Scalability Speed up & Amdhal’s Law

Lecture-2

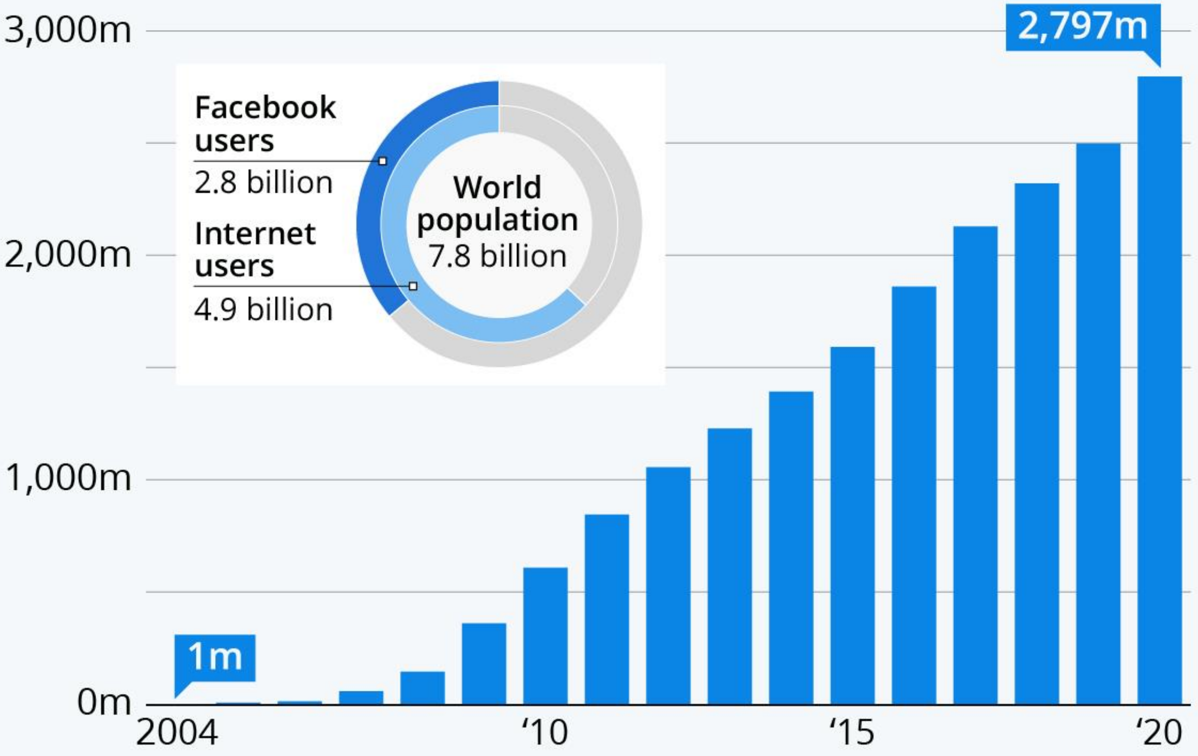
Parallel & Distributed Computing

Speedup and Amdhal’s Law

- ***Amdahl's law*** is a formula which gives the ***theoretical speedup*** in latency of the execution of a ***task*** at ***fixed workload*** that can be expected of a system whose ***resources are improved*** (scalability).
- It is named after computer scientist Gene Amdahl, and was presented at the AFIPS Spring Joint Computer Conference in 1967.
- Amdahl's law is often used in parallel computing to predict the theoretical speedup when using multiple processors.

