Demystifying 3GPP

and the essential role of Qualcomm in leading the expansion of the mobile ecosystem

August 2017

@qualcomm_tech

The revolutionary impact of mobile broadband

High-speed wireless Internet access—in the palm of your hand and on-the-go

~4.4B Mobile broadband connections[1] surpassed fixed in 2010

591 4G LTE networks have been launched in 189 countries[2]

~47 Smartphones ship every second Over 1.5 billion units in 2016[3]

2h 51m The average time a consumer spent on their smartphone per day[4]

~$3.3T Global revenue generated by mobile value chain in 2014—directly responsible for 11 million jobs

At the foundation is evolving 3G and 4G LTE wireless/cellular technology standards

1. GSMA Intelligence, Apr. '17; 2. GSA, May '17; 3. Gartner, May '17; 4. comScore, Dec. '16; 5. BCG, Jan '15

3GPP drives global standards for cellular technology

Develops global technical specifications for 2G, 3G, 4G and 5G wireless devices

18+
Years driving cellular tech evolution

12
Major releases

>1.2K
Tech specifications*

100,000s
Technical contributions

3rd Generation Partnership Project at-a-glance

550+
Member companies

16
Technical working groups

6-8
Working group meetings per year

2,000+
Man years in cumulative meeting time*

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

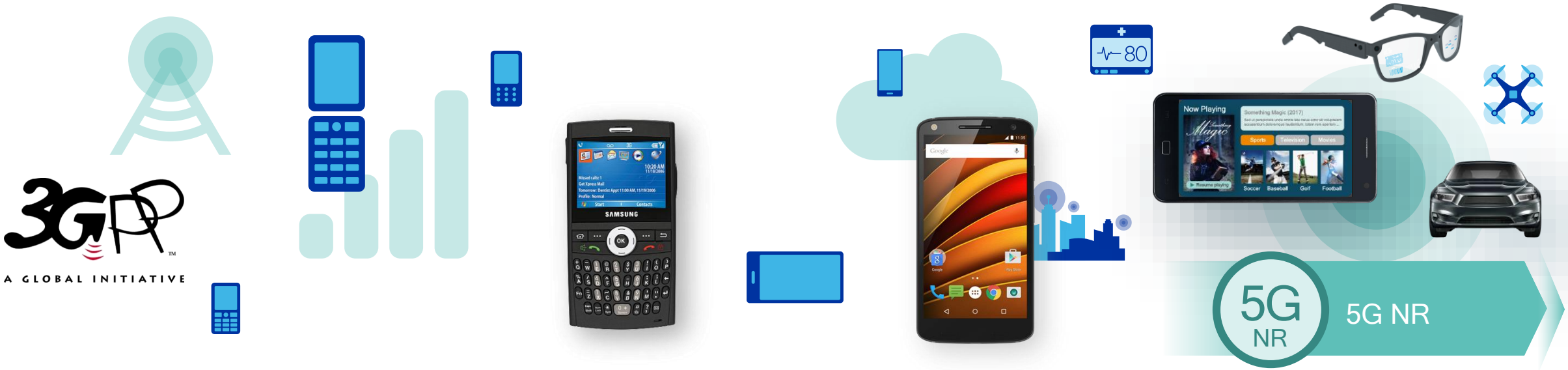
Collaborative engineering effort
Consensus-based, tech-driven effort across 100s of entities

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

* Source: 3GPP Mobile Competence Centre (3GPP Support Team) Summary Report from RAN#76 (RP-170872)

3GPP technologies have fueled mobile innovation

Delivering new levels of performance and efficiency over multiple generations



2G	3G	4G	5G NR
GSM/EDGE	UMTS / HSPA / HSPA+	LTE LTE Advanced	LTE Advanced Pro
1990s	2000s	2010s	2020s
Digital voice	Mobile data	Mobile Internet	Mobile expansion

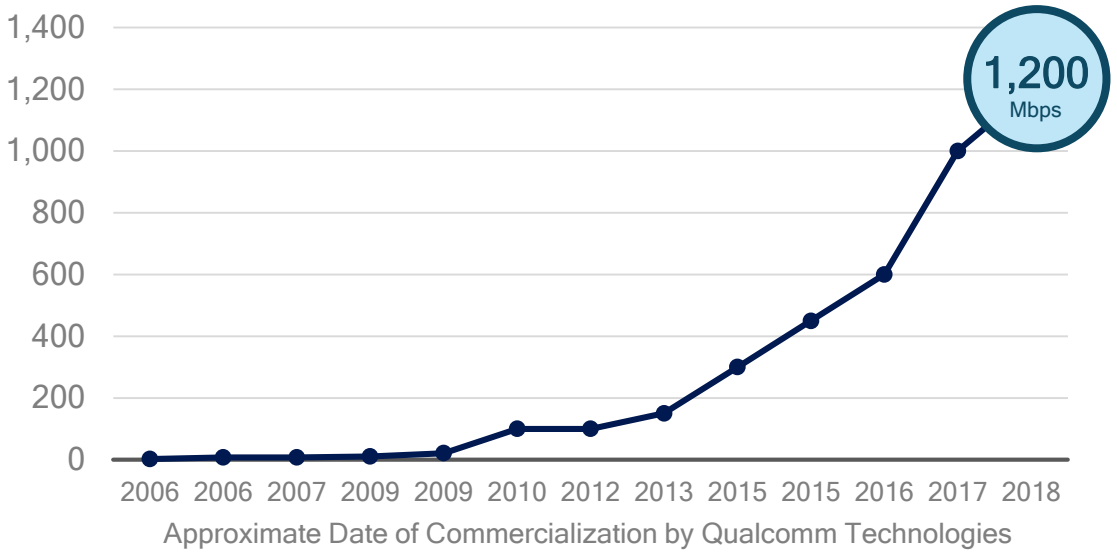
3GPP started 1998 after introduction of 2G, but has been responsible for GSM/EDGE evolution since 1998

Last 15+ years focused on faster, better mobile broadband

Delivering innovations to address the ever-increasing data demand

As wireless technology advances, providing more throughput…

Peak download speed supported in modem (Mbps)

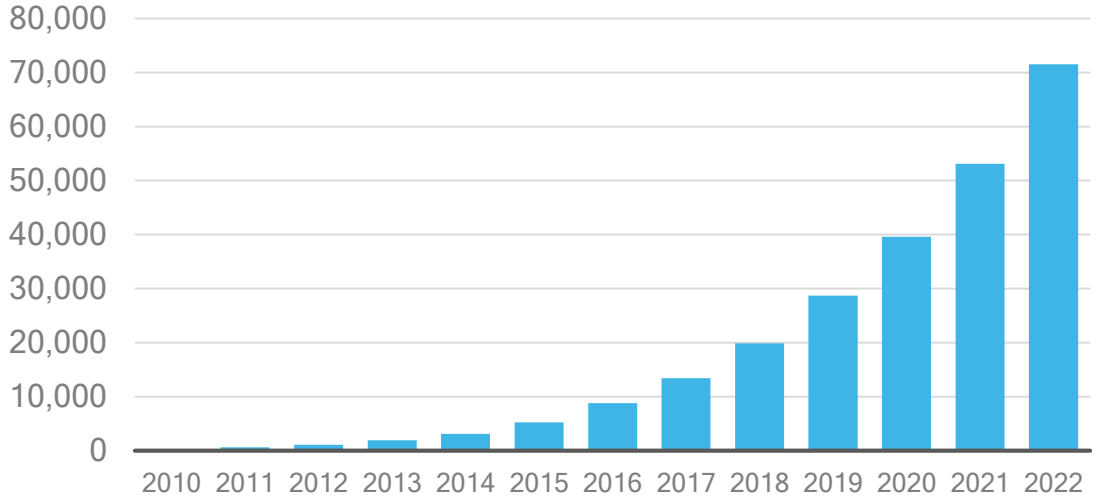


>650x growth

in peak download speeds from early 3G devices

…market demand evolves toward a world of data

Global mobile data traffic (Petabytes per month)



>250x growth

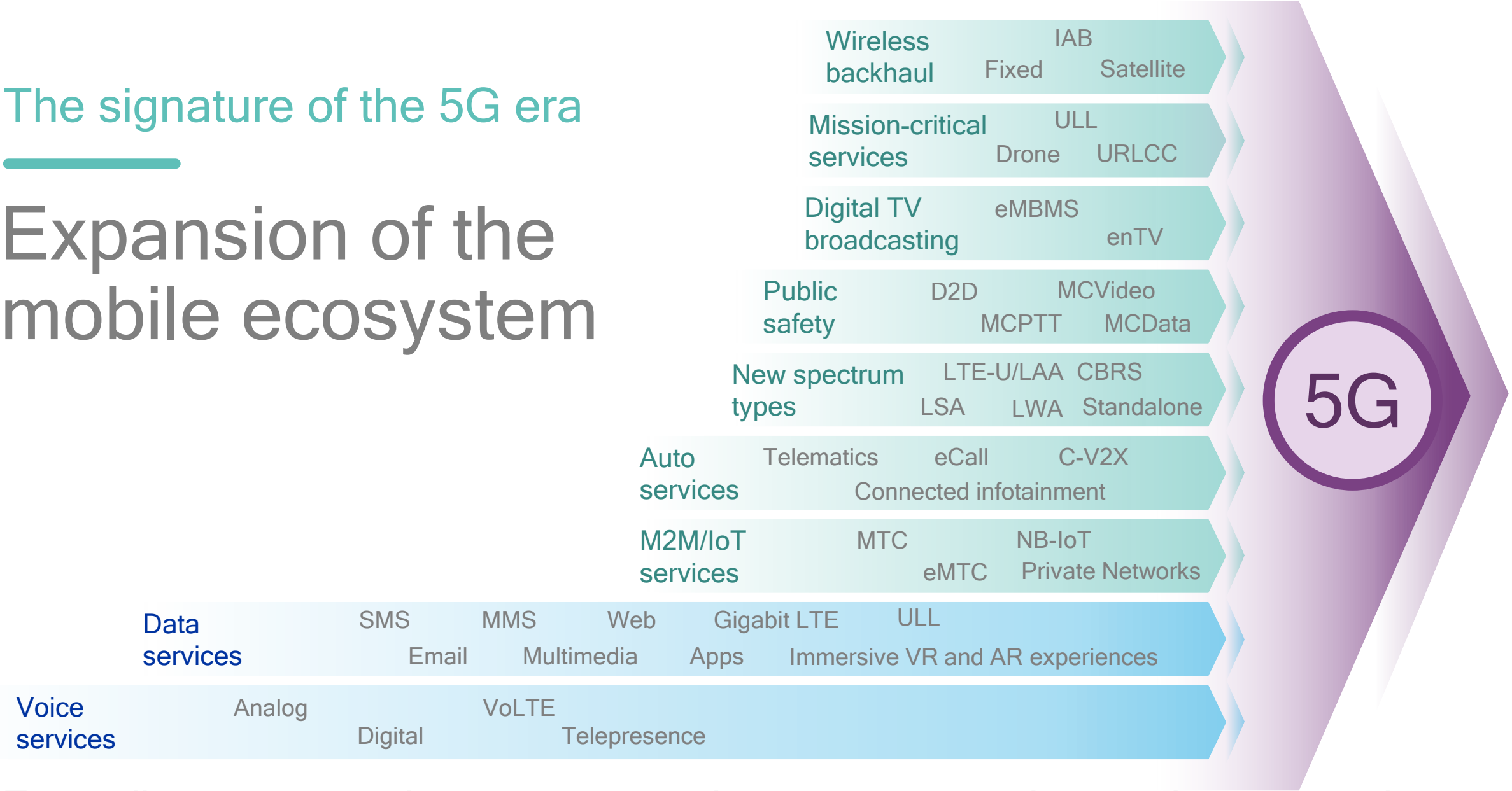
in data traffic between 2010 and 2022

Source: Qualcomm Technologies, Inc.; subject to network availability

Source: Ericsson's Mobility Report 2017

The signature of the 5G era

Expansion of the mobile ecosystem



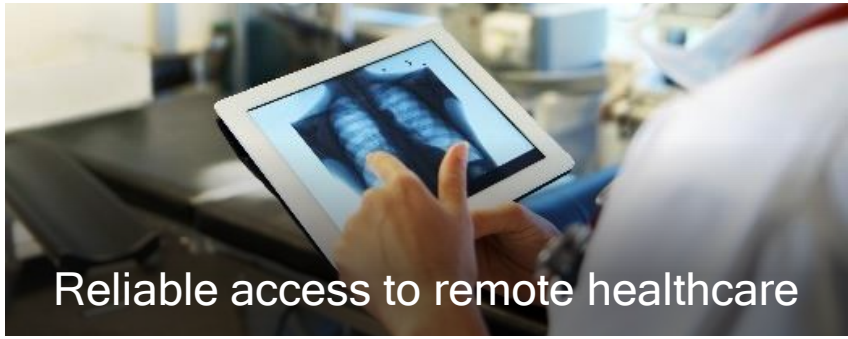
Expanding to new verticals, spectrum, deployments, services and user experiences

