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DLT Session on
5G/6G Enabled Edge Computing and Edge AI

Fawzi Behmann

President TelNet Management Consulting Inc.

September 20, 2023

Greetings from Austin IEEE Chapters

IEEE ComSoc

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IEEE COMMUNICATIONS SOCIETY
Central Texas (Austin) Chapter

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IEEE Communications Society Chapter Awards Program

2015, 2017, 2020 and 2021 AWARDS TO IEEE Central Texas (Austin) Chapter

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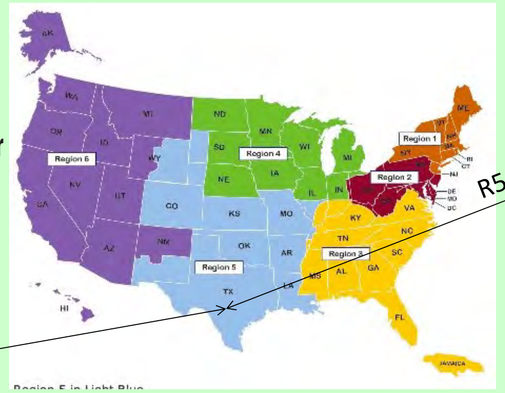


R5/CTS/Austin

Fawzi Behmann Bio

Leadership Experience - “Communications & Networking”

- President TelNet Management Consulting Inc. since 2009
  - Collaborative Technology positioning for smart ecosystem solutions at key markets
  - Distinguished Lecturer and keynote speaker at domestic & international conference
  - Co-author of Collaborative IoT for Future Smart Connected Life and Business
  - Faculty Advisor for Senior Design Program
- Communications & Networking Technology & Applications
  - Director of Strategic Marketing @ Motorola/Freescale/NXP
  - Sr. Product Management Edge/core @ Nortel Networks
  - Telecom Network Management Leader @ Teleglobe
- IEEE

IEEE: Communications Society Director for NA region & BOG

Member, Distinguished Lecturer, Section Chair, R5 Conference

Committee Chair, Chapter Chairs (ComSoc/SP, Computer/EMBS)

- MBA, Queen’s University, Canada
- M. Comp. Sc. , University of Waterloo, Canada
- B.Sc. Hons. With Distinction in Math, Concordia University

Agenda

- A clear understanding of 5G & 6G positioning, features and roadmap
- Architecture evolution pushing intelligence to the edge
- Provide examples empowered by 5G/6G, IoT and AI
- Provide example of network slicing for bandwidth efficiency, security and QoS.

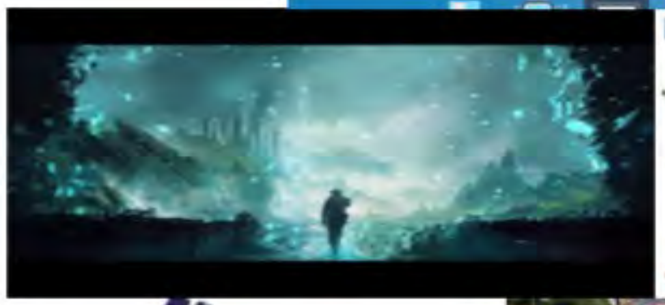
Takeaways:

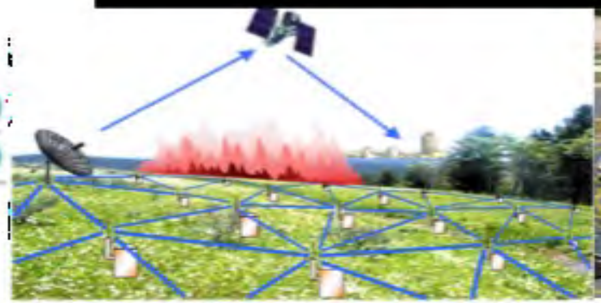
- Collaborative technologies and impact on ecosystems and networking smart solutions.
- Opportunity to participate and drive advancement of IEEE transdisciplinary framework and Future Networks Technology Roadmap (INGR) working groups.

5G Vision

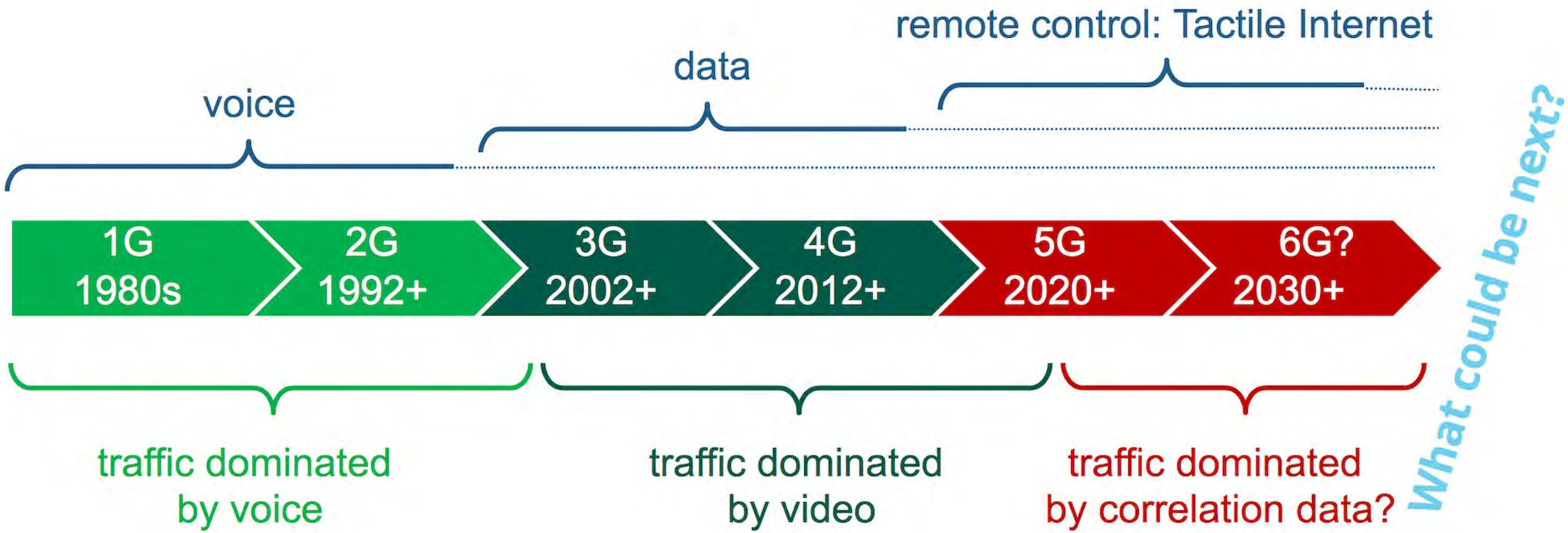
Massive Capacity and Connectivity
Efficient Use of Spectrum and Network Utilization
Flexible and Scalable Infrastructure to
Enable value add services affecting the following use cases

- Internet of Things
- Wireless Sensor Networks
- Smart Homes
- Smart Grid
- Intelligent Transport Systems
- Virtual Reality/Online Gaming
- Medical Sensors



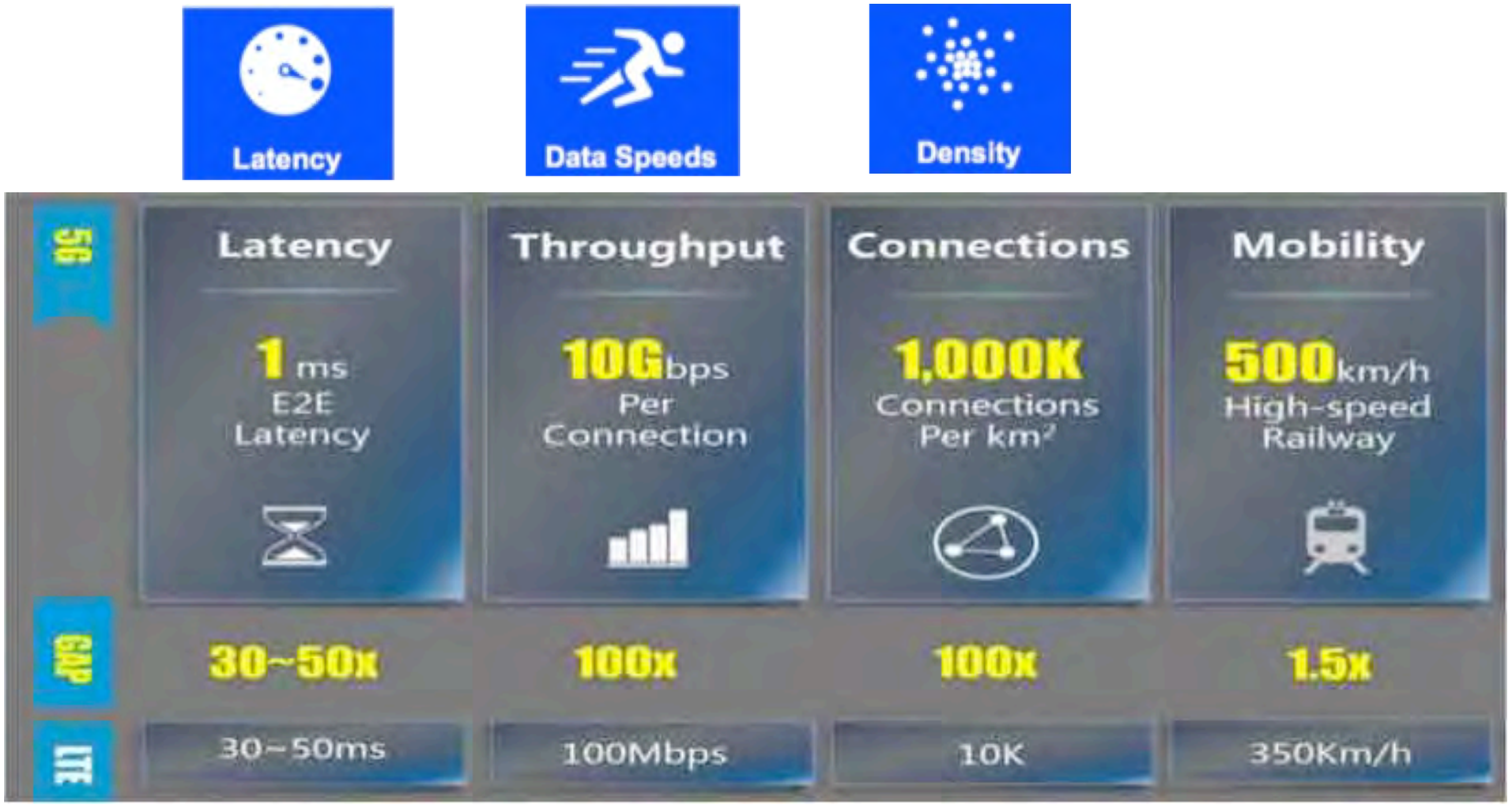


Cellular Generations - Roadmap



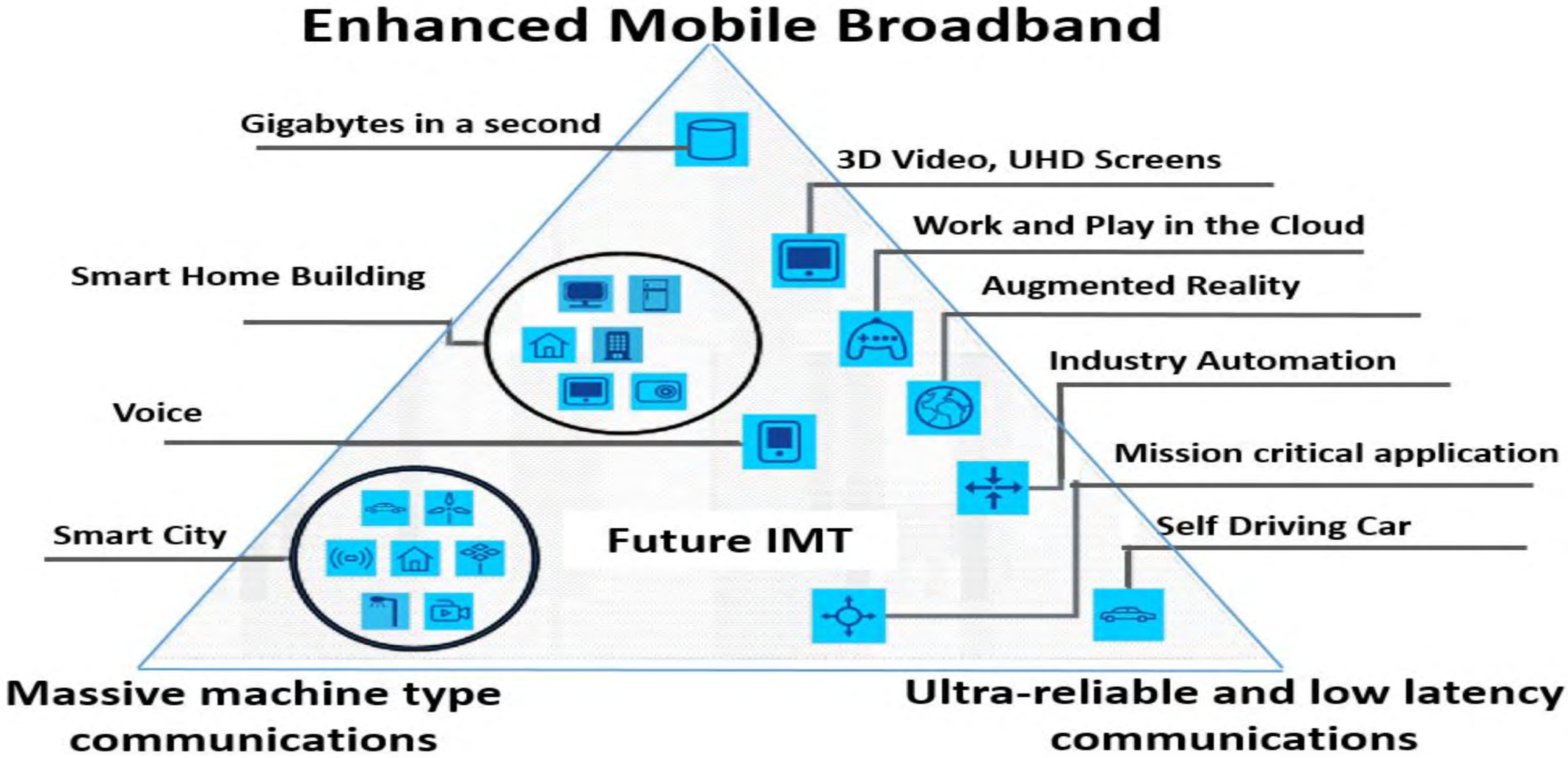
Source: 5G Lab Germany

5G vs LTE/4G

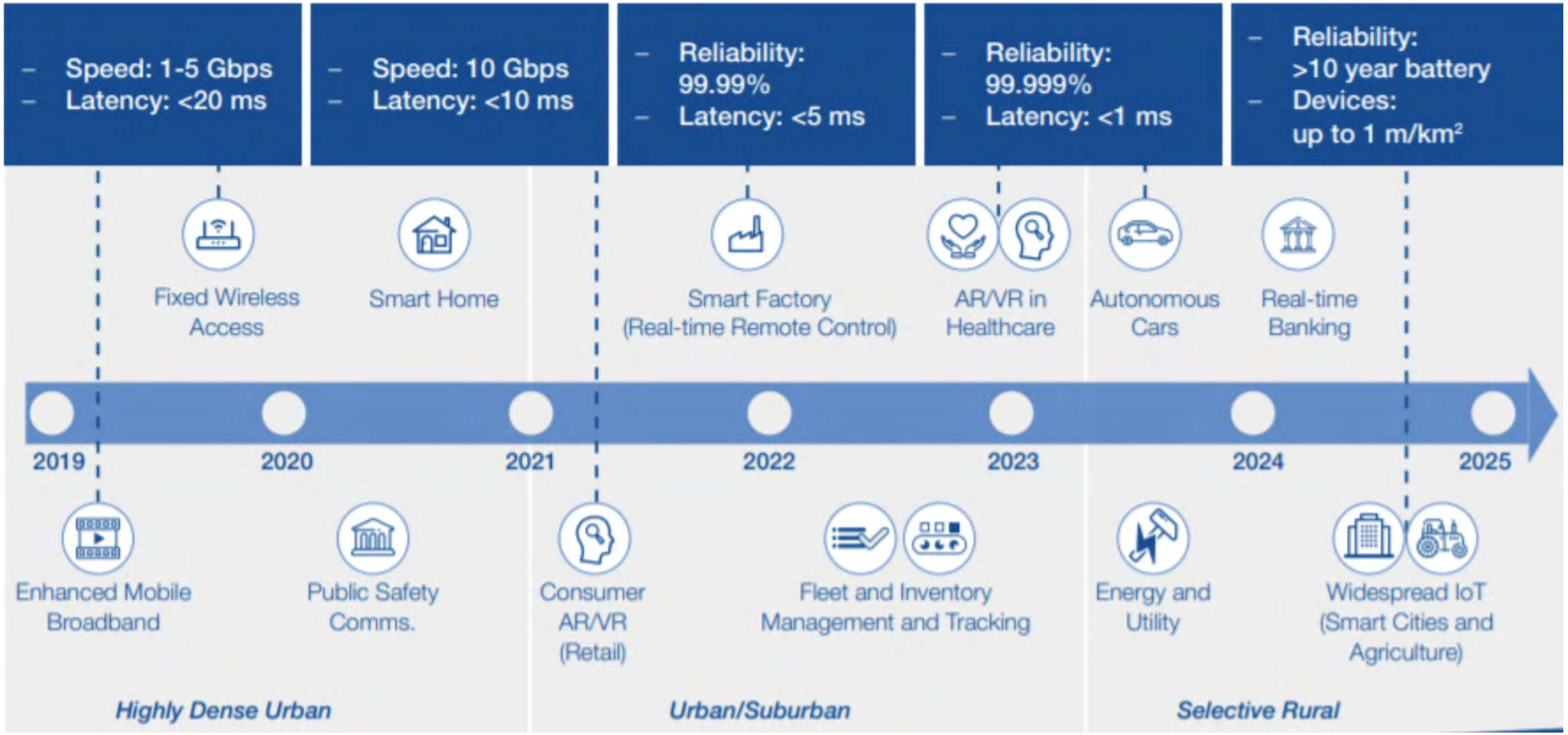


5G is quantum leap in speed, density, latency

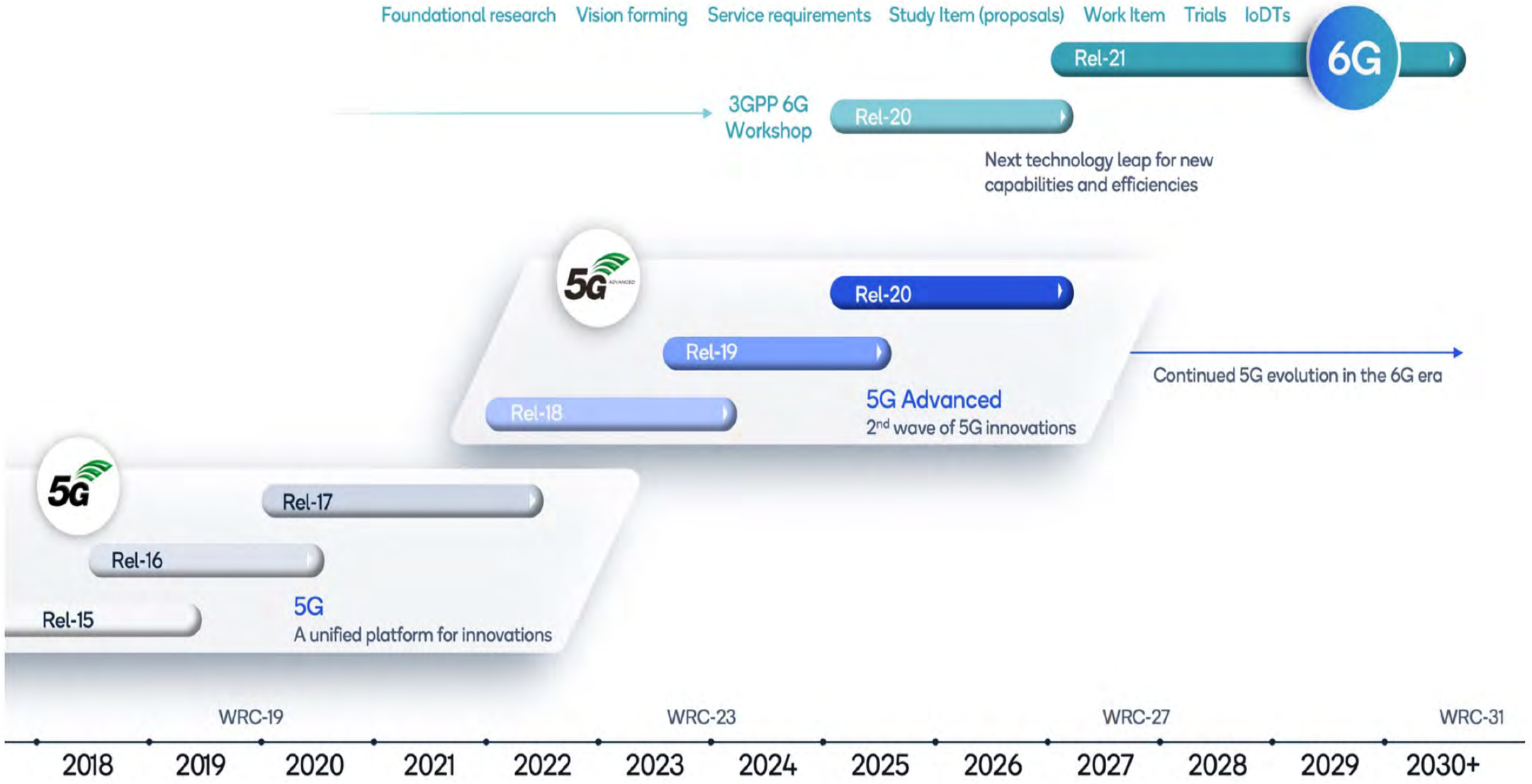
ITU - 5G Use Cases Framework



Use Cases / Feature Roadmap
Industry Sectors enabled by evolving 5G/5G Advanced Features



