# ATIS/3GPP Webinar
## 5G Standards Developments in Release 15 and Beyond

**Iain Sharp**

*Principal Technologist*

ATIS

**July 31, 2019**

***Advancing ICT Industry Transformation***

# Agenda

1. 
   Opening/Overview
   Iain Sharp
   atis

2. 
   Services
   Dr. Farrokh Khatibi
   QUALCOMM

3. 
   System Architecture and Core Network
   Stephen Hayes
   ERICSSON

4. 
   RAN
   Dr. Emad Farag
   NOKIA

5. North American Priorities Recap
   Iain Sharp
   atis

6. Q&A

# 3GPP – Global Partnership for Mobile Specifications


3GPP is a global partnership created and managed by regional standards organizations.

ATIS is the North American 3GPP Organizational Partner (OP)

Companies participate in 3GPP as a member of one of the regional OPs

3GPP™ A GLOBAL INITIATIVE

Delivers

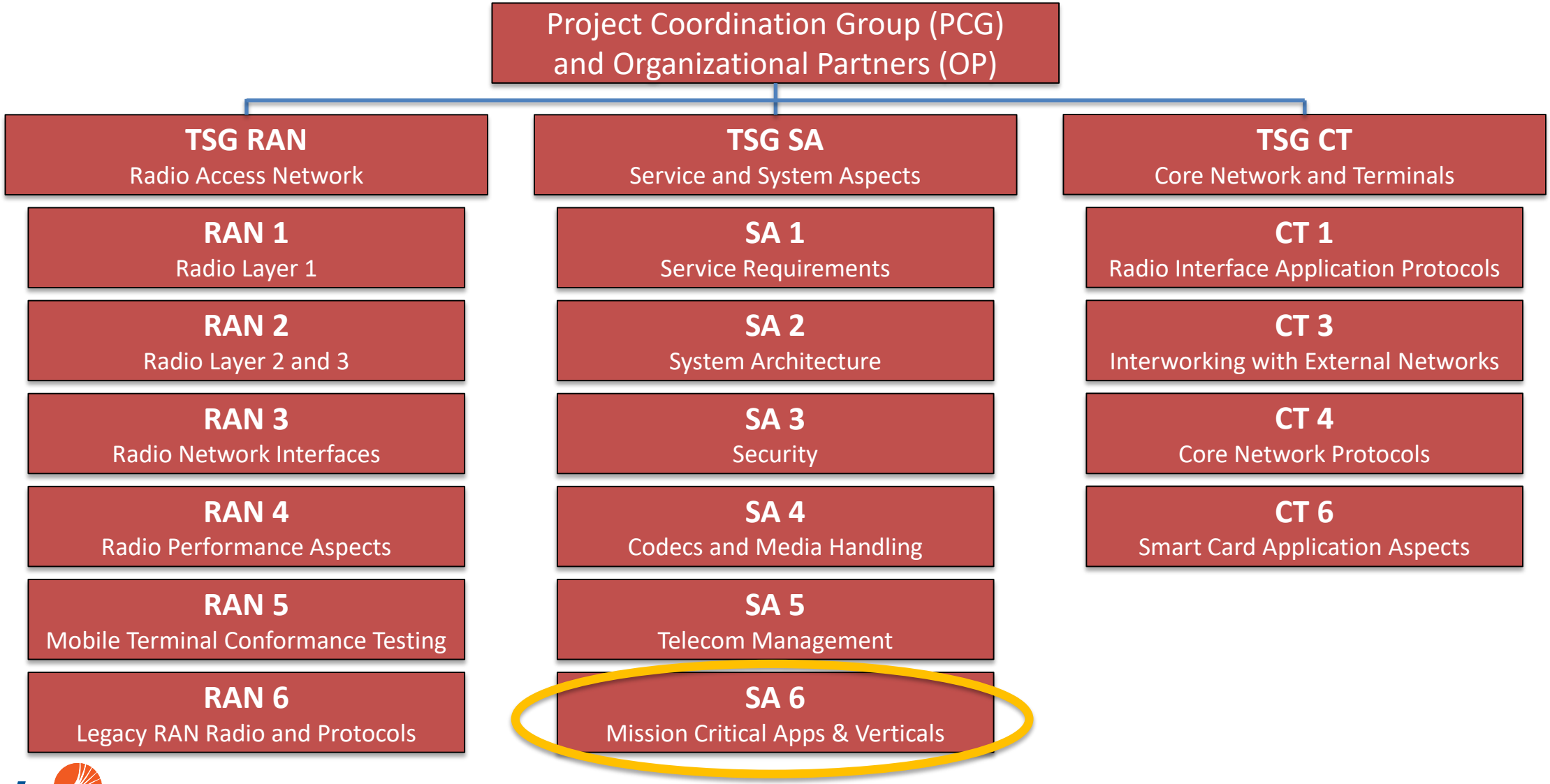
Common technology to achieve economics of global scale

Multivendor interoperability in mobile networks

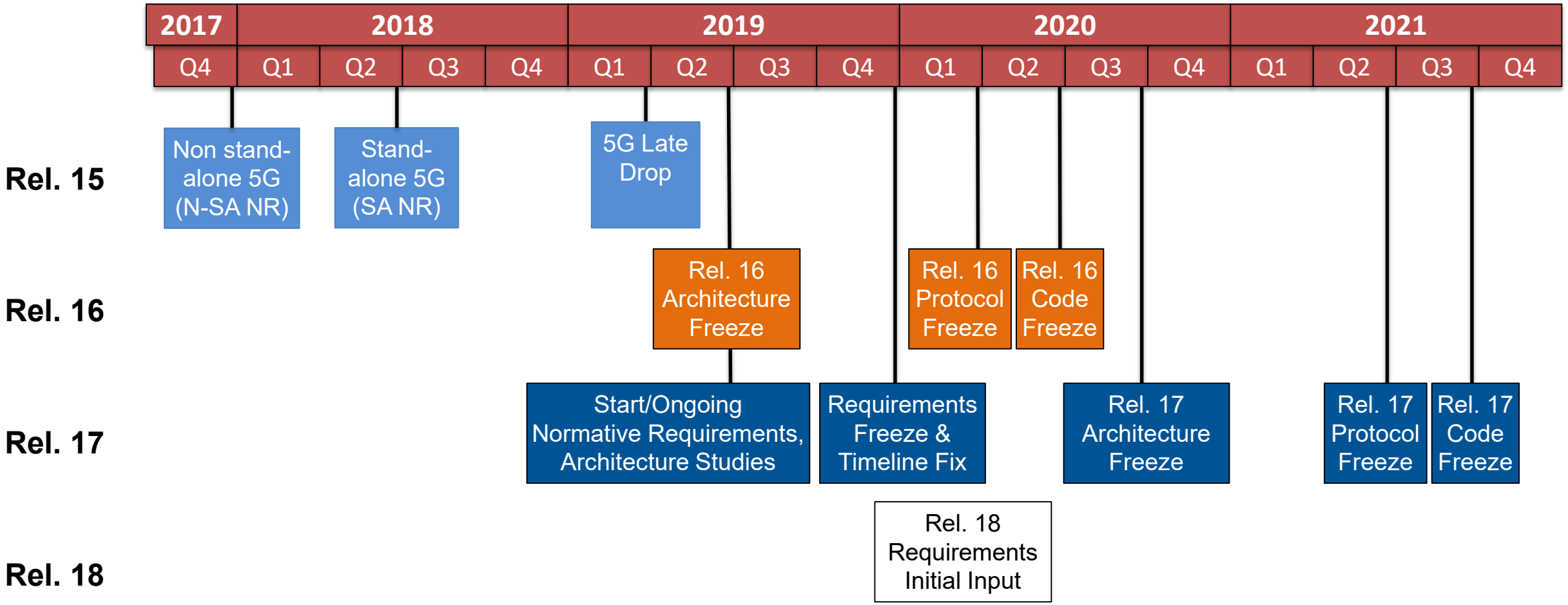
Technical support for global mobile roaming

Global solutions while recognizing the strategic role of regions

# 3GPP Committee Structure



# 3GPP Release Timetable



# Current Technology Themes in 3GPP

- Approval of 5G late drop is a major milestone – 5G is real and solid

- 5G is a flexible strategic platform for further development
  - We are still at the beginning of its potential
  - The power of 5G brings it's own challenges of managing work-load and prioritization

- LTE is still evolving and will remain important in the market

- 5G is enabling a new level of collaboration with vertical industries


**Dr Farrokh Khatibi**

Dir of Engineering

Qualcomm Technologies, Inc.


