



## Overview

### Current Trends in Big Data

- Huge increase in cloud deployments running Big Data analytics
- Analytics performed on data stored in cloud storage
- System and job sizes constantly increasing
- High-performance solutions for Big Data in the cloud essential

### Importance of Big Data in Cloud

- Inherent flexibility and scalability
- Tremendous cost saving
- Built-in reliability and fault-tolerance

### Network Communication Bottlenecks

- Not aware of topology and locality
- Slow TCP-based

### Scalability Issues

- Cloud storage solutions have limited scalability
- Limited number of gateway or proxy servers limits operation throughput

### Consistency Issues

- Cloud storage systems typically provide Eventual Consistency (EC)
- EC is not sufficient for traditional applications expecting POSIX-like consistency

### Proposed Designs

#### High-performance communication<sup>[1]</sup>

- Use of RDMA-based low latency communication
- Use of SR-IOV hardware virtualization with VMs

#### Topology-aware communication<sup>[2]</sup>

- MapReduce-based automatic topology detection
- Locality and topology-aware communication and scheduling

#### High-performance Cloud Storage<sup>[3]</sup>

- RDMA-based communication
- Re-designed scalable architecture with client-based replication

#### POSIX-like consistent Cloud Storage

- Proposed use of atomic operations to provide consistency
- Implemented 2PC for write operations

### Contributions

- Near-native performance (< 9% overhead) for applications in virtualized environments
- Scalable automatic topology detection
- Efficient topology and locality-aware communication
- High-performance and consistent cloud storage
- Ability to run version control, database, and big data applications directly on cloud storage

### Publications

- <sup>[1]</sup> Performance Characterization of Hadoop Workloads on SR-IOV-enabled Virtualized InfiniBand Clusters. (Gugnani et al, BDCAT '16)
- <sup>[2]</sup> Designing Virtualization-aware and Automatic Topology Detection Schemes for Accelerating Hadoop on SR-IOV-enabled Clouds. (Gugnani et al, CloudCom '16)
- <sup>[3]</sup> Swift-X: Accelerating OpenStack Swift with RDMA for Building an Efficient HPC Cloud. (Gugnani et al, CCGrid '17)

### More Information

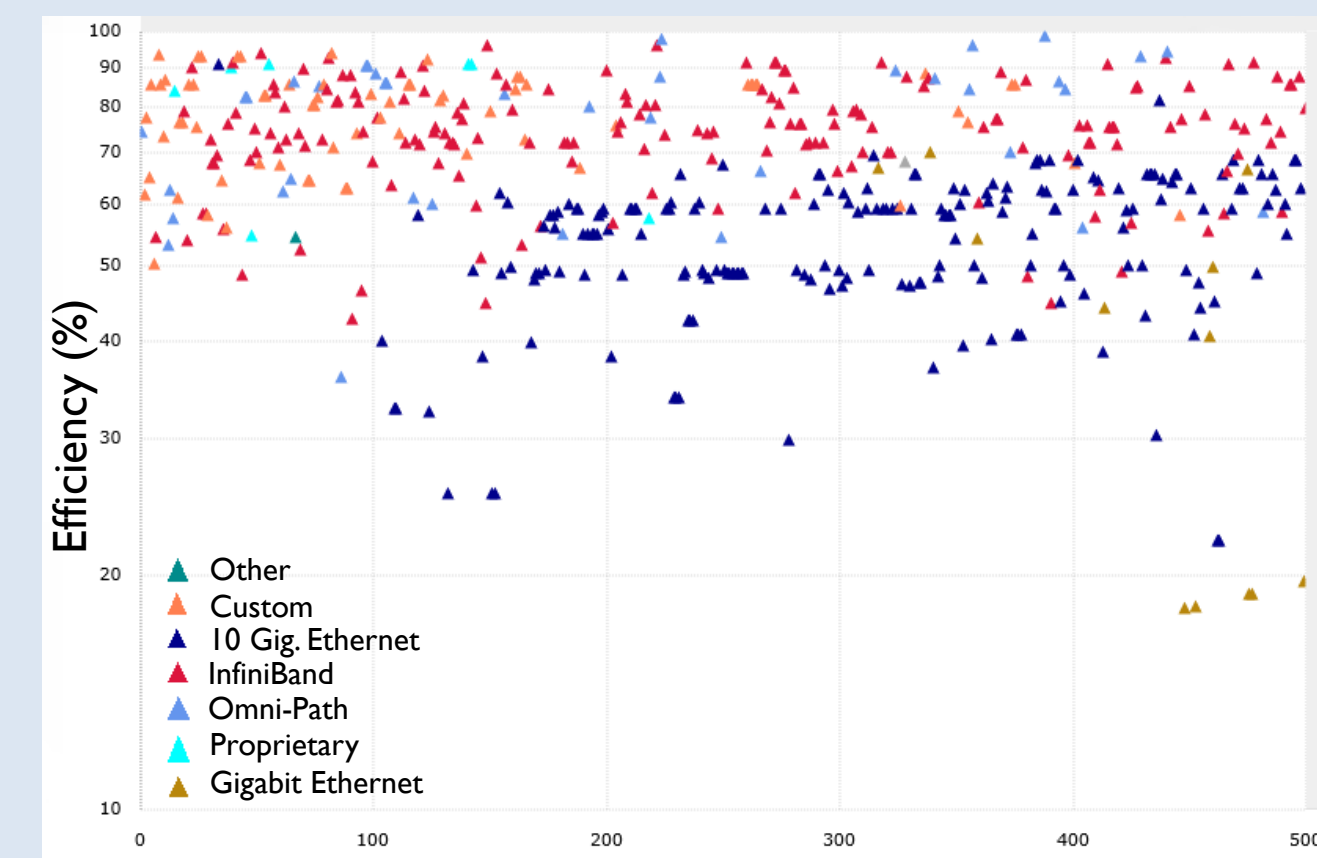
- <http://hibd.cse.ohio-state.edu/>
- Proposed designs will be released soon!



