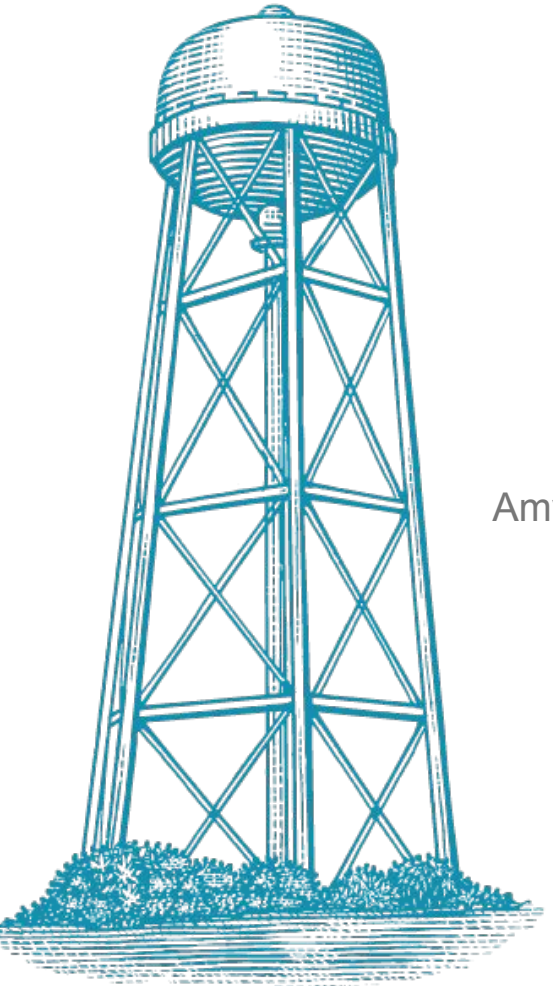


Shenango: Achieving High CPU Efficiency for Latency-sensitive Datacenter Workloads

Amy Ousterhout, Joshua Fried, Jonathan Behrens, Adam Belay,
and Hari Balakrishnan, MIT CSAIL (2019)

Presented by Neha

UCDAVIS
COMPUTER SCIENCE

Trends : Faster Networks

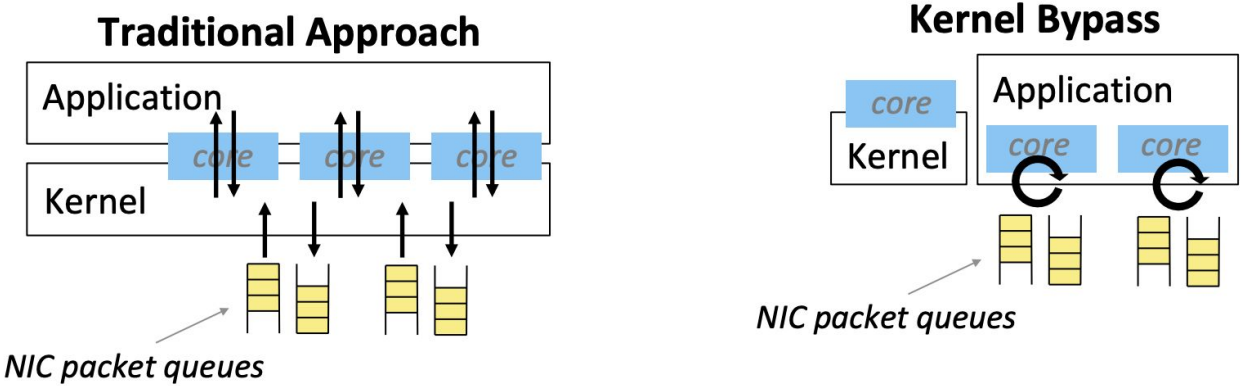
2008
Latency: ~100 µs
Throughput: 1 Gbits/s

20x
100x

2018
Latency: ~5 µs
Throughput: 100 Gbits/s

- But today's operating systems add significant overheads to I/O

The Rise of Kernel Bypass



- Dedicate busy-spinning cores
- Applications directly poll NIC queues
- Enables higher throughput and lower latency

