CREATE
CONNECT
LIVE
inspire

The Path to 6G: Performance Targets and Technology Enablers

Dr Alain Mourad
6G Summit, Levi, 17-20 March 2020

interdigital™

Outline

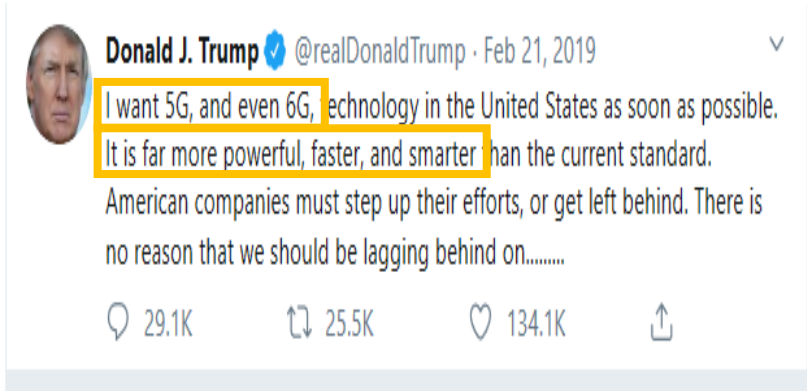
- **6G: The Why, What and How?**
  - Why do we need 6G?
  - What performances shall we target?
  - How do we get there?
- **Insights from EMPOWER B5G Roadmap Consultation**
  - KPIs Evolution
  - Technology Trends
- **Take-aways**

6G: The Why, What and How?

interdigital

6G: The Why (1/2)

- **Political view: Far more powerful, faster, and smarter**
  - Many governments already launched 6G research agendas (e.g. EU, USA, Japan, China, South Korea).



- **Societal view: Greener, smarter and sustainable**
  - United Nations (UN) already announced 17 global sustainable development goals towards 2030.

Source: UN in collaboration with Project Everyone

6G: The Why (2/2)

- **Economical view: Growth through smarter all-digital economy**
  - Digital transformation agendas including Artificial Intelligence (AI) underpin growth strategies in various sectors of the economy.

- **Technological view: Innovation continues to always do better and smarter**
  - This isn't to say that 5G is broken and we need to fix it. This is rather the engineering instinct to create, innovate and continuously advance the state of art.

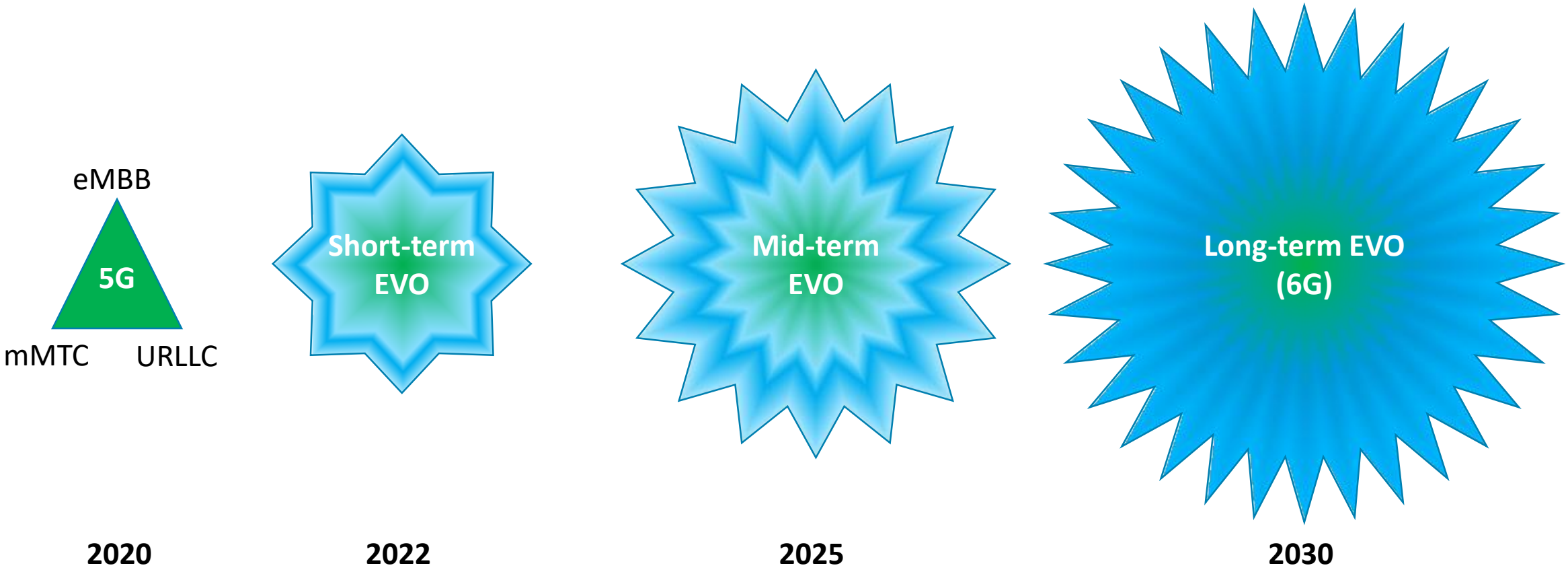
6G Vision

A Smarter Generation fusing Wireless and AI in support of 2030's Global Societal and Economical Goals

The generation with a sixth sense!

Towards 6G – Use Cases (1/2)

A constant **expansion** of the **USER and VERTICAL** use cases towards a **blend of extreme** requirements

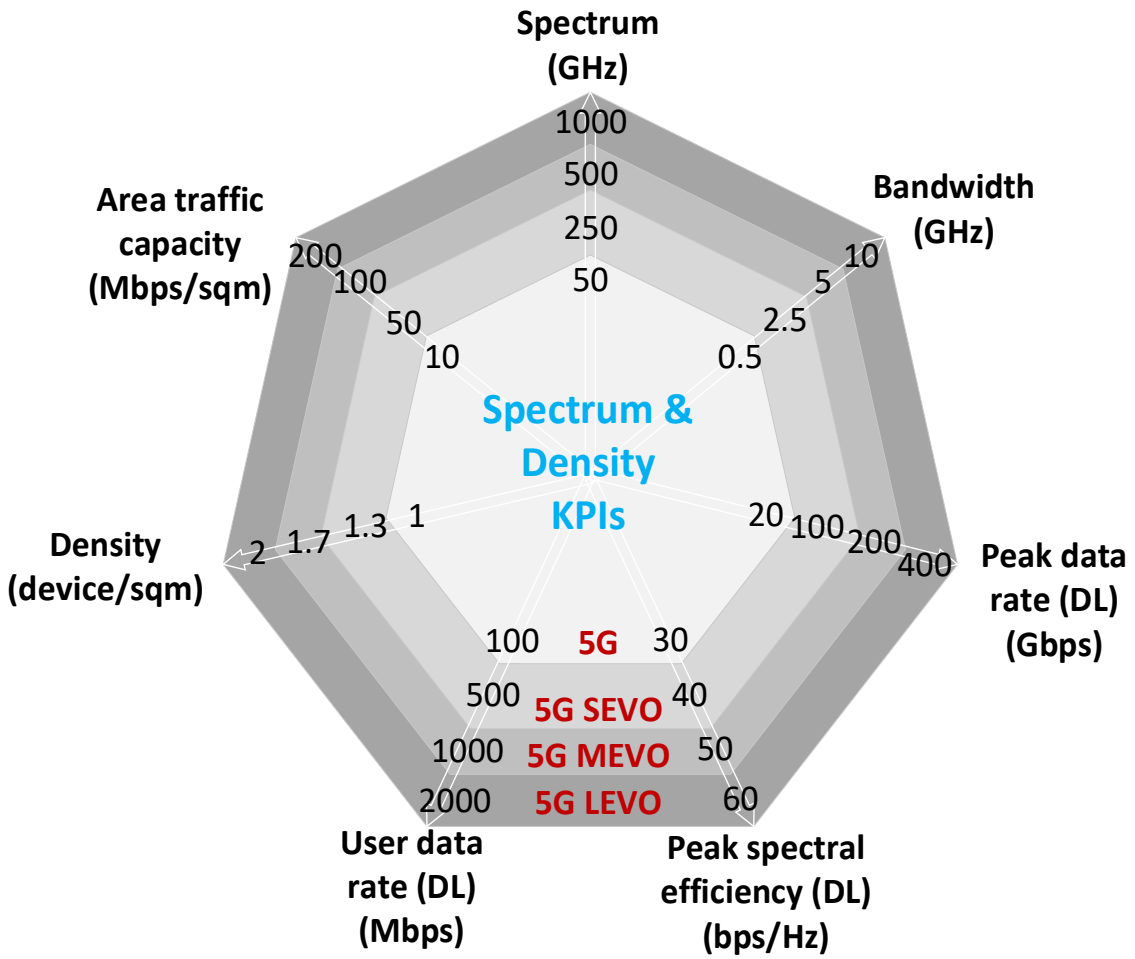


Towards 6G – Use Cases (2/2)

1. Volumetric media streaming
2. Multi-sensory extended reality and haptics
3. Connected industries and automation
4. Autonomous vehicles and swarm systems
5. Aerial and satellite networks and platforms

Towards 6G – Key Requirements (1/2)