## Challenges

### Slow Network Communication

- TCP-based communication causes bottlenecks
- Each message transfer leads to context switches
- Software-based network virtualization leads to further slowdown



### Inefficient Communication

- For large-sized clusters, topology-aware communication is paramount
- Existing topology-aware designs in Hadoop are not optimized for cloud environments
- No service that can automatically detect cluster topology and expose it to Hadoop

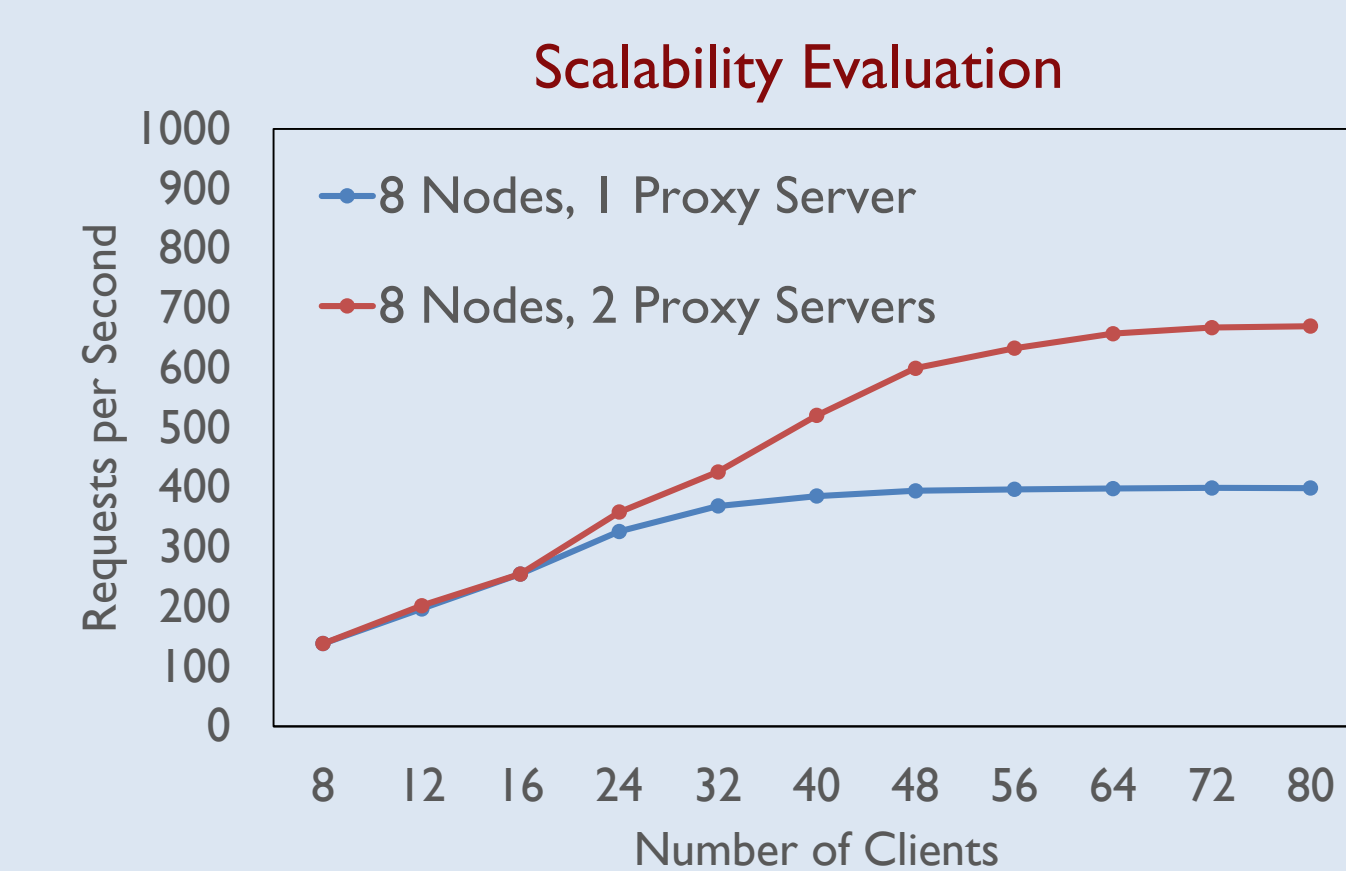
| Process Location | Number of Hops | Latency (us)          |      |
|------------------|----------------|-----------------------|------|
| Intra-Rack       | Inter-Chassis  | 0 Hops in Leaf Switch | 1.57 |
|                  | Intra-Chassis  | 1 Hop in Leaf Switch  | 2.04 |
| Inter-Rack       | -              | 3 Hops in Leaf Switch | 2.45 |
|                  | -              | 5 Hops in Leaf Switch | 2.85 |

