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IIT HYDERABAD

6G India Views

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Where is 5G Headed in India ?

Imagine 970 Million People consuming 66 GB/Month

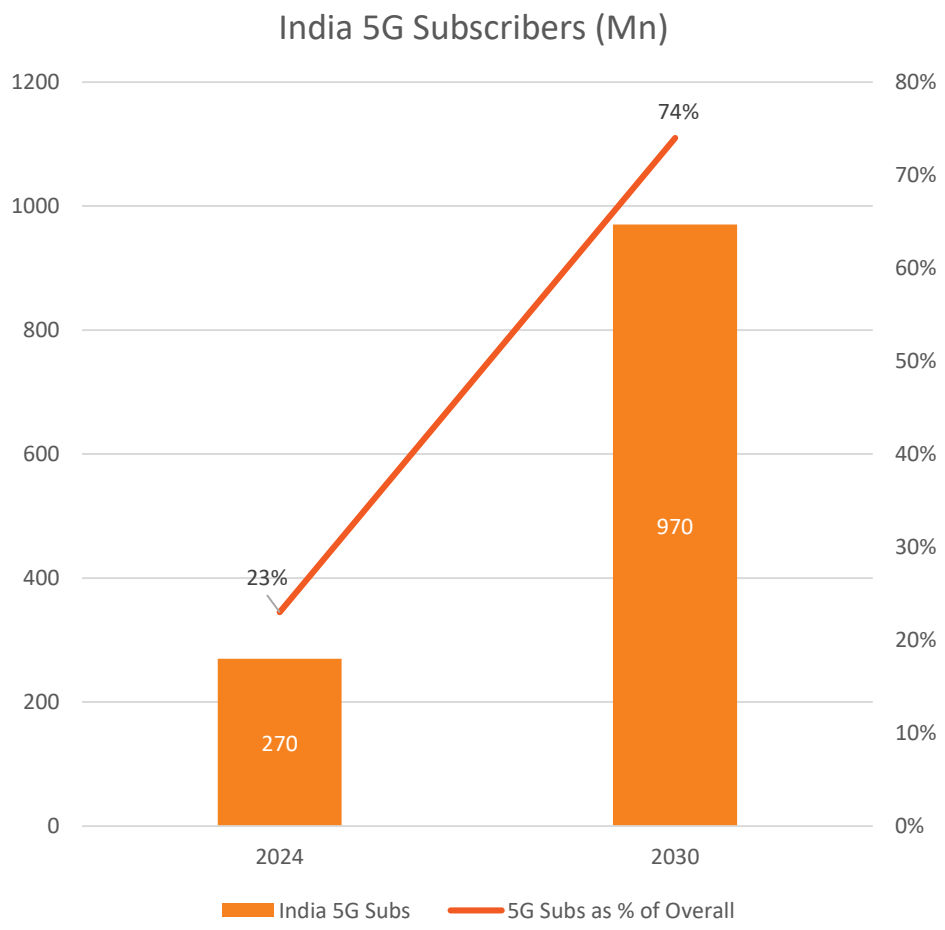
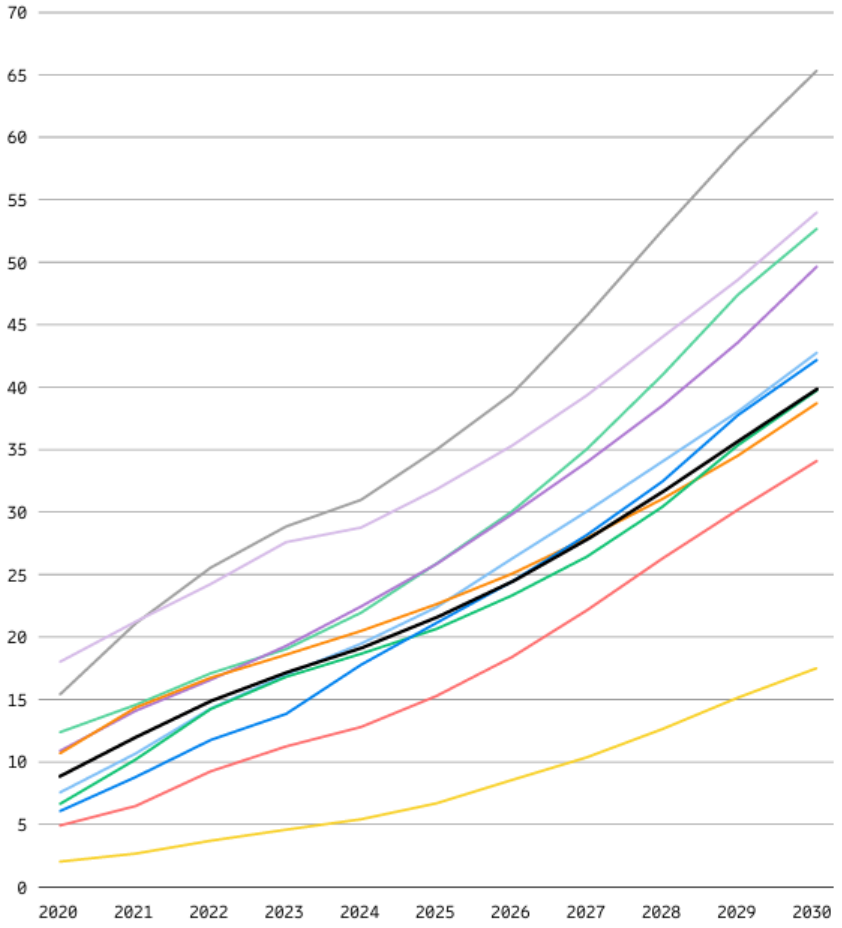