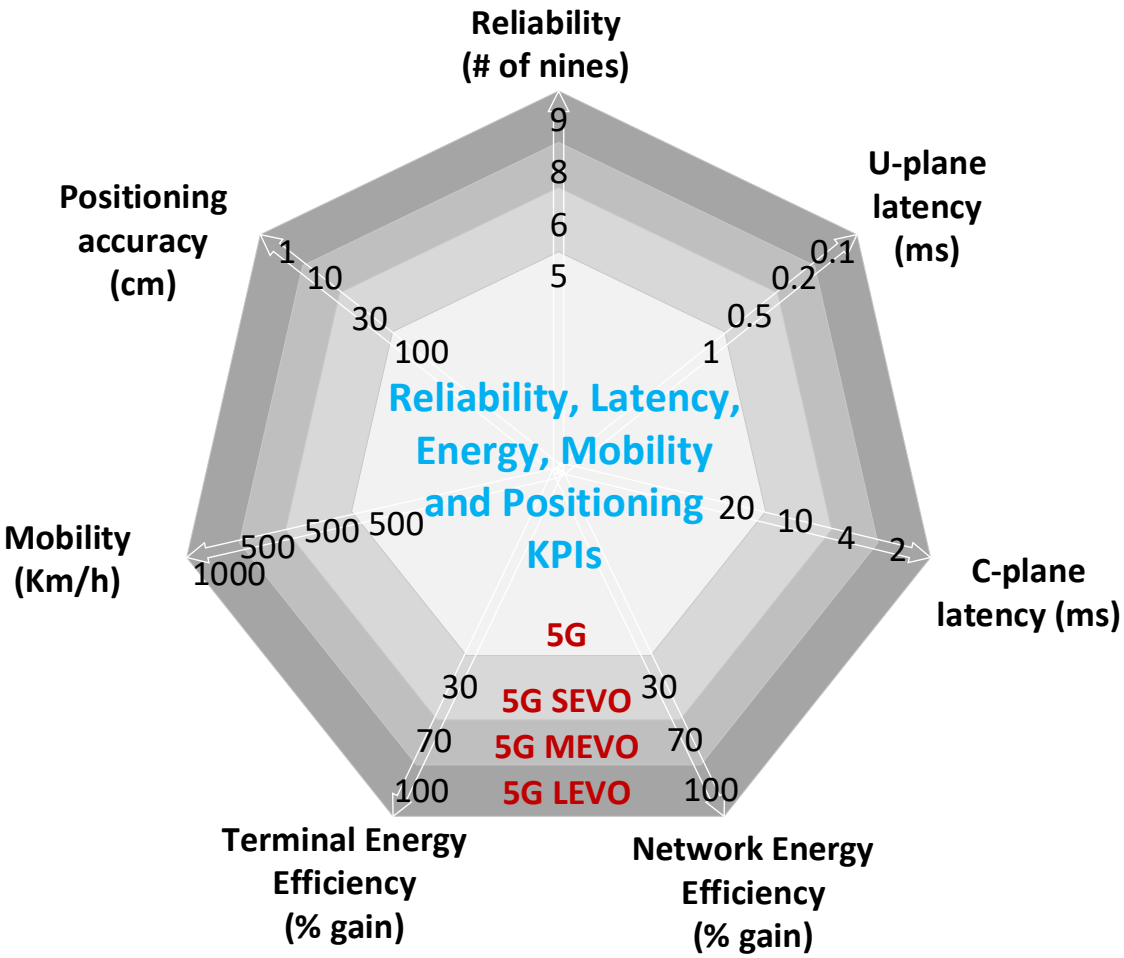
- **Spectrum** with **leap jumps above 100 GHz** all the way up to THz
- **Bandwidth** expansion from 500 MHz today **up to 10 GHz**
- **Peak data rate** moving to a few **100s of Gbps**
- **User data rate** scaling up to a **few Gbps**
- **Connections density** doubling to **2 devices per sqm**



[Source: EMPOWER – www.advancedwireless.eu]

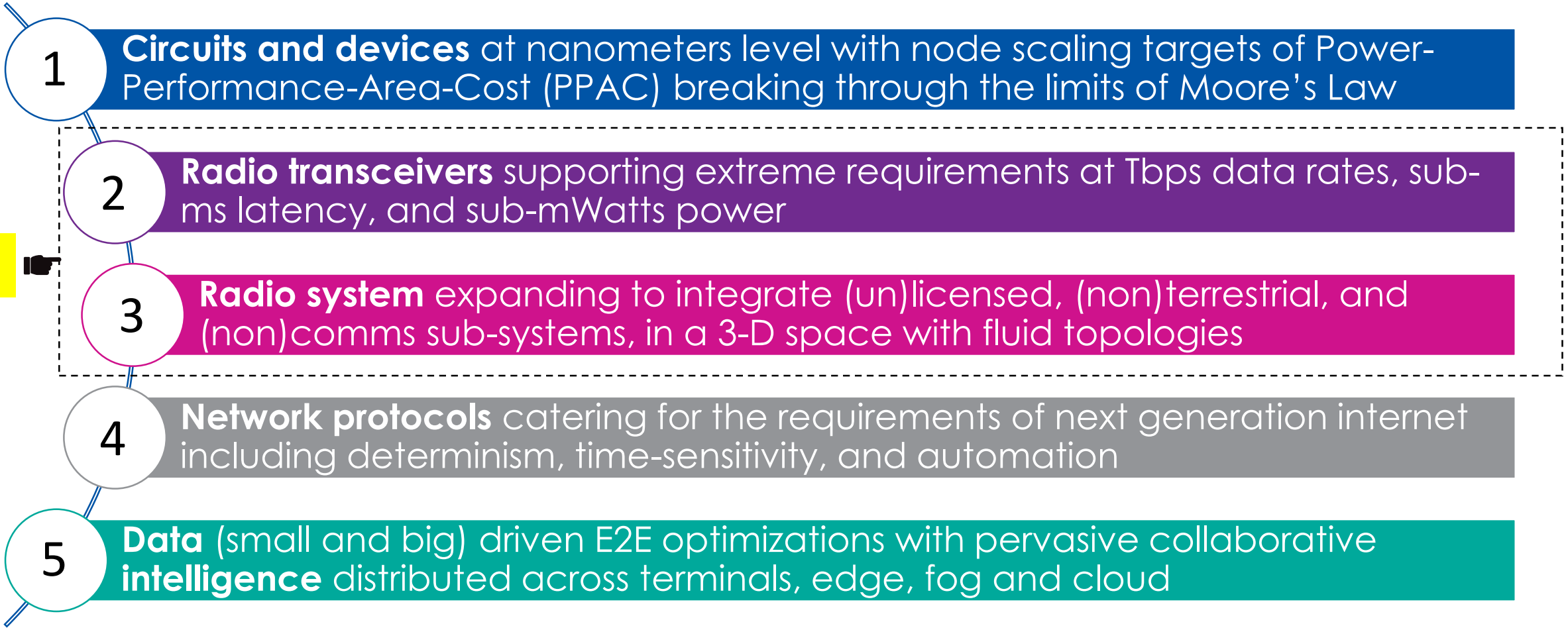
Towards 6G – Key Requirements (2/2)

- **Reliability** gradually increasing to reach highs of **up to 9 nines**
- **U-plane latency** down to a **fraction of millisecond**
- **Energy efficiency** (both network and terminal) improving towards **100% gains vs 5G today**
- **Positioning** accuracy to **few cms**
- **Mobility** up to **1000 km/h**



[Source: EMPOWER – www.advancedwireless.eu]

Towards 6G – Technology Trends



Towards 6G – Enabling Technology (1/3)

SEVO: Short-Term Evolution	MEVO: Medium-Term Evolution	LEVO: Long-Term Evolution
SEVO Transceivers at frequencies up to 250GHz	MEVO Transceivers at frequencies up to 500GHz	LEVO Transceivers at frequencies up to 1THz
SEVO Massive MIMO with arrays of 256 elements	MEVO Massive MIMO with arrays of 512 elements	LEVO Massive MIMO with arrays of 1024 elements
SEVO Multi-RATs integration across licensed and unlicensed spectrum	MEVO Energy efficient waveforms and modulations for low and high spectrum	LEVO Cognitive Multi-WATs access across cellular and non-cellular (WiFi/LiFi)

Towards 6G – Enabling Technology (2/3)

SEVO: Extended support of NR-light (mid-range) devices	MEVO: Support of UAVs/drones as UEs, gNBs, and relays	LEVO: Support of intelligent swarms of heterogeneous devices
SEVO: Support of Non-Terrestrial Networks	MEVO: Integration of Terrestrial and Non-Terrestrial Networks	LEVO: Support of Massive VLEO satellites and HAPs
SEVO: Device and network power savings enhancements	MEVO: Ultra-low energy devices supporting energy harvesting	LEVO: Battery-less devices and nodes supporting wireless power transfer

Towards 6G – Enabling Technology (3/3)

SEVO: Communication-based positioning accuracy <30 cm	MEVO: Joint sensing and communication including position accuracy <10 cm	LEVO: Integrated sensing and communication including position accuracy <1 cm
SEVO: Data Collection from the core, RAN and UE to enable fusion with AI/ML	MEVO: Wireless Fusion with AI/ML limited to C-plane and higher layers in the U-plane	LEVO: Wireless Fusion with AI/ML in every plane and every layer including PHY

Insights from EMPOWER B5G Roadmap Consultation

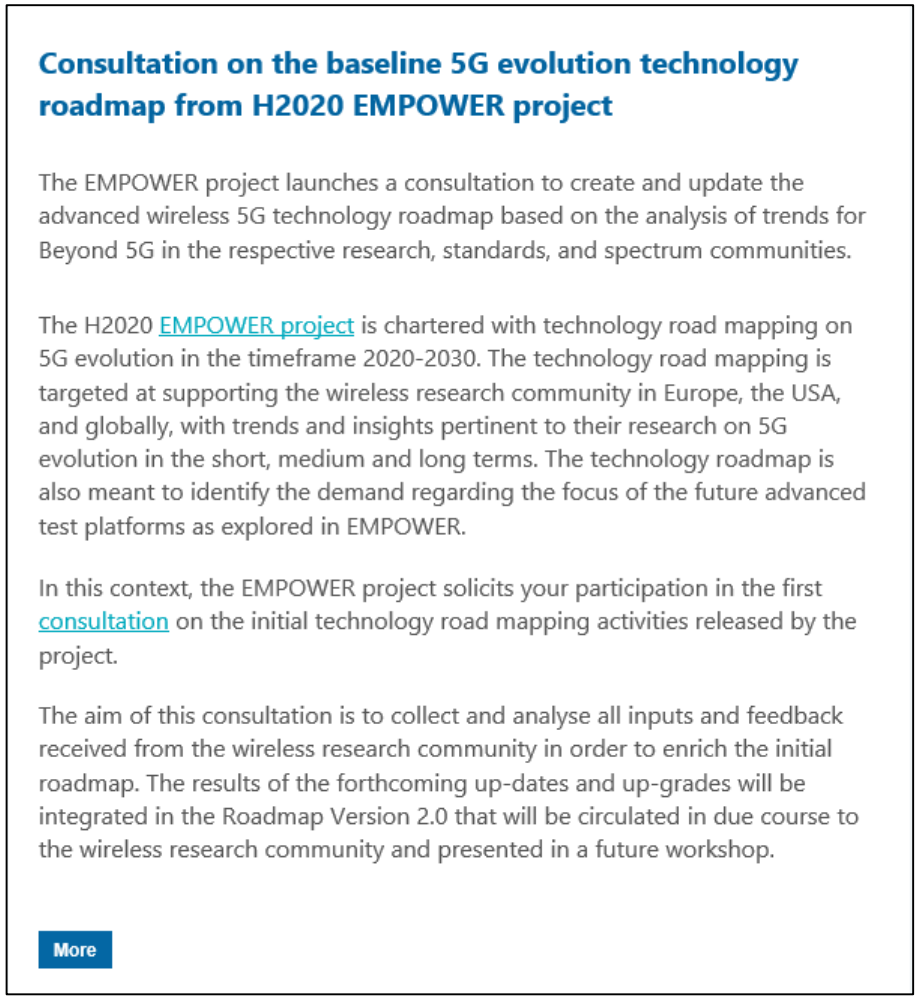
interdigital

H2020 EMPOWER B5G Roadmap Consultation

- Public consultation on 5G evolution towards 6G open **from 03 Feb. 2020 until 20 Mar. 2020**
- Targets gathering the wireless research community feedback towards a **B5G roadmap** including:
  - KPIs evolution
  - Technology trends
  - Experimental challenges

Have your say, it is still open for more responses!

https://www.advancedwireless.eu/index.php/participate-at-the-empower-roadmap-consultation/



Consultation on the baseline 5G evolution technology roadmap from H2020 EMPOWER project

The EMPOWER project launches a consultation to create and update the advanced wireless 5G technology roadmap based on the analysis of trends for Beyond 5G in the respective research, standards, and spectrum communities.

