MXFaaS: Resource Sharing in Serverless Environments for Parallelism and Efficiency

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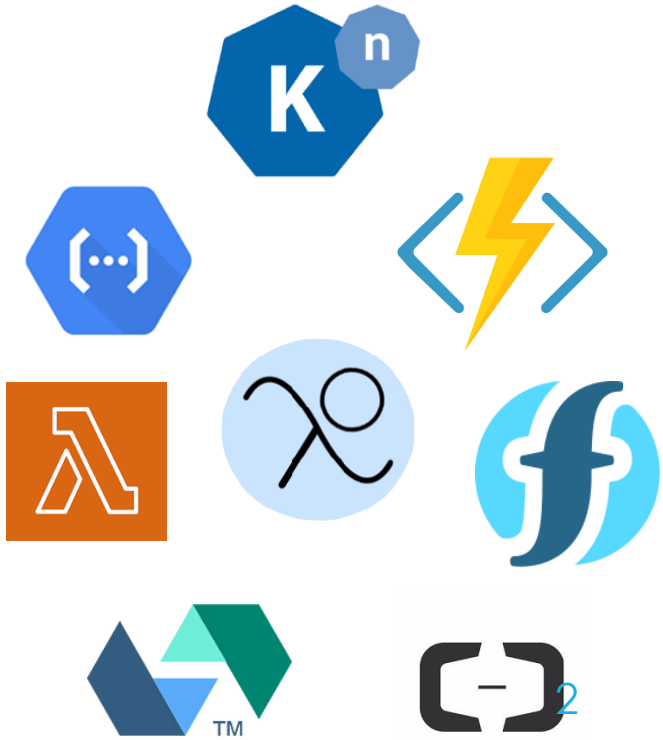
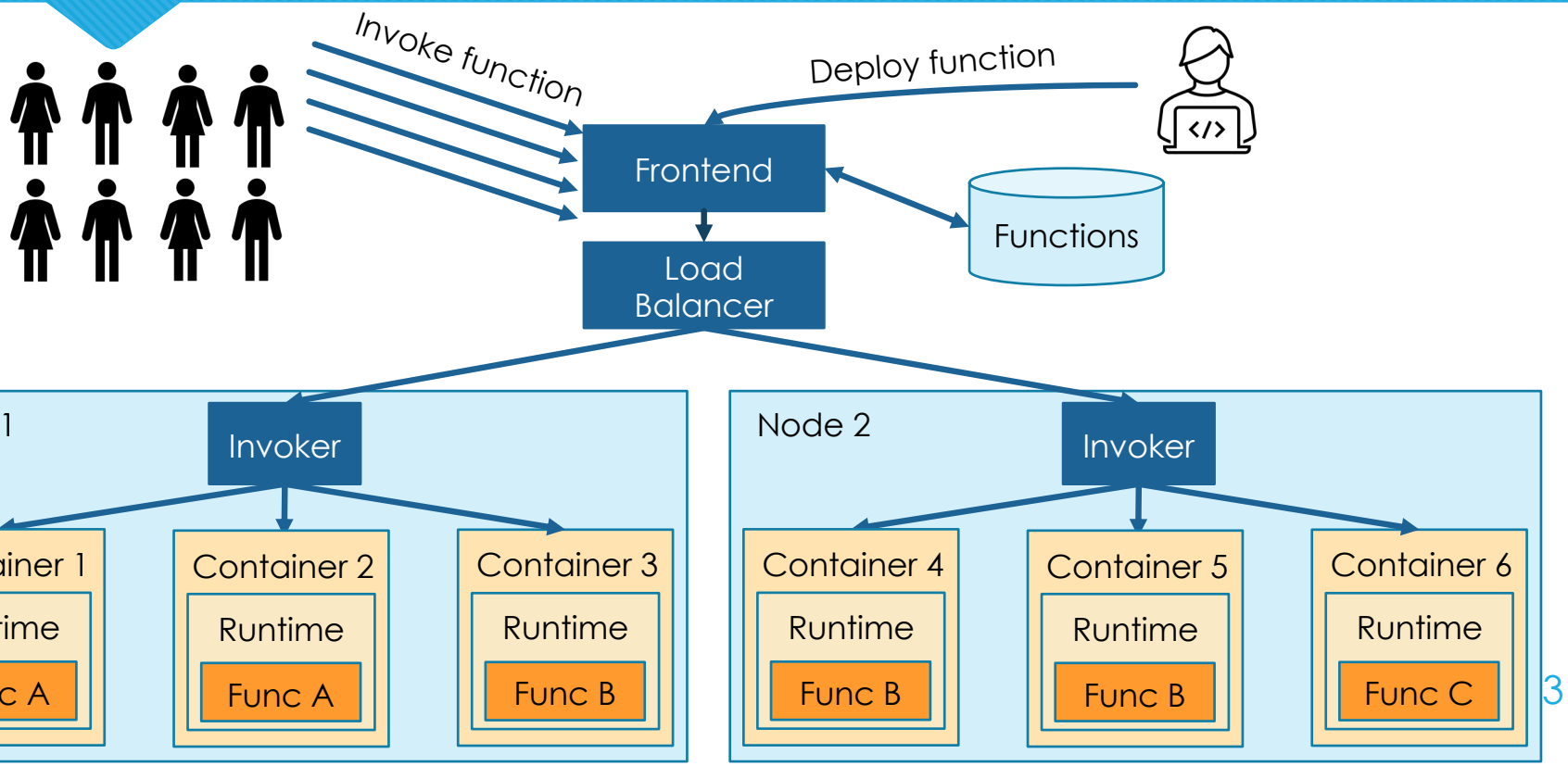
*IBM Research

What is serverless computing?

- Serverless computing is a popular cloud paradigm
  - Users deploy applications, providers provision resources
- Many benefits
  - Simple and modular programming
  - Automatic resource scaling
  - Pay-as-you-go model
- AWS Lambda, Microsoft Azure, Google Cloud, IBM Cloud



How serverless computing works?

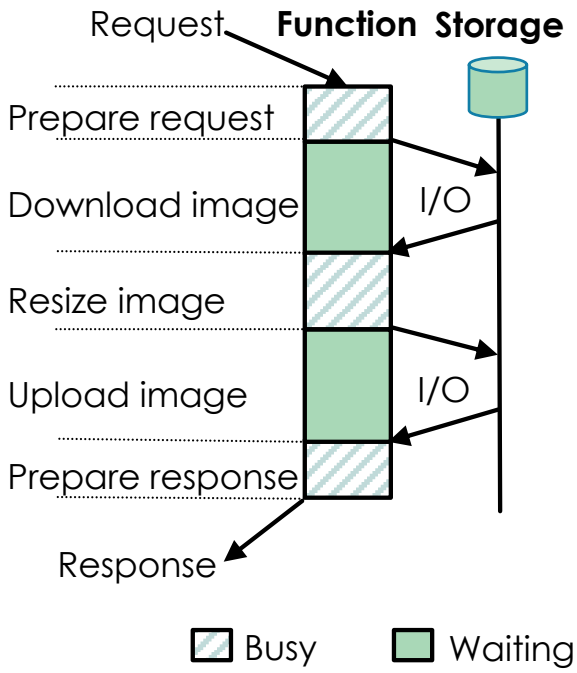


Contributions

- Architectural characterization of serverless environments
- Propose **MXFaaS** – novel serverless platform based on resource sharing/multiplexing across function invocations
  - Efficient use of processor cycles, I/O bandwidth, and memory state
- Average speedup 5.2X, tail latency reduction 7.4X, throughput improvement 4.8X

Idle Time Dominates Function Execution

- Functions synchronously accessing remote storage



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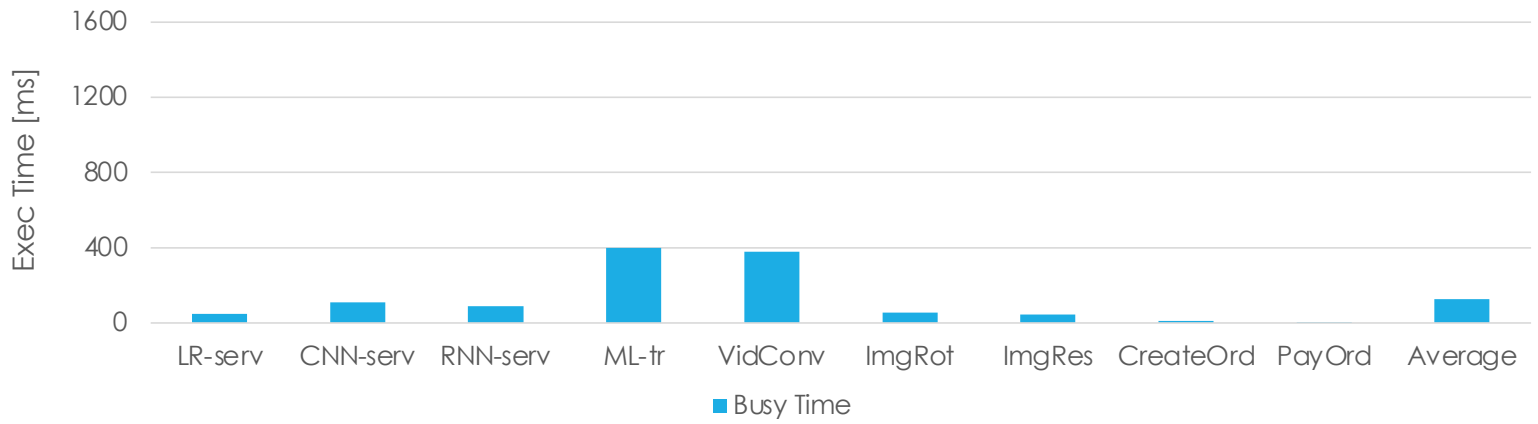

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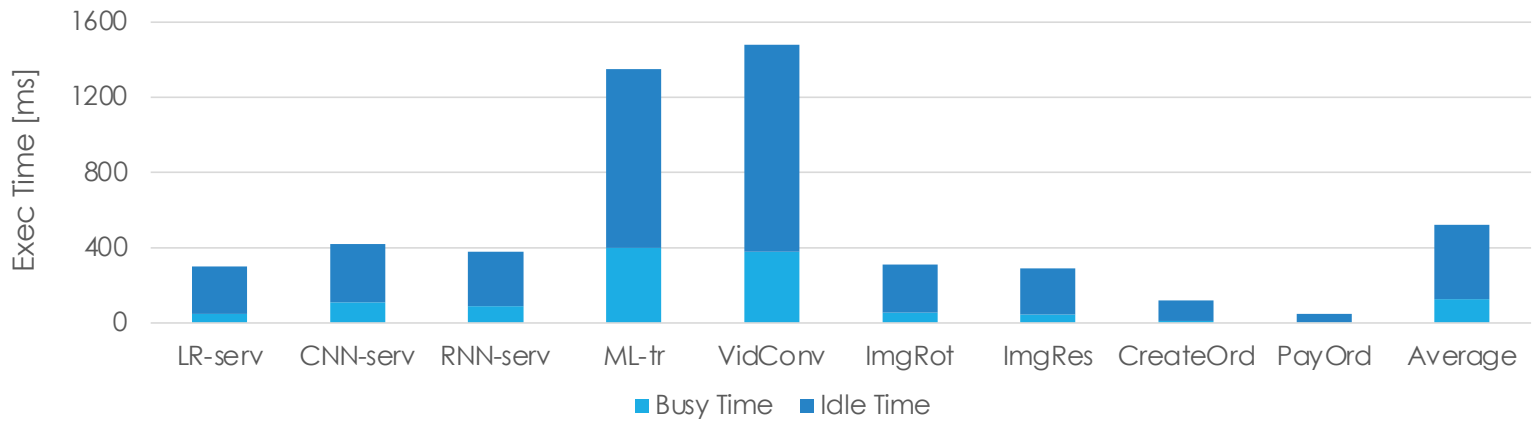

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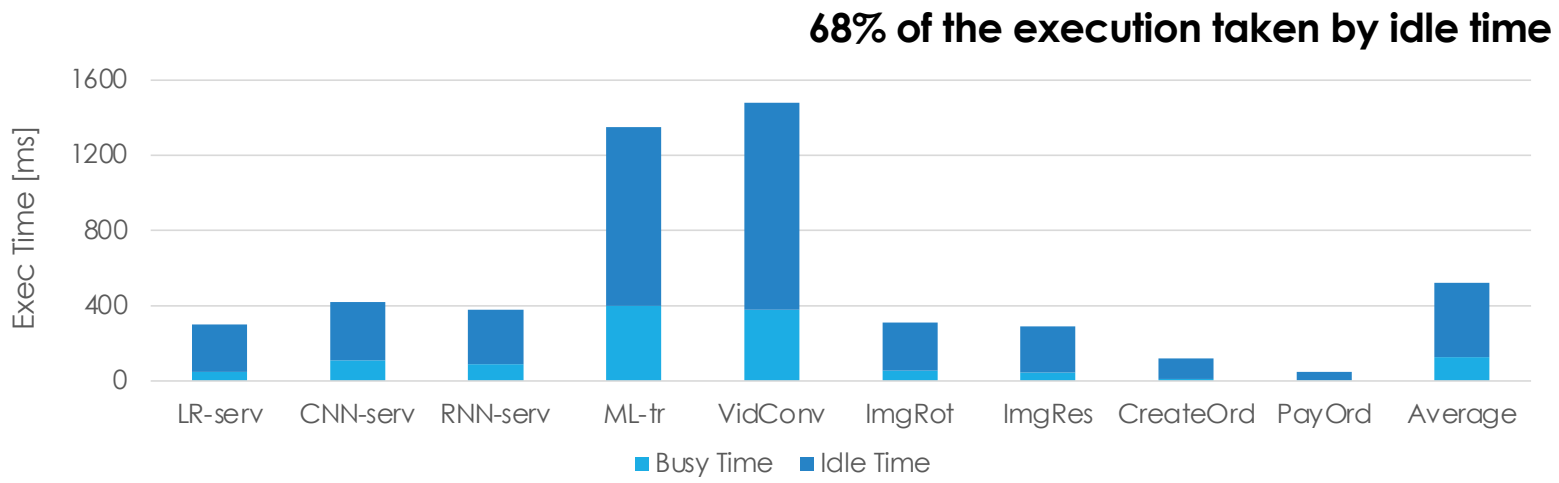

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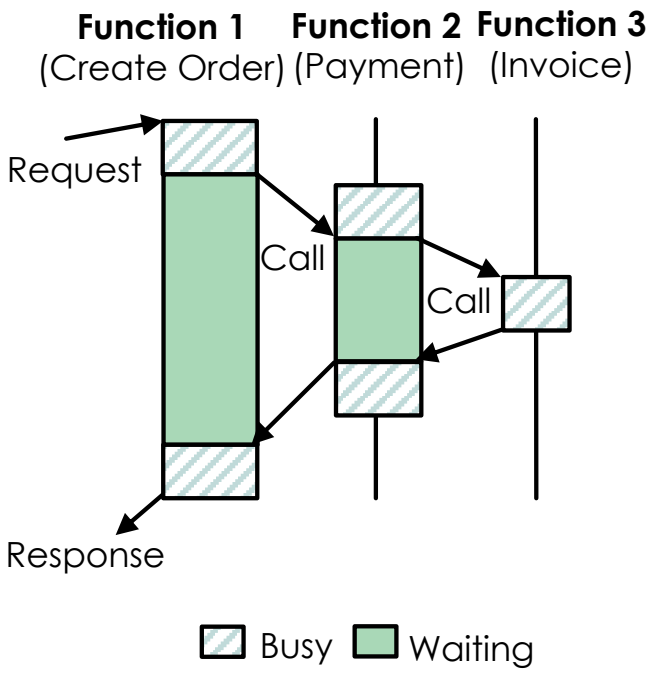
- Functions synchronously invoking other functions



