Qualcomm

San Diego, CA

The essential role of technology standards

Driving interoperability, ecosystem development, and future innovation

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Agenda

- The value of standards
- Standards in mobile devices
- Cellular: demystifying 3GPP
- WLAN: Wi-Fi
- WPAN: Bluetooth

Collaborating across the global wireless ecosystem

- Constantly advancing foundational innovations
- Enabling new capabilities at rapid pace
- Collaborations across ecosystem enables a vibrant, growing market

The value of standards

Why leadership in standards is important

The communications industry is based on technology standards

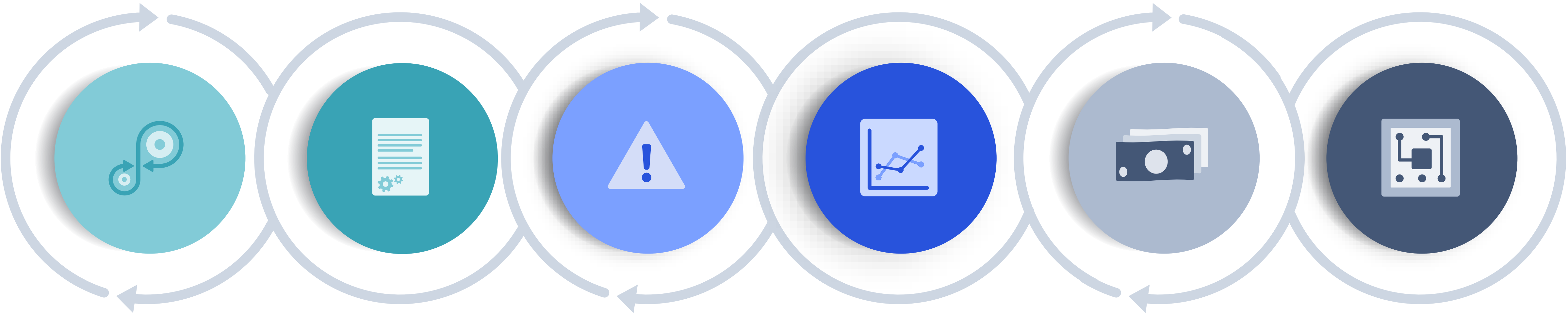
Standards are essential for commercializing new technologies

Ensuring inter-vendor system interoperability

Spurring transparent and fair industry competition

Technology standardization is key for an openly competitive ecosystem

Communications industry is based on technology standards



Ensuring system interoperability
while enabling product differentiation and spurring transparent industry competition

Meeting regulatory requirements
test and certification procedures are developed to aid in meeting obligations

Reducing market risk
especially in areas of large investments (e.g., 5G infra)

Creating new markets
and expanding addressable markets of existing products and technology

Lowering cost
through economies of scale and multi-vendor sourcing

Improving technology
multiple companies participate, collaborate, compete – best prevails

Standards create significant value for the wireless ecosystem

Industry leaders contribute to technology standards

Better, quicker-to-market products

Communications standards are very complex in nature; thus, leadership in designing technology standards goes hand in hand with leadership in product development

Standards leadership

Valuable intellectual property (IP)

When inventions are contributed to standards, they become available to everyone in the ecosystem; therefore, it is important to have a solid IP framework that adequately incentivizes inventors to contribute their innovation to standards bodies

Driving technology forward with new functionalities and efficiencies, fostering healthy market growth that benefits the broader ecosystem

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What are the ingredients of a successful standard?

Exceptional leadership in the standards process

We have the deep technical expertise, broad ecosystem reach, and decades of global experience to drive successful standards

- Addresses the global market need of solving vital technology problems
- Defines great technologies with superior performance and efficiency
- Allows a wide ecosystem to address attractive business opportunities
- Garners broad ecosystem adoption and implementation
- Drives marketing and regulation guiding activities
- Provides the proper tools (e.g., testing, certification) for mass market productization

We participate in

~200 global

standards and industry organizations

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Standards in mobile devices

- Complex systems that require global interoperability
- Also broadly applicable across device categories and industries

Cellular connectivity

3GPP, ATIS, TIA, ETSI, TTA, TTC, ETRI, ARIB, CCSA, TSDSI, GCF, PTCRB, FCC, GSMA, GSA, CCF, RED, Future Forum, 5G Forum, CTIA

WLAN & WPAN connectivity

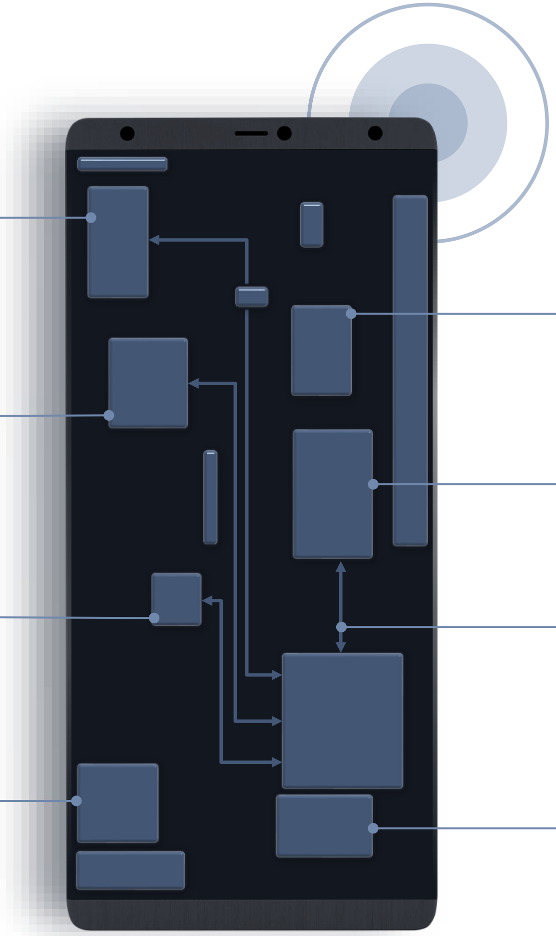
IEEE, WFA, WBA, WAPI Alliance, Bluetooth SIG, NFC forum

Emergency & location services

Galileo, 3GPP, ATIS, CCSA, CEN CENELEC, CSRIC, ETSI, GUTMA, OMA

Security and local content protection

ETSI-SCP, GlobalPlatform, Eurosmart, JHAS-SOGIS, TCA, GSMA, JEDEC, EMVCo, TCG



And many others...

