Performance Isolation and Fairness for Multi-Tenant Cloud Storage

PISCES

David Shue*, Michael Freedman*, and Anees Shaikh✦

*Princeton ✦IBM Research

Setting: Shared Storage in the Cloud

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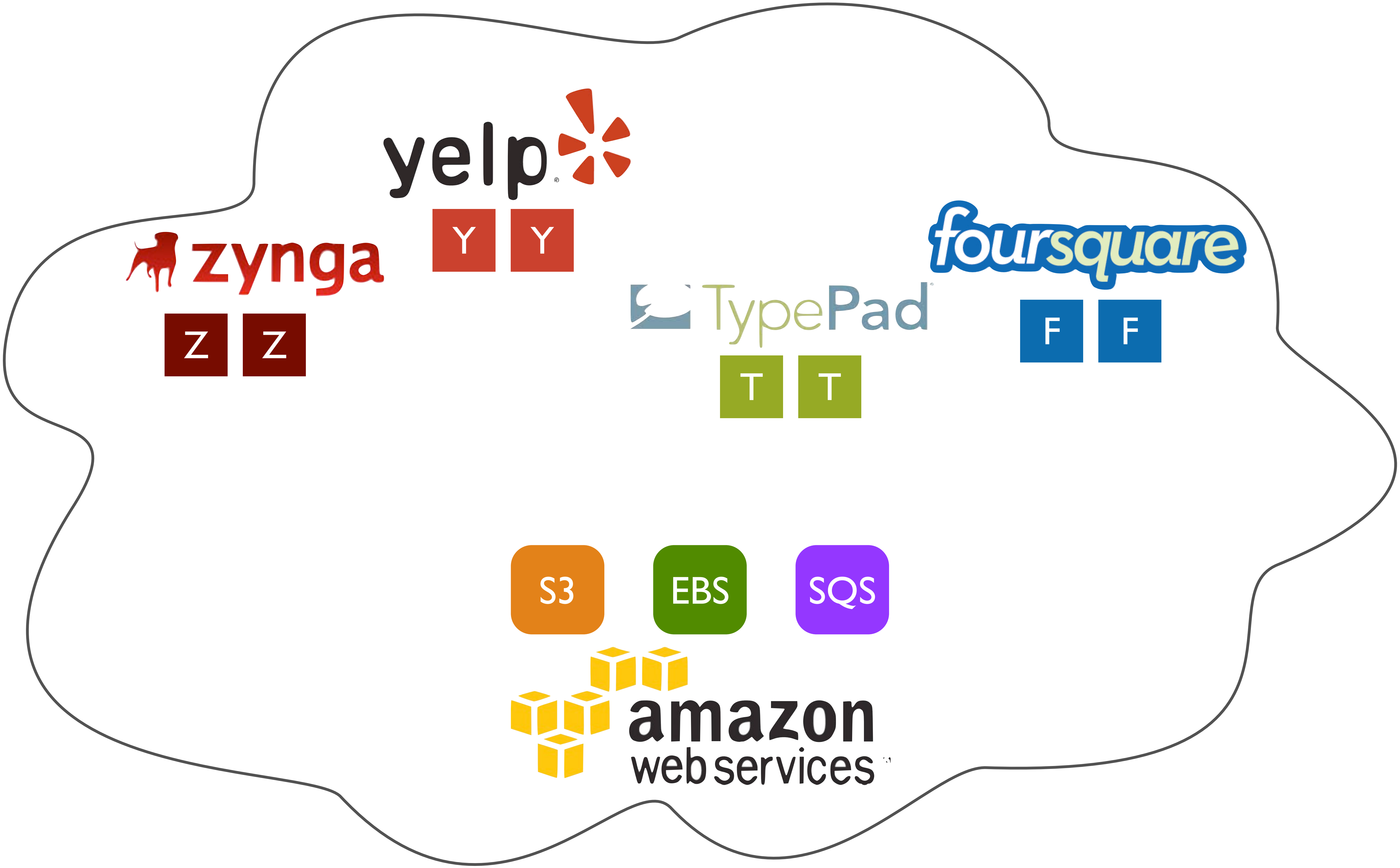

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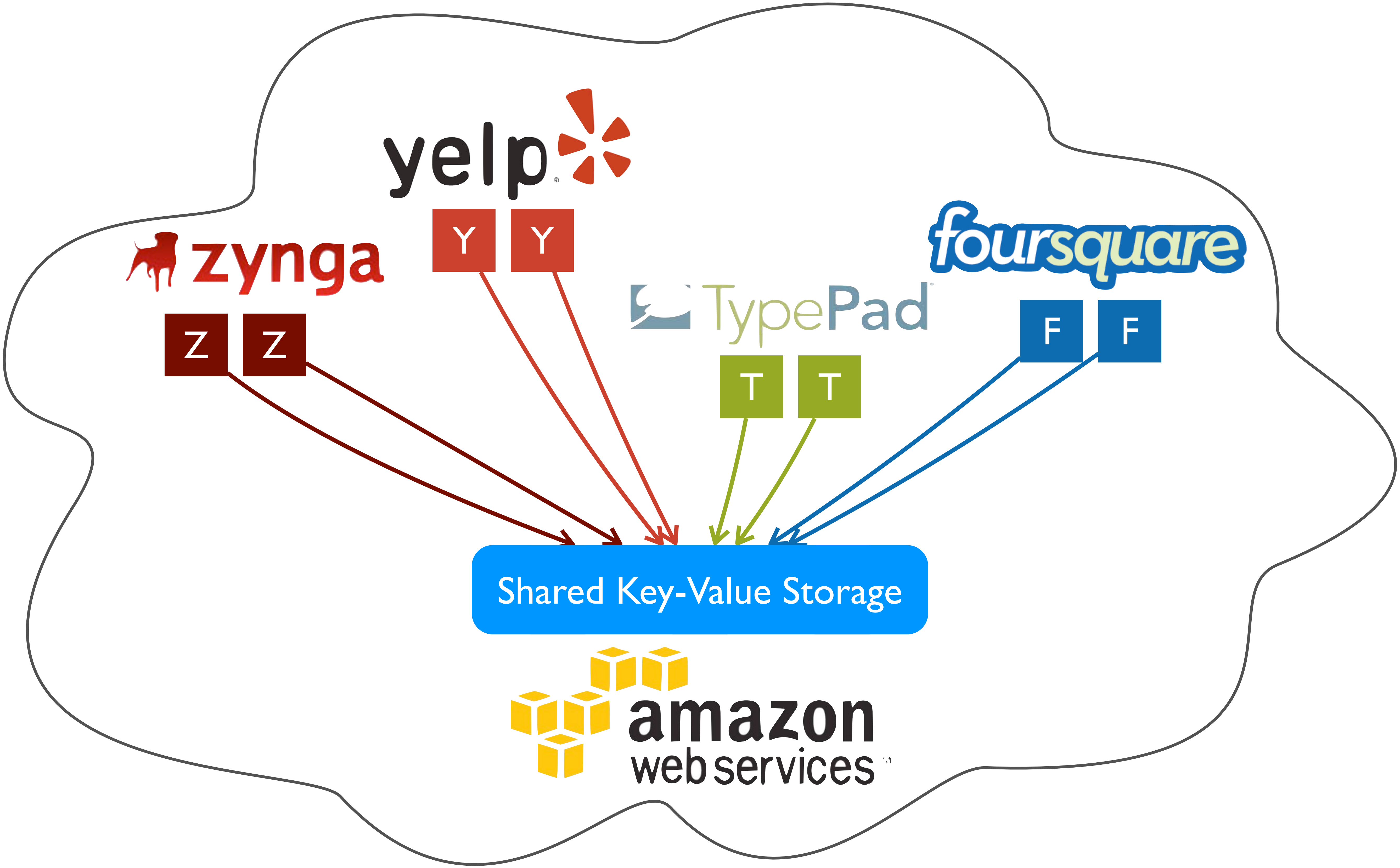
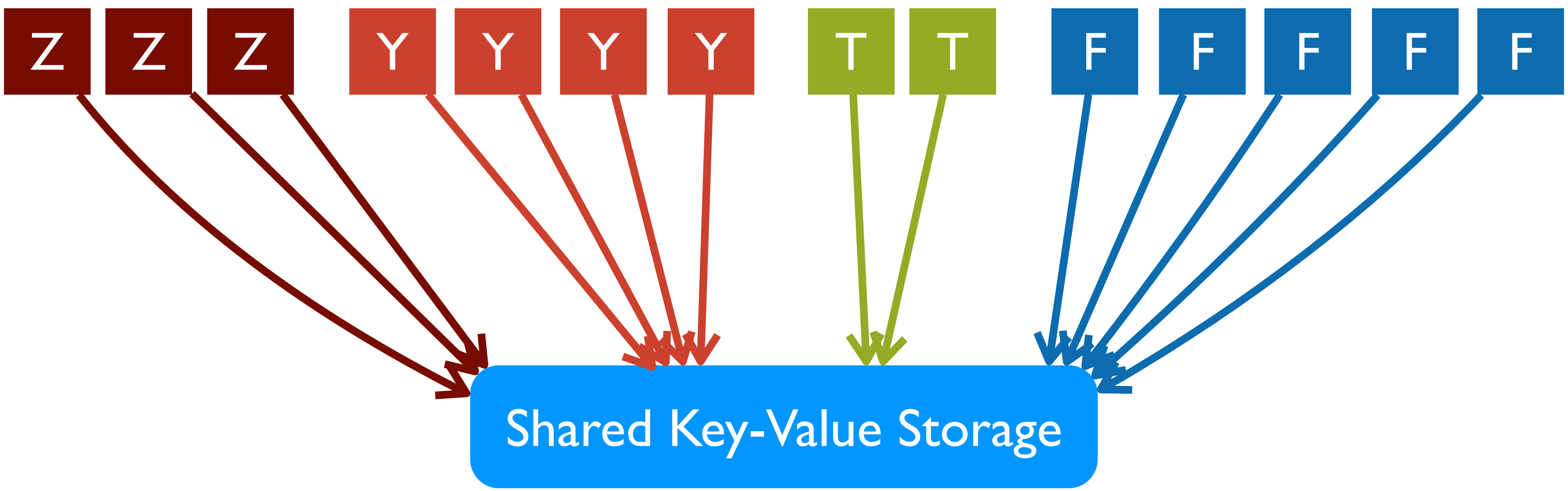


Predictable Performance is Hard



Multiple co-located tenants ⇒ resource contention

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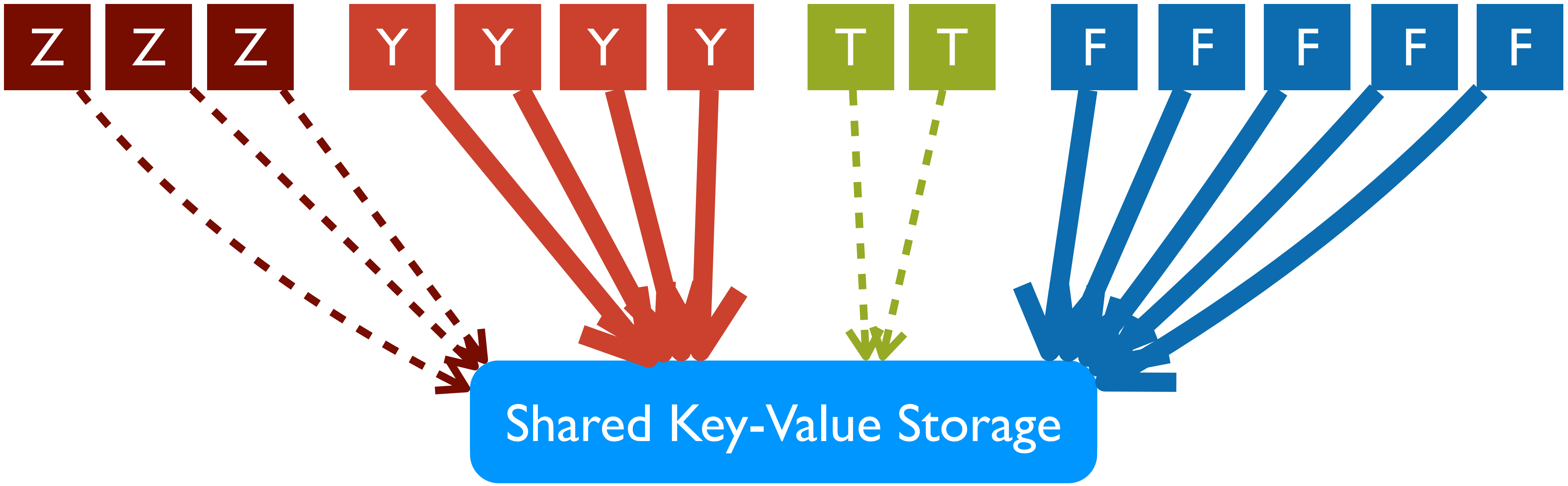

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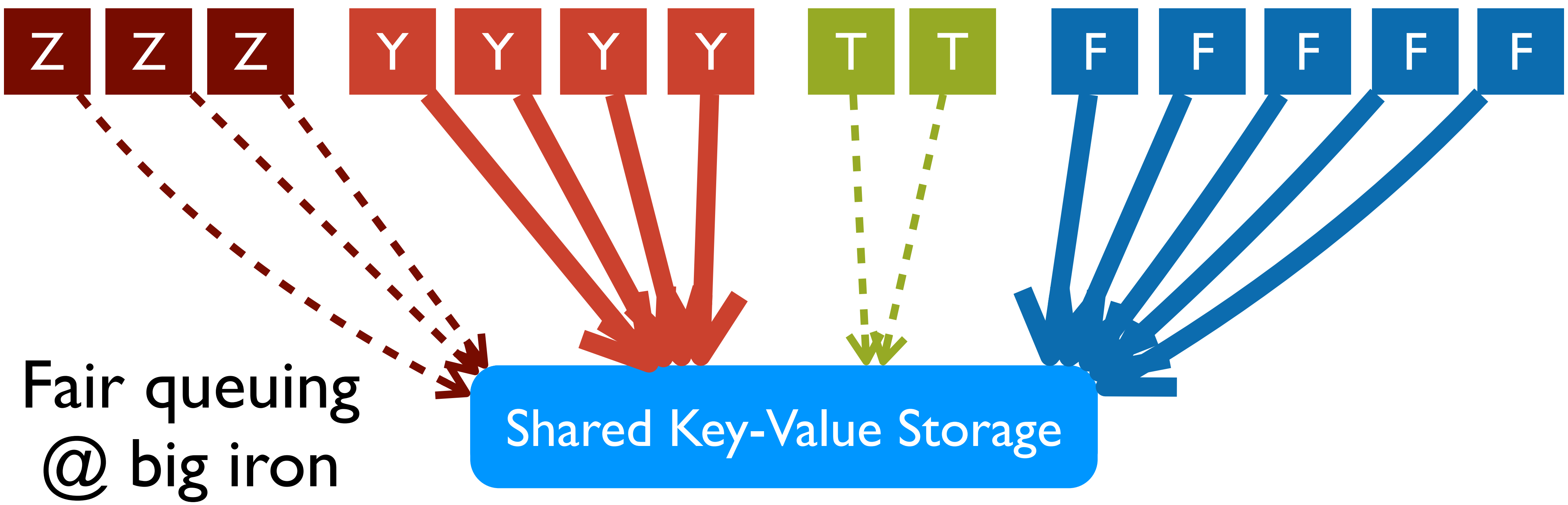

Fair queuing
@ big iron

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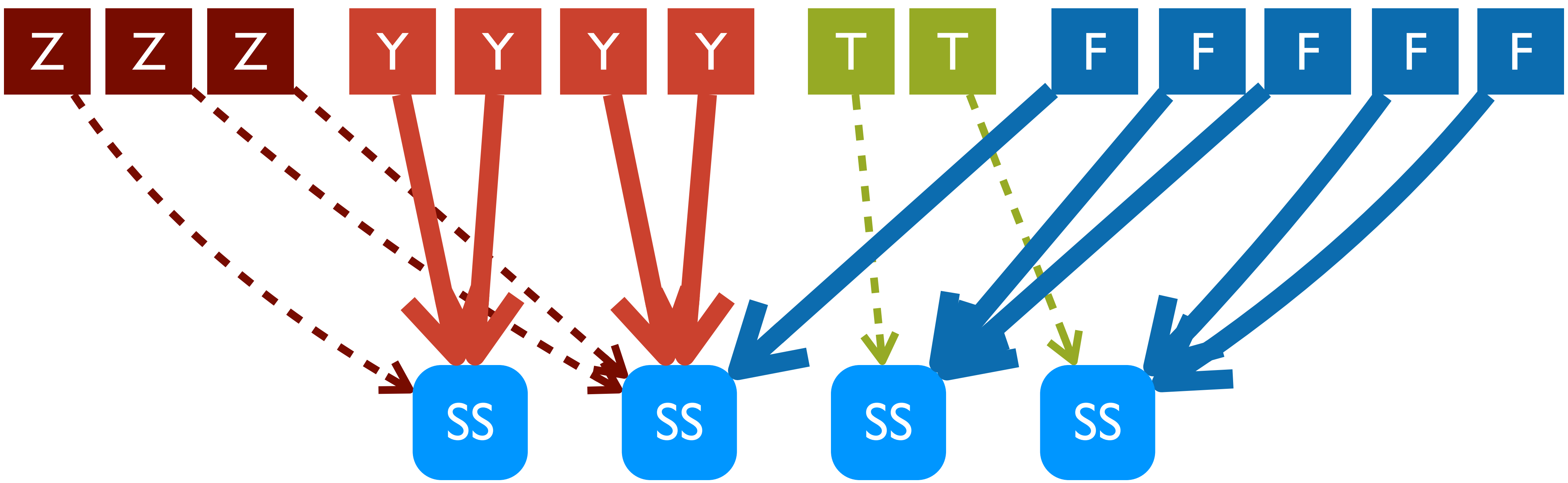

Multiple co-located tenants ⇒ resource contention

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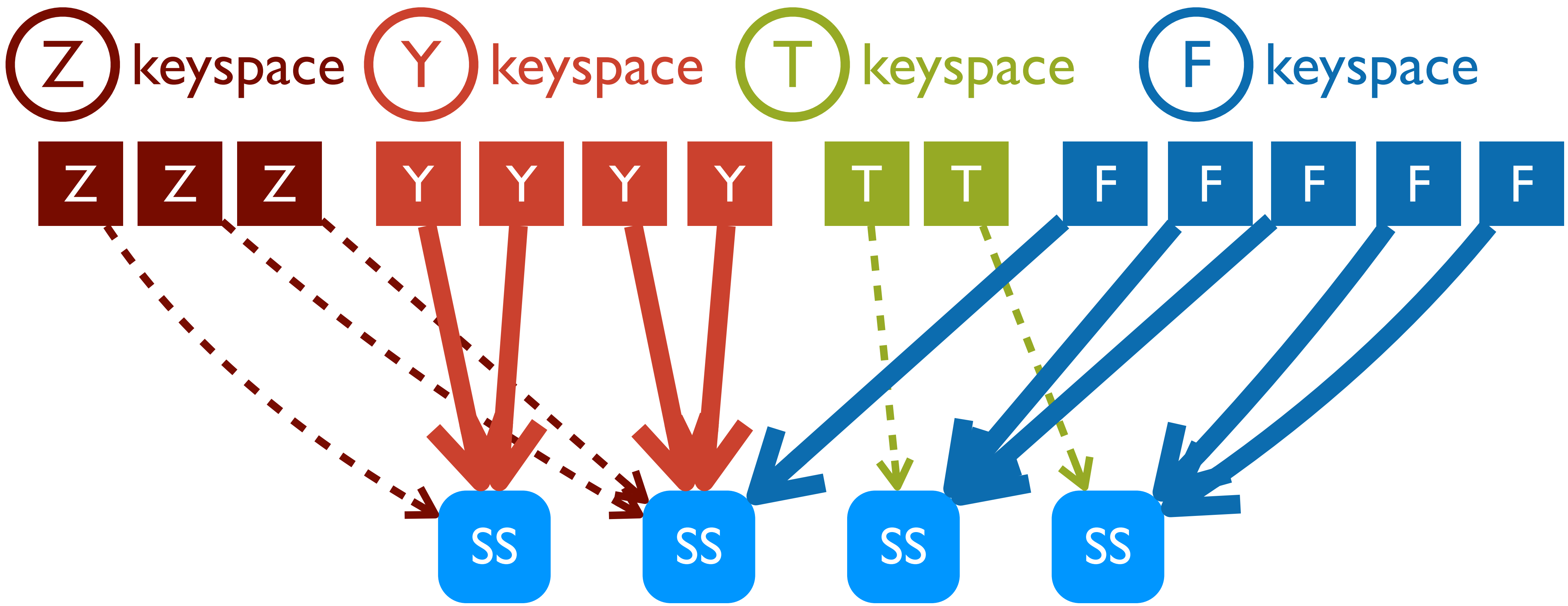

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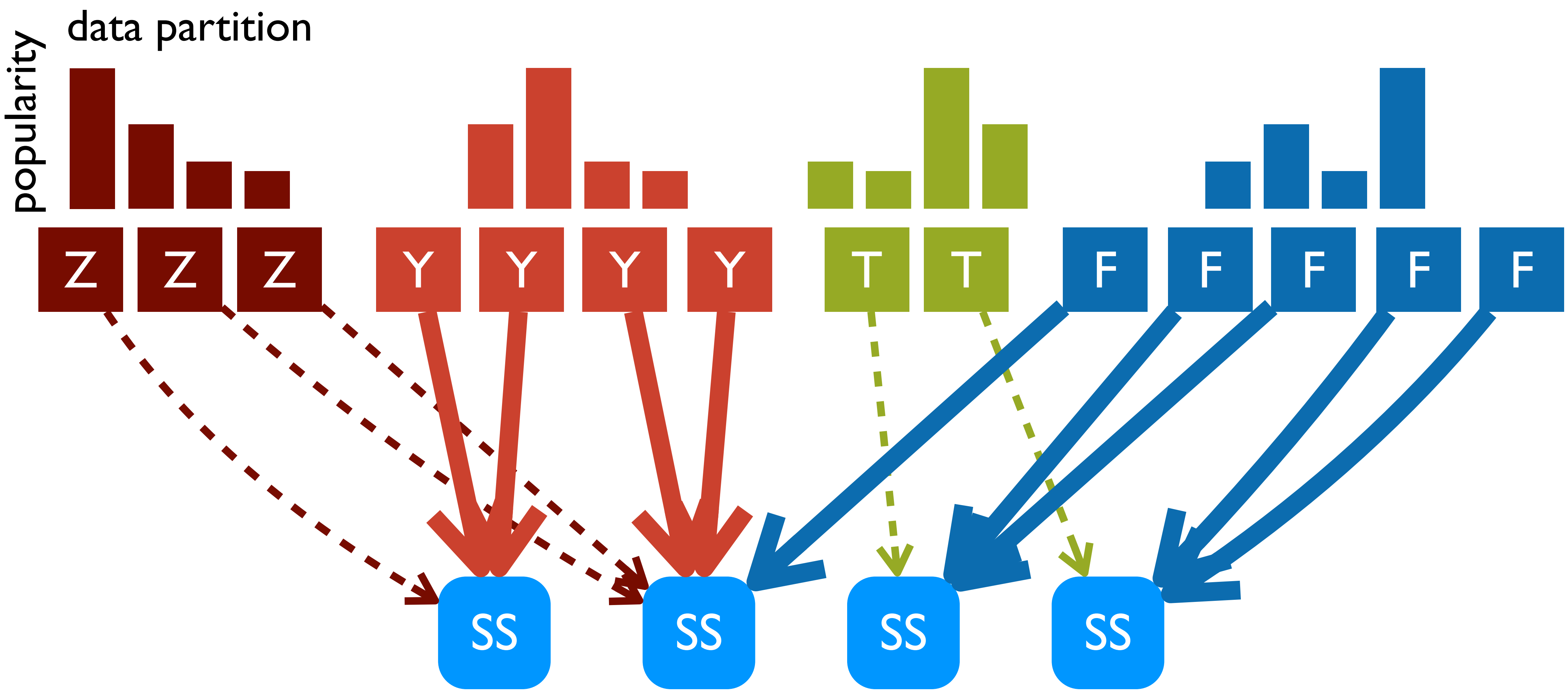

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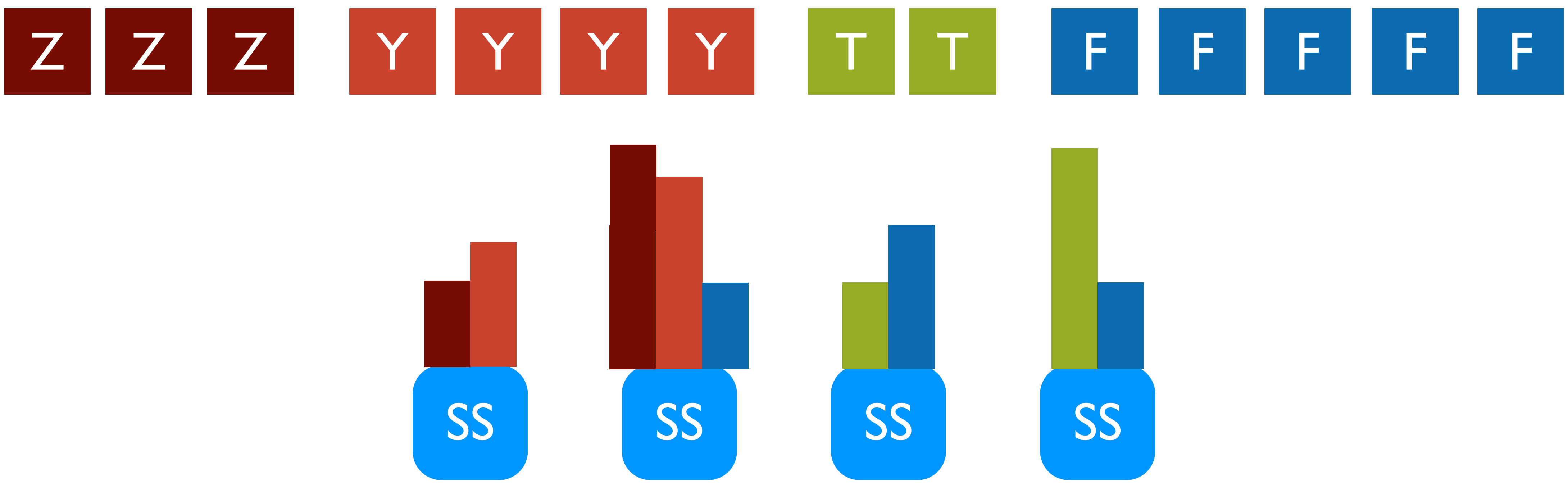

Multiple co-located tenants ⇒ resource contention

Distributed system ⇒ distributed resource allocation

Skewed object popularity ⇒ variable per-node demand

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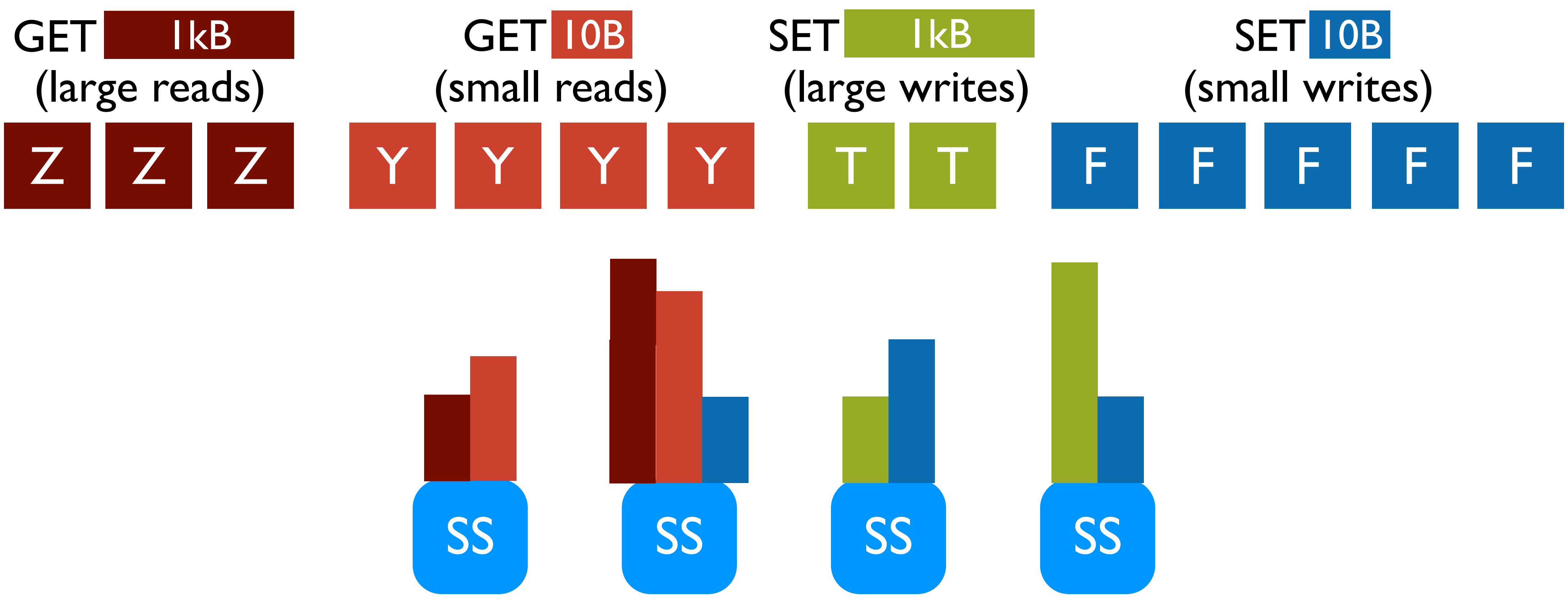


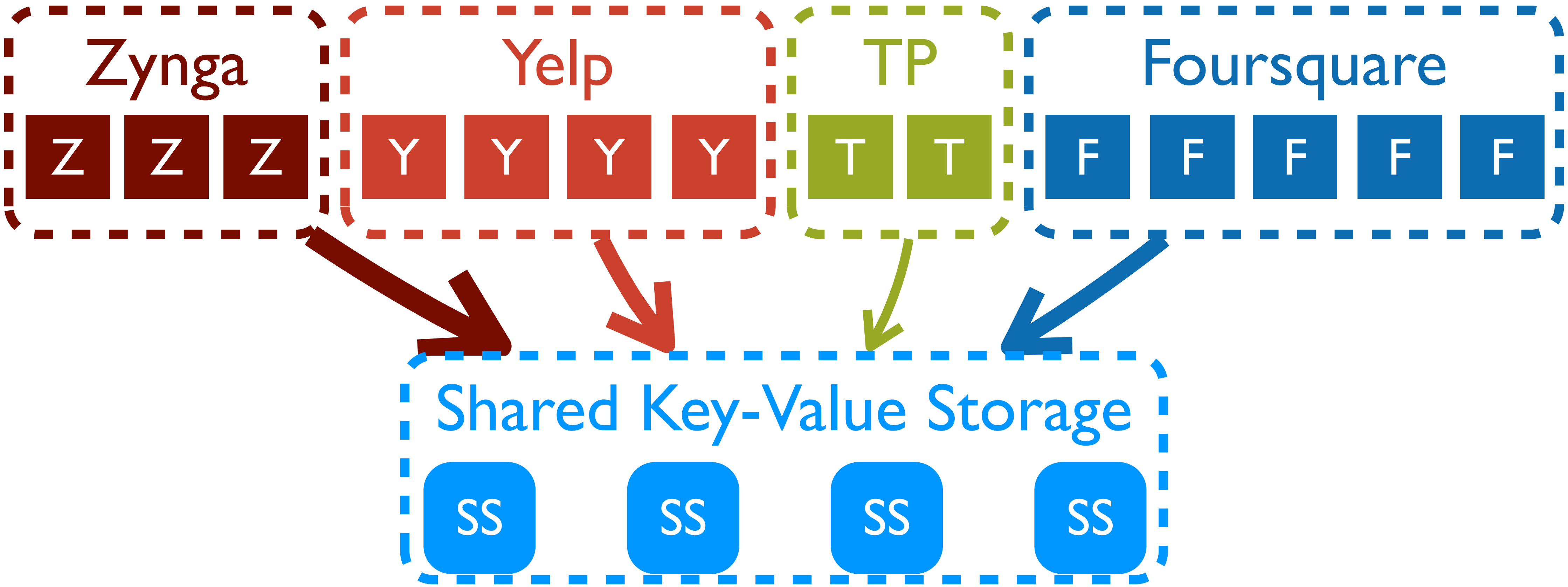
Multiple co-located tenants ⇒ resource contention

Distributed system ⇒ distributed resource allocation

Skewed object popularity ⇒ variable per-node demand

Disparate workloads ⇒ different bottleneck resources

Tenants Want System-wide Resource Guarantees



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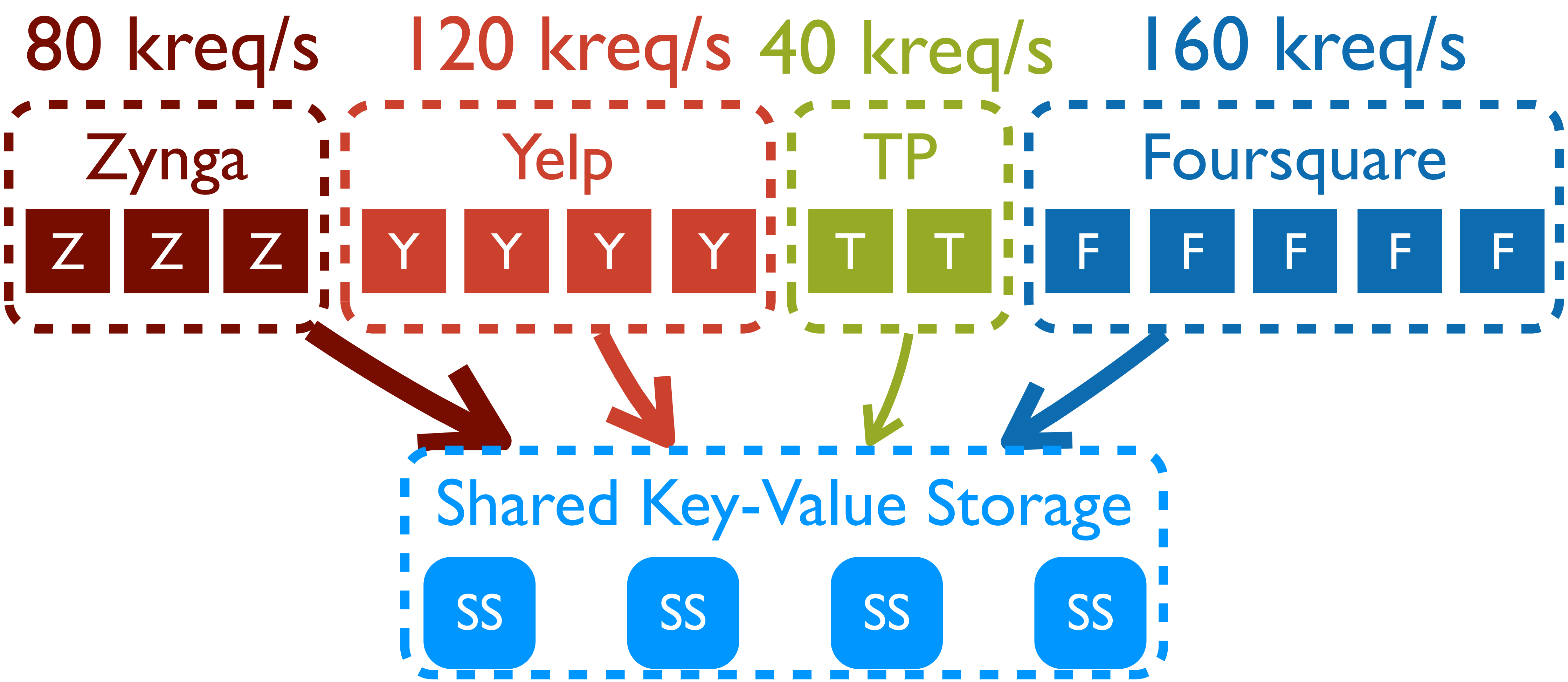

