Towards a Redundancy-Aware Network Stack for Data Centers

Ali Musa Iftikhar (Tufts)

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The Problem of Tail Latency in Data Centers!

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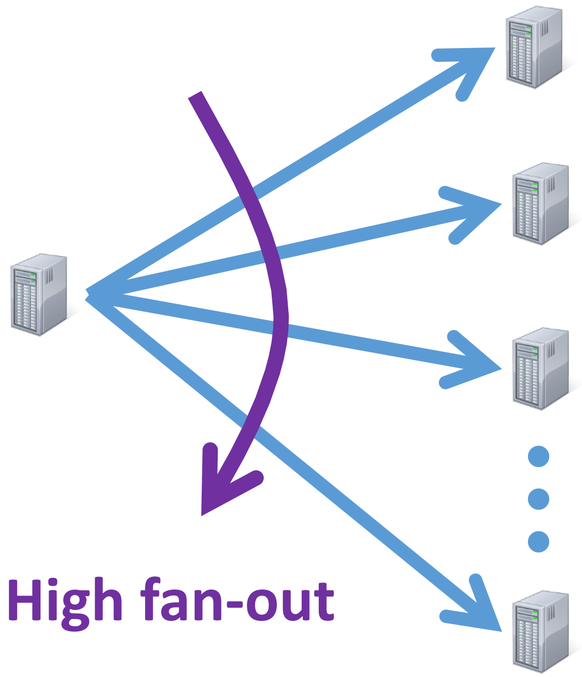

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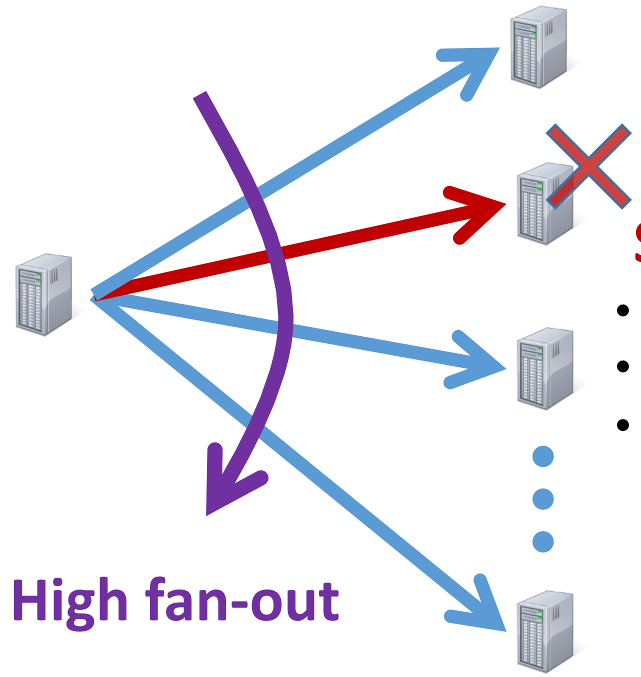

Straggler

- **Load imbalance**
- **Background tasks**
- **Failures, etc.**

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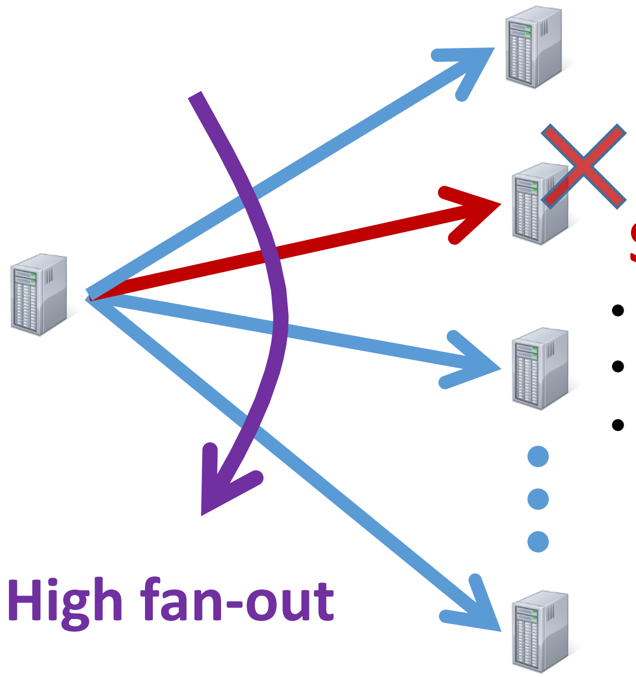
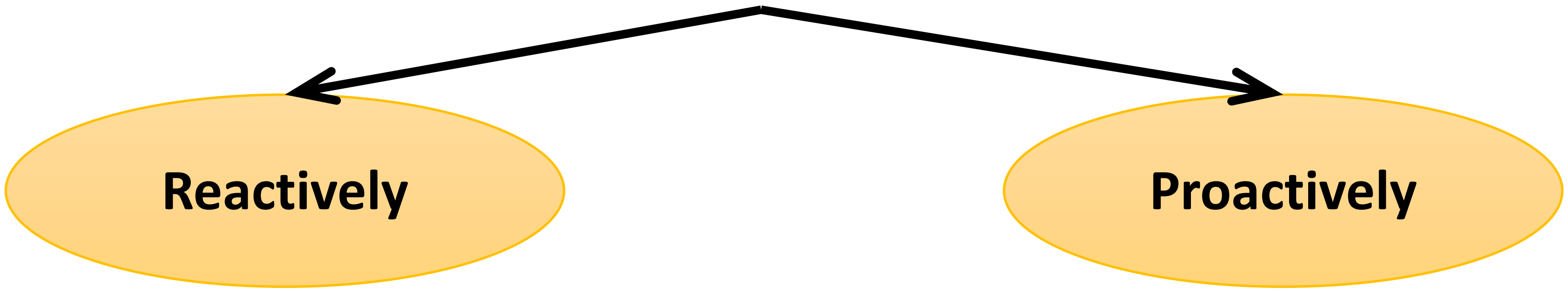


Straggler

- Load imbalance
- Background tasks
- Failures, etc.

High fan-out + Stragglers → Long tail latency

How to avoid stragglers?



How to avoid stragglers?

Reactively

Proactively

Hopper (SIGCOMM'15)
C3 (NSDI'15)
Sinbad(SIGCOMM'13)

PRO: low overhead

CON: requires straggler detection (slow and inaccurate)

How to avoid stragglers?

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Hopper (SIGCOMM'15)
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PRO: low overhead | **CON**: requires straggler detection (slow and inaccurate)

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Dolly (NSDI'13)
Low latency via redundancy (CoNext'13)

PRO: fast and accurate | **CON**: requires determining threshold load (non-trivial)

How to avoid stragglers?

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PRO: low overhead

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PRO: fast and accurate

CON: requires determining threshold load (non-trivial)

Can we achieve the benefits of both without their limitations?

Overview

- **Duplicate-Aware Scheduling Framework**

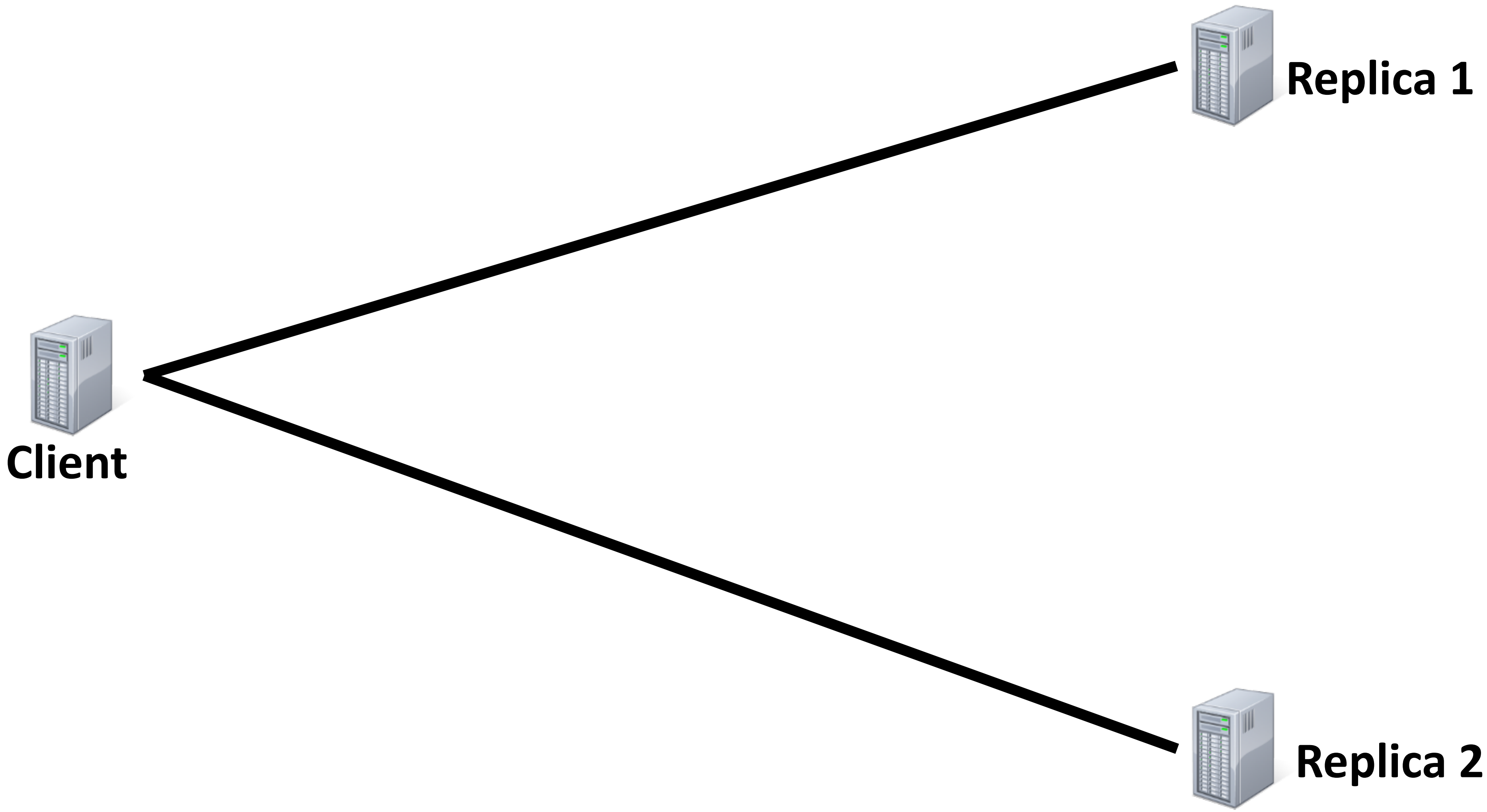
  Generic framework

- **Redundancy-Aware Network Stack**

  New network stack for DC

- **Preliminary Results**

Duplicate-aware scheduling



Duplicate-aware scheduling

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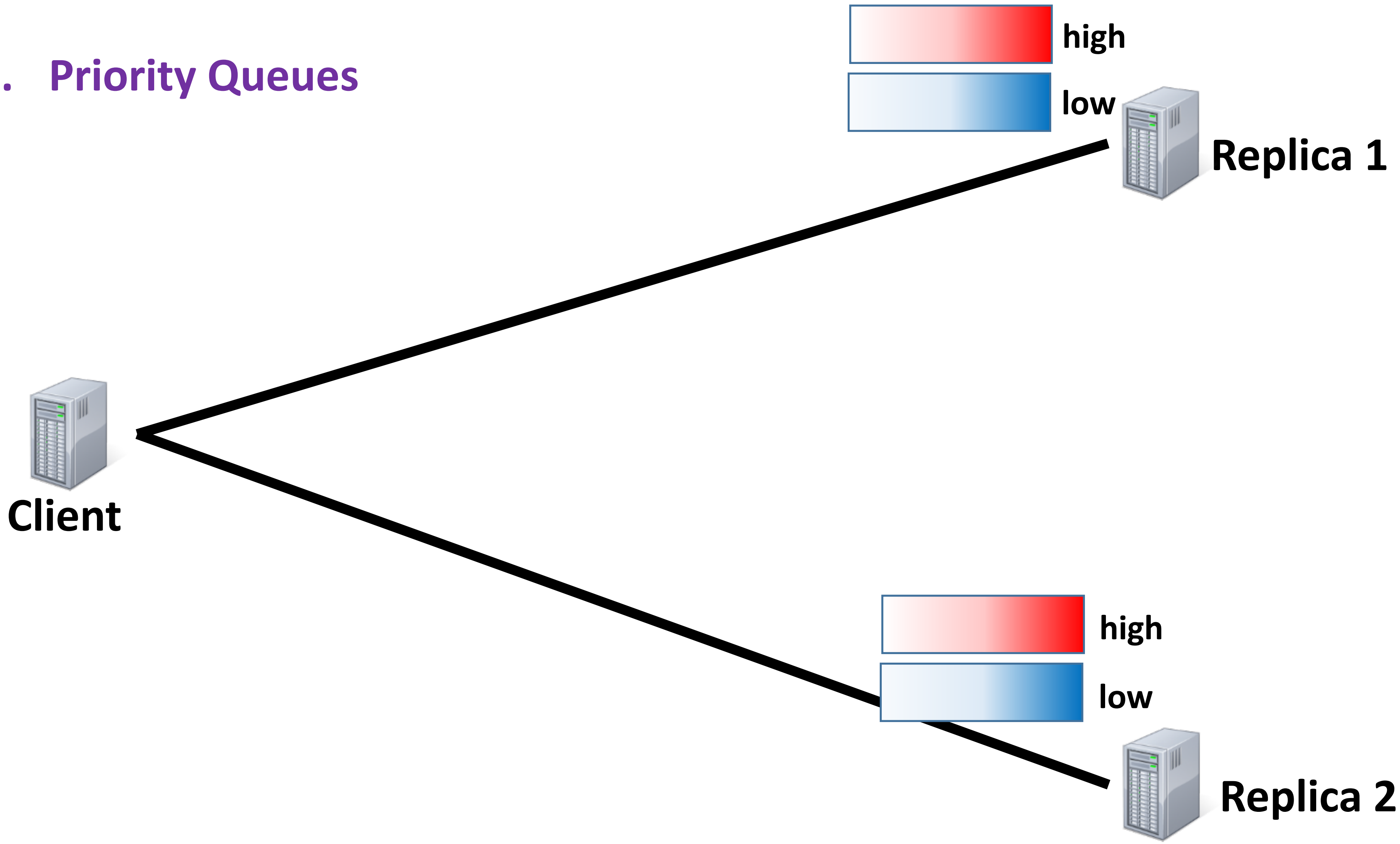

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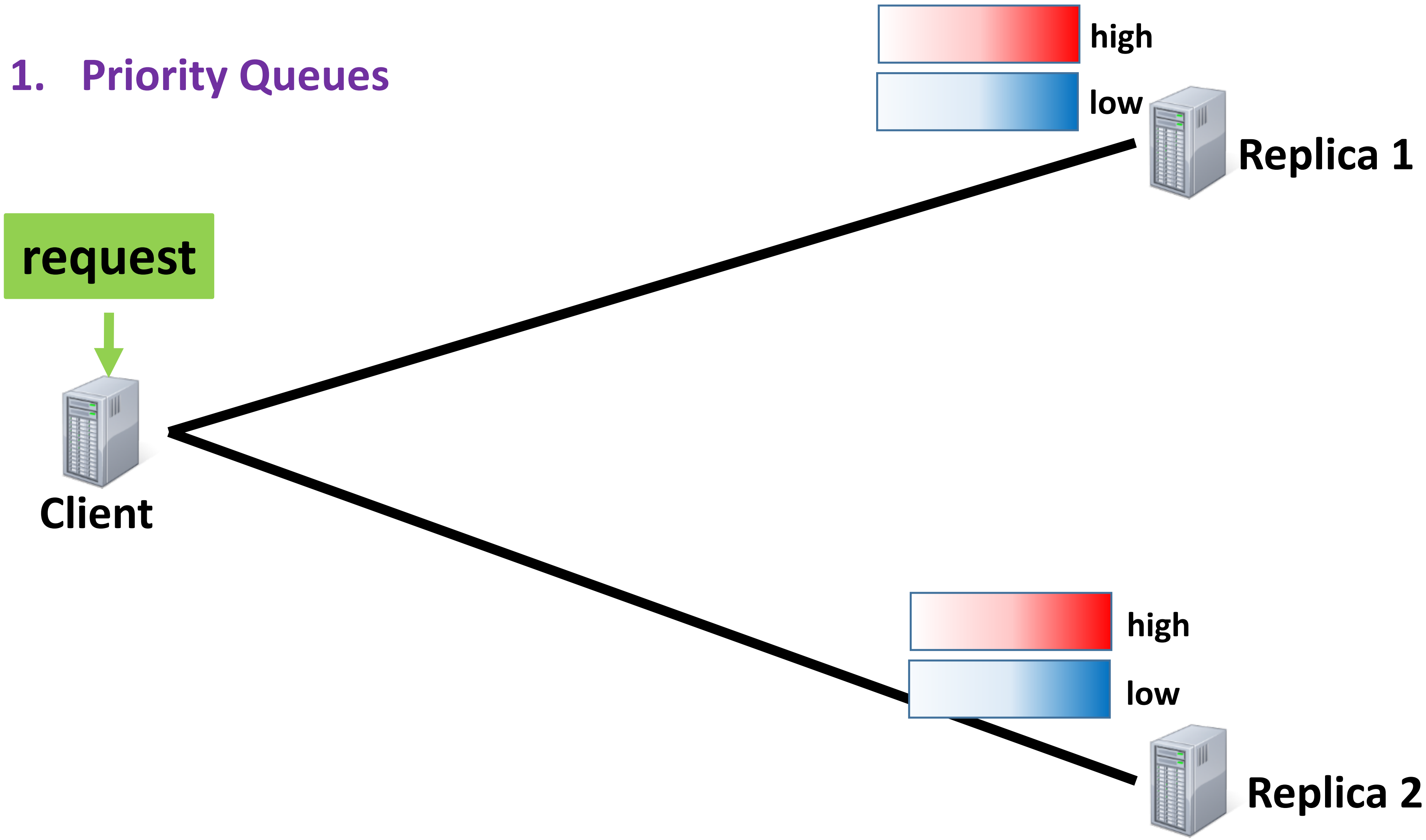

