

# Distributed Computing and Introduction to High Performance Computing

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# Outline of this lecture

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- The flood of Data
- In the future not only heavy computations must be done, but also we will need to handle a huge amount of Data

# The Age of Data

## In 2020

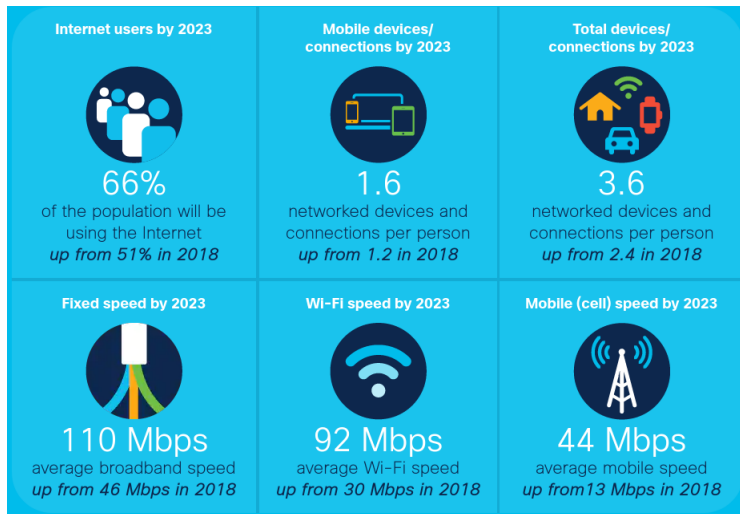
- The average internet user generates  $\sim 1.5$  GB of traffic per day
- Smart Hospitals generate over 3 TB per day
- Each self driving car generate over 4 TB per day
- A connected plane generates over 40 TB per day
- A connected Factory generates over 1 PB per day

## A self-driving car

- Radar  $\sim 10 - 100$  KB per second
- Sonar  $\sim 10 - 100$  KB per second
- GPS  $\sim 50$  KB per second
- Lidar  $\sim 10 - 70$  MB per second
- Cameras  $\sim 20 - 40$  MB per second
- 1 car  $\sim 5$  Exaflops per hour