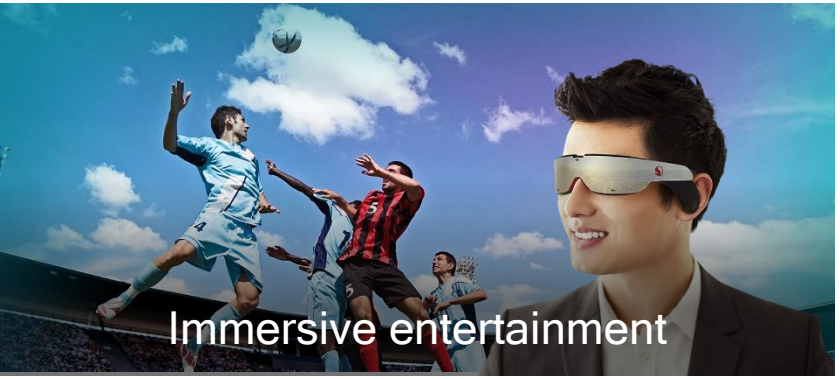
5G expansion will redefine a wide range of industries

A platform for new connected services–existing, emerging and unforeseen

Ultra-high fidelity media anywhere


Safer, more autonomous transportation


Reliable access to remote healthcare

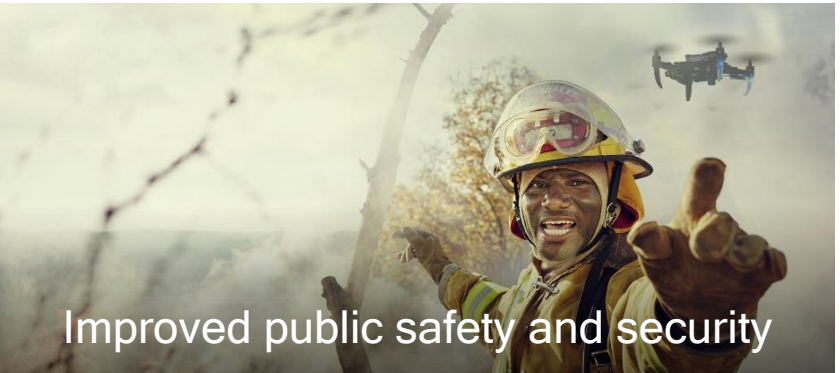

Immersive entertainment

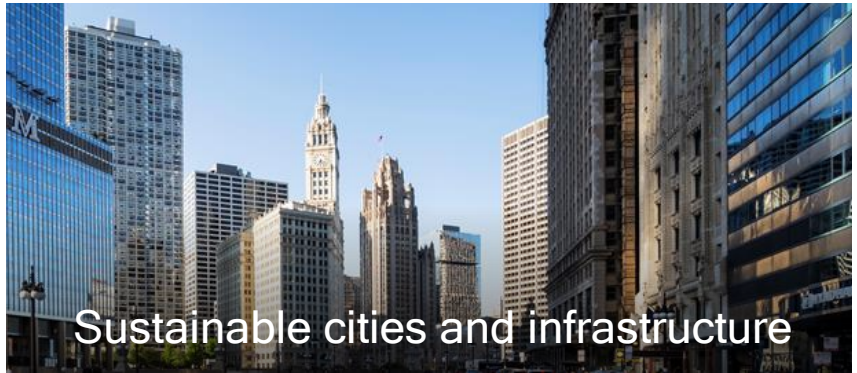
>$12 Trillion

Worth of goods and services by 2035

Learn more at: 5G Economy Study


More efficient use of energy/utilities


Improved public safety and security


Sustainable cities and infrastructure


More autonomous/digitized factories

Demystifying the organization and working procedures of 3GPP

The basics

3GPP is a partnership of seven global SSOs

Formed to create and maintain global wireless communications standards

Regional Standard Setting Organizations (SSOs)[1]

Prepares, approves, enhances and maintains globally applicable tech specifications

Transpose 3GPP specs into standards[3]; also responsible for IPR[2] policy for 3GPP members[4]

Ensures compliance with industry requirements

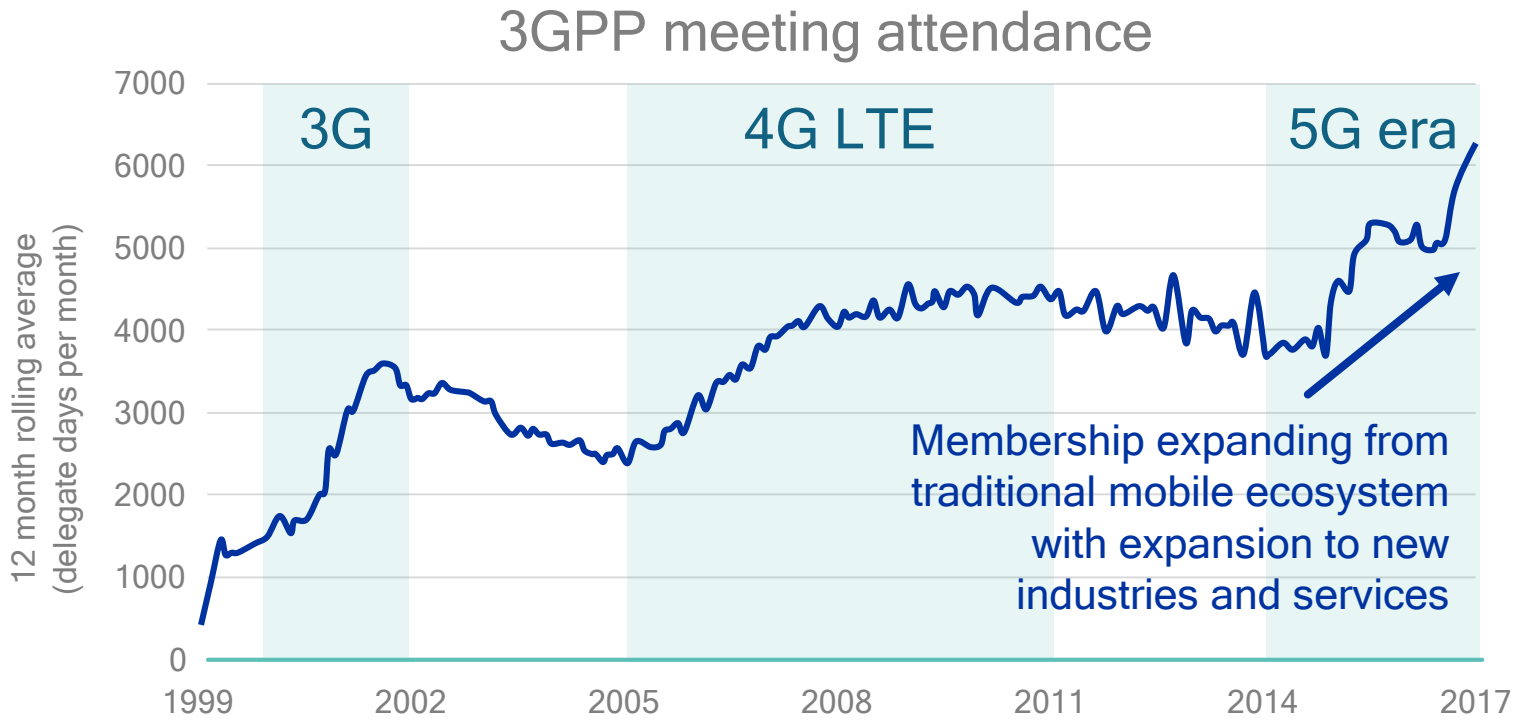
Seamless interoperability between vendors

Delivers global scale necessary for mobile

1. Also Market Representation Partners that provide guidance on market dynamics and requirements, e.g. GSMA, NGMN; 2. Intellectual Property Rights; 3. Regional SDOs transpose 3GPP specs into national standards – ITU responsible for transposing 3GPP specs into international standards; 4. In order to participate in 3GPP, individual members must formally join one of SSOs

3GPP is an expanding, member-driven organization

Substantial effort and collaboration across 100s of organizations



500+ members from across 40+ countries

- Network operators
- Device manufacturers
- Chipset manufacturers
- Infrastructure manufacturers
- Academia
- Research institutions
- Government agencies

Over 2,000+ delegate man years in cumulative meeting time since 1998

Participants in 3GPP meetings are engineers and discussions are purely technical in nature

* Source: 3GPP Mobile Competence Centre (3GPP Support Team) Summary Report from RAN#76 (RP-170872)

3GPP defines complete end-to-end system specifications

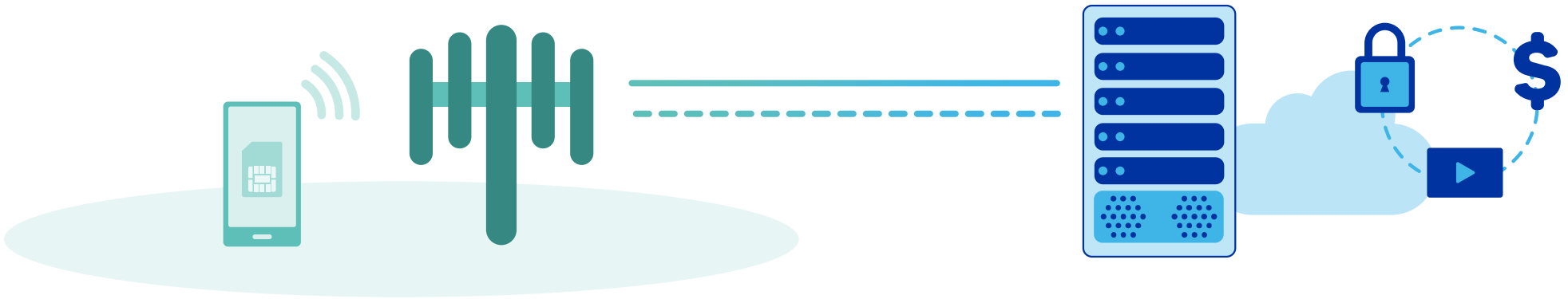
Encapsulates all essential elements to define the overall network

Radio Access Network (RAN)

Implements radio access technology, e.g. LTE, managing radio link to connect UEs to core network

Services

Framework for service architecture, capabilities, multimedia and charging



User Equipment (UEs)

