COL216
Computer Architecture

Input/Output – 5

I/O Performance

28th March 2022

I/O Performance

- It often gets neglected
- Suppose a benchmark executes in 100 sec
  - CPU 90%
  - I/O 10%
- CPU performance improves by 50% every year for 5 years
  - $90 \rightarrow 60 \rightarrow 40 \rightarrow 27 \rightarrow 18 \rightarrow 12$ (total = 7.5 times)
- I/O performance unchanged
- Overall performance
  - $100 \rightarrow 70 \rightarrow 50 \rightarrow 37 \rightarrow 28 \rightarrow 22$ (total = 4.5 times)
- If program is I/O bound, improvement is even smaller

I/O performance definitions

- Throughput
  - Amount of data transfer in unit time (KB/s, MB/s)
  - Number of I/O operations in unit time
- Response time
  - Relevant in interactive environment, embedded systems
- Both important in some cases

Examples

- Supercomputers
  - data throughput (KB or MB/s), more output than input
- Transaction processing
  - transactions per sec, response time
- File server
  - file operations per sec

Discrepancy in units

- Memory size
  - 1 KB = 1024 B (2^{10})
  - 1 MB = 1024 KB (2^{10}) = 1048576 B (2^{10})
- I/O rate
  - 1 KB/s = 1000 B/s (10^3)
  - 1 MB/s = 1000 KB/s (10^3) = 1000000 B/s (10^6)

I/O system performance example

Given :

- Server configuration
- I/O intensive application characteristics

Required :

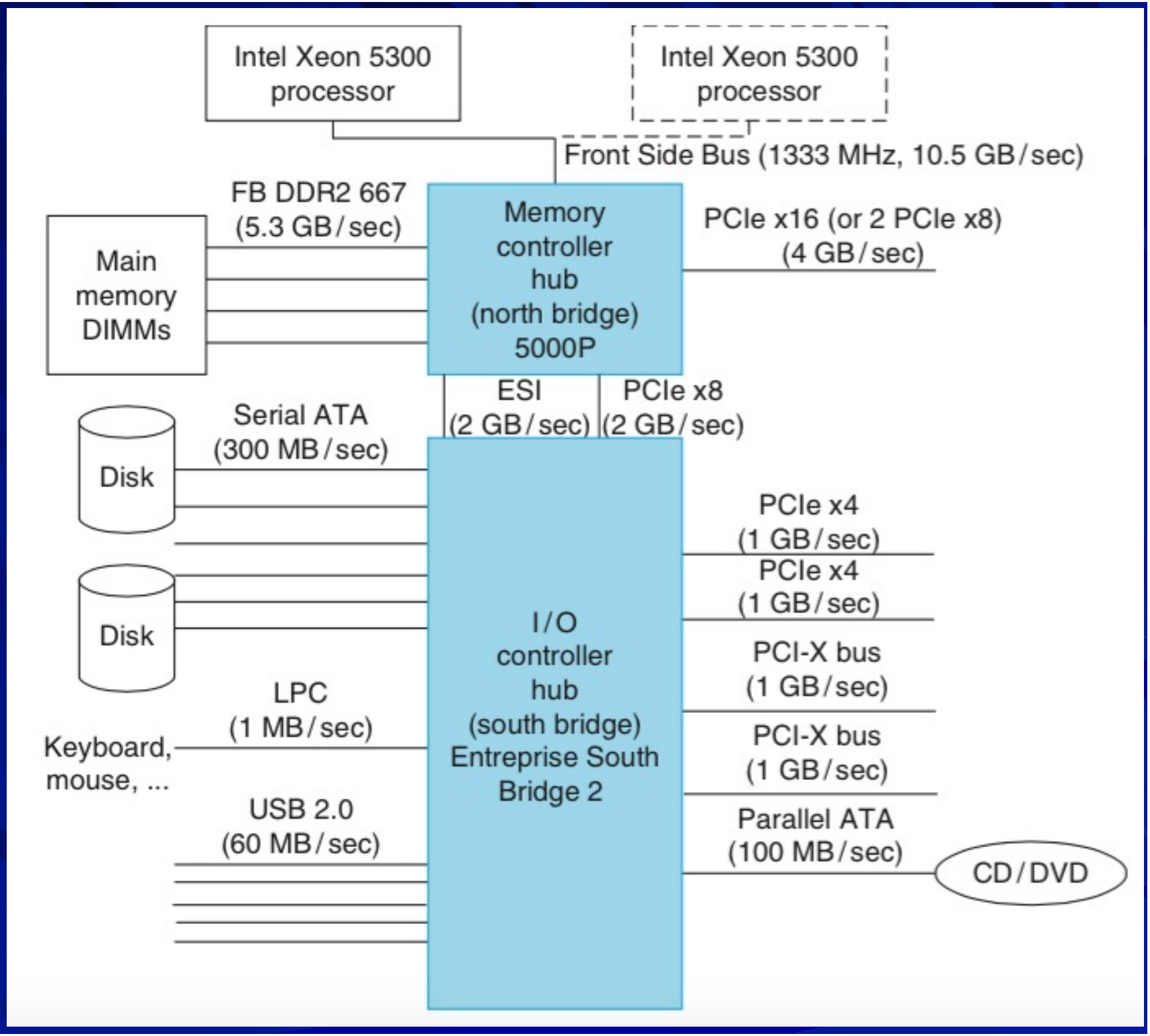
- Maximum sustainable performance
  (in terms of rate of I/O operations)