Qualcomm

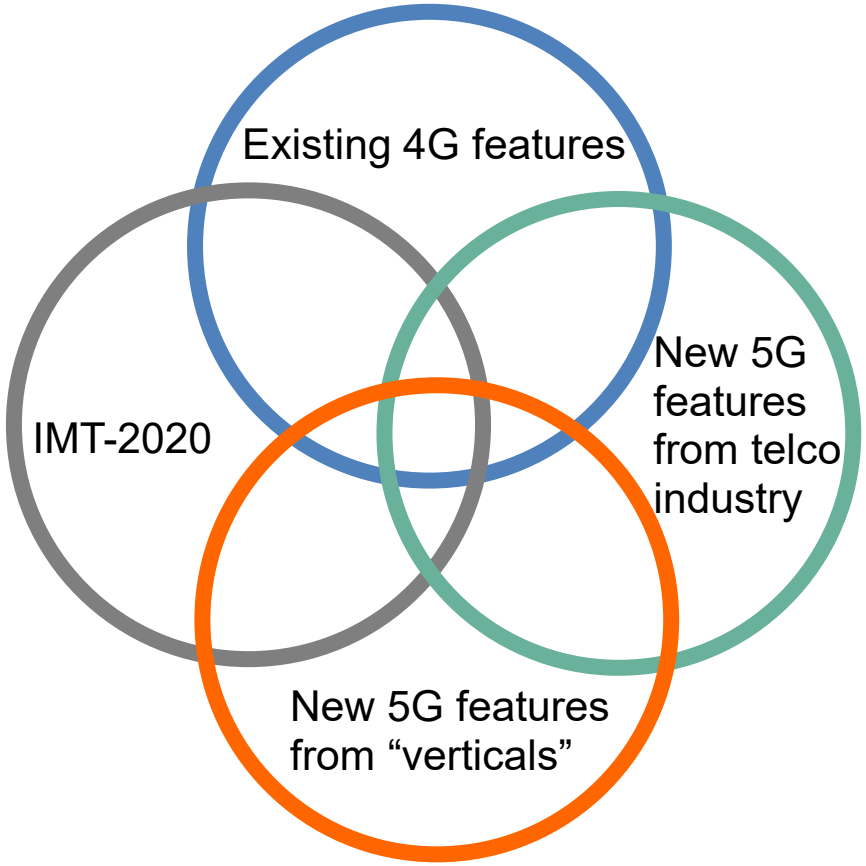
atis

*Advancing ICT Industry Transformation*

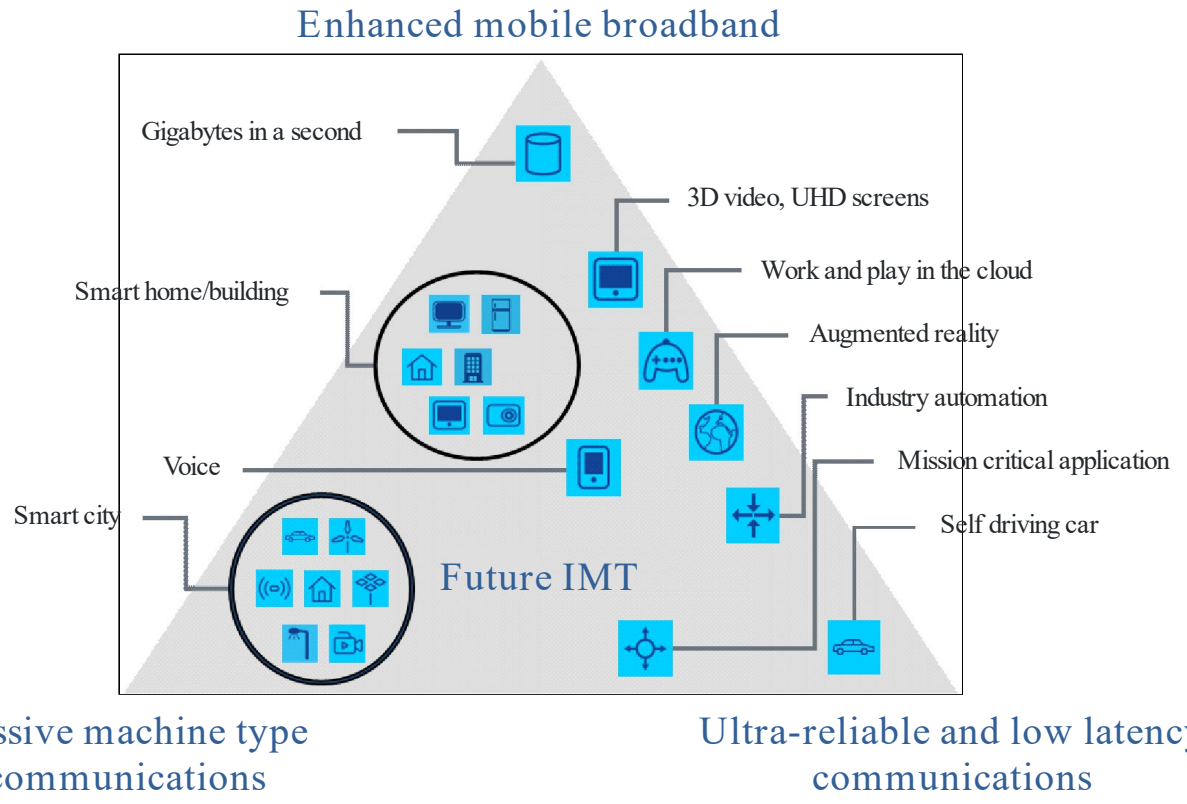
# Release 15 and 5G

- Initial 5G requirements in 3GPP SA1 (TS 22.261)
- 4 sources for new requirements in 3GPP:
  - ITU IMT-2020
  - Existing 4G features which were to be also supported in 5G
  - New features for 5G coming from established telco industry
  - New features which were specifically to support vertical industry

Note that the 3GPP term “verticals” covers all industries which could meet their communication needs using 3GPP technologies



# Usage Scenarios for ITU IMT-2020 (5G)



# Key “new” 5G features from 4G

- The 5G system shall support all EPS capabilities (e.g., from TSs 22.011, 22.101, 22.278, 22.185, 22.071, 22.115, 22.153, 22.173) with the following exceptions:
  - Circuit Switched (CS) fallback to GERAN or UTRAN,
  - Seamless handover between 5G-RAN and GERAN,
  - Seamless handover between 5G-RAN and UTRAN, and
  - Access to a 5G core network via GERAN or UTRAN.

- So essentially 5G had to support almost everything that 4G did

# Key new 5G features from telco industry

- Network Slicing
- QoS enhancements
- User Plane/Control Plane (UP/CP) separation
- RRC-Inactive
- Latency reduction features
- Service Based Architecture (SBA)
- Non-Access Stratum (NAS) capability indication
- Security aspects
- Evolved Packet Core (EPC) enhancements to support 5G New Radio via Dual Connectivity
  - QoS enhancements
  - Usage restriction
  - Selection of Serving Gateway (SGW)/ PDN Gateway (PGW) optimized for NR
  - Security aspects

# Key new 5G features from “verticals”

- Key new 5G features from “verticals”
  - Industrial (factory and process) automation, Ethernet support, and KPIs
    - This was the start of the Industrial IoT work in 3GPP
  - Intelligent transport use cases
    - NR/5GC V2X
  - Electricity distribution
  - Private Networks
    - This was the start of the Non-Public Network (NPN) work in 3GPP
  - Elimination of UICC/eUICC requirement
  - Alternate authentication, credentials and identities for network access
    - This was the start of the EAP-TLS work in 3GPP
- Key actors from Verticals:
  - Industrial (e.g., Siemens, Bosch)
  - Automotive (e.g., Daimler, VW)
  - Mission Critical (e.g., FirstNet, UK Home Office)
  - Satellites (e.g., Thales, ESA, Intelsat)