Trends: Slowing of Moore's Law

Increased demand for servers

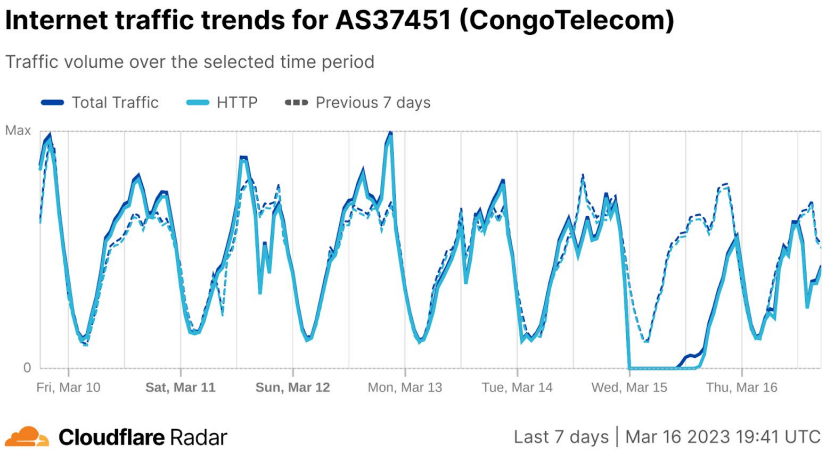
Increased demand for Energy

- CPUs only utilized 10-66% today
- CPU efficiency becomes increasingly important

Load Variation Makes Efficiency Challenging

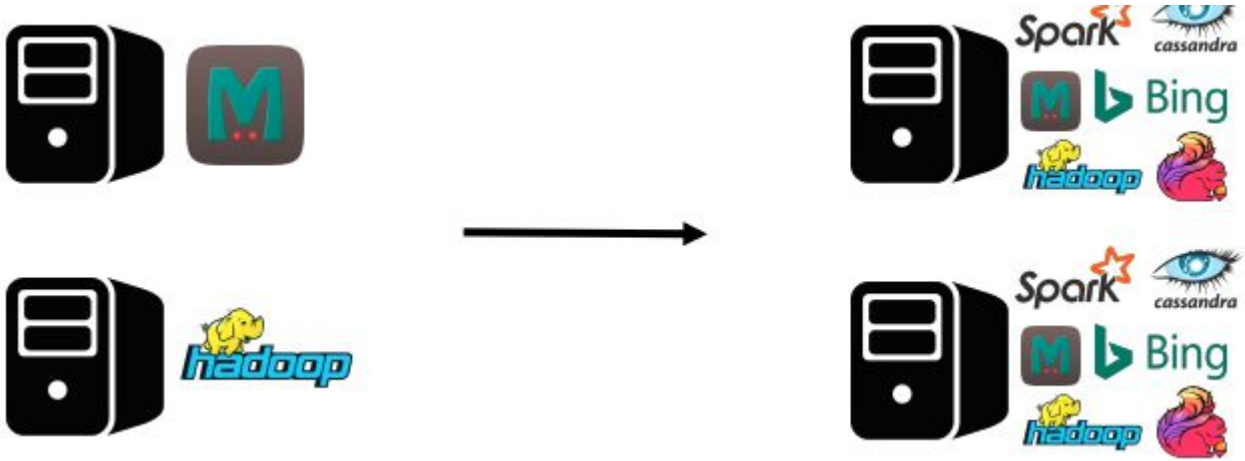
- Load variation for datacenter workloads
  - Days: diurnal cycles
  - Microseconds: packet bursts, thread bursts