Figure 6: Mobile data traffic per active smartphone[1] (GB per month)



Regions	2024	2030	CAGR 2024–2030
India, Nepal and Bhutan	32	66	13%
Gulf Cooperation Council	29	54	11%
North America	22	52	16%
Western Europe	23	49	14%
Central and Eastern Europe	20	42	14%
Middle East and North Africa[2]	19	43	15%
South East Asia and Oceania	19	39	13%
Global average	19	40	13%
North East Asia	21	38	11%
Latin America	13	34	18%
Sub-Saharan Africa	5.4	17	21%

Source: Ericsson Mobility Report Nov 2024

Where is 5G Headed ? – FWA Evolution

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Figure 11: FWA connections (millions)

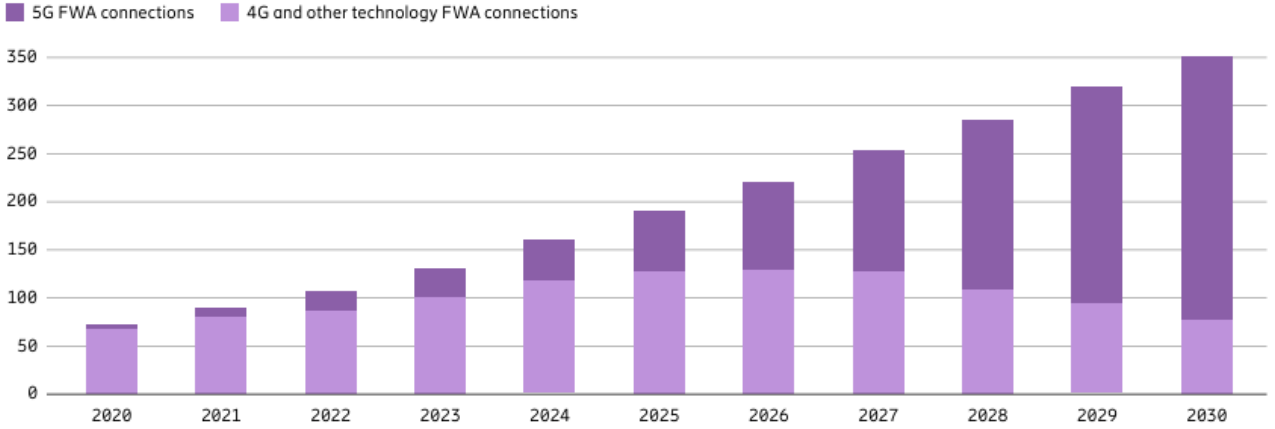
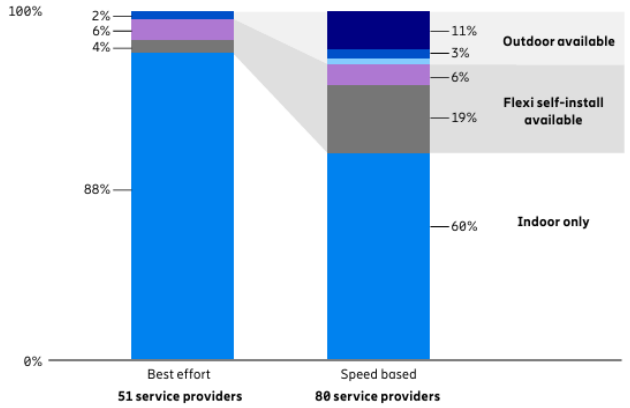


Figure 12: 5G FWA CPE form factor by service-provider offering



[2] Ericsson and GSA, FWA Forum CPE Survey (September 2024).

During the last year, 73 percent of 5G FWA launches occurred in Europe.

