NOKIA Bell Labs

5G – A Key Enabler for New Verticals and Markets

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07.April.2018, Las Vegas, Nevada, USA

Website: www.5g-xcast.eu/about/

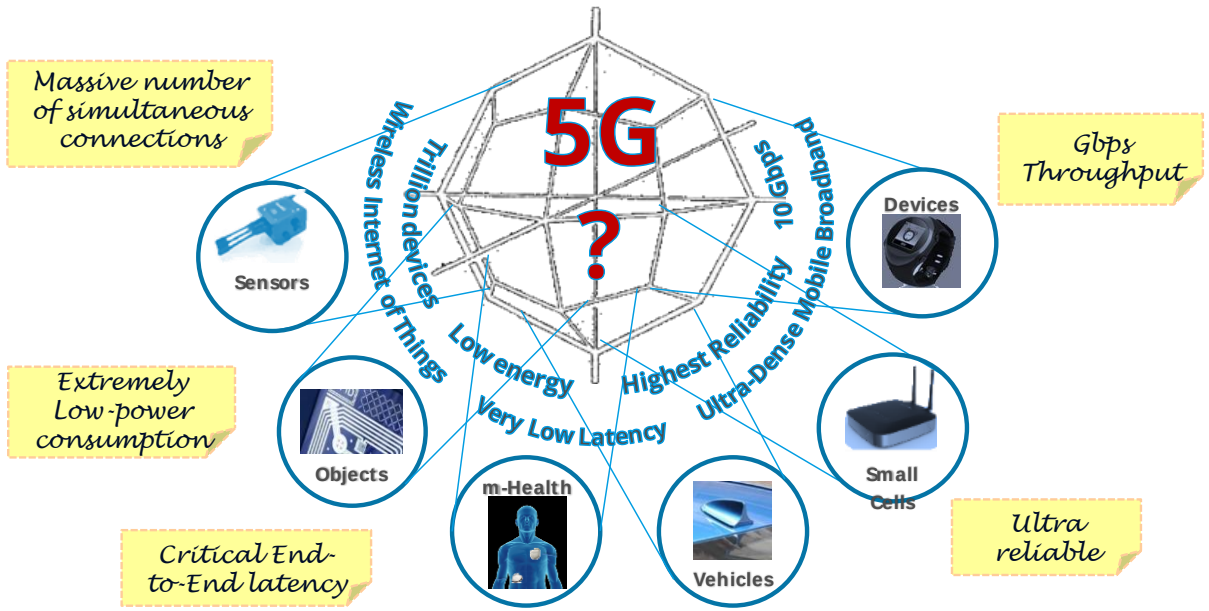
Presentation Outline

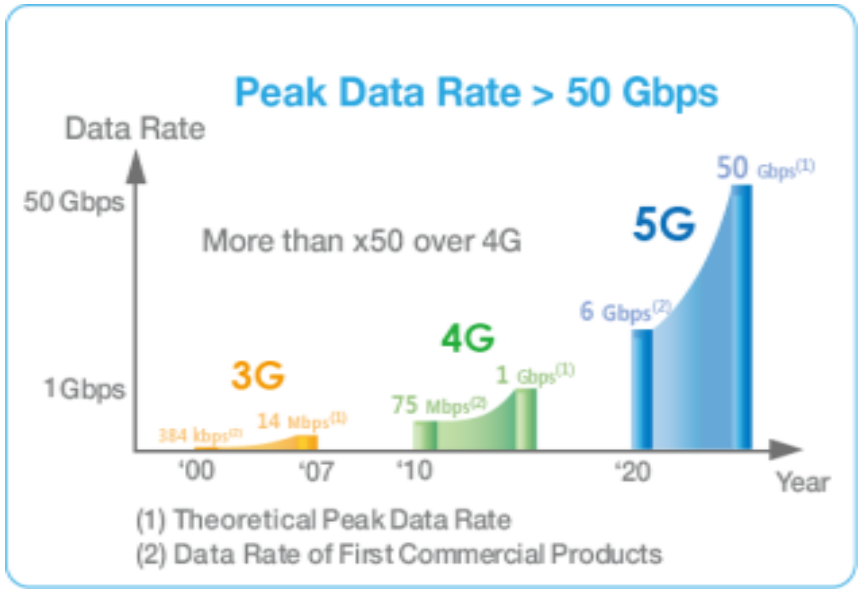
- Overview of 5G
  - Including requirements
  - Key technologies
  - Impact and relevance of new verticals and markets
  - Status in ITU & 3GPP

- 5G-Xcast Project
  - Introduction
  - Status of Xcast standards evolution
  - Key use cases and future outlook

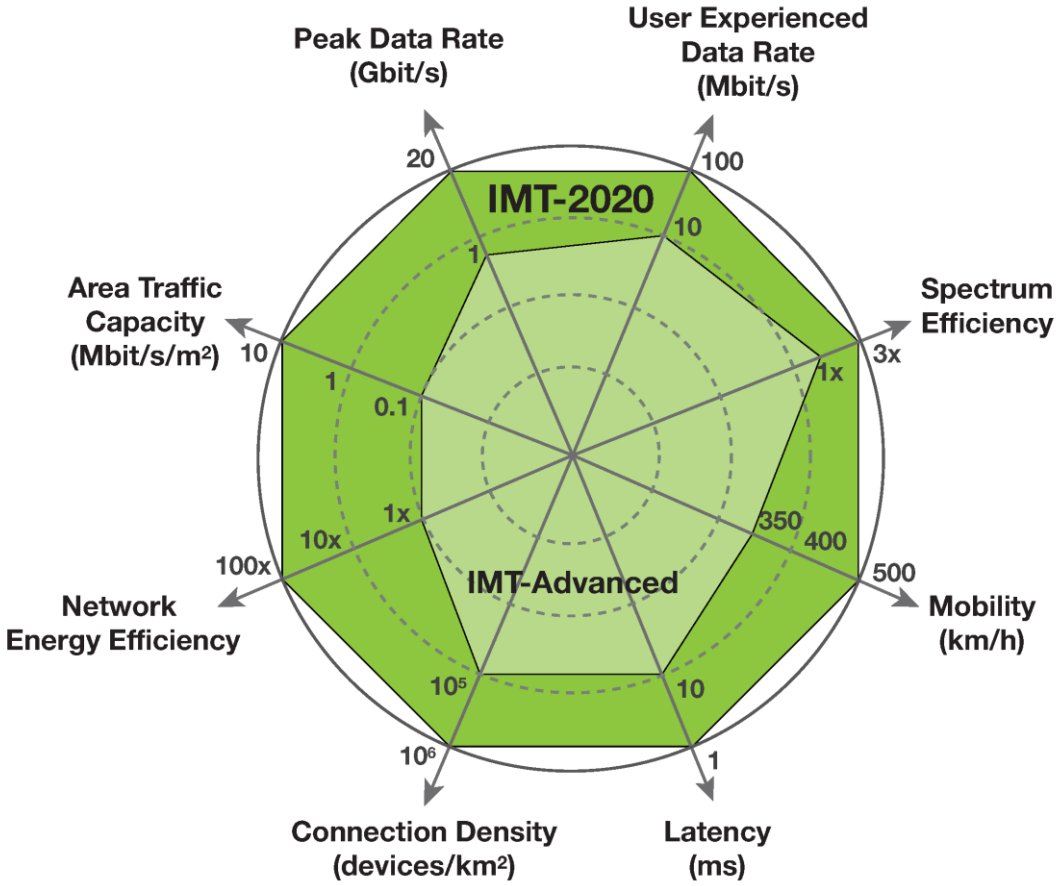
5G
Introduction

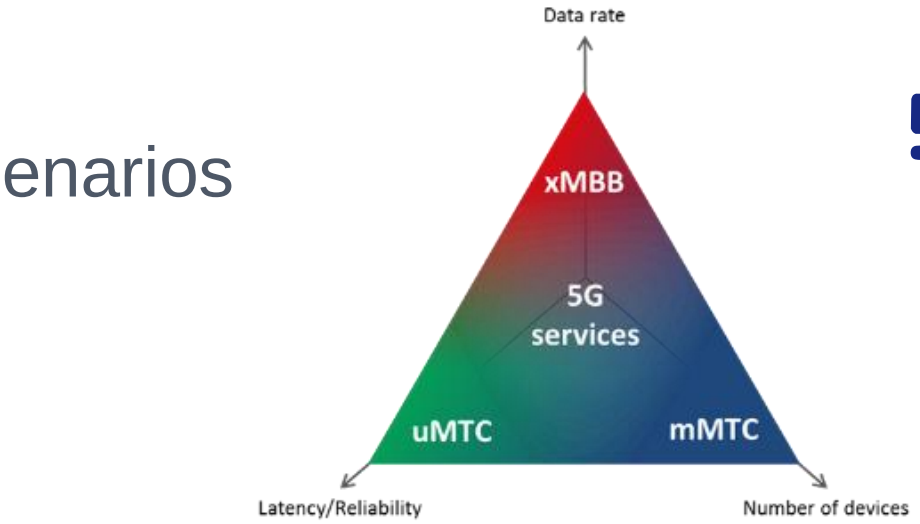
- 5G enables extreme mobile broadband data rates with ultra-reliability and low-latency
  - Designed to meet very challenging technical requirements to support new use cases derived from several vertical industries, not just for mobile broadband
  - **Note**: Total capacity of network is still limited

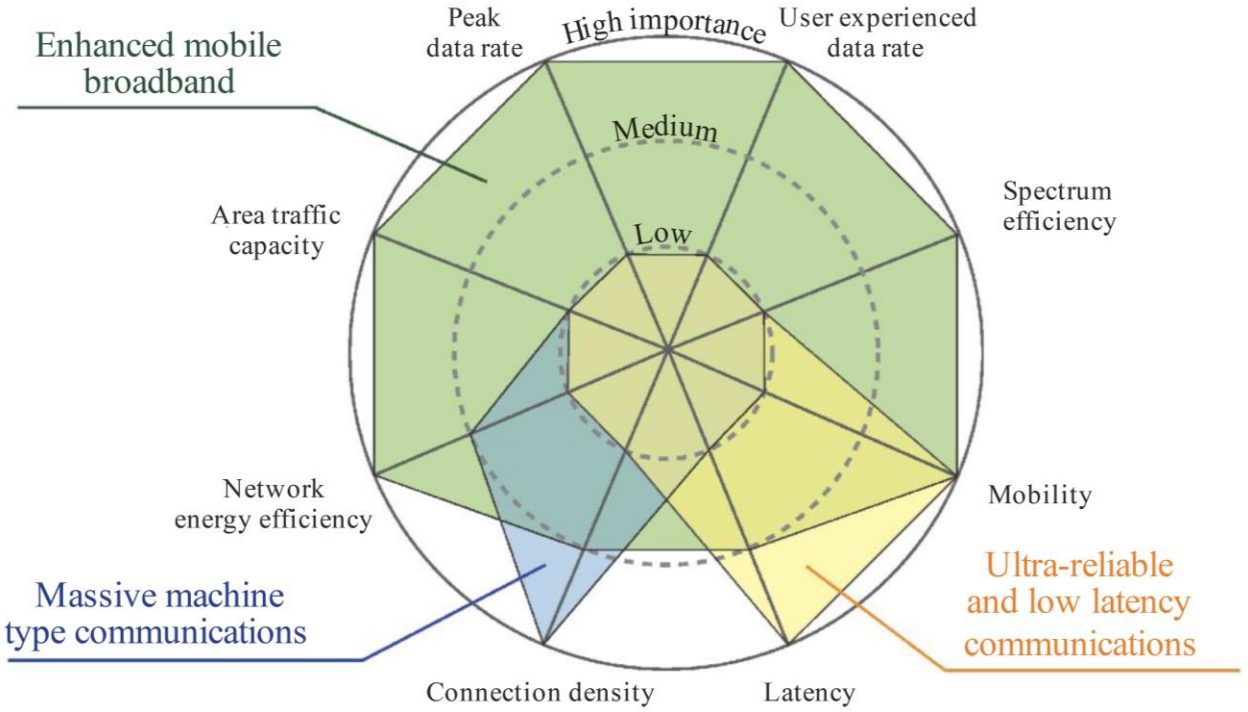




ITU IMT-2020
Key Capabilities and Usage Scenarios







ITU IMT-2020 - Setting Stage for 5G
Minimum Technical Performance Requirements

KPI	Minimum Requirement
Peak Data Rate	20 Gpbs DL 10 Gbps UL
Peak Spectral Efficiency	30 bps/Hz DL 15 bps/Hz UL
User experienced data rate	100 Mbps DL; 50 Mbps UL
5th percentile user spectral efficiency	0.225 bps/Hz DL eMBB in dense urban (0.12 rural)
Average spectral efficiency	9/7.8/3.3 bit/s/Hz/TRxP for eMBB hotspot/urban/rural
Area traffic capacity	10 Mbit/s/m2 in the Indoor Hotspot for eMBB
Bandwidth	at least 100 MHz; 1 GHz above 6 GHz

IMT – International Mobile Telecommunication
ITU – International Telecommunications Union

