COMP90050
Advanced Database Systems

THE UNIVERSITY OF MELBOURNE

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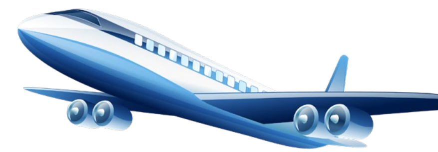
Week 1 part 1

Subject introduction

All successful companies and organizations rely on usage of data

Database: a large, integrated, structured collection of data

Subject introduction

A **Database Management System (DBMS)** is a software system designed to store, manage, and facilitate access to databases.

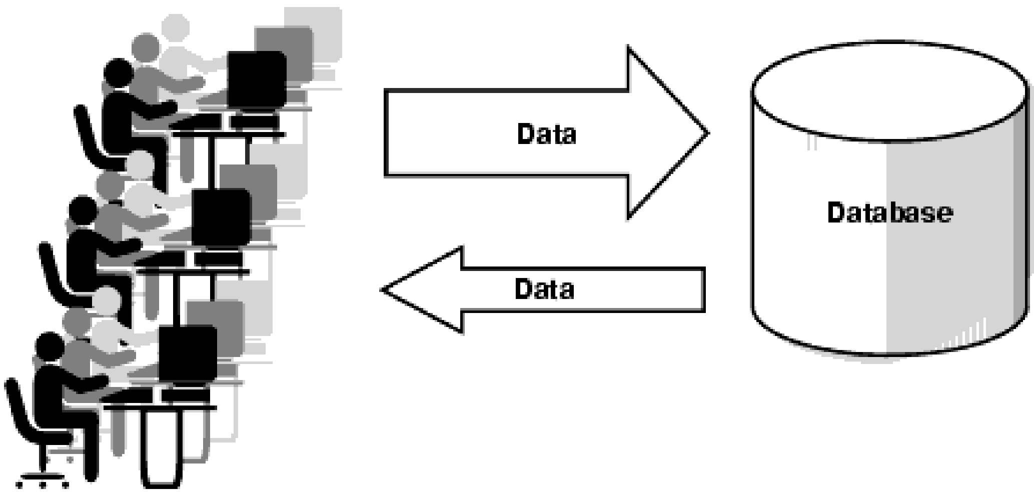
A database system should provide

- Ability to retrieve and process the data **effectively and efficiently**
- **Secure** and **reliable** storage of data

Database performance metrics

Subject introduction

This is more complex due to:

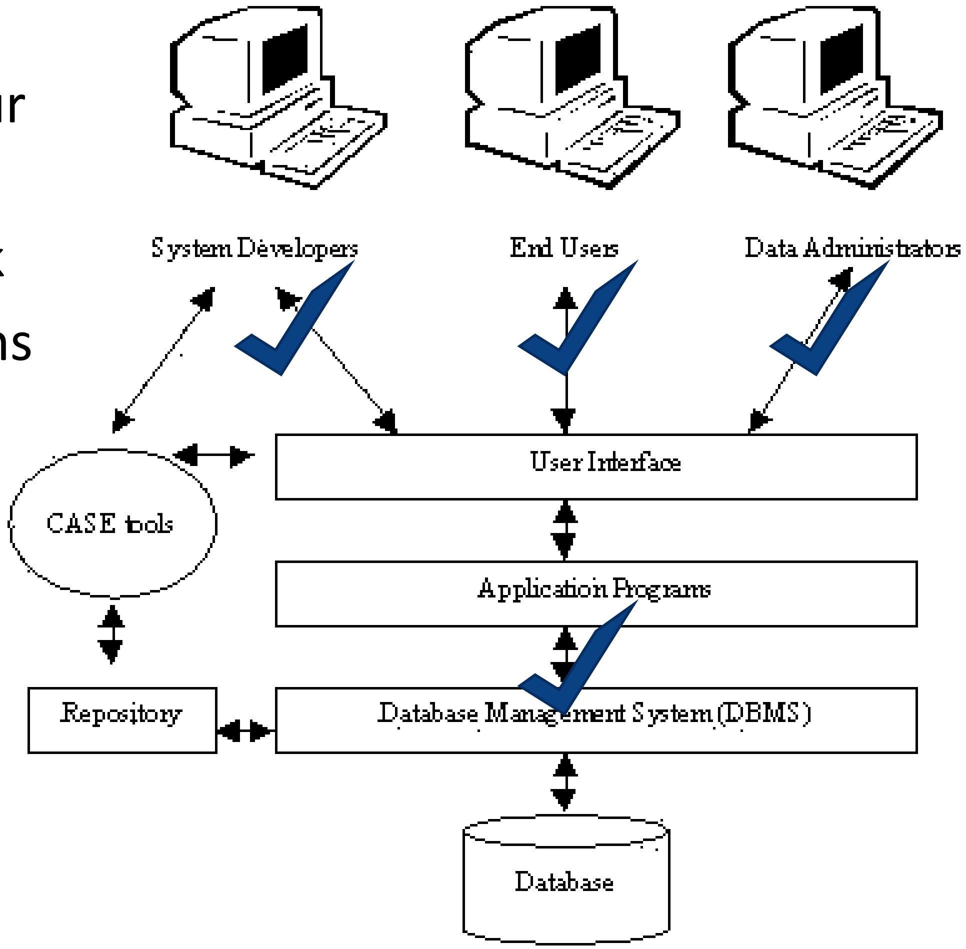


- More data
- More aspects of businesses
- Stored in various sites and accessed by many users
- More complex data types such as images, social network, videos, etc.

We will cover

Essentials to achieve correct behaviour and the best possible performance

- Knowledge of how DB systems work
- Mechanisms used by current systems to provide useful features
- Advanced topics



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Core Concepts of Database management system

Database performance metrics

- Efficiency/speed
- Effectiveness
- Security & Reliability

Efficiency

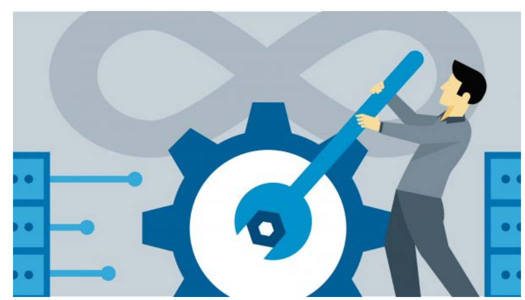
- Hardware
  - Disks and I/O bandwidth
  - Main memory
  - Type of architecture
- Software/ DB tuning
  - Types of DB
  - Indexing
  - Query optimisation

Effectiveness

- Concurrent users: Users reading and writing over the same data
- Transactions: Required tasks are all done together

