Snap: a Microkernel Approach to Host Networking

Qianqian Tan

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Slides largely borrowed from the SOSP talk
https://www.youtube.com/watch?v=S2YJY398oZk

Quick look

- Snap:Framework for packet processing in software
  - Goals: Performance and Deployment Velocity
  - Technique: Microkernel-inspired userspace approach

Quick look

- Snap:Framework for packet processing in software
  - Goals: Performance and Deployment Velocity
  - Technique: Microkernel-inspired userspace approach
- Supports multiple use cases
  - Andromeda: Network virtualization for Google Cloud Platform [NSDI 2018]
  - Espresso: Edge networking [SIGCOMM 2017]
  - Maglev: L4 load balancer [NSDI’16]
  - New: High-performance host communication with “Pony Express”
- 3x throughput efficiency (vs kernel TCP), 5MIOPS, and weekly releases

Part 1: Motivation

Motivation

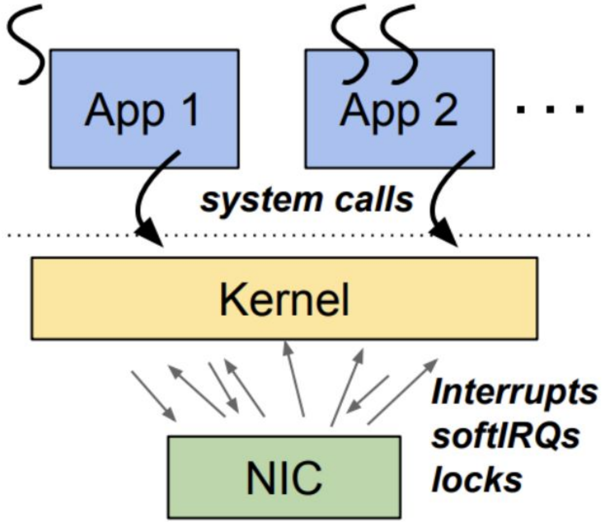
- Growing performance-demanding packet processing needs at Google

- The ability to rapidly develop and deploy new features is just as important!

Monolithic (Linux) Kernel

Deployment Velocity:

- Smaller pool of software developers
- More challenging development environment
- Must drain and reboot a machine to roll out new version
- Typically months to release new feature



Monolithic (Linux) Kernel

Deployment Velocity:

- Smaller pool of software developers
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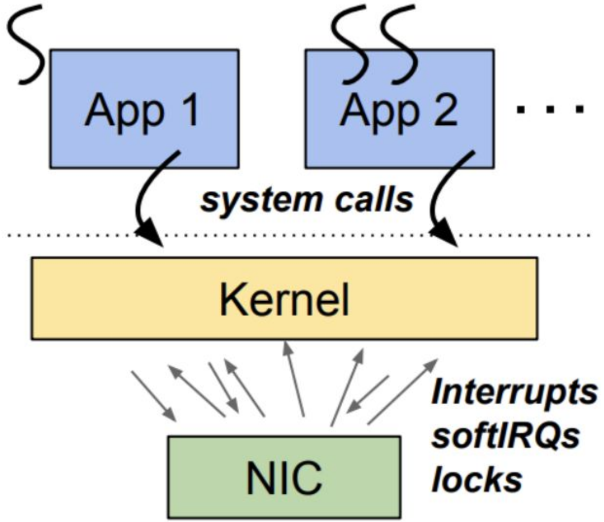
Performance:

- Overheads from system calls,fine-grained synchronization, interrupts, and more.



LibraryOS and OS Bypass

Networking logic in application binaries

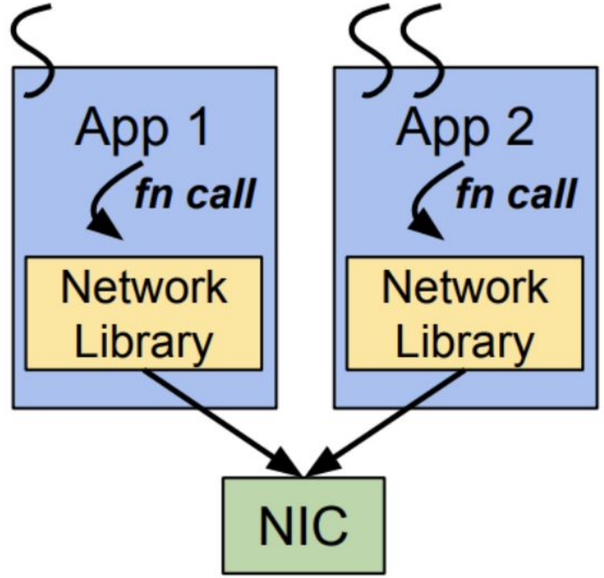
Examples: Arrakis, mTCP, IX, ZygOS, and more

