REMOTE PERSISTENT MEMORY ACCESS
AS SIMPLE AS LOCAL MEMORY ACCESS

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WHAT IS PERSISTENT MEMORY (PMEM)?

- allow accessing data as memory
  - directly
  - byte-addressable
- the contents are non-volatile (preserved across power cycles).
- it doesn’t typically replace either memory or storage

For more information please visit:
- pmem.io
- Persistent Memory Development Kit (PMDK) GitHub repo

pmem.io/book
Storage Networking Industry Association (SNIA) standardized Software Persistent Memory (PMem) programming model

When writing data to PMem, in order for the data to be considered persistent:

- After writing to persistent memory, the software is responsible for flushing data from CPU caches to the Persistence Domain.
- Once the CPU caches are flushed of write data, the platform guarantees the write data is persistent, should power be lost.
IMPLEMENTING THE PMEM PROGRAMMING MODEL OVER AN RDMA NETWORK (APM)

The RDMA Write response only tells the Application that the Target RNIC has sent the write data on to the final storage location in persistent memory. Writing data to remote persistent memory.

As the programming model states, the Application will need to execute a flush to make sure the data has been flushed to the persistence domain.

The RDMA Read forces any write data to the persistence domain before the RDMA Read can proceed. This is because the ordering rules of both RDMA and PCIe.

“Appliance Persistency Method”
**IMPLEMENTING THE PMEM PROGRAMMING MODEL OVER AN RDMA NETWORK (GPSPM)**

1) The Application sends a list of address ranges to flush in the payload of the RDMA Send command. When the Target RNIC executes the RDMA Send message it interrupts the Application running on the Target system.

2) The Application issues CLFLUSHOPT instructions for each cache line (64B) of data in the flush list. It then issues an SFENCE instruction to make sure other reads and writes can't pass this write data.

3) The Application issues an RDMA Send command back to the initiator to acknowledge the completion of the flush operations.

"**General Purpose Server Persistency Method**"
RDMA accesses Intel® Optane™ PMem in the same way it accesses DRAM

Remote PMem (RPMem) is about well-known technologies (like PCIe, RDMA) used in a new way
THE NEW LIBRPMA FOCUSES ON RPMEM USABILITY

- memcpy-like API
- Hidden RDMA complexity
- Application can freely manage your PMEM all the time
- Minimum dependencies
- Enables Persistent Memory Programming Model

*up to 50% RPMem source code reduction in an application that moves from libibverbs to librpma*
• Connection management
  • to ensure operations consistency
  • to hide RDMA complexity
• **Remote Persistent Memory Access (RPMA)**
  • Read, Write, Flush, Atomic write
• Messaging
  • also with PMEM-backed message buffers
• Memory management
  • r_key exchange support
• Ready to incorporate RDMA Memory Placement Extension
**Initiator node**

```c
rpma_mr_reg(peer,
    ptr, size,
    RPMA_MR_USAGE_WRITE_SRC,
    &src_mr);
```

**Target node**

```c
rpma_mr_reg(peer,
    ptr, size,
    RPMA_MR_USAGE_WRITE_DST | RPMA_MR_USAGE_FLUSH_TYPE_PERSISTENT,
    &dst_mr);
```
BASIC EXAMPLE – REMOTE PERSISTENT MEMORY WRITE

rpma_write(conn,
            dst_mr, dst_offset,
            src_mr, src_offset,
            KILOBYTE, RPMA_F_COMPLETION_ON_ERROR, NULL);
BASIC EXAMPLE – REMOTE PERSISTENT MEMORY WRITE

Initiator node

```c
rpma_write(conn,
    dst_mr, dst_offset,
    src_mr, src_offset,
    KILOBYTE, RPMA_F_COMPLETION_ON_ERROR, NULL);
```

Target node

```c
rpma_flush(conn,
    dst_mr, dst_offset,
    KILOBYTE, RPMA_FLUSH_TYPE_PERSISTENT,
    RPMA_F_COMPLETION_ALWAYS, FLUSH_ID);
```

https://github.com/pmem/rpma/tree/master/examples/05-flush-to-persistent
- Connection establishment and management
- Read/write from/to DRAM/PMem
- Multiple connections (scalability)
- Atomic write
- Messaging
- Flush to persistent (both APM and GPSPM)
- Send/Write with immediate data
```c
rpma_utils_get_ibv_context(SERVER_ADDR, RPMA_UTIL_IBV_CONTEXT_REMOTE, &dev);
```

```c
rpma_utils_get_ibv_context(SERVER_ADDR, RPMA_UTIL_IBV_CONTEXT_LOCAL, &dev);
```

```c
rpma_peer_new(dev, &peer);
```
rpma_conn_req_connect(conn_req, NULL, &conn);
rhma_conn_next_event(conn, &conn_event);
assert(conn_event == RPMA_CONN_ESTABLISHED);

