Course "ICT for Industrial Applications"

Introduction to 5G, B2B use cases and B5G

University of Padova, 6-8 March 2024

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Introduction to Huawei and R&D for 5G and beyond

Huawei: Leading provider of ICT infrastructure and smart devices

Vision & mission

Bring digital to every person, home and organization for a fully connected, intelligent world

207,000 employees

55% employees work in R&D

170+ countries and regions

No. 5 in global R&D investment

140,000+ active patents held globally

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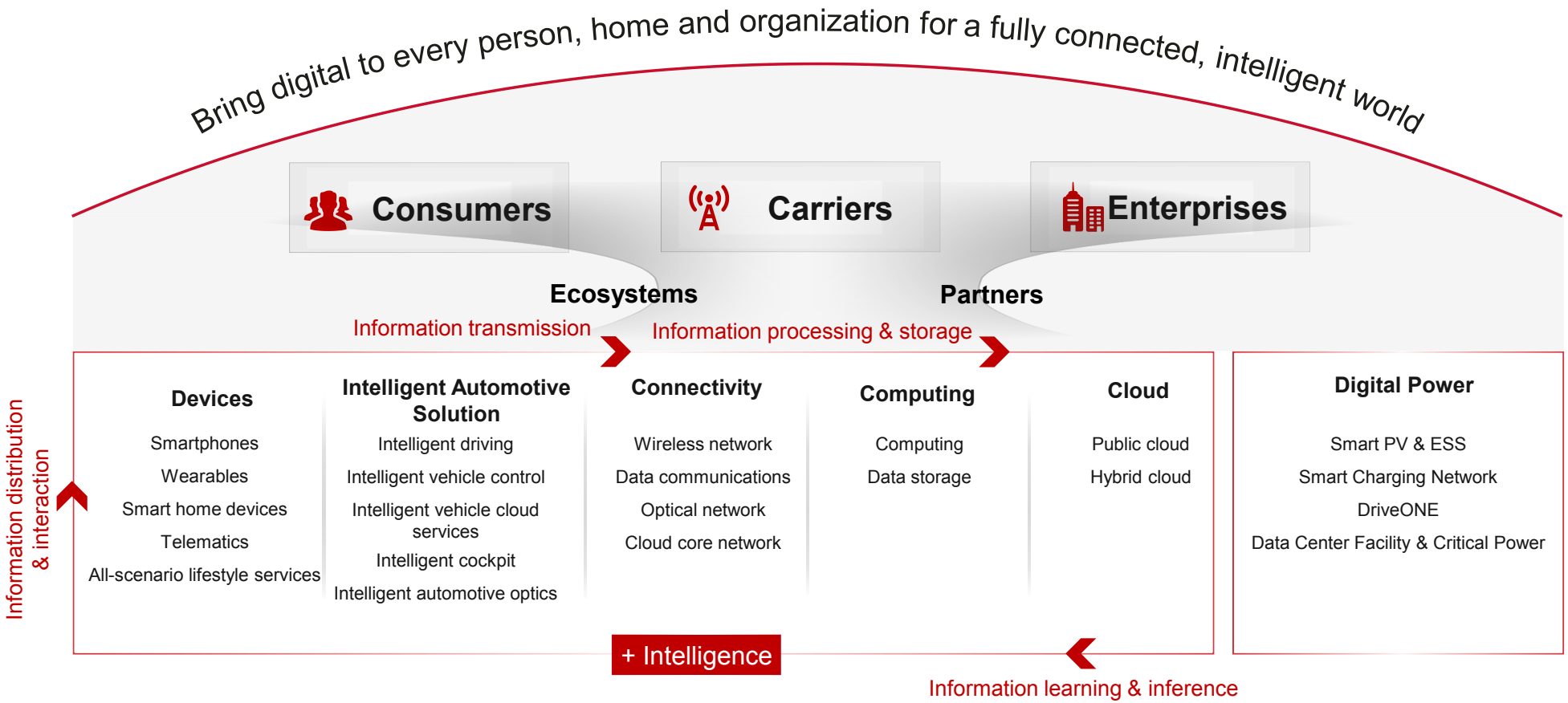
Focusing on ICT to provide products, solutions, and services to three customer groups alongside ecosystems and partners

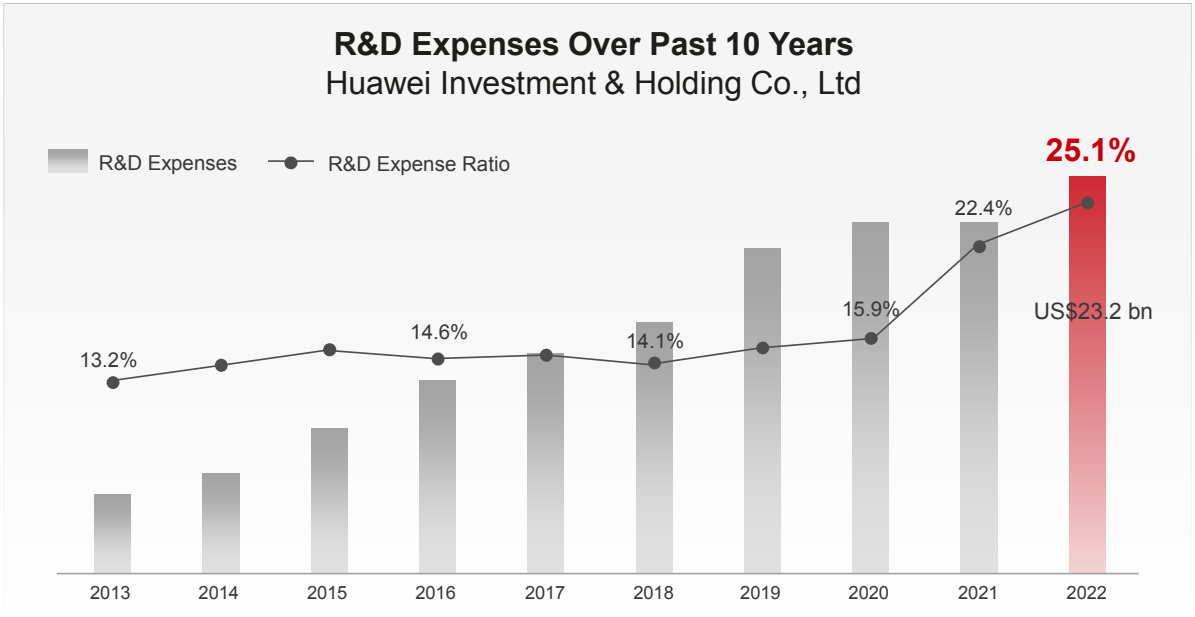


Heavy and sustained R&D investment

US$23.2 bn
R&D expenses in 2022

25.1%
R&D expense ratio in 2022

US$140.6 bn
total R&D expenses over the past decade



140,000+

Active patents held by Huawei globally (as of end 2023)

29

Enterprises signed bilateral agreements with Huawei and paid to obtain Huawei patent licenses (in 2022 alone)

Note: All amounts were converted into USD using the closing rate at the end of 2022 of US$1.00 = CNY6.9533

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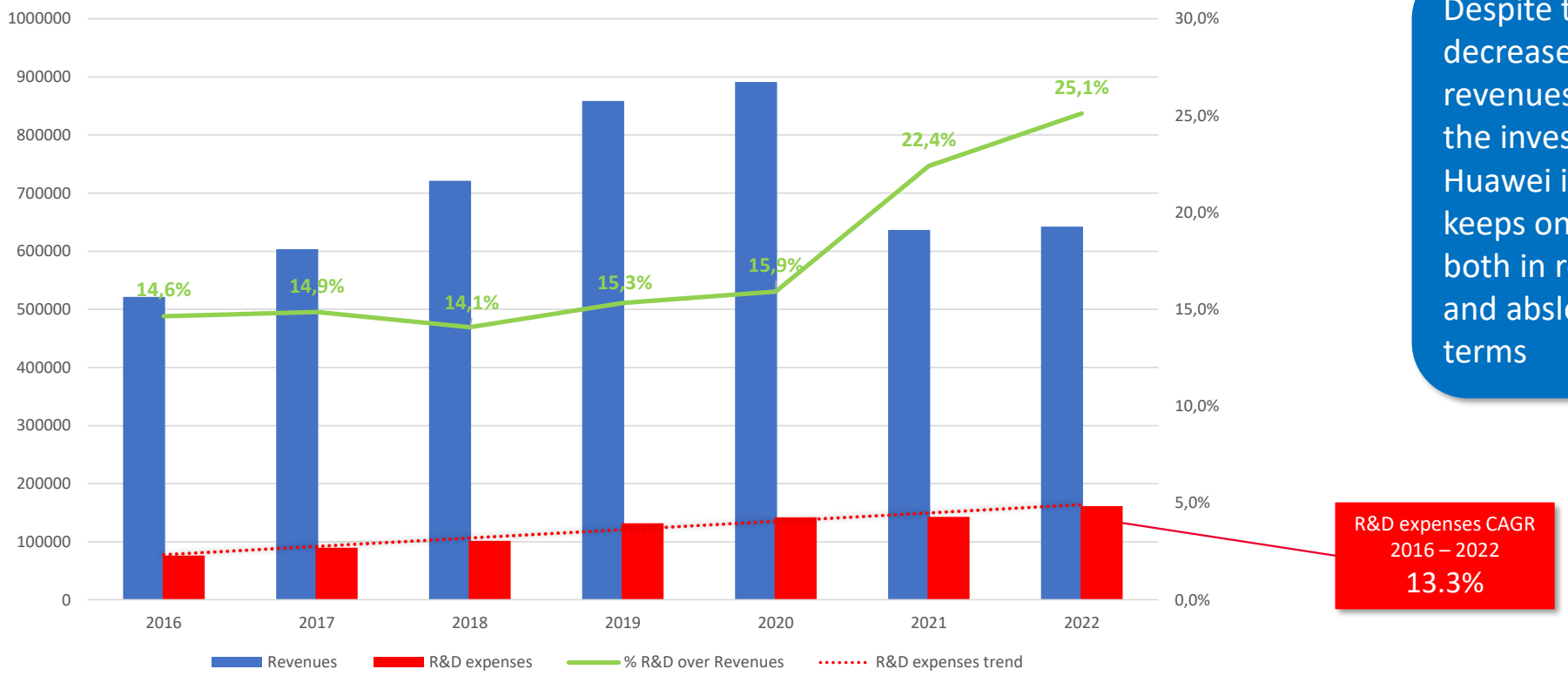
Revenues and R&D expenses 2016 - 2022



Despite the decrease of revenues in 2021, the investment of Huawei in R&D keeps on growing both in relative and absloute terms

Note: data in Million CNY. Rate at the end of 2022 of USD 1 = CNY 6.9533 → 2022 Revenues = 92,379 M$

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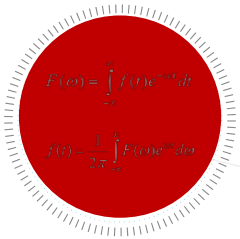
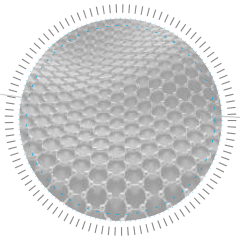
Heavy R&D investment drives innovation and future development

Behind our leading products is solid basic research and technological innovation



Mathematics & algorithms



Chemistry & materials science

Physics & engineering technology

Standards & patents

20%+ revenue reinvested into R&D for past 3 years

86 foundational tech labs

114,000 R&D employees (**55%** of workforce)

180+ joint labs and innovation labs

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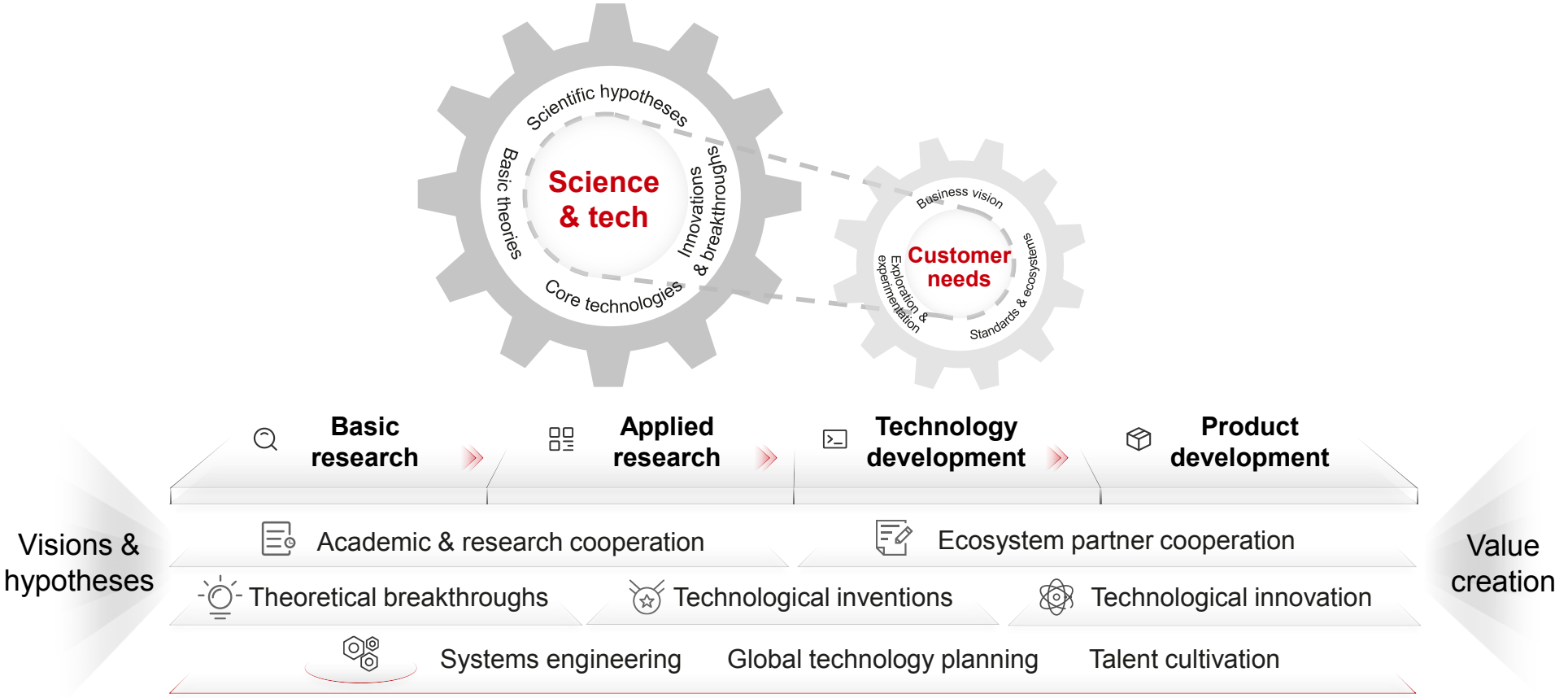
The two drivers of innovation



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Driving ongoing tech innovation through extensive technical cooperation with universities and research institutes

300+
Universities /Research institutes

2,000+
Cooperation projects per year

20,000+
Scientific researchers worldwide

Models for innovation cooperation

Joint/Innovation labs

- Joint research to make breakthroughs in basic research
- Major inventions to drive the industry forward

Technical cooperation

- Identifying industry challenges
- Resolving challenges with scholars

...

Research sponsorship

- Supporting quick exploration into innovative ideas at colleges and universities

Challenges & Spark awards

- Sharing technical challenges
- Finding innovative talent

Huawei Italy Research Centers

Milan Research Center

HF mmWave Technologies
HF 5G Wireless Technologies
Optical RF Chip Technologies

Milan Aesthetic Research Center

Consumer experience design (Product/Service/Communication)

Pisa Research Center

Real-time embedded software

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15 Years of Milan Research Center

Vodafone MW Joint Innovation Center

2011
MMIC

1st world high modulation prototype

2012
E-Band

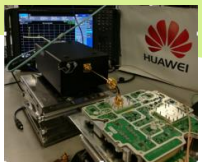
2013
HiSilicon Optical

June 2008
MW ODU

MW Architecture

2015
5G High Frequency

2016
D-Band
1st world trial



2017
Optical RFIC

2020
Expand cooperation footprint

2022

- From ERC to Milan RC
- More research and collaboration with Universities
- New recruitment policy (young talents)

- Joint Labs @ Pavia, Milan, Siena
- New Aesthetic Center in Milan

Joint Labs @ Naples, Turin, Bologna

Joint Lab @ UniMiB

University of Cagliari

University of Padova

Politecnico di Milano

Politecnico di Torino

University of Trento

University of Siena

University of Pavia

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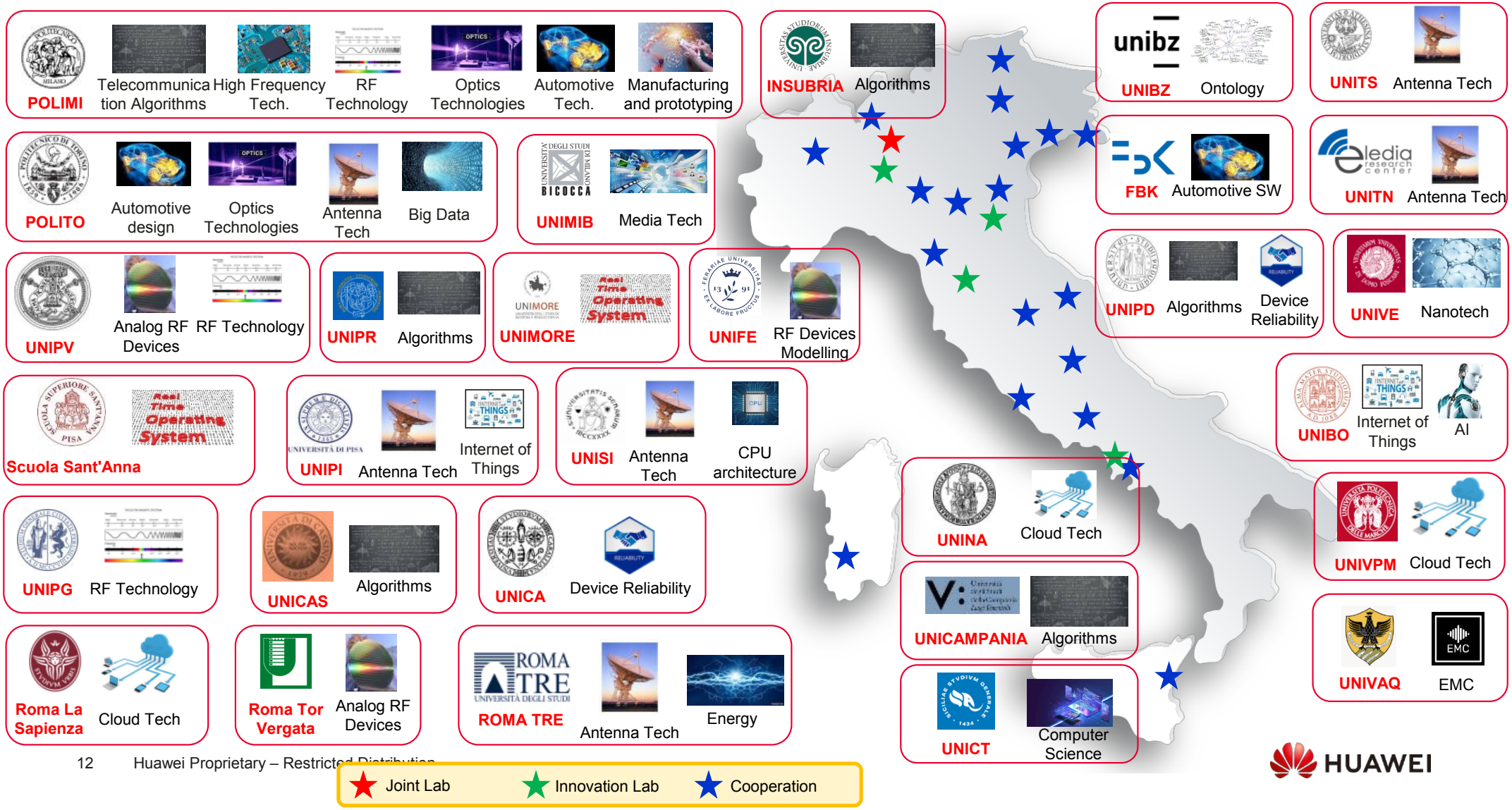
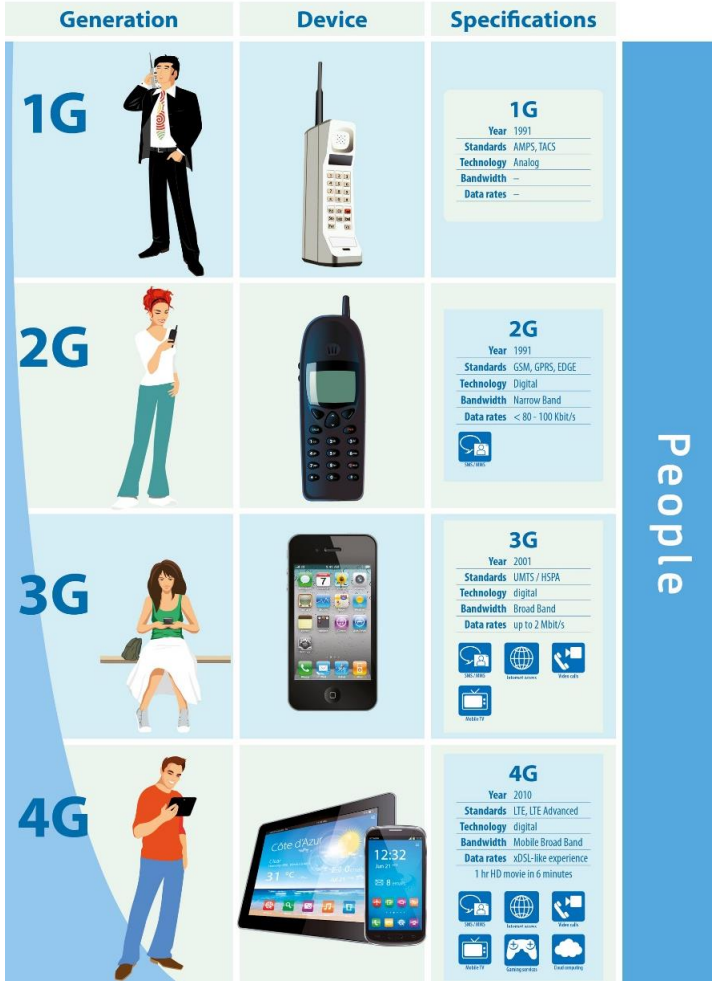
Fuelling Innovation by Collaborating with Top Italian Universities (2022)

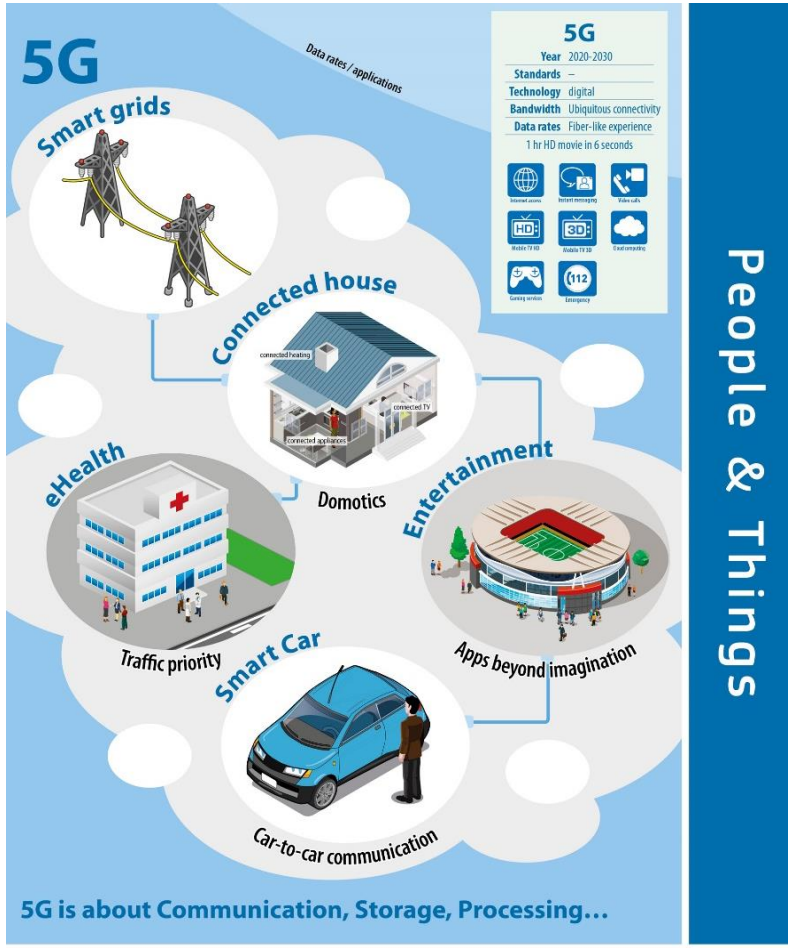


5G overview

What is 5G?
What is behind 5G?
Why do we need 5G?

