QoS-Aware Admission Control in Heterogeneous Datacenters

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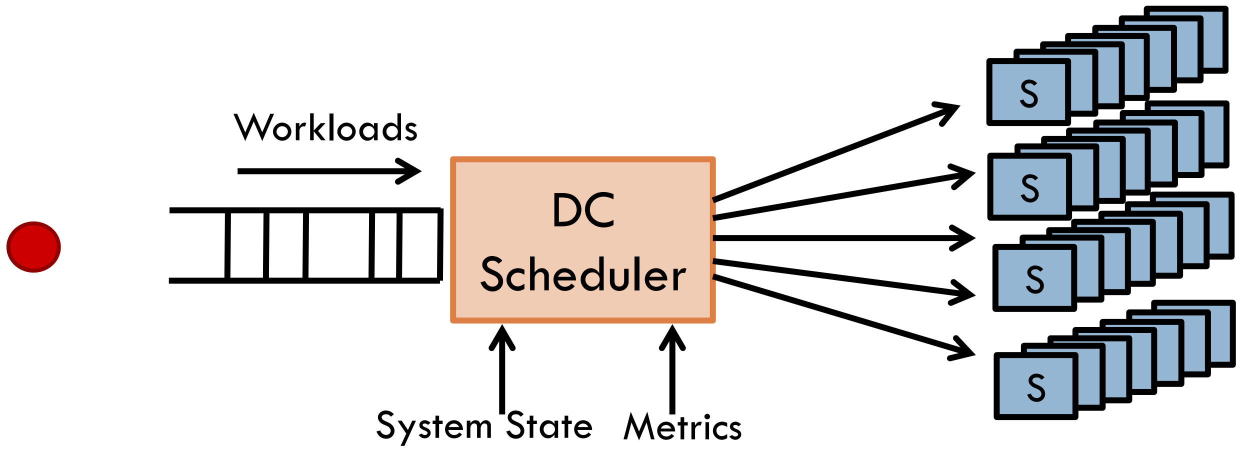
Cloud DC Scheduling



- Workloads are unknown → random apps submitted for short periods
- Significant churn (app arrivals/departures) → not large long-running apps
- High variability in workloads (runtime, number of threads, etc.)
- Fast admission & scheduling decisions

Users are Interested in

Fast Execution Time	The amount of time the job needs to run
Low Waiting Time	The amount of time the job is waiting before it gets scheduled

Executive Summary

- Problem: Admission control in large-scale cloud DCs (e.g., EC2, Azure)
  - Heterogeneity → performance/efficiency
  - Interference → performance loss from high interference
  - High arrival rates → system can become oversubscribed

- Background: Paragon is a heterogeneity and interference-aware scheduler for cloud DCs.

- Limitations: In high-load scenarios demanding workloads can block easy-to-satisfy applications → head-of-line blocking → long waiting time

- ARQ is an admission control protocol for cloud DCs that is:
  - Application-aware: Accounts for the resource quality of each app
  - QoS-aware: Queues applications s.t. their QoS guarantees are preserved
  - Scalable: Scales to 10,000s of applications and servers
  - Lightweight: Low and upper-bound queueing overheads

Users are Interested in

Paragon

Fast Execution Time

The amount of time the job needs to run

ARQ

Low Waiting Time

The amount of time the job is waiting before it gets scheduled

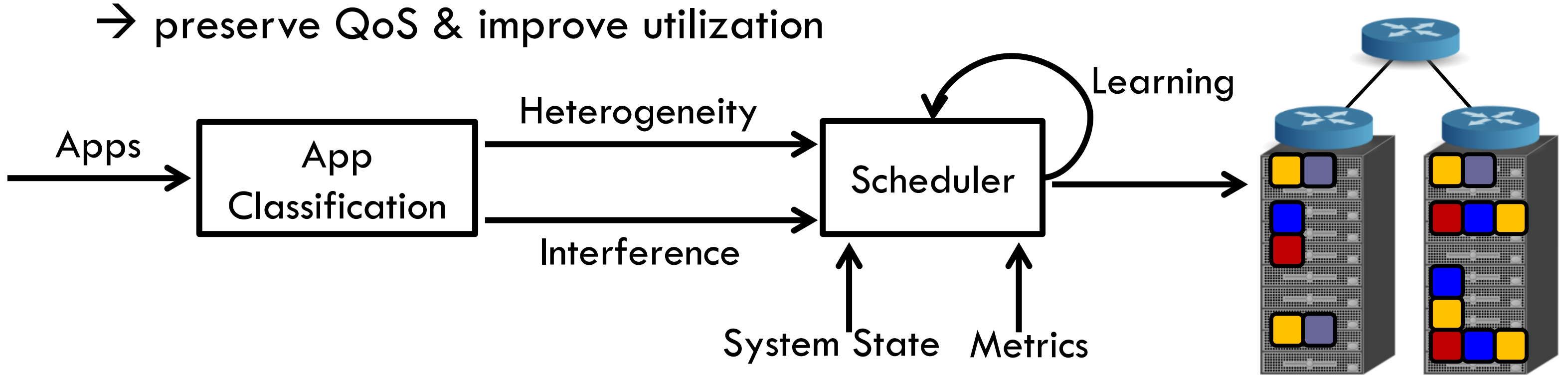
Background: Paragon

- Classification: ~Netflix Challenge
  - Small information signal about new application
  - Leverage system knowledge about previously scheduled applications
  - Collaborative filtering techniques (SVD + PQ reconstruction with SGD)