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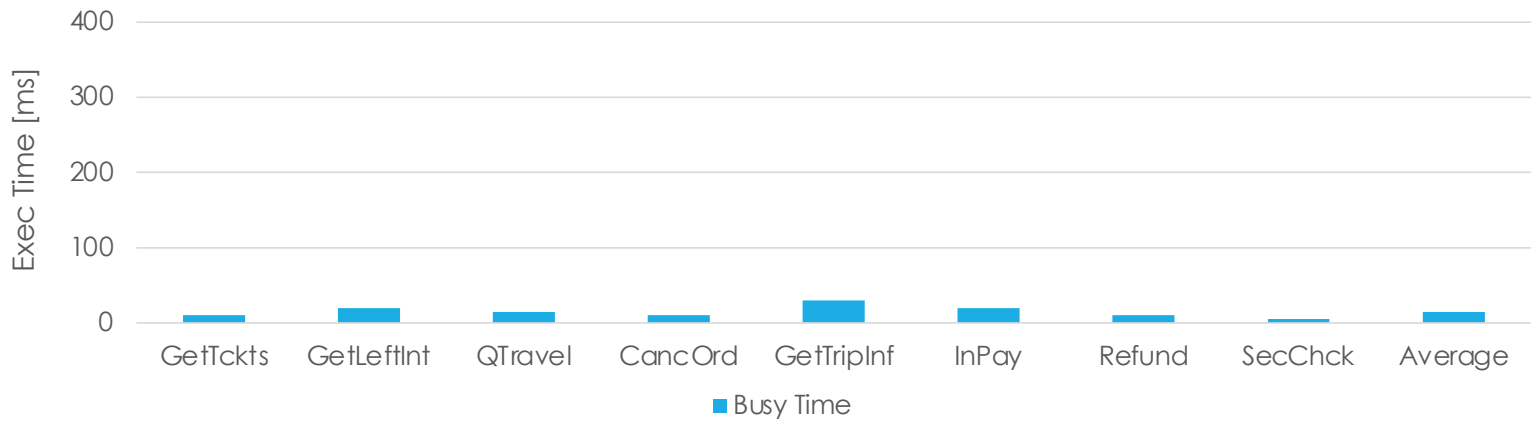

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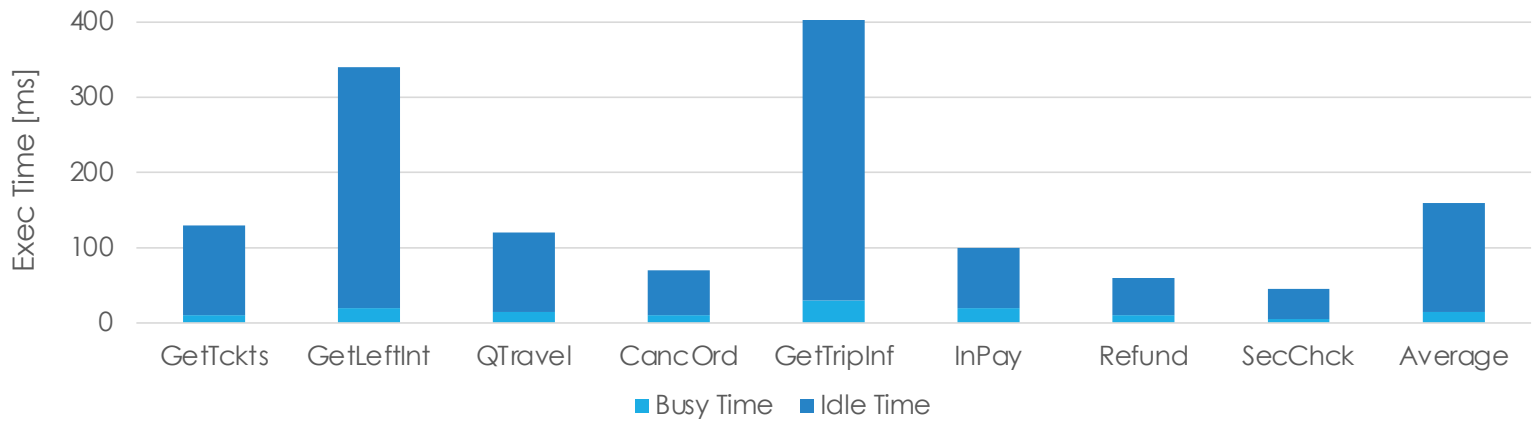

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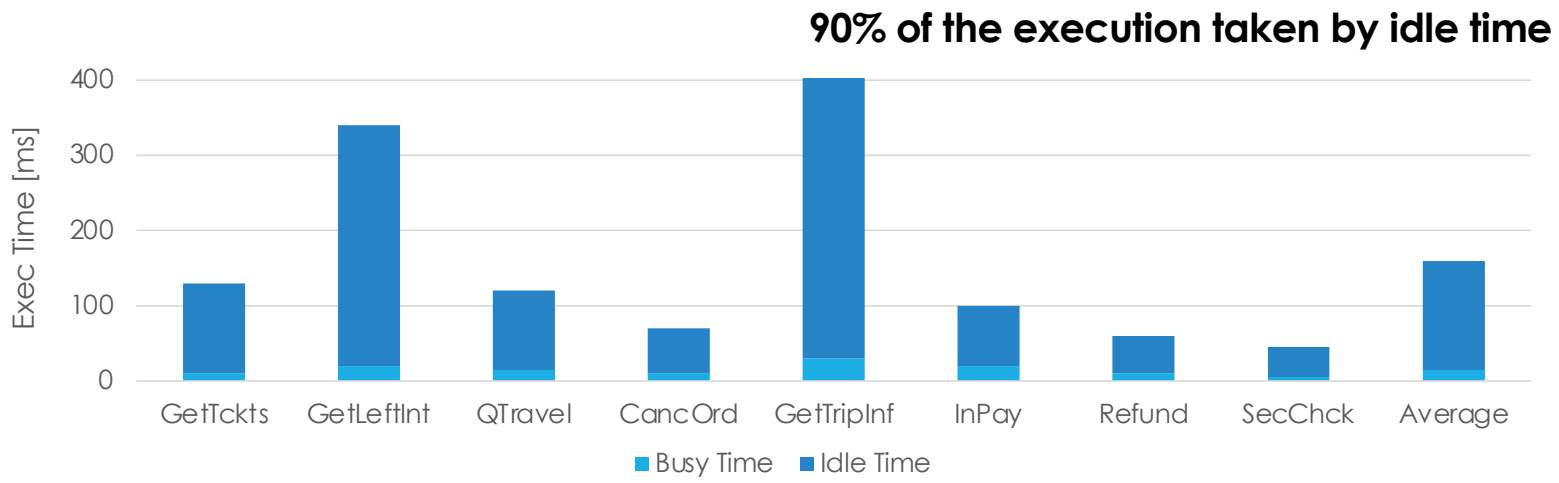
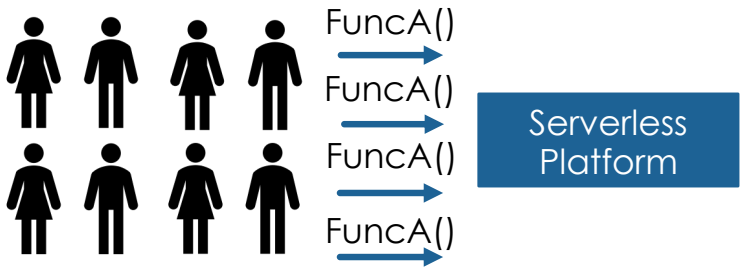


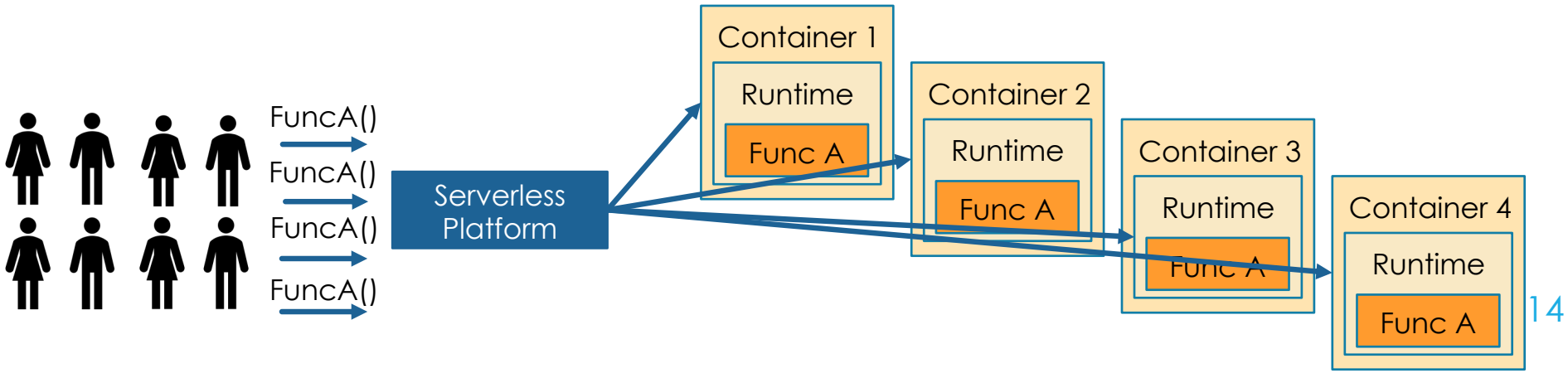
Same-Function Invocations are Bursty

- Serverless computing model promotes autoscaling and request-level parallelism



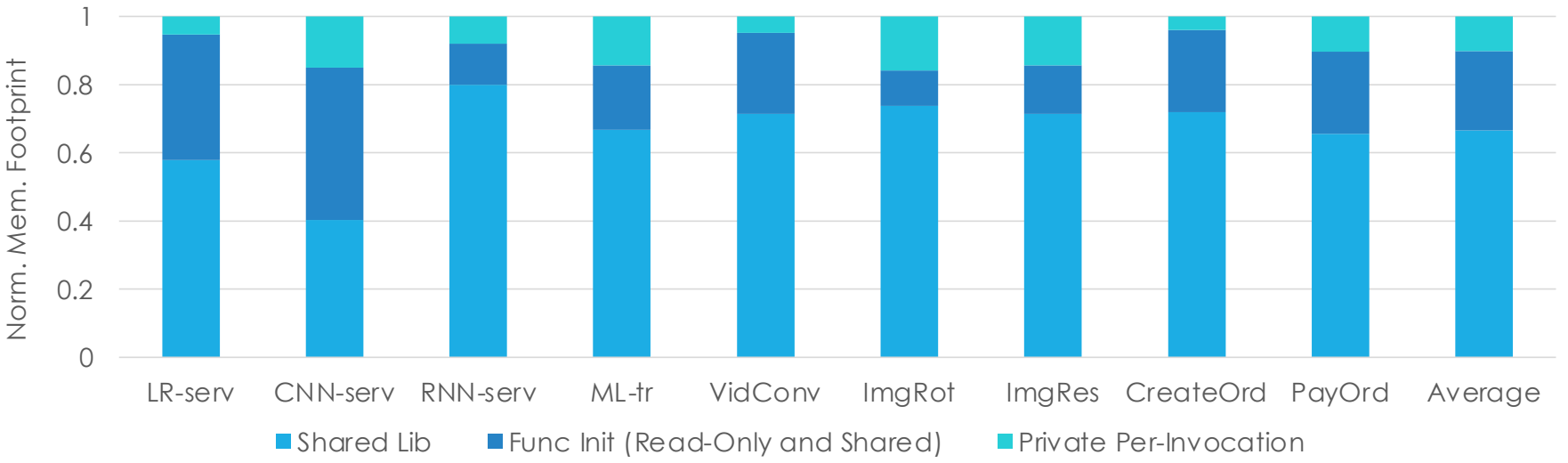
Same-Function Invocations are Bursty

- Current systems handle burstiness inefficiently and spawn many concurrent containers



Implications of Bursty Function Invocations: 1. In-memory State Replication

- Same-function invocations frequently access the same data and instructions
- Shared libraries and function specific read-only data are replicated in memory



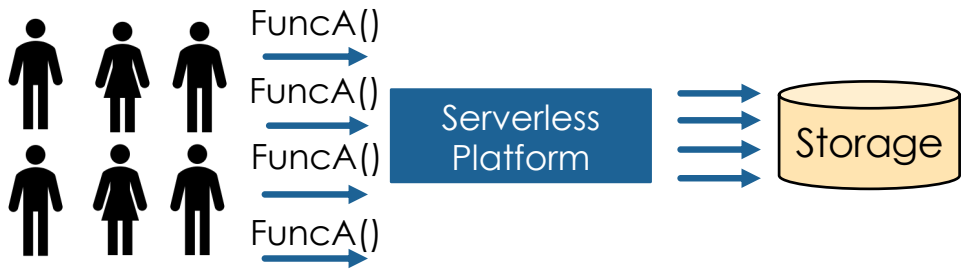
Implications of Bursty Function Invocations: 2. Pressure on Remote Storage

- Same-function invocations execute the same code

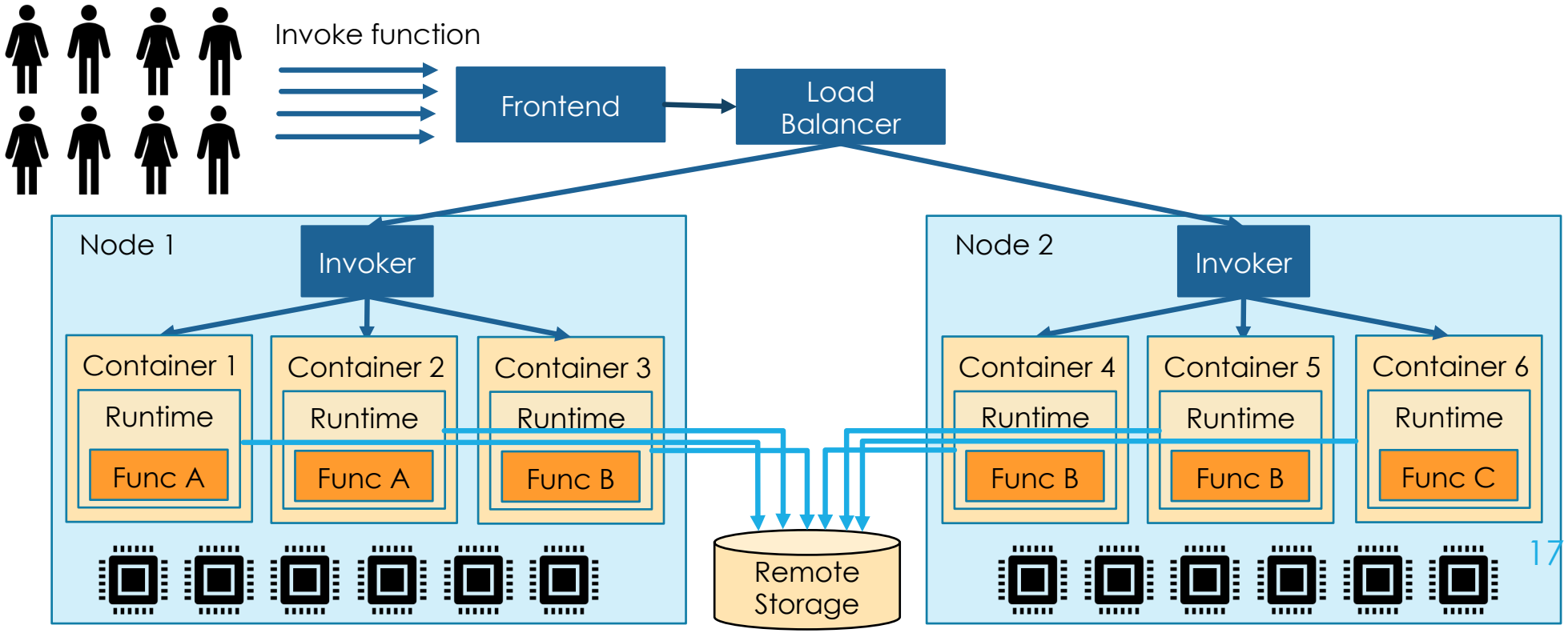
  → access the same storage area for same/similar data