Reference: <https://confluence.pegasus.isi.edu/download/attachments/5242944/topology-aware-poster.pdf>

Communication Data from TACC Ranger System

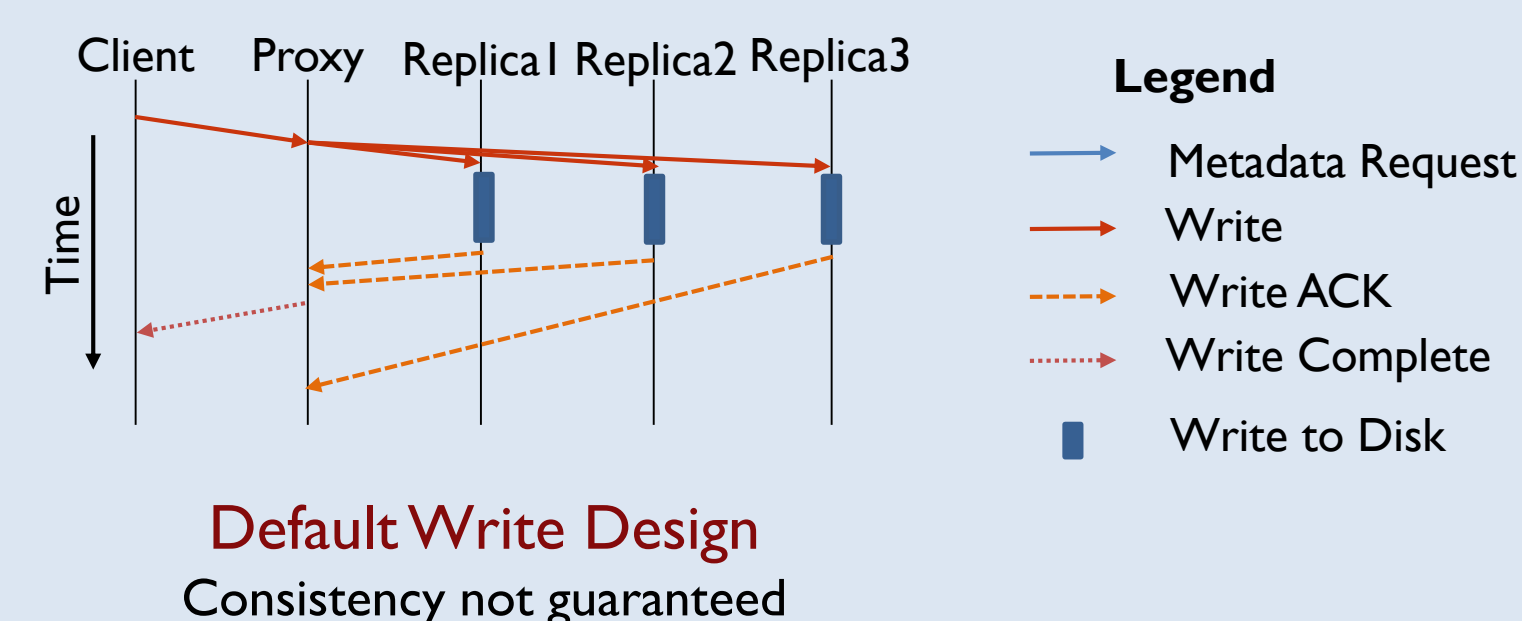
### Limited Scalability in Cloud Storage

