6G: Does it need to be Evolutionary?

Ajay Rajkumar

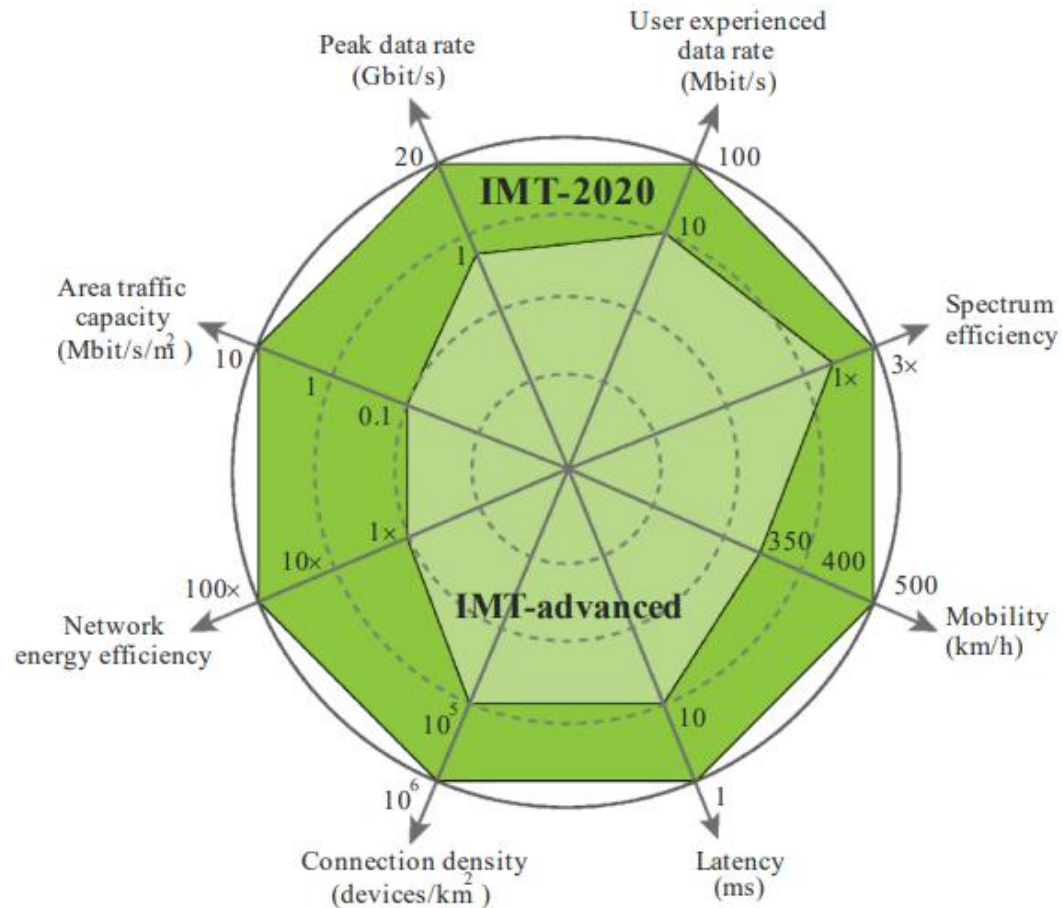**Milap Majmundar**

AT&T Labs

First ACM/IEEE Next G Summit
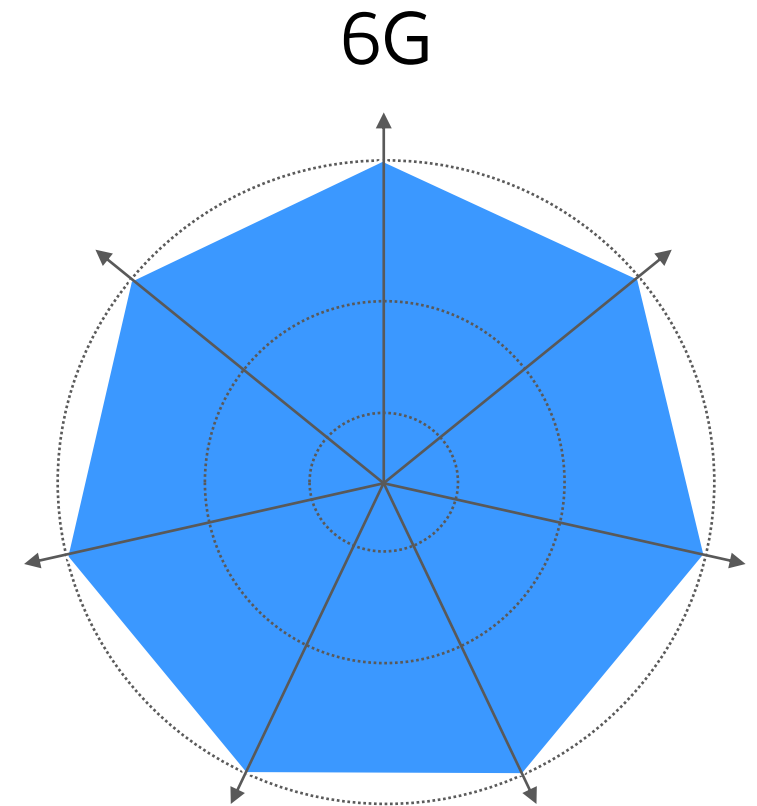**Johns Hopkins University/Applied Physics Lab**
June 14, 2022

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6G Design Requirements

Recommendation ITU-R M.2083-0

More of the same?

6G

New demands on 6G warrant a fresh look at 6G design requirements!

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* 5G-Advanced features for R18 finalized in Dec 2021 and R19+ is TBD

Key Goals for 6G Network

Trustworthy
- Secure
- Trusted
- Resilient
- Reliable
- Private
- Seamless

Efficient
- Green
- Spectrally efficient
- Energy efficient
- Cost efficient
- Innovative