Multimedia services

MPEG, 3GPP, Khronos Group, INCITS, DASH-IF, DVB, CTA WAVE, ATSC, SMPTE, AIS, IVAS

Semiconductor manufacturing

Si2, Accellera, UEFI, GSA, FlexTech, LTAB, CSIA

Wired connectivity

MIPI Alliance, JEDEC, NVMe, PCI-SIG, USB-IF, DMTF, VESA, UHD Alliance, HDMI, RISC-V, xHCI

AI processor

MLPerf/ML-Commons, FIDO, SAE, Khronos, MPEG, NIST, ISO/IEC SC42

Many standardized components and interfaces in a smartphone

ITS/V2X

5GAA, 3GPP, SAE International V2X SC, ETSI TC ITS, IEEE 1609 WG, CAICV, OmniAir Consortium, CAMP, CCSA, C-SAE, NTCAS, ITS America, ERTICO, C-ITS, ITS Forum, ISO TC 204, NEMA

ADAS/Automated Driving

ISO TC 22, SAE International ORAD Committee, ISO TC 204 WG 14, IEEE 2846 WG, IEEE 2851 WG, Accellera Functional Safety WG, Khronos Group Safety Critical WG, 5G ADA

Telematics/Infotainment

CCC, WFA Automotive Market Segment TG, AGL, AEC, AESIN, AEIA

Vehicle Security

SAE International Vehicle Electrical System Security and Vehicle Cybersecurity Systems Engineering Committees, Auto-ISAC

And many others...

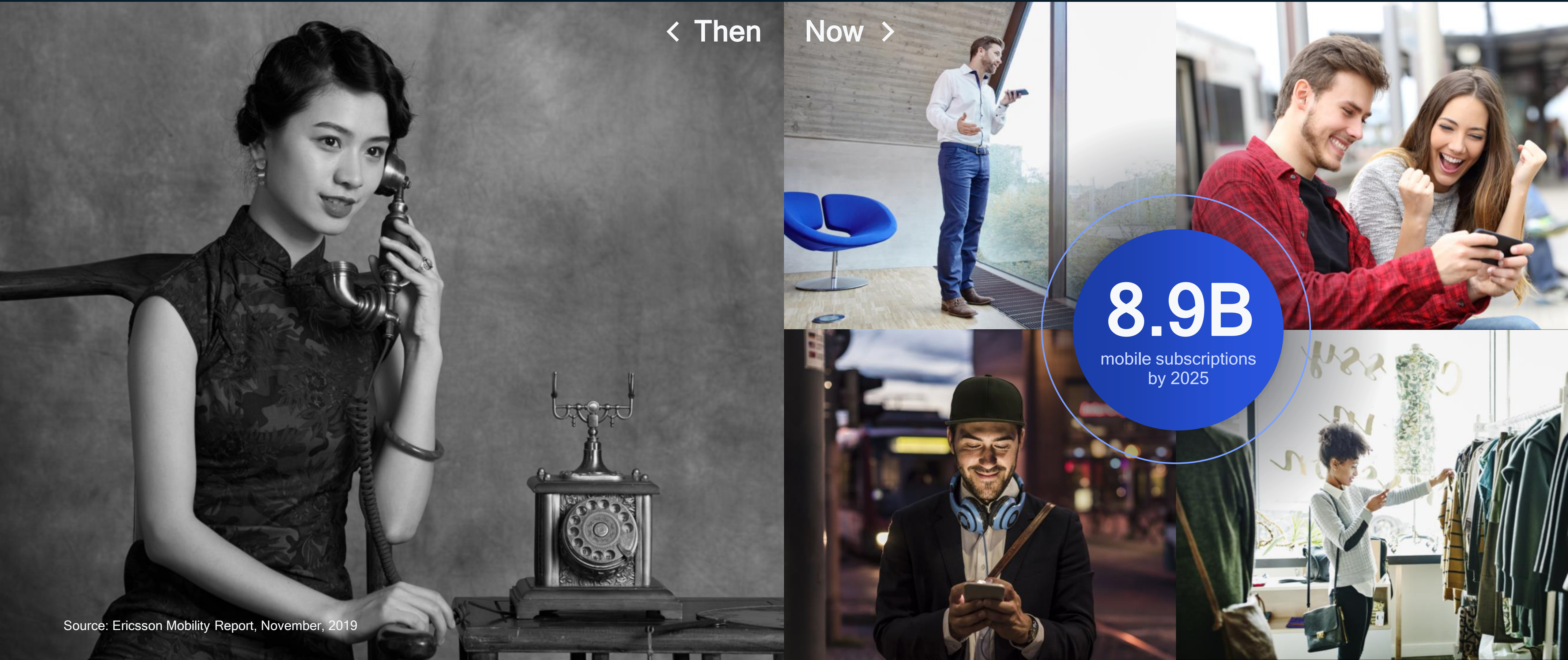
Standardized technology across components and interfaces in automotive

Cellular standards

The heart of the mobile ecosystem – leading standards development and the ecosystem expansion