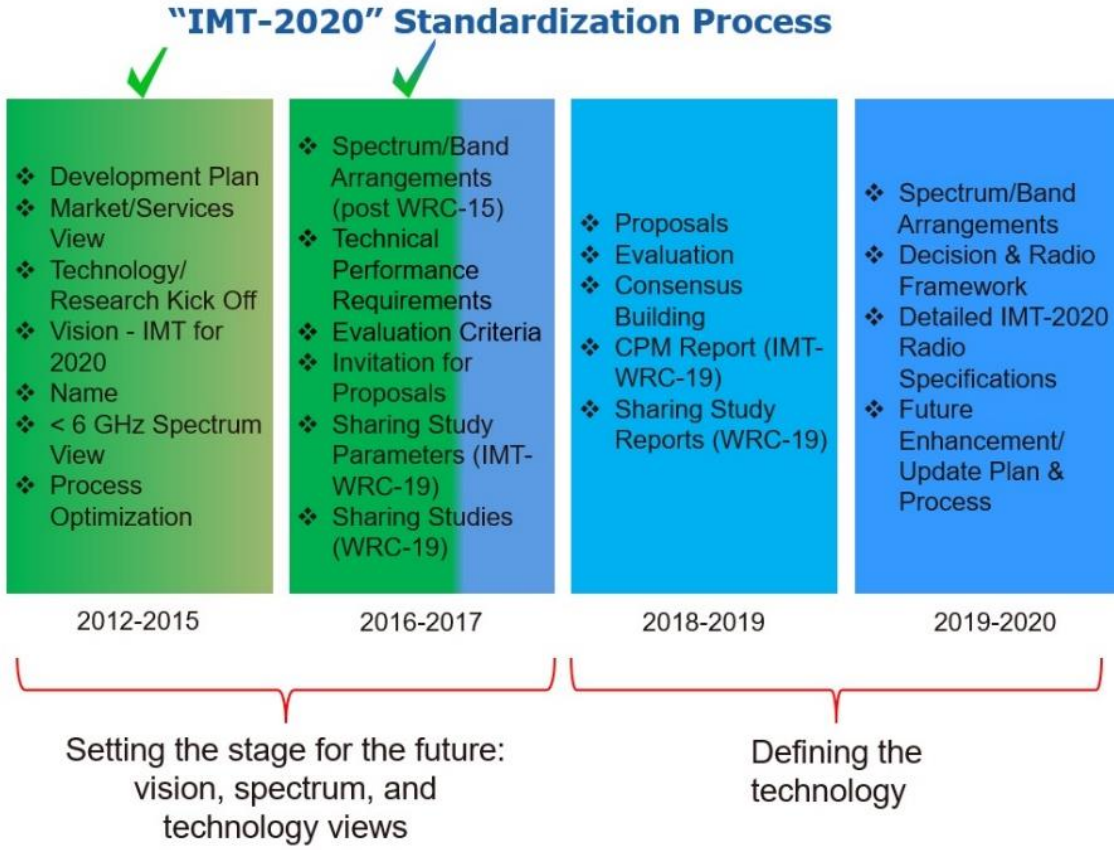
Most challenging requirements

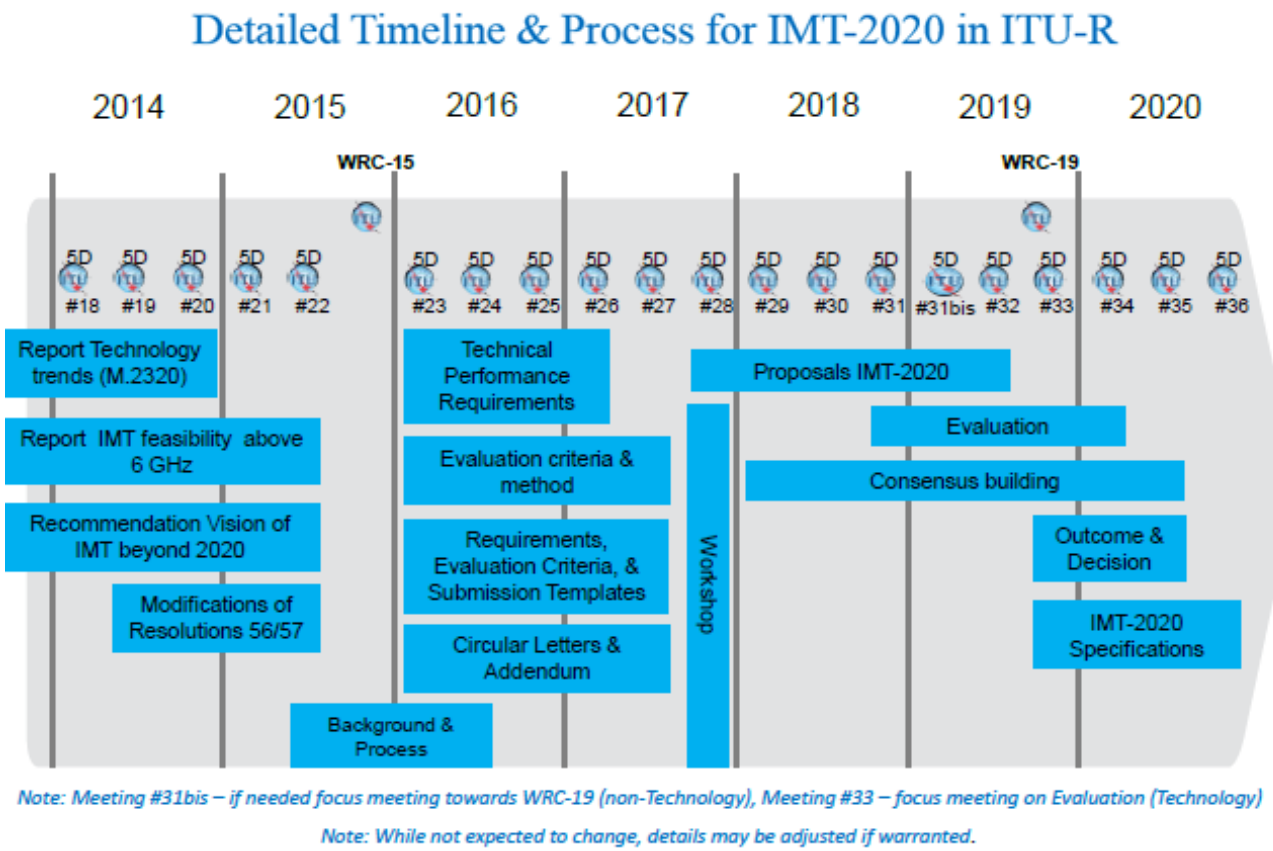
ITU IMT-2020
Minimum Technical Performance Requirements

KPI	Minimum Requirement
Latency	User plane latency: • 4 ms for eMBB; • 1 ms for URLCC Control plane latency: • 20 ms (10 ms encouraged)
Connection density	1.000.000 devices per km2
Reliability	$1\text{-}10^{-5}$ success probability of transmitting a layer 2 PDU of 32 bytes within 1 ms in channel quality of coverage edge for URLLC
Mobility	Up to 500 km/h
Mobility interruption time	0 ms
Energy efficiency	High sleep ratio and long sleep duration for eMBB

ITU IMT-2020
Timeline

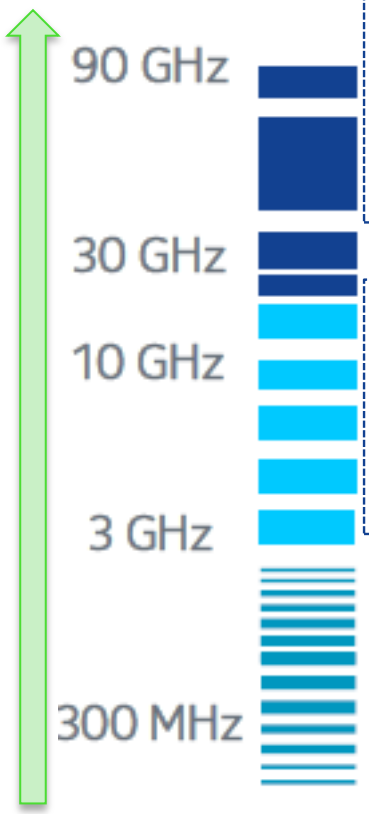
- Proposal submission opened in October 2017 and closes in July 2019





Source: ITU

5G
Key Technologies / Features



Single radio interface for a multitude of frequency bands

Spectrum

Shared bands, wider bandwidth (up to 1 GHz), higher frequency bands (cmW / mmW)

Ultra-Dense Deployments

Small cells, self-backhaul, coordinated RRM, interference coordination

Antenna

Advanced receivers, beamforming, 3D-MIMO, massive MIMO

Waveform

Multi-carrier OFDM, advanced filtering, robust

Availability

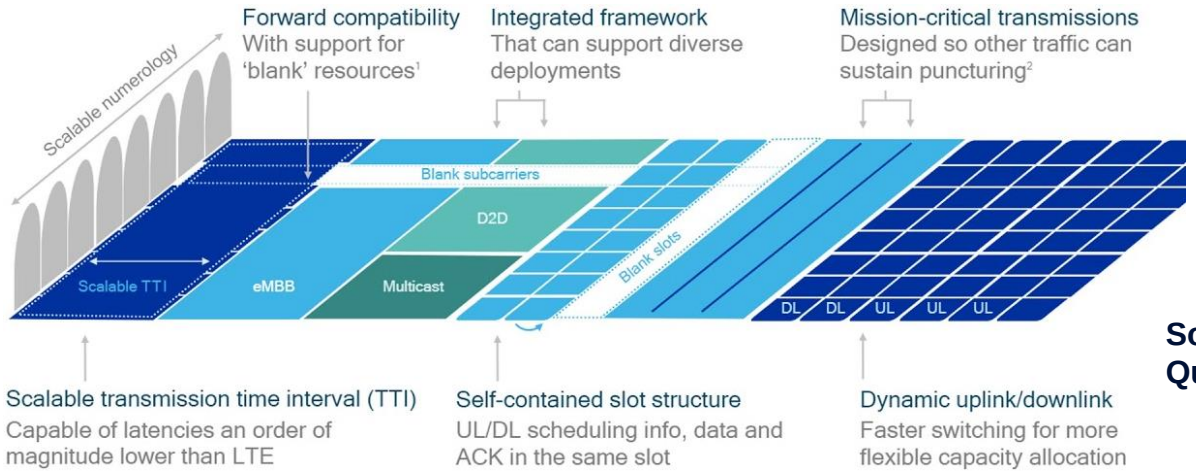
Connectionless operation, grant-free, asynchronous uplink, reliability