Deployment Velocity:

- Difficult to release changes to the fleet
- App binaries may go months between releases

Performance:

- Can be very fast
- But typically requires spin-polling in every application
- Benefits of centralization (i.e.,scheduling) lost
- Delegates all policy to NIC



Microkernel Approach

Hoists functionality to a separate userspace process

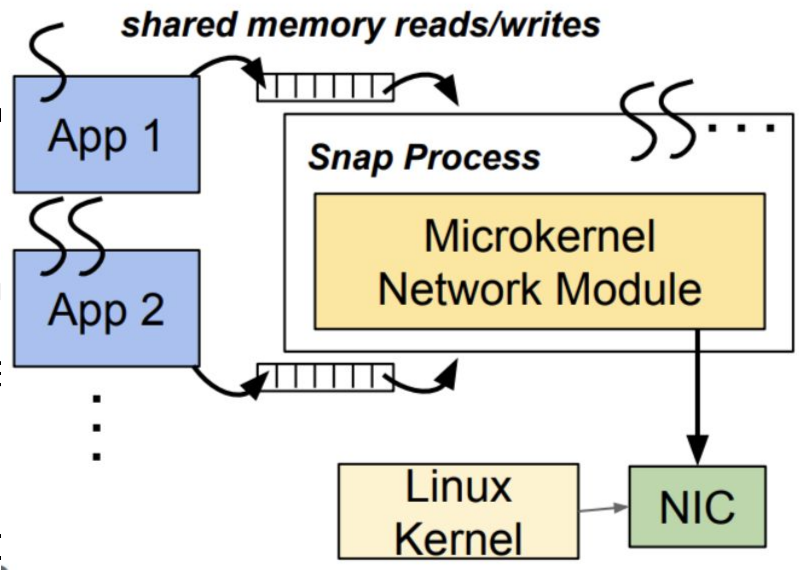
Deployment Velocity:

- Decouples release cycles from application and kernel binaries
- Transparent upgrade with iterative state transfer

Performance:

- Fast! Leverages kernel bypass and many-core CPUs
- Maintains centralization of a kernel
  - Can implement rich scheduling/multiplexing policies

