Managing Parallelism/Concurrency in Servers

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Server

- Computer application serving (potentially many) interactive clients
  - Parallelism: many requests run concurrently in a server
- But unlike the parallel applications we have seen so far
  - Easily partitioned to fine-grained requests without inter-request dependencies, no need for synchronization ⇒ embarrassingly parallel
  - Highly multiprogrammed, many context switches
  - Performance (quality-of-service) and resource accounting at each request

Multi-processing vs. Multi-threading

- Multi-processing server
  - each request is served by a process (Apache)
- Multi-threading server
  - each request is served by a thread.
- Compare multi-processing server with multi-threading server
  - efficiency
  - robustness/isolation
- Pooling can be used to reduce the overhead on process/thread creation and termination

User-level Threads

- Kernel threads
  - thread management/scheduling done by the OS kernel
- User threads
  - thread management/scheduling done at user-level
  - Benefit: efficiency, e.g., less context switching overhead
- Problem of user threads
  - oblivious to kernel events, so all threads in a process are put to wait when only one of them blocks on I/O (e.g., read())
- How to solve this problem?
  - helper (kernel) threads
  - asynchronous I/O
Event-driven Servers

- Event-driven servers divide request processing into stages, each of which is non-blocking.
- Each stage is triggered by an event.
- The whole event controller runs in a single user thread.

- Flash Web server [Pai et al., USENIX1999]
- Problems: difficult programming, hidden I/O?

Request Scheduling

- Scheduling or request execution:
  - Normal multi-tasking (a task is a process/thread or a request)
  - Staged resource-aware request scheduling:
    - Each request execution is partitioned into stages (like in event-driven servers)
    - Each stage has particular resource needs.
    - Throttling early stage for admission control.
  - SEDA [Welsh et al., SOSP2001]

High Concurrency Threaded Server

- What is your first problem when you try to run 10,000 requests/threads concurrently in a server?
- Capriccio [von Behren et al., SOSP2003]

Overhead with High Concurrency

- More frequent context switches? Cache pollution?
- Scalability of the select() system call [Banga et al., USENIX1998]
Overhead with High Load Network Server

- With gigabit Ethernet:
  - 125,000,000 bytes per second for 1,500 bytes/frame
  
    \[ \Rightarrow 12 \text{us per frame} \]
  
    if an interrupt handler consumes 3us CPU, then 25% CPU processing on interrupt handling

- Soft timers [Aron and Druschel, SOSP1999]
  - NIC buffers frames; only interrupt after multiple frames arrive
  - CPU does a coarse-granularity polling

Control the Concurrency

- How to control the execution concurrency?
  - use a request buffer queue

Handle Server Overload

- Overhead of server overload:
  - some requests have to be abandoned
  - when a request has to be abandoned, resources already consumed by this request is wasted

  \textbf{Principle:} when abandoning a request, do so as early as possible
  - drop new requests if the buffer queue is already long

OS Overhead for Each Request
Lazy Receiver Processing
[Druschel&Banga OSDI1996]

Application processes

Sockets
TCP/UDP
IP
Per-socket Interface queue

Network interface

Application access:

Hardware interrupt: