Scaling Large Production Clusters with Partitioned Synchronization

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[†]This work was done when the authors were visiting Alibaba.

Scale of computer clusters

100k

machines

Billions

of tasks

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100k

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Billions

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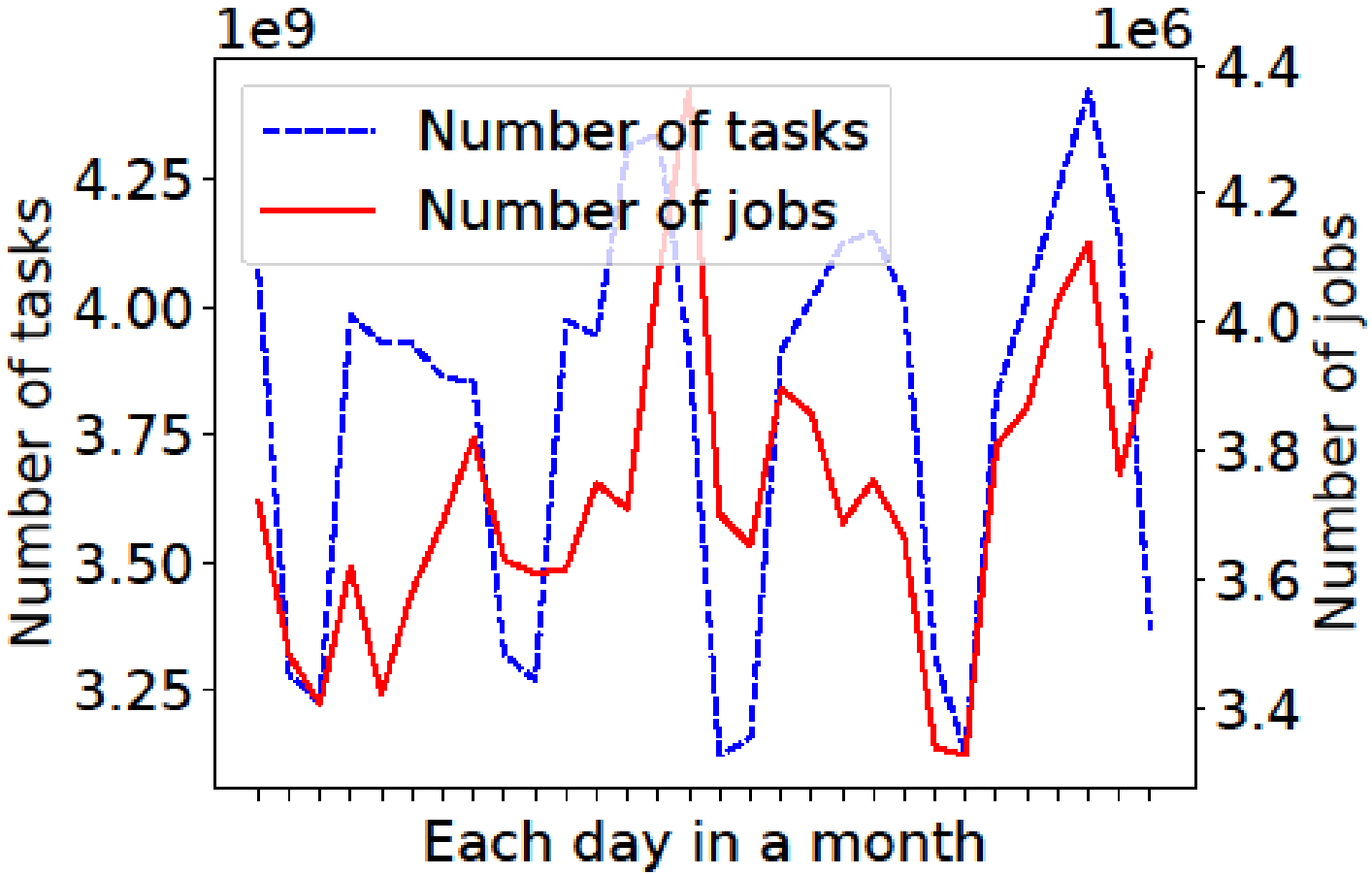
Resource utilization

Cluster upgrade

Job/task statistics in Alibaba



Single-master architecture

- The scheduler can be overloaded with *heartbeat messages* from numerous workers

- The large number of tasks in our current production cluster exceeds the capability of a single scheduler

Scheduling objectives

- Scheduling efficiency, or scheduling delay
- Scheduling quality
- Fairness and priority between jobs and users
- Resource utilization

