Transparently Consistent Asynchronous Shared Memory

Hakan Akkan, Latchesar Ionkov, & **Michael Lang**

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Motivation: Current Trends

- High core count sockets and nodes
- Power is a big concern
- Future architectures suggest
  - Lower clock speeds
  - Less memory per core
- New memory technologies
  - NVRAM
  - Memory Cube
- Therefore, intra-node sharing is becoming more important

Motivation: What problem are we trying to solve?

Data Movement/Memory requirements

- Per core memory is decreasing but total memory will be increasing
- There is more data to move around for analysis, visualization etc.
- New trend: Do it all in the node, while the application is running
  - Reduce the amount of data to store
  - Reduce the power/time to transmit data
- Applications share the node and the data is now local to two or more applications

Goals

TCASM – Shared memory for coupling independent applications

- **T -- Transparent**
  - No large code modifications
  - Publish version
  - Want to allow app to make progress
- **C – Consistent**
  - Data doesn't change while being processed
- **A -- Asynchronous**
  - Want to allow apps to make independent progress
- **SM – Shared Memory.**

Motivation: Who would benefit

- **Analytics**: reduce the data in the node
- **Visualization**: view the data in the node in REALTIME
- **Checkpointing**:
  - Burst-buffer – hierarchical storage, faster than PFS, close to node
- **NVRAM Management**
- **Debugging**: unobtrusively monitor what is happening inside the application
- **Application developers**
  - Just define data
  - No need to link processes
  - Application remain independent

Background/Related work

- **Checkpoint**: BLCR, CRIU
  - No for sharing between apps
- **Distributed memory** MUNIN,…
- **KSM**: Kernel same page merging
  - Kernel thread tries to merge pages with the same data
  - Also uses COW
  - MADVISE marks regions for merging
  - Single process space
  - No versioning
- **Virtual processes:** DUNE
  - Uses virtual processes (rather than virtual machines)
  - Can share pages, need common process parent

Solution

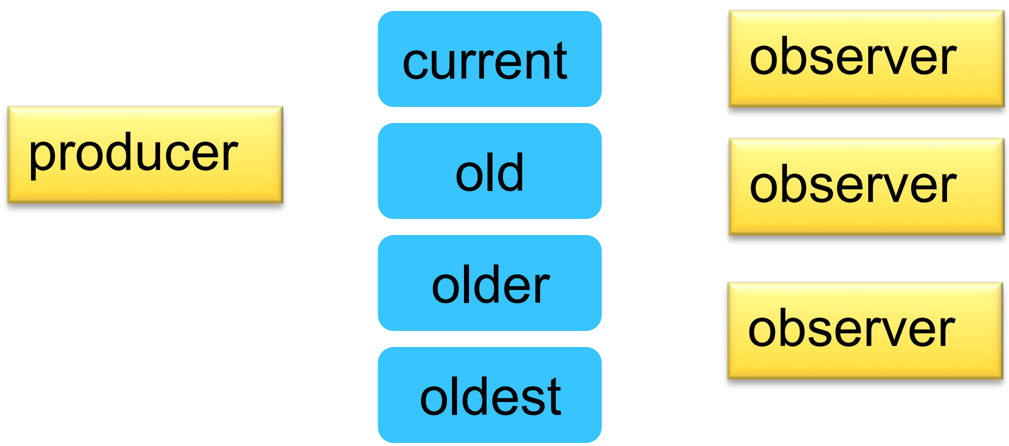
- Producer / Observer(s) Model
  - Producer publishes data at its natural interval
  - Consumer consumes at natural interval
- Need a way for applications to share data with simple semantics
  - Use existing MMAP system call
- No synchronization
  - Producer is never blocked.
- Observer sees consistent view of data
- COW
  - No wasted memory
  - Data is only copied when required
  - Memory use depends on how much memory producer modifies at each iteration

Current methods

- Single Copy – requires locking between processes, standard shared memory

- Double-buffer – Two buffers, still need to coordinate the buffer swap

- Multibuffer – no synchronization, lots of memory (N copies, N-1 observers)

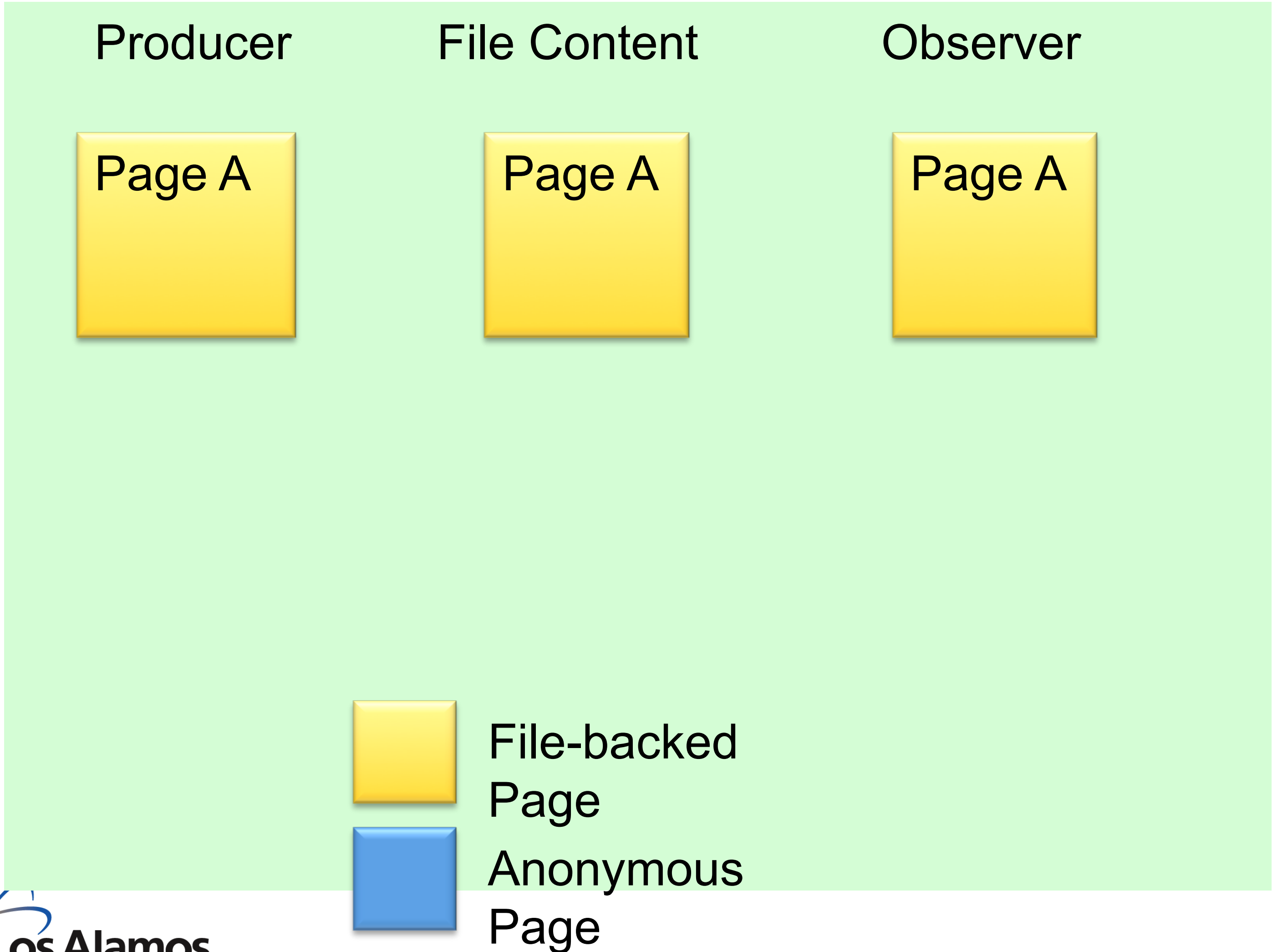


Implementation 1 – anon-asm

- **New flag added to msync() call**
- **Uses a combination of “mmap”ed anonymous and file backed pages to manage versions of data**
- **Write protect pages to get notification when changed**
  - Not cheap but already in use with many incremental checkpoint systems.
- **This implementation has higher overhead with multiple observers**

