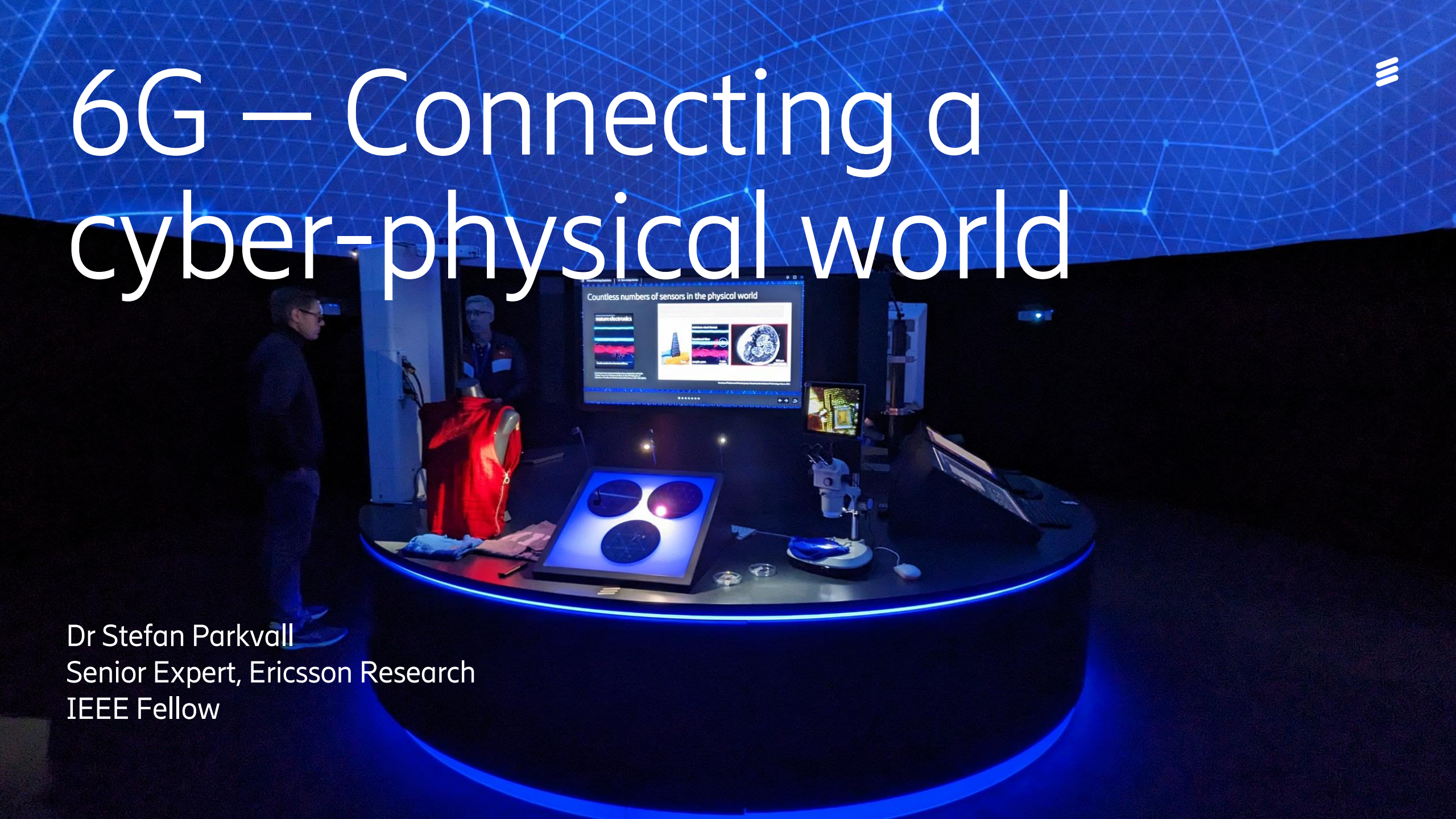
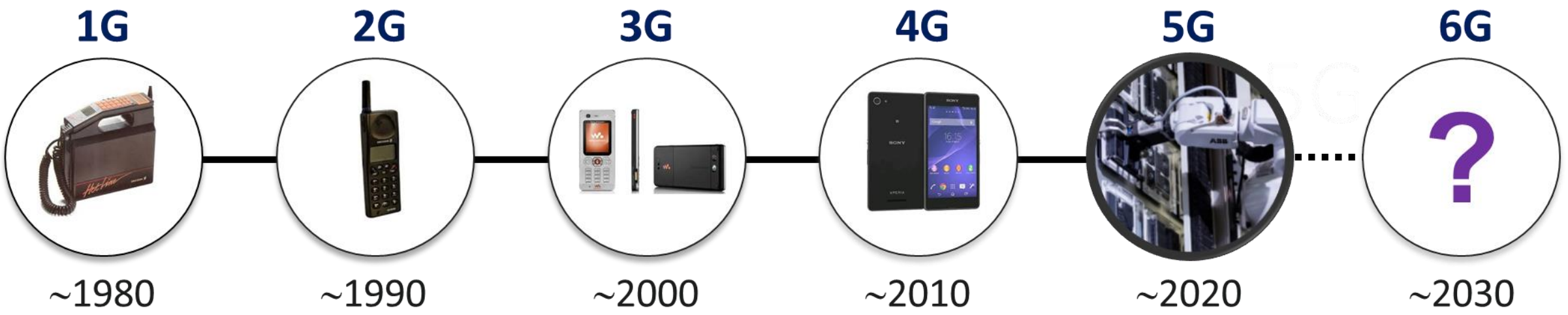
6G – Connecting a cyber-physical world