    → Scheduling recommendations: Heterogeneity + Interference

$$\begin{tikzcd}
\text{Heterogeneity} \arrow[d] & & \text{Interference} \arrow[dl] \arrow[dr] & \\
\text{Server Platform} & \text{Caused (c)} & & \text{Tolerated (t)}
\end{tikzcd}$$

- Greedy Scheduler:
  - Co-schedule workloads with no/small interference on suitable hardware platforms
    → preserve QoS & improve utilization



Limitations

- Scheduling in FIFO order:
  - Applications with small resource requirements get blocked behind demanding workloads → head-of-line-blocking → long queueing delays
  - Short jobs get blocked behind long jobs
  - High-priority jobs get blocked behind low-priority jobs

- Resource-agnostic queueing of applications:
  - Application in the head of the queue gets dispatched to first available server → not necessarily a suitable server for that workload

ARQ: Application-aware Admission Control

- Resource Quality: Degree of tolerated and caused interference in various shared resources (higher quality means more demanding application)

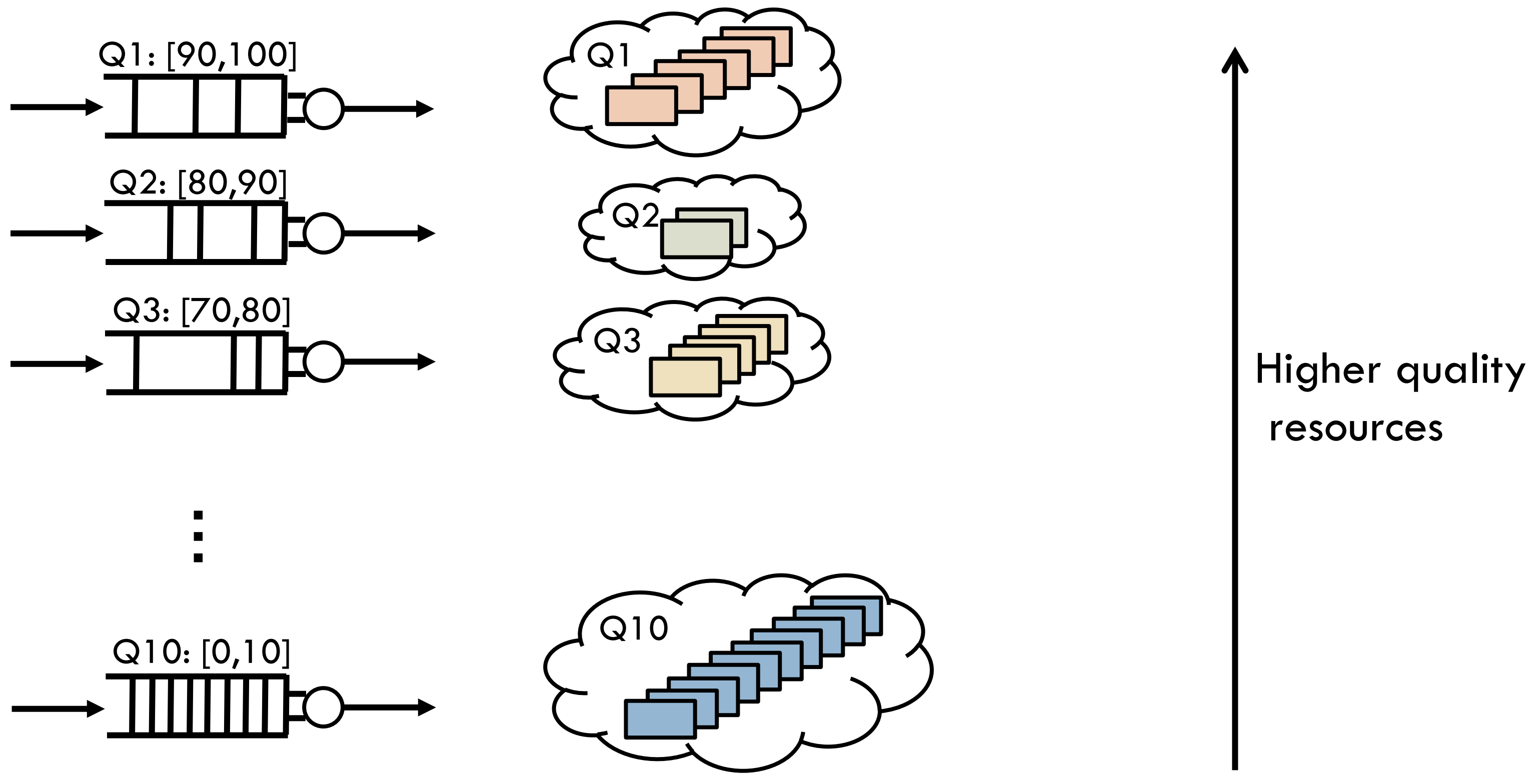
  For application i: $Q_i = \sum_k c_k$ For server j: $Q_j = \sum_k t_k$

