NR evolution – realizing the full potential of 5G

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5G – Beyond Mobile Broadband

Broadband experience everywhere anytime
Mass market personalized media and gaming
Meters, sensors, “Massive MTC”
Remote controlled machines
Smart Transport Infrastructure and vehicles
Human / machines interaction
And much more!

New opportunities and flexibility for the unforeseen
First release of NR (Rel-15) completed in June 2018

Evolution of NR
- First major enhancements already in Rel-16 (IAB, NR-U, ...)
- Continued evolution in subsequent releases including frequencies up to and beyond 52.6 GHz, massive MTC, ...
NR Rel-15

Use case dimension

Feature dimension

IIOT

eMBB/FWA

OFDM, MIMO, FR1 + FR2, EN-DC, CA, lean design ...

dyn. TDD, mini slots, flexible numerology
NR evolution

Feature dimension

- OFDM, MIMO, FR1 + FR2, EN-DC, CA, lean design...
- dyn. TDD, mini slots, flexible numerology
- OTDOA
- Sidelink
- TSN
- MDT, SON
- IAB, NR-U
- >52.6 GHz

Use case dimension

- ... Drones
- NR MTC
- Public Safety
- Positioning
- V2X
- IIOT
- eMBB/FWA

Rel-15 | Rel-16 | Rel-17 | Rel-18 | ...

- Delay tolerance
- Low cost, low power
- Mobile cells, UE-NW relaying
NR Rel-15 key features

- Ultra-lean design
- Wide spectrum range
- Forward compatibility
- Multi-antenna support
- Low latency
NR Rel-15 key features

LTE - NR coexistence

Network slicing

Modular architecture
DU/CU split, SBA
Architectural options

— **Non-standalone NR**
  — LTE handling initial access and mobility
  — NR is a “data rate booster”
  — Connects to EPC

— **Stand-alone NR**
  — NR handles initial access and mobility
  — Connects to 5G CN
Some topics in NR Rel-16

**Unlicensed spectrum**
- LAA and stand-alone

**Integrated Access Backhaul**
- NR for backhauling

**V2X**
- Sidelink, Uu enhancements, QoS,...

**URLLC enhancements**
- Diversity, latency,...

**Industrial IoT**
- TSN support, time synchronization,...

**Multi-antenna enhancements**
- Beam management, CSI reporting,...

**Remote Interference Management**
- TDD, atmospheric ducts, ~300 km

**TSN** time-sensitive networking
**V2X** vehicle-to-anything
**TRP** transmission-reception point
**URLLC** ultra-reliable low latency communication
**TDD** time-division duplex
NR Unlicensed Spectrum operations

- Unlicensed spectrum considered by cellular operators as a complementary tool to augment their service offering

- Adapt initial/ channel access, scheduling/ HARQ, and mobility operations for unlicensed spectrum regulation & characteristics
  - Reuse existing NR as much as possible

- Existing bands and potentially new bands
  - Preferred band is 5/6 GHz
  - Coexistence study for new bands

- Support diverse deployment cases
  - Carrier aggregation NR + NR-U
  - Dual connectivity LTE/NR + NR-U
  - Standalone NR-U
Vehicle-to-everything (3GPP V2X Phase 3)

› Improved support for V2X services
  - LTE-V2X enables day-1 safety
  - NR-V2X is a complementary technology addressing new use cases (e.g. platooning, advanced driving, sensor sharing) and tighter requirements

› Study NR design for V2X
  - Targeting a wider range of frequencies (up to 52.6 GHz), with initial focus on FR1 frequencies.
  - Cellular (Uu) enhancements for high mobility scenarios and improved efficiency when delivering ITS traffic
  - Sensing-based resource allocation scheme mostly designed for aperiodic transmissions.
  - Some unicast/groupcast features such as link adaptation, power control, etc.

› Ensure optimal coexistence
Benefits:
- Coverage extension for >6GHz
- Easy and cost-efficient deployment

Most relevant deployment scenarios:
- Outdoor, small-cell relay nodes (targeting FWA & eMBB)
- Fixed relays, but forward compatible to nomadic/mobile
- Limited number of hops (>=2)
- Star/tree deployment (no mesh)
- Inband and outband relaying using >6GHz
- IAB transparent to UEs (Rel-15 backwards-compatible)
- Support SA and NSA operations
NR URLLC
RAN1-led, L1 focused

- Improved reliability (connectivity and operations) and latency
  - Enhance radio channel reliability
  - Decrease end-to-end latency via faster access

- Improve full automation and flexibility
  - Scheduling enhancements
Industry-grade NR for Industrial IoT

- Ethernet and IEEE 802.1 (e.g. TSN) features often the basis in such networks. 5GC introduces Ethernet-type PDU Session.
  - Optimizations for Ethernet PDU Sessions
    - Header compression
    - Possible QoS enhancements
  - Enabling time-synchronized operations of devices (e.g., time synchronized UEs to enable synchronized operating on joint tasks)
  - Support for redundant PDU sessions
    - aligned with SA2
  - Study and define mid-tier NR UE (no new design)

URLLC use cases in TS 22.261 and TS 22.804
NR Remote Interference Management and Cross-Link Interference

- RIM
  - BS-to-BS interference over large distance (up to 300 km)
  - Due to tropospheric ducting, which occurs in certain weather conditions
  - Static and dynamic RIM
  - Frameworks for centralized and distributed RIM

- CLI
  - Dynamic TDD
Possible topics in Rel-17

Continuation of Rel-16 - examples

- Above 52.6 GHz
- Unlicensed, 60 GHz
- IAB enhancements
- Sidelink
- Non-terrestrial access

New topics - examples

- Drone enhancements
- Multicast/broadcast
- NR MTC for industrial sensors
- Reduced complexity/power consumption
What about the longer time perspective?
Longer-term evolution

Some examples

Beyond 100 GHz

Flexible network topologies

Cellular as a sensor

Massive IoT

Device cooperation

Machine Learning - Artificial Intelligence

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Use case
- Intersection control

Main requirements
— Latency
— Reliability
— Connected devices

Demonstration at AstaZero (test facility Sweden)
— Connecting two XC-90 cars and one Volvo truck
— Coordination application running in cloud

Video available on Youtube!
(search: Ericsson+AstaZero)
Cloud based control logic

Latency requirement for moving control to the cloud

30 ms — Task control

5 ms — Task planner
Trajectory planner

1 ms — Control loop

Task control
4G

Task planner
5G

Trajectory planner

Control loop

Soft-PLC

Work cell PLC

Robot controller

Connected sensors

Robot

Object

Partners: SLF, PLC
A fully 5G connected manufacturing plant

- Digital twins and real-time control loops in edge cloud
- Data management & machine learning to plan and order maintenance and workflow
- AR/VR to visualize workflow & machine status
- Indoor positioning & edge cloud for automatic control of AGVs in factory
- With everything automated, using AR/VR for monitoring and issuing work orders, lights are no longer necessary
Summary

— 5G New Radio has been standardized in Release 15 and deployments are ongoing
— ...but this is only the beginning

— The common 3GPP approach is ongoing with continuous improvements in every release

— Release 16 is in progress, with significant NR improvements including
  — Integrated Access and Backhauling
  — Unlicensed spectrum
  — Improved Industrial IoT
  — Sidelink communication

— Preparations towards Release 17 are on-going