5G for digital healthcare

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Dr. Esteve Hassan

Professor and Canada Industrial Research Chair in Interoperability Sensor Systems for IIoT Applications, Mohawk College, Hamilton (ON)

- 10 years of applied research experience in the design, development, and implementation of wireless sensor devices and smart embedded real-time systems.
- Master of Science (MSc), Master of Engineering (MEng) in Electronic and Computer Engineering and Ph.D. in Biomedical Electronic Engineering.
- Contributes to the development of sustainable IIoT technologies, from platform development to deployment in fields such as transportation and automotive, energy and smart cities, advanced manufacturing, healthcare and wearable devices.
- In 2011, joined Ryerson University (Toronto) as Research Fellow and teaching staff member at the Aerospace Engineering Department, and was nominated by Ryerson University for the prestigious Banting Fellowship. Previously worked at Tyndall National Institute, University College Cork (Ireland), University of Limerick (Ireland), and Brandon University (MB).

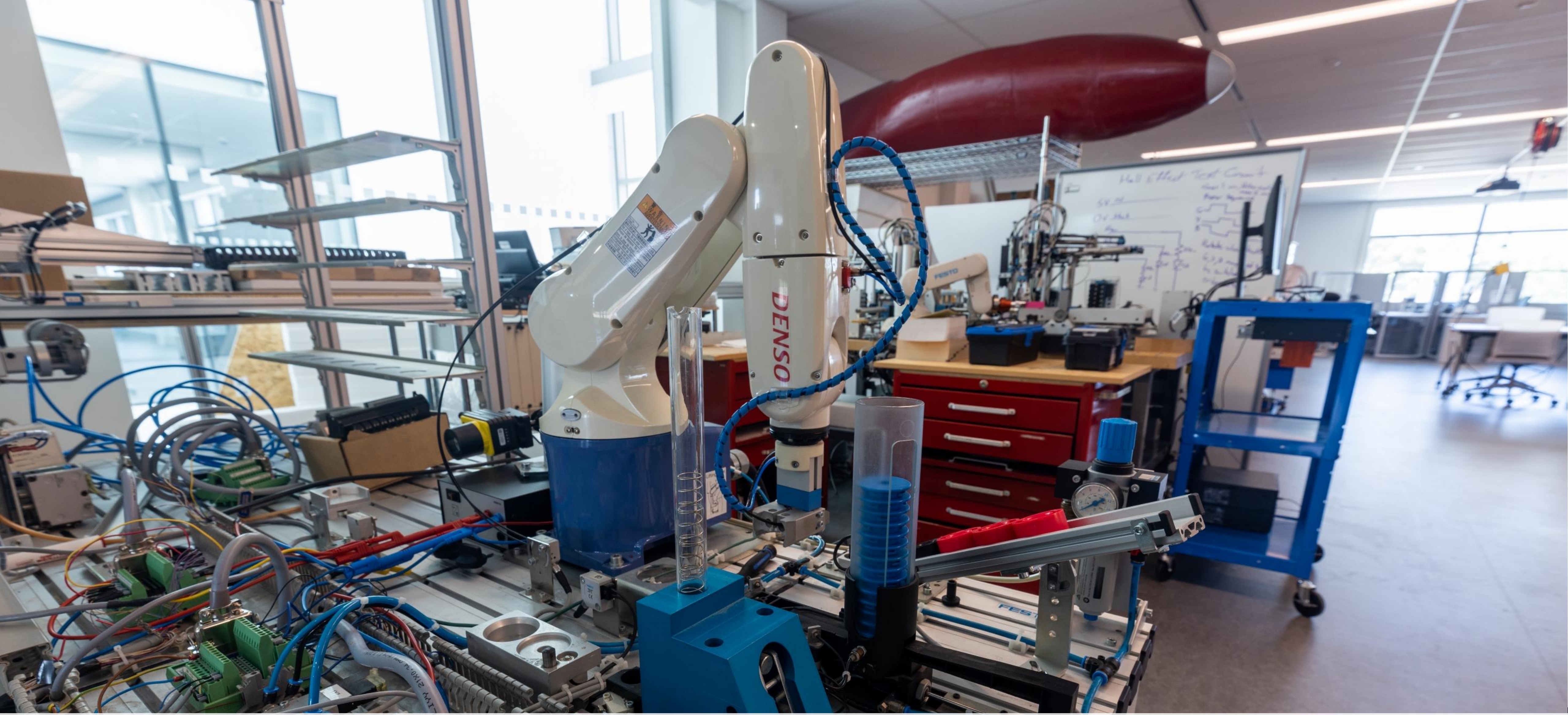
Who We Are and What We Do

- We work with industry partners on applied research projects providing technical solutions in IoT related applications
- Build new IIoT platforms with novel features to meet the needs of industry partners
- Identify primary research goals as driven by current and emerging industry needs
- Support new and existing partners to explore and adopt sensor systems technologies
- Develop curriculum to enhance skills and training opportunities.
- We pair students on joint projects with some of our industry partners, such as IBM, Trucksail Inc, and Handling Specialty to help on design and development of their new challenging projects

Real-World Applications

- Industrial Solutions (I/O Modules and Smart Sensors, machine learning and predictive maintenance, machine vision sensor interfaces).
- Automotive and truck safety industry.
- Predictive analytics in aviation and agriculture.
- Health monitoring and wearable devices.
- Energy Harvesting solutions.

The Sensor Systems and Internet of Things (IOT) Lab is a centre of expertise for industrial IoT research.



Fully equipped with leading IoT hardware and software, the lab is used by the research team to develop, validate and test IIoT hardware and software.

Affiliated Labs

The Sensor Systems and Internet of Things (IoT) research team has access to the IDEAWORKS facilities available at:

- ❖ Additive Manufacturing Innovation Centre (AMIC)
- ❖ Centre for Climate Change Management (CCCM)
- ❖ Cybersecurity Lab
- ❖ Energy & Power Innovation Centre (EPIC)
- ❖ Medical Technologies Innovation Centre (MTIC)
- ❖ mHealth & eHealth Development & Innovation Centre (MEDIC)

