creating the living network. *together*

EMPOWER: Beyond 5G Technology Roadmap

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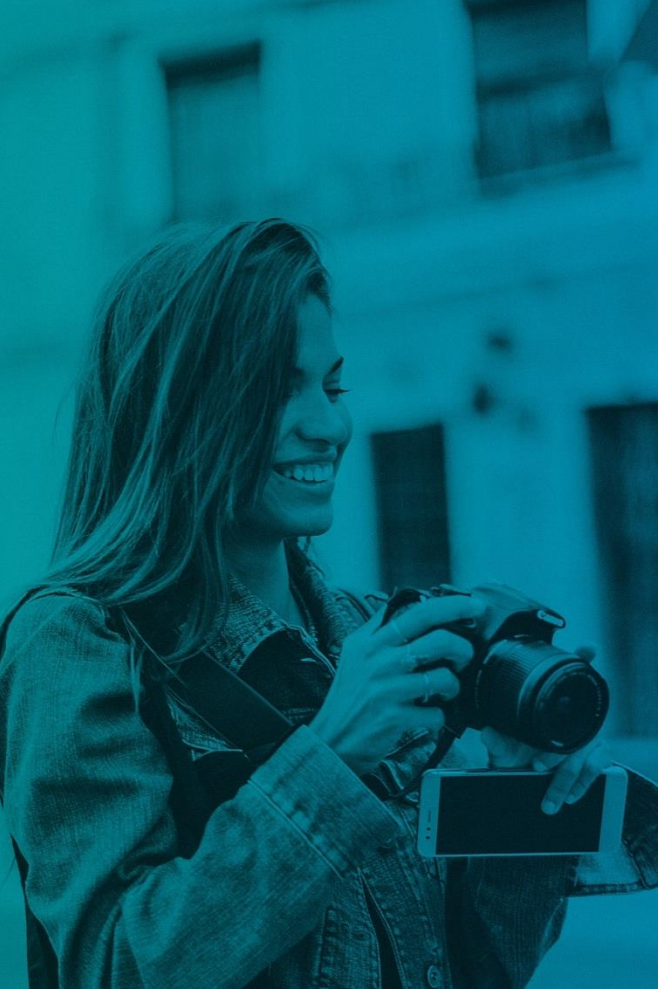


Outline

- Introduction to EMPOWER B5G Technology Roadmap
- Round-table session on B5G experimental challenges

EMPOWER Technology Roadmap Introduction

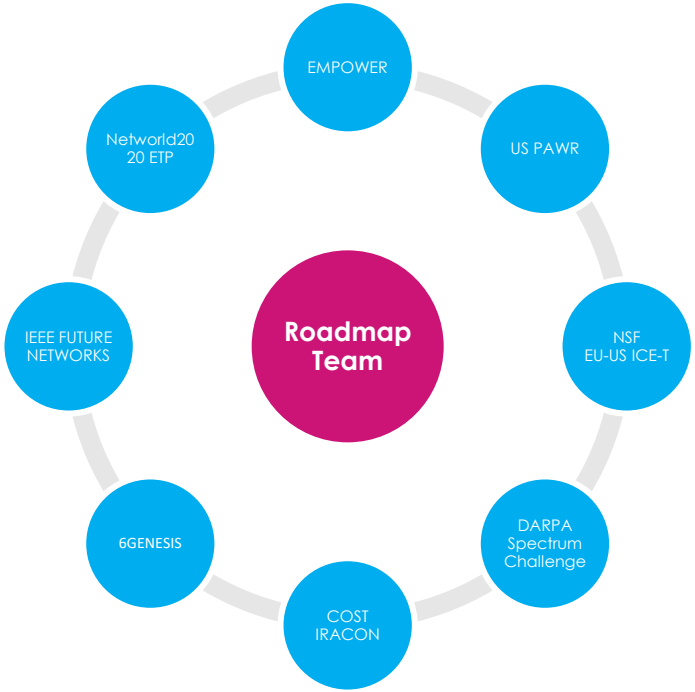
- Purpose is two-fold:
  1. Build a **common knowledge** for the EUUS wireless R&D communities on the future wireless research directions;
  2. To help define **areas of priority** for EUUS to co-work on ahead of worldwide competition for B5G standards
- The roadmap will have an **annual release**, in 2019, 2020, and 2021
- A **public consultation** will be carried out after each release and the results of the consultation will be announced at an annual workshop

