A. Introduction to 5G and AIoT

Chapter #1: Overview of 5G and AIoT

ET0743
5G and AIoT Applications

Week #1

Learning Objectives

At the end of instruction, the learner should be able to:

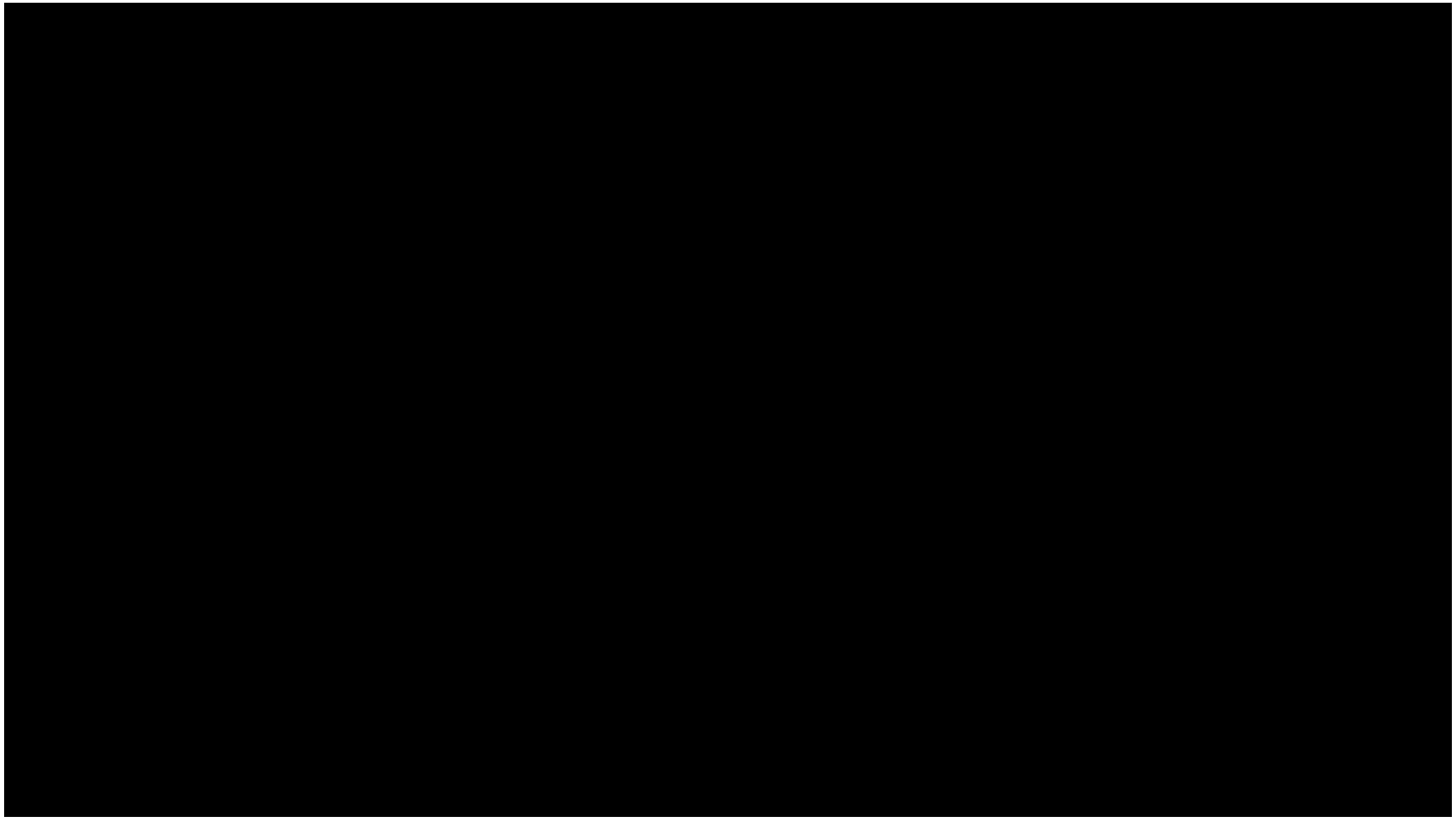
- Understand an overview of 5G.
- Understand an overview of AIoT.
- Describe the importance of 5G and AIoT in current and future applications.

What is 5G?

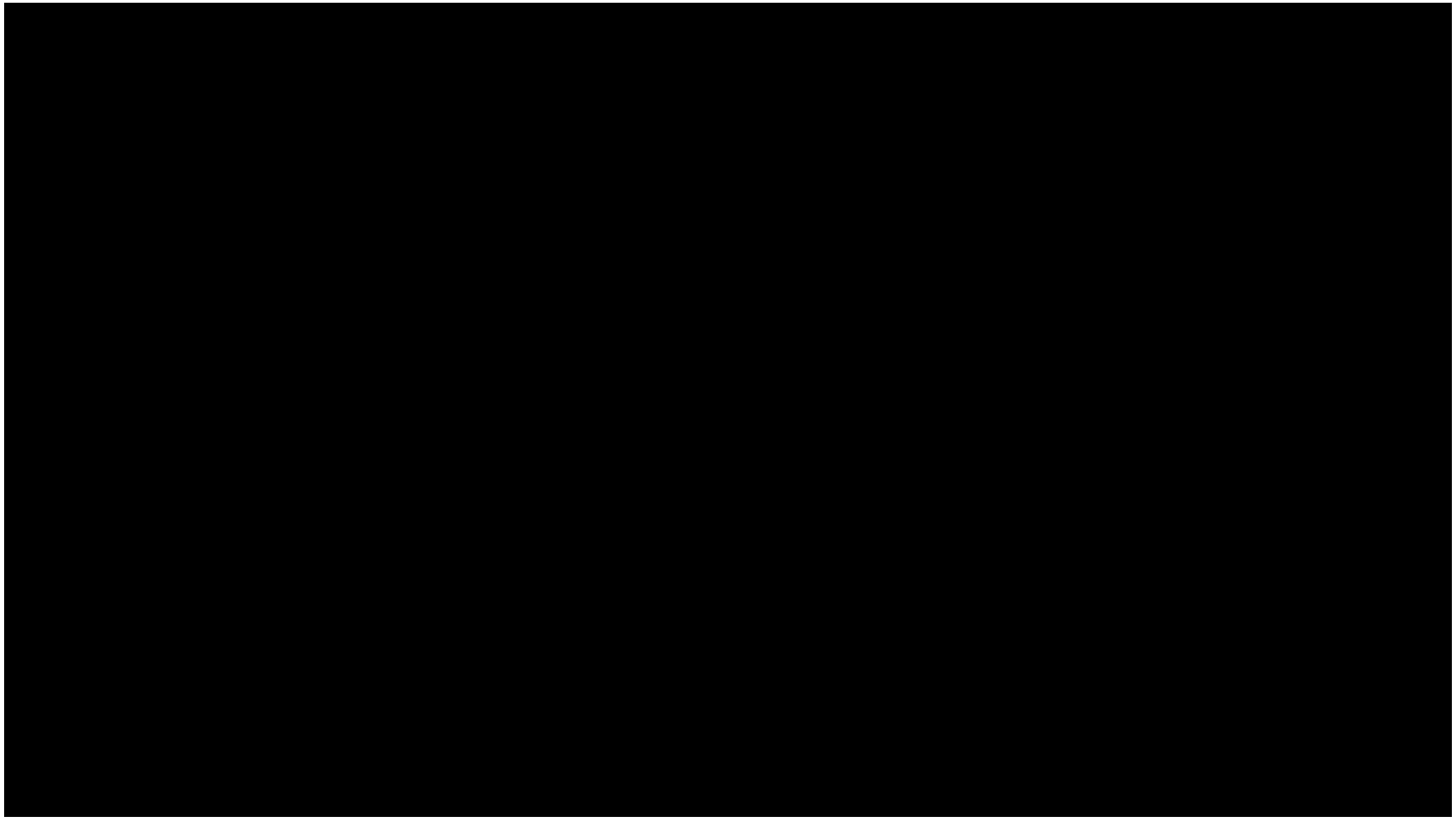
"***5G is an end-to-end ecosystem to enable a fully mobile and connected society. It empowers value creation towards customers and partners, through existing and emerging use cases, delivered with consistent experience, and enabled by sustainable business models***," – NGMN (Next Generation Mobile Networks Alliance)

"***5G enables technologies such as AI, Digital Twin, augmented and extended reality to seamlessly work together, key for businesses at the forefront of digital transformation and providing consumers with a better-quality experience***," – IMDA's press-release about 'IMDA announces new 5G projects, including augmented reality experience in Marina Bay' on CNA (03 Aug 2022)

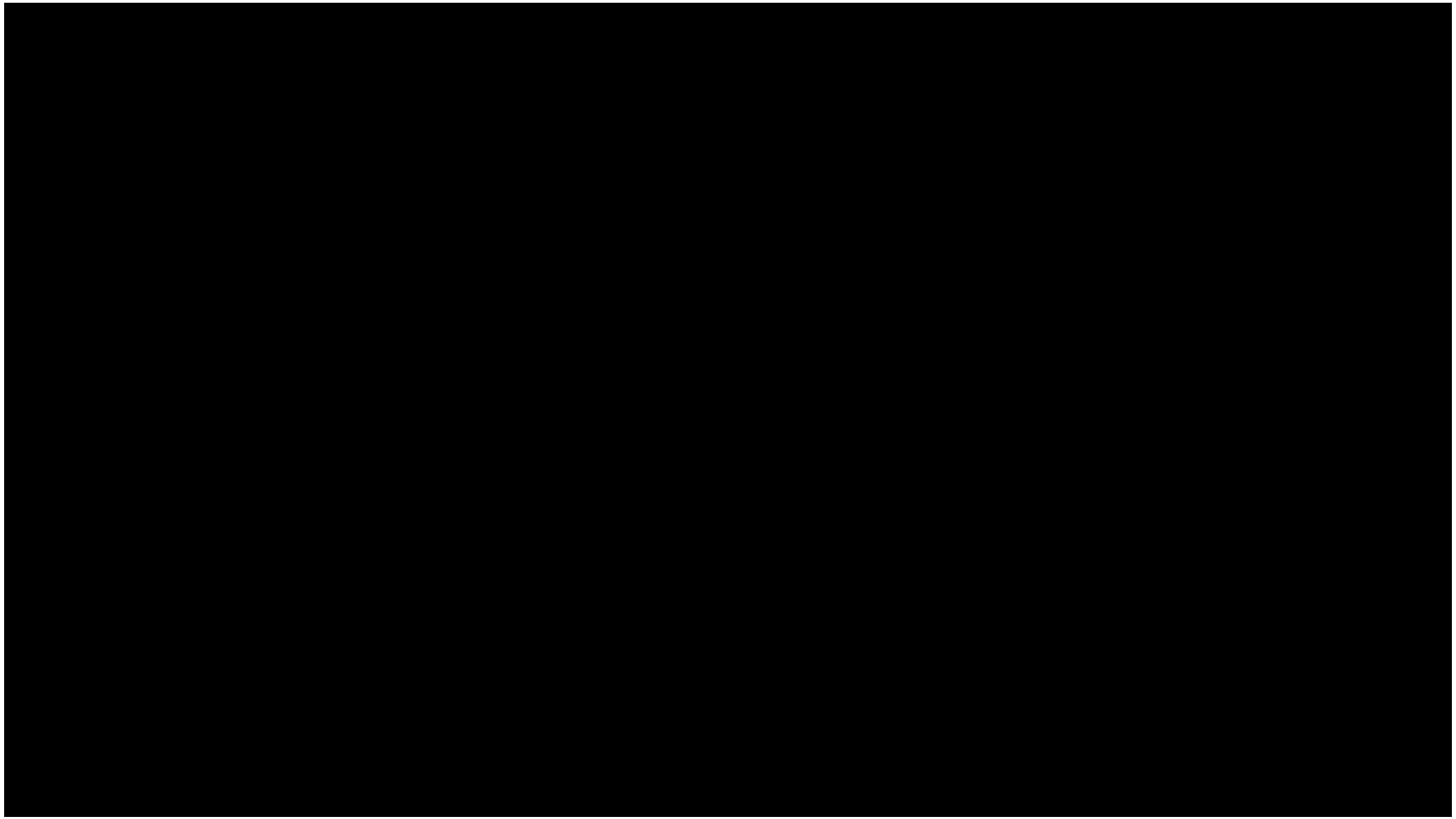
5G Explained in 7 Minutes: https://youtu.be/mo1lNRKnayA



Voices of early 5G consumers: https://youtu.be/-cmNpFxqDng



5G for consumers: https://youtu.be/xJKWH0KD4Wg



Road Map to 5G

1G

1980s

Analogue voice

2G

1990s

Digital voice

SMS

3G

2000s

SMS, MMS, www

4G

2010s

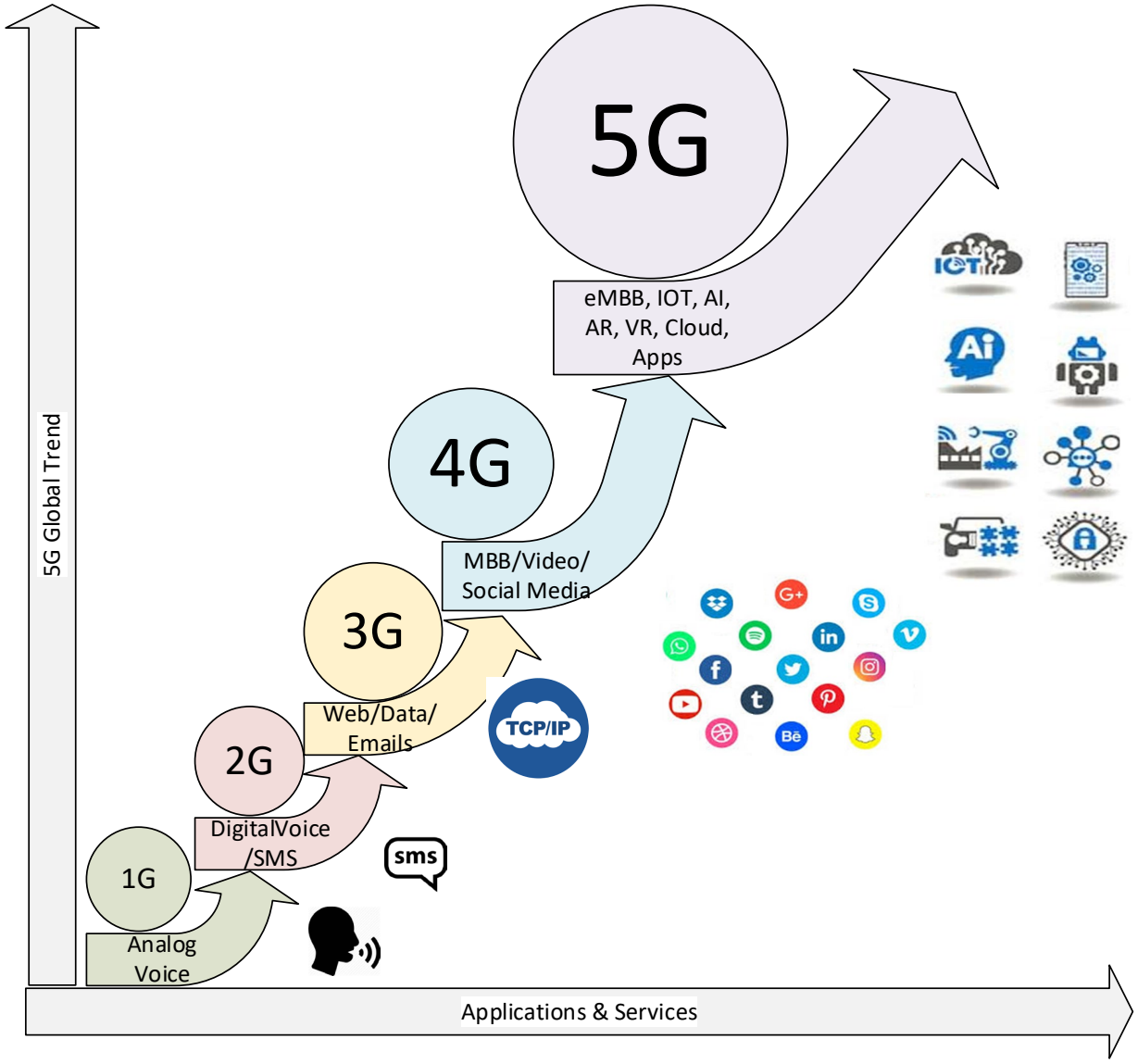
Mobile Broadband, LTE for faster Data transmission fully IP enabled

5G

2020s

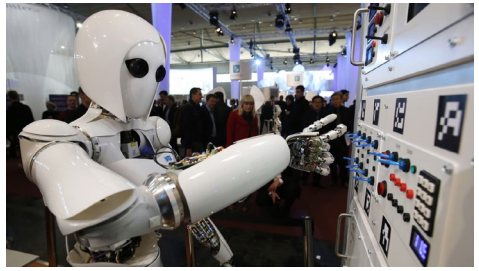
Drives services and applications, defining use cases; Industrial Transformation (i4.0), IoT, AR/VR, etc.

5G Global Trends Driven by Services & Applications



Mobile Broadband

Internet-of-Things (IoT)



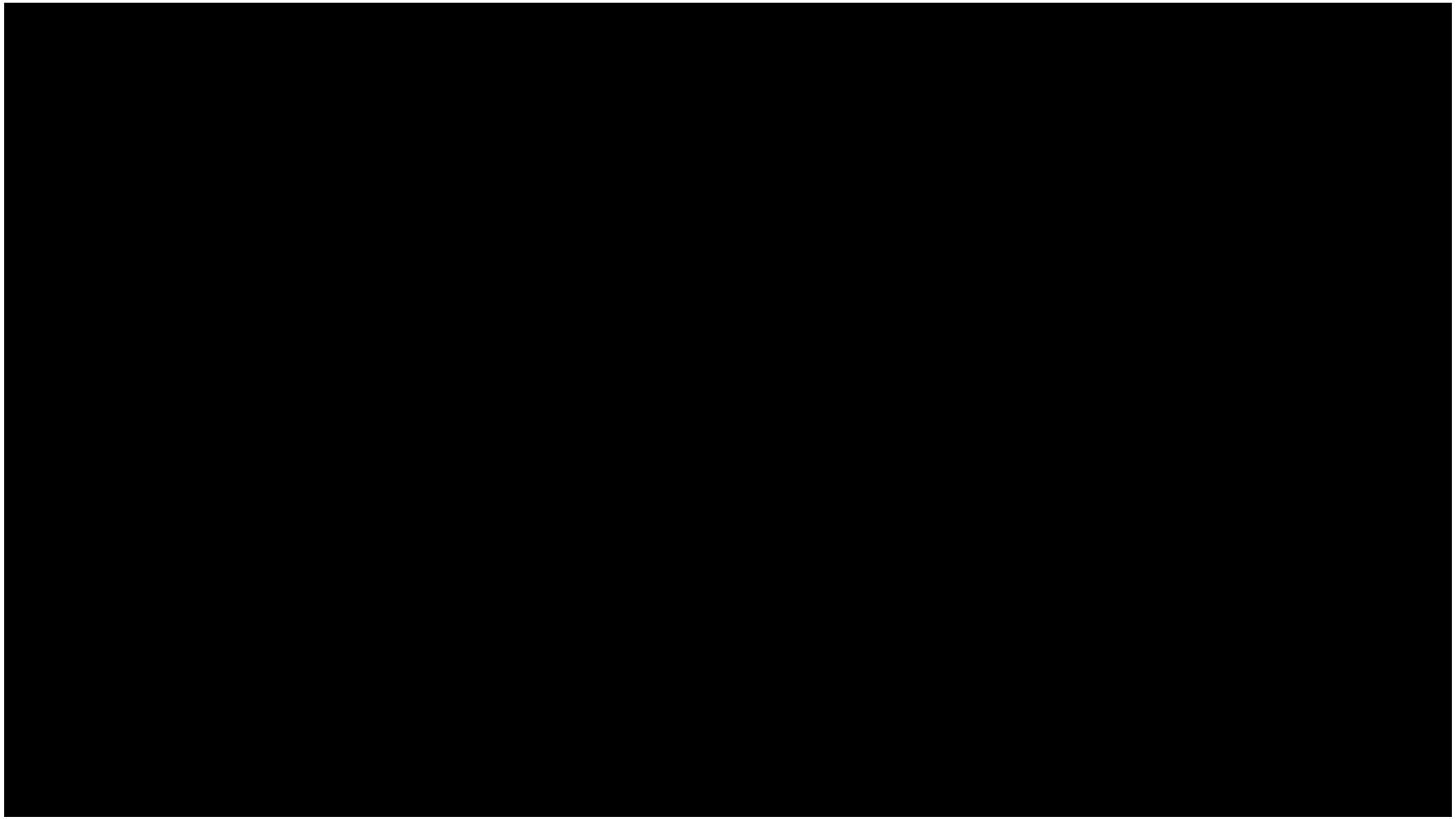
Artificial Intelligence (AI)