5G/5G Advanced/6G Releases



5G Use Cases Market

5G will expand the mobile ecosystem to new industries

Powering the digital economy

$13.1 Trillion

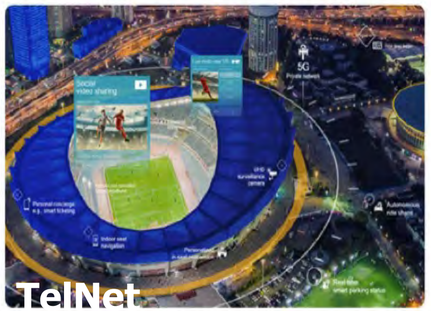
in global sales activities by 2035

Precision agriculture

Construction and mining

Digitized education

Connected healthcare



Rich mobile experiences

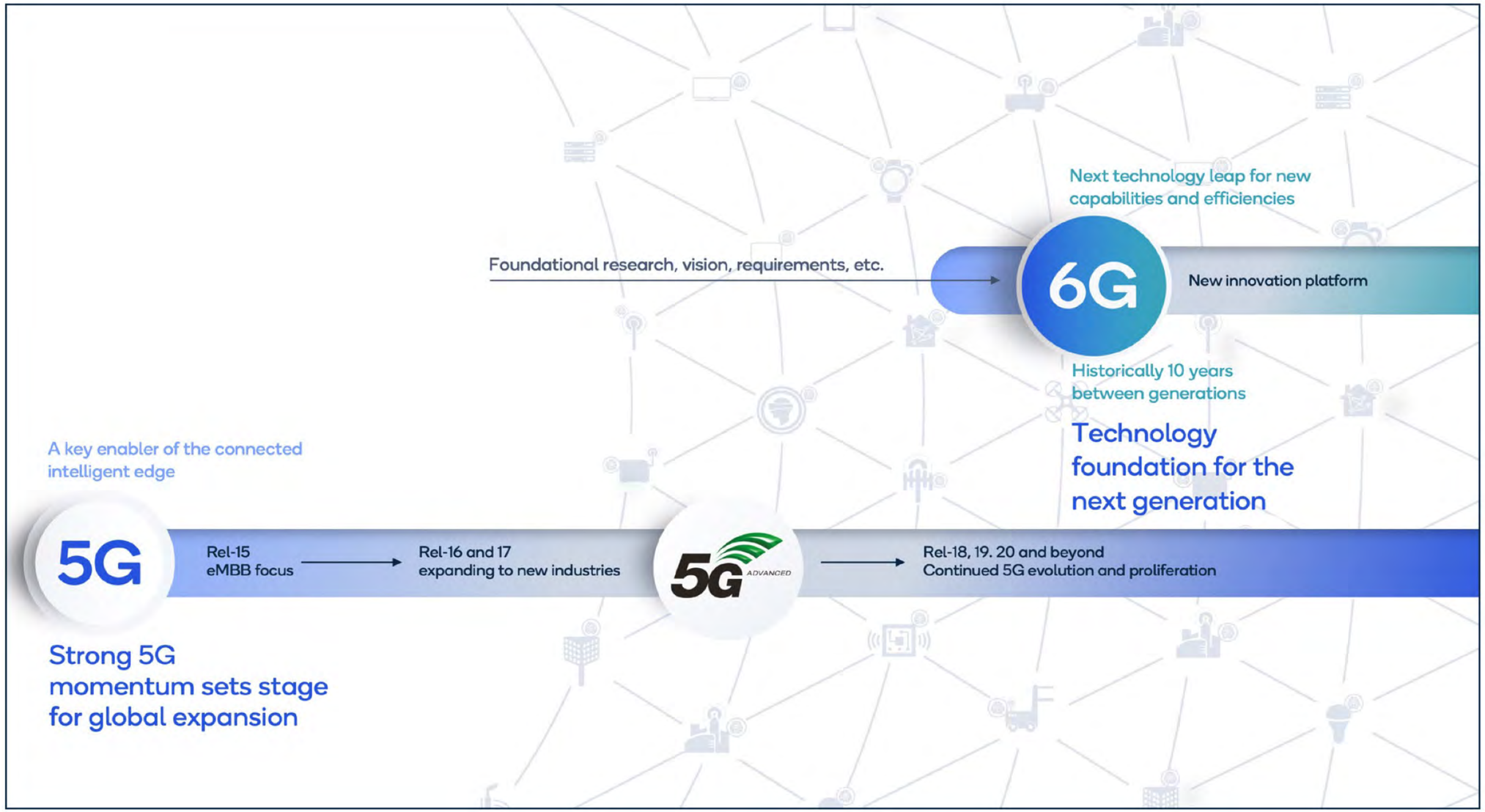
Smart manufacturing

Intelligent retail

Smart city

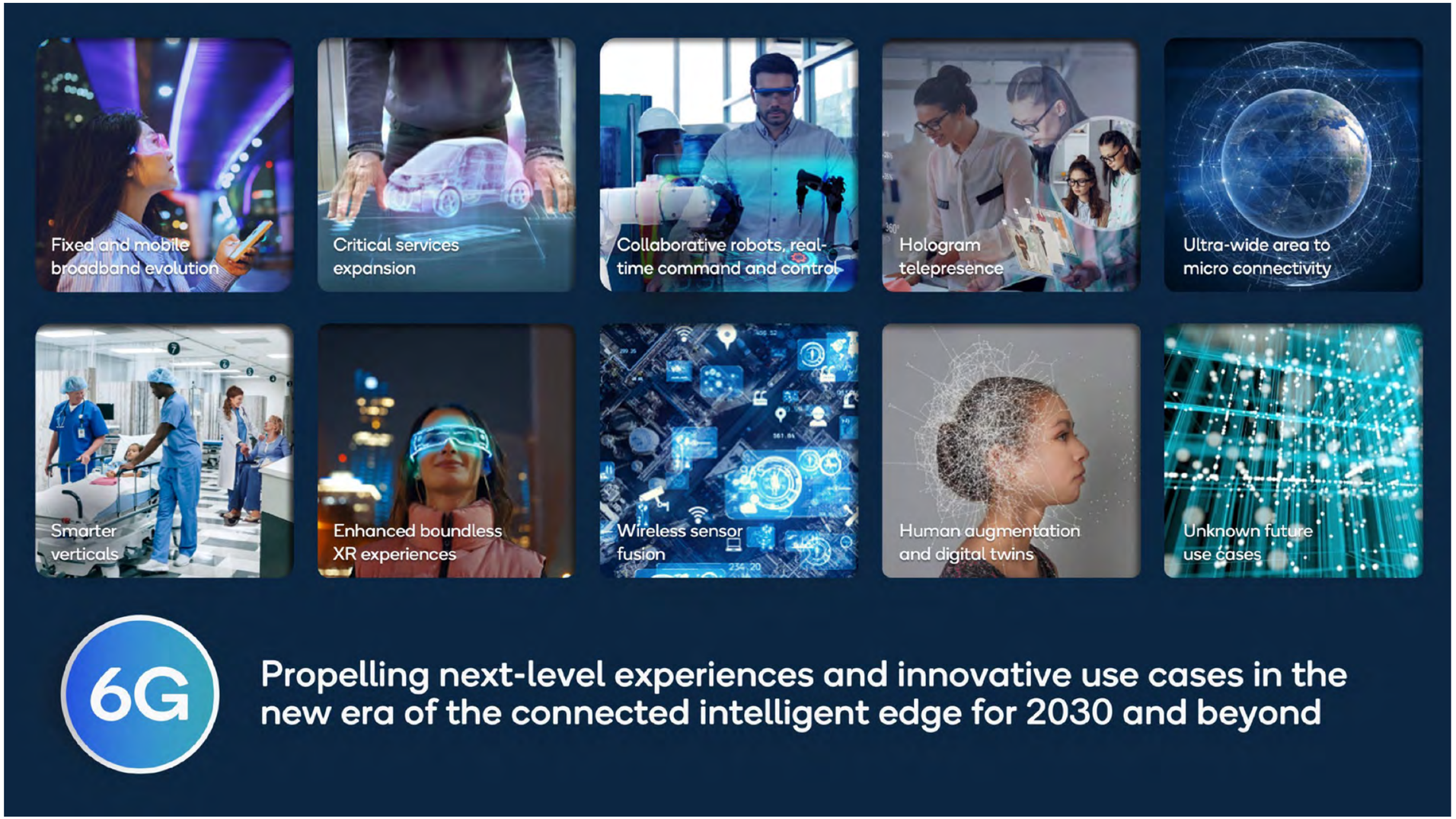
TelNet

5G/5G Advanced Releases - Path to 6G



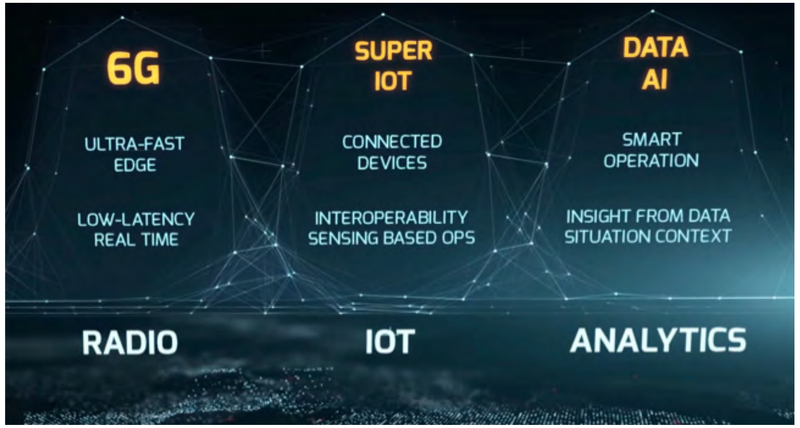
Path to 6G – enabling a connected intelligent future

6G’s Disruptive revolution with novel technologies



6G will bring new and enhanced user experiences across the connected intelligent edge

6G's Evolutionary Challenges "Stretching 5G"



6Genesis 2030 6G Vision 1 Tbps speeds, microsecond latency and AI optimization

Source: 6Gensis

Increase data rate	→ beyond 10Gb/s (e.g. for VR)
Address latency	→ Comms. Control Codesign (e.g. for robotics)
Expand coverage	→ connect 4B people missed-out
Scalable HW/SW	→ enable cost-efficient applications (e.g. verticals)
Tactile Internet - AI	→ transport correlation results, weights,…

"faster, higher, stronger…" ☹☺

Source: 5G Lab Germany

6G's Disruptive revolution with novel technologies

Integrated communication, sensing, compute

Enhanced immersive XR, collaborative positioning, RF sensing for the merging of physical, digital, and virtual worlds, ...

Cloud-native network convergence

Merging of core and RAN as well as application services with distributed service model, ...

Wireless machine learning

Cross-node (i.e., network and device) AI/ML air interface design, and intelligent network operations, ...

Full-duplex communication

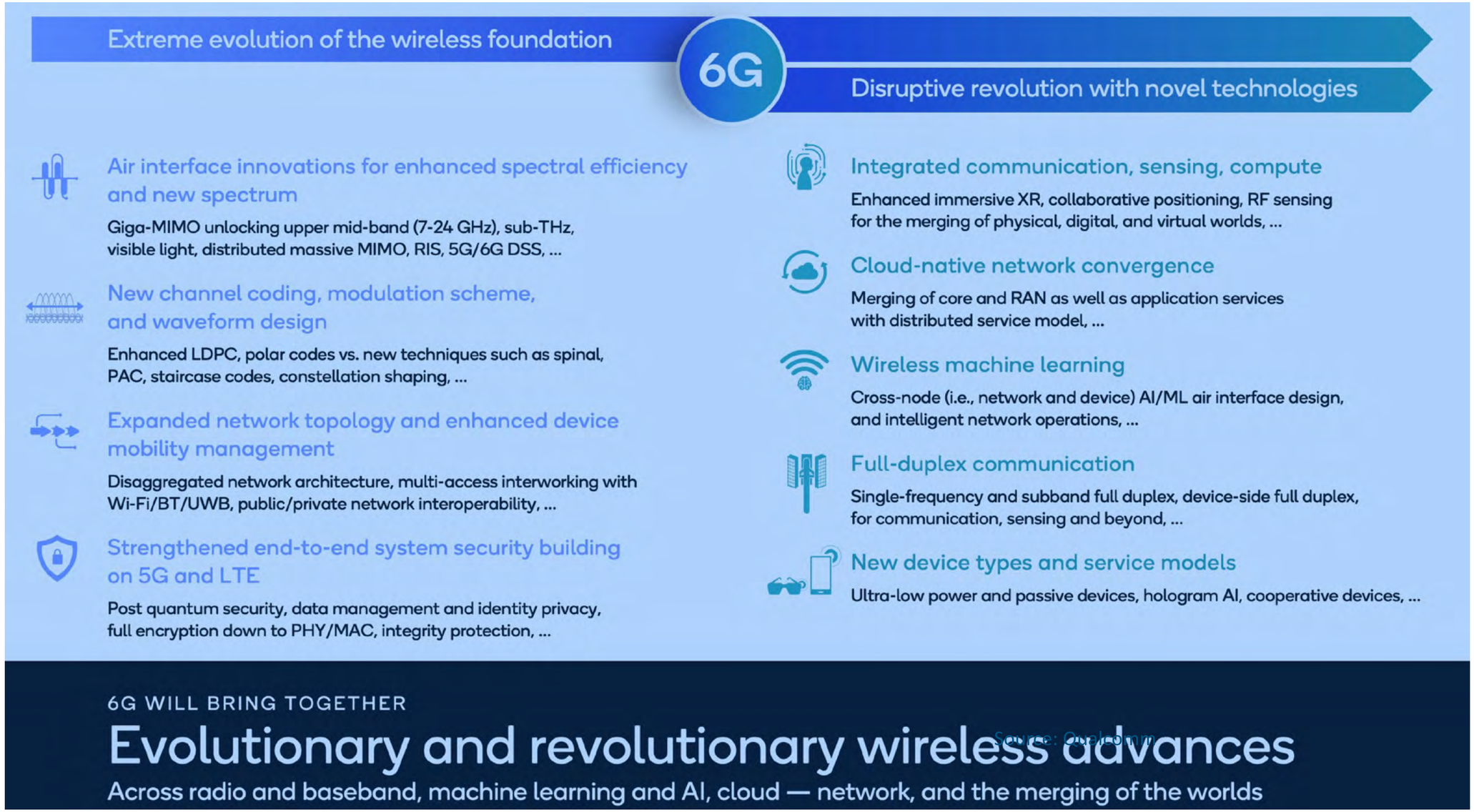
Single-frequency and subband full duplex, device-side full duplex, for communication, sensing and beyond, ...

New device types and service models

Ultra-low power and passive devices, hologram AI, cooperative devices, ...

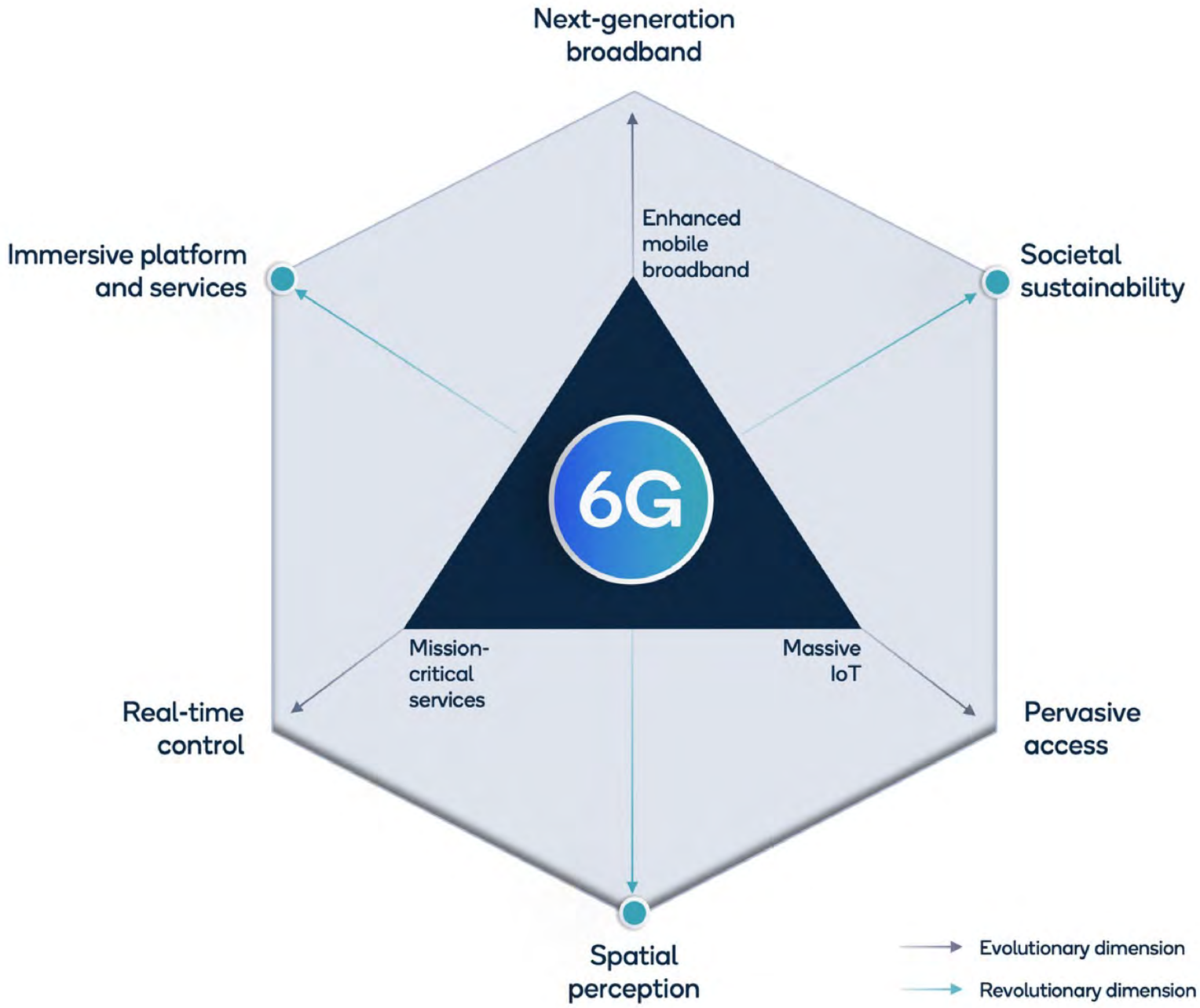
Source: Qualcomm

6G's Disruptive revolution with novel technologies

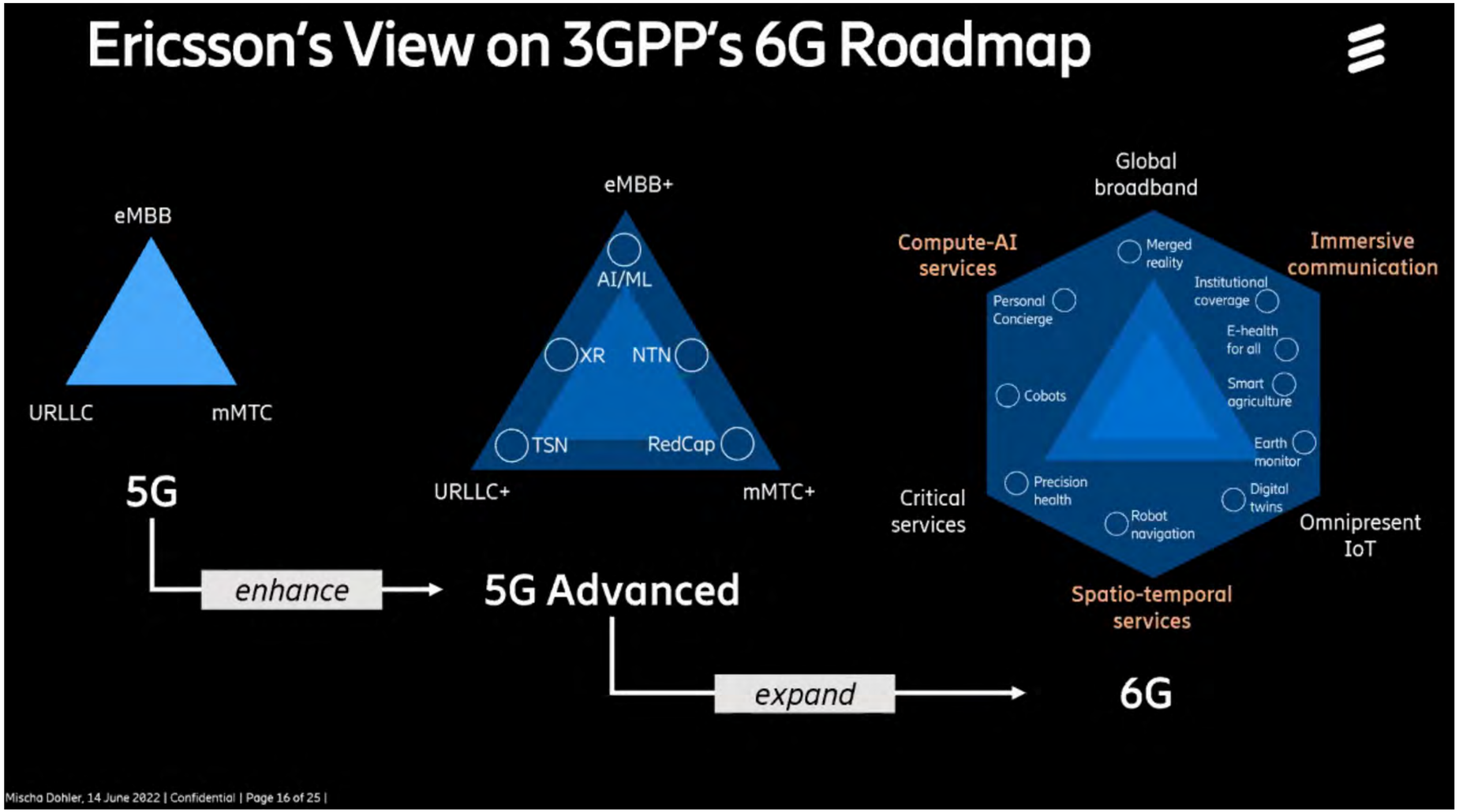


Source: Qualcomm

6G Support enhanced services and new use cases



5G - 5G Advanced- 6G Use cases

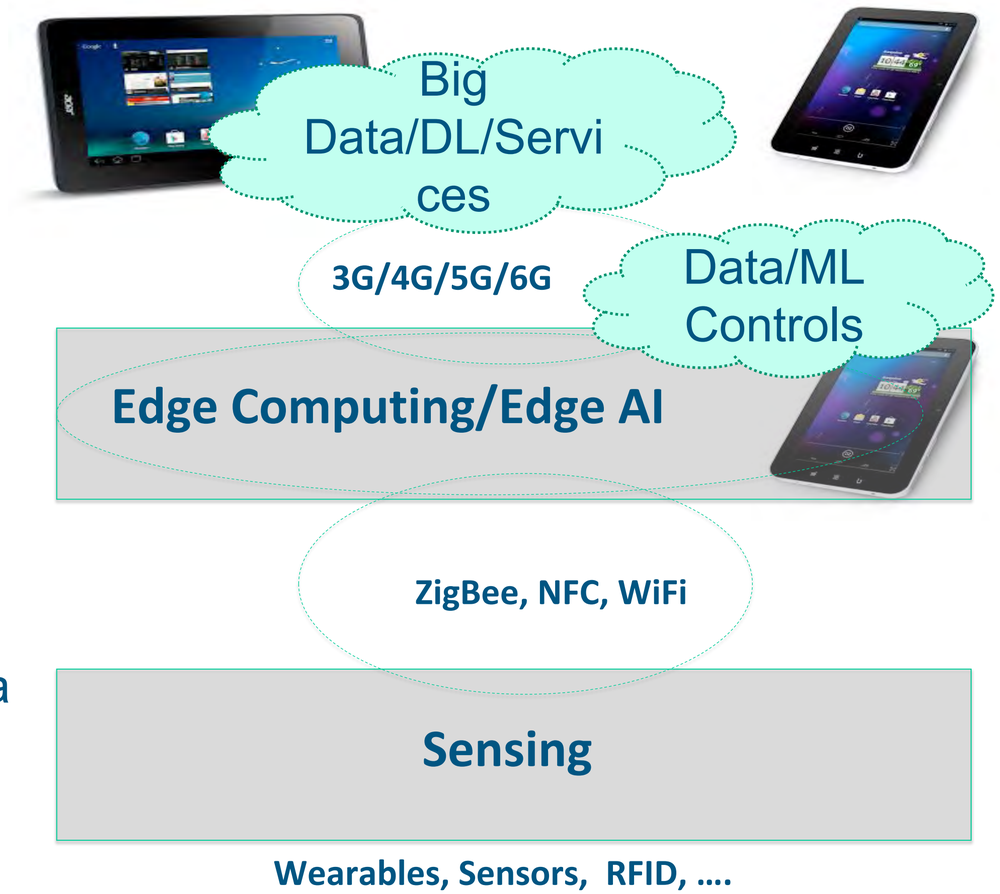


5G/6G – Edge Computing/Edge AI
High Level Model

Center/Apps (Insightful Intelligence)
This layer provides insight to the data collected from all layers and offers the information as a service to individuals, industries or infrastructures.

Edge Computing -> Edge AI (Gateway/Aggregation)
This layer enables the stream of data to move from one level to the next for additional processing.

Sensing
This layer enables interface to objects that are currently passive, where tapping into these objects will generate a stream of pertinent data and information.



