

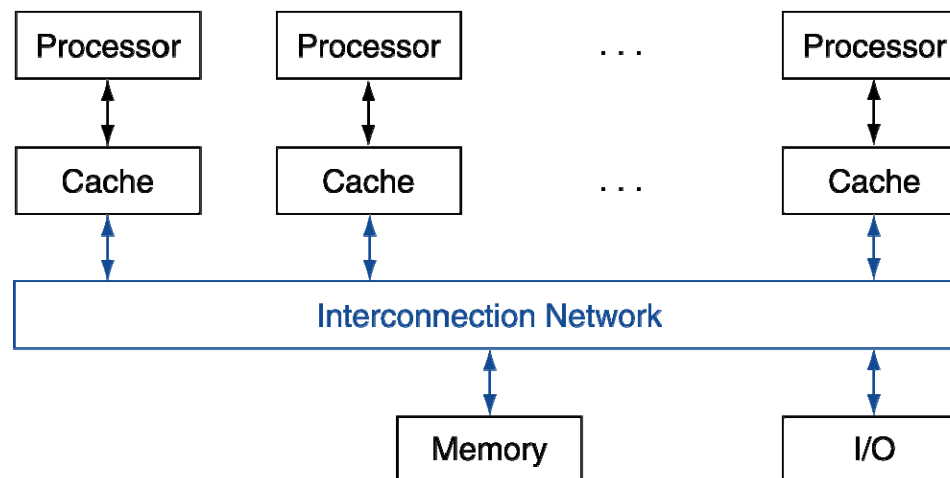
# Chapter 7

Multicores,  
Multiprocessors, and  
Clusters



# Shared Memory

- SMP: shared memory multiprocessor
  - Hardware provides single physical address space for all processors
  - Synchronize shared variables using locks
  - Memory access time
    - UMA (uniform) vs. NUMA (nonuniform)



# Example: Sum Reduction

- Sum 100,000 numbers on 100 processor UMA
  - Each processor has ID:  $0 \leq P_n \leq 99$
  - Partition 1000 numbers per processor
  - Initial summation on each processor

```
sum[Pn] = 0;
for (i = 1000*Pn;
     i < 1000*(Pn+1); i = i + 1)
    sum[Pn] = sum[Pn] + A[i];
```
- Now need to add these partial sums
  - Reduction: divide and conquer
  - Half the processors add pairs, then quarter, ...
  - Need to synchronize between reduction steps



# Example: Sum Reduction

```
half = 100;
```

```
repeat
```

```
    synch();
```

```
    if (half % 2 != 0 && Pn == 0)
```

```
        sum[0] = sum[0] + sum[half-1];
```

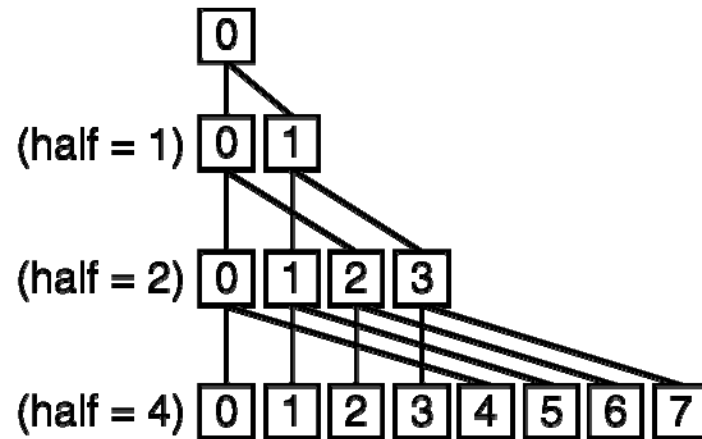
```
        /* Conditional sum needed when half is odd;
```

```
        Processor0 gets missing element */
```

```
    half = half/2; /* dividing line on who sums */
```

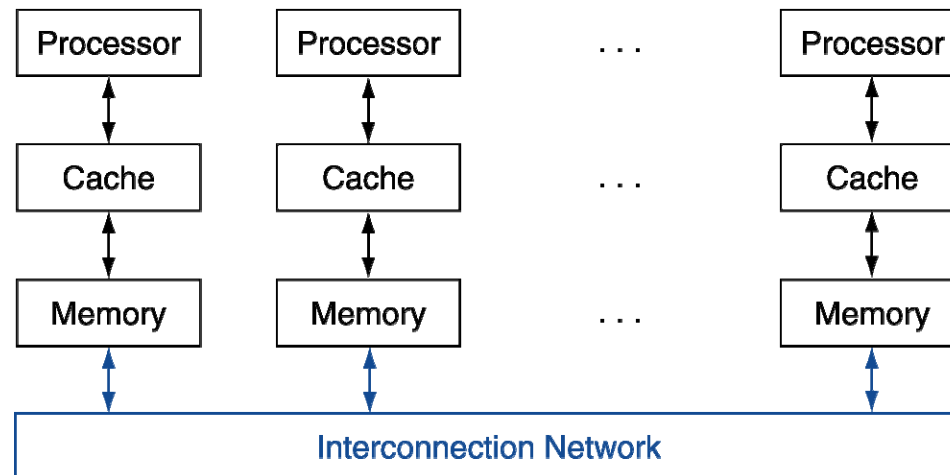
```
    if (Pn < half) sum[Pn] = sum[Pn] + sum[Pn+half];
```

```
until (half == 1);
```



# Message Passing

- Each processor has private physical address space
- Hardware sends/receives messages between processors



# Loosely Coupled Clusters

- Network of independent computers
  - Each has private memory and OS
  - Connected using I/O system
    - E.g., Ethernet/switch, Internet
- Suitable for applications with independent tasks
  - Web servers, databases, simulations, ...
- High availability, scalable, affordable
- Problems
  - Administration cost (prefer virtual machines)
  - Low interconnect bandwidth
    - c.f. processor/memory bandwidth on an SMP



# Sum Reduction (Again)

- Sum 100,000 on 100 processors
- First distribute 100 numbers to each

- The do partial sums

```
sum = 0;
```

```
for (i = 0; i < 1000; i = i + 1)
```

```
    sum = sum + AN[i];
```

- Reduction

- Half the processors send, other half receive and add

- The quarter send, quarter receive and add, ...



# Grid Computing

- Separate computers interconnected by long-haul networks
  - E.g., Internet connections
  - Work units farmed out, results sent back
- Can make use of idle time on PCs
  - E.g., SETI@home, World Community Grid

