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Write-Optimized and Consistent RDMA-based Non-Volatile Main Memory Systems

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Background

- Non-Volatile Main Memory (NVMM)
  - Non-volatility, byte-addressability, high density and DRAM-scale latency.

- Remote Direct Memory Access (RDMA)
  - Allow to directly access remote memory via bypassing kernel and zero memory copy.
    - Two-sided RDMA operations (send and recv):
    - One-sided RDMA operations (read, write and atomic):
      - Provide higher bandwidth/lower latency than two-sided one.
      - Do not involve remote CPU.

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NVMM can be directly accessed through the RDMA network.

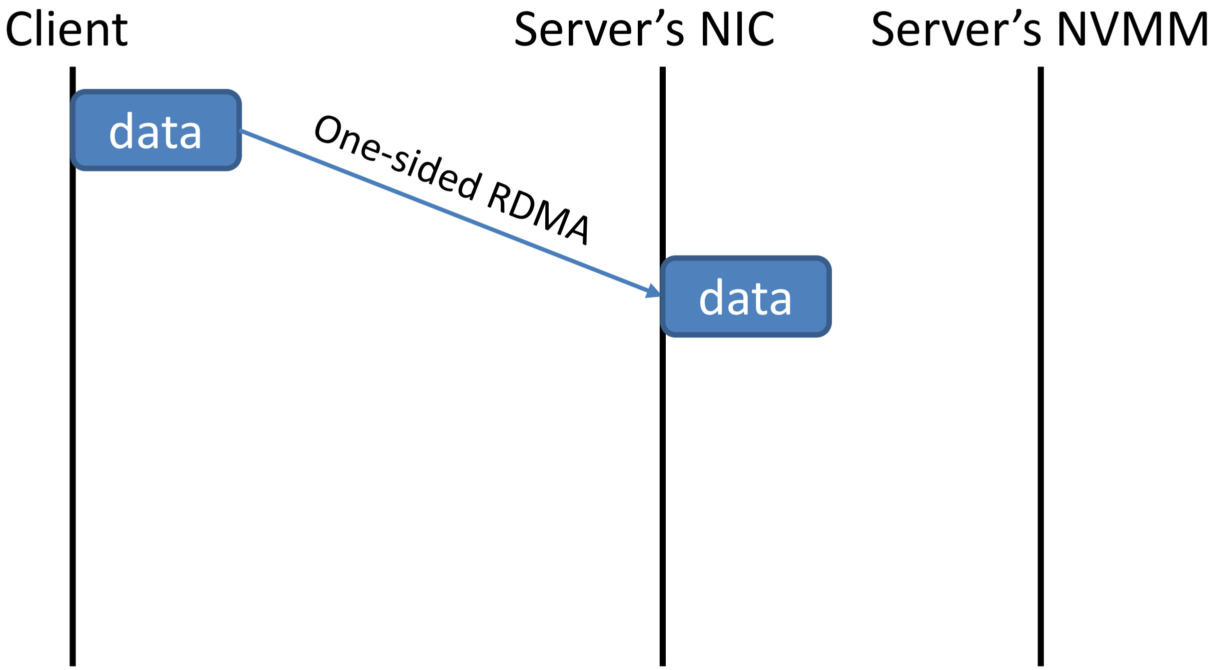
⇩

RDMA-based NVMM systems become an important research topic.

Challenges

➢ RDMA NICs fail to guarantee persistence with NVMM.

➢ Using one-sided RDMA to access remote NVMM needs to address the challenges of guaranteeing Remote Data Atomicity (RDA):