Dr Stefan Parkvall
Senior Expert, Ericsson Research
IEEE Fellow

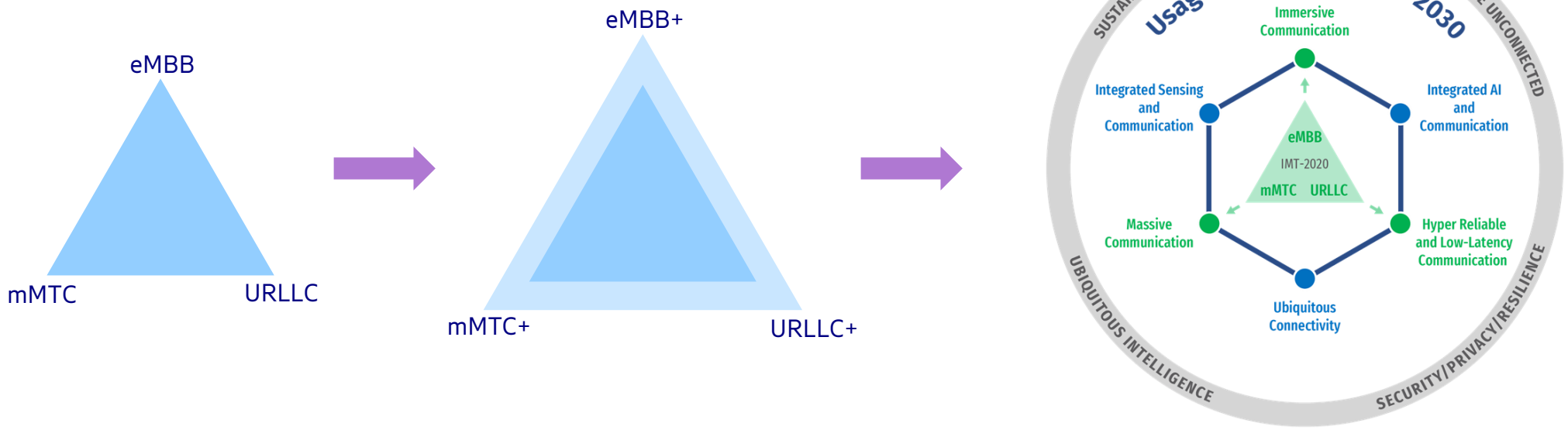
From 1G to 6G



Wireless connectivity for 2030 and beyond

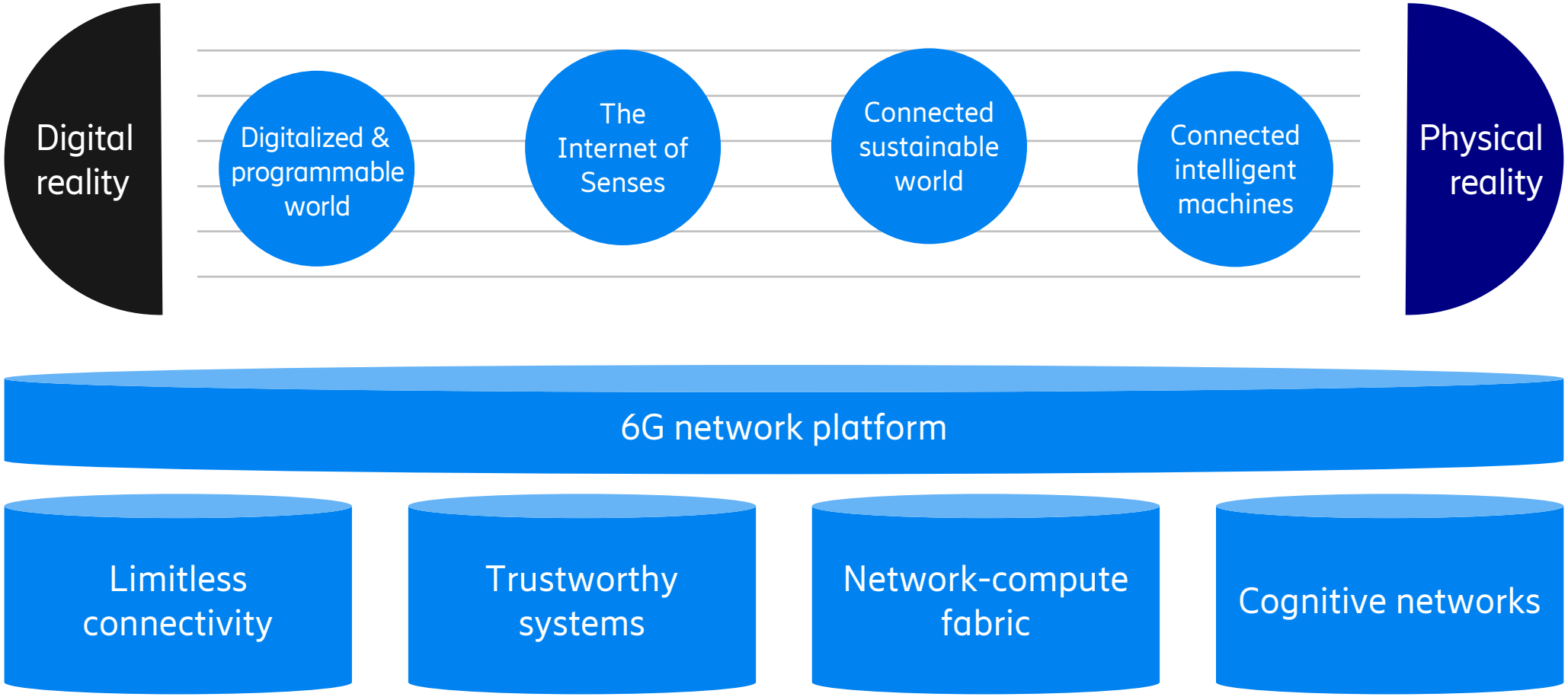
From 5G to 6G

Further enhancing and expanding

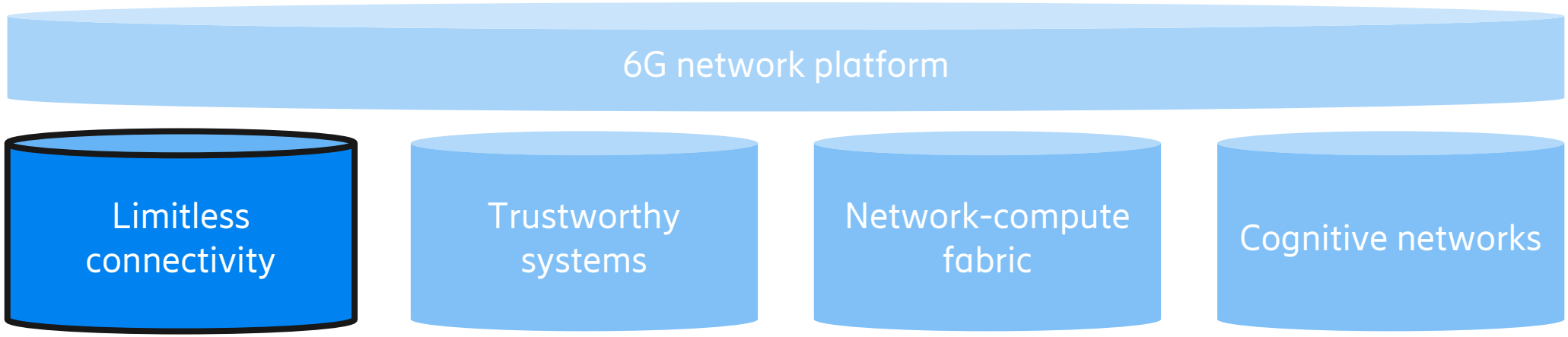


5G **5G Advanced** **6G**

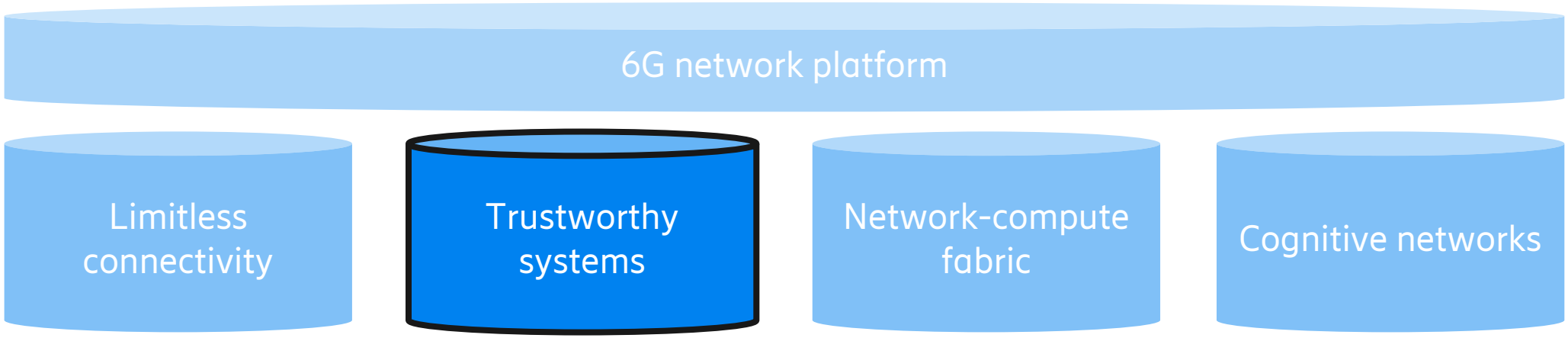
Connecting a cyber-physical world



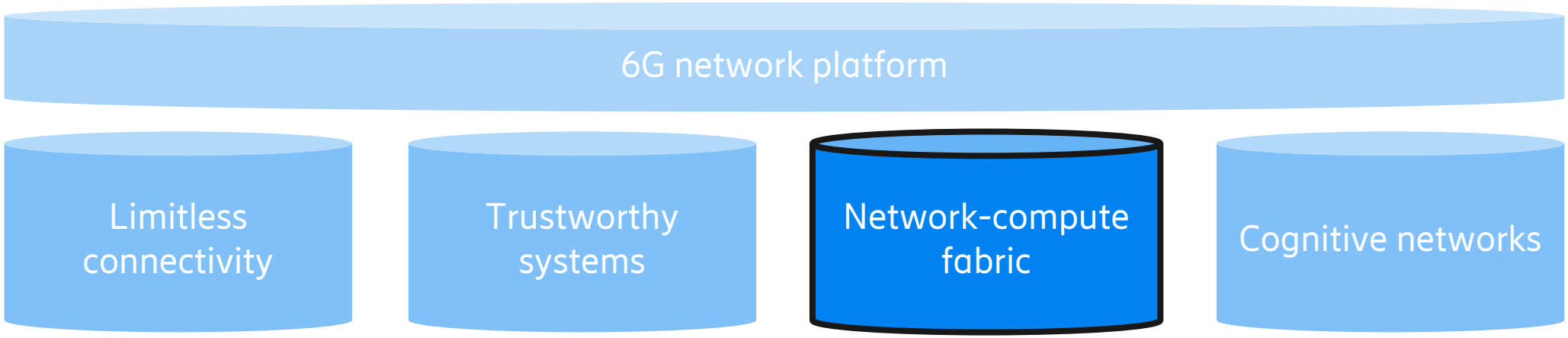
6G network platform



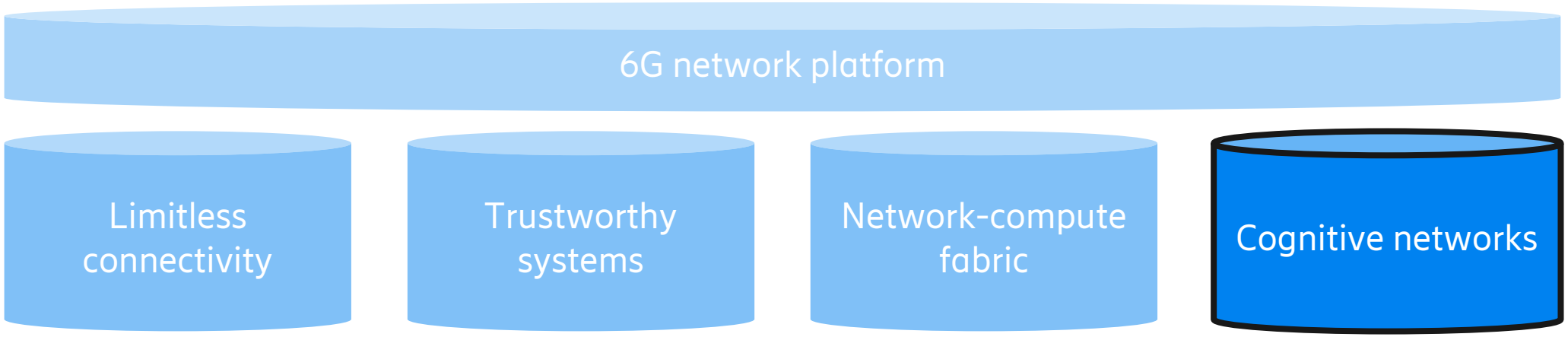
6G network platform



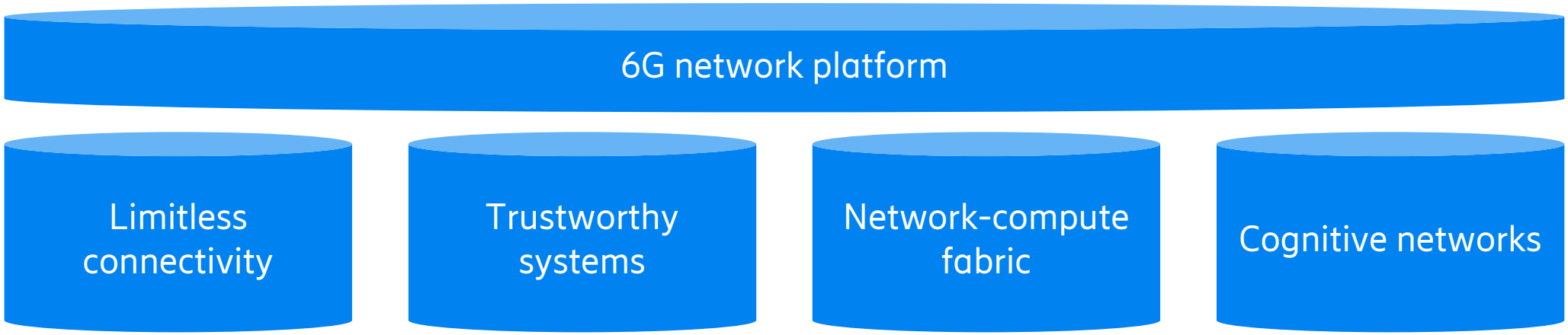
6G network platform



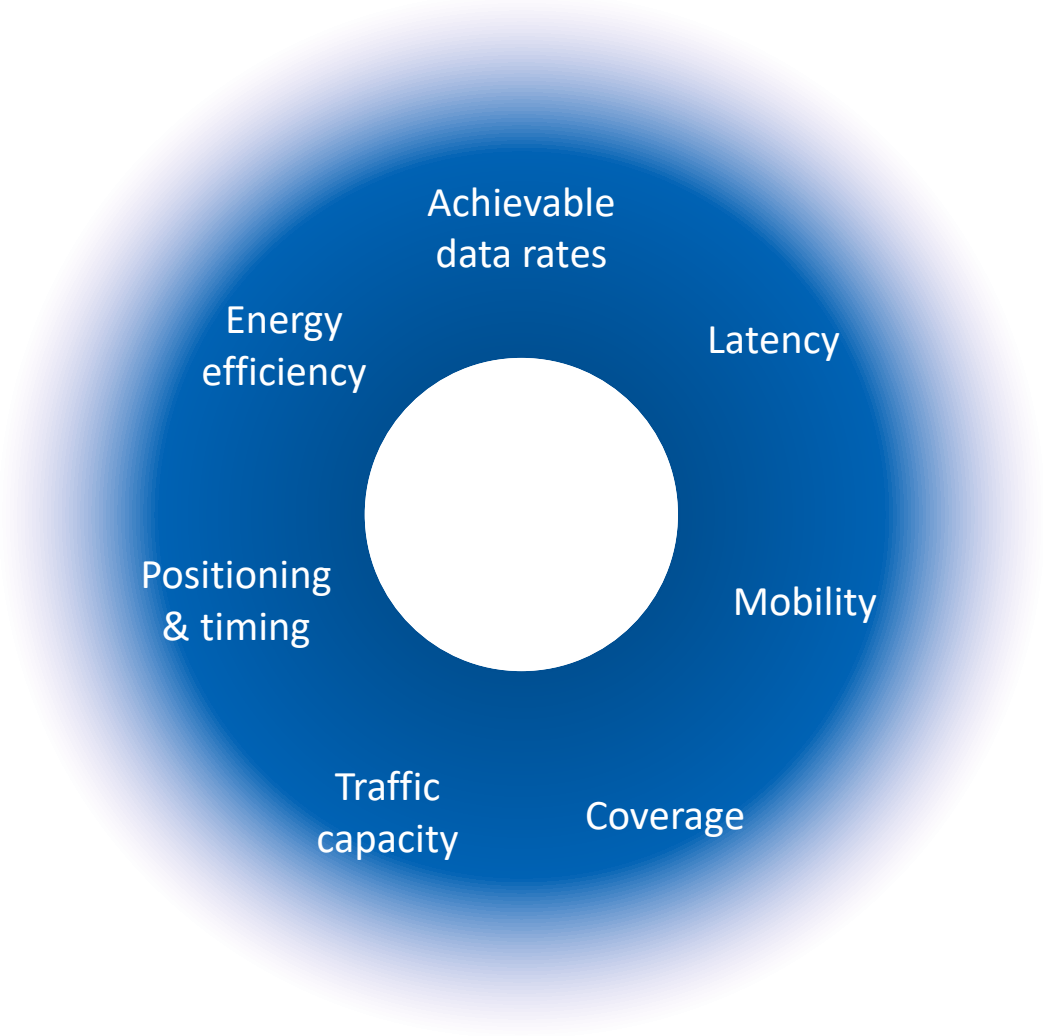