# Verticals involvement


Public Safety


Railway


Automotive


Maritime


AV production


Medical


Industry

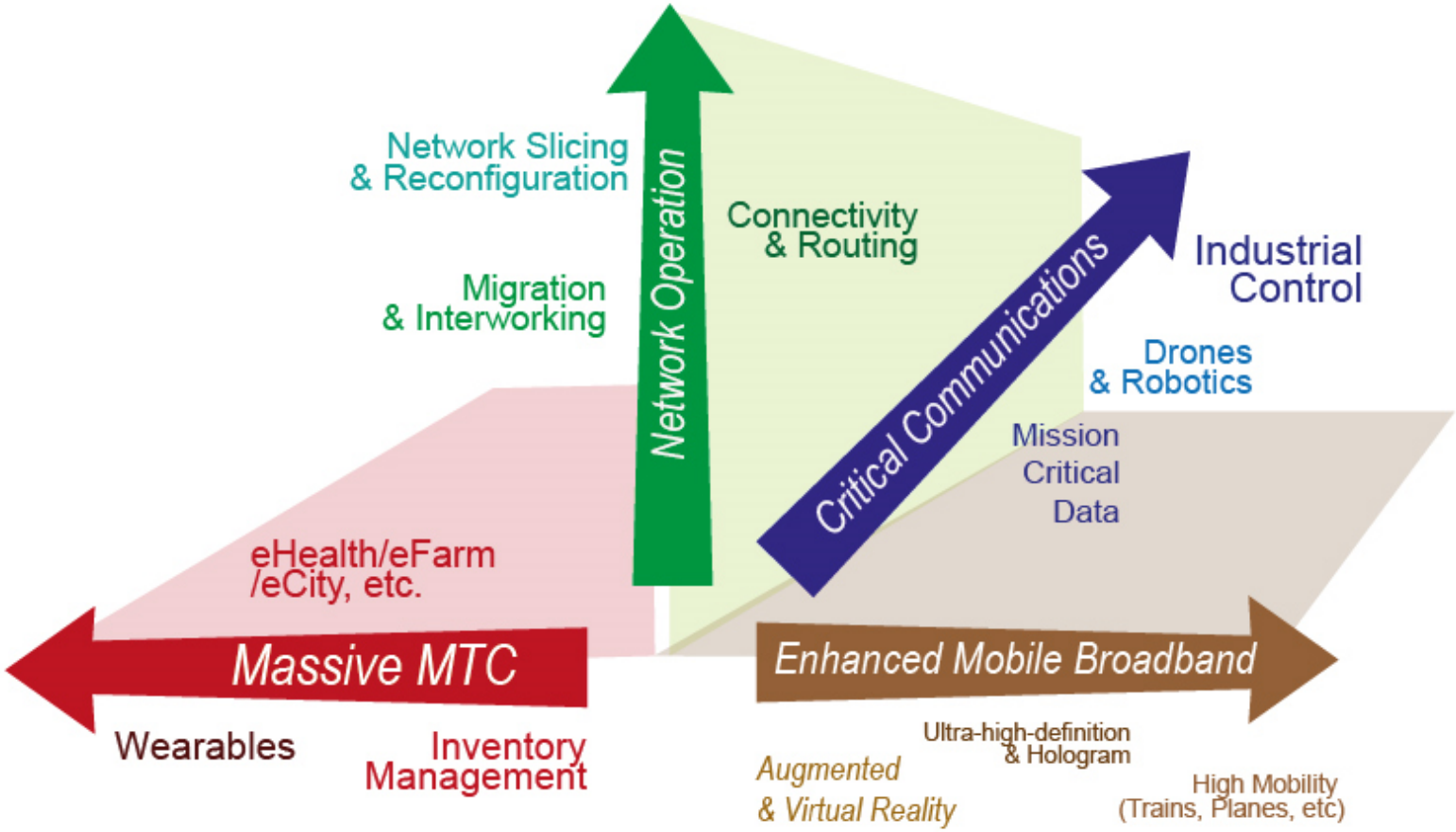
Logistics


UAVs

# Release 15 progress

- 3GPP SA1 divided the work into 4 topics:
  - eMBB; evolved mobile broadband
    - higher data rates, higher density, deployment and coverage, scalable mobility
  - mIoT; massive IoT
    - including high density IoT deployments
  - CRIC; Critical Communications
    - mission critical requirements, industrial automation and tactile Internet
  - NEO; Network Operation
    - horizontal requirements, new business models, migration and interworking, and security.

# Release 15 progress



# Release 15 Status

- The end result for Release 15 was very much focused on eMBB
  - URLLC was not fully addressed
  - Many of the NEO features were postponed (e.g., native multicast/broadcast, Sidelink)
  - mIoT was addressed with NB-IoT and eMTC attached to EPC
- Key focus was on Option 3, Option 2, other deployment options
- SA1 requirements get stacked up for future releases

# Release 16

- SA1 requirements went into much greater detail on the support for verticals in 5G
  - Cyber-physical control applications in vertical domains (CAV)
  - LAN support in 5G (5GLAN)
  - 5G positioning services (HYPOS)
  - Integration of Satellite Access in 5G (5GSAT)
- 3GPP SA also made a decision to focus new work on the 5G system rather than evolving the 4G system further
  - Exceptions may apply ☺
- Some work continued in both 4G and 5G to enable verticals
  - Remote Identification of Unmanned Aerial Systems (ID_UAS)
  - Improvement of V2X service Handling (V2XIMP)

# Key new 5G features from “verticals” in Rel-16

- Massive input into Industrial Automation
  - Mostly coming from Germanic factory operators associated with Industrie 4.0 and ZVEI (German Electrical and Electronic Manufacturers' Association)
  - Electrical grid input coming from China stage grid operators
- New Key Performance Indicators (KPIs), new architecture for Non-Public Networks
- New requirements, KPIs, accuracy bands for positioning (indoor and outdoor)
- QoS “prediction” and monitoring to support high reliability systems

- And new verticals started to engage:
  - Maritime, audio-visual production industry, TV distribution, smart cities, & water management, waste management and energy services.

# Release 16

- Cyber-physical control applications in vertical domains (cyberCAV) has driven substantial work in 3GPP RAN and SA/CT and has provided the KPIs required to drive the URLLC work
  - Vertical_LAN, NR_IIoT, eURLLC
- 5G positioning services (5G_HYPOS) and cyberCAV are providing large input into the RAN NR positioning study
- Integration of Satellite Access in 5G (5G_SAT) is now RAN and SA2 work
- NR in unlicensed band (not SA1 driven, but supported by most verticals)

# And now Release 17…

- The pace of 5G development is slowing in SA1; more evolution, less revolution
- Verticals are still contributing:
  - Audio-visual production, AR/VR, online gaming, edge services
- Key features are still to be determined but expect the following:
  - Strict KPIs on audio/visual sync
  - High bandwidth Sidelink
  - Multi-hop UE to network relays
  - Enhanced integrated Edge

# Some Release 17 Feature or Study Items

- **Enhancements for cyber-physical control applications in vertical domains** (eCAV)
- **5G Enhancement for UAVs** (EAV)
- **Complete Gap Analysis for Railways Mobile Communication System** (MONASTERYEND)
- **Audio-Visual Service Production** (AVPROD)
  - Requirements for using 5GS for the production and contribution of audio-visual content and
- **Network Controlled Interactive Service** (NCIS)
  - Specify KPIs for interactive service

# Some Release 17 Feature or Study Items

- **Support for Multi-USIM Devices** (MUSIM)
- **Multimedia Priority Service (MPS) Phase 2** (MPS2)

- Some of the “potential” requirements from these studies have already been translated to stage-2 studies for Release17 (e.g., AVPROD→FS_eNPN, NCIS→5G_ProSe, MUSIM)

