An Implementation of the Homa Transport Protocol in RAMCloud

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PLATFORMLAB

Introduction

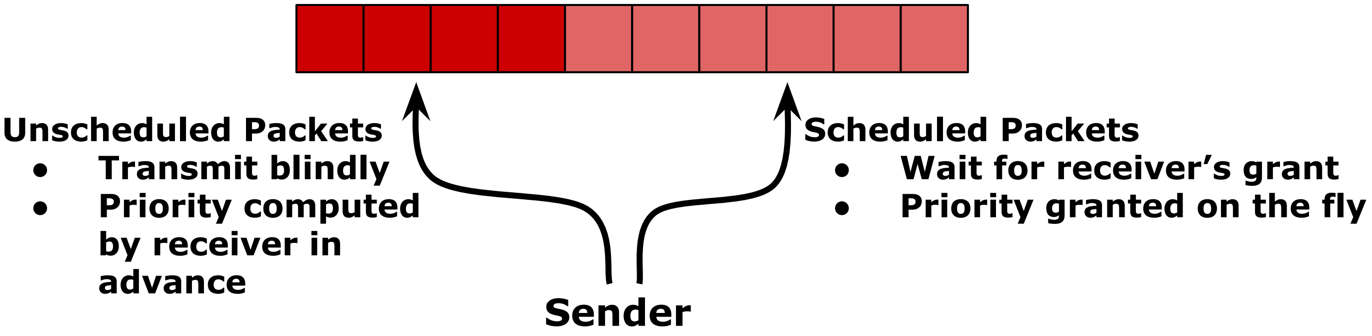
- **Homa: receiver-driven low-latency transport protocol using network priorities**
  - Key ideas and simulation results presented before
- **HomaTransport in RAMCloud: a working implementation**
  - Unusual features: message-oriented, connectionless, no ACKs, etc.
- **Excellent performance**
  - Extreme network condition: **80%** network load on 10 Gbps network
  - Slowdown of 99%-tile latency of almost all message sizes within **2-3.5x**
  - 99%-tile round-trip latencies for small messages < **15** μs
  - Nearly **100x** faster than best published result

Outline

- Homa Overview
- Implementation Features
- Evaluation

Homa Overview

- **Goal: low latency at high network load**
  - Focus on tail (e.g., 99th percentile) message latency
  - Implement shortest-remaining-processing-time (SRPT) policy
- **Key Idea 1: Divide outgoing messages into unscheduled and scheduled portions**



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- **Key Idea 2: Dynamic priority allocation**
  - Receiver can change the priorities granted to incoming messages on the fly
  - … based on the exact set of incoming messages

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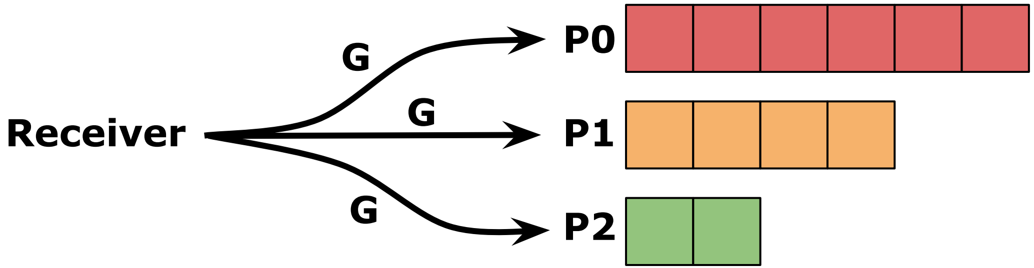
- **Key Idea 3: Controlled overcommitment**
  - Receiver grants to a smaller number of senders simultaneously
  - … to avoid wasting downlink bandwidth
  - … when our most favored sender doesn't send back granted data in time



Implementation in RAMCloud

- **RAMCloud: low-latency key-value store**
  - Modular transport architecture
  - Optimized software stack: 1~2 μs to send/receive an RPC
- **RAMCloud::HomaTransport**
  - Kernel bypass via DPDK
  - Use polling to detect incoming packets
  - ~ 4000 lines of C++ code (including comments)

Homa: Structurally Different From TCP

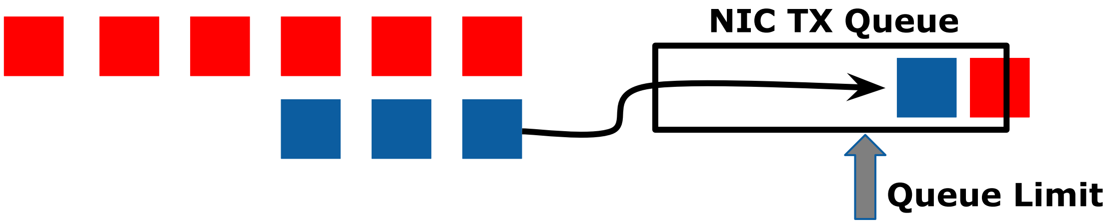
- **Message-oriented, not stream-oriented**
  - Independent delivery of messages: no head-of-line-blocking
  - RPC interface
    - Natural fit for datacenter applications
    - Socket-like byte stream interface on top of Homa
- **Connectionless**
  - No setup phase required before sending an RPC
  - No state kept after RPC completes

Retransmission

- **No explicit ACKs**
  - RPC response as the acknowledgment for the request
  - Optimize for small RPCs: reduce half of the packets required
    - The simplest RPC requires only 1 `DATA` packet in each direction
- **Receiver-driven approach to detect lost packets**
  - Receiver timeouts on messages that have been silent for a long period
    - … and request retransmission for the missing bytes
  - What if all unscheduled packets of a request are lost?
    - Client eventually timeouts on the response message
    - … and request retransmission of the initial bytes of the response
    - Server doesn’t recognize this RPC, assumes that the request must be lost
    - … and request retransmission of the initial bytes of the request