Microkernel Approach



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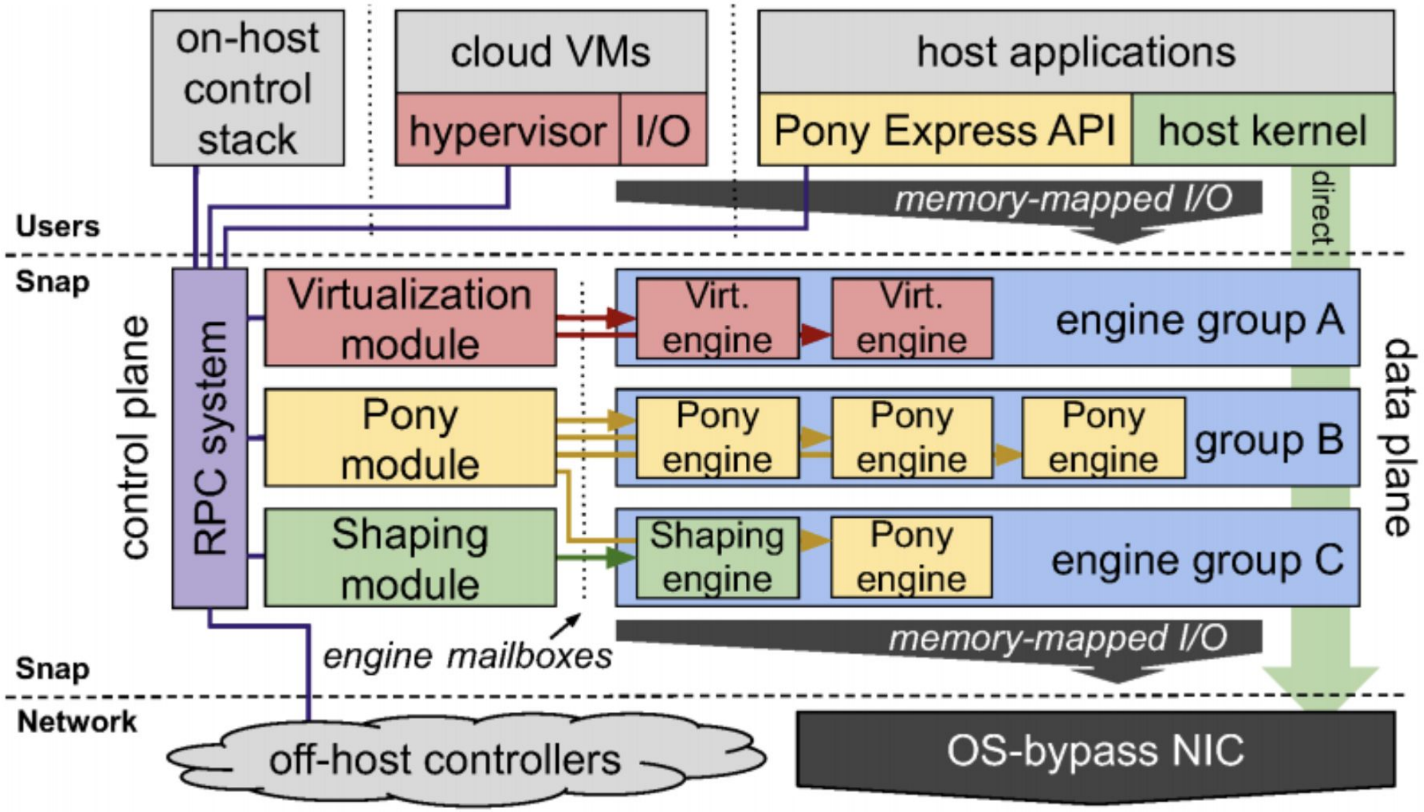
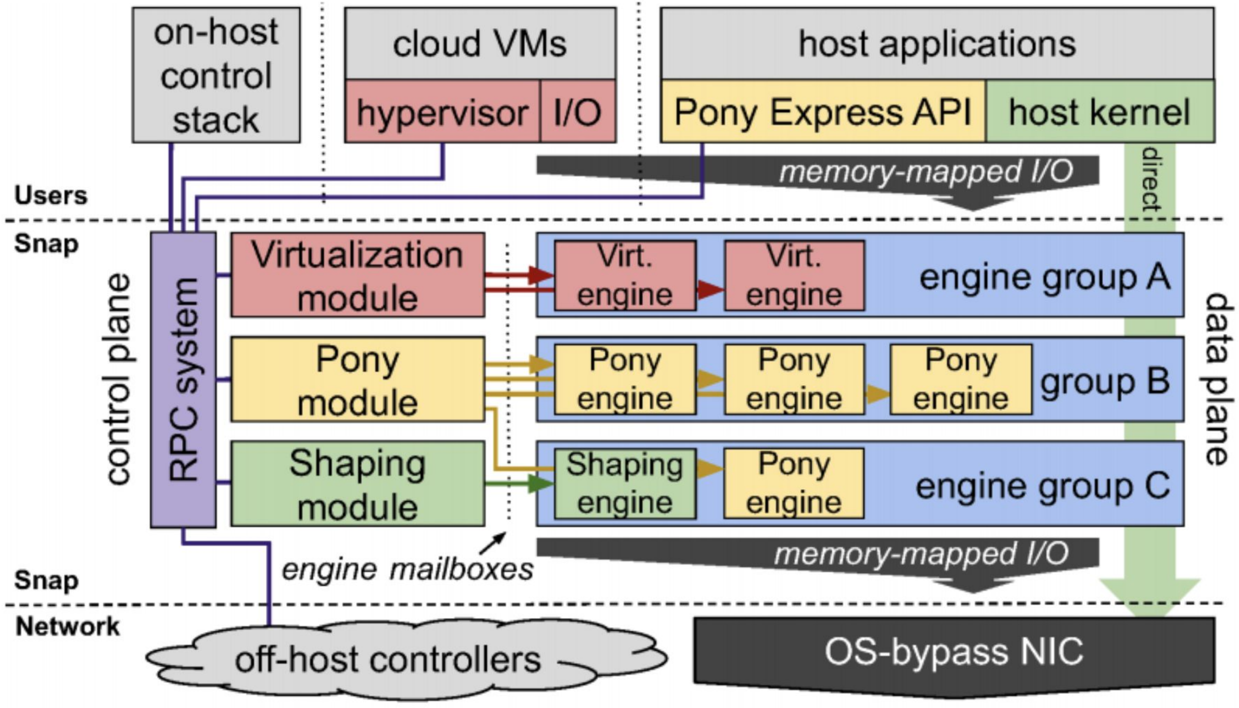
Part 2: Design