Facebook Keeps On Growing

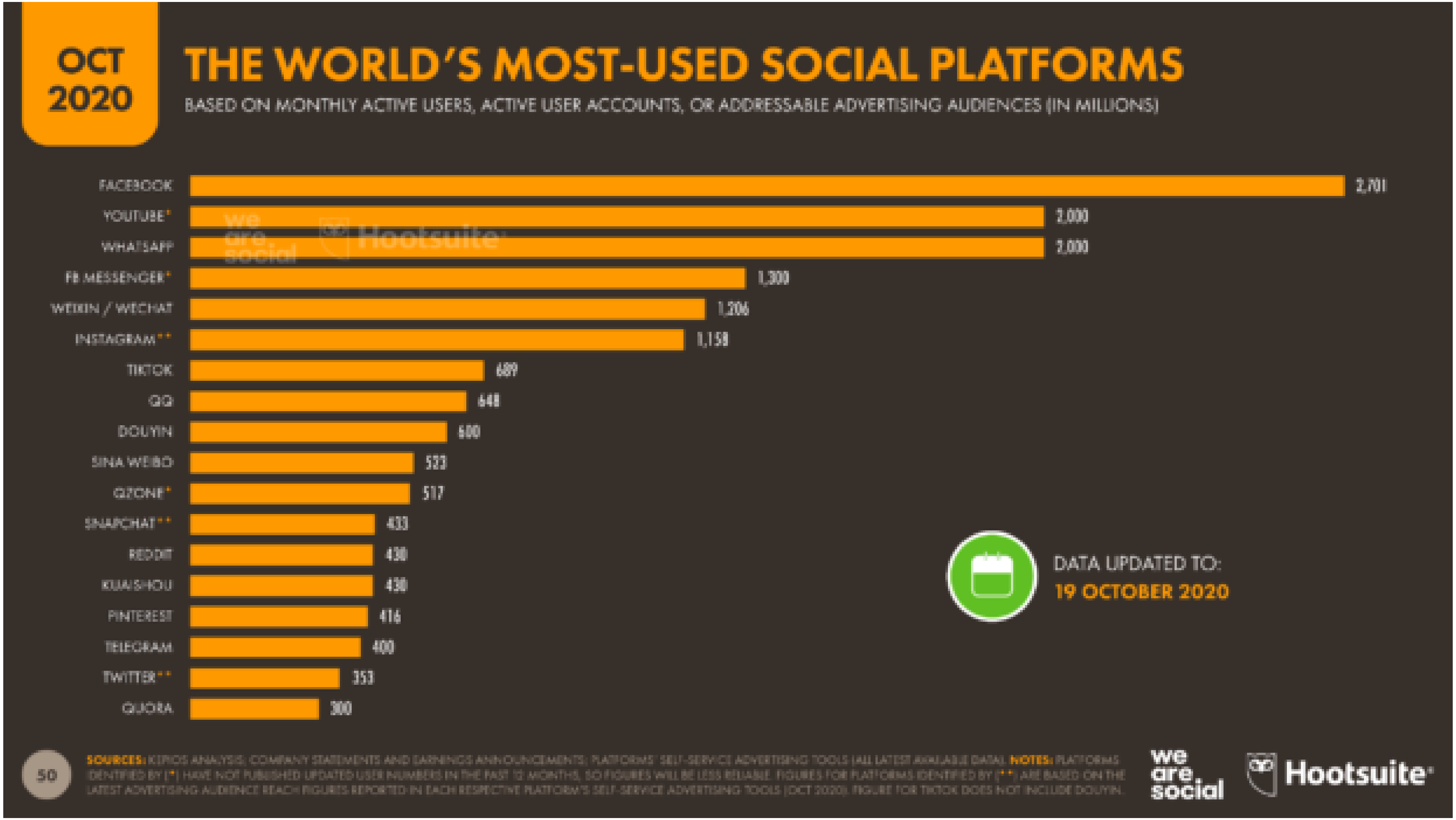
Number of monthly active Facebook users worldwide



Facebook users as of the end of the respective year;
world population and internet usage estimates as of Dec. 31, 2020