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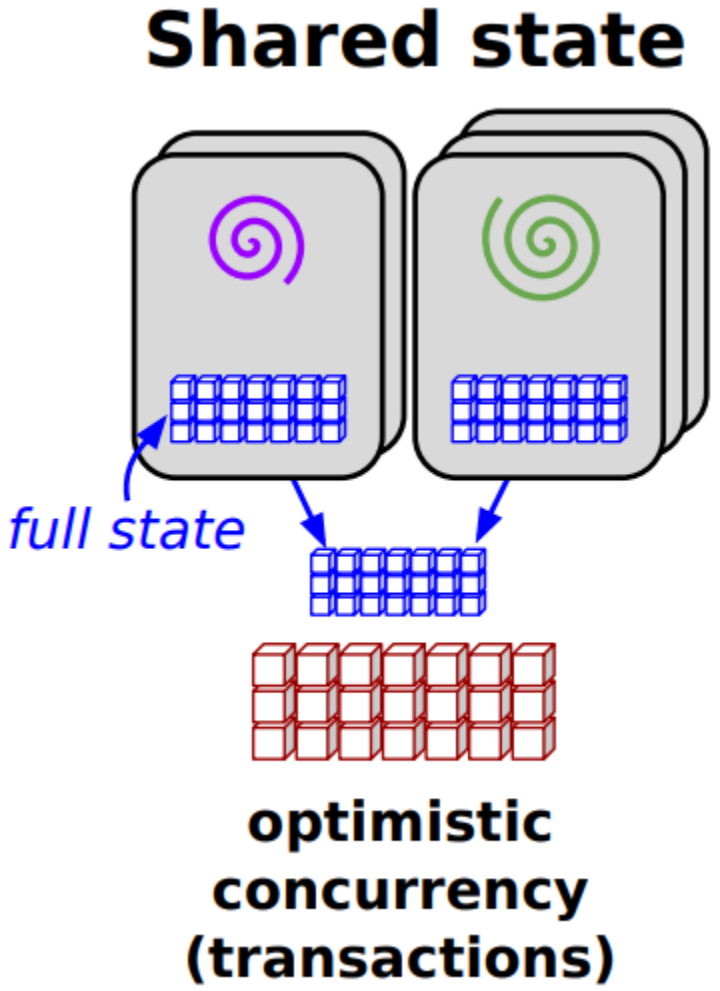
Engineering objectives

- Robustness
- Backward compatibility
- Transparent-to-user upgrade

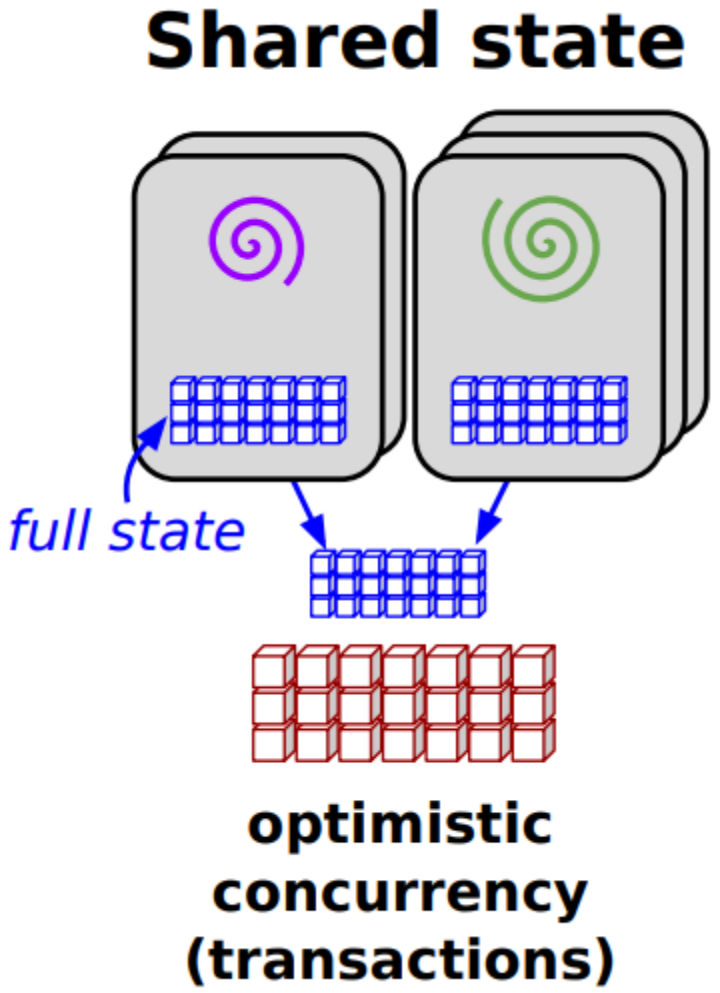
Shared-state architecture

- Malte Schwarzkopf, Andy Konwinski, Michael Abd-El-Malek, John Wilkes. **Omega: flexible, scalable schedulers for large compute clusters**. (EuroSys 2013)



Shared-state architecture: benefits

- Each scheduler can run different scheduling strategies programmed in separate code bases for different types of jobs
- Each scheduler has a global view of the cluster
- Each scheduler can assign tasks to any machine in the cluster instead of a fixed subset of partitions