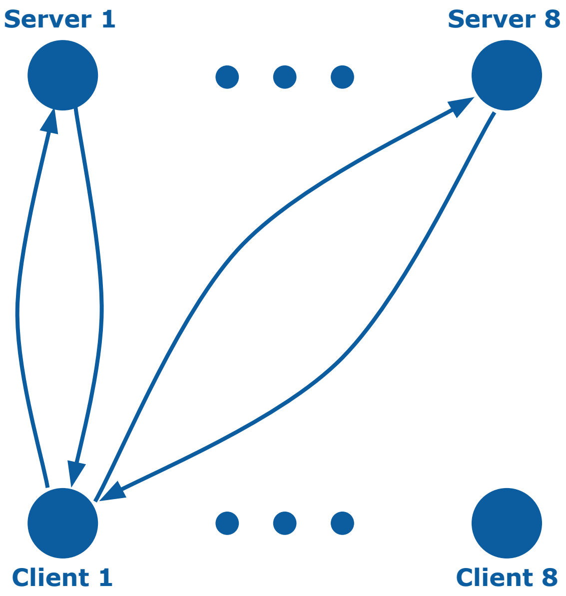
Sender-Side Queue Limiting

- **Sender implements SRPT by default**
  - Need to preempt long messages for short ones
  - Keep the transmit queue in NIC short to avoid queueing delay
- **QueueEstimator**
  - Keep a running estimate of the transmit queue length
- **Limiting queue length**
  - Too large: increase queueing delay for short messages
  - Too small: risk of TX queue running dry
  - Enqueue a packet only if `queueLength` ≤ one full-size packet



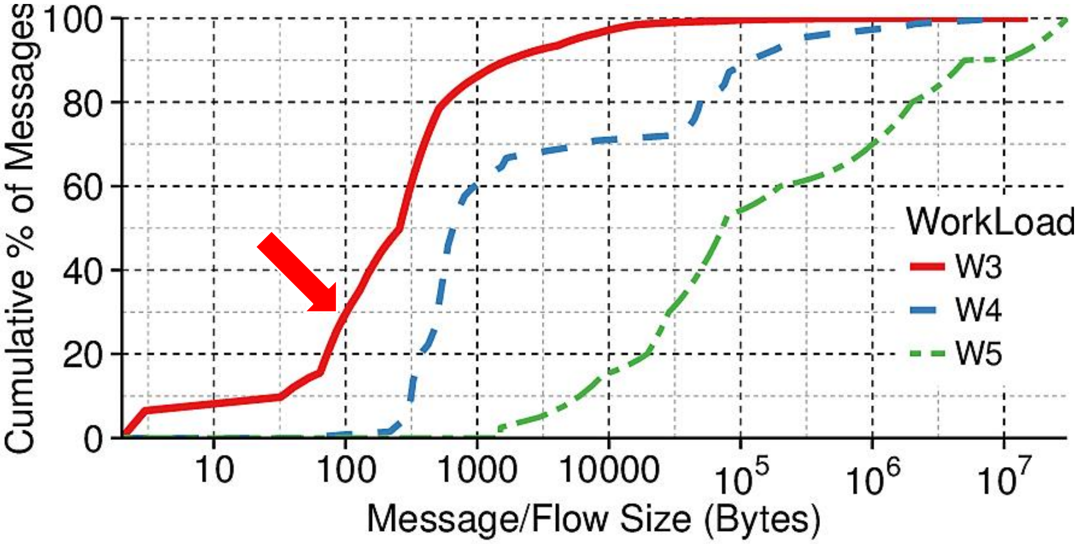
Evaluation Experiment

- **8 clients and 8 servers**
- **Each client generates a series of echo RPCs to random servers**
  - Client sends a message of a given size
  - Server replies with the same message
- **RPC message size chosen randomly to match the given workload**
- **RPC inter-arrival times follow poisson distribution**
  - Average inter-arrival time configured to generate a given network load



Workloads

- **Workload: distribution of message sizes**
  - W3: aggregated RPC workload from Google datacenter applications
  - W4: Facebook Hadoop workload
  - W5: web search workload used for DCTCP