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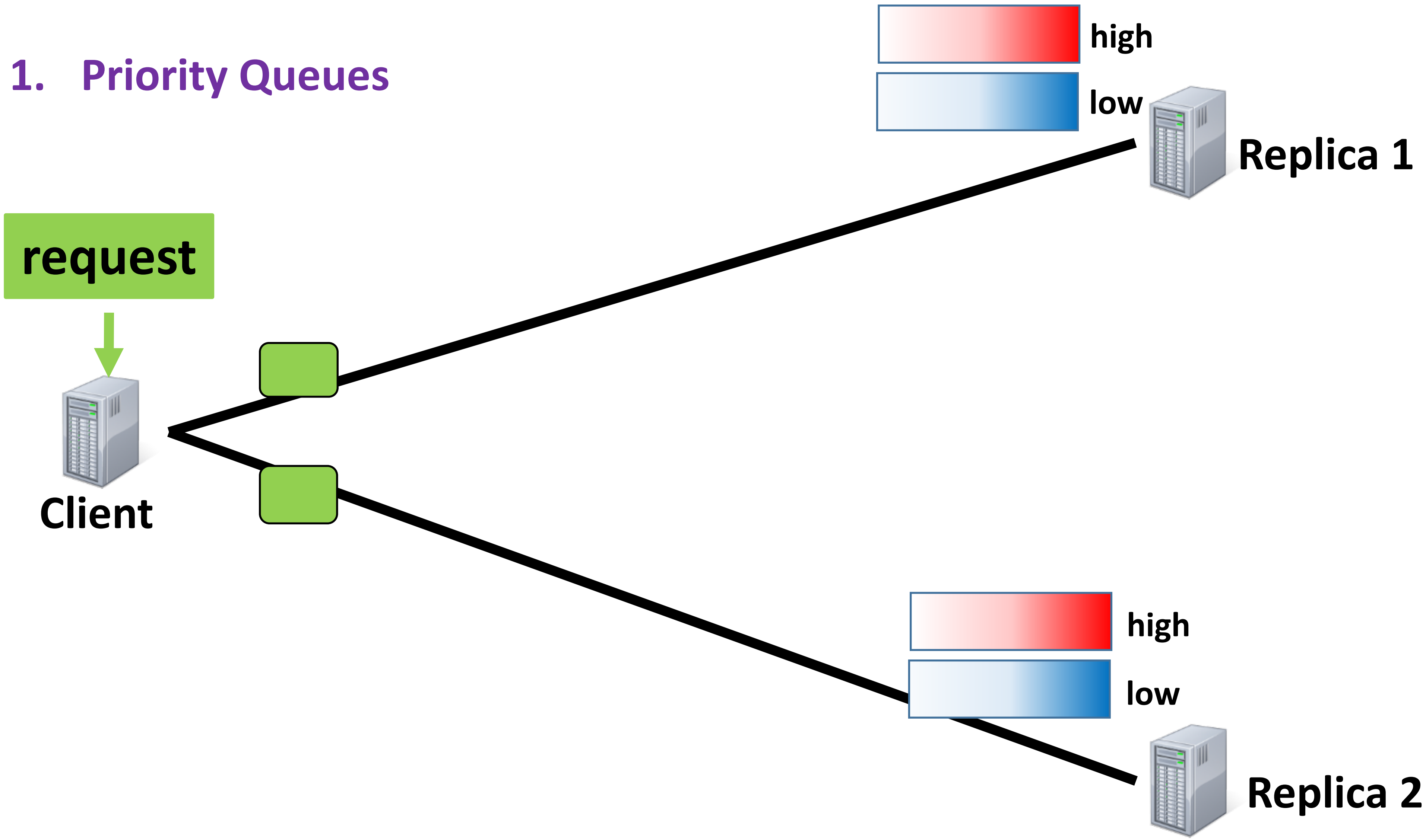

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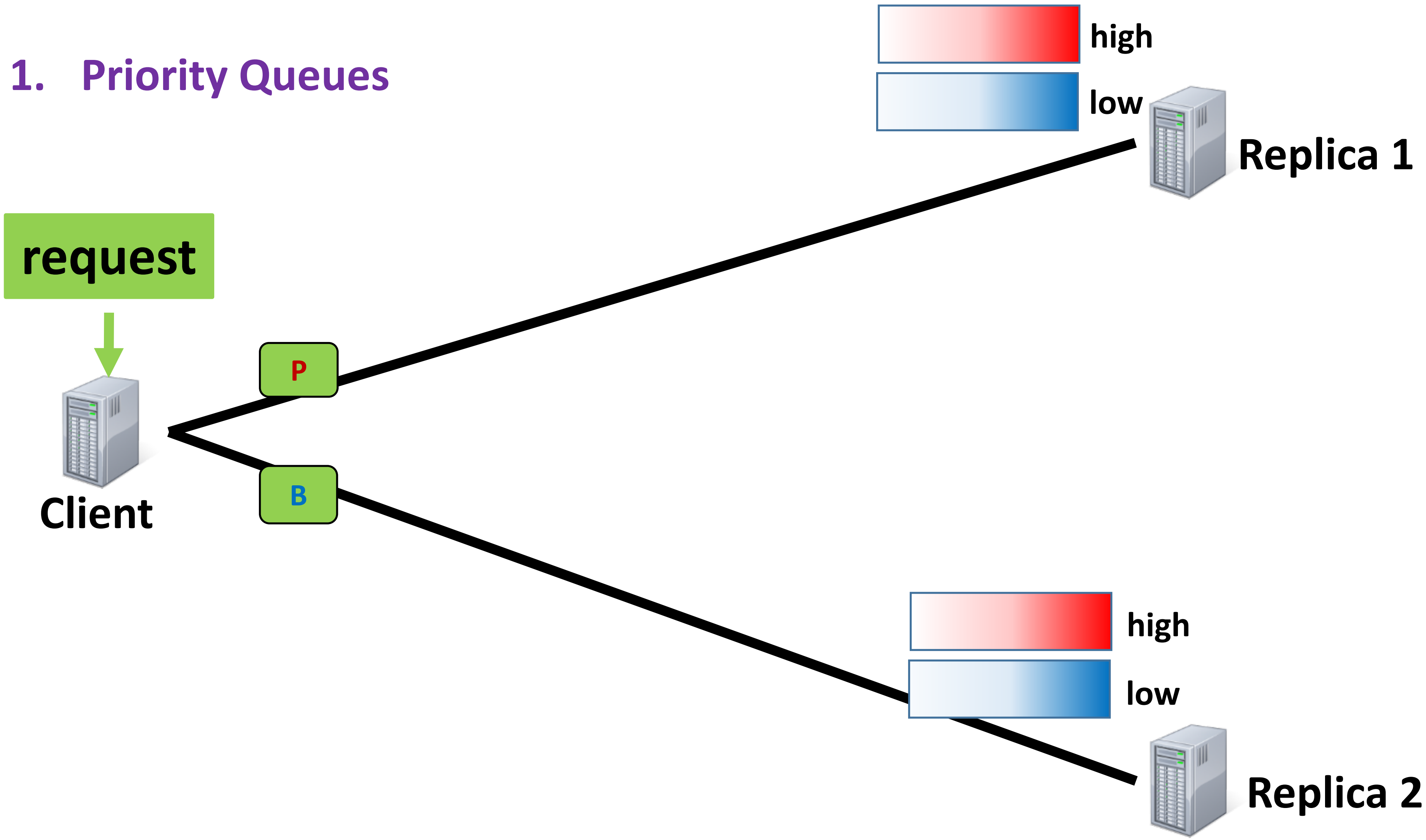

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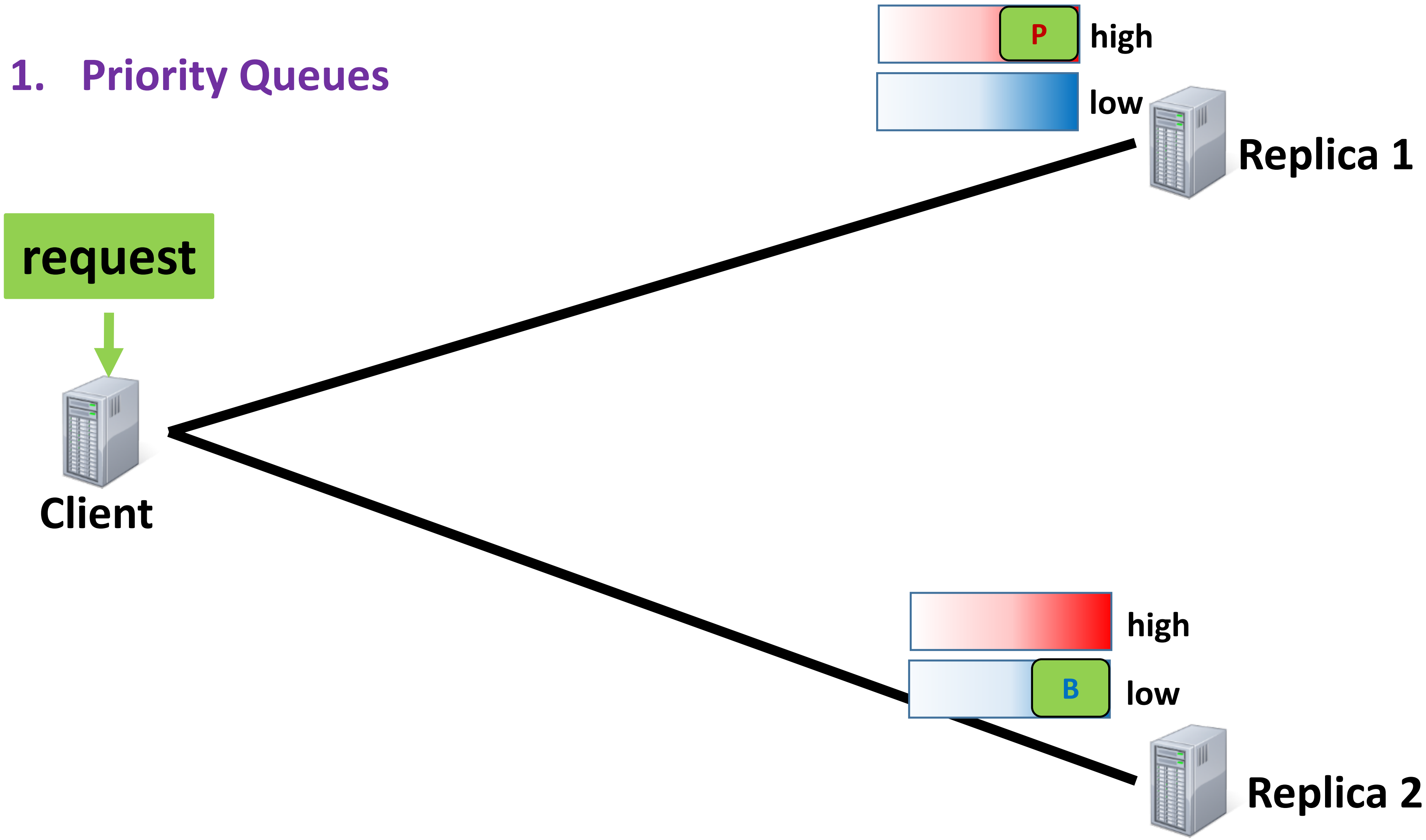

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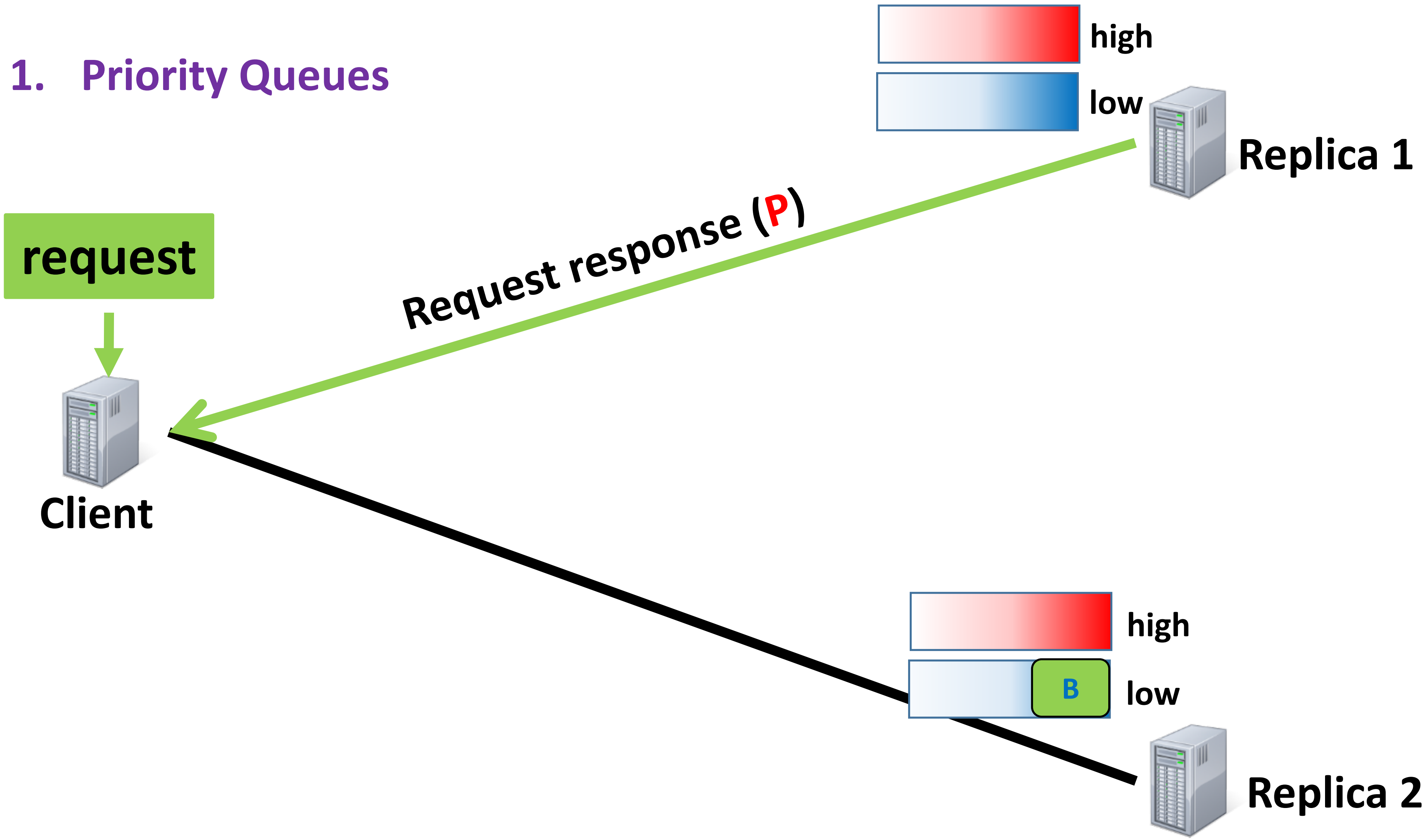
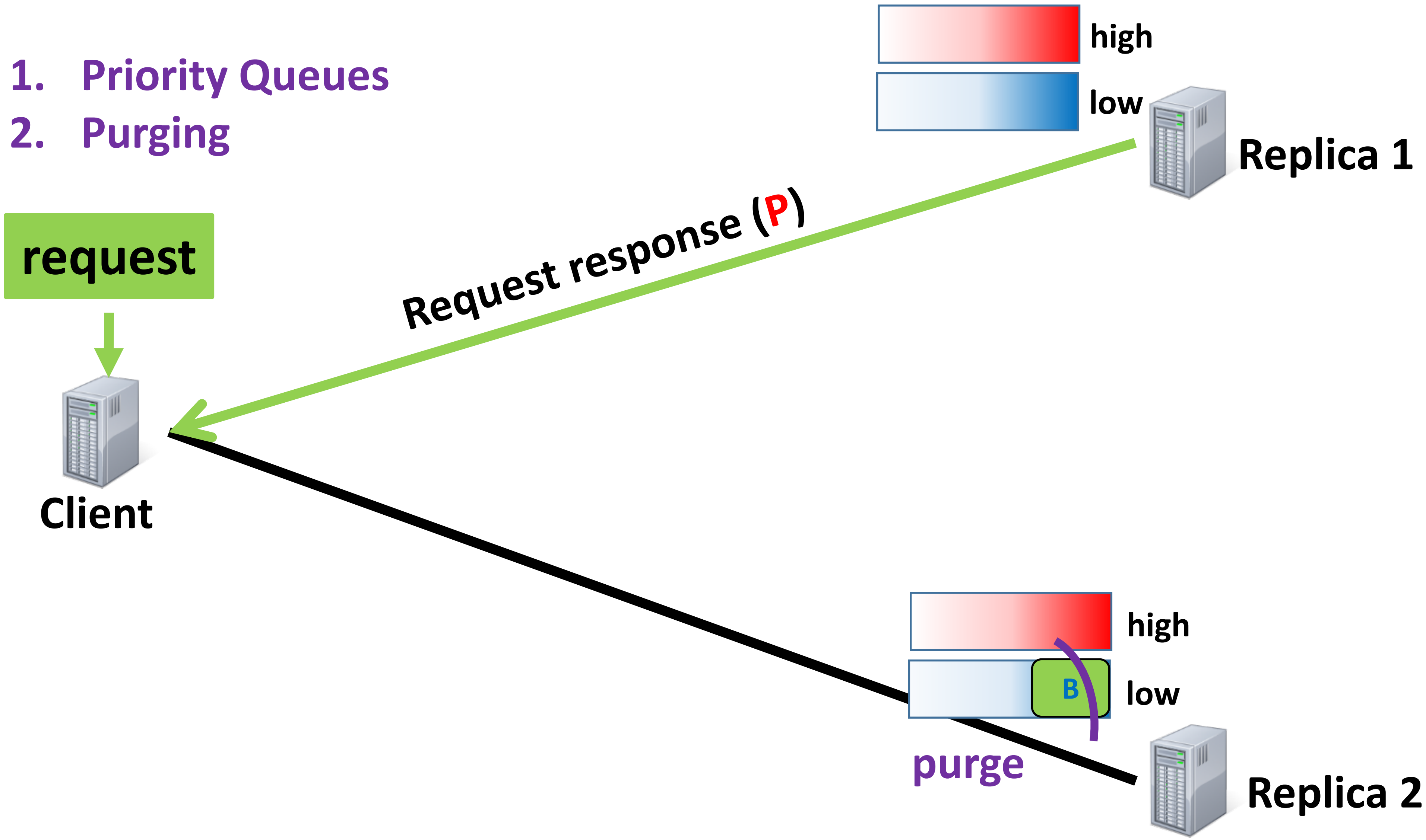


