Big Data Computing

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All the running software was written in AGC assembly language, now also available on [GitHub]

Almost 55 Years Have Passed…

… And The World Has Changed

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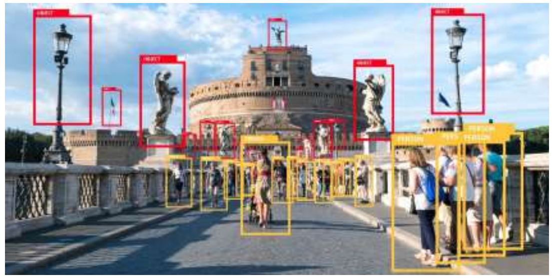

AGC vs. Our Smartphone

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~3 orders of magnitude faster (~1,000x)

~6÷7 orders of magnitude larger RAM and internal storage (up to 10,000,000x)

A Side Note on Units

Prefixes for multiples of bits (bit) or bytes (B)

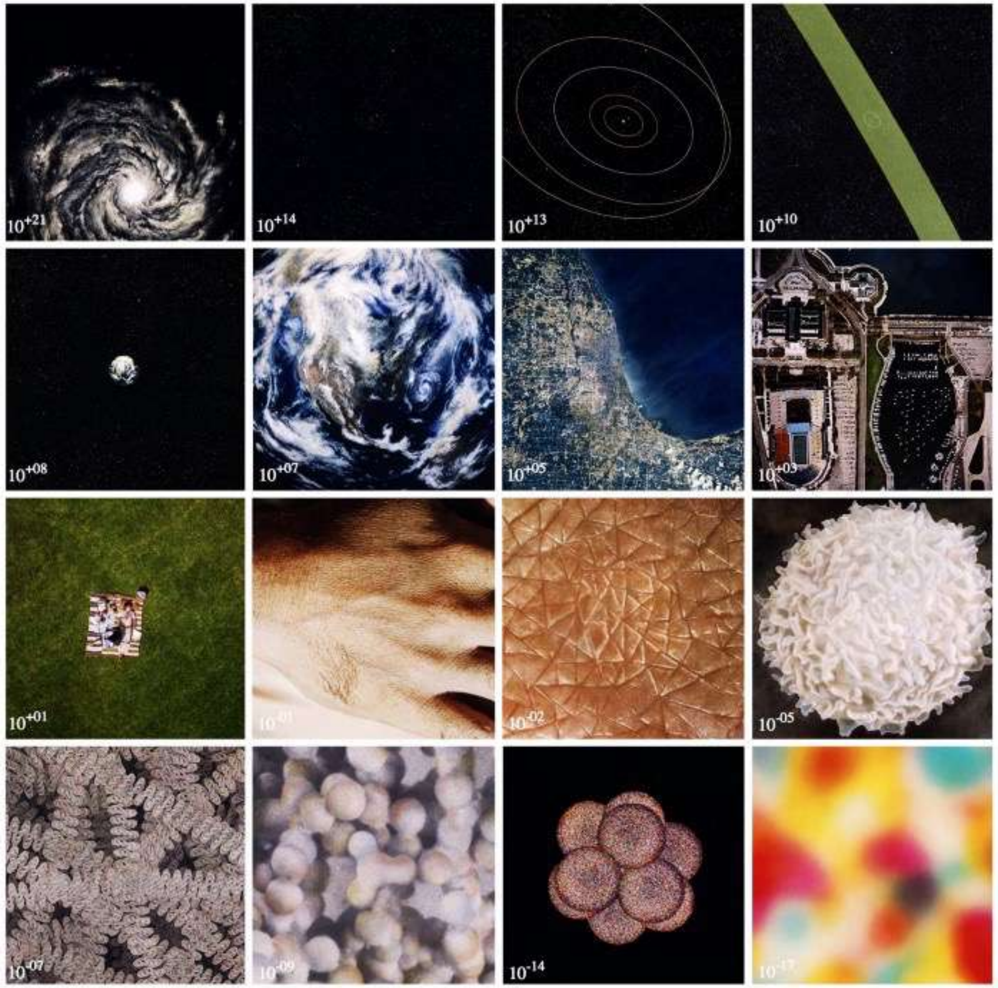
Decimal				Binary					
Value		SI		Value		IEC		JEDEC	
1000	10^3	k	kilo	1024	2^{10}	Ki	kibi	K	kilo
1000^2	10^6	M	mega	1024^2	2^{20}	Mi	mebi	M	mega
1000^3	10^9	G	giga	1024^3	2^{30}	Gi	gibi	G	giga
1000^4	10^{12}	T	tera	1024^4	2^{40}	Ti	tebi	–	
1000^5	10^{15}	P	peta	1024^5	2^{50}	Pi	pebi	–	
1000^6	10^{18}	E	exa	1024^6	2^{60}	Ei	exbi	–	
1000^7	10^{21}	Z	zetta	1024^7	2^{70}	Zi	zebi	–	
1000^8	10^{24}	Y	yotta	1024^8	2^{80}	Yi	yobi	–	

