I226
Computer Networks

Chapter 13
Latest Topics

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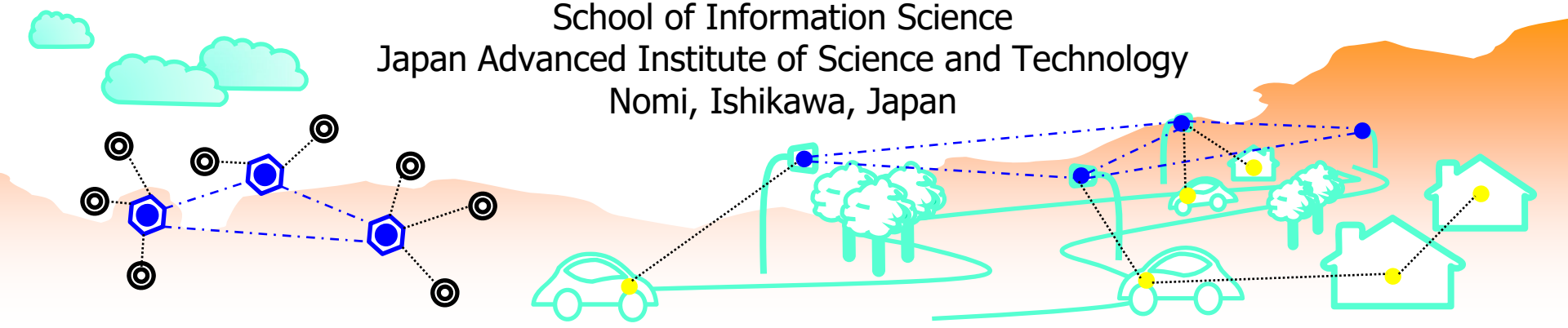


Objectives of this Chapter

- Give an understanding on what are the latest topics that involved in the computing and networking technologies
- Stimulate the future directions of computer networks

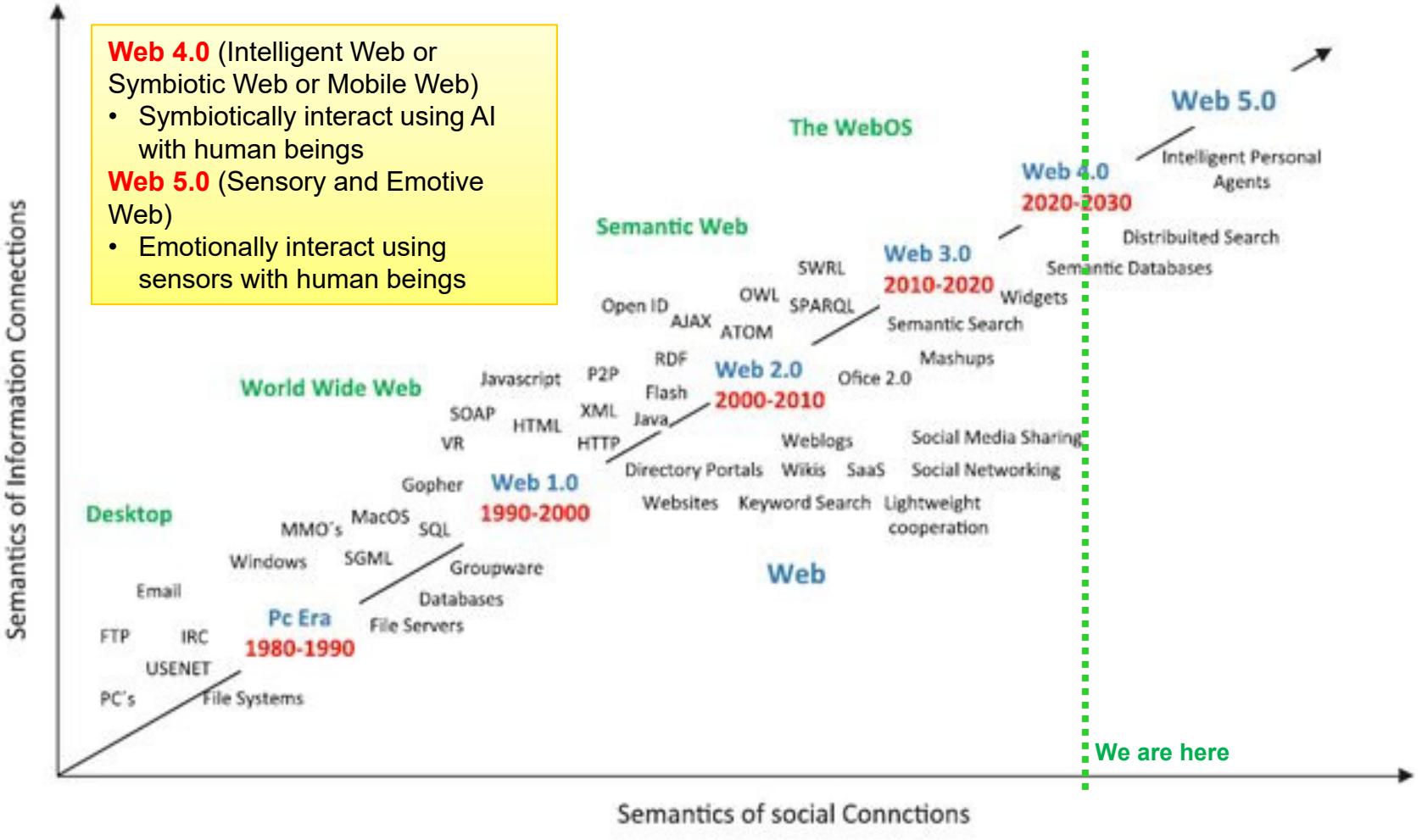
Outline

- The Internet of Things (IoT)
- 6G Wireless
- Society 5.0

The Intelligent is in the Connections

Web 4.0 (Intelligent Web or Symbiotic Web or Mobile Web)
- Symbiotically interact using AI with human beings

Web 5.0 (Sensory and Emotive Web)
- Emotionally interact using sensors with human beings



Source: V. Nedeva and S. Dineva, "Intelligent e-learning with new web technologies," The 10th International Conference on Virtual Learning (ICVL), 31 October 2015

Population and Connected Devices

	2019	2020	2021	2022
World Population	7.76 billions	7.84 billions	7.90 billions	8.00 billions
Connected Devices	20.0 billions	22.5 billions	24.5 billions	26.5 billions
Connected Devices Per Person	**2.58**	**2.87**	**3.10**	**3.31**

More connected devices than people

Source from Cisco IBSG, November 2022

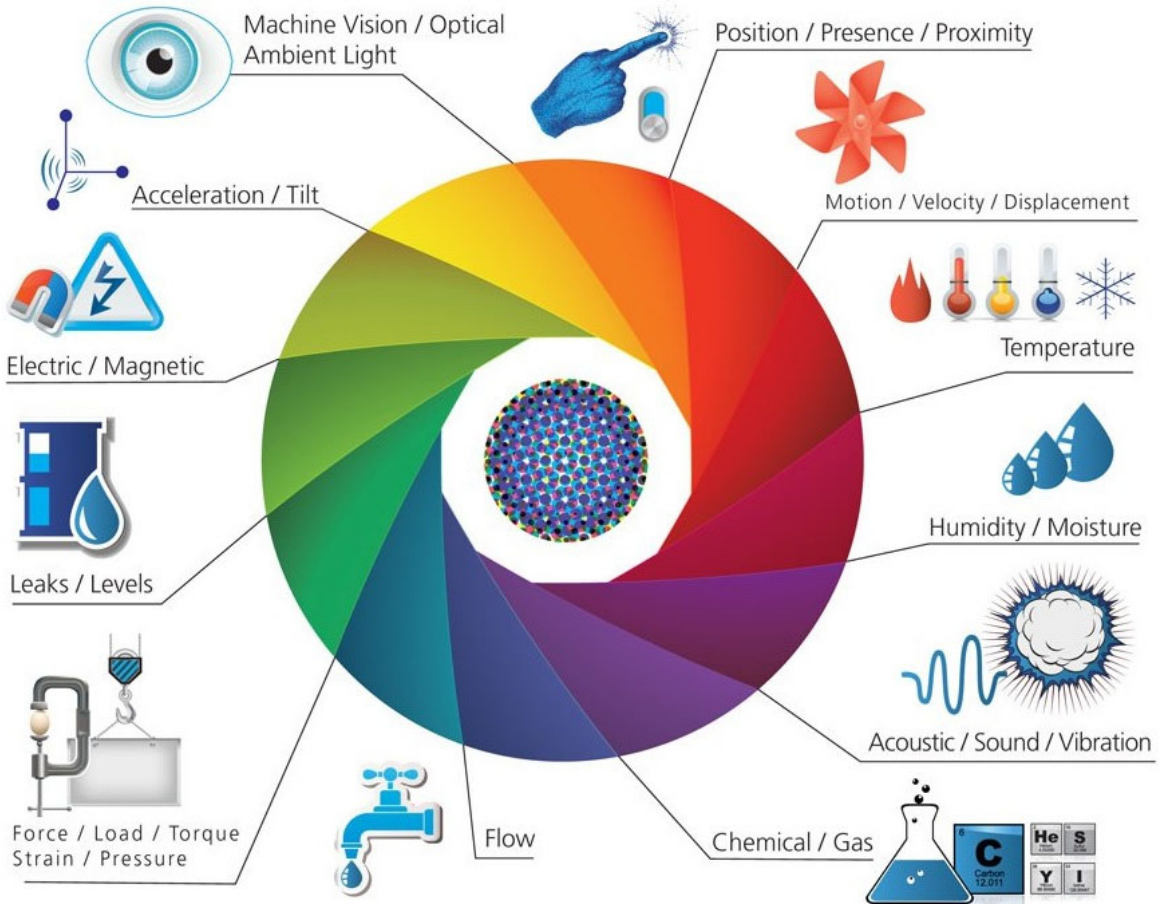
Note: Connected Devices = M2M, Smartphones, Non-smartphones, TVs, PCs, Tablets, others

The Internet of Things

- Internet connects all people, called "the Internet of People (IoP)"
- Internet connects all things, called "the Internet of Things (IoT)"
- Smart systems and IoT are driven by a combination of

① SENSORS & ACTUATORS

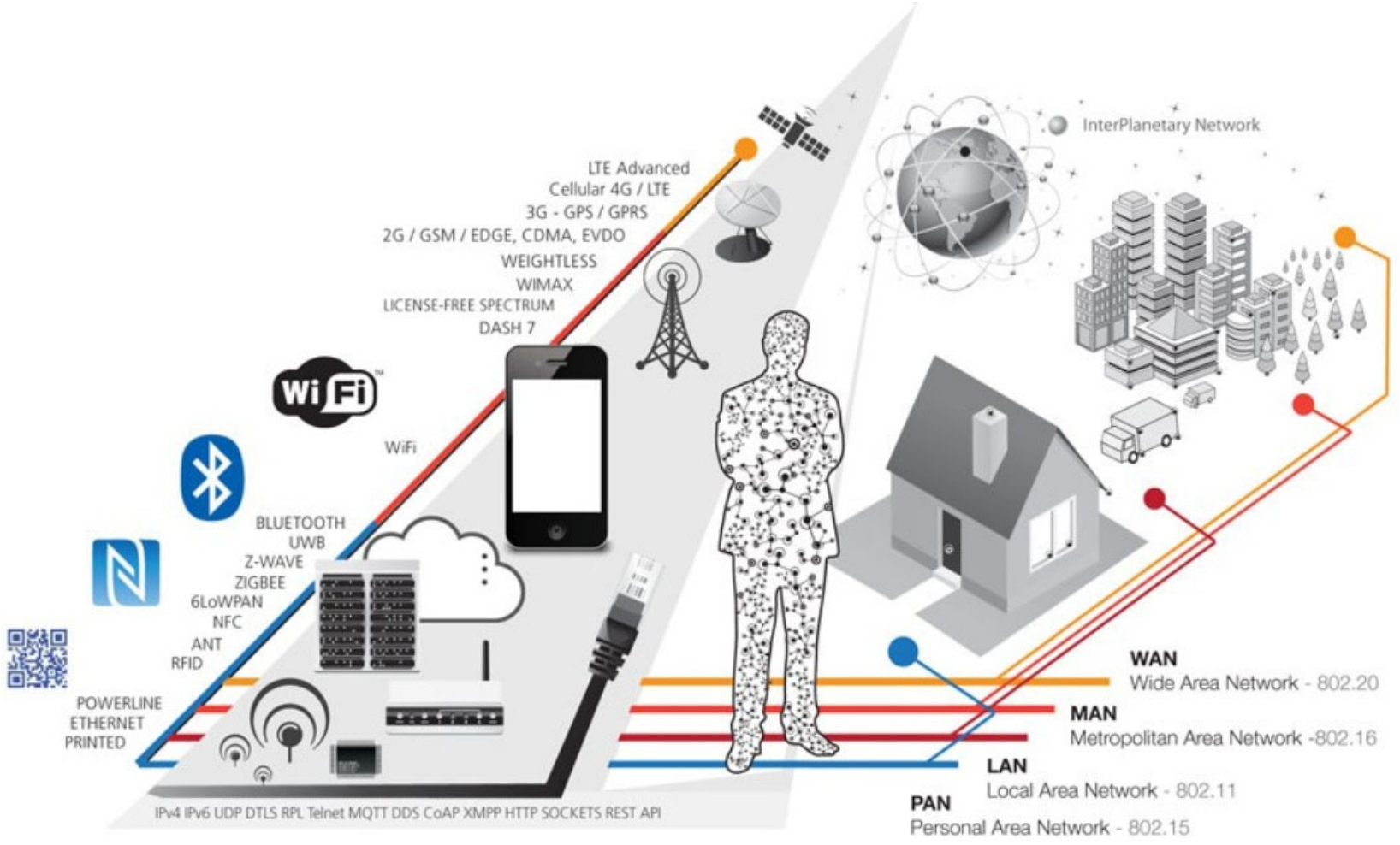
- We give our world a digital nervous system. Location data using GPS sensors. Eyes and ears using cameras and microphones, along with sensory organs that can measure everything from temperature to pressure changes



Source from http://postscapes.com/What-exactly-is-the-internet-of-things-infographic

② CONNECTIVITY

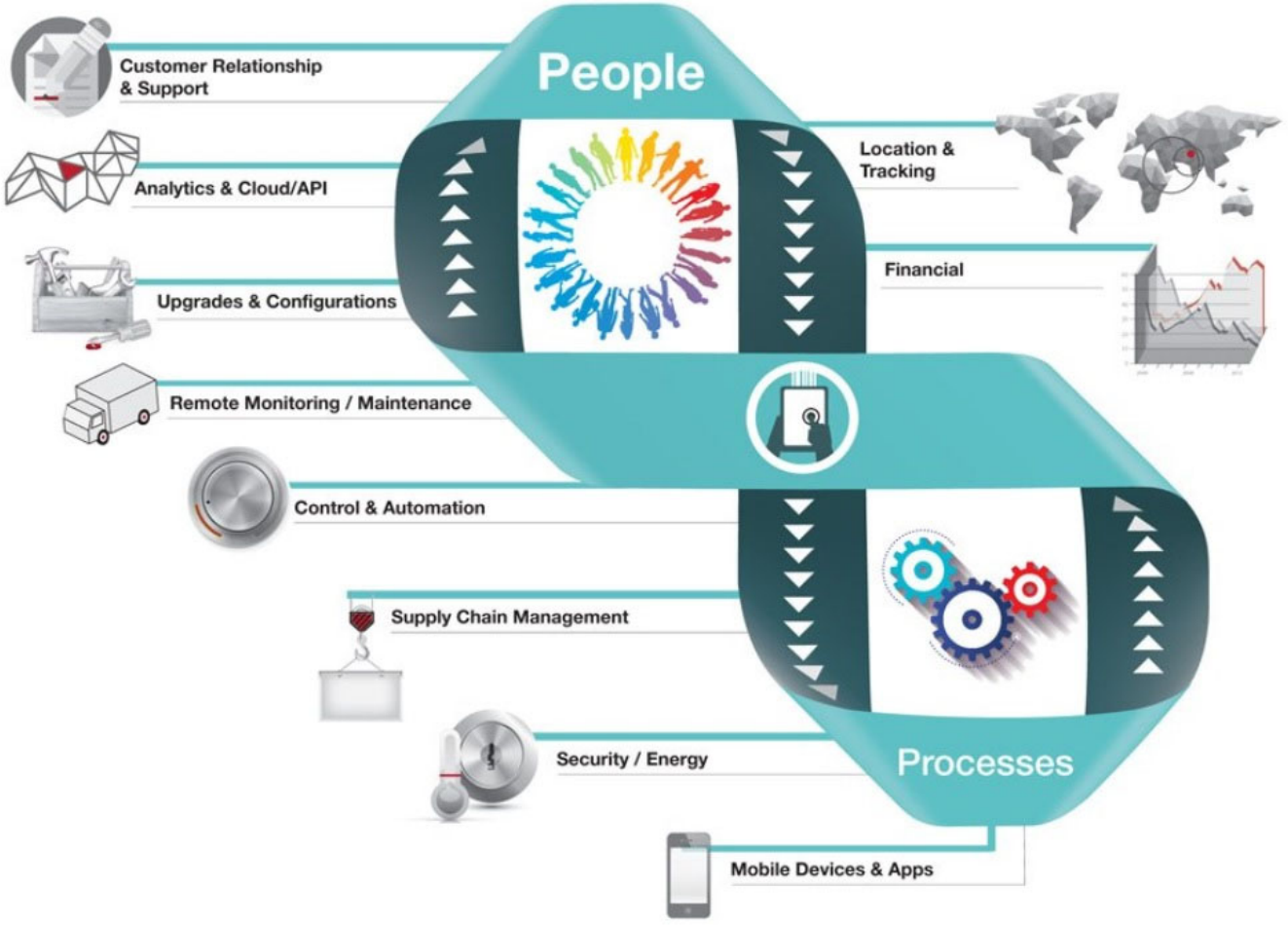
- These inputs are digitized and placed onto networks