- Resource quality-aware queueing: Applications are queued based on the resource quality they need

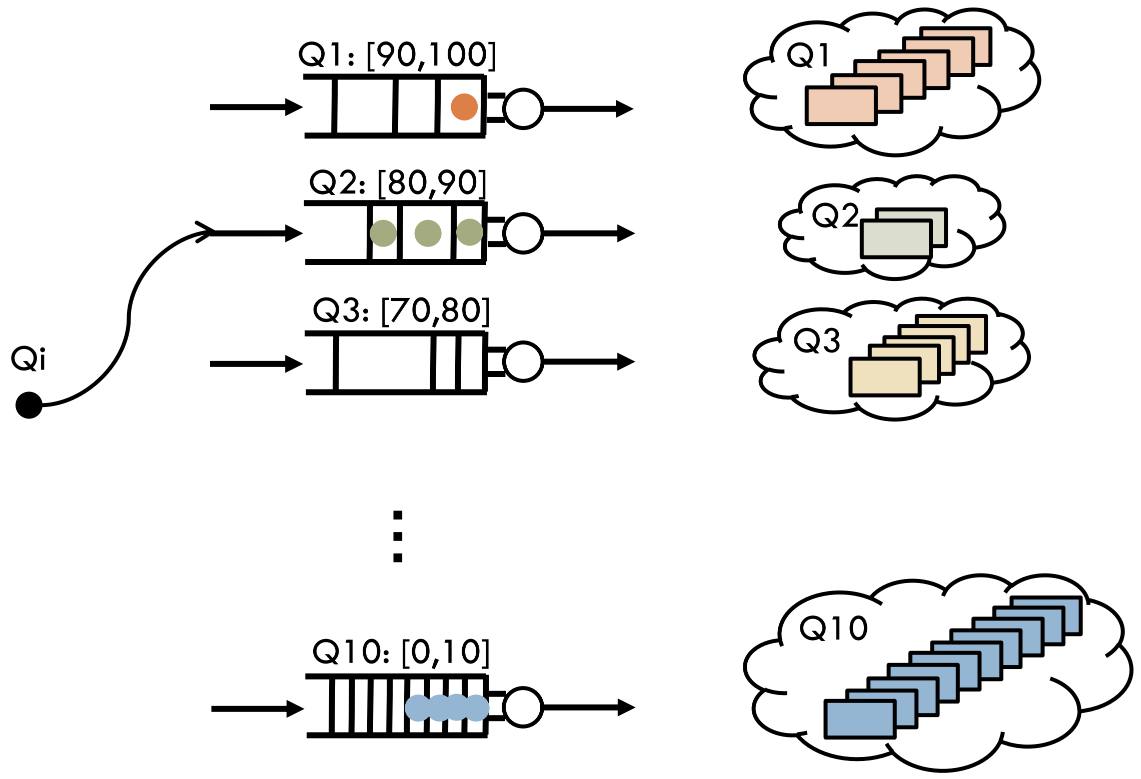
- Multi-class admission control: Each class corresponds to apps with specific range of Qi → dispatched to servers with the required Qj

- Preserving QoS: Applications can be diverged to different queues to preserve their QoS (when waiting time is high)

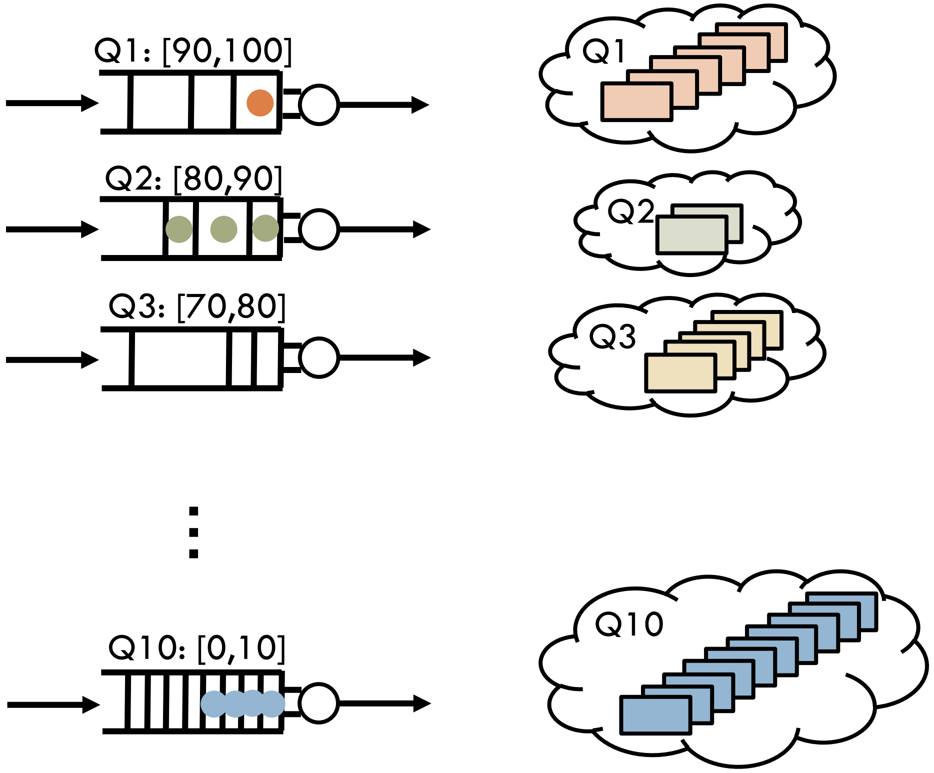
ARQ Design


Q1: [90,100]
Q2: [80,90]
Q3: [70,80]
⋮
Q10: [0,10]
Q1
Q2
Q3
Q10
Higher quality resources