Snap Architecture



Snap Architecture



Snap engine

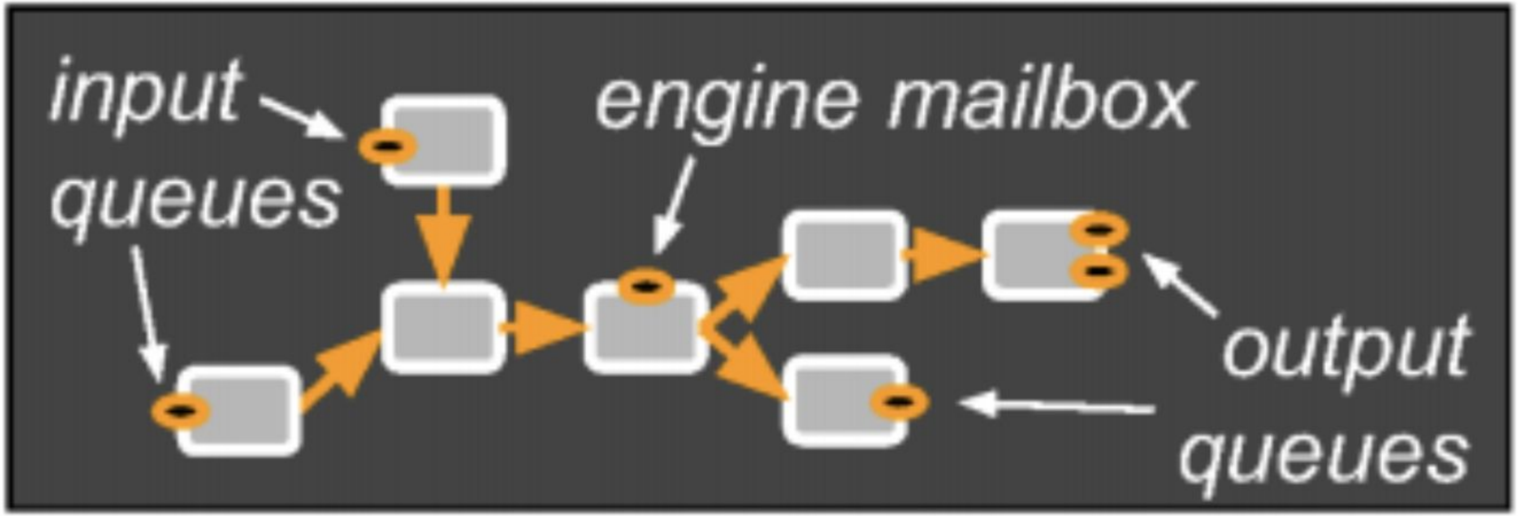
- Key dataplane element
- Implements packet processing piplines
- Unit of CPU scaling

Snap engines implement a Run() menthod invoke by Engine Threads

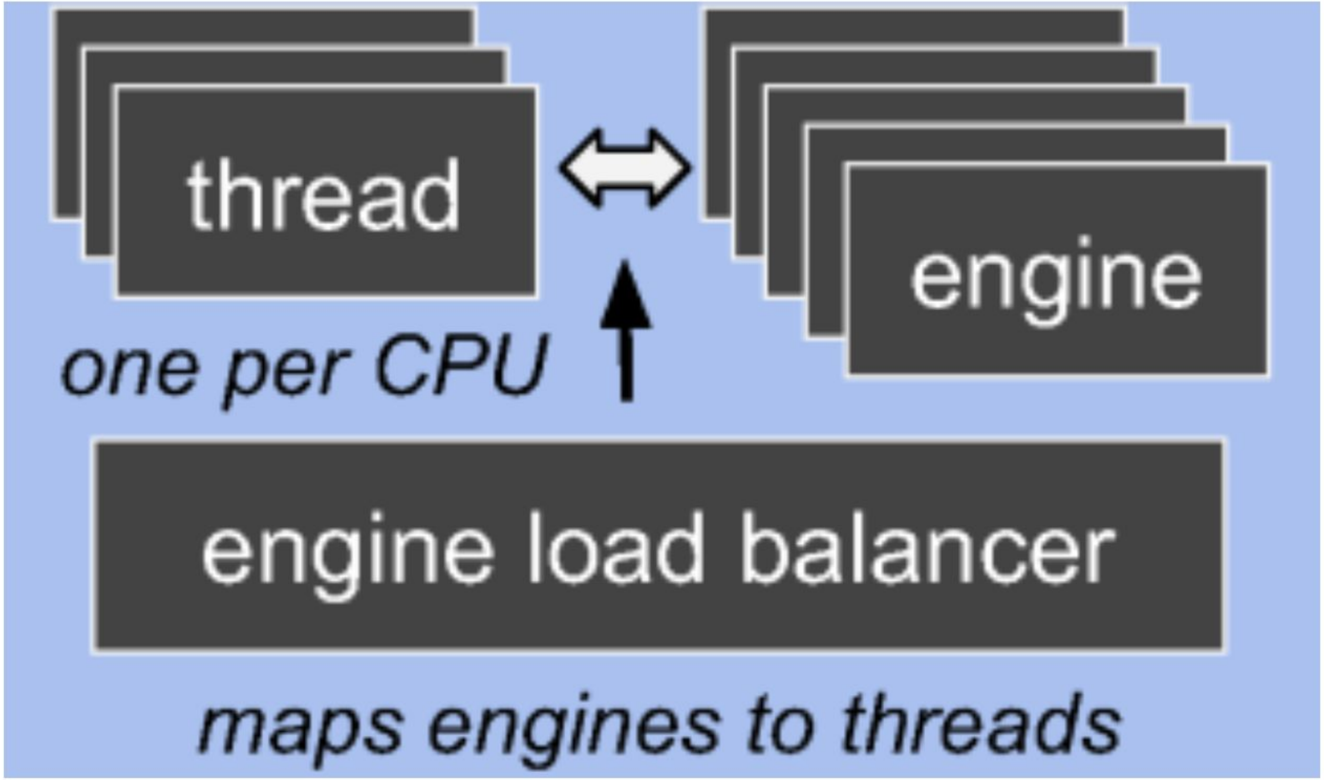
Principle synchronization:

