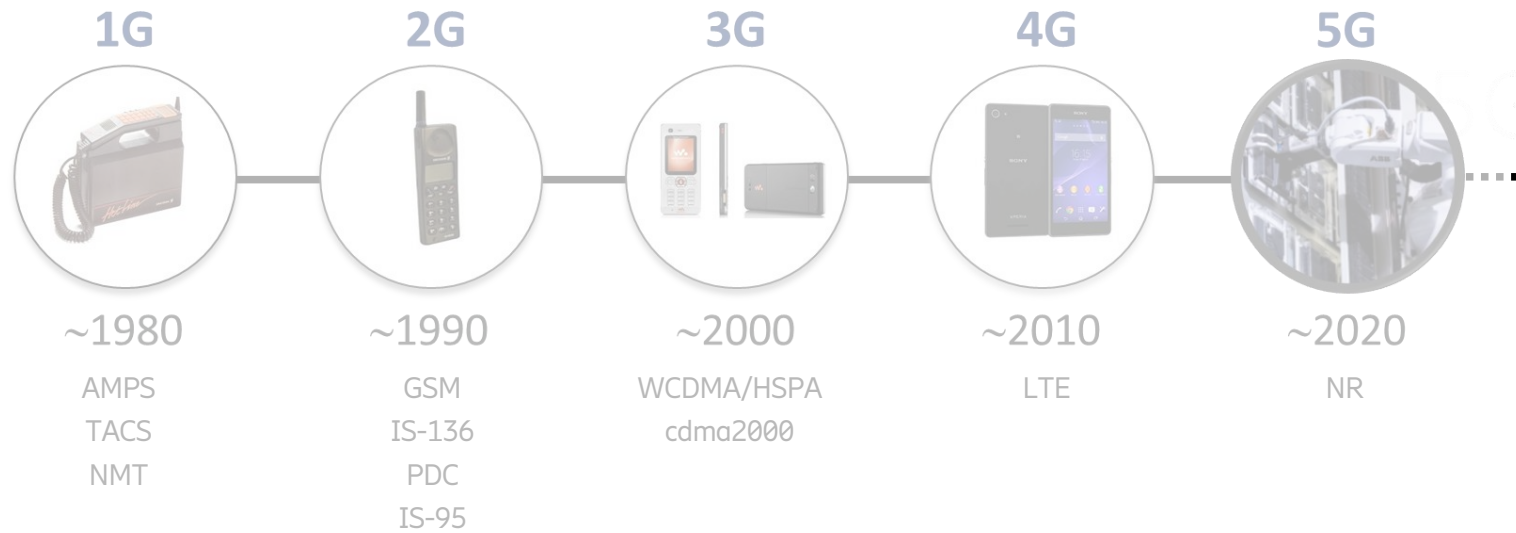




6G wireless connectivity

Something new or more of the same?

Wireless generations



6G – Why, what and how?

What should we focus on?



Don't

- Higher peak rates
- Lower minimum latency
- ...

*Avoid extreme numbers
of no practical relevance !*

Do

- Higher **achievable** data rates
- **Predictable** low latency
- Reliability, availability, resilience, ...
- Improved energy performance
- Lower cost
- ...

