



COMPUTER ENGINEERING



WIRELESS NETWORKS AND INTERNET OF THINGS



Wireless Networks - Course program



- Digital transmission on the wireless channel
- Narrowband transmission
- Broadband transmission
- Multiplexing – diversity
- Cellular systems: from 1G to 6G
- The 802 standard
 - WiFi
 - Bluetooth
 - Zigbee
- Sensor networks
- Internet of Things

- G. L. Stüber, *Principles of Mobile Communication*, Springer, 2011.
- C. Smith, *Wireless networks*, Mcgraw-Hill.
- Martin Sauter, *3G, 4G and Beyond: Bringing Networks, Devices and the Web Together*, 2nd Edition, John Wiley.
- R. Melen, V. Trecordi, *IoT Networking, Ediz. MyLab*, Pearson, 2023.

- The course material is partially accessible on the website moodle2.units.it.
Access key: RW2024
- The course is visible on MS Teams.
- **Matlab.**
 - The course will make extensive use of the Matlab program. To download and install it on your computer, follow the instructions at the link:
<https://dia.units.it/it/dipartimento/node/32619>
- Lesson timetable

Tuesday 8.15 – 9.00 (Aula Arich [Edificio B])

Thursday 9.15 – 10.45 (Aula Arich [Edificio B])

- The test consists of an oral exam in which the main topics of the course will be examined.
- The exam proposes an example of application of the theory related to radio transmission techniques, as well as assessing the knowledge of the main standards and their properties.
- Seven exam sessions are scheduled during the year, but the exam can also be taken by appointment.

- Artificial intelligence. Foundational aspects.
- Energy scenarios of the future.
- Environmental, natural and anthropogenic risks.
- Quantum science and technologies.
- Humanistic culture and cultural heritage as laboratories of innovation and creativity.
- Diagnostics and innovative therapies in precision medicine.
- Cybersecurity, new technologies and protection of rights.
- Consequences and challenges of aging.
- Economic and financial sustainability of systems and territories.
- Models for sustainable nutrition.
- Circular and sustainable Made-in-Italy.
- Neuroscience and neuropharmacology.
- Emerging infectious diseases.
- Telecommunications of the future.

9. Industrial and Digital Transition Networks

- New industrial IoT protocols and network architectures; new radio technologies for ultra-reliable and low latency, and machine to machine type communications; device-edge-cloud continuum for industrial networks and digital transitions; physical layer security and software-defined security in industrial environments; management and orchestration of the secure industrial network infrastructure; green and low-energy communications; THz band transmissions and deterministic field prediction techniques for industrial applications; advanced radio technologies and components for industrial applications; high frequencies technologies and measurement devices; industrial tailored smart electromagnetic environments and devices; data analytics in industrial applications and resilient networks. **Innovative channel coding for modern and green networks.**

10. Services and systems for extreme environments and domain-specific scenarios

- Specific instances of domain-specific networks; energy harvesting-enabled systems; wireless power transfer, long-range low power wireless systems; communications systems for extreme environments (e.g., sea platforms, harbours, underwater, mines, tunnels, pipes, wild); multi-sensor platforms for continuous health monitoring; new IoT antennas, components and devices and nano-things networks; smart city's communication infrastructure; vehicular environments, tactile Internet, smart environments; RF electronics.

11. Integrated terrestrial and non-terrestrial networks

- Flexible multibeam phased arrays and antenna systems for 3D multi-layered networks; propagation and channel modelling for integrated terrestrial and non-terrestrial architectures; NT devices and sensors; hybrid and reconfigurable computing and offloading for NTN; integrated 3D multi-layered networks; ultra-dense networks; aerial access networks; innovative NTN-aided IoT and communication services; Remote IoT; navigation systems and integrated Communication / Sensing for network design and management; handover and beam/mobility management for NTN; architectures and protocols design for 3D multi-layered networks; unified T and NT radio access network; EM interference between terrestrial and non-terrestrial networks; autonomous and smart NTN network and infrastructure resource management; disaggregation and orchestration in 3D networks; data analysis in distributed NT networks; sustainability and energy efficiency in TLC systems and devices; free-space optical communications.

