INTERNATIONAL WEBINAR ON 5G SECURITY IN COMMUNICATIONS

25th MARCH · 10h (CET) · Online

ORGANIZER
Prof. Mário Marques da Silva
Universidade Autónoma de Lisboa, Autónoma TechLab & Instituto de Telecomunicações

CHAIRMAN
Prof. Luís M. Correia
Instituto Superior Técnico from Universidade de Lisboa, INESC-ID/INOV

AGENDA

10h - 10h40
The Evolution of 5G Communications within the scope of the Fourth Industrial Revolution
Prof. Mário Marques da Silva

10h40 - 11h20
Cybersecurity: Advances and Perspectives – The Challenges of 5G
Prof. Joaquim Cunha Viana
Universidade Autónoma de Lisboa & Autonoma TechLab

11h20 - 11h40 – Virtual Coffee Break

11h40 - 12h
5G in Public Safety Networks: Applications and Challenges
Prof. Luís M. Correia

12h20 - 13h
Technology and Criminal Investigation
Subintendente Rui Santos Costa
Polícia de Segurança Pública

13h - 13h30 – Final Discussion & Remarks

FREE ACCESS BUT REGISTRATION IS MANDATORY
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The Evolution of 5G Communications within the scope of the Fourth Industrial Revolution

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Main Reference

- M. Marques da Silva, J. Guerreiro, “On the 5G and Beyond”, MDPI Applied Sciences, 10, 7091, **26 October 2020** (https://www.mdpi.com/2076-3417/10/20/7091)

applied sciences

MDPI

Article

On the 5G and Beyond

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[2] Department of Sciences and Technologies, Autonoma University of Lisbon, 1150-293 Lisboa, Portugal
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Featured Application: Introductory Article of the MDPI Special Issue “Transmission Techniques for 5G and Beyond”.

Abstract: This article provides an overview of the fifth generation of cellular communications (5G) and beyond. It presents the transmission techniques of current 5G communications and those expected of future developments, namely a brief study of non-orthogonal multiple access (NOMA) using the single carrier with frequency domain equalization (SC-FDE) block transmission technique, evidencing its added value in terms of spectral efficiency. An introduction to the sixth generation of cellular communications (6G) is also provided. The insertion of 5G and 6G within the Fourth Industrial Revolution framework (also known as Industry 4.0) is also dealt with. Consisting of a change in paradigm, when compared to previous generations, 5G supports a myriad of new services based on the Internet of things (IoT) and on vehicle-to-vehicle (V2V) communications, supporting technologies such as autonomous driving, smart cities, and remote surgery. The new services provided by 5G are supported by new techniques, such as millimeter waves (mm-wave), in addition to traditional microwave communication, and by massive multiple-input multiple-output (m-MIMO) technology. These techniques were not employed in the fourth generation of cellular communications (4G). While 5G plays an important role in the initial implementation of the Fourth Industrial Revolution, 6G will address a number of new services such as virtual reality (VR), augmented reality (AR), holographic services, the advanced Internet of things (IoT), AI-infused applications, wireless brain–computer interaction (BCI), and mobility at higher speeds. The current research on systems beyond 5G indicates that these applications shall be supported by new MIMO techniques and make use of terahertz (THz) bands.

Keywords: 5G; 6G; NOMA; Industry 4.0; massive MIMO; mm-wave; IoT

1. Introduction

The Fourth Industrial Revolution considers the replacement of humans by machines in certain tasks, or the development of new or more efficient tasks. Making use of robots and artificial intelligence, the Fourth Industrial Revolution is already deeply modifying society and organizations [1]. As seen in Figure 1 the Fourth Industrial Revolution comprises other parameters besides robots and artificial intelligence [2]. Robots need to communicate and to sense the environment (using sensors and communications), for which the Internet of things (IoT) is employed (all over the Internet protocol (IP)). The IoT generates massive quantities of data (big data) that will be processed with artificial intelligence to generate knowledge; that is, the data supports human decision-making, as well as decisions made by the robots. [3]. These new technologies will originate a deep modification of society with great impact on the human way of life, as well as on the employment market [4].

Main Reference

- A. Cabeças, M. Marques da Silva, “Project Management in the Fourth Industrial Revolution”, TECHNO REVIEW, International Technology, Science and Society Review, 9(2), **11 January 2021**, pp. 79-96. https://doi.org/10.37467/gka-revtechno.v9.2804


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https://doi.org/XX.XXXXX/xxxxxxx

PROJECT MANAGEMENT IN THE FOURTH INDUSTRIAL REVOLUTION

ANTÓNIO CABEÇAS, MÁRIO MARQUES DA SILVA
Universidade Autónoma de Lisboa, Portugal

KEY WORDS

Fourth Industrial Revolution
Project Management
Green Project Management
Sustainability

ABSTRACT

The Fourth Industrial Revolution (also referred to as Industry 4.0) is driven by a massive utilization of new technologies, such as robots, artificial intelligence, Internet of Things (IoT), Big Data, Quantum Computing and Quantum Communications, replacing humans by machines in certain tasks or the development of new or more efficient tasks. The Fourth Industrial Revolution is originating huge modifications in society and organizations. Human adaptation to the new paradigm is required, as it will have a high impact on jobs and on the required skills. Project Management has evolved significatively in the last decades, privileging the fulfilment of the scope, time and cost of projects, based on the "triple constraint" classic model, and is still evolving due to the needs of new projects in the Fourth Industrial Revolution. This evolution has taken us to more complex models, with greater concern for the benefits that a project will bring to society and environment, which is a great challenge for Project Managers.

Agenda

1. The Digital Transformation
2. 5G Communications
3. Future Evolutions & NOMA
4. 6G Communications

Agenda

1. **The Digital Transformation**
2. 5G Communications
3. Future Evolutions & NOMA
4. 6G Communications

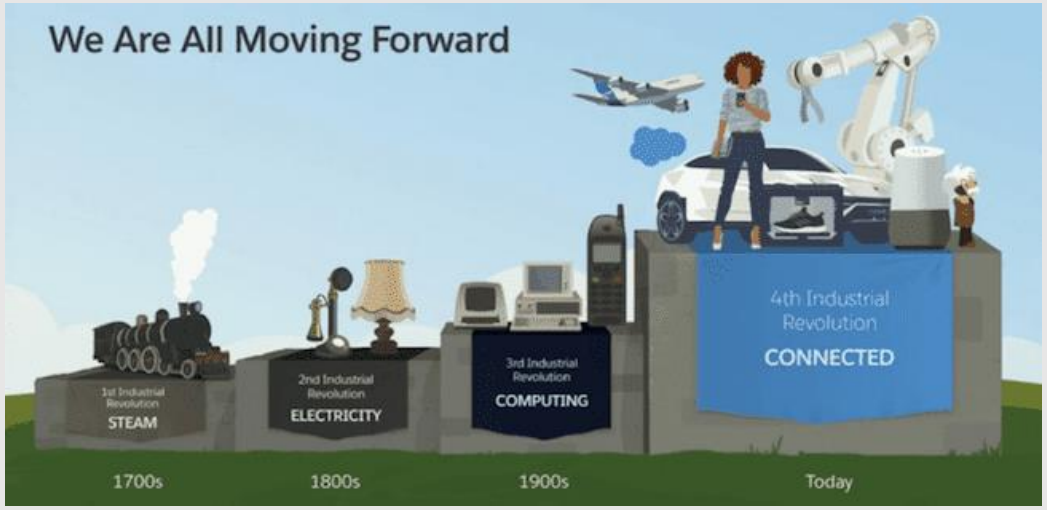
1. The Digital Transformation

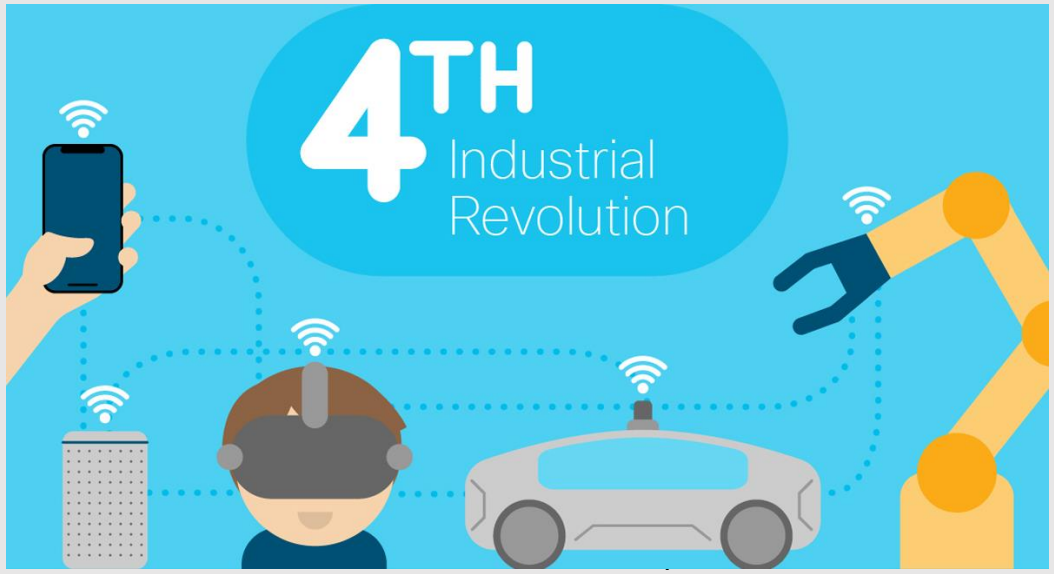
What is “Digital Transformation”?

