

5G - Christmas Update 2019

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5G

Agenda

1

5G vision and status

A unified, more capable air interface for the next decade and beyond

2

5G NR and System design and technologies

Based on the 3GPP Release-15 global standard

3

5G evolution and expansion

Rel-16 and beyond

4

Media and Broadcast in 5G

What is happening in the media context?



5G Vision and Status

3GPP Release-15

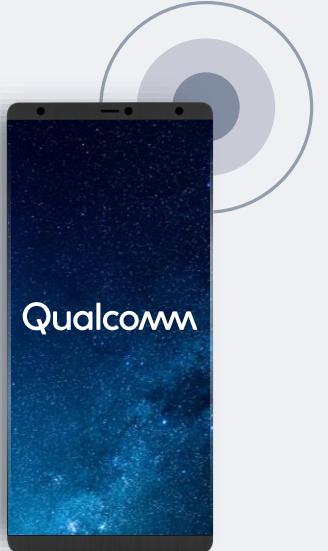


Leading mobile innovation for over 30 years



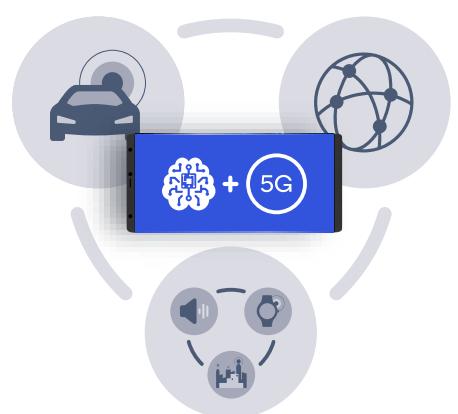
Digitized mobile communications

Analog to digital



Redefined computing

Desktop to smartphones



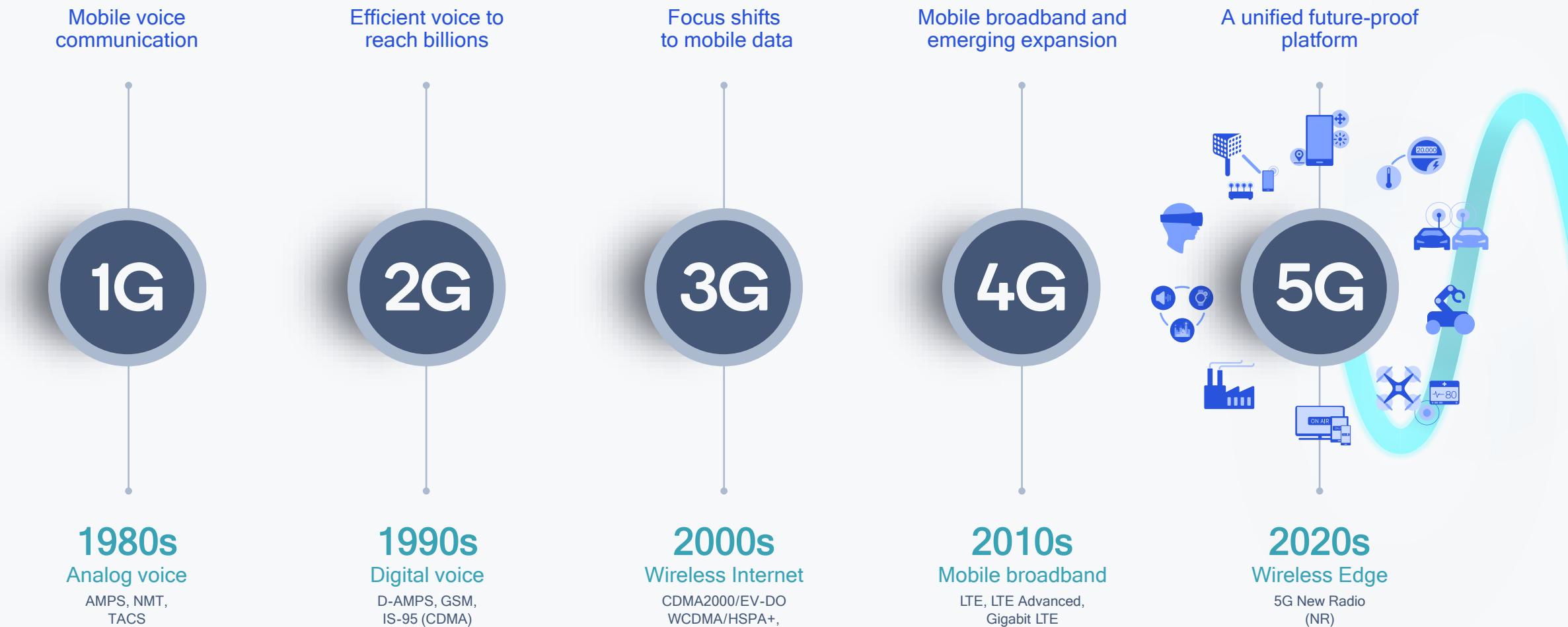
Transforming industries

Connecting virtually everything at the wireless edge

Transforming how the world connects, computes and communicates



Mobile has made a leap every ~10 years



A unifying connectivity fabric for society

Like electricity, you will just expect it everywhere



5G



Scalable to extreme simplicity



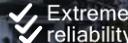
Multi-gigabit speed



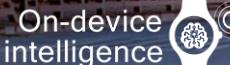
Ultra-low latency



Virtually unlimited capacity



Extreme reliability



On-device intelligence



Delivering on the 5G vision

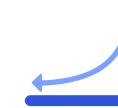
Where virtually everyone and everything is intelligently connected



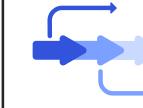


5G

A new kind of network to drive innovation and growth



Significant connectivity upgrade



Smartphone tech extending into many industries



Consumers want 5G smartphones



5G will address the insatiable demand for mobile broadband

Over 60x growth in mobile data traffic from 2013 to 2024

~131B Gigabytes

Monthly global mobile data traffic in 2024



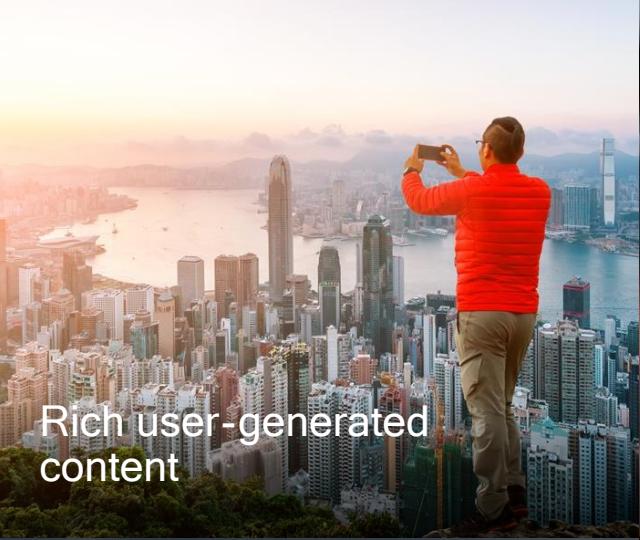
In 2024, ~75% of mobile data traffic from multi-media creation & consumption



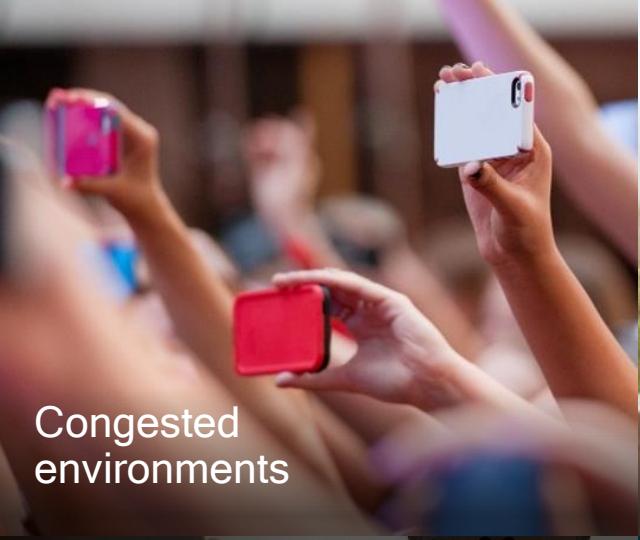
In 2024, 25% of mobile data traffic will be carried by 5G networks – 1.3x more than 4G/3G/2G traffic today



Mobilizing media
and entertainment



Rich user-generated
content



Congested
environments



High-speed
mobility



Connected cloud
computing



Immersive
experiences



Connected
vehicle



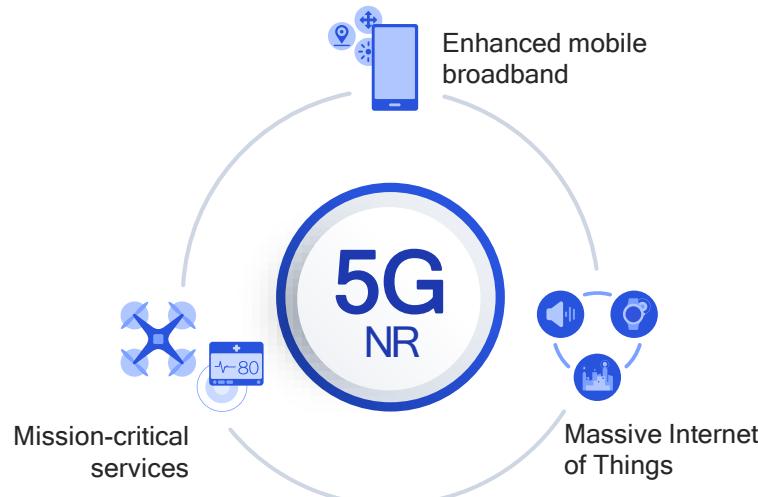
Augmented
reality



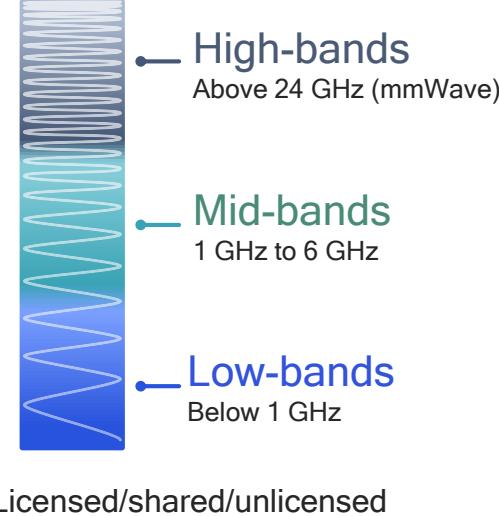
5G is essential for next generation mobile experiences

- Fiber-like data speeds
- Low latency for real-time interactivity
- More consistent performance
- Massive capacity for unlimited data

