IMPERIAL

LSDS
Large-Scale Data & Systems Group

Enabling Cloud Scale Distributed Capabilities

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HCDS '25

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[2]

intel[3] labs

Security in Disaggregated Cloud

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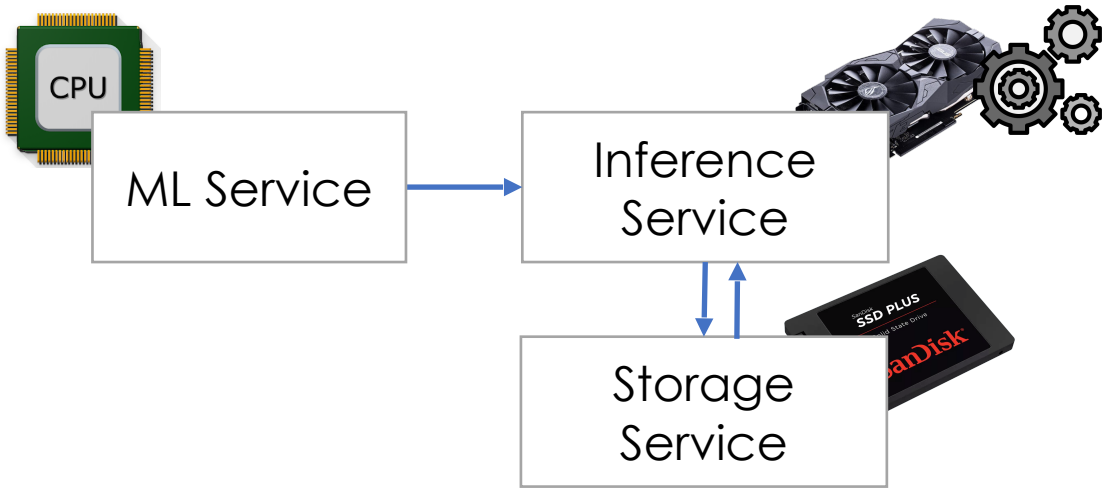
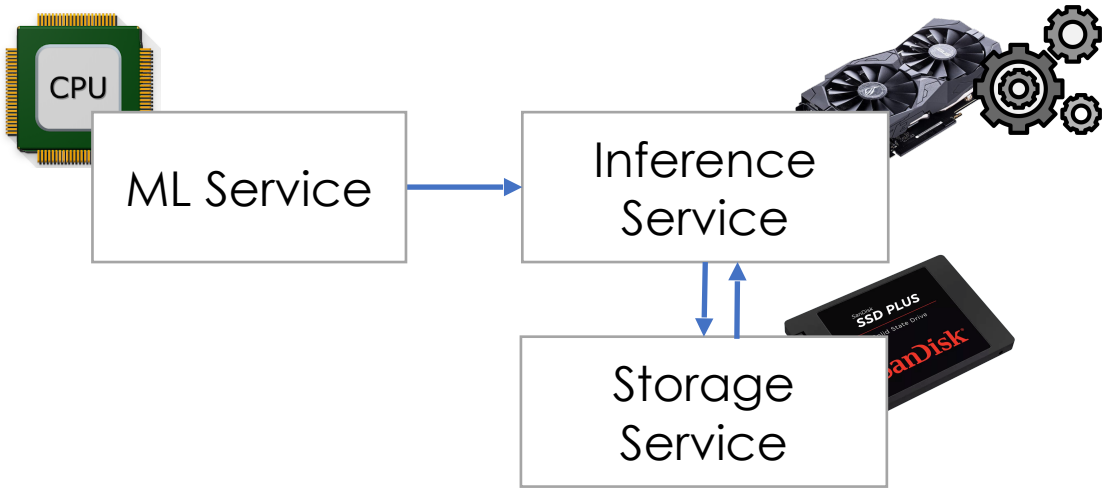


- Disaggregated Service-Oriented Architecture

Security in Disaggregated Cloud



- Disaggregated Service-Oriented Architecture
- Minimizing privilege is essential

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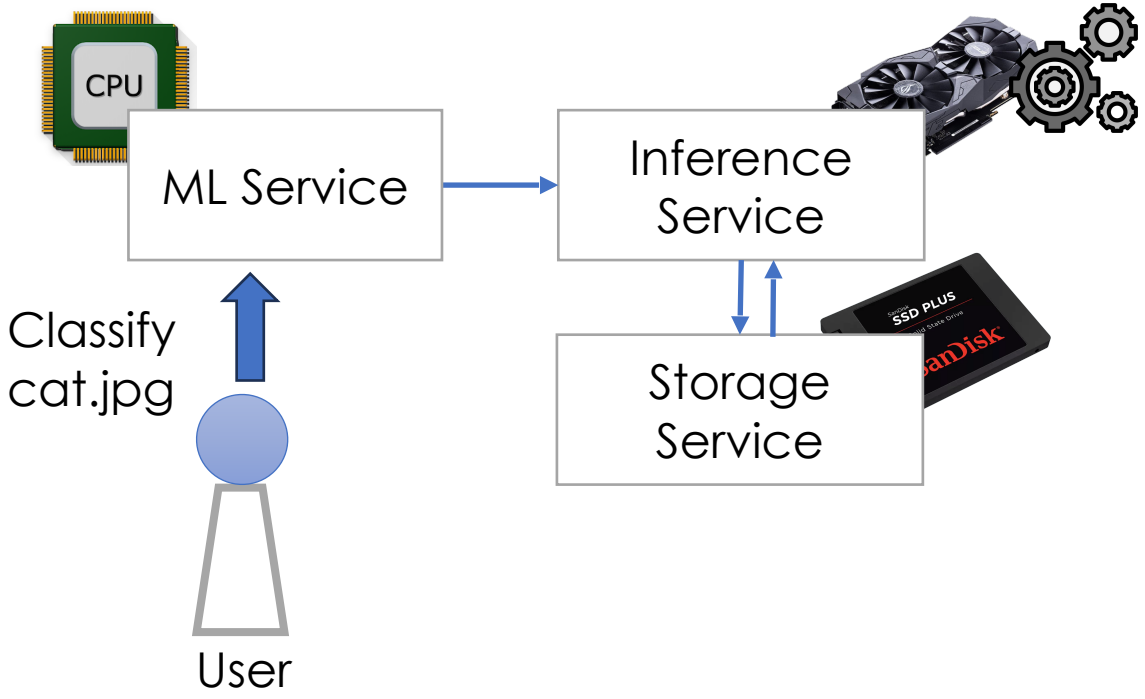

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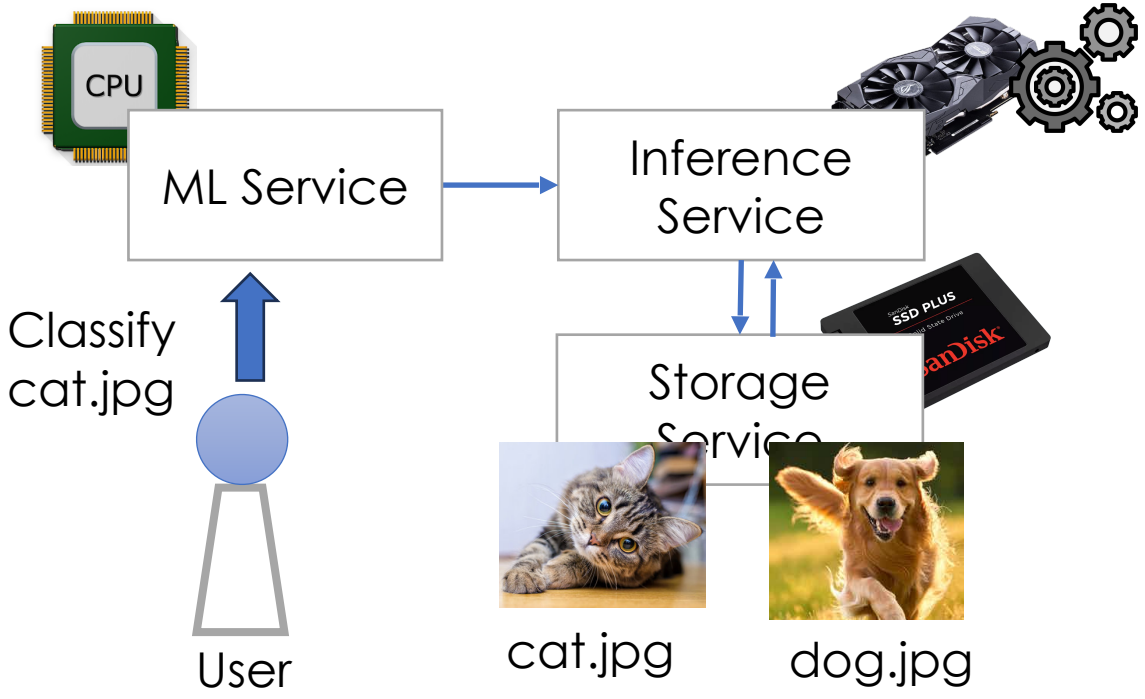

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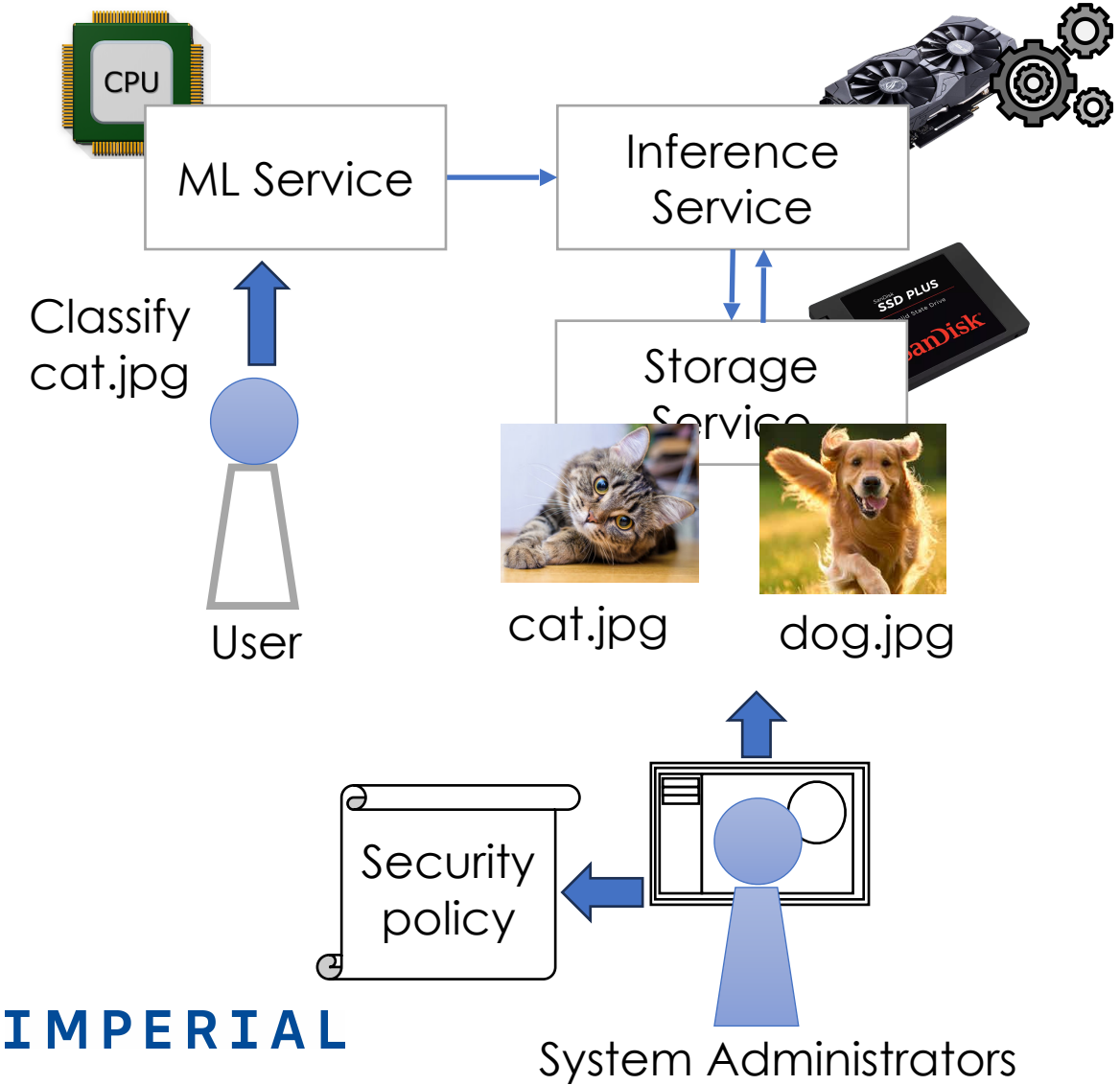

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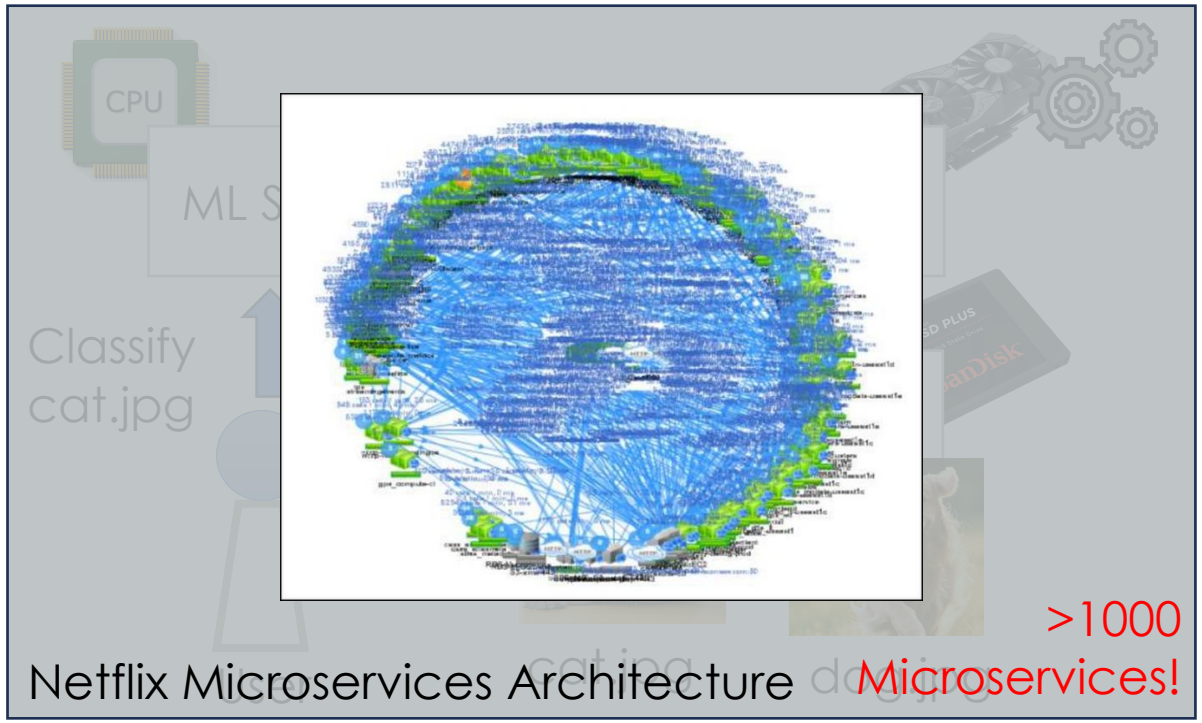

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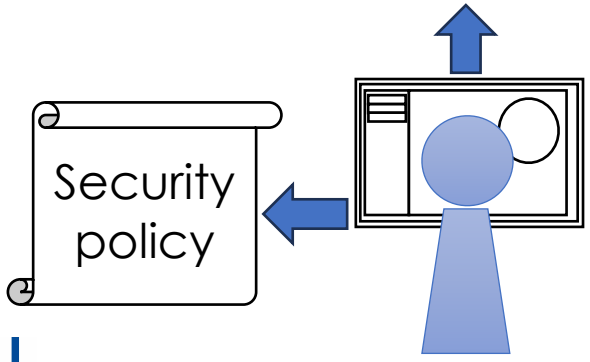

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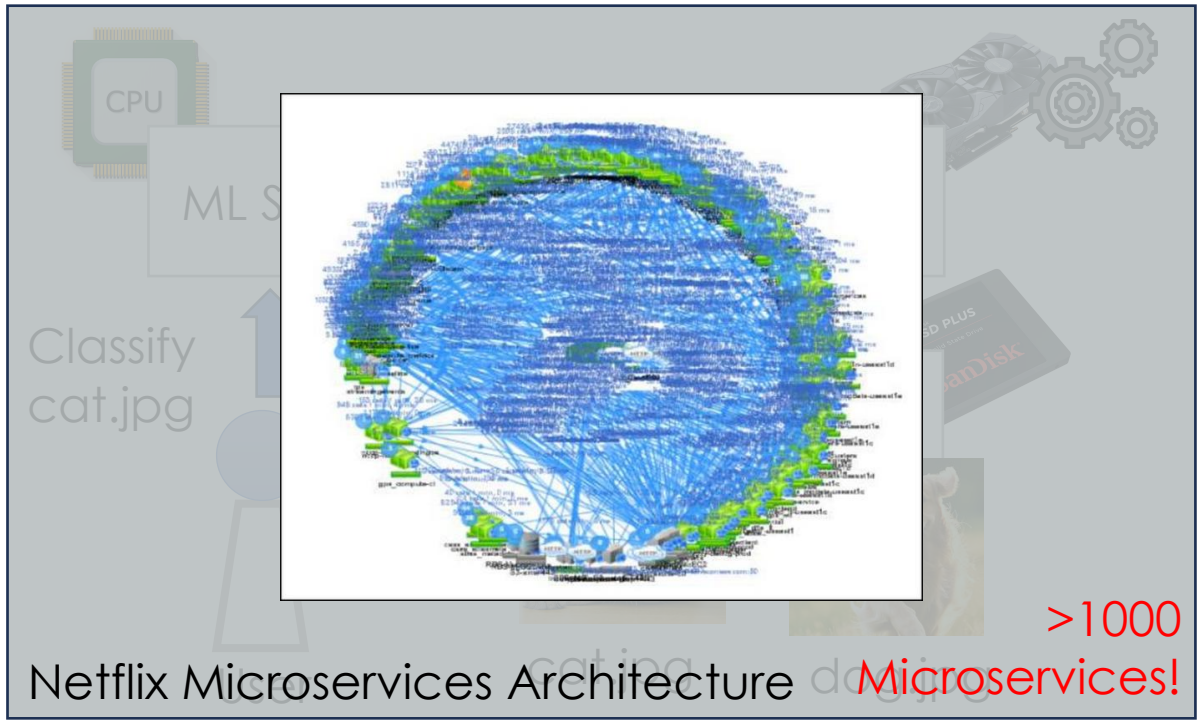
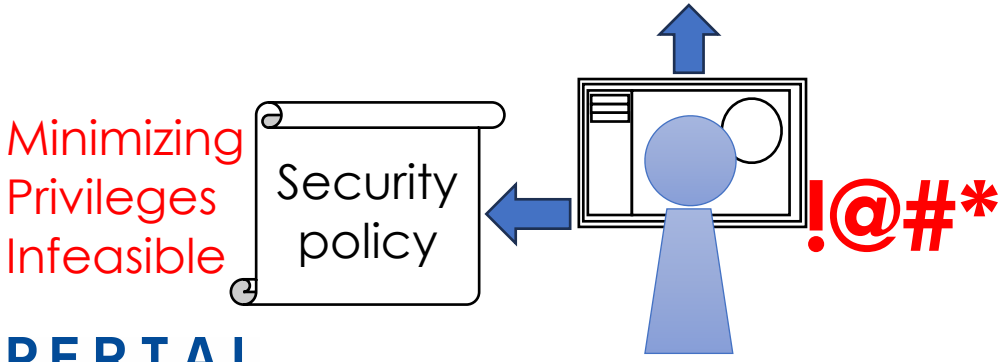


Netflix Microservices Architecture

- Disaggregated Service-Oriented Architecture
- Minimizing privilege is essential
- Policies don't scale to complex systems -> over-privilege



System Administrators

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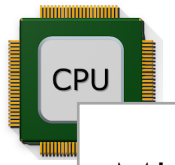
Capabilities for Disaggregated Cloud

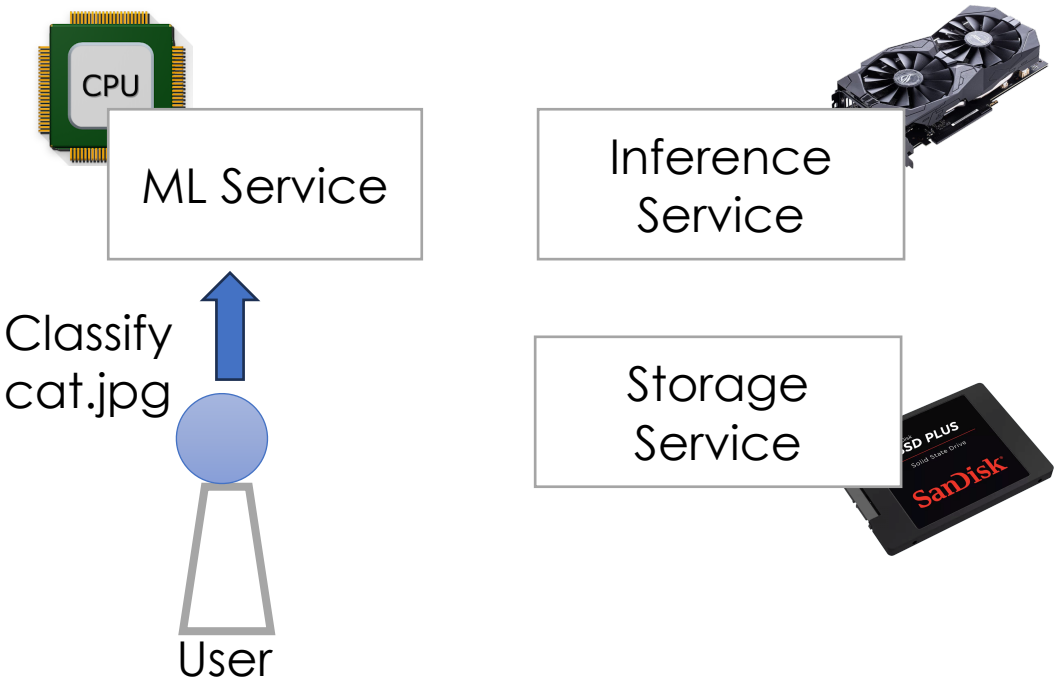


ML Service

Inference Service

Storage Service

Capabilities for Disaggregated Cloud



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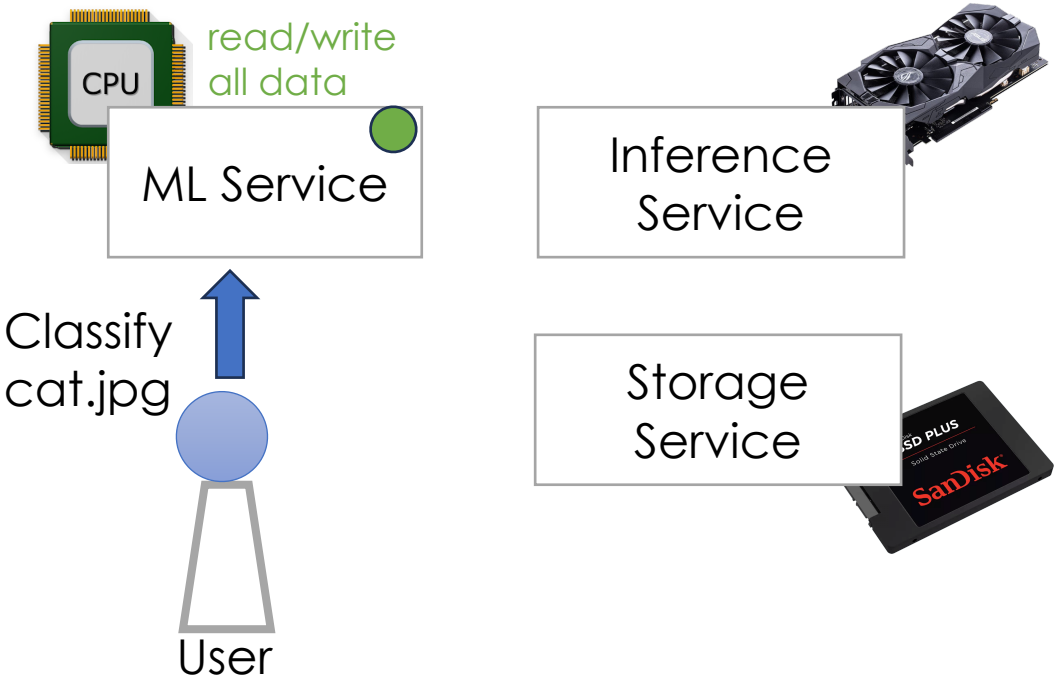

