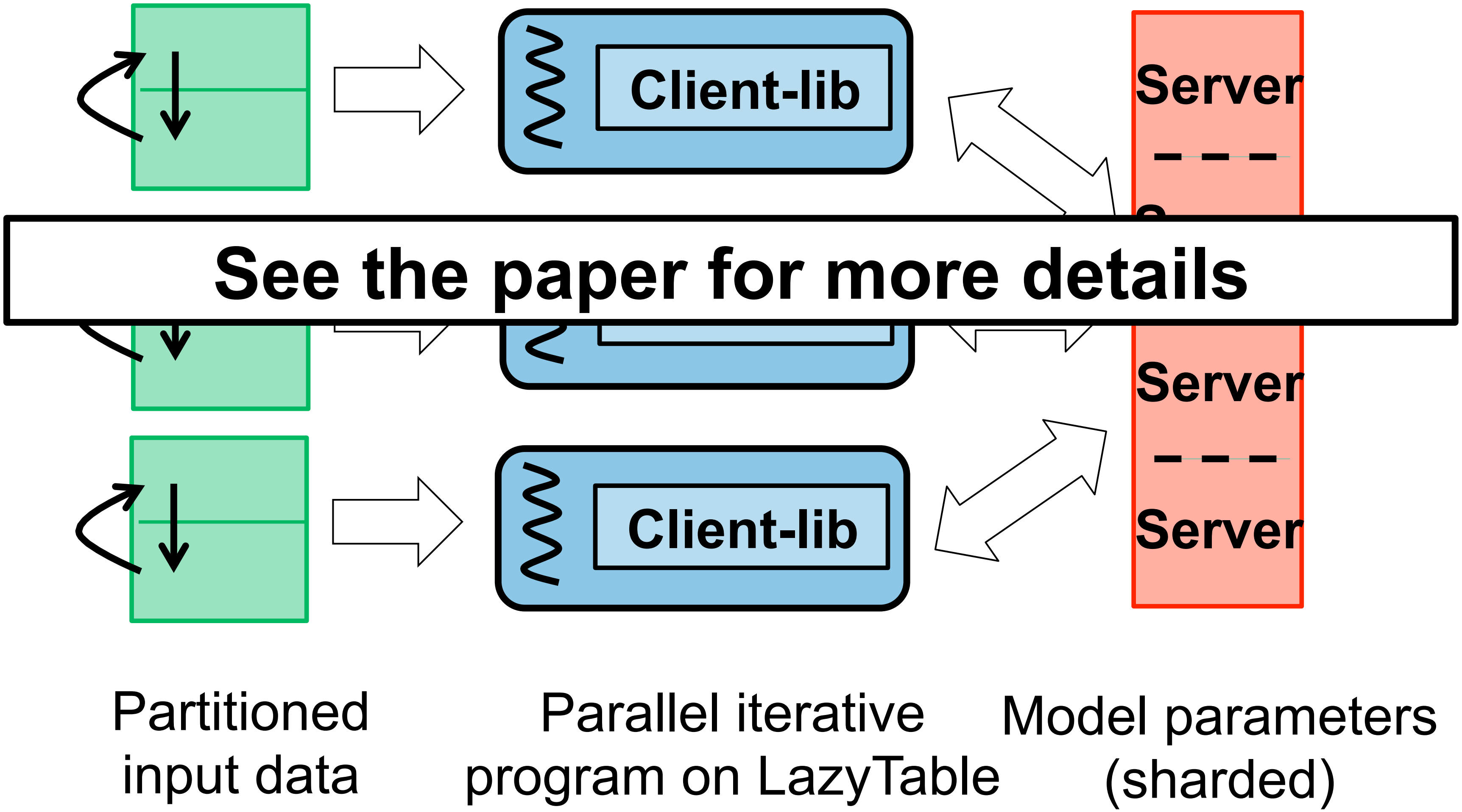


Partitioned input data

Parallel iterative program on LazyTable

Model parameters (sharded)

LazyTable Architecture



Primary Experimental Setup

- Hardware information
  - 8 machines, each with 64 cores & 128GB RAM
- Basic configuration
  - One client & tablet server per machine
  - One computation thread per core

Application Benchmark #1

- Topic Modeling
  - Algorithm: Gibbs Sampling on LDA
  - Input: *NY Times* dataset
    - 300k docs, 100m words, 100k vocabulary
  - Solution quality criterion: Loglikelihood
    - How likely the model generates observed data
    - Becomes higher as the algorithm converges
    - A larger value indicates better quality

More apps described and used in paper

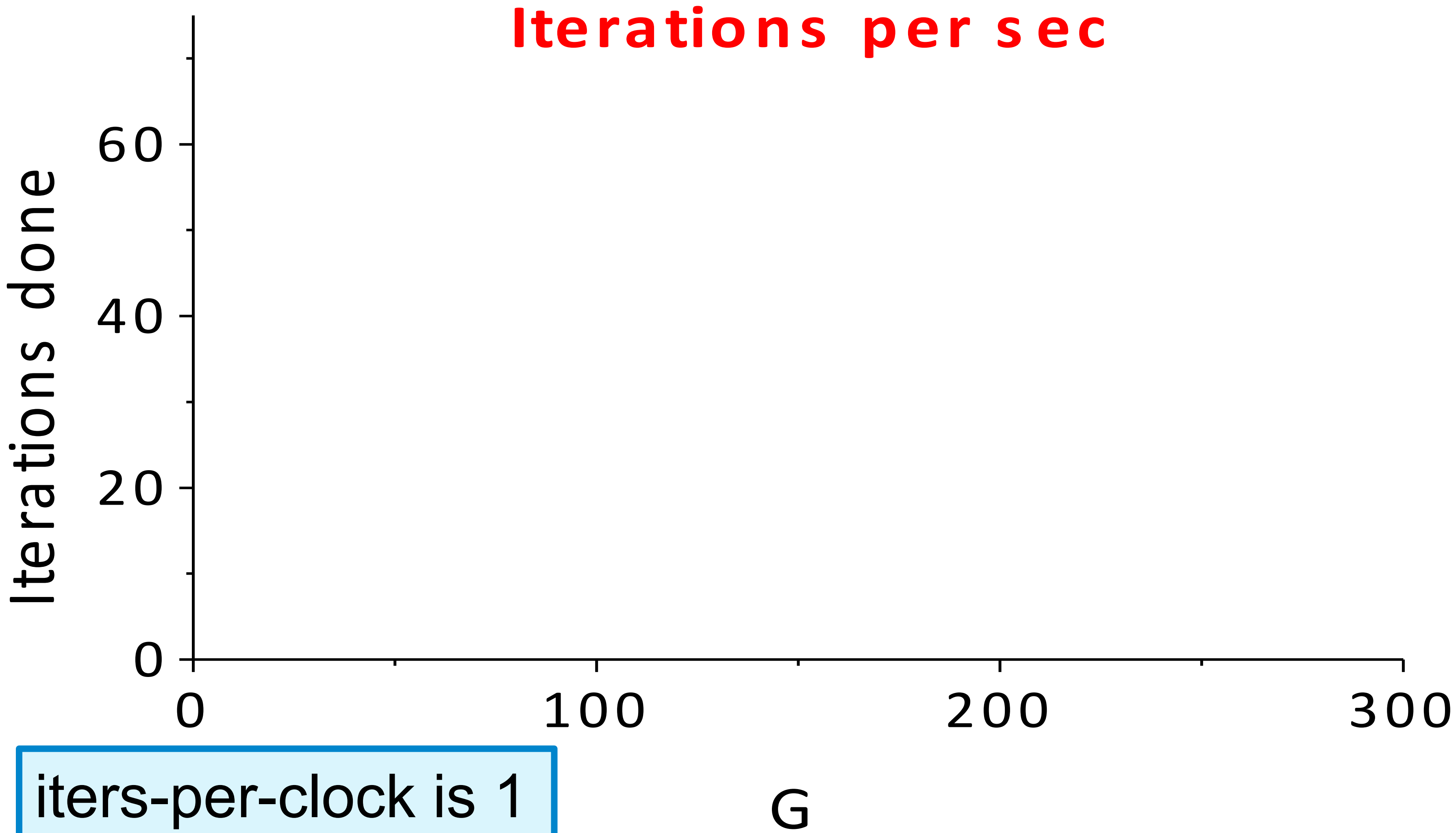
Controlling Data Staleness

- SSP
  - Larger slack -> more staleness

- A-BSP
  - Larger iterations-per-clock -> more staleness

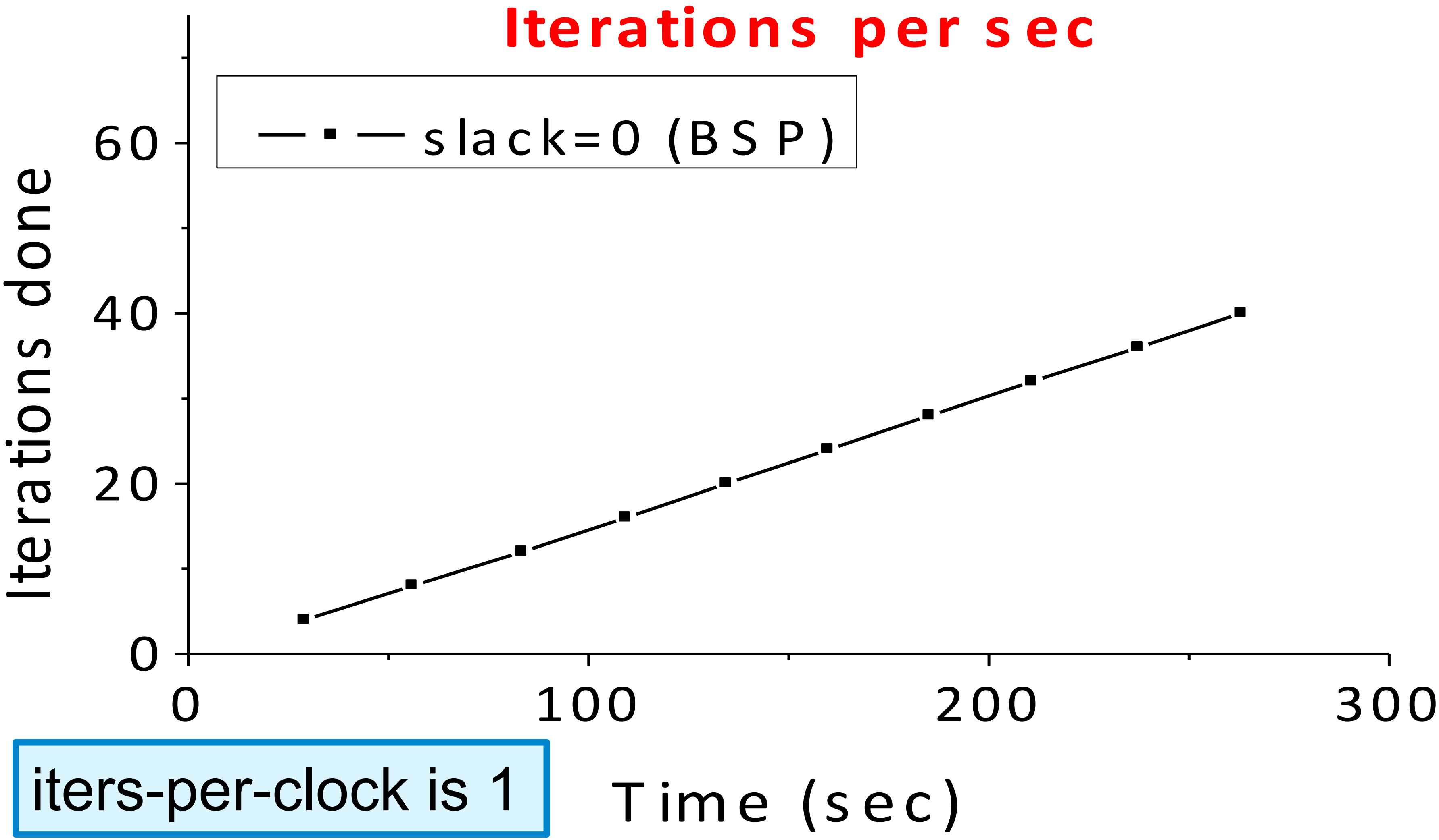
- The tradeoffs with increased staleness