Cellular has revolutionized the way we communicate

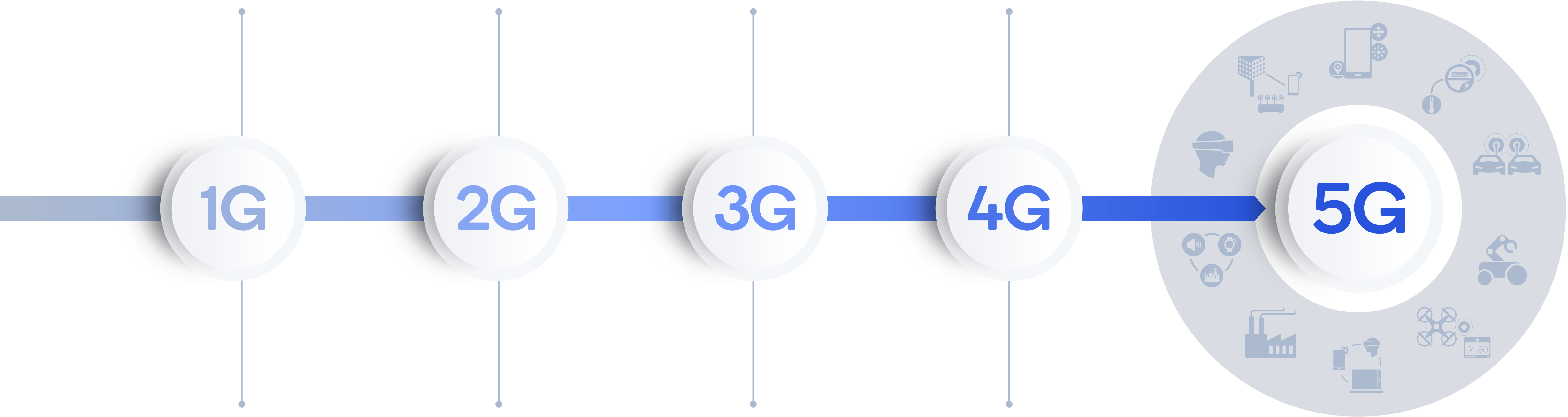
From voice only to a plethora of new services that our lives depend on today (e.g., smartphone)



Source: Ericsson Mobility Report, November, 2019

Mobile has made a leap every ~10 years

Continuous innovation between “G”



1980s — Analog voice
Mobile voice communication
AMPS, NMT, TACS

1990s — Digital voice
Efficient voice to reach billions
D-AMPS, GSM, IS-95 (CDMA)

2000s — Wireless Internet
Focus shifts to mobile data
CDMA2000/EV-DO WCDMA/HSPA+,

2010s — Mobile broadband
Mobile broadband and emerging expansion
LTE, LTE Advanced, Gigabit LTE

2020s — Wireless Edge
A unified future-proof platform
5G New Radio (NR)

3GPP drives global cellular standards

2G, 3G, 4G and 5G

22
Years driving cellular tech evolution

14
Major releases

>1.4K
Tech specifications*

100,000's
Technical contributions

3rd Generation Partnership Project

700+
Member companies

~20
Technical groups

6-8
Working group meetings per year

2,000+
Man years in cumulative meeting time*

* Source: 3GPP Mobile Competence Centre (3GPP Support Team) Summary Report from RAN#86 (RP-192371); Including 3G/4G/5G Release 99/4/5/6/7/8/9/10/11/12/13/14/15/16

Member-driven organization
Relies on R&D and tech inventions from members, e.g., 'contributions'

Collaborative engineering effort
Consensus-based, tech-driven effort across 100s of entities

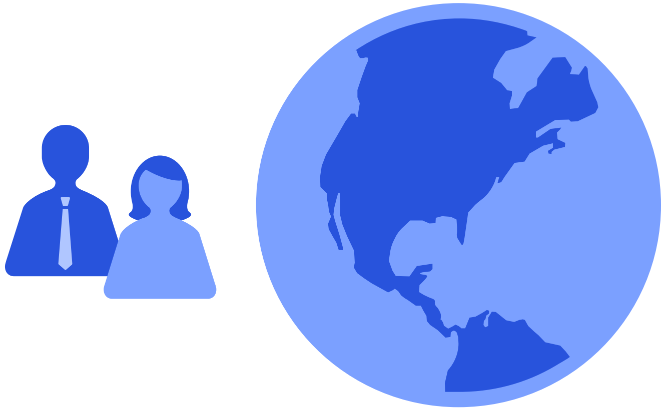
Distributed work-flow
Scale/complexity requires division of work into smaller, specialized pieces

Global events leading to new standardization challenges

Ripple effects of COVID: more remote participation allowed, real decisions happen in face-to-face meetings

Geopolitical tensions disrupting in person participation of key standards members

- Obtaining US visas
- Organizing meetings in Taiwan



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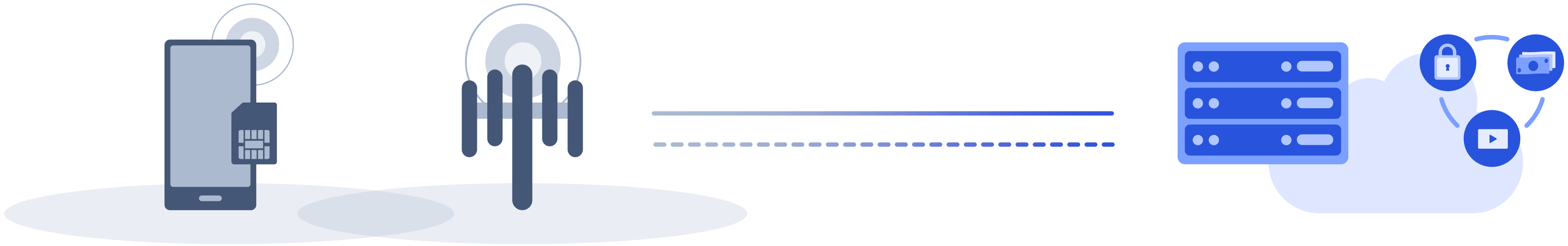
3GPP defines complete end-to-end system specifications

Radio Access Network (RAN)

Implements radio access technology, e.g., 5G NR, LTE, managing radio link to connect UEs to networks

Core Network (CN)

Manages macro-mobility, sessions, quality of service, policies, security, and routes traffic to outside world, e.g., Internet, or local intranet



User Equipment (UEs)

Devices, e.g., smartphones and all types of IoT devices that connect to services via radio access technology

Services

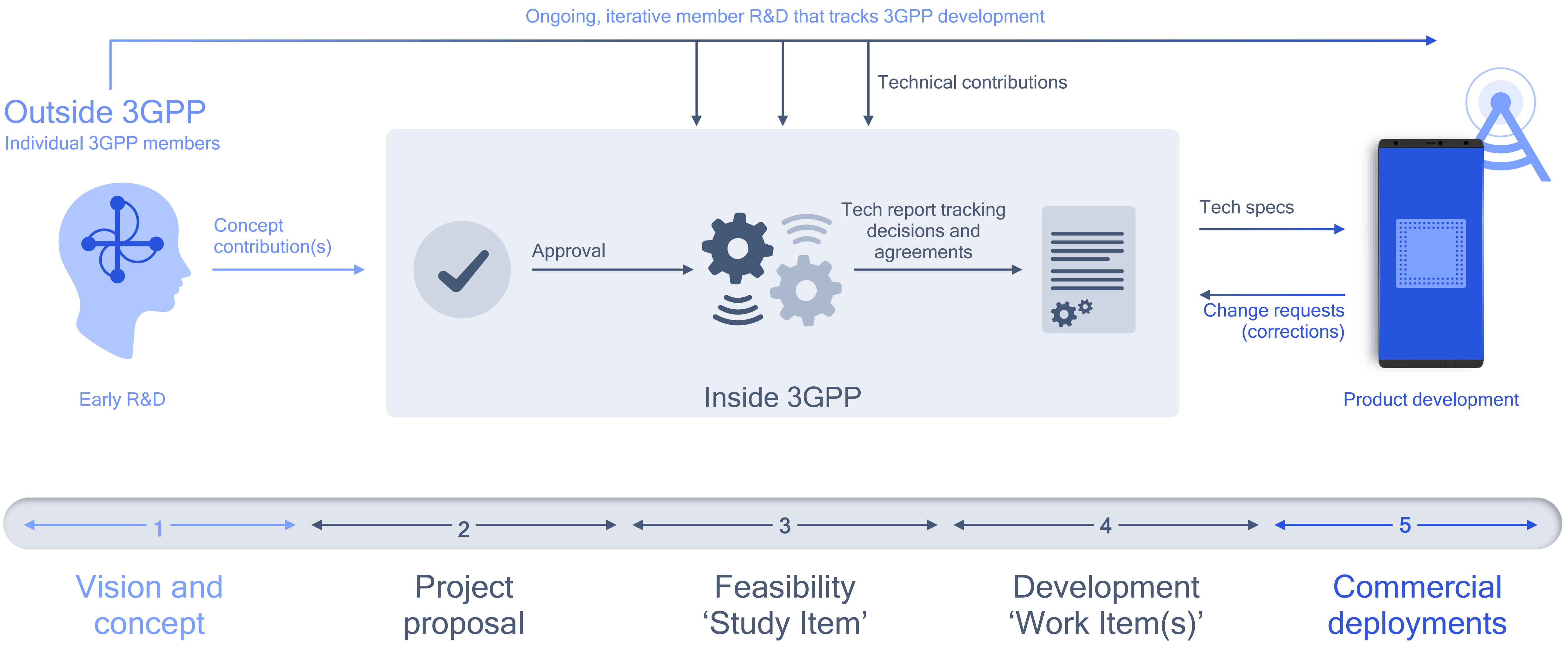
Framework for service delivery architecture, multimedia, billing, charging, etc.

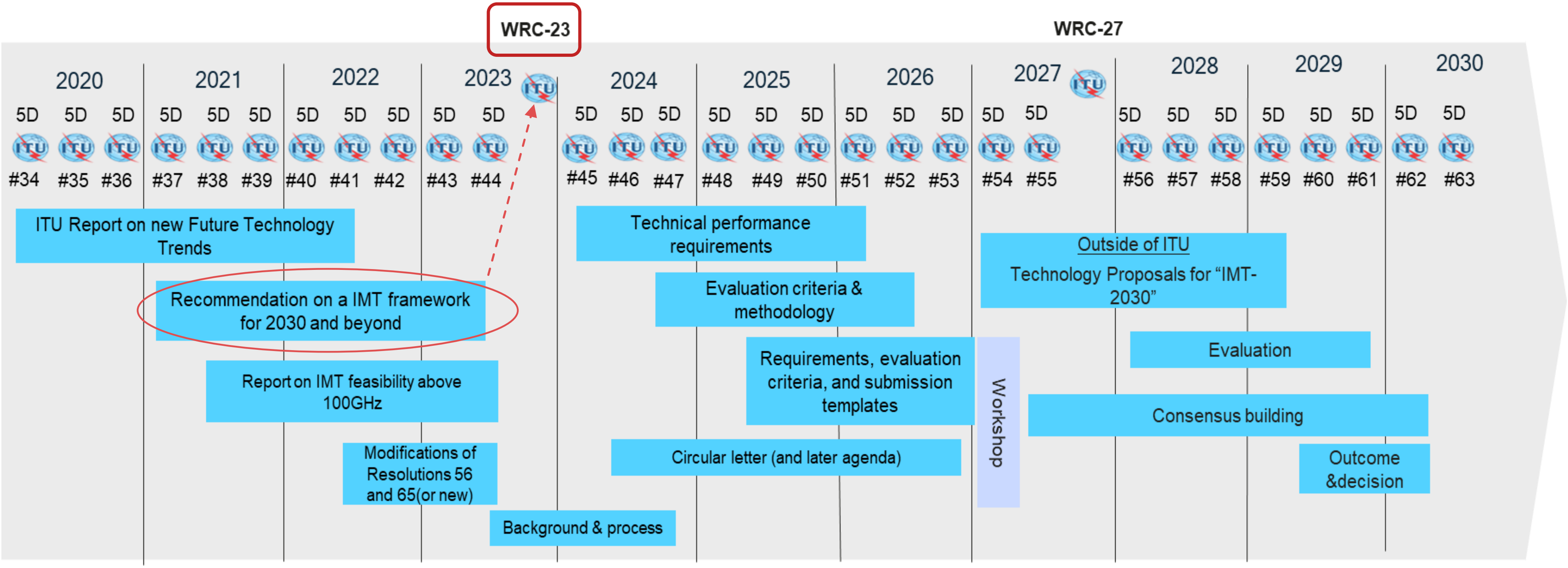
Test Requirements

Defines performance and conformance test procedures to ensure interoperability used for certification (e.g., GCF)