73%

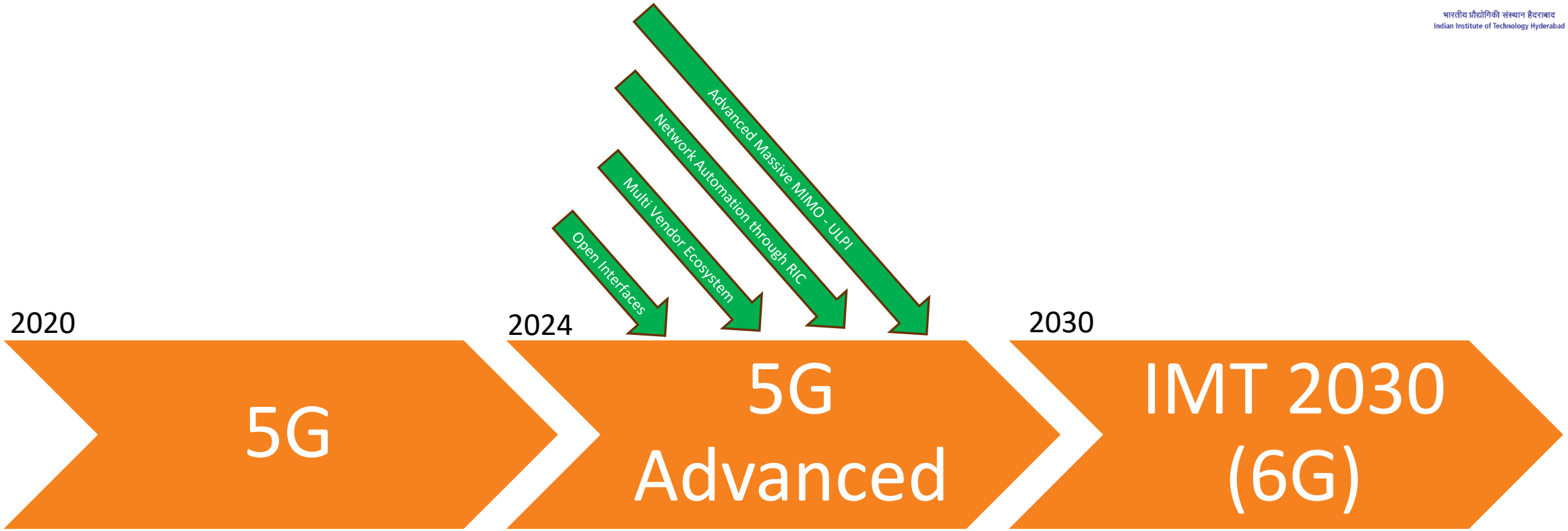
- Outdoor only
- Indoor and outdoor
- Indoor, outdoor and flexi
- Flexi only
- Indoor and flexi
- Indoor only

Global Net FWA additions : 190 Million in next 6 years
Global Net CPE shipments: 37 Million (in last 12 months)
80% of the FWA will be on 5G by 2030
Asia Pacific to account for 40% in 2024 and 48% in 2030
India deployed 3 Million FWA connections in last 12 months

India may add another 15 ~ 18 Million FWA connections over next 6 years

Source: Ericsson Mobility Report Nov 2024

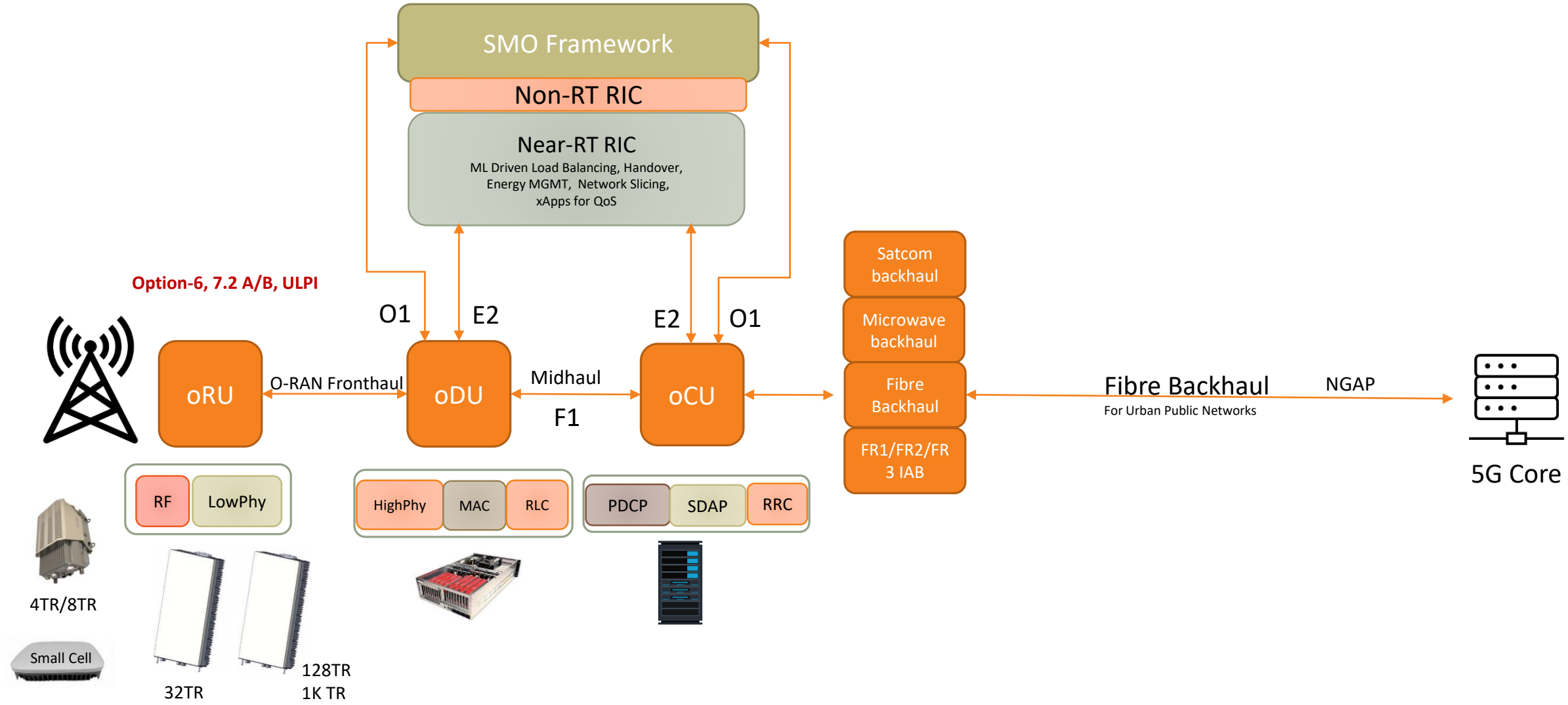
5G transforming into Open Programmable Intelligent Network