The evolution of mobile communication





Source: https://digital-strategy.ec.europa.eu/en/library/1g-5g-infographic

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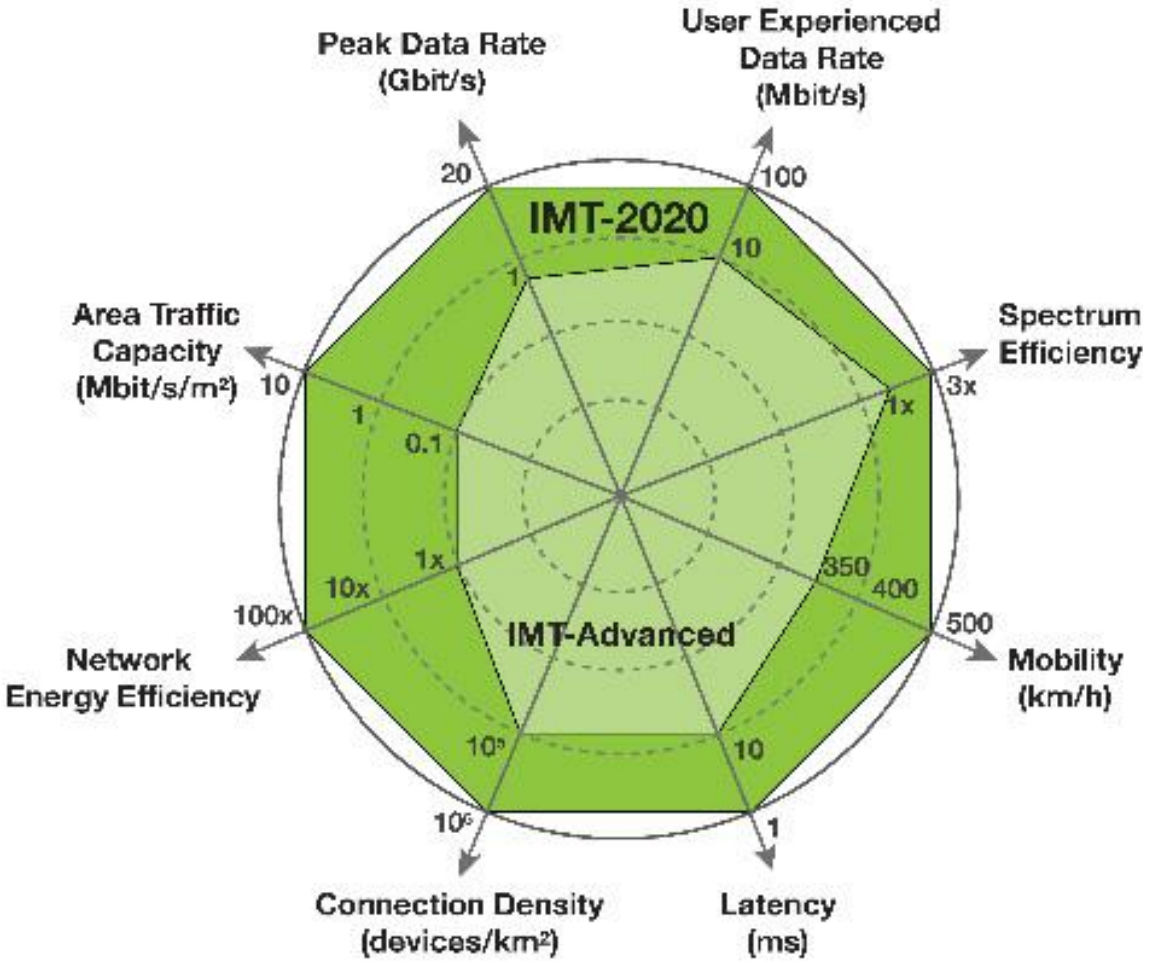
ITU-R 5G network capability requirements



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5G spectrum (Italian case)

Spectrum in the 700 MHz (694MHz-790MHz), 3.6GHz-3.8GHz and 26.5GHz-27.5GHz bands was auctioned in September and October 2018. The whole auction ended after 14 days of intense bidding, far above expectations, reaching 6.55 billion EUR of which 4 billion EUR for the highly-coveted mid-frequencies.

5G spectrum consultation	700 MHz	3.4-3.6 GHz	3.6-3.8 GHz	>24 GHz	Other frequencies
–	✓	–	✓	✓	–
Dec. 2017, Feb. 2018	60 MHz September 2018		200 MHz September 2018	1,000 MHz September 2018	

The 700 MHz auction process ended mid-September 2018. 700 MHz frequencies raised globally 2.04 billion EUR. Telecom Italia announced it had paid 680.2 million EUR for 2×10 MHz. Illiad paid 676.5 million EUR for 2×10 MHz. Vodafone spent 683.2 million EUR for 2×10 MHz. Licenses are valid 15 years, starting on July 1st, 2022.

Mid-2017, the Italian NRA made spectrum in 3.4-3.8 GHz band available for 5G trials.

The mi-band auction ended on October 2nd, 2018, 14 days after start and 171 rounds. Telecom Italia and Vodafone won the largest blocks of spectrum (80 MHz each) for approx.1.7 billion EUR each. Respectively they paid 1.694 billion EUR and 1.685 billion EUR. Wind and Iliad paid 483.9 million EUR each for 20 MHz of spectrum each (483.92 million EUR for Wind and 483.9 million EUR for Illiad). Overall, the 3.7 GHz auction hit over 4 billion EUR reaching 4.3 billion EUR. The average price of spectrum closed at 18 cEUR/MHz/PoP/10 years significantly higher than in the UK or in Spain.

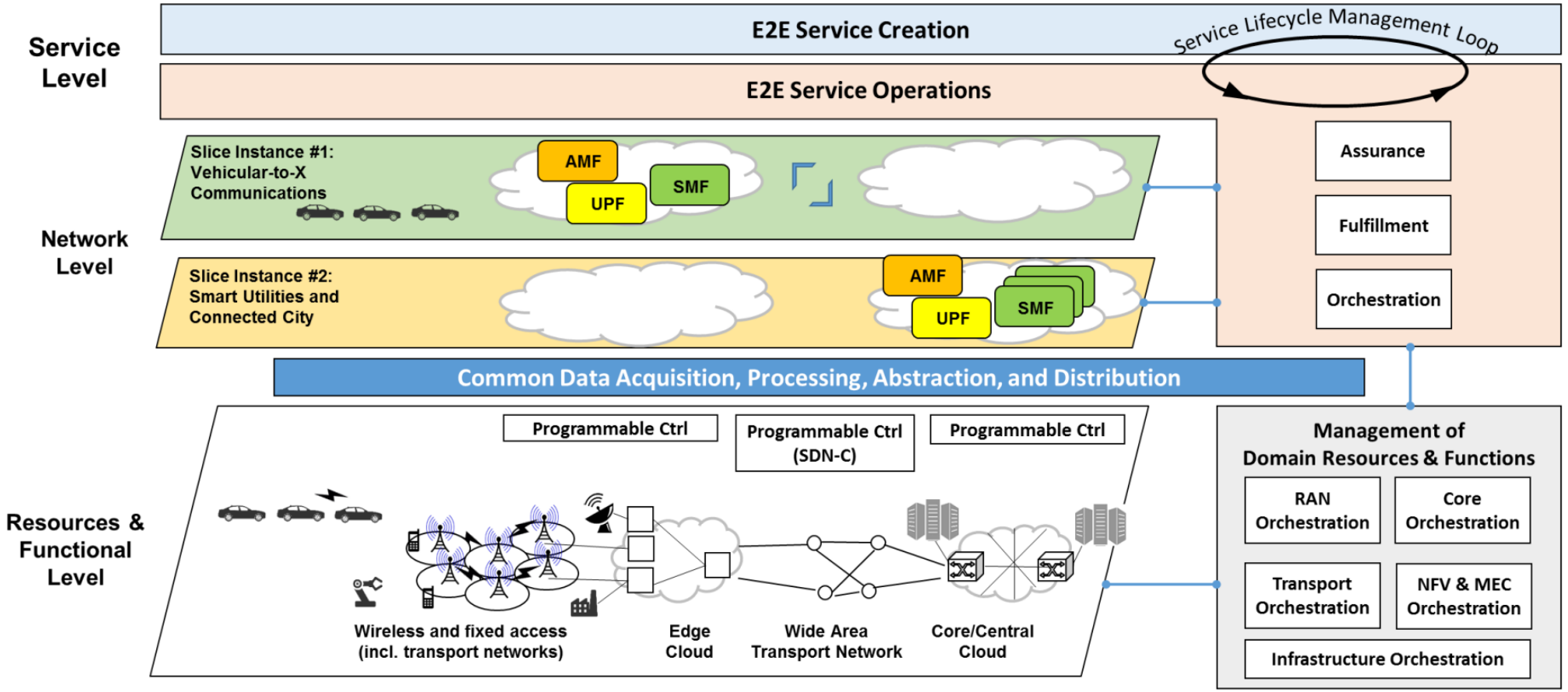
Licences start as of December 1st, 2018.

1,000 MHz of the 26.5GHz-27.5GHz spectrum (split into five lots of 200 MHz) was auctioned in September 2018. The process ended on October 2nd, 2018, 14 days after start. The auction for 26 GHz frequencies have not shown a huge interest by players. The five lots were allocated, raising a total of 167.3 million EUR. Telecom Italia paid its slot 33 million EUR, Illiad received another lot for a little less at 32.9 million EUR, while Fastweb, Wind and Vodafone paid 32.6 million EUR each.

Licenses will be valid until 2037 with the right of use to start as of December 1st, 2018.

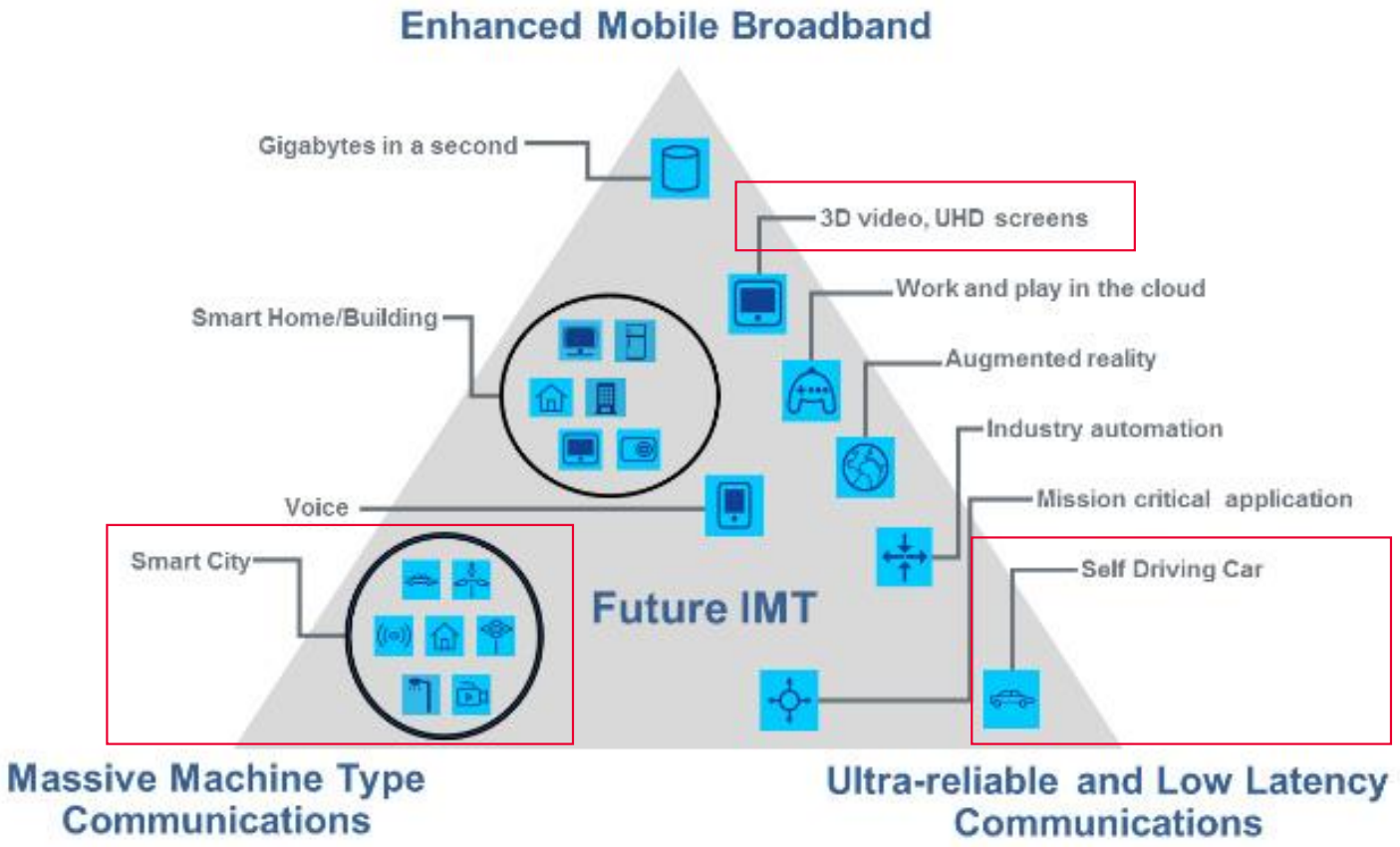
Source: https://5gobservatory.eu/national-5g-spectrum-assignment/#1533310457982-93376798-7871

The overall architecture



Source: https://5g-ppp.eu/wp-content/uploads/2020/02/5G-PPP-5G-Architecture-White-Paper_final.pdf

ITU-R 5G triangle



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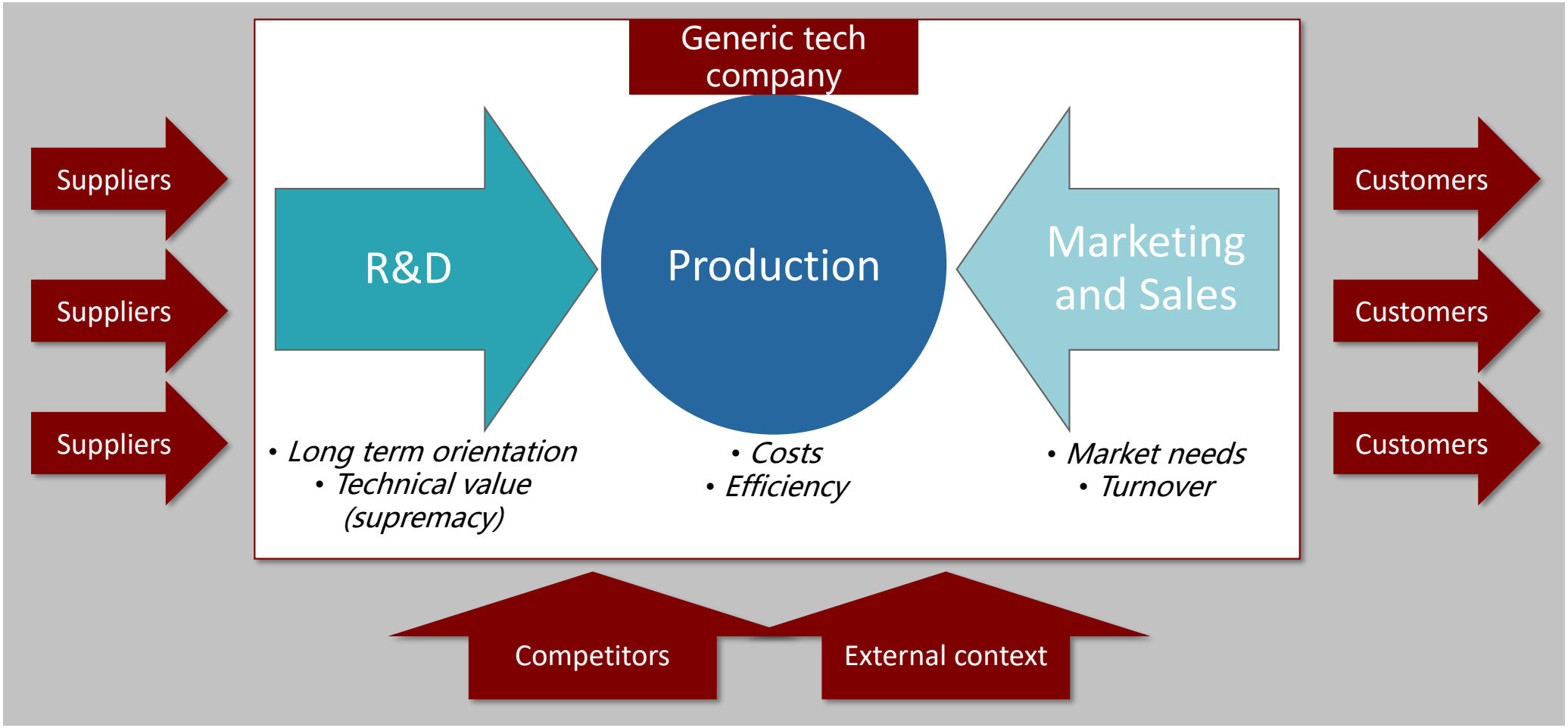
Technology push vs demand pull



Value Chain (vs) Ecosystem

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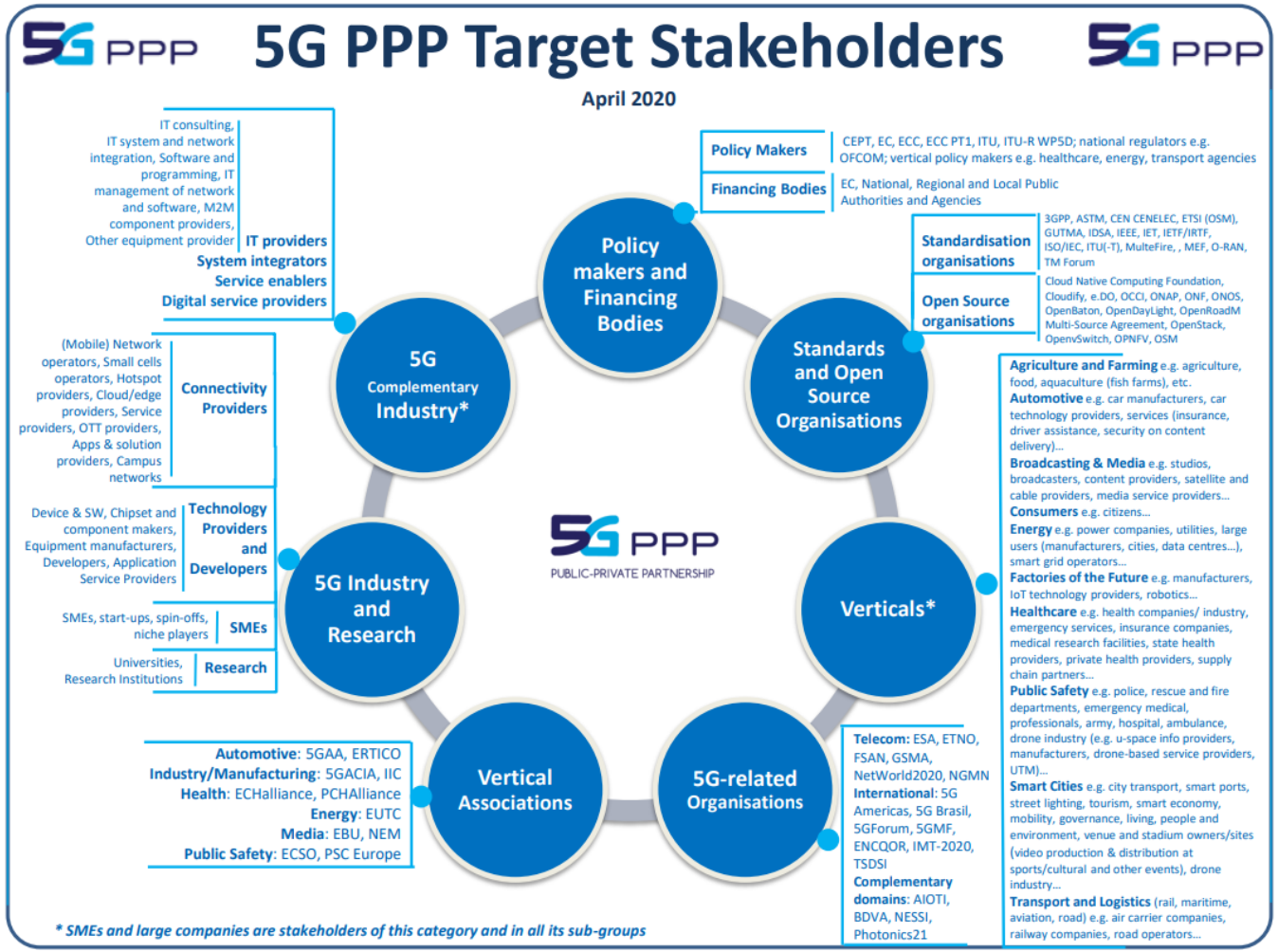
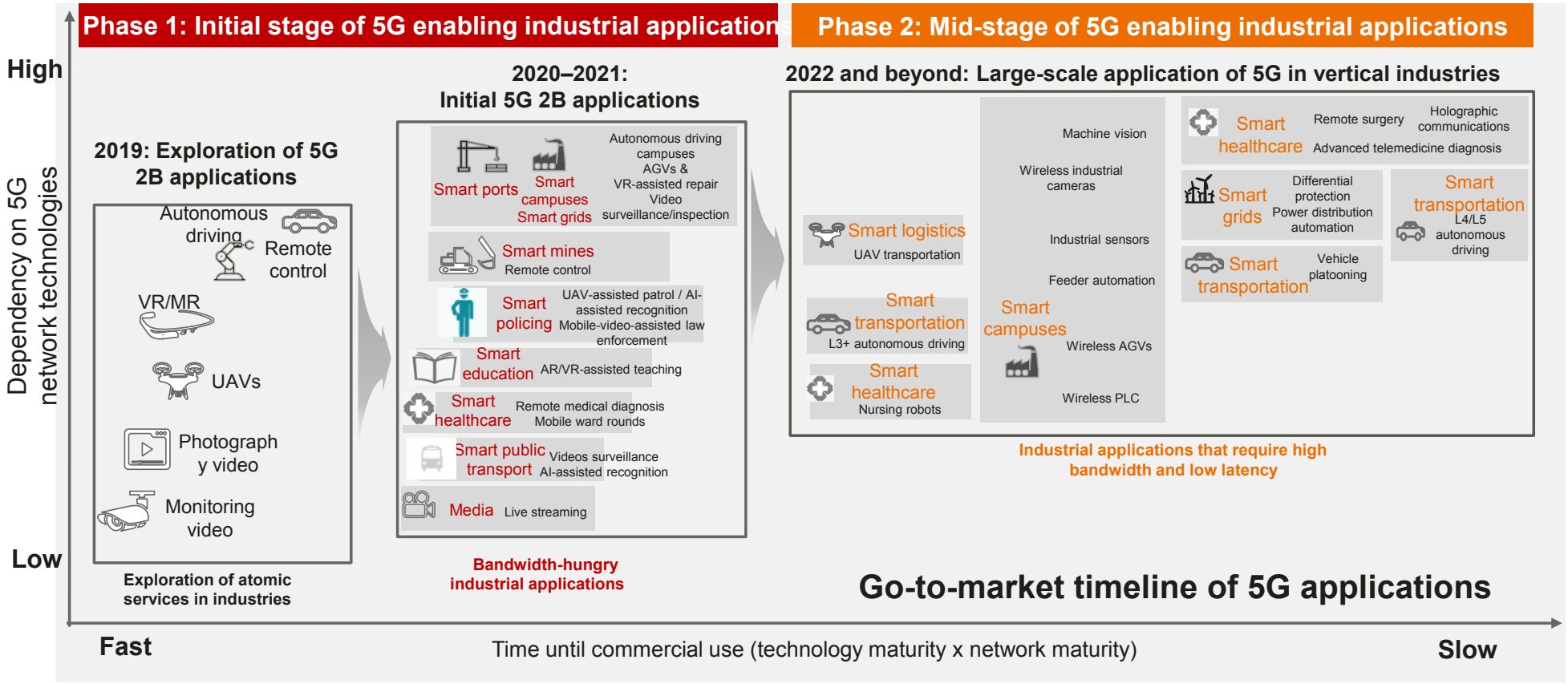
5G PPP target Stakeholders