- Roadmap **development methodology**:
  1. Identify roadmap team & agree need/use
  2. Define scope & boundaries for the technology roadmap
  3. Identify technology areas for roadmapping
  4. Determine critical system requirements (CSRs) for area of focus and define corresponding targets
  5. Specify major technical solutions pertinent to CSR targets and estimate corresponding maturity timelines
  6. Roadmap technologies towards targets
  7. Issue recommendations on areas of priority including analysis of risks

We are here! ☛

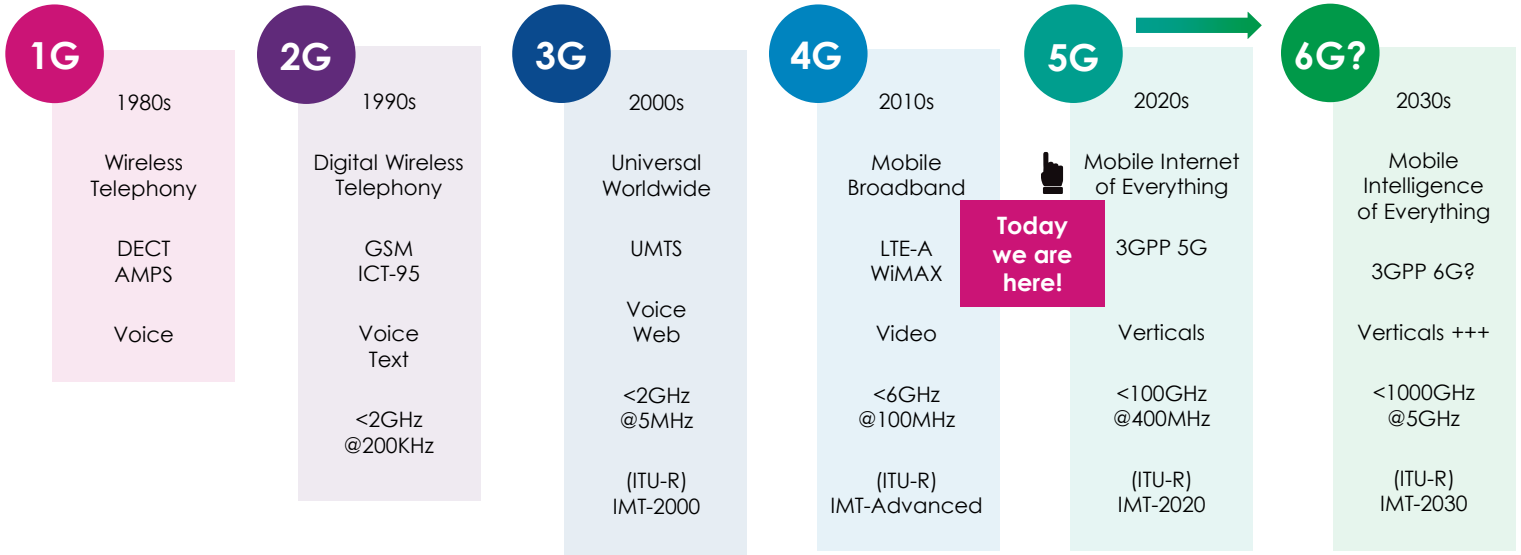
Step 1: Roadmap Team

- A team strong of a dozen experts is being assembled
- Experts involved in B5G roadmap activities in various programmes
  (e.g. PAWR, NSF, NetWorld2020, COST, 6GENESIS, IEEE Future Networks)
- Experts represent a good coverage of different B5G technology areas and from research, standards, and regulatory perspectives



Step 2: Roadmap Scope

- Scope is set on wireless technology advances that are pertinent to the **evolution of 5G over the next decade**



Step 3: Roadmap Technology Areas

1. **Circuits and devices** at nanometers level with node scaling targets of Power-Performance-Area-Cost (PPAC) breaking through the limits of Moore's Law
2. **Radio transceivers** supporting extreme requirements at Tbps data rates, sub-ms latency, and sub-mWatts power
3. **Radio system** expanding to integrate (un)licensed, (non)terrestrial, and (non)comms sub-systems, in a 3-D space with fluid topologies
4. **Network protocols** catering for the requirements of next generation internet including determinism, time-sensitivity, and automation
5. **Data** (small and big) driven E2E optimizations with pervasive collaborative **intelligence** distributed across terminals, edge, fog and cloud