Intelligent
- Designed natively to leverage AI and ML techniques
- AI-based protocols, mobility, resource allocation, security, etc.
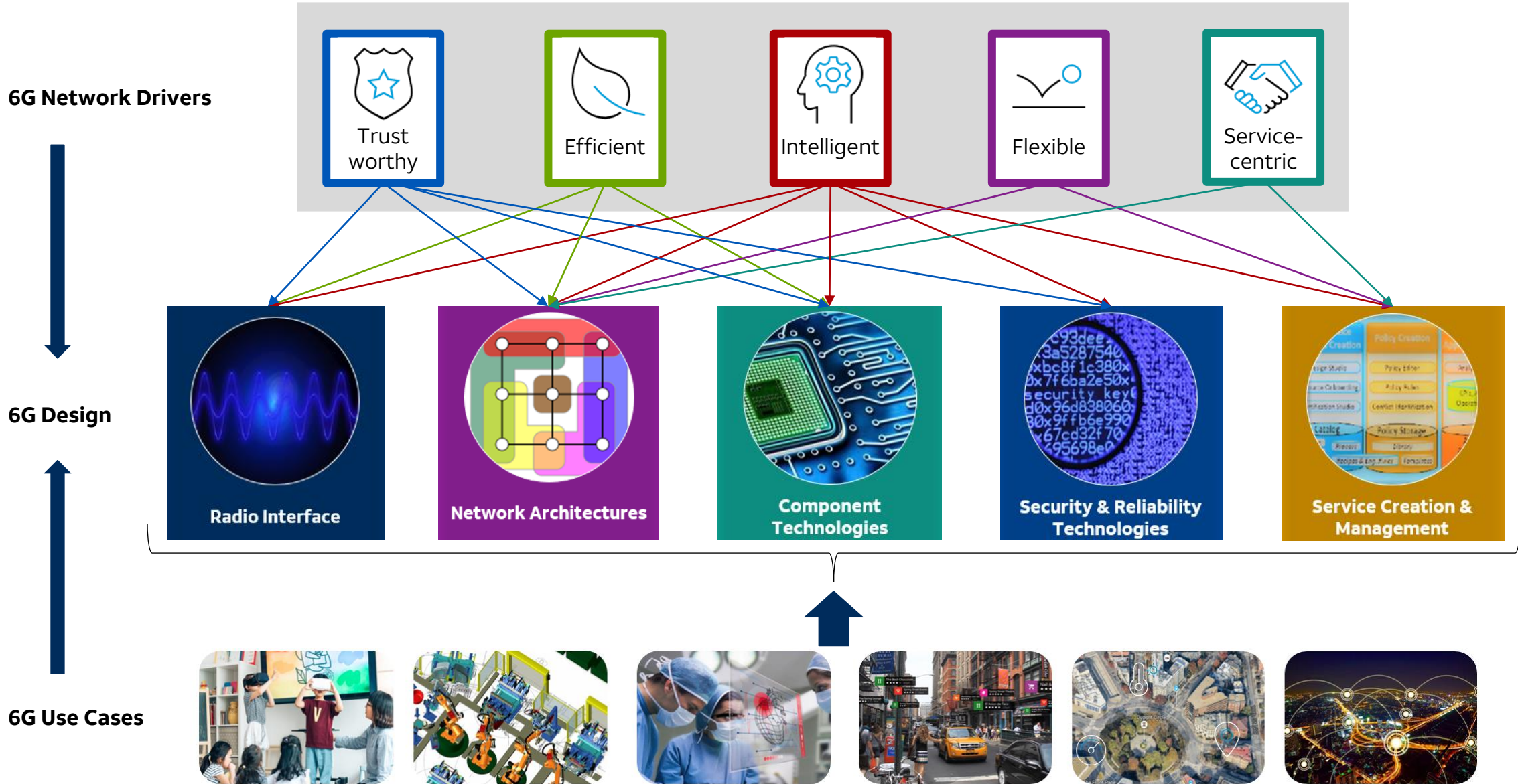
Flexible
- Massively scalable
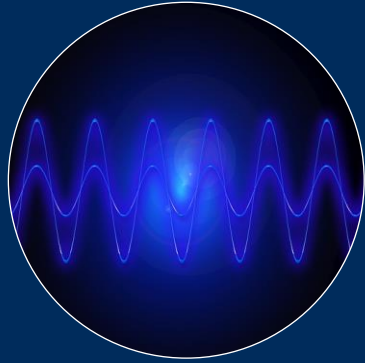- Flexible
- On-demand
- Cloud-native
- Open

Service-centric
- Service mgmt.
- Per user/app service profiles
- E2E
- Data analytics
- Deep learning

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6G Design Drivers

6G Network Drivers

Trust worthy · Efficient · Intelligent · Flexible · Service-centric

6G Design

Radio Interface · Network Architectures · Component Technologies · Security & Reliability Technologies · Service Creation & Management
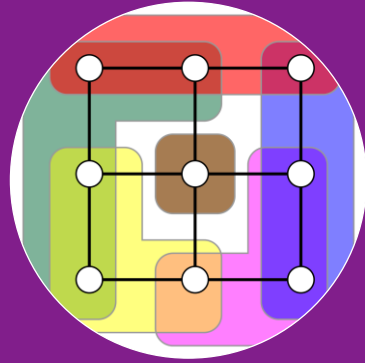
6G Use Cases

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Major 6G Technology Enablers

Radio Interface

New MIMO Techniques, Green Network Technologies, New Duplexing Schemes, New Waveform, Coding, Modulation & Access, Native AI/ML Design, Mesh/Sidelink, Joint Communication & Sensing, FR1/mmWave/sub-THz