Applications

Augmented-/Virtual-Reality (AR/VR)

Distributed Cloud

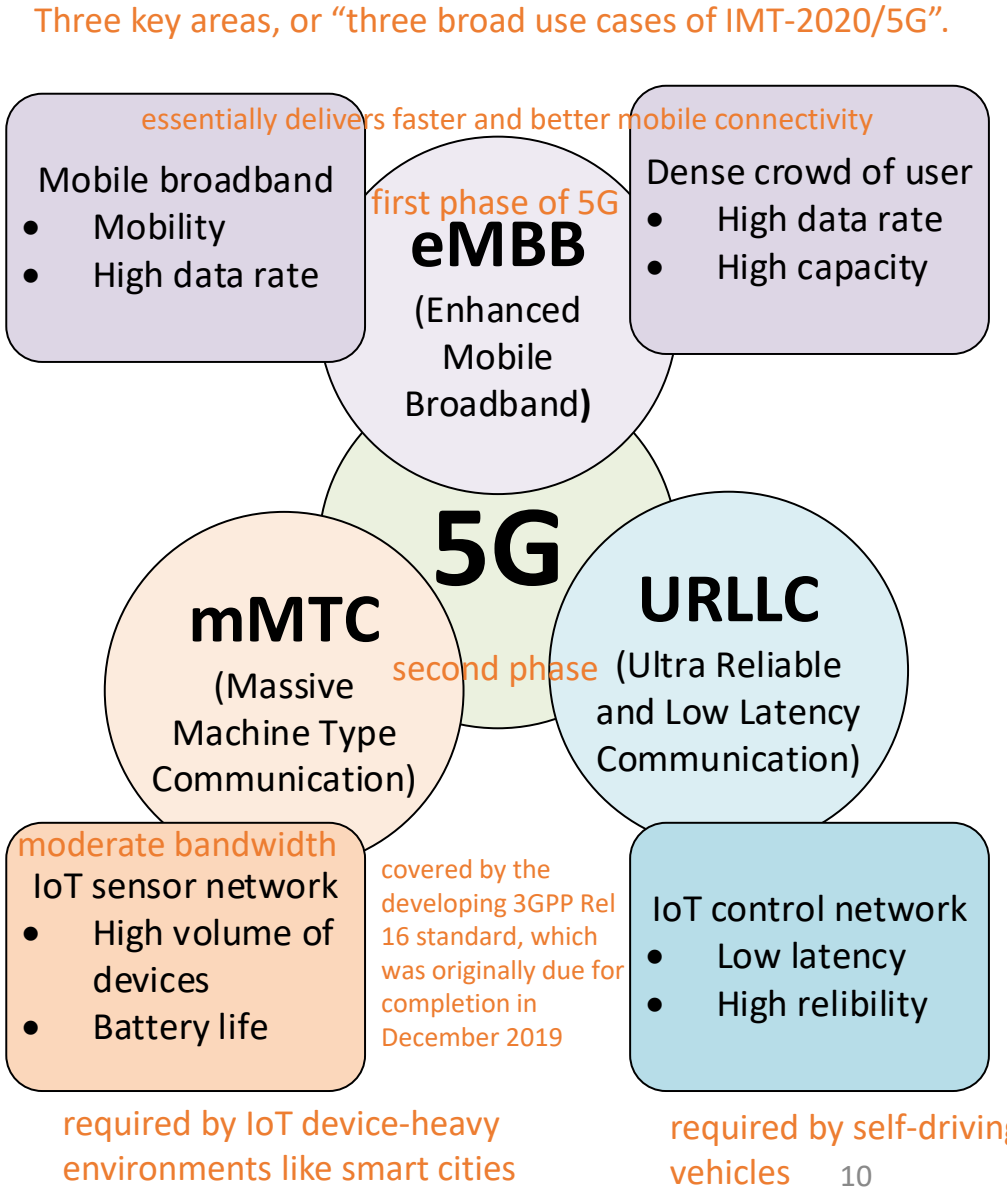
Benefits of 5G for Rural America: https://www.youtube.com/watch?v=g8C4puvlomk



What is 5G wireless technology?

5G Key Areas

- Fifth Generation of mobile networking determined by part of ***3***rd ***G***eneration ***P***artnership ***P***roject (**3GPP**) Release 15 onwards.
- That needs to meet the requirements of the ***I***nternational ***M***obile ***T***elecommunications-2020 (**IMT-2020**; "5G") under ***I***nternational ***T***elecommunication ***U***nion ***R***adio communication Sector (**ITU-R**).
- Addresses three key areas and put into four different usage scenarios:
  - enhanced mobile broadband (**eMBB**),
  - massive machine type communication (**mMTC**) and
  - ultra-reliable and low latency communication (**URLLC**)

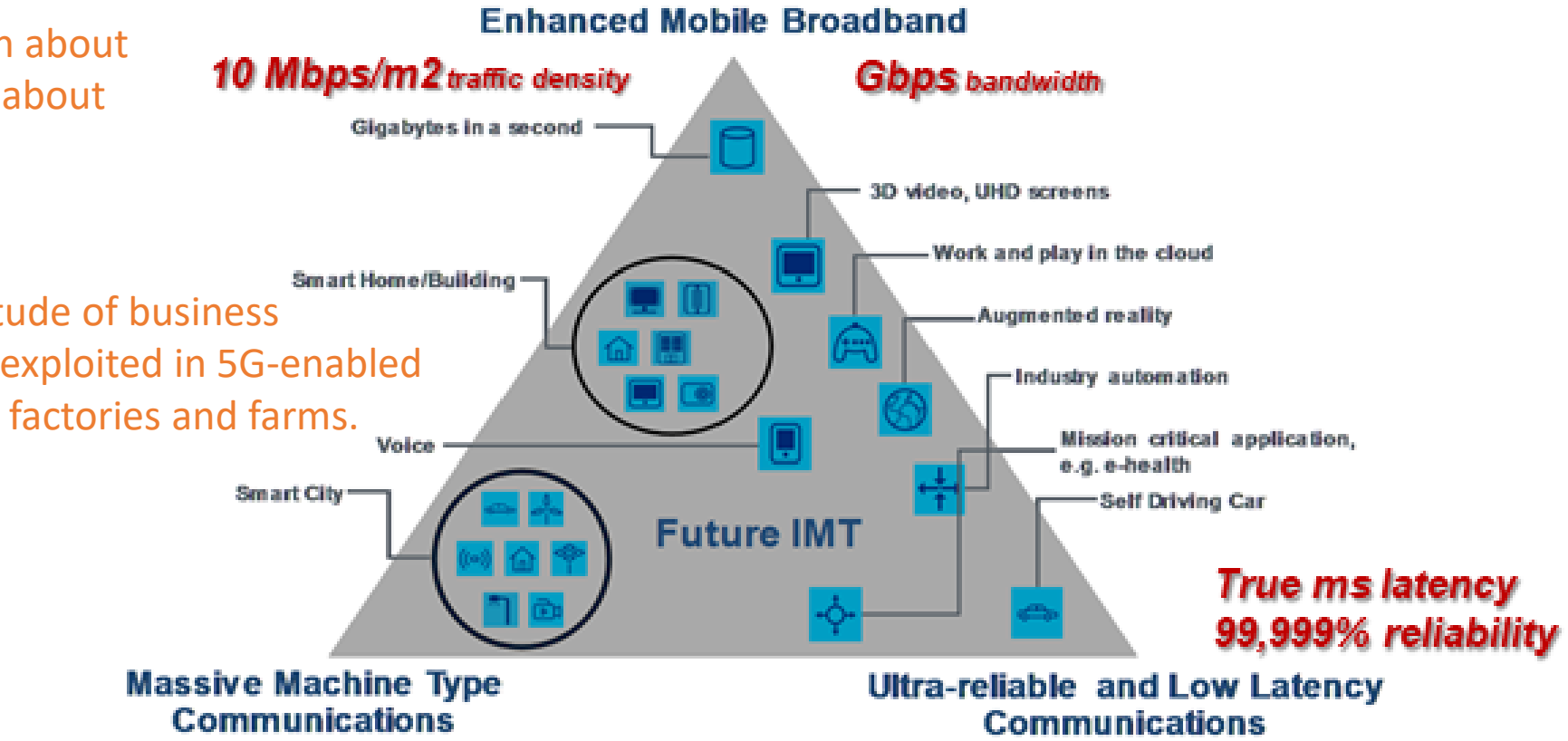


Usage scenarios of IMT-2020 and beyond

How 5G can fulfil multiple use cases in both consumer and enterprise space

5G will be as much about businesses as it is about consumers.