Shared-state architecture: limitations

- Omega assumes no synchronization overhead

- However, in our production system, there is a gap between consecutive synchronizations as our scheduler can be overloaded with network communication:
  - Frequent communication with application masters, a large number of worker machines in different racks, and a massive number of front-end requests
  - Large state in scheduling algorithms

Conflict modeling

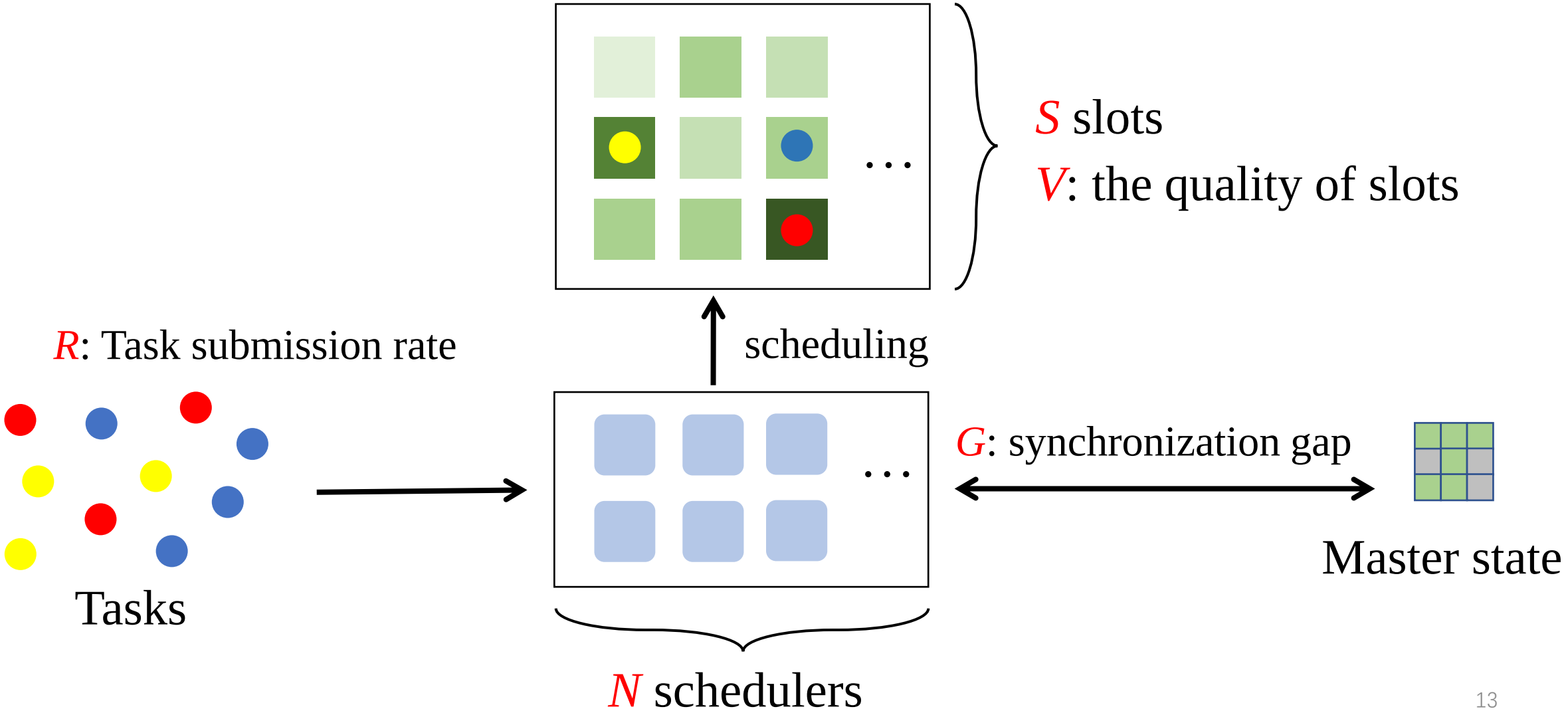
- The expectation of the number of conflicts Y_i at slot i, where S_{idle} is the number of idle slots, N is the number of schedulers and NK is the number of tasks to be scheduled:

$$\mathbb{E}(Y_i) = \frac{NK}{S_{idle}} - 1 + \left(1 - \frac{K}{S_{idle}}\right)^N$$

- The expectation of the total number of conflicts for all the slots, where S is the number of slots:

$$\mathbb{E}(\sum_{i=1}^{S} Y_i) = NK - S_{idle} + S_{idle} * (1 - \frac{K}{S_{idle}})^N$$