Devices, e.g. smartphones, that connect to services via radio access technology

Core Network (CN)

Manages the RAN, e.g. mobility mgmt., and routes data to outside world, e.g. Internet

The scale and complexity of technology requires division of technical problems and work into smaller, specialized pieces in 3GPP

3GPP is a distributed, systems-engineering effort

Technical work occurs across 3 TSGs and 16 specialized WGs*

Radio Access Network (RAN)

Defines the radio communications between UEs and core network

RAN WG1
Layer 1 (Physical) spec

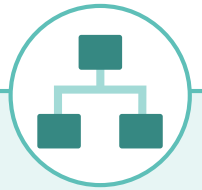
RAN WG2
Layer 2 and 3 (RR) protocols

RAN WG3
Access network interfaces + O&M

RAN WG4
Performance requirements

RAN WG5
UE conformance testing

RAN WG6
Legacy RAN, e.g. GSM, HSPA



Service/System Aspects (SA)

Responsible for overall architecture & service capabilities

SA WG1
Service requirements

SA WG2
Architecture

SA WG3
Security

SA WG4
Codecs, multimedia system

SA WG5
Telecom management

SA WG6
Mission-critical services

Core network & Terminals (CT)

Responsible for core network; defines terminal interfaces & capabilities

CT WG1
Mobility Mgmt, Call Ctrl, Session Mgmt

CT WG3
Policy, QoS and Interworking

CT WG4
Network protocols

CT WG6
Smart card application

* 3 Technical Service Groups (TSGs) and 16 Working Groups (WGs)

Each TSG/WG has elected Chair- & Vice Chairpersons

Elected from member companies – must be impartial and act on behalf of 3GPP

- Responsible for overall management/progress of technical work within their Group
- Manage meeting agenda based on individual member contributions
- Ensure compliance with 3GPP working procedures and policies
- TSG elections are held every two years; serve a maximum of two terms

Example

Dino Flore (right) passes 3GPP RAN Chairman bell to Balázs Bertényi of Nokia Corporation

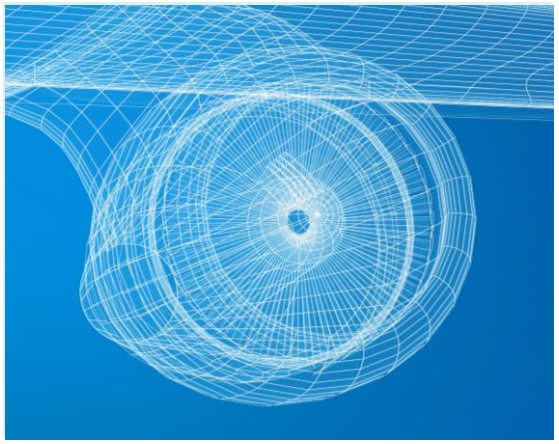
Dino Flore

Qualcomm Technologies, Inc.

Successfully served as RAN Chairman from 2013-2017; led the expansion the mobile ecosystem on path to 5G

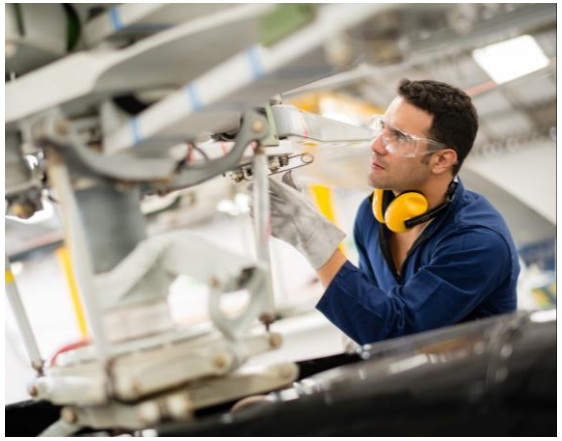
3GPP is a collaborative, system-engineering effort

Managed like any other complex system-engineering effort, e.g. designing a jet plane



1 Early R&D and project proposal to management

2 Break project into specialized areas, e.g. jet engine



3 Feasibility study and explore different technical solutions

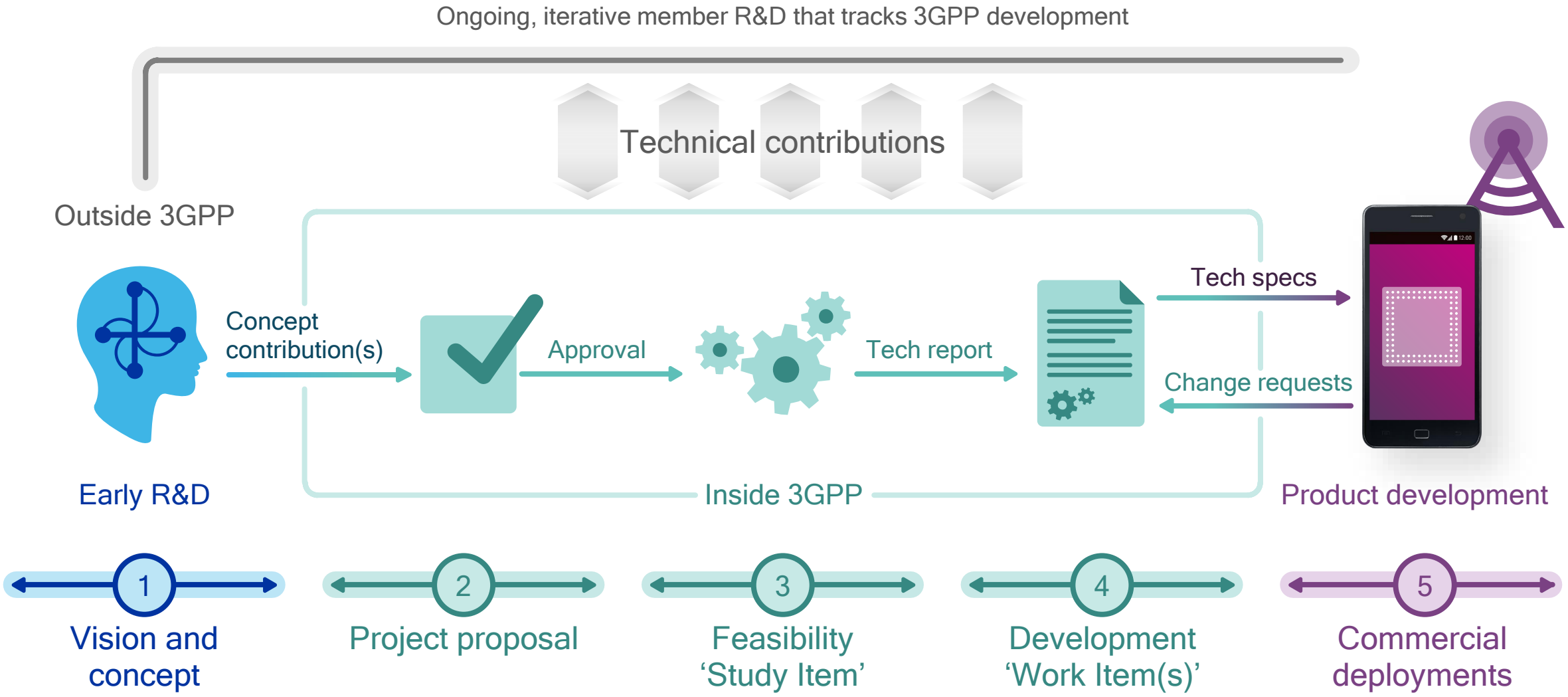
4 Develop solution(s) based on agreed work plan

3GPP A GLOBAL INITIATIVE

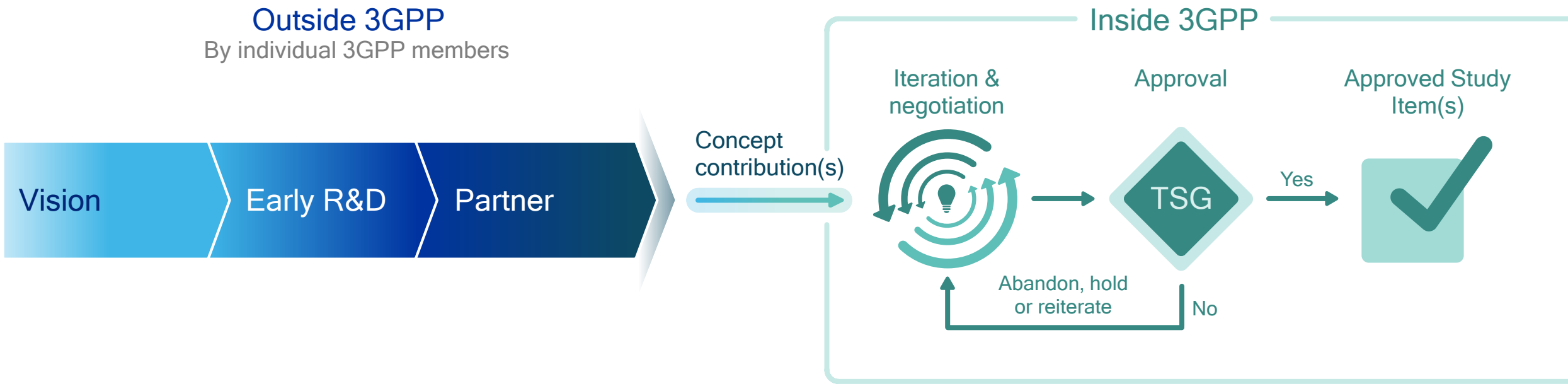
3GPP develops technical specifications (vs. jet planes), is constrained by meeting time (vs. OPEX) and is a collaborative effort across 100s of different entities with potentially diverse interests/incentives

3GPP is a collaborative, system-level engineering effort

And thus, the 3GPP work-flow and working procedures reflect this



Early member R&D fuels new innovations



1 Vision and concept

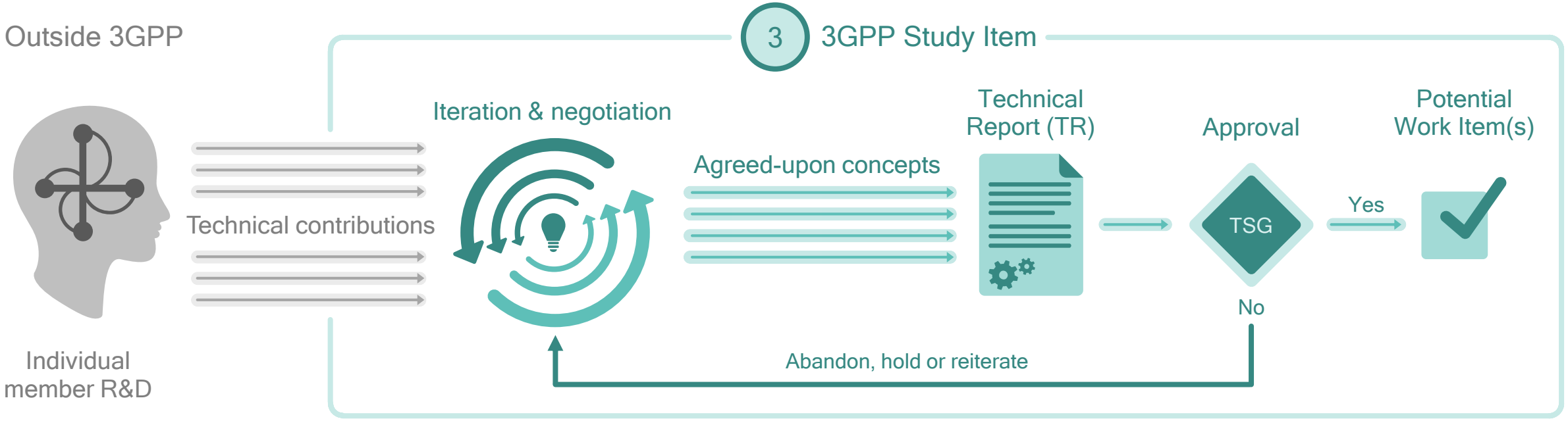
- Define compelling problem or need
- Specify requirements and constraints
- Develop early design and technologies
- Garner support and test assumptions
- Submit 3GPP ‘concept’ tech contribution