5G NR is a unified, more capable air interface



Diverse services



Diverse spectrum



Diverse deployments

10x
Decrease in
end-to-end latency

10x
Experienced
throughput

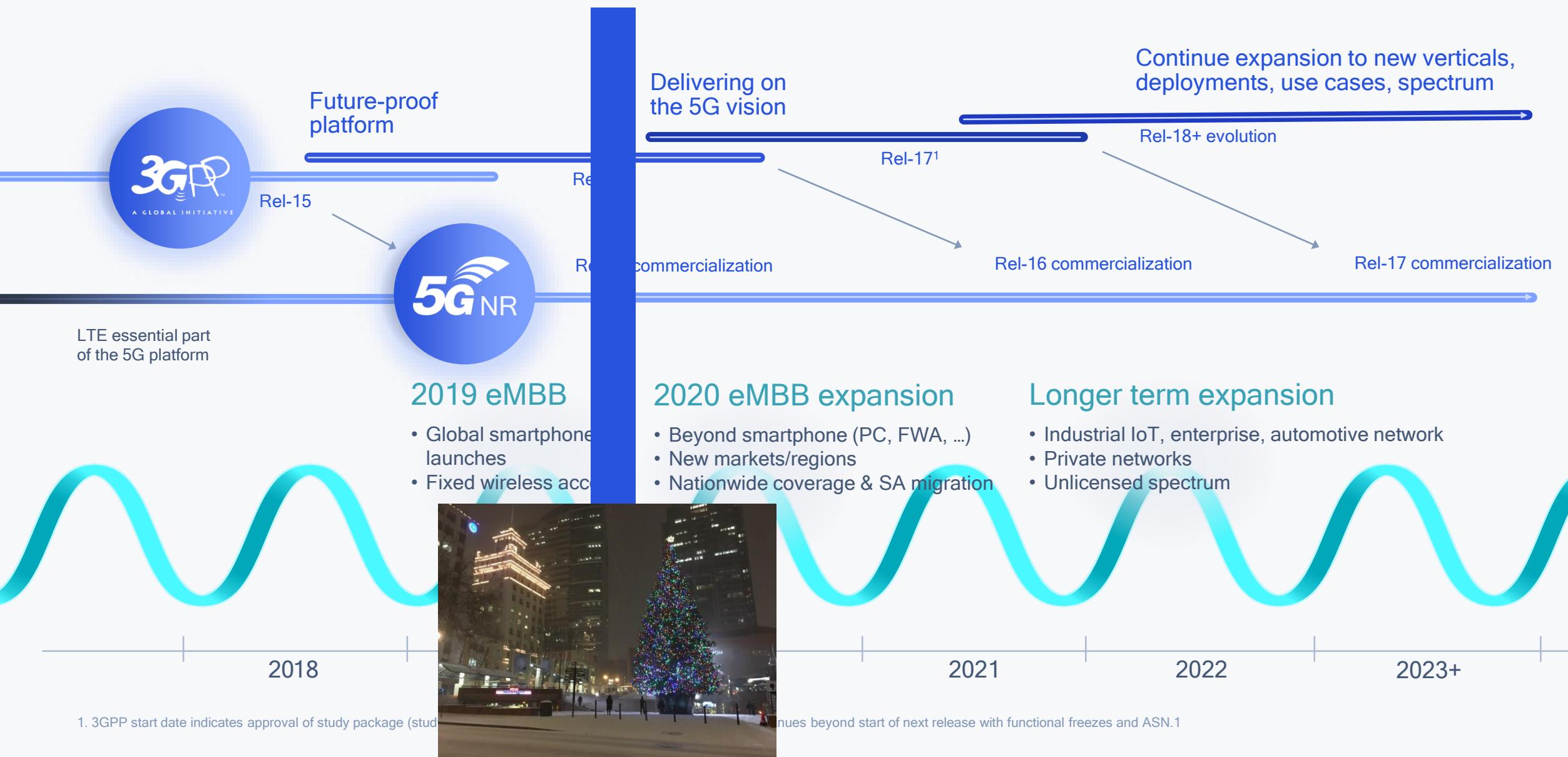
3x
Spectrum
efficiency

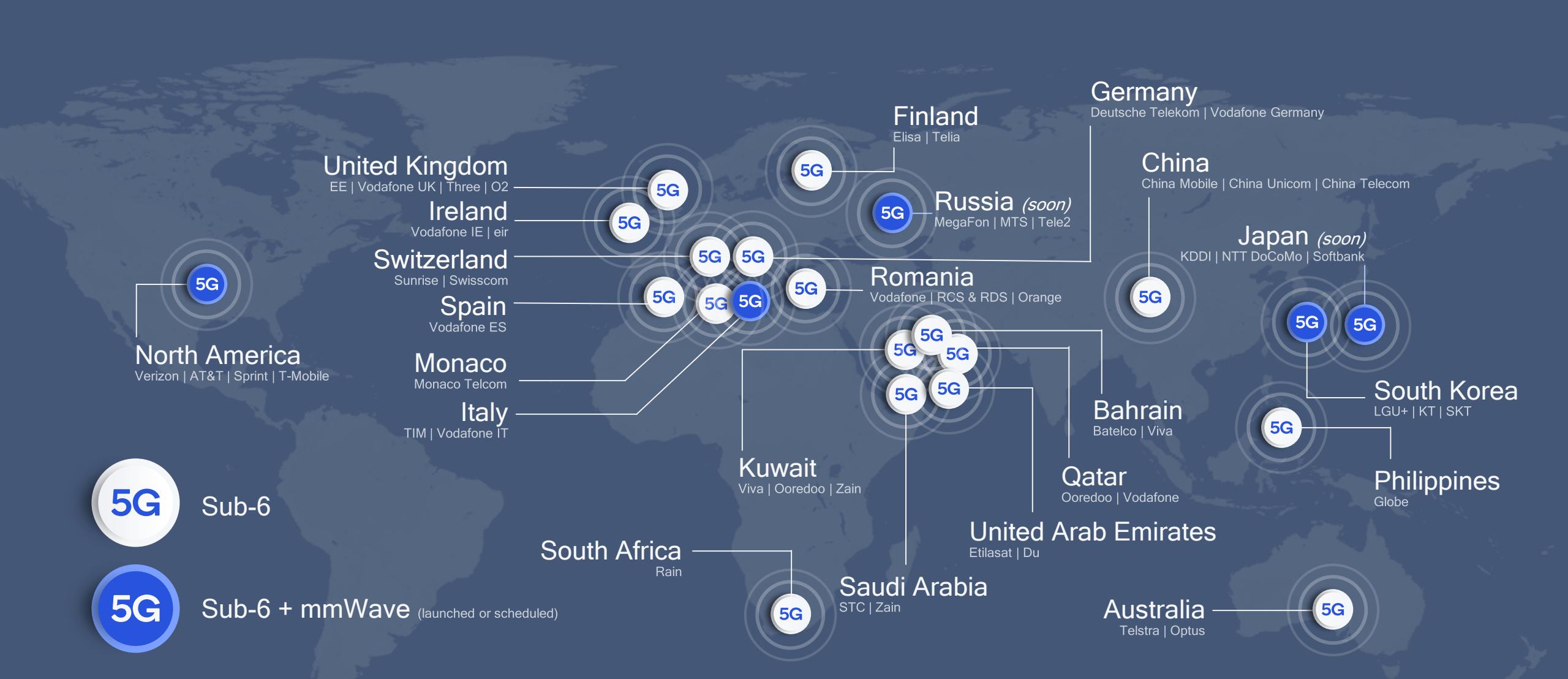
100x
Traffic
capacity

100x
Network
efficiency

10x
Connection
density

Driving the 5G expansion





Comparison of Year 1
announcements



4 Operators launched
3 OEMs launched



40+ Operators launching
40+ OEMs launching

5G smartphones



Hotspots and CPEs



Askey
Inseego

HTC
Netcomm

Netgear
Nokia

WNC
ZTE

5G modules



Compal
Fibocom

Longsung
Quectel

Sierra
Wireless

SIMcom
Telit

Qualcomm
snapdragon



230+
5G devices launched
or in development

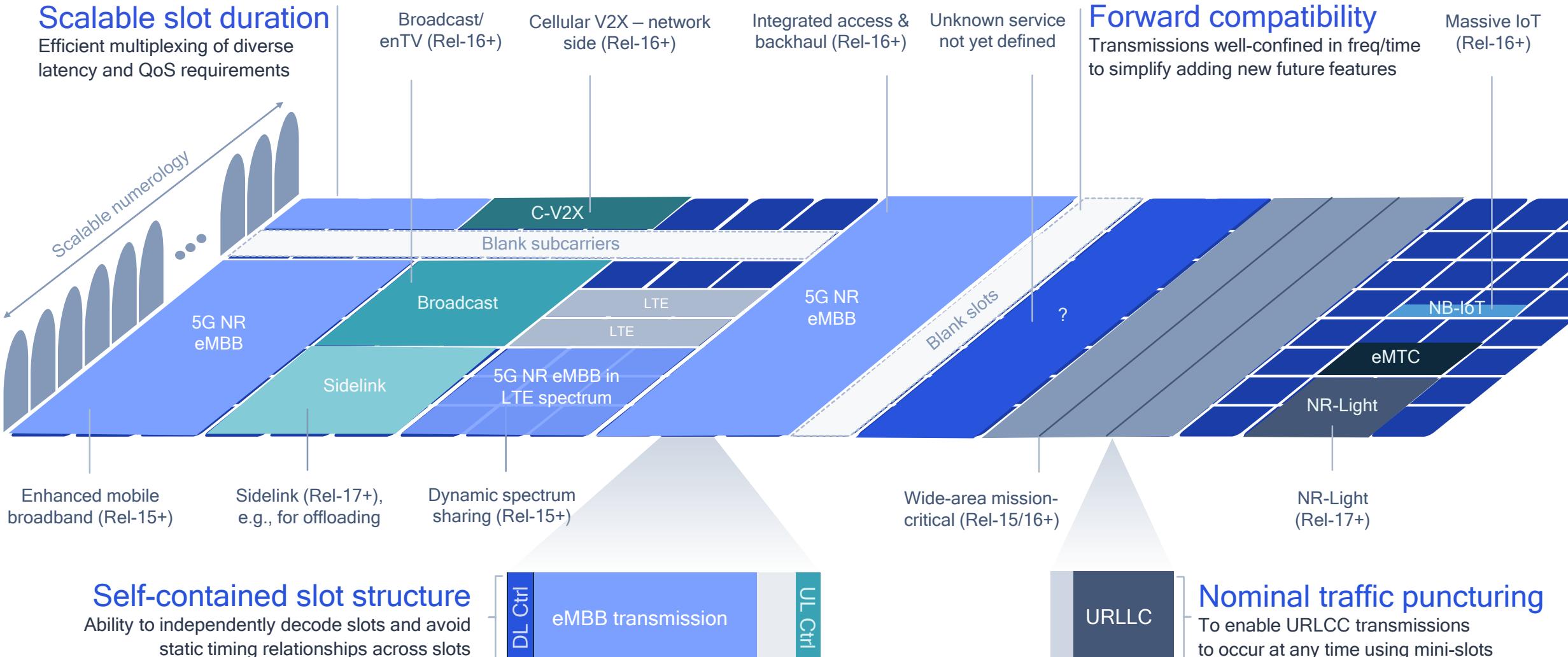
5G NR design and technologies

3GPP Release-15

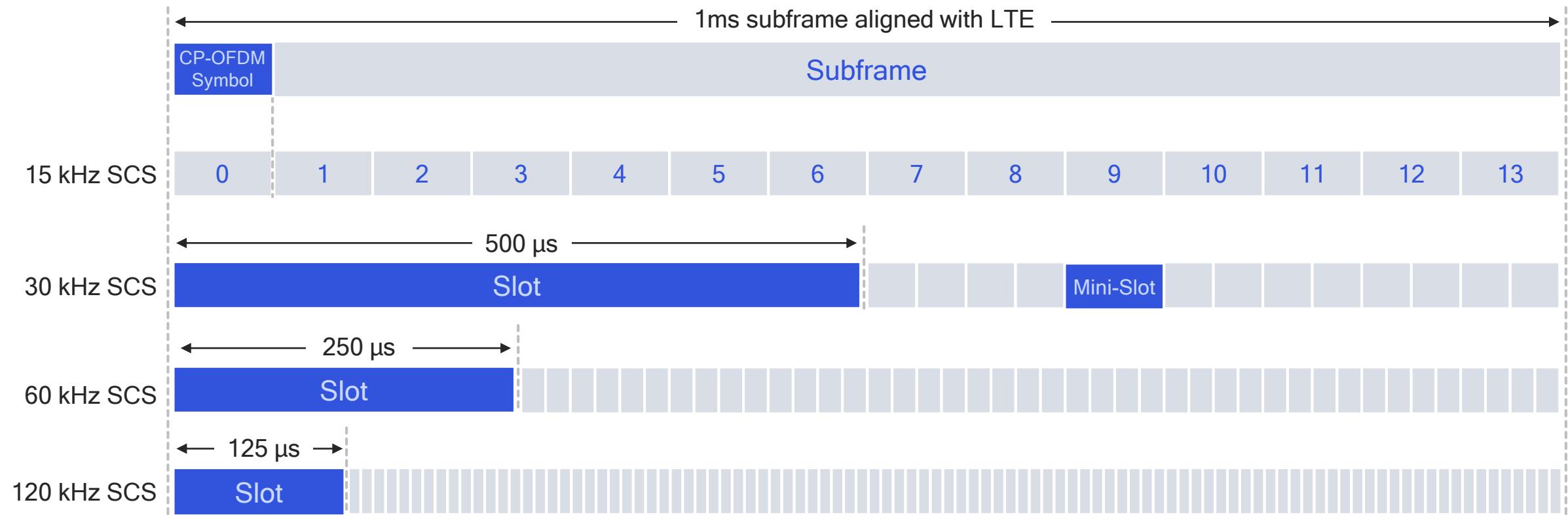


Expanding 5G with the flexible slot-based framework

Efficiently multiplex envisioned and future 5G services on the same frequency



Scalable 5G NR slot duration for diverse latency/QoS



14 OFDM symbols per slot with
mini-slot (2, 4, or 7 symbols)
for shorter transmissions¹

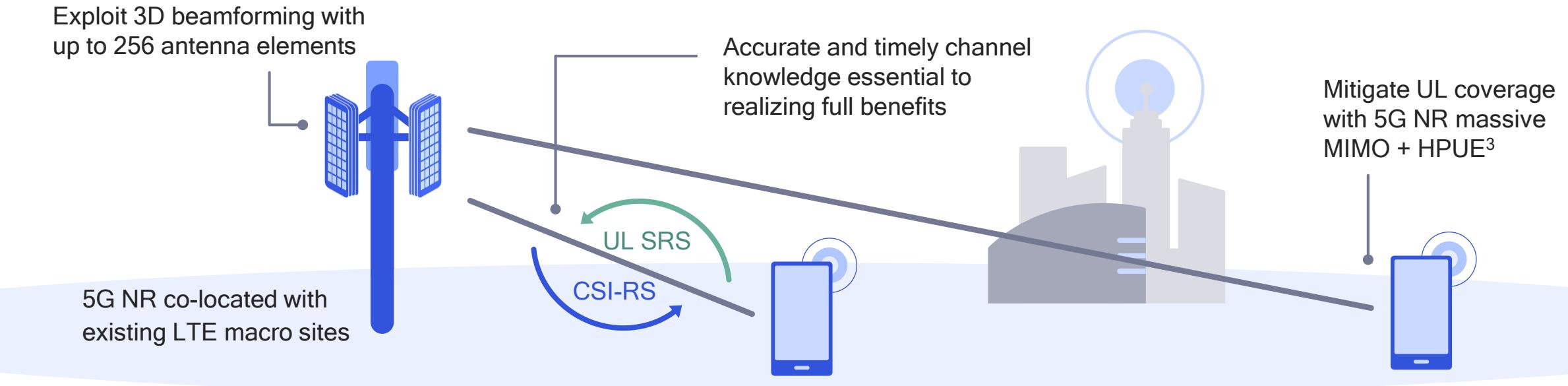
Supports slot
aggregation for data-
heavy transmissions

Efficient multiplexing of
long and short
transmissions²

1. As low as two symbols per mini-slot; 2. Symbols across numerologies align at symbol boundaries and transmissions span an integer # of OFDM symbols

5G NR optimized design for massive MIMO

Key enabler for using higher spectrum bands, e.g. 4 GHz, with existing LTE sites



Enabled through an advanced 5G NR end-to-end Massive MIMO design (network and device)

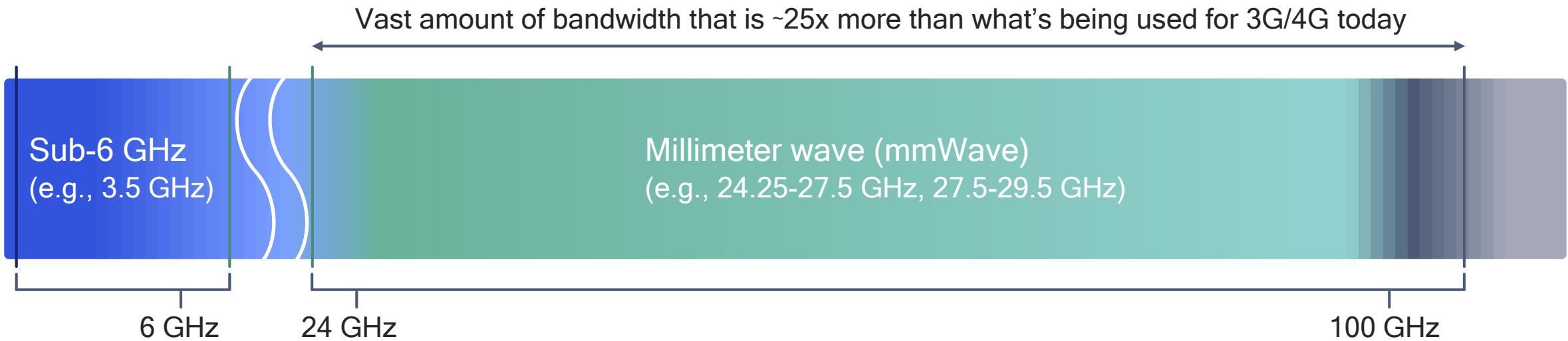
Optimized design for TDD reciprocity procedures utilizing UL SRS¹

Enhanced CSI-RS² design and reporting mechanism

Advanced, high-spatial resolution codebook supporting up to 256 antennas

New features, such as distributed MIMO

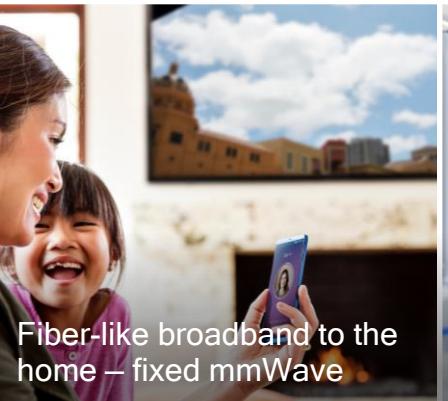
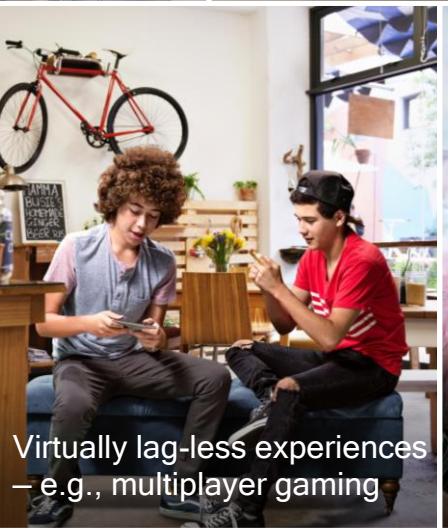
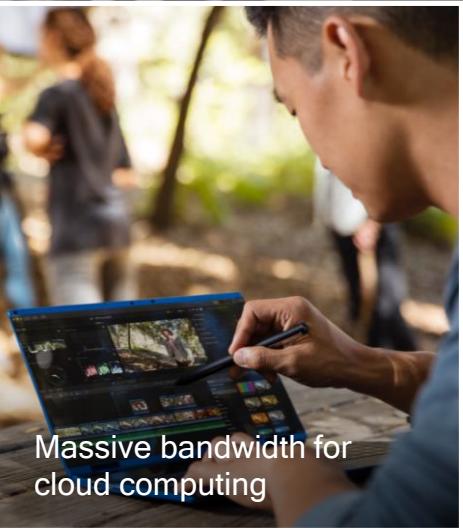
New frontier of mobile broadband – mobilizing mmWave



Multi-Gbps data rates
With large bandwidths (100s of MHz)

Much more capacity
With dense spatial reuse

Lower latency
Bringing new opportunities



5G NR mmWave will support new and enhanced mobile experiences

- Fiber-like data speeds
- Low latency for real-time interactivity
- Massive capacity for unlimited data plans
- Lower cost per bit

Showcasing enhanced mobile mmWave user experiences



Advanced Network Simulations

Deploying 28 GHz 5G NR mobile mmWave at Mobile World Congress venue



Ubiquitous coverage via co-siting

Virtually unlimited capacity

Multi-Gbps speed & low latency

More uniform user experience

For a wide range of mobile devices:

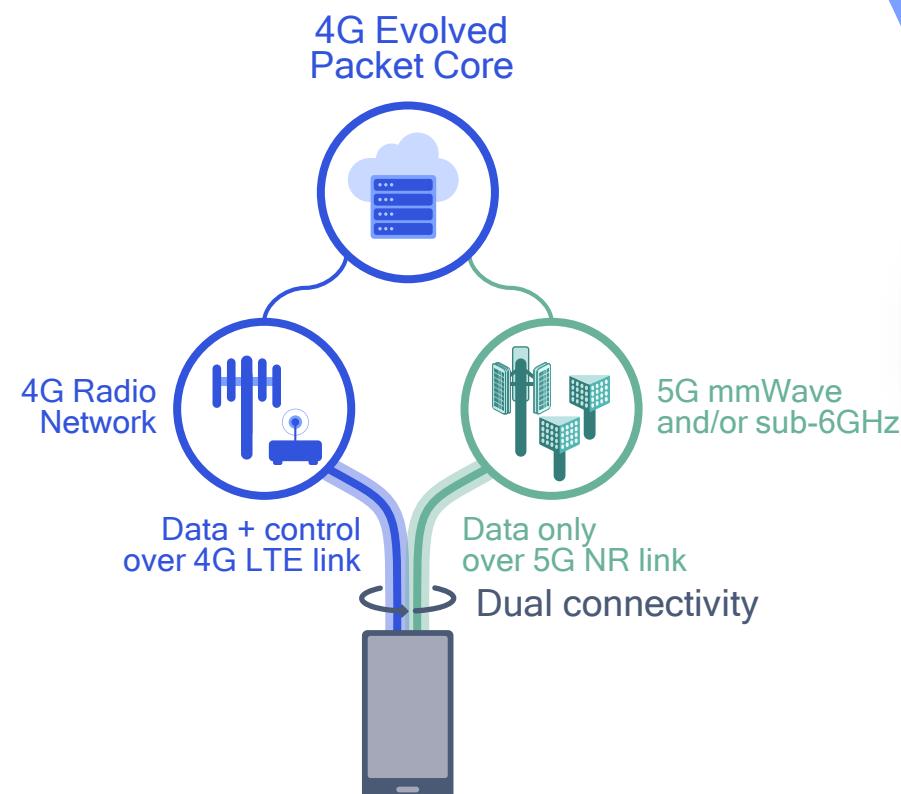


5G System design and technologies

3GPP Release-15

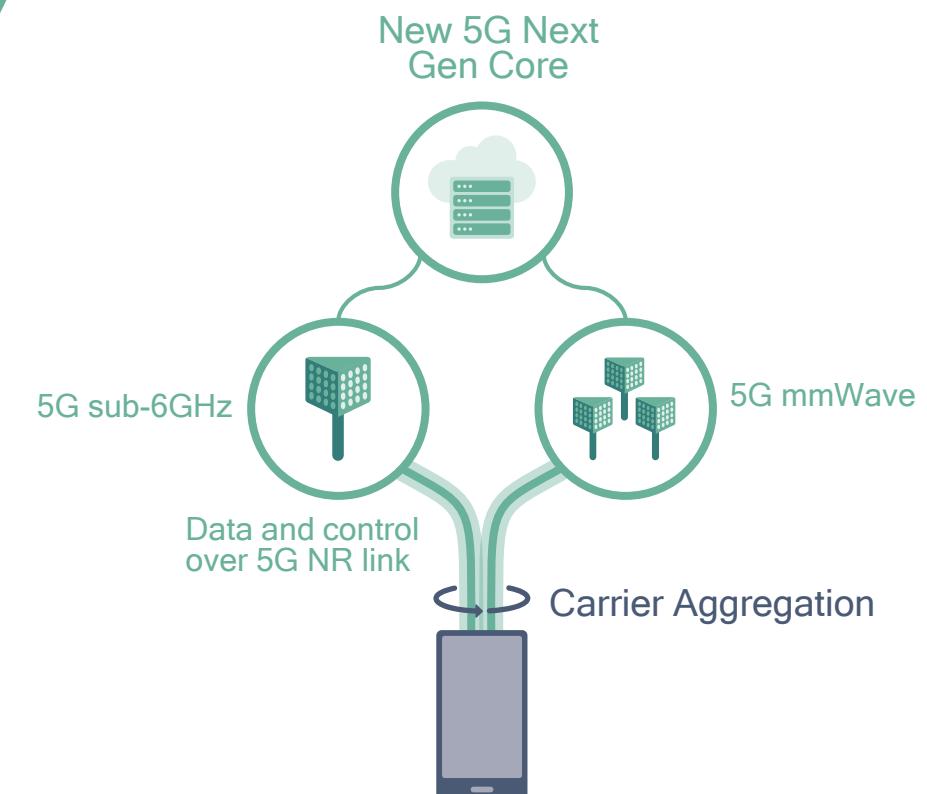


Non-Standalone (NSA) stepping stone to new core



Fast-to-launch | VoLTE & CS voice

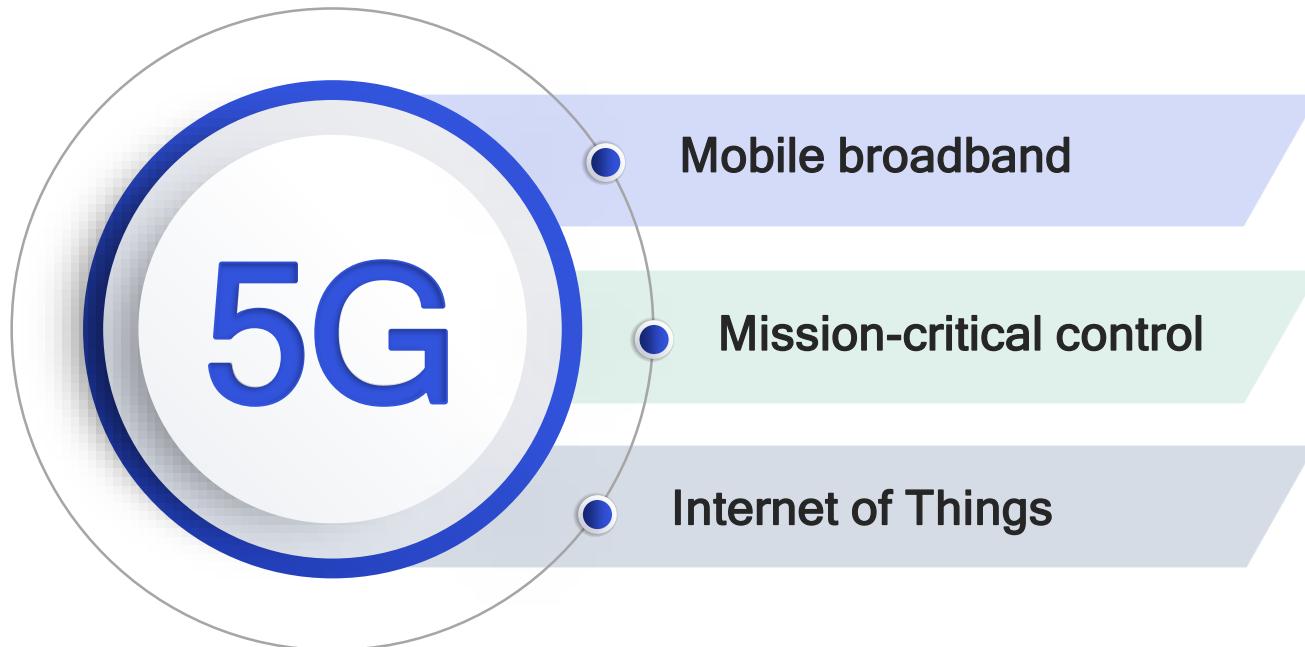
Standalone (SA) for new core benefits



NFV and SDN | VoNR & fallback to VoLTE

5G next Gen Core (NGC) also part of 3GPP Rel-15

Increased flexibility through NFV and SDN – essential to 5G NR expansion



Configurable end-to-end connectivity per vertical

Modular, specialized network functions per service

Flexible subscription models

Dynamic control and user planes with more functionality at the edge

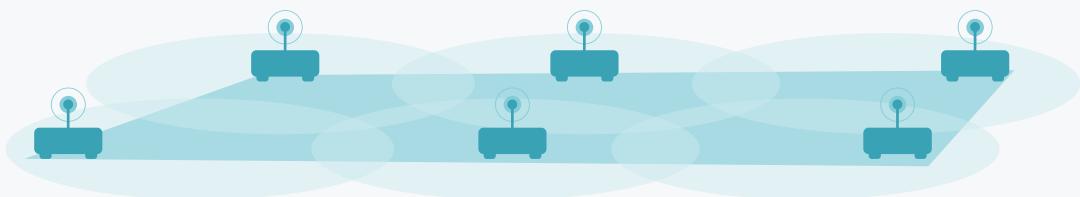
NFV: Network Functions Virtualization; SDN: Software Defined Networking

Better cost/energy efficiency

Optimized performance

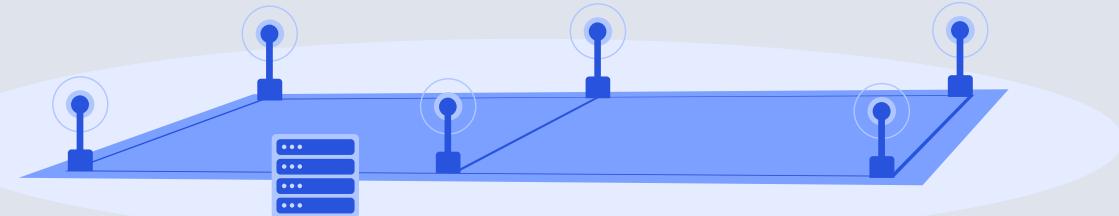
Flexible biz models and deployments

Dynamic creation of services



Traditional RAN

The more you distribute



Virtual RAN (VRAN)

The more you centralize



Lower front-haul requirements



Simplifies support for applications such as IoT and mmWave



Ease of software upgradability



Lower investments



More scalable

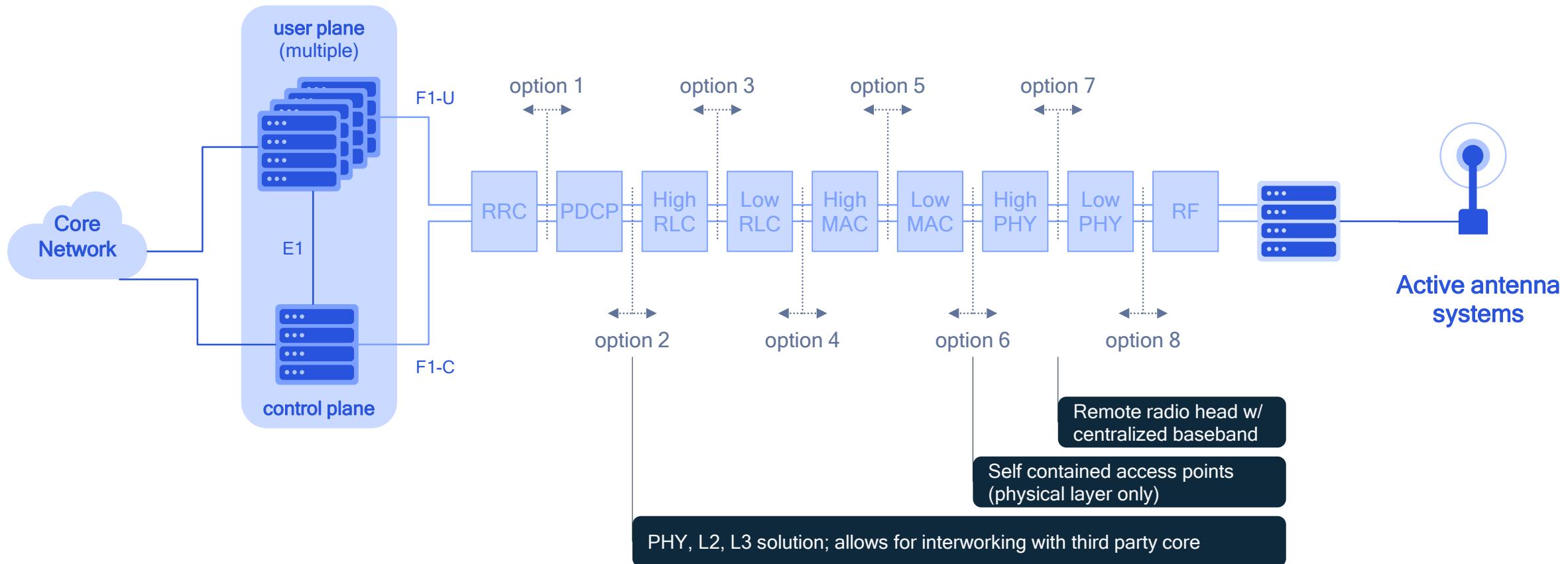
5G

5G opens door for new
Radio Area network (RAN) architecture

Central Unit

Distributed Unit

Control and user plane separation



5G Network based on vRAN

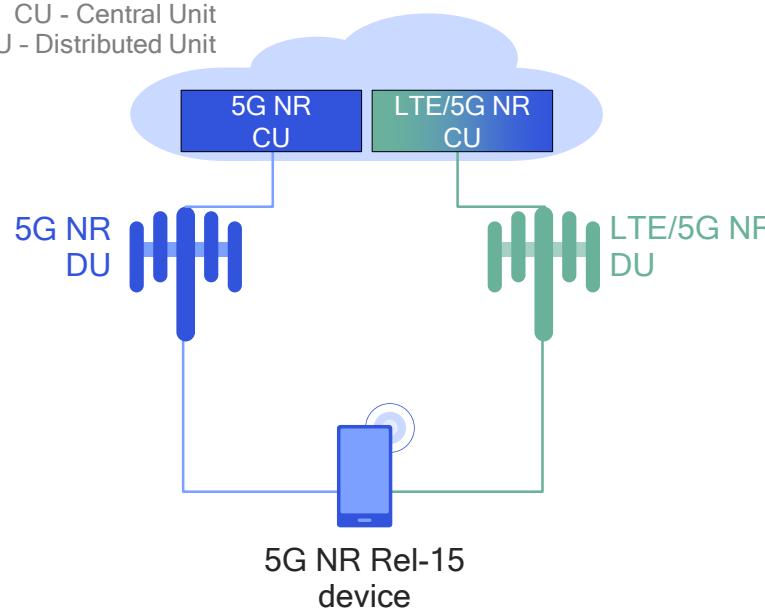
Designed for extremely flexible and cost-effective network deployments

5G NR mobility enhancements in 3GPP Release 16+

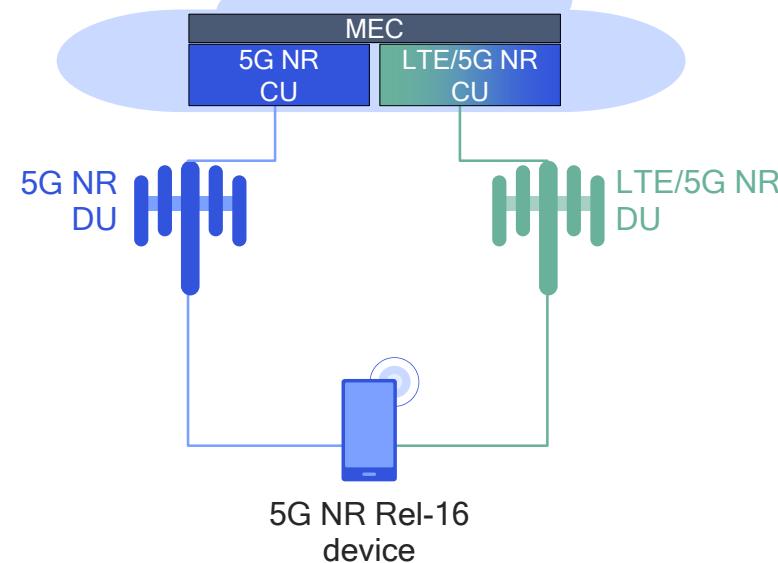
Delivering higher bandwidth, lower latency, and improved reliability during mobility

5G NR SA or dual connected with LTE

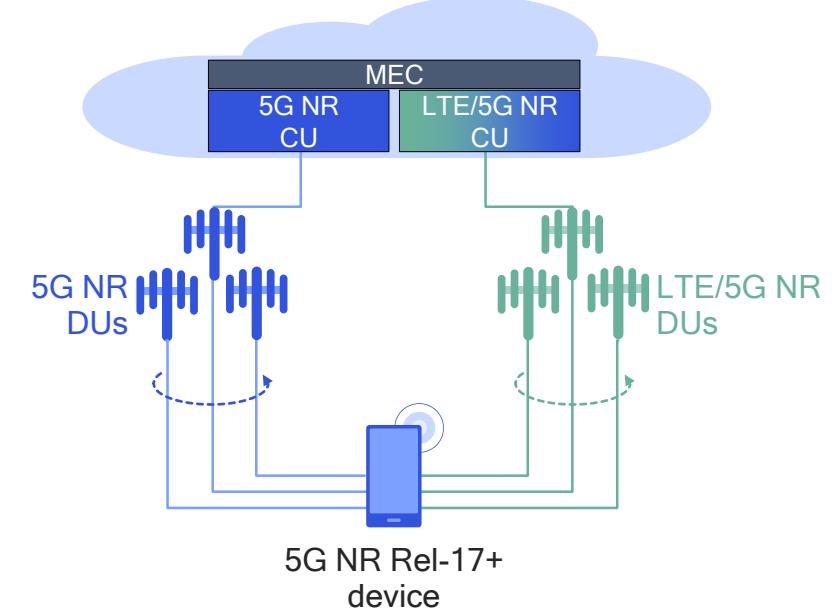
CU - Central Unit
DU - Distributed Unit



Supporting URLLC/MEC services with less interruption & improved reliability



Extending to multiple DUs & faster switching across cell groups



Release 15 baseline

Intra and inter RAT¹ handover that enables high-bandwidth, low-latency, and reliable connectivity during mobility

Enhancements proposed for Rel-16

Faster DC/CA access², reduced mobility interruption to 0ms³, faster recovery in failover⁴, improved coverage and power consumption

Further enhancements

Enabling independent UL/DL operation, device-centric mobility, extending DC beyond 2 DUs, and further power savings



Qualcomm® Snapdragon™

X50

5G Modem family

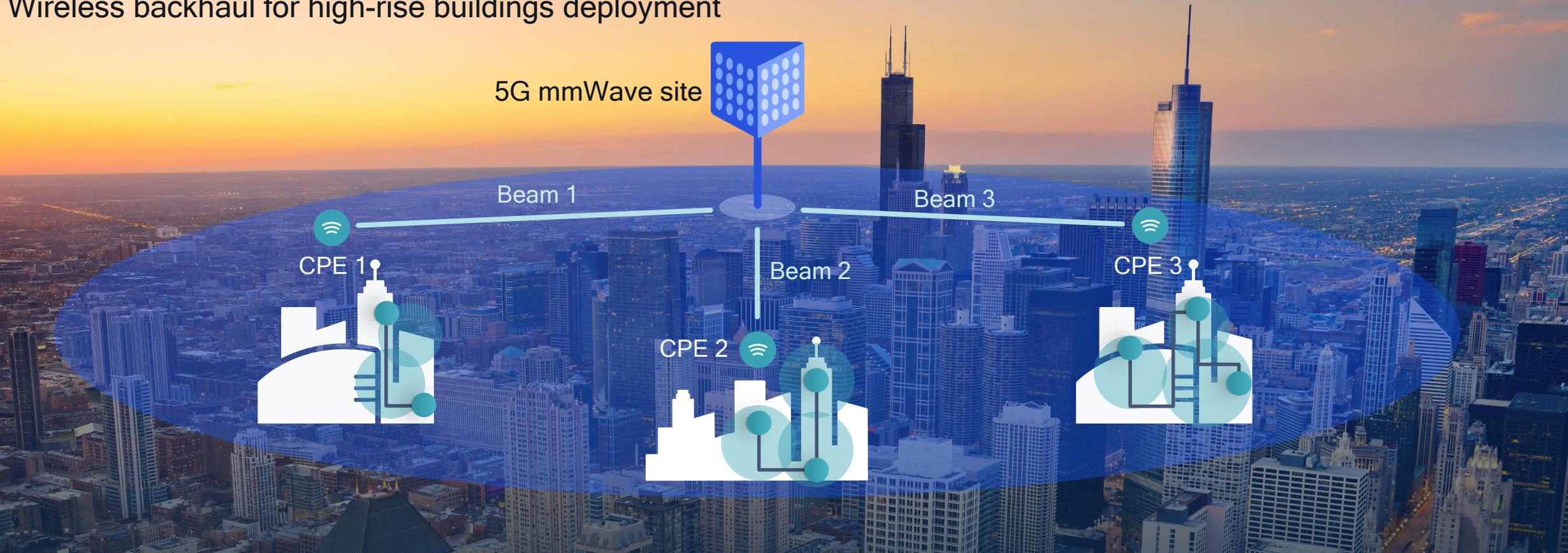
World's first announced
5G NR multimode modems

-  5G NR standards compliant
-  Sub-6 + mmWave
-  Premium-tier
smartphones in 2019