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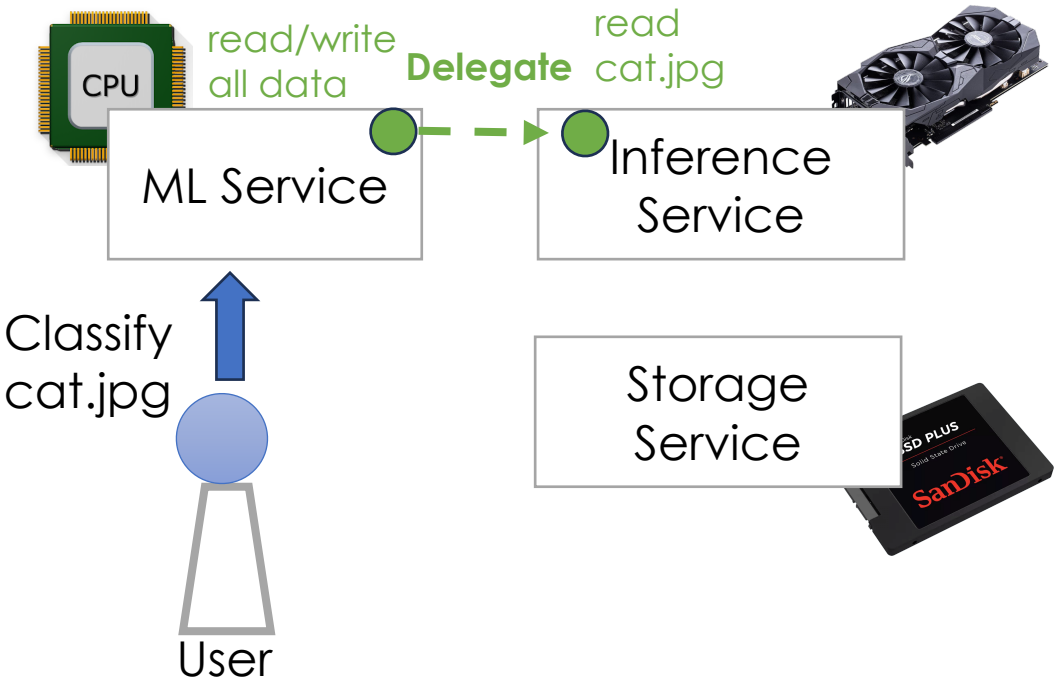

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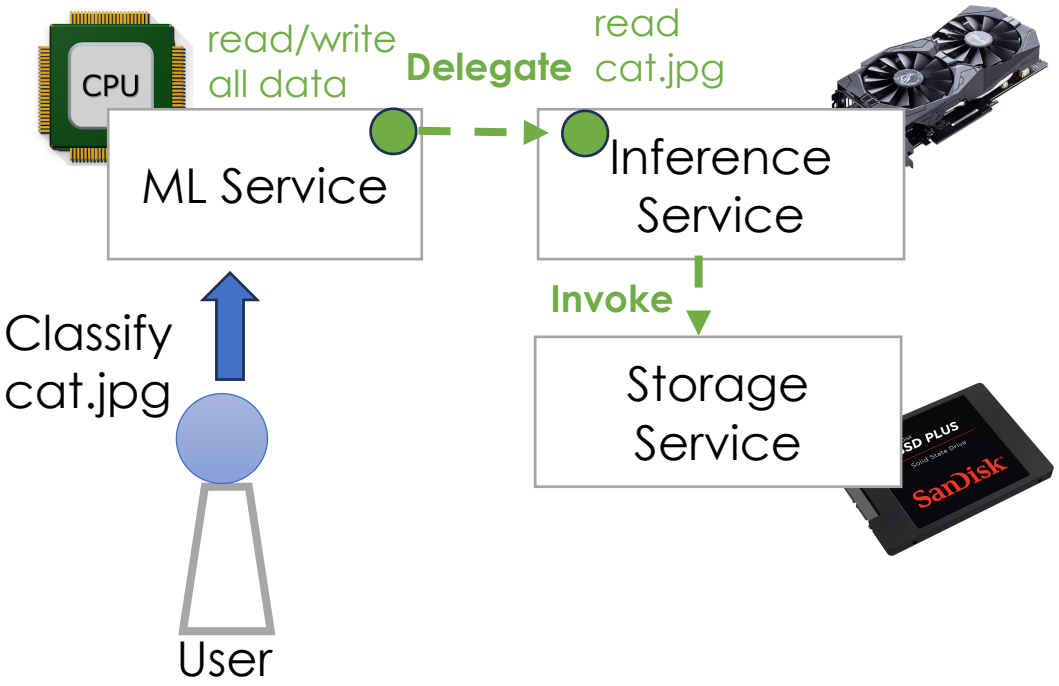

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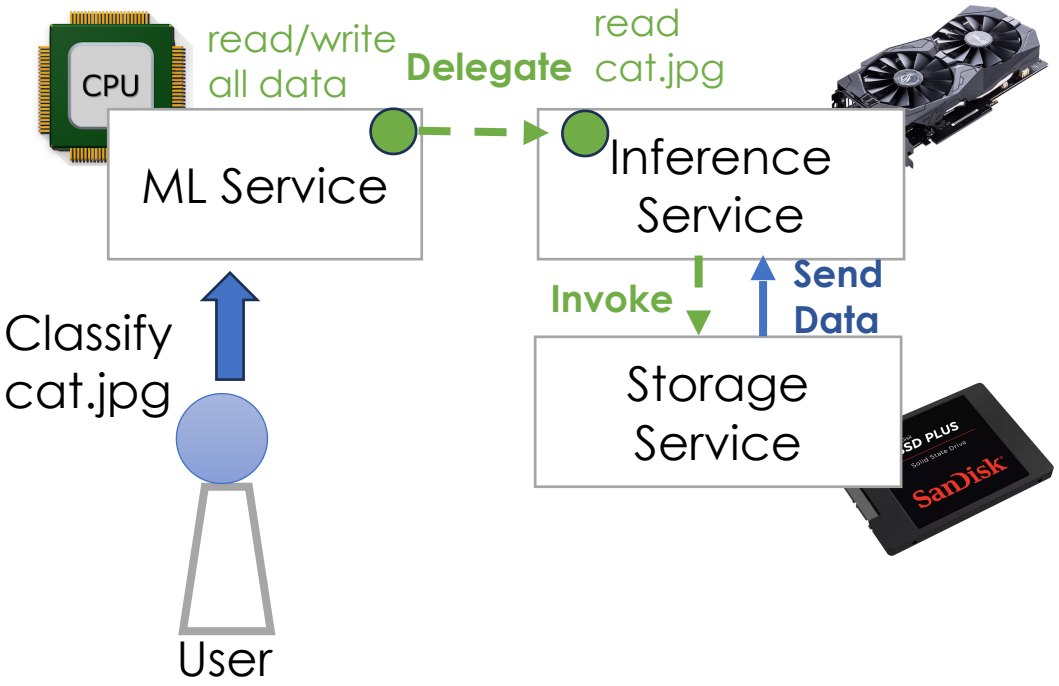

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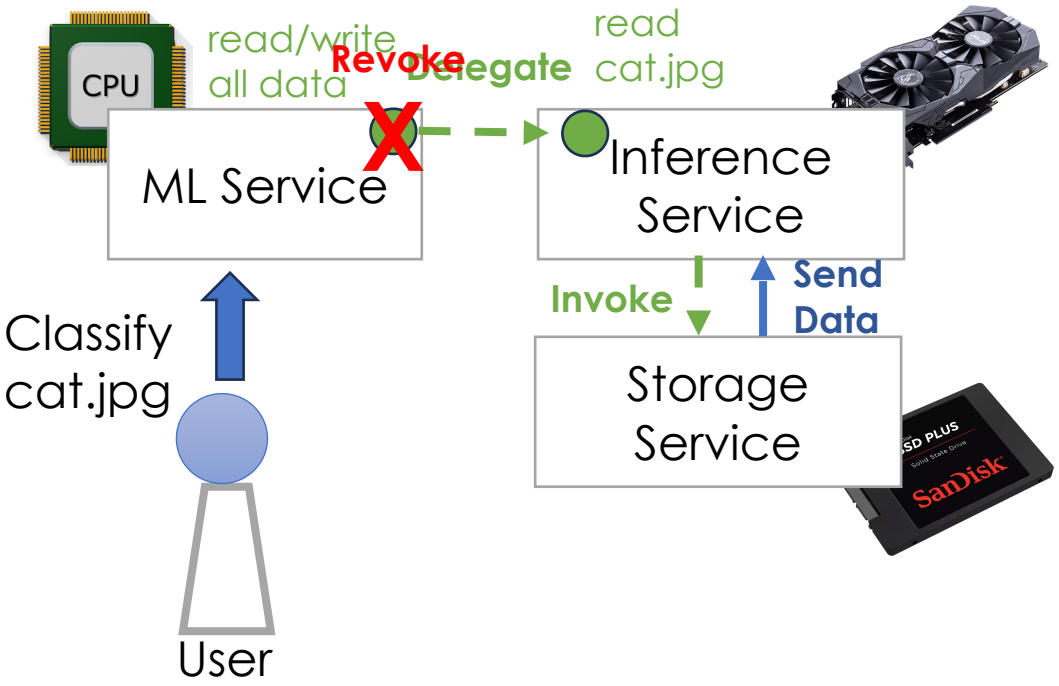

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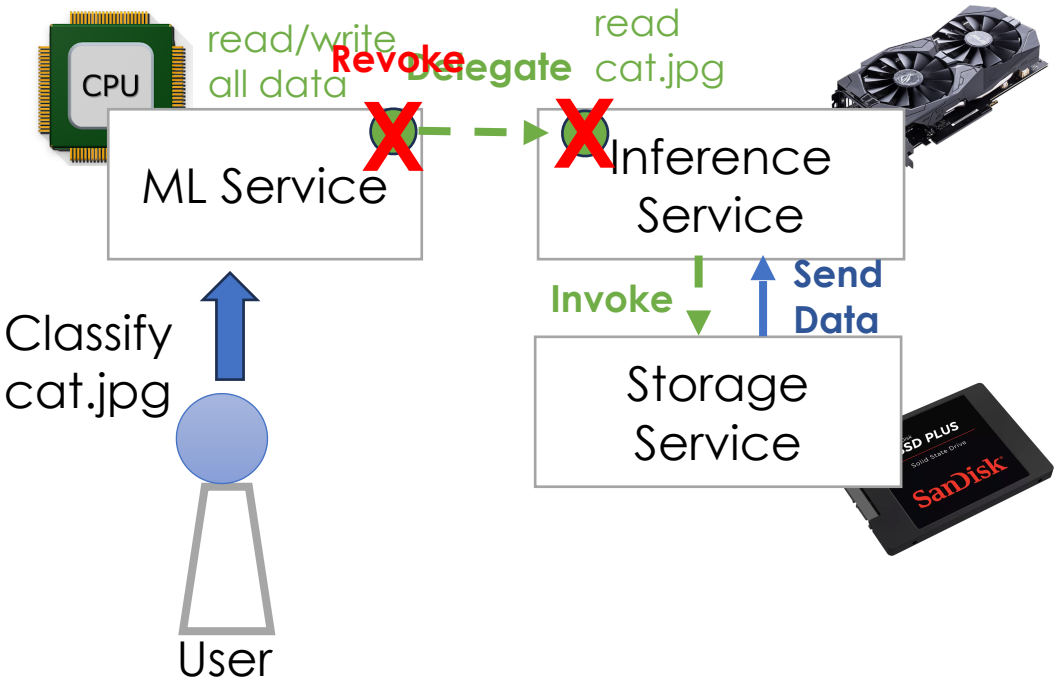

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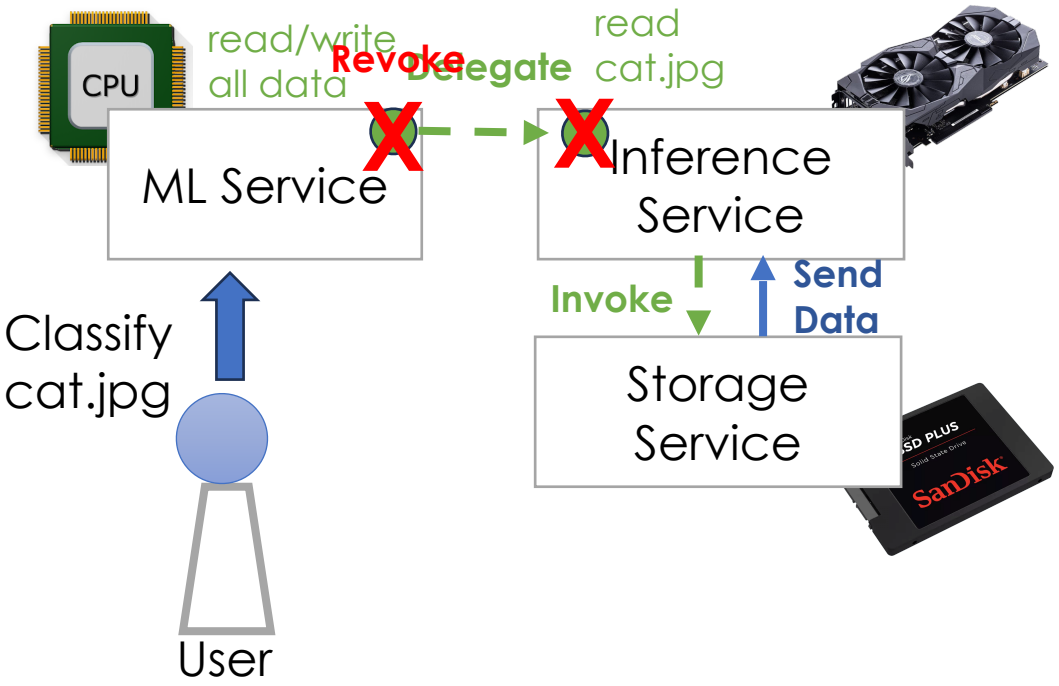
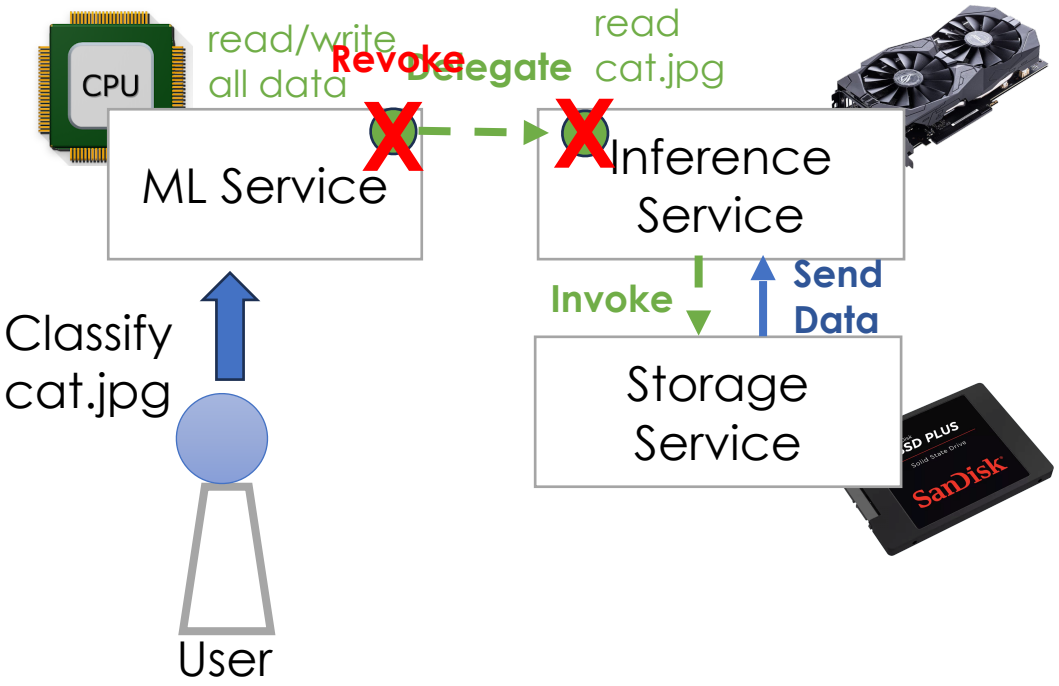


- Application controlled permissions

Capabilities for Disaggregated Cloud



- Application controlled permissions

  – Policy is distributed

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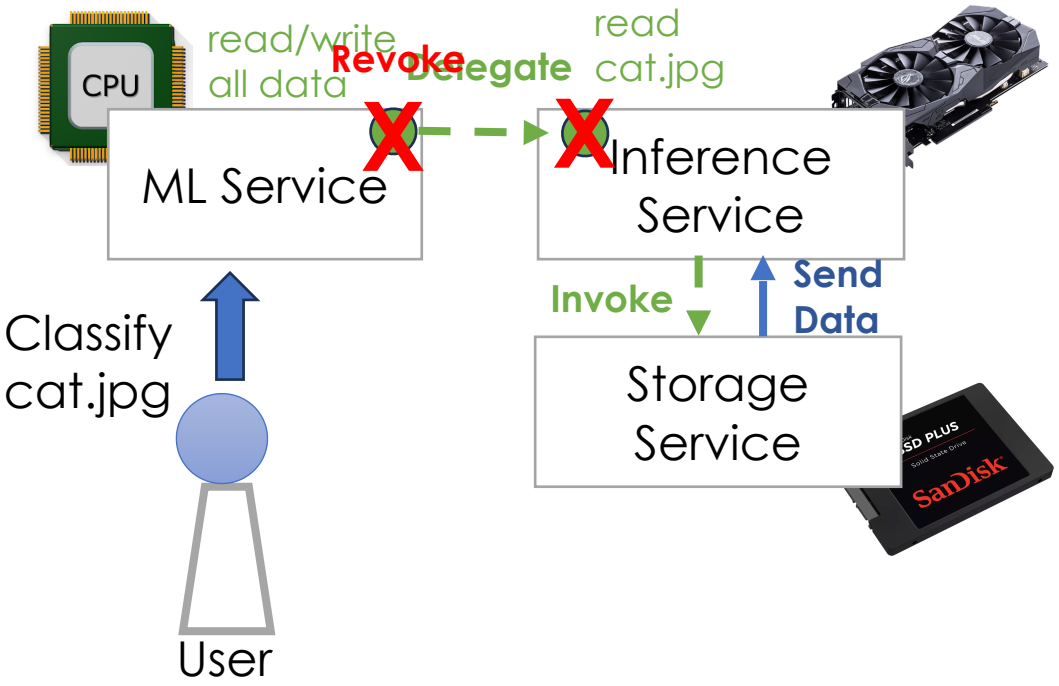
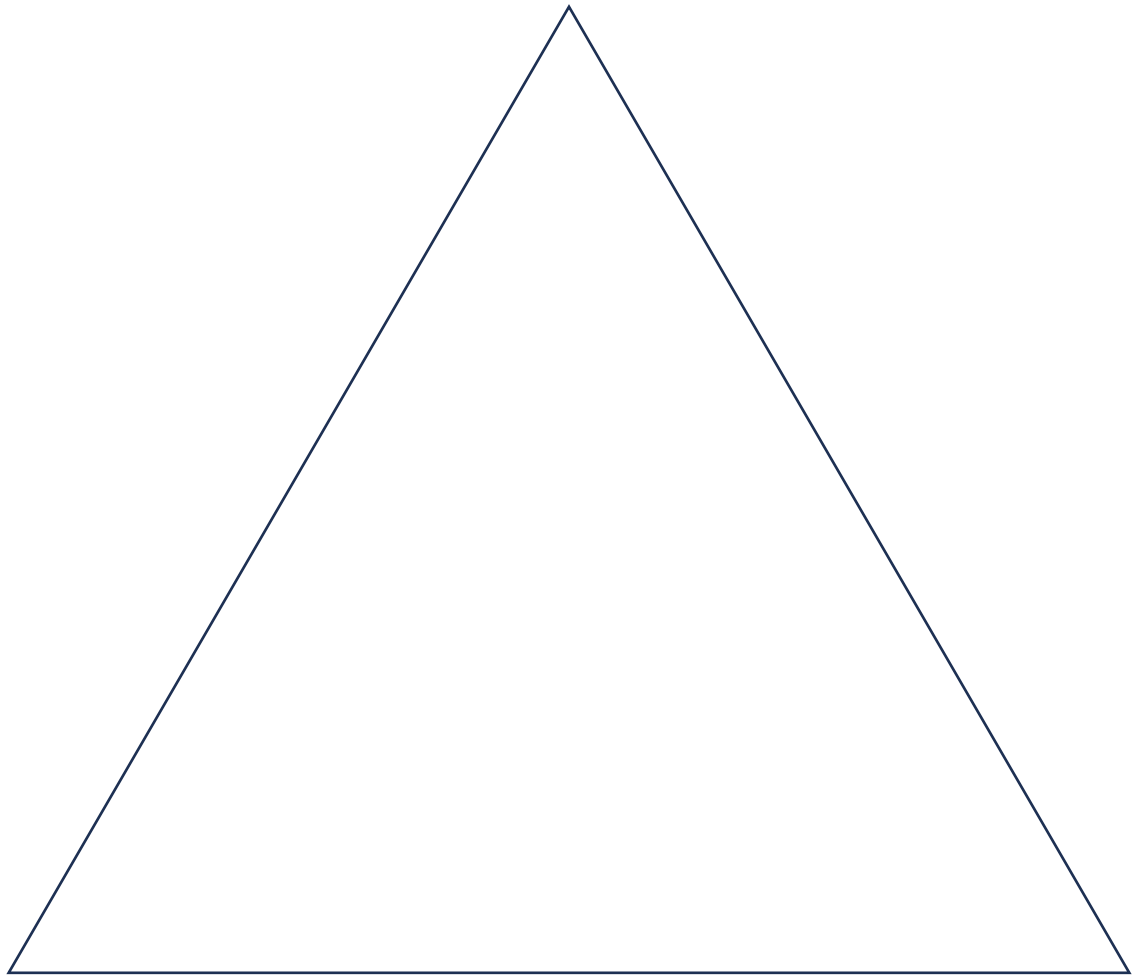


- Application controlled permissions
  - Policy is distributed
  - Privilege minimization scales better to complex systems

