Samsung Research

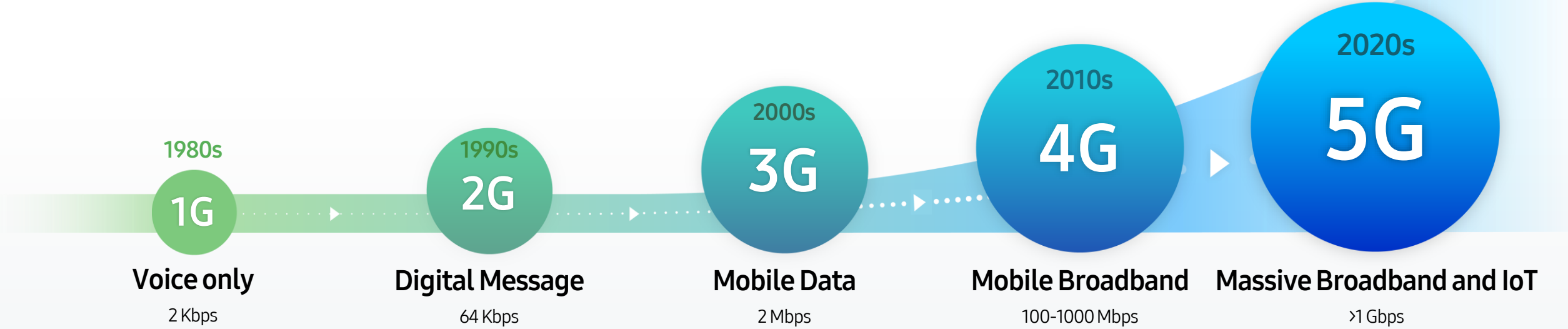
6G: Future Wireless for the AI Era

6G@UT Forum Keynote

Charlie Zhang

3rd April, 2025

Generations Evolution delivering 'WoW' Experiences



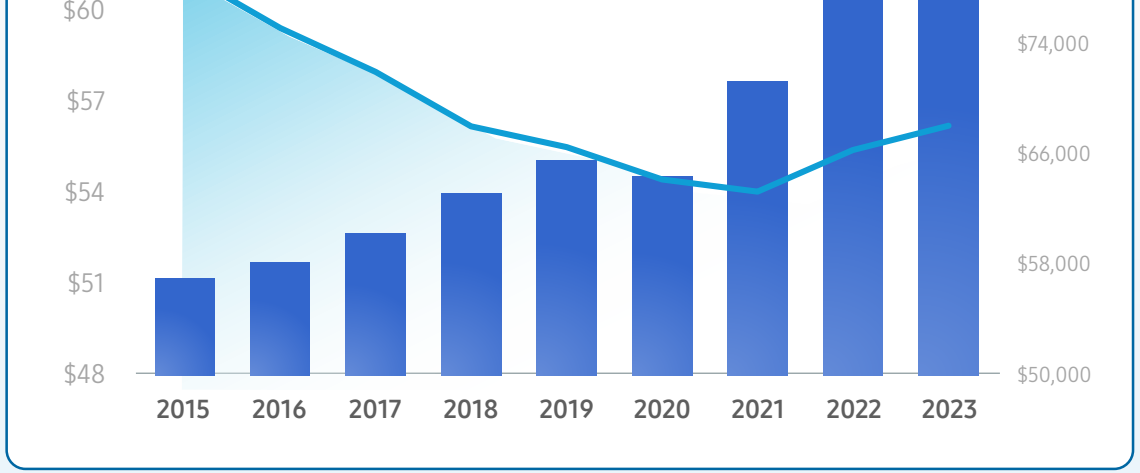
WOW My Number! ▸ Any where, Any time! ▸ Music! Camera! ▸ Game! ▸ Video Streaming! **And...?**

Trends : GDP per Capita and Telecom ARPU

* Average Revenue Per User

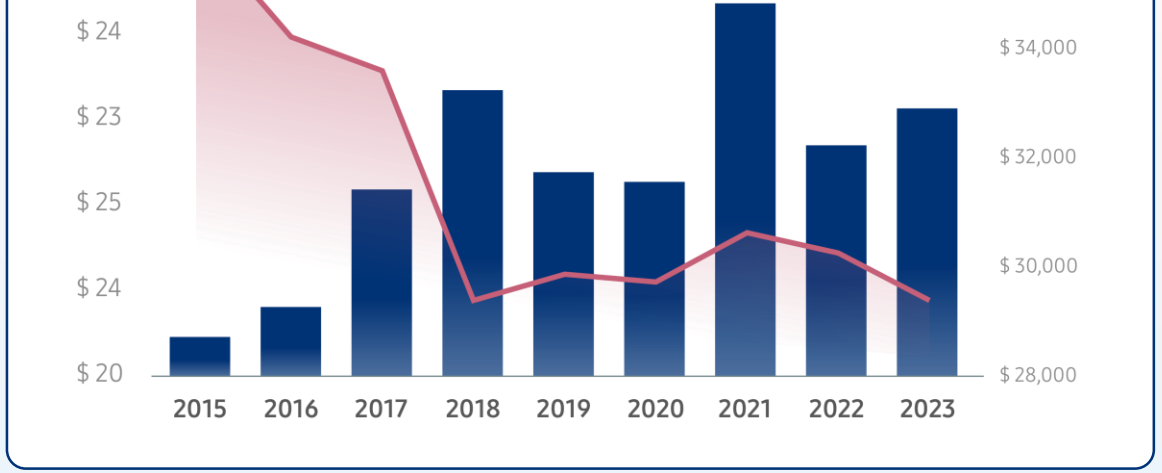
Telecom Economics Diverging from GDP per Capita Growth