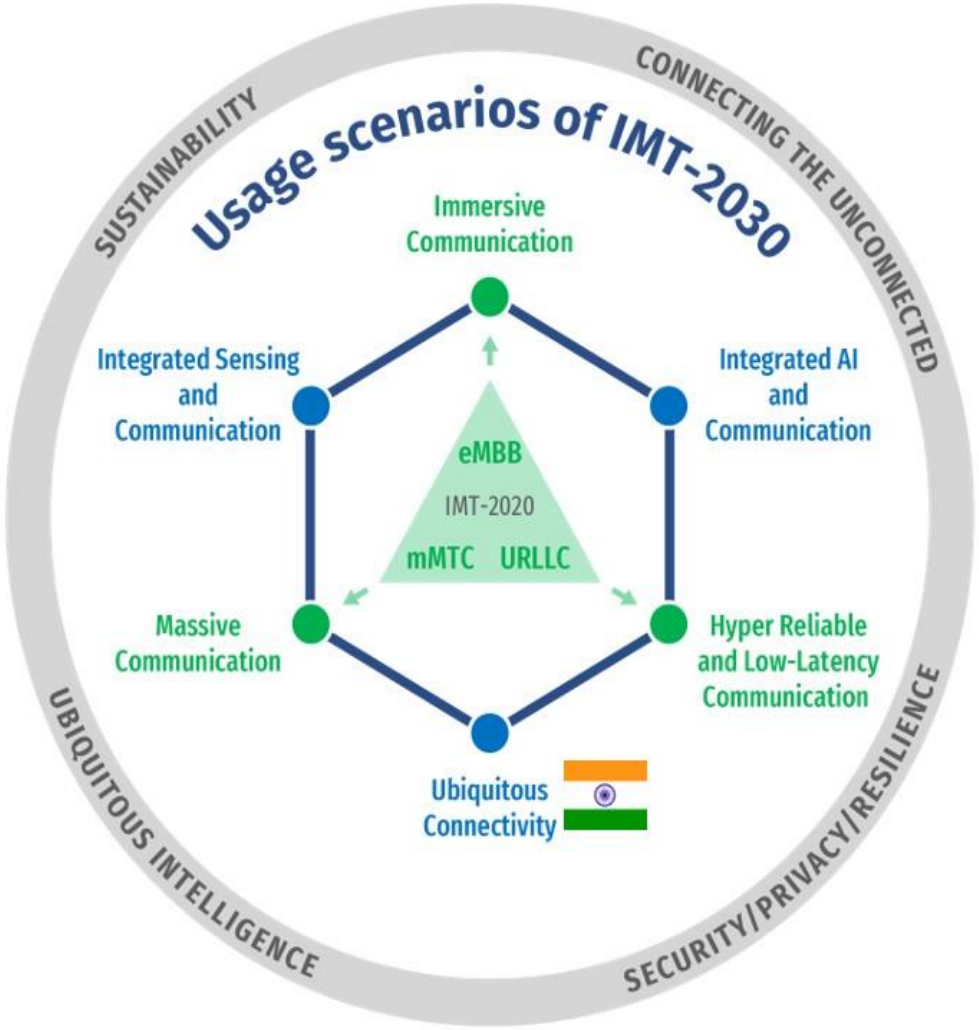
3GPP Release 18 standard.

- performance optimization,
- enhanced spectral & energy efficiency,
- XR and ultra-low latency services
- Integrates Non-Terrestrial Networks

Open Programmable Intelligent Future Networks



Framework & objectives of the future development of IMT for 2030+



Focus on better serving the networked society in developed and developing countries

Evolution of existing IMT, and interworking with other networks such as Satellite are addressed