5G + industries: Sparking a new intelligent connectivity revolution



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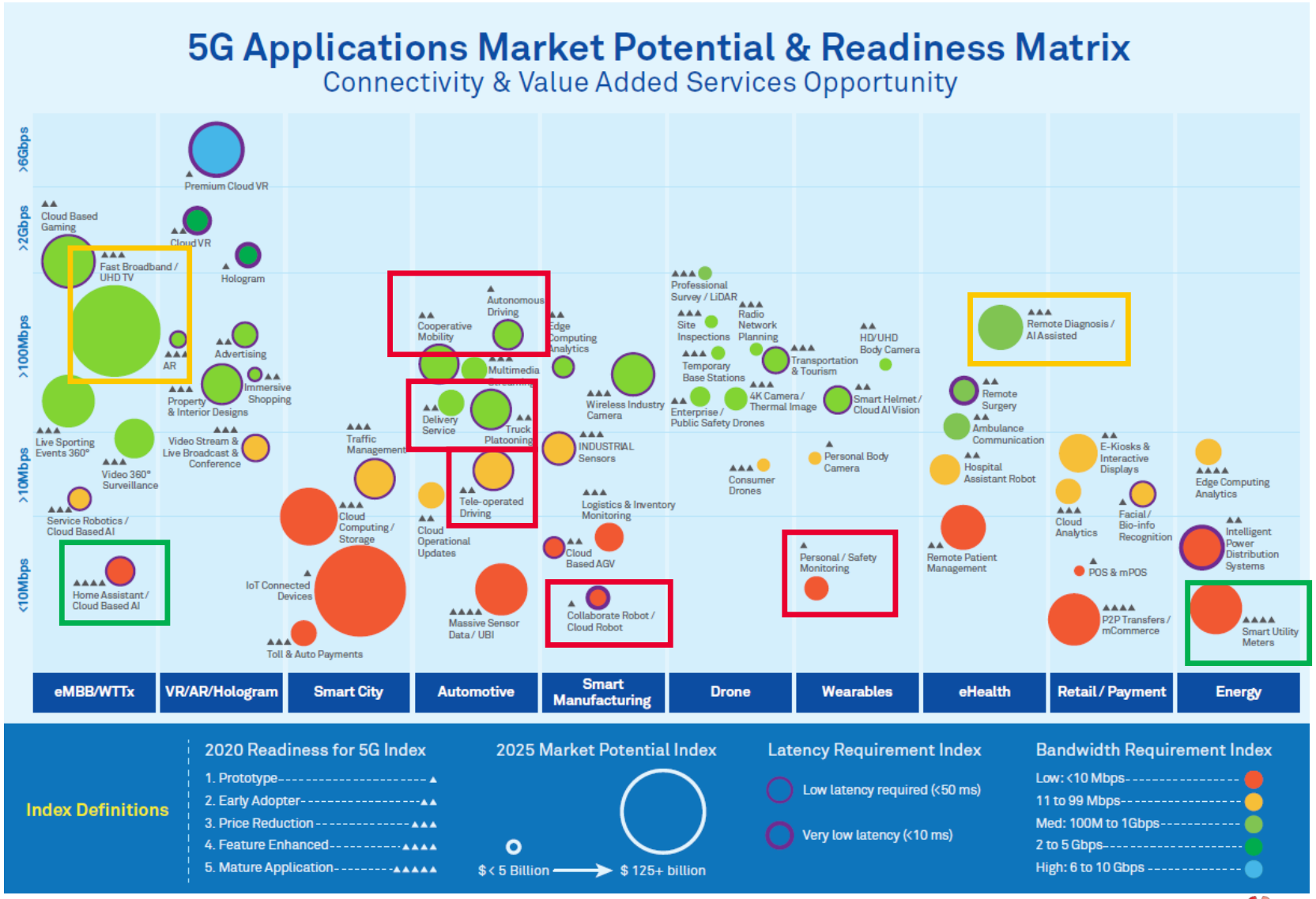

5G Applications Market Potential & Readiness Matrix
Connectivity & Value Added Services Opportunity
>6Gbps
>2Gbps
>100Mbps
>10Mbps
<10Mbps
Premium Cloud VR
Cloud Based Gaming
Cloud VR
Fast Broadband / UHD TV
Hologram
AR
Advertising
Immersive Shopping
Property & Interior Designs
Live Sporting Events 360°
Video 360° Surveillance
Video Stream & Live Broadcast & Conference
Service Robotics / Cloud Based AI
Home Assistant / Cloud Based AI
Traffic Management
Cloud Computing / Storage
IoT Connected Devices
Toll & Auto Payments
Autonomous Driving
Cooperative Mobility
Multimedia
Delivery Service
Truck Platooning
Tele-operated Driving
Cloud Operational Updates
Massive Sensor Data / UBI
Edge Computing Analytics
Wireless Industry Camera
INDUSTRIAL Sensors
Logistics & Inventory Monitoring
Cloud Based AGV
Collaborate Robot / Cloud Robot
Professional Survey / LiDAR
Site Inspections
Radio Network Planning
Temporary Base Stations
Transportation & Tourism
HD/UHD Body Camera
Enterprise / Public Safety Drones
4K Camera / Thermal Image
Smart Helmet / Cloud AI Vision
Consumer Drones
Personal Body Camera
Personal / Safety Monitoring
Remote Diagnosis / AI Assisted
Remote Surgery
Ambulance Communication
Hospital Assistant Robot
Remote Patient Management
E-Kiosks & Interactive Displays
Cloud Analytics
Facial / Bio-info Recognition
POS & mPOS
P2P Transfers / mCommerce
Edge Computing Analytics
Intelligent Power Distribution Systems
Smart Utility Meters
eMBB/WTTx
VR/AR/Hologram
Smart City
Automotive
Smart Manufacturing
Drone
Wearables
eHealth
Retail / Payment
Energy
Index Definitions
2020 Readiness for 5G Index
1. Prototype
2. Early Adopter
3. Price Reduction
4. Feature Enhanced
5. Mature Application
2025 Market Potential Index
$< 5 Billion
$ 125+ billion
Latency Requirement Index
Low latency required (<50 ms)
Very low latency (<10 ms)
Bandwidth Requirement Index
Low: <10 Mbps
11 to 99 Mbps
Med: 100M to 1Gbps
2 to 5 Gbps
High: 6 to 10 Gbps

Ten challenges and research directions ahead

What

Two scientific questions

About the world	1	How do machines perceive the world, and can we build models that teach machines how to understand the world?
About ourselves	2	How can we better understand the physiological mechanisms of the human body, including how the eight systems of the body work, as well as human intent and intelligence?

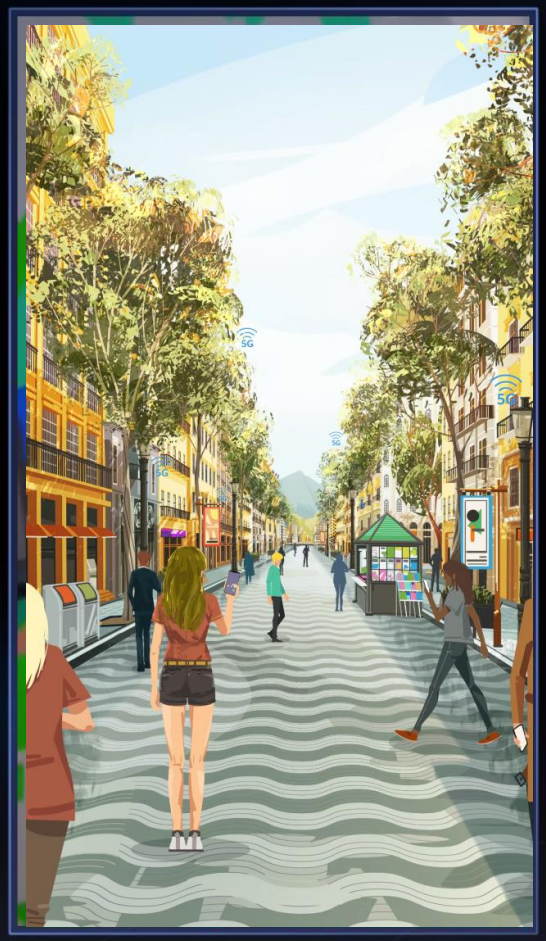
How

Eight tech challenges (e.g., systems engineering, hardware, software)

New HMI	3	New sensing and control capabilities, e.g., brain-computer interfaces, muscle-computer interfaces, 3D displays, virtual touch, virtual smell, and virtual taste
New healthcare	4	Real-time, unobtrusive blood pressure, blood sugar, and heart monitoring, and strong AI-assisted discoveries in chemical pharmaceuticals, biopharmaceuticals, and vaccines
New software	5	Application-centric, efficient, automated, and intelligent software for greater value and better experience
New networks	6	Reaching and circumventing Shannon's limit to enable efficient, high-performance connectivity both regionally and globally
New computing	7	Adaptive and efficient computing models, non-Von Neumann architectures, unconventional components, and explainable and debuggable AI
New materials	8	Inventing new molecules, catalysts, and components with intelligent computing
New processes	9	Developing new processes that surpass CMOS, cost less, and are more efficient
New energy	10	Safe, efficient energy conversion and storage, as well as on-demand services

5G use cases

More Innovations: 5G Contents and Services Gaining Momentum



Legacy Reborn

Video Ringback Tone

5G Message

New Call

3D Video

New Call@1080p: 5 Mbps UL

- **5G Message**
  1 Billion 5G msgs/mo. for CMCC @ 2022.9
- **Video Ringback Tone**
  1.2 Million Users in S. Korea in First 3 Months

Interactive Video

4K Video

Free Viewpoint

Cloud Gaming

Personal Broadcasting

Free Viewpoint: 25 Mbps DL

- **Interactive Video**
  70+ 5G Operators Include in 5G Plans
- **Free Viewpoint Service**
  China, S. Korea, Japan, Greece, Canada

Collaborative Universe

AR City

Metaverse Store

AR City: 120ms E2E Latency

- **XR**
  HongKong 5G AR App:
  > 30% 5G User Penetration
- **Metaverse Store**
  Opeartors in UAE (22.10), Spain (22.9) and Thailand (21.9)

40% 5G Operators Providing 5G-Enabled Contents

Source: Operator Annoucements, Omdia

5G FWA Leap Forward Growth: New Revenue, More Services, Better Experience

2/3 Operators
Vs. 4G Initial Stage 1/3

47% CAGR
Vs. 4G ~ 18%

170M Subs
60% @2027

10% Revenue Ratio
Leading FWA Operators

Faster Speed, Better Experience

Copper Upgrade

- Up to 300 Mbps
- Experience Upgrade @Suburban

Guaranteed Experience

- Minimum 100 Mbps
- WiFi Mesh

Gbps Extended Range MmWave

- 2.5 Gbps @7 km, 26 GHz
- Smart Home Gateway
- High Power Outdoor CPE

Richer Service, More Monetization

Migrate 4G to 5G Home

- Bundle Attractive Contents
- 50% ARPU ↑ vs 4G.

Game Acceleration, Monetize Latency

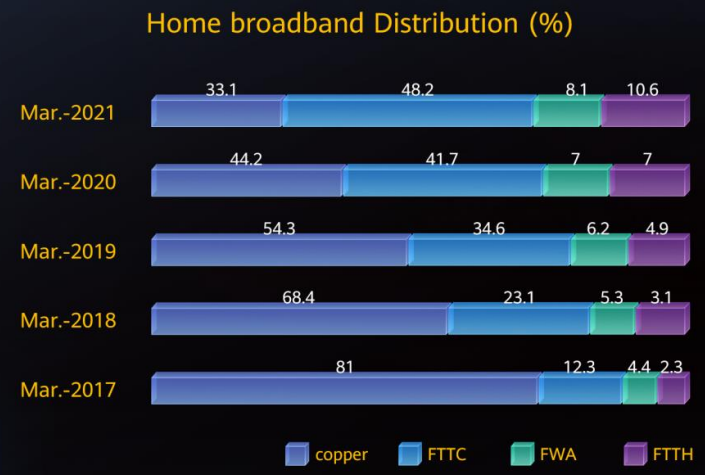
- Service Acceleration
- 60% Latency ↓

Home IoT, Monetize Uplink

- Smart IoT Camera
- 20% Annual Growth ↑

IT Operator A:5G FWA Upgrade Copper Users to Achieve Better Experience

~6.5 million Copper Users in Italy, the copper users are decreasing



- The users of FWA/FTTC/FTTH keep increasing,to get the space from Copper
- FWA already be one of the major tech for home broadband

Operator A deployed 5G C-band Massive MIMO in suburban to migrate copper user within 1 km

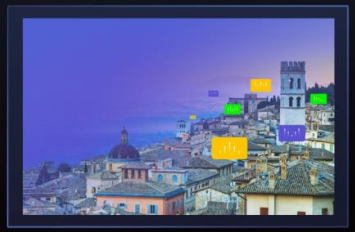
Accurate online provisioning with outdoor CPE for better experience

IT Operator B:Gbps Experience mmWave FWA with Extended Range Coverage

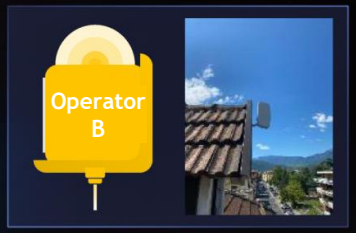
Operator B offer- FWA

	FTTx	5G FWA	5G Mobile
	mn HHs & companies		% outdoor cov.
2021	7.5	1.5	50%
2025	14.5	12	90%

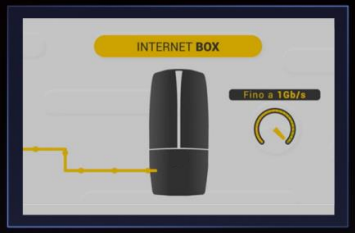
- mmWave as Key Broadband Strategy



- 19.95 €/month
- Internet up to 1 Gigabit/s



- High EIRP and power CPE
- Outdoor rooftop installation



- XXX Internet Box with Wi-Fi 6
- Alexa, voice control and music

Commercial Offering

Gbps Experience with Extended Range Coverage

HAAU 5323
70 dBm

- Highest EIRP
- +30% Coverage
- +70% Experience

Network Deployment

Optimal GP symbol to extend coverage

Further extend to 7 km

Extended Range Coverage and Experience

IoT: Home Applications Booming, UL becomes a new Monetization Method

5G Home Security

- 1 5G Home Gateway
- 1-3 Smart IP Cameras

5G Personal Broadcast

Online Tutor, Yoga Teacher, Busker
Makeup Influencer

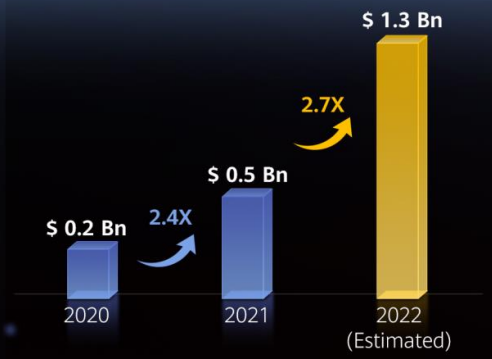
- 1 5G Home Gateway
- 1 4K Camera/Encoder
- Dedicated 5G Live Up Package

5G Work At Home

- Video Conference
- Office
- Educational APPs

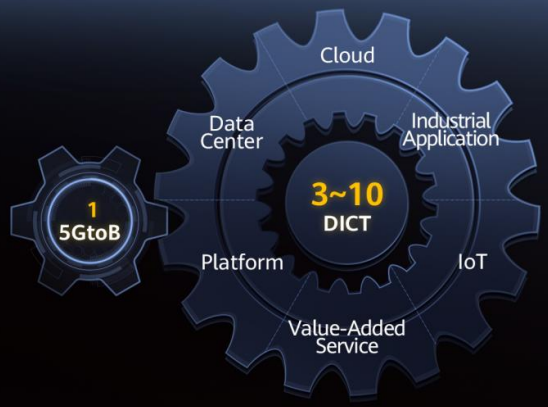
5GtoB Is On the Fast Lane As a New Growth Engine for Telco

2x – 3x Growth in 5G Private Network Revenue

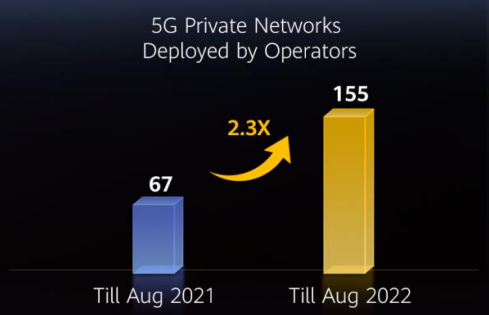


Source: Operator Financial Reports

3x – 10x Enablement Effect of 5GtoB Towards DICT Revenue



Doubling of 5G Private Networks in 12 Months



* Source: GSA Reports

More Industries

- Audi, Germany
- BASF, Germany
- Somboon Group, Thailand
- SCG, Thailand
- Garatau, South Africa
- Kuwait Oil Company
- Petronas, Malaysia
- Siriraj Hospital, Thailand
- Kwong Wah Hospital, Hong Kong
- EWG, Hungary
- Piraeus, Greece
- Deutsche Bahn

Source: Private Mobile Networks 2022 Member Report, GSA

More Use Cases

Helios Germany	Medical Device Tracking with Positioning Precision of 1m @ 90%
EWG EAST-WEST GATE Hungary	RTG Remote Control with Ultra-High Uplink Speed 600+ Mbps @ 70m x 1200m Railway Hub
SCG Thailand	Unmanned EV Truck Platooning with 50 ms Latency @ 99.99% Stable Low Latency

Challenges in 5B 2B exploration

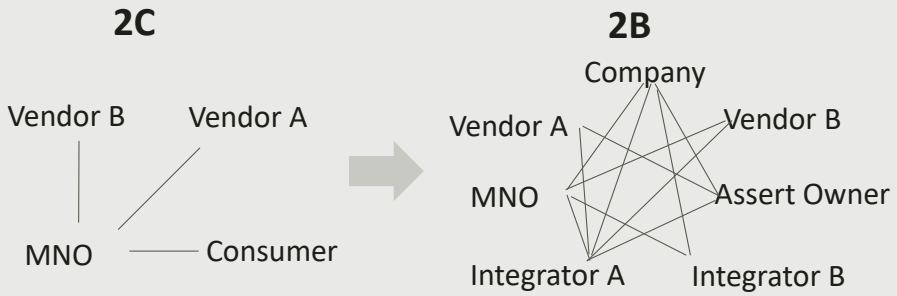
5G network capability cannot meet the needs from enterprise!

Latency <5ms?

Uplink throughput > 1Gbps ?

Reliability > 99.9999% ?

Business model is too complicated!

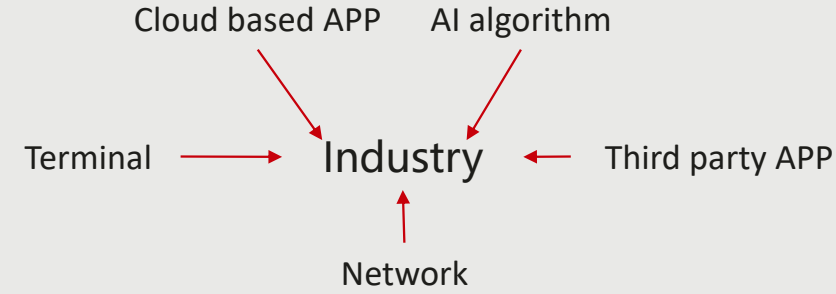


The 2B solution is customized & fragmented, cannot be copied!