5G mmWave fixed wireless access

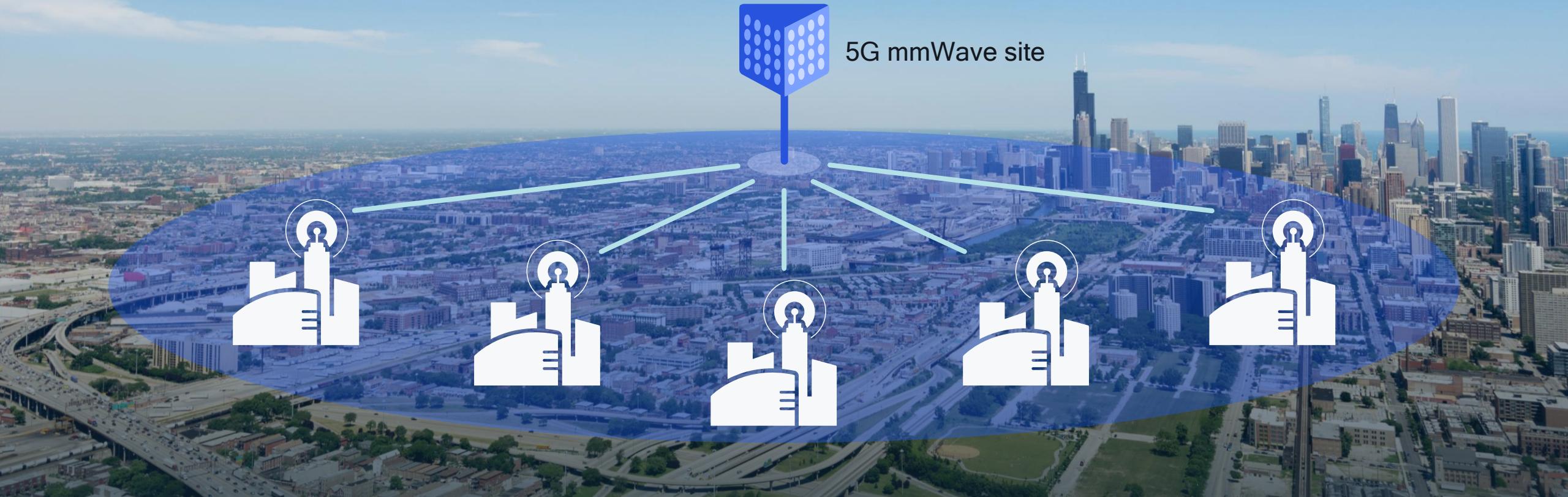
Wireless backhaul for high-rise buildings deployment



A feasible use case for mmWave that provides expedited and low-cost deployment to replace fiber

5G mmWave Fixed Wireless Access

Urban and dense urban deployment

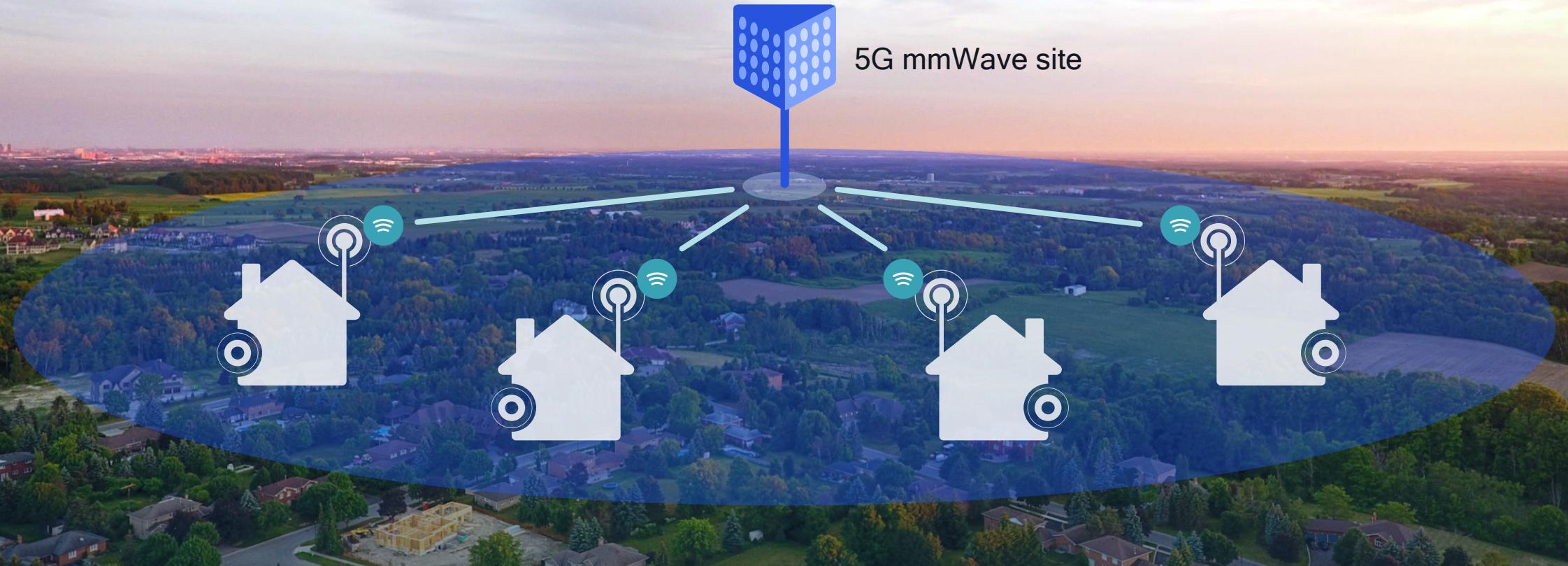


Coverage of up to 1.1 Km distance from base station in urban area
with minimum 50 Mbps data rate

Based on CPE height at 6m above ground, 400MHz on 28 GHz, 7:1 TDD Config, light foliage.

5G mmWave Fixed Wireless Access

Rural / suburban deployment



Coverage of up to 1.7 Km distance from base station
in rural area with minimum 50 Mbps data rate

Based on CPE height at 6m above ground, 400MHz bandwidth on 28 GHz, 7:1 TDD Config, light foliage.

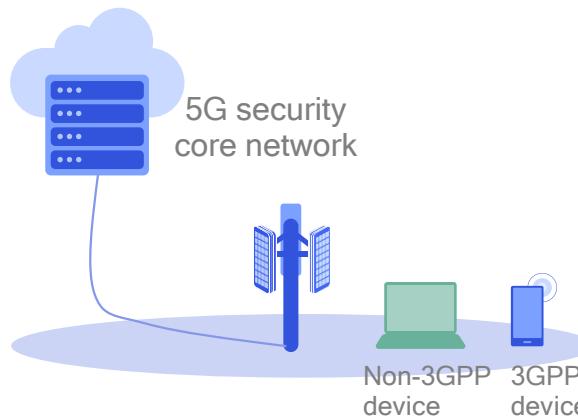
5G system brings enhanced security and privacy

Building on the proven, solid security foundation of 4G LTE

Content Protection
(Laurent Piron,
Nagra)

Flexible framework

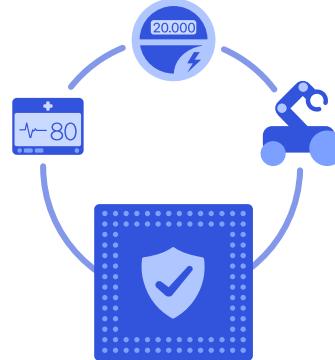
To support new devices, use cases, and deployments



Unified authentication for 3GPP & non-3GPP access (e.g., Wi-Fi), security anchor function, and network slicing

Tighter security

To expand protection and increase flexibility



Added user plane integrity protection; lower trust in serving networks to allow for flexible deployment; subscription credentials can be stored in secure hardware element

Enhanced privacy

To eliminate communication of unprotected device-specific information

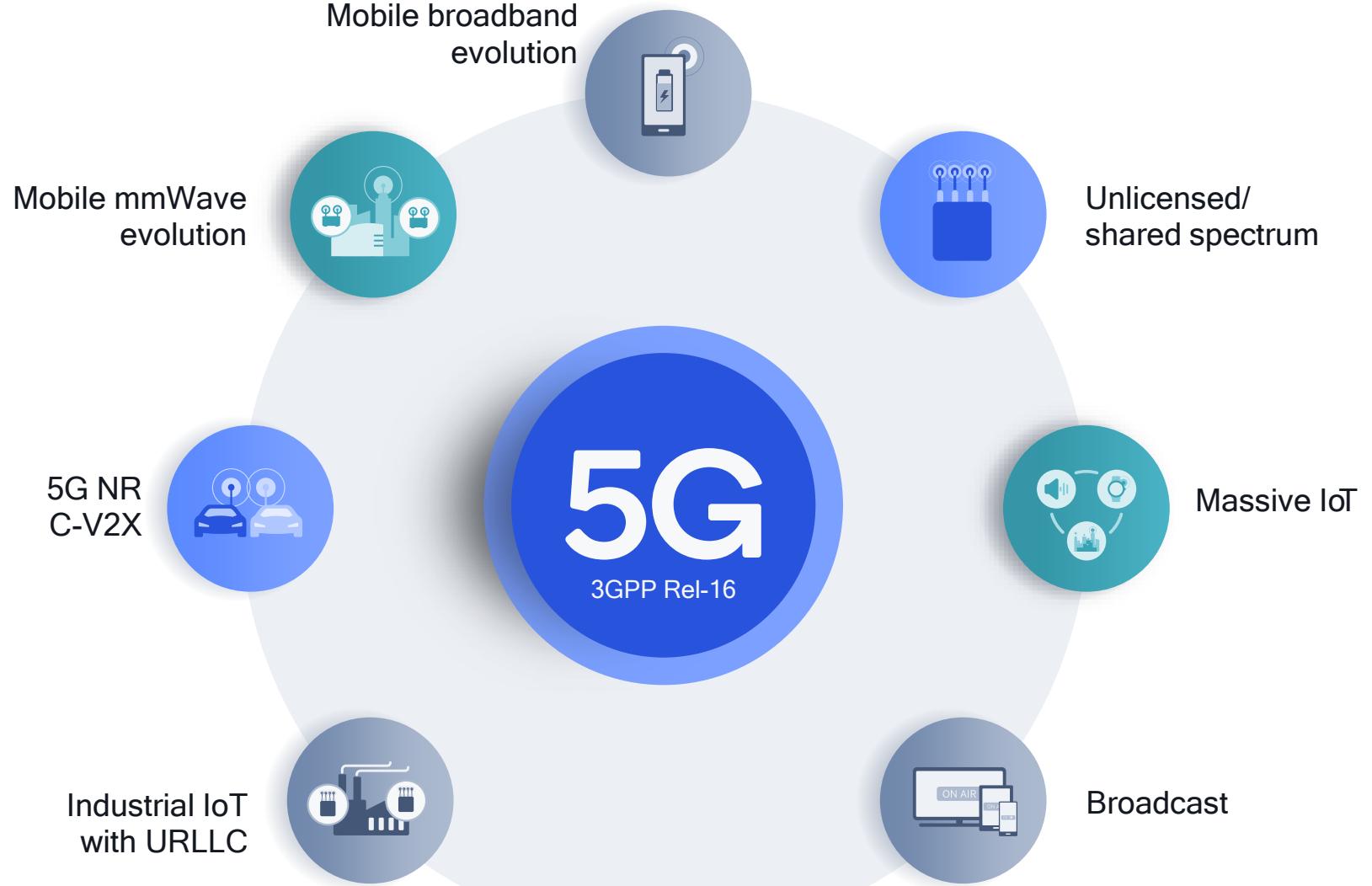


User permanent identity (e.g., IMSI¹) and device-specific information are ciphered before being exchanged over the air