India introduced “Ubiquitous Connectivity” as a Usage Scenario of IMT-2030

Key 6G Capabilities

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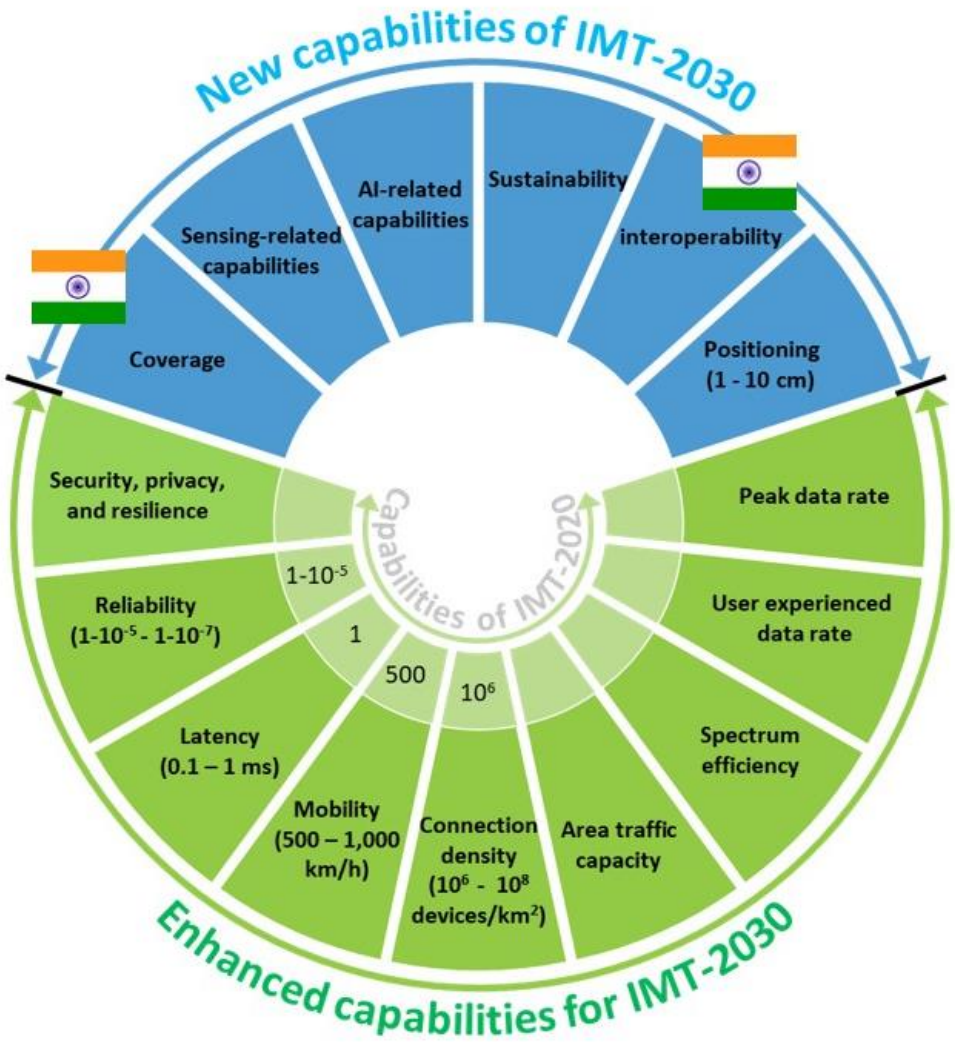

India introduced “Coverage” as a new IMT-2030 capability

IMT-2030 (6G) Applications

Application	Description
Ubiquitous intelligence	AI and ML spread throughout communication, enabling smart cities and autonomous network management
Ubiquitous computing	Data processing expands to cloud & devices, support real-time responses, E2E AI applications
Immersive multimedia & multi-sensory interactions	Personalized Extended Reality (XR) and human-machine interfaces for remote operations
Digital twin and virtual world	Create digital twins, impacting industries like healthcare, agriculture, and construction
Smart industrial applications	Scale smart industrial applications with real-time intelligence and intelligent device connectivity
Digital health and well-being	Enhances digital health services and enables pervasive IoT devices
Ubiquitous connectivity	Connect underserved areas, bridging the digital divide with consistent user experience
Integration of sensing & communication	Integrate sensing for innovative applications and enhanced situational awareness
Sustainability	Aim for environmental, social, economic sustainability, leveraging circular economy principles

Ongoing initiatives at the national level

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6G Communication System

- OTFDM Waveform
- 6.425-7.125GHz System Prototype
- IITH

Extreme Massive MIMO Test Bed

- Structural MIMO and Distribute MIMO, Cell-free
- IITH, IIT Mandi, IIT Roorkie

Advanced Optical Communication Test Bed

- Optical Technologies
- IITM and Consortium

O-RAN

- Bharat RAN Consortium
- A: CDOT, VVDN, WiSig
- B: Lekha, Signalchip, Resonous

* Saankhya Labs

6G THz Test Bed , T-Hz RIS

- SAMEER, IITM, IITG, IIT Roorkee etc.

6G NB-IoT Satcom

- SoC, NB IoT Chip Satcom developed
- IITH, ISRO

5G Advanced Standardization

- IITB, IITM, IITH, IITD, IITK, CEWiT, IISc, IIT KGP,
- 3GPP Rel 18,19,..
- ITU WP 5D

***Tejas/TCS/Saankhya, Jio, HFCL, WiSig**

FR1/FR3 RIS

- IIT Bhilai, SAMEER, IITD, IIT Jodhpur, IITP, IIT Roorkee, CEWiT, Tejas, TSDSI RIC spec.

Funding Agencies: Meity, DOT, DST
5G-advanced Communication System project funded by NMICS program of DST, executed by COMET foundation of IIITB.

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Meeting IMT-2030 performance targets: The potential of OTFDM Waveform and Structural MIMO Technologies

How to achieve Ubiquitous Connectivity?