Source: Collaborative IoT book, Wiley

5G – Application Drivers

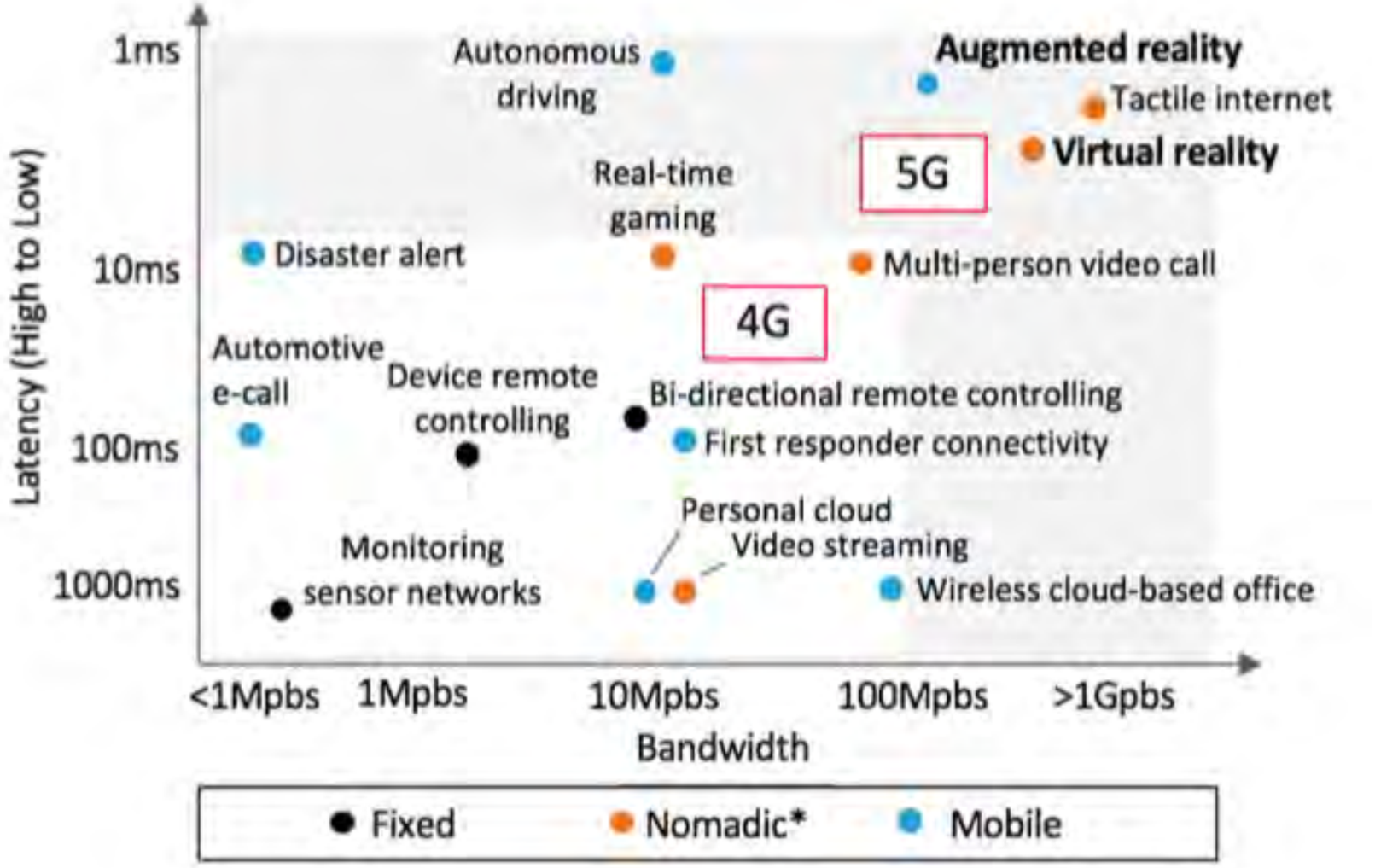
Video streaming is exploding, and buffering is a deal breaker

Billions of devices will become connected, driving the need for network capacity to scale

Machine to machine communications will create opportunities, requiring ultra-low latency

5G Technical Drivers

5G's promise of greater speed and overall network performance brings huge opportunities not only for the Internet of Things, 4K video, augmented and virtual reality, autonomous driving, mission critical and much more.



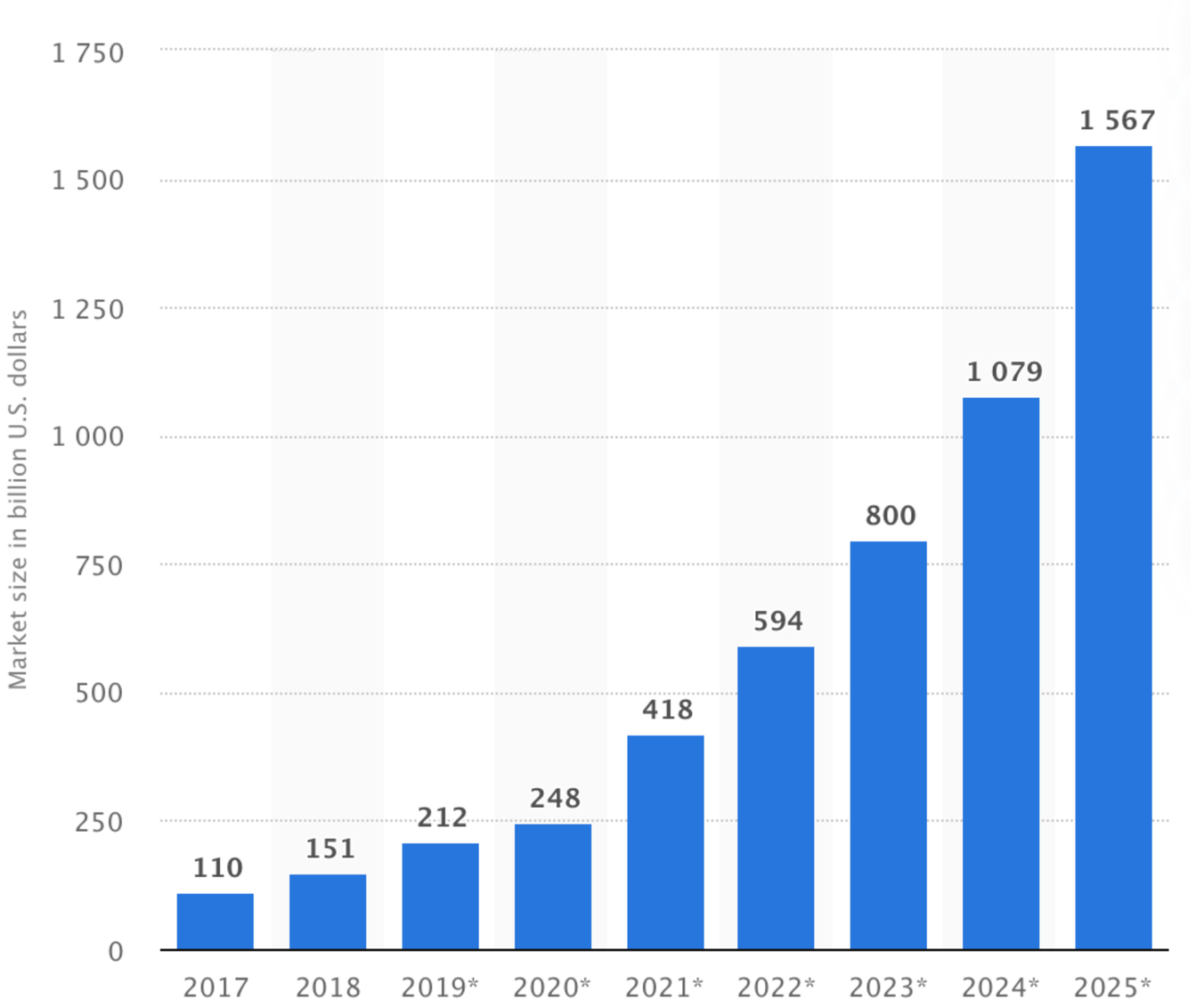
Drivers for the need of 5G - IoT

IoT Global Market

2019: US$ 212 billion

2025: US$ 1.6 trillion

Across multiple of vertical markets



AI/ML/DL

Global AI revenue

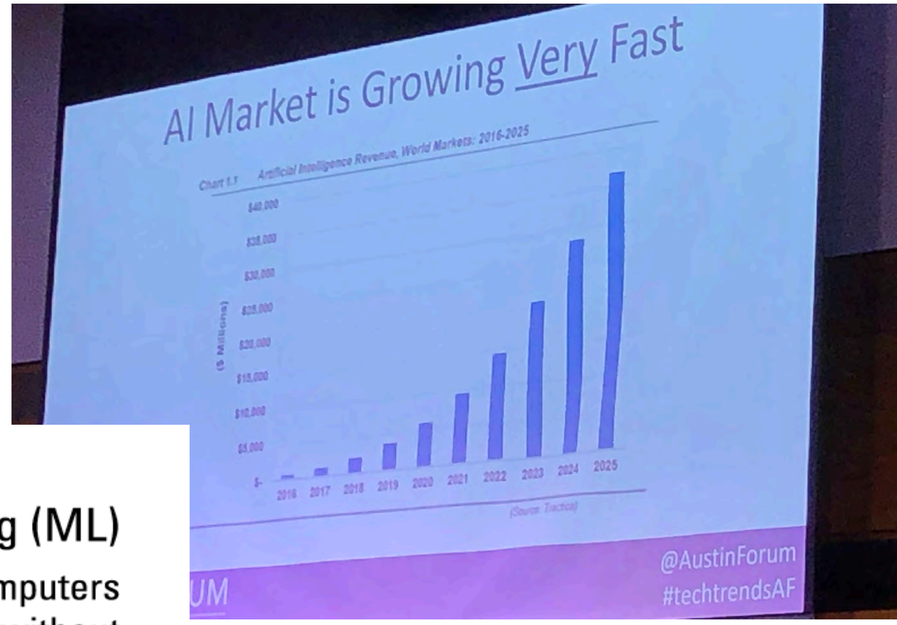
2017: US$ 7.1 billion

2023: US$ 98.4 billion

Growing adoption: Smart Cities initiatives

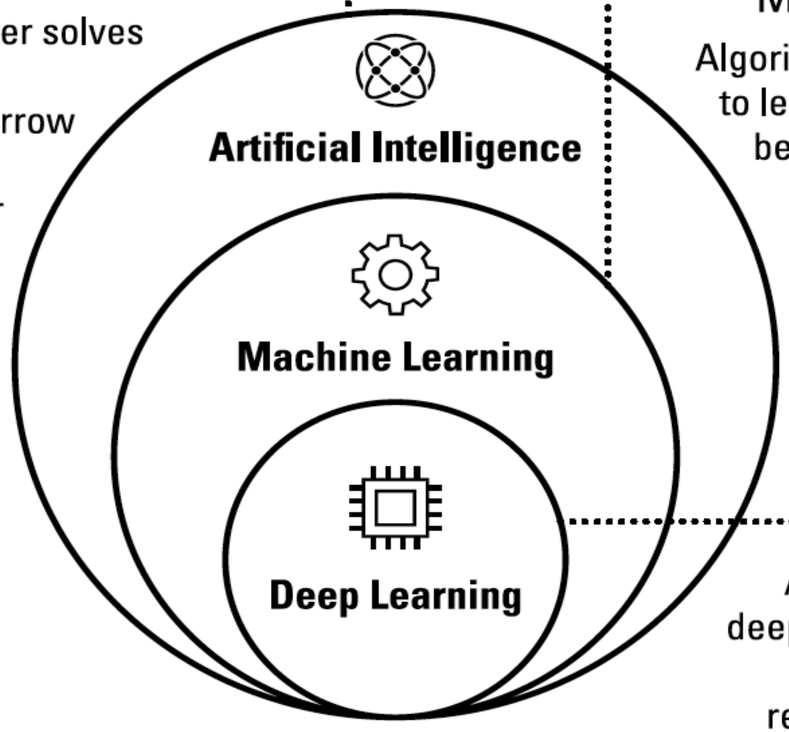
Highest CAGR in APAC followed by Latin America

Source: IDC, Bloomberg NEF, Ericsson, Strategy Analytics



Artificial Intelligence (AI)

A process where a computer solves a task in a way that mimics human behavior. Today, narrow AI—when a machine is trained to do one particular task—is becoming more widely used, from virtual assistants to self-driving cars to automatic tagging your friends in your photos on Facebook.

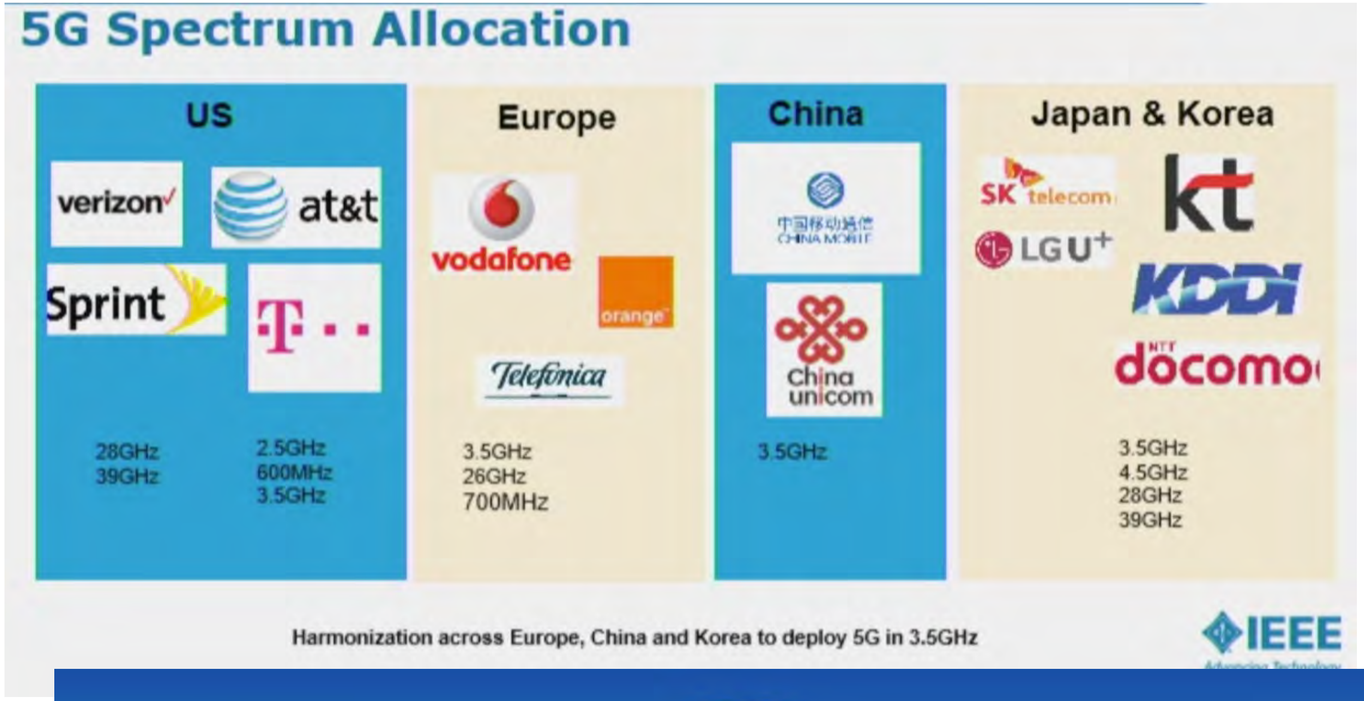


Machine Learning (ML)

Algorithms that allow computers to learn from examples without being explicitly programmed.

Deep Learning (DL)

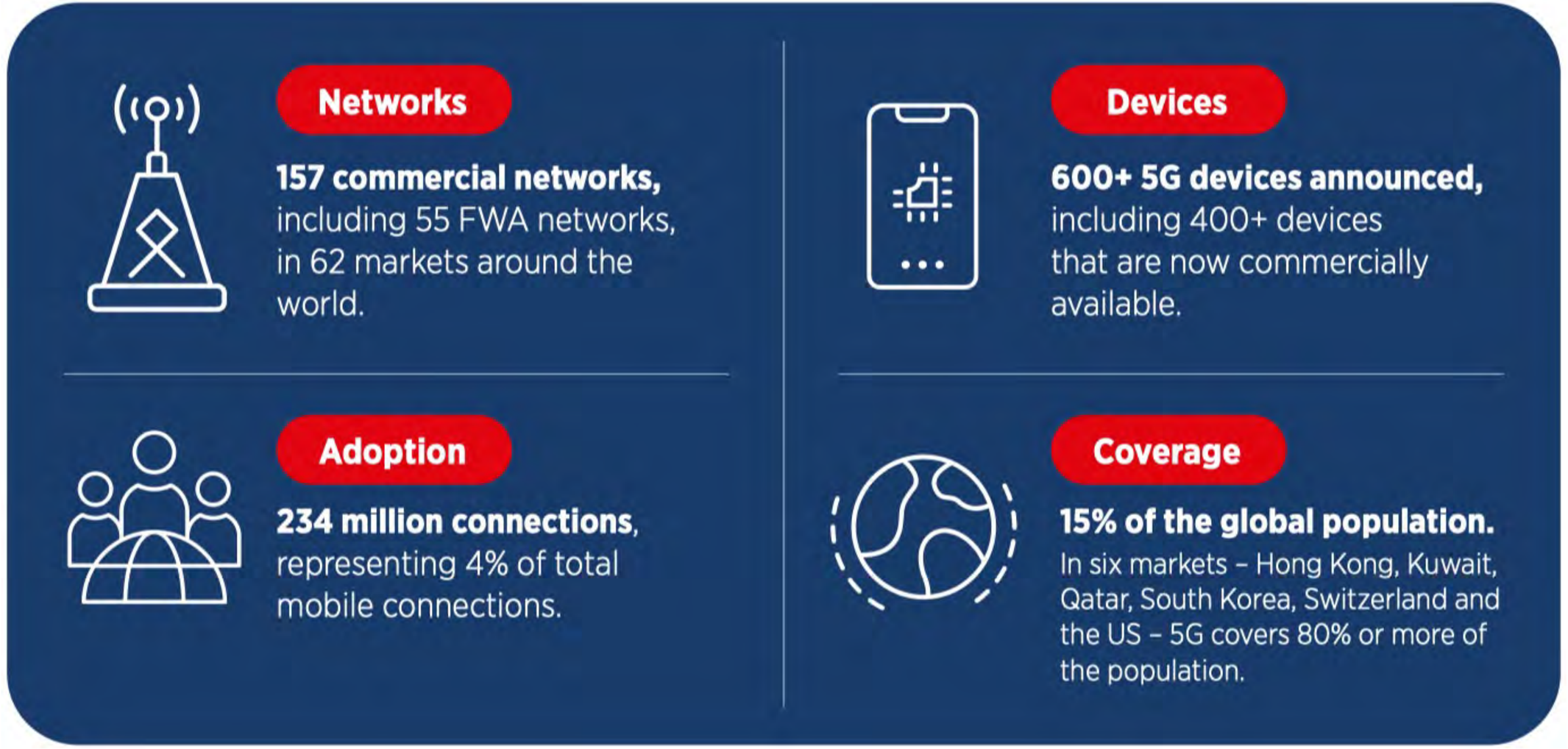
A subset of ML which uses deep artificial neural networks as models and does not require feature engineering.



The FCC defines 5G spectrum in four primary bands,

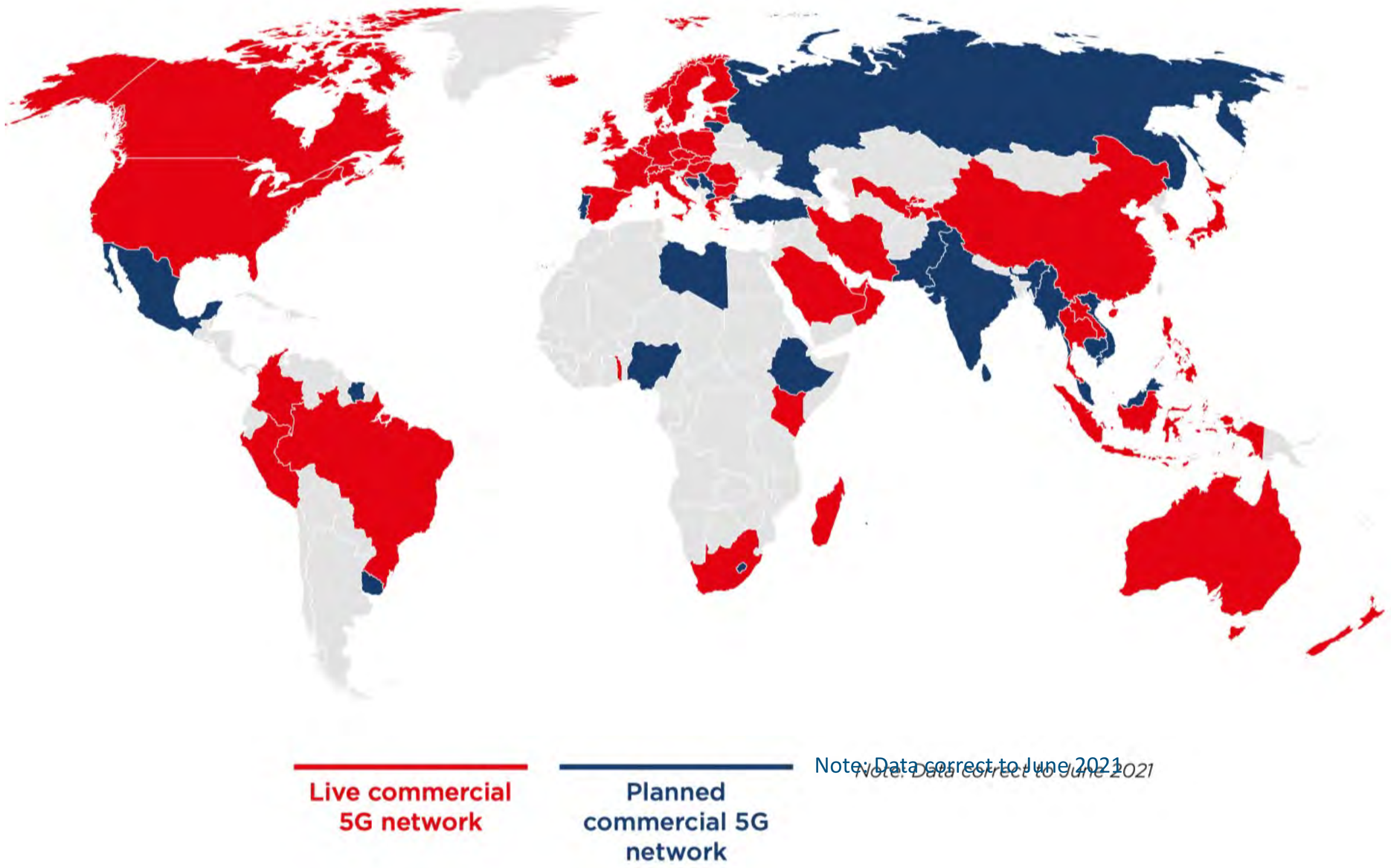
1. Low-band between 600–900MHz,
2. Mid-band between 2.5–4.2GHz also known as Sub-6,
3. frequencies above 24GHz, otherwise known as mmWave,
4. Unlicensed spectrum, that can be accessed for a variety of dedicated uses including 5G.