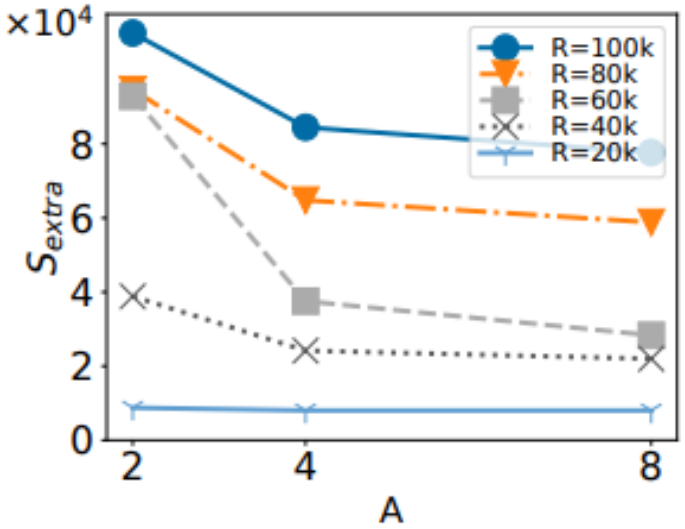
Light weight simulation



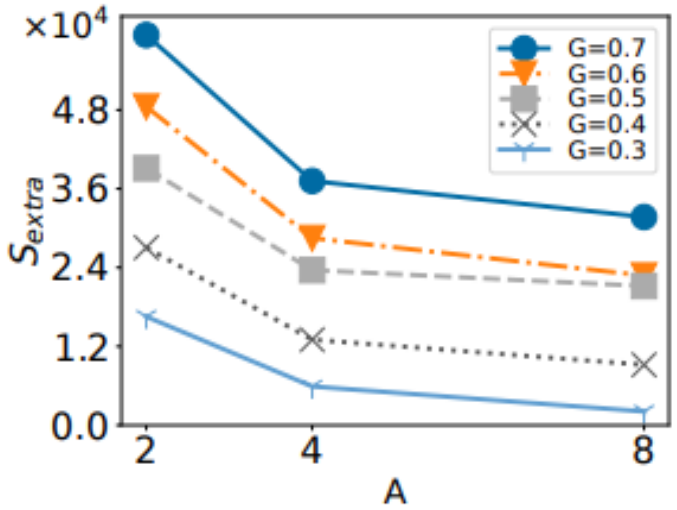
Light weight simulation

- An extreme case: the task submission rate and the resource needs of the tasks match with the total amount of resources in a cluster
- Ideal setting w/o any conflict: N schedulers → 0 scheduling delay
- When conflicts happen, we need extra schedulers and/or slots

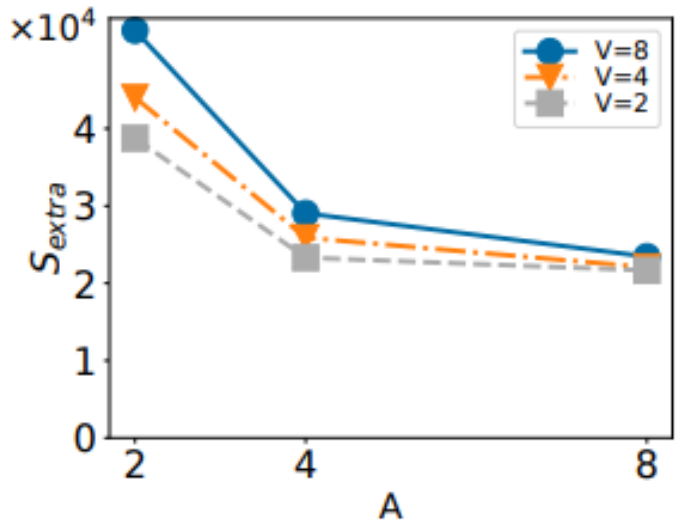
Light weight simulation: results



(a) Task submission rate (R)



(b) Synchronization gap (G)



(c) Variance of slot scores (V)

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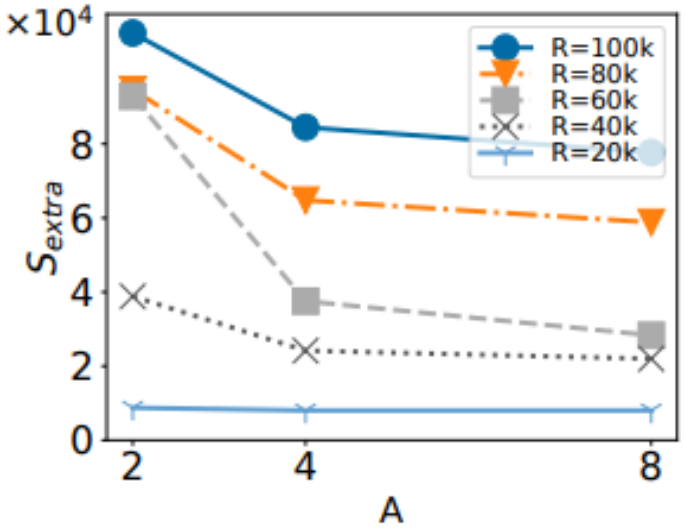

