CS 550:

Advanced Operating Systems

Processes and Threads

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CS 550
Advanced Operating Systems
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Outline for Today

- Motivation and definitions
- Processes
- Threads
- Synchronization constructs
- Speedup issues
  - Overhead
  - Caches
  - Amdahl's Law

How can we make threads cooperate?

- If task can be completely decoupled into independent sub-tasks, cooperation required is minimal
  - Starting and stopping communication
- Trouble when they need to share data!
- Race conditions:

Scenario 1

Thread A	readX		incX		writeX	
Thread B		readX		incX		writeX

time -->

Scenario 2

Thread A	readX	incX	writeX			
Thread B				readX	incX	writeX

time -->

- We need to force some serialization
  - Synchronization constructs do that!

Lock / mutex semantics

- A *lock* (mutual exclusion, mutex) guards a *critical section* in code so that only one thread at a time runs its corresponding section
  - *acquire* a lock before entering crit. section
  - *releases* the lock when exiting crit. section
  - Threads share locks, one per section to synchronize
- If a thread tries to acquire an in-use lock, that thread is put to sleep
  - When the lock is released, the thread wakes up *with the lock*! (blocking call)

Lock / mutex syntax example in PThreads

```
pthread_mutex_t lock = PTHREAD_MUTEX_INITIALIZER;
int x;
```

```
threadA() {
  int temp = foo(x);
  pthread_mutex_lock(&lock);
  x = bar(x) + temp;
  pthread_mutex_unlock(&lock);
  // continue…
}
```

```
threadB() {
  int temp = foo(9000);
  pthread_mutex_lock(&lock);
  baz(x) + bar(x);
  x *= temp;
  pthread_mutex_unlock(&lock);
  // continue…
}
```

Thread A	readX … acquireLock => SLEEP WAKE w/ LOCK… releaseLock
Thread B	… acquireLock readX readX writeX releaseLock …

time -->

- But locks don’t solve everything…
  - Problem: potential deadlock!

```
threadA() {
  pthread_mutex_lock(&lock1);
  pthread_mutex_lock(&lock2);
}
```

```
threadB() {
  pthread_mutex_lock(&lock2);
  pthread_mutex_lock(&lock1);
}
```

Condition variable semantics

- *A condition variable* (CV) is an object that threads can sleep on and be woken from
  - *Wait* or *sleep* on a CV
  - *Signal* a thread sleeping on a CV to wake
  - *Broadcast* all threads sleeping on a CV to wake
  - I like to think of them as thread pillows…
- *Always* associated with a lock!
  - Acquire a lock before touching a CV
  - Sleeping on a CV releases the lock in the thread's sleep
  - If a thread wakes from a CV it will have the lock
- Multiple CVs often share the same lock

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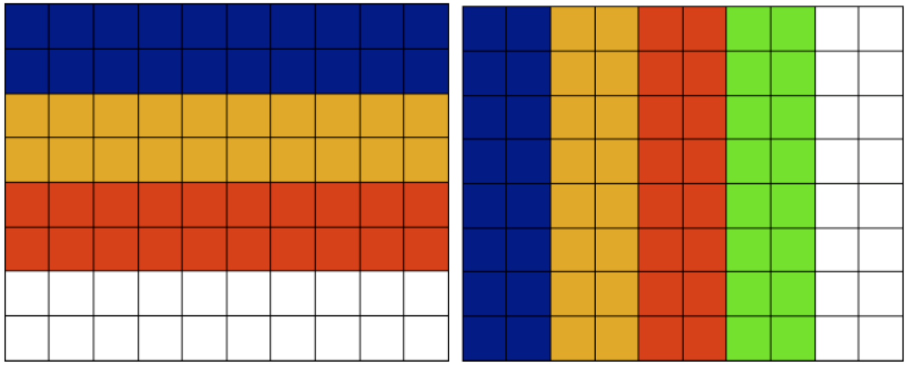
Speedup issues: overhead