- Invocations bursty

  → concurrent requests to the remote storage



Conventional systems are not optimized for bursty invocation patterns



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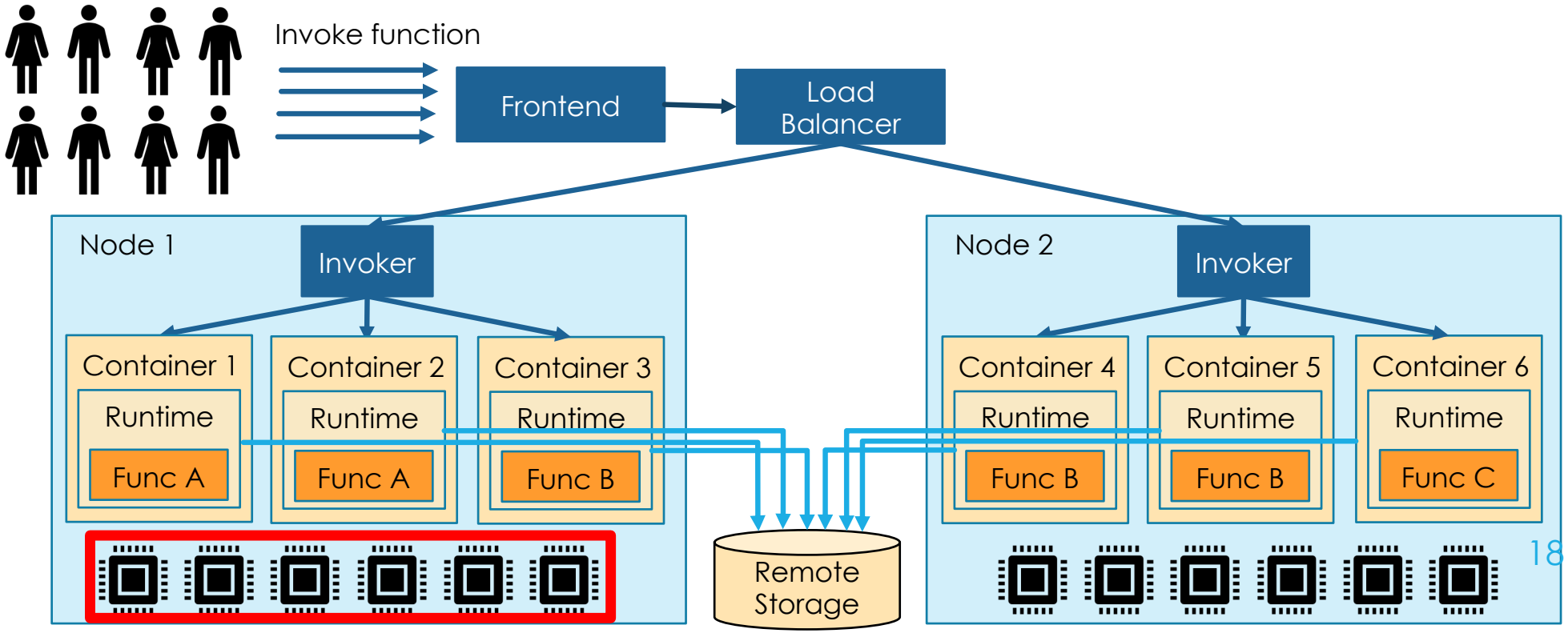

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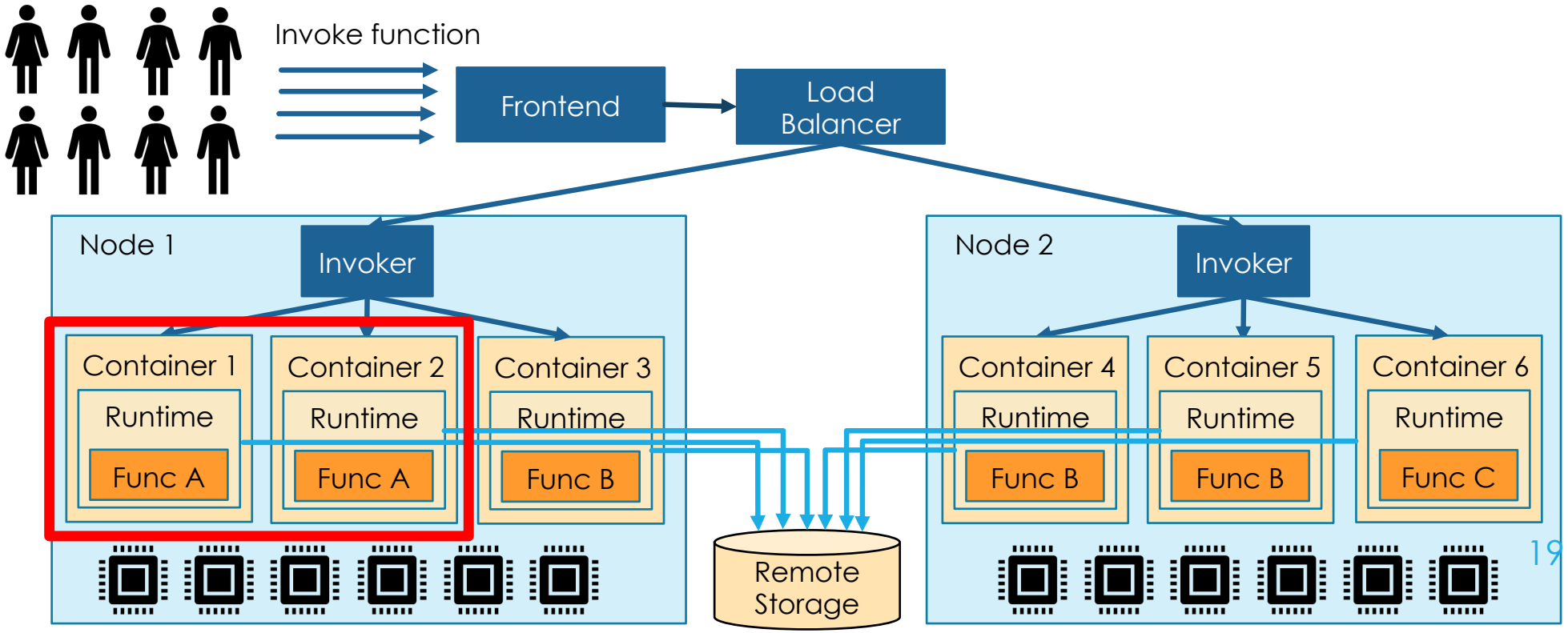

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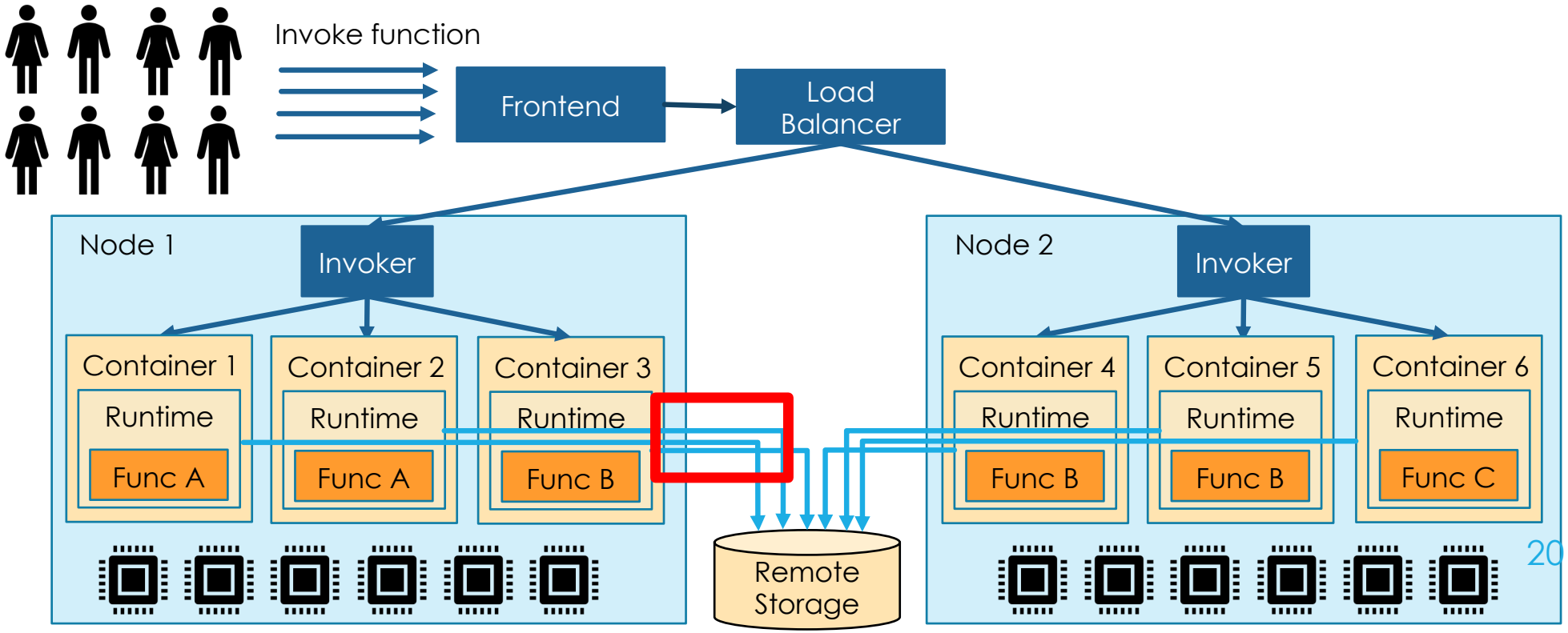
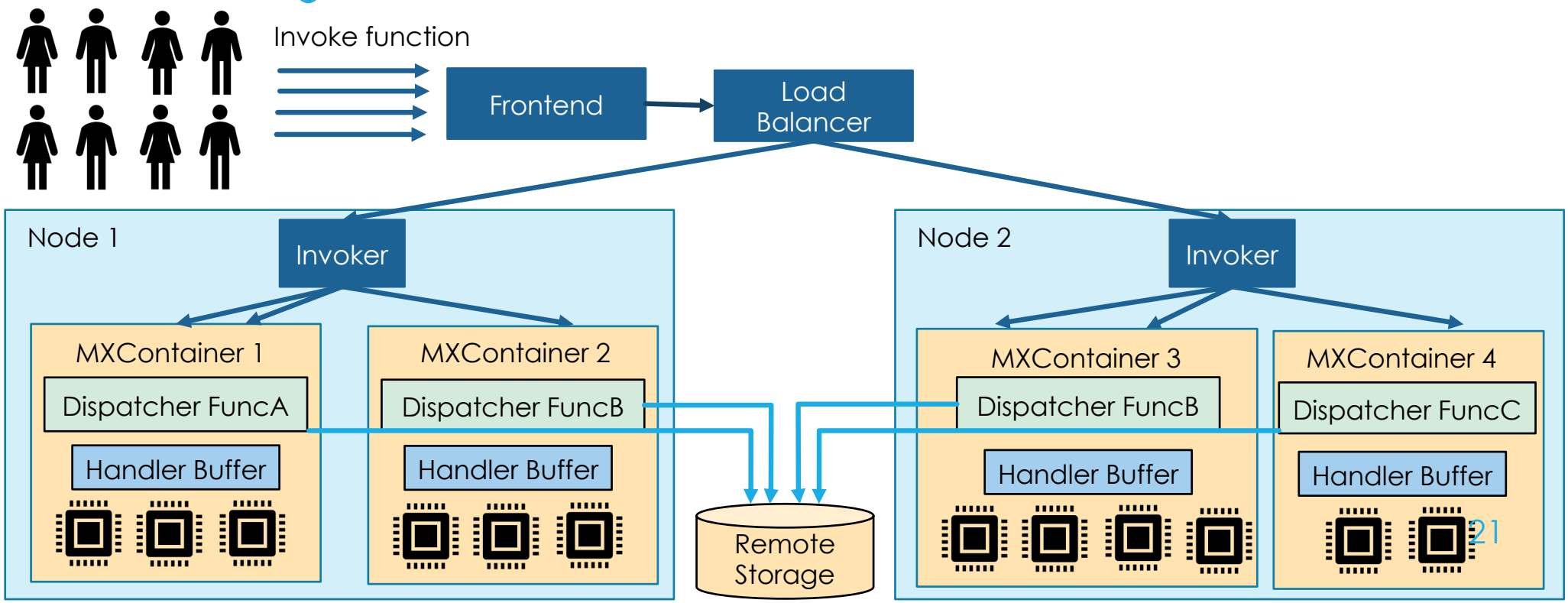