Energy industry ≠ Transportation industry

Manufacture A ≠ Manufacture B

Eco-system not convergent & not mature



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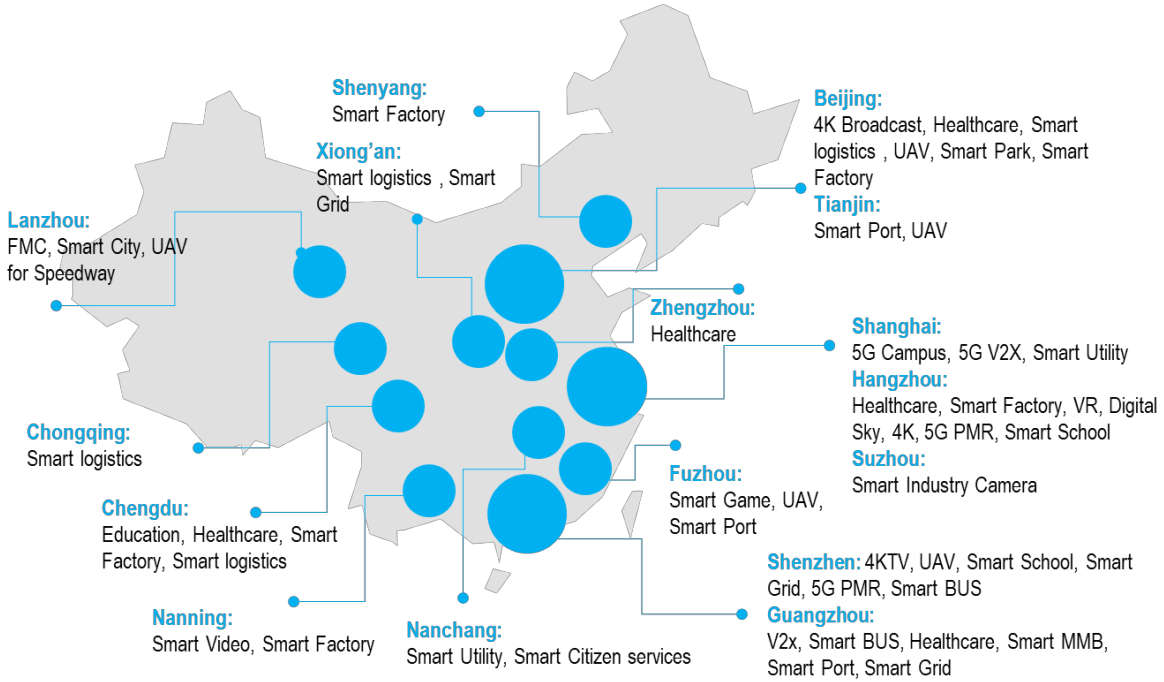
China Market: 5G 2B Massive Commercialization in Y2020

30 Provinces **1000+** commercial trials **200+** enterprises contracted 30+ partners



Manufacture, Transportation, Education, Logistics, Energy, Public security…

Operator build 5G for industry campus

Trialed 2019 & start commercialization in 2020

Partners involved

- Mobile Network Operators - MNO
- Railway companies
- Manufacturing companies
- Port authorities, operators and suppliers
- Car manufacturers

Use cases

5G Factory	5G Surgery
5G Mining	5G Live broadcast
5G port	5G Railway

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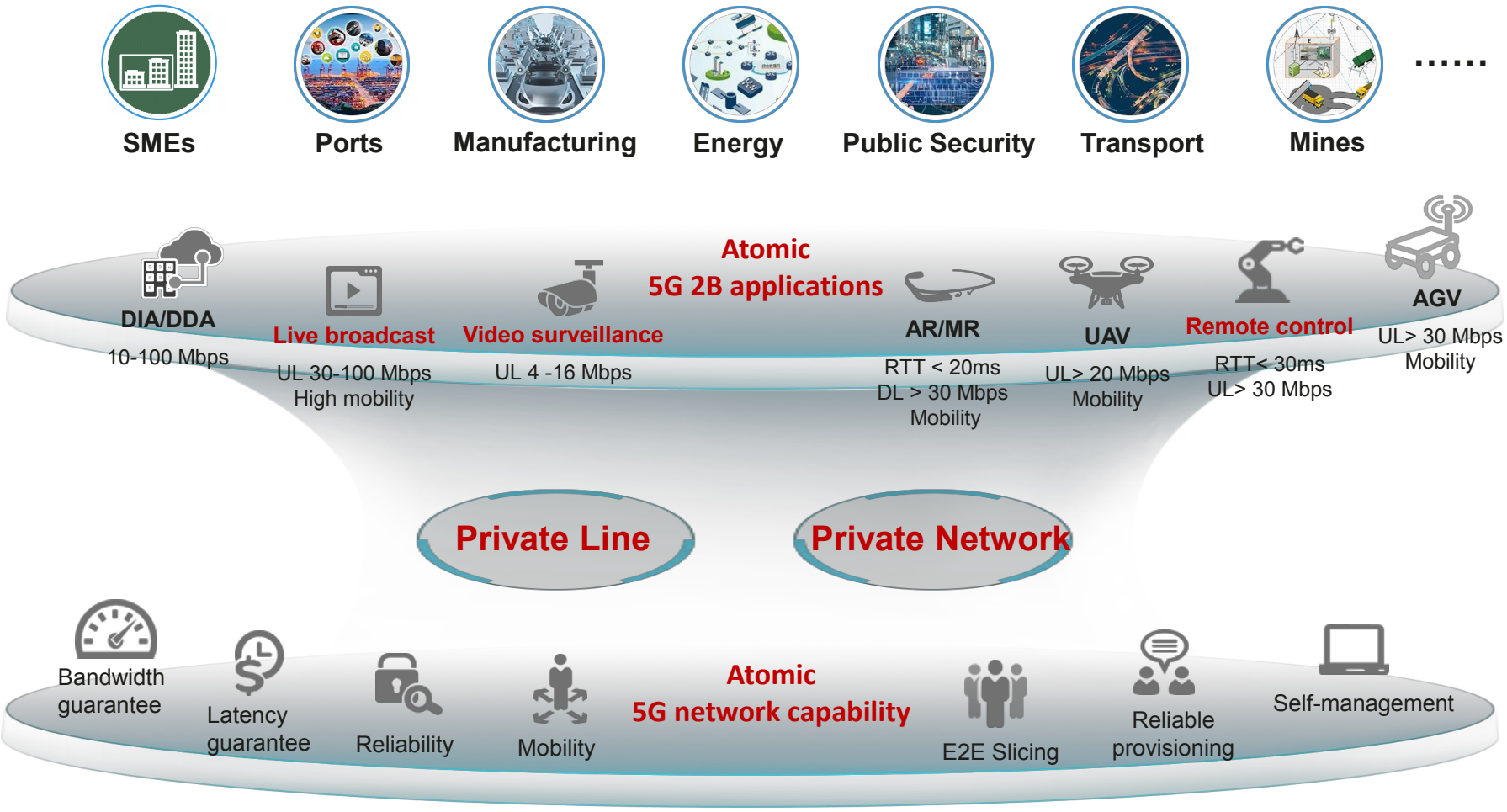
5G 2B applications overview in Y2020-2021



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Quick Win with 5G Wide Area Private Networks

	Private Line	Private Network with QoS	Private Network with Slicing
Product			
Service Offering	Private Line	5G Private Network	Assurance service; Professional Services; 5G Advanced Service
Pricing Dimensions	SIM / Traffic Fee	MEC Usage Fee; SIM / Traffic Fee	Slicing Usage Fee; MEC Usage Fee; Professional Services Fee; Advanced Service Fee


5G Private Line Bring Small Club Play on Big Stage
Live Platform
Video Stream Storage
Live Video Streaming
5G Private Line
Best UL/DL Experience
Absolute Priority Schedule
5G Integrated Camera
Plug & Play
AI-capable motion tracking
Support for video streaming & ad booking
Clubs
Network Guarantee
Monthly Fee
Live Platform
Telcos
Operator D's Live Broadcast Package
Basic
(€69.95 net Monthly)
5G Camera and I&C
Private Line to Live Platform
Home Match Video Transfer
Basic Pro
(€119.95 net Monthly)
Basic
Selected Training Video Transfer

5G Slicing Ensures Railway Service Performance with Public Network

Remote Oilfield Monitoring Empowered by STC 5G Public Networks

Intrusion Detection

No Oil Theft and Tempering

Production Monitoring

PPE Compliance

Safer Production Process

1 Site Covers 20+ Oil Wells
2~4 Mbps/Camera

MEC

Security Centre

Oil Company Campus

Value Chain

Oil Company

Operator C

Company A

Company B

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Video system

Network: RAN, MEC, AR Router etc.

Terminals

Business Model

One Time Fee	Annual Fee
CPE & Installation	Connections
MEC	Self-service
IVS	Reliability

xk $/year Leased Fee for Each Well

Basic Extended

5G Helps Siriraj Build World Class Smart Hospital

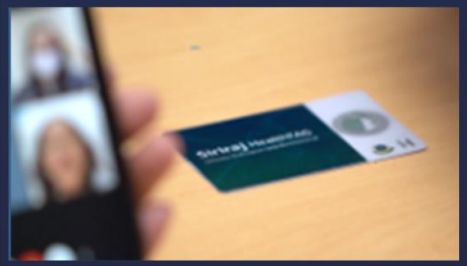
5G Smart Ambulance

Emergency Surgery Within 1h: 80% › 92%

5G Unmanned Vehicle

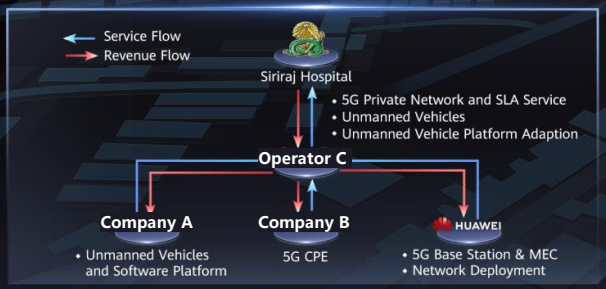
30 Drivers › 4 Staffs; Lower Infection Risk

5G Telemedicine



Remote Consultation Anytime Anywhere

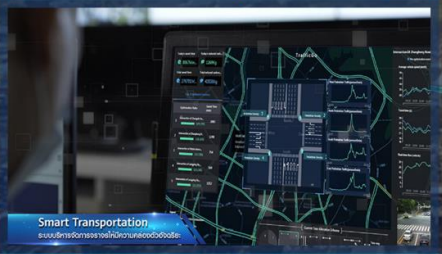
Value Chain



Business Model (Unmanned Vehicle)

5G Smart City Brings Quick Win-win to Pattaya City and Telco

Smart Transportation



Environment Monitoring

Public Wi-Fi

Remote Monitoring Station

Intelligent Operation Center

Shared MEC
security, Lower latency

Public 5G Network
QoS Assurance

5G Smart Pole

Benefits for the Pattaya City

- Better Governance — Traffic jam
- Better Livelihood — Polluted days
- Better Tourism — Tourists

Benefits for the Telco

- New Growth — Premium connectivity (5X vs. toC)
- Low Cost — Public 5G and shared MEC
- Better Brand — Social responsibility

5G Mobile VPN Enables Smart Public Service for Shenzhen Pingshan District

Large File Transmission

- 15M → 170M
- Downloading speed increases **10x**

E-flow Processing

- 3days → 1day
- **Direct connection** within Private network, efficiency improves 3x

3D Map Viewing

- **Switch free** between inter and intranet
- Information loading time saves 1h/day

Access Intranet Anywhere Anytime

- Supporting 4/5G Access
- Supporting Roaming Access

Business Model

Enterprise

10Gbps
5Gbps
2Gbps

Network Construction fee

~~Shared UPF+Private Line~~
/On-premise UPF

+

End User

30G
20G
10G

Network Usage fee

Traffic Package

5G Private Lines One-stop Purchase Help SME Grow Business

Office Video Surveillance

Fast
Plug and Play(< 8 hours)

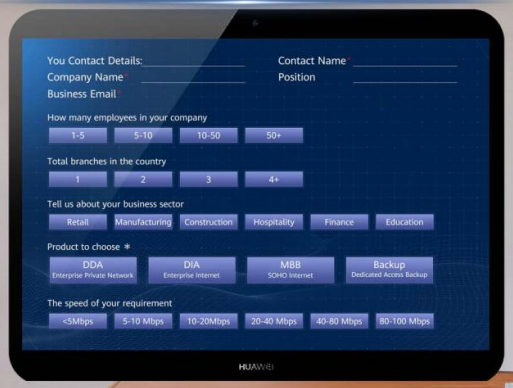
Dedicate Access + VPN + Static IP

Highspeed
100Mbps, Fulfill SME Office Requirement

Video Conference

One-stop
Flexible ICT Add-on Package

Choose Package



5G AR

Empower Industrial Digitalization with Campus Private Networks


Smart Chemical Campus


Port of Piraeus


Thailand SCG Mining


South Africa Garatau Mining


5G Smart Factory


Mining


Sea port


Manufacturing


Land Port


Chemical

Customer Journey

Industry Selection & Engagement

Digitalization Readiness

Market Size

Commercial Feasibility

5GtoB Experience Cloud

Ecosystem Incubation

- Adaption: external 5G CPE → 5G inside
- Accumulation: partners from projects
- Alliance 5GACIA

5GtoB Ecosystem Catalog

Integration & Maintenance

- Industry SLA to network KPI
- One-Stop Deployment
- Self Operating & Maintenance

Netlive.toB / NOE.M+

Business Model

	Network Integration	Application Integration
Network Leasing	CT Services	IT/OT Services
	CT Services	
Basic Network	Basic Network	Basic Network

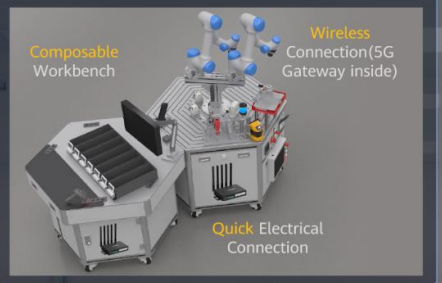
Experience from 5000+ Projects

Flexible Production Line Empowered by 5G Quickly Responds to Customer Needs

High-Mix Low-Volume, 10000+ Type Models; Minimum 1 pcs Order

AS-IS

TO-BE



5G AGV

	AS-IS	TO-BE
Adjustment Time:	> 1 week	< 4 hours
Production Line Utilization:	< 50%	> 80%

24/7 in Operation with 50ms @ 99.99%

40%↓ Area of Production Line

40%↓ Equipment Investment Cost

10%↑ Equipment Utilization

70%↓ Congestion Time

Multi-Campus Architecture

Unified O&M
Simplified Architecture

Standardized Solution
Fast Replication to 26 Factories

Business Model

Area-based Quotation

High Rack/Aisle
XXX USD per month/Site

Production Area
· XXXX USD per month/10000㎡
· Standard Configuration: 18pRRUs/10000㎡

Logistic Area
XXX USD per month/Site

5GtoB Lifting up DICT by 3 times

· 5G Terminals
· Private Line(Branch to HQ)
· Cloud Service Fee
DICT : X M$

· 5G LAN
· Slicing
· 5G Positioning
Add-on Service: X M$

· MPN Service Fee
· MPN O&M
· SIM/Traffic Fee
Basic Service: X M$

5G Brings Digitalization to Port of Piraeus

Crane Remote Control

0 Workers Onsite

+20% Efficiency

Smart Vehicle Management

0 Additional Cabling

4Min→30S / Vehicle

Submarine Cable Backup

0 Network Interruption

€2M Cable Cost Saving

Submarine Cable

Multi Parties Cooperation

Application Suppliers

Terminal Suppliers

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Network Supplier

System Integrator

Mobile Operator

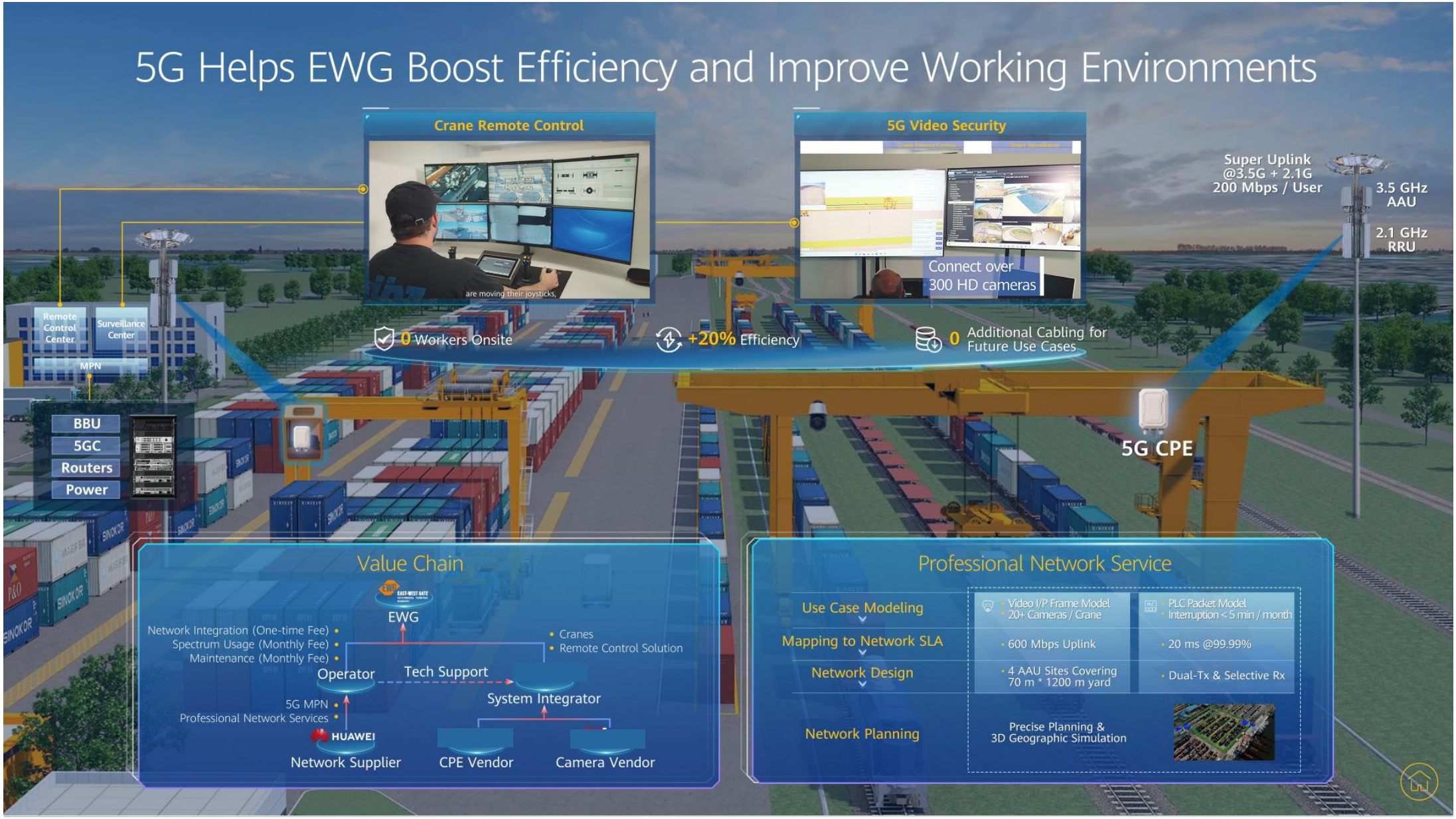
- Consultancy and System Integration
- 5G Private Network and Services

Port of Piraeus

Rich Ecosystem

Application Partners	Company A Remote Control Renovation	Company B Smart Surveillance	Mobile Operator Push to Talk
Terminal Partners	Camera Company B	CPE Company C	Robot Company D

5G Helps EWG Boost Efficiency and Improve Working Environments



Value Chain

- Network Integration (One-time Fee)
- Spectrum Usage (Monthly Fee)
- Maintenance (Monthly Fee)

EWG

- Cranes
- Remote Control Solution

Operator — Tech Support → System Integrator

- 5G MPN
- Professional Network Services

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Network Supplier | CPE Vendor | Camera Vendor

Professional Network Service

Use Case Modeling	• Video I/P Frame Model • 20+ Cameras / Crane	• PLC Packet Model • Interruption < 5 min / month
Mapping to Network SLA	• 600 Mbps Uplink	• 20 ms @99.99%
Network Design	• 4 AAU Sites Covering 70 m * 1200 m yard	• Dual-Tx & Selective Rx
Network Planning	Precise Planning & 3D Geographic Simulation	

5G Enables a Smart and Green Limestone Mine for SCG in Thailand

5G remote control excavator
- Safe production, avoid human injury
- Better working environment for drivers

Autonomous Truck Platooning
- 50% power saving by introducing EV trucks
- 8% increase in trucking capacity
- 80% less of truck drivers

Control Center
- Smart Vehicle Dispatch System
- Remote Control System

MEC

Network Integration for Guaranteed SLA

Profiling & Modeling	Cross Domain Planning	Network SLA Output
• Remote Control • Autonomous Driving	Wireless, Transmission, Terminal, Core, Application	40Mbps Uplink 50ms @ 99.99%

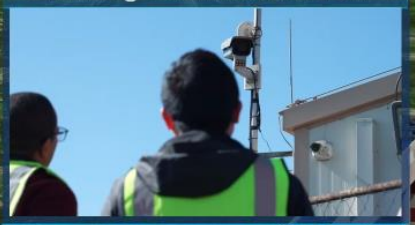
Value Chain

SCG — Mine Owner & SI

Automation Solution Provider	Electric Mining Truck Vender	MPN Service Provider	Network Vender
• autonomous driving and smart dispatch system • remote control system			

5G Enable Safer and Smarter Operation for Metal Mine

Mining Communication



5G **Remote** Coverage for **ToB & ToC** Service

Smart Inspection

3 ~ 5 Times » **0** Time Faulty or Down/Month

Vehicle IOT

Avoid Vehicle Collision Accident, Reliability **@99.99%**

Business Model

None-Recurring Charge		Monthly Recurring Charge
CPE		Network Usage *
Camera	+	SLA Assurance
Network Setup		Vertical Integration

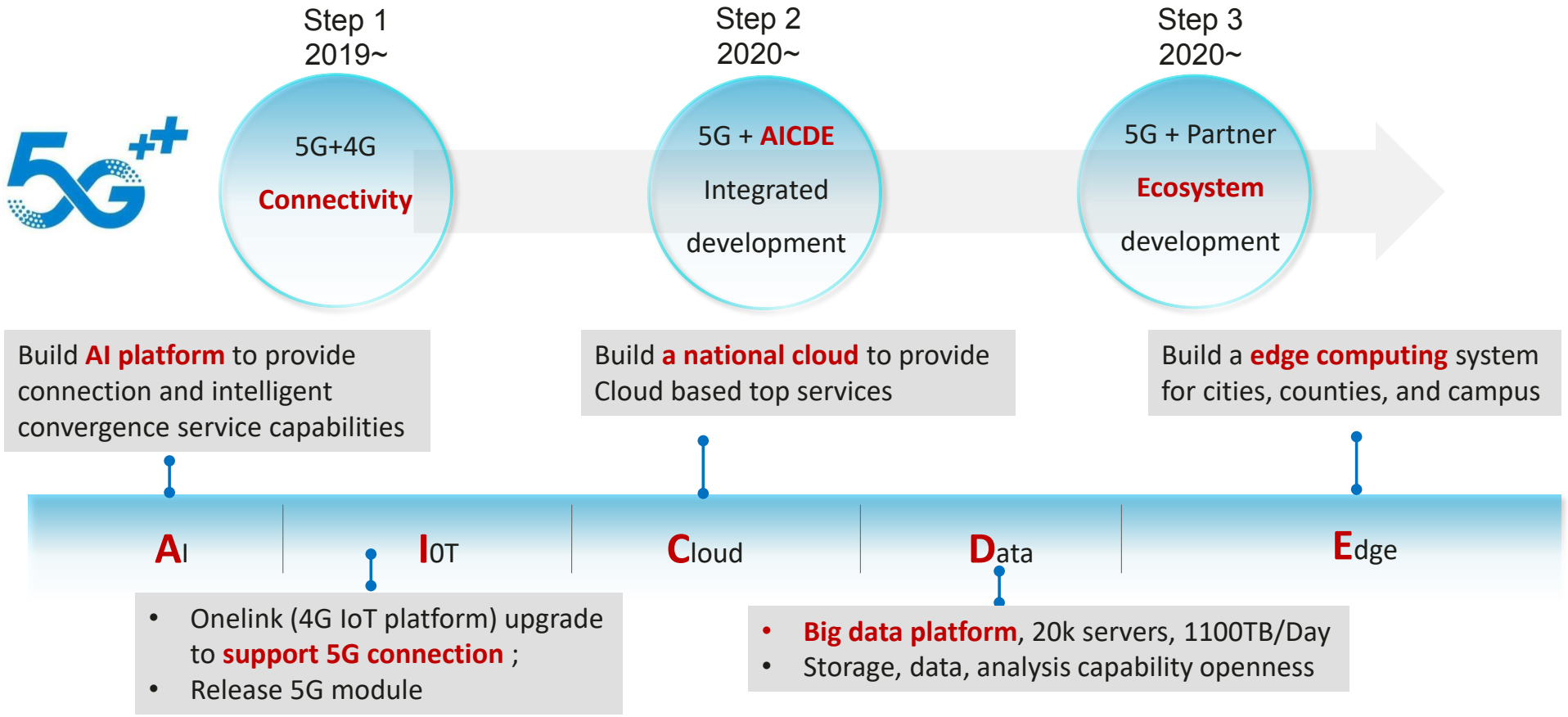
* XXX USD/Month

Integrator 5GtoB ROI < 1.5 year

Basic Extended

Value Chain

Telecom Operator A: “5G+” plan define one 5G network step by step



5G is not only connection, but one E2E network

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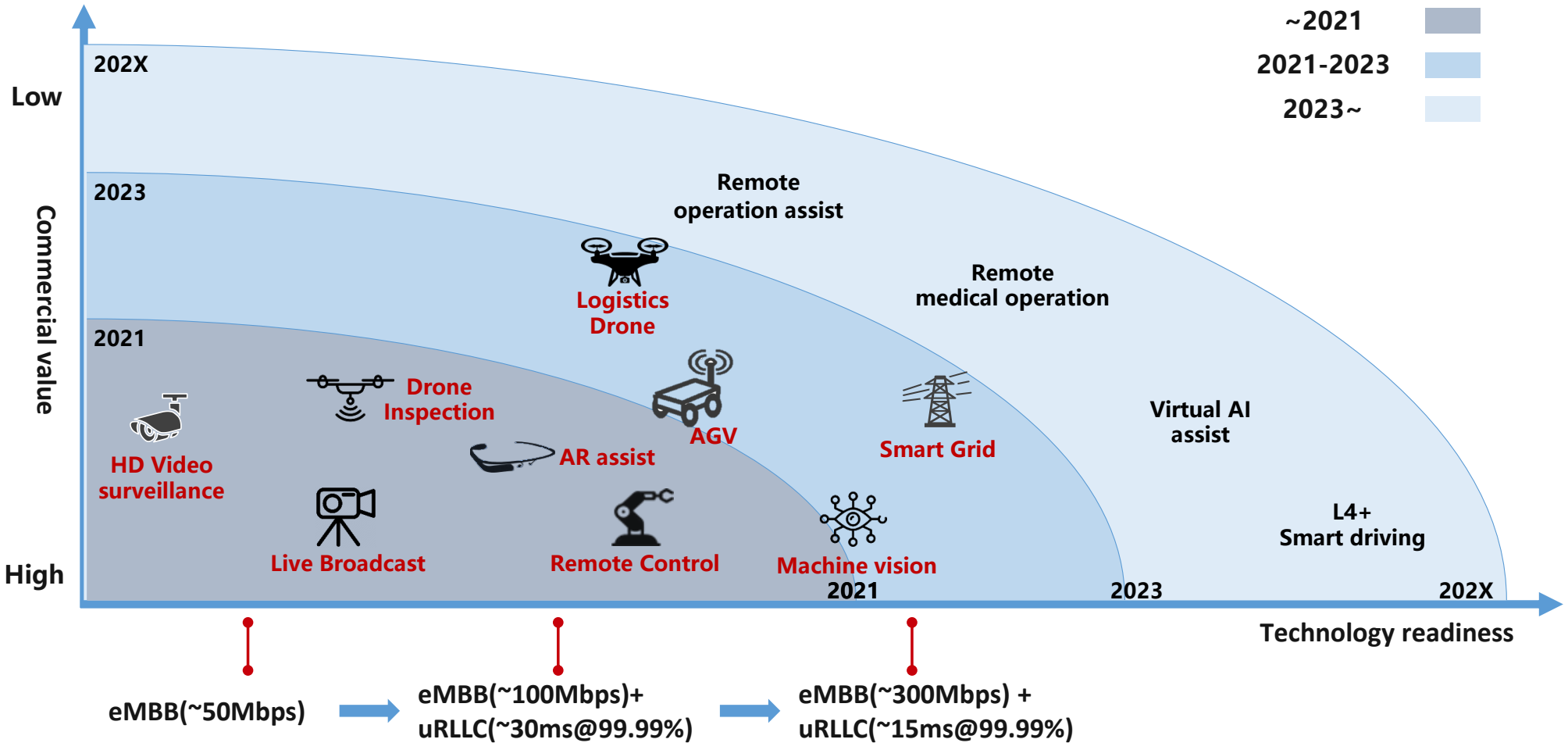
Telecom Operator A: 5G application pace, from eMBB to eMBB+uRLLC



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Private Line: 5G Live Broadcast

5G Live Broadcast refine the video broadcast

	Traditional 4K Live Broadcast truck	5G in Backpack	5G in Pocket
Cost :	~$ 6,500,000	< $ 1000 *	< $ 250 *
Set-up time:	Days	Hours	Anytime
	12 months ago	8 months ago	3 months ago

5G Empowering Live Broadcast

* w/o Camera

Now

5G in Encoder

What is the MNO's offering for 5G live broadcast in China?