I/O example: server configuration

Sun Fire x4150 server

- 8 processors, across two sockets (Xeon 5345)
- 64 GB DRAM (DDR2 667), across 16 FBDIMMs
- 8 HDDs, 2.5 inch, 15,000 RPM 73 GB SAS
- 4 Ethernet ports 10/100/1000 Gbps
- 3 PCI Express x8 ports
- 4 external and 1 internal USB 2.0 ports

Server Architecture



I/O example: application characteristics

- User program uses 200,000 instructions per I/O operation
- Operating system averages 100,000 instructions per I/O operation
- Workload consists of 64 KB reads
- Each processor sustains 1 billion instructions per second

I/O example: requirement

- Find the maximum sustainable I/O rate for a fully loaded Sun Fire x4150
  - for random reads
  - sequential reads
- Assume that the reads can always be done on an idle disk if one exists (i.e., ignore disk conflicts)

IOPS for processors

Maximum I/O rate of 1 processor = Instruction execution rate / Instructions per I/O

$= 1 \times 10^9 / (200 + 100) \times 10^3 = 3{,}333$ IOPS

One socket has four processors

$\Rightarrow$ 4 x 3,3333 = 13,333 IOPS

Two sockets with eight processors

$\Rightarrow$ 2 x 13,333 = 26,666 IOPS.

IOPS for disks

Time per I/O at disk (for random access)

= seek + rotational time + transfer time

= .725 ms + 2 ms + 64 KB / 112 MB/s

= 3.3 ms

Each disk can do 1000/3.3 = 303 IOPS

8 disks can do 8 x 303 = 2,424 IOPS

For sequential access,

time = 64 KB / 112 MB/s => 1,750 IOPS

i.e, 14,000 IOPS for 8 disks

IOPS for PCI express

Bandwidth of a PCIe lane = 250 MB/s

Bandwidth of 8 PCIe lanes = 8 x 250 MB/s
= 2,000 MB/s

IOPS for 8 PCIe lanes = 2,000 MB/s / 64 KB
= 31,250

IOPS for DRAM

Bandwidth of 667 MHz FBDIMM

= 8 x 667 = 5,336 MB/s

IOPS for one FBDIMM = (5,336 / 64) x 1000

= 83,375

Max no. of DIMMs = 16

FSB limit

FSB peak bandwidth = 10.6 GB/s

Sustained bandwidth = 5.3 GB/s

IOPS for each FSB = $5.3 \times 10^6 / 64 = 81{,}540$

For 2 FSBs = > 2 x 81,540 = 163,080 IOPS

IOPS at a glance

- 8 Processors : 26,667
- 8 Disks : 2,424 (random)
  14,000 (sequential)
- PCIe 8x : 31,250
- 1 FBDIMM : 83,375
- 1 FSB : 81,540

THANKS