Network Architectures

Convergence of RAN & Core Open IFs/APIs, Open-source SW, Commodity HW, HW-SW Disaggregation, Heterogeneous Cloud Architectures, On-Demand Distributed Compute Fabric, 6G as Communication & Compute Platform, Dynamic Topology Adaptation
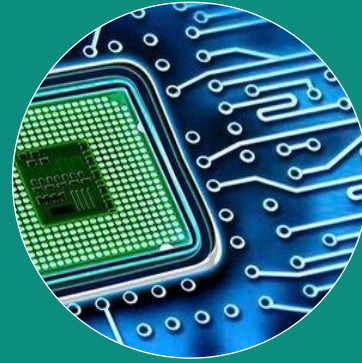
Component Technologies

New Sensor Technologies, 3D Holography and Immersive Displays, New Battery Technologies, Heterogeneous Components, Nanotechnology Components, New RF Transceiver and Antenna Technologies

Security & Reliability Technologies

Flexible Security Architecture, Trusted HW and SW Identities, E2E Privacy, Data Protection, Real-Time Threat/Fault Detection & Recovery, Air Interface Security, AI/ML-based Security and Trust

Service Creation & Management

Intent-Based Service Orchestration & Management, E2E Service Management, AI/ML-based Automated Network Adaptation, Service-Aware Interfaces & Nodes
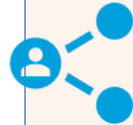
# Radio Interface for Frequencies Ranging <1 GHz to Sub-THz

Waveform, Coding and Modulation

Fully digital, linearly scalable massive MIMO using ultra low-resolution ADCs/DACs

New waveforms and system design, exploiting non-linearities for ultra-low power and cost

Distributed Massive MIMO / Advanced Massive MIMO

100s of separated antenna arrays coherently and jointly serving many users

New channel acquisition frameworks for CSI

Ultra-high massive MIMO and area throughput
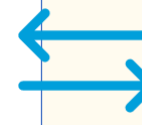
Full Duplex Operation

In-band simultaneous Tx/Rx (single or multi-panel)

Double spectral efficiency & reduce latency

Analog + digital self-interference cancellation

Native full duplex system design

Joint Communication and Sensing

6G network capable of RF sensing

Ultra high accuracy localization and tracking

New waveform/ reference signal design

Spectrum Sharing and Medium Access

New medium access mechanisms in new spectrum bands

Techniques to coexist in unlicensed bands

Mechanisms to share with dissimilar systems

Native AI/ML Design

AI/ML-aware RAN nodes and devices

Continuous AI/ML-based adaptation and optimization of radio resource management, signaling and protocols

Metaverse-related RAN Enhancements

RAN enhancements to support eXtended Reality (XR) and Virtual Reality (VR) services

Service-aware cross-layer optimization

Seamless Connectivity

Mesh and hierarchical topologies

Inherent trust, security and resiliency

Terrestrial, aerial and non-terrestrial links
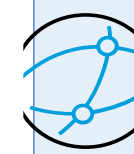
Service-Centric Protocols and Interfaces

Dynamic routing at the edge

Flexible intra- and inter-stack coordination

On-demand RAN resource provisioning

Green Communications

Less stringent linearity requirements

ON/OFF techniques in time/frequency/space

Zero-energy devices and energy harvesting

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6G Spectrum – From <1 GHz to Sub-THz!

Deep Coverage , Low-Res Sensing ←——————————————————→ **Massive Capacity, High-Res Sensing**