- Proxy server design in Swift limits throughput since all operations are routed through the proxy server
- Server-side replication limits scalability
- Network communication is slow TCP-based



### Consistency Issues

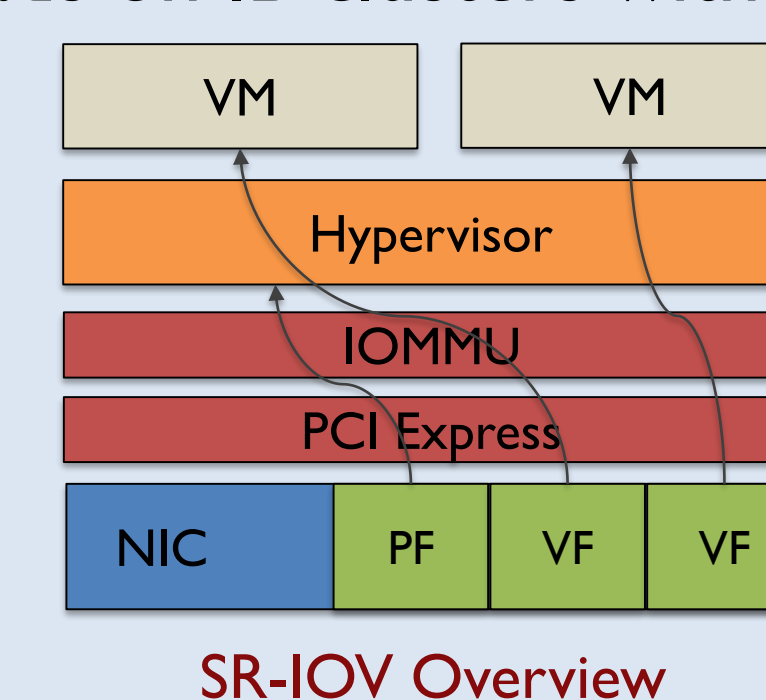
- Traditional applications reliant on POSIX-like consistency
- Cloud storage solutions provide Eventual Consistency (EC)
- Application migration to the cloud is not straightforward
- Consistency guarantees are required



## Proposed Designs

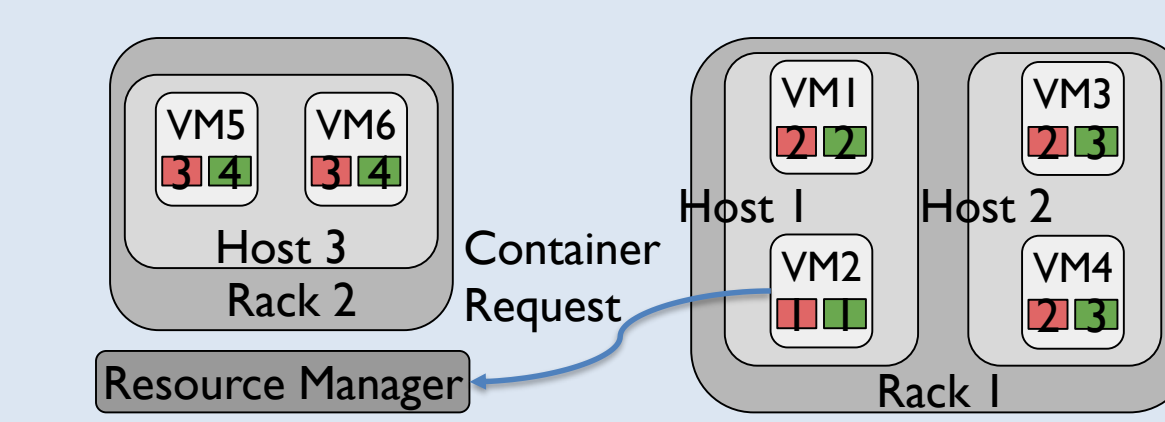
### Modern Networking Protocols

- InfiniBand and RoCE provide RDMA-based efficient communication
- SR-IOV offers hardware-based network virtualization
- With SR-IOV, VMs can directly access the network adapter
- Comprehensive evaluation of Hadoop workloads on IB clusters with SR-IOV



