ADVANCED TOPICS: MULTI CPU SCHEDULING

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CS 537, Fall 2024

ADMINISTRIVIA

Project 6 – last project!

- Deadline end of next week

Midterm 3

- December 19th, 10:05am
- Details on Piazza soon

AGENDA / LEARNING OUTCOMES

How to perform CPU scheduling on multiple processors?

VMM RECAP

Virtual machine: Complete compute environment, isolated

Virtual machine monitor / Hypervisor: control resources (direct or part of OS)

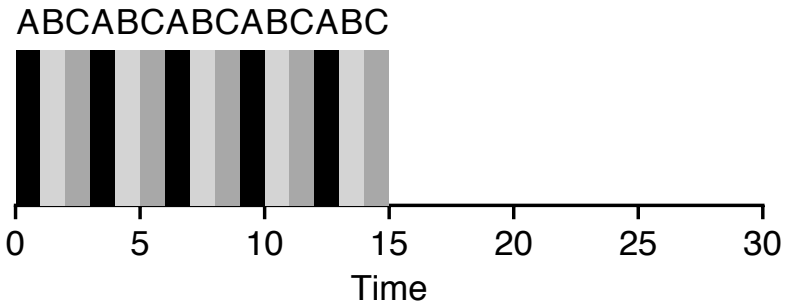
Trap-and-emulate to handle system calls

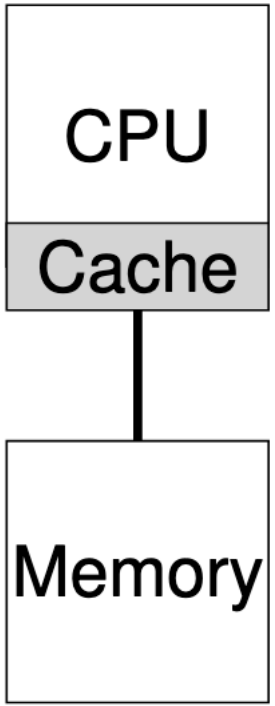
Software TLB handler: maintain Physical → Machine page tables

Paravirtualization - modify guest OS for efficiency

Intel VT-X extensions – new hardware primitives to support virtualization

PREVIOUSLY ON SCHEDULING



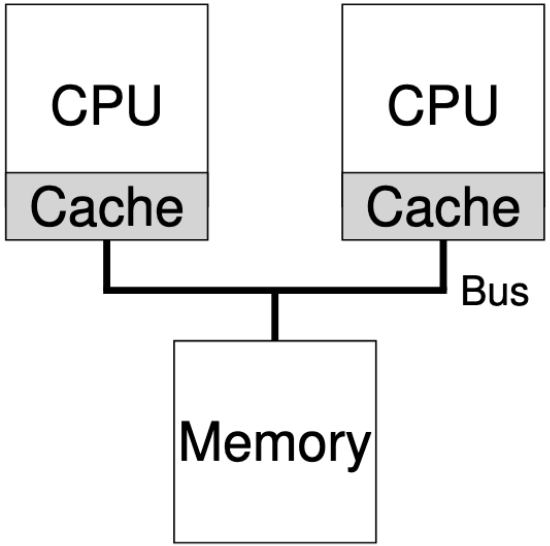


MULTI PROCESSORS

Two key goals

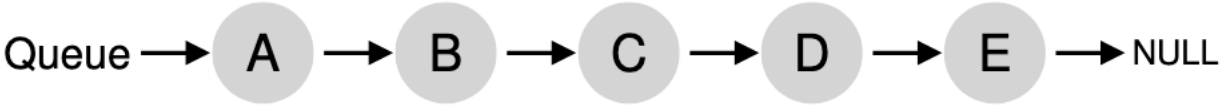
Cache Affinity

Load Balancing



SINGLE QUEUE SCHEDULING

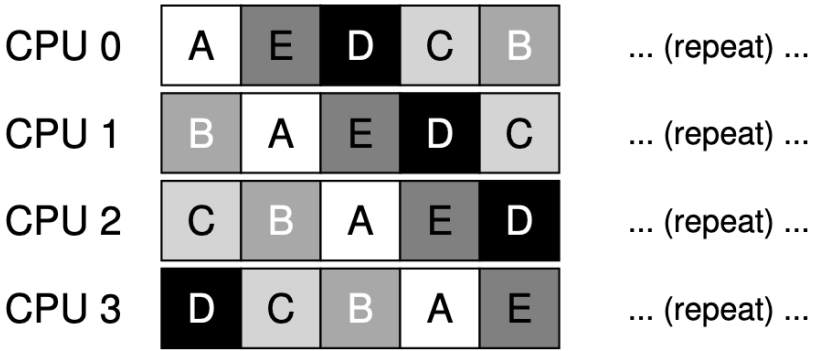
Maintain a single queue of all runnable jobs



Scalability challenge

Locking overhead?

