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6TH GENERATION: AT WHAT COST ?

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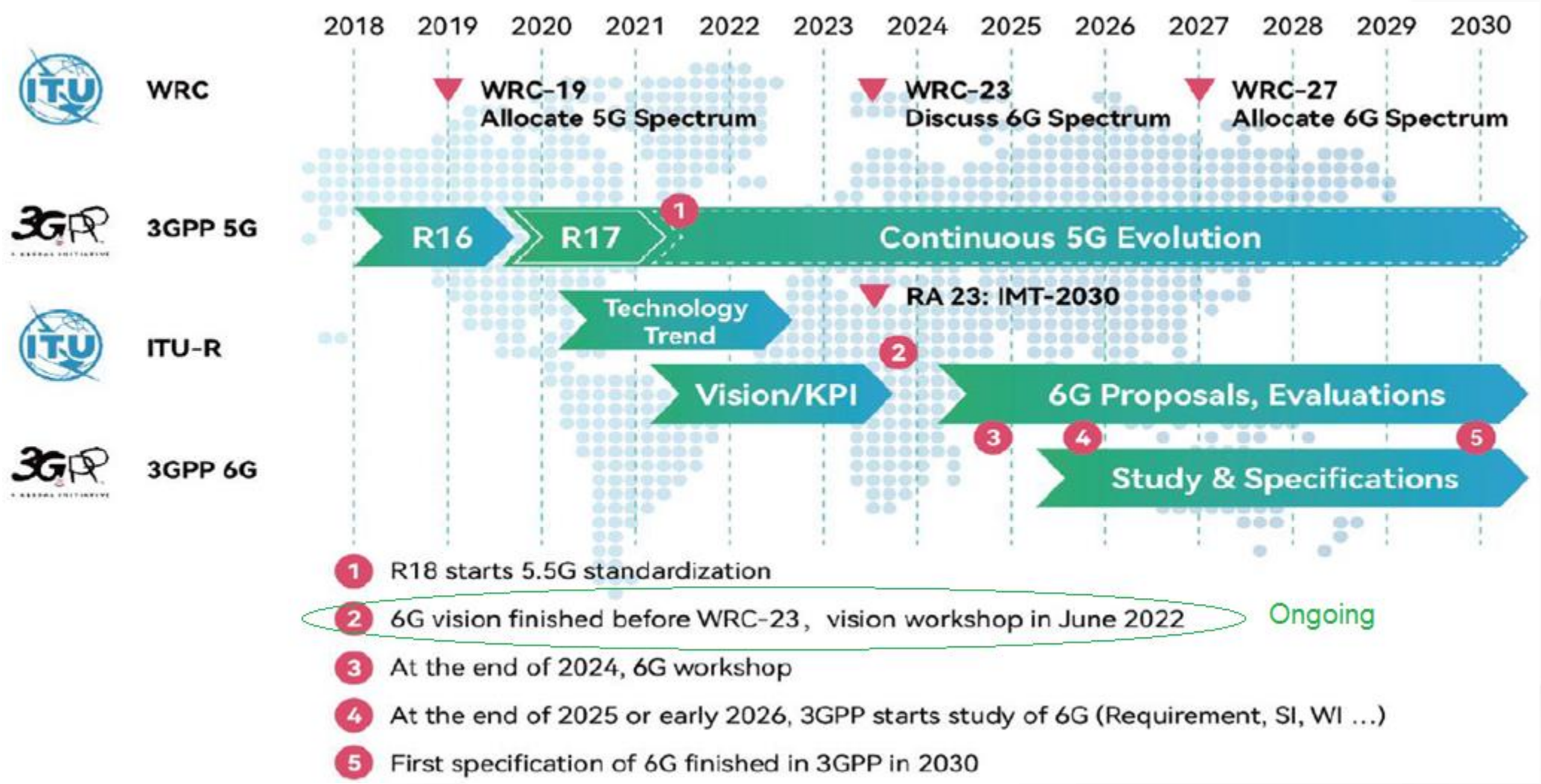
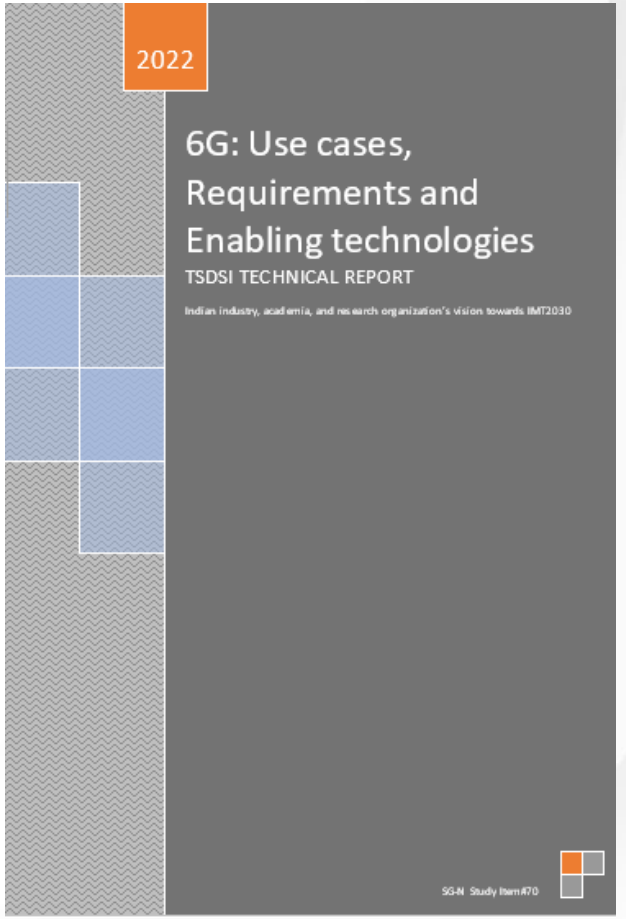
- Two decades of Telecom R&D experience.
- He pursued M.Tech from I.I.T. Roorkee.
- Delegate at ITU-R, 3GPP, TSDSI, and ORAN respectively.
- Actively involved in the modeling, simulation & implementation of various generations of cellular standards working with multiple MNCs during his career.