Walk through an example… next

Anon-asm



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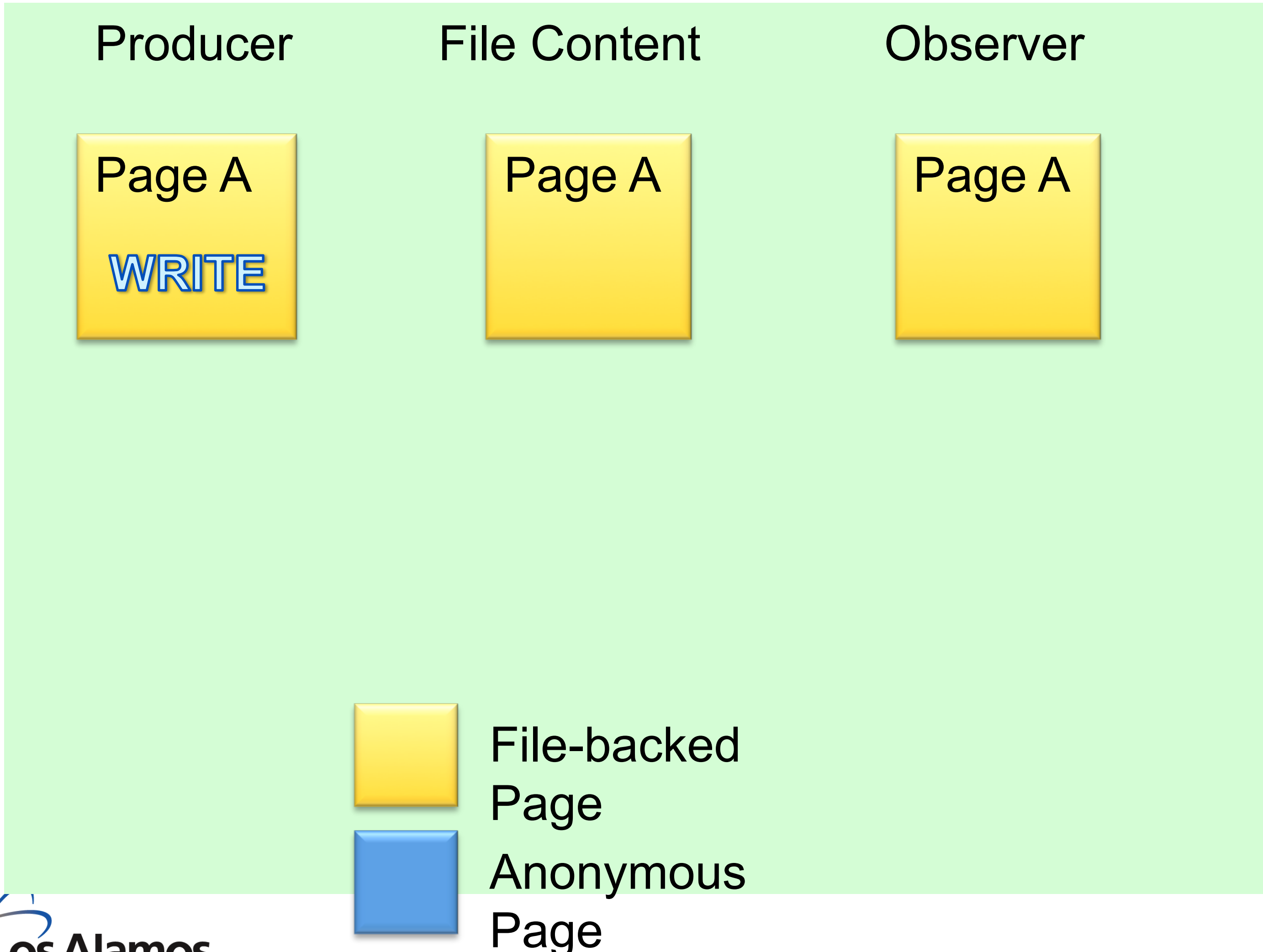
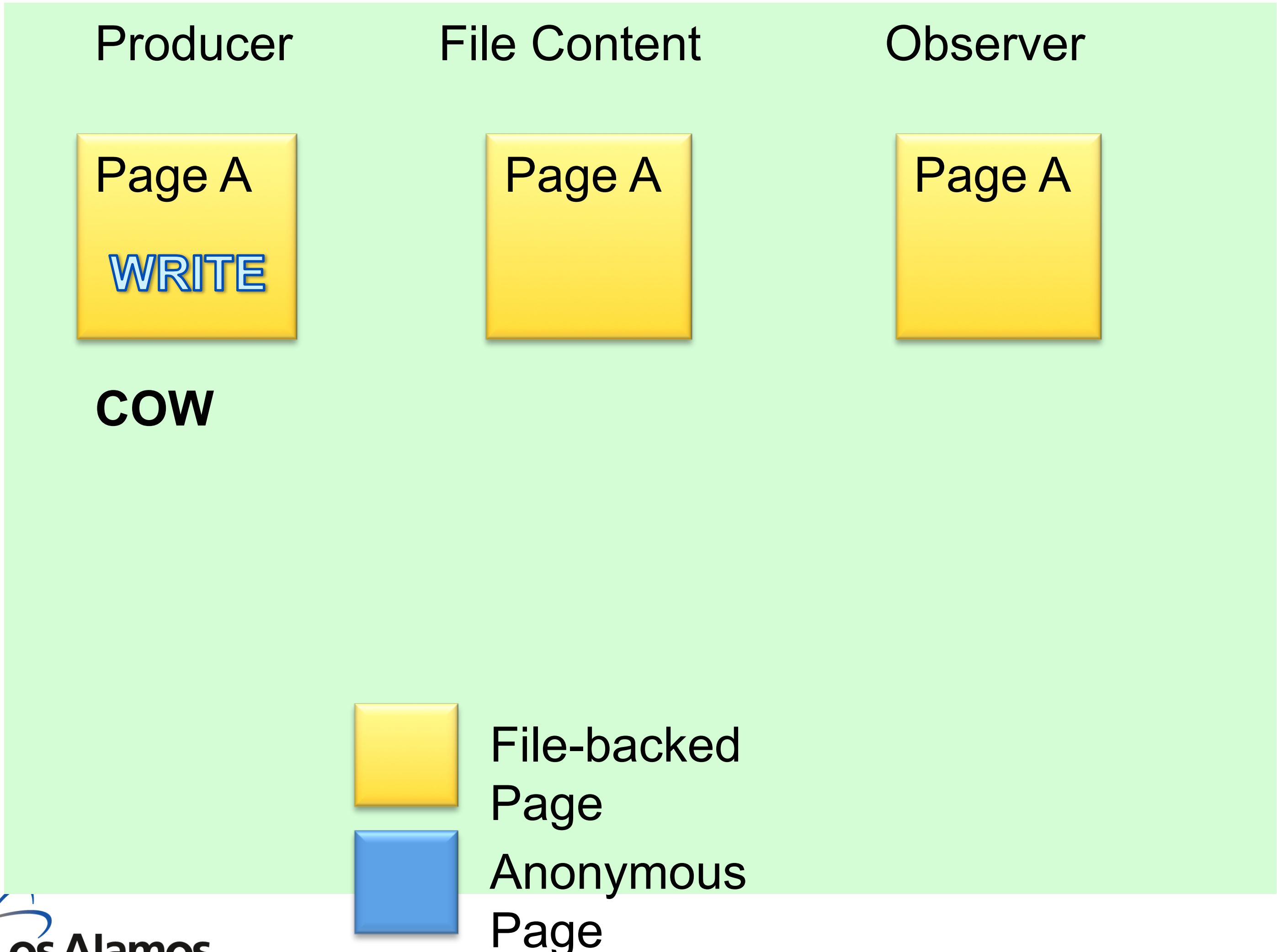
Producer writes