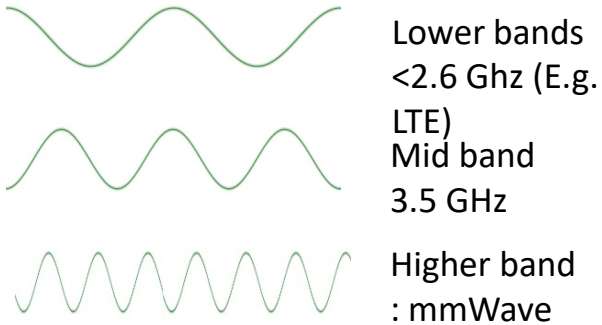
There's also a multitude of business opportunities to be exploited in 5G-enabled smart offices, cities, factories and farms.



Source: 3GPP, “The three broad use cases of IMT 2020 or 5G”, 2018

5G Technology Summary

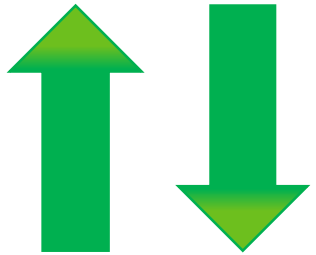
- It is 5th generation of the cellular network technology.

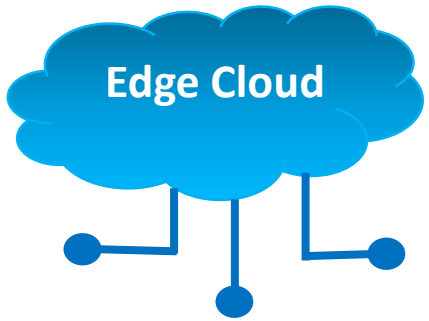


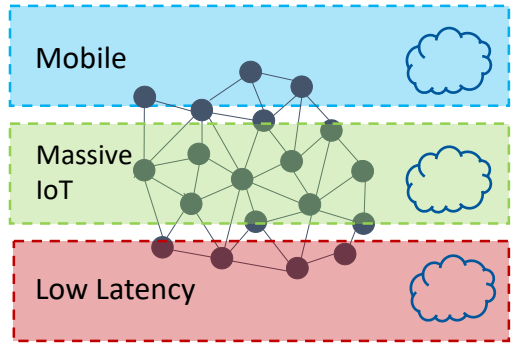
Lower bands <2.6 Ghz (E.g. LTE)

Mid band 3.5 GHz

Higher band : mmWave 26 / 28 Ghz







- Lower-bands to support wider coverage
- Mid-bands offer a balance of benefits between coverage and capacity
- Higher-bands is less crowded and provides the ultra-high bandwidth

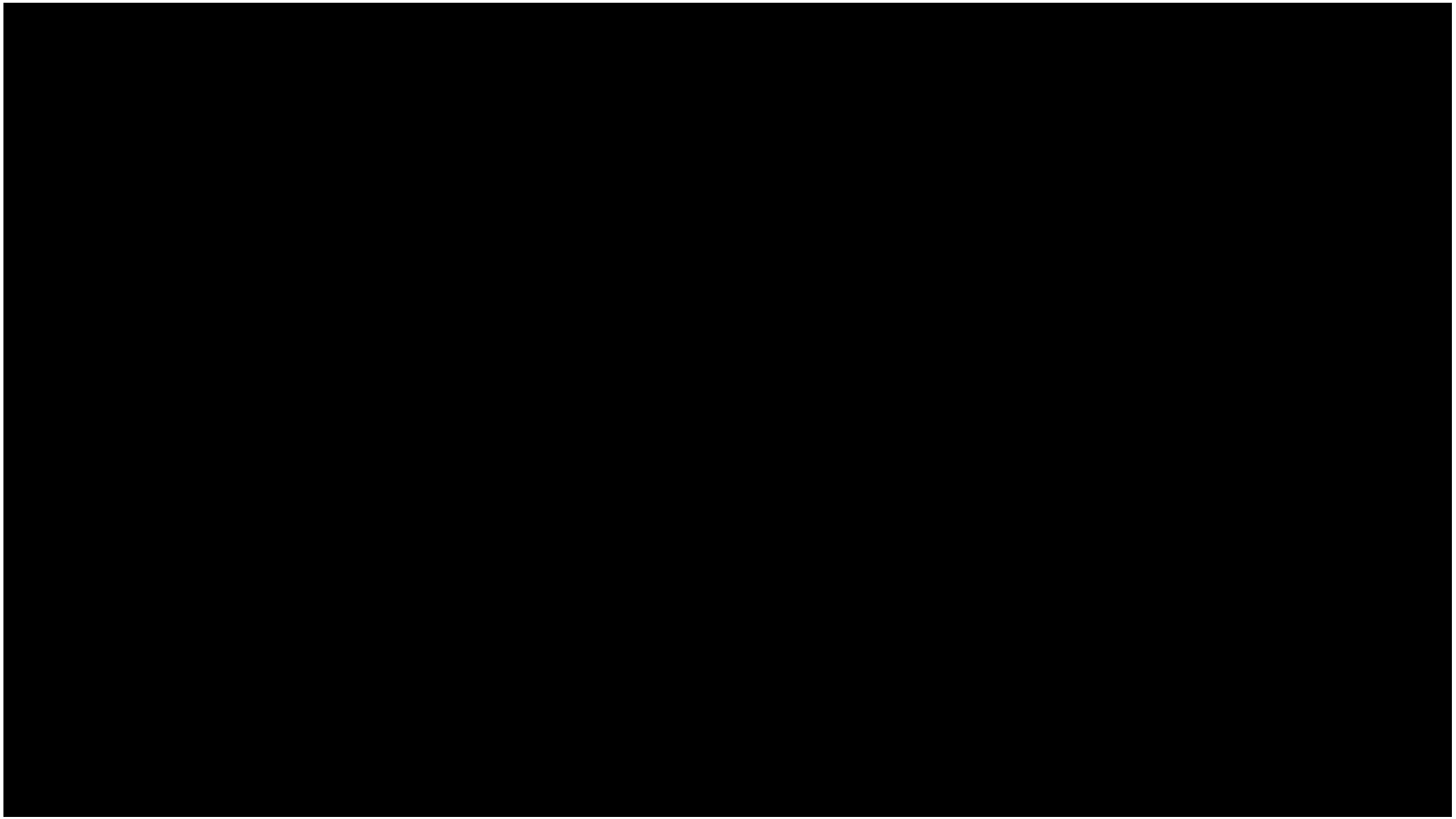
- Higher speed
- Lower latency
- Higher capacity and increased in data bandwidth
- All as when compared to earlier generations

- Multi-access Edge Computing that brings high computational services from centralised cloud closer to end users (the edge)

- Easing the need of having high performance device at end user for computational intensive use cases such as AR/VR

- Network slicing to enable various differentiated services across different industries with assured Quality of Service

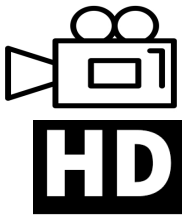
How 5G could change your life. | Ray Bonini | TEDxColumbus: https://youtu.be/tSRRMH8SLzU



What benefits does 5G technology bring?

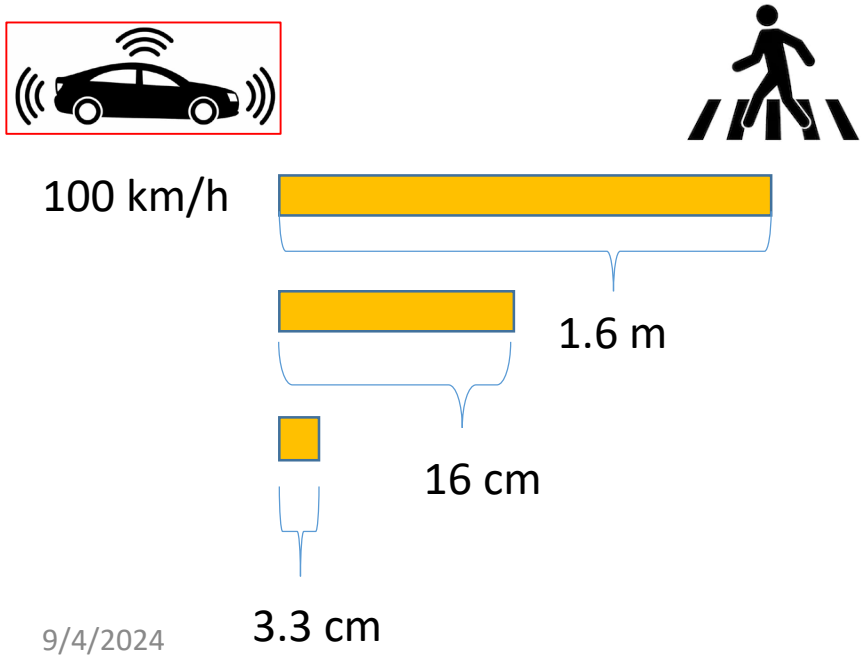
- The benefit of 5G is ***speed***.
  - 100 times faster than standard 4G
  - and 30 times faster than advanced 4G standards like LTE-A.
- Often referred to as “the network of networks”.

Network type	Max download speeds	Time to download a full HD movie
3G	384Kbps	Over a day
4G	100Mbps	Over 7 minutes
4G+	300Mbps	2.5 minutes
5G	1-10Gbps (theoretical)	4-40 seconds



What benefits does 5G technology bring?

- The another benefit of 5G is low latency.
- 50 times faster than standard 4G, and 5 times faster than advanced 4G standards like LTE-Adv, LTE-Adv-Pro.