Staleness Increases Iters/sec



iters-per-clock is 1

Staleness Increases Iters/sec



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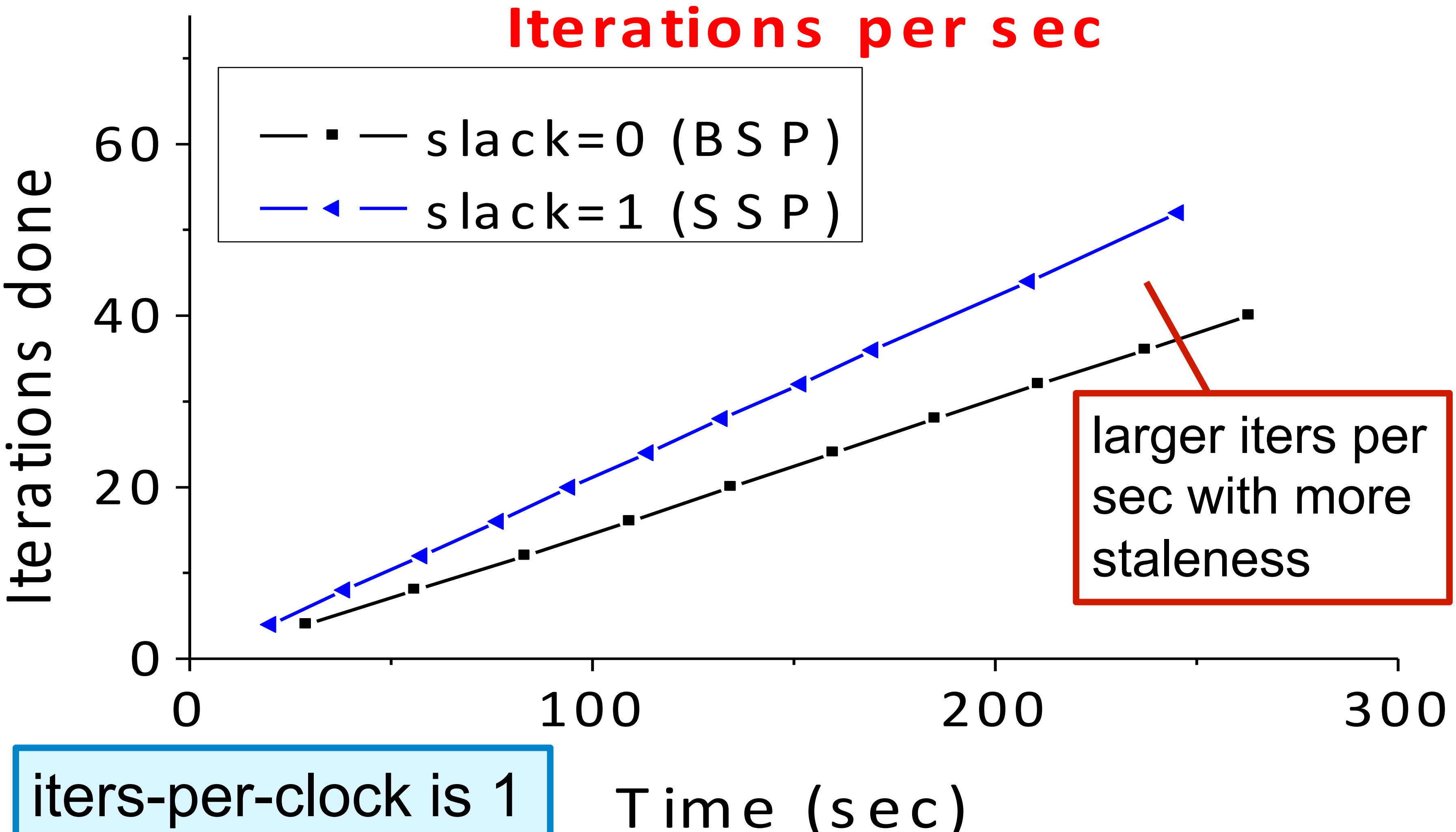

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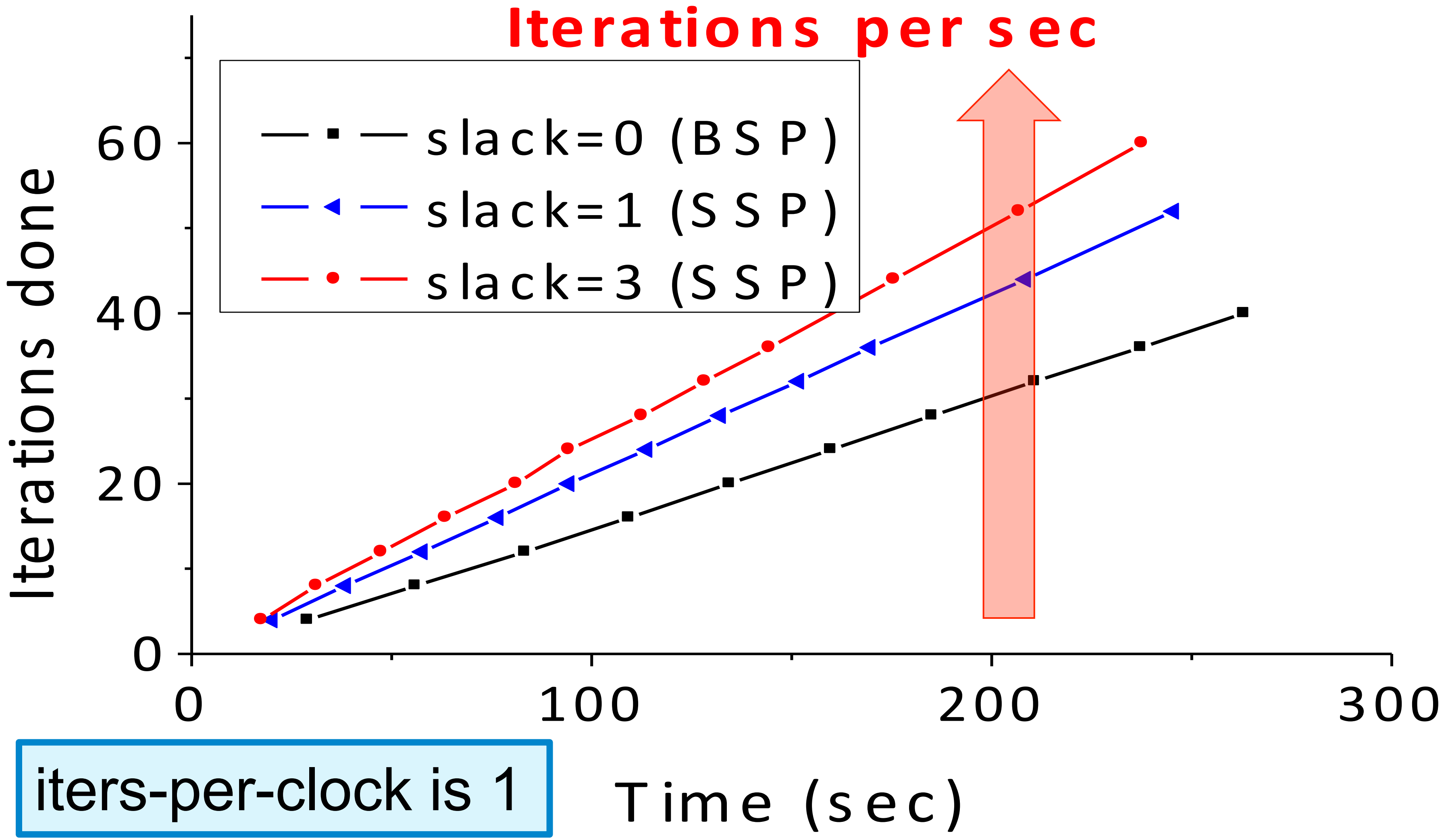
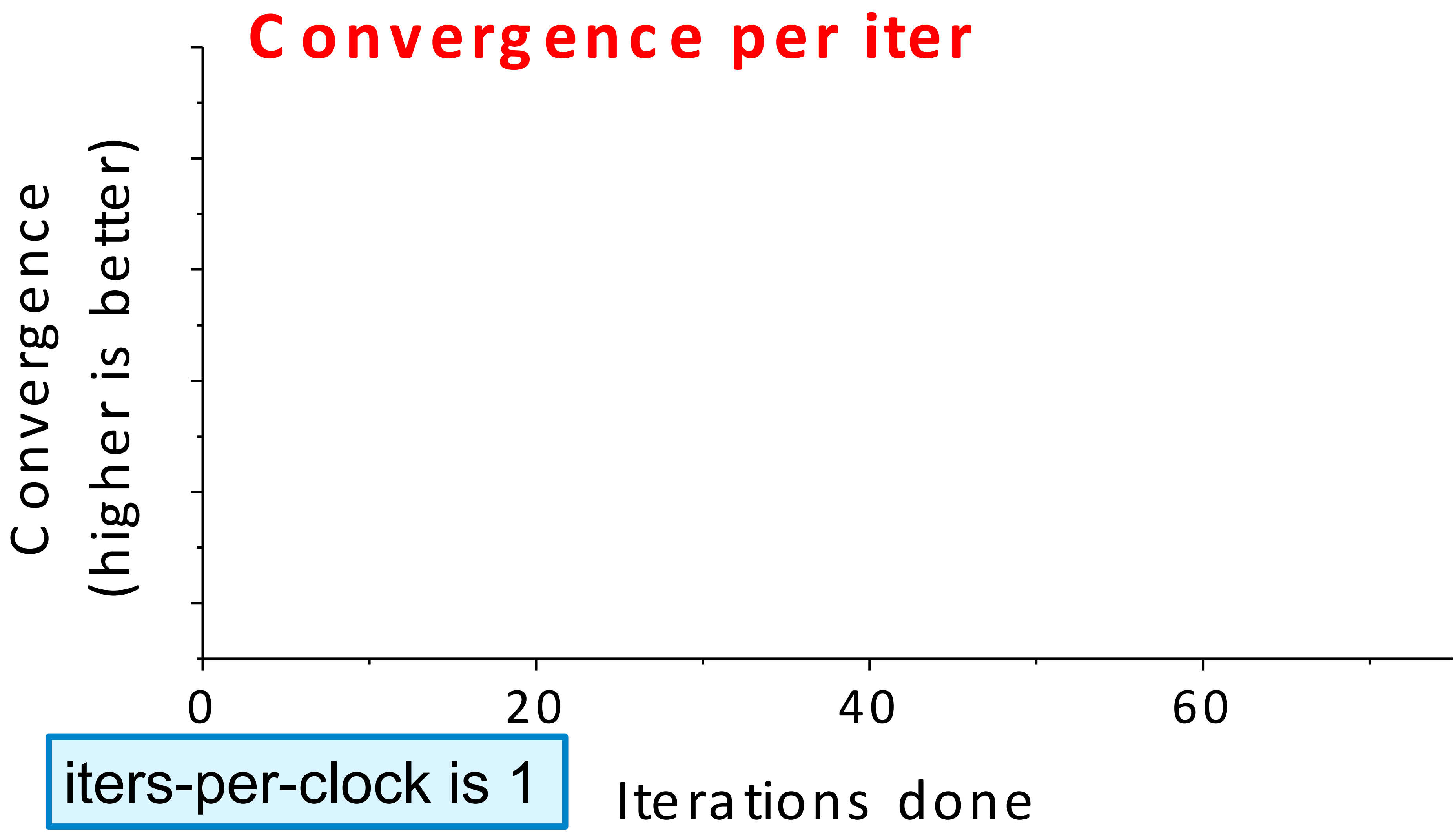