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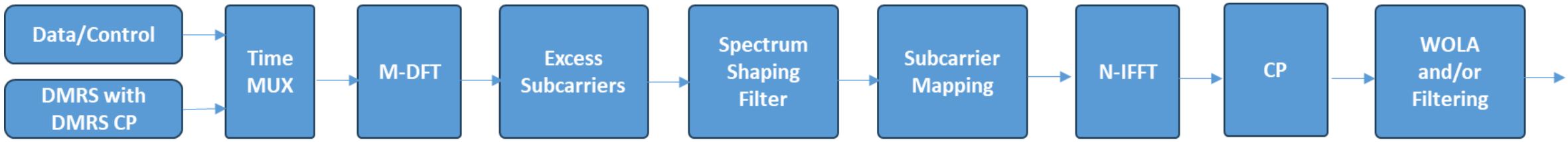
There are four key ingredients

- New Waveform – Energy/Power Efficiency
- S-MIMO: Extremely Large Antenna Arrays
- Chain of Relays (mix of FR1,2,3)
- Tight Integration between Terrestrial and NTN

Orthogonal Time Frequency Division Multiplexing (OTFDM)



Time Division Multiplexing in one Symbol

- Time multiplexing of Data and Control & DMRS with DMRS CP
- Instantaneous Channel Estimation with low DMRS overhead
- Information transfer in one shot with the Least Possible Latency

DFT Excess BW Spectrum Shaping Filter

- Nyquist Criterion for Zero ISI
- Excess BW signal shaping Controls the ISI caused by the pulse, reduces the tails of the ISI channel power to a below-noise floor, Reduces Effective ISI channel length, Enables DMRS-based estimation of the effective ISI channel
- Excess BW reduces PAPR further

Standard OFDM Operations

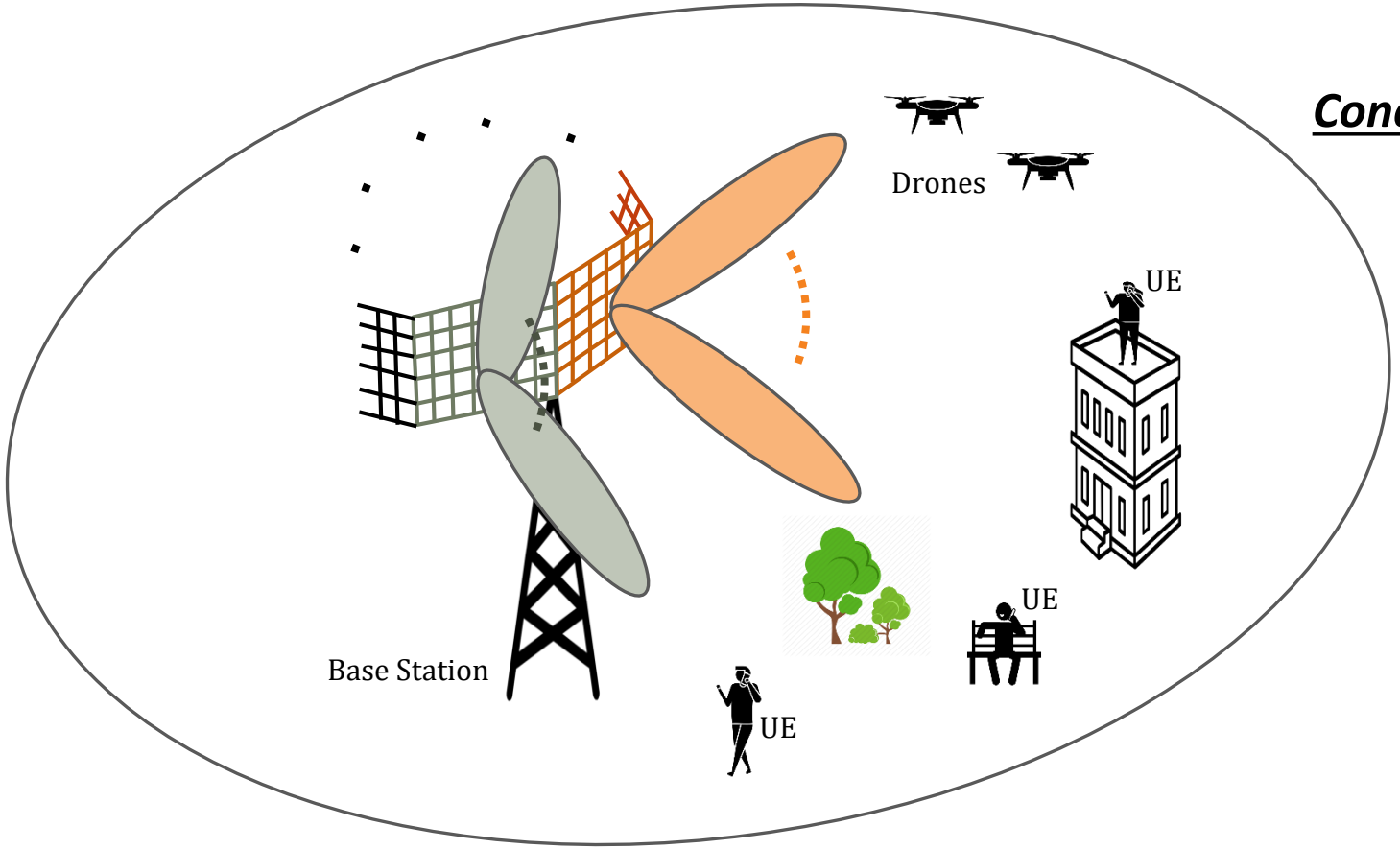
- Subcarrier mapping enables the multiplexing of multiple users/signals
- CP to offer frequency domain receiver processing
- Same spectral properties as OFDM - WOLA/filter for spectral confinement