JOURNEY FROM 5G to 6G: IMT

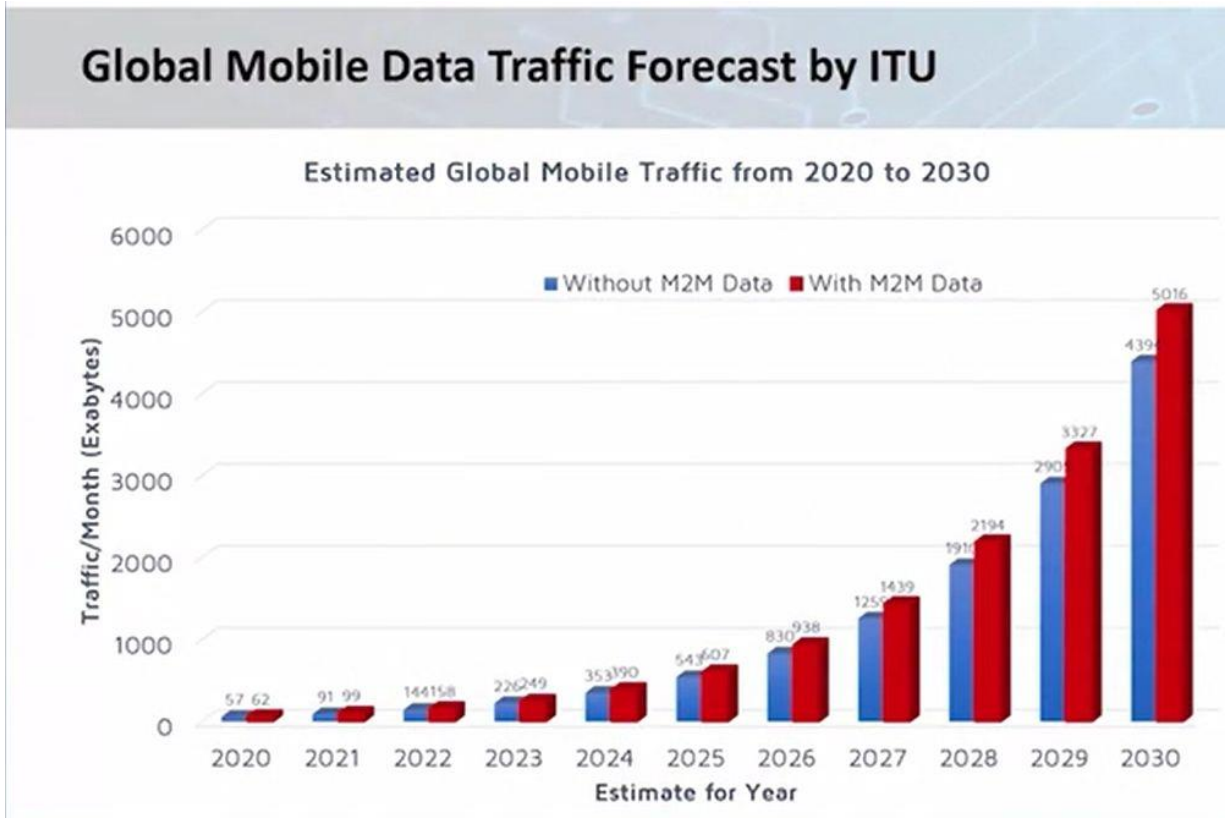