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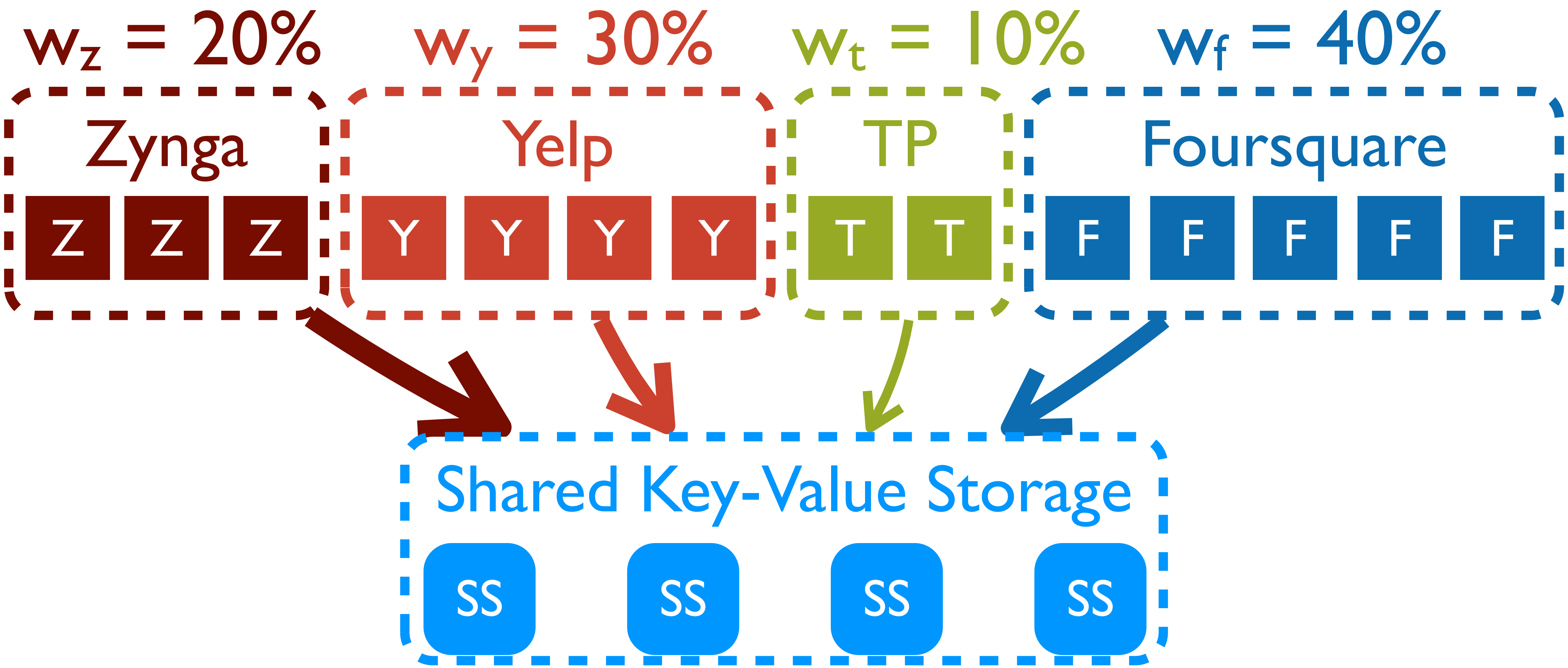
Pisces Provides Weighted Fair-shares



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Pisces: Predictable Shared Cloud Storage

- Pisces
  - Per-tenant max-min fair shares of system-wide resources
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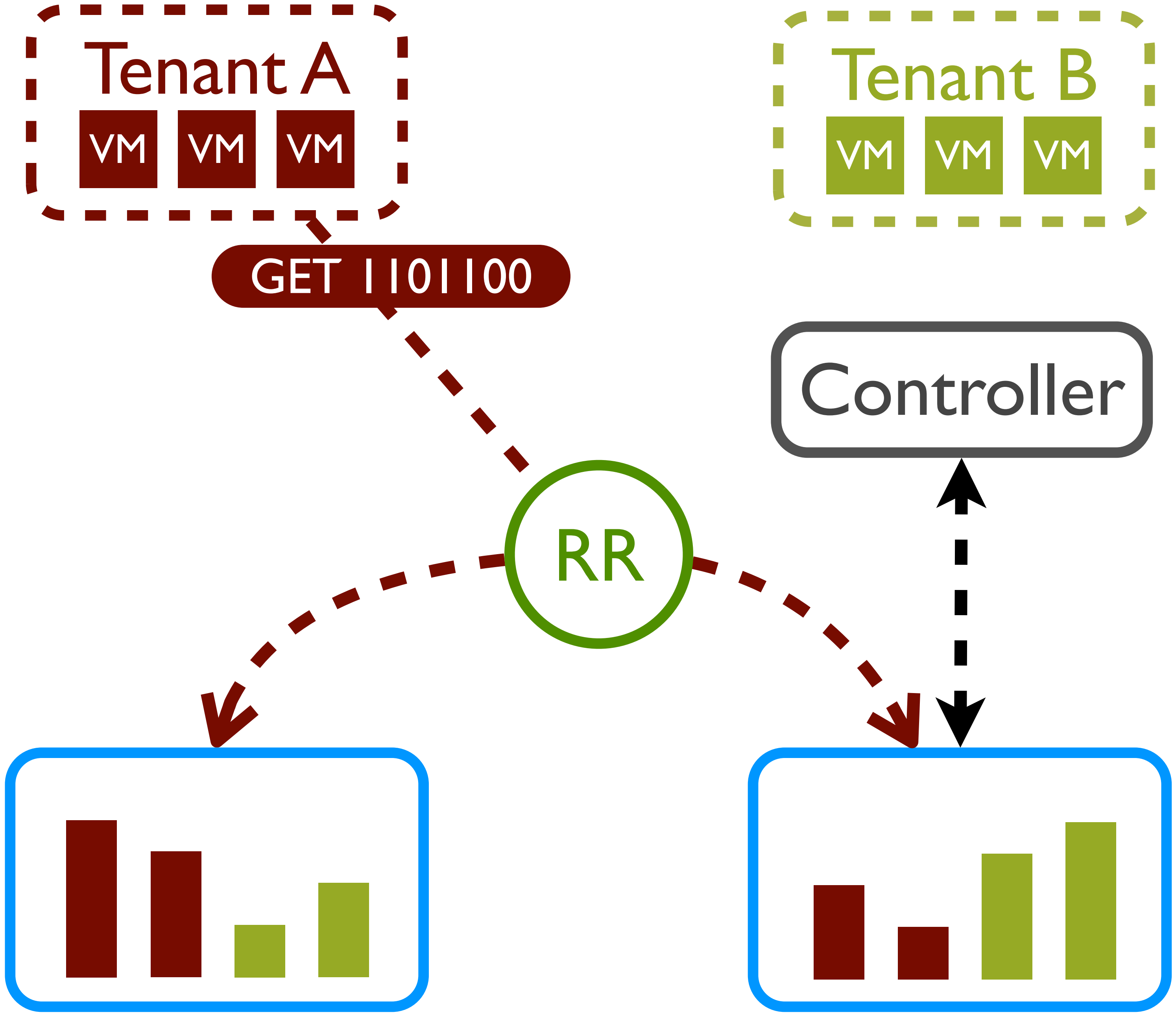
- Amazon DynamoDB
  - Per-tenant provisioned rates
    ~ rate limited, non-work conserving
  - Uniform object popularity
  - Single resource (1kB requests)

Predictable Multi-Tenant Key-Value Storage



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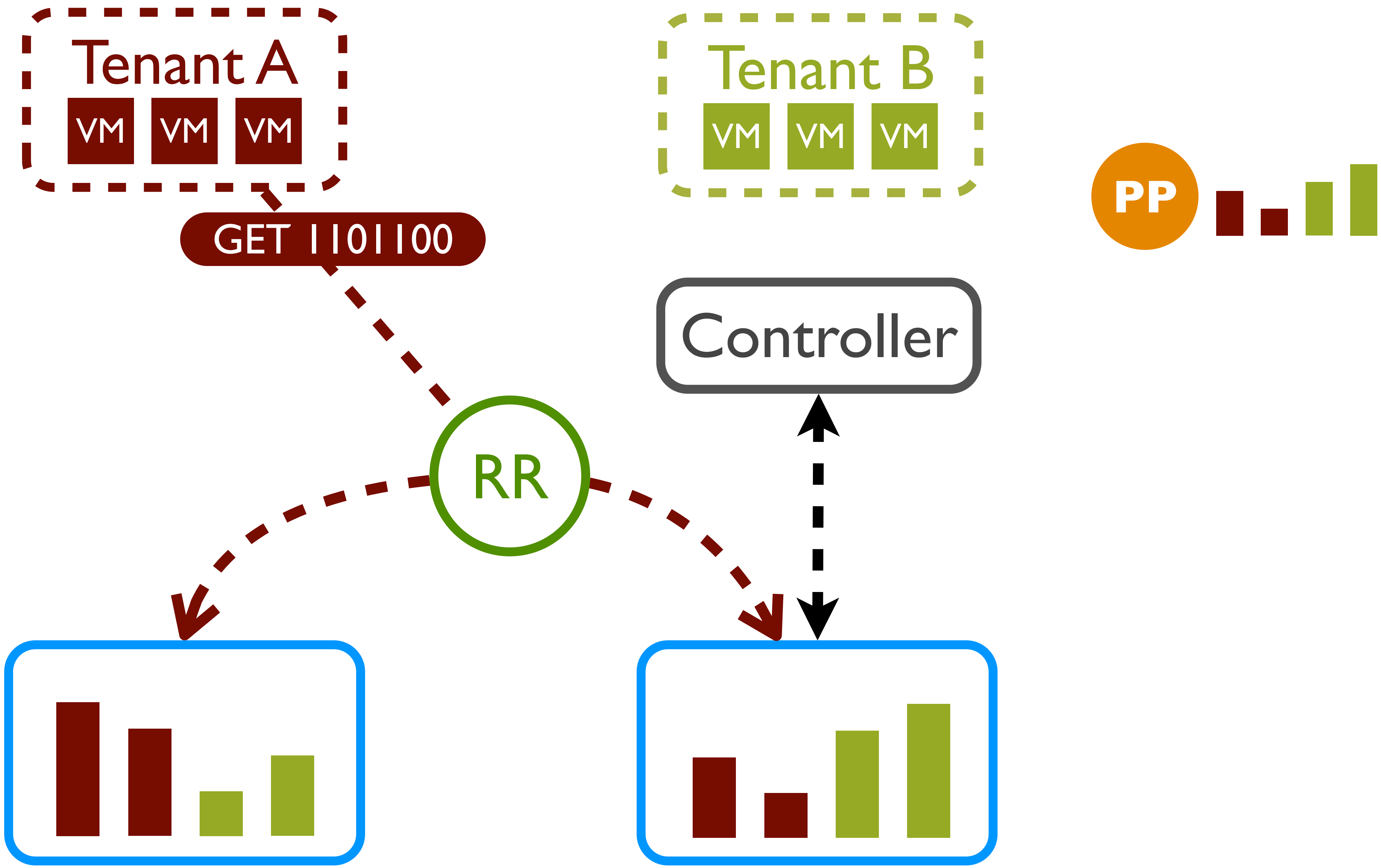

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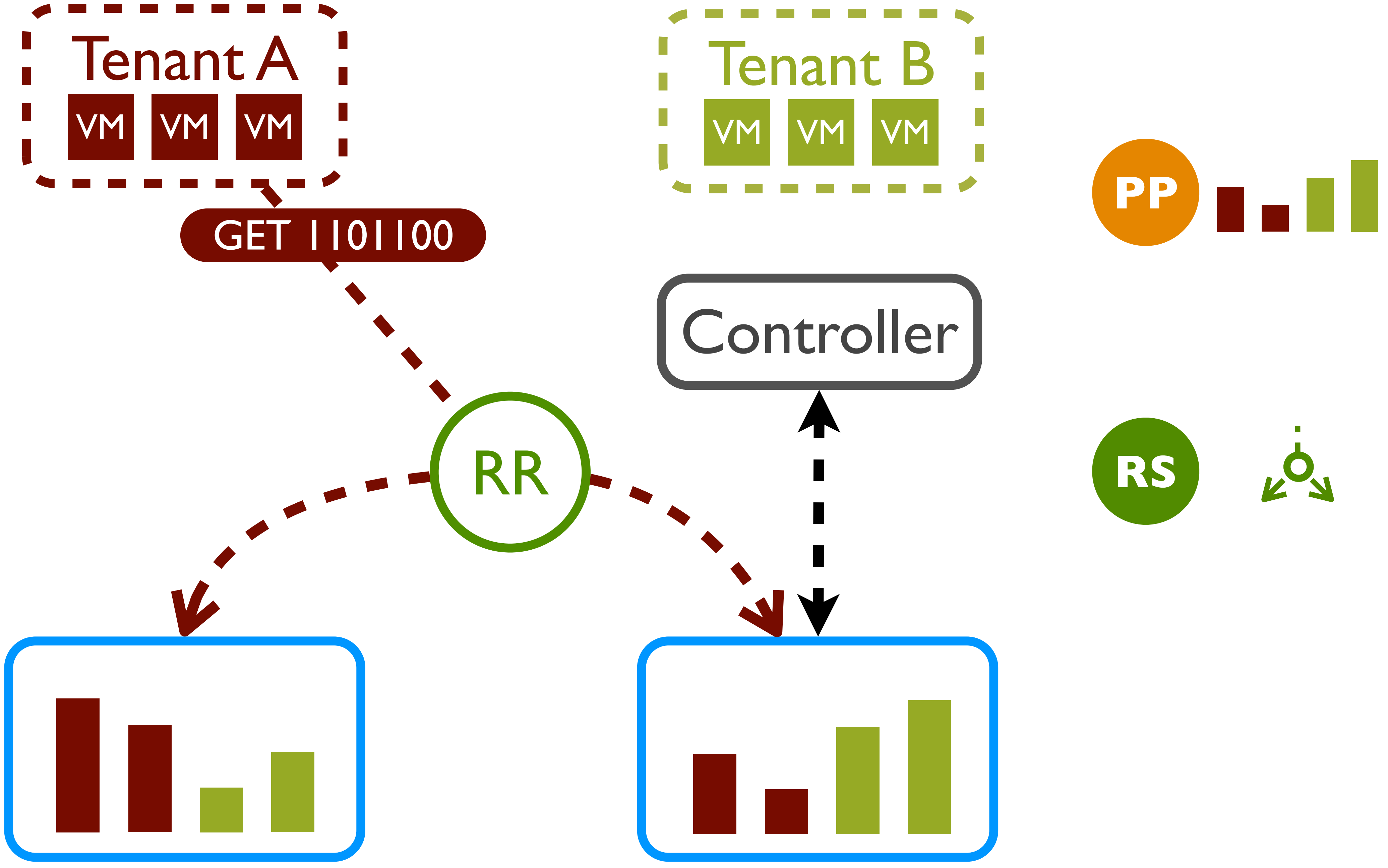

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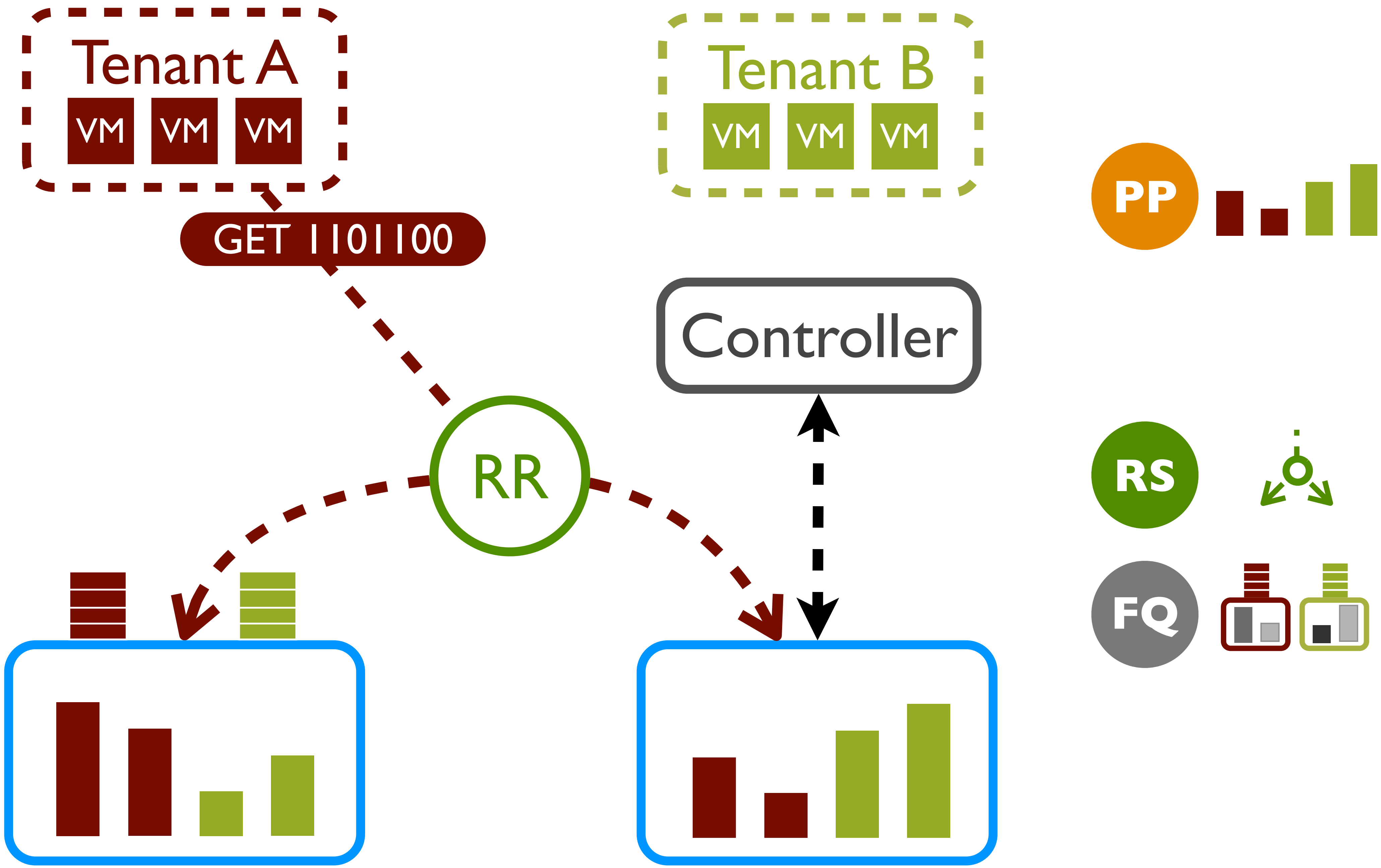

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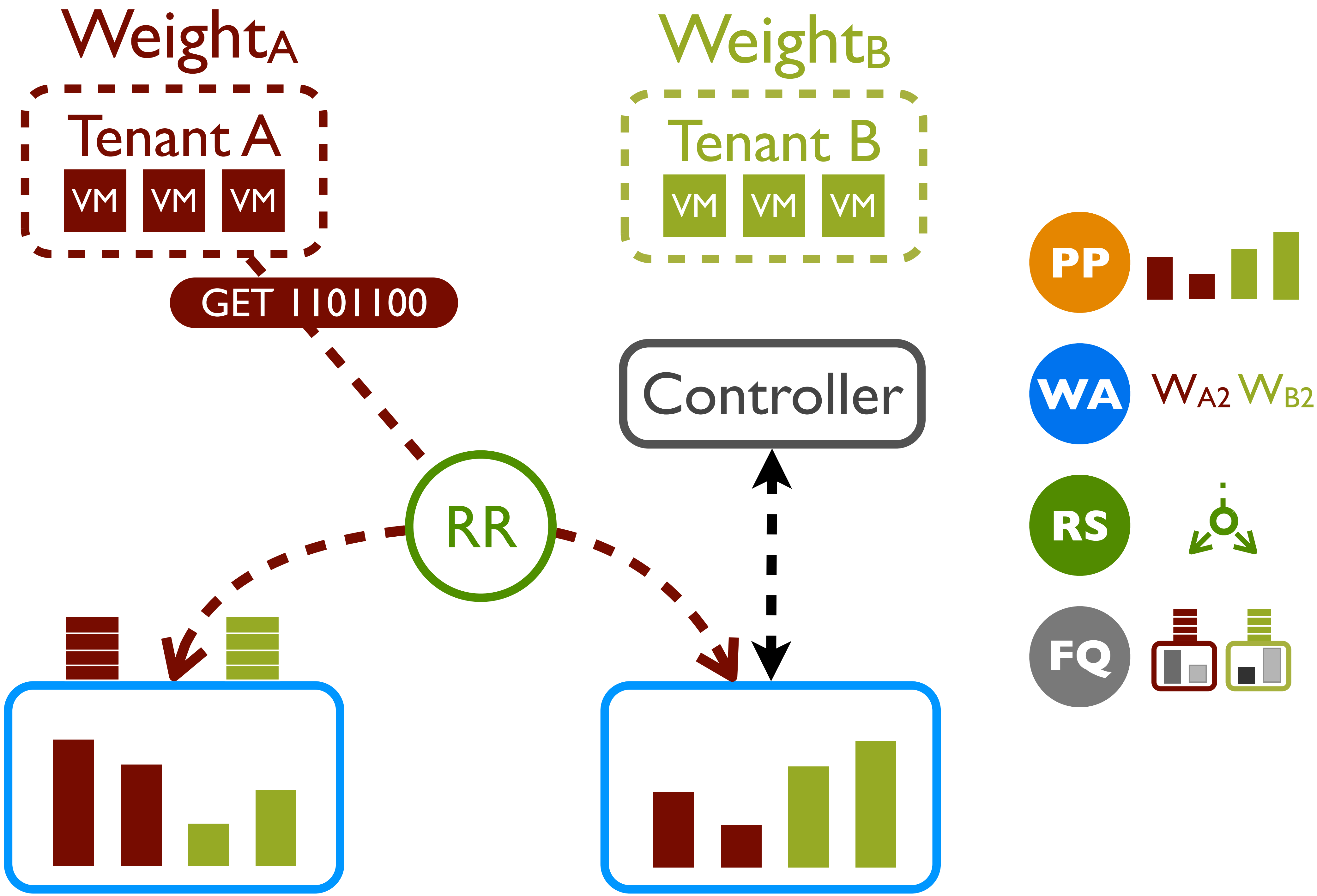

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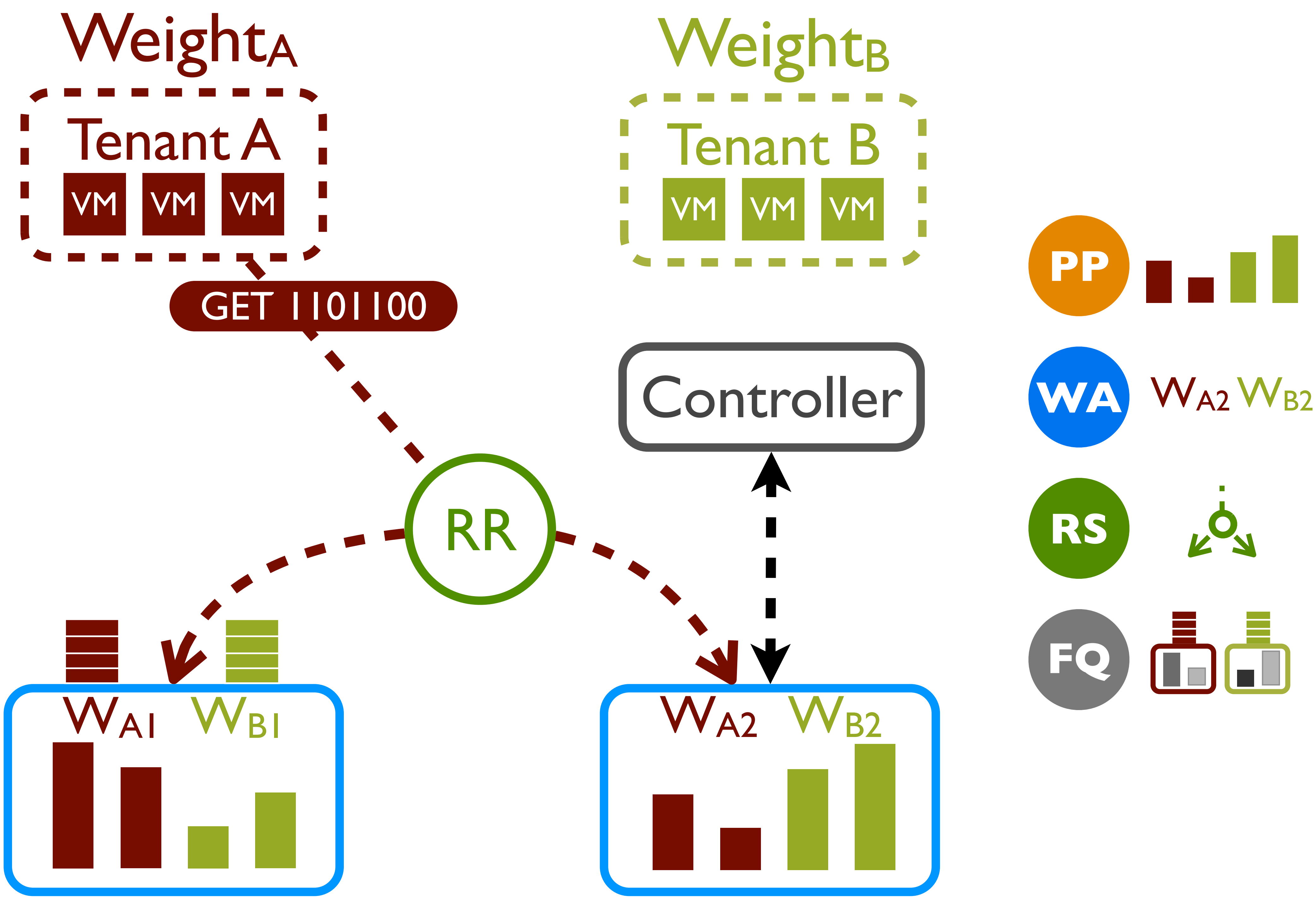
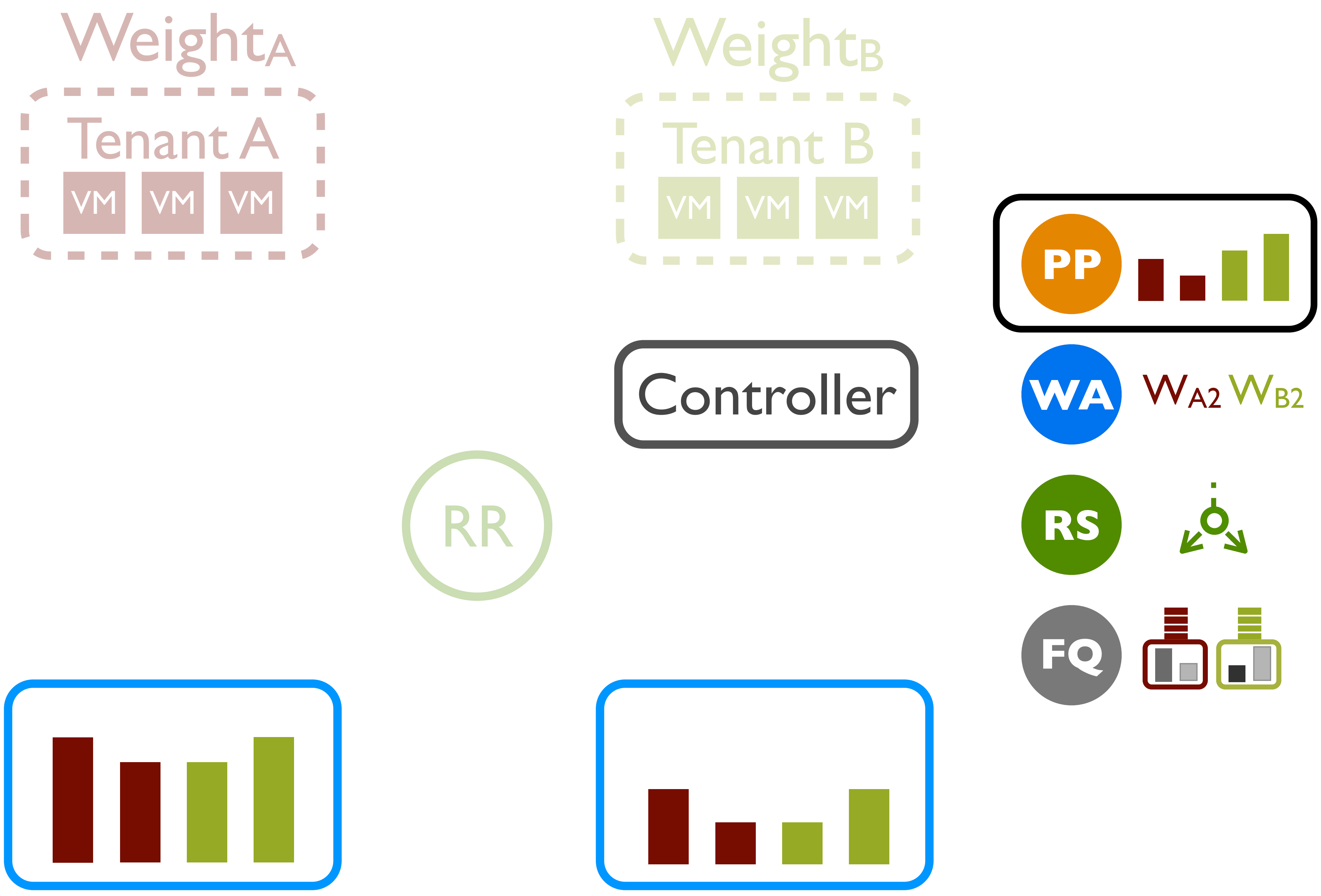


Strawman: Place Partitions Randomly



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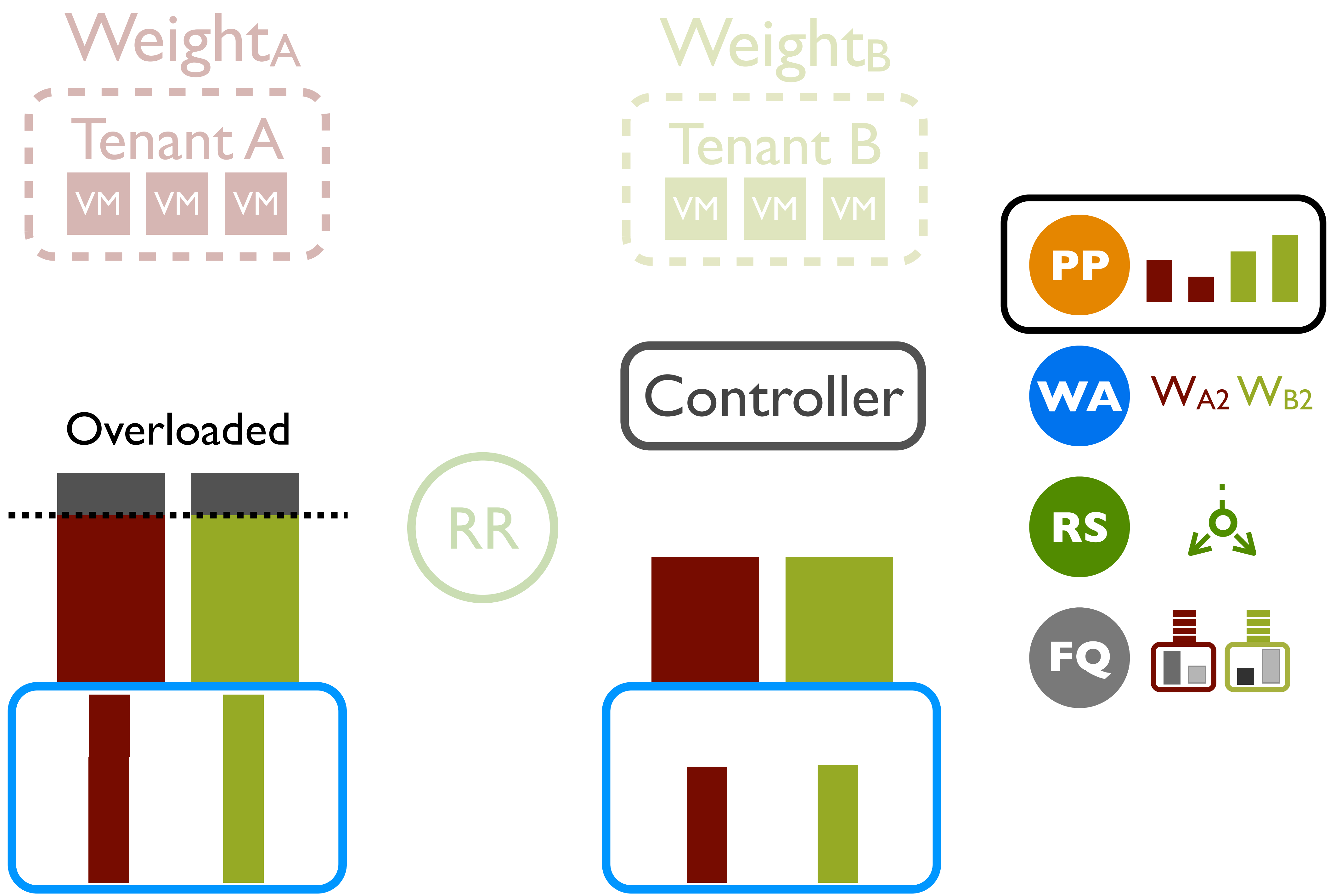
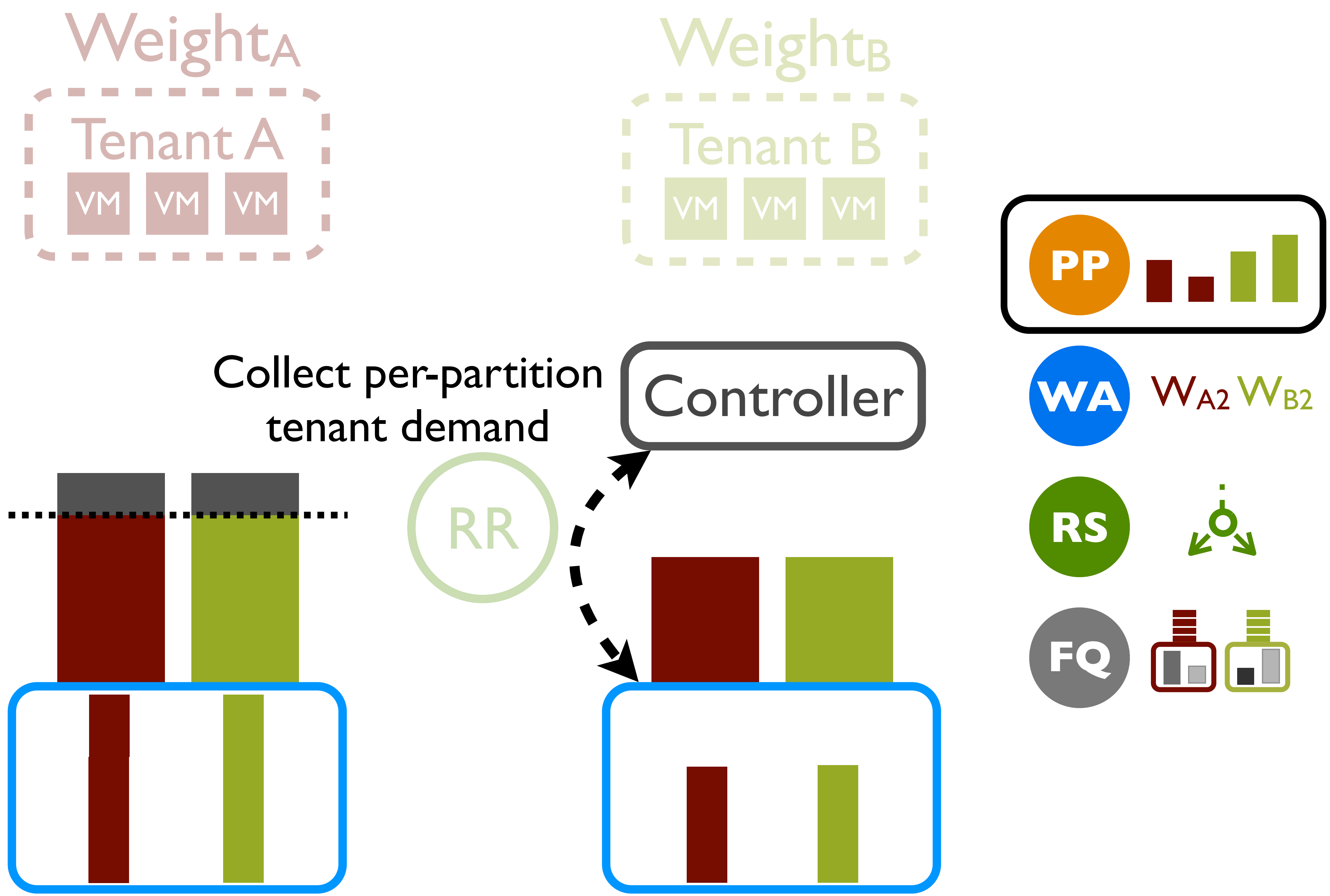


Pisces: Place Partitions By Fairness Constraints



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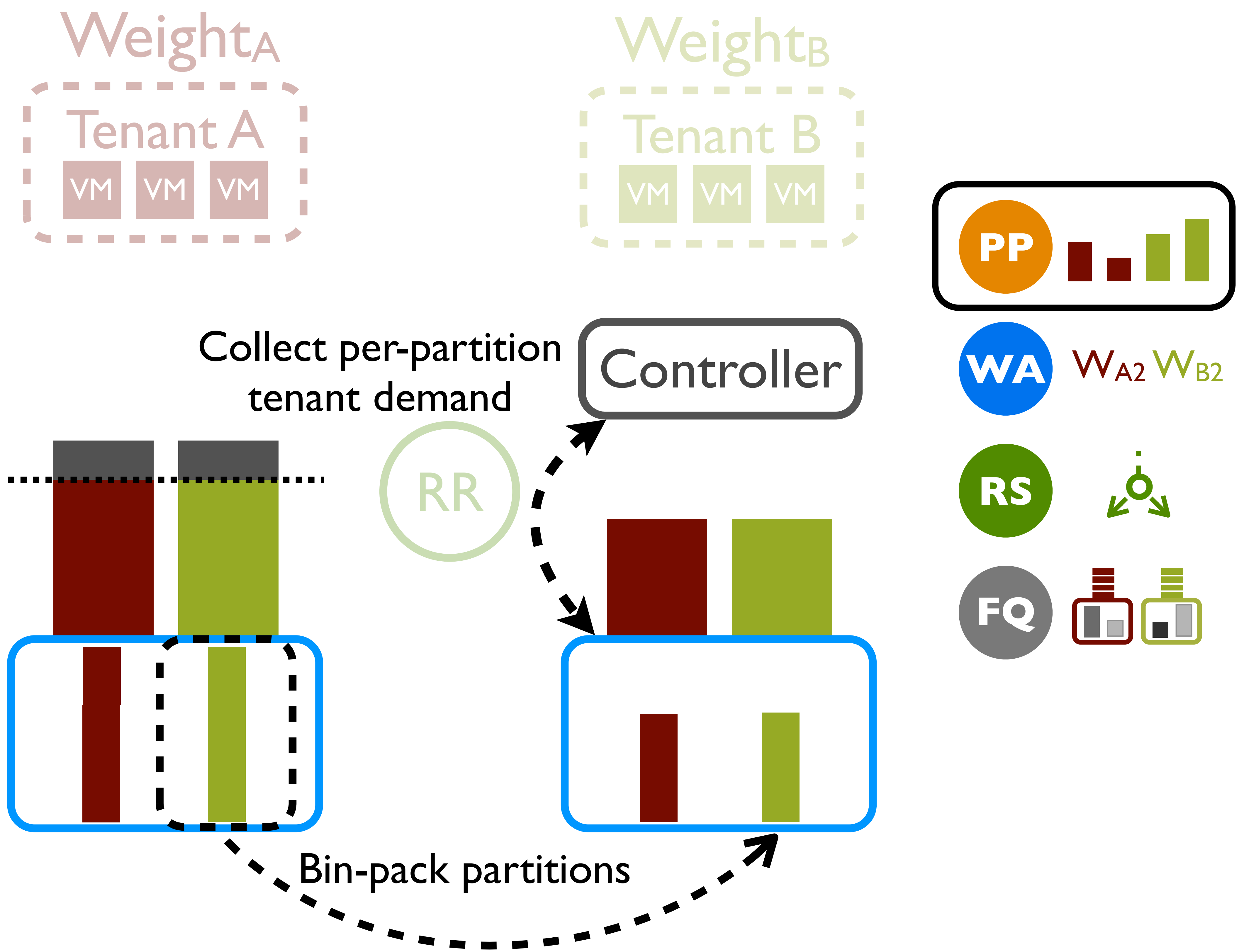