Source from http://postscapes.com/What-exactly-is-the-internet-of-things-infographic

③ PEOPLE & PROCESSES

- These networked inputs can then be combined into bidirectional systems that integrate data, people, processes and systems for better decision making

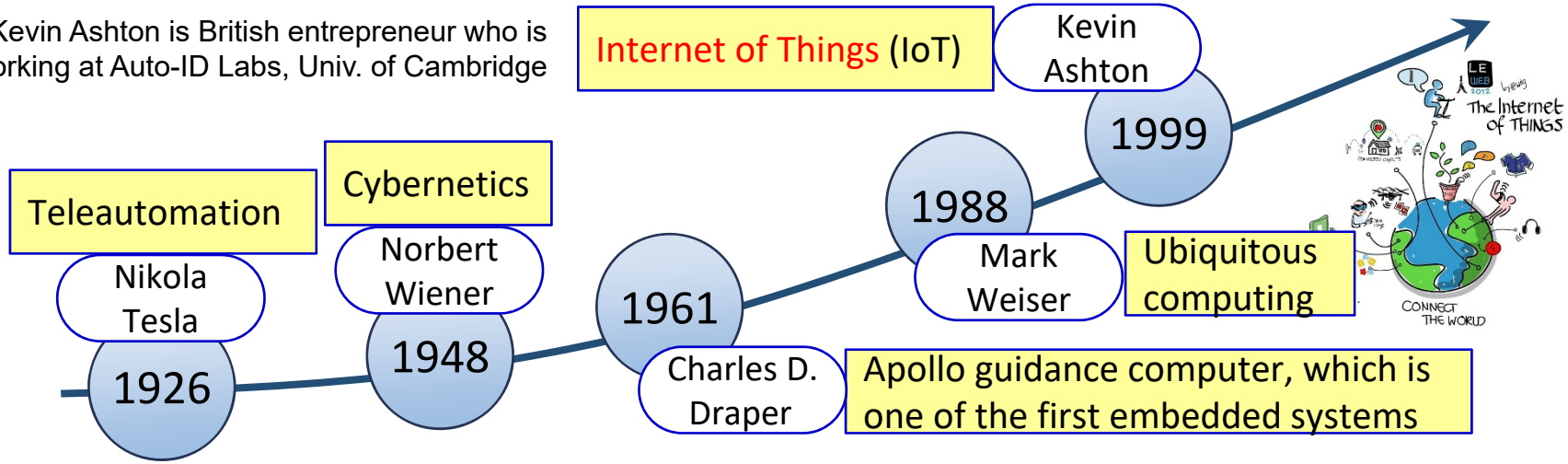


Source from http://postscapes.com/What-exactly-is-the-internet-of-things-infographic

History and its Predecessor

- History
  - 1997, IoT was the seventh in the series of ITU Internet Reports originally launched in 1997 under the title “Challenges to the Network”
  - 2005, IoT was proposed in the World Summit on the Information Society (WSIS) conference, Tunis
  - 2008, first international conference of IoT was held at Zurich

* Kevin Ashton is British entrepreneur who is working at Auto-ID Labs, Univ. of Cambridge



Abstracted from S. Jeschke, RWTH Aachen Univ., “CPS – History, presence and future,” 27 February 2013

Definition

Internet of Objects

Machine-to-Machine Era

Internet of Everything

- Chronology
  - 2005, IoT is a technological revolution that represents the future of computing and communications, and its development depends on dynamic technical innovation in a number of important fields, from wireless sensors to nanotechnology
  - 2008, IoT has come to describe a number of technologies and research disciplines that enable the Internet to reach out into the real world of physical objects
  - 2020, Things having identities and virtual personalities operating in smart spaces using intelligent interfaces to connect and communicate within social, environmental, and user contexts

IoT is the network of physical objects, devices, vehicles, buildings and other items which are embedded with electronics, software, sensors, and network connectivity, which enables these objects to collect and exchange data
(Wikipedia, 2016)

IoT refers to the concept that the Internet is no longer just a global network for people to communicate with one another using computers, but it is also a platform for devices to communicate electronically with the world around them
(Center for Data and Innovation, 2013)
https://www.datainnovation.org/2013/11/the-internet-of-things/

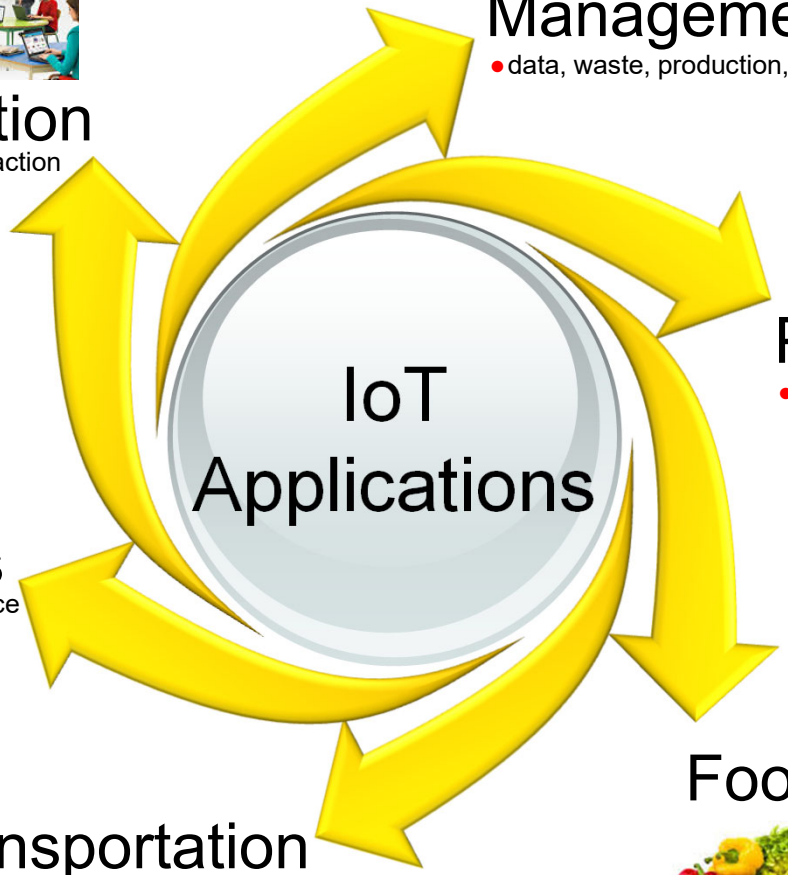
Applications of IoT

Education
- learning, interaction

Management
- data, waste, production, energy

Smart Home

Smart Industry



Pharmaceuticals
- the production and sale of drugs and medicine

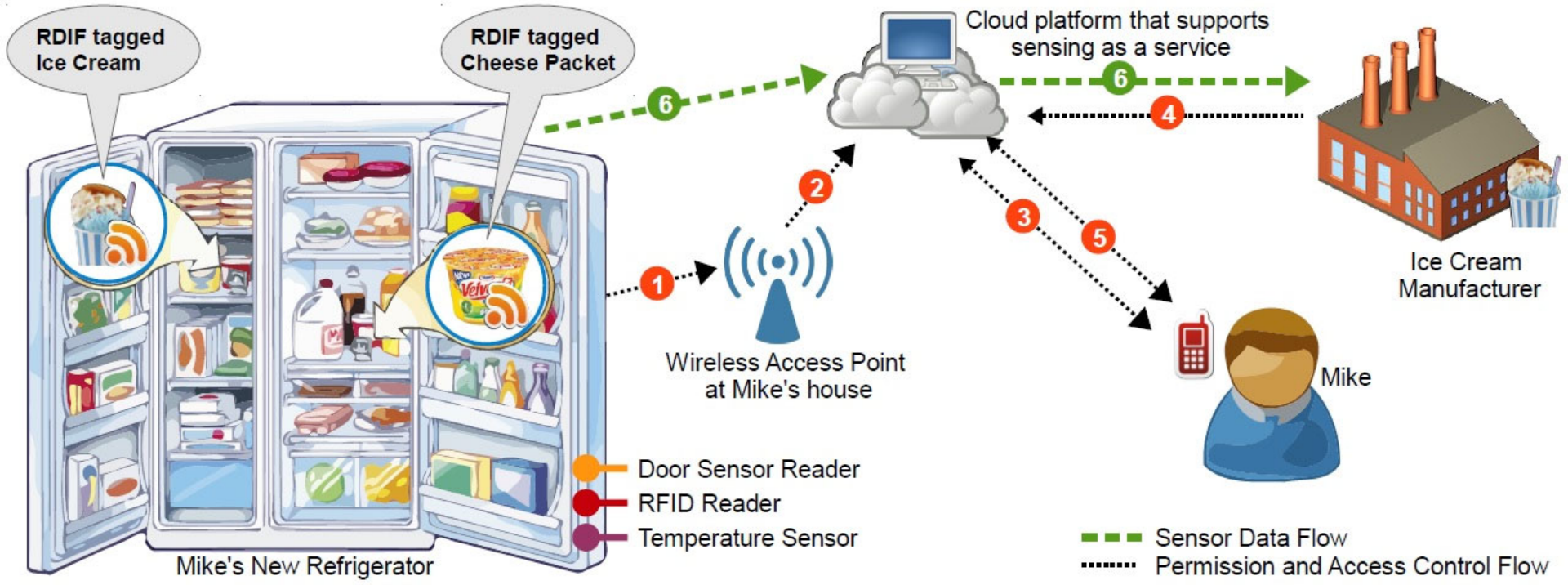
Business
- production chain, price

Smart Healthcare
- shortage, quality, health, safety

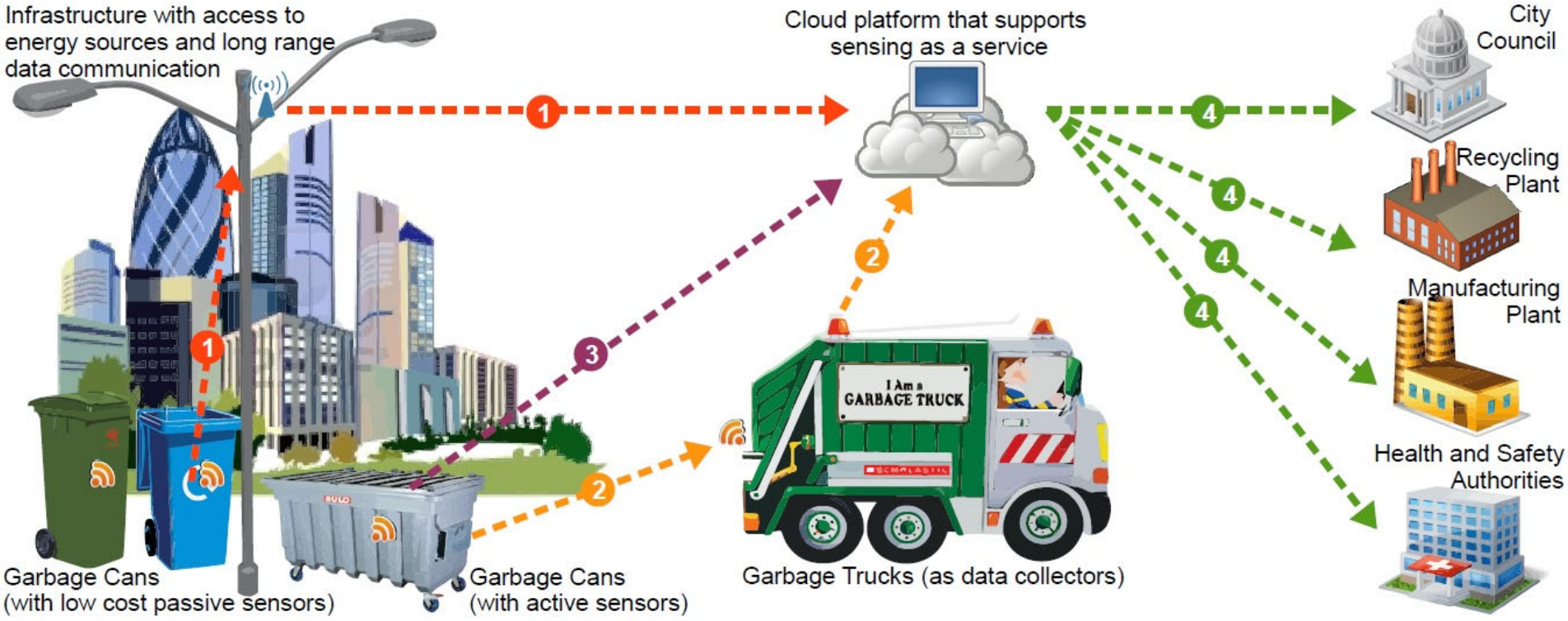
Transportation
- traffic, accident, risk, efficiency