5G commercialization at a glance: network investment and an expanding device ecosystem are helping to drive adoption globally



Note: Data correct to June 2021

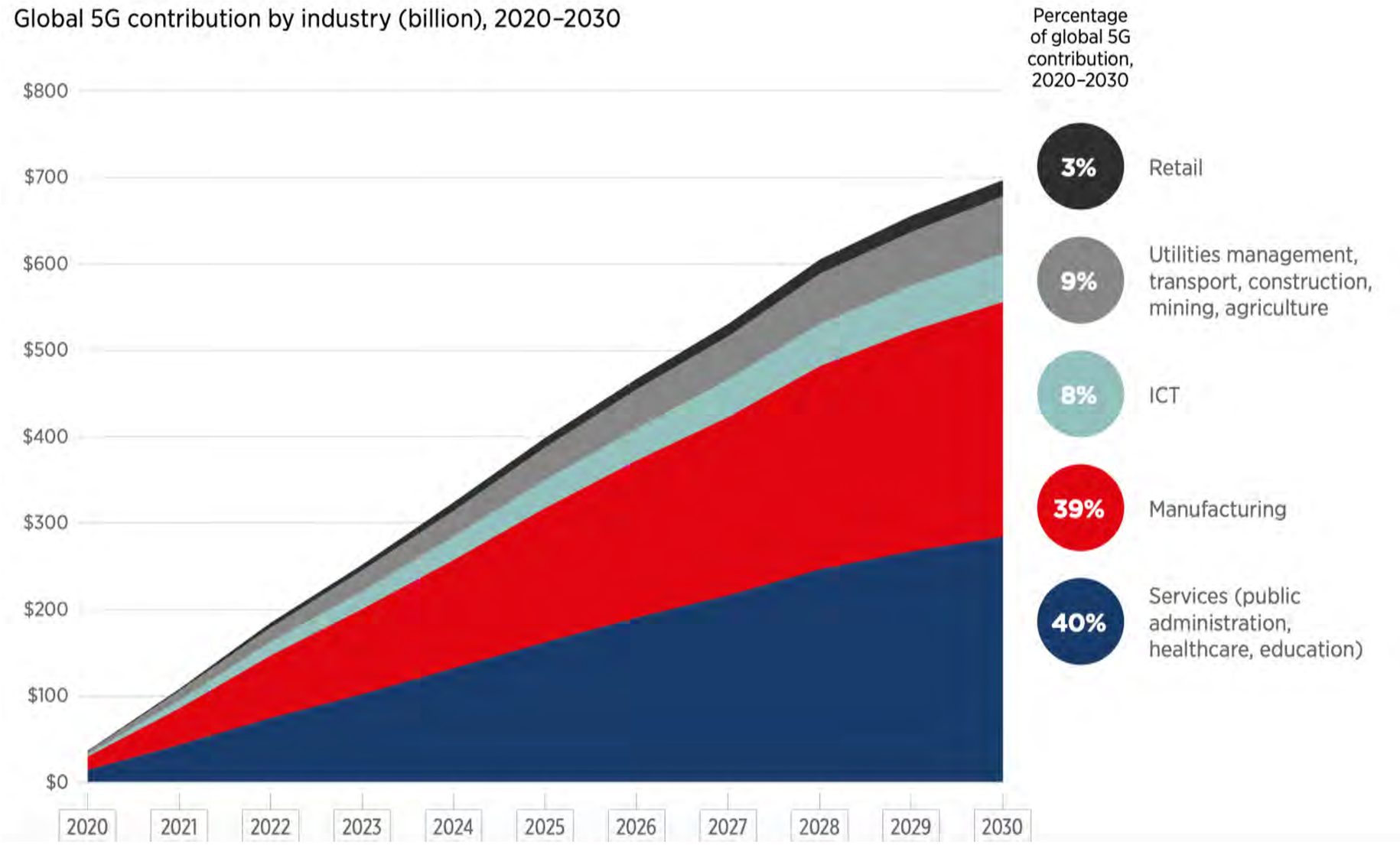
5G is now available in every region, making it a truly global technology



5G – Deployment (Sub-6, Sub-6 + mmWave)

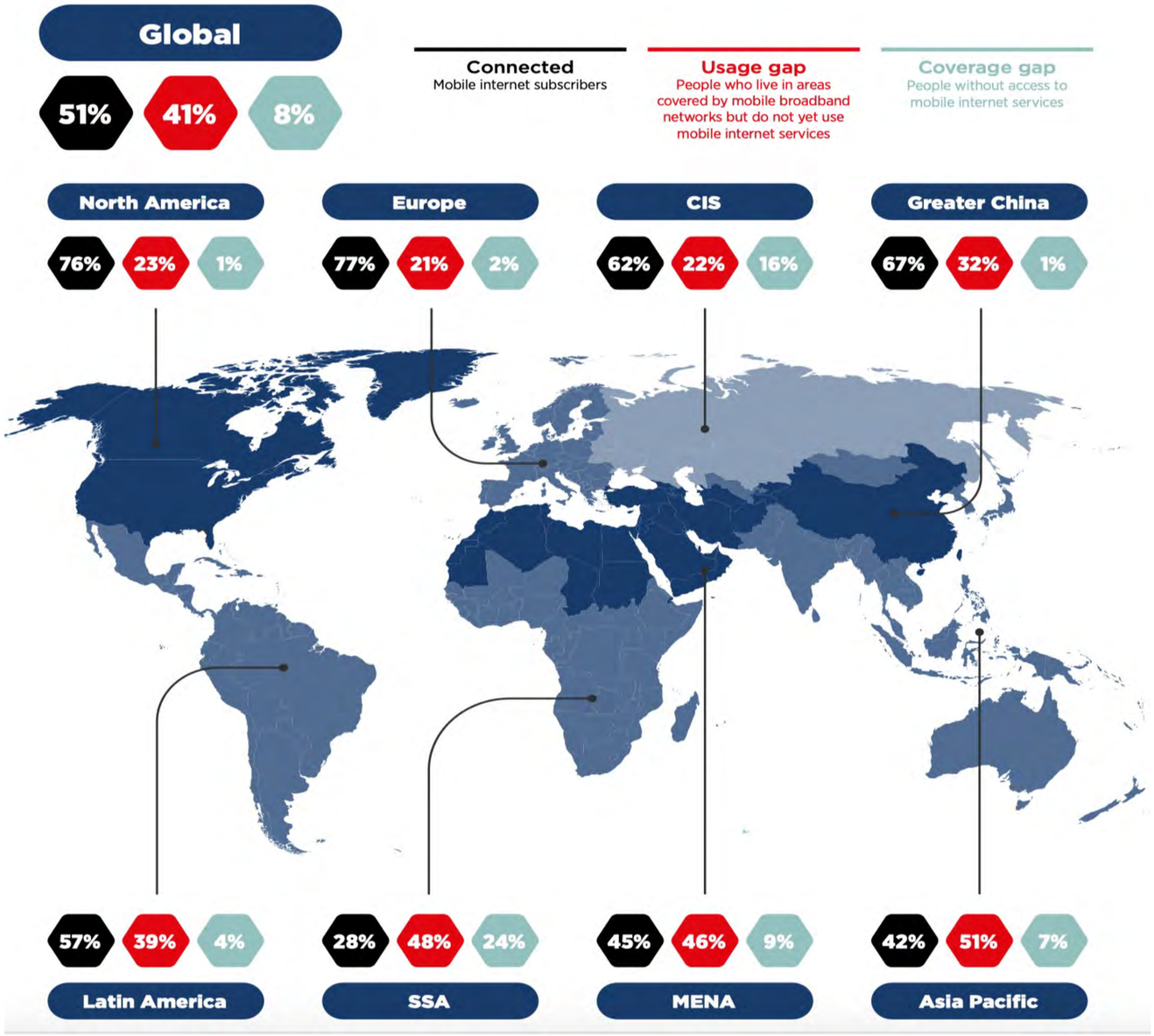
Source: Qualcomm

5G is expected to benefit all economic sectors; some industries will benefit more than others due to their ability to incorporate 5G use cases

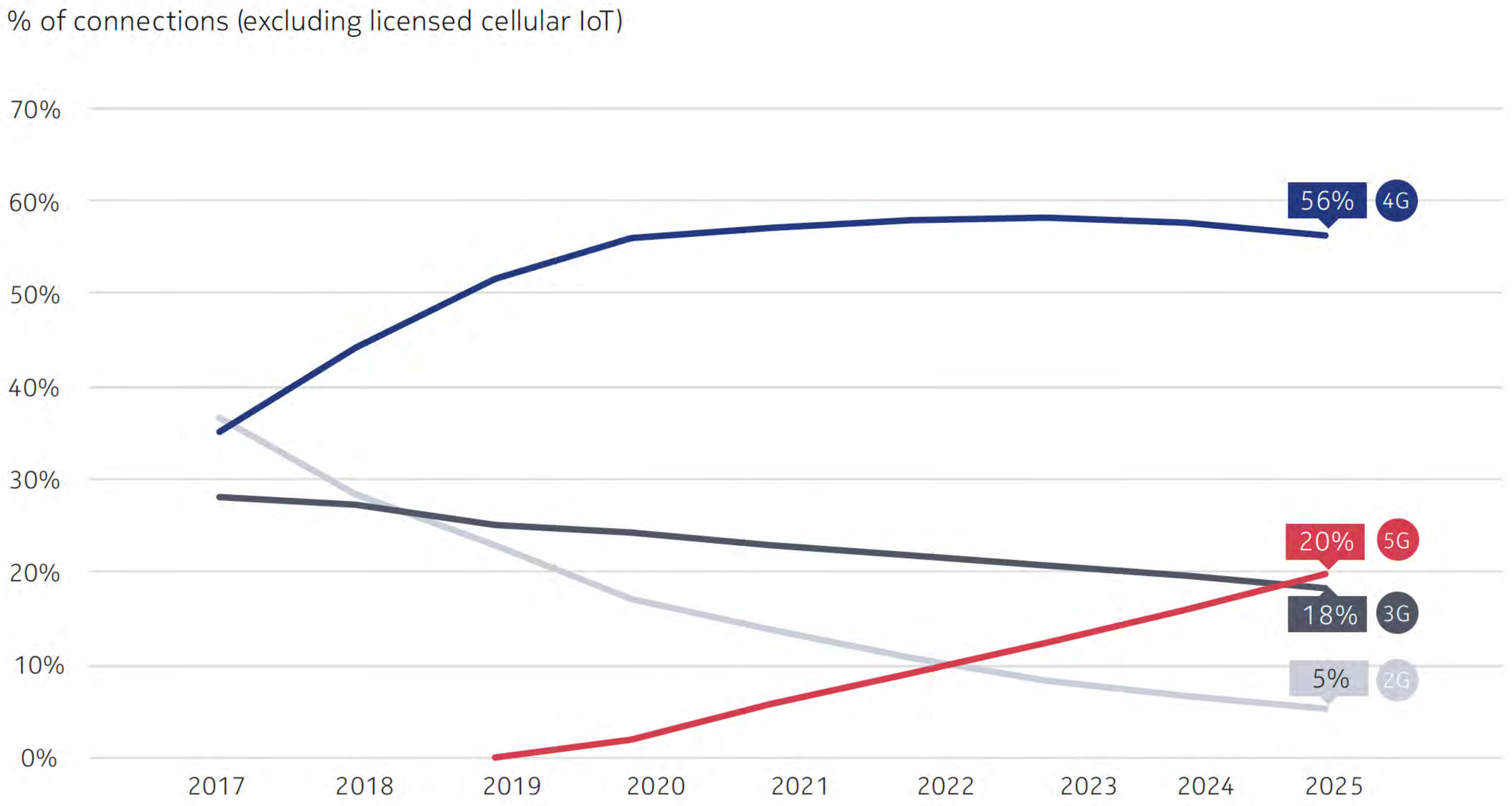


Almost half of the world remains unconnected; Asia Pacific and Sub-Sahara Africa account for the largest unconnected populations

State of global mobile internet connectivity by region (percentage of total population), 2020



4G now accounts for half of total connections; 5G will start moving the needle in 2020



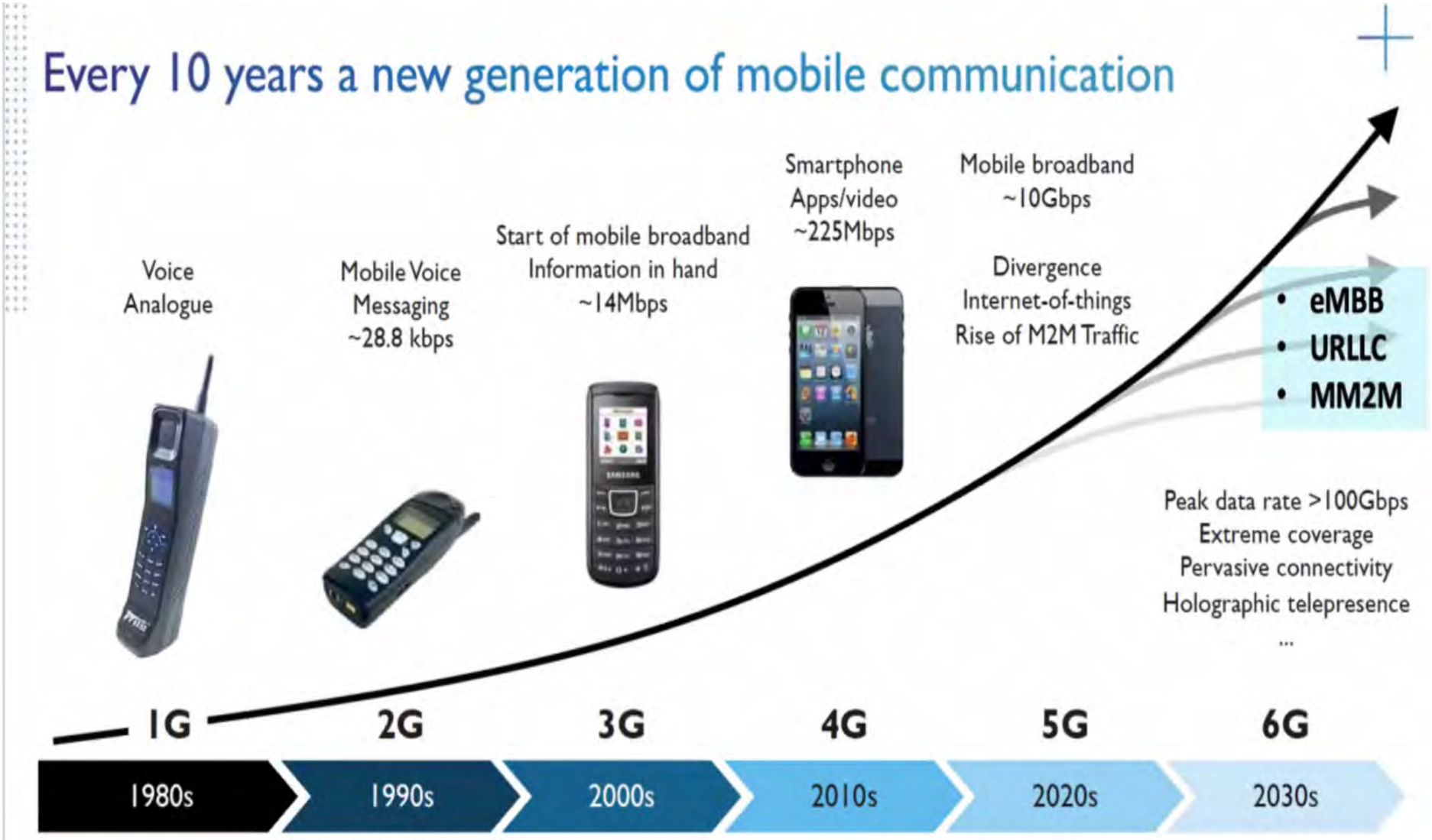
5G Use Cases Categories

Enhanced mobile broadband

Mission-critical services

Massive Internet of Things

Mobile Communications Roadmap



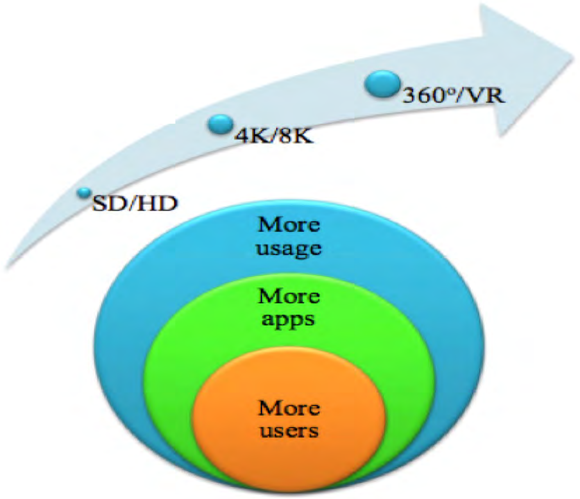
Nadine Collaert, imec, Emerging device and heterogenous integration technologies for sub-THz Applications, ISSCC 2022, 6G Forum.

5G Applications – Enhanced Mobile Broadband

Video Demand for Faster Network:

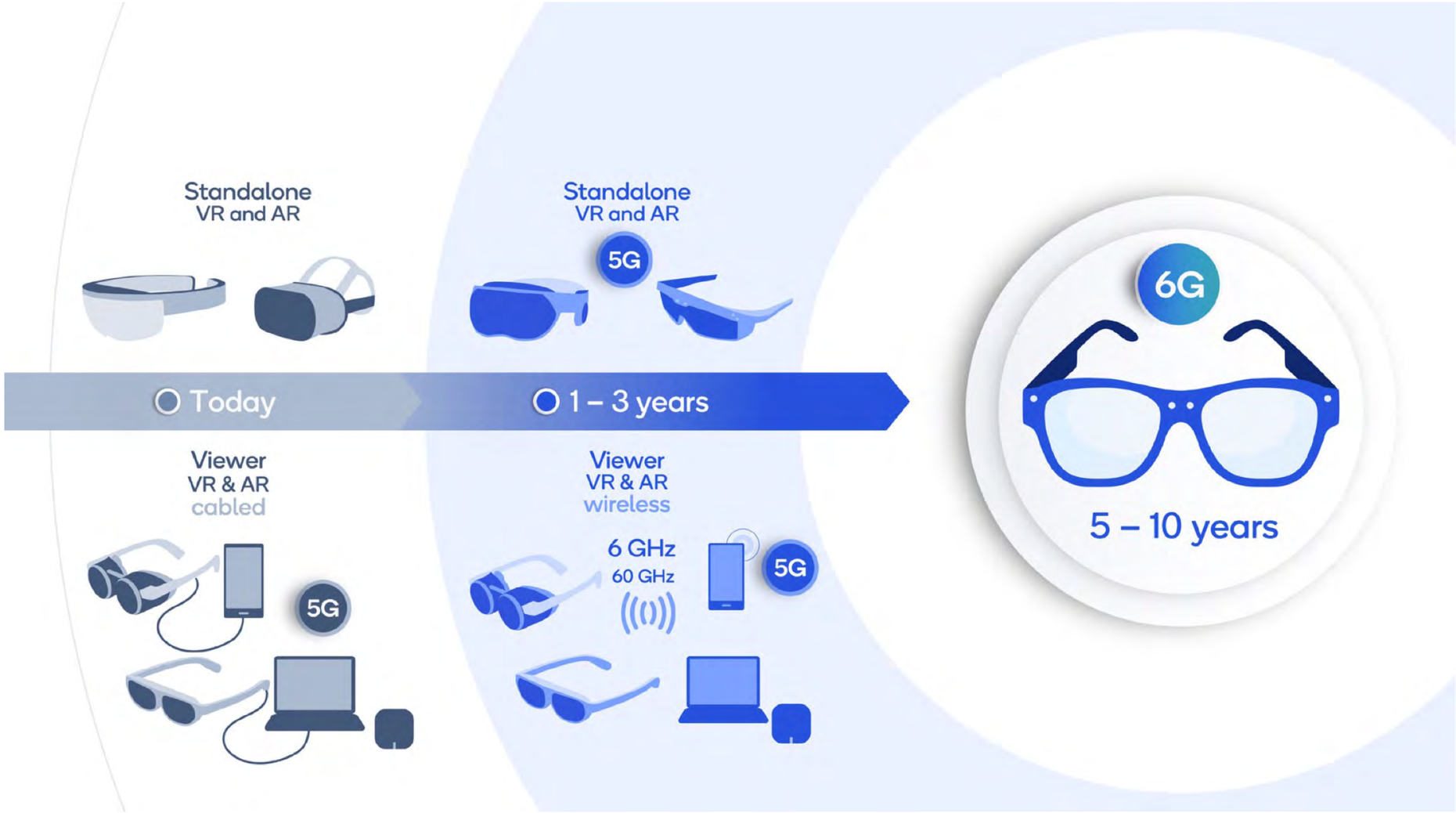
- **Video applications examples:** Streaming video, video conferencing, and virtual reality demands **higher data speeds**.

- **Video** is projected to be 82 percent of all IP traffic by 2022 (video traffic 2017: 56 exabytes, 2022: 240 Exabytes)



5G Faster download of 2hr HD video

Merging of the physical, digital, and virtual worlds



XR will become a mass-market compute platform

5G Applications – Drone

Potential Use Cases

- Delivery of emergency kit or rescue equipment to a disaster area using drones
- Search missions with HD imaging in disaster recovery zones, specifically areas of difficult access
- Coordinated missions where multi drone fleets from multiple countries could be used to inspect an emergency area or perform specific tasks (e.g. load handling)
- Rapid deployment of a temporary cellular network using drones, enabling vital communications for disaster recovery

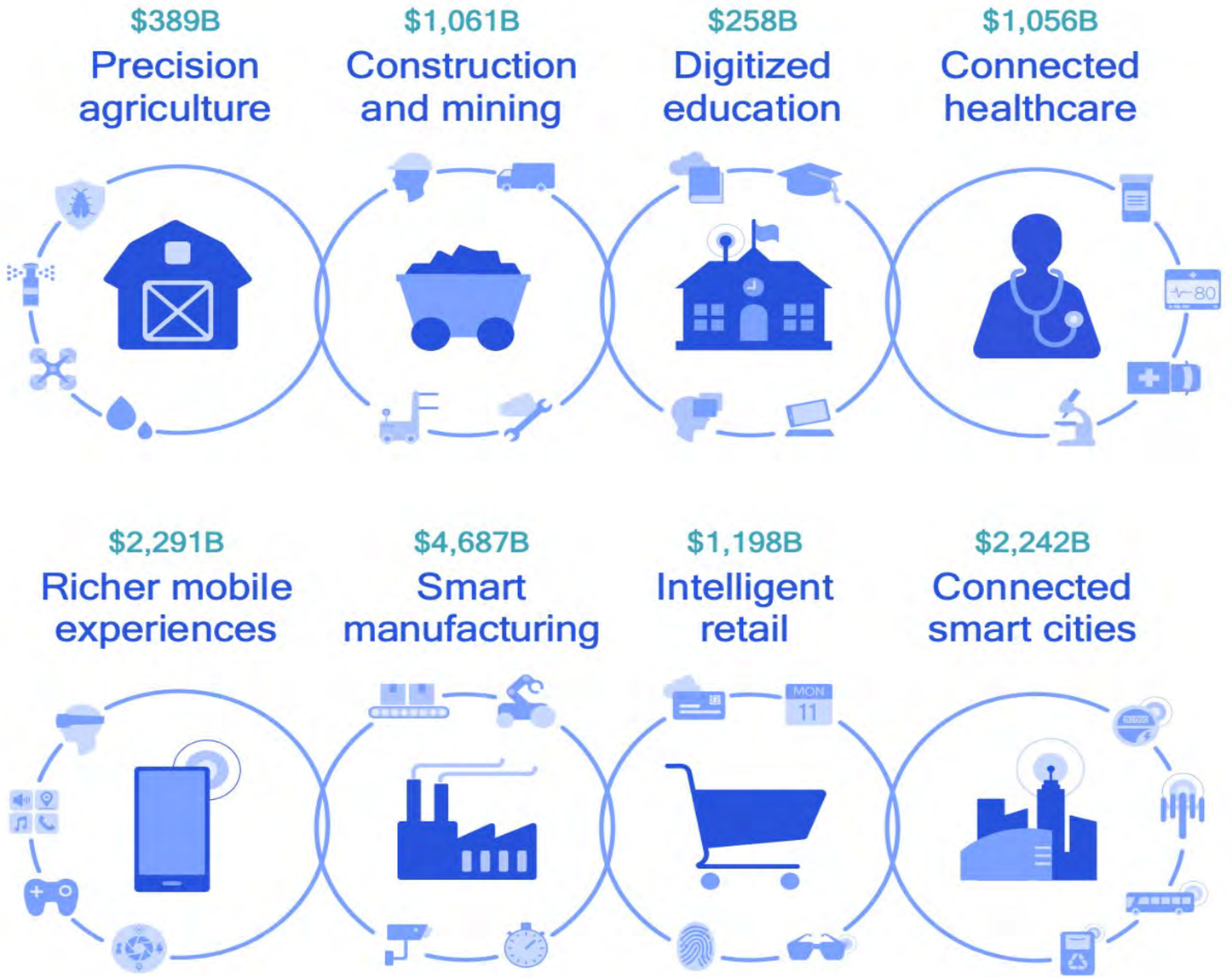
IoT Innovative Approaches

Drone and Future Healthcare

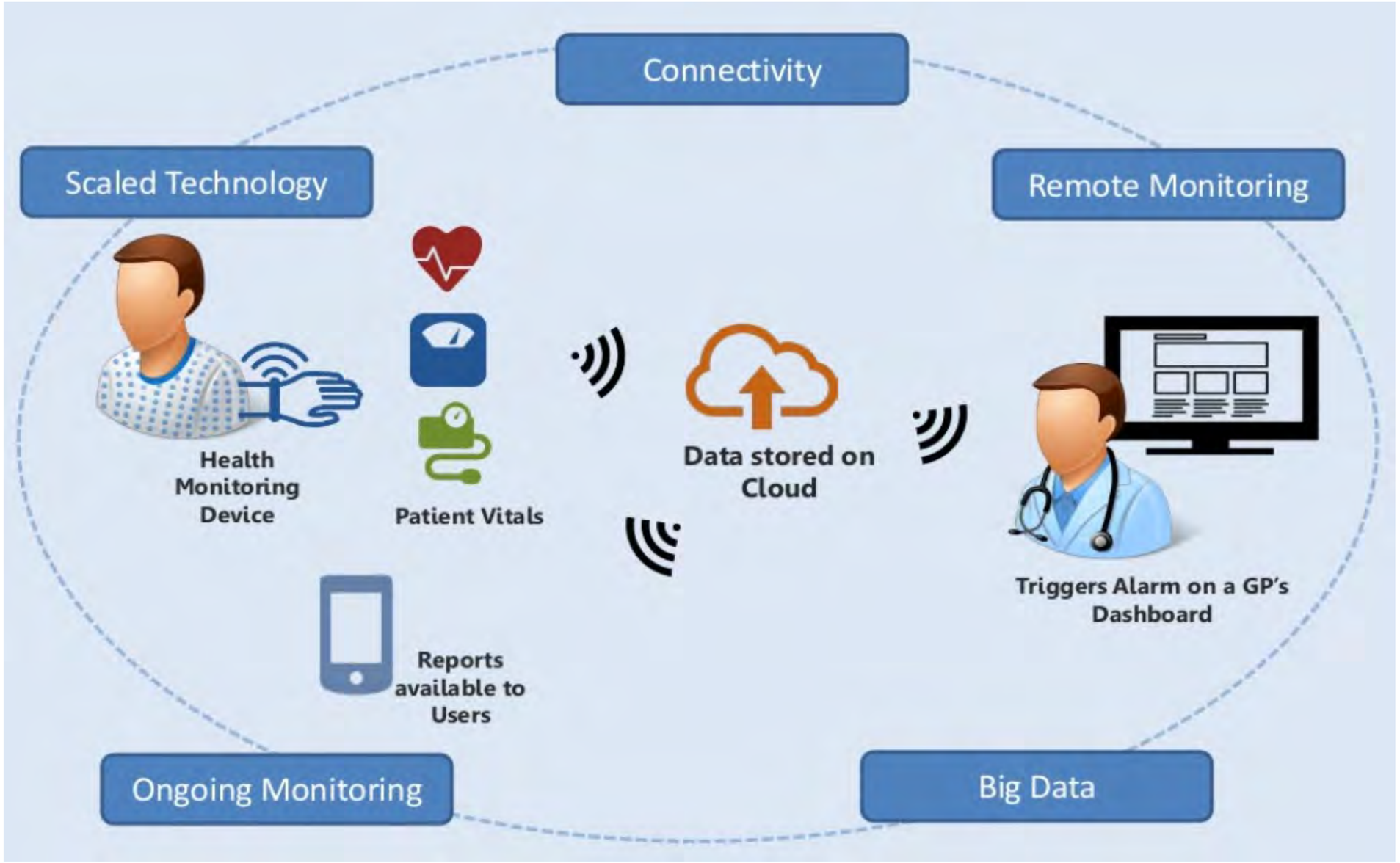
Air delivery of blood samples could save lives