Orders of Magnitude

source: https://www.youtube.com/watch?v=Ww4gYNrOkkg

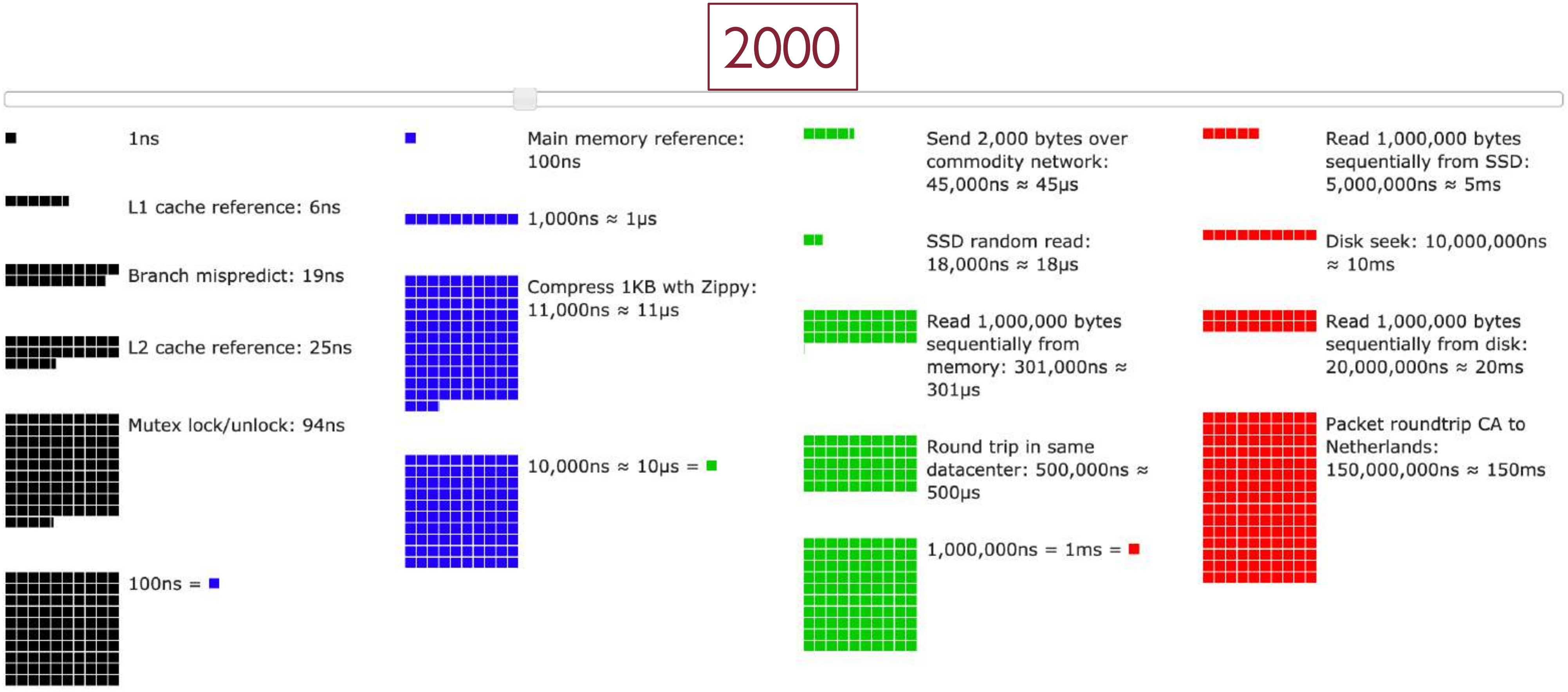
$10^0 = 1$

Orders of Magnitude



Numbers Every Computer Scientist Should Know

Colin Scott's updated and interactive version of Jeff Dean's previous one



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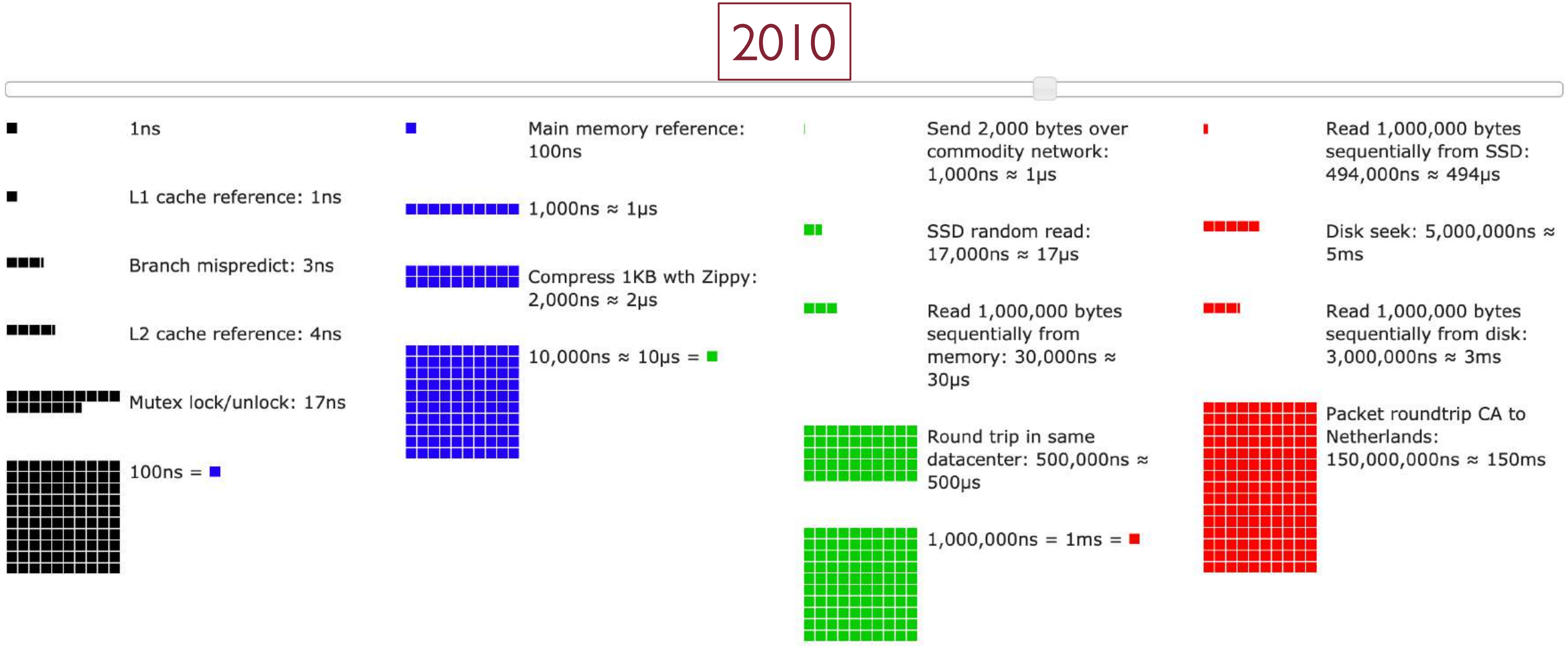

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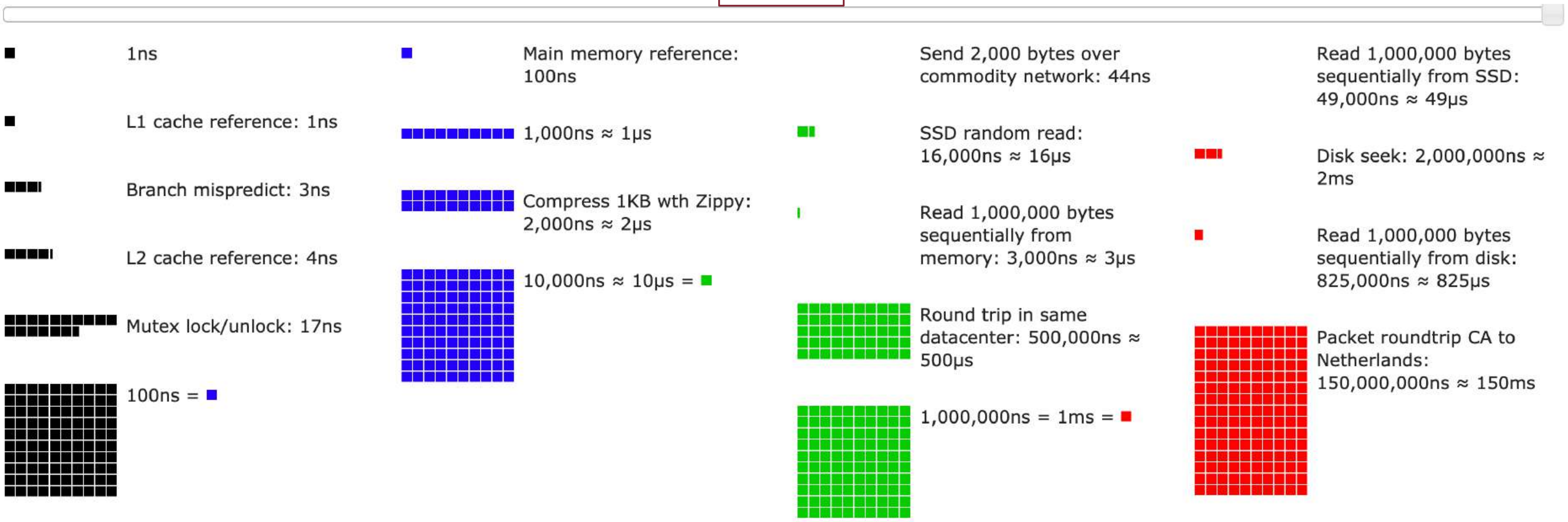
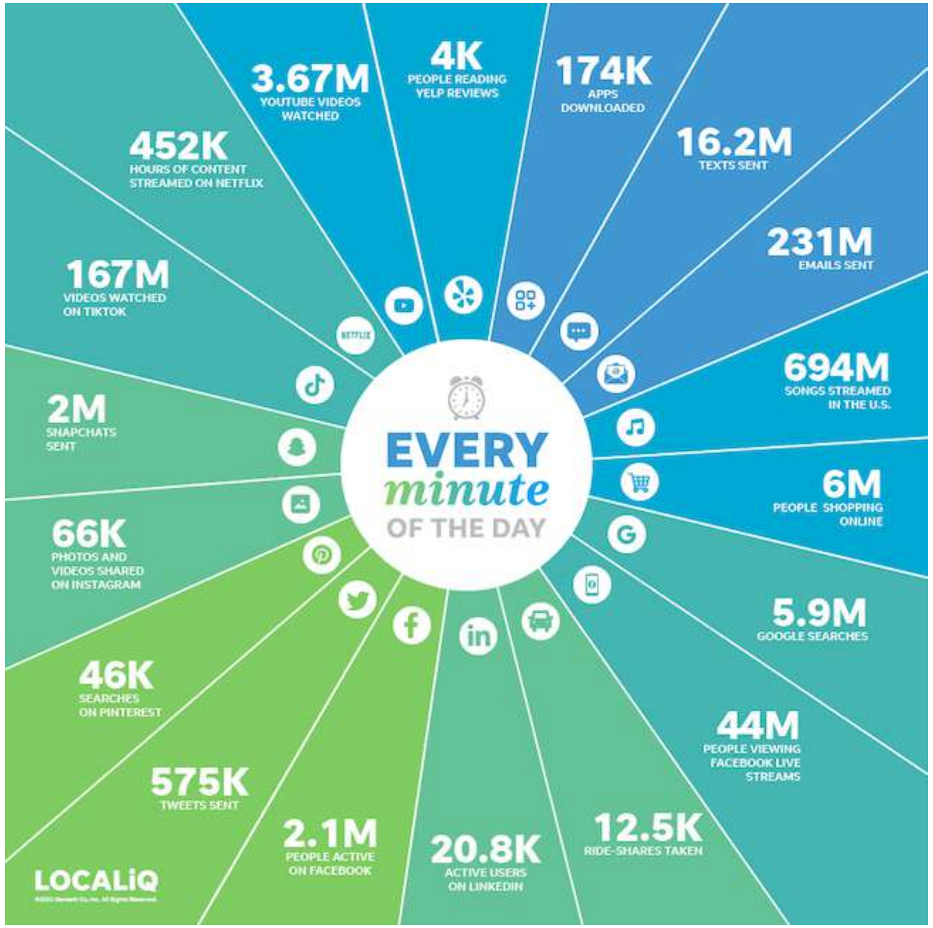
2020