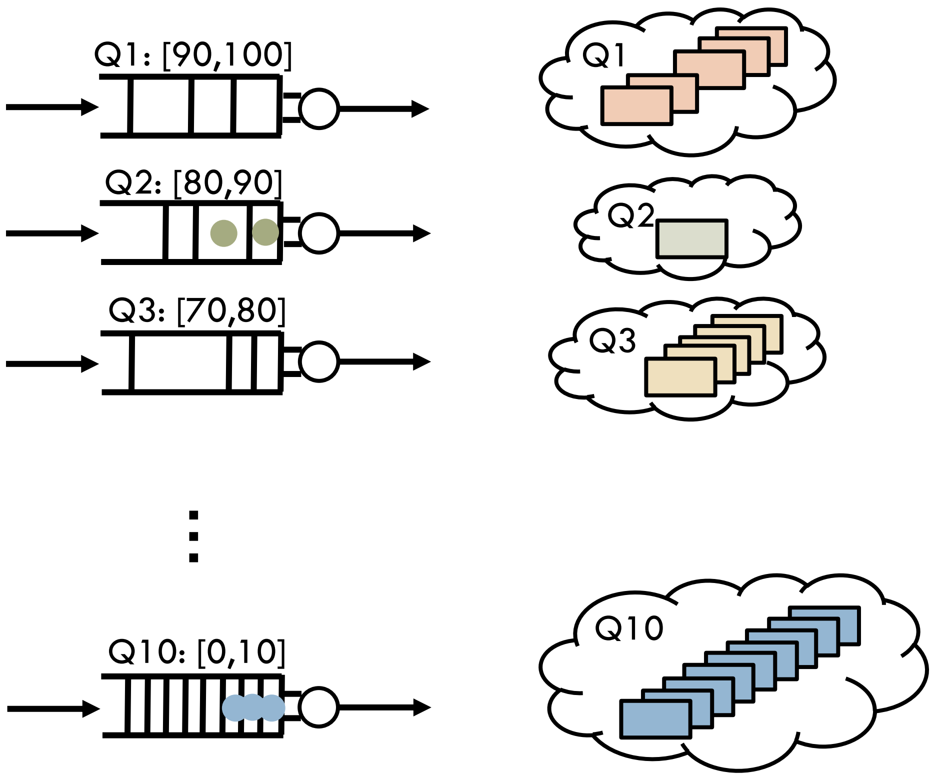
ARQ Design



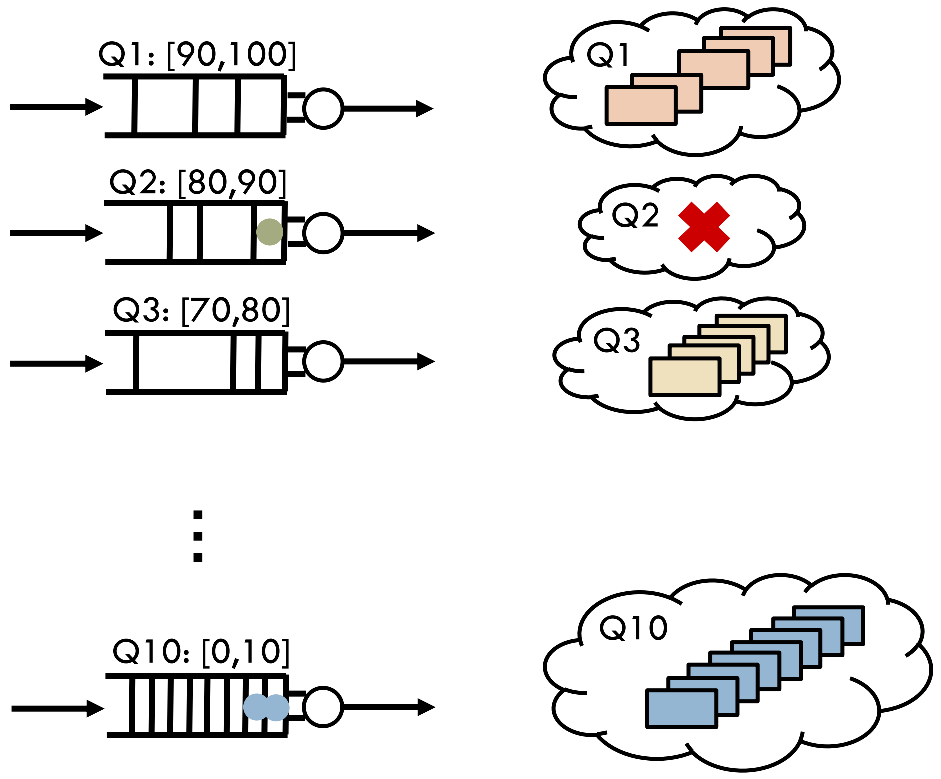
ARQ Design



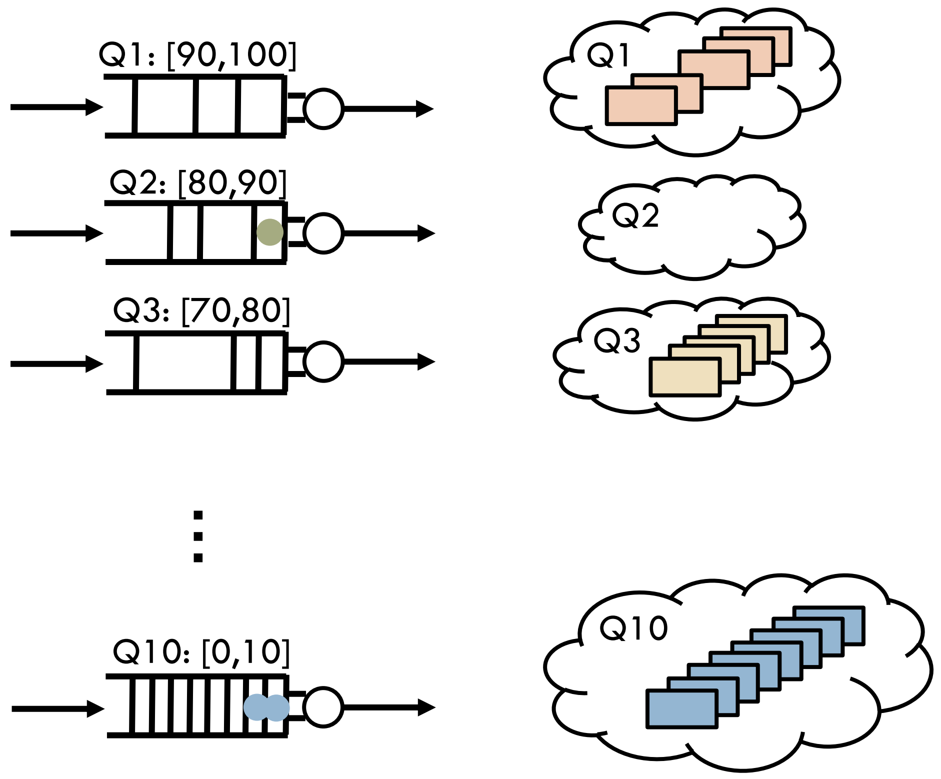
ARQ Design



ARQ Design

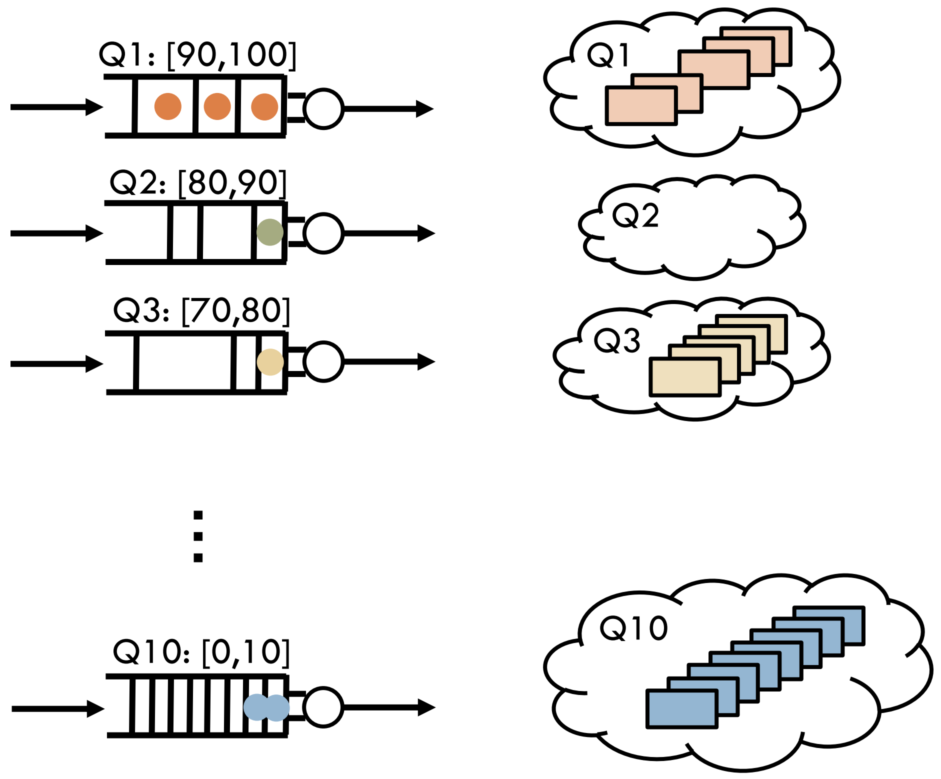


ARQ: Queue Switching -- Utilization



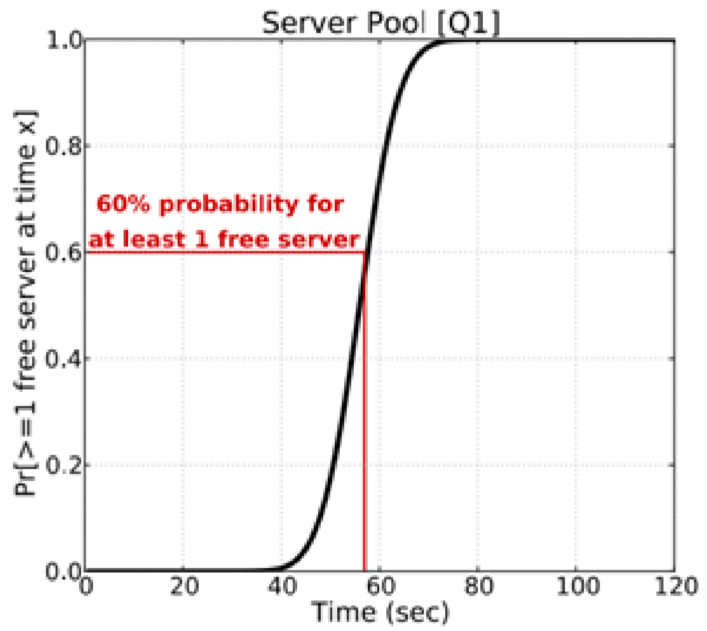