No Capability Systems Are Cloud Ready



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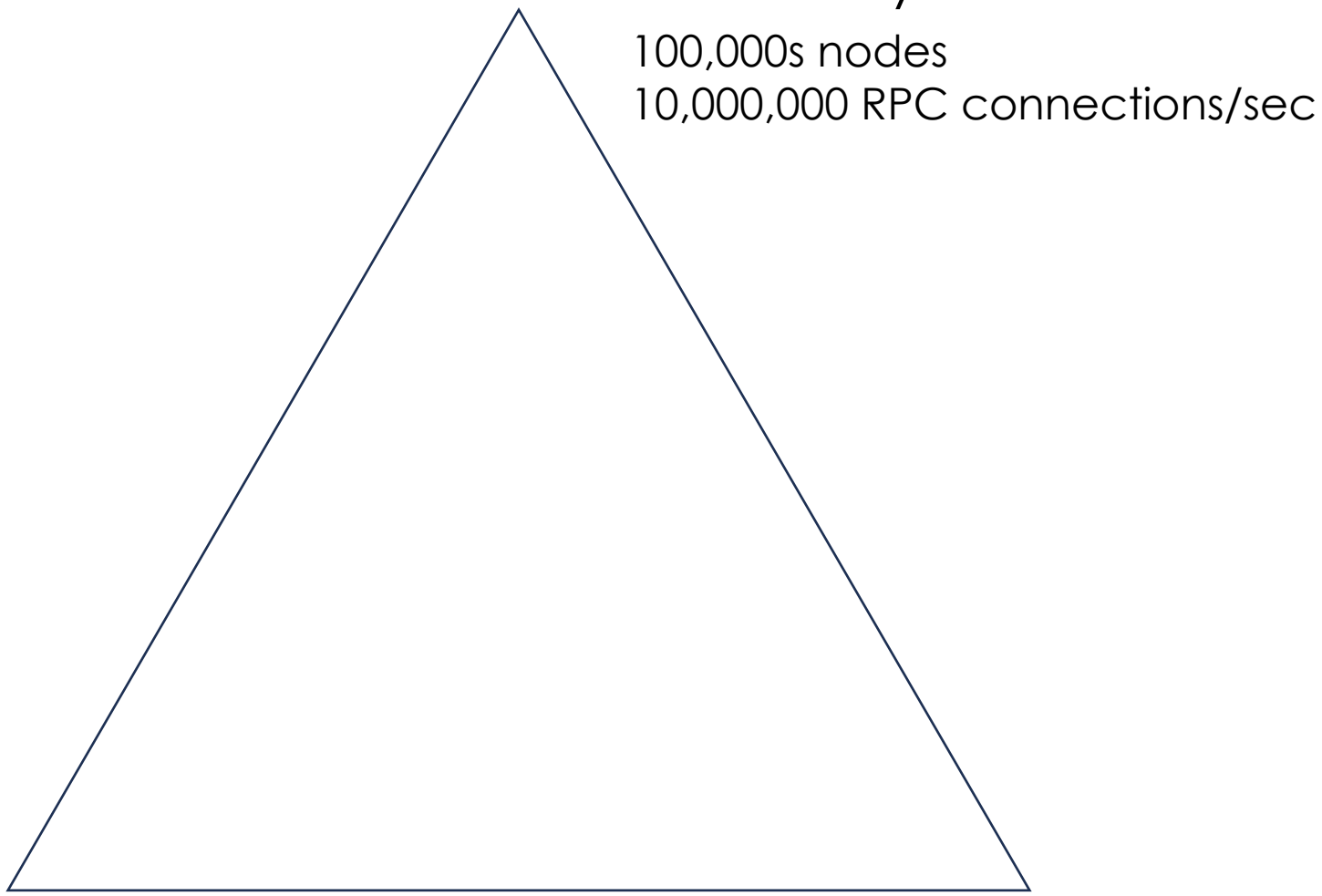

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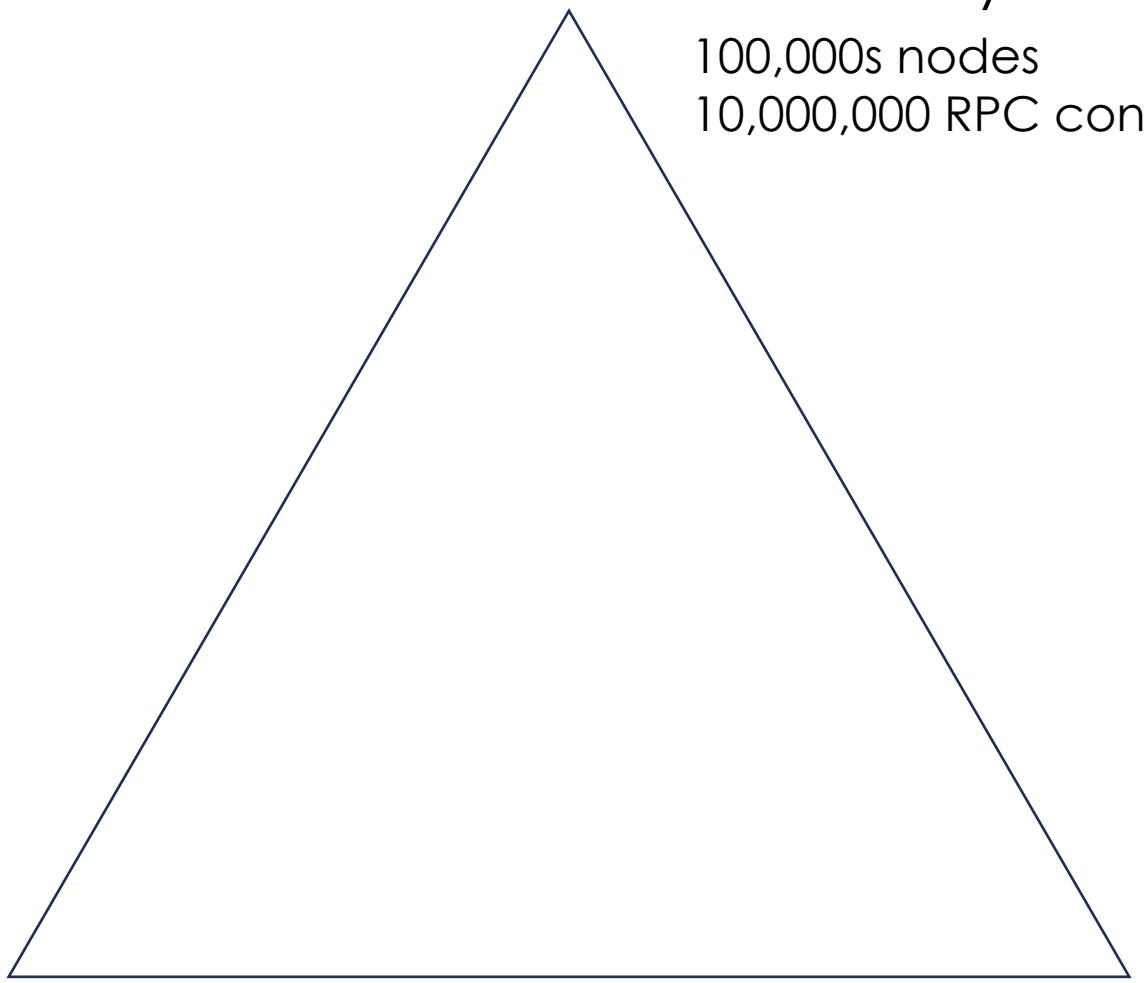
Scalability

100,000s nodes
10,000,000 RPC connections/sec



Critical-path Performance

1-2 µs-scale RPCs

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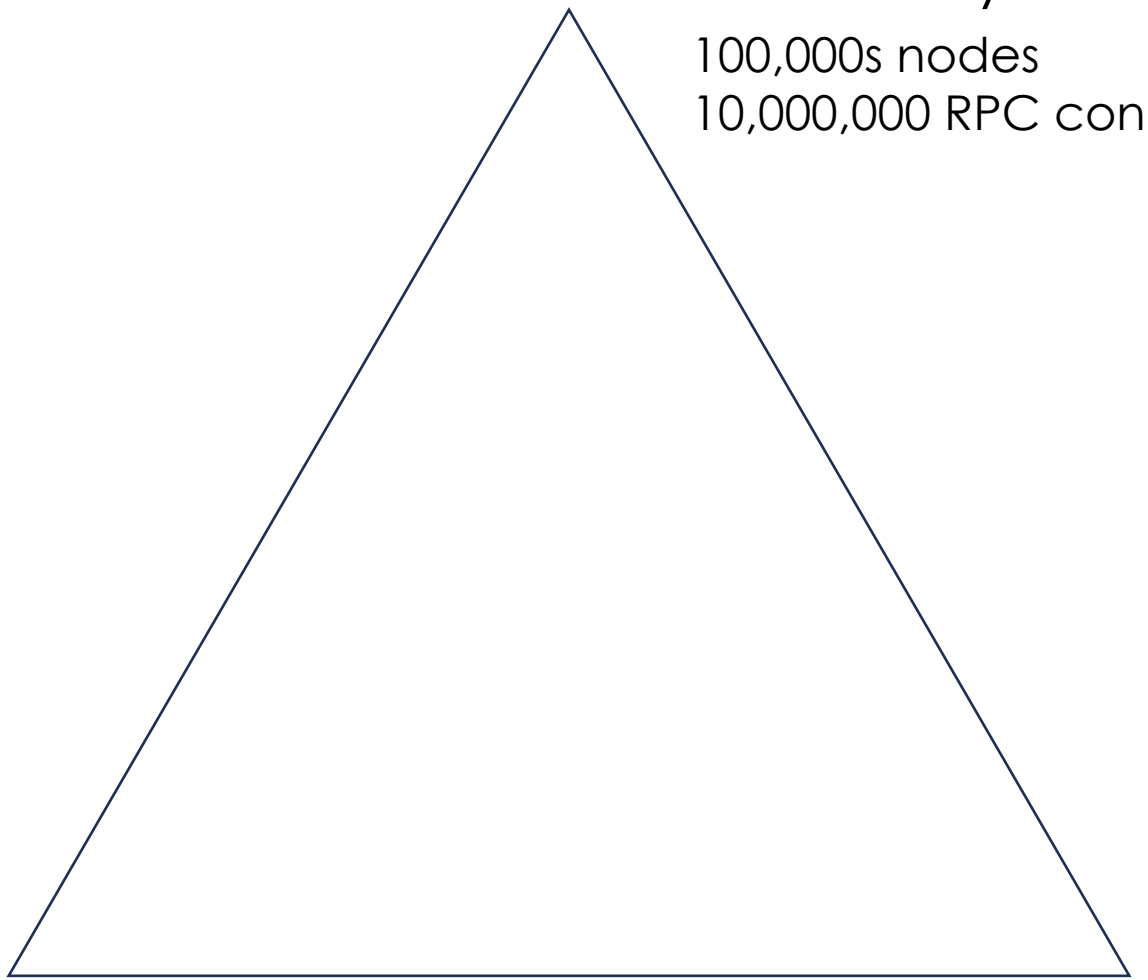

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<17.5 failures/node day
~35,000 failures on 2k nodes

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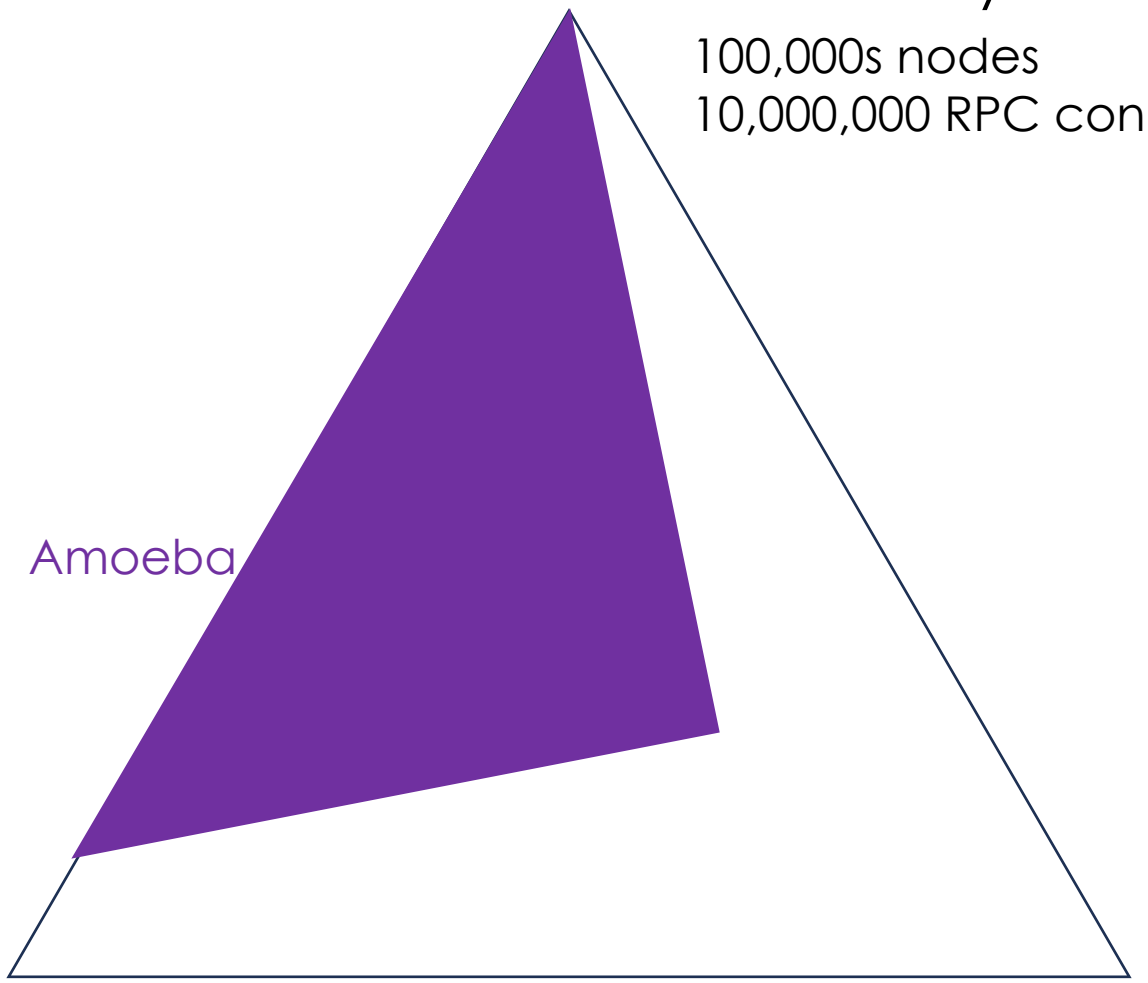

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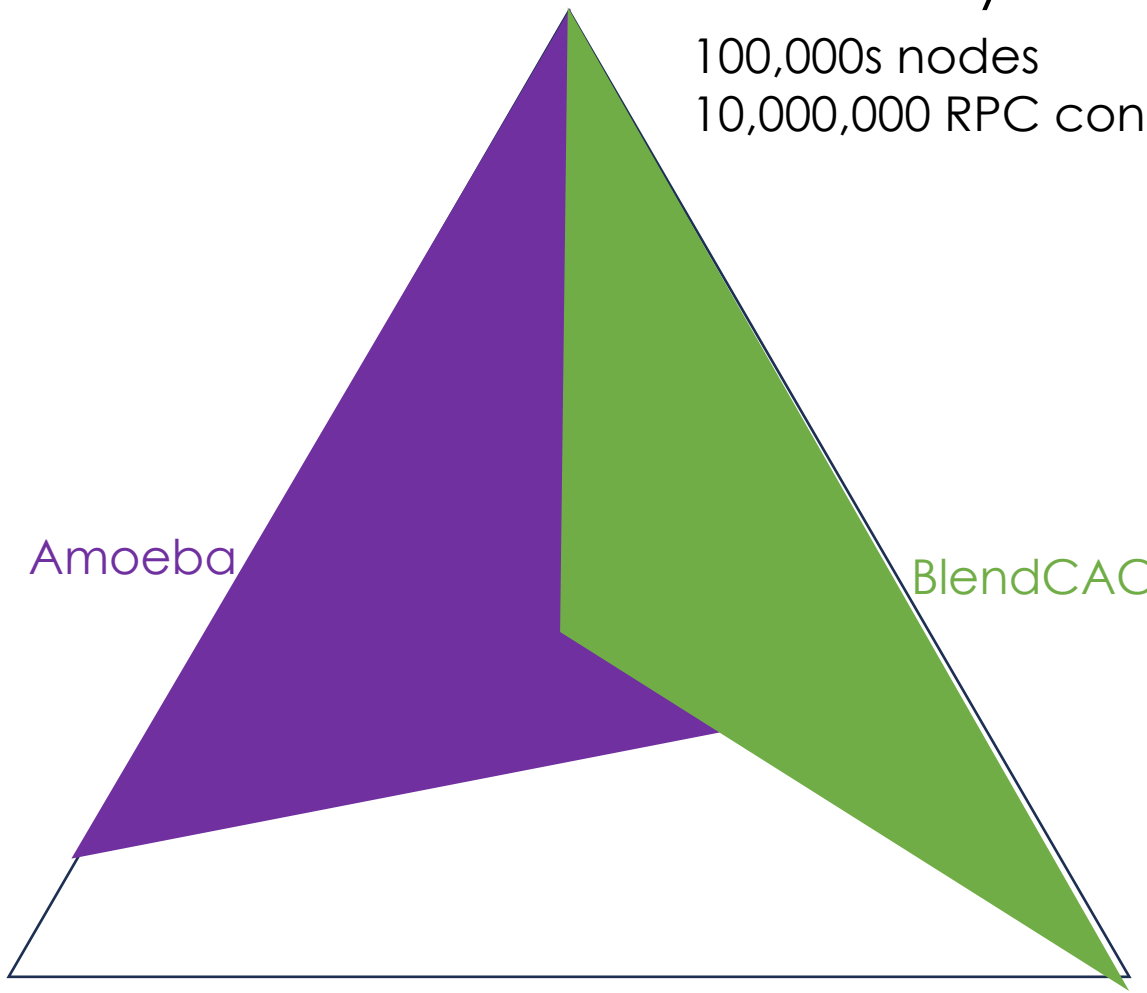

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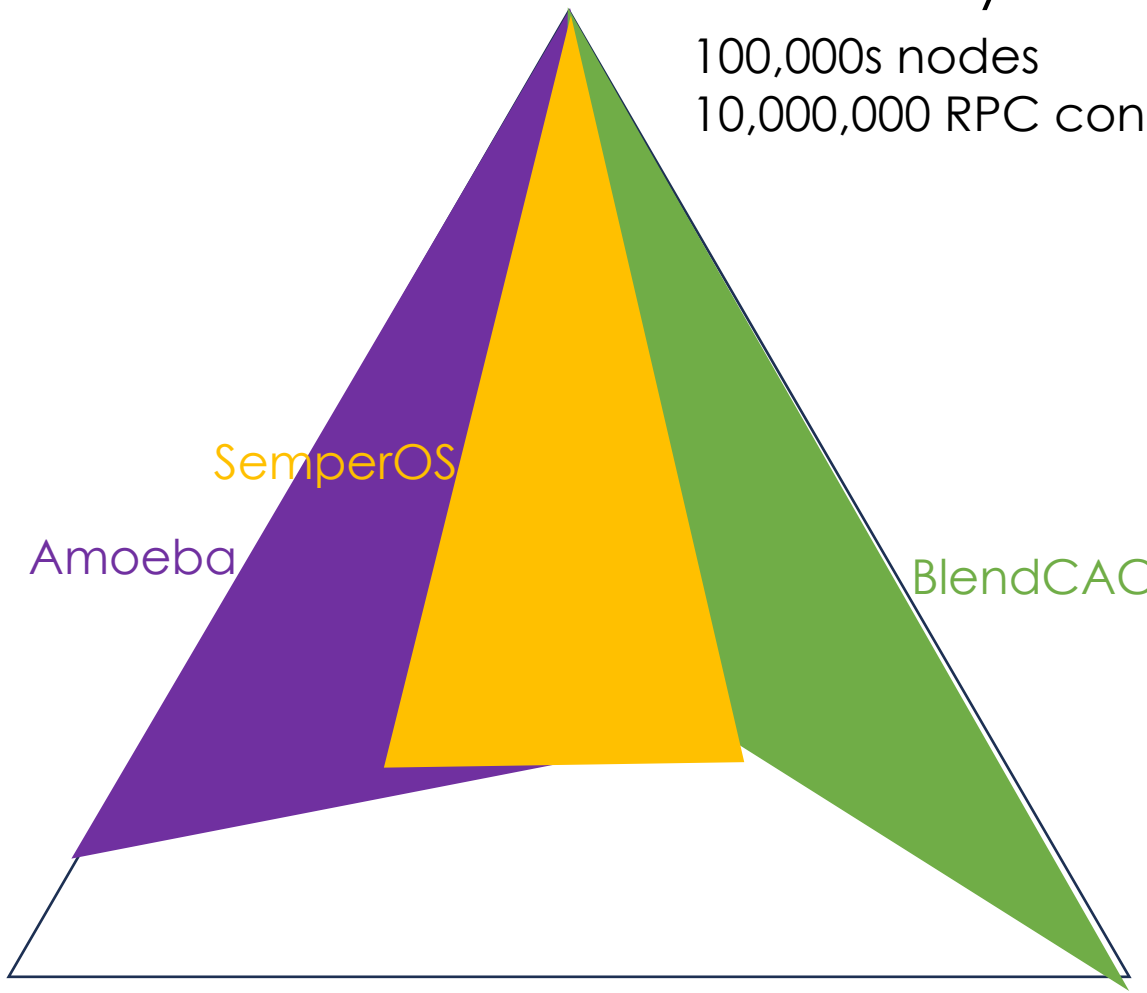

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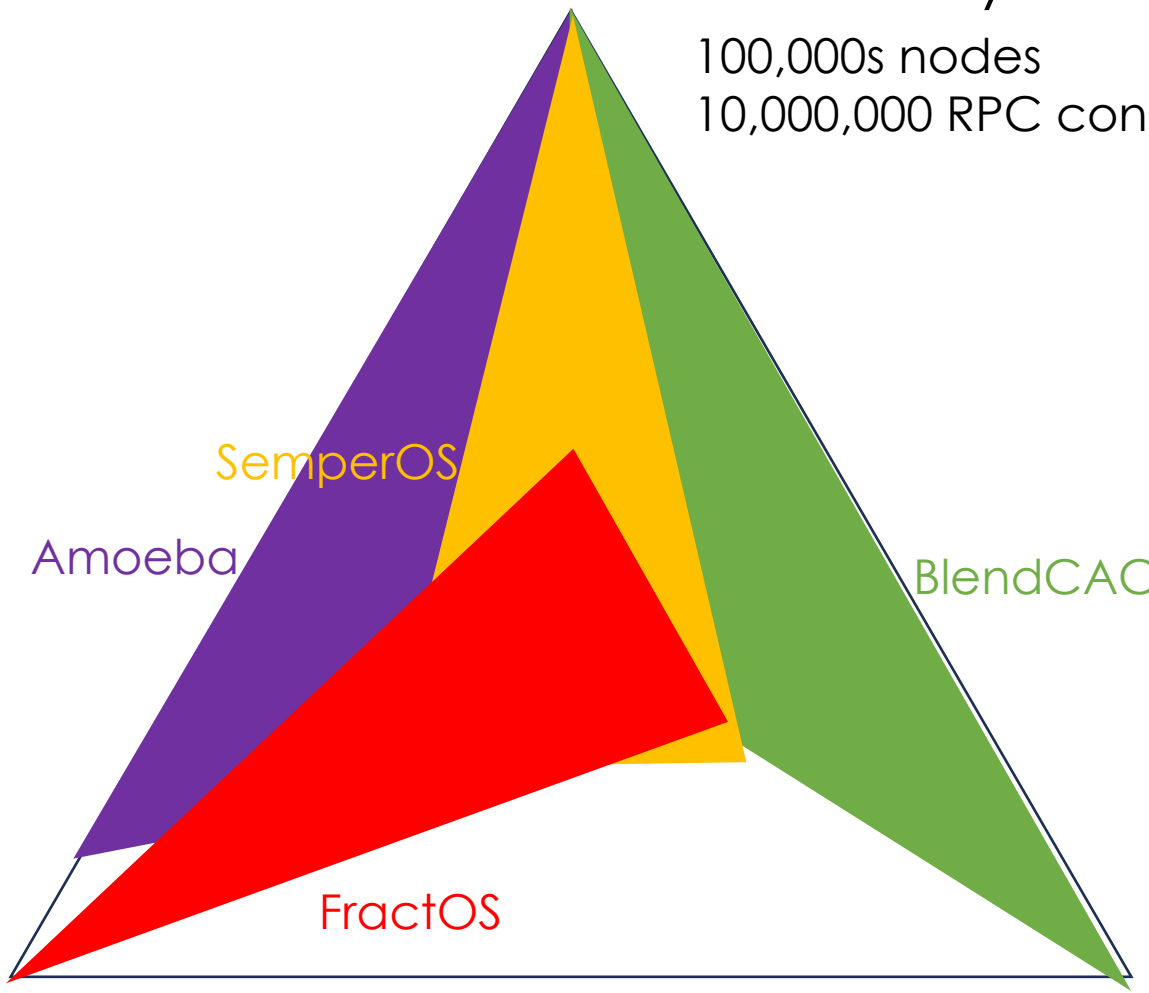