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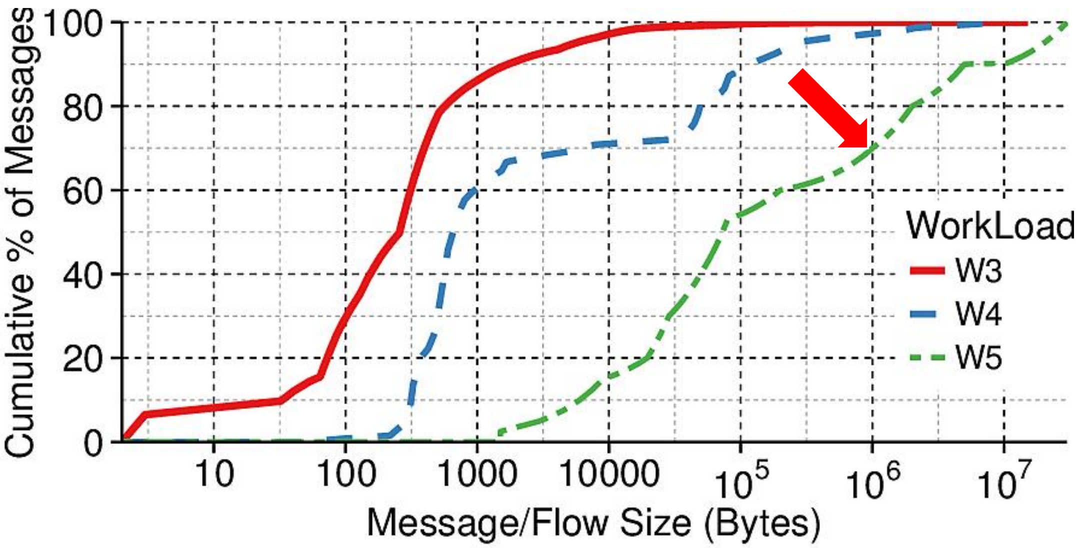
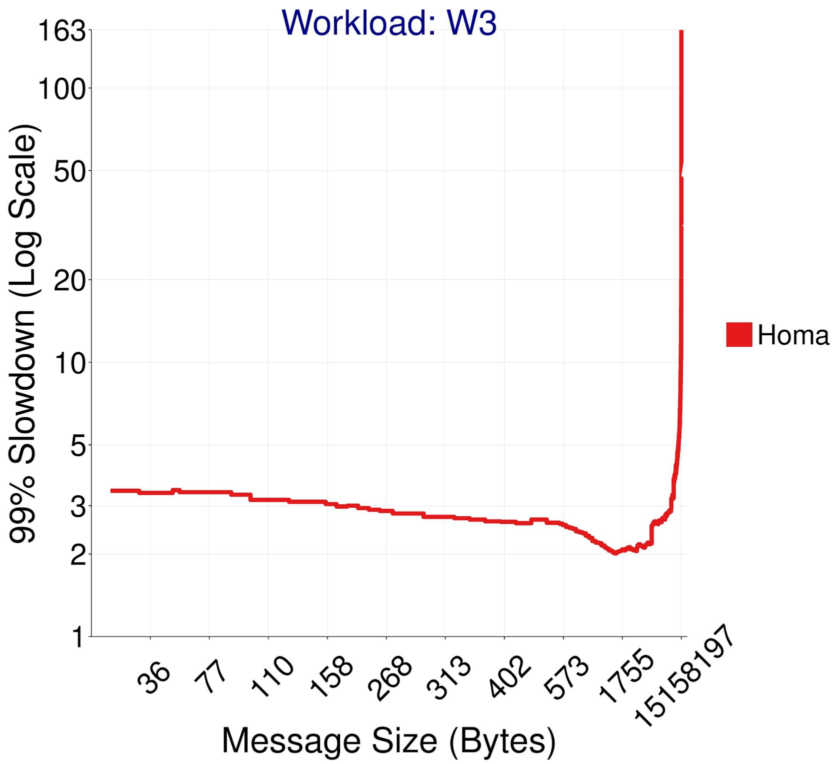


Configuration

- **Hardware configurations**
    - CloudLab m510 cluster: 8-Core Xeon D1548 @ 2.0 GHz, 10 Gbps network
    - Local Infiniband cluster: 4-Core Xeon X3470 @ 2.93 GHz, 24 Gbps network
    - All nodes in a cluster are connected to a single switch

Understanding The Graph

Measurements are taken on 10 Gbps network at 80% network load unless stated otherwise.



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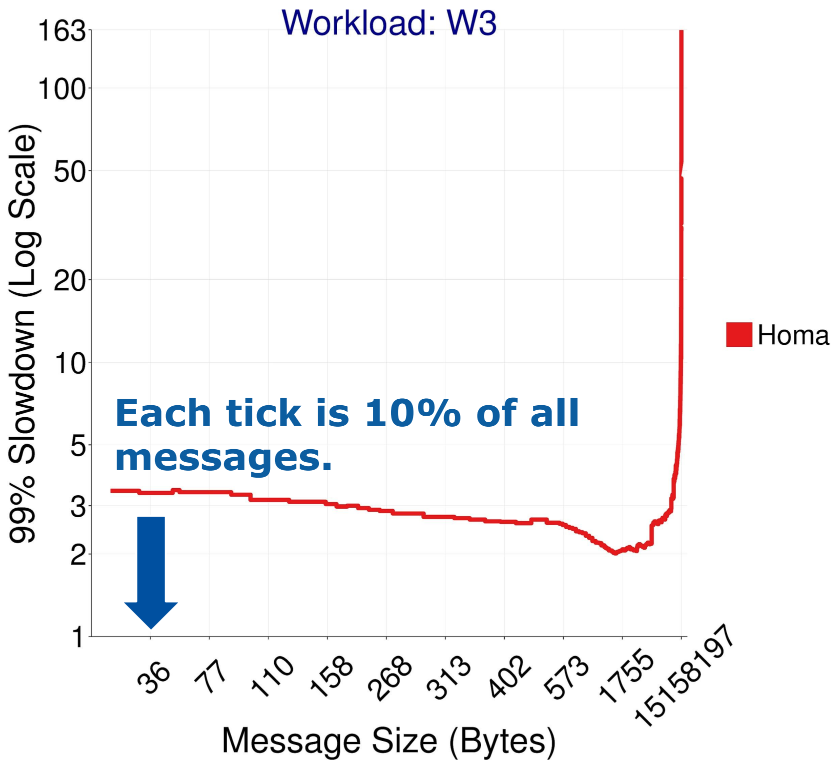

