Evaluating the Impact of RDMA on Storage I/O over InfiniBand

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Presentation Outline

- Introduction/Motivation
- RDMA Assisted iSCSI Overview
- Design and Implementation
- Performance Evaluation
- Conclusion

InfiniBand Overview

- Industry standard
- Interconnect for connecting processing nodes and I/O nodes
- High performance
  - Less than 5us latency
  - Over 840MB/s unidirectional Bandwidth
- InfiniBand clusters are becoming increasingly popular

Storage for InfiniBand Clusters

- Local storage
- Network storage
  - Network Attached Storage (NAS)
  - Storage Area Networks (SANs)

SAN for InfiniBand Clusters

- Fibre Channel (FC)
- SCSI RDMA Protocol (SRP)
- Internet SCSI (iSCSI)

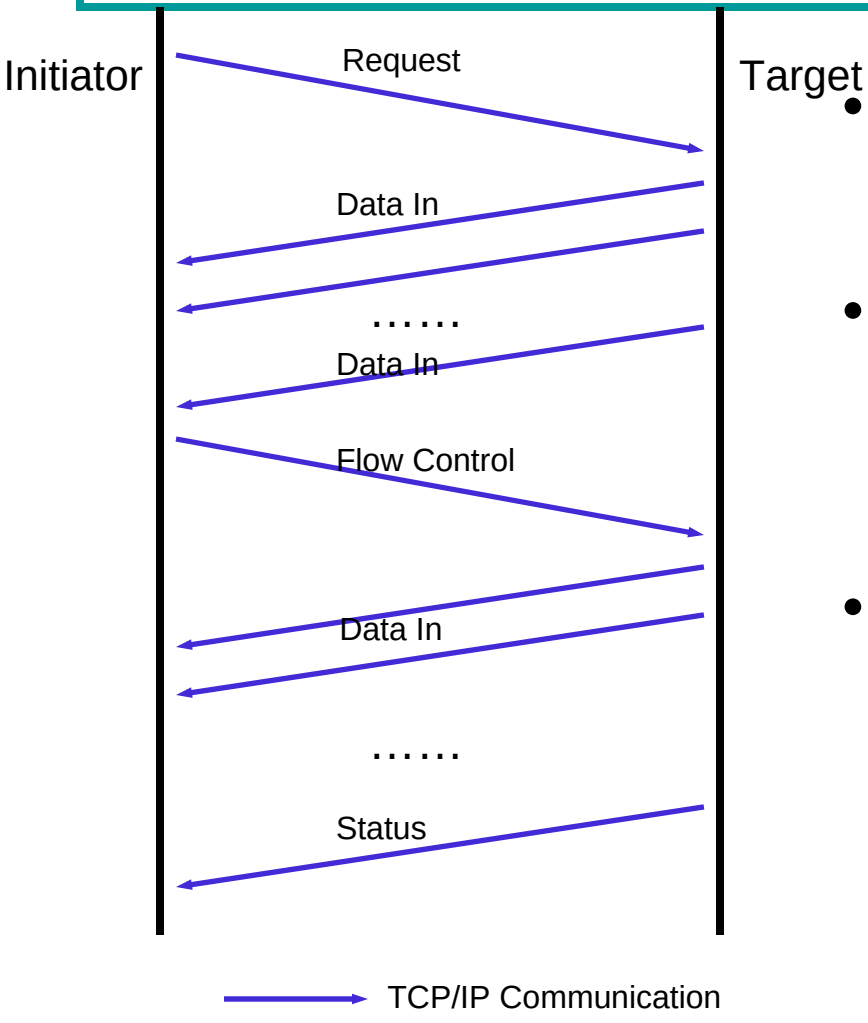
FC and SRP

- Fibre Channel (FC)
  - Good performance
  - Requires new hardware (HBAs, switches)
  - Requires separate management infrastructure
- SCSI RDMA Protocol (SRP)
  - InfiniBand native protocol
  - No new hardware required
  - Requires implementation from scratch
  - Requires new management infrastructure

