Persistent Memory Workshop

libmemkind, libpmem & libpmemobj-cpp hands-on

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https://github.com/pmemhackathon/2019-07-23

What Does “Hackathon” Mean To Us?

- Main goal is to show you how to find, configure, and program pmem
    - All slides are in the GitHub repo
    - All shell commands we type are in the GitHub repo
        - You probably don’t need to write them down
        - You probably don’t even need to type many of them, just cut & paste into the shell
    - Go to https://github.com/pmemhackathon/2019-07-23 to see today’s repo
        - But in a minute, we’ll demonstrate cloning the repo to your VM
- Mostly we will show you how to install stuff and get you going
    - After installing samples, try them out, or write your own
    - We’ll walk through some for everyone, then will walk around & help you

Agenda

- Logistics
  - How to login to your VM & get it ready
- Persistent Memory Platform Support
  - Platform level support
  - Checking out your kernel
  - Finding and configuring your pmem
- Persistent Memory Programming
  - Installing libraries and tools (pmdk, libmemkind, libpmemobj-cpp, valgrind)
  - Using libmemkind and libpmem
  - Using libpmemobj-cpp:
    - Finding bugs related to persistent memory programming
    - Converting volatile queue to persitent one
    - Hashmap example

Login and make a local clone of the hackathon repo

```
Hostname: devhost.pmemhackathon.io       Port: 31005
Username: pmdkuser{1…50}
```

```
$ cd
$ git clone https://github.com/pmemhackathon/2019-07-23
Cloning into '2019-07-23'...
remote: Enumerating objects: 14, done.
remote: Counting objects: 100% (14/14), done.
remote: Compressing objects: 100% (13/13), done.
remote: Total 14 (delta 1), reused 14 (delta 1), pack-reused 0
Unpacking objects: 100% (14/14), done.
$ cd 2019-07-23
$ more README.txt
```

Most of the shell commands we type during demos are in this README.txt

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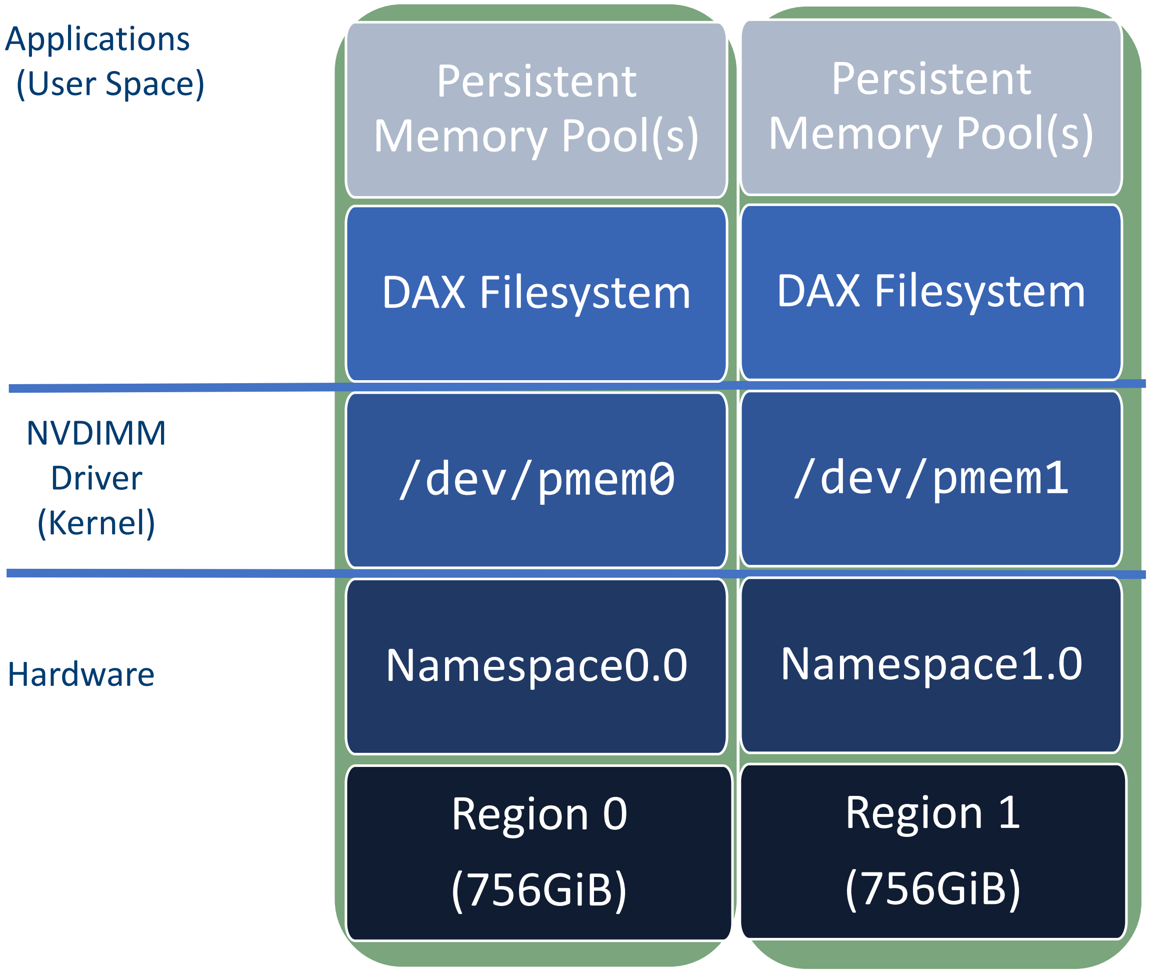
Does your System Support Persistent Memory?

