I/O Hardware

COMP755 Advanced Operating Systems

I/O Devices

- Disk
- hard
- floppy
- CD
- DVD
- Monitor
- Keyboard
- Speakers
- Printer
- Mouse
- Scanner
- Game controller
- Many, many more

I/O Controller

- Connects the I/O devices to the system.
- Communicates with the CPU and the RAM over the bus.
- A single I/O controller may control multiple devices.
- Most computers have several I/O controllers.
- Actions are initiated by the CPU.

Differences in I/O Devices

- Complexity of control
- Unit of transfer
  - stream of bytes
  - large blocks
- Data representation
  - Encoding schemes
- Error conditions
  - Devices respond to errors differently

Differences in I/O Devices

- Programmed I/O
  - Process is busy-waiting for the operation to complete
- Interrupt-driven I/O
  - I/O command is issued
  - Processor continues executing instructions
  - I/O module sends an interrupt when done

Differences in I/O Devices

- Data rate
  - May be differences of several orders of magnitude between the data transfer rates
  - High speed devices may run faster than the CPU or bus can process the input.
Techniques for Performing I/O

• Direct Memory Access (DMA)
  – DMA module controls exchange of data between main memory and the I/O device
  – Processor interrupted only after entire block has been transferred
  – DMA may be built into the device controller or may be a separate bus controller

Direct Memory Access

• Takes control of the system from the CPU to transfer data to and from memory over the system bus
• Cycle stealing is used to transfer data on the system bus
• The instruction cycle is suspended so data can be transferred
• The CPU may pause one bus cycle – No interrupt occurs
• Impact diminished by CPU caching

Buffer Chaining

• Handles multiple transfers without the processor
• Device given linked list of buffers
• Device hardware uses next buffer on list automatically

Scatter Read and Gather Write

• Special case of buffer chaining
• Large data transfer formed from separate blocks
• Example: to write a network packet, combine packet header from buffer 1 and packet data from buffer 2
• Eliminates application program from copying data into single, large buffer

Operation Chaining

• Further optimization for smart device
• Processor gives series of commands to device, sometimes called a channel program
• Device carries out successive commands automatically
Disk Performance Parameters

Disk read or write involves three factors

1. Seek time
   - time it takes to position the head at the desired track
2. Rotational delay or rotational latency
   - time it takes for the beginning of the sector to reach the head
3. Transfer time
   - time required for the data to move under the head

Performance Example

How long does it take to read a 512 byte block from the disk?

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Seek time</td>
<td>8.9 ms</td>
</tr>
<tr>
<td>Average Rotational Delay</td>
<td>4.2 ms</td>
</tr>
<tr>
<td>Transfer time</td>
<td>13.2 ms</td>
</tr>
<tr>
<td>Total</td>
<td>13.2 ms</td>
</tr>
</tbody>
</table>

Performance Example

How long does it take to read two consecutive 512 byte blocks from the disk?

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Seek time</td>
<td>8.9 ms</td>
</tr>
<tr>
<td>Average Rotational Delay</td>
<td>4.2 ms</td>
</tr>
<tr>
<td>Transfer time</td>
<td>13.4 ms</td>
</tr>
<tr>
<td>Total</td>
<td>13.4 ms</td>
</tr>
</tbody>
</table>

Logical vs. Physical

- Many disks present the OS with a logical layout that is different from the physical layout.
- Compatibility with old standards
- Many disks use Logical Block Addressing (LBA) to hide the physical layout.

CD Performance

- The “X” of CD speed claims represents the number of times faster the CD spins than music CD players.
- CDs are written in a long spiral instead of concentric tracks.
- The average seek time for a CD is 90 ms (compare to 9 ms for a hard drive).
- CDs are efficient reading large files but slow reading small files.
RAID Hardware

- Redundant Array of Independent Disks
- A collection of disks are used as one large unit of mass storage.
- Multiple disks operating simultaneously can increase the data transfer rate.
- Extra data stored on the disks can recover the information should a disk fail.

RAID Types

- RAID 0 - Striping
- RAID 1 - Mirroring
- RAID 2 - Hamming code error recovery
- RAID 3 - Bit-interleaved parity
- RAID 4 - Block-level parity
- RAID 5 - Block-level distributed parity
- RAID 6 - Dual redundancy

RAID 0 (non-redundant)

- Improved transfer rate
- Decreased reliability

RAID 1 (mirrored)

- Improved Reliability
- Slightly slower writes.
- Possibly faster reads

RAID 2 (redundancy through Hamming code)

- Error recovery through Hamming code
RAID 3 (bit-interleaved parity)
- Striping improves read performance
- Parity improves reliability

RAID 4 (block-level parity)
- Like RAID 5 but with two parity blocks for each data block
- Slow writes

RAID 5 (distributed block parity)

RAID 6 (dual redundancy)
- Like RAID 5 but with two parity blocks for each data block
- Slow writes