OTFDM achieves the targets: low PAPR, Hyper low-latency
Enables multi-user multiplexing in time/frequency
Applicable in DL and DL

OTFDM publication pre-print

https://arxiv.org/abs/2409.01114

S-MIMO Concept



Concept of S-MIMO

- *Highly directional beams associated with each antenna port/panel*
- *Structural arrangement enabling 360 degree coverage in azimuth and elevation*
- *A joint baseband processing of signals associated with multiple antenna panels*

Existing systems are limited by limited directivity associated with each antenna port

S-MIMO: Spectrum Creation

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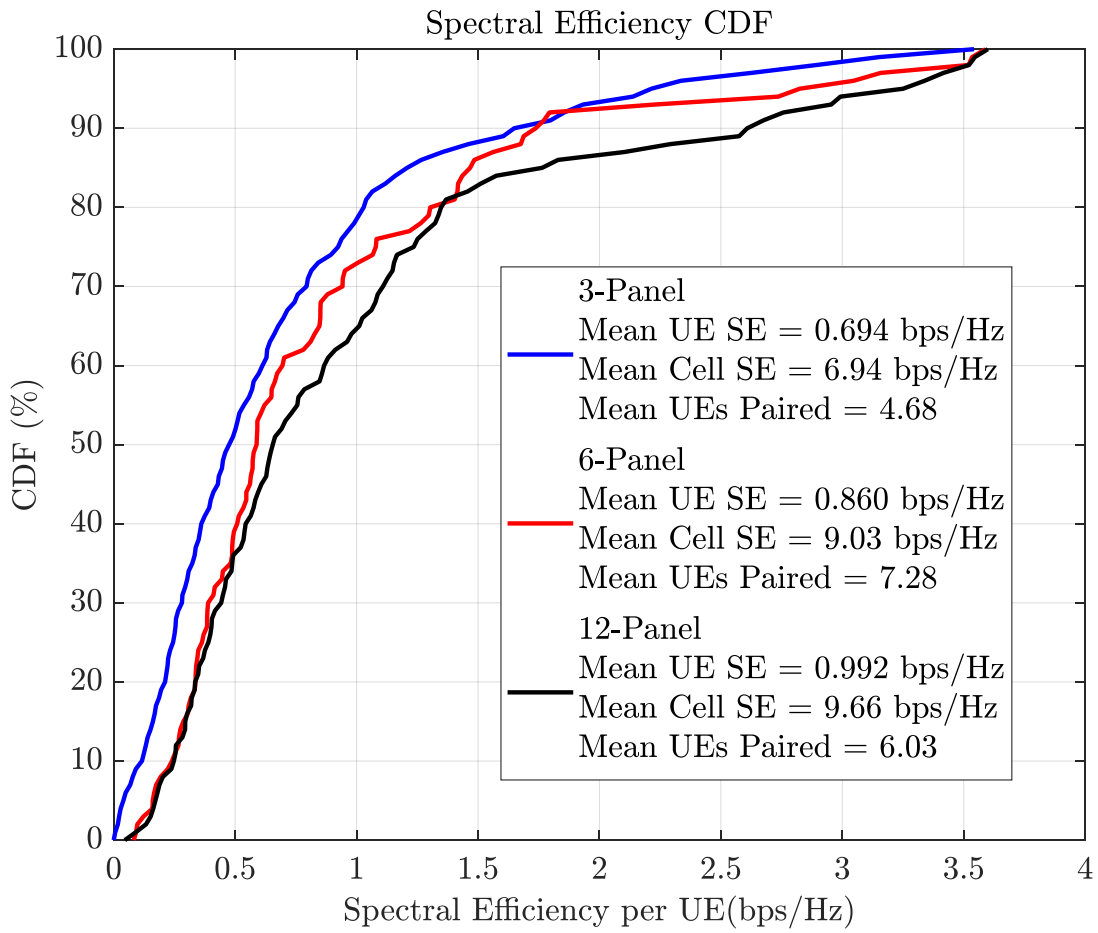
30-deg Beam, 2.4GHz, 12 ports in Azimuth, 4 ports in Elevation, 4-antenna elements per port

- 30-deg Beam allows pairing of 8 users in elevation and Azimuth
- Structural Arrangements of multiple 30-deg beams should allow 100 UEs to be paired at the same time indicating the possibility of reaching 100 Bits/Sec/Hz target