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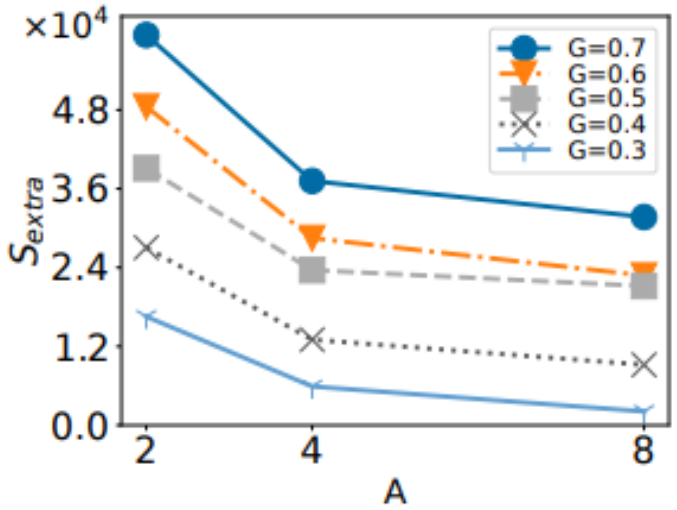

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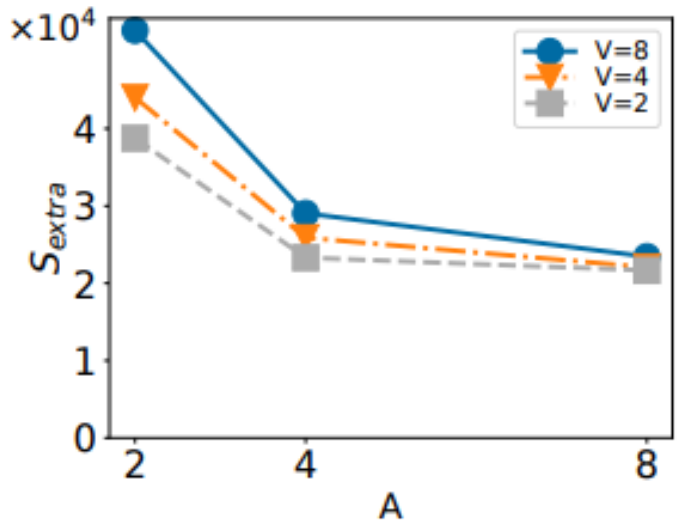
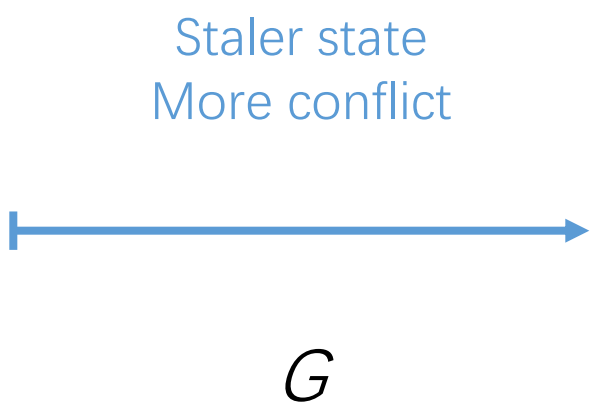


(c) Variance of slot scores (V)