- Does my platform support persistent memory?
  - Your vendor determines this. Buy a system meant for it.
    - Don't just buy an NVDIMM and plug it into a random system – you need platform support (like BIOS, ADR, power supply). You want validated configurations.

```
ndctl list -BN     # check the "provider" field for ACPI.NFIT
```

- Does my OS support persistent memory?
  - Major OS vendors (and Linux distros) will tell you which version supports it
  - Linux kernel support is enabled in the config file used to build the kernel

```
uname -r        # see kernel currently running
grep -i pmem /boot/config-`uname -r`
grep -i nvdimm /boot/config-`uname -r`
```



Persistent Memory Modules
(Interleave sets)

```
$ pmempool create /mnt/pmem-fsdax0/pool0
$ pmempool create /mnt/pmem-fsdax1/pool1


# mkfs.ext4 /dev/pmem0
# mkfs.ext4 /dev/pmem1
# mount -o dax /dev/pmem0 /mnt/pmem-fsdax0
# mount -o dax /dev/pmem1 /mnt/pmem-fsdax1


 # ndctl create-namespace
 # ndctl create-namespace
```

Vendor Neutral

```
 # ipmctl create -goal PersistentMemoryType=AppDirect
```

Vendor Specific

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Essential Programming Background

- Lots of ways to use pmem with existing programs
  - Storage APIs
  - Libraries or kernels using pmem transparently
  - Memory Mode
- This hackathon doesn’t cover the above (too easy!)
  - We assume you want direct access to pmem
  - We show code, but also concepts
  - There are lots of paths you can take, these are just examples

Programming Examples For This Hackathon

- Volatile alloc and free
- Persistent write
- Simple persistent counter
- Converting volatile queue to persistent one
- Implementing a hashmap
- Processing data on persistent memory using map reduce

Resources

- PMDK Resources:
  - Home: https://pmem.io
  - PMDK: https://pmem.io/pmdk
  - PMDK Source Code : https://github.com/pmem/PMDK
  - Google Group: https://groups.google.com/forum/#!forum/pmem
  - Intel Developer Zone: https://software.intel.com/persistent-memory
  - libpmemobj-cpp: https://github.com/pmem/libpmemobj-cpp
  - valgrind: https://github.com/pmem/valgrind
  - memkind: https://github.com/memkind/memkind
- NDCTL: https://pmem.io/ndctl
- SNIA NVM Programming Model: https://www.snia.org/tech_activities/standards/curr_standards/npm
- Getting Started Guides: https://docs.pmem.io