Flexibility

Lean carrier, flexible frame structure, numerology, dynamic UL/DL

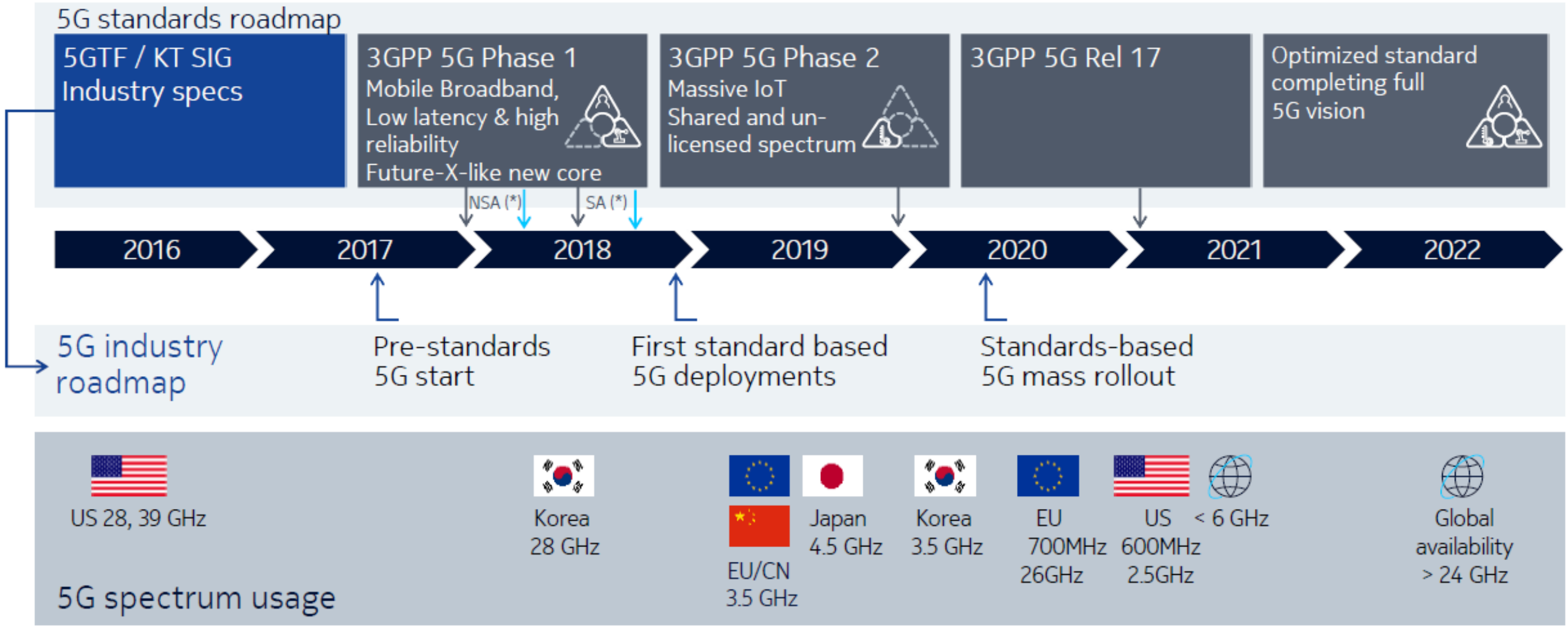
Architecture

Flexible functionality split, cloud-native architecture, service-based



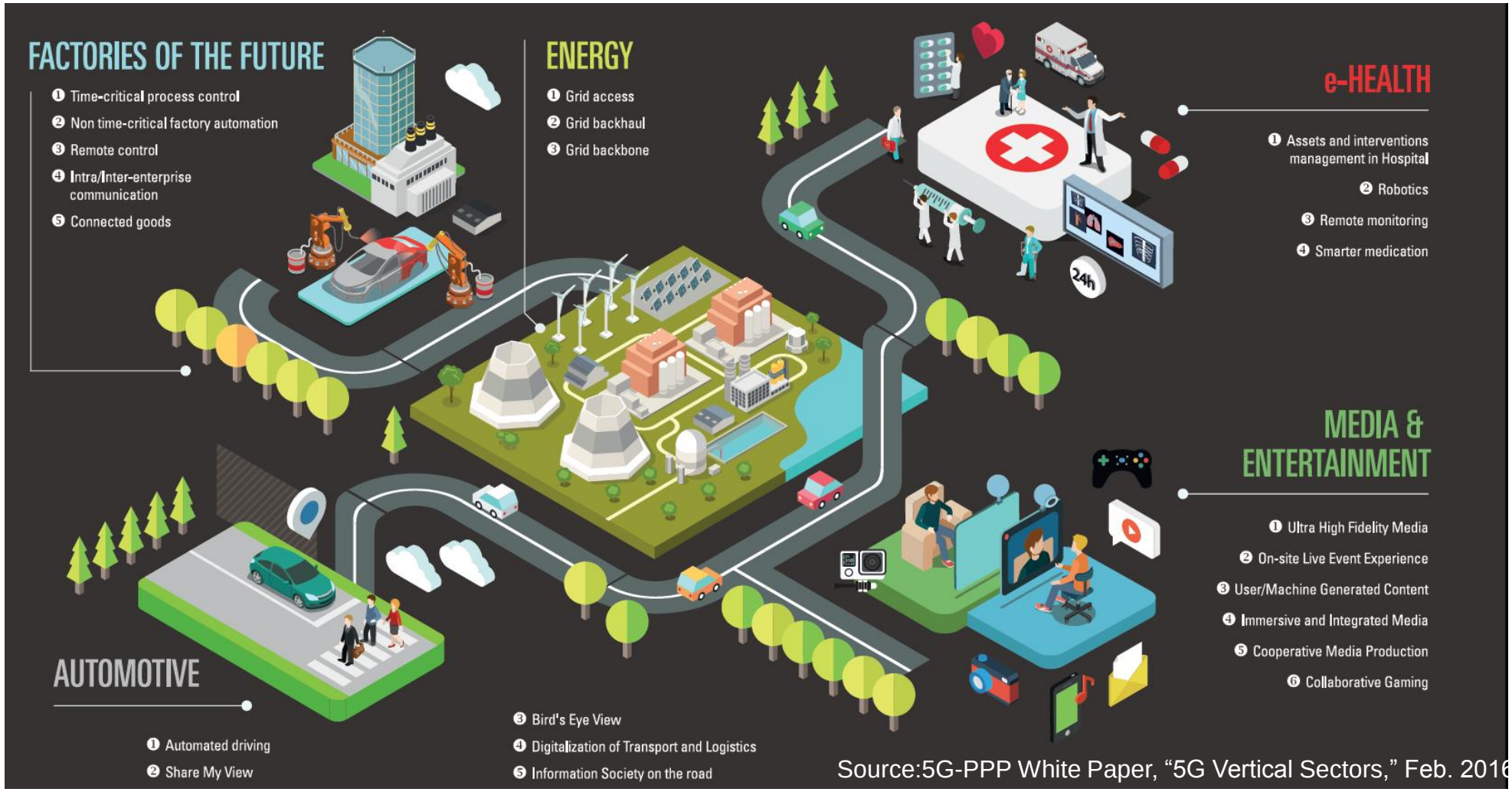
Source: Qualcomm

5G Spectrum
Global Availability



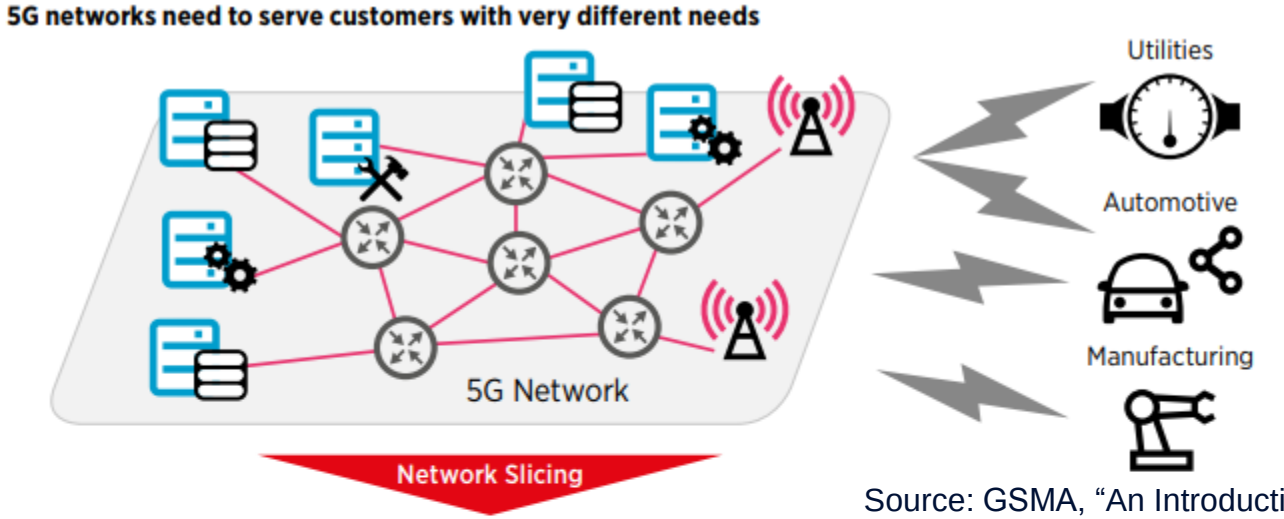
*) NSA: Non standalone; SA: Standalone ... functional freeze ..protocol (ASN.1) freeze

5G – Key Drivers
New Verticals and Markets

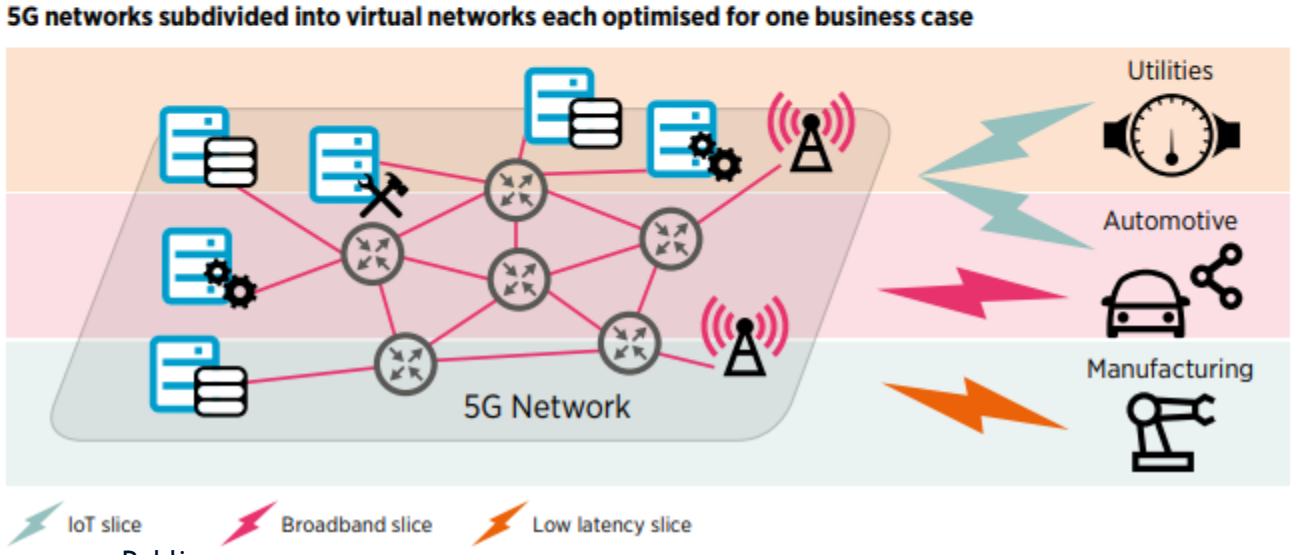


Source:5G-PPP White Paper, "5G Vertical Sectors," Feb. 2016

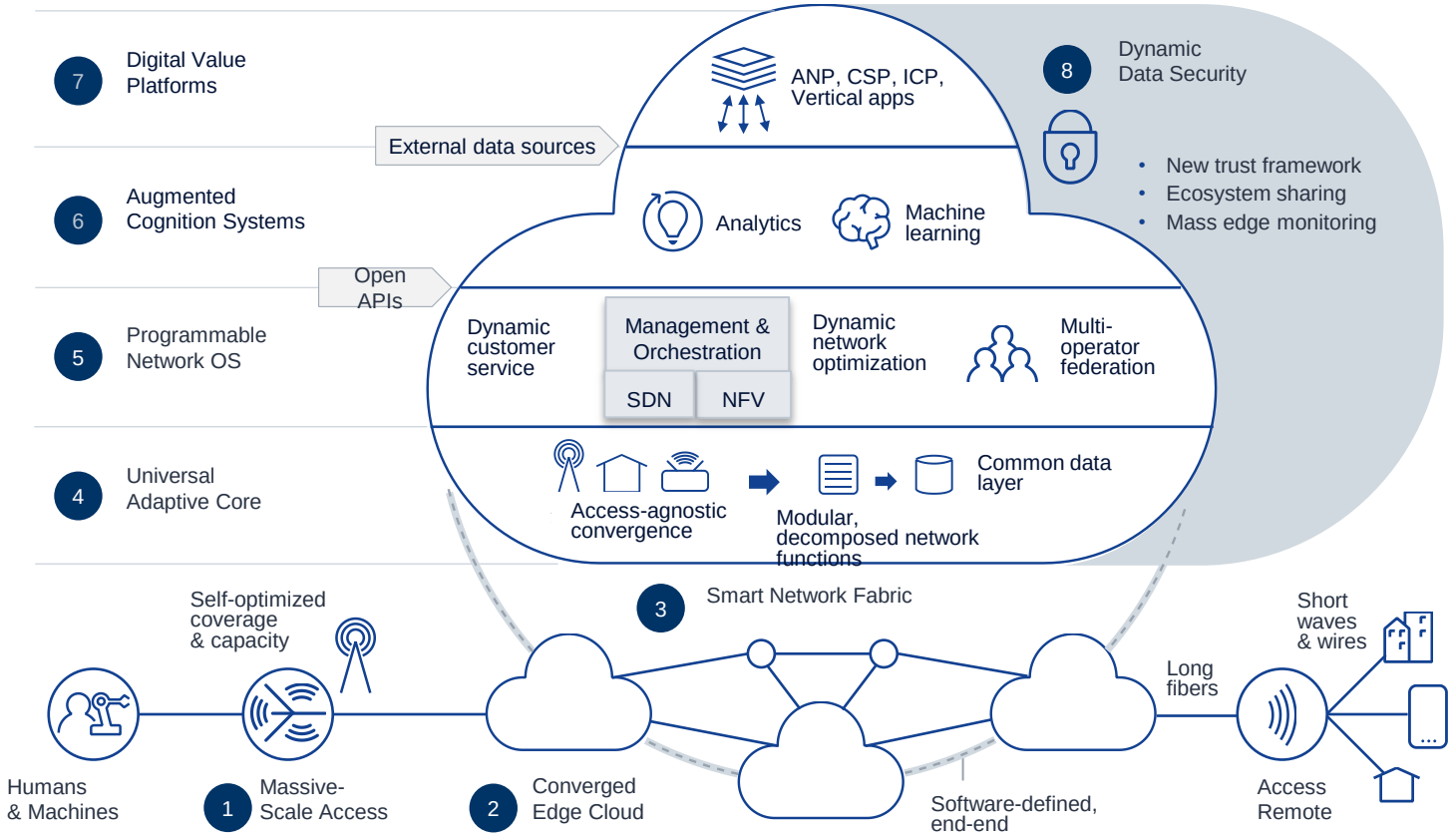
Network Slicing
Service-specific Network Optimizations