# The Age of Data

## Connections: Global and Regional summaries



# The Age of Data

Connections: Global and Regional summaries

## Western Europe

Internet users by 2023



87%

of the population will be  
using the Internet  
*up from 82% in 2018*

Mobile devices/  
connections by 2023



2.9

networked devices and  
connections per person  
*up from 1.7 in 2018*

Total devices/  
connections by 2023



9.4

networked devices and  
connections per person  
*up from 5.6 in 2018*

Fixed speed by 2023



123 Mbps

average broadband speed  
*up from 46 Mbps in 2018*

Wi-Fi speed by 2023



97 Mbps

average Wi-Fi speed  
*up from 31 Mbps in 2018*

Mobile (cell) speed by 2023



62 Mbps

average mobile speed  
*up from 24 Mbps in 2018*

# The Age of Data

Connections: Global and Regional summaries

## Middle East and Africa

Internet users by 2023



35%

of the population will be  
using the Internet  
*up from 24% in 2018*

Mobile devices/  
connections by 2023



1.1

networked devices and  
connections per person  
*up from 0.9 in 2018*

Total devices/  
connections by 2023



1.5

networked devices and  
connections per person  
*up from 1.1 in 2018*

Fixed speed by 2023



41 Mbps

average broadband speed  
*up from 10 Mbps in 2018*

Wi-Fi speed by 2023



26 Mbps

average Wi-Fi speed  
*up from 7 Mbps in 2018*

Mobile (cell) speed by 2023



25 Mbps

average mobile speed  
*up from 7 Mbps in 2018*

# The Age of Data

Connections: Global and Regional summaries

## North America

Internet users by 2023



92%

of the population will be  
using the Internet  
*up from 90% in 2018*

Mobile devices/  
connections by 2023



3.3

networked devices and  
connections per person  
*up from 1.7 in 2018*

Total devices/  
connections by 2023



13.4

networked devices and  
connections per person  
*up from 8.2 in 2018*

Fixed speed by 2023



142 Mbps

average broadband speed  
*up from 57 Mbps in 2018*

Wi-Fi speed by 2023



110 Mbps

average Wi-Fi speed  
*up from 47 Mbps in 2018*

Mobile (cell) speed by 2023

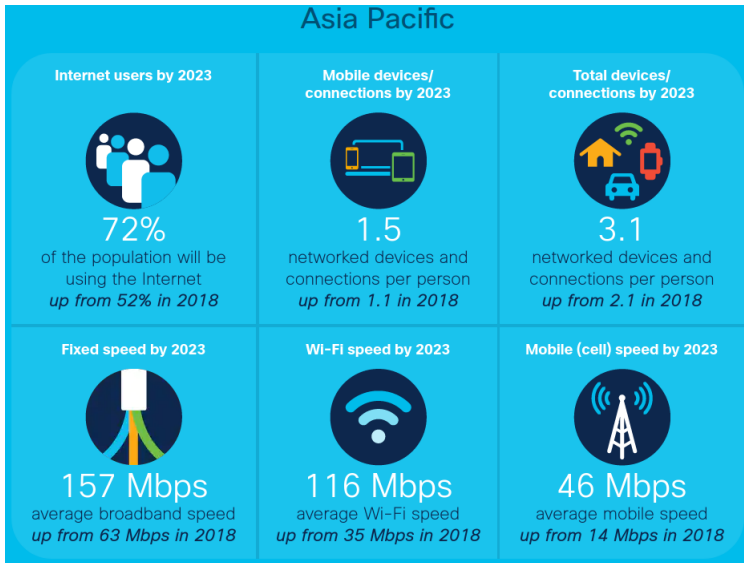


58 Mbps

average mobile speed  
*up from 22 Mbps in 2018*

# The Age of Data

## Connections: Global and Regional summaries





# The Age of Data

## Users/ Devices and connections

Figure 1. Global Internet user growth

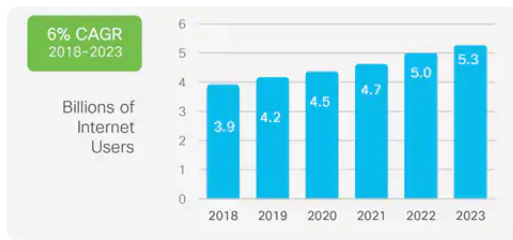


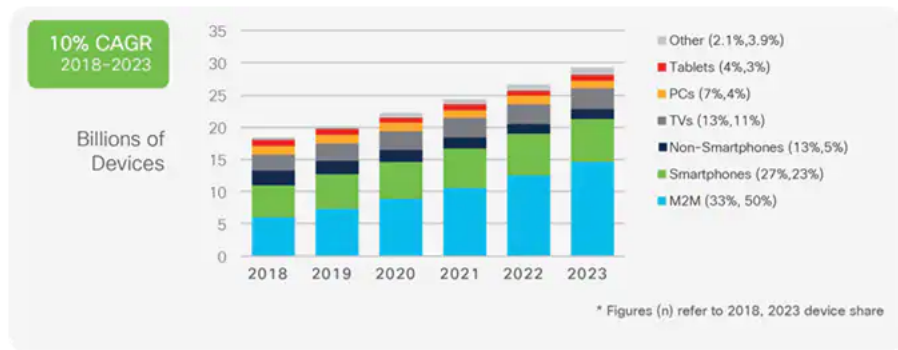
Table 1. Internet users as a percentage of regional population

Region	2018	2023
Global	51%	66%
Asia Pacific	52%	72%
Central and Eastern Europe	65%	78%
Latin America	60%	70%
Middle East and Africa	24%	35%
North America	90%	92%
Western Europe	82%	87%

# The Age of Data

Users/ Devices and connections

Figure 2. Global device and connection growth



# The Age of Data

Users/ Devices and connections

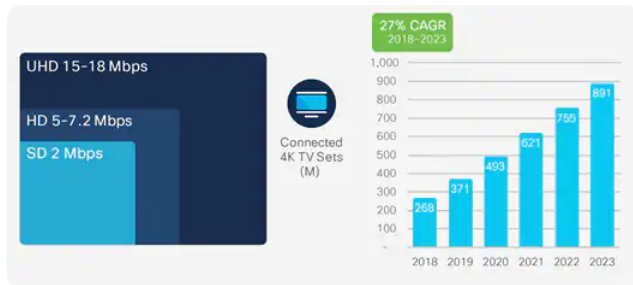
Table 2. Average number of devices and connections per capita

Region	2018	2023
Global	2.4	3.6
Asia Pacific	2.1	3.1
Central and Eastern Europe	2.5	4.0
Latin America	2.2	3.1
Middle East and Africa	1.1	1.5
North America	8.2	13.4
Western Europe	5.6	9.4