- Analog Electronics (Fourties)
- Phase 1: Digital Electronics (Eighties)
- Phase 2: All-over-IP
- **Phase 3: Automation** || 4rd Industrial Revolution (ecology vs technology – strategy of EU) – *Knowledge Age*

3rd Industrial Revolution

Information Age





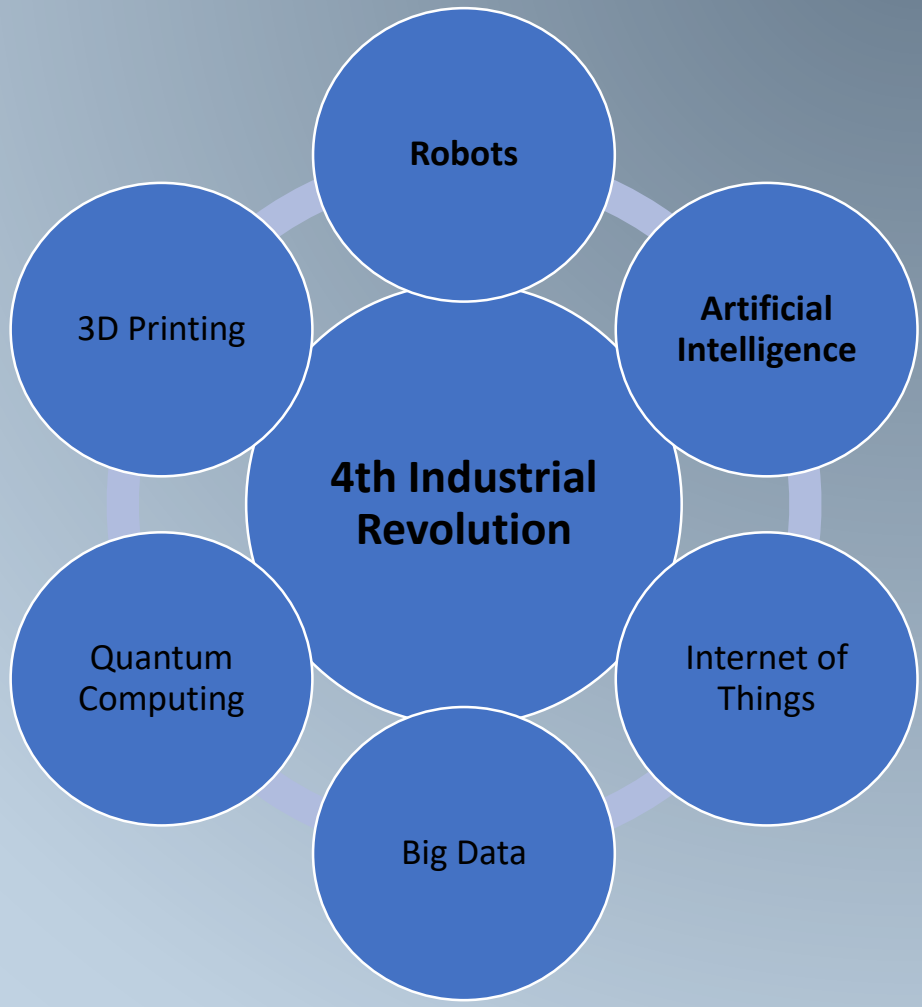
1. The Digital Transformation

The **4th Industrial Revolution** is characterized by the **massive use of Robots**, as well as **Artificial Intelligence, Big Data, Internet of Things, 3D Printing, Quantic Computing**.

More **eficiente use of the Resources**.

These technologies potentiate the **replacement of Humans by Robots** in diferente areas.

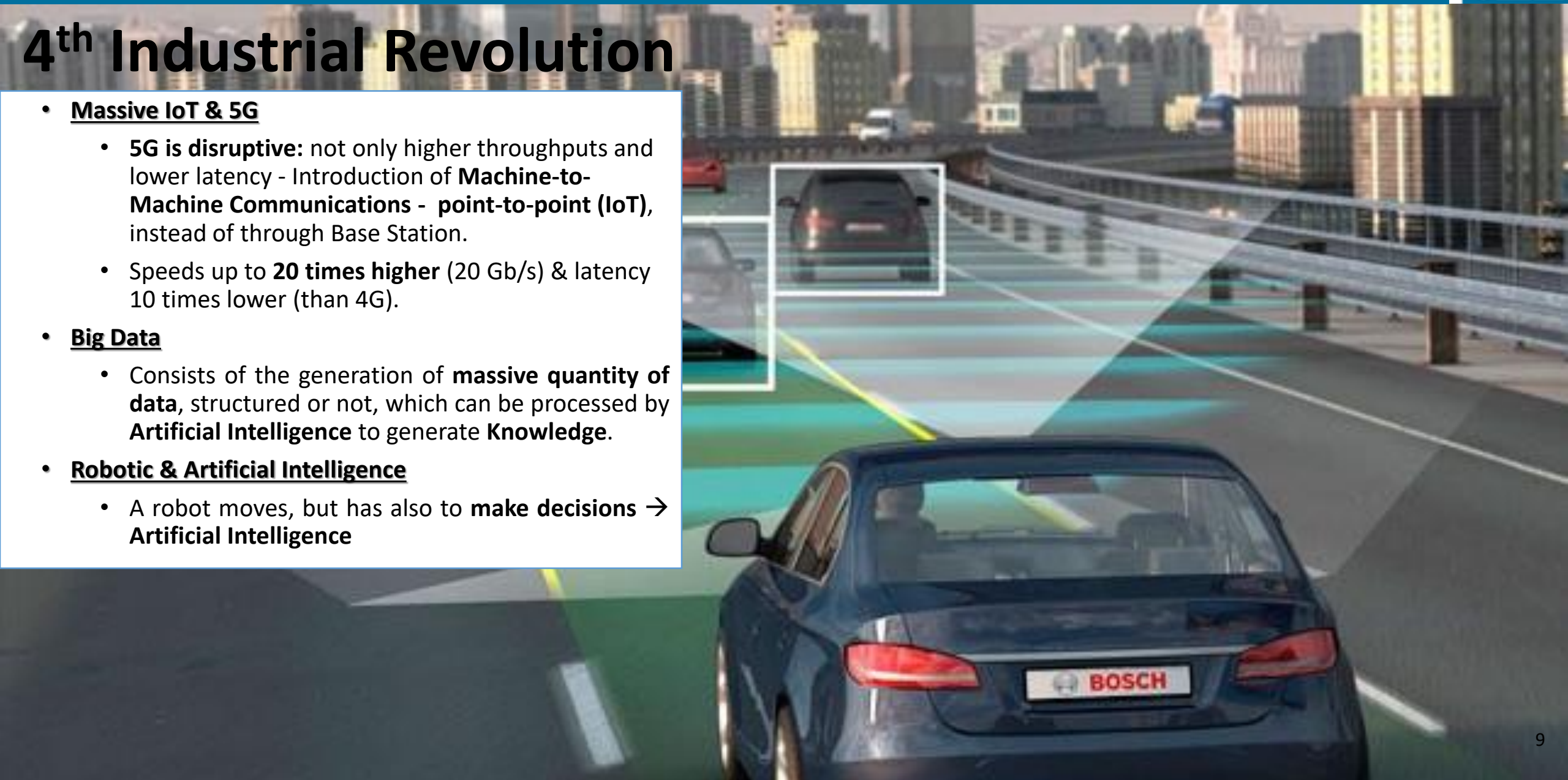
- **Some Jobs disappear, others are created**, requiring a great human **adaptation** to this new **Paradigm**.
- **Knowledge Age – routine decisions (or their support) are implemented by machines.**
  - **Scientific competencies, technical and humans**, critical spirit, emotional intelligence, abstract thinking, became more important assets than tangible goods.



