5G

From Architecture to Business

Sigurd **Goran** Lennart **Formiga** Johnsson

All About IoT (Tudo Sobre IoT)

2021-06-16

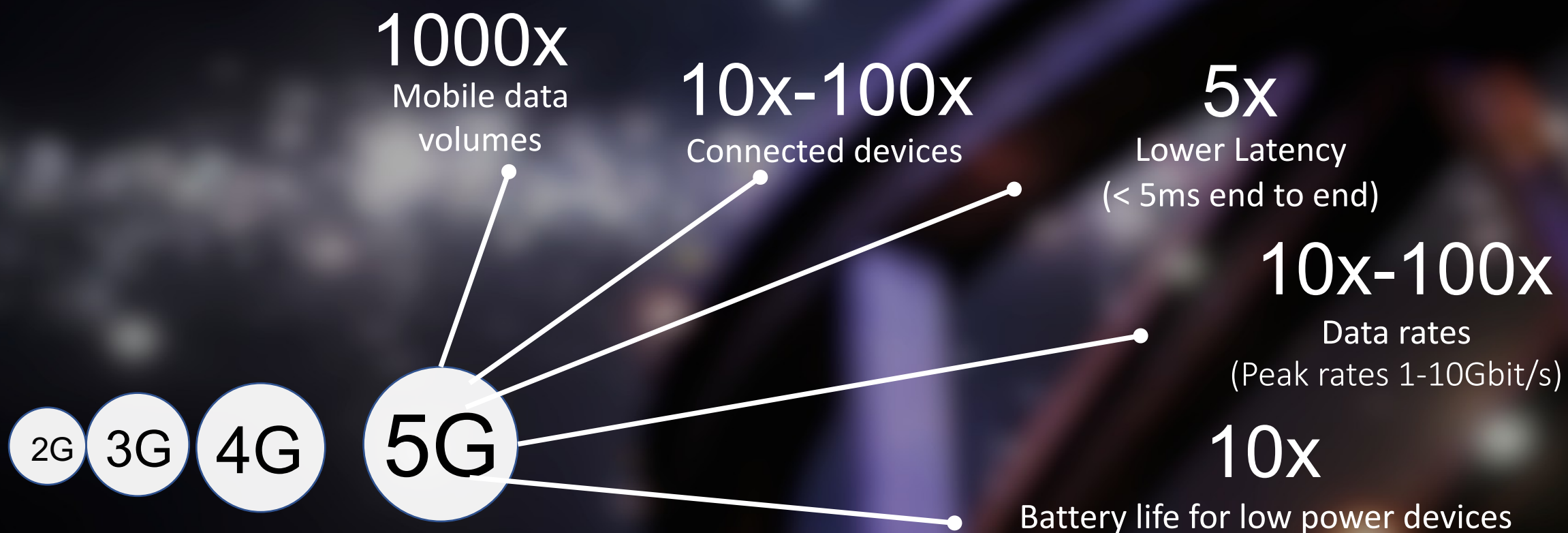
Agenda

- ❑ Architecture: What changes from 4G to 5G architecture?
- ❑ IoT: How does 5G contribute to the Internet of Things?
- ❑ Private 5G: Is it worth it?
- ❑ Value chain players: Equipment suppliers x Potential infrastructure players for private 5G and its variations.
- ❑ Trends: What operators in the world plan with 5G and how is Brazil?
- ❑ Business: Consumers, new products and services: what can we expect and how can we anticipate?
- ❑ Results: When 5G becomes real, where is it real, investments and how to make money with this technology?
- ❑ Masterthings: Interaction and exchange of experience with experts from "Everything About IoT".

Architecture

Architecture: What changes from 4G to 5G architecture?

5G evolution into the future



Source: METIS

Fact or Myth?: The Truth About 5G

TUDO SOBRE iot

- Myth 1: 5G is an untested new technology.
  Fact: The technology that 5G depends on is not new (It's an evolution of 4G); it is an integral part of our lives and is tested to strict international safety standards.

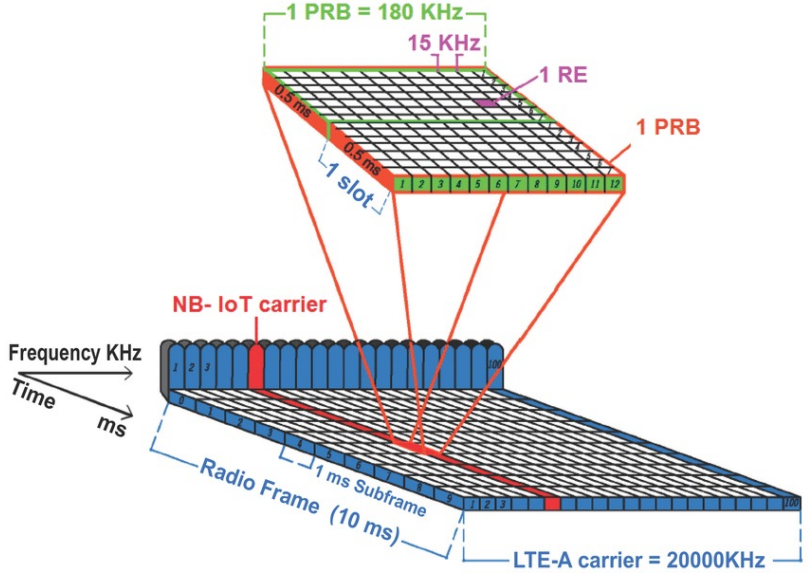
- Myth 2: 5G is harmful to human health.
  Fact: According to WHO, there is no evidence to suggest that 5G is harmful to human health.

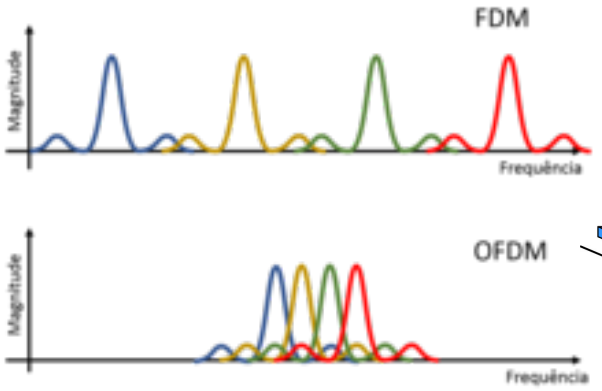
- Myth 3: 5G uses higher frequencies, which means higher levels of radiation.
  Fact: 5G will operate using higher frequencies (less penetration) and generate lower levels of electromagnetic energy.

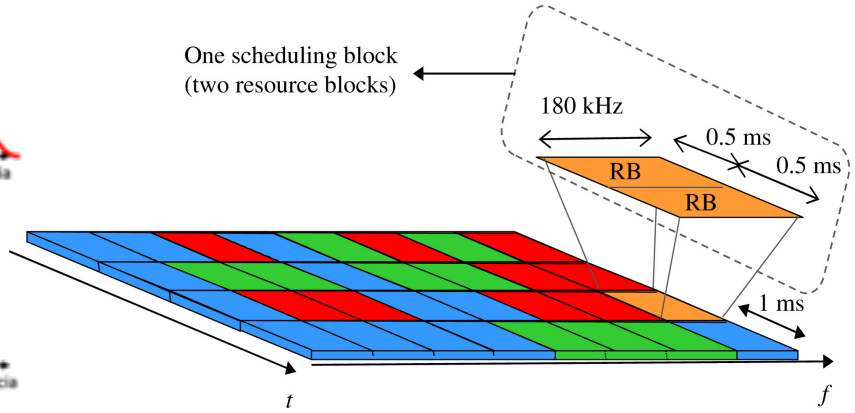
- Myth 4: Electromagnetic energy is emitted only by telecommunications installations.
  Fact: Electromagnetic energy is emitted from a variety of natural and man-made sources, including, but not limited to, telecommunications.

- Myth 5: All electromagnetic energy is dangerous.
  Fact Some electromagnetic energy can be dangerous under some circumstances, but not used for telecommunications.

OFDM LTE (NR)







OFDM: **O**rthogonal **F**requency **D**ivision **M**ultiplexing
PRB*: **P**hysical **R**esource Block
RB*: **R**esource Block
RE: **R**esource **E**lement
NB-IoT: **N**arrow **B**and IoT
(DL 26-127Kbit/s UL ~17-159Kbit/s)

Orthogonal Frequency Division Multiplexing or OFDM is a modulation format that is being used for many of the latest wireless and telecommunications standards such as 4G (LTE) and 5G (NR). OFDM has been adopted in the Wi-Fi field, where standards such as 802.11a, 802.11n, 802.11ac, 802.11ax (Wi-Fi6) and more.

An LTE PRB, Physical Resource Block in 4G, is defined as consisting of 12 consecutive subcarriers for a slot (0.5 ms).

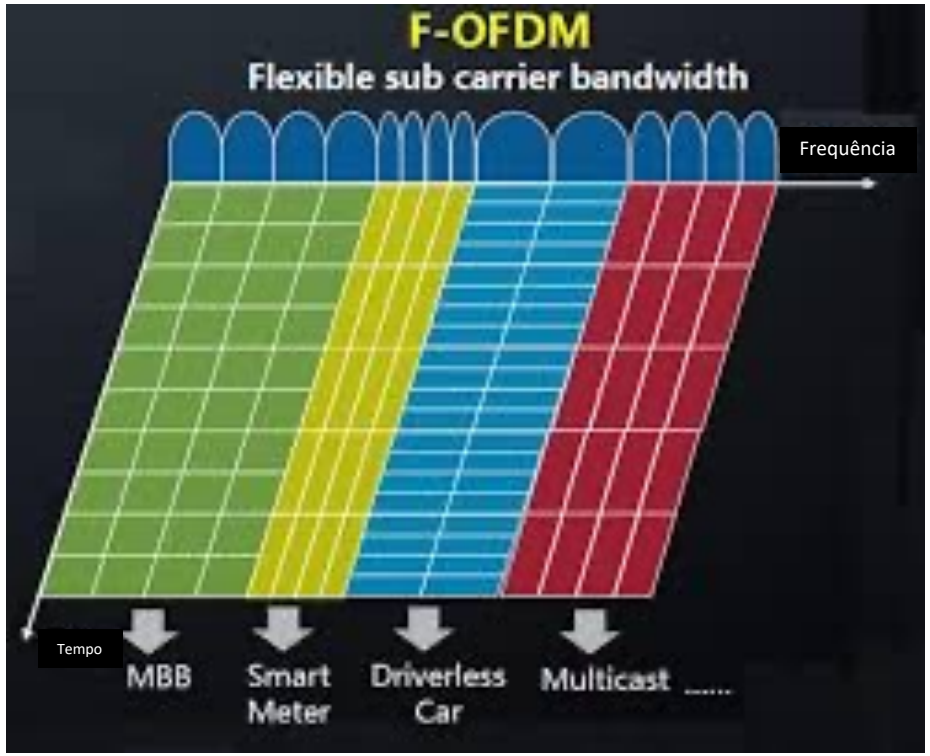
An NR RB, Resource Block in 5G contains 12 subcarriers in the frequency domain similar to LTE.

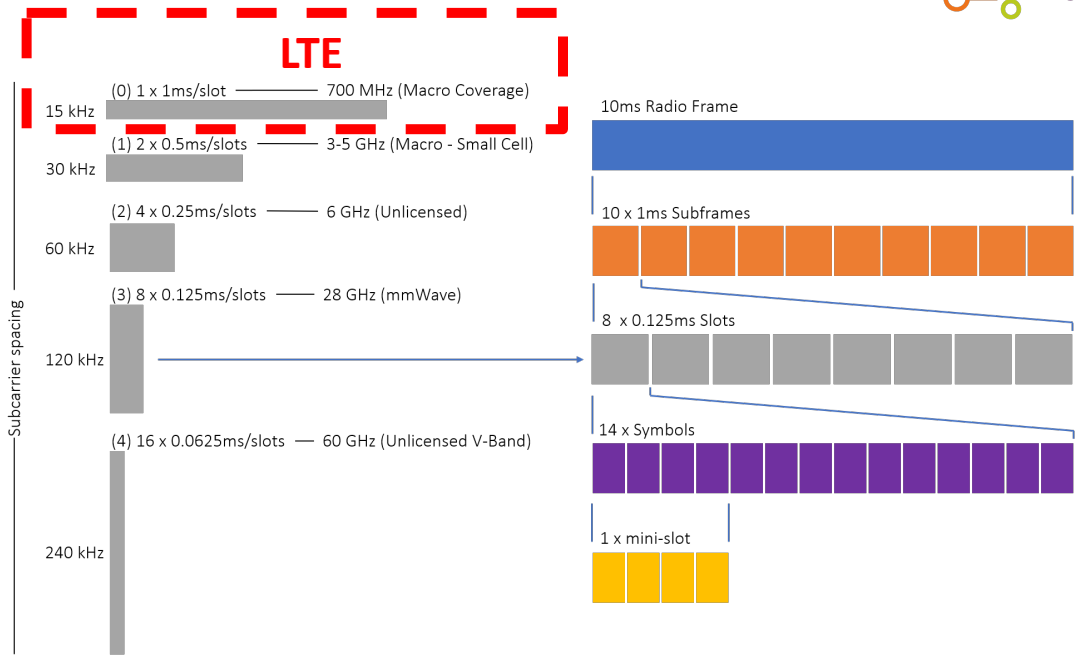
A PRB/RB spans 12 subcarriers in 7 OFDM symbols and in total 12 × 7 = 84 REs