MXFaaS: Resource Sharing for Parallelism and Efficiency



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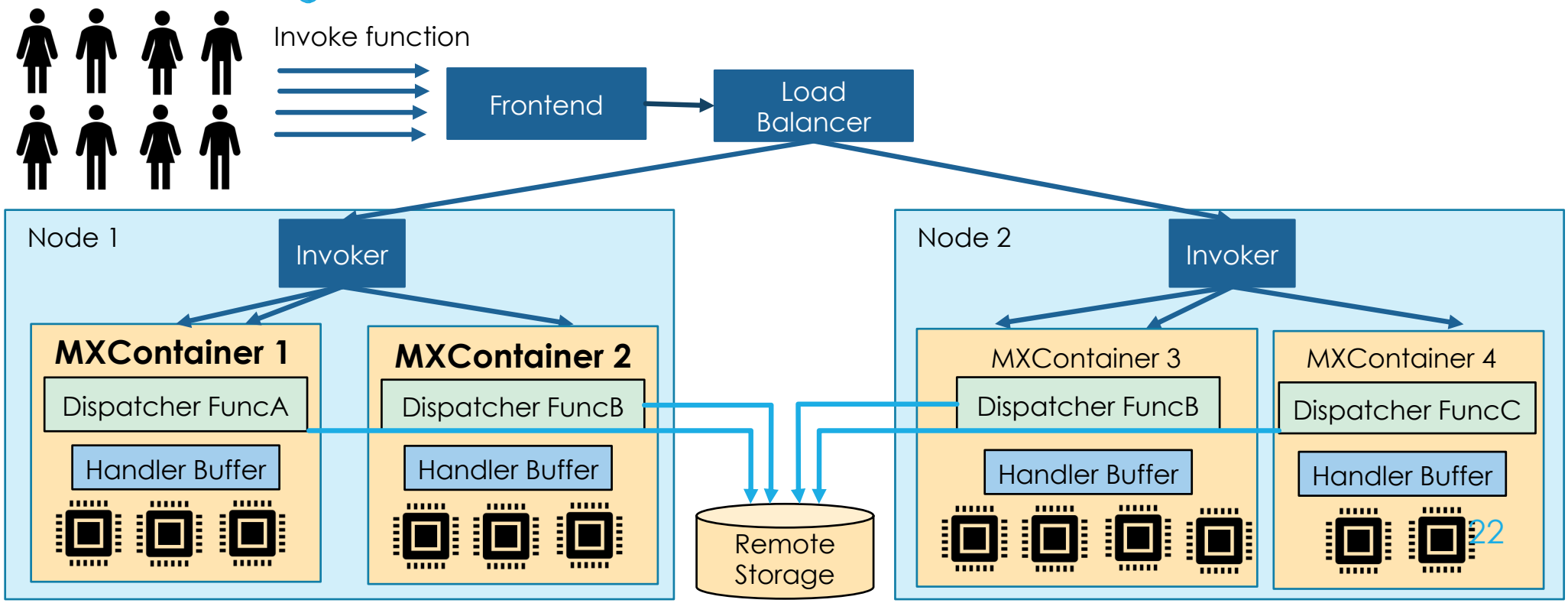

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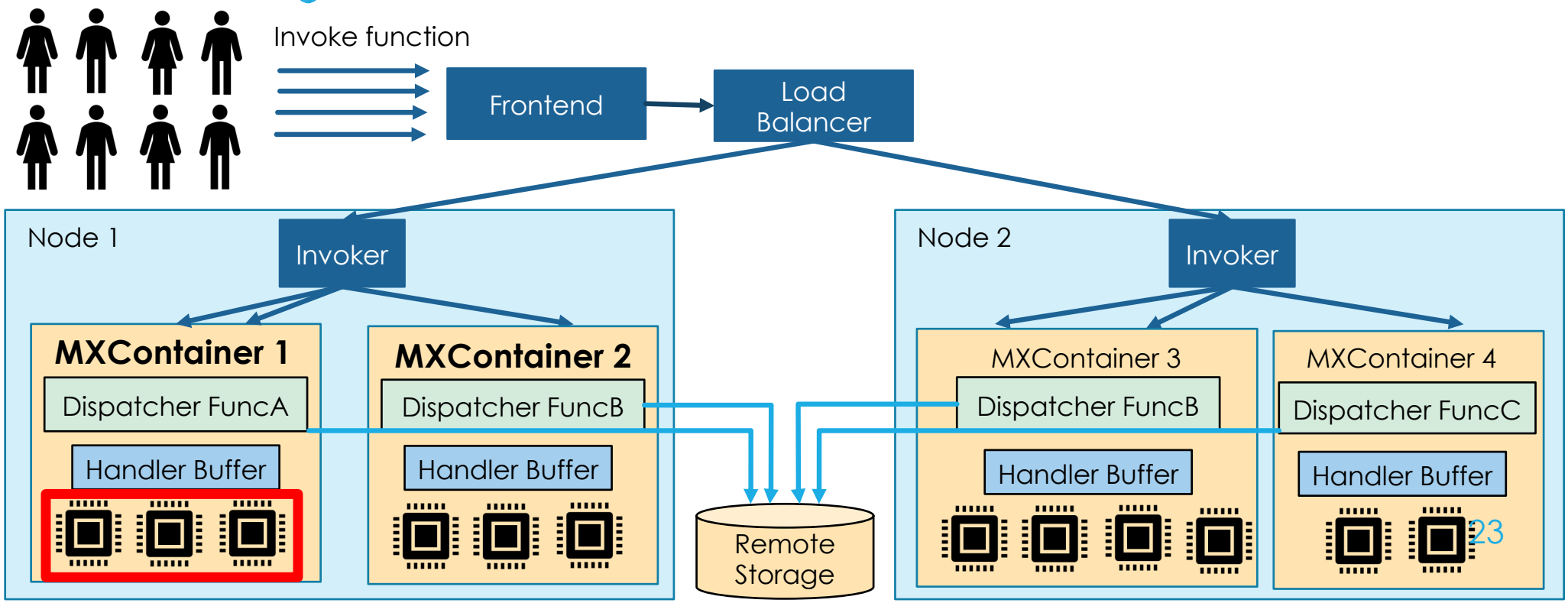

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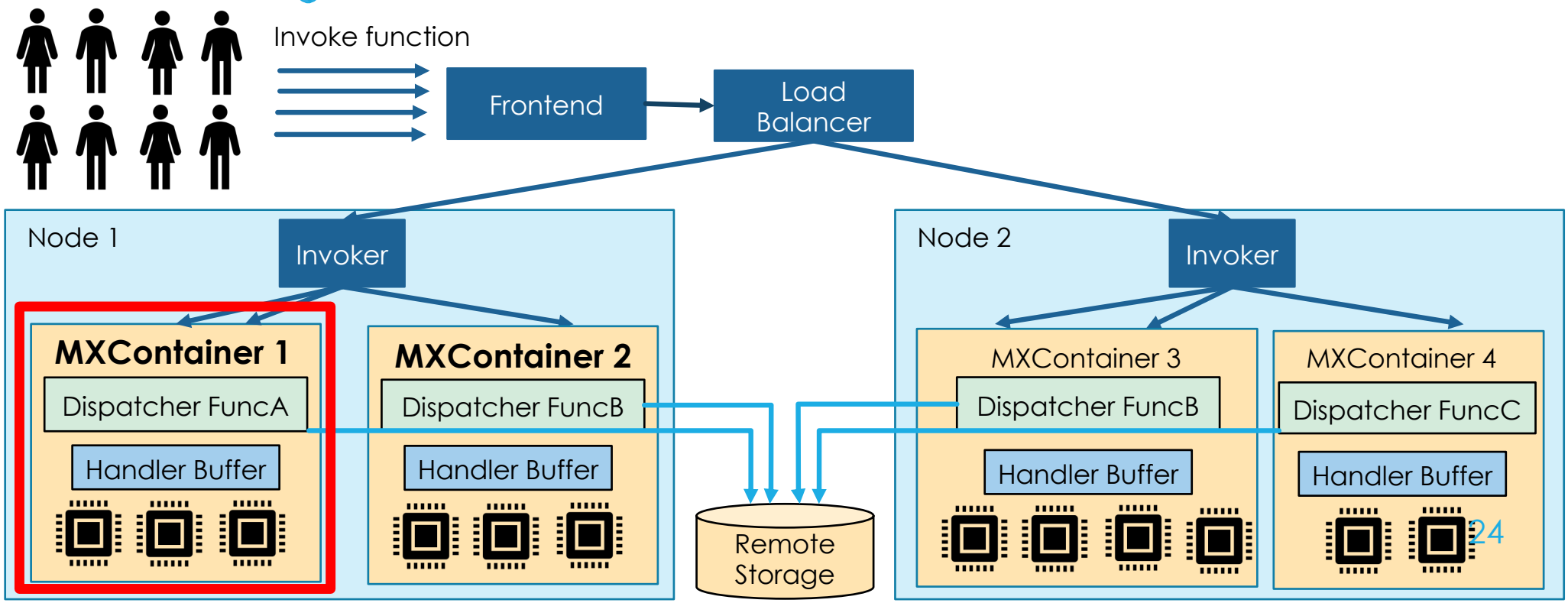

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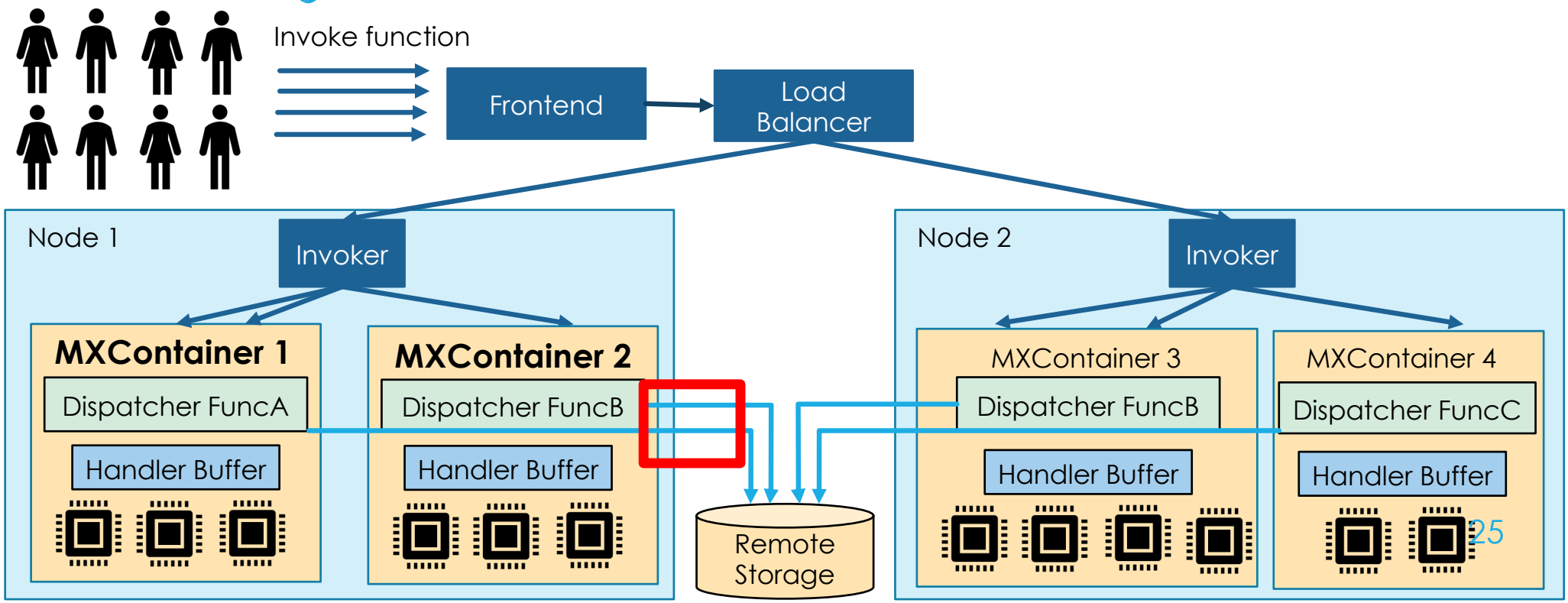
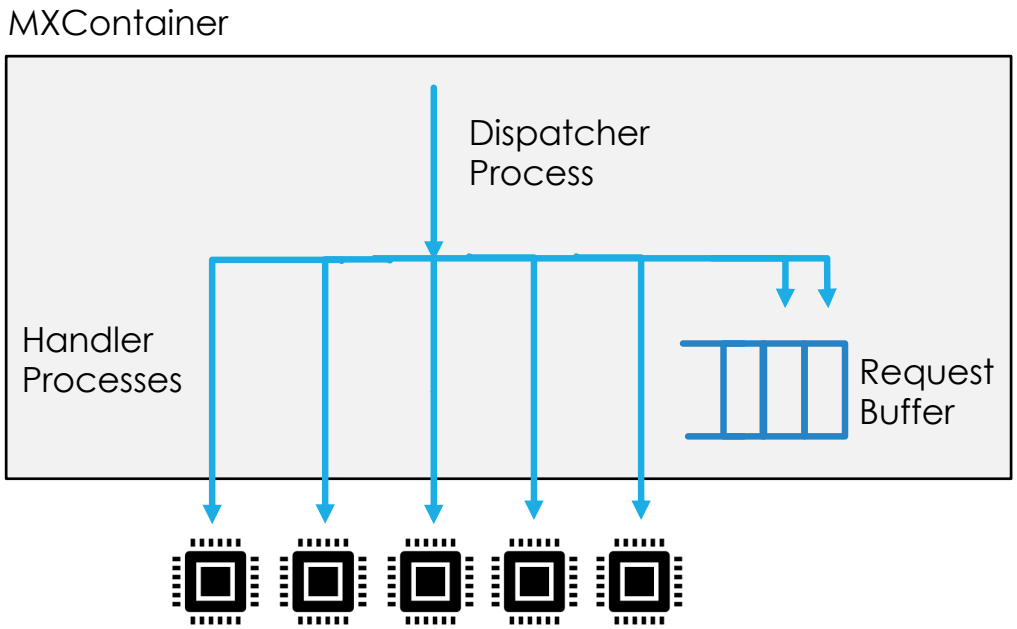
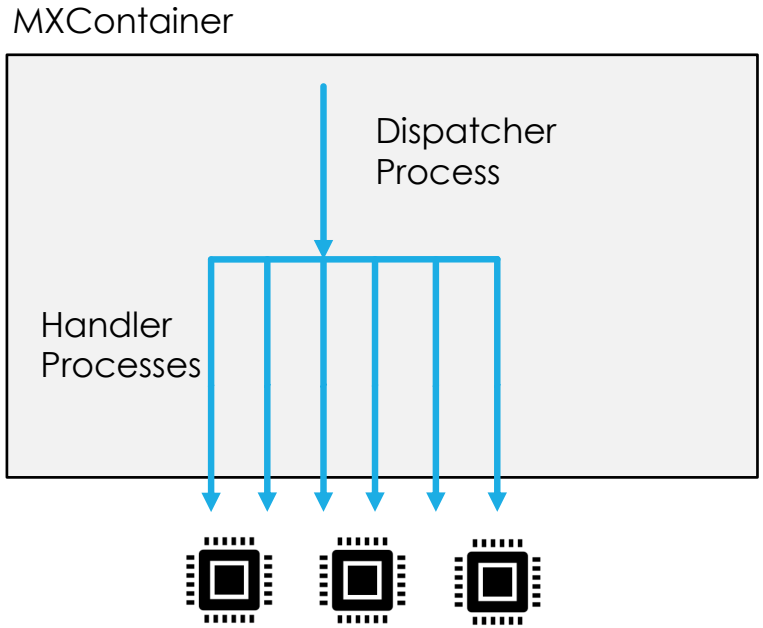