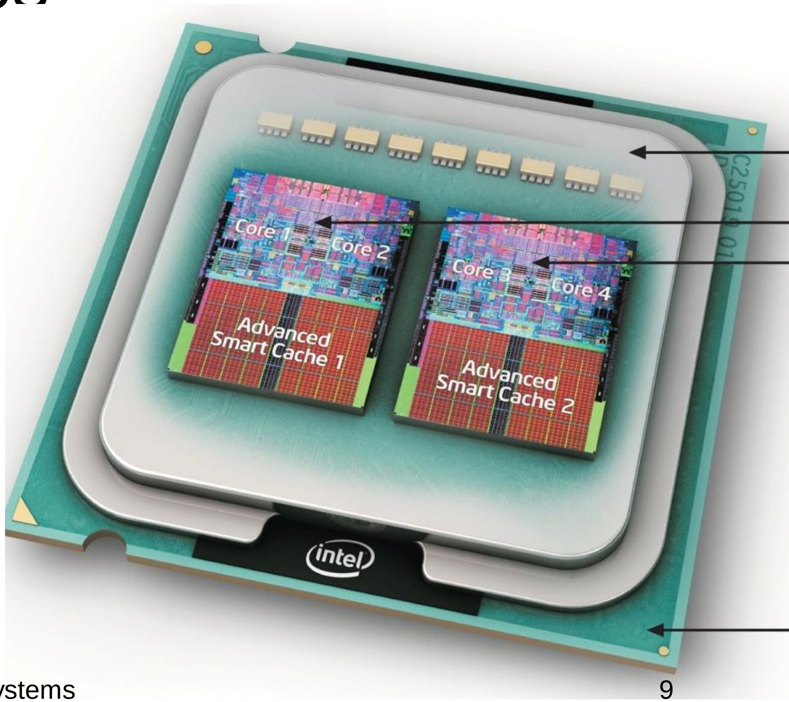
- More threads does not always mean better!
  - I only have two cores…
  - Threads can spend too much time *synchronizing* (e.g. waiting on locks and condition variables)
- Synchronization is a form of overhead
  - Also communication and creation/deletion overhead

Speedup issues: caches

- Caches are often one of the largest considerations in performance
- For multicore, common to have independent L1 caches and shared L2 caches
- Can drive domain decomposition design

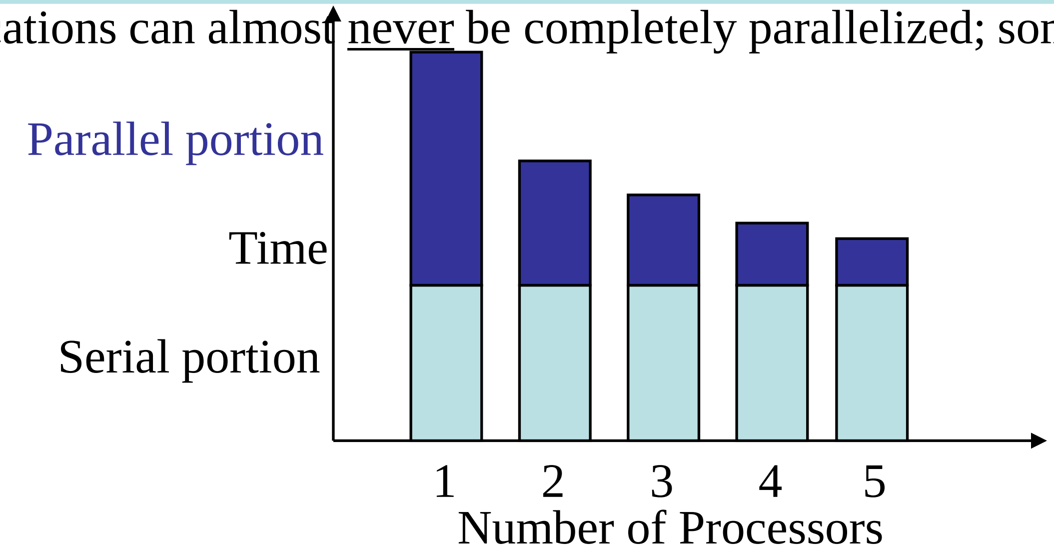


(a) "Horizontal" Decomposition (b) "Vertical" Decomposition



Speedup Issues: Amdahl's Law

- Applications can almost never be completely parallelized; some serial code remains



- s is serial fraction of program, P is # of processors
- Amdahl's law:

Speedup(P) = Time(1) / Time(P)

$\leq 1 / (s + ((1-s) / P))$, and as $P \rightarrow \infty$

$\leq 1/s$

- Even if the parallel portion of your application speeds up perfectly, your performance may be limited by the sequential portion

Pseudo Quiz

- Super-linear speedup is possible
- Multicore is hard for architecture people, but pretty easy for software
- Multicore made it possible for Google to search the web

Quiz Answers!