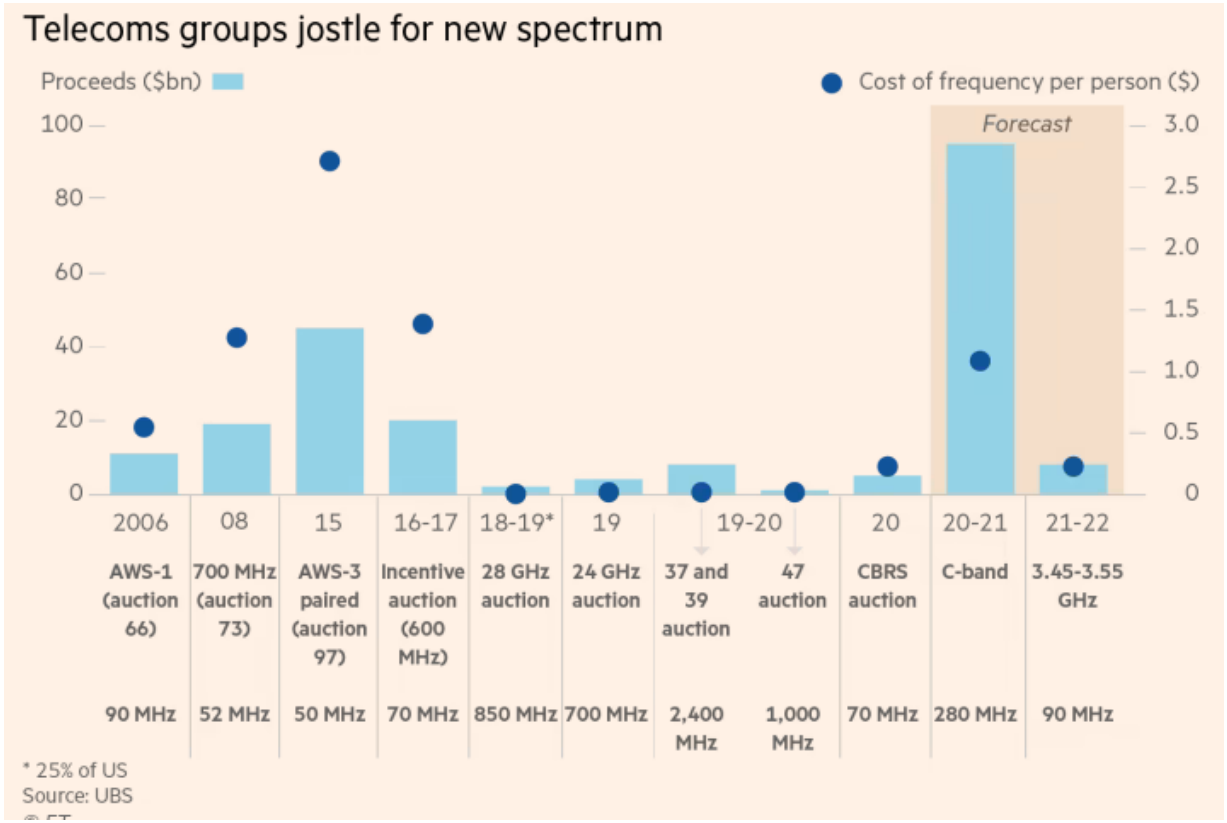
TSDSI Study Group Networks SI70: ITU IMT2030