Full list: https://www.3gpp.org/dynareport/TSG-WG--S1--wis.htm?Itemid=438

# ATIS/3GPP Webinar
## 5G Core Network Standards Developments in Release 15 and Beyond


**Stephen Hayes**

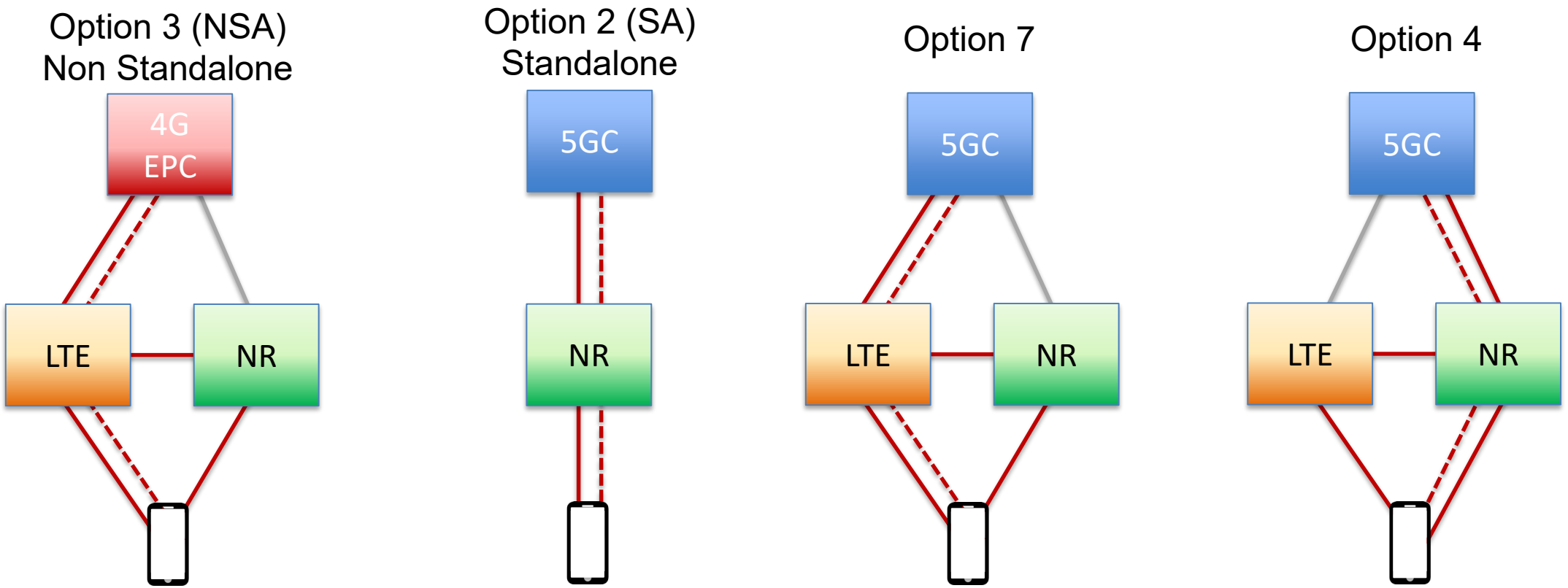
*Director of North American Standards*

ERICSSON


atis

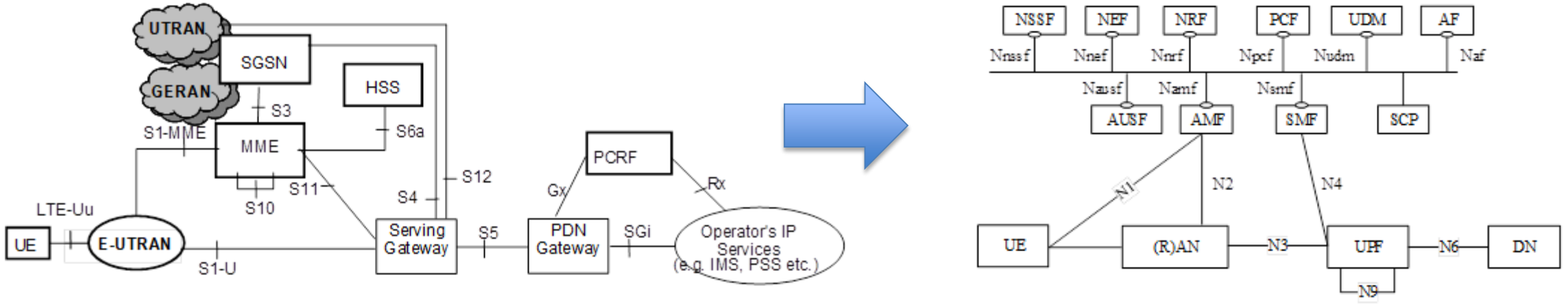
*Advancing ICT Industry Transformation*

# Two Core Networks Support 5G



# 5G Core Networks

- Most Rel.16 work focused on 5GC, but EPC still being enhanced
- 5GC Differentiators
  - Service Based Architecture (SBA)
  - Network Slicing
  - Control Plane/User Plane (CP/UP) Split
  - Integration of cloud/edge computing
  - Flow based QoS



# Missing 5GC functionality added in Rel.16

- Catching up to and passing EPC Functionality
- V2X support for 5G
  - NR Support
  - Enhanced PC5 capabilities such as groupcast and unicast (LTE was broadcast only)
  - Enhanced support for QoS (for both device to device and to/from the network)
  - May use a V2X specific network slice
- NB-IoT support
  - EPC-5GC migration and interoperability
  - Support of optimizations for infrequent small data transmissions and power savings
  - Improved group management
- Location Services (LCS) enhancements
  - Support for commercial use cases
  - Roaming support
  - Local LCS functions in RAN (NG-RAN)

# Further architectural improvements in Rel.16

- Service Based Architecture (SBA) enhancement
  - Indirect communication and delegated discovery through Service Communication Proxy
  - Introduction of NF Set and NF Service sets
  - Selection and reselection within NF Set
  - Convert IMS to use SBA
- Enhancement of network slicing
  - Slice specific authentication and authorization
  - Improvements in slice interworking with EPC
- User data interworking, coexistence, and migration
- Flexible mapping between session management (SMFs) and user plane (UPFs)
- Optimizations on UE radio capability signaling (RACS ID)
- Improved network automation
  - Addition of network analysis functions
  - Management support of new functionality such as slicing and URLLC

# Vertical and non-3GPP support

- Wireless/Wireline Convergence (BBF Support)
  - Supports wireline and hybrid access
  - Trusted access supported in R16
  - Makes use of generic access
- Traffic steering, switching, and splitting
  - **Access Traffic Steering:** Selects an access network for a new data flow.
  - **Access Traffic Switching:** Moves all traffic of a data flow from one access network to another access network (“per flow scheduling”)
  - **Access Traffic Splitting:** Splits the traffic of a single data flow across multiple access networks (“per packet scheduling”).
- Enhanced URLLC support
  - Low latency handoffs
  - Redundant path support

# Vertical and non-3GPP support (cont.)

- Support of Verticals and LANs
  - Non public networks (NPN)
    - Stand-Alone Non-Public Networks
      - No PLMN operator network support
    - Public Network Integrated NPN– PNI NPN
      - with PLMN operator network support
    - Support Service continuity, and support access of NPN services via PLMN and vice versa
  - Support of 5G LAN
    - 5G LAN-Type Service: A service over the 5G system offering private communication using IP and/or non-IP type communications.
    - 5G LAN-Virtual Network: A virtual network over the 5G system capable of supporting 5G LAN-type service.
    - 5GLAN Group: A set of UEs using private communication for 5G LAN-type service.
  - Time sensitive networking (TSN)
    - 5G System working as a TSN Bridge
    - Supports multiple clock domains

# Further Information

- Architecture and Protocol work within the core network:
  - Architecture: https://www.3gpp.org/dynareport/TSG-WG--S2--wis.htm
  - Security: https://www.3gpp.org/dynareport/TSG-WG--S3--wis.htm
  - Media: https://www.3gpp.org/dynareport/TSG-WG--S4--wis.htm
  - O&M: https://www.3gpp.org/dynareport/TSG-WG--S5--wis.htm
  - Application Support: https://www.3gpp.org/dynareport/TSG-WG--S6--wis.htm
  - Protocols:
    - https://www.3gpp.org/dynareport/TSG-WG--C1--wis.htm
    - https://www.3gpp.org/dynareport/TSG-WG--C3--wis.htm
    - https://www.3gpp.org/dynareport/TSG-WG--C4--wis.htm
    - https://www.3gpp.org/dynareport/TSG-WG--C6--wis.htm

# 5G RAN Standards Development in 3GPP Release 15 and Beyond

**Dr Emad Farag**

*Senior 5G Radio Standardization Specialist*

Nokia Bell Labs

NOKIA

atis

**July 31, 2019**

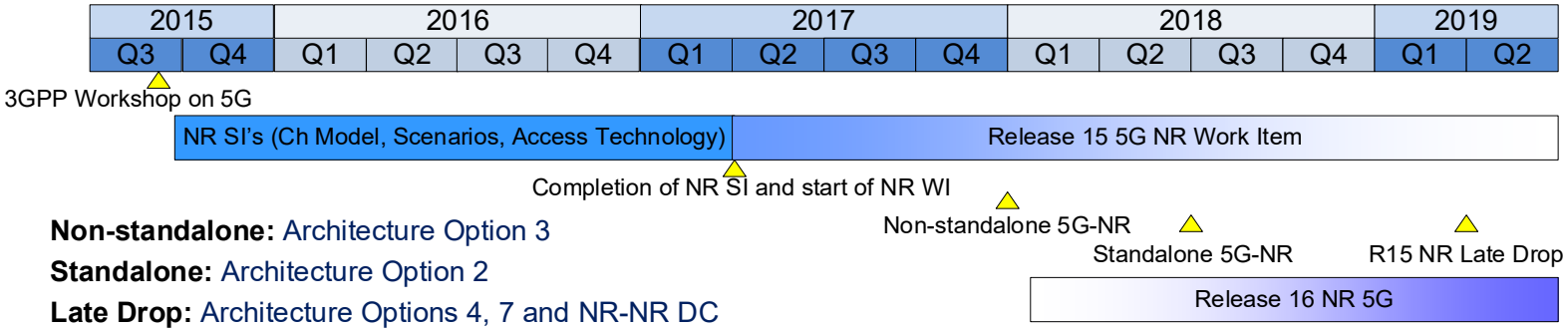
***Advancing ICT Industry Transformation***