The Information Technology (IT) Revolution

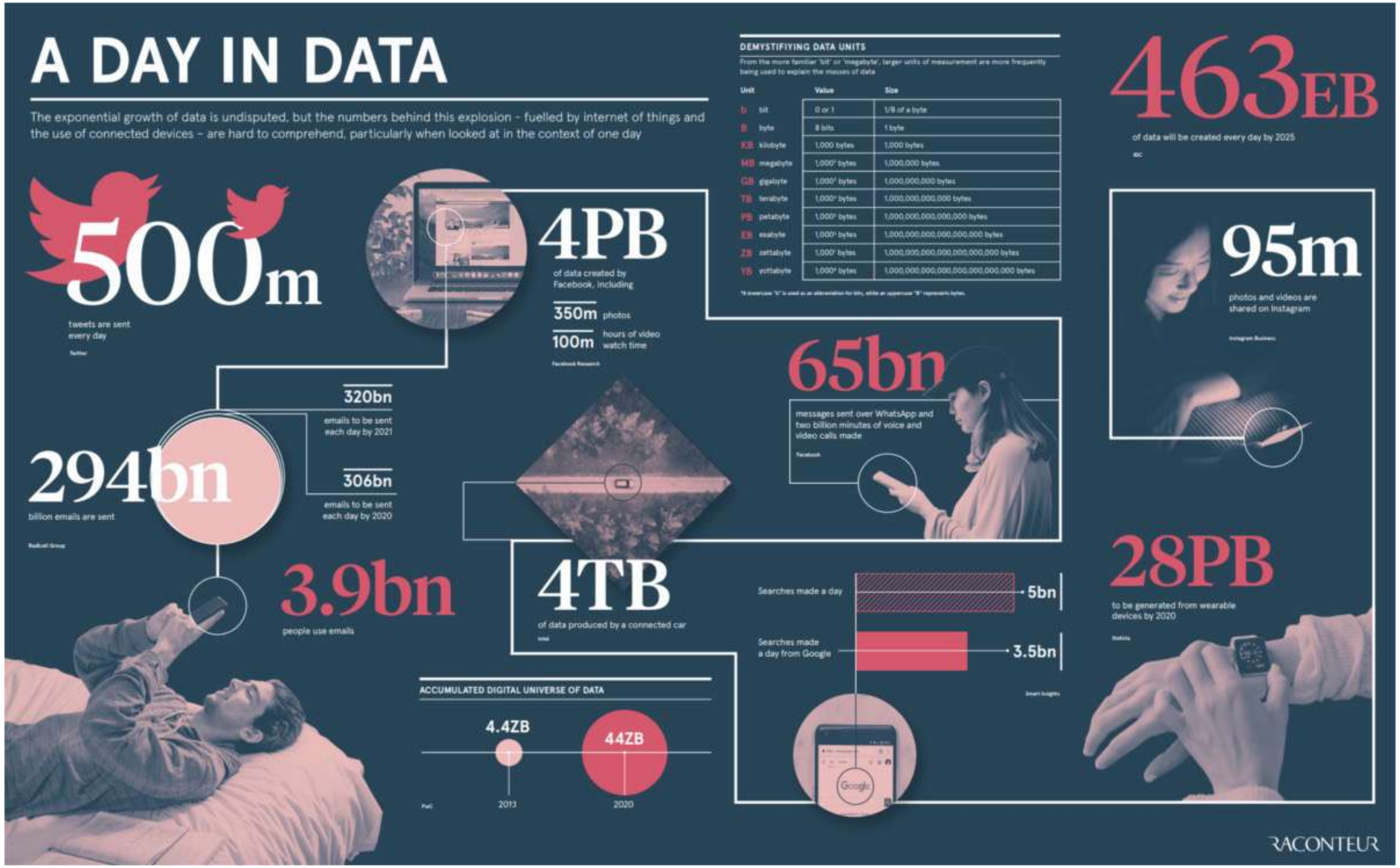
- Started almost 60 years ago and still rocketing
- Driven by:
  - Science/Engineering
  - Business
  - Society

What Happens on the Internet in 1 Minute?



source: LocaliQ

How Much Data is Generated Each Day?



source: VisualCapitalist

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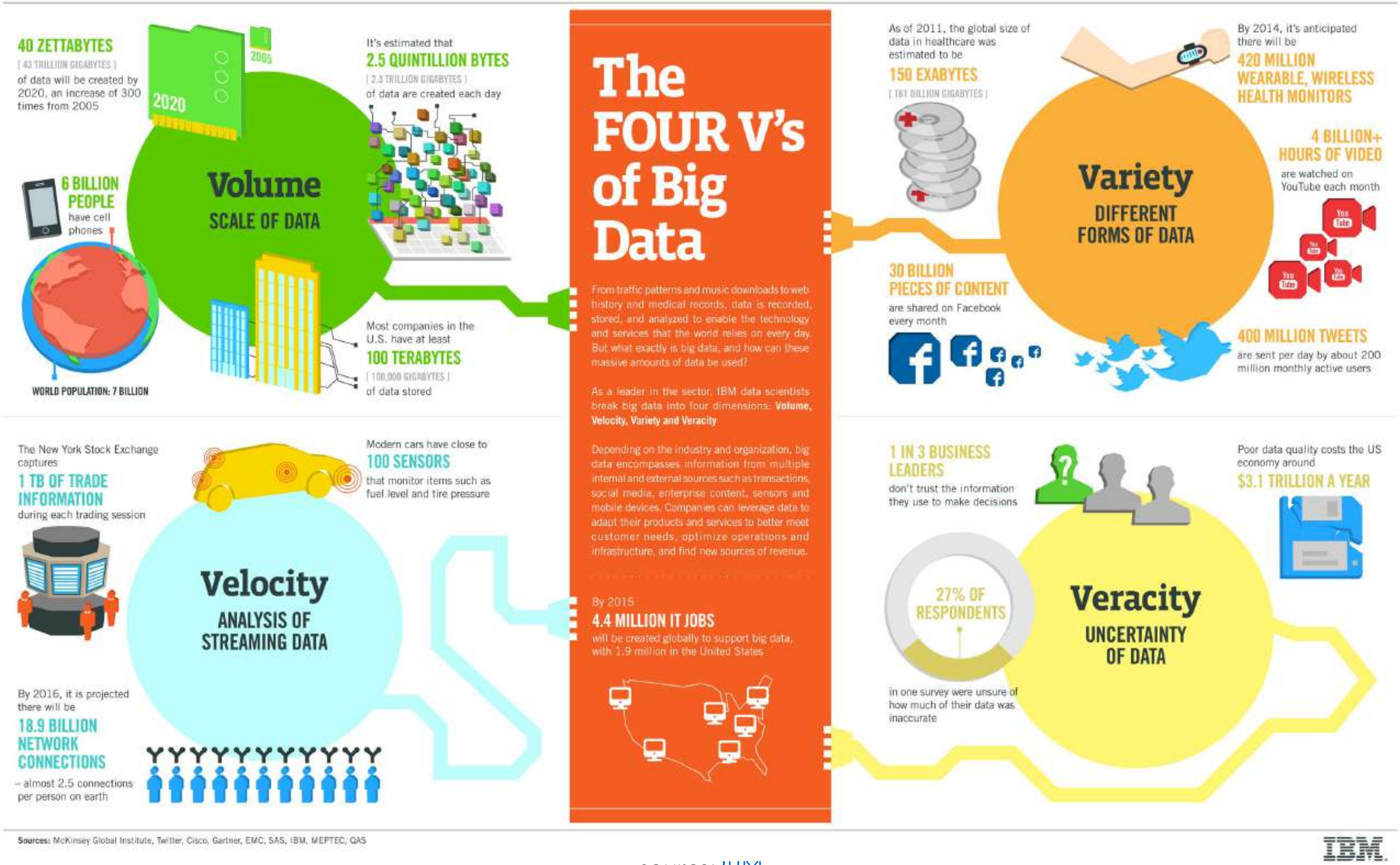
  - Veracity → reliability of the data used to drive decision processes

