RIT

6G Upper Mid-band Technology and Spectrum

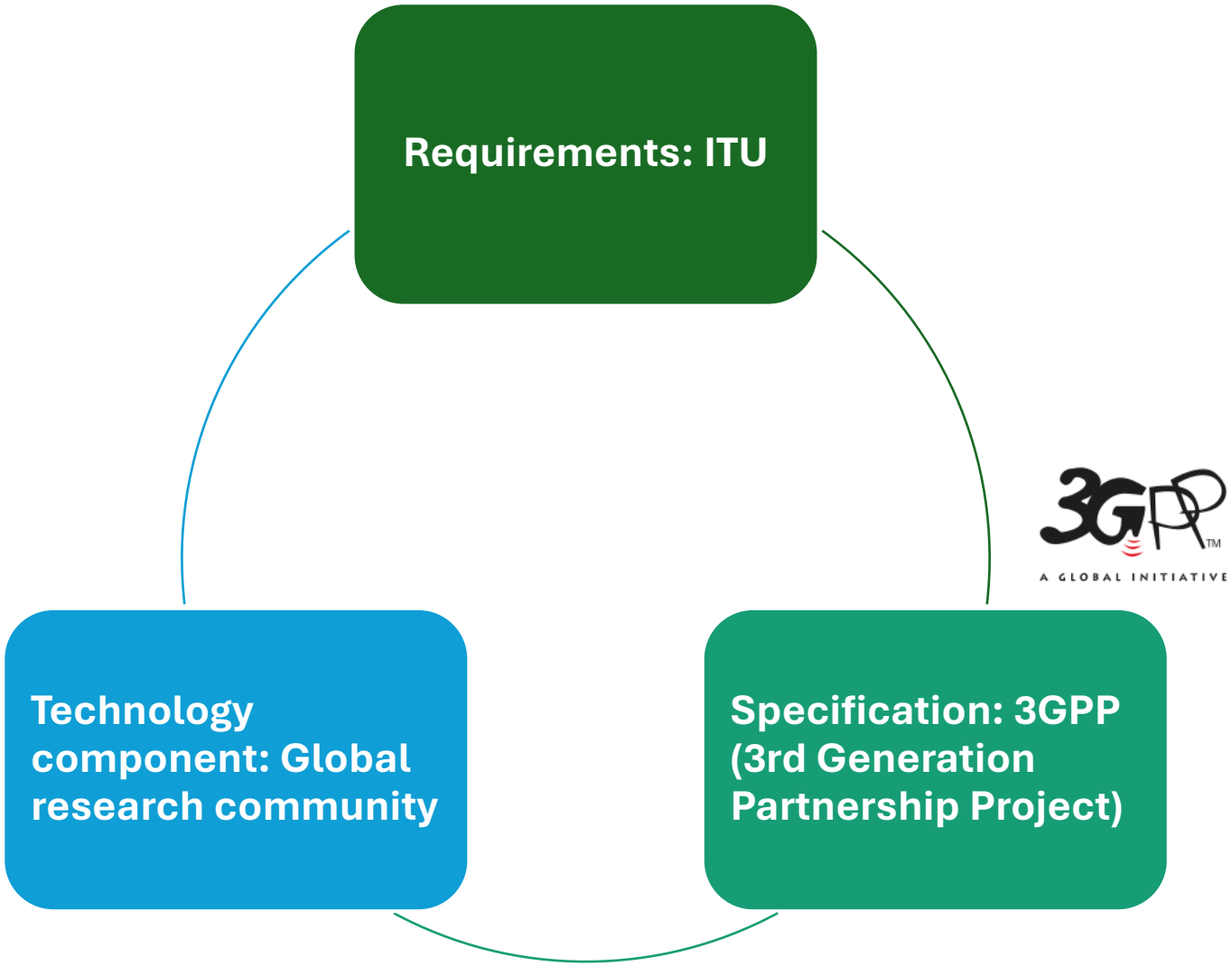
Shima Mashhadi

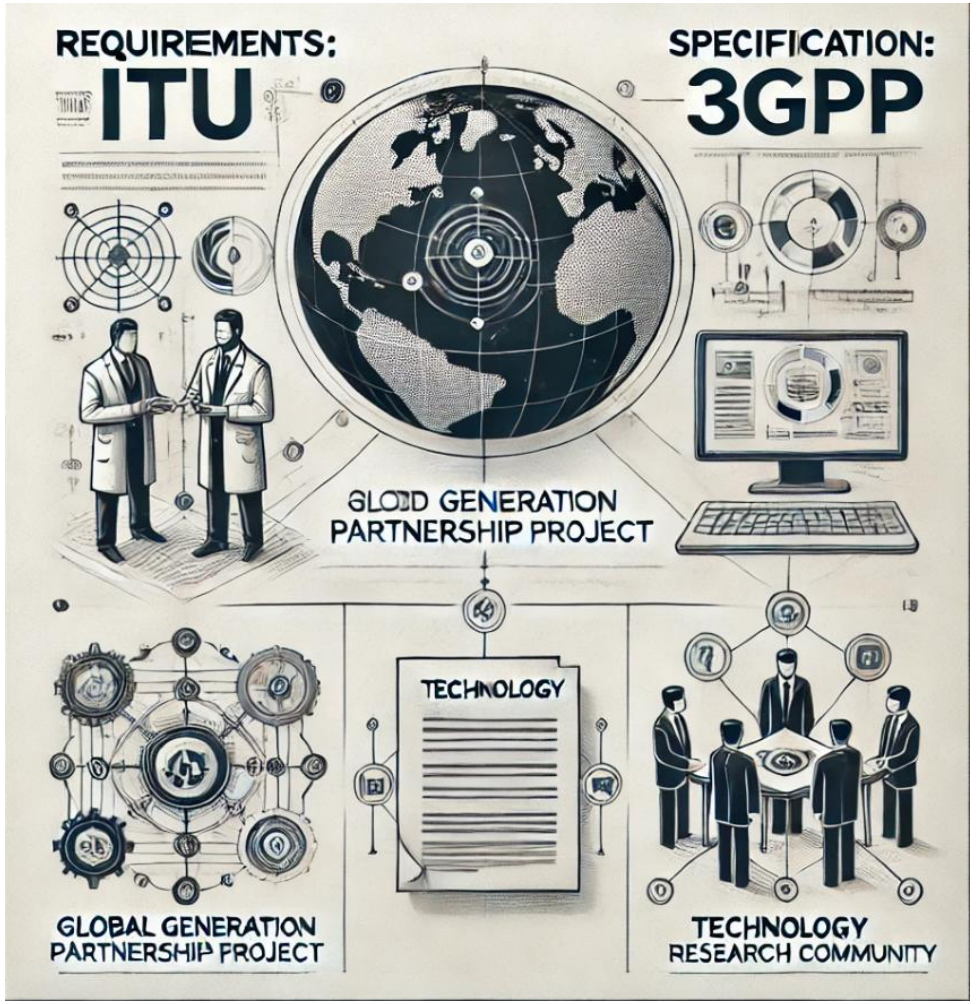
Jan 2025

Topics To Covers

- 6G Technology
  - 6G usage and capabilities
  - 6G spectrum
- Upper Mid-band Outdoor Coverage
- Upper Mid-band Services
- Upper Mid-band Spectrum Sharing

Key Players in 6G Development





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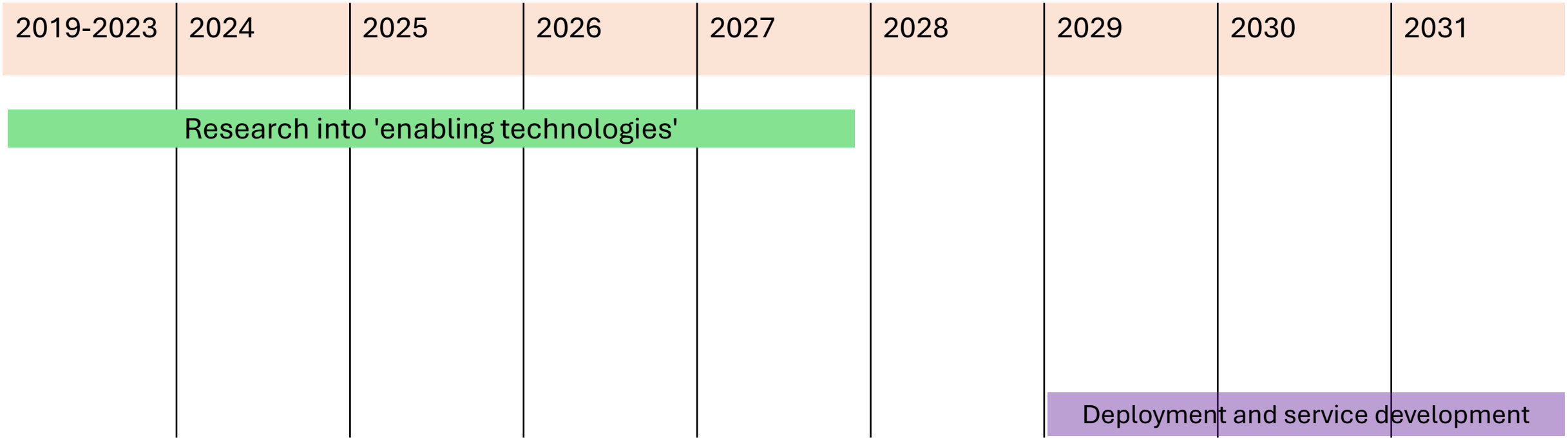
The pathway to 6G Development

- Requirements: ITU
- Specification: 3GPP (3rd Generation Partnership Project)
- Technology component: Global research community



https://www.ericsson.com/49ac9c/assets/local/reports-papers/white-papers/2024/6g-spectrum.pdf
Why it's a great time to start talking 6G - Ericsson
6G standardization timeline and principles – Ericsson
6G: What, why, and how? - YouTube

