A Linux Kernel Implementation of the Homa Transport Protocol

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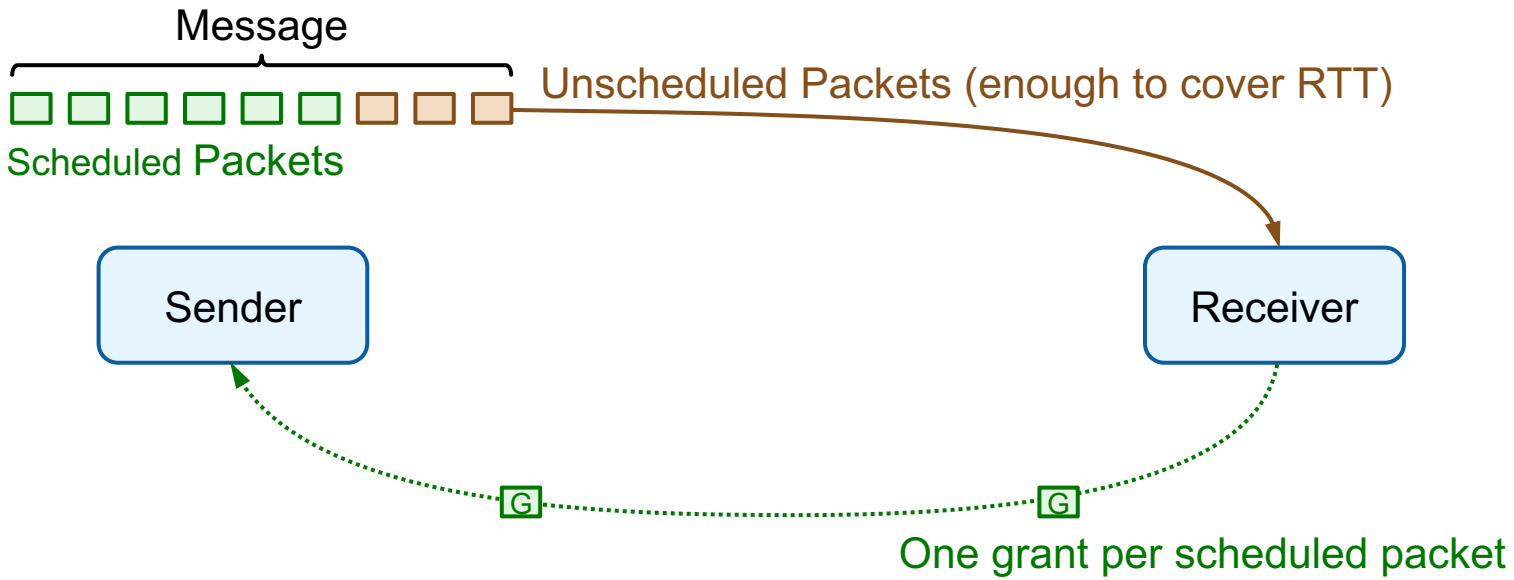
Overview

- **Homa: a new transport protocol for datacenters**
  - Low tail latency for small messages, even under high load
  - Previously evaluated with simulations, RAMCloud implementation
- **Personal mission: replace TCP!**
- **Personal project: Linux kernel implementation**
- **Results: Homa tail latency 10-100x better than TCP**
- **Very difficult to implement high-performance protocols in Linux**
- **Transport protocols no longer make sense in software: must move to NIC**

Homa Basics



- **Receiver-driven flow control limits queue lengths**
- **Use switch priority queues to implement SRPT**
- **Receiver determines priorities dynamically**

More on Homa

- **Low latency for short messages, even under high network load**
  - Uses switch priority queues to implement SRPT
  - Long messages have lower latency also (run to completion)
- **Prevents incast congestion**
  - Receiver-driven flow control limits queue lengths
  - Slight overcommitment/buffering to maintain link utilization
  - Priorities preserve SRPT even with buffering
- **Other features**
  - Message-oriented (not streaming)
  - Connectionless
    - State only for active RPCs
    - One socket per process, not per connection