The H2020 EMPOWER project is chartered with technology road mapping on 5G evolution in the timeframe 2020-2030. The technology road mapping is targeted at supporting the wireless research community in Europe, the USA, and globally, with trends and insights pertinent to their research on 5G evolution in the short, medium and long terms. The technology roadmap is also meant to identify the demand regarding the focus of the future advanced test platforms as explored in EMPOWER.

In this context, the EMPOWER project solicits your participation in the first consultation on the initial technology road mapping activities released by the project.

The aim of this consultation is to collect and analyse all inputs and feedback received from the wireless research community in order to enrich the initial roadmap. The results of the forthcoming up-dates and up-grades will be integrated in the Roadmap Version 2.0 that will be circulated in due course to the wireless research community and presented in a future workshop.

More

Demographic of the Respondents so far

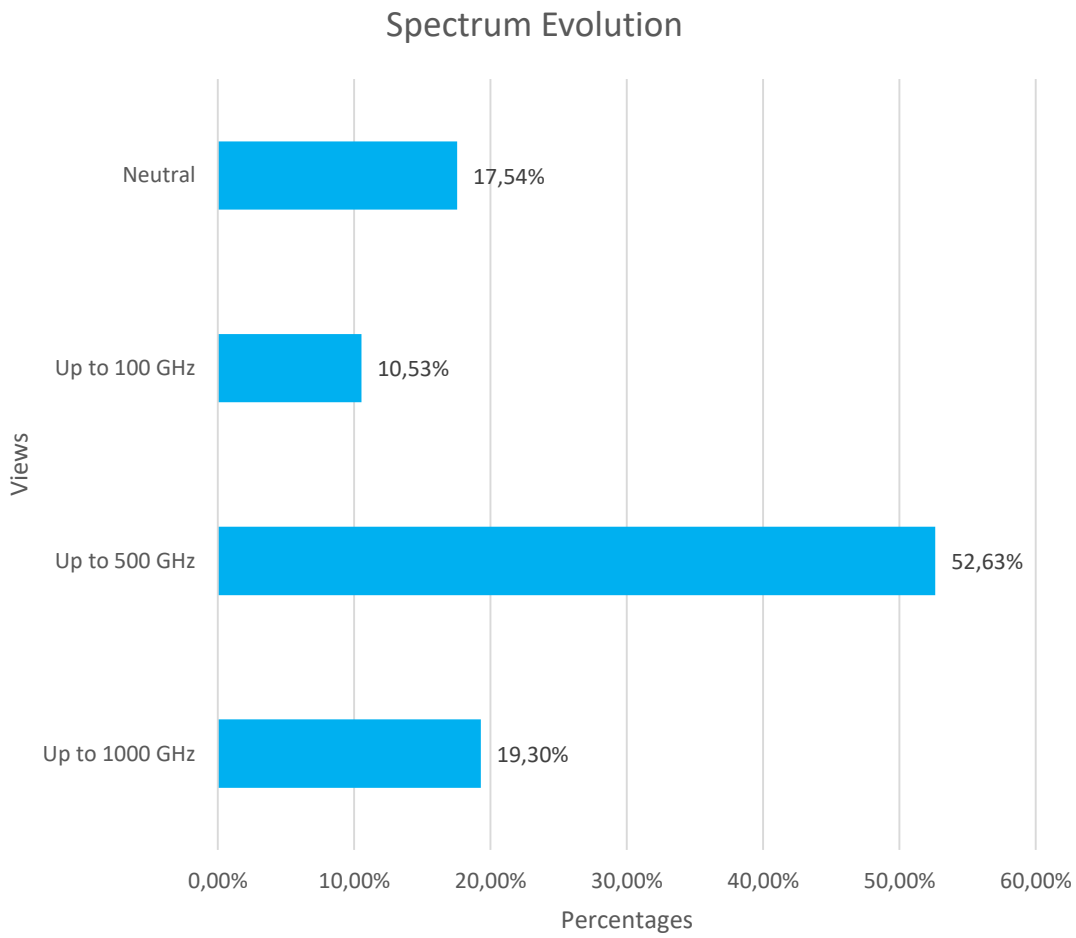
- So far, the consultation collected some **60+ views from experts in the Industry and in Academic Research**
- Respondents have the choice to either **stay anonymous** or **share their affiliations**
- **Nearly half of the respondents** (34) have chosen to **share their names and affiliations**
  - A good mixture of Industry(14 respondents) and Academic research (20 respondents)
  - A good geographic distribution from Europe, UK, Norway, USA, Canada, China, Taiwan
- Extrapolating to all respondents, a **good mixture of stakeholders (≈ 40% Industry – 60% Academia)** and **geographic distribution** across **Europe, North America, and South East Asia**

Insights on KPIs Evolution

interdigital

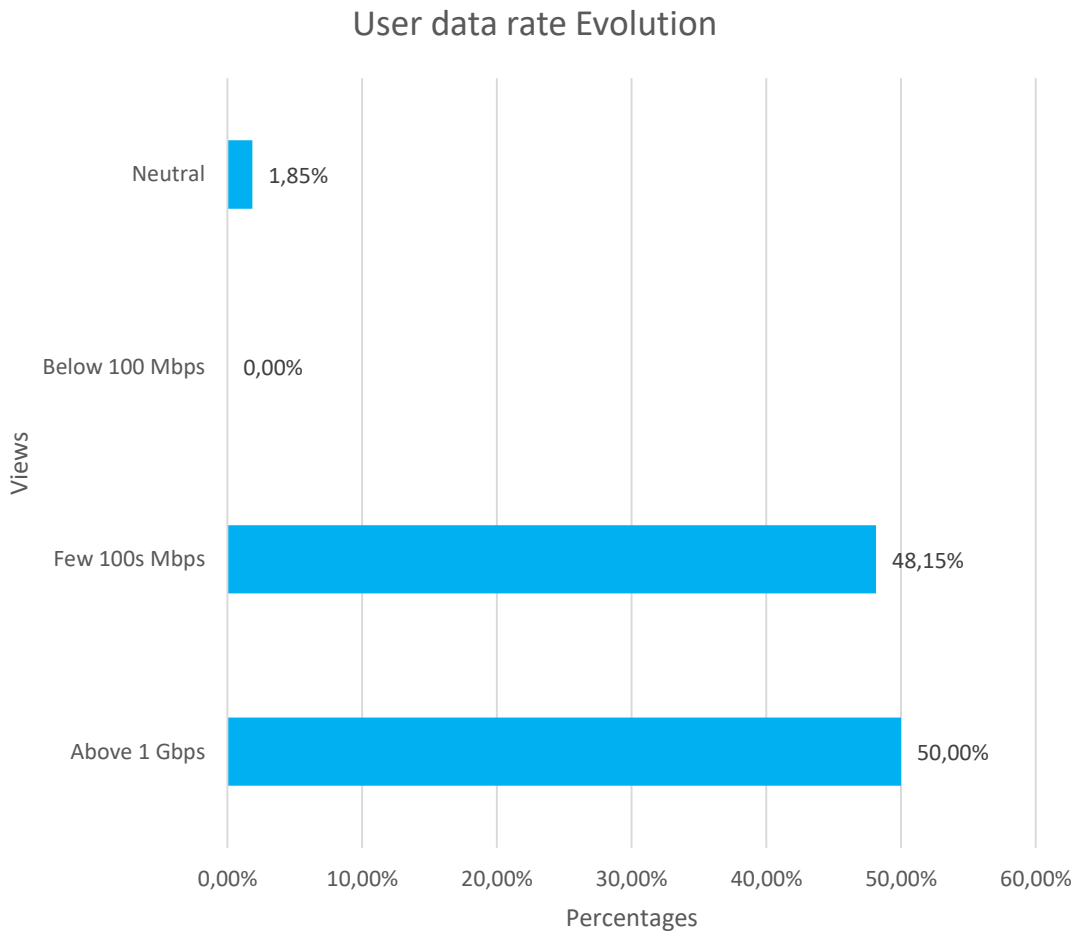
Insights – Spectrum

- **Spectrum** will evolve over the next 10 years to reach THz frequencies?
  - Majority (53%) think we will break the cap of 100 GHz and evolve **up to the limit of 500 GHz**
  - Going above 500 GHz has a limited support (<20%)
  - A minority (10%) think we will not break the bar of 100 GHz