iters-per-clock is 1

Staleness Reduces Converge/iter



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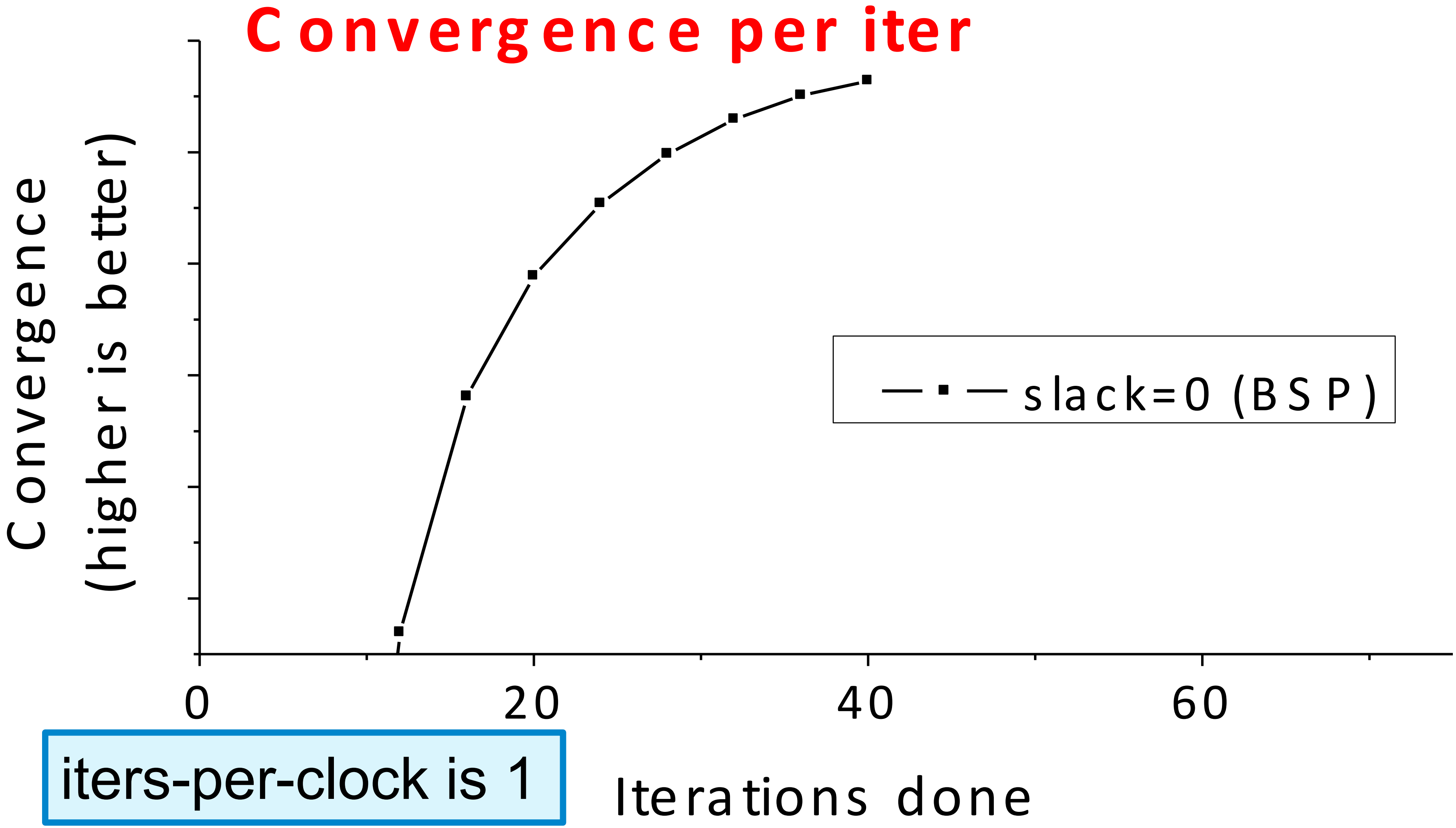

iters-per-clock is 1

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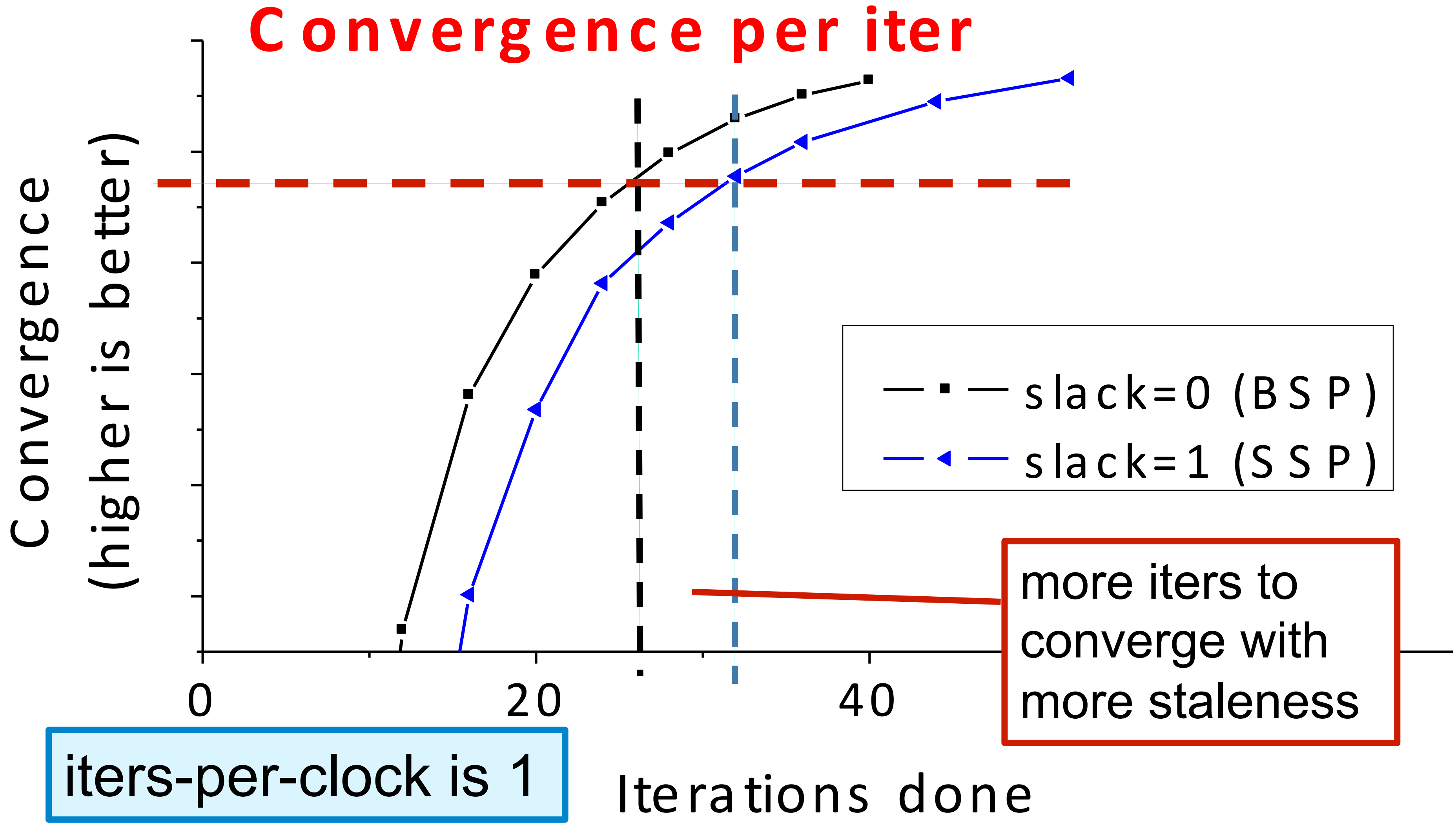
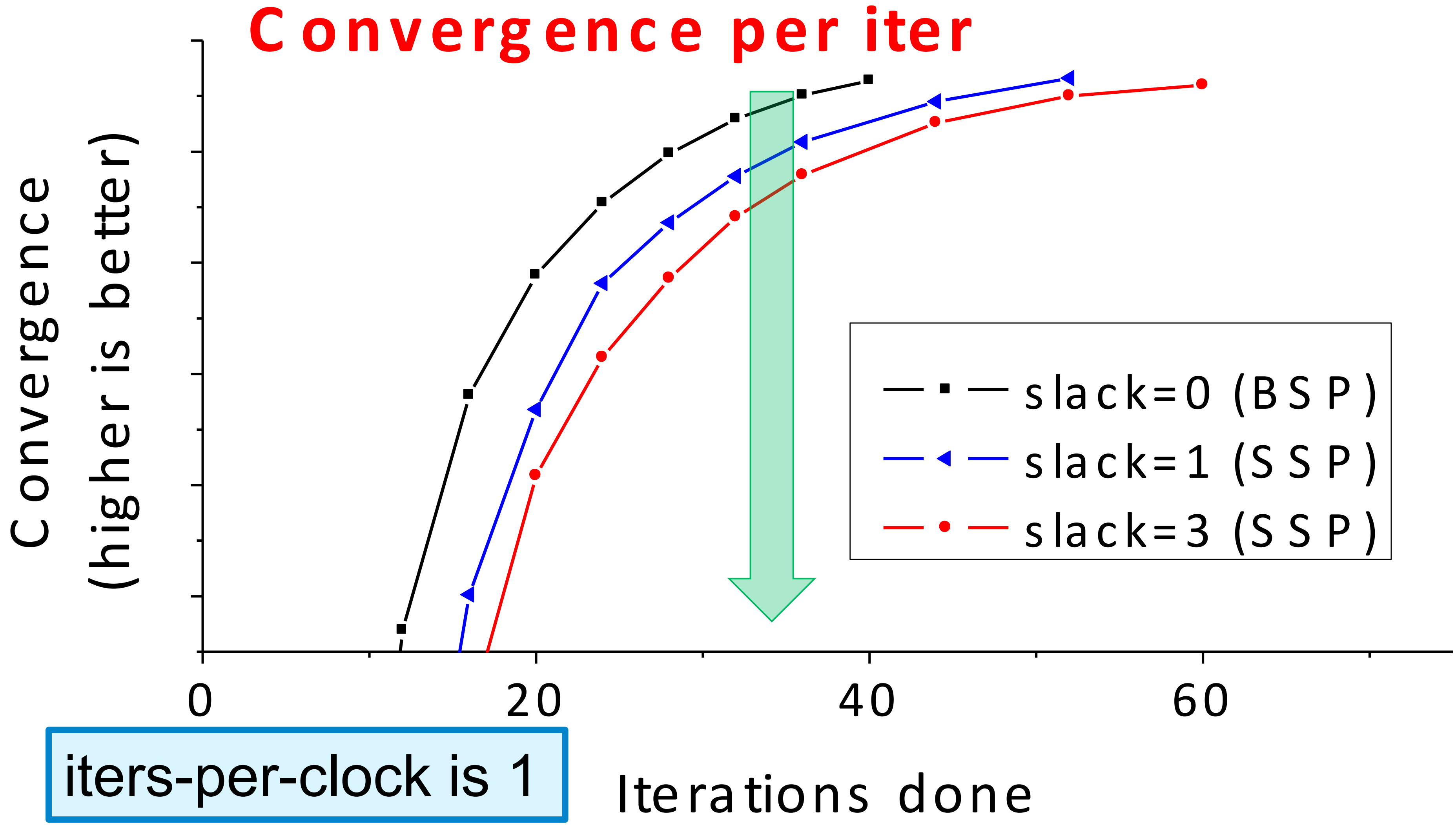


