Data Processing

Venkatesh Vinayakarao
venkateshv@cmi.ac.in
http://vvtesh.co.in

Chennai Mathematical Institute

Data is the new oil. - Clive Humby, 2006.

What Comes Next?

byte

kilobyte

megabyte

gigabyte

??

???

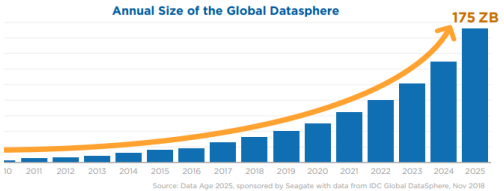
????

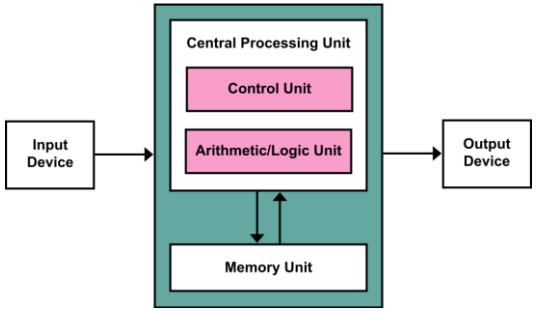
?????

Sizes

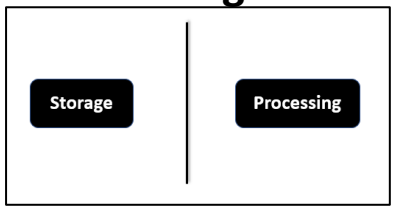
Name	Size
Byte	8 bits
Kilobyte	1024 bytes
Megabyte	1024 kilobytes
Gigabyte	1024 megabytes
Terabyte	1024 gigabytes
Petabyte	1024 terabytes
Exabyte	1024 petabytes
Zettabyte	1024 exabytes
Yottabyte	1024 zettabytes