- The discussion on 6G Vision & Use cases in ITU-R started from Feb. 2021, and the final report will be submitted in June 2023.
- TSDSI Study captures the preliminary understanding on 6G Use cases, enabling technologies, KPIs, Network architecture, spectrum aspects.
- TSDSI made contributions towards the IMT.FUTURE TECHNOLOGY TRENDS & IMT.VISION 2030 document based on outcome of this study. [1][2]
- The TSDSI study does not limit its scope to terrestrial communication. It includes Deep space, Satellite & Under water communications use cases.



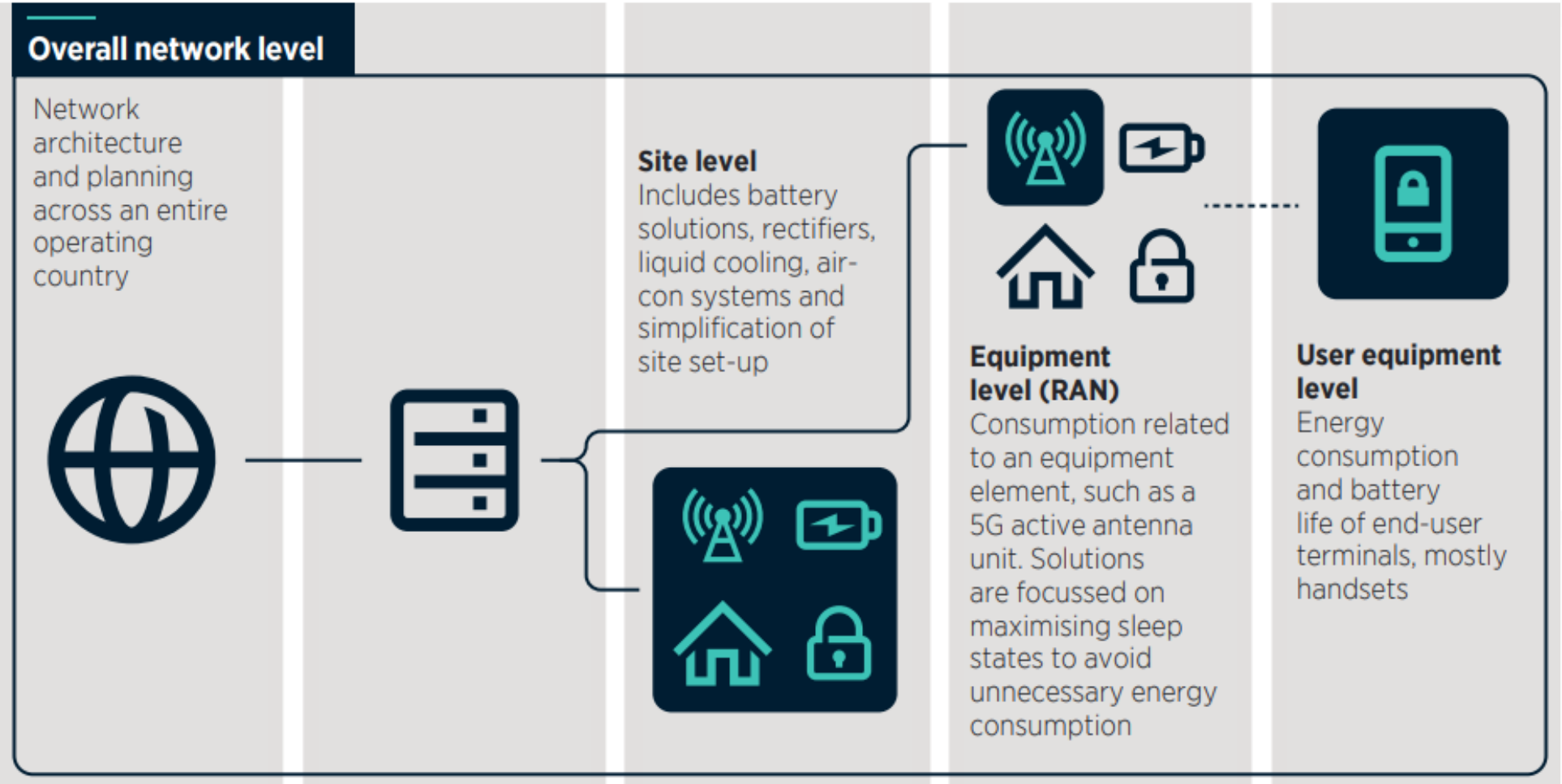
MEASURES OF TECHNOLOGY COST: *CAPEX, OPEX, ENVIRONMENT, SPECTRUM*





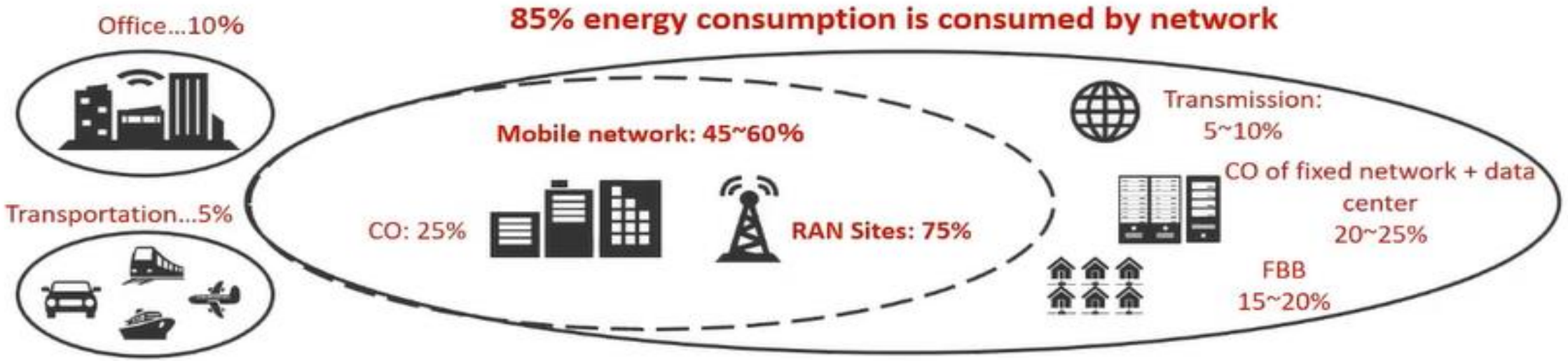
Operators cost

Energy-saving methods differ between site level, RAN equipment and network planning