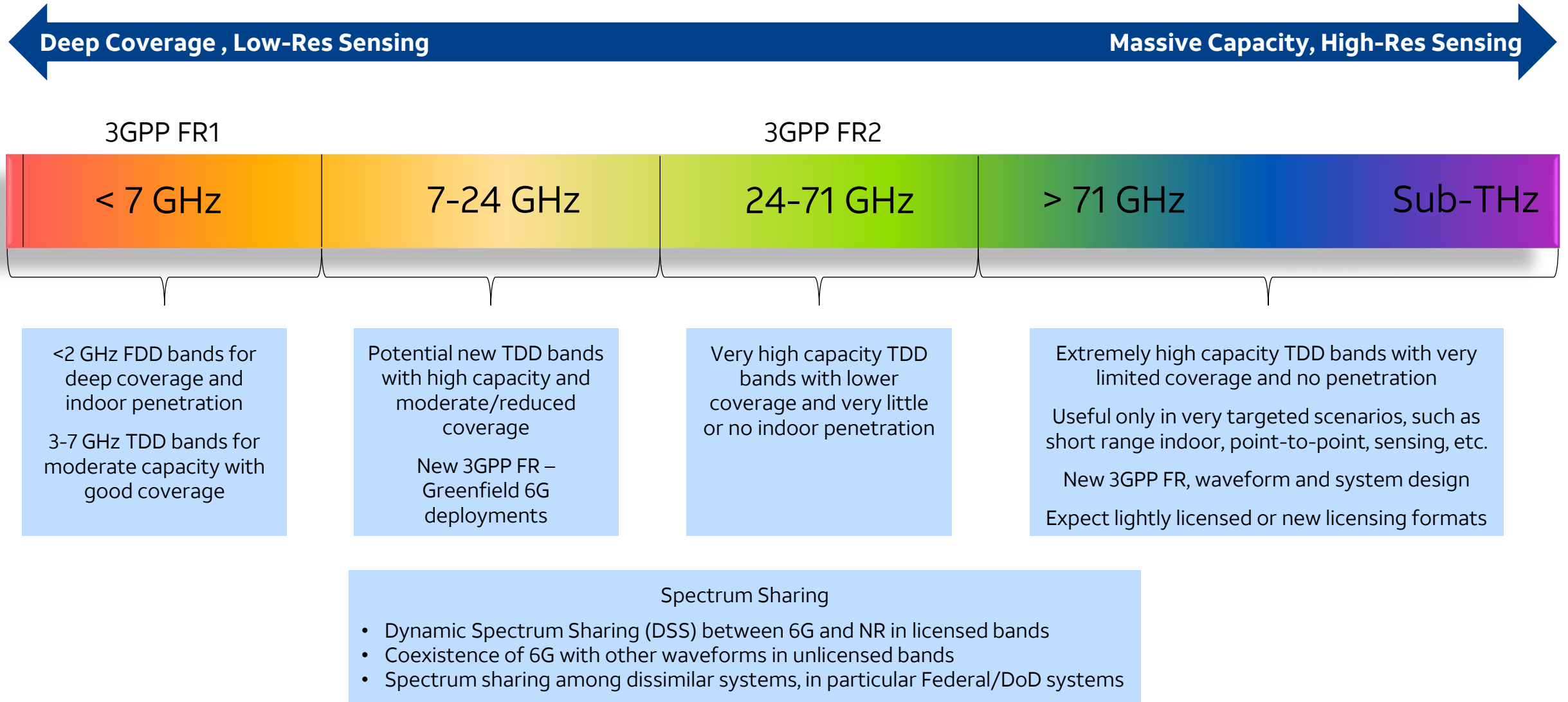| 3GPP FR1		3GPP FR2	
< 7 GHz	7-24 GHz	24-71 GHz	> 71 GHz Sub-THz

< 7 GHz:
<2 GHz FDD bands for deep coverage and indoor penetration

3-7 GHz TDD bands for moderate capacity with good coverage

7-24 GHz:
Potential new TDD bands with high capacity and moderate/reduced coverage

New 3GPP FR – Greenfield 6G deployments

24-71 GHz:
Very high capacity TDD bands with lower coverage and very little or no indoor penetration

> 71 GHz:
Extremely high capacity TDD bands with very limited coverage and no penetration

Useful only in very targeted scenarios, such as short range indoor, point-to-point, sensing, etc.

New 3GPP FR, waveform and system design

Expect lightly licensed or new licensing formats

Spectrum Sharing
- Dynamic Spectrum Sharing (DSS) between 6G and NR in licensed bands
- Coexistence of 6G with other waveforms in unlicensed bands
- Spectrum sharing among dissimilar systems, in particular Federal/DoD systems

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