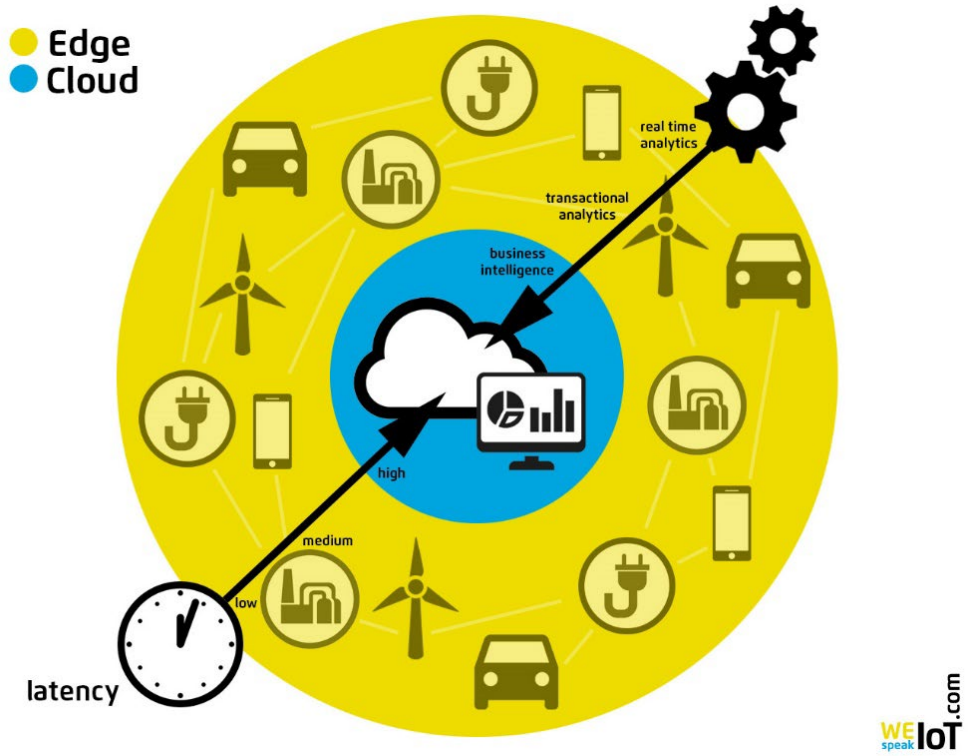


Network type	Latency	Distance travelled even after turnning on the brakes
4G	50 ms	1.6 m
4G+	5 – 10 ms	16 cm
5G	1 ms	3.3 cm

Edge Computing

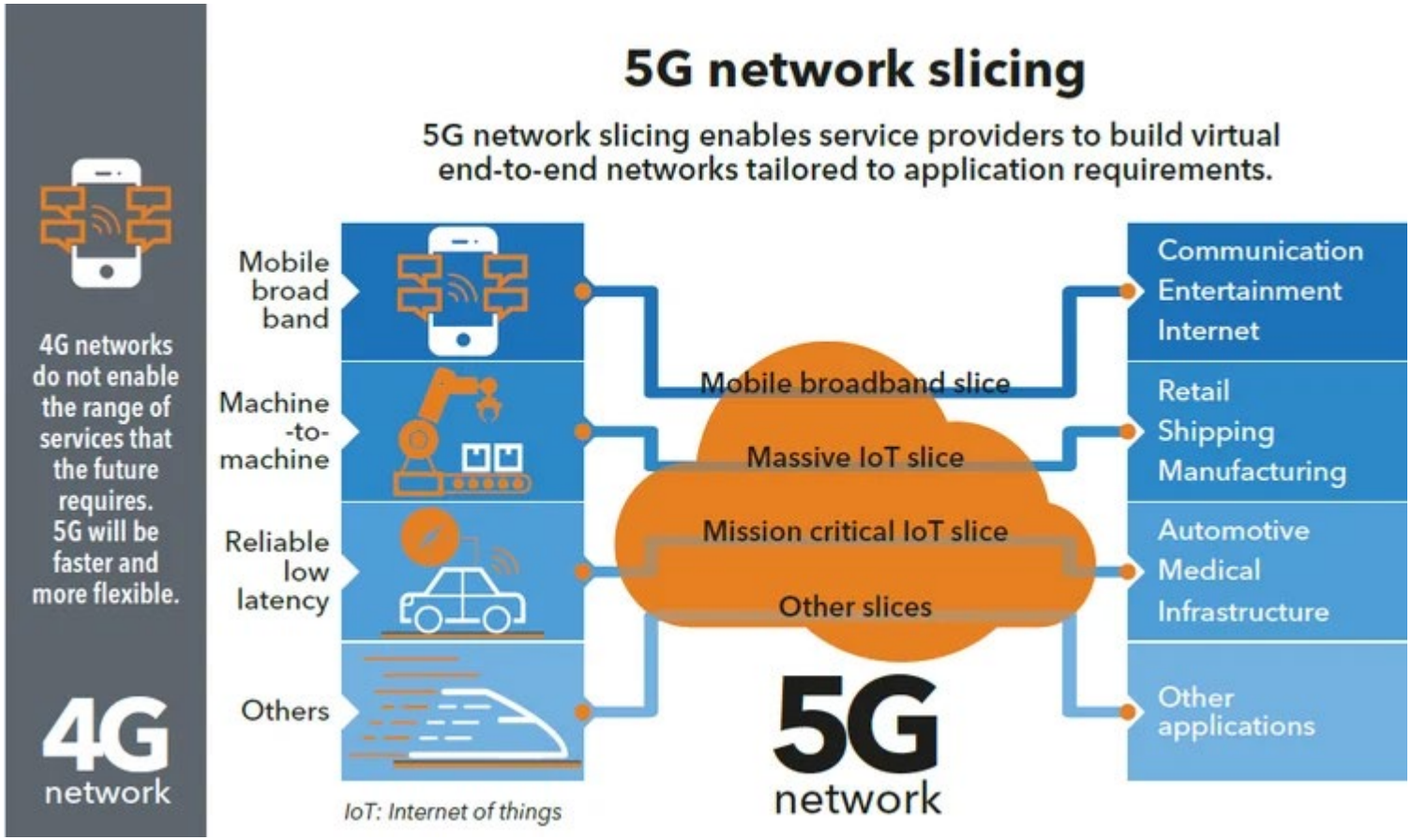
- The word, "**Edge**", refers to the part of the infrastructure that is near to the sources of data. -> at the Device/sensor layer
- Edge Computing simply means performing actions on data such as data analysis, decision making at the Edge. -> e.g. Edge devices/gateway
- Advantages
  - Reduce communication bandwidth between sensors and servers
  - Faster assess of data since the data is stored "near" to the source
  - Fast data analysis, computing and actions. e.g. autonomous vehicles; critical decisions cannot be done at the cloud (i.e. cloud computing)
- Disadvantages
  - Creates duplication of system functionality
  - Replicates fragments of information across distributed networks => increase redundancy

- For time critical and responsive application such autonomous car and industrial automation controllers that needs fast analysis, quick decision making and short data access storage time.



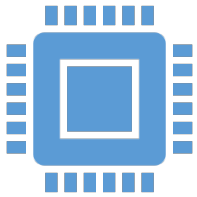
Source : www.wespeakiot.com

Network Slicing



- 5G network slicing is the use of network virtualisation to divide single network connections into multiple distinct virtual connections that provide different amounts of resources to different types of traffic. – SDxCentral article
  - a type of virtual networking architecture
- Providers have to move into a system that's more flexible and adaptable – make the network more software-centric (i.e. away from rigid, hardware-defined systems)
  - to create a single, highly flexible virtualised, software-defined network instead of building multiple purpose-built networks

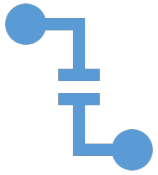
Limitations of 4G Networks



Limited Capacity

Can become congested when many users try to connect at once

Slower data rates can be experienced when they are many users



Limited Connection density

The total number of devices fulfilling a specific quality of service per unit area is limited

Connection to network can be lost or very slow in a crowded area (e.g stadium)

Latency

Not reliable when rapid responses are required such as gaming.

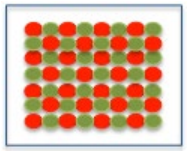
5G Difference in Capabilities from 4G

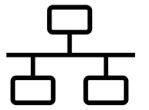
Telecom Operator → Multiple Stakeholders
Phones → Things
Procedures → Services
Static Topology → On-demand Resources
Dedicated Hardware → Orchestrated Resources
Dedicated Network → Network Function Virtualization

Comparing 4G and 5G

	Data Rates	Latency	Connection Density	Mobility	Network
4G	100 Mbps – 1 Gbps	Few 10 ms	10 K Connections per Km^2	350 Km/h	Single Network
	10 – 100 x	30 – 50 x	100 x	1.5 x	
5G	10 Gbps per connection	< 1 ms	1 million connections per Km^2	500 Km/h High speed railway	Network Slice







Features of 5G

Key features of 5G are given below:

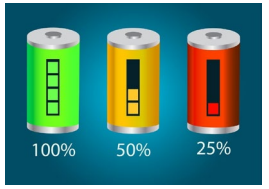
For Users:

- Has low battery consumption and better battery Life for devices
- Around 1 Gbps data rate is easily possible
- Very Low Network Latency

Network latency, sometimes called lag, is the term used to describe delays in communication over a network.