- No blocking locks

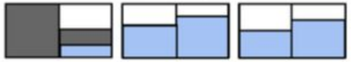
Snap Engine



Snap Engine Scheduling



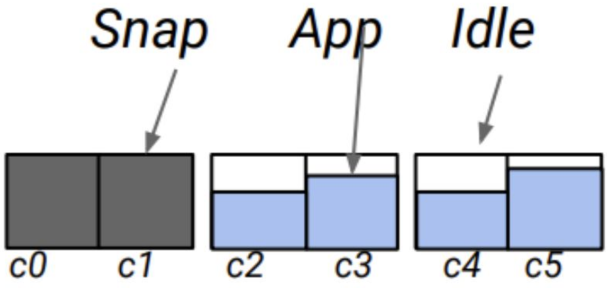
Snap Engine Scheduling Modes

scheduling mode	CPU resources	scheduling latency		CPU efficiency	visualization
		median	tail		
dedicating cores	static	0-1μs	0*-100+μs	poor	
spreading engines	dynamic	3-10μs	10-30**μs	good	
compacting engines	dynamic	0-5μs	50-100**μs	excellent	

Snap Engine Scheduling Modes

Dedicated Cores

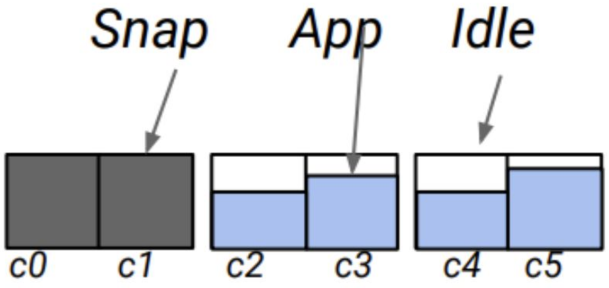
- Static provisioning of N cores to run engines.
  - Fair share these N cores across engines.
- Simple and best for some situations.



Snap Engine Scheduling Modes

Dedicated Cores

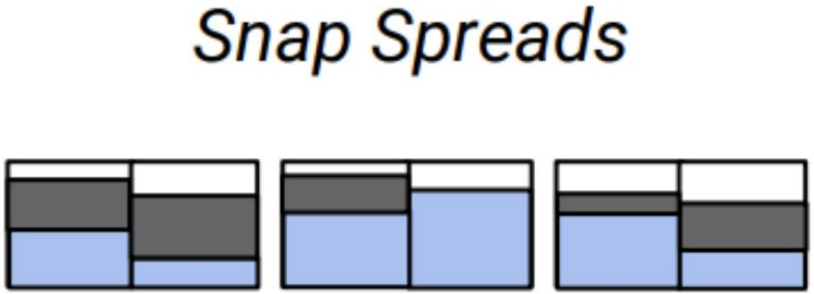
- Static provisioning of N cores to run engines.
  - Fair share these N cores across engines.
- Simple and best for some situations.
- Provisioning for the worst-case is wasteful
- Provisioning for the average case leads to high tail latency