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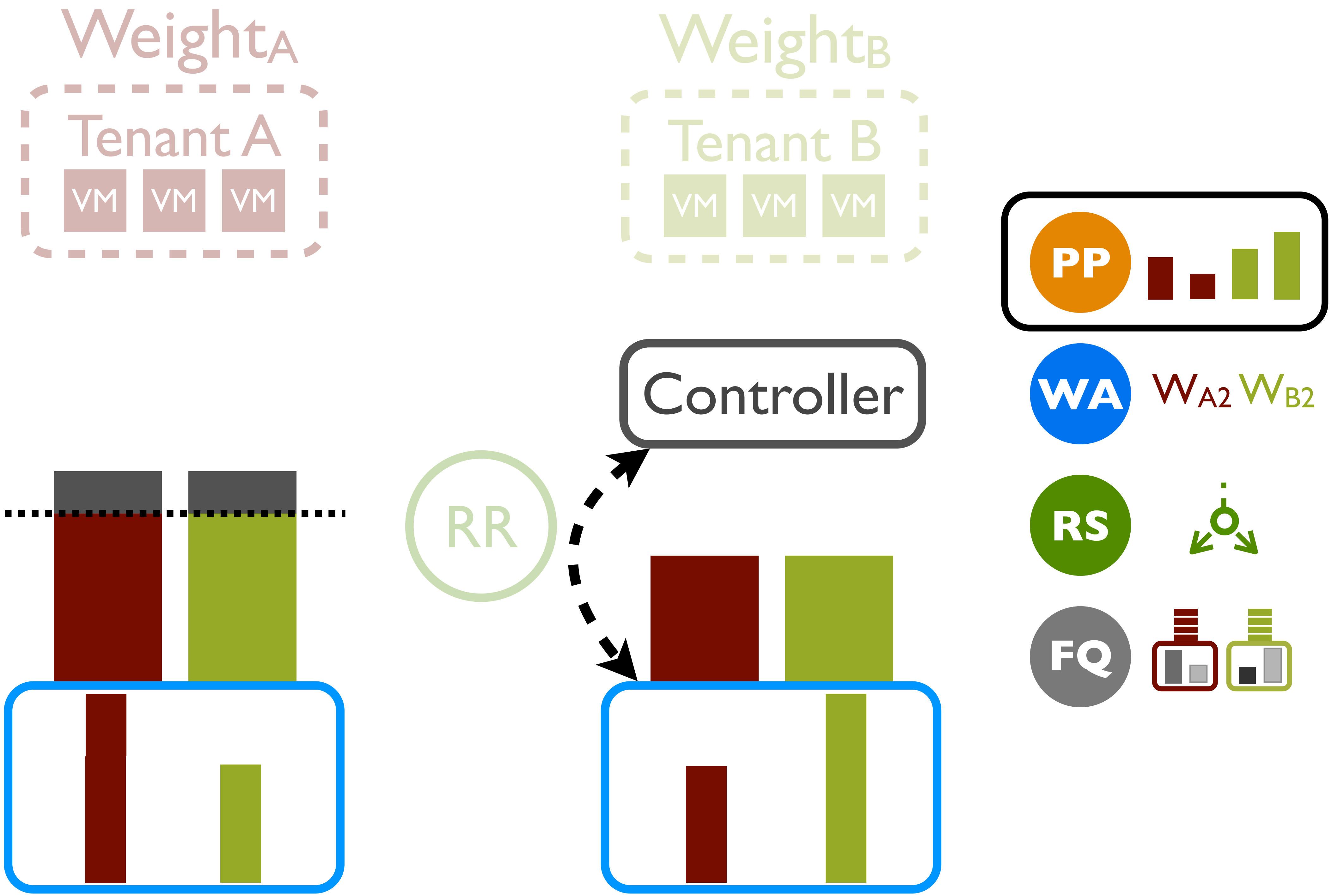

Results in feasible partition placement

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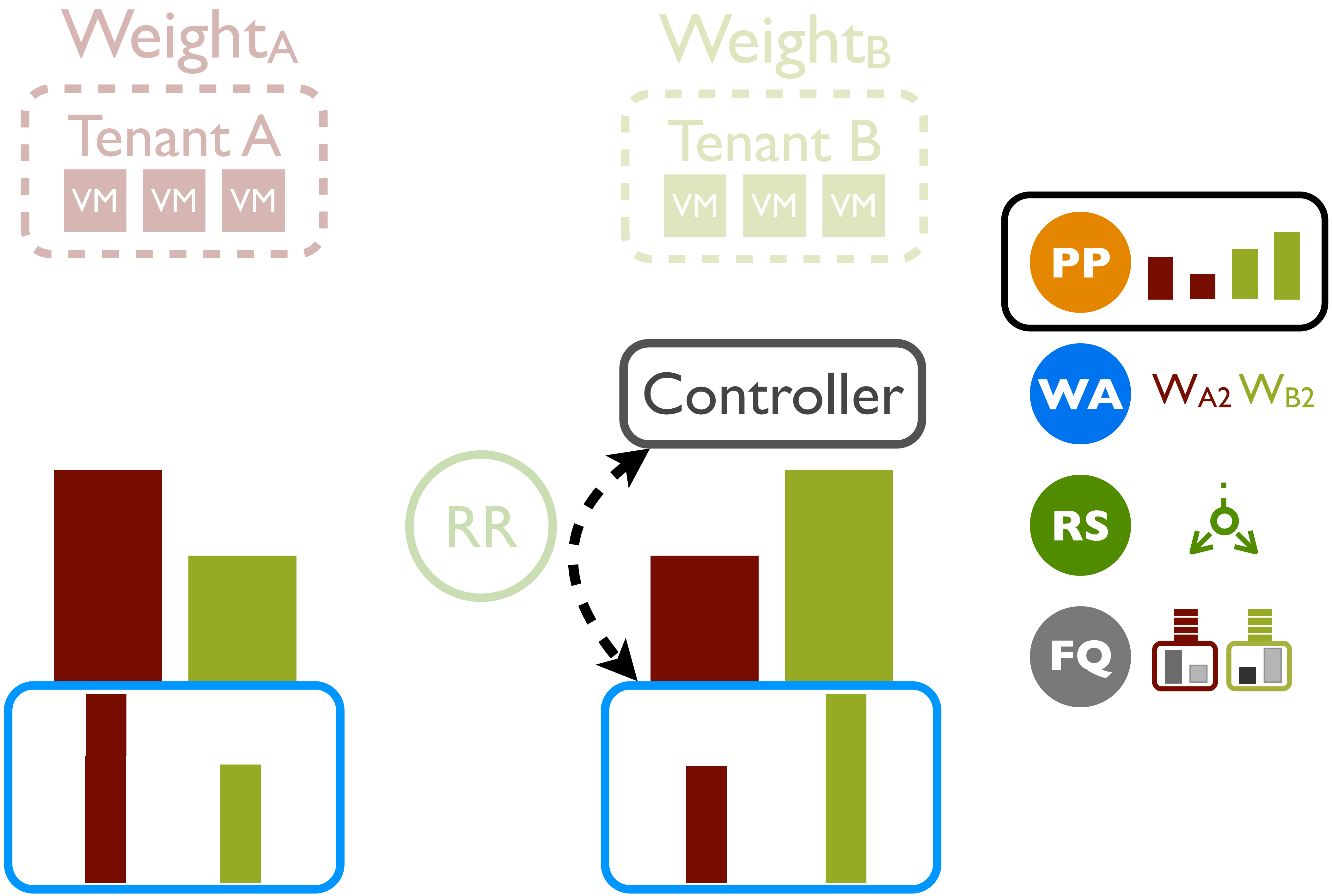

Results in feasible partition placement

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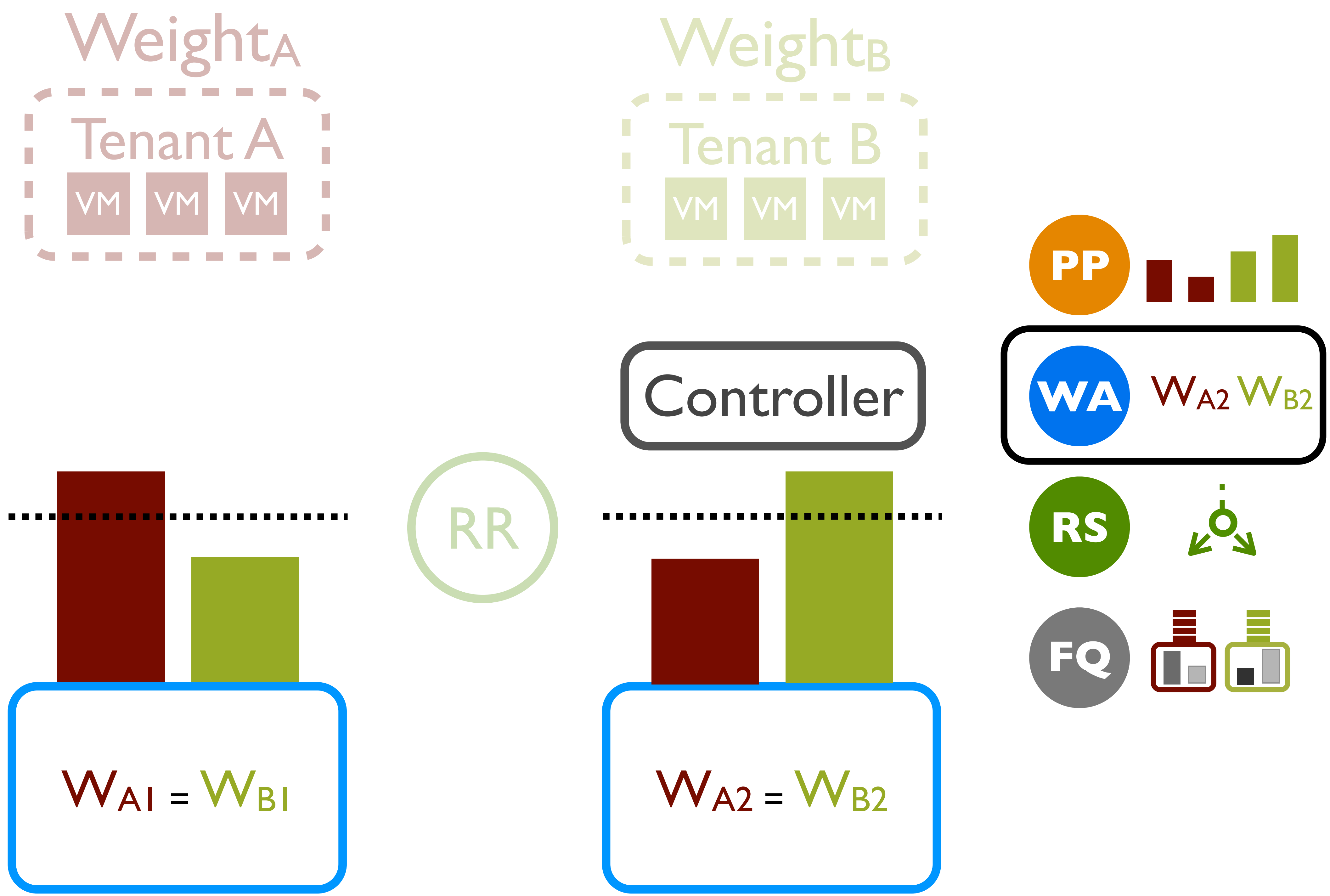

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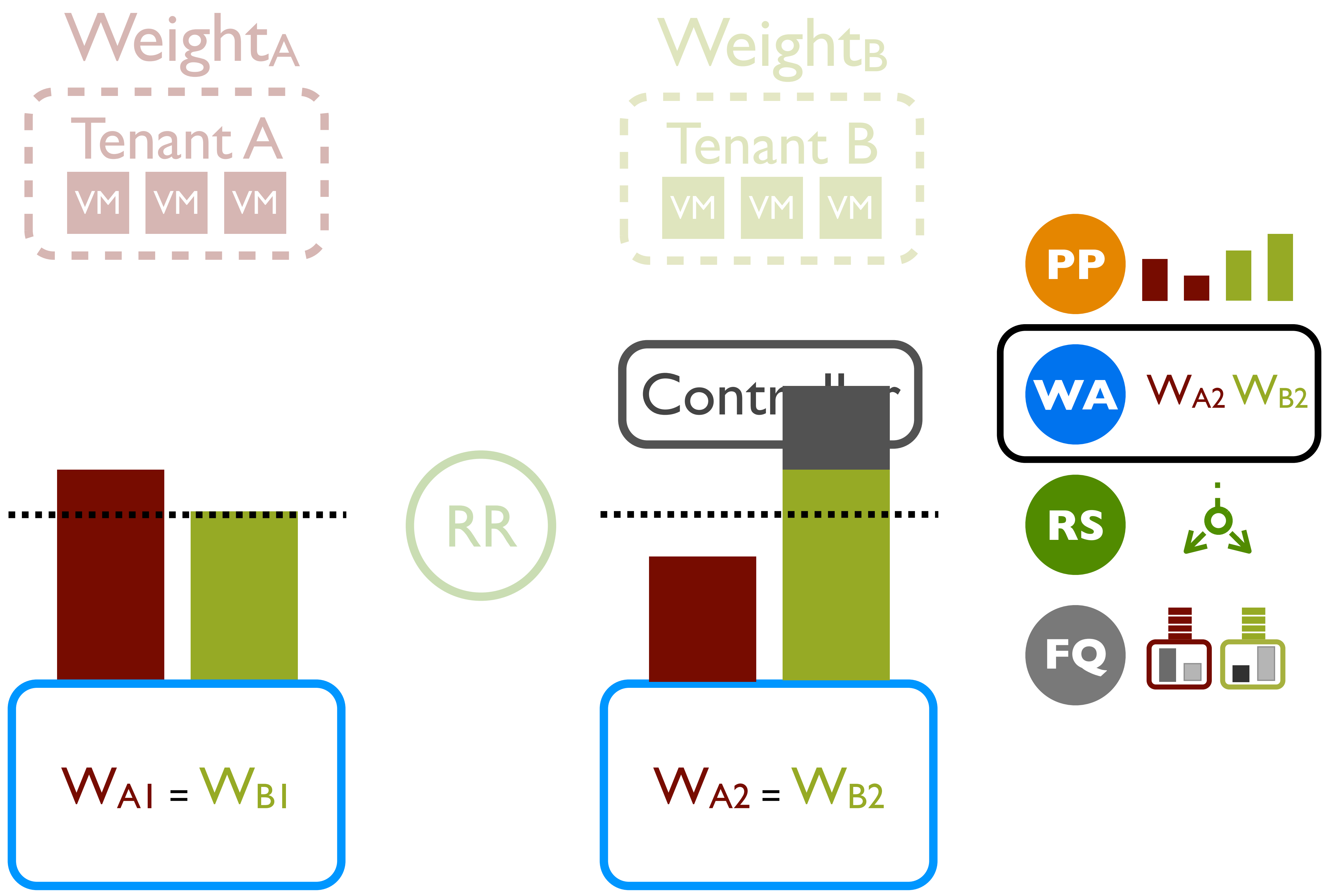

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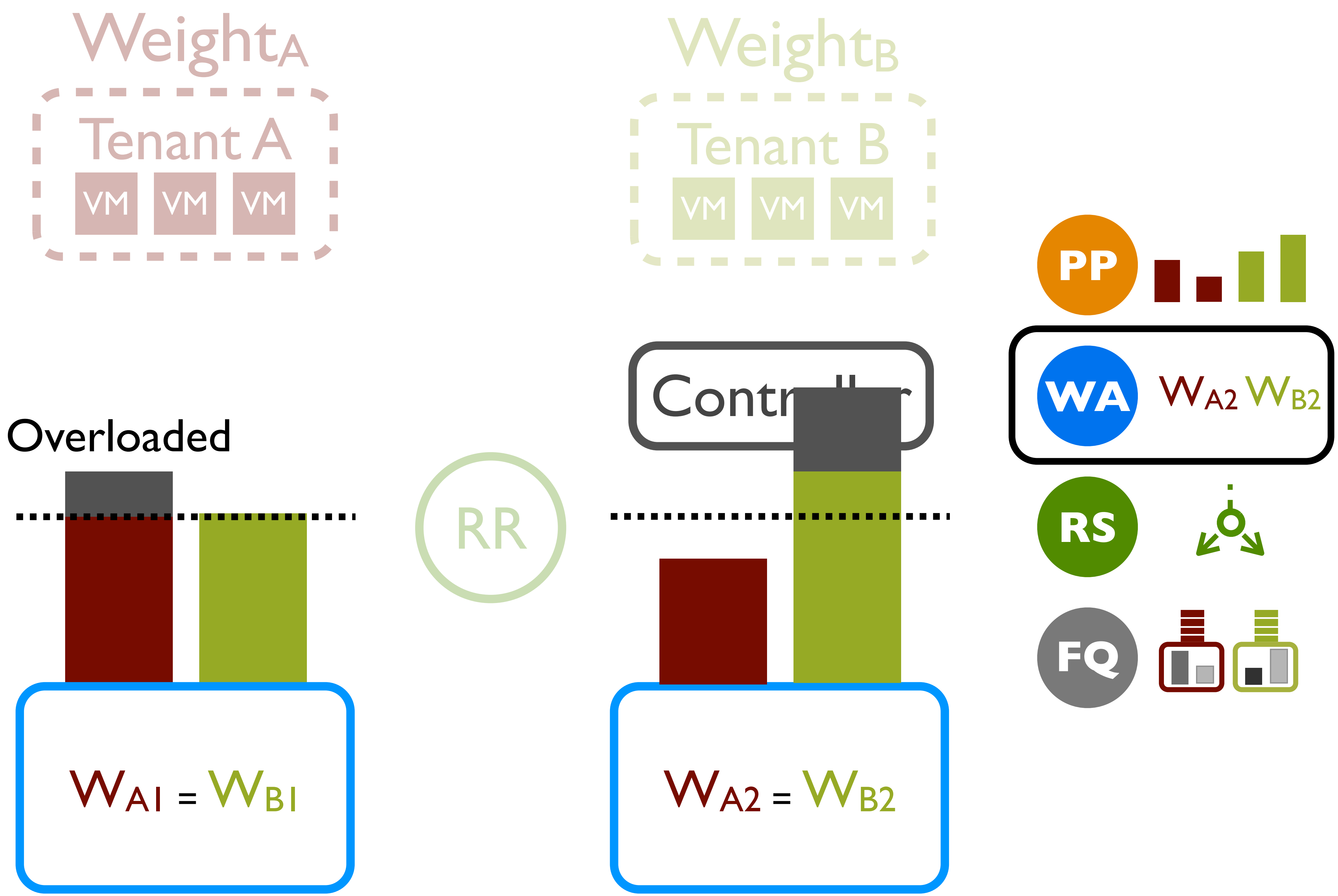

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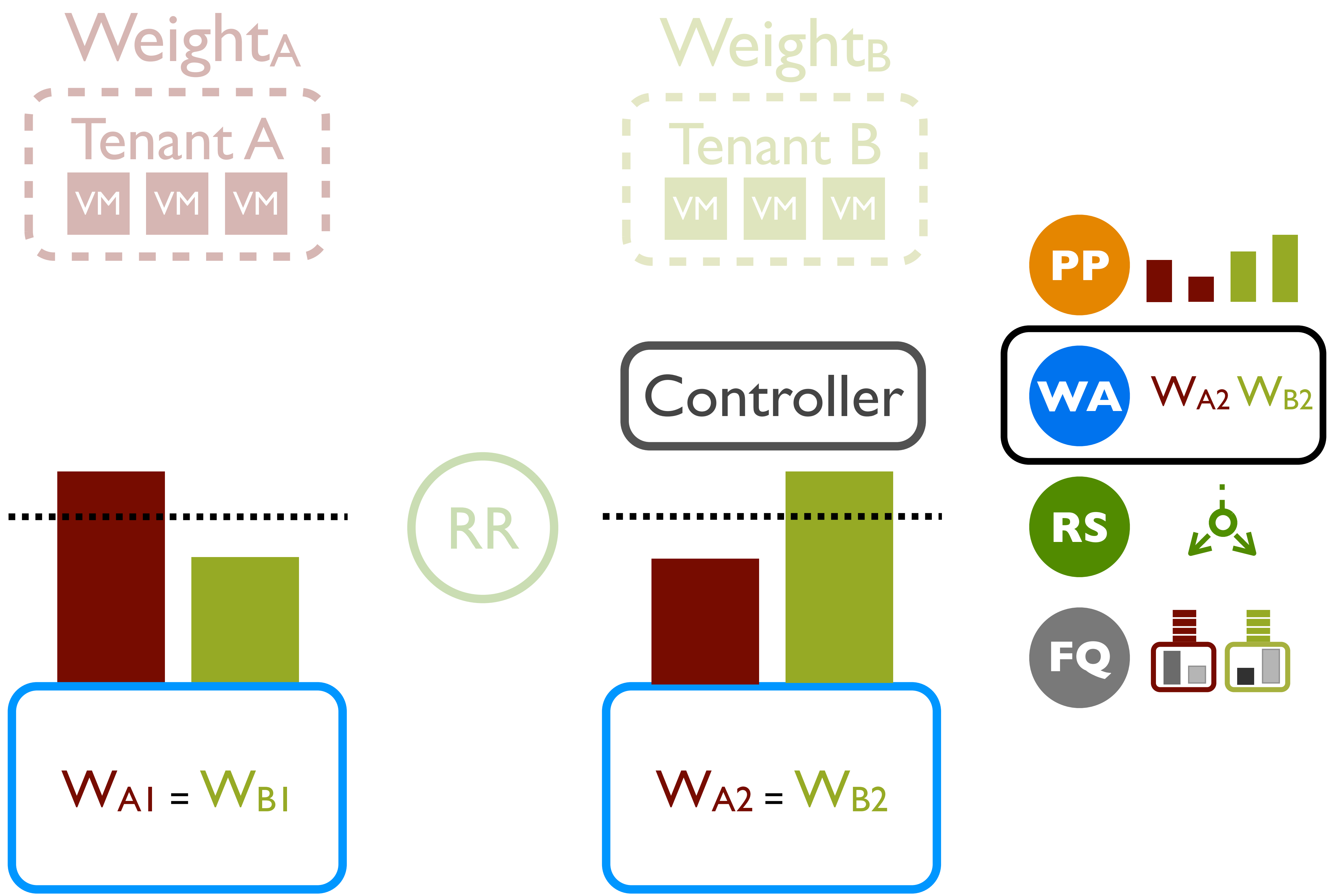

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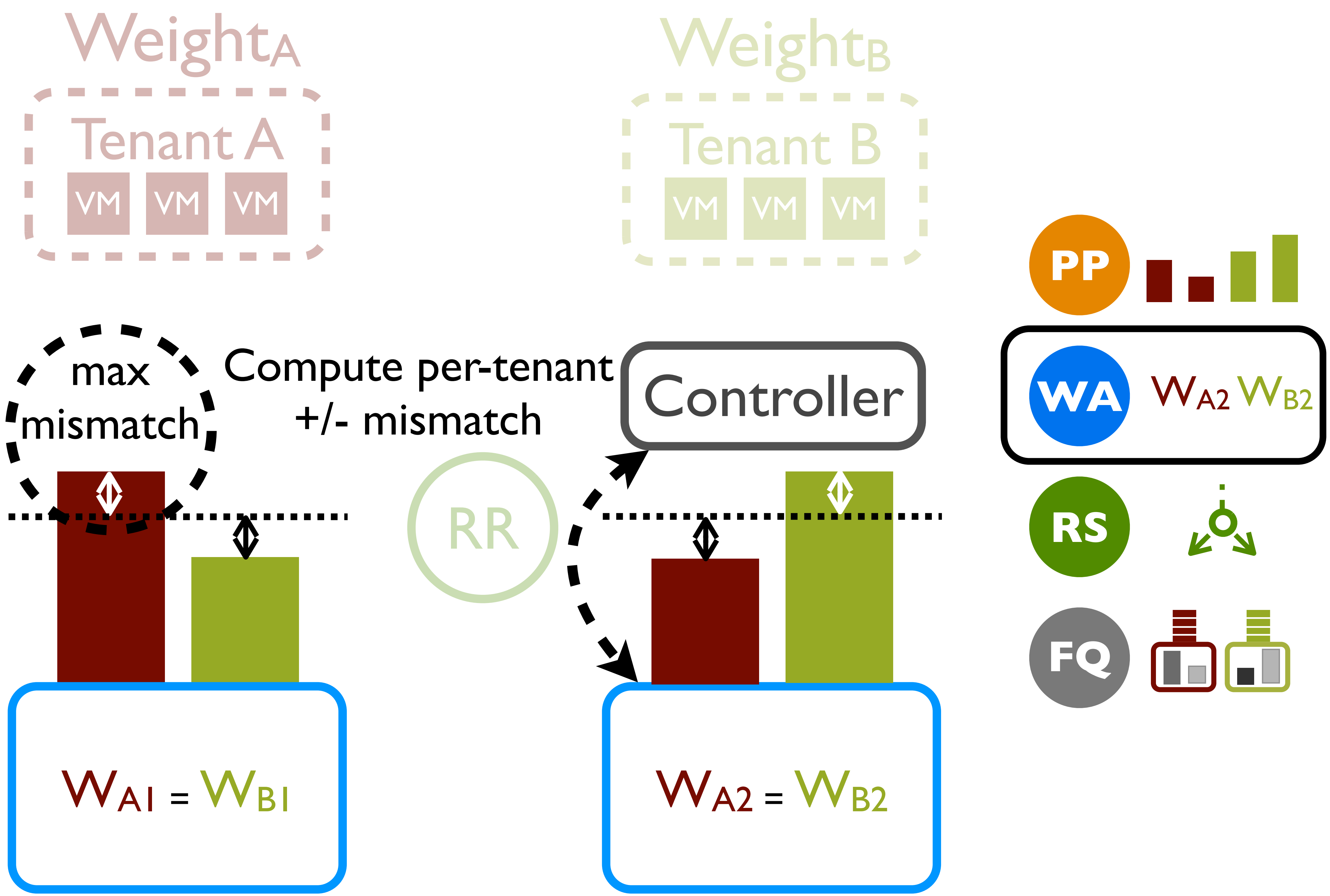

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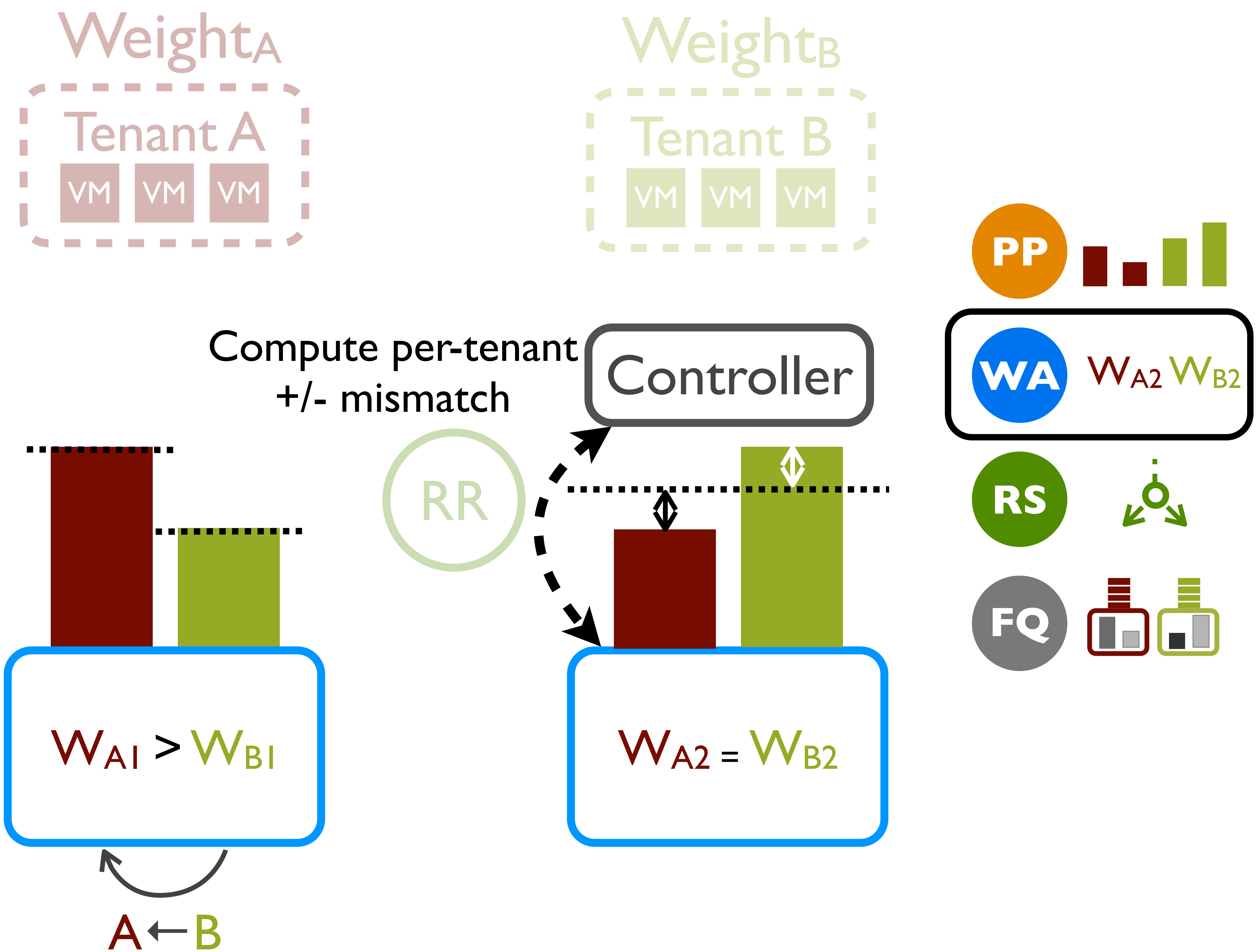

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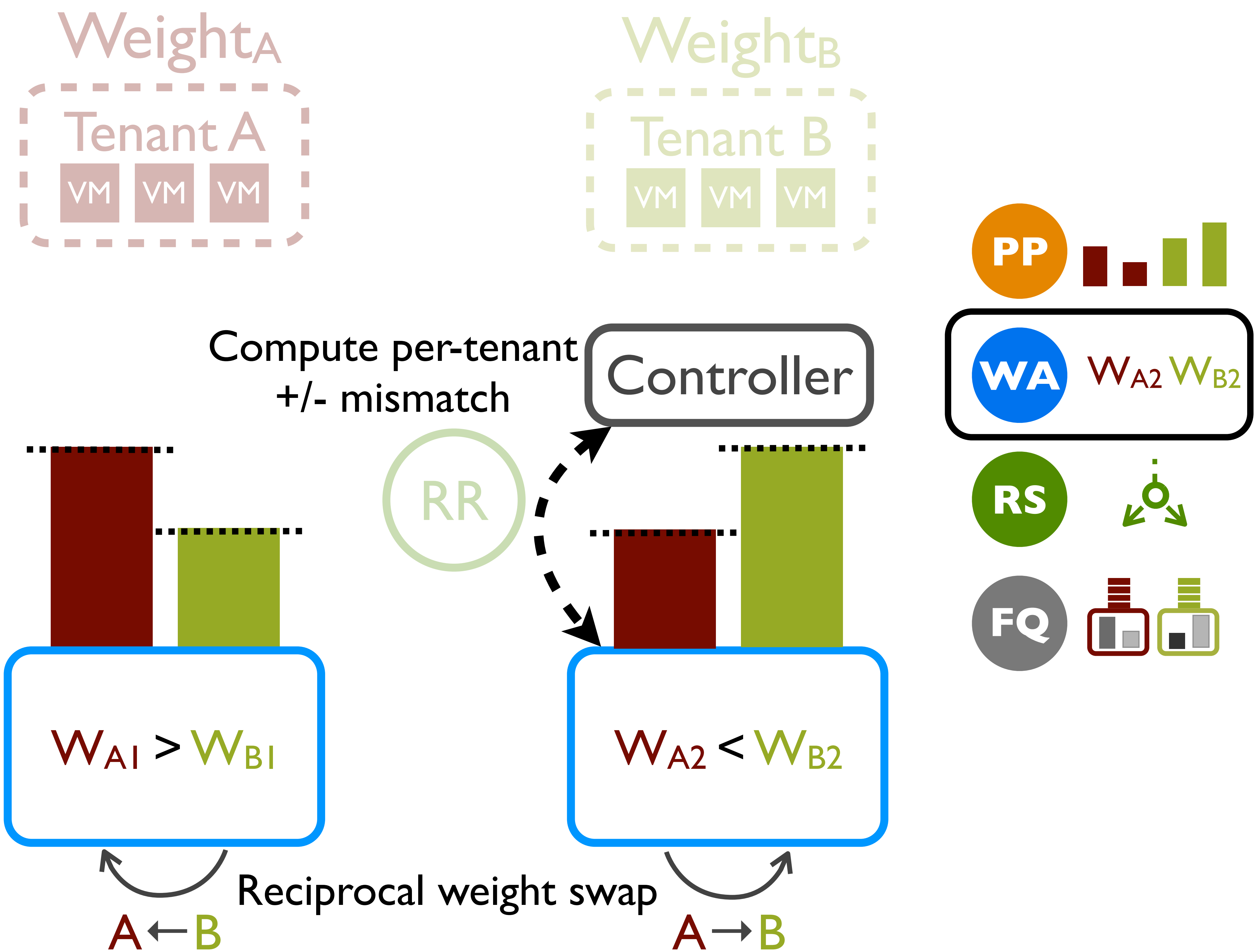

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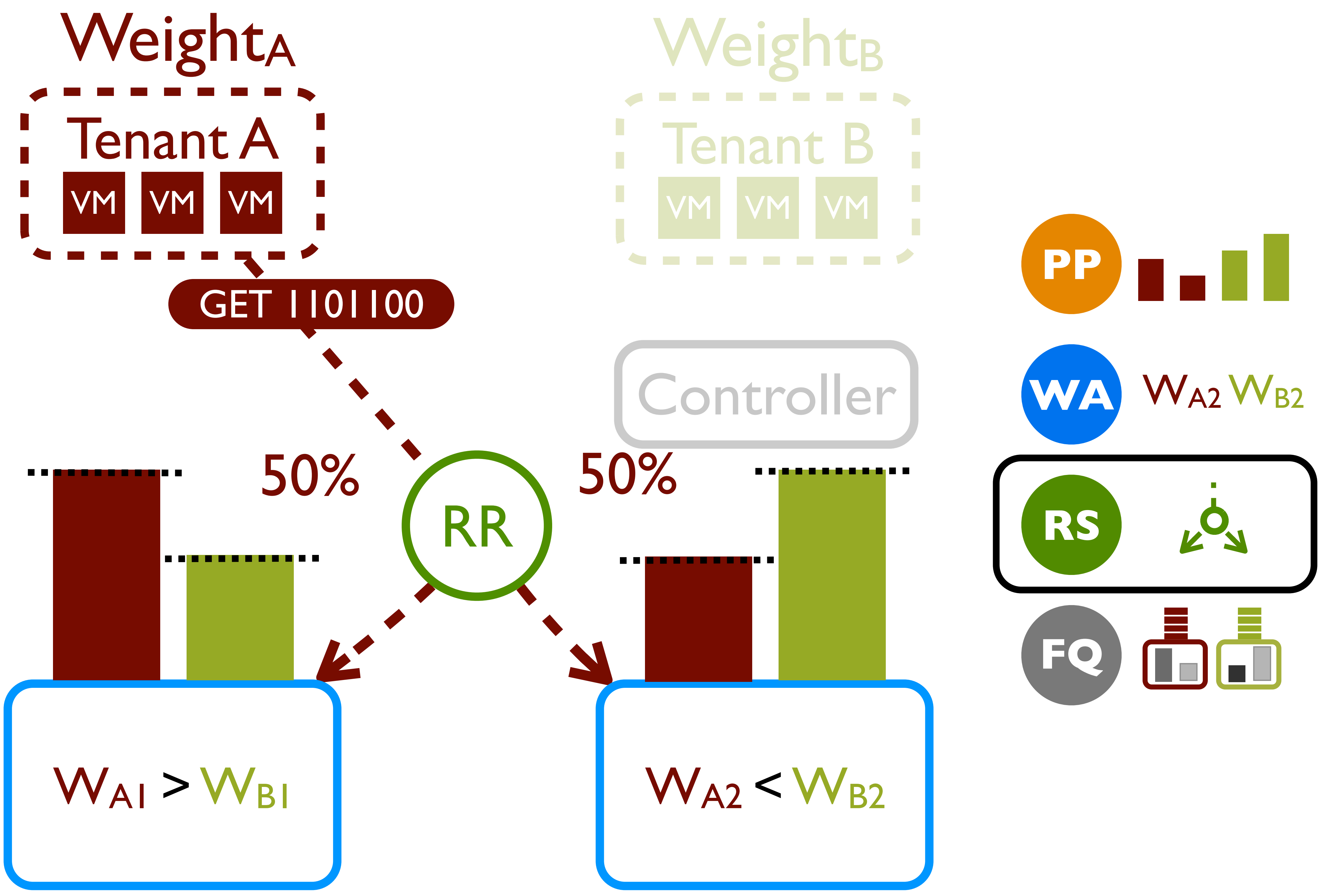