- International Telecommunication Union (ITU)
- 3rd Generation Partnership Project (3GPP)

Agreement between the entities that manage telecommunications in the various states, stipulated with the aim of defining a common standard for 3G starting from GSM, and in accordance with the requirements and specifications of the International Mobile Telecommunications 2000 of the ITU. Today it manages the evolution of cellular standards (5G, 6G, Non Terrestrial Networks).

- Institute of Electrical and Electronic Engineers (IEEE)
 - IEEE 802 LAN/MAN Standards Committee (LMSC)
 - IEEE 802.11 Wireless LAN (WiFi)
 - IEEE 802.15 Wireless Personal Area Networks
 - IEEE 802.16 Broadband Wireless Access (WiMAX)

Version	Date	Information
Phase 1	1992	GSM Features
Phase 2	1995	GSM Features, EFR Codec,
Release 96	1997 Q1	GSM Features, 14.4 kbit/s User Data Rate,
Release 97	1998 Q1	GSM Features, GPRS
Release 98	1999 Q1	GSM Features, AMR, EDGE, GPRS for PCS1900
Release 99	2000 Q1	Specified the first UMTS 3G networks, incorporating a CDMA air interface
Release 4	2001 Q2	Originally called the Release 2000 - added features including an all-IP Core Network
Release 5	2002 Q1	Introduced IMS and HSDPA
Release 6	2004 Q4	Integrated operation with Wireless LAN networks and adds HSUPA.

Release 7	2007 Q4	Focuses on decreasing latency, improvements to QoS and real-time applications such as VoIP. This specification also focus on HSPS (High Speed Packet Access Evolution), EDGE Evolution.
Release 8	2008 Q4	First LTE release. All-IP Network (SAE). New OFDMA, and MIMO based radio interface, not backwards compatible with previous CDMA interfaces.
Release 9	2009 Q4	LTE/UMTS Interoperability.
Release 10	2011 Q1	LTE Advanced fulfilling IMT Advanced 4G requirements. Backwards compatible with release 8 (LTE). Multi-Cell HSDPA (4 carriers).

Release 11

2012 Q3

Advanced IP Interconnection of Services. Service layer interconnection between national operators/carriers as well as third party application providers. Heterogeneous networks (HetNet) improvements, Coordinated Multi-Point operation (CoMP). In-device Co-existence (IDC).

Release 12

2015 Q1

Enhanced Small Cells (higher order modulation, dual connectivity, cell discovery, self configuration), Carrier Aggregation (2 uplink carriers, 3 downlink carriers, FDD/TDD carrier aggregation), MIMO (3D channel modeling, elevation beamforming, massive MIMO), New and Enhanced Services (cost and range of MTC, D2D communication, eMBMS enhancements).

Release 13

March 2016

LTE in unlicensed, LTE enhancements for Machine-Type Communication. Elevation Beamforming / Full-Dimension MIMO, Indoor positioning.