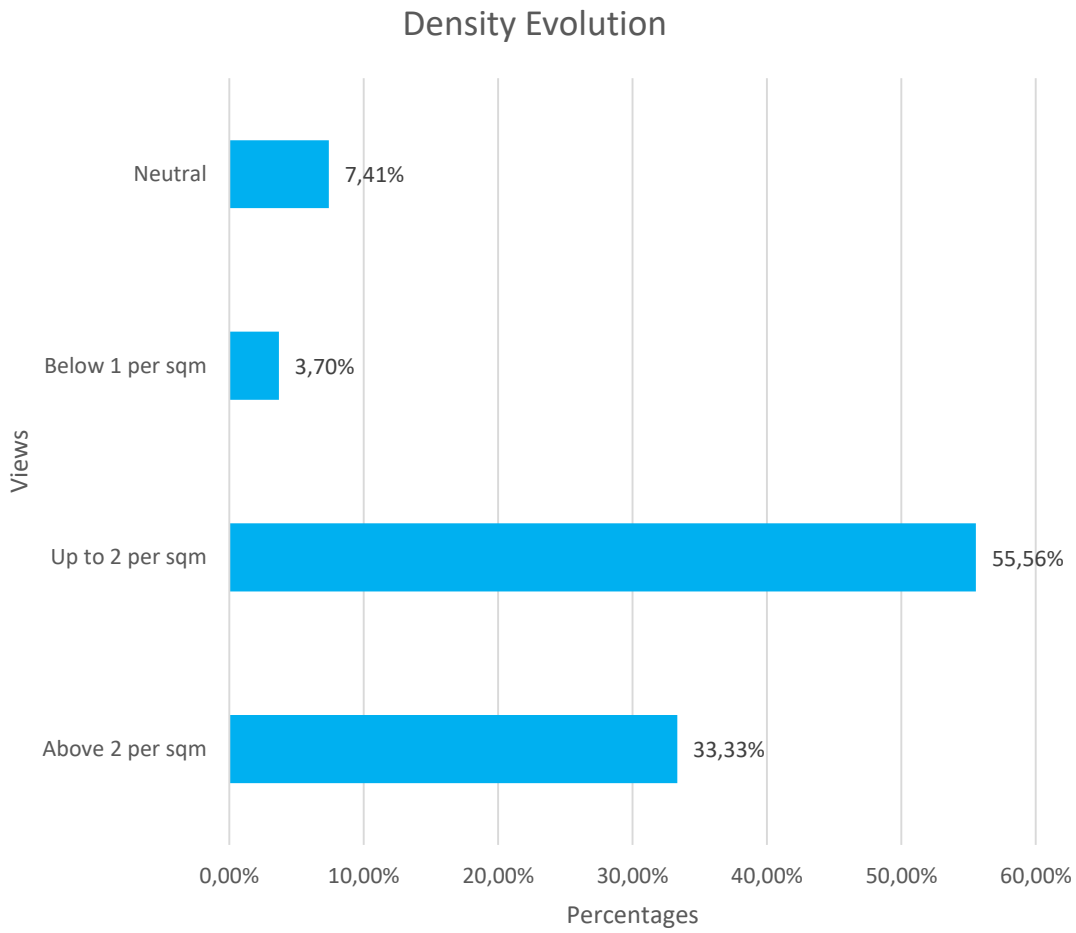
Insights – User Data Rate

- **User data rate** will evolve over the next 10 years to reach a few Gbps in downlink and uplink?
  - 98% of responses think the user data rate will range from **few 100s Mbps (48%) to a few Gbps (50%)**
  - No one think it will stay below 100 Mbps as in 5G today



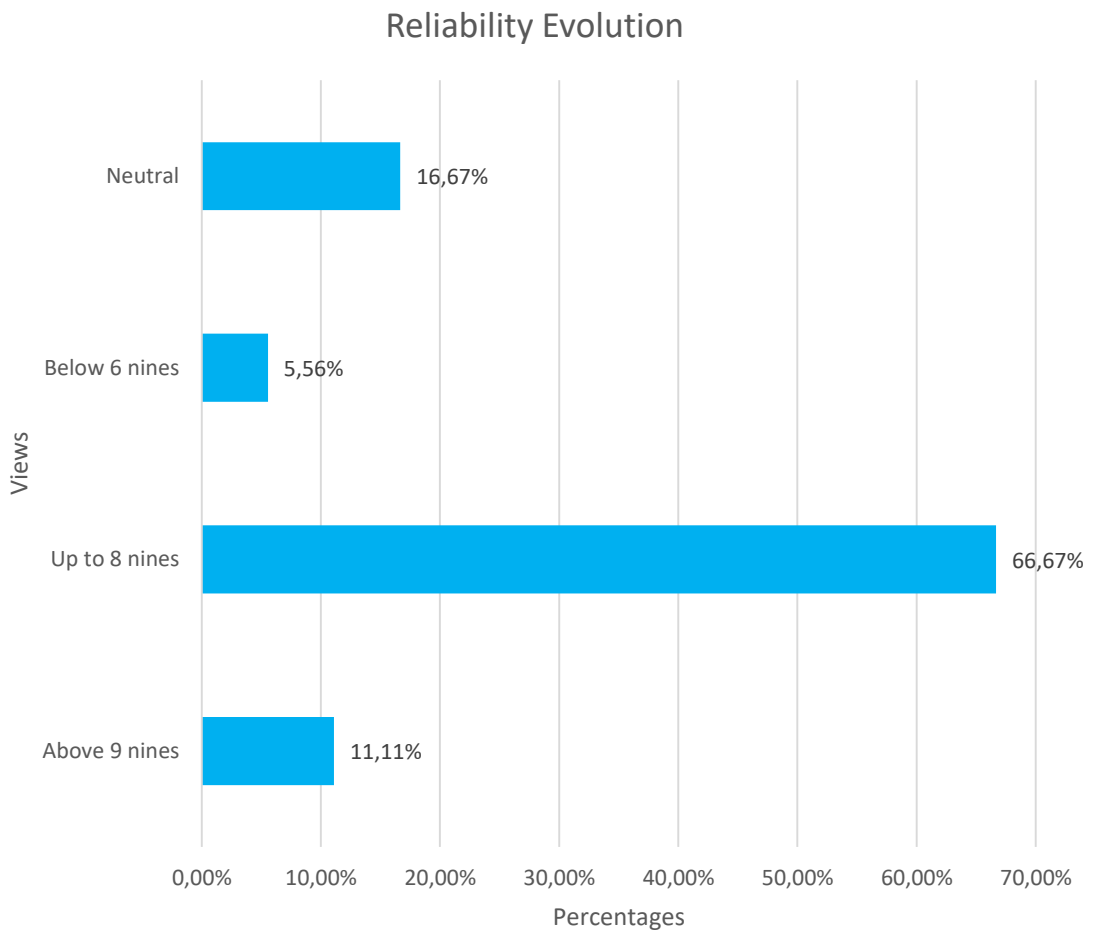
Insights – Density

- **Density** will evolve over the next 10 years to reach above 2 million devices per km2 (= 2 devices per sqm)?
  - Majority (56%) think it will reach **way above 2 devices per sqm**
  - A third (33%) think it will evolve but to less than 2 devices per sqm
  - Almost no one think it will stay below 1 device per sqm (5G target)



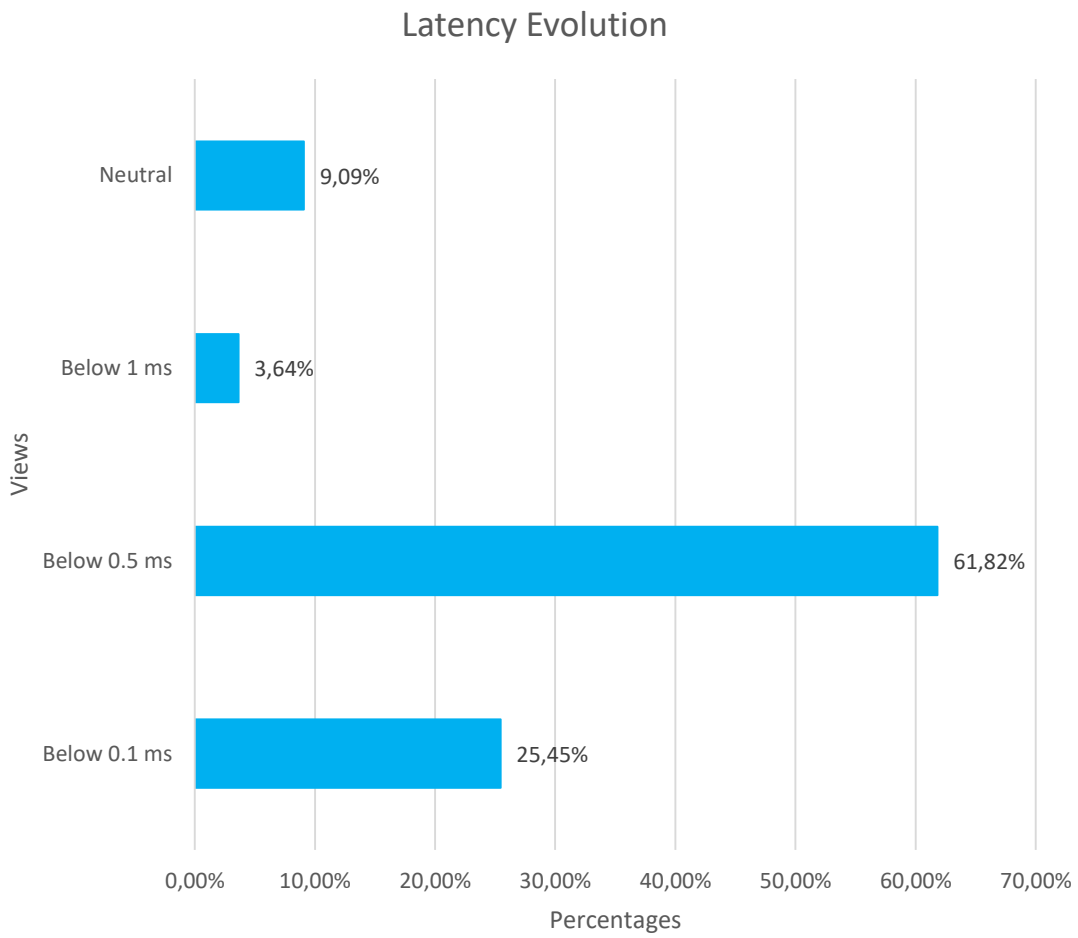
Insights – Reliability

- **Reliability** will evolve over the next 10 years to reach 9 nines?
  - Majority (67%) think reliability will improve **up to 8 nines**
  - A few (11%) think it might go as high as 9 nines
  - Very few think it will stay below 6 nines (like 5G today)