1. The Digital Transformation

4th Industrial Revolution

- **Massive IoT & 5G**
  - **5G is disruptive:** not only higher throughputs and lower latency - Introduction of **Machine-to-Machine Communications - point-to-point (IoT)**, instead of through Base Station.
  - Speeds up to **20 times higher** (20 Gb/s) & latency 10 times lower (than 4G).
- **Big Data**
  - Consists of the generation of **massive quantity of data**, structured or not, which can be processed by **Artificial Intelligence** to generate **Knowledge**.
- **Robotic & Artificial Intelligence**
  - A robot moves, but has also to **make decisions** → **Artificial Intelligence**



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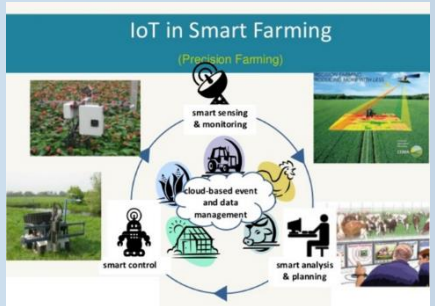
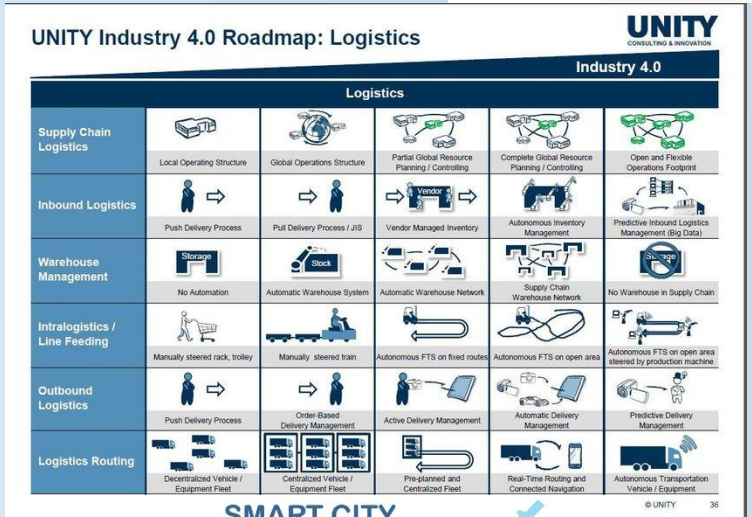
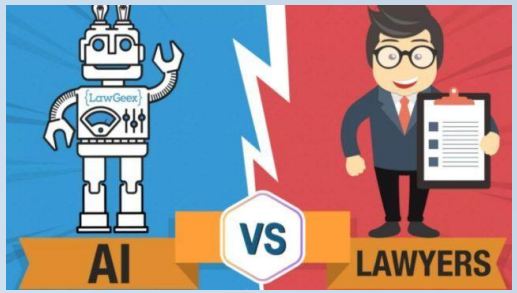


Under the Skin Surveillance





Higher dependency from Cybersecurity, but with new Cybersecurity Solution

1. The Digital Transformation

Employability Post 4th Industrial Revolution (OECD):

- Automation **affects mainly industry and agriculture**, but trade and services are also vulnerable to automation;
- About **14% of existing jobs in OECD are highly automated**, while **32% of jobs can suffer a main change** on the way they are done;
- Higher risk is associated to **jobs with higher level of routines, lower skills and lower incomes**;
- **Younger people who enter the jobs markets are more vulnerable to automation** than jobs developed by more experienced people;
- **Lower risk** is applicable to jobs related to **creation, maintenance and administration of technologies, creative intelligence, organizational manipulation, social intelligence**;
- **Not all the jobs technically automated will disappear**. Moreover, **other jobs will be created**, predicting that **employability will continue to rise**.

1. The Digital Transformation

Artificial Intelligence

- Invented in 1956 (R&D)
- Bursted recently by:
  - **Increase of Processing Power**
  - **Increase of Data (Big Data) that can be used by Learning Algorithms**
  - Development of areas such as Neural Networks or Reinforcement Learning
  - Data: “The Petrol of XXI Century”
  - Sub-delegation in Machines to Decide:
    - **Ethical Issue** (Send or not to Prison? Kill or not to kill?)
    - Machines should have “awareness” of “good or evil”
    - Algorithms to take into account the **Awareness / Impact of Decisions** (not only to decide), considering factors such as **Altruísm & Empathy** .
    - **Altruísm & Empathy** had determinant impact in the survival and prosperity of humans.

Environment vs Technology

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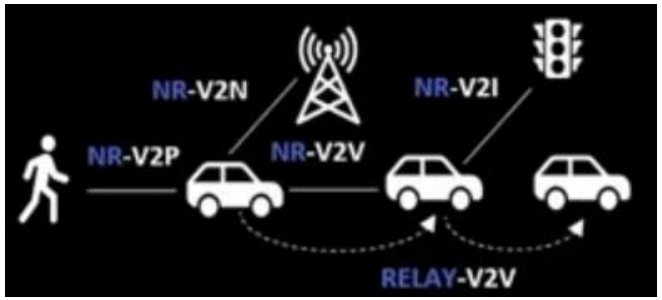
- **Tecnologies** link with **Climate & Environment**, because they allow:
  - M**ore eficiente use of resources**
  - Generation of **renewable energies**
- New Challenges, in terms of **Climate & Environment,** relate with **Mobility, Energy, Industry, Smart Cities**, etc.
- Digital Transformation → Energetic Transformation → Ecological Transformation
  - Telework, eLearning, mobility, robotics, renewable energies.
- Transformations bursted by COVID-19 crisis.

Autonomous Vehicles

- **IoT** and, specifically **5G, is importante in the transition to the 4th Industrial Rev.**, namely for the implementation of **Autonomous Driving**, with the option **V2V** of high data rate and low latency (uRLLC).
- V2X (V2V+V2I+V2P+V2N).
- 5G, namely using **millimeter Waves** of order 60 GHz in V2V, allows the rapid sharing of huge quantities of data, such as **position, direction, speed, point origin and destination, surrounding traffic**, etc.
- **Car-sharing** is bursted by **Autonomous Vehicles**
- **Future**: Use a car of others (shared) or buy and share (investment)
- **Advanced Security, more eficiente use of Resources, lower consumption (+green) & Remote Control of Vehicles**



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2. 5G Communications

3. Future Evolutions & NOMA

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2. 5G Communications

Evolution of Cellular Communications

1G (FDMA) – Analog (voice)

2G (TDMA) – GSM – Digital, Introduction of data and Roaming

3G (WCDMA) – UMTS – Internet Access

4G (OFDM) – VTC (static, hard to equalize)

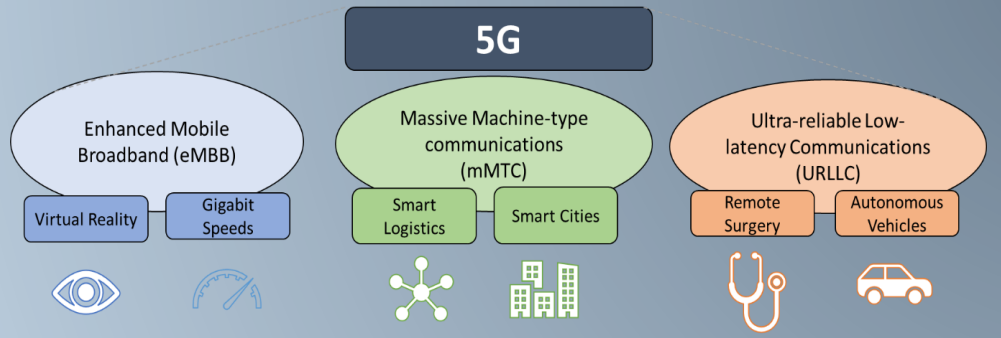
5G (OFDM) – Machine-machine Comm, VTC (on the move), Autonomous Driving, Point-to-point Comms (IoT), Virtual Reality, Artificial Intelligence, etc.

Leadership of European Standards in Cellular Networks

2. 5G Communications

- **Disruptive:** Massive IoT and disruptive services
- **Massive MIMO, Millimeter Waves & V2V**
- **Capacity:** Up to **15 Tbps/km2** Indoor environment.
- **Spectral Efficiency:**
  - Downlink 30bit/s/Hz - services require more in the downlink
  - Uplink 15bit/s/Hz - uplink is the bottleneck, due to lower Tx Power, and lower number of Tx antenas, …

- **Main Differences:** 3 Use Cases – Improved Resilience of services (Network Slicing, ex: Virtual Reality, autonomous vehicles & smart cities):
  - (1) Normal + Higher Speed;
  - (2) Terminal-to-Terminal → Internet of Things & Security (Tetra)
    - [2.1] Sensitive to delay and very reliable (Communication & Sensors) → Edge Computing
    - [2.2] Smart Cities) → one million devices per square kilometer, and each device should have up to 10 years of autonomy or more [ITU]



		4G - LTE	5G - NR	
eMBB	Peak Data Rates	DL: 1Gb/s	DL: 20 Gb/s	20x
	Experienced Data Rates	DL: 10 Mb/s	DL: 100 Mb/s	10x
	Mobility	350 Km/h	500 Km/h	1.5x
URLLC	Radio Latency	10 ms	1 ms	10x
mMTC	Connection Density	10K/Km^2	1000K/Km^2	100x

