Persistent Memory over Fabric (PMoF)

Adding RDMA to Persistent Memory

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Adding RDMA to Persistence memory – Agenda

- PMoF Overview
- Comparison with other remote replication technologies
- RPMEM Library Capabilities
- NVML Architecture with RPMEM library
- RPMEM Library API
- Remote replication using PMEMOBJ library
- Future Improvements
Persistent Memory over Fabric (PMoF) Overview

- Enables low latency and high speed remote replication of persistent memory using various fabrics (IB, RoCE, iWARP, Omnipath, etc)
  - Transport agnostic by using RDMA Verbs
- Many possible non-volatile byte addressable devices are considered in scope (NVDIMMs, 3DXP DIMMs)
- Does not support replication of traditional block-based storage
PMoF – comparison with other remote replication storage technologies

TCP/IP based replication to block storage

RDMA based replication to block storage (e.g. NVMeoF)

PMoF-based replication to Persistent Memory
Rpmem library – PMoF implementation in NVML

- Fabric agnostic
  - Can use any fabric with libfabric and libverbs support
- Supports GPSPM and APM persistency methods*
  - GPSPM uses RDMA Send
  - APM uses RDMA Read
- Utilizes multiple RDMA queue pairs for highly parallel workload
  - Each application thread can replicate data independently without a need for inter-thread synchronization
- Includes RPMEMD daemon process to be run on remote replica node
  - No need to implement application specific target node service

* For details refer to SNIA SDC 2015 presentation by Chet Douglas:
NVML Architecture with RPMEM

Initiator Node

Application

LIBPMEM

LIBPMEMOBJ

LIBPMEMBLOCK / LIBPMEMLOG

Target Node

RPMEMD Deamon

LIBPMEM

Fabric

PMEM

RNIC

DAX-enabled File System

Libfabric

libverbs

SSH

DAX-enabled File System

SSH

Libfabric

libverbs
RPMEM Library API
Remote poolset management functions

- `rpmem_create(...)`
  - Starts RPMEMD process on single remote node using SSH
  - Requests remote RPMEMD to create poolset
  - Establishes RDMA connection to remote node
  - Registers local and remote poolset (persistent memory) in libfabric

- `rpmem_open(...)`
  - Same as `rpmem_create` but opens existing poolset and verifies whether it matches local poolset
RPMEM Library API
Poolset management functions

- `rpmem_close(…)`
  - Deregisters local and remote poolset from libfabric/verbs
  - Disconnects RDMA connection
  - Shuts down RPMEMD process on remote node
- `rpmem_remove (…)`
  - Same as `rpmem_close` but also removes poolset on remote node
RPMEM Library API – memory replication functions

- **rpmem_persist(...)**
  - Replicates data from local to remote poolset using RDMA
  - Allows to specify data offset and size within the pool

- **rpmem_read(...)**
  - Copies data from remote poolset to local memory (either local persistent memory or regular DRAM) using RDMA Read
  - Could be used to verify correctness of remote replica or recover local poolset from remote replica
  - Allows to specify data offset and size within the pool
  - Does not persist data locally (no CPU cache flush etc.)

Refer to pmem.io for more detailed description
Remote replication in PMEMOBJ

- PMEMOBJ can automatically replicate any writes to persistent memory using RPMEM
- Replication process is transparent to application
- Just add one or more remote replicas to pool set definition file

```
PMEMPOOLSET
100G /mountpoint0/myfile.part0

# local replica
REPLICA 100G /mountpoint3/mymirror.part0

# remote replica
REPLICA user@example.com remote-objpool.set
```
Remote replication in PMEMOBJ

Application → PMEMOBJ → Local PMEM → RPMEM → Libfabric/RNIC → Target Node(s)

- **Application**
- **PMEMOBJ**
  - `write`
  - `pmemobj_persist(…)`
- **Local PMEM**
  - `rpmem_persist(target_node1, …)`
- **RPMEM**
  - `fi_writemsg(…)`
  - `fi_readmsg(…)`
  - `fi_cqread(…)`
- **Libfabric/RNIC**
  - RDMA Write
  - RDMA Read
  - RDMA Read ACK
- **Target Node(s)**
  - Repeat for each target node
  - `CLFLUSHOPT/CLWB + SFENCE`
Future improvements and enhancements

- Performance improvements
  - Parallel replication to multiple remote nodes and local replica(s)
  - Use of single RDMA Read/Send for multiple RDMA Write operations – similar to local OPTIMIZED_FLUSH
- Support for Windows OS
- Eventually consistent (aka asynchronous) replication
Key Takeaways

- PMoF improves latency and throughput of remote PMEM replication
- NVML includes RPMEM library implementing PMoF
- Application can either call RPMEM directly or can use PMEMOBJ that use RPMEM for replication
- Start using NVML with RPMEM for remote replication: http://pmem.io