Homa Project Evolution

- **Behnam Montazeri's dissertation project**
- **2 evaluations:**
  - Simulations (Behnam Montazeri)
  - RAMCloud user-space implementation (Yilong Li)
- **Great results:**
  - Dominates all comparison protocols across many workloads
  - 10-100x lower tail latency than TCP
  - P99 latency under load typically within 2-3x of unloaded latency
- **Next steps:**
  - How to gain wide adoption in the datacenter?
  - Build Linux kernel implementation
  - Eventually, build into NIC

HomaModule

- **Dynamically loadable Linux kernel module**
- **Open source: `git@github.com:PlatformLab/HomaModule.git`**
- **10,000 lines C code (heavily commented)**
- **Status:**
  - Functionally complete
  - Still analyzing and tuning performance
  - Fairly stable/robust (but still finding bugs)
- **Preliminary performance takeaways:**
  - Significantly better than TCP
  - Yet still pathetic

Basic Performance

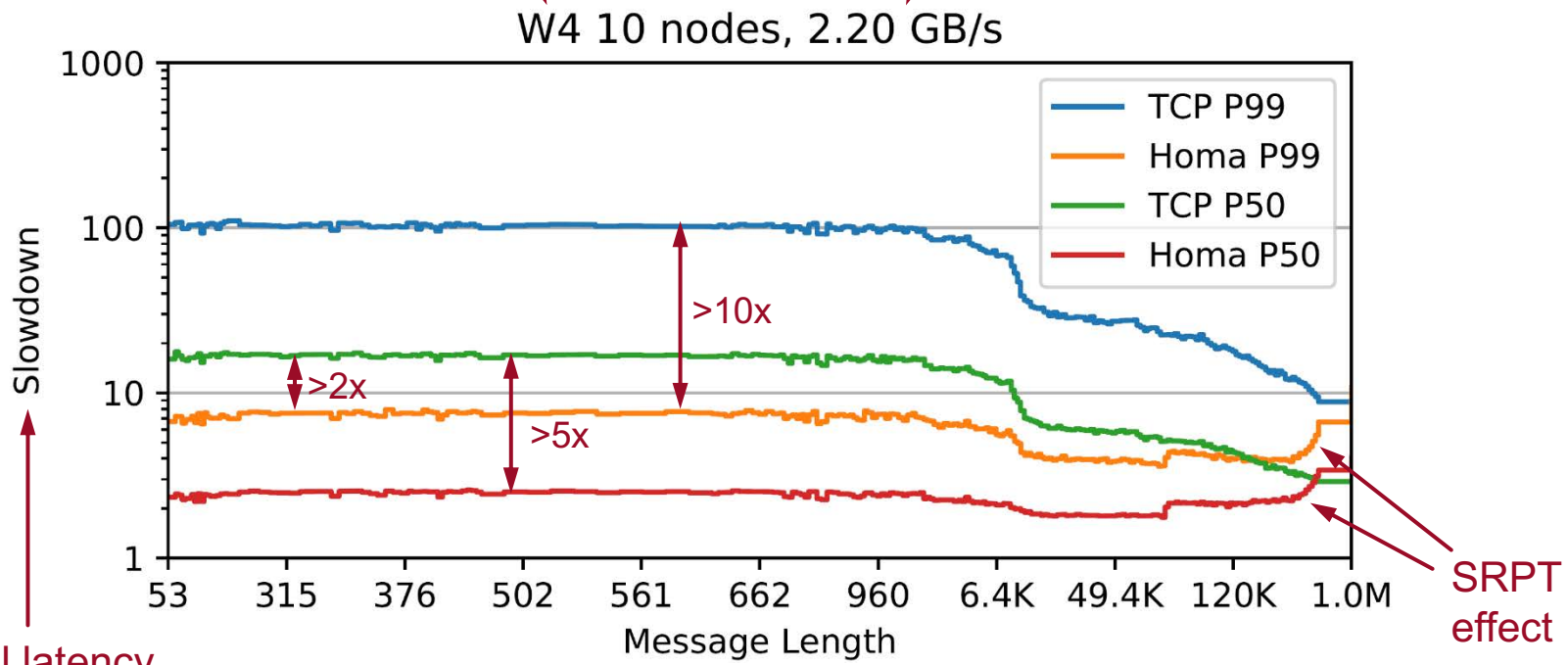
	Homa	TCP
RTT latency (unloaded, 100B messages)	**18 µs**	**21 µs**
Client RPC throughput (small messages)	**1.7 M/s**	**1.2 M/s**
Server RPC throughput (small messages)	**1.8 M/s**	**1.4 M/s**
Client large-message throughput	**2.7 MB/s**	**2.7 MB/s**
Server large-message throughput	**2.7 MB/s**	**2.9 MB/s**