Important to understand real-traffic characteristics

Real traffic is bursty



Efficient handling of small packets

- Do not optimize for full-buffer scenarios

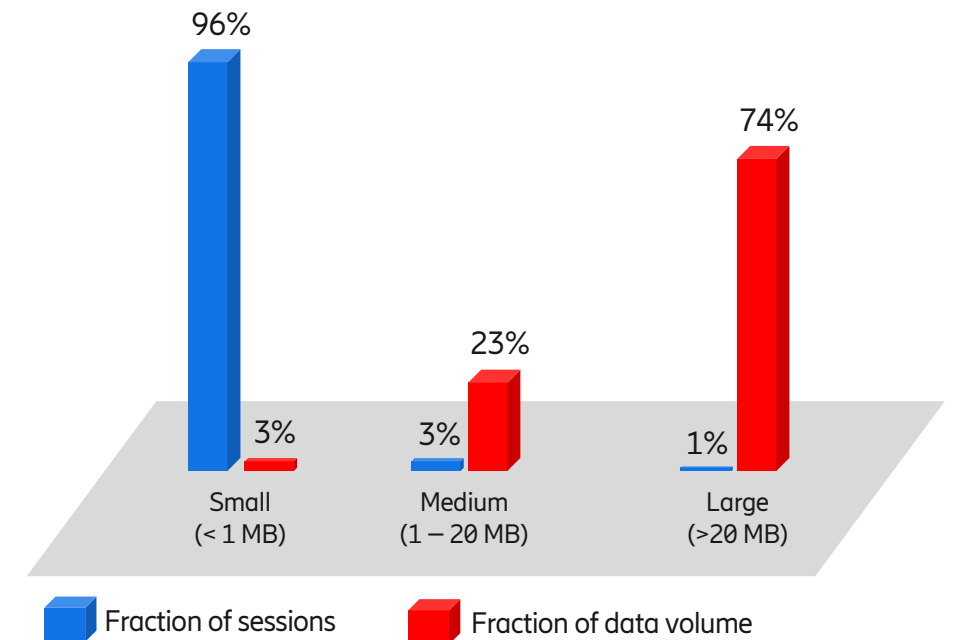
Quickly start transmitting data

- Camp on the right carrier, rapid connection setup, early CSI reports, ...

Spectrum-efficient transmission of large packets

- MIMO, accurate CSI, carrier aggregation, ...

Most sessions (96%) are small
Few sessions (1%) carry most of the data (74%)



6G wireless access



Technology-wise, 6G will inherit much from 5G

Keep things that work well

Waveform, coding, and modulation

No major benefits seen from a radical change of waveform, coding, and modulation compared to 5G NR

- 3GPP should focus on areas with greater potential

MIMO and multi-antenna features

6G MIMO will build on an evolved 5G MIMO framework

- Take learnings from 5G and avoid unnecessary/unused flexibility/complexity

Massive MIMO becoming even more massive

- Support for different architectures (e.g. fully digital hybrid) and for flexible antenna design (e.g. low side-lobe arrays, multi-band antennas)
- Unified MIMO-based CSI reporting (e.g. used Type 1, Type 2, or Type 3...)
- Make reciprocity (SR) based CSI acquisition work in practice (address NR SR implementation problems and foster flexible SR over wide BW)

Multi-TRP becoming interference-aware D-MIMO

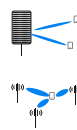
- Support more TRPs than in 5G
 - Increased network deployment flexibility, reduce signaling (e.g. OCL)
 - Location-based or TRP-BS synchronization (SR) based SR
 - Focus on DPS and C/I type solutions and target to maximize SINR instead of only SNR

Lean, dynamic, and energy efficient based MIMO design

- Reduce reference signals and unnecessary transmissions, e.g. combine discovery with DM-RS based CSI measurement
- Dedicated CSI-RS measurement CSI reporting is more an "old school" NR/5G based CSI
- Robustly support dynamically adaptation of number of active RF chains to reduce network energy consumption
- CSI using [sustainable solutions](#) (flexible and adaptable report content with minimum size effort)

UL MIMO

- Codebook based, non-coherent PUSCH
- Low PAPR design (including DFT-s-OFDM) for all PUSCH formats



Change when motivated

Scheduling and control signaling

Processing timeline – avoid scheduling complications from 5G's multiple timelines

- Long CSI reporting time, in-order scheduling of PUSCH
- Scheduling PDSCH based on CSI measurement before transmission report to MAC/PCF



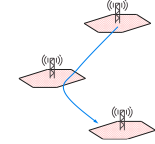
Unified mobility

Unified measurement framework (merge RRM- and L1-CSI measurements)

- Configuration of reference signals (CSI-RS, SSB...)
- Configuration of report formats, conditions/triggers
- Measurement reports (see Unified Uplink Reporting)

Unified mobility mechanism

- Combine L3 + CHO + LTM into a single, unified mobility mechanism, i.e., ...
 - Different ways to switch the UE's set of reference signals (for sync, measurements, OCL)
 - Optionally, reset/reestablish protocols, trigger RA...