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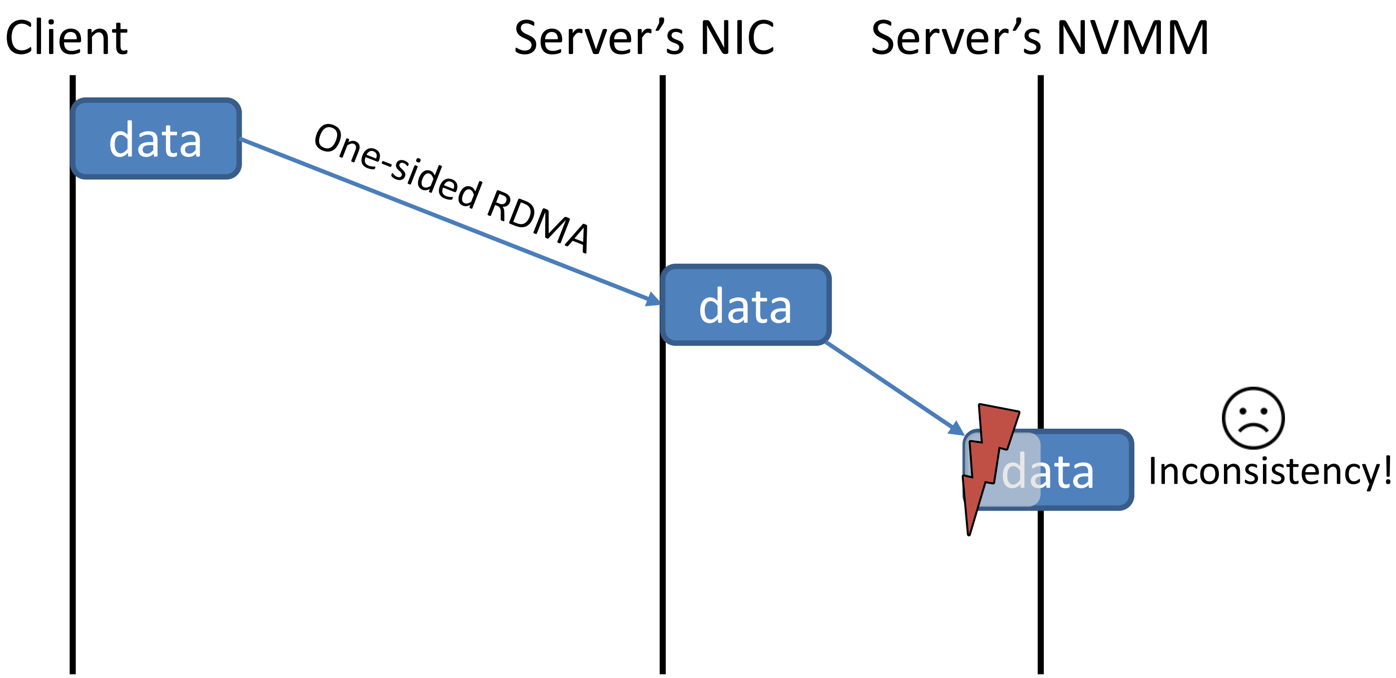