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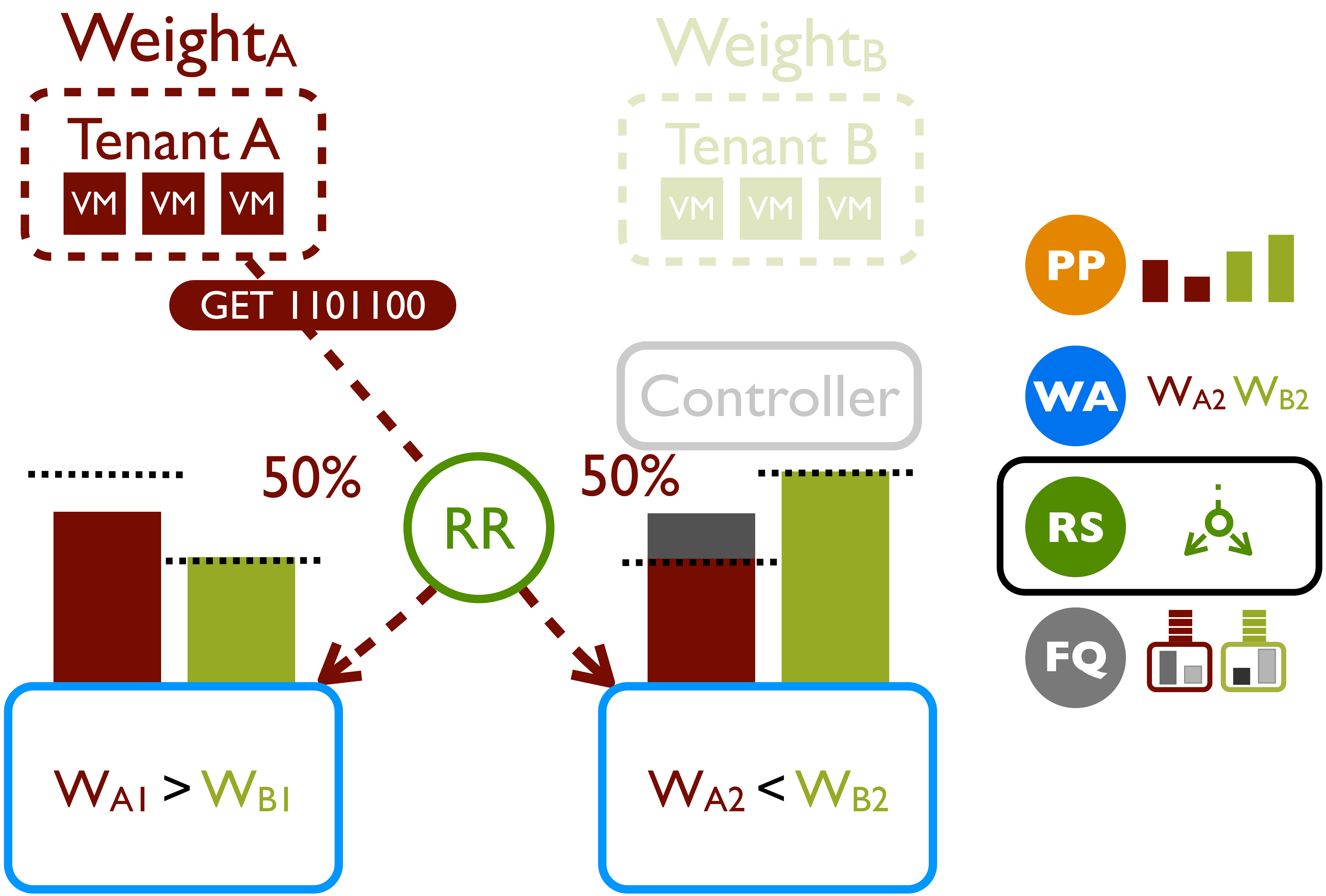

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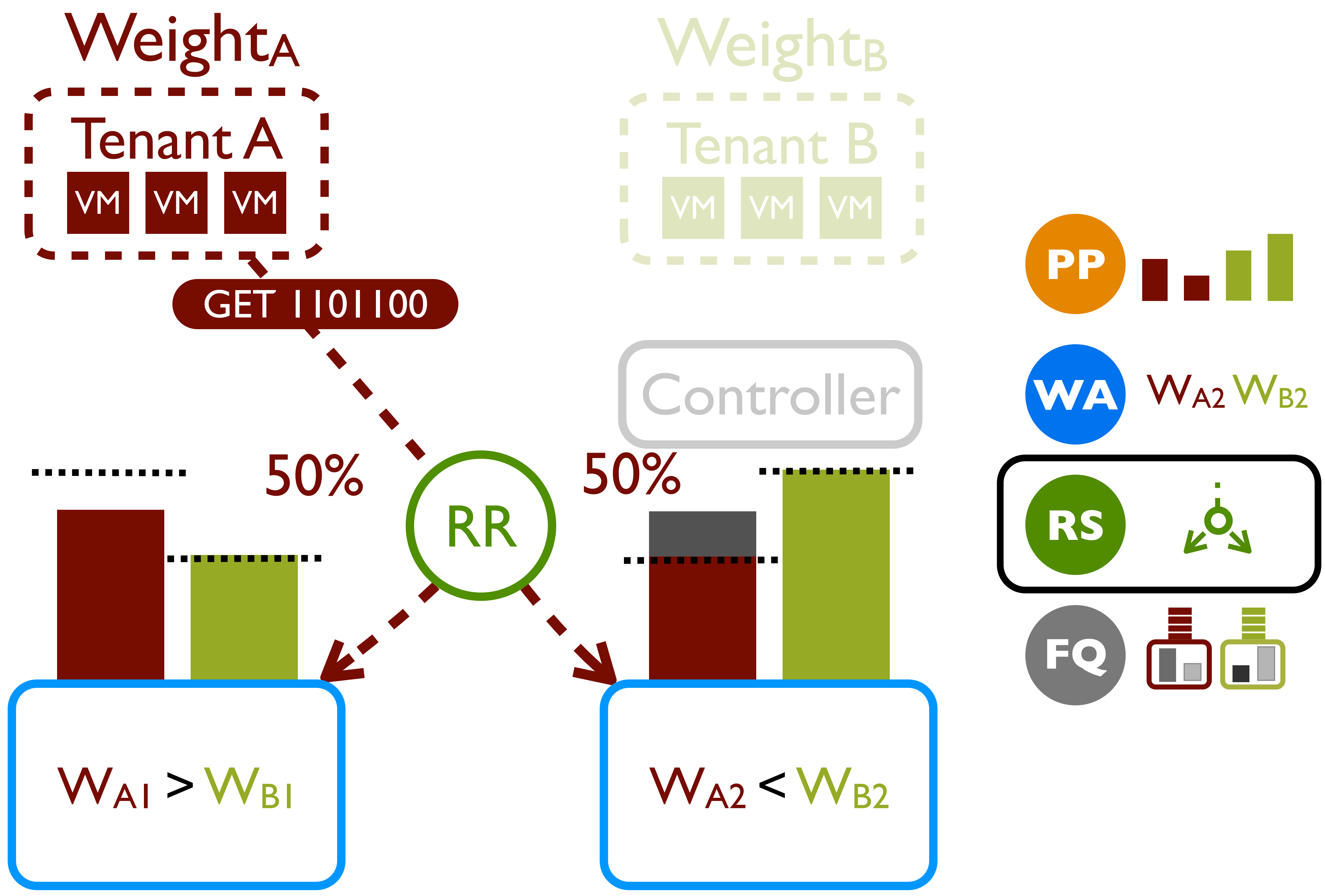

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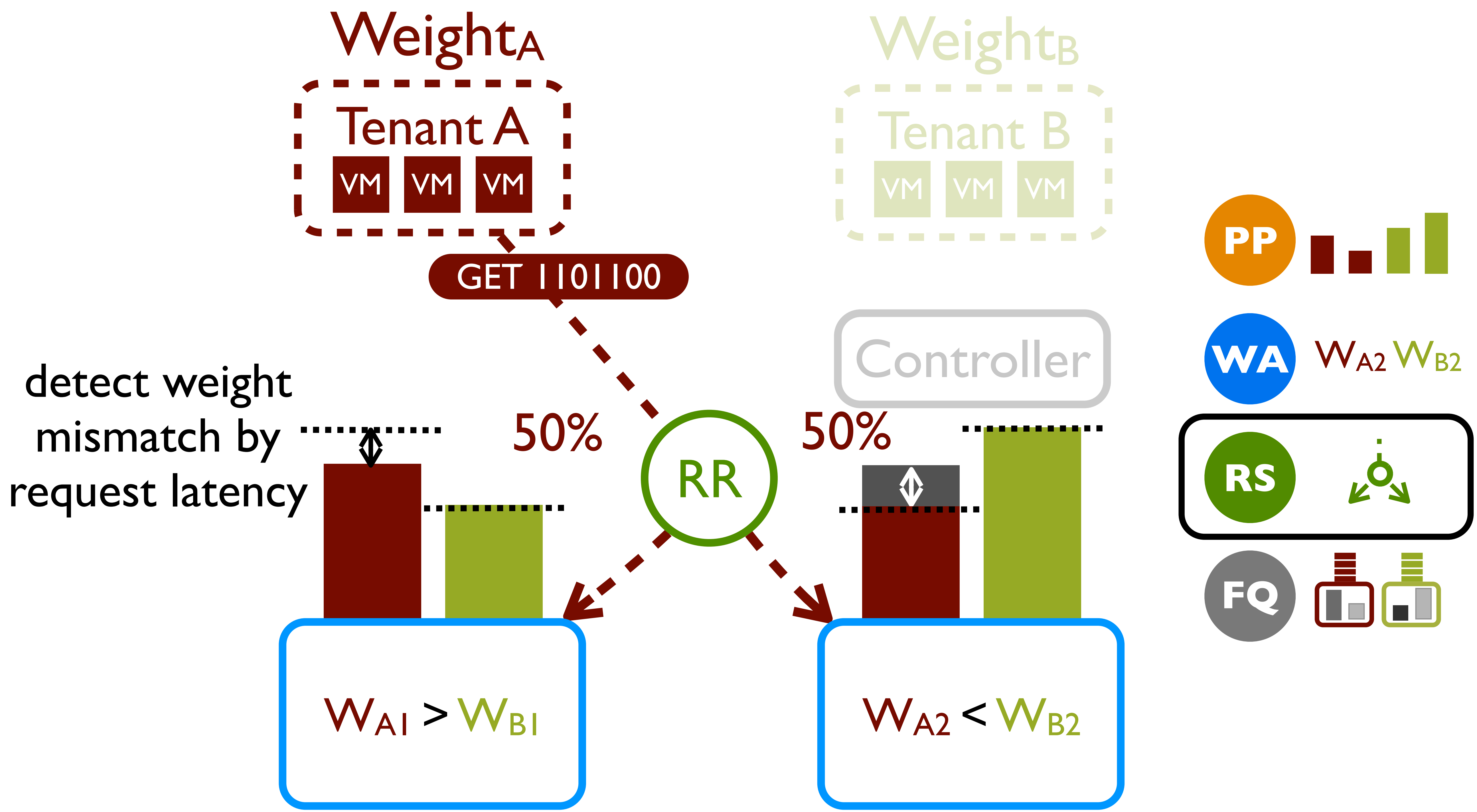

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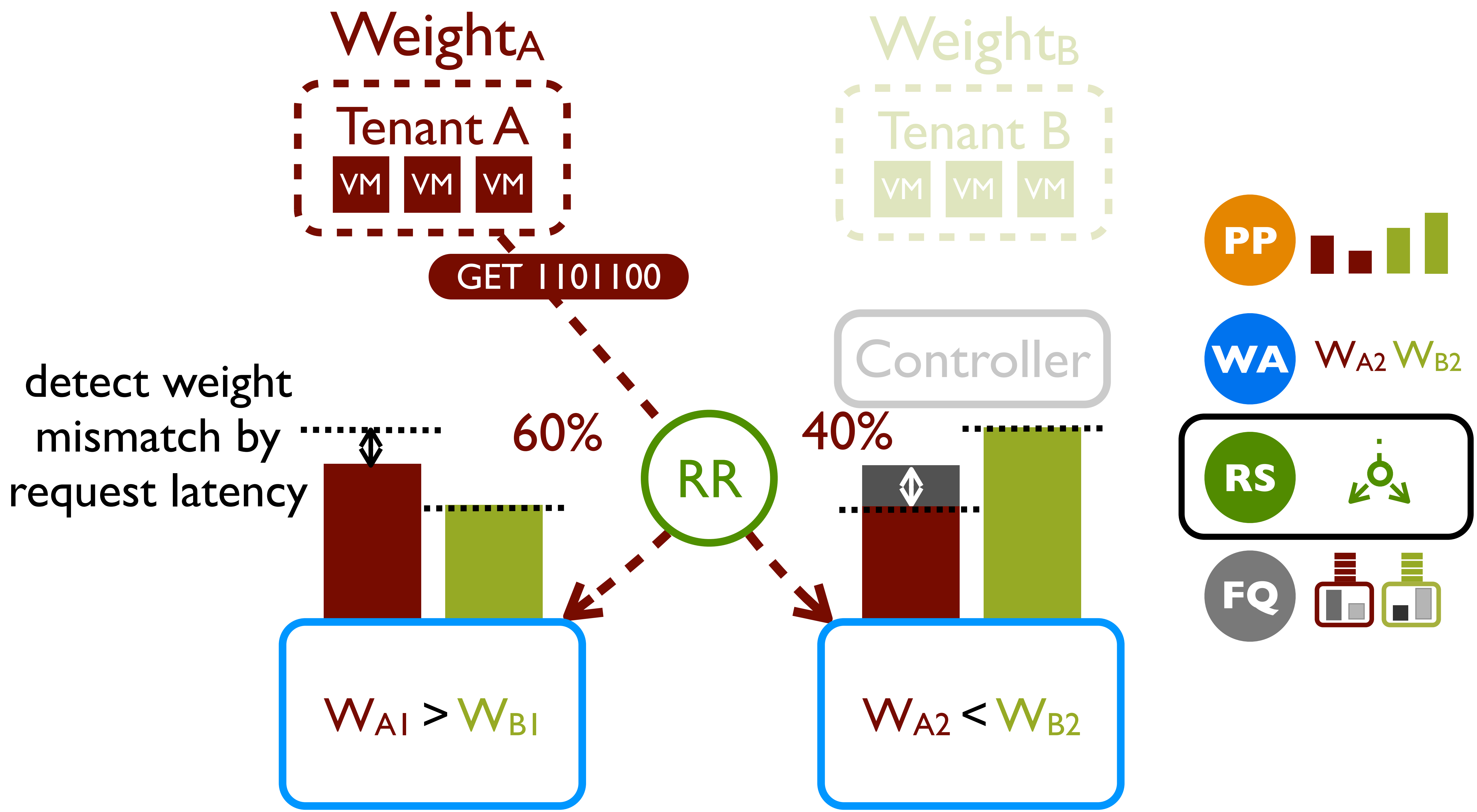
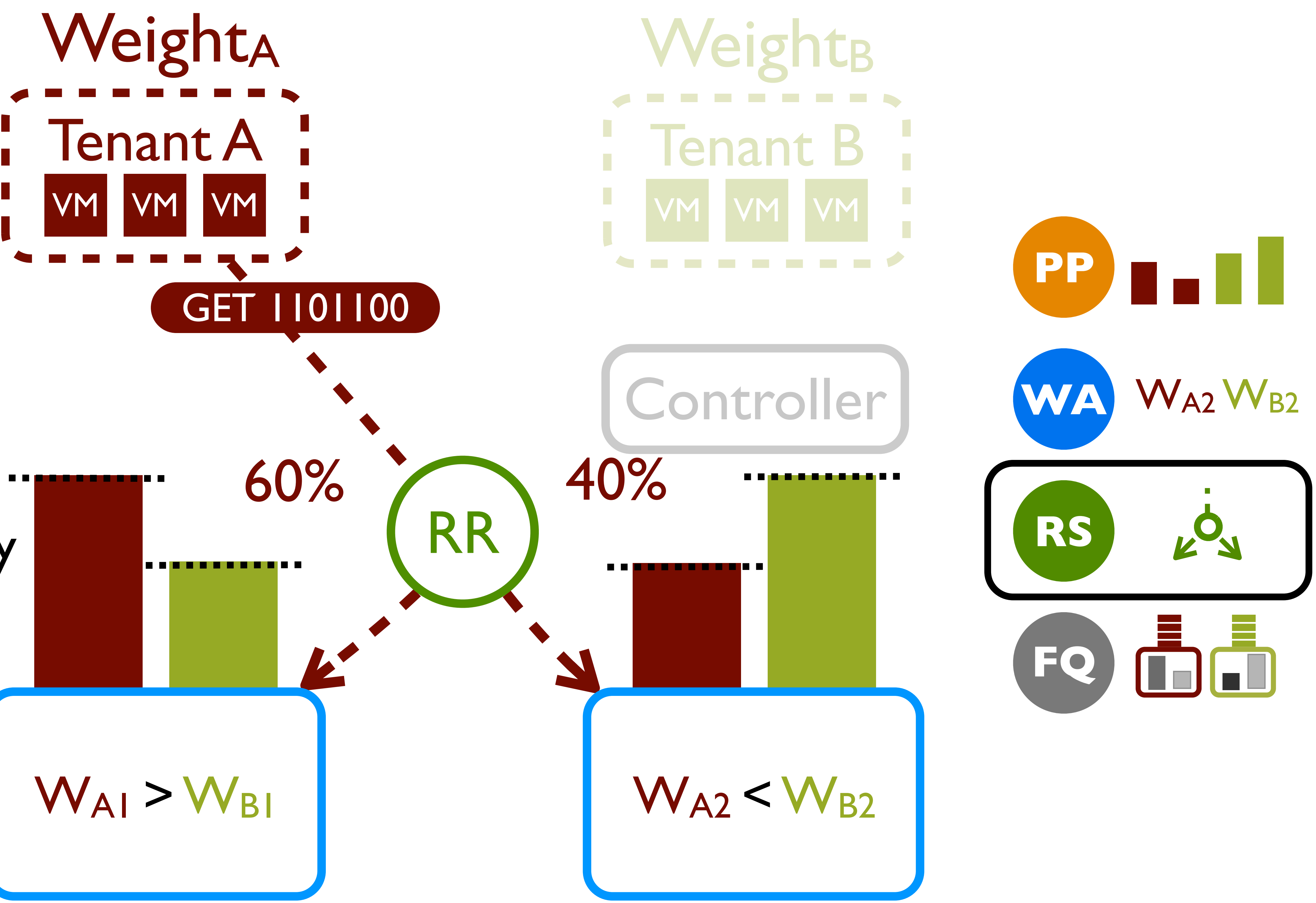
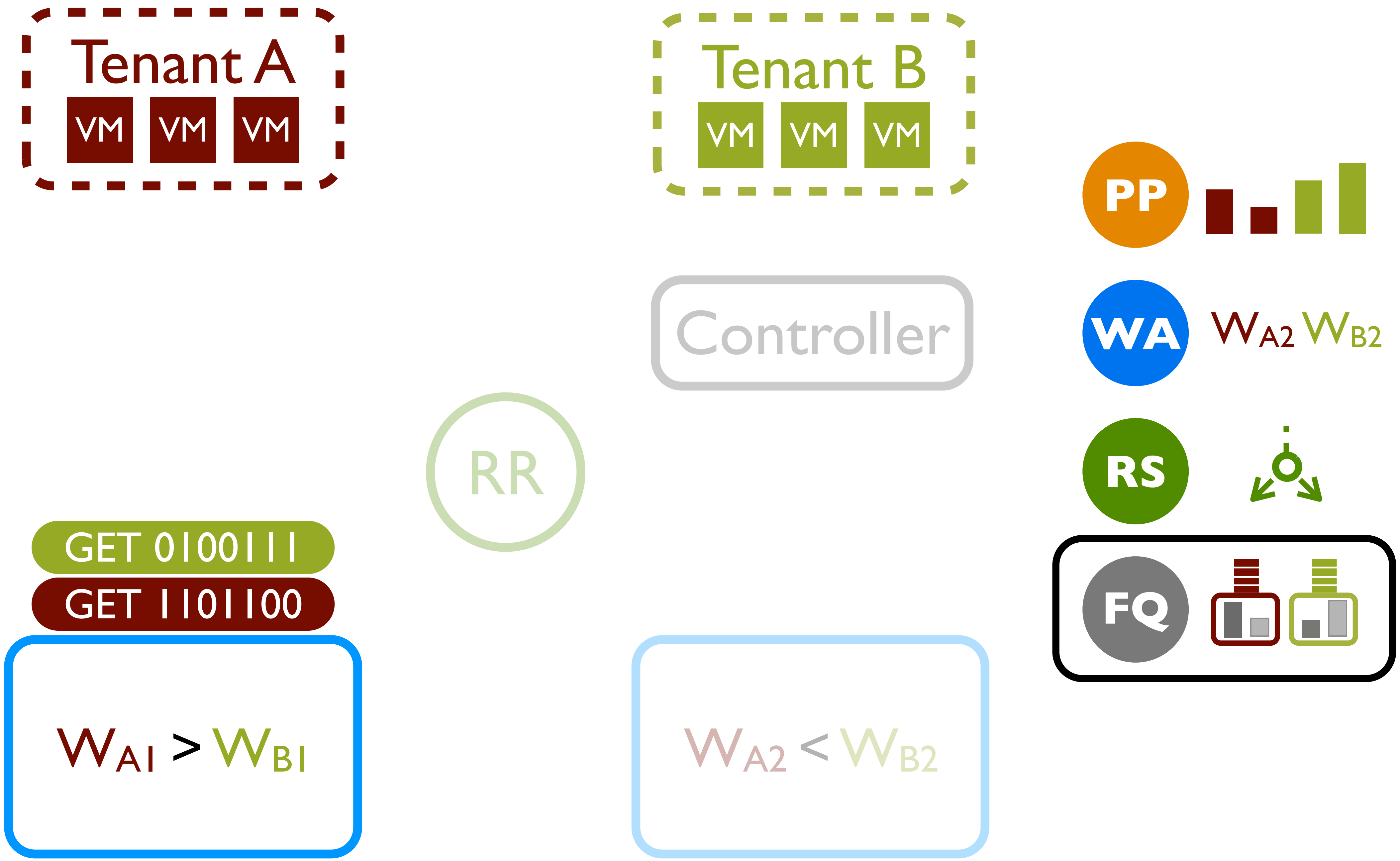


Pisces: Select Replicas By Local Weight

detect weight mismatch by request latency



Strawman: Queue Tenants By Single Resource



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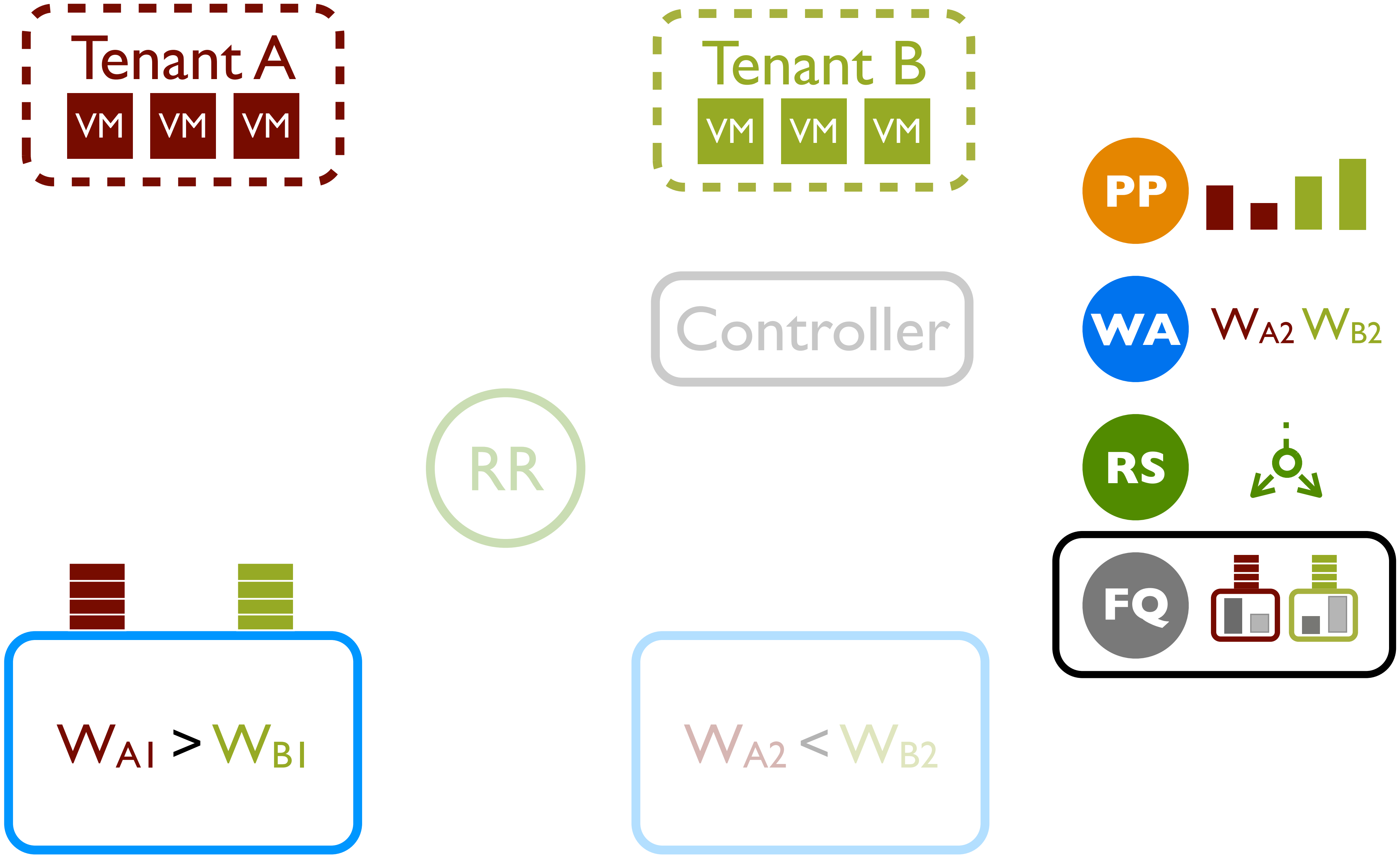

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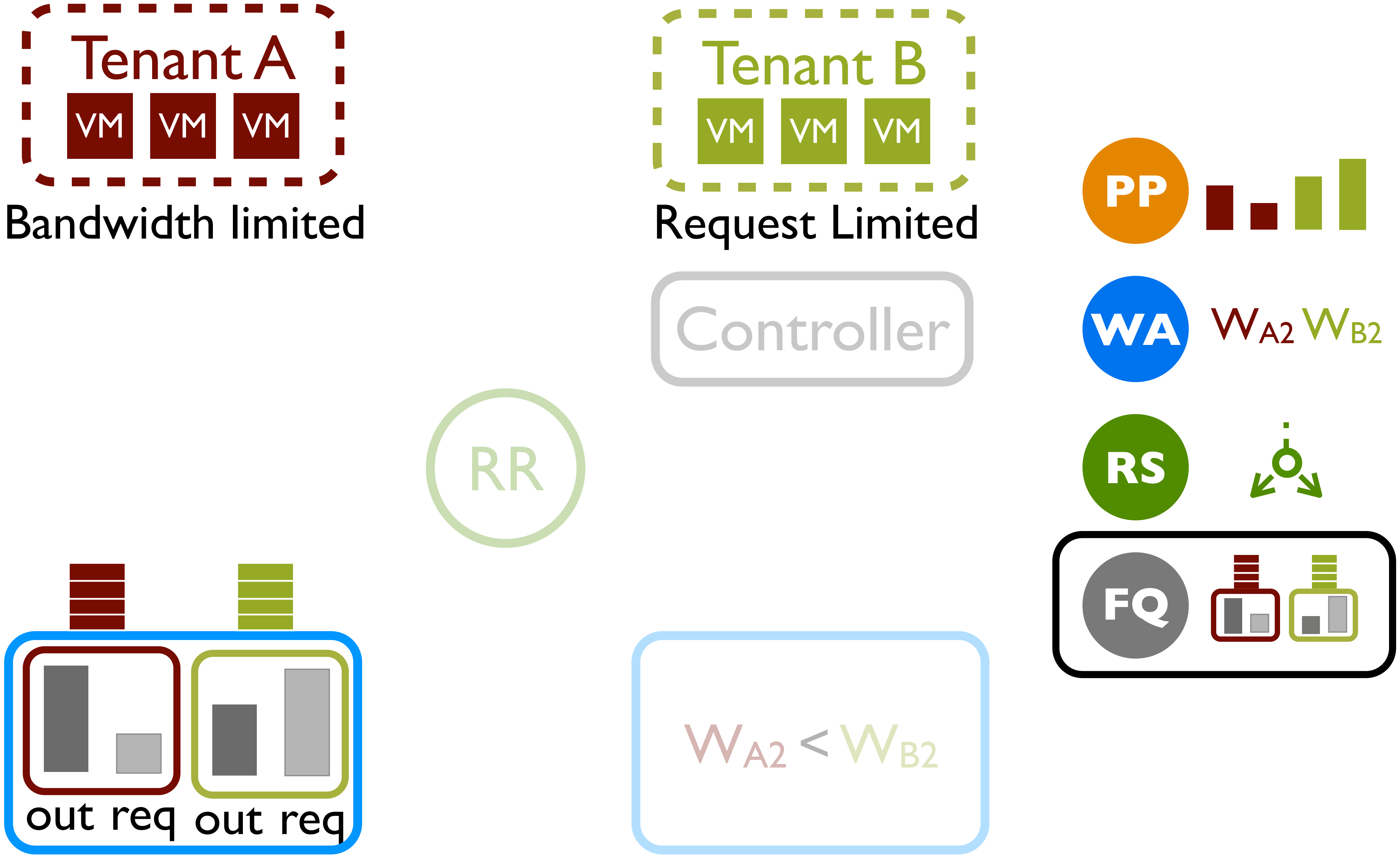

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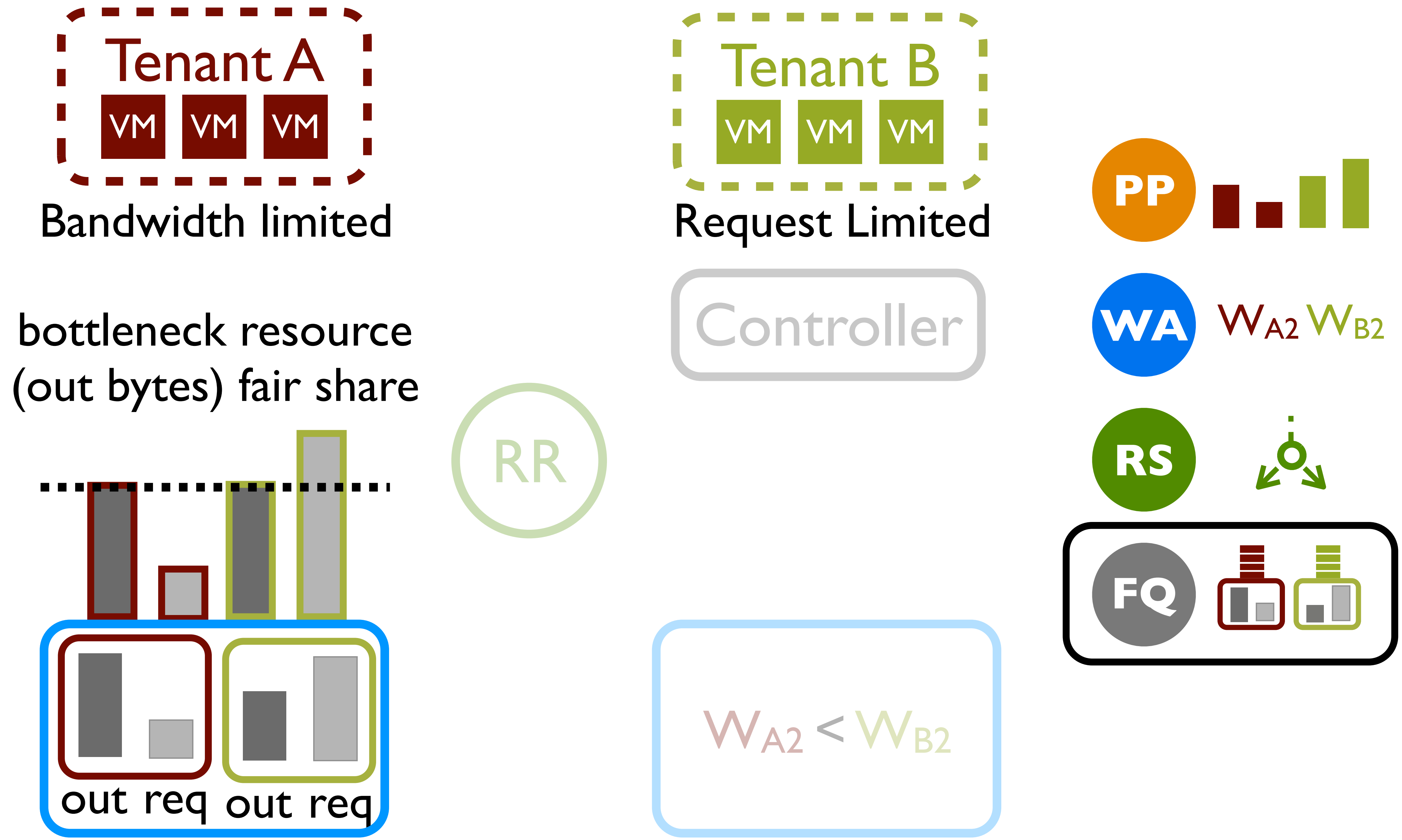
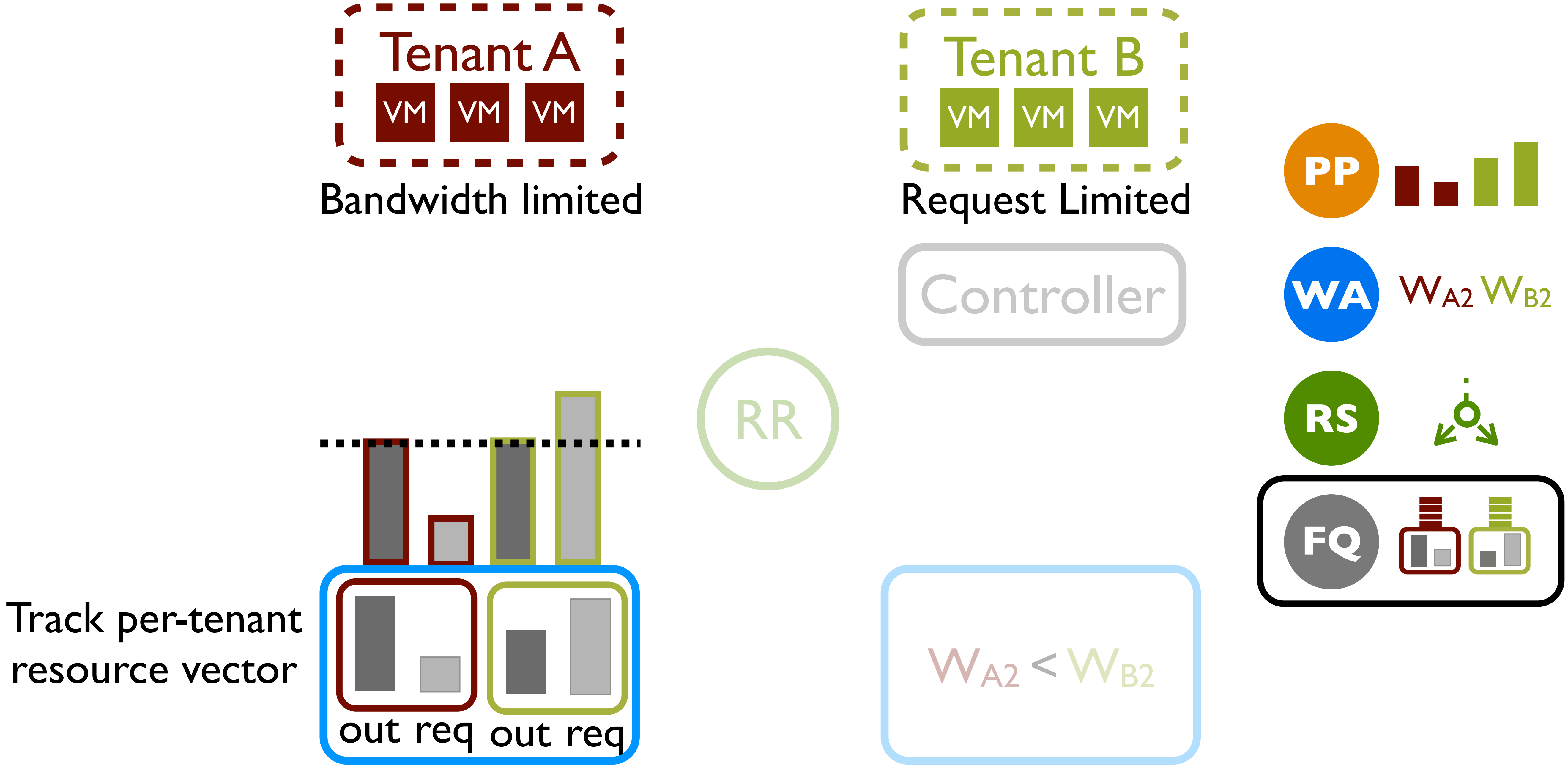