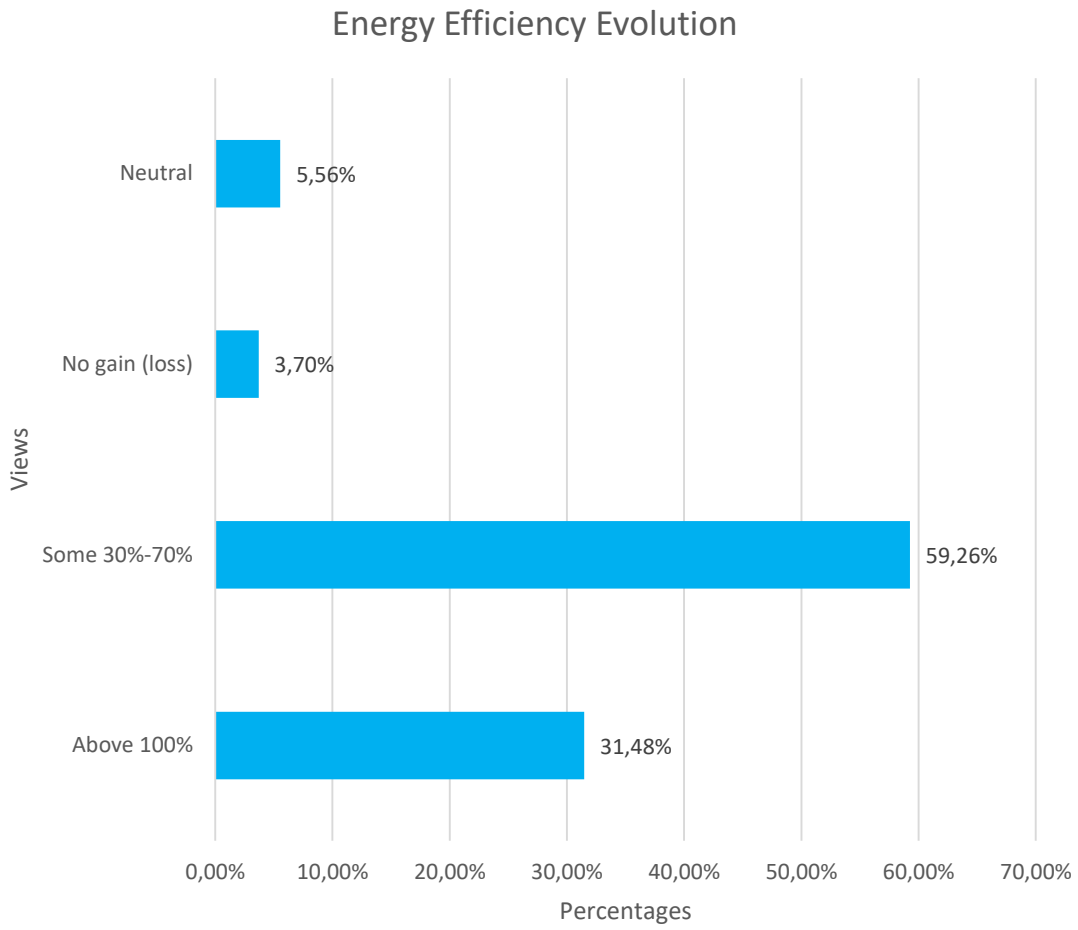
Insights – Latency

- **Latency** will evolve over the next 10 years to reach 0.1 ms in U-plane?
  - Majority (62%) think latency will need to go **below 0.5 ms**
  - A quarter (25%) think it might evolve to less than 0.1 ms
  - Almost no one think it will stay in the 1 ms (5G target)



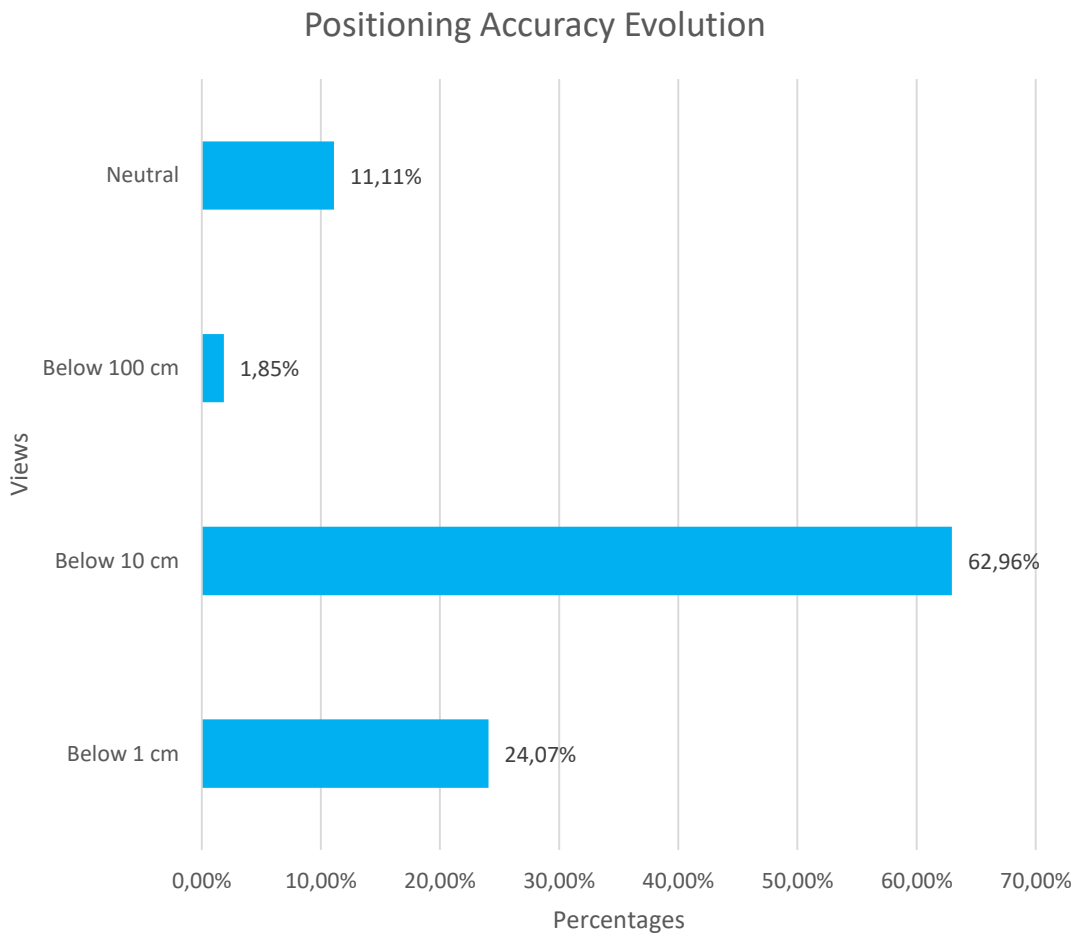
Insights – Energy Efficiency

- **Energy Efficiency** will evolve over the next 10 years and reach 100% improvements compared to today's figures both in the network and in the terminal?
  - Majority (91%) think it will improve compared to 5G with (60%) seeing gains from **30-70%** and (31%) **seeing gains above 100%**
  - Almost no one think it will stay or decrease vs 5G today



Insights – Positioning Accuracy

- **<u>Positioning Accuracy</u>** will evolve over the next 10 years to reach below 1 cm?
  - Majority (63%) think positioning accuracy will improve to **below 10 cm**
  - Nearly a quarter (24%) think it will go as low as below 1 cm
  - Almost no one think it will stay below 100 cm (5G target)



Insights – Target KPIs Refinement

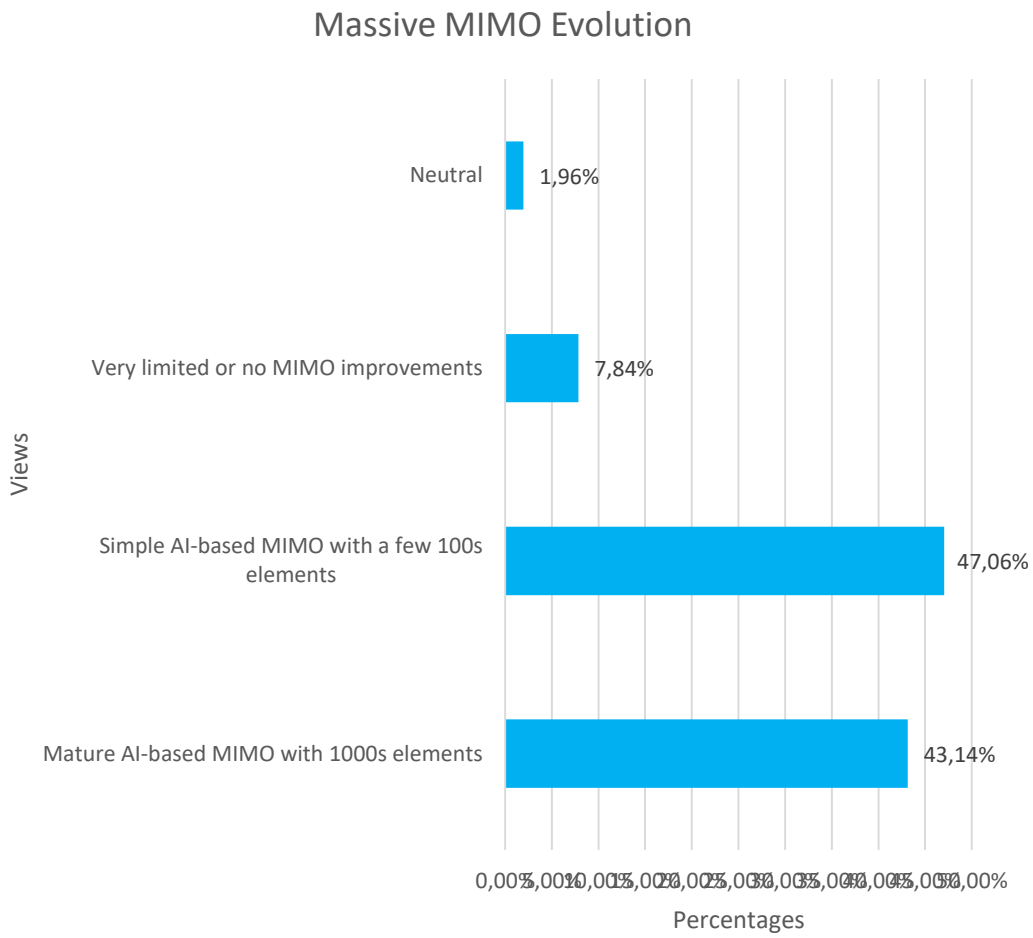
KPI	5G NR (today)	Target KPI in 6G (2030'ish) from EMPOWER	Reference [DOCOMO's 6G Vision Whitepaper]
Spectrum	52.6 GHz	Up to 500 GHz	Up to 500 GHz
User data rate	100 Mbps	Above 1Gbps	NA (Peak data rate >100 Gps vs. A few 100 Gbps from EMPOWER)
Density	1 device per sqm	Significantly above 2 devices per sqm	10 devices per sqm
Reliability	5 nines	Above 8 nines	Up to 7 nines
U-plane latency	<1 ms	<0.5 ms	<1 ms
Energy efficiency	NA	50%-100% gains vs 5G (Rel.16)	Qualitative: Extreme low power including alternative charging
Positioning accuracy	<1 m	<10 cm	NA