Recap

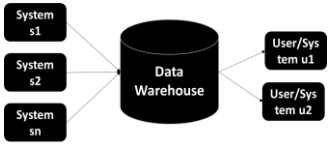


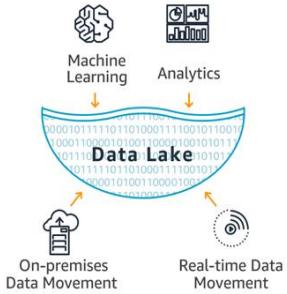


Challenges



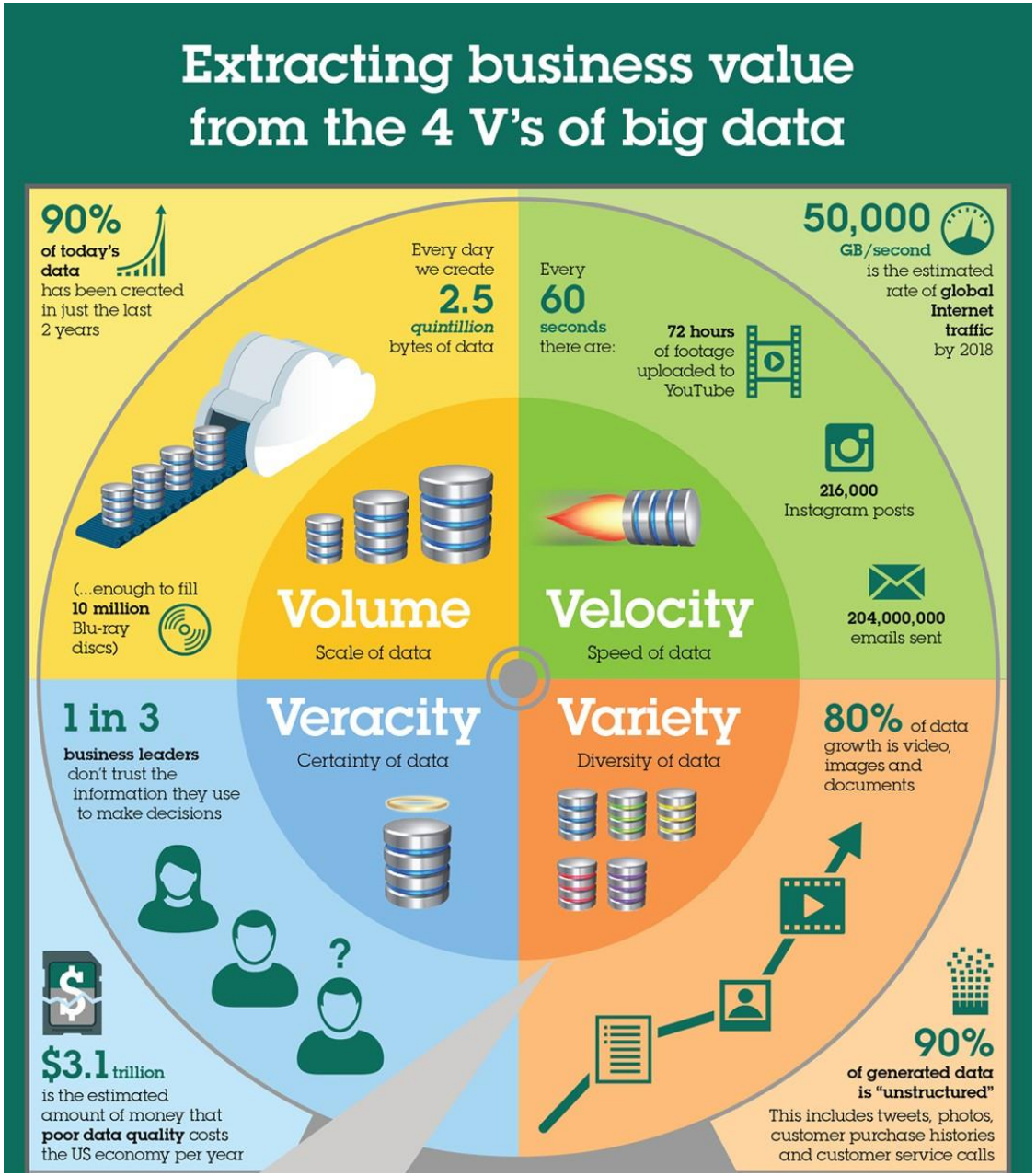
Data Storage





Amazon S3

STaaS



Source: https://itinfrastructure.report/infographics/extracting-business-value-from-the-4-vs-of-big-data

Big Data Characteristics

- Volume
  - Petabytes, exabytes,…
- Variety
  - pdf, json, text, images, …
- Velocity
  - real-time, near real-time, batch
- Veracity
  - Trustworthiness, correctness and consistency

“Where there is data smoke, there is business fire.”

— Thomas Redman, Author.

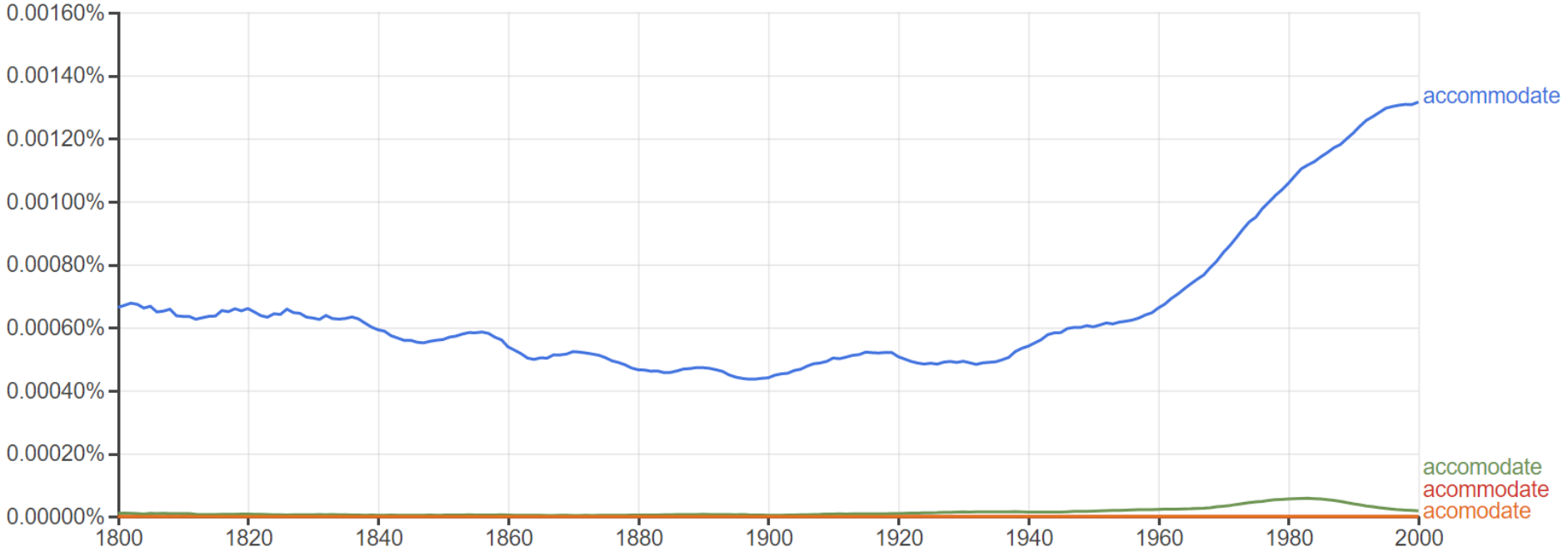
Tuj mein rab diktha hai
Data mein kya karoon