Step 4: Critical System Requirements

- Enhanced Capabilities **beyond IMT2020** through
  i. New targets for existing KPIs; and ii. New and redefined KPIs

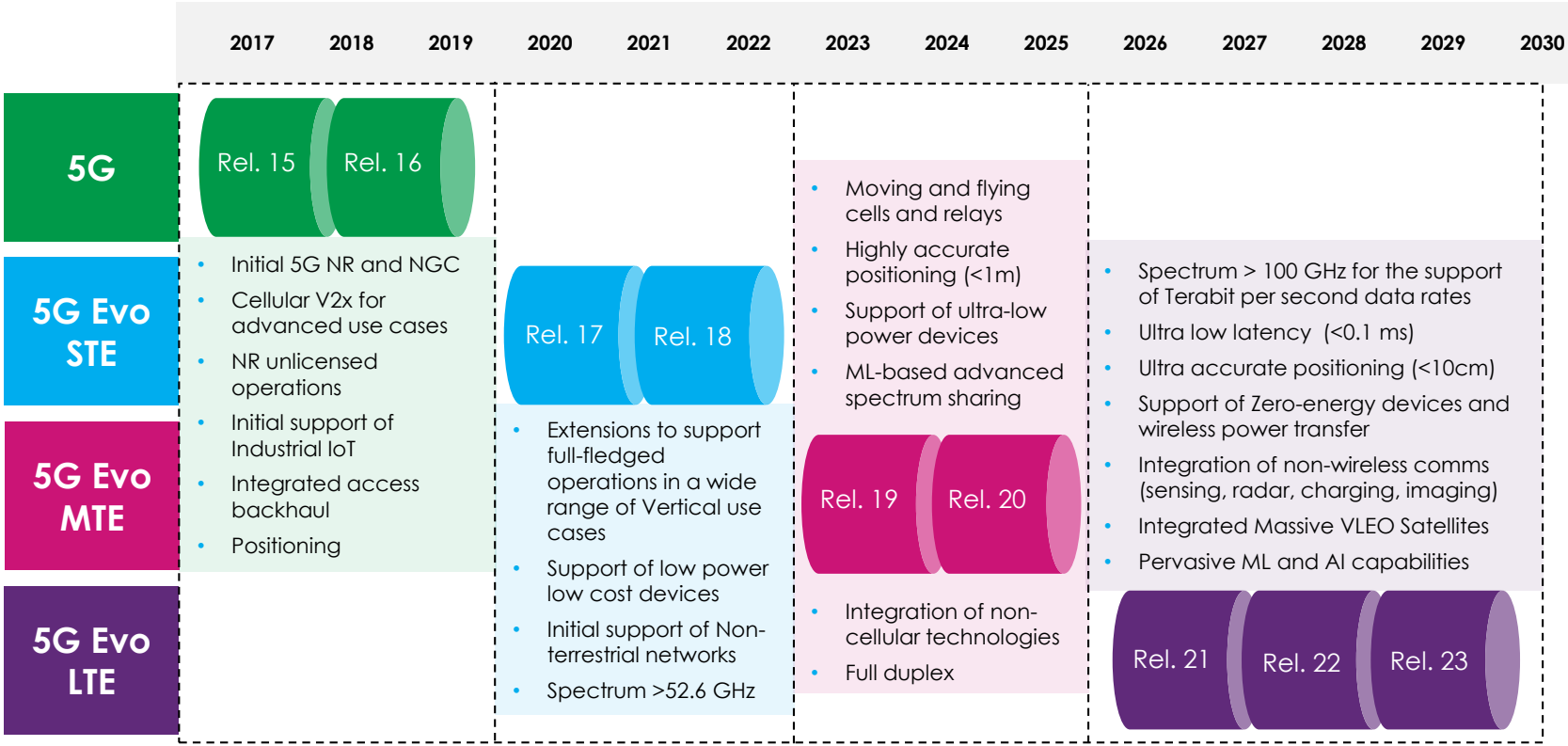
Capability/ CSR	2020-2022 (5G STE)	2022-2025 (5G MTE)	2025-2030 (5G LTE)
Spectrum / Bandwidth	<100 GHz @<1 GHz	<500 GHz @<5 GHz	<1000 GHz @<10 GHz
Peak Data Rate	(DL/UL) >50/25 Gbps	(DL/UL) >200/100 Gbps	(DL/UL) >1000/500 Gbps
User Data Rate	(DL/UL) >100/50 Mbps	(DL/UL) >400/200 Mbps	(DL/UL) >2/1 Gbps
Spectral Efficiency	(DL/UL) >30/15 bpsHz	(DL/UL) >50/25 bpsHz	(DL/UL) >100/50 bpsHz
Traffic Capacity	20 Mbps/sqm	100 Mbps/cum	1000 Mbps/cum
Density	>1 device/sqm	>5 device/cum	>10 device/cum
Reliability	>99.999%	>99.9999%	>99.99999%
U-Plane Latency	<1 ms	<0.5 ms	<0.1 ms
C-Plane Latency	<10 ms	<5 ms	<1 ms
Power (Terminal)	<100's mWatts	<10's mWatts	<1 mWatt
Positioning accuracy	<30 cm	<10 cm	<1 cm
Mobility	<500 Km/h	<1000 Km/h	<1000 Km/h