United States



* Source: GDP per capita-World Bank, ARPU – AT&T's annual reports

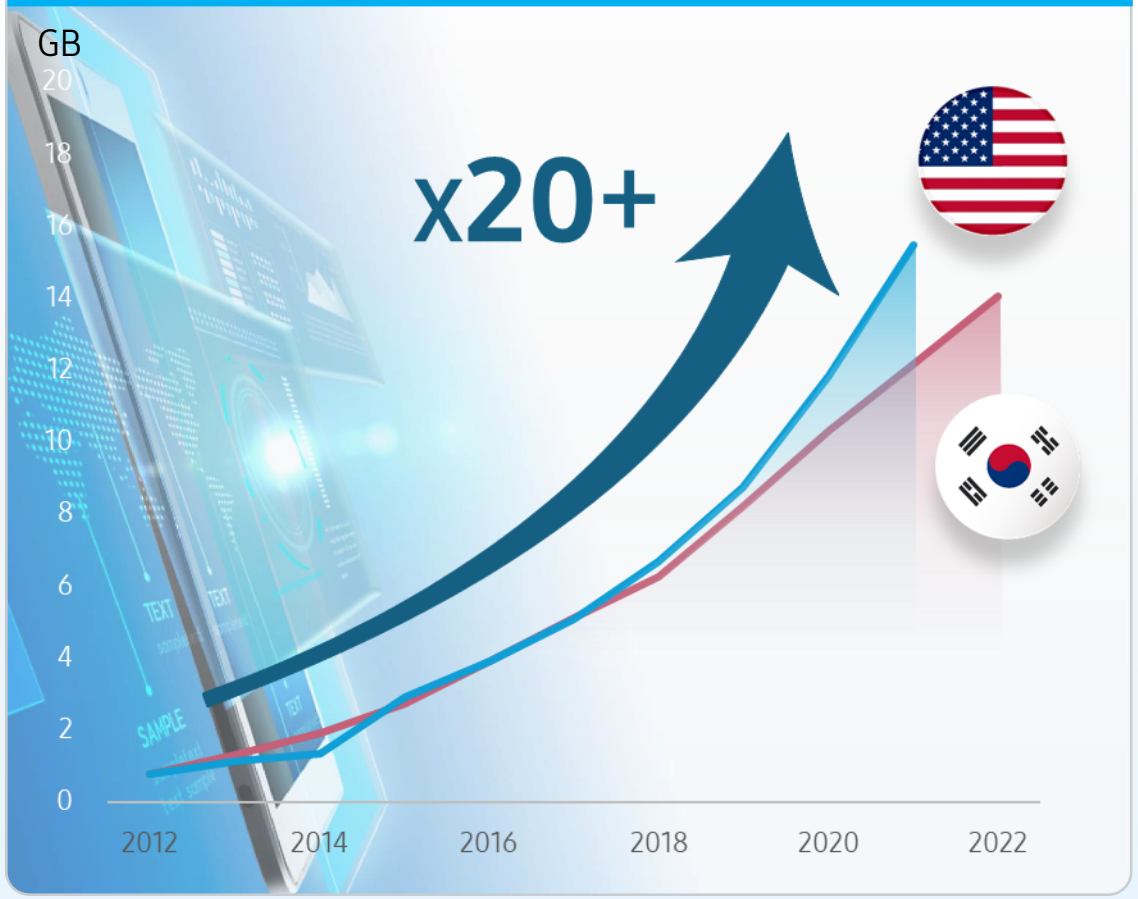
Korea



* Source: GDP per capita-World Bank, ARPU – SKT's Annual Report

More Traffic Grown 20 fold Distributed Evenly across All Users

Mobile Traffic Usage (Per Person, Month)



* Source: Statista

Top 1% Heavy Traffic User Portion

* Source: Cisco Annual Internet Report, 2018-2023

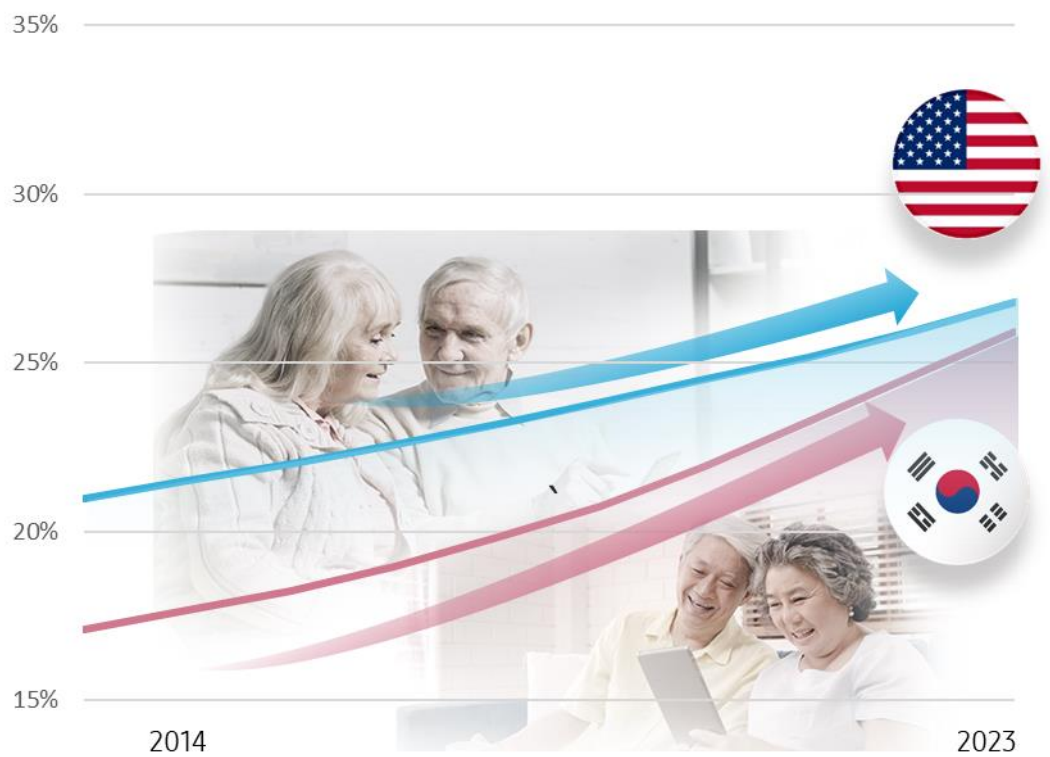
Mobile Data Growth Year-on-year

* Source: Ericsson Mobility Report, June 2024

Aging Population and Rise of Single-Person Household

Driving new lifestyle with automation, unmanned system, personalization and enhanced security