Discuss means to accelerate HO execution

- Keep critical parts of the UE configuration unchanged
- Indicating properties (tight sync of source and target; shared OCL properties...) if beneficial for the UE

Procedures, measurements and conditions ready for using mobility to provide resilience

Mobility measurements in idle and connected mode may use separate signals

- Exemplar 1-SSB for idle mode and M-SSB for connected mode

Add functionality for new use cases

Integrated sensing

To enhance network performance and create new end-user services



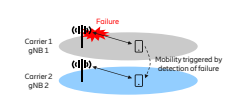
Resilient communications

New business models and monetization opportunities based on service-level agreements require that CSPs assure high connectivity service availability. The necessary resiliency is realized by means of:

- Efficient and cost-effective redundancy to minimize the impact of failures
- Fast detection of failures and failover options

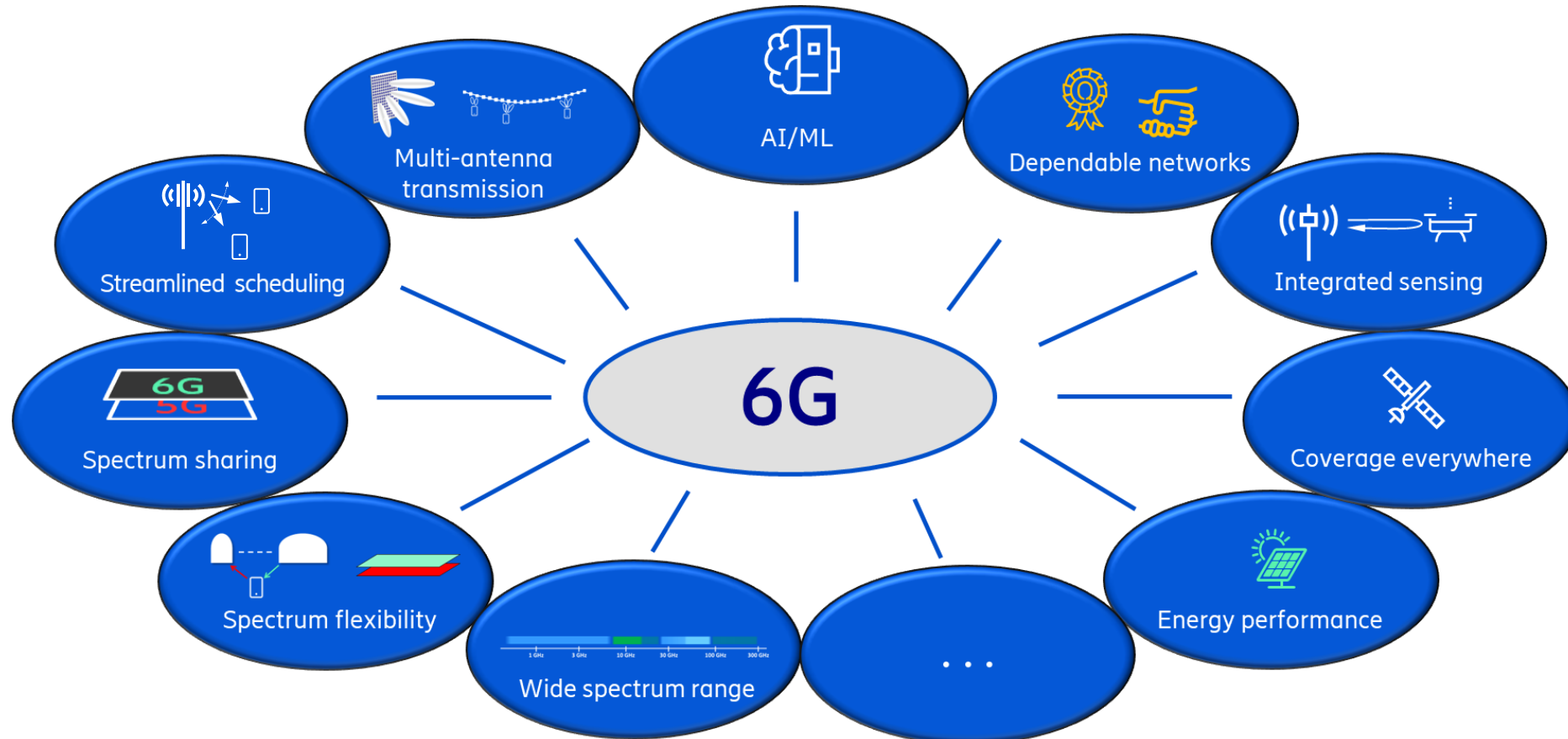
Resilient communications is enabled by 6G features for preventing and reducing service interruption time (e.g., due to link or functional failure):