more iters to converge with more staleness

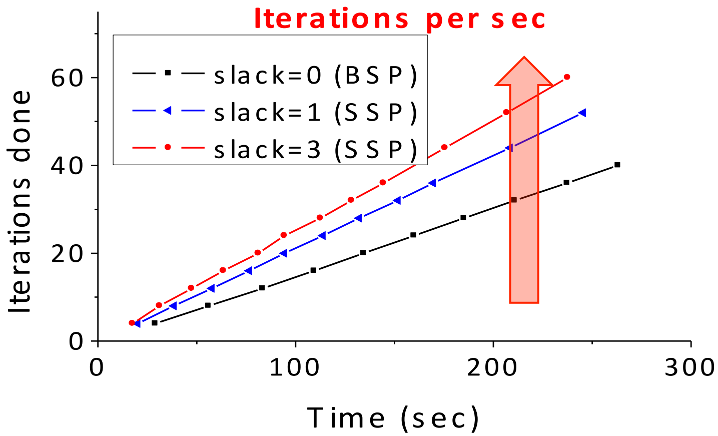
iters-per-clock is 1

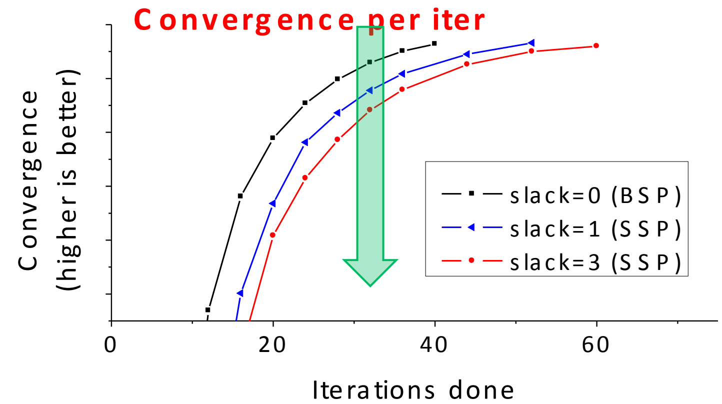
Staleness Reduces Converge/iter

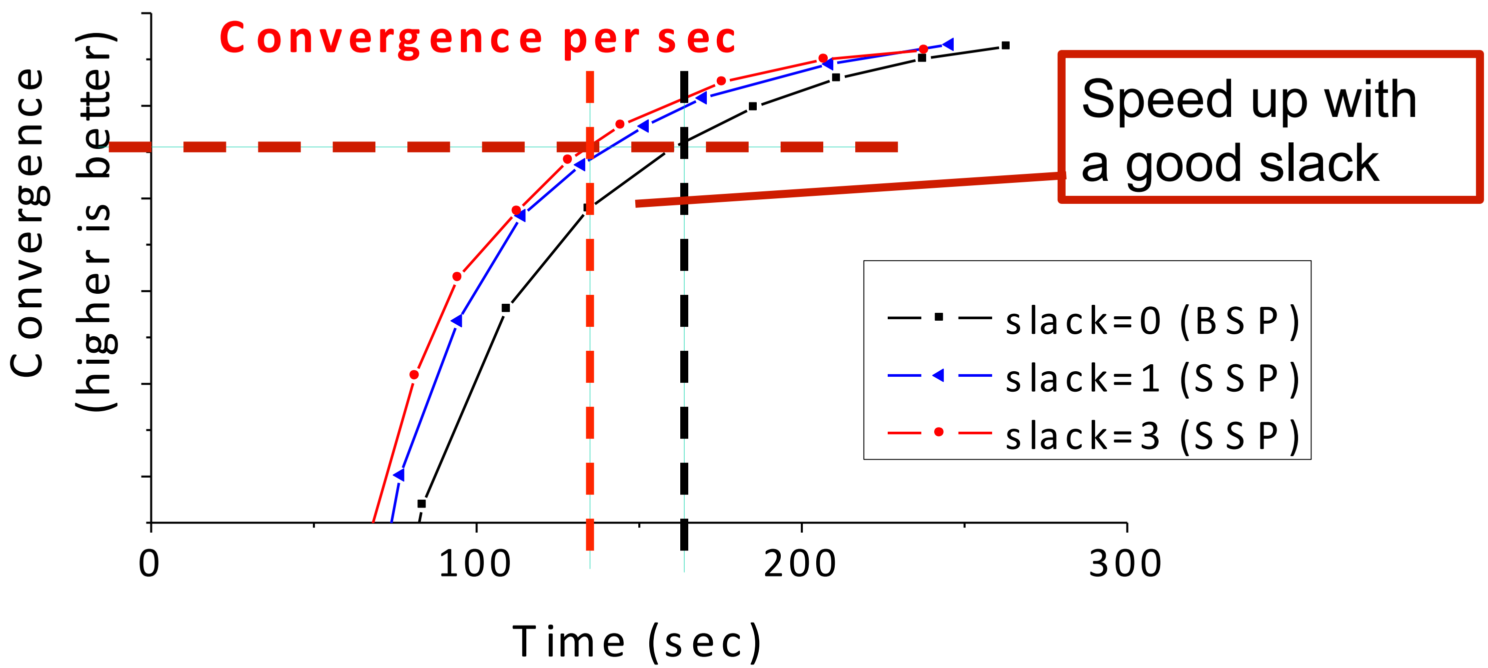


iters-per-clock is 1

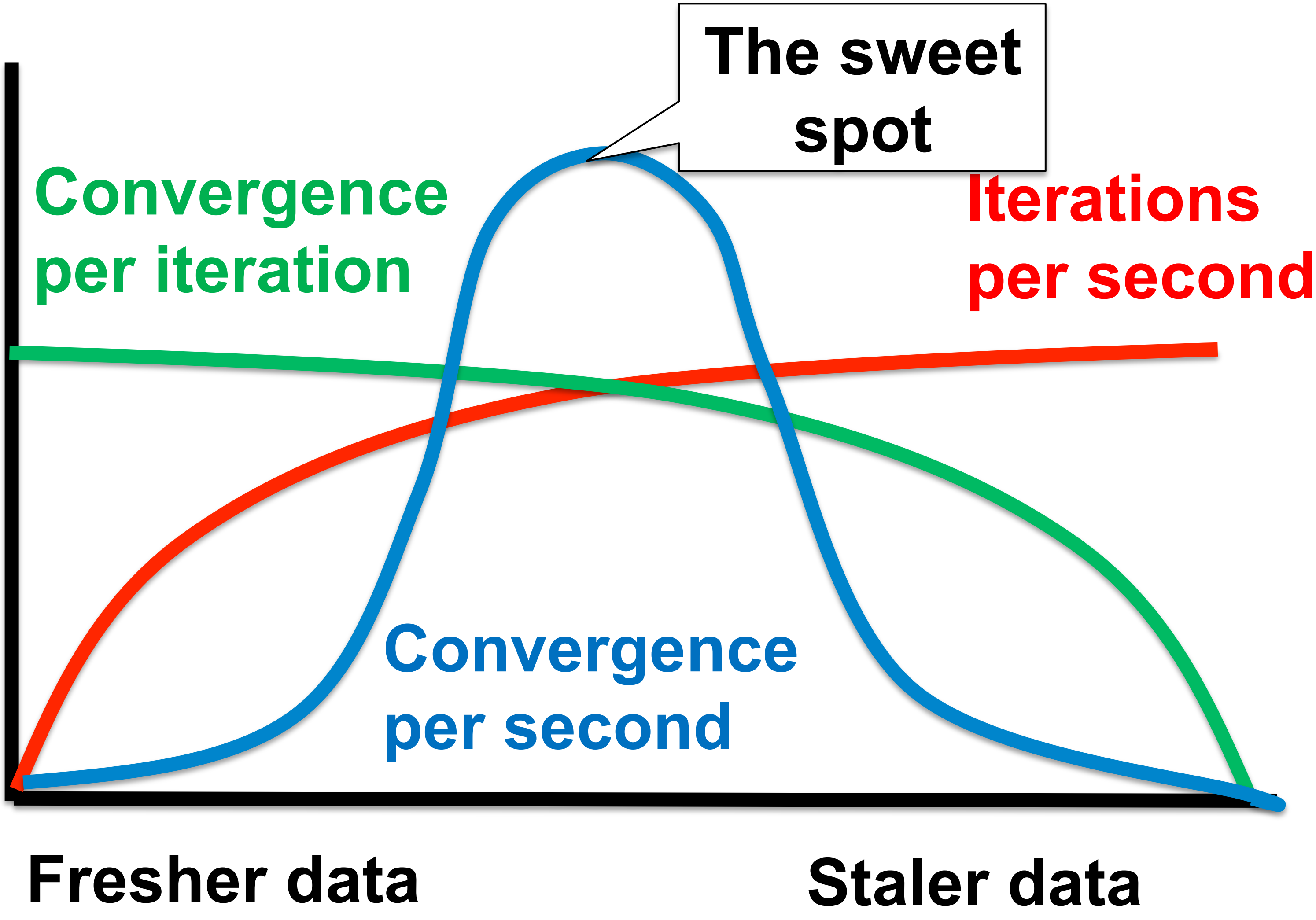
Sweet Spot Balances the Two







Key Takeaway Insight #1



SSP vs A-BSP

- Similar performance
  - In the absence of stragglers

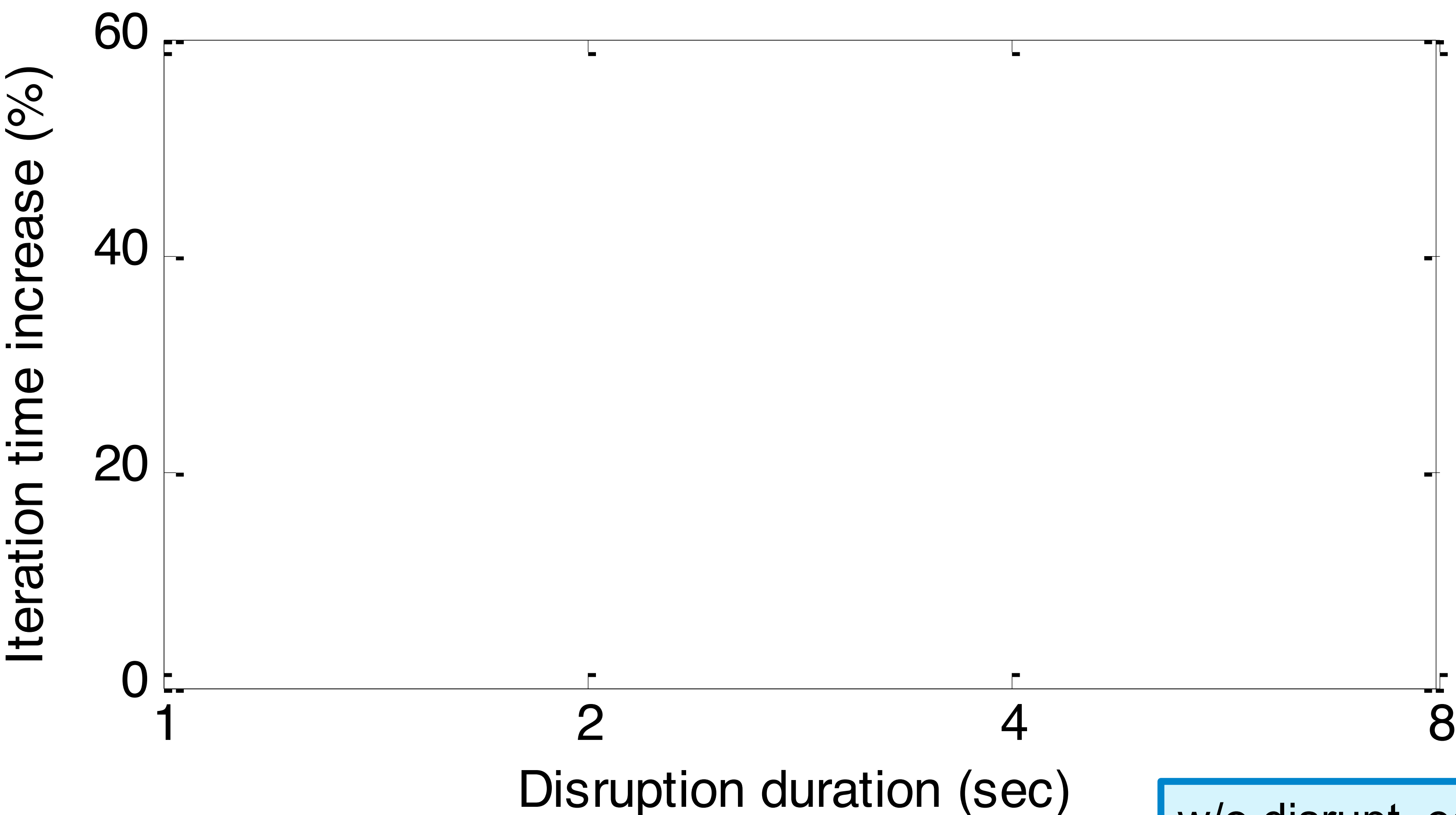
What about environment with stragglers?

Straggler Experiment #1

- Stragglers caused by background disruption
  - Fairly common in large, shared clusters
- Experiment setup
  - One disrupter process per machine
    - Uses 50% of CPU cycles
  - Work (disrupt) or sleep randomly for t seconds
    - 10% work, 90% sleep