Old-age(65+) to Working-age(15-64) Ratio



* Source: ourworldindata.org

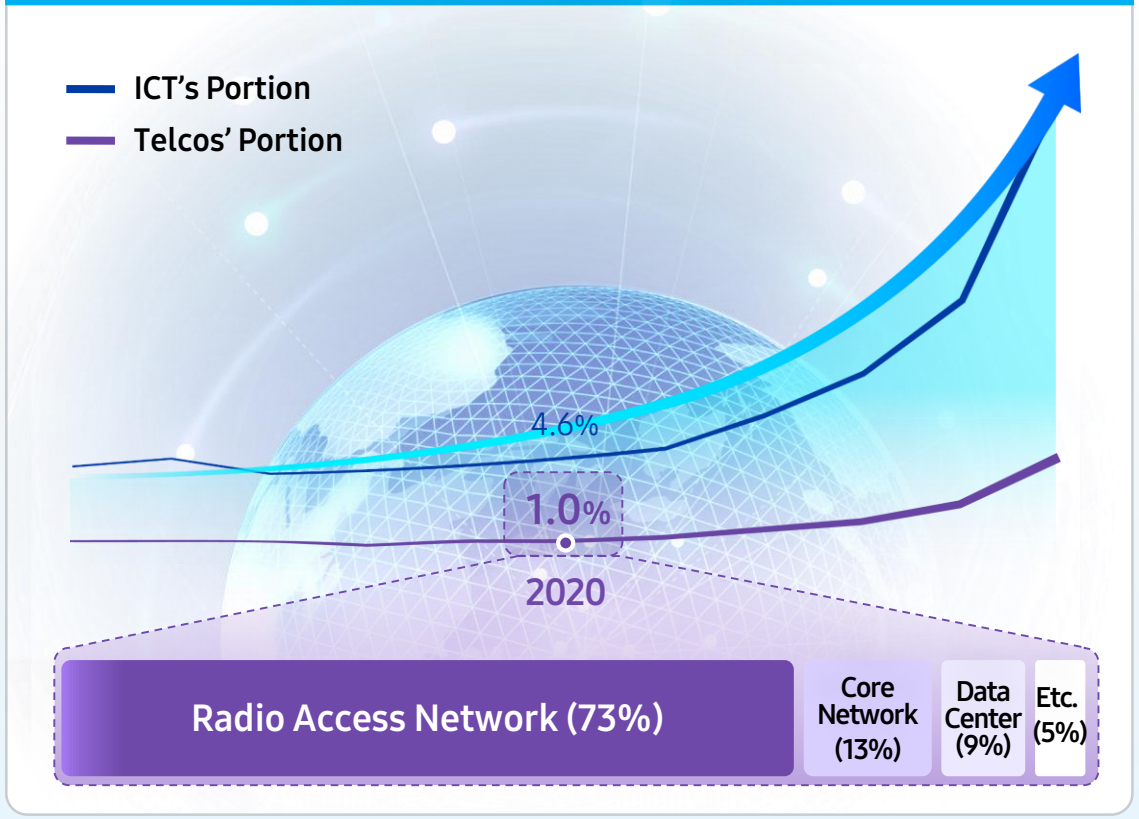
Single-person Households Ratio

* Source: Statista, Statistics Korea

In 2020, Global Telco Consumed 240 Tera Watt-Hour ($120B)

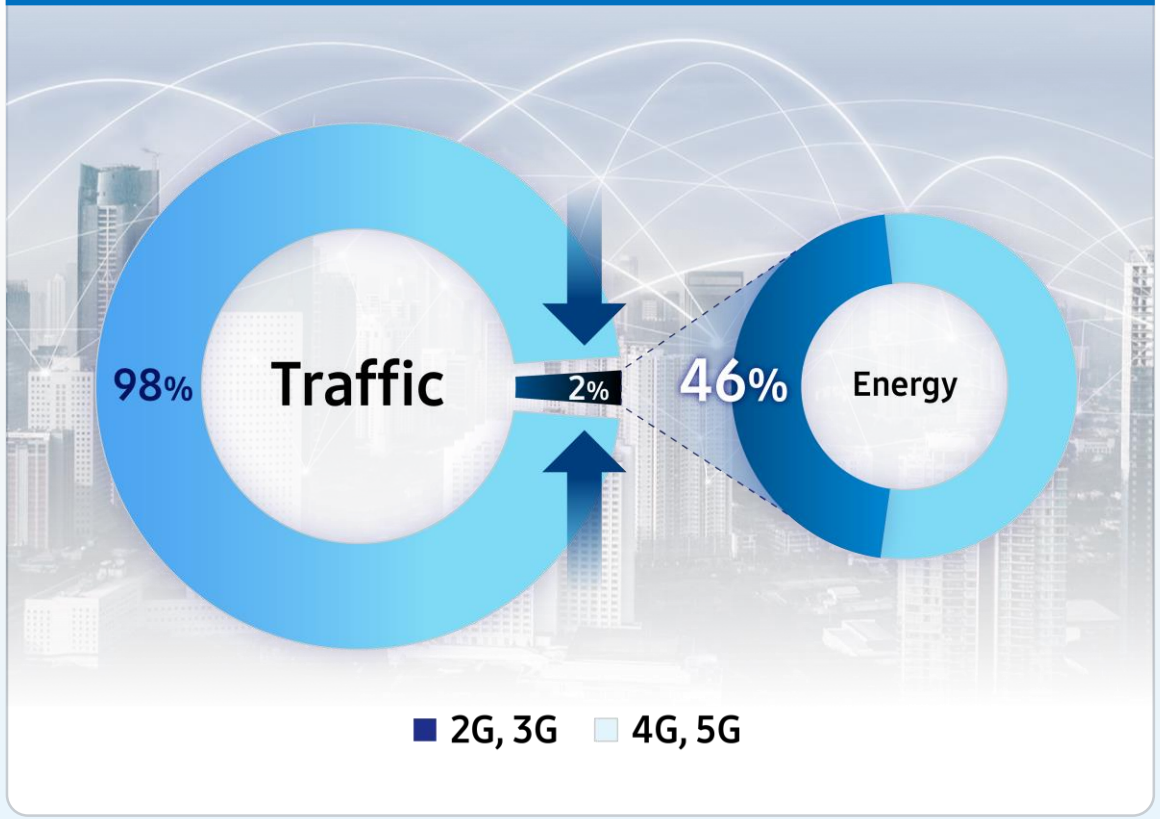
Telco portion expected to increase more, thus critical to modernize and optimize Telco Networks

ICT Energy Forecast



* Source: Nature(Sep 2018), GSMA (June 2021), World Bank (Mar 2024)