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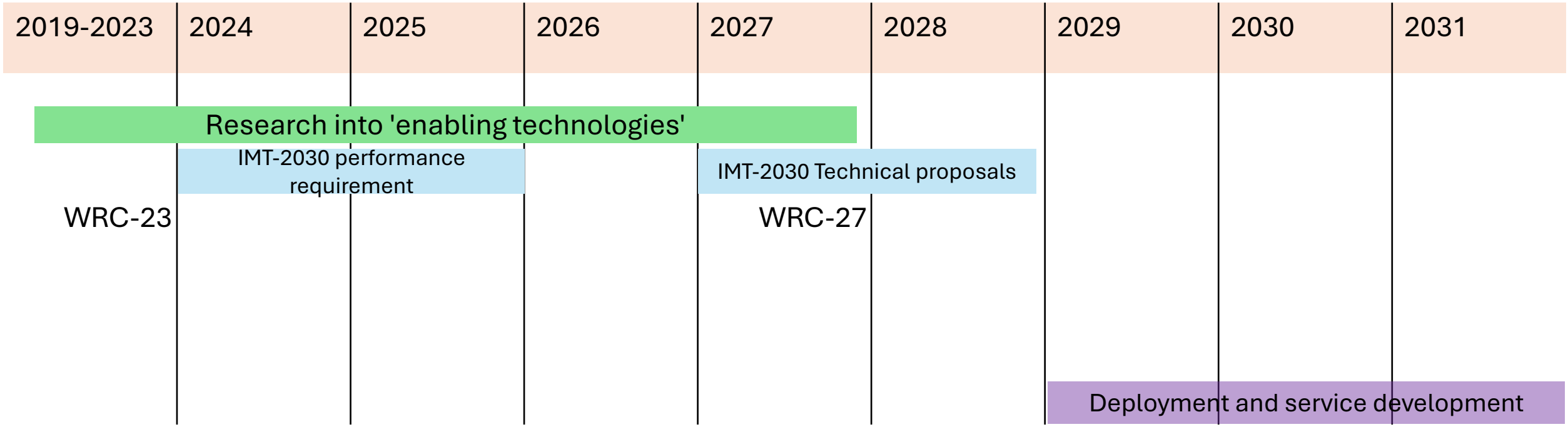

IMT = international Mobile Telecommunication

6G: What, why, and how? - YouTube

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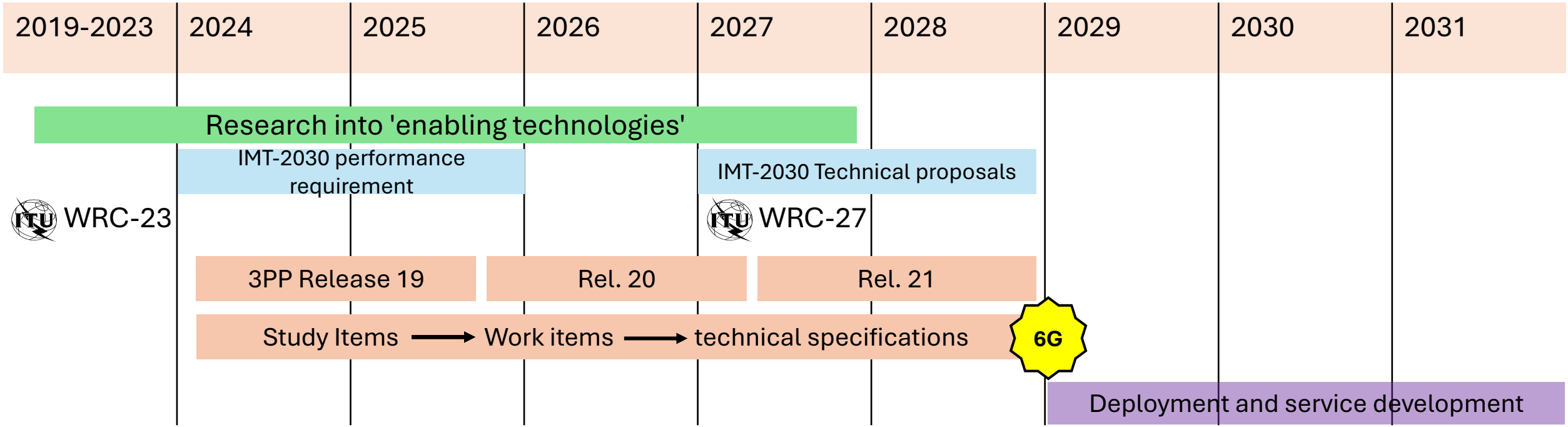

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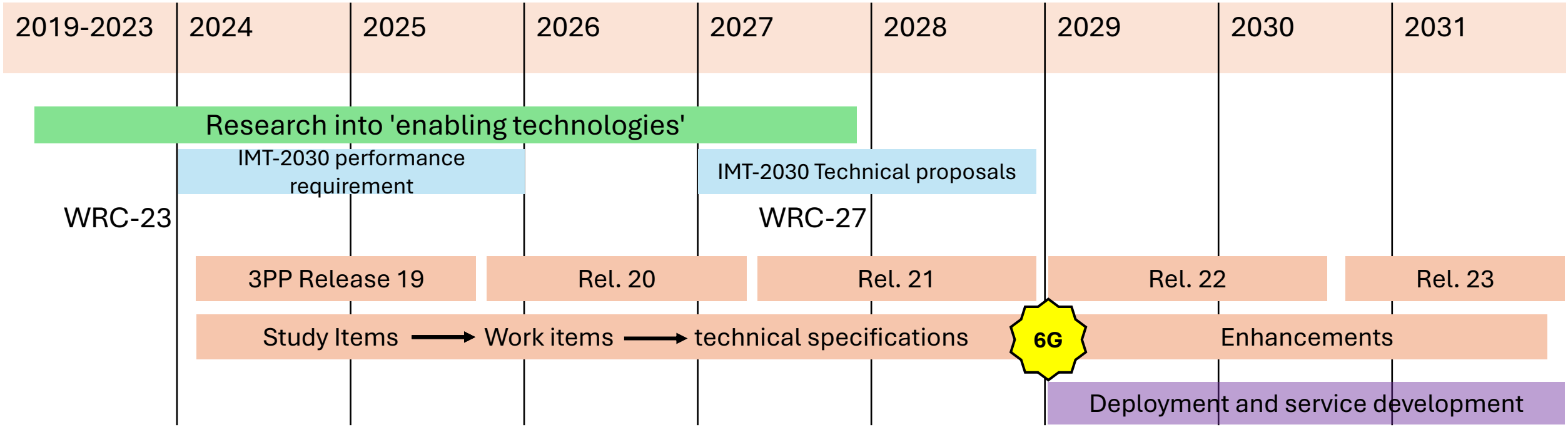

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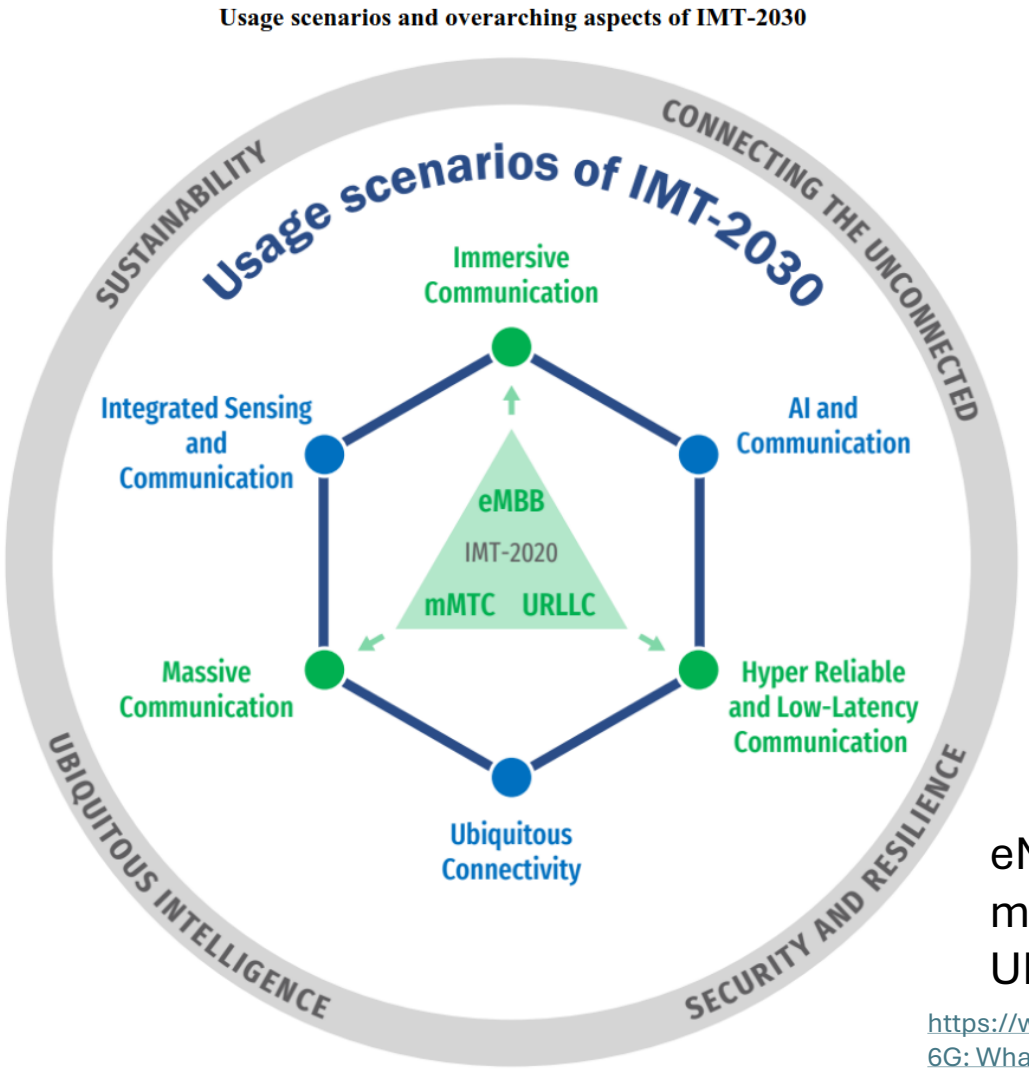
IMT-2030 Requirements: Usage scenarios



- Immersive Communication
- Hyper Reliable and Low-Latency Communication
- Massive Communication