Sources: Facebook, Internet World Stats

statista


OCT 2020
THE WORLD'S MOST-USED SOCIAL PLATFORMS
BASED ON MONTHLY ACTIVE USERS, ACTIVE USER ACCOUNTS, OR ADDRESSABLE ADVERTISING AUDIENCES (IN MILLIONS)
FACEBOOK 2,701
YOUTUBE* 2,000
WHATSAPP 2,000
FB MESSENGER* 1,300
WEIXIN / WECHAT 1,206
INSTAGRAM** 1,158
TIKTOK 689
QQ 648
DOUYIN 600
SINA WEIBO 523
QZONE* 517
SNAPCHAT** 433
REDDIT 430
KUAISHOU 430
PINTEREST 416
TELEGRAM 400
TWITTER** 353
QUORA 300
DATA UPDATED TO:
19 OCTOBER 2020
50
SOURCES: KEPIOS ANALYSIS; COMPANY STATEMENTS AND EARNINGS ANNOUNCEMENTS; PLATFORMS' SELF-SERVICE ADVERTISING TOOLS (ALL LATEST AVAILABLE DATA). NOTES: PLATFORMS IDENTIFIED BY (*) HAVE NOT PUBLISHED UPDATED USER NUMBERS IN THE PAST 12 MONTHS, SO FIGURES WILL BE LESS RELIABLE. FIGURES FOR PLATFORMS IDENTIFIED BY (**) ARE BASED ON THE LATEST ADVERTISING AUDIENCE REACH FIGURES REPORTED IN EACH RESPECTIVE PLATFORM'S SELF-SERVICE ADVERTISING TOOLS (OCT 2020). FIGURE FOR TIKTOK DOES NOT INCLUDE DOUYIN.
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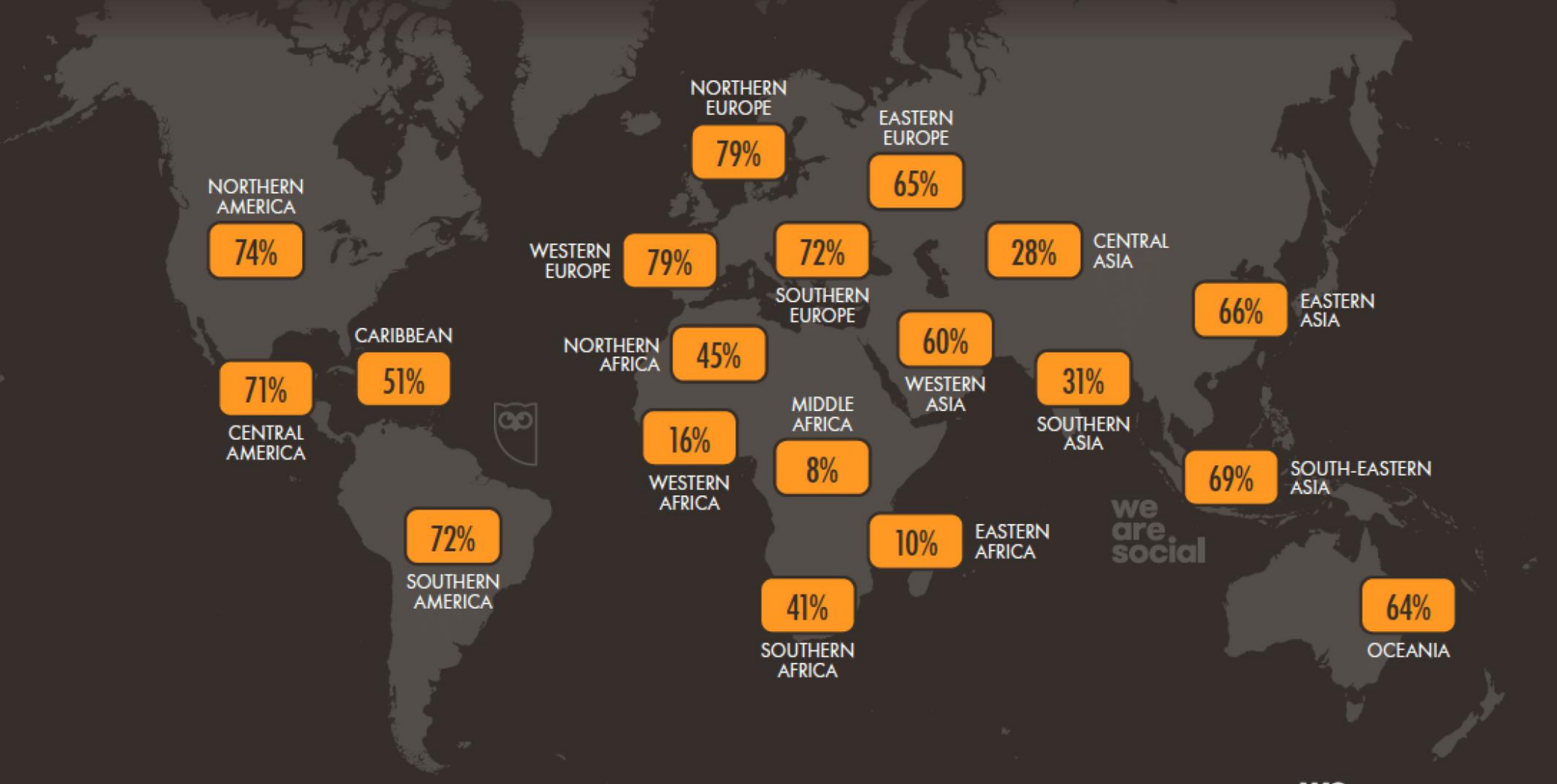
JAN
2021