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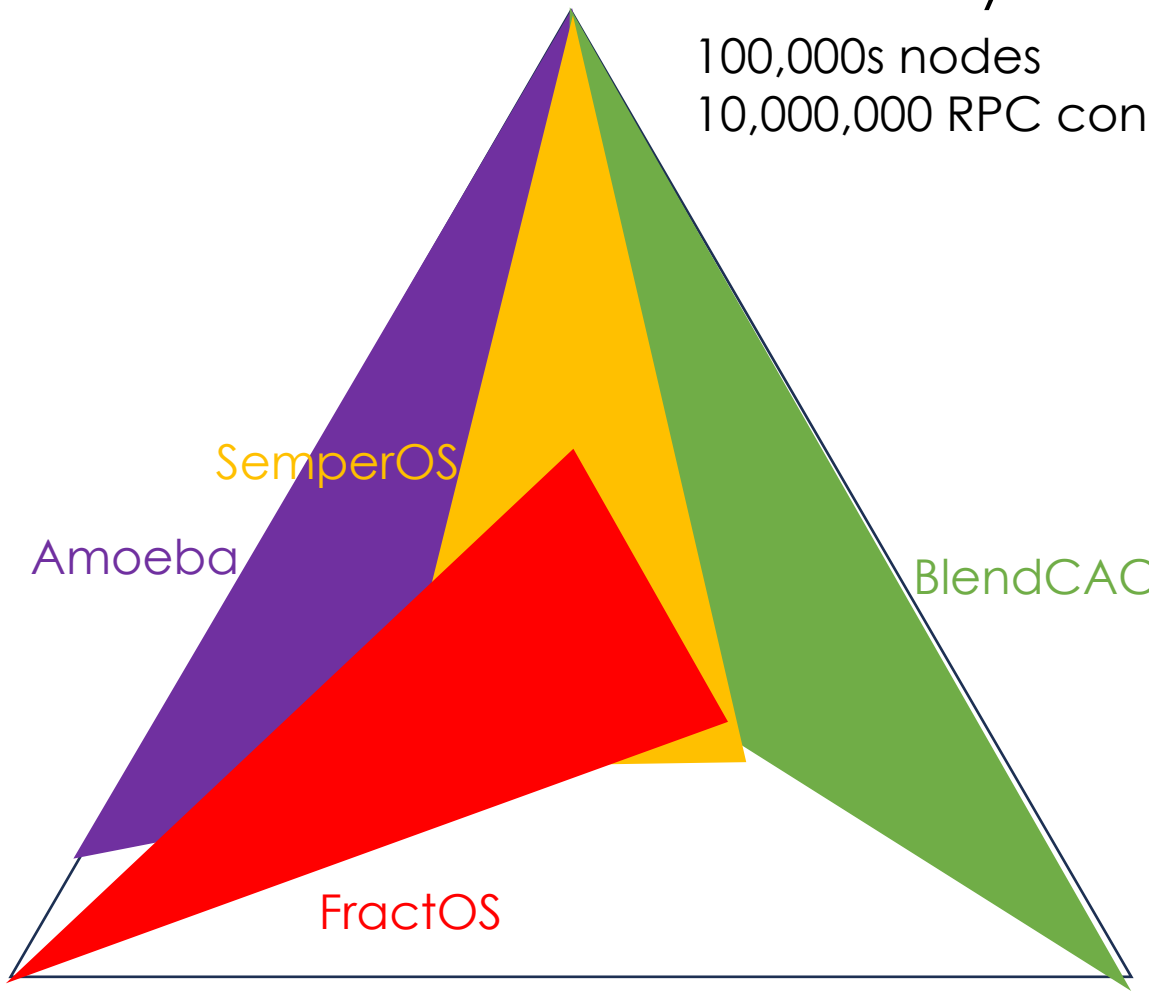
We need all three to achieve cloud scale…



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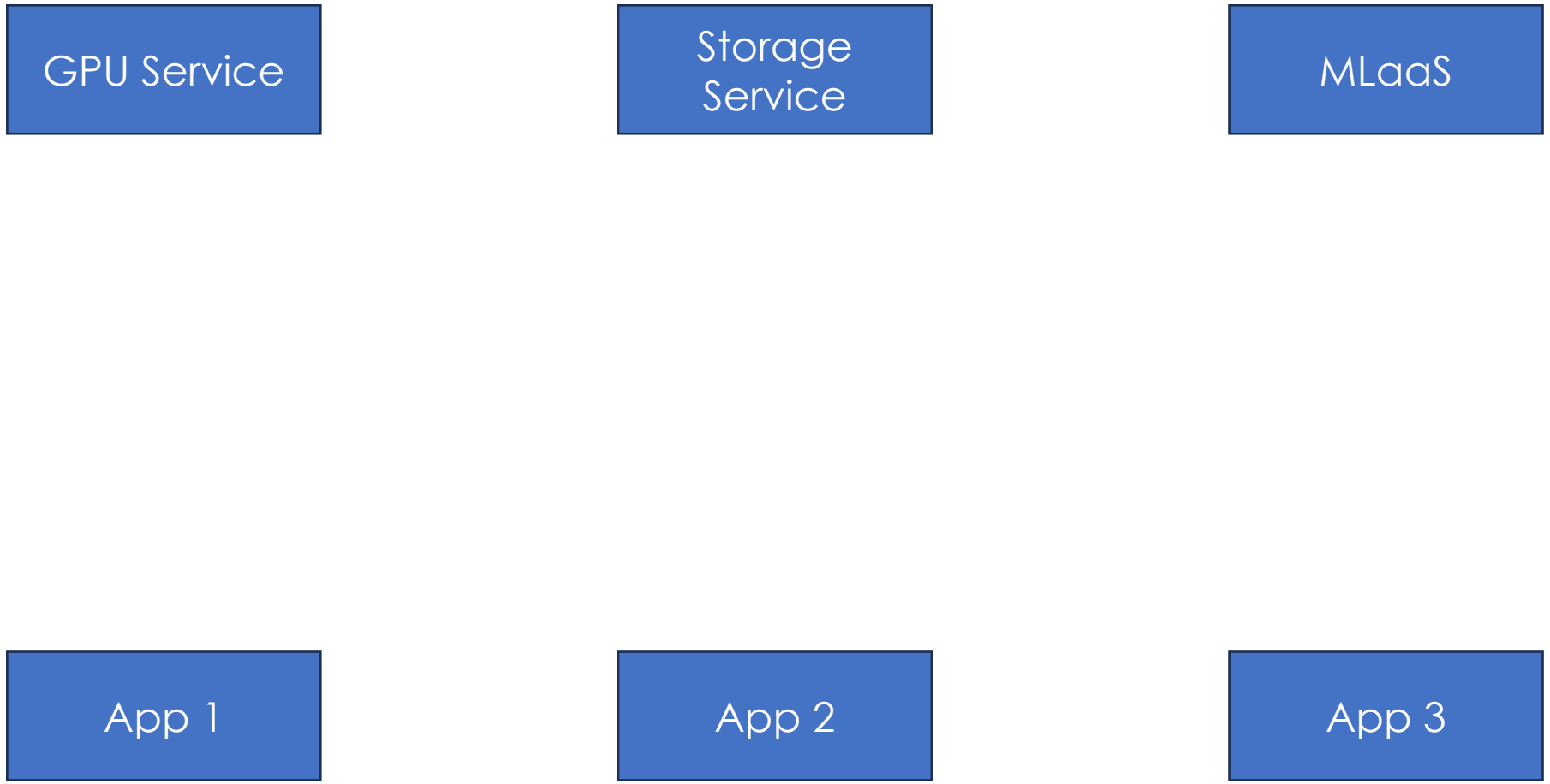

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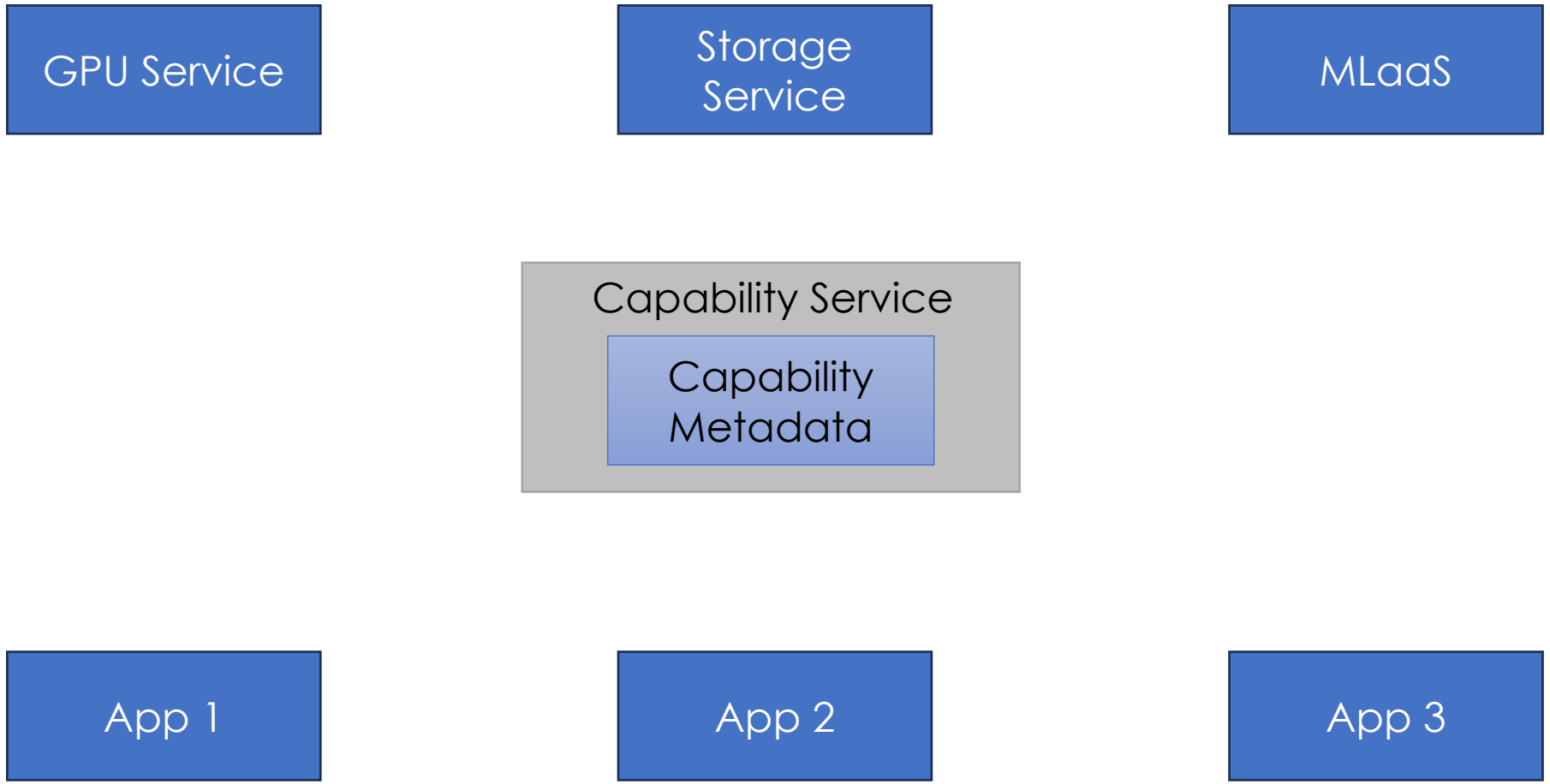

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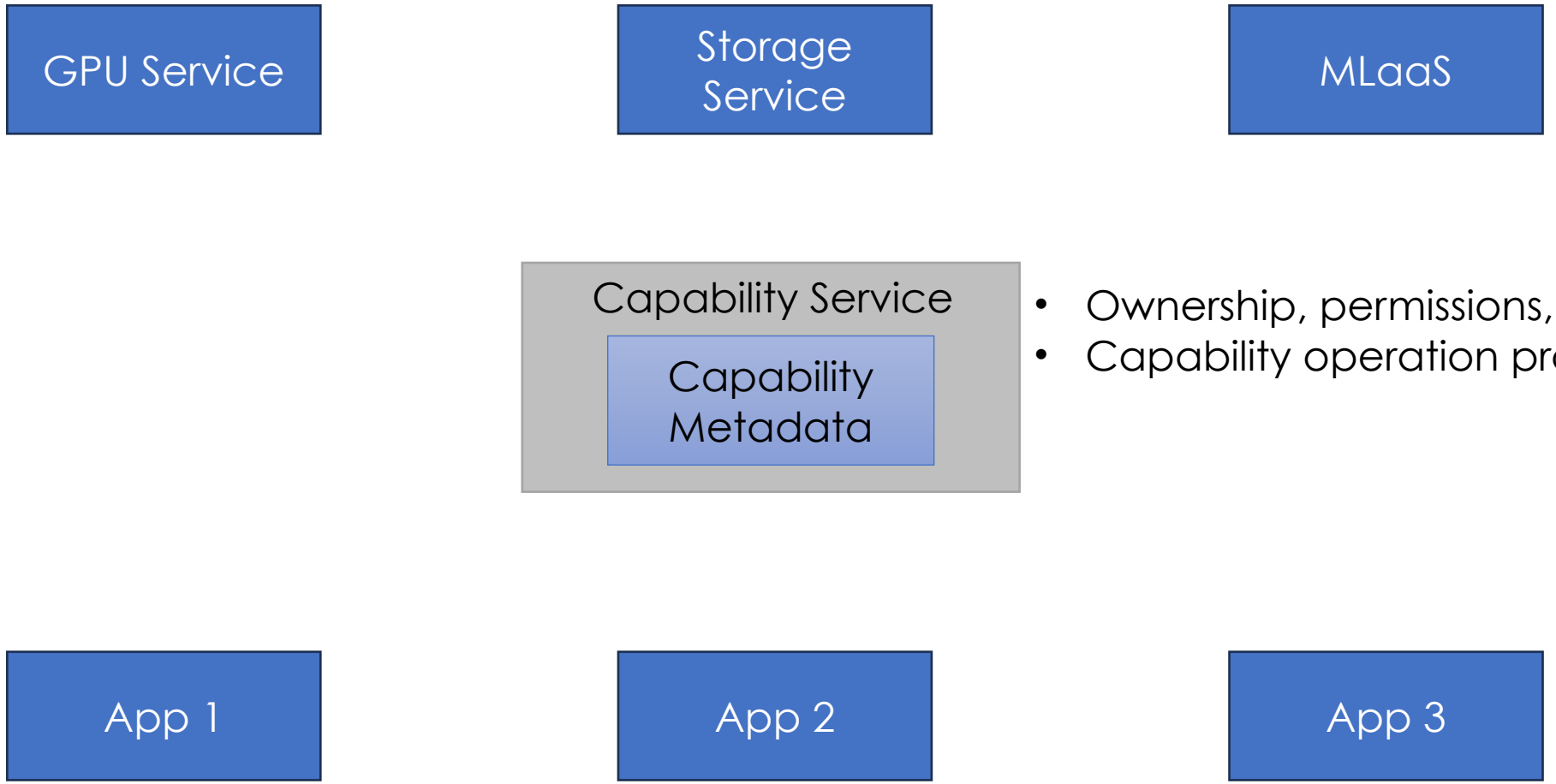

- Ownership, permissions, …
- Capability operation processing

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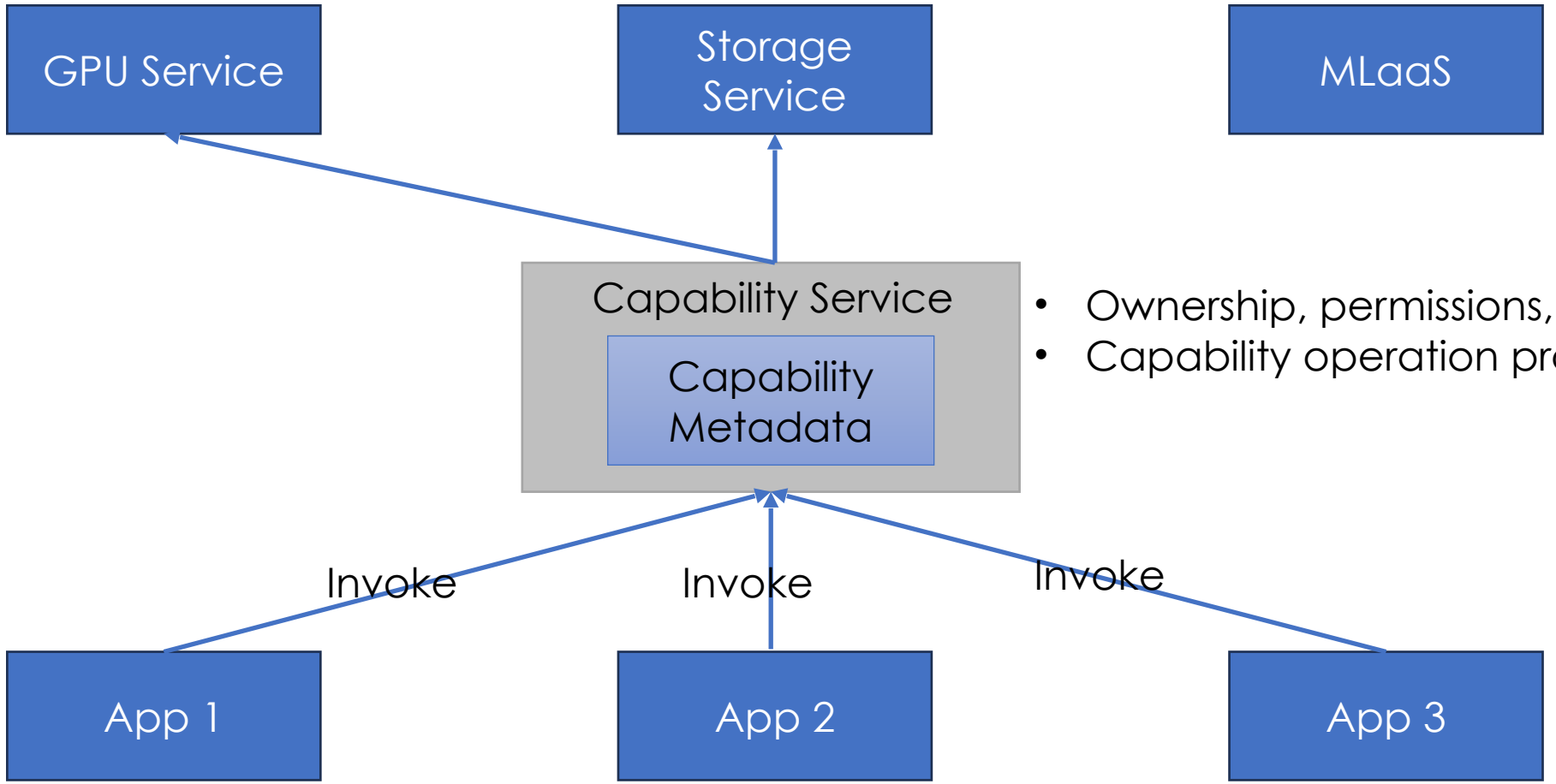

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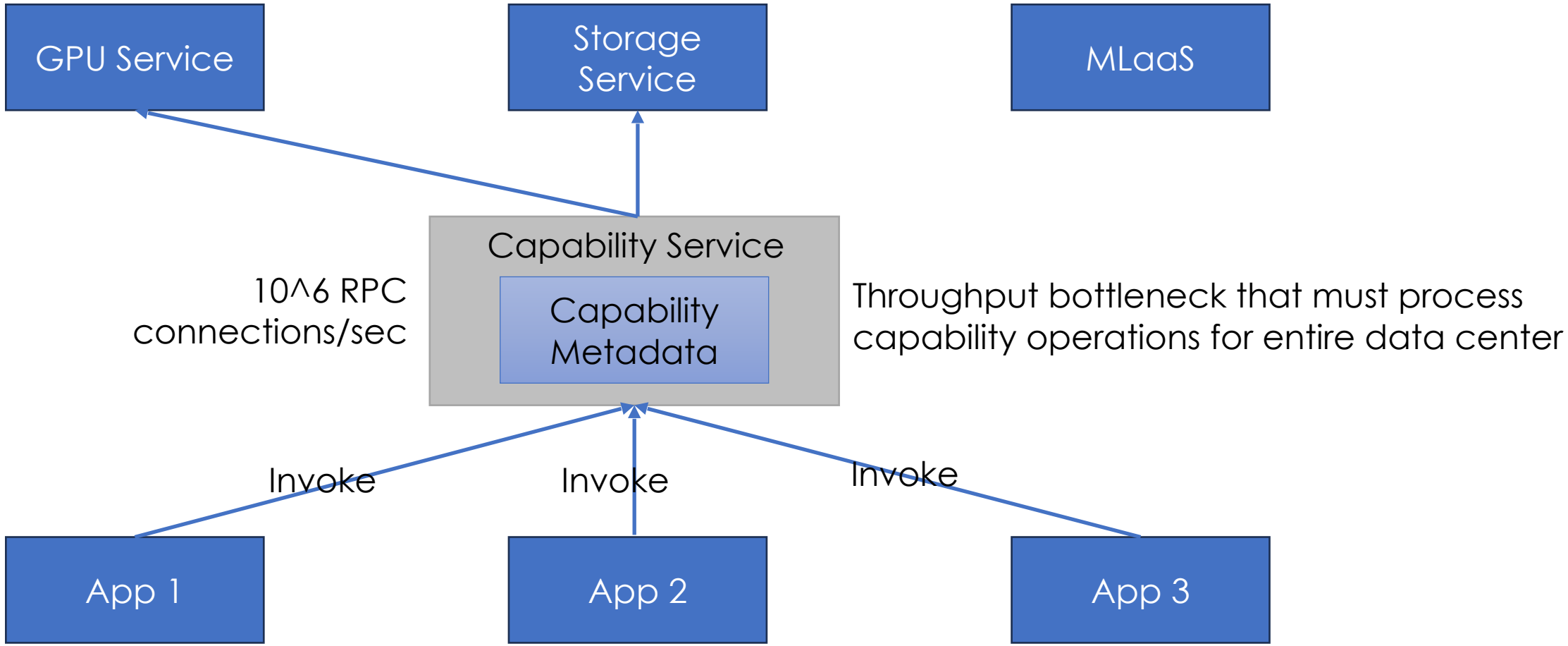