Reliability

- Crash recovery
- Fault tolerance
- Data duplication

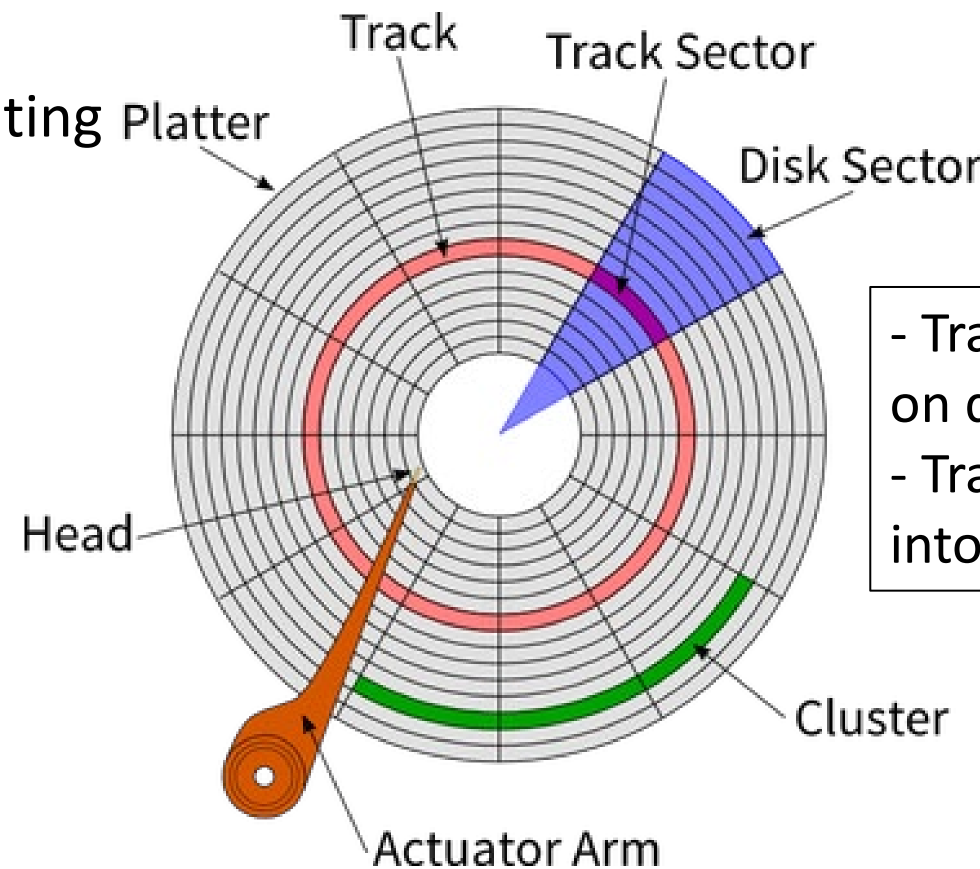


One piece of this became the dominant factor: Access to stored data in an efficient manner

You will find this picture even on the cover of DB books!