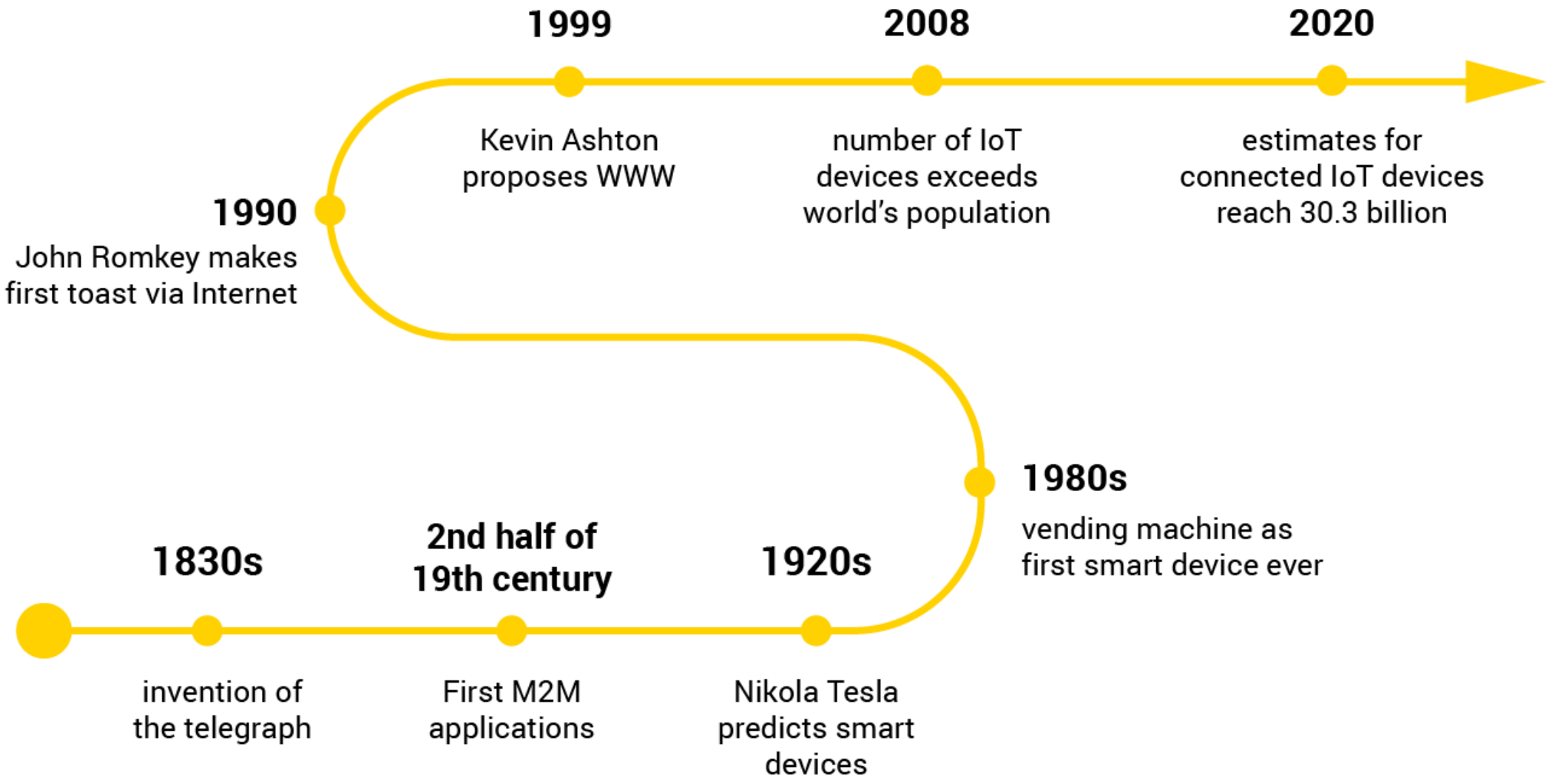
For System:

- More than 100 times more device handling capacity
- 5G has better coverage area and high data rate at the edge of the cell
- Availability of multiple data transfer rates
- 100 times higher data speed over the air
- Multiple Services can run in parallel
- Custom made Network Slices
- Better energy efficiency and spectral efficiency
- Massive MIMO – 10x more antennas than 4G demonstrated



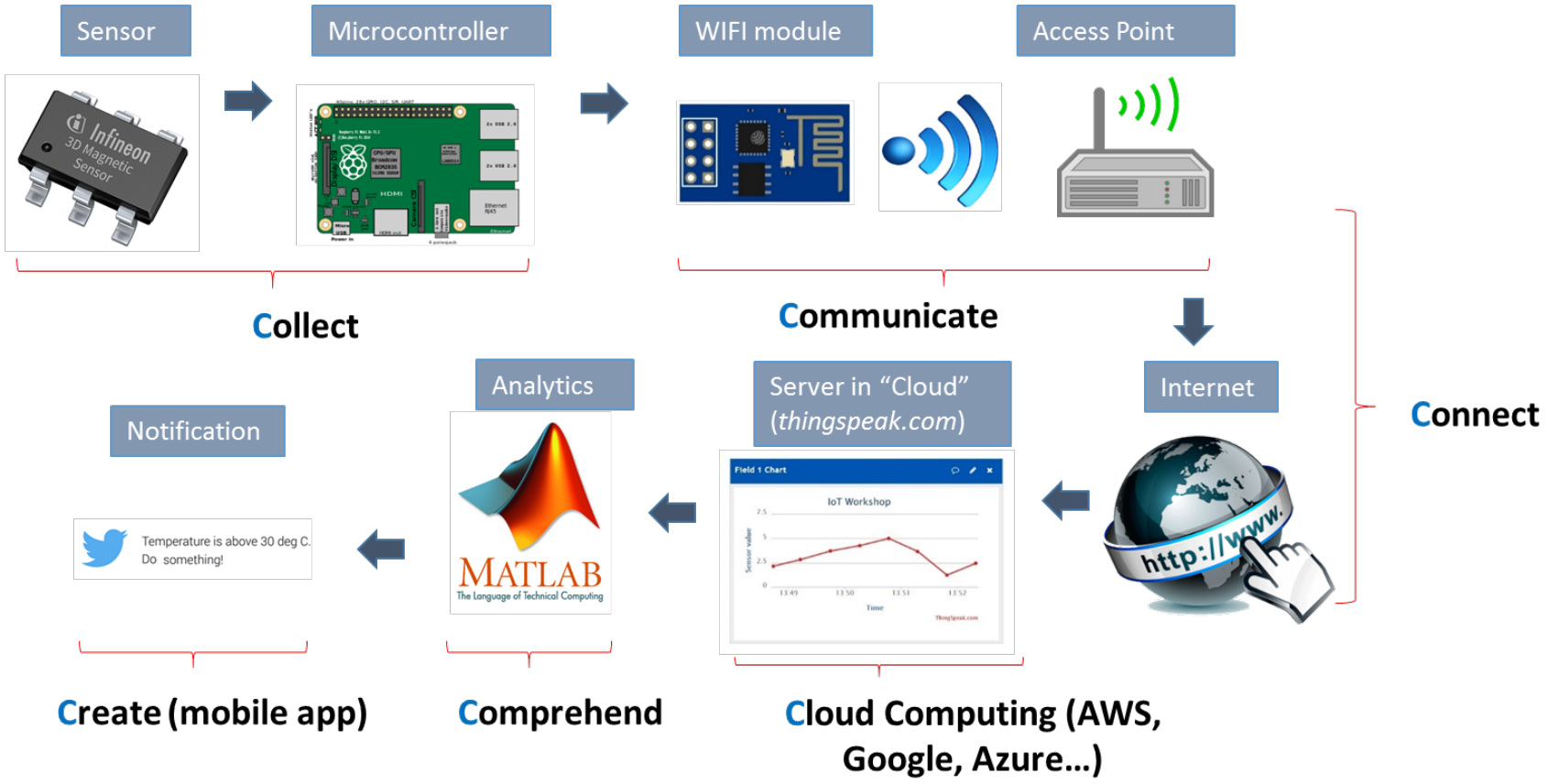
Ultimately, it's about being enabled to provide a service-oriented, cloud-based and software-configurable technology.

What is IoT? – An interesting story



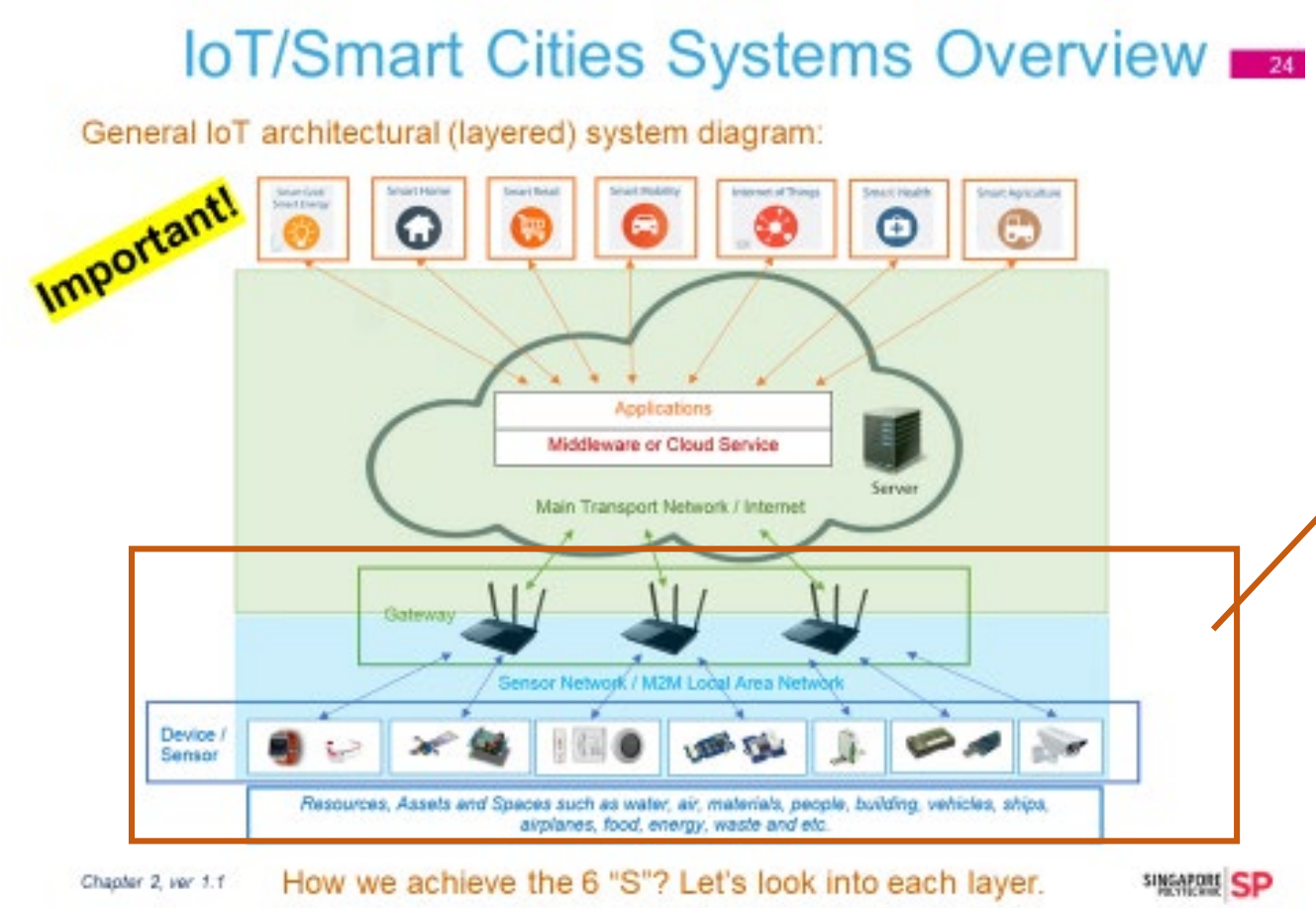
What is IoT?