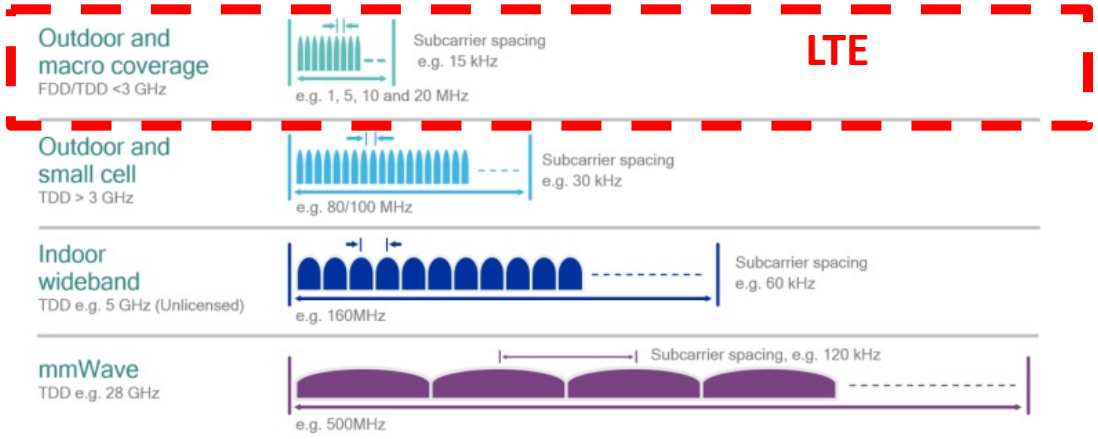
* PRB ⇔ RB

Bandwidth	Resource Blocks	Subcarriers (downlink)
5000 KHz / 5MHz	25	301
10000 KHz / 10 MHz	50	601
15000 KHz / 15 MHz	75	901
20000 KHz / 20 MHz	100	1201

OFDM NR

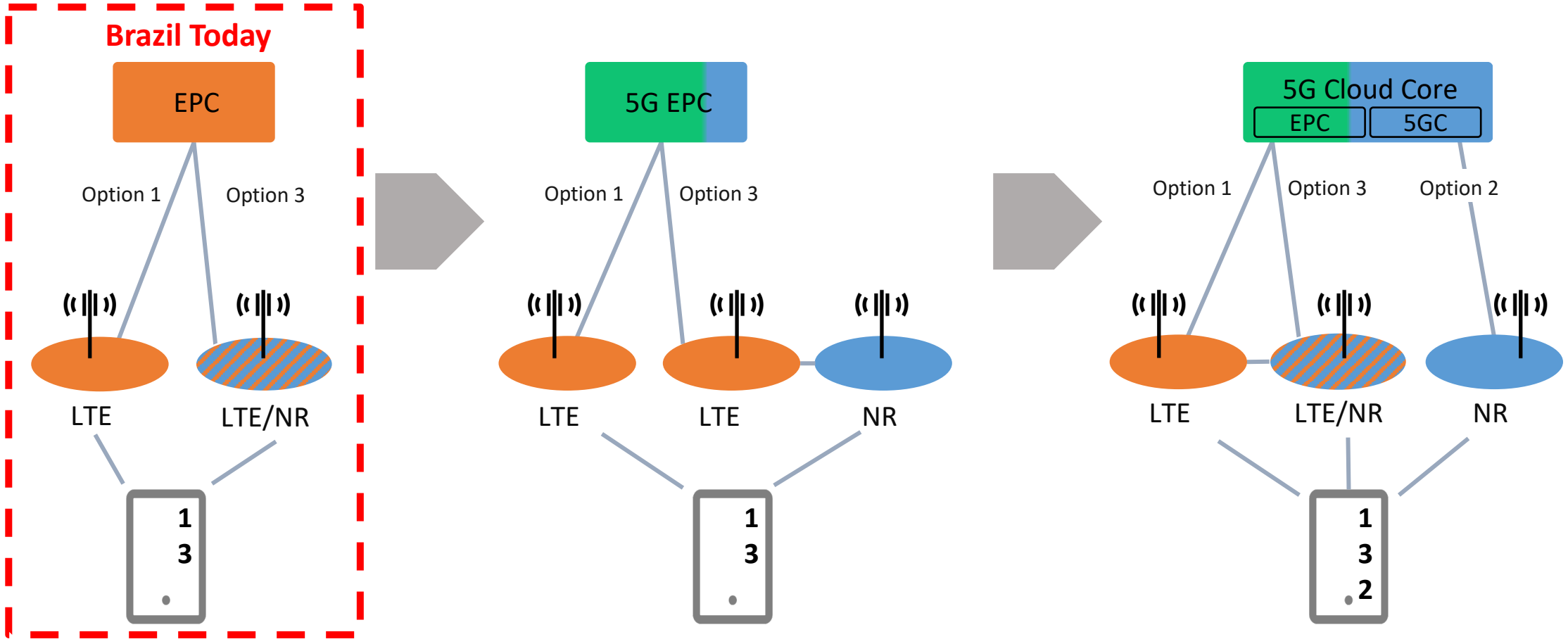






In NR, similar to LTE, a radio frame is fixed at 10 ms, which consists of 10 subframes of 1 ms each. However, unlike LTE, which has a fixed sub-carrier spacing (SCS) of 15 kHz, NR supports scalable numerology for more flexible deployments covering a wide range of carrier frequencies and services

5G Cloud Core: Key enabler for 5G



EPC: Evolved Packet Core
LTE: Long Term Evolution
NR: New Radio
DSS: Dynamic Spectrum Sharing

Option 2 ⇔ SA: Stand Alone
Option 3 ⇔ NSA: None Stand Alone

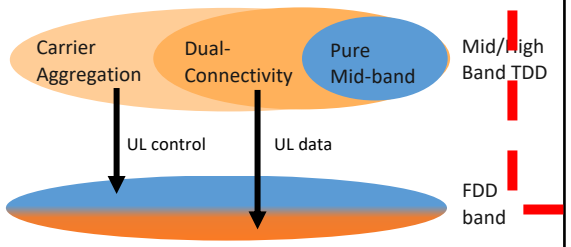
4G 5G 4G/5G DSS

Top 5G Enablers on 5G Platform

Brazil Today

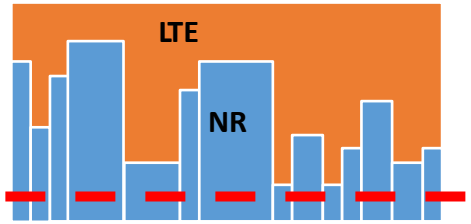
Carrier Aggregation

Extension of cell range by 60%

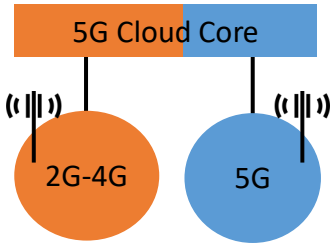


Spectrum Sharing

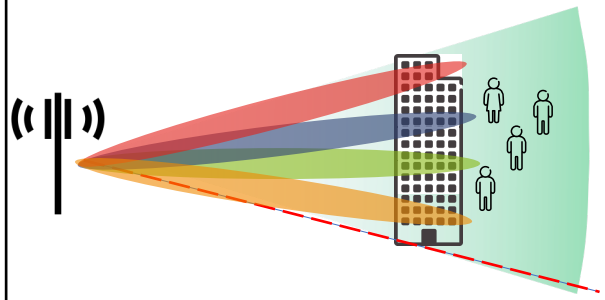
5G wide area coverage delivered quickly



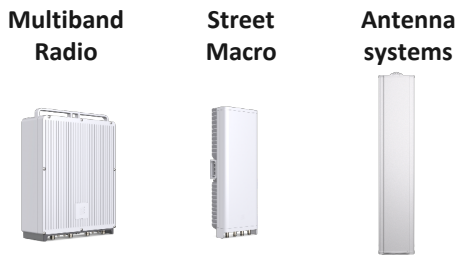
Dual-Mode Core



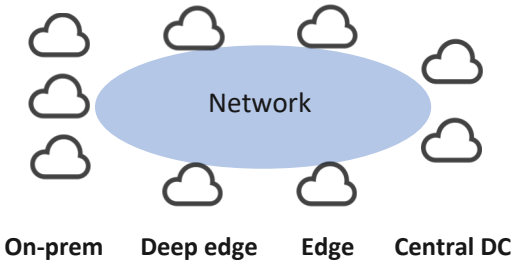
Massive MIMO



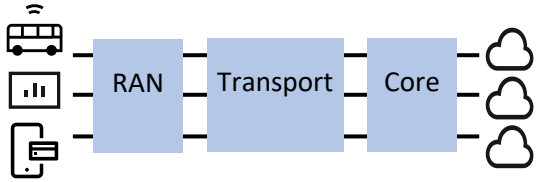
Site efficiency



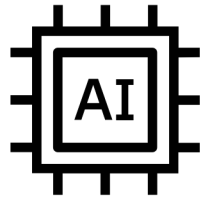
Distributed Cloud



Network Slicing

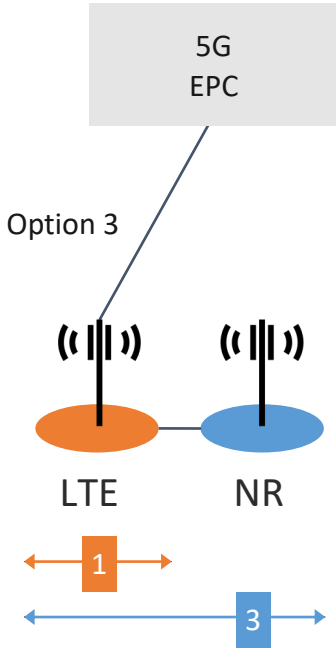


AI / ML

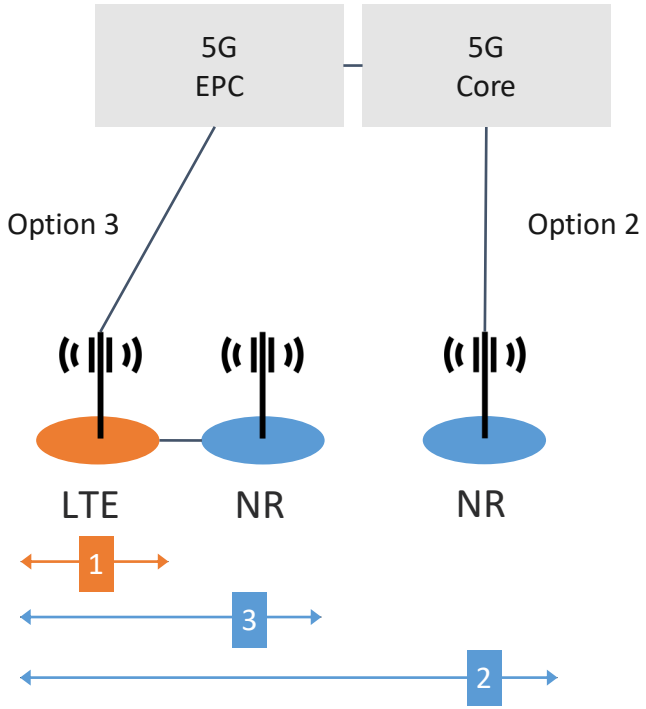


Leverage the 4G/LTE Installed Base

5G/NR uses 4G/LTE coverage to set up a connection...

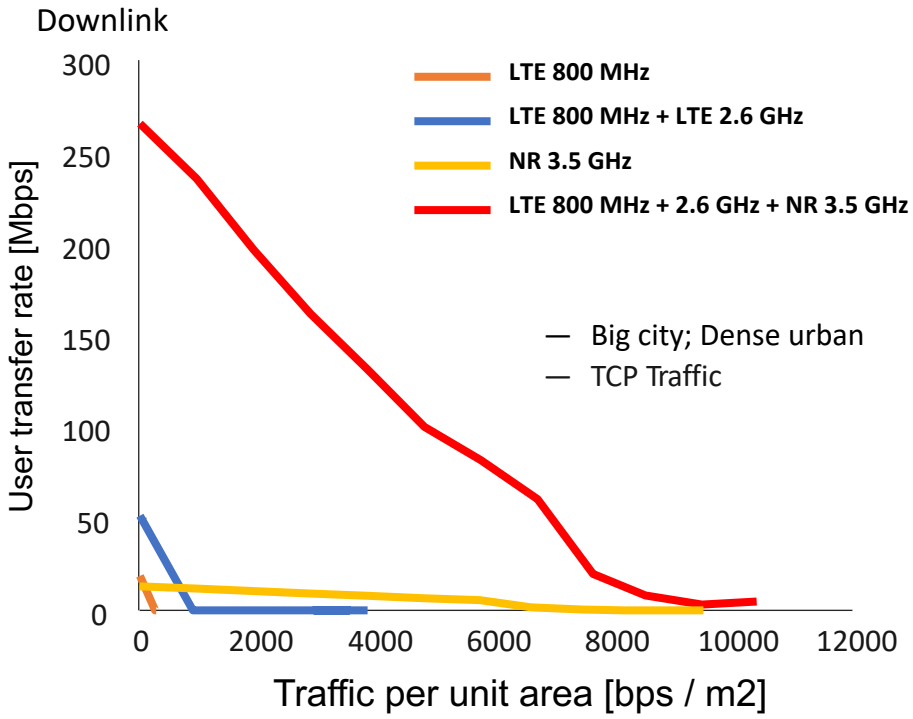


... in the end, the 5G/NR can work alone too, but...