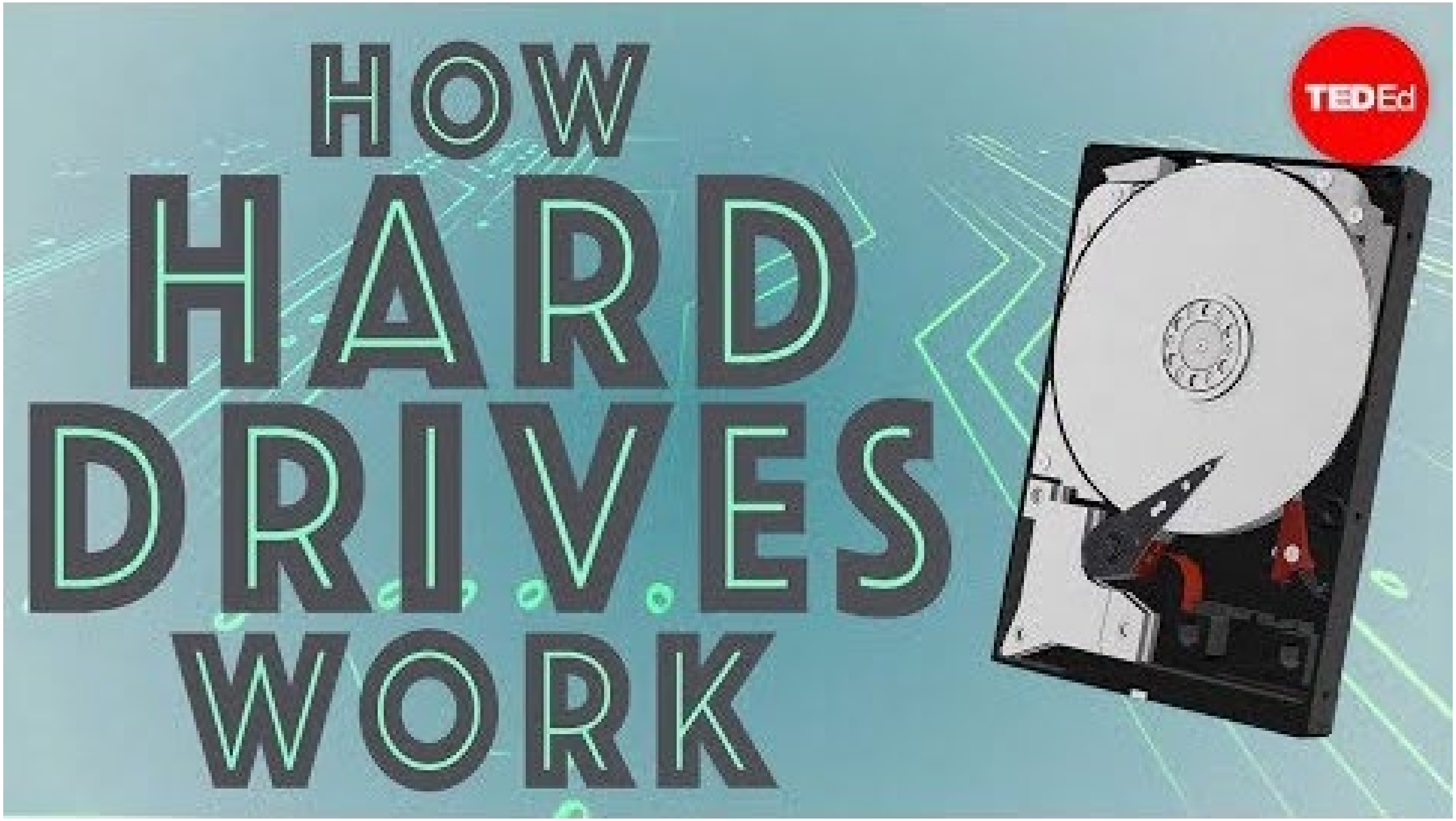
Basic Hardware of a classical disk

Rapidly rotating



- Tracks: circular path on disk surface
- Tracks are subdivided into disk sectors

with magnetic head, which reads
and writes data to the platter surfaces



https://www.youtube.com/watch?v=wteUW2sL7bc

Disk access

$$Disk\ access\ time = seek\ time + rotational\ time + \frac{transferlength}{bandwidth}$$

What is the Disk access time for a transfer size of 4KB, when average seek time is 12 ms, rotation delay 4 ms, transfer rate 4MB/sec?

SSD (Solid-State Drive/Solid-State Disk)

- **No moving parts** like Hard Disk Drive (HDD)
- Silicon rather than magnetic materials