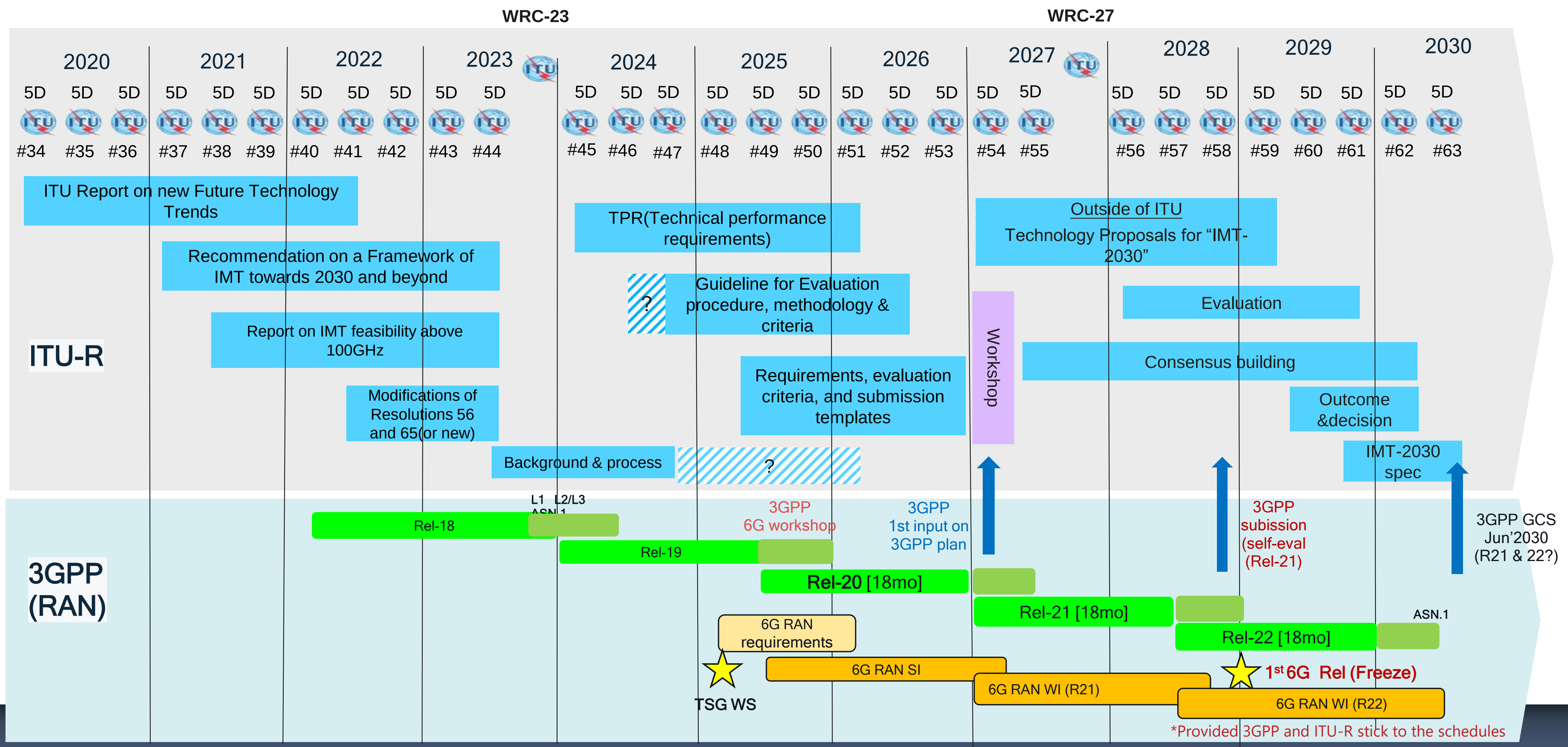
This large scope requires division of work into smaller, specialized working groups in 3GPP