Duplicate-aware scheduling

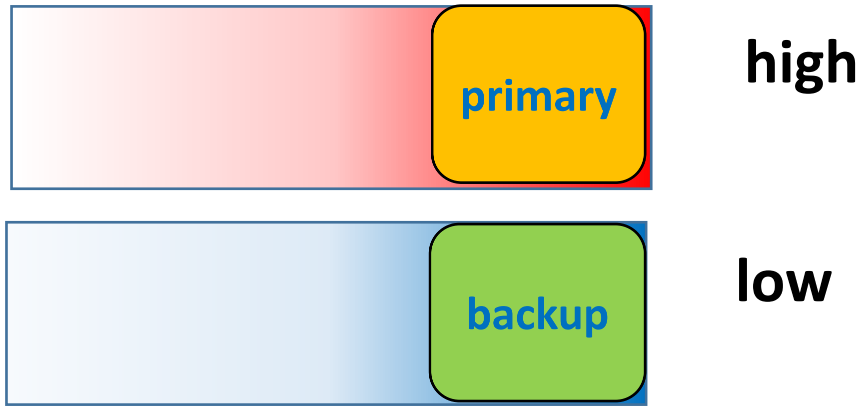
1. Priority Queues
2. Purging



Need for Priority Queuing

- **Duplication has an overhead!**

☹



Need for Priority Queuing

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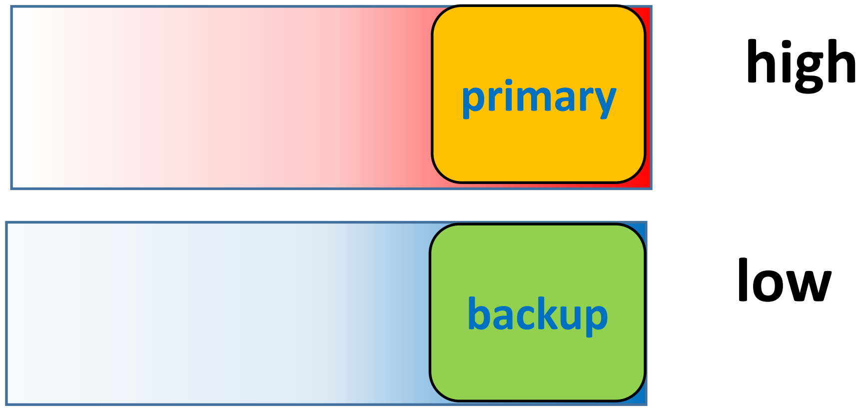
Properties required:

- ✓ **Strict priorities**
- ✓ **Work conservation**
- ✓ **Preemption**



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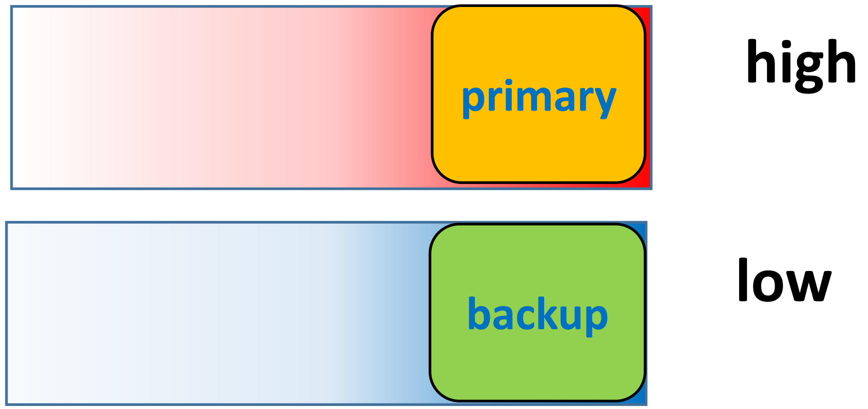

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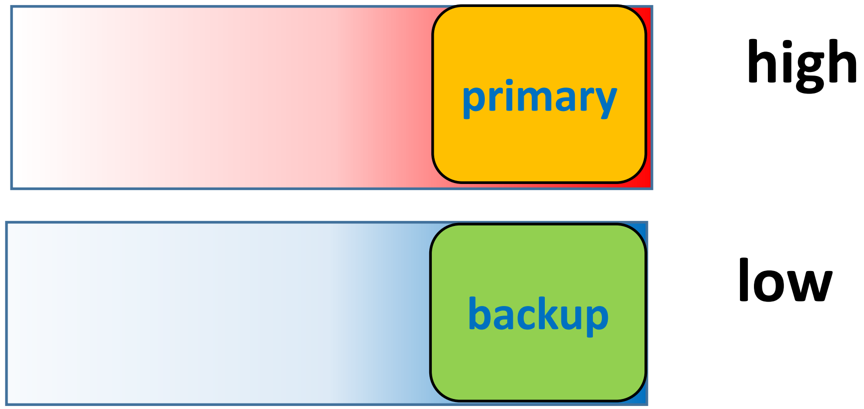


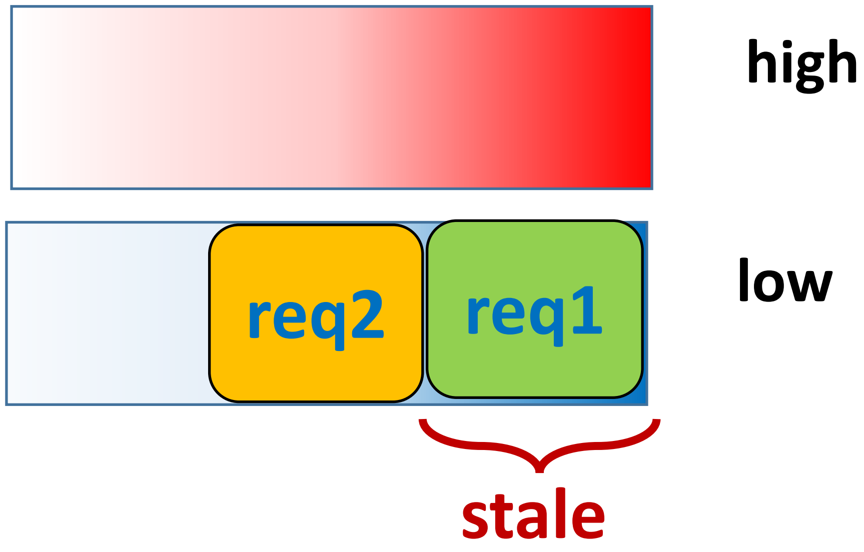
PQ makes the overhead of duplication <u>low</u>.

essential

Importance of Purging

- **Stale requests block new requests.**

☹



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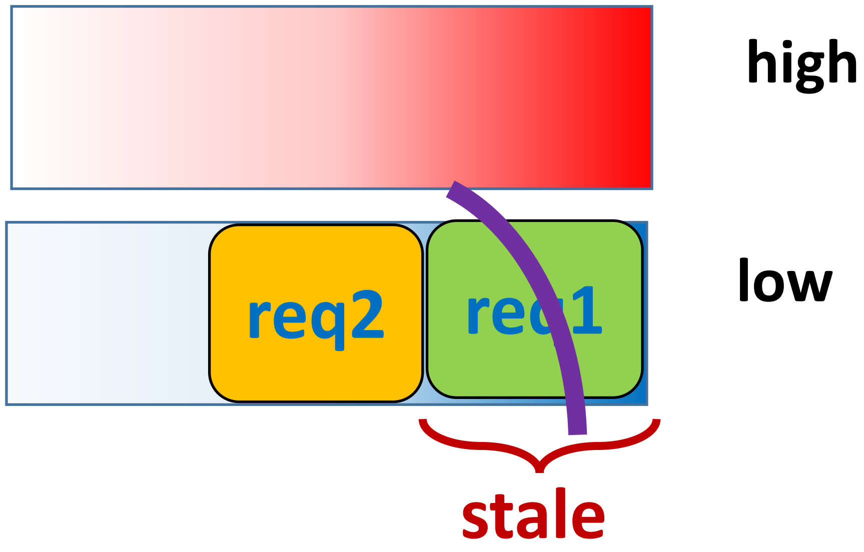

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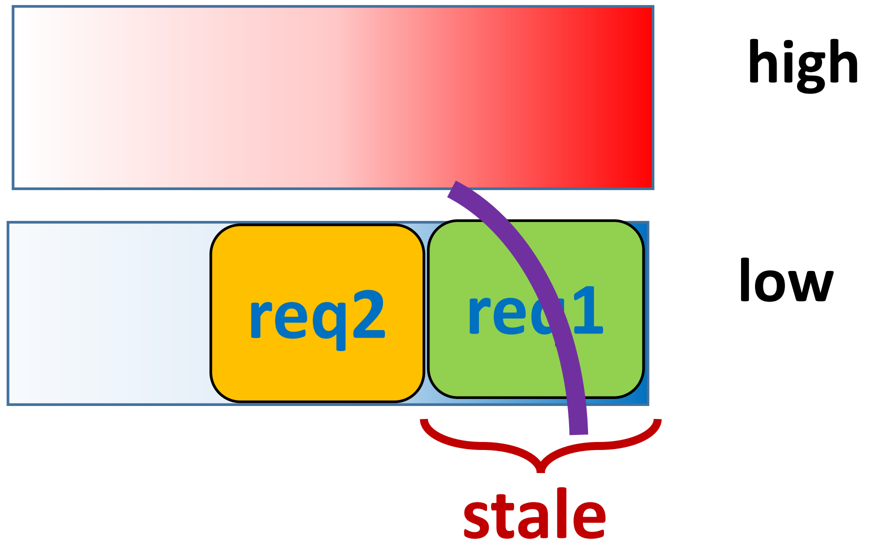

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optimization

Realizing Duplicate-Aware Scheduling

at every **potential bottleneck** resource in a DC

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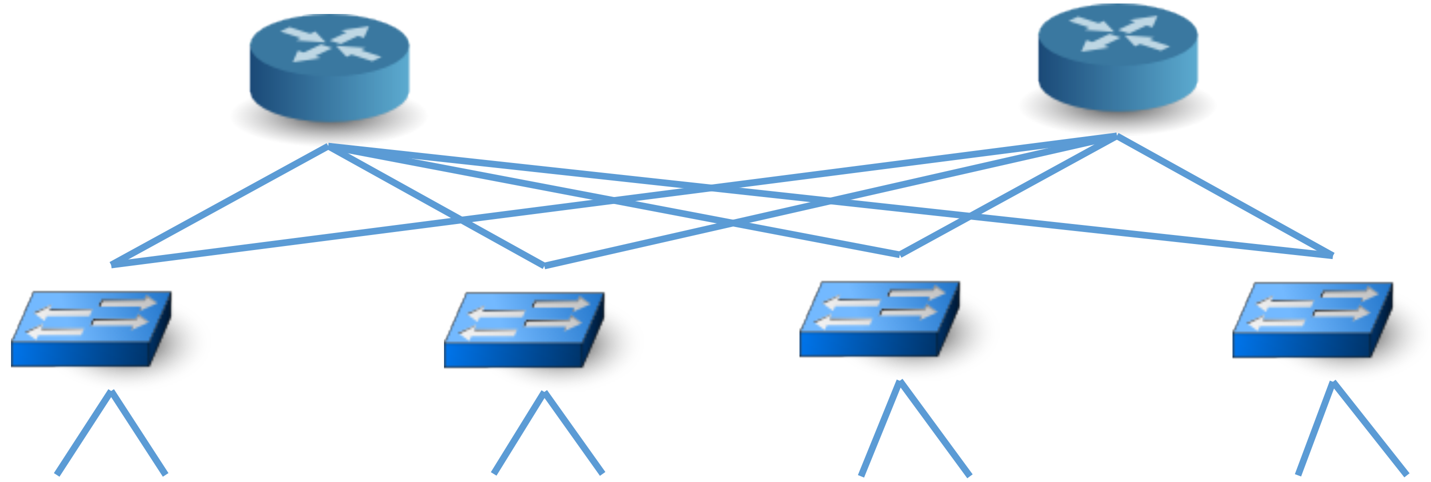
Network



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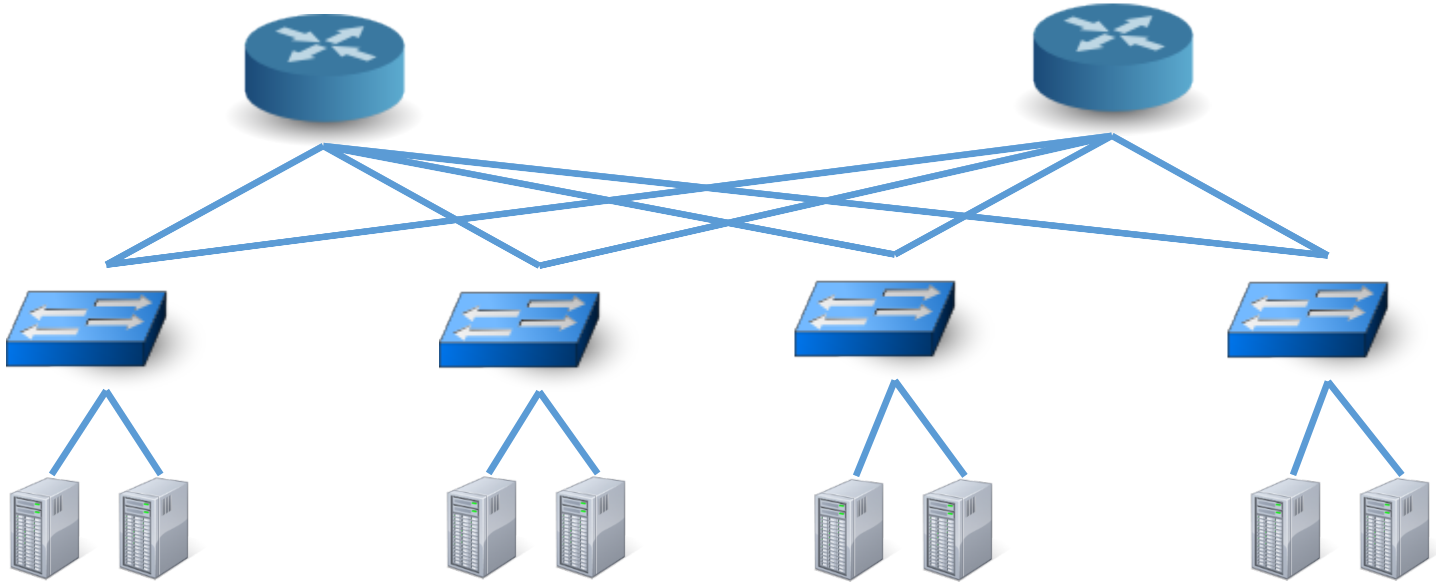
Network