EPC: Evolved Packet Core
LTE: Long Term Evolution
NR: New Radio

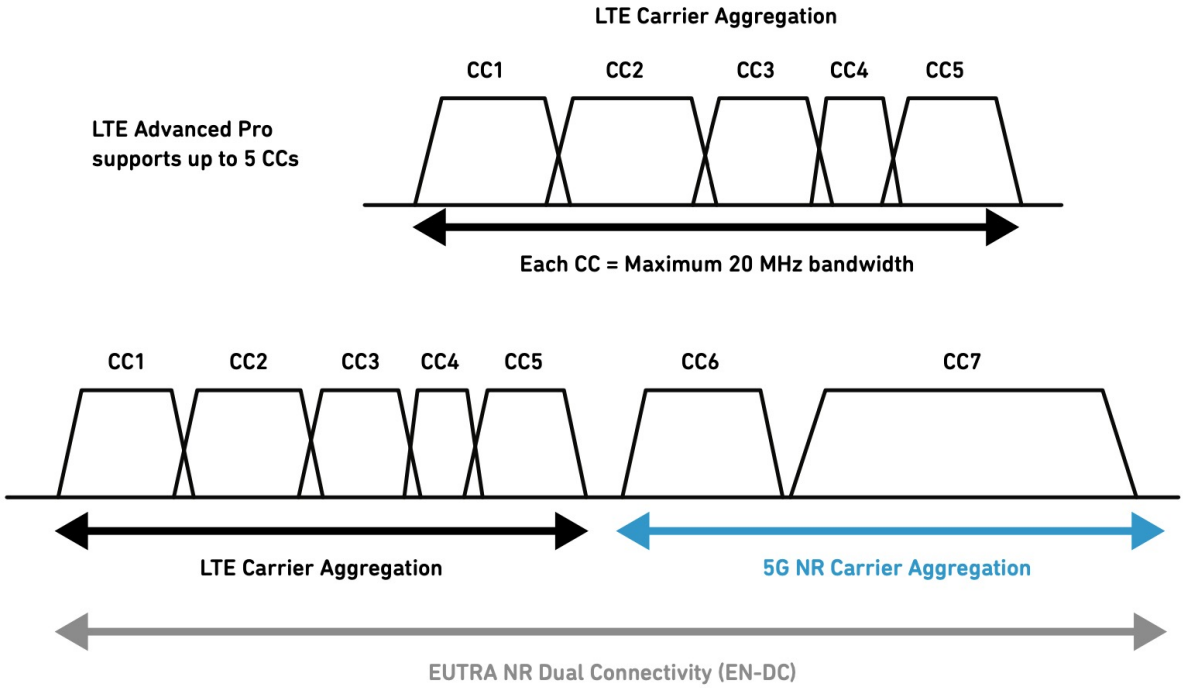
... performance will be higher with 5G/NR + lower (4G/LTE) bands

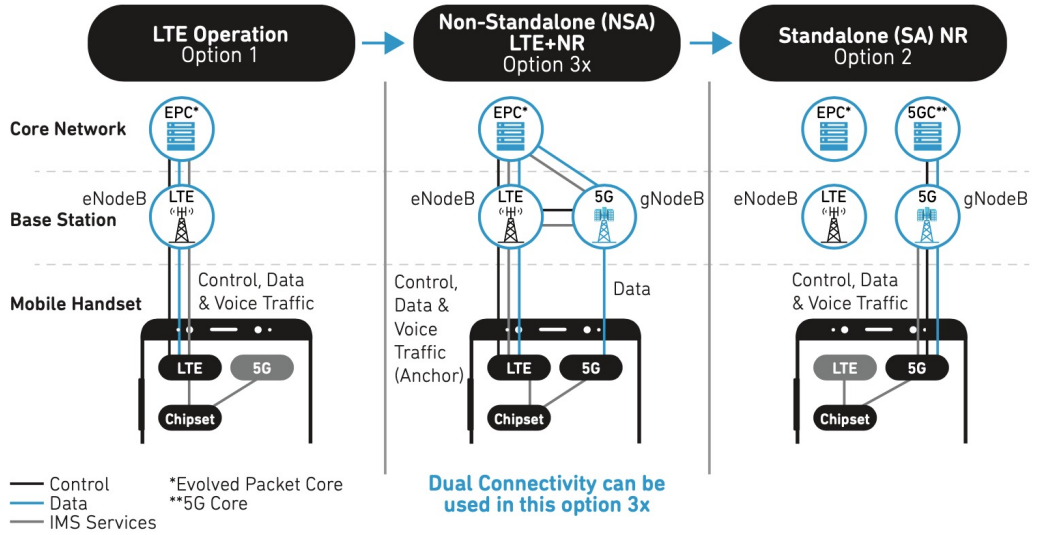


Option 2 ⇔ SA: Stand Alone
Option 3 ⇔ NSA: None Stand Alone

Carrier Aggregation

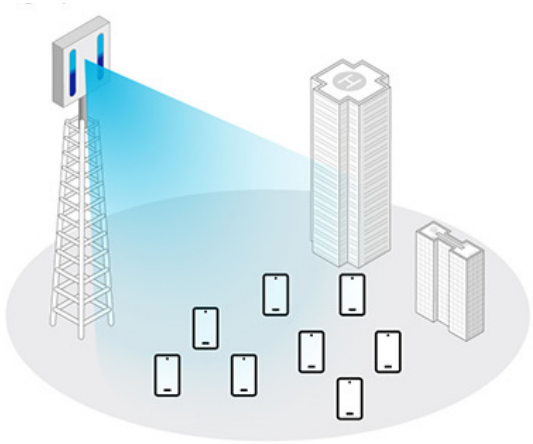
Carrier aggregation is a wireless communication technique used to increase the data rate per user, whereby multiple frequency blocks (called component carriers) are assigned to the same user.



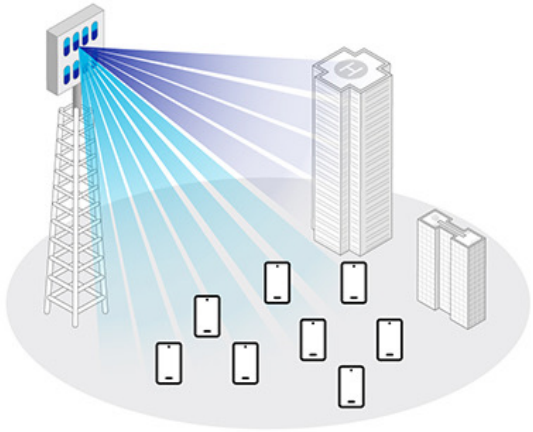


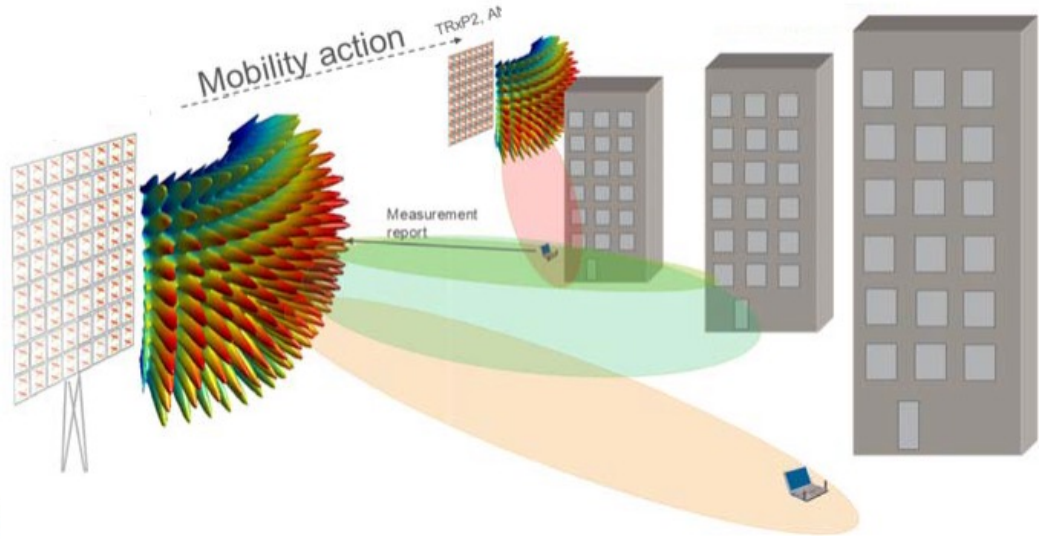
Massive MIMO: Functionality

Legacy antenna

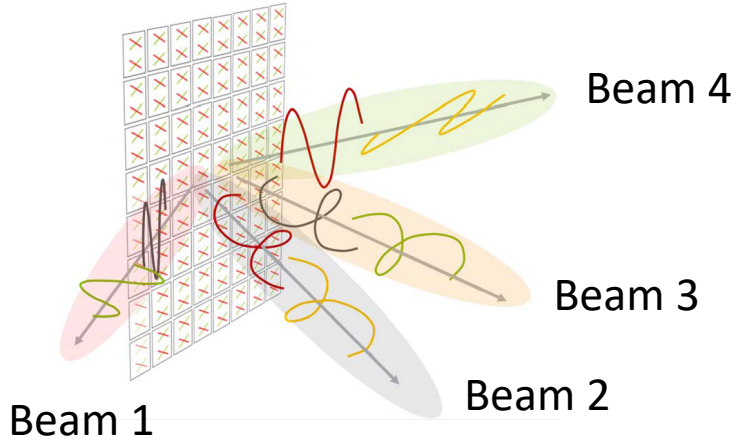


Massive MIMO antenna



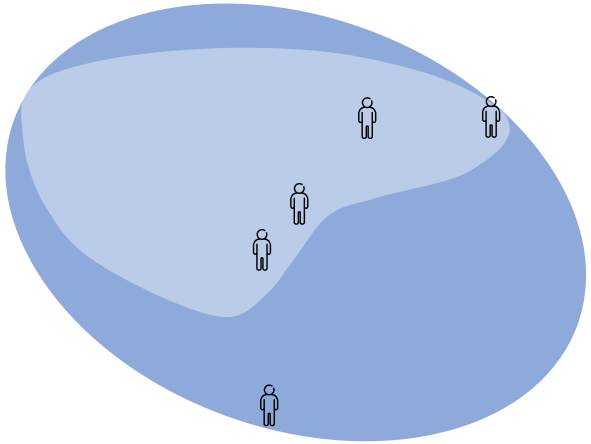


Massive MIMO - which is an extension of MIMO - expands beyond legacy systems by adding a much larger number of antennas to the base station. The “massive” number of antennas helps to focus energy, which brings dramatic improvements in throughput and efficiency.

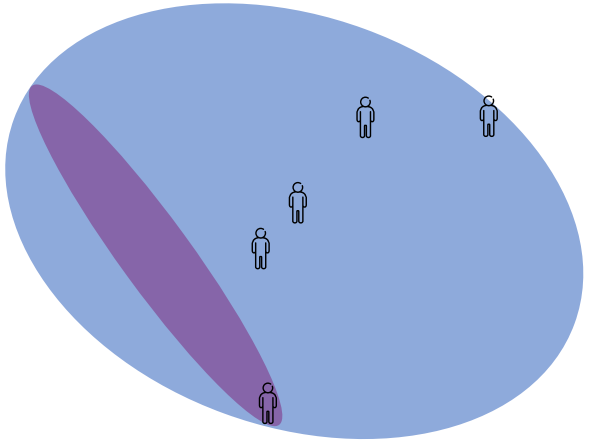


MIMO: Multiple Input Multiple Output

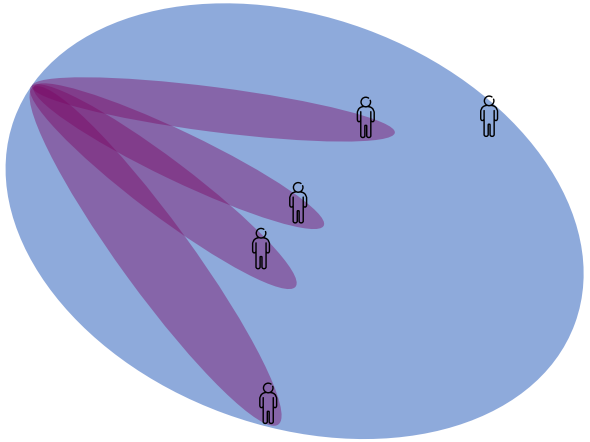
Massive MIMO: Functionality



- Cell Shaping
  - Define cell shape to fit UE distribution
  - Decreases the inter cell interference



- Single-User MIMO
  - Sharp beam follows UE
  - Higher SINR increases data rate
  - Benefit irrespective of load