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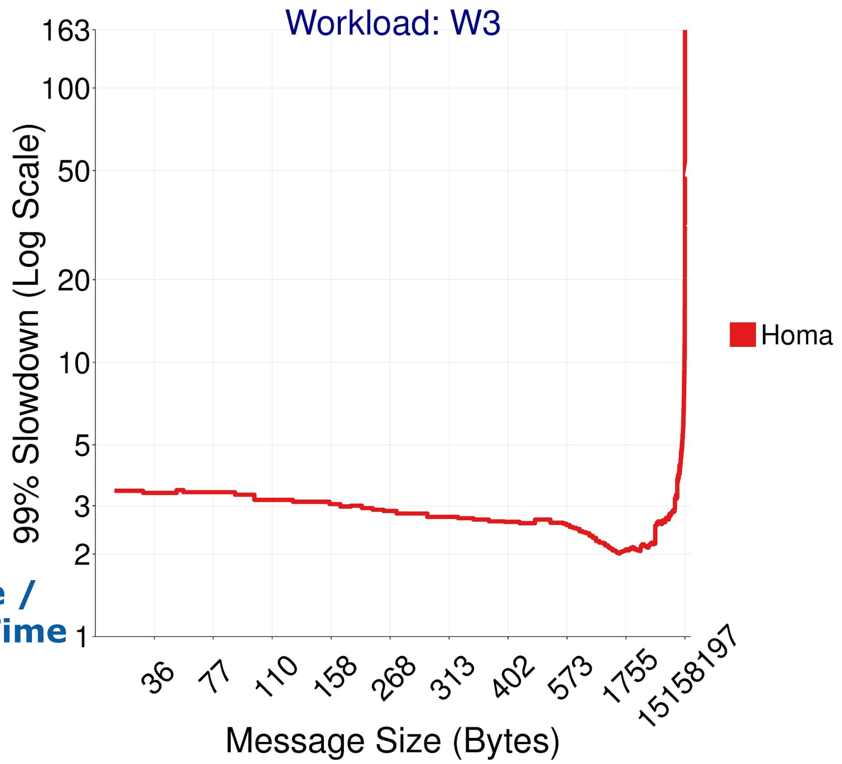
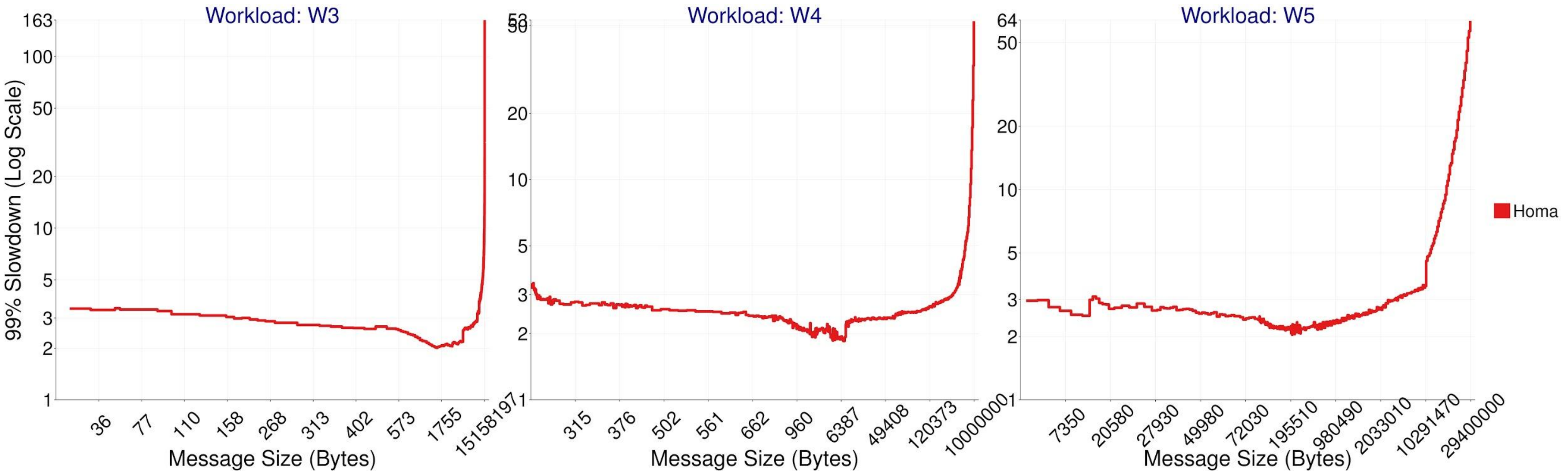


Slowdown =
Actual RPC Completion Time /
Best-case RPC Completion Time
(On Unloaded Network)

Homa Absolute Performance



Best-case RPC time

- 100 bytes: 4.7 µs
- 1000 bytes: 8.8 µs

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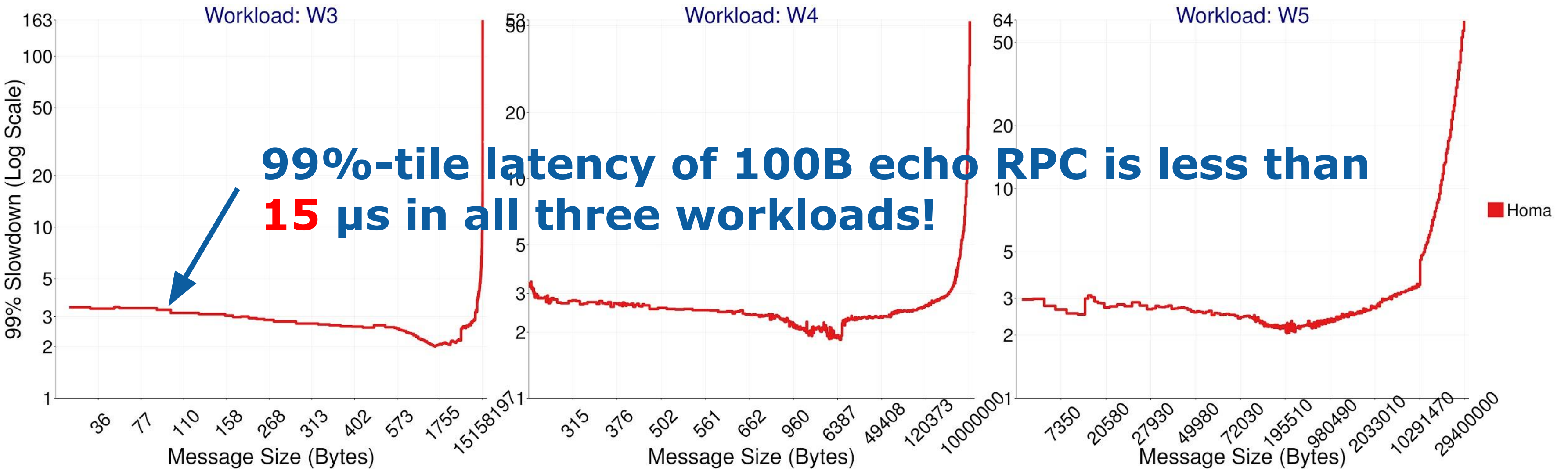

99%-tile latency of 100B echo RPC is less than 15 µs in all three workloads!