Source: GSMA, “An Introduction to Network Slicing,” Feb. 2016

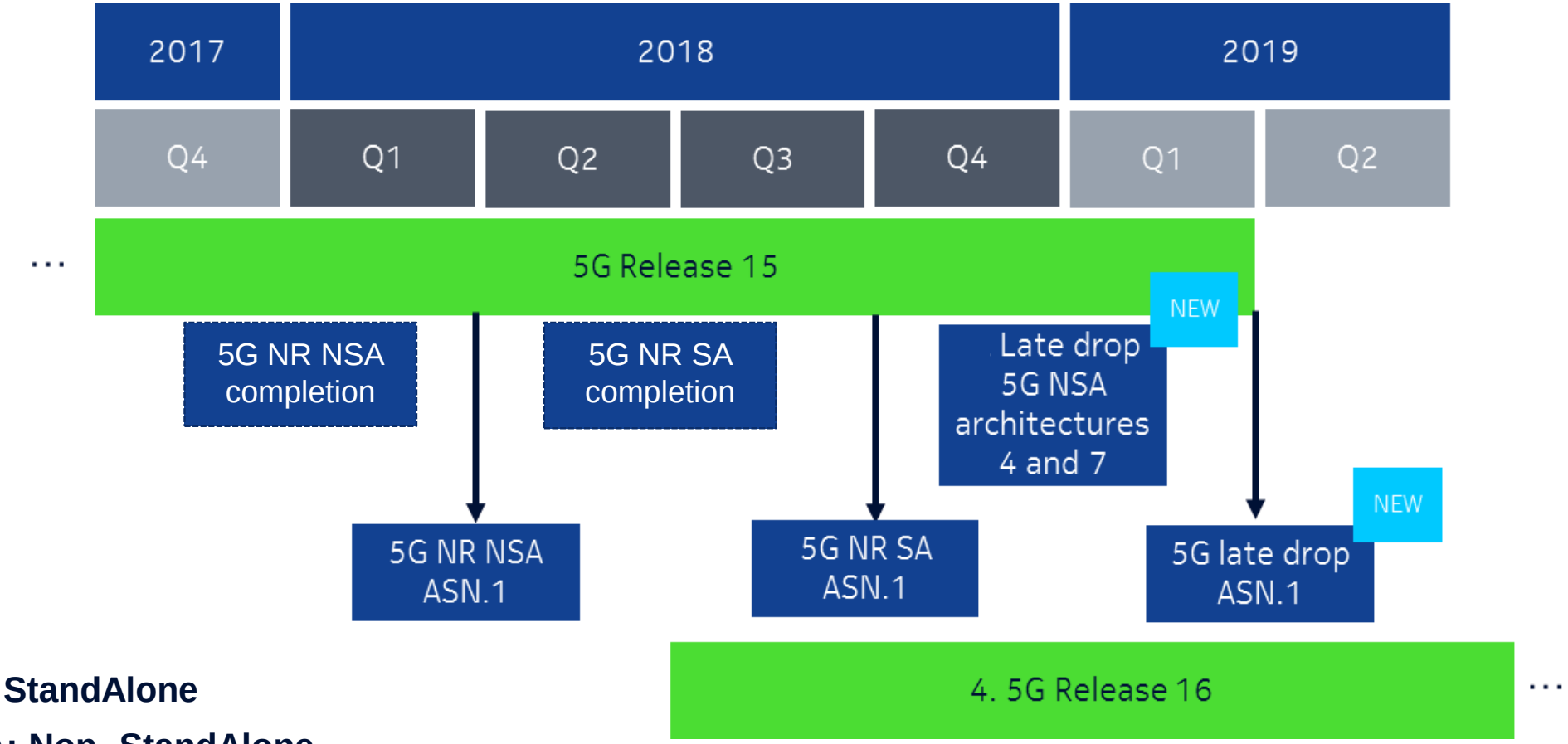


Nokia’s 5G Vision
The Future X Network



Source: M. Weldon, The Future X Network: A Bell Labs Perspective. CRC Press, March 2016.

5G Standards
Current 3GPP Status

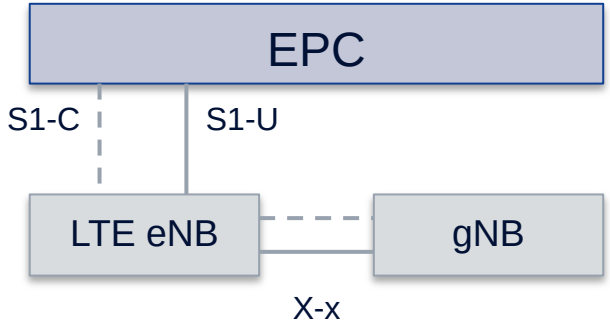


SA: StandAlone

NSA: Non- StandAlone

5G Standards
Various Architecture Options

3



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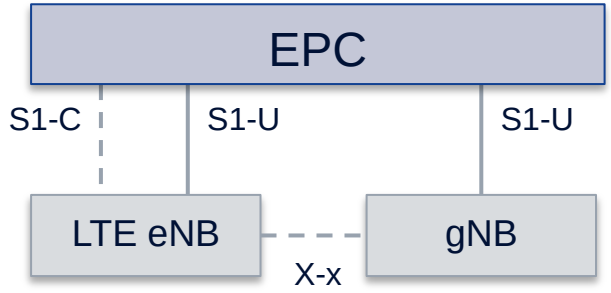

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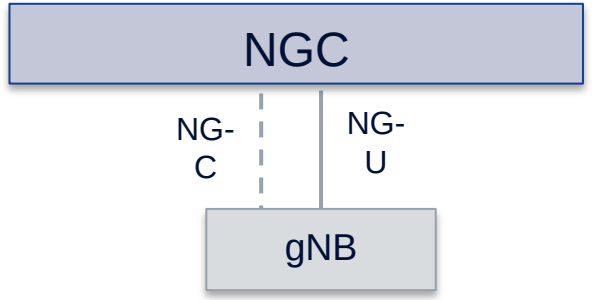

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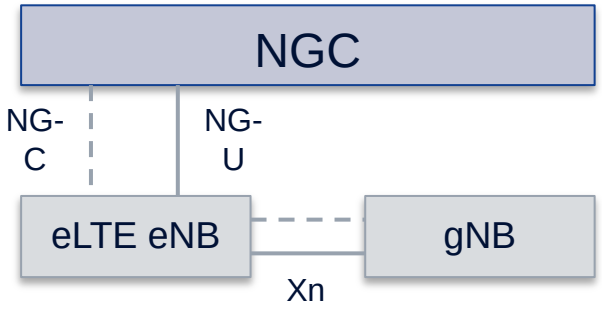

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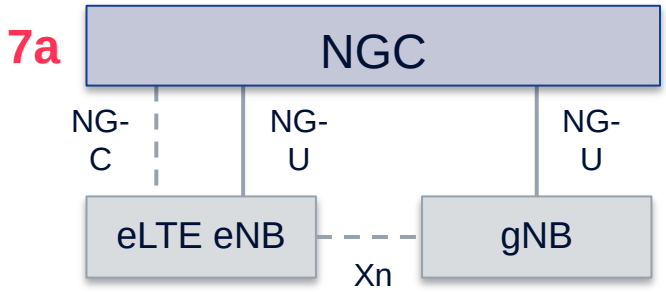

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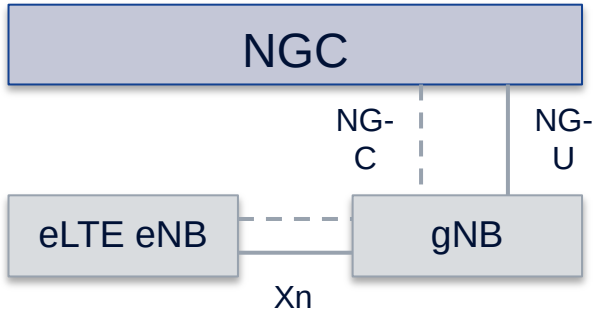

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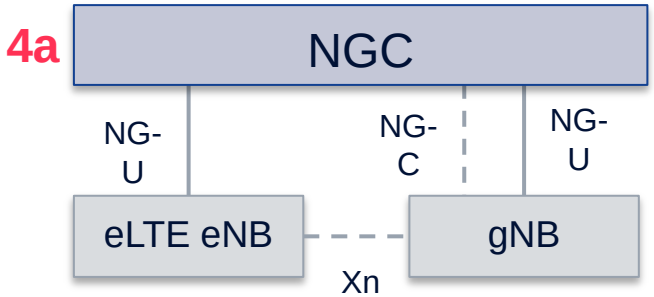
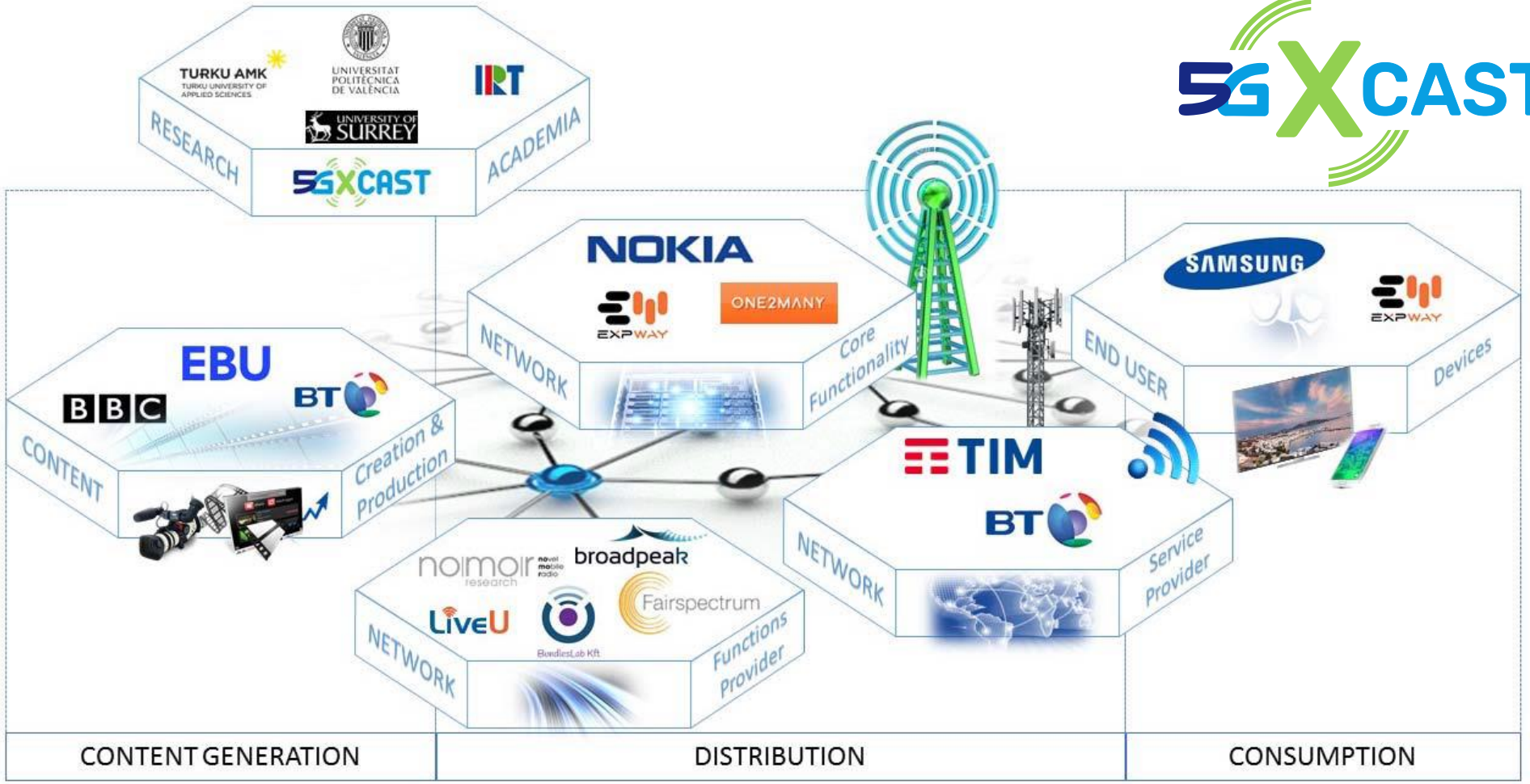


Source: 3GPP, http://www.3gpp.org/news-events/3gpp-news/1929-nsa_nr_5g

5G-Xcast Consortium



- Broadcast and Multicast Communication Enablers for the Fifth-Generation of Wireless Systems (5G-Xcast)
  - Start and end date: June 2017 – May 2019 (24 months)
  - European Union funded project; Call **H2020-ICT-2016-2**; Grant Number: **761498**

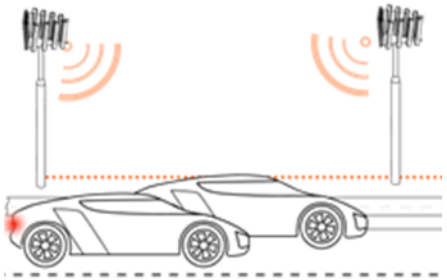
5G-Xcast
Introduction

- A unified framework for multiple verticals
  - Converged and use case independent architecture for Xcasting

Multimedia & Entertainment

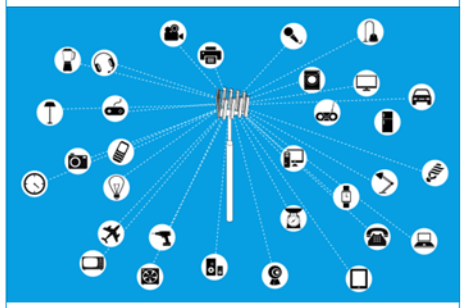
- UHDTV delivery
- VR, AR, 360° video
- Content prepositioning
- Push to X (talk/video)

Automotive



- Autonomous driving information
- Infotainment
- Safety applications
- Signage information

Internet of Things



- Software & firmware updates
- Common control messages to devices

Public Warning

- Disaster alerts (e.g. tsunami, earthquake)
- Emergency alerts (e.g. hazar, amber alerts)

Source: D. Gomez-Barquero, et al., " Point-to-Multipoint Communication Enablers for the Fifth Generation of Wireless Systems," vol. 2 (1), March 2018.