Causes COW



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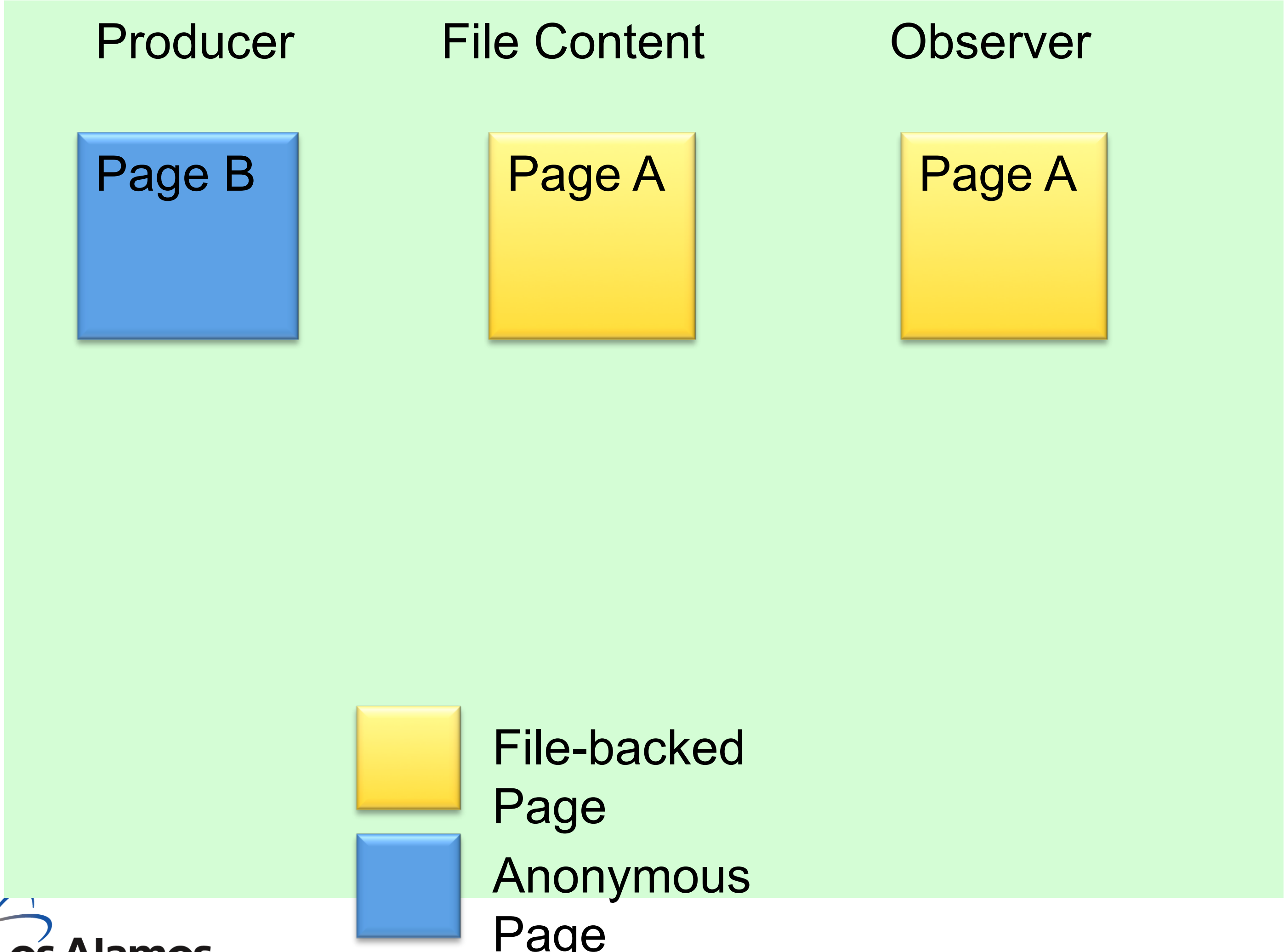
Anonymous page



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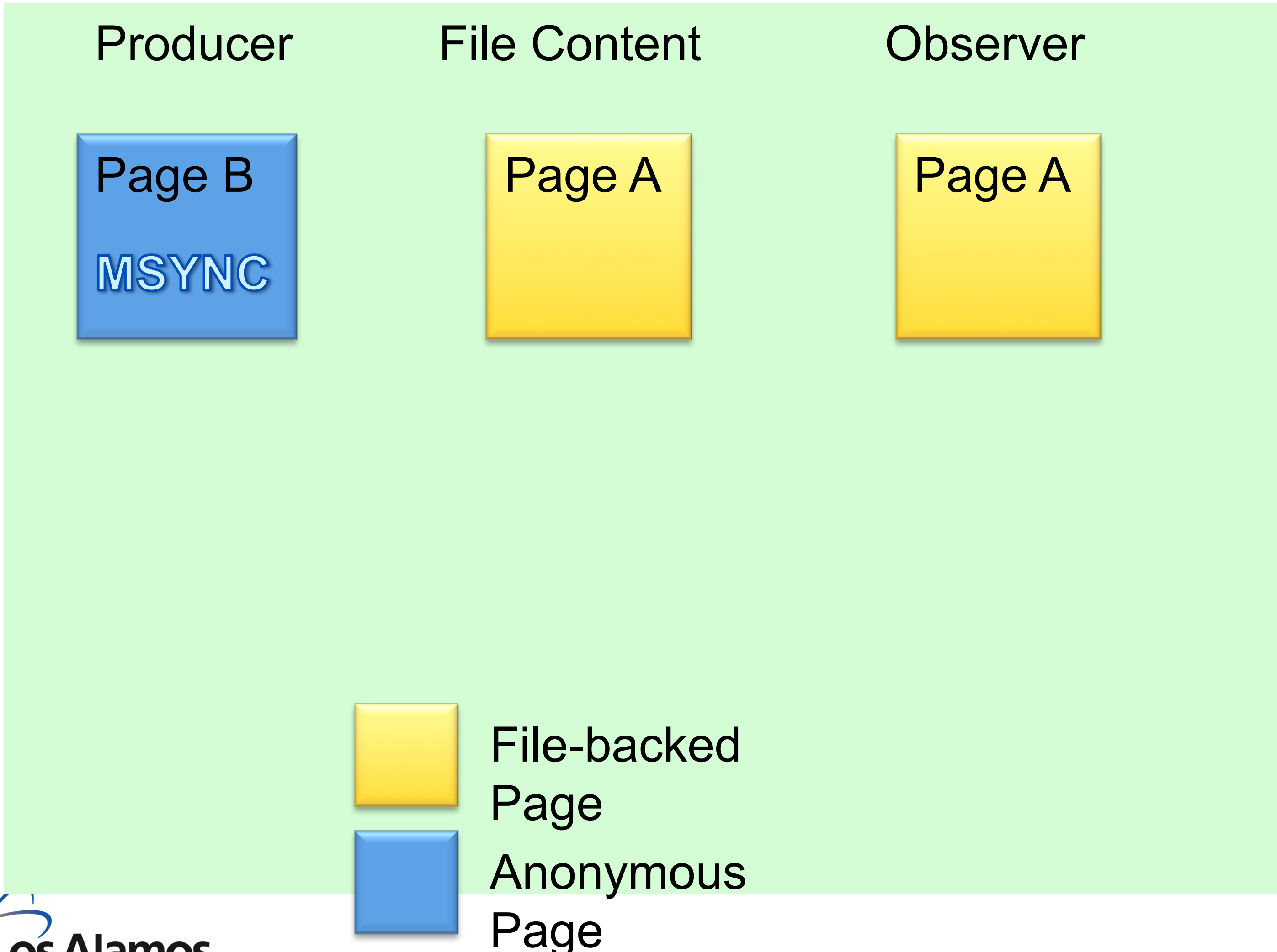
Producer calls msync()