Industry Partnerships

IBM

SIEMENS

CAREGO
the innovators

gapwireless

KEYSIGHT
TECHNOLOGIES

QUAENET

BRIGADE

M TECH HUB

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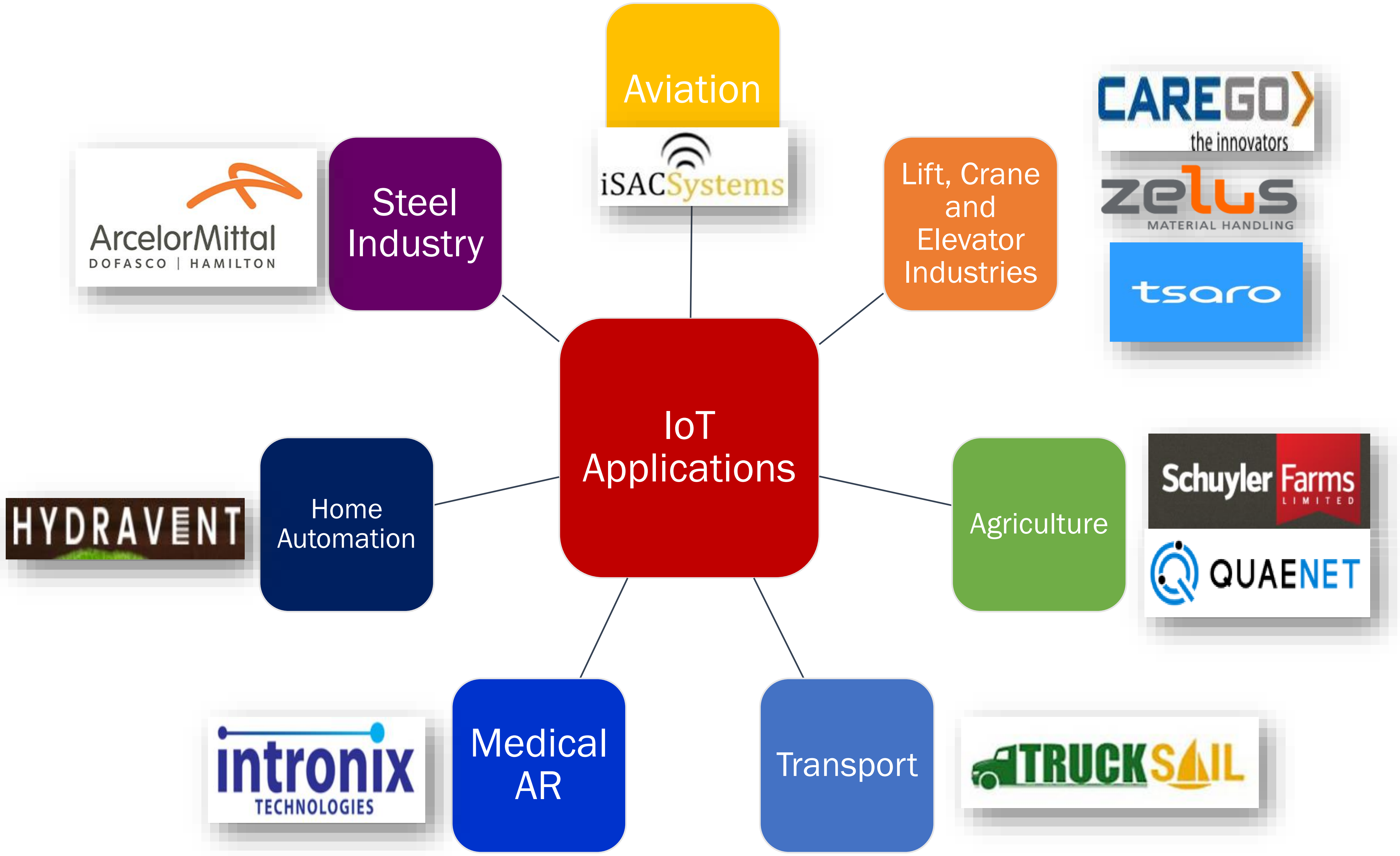
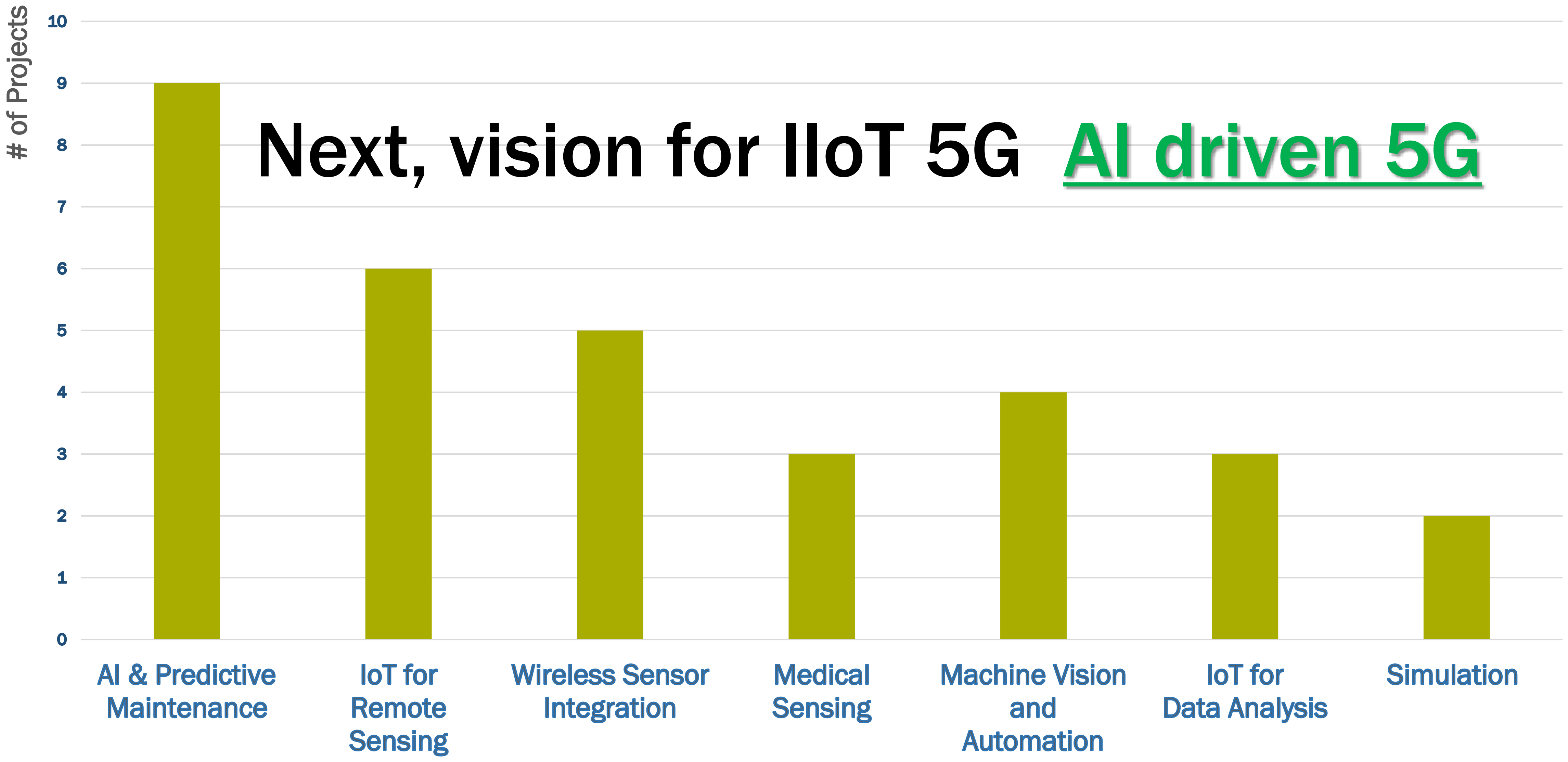
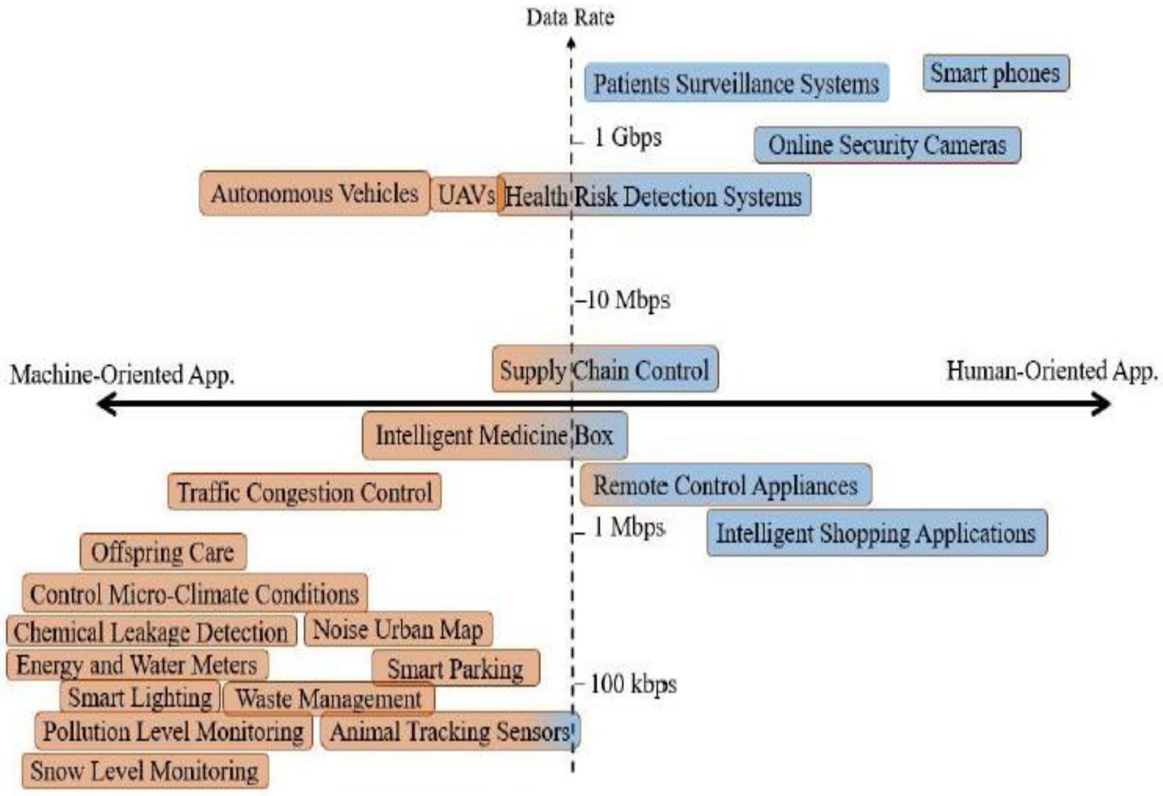