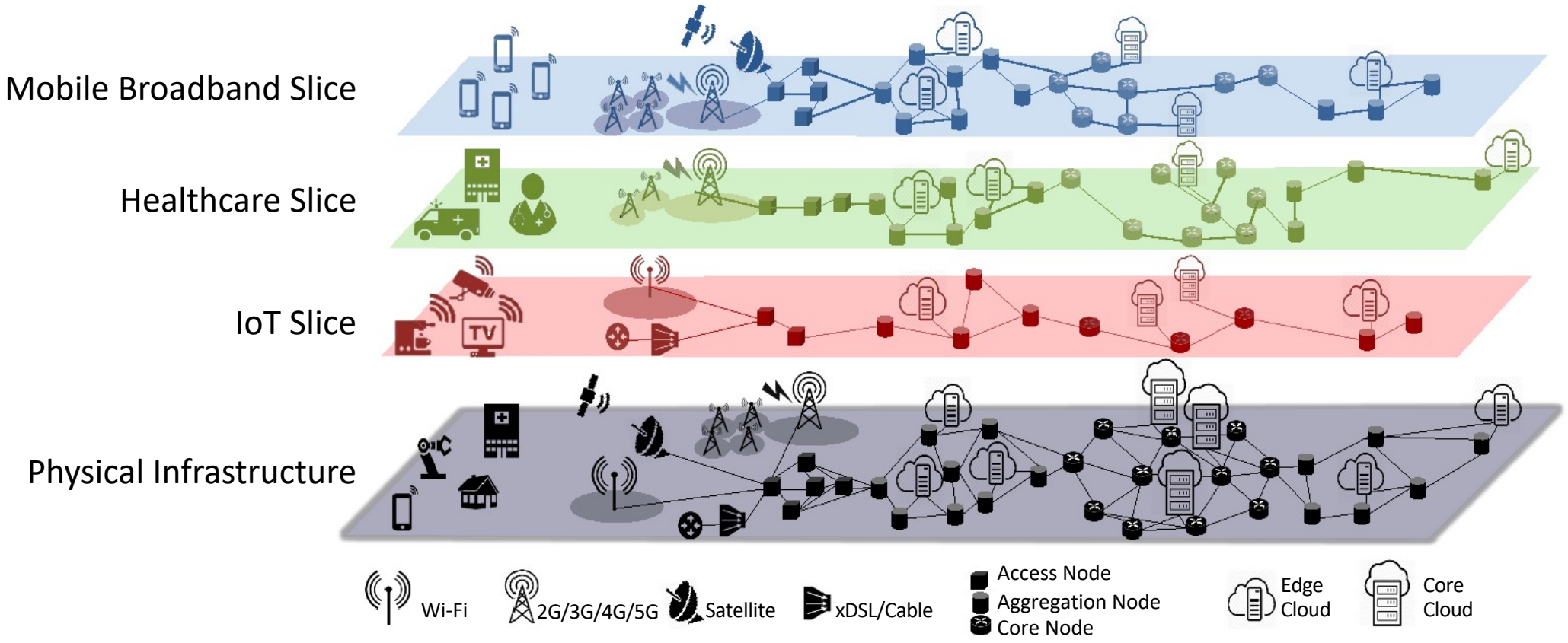


- Multi-User MIMO
  - Multiple UEs reuse same frequency-time resources
  - Capacity gain in high load and when channel is suitable

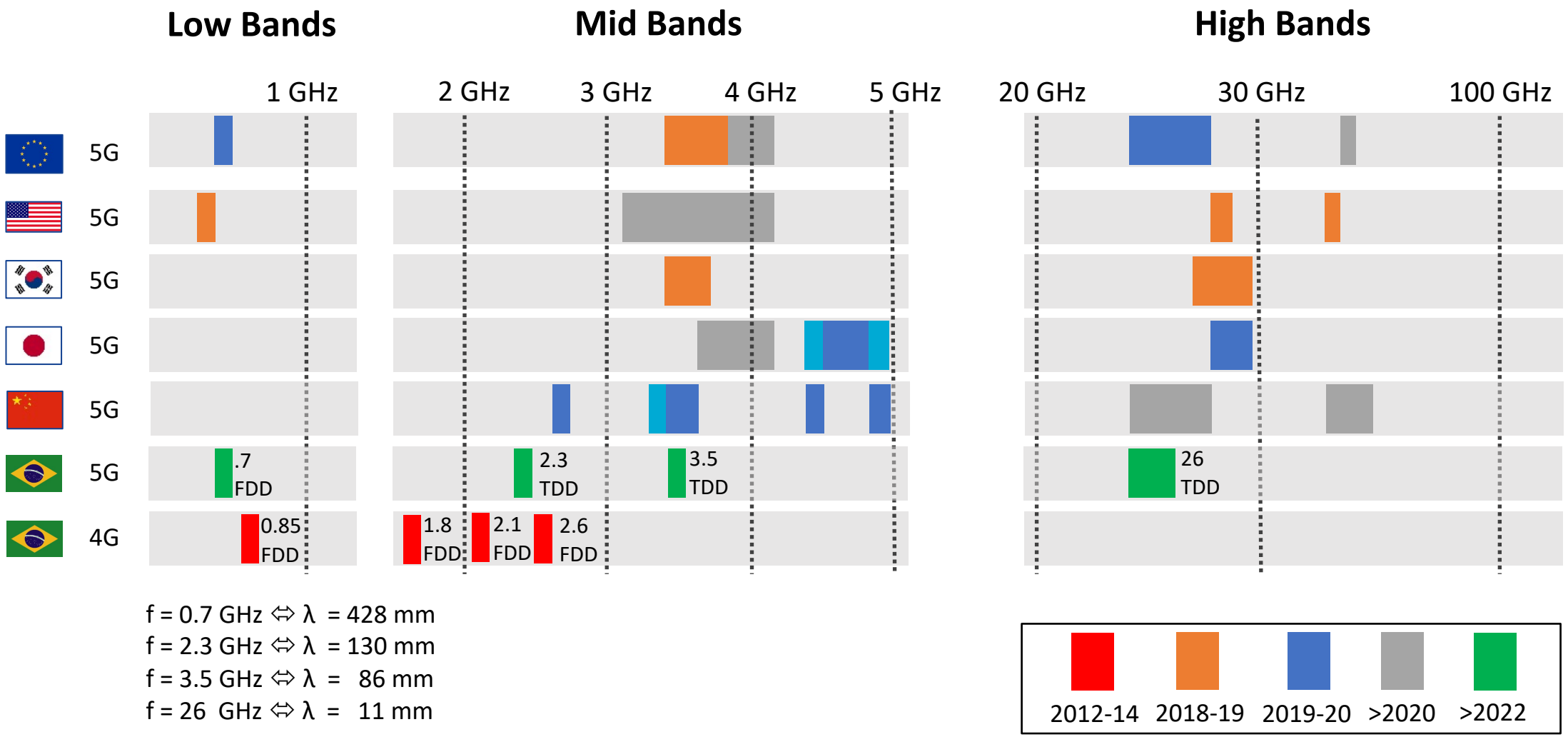
MIMO: Multiple Input Multiple Output

Network Slicing

Network splitting overlaps multiple virtual networks into a shared network. Each slice of the network can have its own logical topology, security rules, and performance characteristics—within the limits imposed by the underlying physical networks.



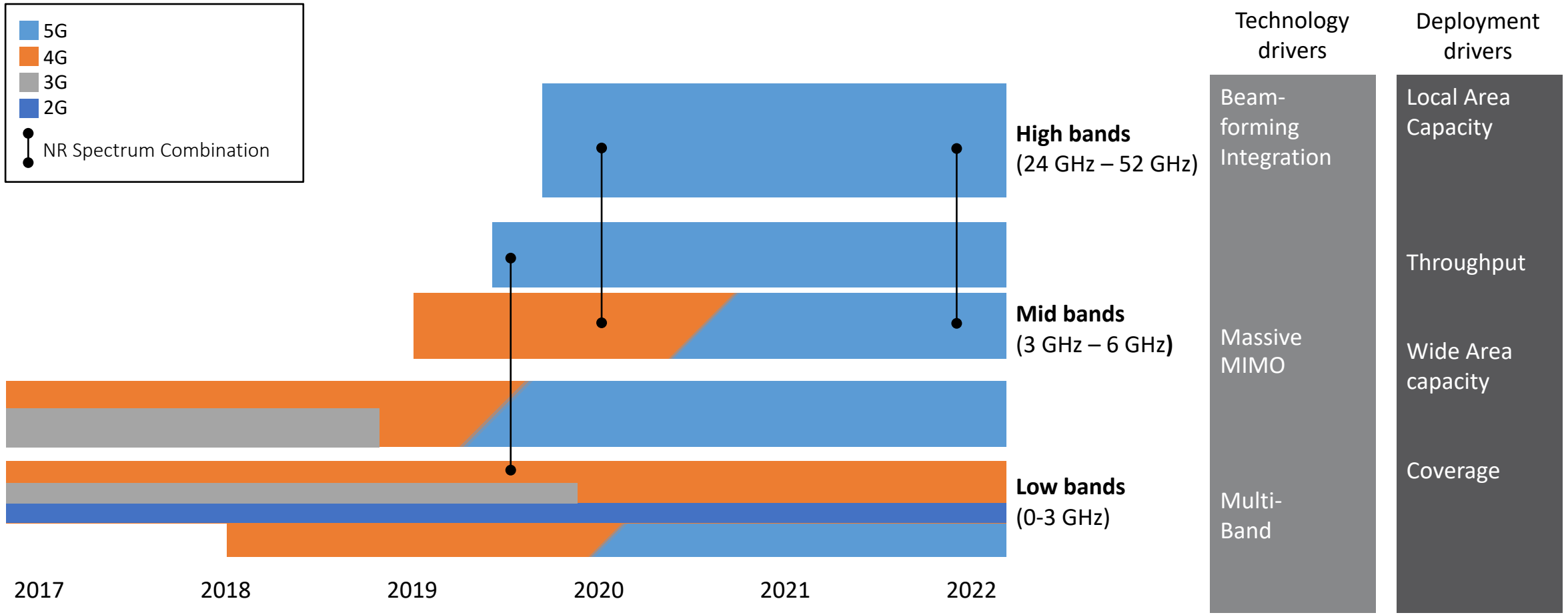
Spectrum



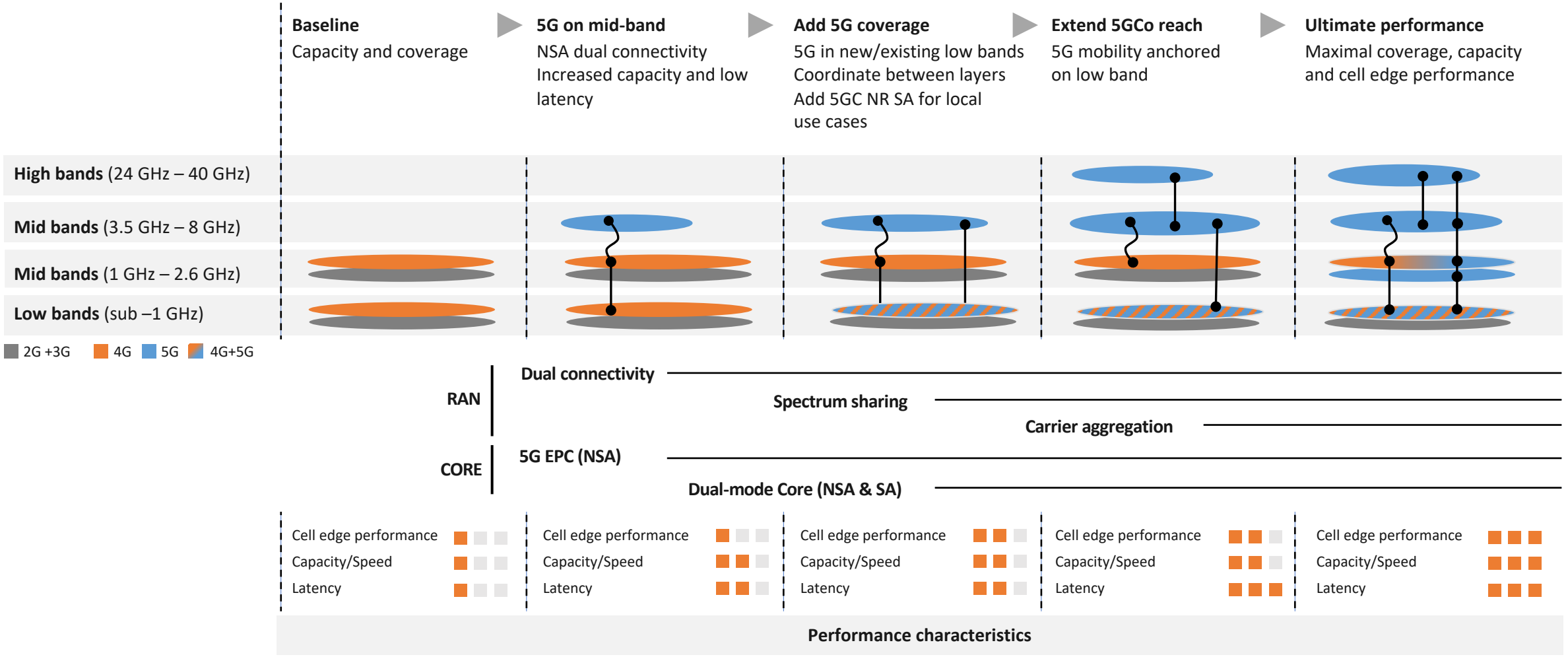
f = 0.7 GHz ⇔ λ = 428 mm
f = 2.3 GHz ⇔ λ = 130 mm
f = 3.5 GHz ⇔ λ = 86 mm
f = 26 GHz ⇔ λ = 11 mm

f = 1000 GHz ⇔ λ = 3 mm (6G)

Spectrum Usage Overview



Operator spectrum evolution for MBB



SA: Stand Alone (Estar Sozinho)
NSA: None Stand Alone (Não estar Sozinho)

IoT

IoT: How does 5G contribute to the Internet of Things?