Pisces: Queue Tenants By Dominant Resource



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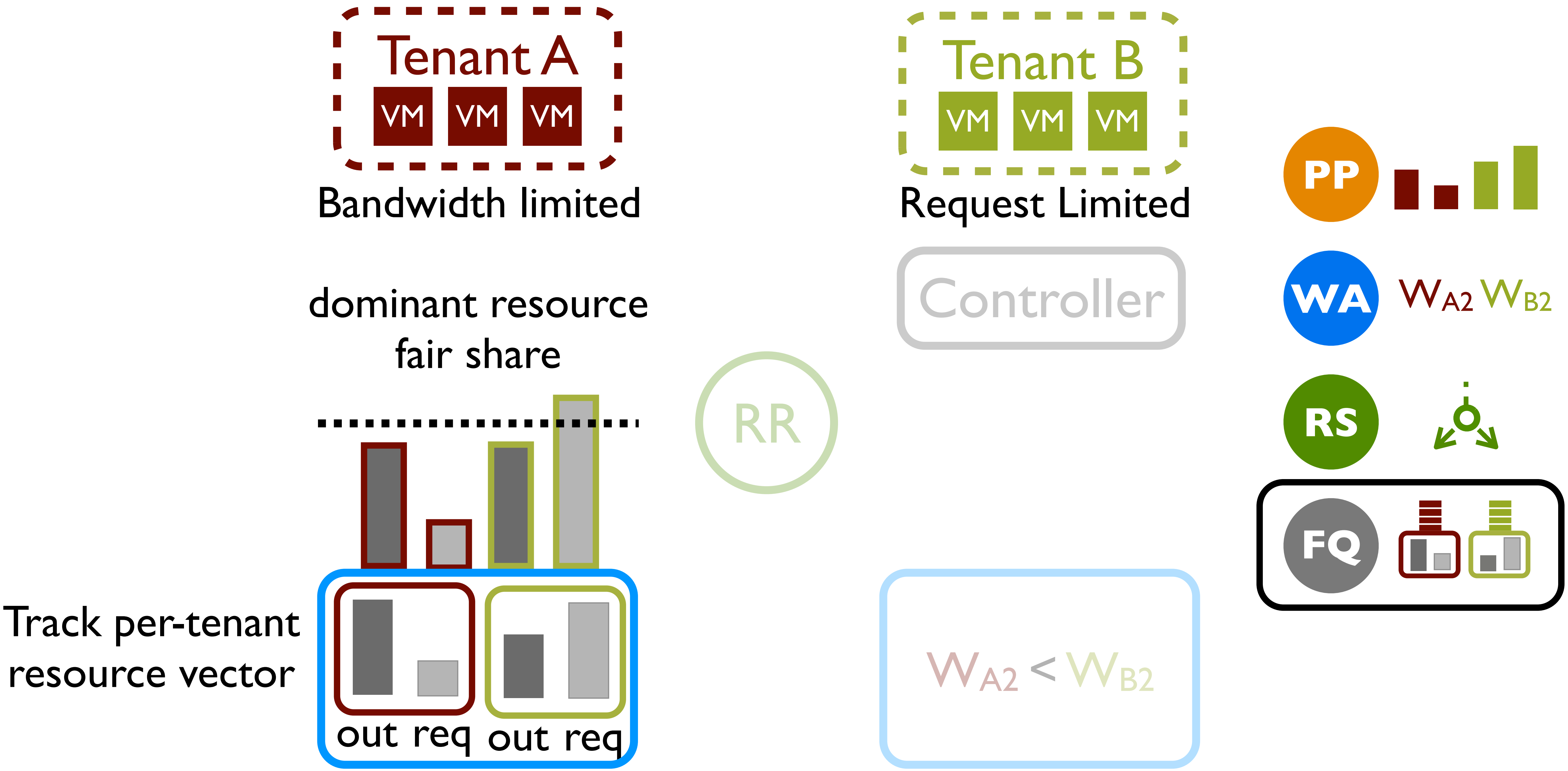

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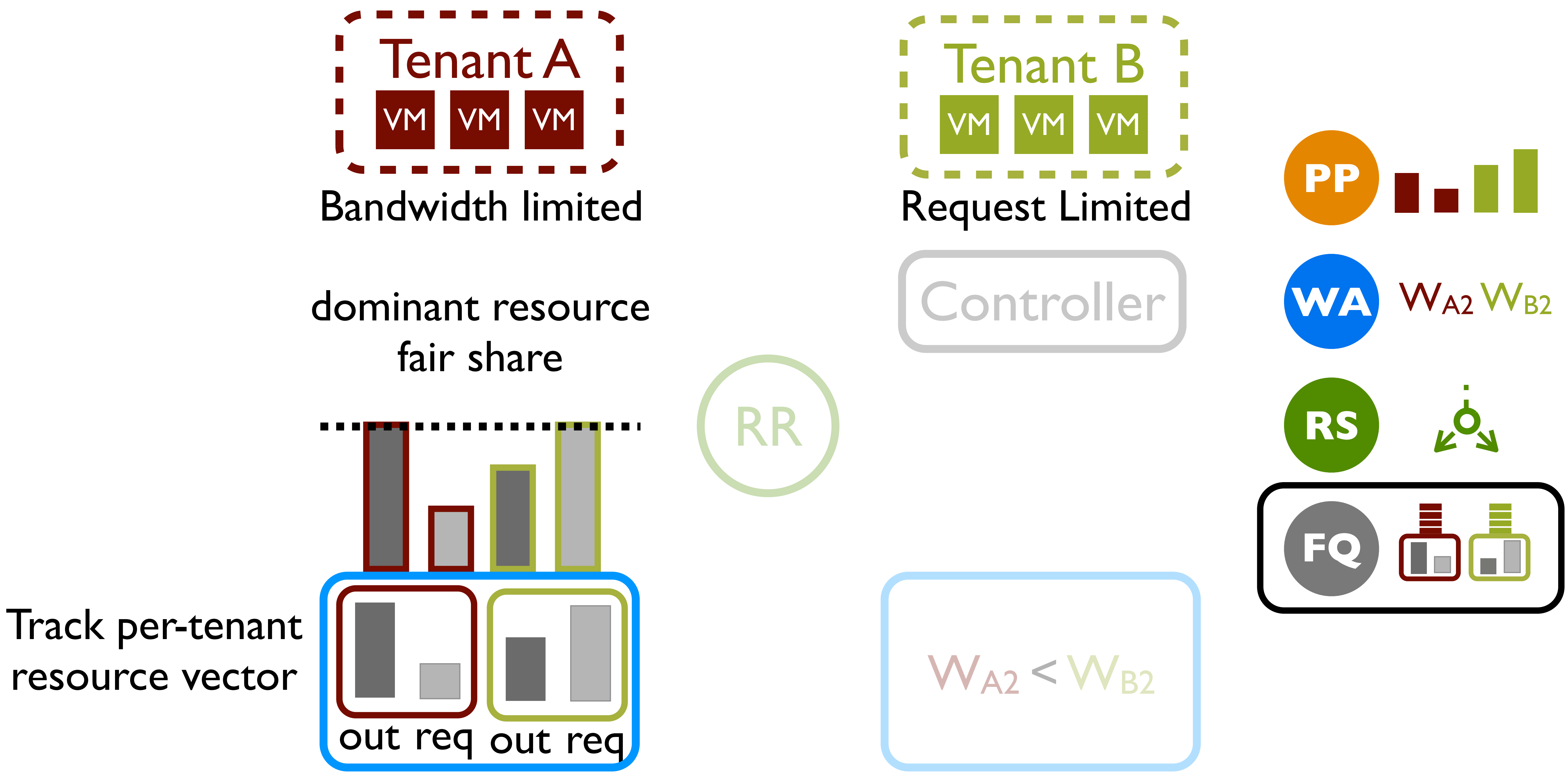
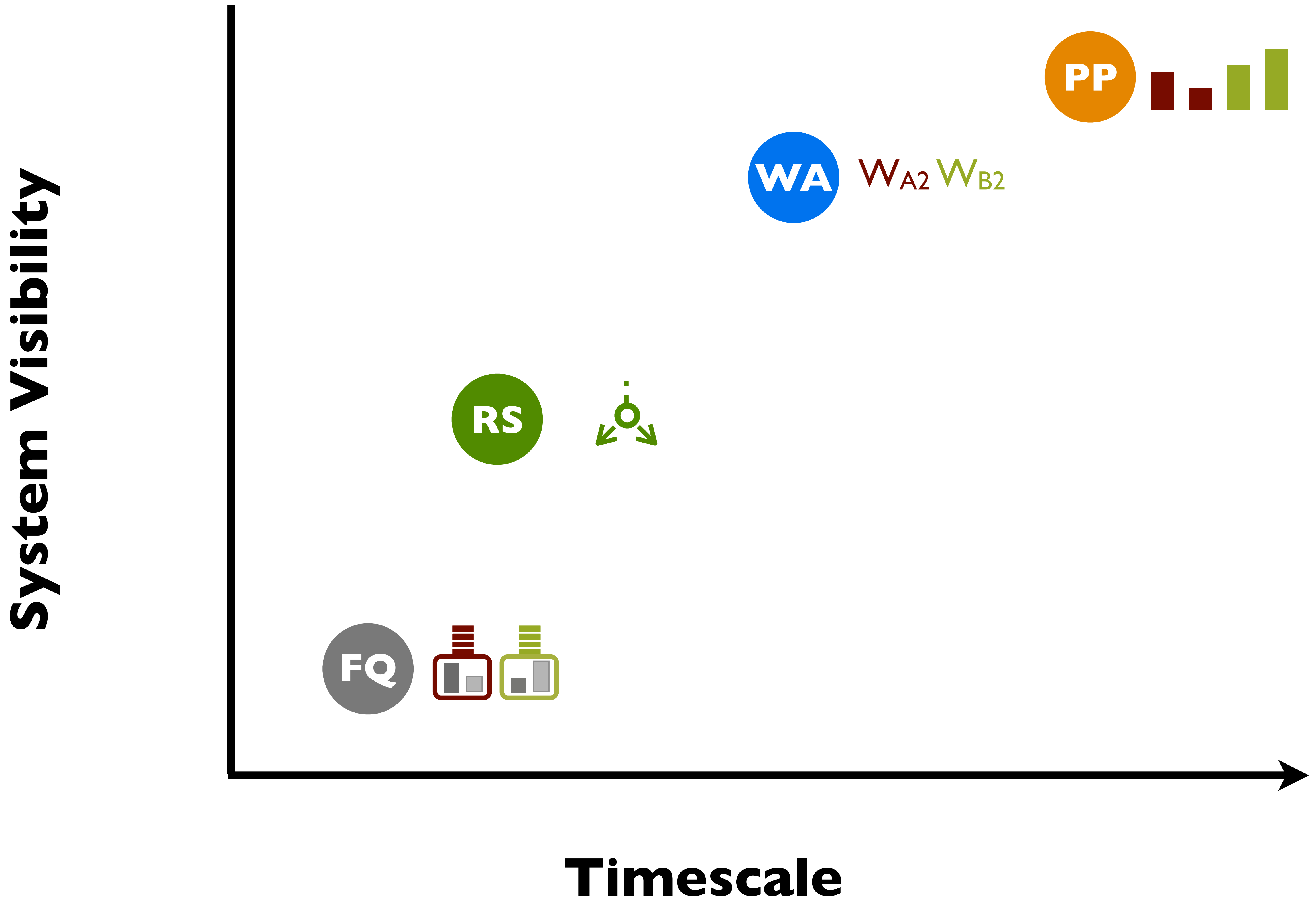


Pisces Mechanisms Solve For Global Fairness



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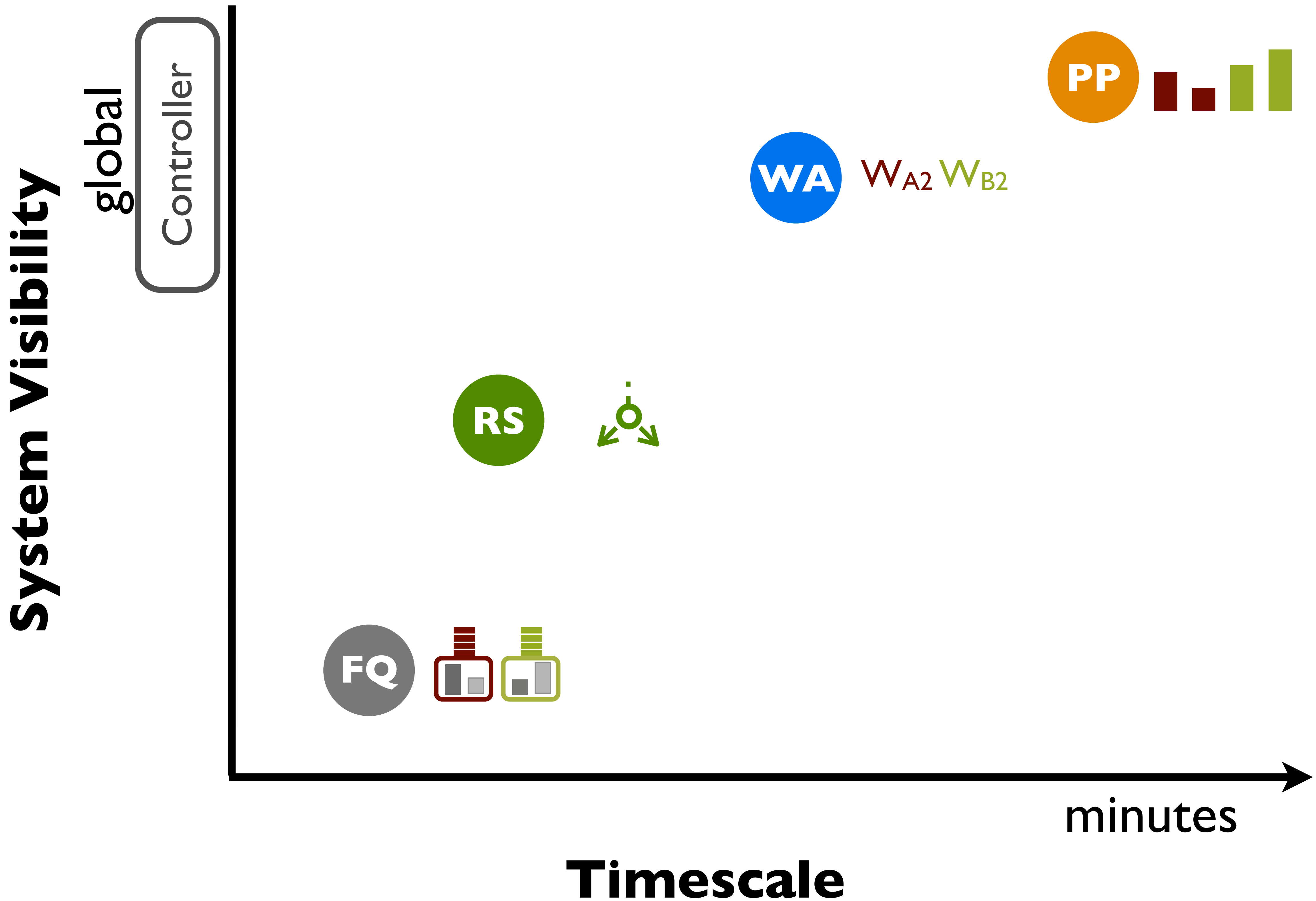

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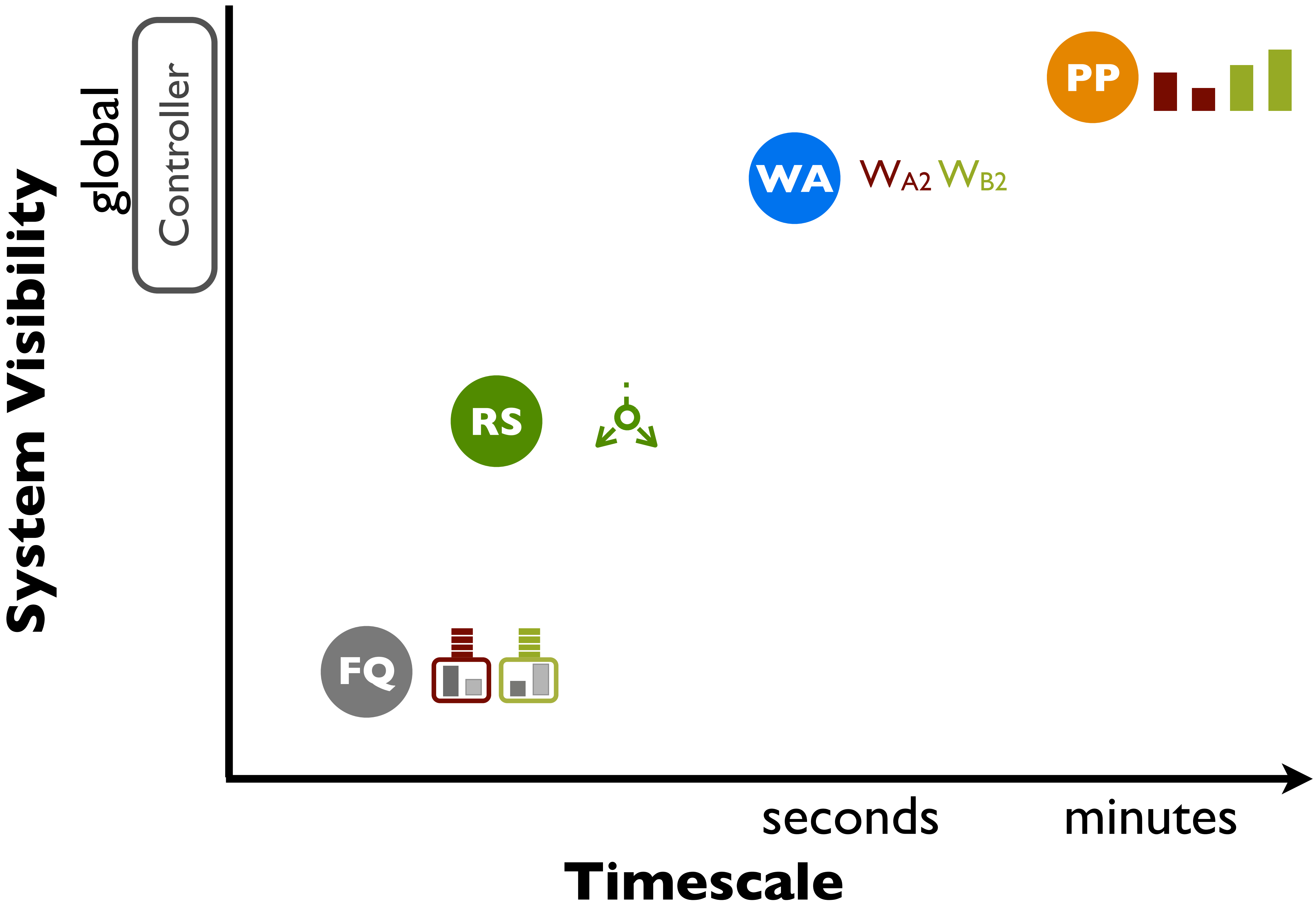

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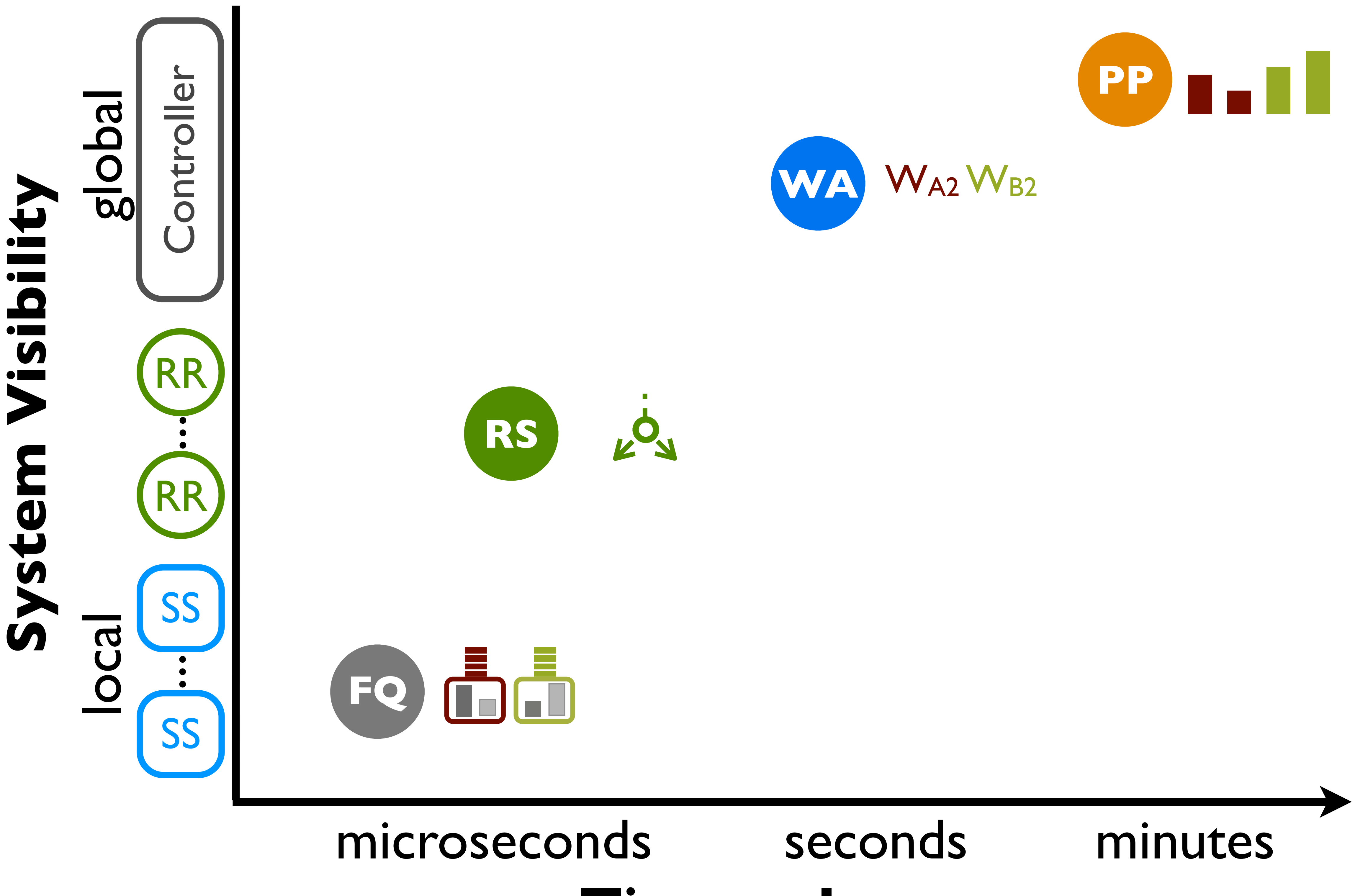

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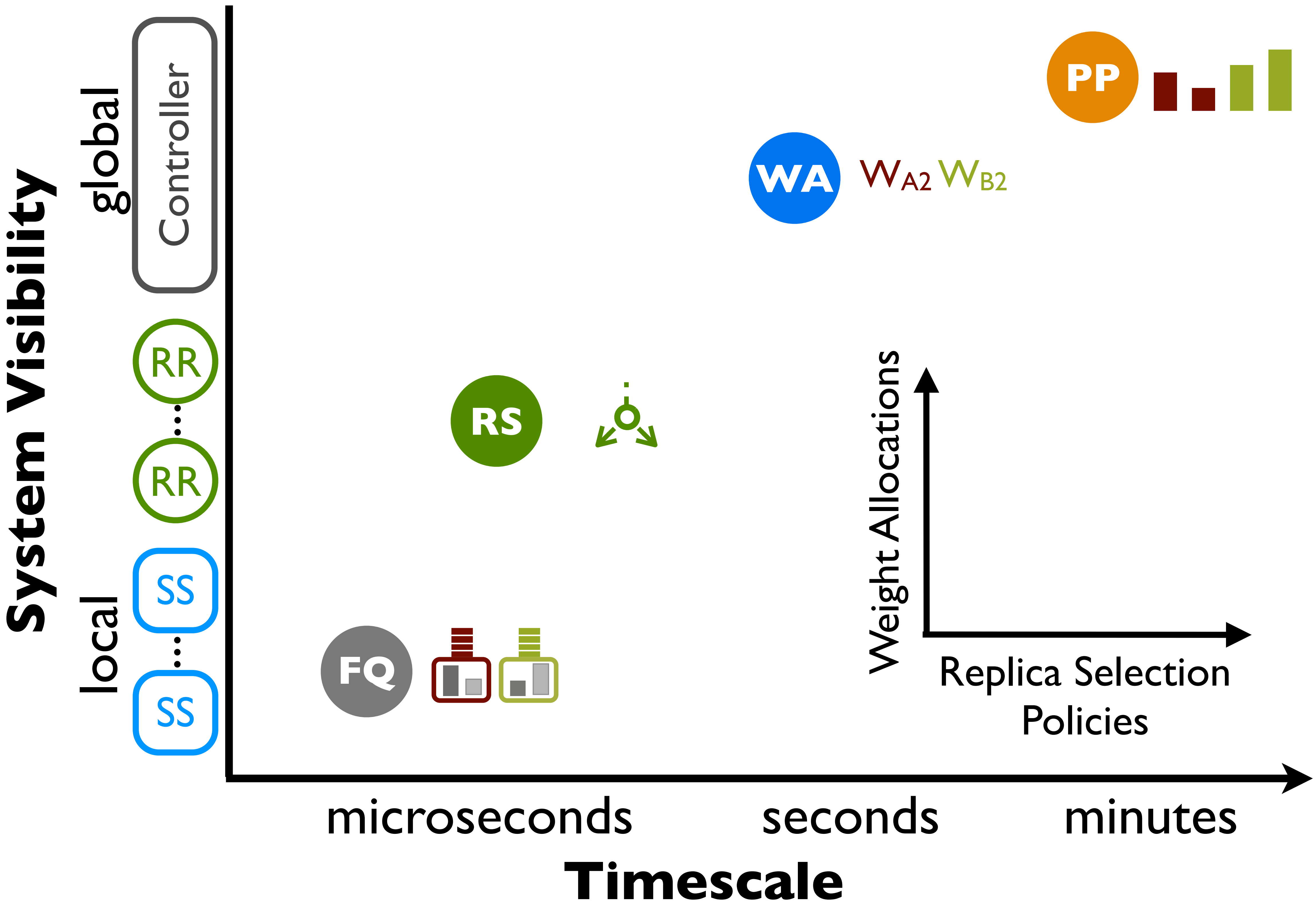

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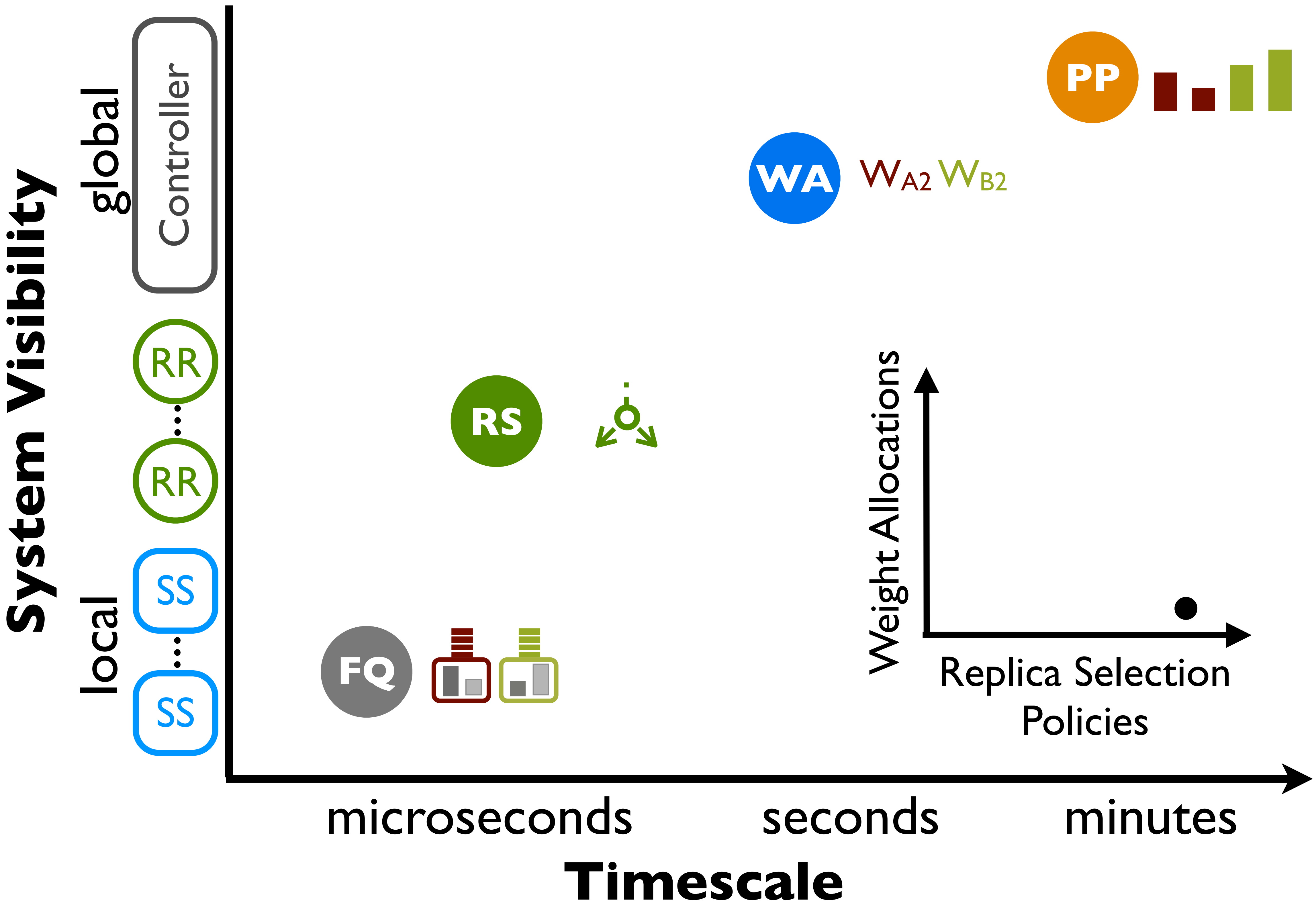

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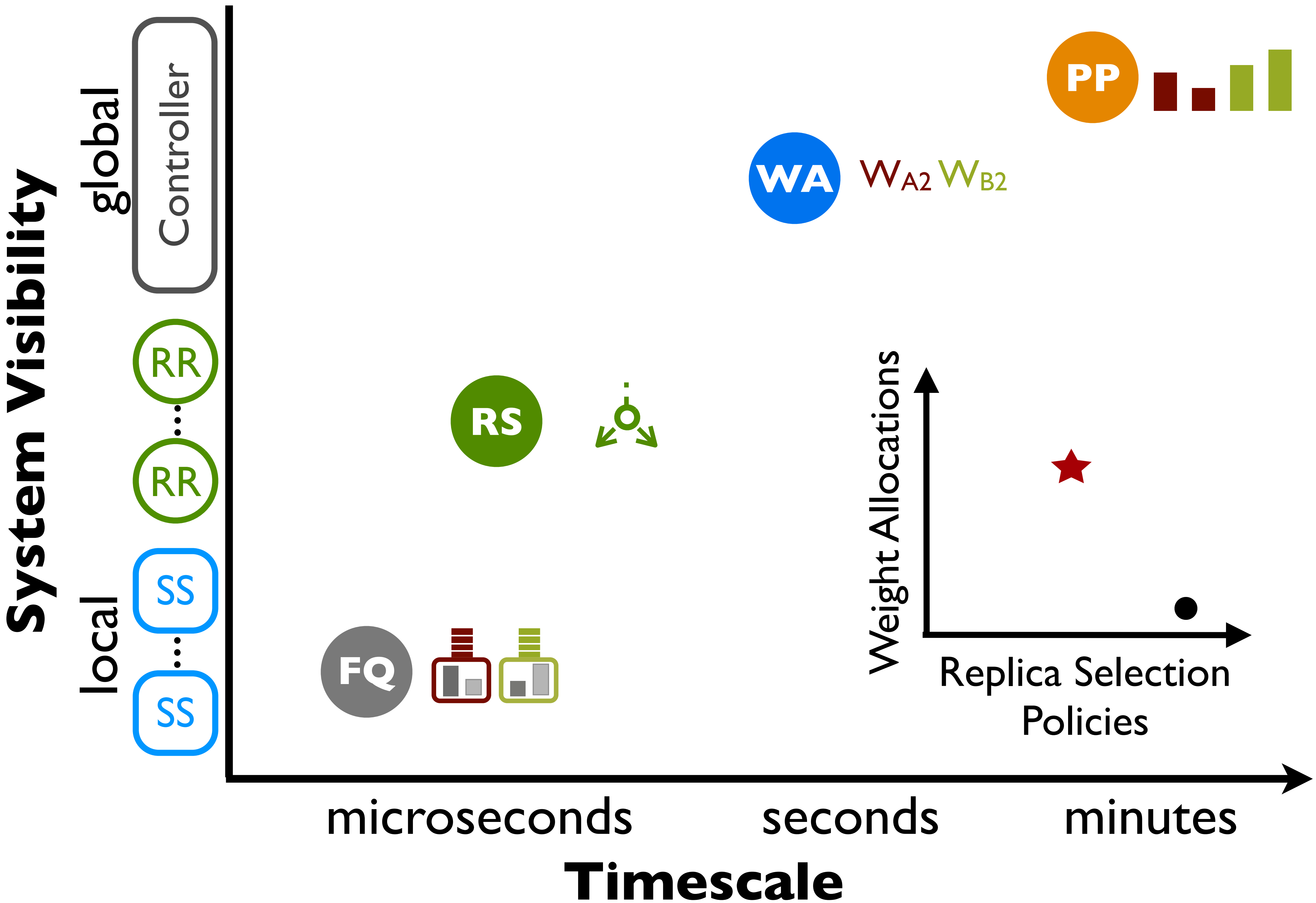

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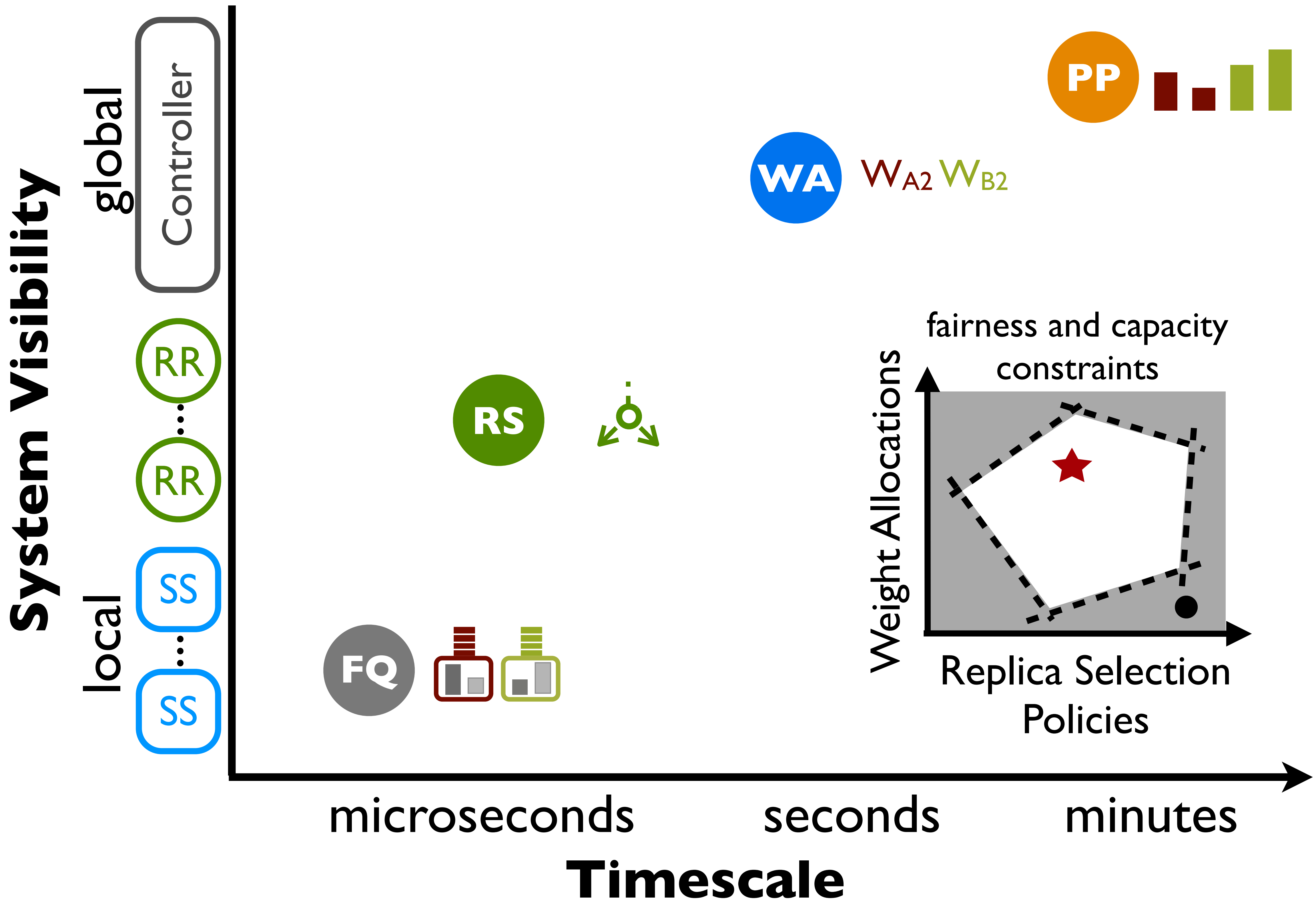