### Topology-aware Communication

- Automatic topology detection module can detect topology changes during runtime
- Maximize communication between co-located VMs
- Allocate Containers and Map tasks on a co-located VM before other VMs

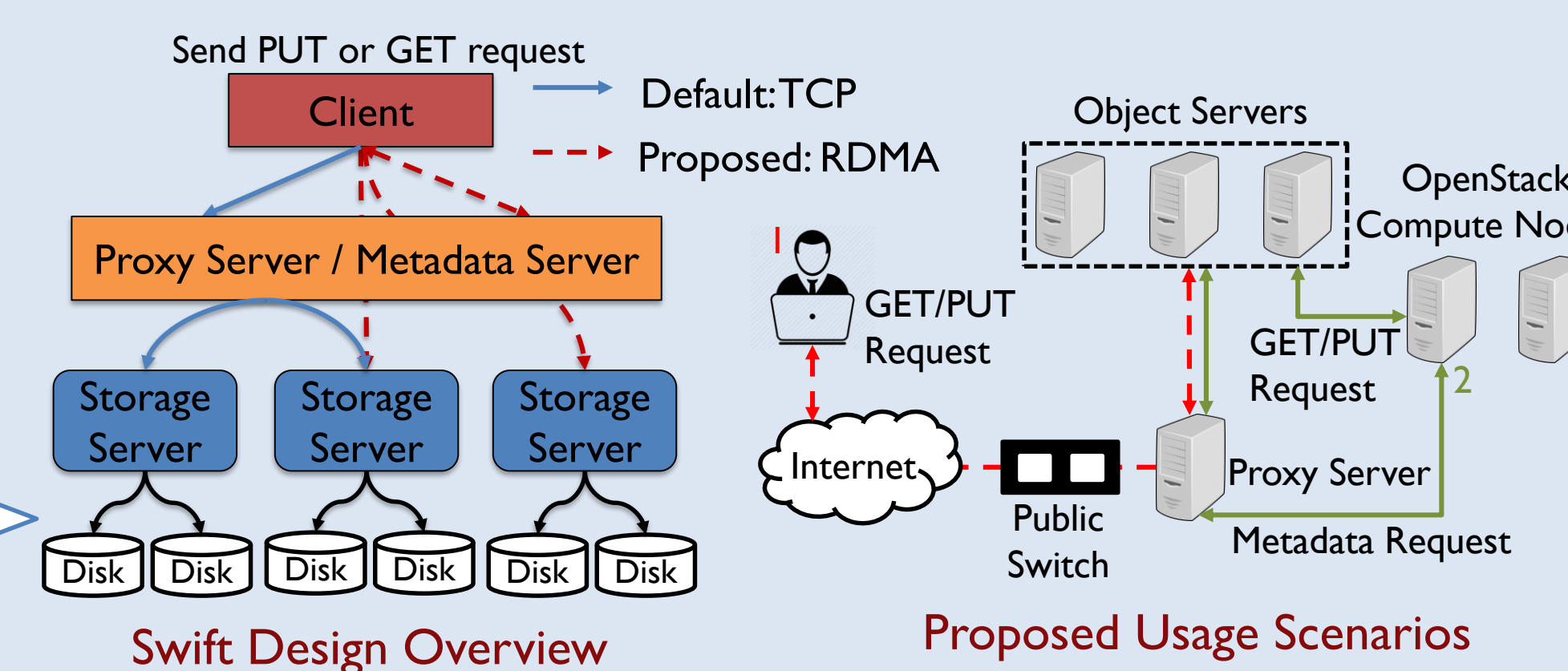


- Default Hadoop Policy
- Node local
  - Rack local
  - Off-rack
- Proposed Policy
- Node local
  - Host local
  - Rack local
  - Off-rack