2 Project proposal

- New feature may be initiated by any member
- Must have support of at least 4 individual members
- Usually iterate on concept over multiple meetings
- New work activity must be approved by TSG plenary
- Approval results in approved Study Item(s)

3GPP feasibility Study Item

Evaluates multiple tech options/solutions



Members submit tech docs (contributions) to propose solutions and technologies

Contributions are made publicly available, discussed in 3GPP meetings (time permitting)

Decisions are tech-driven and result from consensus-based process open to all members

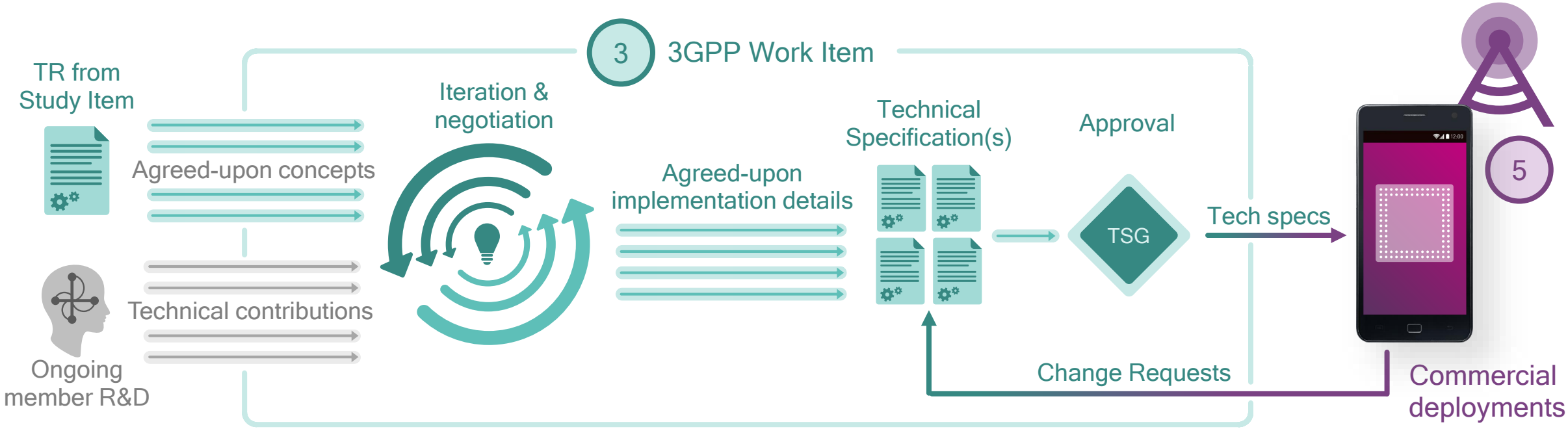
Process is iterative and non-linear–many discussions continue beyond 3GPP agenda

Agreed-upon concepts included in Tech Report–rarely untouched from initial contributions

Approved TR (by TSG) may result in corresponding Work Item(s)–may be less scope than Study

3GPP Work Item develops specification(s)

Based on agreed-upon concepts and solutions from Study Item[1]



Similar contribution-driven, iterative, consensus-based process to specify selected solutions

Complete list of active work-items make up 3GPP work-plan; available on 3GPP website

Each Work Item has supporting companies and rapporteur(s) – the WI manager(s)

Agreed-upon implementation details executed in Tech Specification(s) – either new or existing[1]

Once spec approved, changes can only be accomplished through formal 'change request'[2]

Released specs kick-off race to standards-compliant devices and infrastructure for deployments

[1] Not all Work Items are the result of a Study Item – may start directly and have some study phase at the start of the Work Item; [2] Updates to existing specifications accomplished via Change Requests (type of contribution);
[3] Change Requests are tracked rigorously since it can impact product development for manufacturers of chipset, infrastructure and User Equipment

Tech specs ultimate output of work completed in 3GPP

Over 1,200 active 3GPP technical specifications[1]

- 100s of technical contributions are submitted towards formation of single specification
- Each specification has a Rapporteur (editor and manager) following guidance of WGs
- Owned by a specific TSG – responsible for freezing specs when functionality is stable @ quarterly plenary
- Tech specifications are used by downstream manufacturers for product development
- Identified by a 5 digit number that categorizes specs into meaningful tech categories[2]

25.bbb	Radio access aspects	25.1bb: 25.2bb: 25.3bb: 25.4bb:	UTRAN radio performance UTRA layer 1 UTRA layers 2 & 3 UTRAN Iub, Iur & Iu interfaces

Technical spec example

RRC Protocol specification
(TS 25.331)

3GPP TS 25.331 V13.6.0 (2017-03)

Technical Specification

3rd Generation Partnership Project;
Technical Specification Group Radio Access Network;
Radio Resource Control (RRC);
Protocol specification
(Release 13)

>2,000 pages

1. Source: www.3GPP.com/specifications as of June 2017 2. See TR 21.900

New features are introduced via 3GPP Releases

Measure of real progress – new features are functionally frozen, ready for implementation

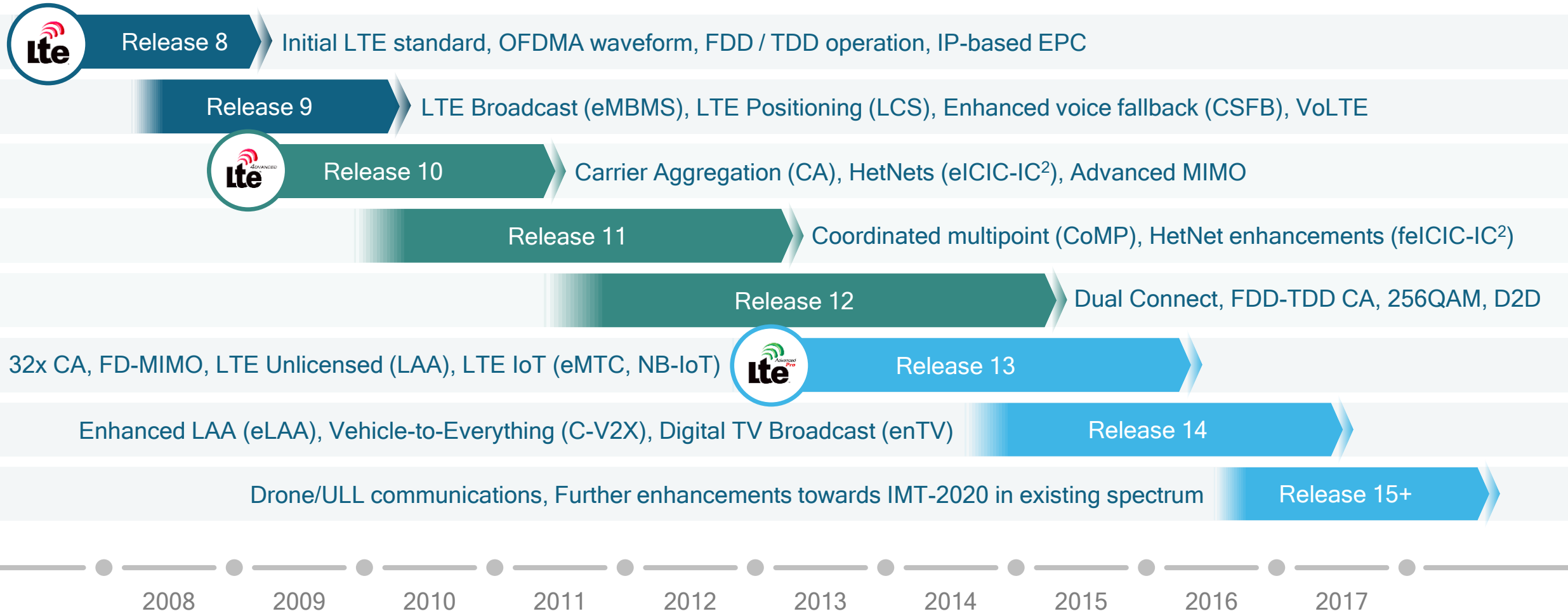
Self-contained – can build system based on the set of frozen specs in a Release

Staggered – 3GPP works on a number of Releases in parallel at different stages

Very similar to major Releases of Operating Systems

The feature-rich evolution of 4G LTE over 8+ Releases

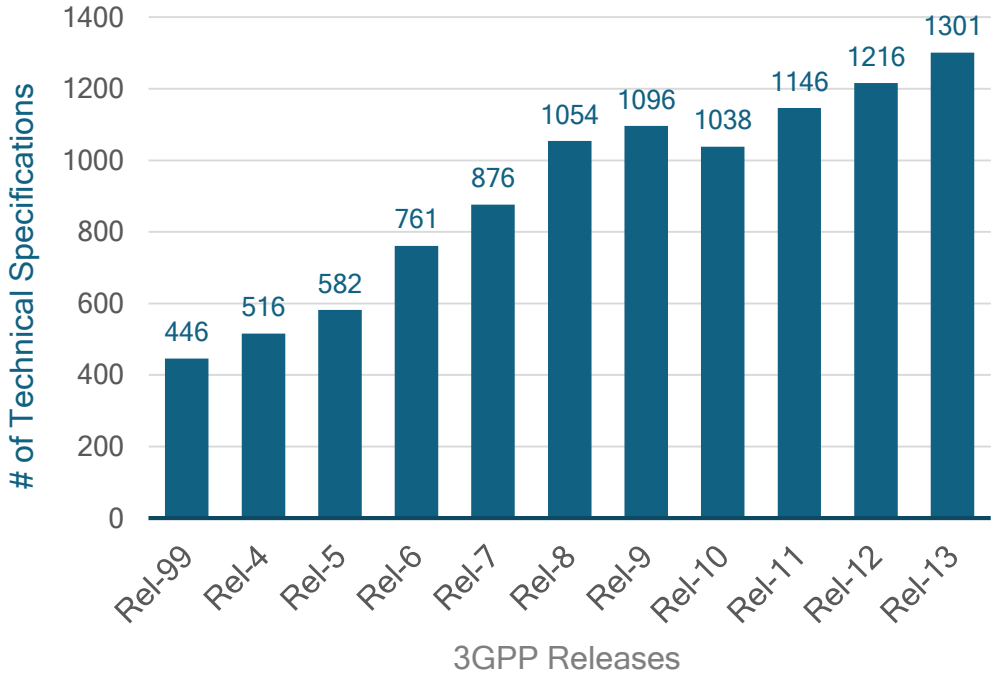
Introducing new features that add significant value to ecosystem