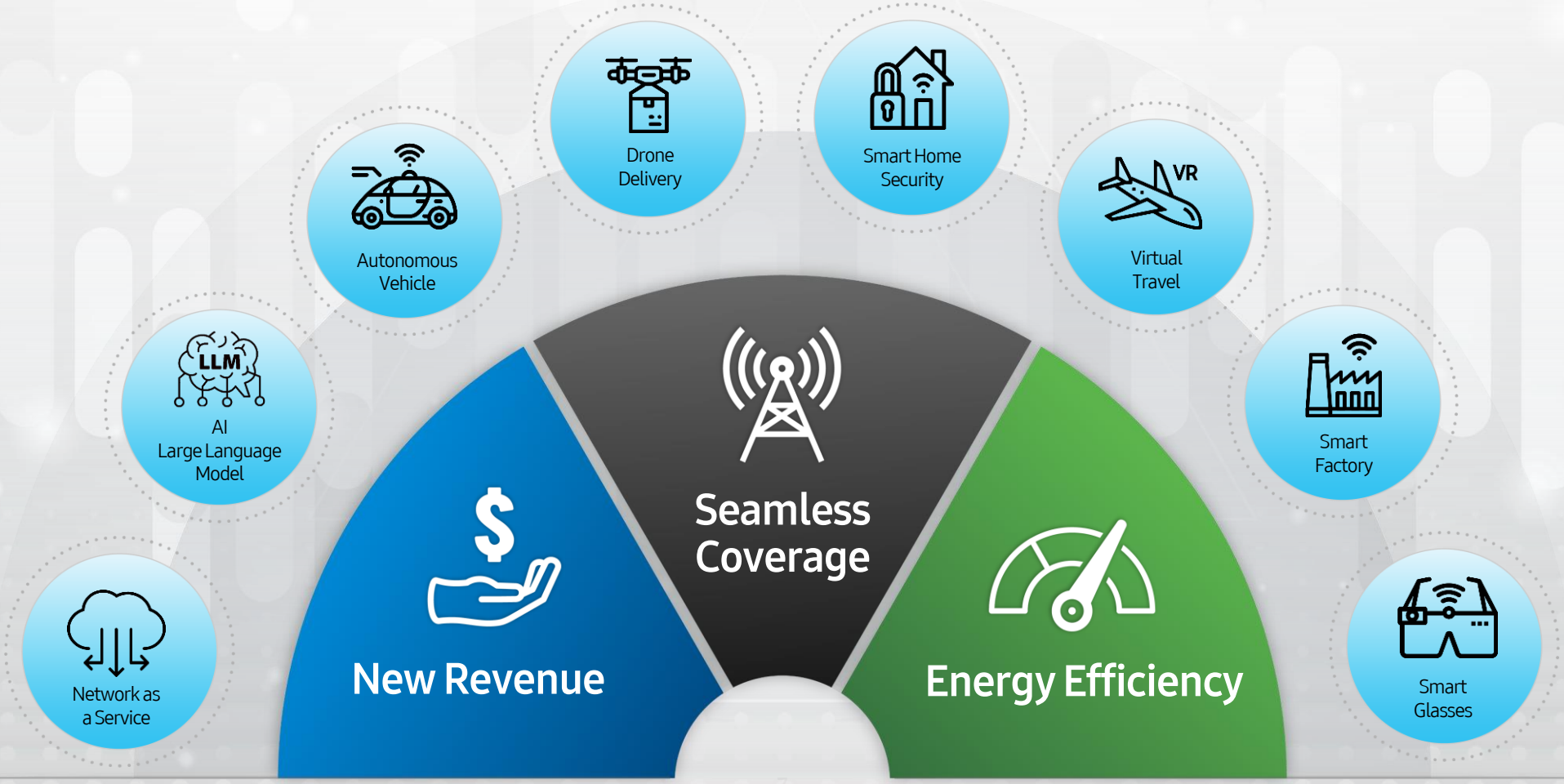
Energy Consumption per Generation



* Source: World Bank (Mar 2024, UAE Telco 'du' case)

New revenue, seamless coverage and higher energy efficiency

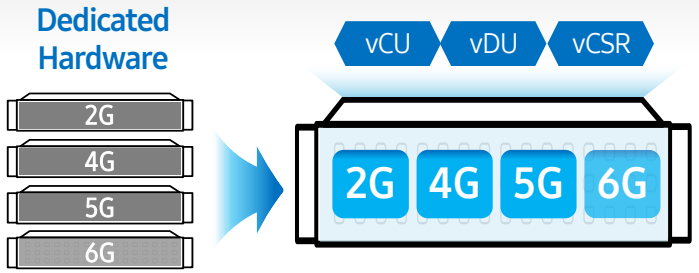
Building foundation for next 'WoW' experiences with "AI-Native" Network