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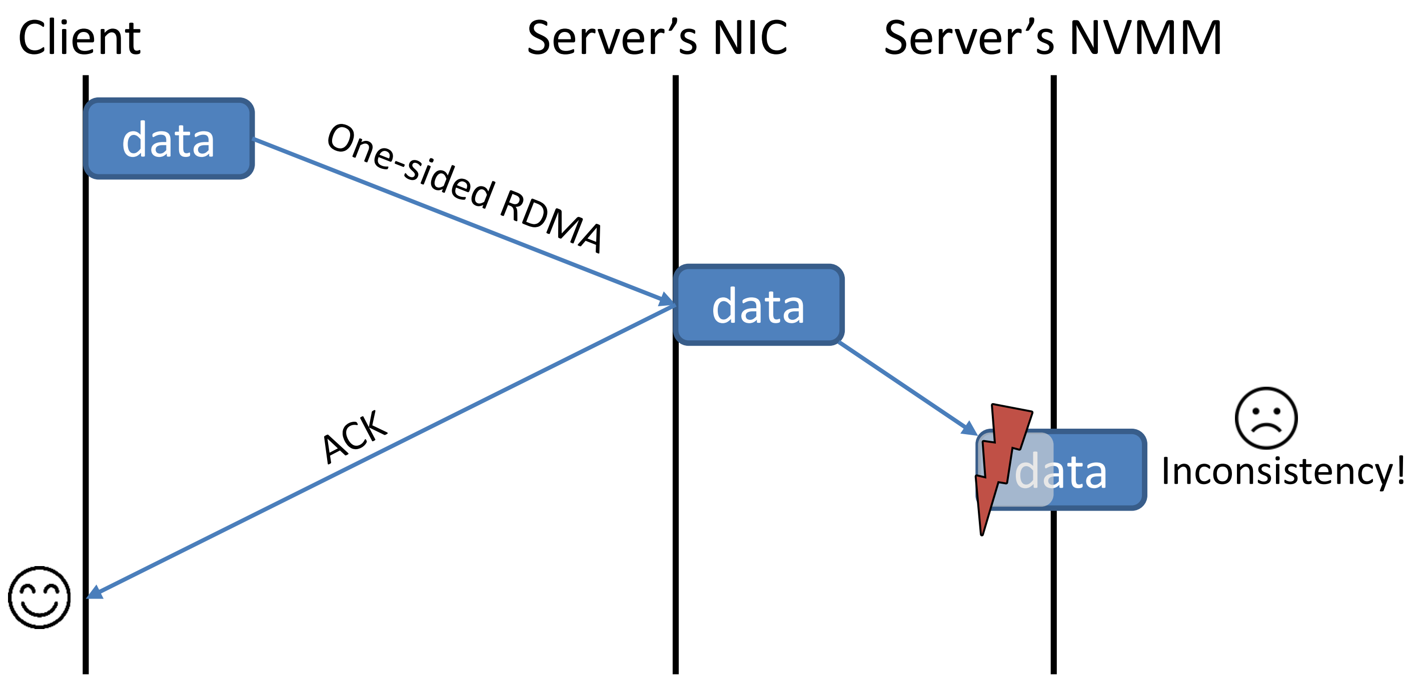