Release 14 Sept. 2017

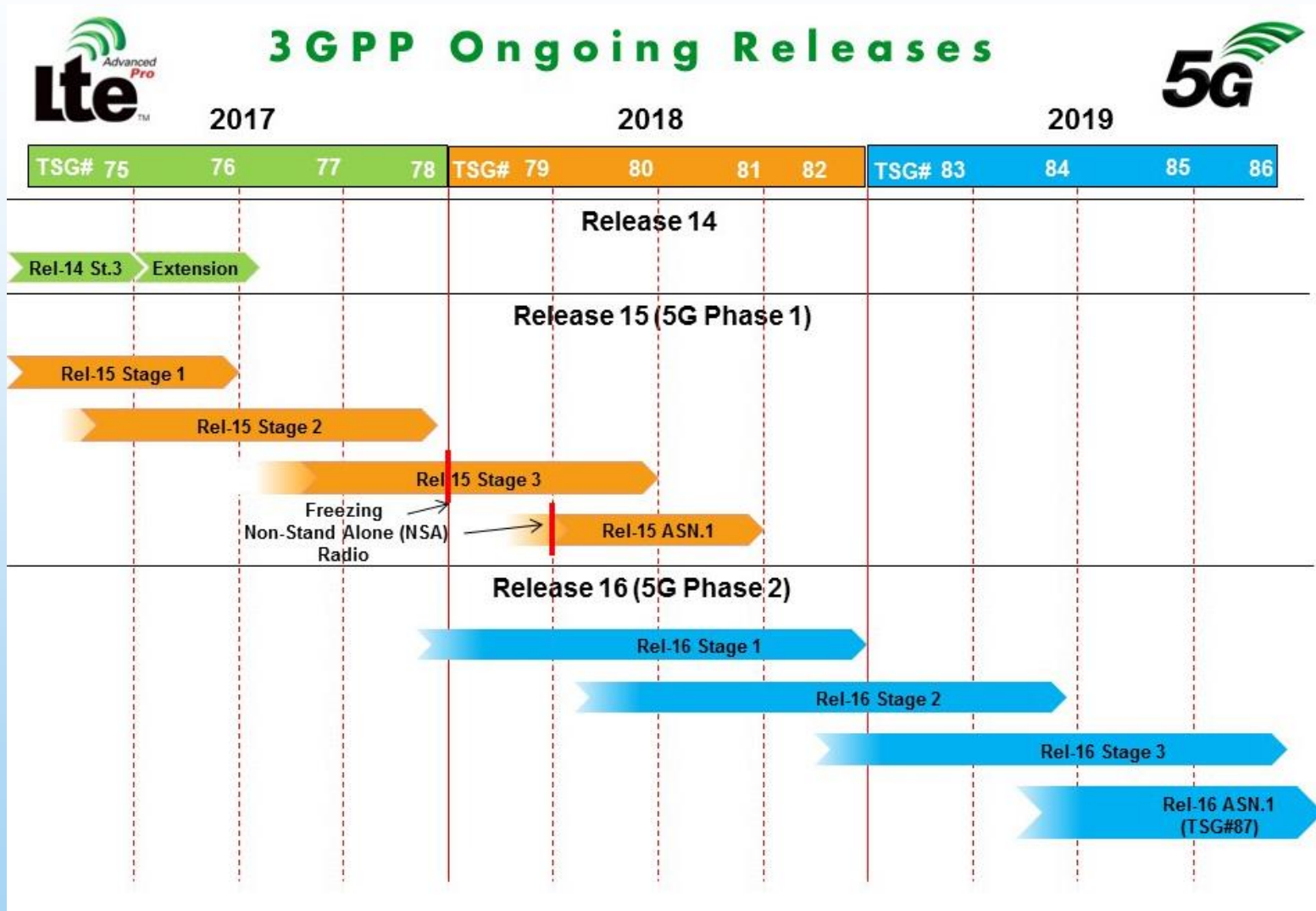
5G requirements, Multimedia Broadcast Supplement for Public Warning System, Location services, Mission Critical Video over LTE, Enhancement for TV Video service, Latency reduction techniques for LTE, Channel model above 6 GHz, Robust Call Setup for VoLTE subscriber in LTE, Requirements for Next Generation Access Technologies, Multi-Carrier Enhancements for UMTS.