CloudLab xl170 cluster:
10 nodes, Intel E5-2640v4@2.4 GHz, 20 cores
25 Gbps network, Mellanox ConnectX-4 NIC

Slowdown vs. TCP

Somewhat heavy-tailed workload

80% of max sustainable goodput

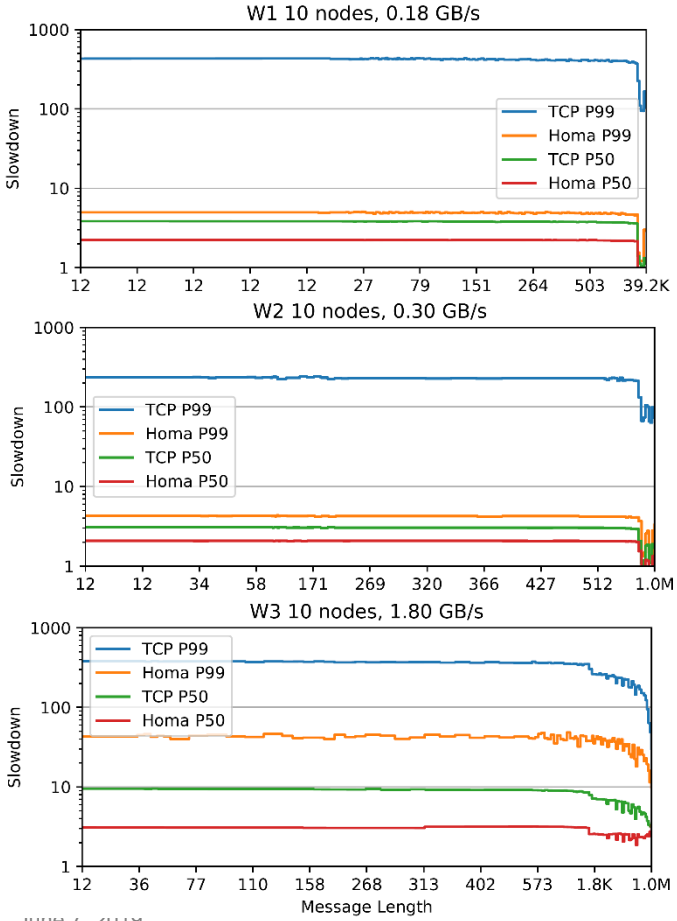


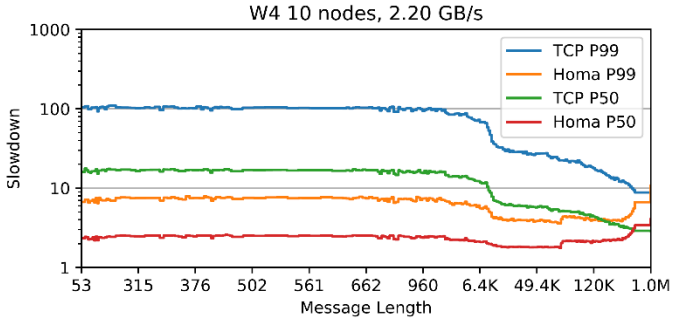
SRPT effect

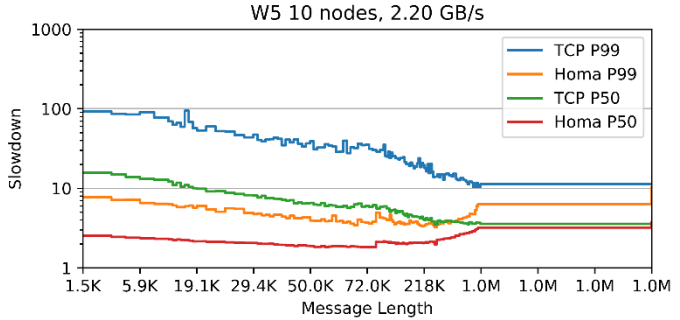
actual latency / unloaded Homa latency