AI-ready, Multi-purpose Single Platform

Delivering flexibility, scalability, automation and versatility

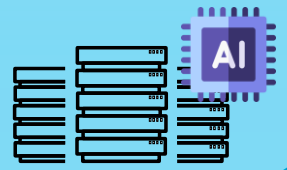
Flexible Architecture & Configurations



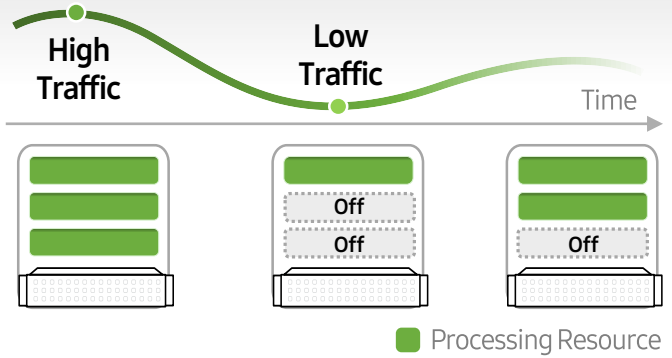
Virtualization

RAN Core IMS Apps

Single Platform



Scalable for Efficiency



Diversified Ecosystem

Autonomous Network

One-click Install & Upgrade

Closed-loop Optimization

Single Point of Control

AI-native Network: Natural Evolution of Virtualized Networks

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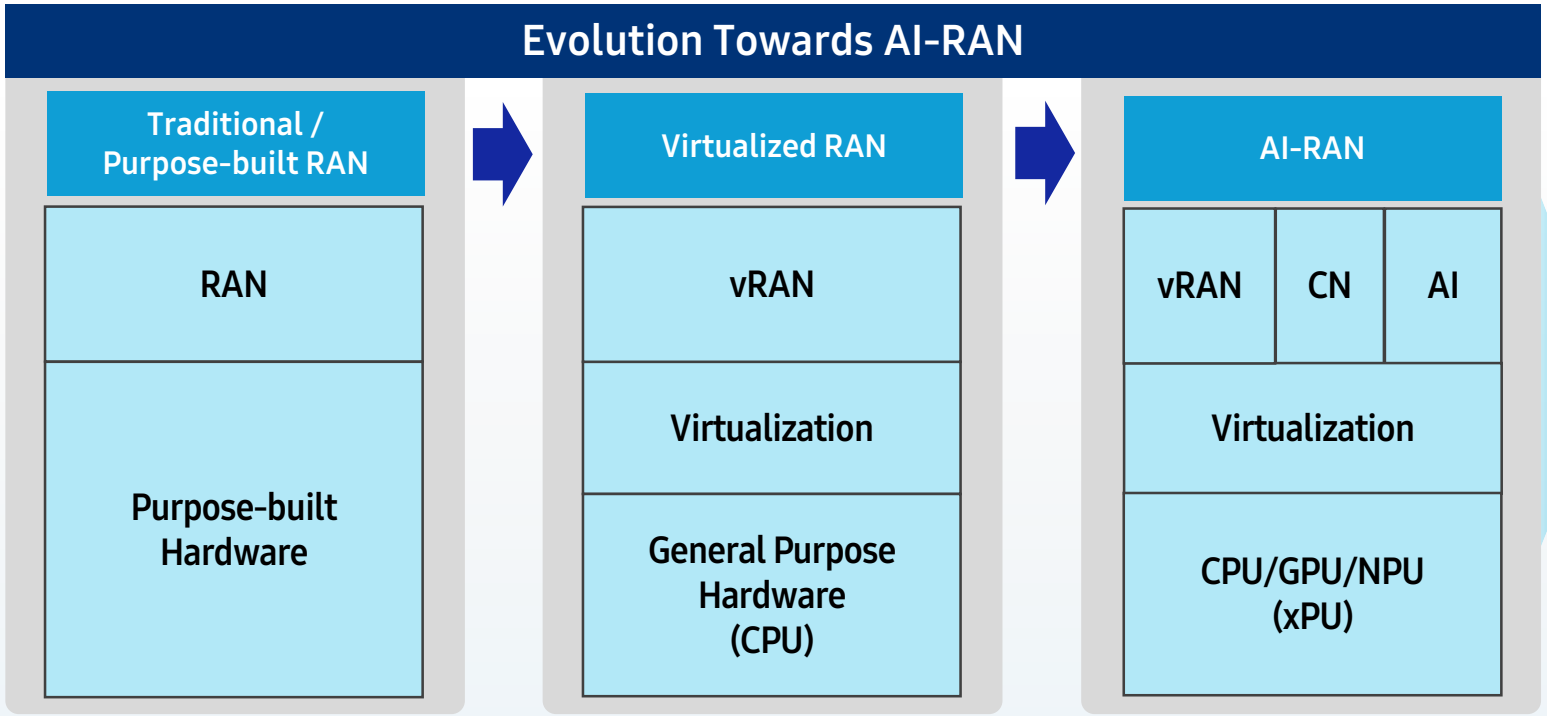
- Enhancing the multi-purpose platform to support AI inferencing capabilities for internal network and third party applications or workloads



AI for Network

AI-native capabilities that improve network performance, ubiquitous coverage and security

Network for AI

Sharing accelerated compute resources for third party AI applications for network monetization

- Participating in the AI-RAN Alliance as a founding member and with leadership positions

*Launched Feb 2024, >70 active members

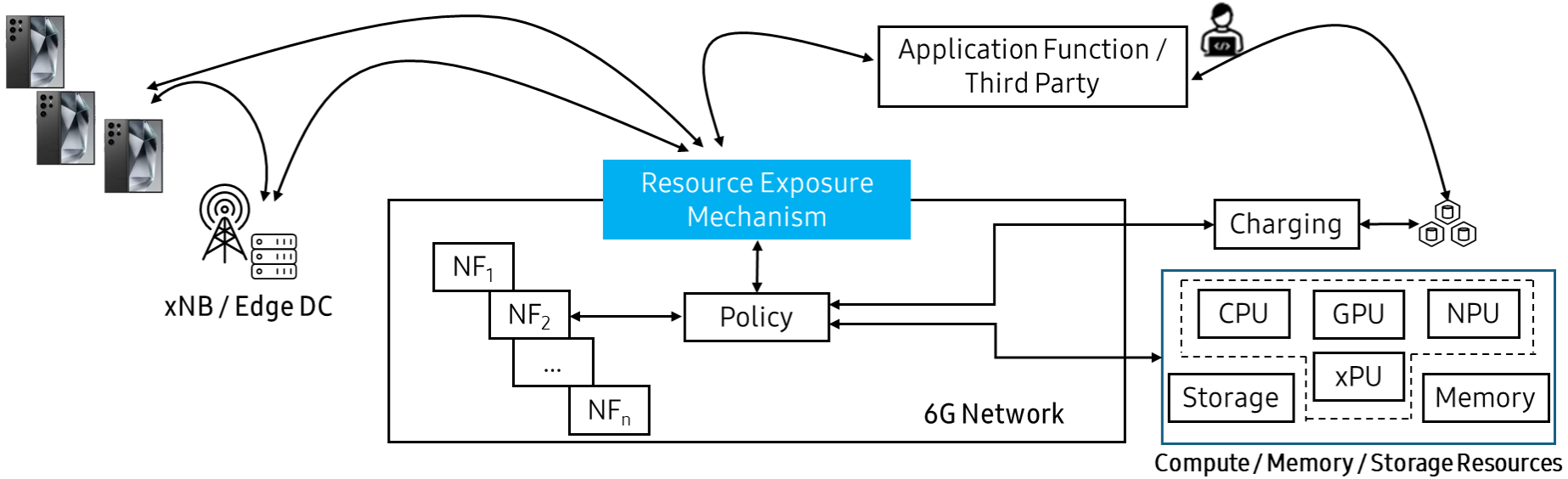
*Vice Chair of BoD, Vice Chair of WG3

Three Working Groups: WG1 AI-for-RAN, WG2 AI-and-RAN, WG3 AI-on-RAN

Network for AI: Architecture Consideration

- Network for AI is a novel way of utilizing virtualized network computing resources for AI training or more importantly inferencing
- 3GPP considering optimizing 6G network infra through resource exposure
- 5G: NaaS already starting (security, OTP authentication) → 6G: ISAC, AI Inferencing, Cloud, etc.