- Peak load requires significantly more cores than average load



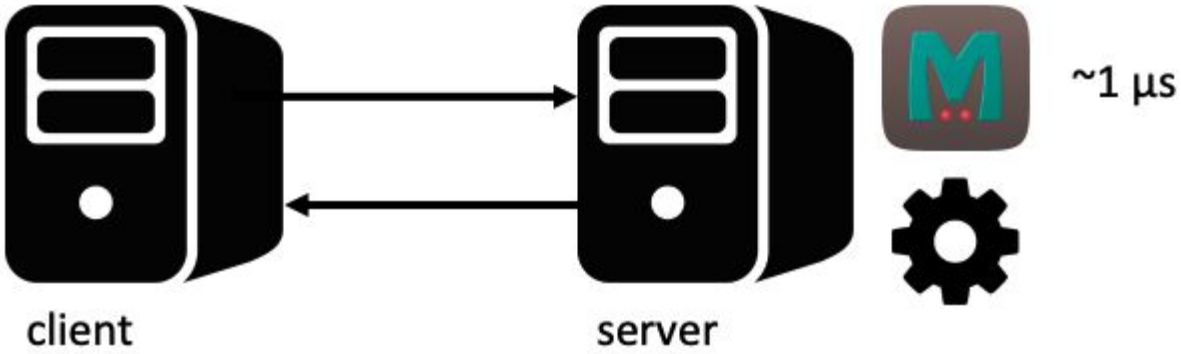
The Need for Multiplexing

- Two types of applications: latency-sensitive and batch processing
- Pack both on the same server – Bing does this on over 90,000 servers

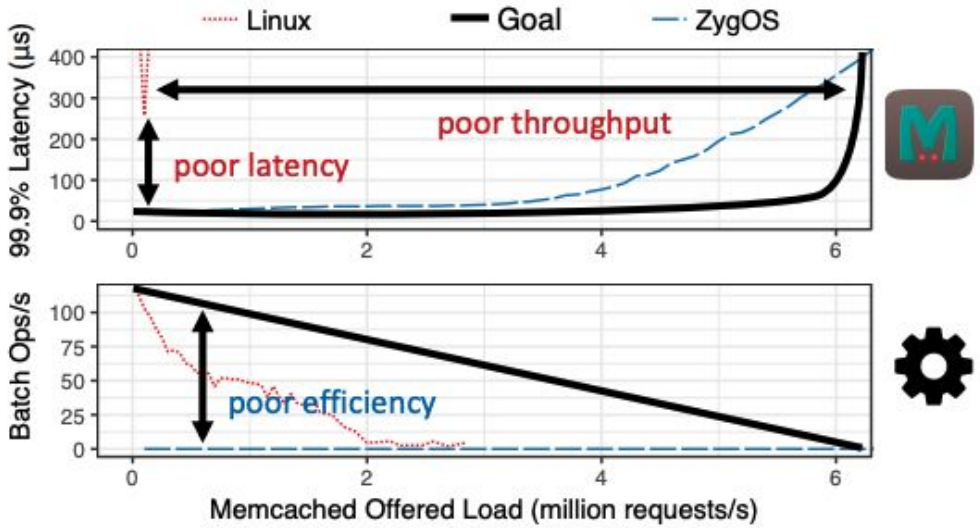


Multiplexing with Existing Approaches

- Memcached + batch processing application



Multiplexing with Existing Approaches



No existing approaches provides high network performance and high CPU efficiency.

Goal

- Reconcile the tradeoff between high CPU efficiency and network performance
- Reallocate cores across applications at **microsecond granularity**

Challenges of Fast Reallocations

- **Application-level metrics are too slow**
- **Multiple sources of load:** packets and threads
- **Overhead of reallocation:** reconfiguring hardware is too slow
- **Existing systems don’t address these challenges**

Shenango's Contributions

Efficient Core Allocation Algorithm

- Detects when an application needs **more CPU cores**
- Decision based on **thread latency** and **packet queueing delay**