5G-Xcast Vision

UNPRECEDENT COMMUNICATION CAPABILITIES

OPPORTUNITY FOR THE CONVERGENCE OF FIXED, MOBILE AND BROADCAST NETWORKS

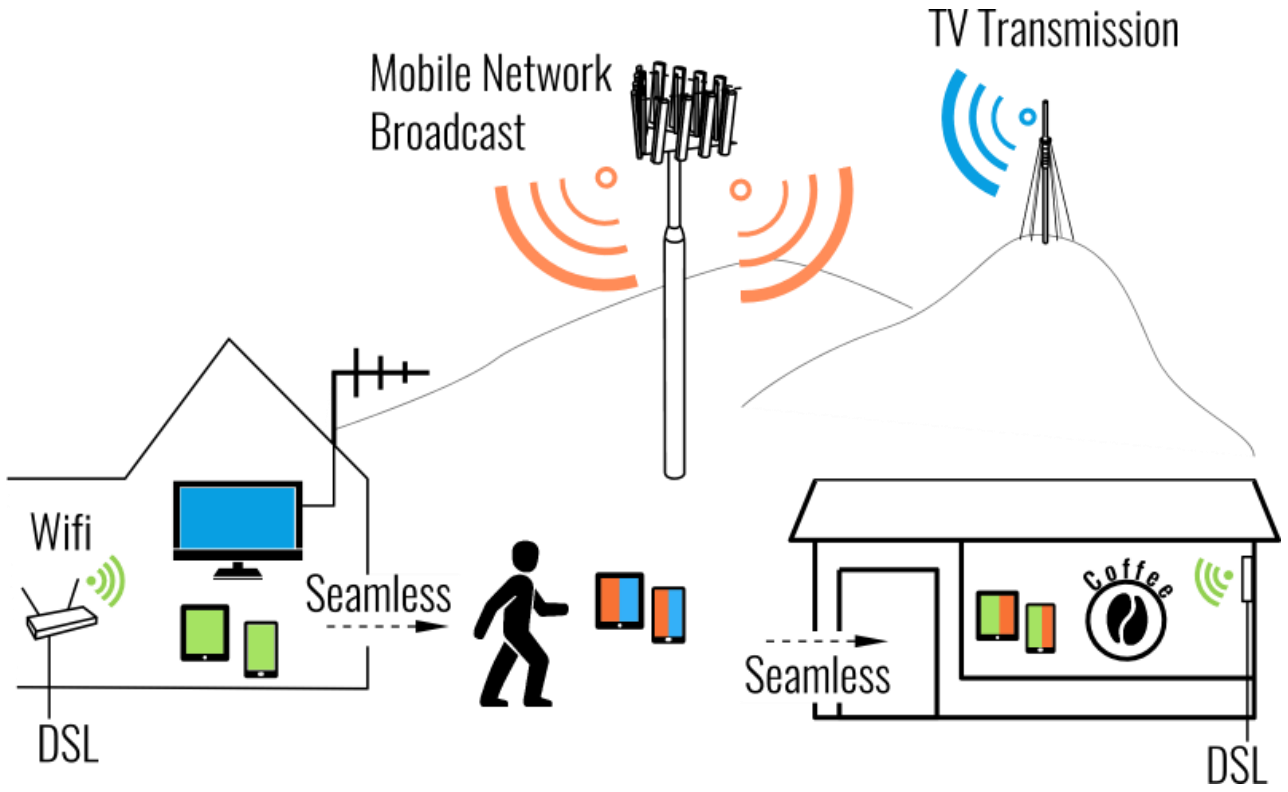
NETWORK SLICING FOR BROADCAST SERVICES

PTM & CONTENT POSITIONING AS BUILT-IN NETWORK DELIVERY OPTIMISATIONS, NOT AS A SERVICE, FOR ALL VERTICALS

PTM: Point-to-Multipoint

5G-Xcast
Convergence Vision

- The converged media delivery architecture of 5G-Xcast
  - Over fixed broadband, mobile broadband and terrestrial broadcast networks
  - Allowing a seamless, uninterrupted service to be offered to the users as they move.



Background
PTM in 4G LTE

- Originally included in Rel'9 (eMBMS), based on 3G MBMS from Rel'6
- It has been significantly enhanced in the latest releases of LTE-Advance Pro for different types of communications:
  - Television services (EnTV) – based on broadcasters' requirements
  - Mission critical / public-safety communications
  - Vehicular communications
  - Machine-type communications
- Two major trends and main technology enhancements:
  - Dedicated broadcast networks for TV services
    - Receive only, shared network infrastructure, external interface towards content providers, …
  - PTM as delivery optimization feature
    - MooD, SC-PTM, …
- But built on top of an initially conceived basic and static TV-like service
  - Following LTE backwards-compatibility design principle

eMBMS: evolved multicast broadcast multimedia service

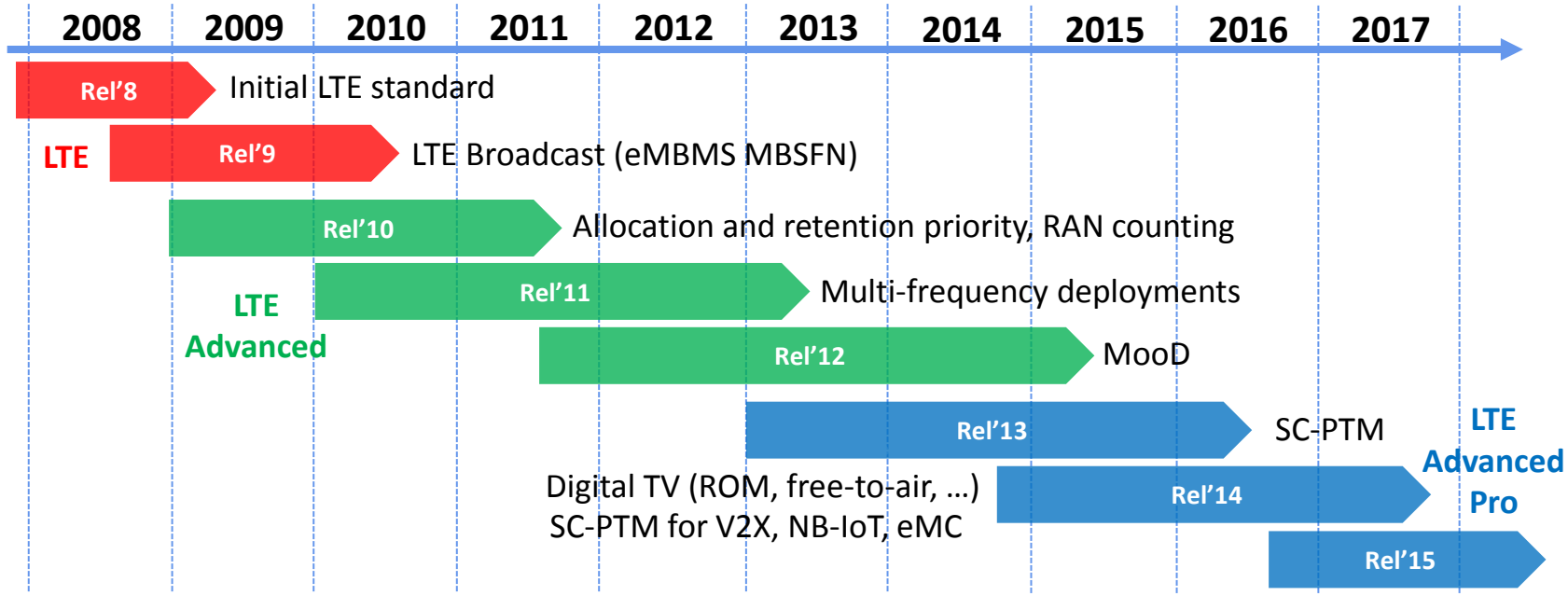
enTV: enhanced TV

MooD: MBMS operation on-demand

SC-PTM: Single Cell PTM

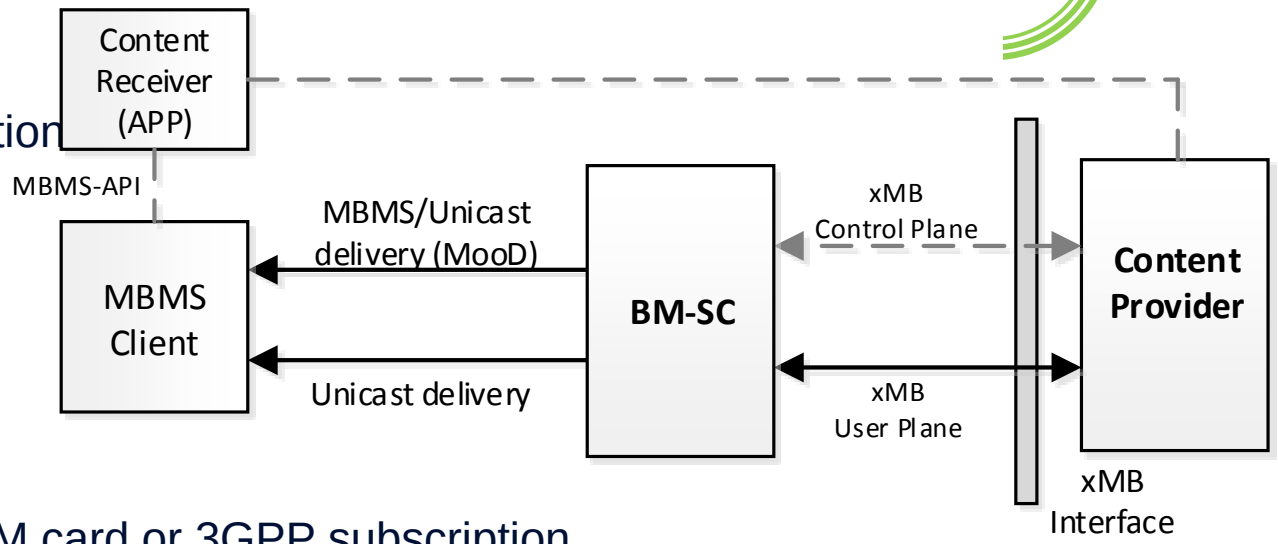
Background
PTM in 4G LTE

- Two major trends from Rel'12 enhancements:
  - Dedicated broadcast networks for TV services
  - PTM as RAN delivery optimization feature



Background
Rel'14 EnTV - Towards Stand-alone eMBMS Broadcast Networks

- Radio Enhancements
  - **Dedicated carriers** with up to 100% MBMS allocation
  - **Self-contained system information** and synchronization signals
  - **200 µs long cyclic prefix** to support large inter-site distances



- Architecture Enhancements
  - **Receive-Only Mode** (ROM) for devices without SIM card or 3GPP subscription
  - New service types to enable **free-to-air** content broadcast that can be received by ROM devices and also **interactive services**
  - **Open standardized broadcasting application programming (xMB) external interface** towards the TV content providers to simplify access to complex eMBMS procedures
  - **Transport-only (pass-through) MBMS bearer service type** to use the eMBMS network as content delivery platform in the native format without transcoding
  - **Shared networks among several MNOs** to avoid broadcasting the same content at the same time over different networks

Broadcast in 5G
Brief Industry Outlook

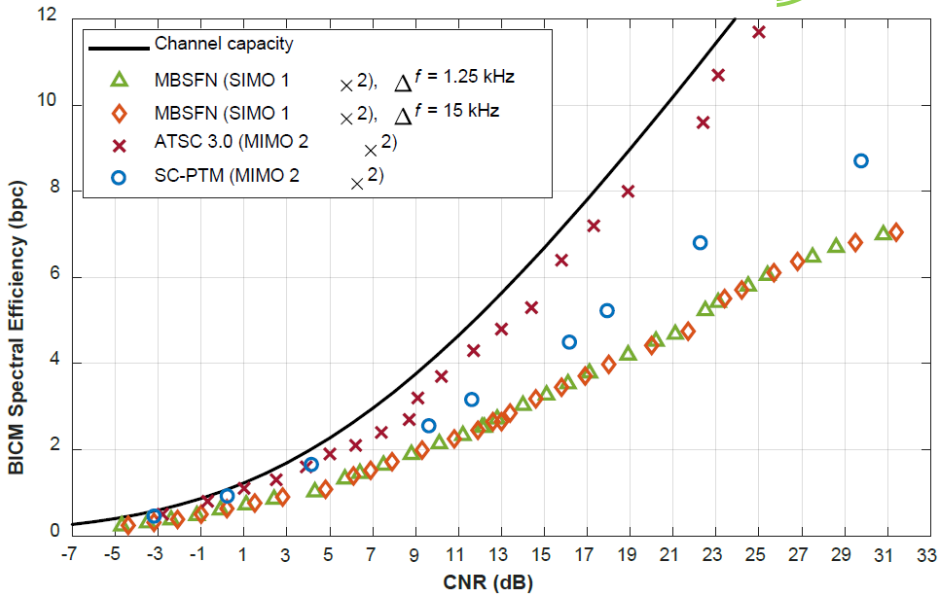
- Broadcasters interest in 3GPP technologies is increasing
  - EBU broadcast requirements taken into account in Rel'14 (EnTV)
    - Not fully clear that eMBMS can be fully deployed in existing HPHT DTT broadcasting infrastructure
  - Rel'14 has a long legacy from Rel'8 – detailed gap-analysis required (e.g. CAS)
  - 5G is an opportunity for broadcasters to define a 5G broadcast mode using the latest 3GPP technology
- Many 5G use cases require PTM transmissions, not just TV broadcast
  - Treat PTM transmissions and caching as delivery optimization tool
- 5G Broadcast not included in the first 5G release (Rel'15) and probably neither in Rel'16
  - Good opportunity in Rel'17 for a solution for all relevant verticals, but important to ensure forward-compatibility
- 5G-Xcast is performing pre-standardization investigations on 5G Broadcast
  - Consensus building for 3GPP activities

Source: 5G-Xcast Deliverable D3.1

Background
A Deeper Look at Legacy

Technology	Antenna Scheme	Peak BICM spectral efficiency (bpc)	Peak spectral efficiency (bits/s/Hz)	Overhead	Peak data rate (Mbps)
ATSC 3.0	SIMO	10.36	9.76	5.6	58.7
	MIMO 2x2	20.72	19.56	5.6	117.3
SC-PTM	SIMO	7.09	4.89	30.9	97.9
	MIMO 2x2	14.16	9.79	30.9	195.8
	MIMO 4x4	28.36	19.58	30.9	391.6
MBSFN (200 µs)	SIMO 1x2	7.06	4.13	41.5	82.6