Snap Engine Scheduling Modes

Spreading Engines

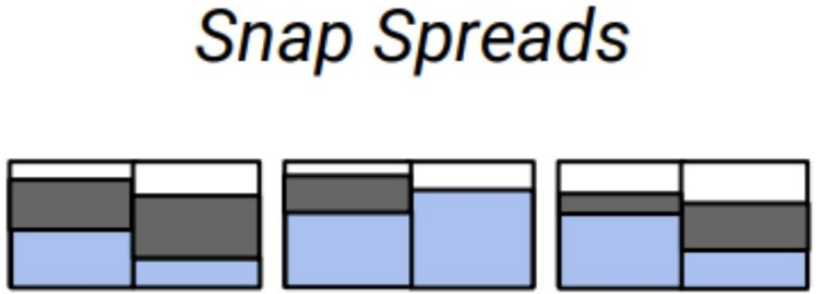
- Bind each engine to a unique thread
- Threads scheduled on-demand based on interrupts triggered from NIC or application
- Leverages new micro-quanta kernel scheduling class for tighter latency



Snap Engine Scheduling Modes

Spreading Engines

- Bind each engine to a unique thread
- Threads scheduled on-demand based on interrupts triggered from NIC or application
- Leverages new micro-quanta kernel scheduling class for tighter latency
- Can provide lowest tail latency
- Scheduling pathologies and overheads



Snap Engine Scheduling Modes

Compacting Engines

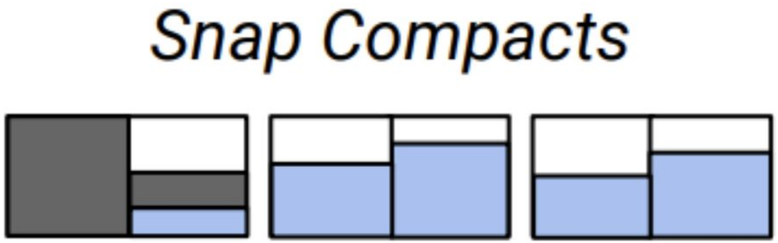
- Compacts engines to as few cores as possible
- Periodic polling of queuing delays to re-balance engines to more cores

Snap Compacts

Snap Engine Scheduling Modes

Compacting Engines

- Compacts engines to as few cores as possible
- Periodic polling of queuing delays to re-balance engines to more cores
- Can provide best CPU efficiency.
- Timely detection of queue build-up.