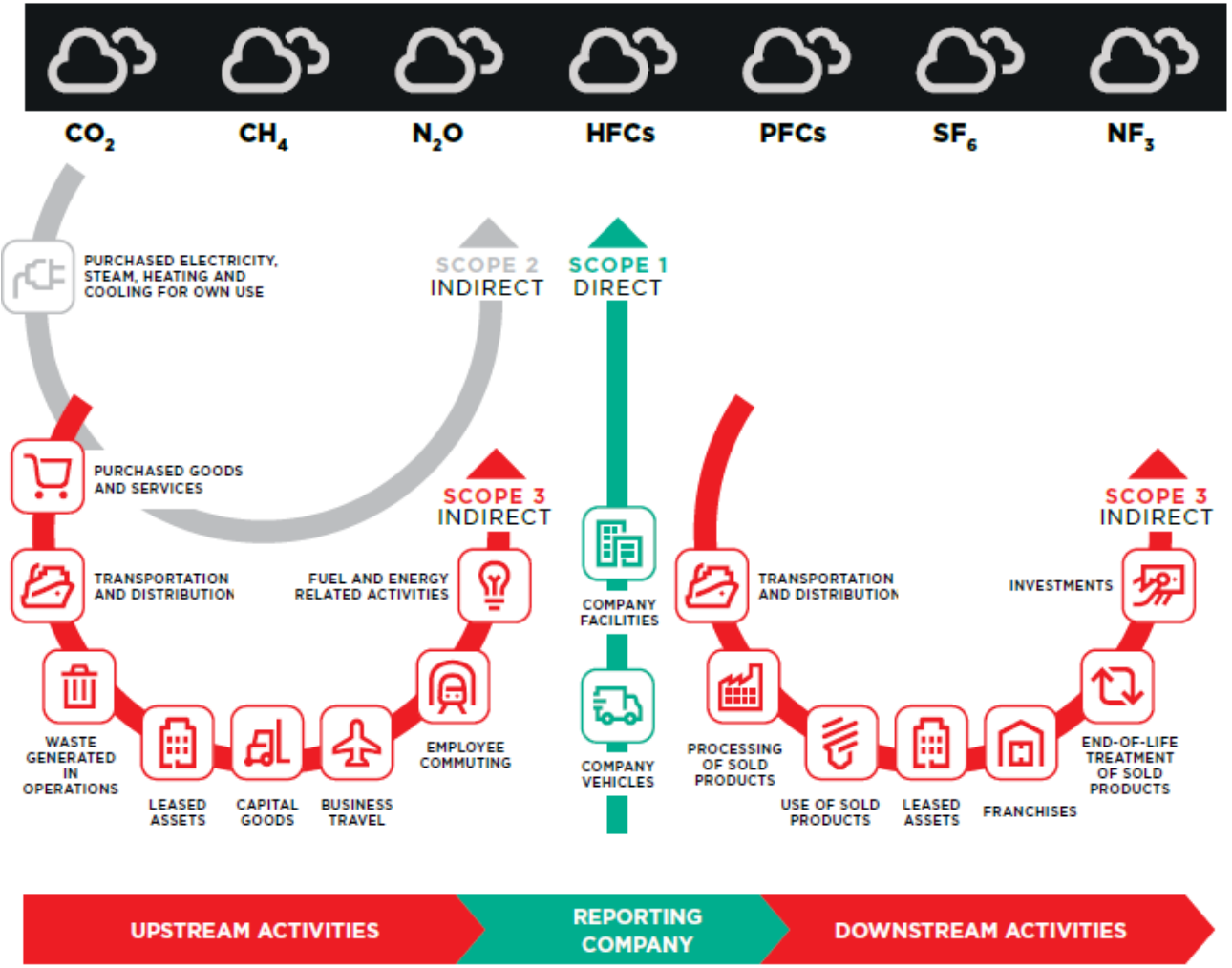
Source: GSMA - Mobile Net Zero State of the Industry on Climate Action 2021

Operators cost: Distribution



80% MNO Energy > Network usage
50% of Total > Mobile Network
75% of Mobile Network: RAN sites

Environmental Cost



Source: Technical Guide for Calculating Scope 3 Emissions Version 1.0, Greenhouse Gas Protocol

Greenhouse Gas Protocol

Scope 1 emissions:

Direct emissions from owned and controlled sources, including fuel combustion, company vehicles, and fugitive emissions.

Scope 2 emissions:

Indirect emissions from generation of purchased electricity, steam, heating and cooling consumed by the reporting company.

Scope 3 emissions:

All other indirect emissions that occur in a company's value chain, including purchased goods and services, business travel, employee commuting, waste disposal, use of sold products, transportation and distribution (upstream and downstream), investments, leased assets and franchises.

The Greenhouse Gas Protocol, 2013, Technical Guide for Calculating Scope 3 Emissions Version 1.0, Supplement to the Corporate Value Chain (Scope 3) Accounting & Reporting Standard

Target Setting

SCIENCE BASED TARGETS (SBTs)

- As defined by the Science-Based Targets Initiative to set carbon reduction targets in line with limiting global heating to below 2C.