- Improved [observability](#) including measurements and reports for failure detection, enabling proactive actions
- Robust [spectrum aggregation](#) providing alternative radio links (e.g., with minimal/no PCeI/SCell distinction; CA from non-collocated RUs)
- [Multi-TRP](#) for spatial redundancy
- [Mobility and RLM procedures](#) allowing for handing over UEs from a failing carrier to a well-functioning one



6G wireless access

Some important technology components



Spectrum for 6G

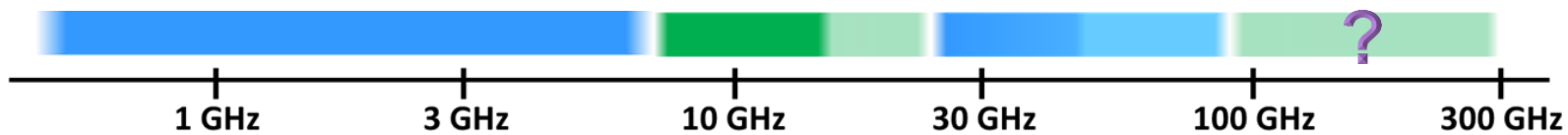


Current 4G/5G spectrum

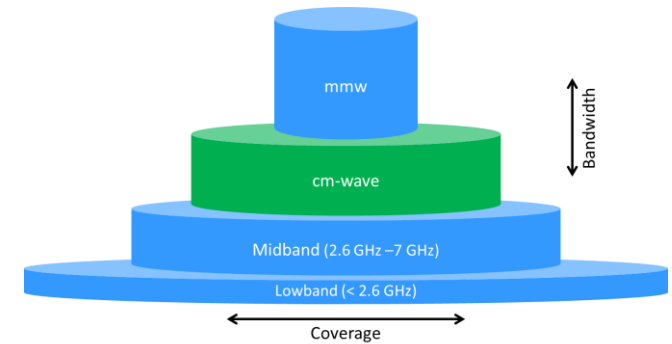
- Below 7 GHz
- mmw

New 6G spectrum

- cm-wave – “the new 6G band”
- Sub-THz?