SOCIAL MEDIA USERS vs. TOTAL POPULATION

THE NUMBER OF ACTIVE SOCIAL MEDIA USERS* IN EACH REGION COMPARED TO TOTAL POPULATION

⚠ *THIS CHART INCLUDES DATA FROM NEW SOURCES, SO VALUES ARE NOT COMPARABLE WITH THOSE PUBLISHED IN PREVIOUS REPORTS*



SOURCES: KEPIOS (JAN 2021), BASED ON DATA FROM: COMPANY EARNINGS ANNOUNCEMENTS; PLATFORMS' SELF-SERVICE ADVERTISING TOOLS; CNNIC; CAFEBAZAAR; OCDH. ***ADVISORY:** "USERS" MAY NOT REPRESENT UNIQUE INDIVIDUALS, SO FIGURES MAY EXCEED INTERNET PENETRATION VALUES. **NOTES:** DIFFERENCES IN DATA AVAILABILITY MEAN REGIONAL FIGURES MAY NOT CORRELATE WITH GLOBAL TOTALS. REGIONS AS PER THE U.N. GEOSCHEME. ◈ **COMPARABILITY ADVISORY:** DATA ARE NOT COMPARABLE WITH PREVIOUS REPORTS.

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Speedup and Amdhal's Law cont… Scalability

- **Scalability** is the *property* of a system to *handle* a ***growing amount of work by adding resources to the system***.
- A system is described as ***scalable*** if it will remain **effective** when there is a significant increase in the number of resources and the number of users

Speedup and Amdhal’s Law cont… Scalability (dimensions)

- Scalability of a system can be measured along the following different dimensions:

1. ***Physical Scalability/ Load Scalability***: a system can be scalable with respect to its **size**, meaning that we can easily **add**/ **remove** more ***users*** and ***resources*** to the system.
2. ***Administrative scalability***: The ability for an increasing number of organizations or users to access a system.

Speedup and Amdhal's Law cont… Scalability (dimensions)

3. ***Functional scalability***: The ability to enhance the system by adding new functionality without disrupting existing activities.

4. ***Geographic scalability***: The ability to maintain effectiveness during expansion from a local area to a larger region.

Speedup and Amdhal’s Law cont… Scalability (dimensions)

5. ***Generation scalability***: The ability of a system to scale by adopting new generations of components.

6. ***Heterogeneous scalability***: is the ability to adopt components from different vendors.

Speedup and Amdhal's Law cont…
Scalability: Scale out (Horizontal) & Scale up (Vertical)