A typical workflow in 3GPP





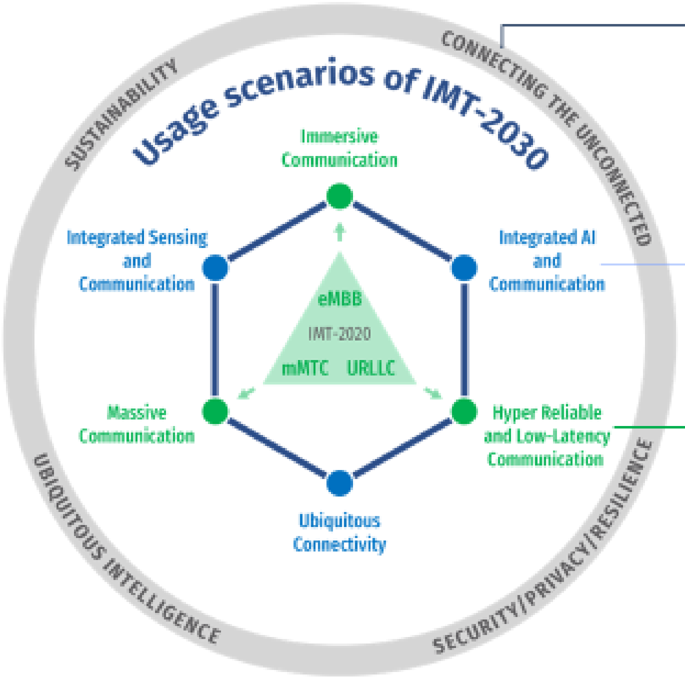
The road to 6G: The timeline



The road to 6G: The timeline

IMT-2030 Usage Scenarios

General



Usage scenarios and overarching aspects of IMT-2030

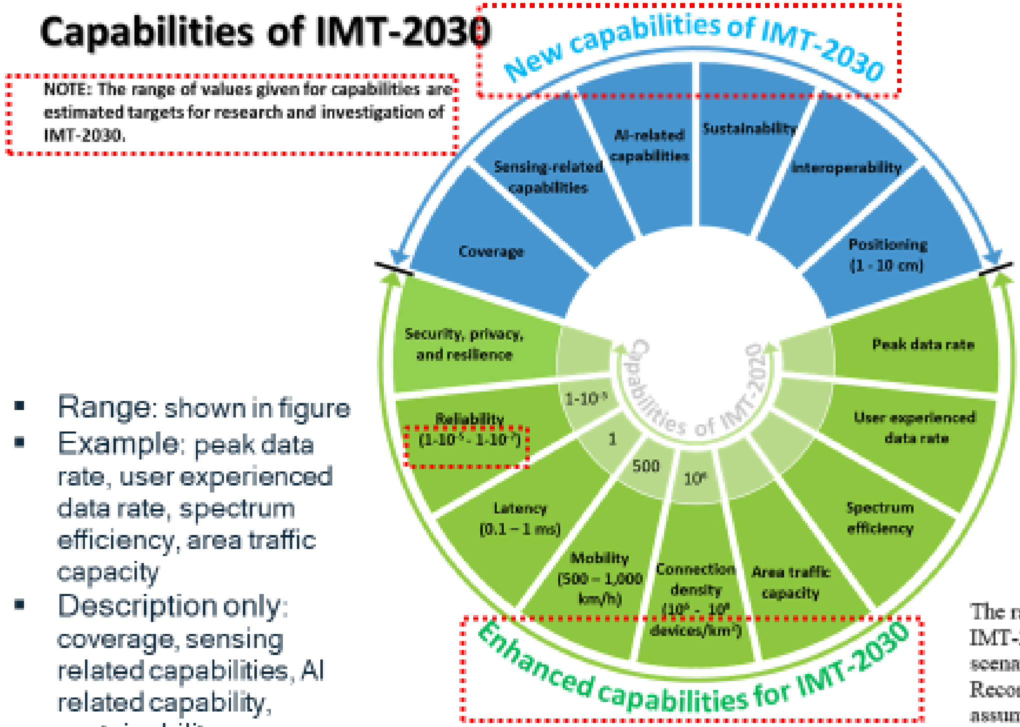
- Overarching aspects
  - Distinguishing design principles commonly applicable to all usage scenarios
  - Sustainability, security/privacy/resilience, connecting the unconnected, ubiquitous intelligence
- Usage Scenarios: 5 Communications and 1 Connectivity
  - 3 enhanced usage scenarios
    - **Mostly** requires **enhanced capabilities/KPI (communication)**
    - Immersive Communication
    - Hyper Reliable and Low-Latency Communication
    - Massive Communication
  - 3 new usage scenarios
    - **enhanced capabilities/KPI (communication)** for IMT-2030
      \+ **New capabilities** of IMT-2030
    - Integrated Artificial Intelligence and Communication
    - Integrated Sensing and Communication
    - Ubiquitous Connectivity: presently uncovered or scarcely covered areas, particularly rural, remote and sparsely populated areas

 13

The road to 6G

IMT-2030 Capabilities

General



- Range: shown in figure
- Example: peak data rate, user experienced data rate, spectrum efficiency, area traffic capacity
- Description only: coverage, sensing related capabilities, AI related capability, sustainability, interoperability

- 6 New capabilities
  - Coverage, Positioning, Sensing-related capabilities, AI-related capabilities, Sustainability, Interoperability
- 9 Enhanced capabilities
- Range of values or example values for some capabilities instead of single value
- General description only (no KPI value) for some capabilities, Details would be defined in detail in TPR (Technical Performance Requirements, year of 2024-2025) phase
- Explicit description: estimated targets for research and investigation

The range of values given for capabilities are estimated targets for research and investigation of IMT-2030. All values in the range have equal priority in research and investigation. For each usage scenario, a single or multiple values within the range would be developed in future in other ITU-R Recommendations/Reports. These values may further depend on certain parameters and assumptions including, but not limited to, frequency range, bandwidth, and deployment scenario. Further these values for the capabilities apply only to some of the usage scenarios and may not be reached simultaneously in a specific usage scenario.

The road to 6G

Wi-Fi Standards

Driving the technology evolution of wireless local area networking

Wi-Fi has revolutionized the way we access the internet

Cutting-the-wire for a wide range of devices – PCs, tablets, TVs, smartphones, etc…

Evolving networks from speed to capacity

Core technology evolution and Qualcomm Technologies leadership

Wi-Fi — The first 10 Billion
Enabling mobility

- Speed #s prioritized
- Increased bandwidth
- Introduced modulation schemes
- Introduced MIMO

Wi-Fi — The next 20 Billion
Connecting everything

- Network efficiency
- Usable performance at device
- Value when AP/Clients reach critical mass
- Scheduled access
- MU-MIMO / OFDMA

1997 802.11	1999 11a/b	2003 11g	2007 11n	2013 11ac (w1)	2015 11ac | Wi-Fi 5	2018/19 11ax | Wi-Fi 6

- OFDM
20 MHz
- Up to 4x4 MIMO
40 MHz
2.4 / 5 GHz
- Up to 8x8 MIMO
80 MHz
5 GHz only
256 QAM
- DL MU-MIMO
5GHz only
- 8x8 MIMO
OFDMA
Scheduled Access
2.4 / 5 GHz
1024 QAM

IEEE 802.11 Working Groups

- Develops and maintains backward compatible global MAC and PHY standards
- Defines spectrum use for Wi-Fi: 2.4 GHz, 5 GHz, 6 GHz, 60 GHz, and sub-1 GHz unlicensed bands
- Releases key MAC and PHY performance upgrades with 4-6 year cadence

Industry standards

Symbiotic relationship since 1999

Feedback on standards and market requirements

Wi-Fi Alliance (WFA)

- Develops test plans, manage interoperability test programs, and organizes industry plug fests
- Develops industry specifications complementary to IEEE standards
- Conducts regulatory advocacy for Wi-Fi technologies
- Drives Wi-Fi technology marketing activities

IEEE 802.11 Working Groups

- Actively drives Wi-Fi technology standardization process
- Holds key leadership positions in working/task groups, e.g., 802.11 Vice Chair, 802.11be Chair, etc.
- Leads in quality contributions to Wi-Fi standards (e.g., 802.11ax)

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Wi-Fi Alliance (WFA)

- Consistently selected to be part of industry interoperability testbeds
- Holds key leadership positions on the Board of Directors (since 2008) and WFA task groups
- Received "Wi-Fi Alliance 2020 Industry Impact Award" and "Outstanding Leadership and Contribution" awards for sponsor members in multiple years

