Thinking Persistently

Designing applications for persistent memory

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Persistent window

- Key concept is persistent window
  - When is data volatile? when is data persistent
- What is required to recover from application/hardware failure?
- What is required for your application?
- pmem_persist() or pmem_flush() pmem_drain() required to ensure data is on disk
  - None of these are atomic!
  - Failure mid drain could result in undefined data state

Volatile Persistent Memory Usage

- For correctness nothing special is required here, you can simply use the persistent memory as volatile memory
- If you are using pmdk pmem then you will want to clean up files after your application finishes
  - Otherwise you will take up space on the device(s) even after reboot
  - Or data may be visible to others after your application has finished
- Performance considerations are important
  - Asymmetry of read and write may have a big impact
  - Caching may help for write, but it depends on your access pattern (write after eviction requires read first)

Non-volatile Persistent Memory Usage

- Strategy needed to recover data on failure
- Transactional approach
  - Use higher level pmem library functions
- Application logic
  - Using low level pmem functions
- Main focus is hardware failure
  - i.e. reboot but memory still intact
- Data resiliency another issue
  - What if an NVDIMM fails
  - Using low level pmem functionality there is no automatic redundancy
  - No RAIDing

Current functionality

- Can your application cope with failure during I/O at the moment?
  - Failure during POSIX I/O can easily lead to files in mixed states
  - Failure even after I/O routines finish may lead to mixed states (O/S caching)

- However, persistent memory usage is likely to change your application design
  - So consider this from the beginning

How to ensure consistency?

- Simplest option is to double up on key data:
  - Work on current data in one set of arrays/variables
  - Have previous iteration/timestep/update of data in another set of arrays/variables
  - Once current data is persisted set a persistent variable to indicate which is correct
  - Then switch to the other set of arrays
- This involves potential data copies and doubling memory requirements, so may not be desirable…
- Read from DRAM/pmem, write to DRAM
  - Persistent to pmem
  - Block dataset and keep working set in DRAM
  - Persist as required
  - Only persisting a subset of data at any one time, so only require duplication of this subset
- Finer granularity
- More sensible performance choices

How to ensure consistency?

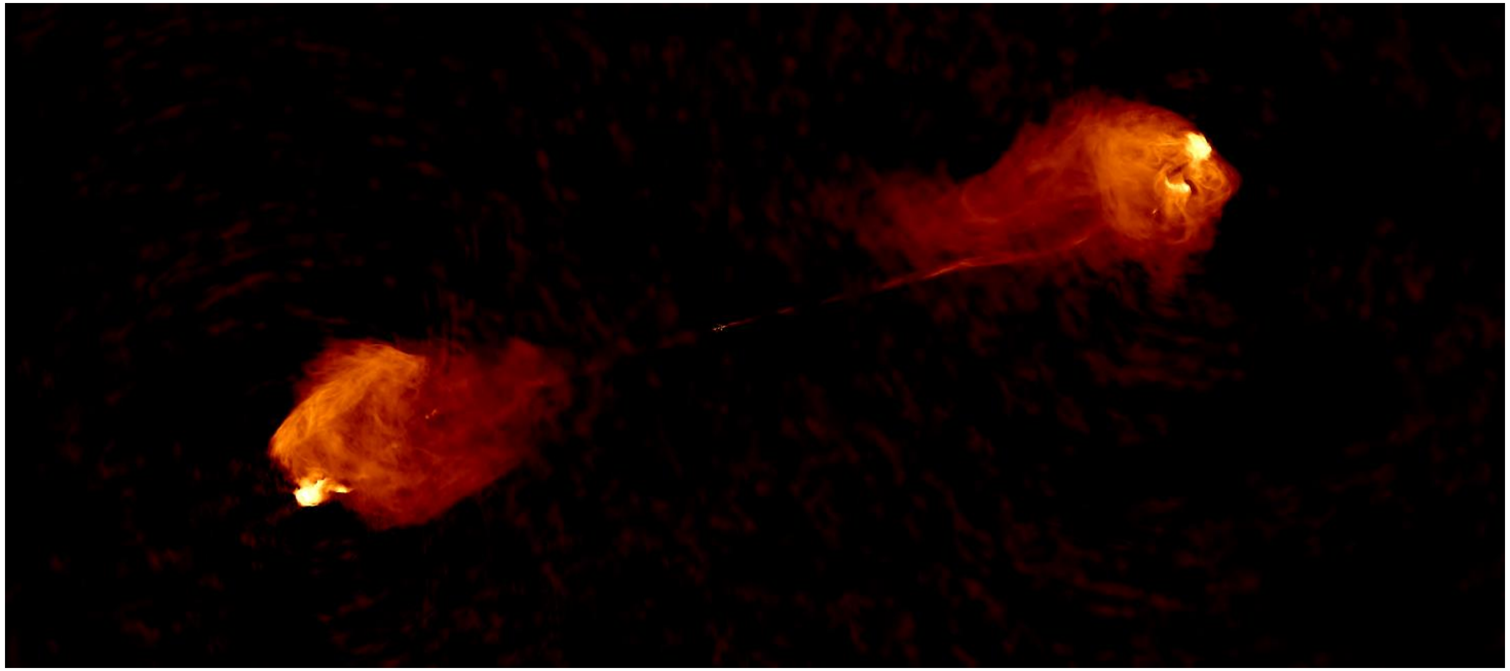
- Guard persist calls with variable change, i.e.:

```
checkpoint_flag = -1
pmem_persist(checkpoint_flag, 1)
pmem_persist(checkpoint, 100000);
checkpoint_flag = 1
pmem_persist(checkpoint_flag, 1)

…
Load checkpoint flag
if(checkpoint_flag == 1){
  read_checkpoint)
}
```

How to ensure consistency?

- Use persistent memory for read only datasets
  - For applications dominated by input datasets may be sensible
  - Bio-informatics, ML, image processing
  - Large datasets that don't get changed



Persistent safety

- As with filesystems, some level of redundancy is required to ensure data is safe
- This could be copies of data
  - Both within a single run, and across runs
- More intellegent safety options are possible
  - Erasure coding
  - Append write
  - Mirroring
- Consider using a higher level product
  - i.e. DAOS

Visibility and Persistency

- Coherency != Persistency
  - There are differences between threading and memory coherency (visibility) and persistence coherency
- Persistency coherency not enforced in hardware
  - Changes to the same non-volatile memory location from different threads
- Avoid multi-threaded *persisting* unless you really know what you're doing

Summary

- Working out what to put in Persistent Memory, when to persist, and when you can be sure something is safe is key
  - This is the main challenge for using byte-addressable persistent memory (B-APM) such as Optane DCPMM
- Using as a filesystem removes this issue
  - Because POSIX
- For true B-APM work filesystems will reduce achievable performance
  - Better off buying SSDs
  - But potentially a sensible stop-gap approach (think OpenMP rather than MPI)