Compute



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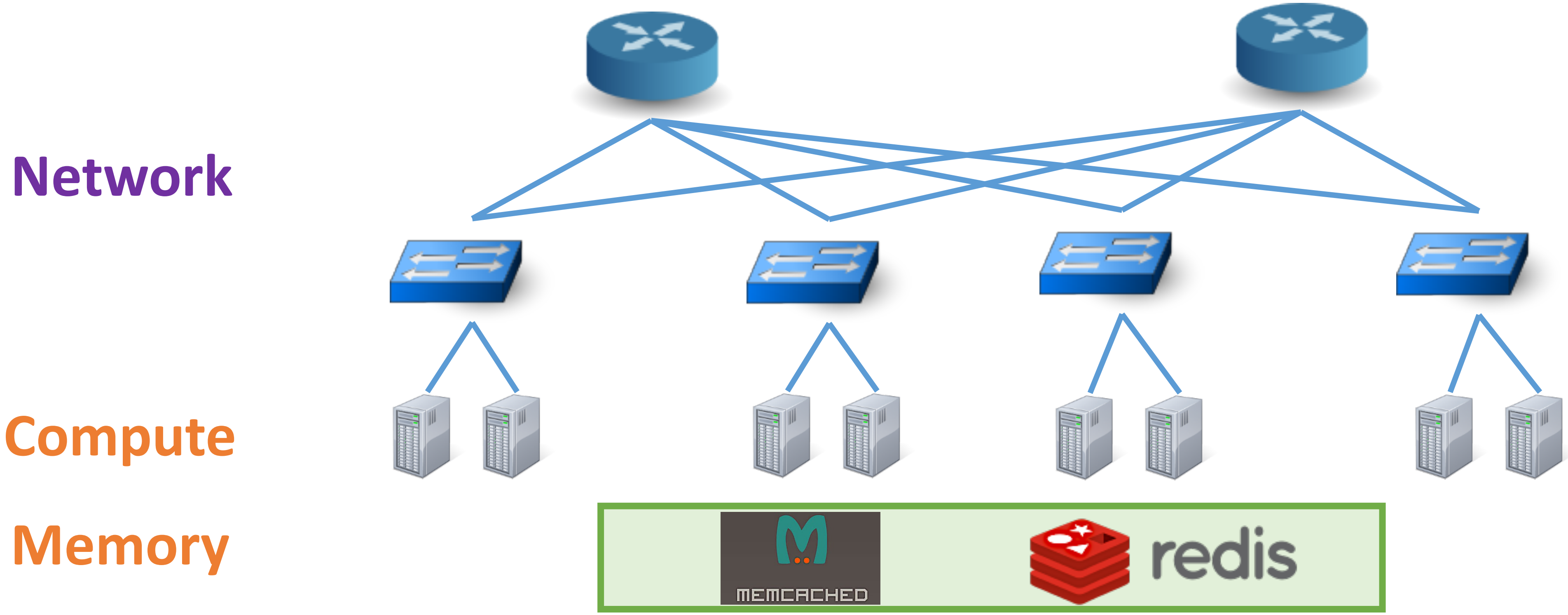

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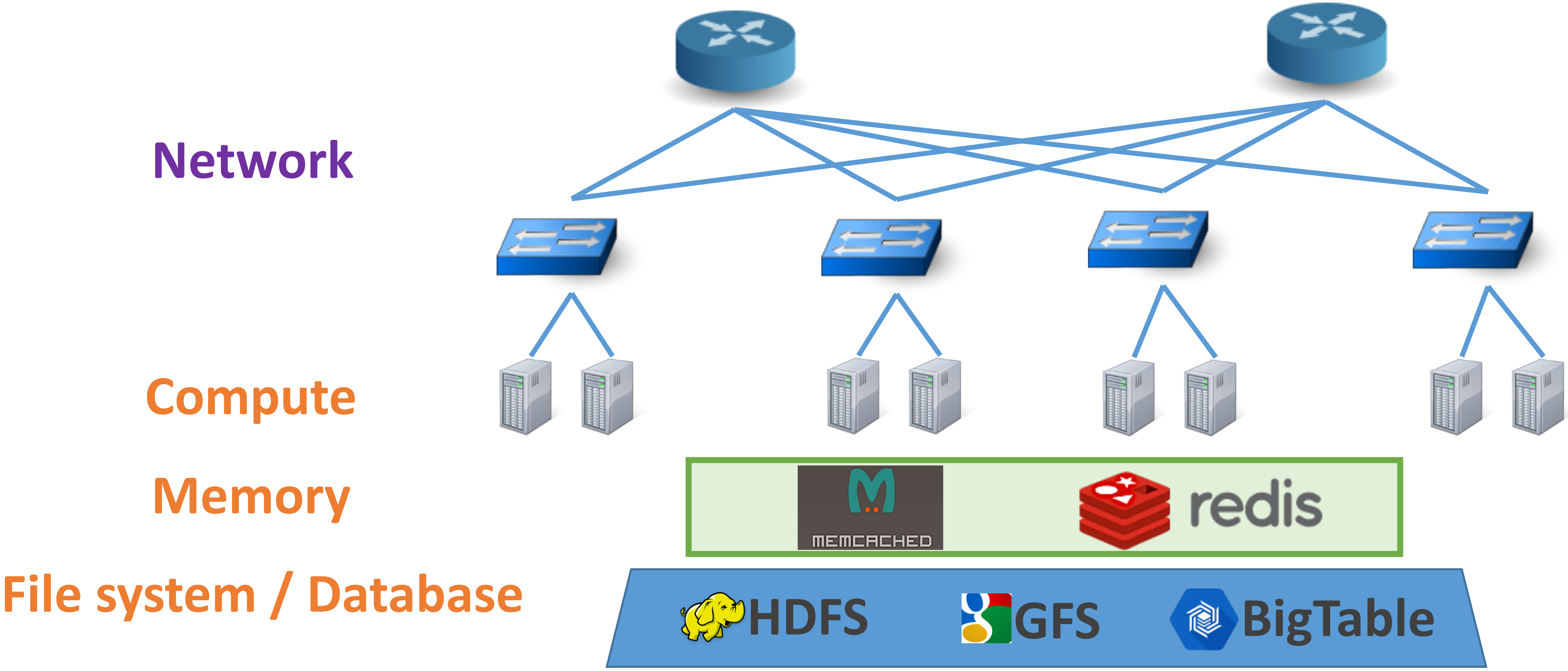

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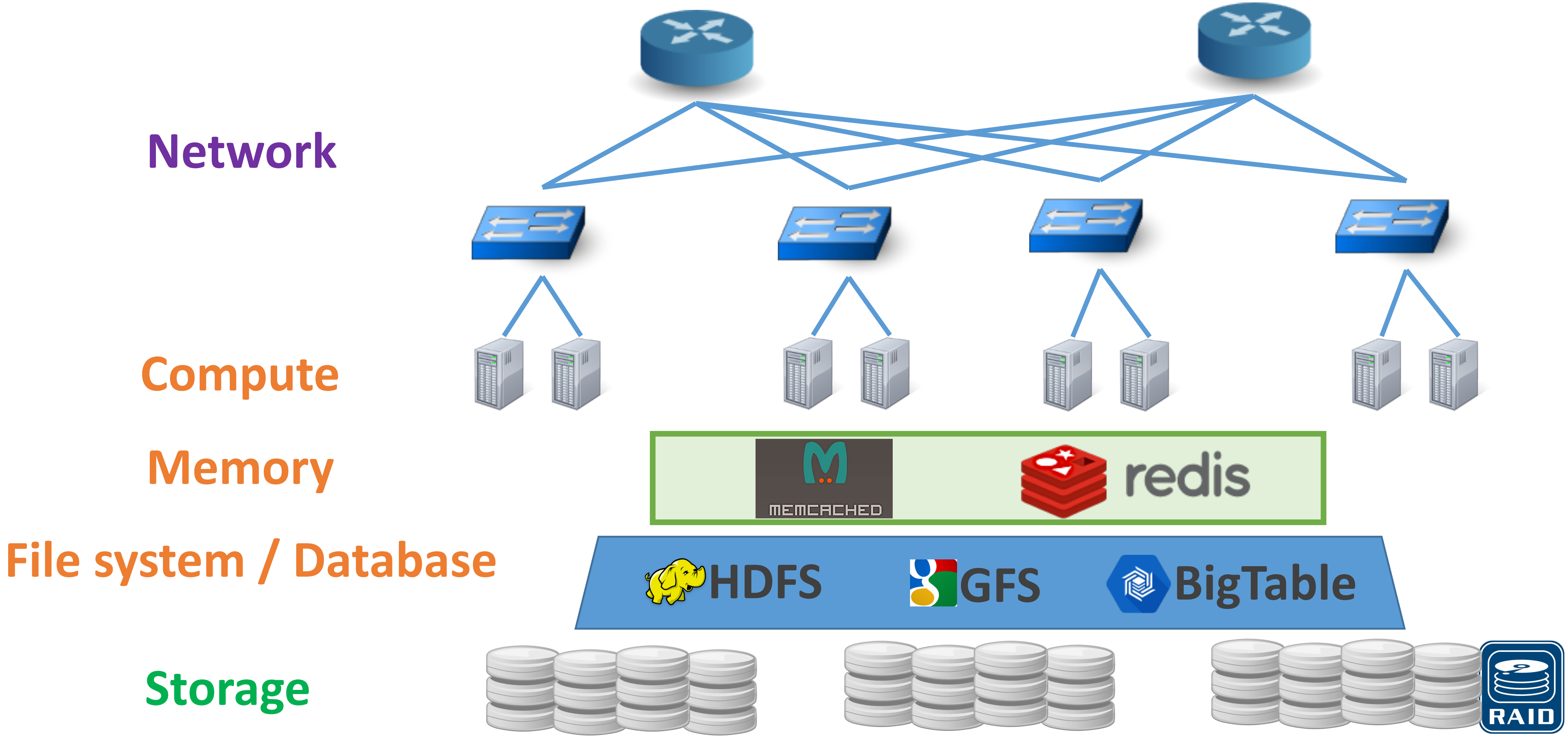


Realizing Duplicate-Aware Scheduling

at every **potential bottleneck** resource in a DC

challenges

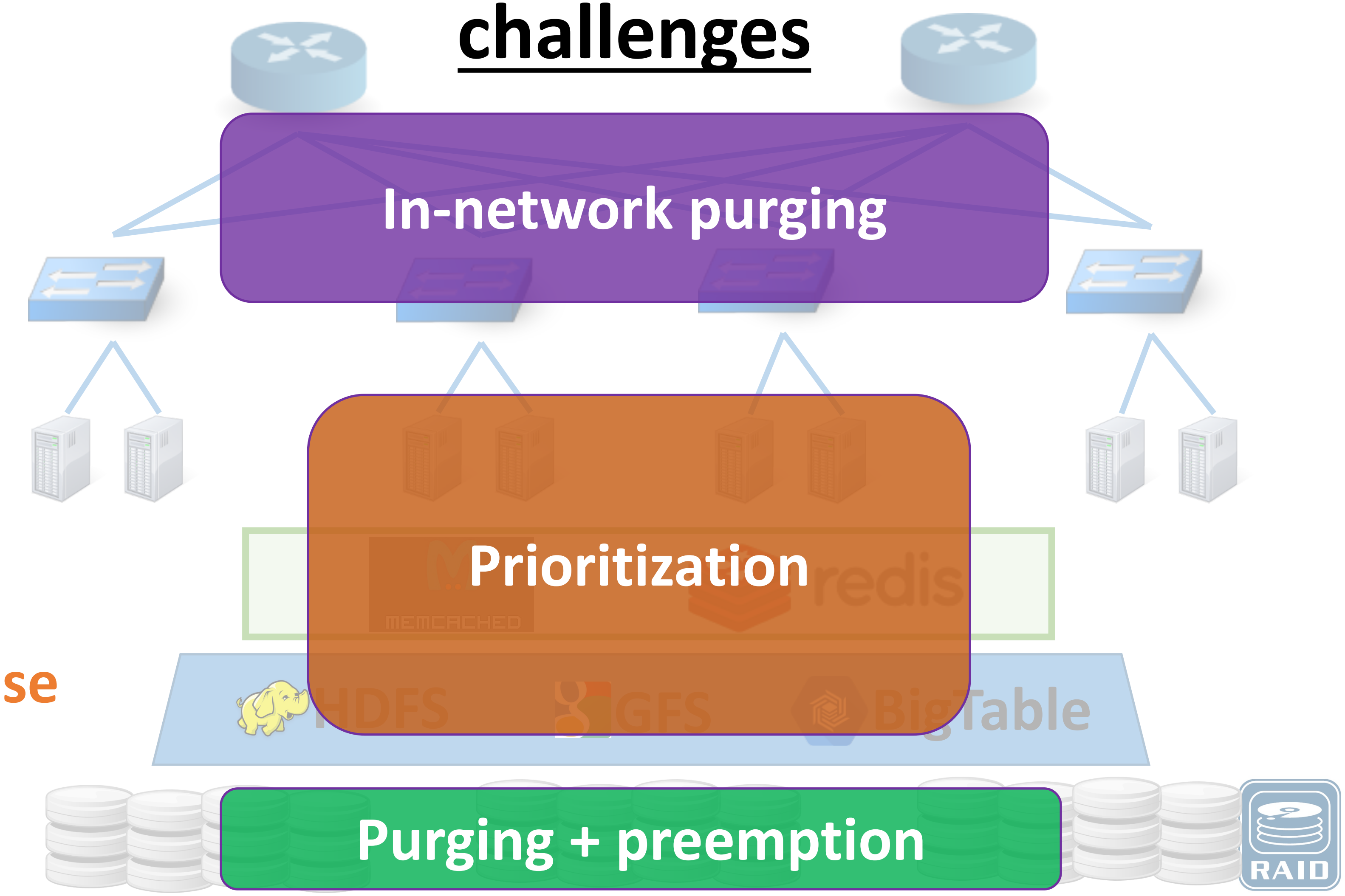
Network

Compute

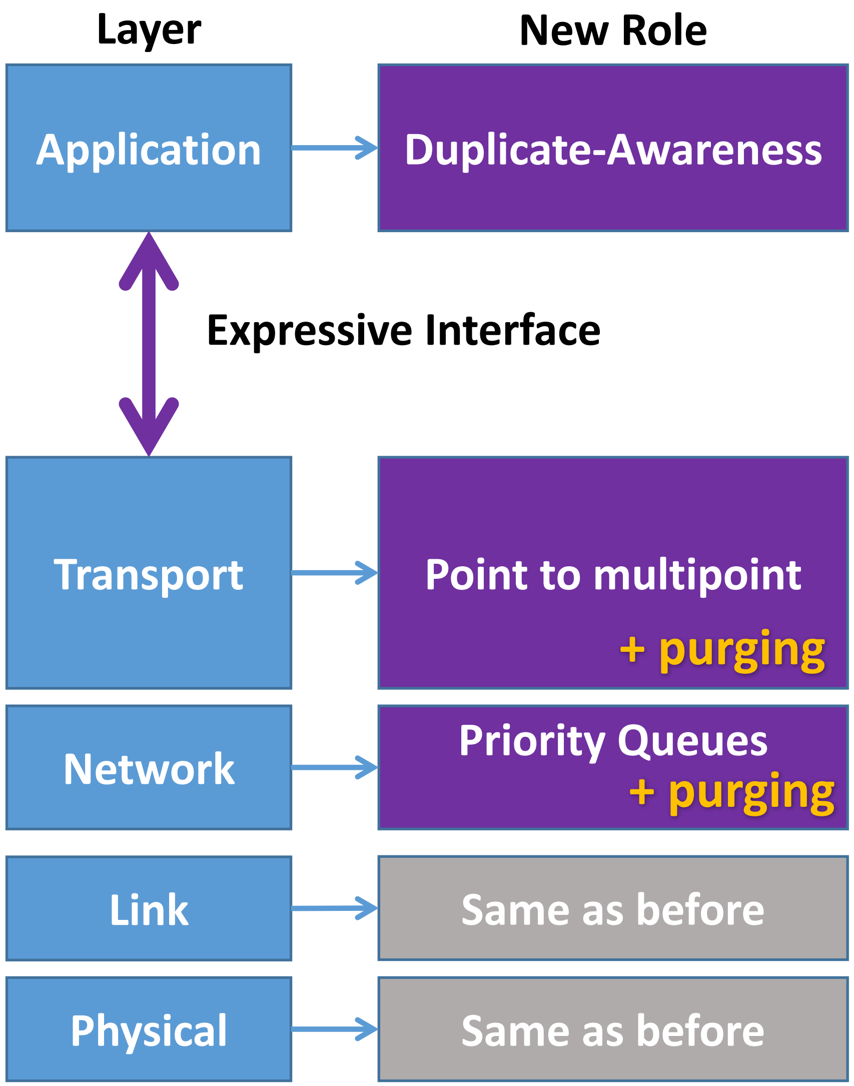
Memory

File system / Database

Storage



Redundancy Aware Network Stack (RANS)



Redundancy Aware Network Stack (RANS)

Layer	New Role
Application	Duplicate-Awareness
Expressive Interface	
Transport	Point to multipoint + purging
Network	Priority Queues + purging
Link	Same as before
Physical	Same as before

challenge

Applications need to be modified.

