Wireless Access Evolution
High-level 5G vision still valid

Non-limiting access to information and sharing of data ... 

... anywhere and anytime ...

... for anyone and anything
Evolved 5G and beyond

New use cases
- Manufacturing and industrial IoT
- Automotive and ITS
- XR (AR/VR/mixed reality/...)
- Fixed wireless access

Devices & Hardware
- Co-operative transmission / D2D
- Zero energy
- Zero cost

Radio access
- Higher frequencies
- Integrated access and backhaul
- New topologies and mesh

Networking
- Encryption compatible/collaborative optimizations
- Artificial Intelligence / Machine Learning
- Intelligent SON-oriented

Network Implementation
- Cloud based
- Service based
- AI
- Open source
- Network service mesh

Integrated connectivity and edge compute
- Zero-touch
- Trusted networking
Longer-term radio-access evolution

— Continued expansion into higher frequencies
— Flexible network topologies
— Device co-operation
— Technology components for massive IoT
— Cellular as a sensor
— Machine learning and artificial intelligence in the wireless-access network
Extension to higher frequencies

NR release 15 supports operation up to 52.6 GHz

Initially considering extension up to approximately 114 GHz

Assumption: Reuse current NR waveform with extended numerology
Extension to higher frequencies

Further extension beyond 100 GHz as part of longer-term radio-access evolution

Based on experience gained from first mmw NR deployments

Potential re-evaluation of basic air-interface design
Flexible network topologies

From a cell-focused topology towards a “best-path” topology under network control

— Multi-site connectivity
— Multi-hop
— Mobile relays
— ...

Diagram of flexible network topologies showing multi-site connectivity, multi-hop, and mobile relays.
Device co-operation

Turning devices into integrated components of the overall connectivity fabric

— Device-based relaying

— Co-operative transmission and reception
  — Turning multiple physical devices into a single virtual device with many antennas

— Especially for future IoT applications
Massive IoT in the 5G era

LTE based technologies will be the main technologies for massive IoT also in the 5G era
— Cat-M and NB-IoT

**Cat-M (“enhanced MTC”)**
— Extension of LTE introduced in Release 13
— Lower device complexity/cost by enabling devices with reduced bandwidth (20 MHz ⇔ 1.25 MHz)
— Enhanced coverage (+15 dB)
— Longer battery life due to enhanced DRX

**NarrowBand-IoT**
— Separate air-interface spectrum compatible with LTE
— 200 kHz bandwidth
— Stand-alone, inband, or guardband deployment
— Intended to replace GSM for mMTC applications

Potential technology areas for future mMTC evolution
— Industrial sensors (cost reduced devices with multi-Mbps data rates without coverage extension functions)
— Zero cost devices
— Zero energy devices.
“Zero-energy” devices

Devices operating on ambient energy only

— Non-radio-based energy source (e.g. solar-powered devices)
— Radio-based energy source (e.g. energy harvesting, backscattering)

Energy harvesting
— Device power extracted from RF wave
— Can be combined with backscattering

Backscattering
— Communication by changing properties of “reflected” wave
— “RF ID over a larger distance”

Example use cases: cargo tracking in a factory hall
Combined with “printables” for “zero-cost”
“Cellular as a sensor”

— Usage of radio signals to “sense” the surroundings

— Examples:

— Weather prediction using pathloss measurements (already demonstrated in practice using MiniLink)

— Local maps created based on signal reflections of mm-wave signals
Artificial Intelligence in Wireless Networks

Challenges for AI in wireless networks:

- Very large number of parameters to be optimized
- Reward-function design often complicated, e.g. number of handover failures minimized by not allowing users in bad radio coverage
- Limited support for data access and actuation

1. Machine learning in current networks
   - ML applied to RRM algorithms
   - Joint training of algorithms to ease integration

2. Enhancements for machine learning
   - Additional device measurements / information
   - Improved access to data (RAN/CN/OSS interfaces)
   - downloadable neural networks

3. AI-native Air Interface (AI-AI)
   - Enable the use of machine-learning algorithms in all parts of the system, potentially even adapting the basic waveform