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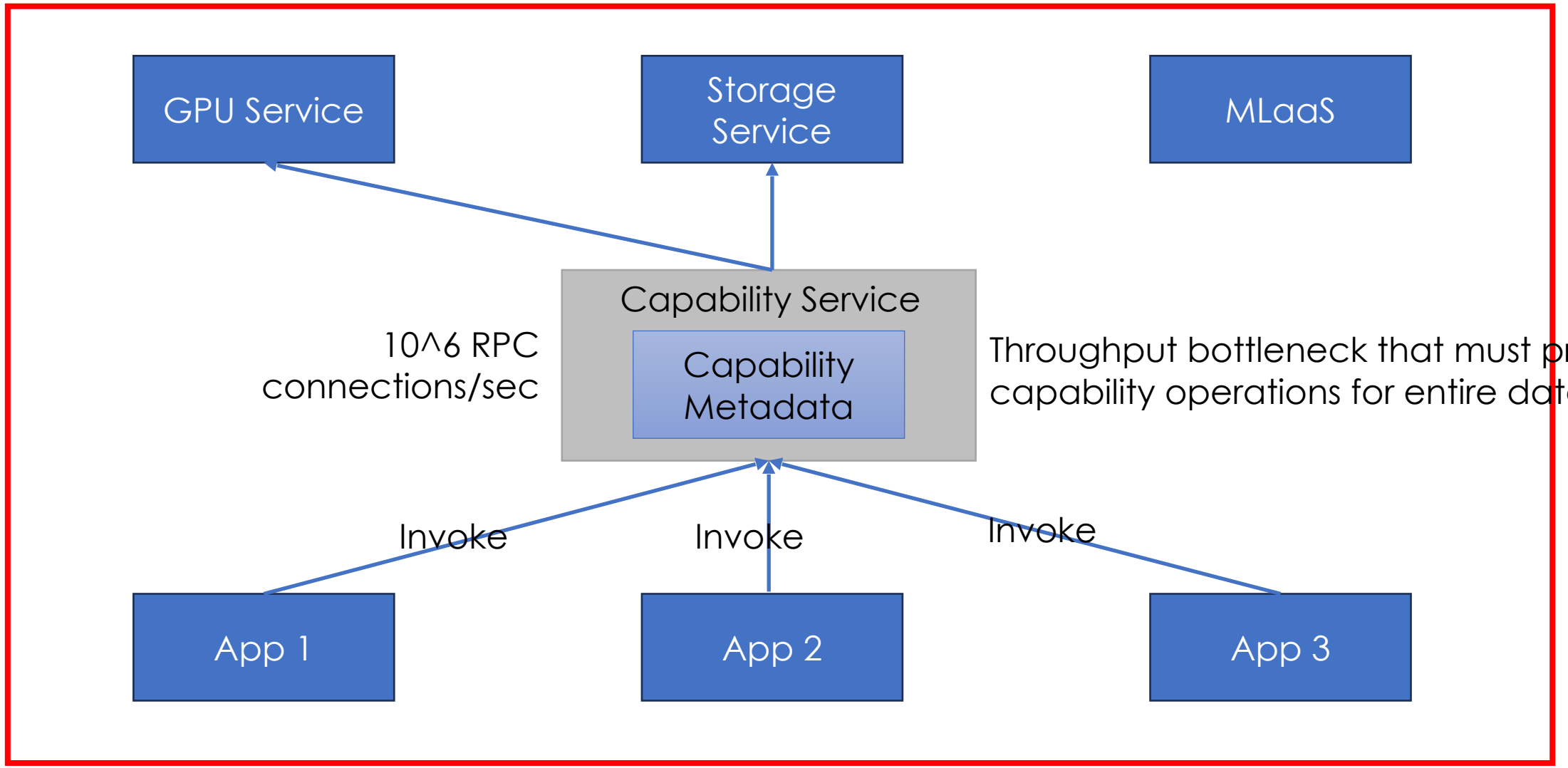
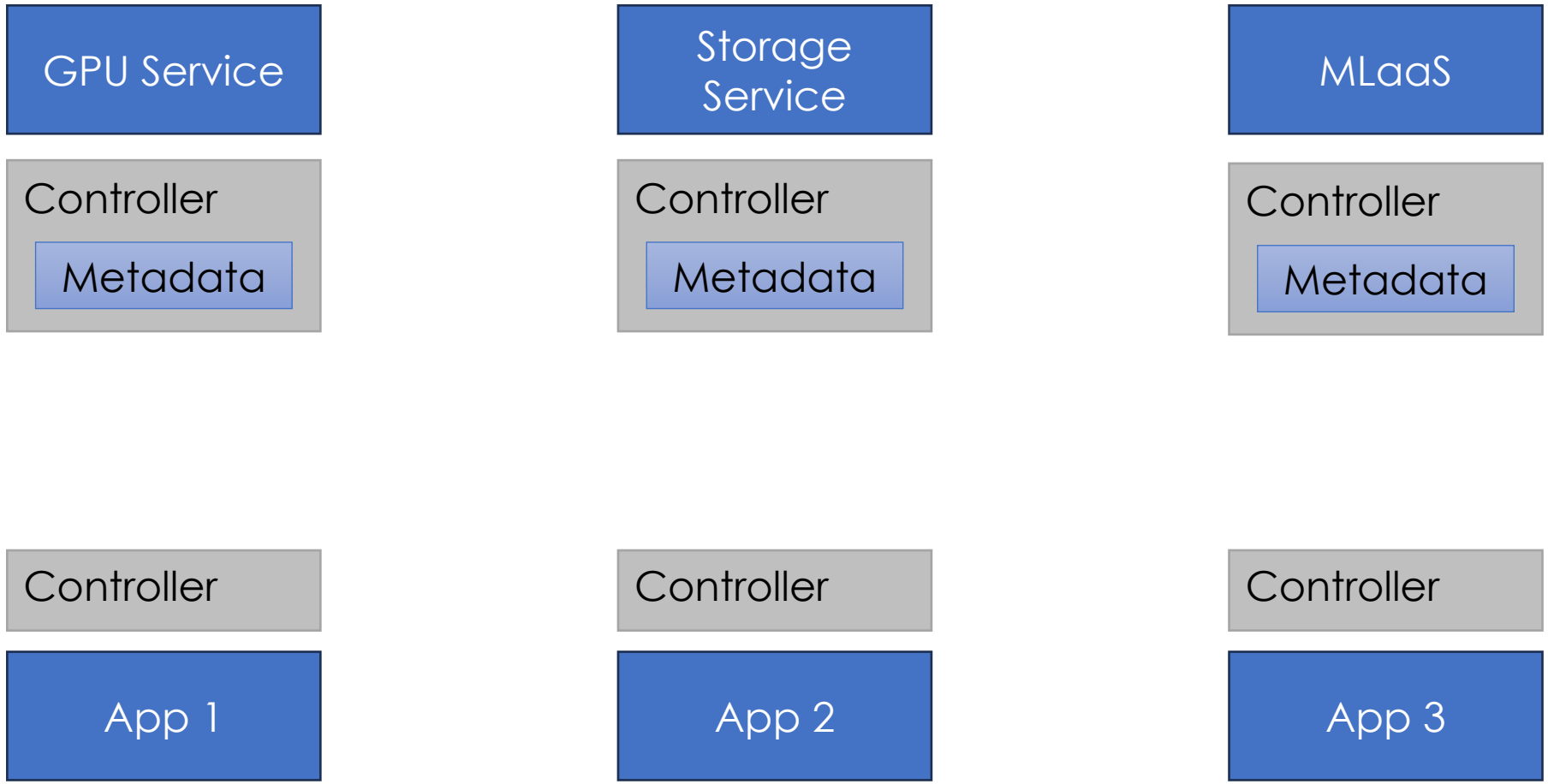


Single point of failure – if the capability service fails the system is no longer usable

Owner-based Metadata Sharding



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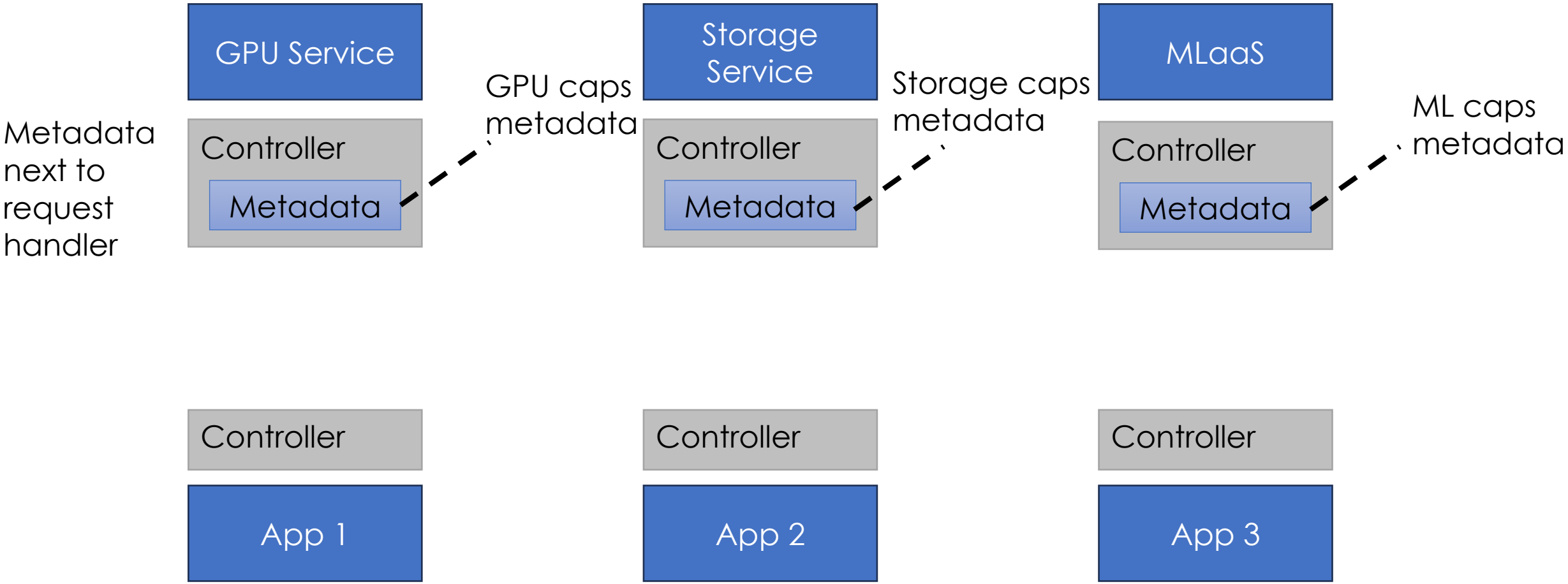

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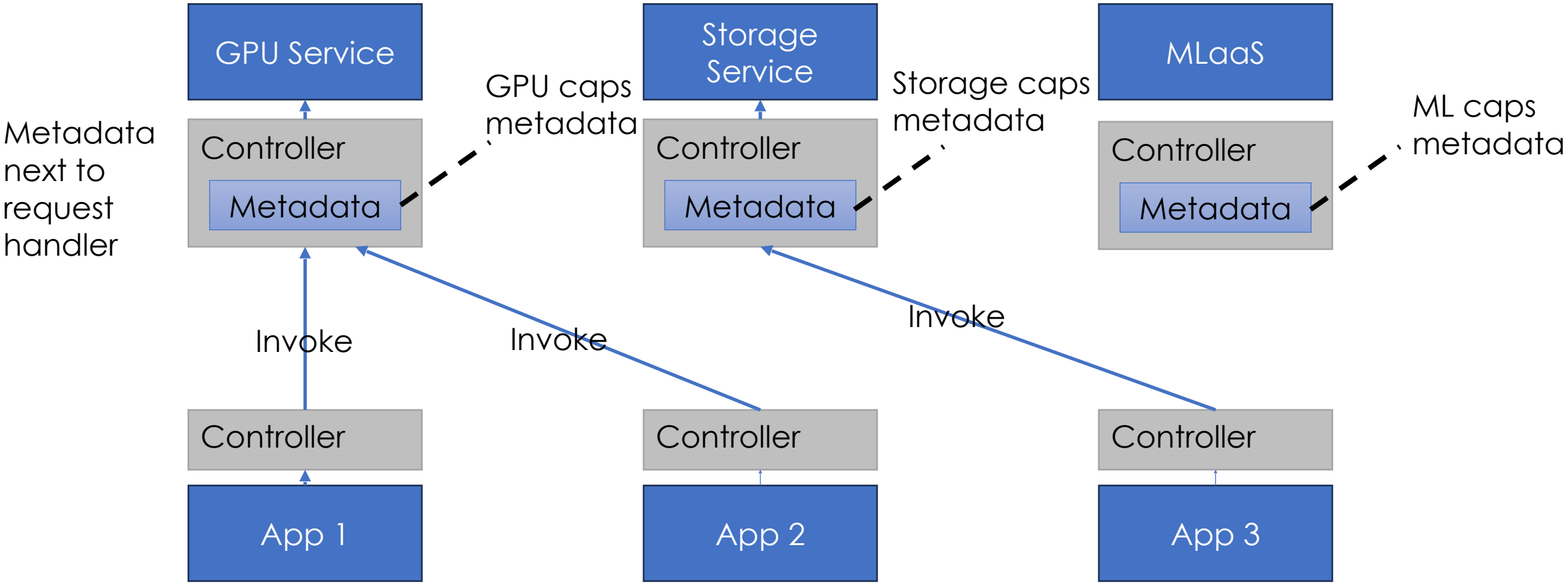

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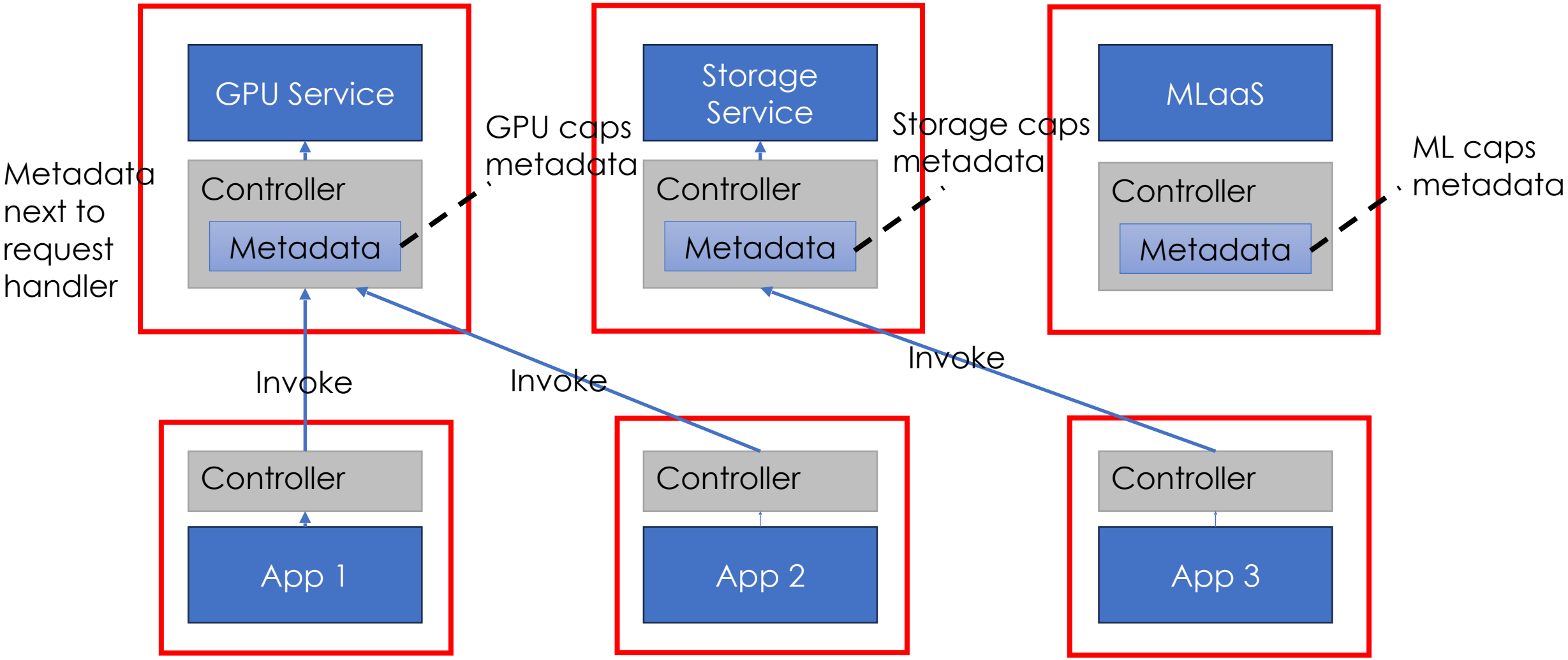
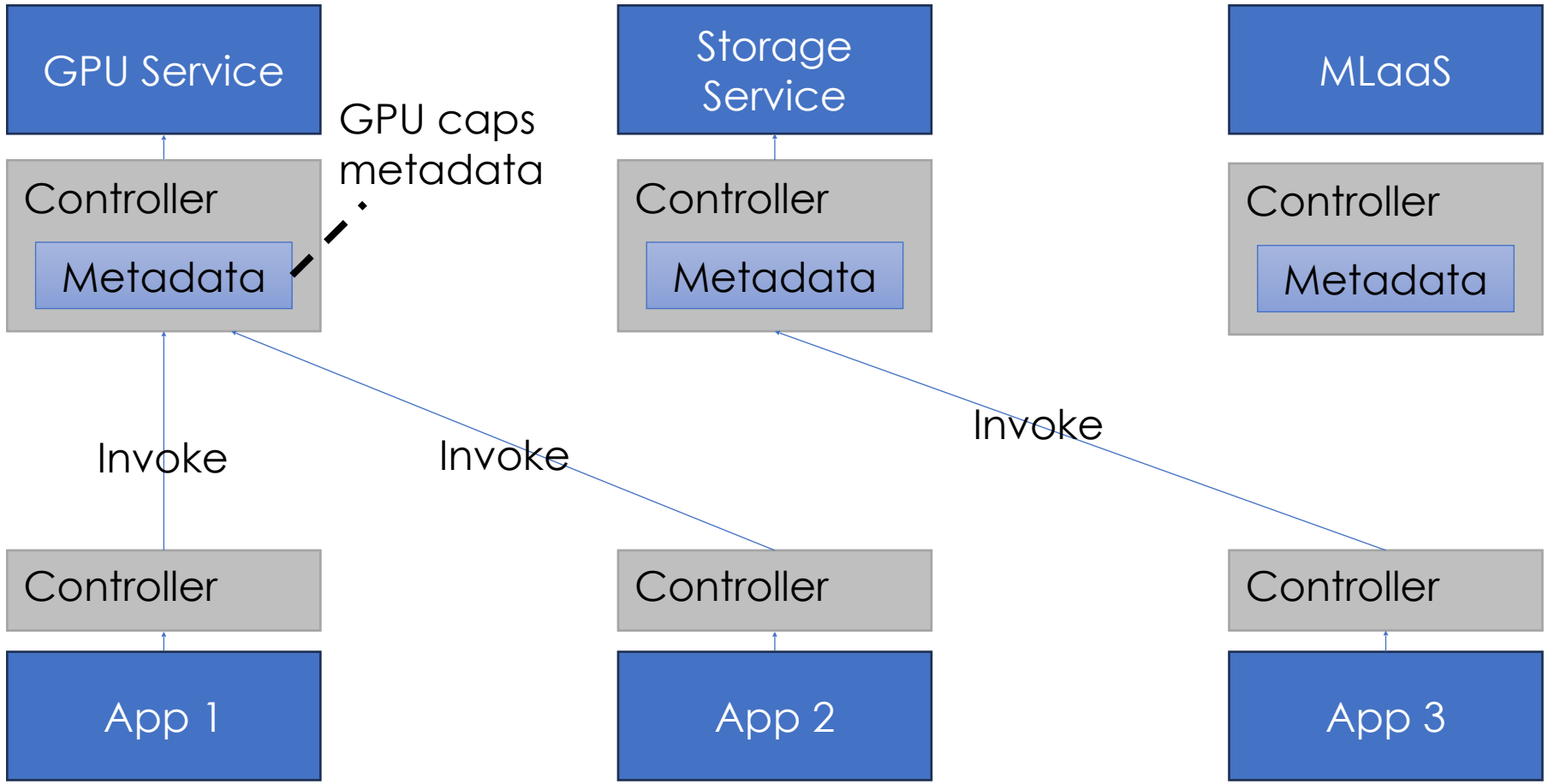


No throughput bottleneck, isolated failure domains

Problem: Inefficient Revocation in Existing Capability Systems



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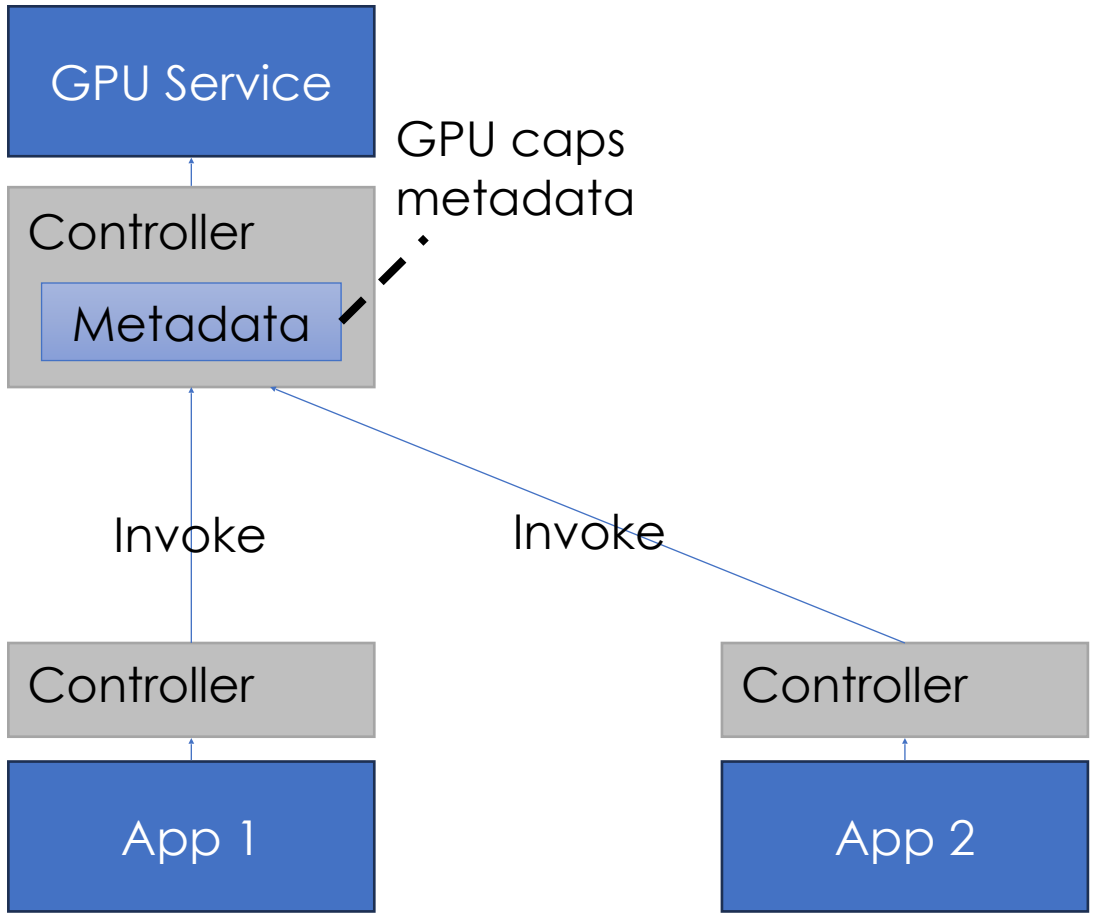