iSCSI

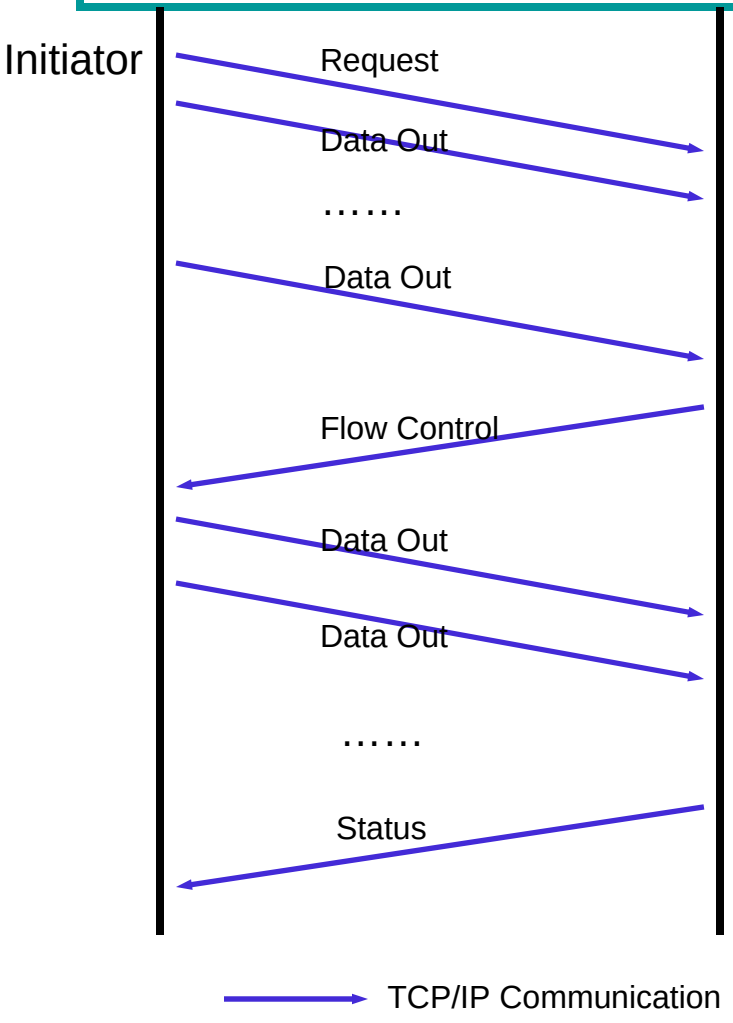
- Uses TCP/IP as the underlying transport layer
  - No additional hardware for hosts (InfiniBand supports IPoIB)
  - Relative less software development effort (Existing management infrastructure in TCP/IP can be reused)
- Performance may be an issue
  - High overhead in the TCP/IP stack

iSCSI Data Transfer: Read



- All communication through TCP/IP
- Multiple data packets may be necessary
- Flow control for data packets may be necessary

iSCSI Data Transfer: Write



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Problems with iSCSI

- Limited Performance because
  - Protocol overhead in TCP/IP
  - Interrupts are generated for each network packet
  - Extra copies when sending and receiving data

Improving iSCSI Performance

- Eliminating receiver side copies in the TCP/IP stack
- Direct data placement in HBA
  - Special hardware
  - Low compatibility
- iSCSI extension for RDMA
  - Special hardware (RNICs)
  - Standard interface (RDMA over IP)
- Using RDMA over InfiniBand
  - RDMA assisted iSCSI

