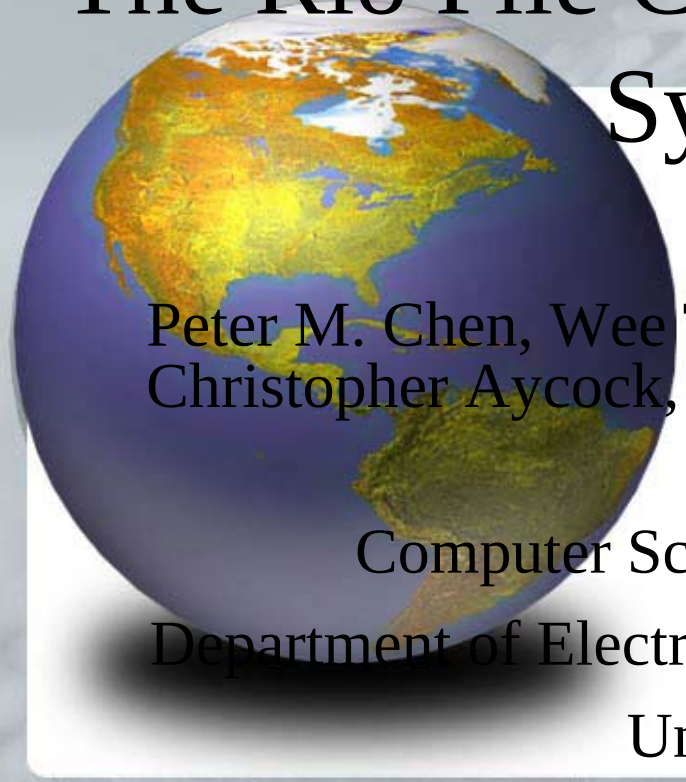
The Rio File Cache: Surviving Operating System Crashes



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Introduction – 1/2

- Memory's vulnerability to power outages is easy to understand and fix.
- Memory's vulnerability to OS crashes is more challenging.

Introduction – 2/2

- A tradeoff between performance and reliability.
  - Asynchronously writing data to disk -- a greater degree of overlap between CPU time and I/O time.
  - delaying some writes to disk. This delay is often set to 30 seconds.
  - maximum performance : a pure write-back scheme -- data is written to disk only when the memory is full.

Design and Implementation : Protection – 1/3

- Access interface is the reason most people view battery-backed memory more vulnerable than disk.
- The interface used to access disk is complex.
- In contrast, the interface used to access memory is simple. It is hence relatively easy for many simple software errors (EX. de-referencing an uninitialized pointer.)

Design and Implementation : Protection – 2/3

- Unified Buffer Cache(regular files) is sometimes not mapped into viutual page –”dynamically” conserve TLB slot.
- Turn off the write-permission bits in the page table to do protection.
- File cache procedure can check corruption after every writing and implement atomic write.

Design and Implementation : Protection – 3/3

- However, some processor can’t disable bypassing TLB access, and we must insert “code patching” in the kernel.

- In every write to physical address, inert code will make sure it’s not in file cache or the file cache has registered this address as writable. (20%~50% slower).

Design and Implementation : Warm Reboot

- Two issues arise during a warm reboot:
  - what additional data the system maintains
  - when the reboot process restores the file cache contents.

- Additional data–which we call registry (file ID, physical memory address, file size) .

- During reboot, before OS and file system initialization, we dump all physical memory to a partition, and restore dirty file cache to disk by using registry.

Design and Implementation : Effects on File System Design

- We disable buffer cache writes by turning most bwrite and bawrite calls to bdwrite.
- we modify sync and fsync calls to return immediately
- Atomicity
  - When system write data into file cache, it first copies the contents to a shadow page and changes the registry entry to point to the shadow.
  - When writing finishes, it atomically points the registry entry back to the original buffer.

Reliability :Two Kinds of Corruption

- *direct* corruption : detected by checksum
  - a series of events eventually causes a non-I/O procedure to accidentally write to file data.
- *indirect* corruption : detected by App level check
  - a series of events eventually causes a procedure to call an I/O procedure with the wrong parameters.
- However, mechanism mentioned before can’t protect against *indirect* corruption.

Reliability : Detecting Indirect Corruption

- We use app ***memTest*** to detect indirect corruption
- ***memTest*** record the stream of file and directory creations, deletions, reads, and writes, and save this status file in the network.
- After system crash and reboot, we can use this stream to reconstruct the correct content to compare with file cache.

Fault Type	Disk-Based	Rio without Protection	Rio with Protection
kernel text	2	1	
kernel heap			
kernel stack		1	1
destination reg.			
source reg.	2		
delete branch	1	1	1
delete random inst.	1		
initialization			1
pointer		1	
allocation			
copy overrun		4	
off-by-one	1	2	1
synchronization			
Total	**7 of 650 (1.1%)**	**10 of 650 (1.5%)**	**4 of 650 (0.6%)**

	Data Permanent	cp+rm (seconds)
Memory File System	never	21 (15+6)
UFS with delayed data and metadata	after 0-30 seconds, asynchronous	81 (76+5)
AdvFS (log metadata updates)	after 0-30 seconds, asynchronous	125 (110+15)
UFS	data after 64 KB, asynchronous metadata synchronous	332 (245+87)
UFS with write-through after each close	after close, synchronous	394 (274+120)
UFS with write-through after each write	after write, synchronous	539 (419+120)
Rio without protection	**after write, synchronous**	**24 (18+6)**
Rio with protection	**after write, synchronous**	**25 (18+7)**

	cp+rm (seconds)	Sdet (5 scripts) (seconds)
Memory File System	21 (15+6)	43
UFS with delayed data and metadata	81 (76+5)	47
AdvFS (log metadata updates)	125 (110+15)	132
UFS	332 (245+87)	401
UFS with write-through after each close	394 (274+120)	699
UFS with write-through after each write	539 (419+120)	910
Rio without protection	**24 (18+6)**	**42**
Rio with protection	**25 (18+7)**	**42**

Architecture Support

- First, hardware should provide the ability to force all accesses through the TLB.

- System should be able to be reset and rebooted without erasing the contents of memory or CPU caches containing memory data.

Conclusion

- Future work : such as writing to disk during idle periods may improve system responsiveness, and we plan to experiment with this in the future.

- We could perform a more wide variety of fault-injection experiment in the future.