IoT Applications
Aviation
iSACSystems
Steel Industry
ArcelorMittal
DOFASCO | HAMILTON
Lift, Crane and Elevator Industries
CAREGO the innovators
zelus MATERIAL HANDLING
tsaro
Home Automation
HYDRAVENT
Agriculture
Schuyler Farms LIMITED
QUAENET
Medical AR
intronix TECHNOLOGIES
Transport
TRUCKSAIL

IoT Emerging Project Areas 2019-2021



Next, vision for IIoT 5G **<u>AI driven 5G</u>**



Classification of IoT applications based on end-user-type and data rate

Main Specifications differences between 4G-LTE and 5G

	4G LTE/LTE-A	5G
Round trip latency	15 ms	1 ms
Peak data rate	1Gbps	20 Gbps
Available spectrum	3 GHz	30 GHz
Channel Bandwidth	20 MHz	100 MHz below 6 GHz 400 MHz above 6GHz
Frequency Band	600 MHz – 5.925 GHz	600 MHz – 80 GHz

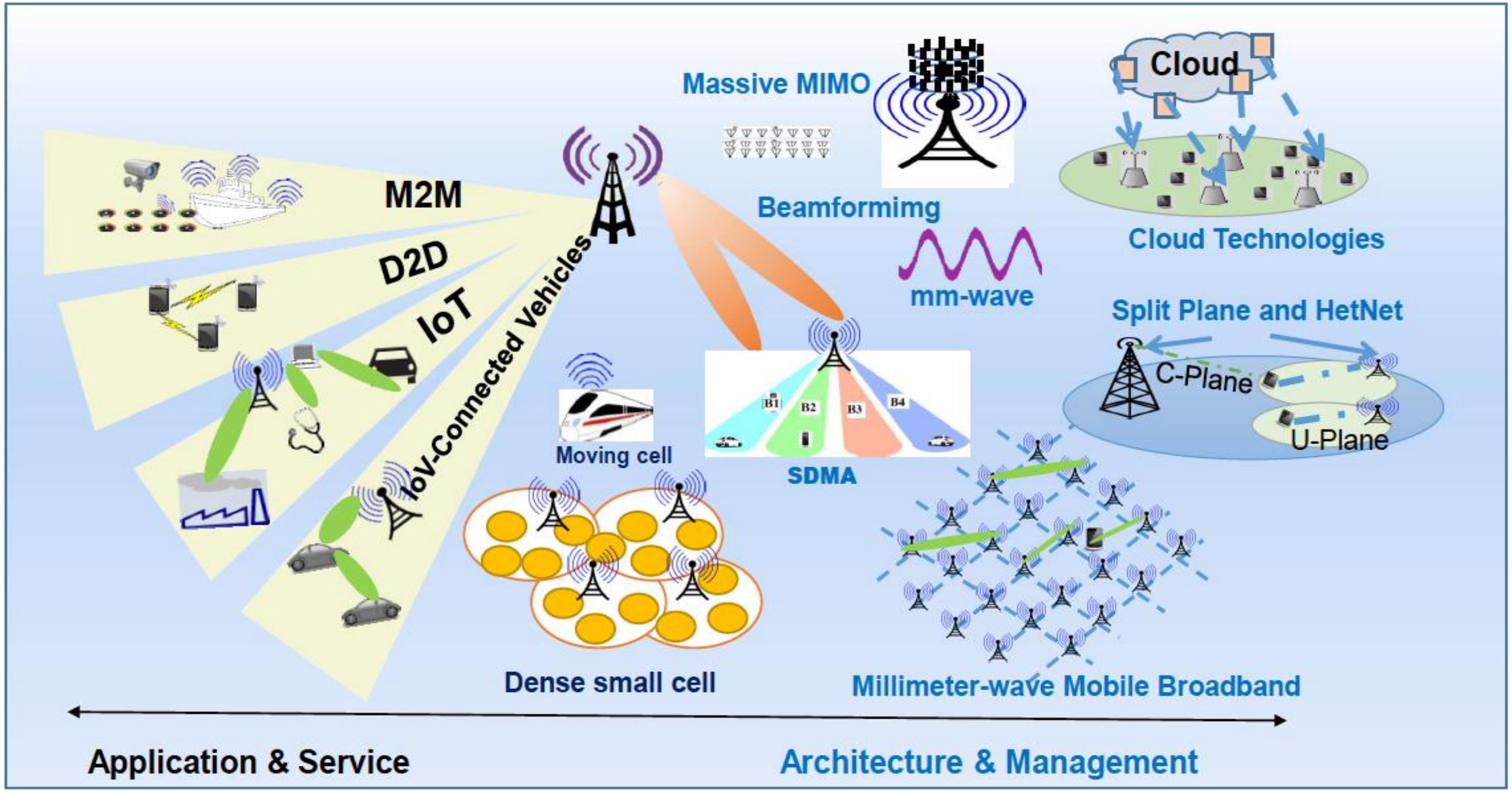
AI driven use cases for 5G-IoT Networks

- Big data processing enhancement
- Expanding the horizon of healthcare
- Intelligent Networking
- Smart transportation systems
- Utilizing massive data of interconnected IoT devices.

Challenges

- Can 5G find the balance between ease of connectivity and security?
- Is 5G flexible enough to facilitate different types of network configuration?
- How will 5G cater higher density of connected devices?

5G Architecture



5G Performances

- Peak data rate ≥ 10Gbps,
- Minimum guaranteed user data rate ≥ 100Mbps,
- Connection density ≥ 1M connections/ km^2,
- Traffic density ≥ 10 Tbps/ km^2 ,
- Radio latency ≤ 1 ms,
- E2E latency ≤ 10 ms,
- Mobility up to 500km/h.

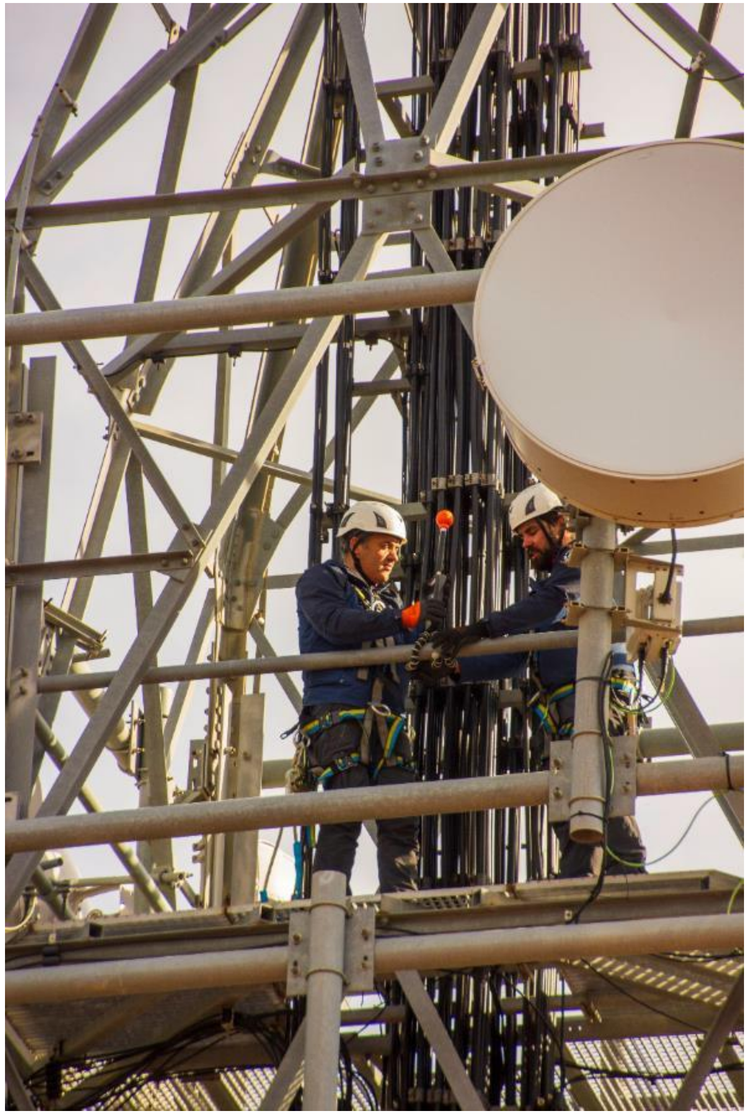
Main characteristics of 5G

5G networks can be envisioned as Soft, Green, and Super Fast:

- Soft: to bring agility into the implementation of each network element from the core network to access network, as well as the building blocks of air interface,
- Green: to heighten efficiency in utilization of any resources supporting wireless communication from the network side to the user terminal side,
- Super Fast: to approach immersive and tactile user experience in various anticipated extreme scenarios.

New advanced services

- Connected Cars-automotive
- e-Health
- Machine-to-machine (M2M)
- Smart-energy



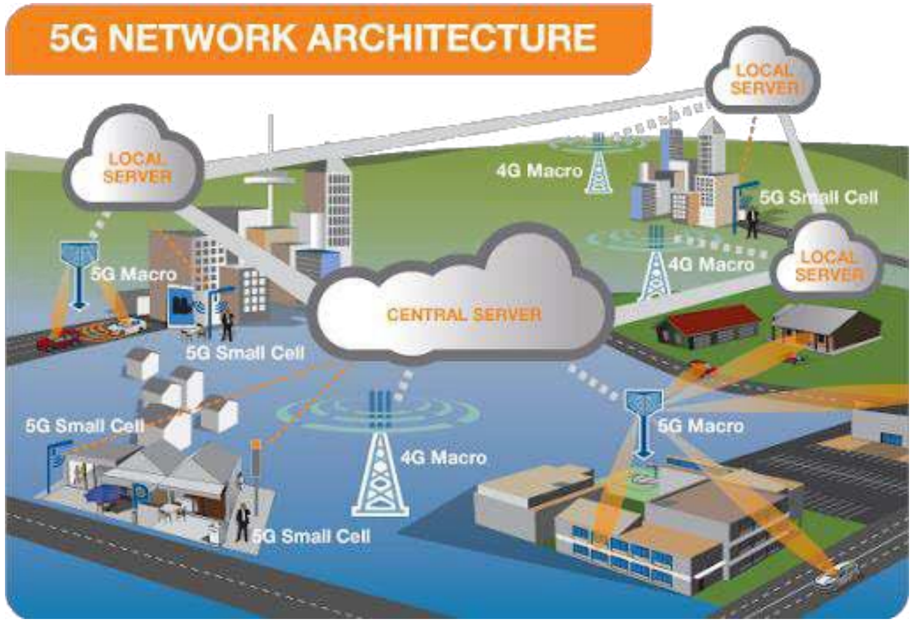

5G
READY
WAVECONTROL
WaveMon
SMP2
4.08

5G NR – Health concerns

With the 5G deployment plans, numerous concerns have arisen regarding RF safety.