6G network platform



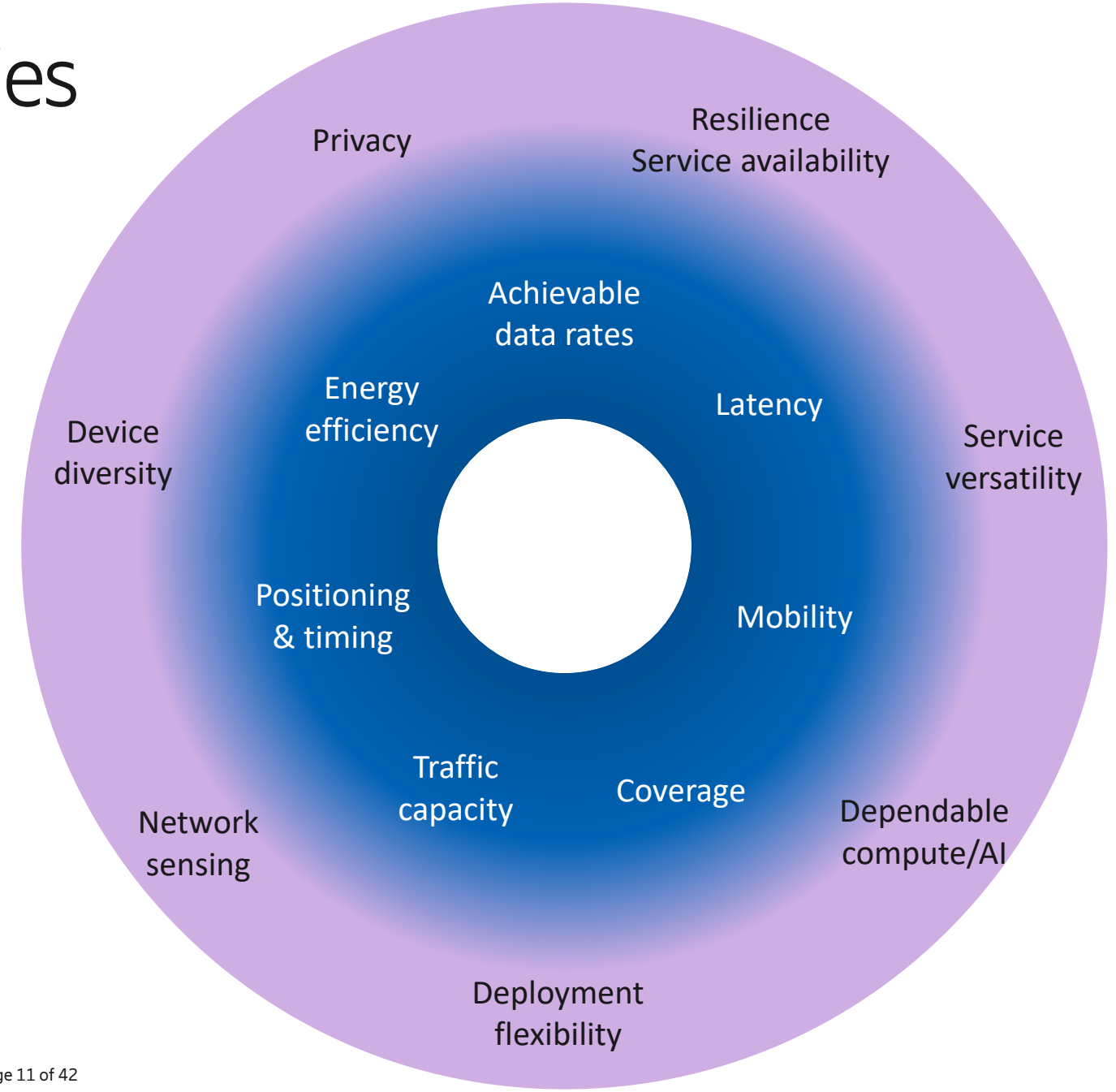
6G network platform



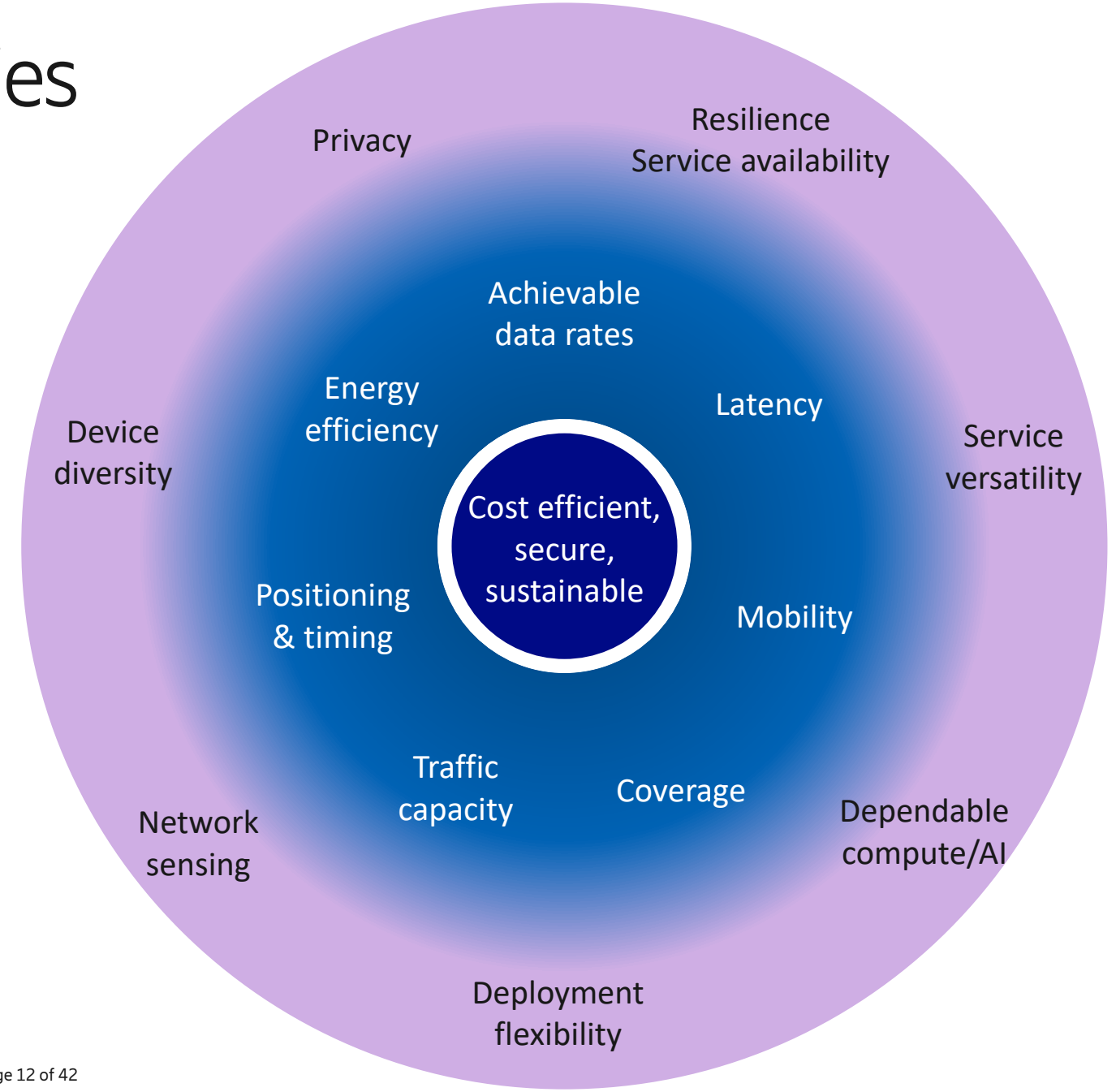
6G capabilities



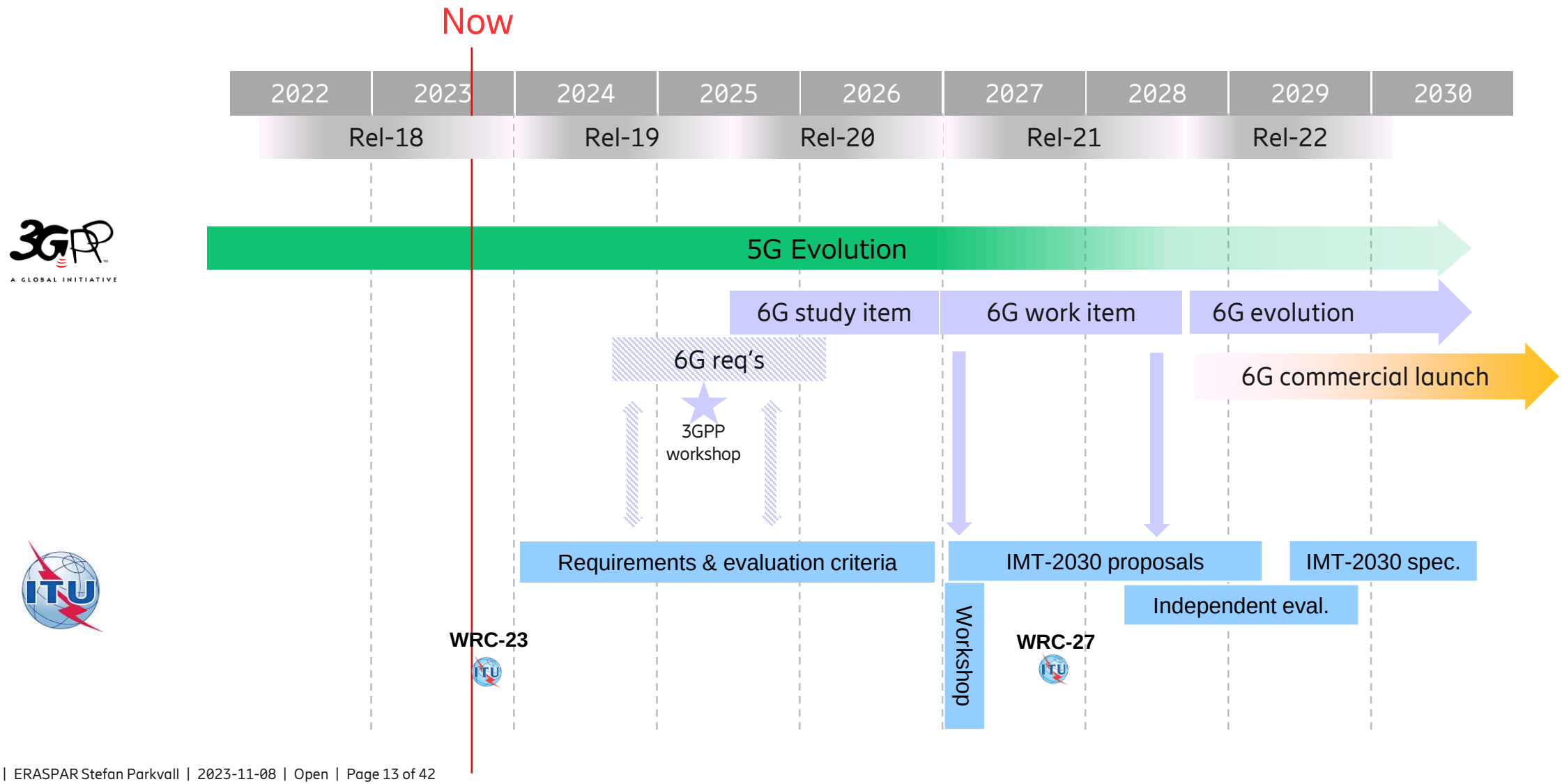
6G capabilities



6G capabilities

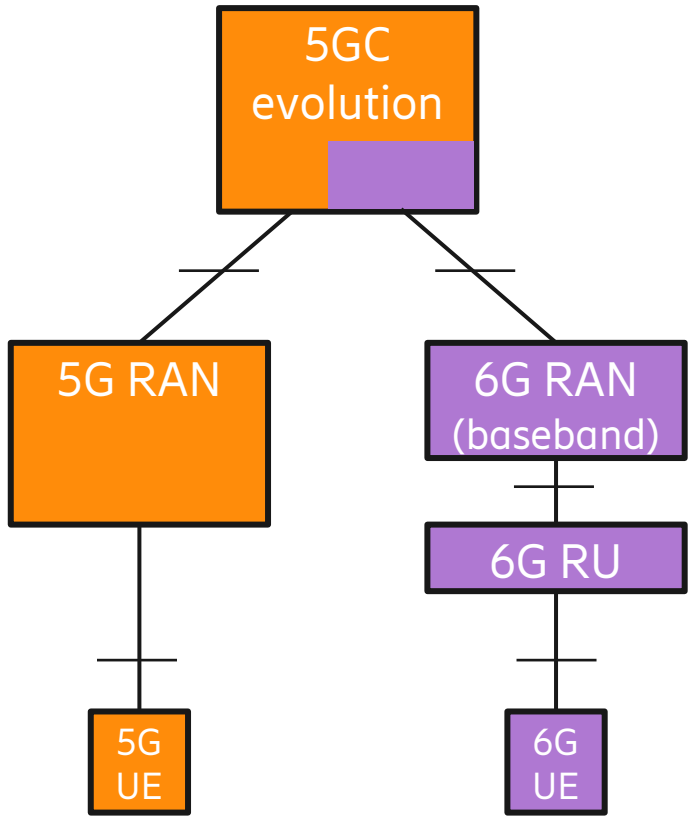


6G timeline

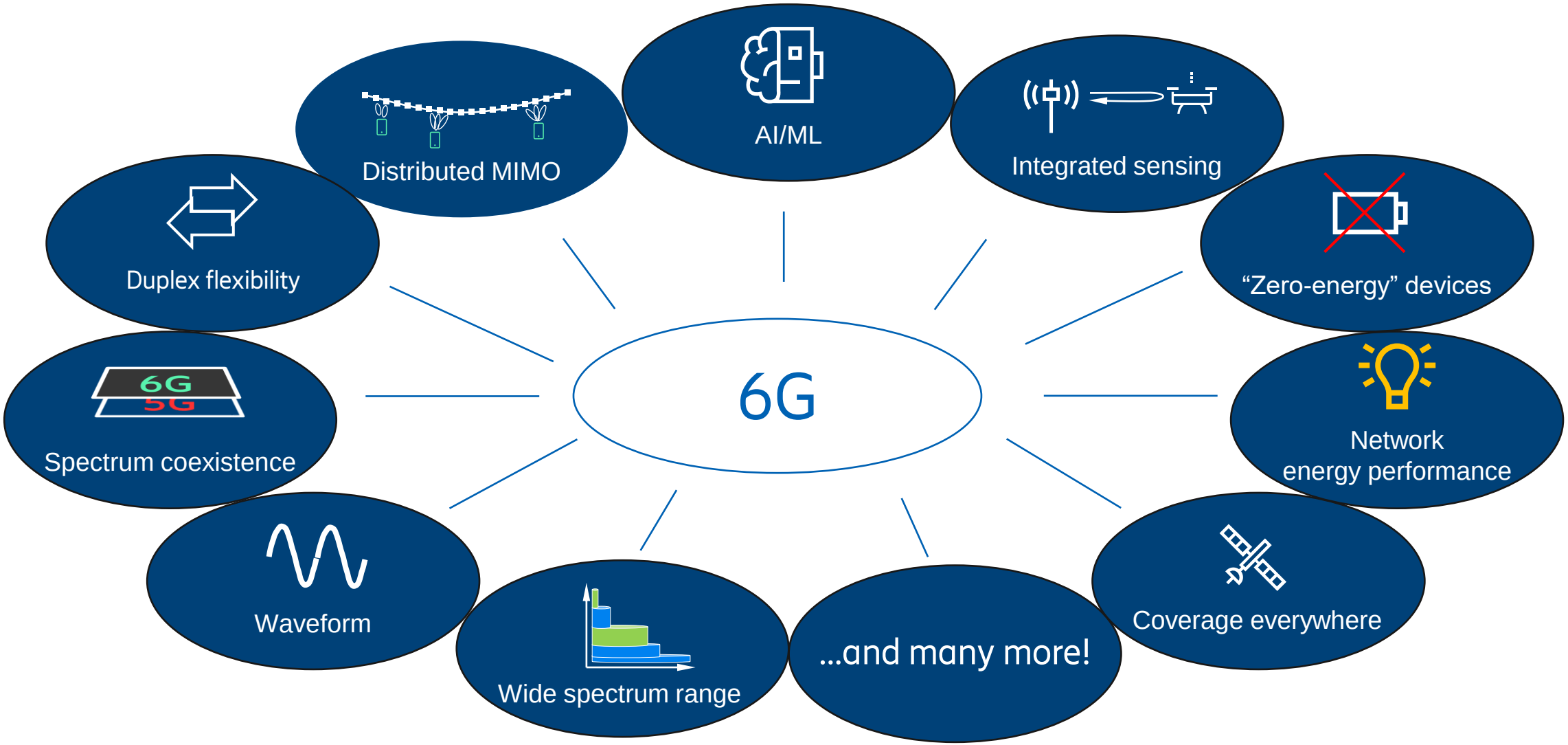

Now
2022
2023
2024
2025
2026
2027
2028
2029
2030
Rel-18
Rel-19
Rel-20
Rel-21
Rel-22
5G Evolution
6G study item
6G work item
6G evolution
6G req's
3GPP workshop
6G commercial launch
Requirements & evaluation criteria
IMT-2030 proposals
IMT-2030 spec.
Independent eval.
Workshop
WRC-23
WRC-27