jab bhi koi **data** dekhun
mera dil deewana bole
ole ole ole…

Quiz

- Which is right?
  - accommodate
  - acommodate
  - accomodate
  - acomodate

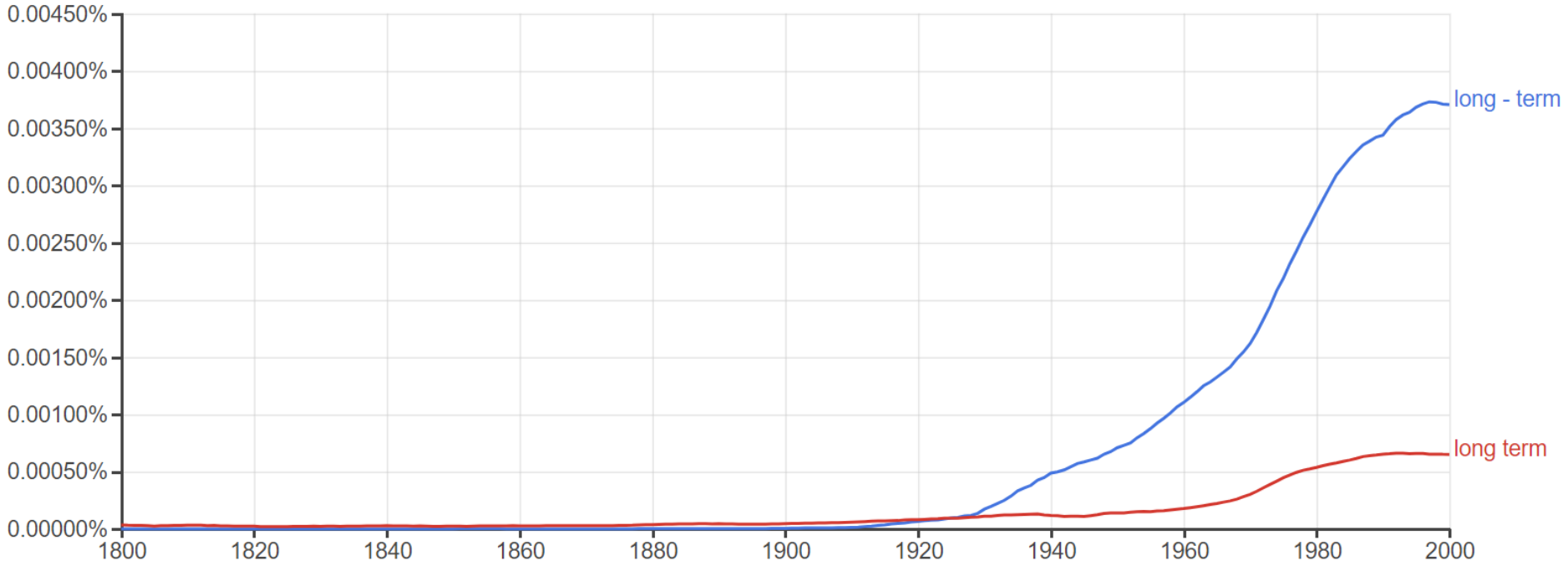
Google n-gram Viewer



https://books.google.com/ngrams

Quiz

- Long-term or long term


0.00450%
0.00400%
0.00350%
0.00300%
0.00250%
0.00200%
0.00150%
0.00100%
0.00050%
0.00000%
1800
1820
1840
1860
1880
1900
1920
1940
1960
1980
2000
long - term
long term

Data Processing

- Microprocessors
- Multi-core Processors
- Supercomputers
- … all roads lead to ~~Rome~~ Cloud!

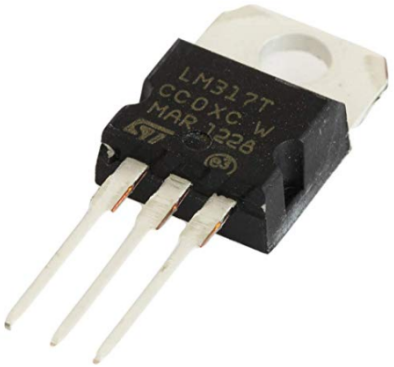
Microprocessors

Processing unit on an integrated circuit

What are ICs made of?

Transistors

- Basic electronic component that alters the flow of current.
- Form the basic building block of an integrated circuit.
- Think of it as an electronic switch



SunRobotics LM317 Voltage Regulator IC TO-220 Adjustable Three-Terminal Regulators Field Effect Transistor Original Integrated circuit electronic Components (5 Pcs)

by sunrobotics

1 rating

M.R.P.: ~~₹ 199.00~~

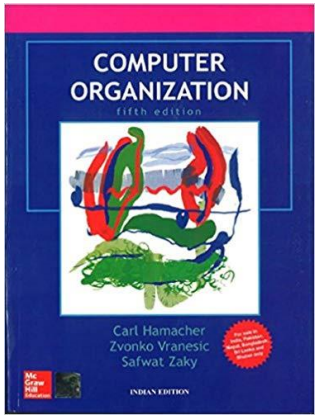
Price: ₹ 165.00

You Save: ₹ 34.00 (17%)