Proposed Container Allocation Policy

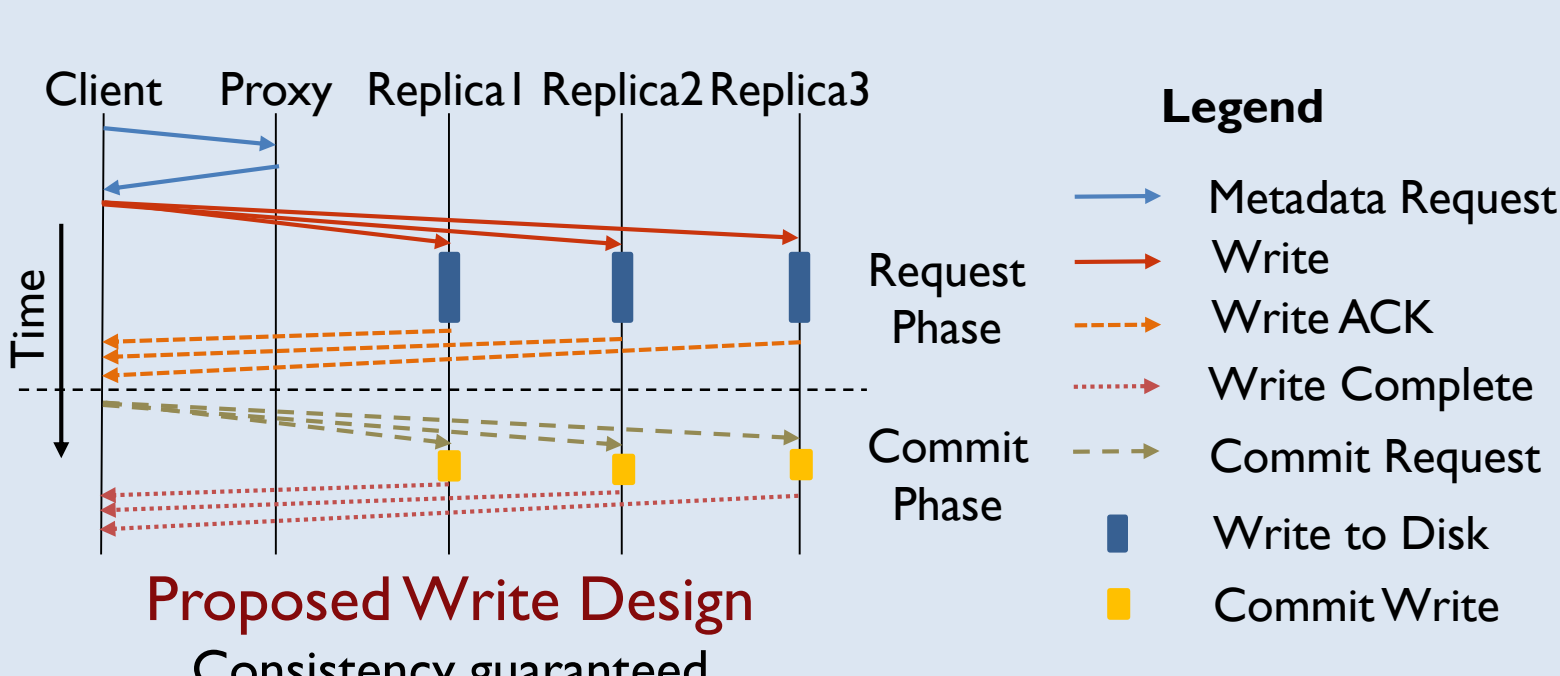
### Scalable Cloud Storage: Swift-X

- Use proxy server only as a metadata server
- Client-based replication for scalability
- RDMA-based communication for high-performance
- Non-blocking semantics for efficient overlap between communication and I/O