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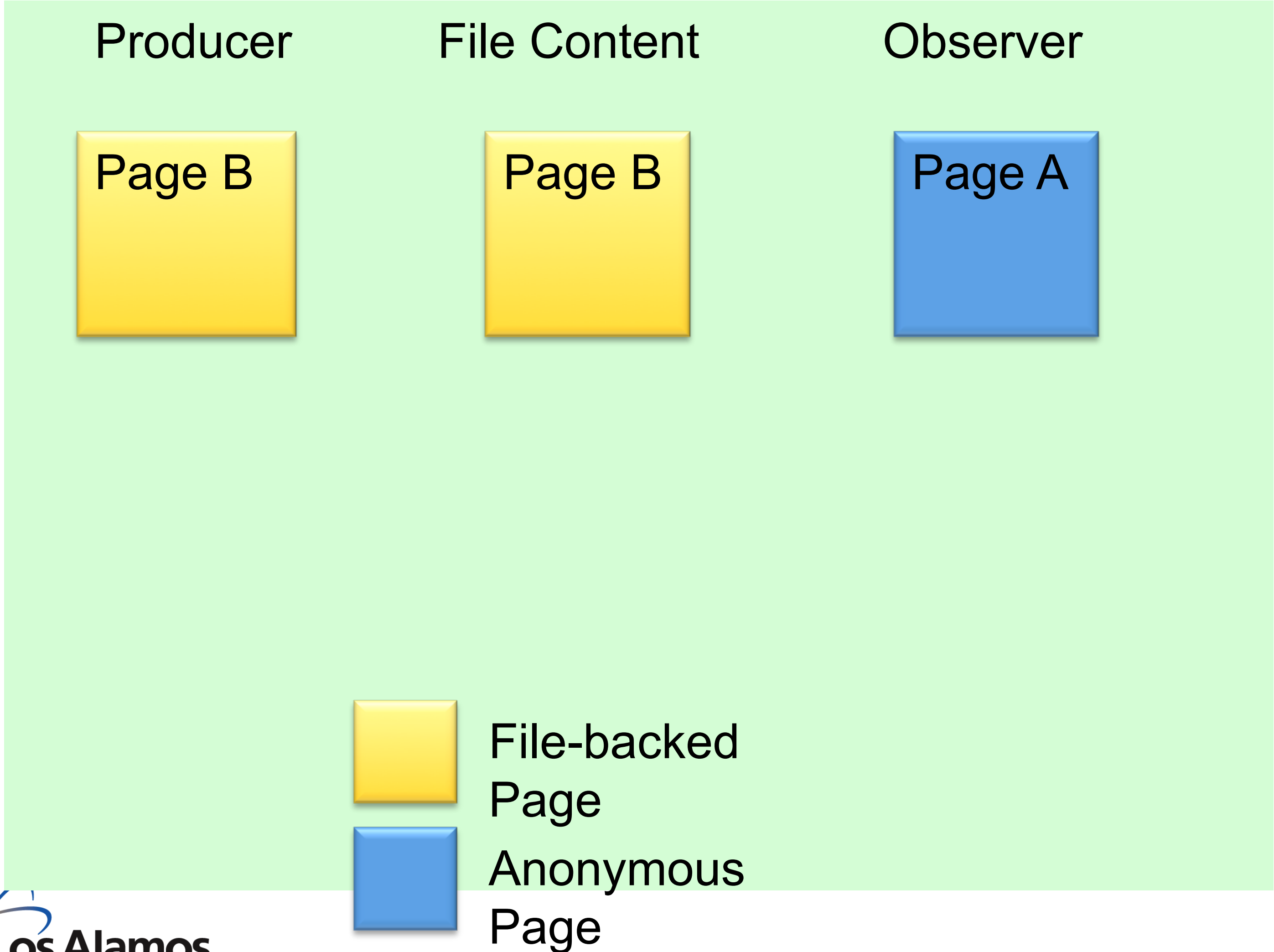
Producer calls msync()



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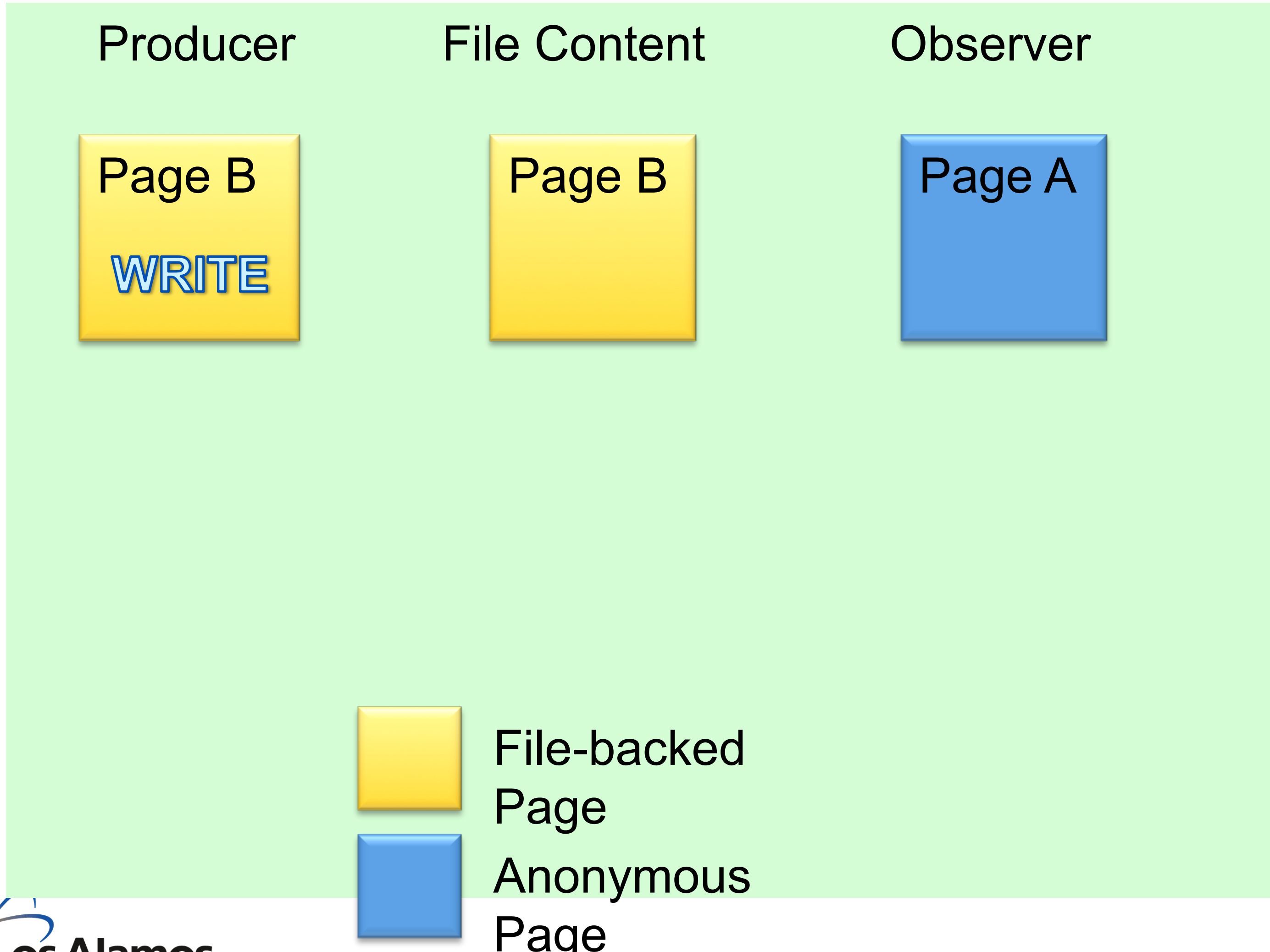
Producer writes again