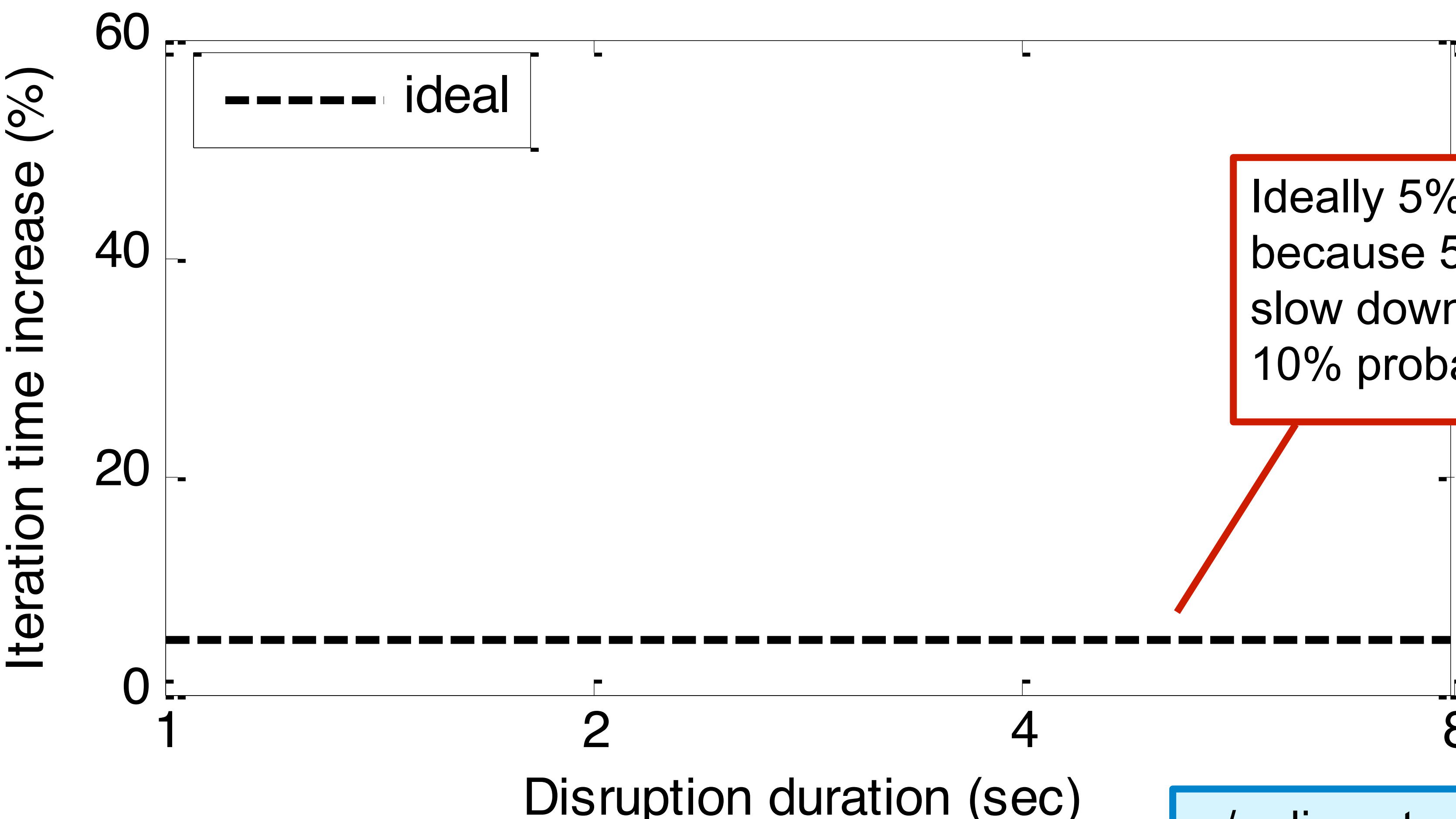
More straggler experiments in the paper

Straggler Results #1



w/o disrupt, each iter takes 4.2 sec

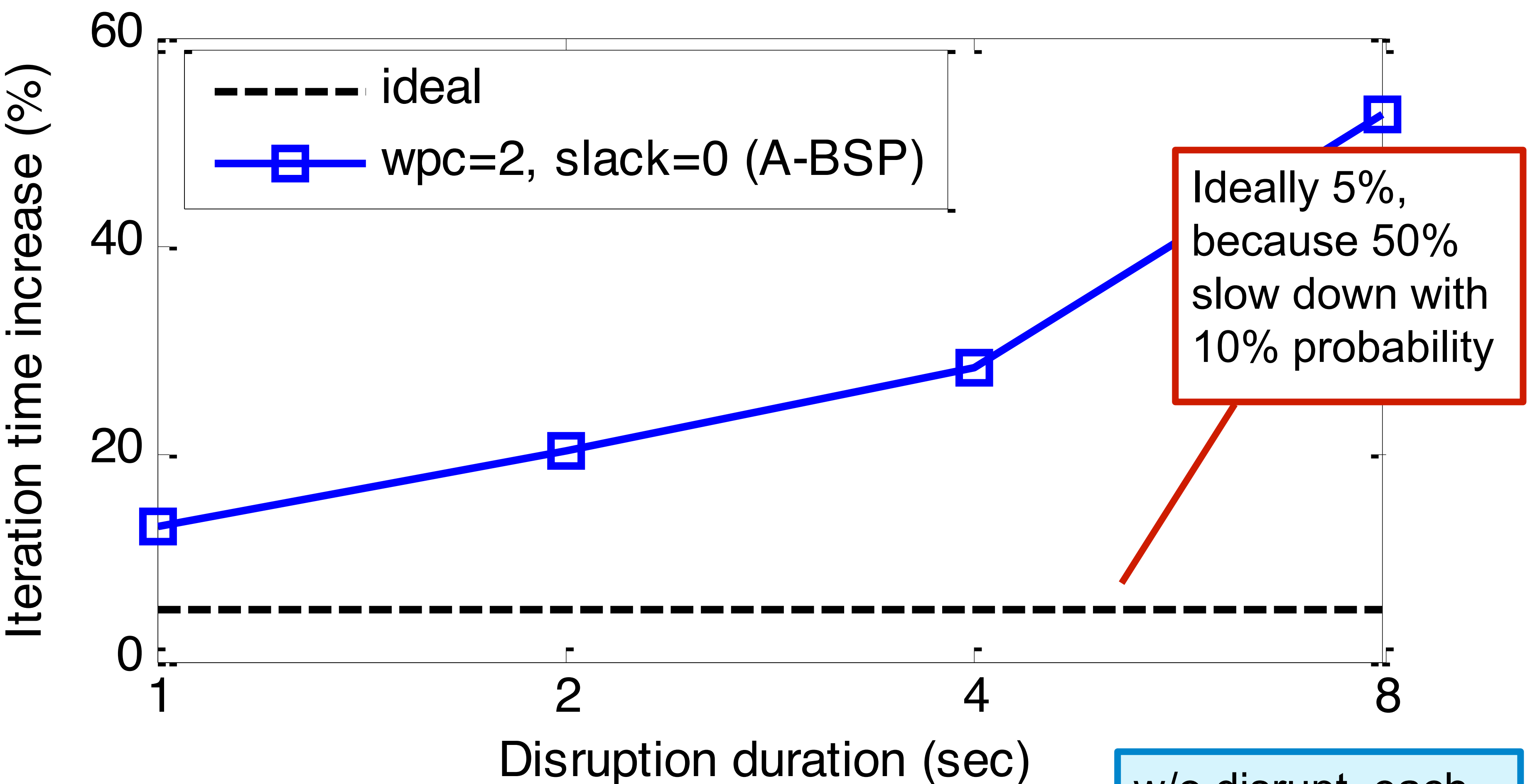
Straggler Results #1



Ideally 5%, because 50% slow down with 10% probability

w/o disrupt, each iter takes 4.2 sec

Straggler Results #1



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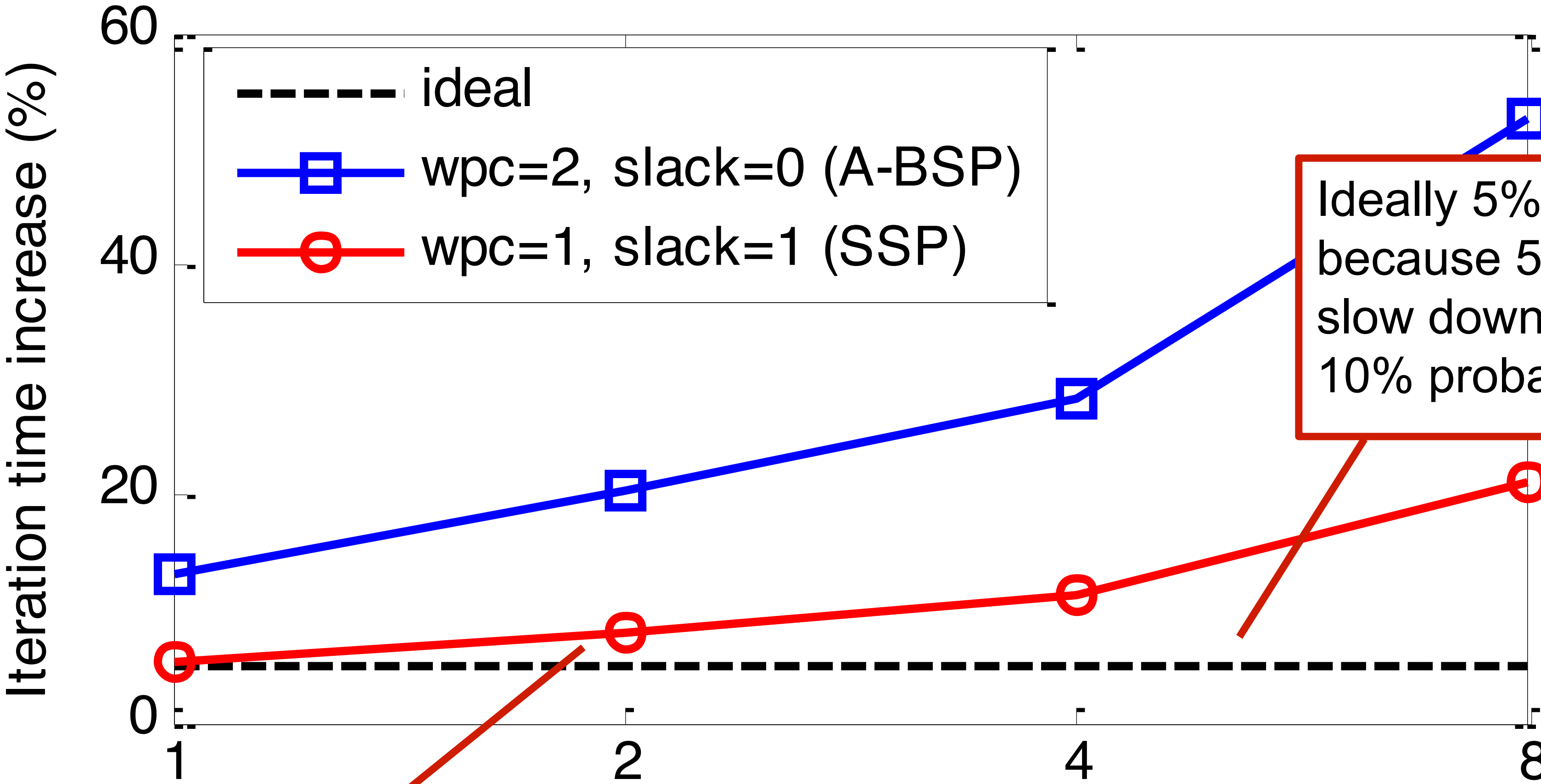
Straggler Results #1



Ideally 5%, because 50% slow down with 10% probability

SSP tolerates transient stragglers

w/o disrupt, each iter takes 4.2 sec

Conclusion

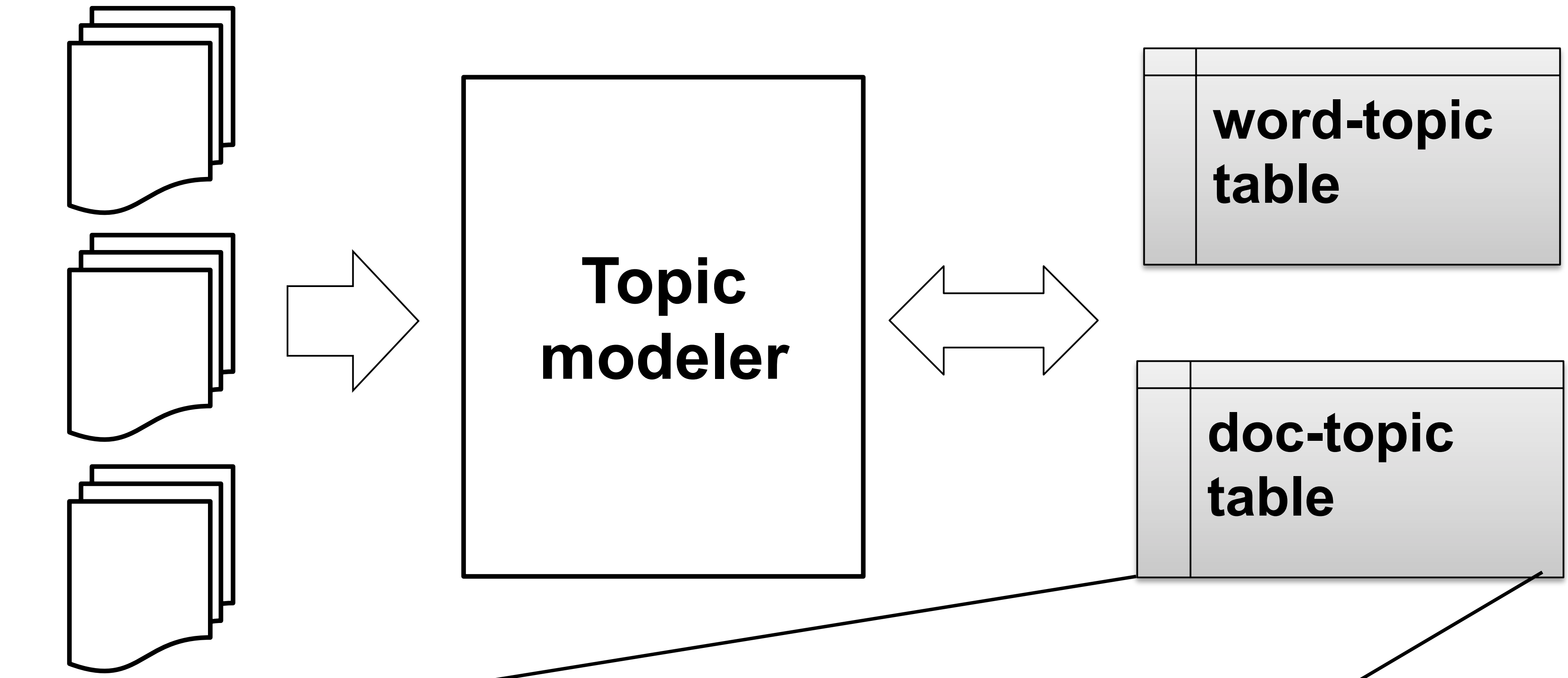
- Staleness should be tuned
  - By iters-per-clock and/or slack
- LazyTable implements SSP and A-BSP
  - See paper for details
- Key results from experiments
  - Both SSP and A-BSP are able to exploit the staleness sweet-spot for faster convergence
  - SSP is tolerant of small transient stragglers
  - But SSP incurs more communication traffic

References

- J. Cipar, G. Ganger, K. Keeton, C. B. Morrey, III, C. A. Soules, and A. Veitch. LazyBase: trading freshness for performance in a scalable database. Eurosys'12.
- J. Cipar, Q. Ho, J. K. Kim, S. Lee, G. R. Ganger, G. Gibson, K. Keeton, and E. Xing. Solving the straggler problem with bounded staleness. HotOS'13.
- NYTimes: http://archive.ics.uci.edu/ml/datasets/Bag+of+Words
- Q. Ho, J. Cipar, H. Cui, S. Lee, J. Kim, P. Gibbons, G. Gibson, G. Ganger, and E. Xing. More effective distributed ML via a stale synchronous parallel parameter server. NIPS'13.