A coverage vs bandwidth trade-off



Limited amount of *new* 6G spectrum

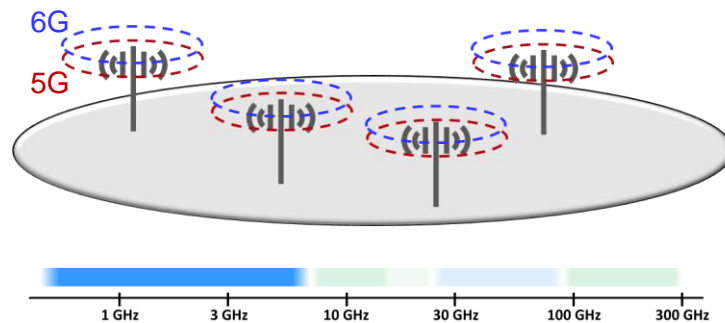
Spectrum sharing



5G/6G spectrum sharing

Allow for 6G to be deployed on top of 5G

⇒ *Smooth introduction of 6G in existing spectrum*



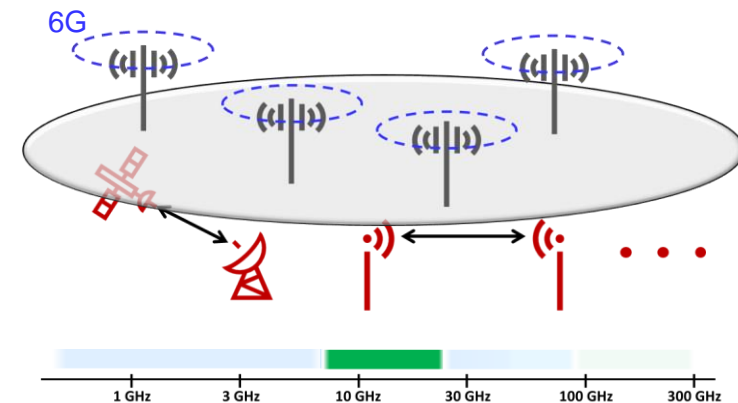
Need for 5G-compatible 6G waveform

Efficient spectrum sharing enabled by 5G "lean design"