x-axis: CDF of message length

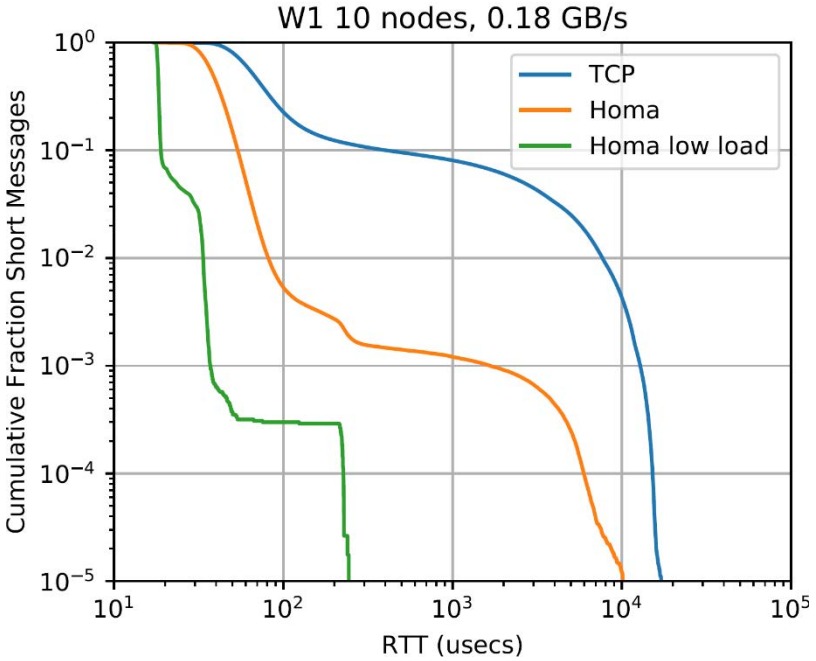
Slowdown, All Workloads

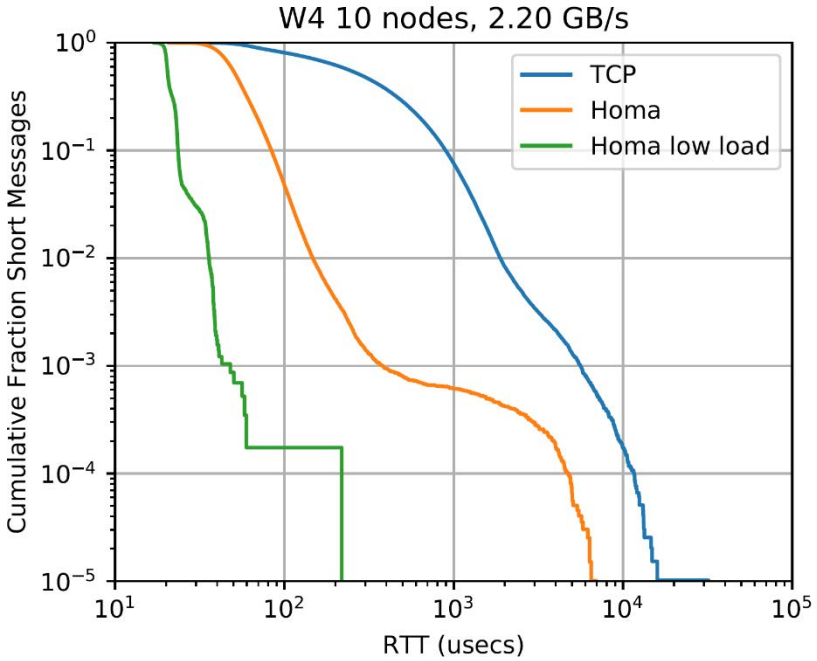




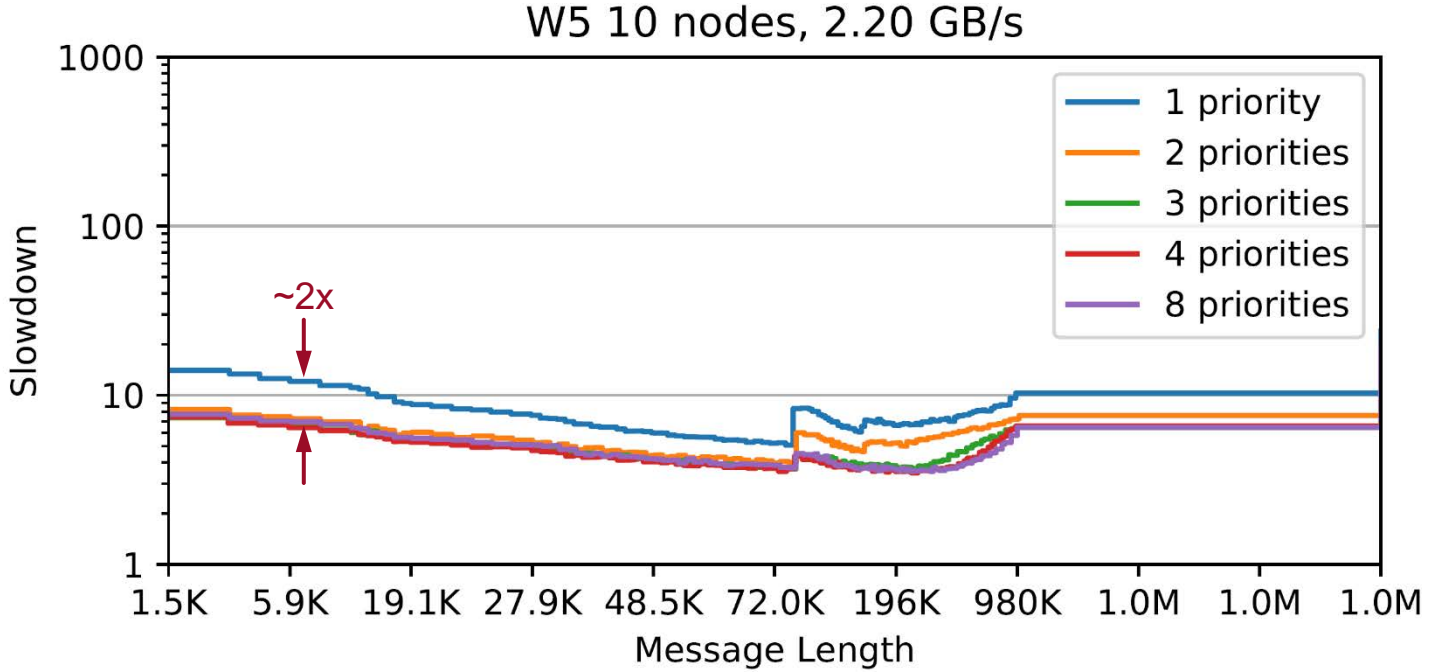


Small Message Latency





A Few Priority Levels is Enough



- **Homa P99 still better than TCP P50 even with only 1 priority level**
- **Short-message workloads don’t need priorities (software limited)**

Next Steps: Industrial Trial

- **Looking for company interested in testing Homa internally**
  - How does Homa compare to your current state of the art?
  - Do real applications see benefits?
- **Prefer to be personally involved**
  - Help with integration
  - Run tests
  - Fix bugs and performance issues

