Ticket to a Tar Pit

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Spinlocks are awesome

- Great way to synchronize
- Almost always very low cost
- Straightforward to use

Spinlocks are Awful

- Spinning is a waste of time
- Spinning for no reason is a complete waste
- Why spin for no reason?

Old-style byte locks

- Not fair
- First CPU to check lock wins
- Locking:

```
while  (test_and_set(&lock))
        relax();
```

- Unlocking:

```
lock = 0;
```

Ticket Locks

- Guaranteed FIFO granting of lock
- Introduced in 2.6.24
- Basic lock algorithm:

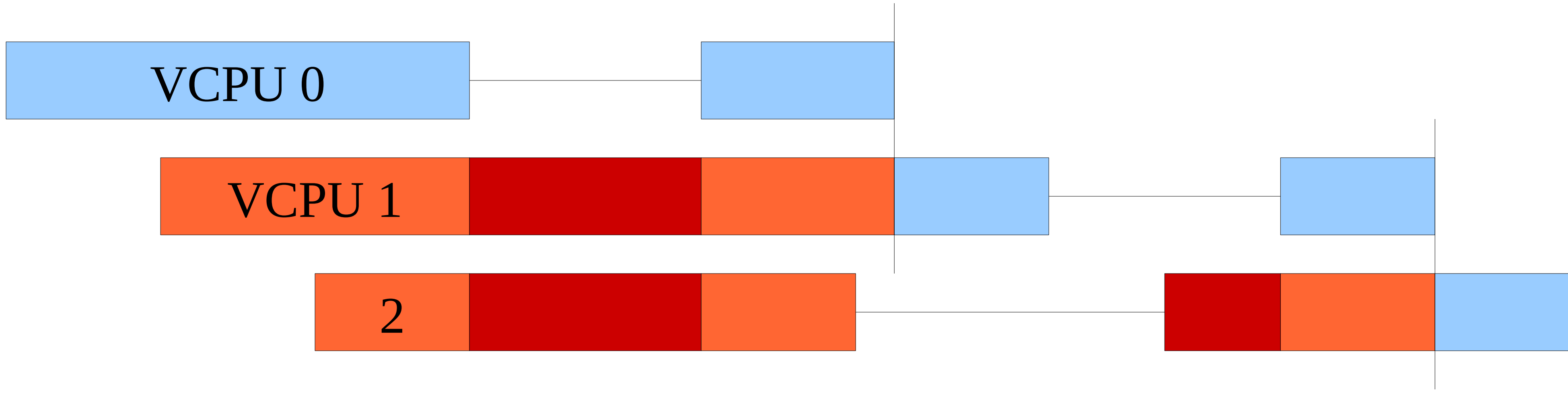
```
myticket = claim_ticket(&lock);
while (!my_turn(&lock, myticket))
        relax();
```