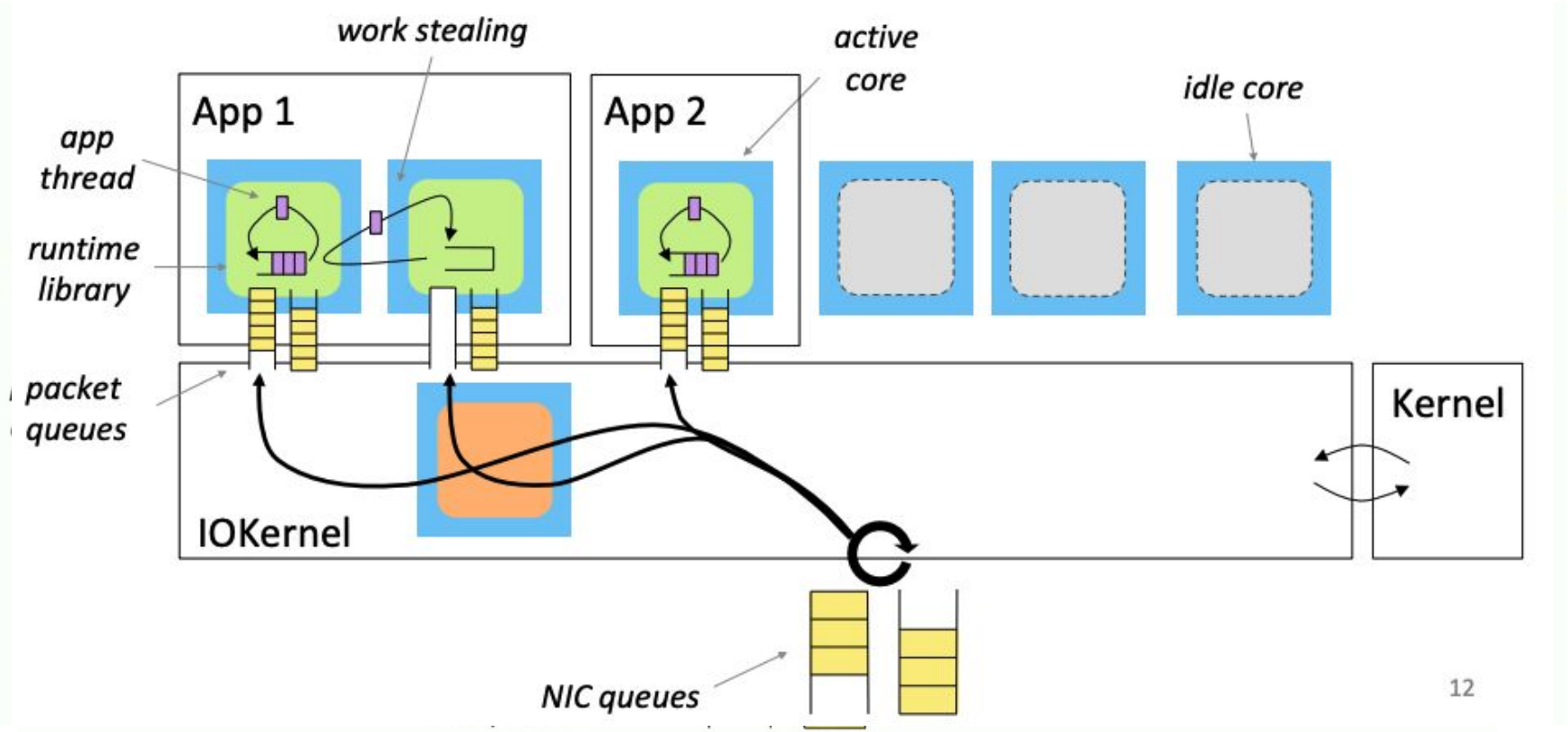
IOKernel Responsibilities

- **Steers incoming packets** in software
- **Allocates or releases cores** dynamically
- Core reallocation latency: **≈ 5 µs**