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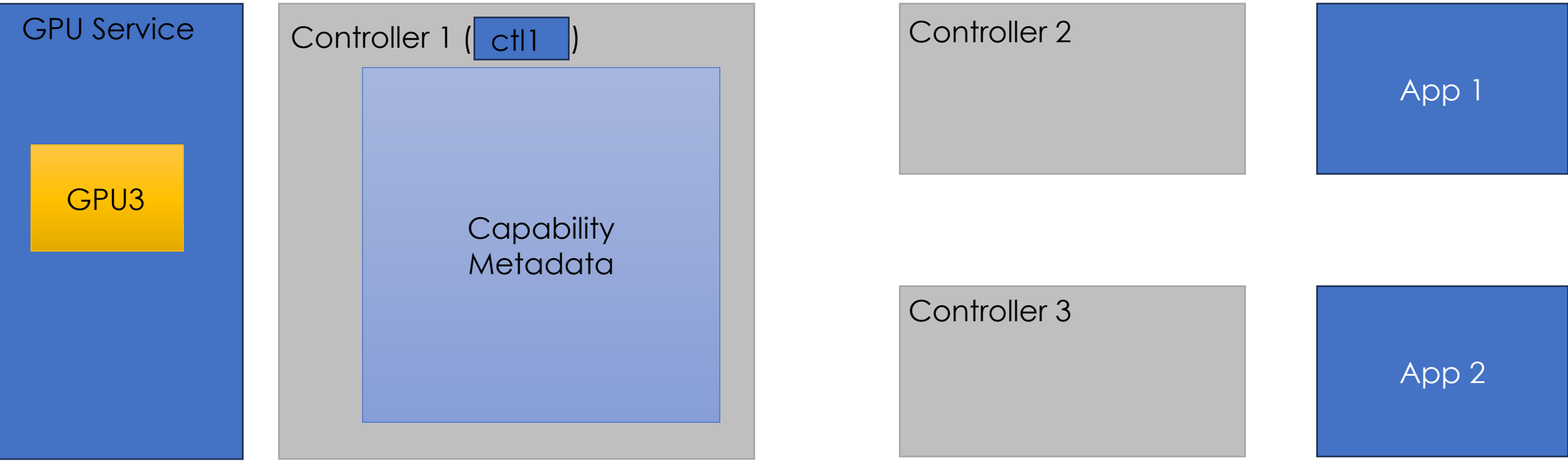

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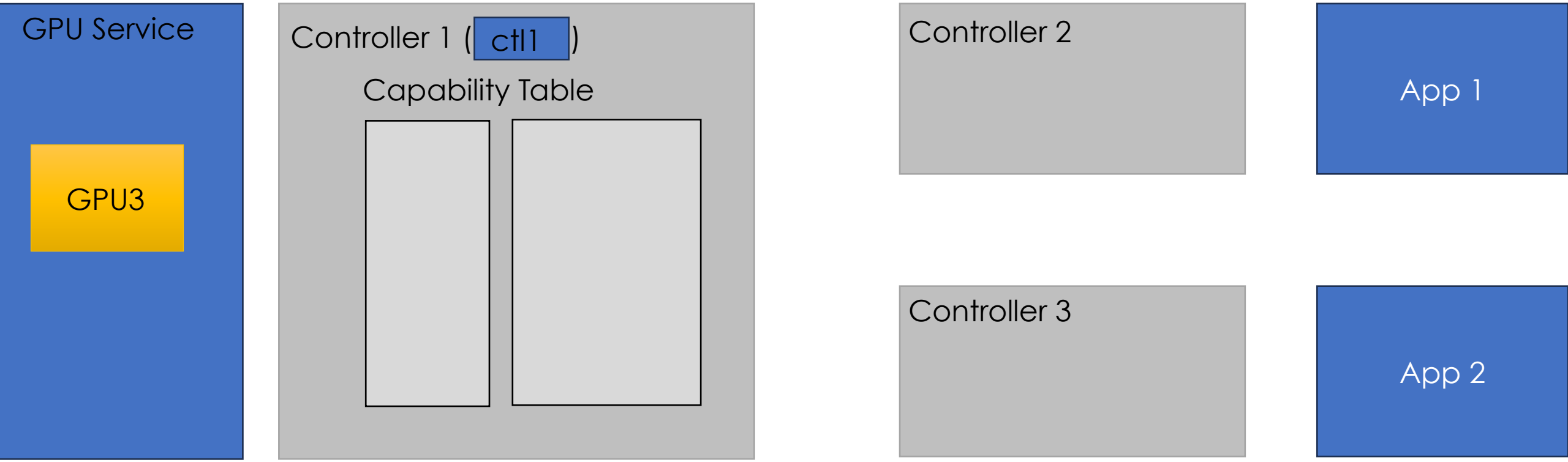

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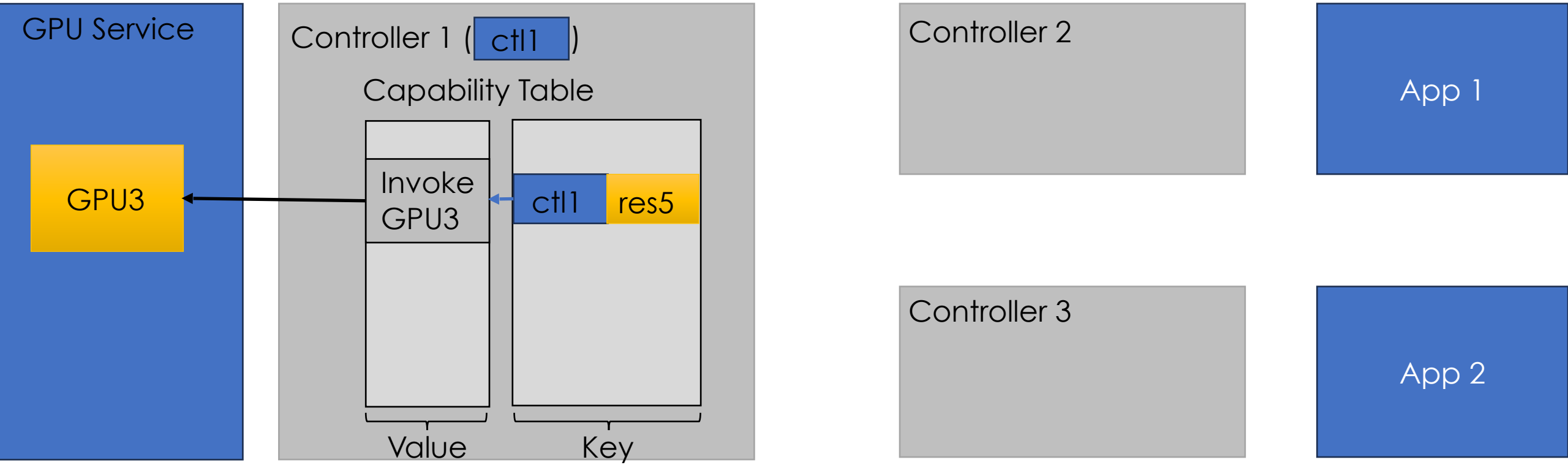

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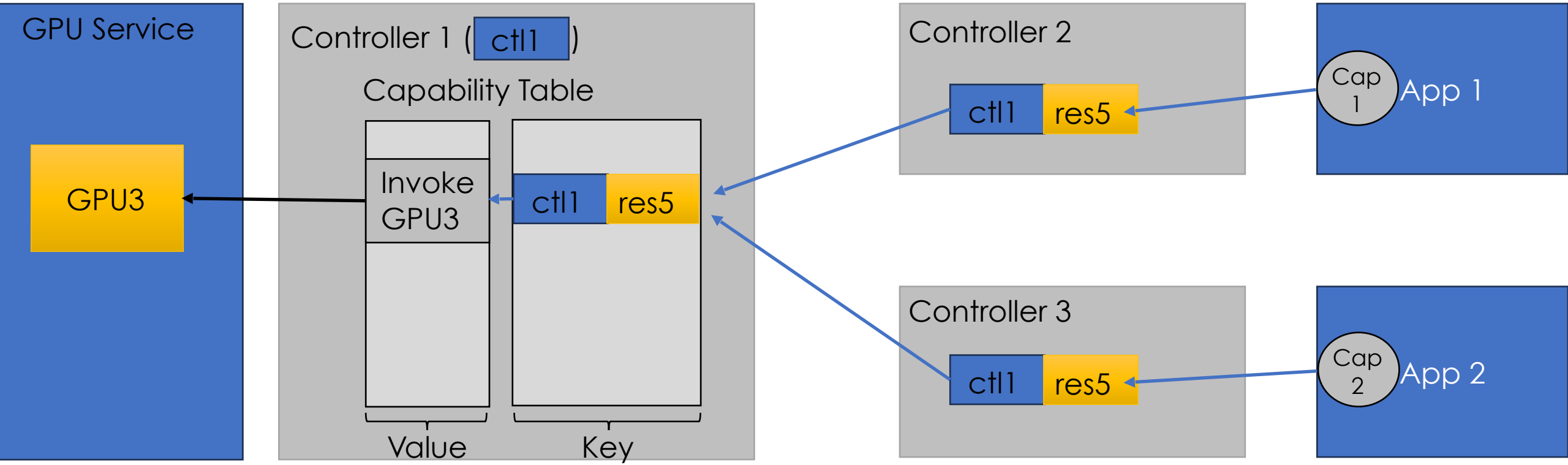

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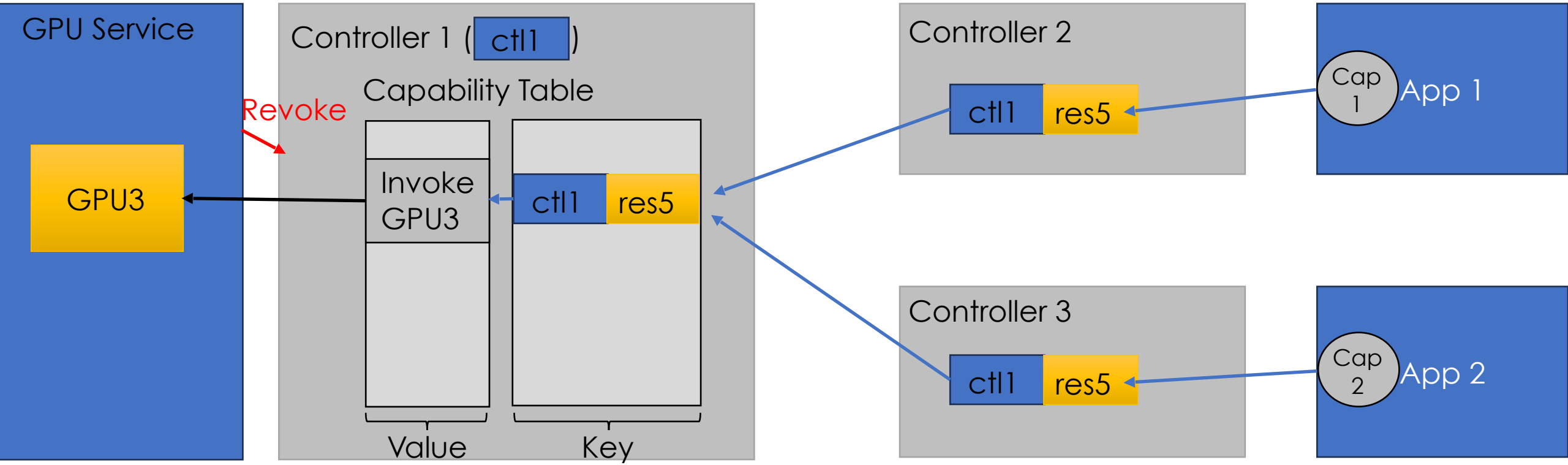

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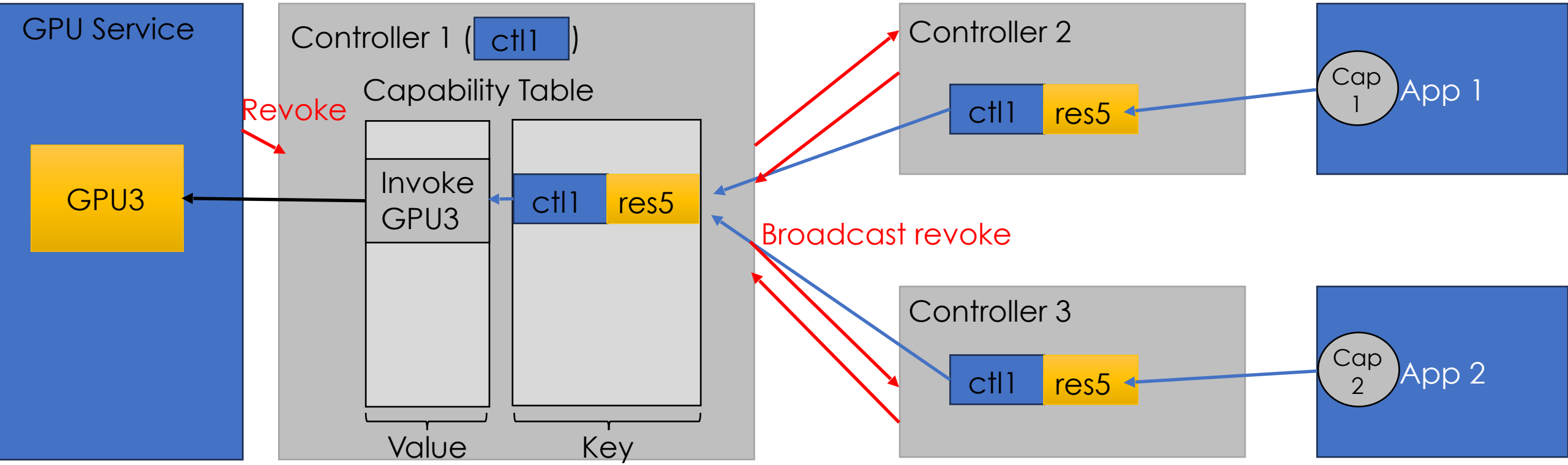

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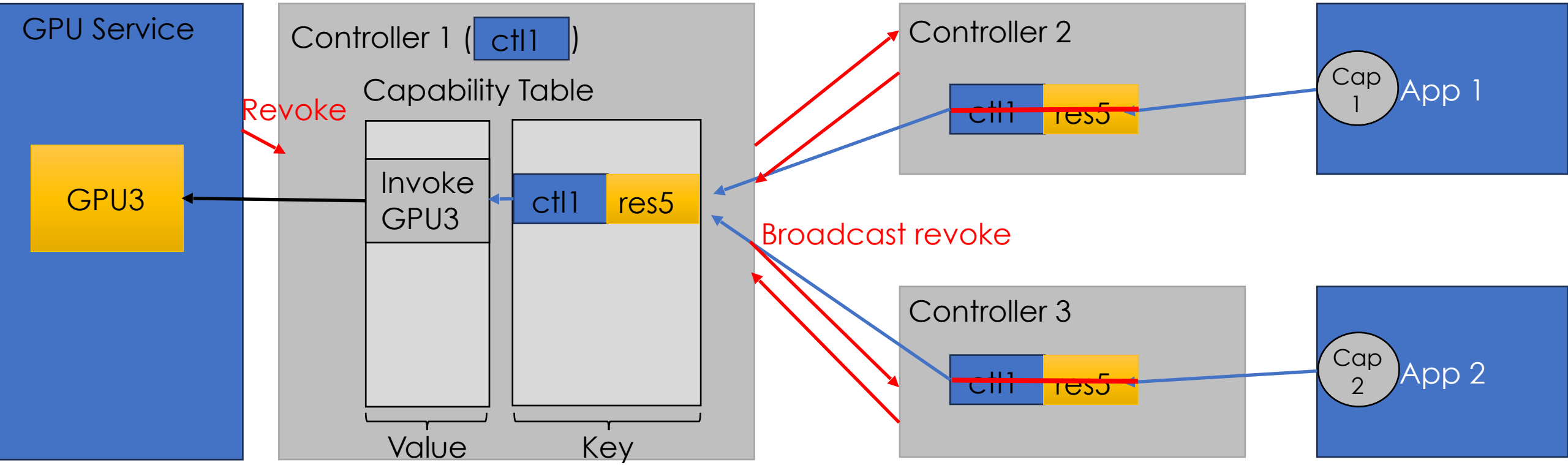

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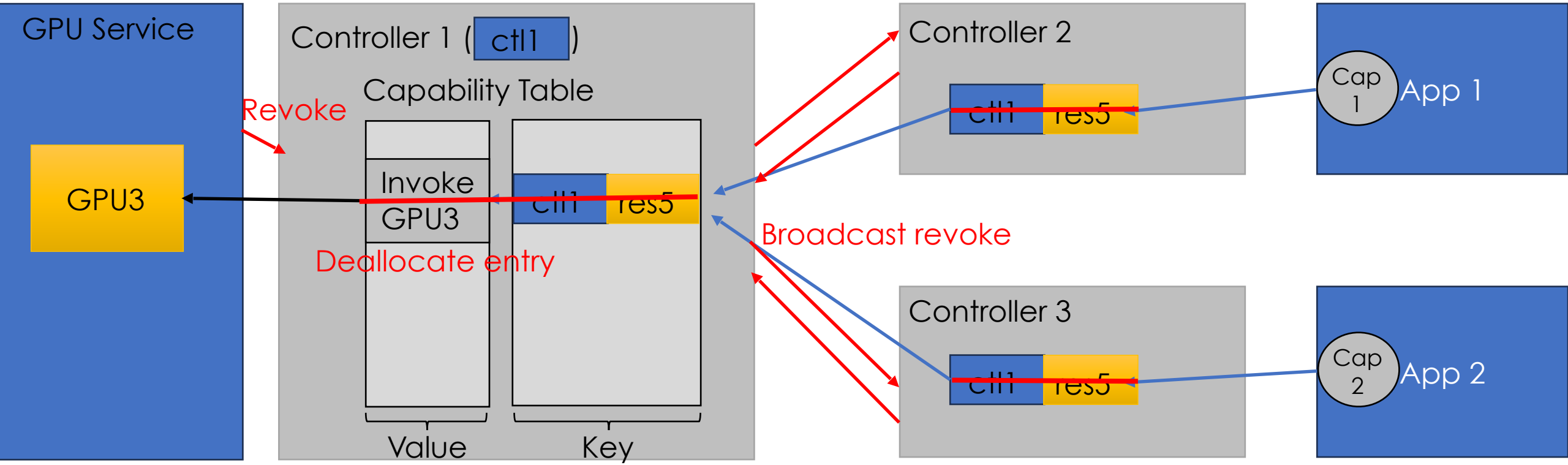

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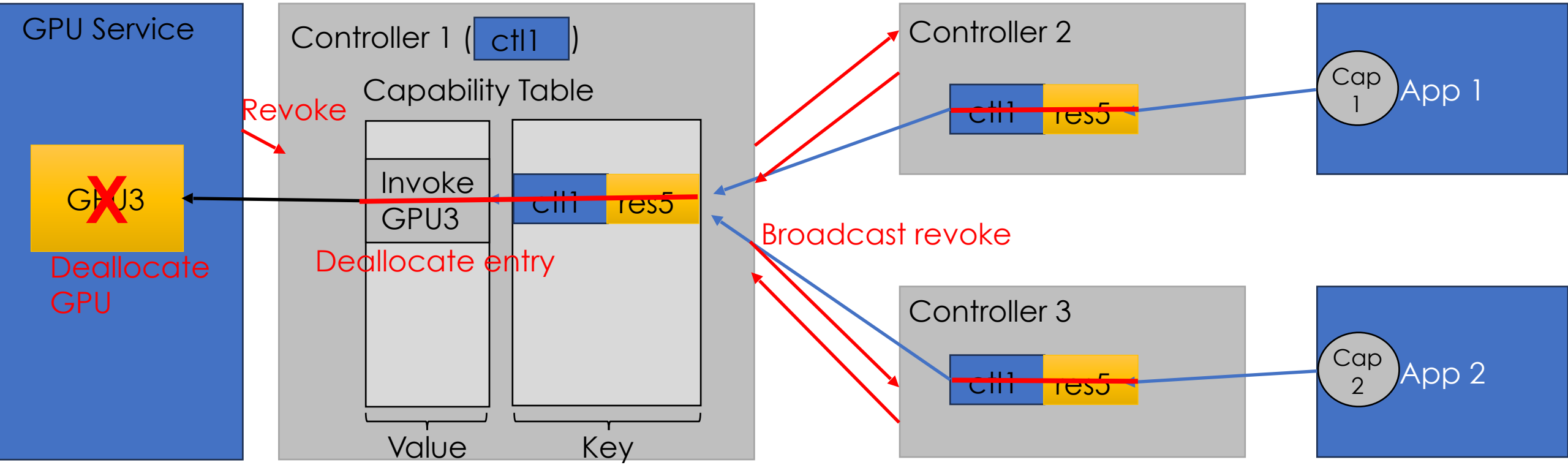