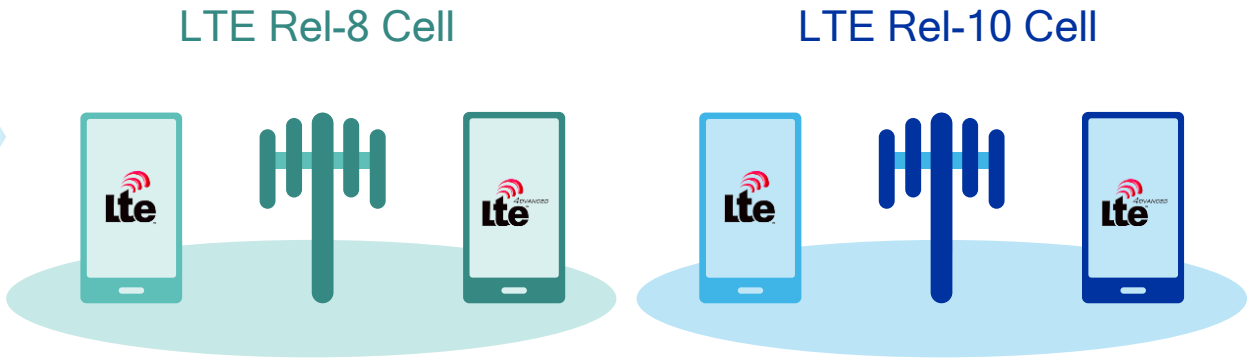
Dates represent Start and End dates for 3GPP Releases; Features shown are representative and do not reflect full-set of features

3GPP specifications evolve in highly iterative manner

Building on top of each other to enable backward compatibility



Example of backward compatibility



An LTE Rel-10 UE can work in a LTE Rel-8 cell

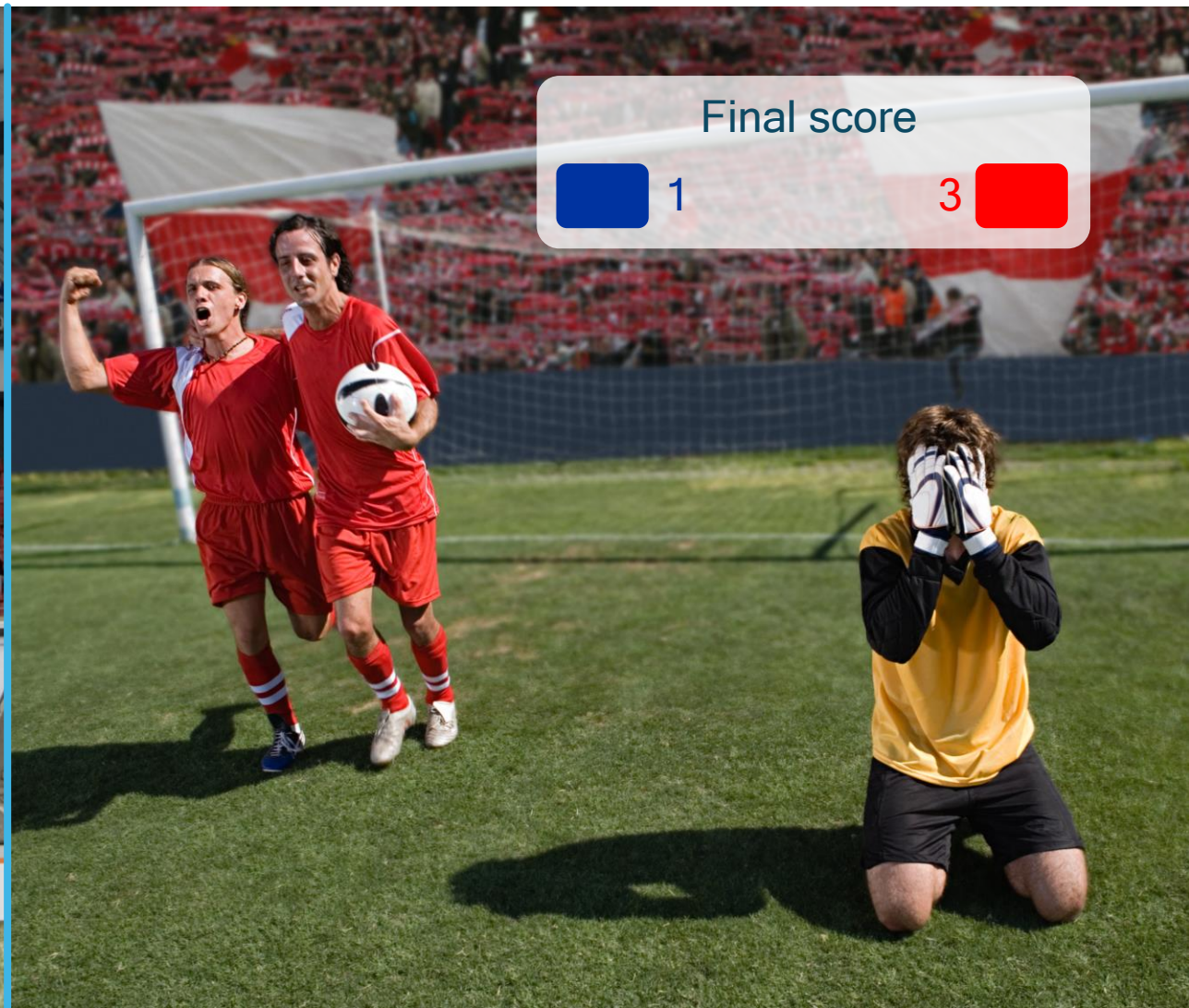
An LTE Rel-8 UE can work in a LTE Rel-10 cell

3GPP standards leadership

Driving end-to-end expansion of the mobile ecosystem

Some assert 3GPP leadership based on # of contributions

Analogous to asserting leadership in sports on the basis of time-of-possession



Contributions fuel process, but not all created equal

Quality (vs. quantity) of contributions far more essential to 3GPP leadership

3GPP technology decisions and specs are not made via a direct mechanism of acceptance or rejection of contributions

Many different types of contributions, including Change Requests – many do not contain new technology inventions

Difficult to assess impact of any single contribution – most focused on one part of one feature or studies that do not get standardized

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Recent example contributions

Introducing LTE in unlicensed spectrum
RP-131635 - Concept Contribution[1]

Way Forward on the 5G NR workplan
RP-170741 - Way Forward Contribution[2]

Physical layer options for LAA
RP-150477 - Seminal technical contribution

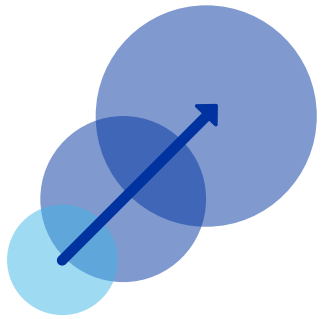
Introduction of new DL category
RP-171037 - Intro new UE category for 1.6 Mbps

FeMBMS/unicast-mixed carrier flag in measurement object
RP-171169 - Change Request

1 Submitted with Ericsson; 2 Submitted with 40+ other members - led by Qualcomm

Contribution counting is not a science

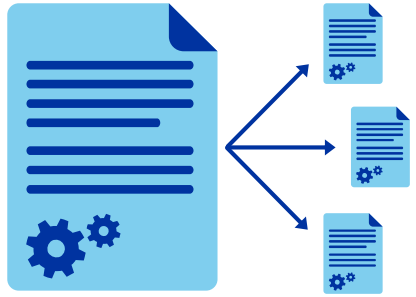
Easily manipulated, susceptible to interpretation, and encourages bad behavior



Siloed approach

Cellular technologies build upon previous work done both in- and outside of 3GPP

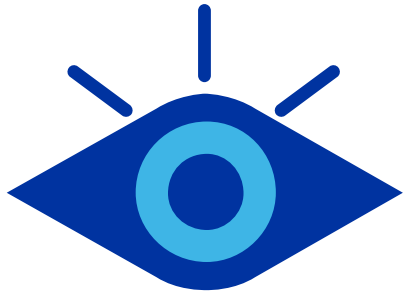
e.g., LTE adopts many technology concepts that first originated with 2G and 3G technologies incl. 3GPP2



“Stacking the deck”

Companies can provide incentives to 3GPP representatives to maximize contributions

Resulted in multiple WGs instituting a policy of “one contribution per company per agenda item”



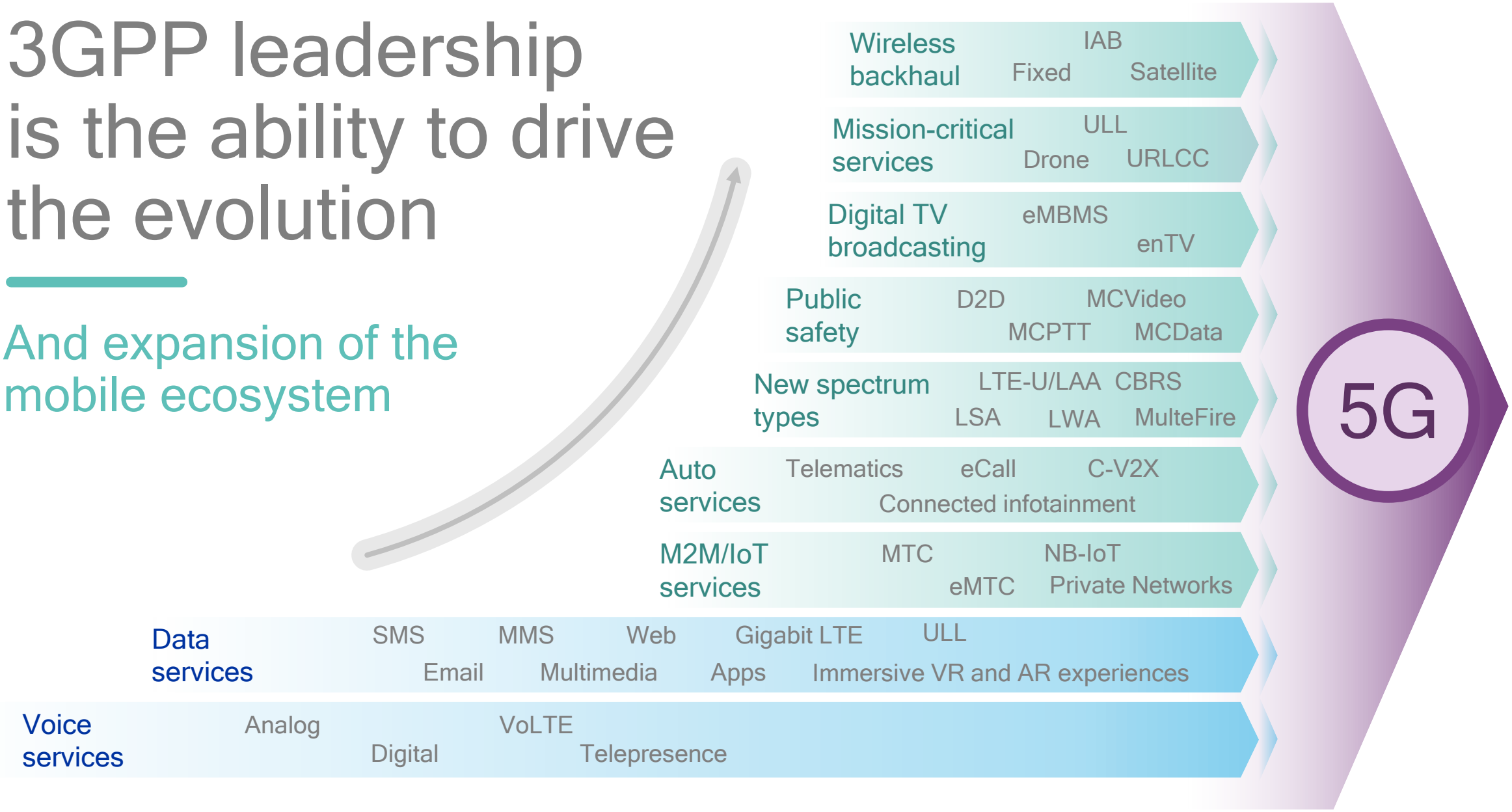
Interpreting the data

Databases built for engineers – not high-level analysis – open to interpretation and manipulation

Exemplified by inconsistencies between published reports on 3GPP contribution counting