Food

Smart Home Scenario

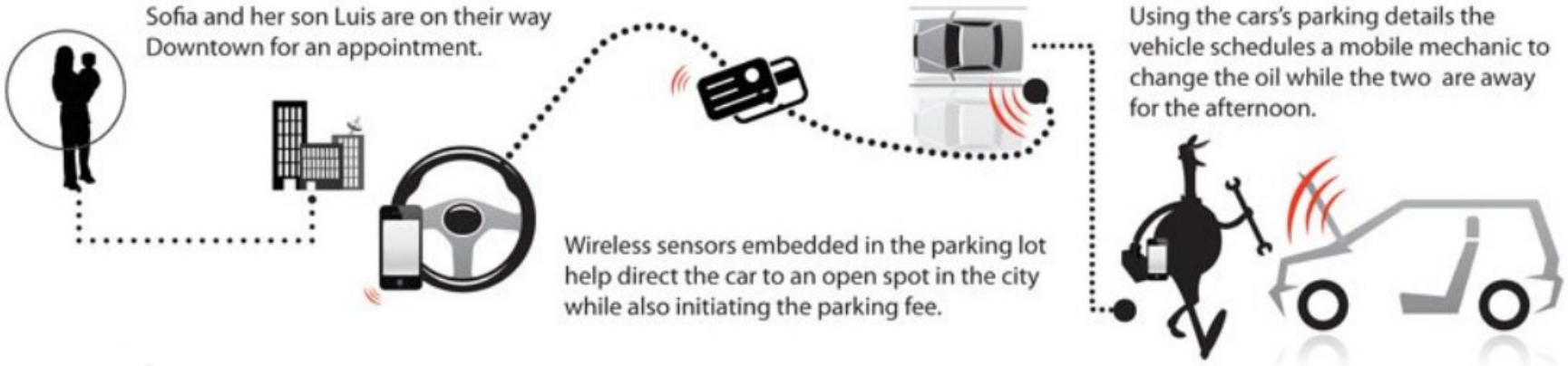


Smart Cities Scenario



Compound Applications of IoT

Transportation



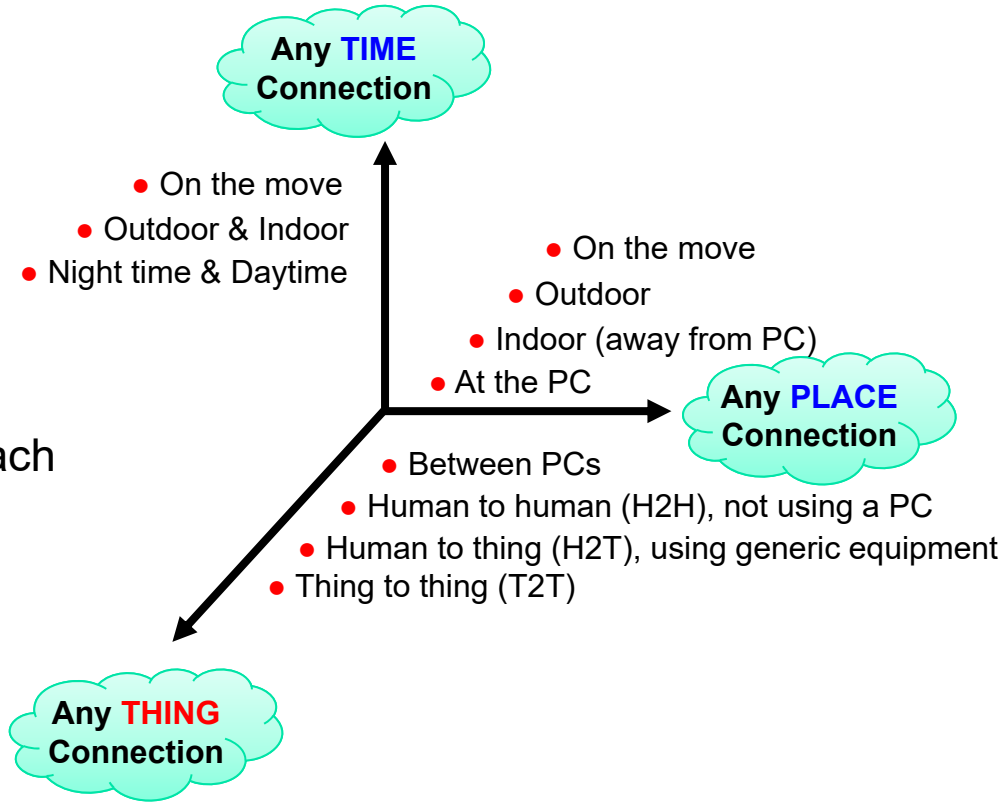
Smart Cities

Healthcare

Smart Home

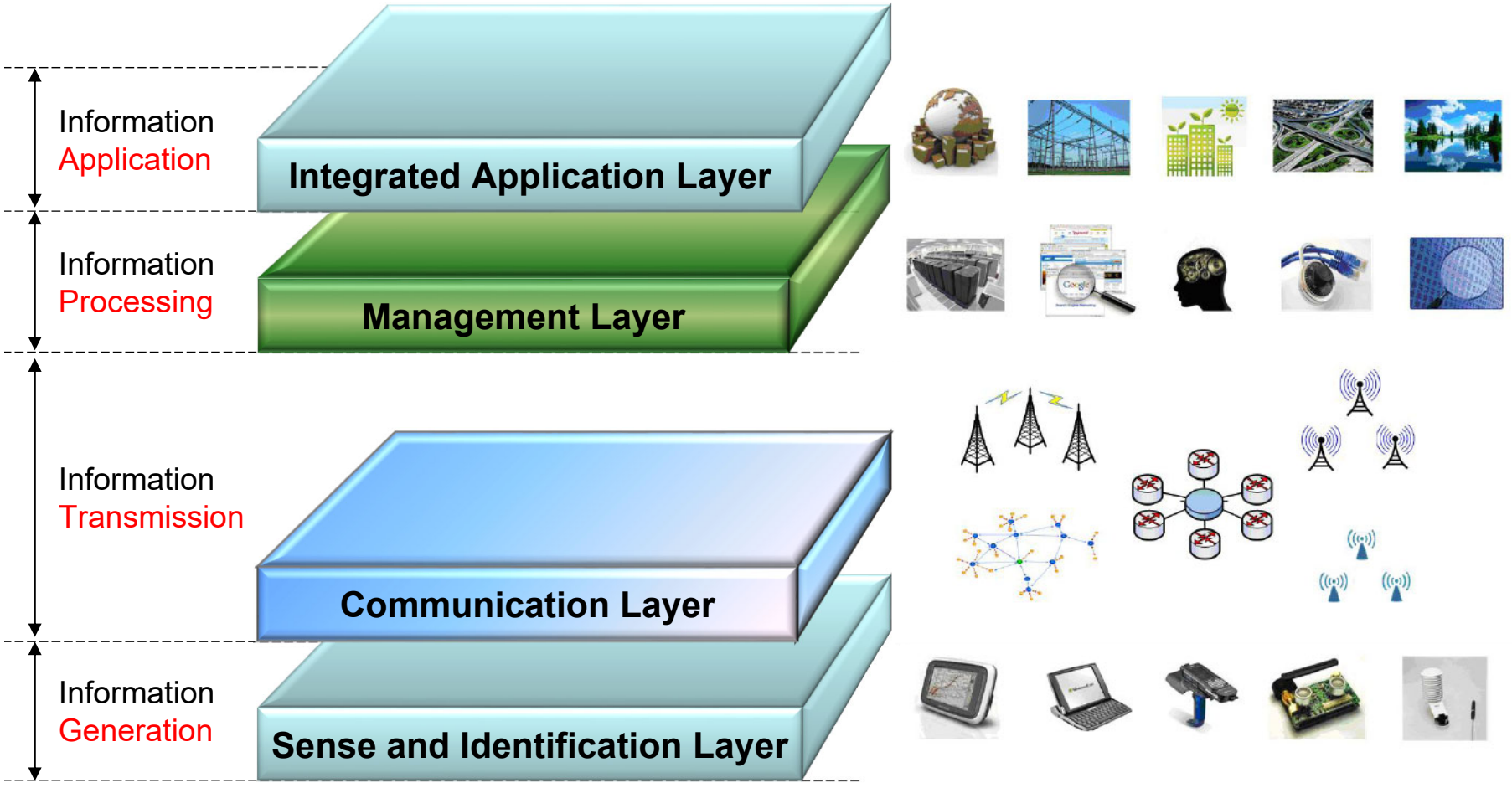
Characteristics

- Pervasive
  - Embedded everywhere
- Ubiquitous
  - Invisible
- Heterogenic
  - Many technologies, interact each other
- Scale
  - Order of magnitude high than current Internet

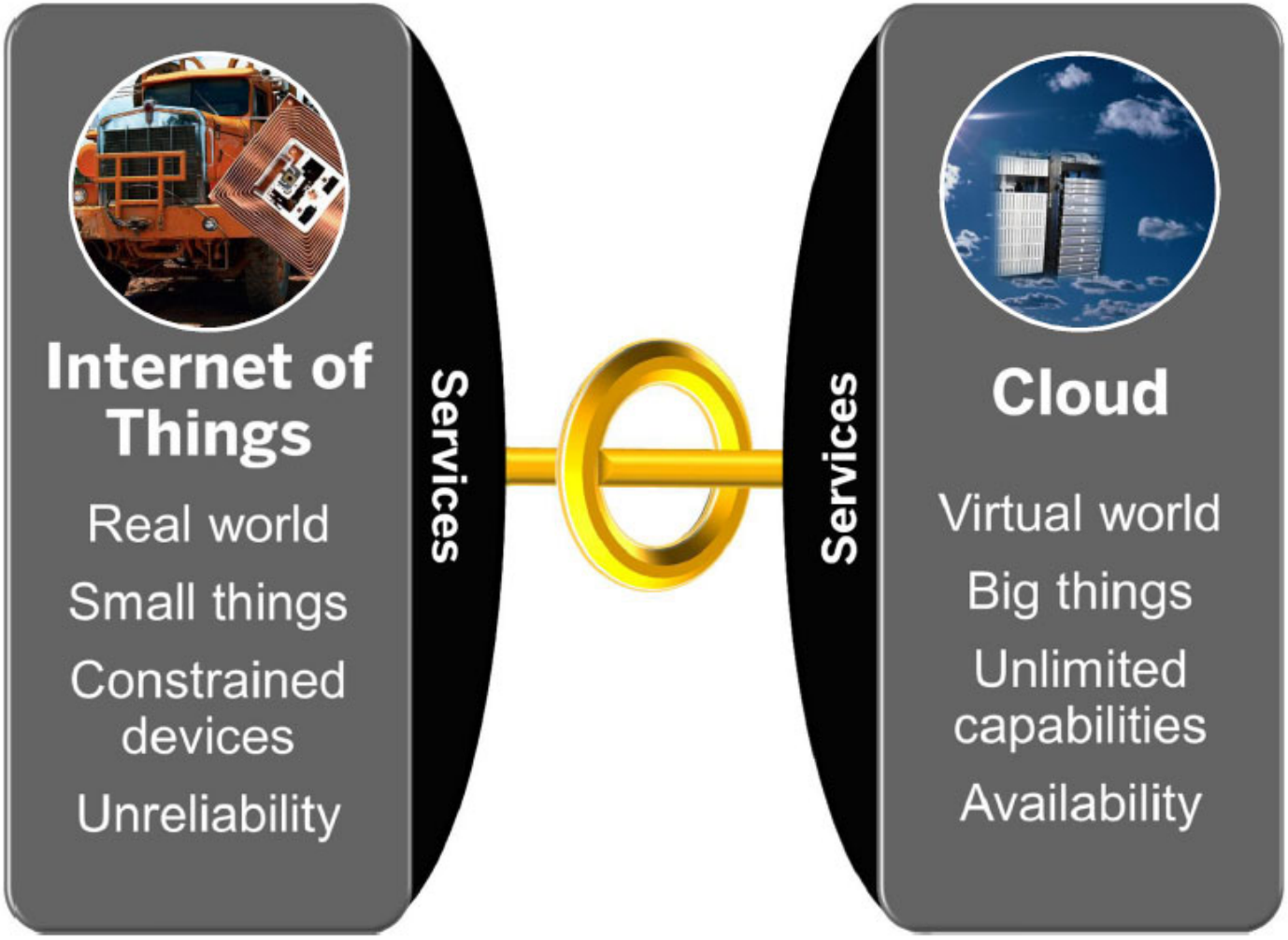


From any time, any place connectivity for anyone,
We will now have connectivity for anything!

4-layer Model for IoT



Relationship of IoT & Cloud



Cloud Computing

- Cloud computing is a phrase used to describe a variety of computing concepts that involve a large no. of computer connected through a real-time communication network (e.g., Internet)
- It is a synonym for distributed computing over a network. This means that the ability to run a program on many connected computers at the same time
- This term became popular after Amazon.com introduced the Elastic Compute Cloud in 2006
- Different perspectives & focuses (Platform, SW, Service Levels, etc)
- Network diagrams, Software-as-a-Service (SaaS)
  - Service is “on a cloud somewhere”
  - “My customer resource management system is out on the Internet!”

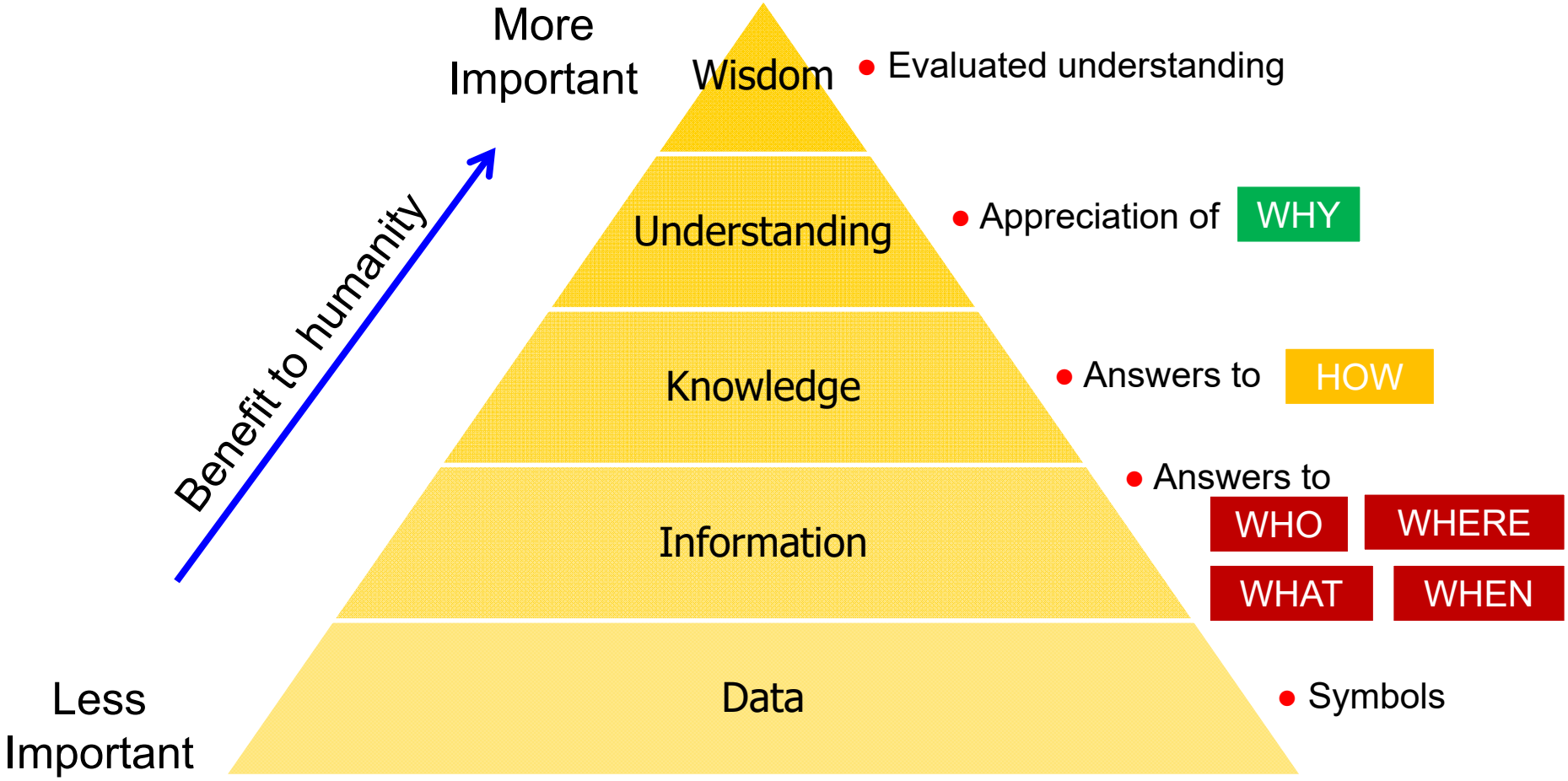
New Business Model

IoT is not just about gathering of data but also about the analysis and use of data

Relationship of IoT & Big Data

Big Data is not magic. It does not matter how much data you have if you cannot make sense of it

IoT Data



The more data that is created, the better understanding and wisdom people can obtain

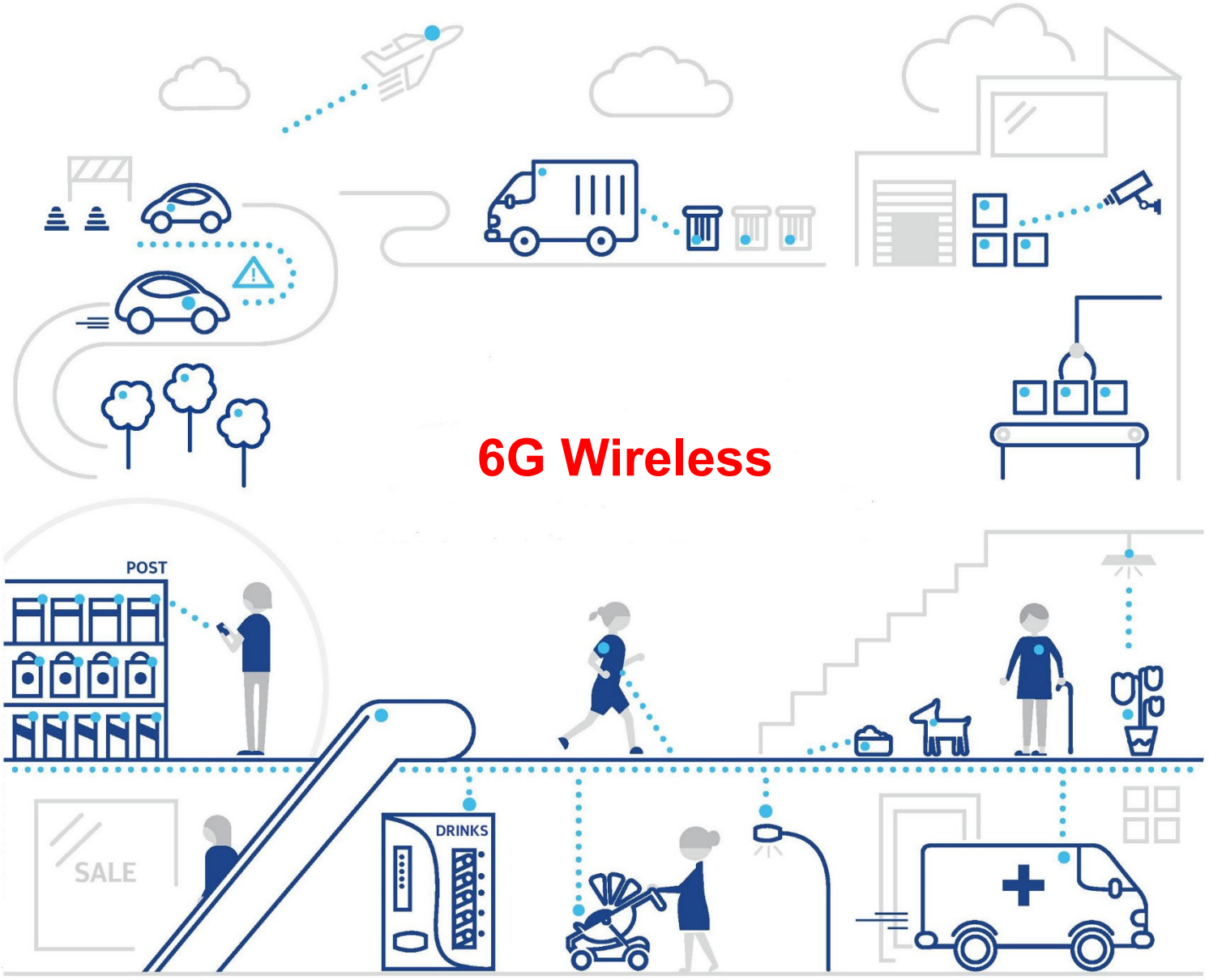
Challenges

- Technological standardization still remain – openness and interoperability
- Efficiency – managing and balancing rapid change of objects
- Absence of governance – decisions
- Privacy and security