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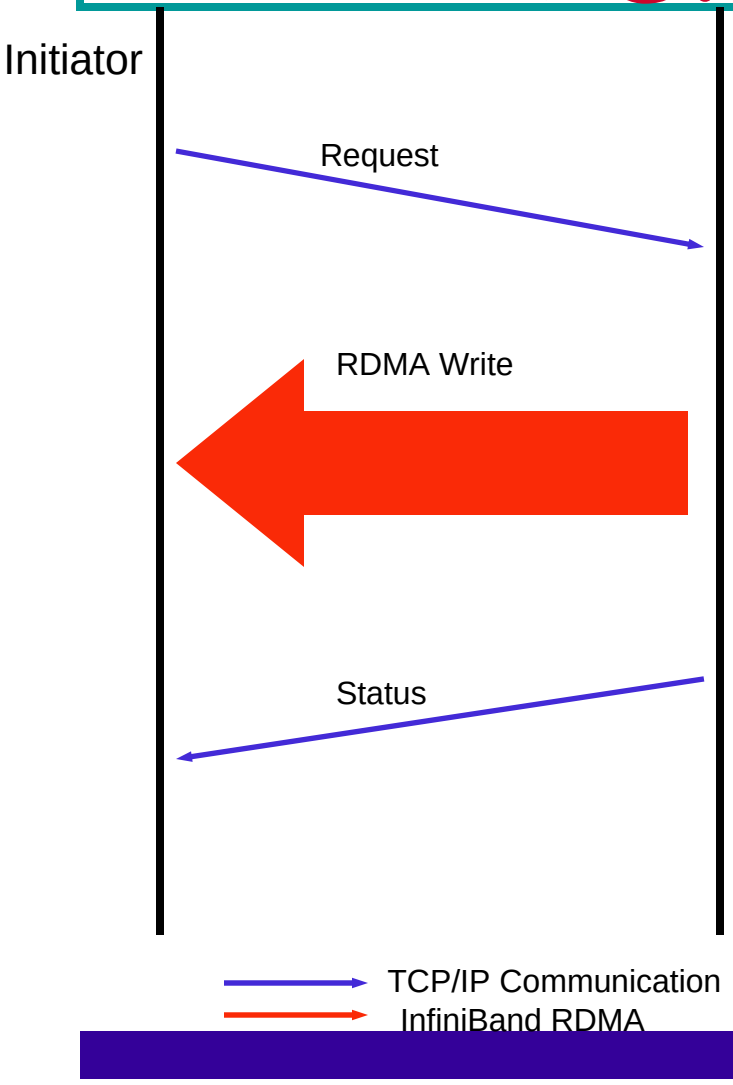
RDMA Assisted iSCSI Overview

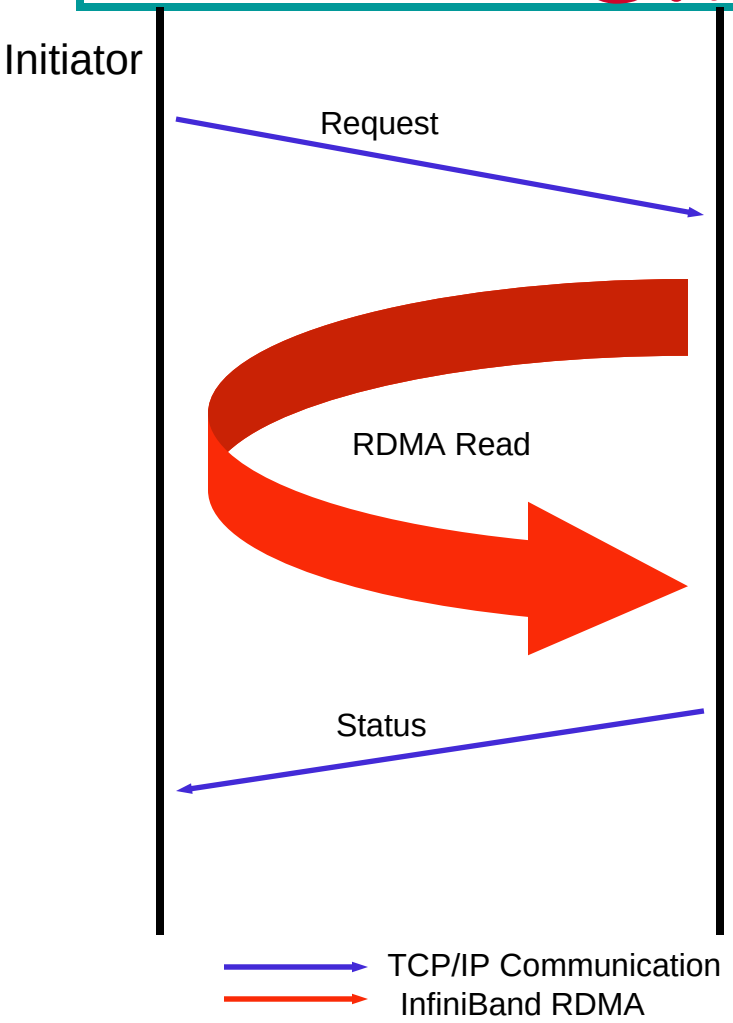
- Combining IPoIB and RDMA over InfiniBand in iSCSI
  - iSCSI control PDUs go through TCP/IP
  - iSCSI data transfers use RDMA
  - IPoIB for compatibility
  - RDMA over InfiniBand for performance
- Reusing existing infrastructure
  - Reusing many existing IP based protocols
  - No additional hardware needed for hosts