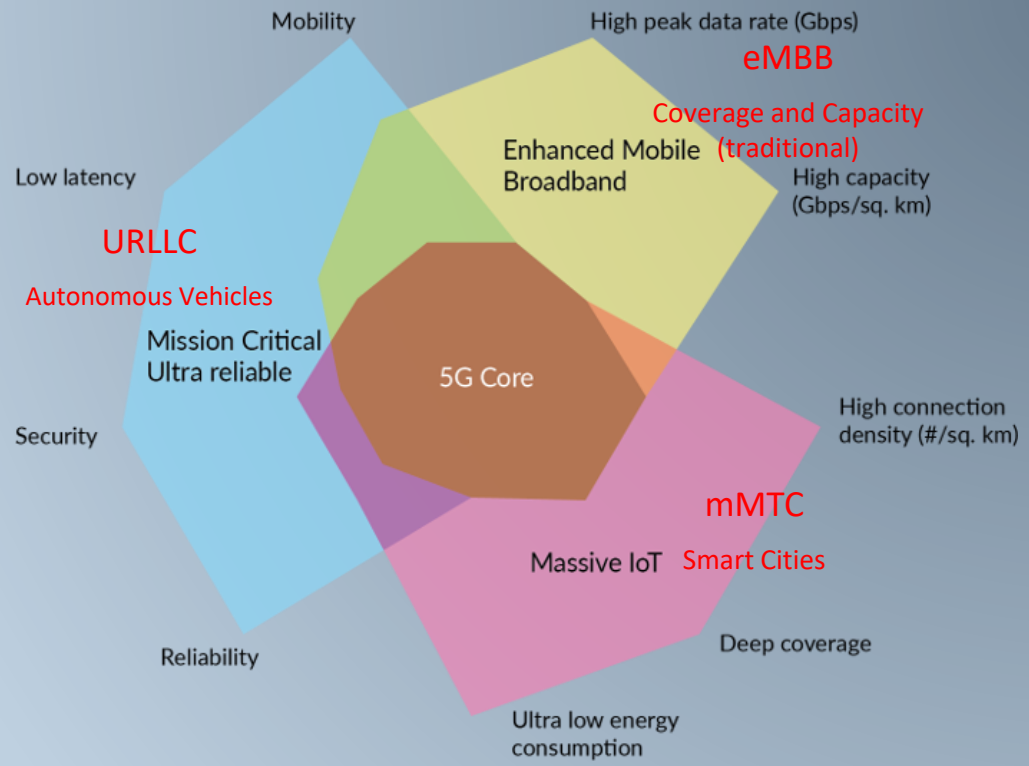
2. 5G Communications

Roadmap to 5G Communications

Phases of 3GPP Standardization for 5G:

1. [2018] **3GPP Release 15:** Improvement of 4G (eMBB), with increased speeds and IoT support, in Non-standalone (NSA) Mode & Standalone (SA) [Radio Access, Core & Transport Networks]
2. [2020] **3GPP release 16:** Implementation of the other two uses cases: mMTC & URLLC, new Air Interface (5G New Radio [SA]), Network Slicing (splitting services in different uses cases/QoS), etc -> Services Resilience.
3. [2022] **3GPP Release 17:** Several improments to 5G, as improvement to URLLC, Network Slicing, improved capacity, remote control of vehicles, etc.

- Phased Implementation and differentiated by different Countries and Operators.



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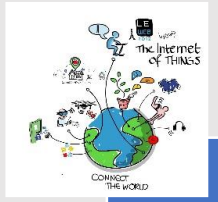
2. 5G Communications

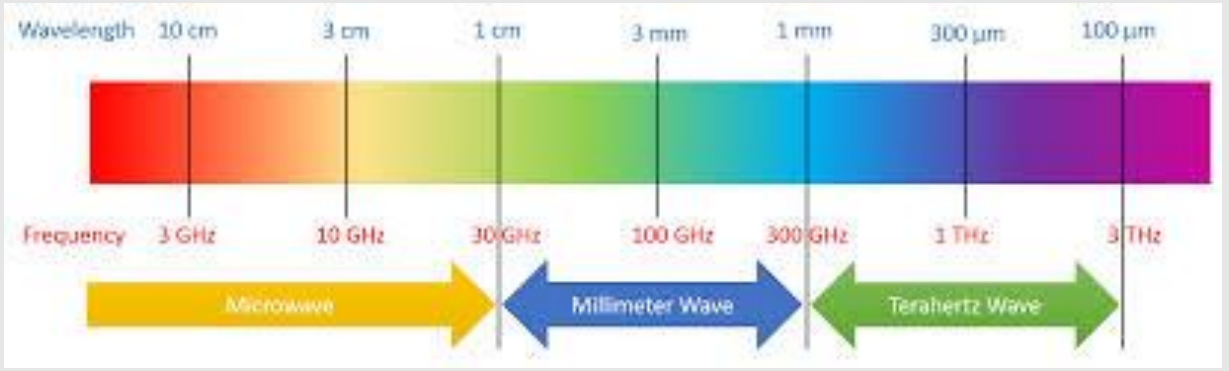
5G systems (2019/20) are aimed to achieve [as compared to 4G]:

- Higher throughputs (20 Gbps)
- Lower Latency (0,5-1 ms)
- Higher Capacity
- Better Spectral Efficiency

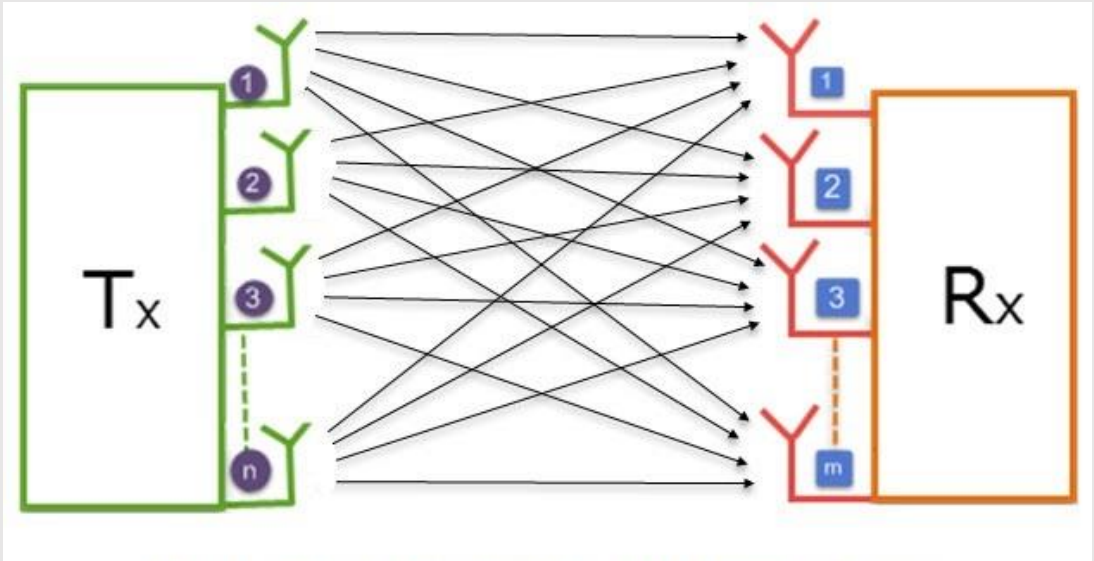


Support of new and Emergent Services:

- **VTC on the Move**
- Real-Time Communications
- Augmented Reality
- **Support of Self-Driving Cars**
- **Machine-to-machine communications** (IoT and Security Apps) – in addition to infrastructure centralized architecture



Millimeter Waves & Massive MIMO schemes involving several hundreds of antenna elements are expected to be central technologies for 5G systems



2. 5G Communications

5G – Security Aspects

- 5G connects billions of IoT devices. While PCs tend to be secure (Firewalls, anti-vírus, etc.), **such concern is normally not taken into account in the majority of IoT devices developed by external entities** but interconnected through 5G (WebCams, Smart TVs, Loudspeakers, refrigerators, smart lockers, Vehicles [autonomous]).
- These **devices act as an input** to 5G network, allowing reaching other devices.
- The extremely high number of 5G devices, with lower latencies and higher bandwidths, make monitorization of cyber attacks more difficult → Rethink Security.
- **What happens within the MANUFACTURER CLOUD?** Which kind of data is stored and for which purposes?
- Aspects of Transmission Security associated to 5G (special concern about millimeter waves).
- Human RF-EMF:
  - Recommendation ITU-T. K-Series, "5G technology and human exposure to RF EMF," 2017
  - International Commission on Non-Ionizing Radiation Protection. Guidelines for limiting exposure to Electromagnetic Fields (100 kHz to 300 GHz), Health Physics 2020, 118(5), pp.483-524
  - Electronic Communications Committee (ECC), within the European Conference of Postal and Telecommunications Administrations (CEPT), Recommendation (02)04 (https://docdb.cept.org/download/d9aa1d17-0482/REC0202.PDF)
  - 1999/519/EC: Council Recommendation of 12 July 1999 on the limitation of exposure of the general public to electromagnetic fields (0 Hz to 300 GHz) (https://op.europa.eu/en/publication-detail/-/publication/9509b04f-1df0-4221-bfa2-c7af77975556/language-en)