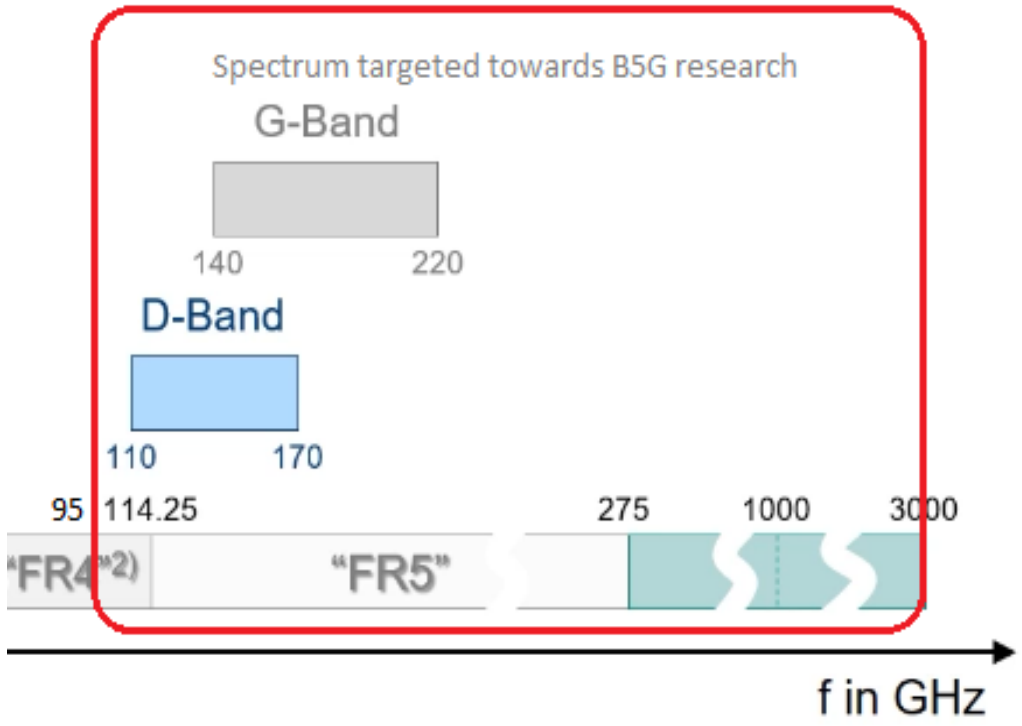
CARBON NEUTRAL

- Refers to reducing and offsetting carbon emissions from own operations (Scope 1 and 2 emissions).
- For MNOs the largest source of Scope 1 and 2 emissions are electricity use for networks and diesel fuel use for transport and generators.

NET ZERO

- Refers to the criteria used by the UN Race To Zero campaign, which includes reductions in Scope 3 emissions across the whole value chain.
- See unfccc.int/climate-action/race to-zero-campaign

NEW SPECTRUM & REGULATIONS



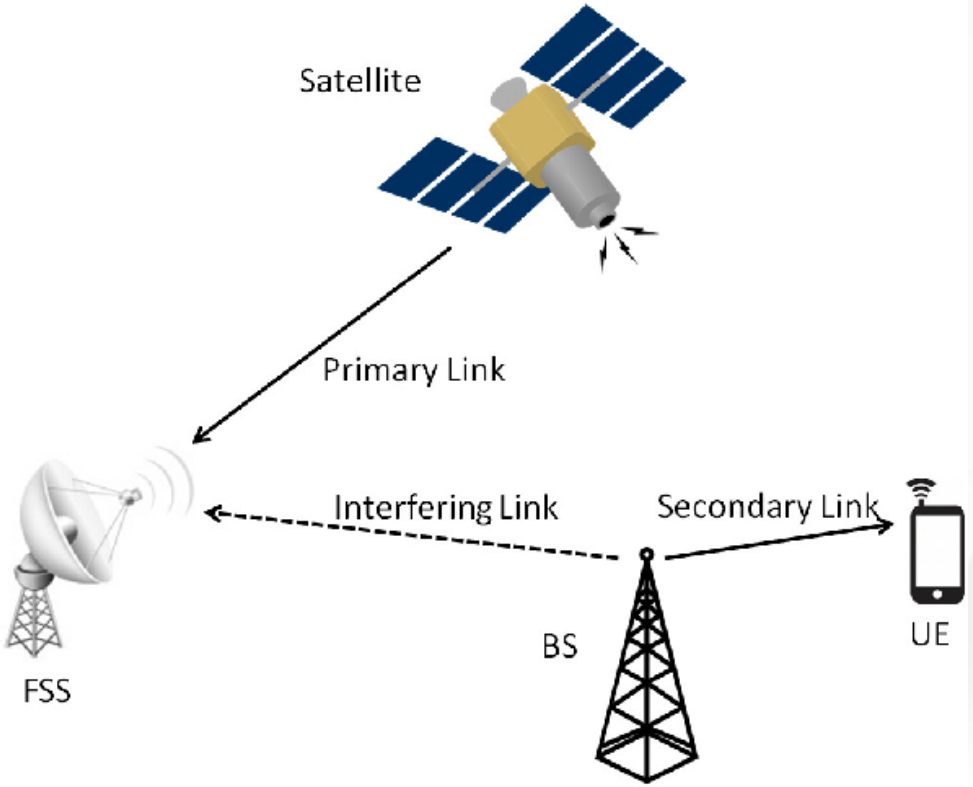
Attaining data rates of the order of 100 Gbps require usage of wider bandwidth available in higher frequency bands.