3GPP leadership is the ability to drive the evolution

And expansion of the mobile ecosystem



Leading the evolution and expansion of the ecosystem

The true measure of 3GPP standards leadership

The proven desire and ability to build broad consensus across the ecosystem towards new directions

The proven expertise and ability to drive an end-to-end design through 3GPP

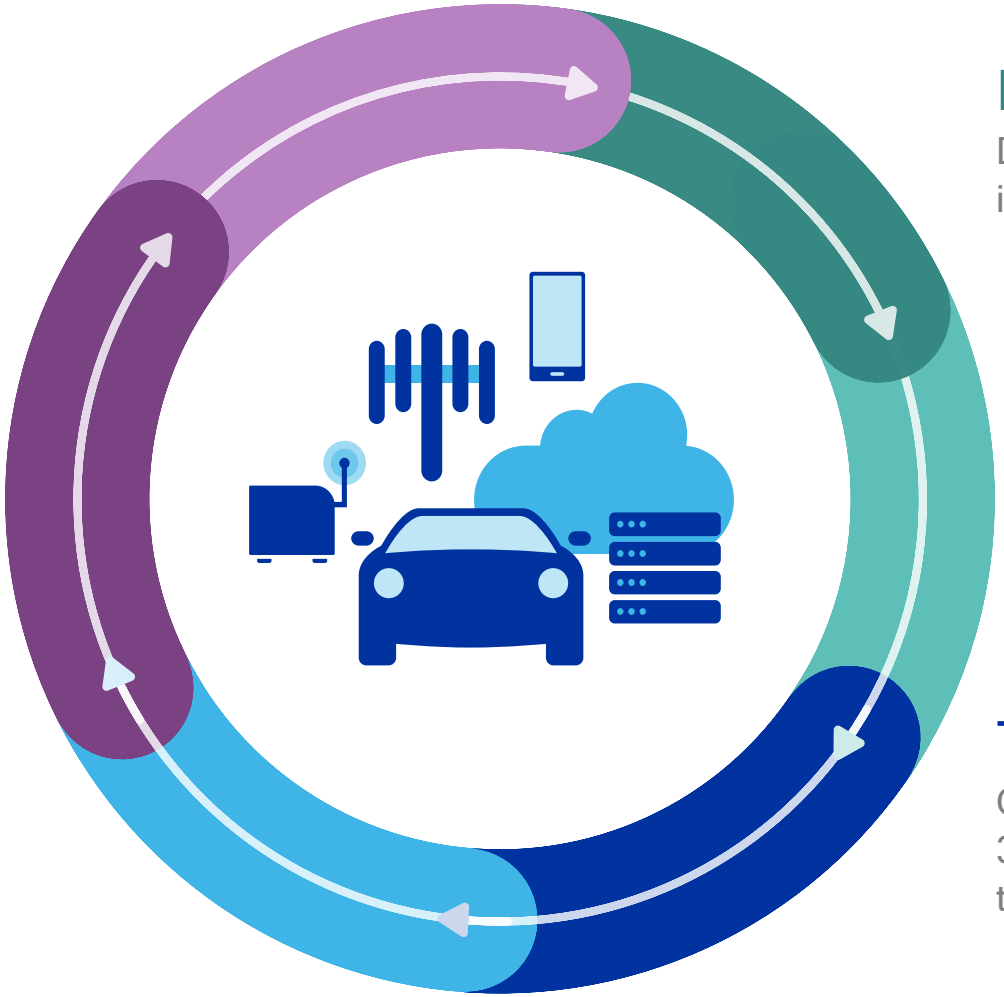
The foundation is end-to-end technology and R&D leadership

Foundation to 3GPP leadership is technology leadership

Early R&D and technology inventions essential to moving ecosystem to new areas

Invention
Invent new technologies and e2e system architecture

Proof-of-concept
Deliver end-to-end prototypes and impactful demonstrations



Vision
Identify a problem or need; establish requirements

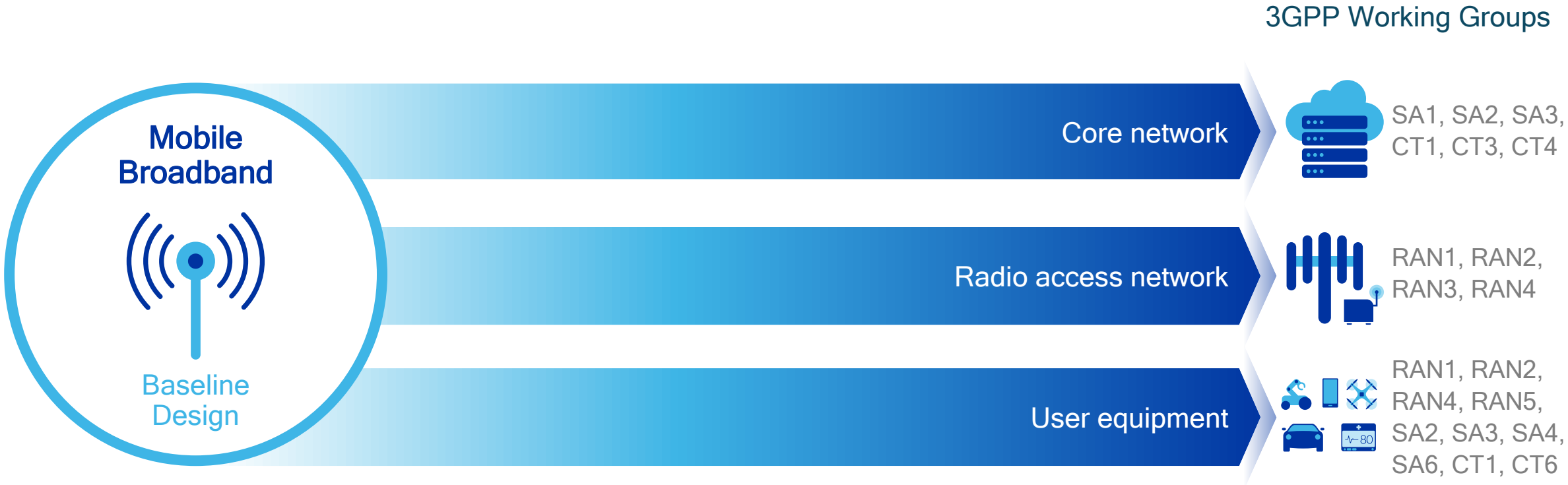
Standardization
Drive e2e design with ecosystem and through standards process

Commercialization
Engage with global network operators to deploy new features with standards-compliant infrastructure and devices

Trials
Collaborate on OTA field trials that track 3GPP standardization and drive ecosystem towards rapid commercialization

In 3GPP, system design is done in piecemeal fashion

Block-by-block decision process across 3GPP WGs with limited e2e supervision

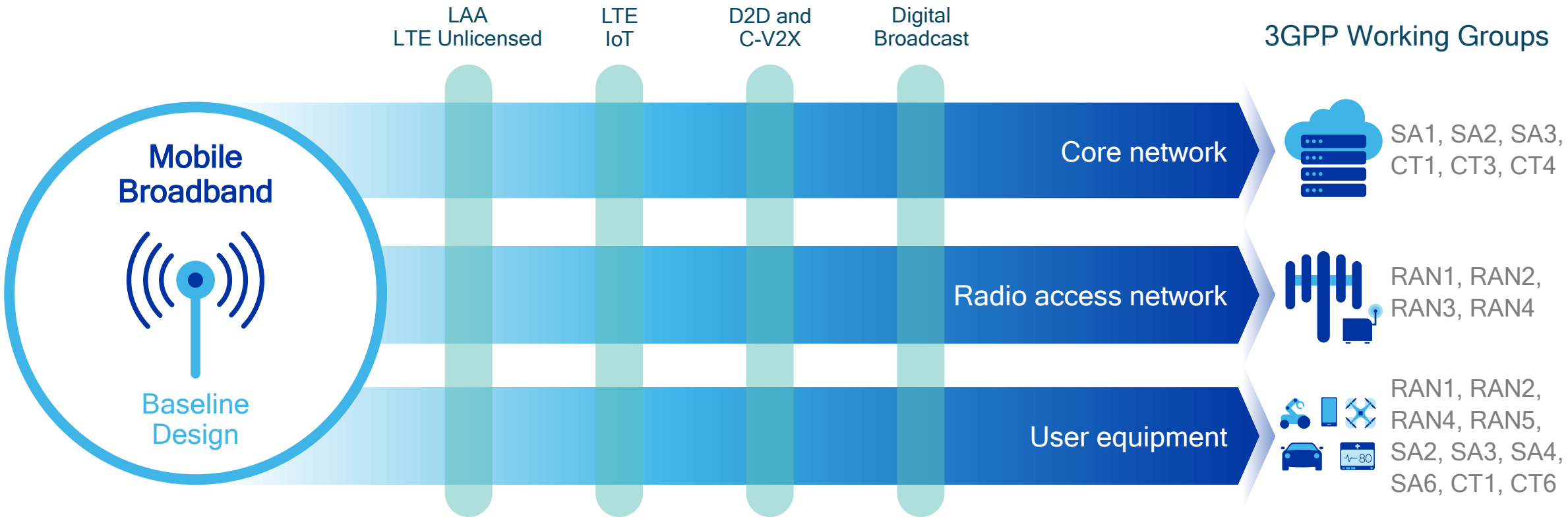


3GPP starts with defining cellular systems for mobile broadband*

* For 4G LTE and 5G NR; 2G and 3G systems started from voice

Expanding into new areas requires an e2e approach

The ability to drive an end-to-end design across multiple 3GPP Working Groups



Each new area requires creating a new sub-system built on top of 'baseline'

Adjusting, optimizing, and redesigning procedures across all layers to address the new requirements

The essential role of Qualcomm in leading the expansion of the mobile ecosystem

30+ years of driving the evolution and expansion of the mobile ecosystem

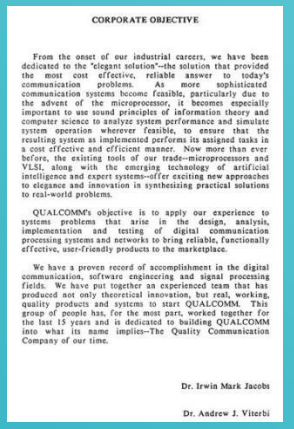
Solving system-level problems is in our DNA

Qualcomm's mission statement

"Qualcomm's objective is to apply our experience to **systems problems** that arise in the design, analysis, implementation and testing of digital communication processing systems and networks to bring reliable, functionally effective, user-friendly products to the marketplace."

Dr. Irwin Mark Jacobs
Dr. Andrew J. Viterbi
July 1, 1985

Qualcomm founders



CORPORATE OBJECTIVE

From the onset of our industrial careers, we have been dedicated to the "elegant solution"--the solution that provided the most cost effective, reliable answer to today's communication problems. As more sophisticated communication systems become feasible, particularly due to the advent of the microprocessor, it becomes especially important to use sound principles of information theory and computer science to analyze system performance and simulate system operation wherever feasible, to ensure that the resulting system as implemented performs its assigned tasks in a cost effective and efficient manner. Now more than ever before, the existing tools of our trade--microprocessors and VLSI, along with the emerging technology of artificial intelligence and expert systems--offer exciting new approaches to elegance and innovation in synthesizing practical solutions to real-world problems.

QUALCOMM's objective is to apply our experience to systems problems that arise in the design, analysis, implementation and testing of digital communication processing systems and networks to bring reliable, functionally effective, user-friendly products to the marketplace.

We have a proven record of accomplishment in the digital communication, software engineering and signal processing fields. We have put together an experienced team that has produced not only theoretical innovation, but real, working, quality products and systems to start QUALCOMM. This group of people has, for the most part, worked together for the last 15 years and is dedicated to building QUALCOMM into what its name implies--The Quality Communication Company of our time.

