

Why Threads Are A Bad Idea (for most purposes)

John Ousterhout

Sun Microsystems Laboratories

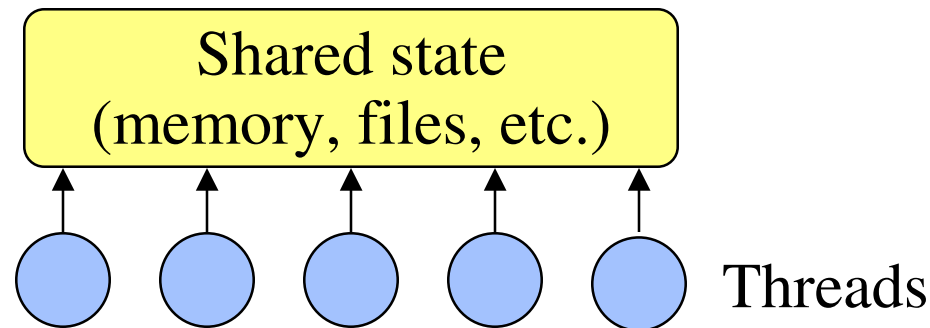
`john.ousterhout@eng.sun.com`

`http://www.sunlabs.com/~ouster`

Introduction

- ▼ **Threads:**
 - Grew up in OS world (processes).
 - Evolved into user-level tool.
 - Proposed as solution for a variety of problems.
 - Every programmer should be a threads programmer?
- ▼ **Problem: threads are very hard to program.**
- ▼ **Alternative: events.**
- ▼ **Claims:**
 - For most purposes proposed for threads, events are better.
 - Threads should be used only when true CPU concurrency is needed.

What Are Threads?



- ▼ **General-purpose solution for managing concurrency.**
- ▼ **Multiple independent execution streams.**
- ▼ **Shared state.**
- ▼ **Pre-emptive scheduling.**
- ▼ **Synchronization (e.g. locks, conditions).**

What Are Threads Used For?

- ▼ **Operating systems:** one kernel thread for each user process.
- ▼ **Scientific applications:** one thread per CPU (solve problems more quickly).
- ▼ **Distributed systems:** process requests concurrently (overlap I/Os).
- ▼ **GUIs:**
 - Threads correspond to user actions; can service display during long-running computations.
 - Multimedia, animations.

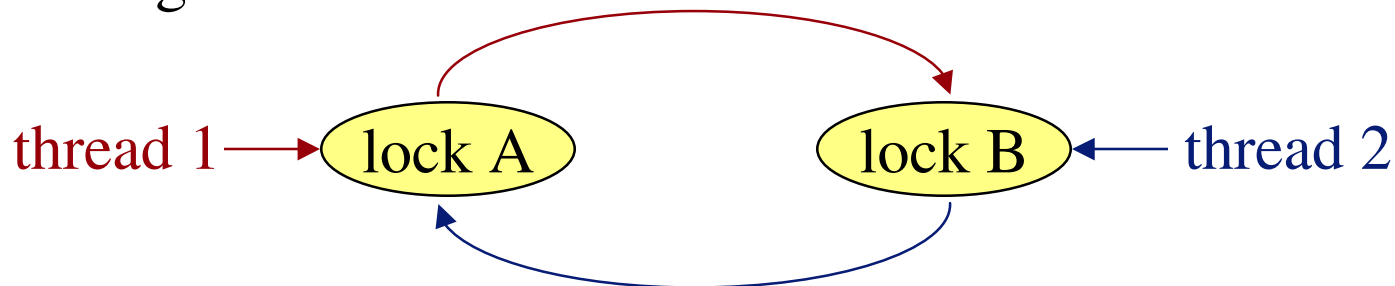
Why Threads Are Hard

- ▼ **Synchronization:**

- Must coordinate access to shared data with locks.
- Forget a lock? Corrupted data.

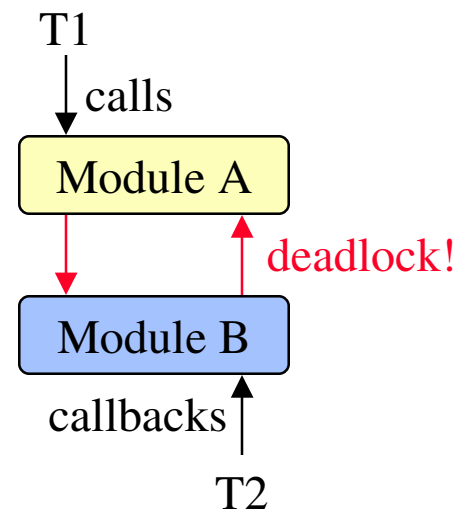
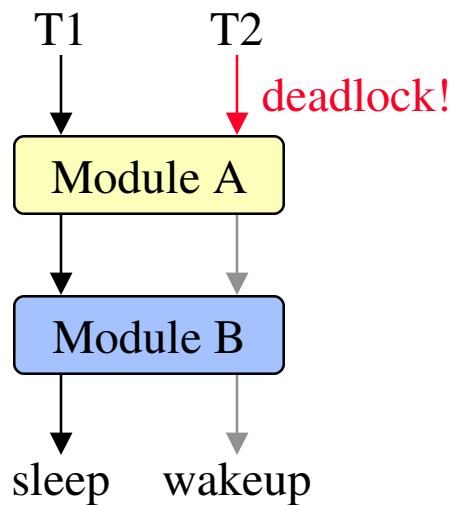
- ▼ **Deadlock:**

- Circular dependencies among locks.
- Each process waits for some other process: system hangs.