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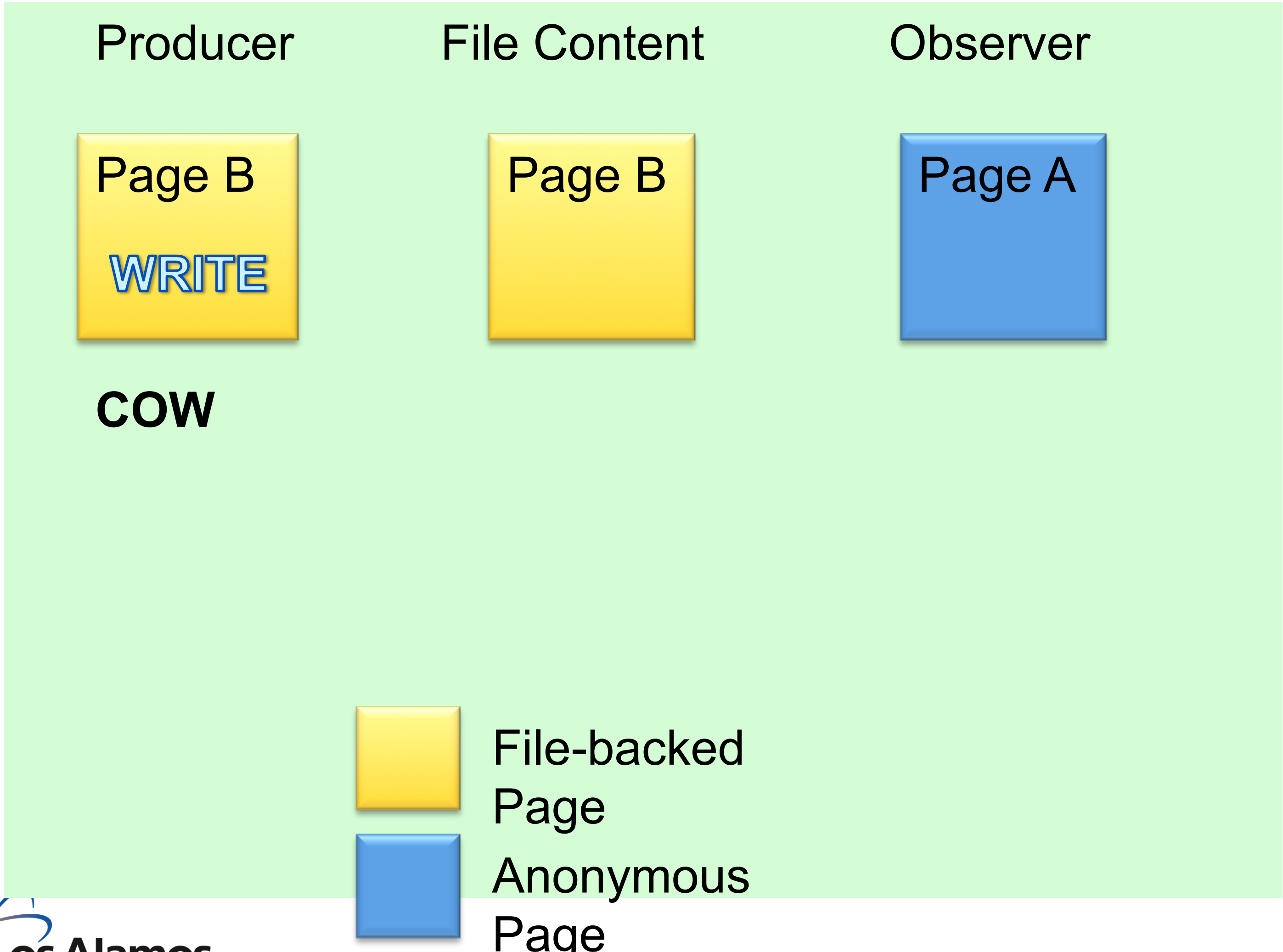
Causes COW



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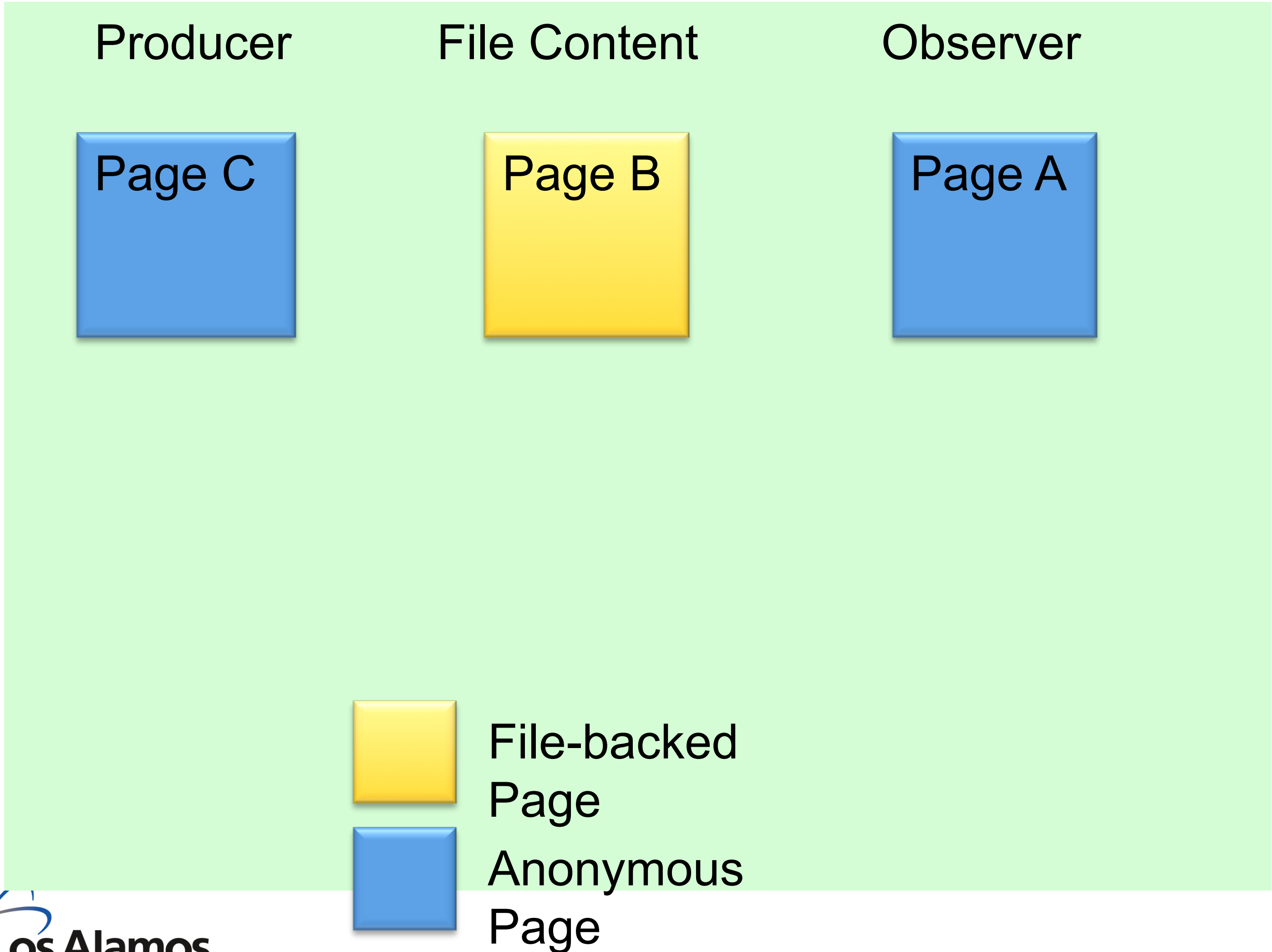
Anonymous pages