Insights on Technology Trends

interdigital

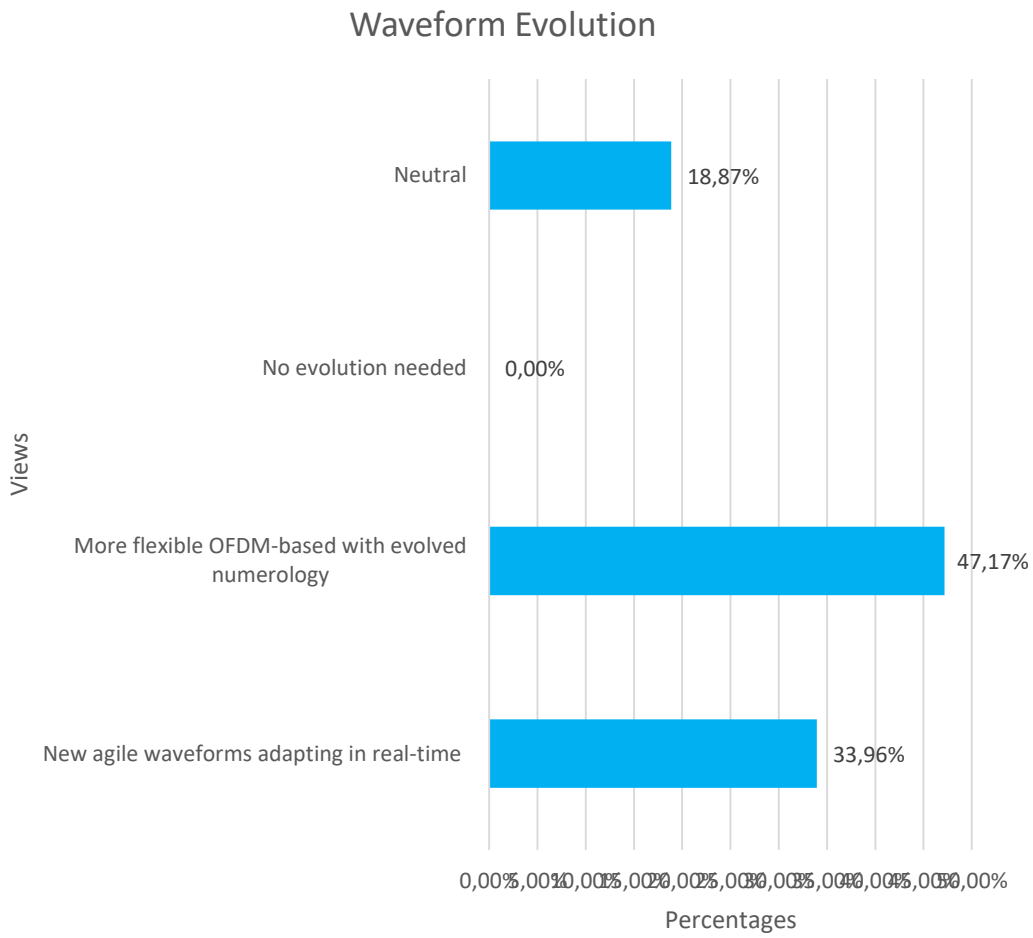
Insights – Massive MIMO

- **Massive MIMO** will evolve over the next 10 years to include many more antenna elements utilizing AI-based beamforming enabling significantly higher spectrum utilization?
  - Nearly 90% majority see Massive MIMO using some form of **AI-based beamforming**, with antenna array sizes from **a few hundreds (47%) to the thousands (43%)**
  - Very few (8%) think it will have limited improvements compared to 5G today



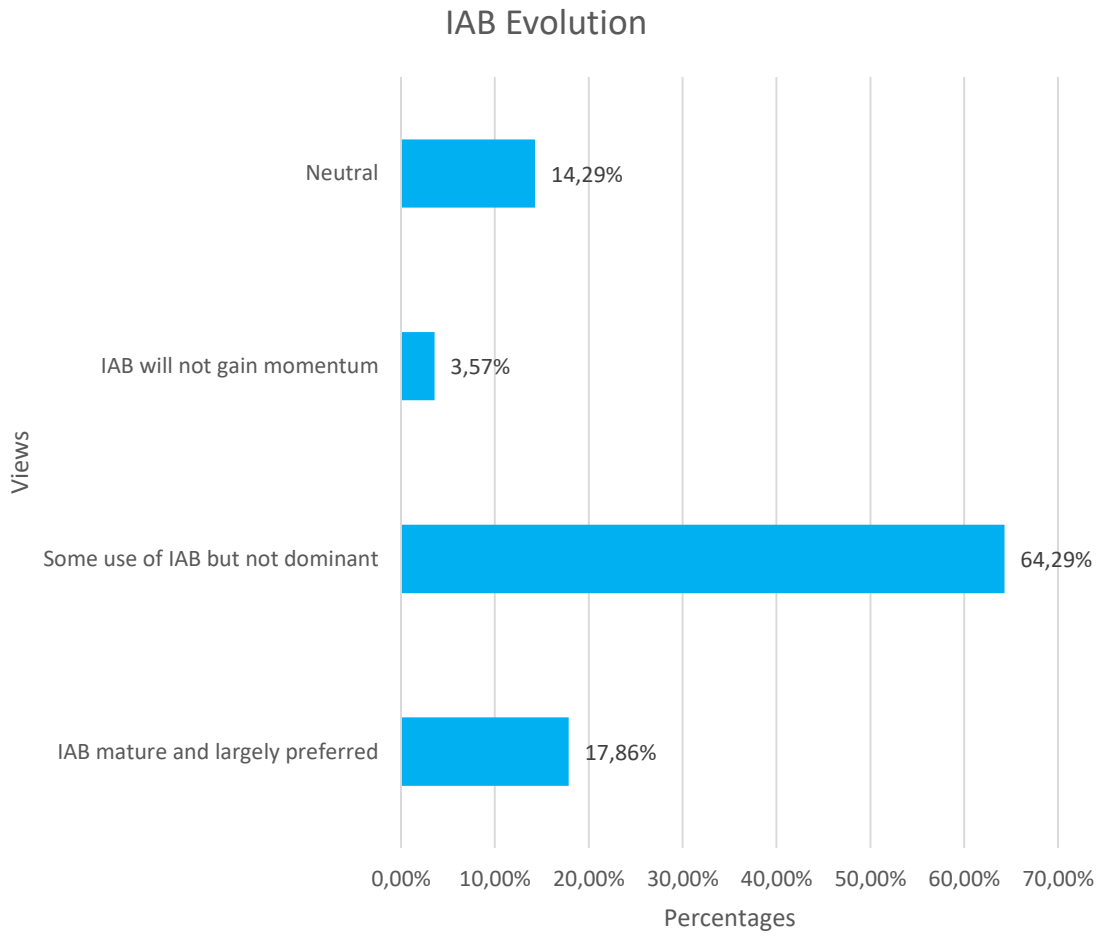
Insights – Waveforms

- During the next 10 years, the **transmitted waveform** will adapt to the propagation scenario and application in real-time with short latencies?
  - Majority (47%) think it will continue to be **OFDM-based with evolved numerology**
  - Nearly a third (34%) think there will be **new agile waveforms**
  - No one think that the waveform will not evolve in some sort



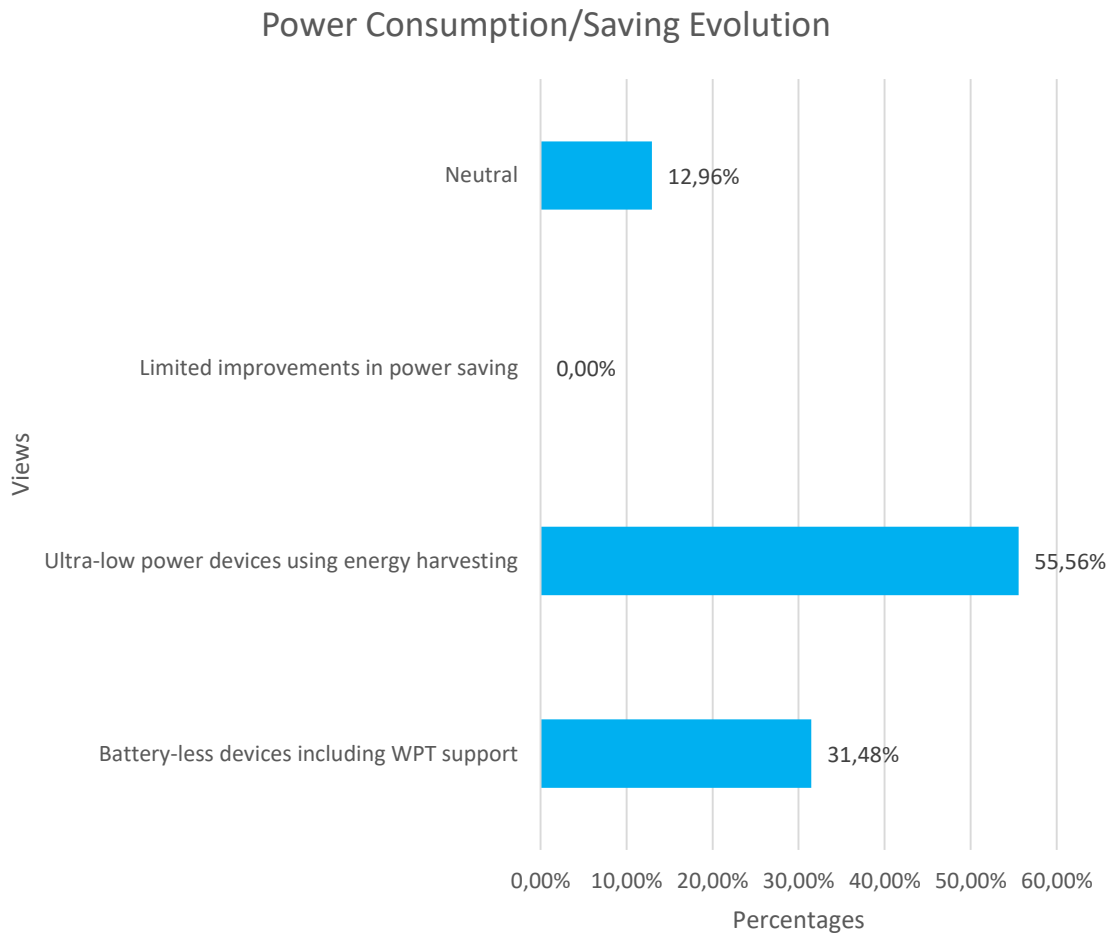
Insights – Integrated Access and Backhaul

- During the next 10 years, **Integrated Access and Backhaul** will be the preferred transmission concept in wireless networks?
  - Majority (64%) think there will be **some use of IAB**, but it will remain complementary (not dominant)
  - A minority (18%) think IAB will mature and be widely used
  - Very few (3%) think that IAB will not gain momentum