Key 6G principles

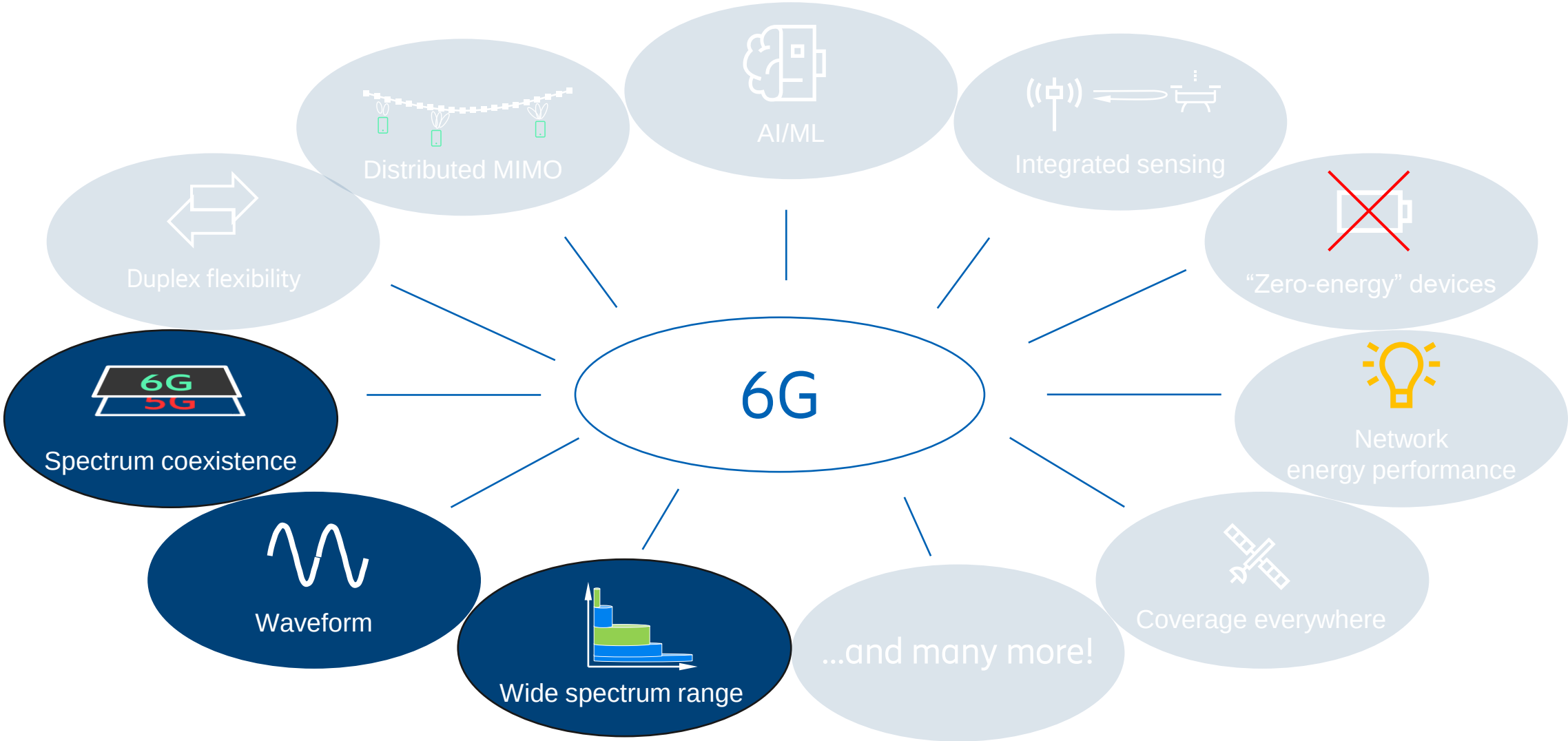
- Strive for a **global 6G standard**
- Single, simple, and **smooth migration path** from 5G to 6G
- 6G RAN shall have a **standalone** architecture
- Include **open interfaces** to facilitate a healthy ecosystem
- 6G shall be possible to **operate in all existing and new 3GPP bands**
- **6G spectrum sharing** shall be supported with selected 3GPP technologies



6G technology components



6G technology components



6G spectrum

From below 500 MHz to beyond 100 GHz

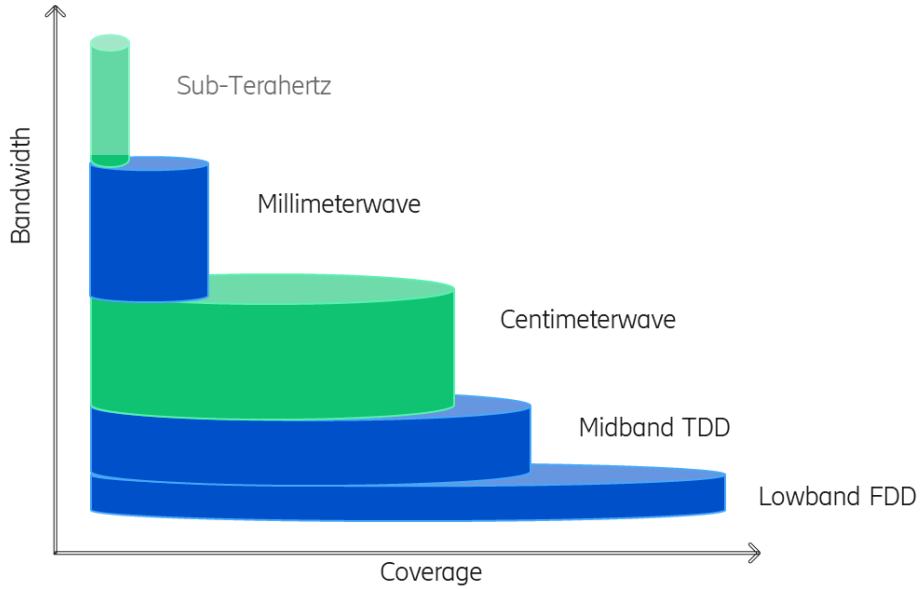
Spectrum used by current systems (“sub-6” and “mmw”)
➡ dynamic spectrum sharing

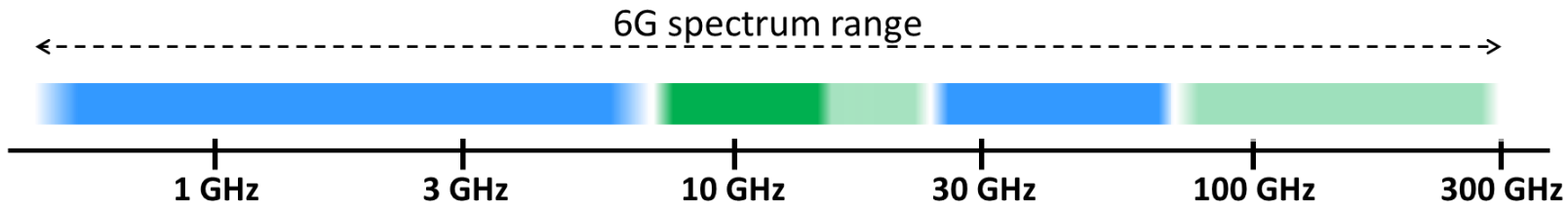
New spectrum between “sub-6” and mmw bands

- “Centimeter-wave”
- Focus on 7-15 GHz

New spectrum above 71 GHz (“sub-THz”)

- For extreme data rates in specific scenarios



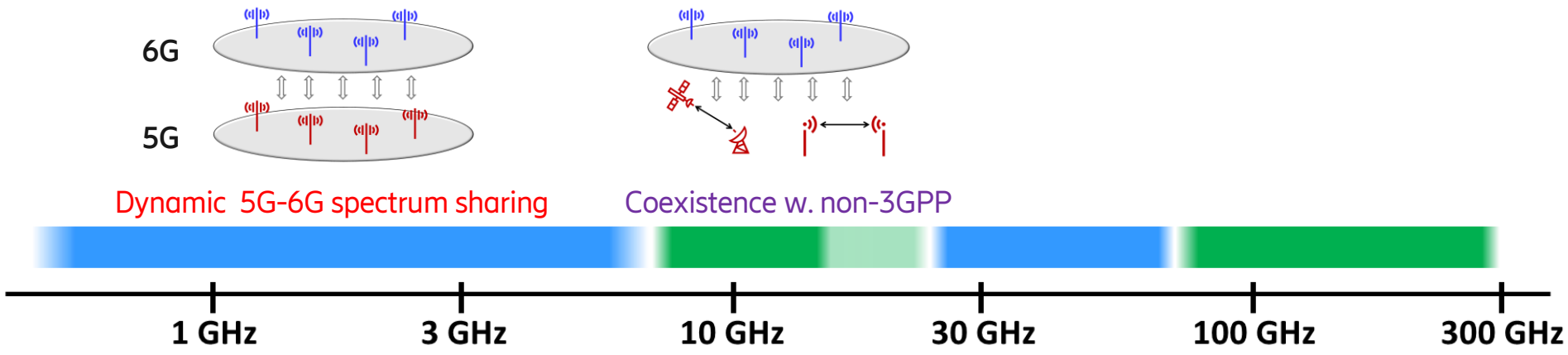


Spectrum sharing

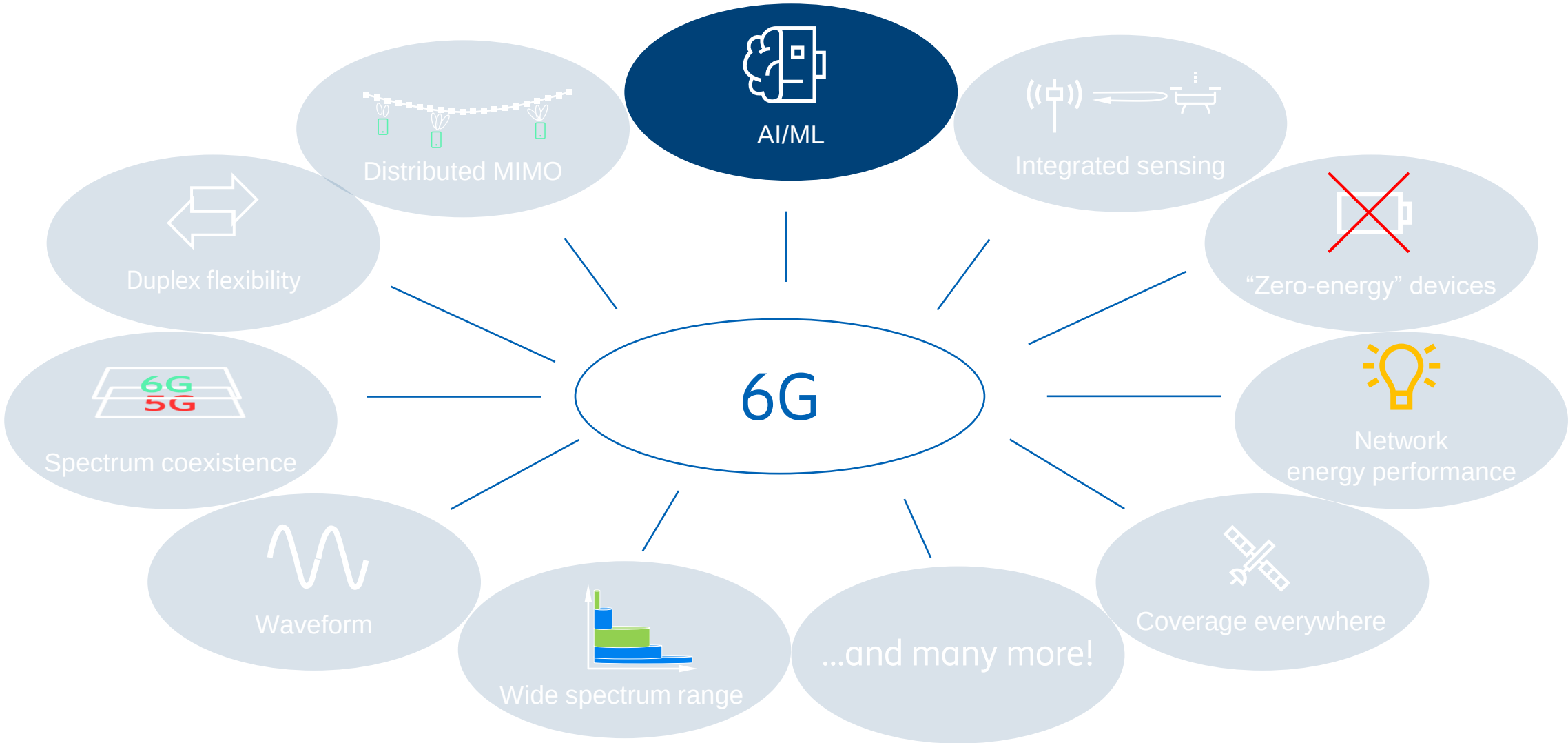
Dynamic spectrum sharing with earlier 3GPP technologies essential for FR1

Spectrum coexistence with non-3GPP technologies for centimeter waves

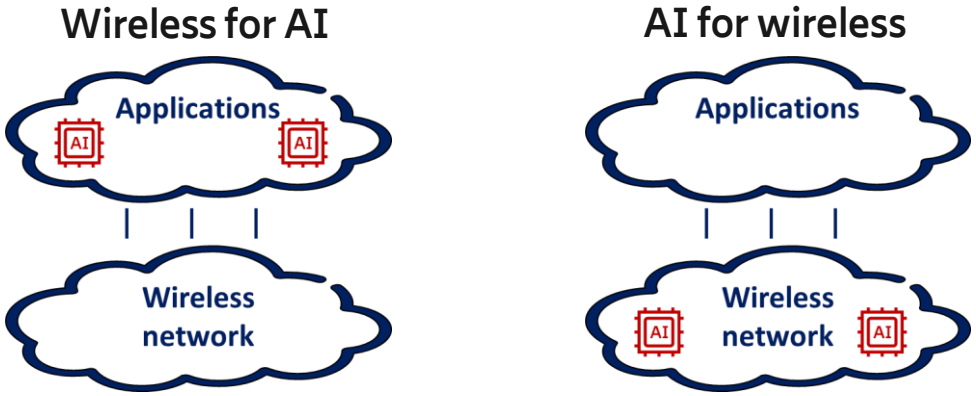
- To access new spectrum currently used for other purposes (satellites, radars, fixed links, …)