Getting started

- Get hackathon repo:

```
$ git clone http://github.com/pmemhackathon/2019-07-23
$ cd 2019-07-23
```

- How to compile examples?
  - Simply run:

```
$ make
```

Libmemkind

Volatile allocate and free

- Use pmem as volatile memory
- Libmemkind provides APIs to manage the space on pmem
- Run:

```
$ ./volatile /mnt/pmem-fsdax0/${USER}/
```

Libpmem

Persistent write

- Libpmem provides primitive APIs to write data on pmem persistently
- Copy a file to pmem and check its content
- Run:

```
$ ./simple_copy simple_copy.c /mnt/pmem-fsdax0/${USER}/simple_copy.c
```

libpmemobj-cpp

libpmemobj-cpp – what you will need?

- **pool<T>** pool<T>::open**(const std::string** &path, **const std::string** &layout)
- **peristent_ptr<T>** pool<T>::root()
- **void** transaction::run(**pool_base**& pool, **std::function<void()>** tx, ...)
- **peristent_ptr<T>** pmem::obj::make_persistent<T>(**Args** &&... args)
- **void** pmem::obj::delete_persistent<T>(**peristent_ptr<T>** &ptr)
- Types: p<T>, peristent_ptr<T>

Persistent counter – what you should do

- Make sure you have the newest version of hackathon repo:
- Change warmup.cpp to print bigger number every time you run it
    - Add variable (a counter) to root struct
    - Increment the variable inside „inc” method
    - Return new value
- Expected result:

```
$ pmempool create obj --layout=warmup -s 100M /mnt/pmem-fsdax0/${USER}/warmup
$ ./warmup /mnt/pmem-fsdax0/${USER}/warmup
1
$ ./warmup /mnt/pmem-fsdax0/${USER}/warmup
2
```

Pmemcheck – persistent memory error detector

- Checks for non-persistent stores
- Checks for overwrites
- Checks for stores made outside of a transaction
- Checks for snapshotting the same object in two different threads
- Can be found here: https://github.com/pmem/valgrind

Pmemcheck – installation and usage

- Installation

```
$ git clone https://github.com/pmem/valgrind
$ cd valgrind
$ ./autogen.sh
$ ./configure [--prefix=/where/to/install]
$ make install
```

- Usage

```
$ valgrind --tool=pmemcheck [valgrind options] <your_app> [your_app options]
```

Find bugs – what you should do

- Run:

```
$ pmempool create obj --layout=find_bugs -s 100M /mnt/pmem-fsdax0/${USER}/find_bugs
$ valgrind –tool=pmemcheck ./find_bugs /mnt/pmem-fsdax0/${USER}/find_bugs
```

- Fix bugs reported by valgrind and run valgrind again

Queue – what you should do

- Implement a persistent version of queue
- It should be based on volatile queue (modify queue.cpp file)
- Usage for volatile version:

```
$ ./queue
$ push 1
$ pop
```

- Usage for persistent version

```
$ pmempool create obj --layout=queue -s 100M /mnt/pmem-fsdax0/${USER}/queue
$ ./queue_pmemobj_cpp /mnt/pmem-fsdax0/${USER}/queue
$ push 1
$ show
```

Step-by-step

1. Open a pool using a **path** variable and supply „queue” as layout.
2. Obtain pointer to the root object
3. Change volatile pointers to persistent ones
4. Change memory allocations
5. Add transactions