# The Age of Data

Users/ Devices and connections

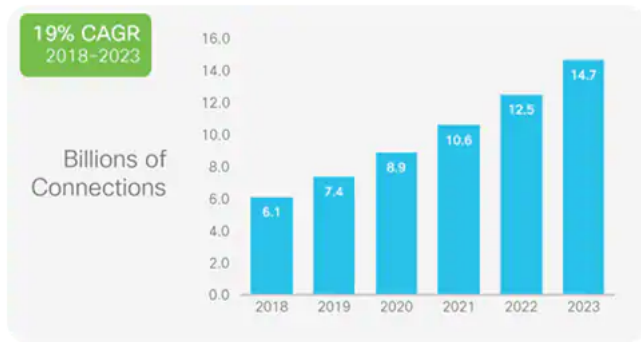
**Figure 3.** Increasing video definition: By 2023, 66 percent of connected flat-panel TV sets will be 4K



# The Age of Data

Users/ Devices and connections

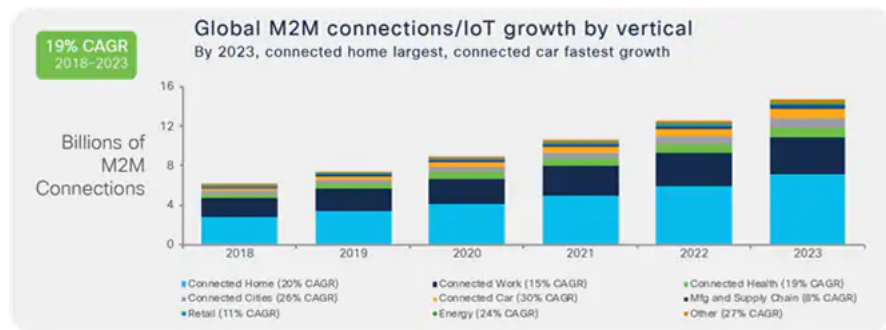
Figure 4. Global M2M connection growth



# The Age of Data

Users/ Devices and connections

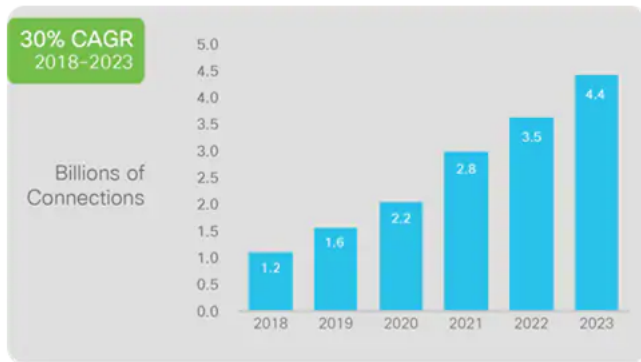
Figure 5. Global M2M connection growth by industries



# The Age of Data

Users/ Devices and connections

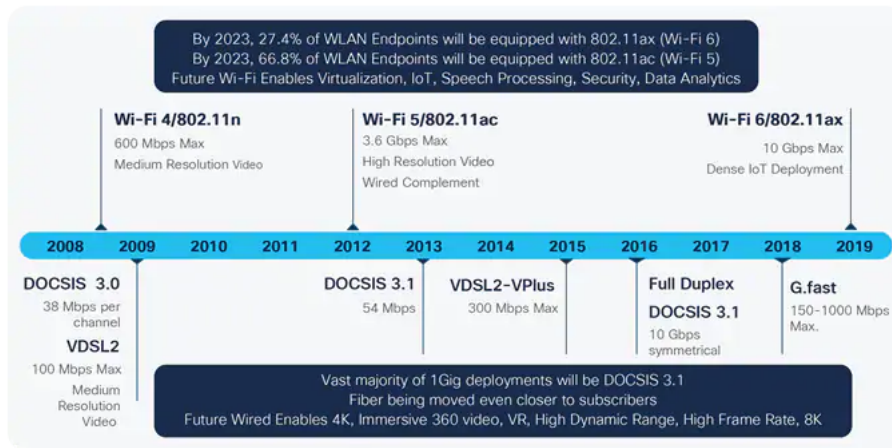
**Figure 9.** Global mobile Machine-To-Machine (M2M) growth