Figure: Hype Cycle for Emerging Technologies, **2015**

Source from http://www.gartner.com/

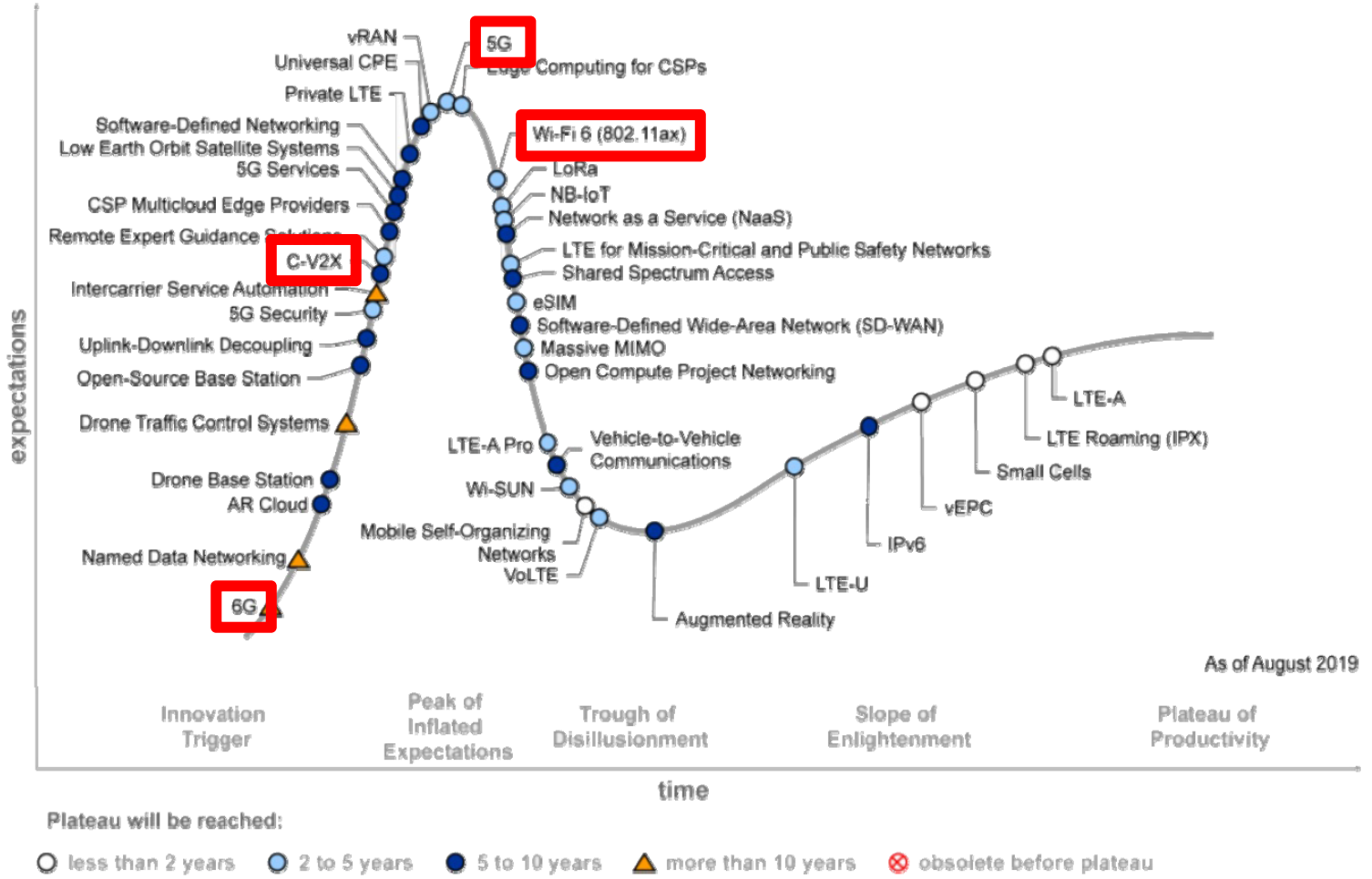
How to convincing users that the IoT technology will protect their data and privacy when tracking?



Emerging Technologies 2019

Source: Gartner, Inc. [online] https://www.gartner.com/smarterwithgartner/

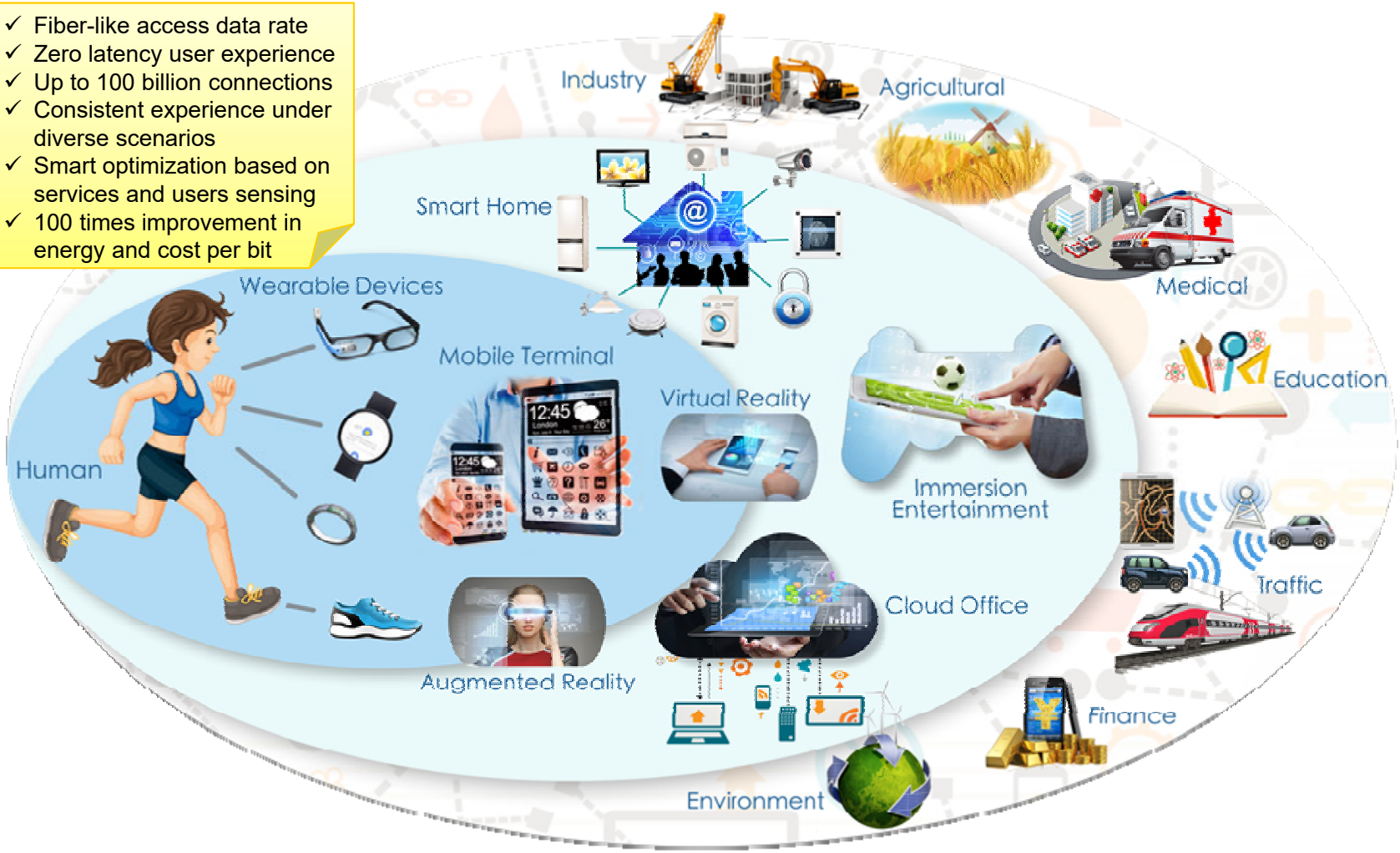
Wireless Networks Infrastructure 2019



Source: Gartner, Inc. [online] https://www.gartner.com/smarterwithgartner/

5G Vision

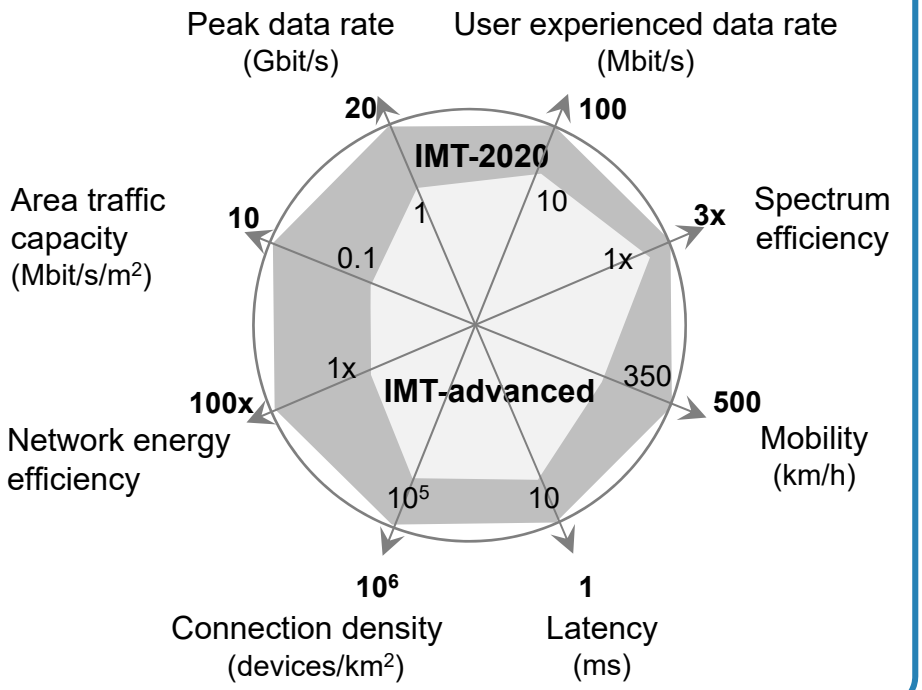
- ✓ Fiber-like access data rate
- ✓ Zero latency user experience
- ✓ Up to 100 billion connections
- ✓ Consistent experience under diverse scenarios
- ✓ Smart optimization based on services and users sensing
- ✓ 100 times improvement in energy and cost per bit

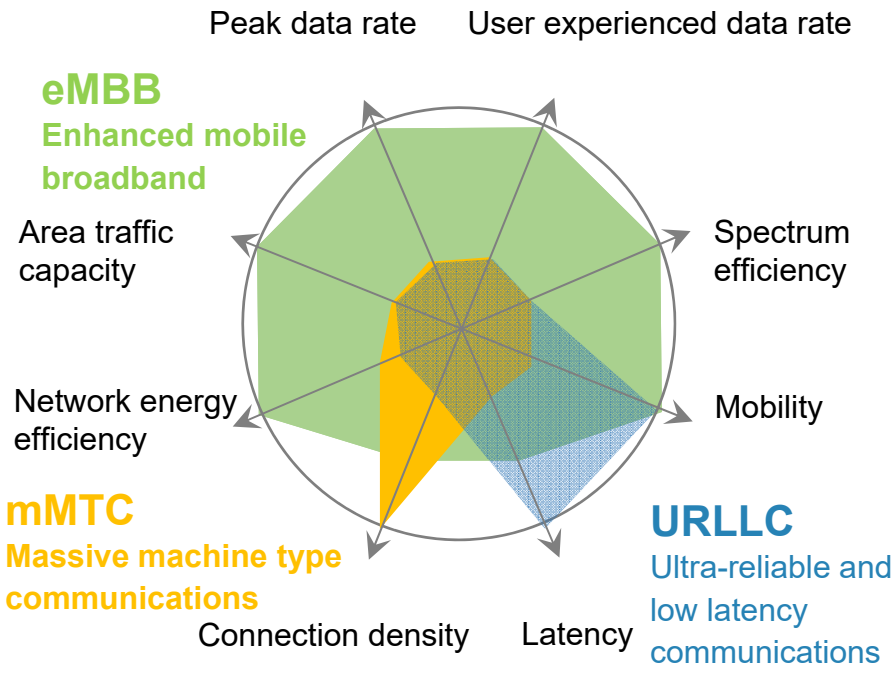


5G: Technology Comparison

Technology	1G	2G/2.5G	3G	4G	5G
Deployment	1970/1984	1980/1999	1990/2002	2000/2010	2020/2022
Rate	2 kbps	14-64 kbps	2 Mbps	200 Mbps	> 1Gbps
Technology	Analog Cellular	Digital Cellular	Broadband CDMA/IP Technology	Unified IP & Seamless Combination of LAN/WAN/WLAN/ PAN	4G + WWWW
Service	Mobile telephony	Digital voice, short messaging	Integrated high quality audio, video & data	Dynamic information and wearable devices	Dynamic information and wearable devices with AI capabilities
Multiplexing	FDMA	TDMA/CDMA	CDMA	OFDMA	NOMA?
Switching	Circuit	Circuit/circuit for access network & air interface	Packet except for air interface	All packet	All packet
Core Network	PSTN	PSTN	Packet Network	Internet	Internet
Handoff	Horizontal	Horizontal	Horizontal	Horizontal & Vertical	Horizontal & Vertical

5G Mobile Communication System





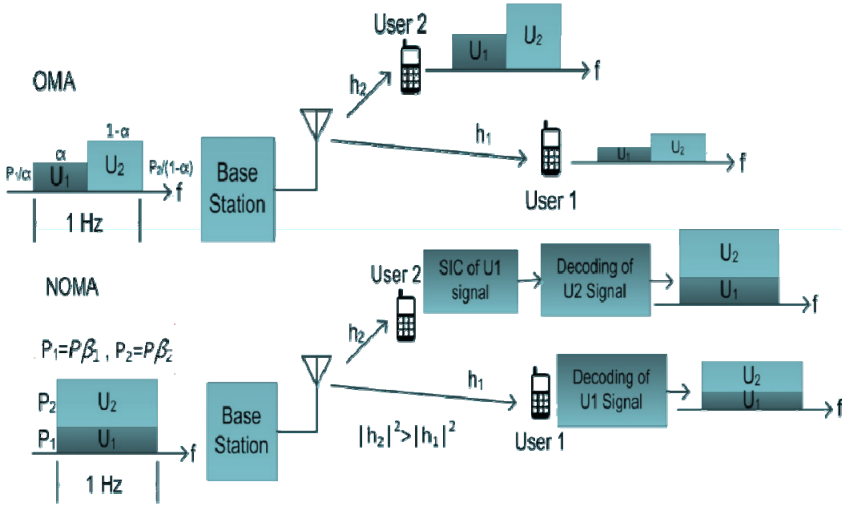
Source: Recommendation ITU-R M.2083

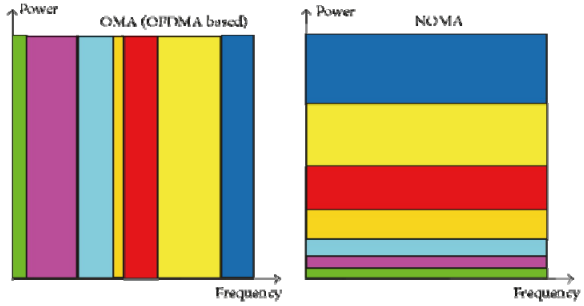
5G is characterized by increased data rate, enhanced spectrum efficiency and reduced latency