The 4 V's of Big Data



source: IBM

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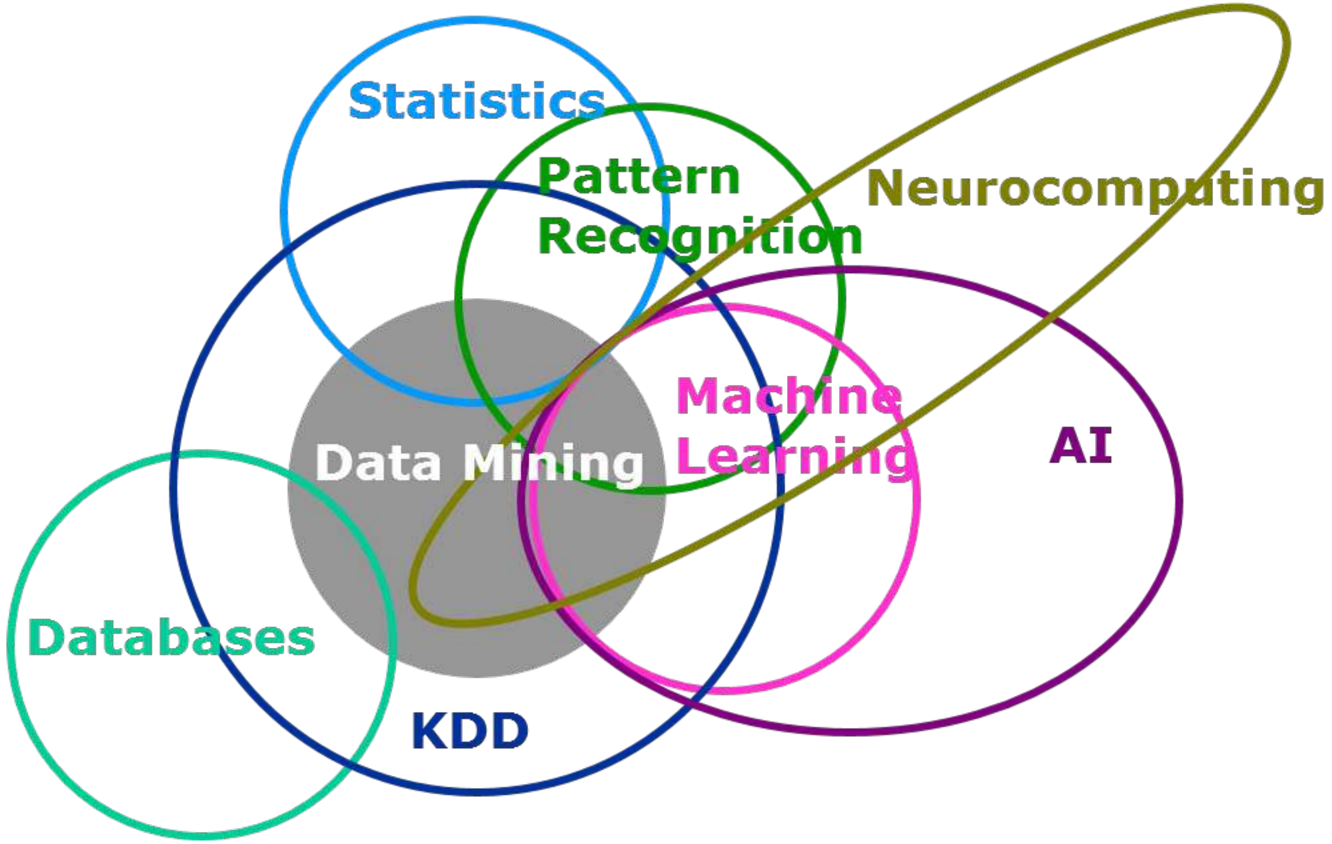
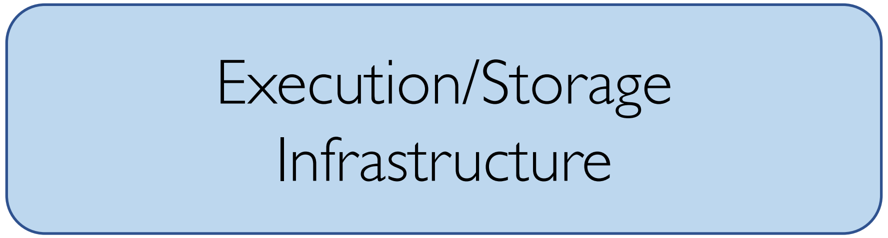
  - 5 out of 6 of the biggest companies in the world are "data companies"
- To get the most value out of it, data has to be:
  - Stored
  - Managed
  - Analyzed

Big Data Analysis: Landscape



Big Data Analysis Stack



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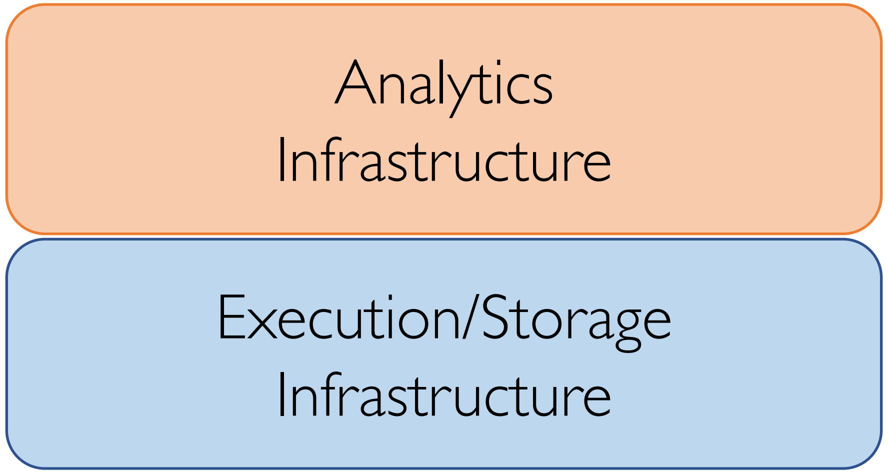

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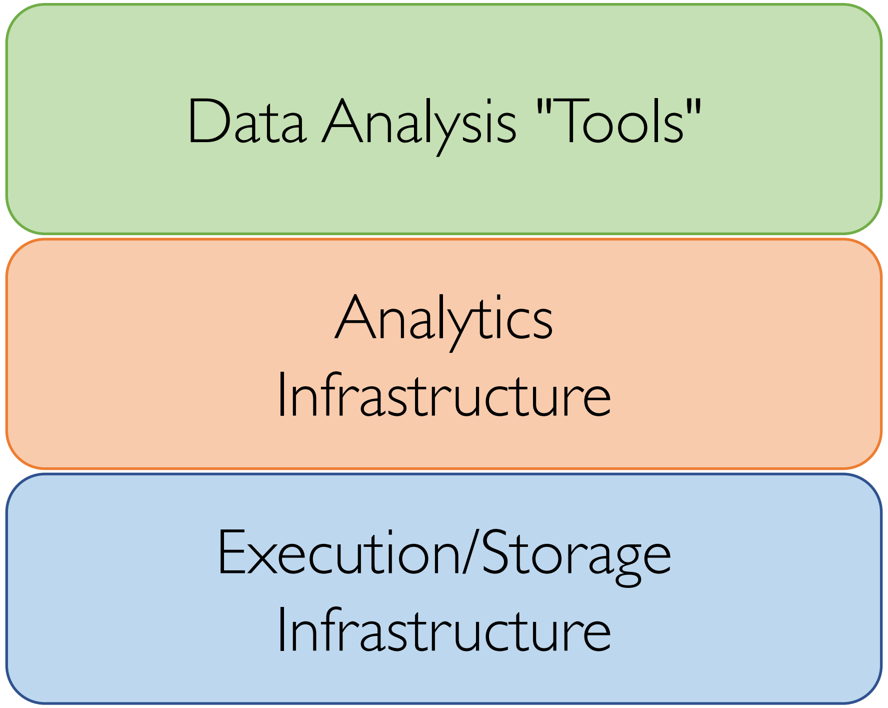

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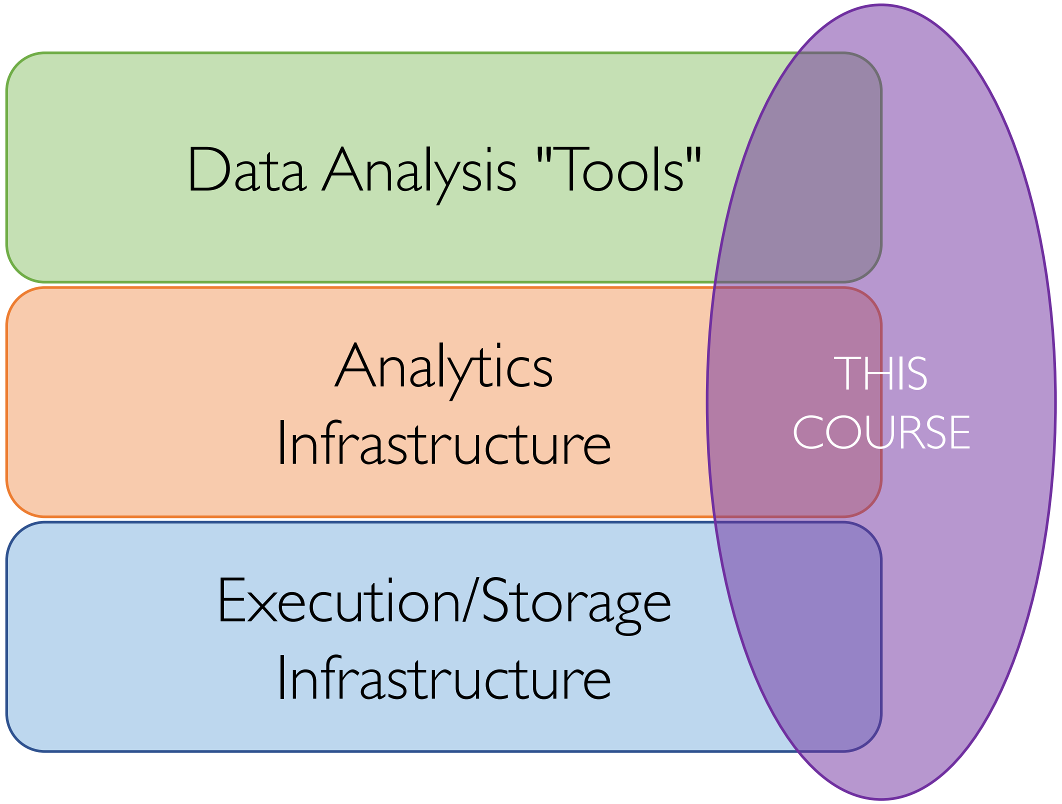


What Will We Learn?