6G technology components



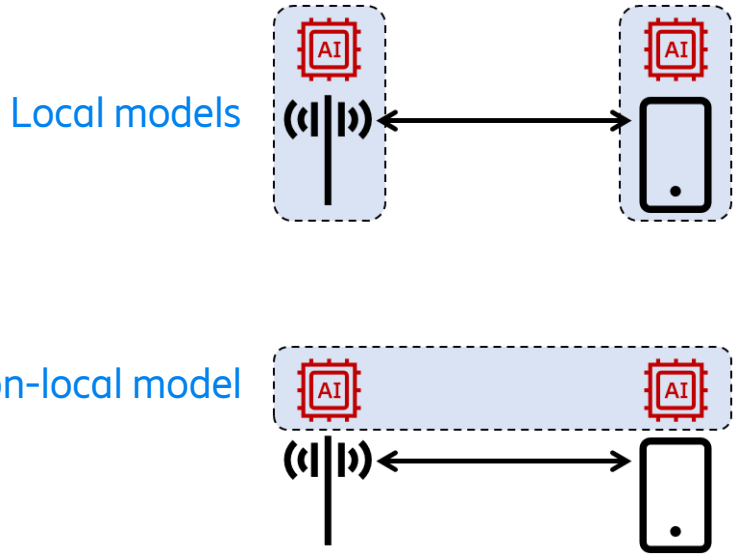
AI/ML for wireless



When one lacks a sufficiently accurate model of the problem to solve

When the problem/model is too complex to solve explicitly

Deployment	Cell planning, ….
RRM	Power settings, handover/cell-reselection, …
MAC	Scheduling, …
PHY	Channel estimation, receiver imperfections, …



AI/ML for wireless – different levels

1) Utilizing AI/ML technology when developing solutions

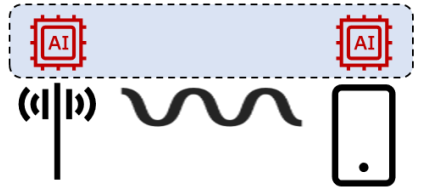
- Example: Deriving new modulation constellations, …

2) Utilizing AI/ML technology in local algorithms

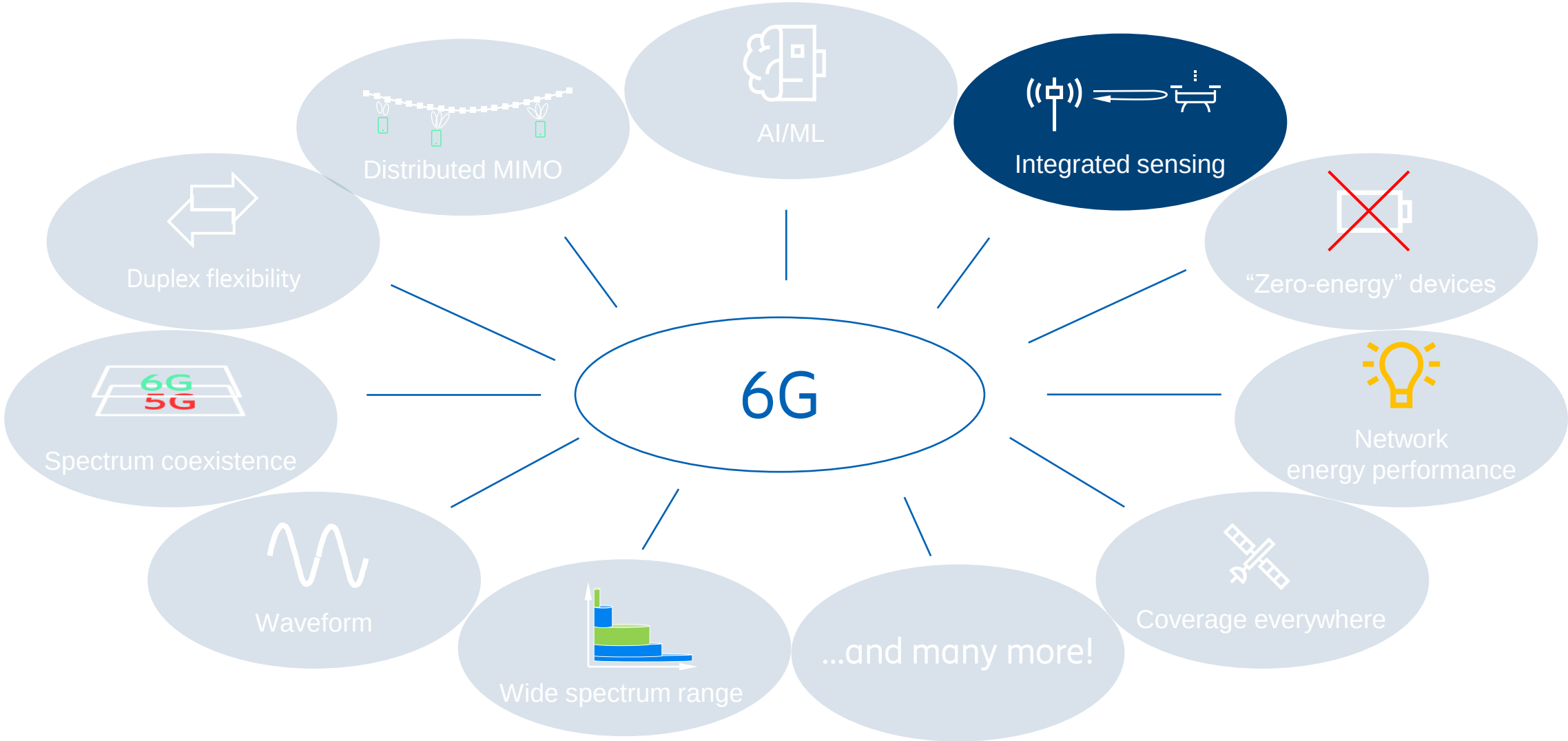
- Local models in network or device
- Examples: Channel estimation, beam management, …

3) Utilizing AI/ML technology in the radio-interface protocols

- Non-local models spanning network+device
- Example: CSI reporting, …



6G technology components



Integrated sensing

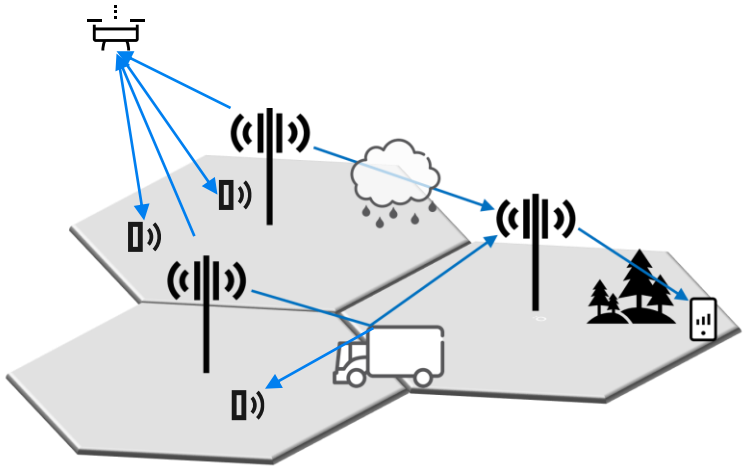
Sensing functionality as an *integrated* part of the communication network

- Reuse the communication spectrum for sensing
- Reuse the communication infra-structure for sensing

⇩

Low-cost introduction of sensing functionality

Benefit from huge number of co-operative network nodes

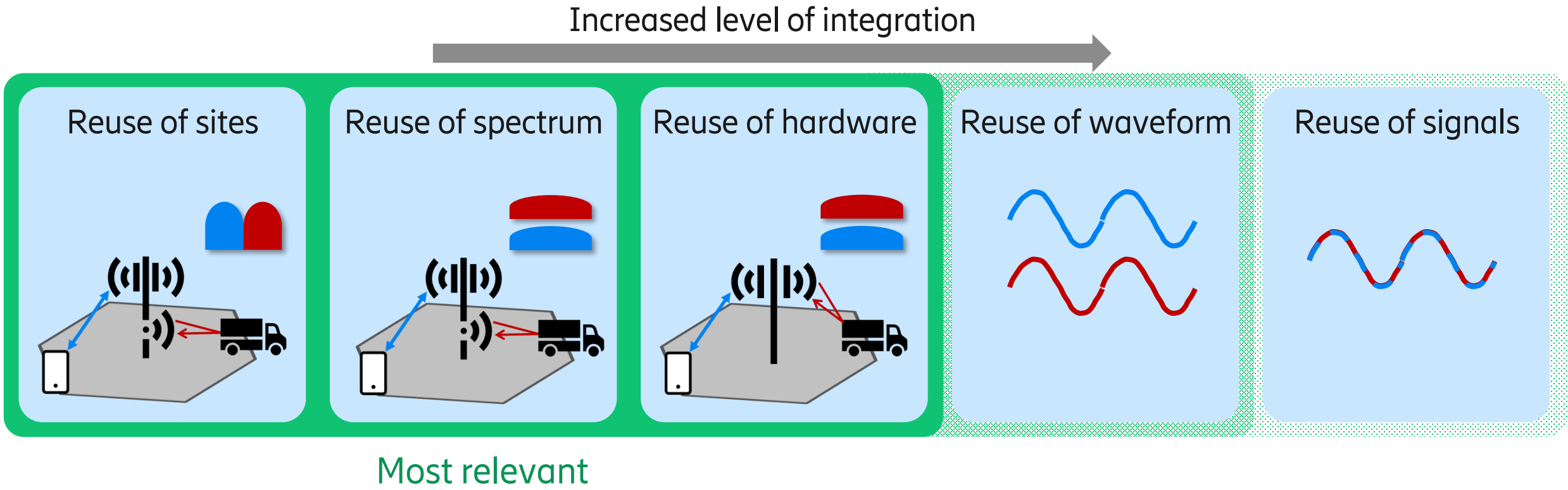


Multiple uses

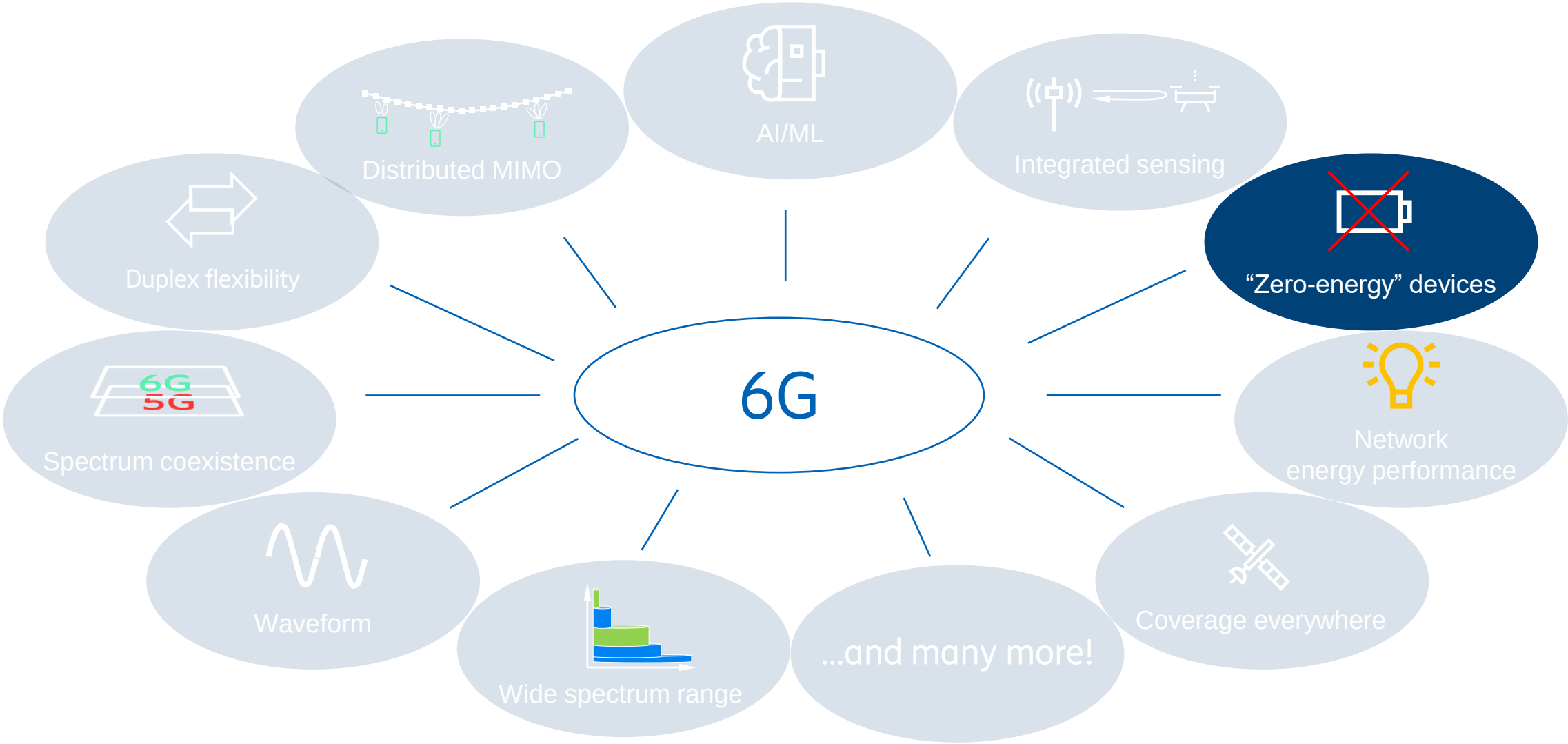
- Enable new/enhanced end-user services
- Enhance the network performance, including detection of electromagnetic threats