### POSIX-like consistent Cloud Storage

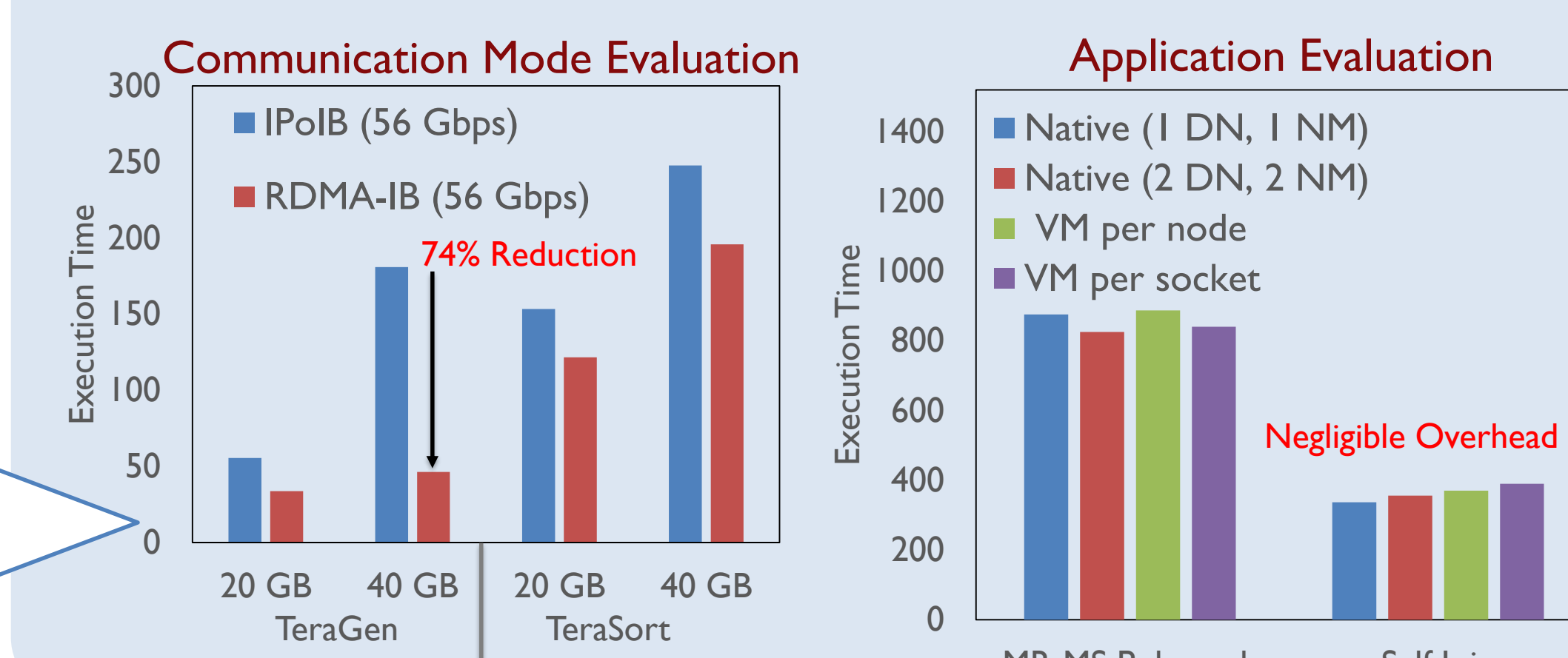
- Atomicity as a way to guarantee consistency
- Two-phase commit (2PC) for atomic write operations
- Client-side caching to improve read/write performance
- Compatibility with HDFS API: MapReduce workloads can directly run on cloud storage



## Results

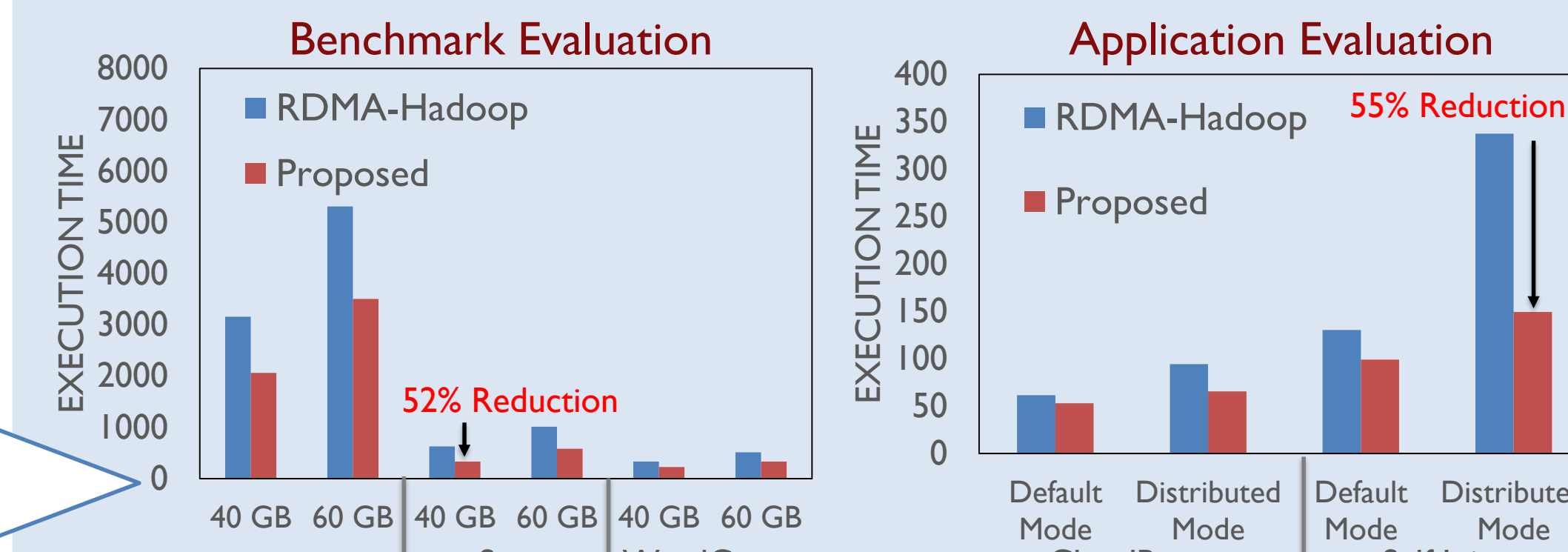
### Evaluation on Virtual Cluster

- Less than 9% overhead for applications compared to native execution
- Selecting correct VM subscription policy can deliver near-native performance
- Up to 74% improvement for TeraGen, 21% for TeraSort for RDMA over IPoIB