- Integrated Sensing and Communication
- Artificial Intelligence and Communication
- Ubiquitous Connectivity

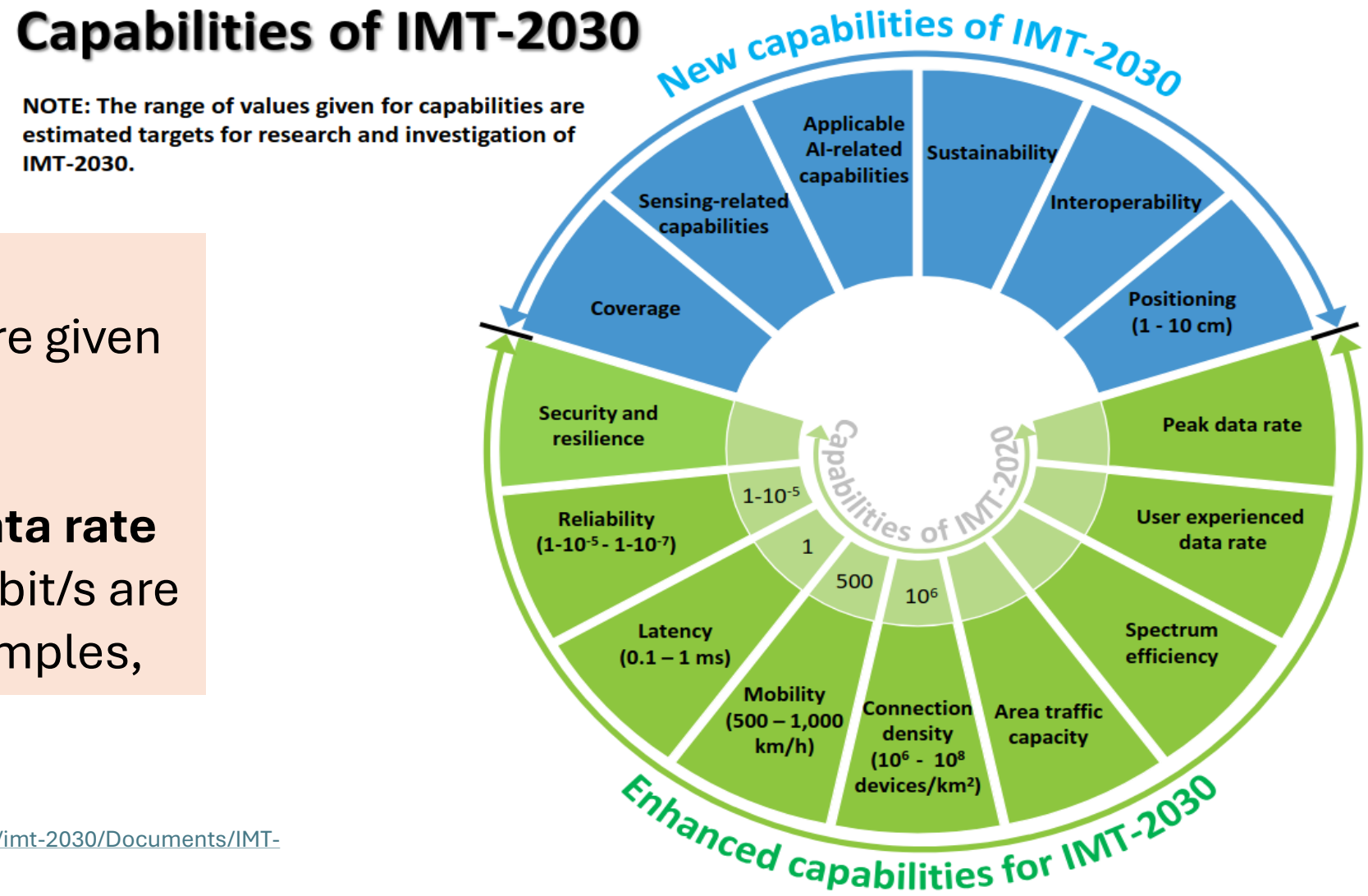
eMBB = Enhnce mobile broadband
mMTC = Massive machine-type communications
URLLC= Ultera-reliable low latency communication

https://www.itu.int/en/ITU-R/study-groups/rsg5/rwp5d/imt-2030/Documents/IMT-2030%20Capabilities%20post%20SG5.pdf
6G: What, why, and how? – YouTube
https://www.sharetechnote.com/html/6G/6G_WhatIsIt.html#ITU

IMT-2030 Requirements: Capabilities

Peak data rate
50, 100, 200 Gbit/s are given as possible examples

User experienced data rate
300 Mbit/s and 500 Mbit/s are given as possible examples,



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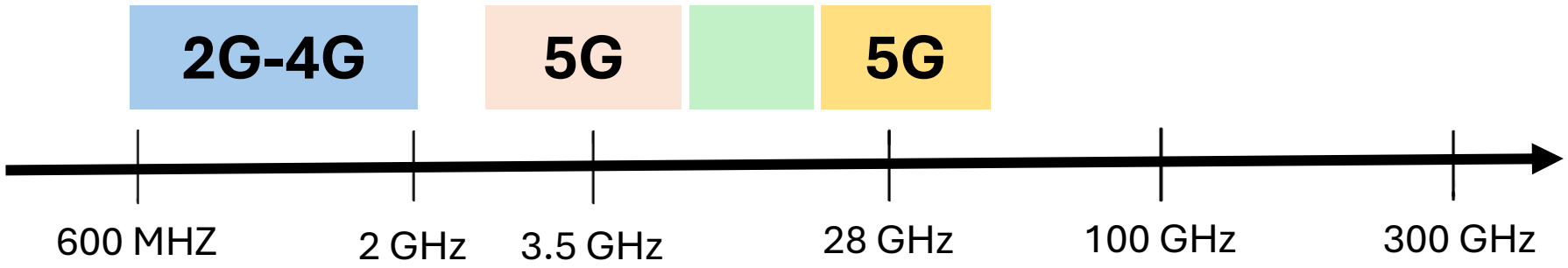
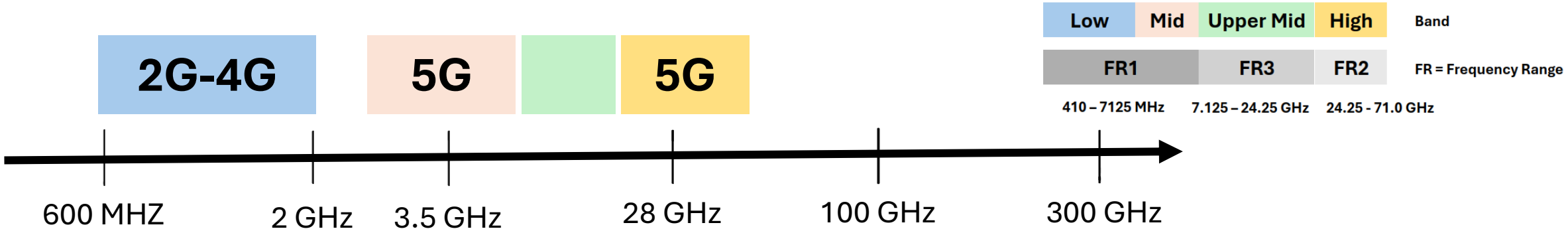
6G Spectrum

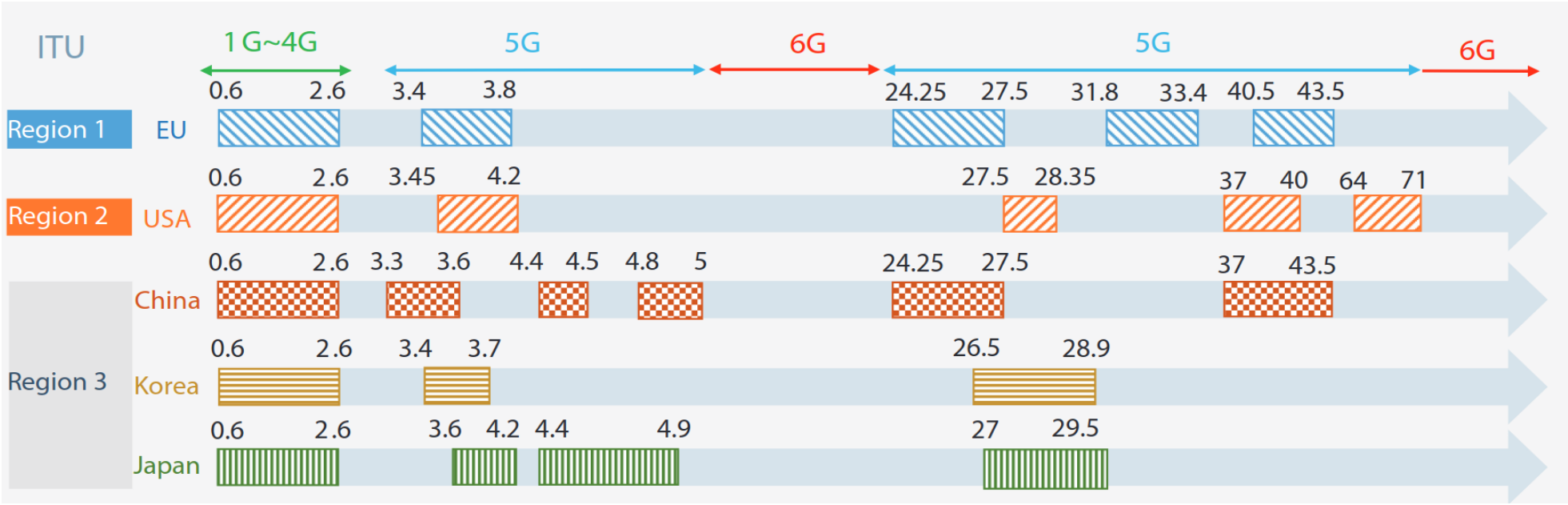


Low	Mid	Upper Mid	High	Band
FR1		FR3	FR2	FR = Frequency Range
410 – 7125 MHz		7.125 – 24.25 GHz	24.25 - 71.0 GHz	