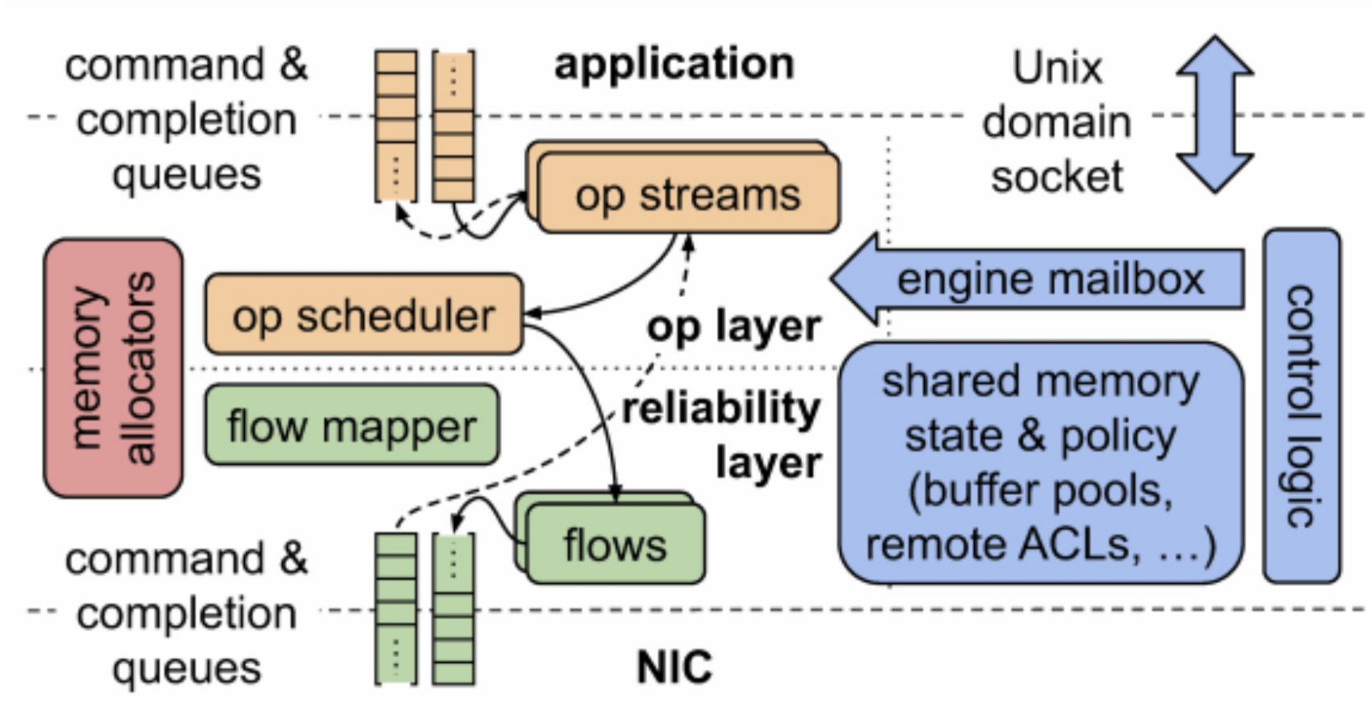
High Performance Communication

Pony Express Communication Stack

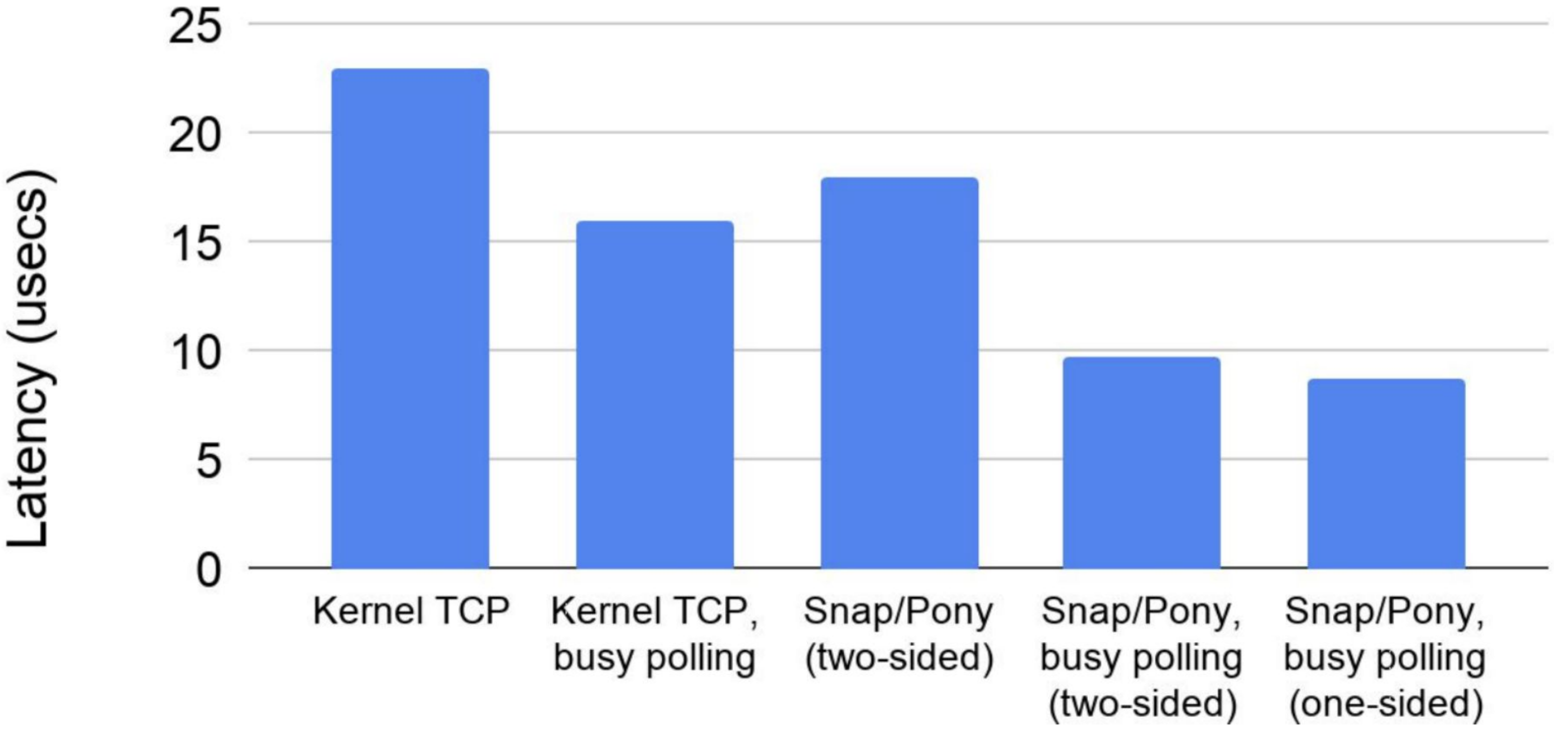
- Implement a full-fledged reliable transport and interface
  - RDMA-like operation interface to applications
  - Two-sided operations for classic RPC
  - One-sided (pseudo RDMA) operations for avoiding invocation of application thread scheduler
  - Custom one-sided operations to avoid shortcomings of RDMA (i.e., pointer chase over fabric)
  - Custom transport and delay-based congestion control (Timely/Swift)