IoT broadband solutions

Enabling more demanding use cases cross verticals, leveraging 4G and 5G

Reduced latency

- LTE Instant UL Access
(e2e Latency 10 ms or below)

Connected Car, AR/VR,
Drones, Camera Surveillance, Remote control

Higher peak rate

- Multi-Gigabit LTE with 7CC
Carrier Aggregation

2Gbps

Connected Car, AR/VR,
Drones, Camera Surveillance, Remote control

Drone solutions

- Drone detection
(AI based)

Drones – UAVs for Delivery,
Infrastructure inspection, Agriculture

RAN slicing

- QoS
- Radio Resource
Partitioning

Public Safety, Train operation, Utilities, Private NWs

Extended coverage

- Extended Coverage for
higher category devices

Automotive, Transport & Logistics, Wearables

Subscriber differentiation

- Advanced Subscriber
Group Handling

Connected Car, Train operation, Utilities

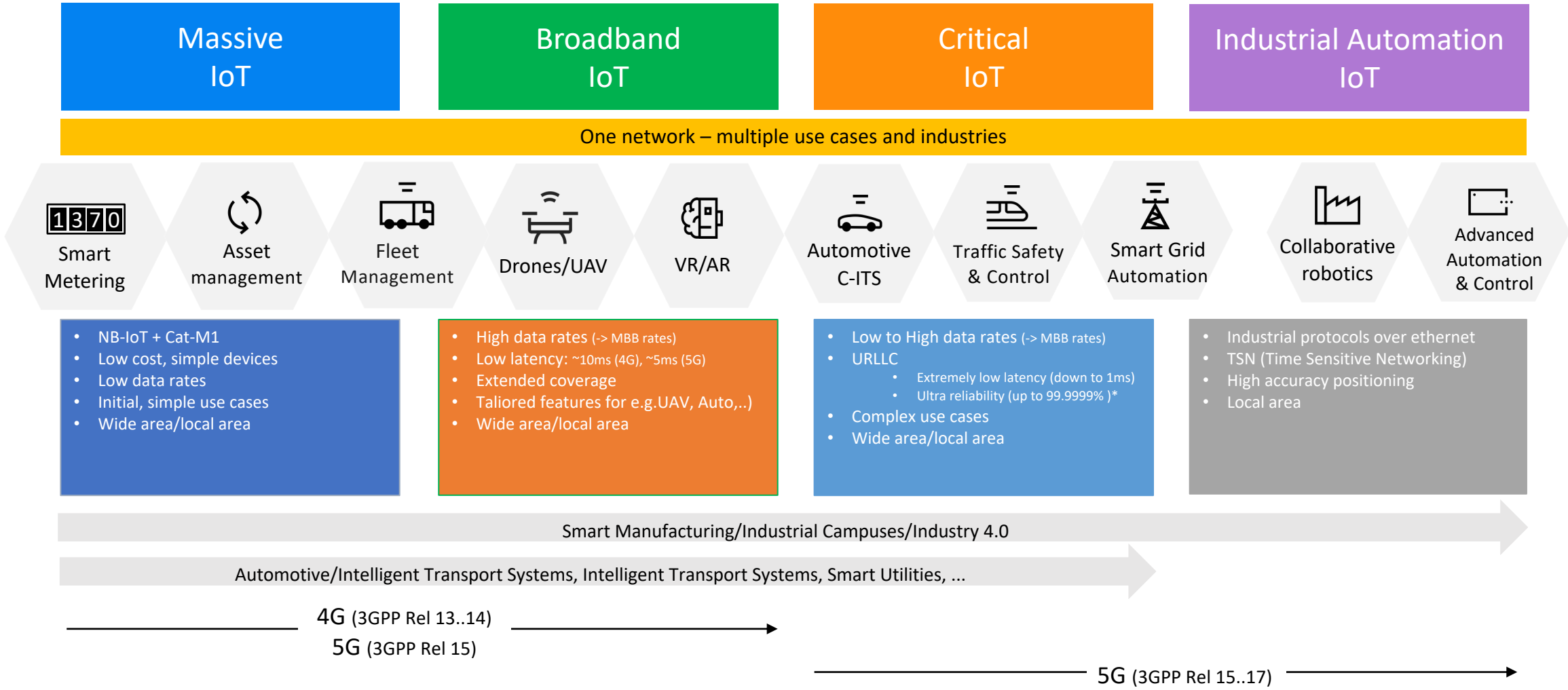
One network - meeting diverse set of use case

Industry 4.0	NR, Ethernet Protocols, TSN	Collaborative robotics in industry settings	Industrial Automation IoT
Latency Reliability	NR + URLLC	Robot control in Manufacturing Autonomous driving for co-operative safety Smart Grid real-time control and automation	Critical IoT
Speed Capacity	LTE, NR	AGV, AR/VR for manufacturing Connected cars, USV/UAV/Drones Camera surveillance for Train operation, Public Safety	Broadband IoT
Low power Low cost	Cat-M, NB-IoT	Asset management, Maintenance monitoring for manufacturing Alarm panel, Pet/Child/Goods/Asset/Vehicle Tracking, Wearables Smart cities, Smart meters, Smart agriculture, Smart buildings	Massive IoT

TSN: Time Sensitive Networking
URLLC: Ultra-reliable low-latency communication
NB-IoT: Narrow Band IoT

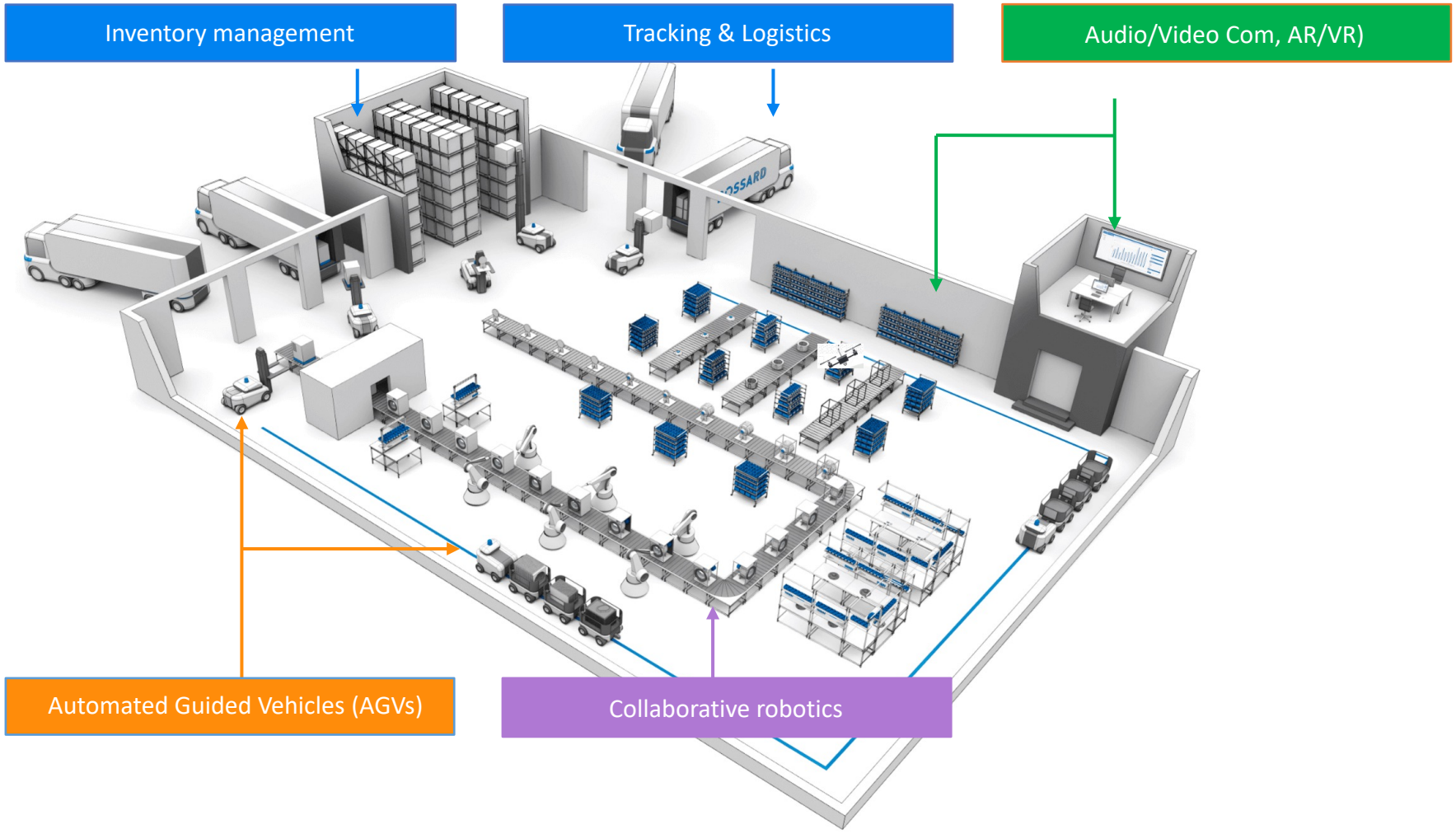
Use Cases beyond eMBB

Start with 4G. Evolve to 5G



** With bounded latency*

Cellular IoT segments for smart manufacturing



TUDO SOBRE iot

Private 5G

Is it worth it?

How Private 5G Networks Can Transform All Industries

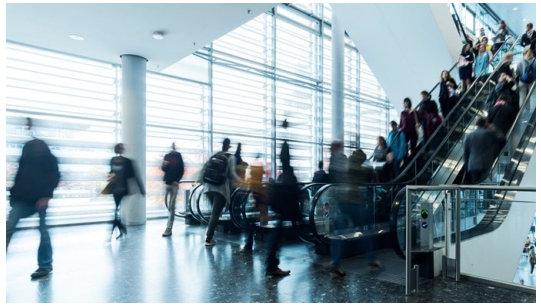
In terms of physical deployment, the term **“Private Network”** refers to **networks with radio, core and transmission resources dedicated to the company** and – crucially – under the control of the company. This generally means that the network equipment will be deployed at the customer's premises, regardless of which party manages it on a day-to-day basis.