6G in the Upper Mid-Band: The Rise of Gigantic MIMO

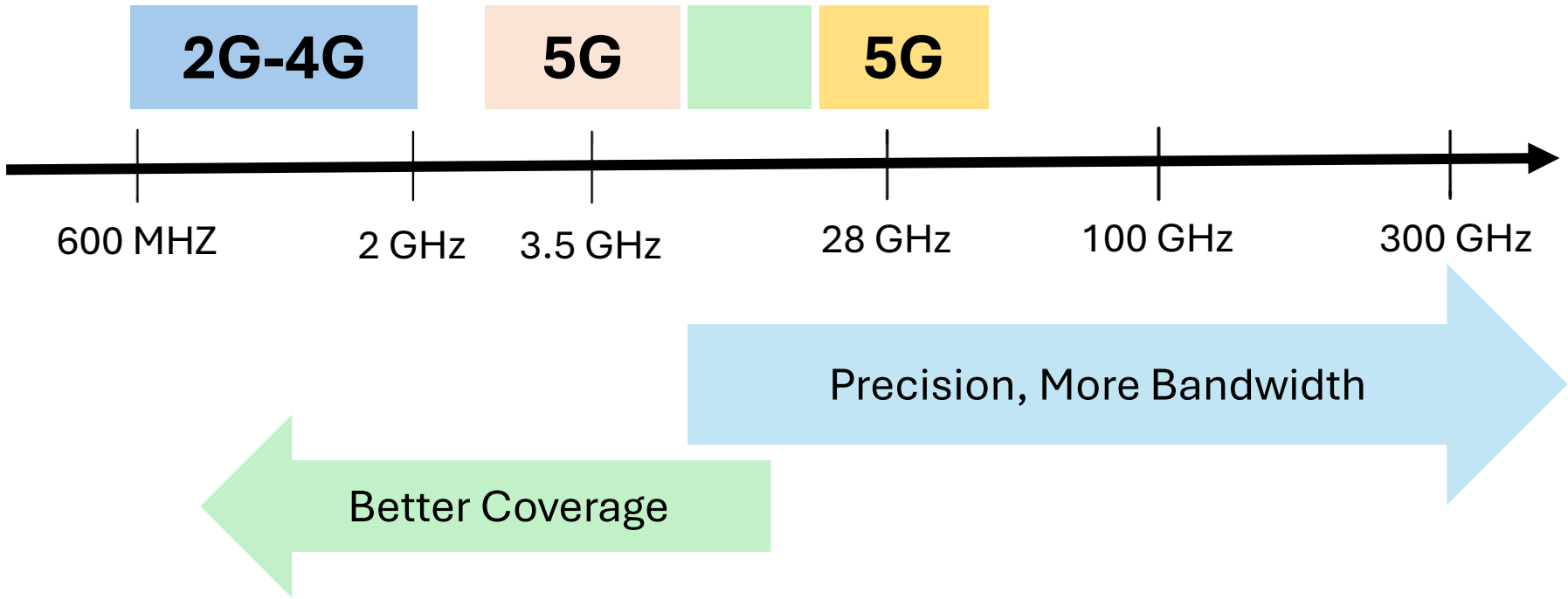
2G-5G Spectrum





J. Zhang, H. Miao, P. Tang, L. Tian and G. Liu, "New Mid-Band for 6G: Several Considerations from the Channel Propagation Characteristics Perspective," in IEEE Communications Magazine, vol. 63, no. 1, pp. 175-180, January 2025, doi: 10.1109/MCOM.001.2300708.https://ieeexplore-ieee-org.ezproxy.rit.edu/stamp/stamp.jsp?tp=&arnumber=10559933

6G Spectrum



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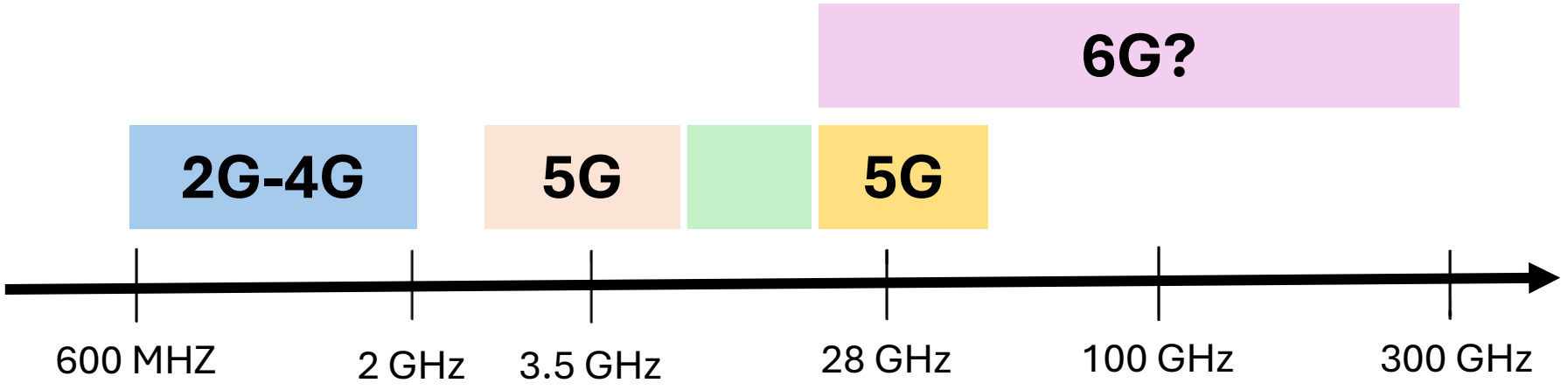
6G Spectrum

mmWave for 6G?



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6G in the Upper Mid-Band: The Rise of Gigantic MIMO

6G Spectrum

The South Korean government said on 18/11/2022 that it would cancel the **spectrum** allocated to local telcos for **5G network** deployment, in light of the insufficient investment they have made in the area.

South Korean Telecom operators without 28GHz 5G spectrum

By **5GWorldPro.com** November 19, 2022 4784 0

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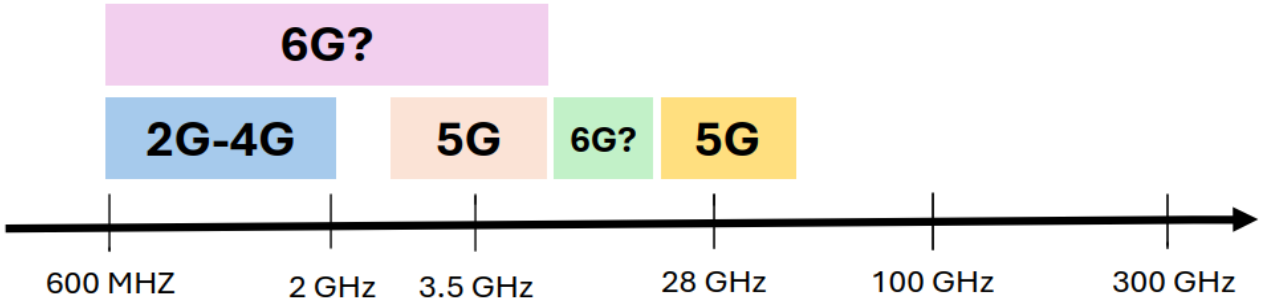
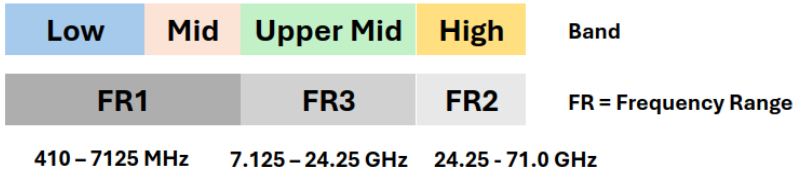
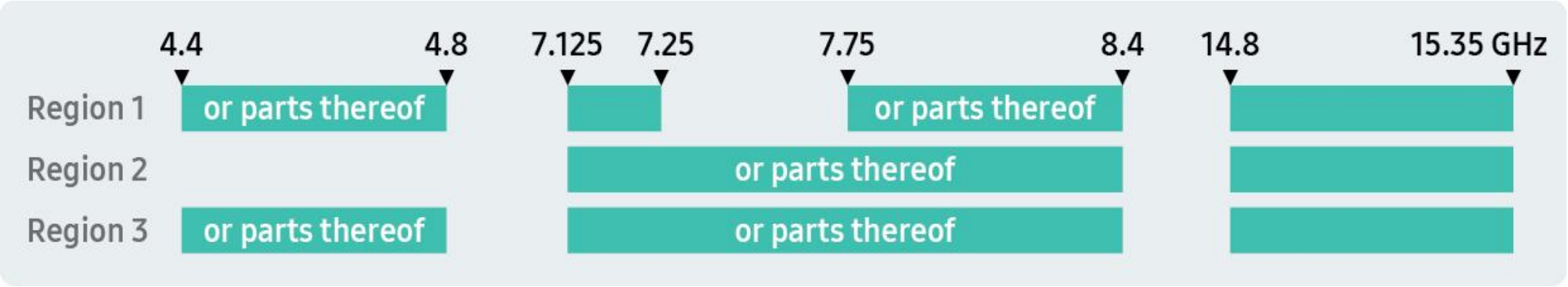
https://www.5gworldpro.com/blog/2022/11/19/south-korean-telecom-operators-without-28ghz-5g-spectrum/

6G Spectrum in Upper Mid-Band







https://research.samsung.com/blog/Upper-Mid-Band-Spectrum-for-6G-Opportunities-and-Key-Enablers