Speed with SLA	50Mbps/2h @$10k (Telecom Operator A)	**Volume with SLA**	Uplink Add-on Boost 500G @ $2k (Telecom Operator B)	**Platform**	CDN / Cloud service 100k Users Online/2h @$5k (Telecom Operator C)

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5G Live Broadcast in a Germany

5G City in City A
>100Mbps@ everywhere

TLC Operator A HUAWEI

Network planning & deployment

5G Broadcast business trial
With Camera & 5G Encoder

TV Broadcaster B

Business discussion with Partner

Bundesliga

Hannover Messe

Network		Now	July	Sep	Phase2
TLC Operator A	HUAWEI	Planning & deployment	First cluster trial(20 sites)	Network Launch (100+ sites)	Copy to other city
Business case		Now	May	Aug	
TLC Operator A	TV Broadcaster A	Case discussion	Technical trail	Trail in Leipzig	Service launch / National cooperation

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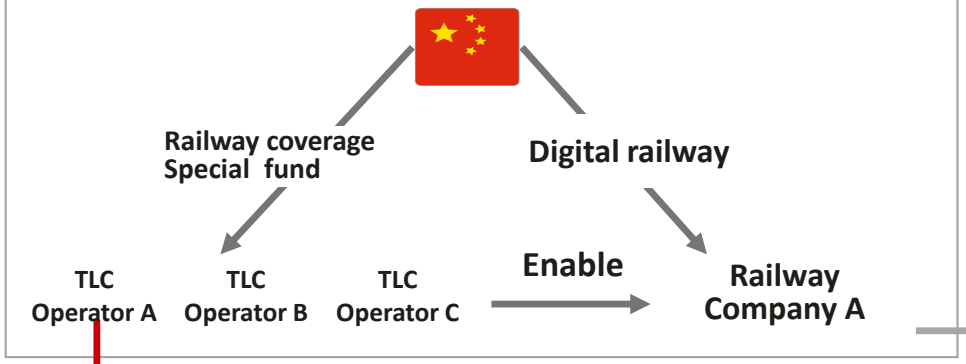
Private Network: 5G Digital Railway

5G railway in China

MNO 5G enable digital entertainment in Train

Chinese Government push progress of digitalization



1st 5G railway: Guangshen high speed railway

TLC
Operator A

Launch on 10th of Jan 2020

300+ sites for 141Km

- **1.1Gbps** as peak
- **>100Mbps** @300km/H

"5G+ Video Cloud+ AI" enable digital station

- Robot assistant
- Security surveillance
- Traffic control
- Asset tracking

... ...

掌上高铁
中国铁路智慧出行

APP portal for rich service on train

Train WIFI access
VIP membership

Food & drink
Online order

New movie
5 ¥ per movie

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5G help improve train data operation efficiency

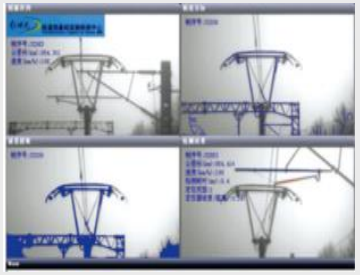
Mass data, manually processing

Cab video monitoring

Carriage monitoring video

Copy data manually

Pantograph Data



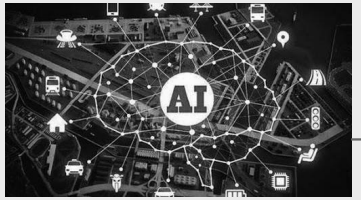
Bogie data

Analyze data manually

1200GB/train/day

5G + Cloud+ AI

Upload train data to IVS (DC) automatically in station



Analyze train data with AI automatically

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Bring 5G digital train in Europe

5G railway coverage enable digital Railway Company A

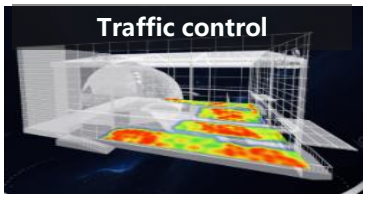
Huawei support MNO A to provide network & service

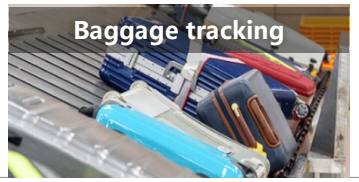
HUAWEI	Mobile Network Operator A
5G network solution	5G network coverage
Deployment	Network O&M
Maintenance	Terminal
Terminal	Digital content
	Cloud
	... ...

Railway Company A

Application 1: Digital Station

Improve operation efficiency





Application 2: Digital Train Trip

Customer service case by APP portal

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Proposal of 5G train : 1st 5G station & 1st golden ICE line

1st 5G train station in an EU Country

5G indoor coverage with 5G Lampsites

Train station A

100Mbps@ average

30~50 pRRU* each floor

**Pico Remote Radio Unit*

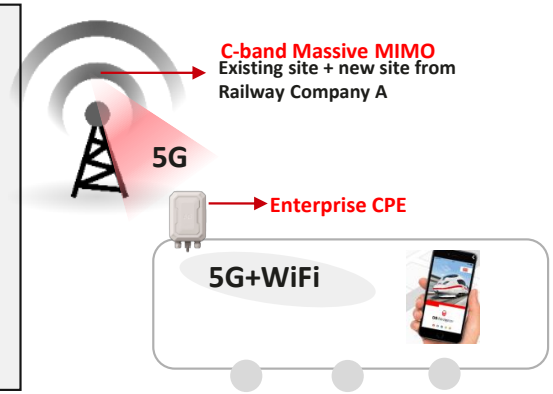
1st Golden ICE line in Germany

5G continuous coverage with Huawei unique solution

Train station A →

Train station B

100Mbps@ average
200 sites
260 KM



Phase 1

Golden cluster & 1st station

POC with Railway Company A
E2E capability verification

Phase 2

Golden line planning

Existing site on air
New site planning

Phase 3

1st Golden line Launch

5G continuous coverage

Extend to other stations & lines

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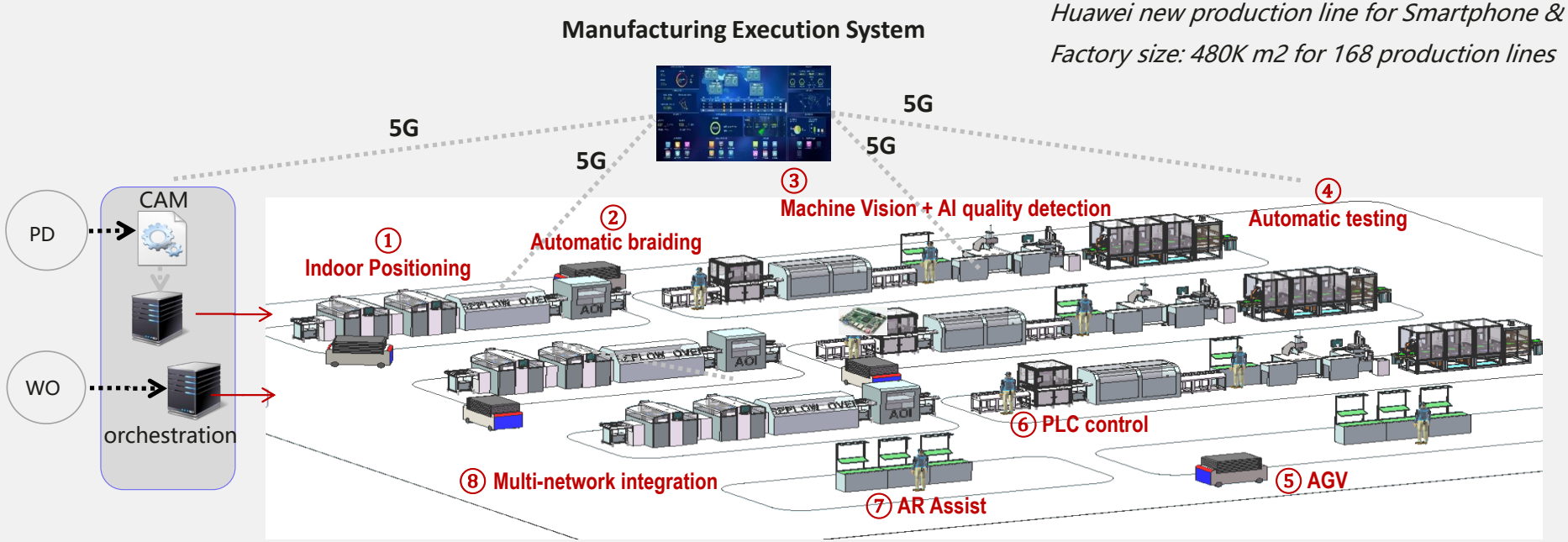
Private Network： 5G Smart Manufacture

Smart Manufacturing: Huawei 5G Southern Factory

Huawei new production line for Smartphone & AAU

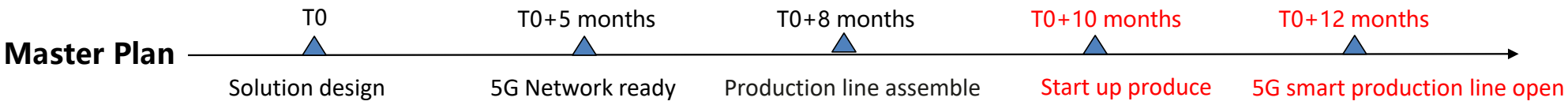
Factory size: 480K m2 for 168 production lines

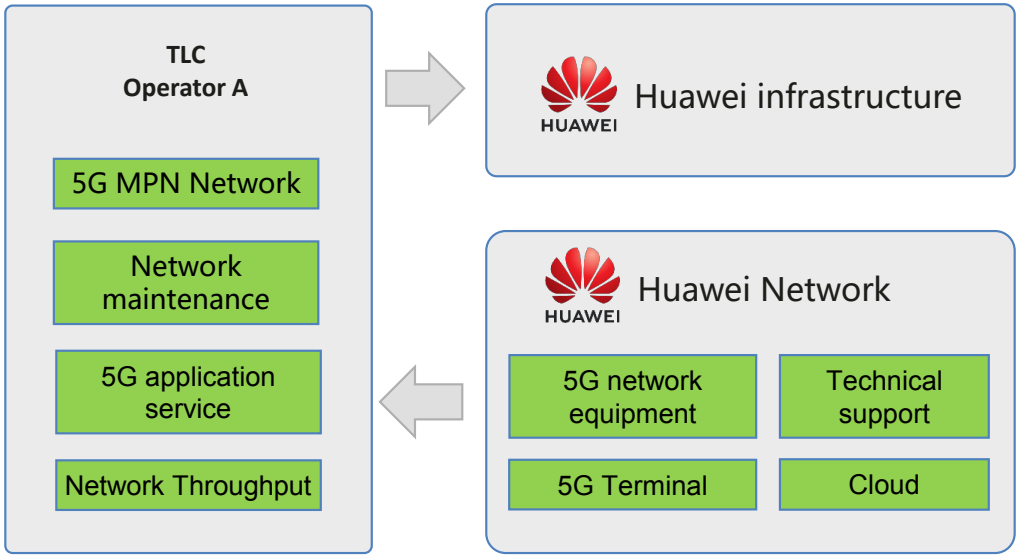


Indoor positioning	● Asset utilization rate increases by 20%, Material searching rate increases by 100%
Automatic braiding	● Save xxxx meters of optical fibers/network cables.
AI quality detection	● Detection efficiency improved by 70%.
Automatic testing	

AGV	● Software loading speed increases by 20%
PLC control	● Logistics, AGV and forklift cost reduction
AR application	● Quick maintenance, reducing downtime loss by 10%
AR Multi-network integration	

5G Smart Manufacturing Business model





Benefits for TLC Operator A:

- Certificate series of standard 5G enterprise terminals: CPE, 5G module, 5G meter, 5G camera…
- Define a set of standard MPN portfolio: MPN network, MPN service, MPN operation…
- Establish standard MPN operating model: Service provisioning, subscriber management,…

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Private Network：5G Smart Port

5G Smart port: Four valuable applications powered by 5G

RTG* Remote Control	AGV/ATT	Video surveillance & inspection	AR Assist
			
5G PLC remote control Video upload and PLC control of cranes improving service availability and reducing costs.	**5G control AGV/ATT:** Monitoring and parallel driving, and supporting V2X autonomous driving in the future	**All-scenario surveillance & inspection** Extending to smart logistics scenarios in the future.	**AR assist maintenance** Improve the efficiency and accuracy

*Rubber-tyre Gaintry Crane

5G smart port commercial practice in China

MNO A + Manufacturing Company A (port machinery) + HUAWEI

Port A 5G

1st Case for Remote Crane Control by 5G

Port B 5G

Remote Crane control & Automatic terminal truck

Port C 5G

Automatic terminal truck and video surveillance

Port D 5G

Remote Crane control

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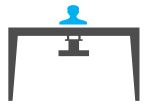
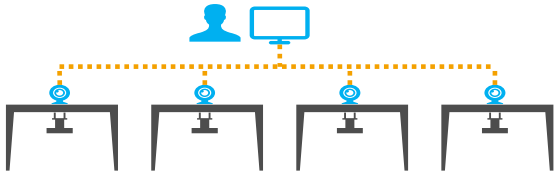
Commercial value of 5G Smart Port

Take an example for RTG remote control scenario

Traditional crane control



Remote RTG control



One worker controls four RTGs

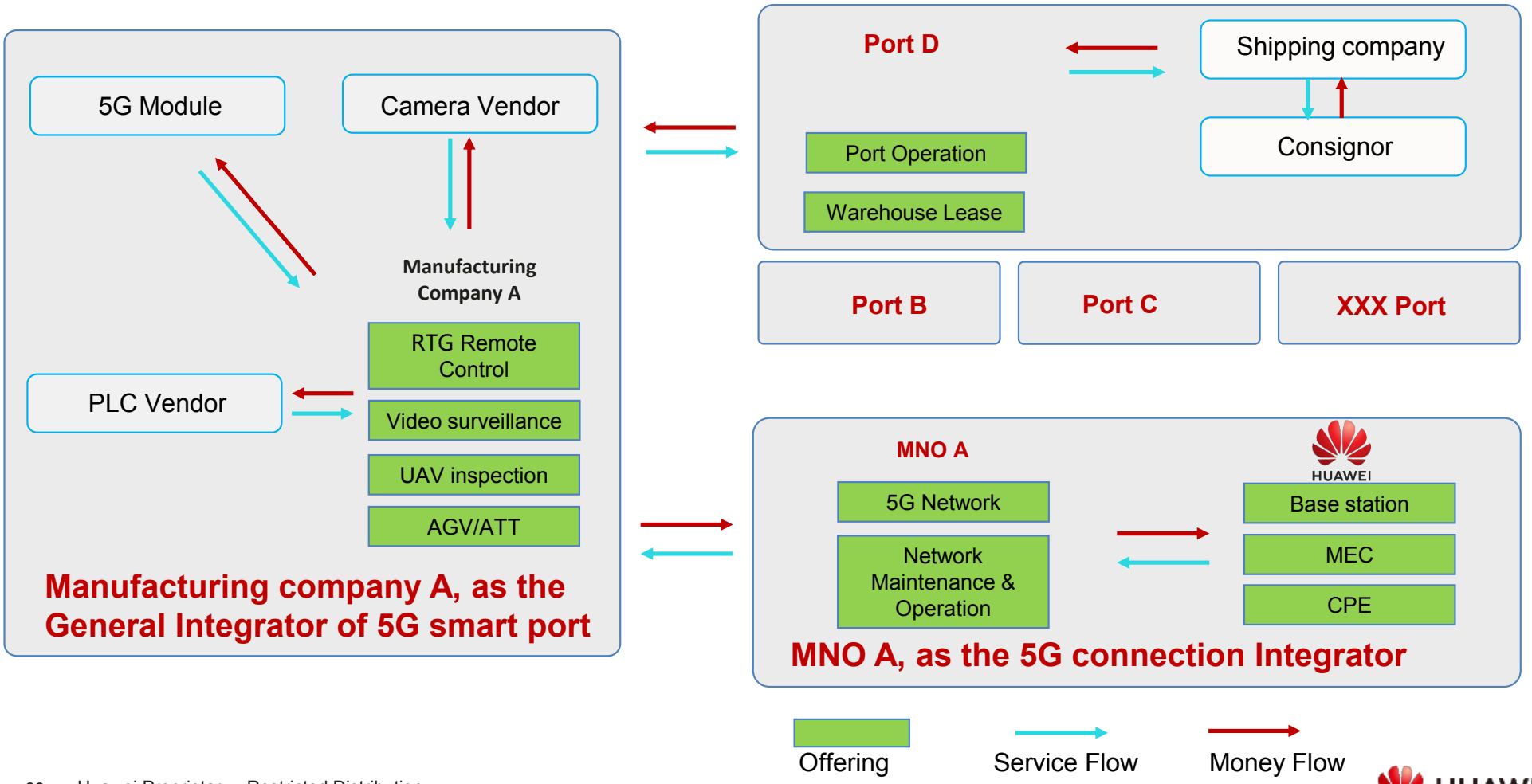
Cost saving

- ✓ Outdoor work is shifted to indoor safe work environment, saving **70K$/year/RTG** (3 shifts @ 24h)
- ✓ The drivers required for RTG change from special profession to normal profession

Security

- ✓ The operation time of personnel working at heights is reduced to **0,** Improve the working environment and operation safety

5G smart port business model



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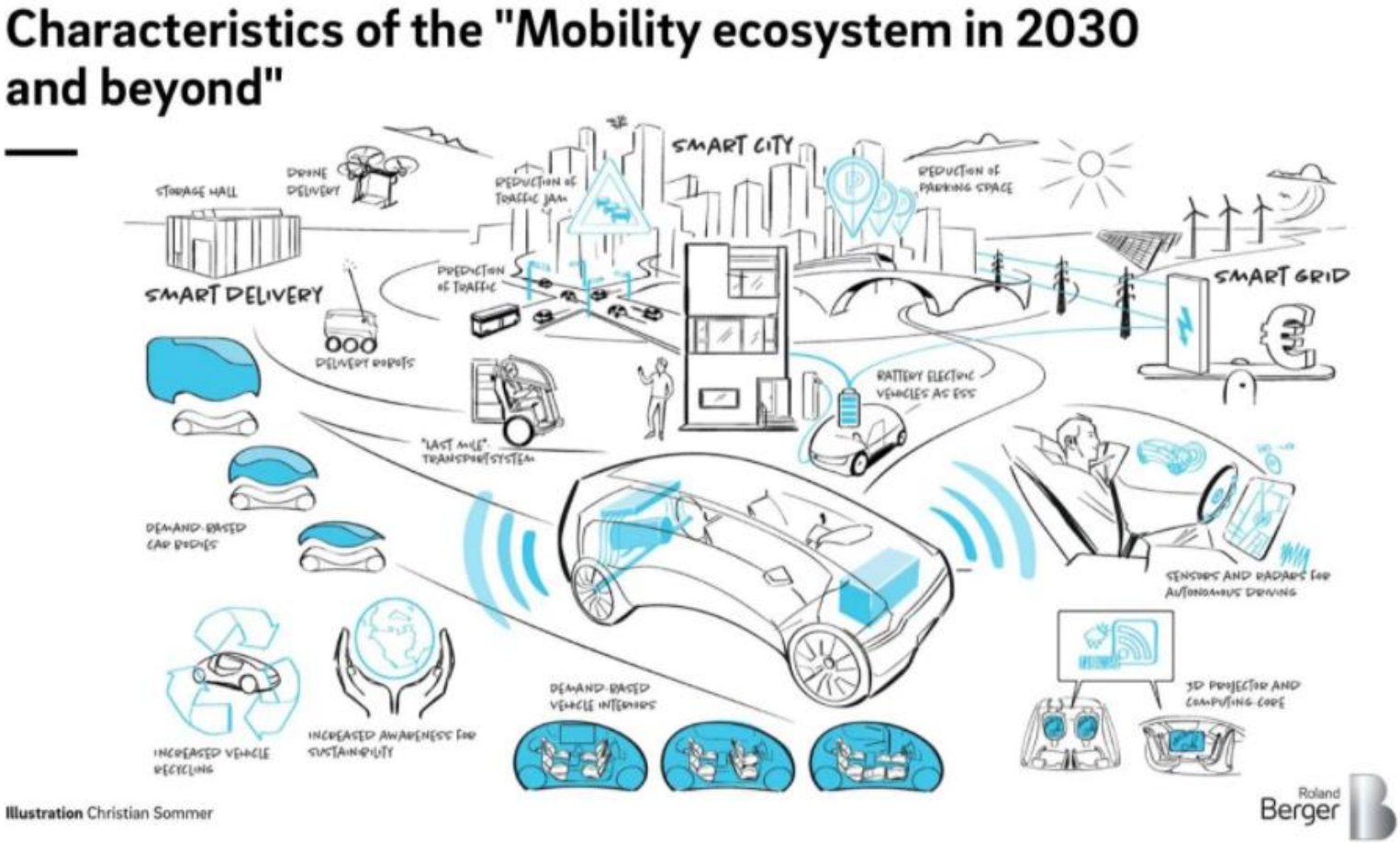
Autonomous driving (B5G)