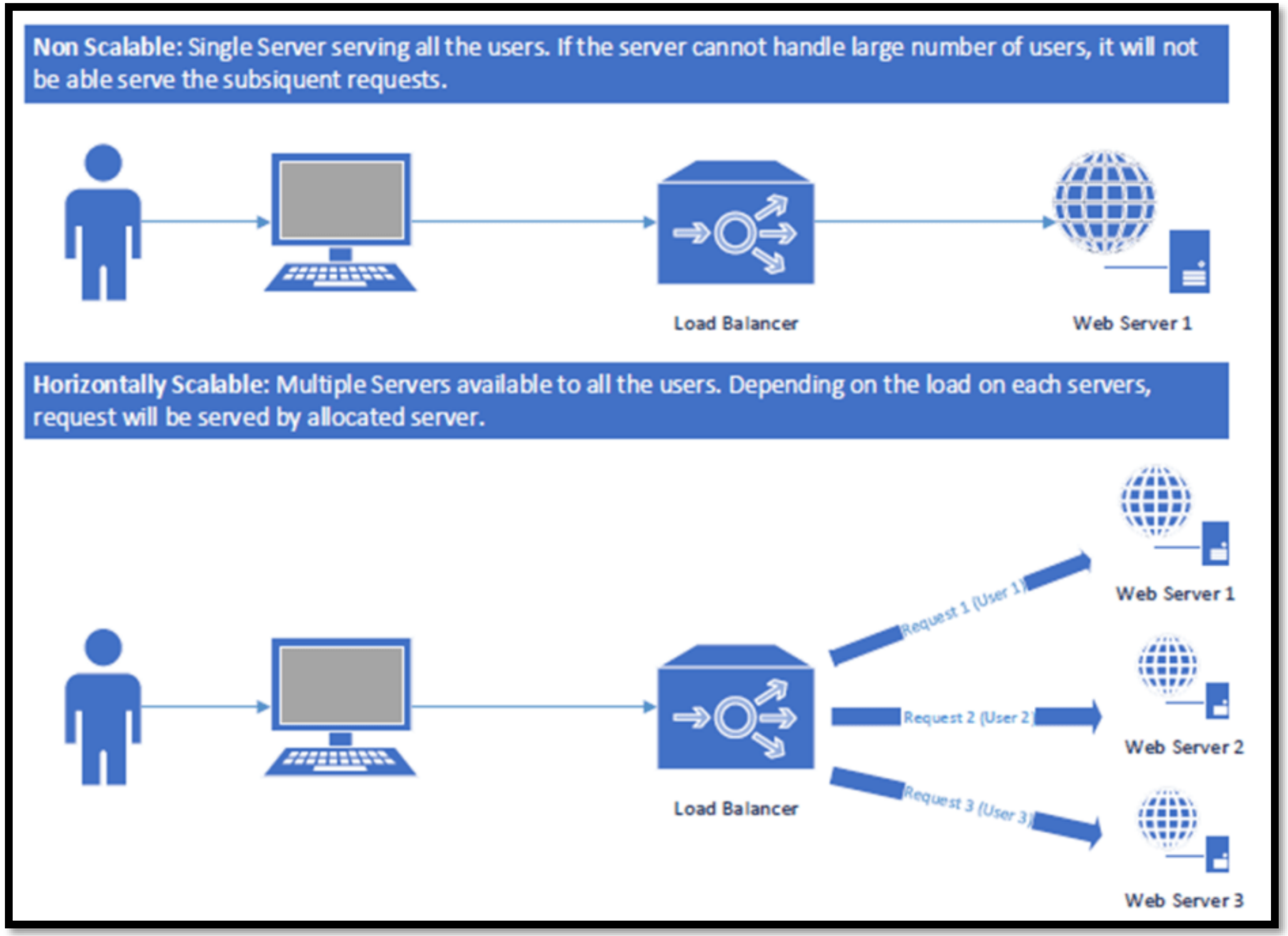
- Resources fall into two broad categories: horizontal and vertical.
- **Scaling horizontally:** (**out/in**) means adding more nodes to (or removing nodes from) a system, such as **adding a new computer to a distributed software application**.

Speedup and Amdhal’s Law cont…
Scalability: Scale out (Horizontal) & Scale up (Vertical)

- An example might involve **scaling out** (to increase) from one web server to three.
- Exploiting this scalability requires software for efficient resource management and maintenance.

Speedup and Amdhal's Law cont…

Scalability: Scale out (Horizontal) & Scale up (Vertical)



Speedup and Amdhal's Law cont…
Scalability: Scale out (Horizontal) & Scale up (Vertical)