If no applications in higher queue diverge up → suboptimal utilization but maintains QoS

ARQ: Queue Switching -- QoS



If server available diverge to lower queue → some QoS degradation

Switching between Queues



- Statistically analyze per-pool freed-server-time → distribution fitting (represent using known distributions)
- Updated every time a new server is freed
- From CDFs of per-pool freed-server-time compute the optimal switching point between queues

Switching between Queues

- Optimization function:
  - Find switching time *t* s.t.:

    maximize Prob[server is freed],

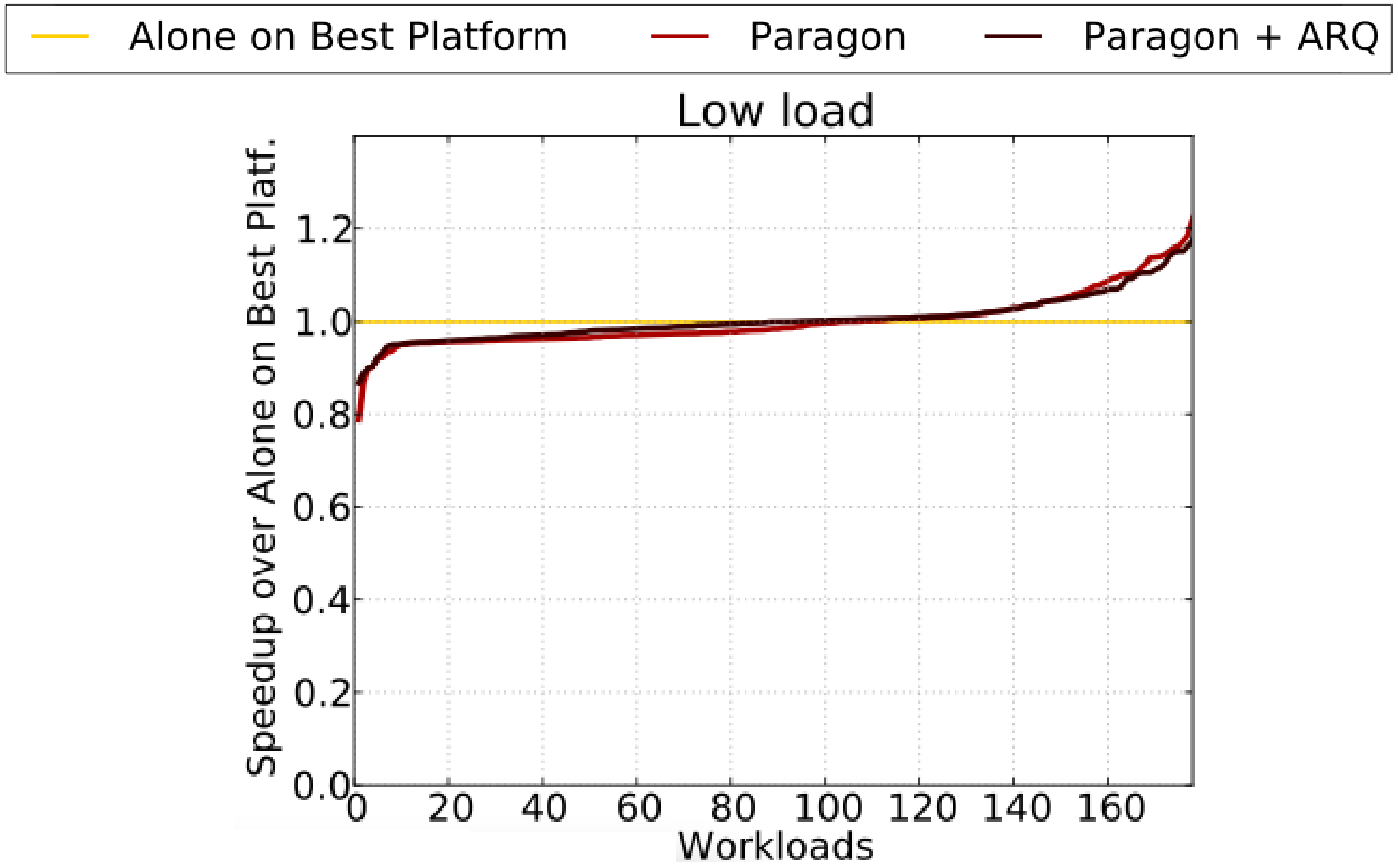
    subj. total waiting time preserves QoS