Co-existence with other usages

Enable 6G deployment on top of other technologies

⇒ *Smooth access to new spectrum*

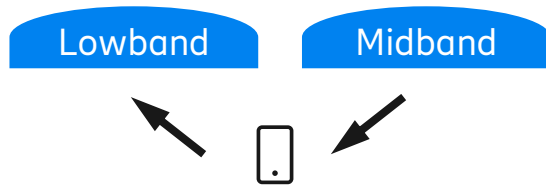


Spectrum flexibility



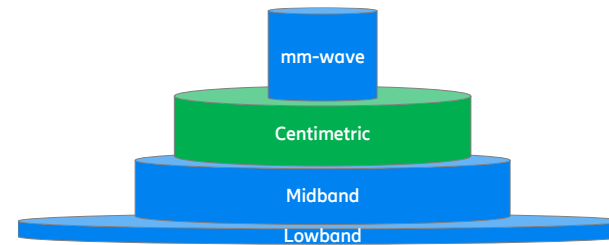
UL-DL decoupling

Best DL band might not be best UL band



Multiple bands at each site

System view – not per-carrier view



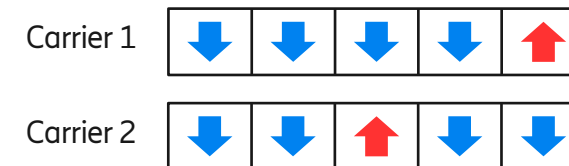
Dynamic TDD and full duplex

Potential for reduced latency
Only feasible for small cells



Staggered TDD aggregation

Potential for reduced latency

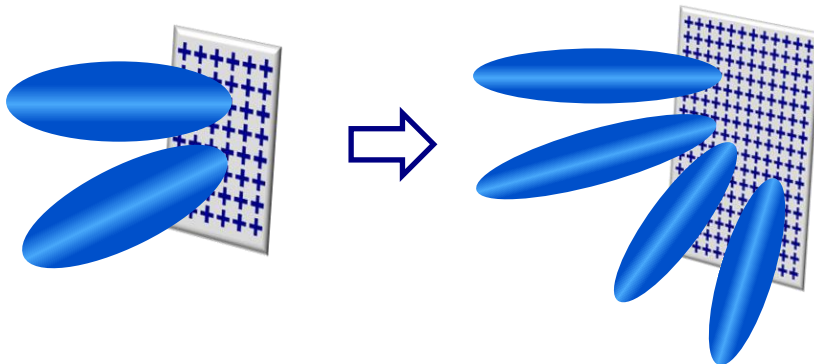


Multi-antenna transmission



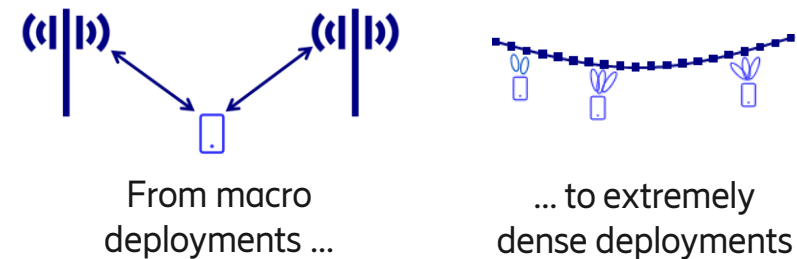
Remains a main tool to enhance link performance within current grid

Even larger arrays



Physically larger antenna constellations
More antenna elements for a given area

Multi-point transmission ("distributed MIMO")



From macro
deployments ...

... to extremely
dense deployments

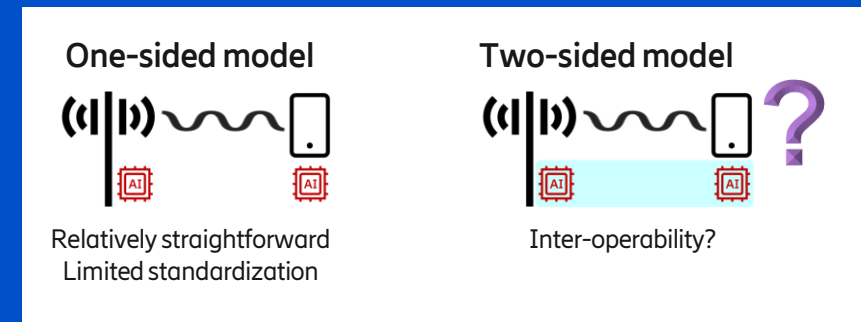
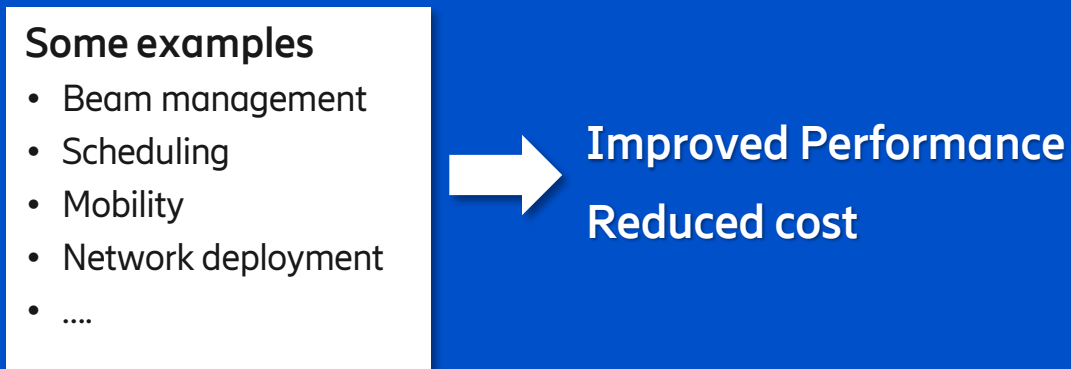
Enables more uniform quality
over the coverage area

AI for communication – where, when and how?