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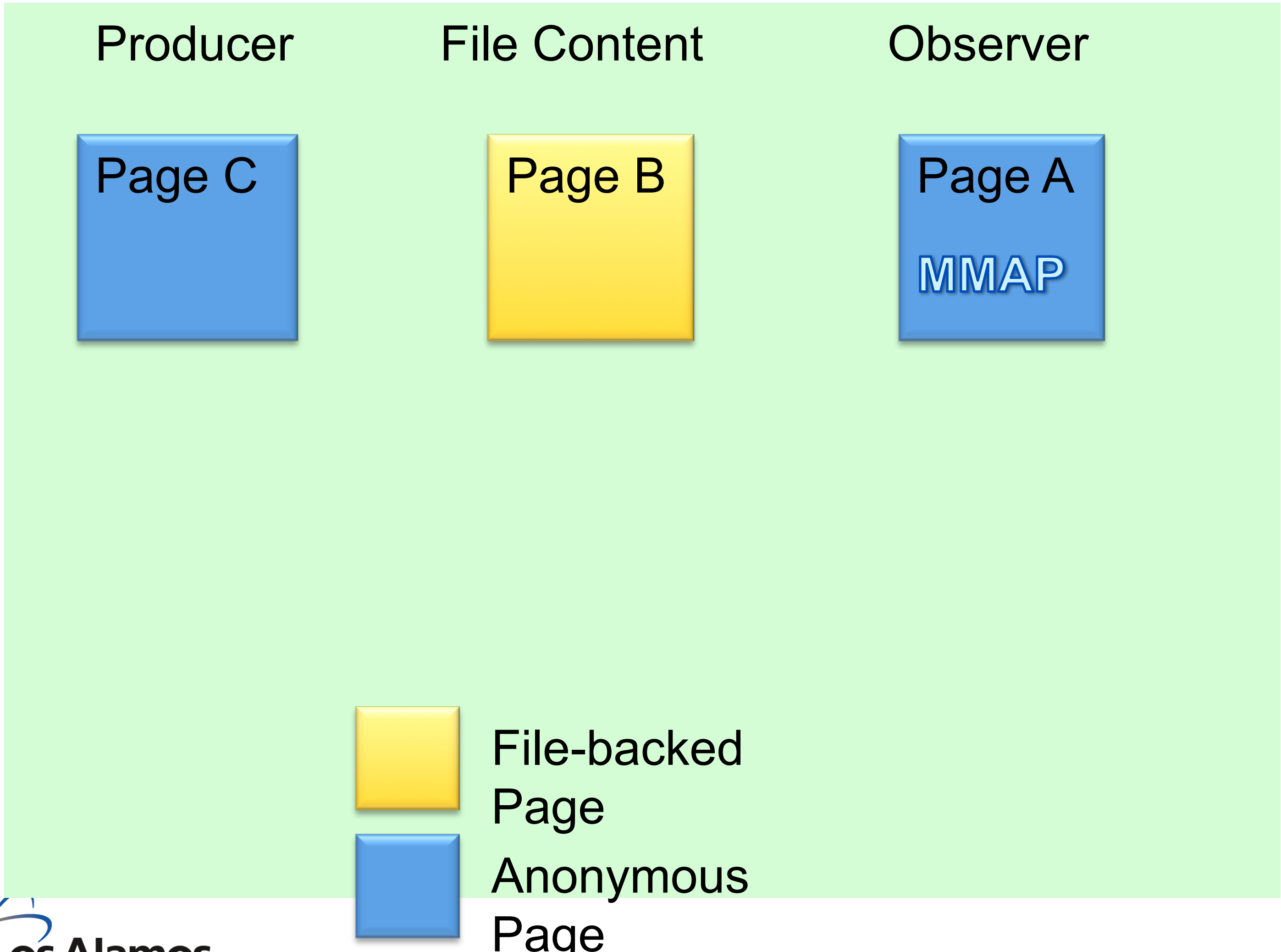
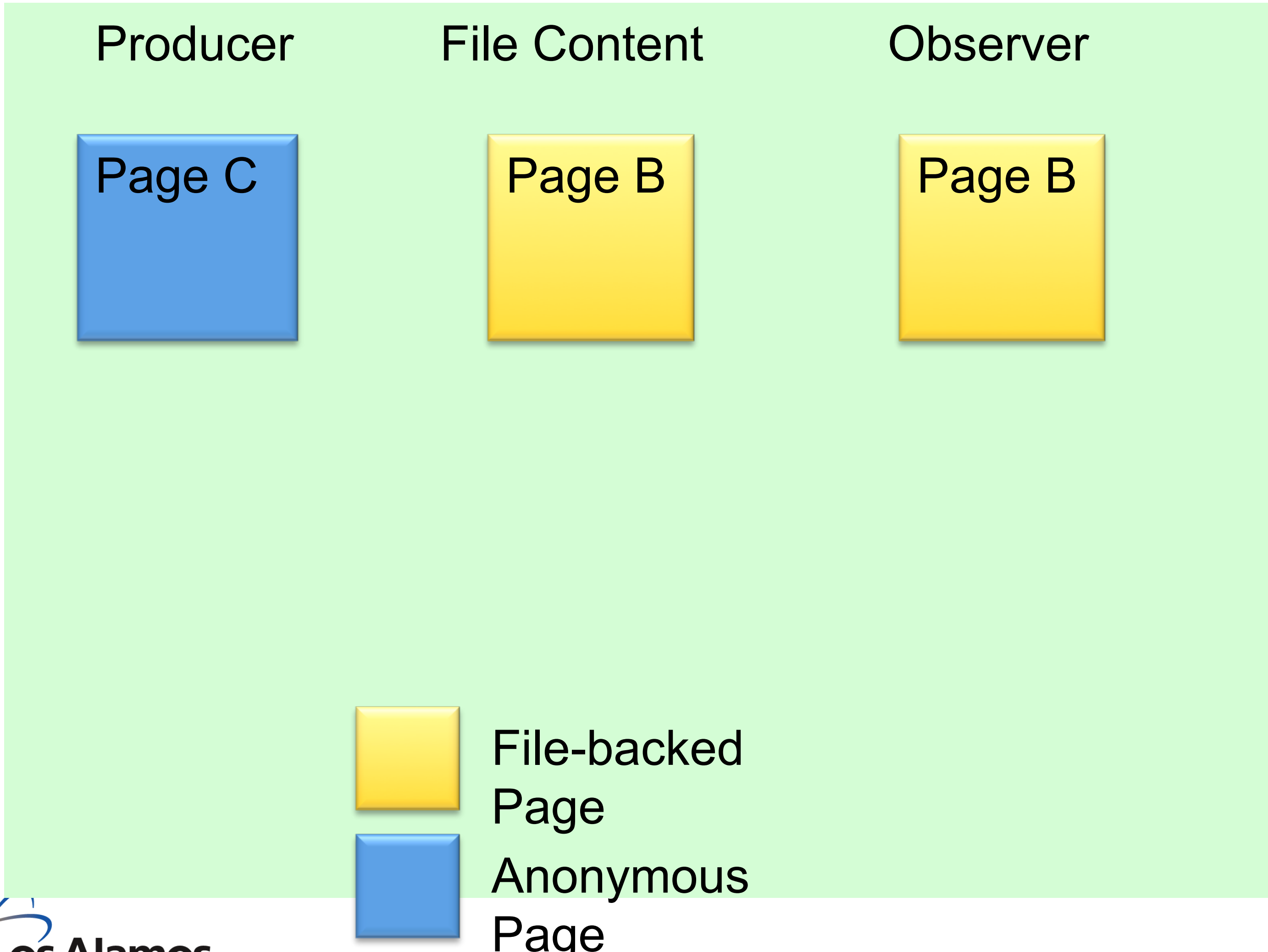
Observers call mmap() for new version



