Scheduler Activations

CS380L: Mike Dahlin

September 24, 2003

1 Preliminaries

1.1 Review

1.2 Outline

- Scheduler activations

1.3 Preview

2 Principle: Expose revocation

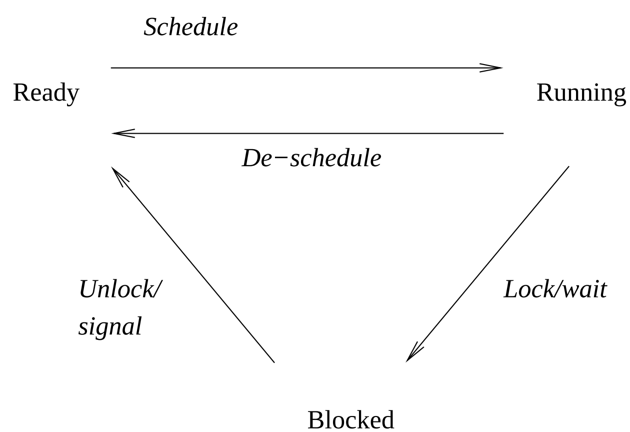
- Exokernel theme: what is minimal abstraction needed for high performance implementations (e.g., to expose resource to application but let application control resource scheduling if it wants to do so.
- "Traditional" abstractions do a little too much
  - Networks: AM says "must be async, no buffering" ($\rightarrow$ add synchronization and buffering at user level if you need it)
  - Network security?
  - File system metadata
  - Shared kernel cache buffer
  - Paging
  - **Today:** *the traditional concurrency abstraction (threads) is too much*
    - QUESTION what is the traditional concurrency abstraction?
    - SA approach
      - don't provide illusion of infinite processors (anti-THE!);
      - don't keep ready list or choose threads to run in kernel.

      - Kernel (1) gives "activations" to user level and (2) informs user-level when "activations" are revoked (and provides the saved processor state),
      - but user-level decides which threads run on which activations

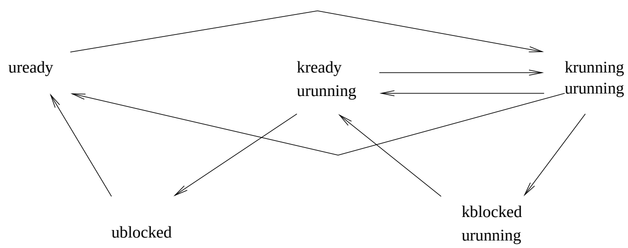
3 Scheduler activations

3.1 Basics

Traditional threads:

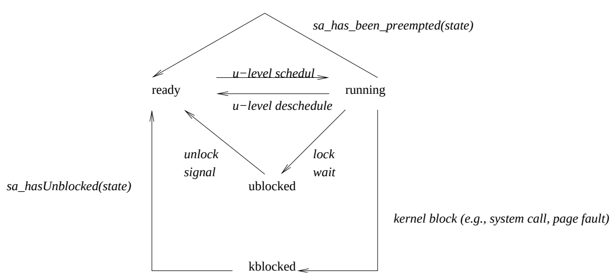


- But people tend to adopt 2-level model: N user-level threads on M kernel threads
- Why?
- Problems with kernel-thread-only approach
- Problems with user-thread-only approach
- But, problem with combined approach:



– How many kthreads?
– Lose control of user-level scheduling (what if thread holding UL lock is preempted or high-priority UL thread is preempted?)
    * Blumofe result

SA:



basic interface:

- add_processor() – an idle processor is now available
- has_blocked() – an idle processor is now available
- has_unblocked(stateA, [stateB]) – thread A unblocked (put it on ready queue); BTW to tell you this I also blocked B (put it on ready queue too, and schedule someone to run with *this* activation

- has_been_preempted(stateA, [stateB]) – thread A got preempted (put it on ready queue); BTW to tell you this I also blocked B (put it on ready queue too, and schedule someone to run with *this* activation

Notice: all schedule activation calls by kernel to user-level handlers provide an activation (that is, a scheduled thread). In order to keep number of threads allocated to a process from growing without bound, processor typically supends a running activation in order to tell you "hasBeenPreempted" or "hasUnblocked"

3.2 Bells and whistles

- Advisory interface to tell kernel how many threads a process can profitably run with
    – Simple interface (could imagine a more complex one...is it worth it?)
    – "Want one more" (I have more ready threads than activations)
    – "Give one back" (I have fewer ready threads than activations)
- In exokernel: before revoking, kernel warns process "I'm about to take a processor away...perhaps you should give one of your choice up voluntarily instead"
    – Would that be useful here?