- Most clinics are primarily collection sites.
- *Blood samples are loaded on the drone and flown around for varying time periods between 6-38 minutes.*
- *The blood samples are completely unaffected by turbulence or changes in air pressure*
- *The samples are packed in a special foam with a sponge that would fully absorb the specimens in the case of a crash.*
- *The regulations for drones differ in every country.*

5G will expand the mobile ecosystem to new industries



Accelerated Tele-Service



Smart Hospital

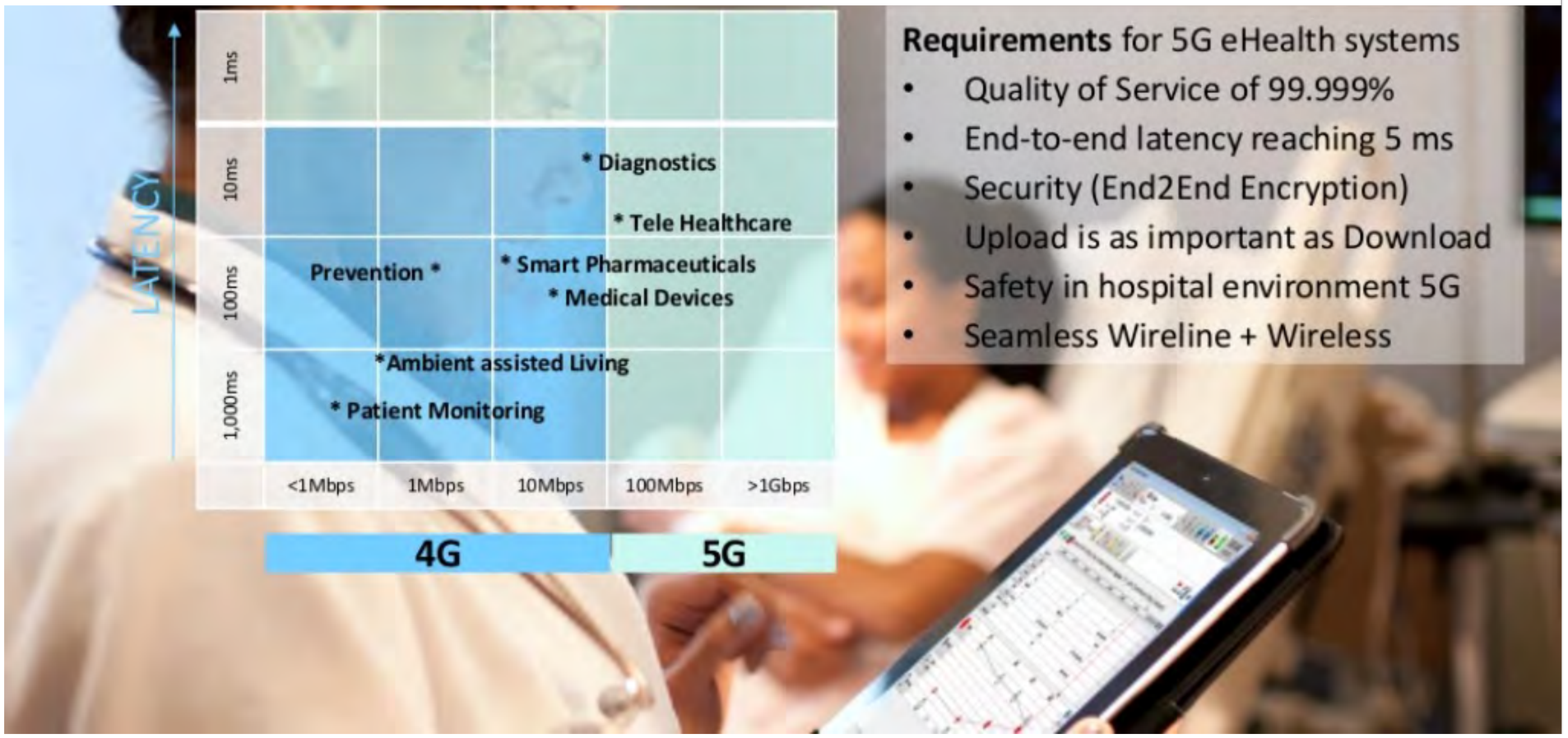
Patient – Nurses care

- Patient Integrated access to services & Environment
- Integrated devices and healthcare records

5G Applications – Healthcare

Potential Use Cases

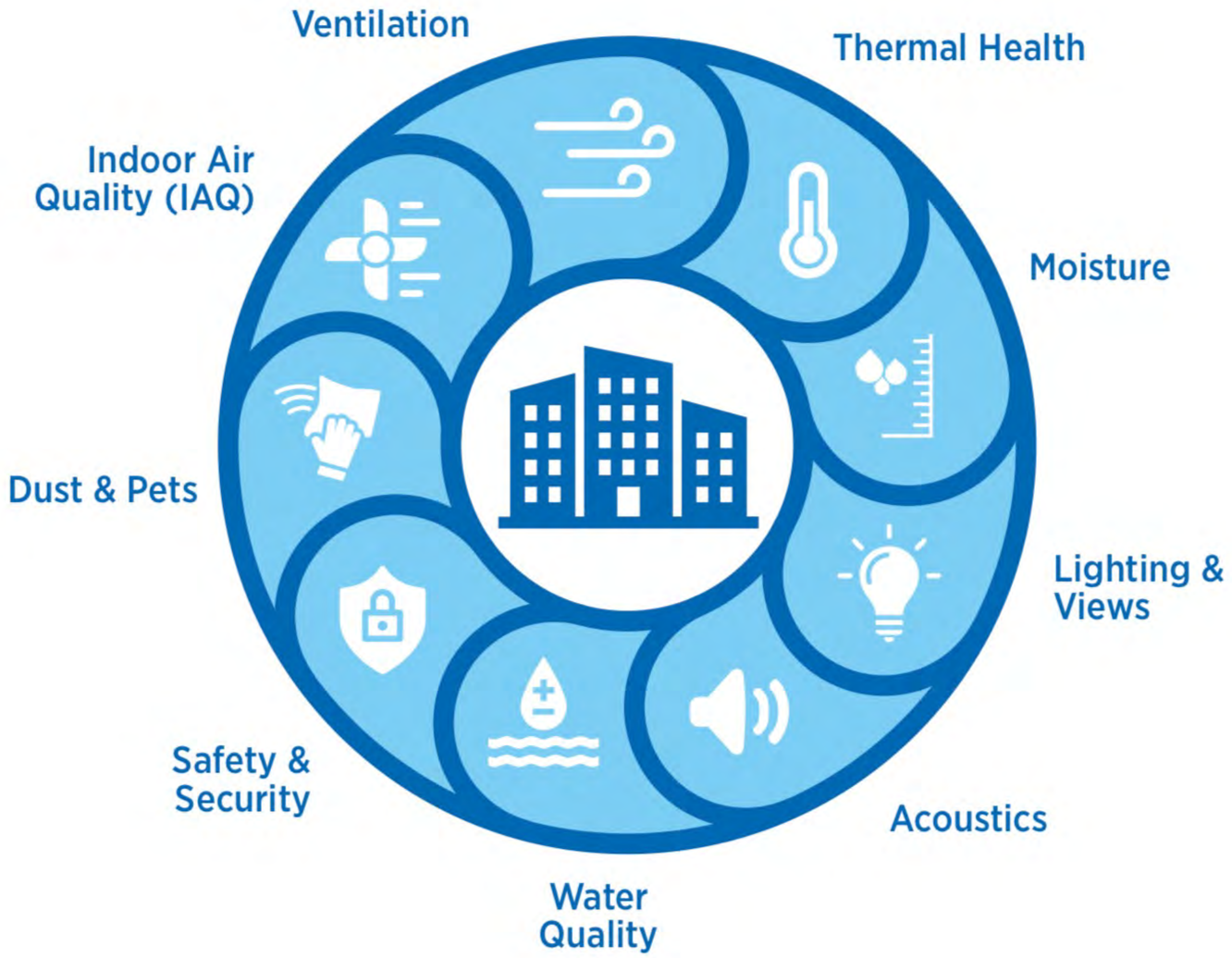
Tele Health, Remote Diagnostics, Surgery



Examples of IoT-enabled healthcare solutions utilized to support patients during the pandemic

Remote patient monitoring	Healthcare professionals use IoT devices to track heart rate, blood pressure and blood glucose levels of patients remotely, particularly the elderly and other vulnerable patients that have had to shield during the pandemic.
Contact tracing	A number of contract tracing systems implemented around the world rely on IoT-based solutions to track the movement of patients and enforce social distancing in public areas.
Vaccine cold chain monitoring	IoT platforms have been used to develop cold chain monitoring systems that track the temperature and location of vaccine carriers. For example, the Electronic Vaccine Intelligence Network, developed by the United Nations Development Programme (UNDP) and the Indian government, has reduced vaccine stock-outs by 80%.
Hospital sanitisation	Non-surgical robots connected to IoT systems have been used to clean patient rooms and to disinfect and sterilise surfaces from Covid-19 contamination with a special UV light and chemicals.
Automated temperature screening	IoT-enabled thermal imaging systems have been used to identify people with elevated body temperatures before they enter buildings, such as airports, office spaces, schools, shopping centres and hospitals, for further screening.
Facilities and PPE stock management	IoT system have been used to provide supply-chain planners and policymakers with actionable information on the availability of hospital beds and personal protective equipment (PPE) for medical staff for the efficient allocation of resources.
Healthcare delivery drones	IoT-enabled drones have been utilised to deliver test kits and results, PPE, medicines and other vital medical supplies, especially in developing regions with poor logistics infrastructure. For example, in Ghana, connected-drone company Zipline is supporting the delivery of vaccines to remote parts of the country.

Foundation of Covid-19 IoT Healthy Home/Building



Source: CABA Intelligent Buildings and COVID-19 2021 Report

COVID-19 Impact Creative Approach To Services

Foundations of a Healthy Building

Lighting & Control

- AI-based lighting control
- Voice enabled Lighting Control
- Human-centric Lighting

Automation & Energy Optimization

- Building energy performance optimization (BEPO)
- Cloud-based remote services
- Predictive maintenance
- Digital twin
- Workplace analytics

HVAC & IAQ

- HVAC optimization
- Indoor air quality (IAQ)-based ventilation
- Ultraviolet germicidal irradiation (UVGI)
- High efficiency particulate air (HEPA) filters

Post-COVID Applications

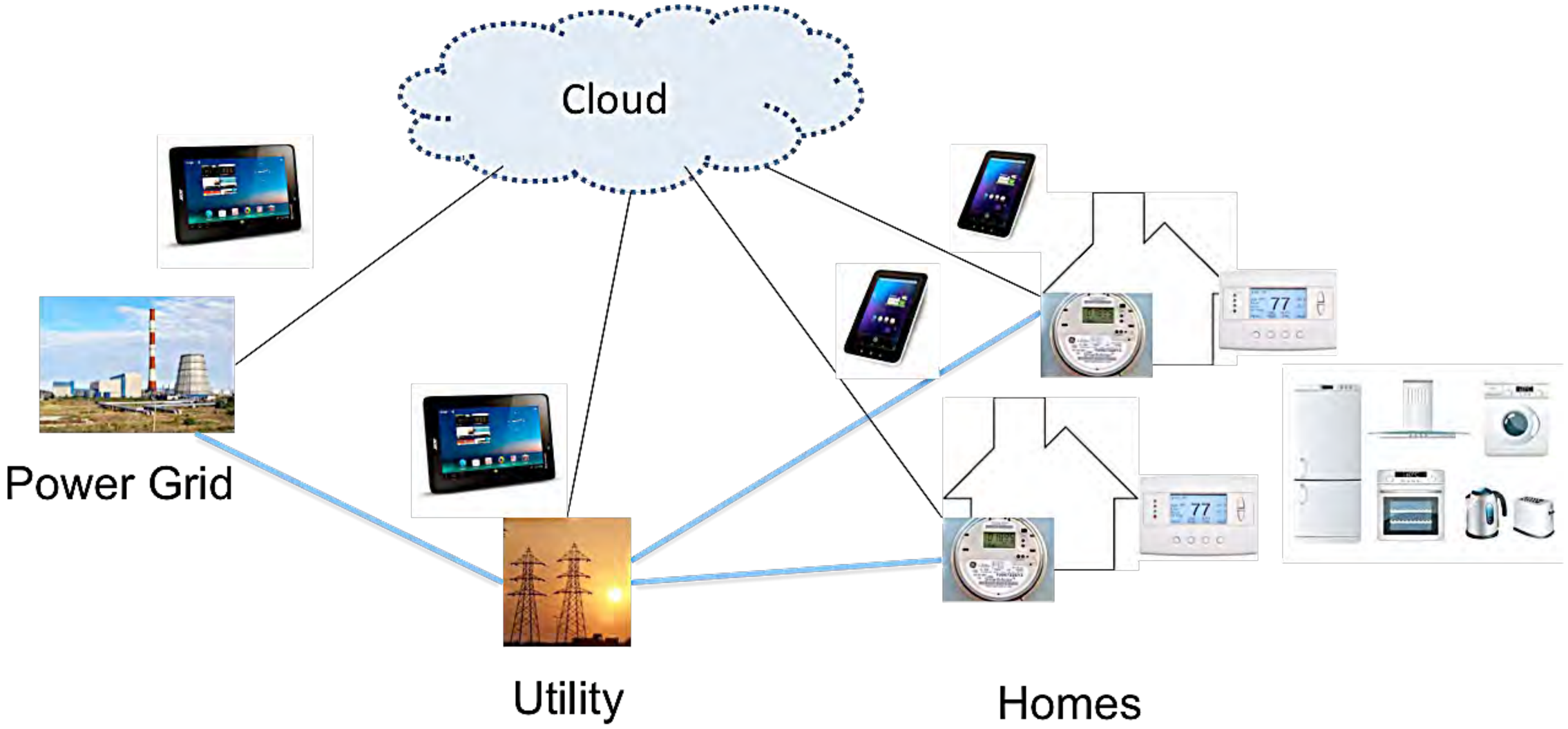
- Occupancy detection (OD) based social distancing
- Indoor positioning (IP) based contact tracing
- AI-based face and mask detection
- Antimicrobial paints in wash rooms
- Foot operated elevator
- Touch-free bathroom fixtures
- Thermal imaging
- AI-based access control
- Building health performance benchmarking (BHPB)
- Pathogen scanner
- Nano technology (NT)-based self cleaning surfaces
- Touch-free toilet seat cover cleaning

Communication

- Power over Ethernet (PoE)
- Narrowband communication
- Bluetooth Low Energy (BLE)

Source: CABA Intelligent Buildings and COVID-19 2021 Report

5G Applications – Smart Energy

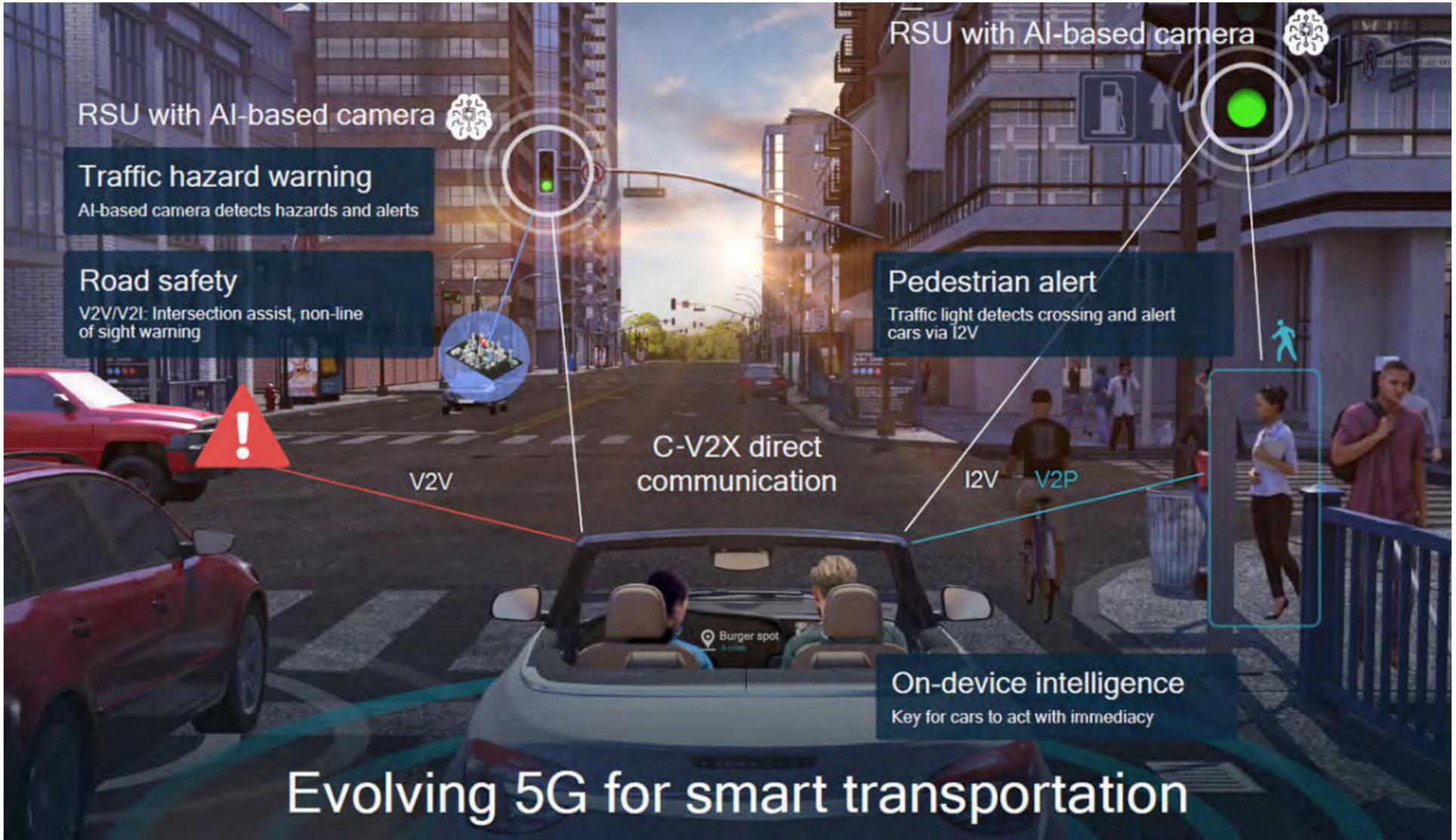


Public Safety – First Responders

Risks	
Classification:	Commercial
Type of construction:	Concrete
Usage:	Dwelling
No of Floors:	4
Danger:	Gaz
Secure Access:	Unknown
Surrounding:	Exposed

Must ensure that public safety vehicles receive the proper prioritization in terms of ultra-high-speed data access for building schematics, local maps, communications, etc.

5G – Enable Smart Transportation and EV/Autonomous driving



IoT Smart Connected Cars
In The Plan – Capabilities/Features Roll-out

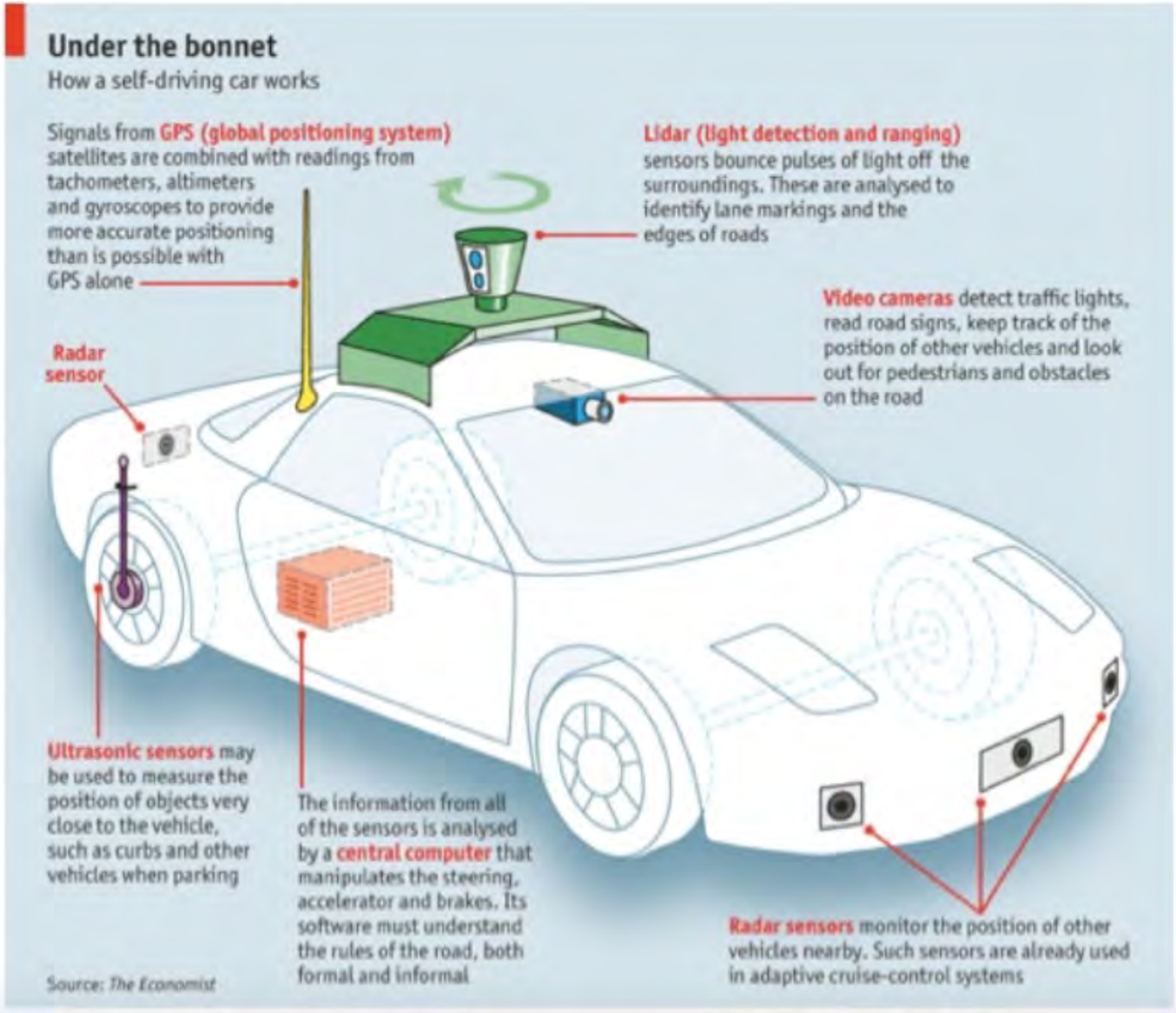
- Active Safety, Accident avoidance V2X (V2V, V2I)
  > Wifi Peer-to-Peer (P2P) Mesh Networking
    802.11p for V2V (Vehicle-to-Vehicle), V2I (Vehicle-to-Infrastructure)

- Car Tracking (Location, Speed etc); Logistics: Taxi, Truck etc

- Autonomous Car (Google Car)

IoT and Sensing for Autonomous car

Capable of sensing the environment and navigate without human input.