rpma_conn_req_new(peer, SERVER_ADDR, SERVER_PORT, conn_cfg, &conn_req);

rpma_ep_listen(peer, SERVER_ADDR, SERVER_PORT, &ep);
rhma_ep_next_conn_req(ep, conn_cfg, &conn_req);

rpma_conn_cfg_new(&conn_cfg);
rhma_conn_cfg_set_cq_size(conn_cfg, 5);
...
rpma_conn_disconnect(conn);

rpma_conn_next_event(conn, &conn_status);
assert(conn_status == RPMA_CONN_CLOSED);
rpmconn_delete(&conn)

if(conn_status == RPMA_CONN_CLOSED) {
    rpma_conn_disconnect(conn);
    rpma_conn_delete(&conn);
}

rpma_conn_next_event(conn, &conn_status);
• APM’s Flush and GPSPM’s Flush do the same thing but they are not semantically the same

• GPSPM Flush can be combined with other application’s operations

• No common API for APM and GPSPM flushes as we want to provide messaging API for applications
LIBRPMA 0.9 FEATURES

- Establishing an **RDMA connection** with a remote node and monitoring connection status
  - **Configurable** connection parameters
  - **Exchanging** small information during the connection establishment process
- **Read** remote **memory** (both **persistent** and volatile)
- **Write** to remote **memory** (both **persistent** and volatile)
- **Ensuring data placement** within the memory subsystem of a remote node (**flush**)
- Executing an **atomic write** (Intel platform-specific via standard aligned RDMA Write with appropriate fencing; native AtomicWrite-ready)
- **Polling**, in a non-blocking way, for RDMA **operations completions** and **connection status** changes
- Logging all **diagnostic/status to syslog** and/or on stderr
- A transparent FileSystem DAX support (on selected RNICs)
- Providing **easy to use RDMA Send/Receive** messaging (also with PMem-backed buffers)

Additionally:
  - Examples collection
  - A Fio based benchmarking environment
THE LIBRPMA LIBRARY ONE YEAR LATER

- **Use cases**
  - The librpma is going to be used in Ceph and SQL-like engine
  - The librpma library is utilized by a number of customers as a reference solution
  - The librpma library is used as a fast RPMem ramp up tool
  
  - FIO engines for APM, GPSPM and AoF are based on librpma
    - all of these allows for easy, on-premise RPMem benchmarking

- **API is stable but small tuning is still possible in response to customer feedback (0.9)**

- **New features under development(performance and usability improvements)**
  - Separate Receive Completion Queue
  - More examples
    - Send/Recv with PMem
    - Connection errors handling
RPMEM BENCHMARKING ENVIRONMENT

- **Fio engines (librpma APM/GPSPM, librpma AoF)**
  
  github.com/pmem/fio => github.com/axboe/fio/pull/1186
  
  - bandwidth/latency
  - remote DRAM vs RPMEM (dev-dax, fs-dax)
  - numjobs, blocksize, iodepth, readwrite

- **pmem.io/rpma**
  
  - *Performance – Tuning* blog describing RPMem related BIOS/OS settings
  - *Direct Write to PMem* blog describing RPMem enabling on Intel servers

- **github.com/pmem/rpma/tree/master/tools/perf**
  
  - `rpma_fio_bench.sh` – to collect performance data
    - Fio job files templates
    - remote DDIO control, local/remote NUMA control, PMem/DRAM
  - `csv_compare.py` – for results comparison (research, manual analysis)
  - `create_report.sh` – for comprehensive performance report
    - `rpma_fio_bench.sh 192.168.1.1 all all all`
    - adjustable report template
BENCHMARKING TOOLSET

github.com/pmem/rpma/tree/master/tools/perf

ib_read.sh

rpma_fio_bench.sh

create_report_figures.sh

csv_compare.py

create_report.py

Fio engines
Visit

- [pmem.io/rpma](https://pmem.io/rpma) for official documentation
- [github.com/pmem/rpma](https://github.com/pmem/rpma) to
  - build the library
  - run the examples
  - setup the benchmarking environment

You do not need neither an Intel® Optane™ PMem nor RDMA-capable NIC to start examples

You can play with RPMA examples on any Linux desktop
THANK YOU
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IS THE LIBRPMA ATOMIC WRITE AN ATOMIC OPERATION?

- IBTA Spec does not support atomicity for RDMA Write

- librpma implementation assumes the aligned 8-byte data won't be torn either in RDMA HW/SW stack or on the PCIe bus level

- The current implementation explicitly uses fencing to ensure ordered data processing according to the upcoming RDMA.AtomicWrite ordering rules

- The native RDMA.AtomicWrite will be used whenever and wherever it will be available