Such initiatives would call for new regulatory models to be implemented.

Some geographies have opened spectrum above 100 GHz encouraging early experimentation in sub-THz bands

SPECTRUM COST: IMPACT & RESEARCH AVENUES

1. Trade-off between spectrum availability and densification of network deployment.
2. Ex. FS, FSS, IMT technologies to be designed to co-exist in same spectrum.
3. Need for Cooperative game theory to be applied across spectrum access by independent services.
4. Technologies to be capable of co-existent in same Space-Freq-Time by:
   - Waveform design – All standards developed together – mutually dependent.
   - Developing a framework to be followed to allow independent specification development.
   - Cognitive Radio based technologies.



Future Research Avenues: 6G RAN

6G Green Networks:
Symbiotic radio
Ambient backscatter communications,
Reconfigurable intelligent surfaces

AI ML in 6G networks
for
Green communications and computing

Low-power 6G network:
Adaptive waveforms,
Battery-less energy harvesting,
and
Adaptive modulation and coding techniques

Sustainable Green 6G networks

SON techniques

Resource constrained Device Support:
Cell-free massive MIMO,
Full duplex and
THz communication

Future Research Avenues: 6G CORE

Smart energy management techniques for **Balancing Energy demand-supply in 6G networks**

Energy efficient edge/fog computing, Computation & Data offloading, Cloud-assisted resource management for **Green IoT networks**

Redesigning network protocols Reinventing Transport technologies For **End to End Low Latency**

Architectures/topologies for **Energy-efficient hierarchical IoT-cloud networks**

Analytical, optimization and experimental approaches for **Green communications and computing in 6G networks**

Others …

Promising Technologies [1]:

Light Communications

Sr	KPI	RF THz	Light
1	**Available bandwidth**	Tens to hundreds of GHz	Hundreds of THz
2	**Transmission distance**	non-line-of-sight (NLOS)	LOS
3	**Electromagnetic radiation**	YES	NO
4	**Data rate achieved**	100Gbps	10Gbps
5	**Spectrum regulatory**	Licensed	Unlicensed
6	**Penetration ability**	Special opaque materials	Transparent materials
7	**Inter-cell interference**	serious	None
8	**Cost**	expensive	Cheap
9	**Transmission power**	High	Low
10	**Diffuse reflection losses**	High	Low

References

1. Document 5D/TEMP/320, Draft working document towards a preliminary draft new Report ITU-R M.[IMT.FUTURE TECHNOLOGY TRENDS OF TERRESTRIAL IMT SYSTEMS TOWARDS 2030 AND BEYOND]
2. Document 5D/TEMP/273, [Draft] detailed workplan for the development of preliminary draft new Recommendation ITU-R M.[IMT.VISION 2030 AND BEYOND].
3. “6G: Use cases, Requirements & Enabling technologies”, Technical Report SI73 TSDSI Study Group Networks
4. The Greenhouse Gas Protocol, 2013, Technical Guide for Calculating Scope 3 Emissions Version 1.0, Supplement to the Corporate Value Chain (Scope 3) Accounting & Reporting Standard.

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