Why Multiprocessors?

Moore’s Law predicted a doubling of processor performance every couple of years
• true until about 2000

Limits on the performance of a single processor: what are they?

1. Utilizes coarser granularities than ILP
2. Lots of workload opportunity
   • Scientific computing/supercomputing
     • Examples: weather simulation, aerodynamics, protein folding
     • Each processor computes for a part of the grid
   • Server workloads
     • Example: airline reservation database
     • Many concurrent updates, searches, lookups, queries
     • Processors handle different requests
   • Media workloads
     • Processors compress/decompress different parts of image/frames
   • Desktop workloads …
   • Gaming workloads …
3. Can now fit multiple processors on a chip; but each one is probably simpler

What would you do with a billion transistors on a chip? Or more?
**What is a Parallel Architecture?**

A parallel computer is a collection of processing elements that cooperate to solve large problems fast.

Some broad issues:

- **Resource Allocation**:
  - How many processing elements (PEs)?
  - How powerful are the PEs?
  - How much memory?

- **Data access, Communication and Synchronization**
  - How do the PEs cooperate and communicate?
  - How are data transmitted between PEs?
  - What are the abstractions and primitives for cooperation?

- **Performance and Scalability**
  - How does a design translate into performance?
  - How does it scale?

**Multiprocessors**

**Low-end**
- bus-based
  - simple, but a bottleneck
  - broadcast cache coherency protocol
- physically centralized memory
- uniform memory access (UMA machine)
- today's small CMPs:
  - Intel Core i3, i5, i7 (2-6 cores), AMD Opteron “Bulldozer” (4-16 cores), Sun SPARC T4 (8 cores per processor, 4 processors per system), ARM Cortex A5 (2 cores), Nvidia Tegra 3 (4 cores)
Low-end MP

Multiprocessors

High-end

- multiple-path interconnect
  - higher bandwidth
  - longer memory latencies
  - more scalable
  - point-to-point cache coherency protocol
- physically distributed memory
- non-uniform memory access (NUMA machine)
- could have processor clusters
- today’s large MPs:
  SGI UV (256 10-core Xeon processors, 2D torus), Cray XE6 (1M Opteron 6200 cores), IBM BlueGene/Q (100K 16-core PowerPCs, 5D torus), Fujitsu K Computer (44K 16-core SPARCsp)
High-end MP

Comparison of Issue Capabilities

Superscalar
horizontal waste
Issue slots

Single-chip
Multiprocessor

vertical waste

Thread 1
Thread 2
Thread 3
Thread 4
Thread 5

hiding horizontal waste
a downside