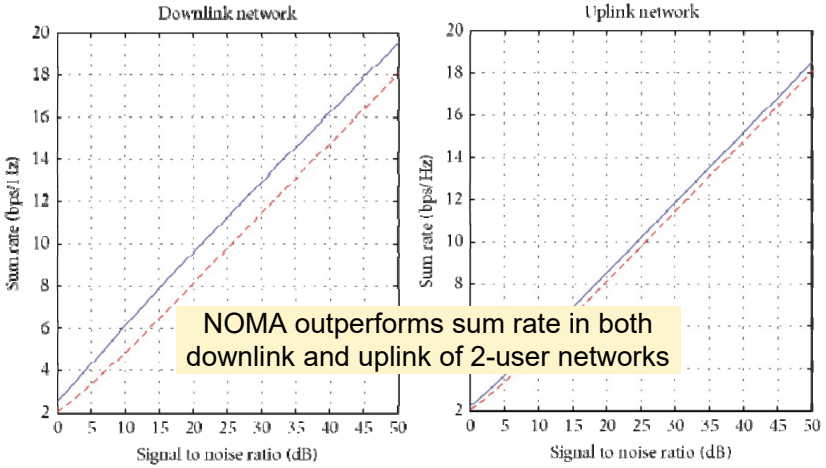
- 1000 times higher mobile data volume per geographical area. 10 to 100 times more connected devices
- 10 times to 100 times higher typical user data rate. 10 times lower energy consumption
- End-to-end latency of < 1ms. Ubiquitous 5G access including in low density areas

5G: NOMA

- To improve capacity and energy efficiency
  - mmWave and MIMO are introduced
  - Focus on orthogonal (OMA) and nonorthogonal (NOMA)
- 2 types of NOMA
  - Power-domain & code-domain multiplexing
- Disadvantages of NOMA
  - Receiver computational complexity (each user requires to decode the signals)
  - Significant channel state information (CSI) feedback overhead
  - Error probability of successive decoding will be increased when any error occur during SIC process
  - restricting no. of users to consider difference in channel gains are required to have a better network performance







Source: M. Aldababsa, M. Toka, S. Gokceli, G.K. Kurt, and O. Kucur, "A tutorial on nonorthogonal multiple access for 5G and beyond," Wireless Commun. and Mobile Computing, 2018

5G: Network Architecture

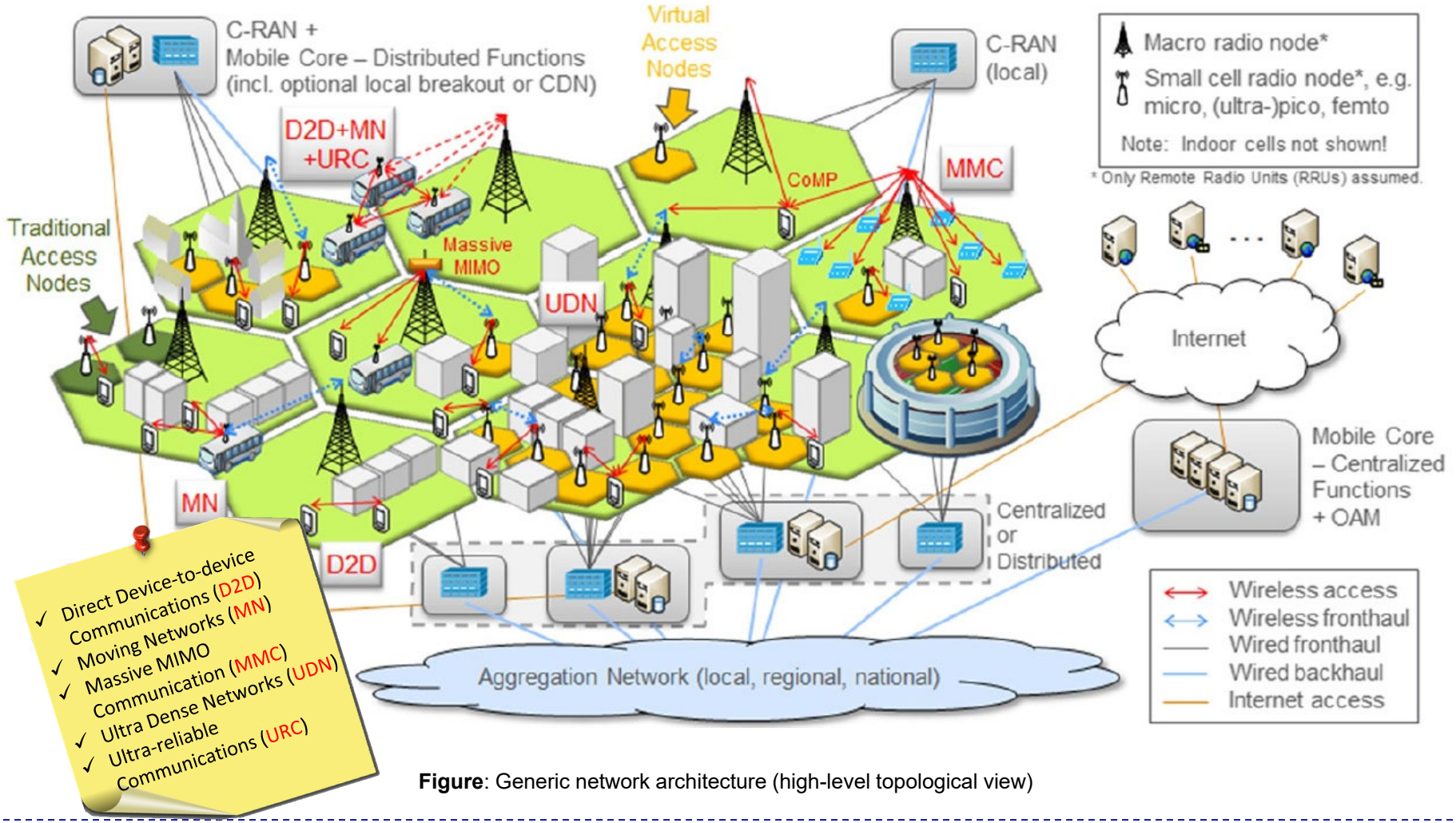


Figure: Generic network architecture (high-level topological view)

5G: RAN 2.0

- RAN 2.0 implies a flat architecture from service point of view resulting in low latency. It is also accompanied by an agile infrastructure support, since ad hoc and smart coordinated entails a different distribution of intrinsic functions that can be executed in any node depending on its hardware and software capabilities

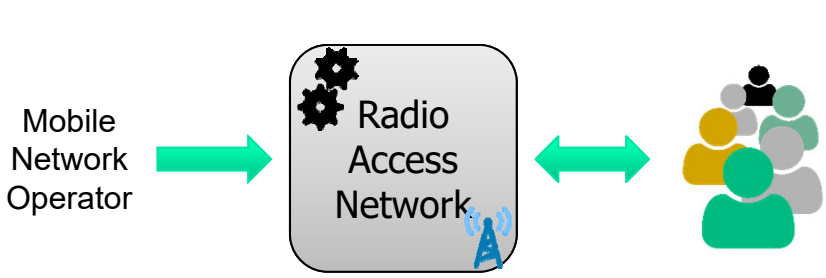


Figure: RAN 1.0

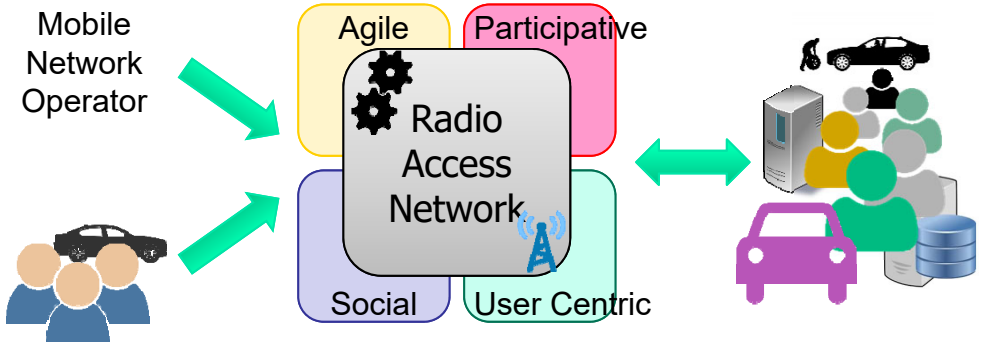


Figure: RAN 2.0

5G: 3-plane based Architecture

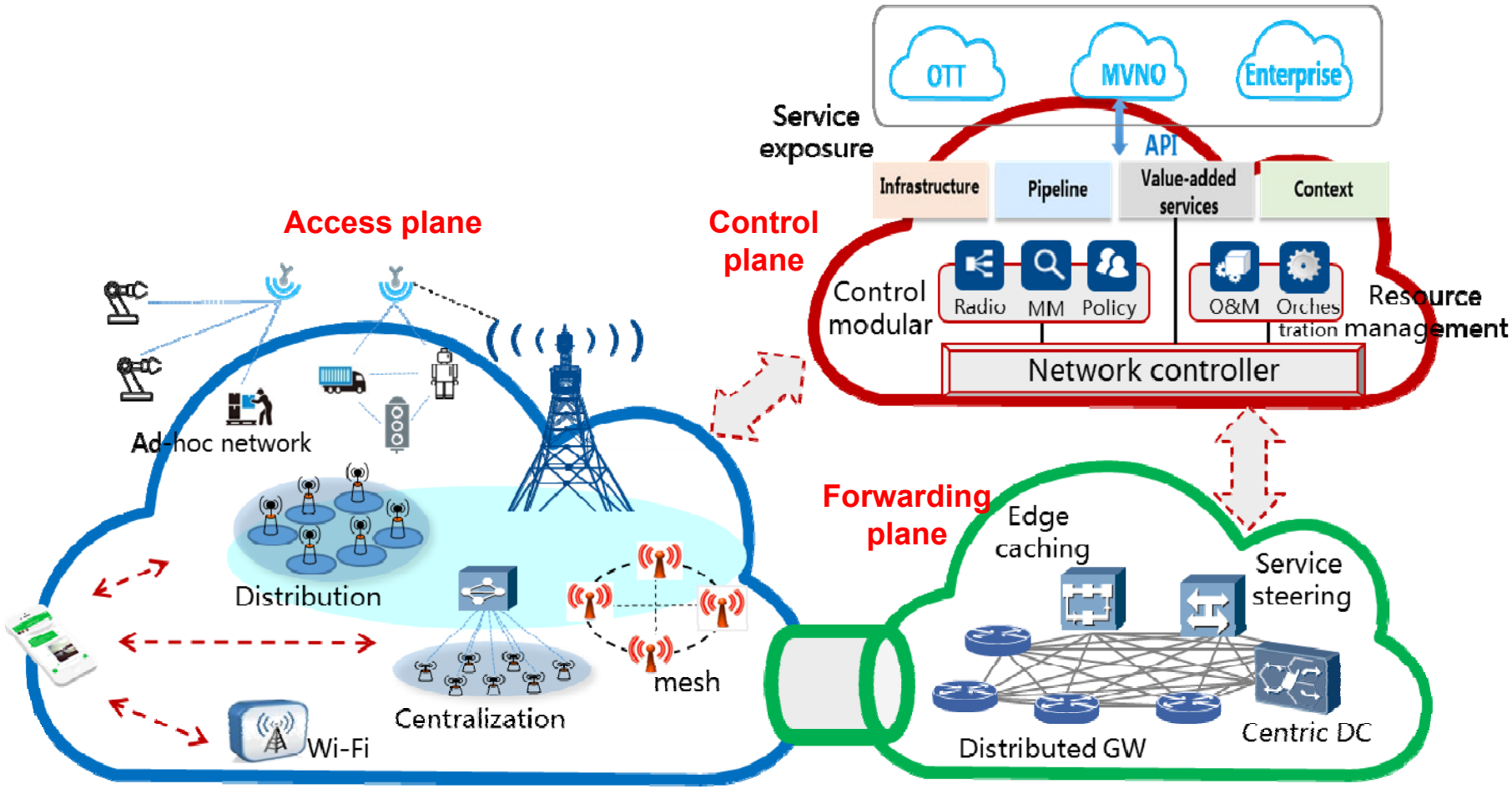
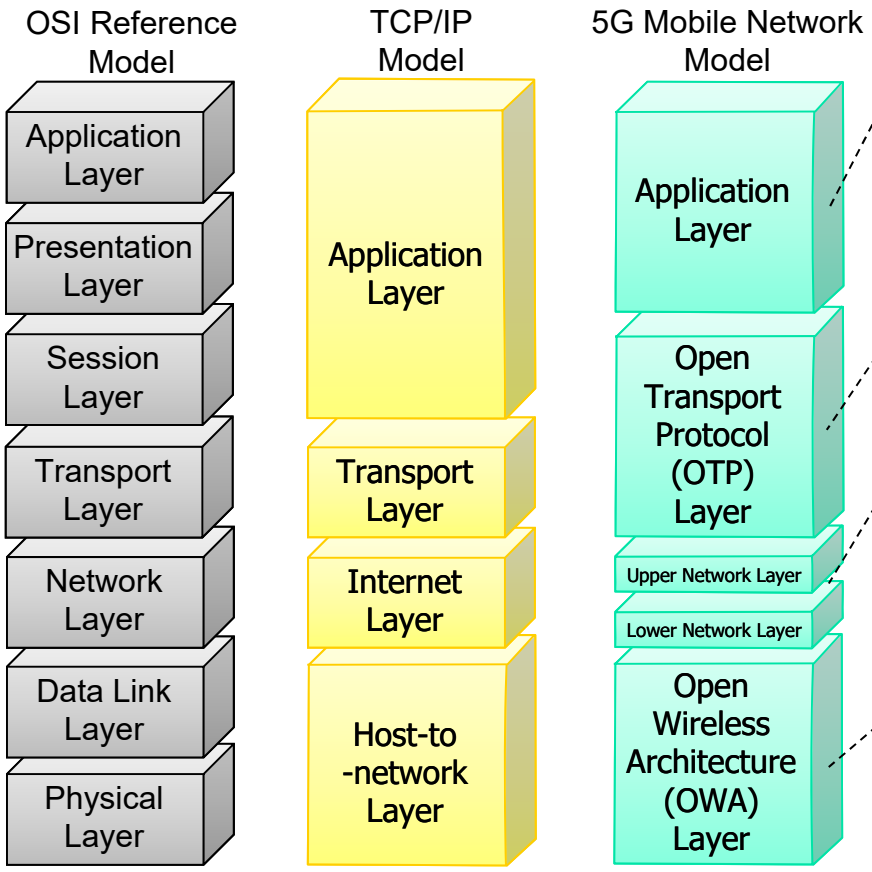


Figure: Three-plane based 5G network architecture

5G: Protocol Suite Architecture



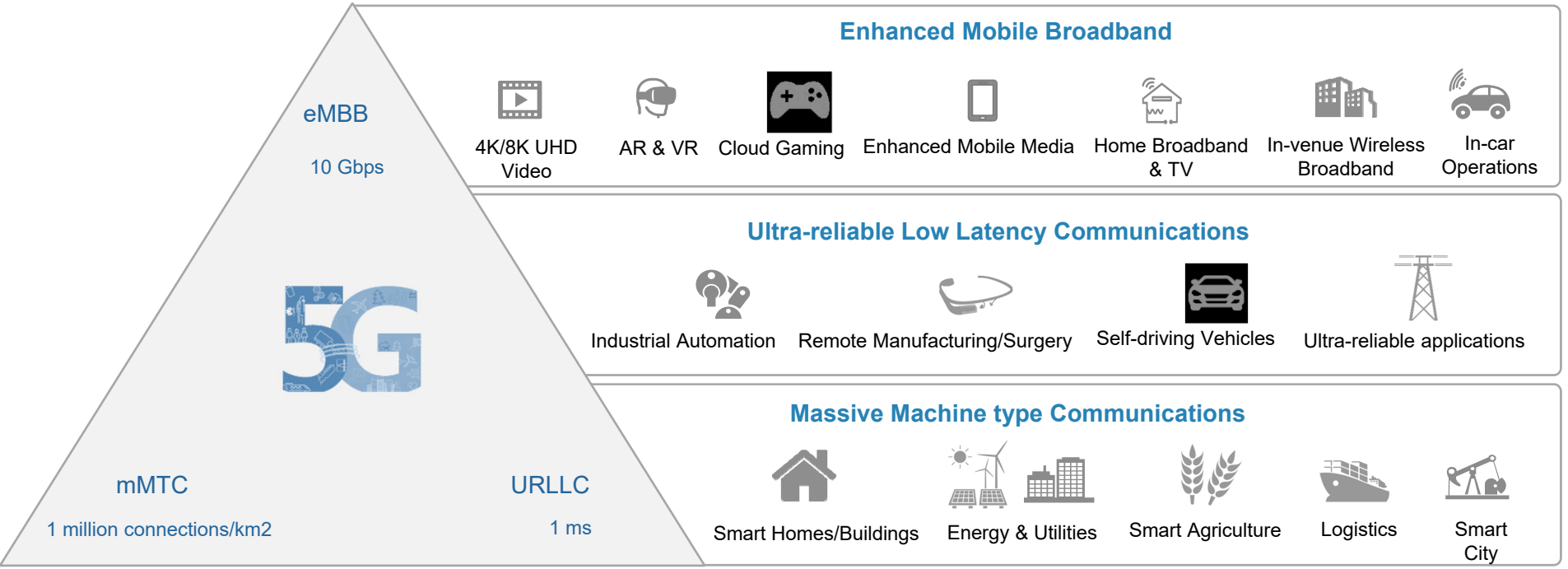
- Software defined radio, encryption, flexibility, anti-virus software
- It unifies all the different standard wireless networks, including LAN, WAN, world wide wireless web (WWWW), unified IPv6, seamless combination of broadband