Integrated sensing

Sensing functionality as an *integrated* part of the communication network



6G technology components



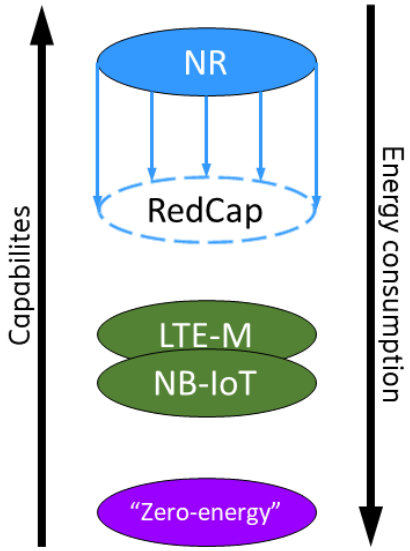
"Zero-energy" devices

Devices harvesting ambient energy (solar, temperature, vibrations, RF, …)

- *"No need to change battery"*
- Enabling sustainable asset trackers, sensors for mass deployment, …

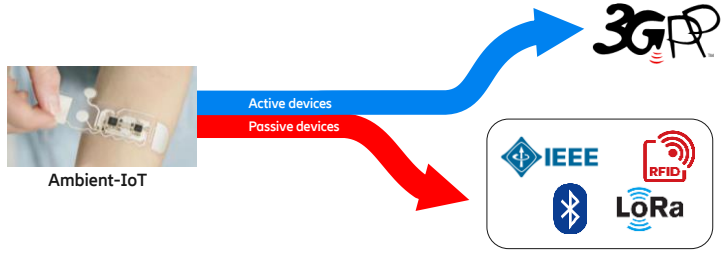
Very small amounts of energy available

- PHY; waveform suitable for Rx/Tx device imperfections
- Mobility; energy-efficient mobility mechanisms
- Security; power-efficient security mechanisms
- …



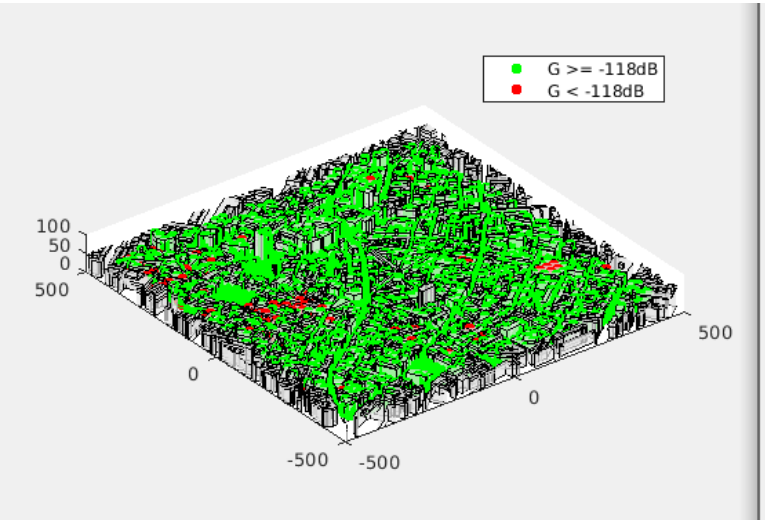
Rel-19 ambient IoT has a partially similar scope

- Focus on active Tx/Rx solutions, not backscattering (backscattering has a limited coverage of ~10 m)

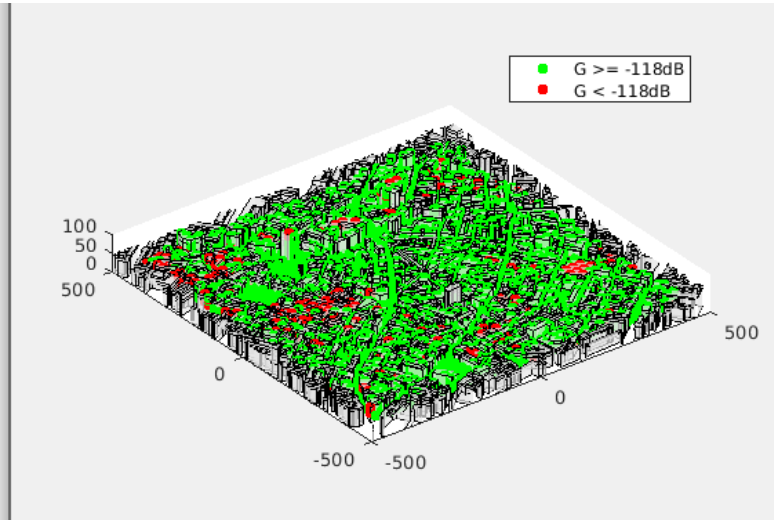


Where does it work? Initial estimates for London

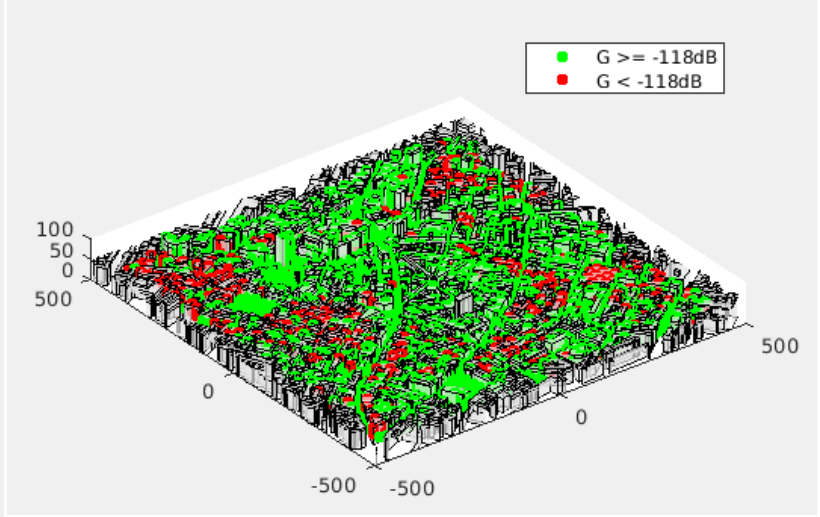
800MHz



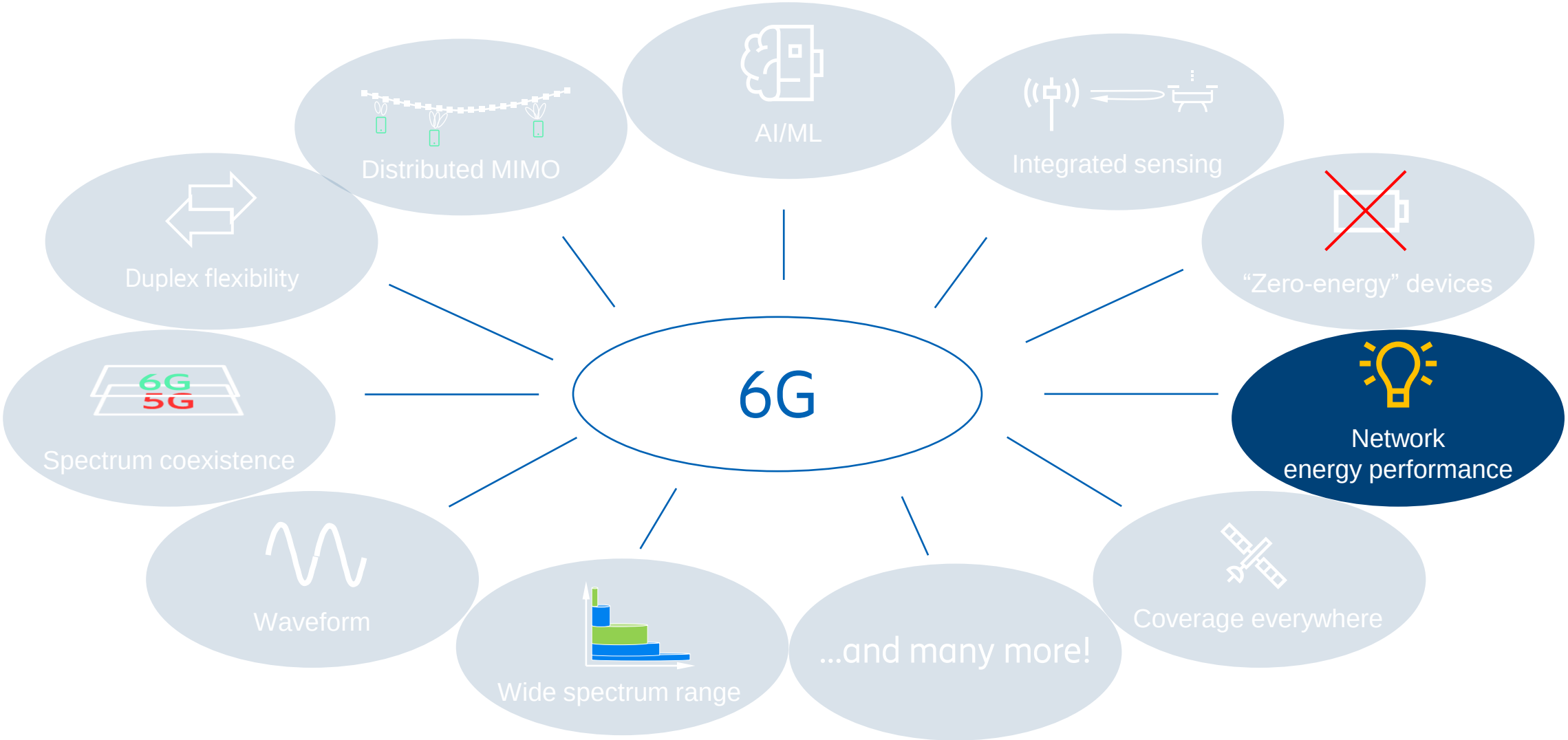
1800MHz



3.5GHz (No BF)

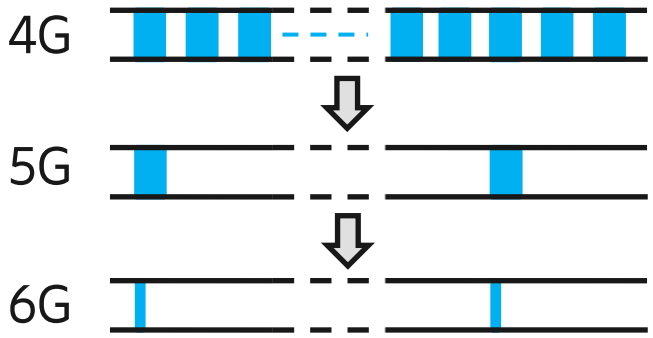


6G technology components

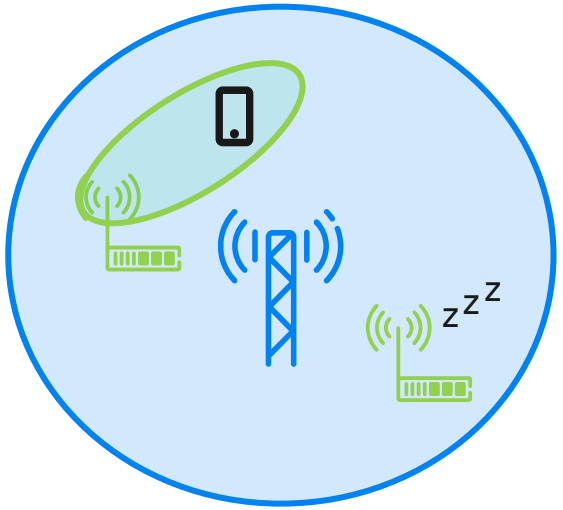


Energy efficiency – Lean design remains key!

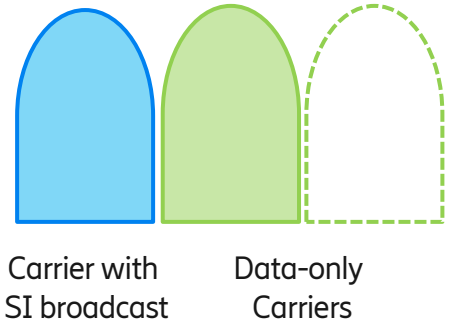
Enhance lean design in time domain



Extend lean design to spatial/node domain



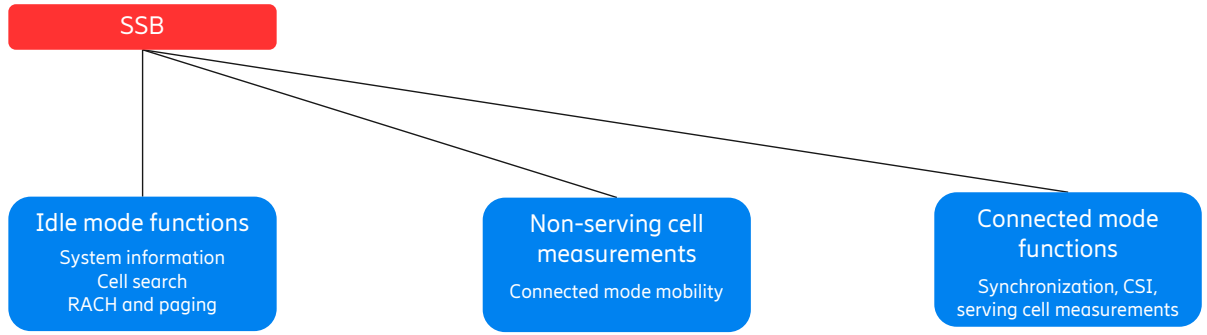
Extend lean design to frequency domain



Decoupling idle and active states

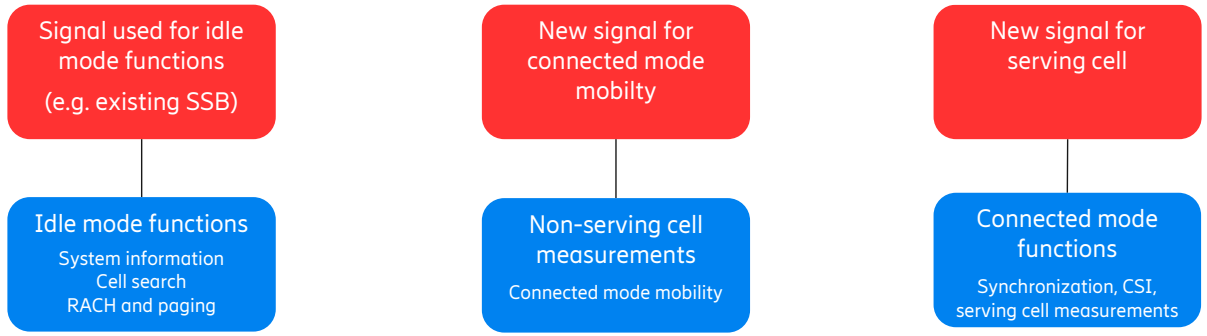
5G

- SSB used for both idle and connected mode procedures
- The spec allows mobility measurements on CSI-RS but it is not used in the field