5G evolution and expansion

3GPP Release-16 and beyond





5G NR is expanding to new use cases and verticals

Ongoing innovation through 5G releases

Enhancing broadband and enabling new verticals



Continuing pipeline of high value, foundational IP

Continued evolution to deliver on the 5G vision

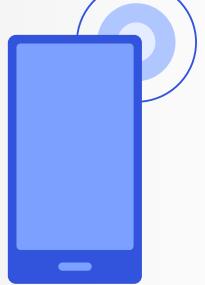


Established 5G NR technology foundation

Expanding to new use cases and industries

Continued expansion and enhancements

5G is a connectivity fabric for virtually everything



Fixed
Wireless
Access



Mobile
Compute



XR



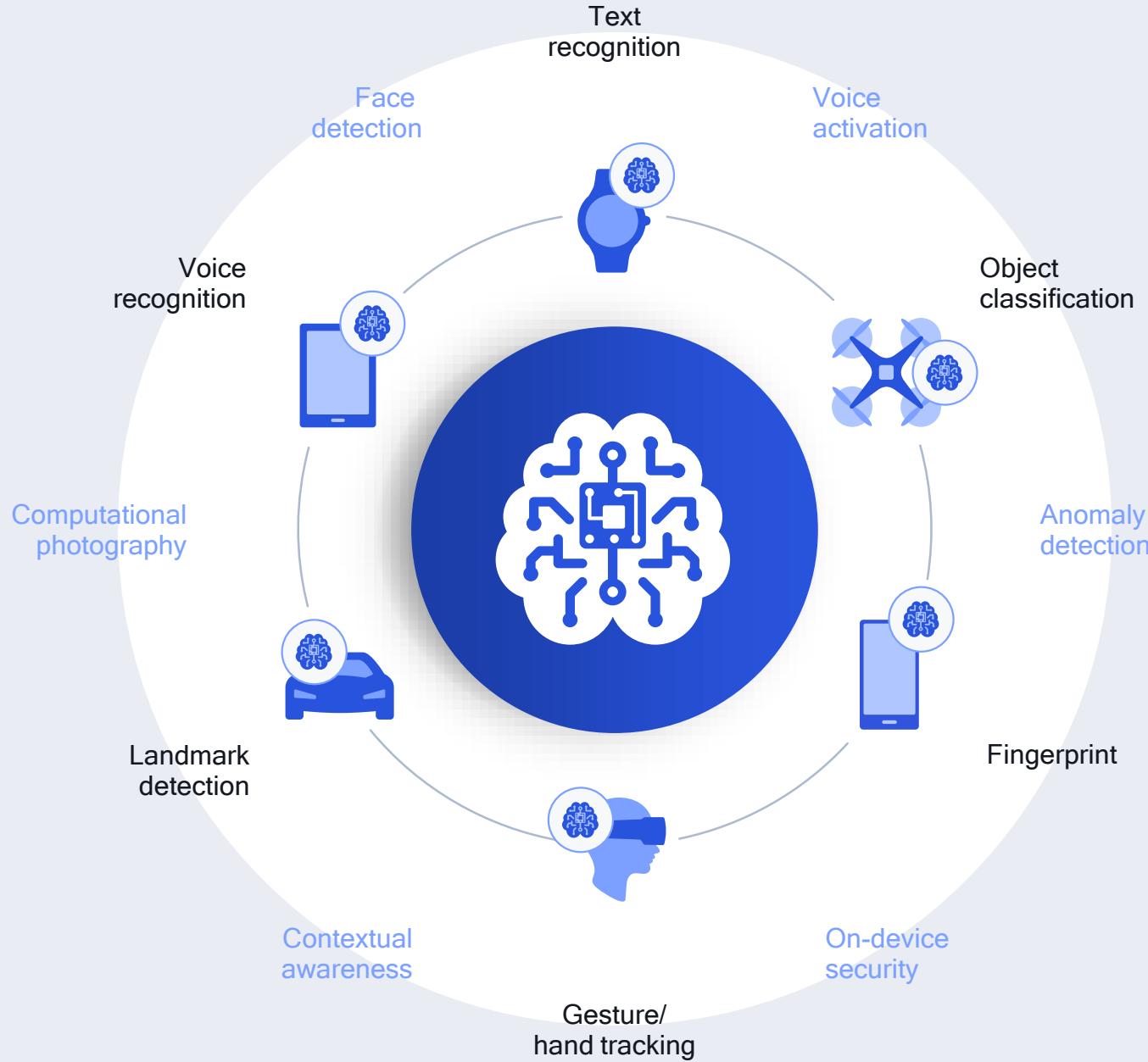
IoT



Networks

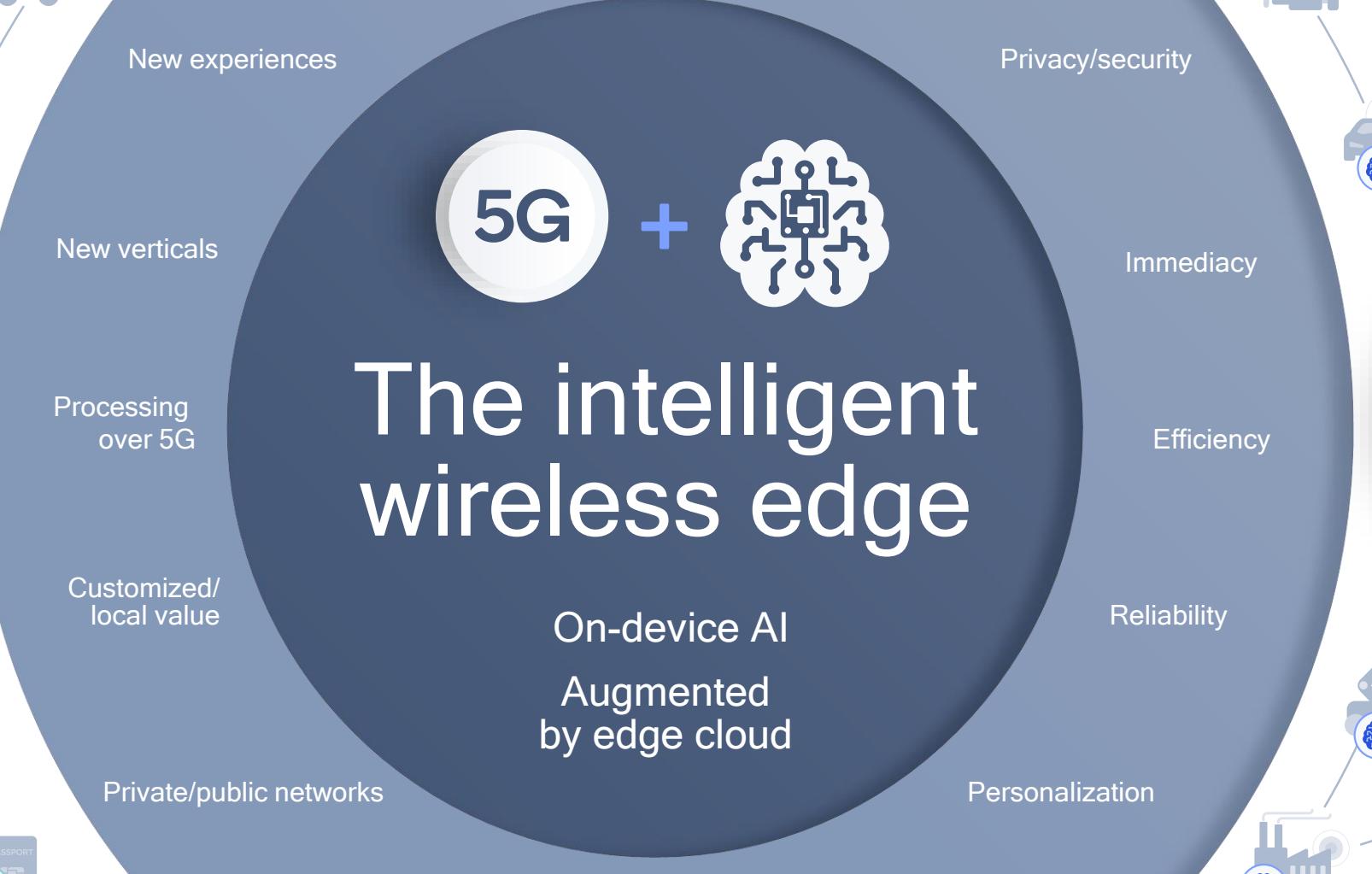


Automotive



On-device AI use-cases today

But we can do more
with 5G



The intelligent wireless edge

On-device AI
Augmented
by edge cloud



New experiences

New verticals

Processing over 5G

Customized/local value

Private/public networks

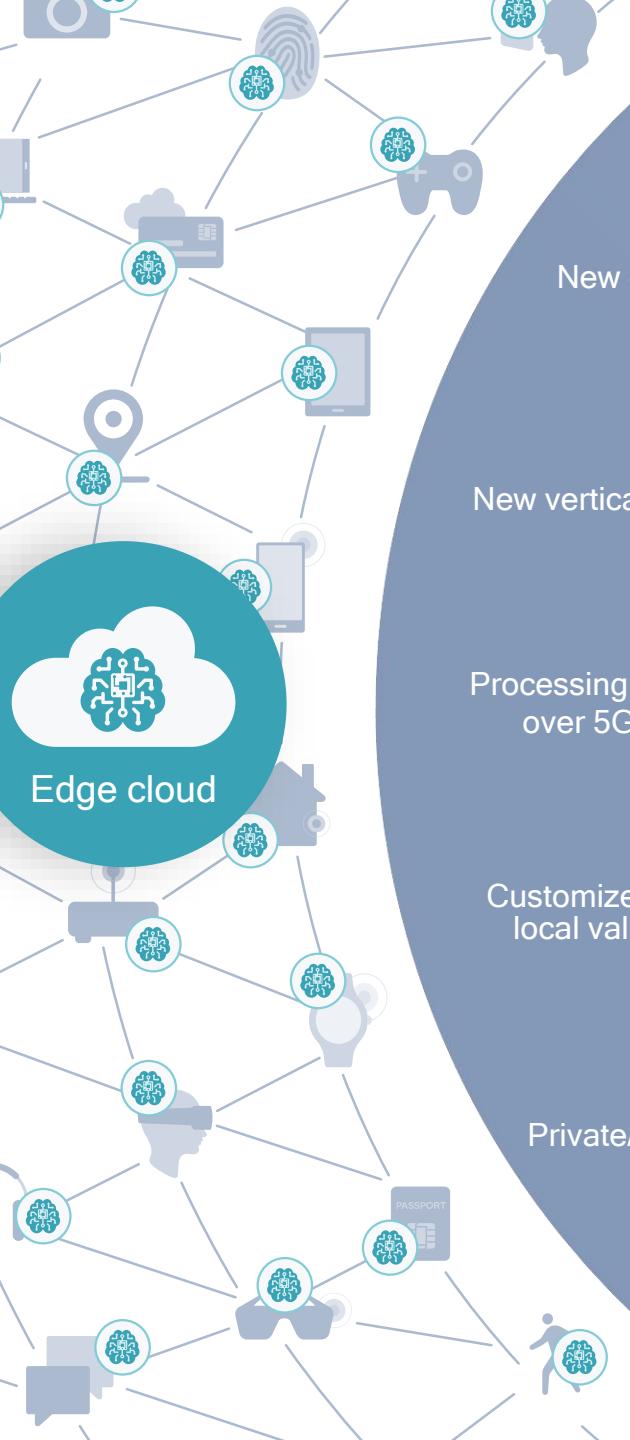
Privacy/security

Immediacy

Efficiency

Reliability

Personalization



Process data at the source to scale and make sense of a digitized world

Past

Cloud-centric AI

AI training and AI inference
in the central cloud



Today

Partially-distributed AI

Power efficient
on-device AI inference



Future

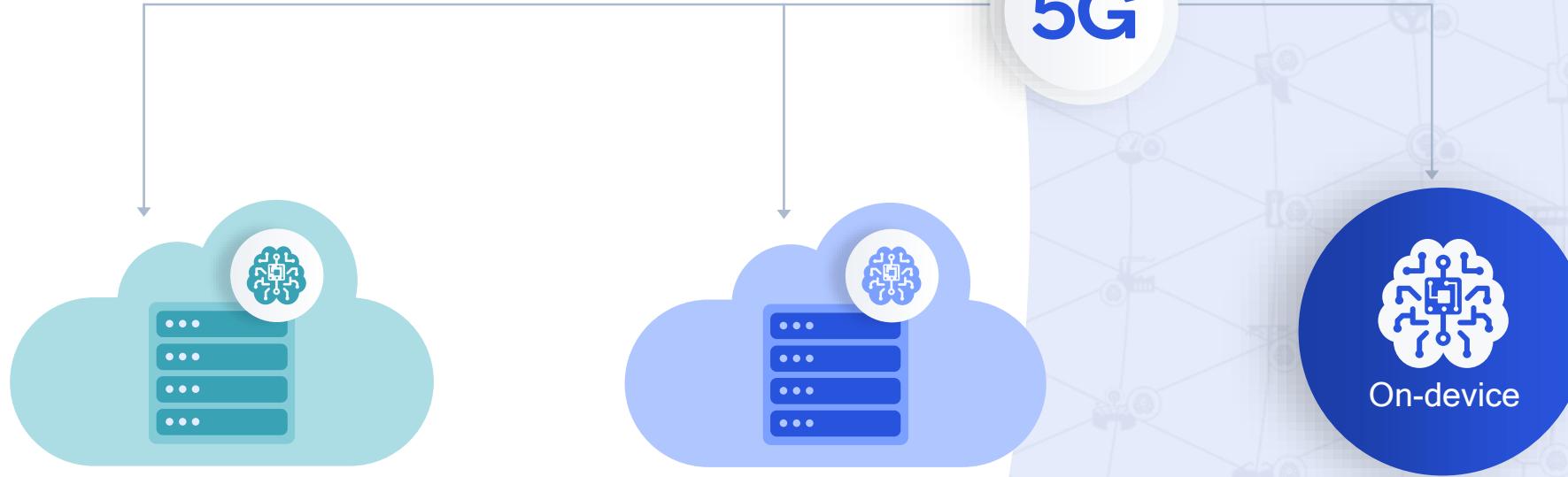
Fully-distributed AI

With lifelong on-device learning



Enriched user experiences, new use case, new verticals

Distributed functionality



Longer latency
Big data/aggregated value
Content/storage/AI/processing

5G low latency
Customized/local value
Content/storage/AI/processing

Compute, vision, sensing
AI powered use cases
Internal AI optimizations

- On-premise control for ultra-low latency
- On-device intelligence assisted by cloud
- Distributed processing, like boundless XR
- New services
- Cloud computing, storage, instant access
- Low-latency gaming
- Real time assisted services like voice UI

5G Core Technologies

- » **Orchestration and Virtualization (NFV)** – de-couple logical function from hardware
- » **Slicing** – logical end-2-end networks tailored to customer needs
- » **Mobile Edge Computing (MEC)** – resources where they are needed (especially for URLLC)
- » **API Exposure** – 3rd party access to 5G services
- » **Service Based Architecture (SBA)** – stateless, open, flexible
- » **Harmonized Protocols & Access Agnostic** – generic solutions with integrated support for fixed networking , 5G satellite access, ...
- » **5G Media Streaming**
- » **New Media (Virtual Reality, Extended Reality, ...)**
- » Specific ‘vertical industry support’: **Broadcasting**, Mission Critical Communications, Vehicle to Everything, Industrial Automation, Future Railway Mobile Communication System, ...

Media and Broadcast in 5G

Rel-16 Work and beyond



5GMSA

5G Media Streaming Architecture

5GMSA (5G Media streaming architecture)

- Summary

- Defines a significantly more modular set of enablers (compared to PSS) for downlink and uplink streaming services
- MNO and 3rd party Media Downlink Streaming Services with relevant functions and interfaces
- MNO and 3rd party Media Uplink Streaming Services based on the non-IMS FLUS architecture
- Procedures include: Progressive Download, DASH-based Streaming and Uplink Streaming

- Other

- Enables different deployments with various degrees of integration between 5G MNOs and Content Providers
- Usage of 5G specific features such as network slicing and edge computing envisioned

- Interested companies

- Ericsson, Qualcomm, Enensys, Samsung, KPN, Sony, AT&T, Orange, BBC, others

- Status

- WI was nominally completed in June '19, but significant corrections happening

Content-Aware Encoding (Yuriy Reznik, Brightcove)

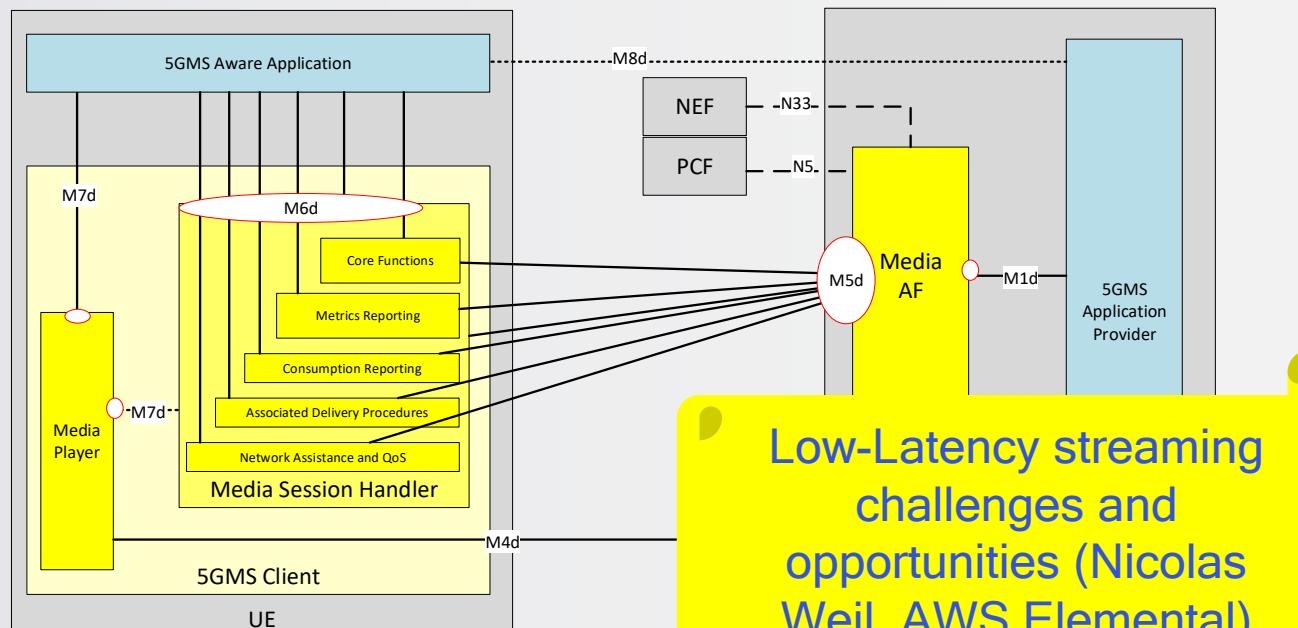
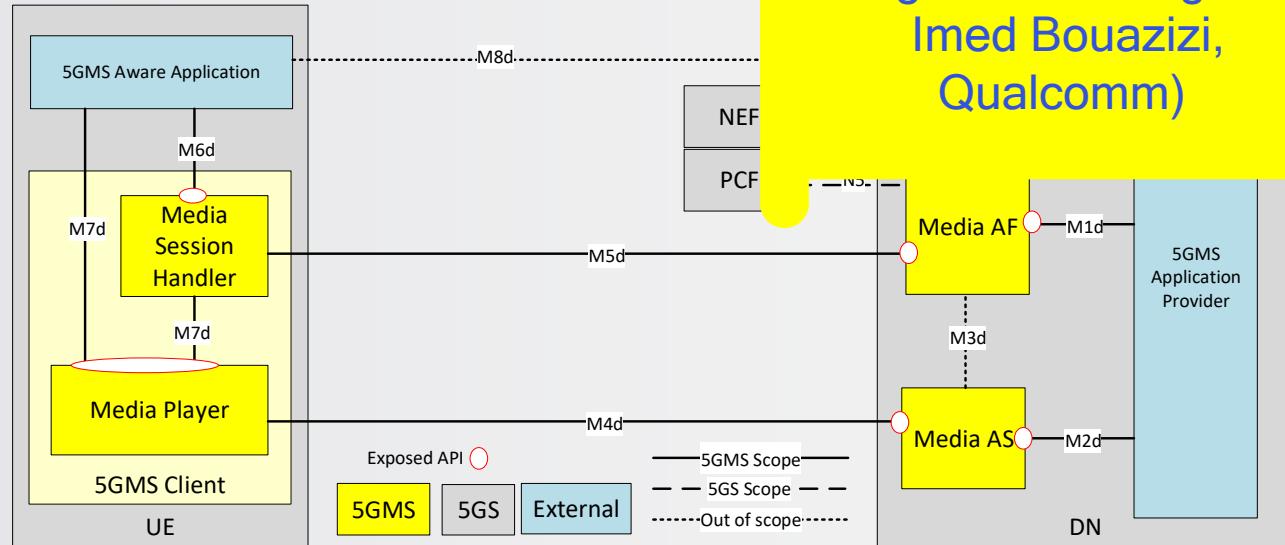
Ad Insertion (Iraj Sodagar, Tencent)

5GMSA (5G Media streaming architecture)

- Key functional scenarios for downlink streaming are
 - Progressive Download
 - Live and On-Demand DASH-based Streaming
 - Consumption Reporting
 - Network Assistance
 - QoE Reporting
 - Dynamic Policies based on AppFilters and Slicing

- Interfaces of relevance

- M1d (5GMSd Provisioning API)
- M2d (5GMSd Ingest API)
- M3d (Internal and NOT SPECIFIED)
- M4d (Media Streaming APIs)
- M5d (Media Session Handling API)
- M6d (UE Media Session Handling APIs)
- M7d (UE Media Player APIs)
- M8d: (EXTERNAL and NOT SPECIFIED): unspecified application interface, which is used for information exchange between the 5GMS Aware application



UE 5G Media Streaming Functions (Control-Centric)

Ingest technologies
Imed Bouazizi,
Qualcomm)

Low-Latency streaming
challenges and
opportunities (Nicolas
Weil, AWS Elemental)

5GMS3

5G Media Streaming Stage 3

5GMS3 (5G Media Streaming stage 3)

- **Summary**

- Based on the 5GMS Architecture specified in TS 26.501, creates new 5G Media Streaming (5GMS) stage 3 specifications and update existing ones to come up with a modular but consistent set of specifications enabling deployment of multimedia streaming services.
- New specifications for:
 - 26.511: 5G Media Streaming (5GMS); Profiles, Codecs and formats
 - 26.117: 5G Media Streaming (5GMS); speech and audio profiles
 - 26.512: 5G Media Streaming (5GMS); Protocols
- Potentially update specification for DASH and video profiles.



Impact of new
protocols
(Ali Begen)

- **Other**

- Work considers existing work from external specifications and industry organizations such as DASH-IF, MPEG and CTA WAVE as well as input from key industry players on their requirements and usage scenarios for media streaming over 5G.
- The work also considers aligning with existing industry efforts on testing, conformance and reference tools.

