Tuning SCHED_ULE on FreeBSD

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Outline

- BSD Scheduler History
- SCHED_ULE
- Tuning Hooks
- Testing Methodology
- Effects

BSD Scheduler History

- BSD written for uni-processor machines
- No SMP
- No HTT
- No multicores
- Up through FreeBSD 5 only modified not wholesale rewritten

Why SCHED_ULE?

- SMP and multi-core
- SMP is NOT multi-core
- Cache effects

Why keep SCHED_BSD?

- One size does not fit all
- There are still uniprocessors
- Embedded systems
- A baseline to compare against

Scheduler Responsibilities and Goals

- Arbitrate amongst competing processes
- Adhere to the will of the administrator
- Stay out of the way

Why tune the scheduler?

- Can change overall performance of the system
- Favor one type of job over another
- Not all workloads are interactive

Don’t Panic

- The scheduler is one of the most important components of the kernel
- You (probably) cannot destroy your system via scheduler tuning
- Proceed with caution
- *Measure*, modify, *measure*, modify
- All of the tunables can simply turned off if they cause trouble

Interactivity Tunables

name	Name of scheduler, ULE or 4BSD
interact	Interactivity score threshold
slice	Time slice for timeshare threads (100ms)

SCHED_ULE Tuning Hooks

steal_thresh Minimum load on a remote CPU before we'll steal work.

steal_idle Attempt to steal idle work from other CPUs before this CPU goes idle.

steal_htt Steals work from another core on idle.

Stealing

- Stealing in SCHED_ULE can be virtuous
- Cores can steal work from each other
- It is a way of balancing work in an SMP/multi-core system

SCHED_ULE Tuning Hooks

balance
: Enable the long term load balancer.

balance_interval
: Average frequency in *stathz* ticks to run the long term load balancer (below).

affinity
: Number of ticks to keep a thread from changing CPU.

SCHED_ULE Tuning Hooks

idlespinthresh Threshold before idle spinning can occur

idlespins Number of times the idle thread will spin waiting for new work

static_boost Assign static priorities to sleeping threads

preepmt_thresh Minimum priority for preemption, lower priorities are more likely to be picked.

Testing Methodology

- We introduce a dummy load on the system
- Read data from another process
- Do some math in a loop
- Should have few or no voluntary context switches
- Wish to reduce involuntary context switches

Context Switching

- Changing the process which is executing on a core

  Voluntary Process takes an action that blocks or calls sched_yield()

  Involuntary with Preemption On exiting a critical section or interrupt service routine a process may be pre-empted.

  Involuntary without Preemption

The output of top(1)

```
last pid:  1023;  load averages:  0.96,  0.53,  0.25    up 0+00:08:21  14:40:28
100 processes: 10 running, 58 sleeping, 32 waiting
CPU: 12.5% user,  0.0% nice,  0.0% system,  0.0% interrupt, 87.5% idle
Mem: 17M Active, 9848K Inact, 106M Wired, 68K Cache, 16M Buf, 7785M Free
Swap: 8192M Total, 8192M Free

  PID USERNAME     VCSW  IVCSW   READ  WRITE  FAULT  TOTAL PERCENT COMMAND
 1019 gnn             0     21      0      0      0      0   0.00% dummy2
  982 gnn             0      0      0      0      0      0   0.00% tcsh
 1015 gnn             0      0      0      0      0      0   0.00% dummy1
 1011 gnn             0      0      0      0      0      0   0.00% usdlogd
```

Tuning Tests

- Turn off balancing
- Change the time slice
- Test system has eight cores total
- Each test was run for 15 minutes while observing top.

Turn off Balancing

- The CPU balancer runs every 133 ticks
- In a system that is being hand tuned why run the balancer?
- What's the effect of turning off the balancer

With Balancing

```
last pid:  1023;  load averages:  0.96,  0.53,  0.25    up 0+00:08:21  14:40:28
100 processes: 10 running, 58 sleeping, 32 waiting
CPU: 12.5% user,  0.0% nice,  0.0% system,  0.0% interrupt, 87.5% idle
Mem: 17M Active, 9848K Inact, 106M Wired, 68K Cache, 16M Buf, 7785M Free
Swap: 8192M Total, 8192M Free

  PID USERNAME     VCSW  IVCSW   READ  WRITE  FAULT  TOTAL PERCENT COMMAND
 1019 gnn             0     21      0      0      0      0   0.00% dummy2
  982 gnn             0      0      0      0      0      0   0.00% tcsh
 1015 gnn             0      0      0      0      0      0   0.00% dummy1
 1011 gnn             0      0      0      0      0      0   0.00% usdlogd
```

Without Balancing

```
last pid:  1024;  load averages:  0.98,  0.61,  0.30    up 0+00:09:21  14:41:28
100 processes: 10 running, 58 sleeping, 32 waiting
CPU: 12.4% user,  0.0% nice,  0.1% system,  0.0% interrupt, 87.5% idle
Mem: 17M Active, 9852K Inact, 106M Wired, 68K Cache, 16M Buf, 7785M Free
Swap: 8192M Total, 8192M Free

  PID USERNAME      VCSW  IVCSW   READ  WRITE  FAULT  TOTAL PERCENT COMMAND
 1019 gnn              0     20      0      0      0      0   0.00% dummy2
  982 gnn              0      0      0      0      0      0   0.00% tcsh
 1015 gnn              0      0      0      0      0      0   0.00% dummy1
 1011 gnn              0      0      0      0      0      0   0.00% usdlogd
```