iSCSI Data Transfer with RDMA: Read



- Requests carry buffer information (address, length, tags …)
- All control transfer through TCP/IP
- All data transfer through InfiniBand RDMA
- No need for multiple data packets
- No flow control for data packets necessary

iSCSI Data Transfer with RDMA: Write



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- All control transfer through TCP/IP
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Advantages of Using RDMA

- Improved performance
  - Much less protocol overhead (TCP/IP bypassed for data transfer)
  - No data copies in the protocol
  - Reduced number of interrupts at the client

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Design Issues

- Memory Registration
- Session Management
- Reliability and Security

Memory Registration

- Memory needs to be registered before it can be used for RDMA in InfiniBand
- Memory registration cost is high
  - Targets can usually pre-registered all the memory to avoid the cost
  - More difficult for hosts (clients) because they do not have total control over the memory buffers

Techniques to Improve Memory Registration

- Memory Registration Cache (MRC)
  - Maintains a "cache" of registered buffer and de-register buffer in a lazy manner
  - Depends on buffer reuse
  - May not be effective for storage buffers
- Fast Memory Registration (FMR)
  - Divide registration into two steps (preparation and mapping)
    - Only mapping appears in the critical path
  - Supported in some InfiniBand implementations
- Zero-Cost Kernel Memory Registration (ZKMR)
  - Map physical memory to virtual address space in kernel and pre-register the mapped virtual address space
  - Do "virtual" to "mapped" address translation during communication (very fast)
  - Some limitations

Session Management

- Use TCP/IP exclusively for LOGIN phase
  - Reusing existing bootstrapping and target discovering protocols
- LOGIN phase negotiate the use of InfiniBand RDMA
  - Fall back on the original iSCSI if RDMA cannot be used

Reliability and Security

- Reliability
  - TCP/IP checksum may be insufficient for some applications
  - iSCSI supports CRC
  - No need to use CRC in RDMA assisted iSCSI because InfiniBand has end-to-end CRC
- Security
  - RDMA assisted iSCSI can take advantage of existing authentication protocols
  - However, IPSec cannot be used directly

Implementation

- Linux 2.4.18
- Based on Intel v18 iSCSI implementation
- InfiniBand Access Layer and IPoIB
- Ram disk based target implementation
- Kernel SCSI driver at the client