Observation

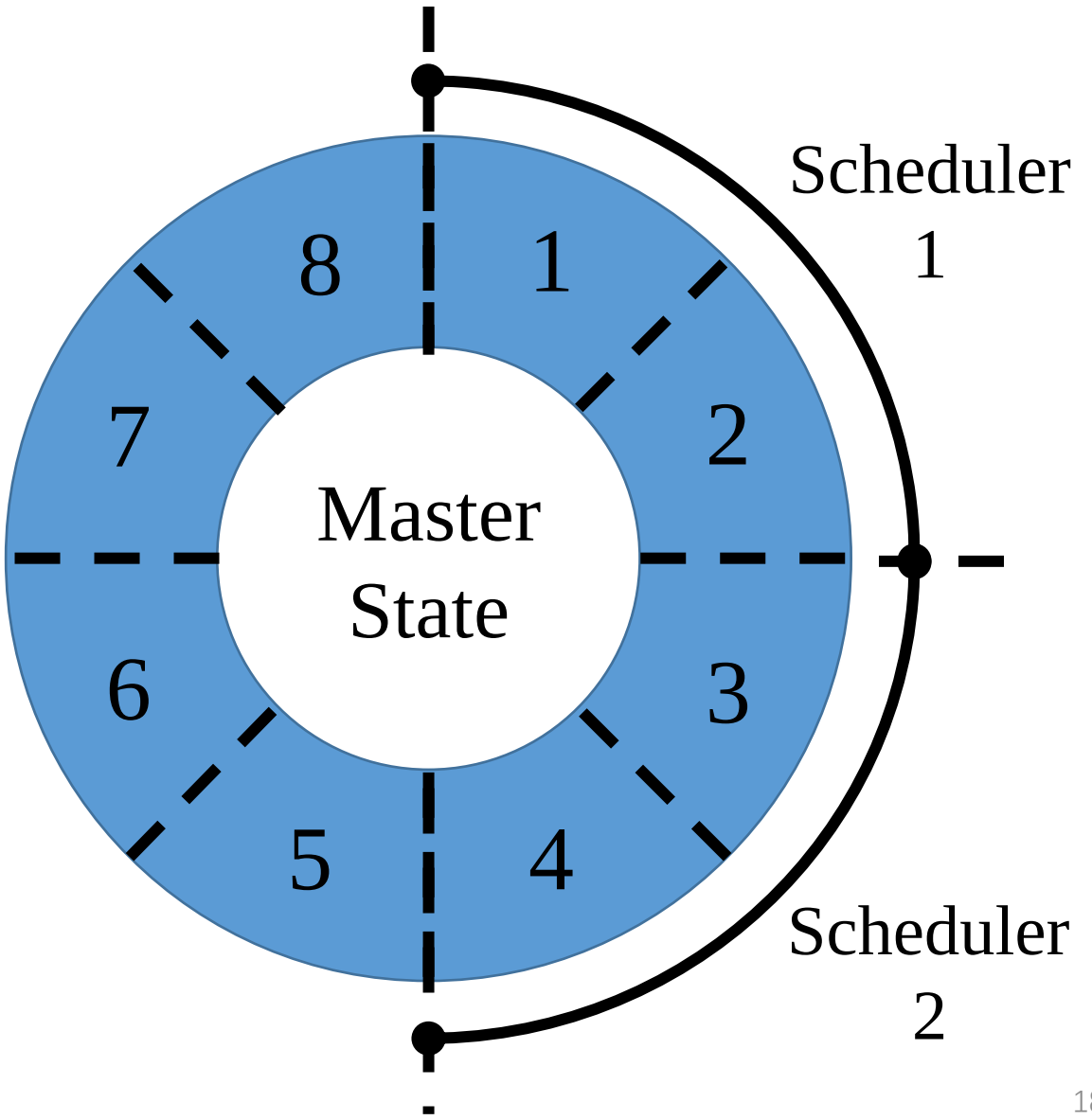
- Scheduling delay increases disproportionally within the gap G
  - When the state is synchronized, the scheduling has fewer conflicts
  - When the state is outdated, the scheduling results in more conflicts



- Most of the delay is caused by the staler view of the state in the later interval of the gap

ParSync

- The master state is divided into P = 8 parts
- There are N = 4 schedulers
- Synchronization continues in a round-robin manner