Best-case RPC time

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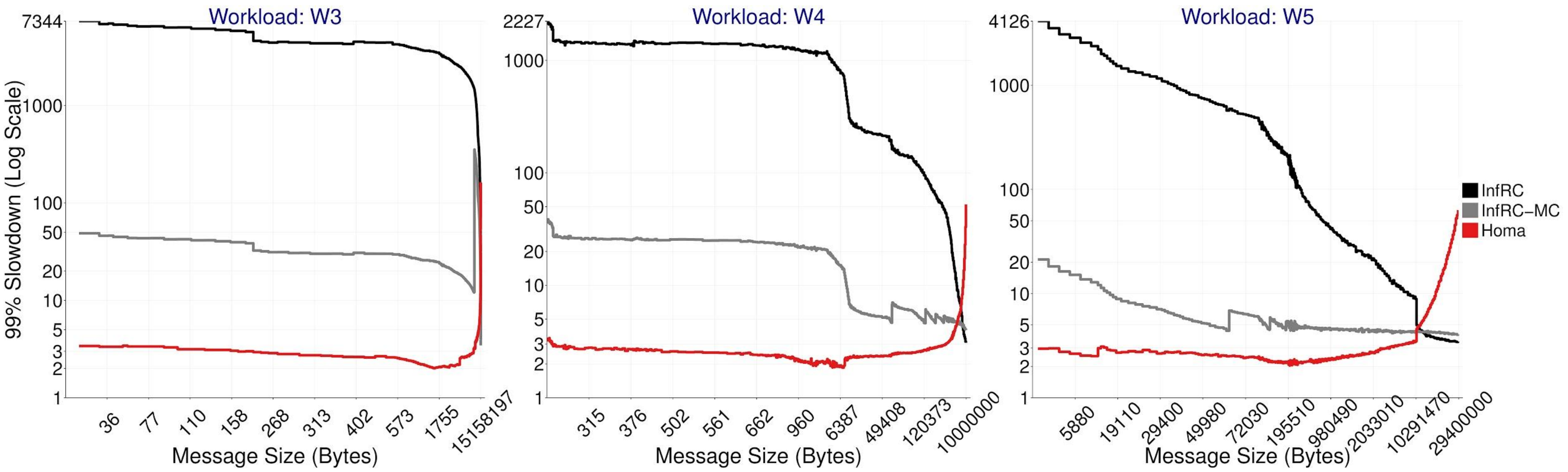
HOL Blocking = 100x Tail Latency



Note: InfRC measurements are taken on a 24 Gbps Infiniband network using the absolute same workload, so the actual network load is only 33%.

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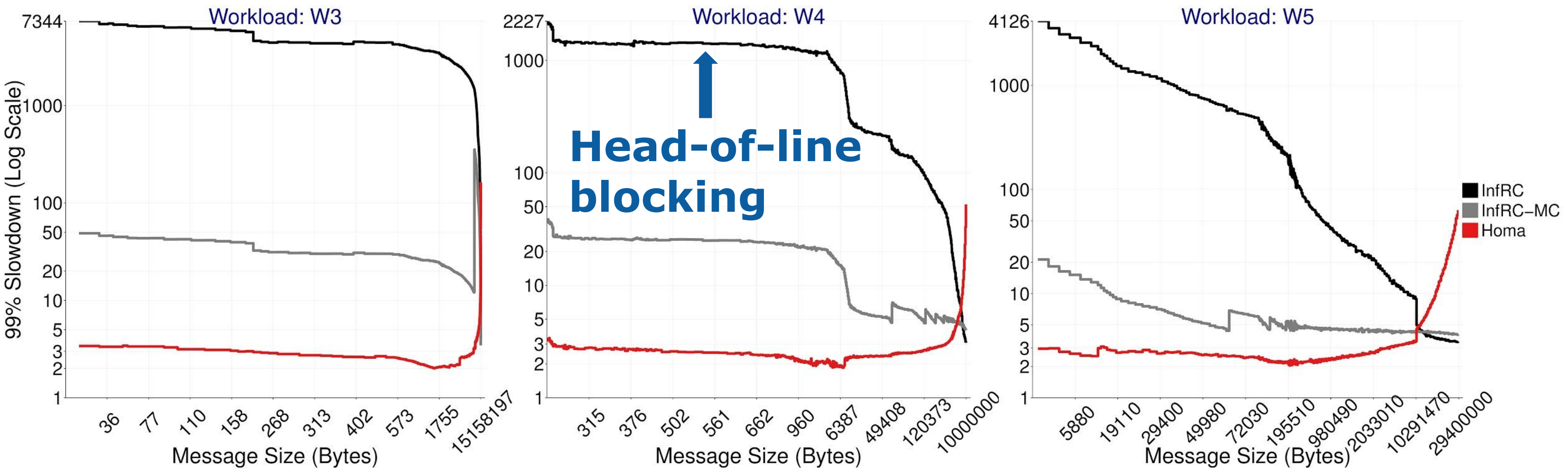