High-dimensional problems for which

- there is no good model
- deriving the “optimal” solution is difficult/impossible



Mainly implementation with limited specification impact

Mission-critical connectivity and dependable networks

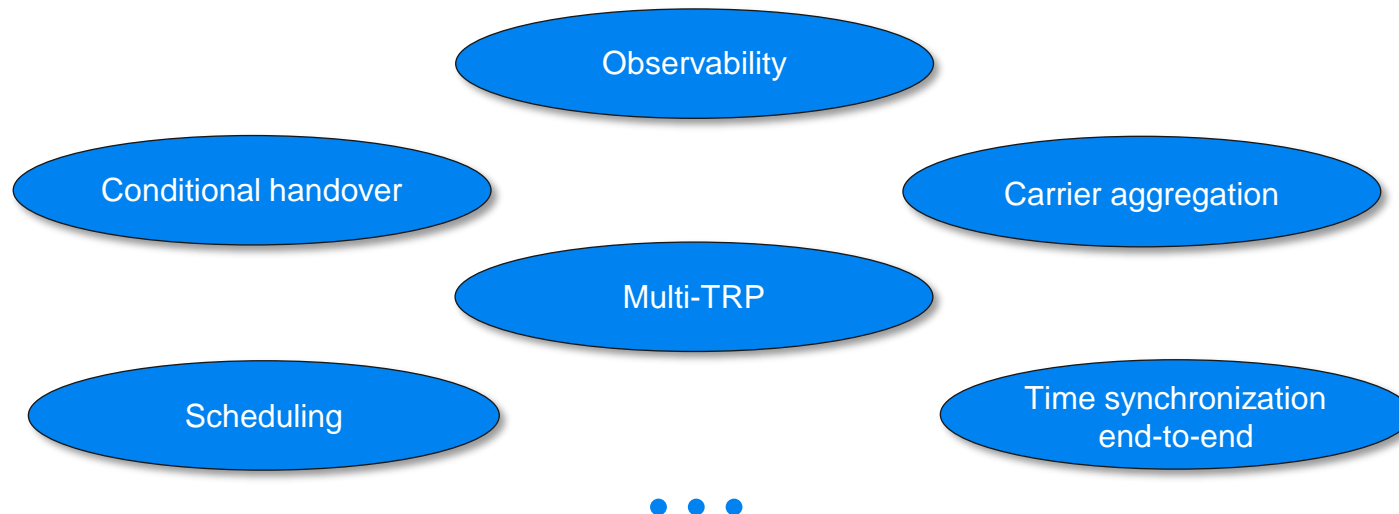


A high-performance network that one can truly trust and depend on

Observability to detect problems before they happen

Redundancy to ensure availability

Synchronization to enable extreme time-critical services



- Public networks
- Highly automated vehicles
 - Professional video production
 - Managed IT devices
 - ...

- Dedicated networks
- Manufacturing
 - Mining
 - Connected workers
 - ...

Integrated communication and sensing

“Situational awareness”