Agenda

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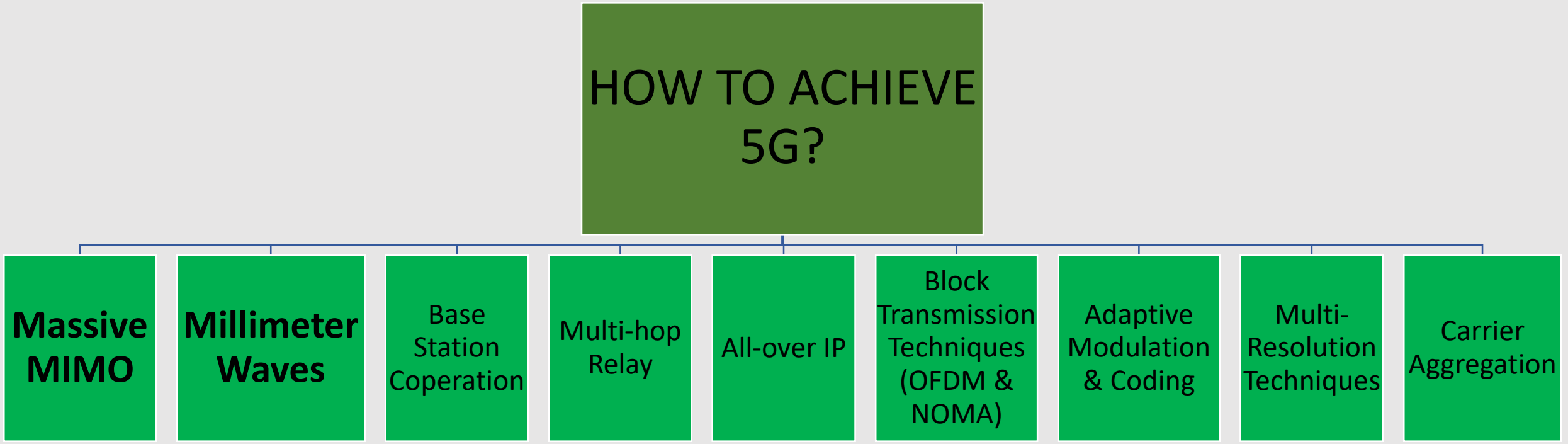
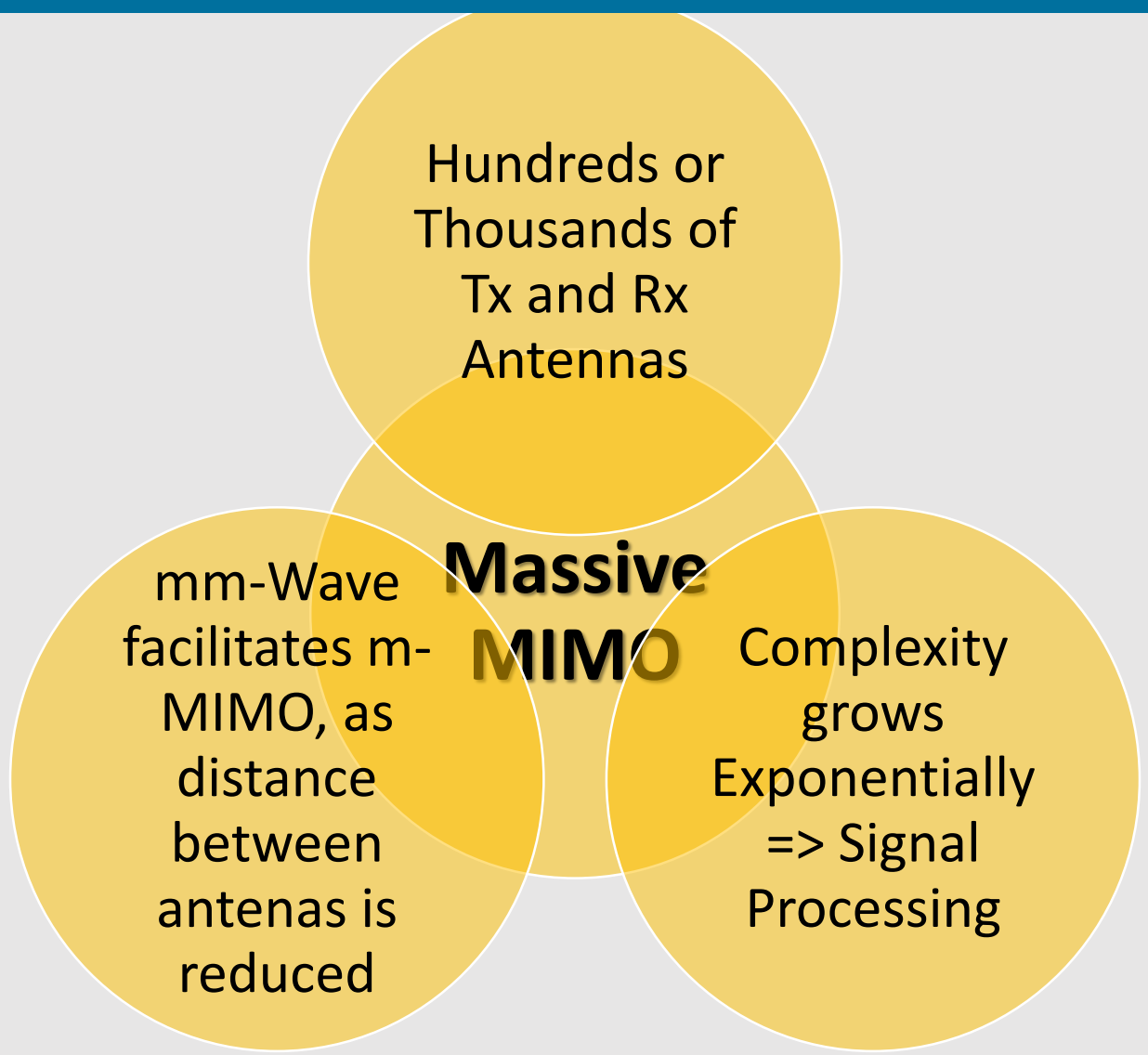
2. 5G Communications
3. **Future Evolutions & NOMA**
4. 6G Communications

3. Future Evolutions & NOMA



3. Future Evolutions & NOMA



3. Future Evolutions & NOMA

mm-Wave and Massive MIMO (Large Capacity Gains)

mm-Wave communications (30-300GHz - EHF) are expected to be a crucial part of 5G systems due to their **increased channel coherence bandwidth**, as compared to centimeter Wave. These systems use carrier frequencies of 30 - 70 GHz, where we have large unoccupied bandwidth. – E.g.: IEEE802.11ad uses 2.16 GHz of BW in **60 GHz band** (ISM band), supporting up to 7 Gbps.

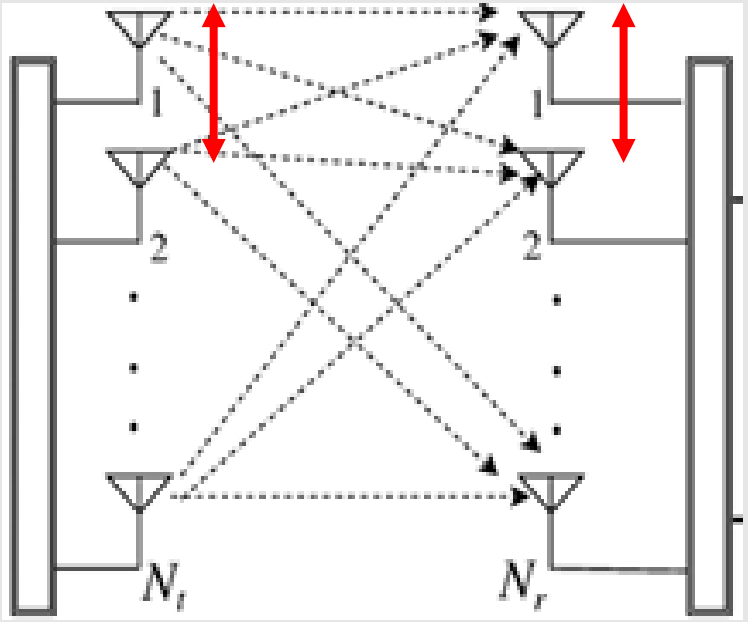
The **distance between antennas is reduced**, facilitating a higher number of antenna elements (Massive MIMO).

Moreover, antennas size are also reduced.

However, mm-Wave suffers from high path loss and rain and oxygen absorption.

Moreover, **higher frequencies present higher propagation path losses.**

5G will overcome this problem with m-MIMO techniques, such as beamforming.



$$c = \lambda \cdot f$$

$$\lambda = c / f$$

$$with \ f = 60\ GHz$$

$$\lambda = \frac{3\times10^{8}}{60\times10^{9}} = \frac{1}{200} = 0,005\ m = 5\ mm$$

3. Future Evolutions & NOMA

$$y'_n = y_{u,n} - \sum_{i=1}^{U'} \hat{y}_{i,n} ,$$

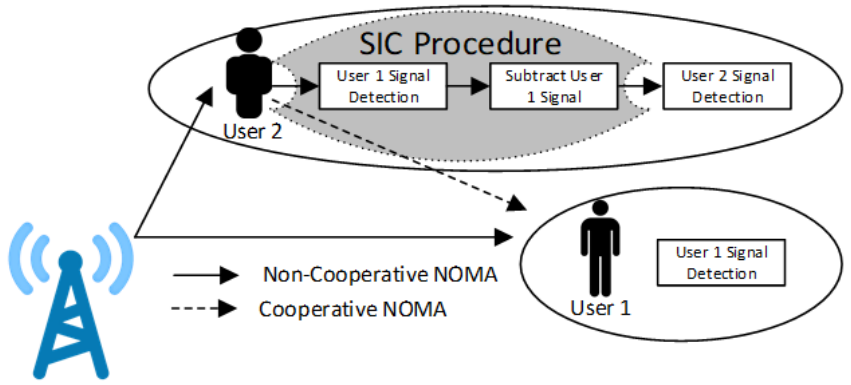


Figure 3 Illustration of NOMA and Cooperative NOMA

NOMA

Non-Orthogonal Multiple Access

- Due to the **near–far problem and power control, the received power of different users suffers variations**.
- By **exploiting different power levels, NOMA aims to serve multiple users using the same time and frequency**, leading to an **improved spectral efficiency** when compared with OFDMA.
- By employing SIC and detecting users' signals in descending order, NOMA can detect different users that **share the same time and frequency**.
- NOMA leads to a **higher channel capacity**, especially useful in scenarios with extremely high numbers of mobile terminals, such as in 5G use cases with **mMTC or URLLC**.