- No seek/rotational latency
- No start-up times like HDD
- Runs silently
- Random access of typically under 100 micro-seconds compared 2000 - 3000 micro-seconds for HDD
- Relatively very expensive, thus did not dominate at all fronts yet
- Certain read/write limitations plagued it for years

$$\text{Disk access time} = \frac{\mathit{transferlength}}{\mathit{bandwidth}}$$

SSD specification example

Samsung 860 PRO SATA III 2.5-inch

Capacity: 4TB SSD

Price: Many hundreds of dollars

Weight: < 62 grams

Bandwidth Performance (SATA Standard Serial)

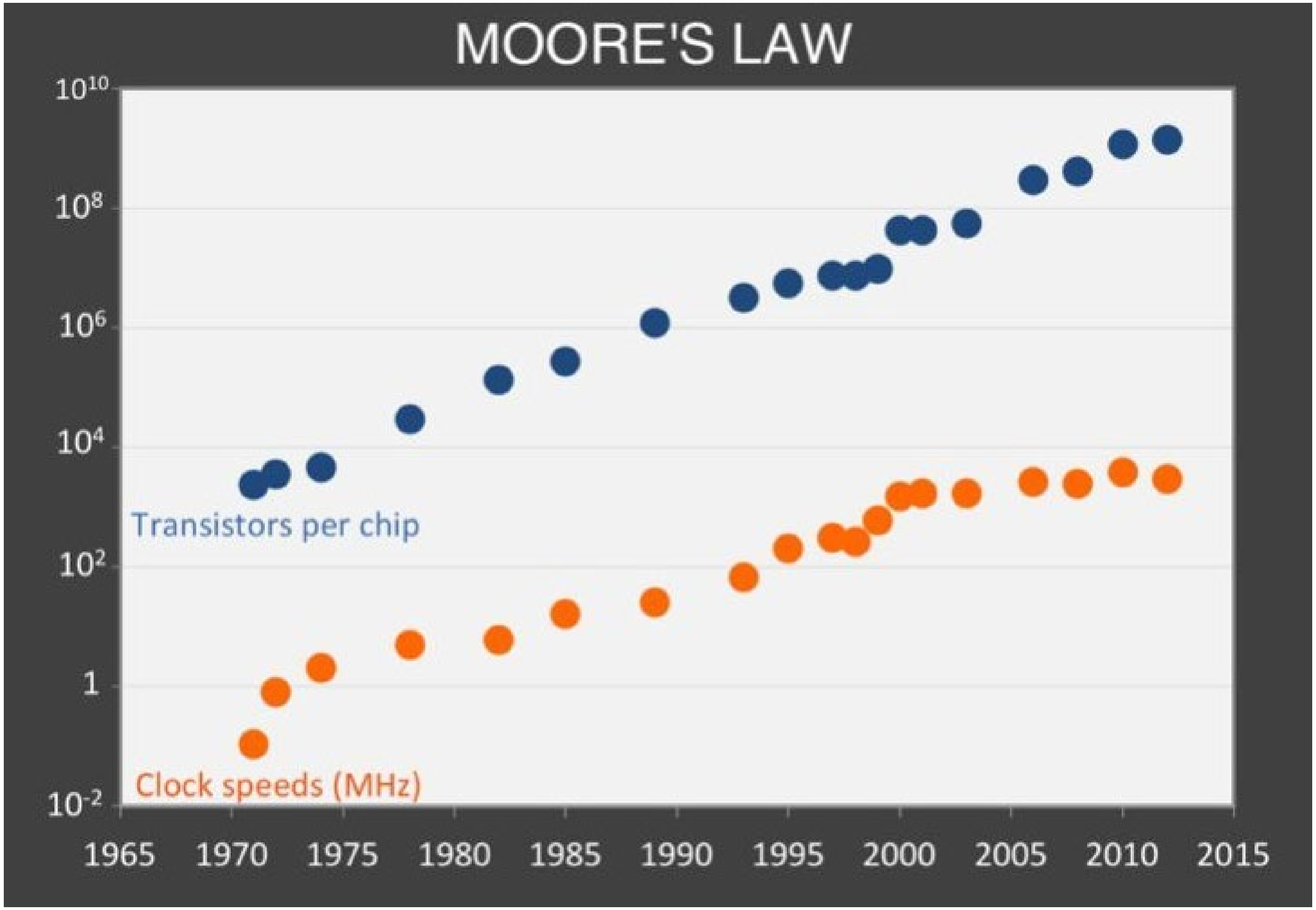
- Sustained Sequential Read: up to 560 MB/s
- Sustained Sequential Write: up to 530MB/s