Inclusive of all taxes

prime FREE Delivery by **Monday**

Pay on Delivery | 10 Days Returnable | Amazon Delivered

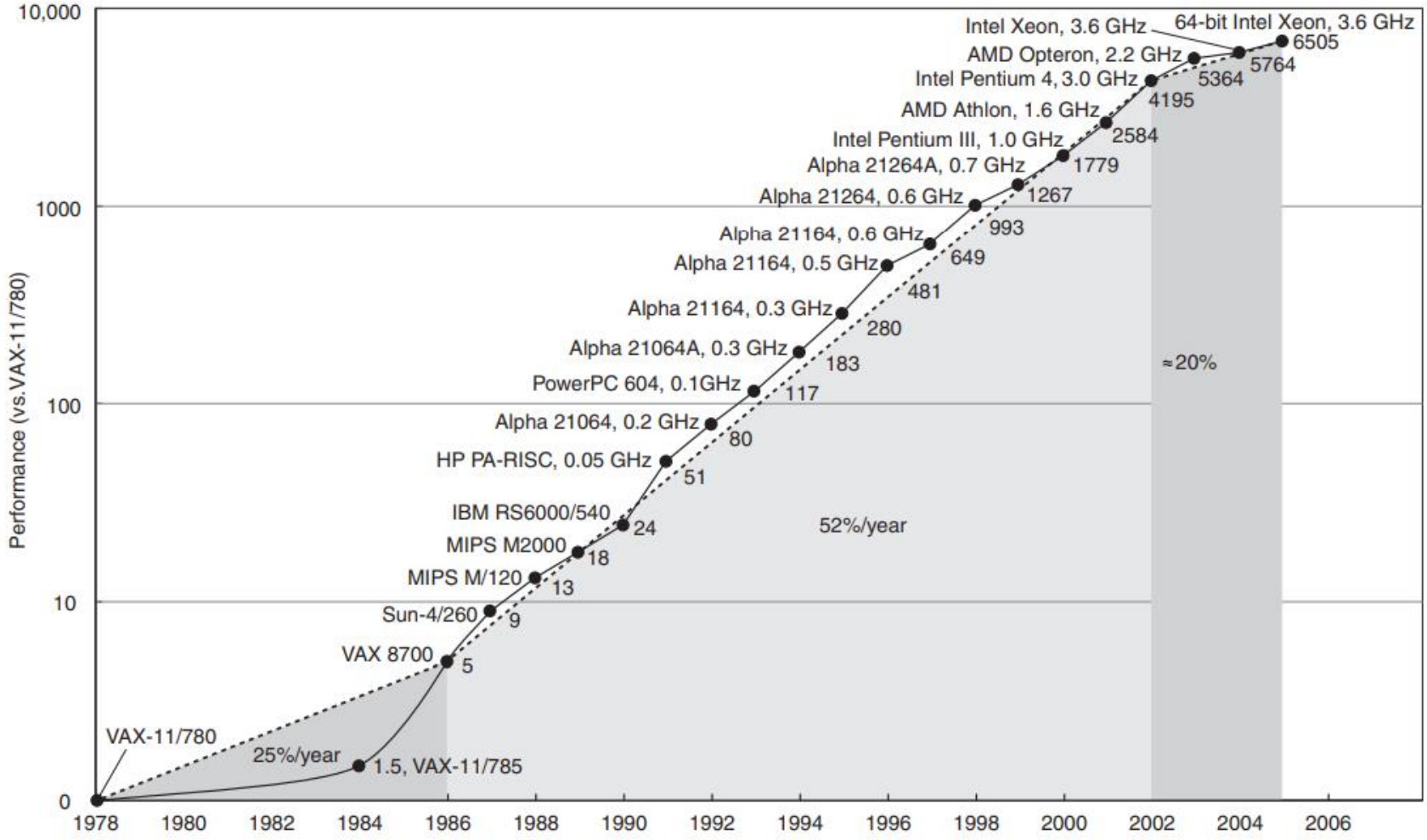


Logic Gates

- Implements Boolean functions (thus performs logical operations)
- Implemented using Transistors

Microprocessors contain millions of logic gates.

Processor Performance



Moore’s Law

The number of transistors on a microchip doubles every two years, though the cost of computers is halved.