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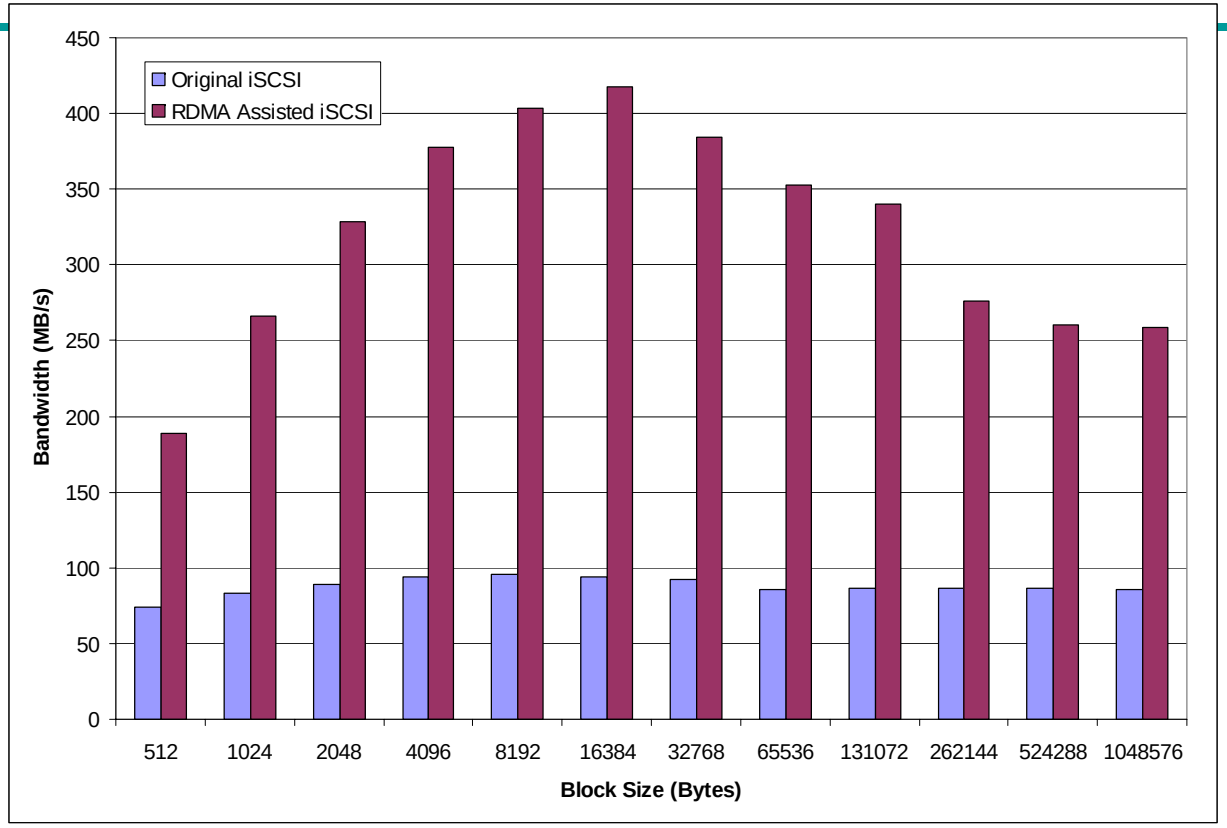
Experimental Testbed

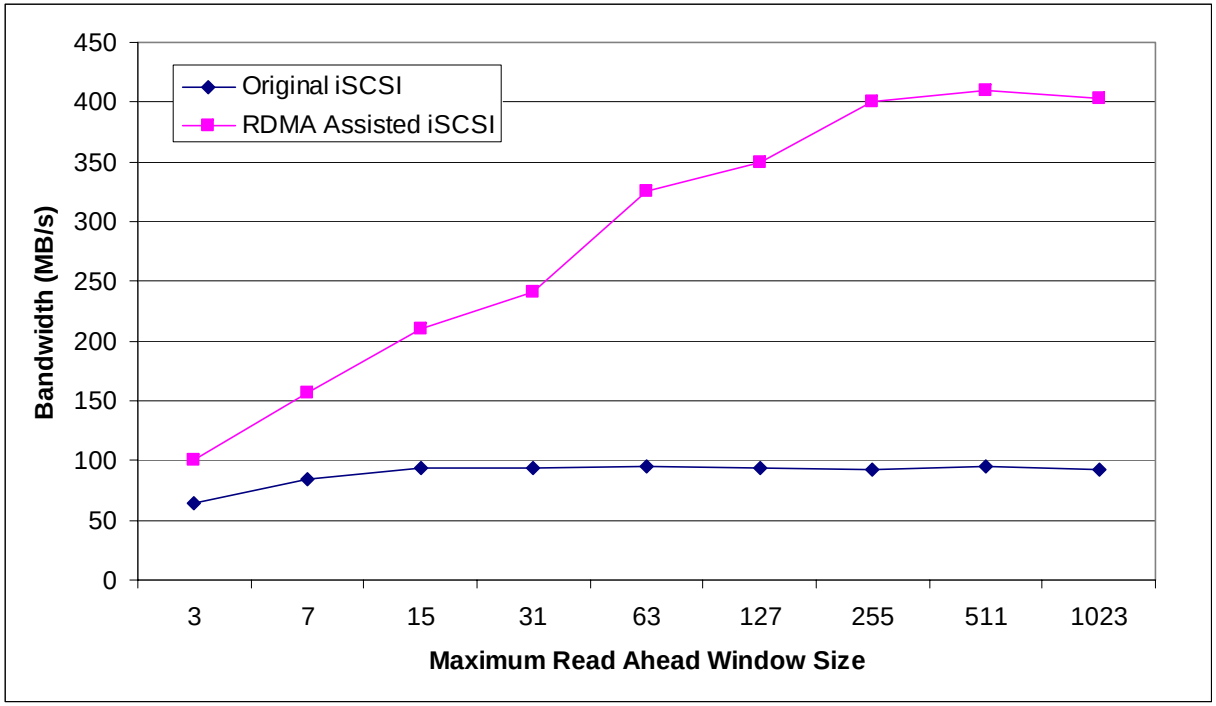
- SuperMicro SUPER P4DL6 nodes (2.4 GHz Xeon, 400MHz FSB, 512K L2 cache)
- Mellanox InfiniHost MT23108 4X HCAs (A1 silicon), PCIX 66bit 133MHz
- Mellanox InfiniScale MT43132 switch