- **Status**

- WI scheduled for completion Mar '20, but expected to use an extension until Jun '20

5GMS3 (5G Media Streaming stage 3)

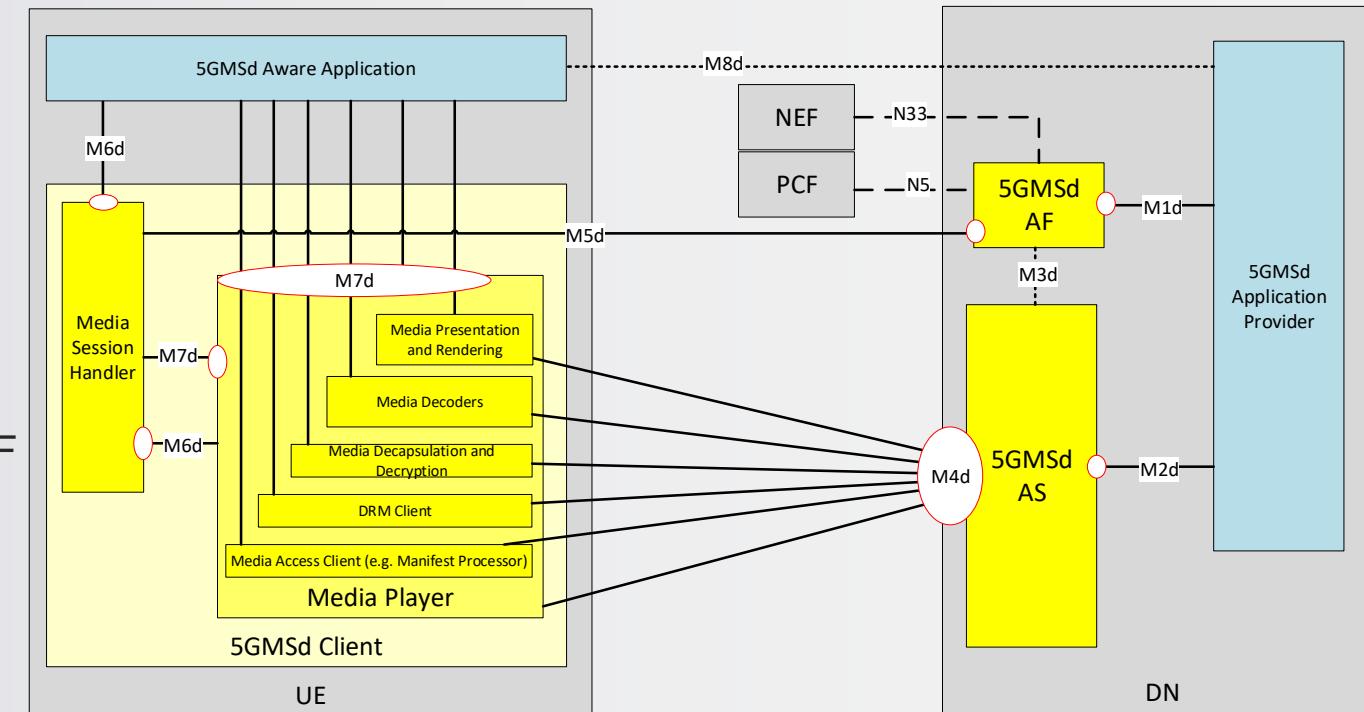
New codecs
(Thierry Fautier,
Harmonic)

- Selected Key Issues

- Network Assistance: radio or core network based
- Video codec status: make HEVC mandatory?
- Audio codecs: AAC, EVS - enough? EVS how?
- Playback requirements: CTA WAVE Device Playback?
- Streaming Ingest: Provisioning and Ingest based on DASH-IF Ingest Specification
- Media Player APIs: dash.js based
- Media Session Handler APIs: TRAPI-based
- Streaming Format: DASH & CMAF
- Low-Latency Streaming: LL-DASH & chunked CMAF
- Encryption and DRM: CMAF and anything else?

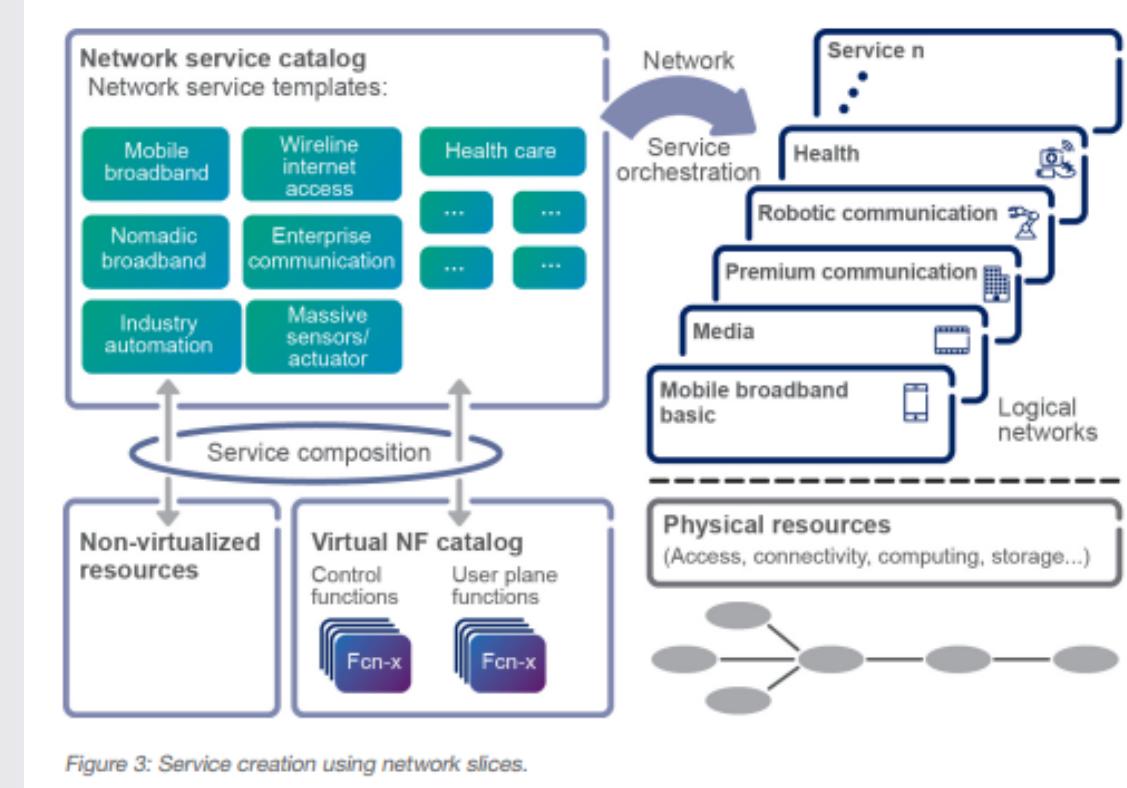
- Can only serve as baseline for future work

- Unicast
- Multicast
- XR integration



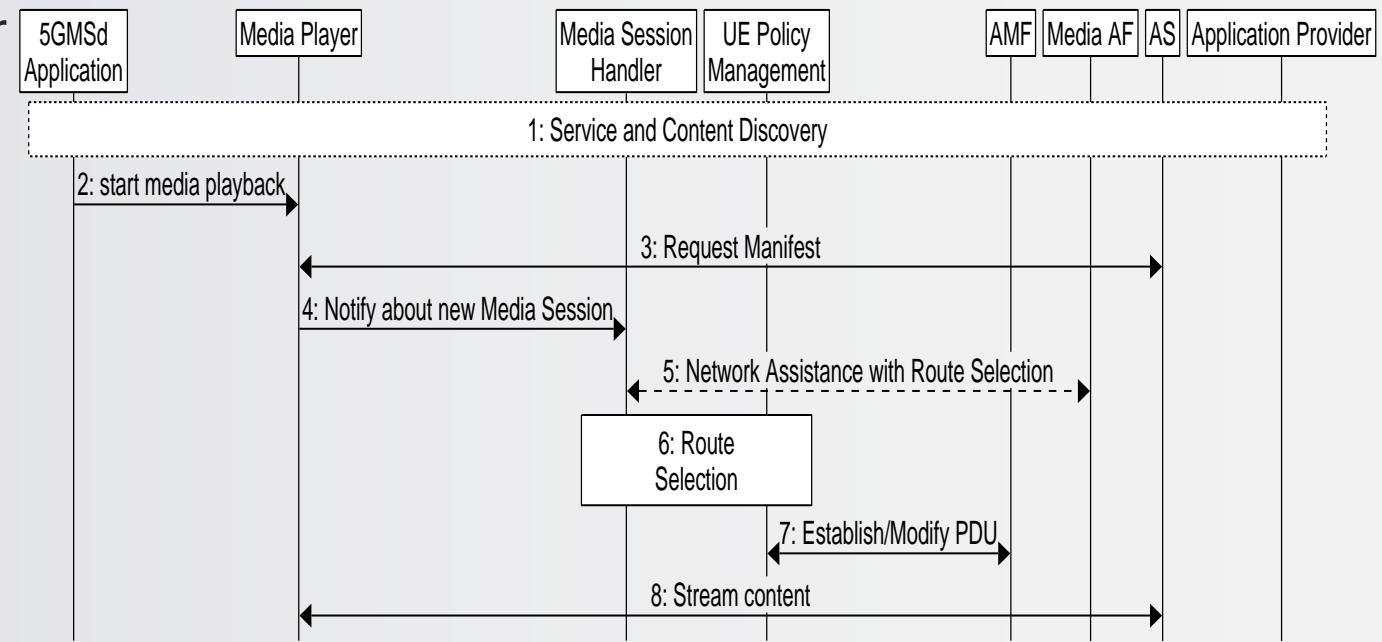
Network Slicing in 5G

- Network Slicing:
 - Allows MNOs to completely isolate traffic for a particular service
 - Customized traffic routing and handling, QoS treatment, and charging policies
- Network Slicing as a Service
 - Content and service providers may opt for a network slice for their traffic
 - This can be setup through SLAs with the MNO or directly using the offered Nmf interface by the NSMF
- Example Use Cases:
 - Binge On: fixed QoS, sponsored traffic
 - Game and AR Streaming: edge processing



Network Slicing for Media Distribution

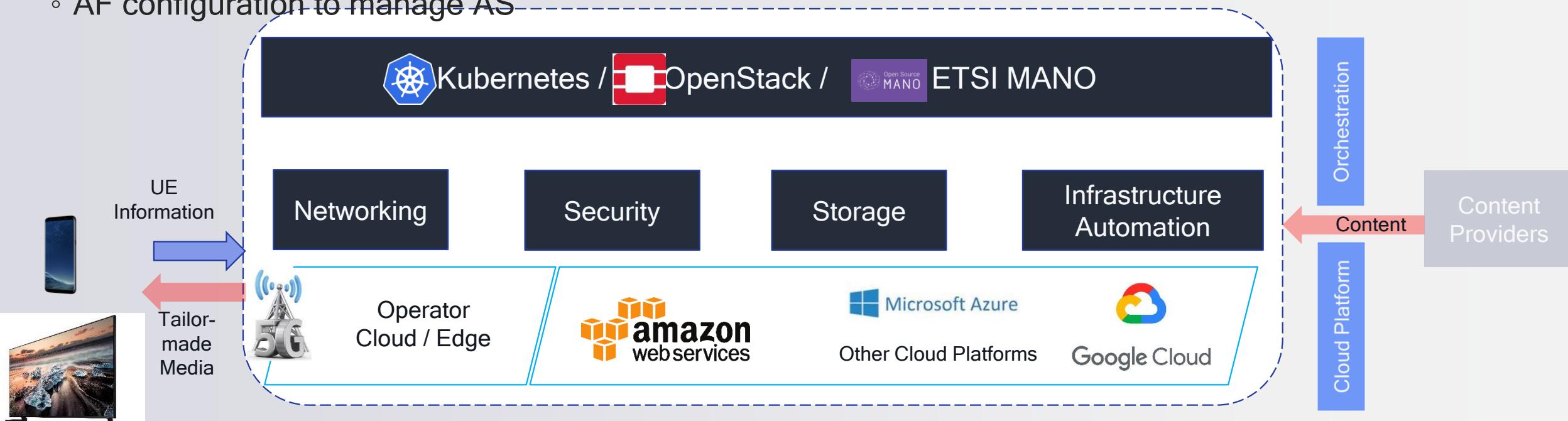
- UE requesting Network Slice
 - UE uses traffic filters information from the session to identify which slice to use for the traffic
 - Filters may include FQDN, IP addresses, or Application Identifier
 - UE establishes or modifies the PDU session that will be used for the traffic
 - Alternatively, Network may also trigger the establishment or modification of the PDU session
- QoS and Charging rules
 - PCF uses pre-stored rules for the network slice to determine the QoS Profile and the charging policy
 - Dynamic variations can be handled by a Media AF



Edge Processing in 5G Network Slice

- Traffic Routing:
 - Through appropriate Filtering rules, traffic is routed to an edge network (e.g. LAN)
 - Through appropriate DNS resolution, an Application Server is selected in the LAN
 - If no AS instance is running, AF together with Orchestrator launch a new instance of the AS
- Slice Configuration:
 - AS criteria and requirements
 - DNS resolution rules
 - AF configuration to manage AS

Cloud computing, edge computing, and media on cloud (Imed Bouazizi, Qualcomm)



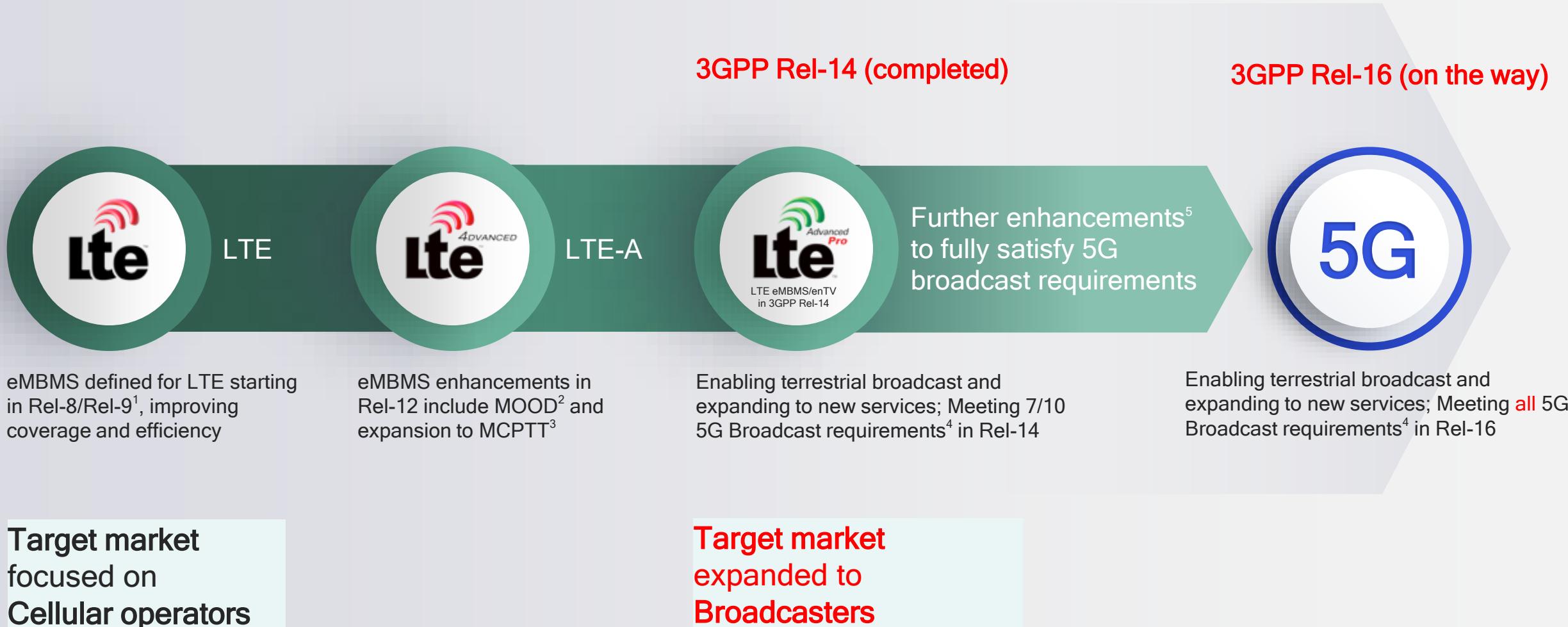
Broadcast/multicast and hybrid delivery (Thomas Stockhammer, Qualcomm)

enTV and MBMS

Terrestrial broadcast for next-gen digital TV delivery

MBMS/LTE eMBMS/enTV History

Building upon a strong 3GPP technology foundation



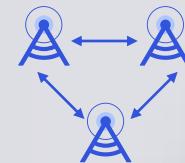
Terrestrial broadcast for next-gen digital TV delivery

enTV¹ – part of 3GPP Rel-16 – meets terrestrial TV broadcast requirements

Radio access enhancements

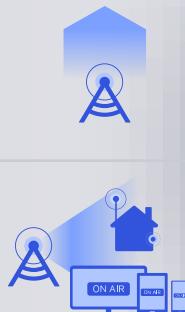
Longer range

New 1-symbol numerology with longer 200us CP² to support 15 km ISD³



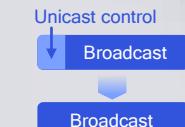
More broadcast capacity

Supports dedicated broadcast network with 100% eMBMS carrier allocation



More deployment flexibility

Single network for mobile and fixed devices with enhanced support for rooftop reception



Better efficiency

New subframe design reduces overhead in dedicated broadcast transmissions



Rel-16 adds in addition

- ~15km ISD (optimized for higher speeds, e.g. audio)
- 50km ISD+ (rooftop reception, limited outdoor depending on Tx power)
- 250km ISD (TBC)

System layer enhancements

Receive only mode

Delivery of free-to-air content to devices without SIM/service subscription



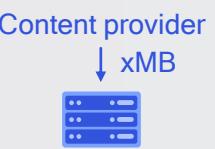
Transport only service

TV broadcasters can deliver content in native format without transcoding



Standardized interface

Content providers can deliver media over LTE with a unified framework



Shared broadcast

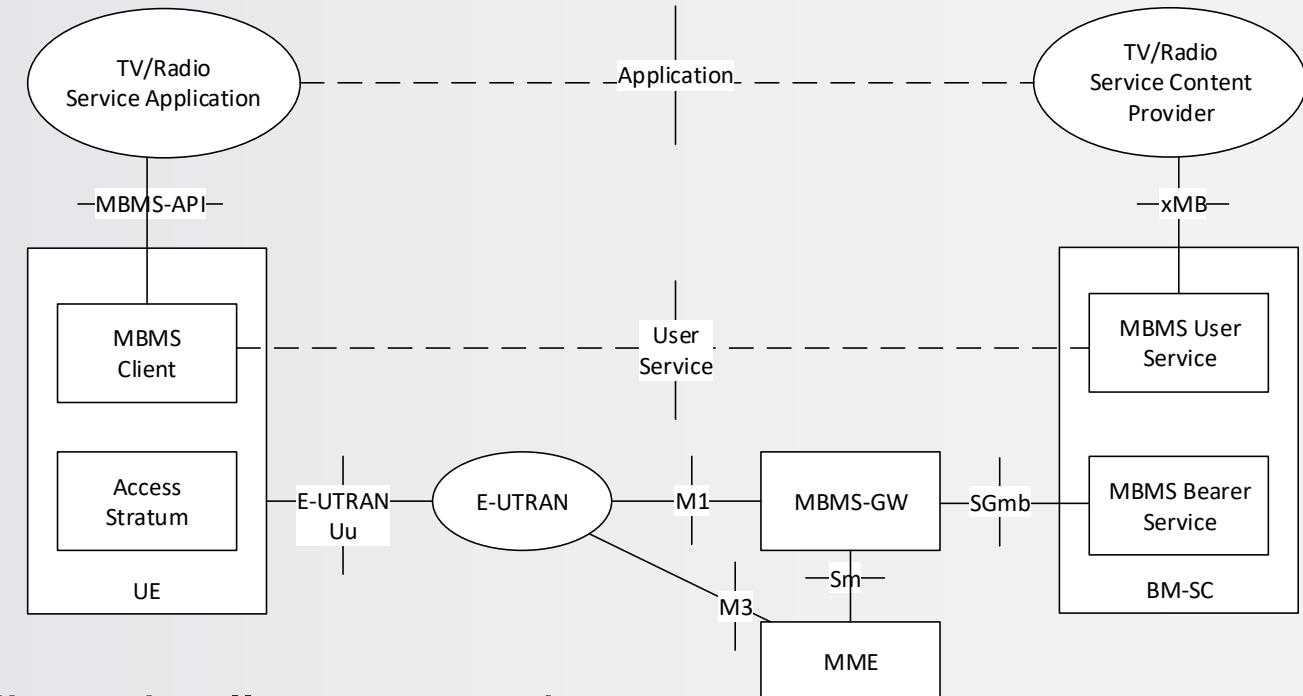
Multiple operators can serve users on a common broadcast carrier



ETSI JTC Broadcast

ETSI TS 103 720: 5G Broadcast **System** for linear TV and radio services

- A single overview and system specification that profiles and restricts existing 3GPP specifications in the context of 5G in order to enable the deployment of linear TV and radio services.
- The work item is aligned with ongoing 3GPP standardization work, in particular the "LTE-based 5G terrestrial broadcast"
- Main features
 - radio network comprising only MBMS-dedicated cells as transmitters;
 - Receive-Only-Mode (ROM) devices and UEs supporting FeMBMS [x23.246] as receivers;
 - A down-striped EPS dedicated to TV and Radio Services with E-UTRAN;
 - A down-striped MBMS User Service [x26.346] dedicated to TV and Radio Services;
 - A set of MBMS-APIs [x26.347] that permits to use third-party service layers.