* Network as a Service



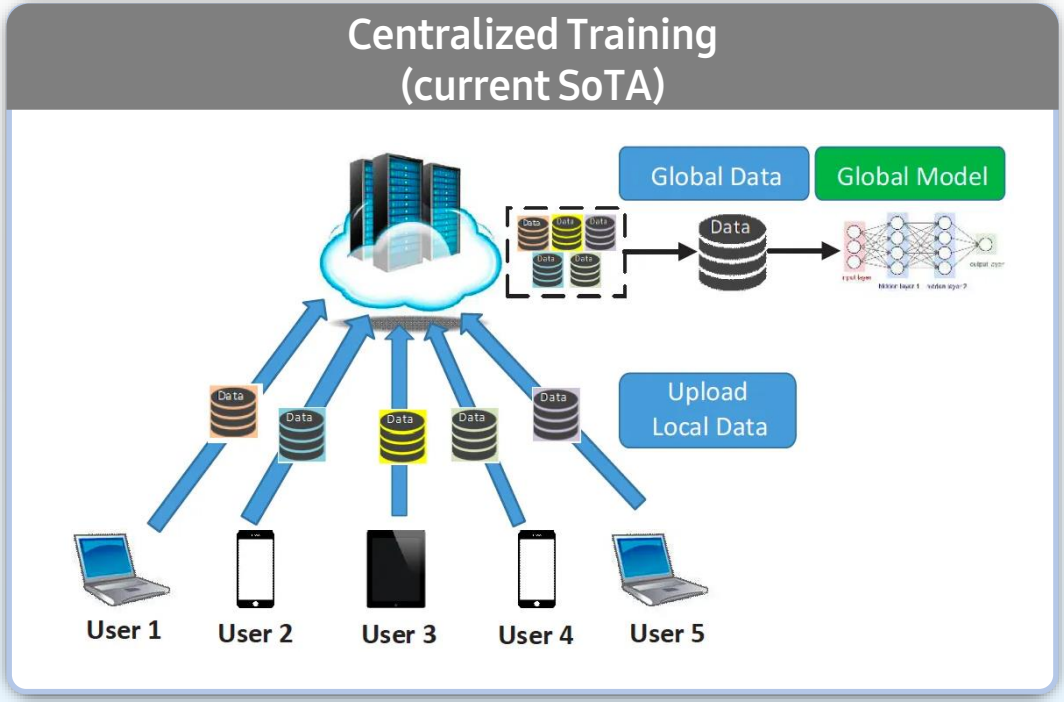
CPU: Central Processing Unit; DC: Data Center; GPU: Graphics Processing Unit; NF: Network Function; NPU: Neural Processing Unit

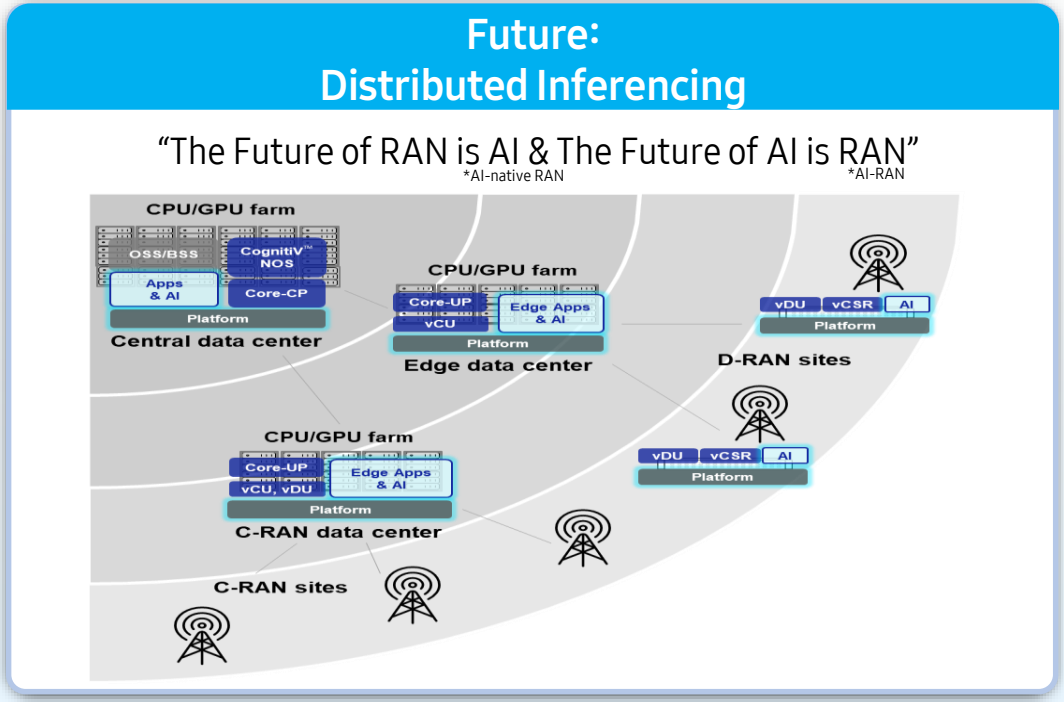
Supporting AI services with 6G network

Current AI industry focus: Centralized LLM Training

- Nvidia CEO Jensen Huang's GTC Keynote: 2.5h of speaking; 17,500+ words; Not one single mention of AI training
- This might be a unique revenue opportunity for network operators:
  - Training models is a CAPEX problem vs. inferencing which is purely OPEX
  - Inference costs are embedded into day-to-day operations, which is less price-sensitive, and the priority is uptime, not cost optimization

Future AI industry focus: Distributed LLM/SLM/VLM Inference





LLM: Large Lang Model, SoTA: State of The Art, SLM: Small Lang Model, VLM: Vision Lang Model