Scenario - Vision



Source: Roland Berger

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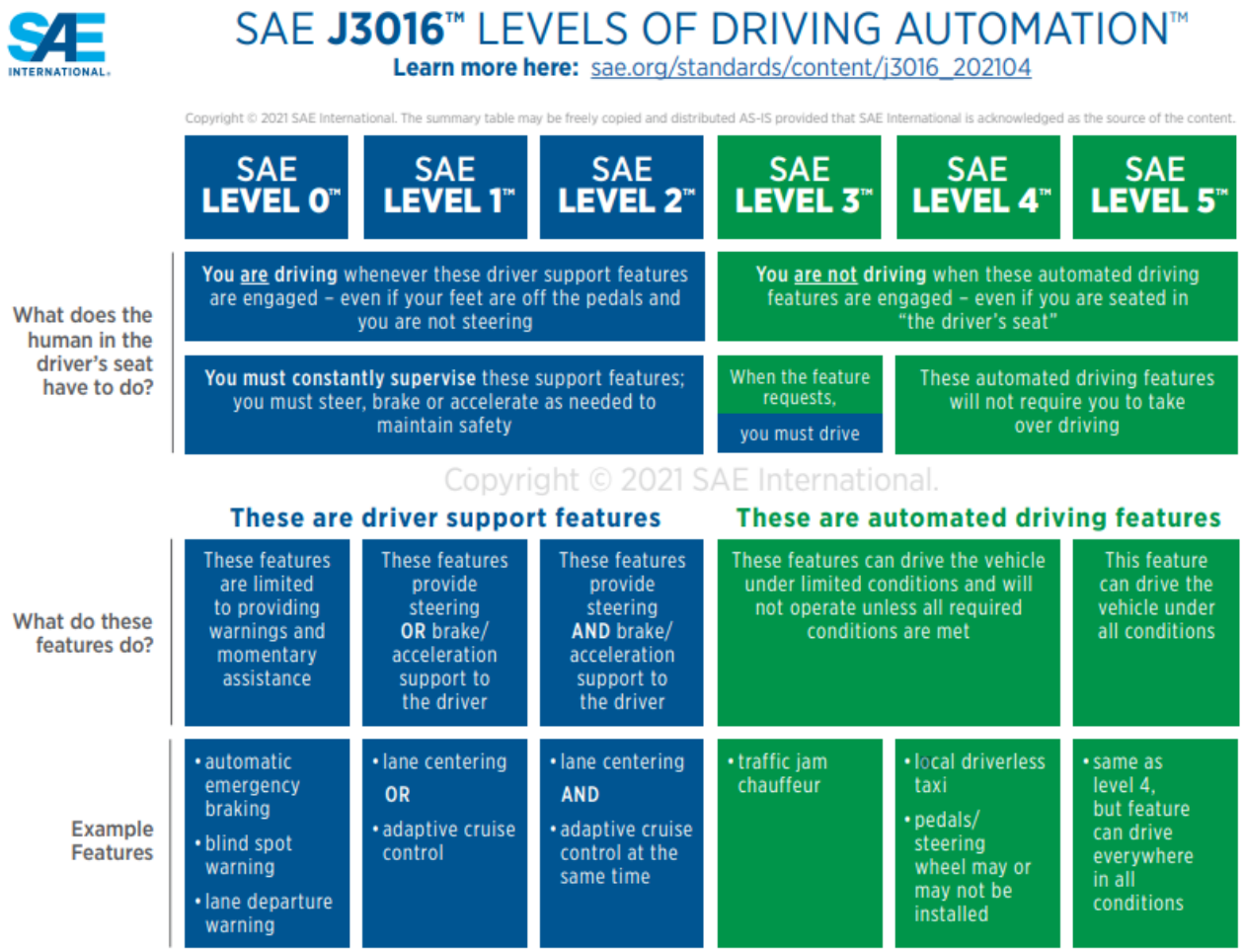
SAE Levels for autonomous driving



1. Level 0:.
   No Driving Automation
2. Level 1:.
   Driver Assistance
3. Level 2:.
   Partial Driving Automation
4. Level 3:.
   Conditional Driving Automation
5. Level 4:.
   High Driving Automation
6. Level 5:.
   Full Driving Automation

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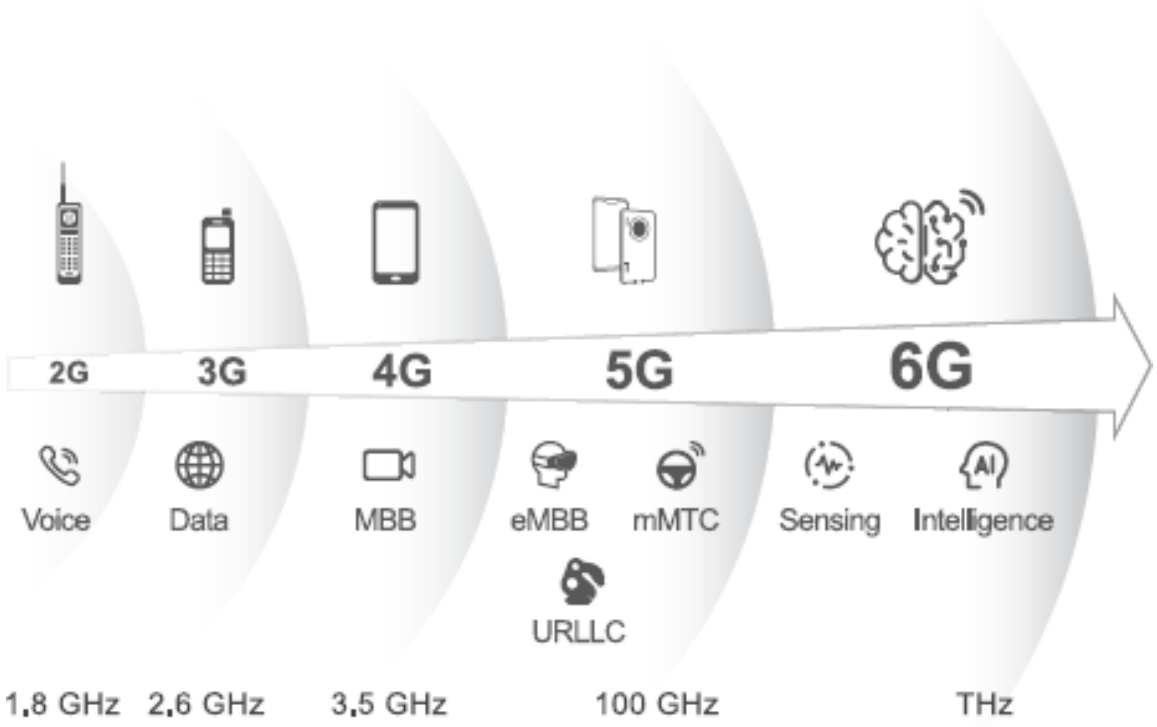
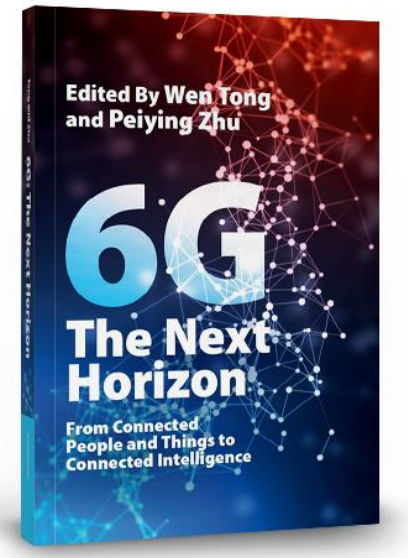
Use cases

- RoboTaxi *(«From selling cars to selling rides»)*
- Autonomous freight transport
- Autonomous driving for specific sectors: mining, building, …
- Tele-Operated Driving
- Closed networks operated by independent companies such as business parks, shopping centers, parkings
- Freight movement and handling: ports, airports, logistic parks
- Payments related to mobility (tolling, parking, different means of transport, third party services)
- Insurances (rewards/penalties)
- Advanced infotainment services
- Additional services: predictive maintainance, driving suggestions, doors opening, remote temperature control, restaurants/service reservation
- OTA car OS/SW update
- HD Map Sharing
- Cooperative Manoeuvres
- Sensor Sharing
- Dynamic Intersection Management
- Dynamic Cooperative Traffic Flow
- Complex Interactions with VRUs
- Flying cars

Beyond 5G

6G: From Connected People and Things to Connected Intelligence





** Main source used in next slides along with the corresponding **white paper** available at https://www.huawei.com/en/technology-insights/future-technologies/6g-white-paper*

https://www.huawei.com/en/technology-insights/future-technologies/6g-the-next-horizon (play the video)

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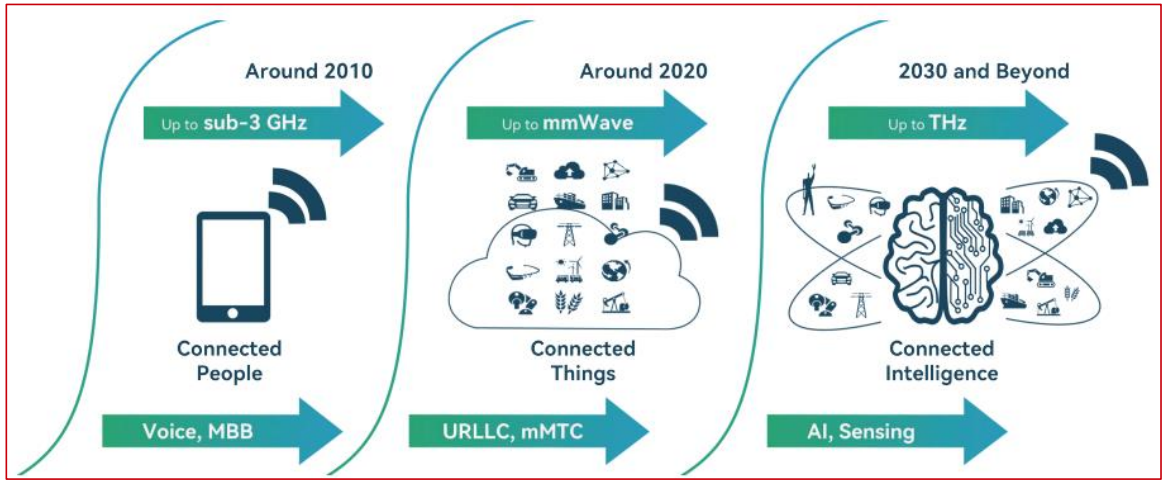
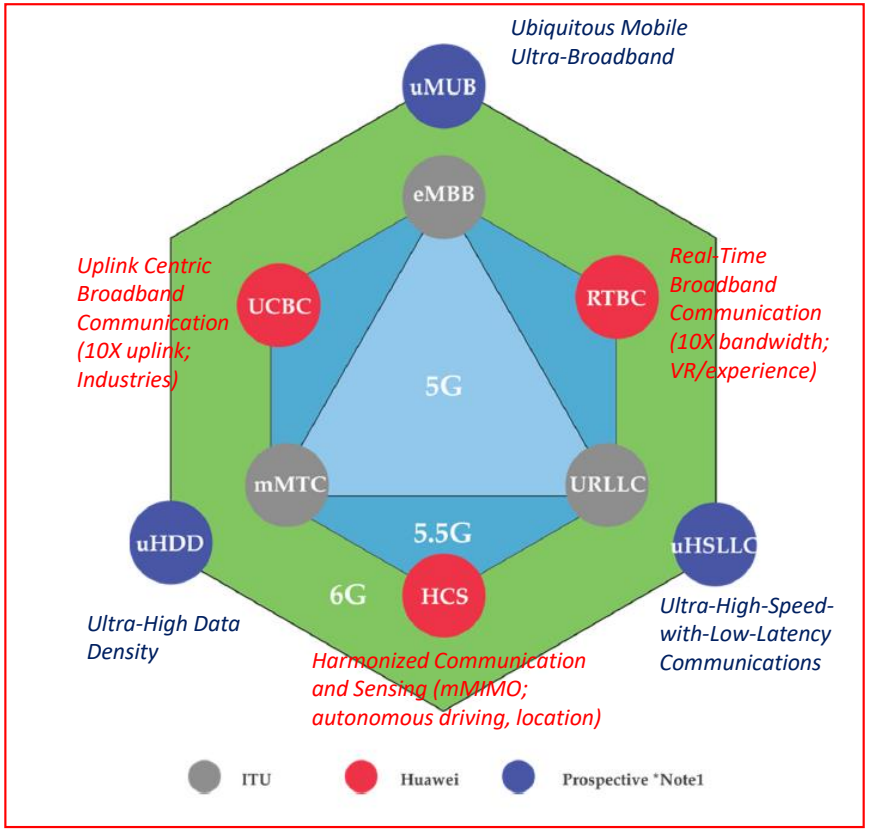
6G: From Connected People and Things to Connected Intelligence (1/2)





Source: Alraih, S.; Shayea, I.; Behjati, M.; Nordin, R.; Abdullah, N.F.; Abu-Samah, A.; Nandi, D. *Revolution or Evolution? Technical Requirements and Considerations towards 6G Mobile Communications.* Sensors 2022, 22, 762

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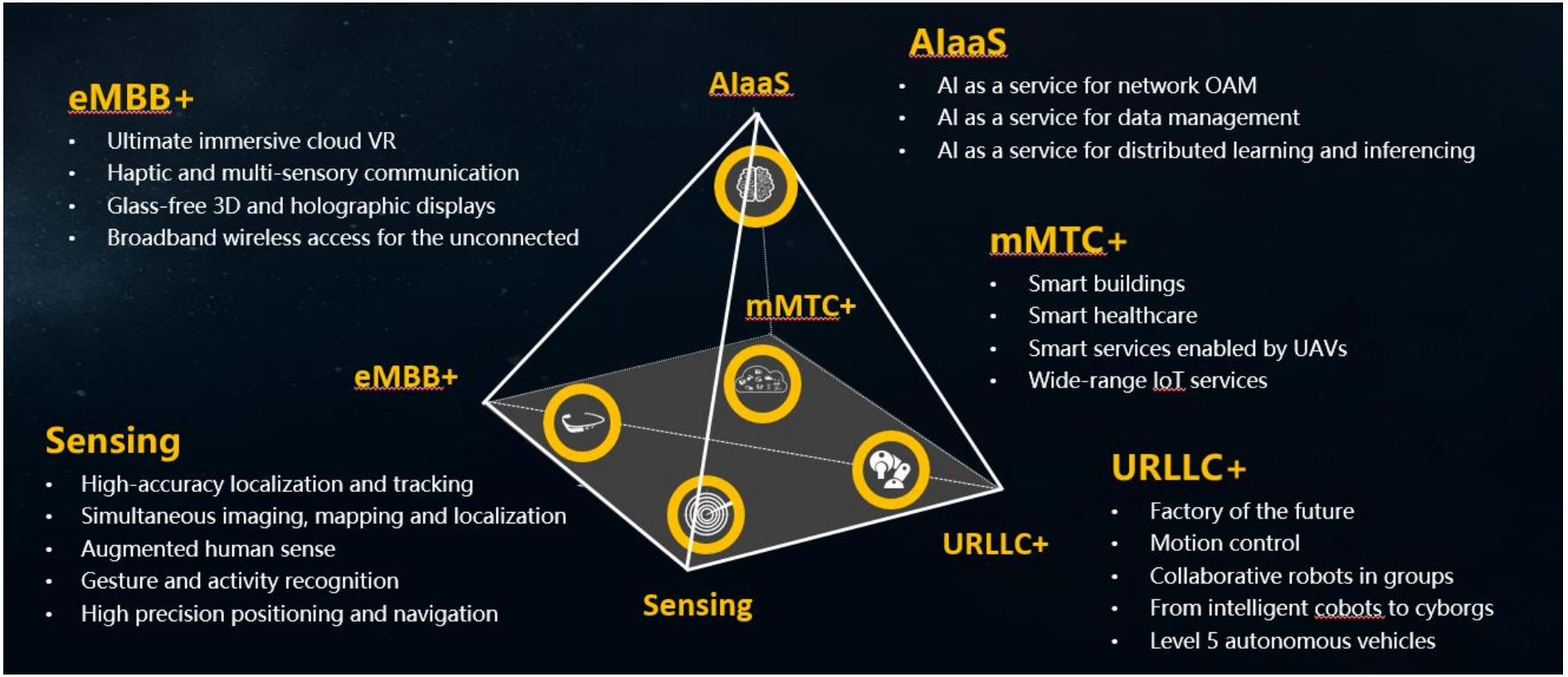
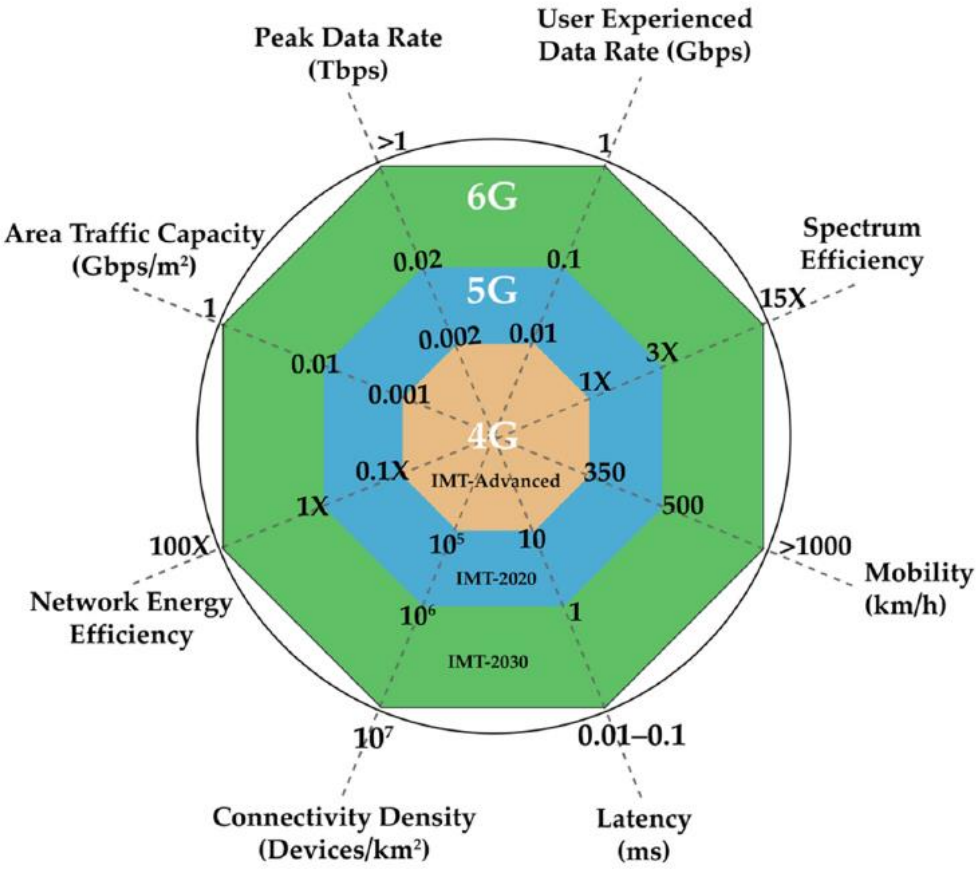
6G: From Connected People and Things to Connected Intelligence (2/2)



Expectations about 6G technical capabilities



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Comparison of 5G and 6G communication techniques

Characteristic	5G	6G
Operating frequency	3 GHz–300 GHz	Up to 1 THz
Peak data rate	20 Gbps	1 Tbps
Latency	1 ms	10–100 μs
Mobility	500 km/h	>1000 km/h
Available spectrum	30 GHz	10–100 times higher than 5G
Spectral efficiency	30 bps/Hz	100 bps/Hz
Energy efficiency	High	Ultra-high
Connection density	106 devices/km^2	107 devices/km^2
Coverage	99.99%	99.9999%
Positioning precision	Meter precision	Centimeter precision
Satellite integration	Partial	Fully
Automation integration	Partial	Fully
Network awareness	Partial intelligibility	Ubiquitous intelligence
Reliability	1–10^{-5}	1–10^{-9}
Service level	VR/AR/3D	Tactile
XR	Partial	Fully

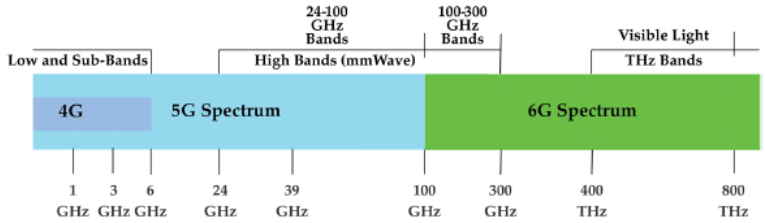
Characteristic	5G	6G
Haptic communication	Partial	Fully
Smart city components	Separated	Integrated
IRS	-	Yes
Standards	5G/NR	-
Core network	IoT	IoE
HetNets	Flexible	Ultra-flexible
Usage scenarios	EMBB, URLLC & mMTC	uMUB, uHSLLC & uHDD
Main technologies	mmWave, mMIMO, UDN, SDN	THz, SM-MIMO, Laser and VLC, Quantum, Blockchain, AI/ML
Applications	VR/AR/360° videos, UHD videos, V2X, IoT, Smart city/factory/home, telemedicine, and wearable devices	Holographic, tactile/haptic internet, full-sensory and reality, fully automated driving, industrial internet, space travel, deep-sea sightseeing, and Internet of bio-nano-things
Flexible spectrum	Flexible duplex	Free duplex

Source: Alraih, S.; Shayea, I.; Behjati, M.; Nordin, R.; Abdullah, N.F.; Abu-Samah, A.; Nandi, D. *Revolution or Evolution? Technical Requirements and Considerations towards 6G Mobile Communications.* Sensors 2022, 22, 762

Comparison of 5G (mmWaves) and 6G (THz and VLC) technologies

4G, 5G, and 6G spectrum bands

	5G Technology	6G Technology	
	mmWaves	**THz**	**VLC**
Frequency band	3 GHz–99 GHz	100 GHz–10 THz	430 THz–790THz
Supporting data rate	Gigabits/second	Terabits/second	Gigabits/second
Propagation loss	Low propagation loss (compared to THz)	High propagation loss	High
Underwater communication	No	No	Yes
Link	NLOS	NLOS	LOS
Spectrum	Licensed	Licensed	Unlicensed
Electromagnetic interference	Yes	Yes	No
Penetrate through opaque objects	Yes	Yes	No
Challenges	Circuit design, High propagation loss	Molecular absorption, circuit design challenges, higher propagation loss (compared to mmWave), high penetration loss	Small coverage, require RF uplink, dark objects absorb light waves, suffer from shot noise caused by another light source
Environment communication	Indoor/outdoor	Indoor/outdoor	Mostly indoor
Potential	Wide bandwidth, small antenna size, focused beams, path loss can be compensated, and allowing spatial multiplexing	High bandwidth (100x mmWave), small antenna size, focused beams	Low-cost hardware, low interference, unlicensed spectrum
Potential applications	Small cell access, cellular access, and wireless backhaul	Autonomous vehicles, cloud, mobile HetNets	Li-Fi, visible light ID system, hospital robots, underwater communication, and traffic communication systems
Transmission power	High	High	Low



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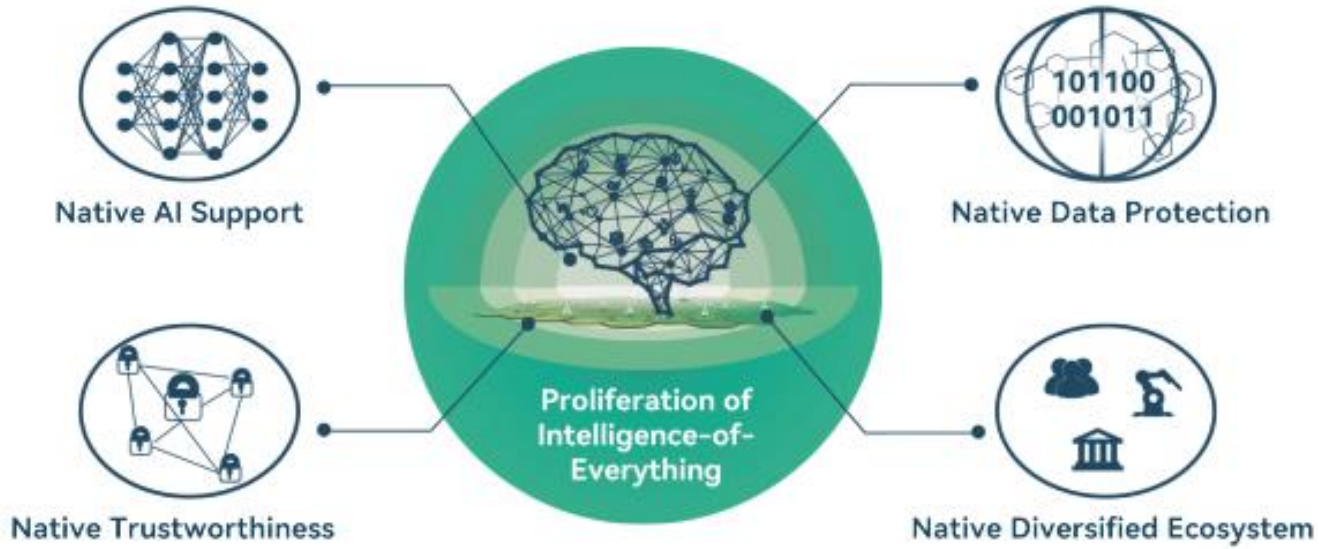
Overall vision