BACK-UP

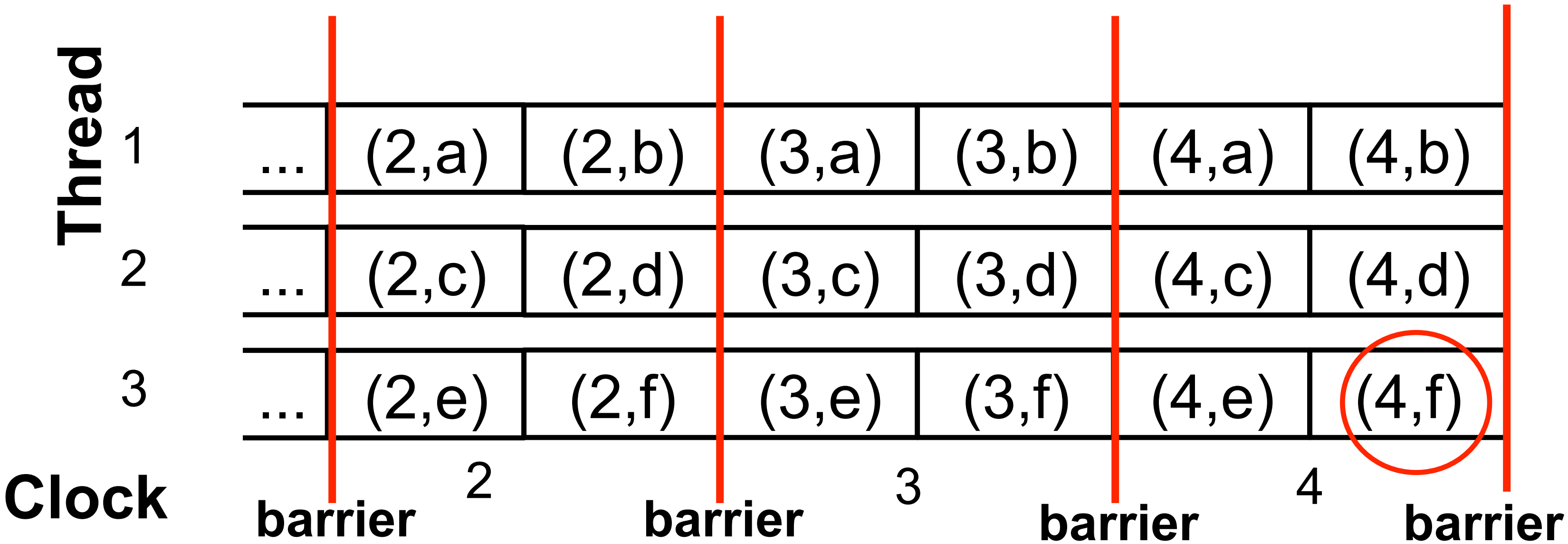
Example: Topic Modeling



...	...	...	...
Doc i	Topic 1: 0.8	Topic 2: 0.1	...
...	...	...	...

BSP Progress and Staleness

- `(i, j)` represents `iteration i`, `work uint j`



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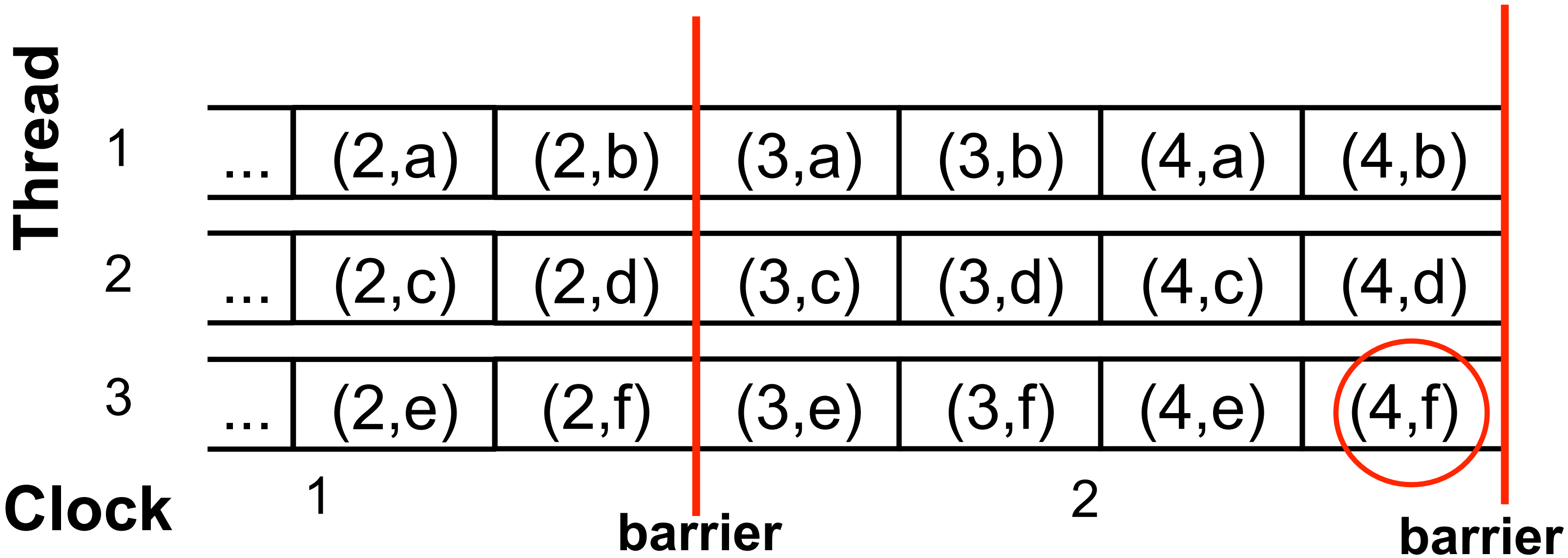
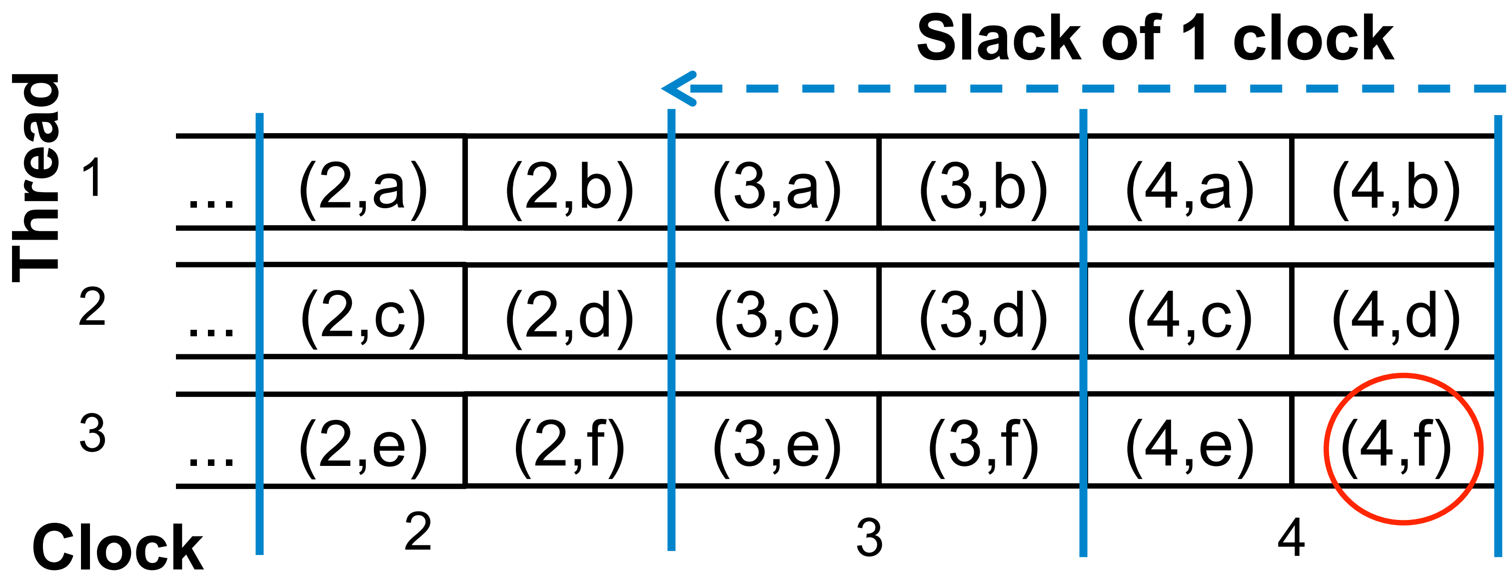
A-BSP Progress and Staleness