Read and Write IOPS (Input/Output Per Second) – QD32

- Random 4 KB Reads: Up to 100,000 IOPS
- Random 4 KB Writes: Up to 90,000 IOPS

Other Hardware Considerations

Observations on historical trends on chips



Basically: are we going into the age of CPUs?

- Moore's law: memory chip capacity doubles every 18 months since 1970

$$= 2^{\frac{(year-1970)*2}{3}} \; Kb/chip$$

- Joy's law for processors: processor performance doubles every two years since 1984

$$= 2^{(year-1984)/2} \; mips$$

Hardware spec examples

How's recent hardwares are doing…

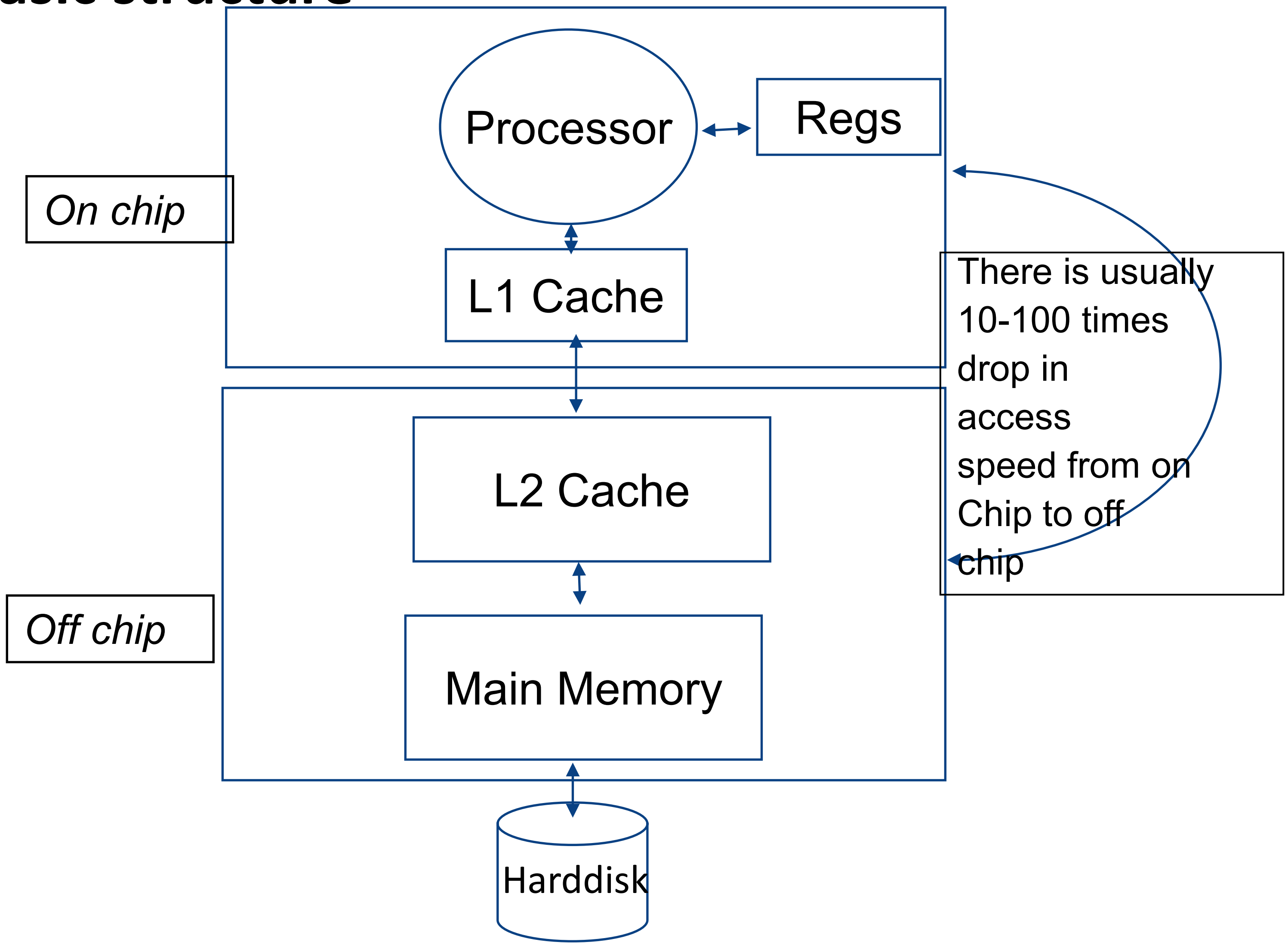
- **Blue Gene/P** performs 1 Petaflops (2^{50})/s using ~300,000 CPUs, a decade ago…
- **IBM Summit** (2019) performs 200 Petaflops (200,000 trillion calculations/second). Summit more than doubles the top speeds of **TaihuLight Supercomputer** (2018) which was 1 year older
- Very soon we will be measuring the performance by number of cores as individual CPU is reaching its maximum clock speeds
- Intel's Xeon Cascade Lake series can have up to 48 cores