Mining

Energy

Industry 4.0

Airports

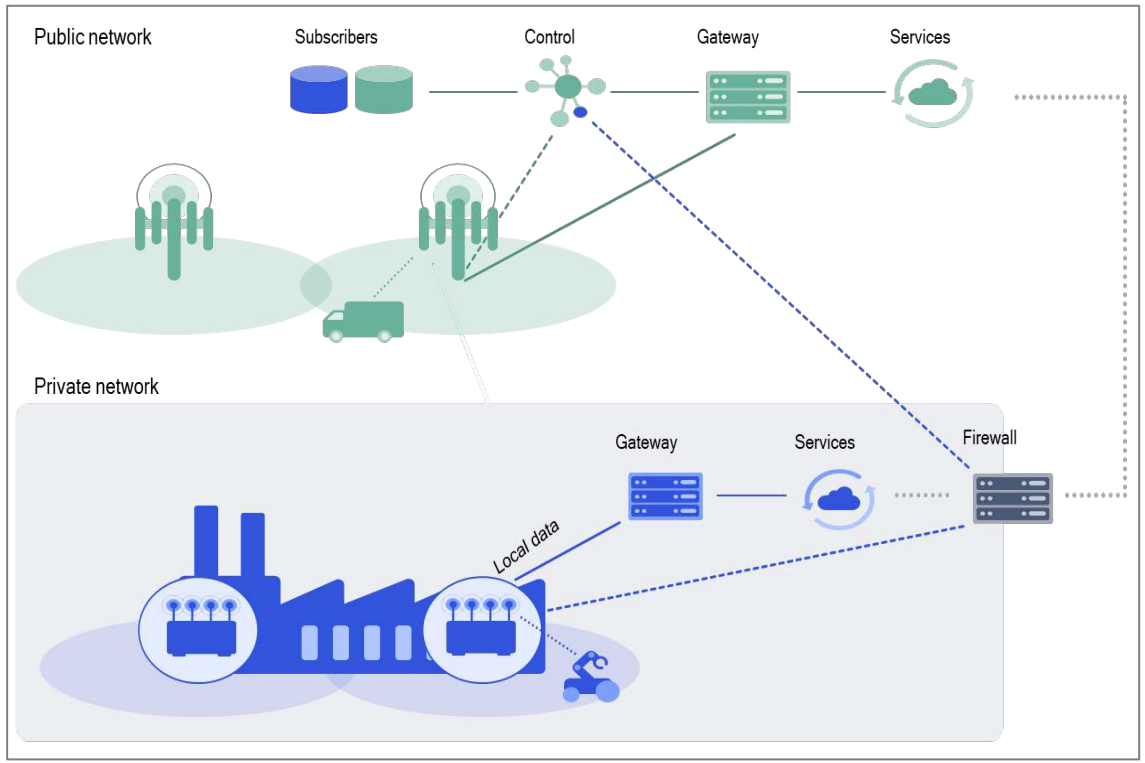


Ports

Source: Qualcomm Whitepaper

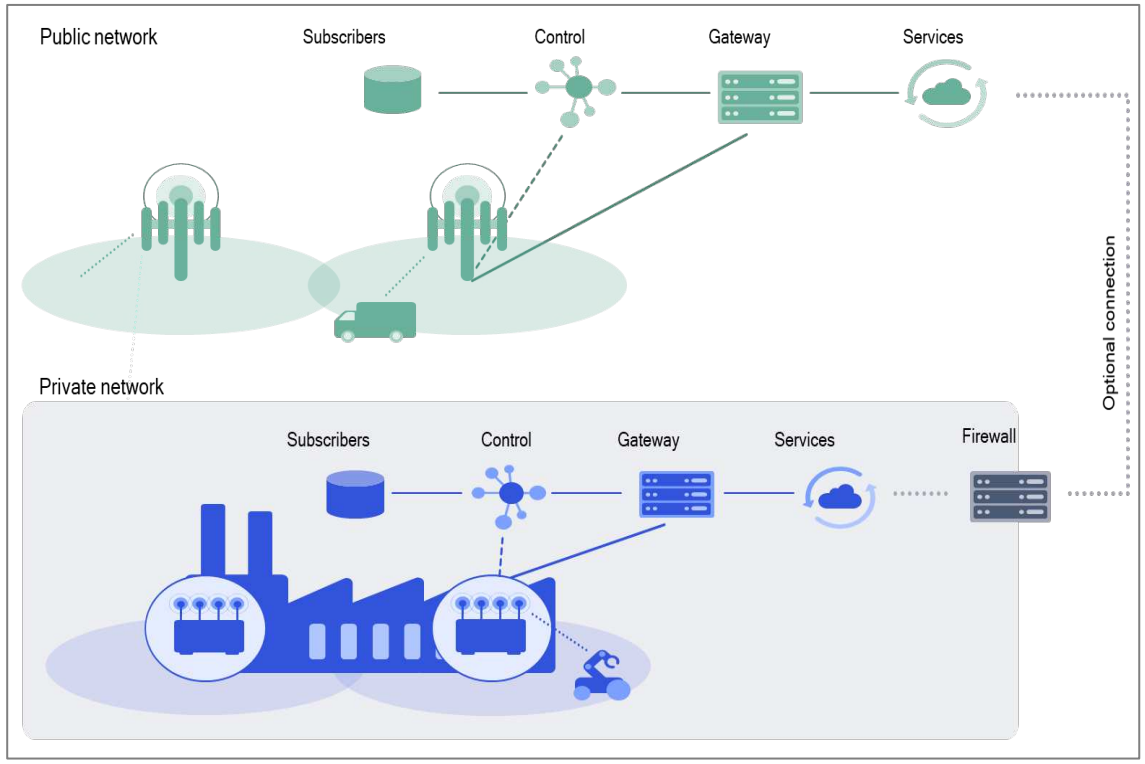
Private Network Implementation Models

Network integrated with the operator's network



Private networks implemented in conjunction with a public network. Several levels of integration are possible.

Independent private 5G network



Independent private networks, without dependencies on a licensed public operator or a long-distance network. Integration with the public network is possible, but optional.

Source: Qualcomm Whitepaper

Private Network Implementation Models

Spectrum Options for Industrial IoT

Spectrum Type	Description
Licensed spectrum owned by operators	• Continuation of the classic spectrum licensing model • Protected use makes this spectrum attractive for users with reliability concerns • Mechanisms for renting/sharing spectrum for private networks are under development
Dedicated Corporate Spectrum	• Model pursued in various markets For example, Germany must allocate 100 MHz (3.7-3.8 GHz) to industrial users • Attractive where available; however, there is some risk of being a niche ecosystem.
*Unlicensed spectrum (with asynchronous sharing)**	• *5GHz is the main band; US to open 6 GHz, with Europe to follow* • *Listen-before-speak regulations already built into 5GHz* • *Most useful for private 5G networks that don't require URLLC*
*Unlicensed spectrum with synchronized sharing**	• On new unlicensed allocations (eg 6GHz), there is an opportunity to introduce new sharing mechanisms • Over-the-air sync is a lightweight way to improve sharing • Allows for more reliable performance in co-located deployments; makes unlicensed spectrum suitable for URLLC applications

URLLC: Ultra-reliable low-latency communication

* 6 GHz in Brazil would be for WiFi-6 and 100% unlicensed

Source: Qualcomm Whitepaper

Value chain players

Equipment suppliers x Potential infrastructure players for private 5G and its variations.

5G network providers

Traditional providers:

- Ericsson
- Huawei
- Nokia Siemens
- ZTE

"New" Providers:

- Altiostar
- Cisco Systems
- Datang Telecom
- Qualcomm
- Samsung

Trends

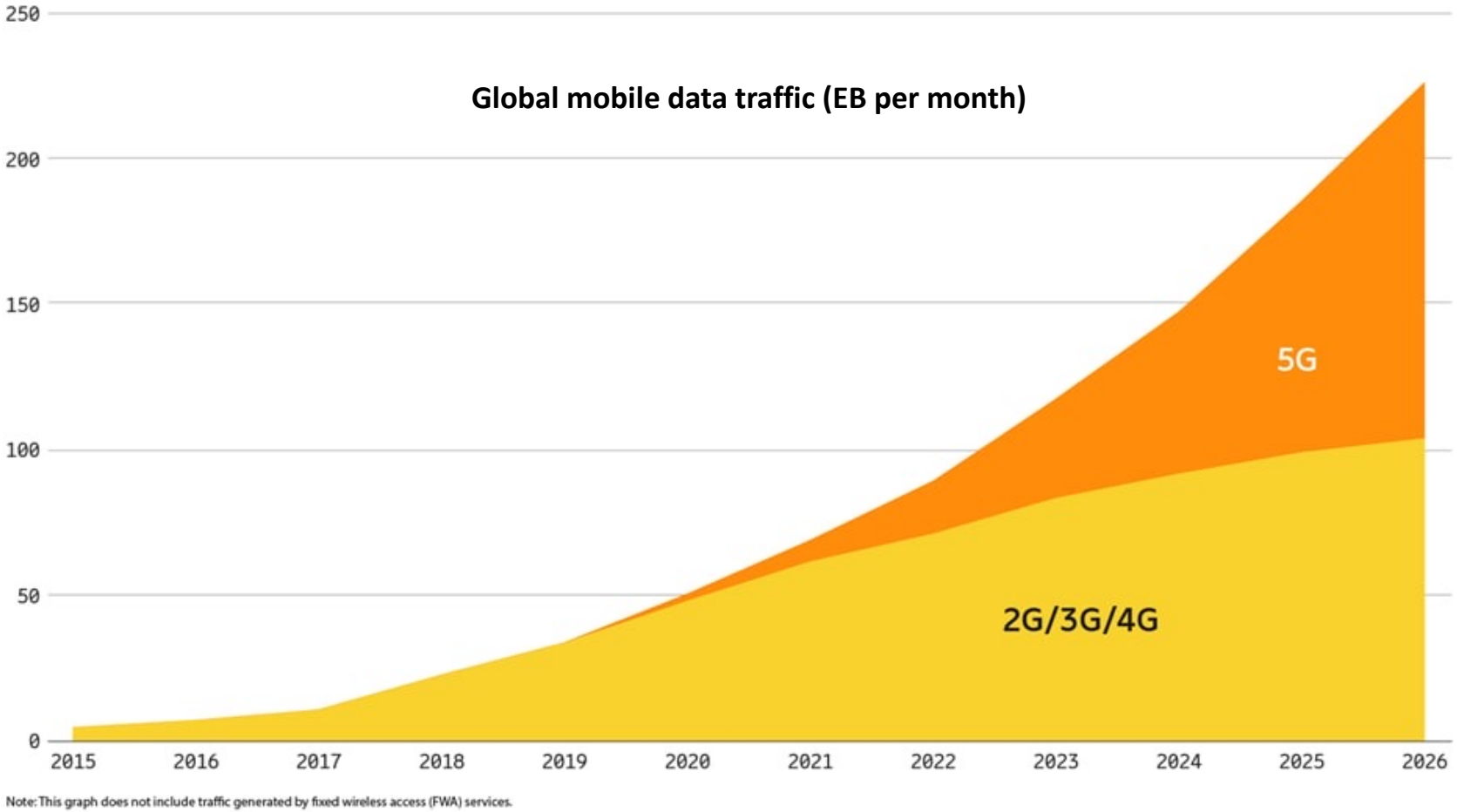
What operators in the world plan with 5G and how is Brazil?

5G networks are expected to carry 54% of all mobile data traffic by 2026

Smartphones continue to generate the most mobile data traffic - nearly 90% today and projected to reach 95% by the end of 2026

226EB

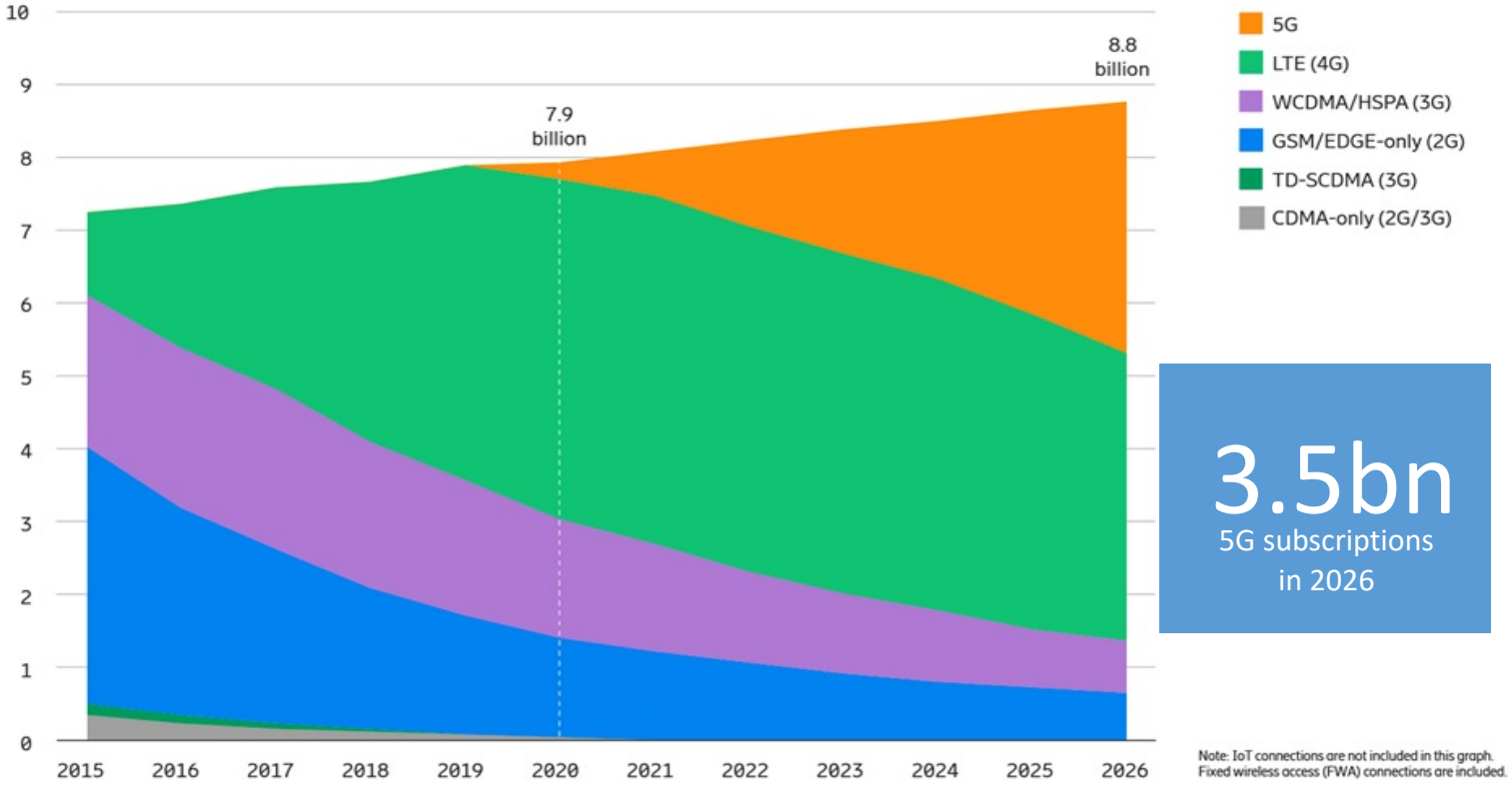
Total traffic predicted to reach 226 Exabytes per month in 2026



Source: Ericsson Mobility Report

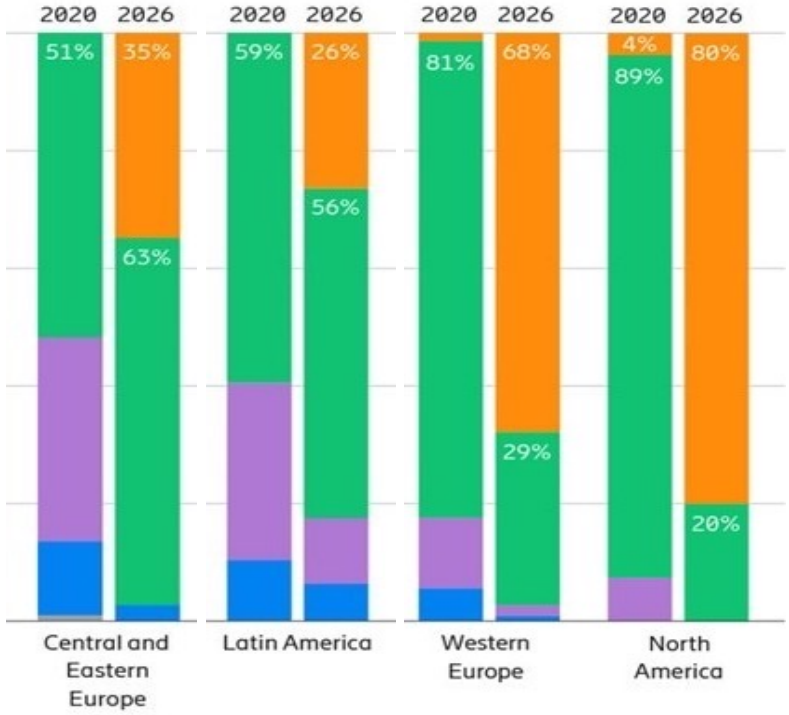
Strong Moment for 5G - Forecast in 2020

Mobile subscriptions by technology (billions)