Structure of an MXContainer



Naïve Request Scheduling



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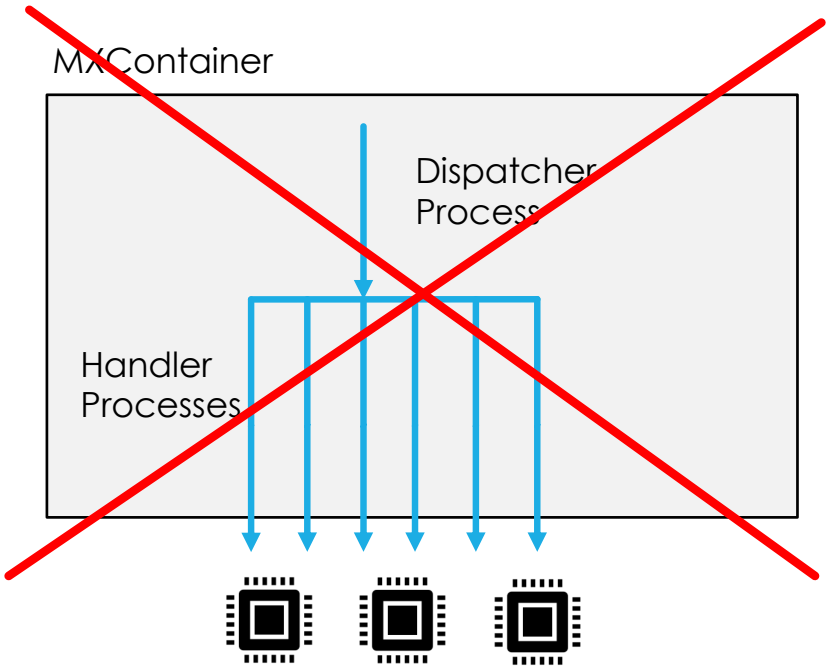

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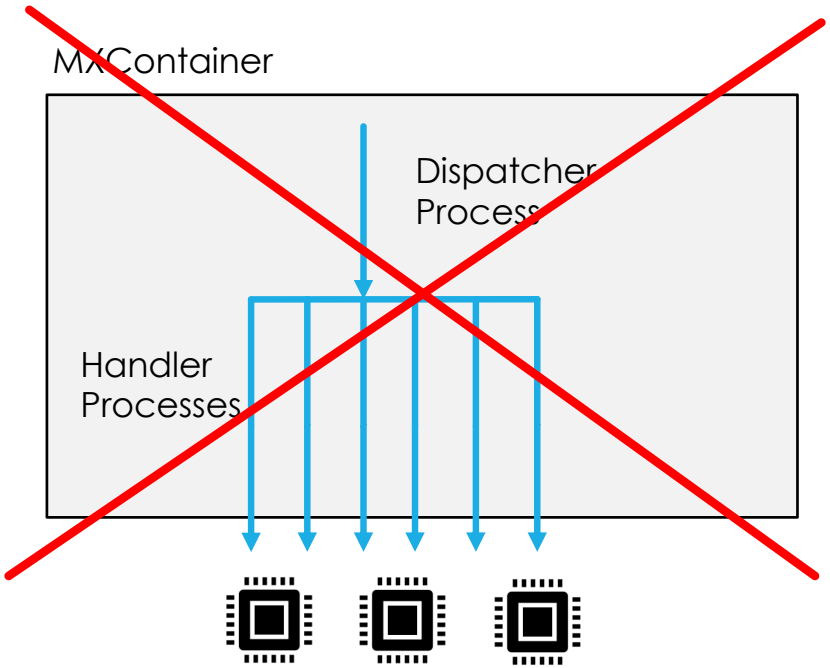

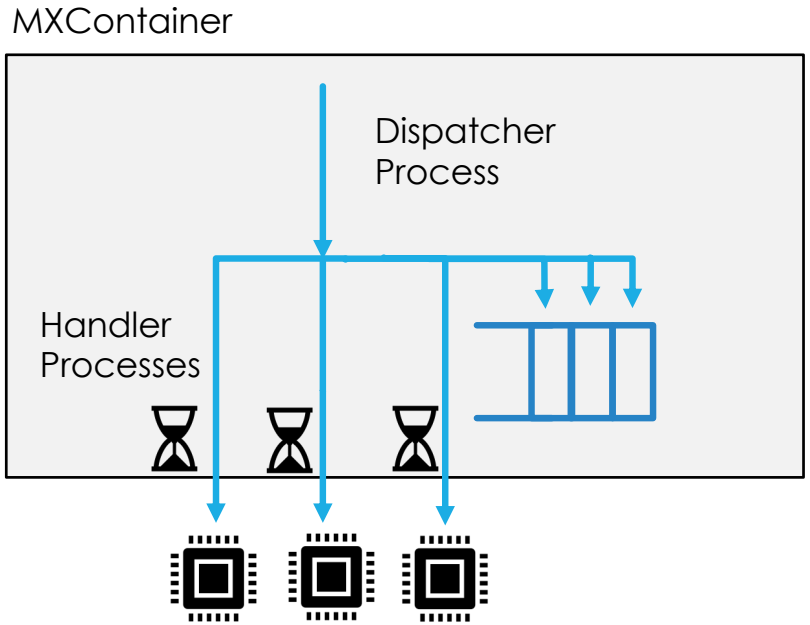

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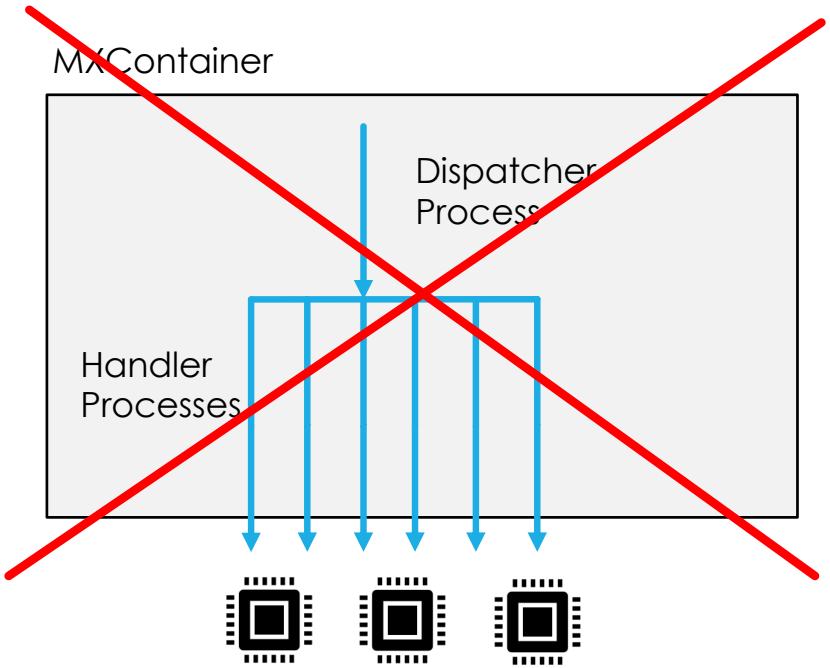
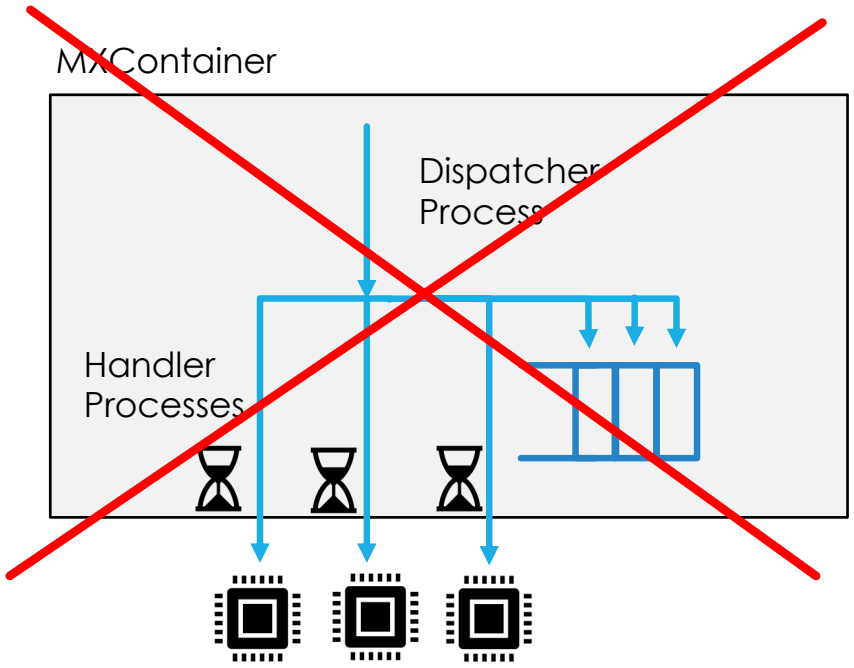
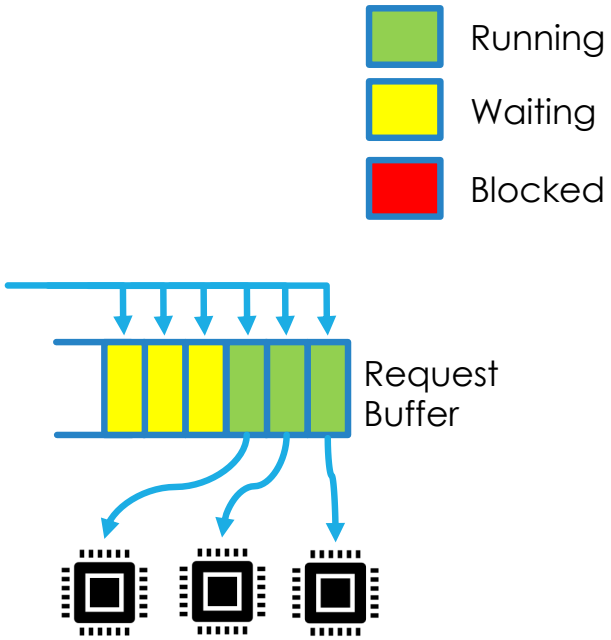




Sharing CPU Cycles with MXContainers

- Multiplexing CPU with ***smart handler scheduling***



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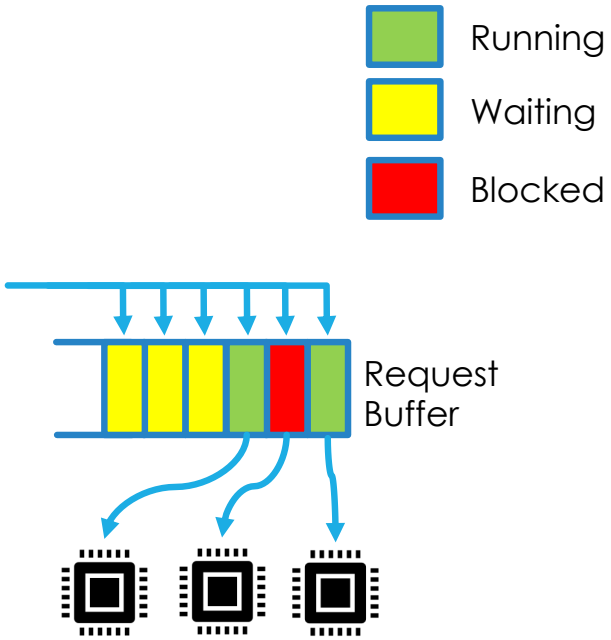

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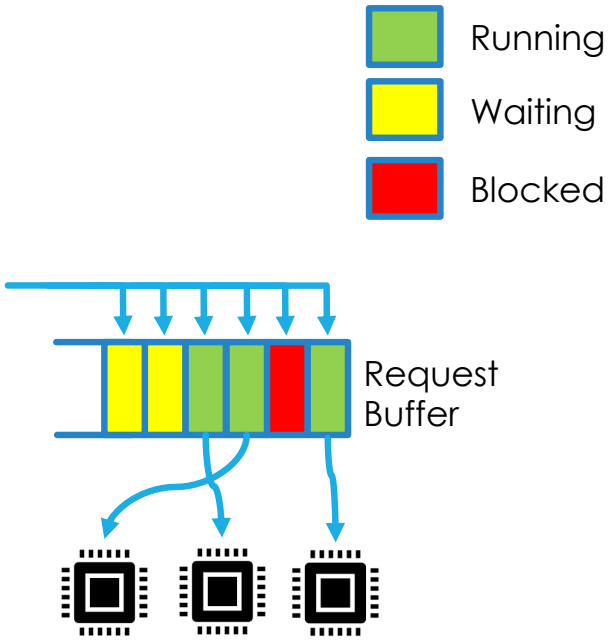

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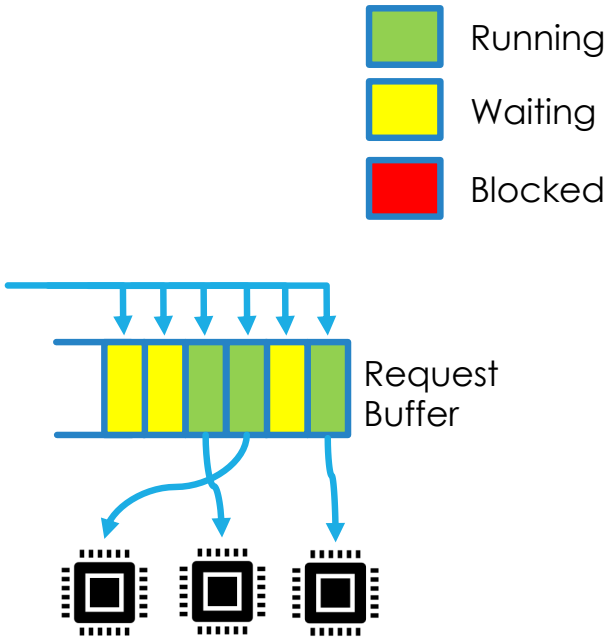

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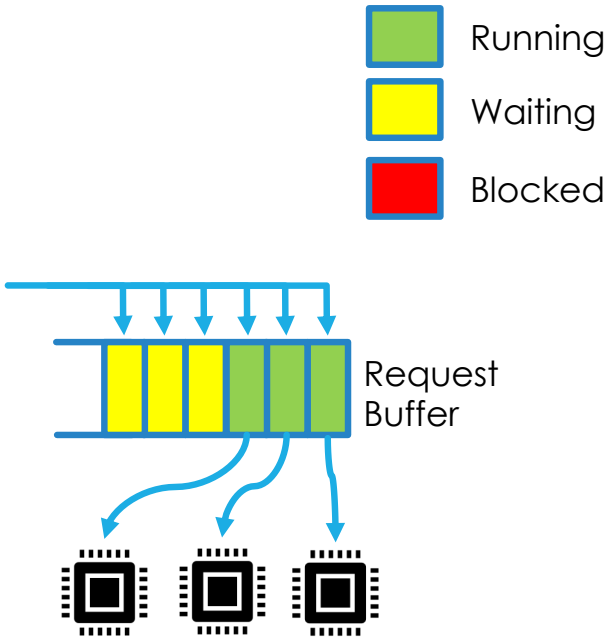

Sharing CPU Cycles with MXContainers

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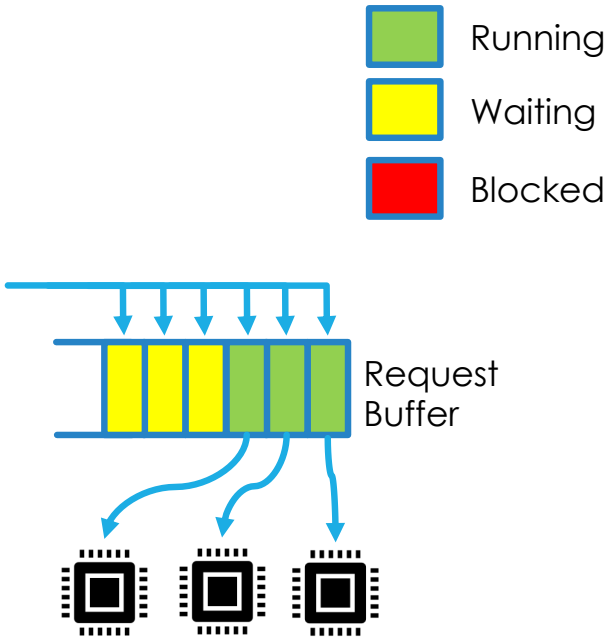
  - ➔ High utilization of CPU cycles + low tail latency