Observers gets new version



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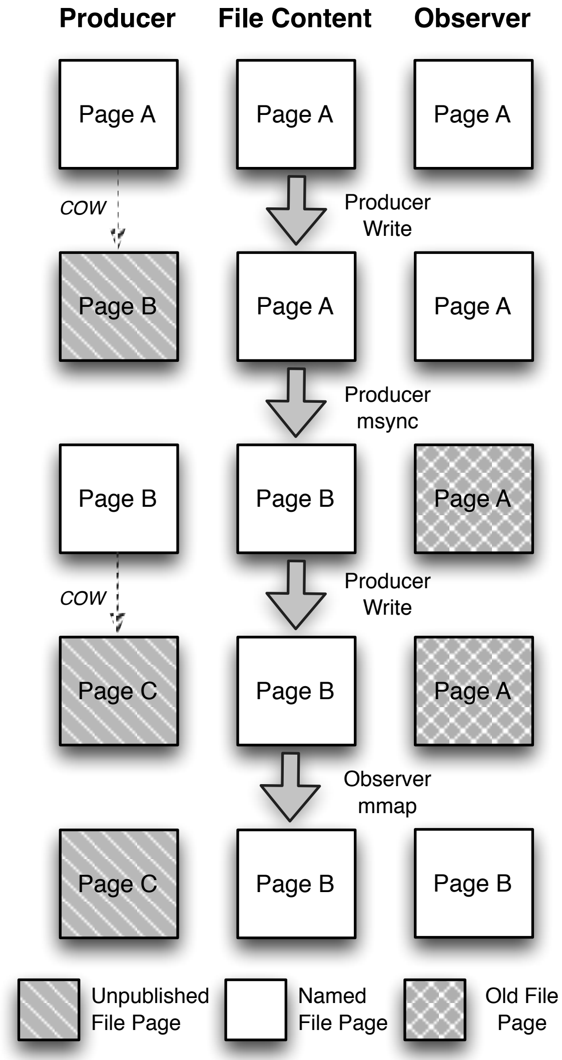
Implementation 2 – file-asm

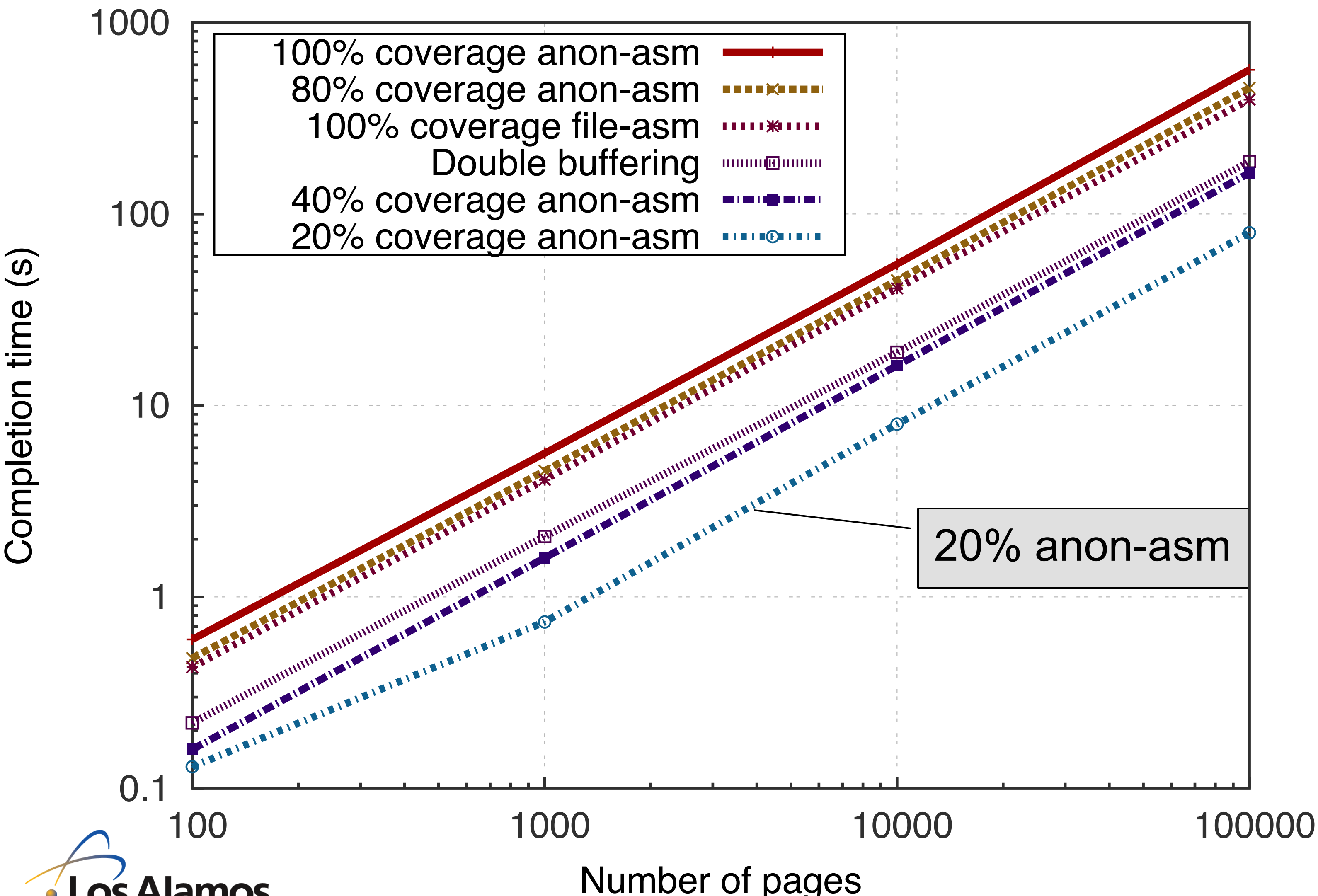
- **Again we use flags to msync**
- **When producers write we create a file-backed page, “unpublished”**
- **Then when producers call msync we swap files**
  - Unlink old file, give unpublished file proper name
- **Observer unmap – open “file” -- mmap to access latest copy**
- **Easier implementation**
- **Better performance with multiple observers, but there is a downside…**
  - “file-asm” implementation incurs the "full-copy" penalty due to a Linux restriction that only allows pages to belong to a singe file
  - A kernel module can remedy this, work-in-progress