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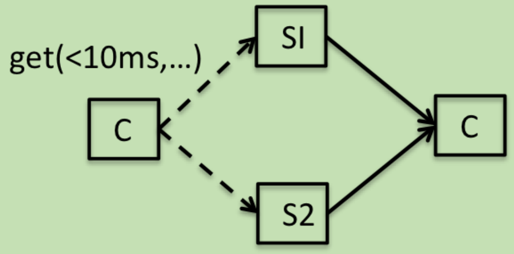
Expressive interface allows rich communication b/w App and Transport.
E.g. DAG



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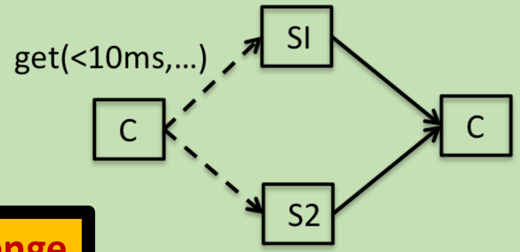

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Hard to implement per packet purging.

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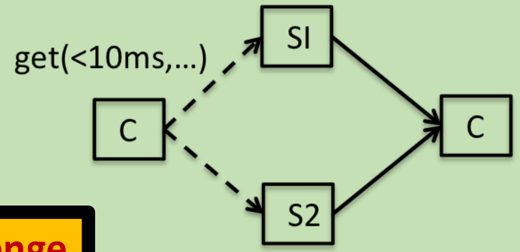

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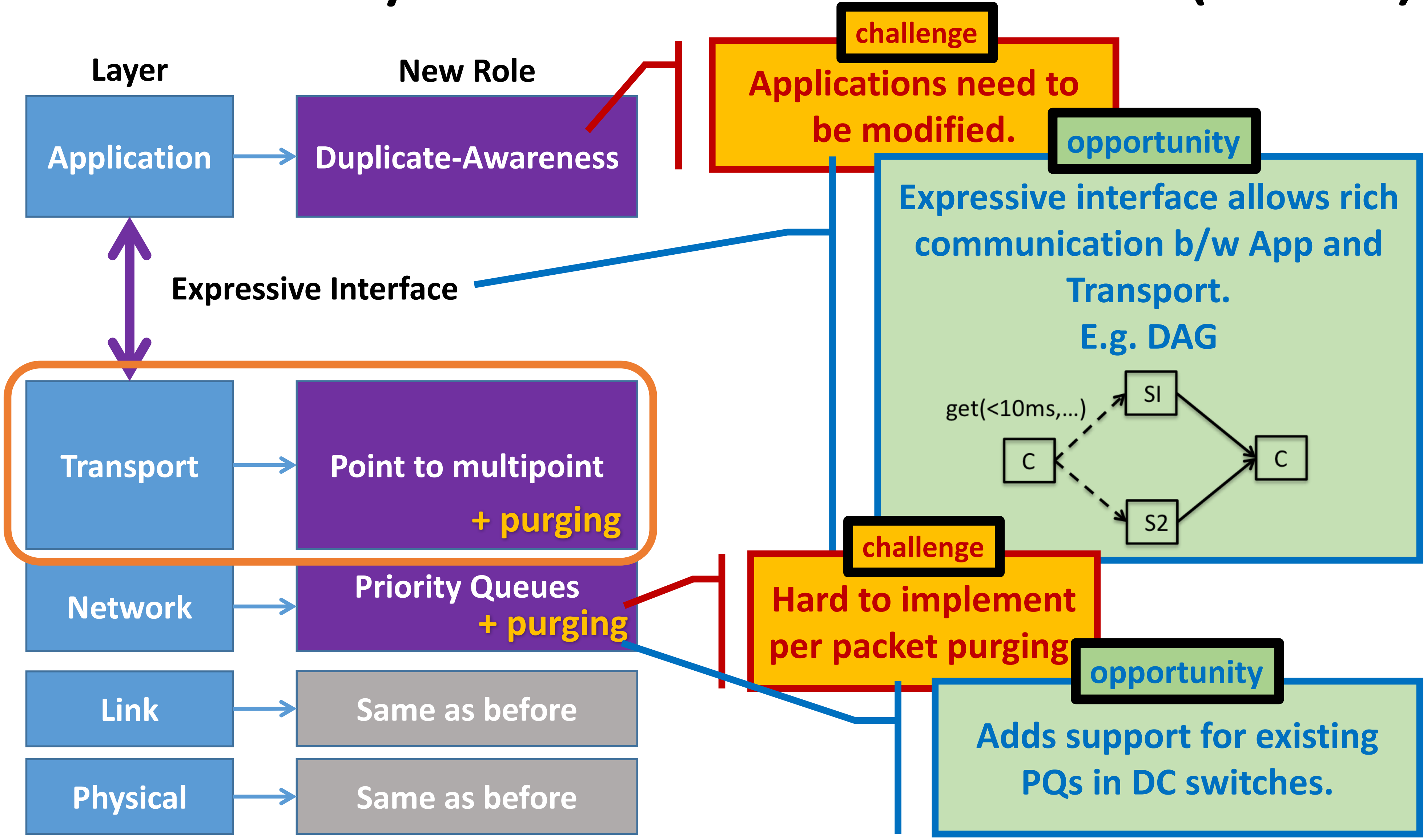
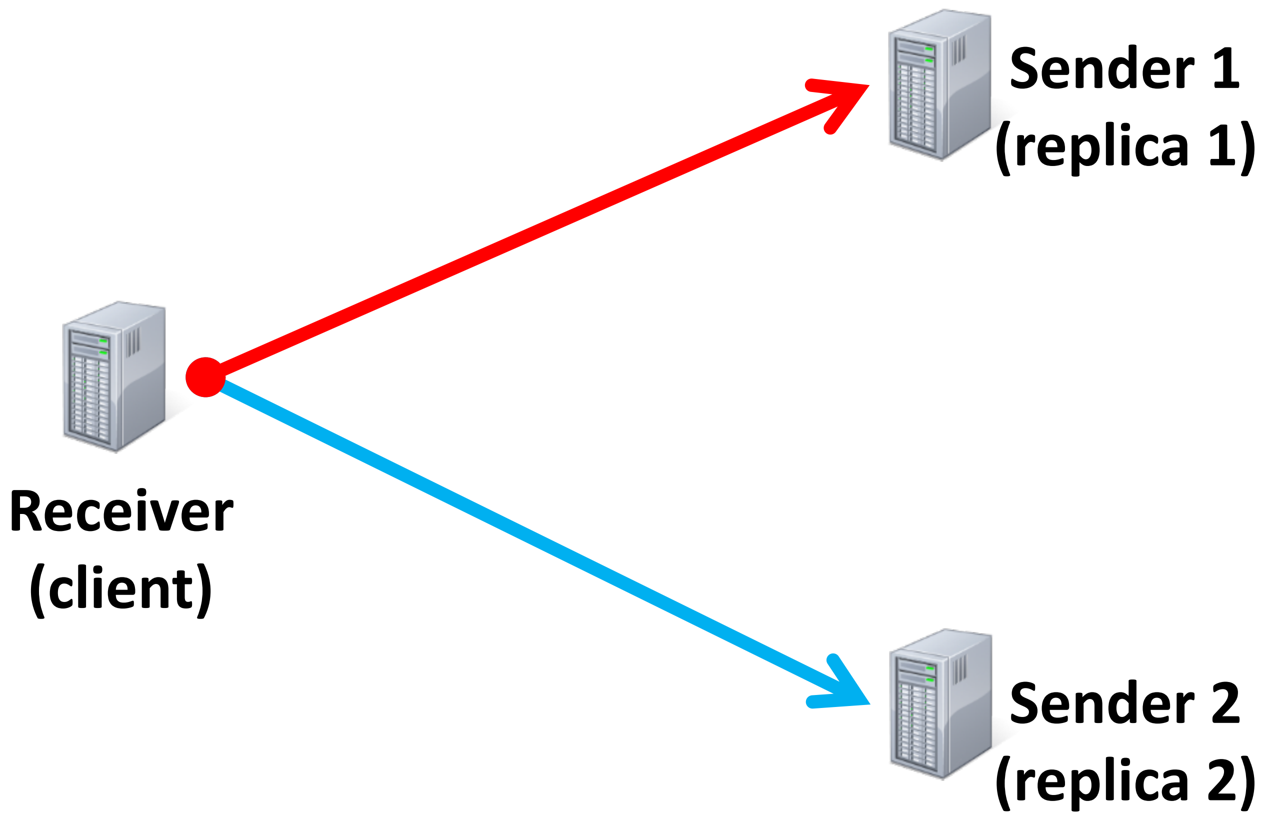
Adds support for existing PQs in DC switches.

Redundancy Aware Network Stack (RANS)



RANS Transport: Point to Multi-point

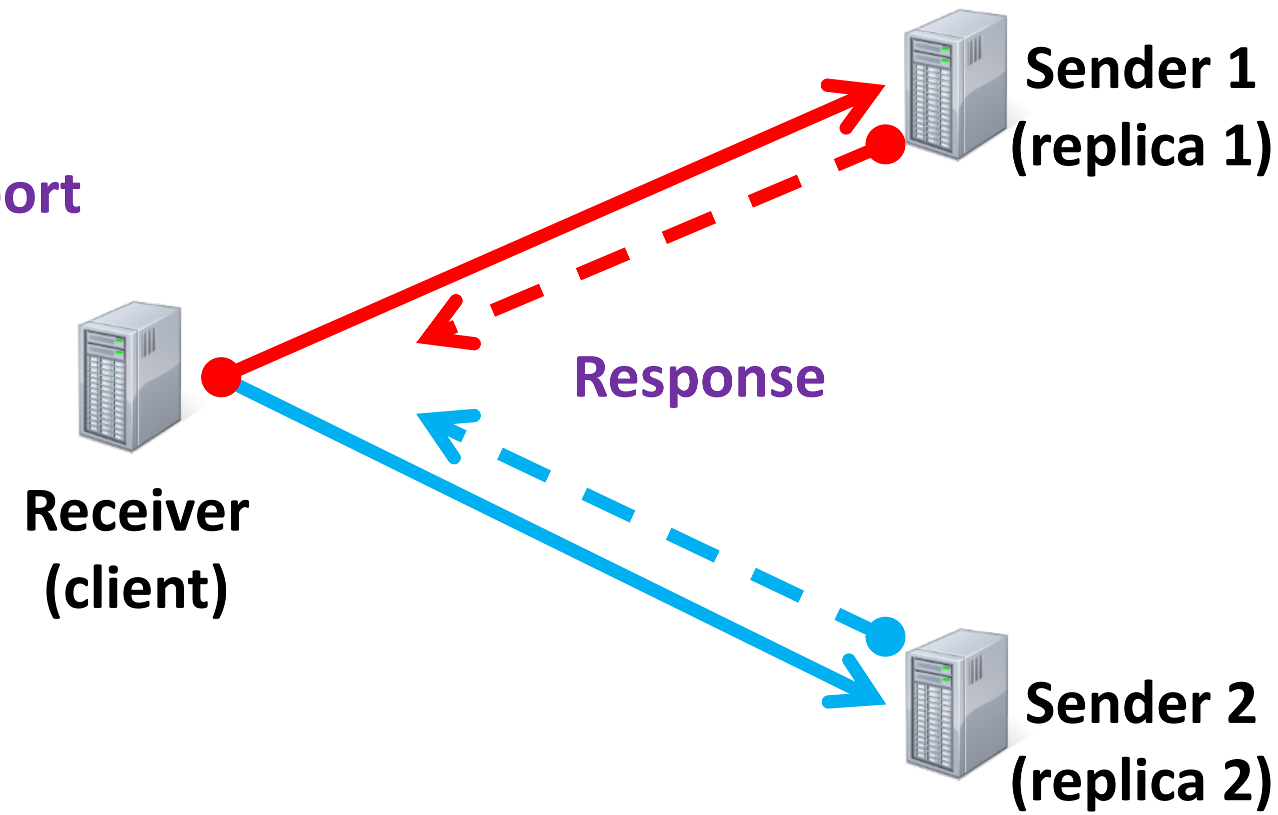
- Enables: Rich transport
  - ✓ Multipath
  - ✓ Multi-destination
    - e.g. Improved fault tolerance



RANS Transport: Byte Aggregation

- Opportunity: Receiver driven transport
  - ✓ Two or more response streams
  - ✓ Aggregate bytes at receiver side

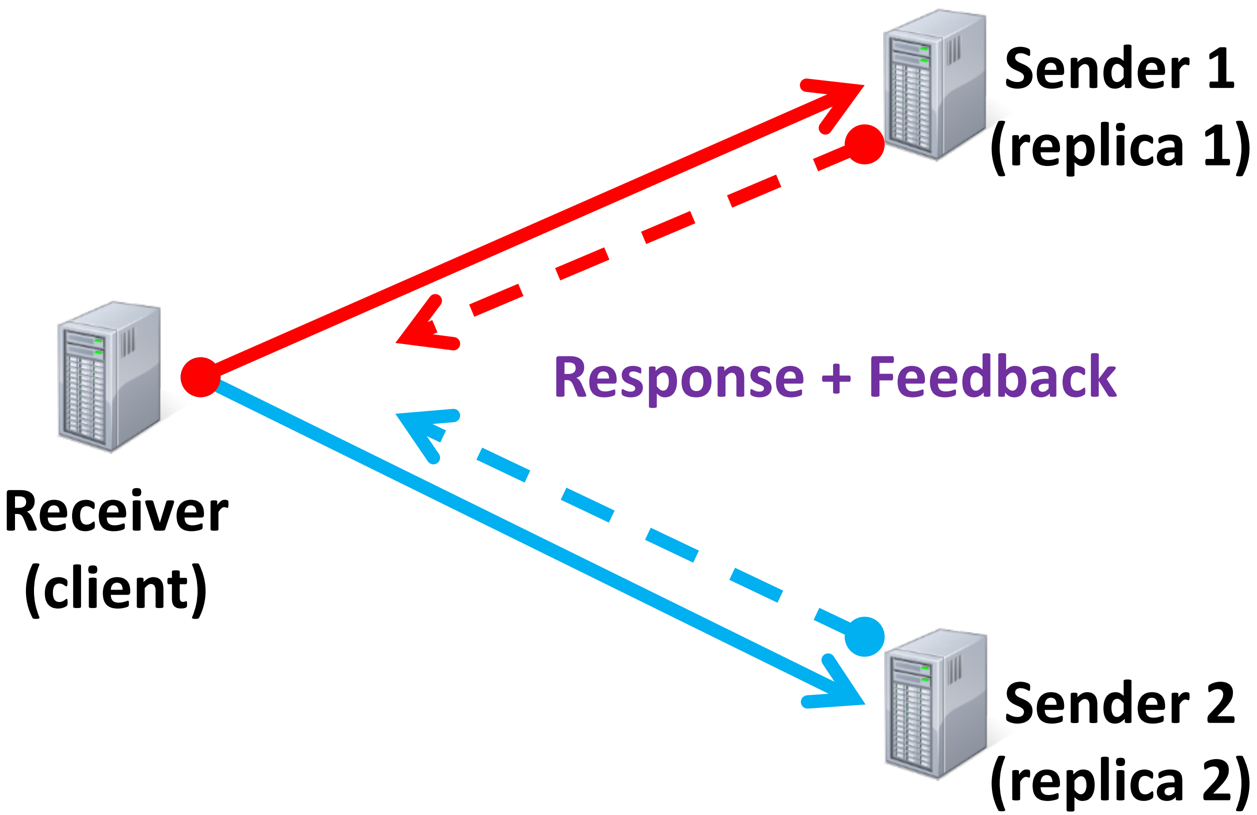
    e.g. More efficient congestion control (2x or more)