- The internet of things (IoT) is the network of physical devices, vehicles, buildings and other items - embedded with electronics, software, sensors, actuators, and network connectivity that enable these objects to collect and exchange data



Enabling Massive IoT

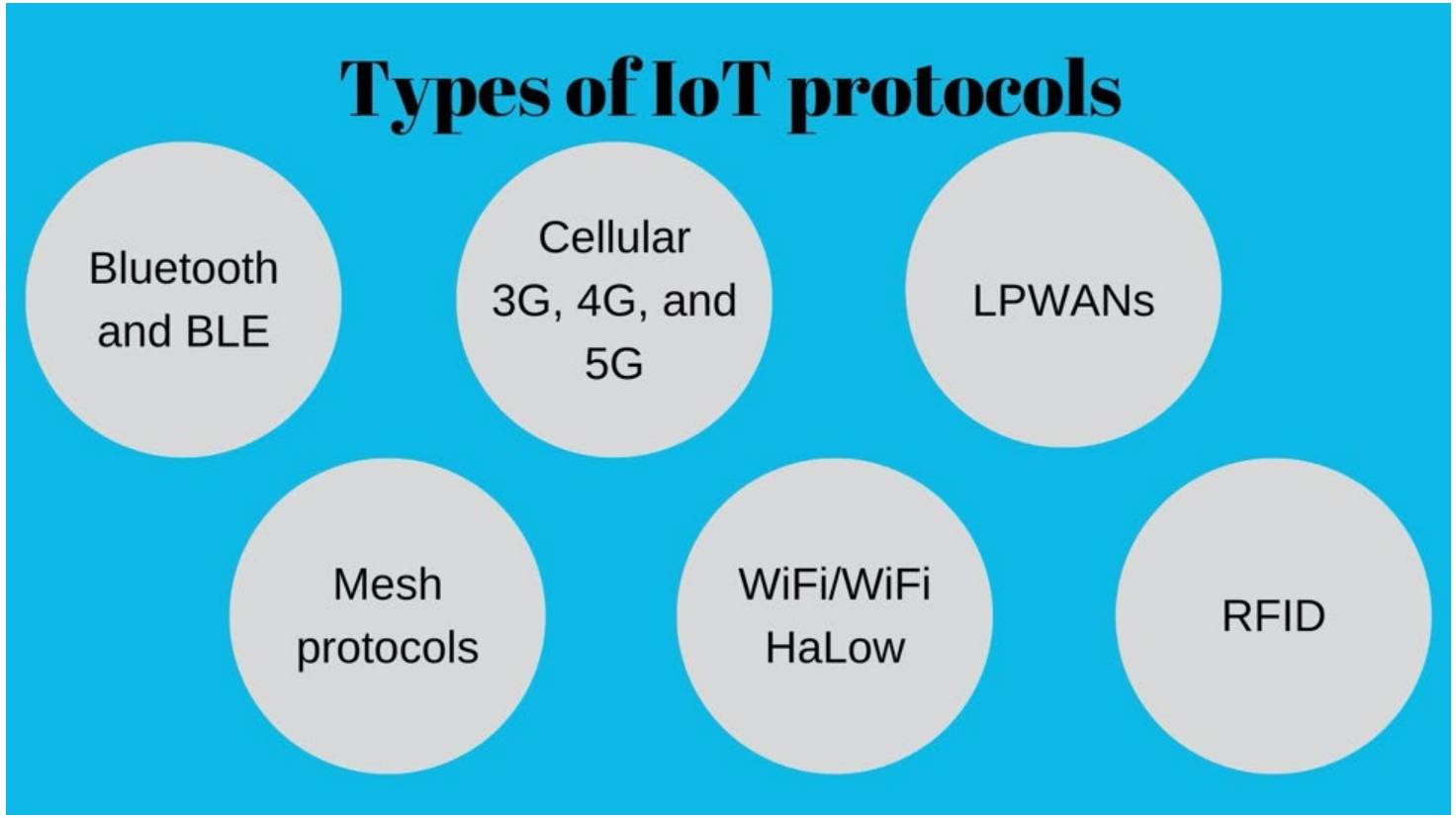
- **Cellular standards** like 5G provide a network backbone for IoT services, supporting both high data rates and long-range communications.



Sensor Network or M2M Local Area Network – This specify the wired such as USB, Ethernet, Serial, or wireless technology such as WiFi, LoRa, Bluetooth, DSRC, used to connect between various devices or sensors to its respective localise Gateway for local centralise control before communicating out to the Main Transport Network or internet.

Enabling Massive IoT

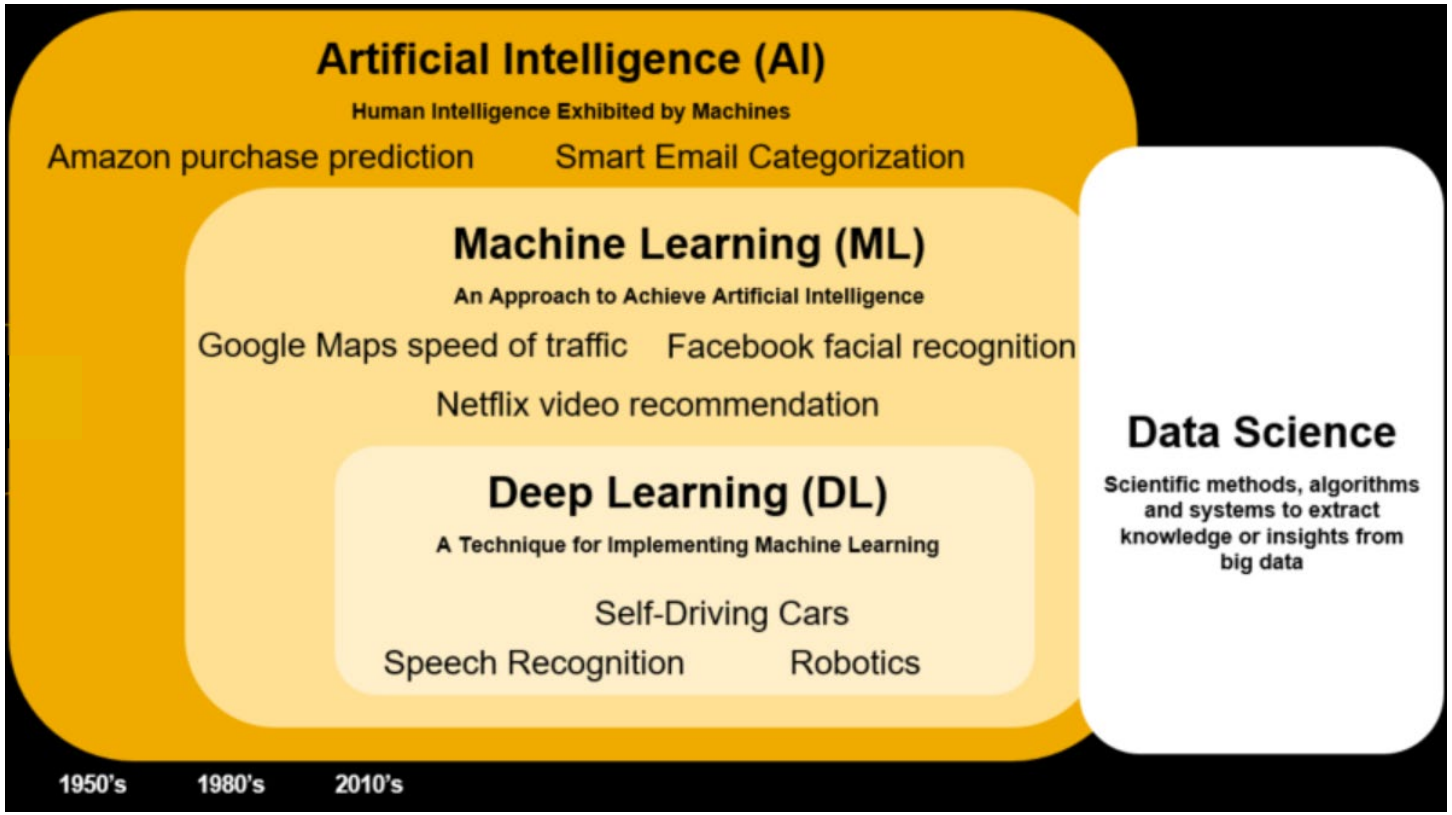
- Evolving IoT networks are being designed to accommodate these devices through several new technologies shown in



Source: https://www.allerin.com/blog/six-types-of-iot-network-protocols

What are AI and Machine Learning?