Some numbers to recall before looking at storage

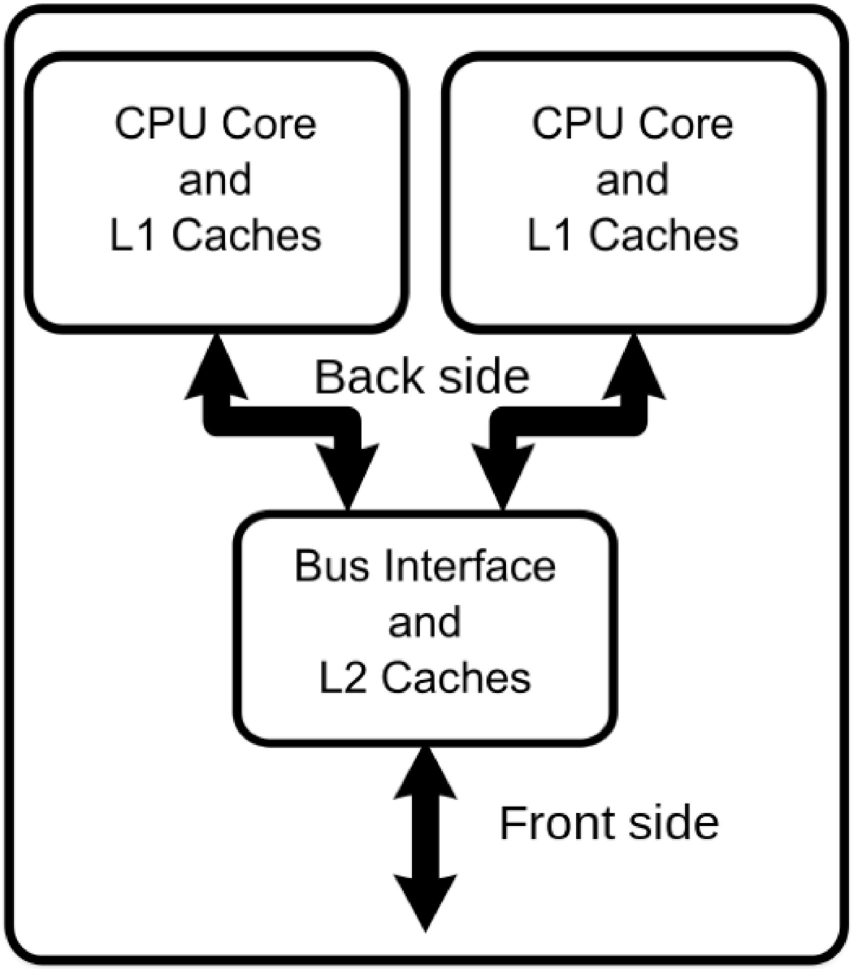
Metric	Value			Bytes
Byte (B)	1	2^{0}	10^{0}	1
Kilobyte (KB)	$1{,}024^{1}$	2^{10}	10^{3}	1,024
Megabyte (MB)	$1{,}024^{2}$	2^{20}	10^{6}	1,048,576
Gigabyte (GB)	$1{,}024^{3}$	2^{30}	10^{9}	1,073,741,824
Terabyte (TB)	$1{,}024^{4}$	2^{40}	10^{12}	1,099,511,627,776
Petabyte (PB)	$1{,}024^{5}$	2^{50}	10^{18}	1,125,899,906,842,624
Exabyte (EB)	$1{,}024^{6}$	2^{60}	10^{21}	1,152,921,504,606,846,976
Zettabyte (ZB)	$1{,}024^{7}$	2^{70}	10^{24}	1,180,591,620,717,411,303,424
Yottabyte (YB)	$1{,}024^{8}$	2^{80}	10^{27}	1,208,925,819,614,629,174,706,176