- To extract knowledge from different types of data
  - High-dimensional
  - Unlabeled/Labeled
  - Graph-based
  - Infinite/never-ending streams

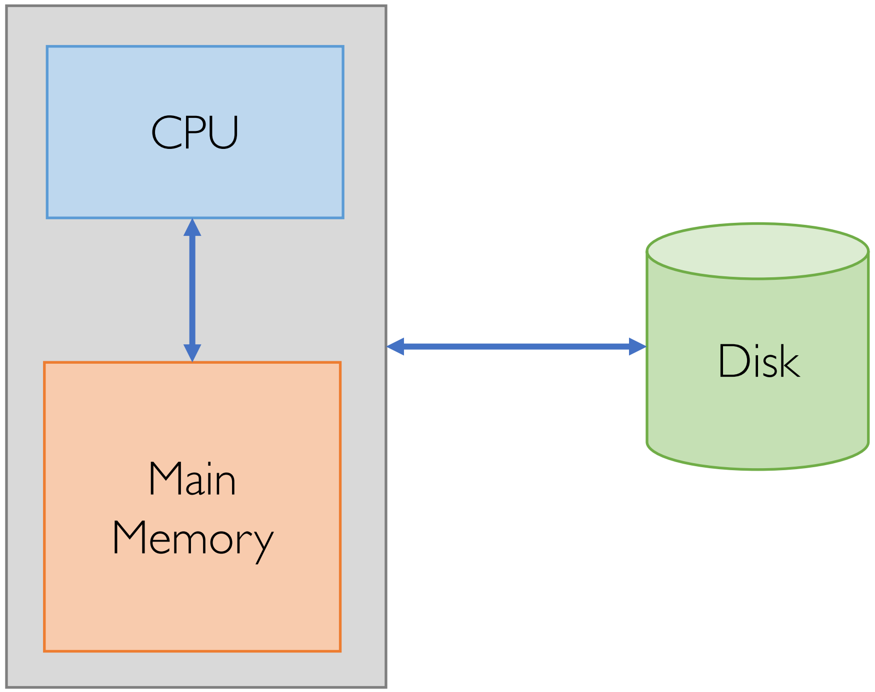
What Will We Learn?

- To use different models of computation
  - MapReduce
  - Streams and online algorithms
  - Single machine in-memory

What Will We Learn?

- To apply big data analysis to actually solve real-world problems
  - Clustering
  - Predictive Analysis
  - Recommender Systems
  - Graph Analysis
  - Stream Processing
  - …

The Single-Node Architecture



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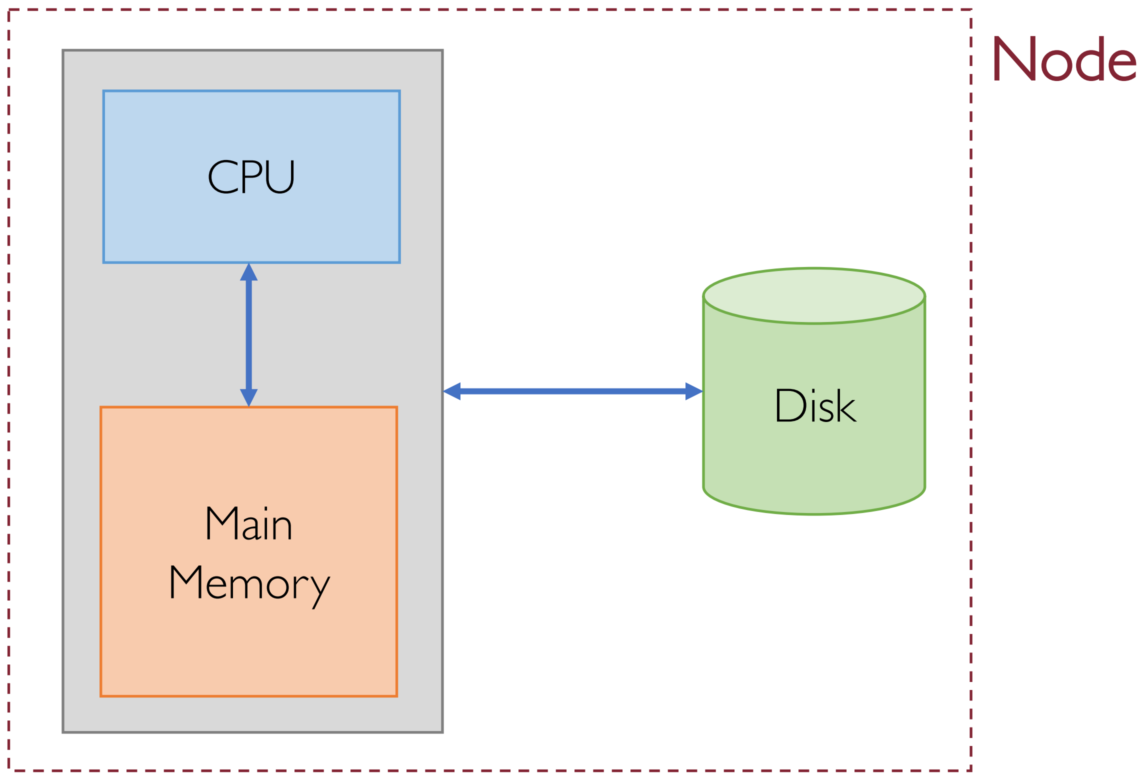
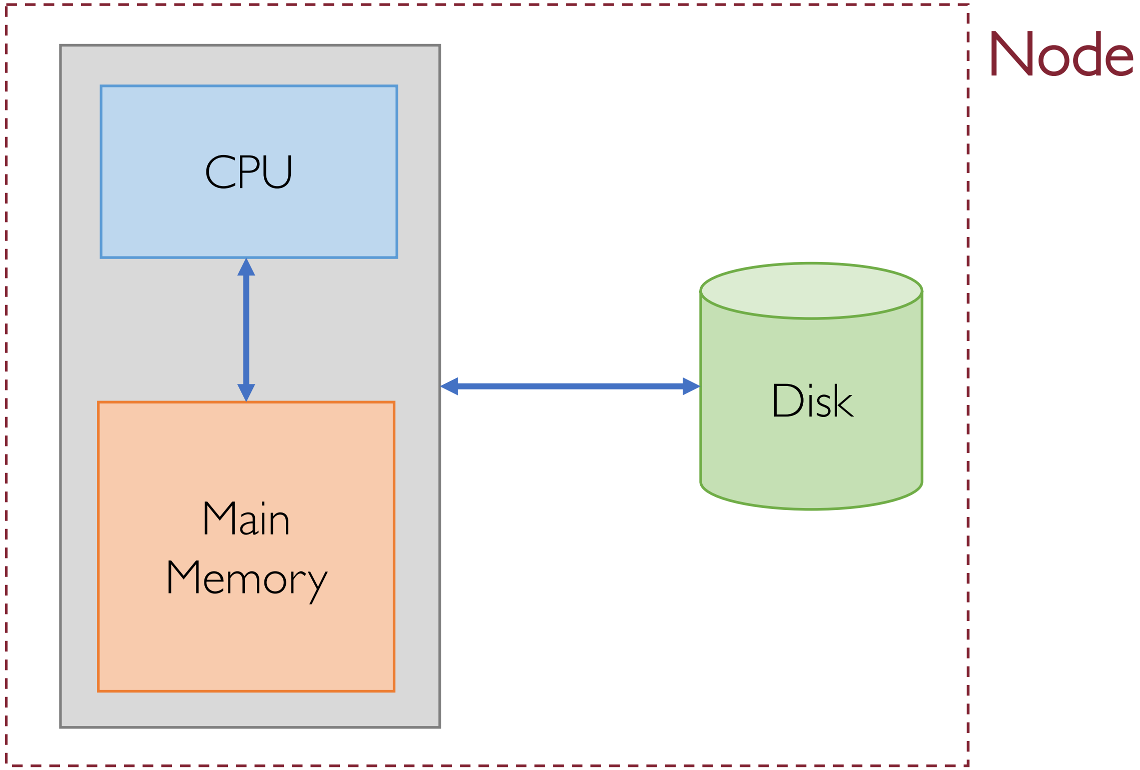


The Single-Node Architecture

Everything is ok as long as data fits entirely into main memory
(few accesses to the disk are still tolerated)