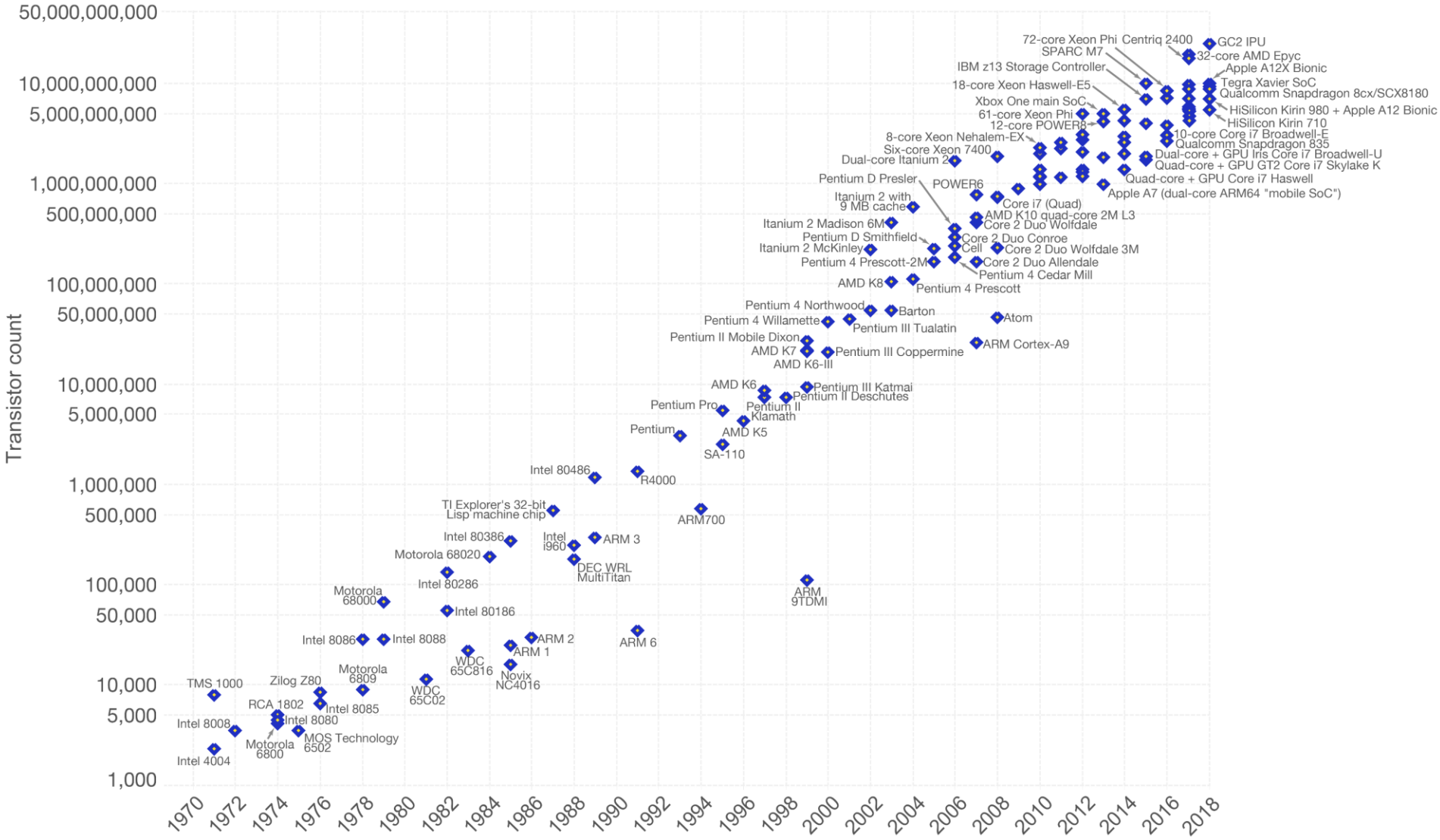
CES 2019: **Moore's Law** is **dead**, says Nvidia's CEO
CNET - 10-Jan-2019
Intel, for its part, doesn't think **Moore's Law** is **dead**. Companies are just finding new ways to keep it going, like Intel's new 3D chip stacking.

Moores Law is far from death, according to Intel's Jim Keller
TweakTown - 10-Dec-2019
"The death of **Moores Law** is coming and will limit how far we can go ... explanation of what **Moores law** is, from Intel's co-founder, engineer, ...

Moore's Law – The number of transistors on integrated circuit chips (1971-2018)

Our World in Data

Moore's law describes the empirical regularity that the number of transistors on integrated circuits doubles approximately every two years. This advancement is important as other aspects of technological progress – such as processing speed or the price of electronic products – are linked to Moore's law.



Source: https://www.visualcapitalist.com/visualizing-moores-law-in-action-1971-2019/

Multi-Core Processors

- Two or more separate processing units (called cores)
- Enhances parallel processing

intel core duo
(has 2 cores, 2.66 GHz)

intel core i7
(has 4 cores, 4 GHz)

Quality Up

What do we achieve when we use p processors?

$$\text{Quality Up} = \frac{quality\ on\ p\ processors}{quality\ on\ 1\ processor}$$

Read Section 1.1 of Jan Verschelde's book on "Introduction to Supercomputing".

Can we use multiple processors?