Dr. Irwin Mark Jacobs

Dr. Andrew J. Viterbi

Our system-level inventions fuel the mobile industry

Taking significant risks to start early with an end-to-end design

>$46 Billion*

In research and development

QUALCOMM®

*Cumulative expenditures to date since 1985

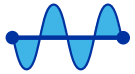
Qualcomm has led the evolution and expansion of LTE

Delivering fundamental systems-level inventions and driving e2e design in 3GPP

Carrier aggregation

Hybrid ARQ

Fast link adaptation



OFDMA, SC-FDMA waveforms

CoMP

CSFB

LTE-U/LAA/ eLAA

MulteFire

Lower power consumption technologies, e.g. DTX/DRX

LTE Broadcast (eMBMS)

Small cells interference management

LWA

Handover procedure

Small cell self-configuration techniques

Advanced MIMO technologies, e.g. UL MIMO

LTE Direct and C-V2X

Leading in 5G requires

4G LTE leadership

Our LTE advancements are expanding the mobile ecosystem

Essential to leading in 5G

Leading the expansion of LTE to unlicensed spectrum

Licensed Assisted Access (LAA)

Technology and R&D leadership

MWC 2014: First demo (Wi-Fi coexistence)
MWC 2015: First live LAA demo
MWC 2016: First live eLAA demo

3GPP standards leadership

3GPP™
A GLOBAL INITIATIVE

Introduced concept Dec 2013 and pioneered work in 3GPP across multiple working groups

Impactful trials with network operators

First over-the-air trials, LAA with DT Nov 2015 and eLAA with SK Telecom Sep. 2016

Industry-first chipsets

Qualcomm Snapdragon™

Qualcomm® Snapdragon™ X16 LTE modem

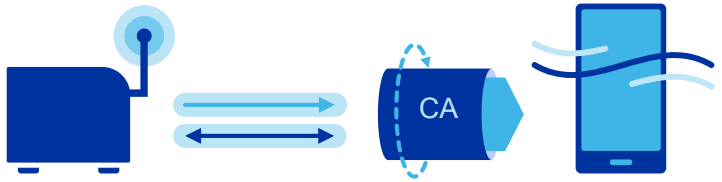
Announced industry's first modem to support LAA in Feb '16; Commercial devices have since launched

Qualcomm Snapdragon is a product of Qualcomm Technologies, Inc.

Our technology inventions drove the LAA standard

- Floating frame structure and signaling
- Dynamic UL-DL sub-frames per TxOP
- LBT self-deferral for synchronization
- Multi-carrier LBT
- UL-interlaced waveform
- Dynamic TX power per TxOP
- Multi-TTI UL grants
- Cross-TxOP triggered UL grants
- Self-schedule DL & cross-carrier UL scheduling

3GPP A GLOBAL INITIATIVE



LAA part of Release 13

Boosts downlink data rates and capacity—key aspect for Gigabit LTE

5G NR

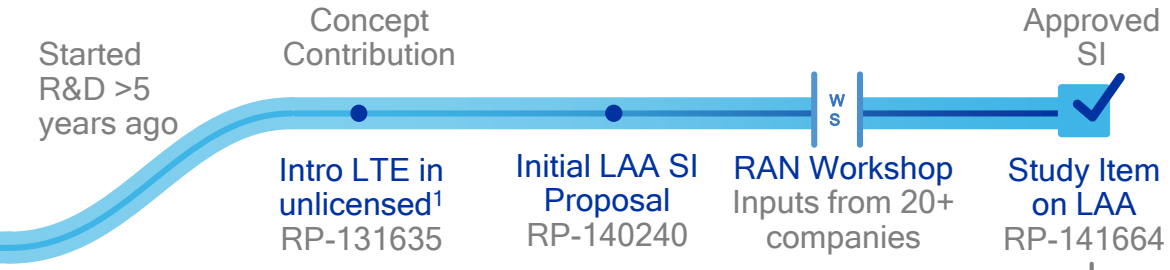
Broadening to new areas

- Enhancing LAA, e.g. UL (eLAA, feLAA)
- Standalone operation with MulteFire™
- New deployment types, e.g. Private IoT
- New capabilities/efficiencies with 5G NR

Pioneered and led work on LAA in 3GPP – part of Rel-13

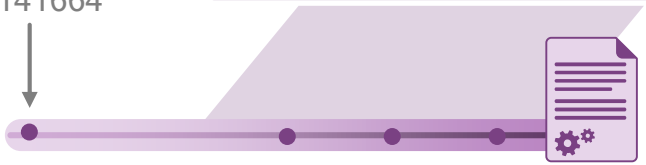
Building broad consensus across ecosystem and driving e2e design across WGs

Led project proposal phase in RAN TSG



"Physical layer options for LAA"[2], R1-150477
"Adaptive frame structure and DL-UL configuration", R1-150977
"Discovery procedure, RRM, CQI measurement, and reporting", R1-150998
"Reservation signal design for LAA", R1-151406
"Multi-carrier LBT operation for LAA", R1-152784

Delivered numerous seminal contributions during Study Item in RAN1



Study complete TR 36.889

"Proposal for coexistence testing"[4], R4-156326
"Way forward on band definition", R4-156785
"Way forward on coexistence tests", R4-158436

Drove Wi-Fi coexistence testing[3] & band definition during Work Item in RAN4

New Work Item on LAA RP-151045

3GPP-IEEE-WFA workshop on coexistence

WI complete Updates to 16 existing specs

Led continued work in SA1/2 on USOS[5] + RAN4 on multi-node coexistence tests[6]

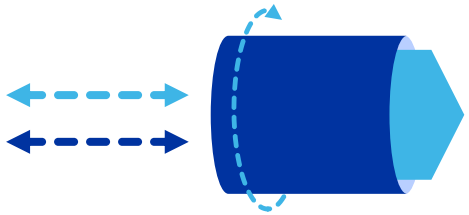
2013 2014 2015 2016

[1] Made in collaboration with Ericsson; [2] Such as Load Based Equipment channel access protocol, DRS-based RRM procedure, Reservation signal; [3] Led engagements with IEEE and WFA; [4] Also R4-156327;
[5] Unlicensed Spectrum Offloading System-enhancements - design work related to identification of traffic carried over unlicensed spectrum (reporting from RAN to CN) to be used for charging, etc. and for regulatory reasons;
[6] R4-1706224 - "Way Forward on Multi-node tests" - Introduces ability to have coexistence tests among LTE base stations and Wi-Fi Access Points for LAA

Initial work on LAA broadening to new technology areas

Qualcomm continuing to lead the way

Evolving LAA with new functionality and enhancements



E.g., UL and DL aggregation

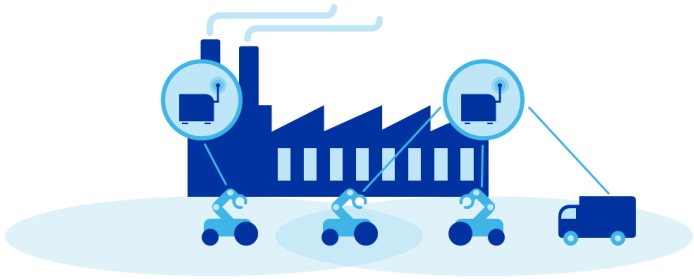
Drove key technologies in 3GPP[1]; first OTA demo at MWC 2016; first OTA field trial with SKT Sep 2016

Opening up new opportunities with MulteFire™

LTE operation solely in unlicensed spectrum

Introduced concept[1] in June 2015; founding member of MulteFire alliance; first OTA demo at MWC 2017

Extending to new deployment types, e.g. Private IoT



Factories, ports, mines, warehouses smart buildings, …

First demo[3] in CBRS shared spectrum Feb 2017 (venues, enterprise); Industrial IoT demo[4] at MWC 2017

3GPP is studying NR in unlicensed spectrum

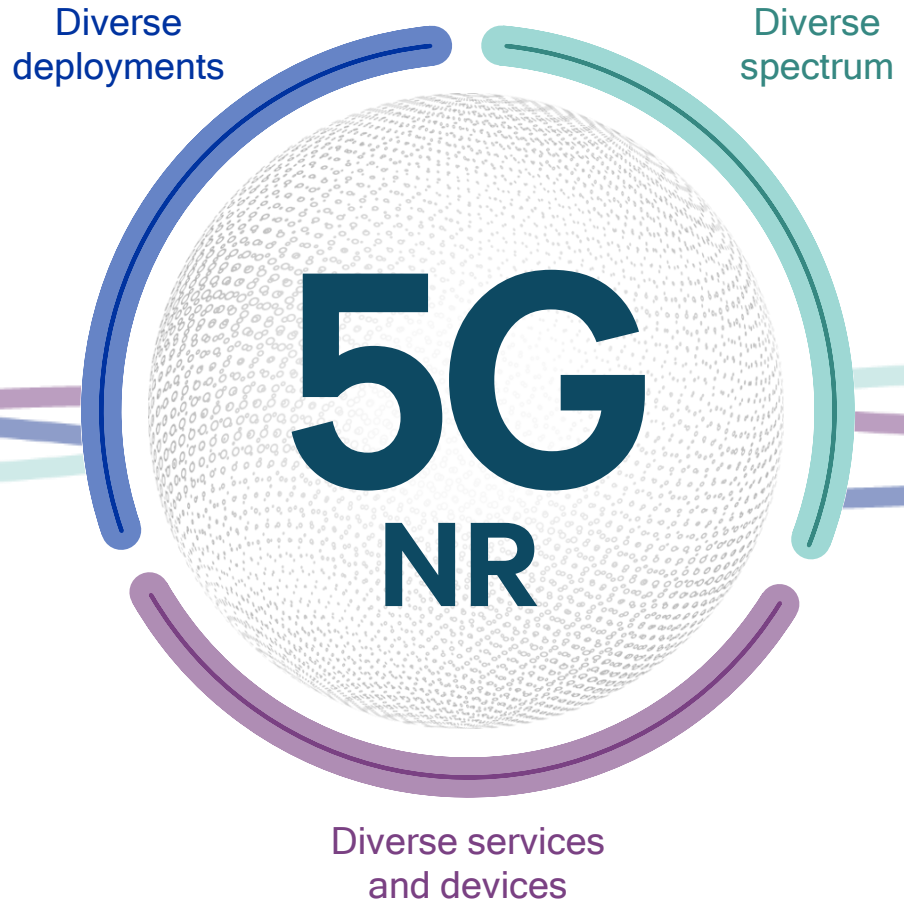
Licensed-assisted and standalone operation

Drove new Release 15 Study Item that was approved in March 2017 RAN plenary with Qualcomm as rapporteur

[1] E.g., "New interleaved UL waveform: to satisfy bandwidth and PSD constraints" R1-150477; [2] OnQ Blog: "Introducing MulteFire: LTE-like performance with Wi-Fi-like simplicity"; 3 with Nokia and Alphabet's Access Group; 4 with Nokia and GE

Making 5G NR a reality

Leading the technology inventions to meet an extreme variation of requirements



QUALCOMM®

Making 5G NR a reality

Best-in-class 5G prototype systems and testbeds

Test, demonstrate and verify our innovative 5G designs to contribute to and drive standardization

5G standards, technology and research leadership

3GPP™

A GLOBAL INITIATIVE

Such as advanced channel coding, self-contained subframe, mobilizing mmWave, …

Impactful trials and early deployments with network operators

Over-the-air interoperability testing leveraging prototype systems and our leading global network experience

Modem and RFFE leadership to solve 5G complexity

Qualcomm Snapdragon X50 5G Modem Family

Announced the world's first 5G NR multimode modems for premium smartphones in 2019

Qualcomm Snapdragon is a product of Qualcomm Technologies, Inc.