# NR Release 15 – Overview and Status

## Scope:

- Enhanced Mobile Broadband (eMBB)
- Basic URLLC
- Up to 52.6 GHz

## Timeline




**Non-standalone:** Architecture Option 3
**Standalone:** Architecture Option 2
**Late Drop:** Architecture Options 4, 7 and NR-NR DC

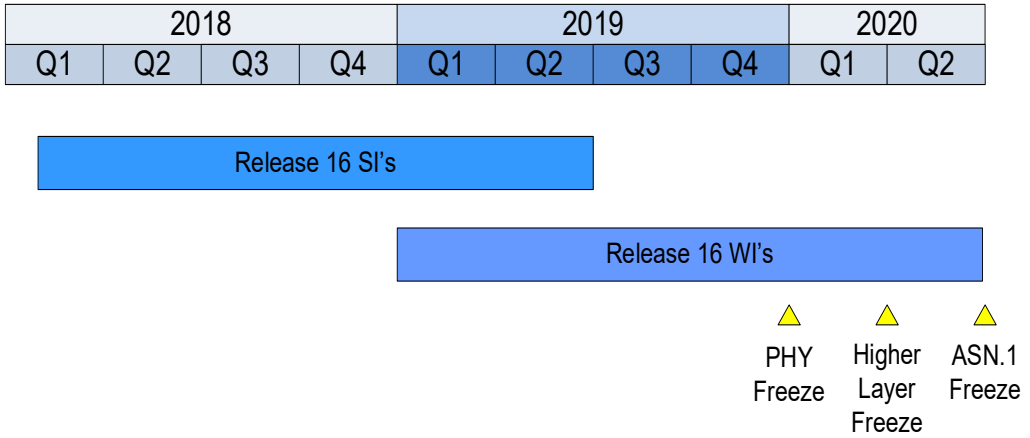
## 5G NR Enabling Technologies

| Scalable Numerology | Flexible Frame Structure | Advanced Channel Coding | Enhanced MIMO | Beam Forming |
|---|---|---|---|---|
| Single framework for $f_c$ = sub 1-GHz – 50+ GHz<br>Low latency*<br>* One way latency ~ 1ms | Forward compatible design<br>Flexible TDD | **LDPC** for high through-put low latency data channels.<br>**Polar** codes for control channels. | Higher spectral efficiency<br>MU-MIMO support | mmWave support<br>Enhanced coverage |

**New radio interface designed from ground-up to set the foundation to meet IMT 2020 requirements**

# Release 16 - Overview

- **Focus**
  - Capacity enhancement
  - Operation efficiency
  - Expansion to vertical markets
- **Timeline**



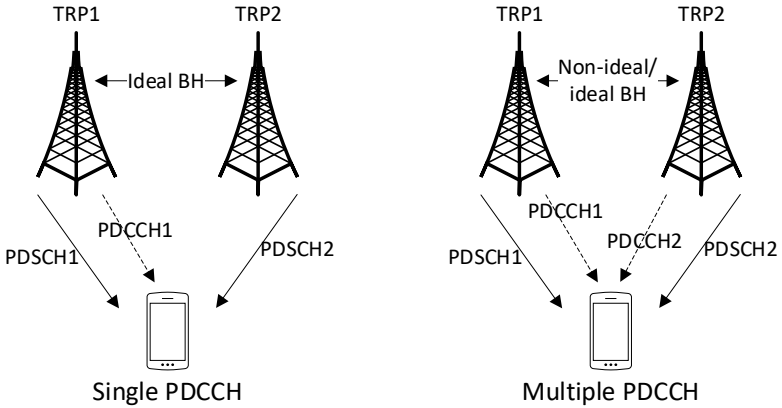

- **Main features**

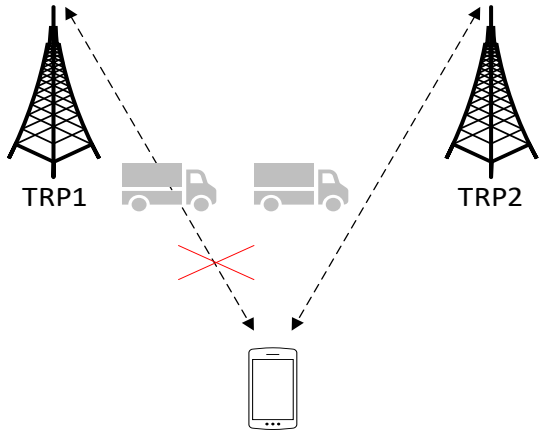
| Capacity and Operational efficiency | |
|---|---|
| • MIMO enhancements<br>• MR-DC (Multi-RAT Dual Connectivity)<br>• IAB (Integrated Access and Backhaul) | • Mobility enhancements<br>• CLI/RIM (Cross Link Interference/Remote interference Management)<br>• UE Power savings |

| Vertical expansion | |
|---|---|
| • IIoT (Industrial IoT)<br>• URLLC (Ultra Reliable Low Latency Communications)<br>• 2-step RACH | • NR Positioning<br>• NR unlicensed<br>• V2X (Vehicle to Everything) |

# MIMO Enhancements

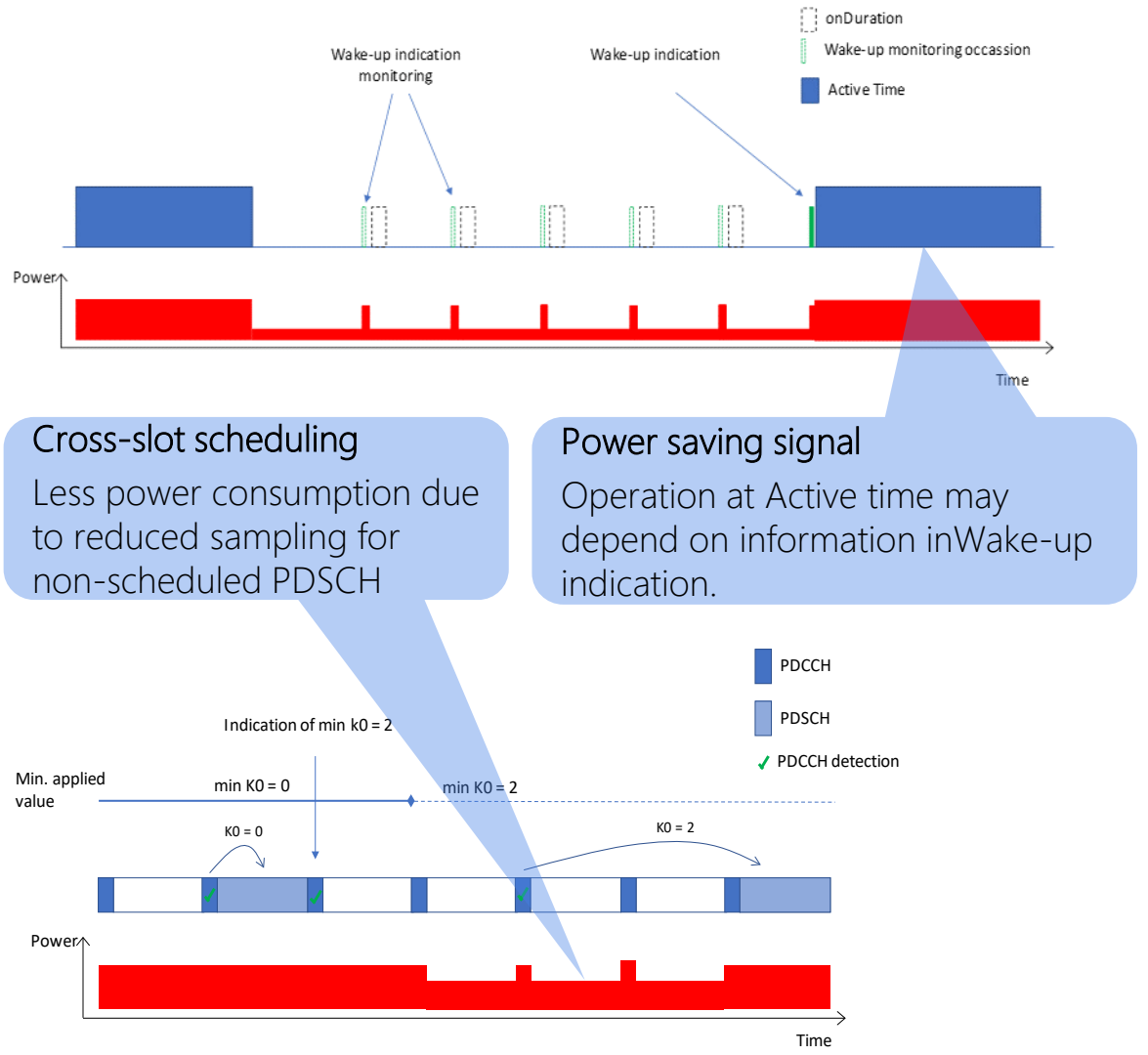
- **Release15 NR MIMO Framework**
  - Introduced beam-based operation
  - Scalable and flexible CSI-framework and RS design
  - Type II CSI codebook – significant improvement over LTE
- **Release 16 NR MIMO enhancements**
  - **CSI enhancements for MU-MIMO:** Overhead reduction, and extension of Type II CSI to rank > 2
  - **Multi-TRP/Panel transmission enhancements:** With ideal and non-ideal backhaul. Includes downlink (see example to right) and uplink control signaling for non-coherent joint transmission. Also includes URLLC aspects related to multiple TRP.
  - **Multi-beam operation enhancements:** Reduce latency and overhead, UE multi-panel beam indication, beam failure recovery for Scell, and beam measurement based on UL-SINR.
  - **Full Tx Power UL** transmissions with multiple power amplifiers.
  - **Low PAPR RS:** New Reference Signals defined lowering PAPR.