We are committed in pushing standardized Wi-Fi technology forward

Multiple generations of successful global Wi-Fi standards

1 PAR (Project Approval Request) approval; 2 SASB (Standards Association Standards Board) approval

A rich history of leading key Wi-Fi innovations

Advanced R&D | Standardization | Successful commercialization

802.11g

Drove OFDM into the 802.11g standard

Implemented OFDM in 1st commercial CMOS 5GHz product[1], then rapidly ported to 2.4 GHz

Enabled successful proliferation of 802.11g that greatly expanded the Wi-Fi ecosystem

Wi-Fi 4: 802.11n

MIMO-OFDM (spatial multiplexing) and transmit beamforming

Implemented MIMO-OFDM system architecture for mass market products[2] (e.g., PCs, routers)

Drove the success of “pre-standard” MIMO products

Wi-Fi Mesh

Pioneered multi access point (AP) technology

Led contributions to the Wi-Fi EasyMesh industry specification

802.11ad / ay

Pioneered mmWave beam forming & antenna designs

Delivered the highest performing mmWave implementation, proving the viability of mmWave

Drove mmWave into the 802.11ad and brought wider bandwidths via channel bonding in 802.11ay

Wi-Fi 5: 802.11ac

Drove MU-MIMO – the foundational technology – into the 802.11ac standard

Proved to the ecosystem on the viability and value of MU-MIMO for Wi-Fi systems

802.11ah

Drove key technologies enabling extended range, small battery operation and low-power for Wi-Fi operating in sub-1 GHz

Facilitated opening of spectrum for 802.11ah sensors in Europe

Wi-Fi 6: 802.11ax

Drove key UL OFDMA and UL MU-MIMO designs into the 802.11ax standards

Developed synchronized AP scheduling, trigger-based OFDMA and MU-MIMO

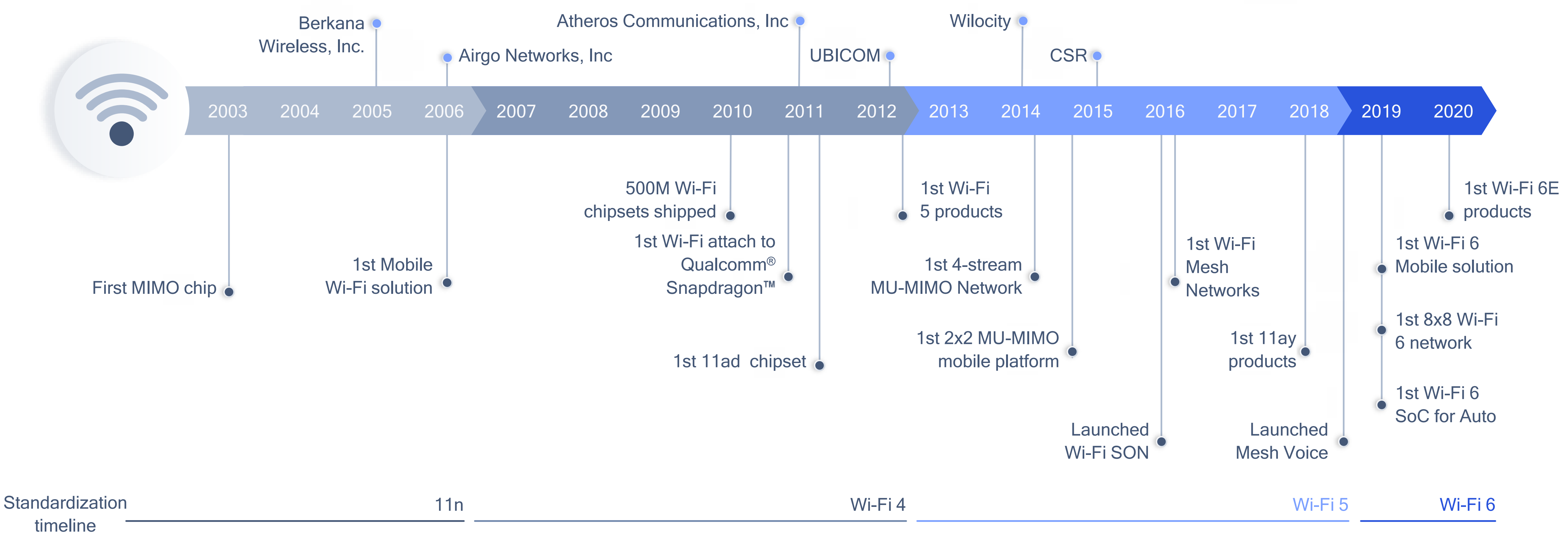
Continued leadership in IEEE and WFA

Nominal work on Wi-Fi 7 / 802.11be is just starting

1 Based on 802.11a; 2 Including Airgo, Atheros, and Wilocity

Our historical Wi-Fi pedigree

Acquisitions
Product milestones



4B+ Wi-Fi chips shipped since 2015

Bluetooth®

Bluetooth Standards

Connecting wireless
personal area networks

Founded in 1998

Bluetooth

Special Interest Group (SIG)

14
Working Groups (WG)[1]

80
Active specification projects

Driving the technology evolution and commercial success

Technology standardization

~15 promoter/associate members are currently actively contributing to Core WG meetings to evolve Bluetooth specifications[2]

Product qualification

World-class programs that drive product interoperability, and give access to technology and trademark licensing

Brand promotion

Campaigns to increase the awareness, understanding, and adoption of Bluetooth technology

Source: Bluetooth SIG Market Update 2020;
1 Audio/Telephony/Auto, Automation, Core Specification, Direction Finding, Discovery of Things, Easy Pairing, Generic Audio, Hearing Aid, HID, Internet, Medical Devices, Mesh, PUID, Sports and Fitness
2 Based on 6 months attendance records, analysis done in June 2020

A rich history of leading key Bluetooth innovations

Advanced R&D | Standardization | Successful commercialization

Joined BT SIG as associate member since 2000

Bluetooth 1.2
Adaptive frequency hopping

Bluetooth 2.0
Enhanced data rate design (EDR)

Bluetooth 2.1
Secure pairing/ connection

Bluetooth 4.0
Low energy (LE) design
Attribute protocol (ATT)
Generic attribute profile (GATT)