S-MIMO: Network Simulation

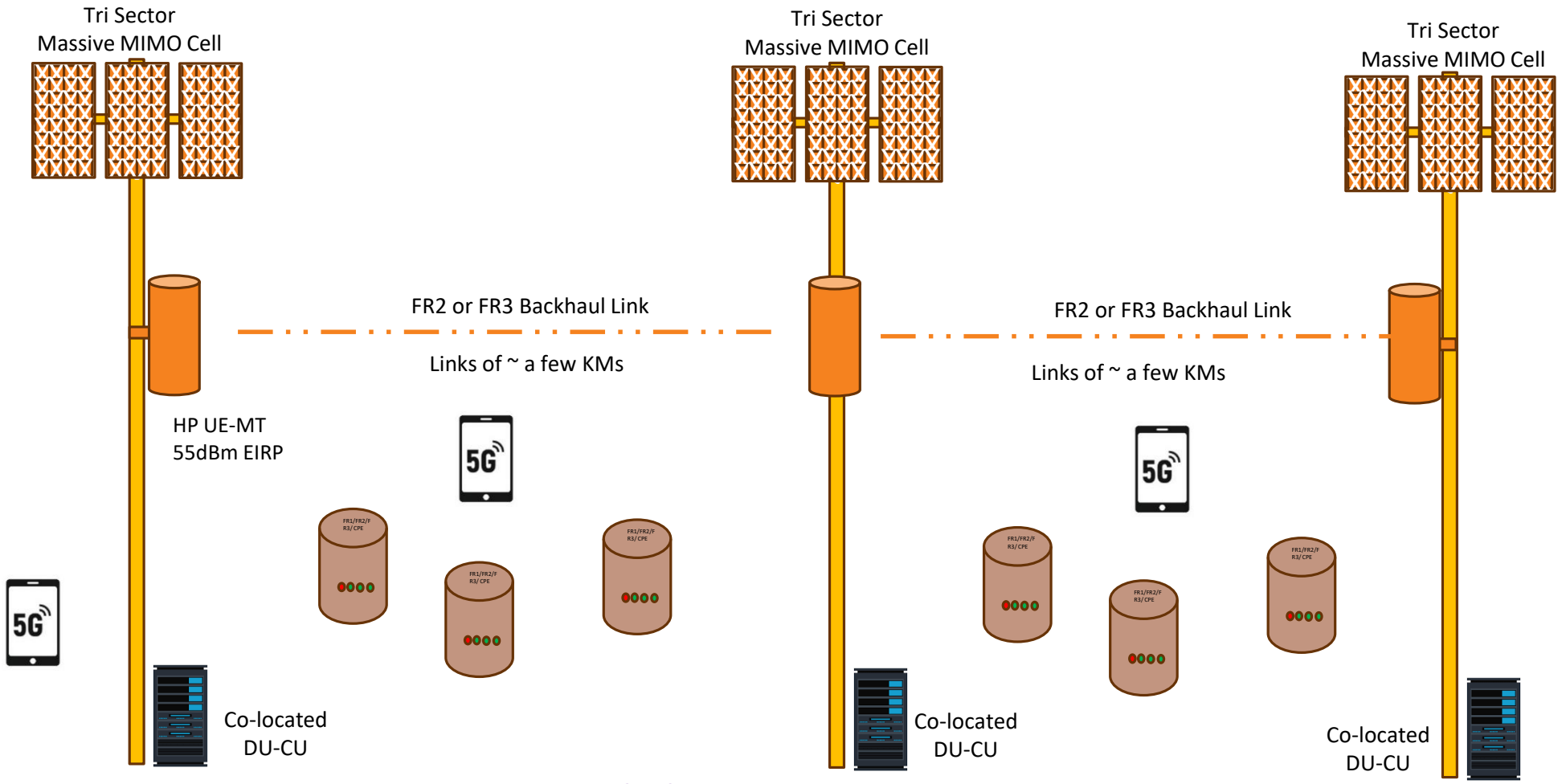


SE numbers in bps/Hz

Antenna Panels	No of Tx Ports /Panel	No of Antenna elements all Panels combined	5% SE	Mean UE SE	Average SE/Panel (Bits/sec/Hz)	Total SE in 360-deg (Bits/sec/Hz)
3	32	192	0.040	0.694	6.94	21
6		1152	0.161	0.860	9.03	54
12		4608	0.172	0.992	9.66	116
DL S-MIMO MU MIMO SE with multiple antenna panels – Mid-band						

- 116 Bits/Sec/Hz feasible in 6G v/s 24 bits / sec / Hz in 5G
- 4.8 fold SE improvement feasible

6G Distributed Hybrid Radio Network



Distributed

- Terrestrial Area
- Dense Complex Environment
- No Centralization

Hybrid

- Dual Mode
- Self Backhauling
- Adaptive Spectrum & Energy Usage

Radios

- Base Station
- UE / CPE
- Wireless Backhaul

Summary

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Enable open interfaces in 6G RAN for improved interoperability across building blocks

Ubiquitous connectivity ensured through multiple spectrum bands across terrestrial 5G, 6G and non-terrestrial network technologies

6.425-7.125GHz is the prime 6G band for India – Testbed results to be published in Q2 2025

6G base station for sensing applications - Testbed results to be published in Q4 2025

Energy efficiency, Coverage, Sustainability, AI for network, etc., need to be part of design

6G RAT should be backward compatible (IoT devices) in existing bands, able to co-exist with 5G and smooth migration

Mobility, FWA, IAB using a mix of 5G and 6G frequency bands for capacity and large coverage

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Thank You !!

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