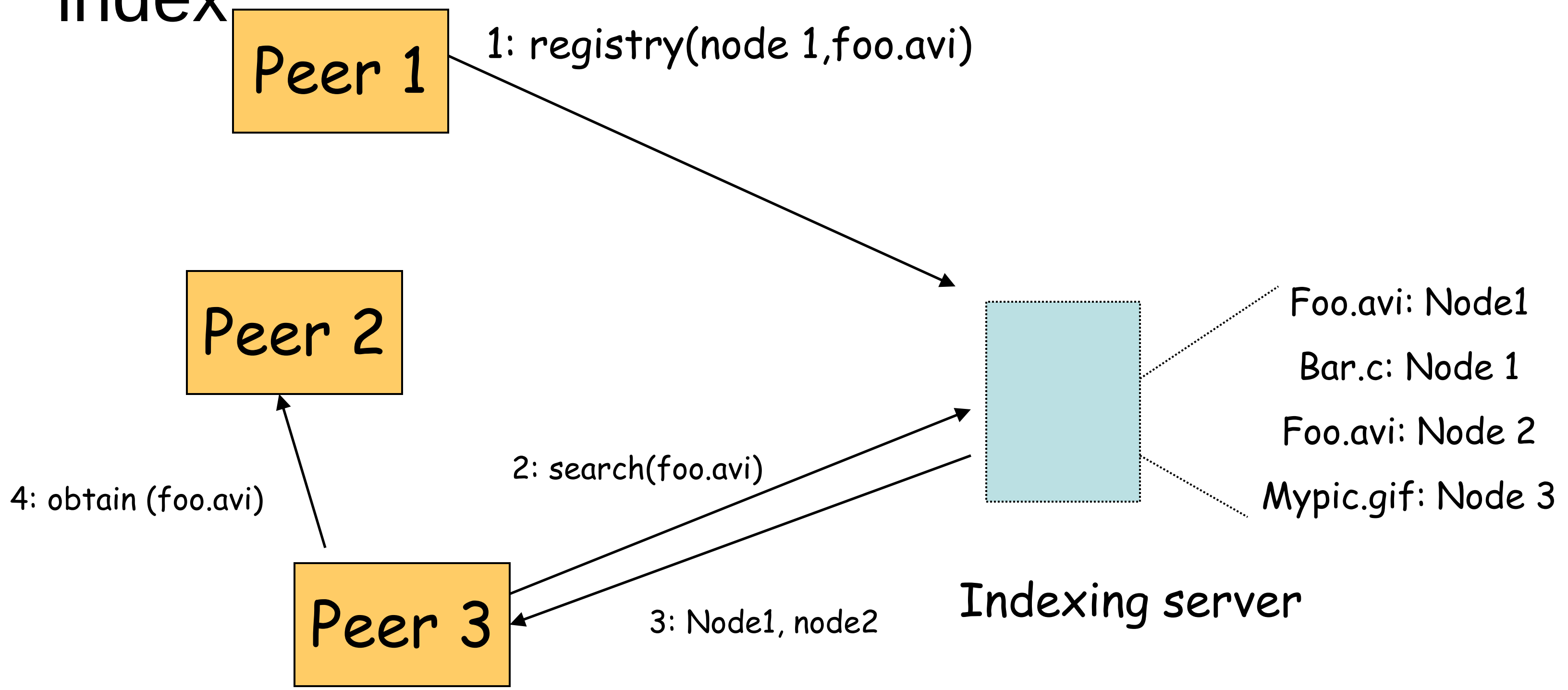
- Super-linear speedup is possible
  True: more cores means simply more cache accessible (e.g. L1), so some problems may see super-linear speedup
- Multicore is hard for architecture people, but pretty easy for software
  False: parallel processors put the burden of concurrency largely on the SW side
- Multicore made it possible for Google to search the web
  False: web search and other Google problems have huge amounts of data. The performance bottleneck becomes RAM amounts and speeds! (CPU-RAM gap)

Summary

- Threads can be *awake* and ready/running on a core or *asleep* for sync. (or blocking I/O)
- Use PThreads to thread C code and use your multicore processors to their full extent!
  - `pthread_create(), pthread_join(), pthread_exit()`
  - `pthread_mutex_t, pthread_mutex_lock(), pthread_mutex_unlock()`
  - `pthread_cond_t, pthread_cond_wait(), pthread_cond_signal(), pthread_cond_broadcast()`
- Domain decomposition is a common technique for multithreading programs
- Watch out for
  - Synchronization overhead
  - Cache issues (for sharing data, decomposing)
  - Amdahl's Law and algorithm parallelizability
- Reading Ch. 3
- Programming Assignment – Part 1

Programming Assignment

- Part 1: Peer-to-peer file sharing with centralized index



Programming Assignment

- Two entities
  - Central indexing server
    - List of all files at peers
  - Peer (both client and server)
    - [client] Search for a file at the indexing server
    - Download file from a peer, update indexing server
    - [server] listen for download requests and service
  - Provide concurrency at the central indexing server and peer
- Feel free to use any prog language and any mechanism (threads, RPC, RMI, sockets, semaphores…)

Questions

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