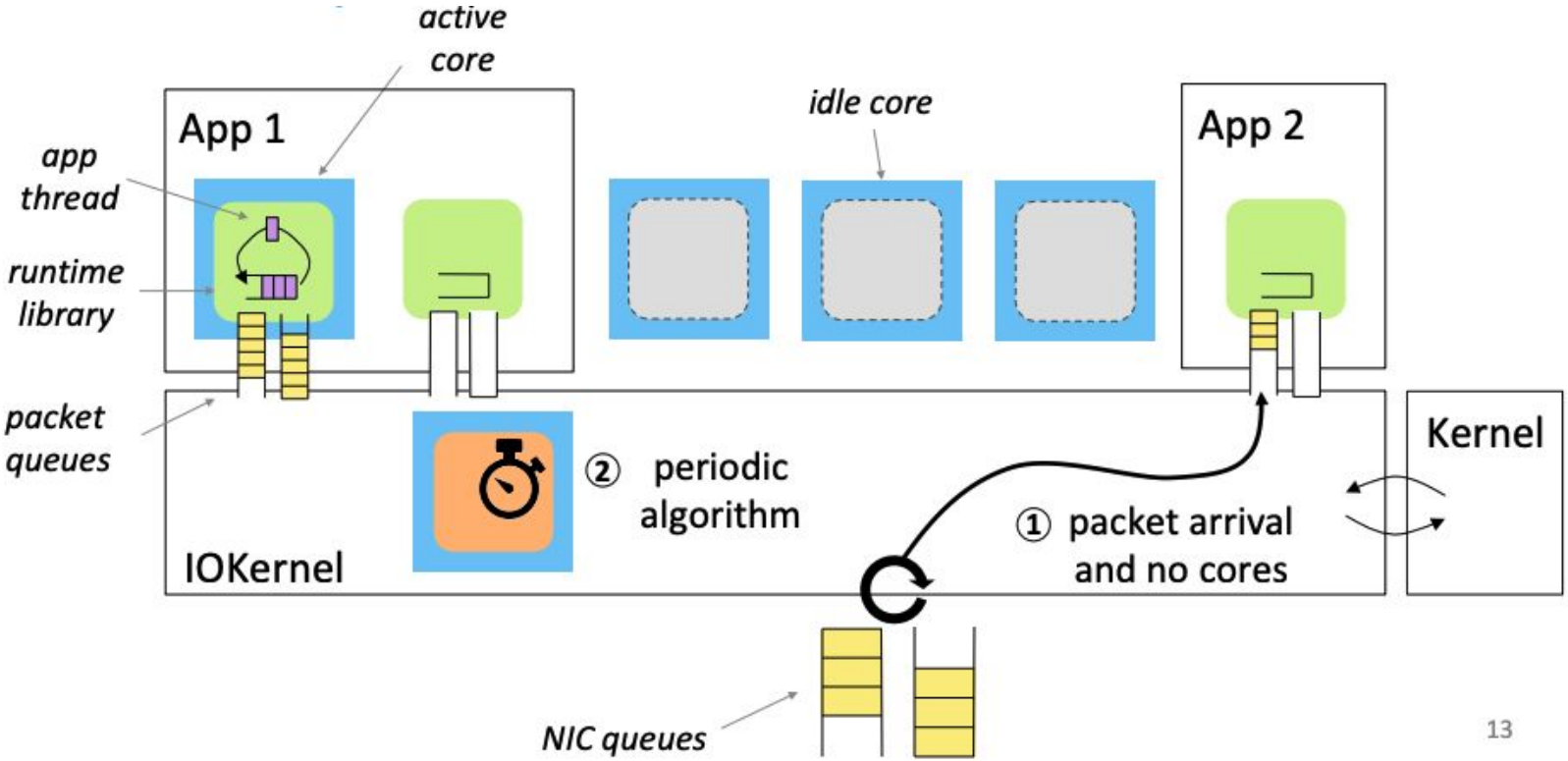
Optimizations

- **Cache-aware core selection** - keeps related threads on nearby cores
- **Load-balances** TCP and other protocol handling across cores

Shenango's Design



How many cores should the IOKernel Allocate?

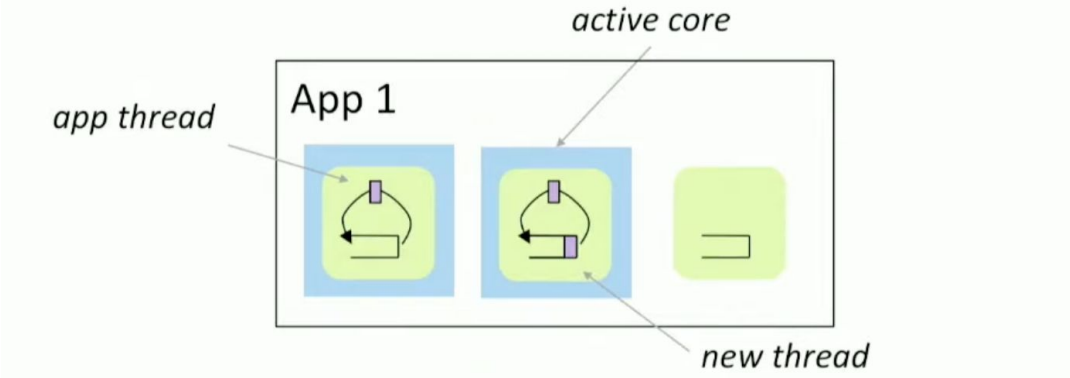


Compute Congestion

Occurs when granting an additional core allows an application to finish faster.