Golden band
satisfy both capacity and coverage requirements

Enabling 6G Performance in the Upper Mid-Band Through Gigantic MIMO

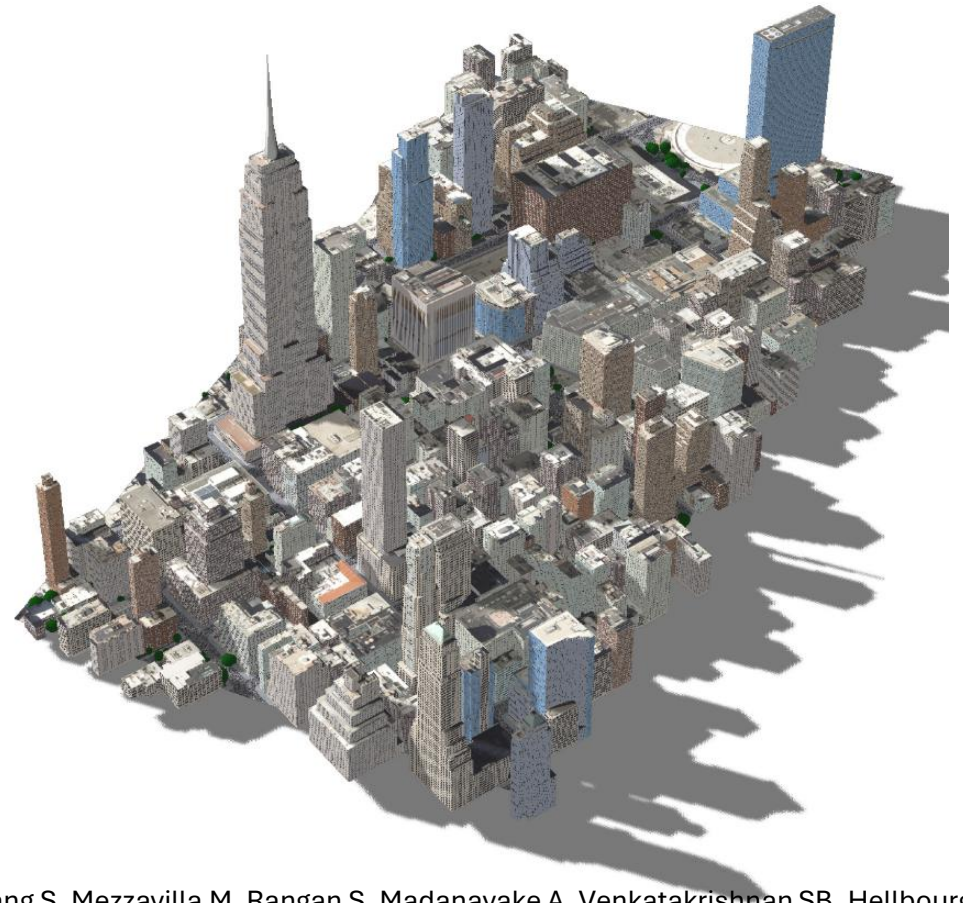
Emil Björnson, Ferdi Kara, Nikolaos Kolomvakis, Alva Kosasih, Parisa Ramezani, and Murat Babek Salman

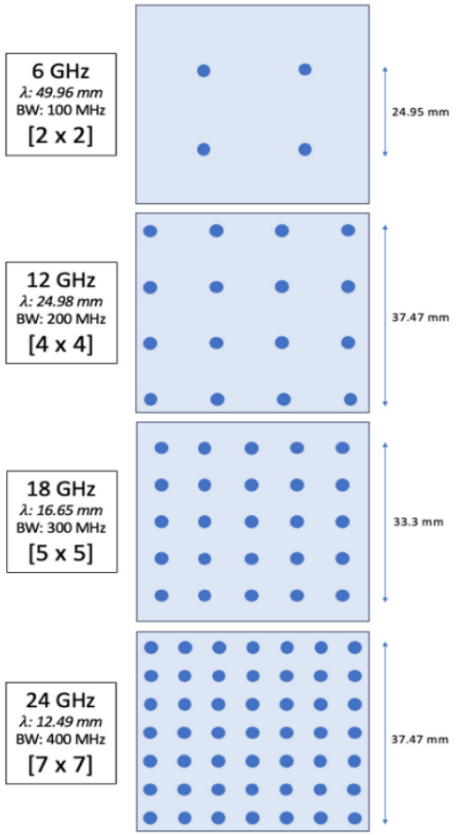
***Abstract*—The initial 6G networks will likely operate in the upper mid-band (7-24 GHz), which has decent propagation conditions but underwhelming new spectrum availability. In this paper, we explore whether we can anyway reach the ambitious 6G performance goals by evolving the multiple-input multiple-output (MIMO) technology from being massive to gigantic. We describe how many**

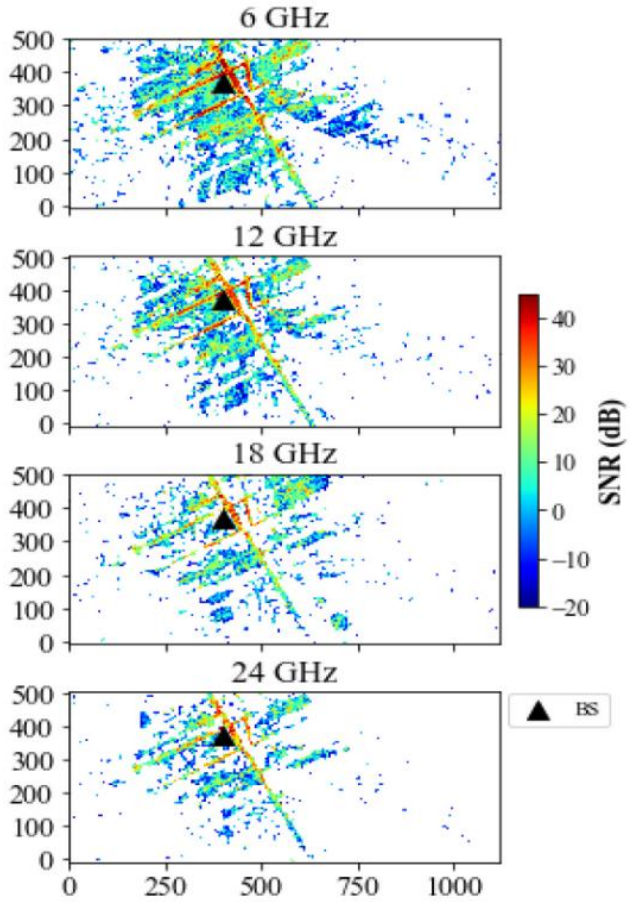
standardization and technology development. Evidently, 6G must provide more capacity to meet the ever-increasing traffic demands and enable new data-intensive applications such as virtual reality (VR), augmented reality (AR), and ultra-high-definition video streaming. To achieve commercial viability, 6G must also support new use cases and functionalities and ensure connectiv-

Upper Mid-band Outdoor Coverage

- Ray tracing simulation for **Herald Square in New York City**







Kang S, Mezzavilla M, Rangan S, Madanayake A, Venkatakrishnan SB, Hellbourg G, Ghosh M, Rahmani H, Dhananjay A. Cellular wireless networks in the upper mid-band. IEEE Open Journal of the Communications Society. 2024 Mar 5.

https://www.free6gtraining.com/2024/12/6g-midband-spectrum-discussions-from.html?m=1

Upper Mid-band Outdoor Coverage

	FR1	FR3
Center frequency	3.7 GHz	7.4 GHz
Bandwidth	100 MHz	
# od Antenna elements	32 (Digital BF)	128 (Hybrid BF)
# of TRx	32	
Transmission power	23 dBm per TRx	
# of gNBs	200	
UE antenna gain	0 dBi	
Simulation area	2km x 2km	
# of considered rays	4 Reflections- 1 Diffractions	

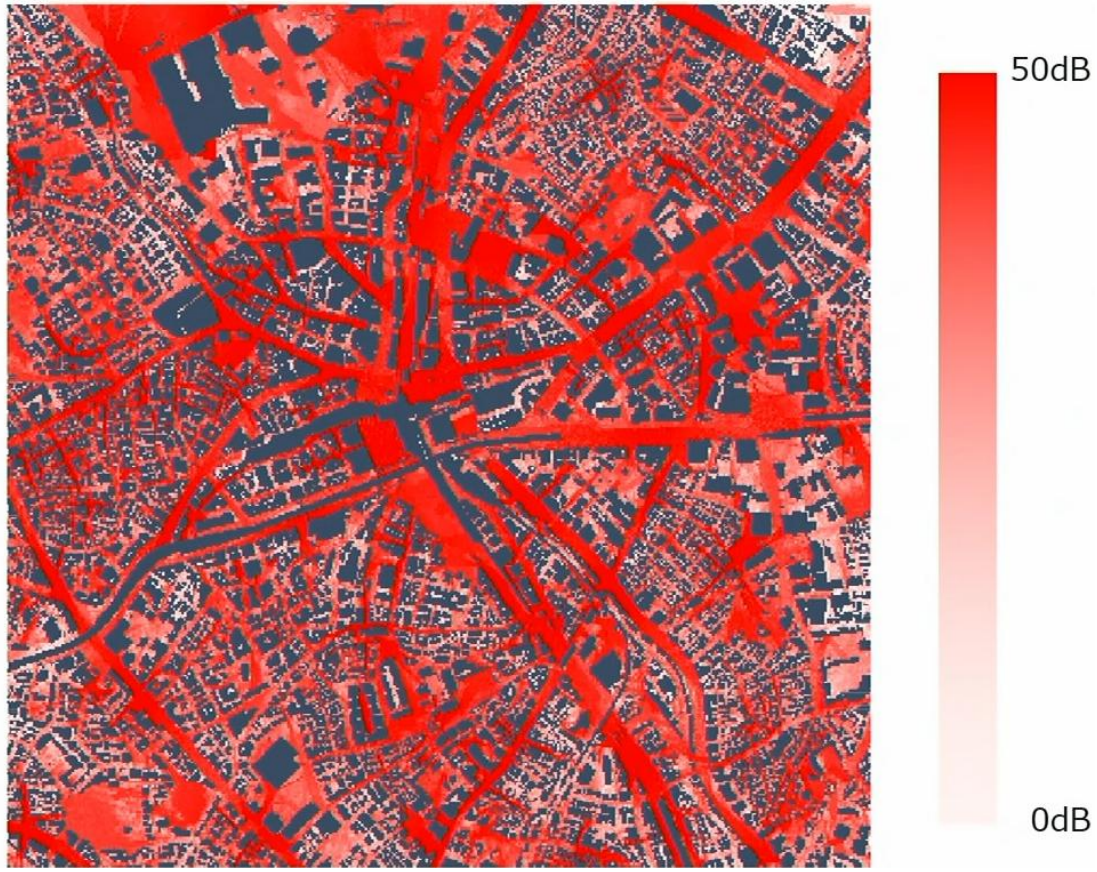
Antenna sites in a dense urban area in Tokyo

https://www.free6gtraining.com/2024/12/6g-midband-spectrum-discussions-from.html?m=1