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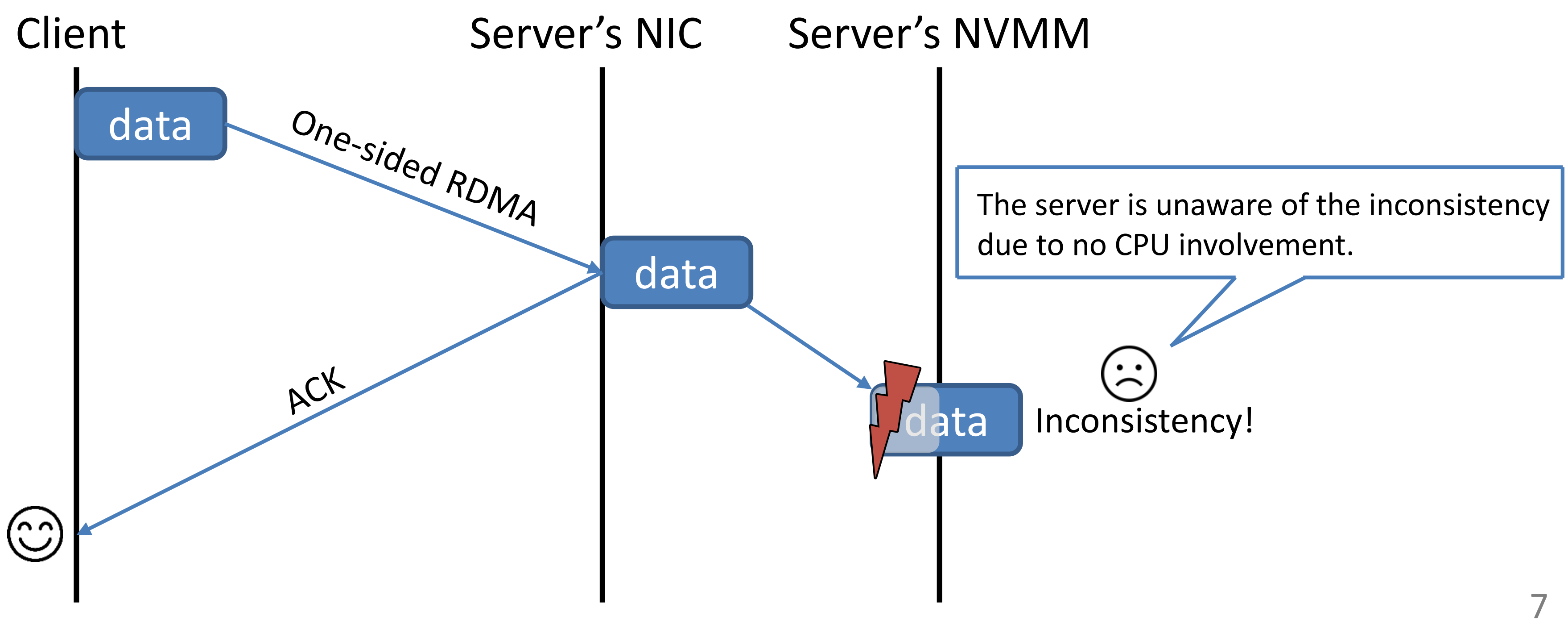
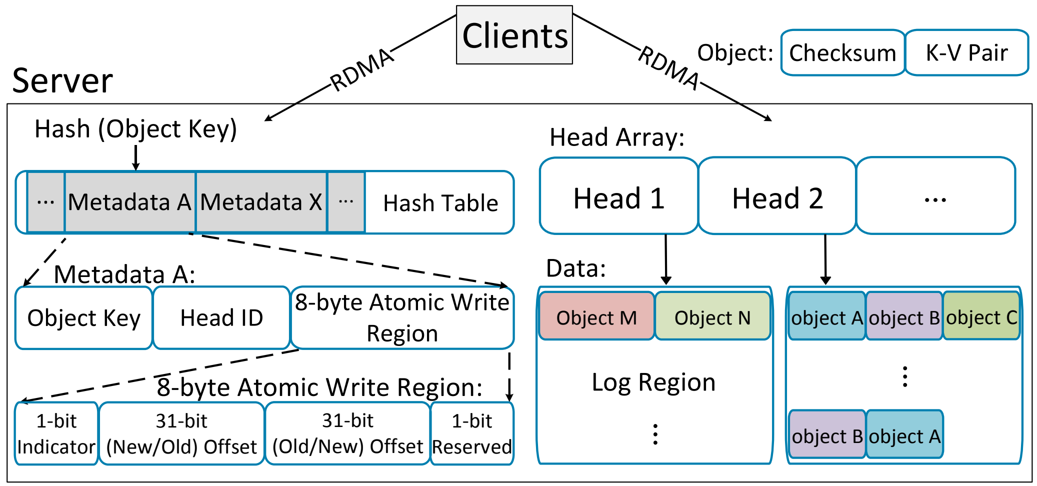


Existing Solutions

Inefficiency due to:

- **High Network Overheads**
  - ✓ Leverage an extra RDMA read after RDMA write(s)
- **High CPU Consumption**
  - ✓ Logging and COW require the remote CPU to control the sequence among operations.
- **Double NVMM Writes**
  - ✓ Consuming the limited NVMM endurance due to first checking the written data in buffers, and then applying them into the destination addresses.