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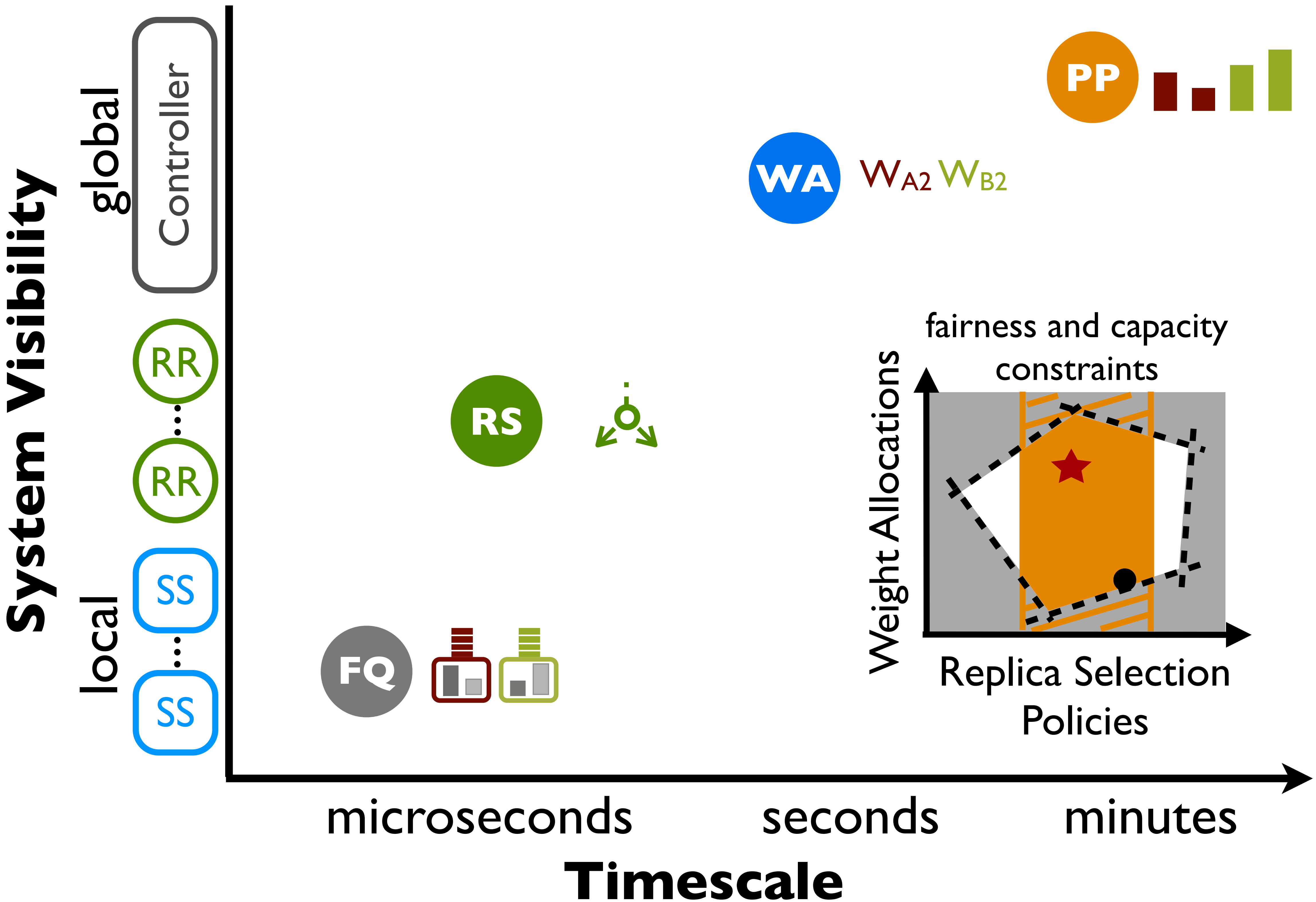

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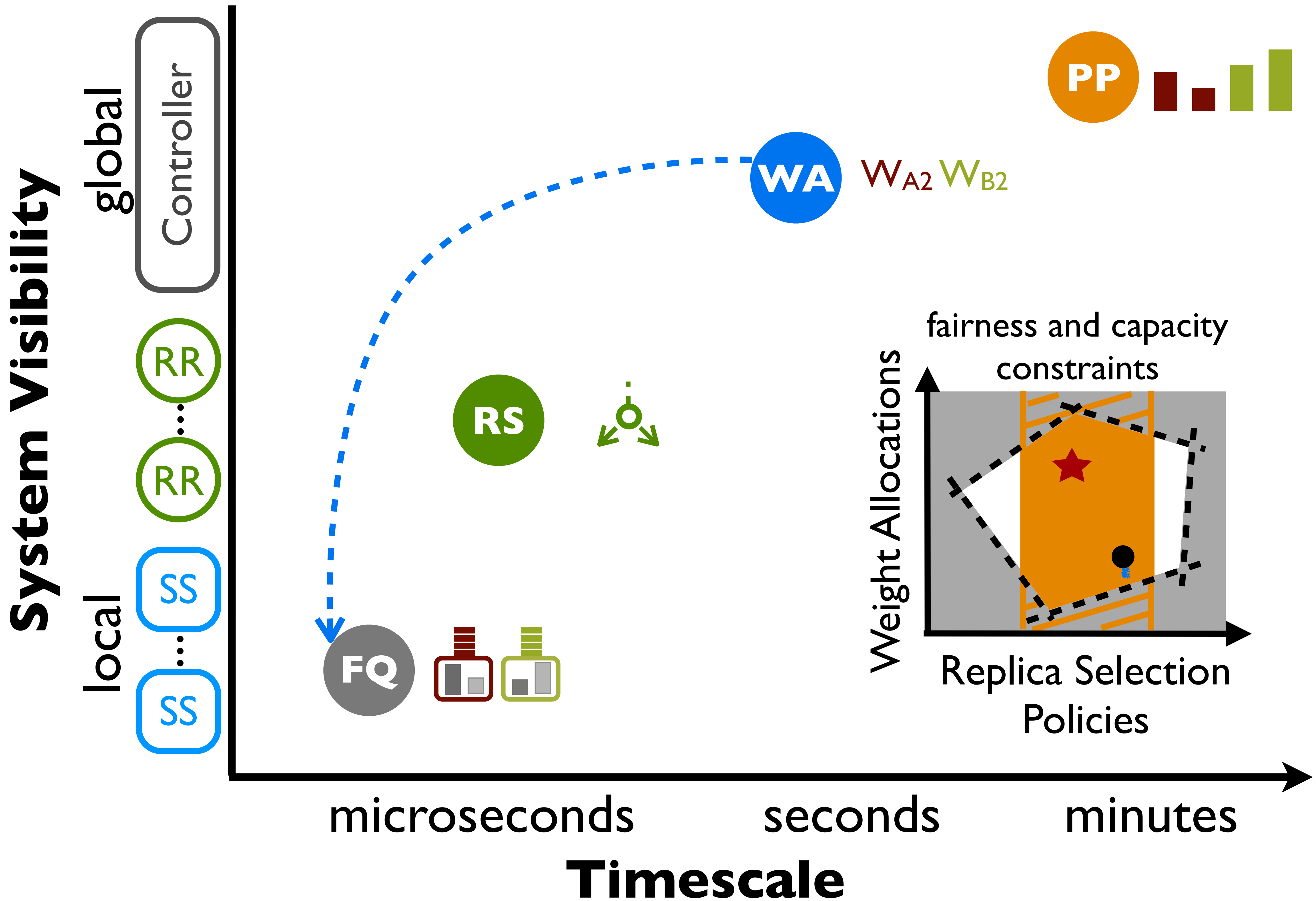

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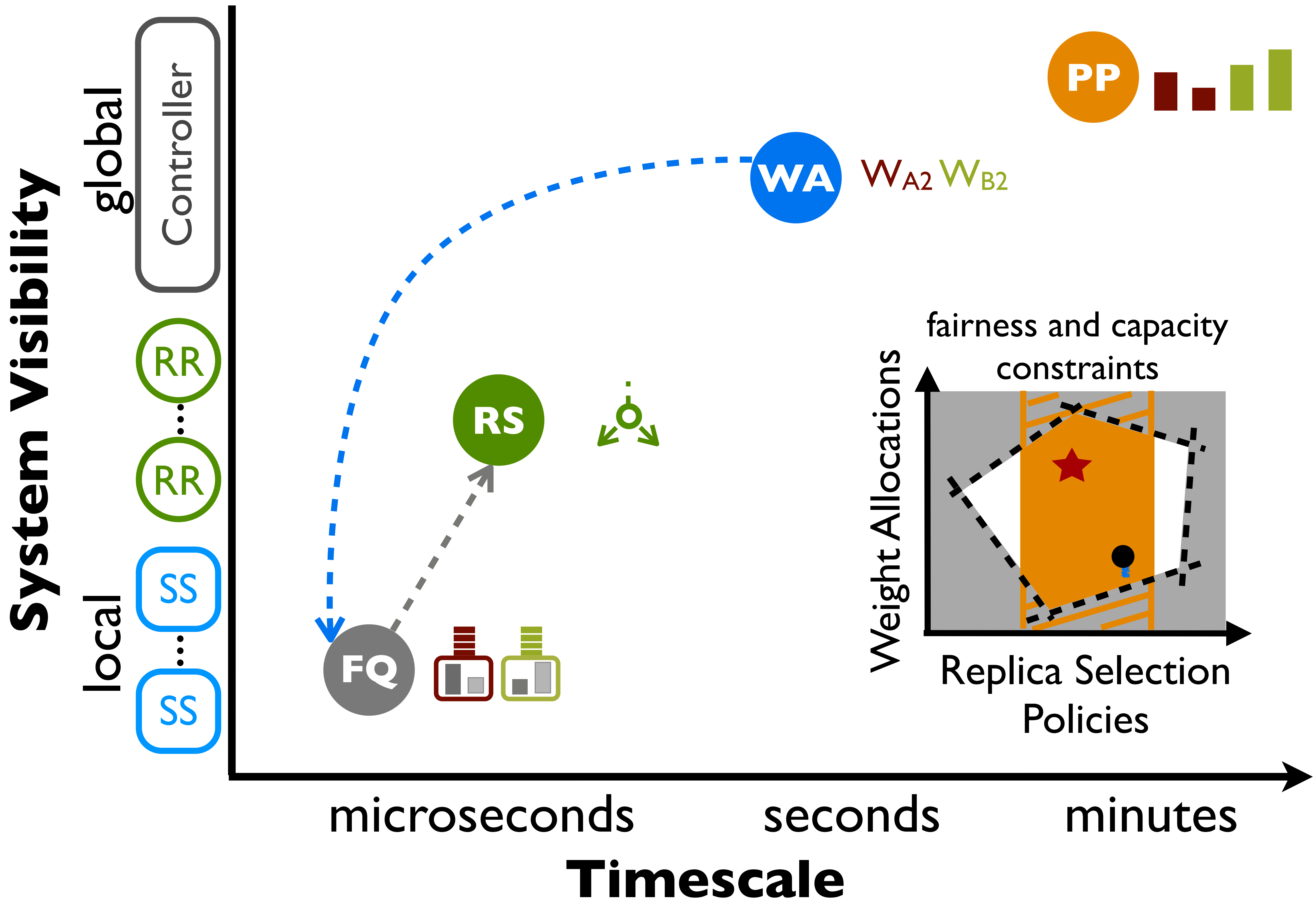

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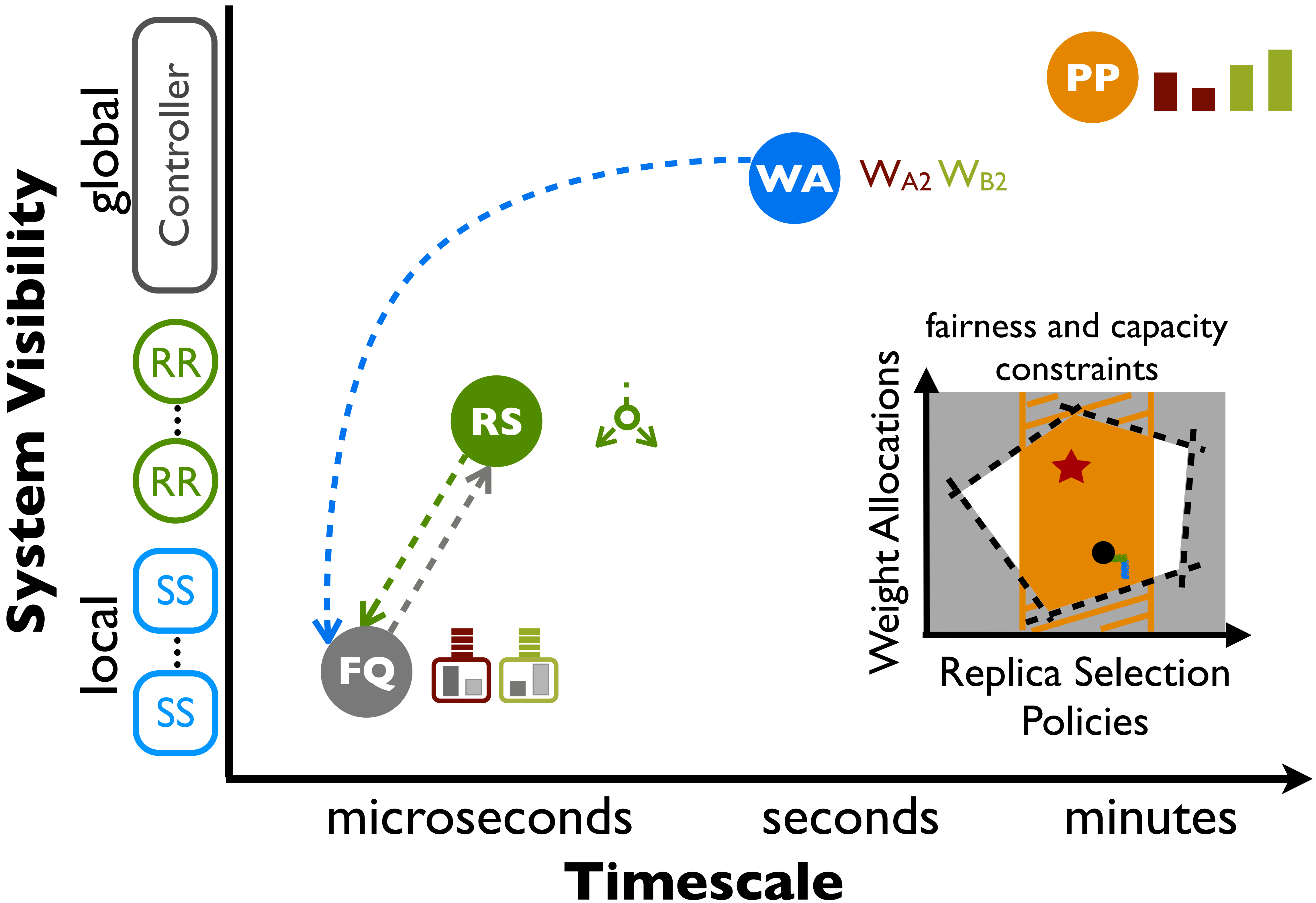

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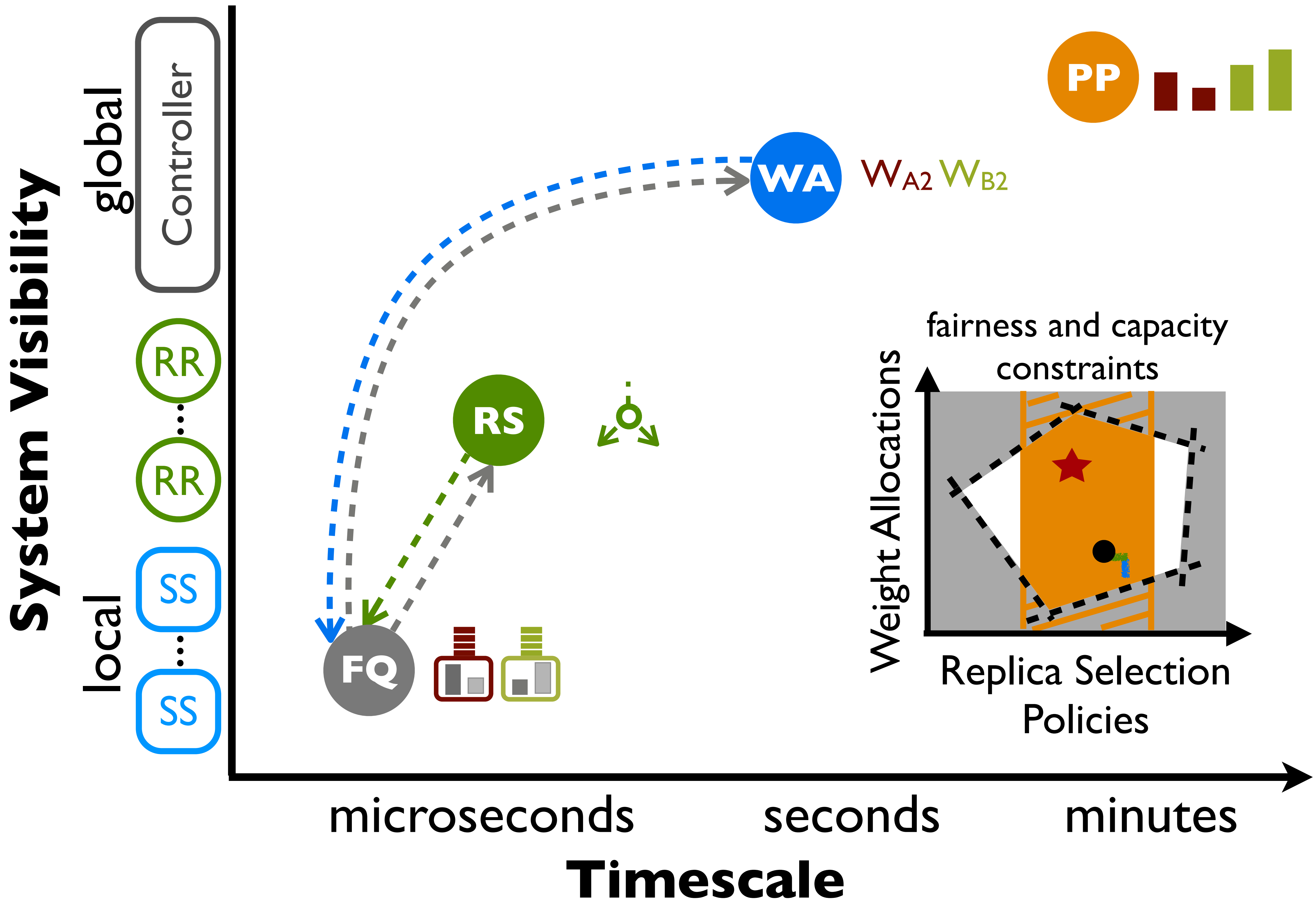

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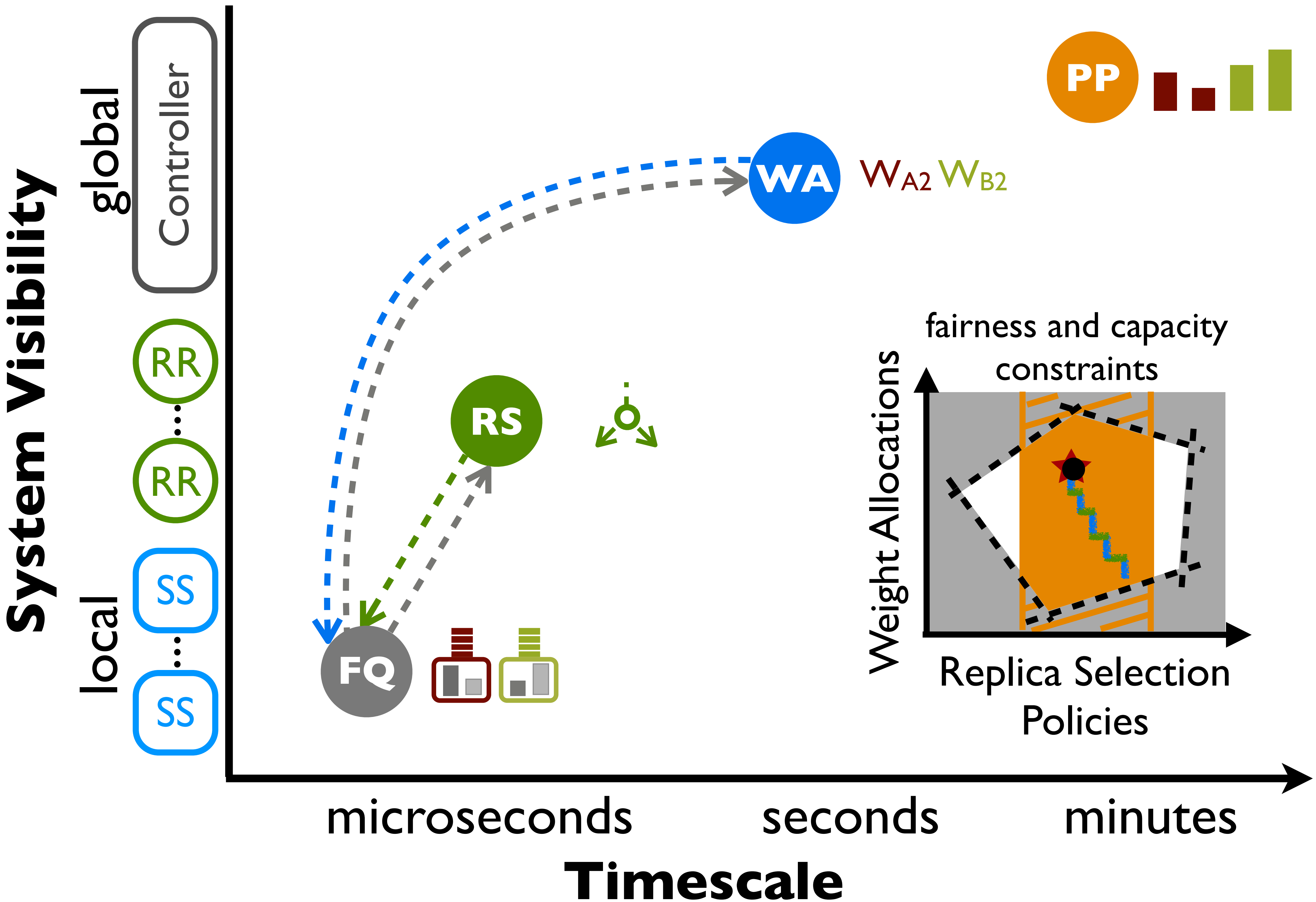

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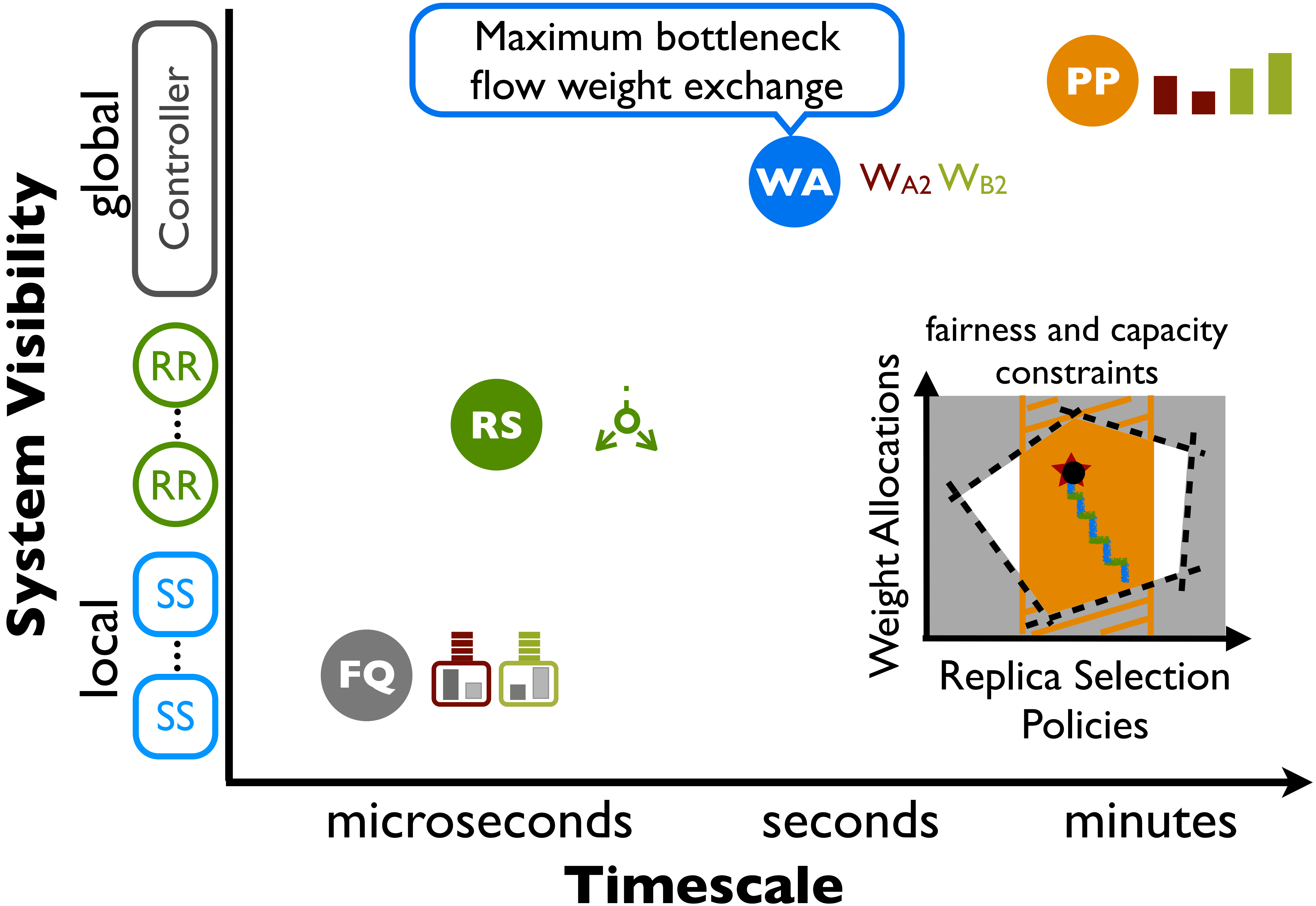

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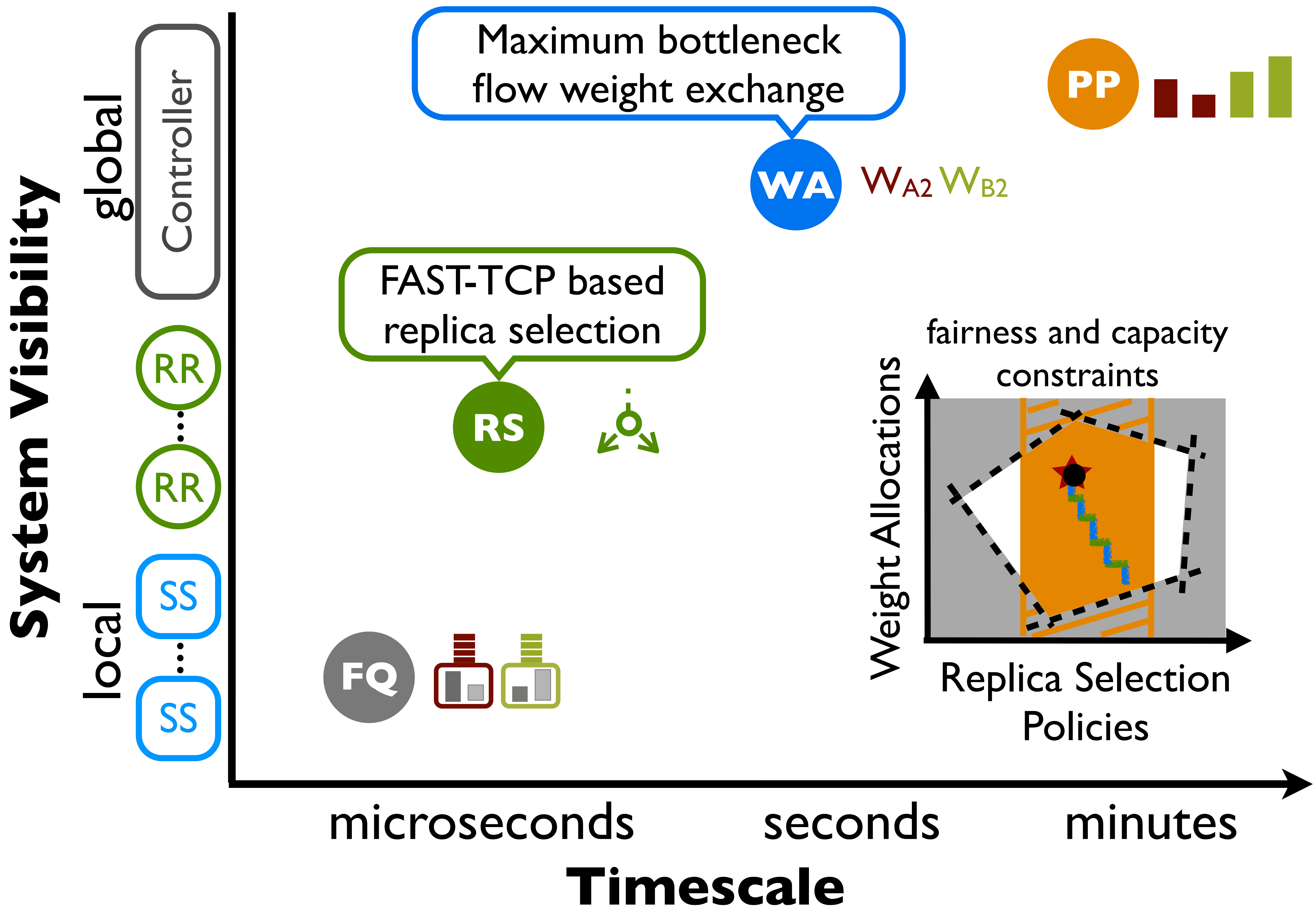

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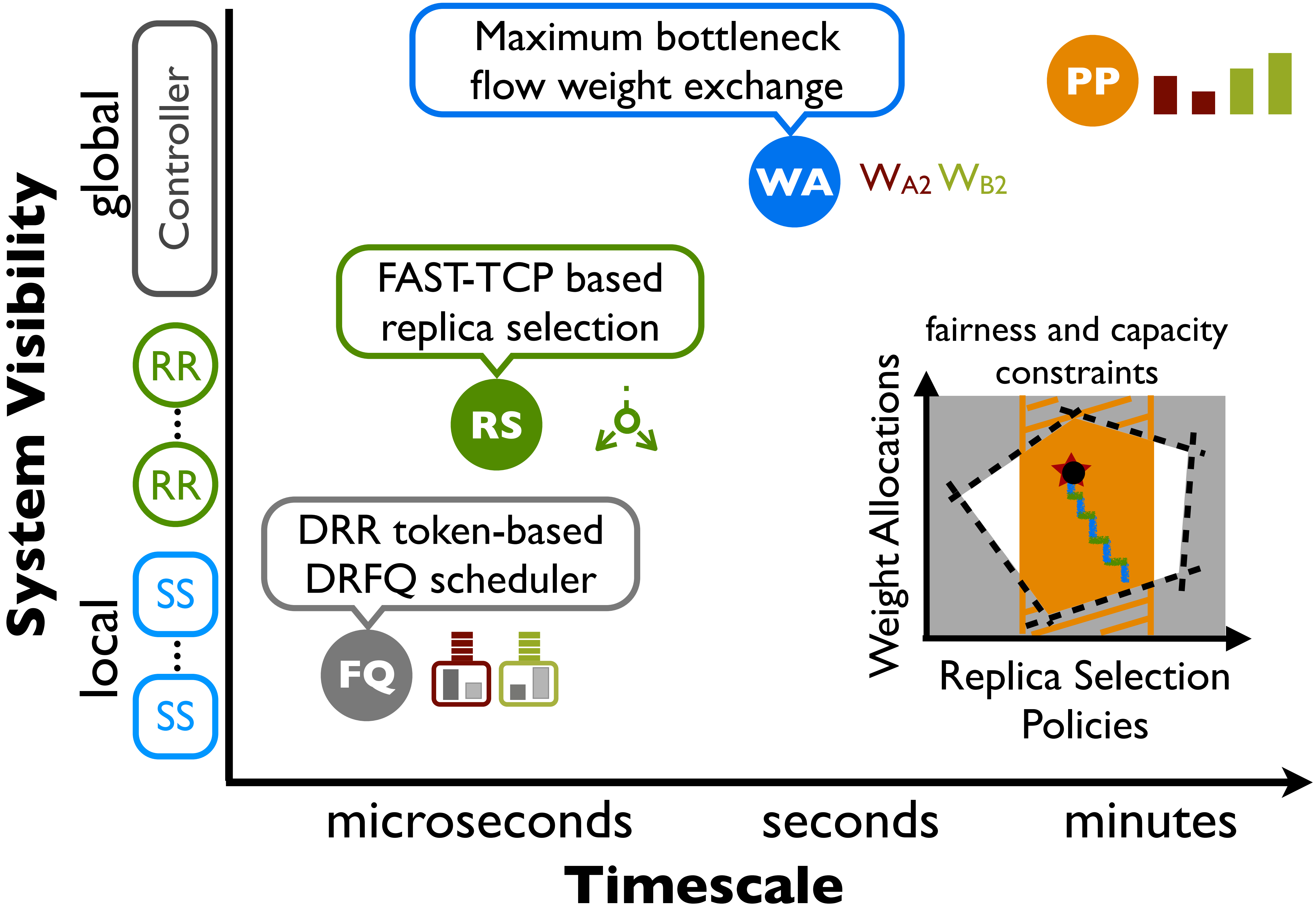

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- Does Pisces provide local dominant resource fairness?