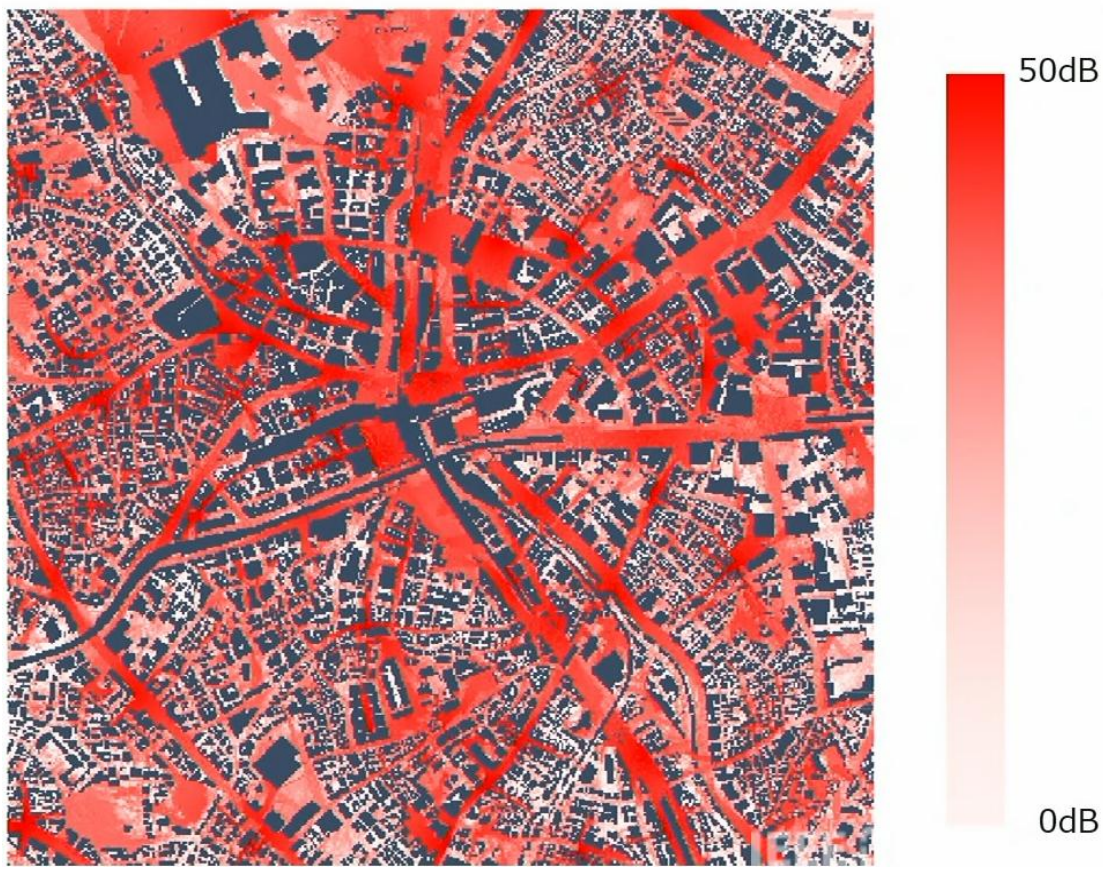
KDDI Research

Upper Mid-band Outdoor Coverage

3.7GHz



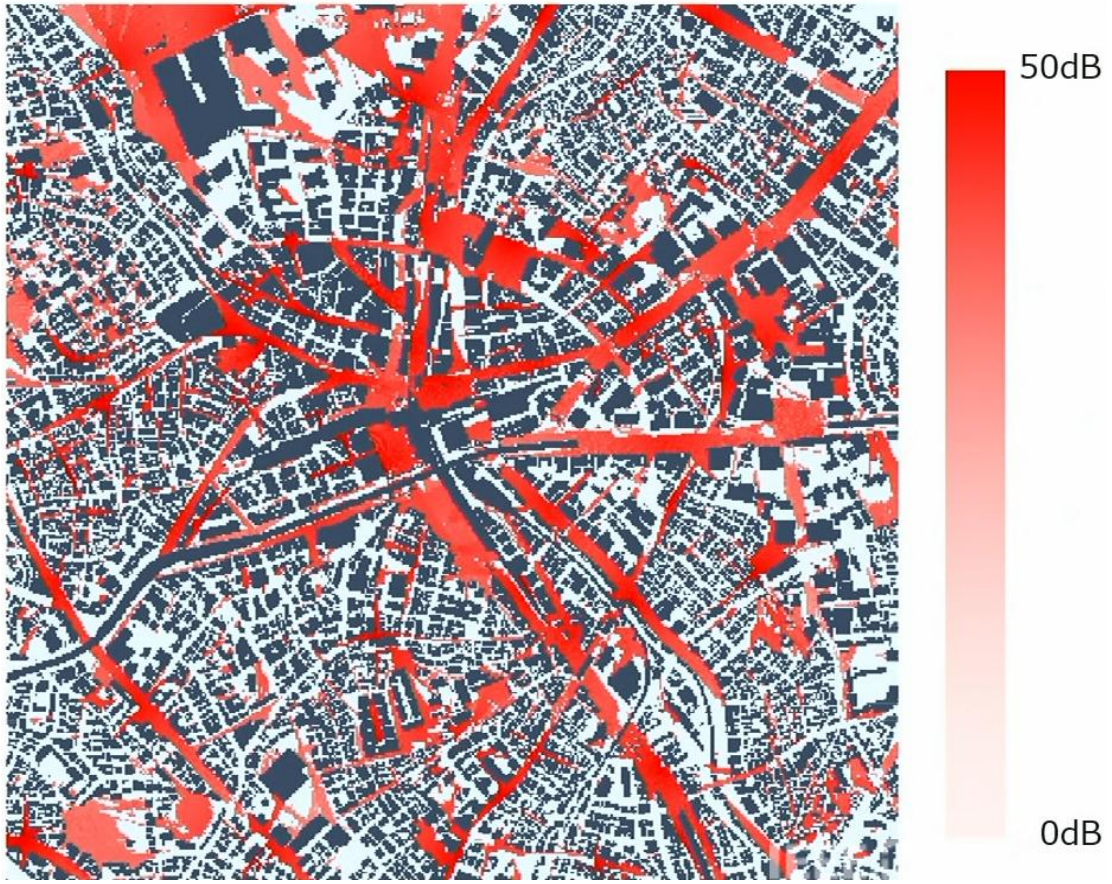
7.4 GHz



Upper Mid-band Outdoor Coverage

3.7GHz

7.4 GHz



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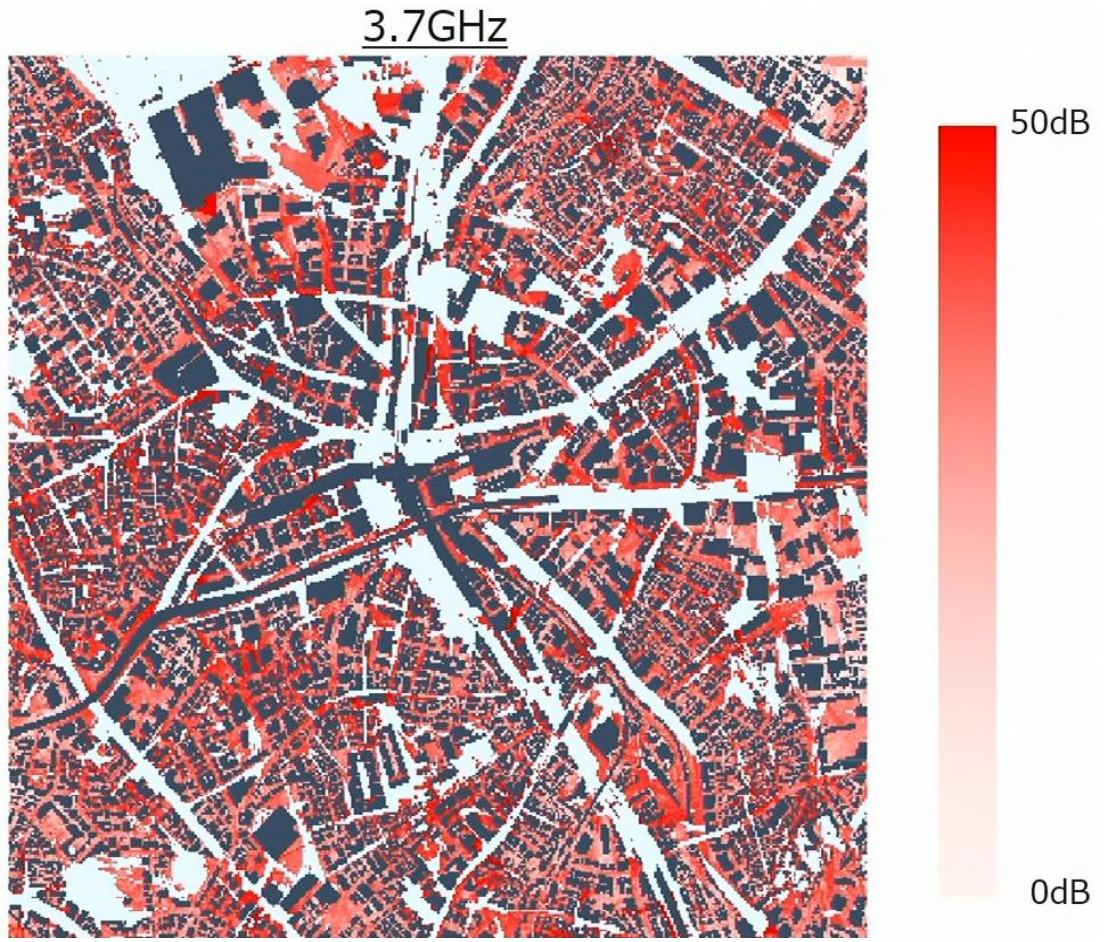