- Solving the optimization problem is fast (~msec) and scalable (O(n)) even for large numbers of applications and servers

Methodology

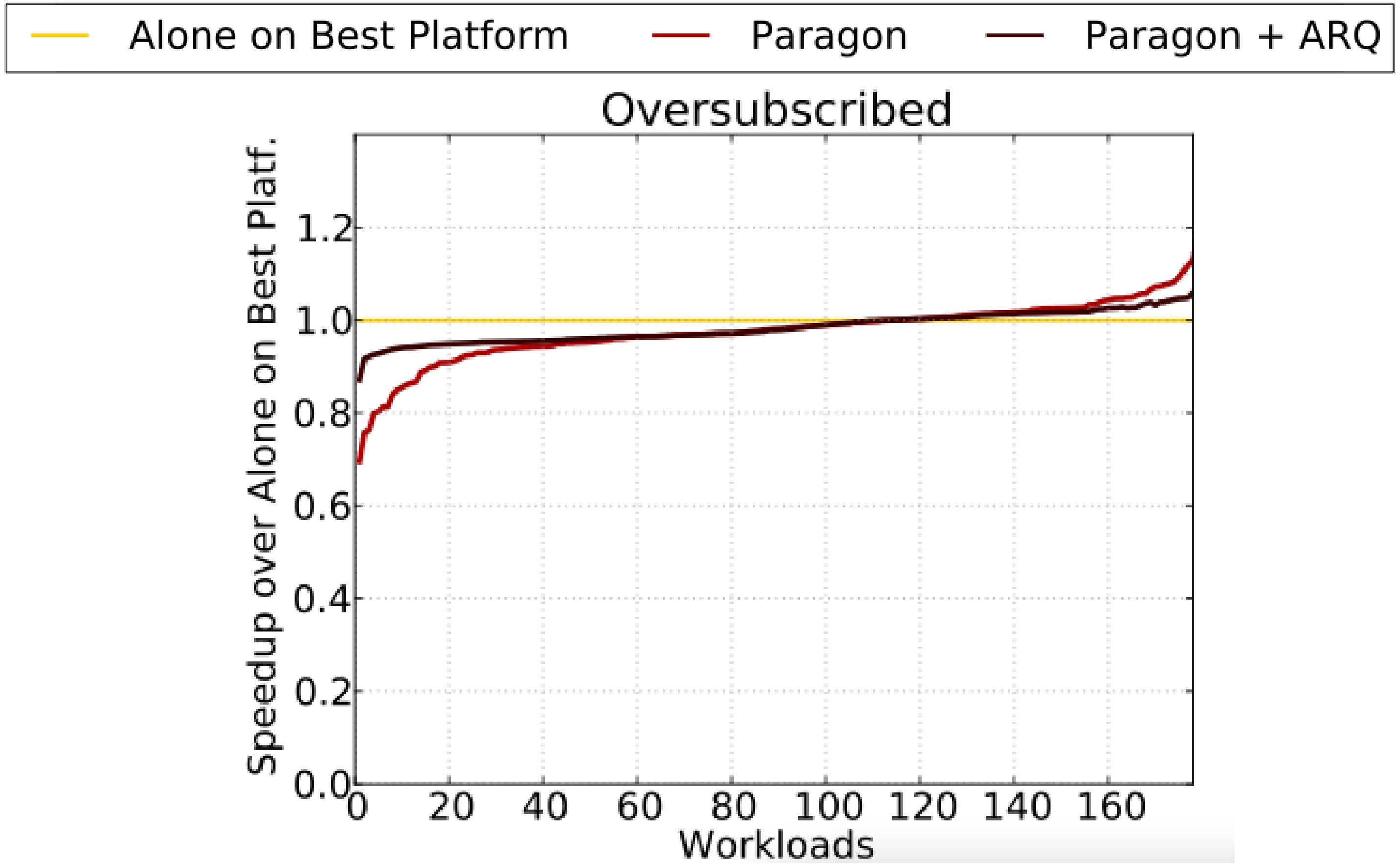
- Workloads:
  - Single-threaded: SPEC CPU2006
  - Multi-threaded: PARSEC, SPLASH-2, BioParallel, Minebench, Specjbb
  - Multiprogrammed: 4-app mixes of SPEC CPU2006 workloads
  - I/O-bound: Hadoop + data mining (Matlab)
- Small scale:
  - 40 servers, 10 server configurations (Xeons, Atoms, etc.)
  - 178 applications used in four *workload scenarios:*
    - *Low* load, *high* load and *oversubscribed*
- Large scale: 1,000 EC2 servers, oversubscribed scenario (8,500 apps)