Goal:

- Allocate the minimal number of cores required per application
- Avoid compute congestion while optimizing CPU utilization



Congestion Detection Algorithm

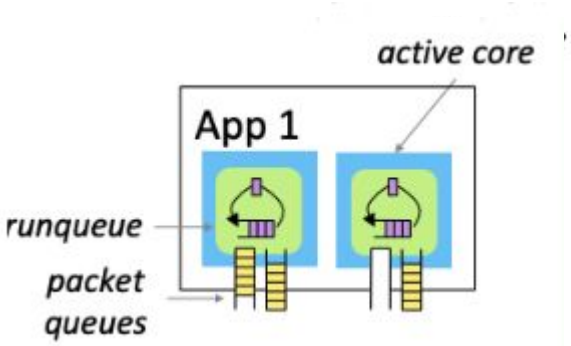
Queued threads or packets indicate congestion

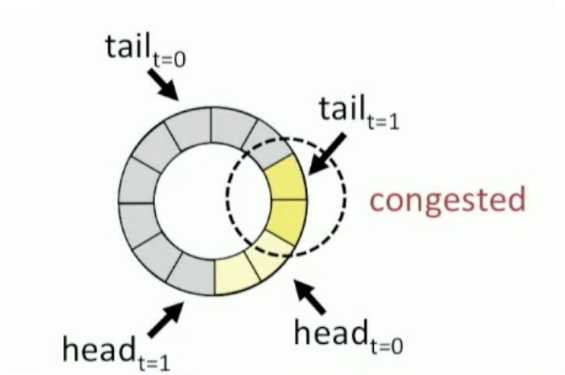
Any packets or threads queued since the last run (5 µs ago)?

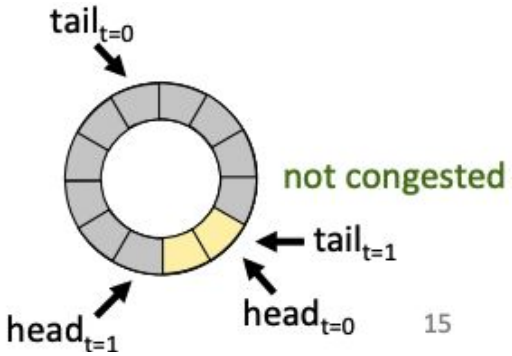
- Grant one more core

Ring-buffers enable an efficient check

- head_t=n-1 > tail_t=n implies congestion







Implementation

IOKernel

- Uses **DPDK 18.11**

Runtime

- Supports **UDP and TCP**
- Provides **C++ and Rust bindings**

Codebase

- ~13,000 lines of code total

Evaluation Questions

- How well does Shenango reconcile the tradeoff between **CPU efficiency** and **network performance**?
- How does Shenango respond to **sudden bursts in load**?
- How do Shenango's **individual mechanisms** contribute to its overall performance?