IoT Smart Connected Cars
Self-Driving Cars challenge at Intersection

Bigger issues regarding IoT Smart Transportation (V2V & V2I)

IoT Smart Connected Cars
DSRC and C– V2X

DSRC Technology

Dedicated Short-Range Communication

- Ad hoc networking technology that allows vehicles to communicate with each other, roadside devices, pedestrians, bicycles, trains, ….
- IEEE portions also called WAVE (Wireless Access in Vehicular Environments)

V2X Communications

- Long range sensing
- Non line-of-sight capability
- Collaborated driving

V2I

- Red Light Violation Warning
- Curve Speed Warning
- Stop Signal Gap Assist
- Reduced Speed/Work Zone Warning
- Pedestrian in Signalized crosswalk Warning

V2V

- Emergency Electronic Brake Lights
- Forward Collision Warning
- Intersection Management Asist
- Left Turn Assist
- Blind Spot/lane change warning
- Do not pass warning

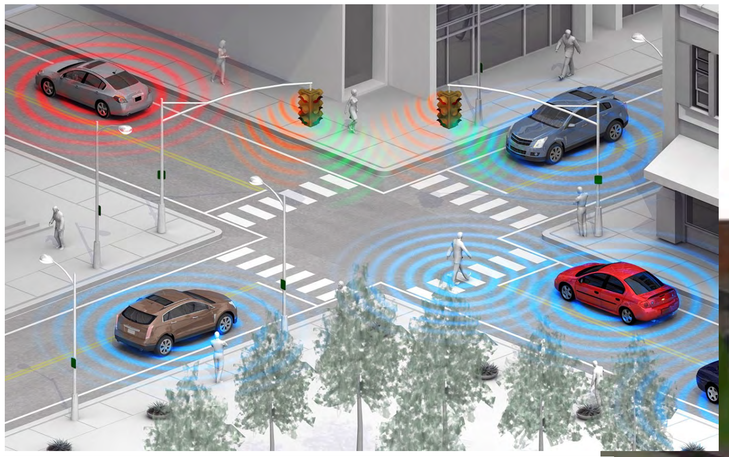
Disruptive Technologies for 5G New Radio (NR)

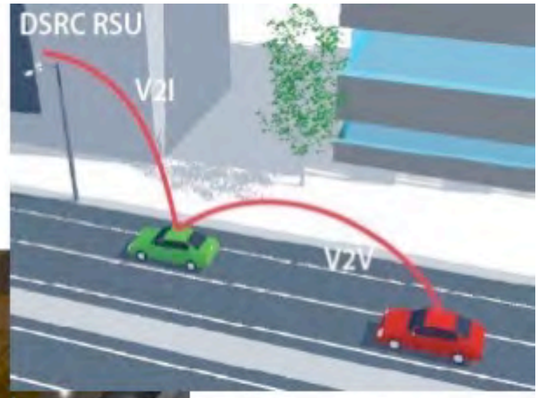
High reliability, low latency and high data rates are required

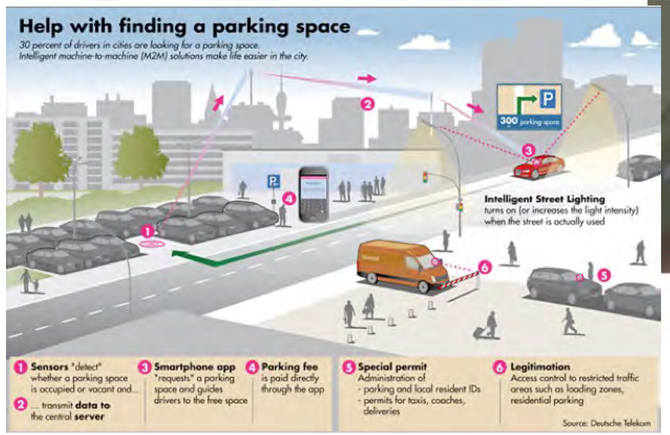
Use Case	Latency	Reliability	Data Rate
Vehicle platooning	<25 ms	>90%	Low
Remote Driving	<5 ms	>99.99%	>10 Mbps DL, >20 Mbps UL
Collective perception of environment	<3 ms	>99%	1 Gbps for a single UE
Cooperative collision avoidance	<10 ms	>99.99%	>10Mbps
Info sharing for level 2/3	<100 ms	>90%	> 50 Mbps
Info sharing for level 4/5	<100 ms	>99.99%	100-700 Mbps

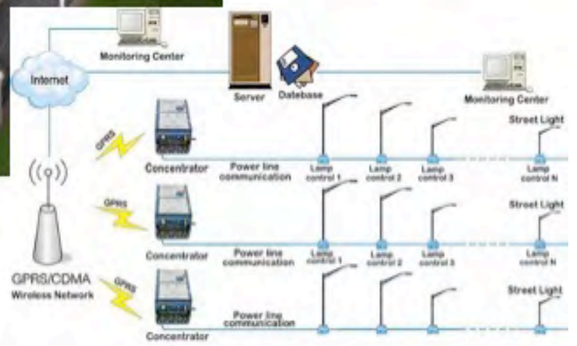
5G Applications – Green & Smart Infrastructure

Integration of **smart vehicles** which can act as storage devices to reduce transmission losses and promote **cleaner transport** and the introduction of **smart infrastructure, and intelligent** demand response systems.



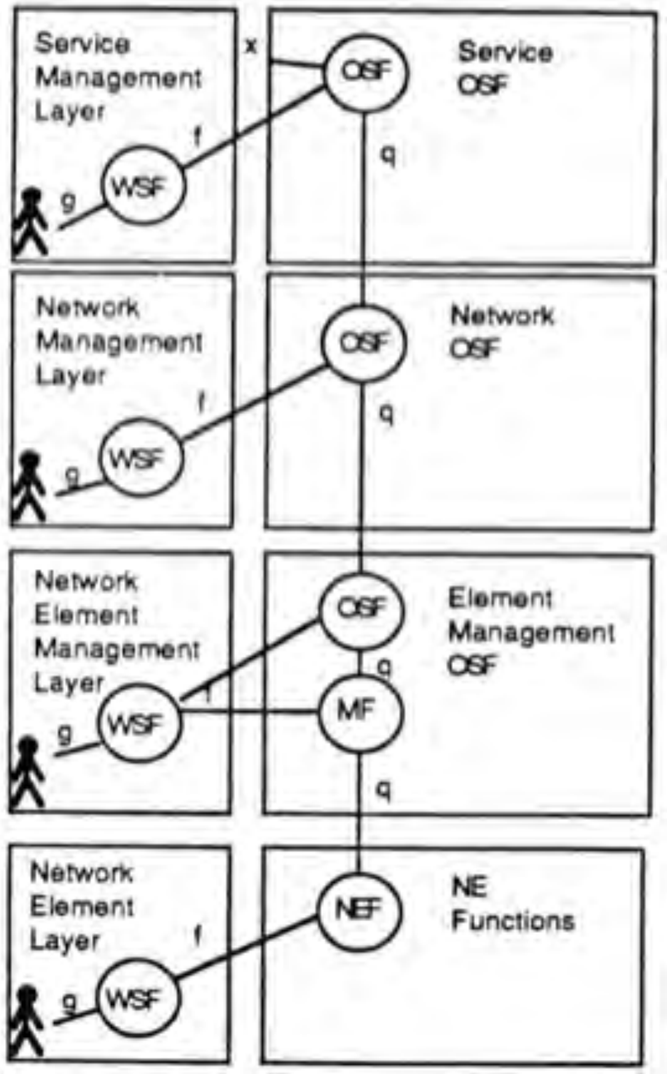






Telecom: ITU TMN versus IoT Functional Models

ITU TMN

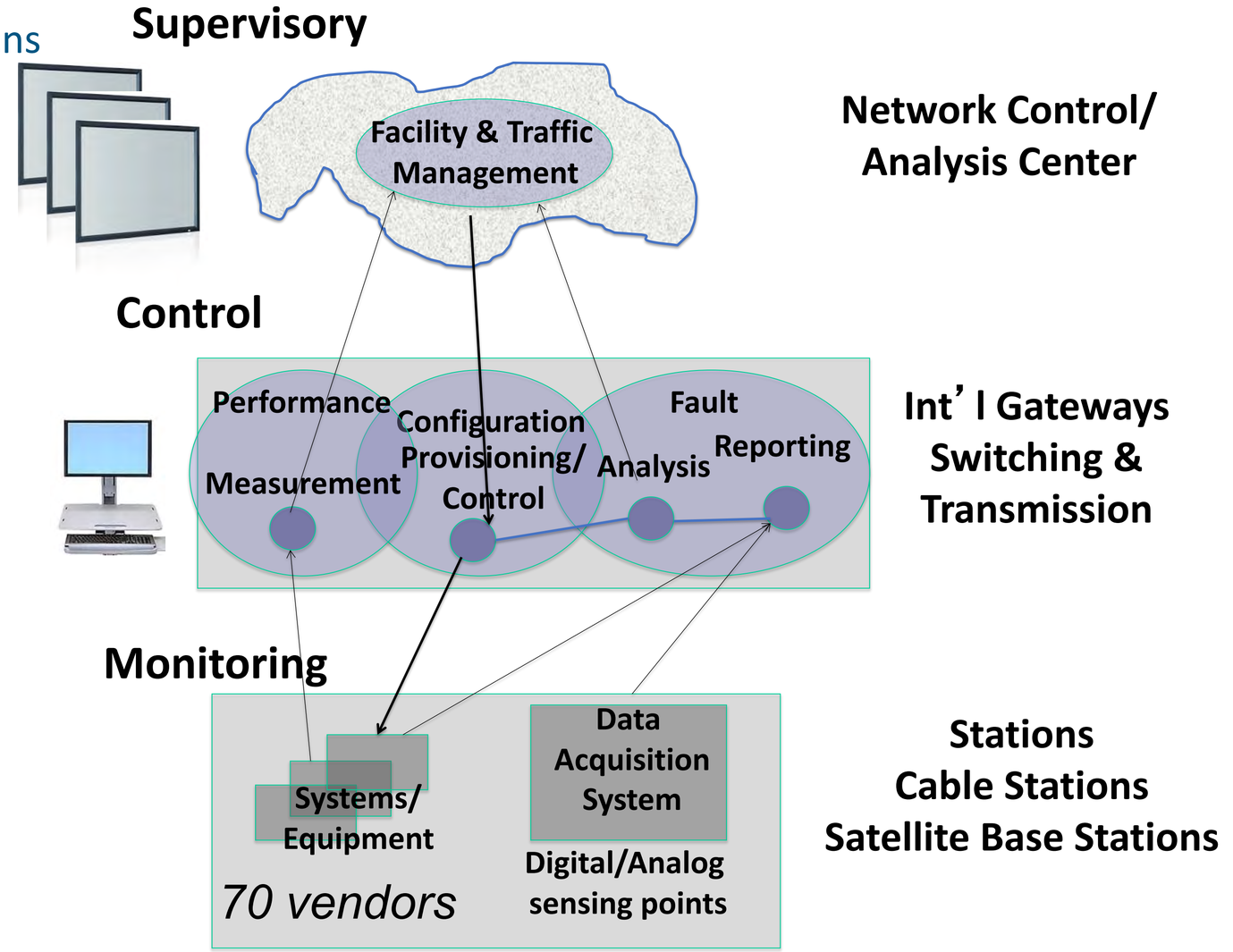


Telecom Functional Network Management Systems

Monitors/Projection Screens
- Graphical views
- Service Performance

Smart Work Stations
- TMN Functions (Multiple views)
- ACK/Control

Work Stations
- Elements of TMN
- Sensing (analog, digital)
- RS-xxx



Use of the Drone in Public Safety

- Search and rescue
- Situational awareness
- Safety – Egress
- Medical delivery

IoT *Smart* Streetlight

IoT Smart Streetlight

IEEE ComSoc

Sensing
- Smart Grid lighting
- Image sensors
- Environmental/Water

Gateway/Control
- Notification light
- Audio
- Signage
- Push to talk
- App based wireless control

Services/Data Analytics
- First Responders
- Interact with traffic light control
- Stat/Planning for safety

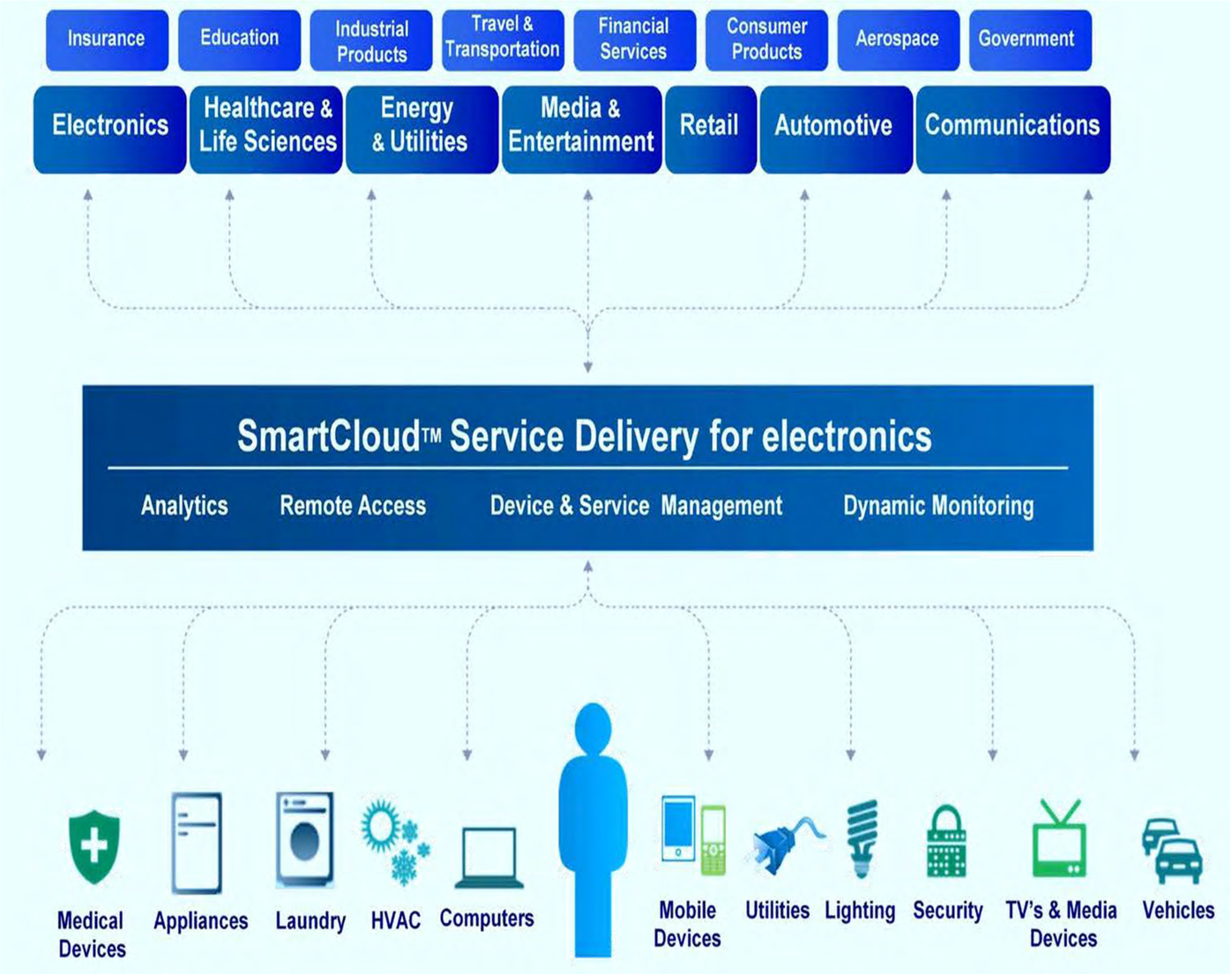
FACILITY MANAGER – NEW JOB DESCRIPTION!

- Building health assessment
- Indoor air quality (IAQ) solutions
- Data driven services
- Health and wellness standards

Source: CABA Intelligent Buildings and COVID-19 Report

Smart Connected Building

AI-driven building solutions and cloud-based remote services



Source: CABA Intelligent Buildings and COVID-19 2021 Report

5G/IoT/AI Use Cases: Smart City

Economic Growth

Quality of Life

Ecological Footprint, Sustainability

Across multiple Sectors

Smart Mobility

Smart Safety

Smart Energy, Water & Waste

Smart Building & Living

Smart Health

Smart Educa-tion

Smart Finance

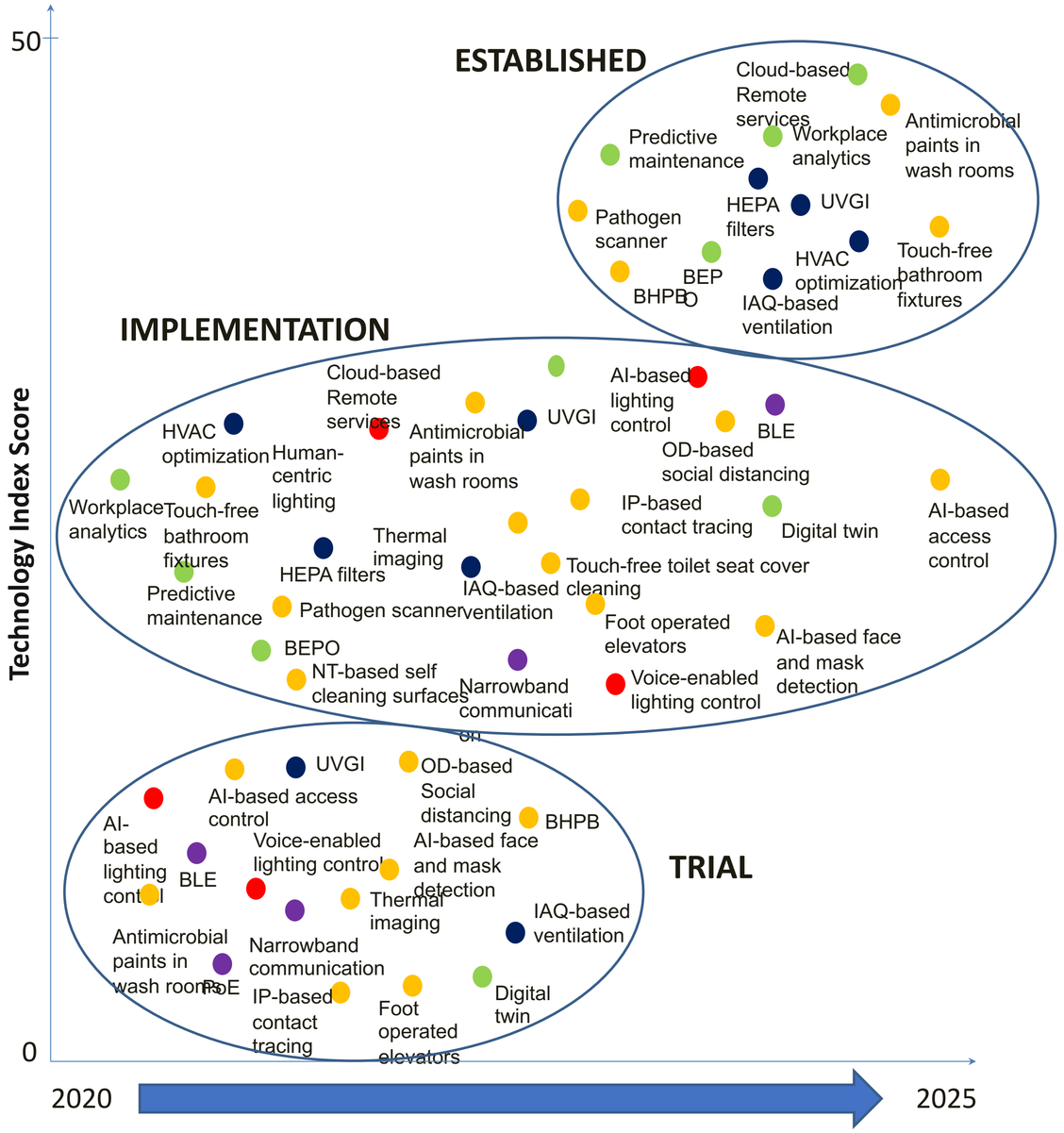
Smart Tourism

Smart Retail & Logistics

Smart Manuf-acuring

Smart Gover-onment

Technology Roadmap 2020-2025



Lighting & Control

- AI-based lighting control
- Voice enabled Lighting Control
- Human-centric Lighting

Automation & Energy Optimization

- Building energy performance optimization (BEPO)
- Cloud-based remote services
- Predictive maintenance
- Digital twin
- Workplace analytics

HVAC & IAQ

- HVAC optimization
- Indoor air quality (IAQ)-based ventilation
- Ultraviolet germicidal irradiation (UVGI)
- High efficiency particulate air (HEPA) filters

Post-COVID Applications

- Occupancy detection (OD) based social distancing
- Indoor positioning (IP) based contact tracing
- AI-based face and mask detection
- Antimicrobial paints in wash rooms
- Foot operated elevator
- Touch-free bathroom fixtures
- Thermal imaging
- AI-based access control
- Building health performance benchmarking (BHPB)
- Pathogen scanner
- Nano technology (NT)-based self cleaning surfaces
- Touch-free toilet seat cover cleaning

Communication

- Power over Ethernet (PoE)
- Narrowband communication
- Bluetooth Low Energy (BLE)

Source: CABA Intelligent Buildings and COVID-19 Report

IoT - 5G/6G – Edge Computing/Edge AI

High Level Model

Center/Apps (Insightful Intelligence)

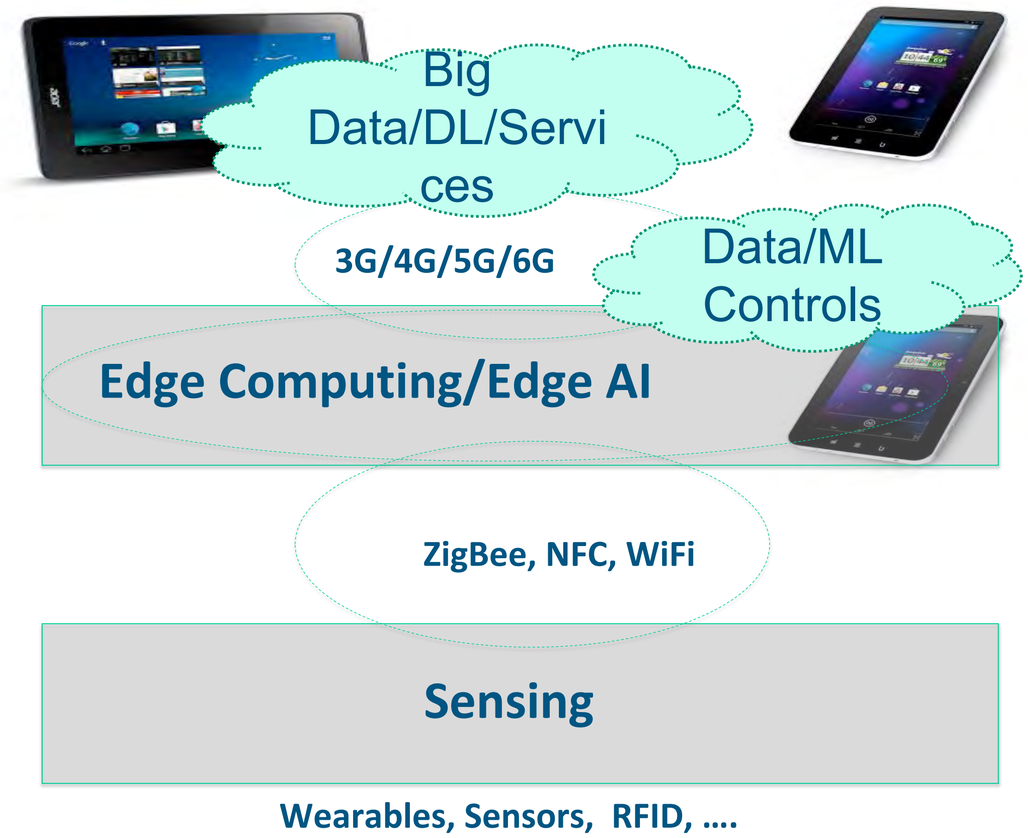
This layer provides insight to the data collected from all layers and offers the information as a service to individuals, industries or infrastructures.

Edge Computing -> Edge AI (Gateway/Aggregation)

This layer enables the stream of data to move from one level to the next for additional processing.

