

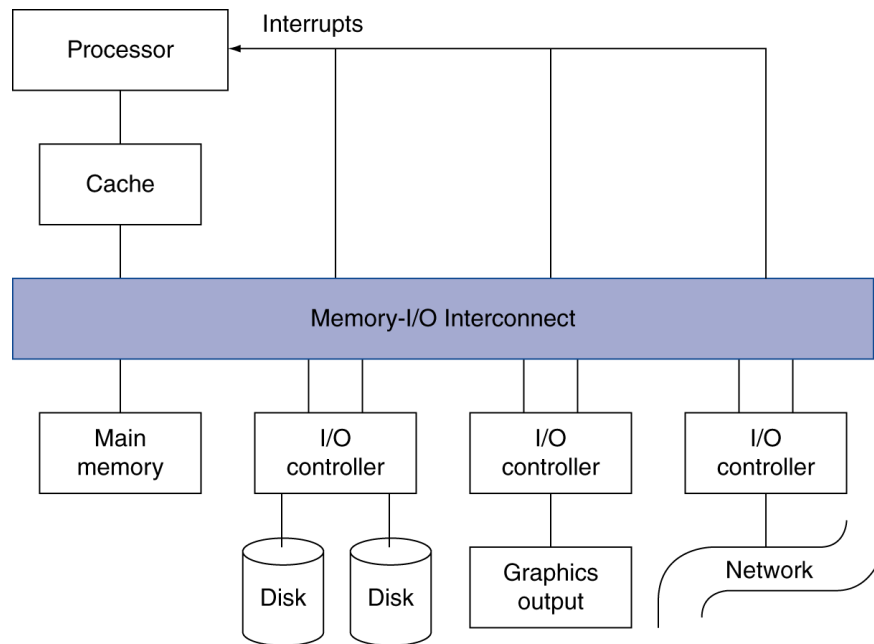


Chapter 6

Storage and Other I/O Topics

Introduction

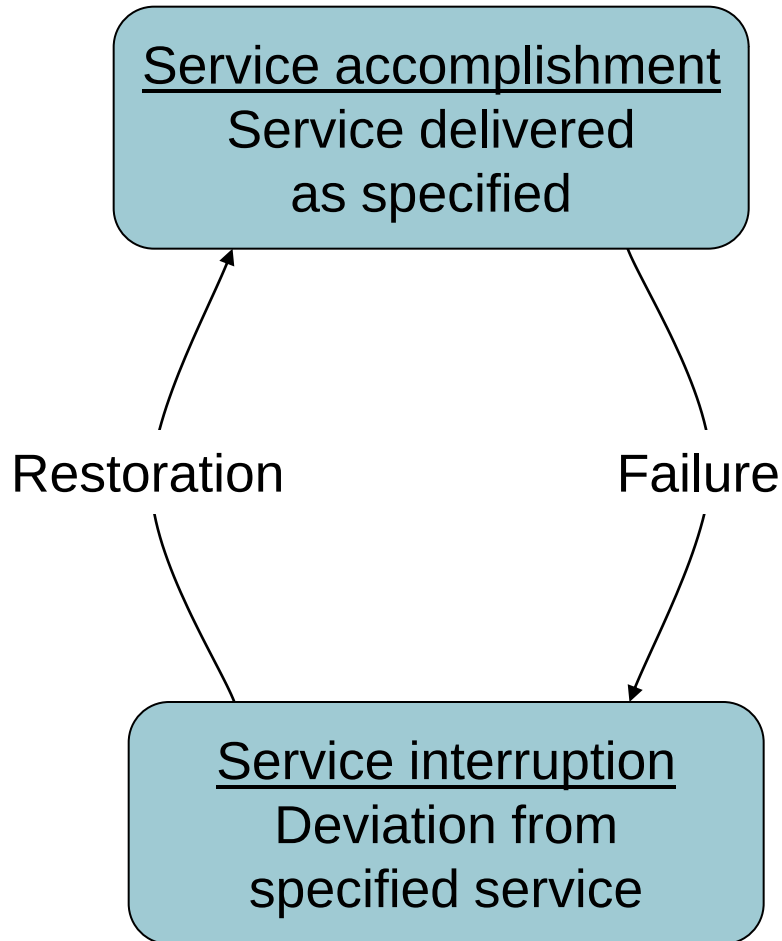
- I/O devices can be characterized by
 - Behaviour: input, output, storage
 - Partner: human or machine
 - Data rate: bytes/sec, transfers/sec
- I/O bus connections



I/O System Characteristics

- Dependability is important
 - Particularly for storage devices
- Performance measures
 - Latency (response time)
 - Throughput (bandwidth)
 - Desktops & embedded systems
 - Mainly interested in response time & diversity of devices
 - Servers
 - Mainly interested in throughput & expandability of devices