RANS Transport: Priority Assignment

- Dynamic replica assignment
  - ✓ Fine grained monitoring of congestion window
  - ✓ Dynamically reprioritize flows
  - ✓ Feedback to Application

    e.g. Improved replica assignment

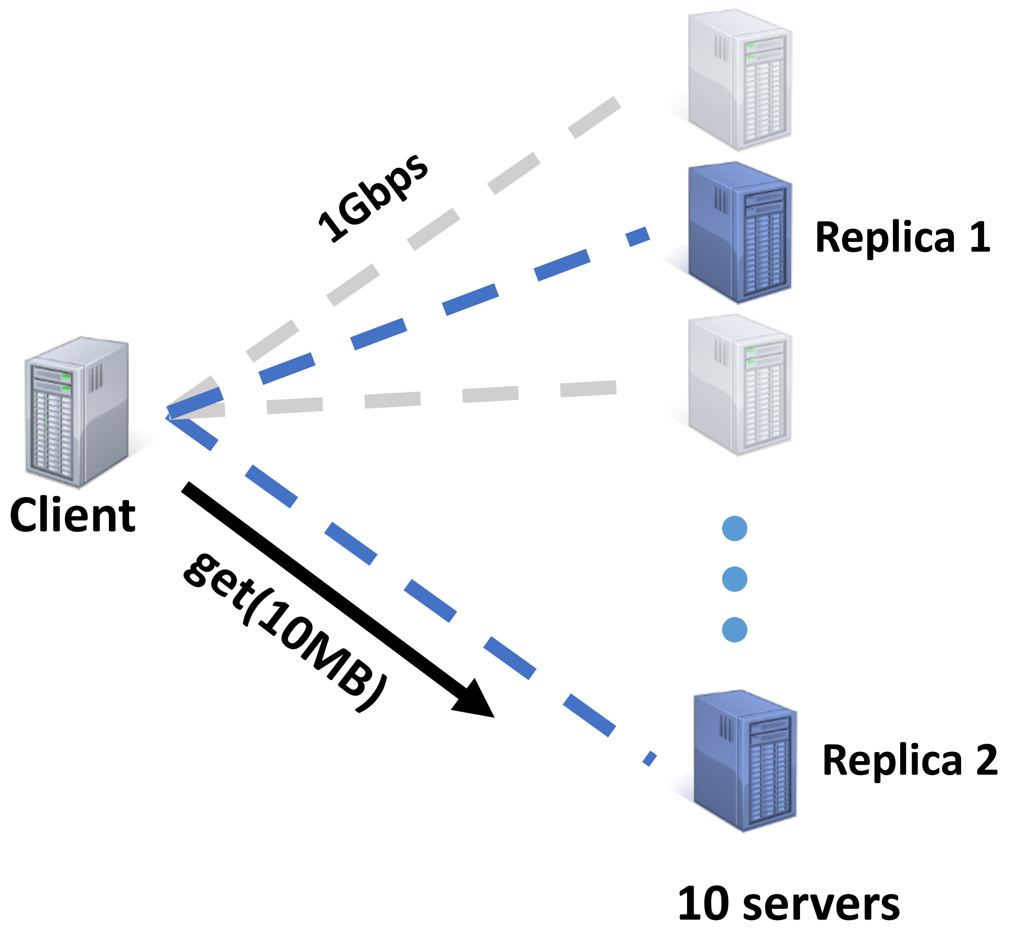


Overview

- Duplicate-Aware Scheduling Framework
- Redundancy-Aware Network Stack
- **Preliminary Results**

Preliminary Evaluation: ns-2 setup details

➢ **Storage scenario**



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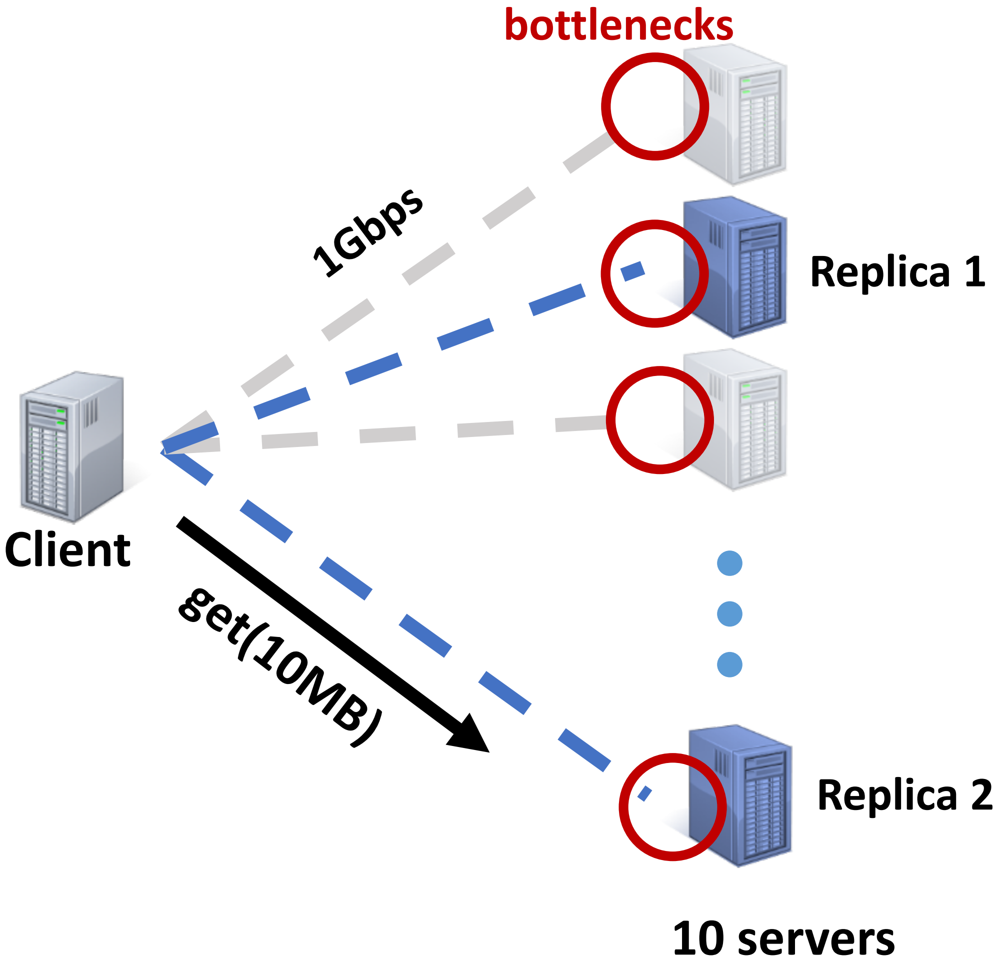

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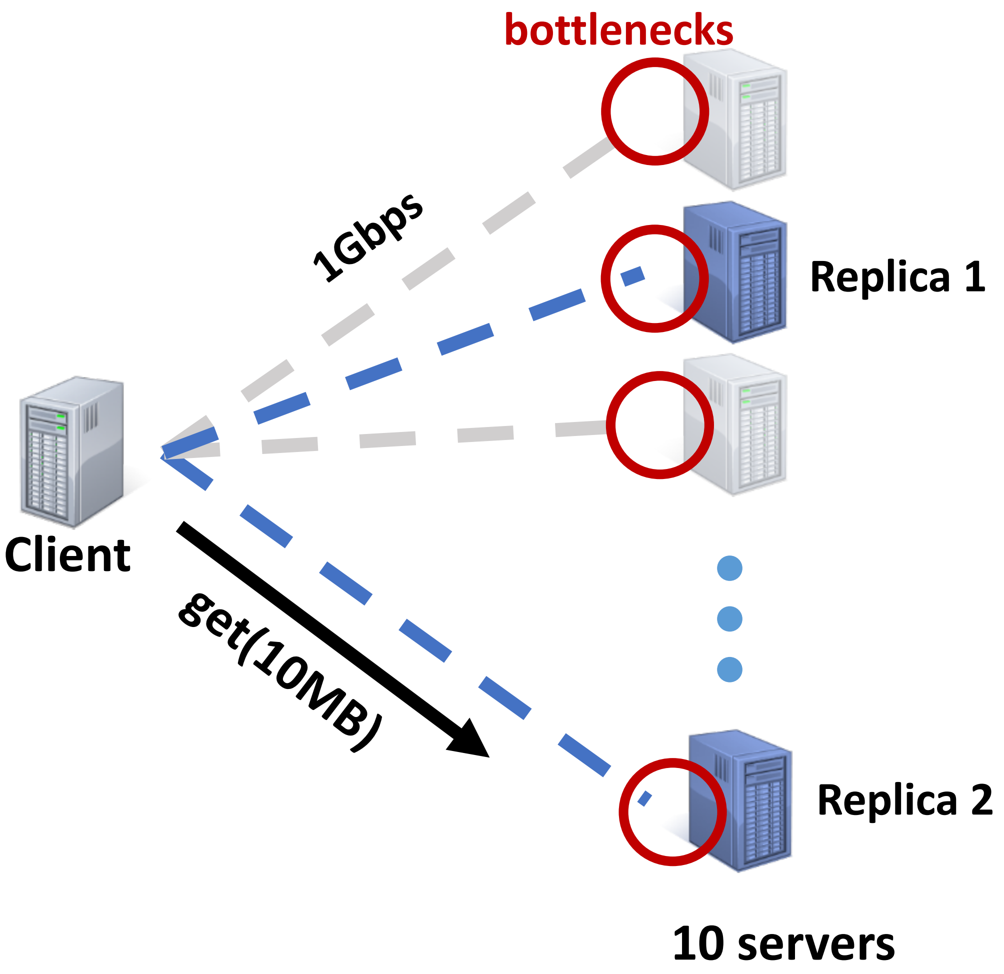

Traffic Details	
Total requests	20K
Arrival process	Poisson
Server & replica selection	Uniformly random

Preliminary Evaluation: ns-2 setup details

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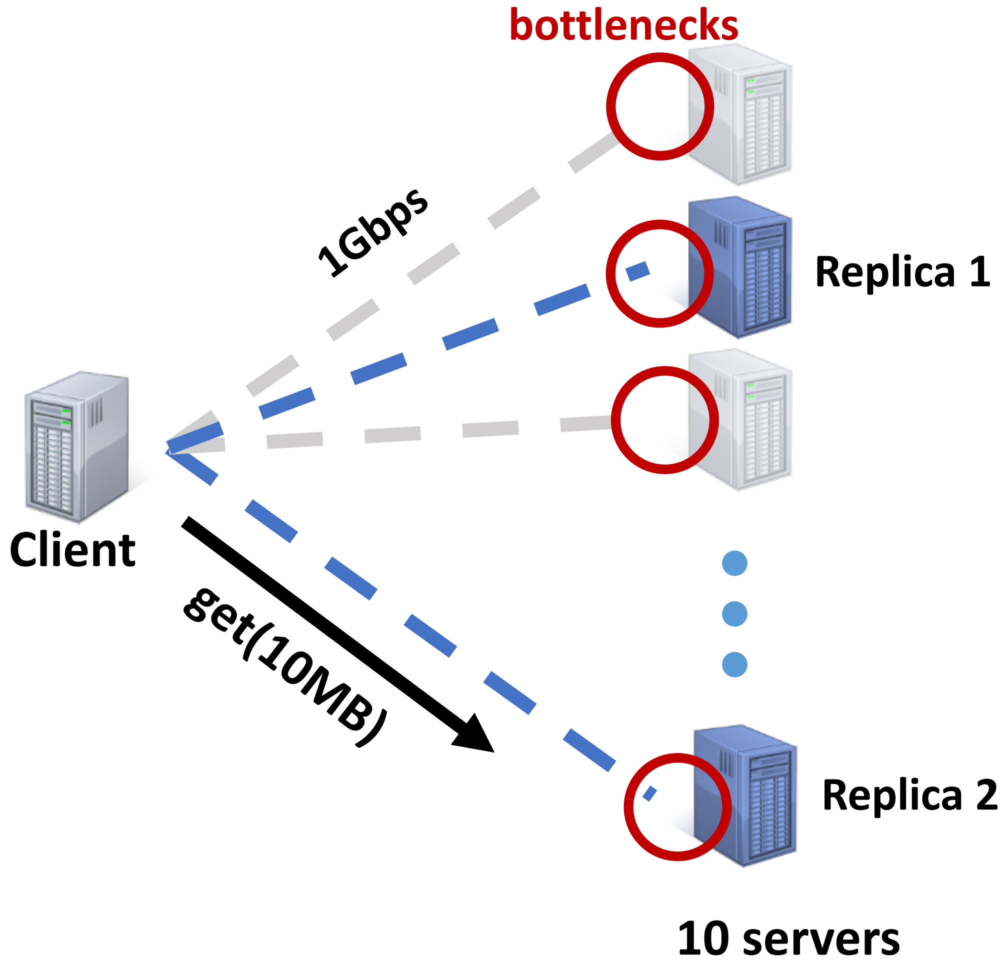
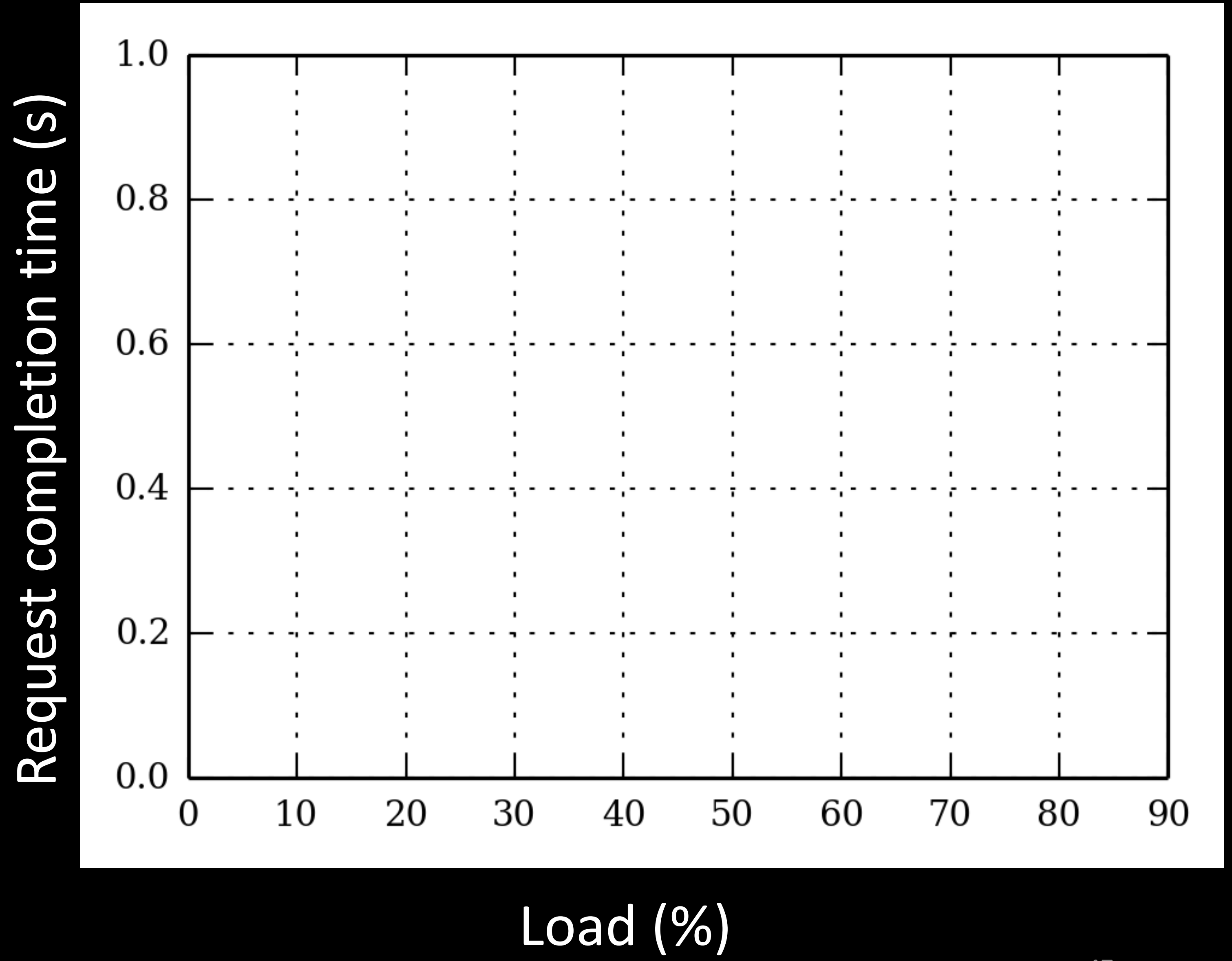


Traffic Details	
Total requests	20K
Arrival process	Poisson
Server & replica selection	Uniformly random

The only source of stragglers is load imbalance.