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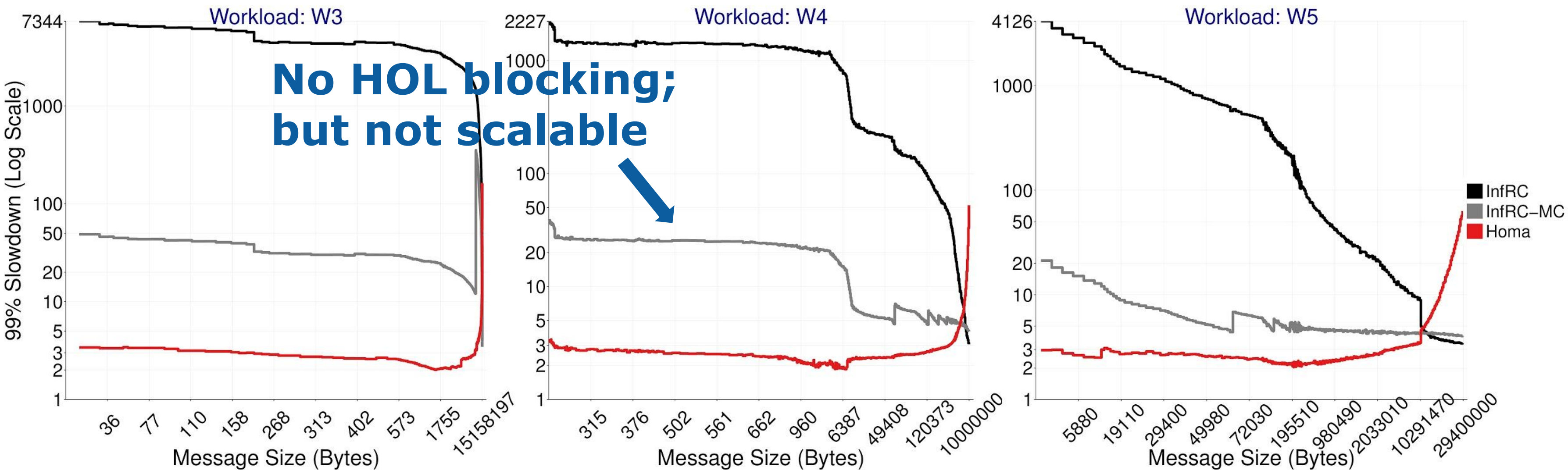
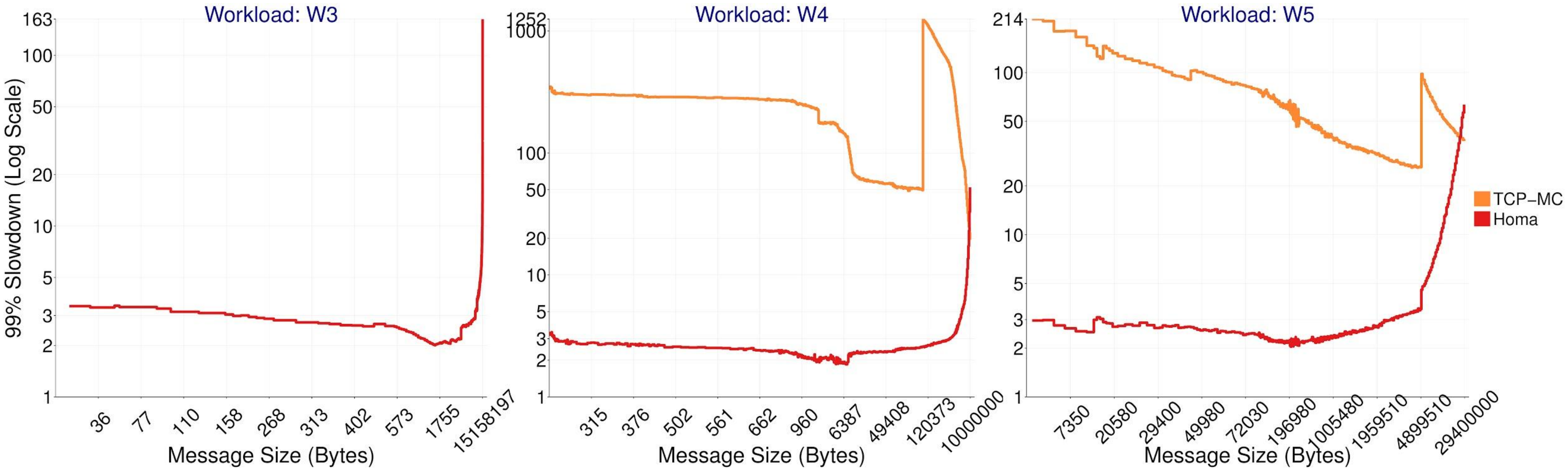


