Open Source NFS/RDMA Roadmap

NFS/RDMA activity in 2016-2017

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Program Agenda

1. Upstream progress and forecast
2. RPC-over-RDMA Version One shortcomings
3. Addressing transport protocol issues
Upstream Activity In 2016
Linux NFS/RDMA Client

Major New Features

• NFSv4.1 support with backchannel
• NFS/RDMA with krb5, krb5i, krb5p
• Regular testing with IOMMU enabled
• Memory registration mode changes
  – Unsafe ALLPHYSICAL mode removed
  – Support for SG_GAP added to FRWR
  – Remaining modes are FRWR and FMR
Linux NFS/RDMA Client

Internal Improvements

• Transport resource requirements reduced
  – MRs allocated on demand (sets of 32)
  – Some large data structures moved off the stack

• Disconnection recovery made even more robust

• Converted to new rdma core APIs
  – ib_alloc_cq
  – ib_drain_qp
  – FMR scatterlist
Linux NFS/RDMA Client

Experimental Features

• Responder’s choice Remote Invalidation
• Inline thresholds up to 64KB using gathered Send
• On connection, transport properties exchange via CM private data
Linux NFS/RDMA Server

Major New Features

- NFSv4.1 support with backchannel
- NFS/RDMA with krb5, krb5i, krb5p
- Regular testing with IOMMU enabled
Linux NFS/RDMA Server

Internal Improvements

• Complete support for RDMA_ERROR type messages
• IPv6 support completed
• Converted to new rdma core APIs
  – ib_alloc_cq
Linux NFS/RDMA Server

Experimental Features

- Responder’s choice Remote Invalidation
- Inline thresholds up to 64KB
- On connection, transport properties exchange via CM private data
Wireshark

Fixes now in 2.3.0-rc and 2.2

• RPC-over-RDMA frame detection is now reliable
• RPC-over-RDMA Transport header parsing is working
  – Parse tree constructed and displayed properly
  – Display filters on header fields now functional
• RPC Call/Reply matching has been improved
Linux NFS/RDMA Client

- Multi-path support
- Faster recovery from server reboot/failover
- Handle device driver unloading
- Move development platform from IB to RoCE
- Focus on full stack performance
Linux NFS/RDMA Server

• Conversion to core rdma_rw API
• Multi-path support
• Improve Receive efficiency
  – Reduce load on memory allocator
  – Less DMA mapping
• Move development platform from IB to RoCE
Wireshark

Next Steps

• Re-assembly of RDMA_NOMSG messages
• Re-assembly of RDMA_MSG messages with chunks
Known RPC-over-RDMA Deficiencies
Reply Size Estimation

• Requesters must provide adequate resources to receive RPC replies

• Requesters struggle to determine the maximum size of certain variable-length elements in Upper Layer Protocols
  – Examples include ACLs, NFSv4.2 READ_PLUS results
  – Is this a ULP design problem, or a deficiency in the transport?

• Responders have no mechanism to report a catastrophic lack of reply resources
Cancelled RPCs

• An RPC transaction can be cancelled due to an asynchronous event on the requester (e.g. ^C)

• Nevertheless, responder still tries to write results into a Write or Reply chunk
  – If the MR is now invalid, connection is lost
  – If the MR was re-used, reply data might be corrupted

• Requesters must invalidate chunks immediately or set them aside until the responder has sent a matching reply
Multiple Write Chunks

• Read chunks have XDR position fields, Write chunks do not
  – In other words, Write chunks are not fully self-describing
• Requester can provide multiple Write chunks, but it may be ambiguous how the responder consumes them
• How does requester know which result went into which Write chunk?
Security Issues

• RPC-over-RDMA Transport header fields are not protected by RPCSEC GSS
• GSS integrity and privacy services make it difficult to offload data transfer
• RDMA consumers need to detect the presence of offloaded security (e.g. iWARP on IPsec)
Performance Issues

• No convenient way to support Remote Invalidation with clients who use persistent memory registration
• Receive still requires some data copying
• Default inline threshold (1KB) is inadequate for NFSv4
• Existing RPC stacks are too slow for low-latency transports and storage
• Single QP I/O throughput is hardware-limited
Performance Issues

RDMA Read

• RDMA Read requires an extra round trip
• Transport cannot do RDMA Read efficiently by itself
  – Current implementations Read into anonymous pages and copy or flip them into their page cache
  – Upper layer (NFS) knows the eventual pages where data needs to land
  – Upper layer must handle non-page-aligned NFS WRITE requests, in order to avoid copying some payload data
Structural Issues

• Computing precisely how much RPC message data can fit inline is difficult because chunk lists, which share the inline space with the RPC message, vary in length

• No clean way to extend the RPC-over-RDMA protocol without a new version

• No control plane to do things such as:
  – Connection keep-alive and testing
  – Exchange of transport properties
  – Post-retransmit credit resyncs
Structural Issues

Credit Accounting

- Credit accounting assumes every RPC-over-RDMA message today is associated with exactly one RPC message
  - Might want to send a keep-alive, or exchange transport properties
  - A control plane would have to share Receive resources with data plane
  - Might want to send a single large RPC using multiple RDMA Sends (credits)
  - Might want to send several RPCs in one RDMA Send
  - No call direction field in RPC-over-RDMA Transport header: direction of an RPC-over-RDMA message not carrying an RPC message is not known
Meeting These Challenges
Performance On RPC-over-RDMA Version One

Use NFSv4.1 and pNFS

• Multi-path enables the use of more than one QP per mount point
• pNFS block layouts with iSER or NVMe/F enables efficient RDMA-native I/O to multiple DSes
• Possible new “push mode” layout type enables client to drive RDMA Read and Write directly to remote persistent memory
  – No extra RDMA Read round-trip when client initiates RDMA
  – No interrupts on the server during read and write I/O
  – Direct access to storage
RPC-over-RDMA Version Two

New Transport Protocol Features

• Larger default inline threshold
• Flexible support for Remote Invalidation
• Message direction now part of Transport header
• Extensibility
  – Built-in exchange of transport properties
  – Ability to introduce new message types
RPC-over-RDMA Version Two

Extensions To Make More Use of RDMA Send

• Message Continuation
  – Use multiple RDMA Send operations to transmit a large RPC
  – No memory registration or invalidation is needed
  – Reduces the risk of requesters providing inadequate receive resources
  – Makes credit accounting more complex
RPC-over-RDMA Version Two

Extensions To Make More Use of RDMA Send

- Send-based direct data placement
  - Enable the receiver to catch aligned data in buffers that can be flipped into a file’s page cache
  - Used to transfer DDP eligible data items
  - Not effective for updating data in a page with other data, or data that starts in the middle of a page
  - Not effective for platforms with pages larger than the inline threshold
Unresolved Areas

• Handling cancelled RPCs
• Creating and managing a control plane
• Generic zero-copy receive
• Protecting the Transport header
• Reliably matching Write chunks to results
• Using chunks in the backchannel
Follow Along At Home

• draft-andros-nfsv4-client-multipath-discovery
• draft-cel-nfsv4-reminv-design
• draft-cel-nfsv4-rpcrdma-cm-pvt-msg
• draft-cel-nfsv4-rpcrdma-version-two
• draft-dnoveck-nfsv4-rpcrdma-rtissues
• draft-dnoveck-nfsv4-rpcrdma-rtrext
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