# UE Power Saving

- **Motivation:**
  - Improved UE battery life.
  - Target is that 5G NR has better power efficiency than LTE.
  - The RAN1 study of the Rel-16 UE power saving had shown substantial power saving gain based on UE power consumption model.
- **UE Power Saving techniques (specified/considered):**
  - PDCCH-based power saving signal/channel triggering UE adaptation in RRC-Connected
  - Cross-slot scheduling power saving
  - Adaption of MIMO layers
  - Indicator to transition out of RRC-Connected.
  - UE assistance information.
  - Intra and inter-frequency RRM measurement relaxation in IDLE and INACTIVE modes.



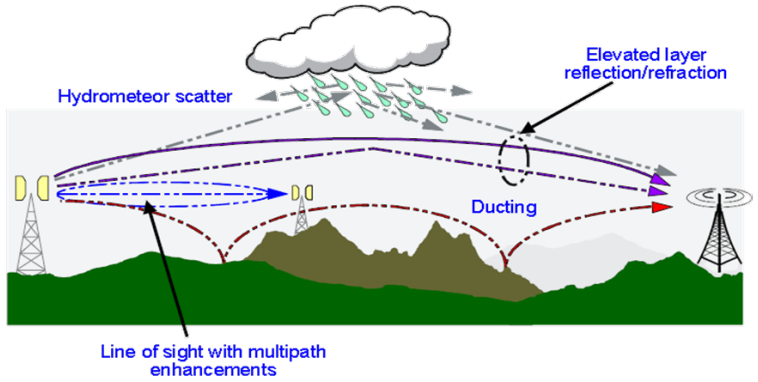
# Cross Link Interference (CLI) and Remote Interference Management (RIM)

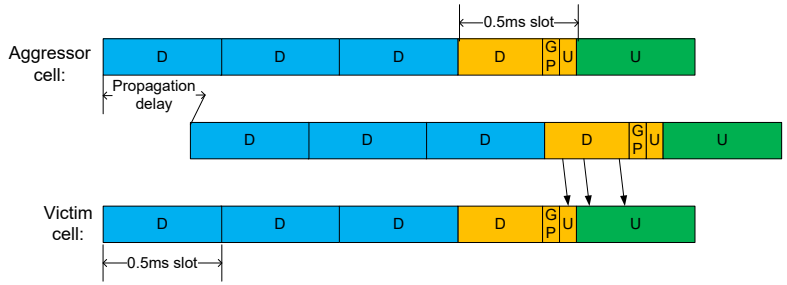
## Cross link Interference (CLI) Mitigation

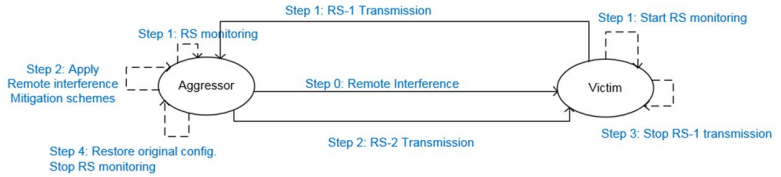
- **Motivation:** Support flexible resource sharing in unpaired spectrum
- **Realization (CLI):**
  - CLI measurements and reporting at UE
    - SRS-RSRP and CLI-RSSI.
  - Network co-ordination: Exchange intended UL/DL config

## Remote Interference Management (RIM)

- **Motivation:** Detect/mitigate interference from remote base station due to ducting.
- **Realization (RIM):**
  - RIM RS (detection/conveying information)
    - RIM-RS1: From Victim to Aggressor.
    - RIM-RS2: From Aggressor to Victim.
  - RIM backhaul signaling
  - OAM functions to support RIM.



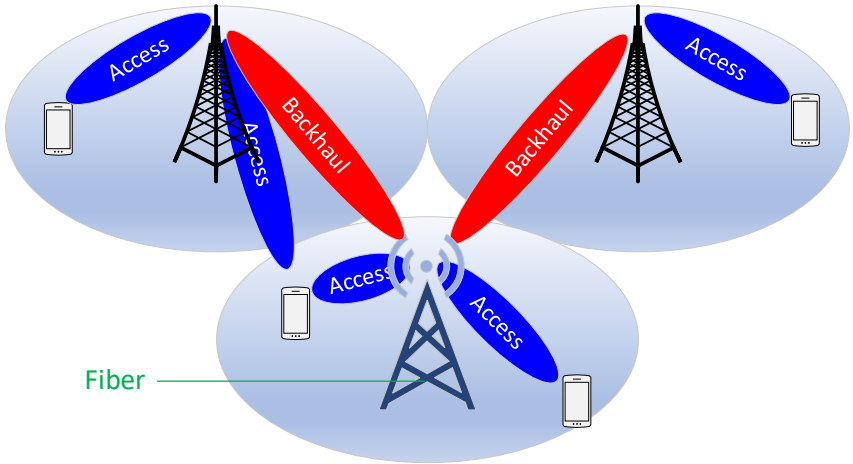

**RIM Framework1**

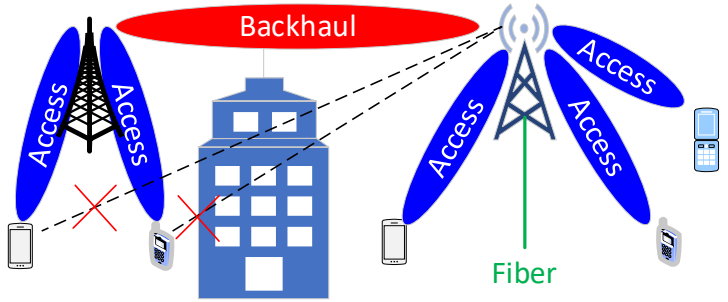
# Fibreless Backhaul – Integrated Access and Backhaul (IAB)

- Support wireless backhaul and relay links in-band and out-of-band with access links.