So where do we store data: The Memory Hierarchy

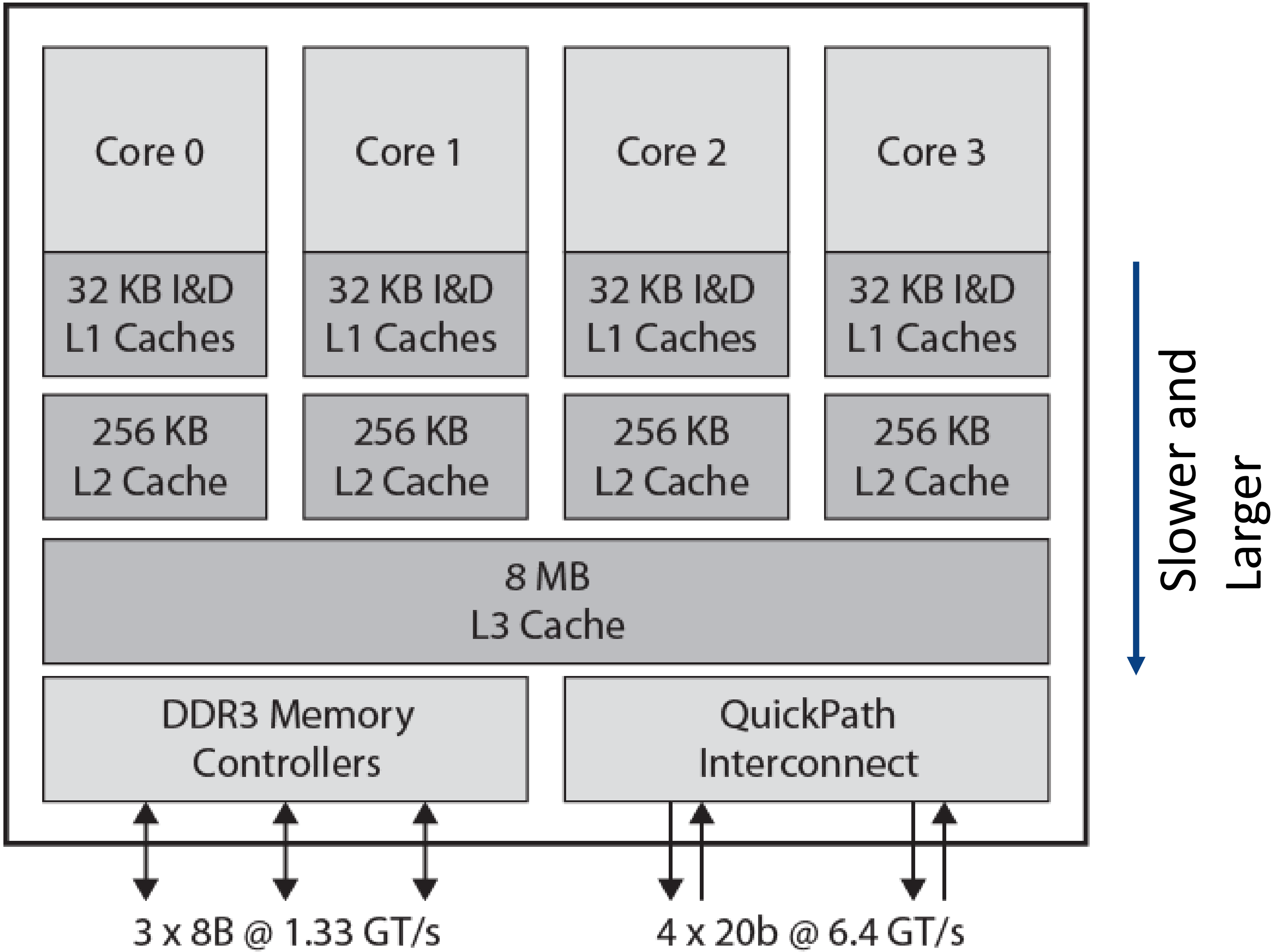
Basic structure



Multi-Core System



Increasingly **L1, L2 and L3** caches are on the chip now!



Memory hierarchy

$$Hit\ ratio = \frac{references\ satisfied\ by\ cache}{total\ references}$$

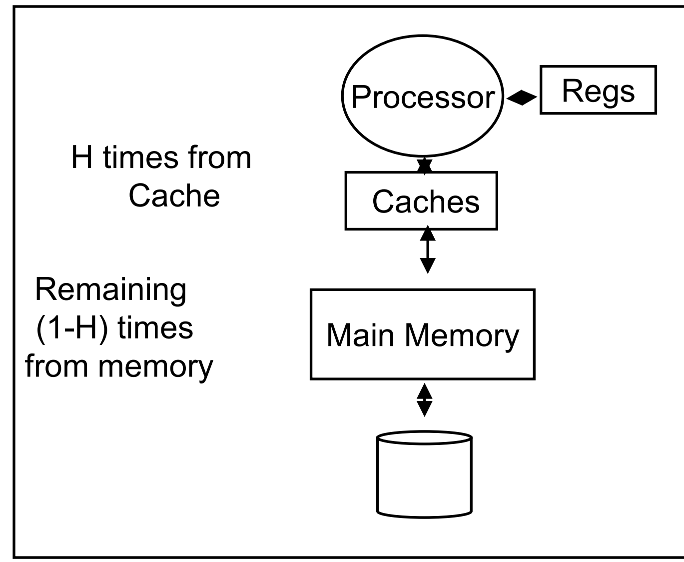
Effective memory access time,

EA = H*C+(1-H)*M

where H = hit ratio,

C = cache access time;

M = memory access time



Hit ratio	Effective access time as multiple of C, M = 100 C
50.00%	50.5
90.00%	10.9
99.90%	1.1

Memory hierarchy

If data needs to be transferred from HDD

$$Disk\ access\ time = seek\ time + rotational\ time + \frac{transferlength}{bandwidth}$$

Caching provided with HDD for access

Effective $\overbrace{\text{disk buffer}}$ access time,

EA = HB*BC+(1-HB)*D where

HB = hit ratio of the disk buffer , BC = buffer access time; D = disk access time

Hit ratio	Effective access time as multiple of BC, D = 1000 C
50.00%	500.5
99.00%	100.9
99.90%	1.999
99.99%	1.099

Memory hierarchy example