# The Age of Data

Users/ Devices and connections

**Figure 12.** Historical evolution and future of wired and wireless technologies

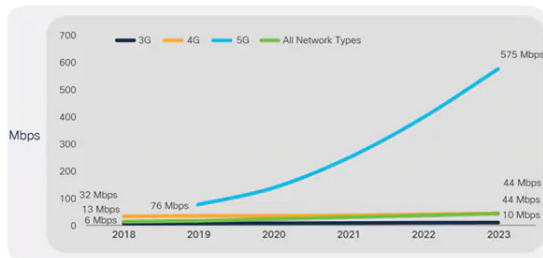




# The Age of Data

## Users/ Devices and connections

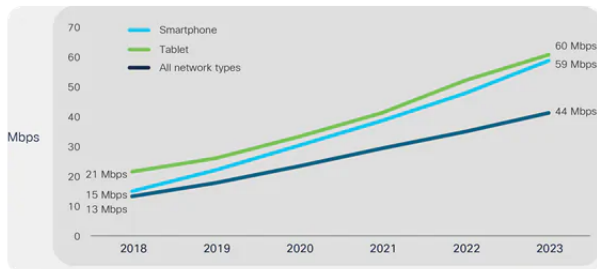
**Figure 15.** Global mobile average speeds by network type: 5G speeds will be 13 times higher than the average mobile connection by 2023



# The Age of Data

Users/ Devices and connections

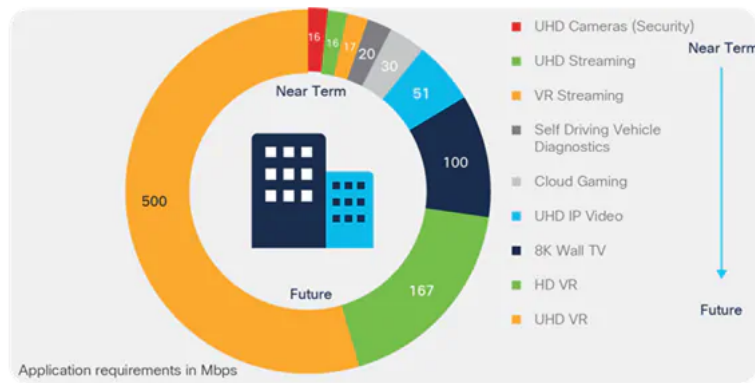
**Figure 14.** Global mobile average speeds by device type: Smartphone and tablet speeds accelerate due to 5G



# The Age of Data

Users/ Devices and connections

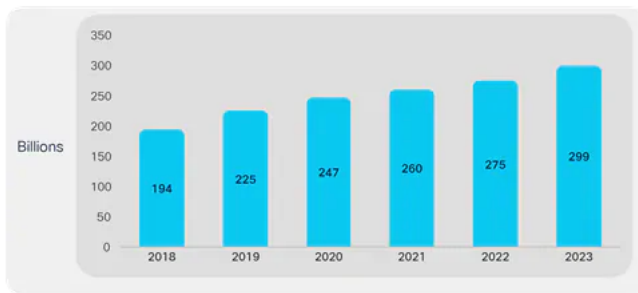
**Figure 13.** Significant demand for bandwidth and video in the connected home of the future



# The Age of Data

Users/ Devices and connections

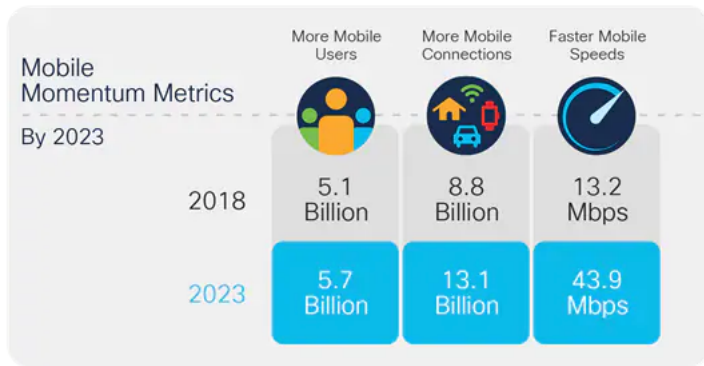
**Figure 22.** Nearly 300 billion mobile applications to be downloaded by 2023