- Unlock:

```
grant_ticket(&lock, myticket + 1);
```

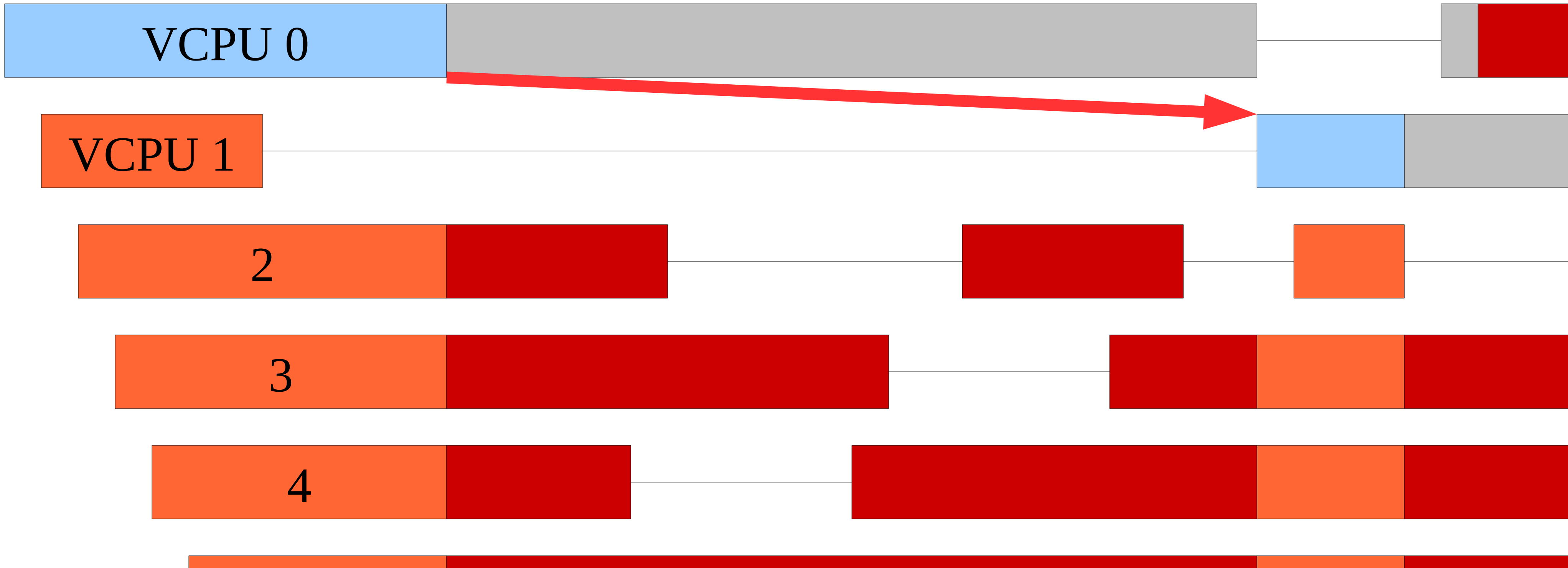
Lockholder Preemption (LHP)

- If a VCPU has no PCPU while holding a lock everyone else wastes time
- Variation of priority inversion
- Can be annoying source of inefficiency, but not a box-killer
- Applies to all spinlock implementations



Lock Claim Scheduling

- Big problem when releasing a lock:
  - How to make sure next person gets CPU?
  - VCPU scheduler doesn't know
- Can easily get to 90%+ time spent spinning



Paravirtualizing Spinlocks

- Current approach: completely replace spinlocks
- pv_lock_ops intercepts:
  - spin_lock
  - spin_unlock
  - spin_trylock
  - spin_is_locked
  - spin_is_contended

Xen PV Spinlocks

- spin_lock: spin for a while, then block on event channel
- spin_unlock: unlock, then check to see if anyone blocked
  - If so, kick them with an event
  - event never delivered; just a blocking poll operation
- Per-VCPU array of who's waiting on what
  - Checking = linear scan
- Keep counter of waiters in lock

Downsides of PV Spinlocks

- Adds indirection to all lock operations
  - Better than an indirect call, but still an extra call
  - Measurable performance hit on some architectures
- Completely new lock implementation
  - Old-style lock
  - Different characteristics from native lock
  - Sleazy hack in relying on same initializer

Paravirtualized Ticket locks

- Leave fast-path of ticketlocks intact
- Only put pv-ops in the slow path
  - lock_spinning
  - unlock_kick
- Removes a layer of complexity in common code
- Much less per-hypervisor code

Lock Details

–
```
myticket = claim_ticket(&lock);
for (;;) {
  int count = THRESHOLD;
  do {
        if (my_turn(&lock, myticket))
              goto out;
        relax();
  } while(--count);
  pv_lock_ops.lock_spinning(&lock, myticket);
}
```

Unlock details

-
  ```
  next = lock->tail + 1;
  grant_ticket(&lock, next);
  if (are_waiters(&lock))
      unlock_kick(&lock, next);
  ```
- Implementing are_waiters()
  - Check for any queued lock
    - Unchanged lock size, but lots of spurious kicks
  - Add “waiters” counter to lock
    - Fewer kicks, but increase lock size