Main reasons are:

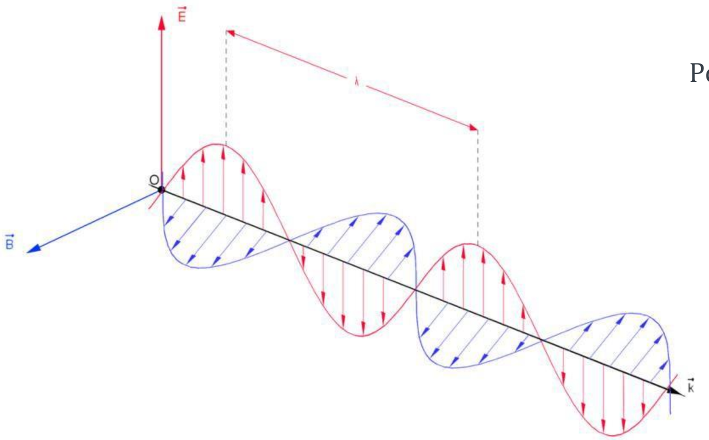
- Higher frequency bands usage
- Higher number of antennas
- higher maximum power



Source: www.emfexplained.info

EMF interaction with the human body

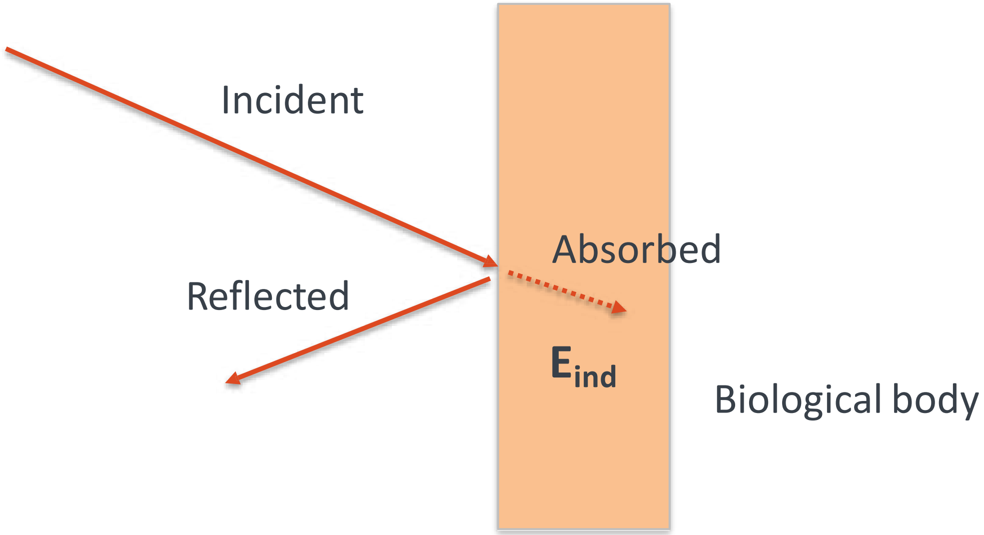
Radiofrequency EMFs transfer power from its source



$$\text{Power} = \frac{\text{Energy (Joules, J)}}{\text{Unit time } (s)} = \text{W}$$

Some of the power is reflected and some is absorbed.

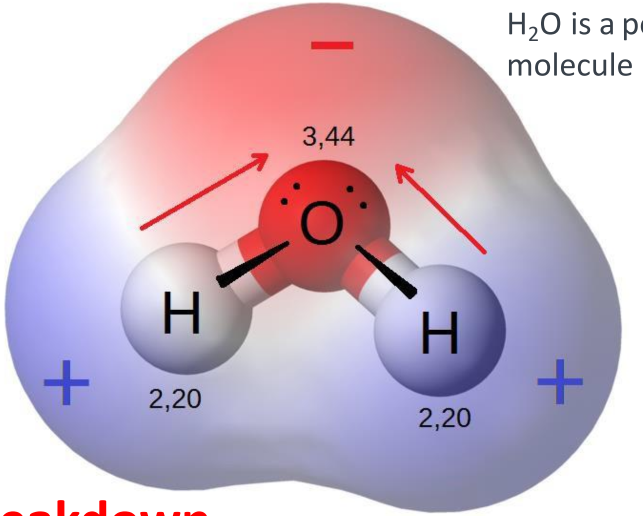
The main component of the RF EMF that affects the body is the induced electric field inside the body, E_{ind} (V/m)



EMF Relevant biological Interaction mechanisms

Interaction mechanism 1: **Heat**

E_{ind} exerts a force on both polar molecules (mainly water molecules) and free moving charged particles such as electrons and ions, forcing them to move, and converting the energy to **heat**.