File-asm

Same flow, exchange of *named* files and *unpublished* files



Results – varying pages touched



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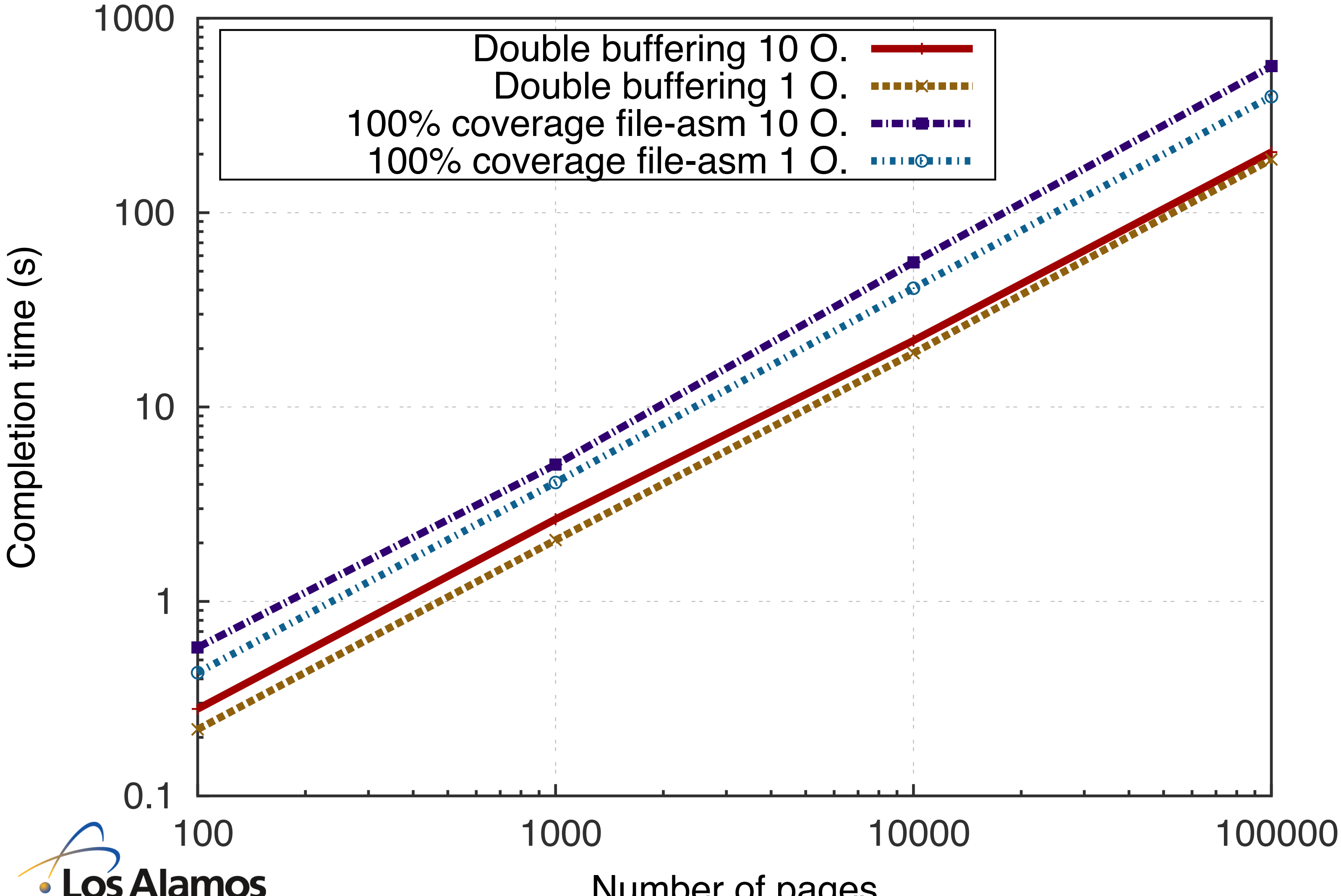
Results 100% coverage, with 1 or 10 observers

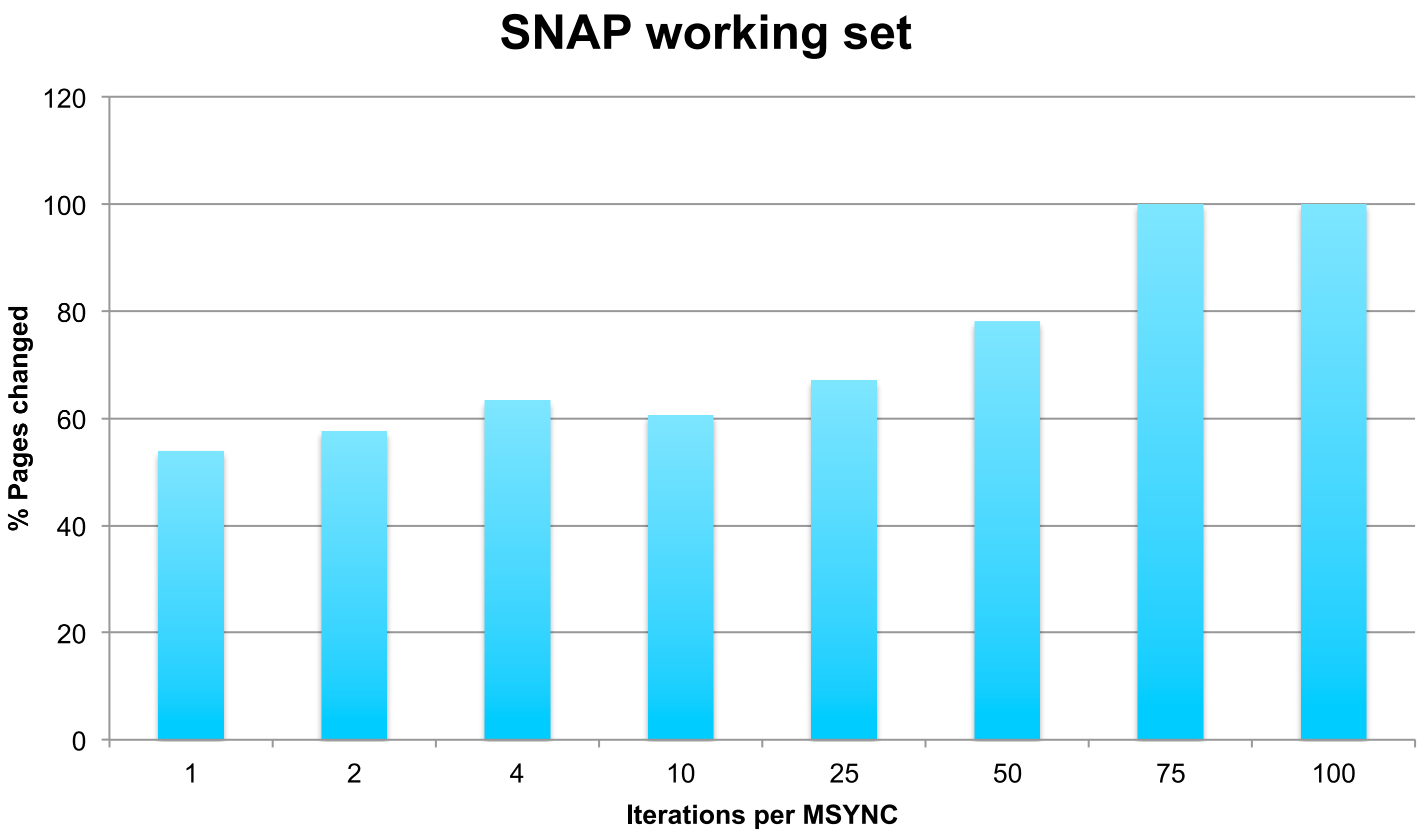


Application testing (new work since publication *)

- **Currently integrated with LANL mini-app SNAP (SN transport proxy)**
  - Implemented FORTRAN callable library in C
    - MMAP and MSYNC
  - Implemented consumer to copy data to stable storage (ie burst-buffer)
  - Tested with multiple threads

*Doug Otstott (Florida International University)

“New” initial DATA



Conclusions

- Prototype shows benefit of approach
- COW shared memory for symbiotic applications
- No synchronization requirement
- Saves memory (SNAP use case)

Future Work

- Complete burst-buffer use case
- Additional use case for visualization (paraview)
- Performance with many producers/consumers in the system
- Looking at porting to Kitten/Palacious

Questions ???

Targeted for open source, paperwork in the system.

Thanks