# The Age of Data

Users/ Devices and connections

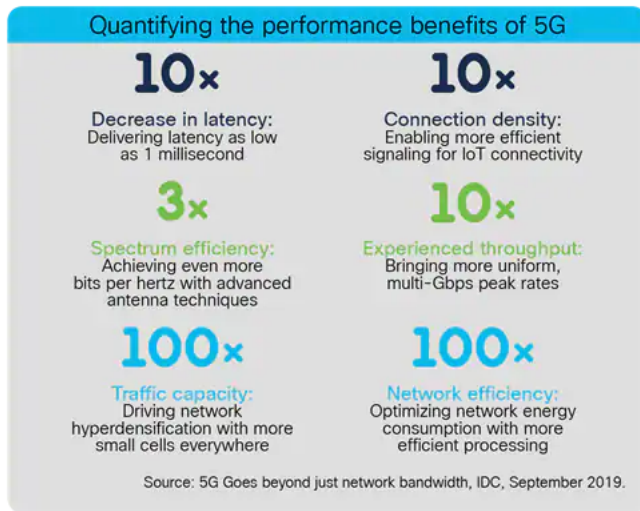
**Figure 35.** Global wireless networking metrics



# The Age of Data

Users/ Devices and connections

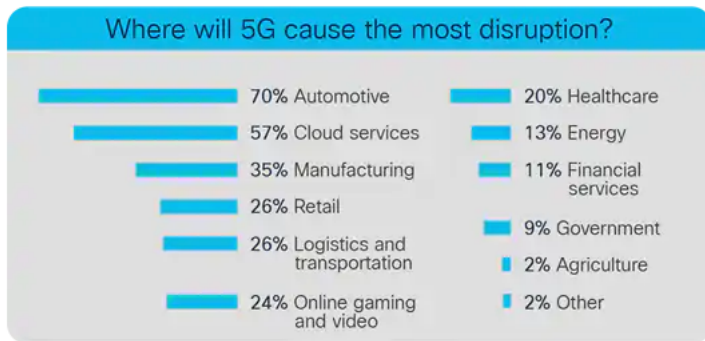
Figure 24. Quantifying the performance benefits of 5G



# The Age of Data

Users/ Devices and connections

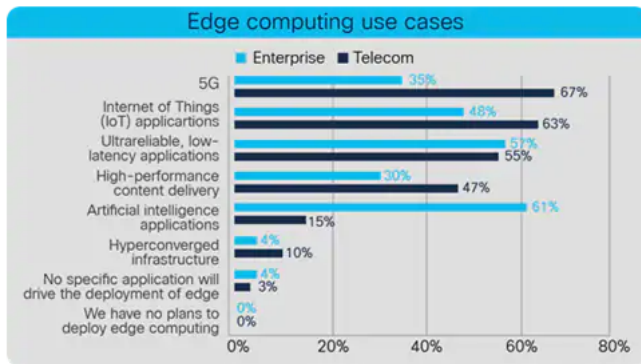
Figure 28. Where will 5G cause the most disruption?



# The Age of Data

Users/ Devices and connections

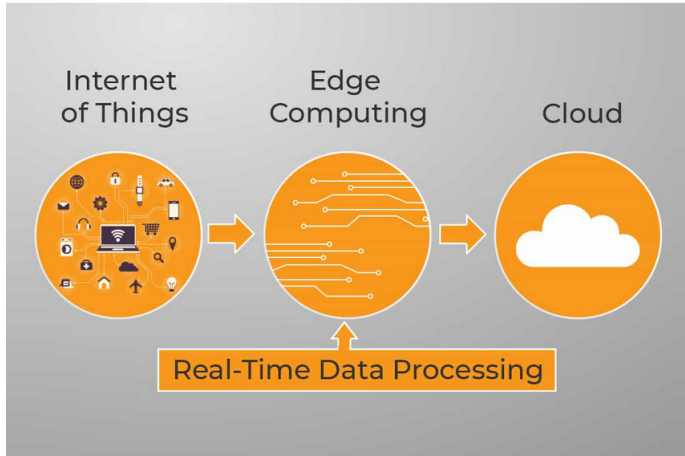
Figure 27. Edge computing use cases





# The Age of Data

## Edge vs Cloud computing



# The Age of Data

## Edge vs Cloud computing

Edge Computing allows computing resources and application services to be distributed along the communication path, via decentralized computing infrastructure :

- Improved Performance
- Reducing Operational Costs
- Examples:
  - Streaming Services
  - Autonomous Vehicles
  - Smart Homes