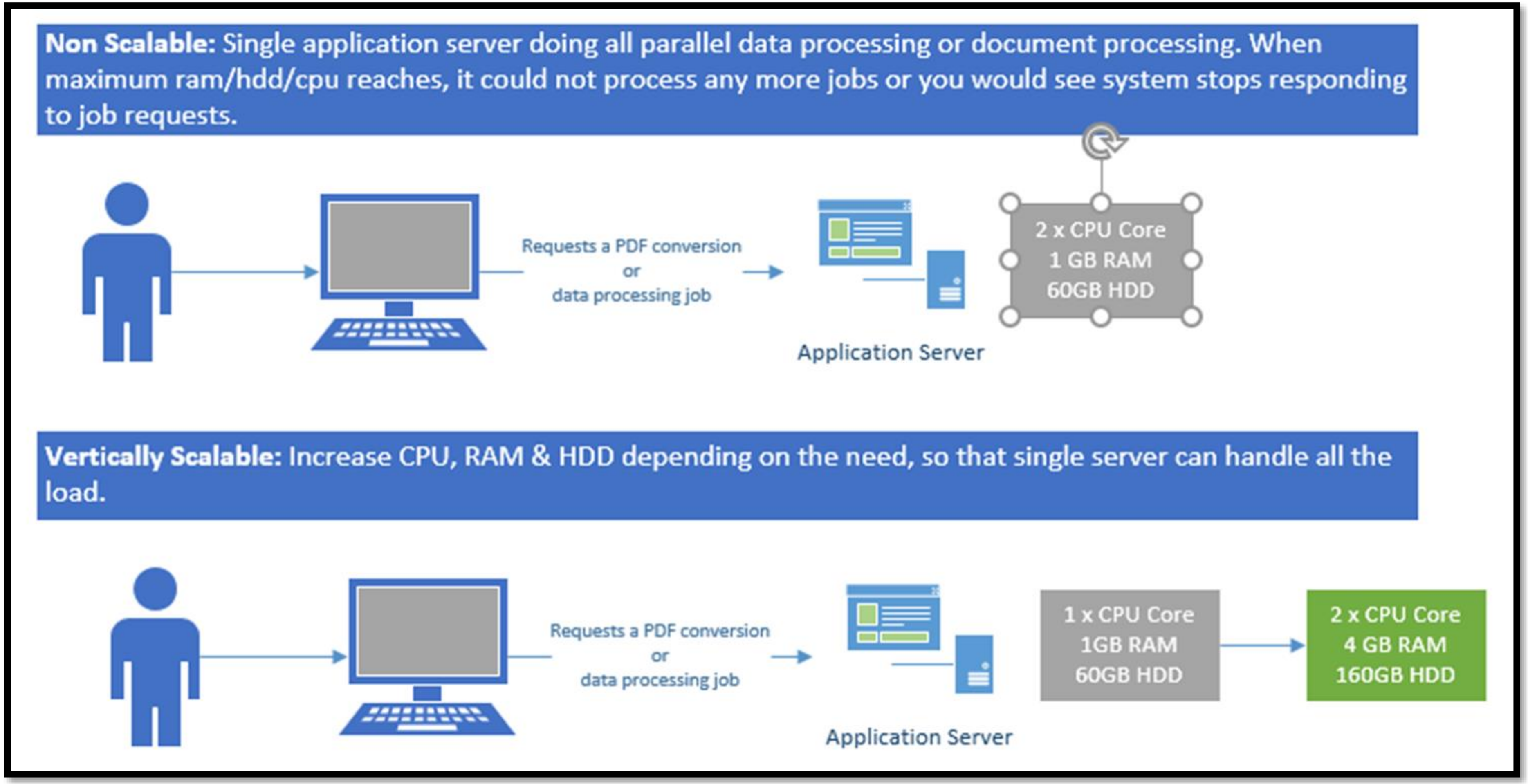
- **Scaling vertically:** (**up/down**) means adding resources to (or removing resources from) a single node, typically **involving the addition of CPUs, memory or storage to a single computer**.

Speedup and Amdhal’s Law cont…
Scalability: Scale out (Horizontal) & Scale up (Vertical)

- Larger numbers of elements increases **management complexity**, more sophisticated **programming** to ***allocate tasks among resources*** and handle issues such as ***throughput*** and ***latency*** across nodes.