3.3 Details

Interaction of user-level critical section and kernel suspensions

- Problem: What if thread is suspended while holding lock on user-level scheduler?
    – Possible deadlock: activation call tries to grab lock to move suspended thread to ready list
- Example of general problem we've seen several times:
    – Mesa device drivers: kernel monitors v. hardware
    – Active messages: enqueue incoming message w/o grabbing a lock (handler cannot block)
    – This really is same problem: "interrupt handlers cannot block"
- Proposed approaches

- Prevent: if thread is holding THE lock (not all locks), tell kernel to let it keep running
  * More generally: tell kernel the priority of the running thread?
  * DA: overhead to tell kernel this whenever lock is grabbed
  * DA: need to "pin" pages
  * (Moral equivalent to AM: run with interrupts turned off...)
- Recover: Set flag when grabbing "THE" lock; activation handler checks flag, if flag set, set YIELD flag; run current thread (without touching normal scheduling data structures); when flag releases THE lock, check YIELD flag and yield() if set
  * DA: slows down common case for rare case
  * Cute fix: 2 versions of code
- This is semantically equilvalent to '‘turning off interrupts", but w/o the cost
- Other alternative: wait-free synchronization (e.g., Blumofe Cilk)

4 User-level threads v. kernel-level threads v. events

5 Subsequent systems

- Exokernel
  - How differ from Anderson?
- K42
- Solaris

  See *Solaris Internals: Core Kernel Architecture* by Mauro and McDougall, Prentice Hall, 2001; chapter 9 "The Solaris Kernel Dispatcher" section 9.4 "Scheduler Activations."

  - Solaris: user-level threads and "LWPs" (kernel-level threads)
  - Limits of "old" Solaris (pre 2.6 – no scheduler activations)
    * No correlation between priority of user thread and priority of underlying LWP
    * User-level threads prone to priority inversion (fixed in Solaris for kernel threads, but not for user threads)
    * No inheritance (e.g., inherit priority of parent) at user threads level
    * Difficult to implement adaptive locks (b/c kernel state not available to threads library)
    * Keeping sufficient pool of kernel threads s.t. runnable threads can run was not easily solved
      · Workaround in 2.6: "SIGWAITING" signalled when last runnable kernel thread blocks; handler can create new kernel thread
  - Kernel threads only block on condition variables. The kernel CV wait() code calls schedctl_check(SC_BLOCK) ("are all kernel threads for this process blocked?")
  - If all kernel threads are now blocked
    * currentThread.khandoff = Get a new kernel thread from the process's pool of inactive threads ()
  - After returning from schedctl_check(), the thread calls switch() which notices that khandoff is non-null, so it passes control to the specified kernel thread
  - The specified kernel thread wakes up (in user mode), calls the scheduler library, which hands it a user-level thread to run.
  - Questions:
    * Why do they only kick off a new activation/kernel thread if the active number reaches 0? Would the implementation have to change if they did something more general (like in original scheduler activations – call *any time* a user-thread blocks?
    * How else do they differ? What are pros and cons?

6 Project idea

Project 1: Perfect threads

I think you can build scheduler activations without modifying the kernel. (Idea is: use /proc). (Possible exception is: multiprogramming descheduling, but this should not be common for demanding apps. Actually, can still do it at user level, but probably need to be root...)

Part 1: Build SA w/o modifying kernel

SEDA is weird – lots of kernel threads (but not too many!) to hide I/O, utilize many processors (but don't overload machine)

Part 2: Use lightweight user-level threads abstraction (e.g., get rid of space overhead of utilizing many threads by using Mesa-style linked allocation of stack frames). Use scheduler activations to keep 1 kernel thread per processor active. → programming model is equilvalent to one-kernel-thread-per-request. Space overhead is similar to events. Other overheads similar to having the minimum number of kernel threads needed.

```
               kernel threads              user threads                 ev
mem overhead       1page                     1page                        N/
ctx-switch overhead  ctxsw+copy-all-reg     copy-all-reg                   c
wait/signal/lock   ctx-sw
programming convenience  yes                   yes                        n
tolerate blocking    yes                       no                         n


      SA makes user-threads                                      heap alloca
      have the good k-thread                                     frames make
      properties                                                 have the go
------------------------------------------>   SA+HF  <--------------------
```

Project 2: Add scheduler activations to vin et al's hierarchical CPU scheduler (e.g., in QLinux)?

7 Admin

- Exam – 10/21
- Project checkpoint 10/30 – briefly list status and plan (e.g., orig 4 milestones. what has changed. New schedule)
- Lecture series –