Evaluation: Small Scale



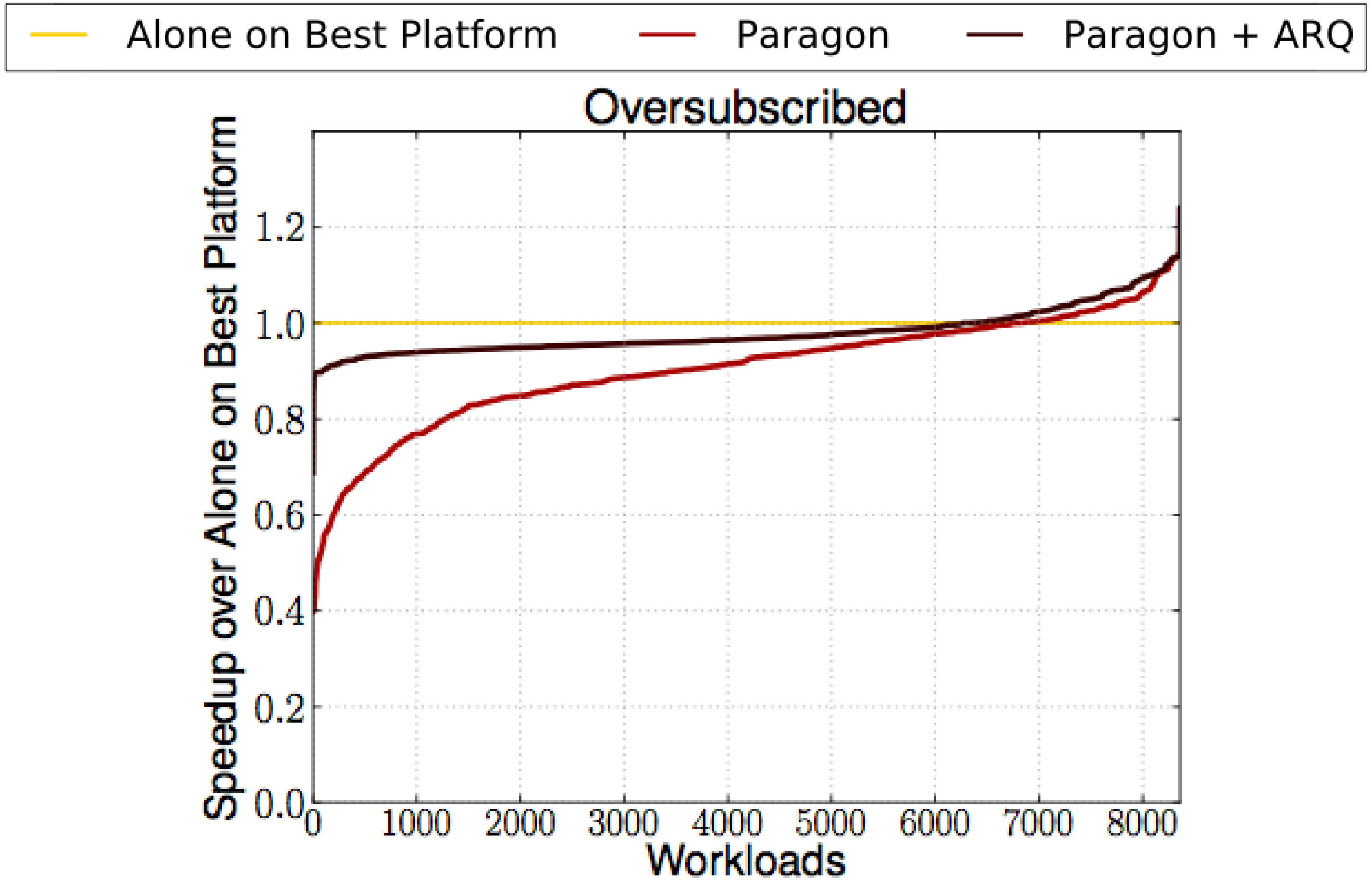
- Paragon + ARQ preserves QoS for 95% of workloads → 94% without ARQ
- Average performance is 99.6% of optimal

Evaluation: Small Scale



- Paragon + ARQ preserves QoS for 82% of workloads → 64% without ARQ
- Average performance is 98% of optimal

Evaluation: Large Scale (EC2)



- Paragon preserves QoS for 75% of workloads → 61% without ARQ
- Bounds degradation to less than 10% for 99% of workloads

Other experiments

- Workload scenario with application phases (app requirements change)
- Shortest Job First (SJF) and priorities
- Queueing overheads
- Sensitivity to parameters (e.g., number of queues, etc.)
- Distributions of server freed times

Conclusions

- ARQ leverages Paragon to classify applications in multiple queues such that QoS guarantees are preserved and utilization is maximized
- It improves performance both for low and especially for oversubscribed workload scenarios
- It is scalable and lightweight

Questions??

Thank you