- Complex architecture
  - Significant UE impacts → Limited technology adoption (15[δ] / ~24000 commercial Android device models)
- Sub-optimal performance for MBSFN
  - Significantly higher overhead with significantly lower spectral efficiency
  - Limited device support, no significant motivation to adopt this solution
- Observations:
  - Delivering TV broadcast content using mobile network is not currently efficient



Link-level results, Source: 5G-Xcast Deliverable D3.1

[δ]GSA: LTE Broadcast (eMBMS) Market Update, Nov. 2017

Viewing Trends
Non-Linear Broadcasting

- Linear TV audiences are decreasing
  - Younger audiences shifting to online / on - demand
    - Time spent by 16-24 years old on BBC linear channels fell by 32% from 2012 - EBU Forecast 2017
  - Subscriptions to online TV platforms increasing, both premium and free content

Figure 2.2: Use of on-demand and streaming services to watch TV programmes/films

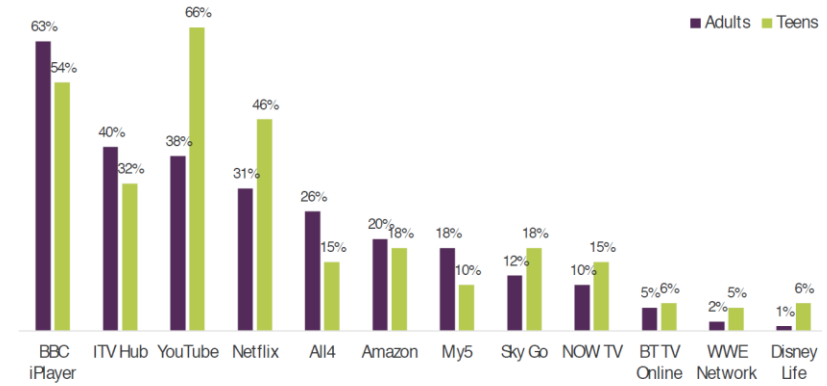


Figure 2.3: On-demand/streaming service subscription numbers: 2014-2016 (000s)

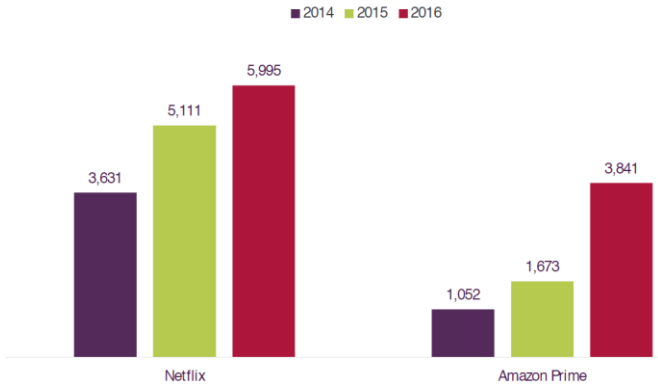
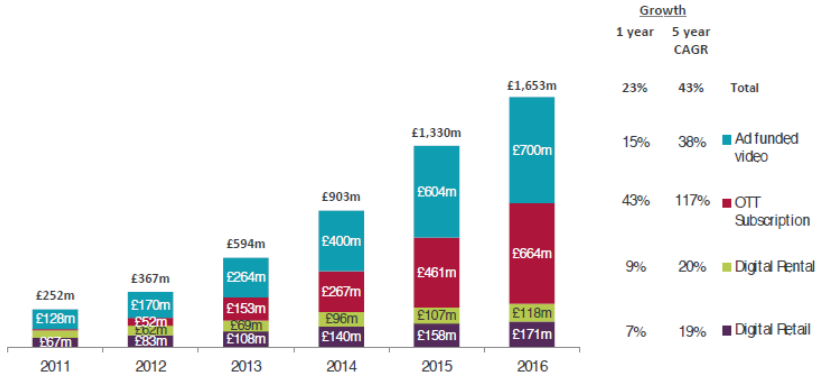


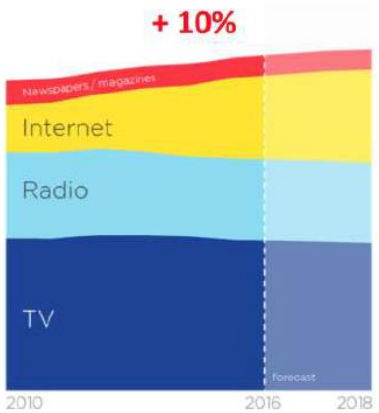
Figure 2.13: Online audio visual revenues

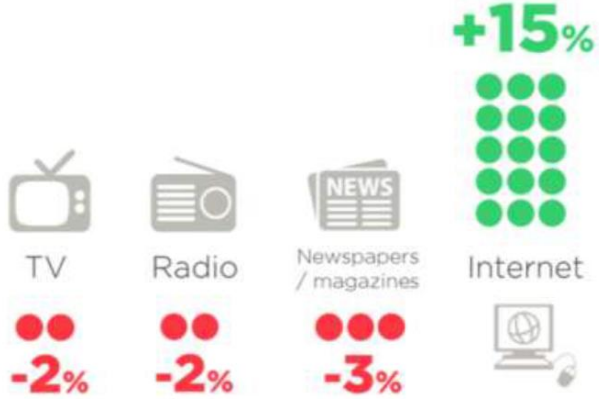


Ofcom, Communications Market Report 2017
https://www.ofcom.org.uk/__data/assets/pdf_file/0017/105074/cmr-2017-uk.pdf

Viewing Trends
Linear TV remains Relevant

- The shift to online TV is happening slowly
  - People are spending more and more time on media
  - The growth of Internet time has limited impact on media consumption
- Online viewers are “live TV hungry”
  - Netflix users dedicate two thirds on their daily viewing to linear TV
- Particularly important for Public Service Media with coverage and cultural obligations
- Major sport events strong use case





P. MacAvoc, EBU Forecast 2017

Viewing Trends
User Experience

- TV marketplace is actually thriving and user experience is continuously evolving thanks to new technology improvements and online Internet delivery
  - QoS/QoE of new media content better than ever, and constantly improving
  - Choice of content larger than ever, and constantly increasing
    - More money than ever spent on Premium content (10M$/h)
  - Personalization: Right content for the right person at the right moment and the right device

- Changing user habits and expectations
  - Quality, Variety and Interactivity while user having the Control

Technology Trends
Online / On-demand Media

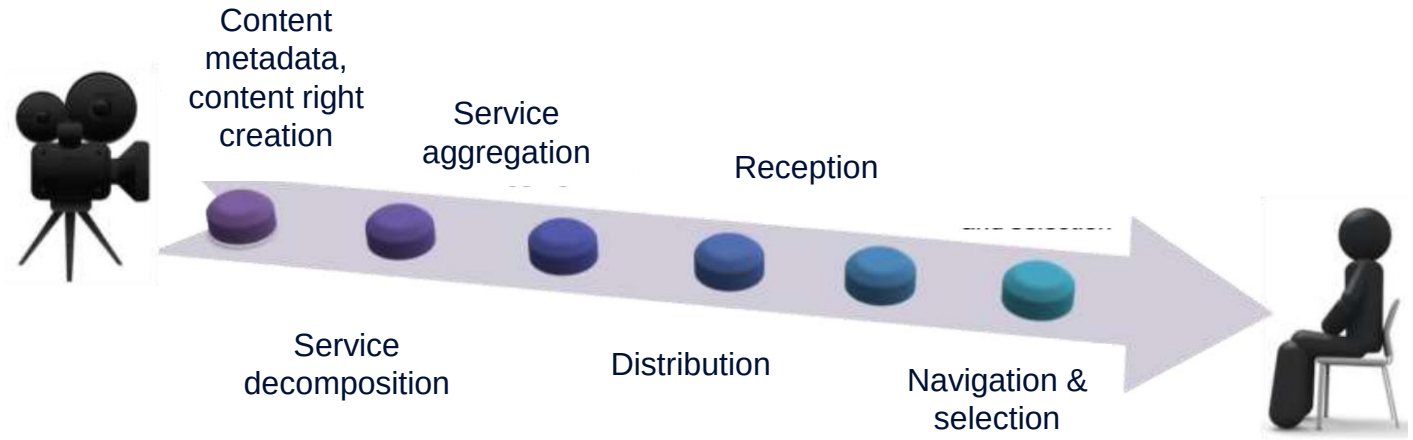
- Main Technology Trends
  - Internet infrastructure enhancing – both at home and mobile
  - Over-the-top (OTT) content increasing
  - Ability to tailor audience experiences
  - Online Tech-Giants
    - With very different business models

  - User-generated content increasing and improving

- **Enabling technologies:**
  - UHD (4k/8k), HFR/HDR/WCG, AR/VR, 360º, H266, immersive audio, object-based broadcasting, …
  - What about distribution technologies?
  - And convergence?

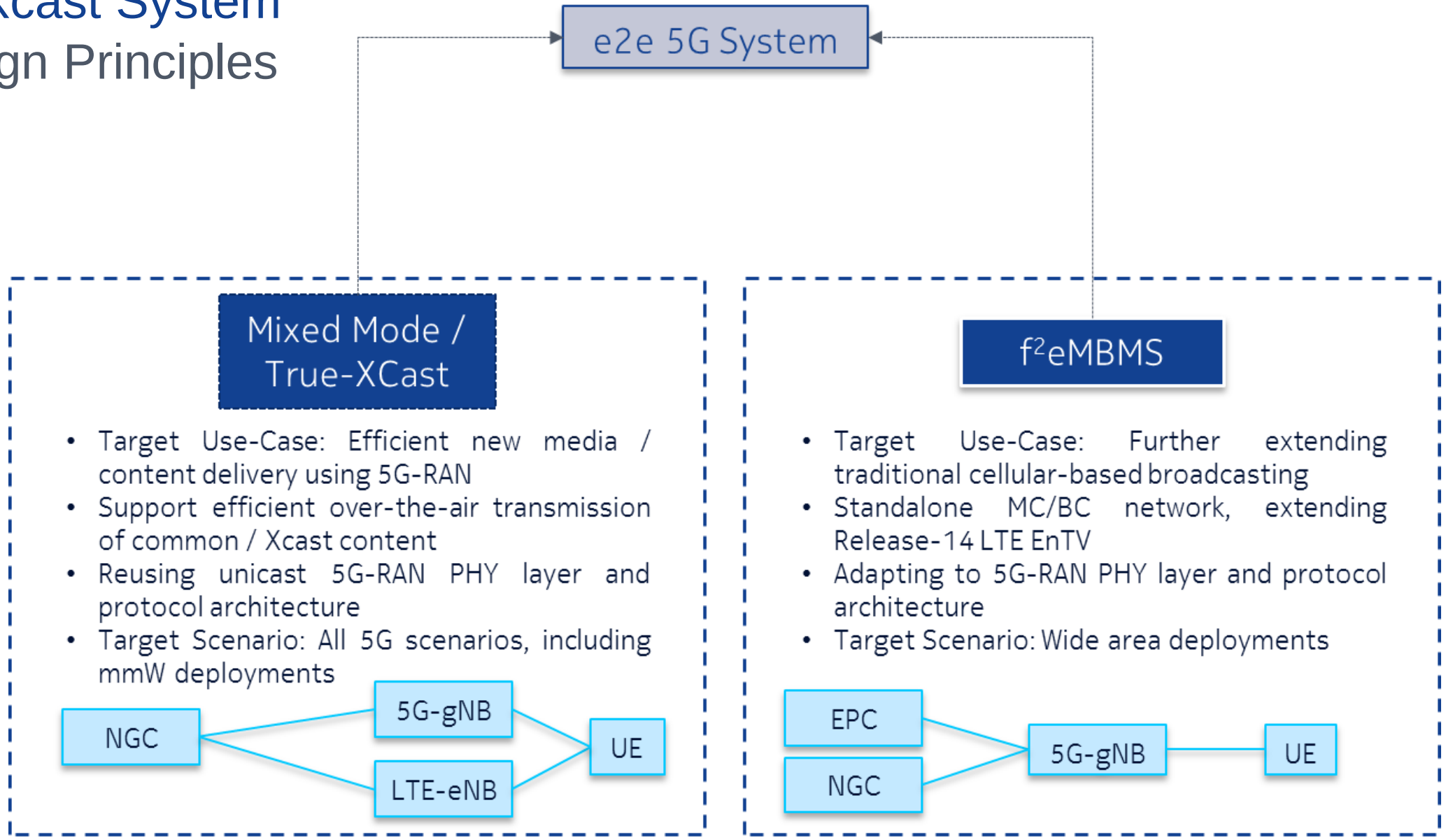
Key Question
Will 5G create a disruption in broadcasting?