Rel-17 Multicast Broadcast Considerations

LTE MBMS

Initial Service Targeted

- Video Content and Streaming

Focus on one type of service

- Joint Transport/Service Layer

Service independent of unicast

- Separate core network

Service oriented architecture

- Functionality at the core network
- Reliability, unicast/Broadcast decision
- Security also on application layer

Service oriented architecture

- Flow identified by TMGI (service)
- Maps to MBMS bearer

5G Mixed Mode

Multiple Services Targeted

- C2VX, public safety, I-IoT, IP Multicast

Multiple Services with different characteristics

- Common Transport/Separate Service Layer

Service have unicast and broadcast components

- Transport integrated with 5GS unicast

Enable high reliability + low latency

- Functionality provided at the transport
- RAN Reliability, unicast/Broadcast decision
- Security: encryption at either RAN or UPF

Transport oriented architecture

- Flow identified by MB-QoS flow ID
- Maps to Radio Bearer in RAN

Device platform diversity and hybrid
DASH/HLS (Cedric Thienot, Enesys tbc
and Thomas Stockhammer, Qualcomm)



DAHOE

Support of hybrid DASH/HLS over MBMS

DAHOE (support of hybrid DASH/HLS over MBMS)

- **Summary**
 - CMAF (Common Media Application Format), uses fragmented MP4 (a.k.a. fMP4) as segment format based on the ISO base media file format, supported both by DASH and HLS. This way the same segments can be referenced both by DASH MPDs and HLS playlists. Such content is referred to as hybrid DASH/HLS service.
 - Distribution of HLS-based CMAF and hybrid services over MBMS is expected to be supported
 - Based on Rel-12 AppService concept already introduced by QC
 - Two approaches possible: DASH-distribution and HLS conversion in MBMS client, 2 manifests distributed
- **Other**
 - hybrid DASH/HLS service is an important concept and should be well defined
- **UE impact**
 - Updates to MBMS client necessary to support one or both modes
- **Interested companies**
 - Apple, ENENSYS, Ericsson, Samsung, Qualcomm
- **Status**
 - WI will be completed in Mar '20

DAHOE (support of hybrid DASH/HLS over MBMS)

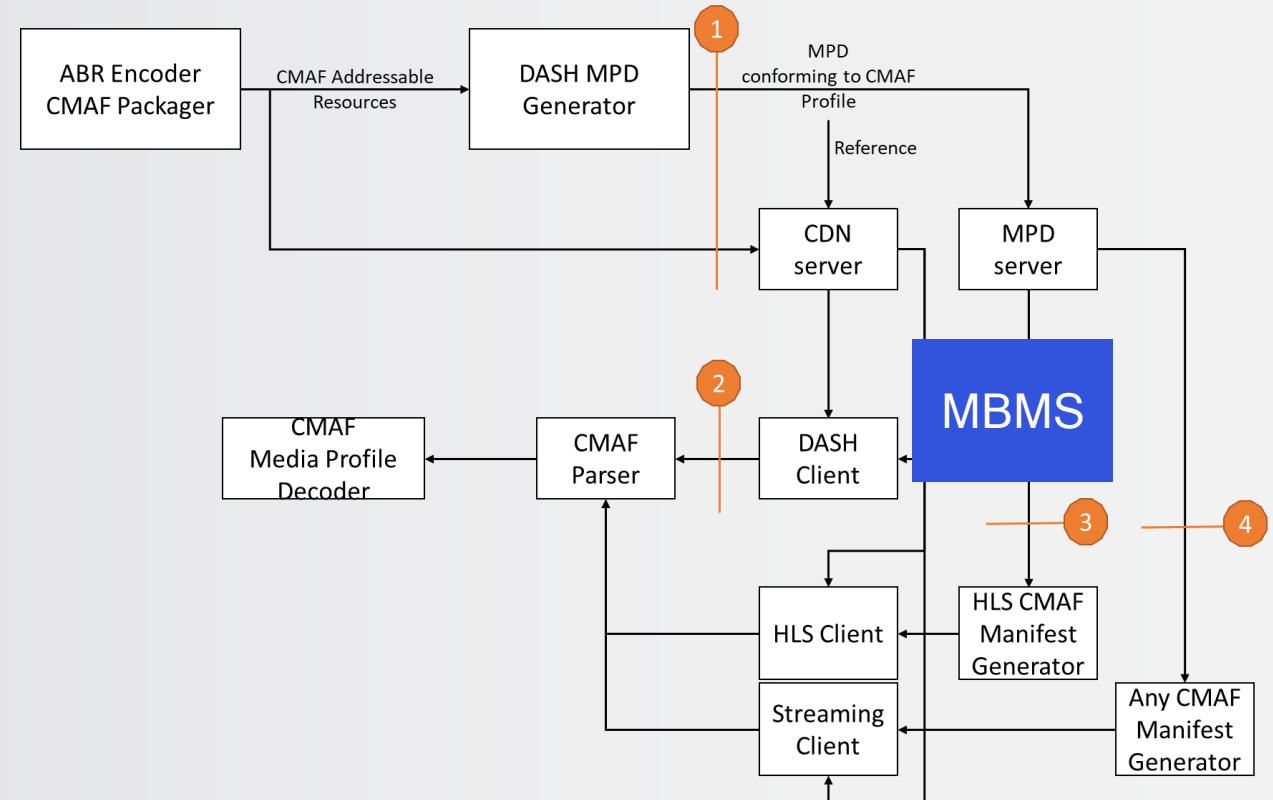
- DASH Amd.1 CMAF work and CTA

WAVE

- This allows to generate content once using an MPD as manifest and do a conversion to other streaming formats such as HLS in the network, for example in a proxy or edge cache or also for example in an end device that includes a streaming client, for example and HLS player.

- Conversion tools based on this format are available and will updated according to this specification:

- JavaScript based conversion in the client here:
<http://vm1.dashif.org/DASHtoHLS/>
- server-side conversion using a PHP script. Source code at: <https://github.com/waqarz/DASH-to-HLS-Playback>



FS_5GXR

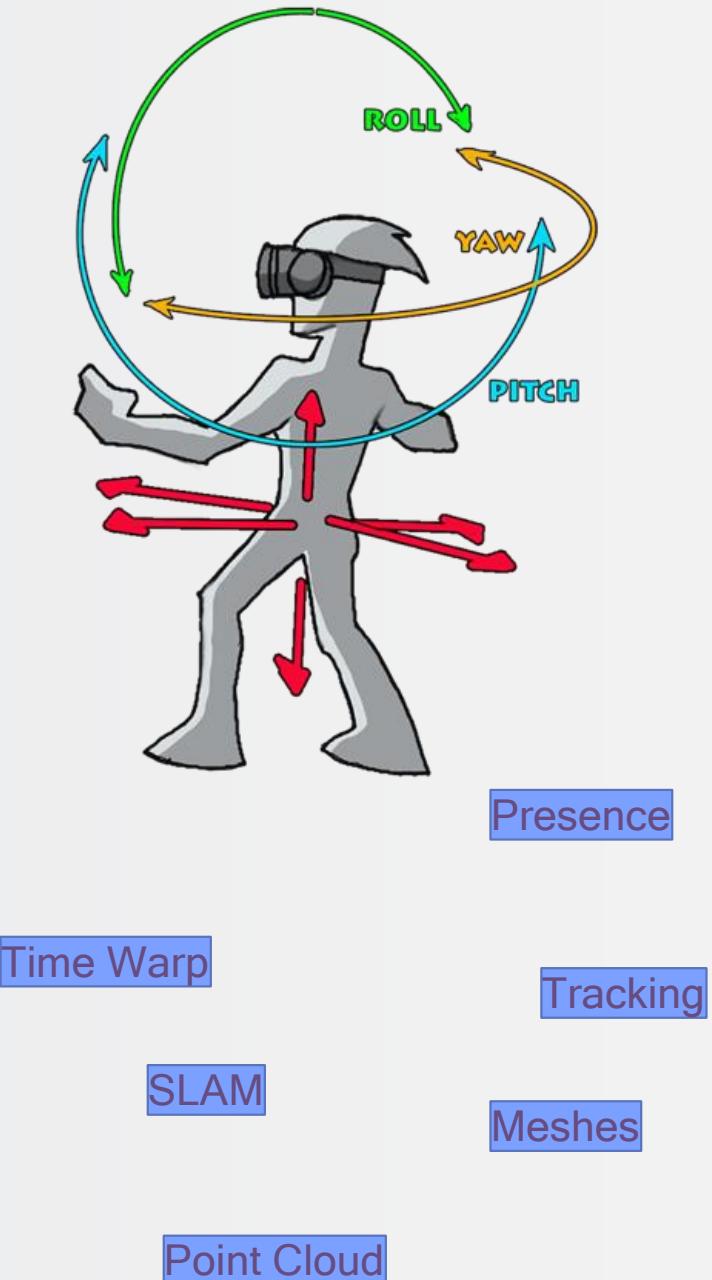
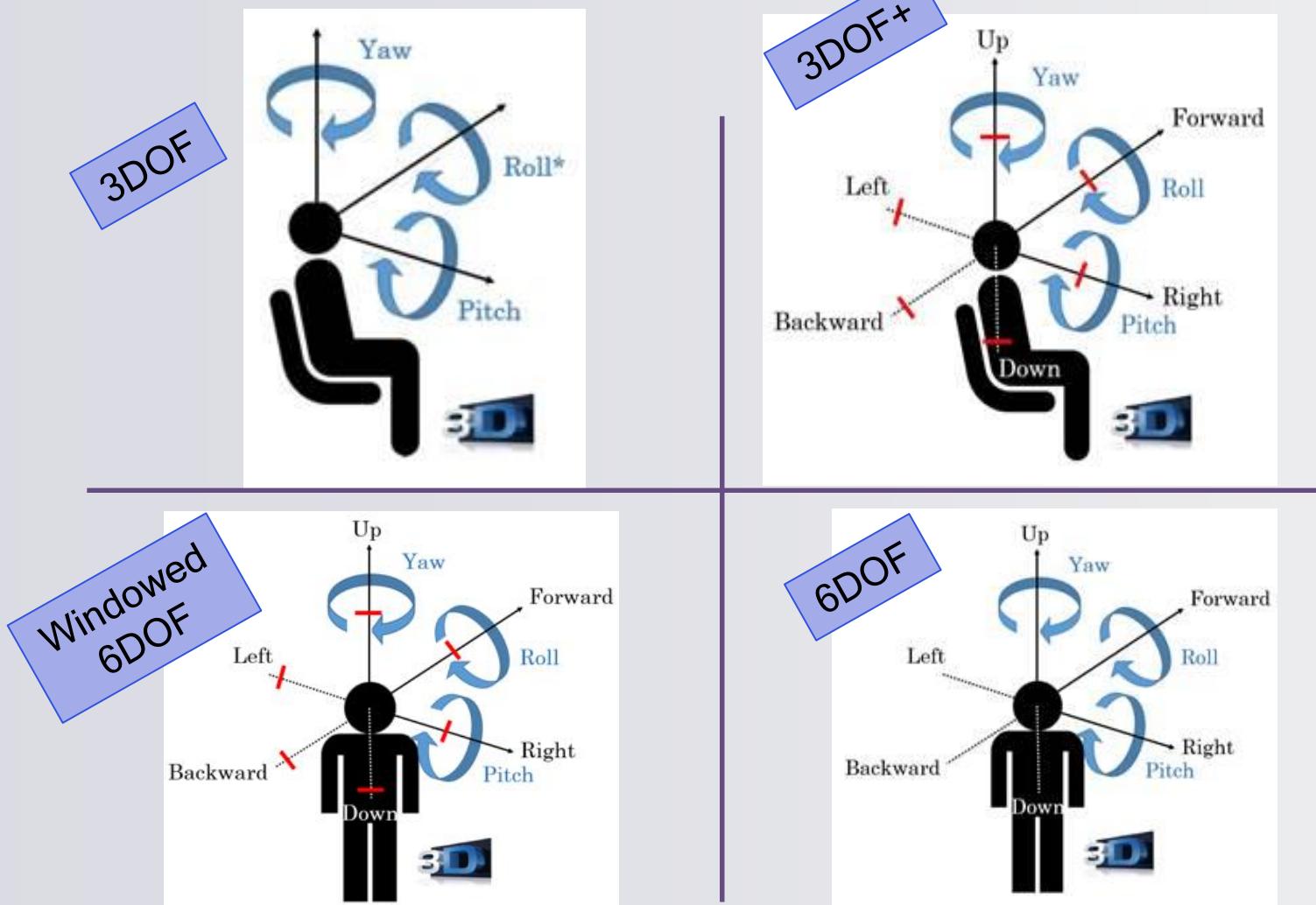
eXtended Reality (XR) in 5G



FS_XR5G (eXtended Reality (XR) in 5G)

- **Summary**
 - Define Extended Reality and Terms in 3GPP, including quality-of-experience with XR services
 - Collects the technologies in the context of XR and their potential relation to 5G System
 - Collects 23 use cases in the context of XR and 5G that are analyzed in terms of potential specification needs
 - Breaks down the use cases in architectures, functions and interfaces
 - Create specific conclusions on normative work in Rel-17
 - Support other 3GPP groups on the definition of system and radio specifications for XR
- **Other**
 - The study is supported by a workshop, for a summary please refer to [S4-191019](#)
- **UE impact**
 - Nothing immediately, but defines device types for XR, including VR and AR
- **Interested companies**
 - Qualcomm, Ericsson, Orange, KPN, LG Electronics, Fraunhofer HHI, Intel, Fraunhofer IIS, Samsung, Facebook, Xiaomi, Nokia, Tencent, Oppo, AT&T
- **Status**
 - SI expected to be completed in Mar '20
 - Normative work in Rel-17

Terms and Definitions



No	Use Case	Type	Experience	Delivery	Device
1	3D Image Messaging	AR	3DoF+, 6DoF	Upload and Download	Phone
2	AR Sharing	AR, MR	6DoF	Local, Messaging Download and Upload	Phone
3	Streaming of Immersive 6DoF	VR	3DoF+, 6DoF	Streaming, Interactive, Split	HMD with a controller
4	Emotional Streaming	2D, AR and VR	2D, 3DoF+, 6DoF	Streaming Interactive, Split	Phone and HMD
5	Untethered Immersive Online Gaming	VR	6DoF	Streaming, Interactive, Split	HMD with a Gaming controller
6	Video Game Live Streaming	VR	6DoF	Streaming, Split	2D screen or HMD with a controller
7	Real-time 3D Communication	3D, AR	3DoF+	Conversational	Phone
8	AR guided assistant at remote location (industrial services)	2D video + AR	6DoF (2D + AR)	Local, Streaming, Interactive, Conversational	5G AR Glasses, 5G touchscreen computer or tablet
9	Police Critical Mission with AR	AR, VR	3DoF to 6DoF	Local, Streaming, Interactive, Conversational, Group Communication	5G AR Glasses/Helmet, VR camera/microphone, Audio stereo headset, 5G accurate positioning
10	Online shopping from a catalogue - downloading	AR	6DoF	Download	AR Glasses, Rendering system, Tablet (or smartphone), Capture device
11	Real-time communication with the shop assistant	AR	6DoF	Interactive, Conversational	AR Glasses, Rendering system, Tablet (or smartphone), Capture device
12	360-degree conference meeting	AR, MR, VR	3DoF	Conversational	Mobile / Laptop
13	3D shared experience	AR, MR, VR	3DoF+, 6DoF	Conversational	Mobile / Laptop
14	6DOF VR conferencing	VR	6DoF	Interactive, Conversational	VR gear with binaural playback and HMD video playback, Call server
15	XR Meeting	AR, VR, XR	6DoF	Interactive Conversational	Phone, HMD, Glasses, headphones
16	Convention / Poster Session	AR, VR, MR	6DoF	Interactive, Conversational	Phone, HMD, AR Glasses, VR controller/pointing device, headphones
17	AR animated avatar calls	AR	2D, 3DoF	Conversational	Phone, HMD, Glasses, headphones
18	Online shopping from a catalogue - downloading	AR	6DoF	Download	AR Glasses, Rendering system, Tablet (or smartphone), Capture device
19	Front-facing camera video multi-party calls	AR	3DoF	Conversational	Smartphone with front-facing camera, headset
20	AR Streaming with Localization Registry	AR, Social AR	6DoF	Streaming, Interactive, Conversational	AR glasses with binaural audio playback support
21	Immersive 6DoF Streaming with Social Interaction	VR and Social VR	3DoF+, 6DoF	Streaming, Interactive, Conversational, Split	HMD with a controller
22	5G Online Gaming Party	VR	6DoF	Streaming, Interactive, Split, D2D	HMD with a Gaming controller
23	Spatial Shared Data	AR	6DoF	Streaming, Interactive, Conversational, Split	HMD, AR Glasses