3. Future Evolutions & NOMA

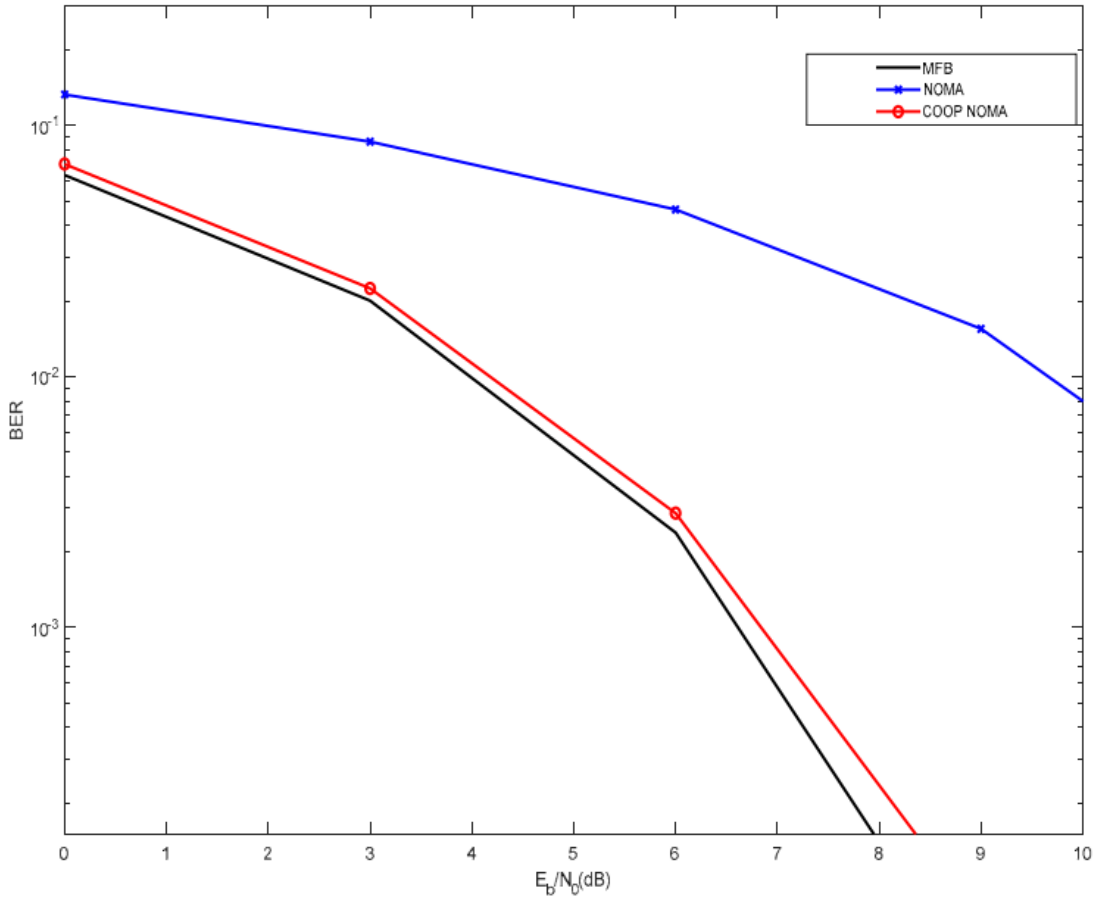
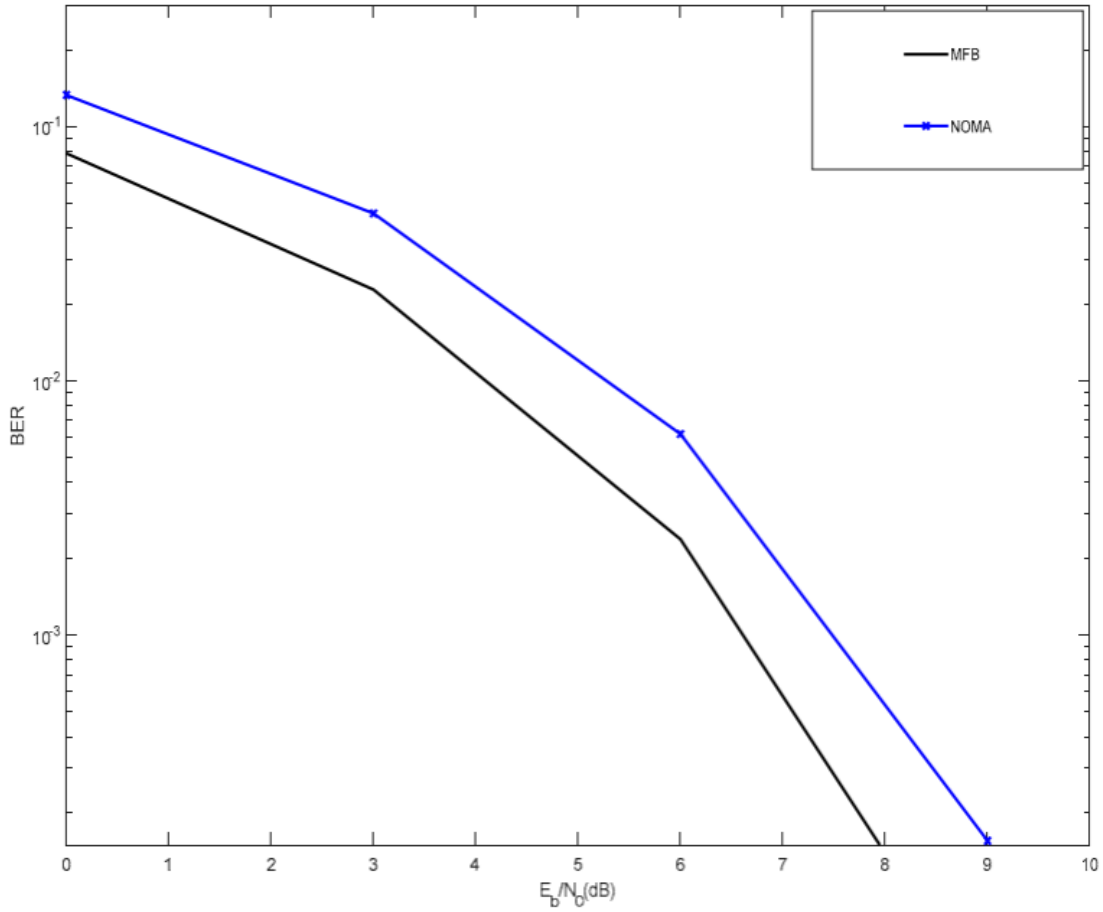


Figure 6. Results for two NOMA users with powers of (1, 0.5), with 4 × 32 MIMO.