- Likely yes, since the relevance of mobile/personal devices is increasing for consumption of media services
  - TV wireless production is also a very good use case for 5G
  - Role of stakeholders along the broadcast value chain will probably change

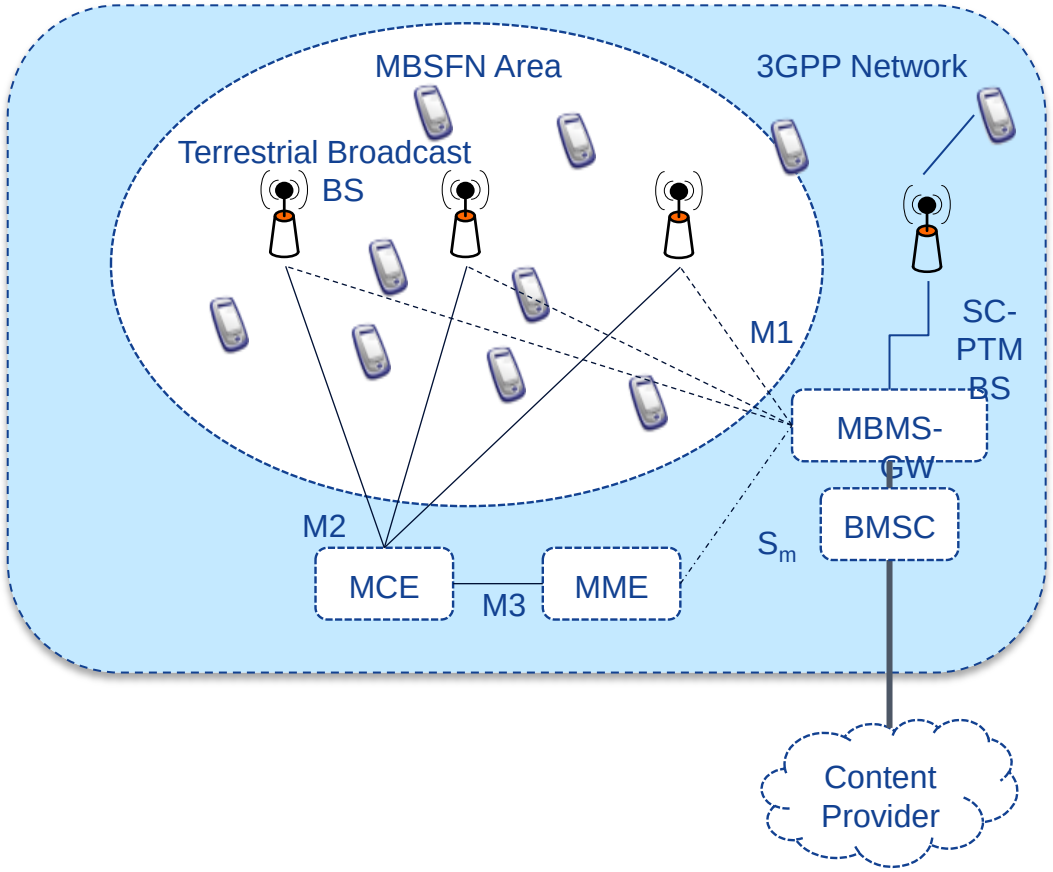


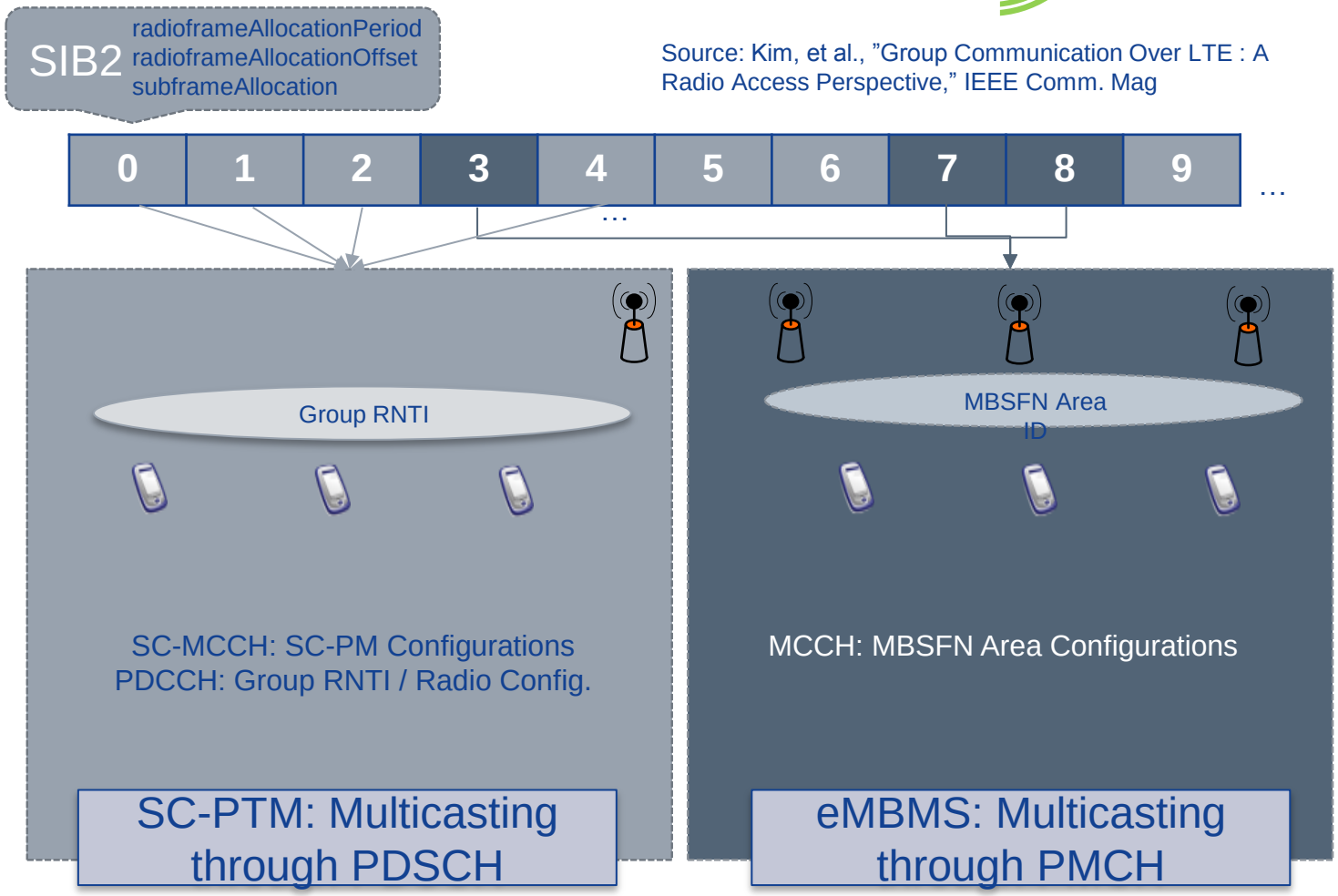
- Will digital terrestrial TV continue being an appealing platform by itself?
  - New win-win business arrangements and regulations needed for a commercial success of new convergence scenarios

5G-Xcast System
Design Principles



System Architecture
Legacy – eMBMS & SC-PTM

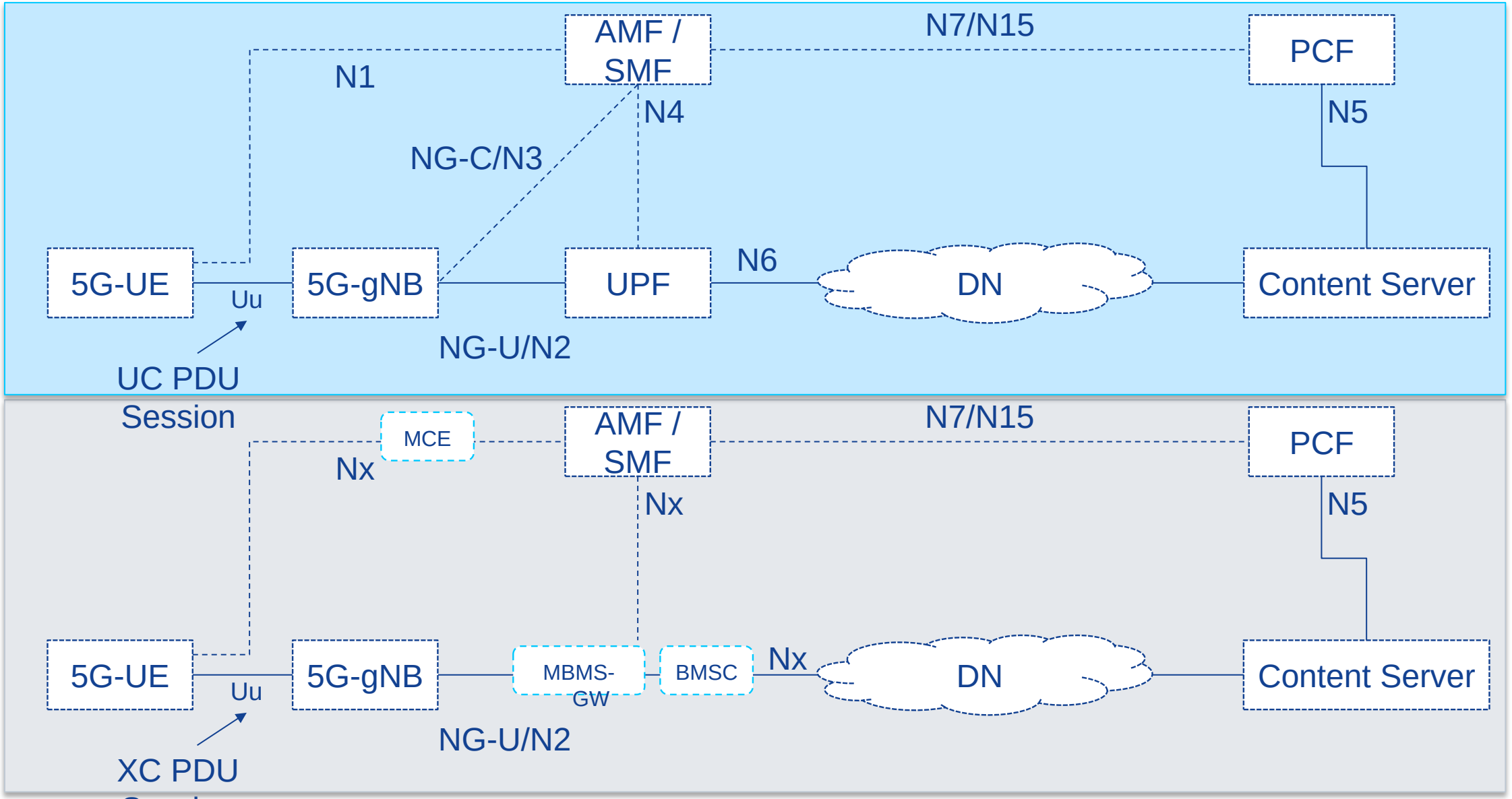




Source: Kim, et al., "Group Communication Over LTE : A Radio Access Perspective," IEEE Comm. Mag

5G/NR PTP → PTM Architecture?

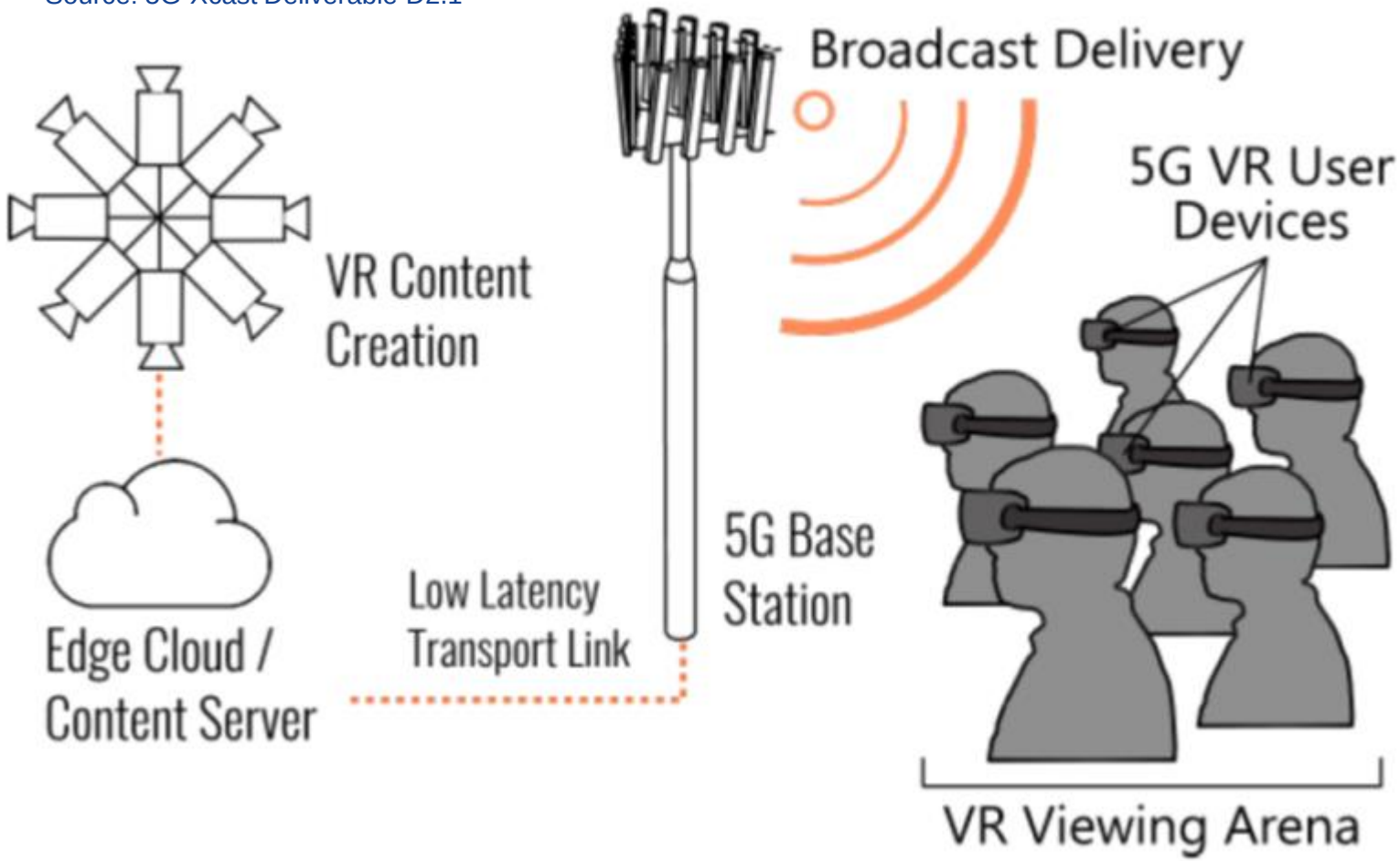
Source: 3GPP TS 23.501



Disruptive Use Cases
Towards Interconnected Social Experiences

- Latency and reliability critical
  - < 7 ms OTA latency
  - With high user density