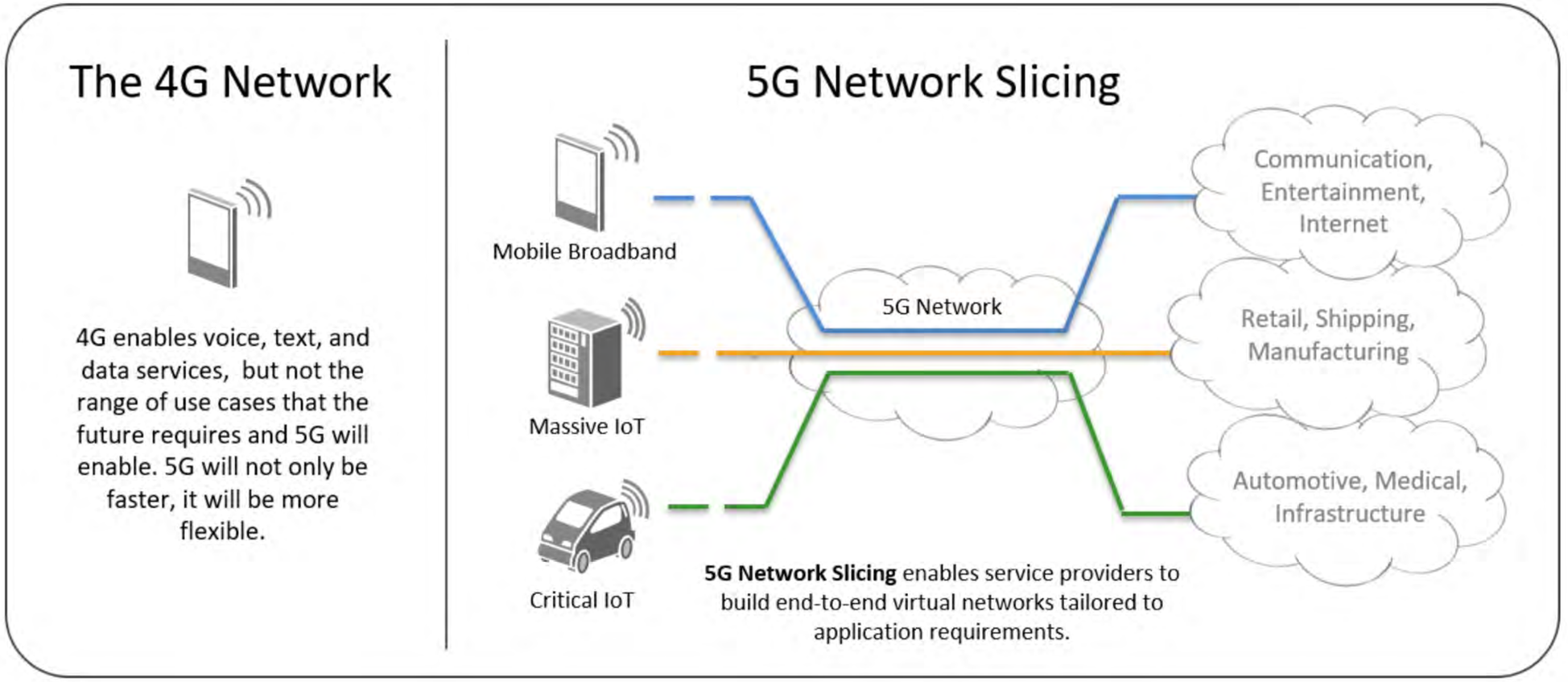
Sensing

This layer enables interface to objects that are currently passive, where tapping into these objects will generate a stream of pertinent data and information.



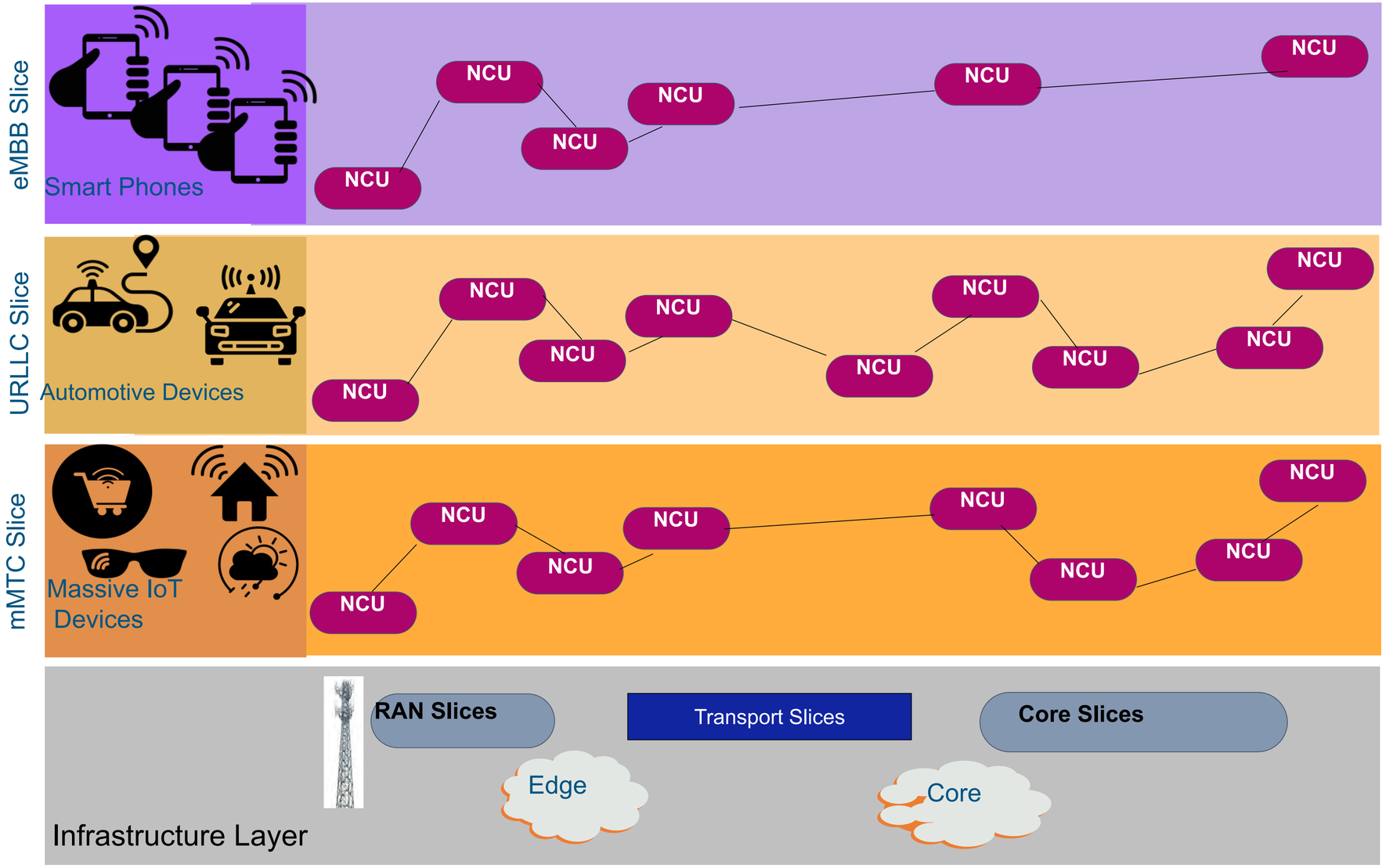
Source: Collaborative IoT book, Wiley

5G Network Slicing (NS) Difference from 4G



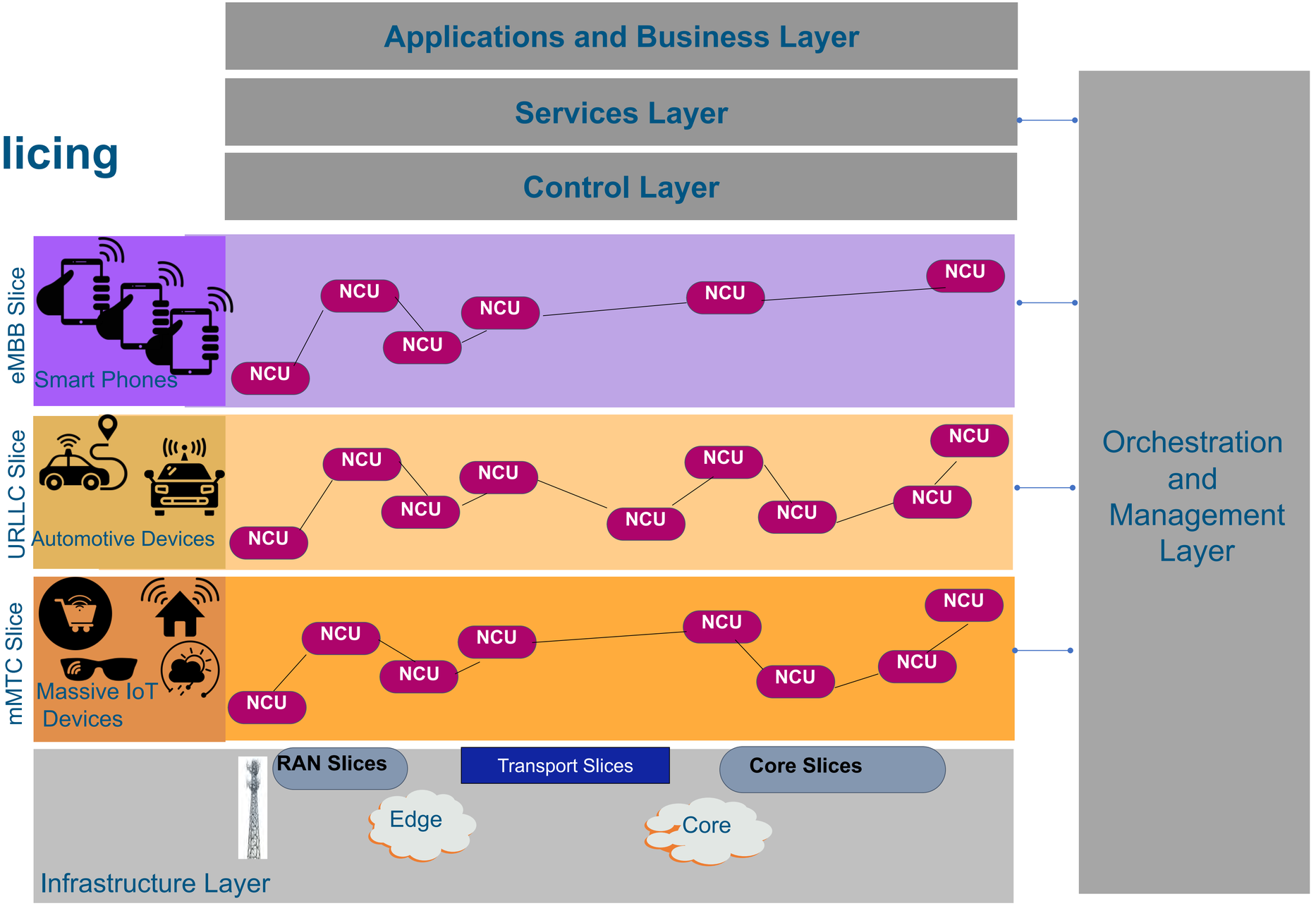
- **Each slice is optimized to meet different KPIs: wide coverage, massive connection, low latency and high reliability, high data rate, etc.**
- However, not all network slices are created equal

5G Network Slicing (NS)



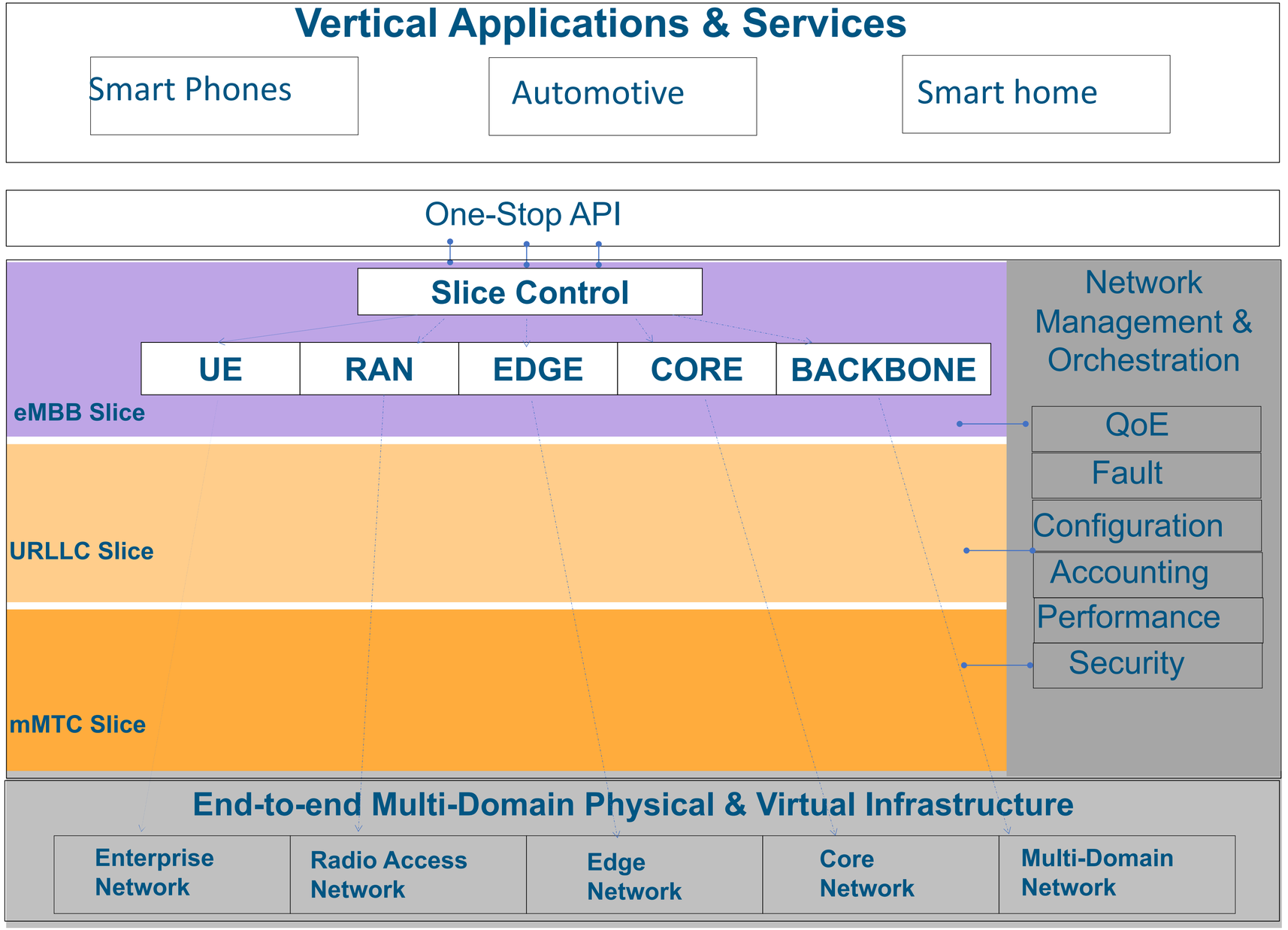
Network Slicing (NS) partitions common network infrastructure into multiple, logical, end-to-end, virtual network instances to provide customized virtual private services

5G
Network Slicing



Orchestration deliver cost effective, timely and efficient NS governed by a service level agreement

5G Network Slicing



Network slices and major network components

5G Network Slicing – Network Edge and AI

Network Slicing and Multi-access Edge Computing (MEC) are two key enablers for 5G QoS service differentiation optimizing use of resources in the network and use of network slicing.

Flexible orchestration of network slices is realized using software defined functions and programmable infrastructures. RAN's backhaul are governed by the NFV infrastructure, the control of which relies on the MEC

The intelligence data comes in streams: from multiple sites; in multiple forms that include videos from surveillance systems, images from cameras, verbal reports in many languages and dialects, and responses from databases to queries.

Actionable information must be extracted continuously from this streaming data and delivered in customized form to appropriate addresses.

5G/6G and Edge Computing Takeaways

- 5G Commercial trials/deployment are progressing (eMBB, mMTC, URLLC)
- Collaborative 5G & IoT transform from identifying symptoms to identifying root cause leveraging mass connectivity, low latency and higher speed.
- IoT, 5G/6G and AI usher a beginning of collaborative, end-to-end, scalable services aimed at improving business process, quality of life and personalization of services.
- Multi-access Edge Computing (MEC) and Edge Intelligence allows for faster processing closer to the equipment at lower latency.
- Network Slicing enable QoS service differentiation, optimizing use of resources in the network and revenue generation.

5G Network Slicing - Examples

eMBB:

- Video applications for faster download or streaming, video conferencing and virtual reality demanding **higher data speeds**.
- The network will likely need a lot of small cell coverage and will take advantage of higher bandwidth spectrum.

Automotive

Network slices may be needed for high throughput needs for in-vehicle entertainment, and ultra-reliable and low latency (URLLC) needs for assisted/autonomous driving, data gathering and analysis from telemetry sensors, device to device communication, etc.

Massive IoT:

- Support a huge number of devices, many of which require longer battery life, the 5G network will be building off of the LTE Advanced Pro platform.
- 5G will use the platform's **two** narrowband technologies, enhanced machine-type communication (**eMTC**) and narrowband IoT **(NB-IoT**). Examples: Transport traffic management department may use a massive IoT network slice to monitor and manage the real-time status of their systems.

Future Networks Technical Community

Collaboration

+ other IEEE and non-IEEE collaborators

Content

technical newsletter, podcasts, videos, articles

Events

IEEE Future Networks™ WORLD FORUM • 2022

IEEE Connecting the UNCONNECTED™

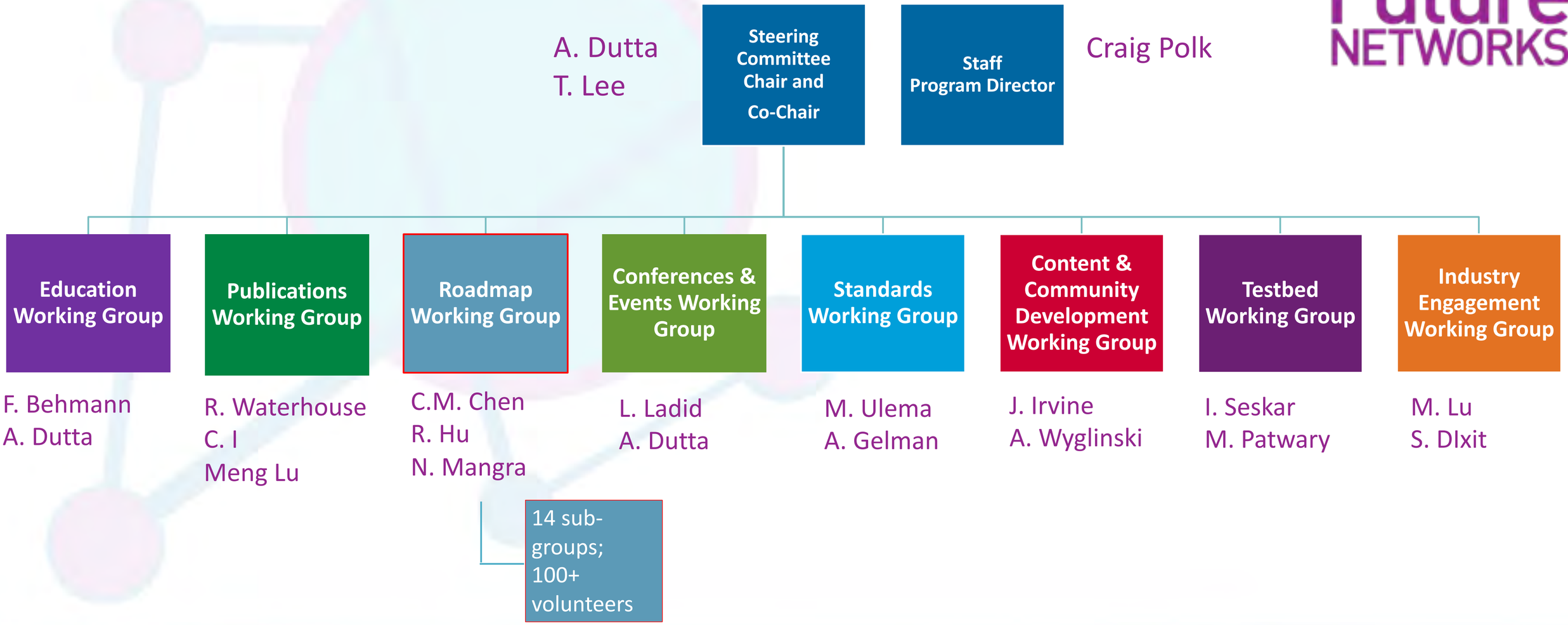
+ workshops and more

Research & Education

IEEE INGR International Network Generations Roadmap

+ eLearning courses, webinar series, tutorials

IEEE Future Networks Organization Structure



INGR Strategic Objectives

Address diverse areas of interest through targeted working groups that benefit humanity through technology

- 14 Working Groups focused on technology and society

Provide a suite of technology roadmaps to identify risks and opportunities within 3, 5, and 10 year periods

- 2022 INGR Edition released
- **2023 INGR Edition coming soon**

Engage stakeholder groups within and across IEEE initiatives and external entities for added value

- Internal INGR community
- IEEE and IEEE SA entities
- External entities

https://futurenetworks.ieee.org/roadmap

IEEE INGR International Network Generations Roadmap

- Annual technical document highlighting network technology evolutions over 3-, 5- and 10-year horizons
- Created by 100+ international experts across 14 working groups
- 2022 Edition (3rd) was 14 chapters, 1000+ pages
- Available exclusively to Future Networks participants
- 14,500+ total INGR downloads
- Events and outreach:
  - Presentations and readouts at conferences
  - Technical workshops
  - 2021-22 webinar series
  - Paid advertising campaigns
  - In 2021, FNI's INGR events compiled 6,200 registrants

INGR Editions

Scope.

- High-level perspective and projection of how the industry could evolve
- Highlights of common needs
- Challenges to achieving those needs
- Potential solutions to those challenges

Projections

- INGR projections for the next 10 years:
  - Key Timeframe points at 3, 5, and 10 years.

Foundation for future editions

- This INGR 1st edition was released in 2020 and was followed by 2021 and 2022 Editions. They laid the foundation for subsequent editions that will include a description and evaluation of 6G and other future network enhancements.

2023 Edition

- Extend the range and depth of the 2022 Edition

IEEE International Networks Generations Roadmap (INGR) 2022 Edition

https://futurenetworks.ieee.org/roadmap

IEEE INGR Structure and Working Groups

CATEGORY	DESCRIPTION	INGR WORKING GROUP CHAPTERS
User Access	This group describes how the users reach the network	• Satellites • Deployment • Connecting the Unconnected (CTU)
Network Components and Performance	This group describes how the networks are interconnected	• Edge Automation Platform • Massive MIMO • Systems Optimization • Optics • mmWave
Systems and Standards	This group describes system standards and testability	• Standardization Building Blocks • Testbed • Energy Efficiency
Services and Enablers	This group represents all the elements that enable deployment, assure functionality and security and address impact on society and environment	• Security • Applications and Services • Artificial Intelligence and Machine Learning (AI/ML)

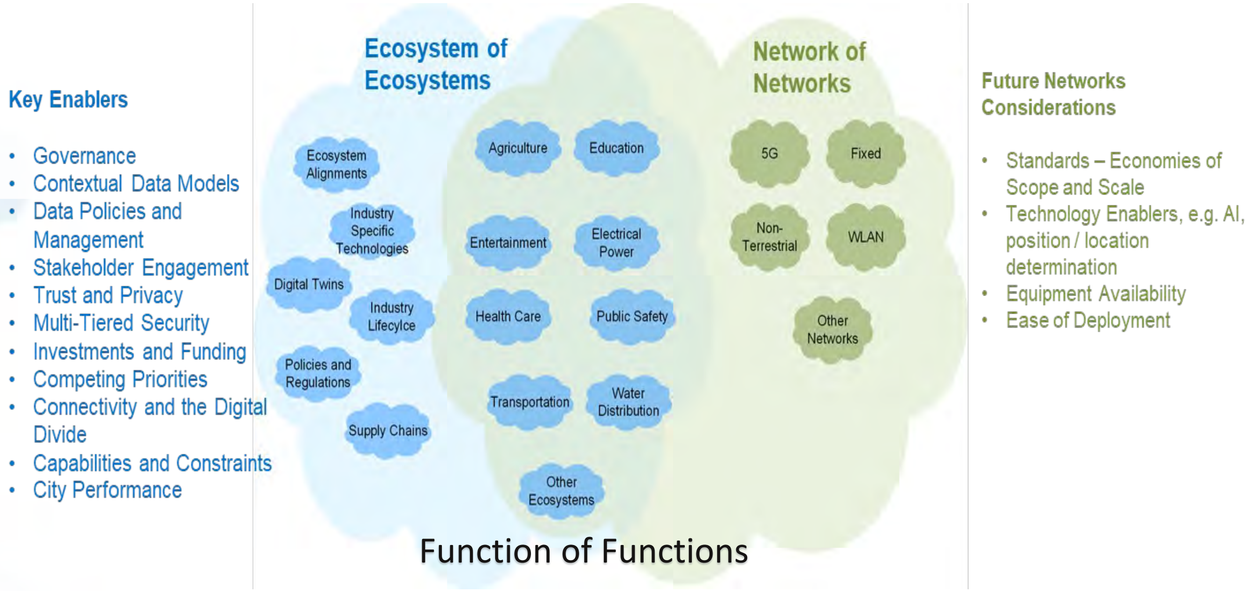
Applications and Services WG

INGR Applications and Services WG Focus

- Provides a sustainable **transdisciplinary framework** across end-to-end ecosystems in urban and non-urban areas, and caters to different stages of priorities, resources, and technologies.