H_2O is a polar molecule

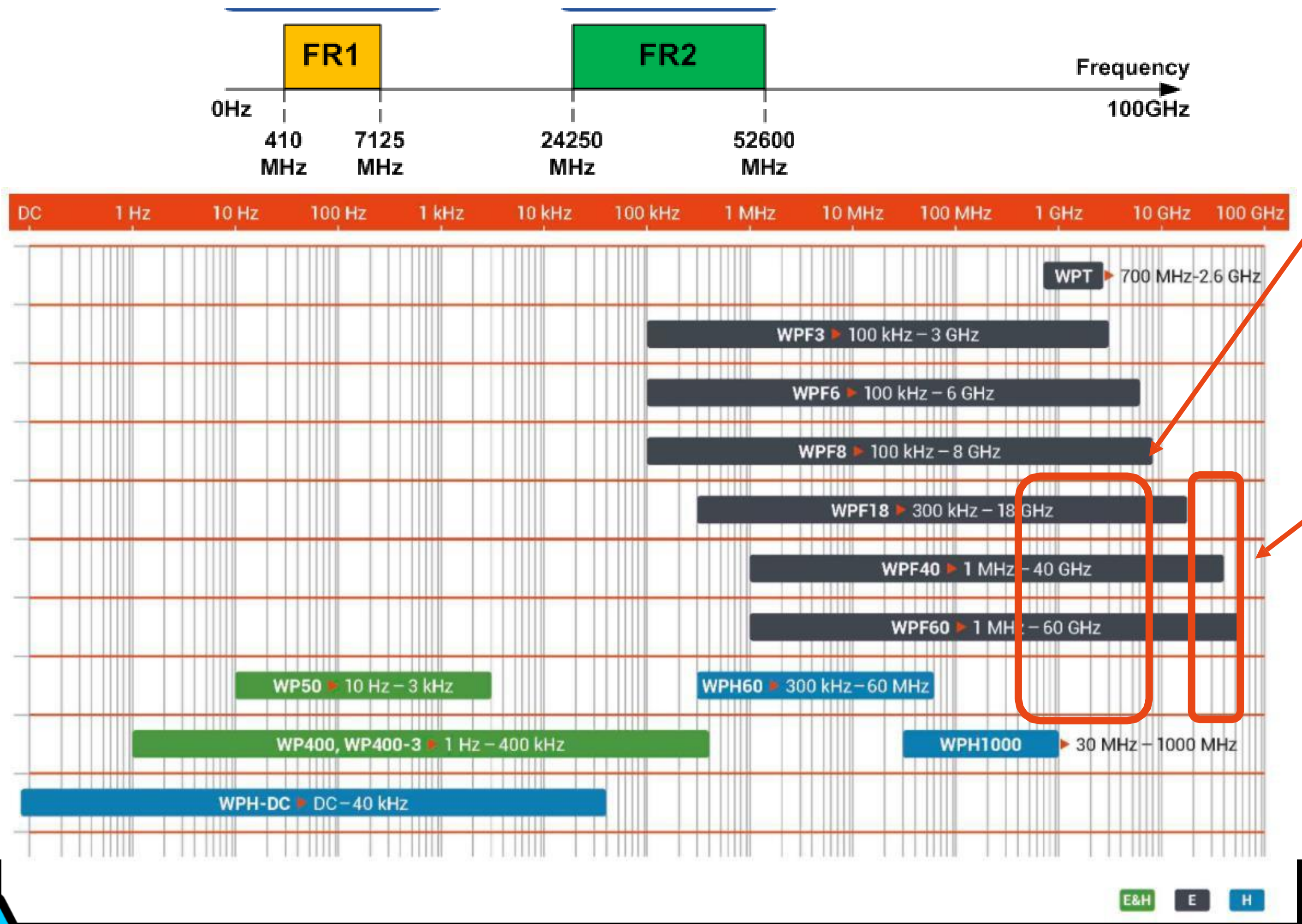
Source: Riccardo Rovinetti (creative commons)

Interaction mechanism 2: **Nerve stimulation and dielectric breakdown**

If the E_{ind} is below about 10 MHz and strong enough, it can exert electrical forces that are sufficient to **stimulate nerves**, and

If the E_{ind} is strong and brief enough (pulsed low frequency EMFs), it can cause **dielectric breakdown** of biological membranes.

Frequency ranges



Frequency Range 1 (FR1) (Sub 6 GHz)

- From 410 MHz to 7 125 MHz.
- Maximum bandwidth: 100 MHz.

Frequency Range 2 (FR2) (mmWave)

- From 24 GHz to 52.6 GHz.
- Maximum bandwidth: 400 MHz.

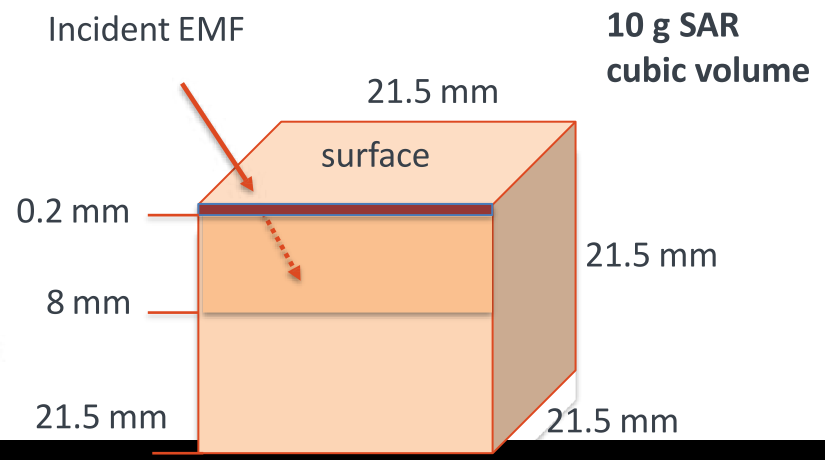
EMF penetration depth

Frequency range				relevant physical quantity
FR1	→	EMF energy can deeply penetrate the body	→	**SAR (W/kg)** Specific energy Absorption Rate
FR2	→	EMF energy is deposited mainly in superficial tissues	→	**S_{ab} (W/m²)** Absorbed power density

At 6 GHz, most of the absorbed power is within the cutaneous tissue, so within the upper half of a 10-g SAR cubic volume.

For example, 86% of the power:

- at 300 GHz is absorbed within 0.2 mm
- at 6 GHz is absorbed within 8 mm



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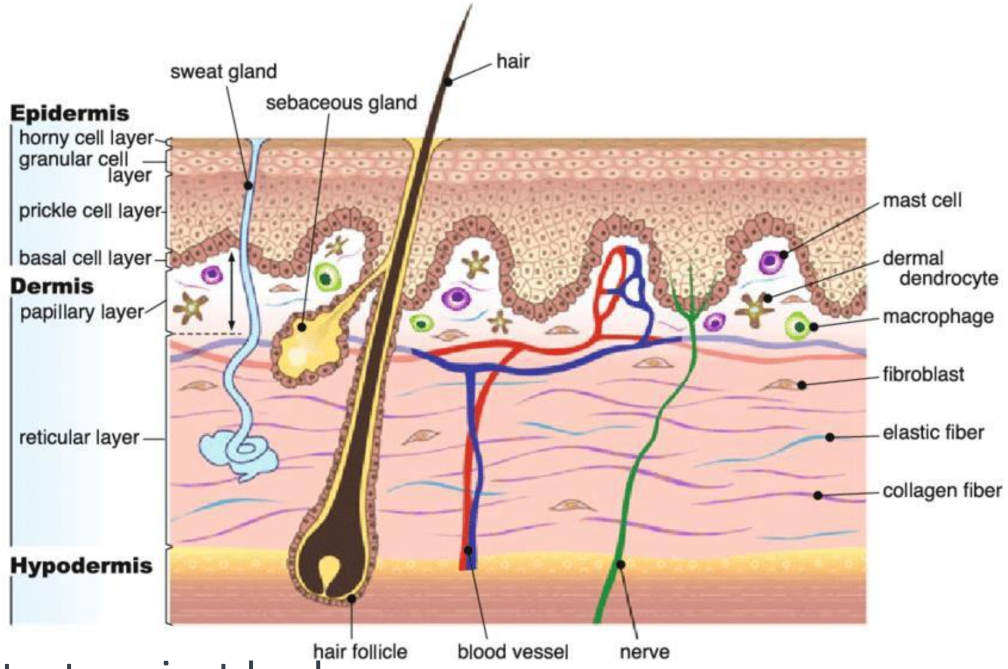
EMF penetration depth

As EMF frequency increases, exposure of the body and the resultant heating becomes more superficial, and above about 6 GHz this heating occurs predominantly within the skin.