- A-BSP, wpc = 2 iterations



SSP Progress and Staleness

- SSP, wpc = 1 iteration, slack = 1 clock



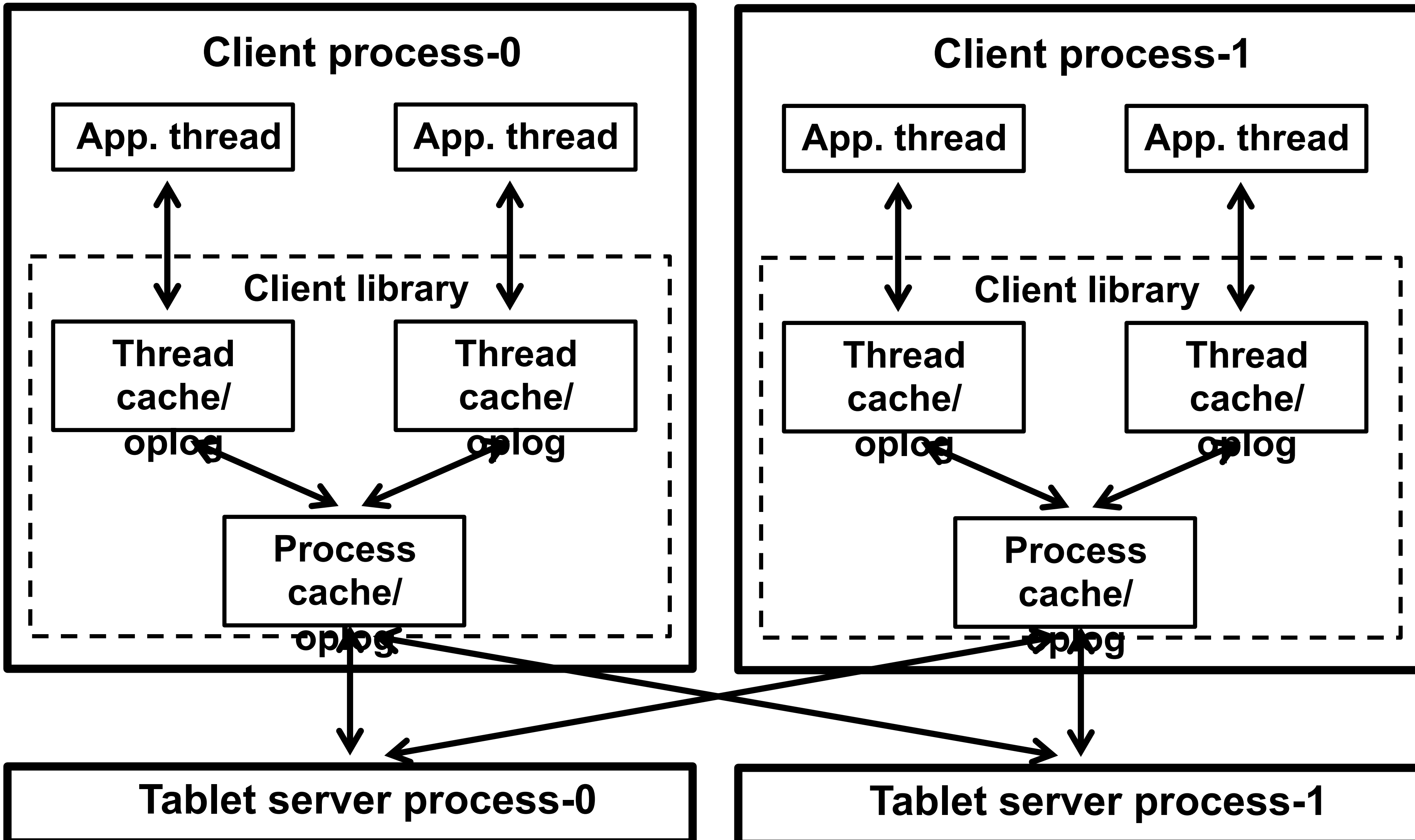
- Same staleness bound as the A-BSP one
  - But more flexible
- Data staleness for SSP with wpc and slack:

wpc x (slack + 1) - 1

SSP VS A-BSP

- A-BSP is SSP with a slack of zero
- Data staleness bound
  - SSP {wpc, slack} == A-BSP {wpc x (slack + 1), 0}
- SSP is a "pipelined" version of A-BSP
  - Tolerates transient stragglers

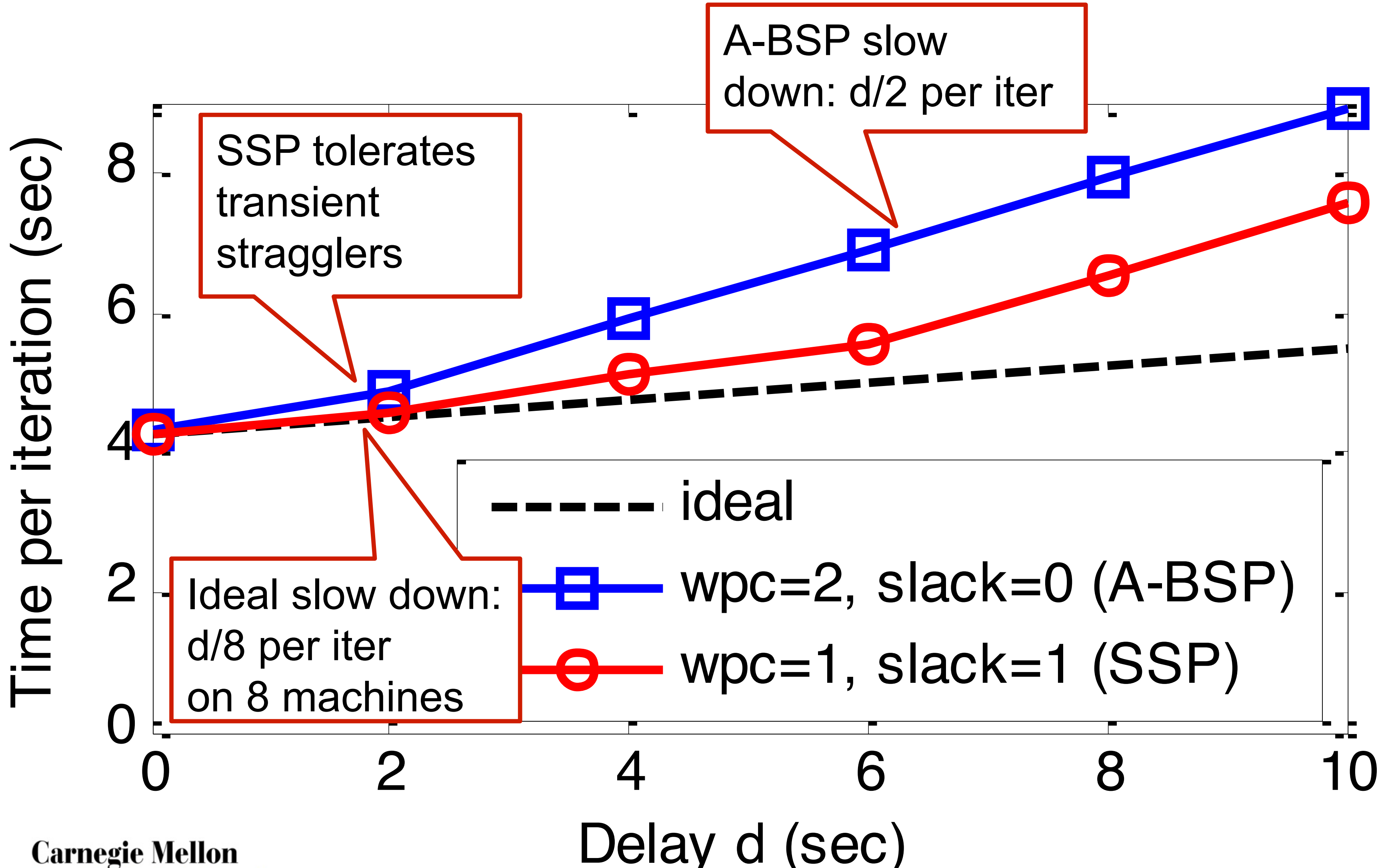
LazyTable Architecture



Stragglers: Delay

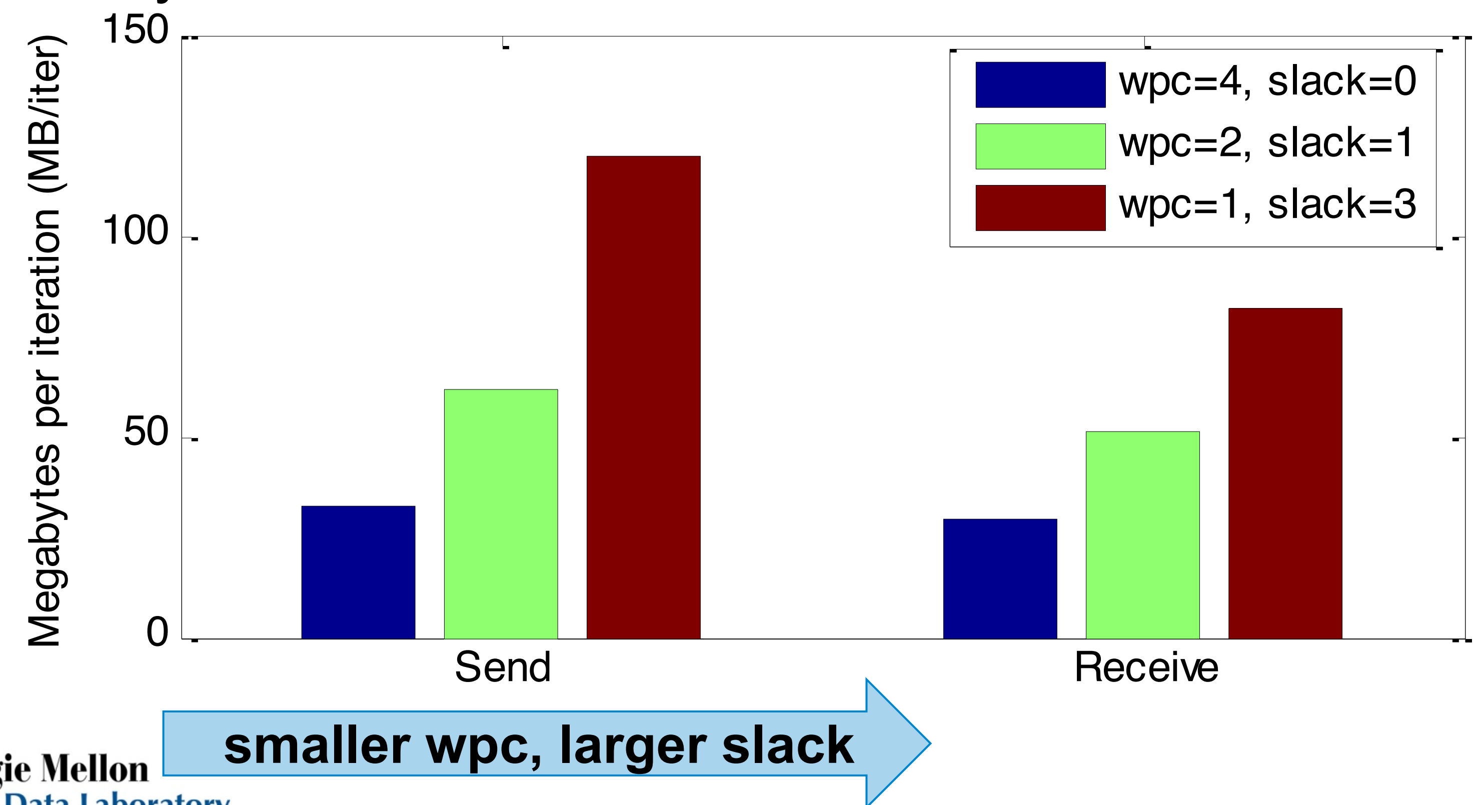
- Delaying some threads
  - Artificially introduce stragglers to the system
  - Have some threads sleep() for a time
- Experiment setup
  - Threads sleep "d" seconds in turn
    - Threads of machine "i" sleep at iteration "i"
  - Compare influence of different "d"

Stragglers: Delay (Results)



The Cost of Increased Flexibility

- Comparing {wpc=X, ...} with {wpc=2X, ...}
  - Bytes sent doubled (send update twice as often)
  - Bytes received almost doubled



Key Takeaway Insight #3

- SSP incurs more traffic
  - Finer grained division of clocks
  - Avoiding barriers is still a win,
    if communication is not the bottleneck

Prefetching

- Conservative prefetch
  - refresh row only when it's too stale
- Aggressive prefetch
  - refresh row every clock

Prefetching (results)

- wpc = 1 iter, slack = 7 clocks