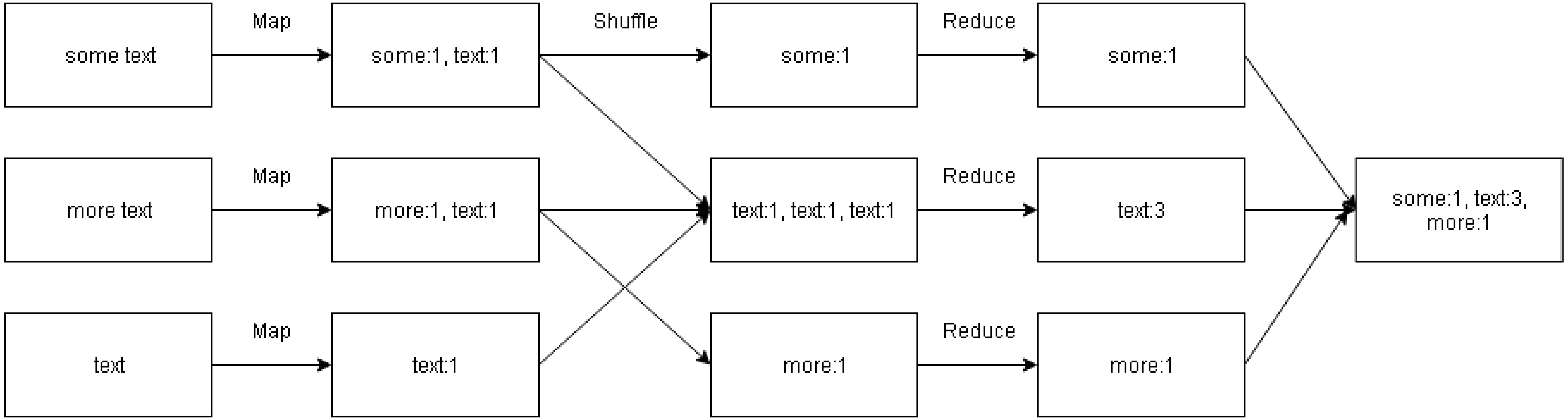
Hashmap

- Implement a hashmap with following interface:
  - at(key)
  - Insert(key, value)
- To check if it works, compile and run:

```
$ pmempool create obj --layout=simplekv -s 100M /mnt/pmem-fsdax0/${USER}/simplekv-simple
$ ./simplekv_simple /mnt/pmem-fsdax0/${USER}/simplekv-simple
```

Map reduce

- Programming model for processing and generating big data sets
- Consists of Map, Reduce and Shuffle steps
  - Map – performs filtering, transformation or sorting
  - Shuffle – redistributes data based on the output keys produced by map step
  - Reduce – summary operation (reducing list of values)



Map reduce example

- This example uses MapReduce to count words in text files
- MapReduce is implemented using:
  - std::transform - https://en.cppreference.com/w/cpp/algorithm/transform
  - std::accumulate - https://en.cppreference.com/w/cpp/algorithm/accumulate
- usage (also in README.txt):

```
$ pmempool create obj --layout=simplekv -s 100M /mnt/pmem-fsdax0/${USER}/simplekv-words
$ ./simplekv_word_count /mnt/pmem-fsdax0/${USER}/simplekv-words words1.txt words2.txt
```

More Developer Resources

- Find the PMDK (Persistent Memory Development Kit) at http://pmem.io/pmdk/
- Getting Started
  - Intel IDZ persistent memory- https://software.intel.com/en-us/persistent-memory
  - Entry into overall architecture - http://pmem.io/2014/08/27/crawl-walk-run.html
  - Emulate persistent memory - http://pmem.io/2016/02/22/pm-emulation.html
- Linux Resources
  - Linux Community Pmem Wiki - https://nvdimm.wiki.kernel.org/
  - Pmem enabling in SUSE Linux Enterprise 12 SP2 - https://www.suse.com/communities/blog/nvdimm-enabling-suse-linux-enterprise-12-service-pack-2/
- Windows Resources
  - Using Byte-Addressable Storage in Windows Server 2016 -https://channel9.msdn.com/Events/Build/2016/P470
  - Accelerating SQL Server 2016 using Pmem - https://channel9.msdn.com/Shows/Data-Exposed/SQL-Server-2016-and-Windows-Server-2016-SCM--FAST
- Other Resources
  - SNIA Persistent Memory Summit 2018 - https://www.snia.org/pm-summit
  - Intel manageability tools for Pmem - https://01.org/ixpdimm-sw/