Example: Google (Toy) Index

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Main Memory

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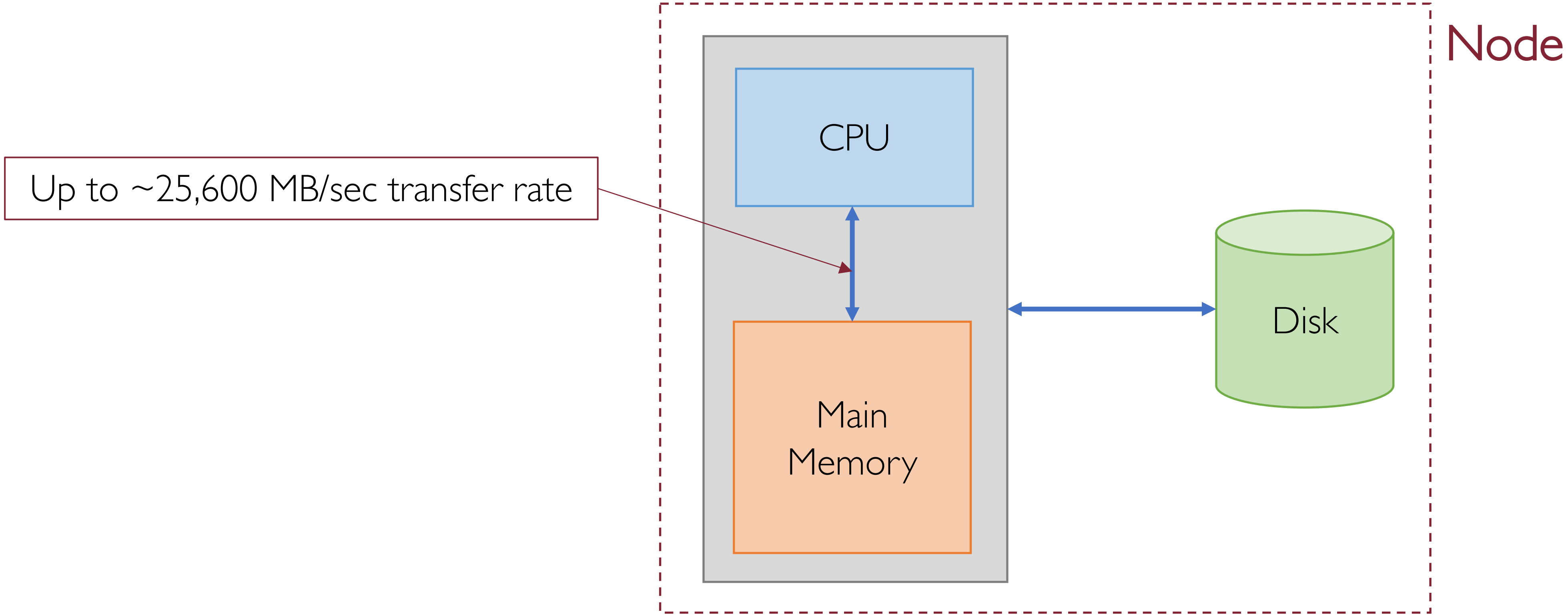

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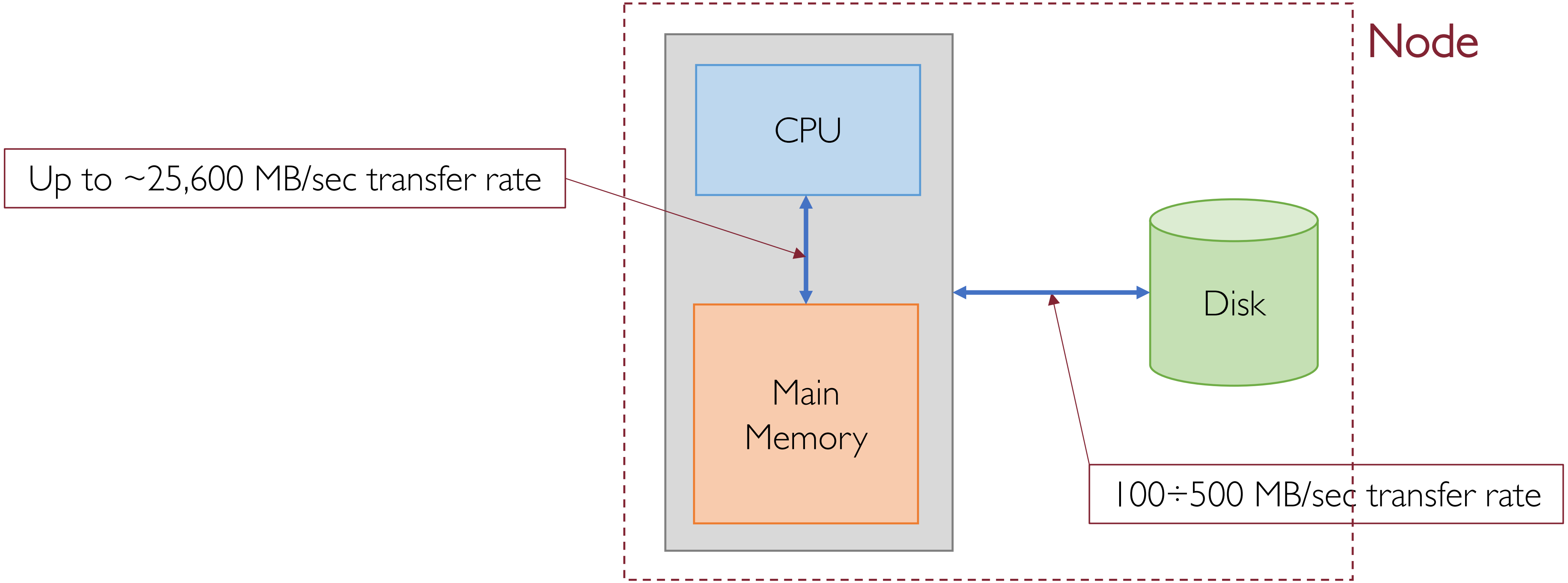

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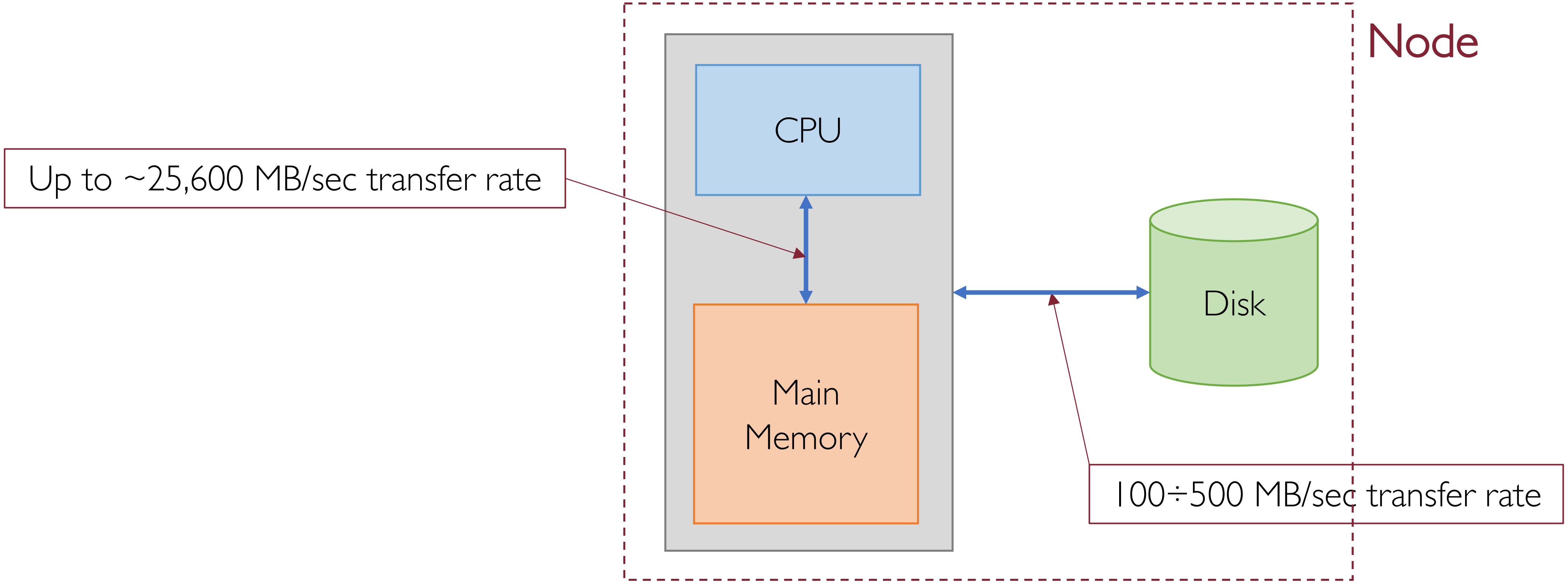

2 orders of magnitude difference between data transfer rate

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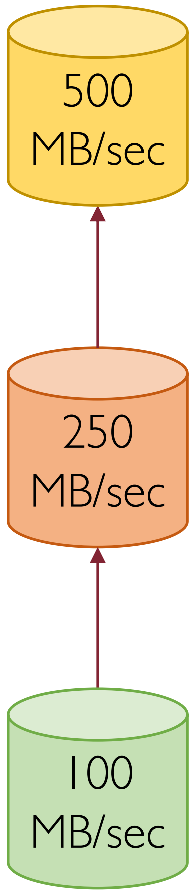
- Single-node architecture is clearly not enough here
  - Scaling Up vs. Scaling Out