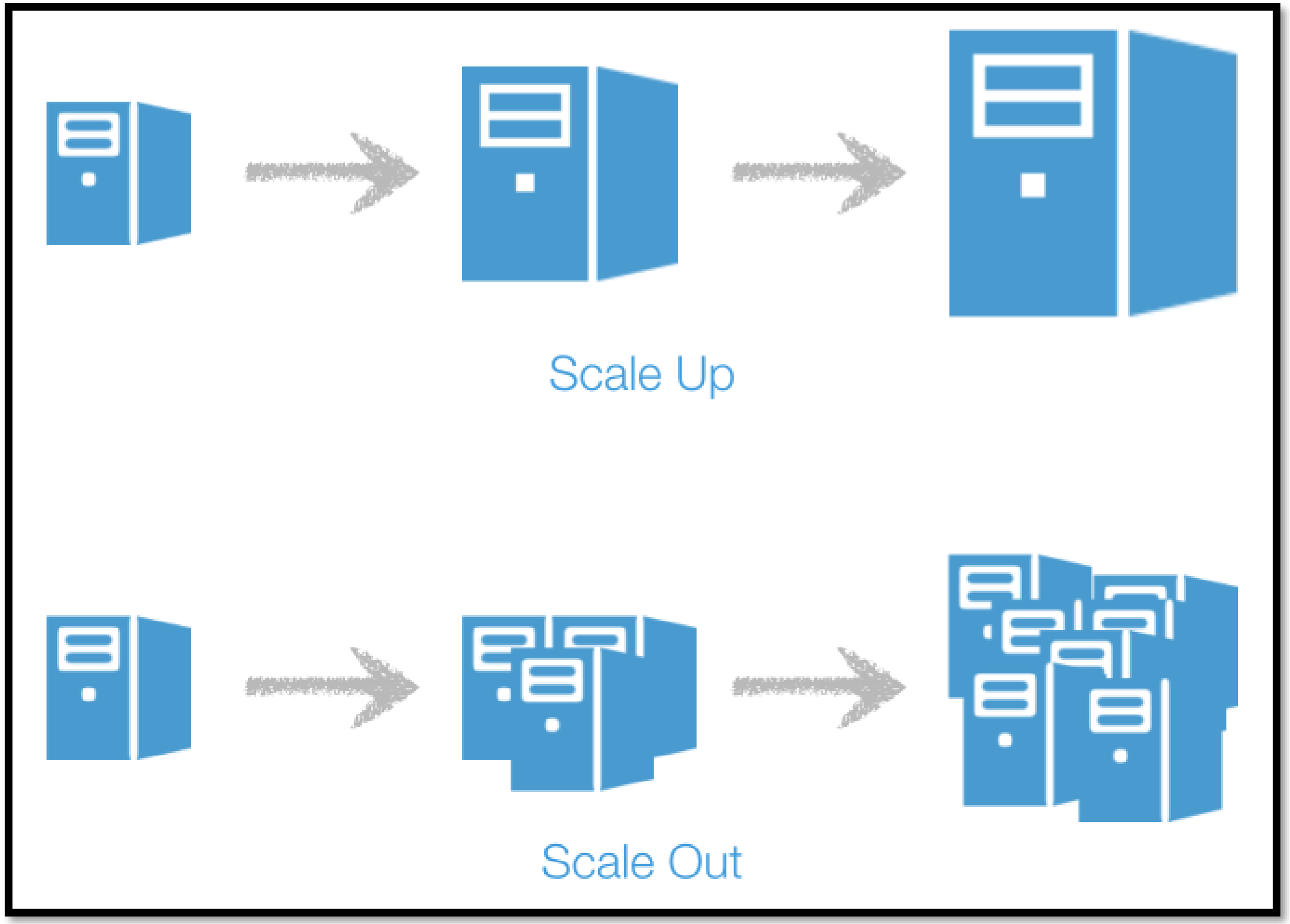
Speedup and Amdhal's Law cont…

Scalability: Scale out (Horizontal) & Scale up (Vertical)



Speedup and Amdhal's Law cont…

Scalability: Scale out (Horizontal) & Scale up (Vertical)



Speedup and Amdhal's Law cont…
Scalability: Issues

- The design of scalable distributed systems presents the following challenges:
- ***<u>1- Controlling the cost of physical resources</u>***: As the demand for a resource grows, it should be possible to extend the system, at **reasonable cost**, to meet it. **Return on Investment (ROI)**.