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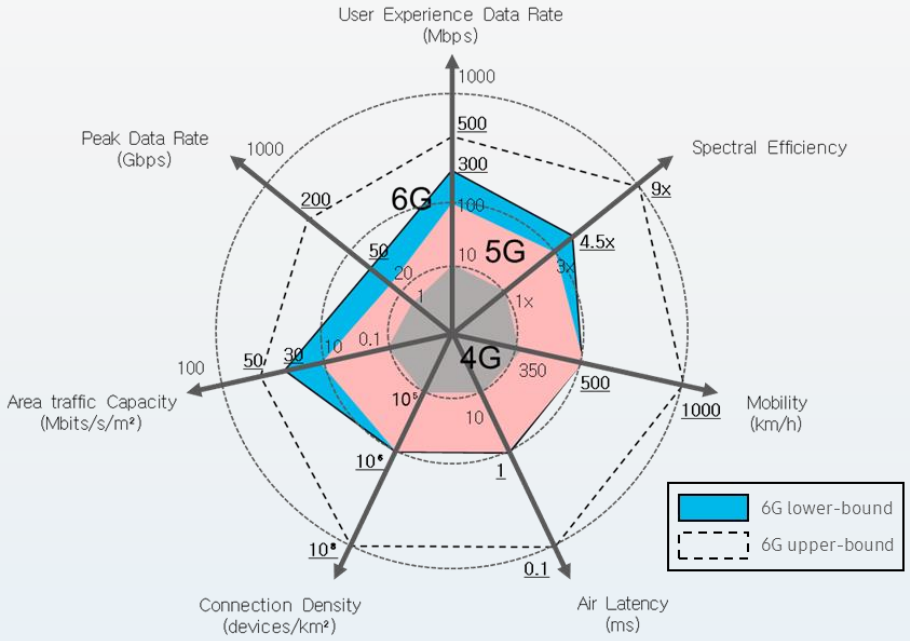
Key 6G Technologies

New ways of thinking to enable unique user experience and service

Past 'G's Focus

4G → 5G, major upgrade in peak rate & latency

5G → 6G, moderate change expected



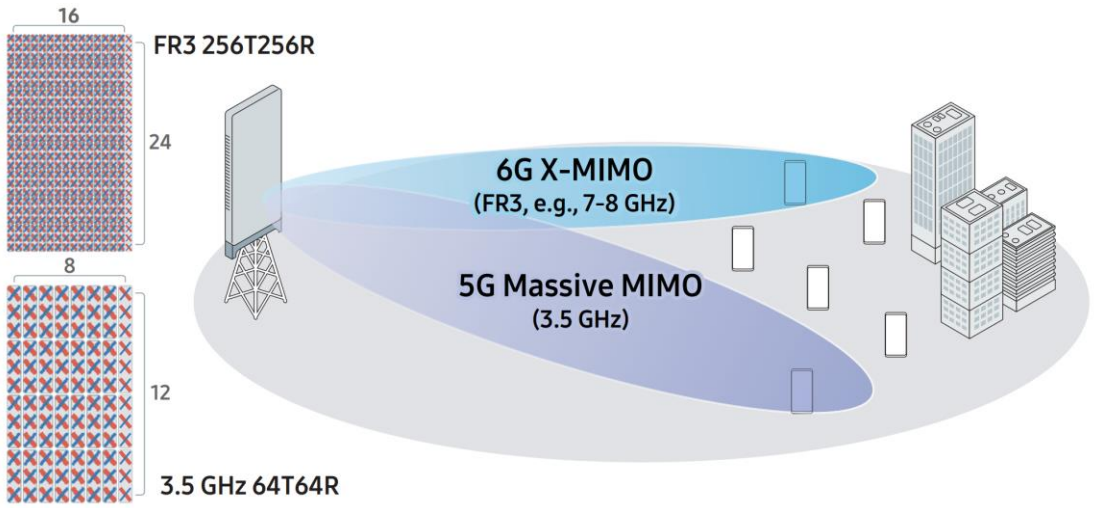
* ITU-R M.2160, IMT-2030 Framework

6G New Attributes

'Future-proof and sustainable user experience'

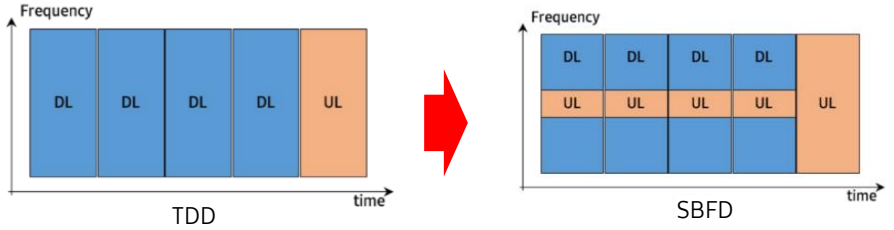
X-MIMO, SBFD, NTN

eXtreme MIMO
(FR3, e.g., 7.125-8.4 GHz, 12.7-13.25 GHz)



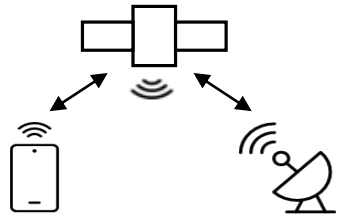
- Extremely large dimensional MIMO technology
- More antennas can be packed within the same area for the higher carrier frequency
- Better beamforming gain can be achieved with more antennas

Duplex Evolution - SBFD



- SBFD (Sub-Band non-overlapping Full Duplex) for UL coverage extension (Rel-19 5G-Advanced in 3GPP)
- Potential enhancement of SBFD in 6G, e.g., UL/DL overlapping

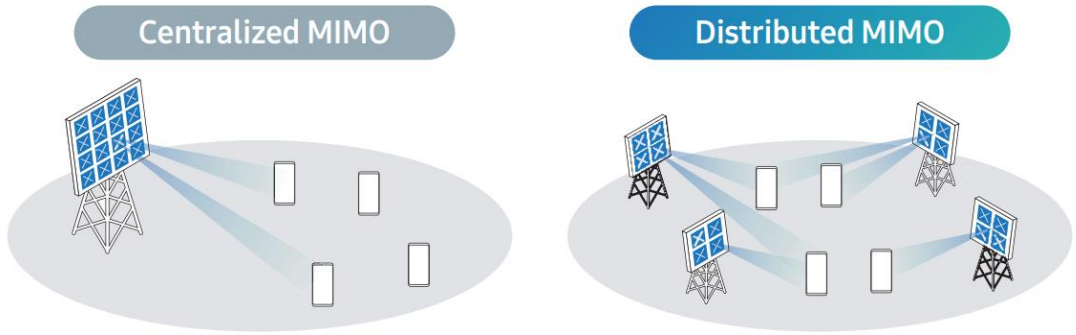
Non-Terrestrial Networks



Provide ubiquitous coverage even in the areas where there is no terrestrial network (TN)