Release 15 Sept. 2018

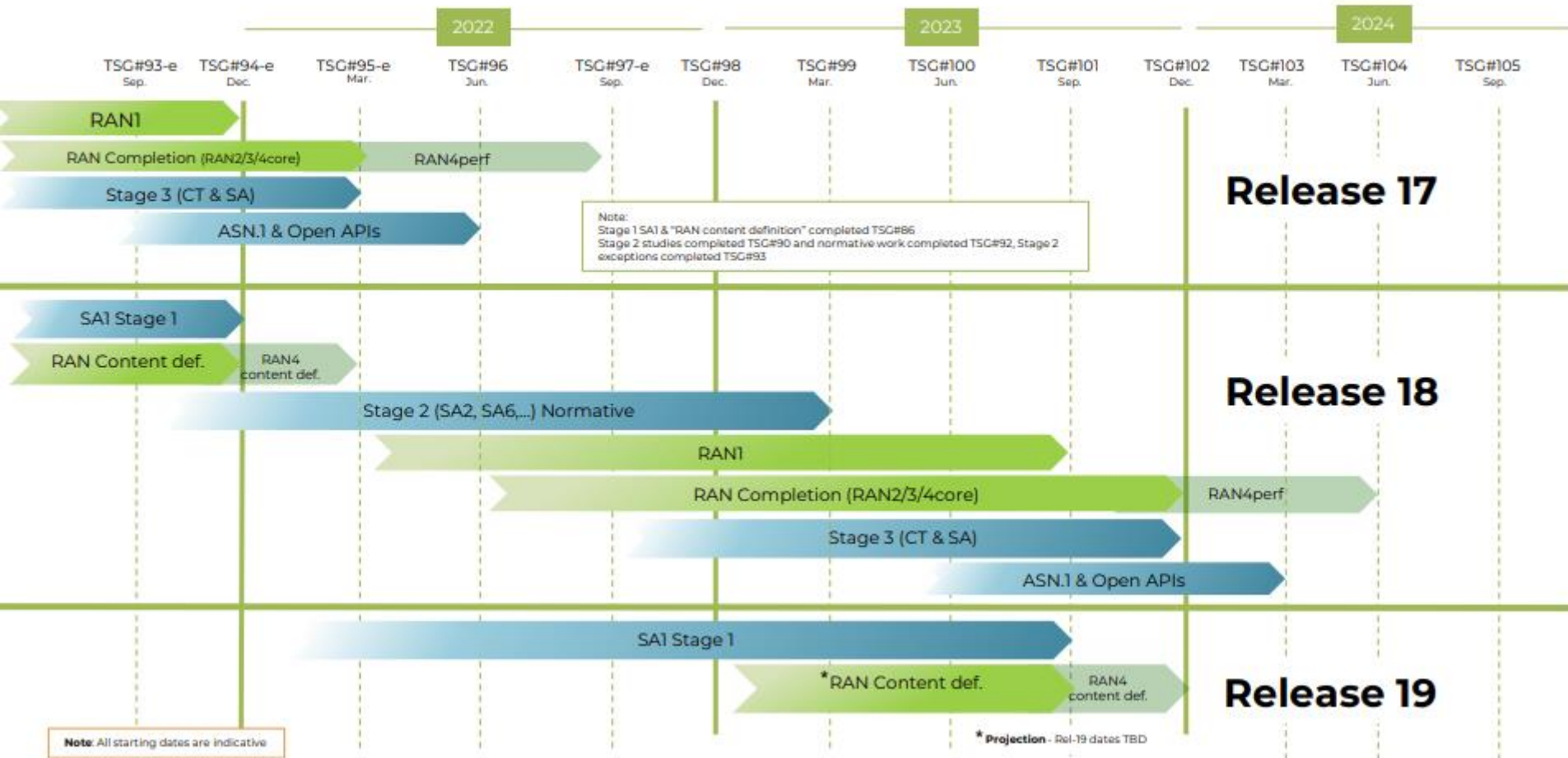
5G: Phase 1. First set of 5G standards - including new work as well as the maturing of the LTE-Advanced Pro specifications.