Scaling Up/Vertical Scaling

- Buy a more performing disk (e.g., 250 or 500 MB/sec transfer rate)



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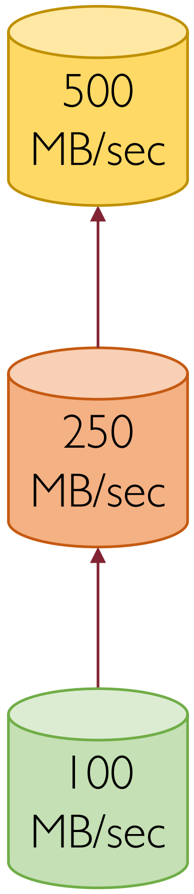

Scaling Up/Vertical Scaling

- Buy a more performing disk (e.g., 250 or 500 MB/sec transfer rate)
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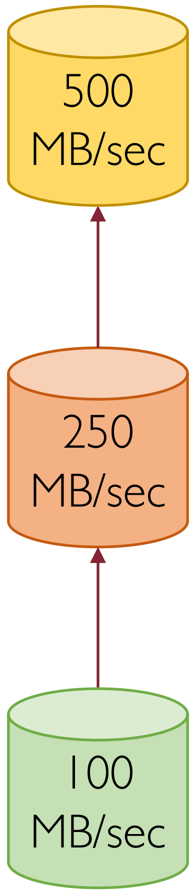
- CON
  - Improvement is physically-limited (e.g., 2.5x or 5x)
  - Expensive



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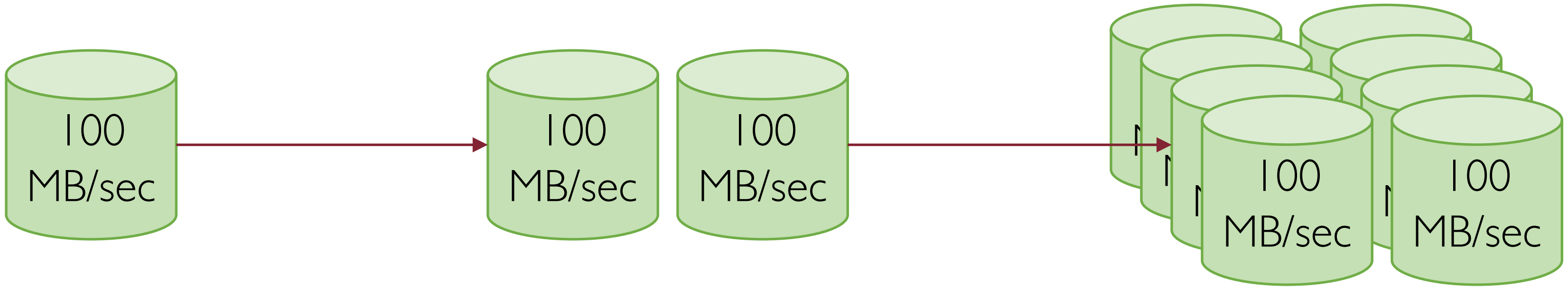

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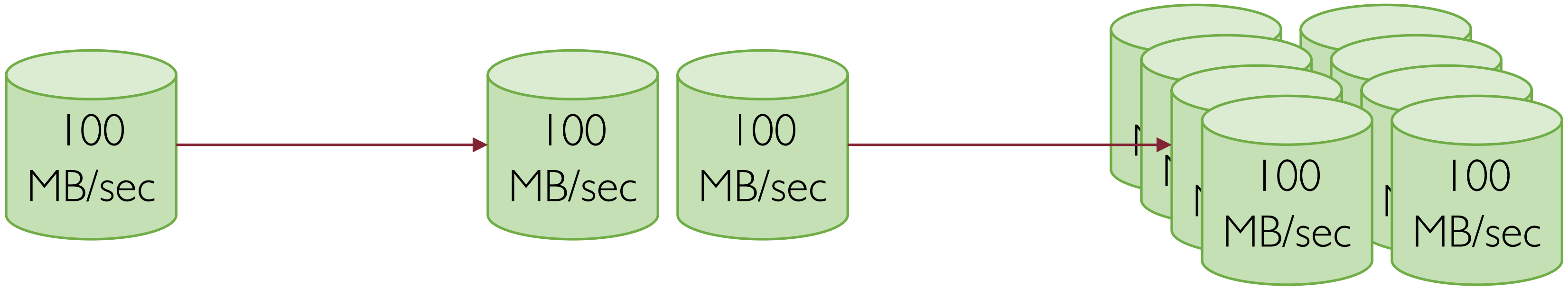

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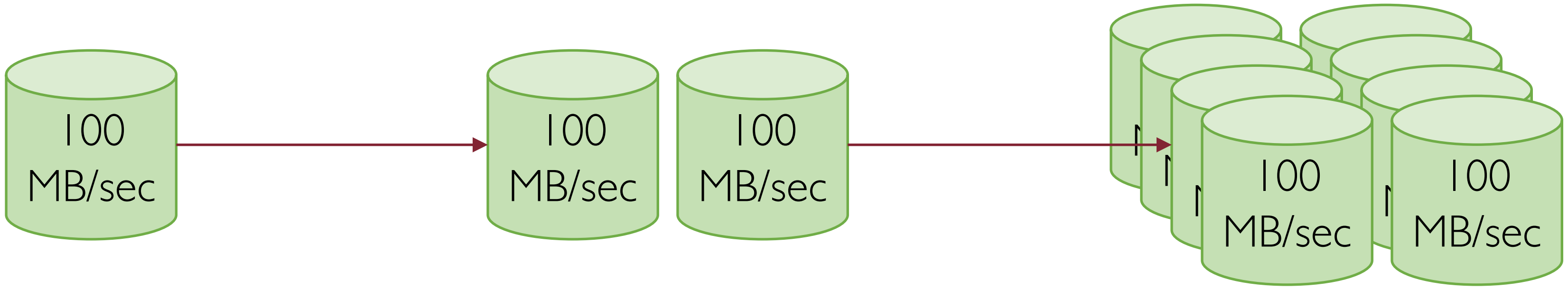

Cluster Architecture

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- Each group of 16÷64 nodes is arranged in a so-called rack
- A cluster is made of multiple racks
- Network switches enabling node communication
  - 1 Gbps (inter-rack)
  - 2÷10 Gbps (intra-rack)

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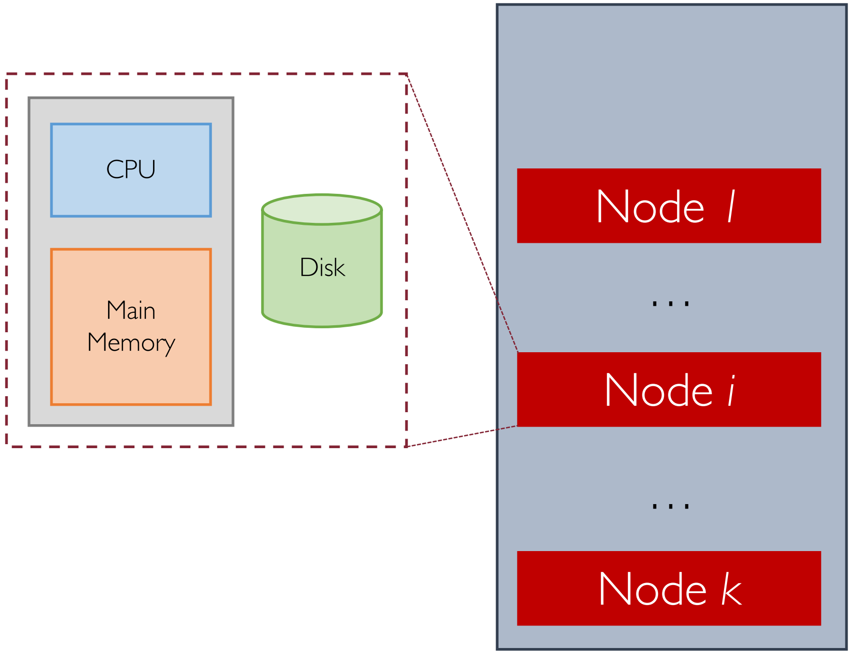