- Amdahl's law
  - Let R be the fraction of the operations which cannot be parallelized. The speedup with p processors is bound by $\frac{1}{R+\frac{1-R}{p}}$.
- Example
  - Say, 10% cannot be parallelized, and we have 8 processors. Best speedup = $\frac{1}{1/10+\frac{1-1/10}{8}} \approx 4.7x$.

Multiple Processors for Speedup

- Amdahl's law
  - Let R be the fraction of the operations which cannot be parallelized. The speedup with p processors is bound by $\frac{1}{R+\frac{1-R}{p}}$.

Speed up in terms of problem size.

- Example
  - Say, 10% cannot be parallelized, and we have 8 processors. Best speedup = $\frac{1}{1/10+\frac{1-1/10}{8}} \approx 4.7x$.
  - What happens if we had infinite processors?

Quiz

- Say, 10% of the operations cannot be parallelized. What happens if we had infinite processors?
- Answer: 10x.

Our ability to parallelize determines the successful use of multi-core processors.

Supercomputer

- A computing system that provides close to the best currently achievable sustained performance on demanding computational problems.

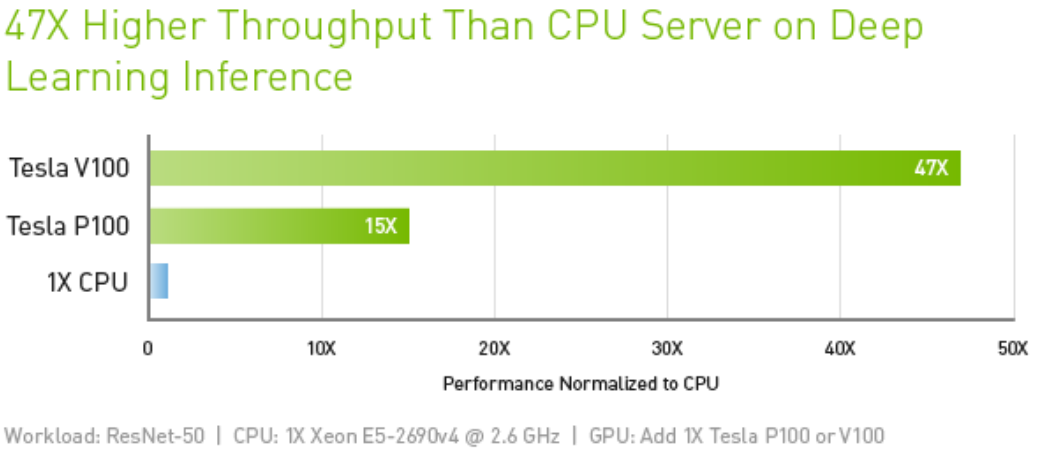
How do supercomputers achieve such performance levels?

GPUs and GPGPUs

- Graphics Processing Unit (GPU)
  - Massive parallelization
  - Thousands of cores
  - Originally created for the gaming industry
- General Purpose GPU (GPGPU)
  - Architecture allows for programming (Example: Compute Unified Device Architecture (CUDA) on NVIDIA GPGPUs).
- Performance is measured in FLOP (Floating Point Operation)
  - sometimes, FLOPS (floating point operations per second)

CPU vs. GPU

- Say, two floating point operations could be performed in a clock cycle,
  - 3 GHz processor ➔ 6 gigaflop per second.
- Top GPUs achieve petaflop per second.
  - Achieved through an array of cores (V100 has 5120 cores)



My System

My Lenovo X390 uses
Intel® Core™ i7-8565U CPU @ 1.8 GHz

4 cores only! ☹

Deep Blue

- Beat Chess World Champion Garry Kasparov in 1997

259th most powerful supercomputer.
Achieved 11.38 GFLOPS.

IBM Watson and Jeopardy Game, 2011

- Cluster of **90 servers** each having **3.5GHz eight-core processor** and **16 TB of RAM**.
- Equivalent to 80 Teraflops (a slow supercomputer by today's standards).

Trivia

- Can you name the fastest supercomputer as of date?
  - How much data can it store?
  - How fast is it?

Trivia

- Can you name the fastest supercomputer as of date? IBM SUMMIT (as on 2023, it is Frontier of Oak Ridge National Laboratory)
  - How much data can it store? 250 PB (Frontier: 700 PB)
  - How fast is it? 200 petaflops (Frontier: 1.1 exaflops)

For more info, see https://www.livescience.com/62827-fastest-supercomputer.html

How fast is 200 petaflops?

Uses NVIDIA Tesla V100 GPU – How fast is its 200 petaflops?

"If every person on Earth completed one calculation per second, it would take the world population 305 days to do what Summit can do in 1 second" - Oak Ridge National Laboratory.

That is 200 quadrillion calculations in one second!