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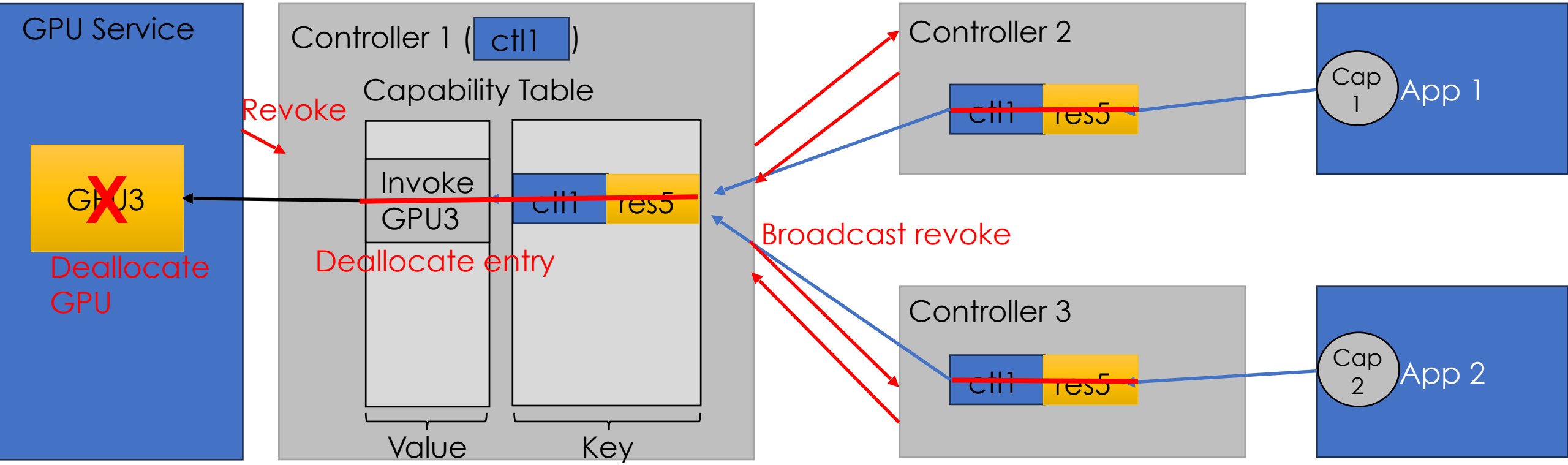
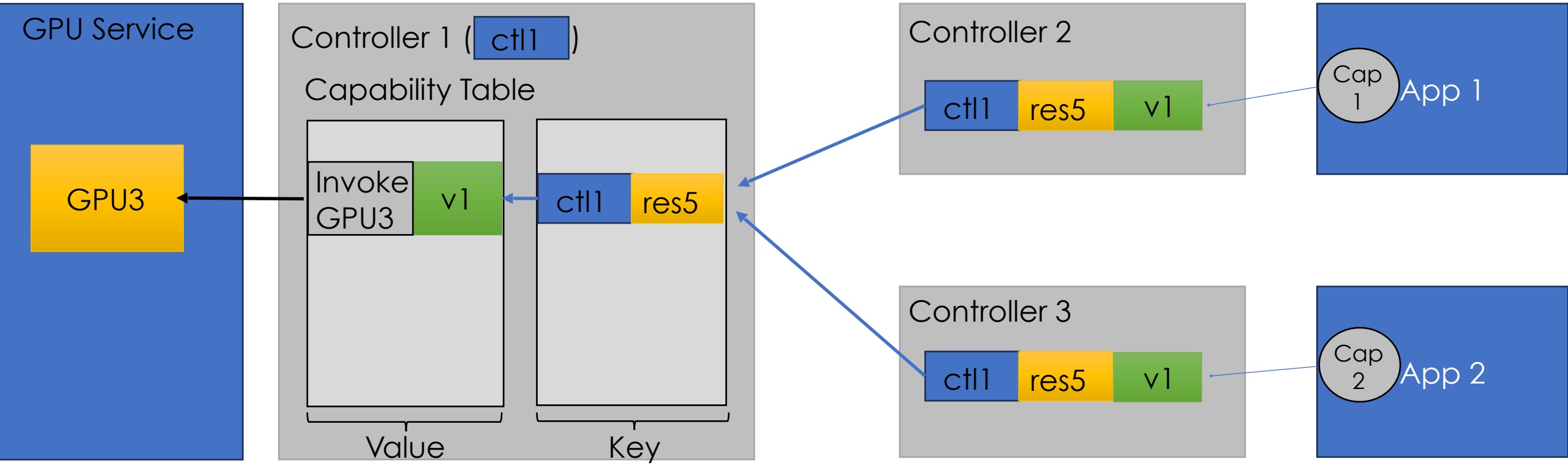
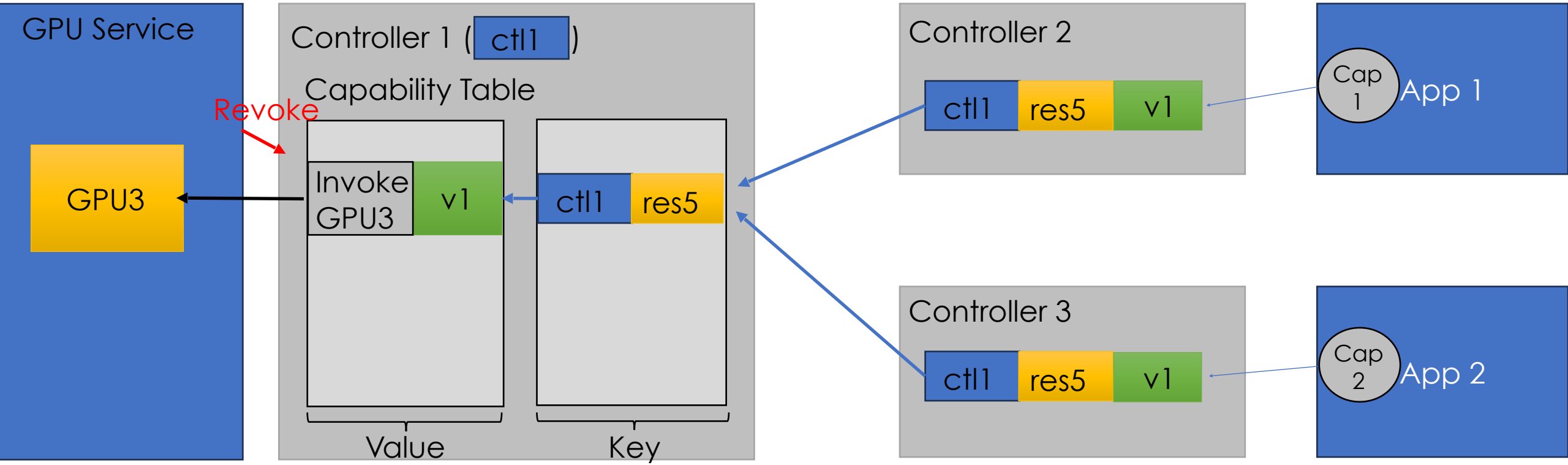


Revocation requires O(N) network messages (and CPU)

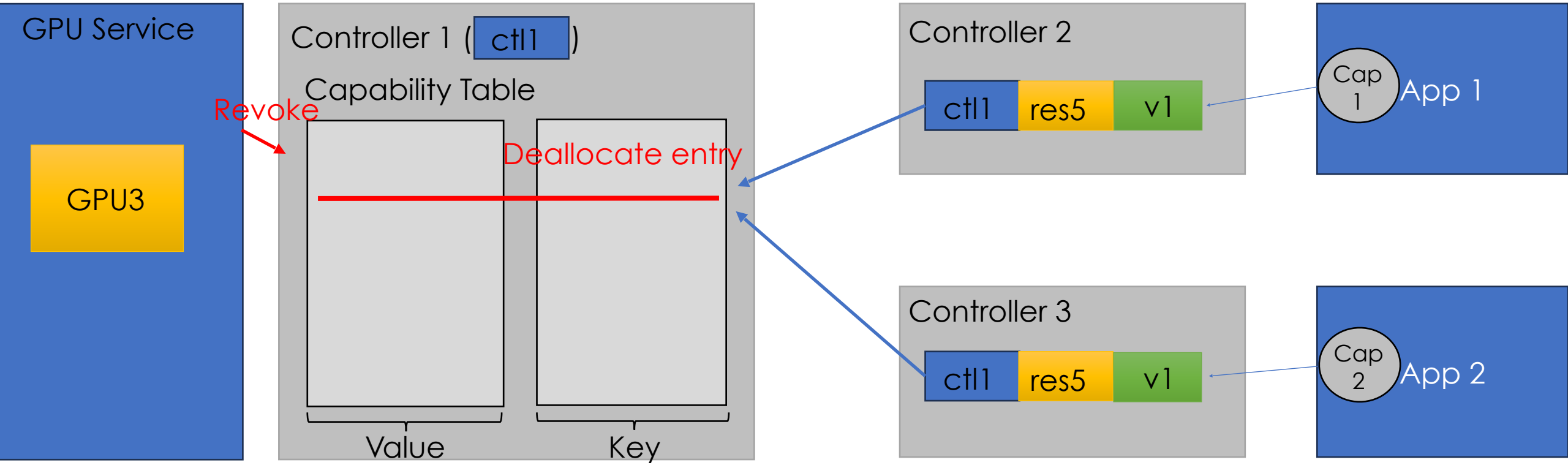
Versioned Capabilities



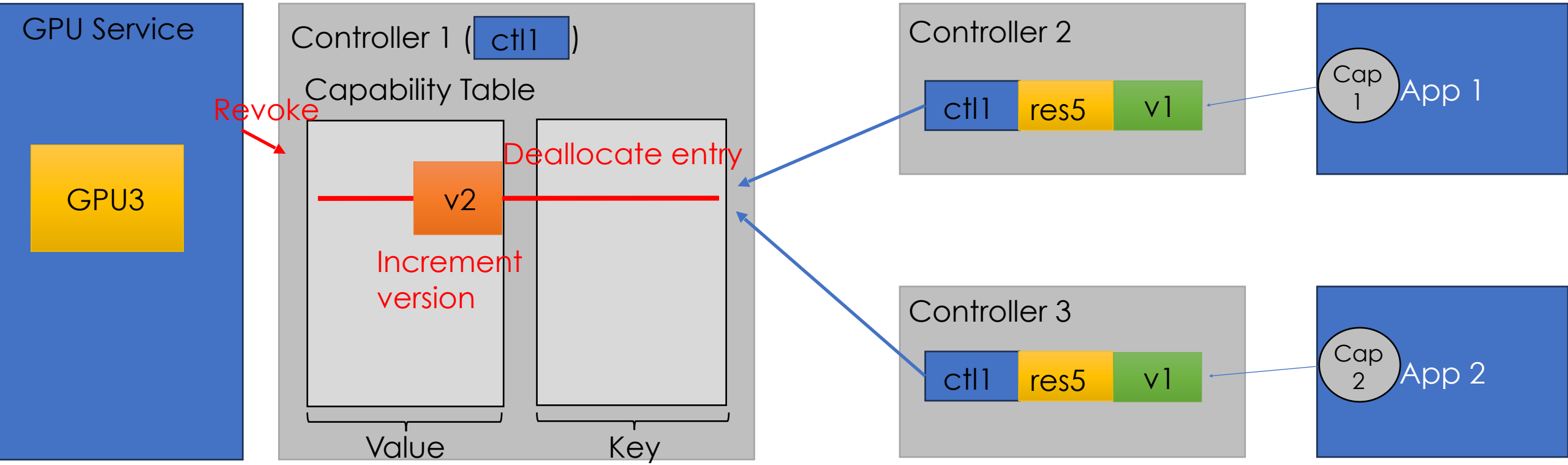
Versioned Capabilities



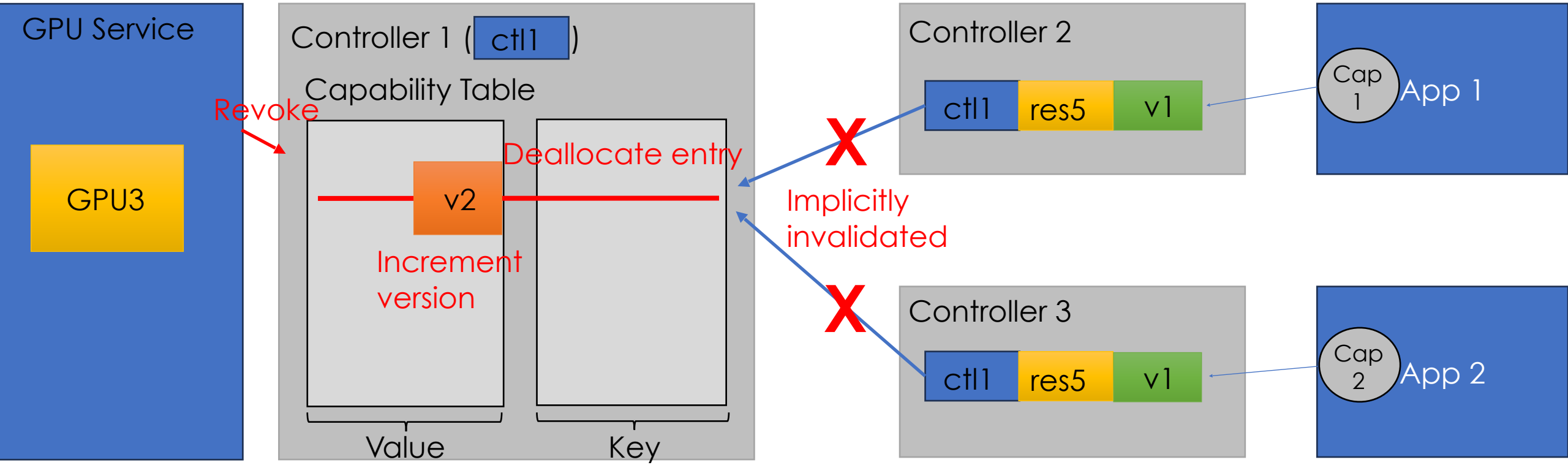
Versioned Capabilities



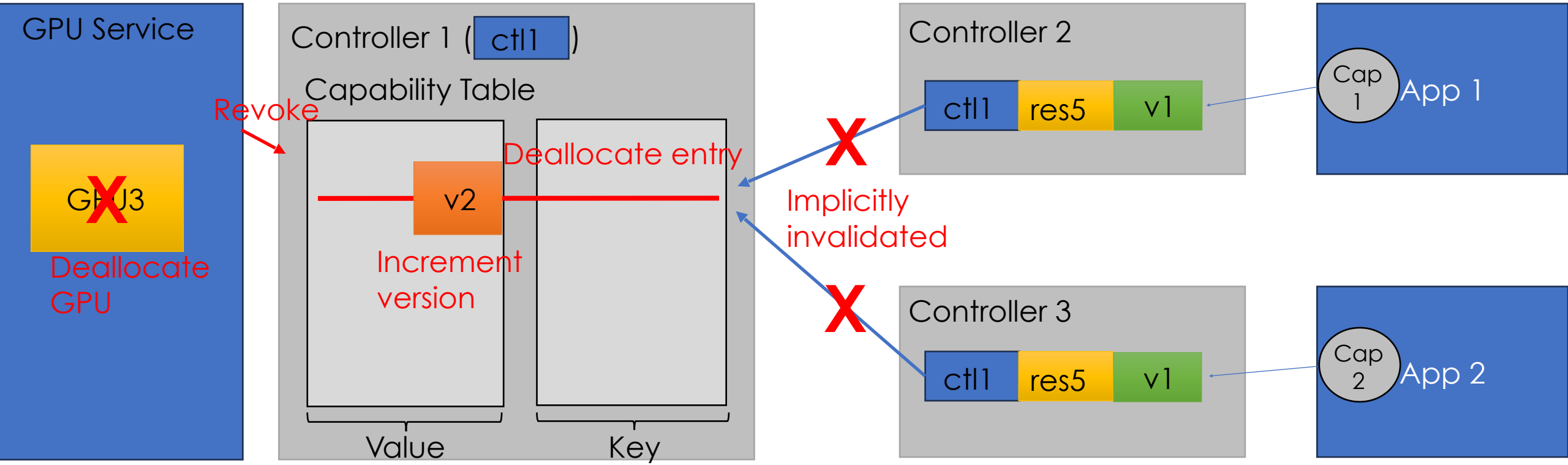
Versioned Capabilities



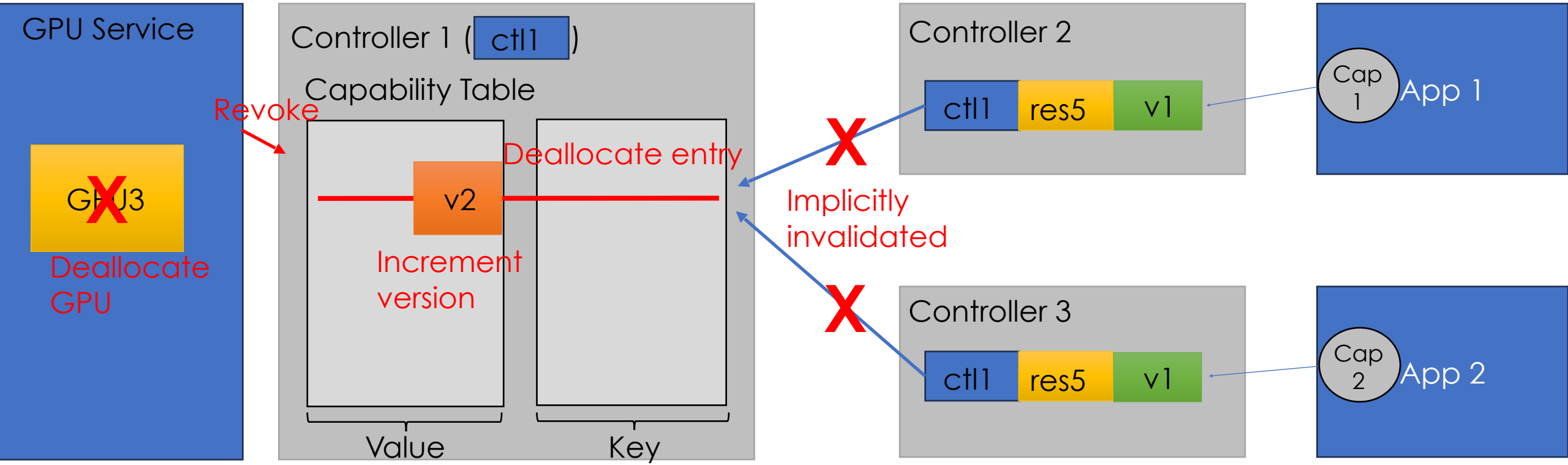
Versioned Capabilities



Versioned Capabilities

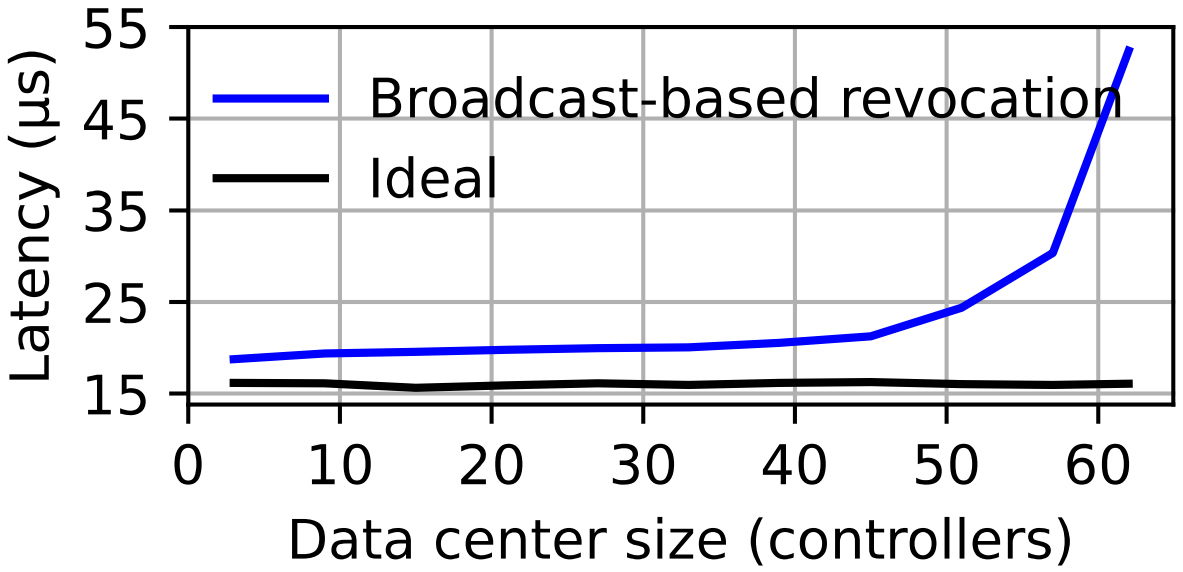


Versioned Capabilities

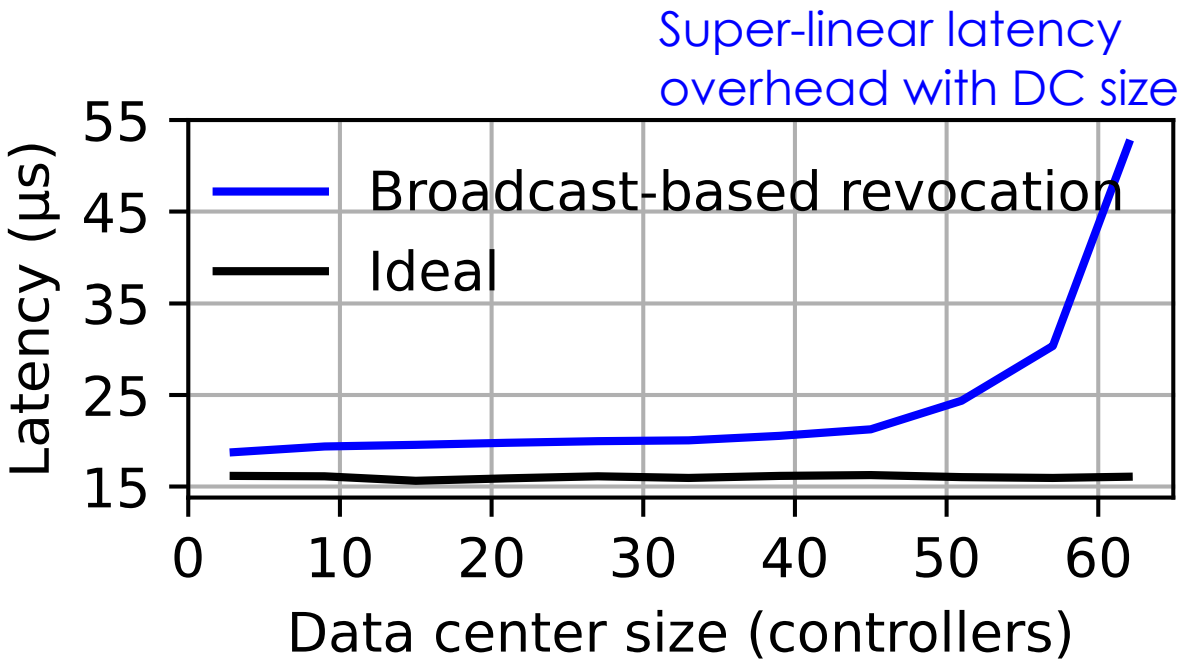


Revocation requires zero network transmission (or CPU)

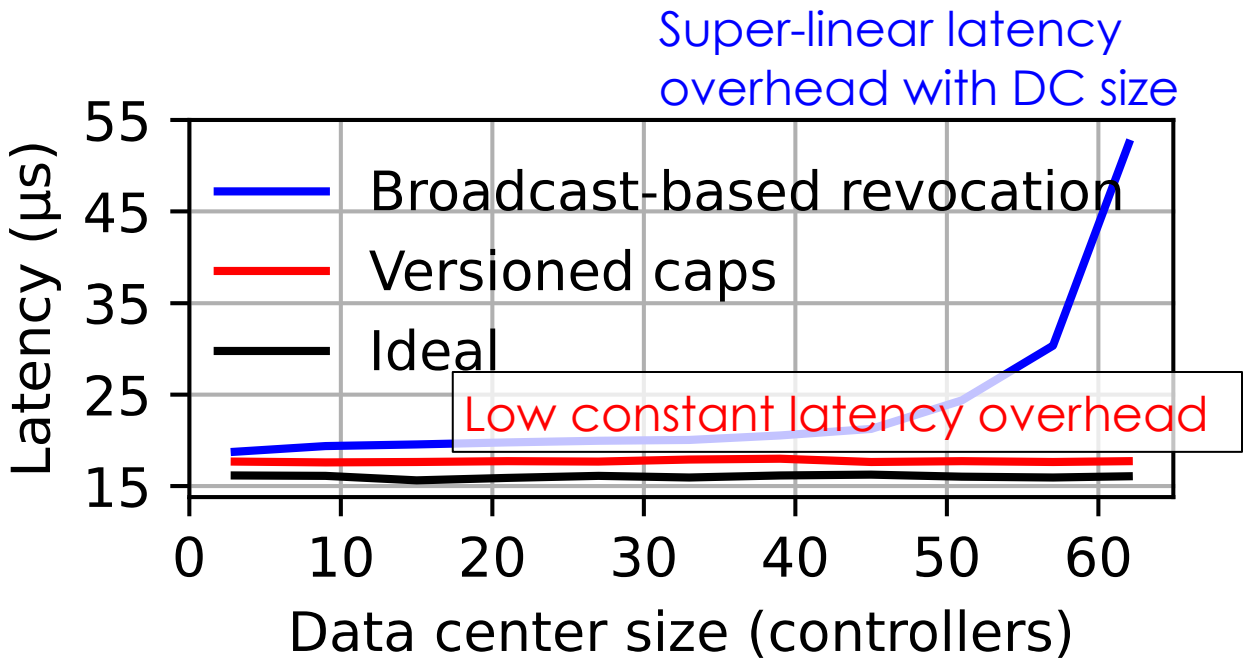
Evaluation


Latency (µs)
55
45
35
25
15
0
10
20
30
40
50
60
Data center size (controllers)
Broadcast-based revocation
Ideal