- In mobile device, this transport layer is possible to be downloaded & installed

- Lower network layer for each interface, whereas upper network layer for mobile device
- All mobile networks will use mobile IP
- Each mobile device will be foreign agent (FA)
- Mobile device can be attached to several mobile devices or wireless networks at the same time

- Physical hardware uses ultra wide band (UWB) networks with higher bandwidth at low energy levels
- Bandwidth is of 4 Gbps, which is 400 times faster than today's wireless networks
- Also it uses smart antenna

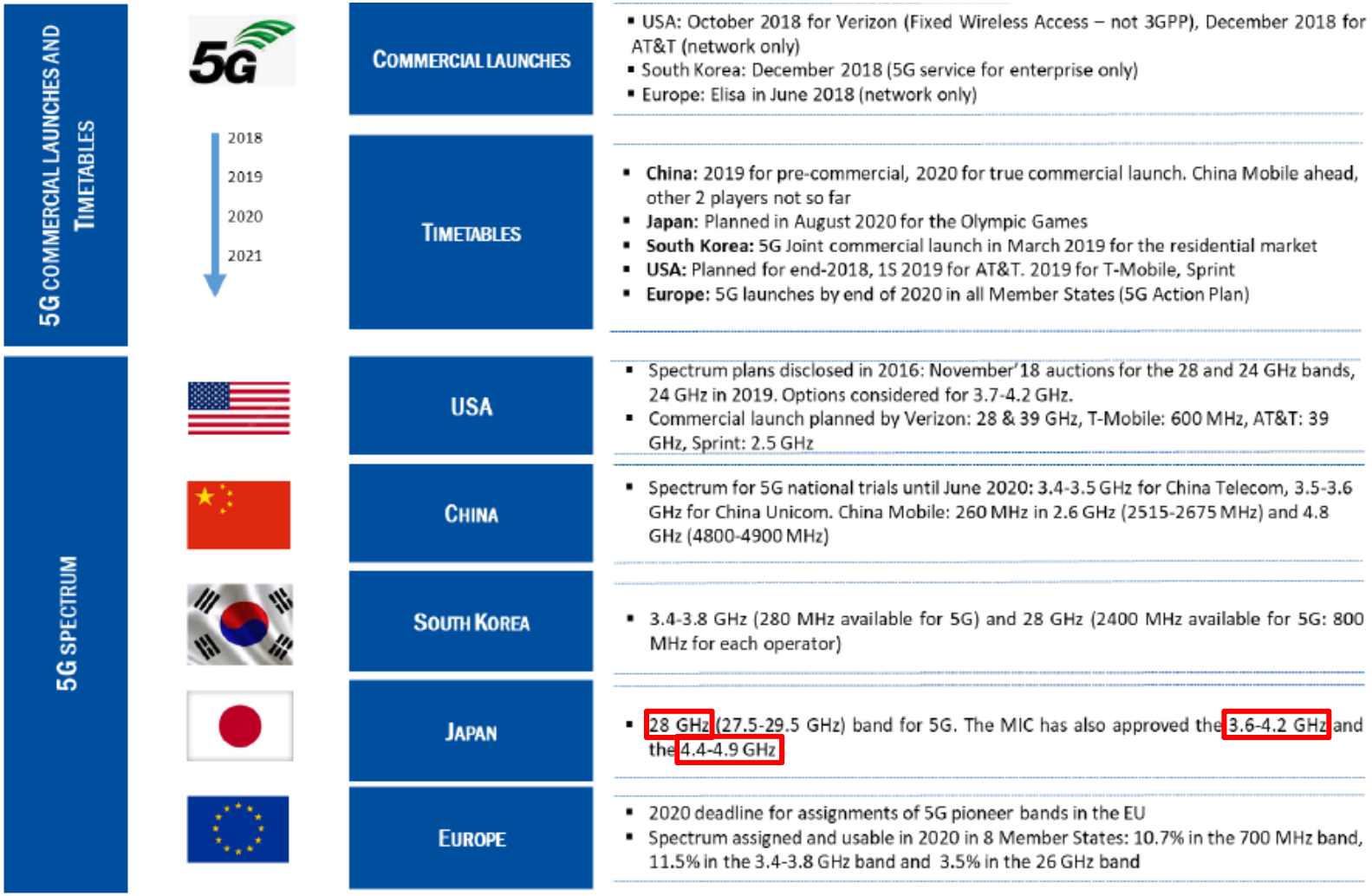
5G: Usage Scenarios



Source: Recommendation ITU-R M.2083

5G connections will go beyond human beings' communications, and will enable intelligent internet of things in the future. Next generation of telecommunication technologies will be adopted by a wider range of industries and sectors

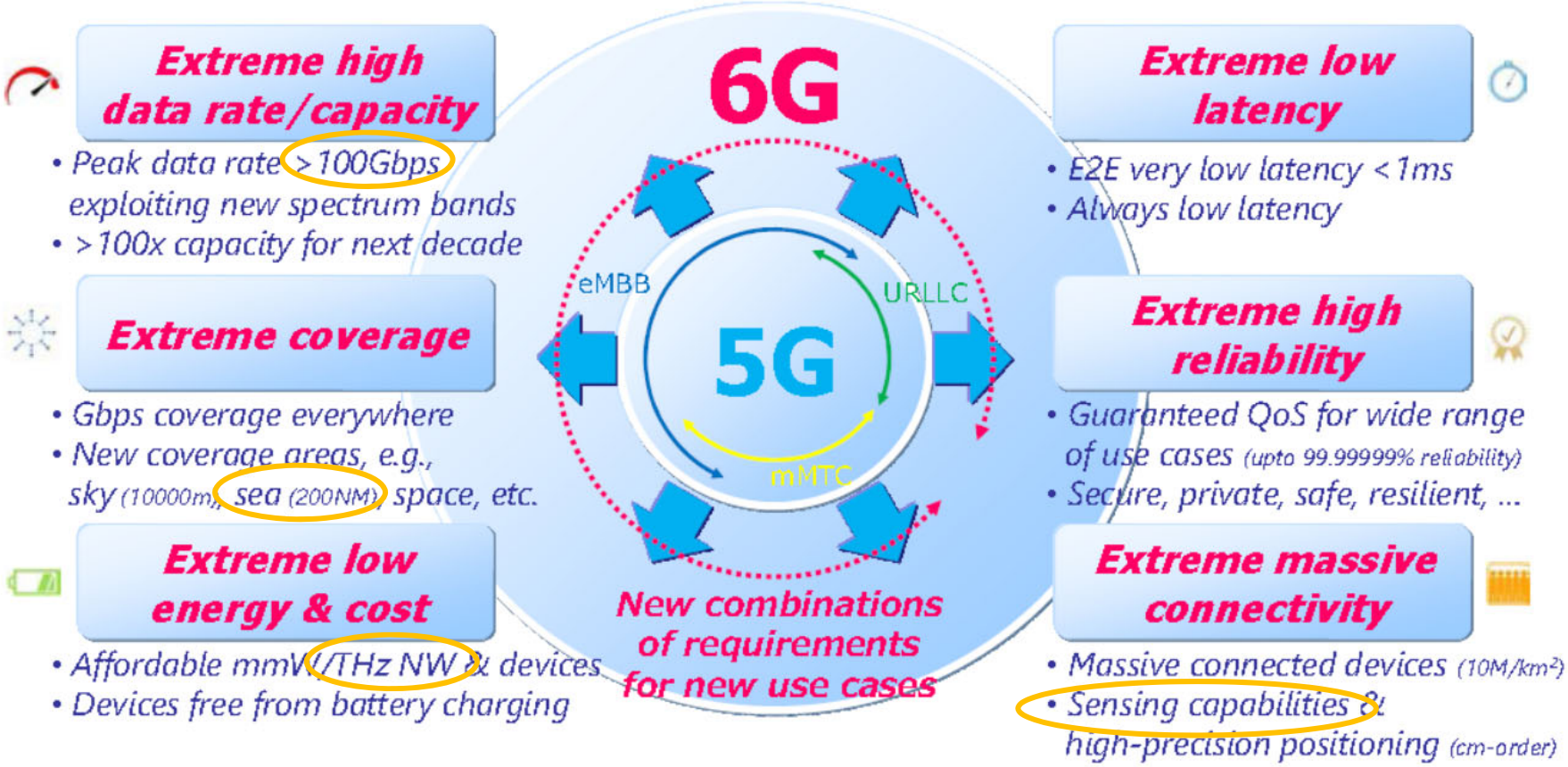
5G: Commercial Status



Source: 5G Observatory report ii

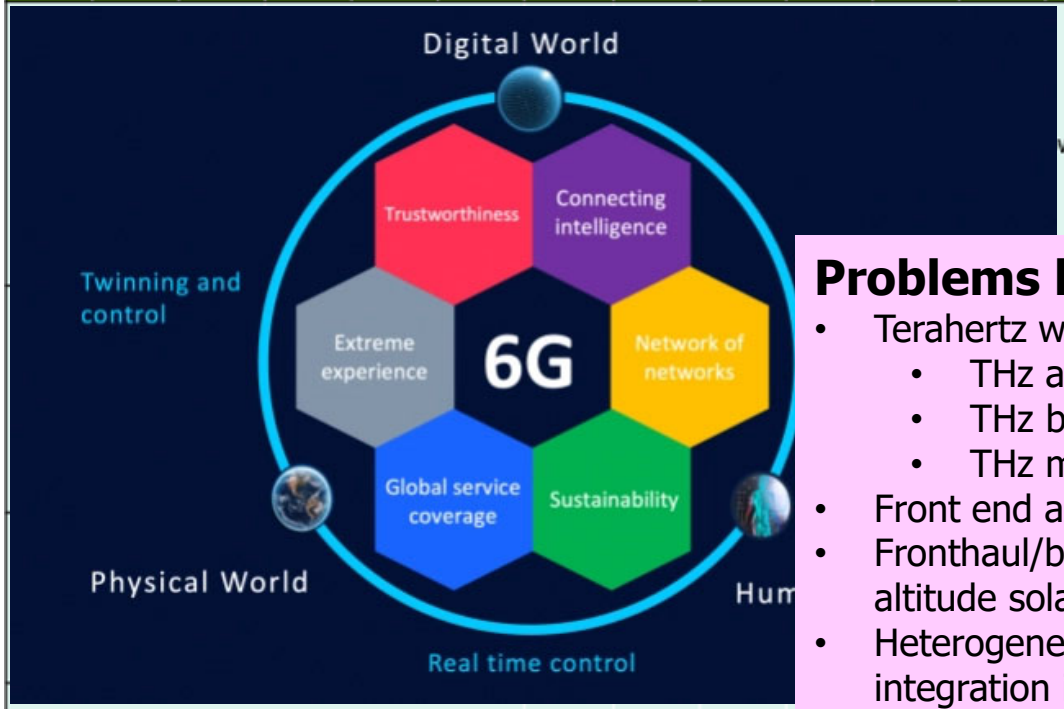
6G is coming around 2030

- News! 21st January 2020 (Tuesday)
  - Japan government develops a comprehensive strategy for 6G



Source: DOCOMO: Advanced 5G and 6G White Paper, January 2020

Roadmap of 6G

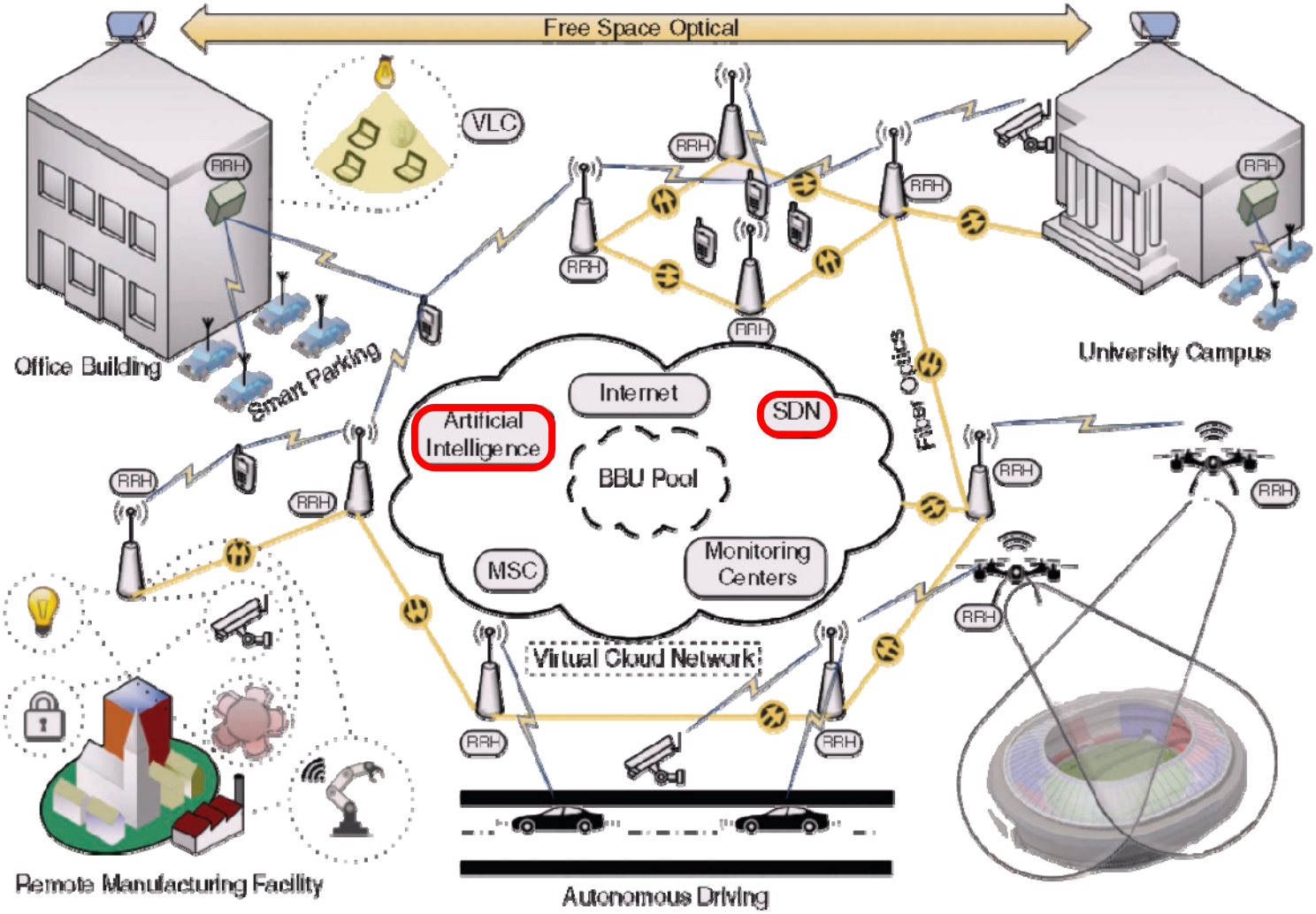
2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041
												w THz	Widespread deployment at around 1THz. Massive impact on sensing, IoT, positioning, XR, medical, military, personal electronics. Many end-of-network devices have supercapacitors and no battery				Batteryless devices commonplace, either powered by beam only or mainly powered by energy harvesting. This means genuine things-collaborating-with-things, directly-internet-connected IoT			
FP7 European Commission Program strongly embracing 6G Thales-Alenia's Stratobus airship flying trial																				

Problems become opportunities

- Terahertz waves (THz)
  - THz atmospheric absorption
  - THz beam management
  - THz modeling
- Front end and modem chips for the higher frequencies
- Fronthaul/backhaul High-capacity connectivity and high-altitude solar drones aloft for 5 years on sunshine alone
- Heterogeneous hardware restraints on the complex integration into a single platform
- Edge-of-network device capability to realize the benefits
- Complex resource management of 3D networks
- Spectrum and interference management
- Physical layer security
- Cost control

