Operating System Transactions

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An OS Concurrency Crisis

The POSIX API is not designed for concurrency

- Shift from time-sharing uniprocessor machines to multi-core
  - 12 core AMD chip due in January 2010
- OS state may change between any two system calls
- API race conditions are problematic for complex operations
  - Distill to single system call in simple cases (e.g. `rename()`)
  - Some operations cannot be distilled to a single system call
- Proliferation of *ad hoc* solutions to race conditions
  - New file system extensions: openat, CLOSE_ON_EXEC
  - New signal handling API: sigaction, pselect, etc.
- Developers need transactions to ensure consistency from OS

Example API Race Condition

Time-of-check-to-time-of-use (TOCTTOU) Attacks

- Attacker exploits race condition to trick a setuid program
- Changes a symbolic link between check and use

Victim	Attacker
`if(access('foo')) {`	
	`symlink('secret','foo');`
`  fd=open('foo');`	
`  ...`	
`}`	

- No deterministic solution without changing API
- 600+ hits in National Vulnerability DB for "*symlink attack*"
- Solved deterministically with transactions:

Victim	Attacker
	`symlink('secret','foo');`
`sys_xbegin();`	
`if(access('foo')) {`	
`  fd=open('foo');`	
`  ...`	
`}`	
`sys_xend();`	
	`symlink('secret','foo');`

Developers Need Transactions

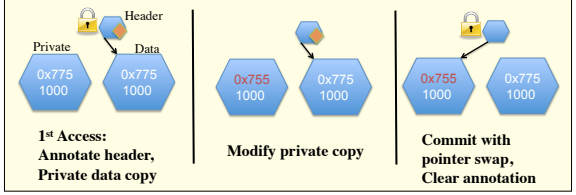
System transactions synchronize access to system resources

- Simple API: **sys_xbegin, sys_xend, sys_xabort**
- Transaction wraps a group of system calls
  - Results isolated from system until commit
  - Interfering operations automatically serialized
- Atomic and isolated access to local resources
  - Support for files, memory allocation, process creation, etc.
  - Network, graphics, etc. left for future work
- Previous systems hit implementation challenges, compromised isolation

Implementation Overview

TxOS: System transactions in Linux 2.6.22.6

- How are old and new versions of data tracked?
  - Previous systems used in-place updates, undo log
    - Issues with priority inversion waiting for long aborts
  - TxOS operates on private copies of objects
    - Avoids priority inversion; keeps data structures consistent
    - Split objects into header and data component
      - Commit updates with a single pointer swap per object
- How are updates isolated?
  - Previous systems use two-phase locking (2PL)
    - 2PL is deadlock prone; can't order lock acquisition
  - TxOS updates private copies, eliminating deadlock
    - Locks only held to make copies and commit



1st Access: Annotate header, Private data copy | **Modify private copy** | **Commit with pointer swap, Clear annotation**

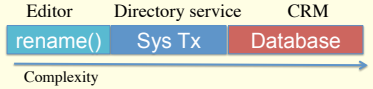
Useful Applications

Transactional Software Install

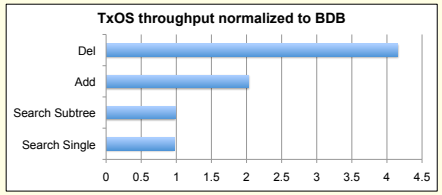
`sys_xbegin();`	`sys_xbegin();`
`dpkg -i openssh;`	`make install svn;`
`sys_xend();`	`sys_xend();`
10% overhead	**70% overhead**

- With no code changes to installer:
  - A failed install is rolled back
  - If the system crashes, reboot to entire install or none
  - Concurrent applications see consistent libraries, config files

Lightweight Database Alternative



- Rename insufficient for middle ground, databases are overkill
- Case study: OpenLDAP directory server:
  - Replaced BDB backend with TxOS + flat files



Reasonable Overheads

- Overhead of using transactions ranges from 1-2.4x
  - 1.7-20x speedups for write-intensive workloads
- Non-transactional Linux compile: <2% overhead
- Individual, non-transactional system calls: 42% mean overhead
  - Can be reduced to 14% with better compilation support