Sharing Memory and Processor State with MXContainers

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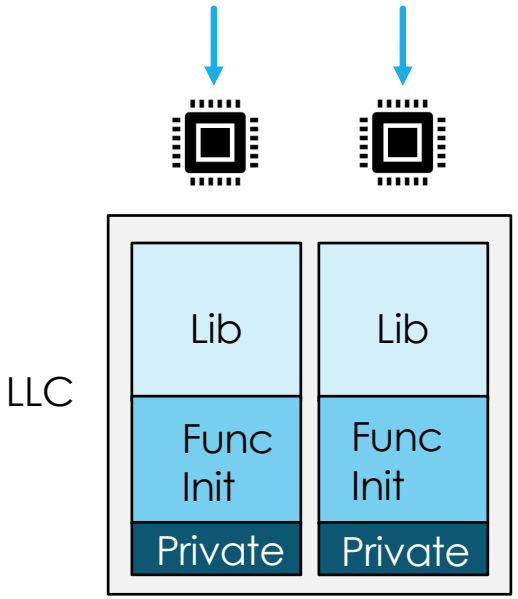

Sharing Memory and Processor State with MXContainers

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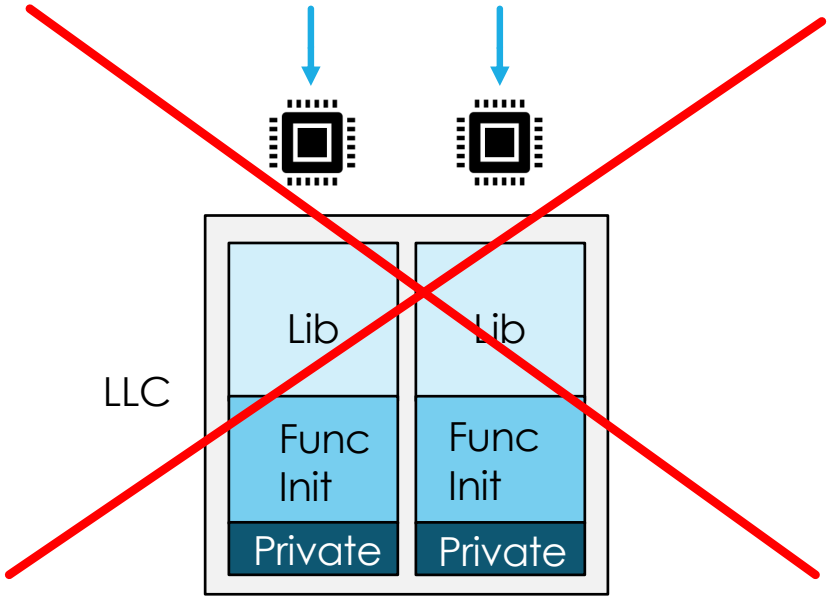

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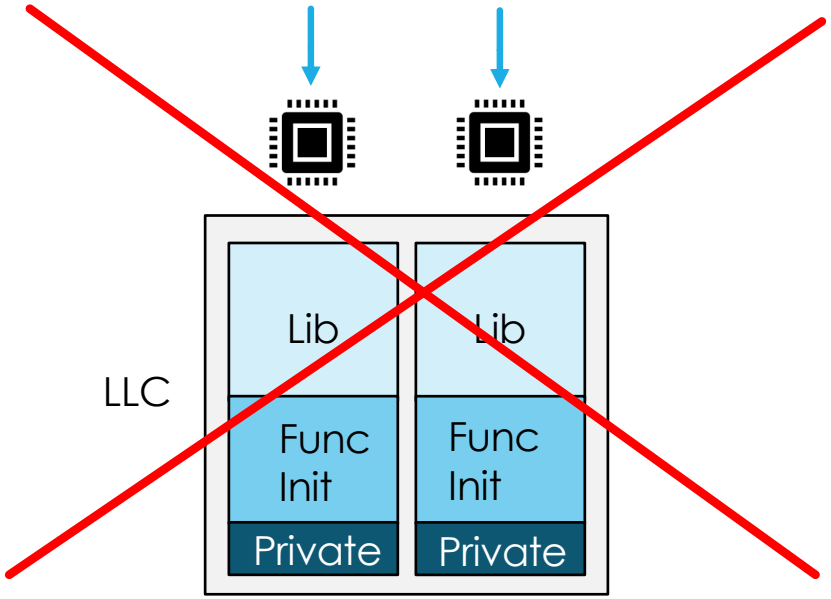

- MXFaaS: sharing memory state

Sharing Memory and Processor State with MXContainers

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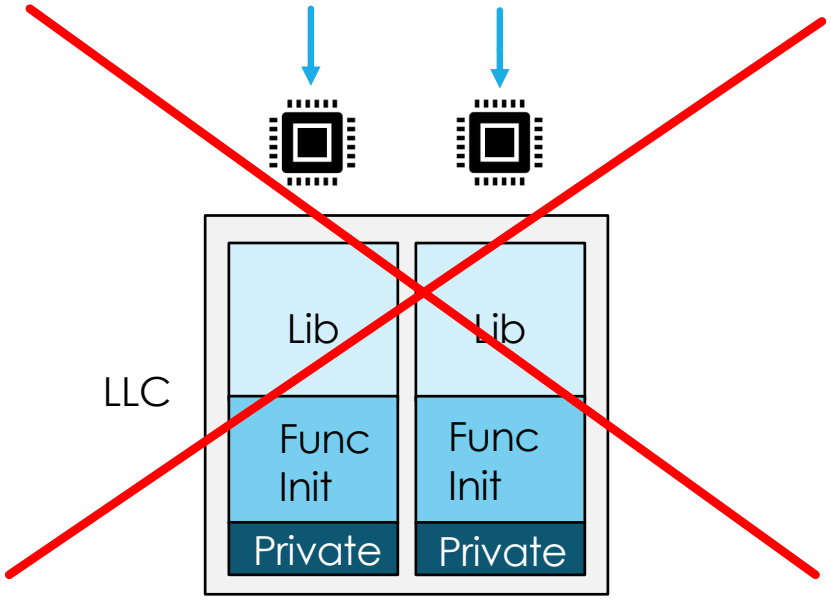

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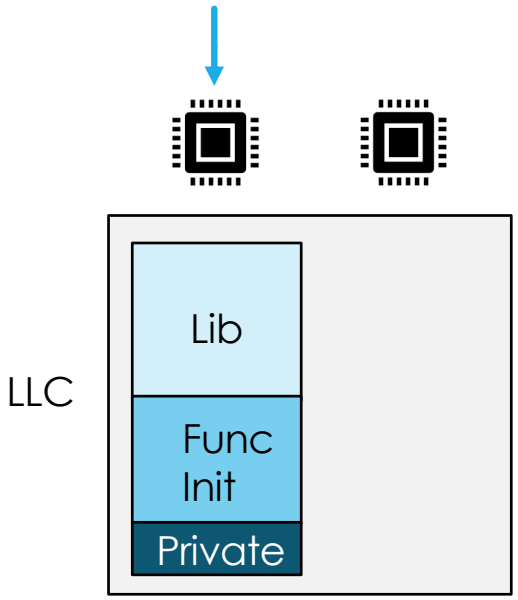

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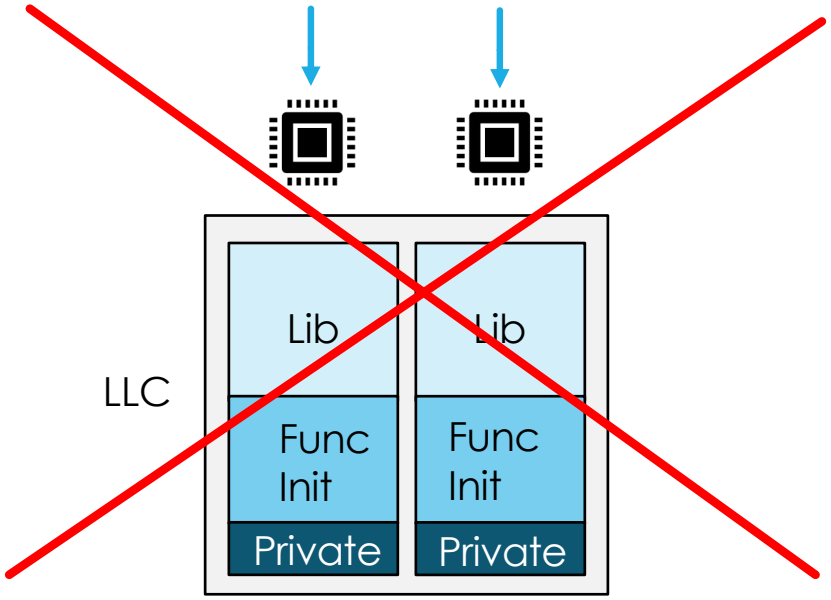
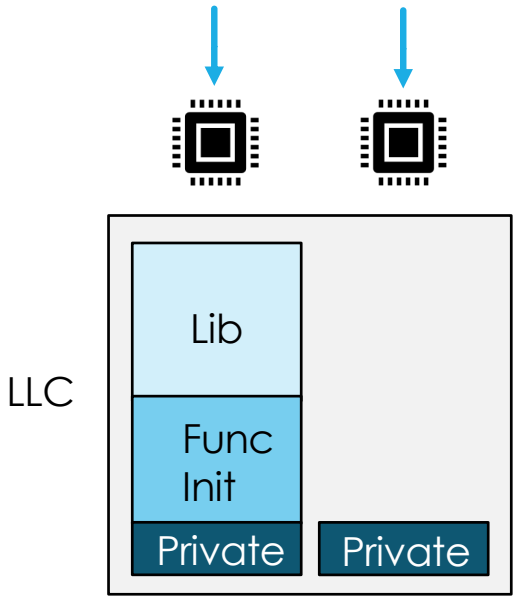
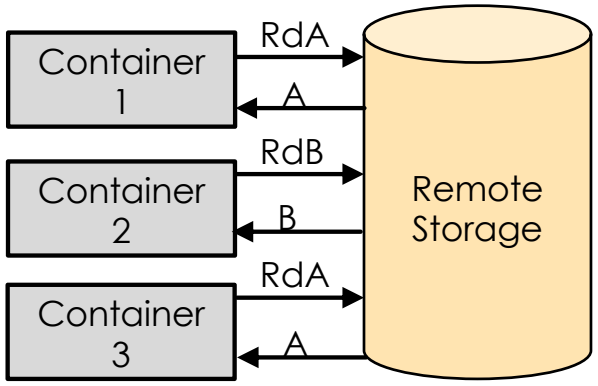


- MXFaaS: sharing memory state
  efficient memory use



Conventional I/O Bandwidth Use

- Conventional: each requests creates independent connection with the remote storage



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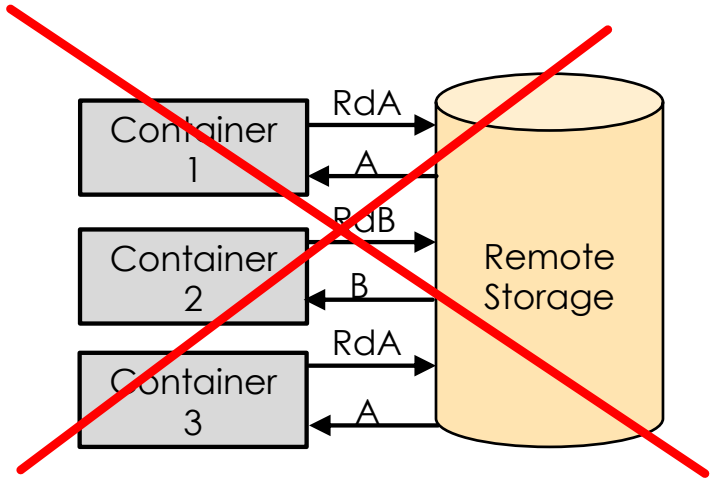
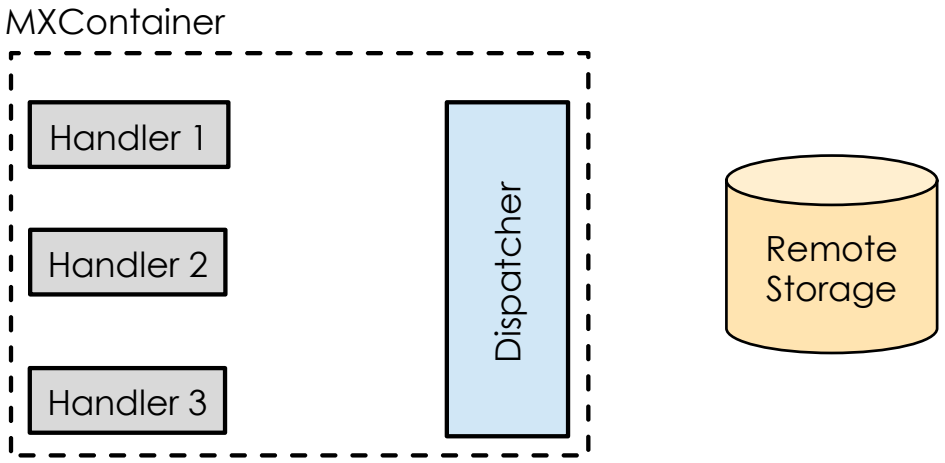


Sharing I/O Bandwidth with MXContainers

- MXFaaS: coalescing remote storage accesses
  - Same data: software Miss Status Holding Table (MSHT)



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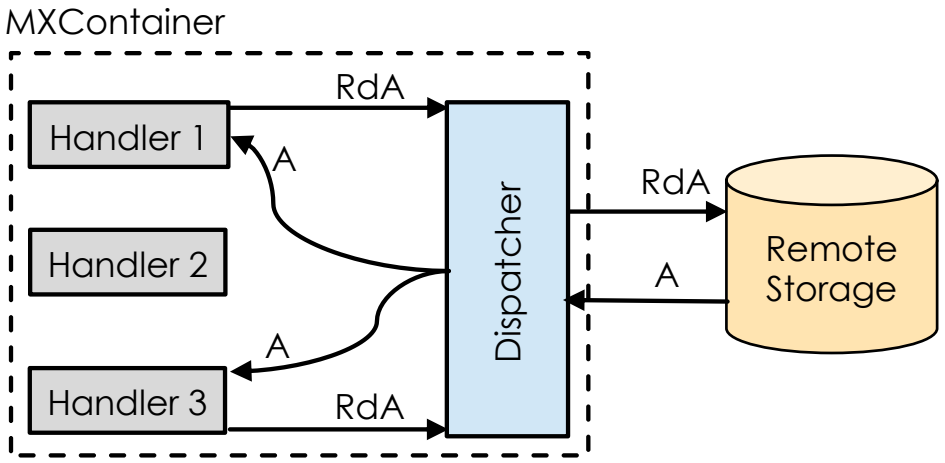