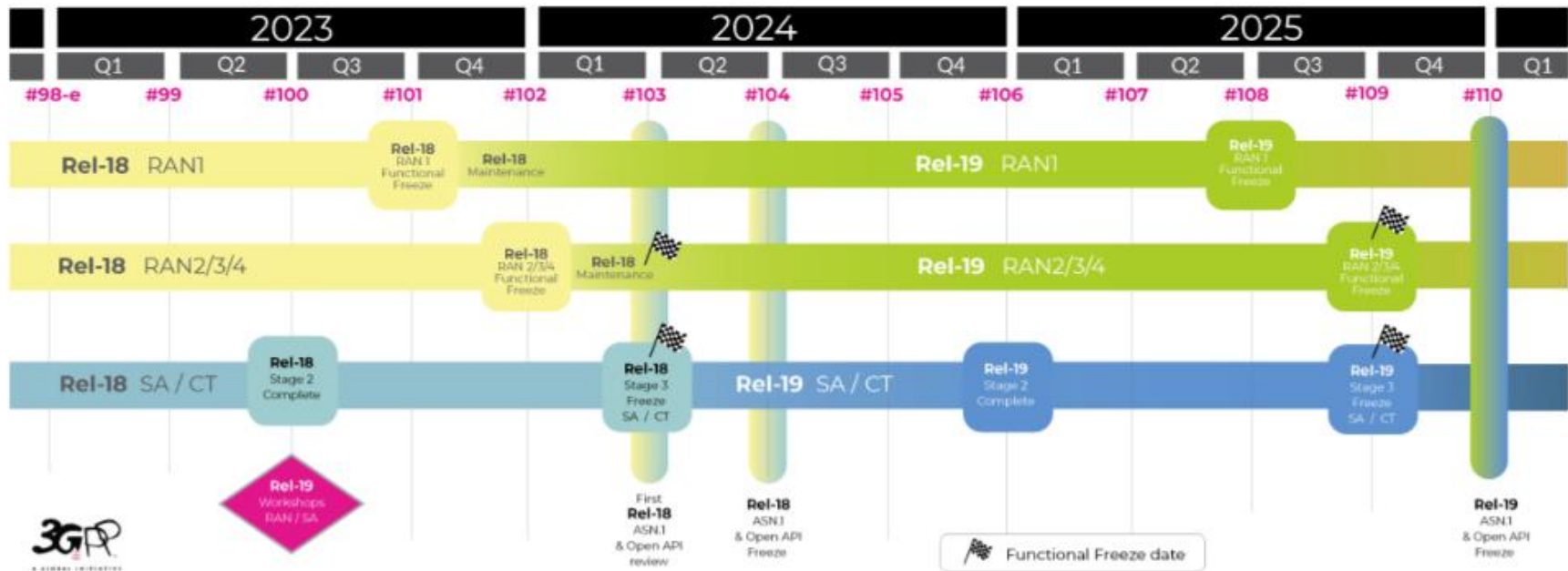
Release 16

5G: Phase 2.



Ongoing Release timelines (March 2022)





The data is extracted from the 3GPP portal at <https://portal.3gpp.org/>, select the "Releases" tab, which shows all of the Release dates (since 1987). Please refer to the Portal page for the most up-to-date information.



Release 17

- NR MIMO
- NR Sidelink enh.
- 52.6 - 71 GHz with existing waveform
- Dynamic Spectrum Sharing (DSS) enh.
- Industrial IoT / URLLC enh.
- IoT over Non Terrestrial Networks (NTN)
- NR over Non Terrestrial Networks (NTN)
- NR Positioning enh.
- Low complexity NR devices
- Power saving
- NR Coverage enh.
- NR eXtended Reality (XR)
- NB-IoT and LTE-MTC enh.
- 5G Multicast broadcast
- Multi-Radio DCCA enh.
- Multi SIM
- Integrated Access and Backhaul (IAB) enh.
- NR Sidelink relay
- RAN Slicing
- Enh. for small data
- SON / Minimization of drive tests (MDT) enh.
- NR Quality of Experience
- eNB architecture evolution, LTE C-plane / U-plane split
- Satellite components in the 5G architecture
- Non-Public Networks enh.
- Network Automation for 5G - phase 2
- Edge Computing in 5GC
- Proximity based Services in 5GS
- Network Slicing Phase 2
- Enh. V2x Services
- Advanced Interactive Services
- Access Traffic Steering, Switch and Splitting support in the 5G system architecture
- Unmanned Aerial Systems
- 5GC LoCation Services
- Multimedia Priority Service (MPS)
- 5G Wireless and Wireline Convergence
- 5G LAN-type services
- User Plane Function (UPF) enh. for control and 5G Service Based Architecture (SBA)

These are the Rel-17 headline features, prioritized during the December 2019 Plenaries (TSG#86)