File Read Bandwidth



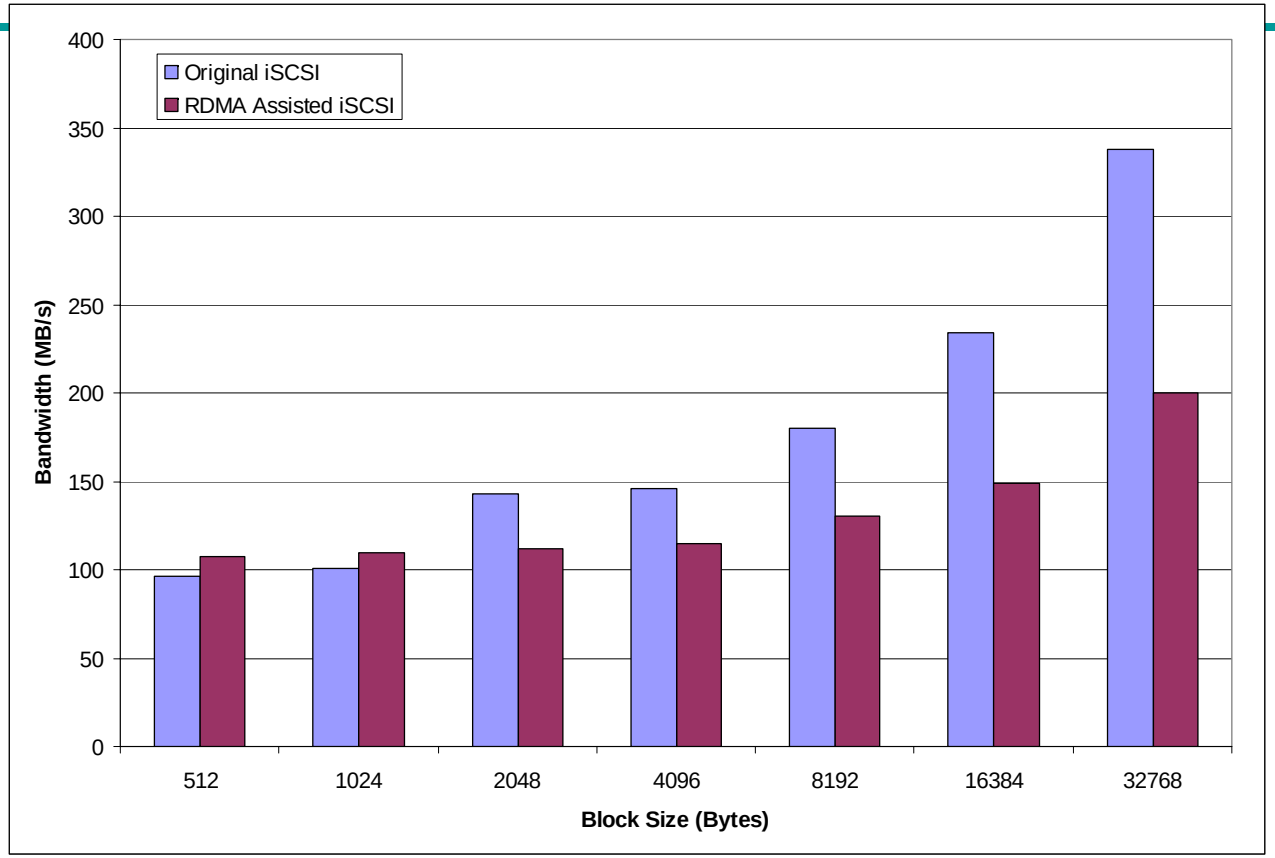
- Buffered I/O used
- RDMA can improve peak bandwidth from 97MB/s to over 400MB/s
- 16KB block size performs best