Our technology inventions are driving the 5G NR standard

- Scalable OFDM numerology
- Multi-user Massive MIMO
- Advanced LDPC channel coding
- Self-contained TDD sub-frame
- Low-latency slot structure design
- Adaptive beamforming/tracking (mmW)

5G NR

R&D leadership

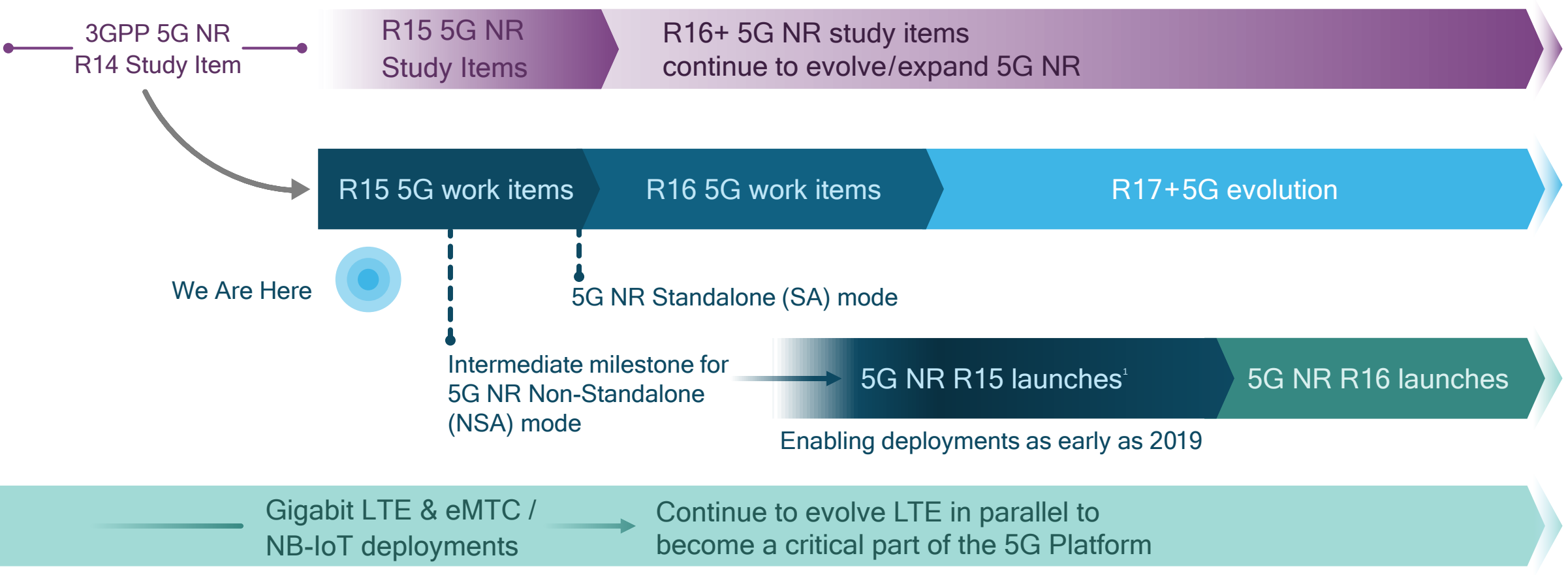
First successful 5G NR connection based on 3GPP

3GPP A GLOBAL INITIATIVE

Standards leadership

Technologies part of ongoing 5G NR Study Item

Accelerating 5G NR, the global standard for 5G



1. Forward compatibility with R16 and beyond

Qualcomm led way forward on 5G NR eMBB workplan

RP-170741 agreed upon at 3GPP RAN #75 in March 2017

Stage 3 completion for 5G NR NSA by December 2017 (RAN#78)[1]

Stage 3 completion for 5G NR SA by June 2018 (RAN #80)[2]

Broad support to meet increasing mobile broadband needs with global 5G NR standard

AT&T NTT DOCOMO SK Telecom Vodafone Ericsson Nokia Qualcomm

Alcatel-Lucent Shanghai-Bell Alibaba Apple British Telecom Broadcom CATT China Telecom China Unicom China Mobile Cisco

Convida Wireless Deutsche Telekom Etisalat Fujitsu Huawei Intel Interdigital KDDI Korea Telecom LG Electronics

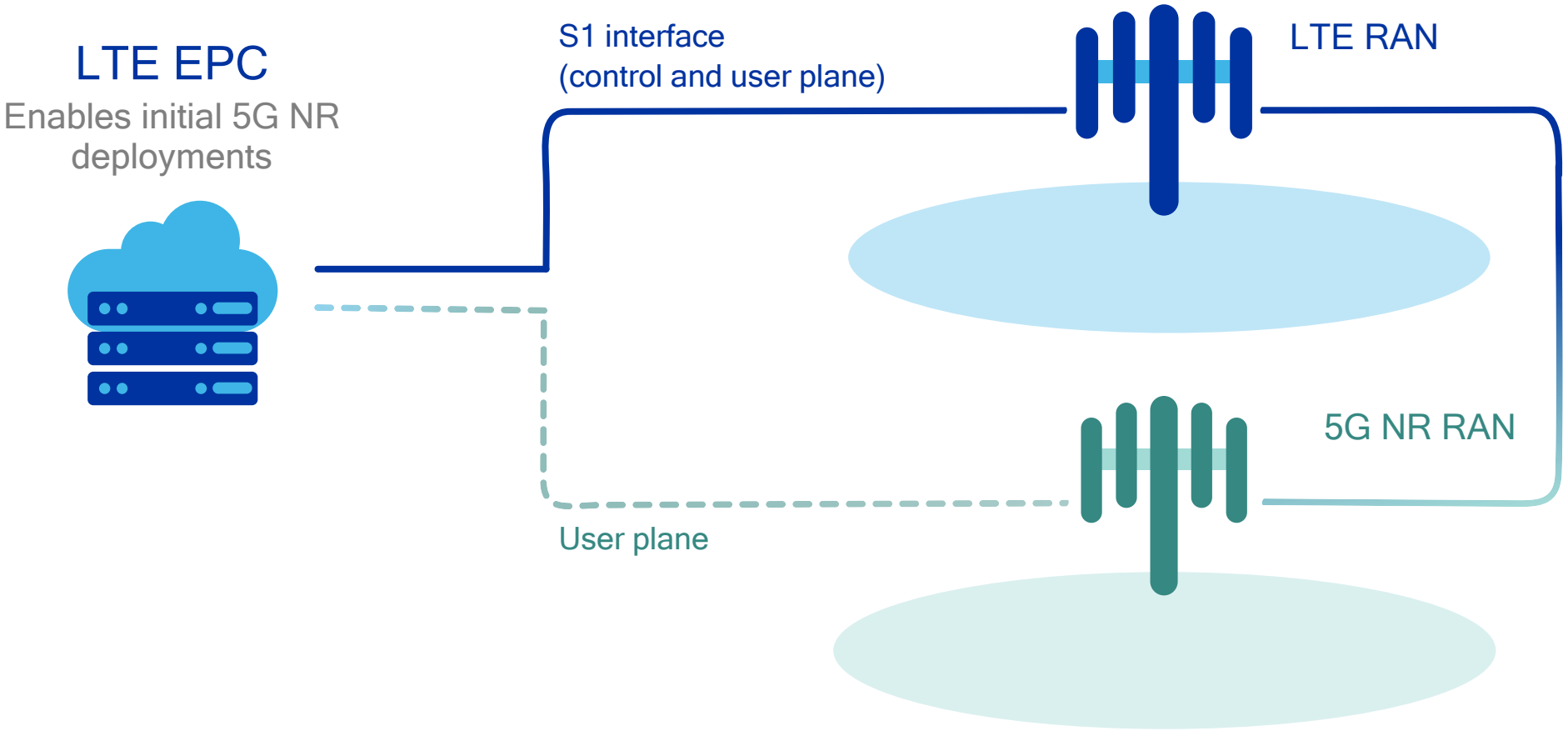
LGU+ MediaTek NEC Ooredoo OPPO Samsung Sierra Wireless Sony Sprint Swisscom TCL

Telecom Italia Telefonica TeliaSonera Telstra Tmobile USA Verizon vivo Xiaomi ZTE

1 NSA Option 3 family ASN.1 by March 2018; 2 Release-15 ASN.1 for 5G NR NSA and SA by September 2018

5G NR acceleration based on NSA architecture

Ensuring commonality with Standalone 5G NR, plus forward compatibility



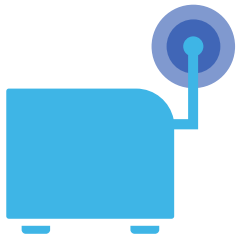
NSA operation requires aggregation of LTE-band and NR-band via Dual Connectivity

5G NR evolution and expansion beyond eMBB

URLLC part of Rel-15 Work Item; also new Rel-15 5G NR Study Items approved

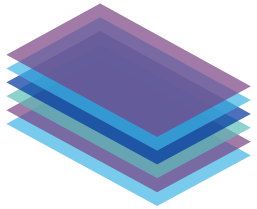
Work on 5G NR Ultra-Reliable Low Latency Communications[1]

For mission-critical control services like industrial automation, incl. efficient multiplexing with mobile broadband



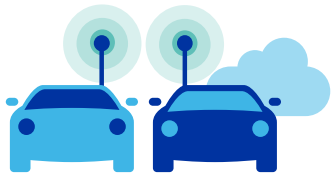
Study on 5G NR operation in unlicensed spectrum

For both licensed-assisted access (aka LAA) and standalone operation (aka MulteFire™) in sub-6 GHz and mmWave spectrum bands



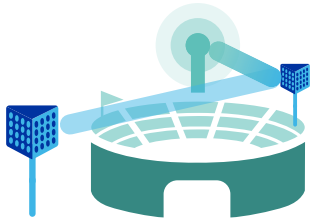
Study on 5G NR non-orthogonal multiple access, e.g. RSMA[2]

For grant-free uplink transmissions that can be utilized e.g. for small data exchanges in IoT communications



Evaluation of 5G NR for C-V2X communications

For augmenting today's C-V2X technology with use of high-frequency ITS bands



Study on 5G NR Integrated Access & Backhaul

For enabling easy/low-cost deployment of small cells with integrated access and backhaul

Study on 5G NR for non-terrestrial networks

Explore deployment scenarios and channel models for utilizing 5G NR for satellite operation

1 Part of 5G NR Rel-15 Work Item with identification of necessary techniques starting in Q3'17 and normative work 1H'18; 2 Resource Spread Multiple Access

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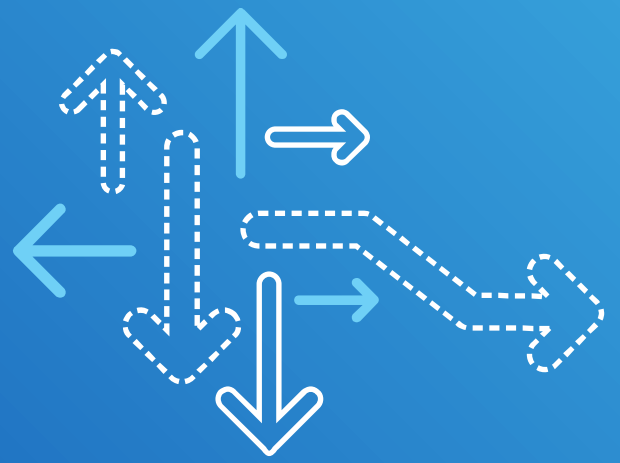
http://www.slideshare.net/qualcommwirelessevolution



Thank you

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