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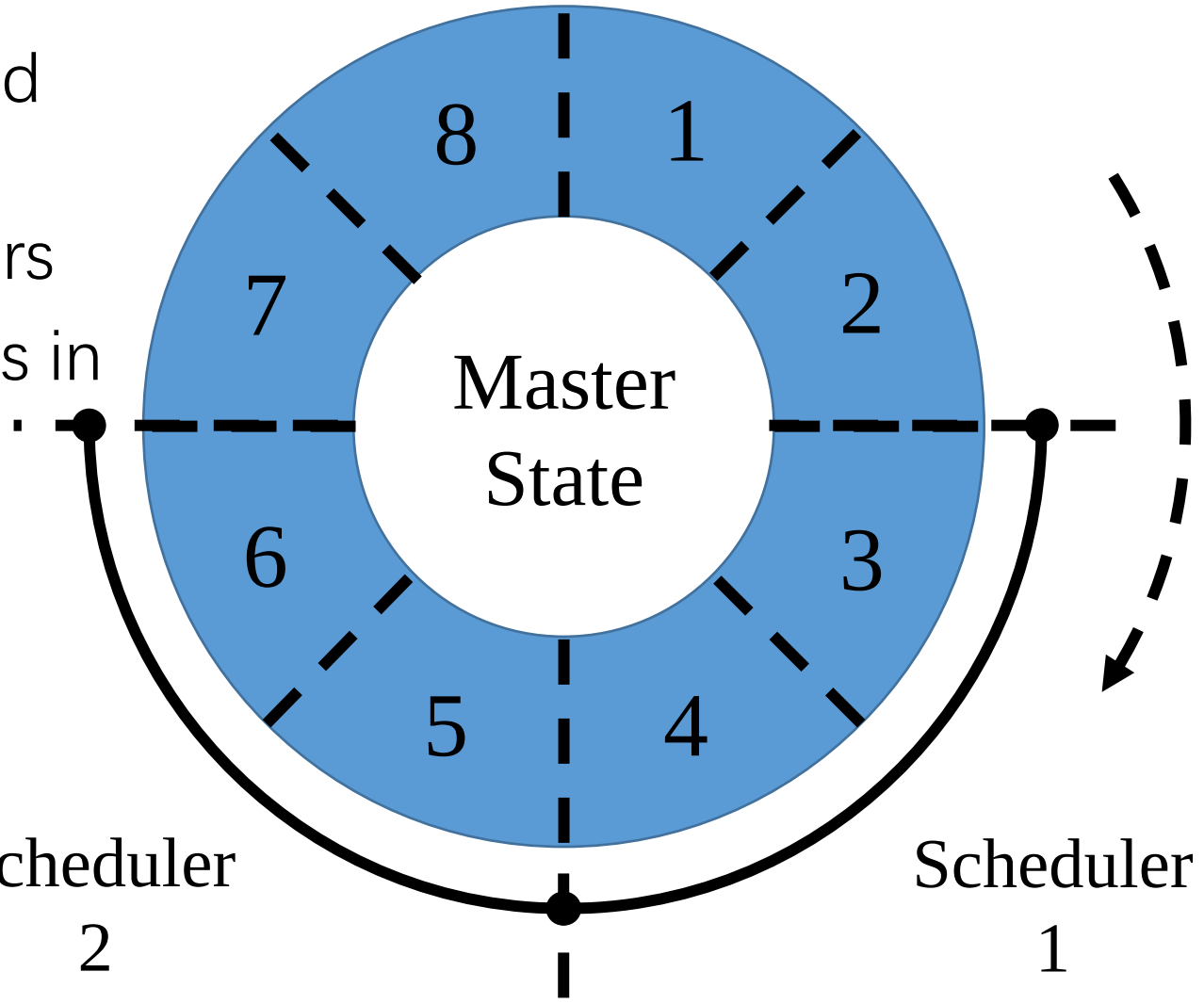
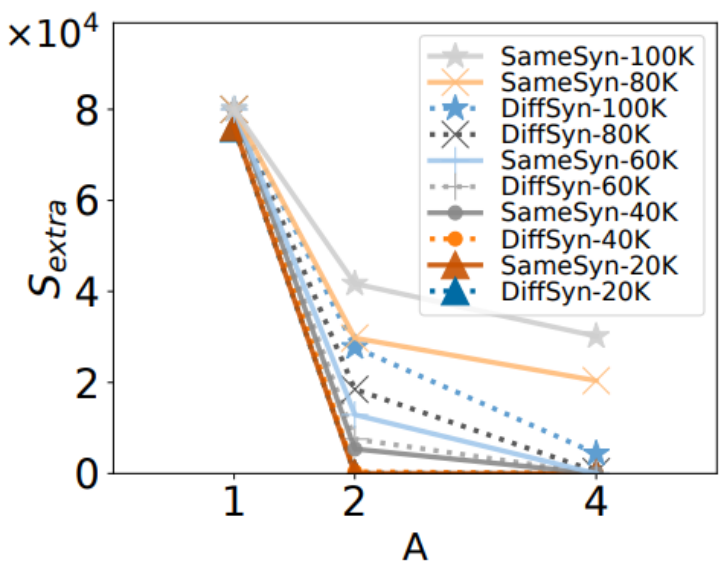


Effects of synchronization strategies



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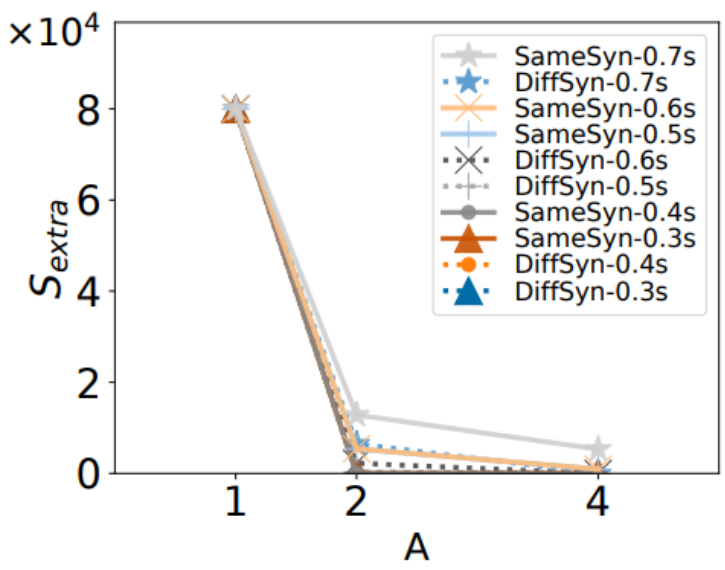