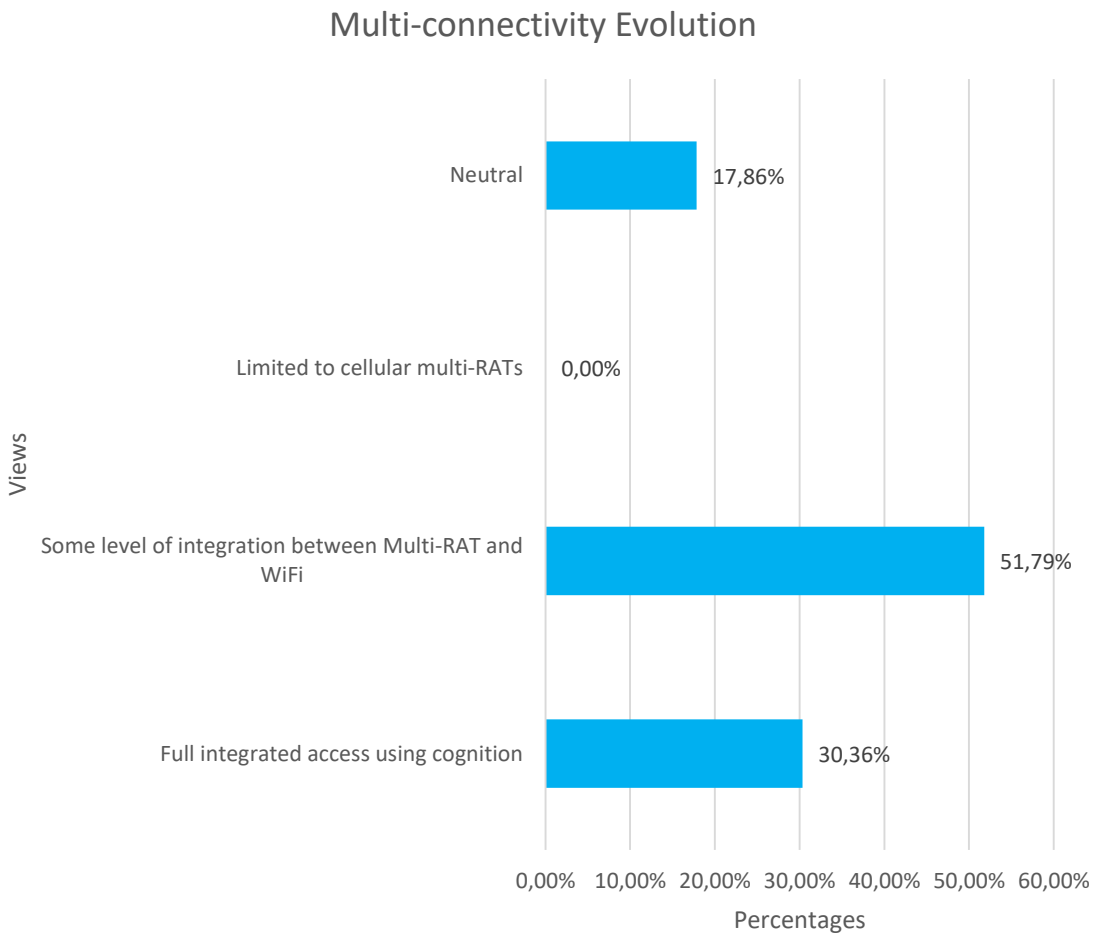
Insights – Power consumption/saving

- Battery-less **low power** devices and sensors will in 10 years be supported together with significant advances in **power saving**?
  - Majority (56%) think **ultra-low power devices using energy harvesting** will be supported
  - A third (31%) see more disruptive **battery-less devices** including support for **wireless power transfer**
  - No one see only limited improvements in power saving



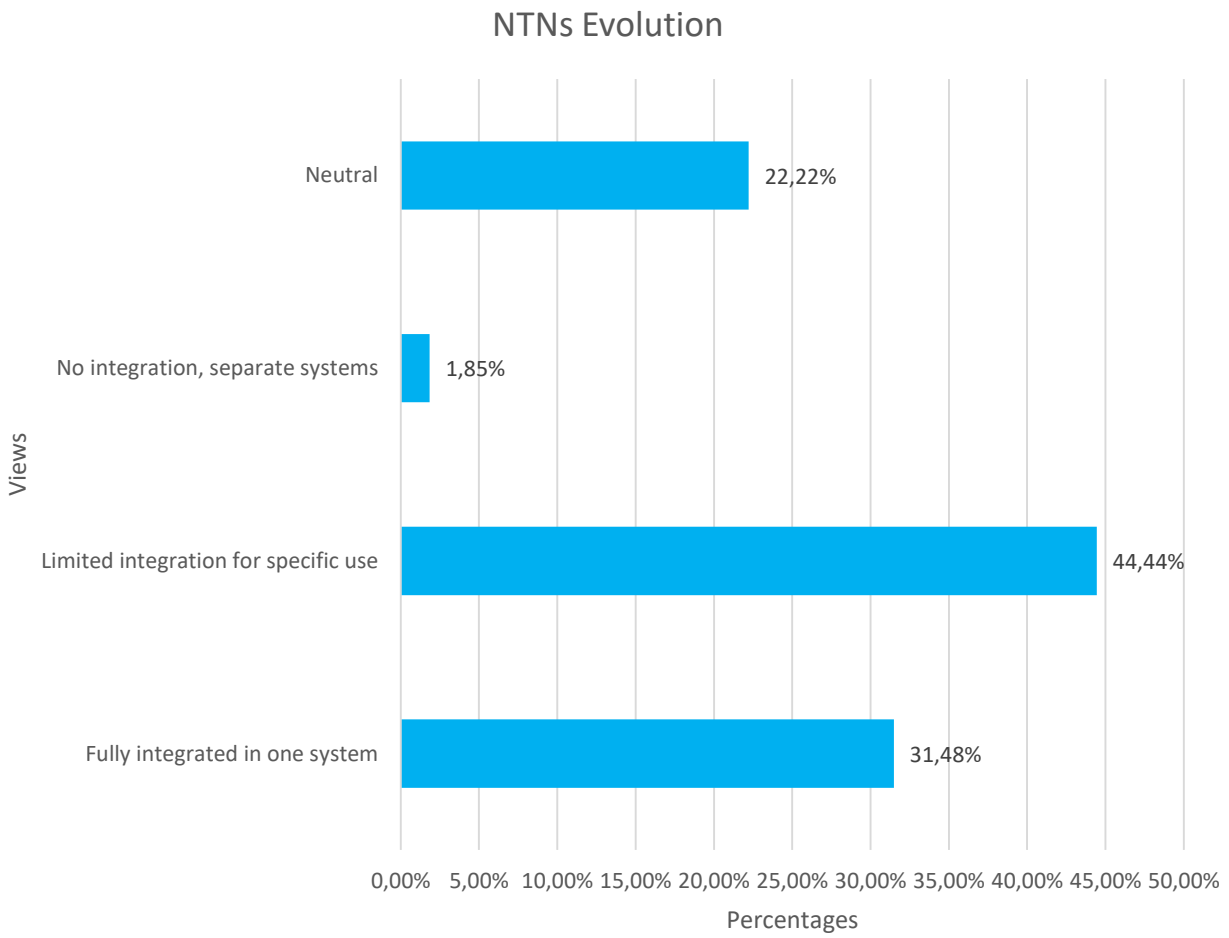
Insights – Multi-Connectivity

- **Multi-connectivity** across cellular and non-cellular technologies will reach maturity in 10 years and be implemented in networks and devices?
  - Majority (82%) see multi-connectivity widely supported with **some level of integration across wireless accesses**
  - A third (30%) see **fully integrated multi-access** using cognitive schemes
  - No one see multi-connectivity continuing to be limited to within cellular multi-RATs only



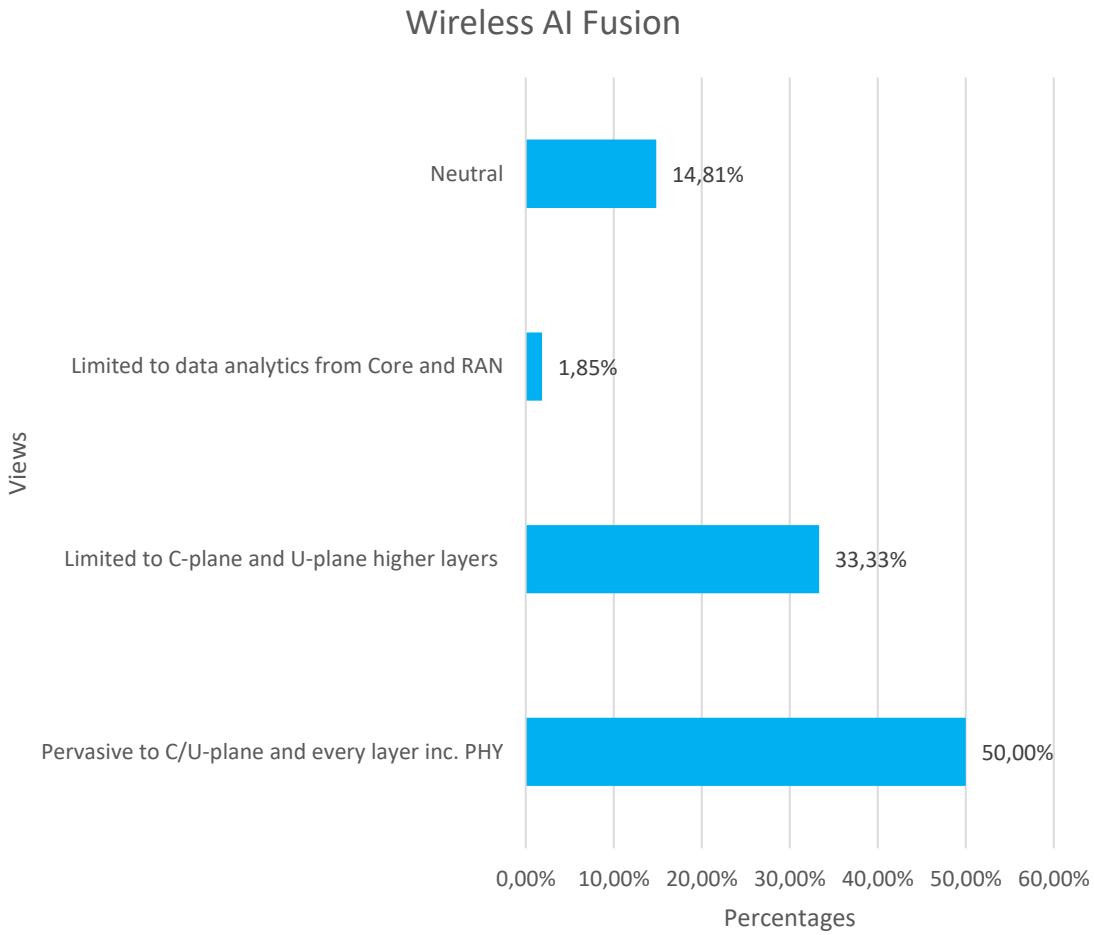
Insights – Non-Terrestrial Networks

- **Non-Terrestrial Networks (NTN)** like low-orbit satellites (LEO) and high-altitude platforms (HAP) will in 10 years be operational and integrated and supported?
  - Majority (75%) foresee **NTNs integrated with terrestrial networks either partially (44%) or fully (31%)**
  - Almost no one (2%) think that NTNs will continue to be segregated from terrestrial networks



