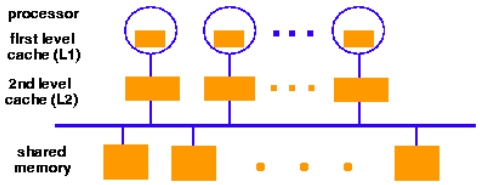
Multiprocessor Scheduling

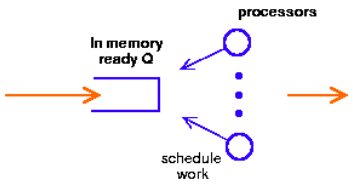
- Will consider only shared memory multiprocessor or multi-core CPU



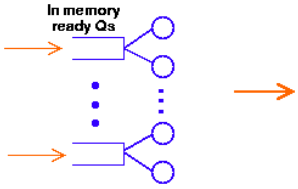
- Salient features:
  - One or more caches: cache affinity is important
  - Semaphores/locks typically implemented as spin-locks: preemption during critical sections
- Multi-core systems: some caches shared (L2,L3); others are not

Multiprocessor Scheduling

- Central queue – queue can be a bottleneck



- Distributed queue – load balancing between queue

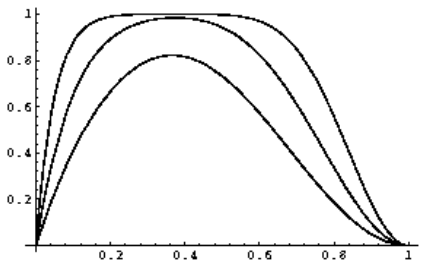


Scheduling

- Common mechanisms combine central queue with per processor queue (SGI IRIX)
- Exploit *cache affinity* – try to schedule on the same processor that a process/thread executed last
- Context switch overhead
  - Quantum sizes larger on multiprocessors than uniprocessors

Distributed Scheduling: Motivation

- Distributed system with N workstations
  - Model each w/s as identical, independent M/M/1 systems
  - Utilization u, P(system idle)=1-u
- What is the probability that at least one system is idle and one job is waiting?



Implications

- Probability high for moderate system utilization
  - Potential for performance improvement via load distribution
- High utilization => little benefit
- Low utilization => rarely job waiting
- Distributed scheduling (aka load balancing) potentially useful
- What is the performance metric?
  - Mean response time
- What is the measure of load?
  - Must be easy to measure
  - Must reflect performance improvement

Design Issues

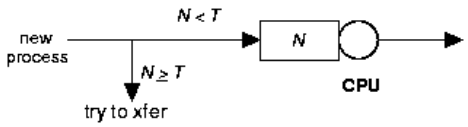
- Measure of load
  - Queue lengths at CPU, CPU utilization
- Types of policies
  - Static: decisions hardwired into system
  - Dynamic: uses load information
  - Adaptive: policy varies according to load
- Preemptive versus non-preemptive
- Centralized versus decentralized
- Stability: $\lambda > \mu$ => instability, $\lambda_1+\lambda_2 < \mu_1+\mu_2$ => load balance
  - Job floats around and load oscillates

Components

- *Transfer policy:* **when** to transfer a process?
  - Threshold-based policies are common and easy
- *Selection policy:* **which** process to transfer?
  - Prefer new processes
  - Transfer cost should be small compared to execution cost
    - Select processes with long execution times
- *Location policy:* **where** to transfer the process?
  - Polling, random, nearest neighbor
- *Information policy*: when and from where?
  - Demand driven [only if sender/receiver], time-driven [periodic], state-change-driven [send update if load changes]

Sender-initiated Policy

- *Transfer policy*



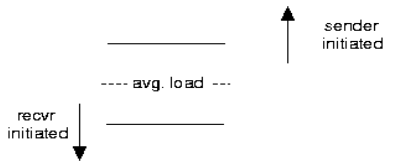
- *Selection policy*: newly arrived process
- *Location policy*: three variations
  - *Random*: may generate lots of transfers => limit max transfers
  - *Threshold:* probe *n* nodes sequentially
    - Transfer to first node below threshold, if none, keep job
  - *Shortest*: poll N_p nodes in parallel
    - Choose least loaded node below *T*

Receiver-initiated Policy

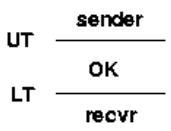
- Transfer policy: If departing process causes load < T, find a process from elsewhere
- Selection policy: newly arrived or partially executed process
- Location policy:
  - Threshold: probe up to N_p other nodes sequentially
    - Transfer from first one above threshold, if none, do nothing
  - Shortest: poll n nodes in parallel, choose node with heaviest load above T

Symmetric Policies

- Nodes act as both senders and receivers: combine previous two policies without change
  - Use average load as threshold



- Improved symmetric policy: exploit polling information
  - Two thresholds: *LT, UT, LT <= UT*
  - Maintain sender, receiver and OK nodes using polling info
  - Sender: poll first node on receiver list …
  - Receiver: poll first node on sender list …



Case Study: V-System (Stanford)

- State-change driven information policy
  - Significant change in CPU/memory utilization is broadcast to all other nodes
- *M* least loaded nodes are receivers, others are senders
- Sender-initiated with new job selection policy
- Location policy: probe random receiver, if still receiver, transfer job, else try another

Sprite (Berkeley)

- Workstation environment => owner is king!
- Centralized information policy: coordinator keeps info
  - State-change driven information policy
  - Receiver: workstation with no keyboard/mouse activity for 30 seconds *and* # active processes < number of processors
- Selection policy: manually done by user => workstation becomes sender
- Location policy: sender queries coordinator
- WS with foreign process becomes sender if user becomes active: selection policy=> home workstation

Sprite (contd)

- Sprite process migration
  - Facilitated by the Sprite file system
  - State transfer
    - Swap everything out
    - Send page tables and file descriptors to receiver
    - Demand page process in
    - Only dependencies are communication-related
      - Redirect communication from home WS to receiver