Step 5: Enabling Technical Solutions

- **Work in progress** to specify major technical solutions pertinent to the CSR targets and estimate corresponding maturity timelines

Technology Area	Evolution Trend	Reference Roadmap(s)
Circuit & Device	Nanometers level with node scaling targets of Power-Performance-Area-Cost (PPAC) breaking through the limits of Moore's Law	ITRS 2.0
Radio transceiver	RF frontend and baseband design to support extreme requirements (e.g. Tbps data rate, sub-ms latency, sub-mWatt power)	3GPP 5G NR Evolution WiFi 802.11 Evolution NFC 2.0 IEEE Future Networks Networld2020 SRIA
Radio system	Integrating licensed and unlicensed, terrestrial and non-terrestrial, comms and non-comms, in a volumetric space with fluid topologies	
Network	Protocols catering for the requirements of next generation internet including determinism, time-sensitivity, and automation	3GPP 5G Core Evolution IRTF RGs ITU-T NET2030 FG Networld2020 SRIA
Data & Intelligence	Data-driven E2E optimizations with pervasive collaborative intelligence distributed across terminals, edge, fog and cloud	ITU-T ML5G FG ETSI ENI ISG

Reference Example – 3GPP 5G NR Evolution



Steps 6-7: Roadmap & Recommendations

- **Step 6:** Roadmap technologies towards targets
- **Step 7:** Issue recommendations on areas of priority including analysis of risks

Round-Table Session: B5G Experimental Challenges

- **Q1: Data-driven design – How to leverage Open Source towards Open Data?**
- **Q2: Convergence multiplying – How to cope with the resultant complexity?**
- **Q3: Regulatory framework extending – How to speed up and ease experimental regulatory licenses?**
- **Q4: Extreme KPIs – What new experimental approaches and tools may be needed?**

Questions – B5G Experimental Challenges

- **DATA:** B5G is envisioned as data-driven and ML/AI-powered – DATA (Big or small) is therefore key to B5G research, and such DATA depends on the experimental/commercial setup used
  - **Q1: From Open Source to Open Data: Riding the current tide of open-source platforms to enable open-data? What is being done today in support of open data and what is still missing? Examples: H2020 ICT-17 E2E 5G facilities and associated ICT-19 projects, US PAWR platforms, forums like O-RAN, etc.**
- **COMPLEXITY:** B5G is set to accelerate convergence between terrestrial licensed and unlicensed, terrestrial and non-terrestrial, communications and non-communications (e.g. sensing, radar)
  - **Q2: Experimentation complexity exploding in all dimensions of convergence – Is it time to rethink our conventional experimentation methodology (simulation, emulation, trial)? Which tools and skillsets are needed to enable meaningful and feasible experimtation with such complexity?**

Questions – B5G Experimental Challenges

- **REGULATORY:** Flying/Moving cells and terminals, in addition to metamaterials-based surfaces, are all envisioned in B5G, in addition to a wide variety of sensors including cameras and radars
  - **Q3: From as little as an experimental frequency license to a whole set of regulatory licenses – How long and how complicated would it be to obtain and comply with all the necessary licenses? What is being done to speed up and ease/simplify the future experimental regulatory framework?**
- **EXTREME KPIs:** B5G is envisioned to include disruptive transceivers achieving extreme KPIs such as Tbps throughput, sub-ms latency, sub-mWatt energy, cm-level positioning accuracy, etc.
  - **Q4: Are these KPIs measurable in today's experimental platforms? Which approaches and tools may be needed to support experimentation with and validation of these extreme KPIs?**

Thank You

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