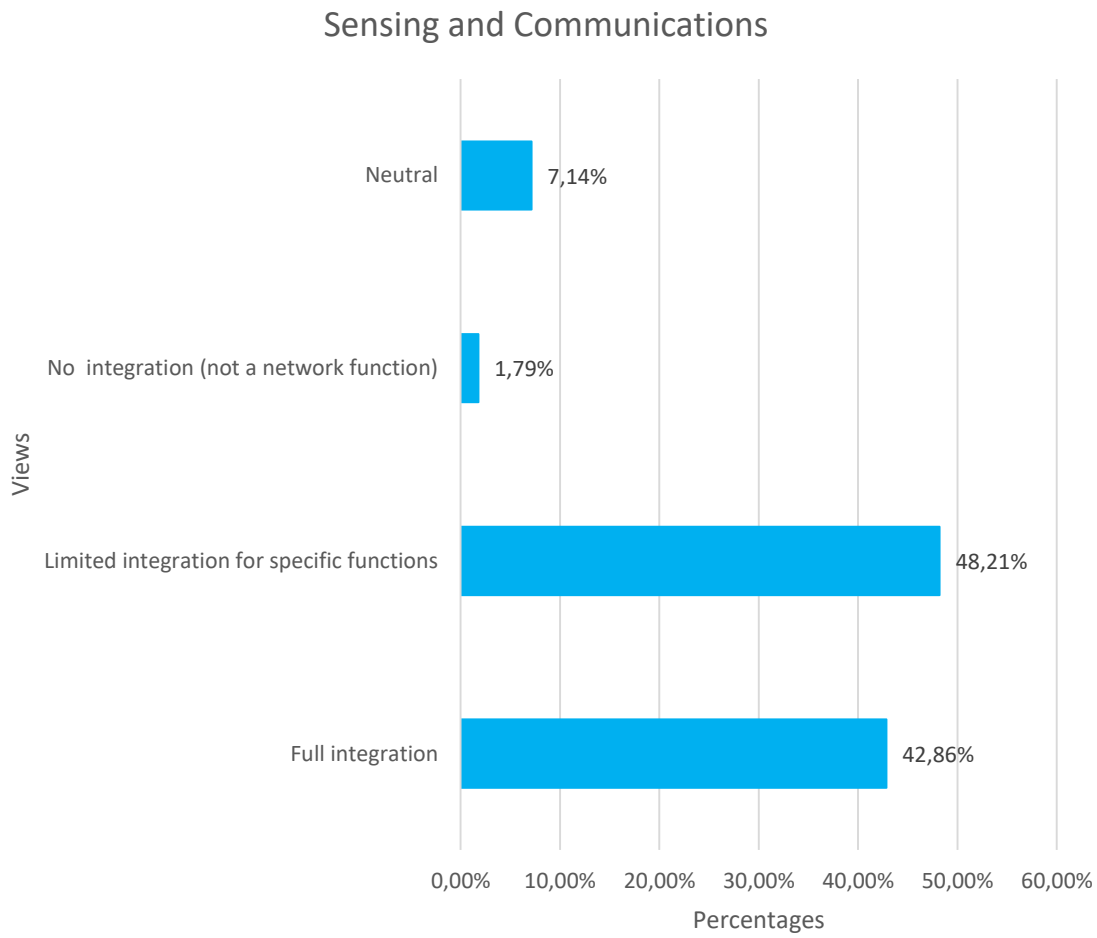
Insights – Wireless AI fusion

- In 10 years, **Wireless AI fusion** based on data collection and analytics rom the core, RAN and UE will be pervasive?
  - Majority (83%) see **wireless AI fusion happening**, with (50%) foreseeing it will be **pervasive in every plane and every layer including PHY**, whereas (33%) foreseeing it will be **limited to C-plane and U-plane higher layers**
  - Almost no one (2%) think that Wireless AI fusion will be limited to some data analytics in Core and RAN



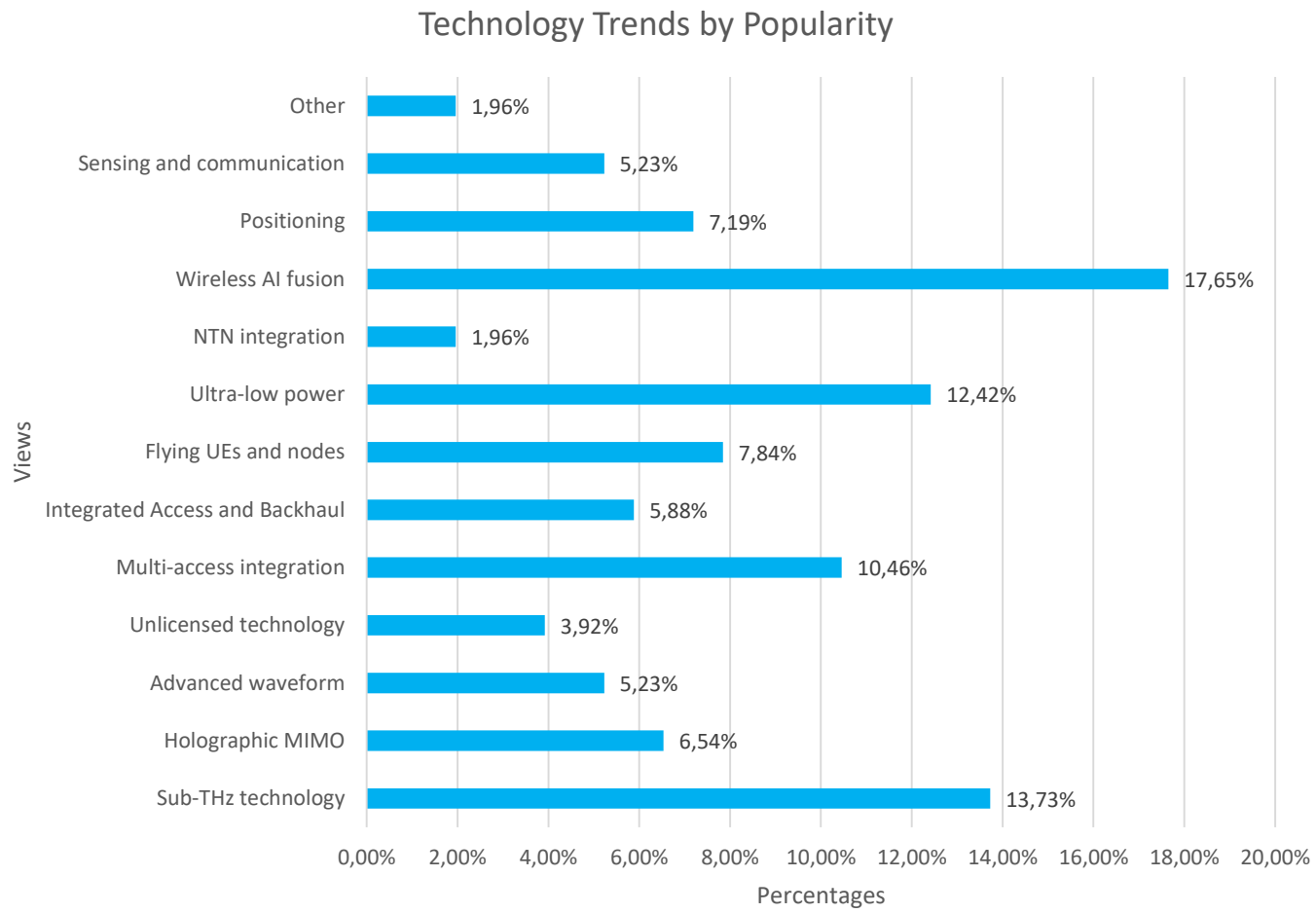
Insights – Sensing and communications

- In 10 years, wireless networks will integrate **sensing, imaging and radar** to improve tracking, monitoring and positioning?
  - Majority (91%) think **sensing will be integrated in the network in some form, limited (48%) or full (43%)**
  - Almost no one (2%) think sensing will not be a function or service embedded in the network



Insights – Top 10 technology trends

1. **Wireless AI fusion (18%)**
2. **Sub-THz technology (14%)**
3. **Ultra-low power (12%)**
4. Multi-access (10%)
5. Flying UEs/Nodes (8%)
6. Positioning (7%)
7. Holographic MIMO (7%)
8. IAB (6%)
9. Sensing and Comms (5%)
10. Advanced waveforms (5%)



Take-aways

interdigital

Take-aways

- The journey of **5G evolution** has **already begun** in 3GPP!
- **Visions for 6G** are being laid out, **performance targets and technology trends are emerging**
- **Consensus emerging** on 6G targeting **extreme KPIs** vs 5G today (e.g. 500 GHz spectrum, 100s of Gbps peak rate, Gbps user rate, 0.5 ms latency, 8 nines reliability, etc.)
- **Technology trends** are emerging with **noticeable popularity** to **Wireless-AI fusion, Sub-THz, and Ultra-low power**
- As ITU-R finalizes its IMT-2020 recommendations this year, it may be timely to **kick start ITU-R IMT-2030 planning now with the aim to set a global vision and requirement for 6G by 2023**

Key References

1. EMPOWER project, www.advancedwireless.eu

2. A. Mourad, R. Yang, P.H. Lehner, and A. De La Oliva, "A Baseline Roadmap for Advanced Wireless Research Beyond 5G", Electronics 2020, February 2020 https://doi.org/10.3390/electronics9020351

3. NTT DOCOMO, "5G Evolution and 6G", Whitepaper, January 2020, DOCOMO_6G_White_PaperEN_20200124.pdf

Acknowledgment to our Partners

www.advancedwireless.eu

Thank You – Q&A

Alain MOURAD, PhD
Director Engineering R&D

InterDigital Europe Ltd.
64 Great Eastern Street
London, EC2A 3QR
United Kingdom

Contact:
Alain.Mourad@InterDigital.com