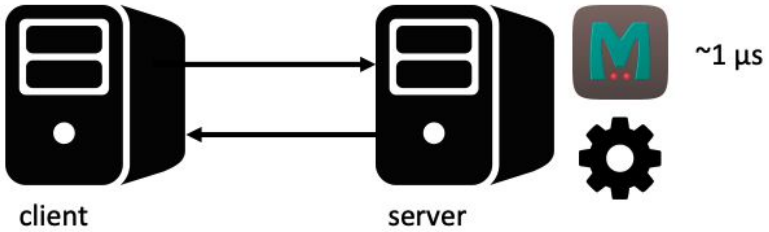
Experimental Setup

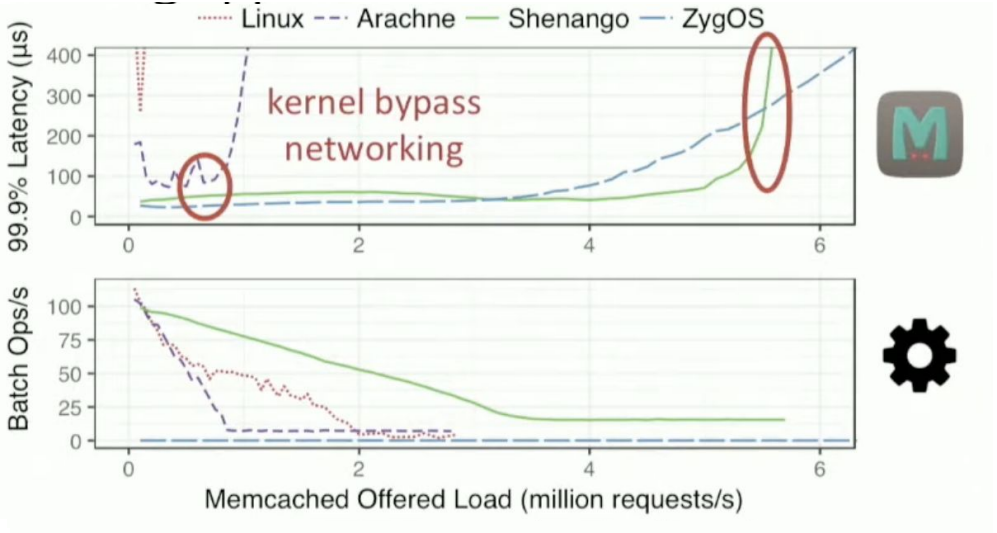
- 1 server + 6 clients, 10 Gbits/s NICs
- Clients run over open-loop load generator built on Shenango
  - Requests follow Poisson arrivals, use TCP

System	Kernel Bypass Networking	Lightweight Threading	Balancing Interval
Linux	✗	✗	4000 µs
ZygOS (SOSP '17)	✓	✗	N/A
Arachne (OSDI '18)	✗	✓	50000 µs
Shenango	✓	✓	5 µs

CPU Efficiency and Network Performance with Memcached

- Memcached +batch processing application

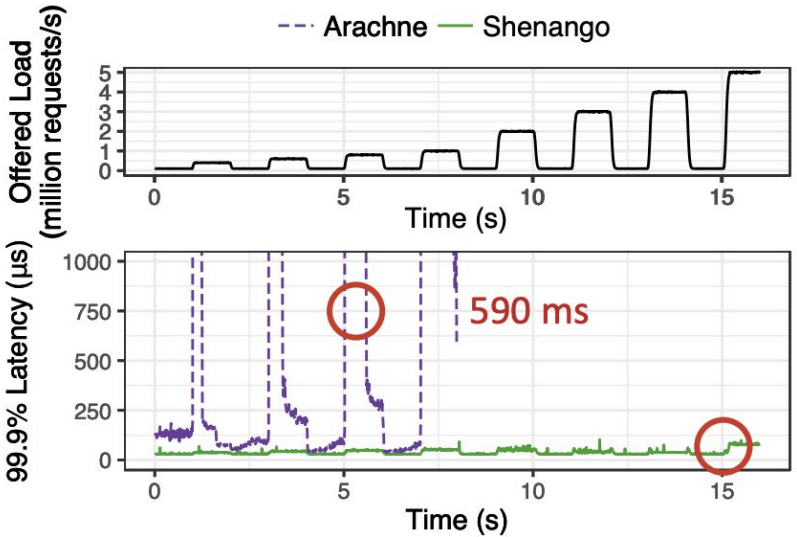




- Shenango matches ZygOS's tail latency with high CPU efficiency

Shenango is resilient to Bursts in Load

- TCP requests with 1 µs synthetic work + batch processing application
- Increase or decrease the load every 1s



Reallocates cores 10,000x as often

Conclusion

- Shenango reconciles the tradeoff between low tail latency and high CPU efficiency
- Reallocates cores at microsecond granularity
  - – Efficient congestion detection algorithm
  - – IOKernel: allocates cores and steers packets in software

Questions?