CACHE AFFINITY



Associate affinity with each job

Move jobs to ensure fairness / load balance

MULTI QUEUE SCHEDULING

Maintain a queue per CPU
Within each queue, use existing scheduling algorithms

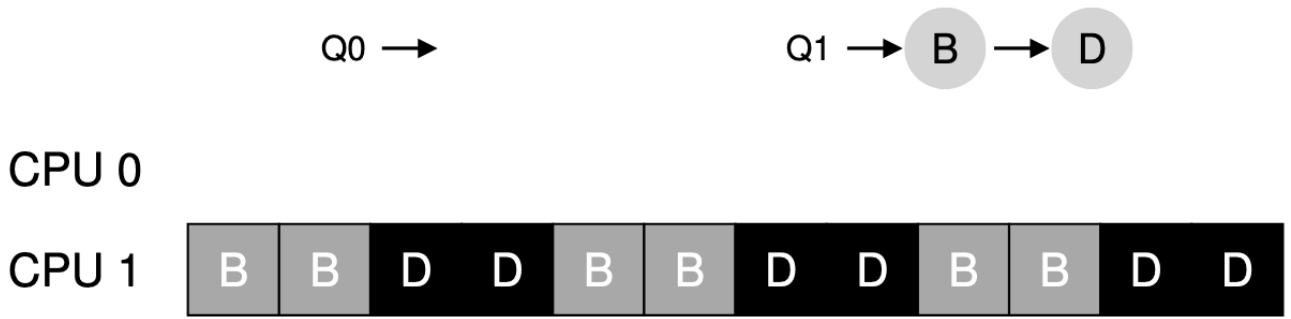
Scalability?

Cache affinity?

MULTI QUEUE CHALLENGES → CFS

How to place new jobs in queues?

Load balancing



LINUX: COMPLETELY FAIR SCHEDULER (CFS)

Similar approach to stride scheduler (remember P4!?)

Goal: Divide a CPU using the concept of virtual runtime (vruntime)

Approach: Pick the process which has the lowest vruntime

When to switch processes:

sched_latency – how long before switch ("fairness window")

min_granularity

PRIORITY IN CFS

Niceness: Parameter can be set anywhere from -20 to +19

Positive nice values lower priority, negative values higher priority

nice(1) - Linux man page

Name

nice - run a program with modified scheduling priority

Map niceness value to weight

- Higher priority gets larger time slice
- vruntime increment is scaled inversely to weight

COURSE FEEDBACK SURVEY, QUIZ

https://heliocampusac.wisc.edu/

QUIZ 21

What is the difference between a Type 1 and Type 2 Hypervisor?

Which of the following is not part of the Processor Status Word?

True or False: Executing a system call in a VM is no more expensive than a normal system call.

When a virtual machine experiences a page fault, which of the following is NOT true?

CFS: HANDLING THREAD JOINS

New thread or thread wakes up from sleep

How to set vruntime?

New thread: vruntime equal to the maximum vruntime of runnable threads

I/O wakeup: Set to minimum of all runnable jobs right now

CFS ON MULTI PROCESSORS

Load Balancing: Goal is to balance out work (or load) across all cores

Example: 1 CPU-intensive thread vs. 10 threads that mostly sleep

Load of a thread: average CPU utilization of a thread

Effective goal: Balance sum of load across cores

CFS: THREAD CREATION

Decide which cores are suitable to host the thread

Approach: heuristics to decide suitable cores.
Pick core among those with lowest load

1-to-many producer-consumer: Spread out consumers across cores
1-to-1 communication: Restricts to cores sharing a cache

CFS: LOAD BALANCING

Periodically (e.g., 4ms) steal work from other cores

When stealing work, even out the load between the two cores

CFS: LOAD BALANCING

Topology awareness while work stealing

> Try to steal work more frequently from cores that are "close" vs. cores that are "remote" (e.g., on a remote NUMA node)