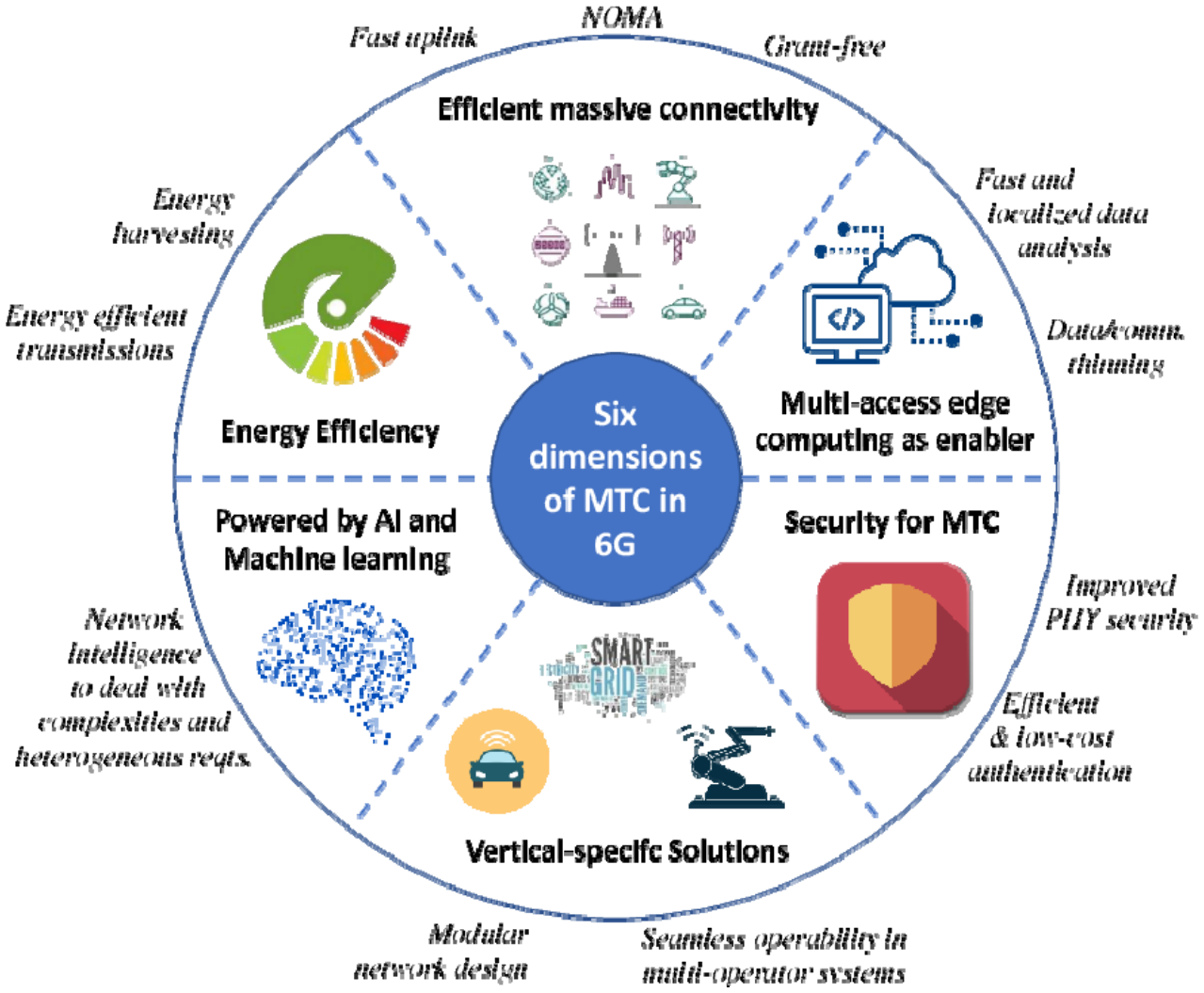
Source: AspenCore, Inc. [online] https://www.eetimes.eu/6g-roadmap-challenges-and-opportunities/

Network Architecture of 6G



Source: Y. Al-Eryani and E. Hossain, "The D-OMA method for massive multiple access in 6G: Performance, security, and challenges," IEEE Vehicular Tech. Mag., vol. 14, no. 3, pp. 92-99, 2019

6 Key Enablers for MTC in 6G



Source: N.H. Mahmood, H. Alves, O.L. López, M. Shehab, D.P. Osorio, and M. Latva-aho, "Six key enablers for machine type communication in 6G," 2019

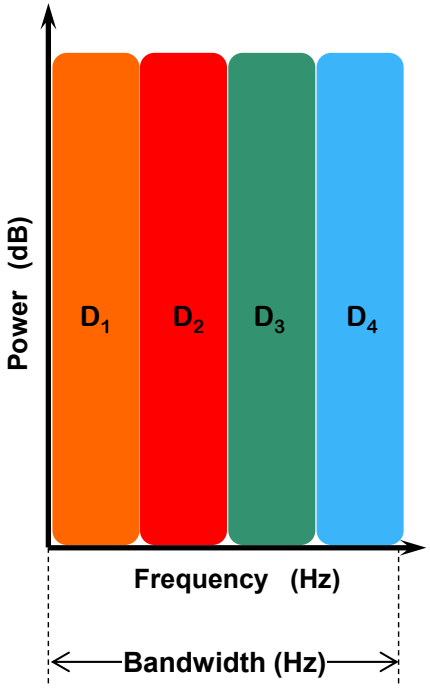
5G versus 6G

		5G	6G
Technology Features	Deployment Year	2015 onwards	2030 onwards
	Data Rate	> 1 Gbps	**> 10 Gbps**
	Technology Used	4G, WWWW	5G, Satellite Communication
	Multiplexing	NOMA	D-OMA
	Switching Method	Packet Switching	Packet Switching
	Handoff Type	Horizontal & Vertical	Horizontal & Vertical
	Service	Dynamic information & wearable devices with AI	Very fast Internet access
Key Performance Indicators (KPIs)	Traffic Size	10 Mbps/m^2	1~10 Gbps/m^2
	Data Rate (DL)	20 Gbps	1 Tbps
	Data Rate (UL)	10 Gbps	1 Tbps
	Uniform User Experience	50 Mbps 2D everywhere	**10 Gbps** 3D everywhere
	Latency (Radio Interface)	1 ms	0.1 ms
	Jitter	not specified	1 μs
	Reliability (Frame Error Rate)	1 x 10^{-5}	1 x 10^{-9}
	Energy Bit	not specified	1 pJ/bit
	Localization Accuracy	10 cm in 2D	1 cm in 3D

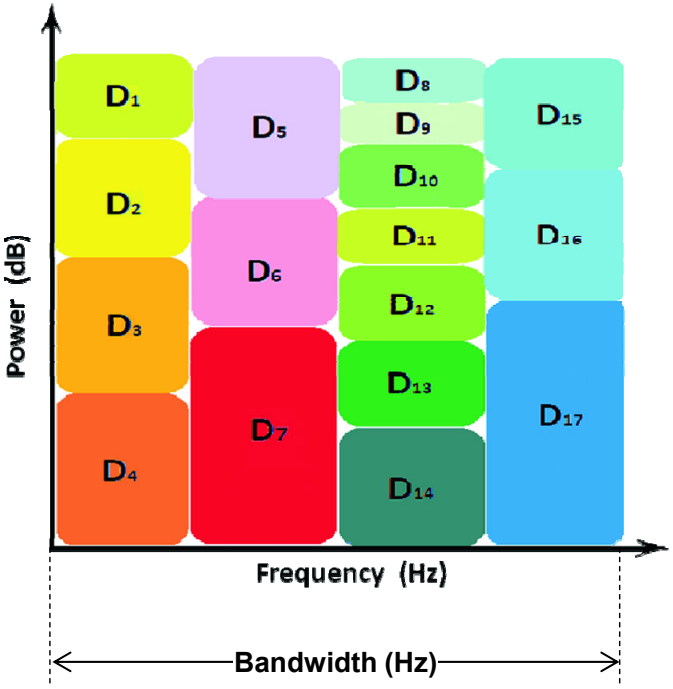
Source: F. Nawaz, J. Ibrahim, M. Junaid, S. Kousar, T. Parveen, M.A. Ali, "A review of vision and challenges of 6G technology," Int. J. of Adv. Comp. Sci. and Appli., vol. 11, no. 2, 2020

Multiple Access Methods

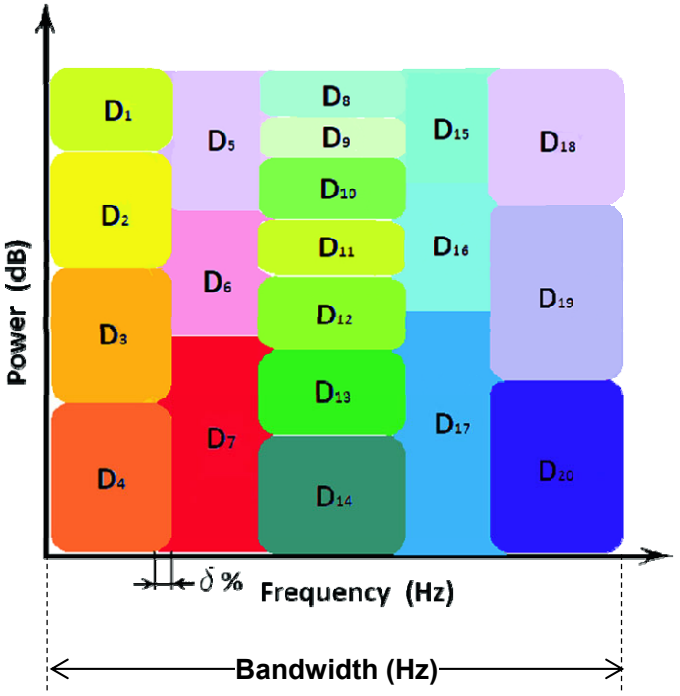
4G
Orthogonal Multiple Access (OMA)



5G
Non-orthogonal Multiple Access (NOMA)



6G
Delta-orthogonal Multiple Access (D-OMA)



Source: J. Martyna, "Downlink power allocation in delta-OMA (D-OMA) 6G networks," Lecture Notes in Comp. Sci., Springer, vol. 11660, pp. 390-401, 2019

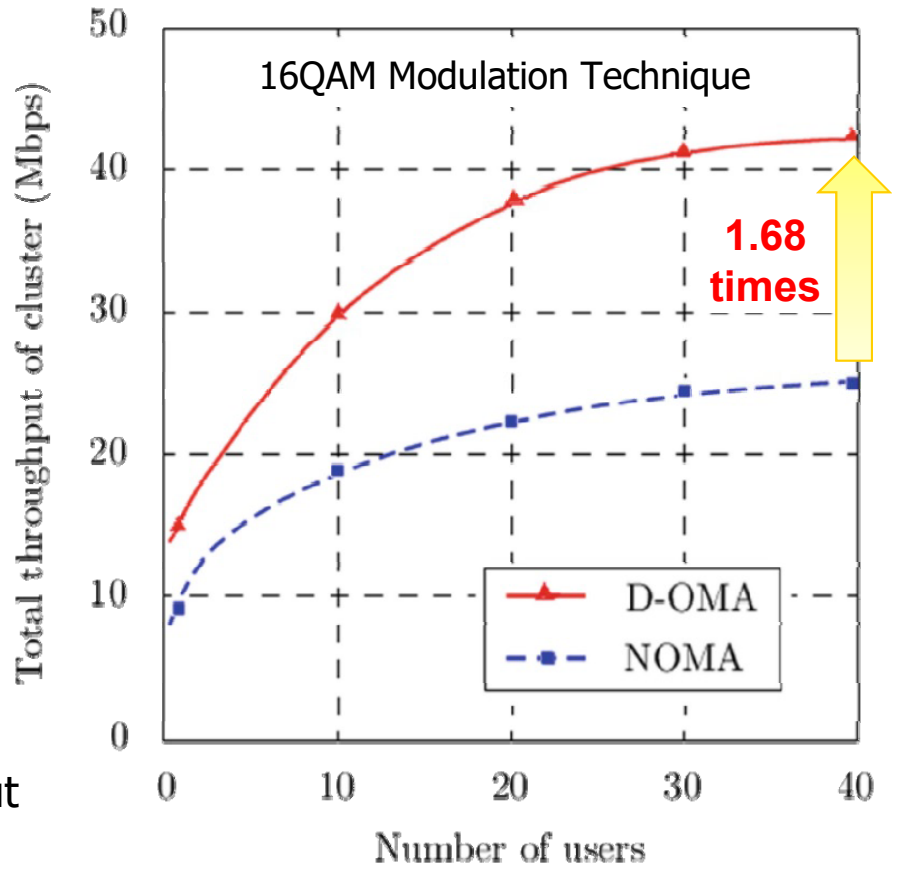
Evaluation of NOMA and D-OMA

- Parameter settings
  - System effective bandwidth is 20 MHz
  - Bandwidth of one resource block is 160 kHz
  - No. of frequency blocks = 24
  - No. of users per cell is 5 to 50
  - Transmission power of BS is 24 dBm
  - Max. transmission power of user is 50 dBm
  - Distance-dependent pathloss
    = 128 + $37\log_{10}(d)$ dB where d km
  - Lognormal shadowing is 6 dB
  - Instantaneous fading is 6-path Rayleigh
  - Receiver noise density is –160 dBm/Hz
  - Scheduling interval is 1 ms
  - All users are uniformly distributed from 10~500 m
  - Using the access method below, BS sends no. of messages to n-th user is given by

$$M_n = \sum_{n=1}^{N} \sqrt{\alpha_n P} \cdot s_n$$

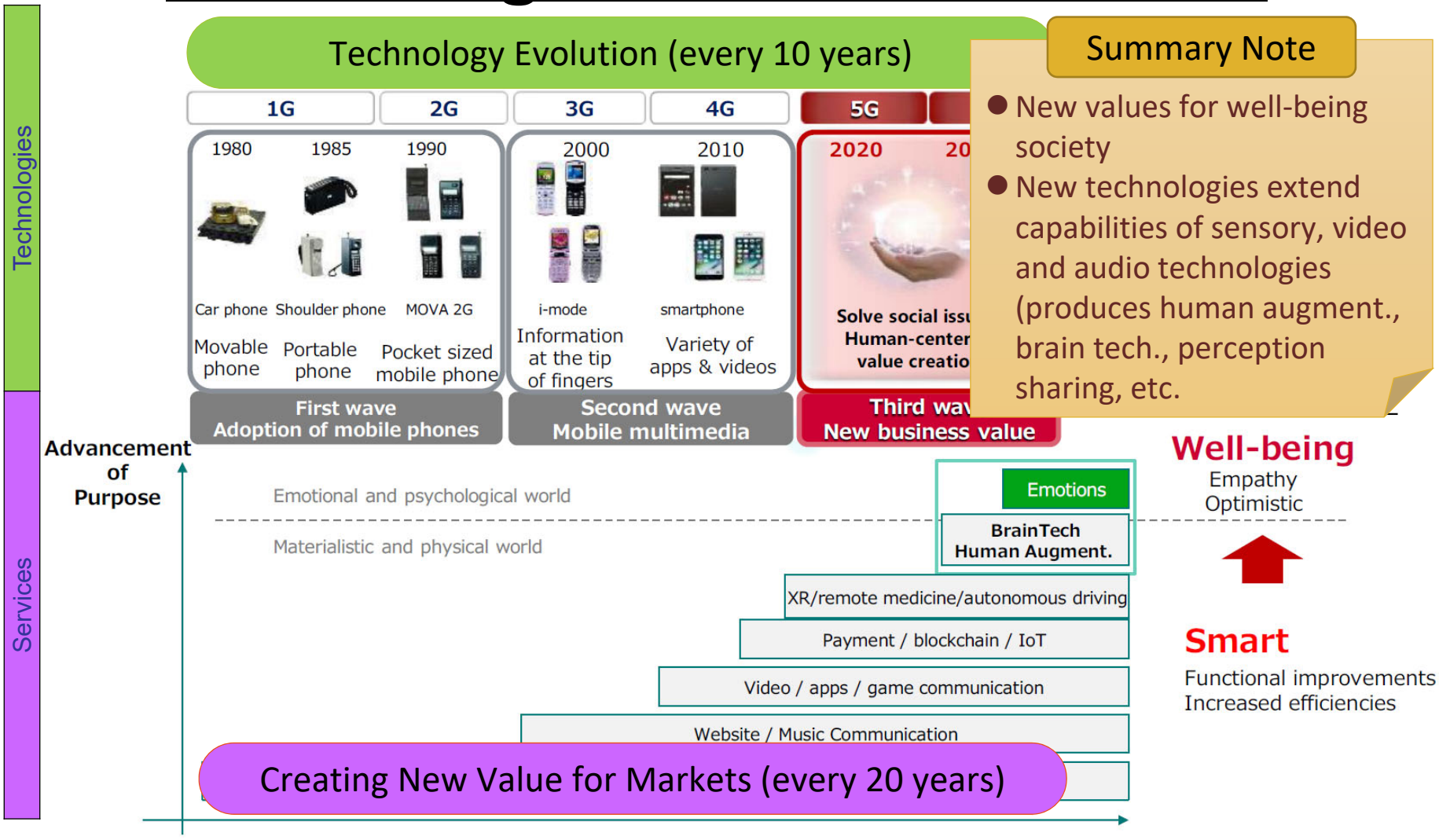
where
s_n = message size for n-th user
P = transmission power of BS
α_n = power allocation coefficient
(i.e., $\alpha_1 \geq \cdots \geq \alpha_n$)