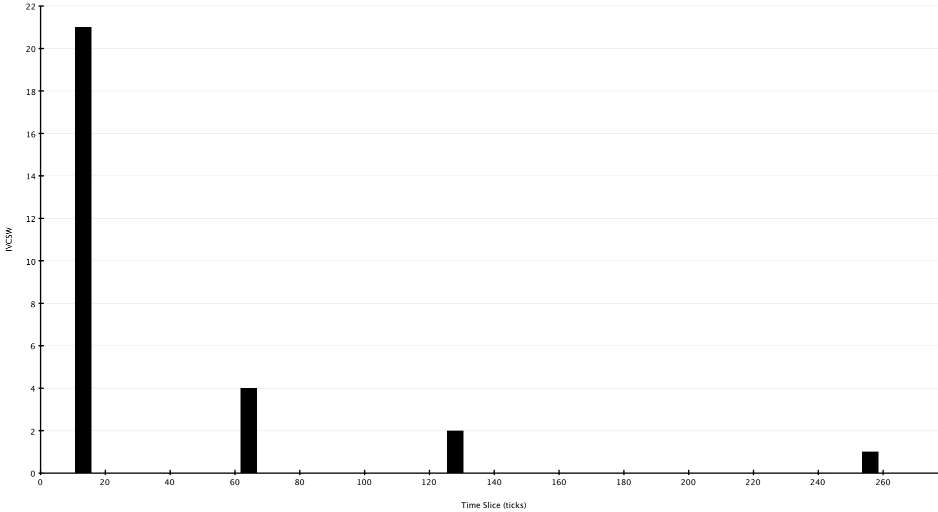
Balancing Results

- A slight increase in load average (0.96 to 0.99)
- The load average remains slightly higher
- The number if involuntary context switches does not change

Time Slice

- The default time slice is 13 ticks
- Increase the time slice to 64, 128, and 256 ticks
- At each level run for 15 minutes

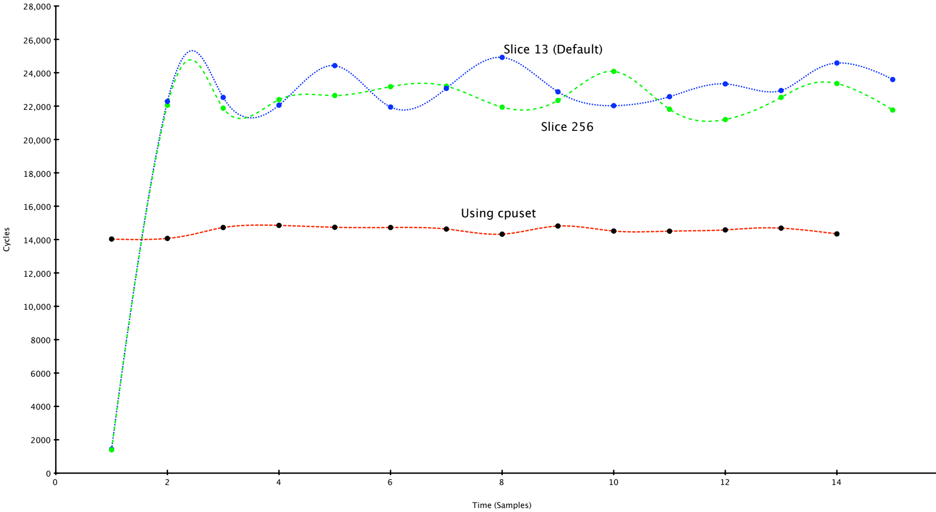
Time Slice Evaluation



How long does a switch take?

- A set of scheduler stats are available
- Need to build the kernel with SCHED_STATS
- Locally added calls to rdtsc to mi_switch
- Store the difference between these values on each switch
- Crude but effective
- Reading the sysctl every 3 seconds

Switch Timing Results



Scheduler Statistics

preempt	Pre emptions anywhere in the system
owepreempt	Were in a critical section and should have pre-empted
turnstile	Switches due to mutex contention
sleepq	Switches due to sleep
relinquish	Called a yield function
needresched	Pre emption of user processes on exit from the kernel

Turning All This Off

- Sometimes you *know* what must be done
- Assigning processes to cores is also possible
- See cpuset(4) man page
- See also Brooks Davis' presentation

Further Reading

- /usr/src/sys/kern/sched_ule.c
- /usr/src/sys/kern/sched_switch.c
- “ULE: A Modern Scheduler for FreeBSD”, by Jeff Roberson
- “The Design and Implementation of the FreeBSD Operating System”, by McKusick and Neville-Neil
- R. Jain, “The Art of Computer Systems Performance Analysis: Techniques for Experimental Design, Measurement, Simulation, and Modeling,”

Questions?