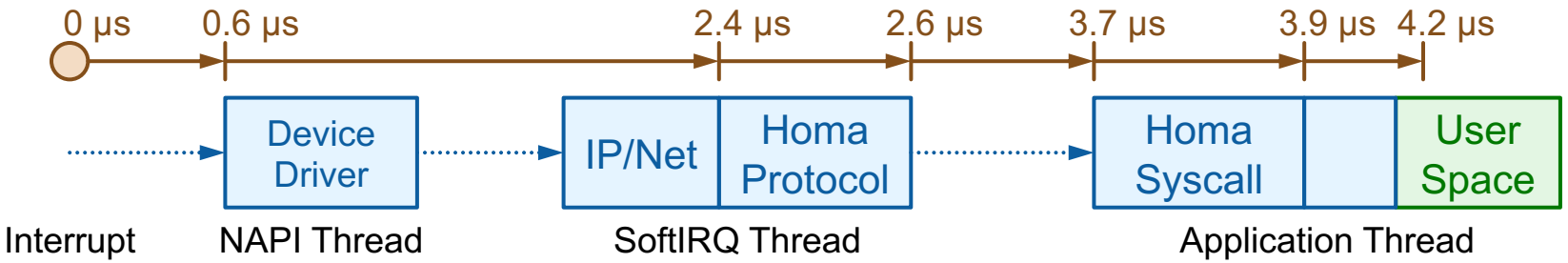
Challenges

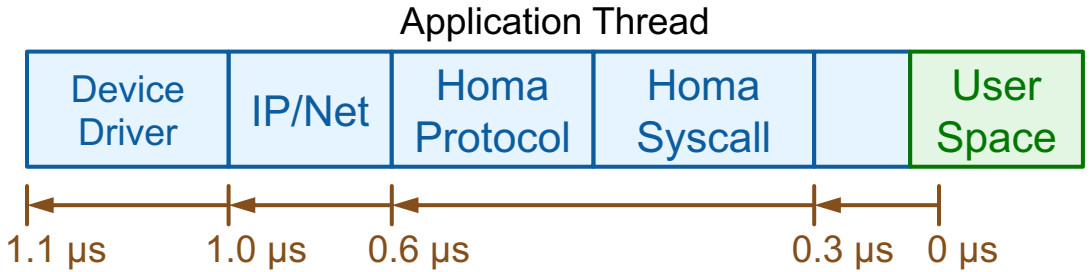
- **Very difficult to implement a high-performance transport protocol in software**
  - Networks getting faster
  - CPUs not getting faster
  - Even harder in an OS like Linux (many layers)
- **Latency**
- **RPC throughput**
- **Utilizing fast networks**
  - Load balancing
  - Packet aggregation

Latency

- **Unloaded latency too high:**
  - TCP: 21 µs
  - Homa: 18 µs
  - Snap: 10 µs
  - RAMCloud: 4.7 µs
- **P99 slowdown also too high:**
  - Homa: 10x
  - RAMCloud: 2-3x
  - Simulations: 2-3x
- **No OS implementation can get close to hardware potential (3 – 3.5 µs)**

Latency (100B Messages)





	Total	Homa
Receive	4.2 µs	0.4 µs
Send	1.1 µs	0.3 µs

Throughput

- **High software overheads:**
  - Handling short RPCs on server side:
    - Homa: 4 cores/ 1M RPCs/
    - RAMCloud: 1 core/ 1M RPCs/sec
    - MICA: 0.2 core/ 1M RPCs/sec
  - Utilizing network bandwidth with large messages:
    - Homa: 0.12 core/Gbps (24 cores for 100 Gbps)
    - Snap: 0.06 – 0.09 core/Gbps (12-18 cores for 100 Gbps) (but only with 5000B MTU)
- **Must balance load across many cores**
  - Hard to do well
- **Must aggregate packets for stack traversal**
  - Linux: GSO, GRO
  - Complex mechanism (Homa impersonates TCP packets)
  - Increases receive latency

Throughput

- **High overheads for short messages; server-side:**
  - Homa: 0.25 M RPCs/sec/core
  - RAMCloud: 1 M RPCs/sec/core
  - MICA: 5 M RPCs/sec/core
- **Expensive to utilize full network bandwidth**
  - Homa: 0.12 core/Gbps (24 cores for 100 Gbps)
  - Snap: 0.06 – 0.09 core/Gbps (12-18 cores for 100 Gbps) (but only with 5000B MTU)
- **Must balance load across many cores**
  - Hard to do well
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Conclusion

- **Homa >> TCP**
- **Software protocol implementations are on their last legs**
  - Impractical beyond 25 Gbps
- **Need to move transport protocols to the NIC (needs new NIC architecture)**
- **Homa is ready for testing in industry; interested?**