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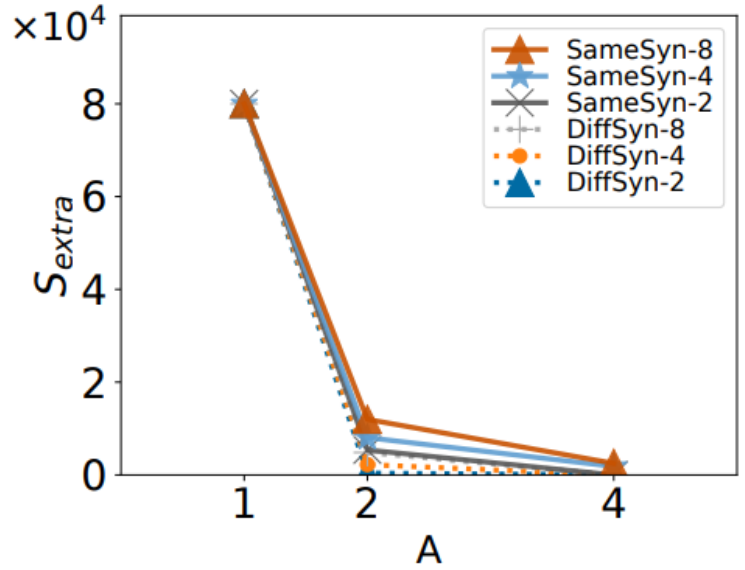


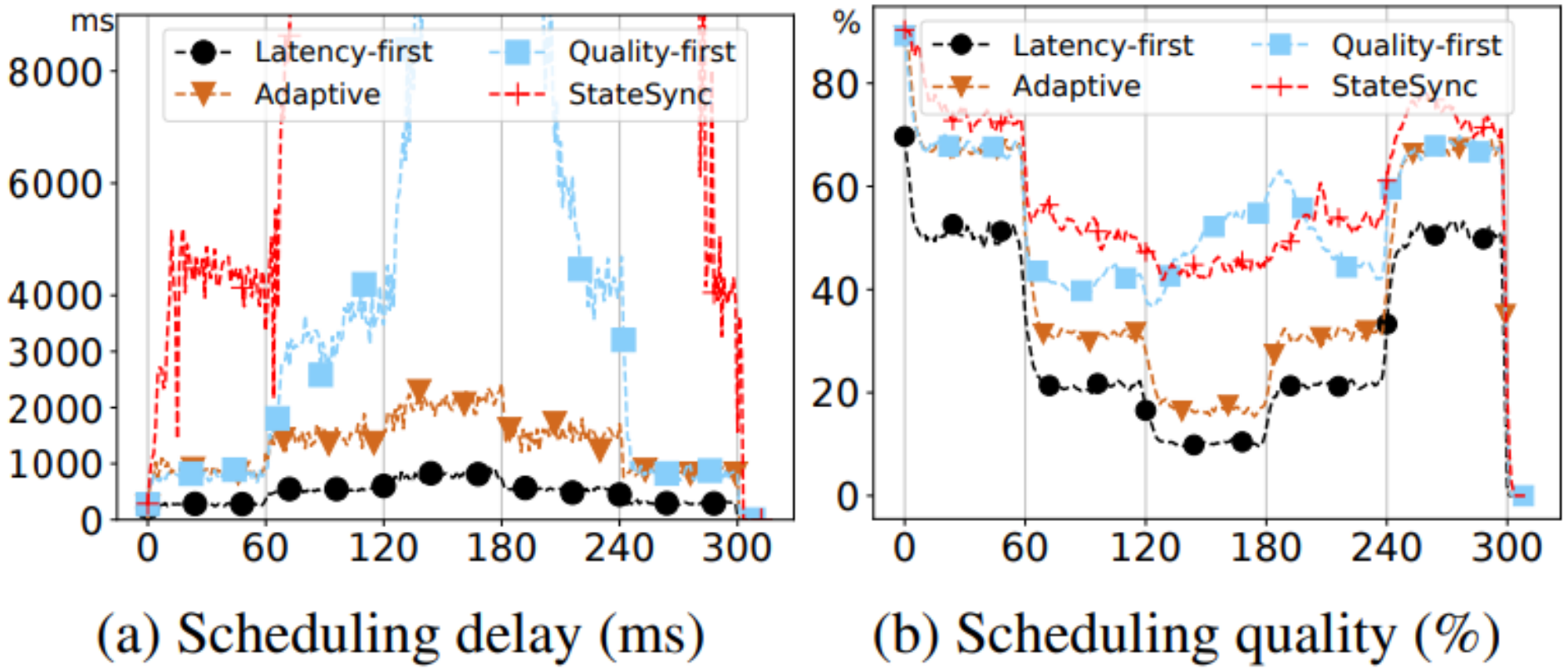
(c) Variance of slot scores (V)

Adaptive scheduling strategy

Quality-first	Latency-first	Adaptive	StateSync
Prioritize choosing of high-quality slots	Prioritize choosing of slots with fresher state	Hybrid of quality-first and latency-first	Synchronize entire state each time

DiffSync

Adaptive scheduling strategy



(a) Scheduling delay (ms)

(b) Scheduling quality (%)

Conclusions

ParSync

- Increases the scheduling capacity of our production cluster
- Reduces conflicts in contending resources to achieve low scheduling delay and high scheduling quality
- Allows us to maintain user transparency and backward compatibility

Thank you!

Q & A

If you have any question about our work, please contact

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