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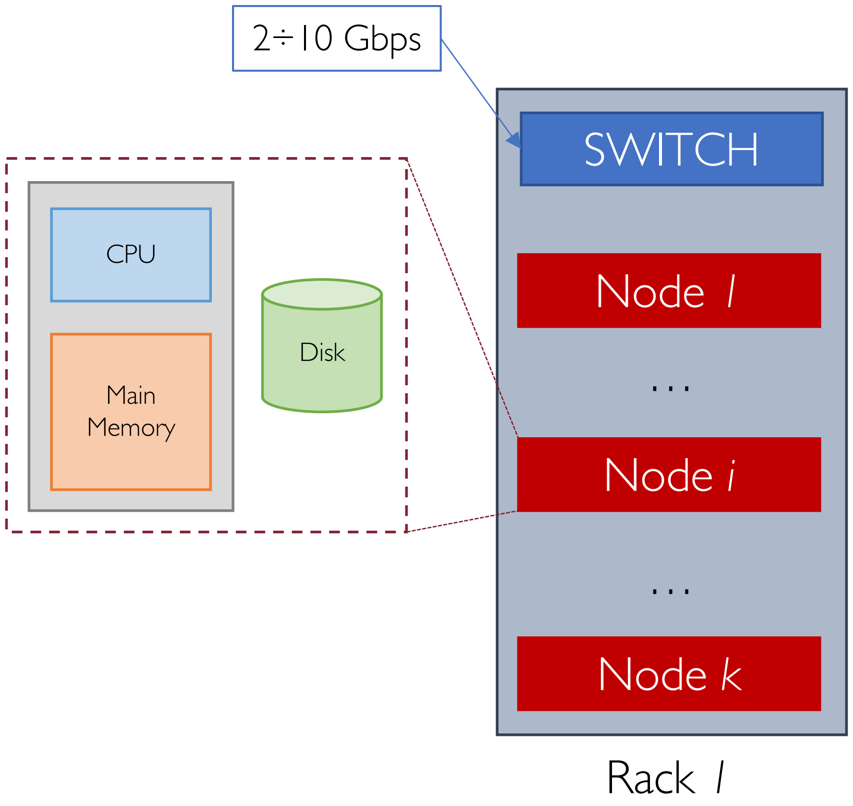

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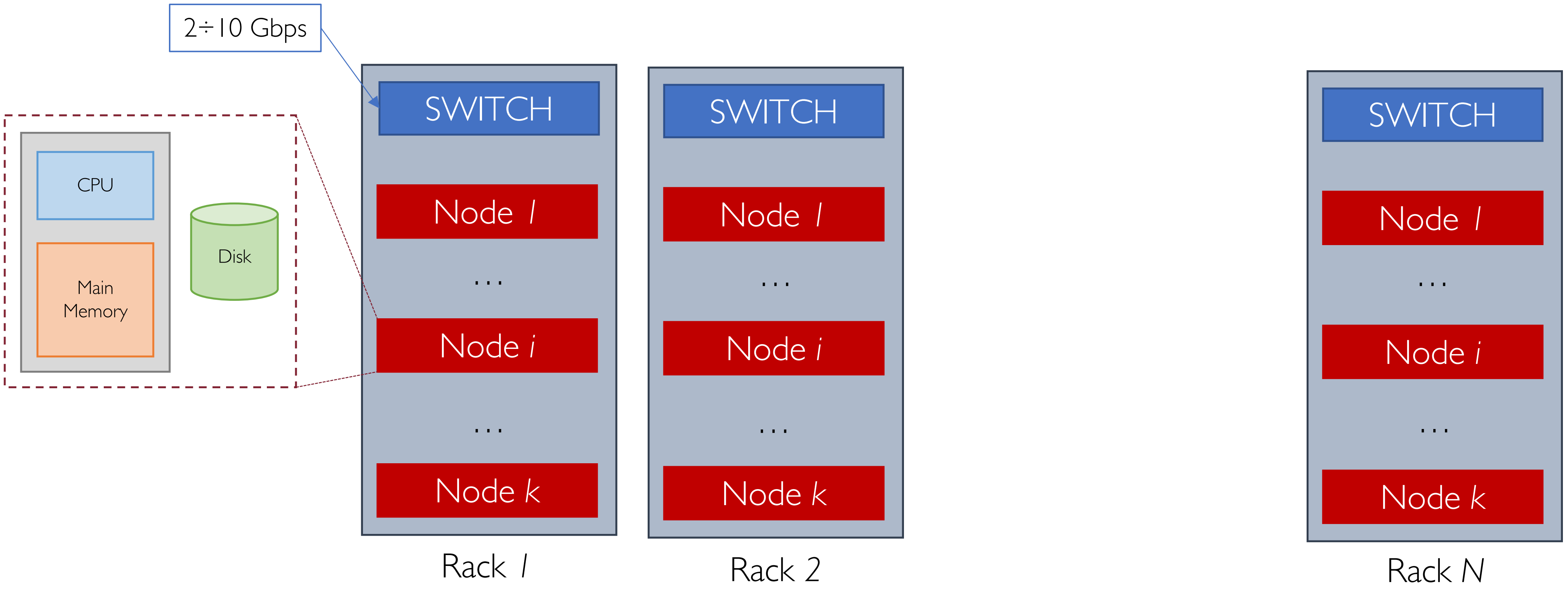

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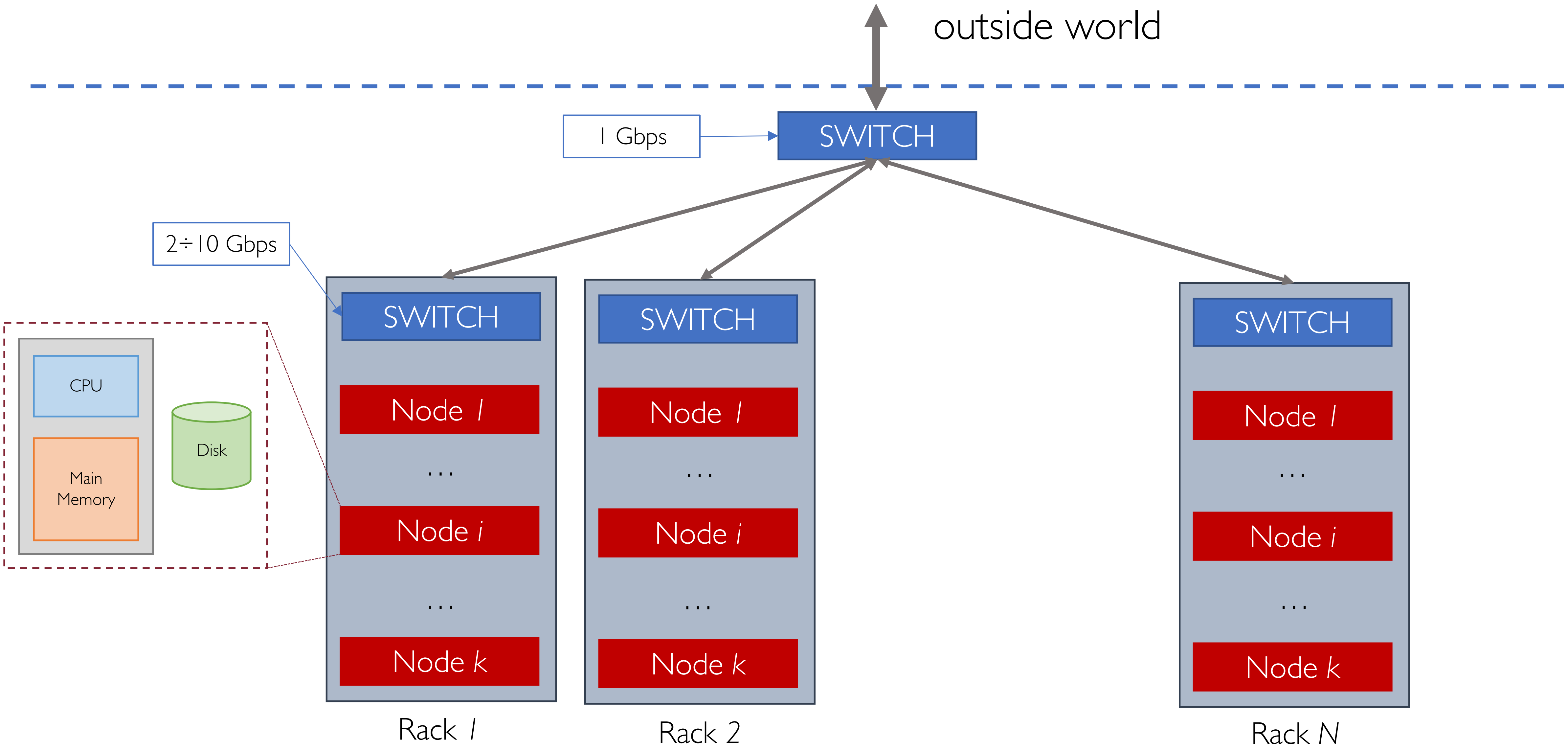

Cluster Architecture: Challenges

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  - Ease distributed programming model

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$$E[T] = Np$$

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Q1: How to make data and computation resilient to node failures?

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Q2: How to minimize data tranfers so as to reduce network communications?

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Q3: How to implement algorithms which take advantage of the distributed infrastructure without worrying about its complexities?

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- Traditional algorithms/techniques often don't scale very well
- There is the need for new "tools" which allow storing, managing, and analyzing big data painlessly