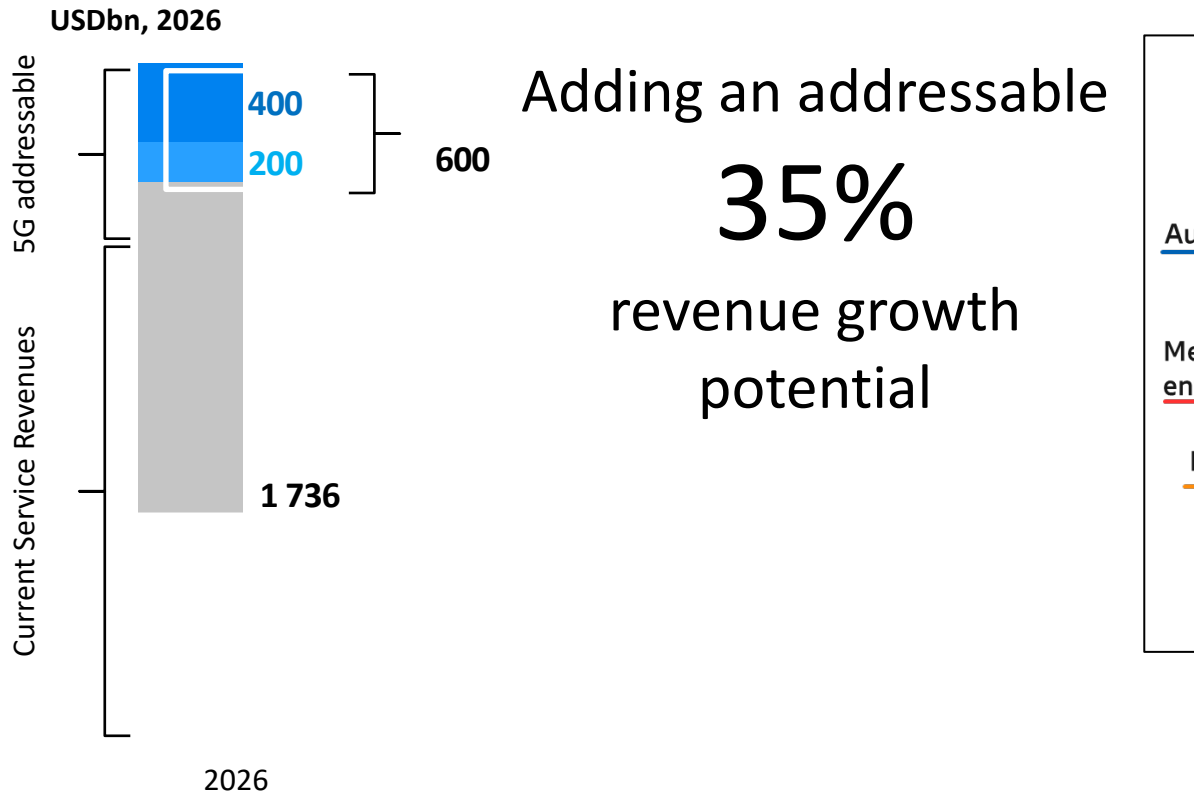
3.5bn
5G subscriptions in 2026

Mobile subscription (percentage)



Source: Ericsson Mobility Report

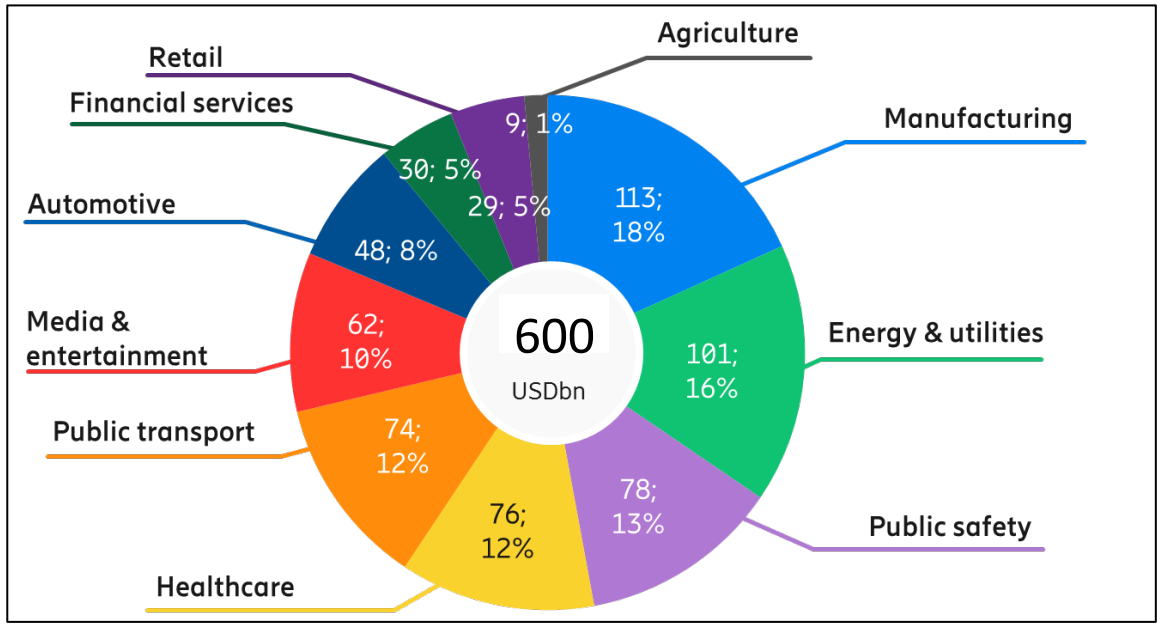
5G Revenue Potential for Operators Addressing Industry Digitization



Adding an addressable

35%

revenue growth potential

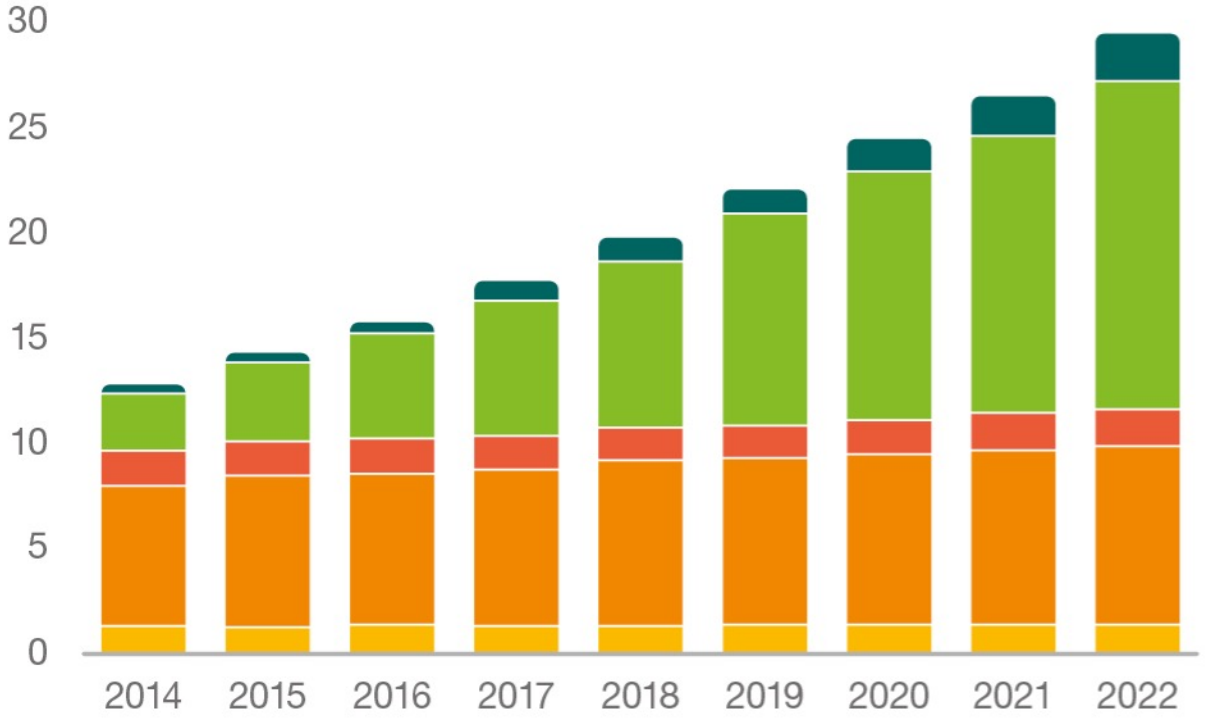


Service enabler and service creator revenue potential

Network Developer Revenue Potential

70% of Wide Area IoT Devices Will Use Cellular Technology by 2022

Connected Devices (Billions)



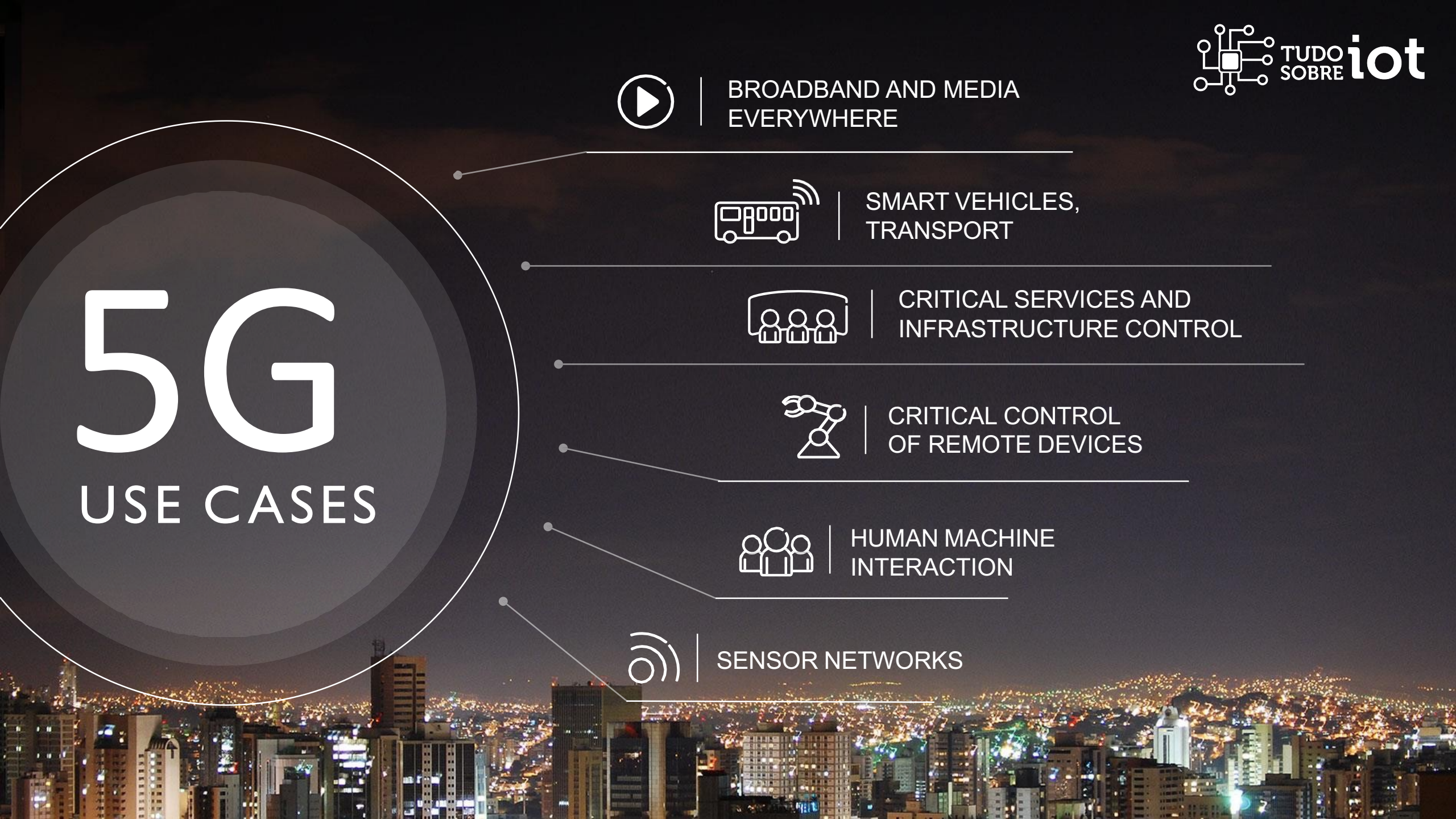
	2016	2022	CAGR
Wide-area IoT	0.4	2.1	30%
Short-range IoT	5.2	16	20%
PC/laptop/tablet	1.6	1.7	0%
Mobile phones	7.3	8.6	3%
Fixed phones	1.4	1.3	0%
	16	29	10%

Billions

CAGR: Compound annual growth rate

Business

Consumers, new products and services: what can we expect and how can we anticipate?