Average request completion time of:

- No duplicates (baseline)
- 2-copies (proactive w/o PQ)
- + PQs
- + Purging
- + Byte Aggregation (RANS)



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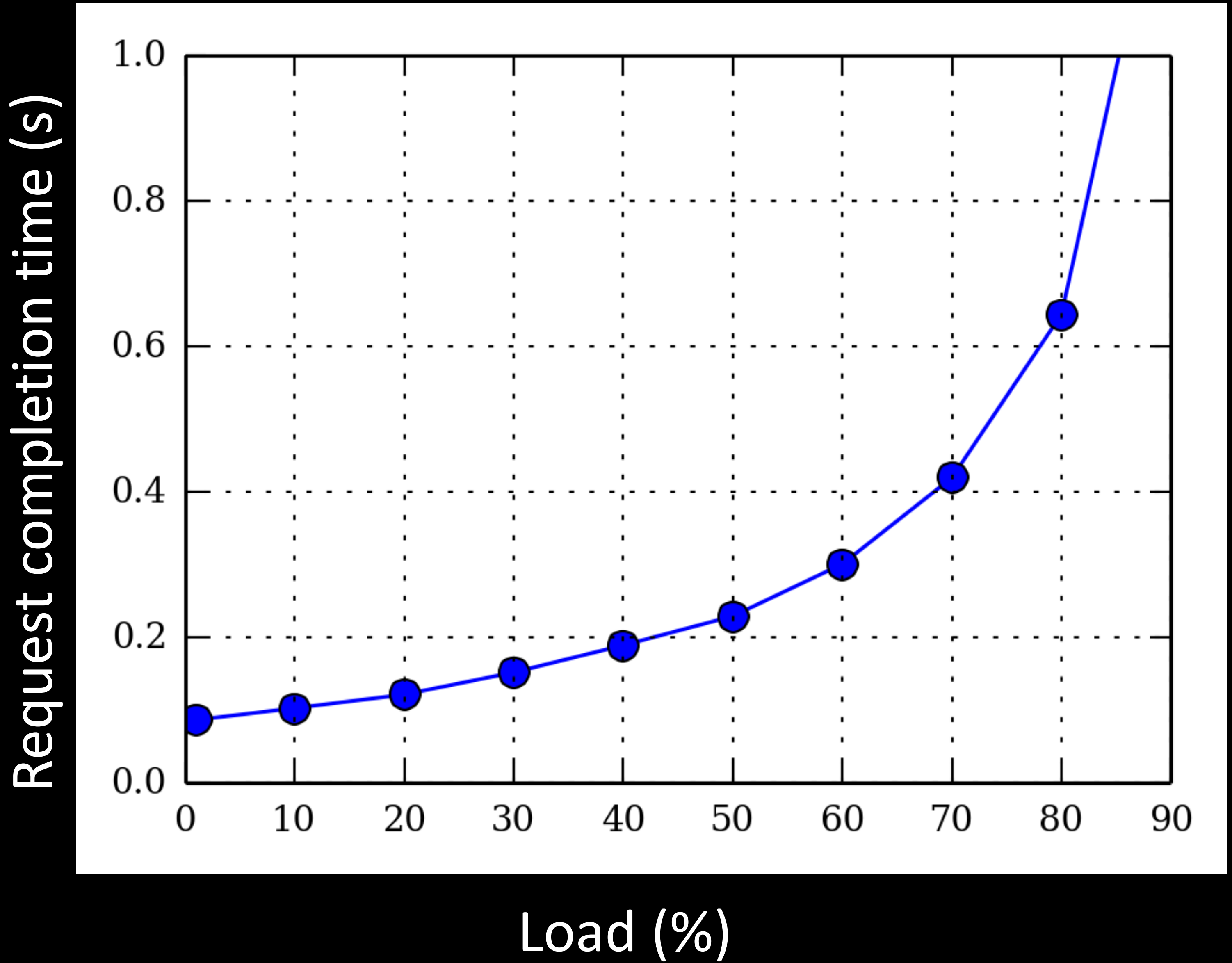

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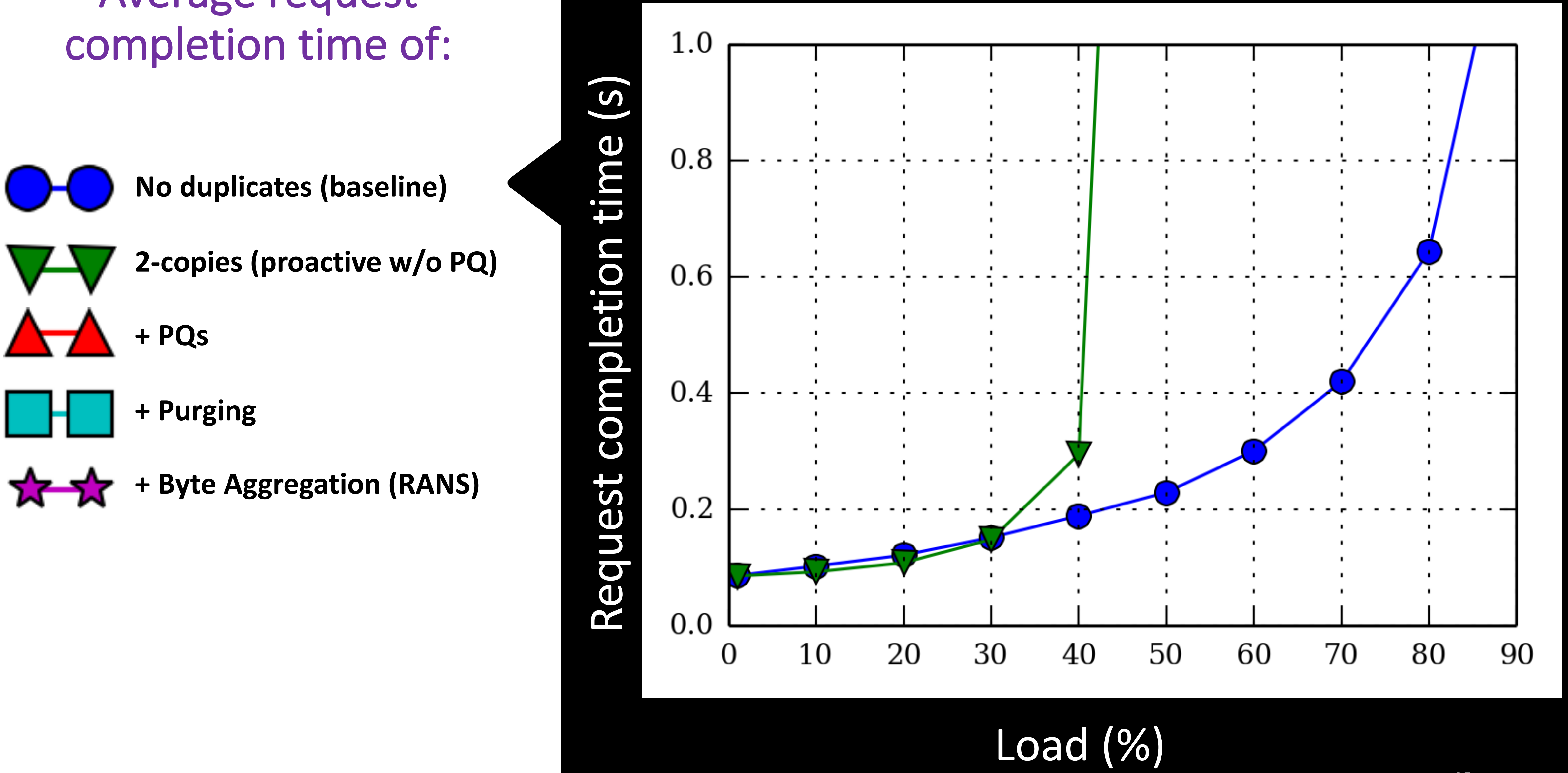

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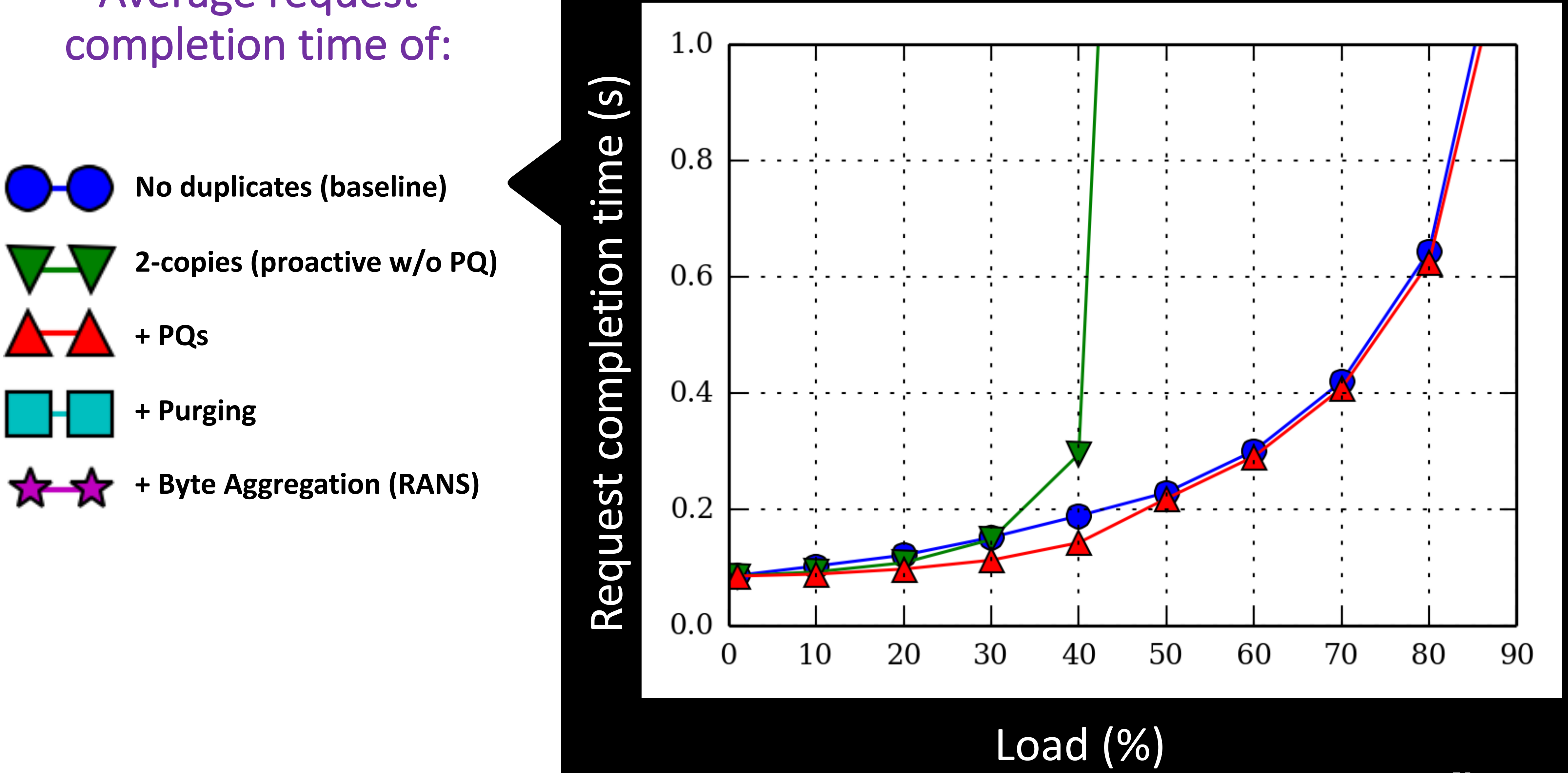

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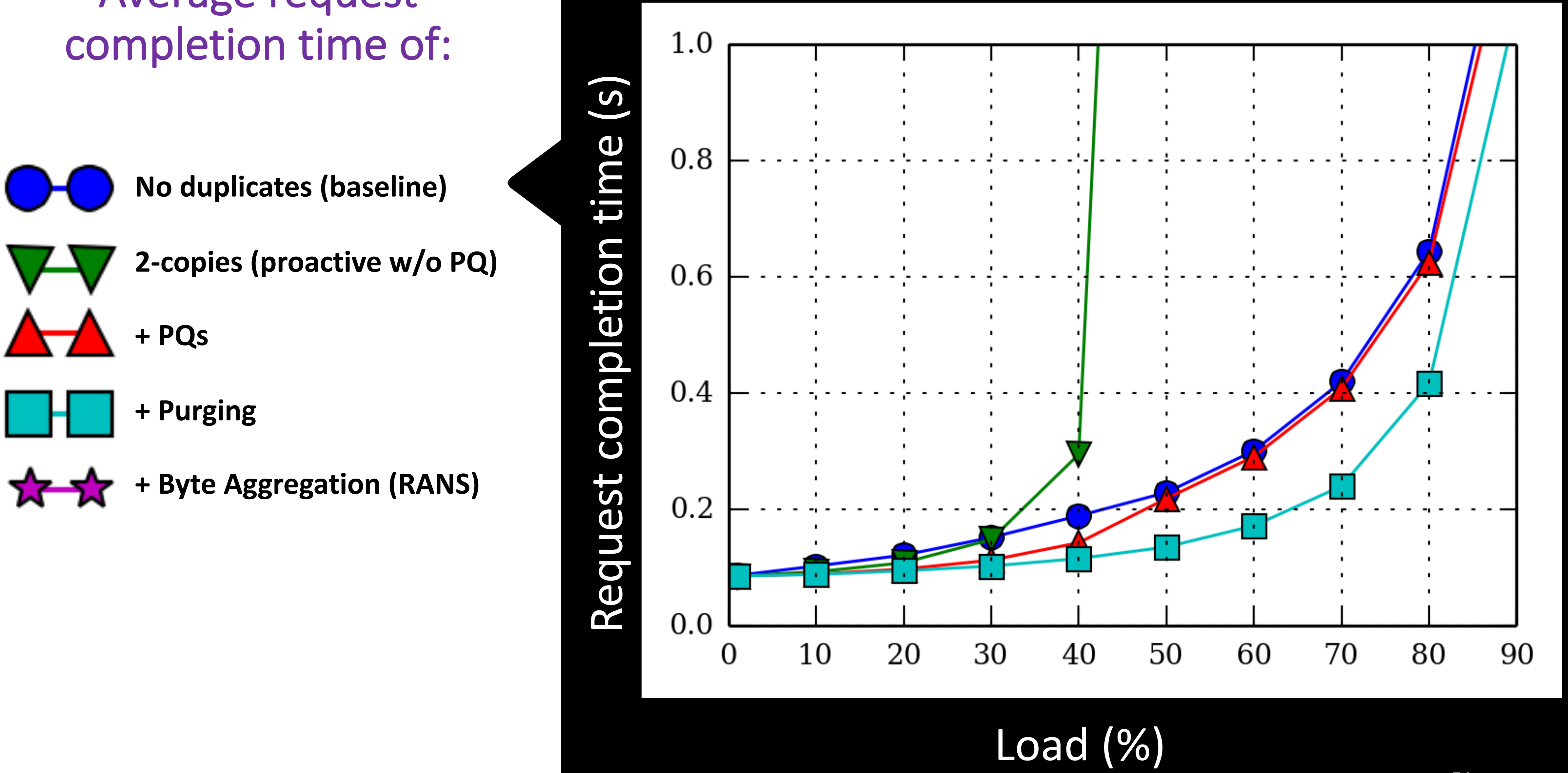

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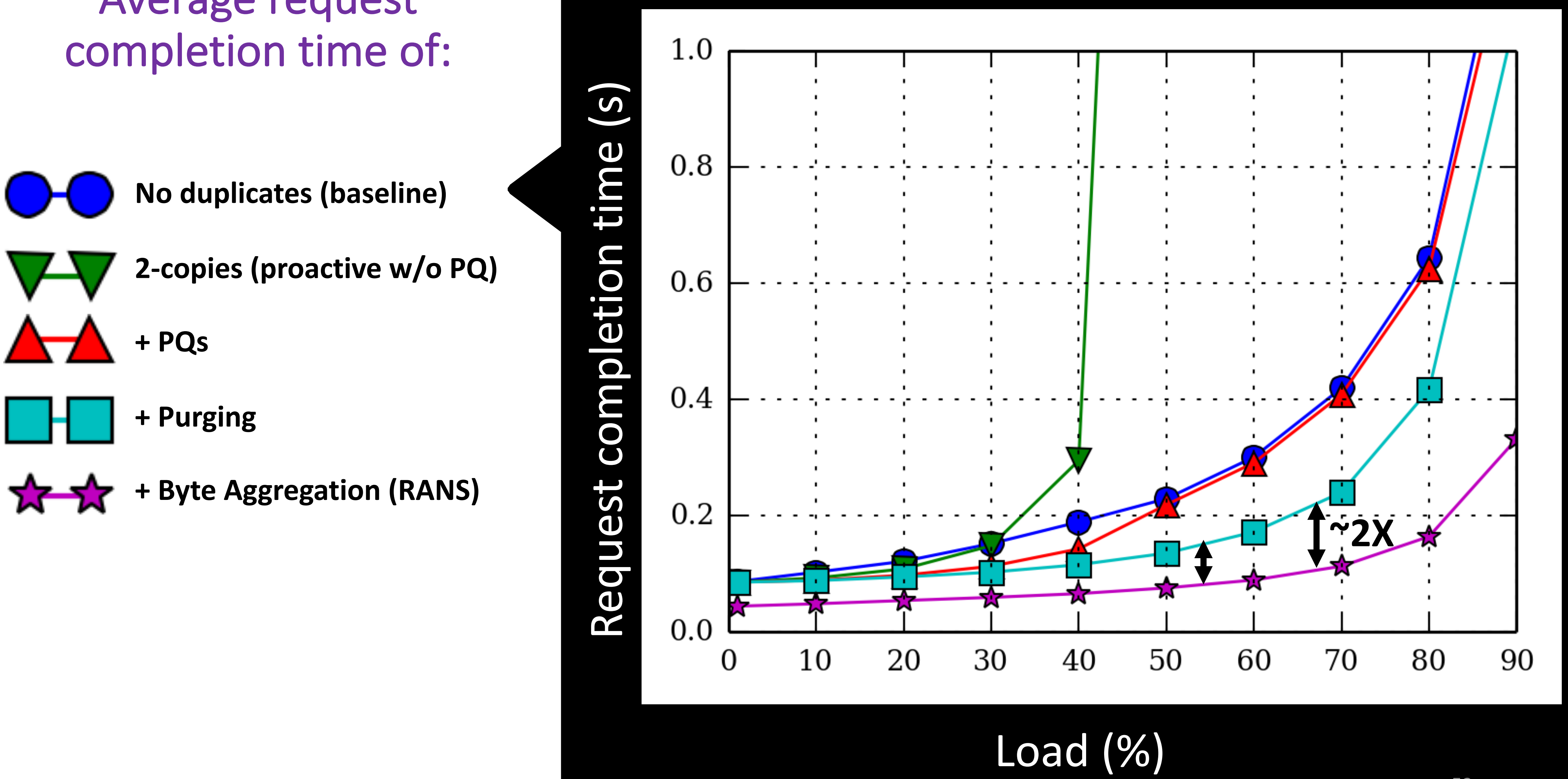