NOMA Simulation Results

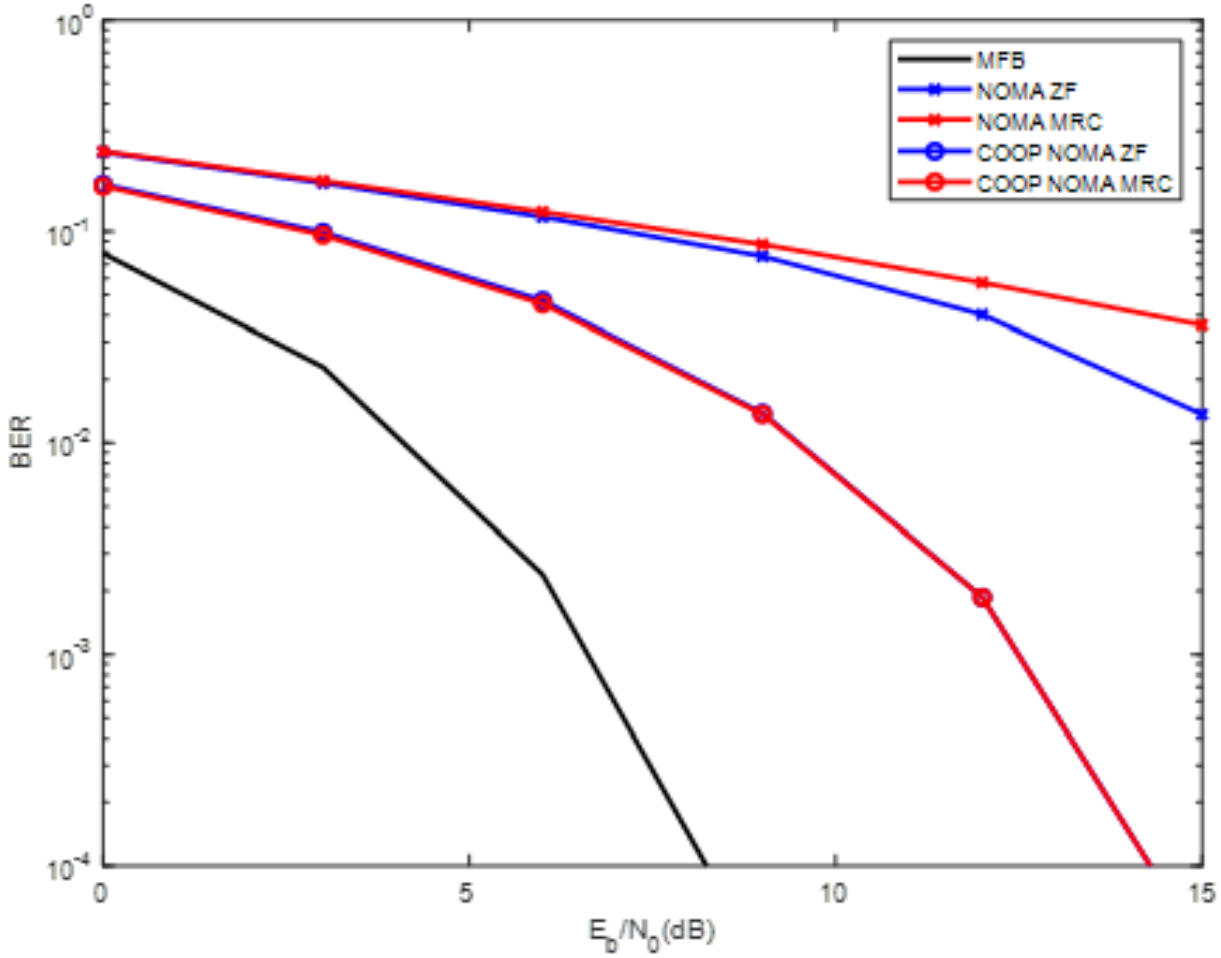
3. Future Evolutions & NOMA

NOMA Simulation Results



re 7. Results for two NOMA users with powers of (0.5, 1), with 4 × 32 N

3. Future Evolutions & NOMA



9 – Results for 2 NOMA users with powers [2 1 0.5 4 8], with 4x32 MIM

NOMA Simulation Results

3. Future Evolutions & NOMA

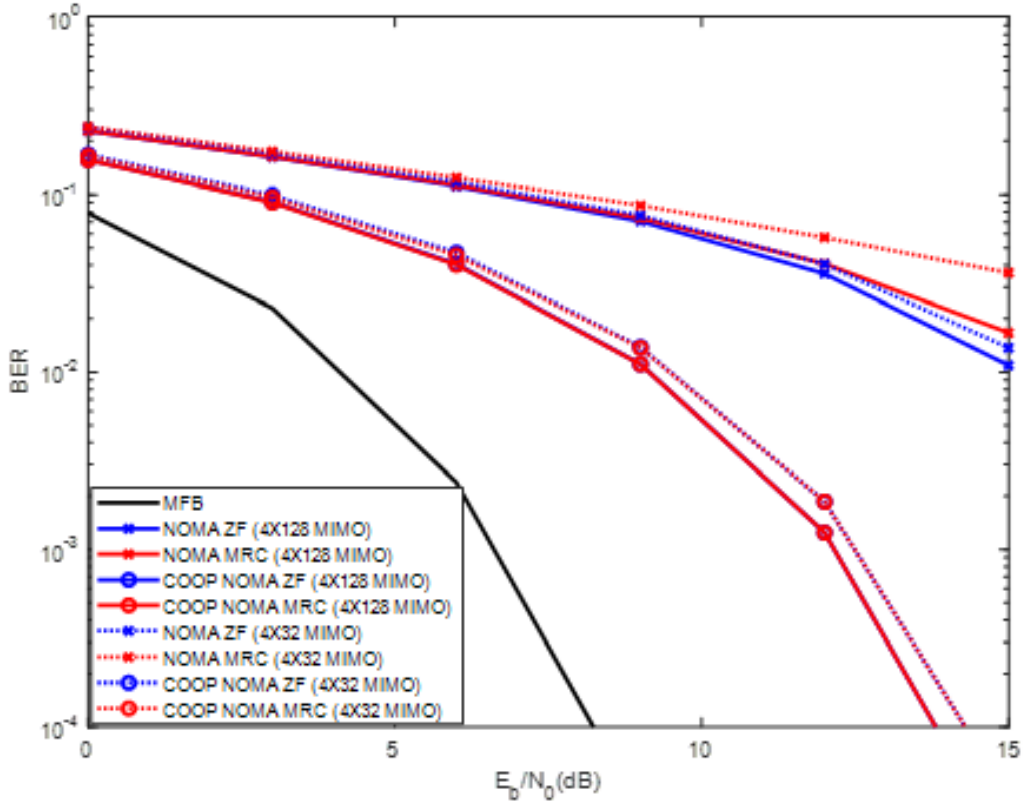


Figure 10 – Results for 5 NOMA users with powers [2 1 0.5 4 8], with 4x128 versus 4x32 MIMO

NOMA Simulation Results

Agenda

1. The Digital Transformation
2. 5G Communications
3. Future Evolutions & NOMA
4. **6G Communications**

4. 6G Communications

- 5G focus on the initial requirements of the 4th Industrial Revolution.
- 6G (2030) aims to improve such implementation.
- The digital society of 2030 and beyond, comprises more and more connected devices (IoT), including sensors, vehicles, aerial drones, and data.
- 6G aims to consider:
  - **Augmented Reality (AR) and Extended Reality (XR)**
  - **Artificial Intelligence (AI) infused applications**
  - Wireless Brain-Computer Interactions (BCI)
  - **Holographic services**
  - The integration of communications with localization, mapping and remote control
  - Emerging eHealth applications
  - **Improved autonomous vehicles**
  - More efficient support of IoT, namely smart cities and smart houses, supporting extremely high number of low-power devices
  - Support of flying vehicles and increased mobility speed