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- Does Pisces provide local dominant resource fairness?
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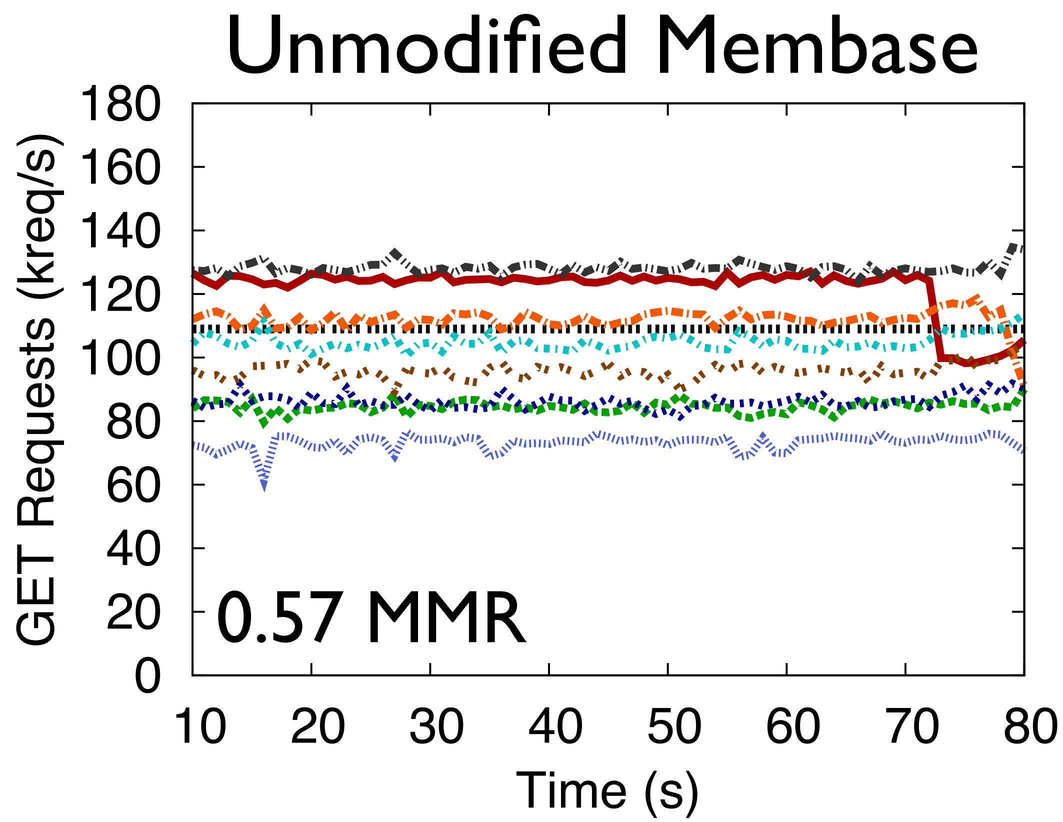
Pisces Achieves System-wide Per-tenant Fairness

Ideal fair share: 110 kreq/s (1kB requests)



8 Tenants - 8 Client - 8 Storage Nodes

Zipfian object popularity distribution

Min-Max Ratio: min rate/max rate (0,1]

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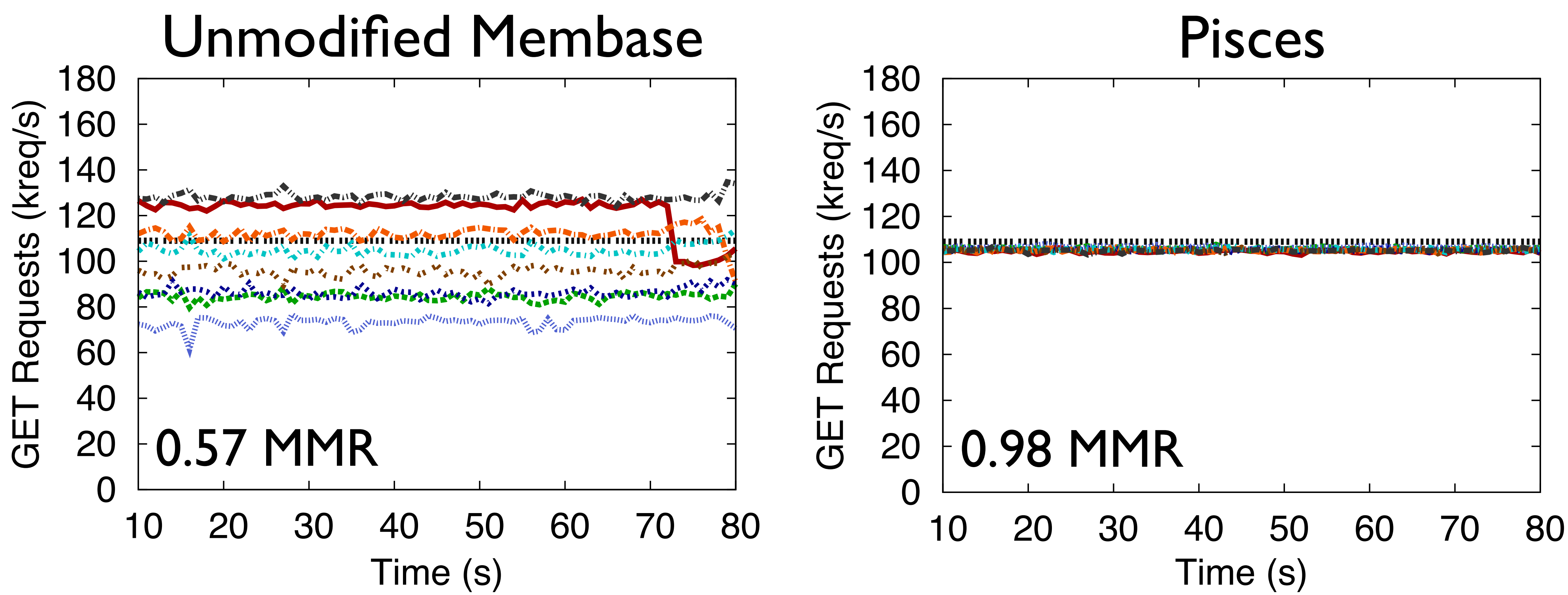

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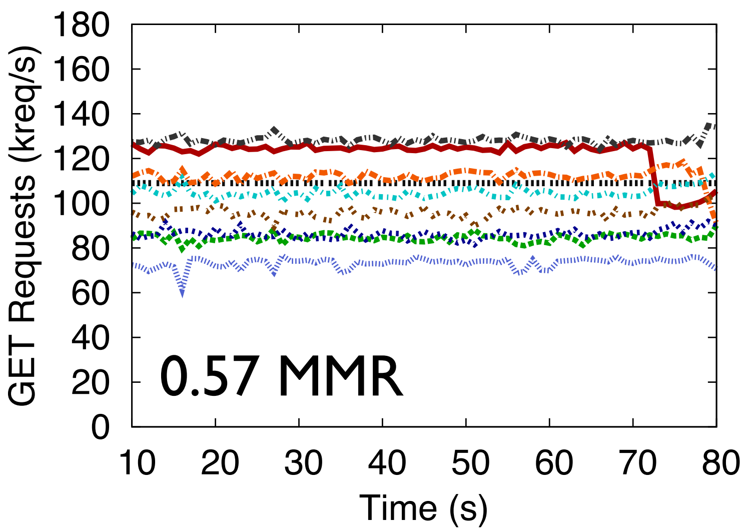
Each Pisces Mechanism Contributes to System-wide Fairness and Isolation

Unmodified Membase



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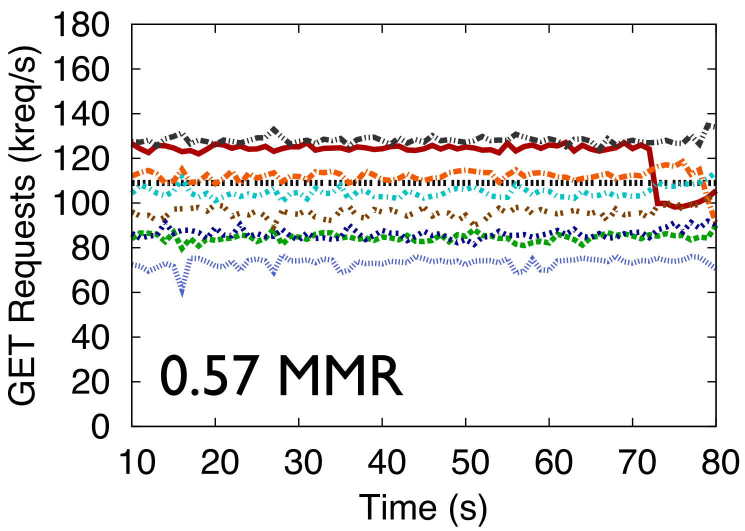
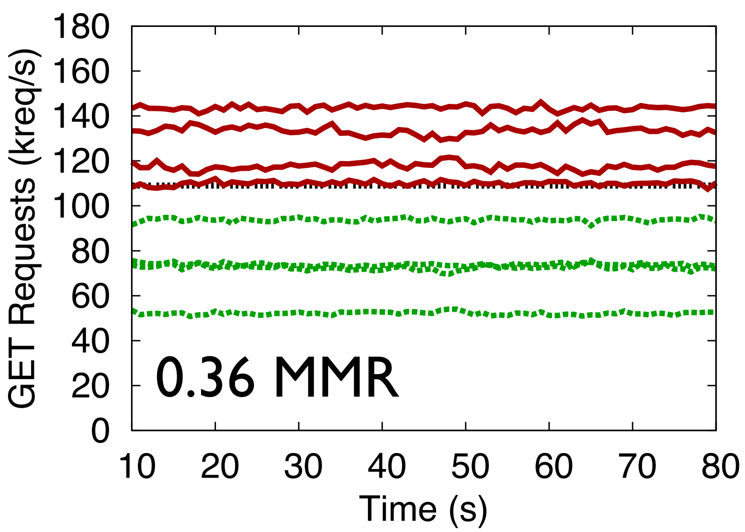


2x vs 1x demand



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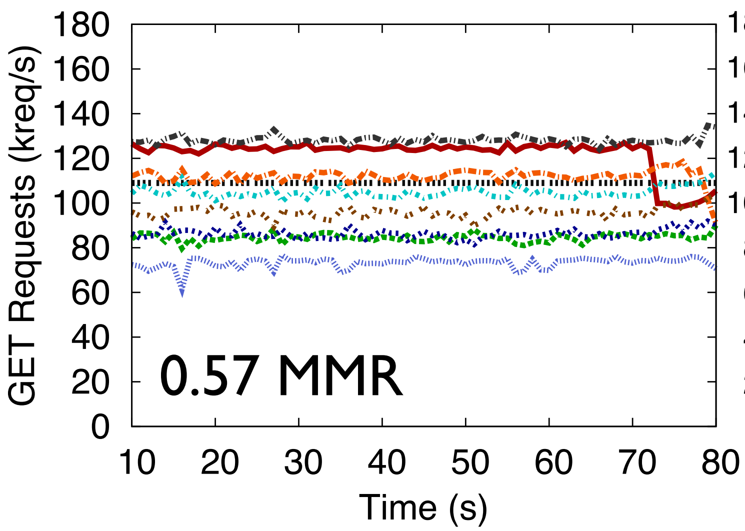
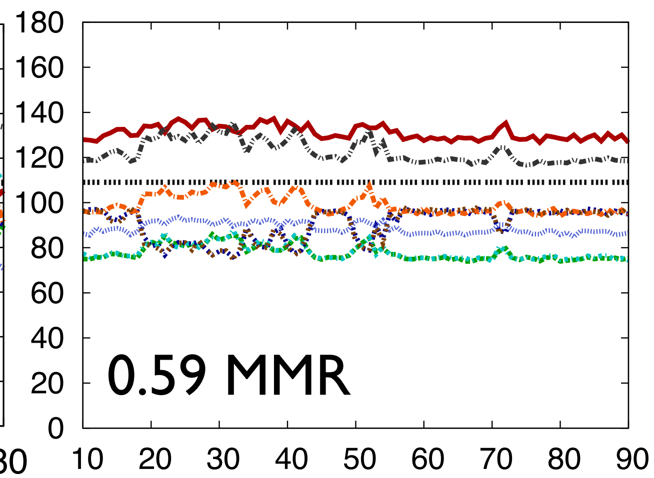
FQ





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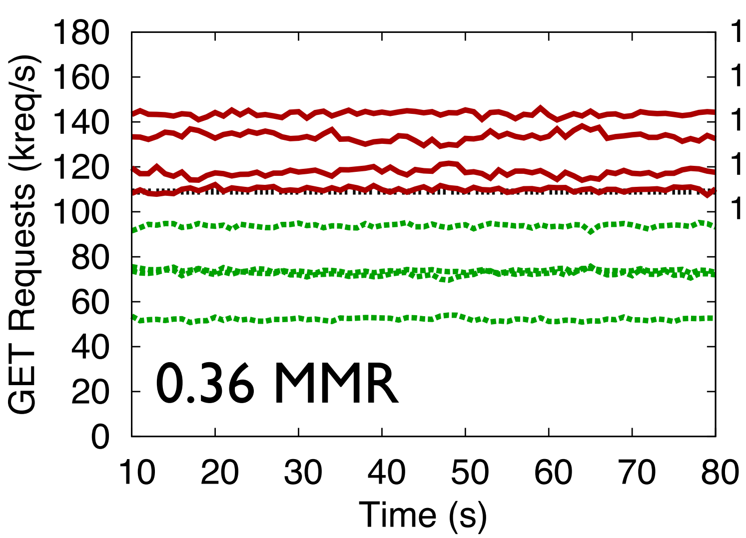

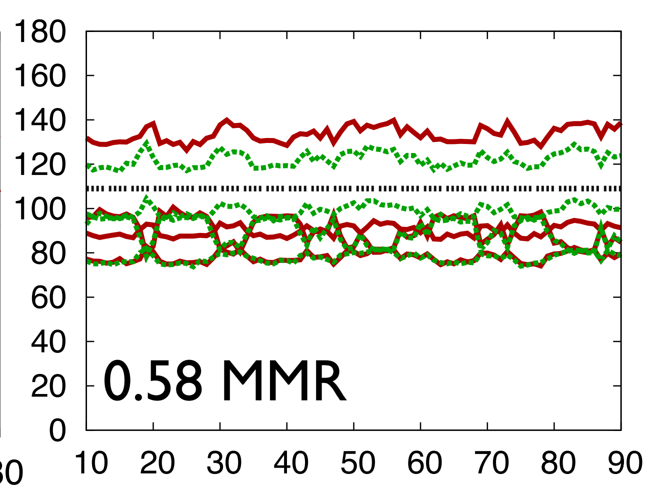

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FQ

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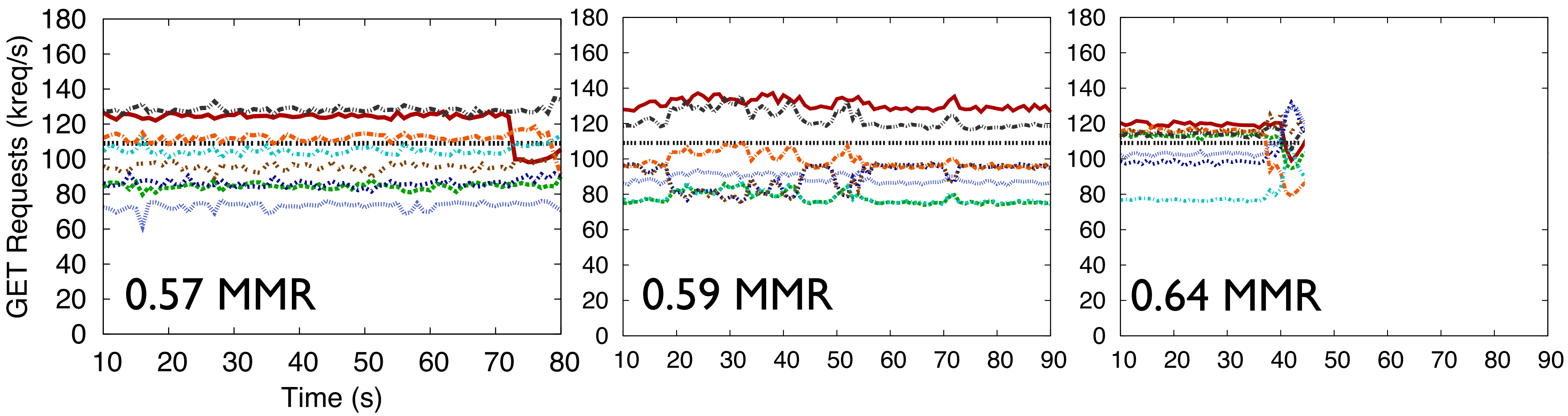
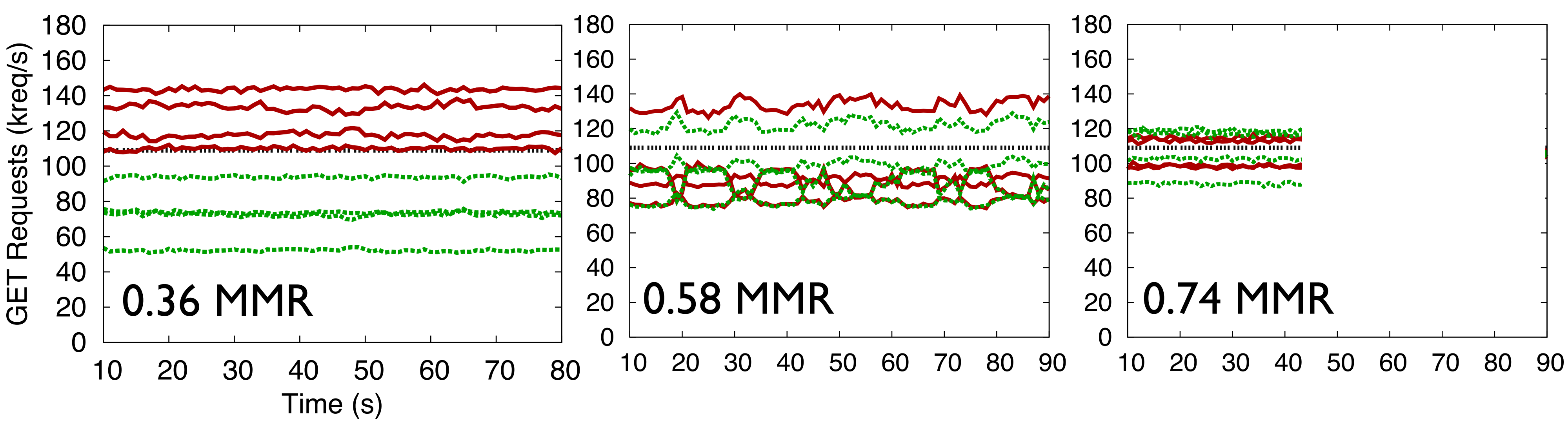


2x vs 1x demand



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Unmodified Membase

FQ

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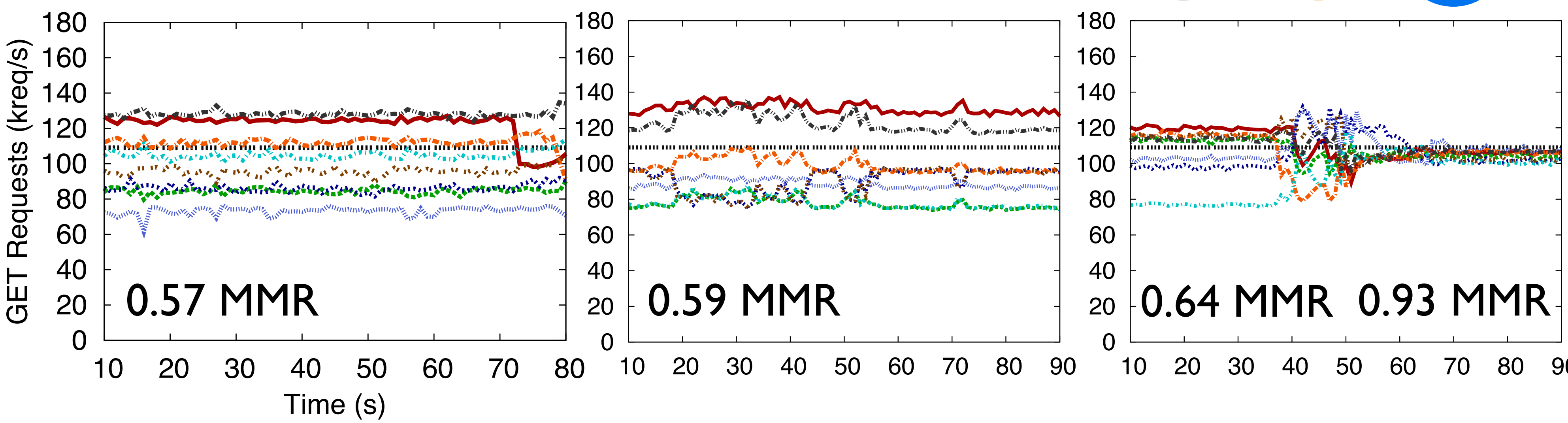

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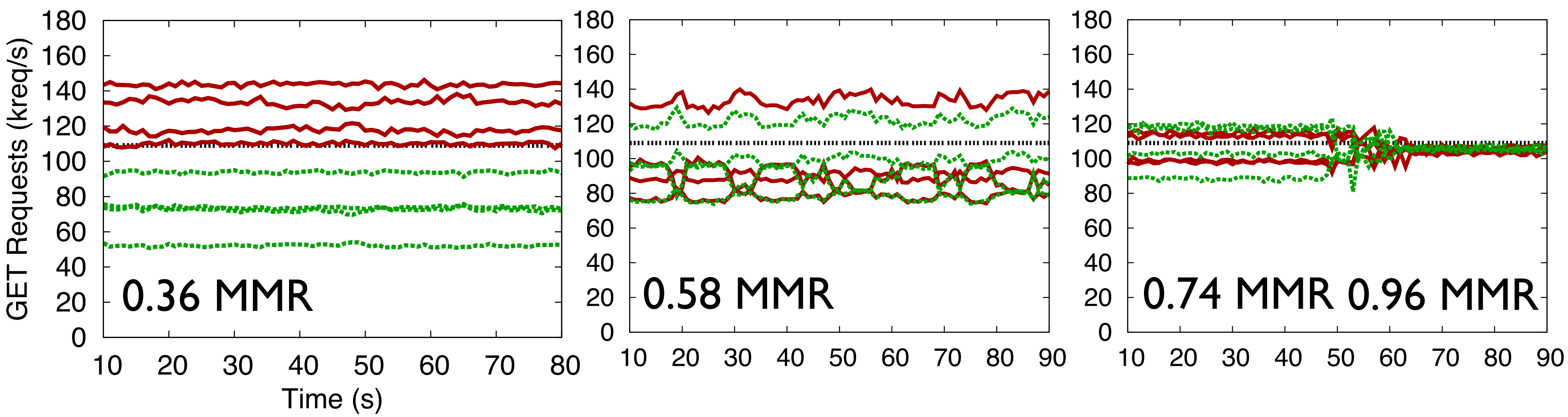

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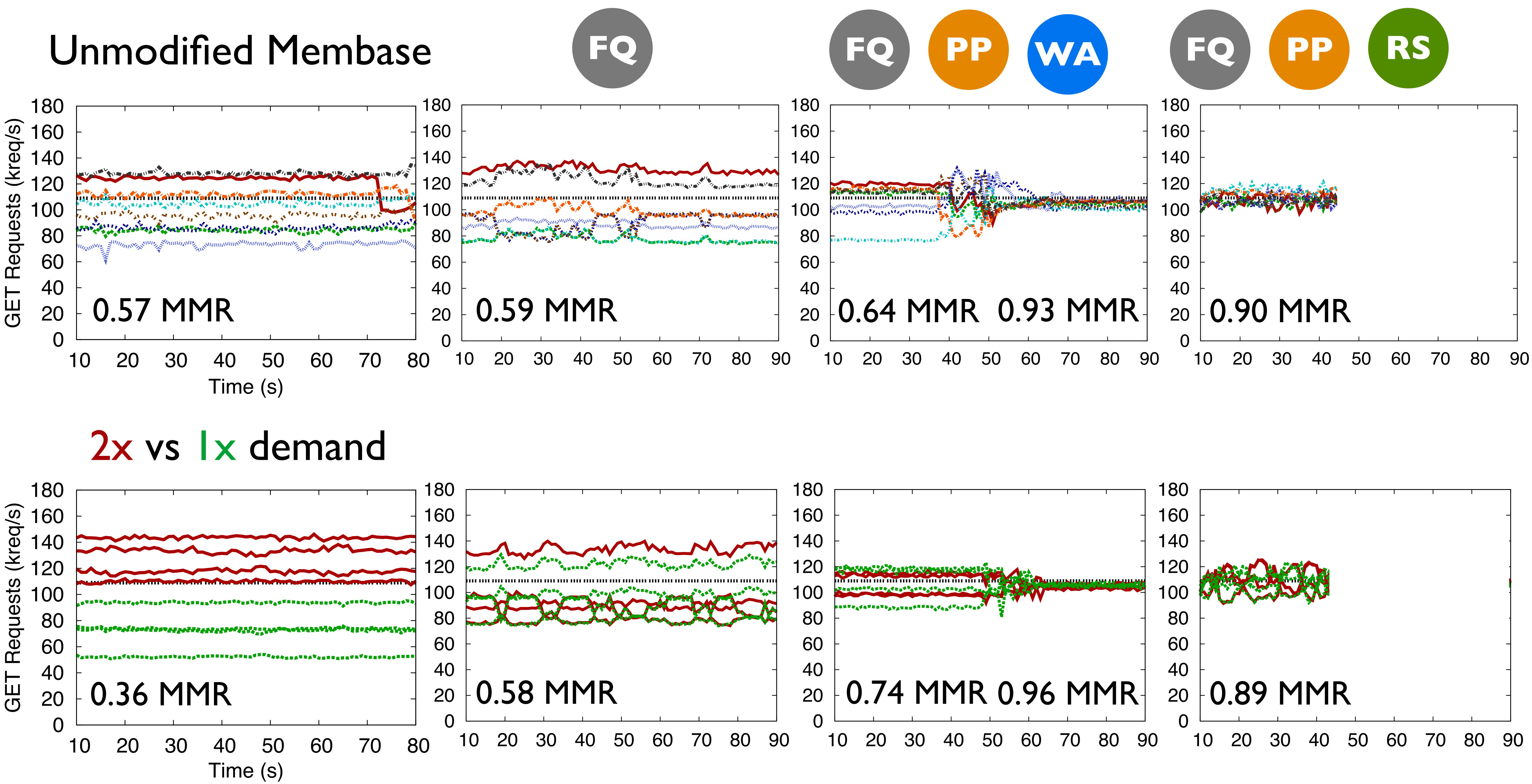
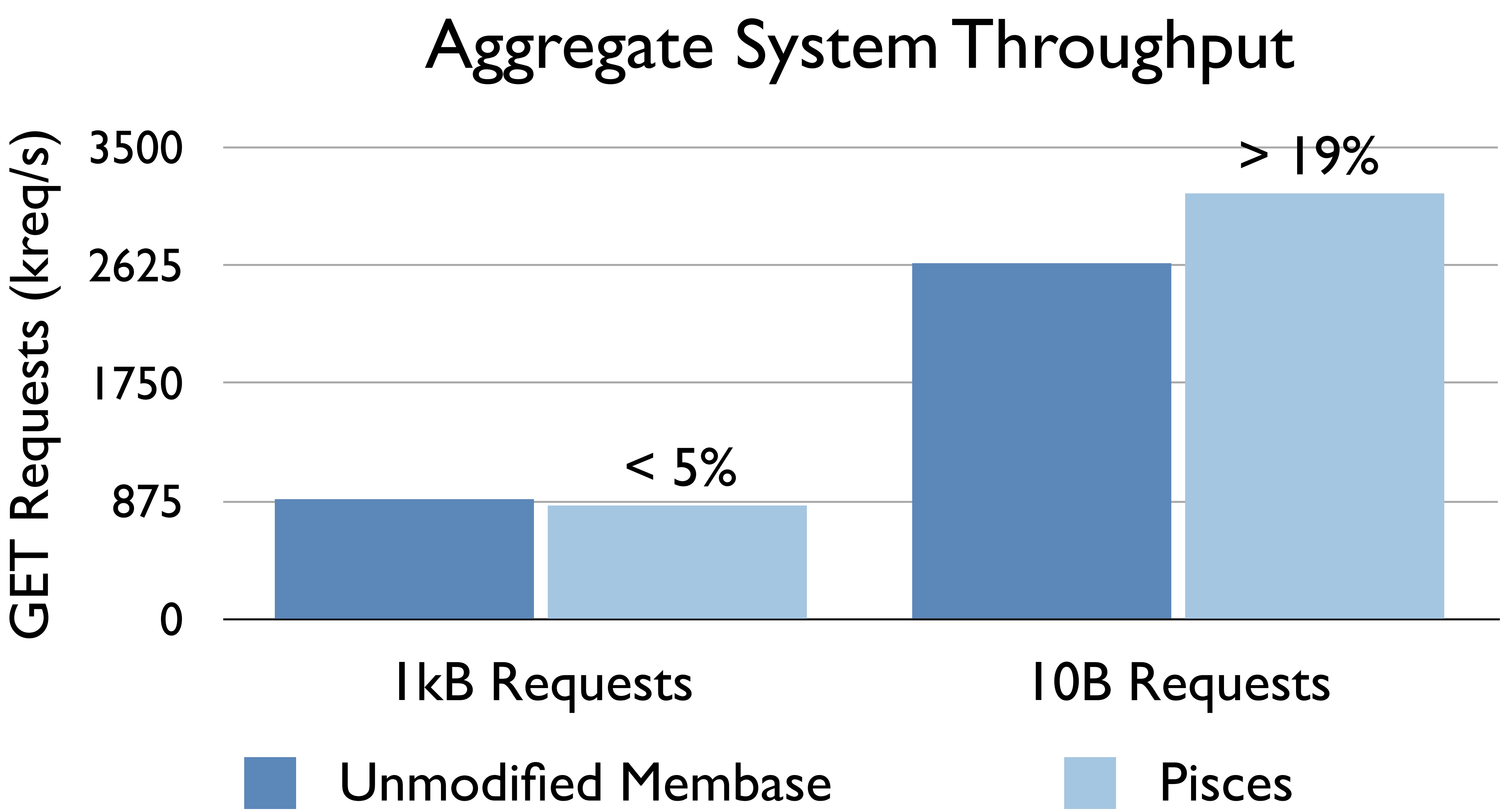


Each Pisces Mechanism Contributes to System-wide Fairness and Isolation

Pisces Imposes Low-overhead



Pisces Achieves System-wide Weighted Fairness

4 heavy hitters   20 moderate demand   40 low demand

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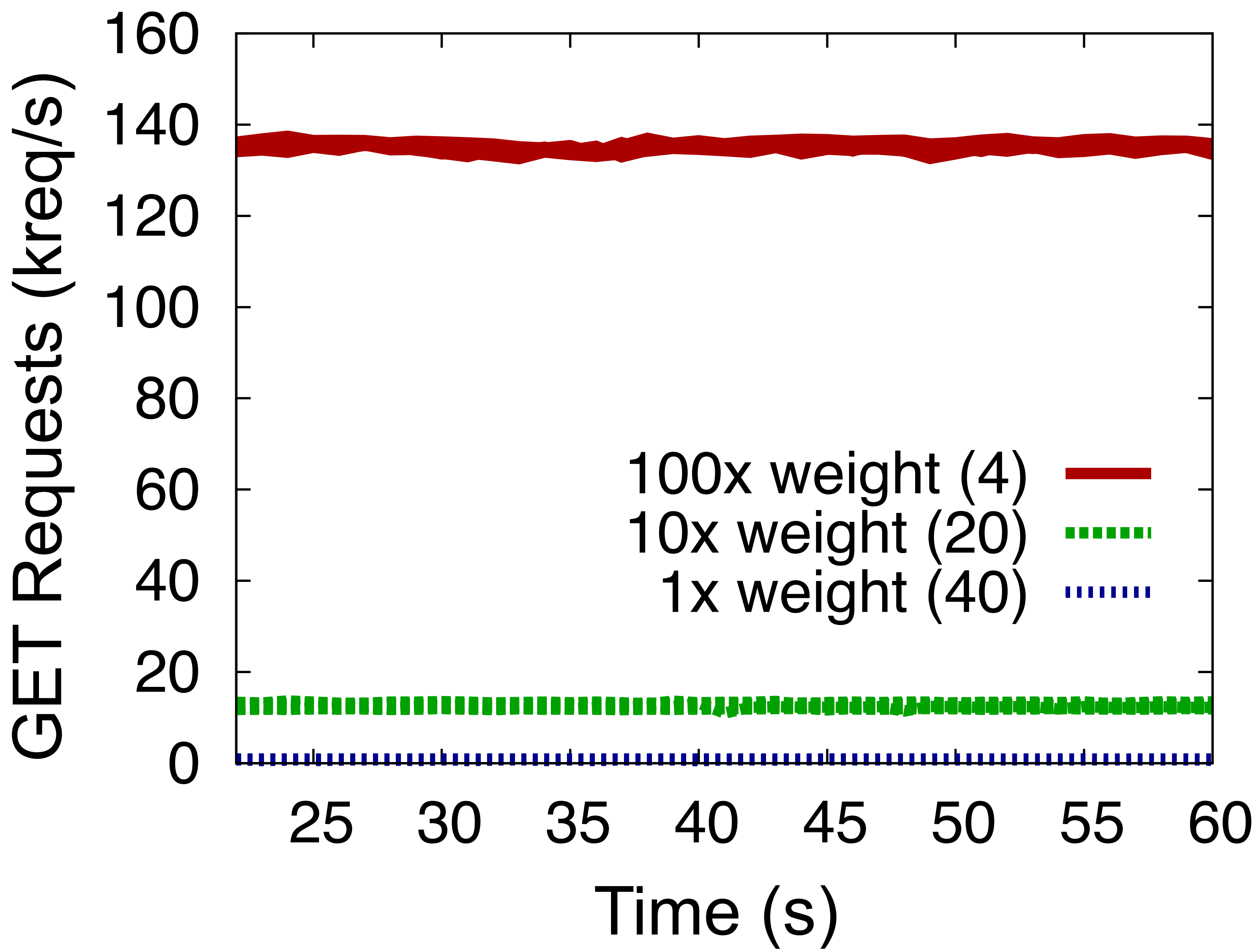

Pisces Achieves System-wide Weighted Fairness

0.98 MMR	0.89 MMR	0.91 MMR
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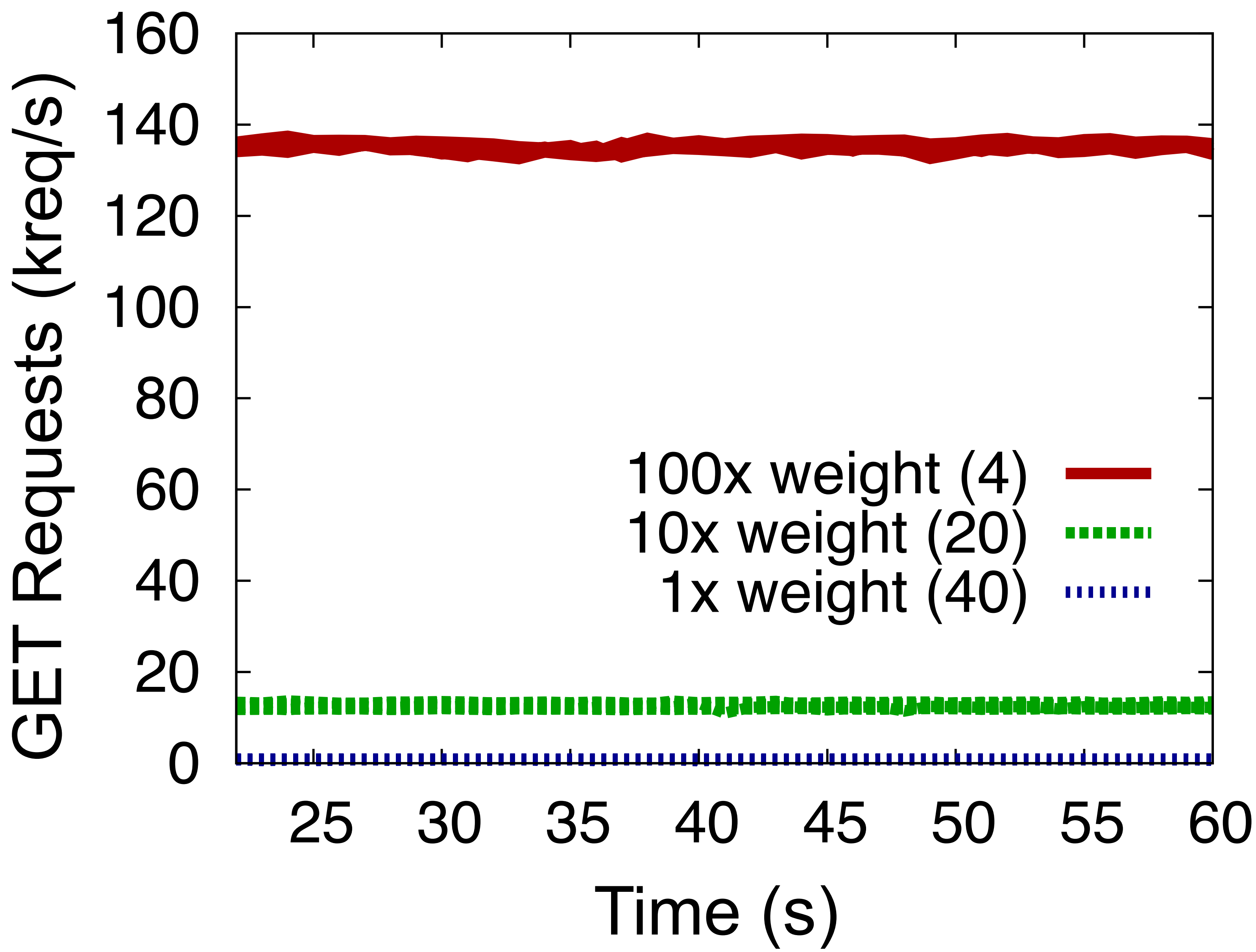

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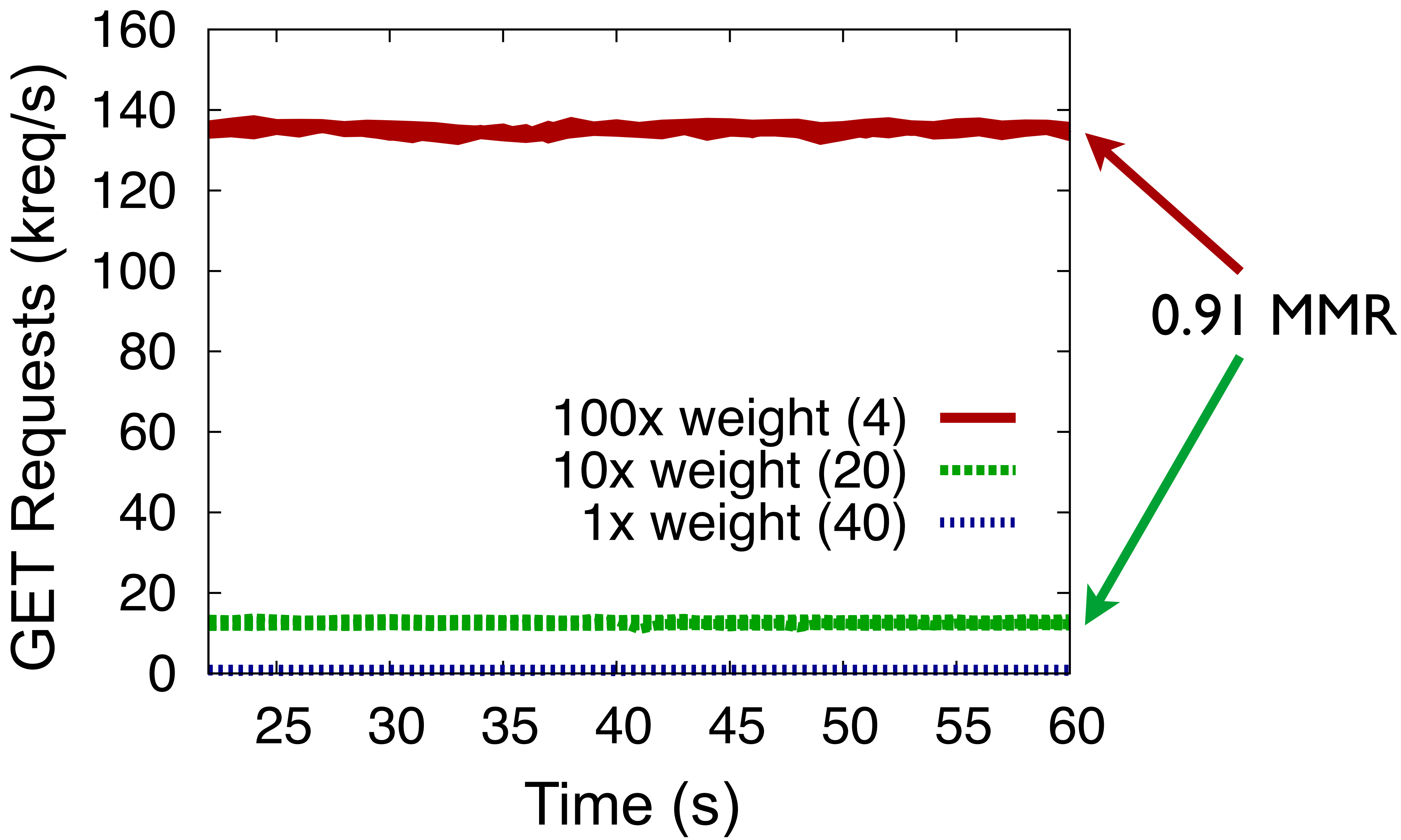