Load difference is small (less than 25% in practice), no load balancing

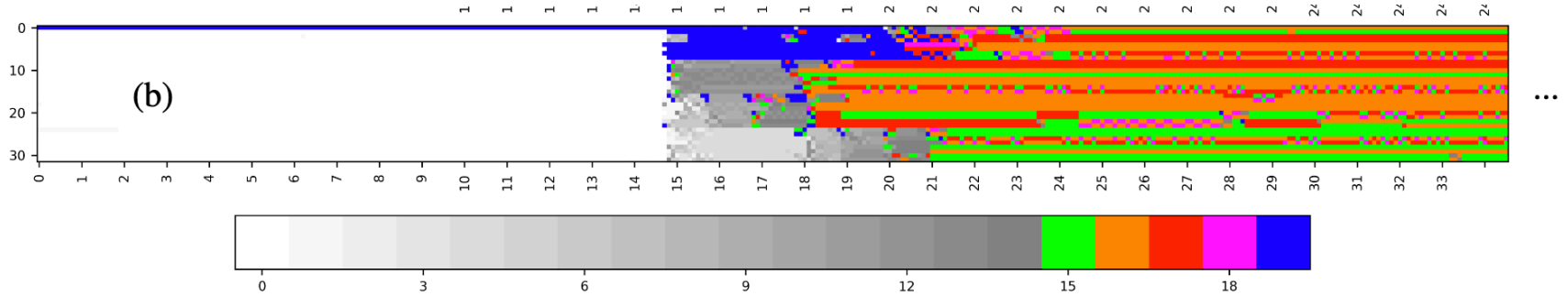


Figure 6: Number of threads per core over time on (a) ULE and (b) CFS. Each line represents a core (32 in total), time passes on the x-axis (in seconds), and colors represent the numbers of threads on the core. Thread counts below 15 are represented in shades of grey. Threads are pinned on core 0 for the first 14.5 seconds of the execution.

Start 512 spinning threads on core 0. Let load balancer work

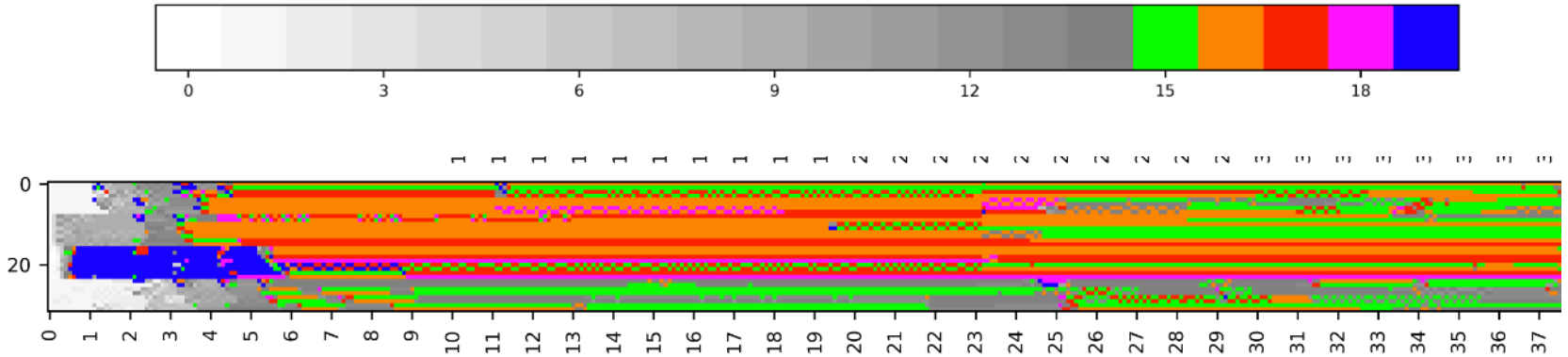


Figure 7: Number of threads per core over time on c-ray on (a) ULE and (b) CFS. start pinned on core 0.

Create 512 threads.
Threads are not pinned at creation time
scheduler chooses a core for each thread
All threads wait on a barrier before computation

ULE (BSD SCHEDULER)

Aims to even out the number of threads per core (not load)

Choosing a core for a newly created thread: affinity heuristic

Periodic load balancing only by core 0.

a thread from the most loaded core, the (donor)

to the less loaded core, the (receiver)

Next class: Distributed Systems

Last week!