Source: 5G-Xcast Deliverable D2.1

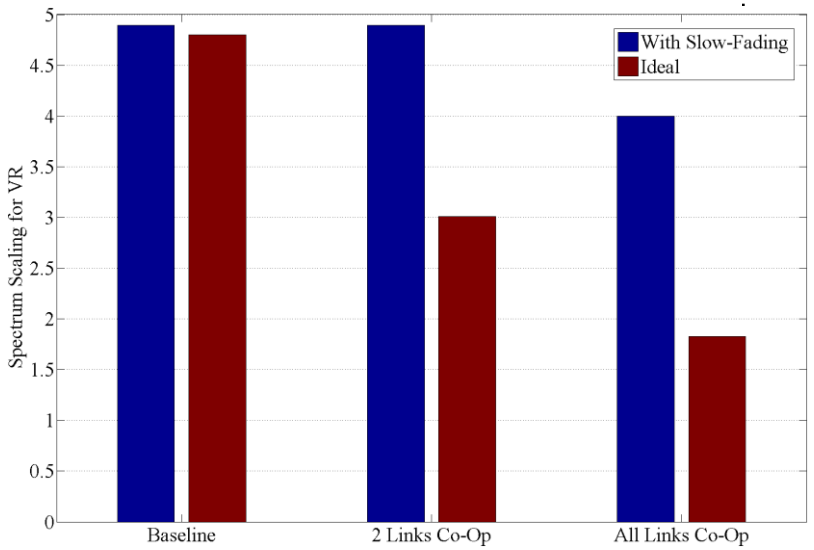


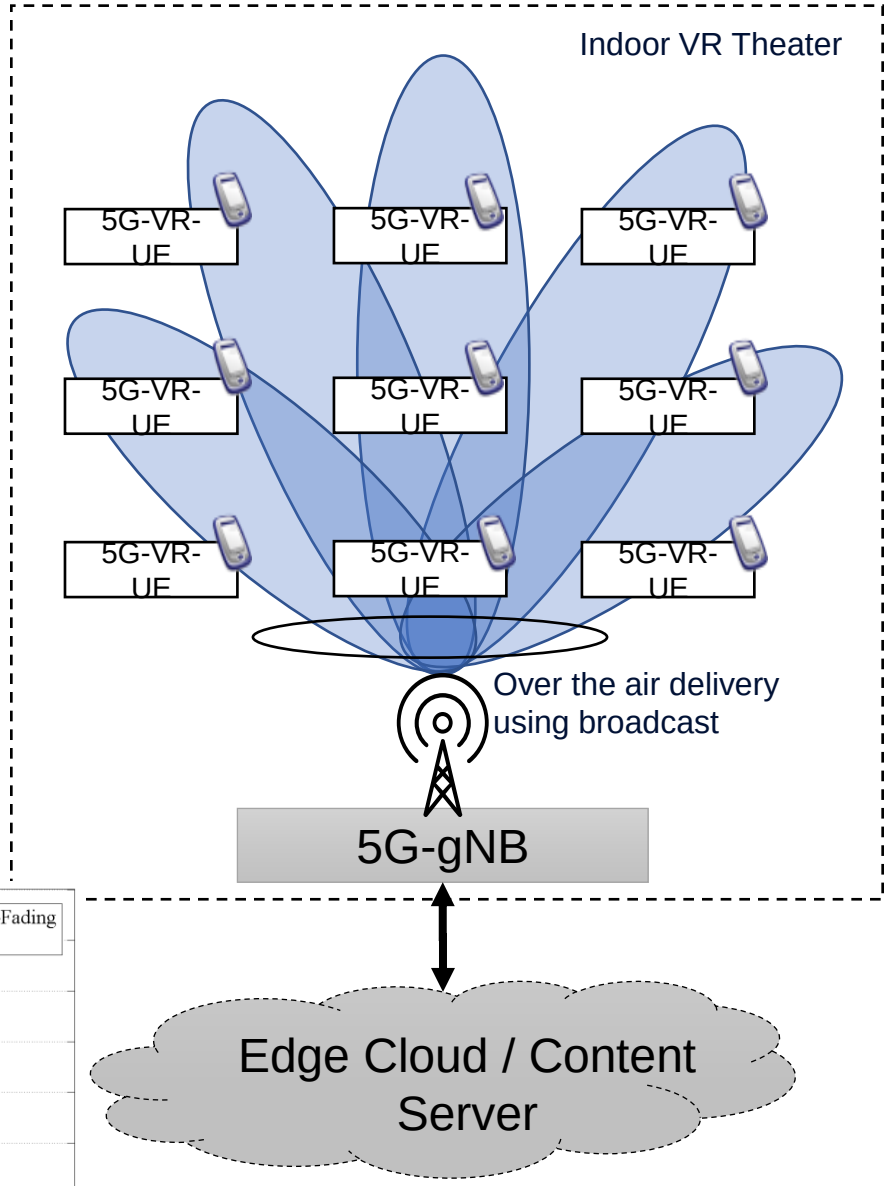
- The current state-of-the-art (which could be called pre-VR) would require several 10s of Mbit/s. Here the content could be clearly distinguishable from reality.
- Fully immersive VR content delivery would require in the order of several Gbit/s, e.g. 5 Gbit/s.

Enabling New Media Delivery
Towards Interconnected Social Experiences

- Interconnected social experiences such as augmented / virtual reality (AR/VR) requires mass-delivery of immersive content.
- Current networks have limited peak data rate capabilites for delivering such traffic.
  - With current system performance benchmark, significant spectrum scaling required for delivering fully-immersive VR – even under ideal conditions

- New media delivery requires near-unicast spectral efficiency for Xcasting
- Agile and flexible architecture, with minimal latency inducing elements





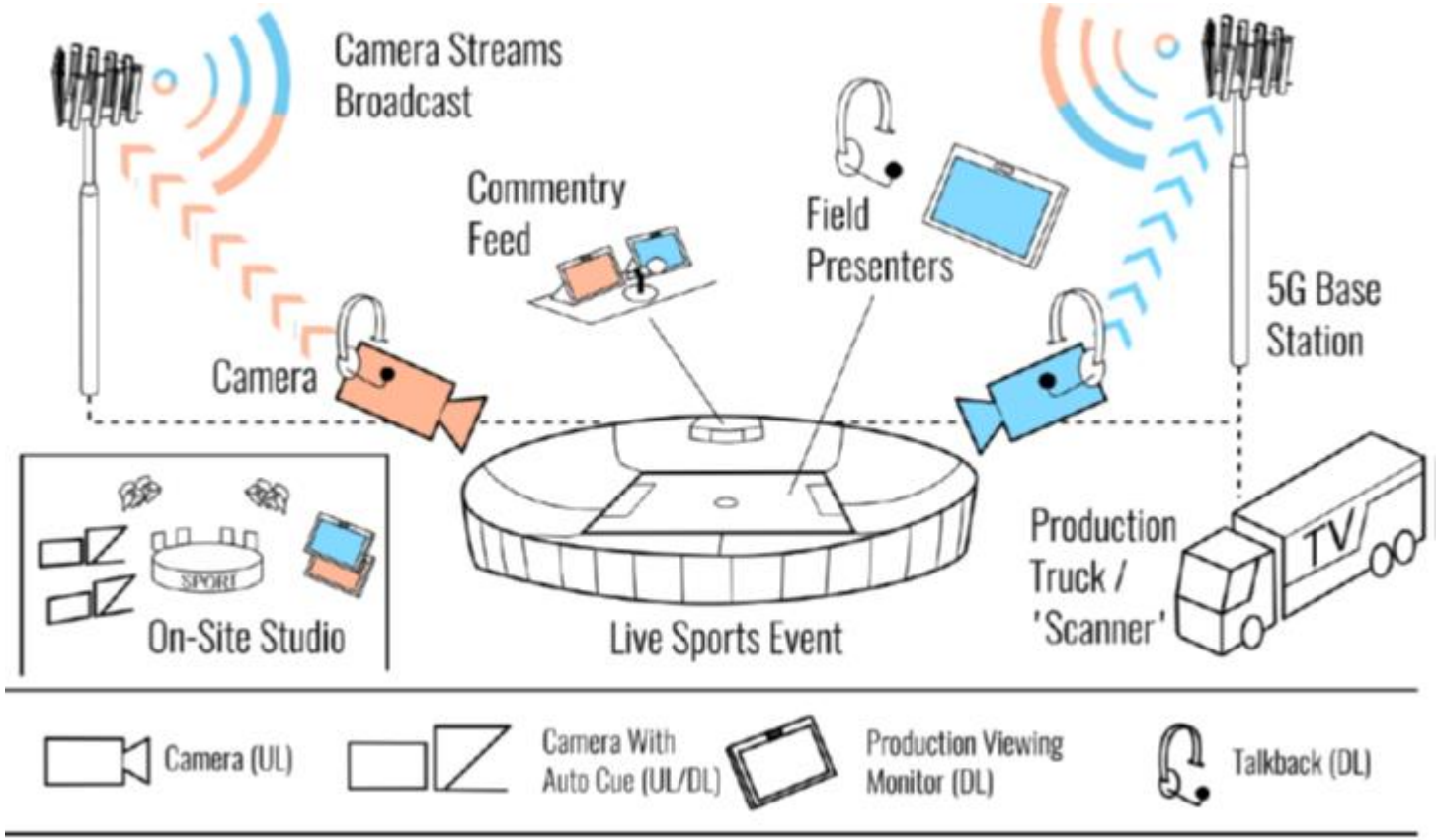
Source: A. Prasad, M.A. Uusitalo, D. Navratil, and M. Säily, "Challenges for Enabling Virtual Reality Broadcast Using 5G Small Cell Network," IEEE WCNC Workshops, Barcelona, April 2018.

NOKIA Bell Labs

Source: 5G-Xcast Deliverable D2.1

Remote Live Production
Downlink & Uplink Intensive

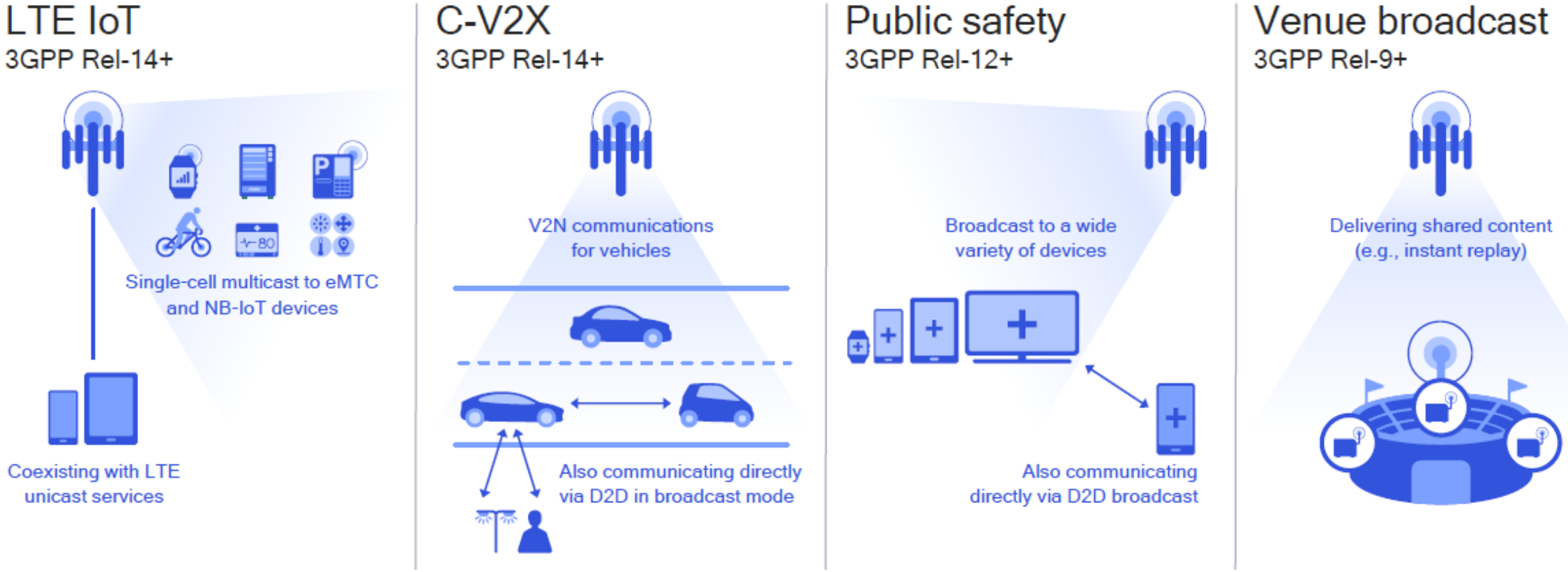
- Latency and reliability critical
  - < 10 ms OTA latency
  - Very low bit error rates



- Very high-quality audio and video to be transported such that it is suitable for later processing within the production chain:
- ~100 Mbit/s for mezzanine quality (i.e. lightly compressed) per video stream; and
- ~9 Gbit/s for uncompressed quality (UHD p50) per video stream

5G-Xcast
Conclusions and Future Work

- Unified framework for mass delivery of common content
- Impacting a multitude of new verticals and use cases



Source: Qualcomm, ”Accelerating the mobile ecosystem expansion in the 5G era with LTE-Advanced Pro,” Jan. 2018 link

Public deliverables, scientific papers, presentations:
http://5g-xcast.eu/documents/

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