However, research has shown that high EMF frequencies cause heating within the dermis, and the vascular network can transport this heat deep within the body, which can increase body core temperature beyond the 1°C.



So, it is ICNIRP's opinion that it is still appropriate to also protect against body core temperature rise above 6 GHz.

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5G EMF Assessment

- ✓ Beam Forming
- ✓ Beam steering
- ✓ Coexisting Technologies: 3G, 4G, FM, TV, etc.

EMF exposure challenges:

- To force 5G beams
- To assess the total exposure

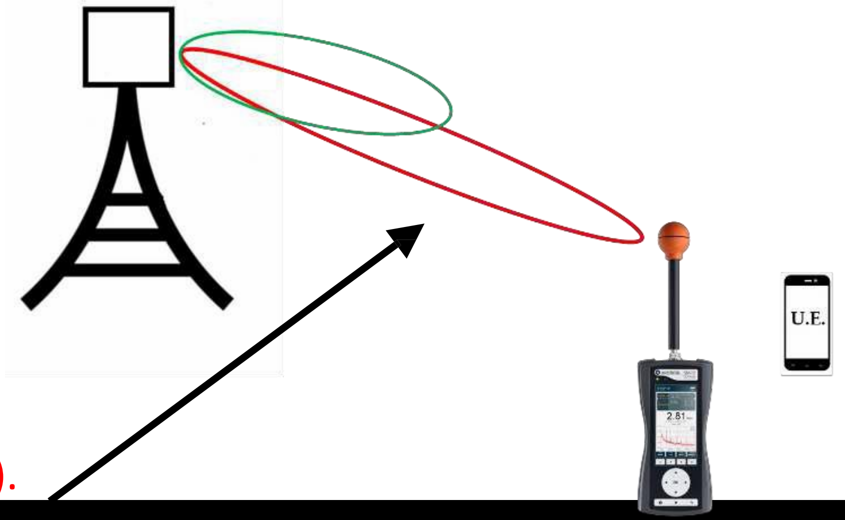
Source: www.emfexplained.info

EMF total exposure assessment

To consider all EMF environment, including FM, TV, 3G, 4G and 5G's FR1 and FR2. → Broadband field probe. Example: Wavecontrol WPF60 (1 MHz – 60 GHz)

To consider all EMF environment, including FM, TV, 3G, 4G and 5G's FR1. → Broadband field probe. Example: Wavecontrol WPF8 (100 kHz – 8 GHz)

You may want to consider all present cellular energy, forcing a 5G connection.



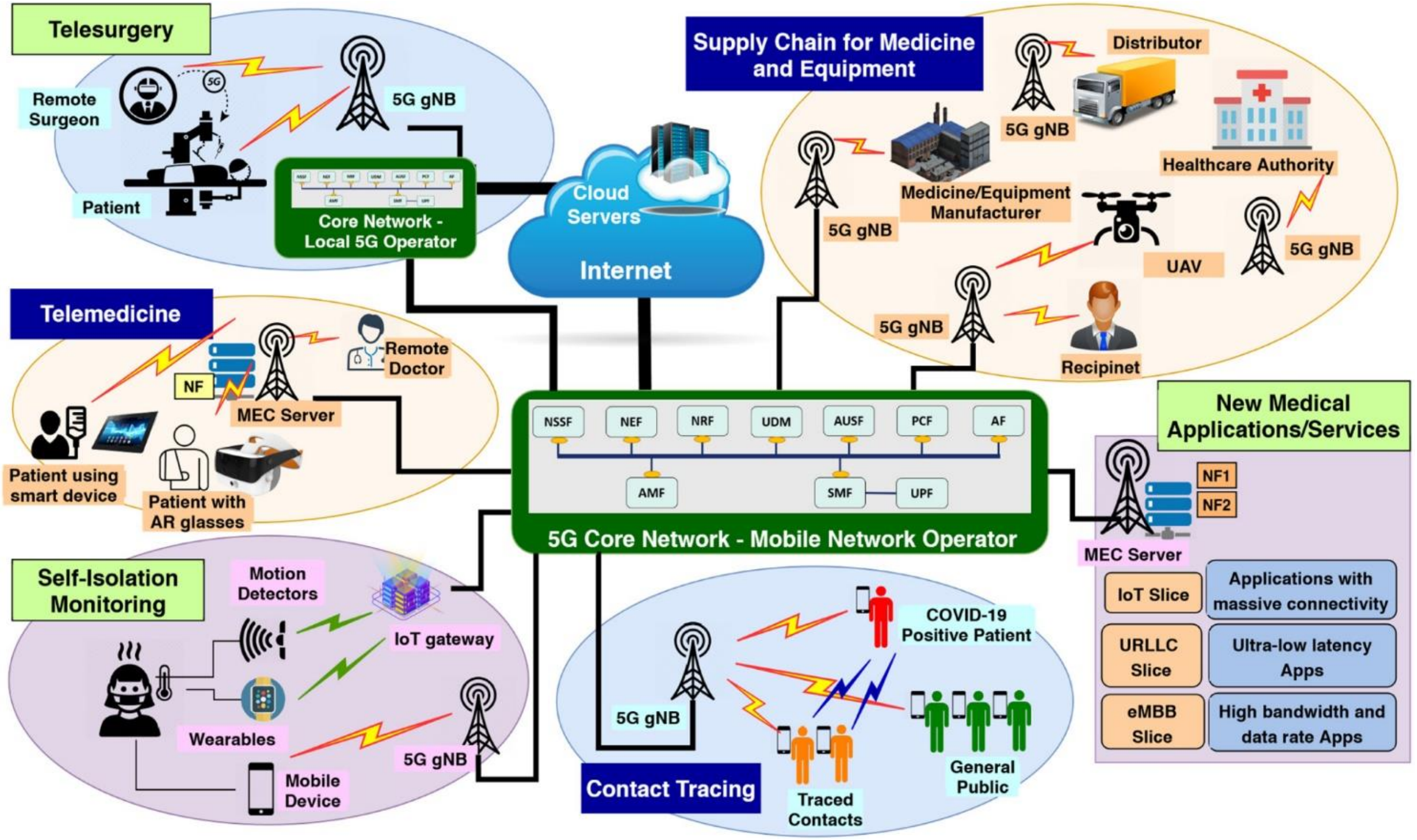
Traffic beam forced towards a Wavecontrol SMP2 field meter by means of the user equipment (U.E.).