- Artificial Intelligence
  - The science and engineering of making intelligent machines, especially intelligent computer programs
- Machine Learning
  - An application of AI that provides systems the ability to automatically learn and improve from experience without being explicitly programmed.



What is AIoT?

- Today AI has evolved from algorithm approach into self-learning and big data management; processing, connectivity, sensing and actuating along with security are the key enablers of AI.
- The Internet of Things (IoT) is a popular technology trend, which in recent years has been joined with another popular trend, Artificial Intelligence (AI) to form a brand new keyword “AIoT”.
- Artificial Intelligence of Things (AIoT) is the Internet of Things, with embedded Artificial Intelligence. Without AI, the data pool created by IoT devices would fail to reach its full potential and, without the IoT, AI systems won’t have required data sets.
- The IoT benefits from AI’s advanced data analytics capabilities, while AI applications receive real time information from extensive networks. By merging capabilities of AI & IoT helps to bring our best of the two, it helps to turn IoT connected devices from passive sensors into data learning machines.
- E.g. Self-driving cars and AI will help to augment our transportation. In future, there will be many applications of AI on end devices; which are also known as Edge devices.

Source: element14 e-book, “The era of AIoT: Context, Capabilities and Future of AIoT”, 2020.

Several elements make up an autonomous driving system.

Singapore Polytechnic

Elements of autonomous driving system

Actuation
Steering, braking, and acceleration

Cloud
Learning and updating high-definition maps, including traffic data, as well as algorithms for object detection, classification, and decision making

Perception and object analysis
Object and obstacle detection, classification, and tracking

Drive control
Converting algorithm outputs into drive signal for actuators

Decision making
Planning vehicle path, trajectory, and maneuvers

Localization and mapping
Data fusion for environment mapping and vehicle localization

Analytics
Platform for monitoring autonomous system's operation, detecting faults, and generating recommendations

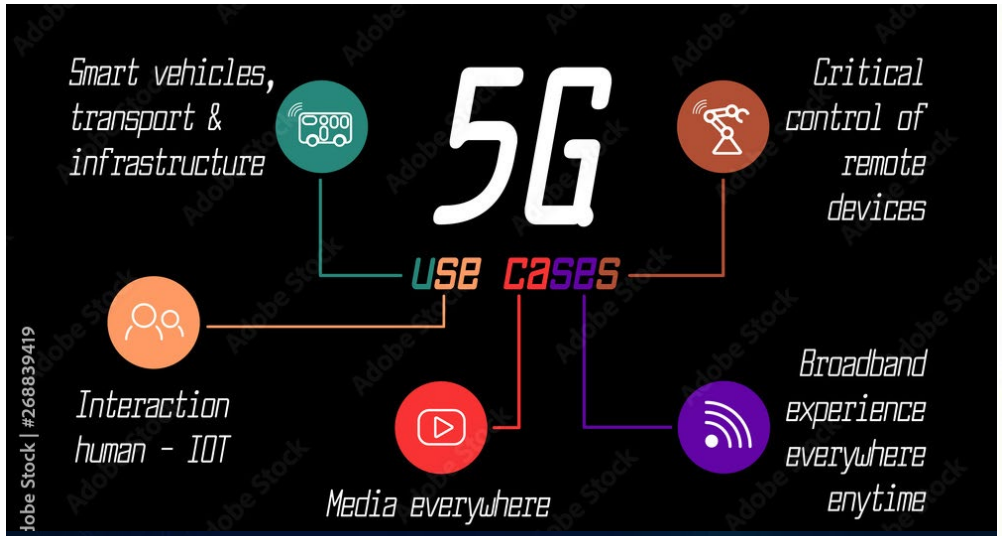
Middleware or operating system
Middleware and real-time operating system to run algorithms

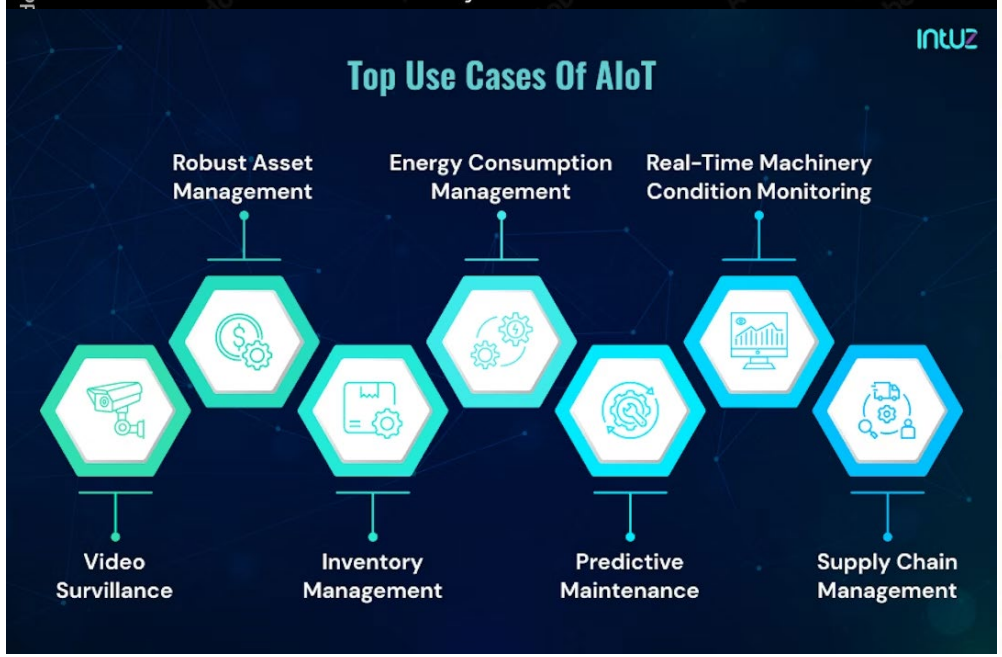
Computer hardware
High-performance, low-power-consumption system on a chip (SOC) with high reliability

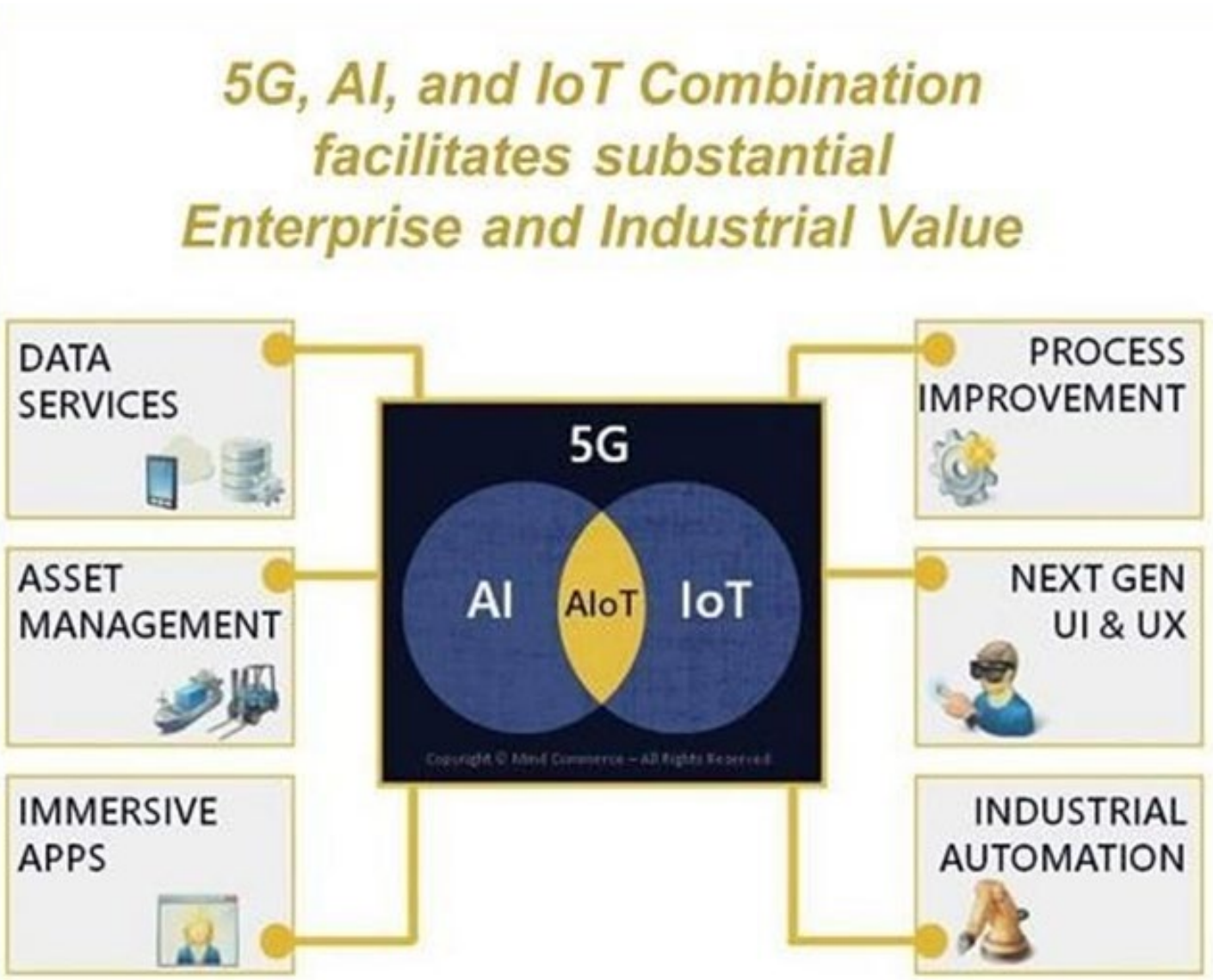
Sensors
Multiple sensors, including lidar, sonar, radar, and cameras

Source: Wikipedia

1.1 The Importance of 5G and AIoT in current and Future Applications







Any

Question