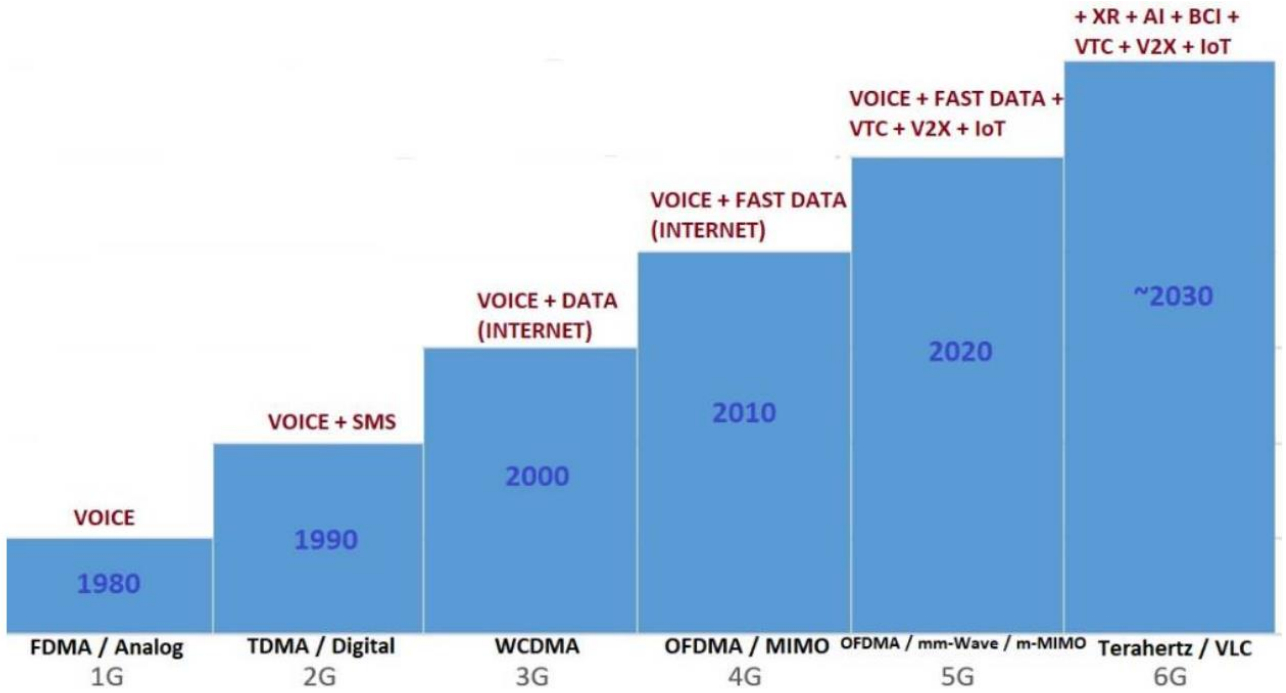


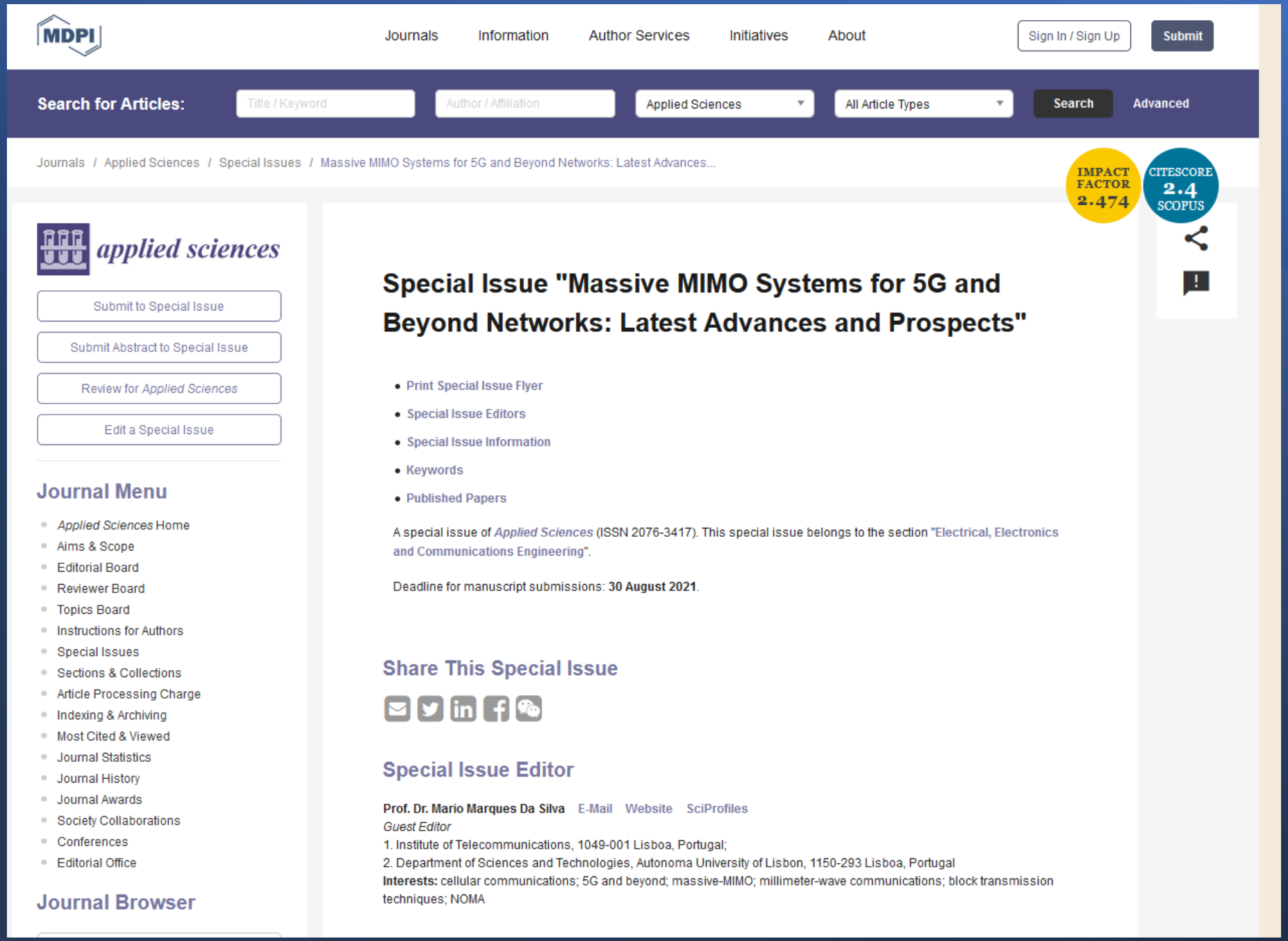
Figure 8. Evolution of cellular generations.

4. 6G Communications

Perspectives for 6G

- Some of the **foreseen requirements** for 6G include:
  - Nomadic peak data rate of at least 1 Tbps (100 times higher than 5G)
  - Mobile data rate of 1 Gbps (10 times higher than 5G)
  - Energy efficiency 10 to 100 times better than 5G
  - Spectral efficiency 5 to 10 times better than 5G
- While 5G requirements are achieved based on mm-Wave and m-MIMO, 6G must incorporate new concepts and frequency bands not yet considered for cellular communications.
  - This includes **Visible Light Communications** (VLC) and **Terahertz bands** (100 GHz – 10 THz).

Special Issue



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Prof. Dr. Mario Marques Da Silva E-Mail Website SciProfiles
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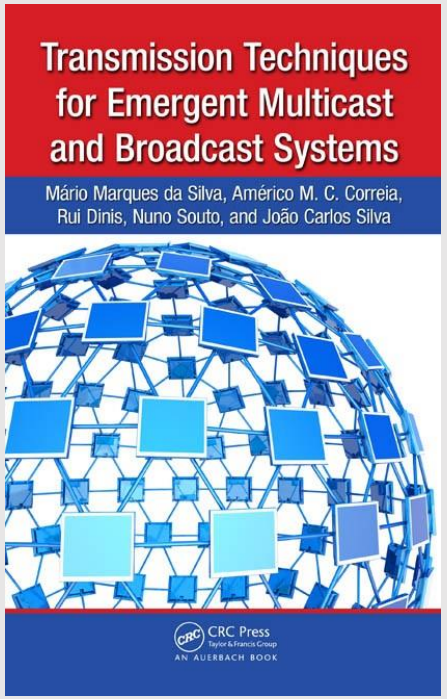
1. Institute of Telecommunications, 1049-001 Lisboa, Portugal;
2. Department of Sciences and Technologies, Autonoma University of Lisbon, 1150-293 Lisboa, Portugal
Interests: cellular communications; 5G and beyond; massive-MIMO; millimeter-wave communications; block transmission techniques; NOMA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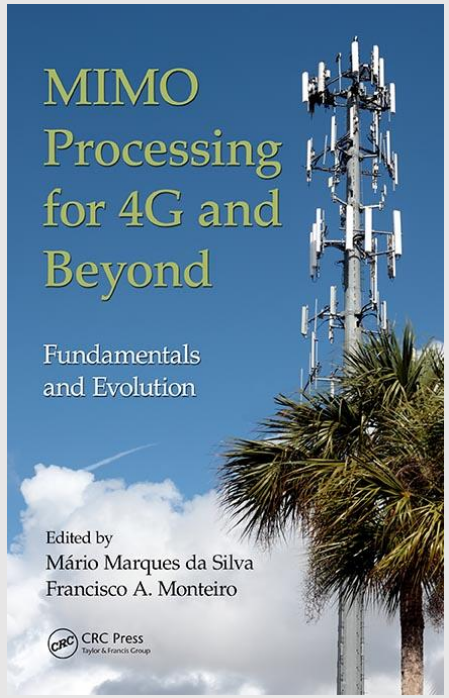
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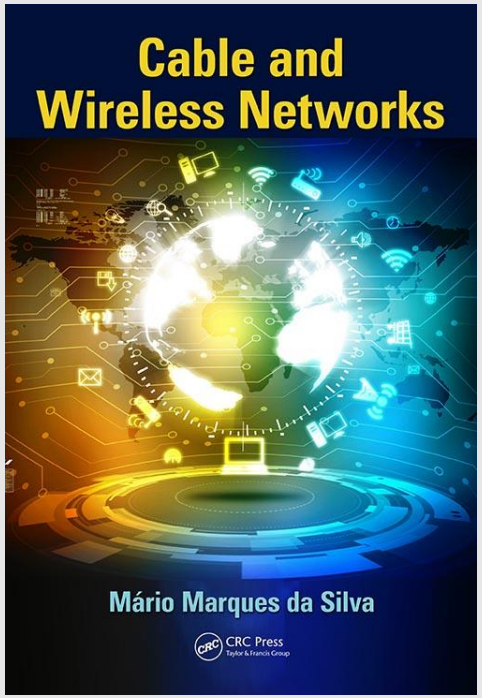
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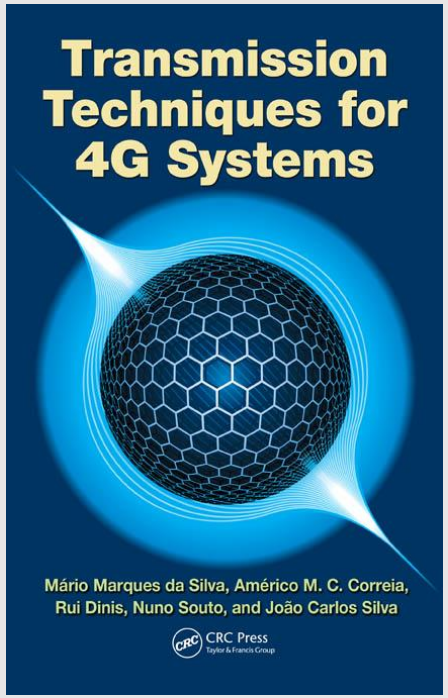
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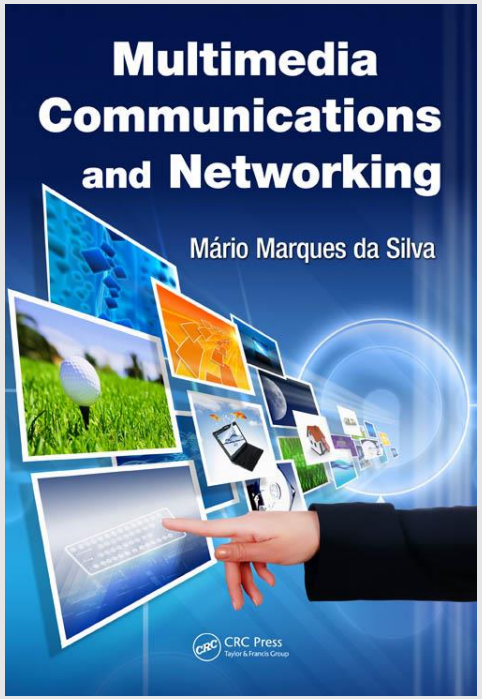
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