**Motivation**:

- Improve capacity by allowing flexible dense network deployment with sparse fiber availability.
- Improve coverage (e.g. range extension, coverage gaps or indoor coverage).
- Group mobility (not within the scope of release 16)




**Scope:**

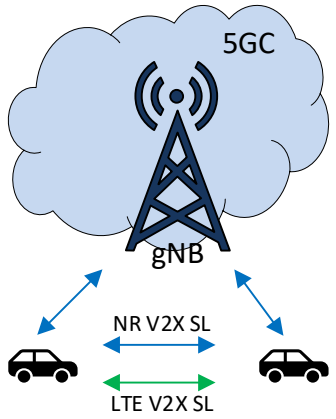
- Multi-hop backhauling
- Topology adaptation/redundant backhauling
- E2E QoS enforcement
- Scalability to large number of UEs
- Flexible deployment (EN-DC+EPC or SA NR + 5GC)
- NR-NR DC for UE and IAB-nodes
- In-band and out-of-band operation
- OTA synchronization across IAB topology
- Support release 15 UEs

# Ultra-Reliable Low Latency Communication (URLLC) IIOT

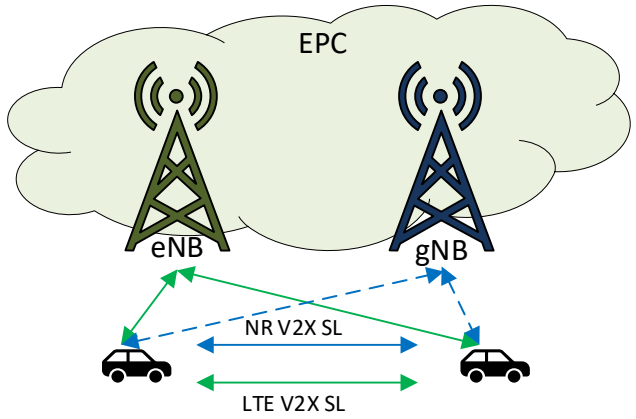
- **Release 15 provided basic URLLC functionality**
  - Low latency: Larger SCS, mini-slots, configured grant.
  - Higher reliability: PDCP duplication, Low SE MCS/CQI tables
- **Release 16 motivation to further enhance URLLC**
  - Latency in range of 0.5 – 1 ms, reliability in range of 10^-6
  - Support new use cases, factory automation, transport industry, etc.
  - Further enhance release 15 use cases, AR/VR, entertainment, etc.
- **URLLC objectives**
  - **PDCCH enhancements:** DCI with configurable field sizes, increase PDCCH monitoring capability
  - **UCI enhancements:** Multiple HARQ-ACK per slot, multiple HARQ-ACK codebooks
  - **Scheduling and HARQ enhancements:** Out-of-order HARQ-ACK and PUSCH scheduling, overlapping of dynamic PDSCH.
  - **Inter UE Tx prioritization and multiplexing:** UL preemption and enhanced UL power control
  - **Configured grant enhancements:** Multiple active configurations

# Vehicle-to-Everything (V2X)

- Demonstrates continuous evolution of Cellular V2X.
  - R14 LTE V2X provides basic road safety support.
  - R15 LTE V2X (phase 2) introduced features to increase data speed and reduce latency.
  - NR V2X complements LTE V2X by providing support for advanced use cases
- Advanced use cases for NR V2X (identified by SA and classified into 4 groups)
  - Platooning
  - Extended sensors
  - Advanced driving
  - Remote driving
- Release 16 enhancements
  - Slidelink enhancements
  - Cross-RAT control (NR Uu controls LTE PC5)
  - UE assistance information to gNB
  - QoS management



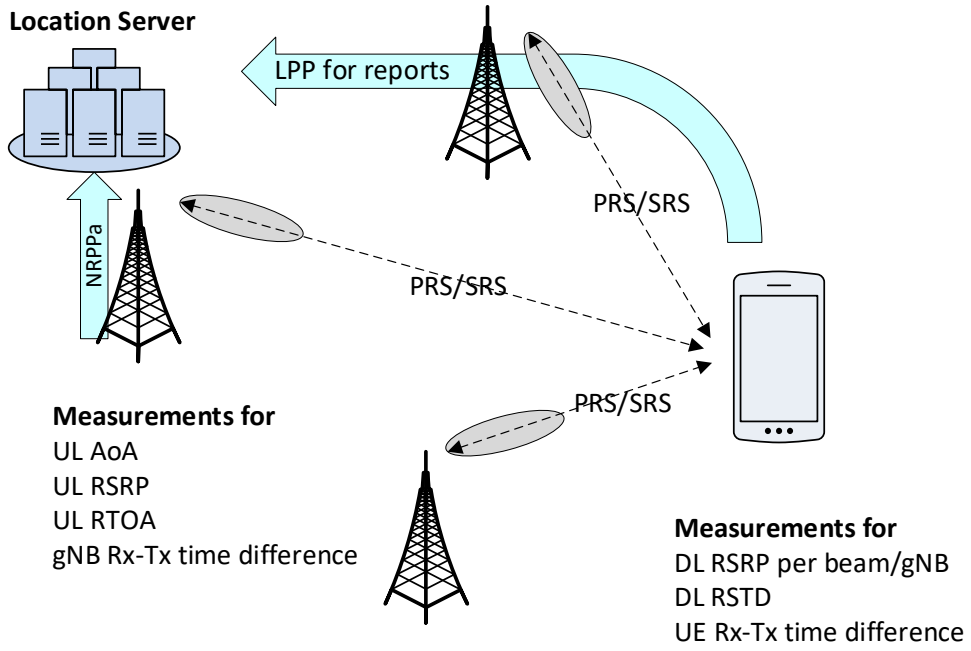

Scenario 1
SA NR




Scenario 6
EN-DC

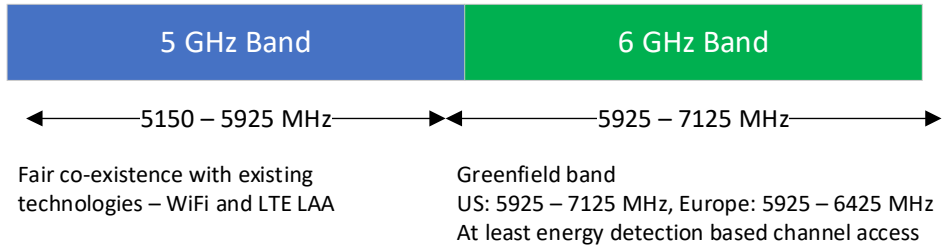
# NR Positioning

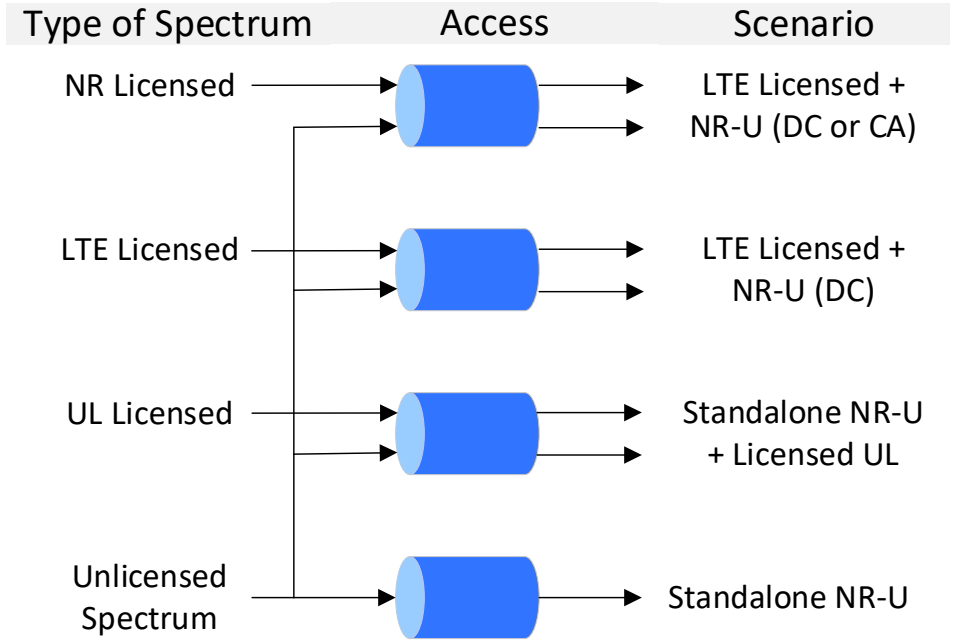
- **Native NR support for UE positioning to support regulatory and commercial requirements:**
  - Regulatory requirement: horizontal error <50 m with 80% confidence
  - Commercial requirement: Outdoor horizontal error < 10 m with 80% confidence. Indoor horizontal error < 3 m with 80% confidence.
  - Utilize NR capabilities e.g. operation in FR1 and FR2, higher BW and massive antenna arrays.
- **RAT dependent positioning schemes:**
  - DL-Time Difference Of Arrival (TDOA)
  - UL-TDOA
  - DL-Angle of Departure (AoD)
  - UL-Angle of Arrival (AoA)
  - Multi-cell Round trip time (RTT)
  - E-CID
- **Extension of RAT independent positioning schemes:**
  - LPP A-GNSS to provide assistance data message based on compact SSR messages from QZSS interface specification