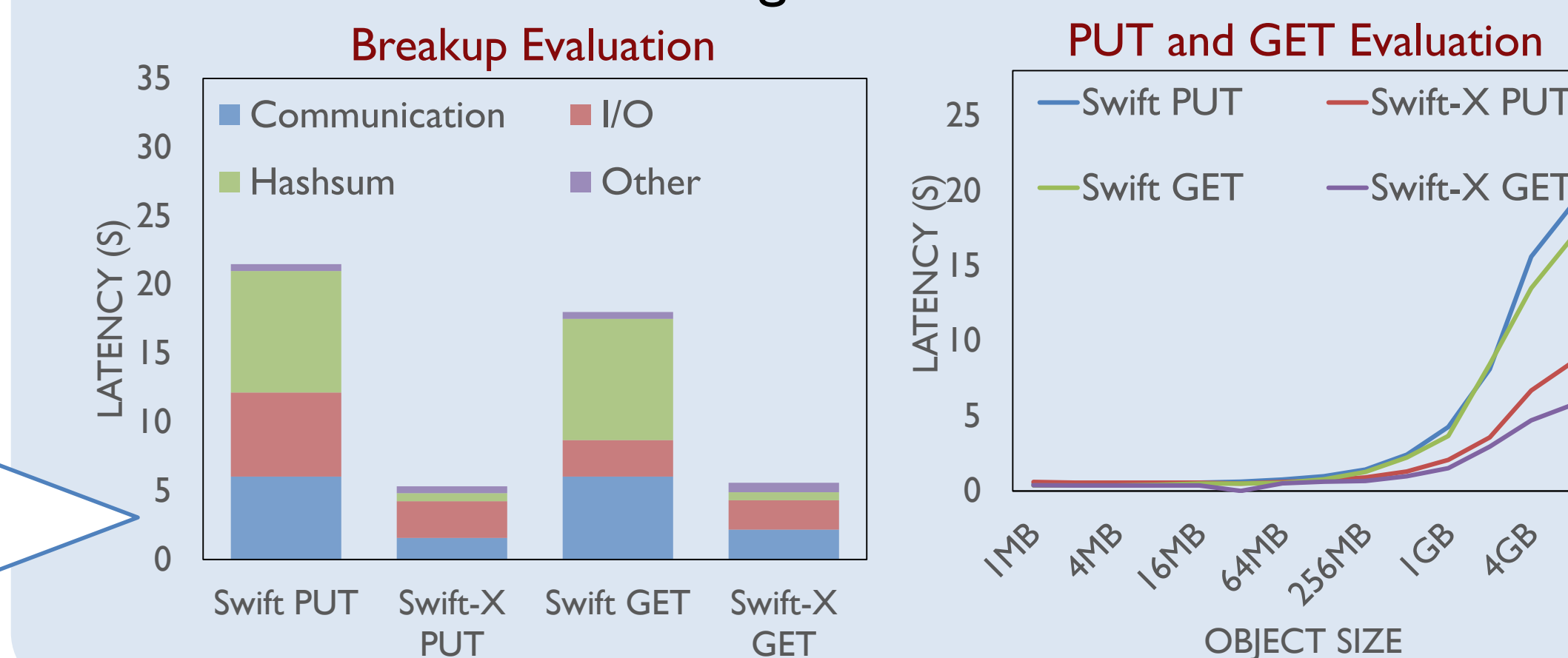
### Evaluation with RDMA-Hadoop

- Up to 52% improvement over RDMA-Hadoop for benchmarks
- Up to 55% improvement over RDMA-Hadoop for applications
- Proposed design delivers the best performance and fault-tolerance



### Evaluation with OpenStack Swift

- Up to 47% and 66% reduction in PUT and GET latencies
- Communication time reduced by up to 3.8x for PUT and up to 2.8x for GET
- Up to 7.3x improvement in read throughput for cloud storage



### Evaluation with SwiftFS and HDFS

- Up to 83% improvement over SwiftFS
- Up to 64% improvement over HDFS
- With HDFS, data is copied from Swift
- Best performance and guaranteed consistency