Speedup and Amdhal's Law cont… Scalability: Issues

- It must be possible to **add server computers to avoid the performance bottleneck** that would arise if a single file server had to handle all file access requests.
- For example, if a single file server can support 20 users, then two such servers should be able to support 40 users. Although that sounds an obvious goal, it is not necessarily easy to achieve in practice.

Speedup and Amdhal's Law cont… Scalability: Issues

- ***<u>2- Controlling the performance loss</u>***: Consider the management of a set of data whose **size is proportional to the number of users** or resources in the system.
- As we know algorithms have advantages and disadvantages.
- So, we should use such algorithms which may support Scaling up/ Scaling out, to prevent performance loss.

Speedup and Amdhal's Law cont…
Scalability: Issues

- If we scale up our system from 32 bit to 64 bit, but we are using old 32 bit algorithms (software), ➔ **performance loss**.
- **Algorithm (software)** is a finite set of instructions, when we execute these instruction in a sequence our problem get solved.

Speedup and Amdhal’s Law cont… Scalability: Issues

- ***<u>3- Preventing software resources running out</u>***: An example of lack of scalability is shown by the numbers used as Internet (IP) addresses (computer addresses in the Internet).
- In the late 1970s, it was decided to use 32 bits for this purpose, the supply of available Internet addresses is running out.

Speedup and Amdhal's Law cont… Scalability: Issues

- For this reason, a new version of the protocol with 128-bit Internet addresses is being adopted, and this will require modifications to many software components.

IPv4	IPv6
Deployed 1981	Deployed 1998
32-bit IP address	128-bit IP address
4.3 billion addresses Addresses must be reused and masked	7.9×10^{28} addresses Every device can have a unique address
Numeric dot-decimal notation 192.168.5.18	Alphanumeric hexadecimal notation 50b2:6400:0000:0000:6c3a:b17d:0000:10a9 (Simplified - 50b2:6400::6c3a:b17d:0:10a9)
DHCP or manual configuration	Supports autoconfiguration

Speedup and Amdhal's Law cont… Scalability: Issues

- ***4- Avoiding performance bottlenecks***: In general, algorithms should be decentralized to avoid having performance bottlenecks.
- The term "**bottleneck**" refers to both an ***overloaded network*** and the ***state of a computing device*** in which one **component is unable to keep pace with the rest of the system**, thus slowing overall **performance**.

Speedup and Amdhal’s Law cont… Scalability: Issues

- So balance in all the computing components is much necessary.
- For example, we normally install SSD’s rather than HDD, for quick response from secondary storage devices, and so on.

Speedup and Amdhal's Law cont…

- ***Amdahl's law*** is a formula which gives the ***theoretical speedup*** in latency of the execution of a ***task*** at ***fixed workload*** that can be expected of a system whose ***resources are improved*** (scalability).

Speedup and Amdhal's Law cont…

- Amdahl's law can be formulated in the following way:

$$S_{\text{latency}}(s) = \frac{1}{(1-p) + \frac{p}{s}}$$

where

- ***S***

- ***s*** is the speedup of the part of the task that benefits from improved system resources;
- ***p*** is the proportion of execution time that the part benefiting from improved resources originally occupied.

Speedup and Amdhal's Law cont…

- For example, if a program needs ***20 hours*** using a ***single processor*** core, and a ***particular part of the program*** which takes one hour to execute cannot be parallelized.
- While the remaining 19 hours [19/20=0.95] (p = 0.95) 95% of execution time can be parallelized.
- But 0.05 (1 hour) 5% part of the program can't be parallelized.

Speedup and Amdhal's Law cont…

- Then regardless of how many processors are devoted to a parallelized execution of this program, the minimum execution time cannot be less than that critical one hour.
- In the previous example 95% portion of process is subject to speed up, p will be 0.95 ($p=0.95$), and the portion which will get benefit of speed up twice of original then $s=2$.

Speedup and Amdhal's Law cont…

- So by using Amdhal's law overall speed up will be:
- Formula: $S = 1/\ (1-p)+(p/s)$
- By putting values: $S = 1/(1-0.95)+(0.95/2)$
- So the speed up (S): $S = 1/\ (0.05)+(0.475) \rightarrow 1/\ 0.525 \rightarrow$ **1.907**

Speedup and Amdhal's Law cont…