High Performance Communication

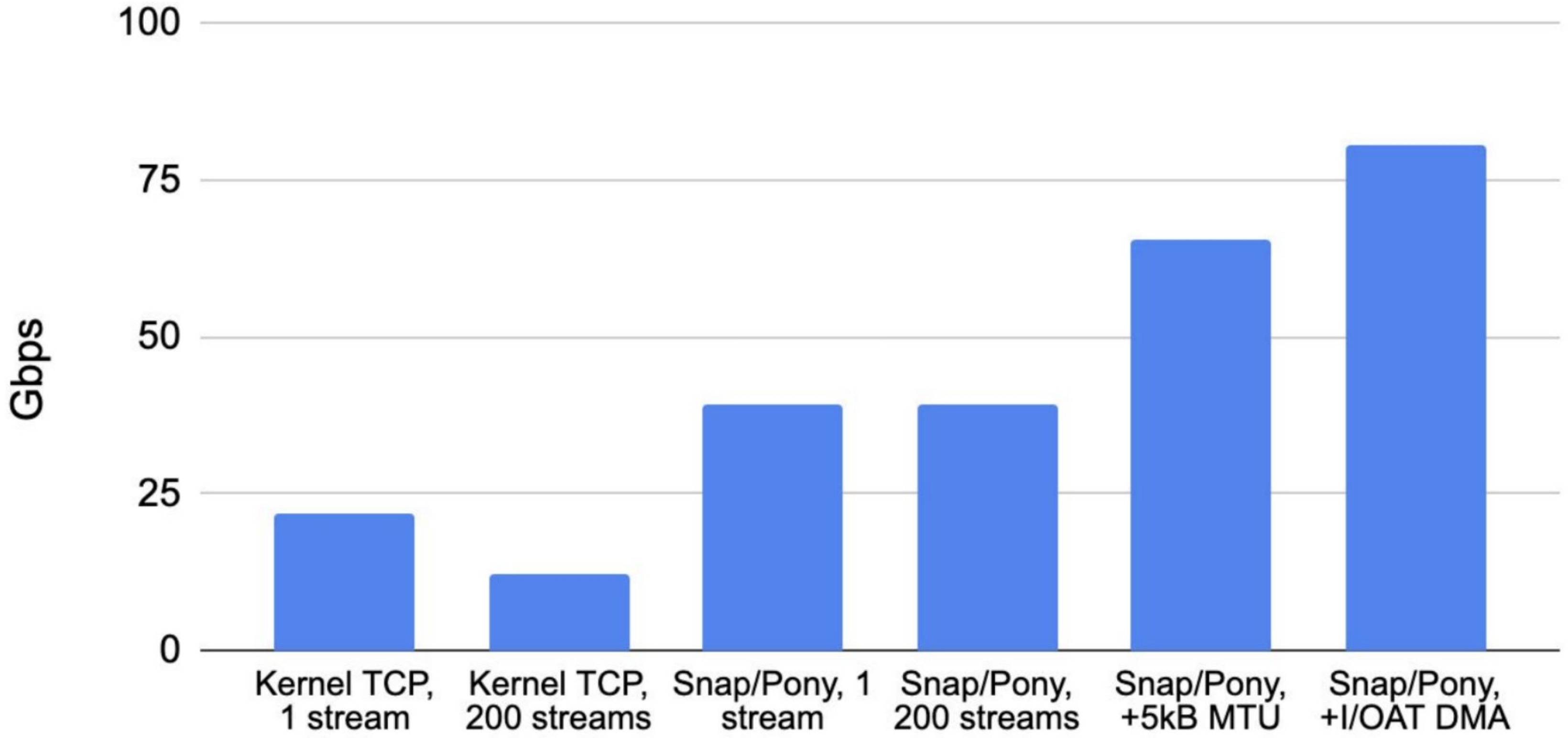
Pony Express Communication Stack



Evaluation: Ping-pong latency



Evaluation: Throughput



Evaluation: Comparison with RDMA

- Switching to Pony Express “doubled the production performance of the data analytics service”.
- Stringent RDMA rate limits applied to prevent NIC cache overflow, and ensuing PFCs.
- Could be disabled with Pony Express.

Thank you!

Q & A