Device Types and Power Considerations

Smartphone



AR



VR

Standalone



Tethered - Smartphone,

PC or Console



Smartphone Enterprise PC



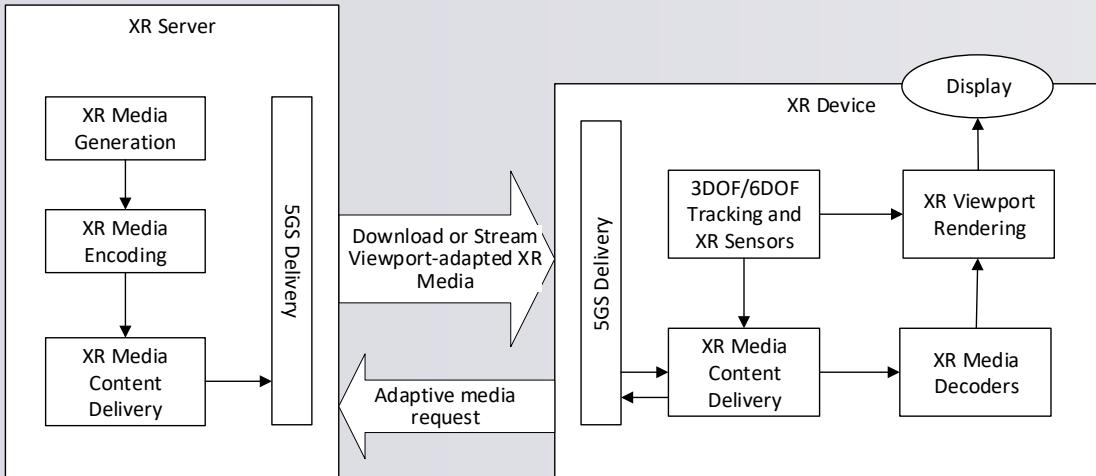
Smartphone Gaming PC

XR Type Number	XR Device Type Name	Tethering Examples	5G Uu Modem	XR Engine Localization	Power Supply	Typical Max Avail Power
XR5G-P1	Phone	n/a	XR device	XR device or split	Internal	3-5 W
XR5G-V1	Simple VR Viewer wired tethering	USB-C	External	External	External	2-5 W
XR5G-V2	Simple VR Viewer wireless tethering	802.11ad/y, 5G sidelink, etc.	External	External	Internal	2-3 W
XR5G-V3	Smart VR Viewer wireless tethering	802.11ad/y, 5G sidelink, etc.	External	XR device or Split	Internal	2-3 W
XR5G-V4	VR HMD Standalone	n/a	XR device	XR device or Split	Internal	3-7 W
XR5G-A1	AR Wearable standalone	n/a	XR device	XR device or Split	Internal	2 - 4 W
XR5G-A2	Simple AR Wearable wired tethering	USB-C	External	External	External	1-3 W
XR5G-A3	Simple AR Wearable wireless tethering	802.11ad/y, 5G sidelink. etc.	External	External	Internal	0.5 - 2 W
XR5G-A4	Smart AR Wearable wireless tethering	802.11ad/y, 5G sidelink. etc.	External	XR device or Split	Internal	0.5 - 2 W

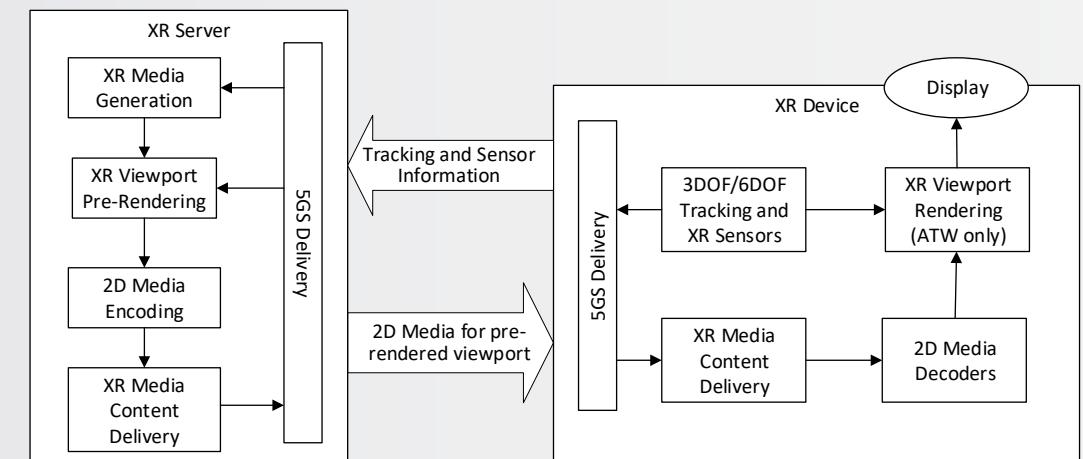
Architecture Examples

Identifying interfaces, APIs, formats, protocols

Viewport-Dependent Streaming

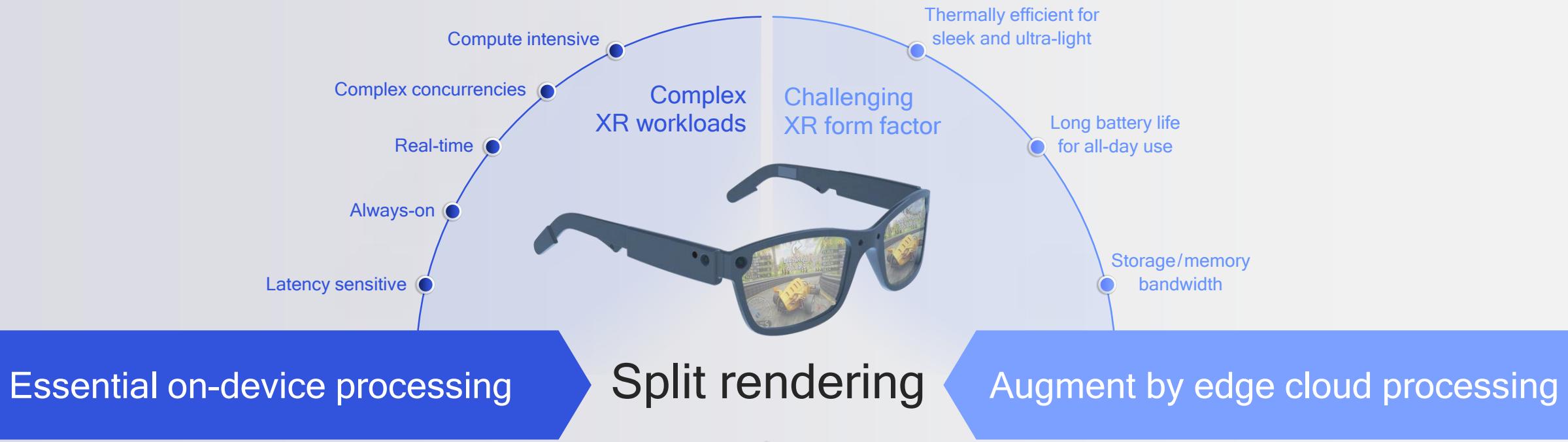


Split Rendering with Time Warp



- Rendering-centric architectures
- Other architectures look at AR localization or network-based rendering
- Identified an initial set of latency, bandwidth and reliability requirements

A new era in distributed processing



Optimized under strict power,
thermal, size constraints

Premium experiences today that
continuously improve

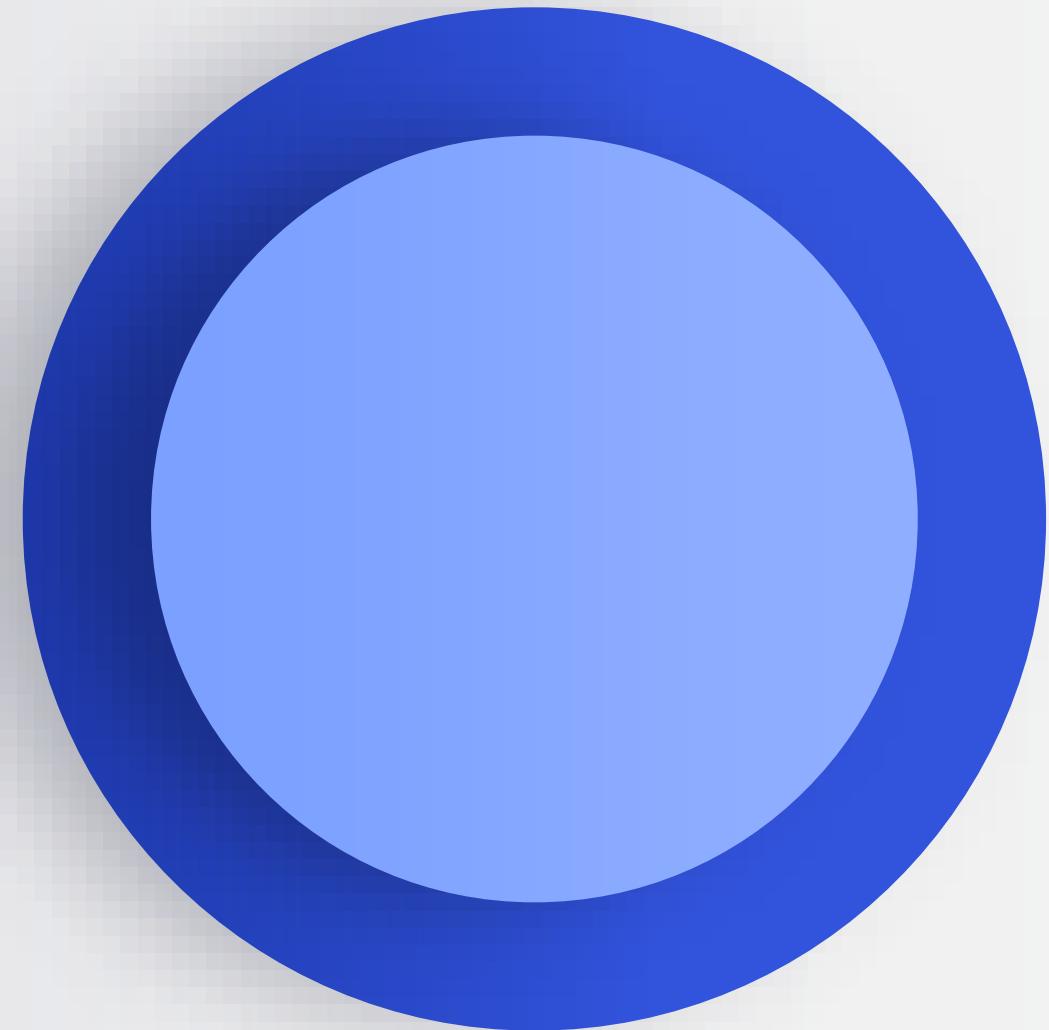
5G

Low latency
High capacity
Reliable link

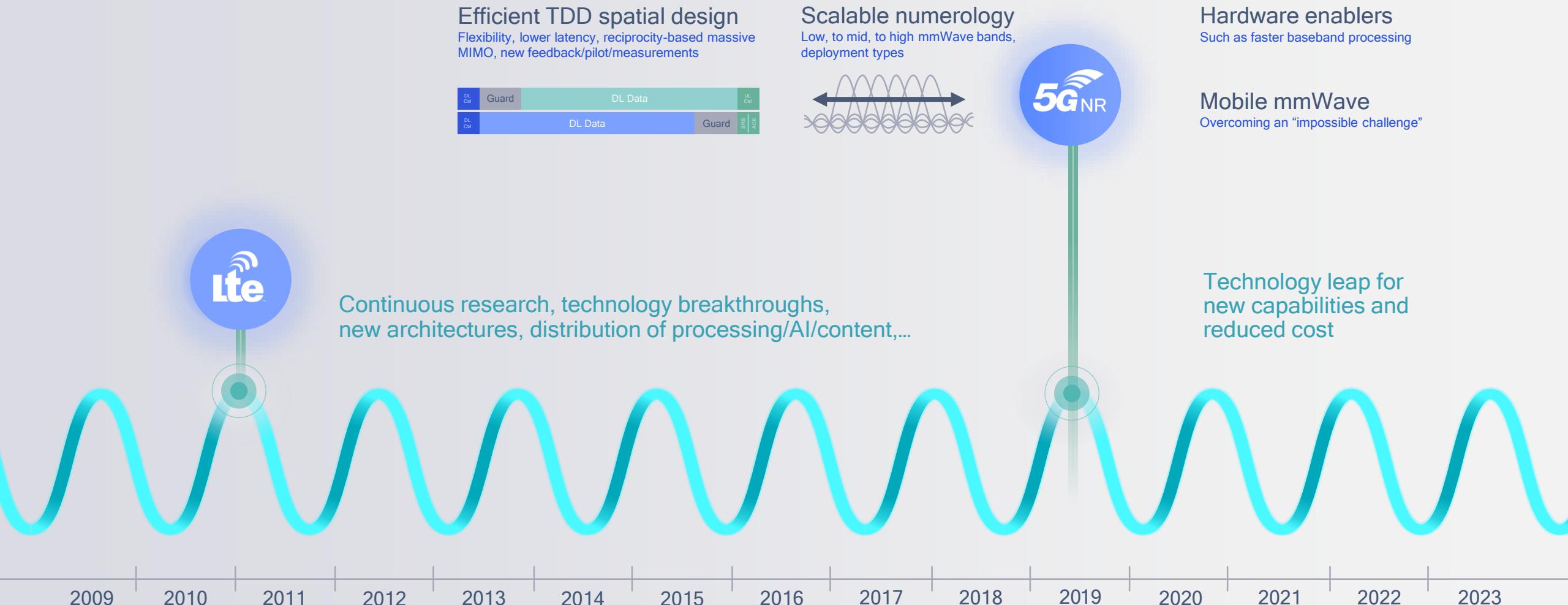
Significant higher power
envelope—beyond PC class

Augment on-device rendering with
edge cloud rendering

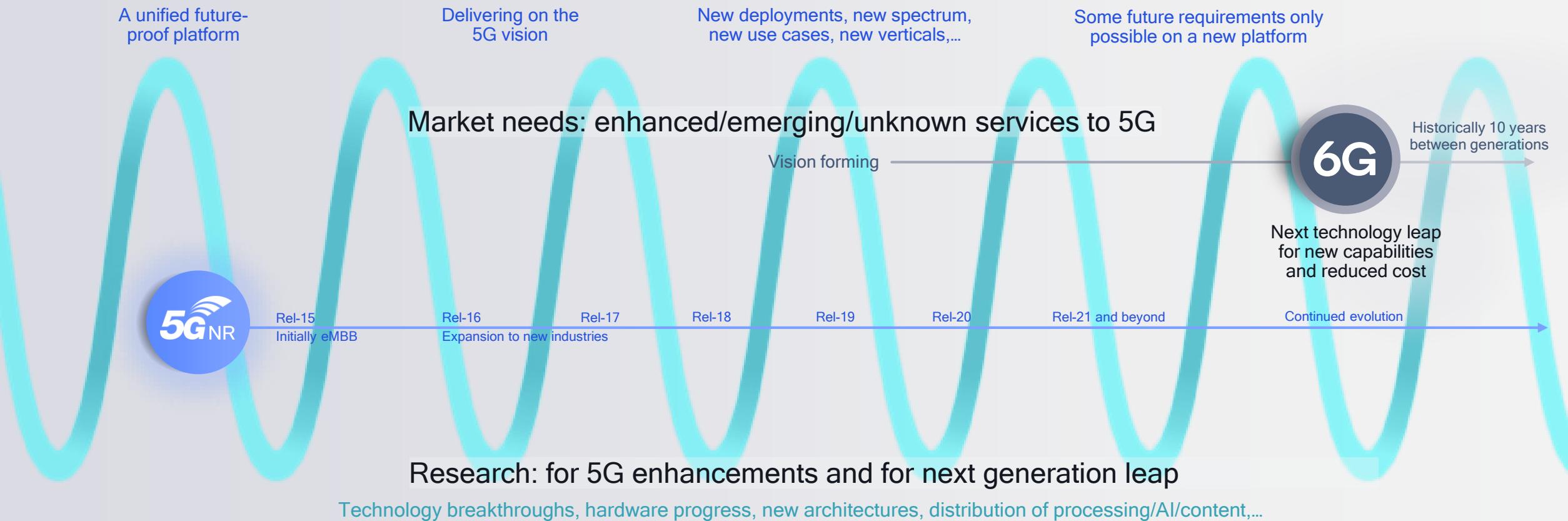
Wrap Up



5G enabled capabilities not possible when 4G was defined



5G is the innovation platform for the next decade



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