INGR Applications and Services Chapter Highlights include

- **Applications and Services Framework**
  - **Ecosystem of Ecosystems:** intra-ecosystem and inter-ecosystem alignments. **Eight ecosystems** are addressed – Agriculture, Education, Electrical Power, Health Care, Media and Entertainment, Public Safety, Transportation, and Water Distribution & Wastewater Treatment.
  - **Network of Networks:** Future networks components (**access, service delivery, operations and service management, and network extensions**), use case categories and deployment drivers, and network operations enhancements.
  - **Function of Functions:** strategic, tactical and operational **governance** functions.
- **Scenarios:** Smart Cities, Smart Regions, and Pandemic Response Scenarios



WG Recommendations / Highlights of 2022 Edition Topics

- **Framework Enhancements** – Additional details on ecosystem enhancements, cross-ecosystem touchpoints, and KPIs
- **Inter-INGR WG Collaboration**, e,g, AI/ML use cases, Comprehensive Plans, Rural Development, Trust, Multi-tiered security, etc

IEEE INGR Applications and Services WG

- ***Roadmap Details – Refer to INGR WG chapter***
- ***WG Participation –*** 5GRM-appssvcs@ieee.org

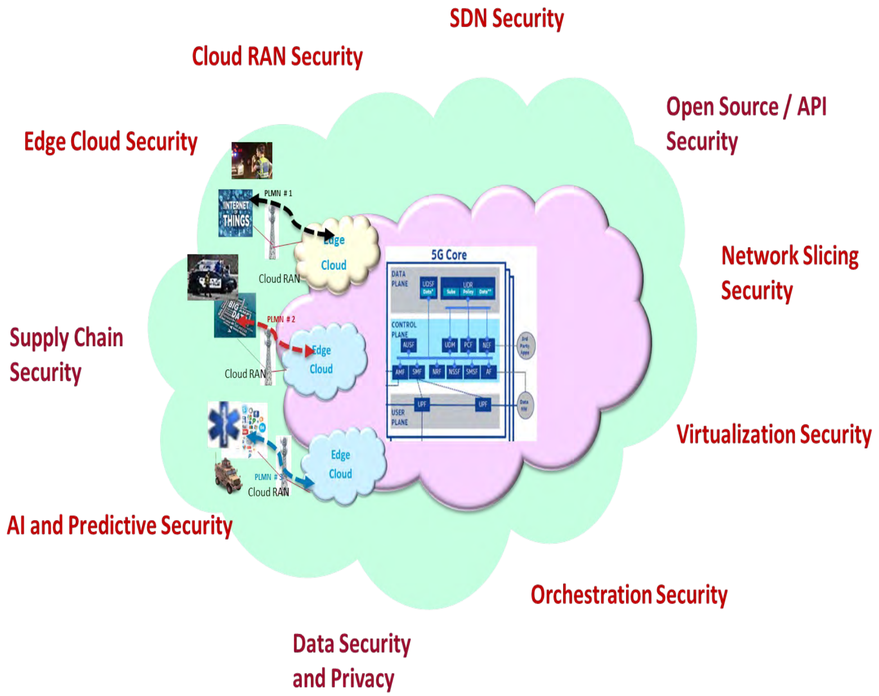
Security WG

INGR Security WG Focus

- 5G security considerations for different layers (physical, network, and application).
  - **Security challenges and opportunities**.

INGR Security Chapter Highlights include

- **Foundational Concepts**: NIST CyberSecurity Framework and SecurityThreat Models
- **Security and Privacy Domains**: Security focus on Management and Orchestration, Edge, Third Parties, Data Privacy, Satellite, Virtualized RAN, Massive MIMO, Spectrum, Physical Layer, Security Monitoring and Analytics, Predictive/ Proactive Security and 5G Digital Forensics.
- **Security Use-Cases for various Verticals**: Security focus on Applications, Critical Infrastructure Systems, AI/ML, Interoperability, Industrial Control Systems (ISC), Safety & Security, etc



WG Recommendations / Highlights 2022 Edition Topics

- **2022 Edition** to include additional coverage of data sharing and privacy, satellite communication, physical layer security, identity and access management, application security KPI/SLA, etc.
- Perform an **in-depth security gap analysis** with current industry standards
- **Enable studies (research, verification)** via established 5G test-beds
- **Publications** to inform/guide/socialize 5G security directions/focus areas.
- **Collaborations with ONF, ORAN, Linux Foundation** to develop an open source security framework
- **Engagement, education and socialization**, e.g. conferences, webinars, world forum

IEEE INGR Security WG

- ***Roadmap Details – Refer to INGR WG chapter***
- ***WG Participation –*** 5GRM-security@ieee.org

Artificial Intelligence / Machine Learning (AI/ML) WG

INGR Artificial Intelligence / Machine Learning (AI/ML) WG Focus

- Provide the Roadmap based on research and industry advancement to deliver the AI/ML vision beyond 5G.
- Identify and define the taxonomy and state of *AI (sense, think, and act like a human)* and *ML (detection, classification, segmentation, predictions, and recommendations)*.
- Survey existing frameworks that support AI/ML workloads for different domains and identify a reference architecture to compare emerging protocol stacks and infrastructure elements.

INGR AI/ML WG Areas of Interest include:

- **Network Automation**
- **Network Slicing**
- **Network Digital Twins**
- **Security**
- **Dynamic Spectrum Access**
- **Cloud Computing**
- **Multi-access Edge Computing**

Highlights of AI/ML Topics for INGR 2022 Edition include

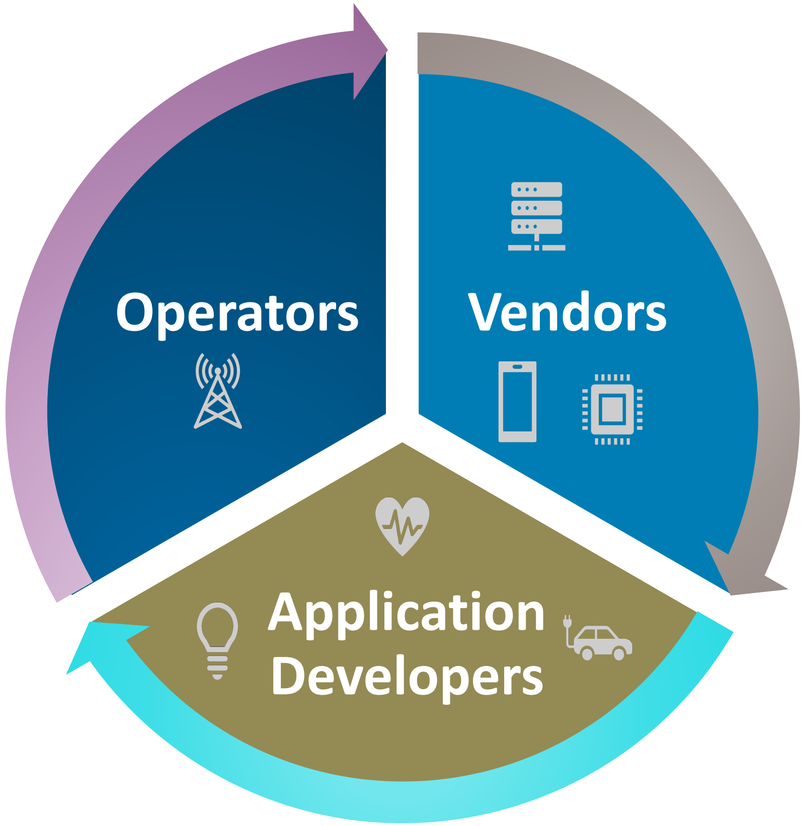
- **Cross-team collaboration with other FNI WGs** for AI/ML augmentation.
- **Investigate additional 5G and Future Networks areas** where technology gaps can be closed using AI/ML, e.g. Quantum Computing and Security.
- **Set priorities for future development** to include both technological advances and AI/ML developments that are being undertaken by other organizations, e.g. ETSI, 3GPP, etc.
- **Develop an AI/ML based management and orchestration framework**.
- **Define how open source and open architectures can be used and adopted**, e.g. a joint effort for Open RAN technologies may be adopted by industry via the O-RAN Alliance and Telecom Infra Project (TIP).
- **Develop and demonstrate AI/ML 5G and Future Networks use cases**

IEEE INGR Artificial Intelligence / Machine Learning (AI/ML) WG

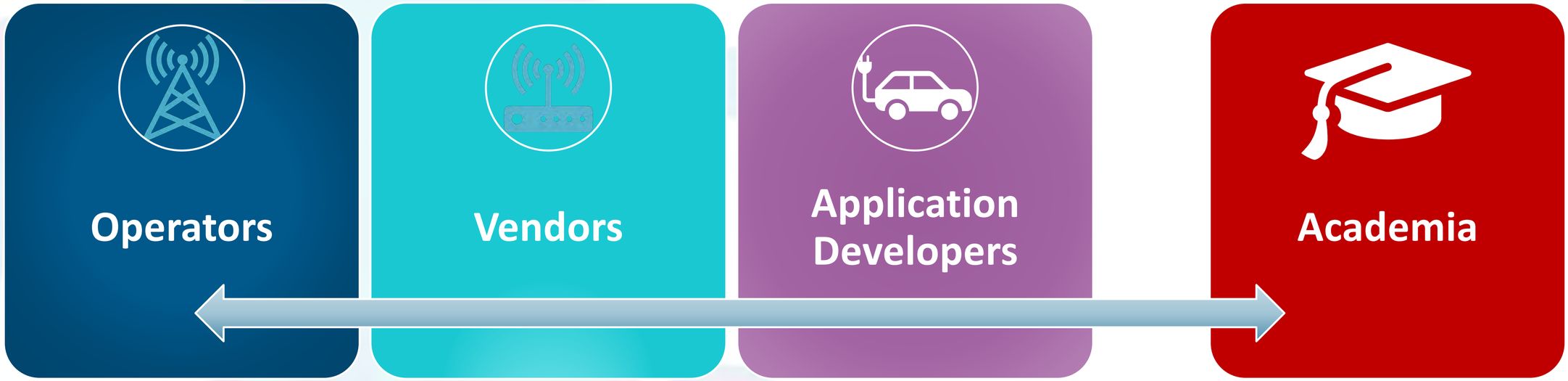
- ***Roadmap Details – Refer to INGR WG chapter***
- ***WG Participation –*** 5GRM-AIML@ieee.org

The 5G & Beyond Testbed

- A virtual end-to-end network testing and innovation platform
- Reduced-cost innovation across interdependent industry players
- Win-win collaboration opportunities across the broad range of 5G/6G technologies
- Academic/education opportunities

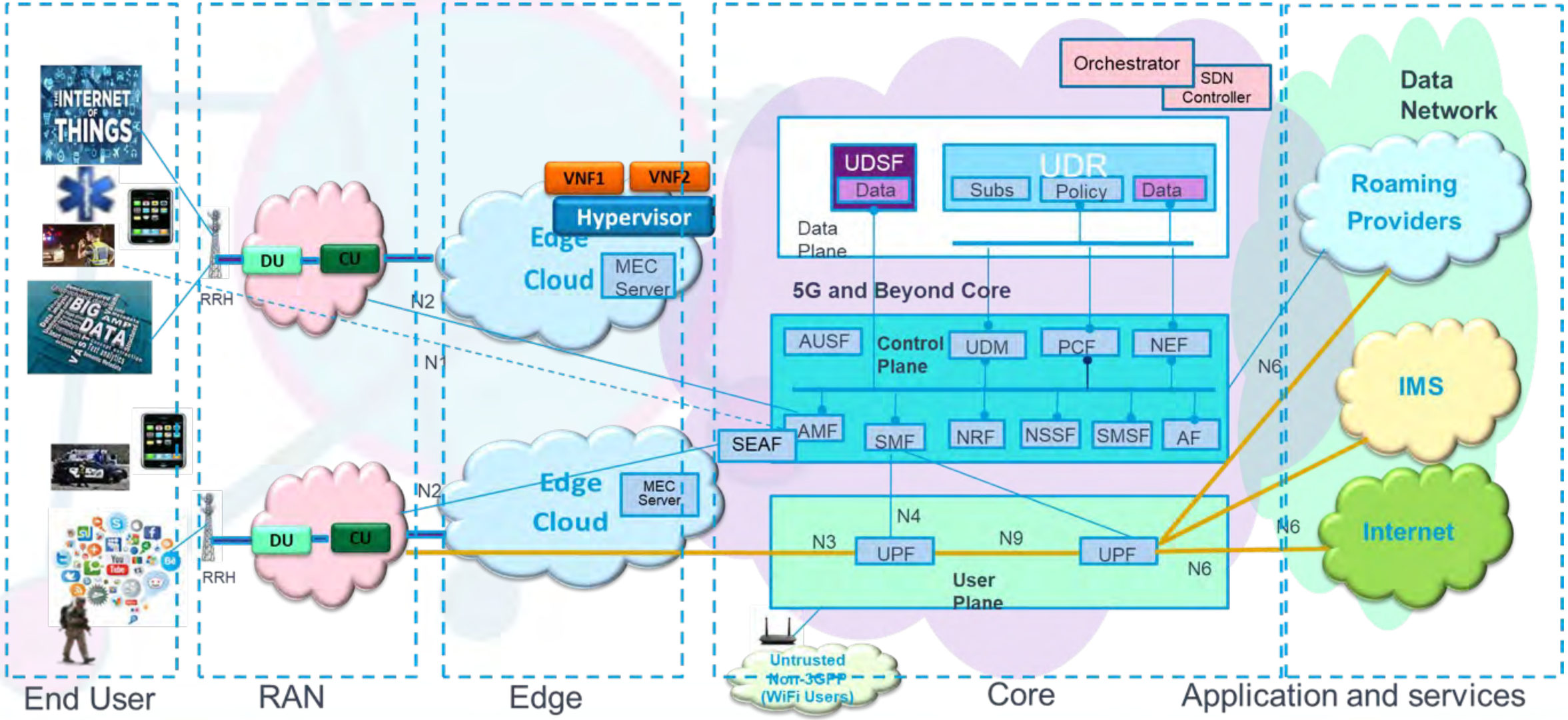


End Users for 5G Testbed Project



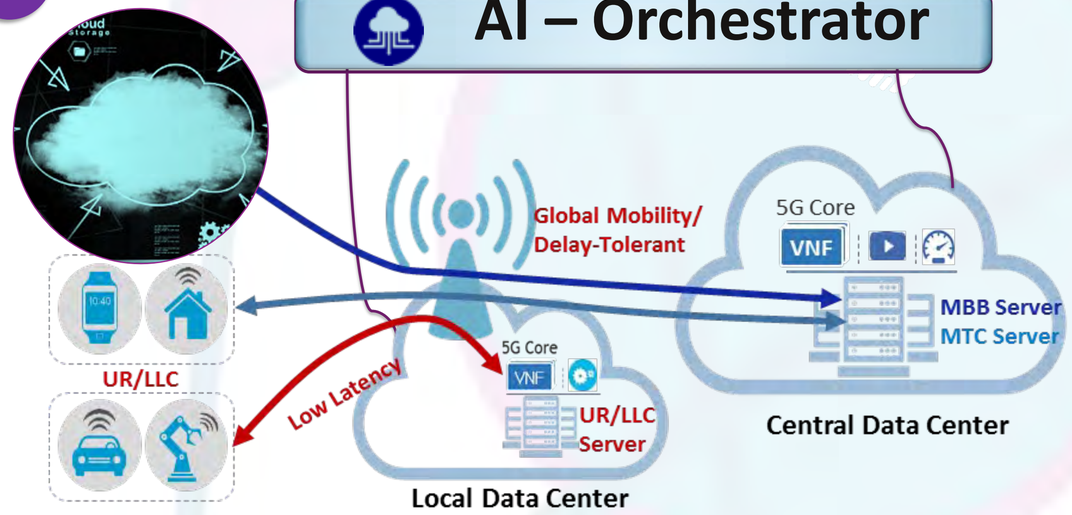
- The 5G & Beyond Testbed Project will bring together industry participants across the broad range of 5G/6G technologies to enable win-win collaboration opportunities and contribute to the roadmap for future technological direction
- The academic institutes will have access to the testbed grand branch in later stages

End-to-End Overview of 5G System



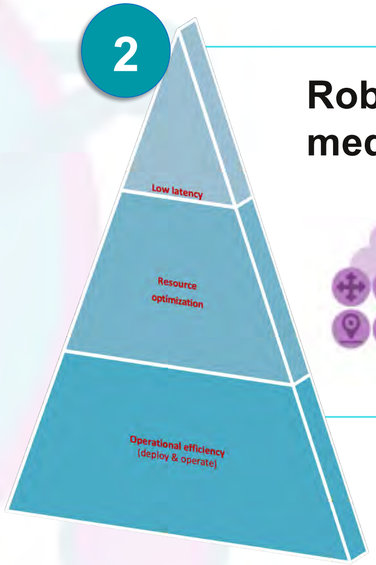
5G & Beyond Testbed Enables New Use Cases for Industry

1 Cloud



Embedding cloud technologies into the mobile network

2



Robust networks that can support drone operations, medical monitoring and surgeries, autonomous cars, etc.

3

Opportunity for startups to develop new products and applications

4

Enhance knowledge and skills for students and faculty staff

INGR 2nd Edition Release

- Access the documents online at **futurenetworks.ieee.org/roadmap**
- **The roadmap documents will also be available at IEEE Xplore**

- INGR is a program of the **IEEE Future Networks Initiative**

Reduce technical and engineering risks associated with the migration to 5G and beyond

IEEE INGR
International Network Generations Roadmap

The purpose of the International Network Generations Roadmap (INGR) is to stimulate an industry-wide dialogue to address the many facets and challenges of the development and deployment of 5G in a well-coordinated and comprehensive manner.

The First Edition is accessible via the IEEE Future Networks Initiative website:
https://futurenetworks.ieee.org/roadmap

- Applications & Services
  - Edge Automation Platform
- Hardware
- Massive MIMO
- Millimeter Wave
- Optics
- Satellite
- Security
- Standardization Building Blocks

The INGR authors believe that, with widespread participation, the roadmap process can reduce some of the technical and engineering risks associated with the migration beyond 4G and related technologies. As work continues with the Second Edition, new experts are encouraged to participate, to evolve and strengthen this crucial set of documents. Join us!

futurenetworks.ieee.org/roadmap

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Call for Papers and Proposals

IMAGINING THE NETWORK OF THE FUTURE

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The 2023 IEEE Future Networks World Forum (FNWF'23) will continue the path set in 2018 by the IEEE 5G World Forum in bringing together experts from industry, academia, and research to exchange their vision as well as their achieved advances in the continuing evolution of network technology, including 5G, 6G, and other innovative cross-domain breakthroughs. Located in ***Baltimore, USA***, IEEE FNWF'23 seeks contributions on how to nurture and cultivate future network technologies and applications for the benefit of society. Workshop, tutorial, industry forum, and demonstration proposals and original, innovative, and high-quality papers are solicited on the technical topics of Future Networks.

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TECHNICAL TRACK PAPERS
SYMPOSIUM PAPERS
Submission: 8 September 2023

Notification: Rolling
Camera-ready: 15 September 2023

CALL FOR PROPOSALS

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IoT – Reference Resource

"Future of IoT – 2020's and 2030's"

IEEE ComSoc

C-IoT Book by

Fawzi Behmann &
Kwok Wu

Roadmap & Opportunities for 2020's and 2030's and impact in improving quality of life and business processes

Requirements & Solutions

- Health & Fitness
- Smart Home/Building/Factory
- Smart Energy
- Smart Car
- Smart City

For Individual, Industry and Infrastructure

Covering

- Sensing
- Gateway
- Services

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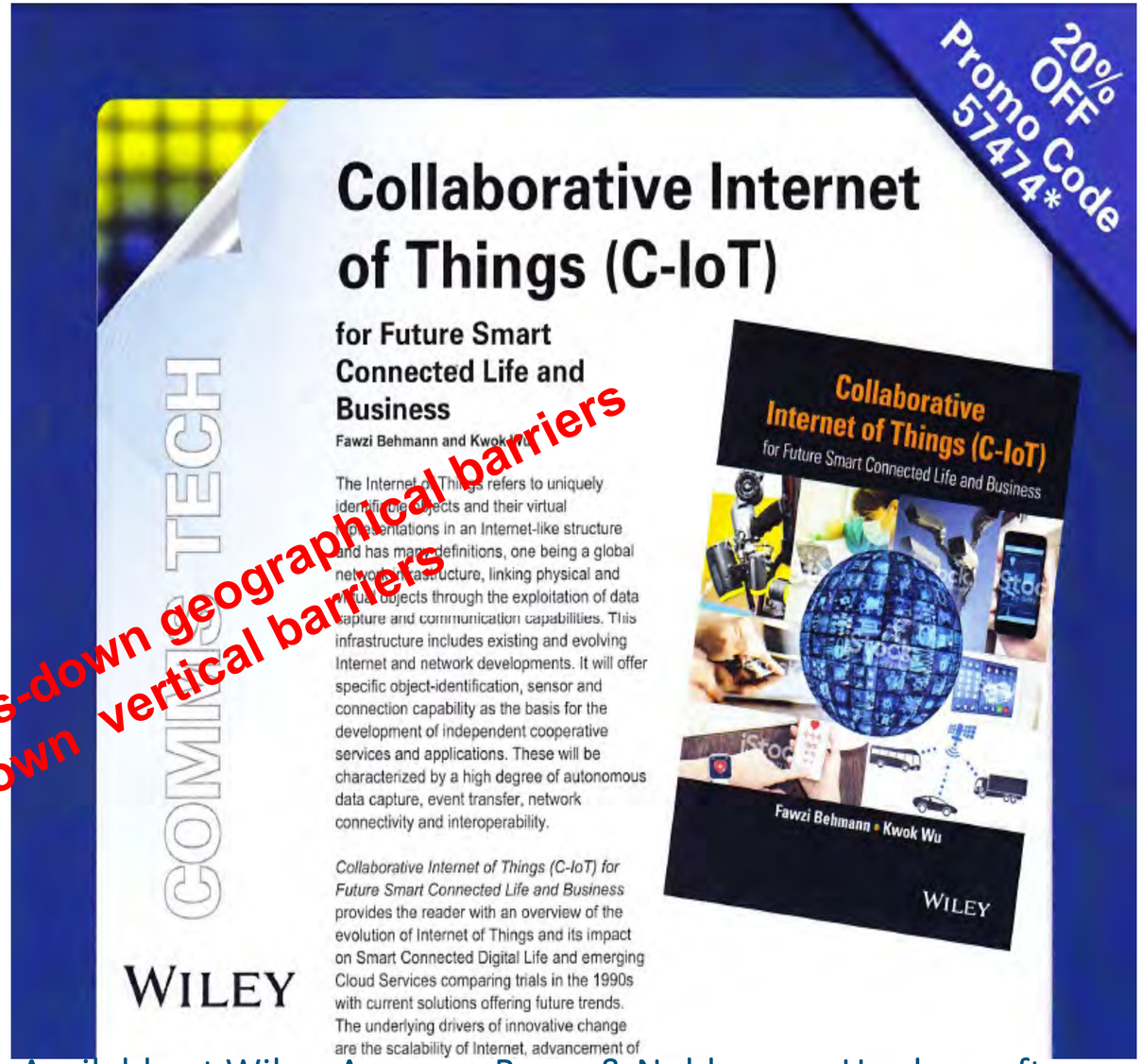
Standards Initiatives



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Questions?

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