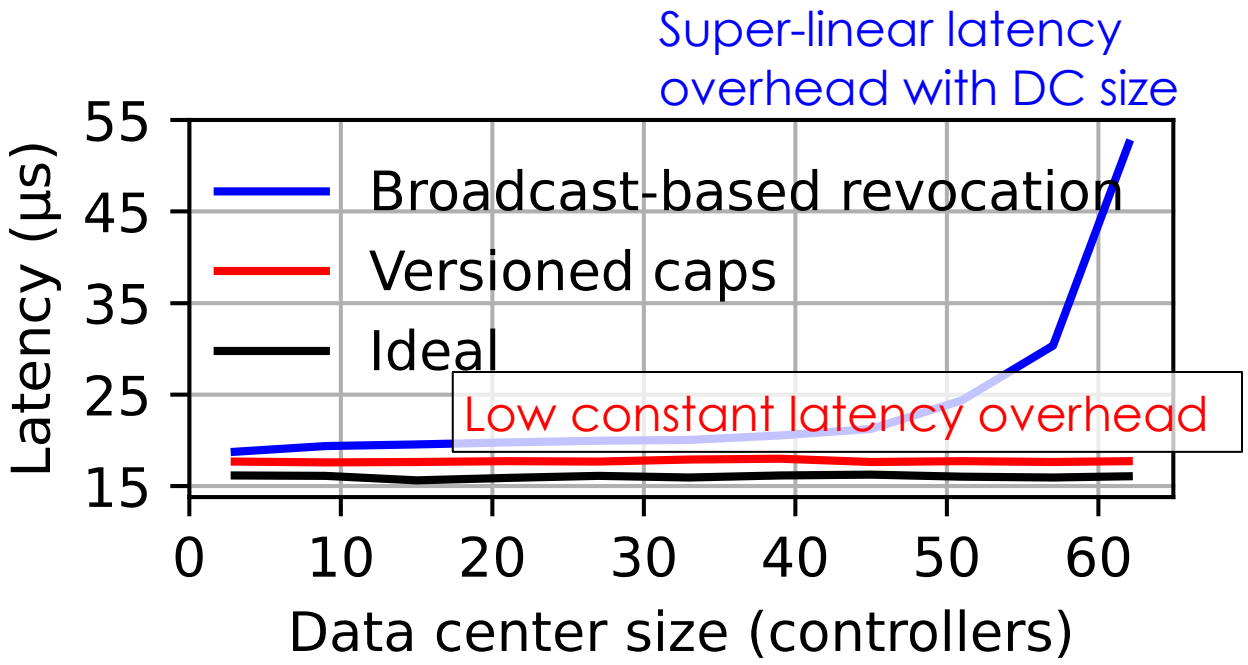
Evaluation


Super-linear latency
overhead with DC size
Latency (µs)
55
45
35
25
15
Broadcast-based revocation
Ideal
0
10
20
30
40
50
60
Data center size (controllers)

Evaluation


Super-linear latency
overhead with DC size
Broadcast-based revocation
Versioned caps
Ideal
Low constant latency overhead
Latency (µs)
55
45
35
25
15
0
10
20
30
40
50
60
Data center size (controllers)

Evaluation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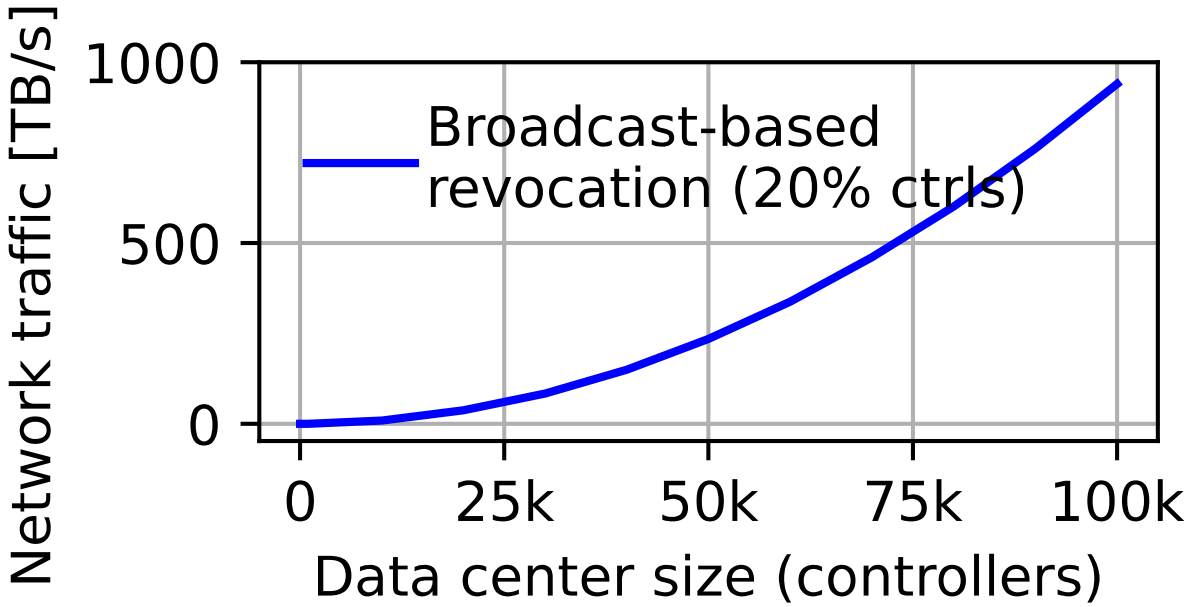
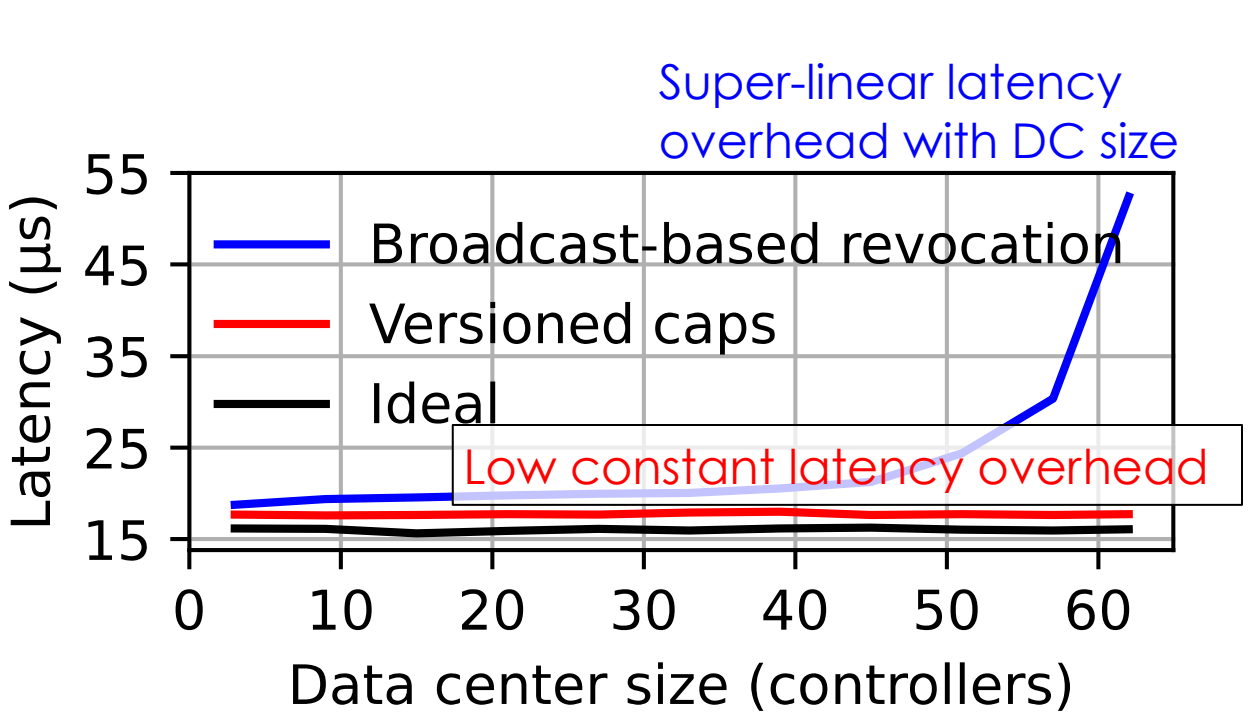
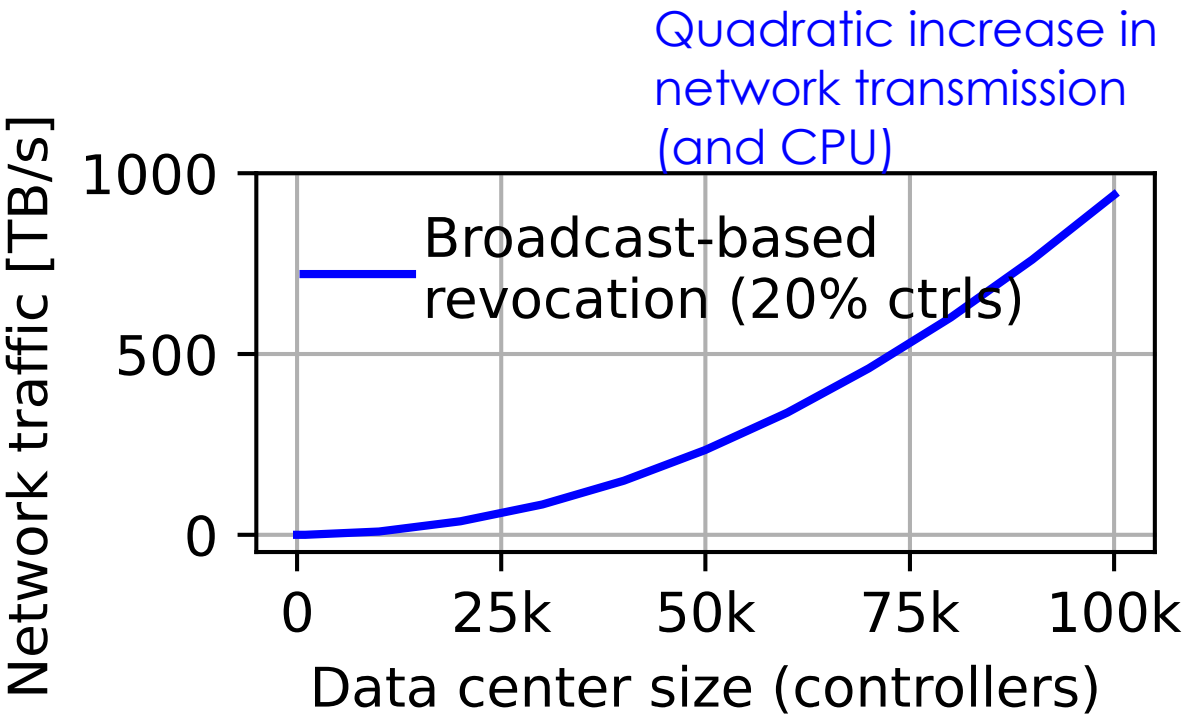
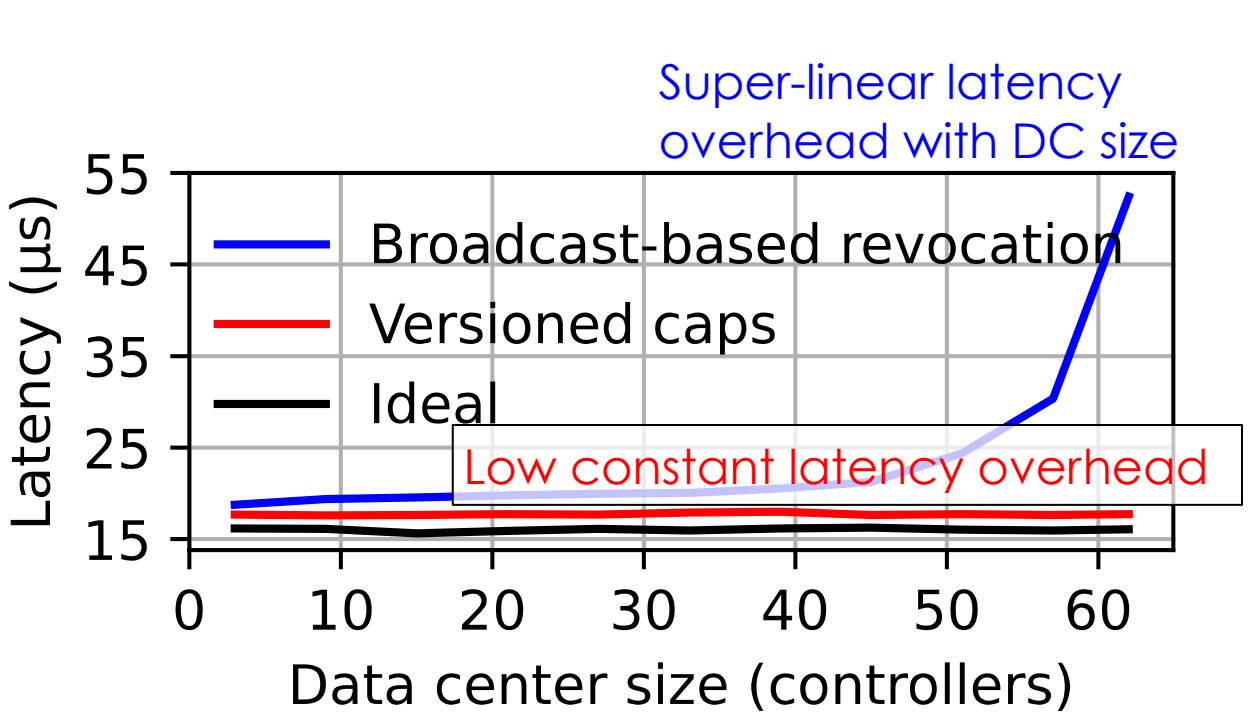

Network traffic [TB/s]
1000
500
0
Broadcast-based
revocation (20% ctrls)
0
25k
50k
75k
100k
Data center size (controllers)

Evaluation


Super-linear latency overhead with DC size
Latency (µs)
55
45
35
25
15
Broadcast-based revocation
Versioned caps
Ideal
Low constant latency overhead
0
10
20
30
40
50
60
Data center size (controllers)


Quadratic increase in network transmission (and CPU)
Network traffic [TB/s]
1000
500
0
Broadcast-based revocation (20% ctrls)
0
25k
50k
75k
100k
Data center size (controllers)

Evaluation


Super-linear latency overhead with DC size
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55
45
35
25
15
0
10
20
30
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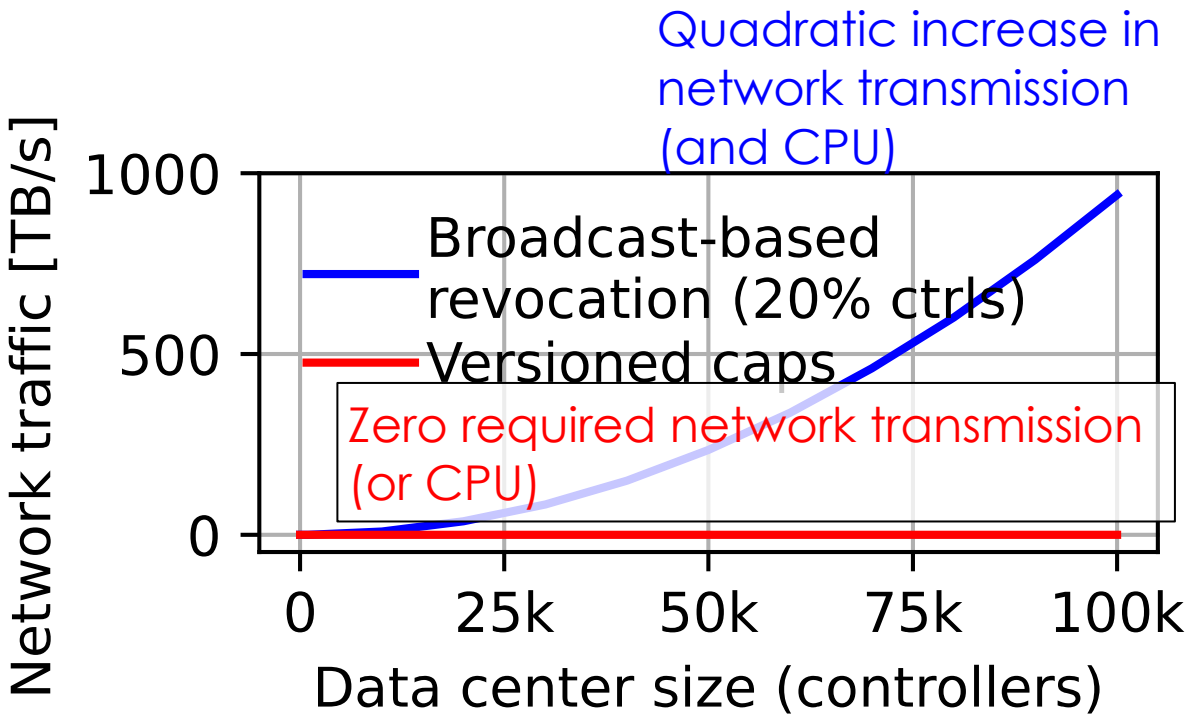
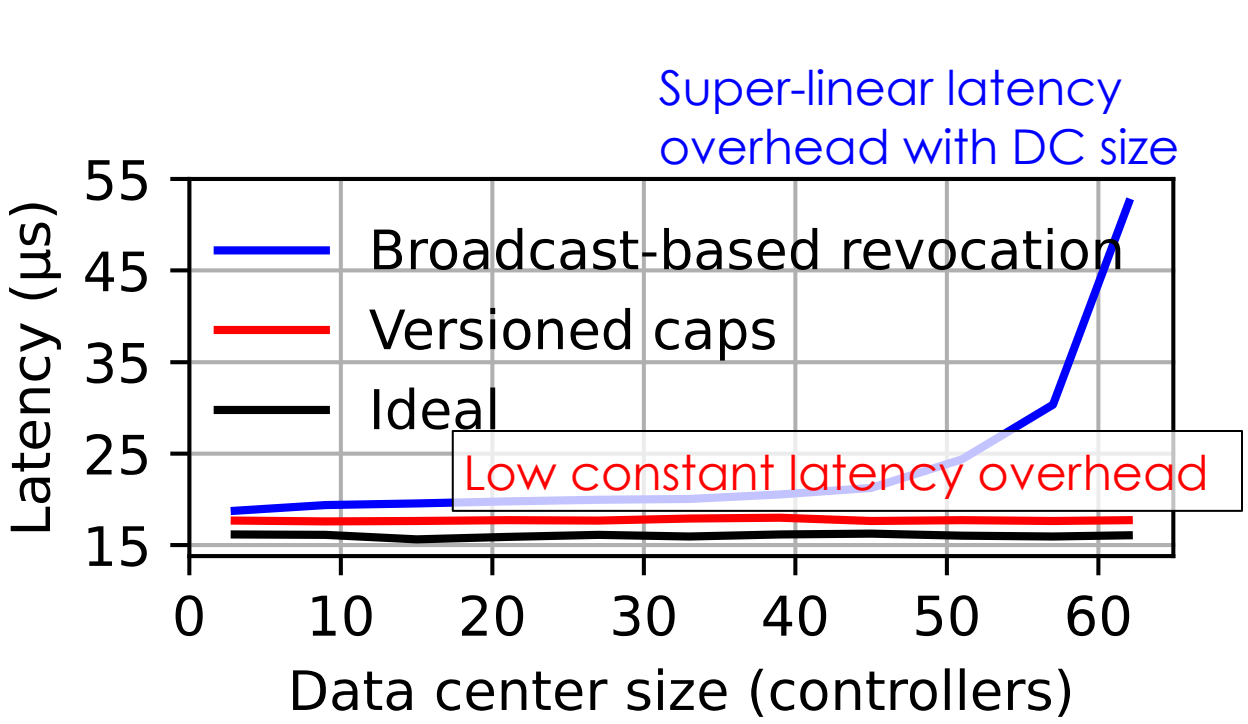
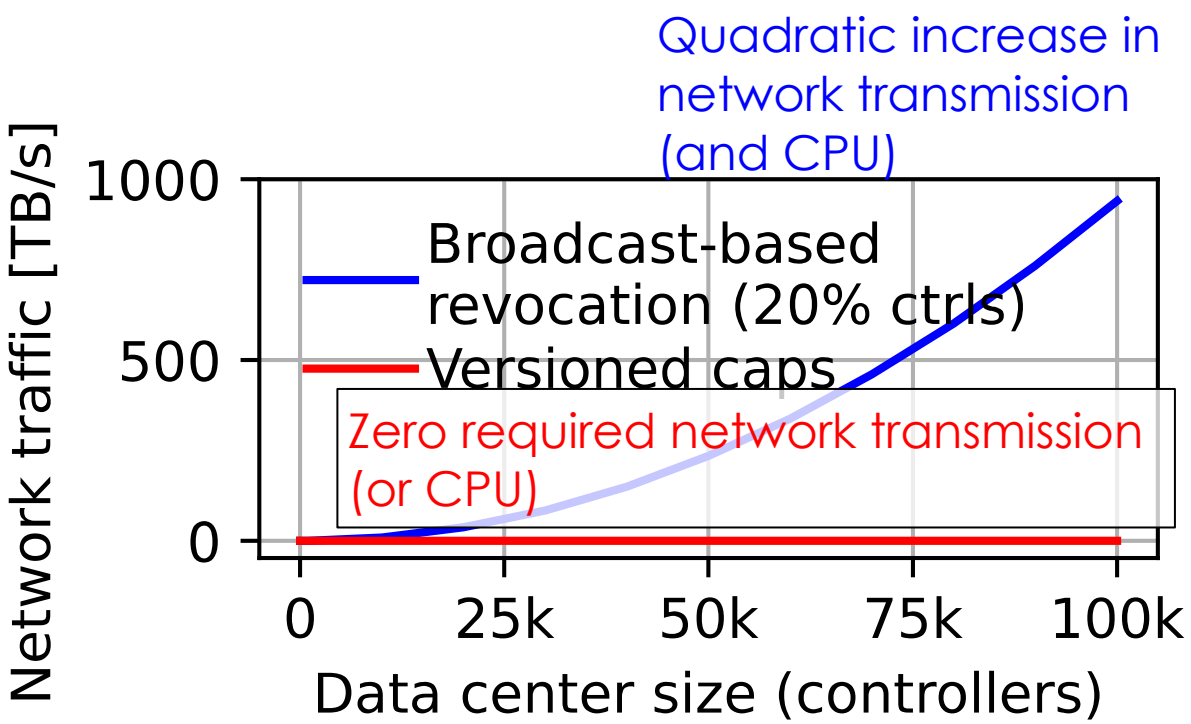
50
60
Data center size (controllers)
Broadcast-based revocation
Versioned caps
Ideal
Low constant latency overhead


Quadratic increase in network transmission (and CPU)
Network traffic [TB/s]
1000
500
0
0
25k
50k
75k
100k
Data center size (controllers)
Broadcast-based revocation (20% ctrls)
Versioned caps
Zero required network transmission (or CPU)

Evaluation





- Constant-cost, low µs-scale cap operations (eval in paper)

Conclusion

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- Three key innovations
  - Owner-based metadata sharding, versioned capabilities and guards (detail in paper)

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