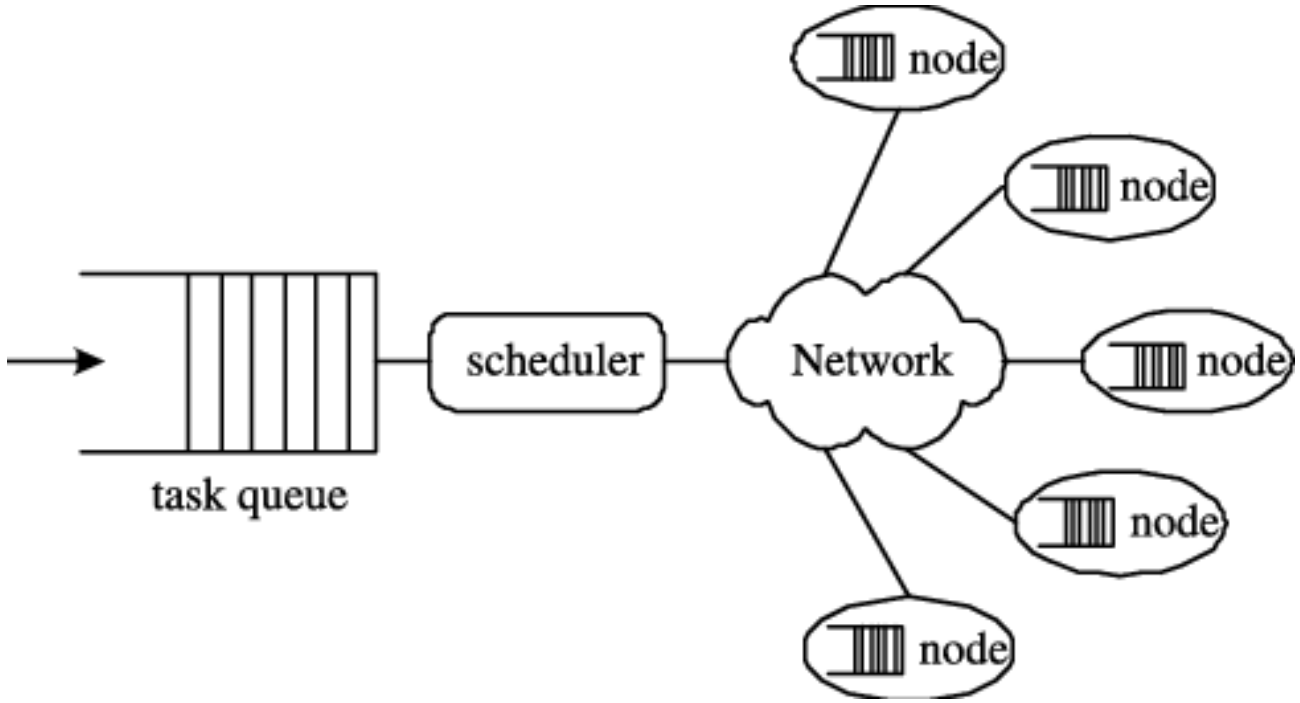
Limitations and Opportunities

- Supercomputers
  - are too expensive
  - still far away from achieving desirable speedups
  - need skilled programming (distributed computing algorithms, parallelizable code)
- But,
  - GPUs are becoming commonplace
  - High Performance Clusters are increasingly available

The Central Question!!!!!

Instead of using supercomputers, can we put commodity hardware into a cluster and achieve speedup?

Computing with Commodity Hardware – Distributed Computing



Sun et al., Dynamic Task Flow Scheduling for Heterogeneous Distributed Computing, 2007.

Cluster Computing

- Multiple nodes acting as a single node
- High Performance Computing (HPC) clusters are becoming increasingly popular

Sun Microsystems, Solaris Cluster

Source: chrisdag, flickr.

Grid Vs. Cluster Computing

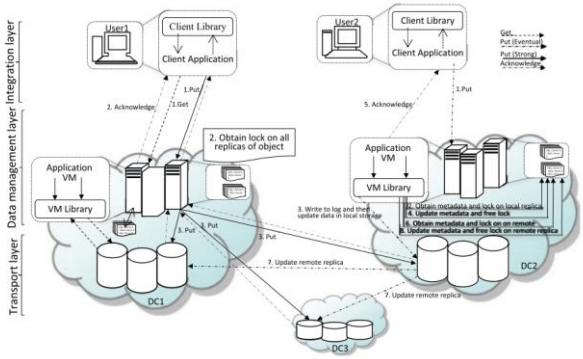
- Clusters have homogenous set of nodes.
- Grid refers to heterogenous systems.