Impact of Read Ahead



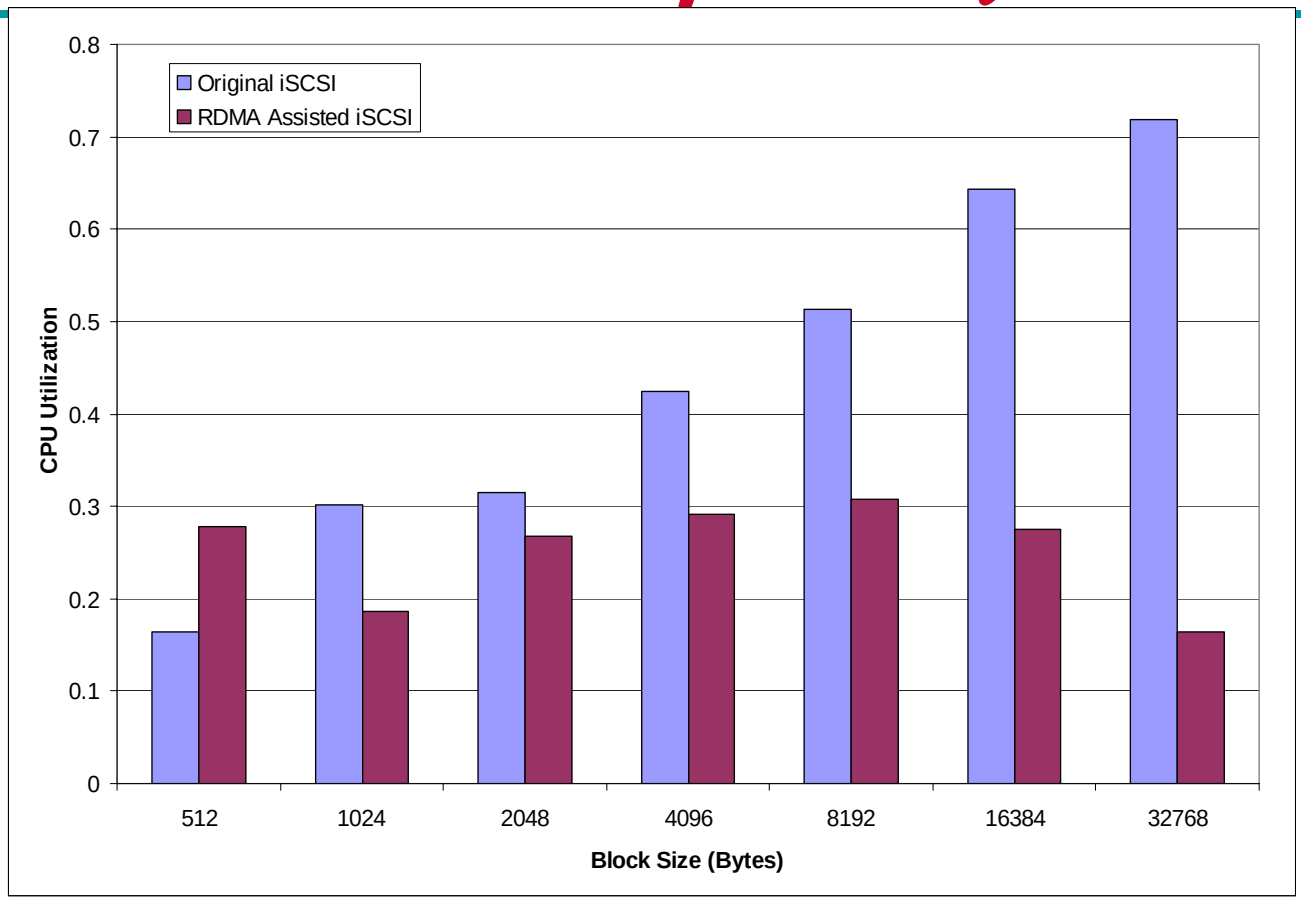
- Prefetching has greater impact on the performance of RDMA assisted iSCSI