TUDO SOBRE iot
5G
USE CASES
BROADBAND AND MEDIA EVERYWHERE
SMART VEHICLES, TRANSPORT
CRITICAL SERVICES AND INFRASTRUCTURE CONTROL
CRITICAL CONTROL OF REMOTE DEVICES
HUMAN MACHINE INTERACTION
SENSOR NETWORKS

USE CASE 1

BROADBAND and media everywhere

Opportunity areas

- Mobile Broadband evolution
- On-demand anything
- Events platform
- Live TV at scale

Benefits

- **Maximizes customer experience** in both indoor & outdoor environments
- Enables industry **transformation**
- Meets **consumer demands** for TV on their terms

5G technology brings

- Mobile broadband in crowded areas
- Media consumption on consumers' terms
- TV for in-home screens and mobile devices
- Evolved Mobile Enterprise collaboration services

Target Users

- Mobile operators
- Pay TV Operators
- Broadcasters
- Over The Top providers

USE CASE 2

SMART VEHICLES and TRANSPORT

Opportunity areas

- Autonomous vehicles
- Connected bus-stops
- Connected trucks
- Connected cars

Benefits

- **Intelligent transport** systems and **massive machine type communication**
- New services and business models can be supported with **sensors** embedded in **roads**, **railways** and **airfields** to communicate to each other and/or with **smart vehicles**

5G technology brings

- Sustainability
- Safety
- Fleet monitoring
- Navigation & augmented reality
- Eco-system scale and diversity

Target Users

- Automotive
- Security & insurance
- Transport & infrastructure companies
- Administration/governments

USE CASE 3

CRITICAL services and INFRASTRUCTURE CONTROL

Opportunity areas

- Public Safety
- Mission critical utilities – Energy active grid
- Mission critical utilities – Water active grid

Benefits

- Manage **massive number of connections**
- Energy and water utilities connecting to **millions of networked devices,** enabling **real-time intelligent** and **autonomous** decisions

5G technology brings

- Security
- Enable real-time, intelligent and autonomous decisions
- Robust coverage
- Reliability
- Sustainability

Target Users

- Police and security services
- Health care
- Agriculture
- Energy utilities
- Water utilities

USE CASE 4

critical Control of remote devices

Opportunity areas

- Remote control of heavy machinery
- Real-time process control
- Factory automation
- Remote surgery

Benefits

- Controlling heavy machinery remotely to lower risks in hazardous environments
- Increase efficiency and reduce costs. Replace communication bus with wireless links

5G technology brings

- Unique performance and latency characteristics required for these critical tasks
- Mobility
- Security

Target Users

- Manufacturing
- Oil plant
- Mines
- Healthcare

USE CASE 5

human machine interaction

Opportunity areas

- Immersive augmented reality
- Immersive gaming
- Surveillance
- Tactile internet
- Smart biker-helmets
- Child monitoring
- Smart houses
- Smart shipping/post

Benefits

- **Tactile internet** and smart interaction between **humans and machines**
- New business opportunities based on **context awareness** as the main difference from M2M

5G technology brings

- Reliable & Precise
- Non Intrusiveness
- Privacy
- Real-time
- Sustainability

Target Users

- Health care – remote check up
- Universities & researchers
- Municipalities
- Fitness

USE CASE 6

Sensor Networks

Opportunity areas

- Agriculture & Environment
- Smart buildings & Cities
- Consumers & Utilities

Benefits

- **Maximizes productivity** in both indoor & outdoor environments
- **Expand business opportunities** and business models through monitoring, tracking and automation capabilities in large scale

5G technology brings

- Efficiency - smart grid, asset tracking
- Eco-system scalability
- Security
- Business Intelligence
- Sustainability

Target Users

- Municipalities
- Farm
- Agriculture
- Water and electricity distributors

Results

When 5G becomes real, where is it real, investments and how to make money with this technology?

When?

Anatel Auction of spectrum 700 MHz, 2.3Ghz, 3.5GHz and 26GHz

- When: **July 2022** (Auction Q1 2020 -> Q3 2021?>);
- Licenses Price: ? (At least R$ 40 Billion);
- Investment money: (Infra required Division of OI)?
- Offer **4G internet signal on approximately 27 thousand kilometers** of federal highways. The deadline is until 2029, with 50% of the sections indicated in the notice covered by 2025;
- Bring 5G to the **26 capitals of Brazil** and the Federal District until **July 2022;**
- For all cities in Brazil with more than **30,000 inhabitants, the deadline is July 2029;**
- Bring 4G internet or above to all locations with more than **600 inhabitants by 2028**;
- Build an optical **fiber network, with about 13 thousand km**, to benefit the North region;
- **Migrate open TV from the 3.5GHz band**, which will be used on 5G, to the Ku band. Bands are frequency bands in the air used for data transmission; and
- Build a private communications network for the government.
- And Huawei?

ANATEL
Agência Nacional de Telecomunicações

“A lei das Antenas”

- Municipal (5570) **2 months to 2 years to install antennas**
- 5G will have **10x more antennas** than 4G (~20 000 -> ~200 000 / Operator)

Challenges

Operators

Network

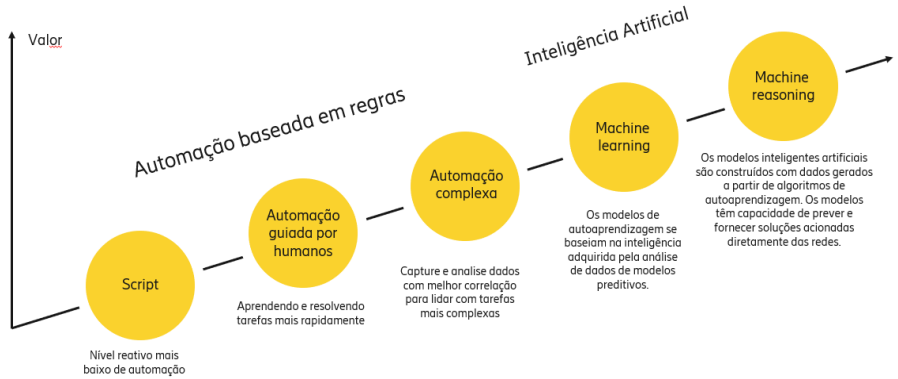
- *Prepare & Plan Coverage*
- *Prepare & Plan Capacity*
- Network performance - Latency - Synchronization

Learn New Technologies

- *5G*
- *IoT Devices*
- *Artificial Intelligence*
- *Cloud Systems*

Network Operation

- Rules based -> Artificial Intelligence
- Own network and private networks

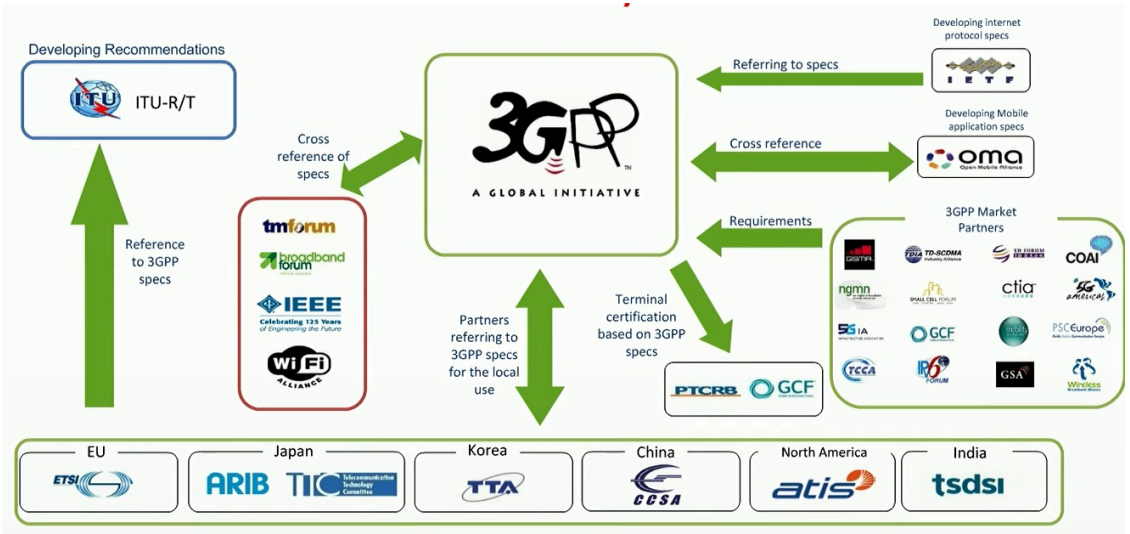


Challenges and Opportunities

Technology

Standardization and regulation

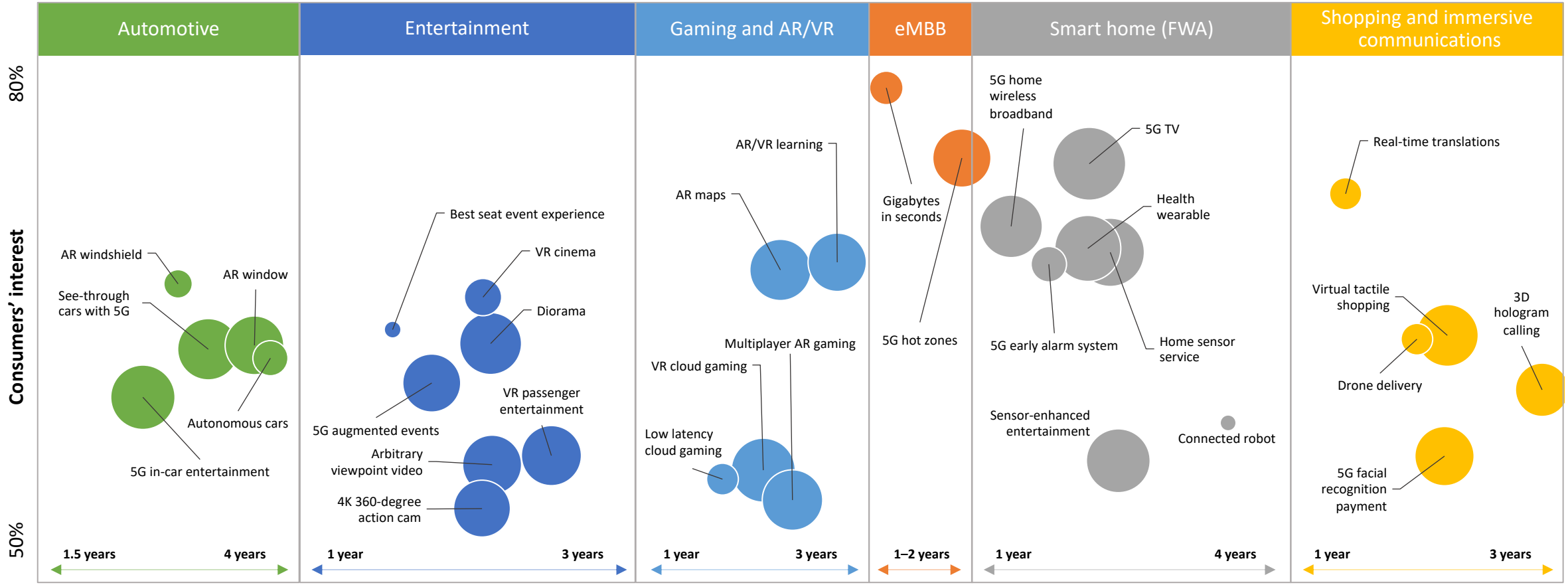
- *Standards Development Organizations*
- *Industry Forums*
- *Regulatory Bodies and Administrations*
- *5G to 6G (Tbits/s, 100GHz, λ = 3mm, 2030))*



The Perfect Tech Storm for Society 5.0

- *5G (Speed + Low Latency)*
- *Artificial Intelligence and Automation*
- *Cloud Systems Device Revolution for Augmented / Virtual Reality*
- *Quantum Computing / Quantum Computers*
- *Network Virtualization*
- *Wireless Vertical Industries*

5G Consumer Use Case Roadmap



Base: Usuários de smartphones com idade 15–69 na Australia, Argentina, Brazil, Belgium, China, Canada, Chile, France, Finland, Germany, India, Indonesia, Ireland, Italy, KSA, South Korea, Singapore, Thailand, Uruguay, the UAE, the UK and the US
Source: Ericsson Consumer & IndustryLab, 5G consumer potential (May 2019)

Willingness to pay

Lowest (47%) → Highest (79%)

TUDO SOBRE iot

Masterthings

Interaction and exchange of experience with experts from "Everything About IoT".

Top Six IoT Network Technologies Compared Advantages

5G	LoRa/LoRaWAN	NB-IoT/LTE-M	Wi-Fi	BLE	Zigbee
• Greater capacity • Higher Data Rate • Lower latency	• Low battery consumption • Economic implementation	• Take advantage of existing 4G coverage • Large volume of data • Downloadability on licensed spectrum	• Simplified and cost-effective deploymen • Alternative to 5G (Wi-Fi6) • Ubiquitous mobility	• Low cost • Simple setup • No hardware needed	• Device security • Better mesh capabilities compared to Wi-Fi • Flexibility for users and developers

Source: Ericsson Mobility Report

Six Top IoT Network Technologies Compared Disadvantages

5G	LoRa/LoRaWAN	NB-IoT/LTE-M	Wi-Fi	BLE	Zigbee
• High cost and complex infrastructure • Complex SW release ecosystem • Short range on mm waves	• Not ideal for applications that require high data rates • Not ideal for applications that require lower latency • Limited security	• High battery consumption • Complex SW release ecosystem • High cost LTE implementation for massive IoT use cases only	• Limited coverage range • Limited security • High energy requirements	• Short connection time • Short range • Low bandwidth	• Low transmission and network stability • Short range • High maintenance cost

Source: Ericsson Mobility Report

What is the best technology for my IoT?

5G?
LoRa/LoRaWAN?
NB-IoT?
LTE-M?
Wi-Fi?
BLE?
Zigbee?

Other...?

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