EMF total exposure assessment

5G for digital healthcare against COVID-19 pandemic

5G based healthcare use cases for COVID-19

1. Telehealth for patients

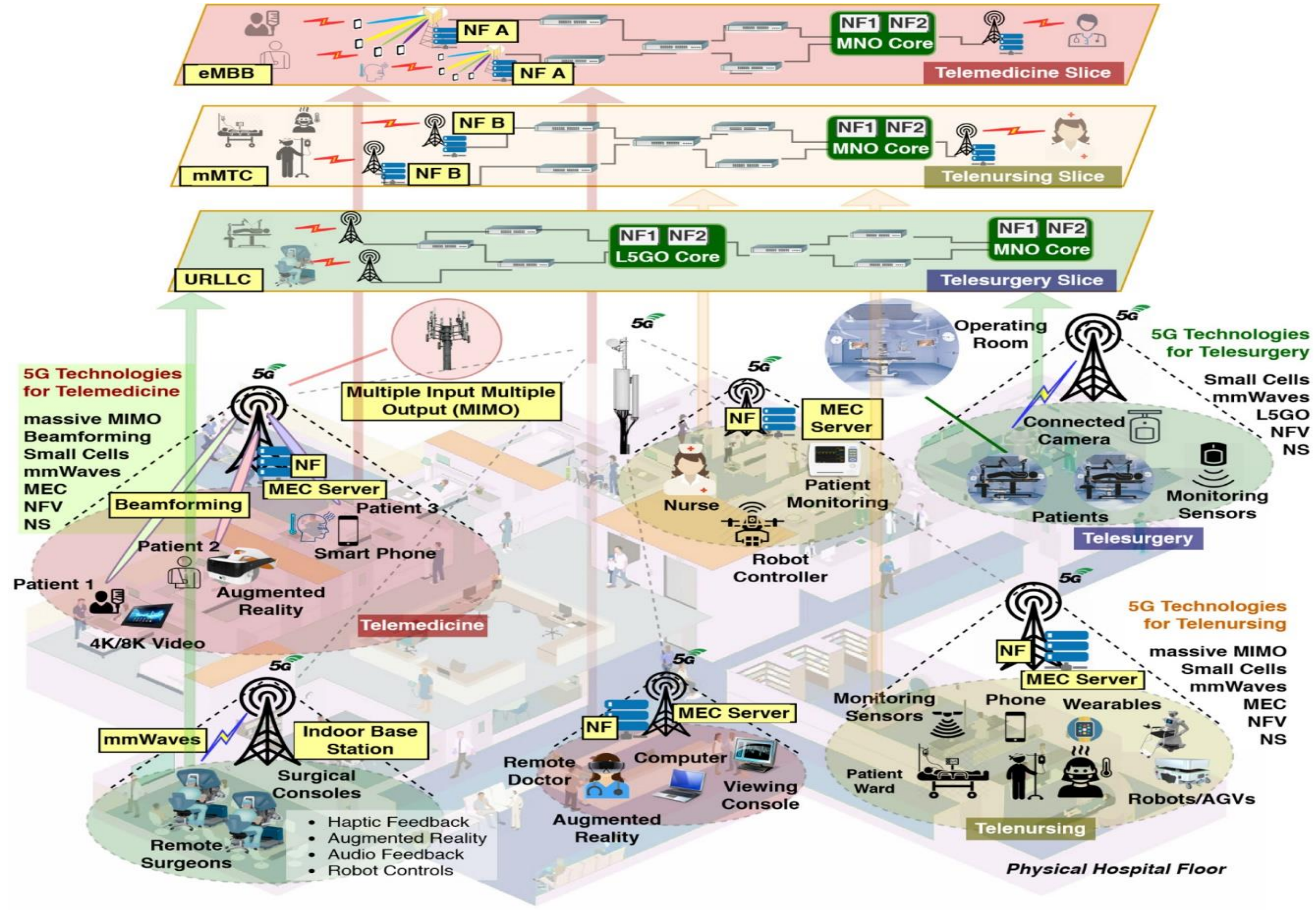


- Telemedicine
- Telenursing
- Telepharmacy
- Telesurgery

These teleservices sometimes have strict requirements and call for sophisticated underlying technologies for proper functionality.

As an example, a telemedicine follow-up visit between the patient and the doctor would require 4K/8K video streaming with low-latency

2. Supply chain management for healthcare



- Surge in demand for Personal Protective Equipment (PPE), ventilators and certain drugs was observed at the beginning of the COVID-19 spread.
- Delivery of the items to the final consumer was a concern due to the risk of COVID-19 spread
- To address the issues in healthcare related supply chains, industries can adopt smart manufacturing techniques equipped with IoT sensor networks, automated production lines which dynamically adapt to the variations in demand, and sophisticated monitoring systems

Implementation Challenges

- Privacy protection issues
- Security challenges
- Scalability and QoS provisioning in massive connectivity regime
- 5G deployment and limited connectivity challenges
- Societal issues and the human factor

Use Case	Application	Deployment Challenges							
		Privacy Issues	Security Challenges	Scalability Issues	QoS Provisioning	Limited Connectivity	Societal Impact	Legal Issues	Regulatory Restrictions
Telehealth	Telemedicine	H	H	H	M	H	H	M	H
	Telenursing	M	M	M	L	L	H	M	M
	Telesurgery	M	H	L	H	L	H	H	H
	Telepharmacy	L	H	H	L	H	L	L	M
Supply Chain	Connected Goods	M	H	H	L	L	M	L	L
	Manufacturing	L	M	H	H	L	L	L	L
Containment	Contact Tracing	H	M	H	L	H	H	H	H
	Self Isolation	H	M	H	L	H	H	H	H

L = Low Impact, M = Medium Impact, H = High Impact

Technical requirements of digital healthcare related use cases

Use case	Application	Expected capacity	Expected latency	Number of devices	Other requirements
Telehealth	Telemedicine	>500 million visits per year	<1–100 ms	1–10 per appointment	Real-time backhaul connectivity Streaming data type
	Telenursing	<50 Mbps	<1–100 ms	1–10 per appointment	Real-time backhaul connectivity Streaming data type
	Telesurgery	30–50 Mbps >1 Gbps for holographic rendering	<1 ms	10–100 per surgery	Real-time backhaul connectivity Streaming data type >99.999% availability required >99.999% reliability required
	Telepharmacy	<50 Mbps	<1000 ms	1–10 per appointment	Real-time backhaul connectivity Streaming data type
Supply chain	Connected goods	Small-data (<1 kbps) per device, >1–10 Gbps of data per supply chain	<10 000 ms	Up to millions per supply chain	Intermittent backhaul connectivity Streaming/historical data >95% availability required
	Manufacturing	>1–10 Gbps of data per plant	wide range: <1 ms for time-critical (e.g.robotics), <10 000 ms for non-time-critical optimizations (e.g. asset localization)	1000–one million per plant	Real-time backhaul connectivity Streaming data Indoor connectivity and high availability
Contact tracing	Using sensor data for contact tracing	>10–100 GB of data per city per day	<1 ms	1000–one million per city	Real-time backhaul connectivity Streaming data type Low power consumption
	Self isolation	<1 GB of data per isolated person per day	<1000 ms	1–10 per isolated person	Real-time/intermittent backhaul connectivity Streaming data type

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