File Read Latency



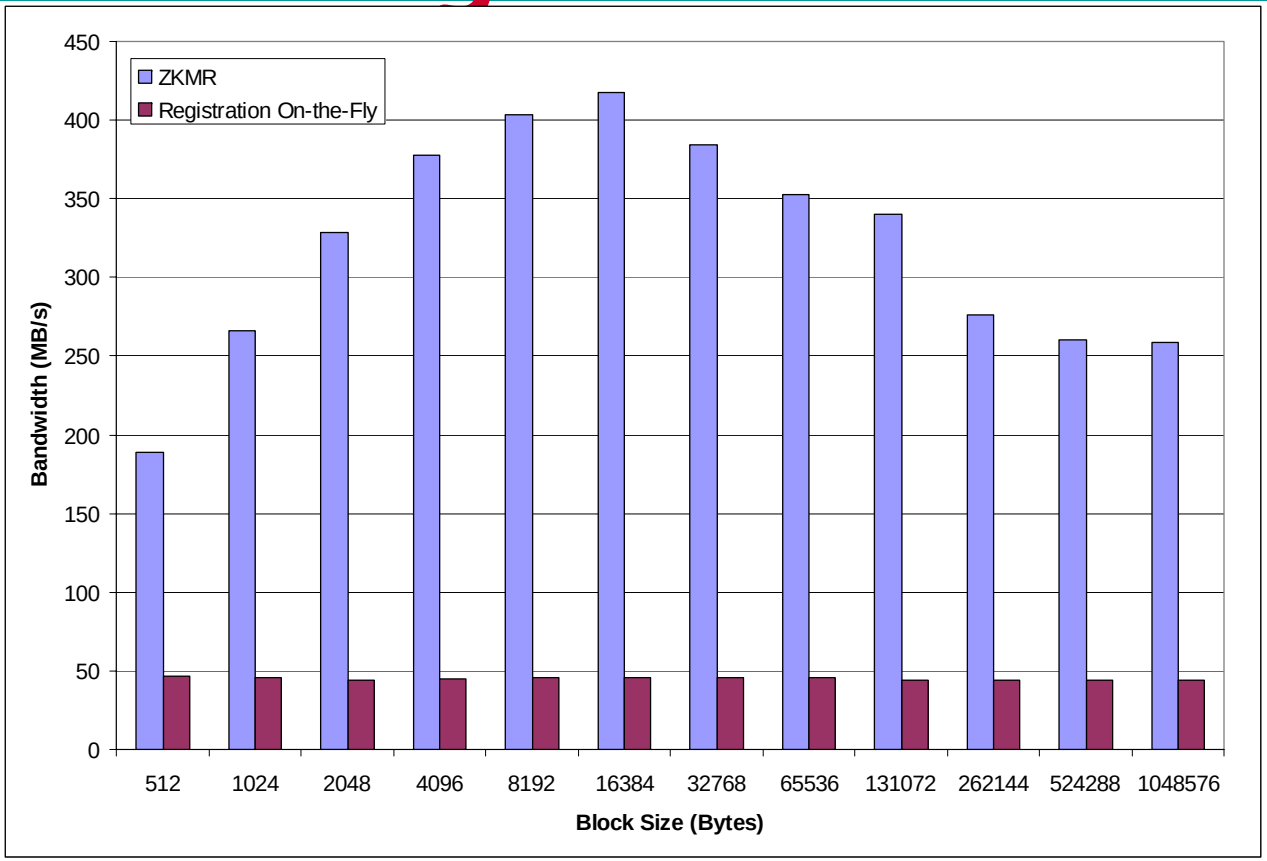
- RAW I/O used instead of buffered I/O
- RDMA improves performance for large block sizes

Host CPU Utiliazation (File Read Latency Test)



- RDMA reduces CPU untilization for large block sizes

Impact of Buffer Registration



- Registration cost significantly degrades performance
- RDMA is beneficial only when registration cost can be avoided/reduced

Conclusion

- RDMA assisted iSCSI over InfiniBand
  - Evaluating the use of RDMA in storage protocols
    - RDMA can significantly improve storage communication performance
    - Provide useful insight for other protocols such as iSER and SRP
  - A practical storage solution for InfiniBand clusters