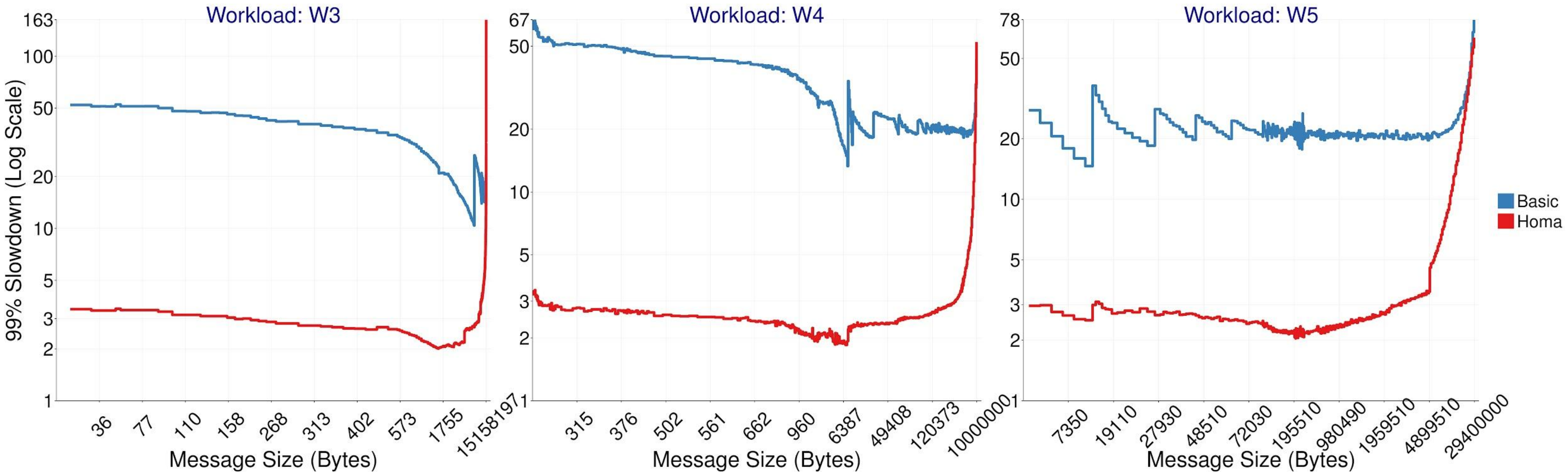
Homa vs. TCP



Workload: W3
Workload: W4
Workload: W5
99% Slowdown (Log Scale)
Message Size (Bytes)
Message Size (Bytes)
Message Size (Bytes)
TCP−MC
Homa

Priority & Controlled Overcommitment

Basic vs. Homa: 5 - 15x higher tail latency for most RPCs



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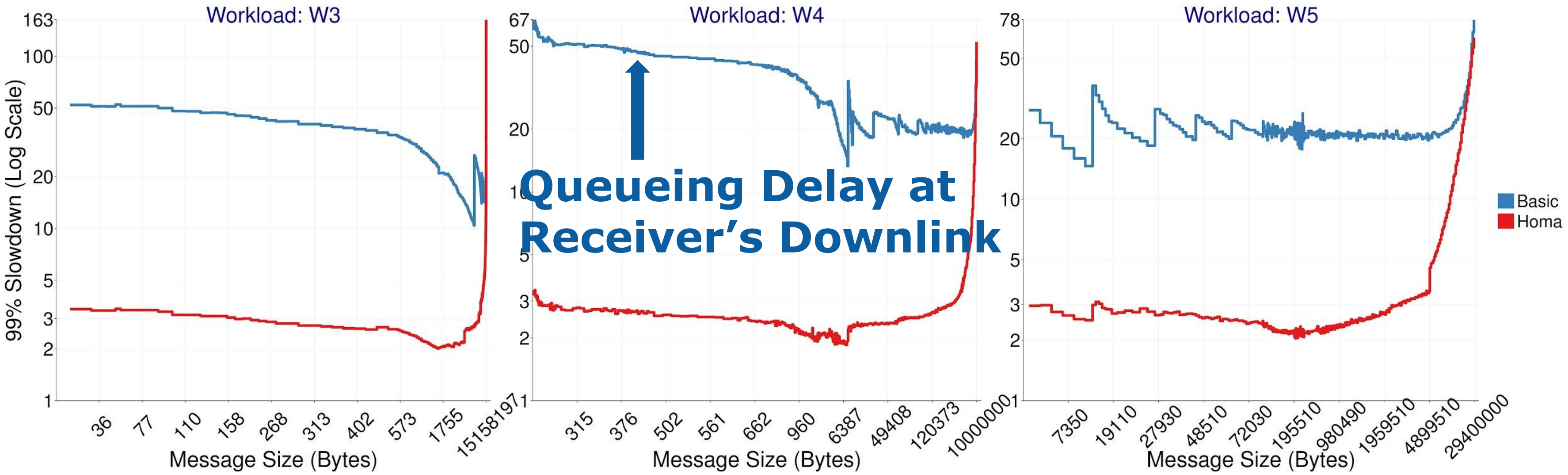