Sharing I/O Bandwidth with MXContainers

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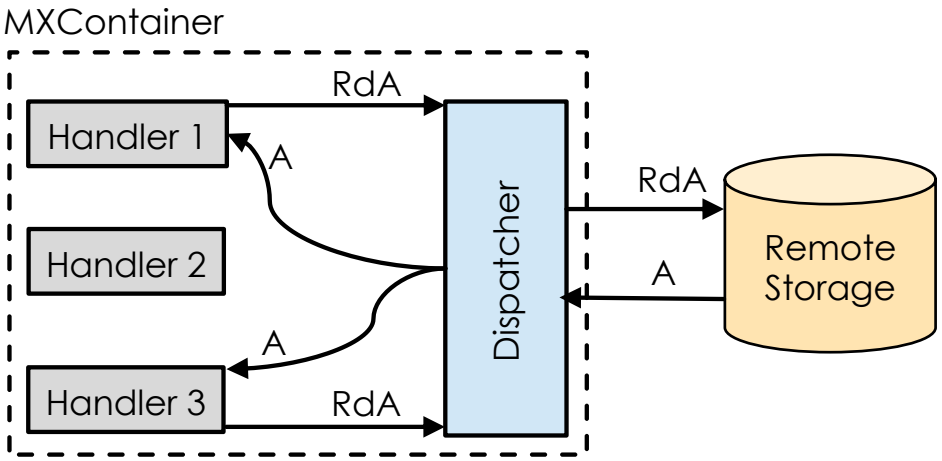
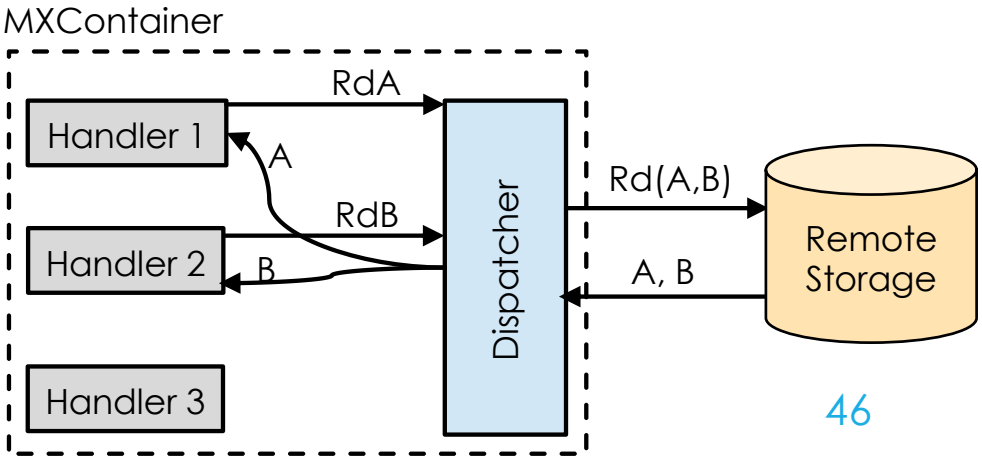
  - Same data: software Miss Status Holding Table (MSHT)
  - Different data: combine scalars into a single vector request



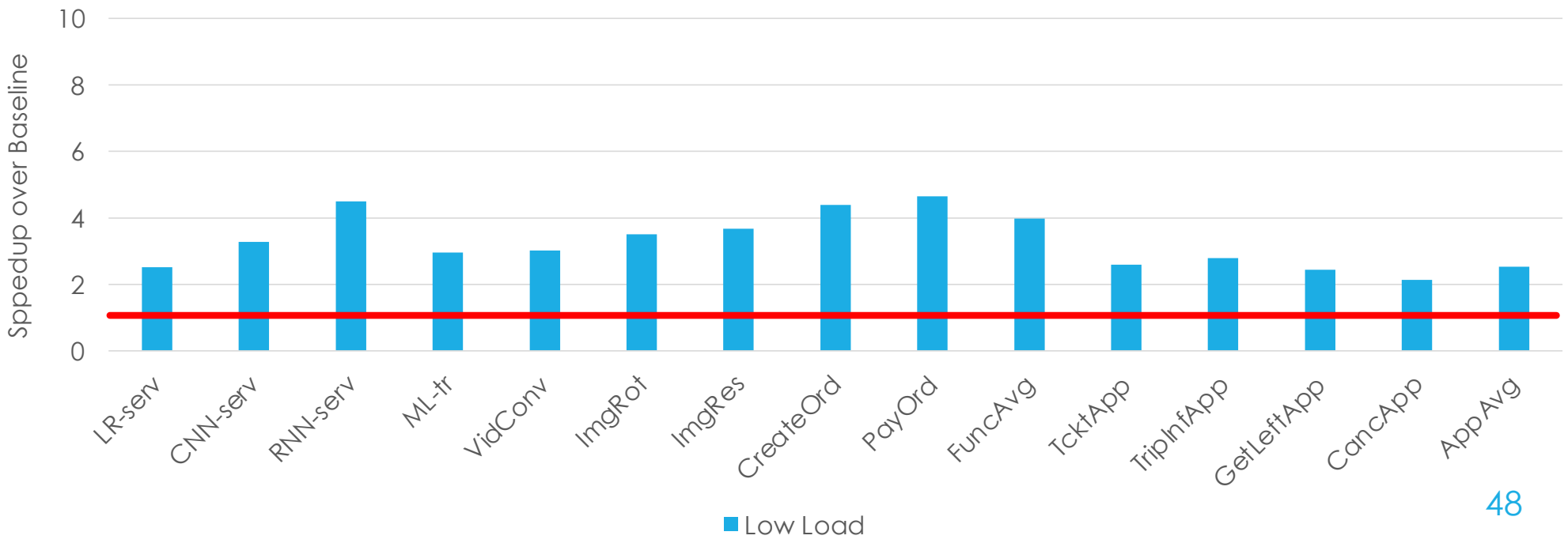


Evaluation Methodology

- Cluster with 15 AMD Epyc servers (24 cores, each)
- Platforms: OpenWhisk and KNative
- Baseline: state-of-the-art research platform (Nightcore ASPLOS'21)
- Various functions and applications from two benchmark suites
- 3 system loads
  - Low (450 RPS*)
  - Medium (1000 RPS)
  - High (1800 RPS)

* RPS = Requests Per Second

MXFaaS Delivers High Speedups



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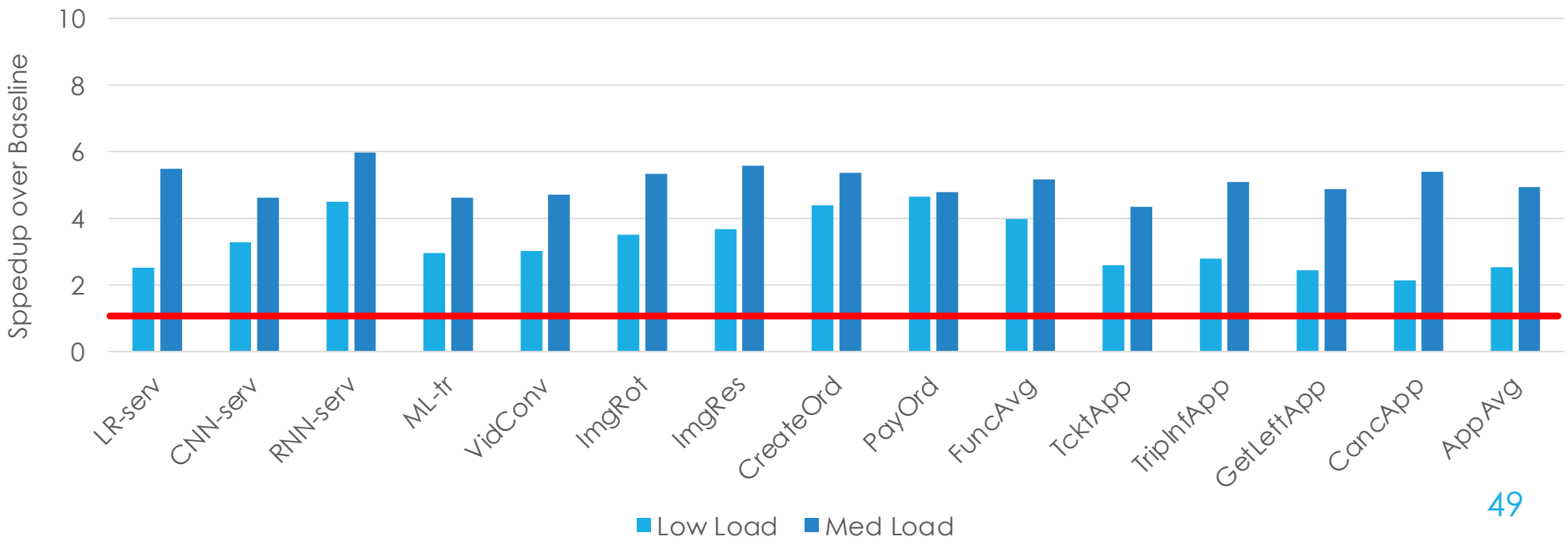

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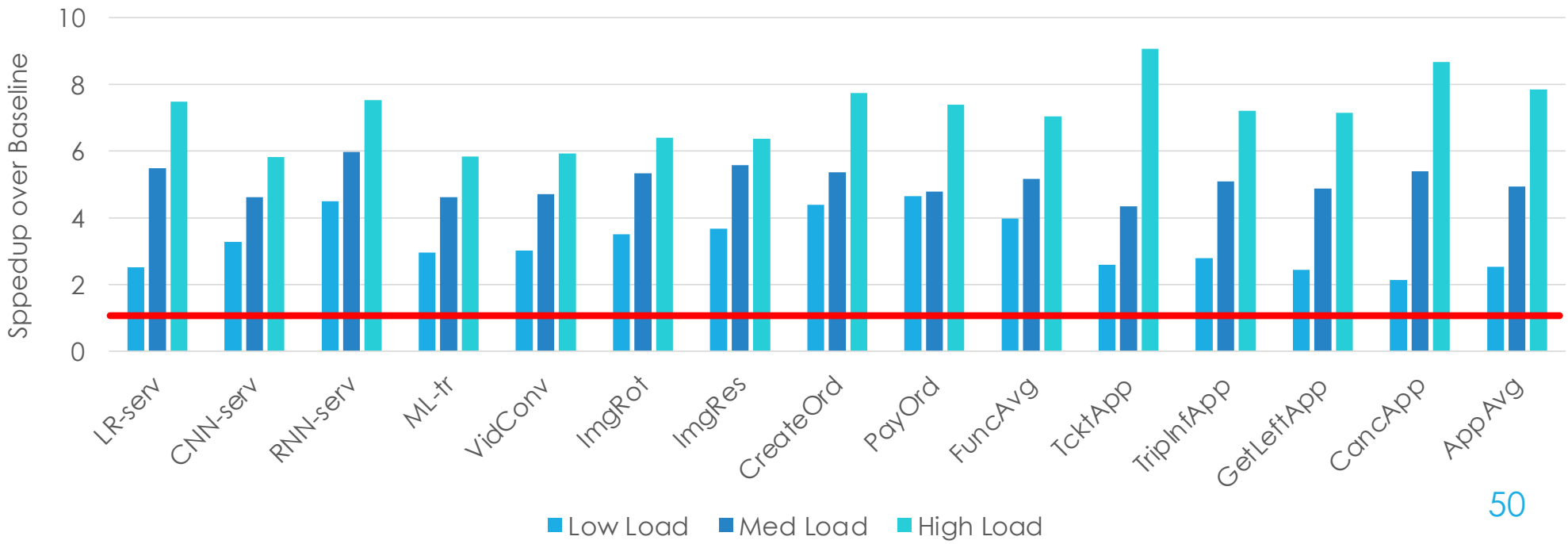
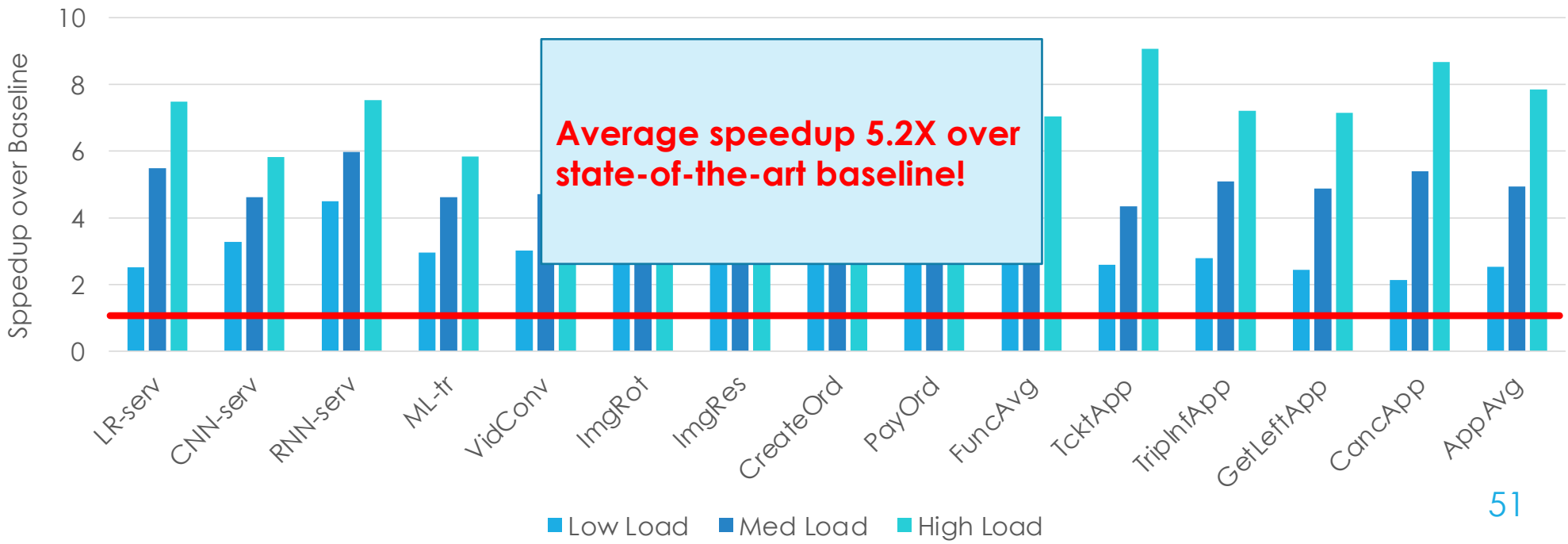


MXFaaS Delivers High Speedups



Conclusion

- Serverless computing brings benefits, but its current execution is inefficient
- Propose **MXFaaS** – novel serverless execution model based on resource multiplexing/sharing
  - MXContainers enables sharing CPU cycles, I/O bandwidth and processor/memory state across function invoc
- Average speedup 5.2X, tail latency reduction 7.4X, throughput improvement 4.8X

MXFaaS: Resource Sharing in Serverless Environments for Parallelism and Efficiency