Dependability



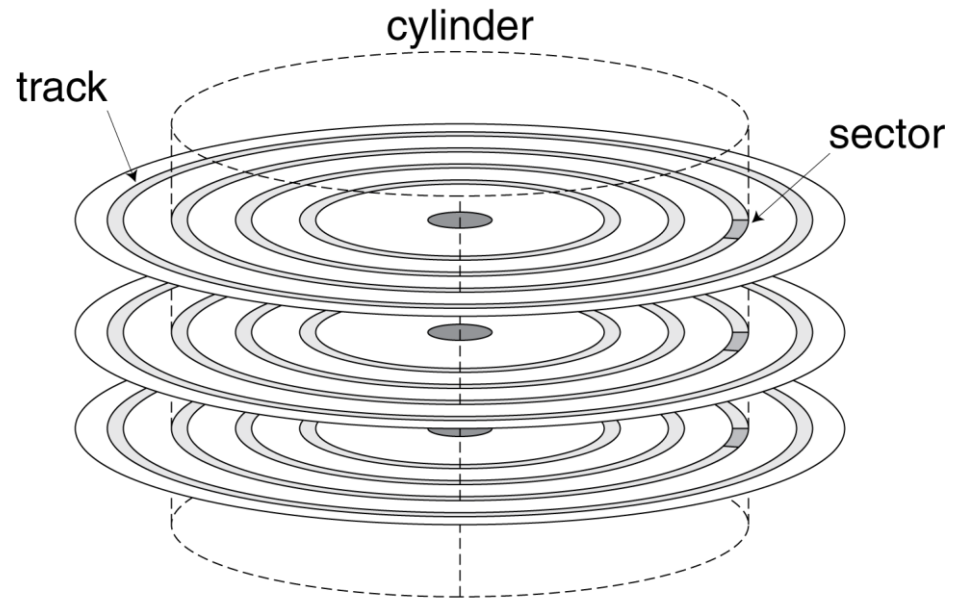
- Fault: failure of a component
 - May or may not lead to system failure

Dependability Measures

- Reliability: mean time to failure (MTTF)
- Service interruption: mean time to repair (MTTR)
- Mean time between failures
 - $MTBF = MTTF + MTTR$
- $Availability = MTTF / (MTTF + MTTR)$
- Improving Availability
 - Increase MTTF: fault avoidance, fault tolerance, fault forecasting
 - Reduce MTTR: improved tools and processes for diagnosis and repair

Disk Storage

- Nonvolatile, rotating magnetic storage



Disk Sectors and Access

- Each sector records
 - Sector ID
 - Data (512 bytes, 4096 bytes proposed)
 - Error correcting code (ECC)
 - Used to hide defects and recording errors
 - Synchronization fields and gaps
- Access to a sector involves
 - Queuing delay if other accesses are pending
 - Seek: move the heads
 - Rotational latency
 - Data transfer
 - Controller overhead

Disk Access Example

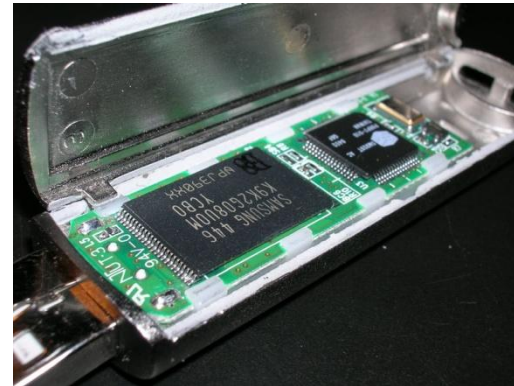
- Given
 - 512B sector, 15,000rpm, 4ms average seek time, 100MB/s transfer rate, 0.2ms controller overhead, idle disk
- Average read time
 - 4ms seek time
 - + $\frac{1}{2} / (15,000/60) = 2\text{ms}$ rotational latency
 - + $512 / 100\text{MB/s} = 0.005\text{ms}$ transfer time
 - + 0.2ms controller delay
 - = 6.2ms
- If actual average seek time is 1ms
 - Average read time = 3.2ms

Disk Performance Issues

- Manufacturers quote average seek time
 - Based on all possible seeks
 - Locality and OS scheduling lead to smaller actual average seek times
- Smart disk controller allocate physical sectors on disk
 - Present logical sector interface to host
 - SCSI, ATA, SATA
- Disk drives include caches
 - Prefetch sectors in anticipation of access
 - Avoid seek and rotational delay

Flash Storage

- Nonvolatile semiconductor storage
 - 100 – 1000 faster than disk
 - Smaller, lower power, more robust
 - But more \$/GB (between disk and DRAM)



Flash Types

- NOR flash: bit cell like a NOR gate
 - Random read/write access
 - Used for instruction memory in embedded systems
- NAND flash: bit cell like a NAND gate
 - Denser (bits/area), but block-at-a-time access
 - Cheaper per GB
 - Used for USB keys, media storage, ...
- Flash bits wears out after 1000's of accesses
 - Not suitable for direct RAM or disk replacement
 - Wear leveling: remap data to less used blocks

Interconnecting Components

- Need interconnections between
 - CPU, memory, I/O controllers
- Bus: shared communication channel
 - Parallel set of wires for data and synchronization of data transfer
 - Can become a bottleneck
- Performance limited by physical factors
 - Wire length, number of connections
- More recent alternative: high-speed serial connections with switches
 - Like networks



Bus Types

- Processor-Memory buses
 - Short, high speed
 - Design is matched to memory organization
- I/O buses
 - Longer, allowing multiple connections
 - Specified by standards for interoperability
 - Connect to processor-memory bus through a bridge

Bus Signals and Synchronization

- Data lines
 - Carry address and data
 - Multiplexed or separate
- Control lines
 - Indicate data type, synchronize transactions
- Synchronous
 - Uses a bus clock
- Asynchronous
 - Uses request/acknowledge control lines for handshaking