Sensing: Detect the presence/location/movement of passive objects

ICAS: Sensing as an integrated part of the communication network

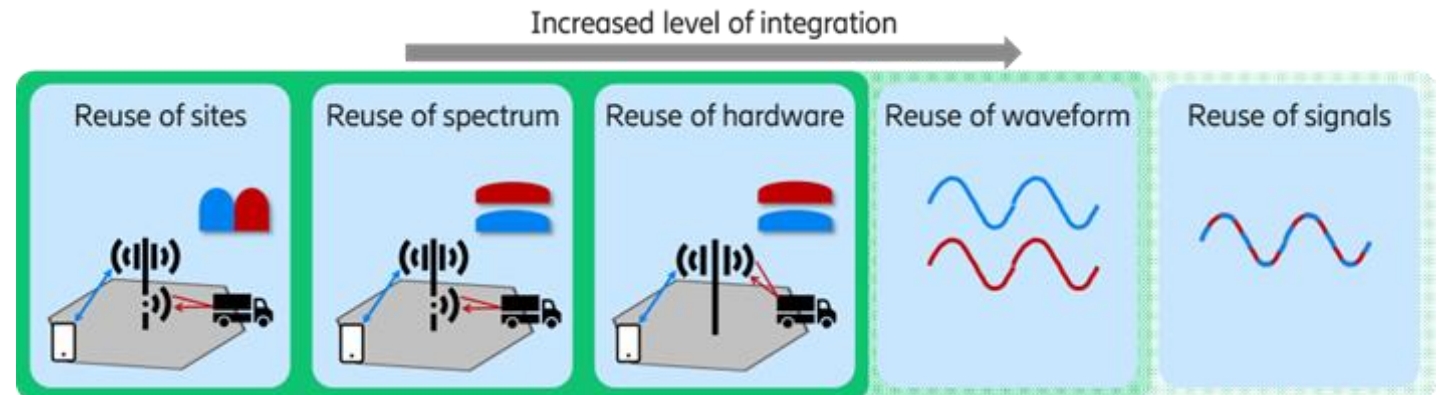
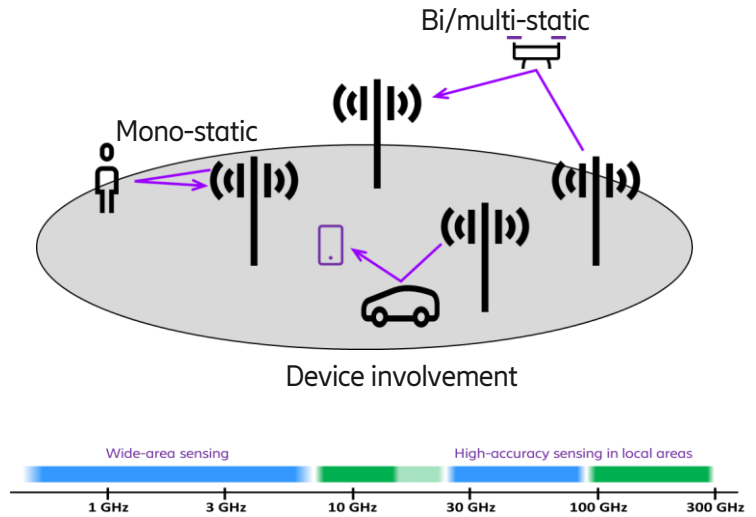
- Reuse of communication resources (infra-structure, spectrum, devices, ...) for sensing



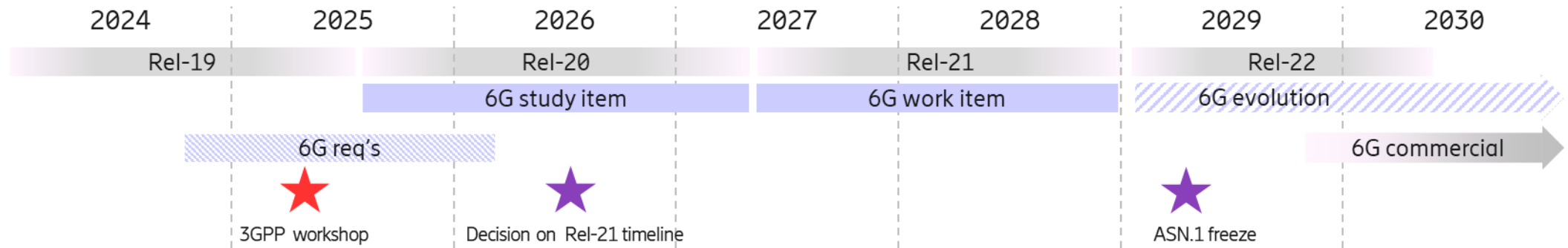
Introduction of sensing functionality with low incremental cost

Enable new/enhanced services

Enhanced network performance



6G wireless access – Standardization timeline



Summary



6G will inherit much from 5G

- Keep when working well, change when motivated, add features enabling new use cases
- Avoid spending time/effort on solving already solved problems

6G will further extend the capabilities of wireless access

- Dependable communication, situational awareness, ...

6G standardization activities have started

6G is critical to ensure the long-term evolution of wireless connectivity

Thank you!