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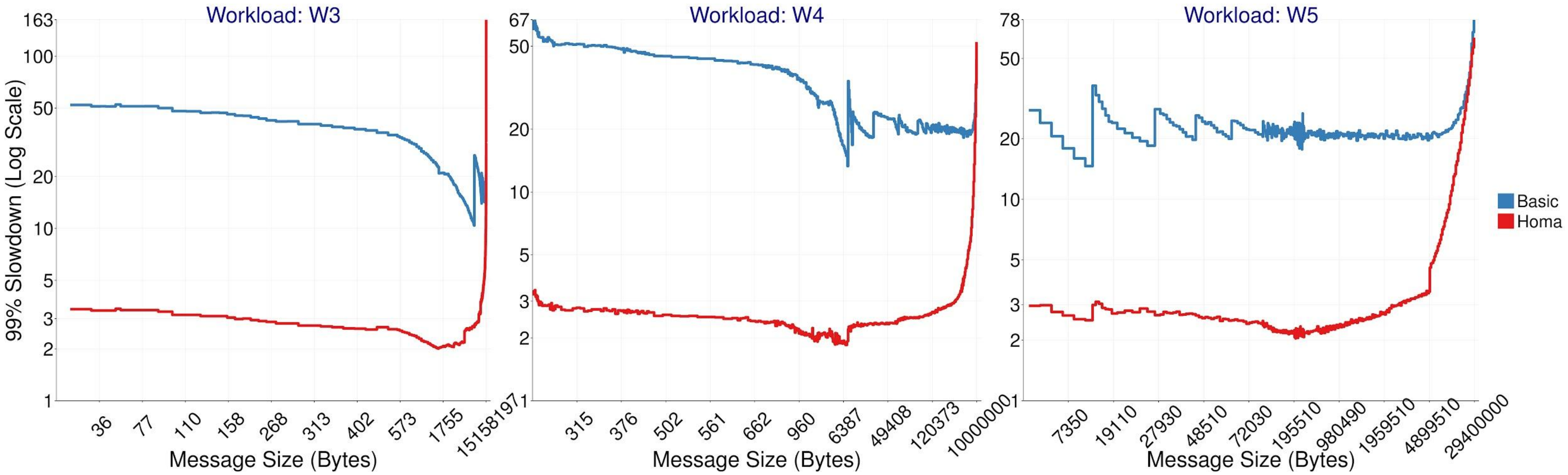
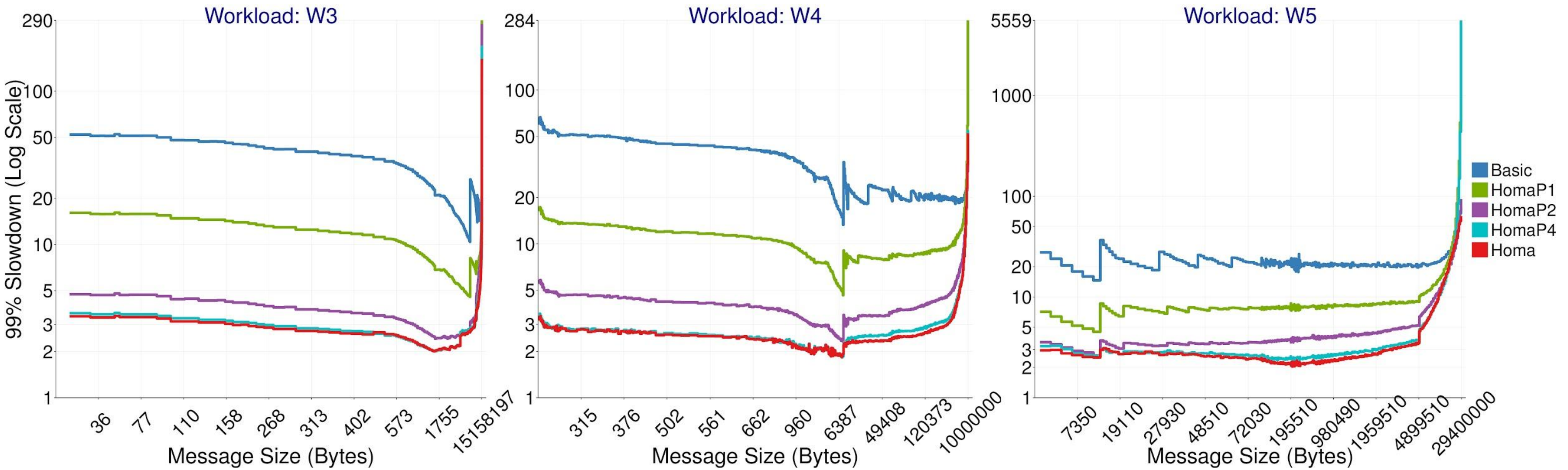


SRPT tends to produce run-to-completion behavior

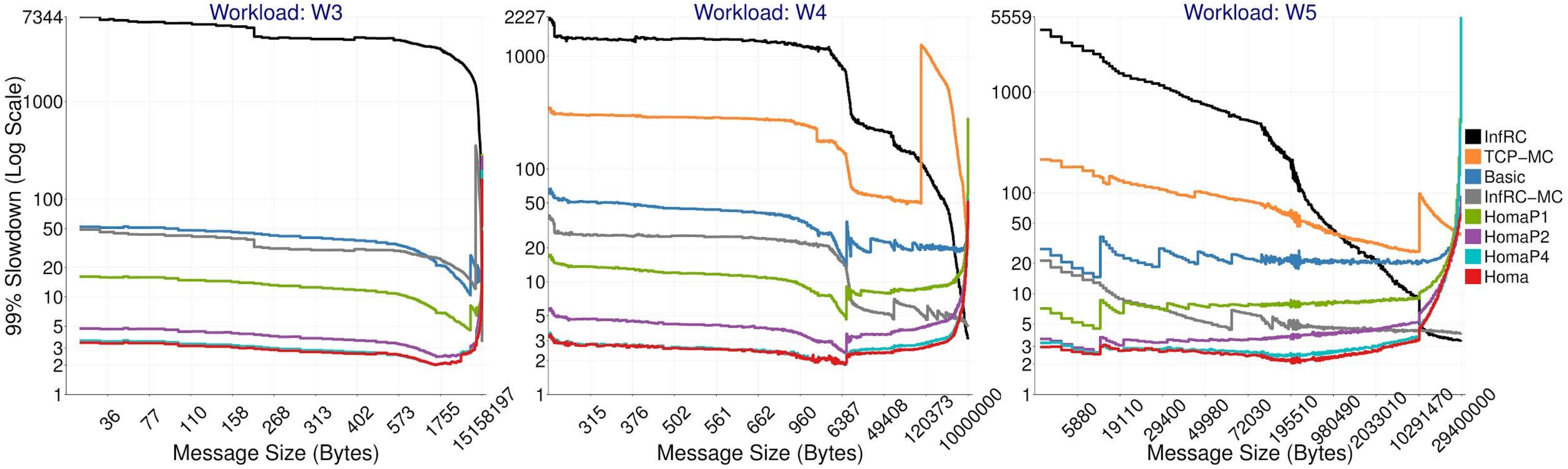
How Many Priorities Does Homa Need?



4 priority levels is almost as good as 8.

Results Overview

- **Homa vs. Other RAMCloud transports at 80% load (except InfRC)**



Conclusion

- **We designed and implemented Homa, a new transport protocol for datacenter networks**
  - Provide very low latency for short messages
  - Support high network utilization

- **Our Homa implementation has several unusual features**
  - Message-oriented, connectionless, no explicit ACKs, etc.

- **Implementation measurements show excellent performance numbers across various workloads**

Questions?