All Roads Lead To…. Cloud

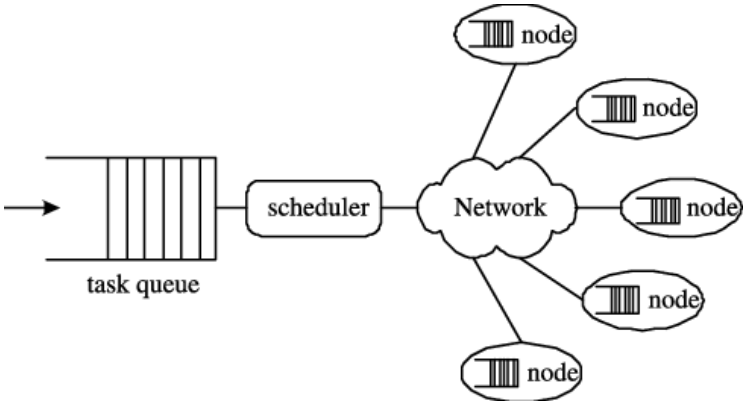
We are in the Big Data era!

Two kinds of Big Data Opportunities

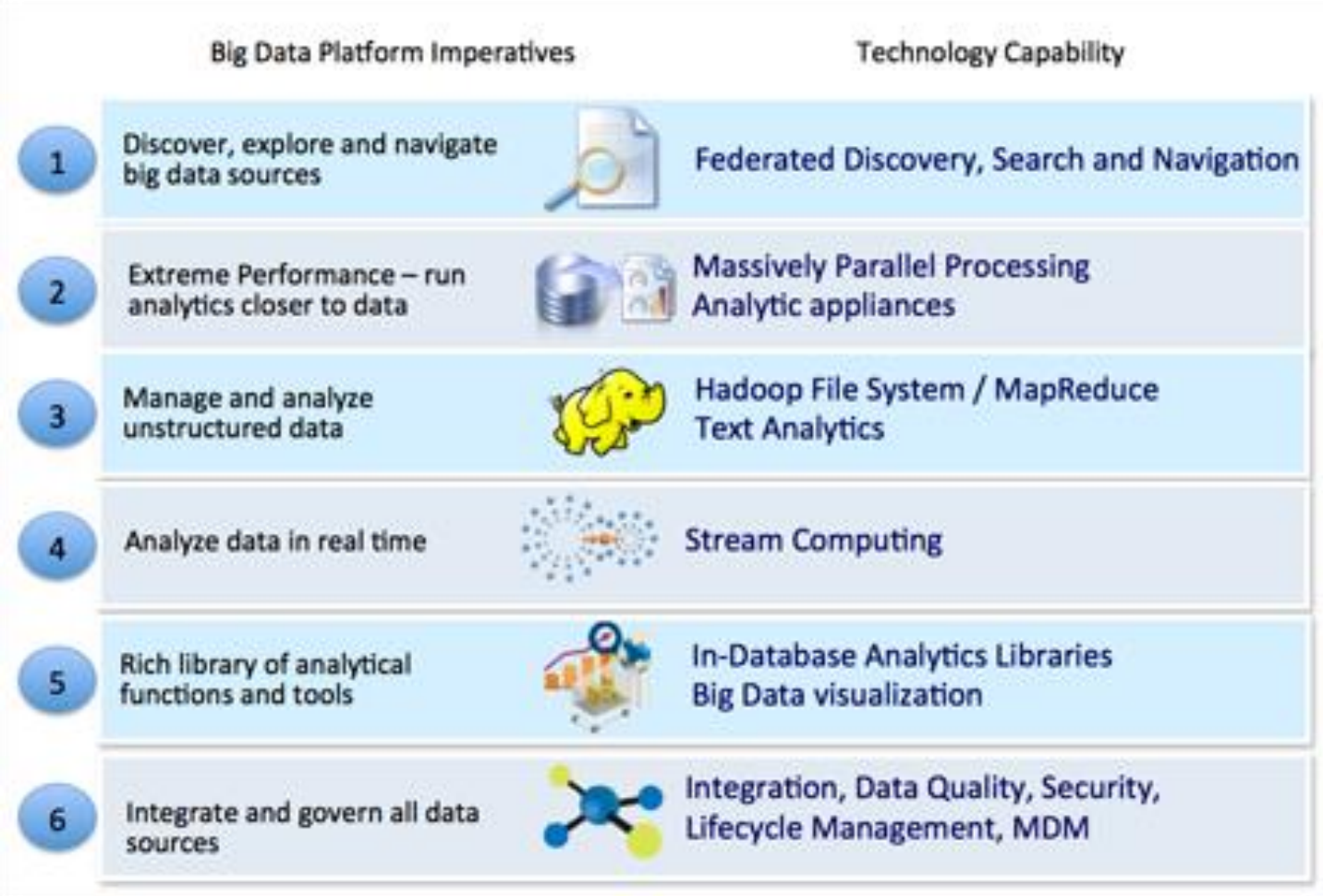
Storage



Processing



Imperatives for Big Data Platform



Source: https://www.ibmbigdatahub.com/blog/part-ii-big-data-platform-manifesto

Key Questions

- How to setup and manage such clusters?
- How to achieve reliability, availability, scalability, …?
- How to build services on cloud?

Apache Hadoop

Open source platform - reliable, scalable, - distributed processing of large data sets - built on clusters of commodity computers.