Why Threads Are Hard, cont'd

- ▼ **Hard to debug:** data dependencies, timing dependencies.
- ▼ **Threads break abstraction:** can't design modules independently.
- ▼ **Callbacks don't work with locks.**

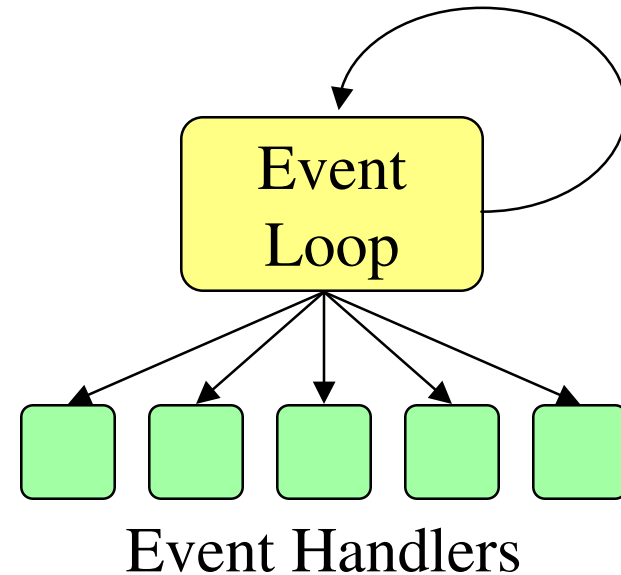


Why Threads Are Hard, cont'd

- ▼ **Achieving good performance is hard:**
 - Simple locking (e.g. monitors) yields low concurrency.
 - Fine-grain locking increases complexity, reduces performance in normal case.
 - OSes limit performance (scheduling, context switches).
- ▼ **Threads not well supported:**
 - Hard to port threaded code (PCs? Macs?).
 - Standard libraries not thread-safe.
 - Kernel calls, window systems not multi-threaded.
 - Few debugging tools (LockLint, debuggers?).
- ▼ **Often don't want concurrency anyway (e.g. window events).**

Event-Driven Programming

- ▼ **One execution stream: no CPU concurrency.**
- ▼ **Register interest in events (callbacks).**
- ▼ **Event loop waits for events, invokes handlers.**
- ▼ **No preemption of event handlers.**
- ▼ **Handlers generally short-lived.**



What Are Events Used For?

- ▼ **Mostly GUIs:**
 - One handler for each event (press button, invoke menu entry, etc.).
 - Handler implements behavior (undo, delete file, etc.).
- ▼ **Distributed systems:**
 - One handler for each source of input (socket, etc.).
 - Handler processes incoming request, sends response.
 - Event-driven I/O for I/O overlap.

Problems With Events

- ▼ **Long-running handlers** make application non-responsive.
 - Fork off subprocesses for long-running things (e.g. multimedia), use events to find out when done.
 - Break up handlers (e.g. event-driven I/O).
 - Periodically call event loop in handler (reentrancy adds complexity).
- ▼ **Can't maintain local state** across events (handler must return).
- ▼ **No CPU concurrency** (not suitable for scientific apps).
- ▼ **Event-driven I/O** not always well supported (e.g. poor write buffering).

Events vs. Threads

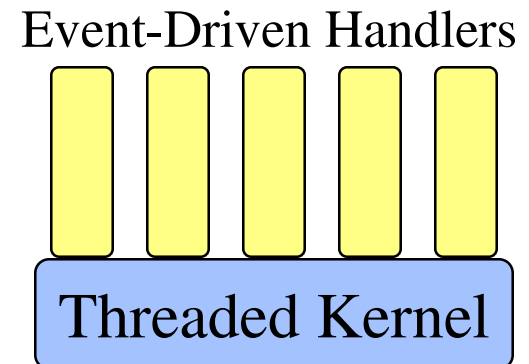
- ▼ **Events avoid concurrency as much as possible, threads embrace:**
 - Easy to get started with events: no concurrency, no preemption, no synchronization, no deadlock.
 - Use complicated techniques only for unusual cases.
 - With threads, even the simplest application faces the full complexity.
- ▼ **Debugging easier with events:**
 - Timing dependencies only related to events, not to internal scheduling.
 - Problems easier to track down: slow response to button vs. corrupted memory.

Events vs. Threads, cont'd

- ▼ **Events faster than threads on single CPU:**
 - No locking overheads.
 - No context switching.
- ▼ **Events more portable than threads.**
- ▼ **Threads provide true concurrency:**
 - Can have long-running stateful handlers without freezes.
 - Scalable performance on multiple CPUs.

Should You Abandon Threads?

- ▼ **No:** important for high-end servers (e.g. databases).
- ▼ **But, avoid threads wherever possible:**
 - Use events, not threads, for GUIs, distributed systems, low-end servers.
 - Only use threads where true CPU concurrency is needed.
 - Where threads needed, isolate usage in threaded application kernel: keep most of code single-threaded.



Conclusions

- ▼ **Concurrency is fundamentally hard; avoid whenever possible.**
- ▼ **Threads more powerful than events, but power is rarely needed.**
- ▼ **Threads much harder to program than events; for experts only.**
- ▼ **Use events as primary development tool (both GUIs and distributed systems).**
- ▼ **Use threads only for performance-critical kernels.**