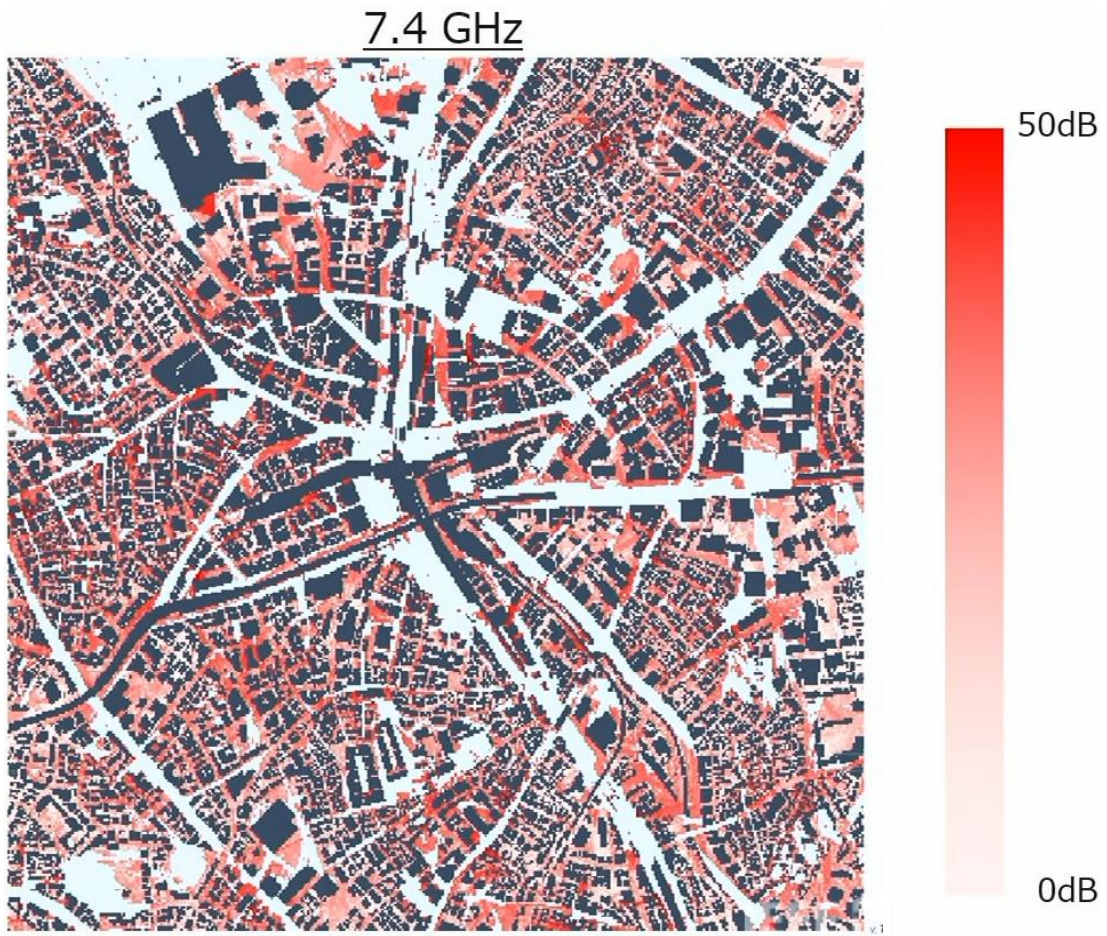

Upper Mid-band Spectrum Sharing

Federal Communications Commission – Technological Advisory Council
Advanced Spectrum Sharing Working Group

A Preliminary View of Spectrum Bands in the 7.125 - 24 GHz Range; and a Summary of Spectrum Sharing Frameworks

August 17, 2023

Need for spectrum sharing

"There is no more spectrum available." by Herbert Hoover, the US Secretary of Commerce, in 1925.

"Given that no desirable spectrum band is currently free of incumbents, the need for spectrum sharing is obvious." FCC report in 2023.

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6G demand : **Peak data rate** 200 Gbit/s

Channel capacity (bit/s per access point)

$$c = Bandwidth \,.\, Layer \,.\log_2(1 + SNR)$$

More Bandwidth?

Bigger MIMO

Upper Mid-Band Services

- **Scientific Services in FR-3**
  - Earth Exploration Satellites (EESS)
  - Inter Satellite (ISS)
  - Meteorological Satellite Service (MetSat)
  - Space Research (SRS)
  - Radio Astronomy (RAS)

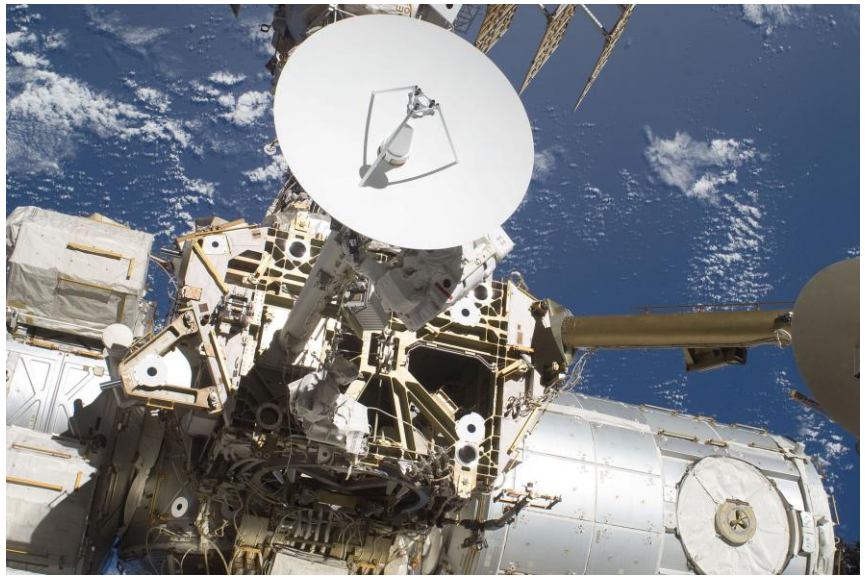
- **Non-Scientific Services in FR-3**
  - Fixed
  - Mobile
  - Fixed Satellite (FSS)
  - Maritime Mobile Satellite (MMSS)
  - Radiolocation (RLS)
  - Aeronautical Radionavigation (AR)
  - Mobile Satellite (MSS)

Scientific Services: Space Research (SRS)

A radiocommunication service in which spacecraft or other objects in space are used for scientific or technological research purposes.

NASA's Deep Space Network
Communications with Mars rovers or telescopes like the James Webb or Hubble Space

https://en.wikipedia.org/wiki/Spacecraft



https://en.wikipedia.org/wiki/Space_research_service

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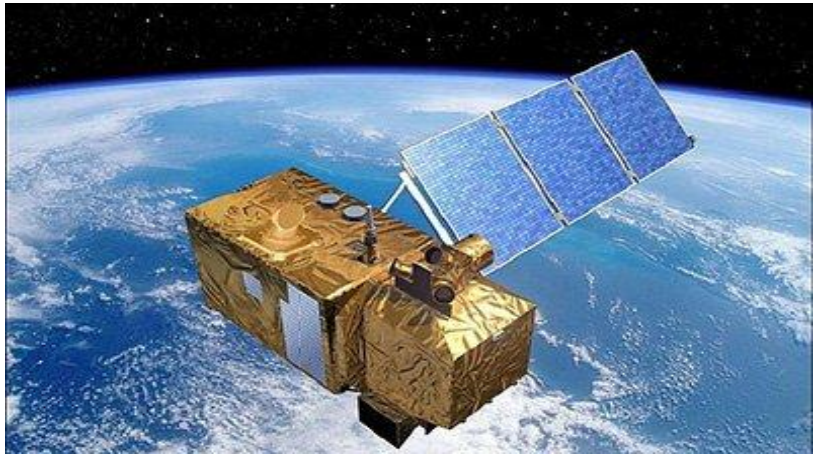
Scientific Services : Earth Exploration Satellites (EESS)

Using satellites to collect environmental data about the Earth's surface, atmosphere, and oceans.

- Remote sensing
- Weather satellites
- weather forecasting, climate monitoring, natural disaster prediction,



Scientific Services: Meteorological Satellite Service (MetSat)

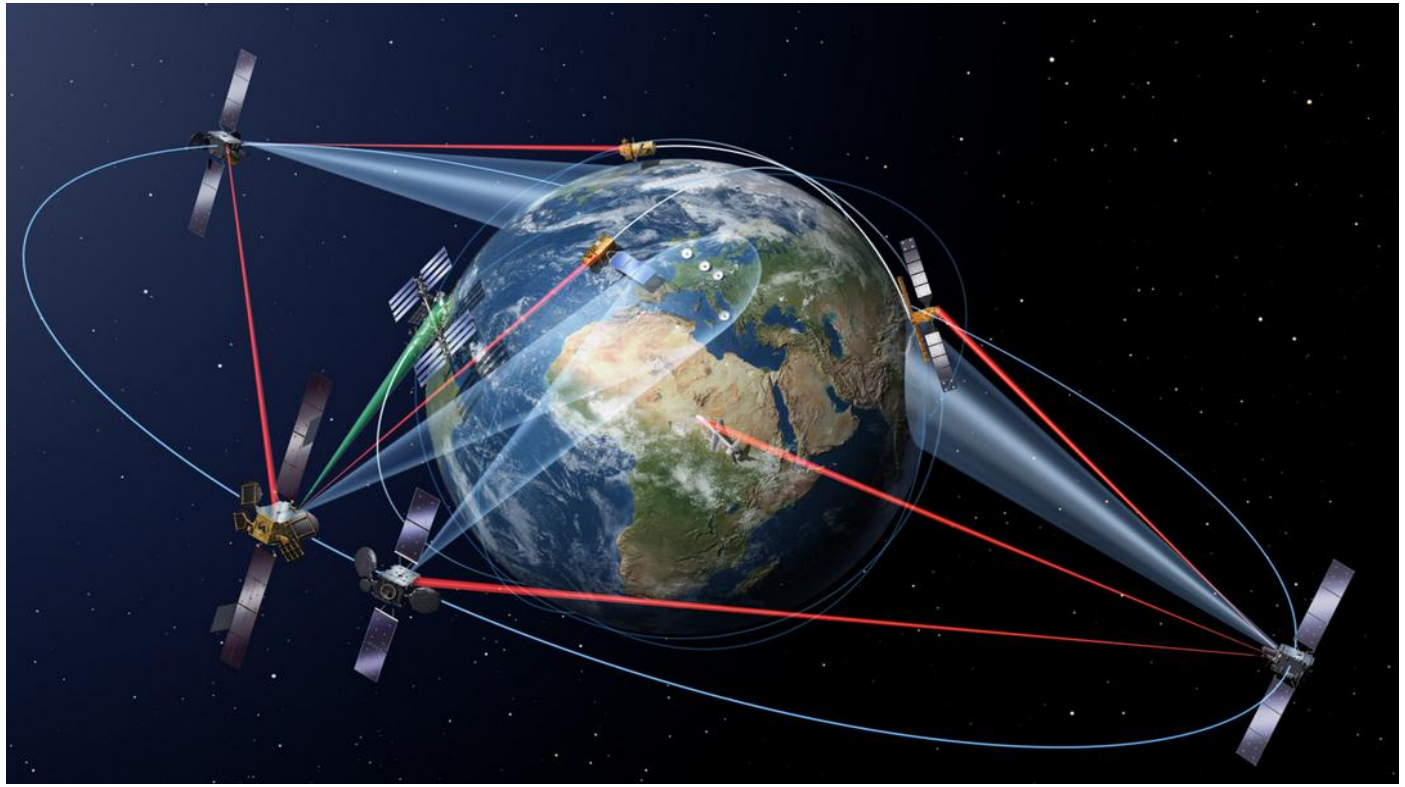
An Earth exploration-satellite service for meteorological purposes. Satellites use sensors to collect data on weather conditions, including temperature, humidity, cloud cover, and wind patterns. These satellites send the collected information back to Earth.