System Design of Erda



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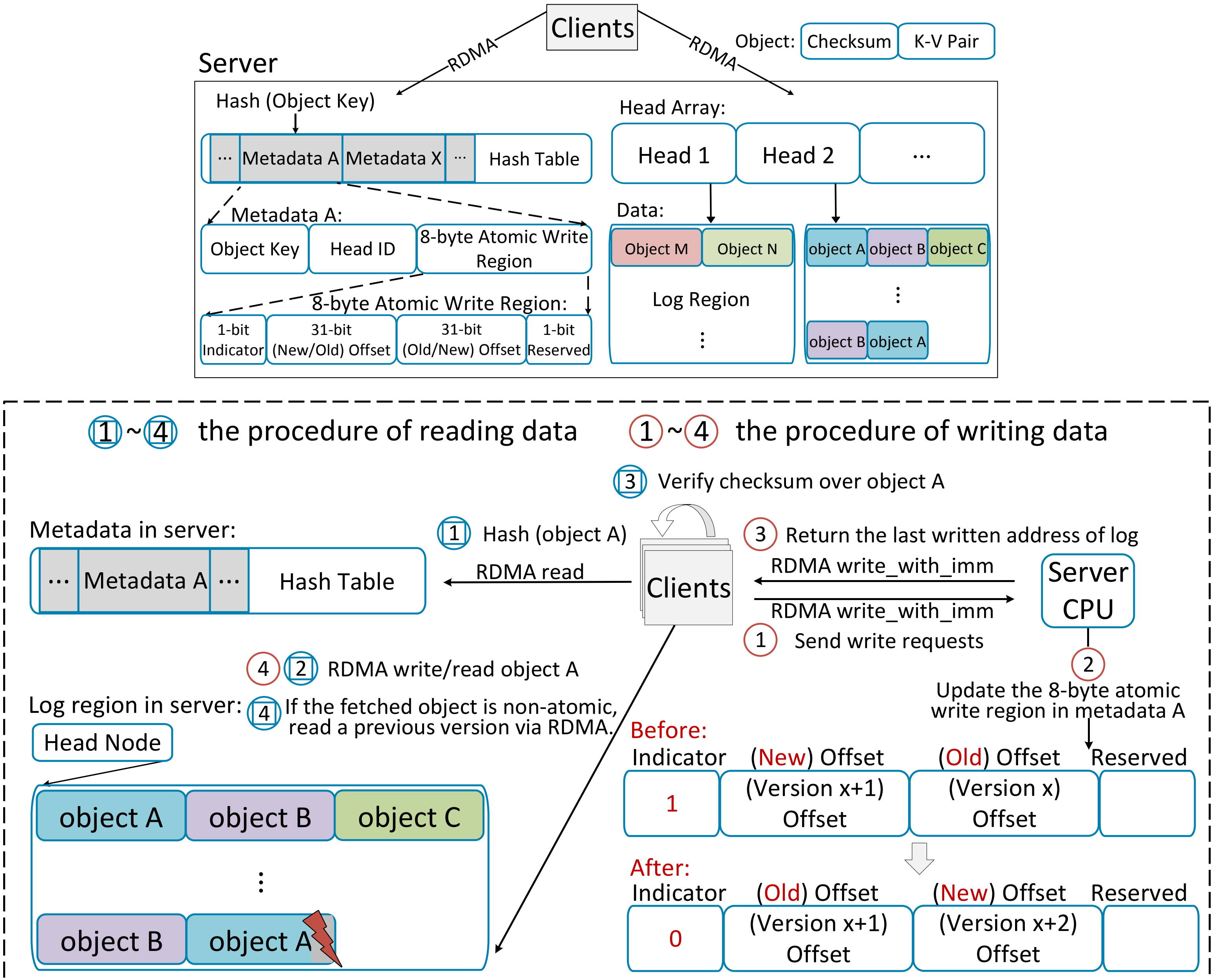
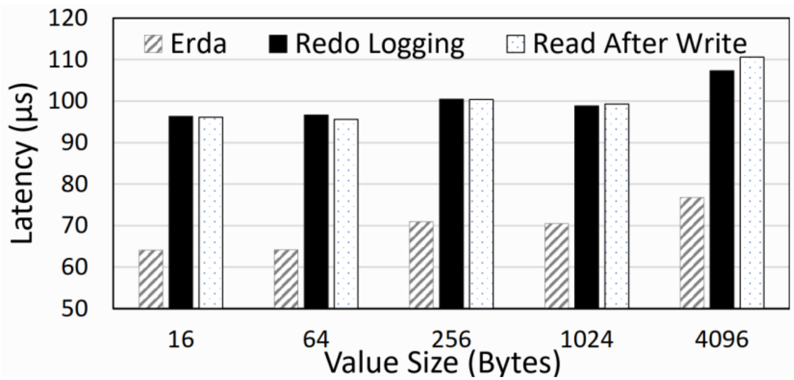
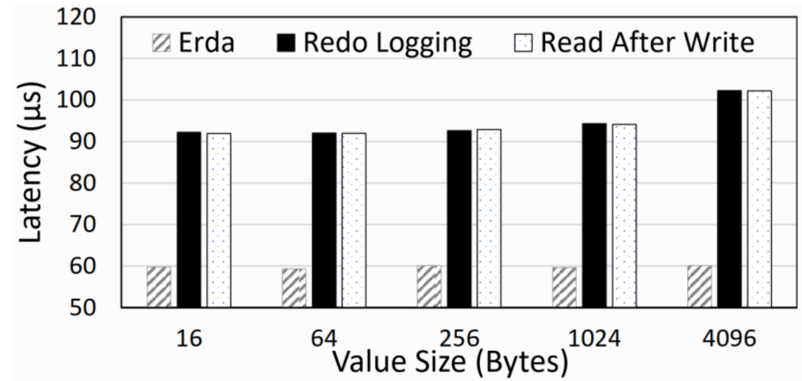