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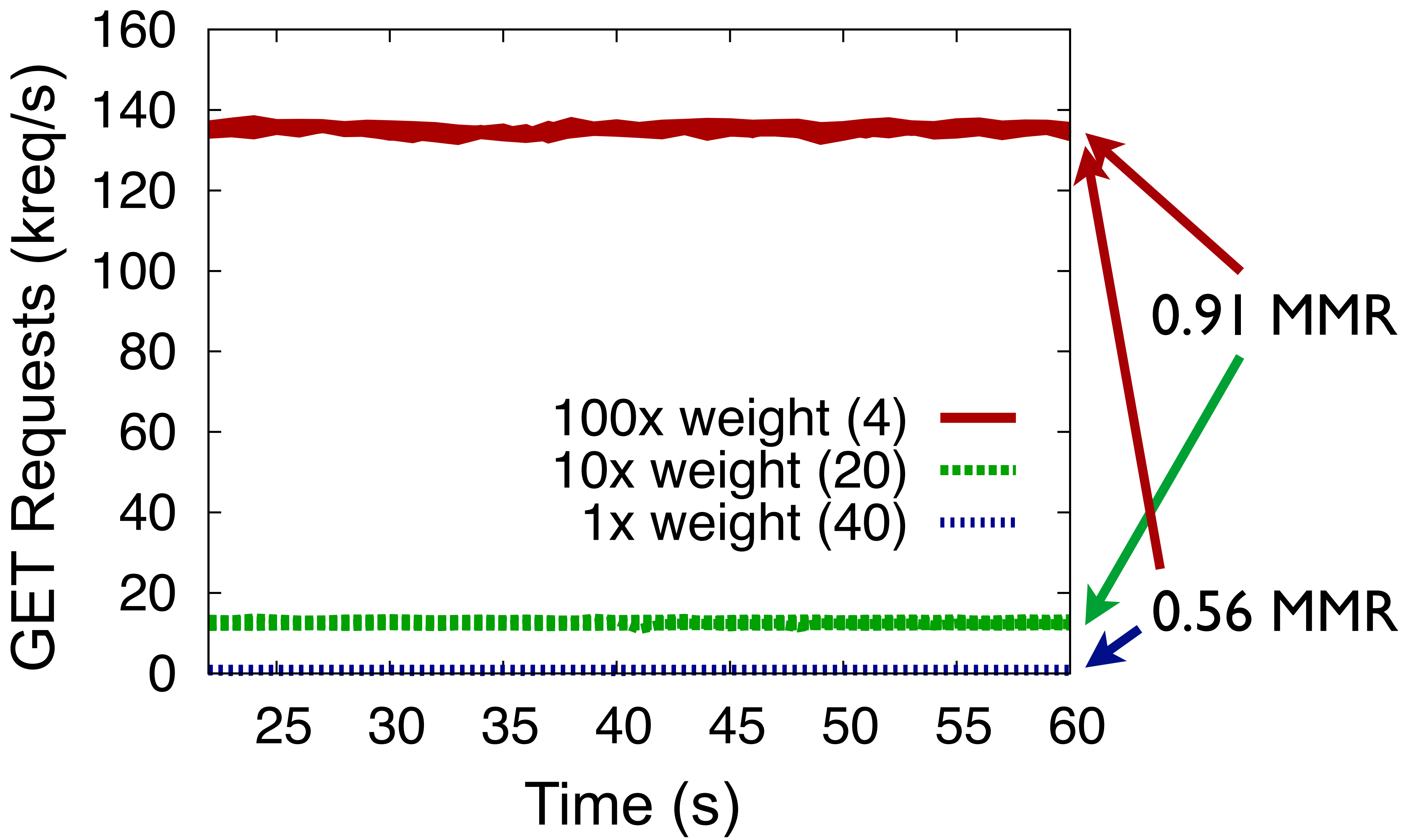

Pisces Achieves Dominant Resource Fairness

1kB workload
bandwidth limited

10B workload
request limited

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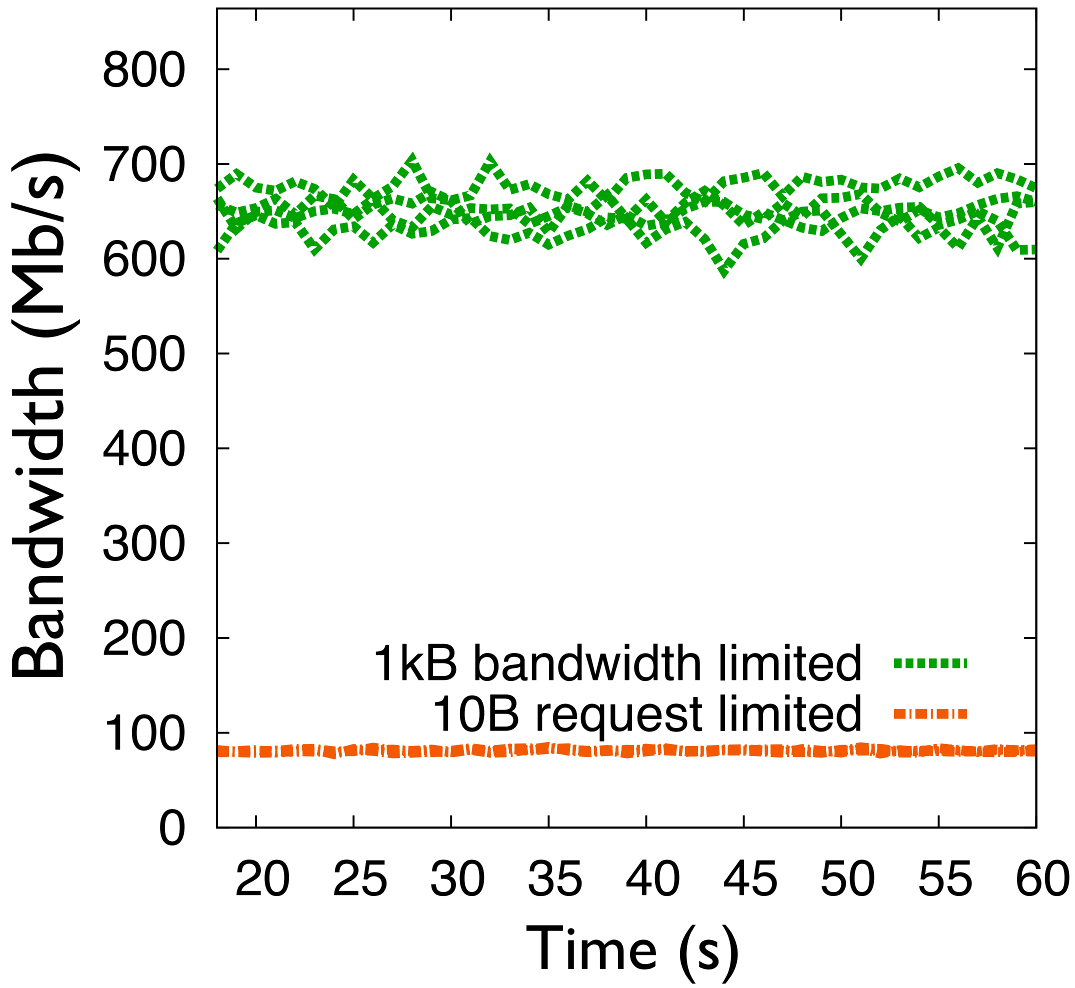

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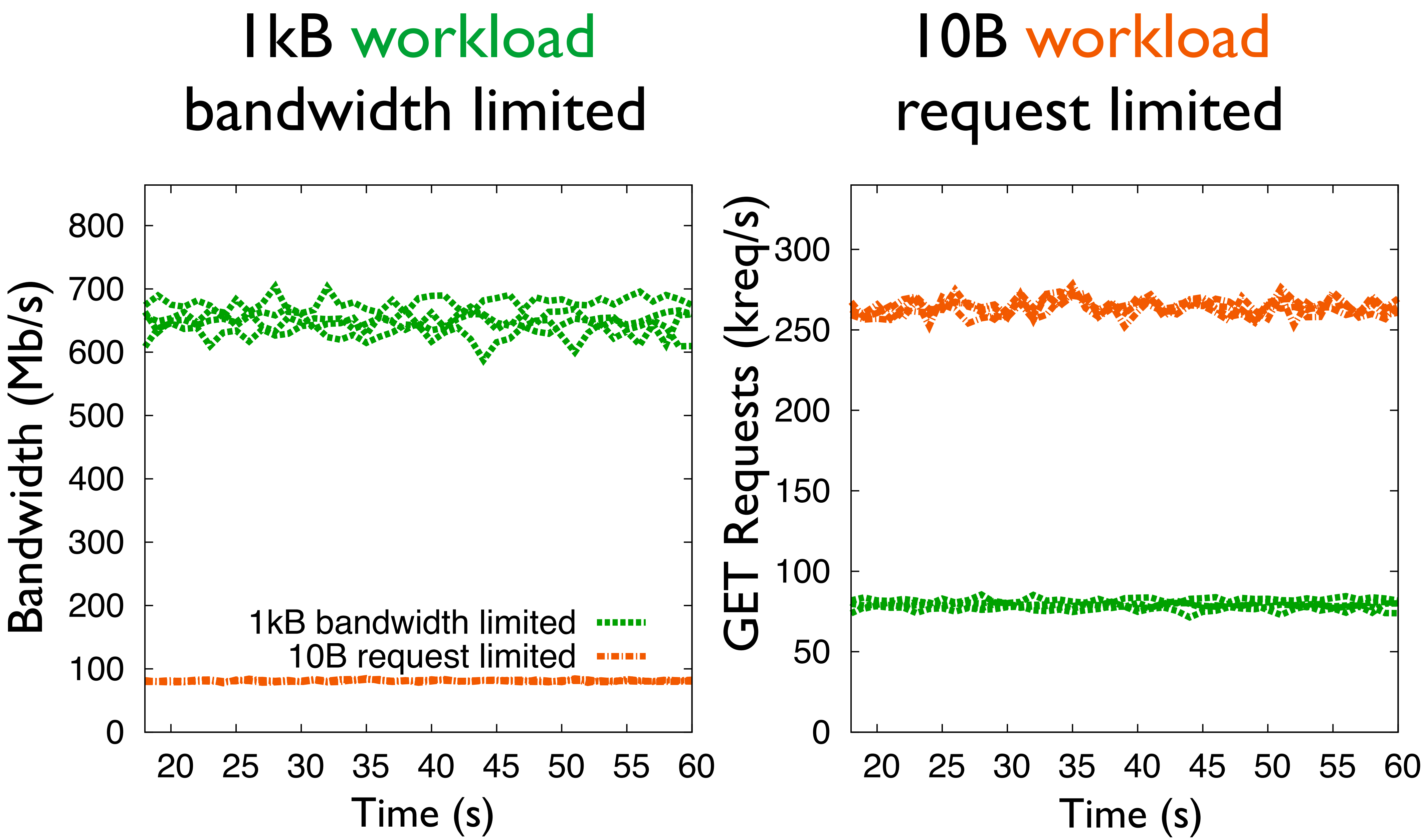

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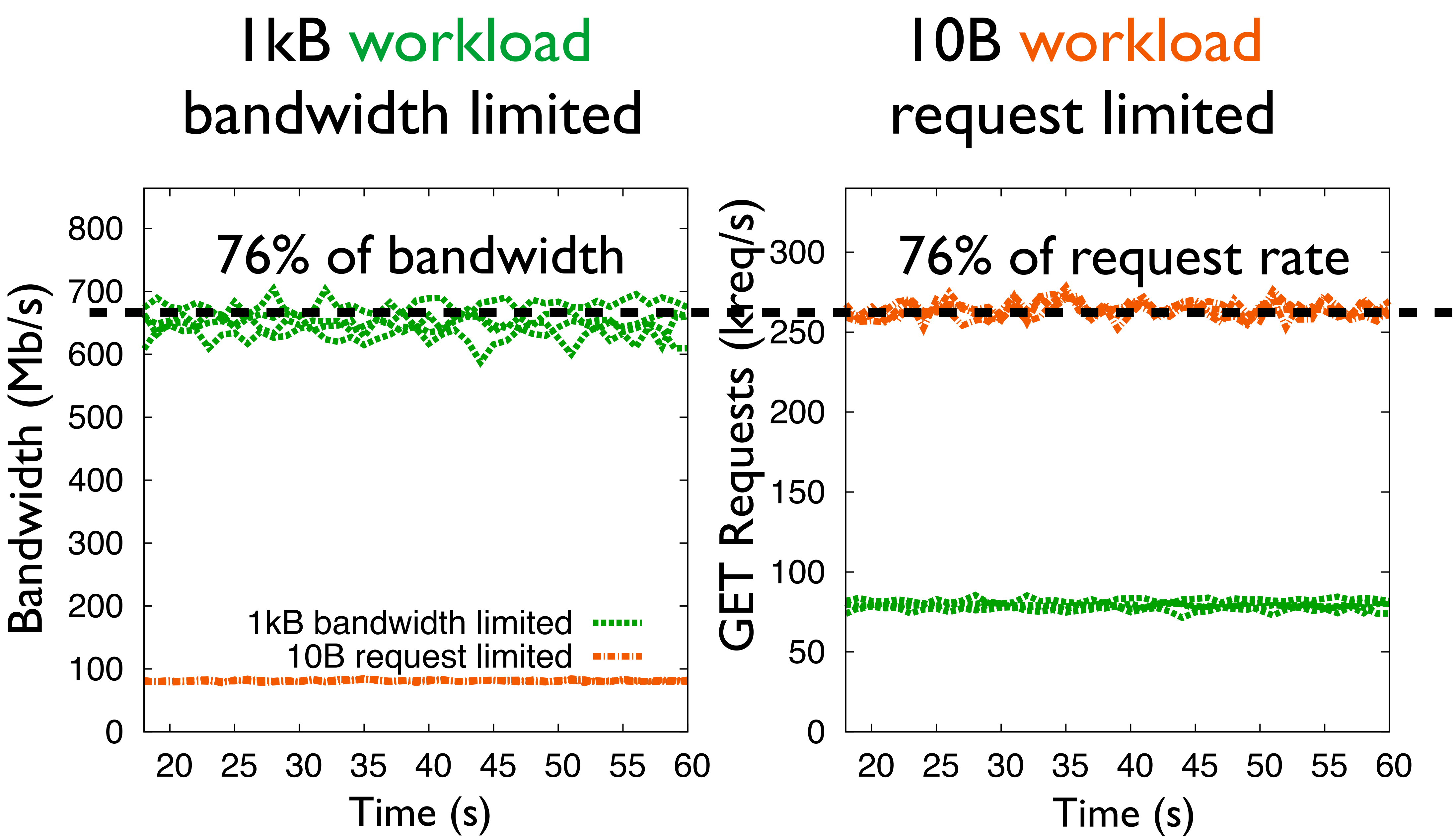

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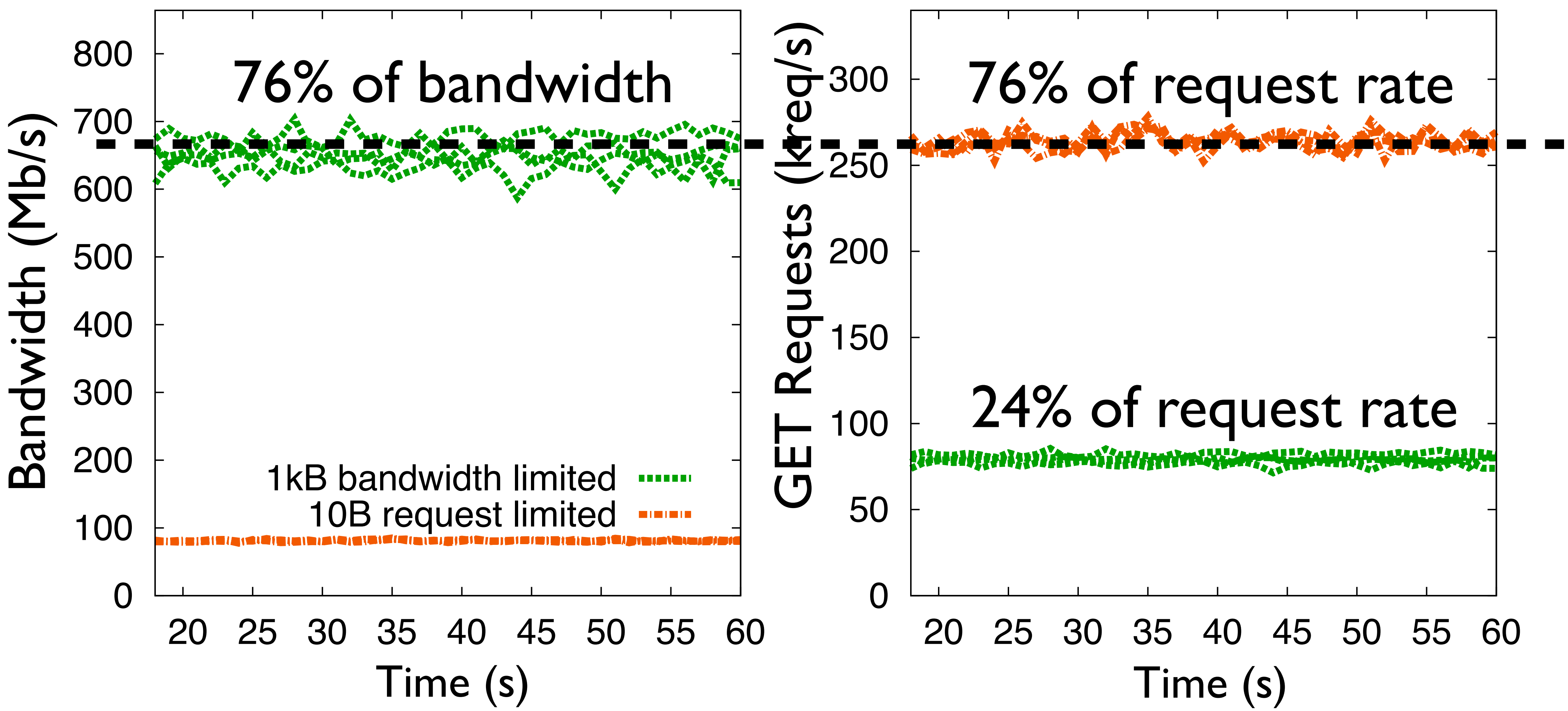
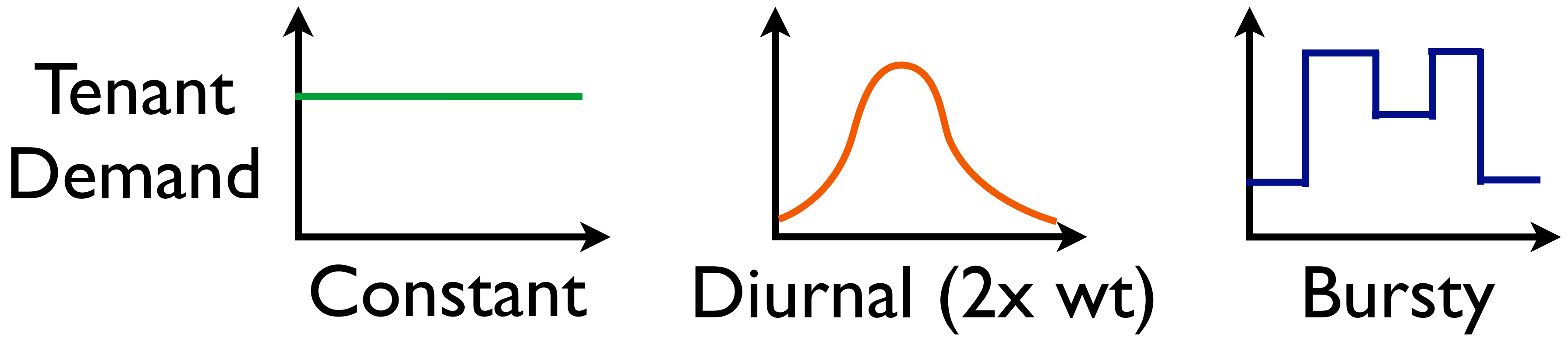


Pisces Adapts to Dynamic Demand



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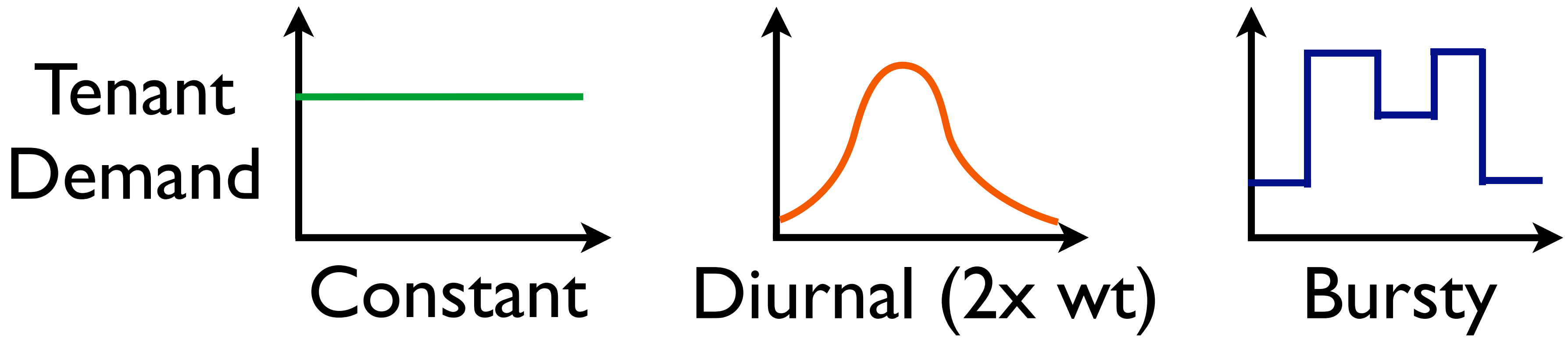

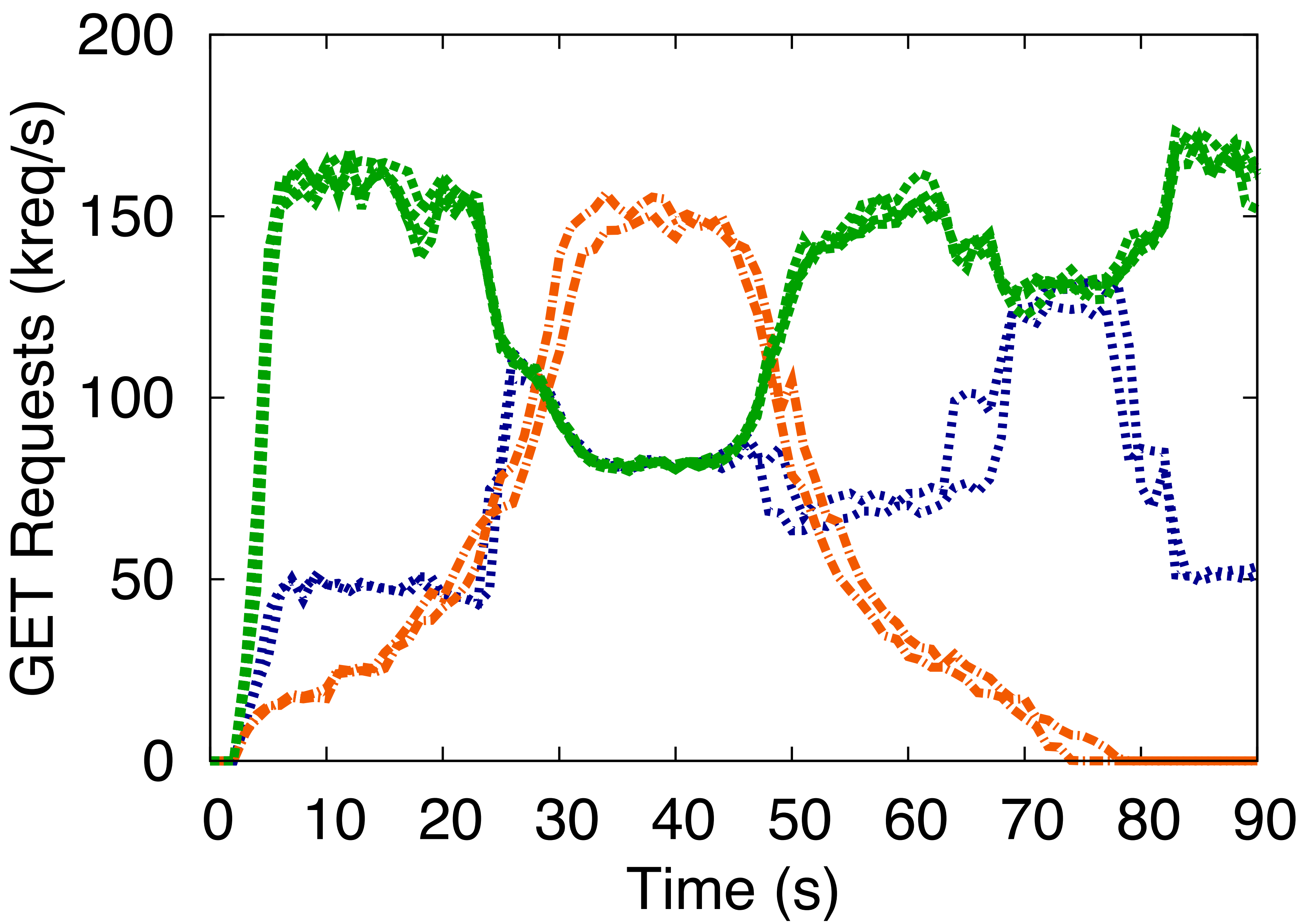

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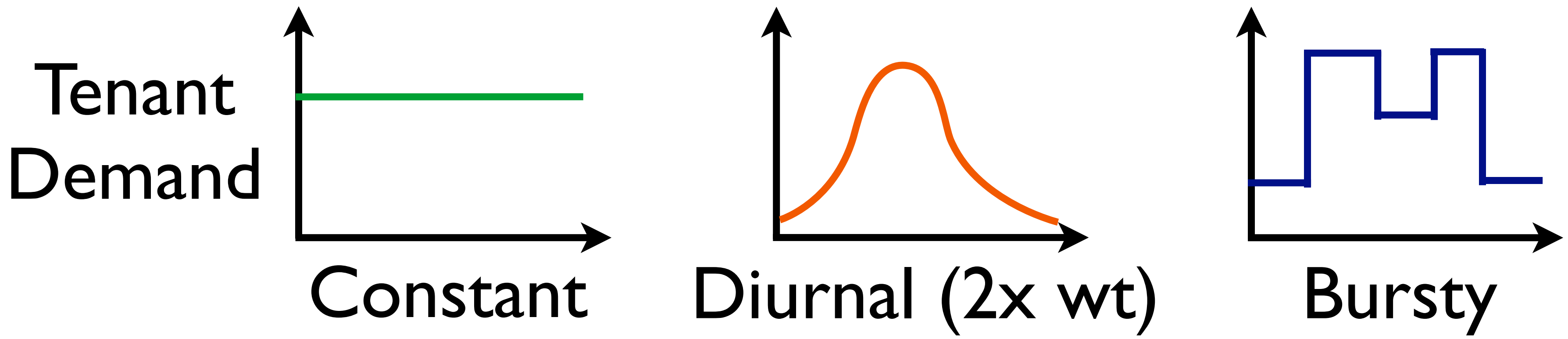

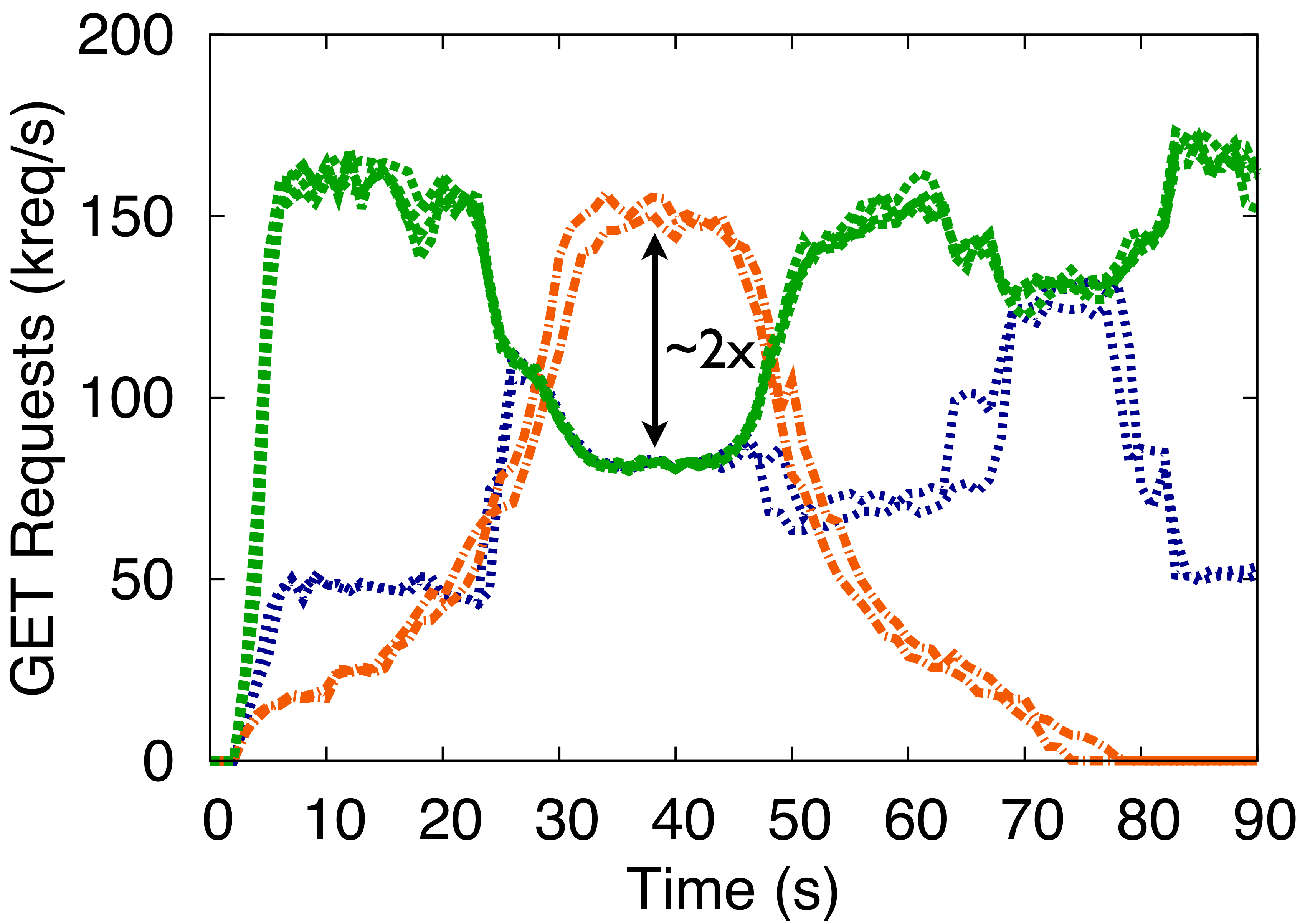

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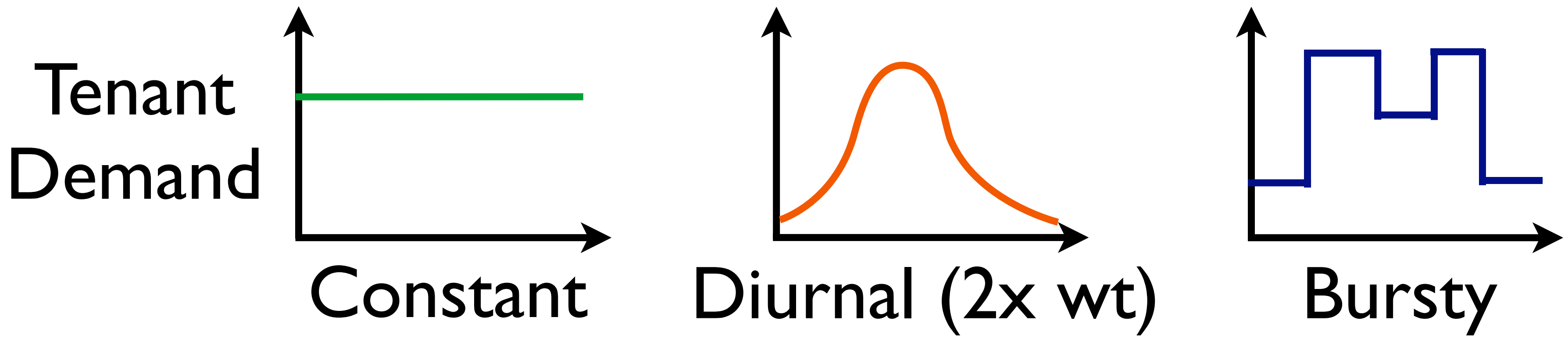

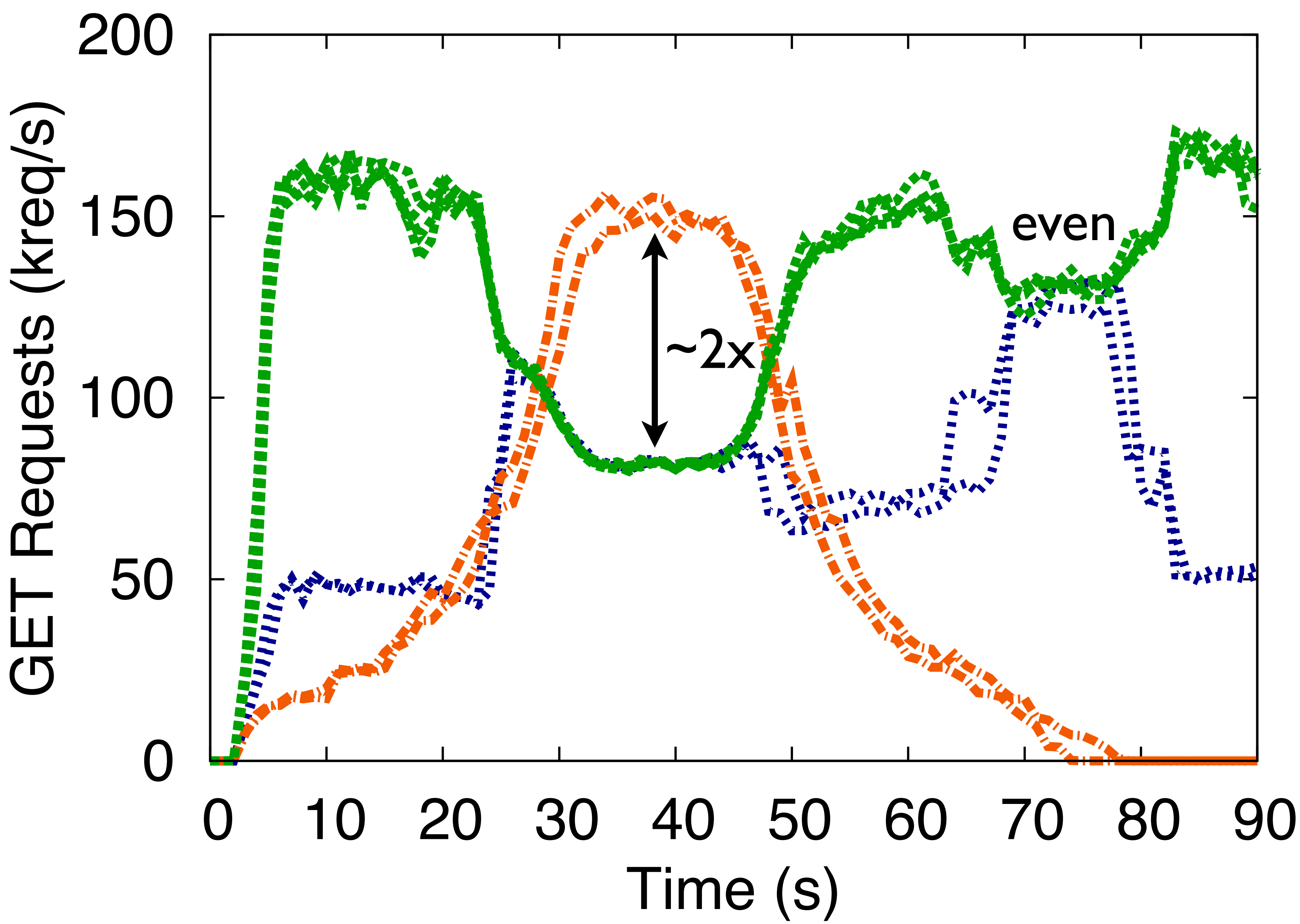

Conclusion

- Pisces Contributions
  - Per-tenant weighted max-min fair shares of system-wide resources w/ high utilization
  - Arbitrary object distributions
  - Different resource bottlenecks
  - Novel decomposition into 4 complementary mechanisms

PP Partition Placement | WA Weight Allocation | RS Replica Selection | FQ Fair Queuing