- 6G will reach the ultimate level of connectivity supremacy, employing all radio frequencies up to terahertz or even visible light
- 6G will support AI natively, connecting intelligent things and connecting things intelligently
- 6G will be networked AI, redefining networking and computing
- 6G will function as a networked sensor, enabling the fusion of cyber, physical, and biological worlds
- 6G with integrated terrestrial and non-terrestrial networks will deliver complete full-earth coverage, eliminating digital divide
- 6G will support a prosumer-centric instead of operator-centric network architecture, embracing an inclusive open ecosystem

Key drivers



+ New Applications and New Businesses
+ Sustainability and Social Responsibility

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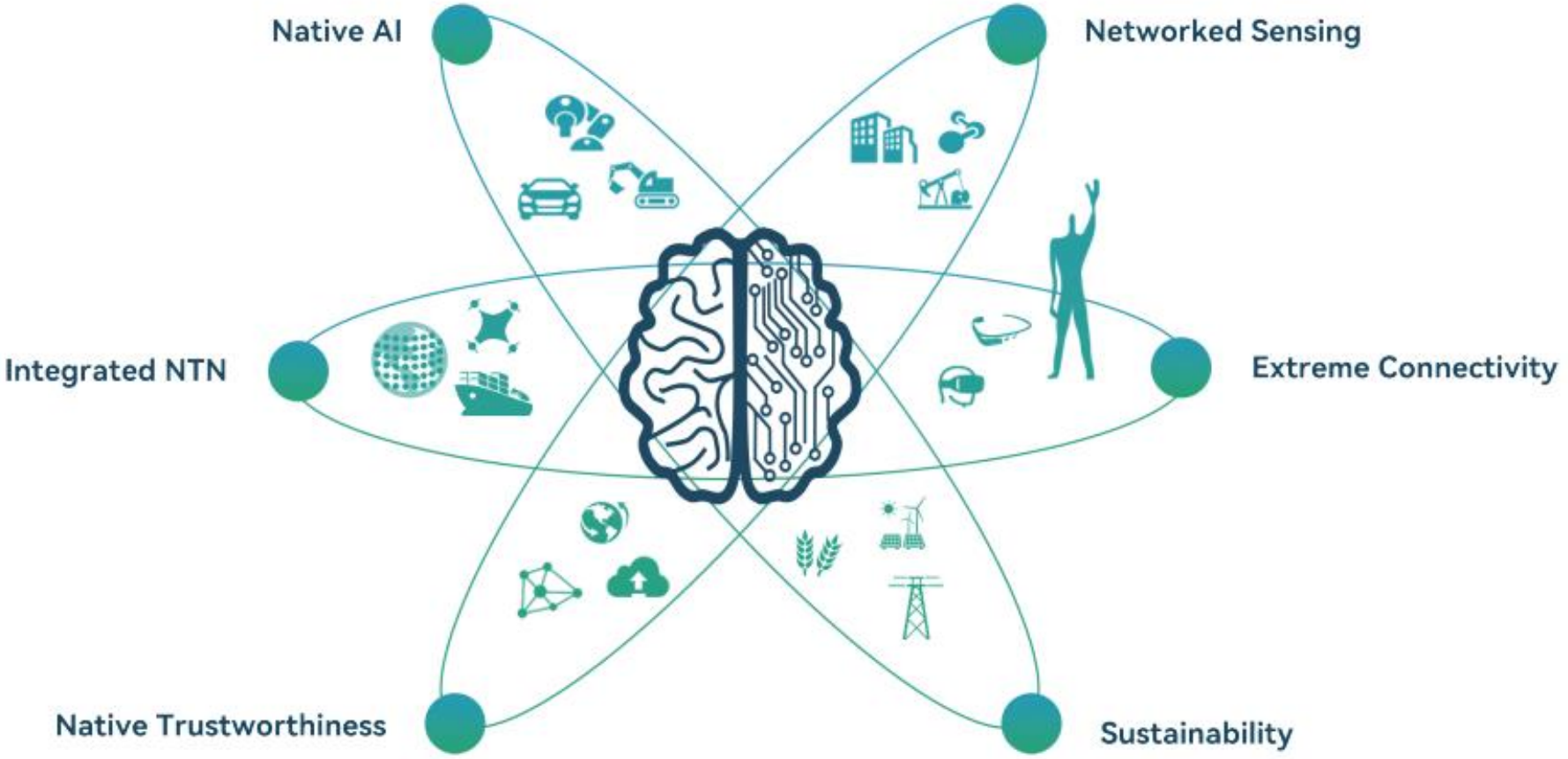
6G pillars



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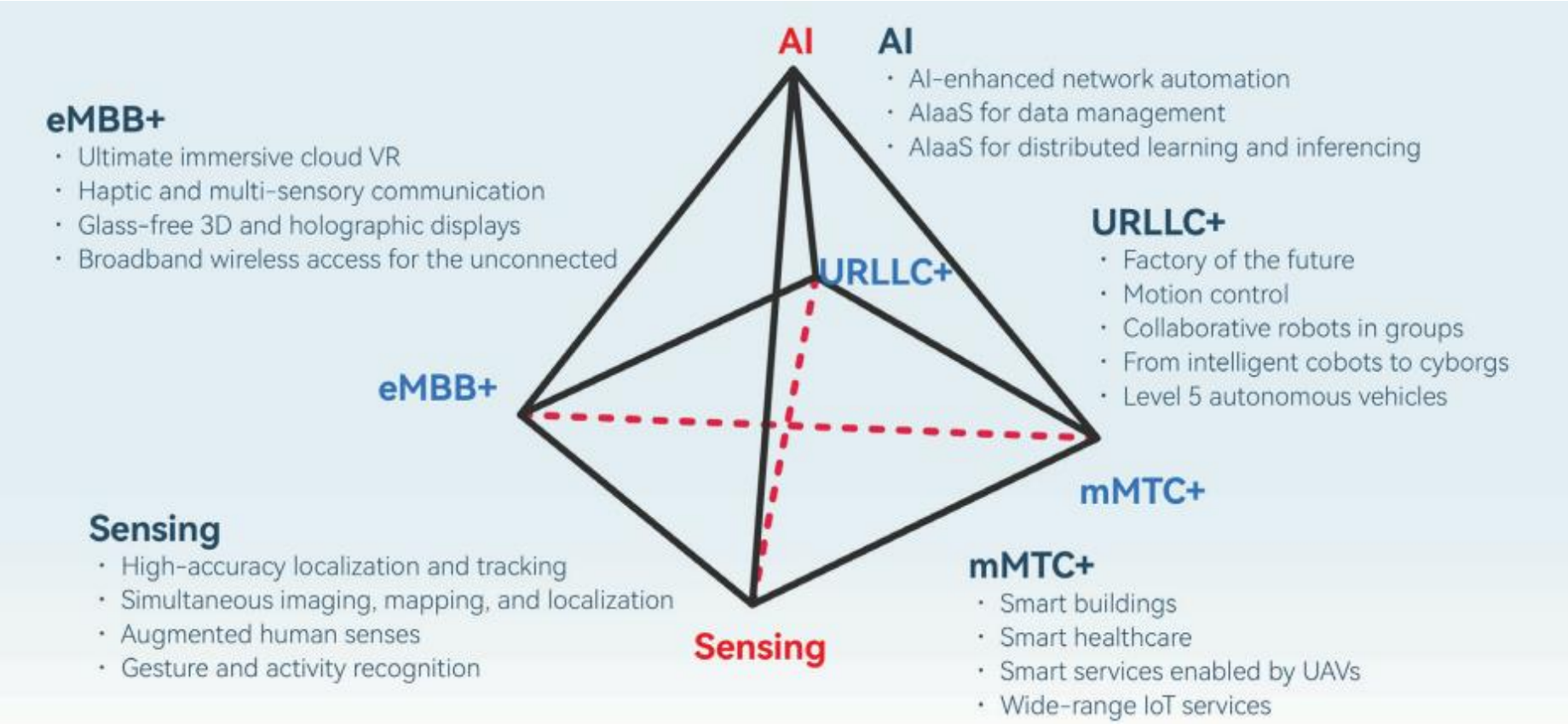
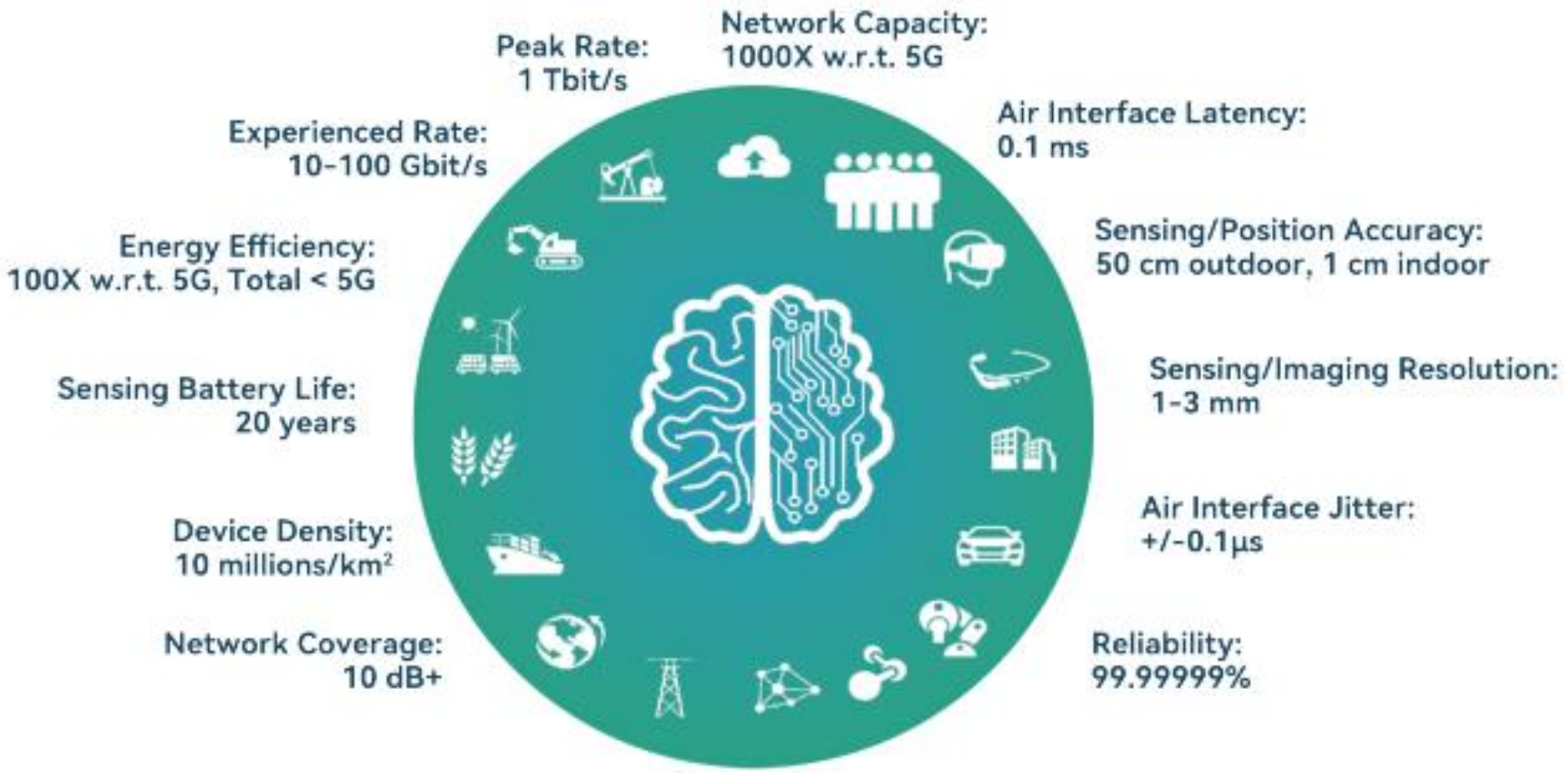
Typical use cases



Target RAN KPIs



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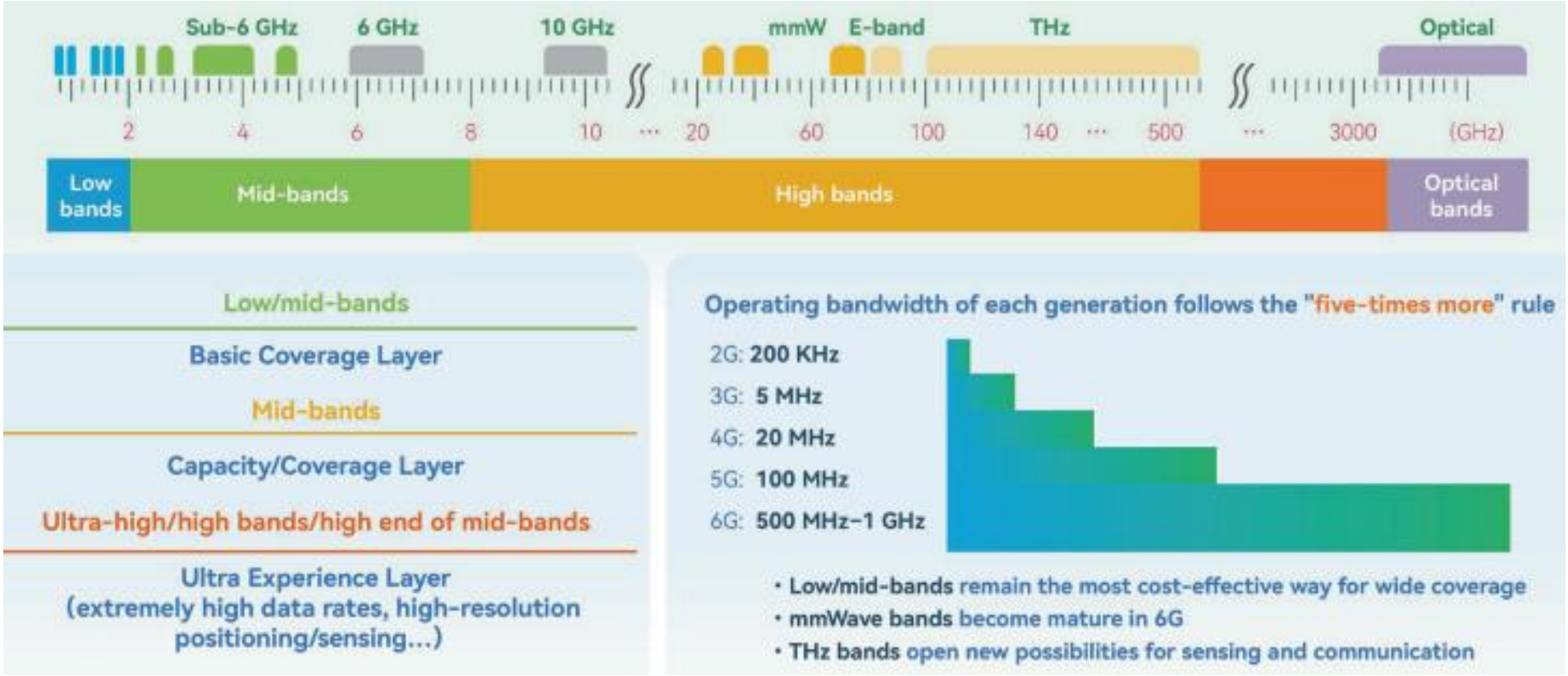
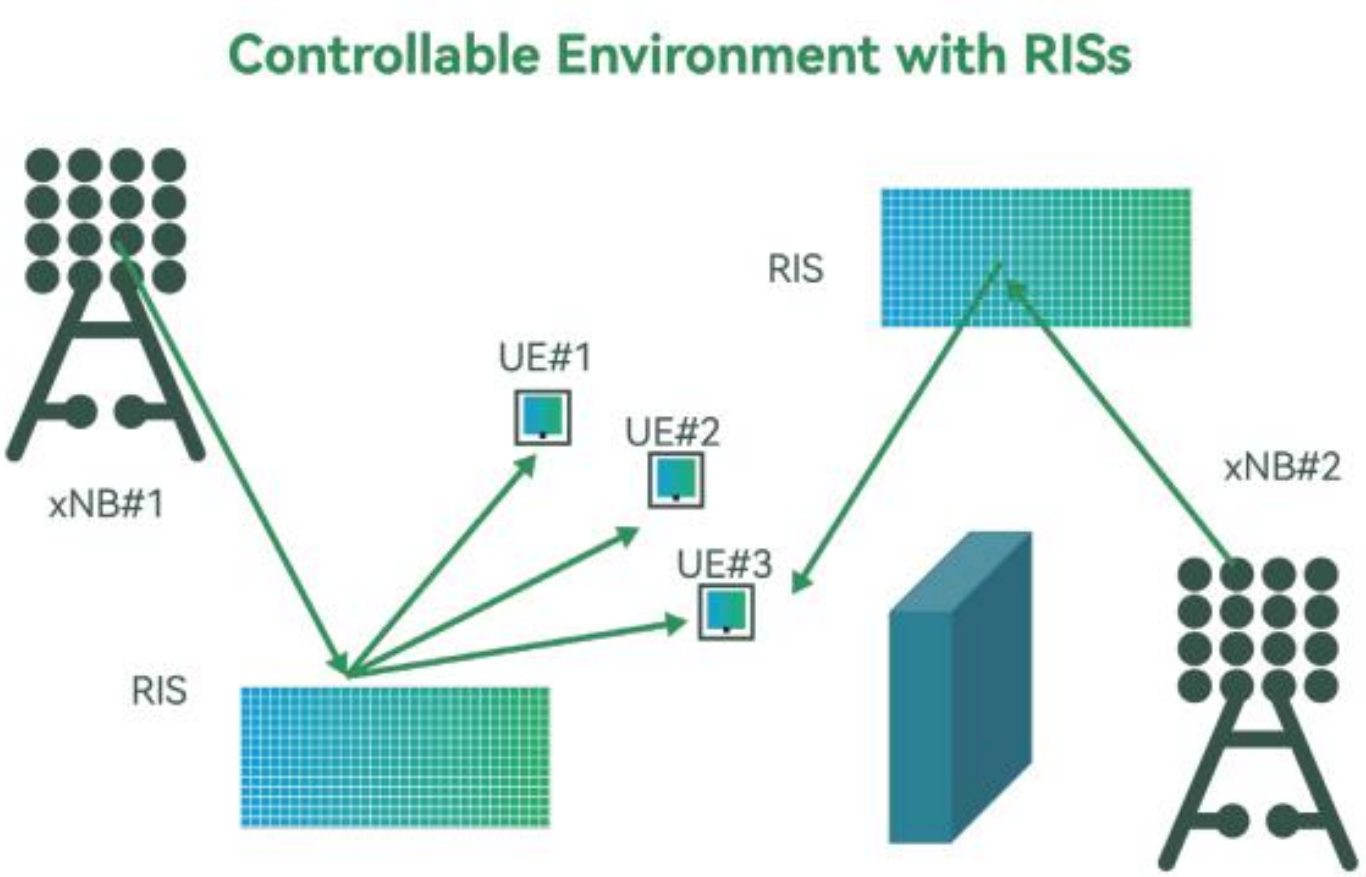
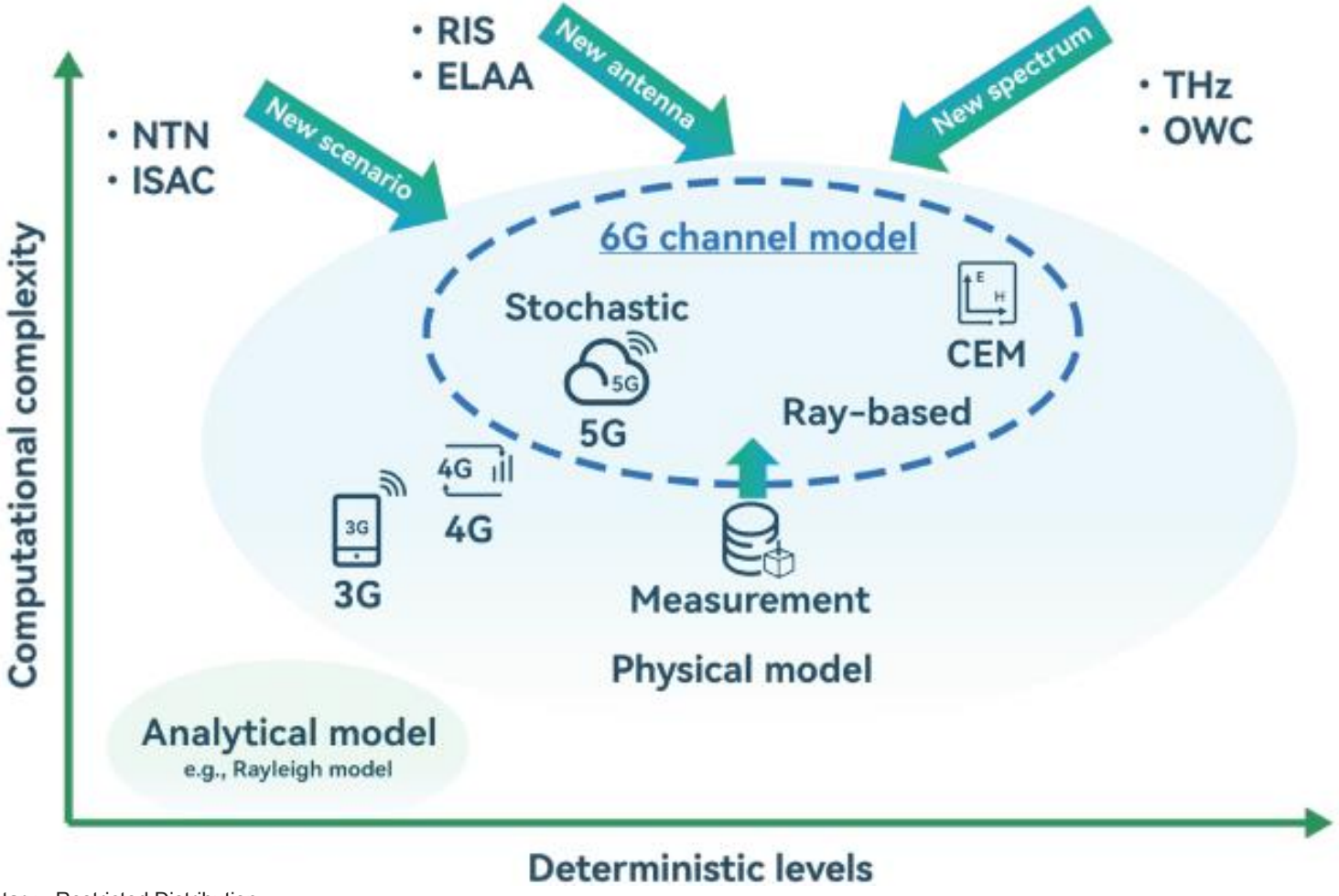
New Elements – 1: New Spectrum