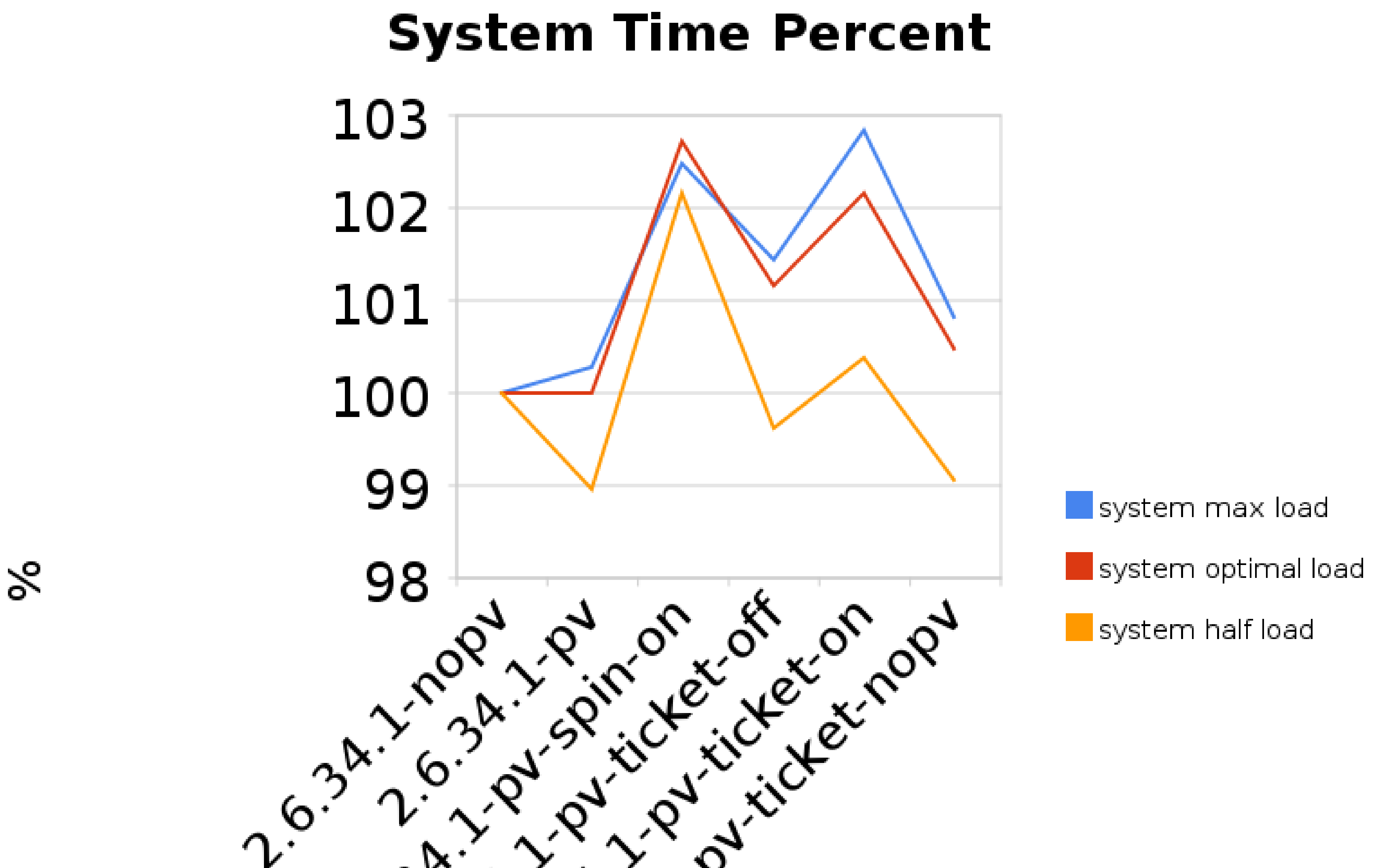
Xen PV ticketlocks

- Per-VCPU vars of which lock, and which ticket
- lock_spinning records lock+ticket for VCPU, blocks on event channel
- unlock_kick scans for matching lock+ticket and kicks any it finds

Performance

- Very preliminary numbers
- +1 - -2% on native vs no PV ticketlock
  - About the same as PV spinlocks
- About the same as PV spinlock under Xen
  - Same good properties
- Overall, a bit disappointing
- Still seems like a better approach architecturally
- (What's a useful benchmark?)

Look, A Graph!


System Time Percent
103
102
101
100
99
98
%
2.6.34.1-nopv
2.6.34.1-pv
4.1-pv-spin-on
1-pv-ticket-off
1-pv-ticket-on
pv-ticket-nopv
🟦 system max load
🟥 system optimal load
🟧 system half load