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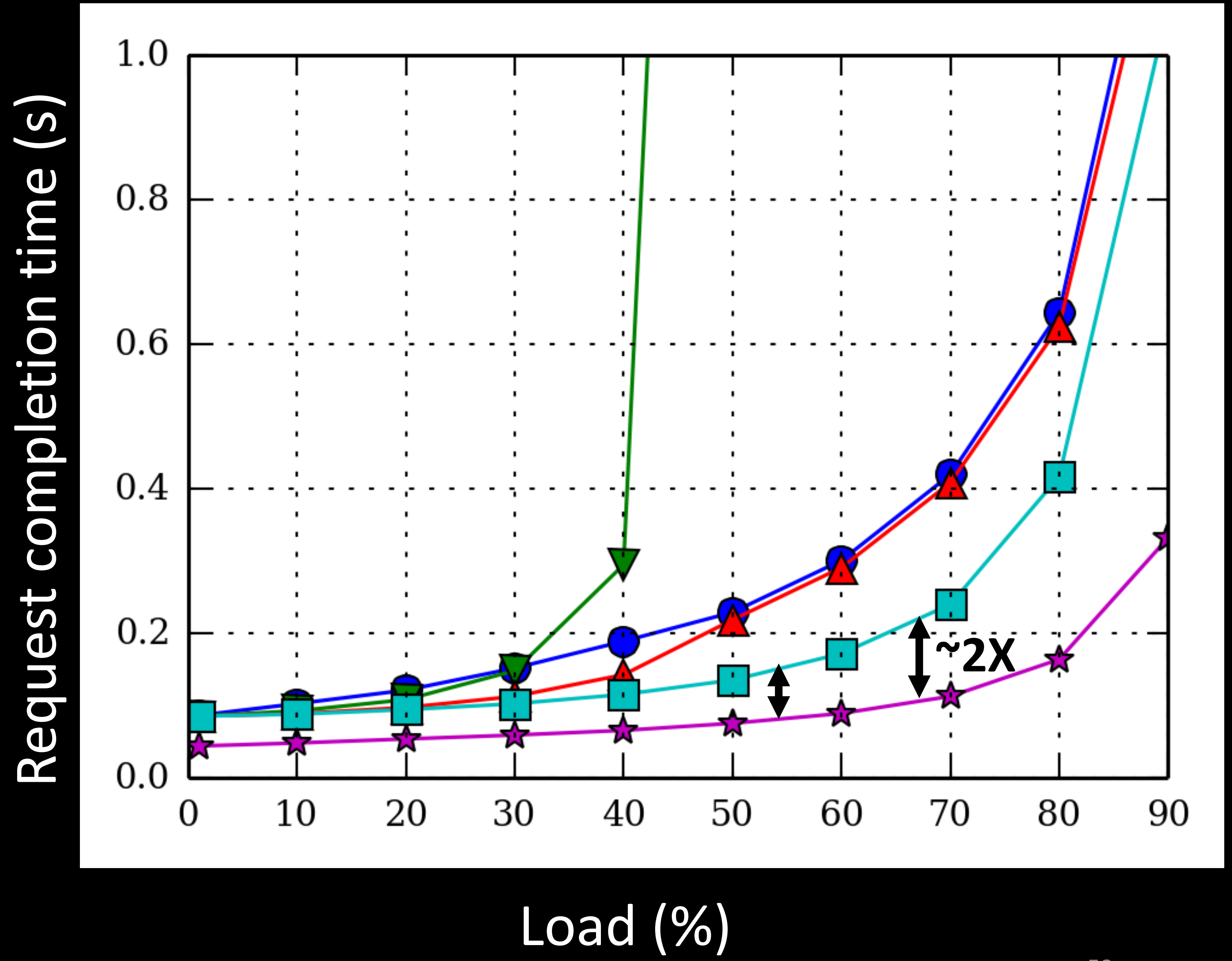
Expecting more gains even at lower loads with additional straggler sources.



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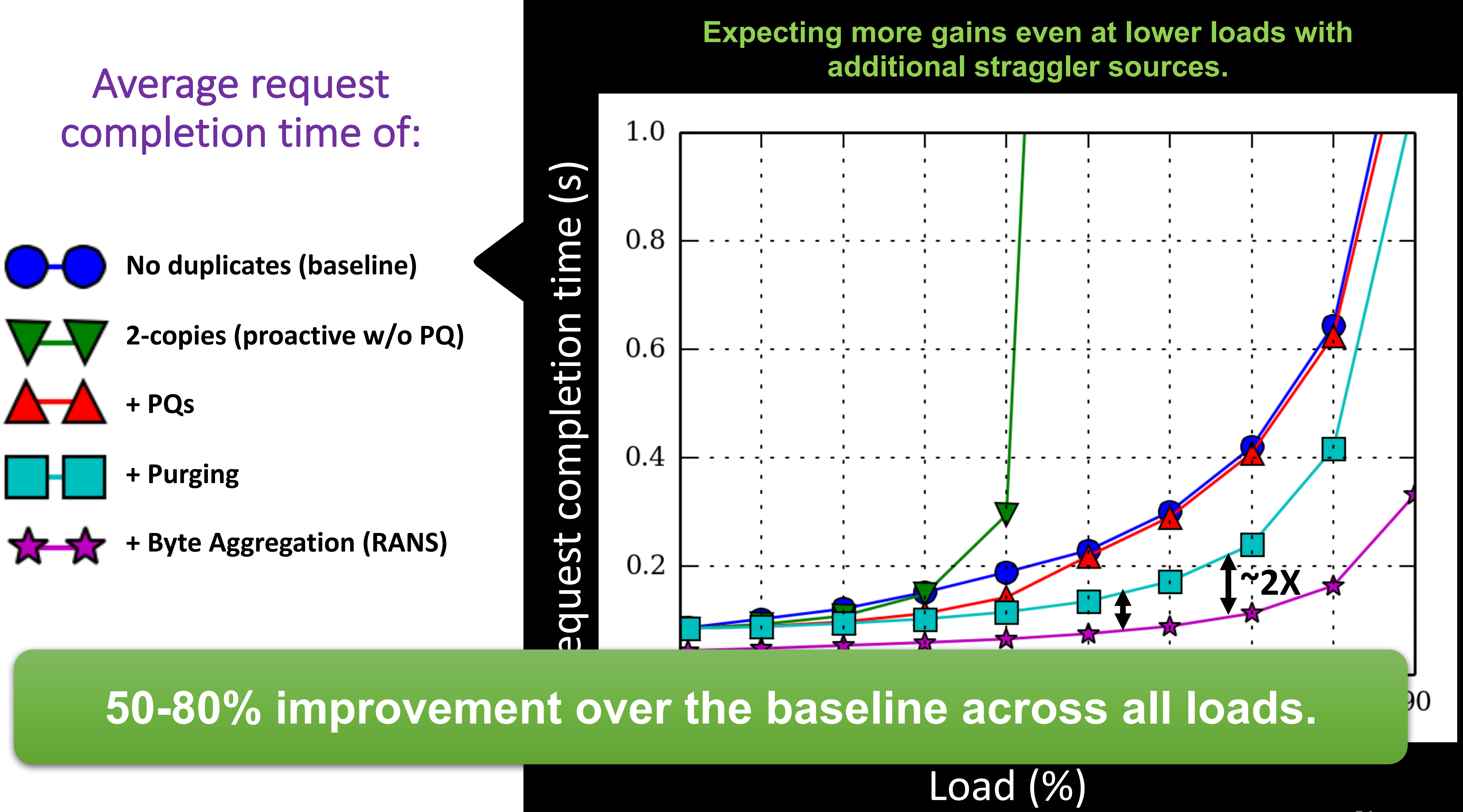

50-80% improvement over the baseline across all loads.

Summary & Future work

- **The Issue of Stragglers**
- **Duplicate-Aware Scheduling Framework**

  Simple yet challenging solution
- **RANS**

  A first step towards a duplicate-aware network
- **Implementing in HDFS and Cassandra**

RANS: Feedback and Discussion

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- **Fahad R. Dogar (fahad@cs.tufts.edu)**
- **Ihsan A. Qazi (ihsan.qazi@lums.edu.pk)**

Layer	**New Role**
Application	Duplicate-Awareness
Expressive Interface	
Transport	Point to multipoint Byte aggregation Priority assignment + purging
Network	Priority Queues + purging
Link	Same as before
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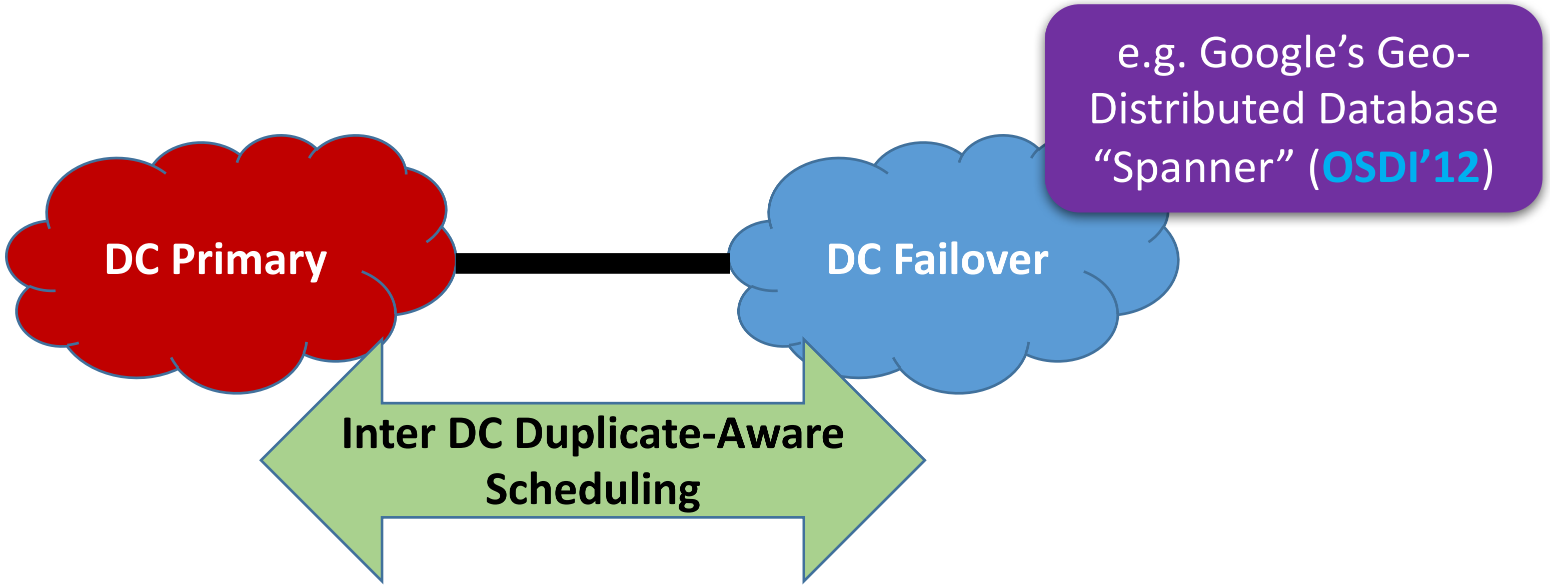
Possible questions – backup slide

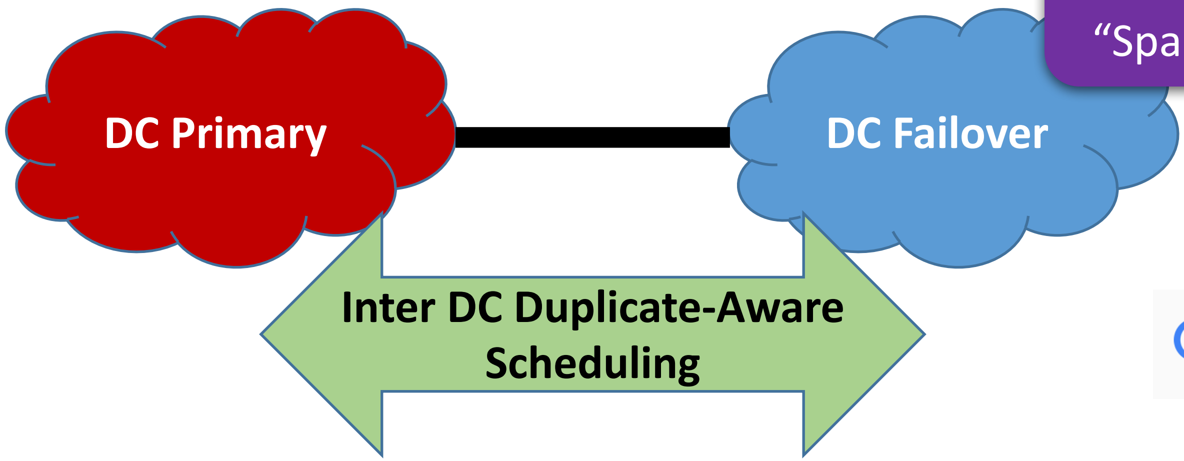
- Preemption overhead
  - Not really an issue in the network because packets are small.
- Packet purging
  - PFC (back pressure, build queues at the end hosts and purge them)
  - Drop the entire duplicate queue (easier than per-packet drops)
  - Recent trend towards programmable switches
- Gains with PQ
  - More gains with failures as stragglers (primary undergoes a failure)
  - Also more benefits with different resources
- Duplication overhead at client
  - Client is usually not the bottleneck
- Non-Idempotent requests
  - We are targeting the class of apps which have flexible end points and require at least once semantics
- Replicating only small packets and prioritizing them
  - Only beneficial with bursty small flows
  - HDFS have a typical chunk size b/w 64MB-128MB
- Quorum systems
  - RANS complements such systems, they can use this technique and send K out of N requests at high prio while N-K as backups
- Can’t just implement at the app and get the same benefits?
  - Network could be a bottleneck
  - Fine grained control, much more control
- Root causes of performance improvement
  - PQ avoids overheads
  - Now we can easily get the benefits of duplications like aggregation etc.
  - Purging will also at times purge primary making the system more efficient.

Food for thought



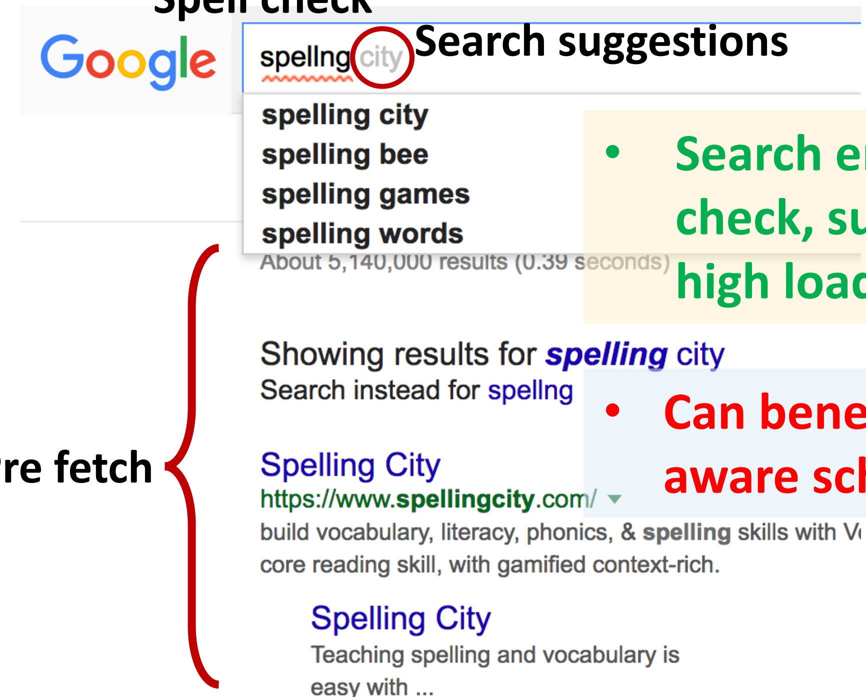
Food for thought

e.g. Google's Geo-Distributed Database "Spanner" (OSDI'12)



Spell check

Search suggestions



Pre fetch

- Search engines drop spell check, suggestions, etc. at high loads.
- Can benefit from duplicate-aware scheduling.

When RANS works best?

- Application fanout is high and stragglers are frequent.
- End-points are flexible and “at least once” semantics are sufficient.
- Client is not the bottleneck.
- Request sizes are small (or preemption overhead is minimal).