Weather forecasting using satellites:
GOES (USA)
Himawari (Japan)
Sentinel (Europe)

Scientific Services: Inter Satellite (ISS)

A radiocommunication service in which spacecraft or other objects in space are used for scientific or technological research purposes.

- Communication within satellite constellations, such as Starlink.



https://www.esa.int/ESA_Multimedia/Images/2016/02/Inter-satellite_laser_links

https://en.wikipedia.org/wiki/Inter-satellite_service

Scientific Services : Radio Astronomy (RAS)

Radio Astronomy uses **radio waves** to study objects in space. It helps scientists learn about things in the universe that we can't see with regular telescopes. RAS uses radio telescopes to captures faint radio signals.

Stars, planets, and galaxies far away and other mysterious objects. The leftover energy from the **Big Bang**.

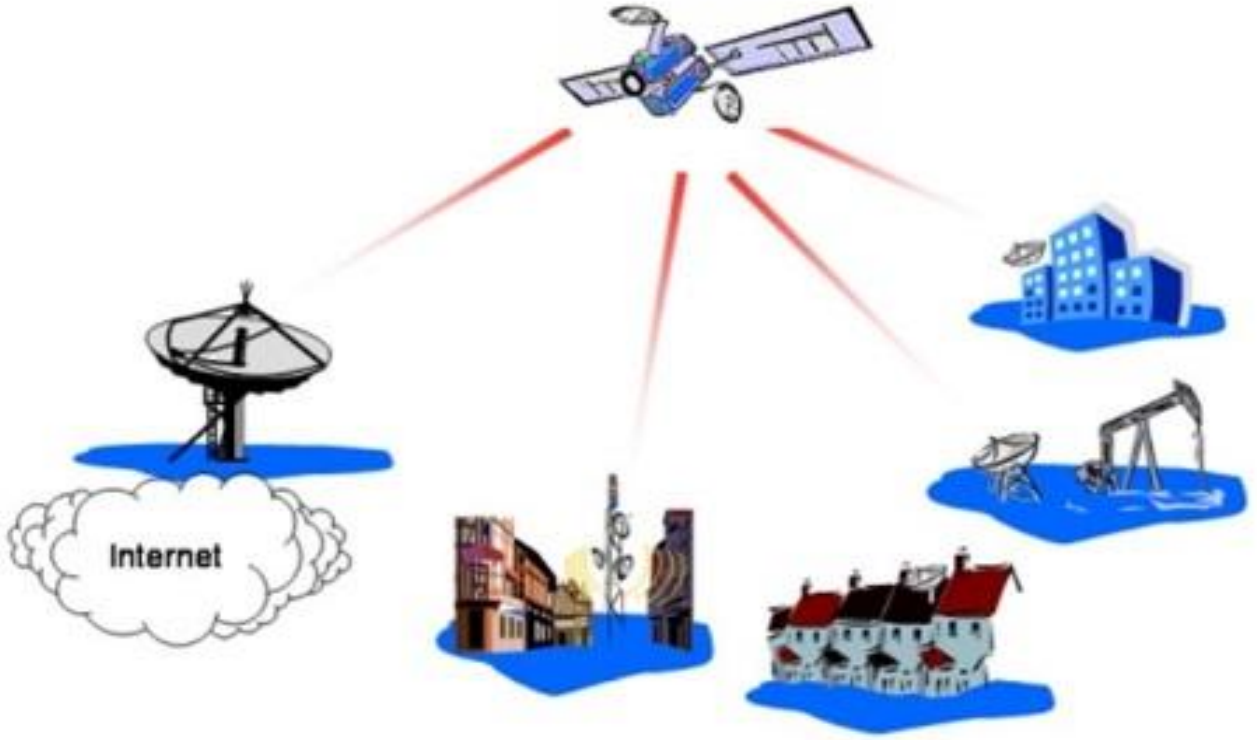
https://public.nrao.edu/radio-astronomy/the-technology-of-radio-astronomy/

https://en.wikipedia.org/wiki/Radio_astronomy

Non-scientific Services: Fixed Satellite (FSS)

FSS involves communications between ground stations and satellites in fixed locations. This service includes the ISS.

Television broadcasts,
International internet connectivity,
Data transmission over long distances.



Non-scientific Services: Mobile Satellite (MSS)

Provide two-way voice and data communications to global users who are in remote locations. It ensures communication connectivity while on the move.

Satellite phones, Emergency satellite phones,

Non-scientific Services : Radiolocation (RLS)

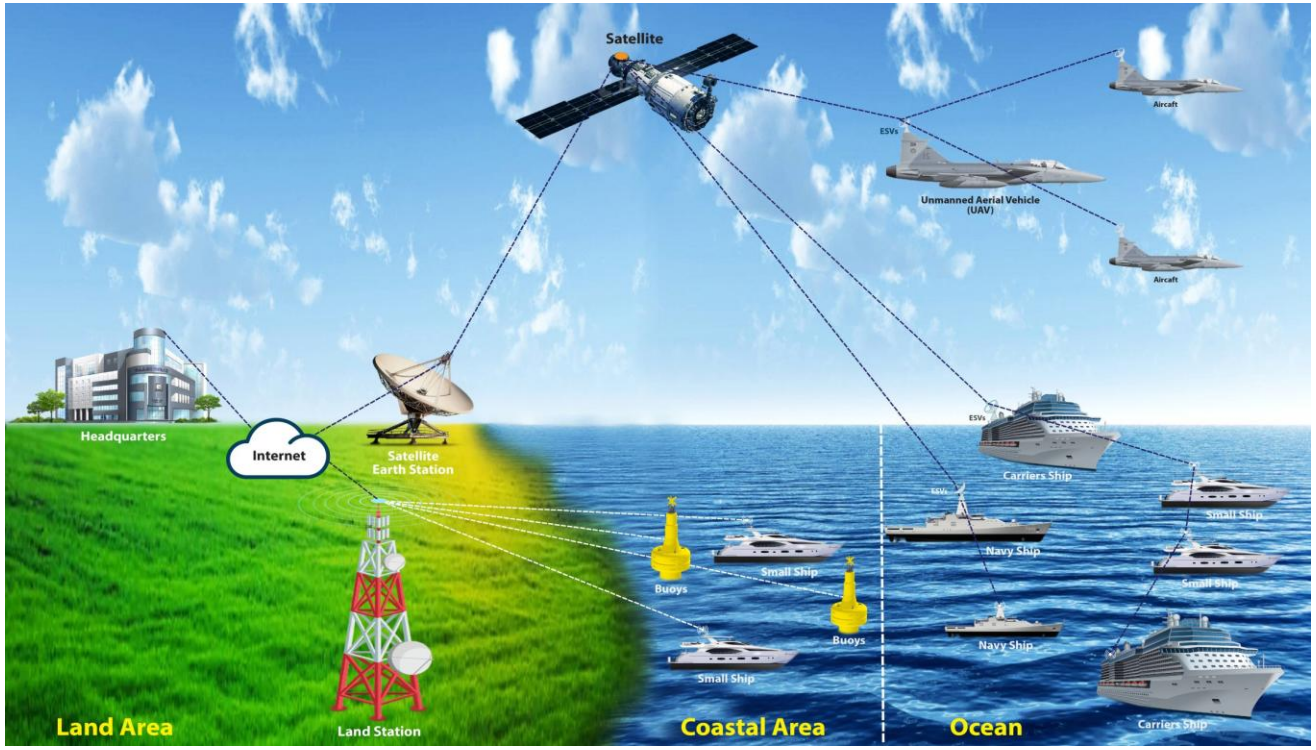
Radiolocation Service (RLS) uses radio waves to determine the position, speed, and movement of objects. It is widely applied in systems like radar, which detect and track objects for navigation, safety, and surveillance.

Tracking airplanes, ships, or vehicles.

Non-scientific Services : Maritime Mobile Satellite (MMSS)

Provides communication between ships at sea and satellites in space, ensuring reliable connectivity for navigation, safety, and operational needs even in remote oceanic areas where traditional networks do not reach.

Communication between ships and their headquarters
Internet and Crew Welfare
navigation data and weather updates.



Non-scientific Services: Aeronautical Radionavigation (AR)

Helps pilots and air traffic controllers guide airplanes safely during flight, takeoff, and landing.

- Navigation Systems
- Landing Assistance
- Collision Avoidance
- Search and Rescue