# NR Unlicensed – NR-U

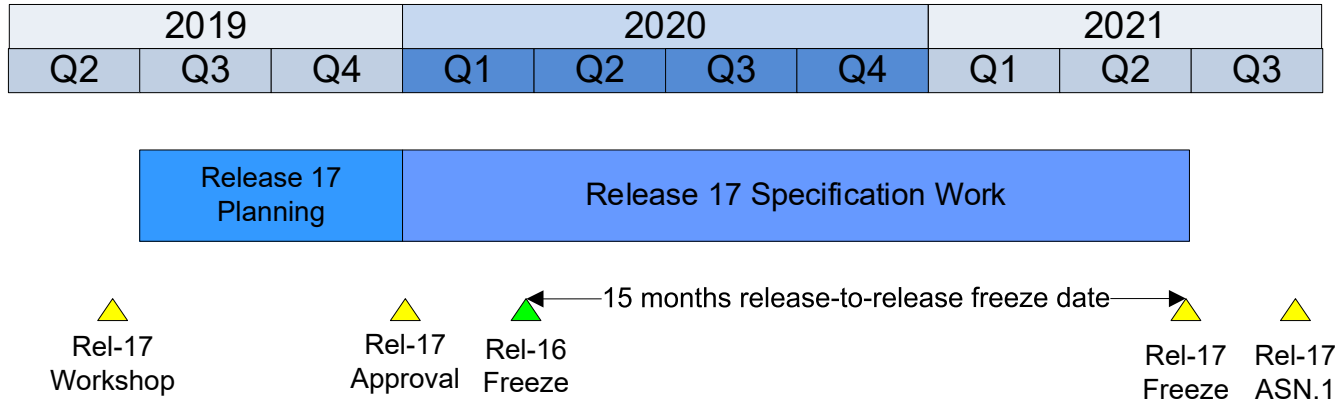
- Licensed spectrum is the corner stone of wireless-mobile service (coverage/efficiency /reliability).
- Unlicensed spectrum completements, boosting capacity and improving data connectivity.
- **Access Scenarios:**
  - **Scenario A:** Carrier aggregation NR in licensed band (Pcell) and NR-U (Scell)
  - **Scenario B:** Dual connectivity LTE in licensed band (Pcell) and NR-U (PSCell)
  - **Scenario C:** Standalone-NR
  - **Scenario D:** Standalone cell in unlicensed band and UL in licensed band
  - **Scenario E:** Dual connectivity NR in licensed band and NR-U



# A Glimpse into the Future – Release 17

- **Release 17 planning**
  - **RAN#84 (Jun'19):** One-day presentations on Rel-17 proposals.
  - **RAN#85 (Sep'19):** Review Rel-17 email discussions
  - **RAN#86 (Dec'19):** Finalization/ approval of Rel-17 content.




- **Rel-17 content discussion (Work Areas) – Not all of these will become Rel-17 SI/WI**
  - New items for Rel-17
  - Continuation of items from earlier releases

| | | | |
|---|---|---|---|
| NR Light | Multi-SIM | IIoT/URLLC enhancements | NR-U Enhancements |
| Small data Enhancements | NR Multicast/ Broadcast | MIMO Enhancements | Power saving Enhancements |
| Sidelink Enhancements | Coverage Enhancements | NTN Enhancements | Data collection Enhancements |
| Above 52.6 GHz | NB-IoT Enhancements | IAB Enhancements | Positioning Enhancements |

# ATIS/3GPP Webinar
## North American Priorities Recap

**Iain Sharp**

*Advancing ICT Industry Transformation*

# ATIS Leadership Areas in Mobile Standards

Satellite integration with terrestrial mobile

Establishing regional leadership for next generation (“6G”) mobile

Alignment of North American requirements for 3GPP Release 17 and Beyond


5G as an enabler for ATIS Innovation Agenda (e.g., Connected Car, Smart Cities, UAVs)

5G dense deployment solutions using neutral host

System-wide architectural security

# ATIS Ensures 3GPP Meets North American Needs

Development of mobile-directed **geo-targeting standards**

Architecture and standards for **wireless emergency alerts** to public via wireless broadcast notifications

Program manager for **911 location technologies** test bed and National Emergency Address Database projects

**Critical communication** in 4G and 5G systems and interworking to legacy technology


Support of **regional spectrum bands** and spectrum sharing innovation, e.g. CBRS

**Lawful intercept**

# Q&A

Thank you for attending the
5G Standards Developments in Release 15
and Beyond Webinar

All registered attendees will receive a follow up email containing links to a recording and the slides from this presentation.

For information on upcoming ATIS events, visit
**www.atis.org/**

# Selected Acronyms

- BBF Broadband Forum
- CLI Cross Link Interference
- CSI Channel State Information
- eMBB Enhanced Mobile Broadband
- EPC Enhanced Packet Core
- IAB Integrated Access and Backhaul
- MIMO Multiple Input, Multiple Output
- mIoT Massive Internet of Things
- NAS Non Access Stratum
- NPN Non-Public Network
- NR New Radio
- PARP Peak to Average Power Ratio
- PDCP Packet Data Convergence Protocol
- PGW Packet Gateway
- PLMN Public Land Mobile Network
- RACH Random Access Channel
- RIM Remove Interference Management
- RS Reference Signal
- SBA Service Based Architecture
- SCS Subcarrier Spacing
- SGW Serving Gateway
- SINR Signal to Noise Ratio
- TSG Technical Specification Group
- TSN Time Sensitive Networking
- TRP Transmission and Reception Point
- UE User Equipment
- UICC Universal integrated circuit card
- UL Uplink
- URLLC Ultra-reliable low latency communication
- V2x Vehicle to Anything

# Speakers Biographies (1)

- **Dr. Farrokh Khatibi**
  Director of Engineering
  Qualcomm

  Dr. Farrokh Khatibi joined QUALCOMM in 1990 to help design the CDMA cellular system. In 1992 he initiated a research project which led to Qualcomm's first IP-based infrastructure that was later acquired by Ericsson. He started attending 3GPP SA1 and SA2 in 1999. He has been attending the 3GPP PCG/OP meeting as part of the ATIS delegation for the past few years.

  Dr. Khatibi is the Chair of WTSC RAN group and co-lead of the ATIS Open Source IoT group. He also actively participates in a number of ATIS TOPS and Strategic Initiatives such as 5G, Smart Cities, and UAV.

- **Stephen Hayes**
  Director
  North American Standards
  Ericsson

  Stephen Hayes is the Director of Standards for Ericsson in North America. His current focus includes the ATIS committees and 3GPP. He is also involved in several US advisory groups such as the FCC TAC (Technical Advisory Committee) and NSTAC (National Security Telecom Advisory Committee).

  Stephen was chairman of the 3GPP systems group (3GPP-SA) from 2006- 2011. The 3GPP-SA group is responsible for all requirements, architectural, system and coordination issues for GSM, UMTS, LTE, and LTE Advanced systems and networks. Under his tenure 3GPP successfully developed Releases R7, R8, R9, and R10. Before that, Stephen was the chair of the Core Network group in 3GPP.

  Stephen was instrumental in the development of IMS as chair of the core network group. He has been heavily involved in the collaboration efforts with other organizations such as IETF, 3GPP2, TMF, and the BBF.

  Mr. Hayes has participated and held various leadership positions within the ATIS committees including WTSC (Wireless Technology and Systems Committee). He has written various articles for IEEE communications and holds numerous patents in the area of telecommunications. Mr. Hayes resides in Flower Mound, Texas.

# Speakers Biographies (2)

- **Dr. Emad Farag**
  Senior 5G Physical Standards Engineer
  Nokia

  Dr. Emad Farag is a senior 5G physical layer standards engineer at Nokia. He has been with Nokia for 20 years, working on the Physical Layer architecture, algorithms and software of wireless base station modems, and now is part of Nokia's 3GPP TSG RAN WG1 team focusing on developing and introducing new physical layer concepts for the New Radio interface to the 3GPP standard. Dr Farag received his Ph.D. degree in Electrical Engineering from the University of Waterloo, Waterloo, Ontario, Canada. He is the recipient of the 2015 IEEE Region 1 Technical Innovation Award for innovations in Wireless Modem Architectures.

- **Iain Sharp**
  Principal Technologist
  ATIS

  Iain has been an active contributor to the development of mobile standards since the early days of GSM. His work in standards includes serving for 4 years as the vice chair of 3GPP Core Networks and Terminals plenary. As well as work in standards Iain has contributed to the development of product and technology strategies for leading vendors. Since 2015 Iain has been a principle technologist at ATIS and has worked in diverse technical issues including IoT, network security, unmanned aerial vehicles and 5G.