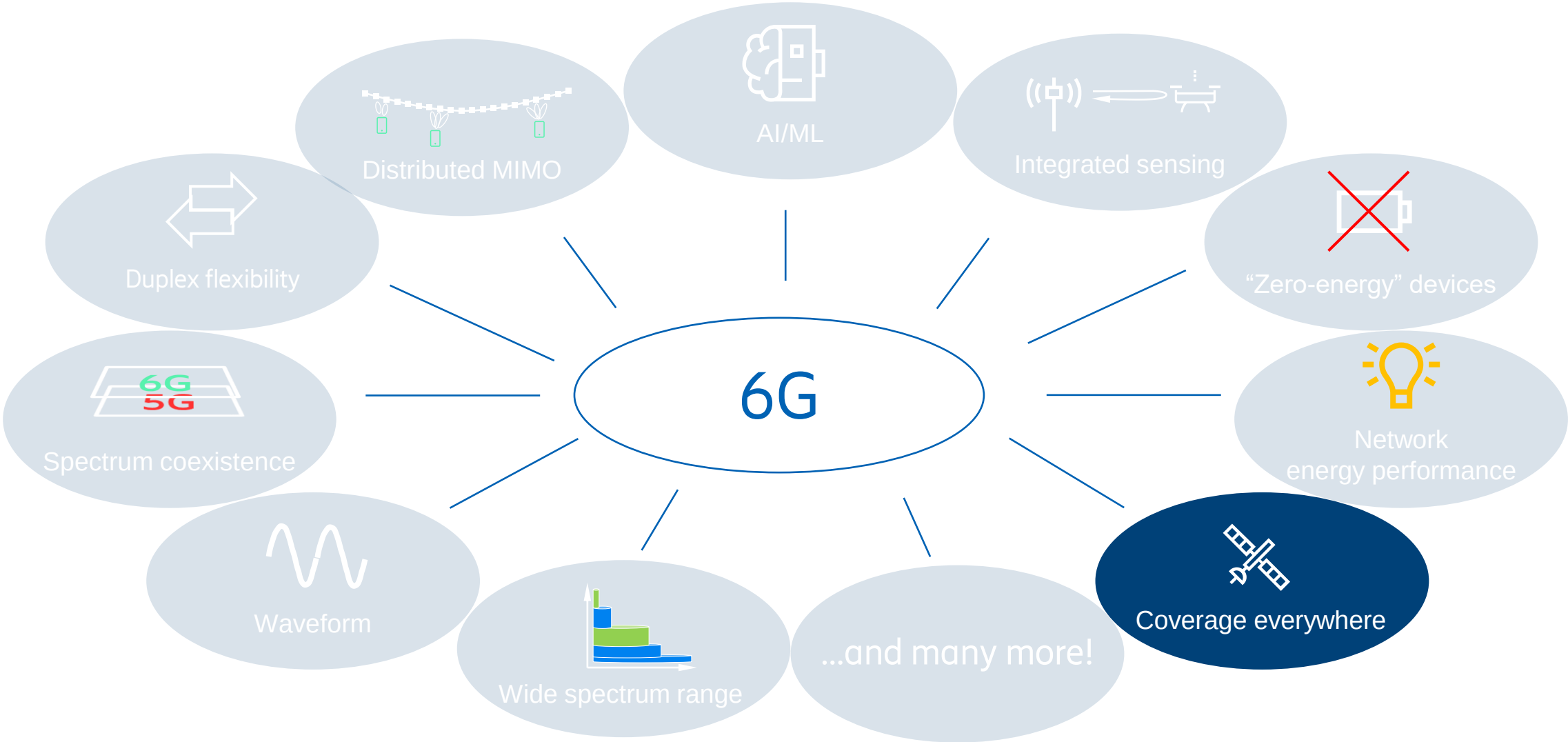


6G

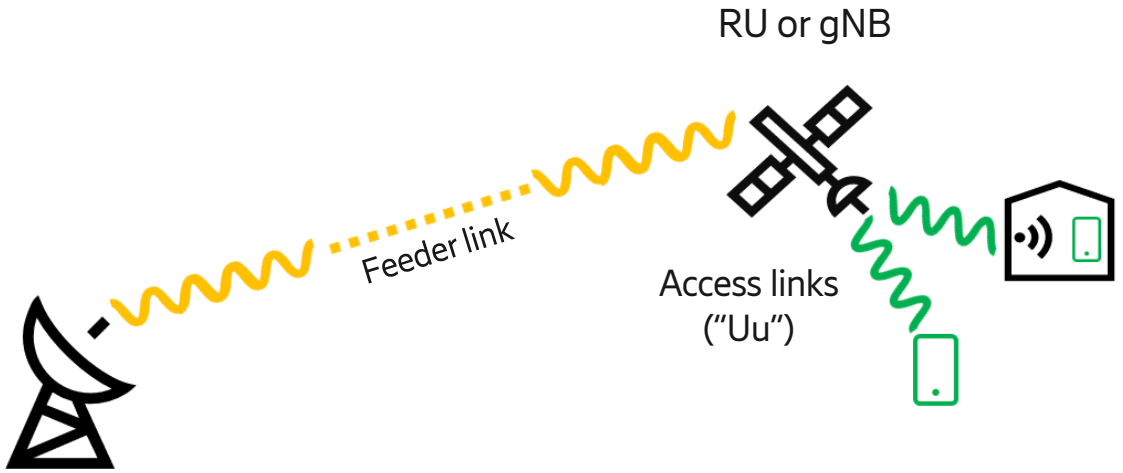
- Separate signals for idle and connected mode procedures
- Enables separate optimization for different states



6G technology components



Non-terrestrial access

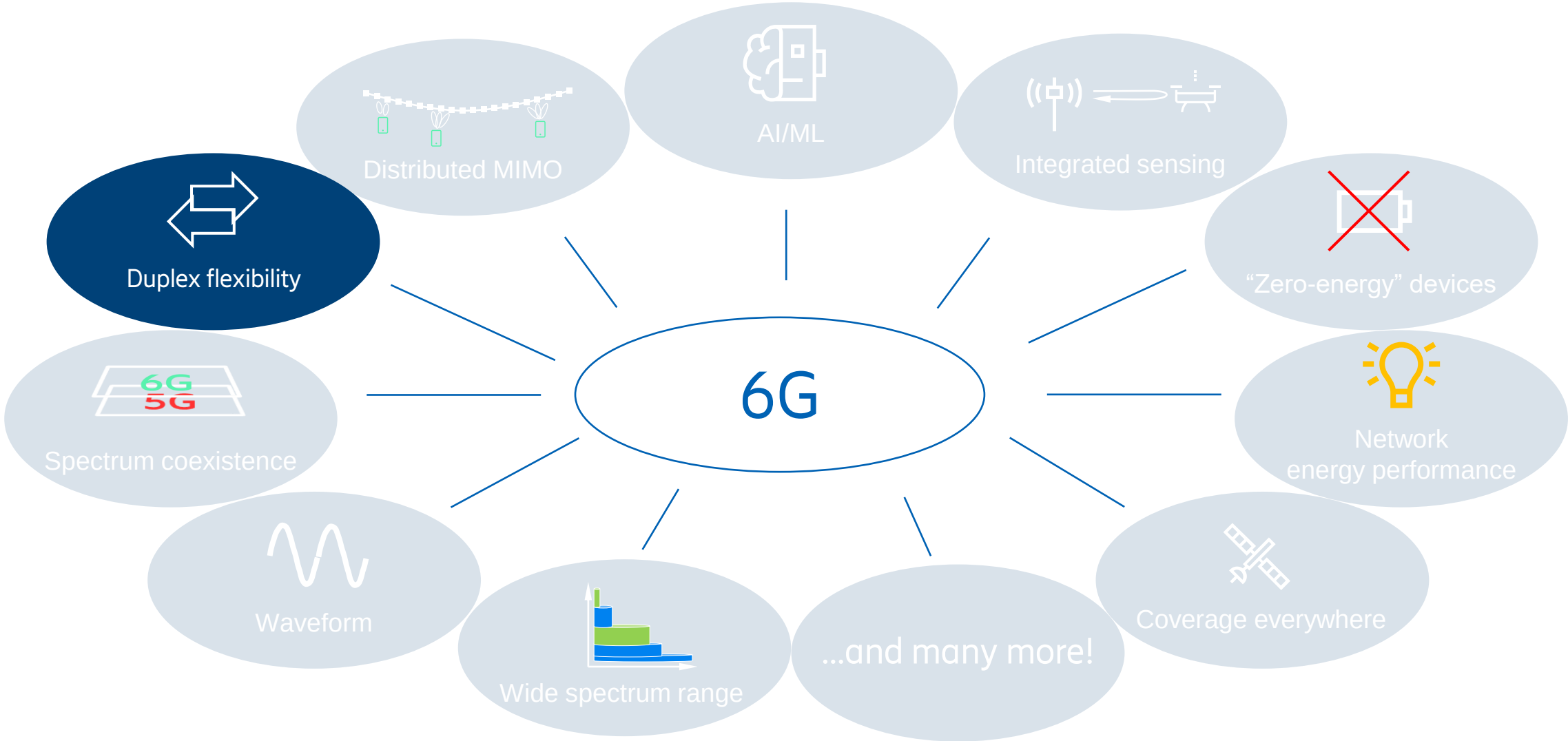


NTN as a *complement* to terrestrial access to provide coverage

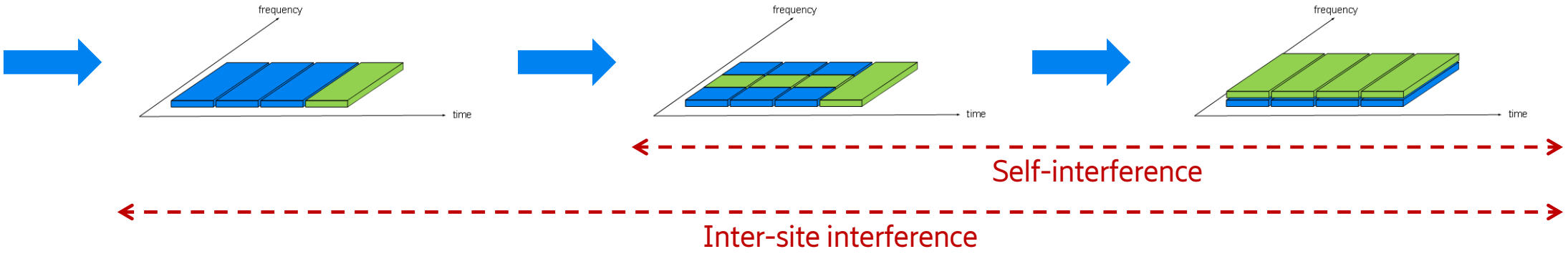
Reuse terrestrial access-link technology for the satellite access link

Allow for either RU or complete gNB to be located in the satellite

6G technology components



Duplex evolution/flexibility



Dynamic TDD

- Inter-site interference needs to be handled before considering the self interference

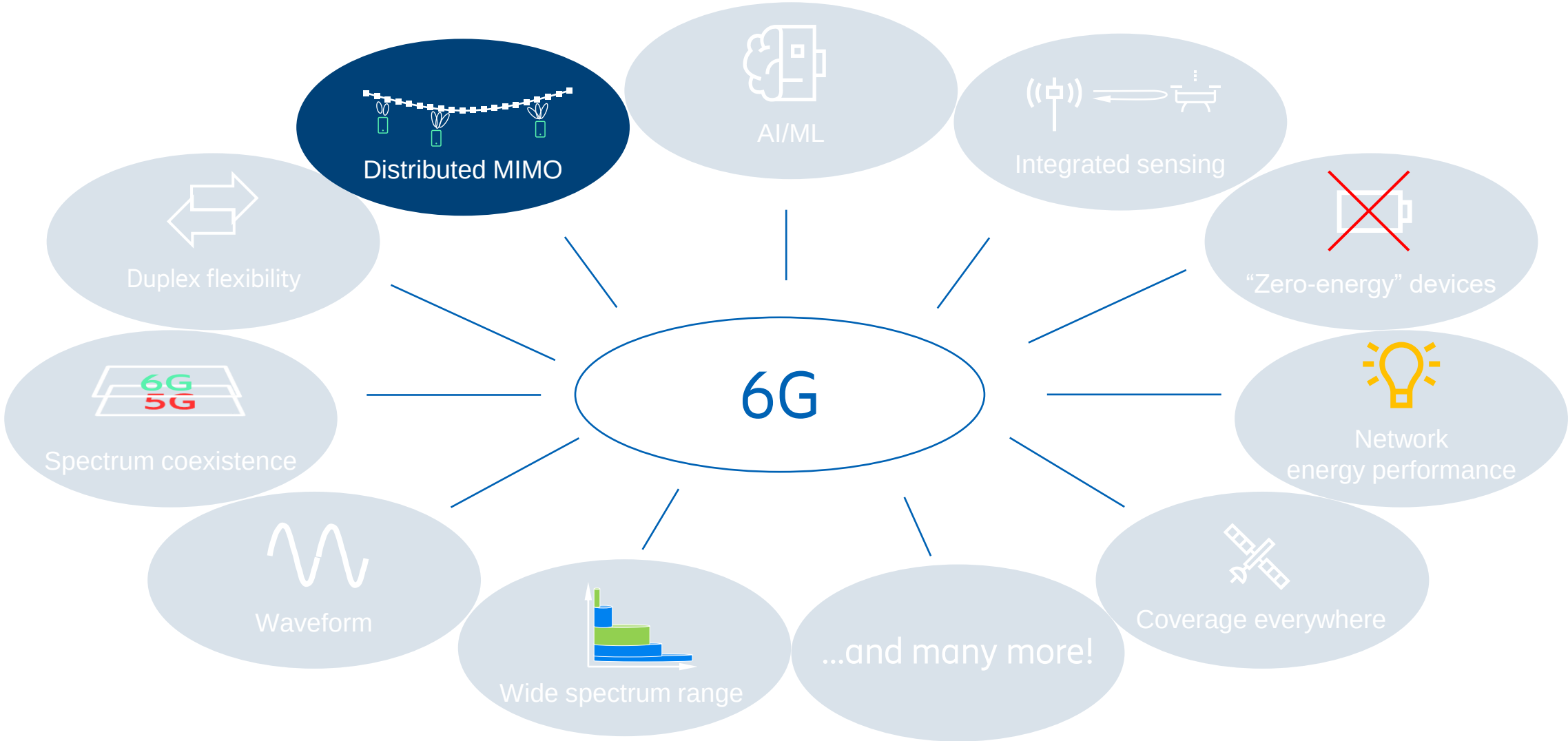
Subband full duplex:

- Possible for low-power nodes

Same-frequency full duplex

- Difficult implementation, limited capacity gain

6G technology components



MIMO in 6G

6G MIMO will build on the 5G MIMO framework

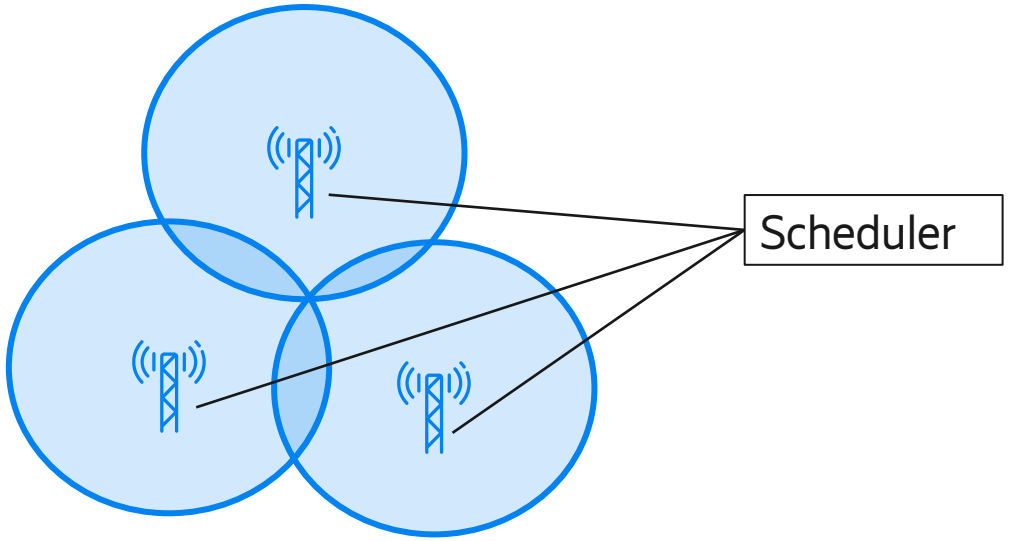
- Massive MIMO will remain important – reuse of current site grid
- Distributed MIMO will increase in importance – useful for dense deployments

"Scalable" design

- Dynamically adapt number of RF chains to reduce energy consumption

Trend towards scheduling across multiple TRPs and carriers

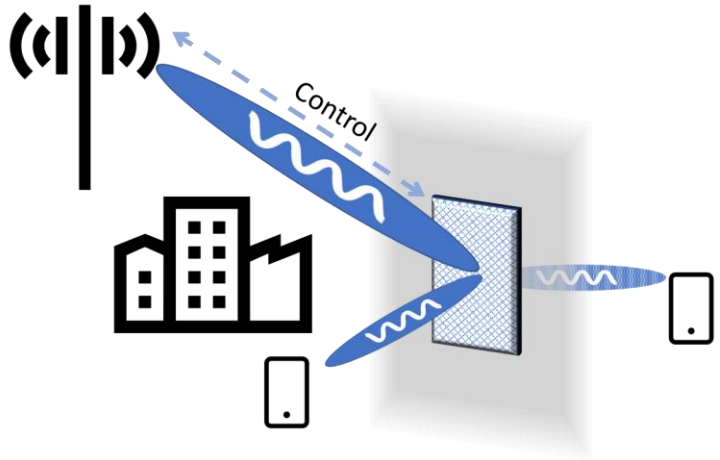
- Largely an implementation aspect but refined signaling structures can simplify coordination
- Improved spectral efficiency, improved energy efficiency, cloud-friendly implementation



Reconfigurable Intelligent Surfaces (RIS)

Surfaces with controllable reflection and/or *transparency/refraction*

- Meta materials or “discrete” elements
- Network control of direction of reflection and/or *refraction*
- Network control of transparency
- …



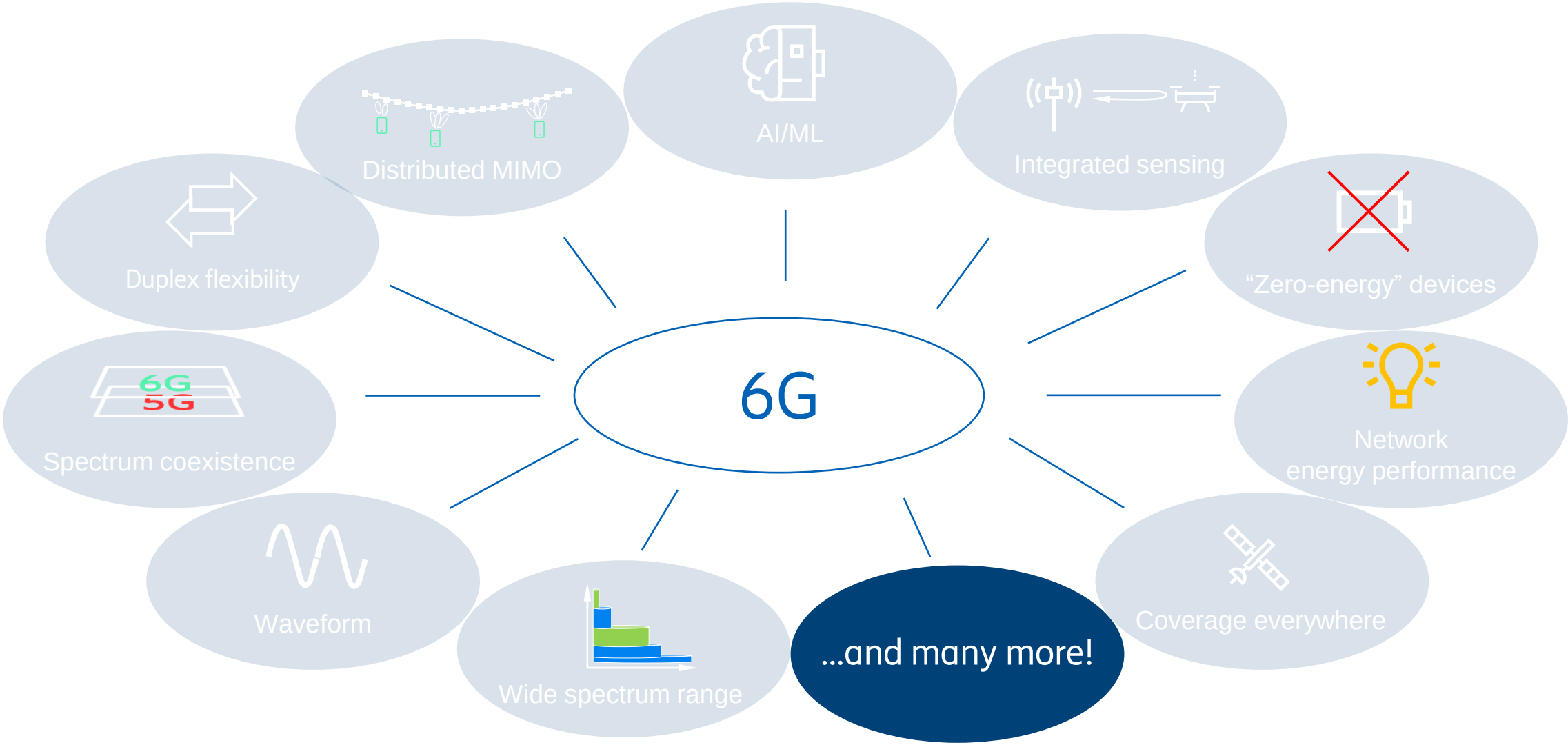
Essentially a smart/controllable repeater with gain < 0 dB

Potential gains are questionable

- Lower cost?
- Regulatory benefits (no active transmissions)?

?

6G technology components

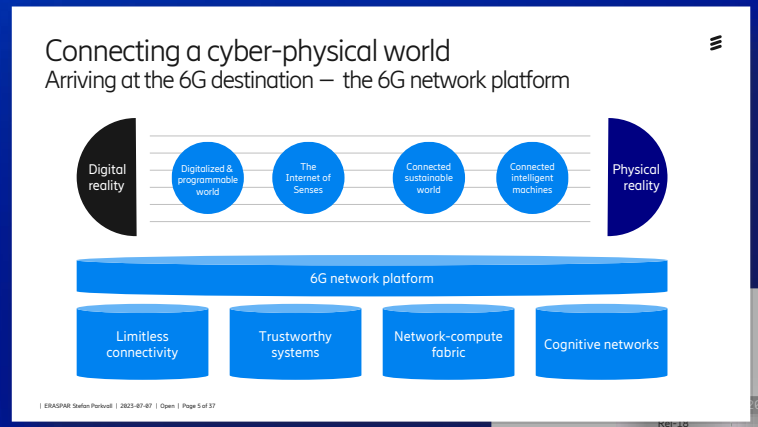


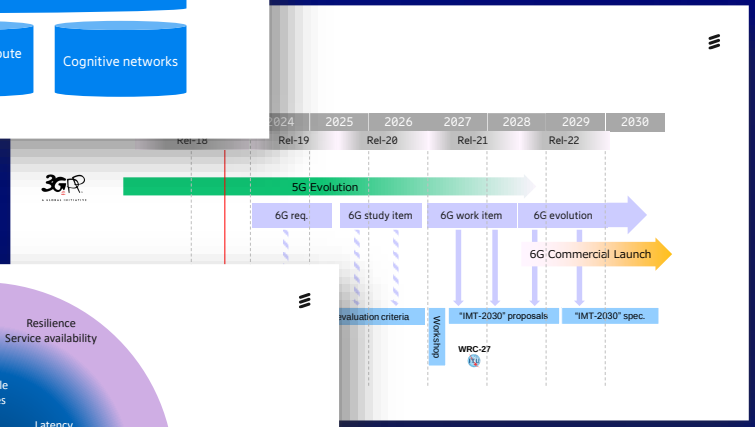
Summary

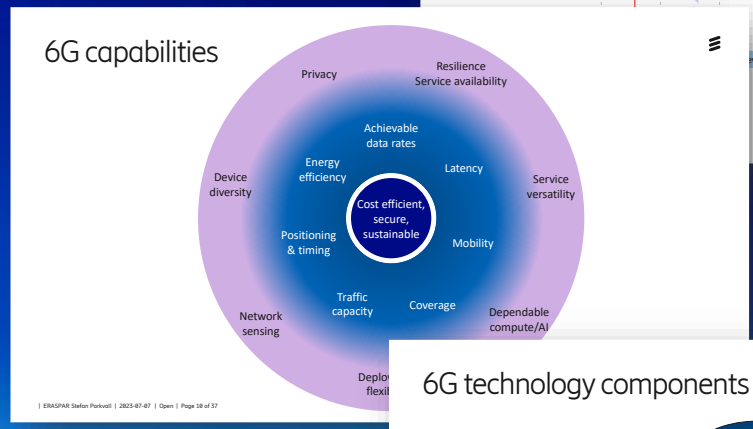
"6G" is the overall platform solution around 2030
Standardization to start in 2024

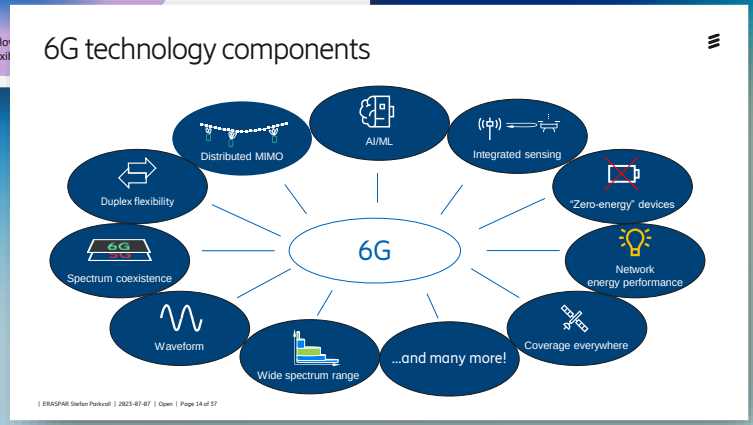
New capabilities for new use cases

Wide range of technologies considered










Countless numbers of sensors in the physical world
nature electronics