Bluetooth 4.1
Dual mode devices

Bluetooth 5.0
Long range PHY
Advertising extensions

Mesh networking
Mesh design[1]

Bluetooth 5.1
Location services (AoA/AoD[2])

Bluetooth 5.2
Enhanced Attribute Protocol

Continued leadership in Bluetooth SIG

Also actively involved in creation/revisions of various Bluetooth SIG processes

(e.g., Bluetooth Specification Development Process, Qualification Process)

1 As part of Mesh Networking specifications v1.0 first adopted on July 13, 2017; 2 Angle of Arrival/Departure

Leading the way in Bluetooth SIG

Working Group/committee leadership and participation

Current working groups

Core Specification (CSWG) – **Chair**

Generic Audio (GAWG) – **Chair**

Bluetooth Test and Interoperability (BTI) – **Chair**

Automotive, Telephony, Audio (ATA)

Mesh

Current committees

Bluetooth Architecture Review Board (BARB)

Bluetooth Qualification Review Board (BQRB)

Bluetooth (Qualification) Technical Advisory Board (BTAB)

Past leadership positions

Board member: 2012-2014 (CSR), 2014-2016 (Qualcomm)

Chairs or vice chairs: BARB, BQRB, Regulatory, ATA, Automation, Mesh, Internet, HID, HCI, Radio Improvements

Contributing member: Regulatory, Automation, Direction Finding, HID, Internet, Medical Devices, PUID, Sports and Fitness, HCI, Radio Improvements

Key recognitions for our leadership role

- Awarded "Outstanding Technical Contributor" in 2011, 2012, 2014, 2015 (x2), 2016, 2017 (x3)
- Awarded "Working Group and Committee Chair of the Year" in 2010, 2018, 2019
- Awarded "Bluetooth Core Specification Team Award" in 2014, 2016
- Inducted to "Bluetooth Hall of Fame" in 2017 (x2), 2010, 2011

Backup

Text from a physical layer specification

TS 38.212 v15.0 - NR
Section on Channel Coding
Polar Code Ceremony
Standards Engineer Recognition

5.3 Channel coding

Usage of coding scheme for the different types of TrCH is shown in table 5.3-1. Usage of coding scheme for the different control information types is shown in table 5.3-2.

Table 5.3-1: Usage of channel coding scheme and coding rate for TrCHs

TrCH	Coding scheme
UL-SCH	LDPC
DL-SCH	
PCH	
BCH	Polar code

Table 5.3-2: Usage of channel coding scheme and coding rate for control information

Control Information	Coding scheme
DCI	Polar code
UCI	Block code
	Polar code

5.3.1 Polar coding

The bit sequence input for a given code block to channel coding is denoted by $c_0, c_1, c_2, c_3, ..., c_{K-1}$, where K is the number of bits to encode. After encoding the bits are denoted by $d_0, d_1, d_2, ..., d_{N-1}$, where $N = 2^n$ and the value of n is determined by the following:

Denote by E the rate matching output sequence length as given in Subclause 5.4.1;

If $E \le (9/8) \cdot 2^{(\lceil \log_2 E \rceil - 1)}$ and $K/E < 9/16$

$n_1 = \lceil \log_2 E \rceil - 1;$

else

$n_1 = \lceil \log_2 E \rceil;$

end if

$R_{min} = 1/8;$

$n_2 = \lceil \log_2 (K / R_{min}) \rceil;$

$n = \max\{\min\{n_1, n_2, n_{max}\}, n_{min}\}$

where $n_{min} = 5$.

Example of Chairman minutes

3GPP TSG RAN WG2 #67bis

12 - 16 October 2009, Miyazaki, Japan

R2-095920 RLC UM ciphering problem recovery — Nokia Corporation, Nokia Siemens Networks — Disc — REL-8 RlnImp8-CsHspa

-Samsung asks how much this issue happens in the field. Samsung considers the problem may happen in the DL because of the dissociation between RNC and NB but in the UL it should be extremely rare because RLC/MAC are co-located.
-Samsung assumes assumes voice will be transmitted using NS-grants but the packet won't be transmitted from UE side if UE doesn't have enough power, hence RLC won't create a PDU.
-Interdigital considers minimum set could be set such that the packet would be always transmitted and then in power limited conditions the UE will loose the packets.
-Qualcomm asks if for voice packets the UE won't anyways create the packets. Samsung considers this depends on UE implementation. UE implementation could be set in a way that RLC PDUs aren't created.
-Nokia thinks this is an issue because then NW cannot know what UE will do.
-Samsung thinks that could be solved more easily by indicating in the spec that UE should not create those packets. Nokia points out it cannot be guaranteed there isn't an UL problem.
-Vdf considers UE wouldn't know if HARQ drops the packet at the end of the transmission.
-Samsung asks if it can be seen in the field that 128 packets are lost consecutively.
-Interdigital considers that for other types of implementations the issue will occur.

-Samsung agrees the issue can occur for DL and it can be solved by UE implementations.
-For UL, Samsung considers that UE can solve this but NW can decide to solve the problem but through NW implementation specific solution like the trying other HFNs; as this will recover packet loss.
-DL resolution: UE specific?
    -Vdf wants to know what the solution is and be convinced that it works.
    -Samsung considers in this case, detection of the issue can be done in UE through trying HFNs and UE can report through cell update confirm addition.
    -Vdf would like that detection of the issue should be discussed.
    -Nokia points out in this case there is no guarantee that all UEs will be able to detect the issue.
    -Alu considers the proposal E by Nokia is preferred.
    -Infineon considers that the cell update improvement will only be useful if HFN has incremeted by more than one wrap-around
-The group agrees with proposal 1: there is an issue to solve.
-Nokia to report after coffee break on the status:
    -the group agrees with proposal 2
    -whether the detection mechanism should be specified if FFS
Way forward:
    -agree RRC CR in principle
        -The CR had been submitted at the last meeting.
        -Tdoc for the CR is R2-096082
    -Finalize detection discussion at the next meeting. The discussion can continue by email
    -Email discussion to discuss detection mechanism (for DL)
        -to address CsoHS case or also other cases
        -How much it should be specified