- Results: up to 1.68 times of overall throughput when no. of users is 40



Source: J. Martyna, "Downlink power allocation in delta-OMA (D-OMA) 6G networks," Lecture Notes in Comp. Sci., Springer, vol. 11660, pp. 390-401, 2019

Technologies & Services of 6G



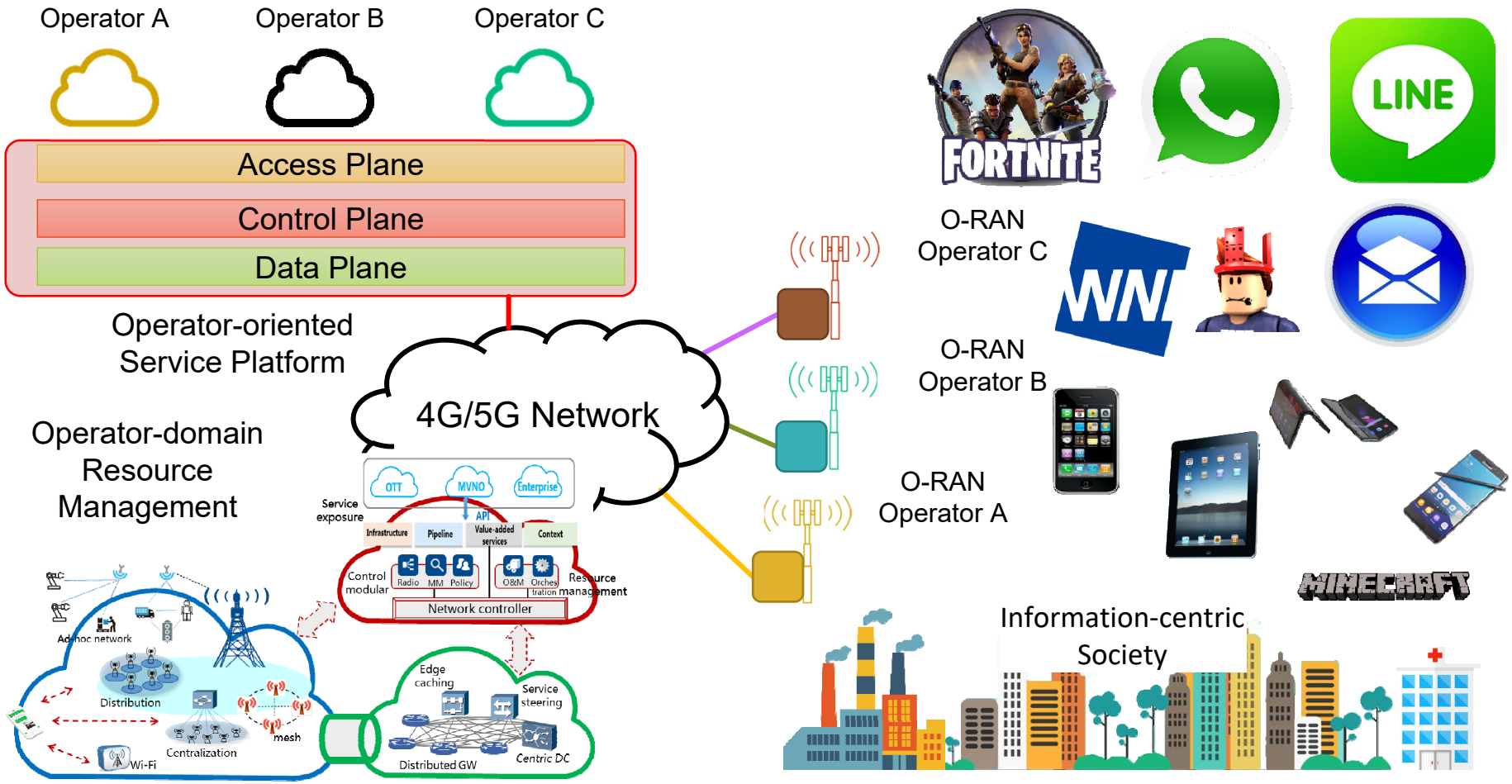
Summary Note

- New values for well-being society
- New technologies extend capabilities of sensory, video and audio technologies (produces human augment., brain tech., perception sharing, etc.

Source: White Paper (version 4.0), NTT DoCoMo, "5G Evolution and 6G," Jan. 2022

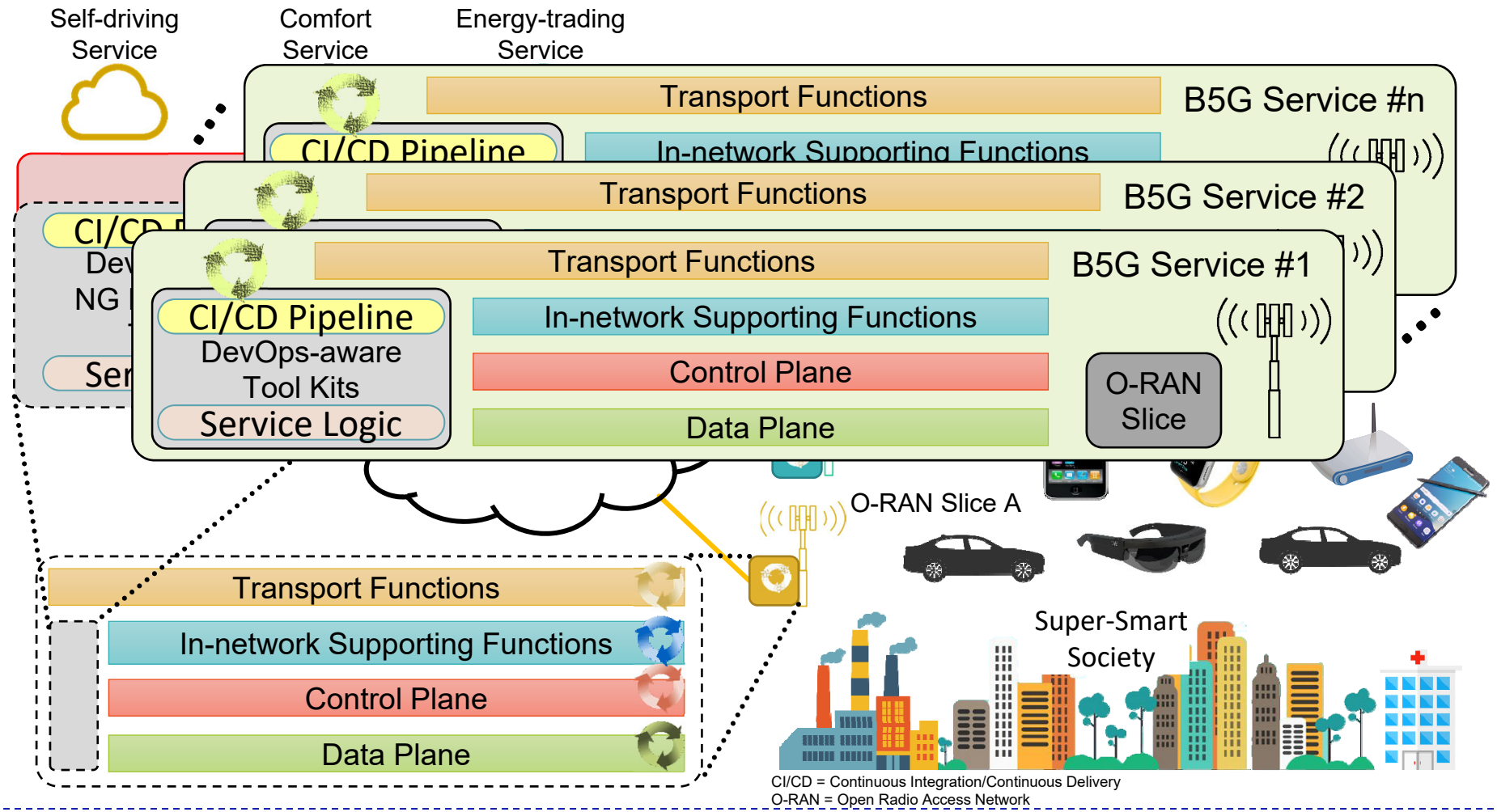
System Architecture of 5G

Current Problem: App services are all the way towards mobile/device users ONLY



System Architecture of 6G

Openness Network Slicing and Softwarization (Customized for service-specific purpose)

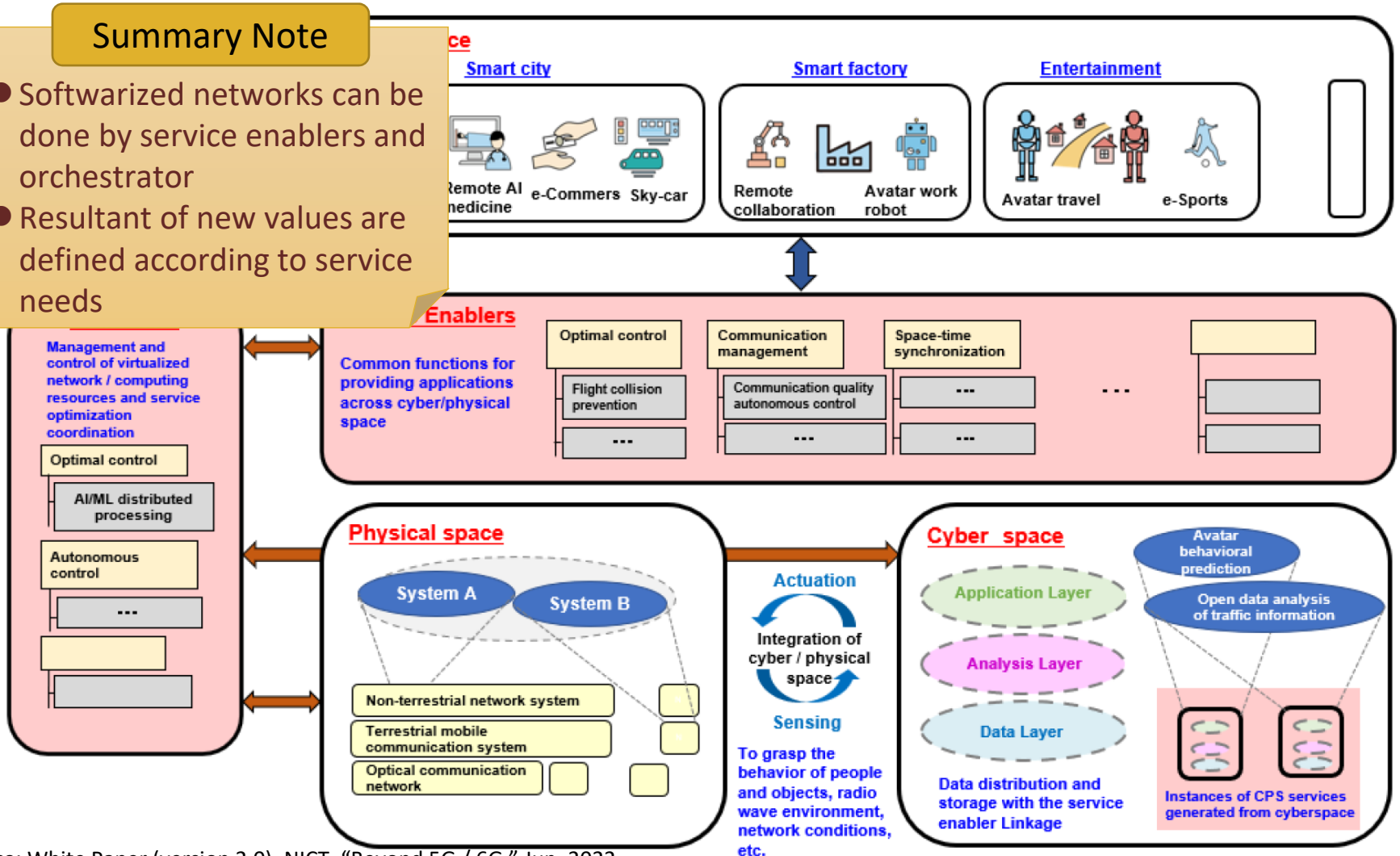


CI/CD = Continuous Integration/Continuous Delivery
O-RAN = Open Radio Access Network

Functional Architecture of 6G

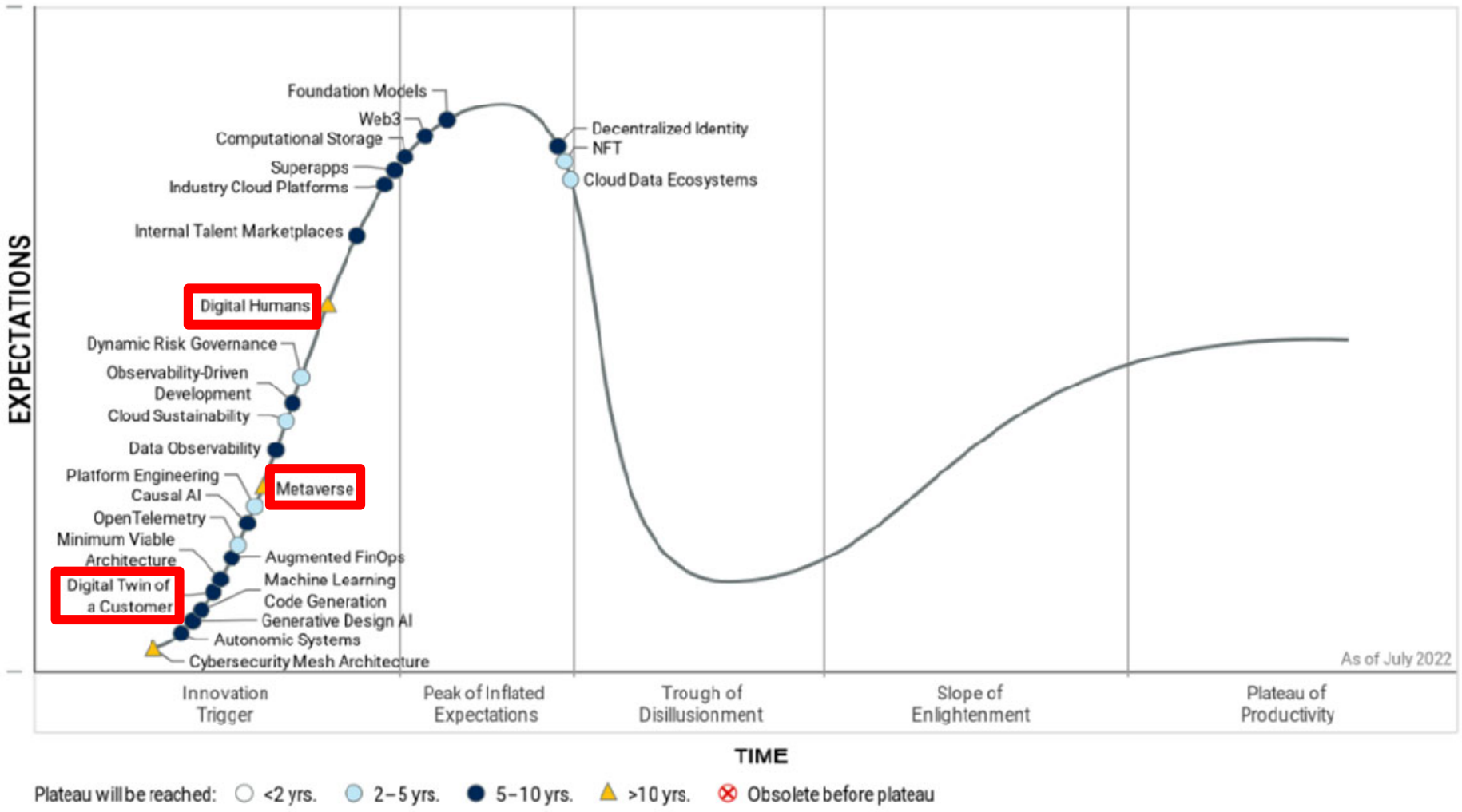
Summary Note

- Softwarized networks can be done by service enablers and orchestrator
- Resultant of new values are defined according to service needs



Source: White Paper (version 2.0), NICT, "Beyond 5G / 6G," Jun. 2022

Emerging Technologies 2022



Source: Gartner, Inc. [online] https://www.gartner.com/smarterwithgartner/

Towards to Society 5.0

Summary Note

A human-centered society that balances economic advancement with social problem resolutions by integrating the Cyber-Physical System (CPS) approach

Source: White Paper 2021, MEXT Japan, "Toward realizing society 5.0," [online] https://www.mext.go.jp/en/publication/whitepaper/

Announcement

- Final Examination
- 09:00 ~ 10:40 on 5 December (Monday)

Thank you very much for taking this course!