ISCA 2023

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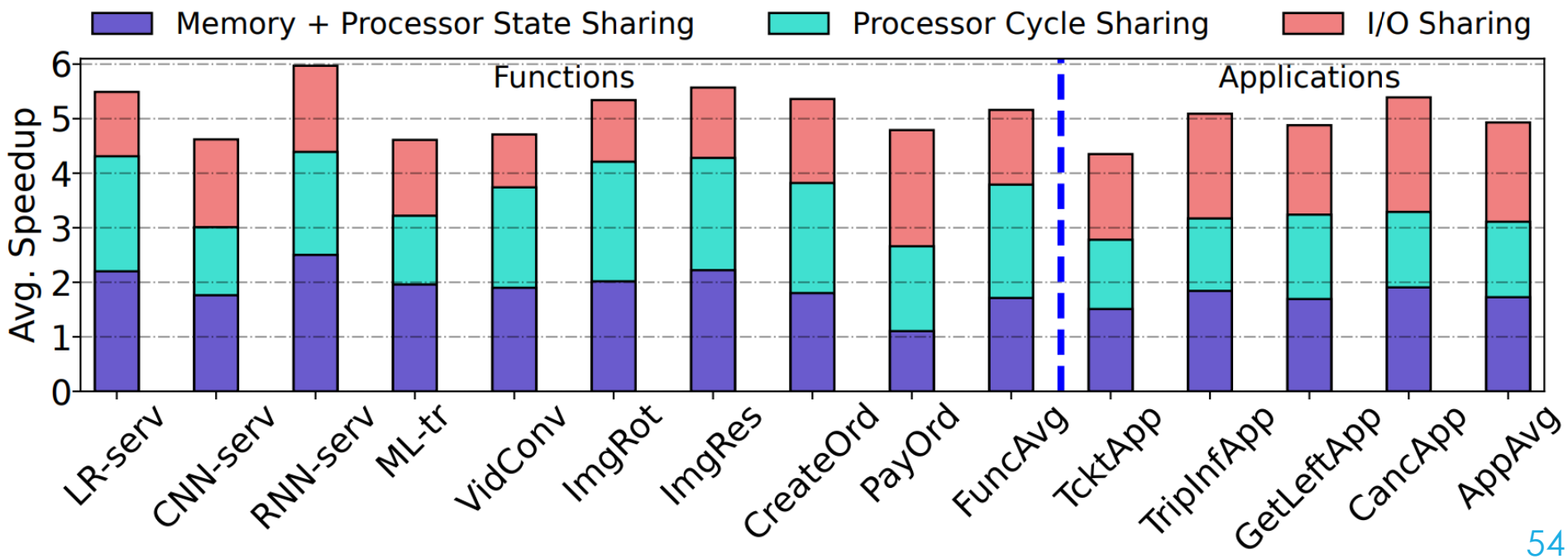
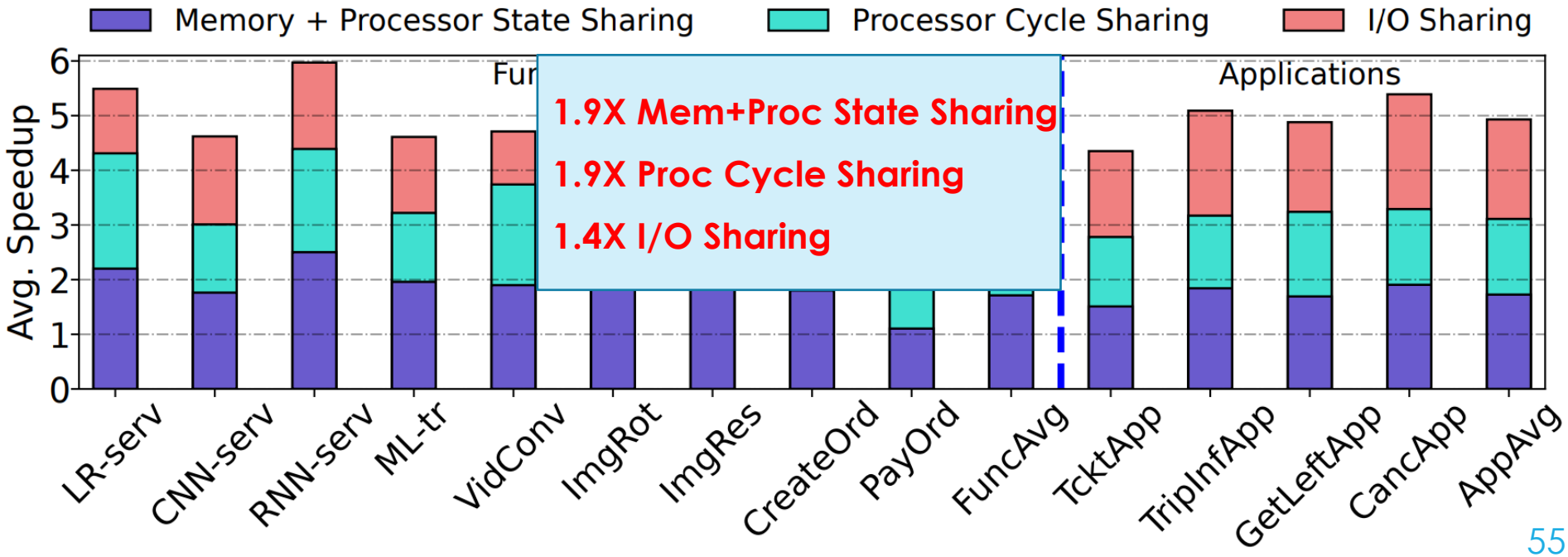
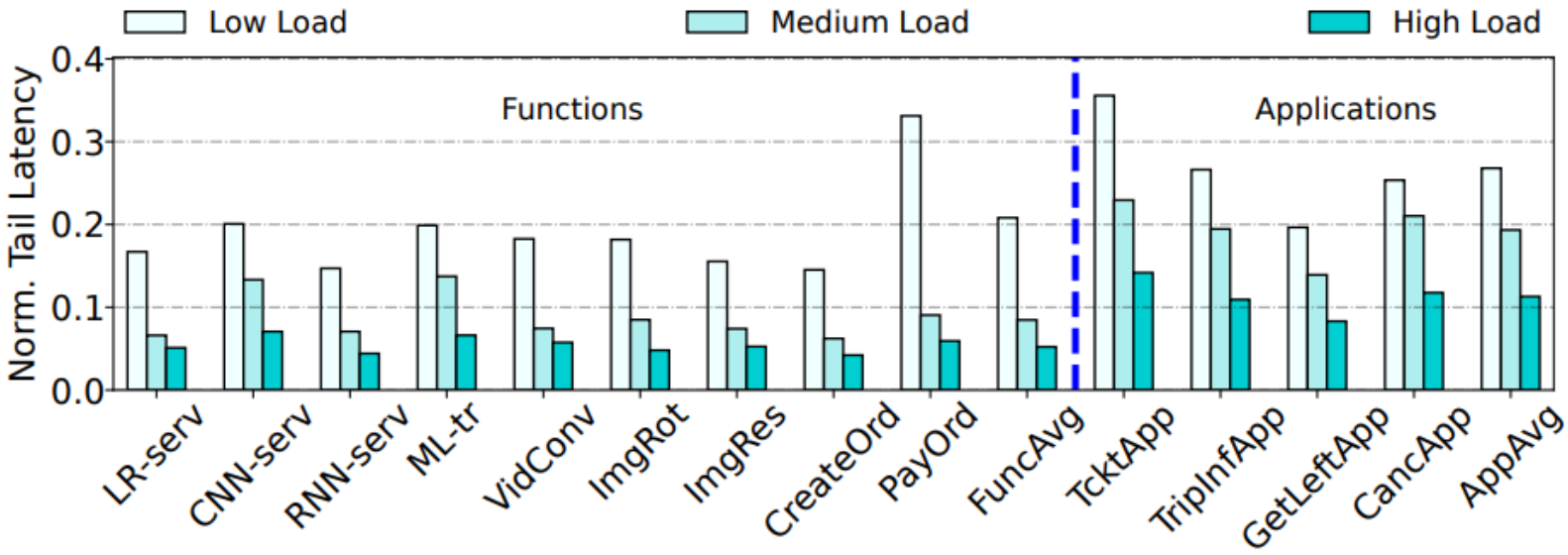
Speedup Breakdown



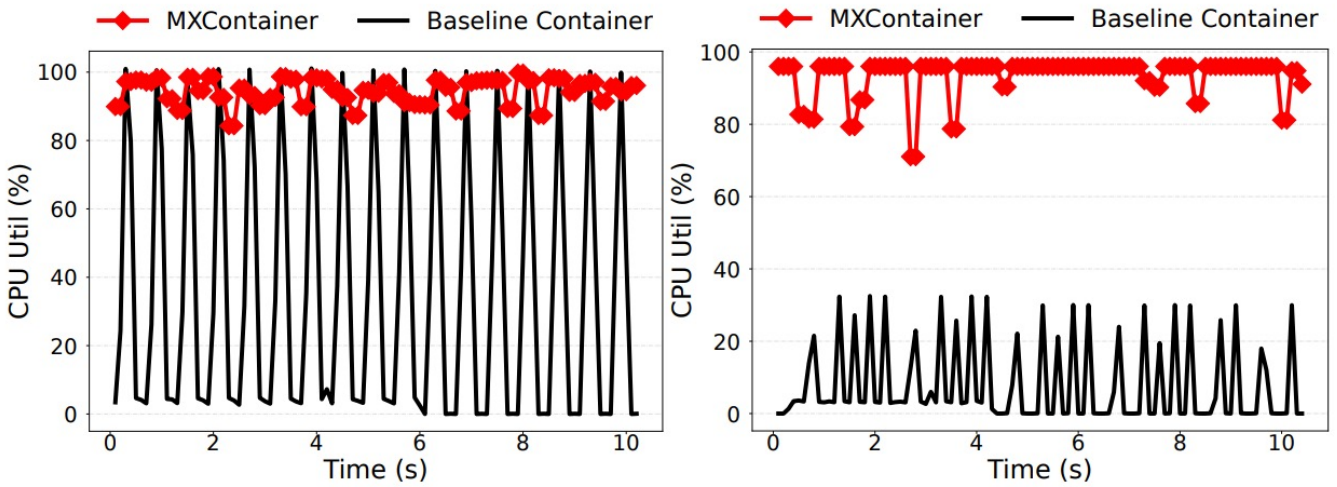
Speedup Breakdown



Tail Latency Reduction



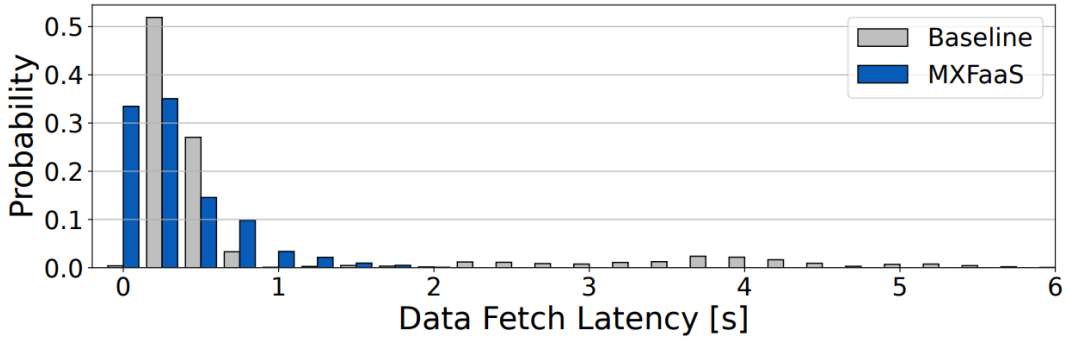
CPU Utilization

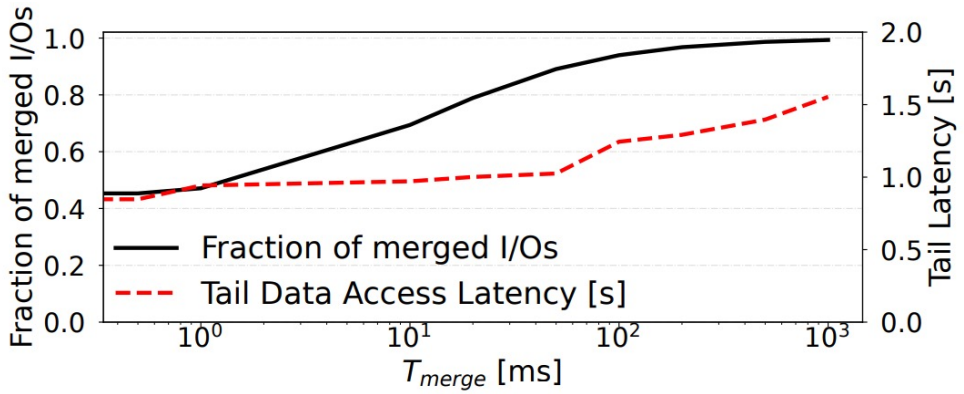


(a) CNN-serv (least idle workload) (b) CreateOrd (most idle workload)

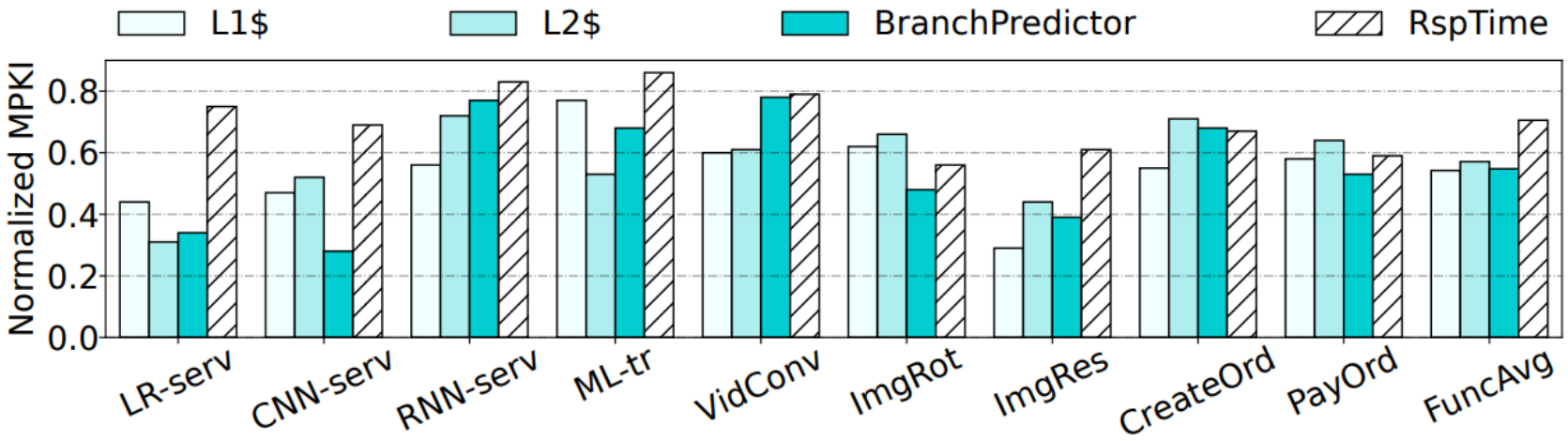
Figure 12: Container CPU utilization over time.

I/O Bandwidth Savings





Microarchitectural State Reuse



MXFaaS Scalability