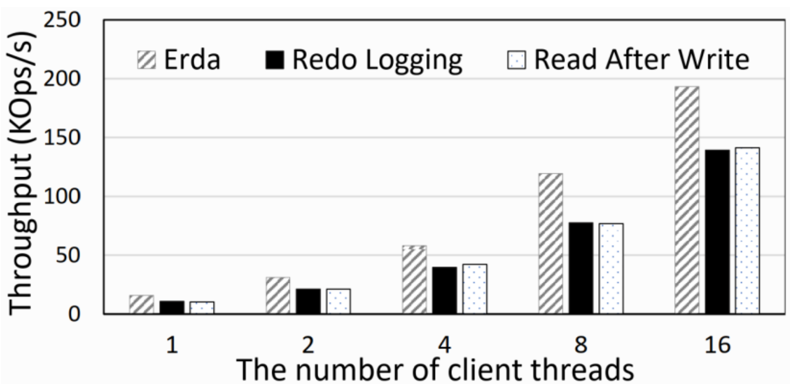
Evaluation



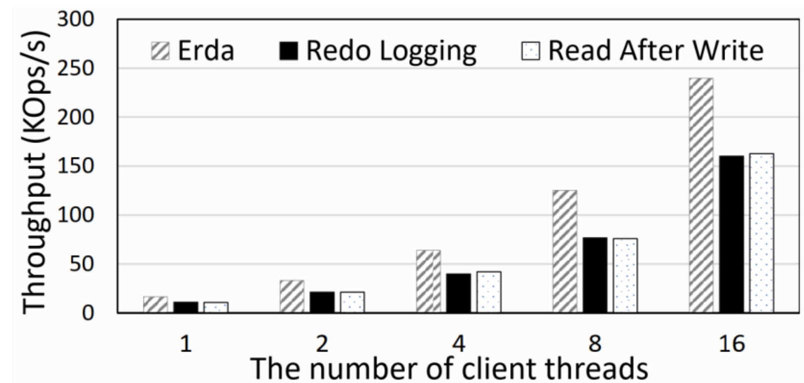
The latency of the update-heavy workload.



The latency of the read-mostly workload.



The throughput of the update-heavy workload.



The throughput of the read-mostly workload.

- The number of written bytes. ***N*** is the size of one KV pair. ***Size(key)*** is the key

	Create	Update	Delete
Erda	Size(key)+9+N	8+N	Size(key)+9
Redo Logging	Size(key)+12+2N	4+2N	Size(key)+8
Read After Write	Size(key)+12+2N	4+2N	Size(key)+8

Conclusion

- **Challenges of guaranteeing Remote Data Atomicity (RDA):**
  - ✓ High Network Overheads
  - ✓ High CPU Consumption
  - ✓ Double NVMM Writes

- **Erda:**
  - ✓ A write-optimized log-structured NVMM design for Efficient Remote Data Atomicity.
  - ✓ Leverage Out-of-Place Updates & CRC Checksum & 8-Byte Atomic Write.

- Compared with state-of-the-art schemes, **Erda reduces NVMM writes** by 50%, significantly **improves throughput** and **decreases latency.**

Thanks! Q&A