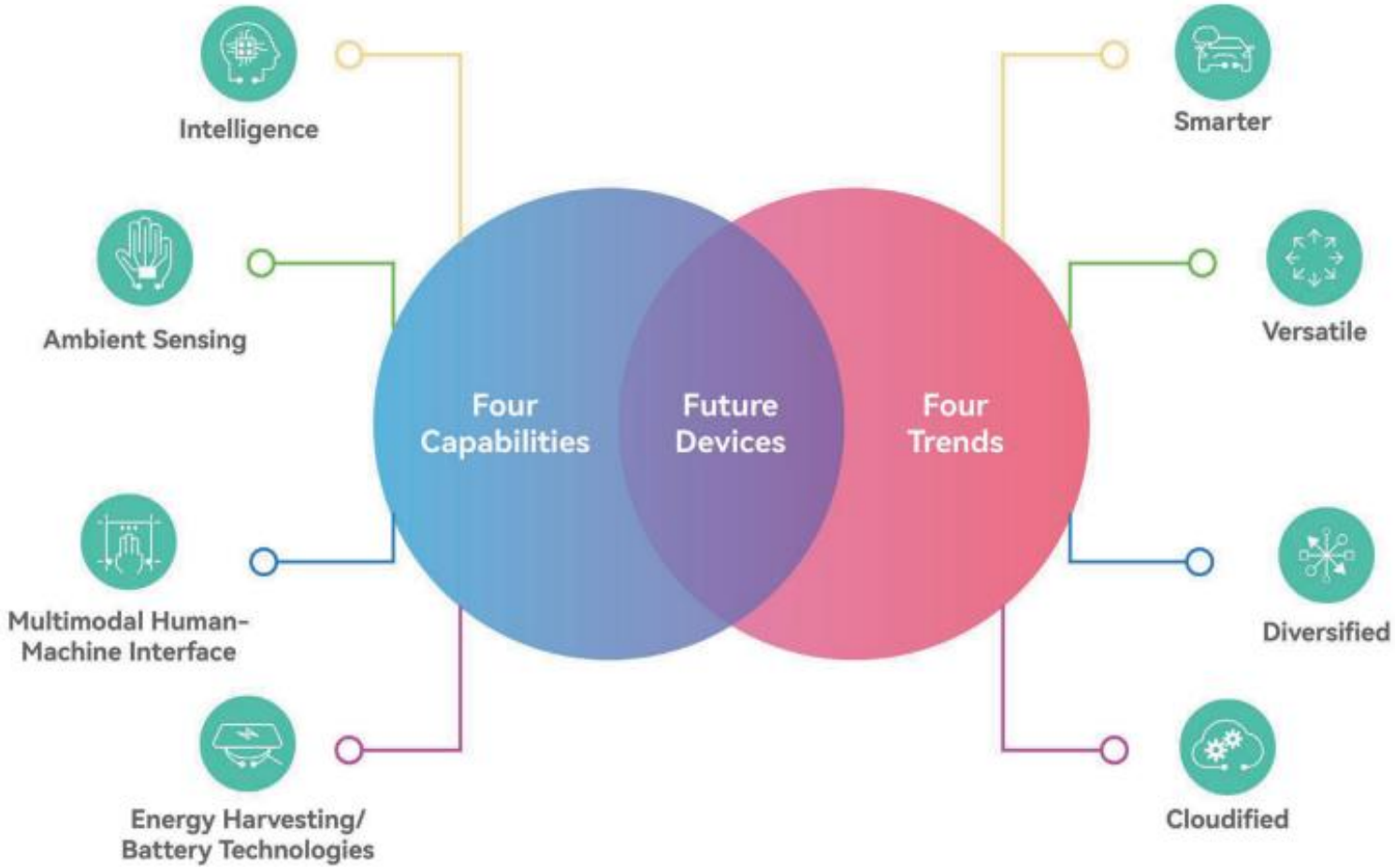
New Elements – 2: New Materials and Antennas



New Elements – 3: New Channels



New Elements – 4: New Devices



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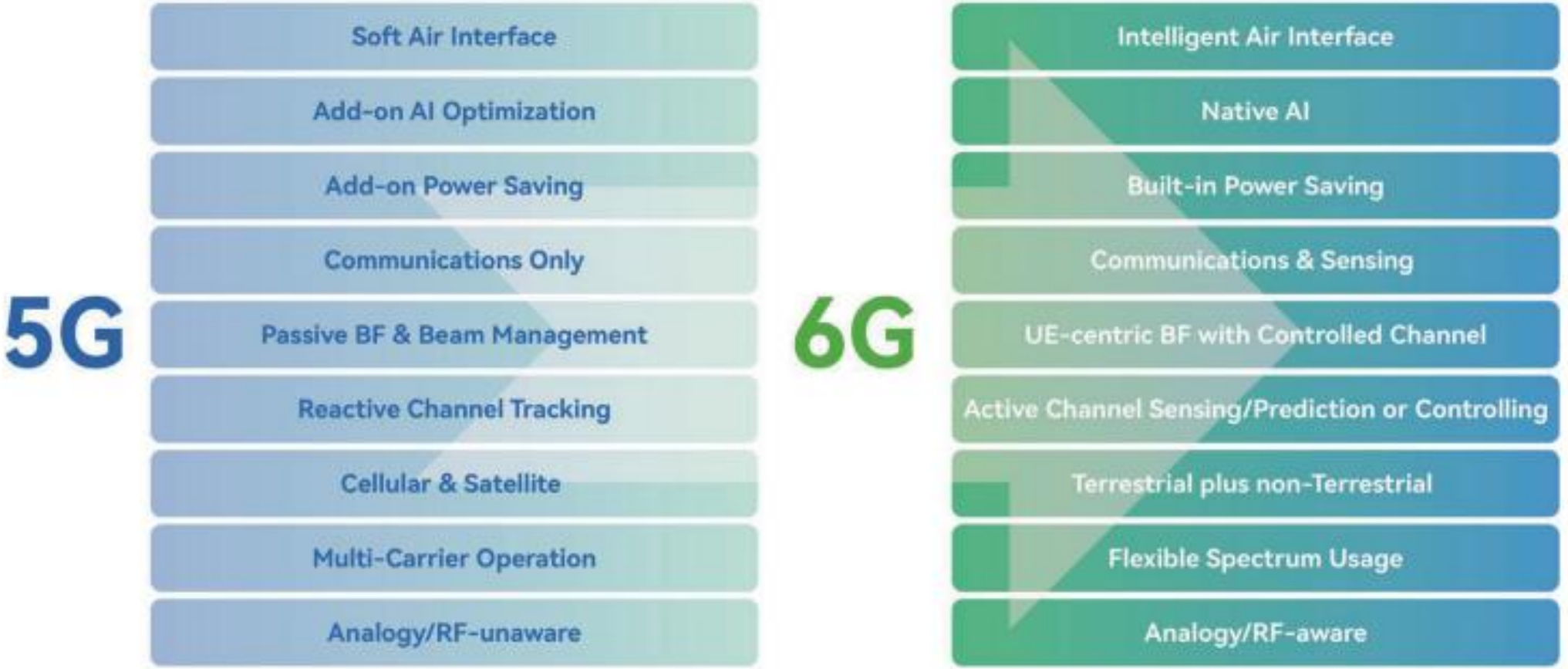
Enabling Technologies and Architectures – 1: Air Interface Design



Enabling Technologies and Architectures – 2: Network Architecture Design

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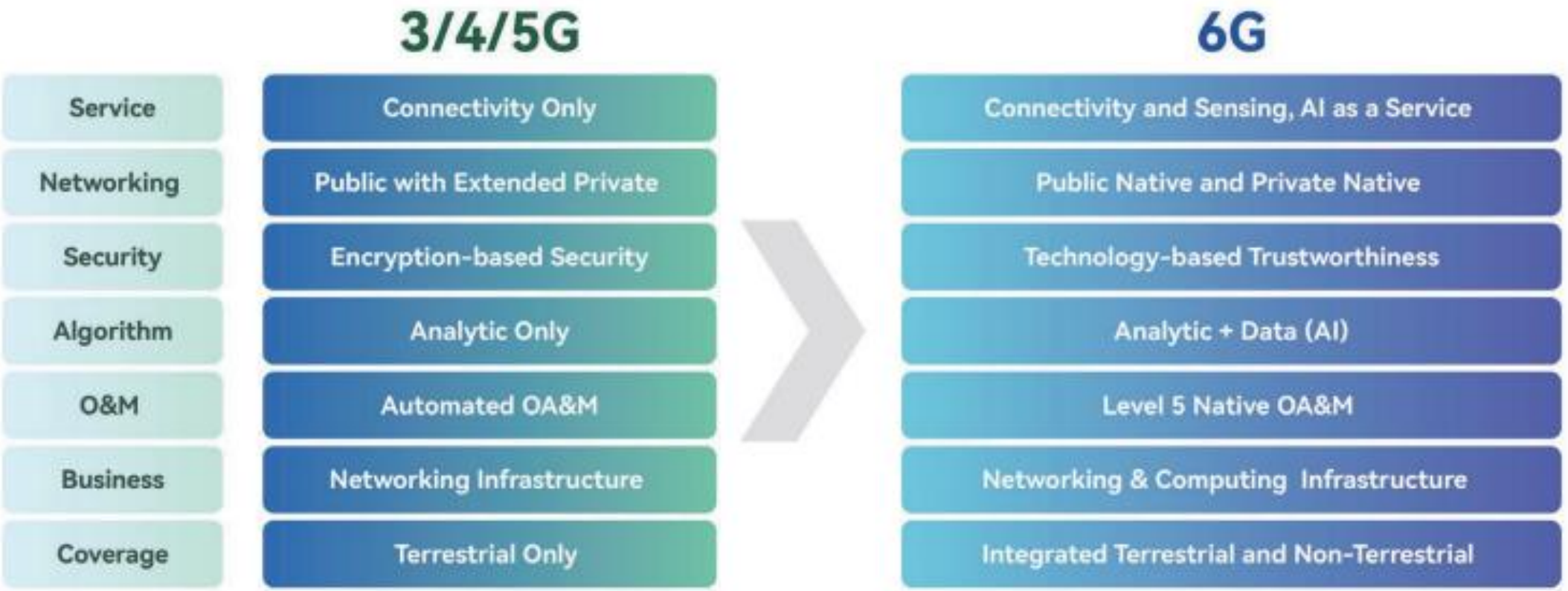
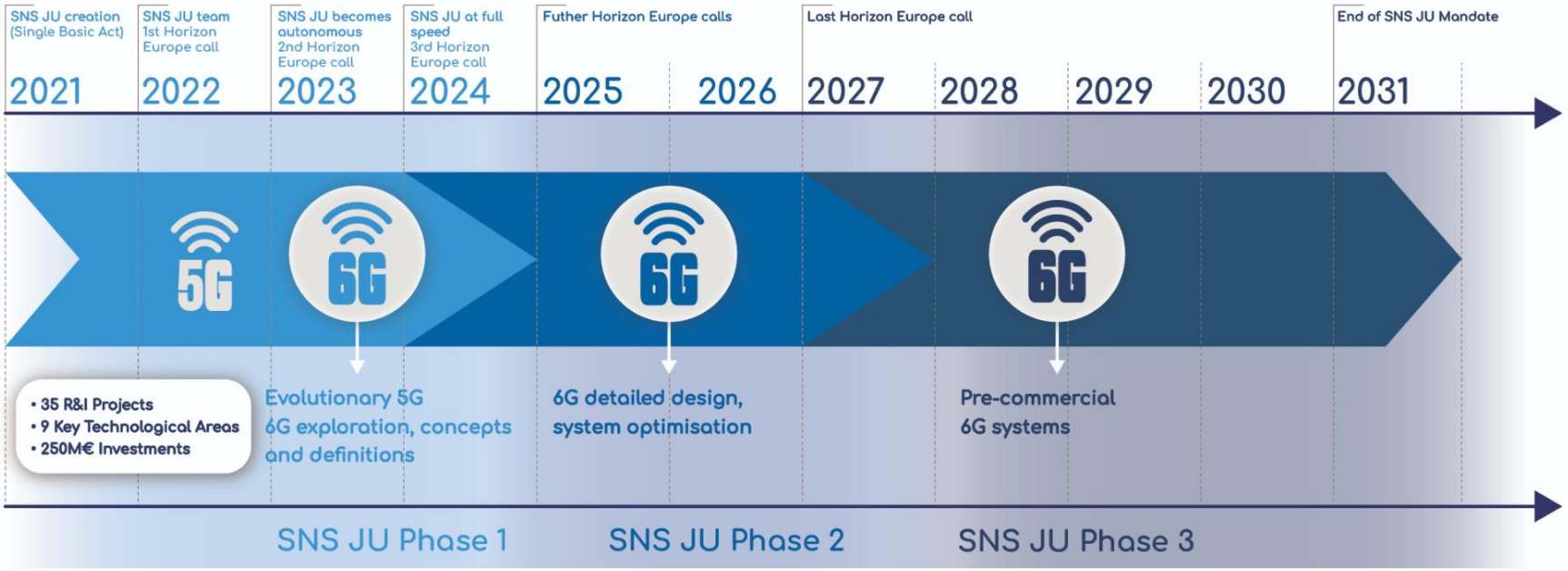
Summary of paradigm shifts



EU view: 6G SNS - Smart Network and Services



PDF

SRIA 2020

PDF

SNS WPs 2023-24

- https://smart-networks.europa.eu/
- https://bscw.5g-ppp.eu/pub/bscw.cgi/d367342/Networld2020%20SRIA%202020%20Final%20Version%202.2%20.pdf
- https://smart-networks.europa.eu/wp-content/uploads/2022/12/sns_ri_wp_2023-24.pdf

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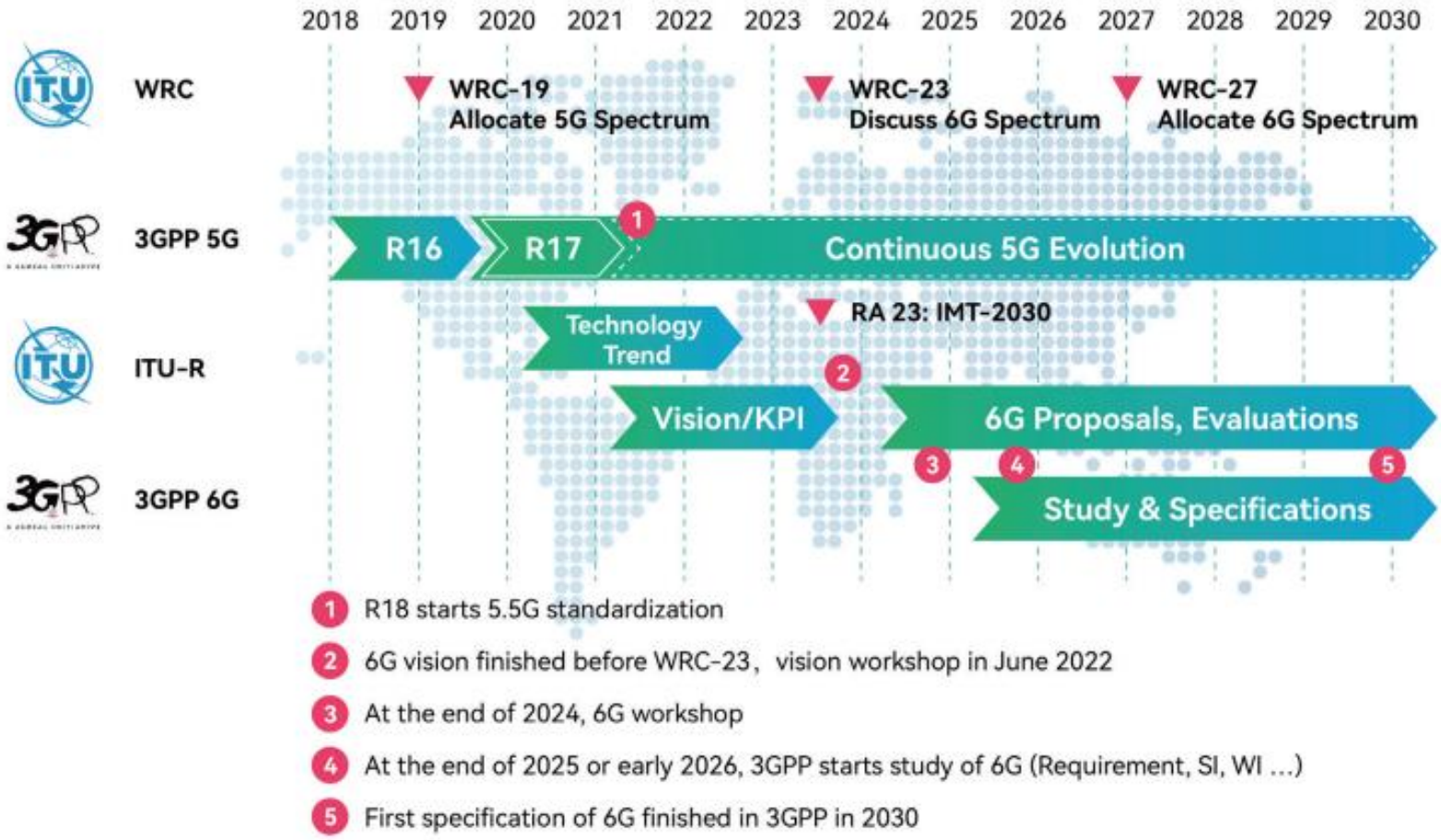
TRL

- TRL 1 — Basic principles observed
- TRL 2 — Technology concept formulated
- TRL 3 — Experimental proof of concept
- TRL 4 — Technology validated in a lab
- TRL 5 — Technology validated in a relevant environment (industrially relevant environment in the case of key enabling technologies)
- TRL 6 — Technology demonstrated in a relevant environment (industrially relevant environment in the case of key enabling technologies)
- TRL 7 — System prototype demonstration in an operational environment
- TRL 8 — System complete and qualified
- TRL 9 — Actual system proven in an operational environment (competitive manufacturing in the case of key enabling technologies, or in space)

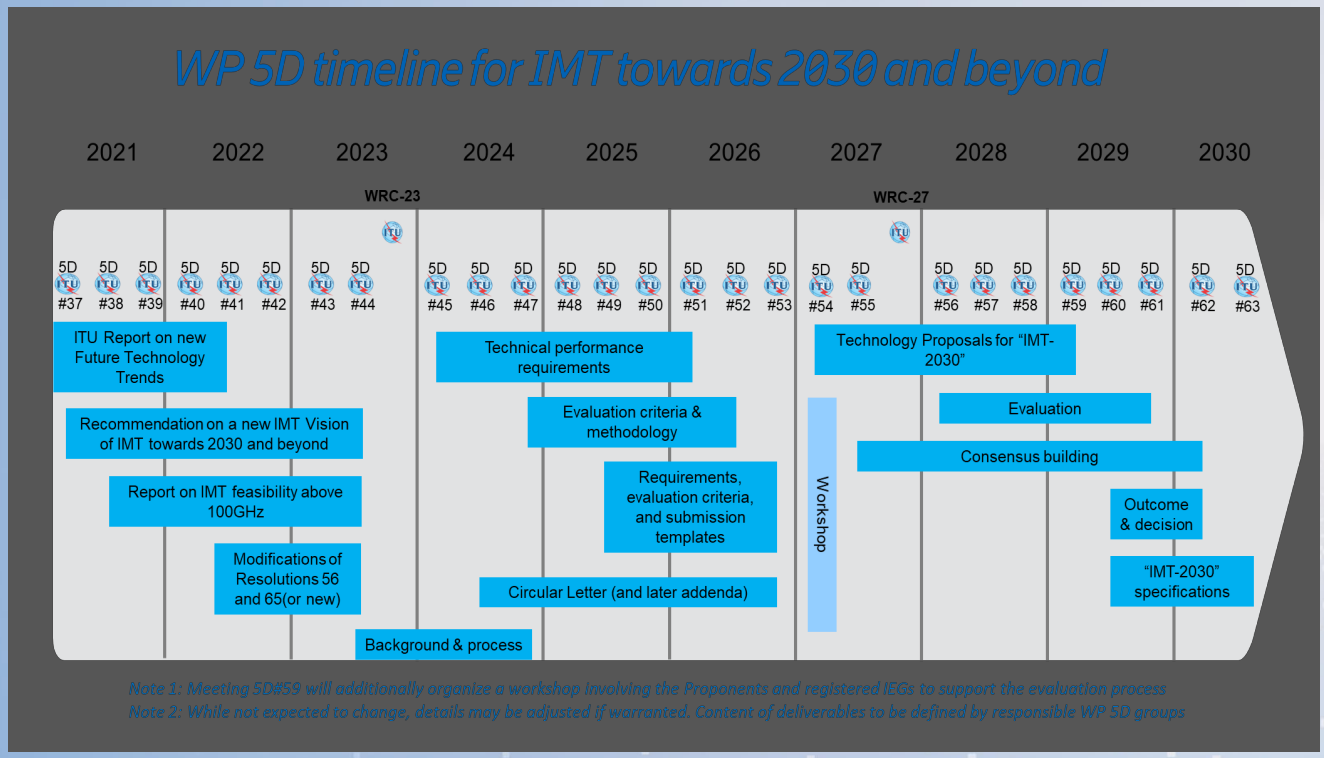
Main actors involved in defining the path towards 6G

- ITU-R: https://www.itu.int/en/ITU-R/Pages/default.aspx
- 3GPPP: https://www.3gpp.org/
- Horizon Europe: https://ec.europa.eu/info/research-and-innovation/funding/funding-opportunities/funding-programmes-and-open-calls/horizon-europe_en
- 6GIA: https://6g-ia.eu/
- SNS JU: https://digital-strategy.ec.europa.eu/en/policies/smart-networks-and-services-joint-undertaking
- One6G: https://one6g.org/
- ETSI: https://www.etsi.org/
- IMT-2030 Promotion Group (China): http://www.caict.ac.cn/english/news/202106/P020210608349616163475.pdf
- Beyond 5G Promotion Strategy (Japan): https://b5g.jp/en/about.html
- ATIS – Alliance for Telecommunications Industry Solutions (USA): https://www.atis.org/
- MSIT (South Korea): https://www.msit.go.kr/eng/bbs/view.do?sCode=eng&mId=4&mPid=2&pageIndex=&bbsSeqNo=42&nttSeqNo=517&searchOpt=ALL&searchTxt=

Expected timeline for 6G standardization



6G Timeline – ITU-R View



- 6G Commercialization will be around **2030**.
- ITU-R is working on **Vision Recommendation** for IMT 2030 and beyond, which will be completed in June 2023, i.e. the global definition of 6G
- A **unified global 6G standard** is the key to the success of 6G

Outline day 2

12,30 – 12,35: Introduction

12,35 – 12,55: Workgoup – part 1

12,55 – 13,15: Plenary discussion

13,15 – 13,35: Workgroup – part 2

13,35 – 13-55: Plenary discussion

13,55 – 14,00: Takeways

Use case for discussion

Smart Transportation

Example 5.1 Summer holidays are coming, and Mark, his wife Jennifer, and three kids are on a road trip. It will take them 12 hours to get to their destination, and, as such, long-distance driving would have been both tiring and dangerous, but not this time. Their new car is equipped with the Level 5 autonomous driving capability, which makes the journey fun, relaxing, and enjoyable. The intelligent vehicle completely takes over driving and Mark and Jennifer can now enjoy the beautiful scenery while also playing games with their family.

Source: Tong, W and Zhu, P. (Eds.). (2021). "6G: The next horizon: From connected people and things to connected intelligence." Cambridge: Cambridge University Press.

Use case analysis (for discussion)

12,35 -12,55

1) According to the previous business case, let' s define:

- The general **need** addressed;
- The **sources of value** related to autonomous driving (why should people buy an autonomous vehicle? What are the impacts on their lives?)
- The **technologies** needed to turn that vision into reality;
- The **business actors** involved (the value chain / ecosystem)

2) You are working in a company involved in the value chain / ecosystem you previously defined. Divide your group in two sub-groups:

- Group A: R&D
- Group B: Marketing and sales

Your mission is to develop a strategy to realize the *Smart transportation* use case by 2030. Please define and consider the following elements:

1. **Overall value proposition**
2. **Involved technologies**
3. **Strategic partners**
4. **Revenue sources**
5. **Costs**