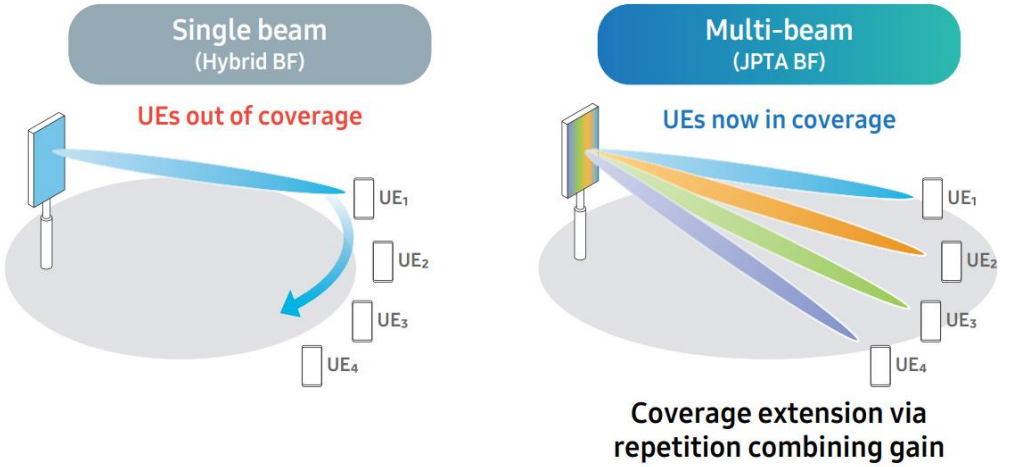
D-MIMO, JPTA

Distributed MIMO
(FR1, sub-3.5 GHz)



- Spatial diversity and additional beamforming gain enabled by the joint use of multiple TRPs
- Better coverage and capacity

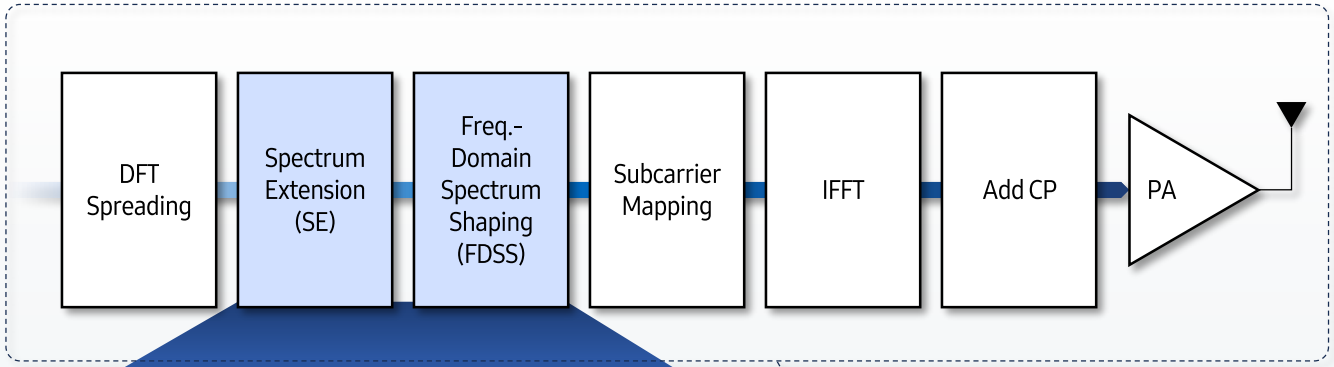
Joint Phase and Time Array
(FR2, mmWave)

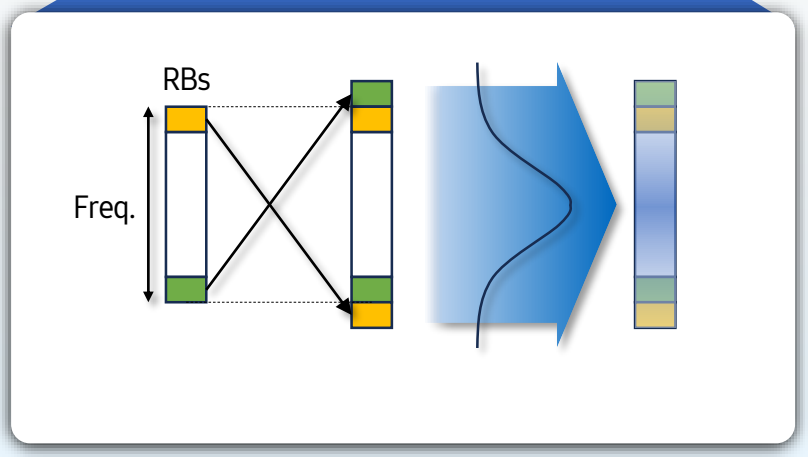


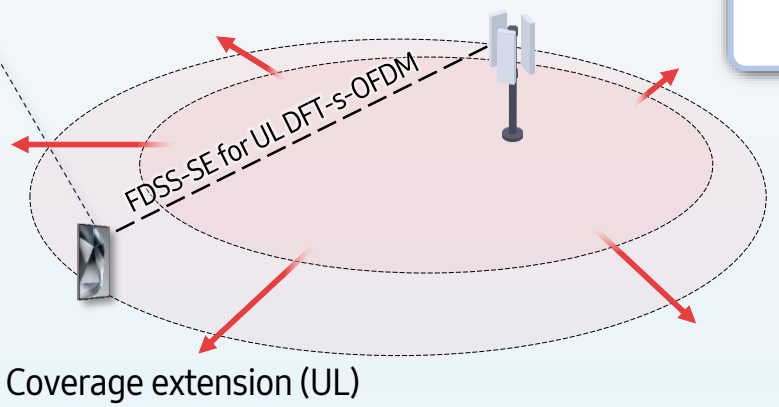
- Concurrent multiple beams for different users
- JPTA (Joint Phase and Time Array) enables uplink coverage extension via repetition combining gain

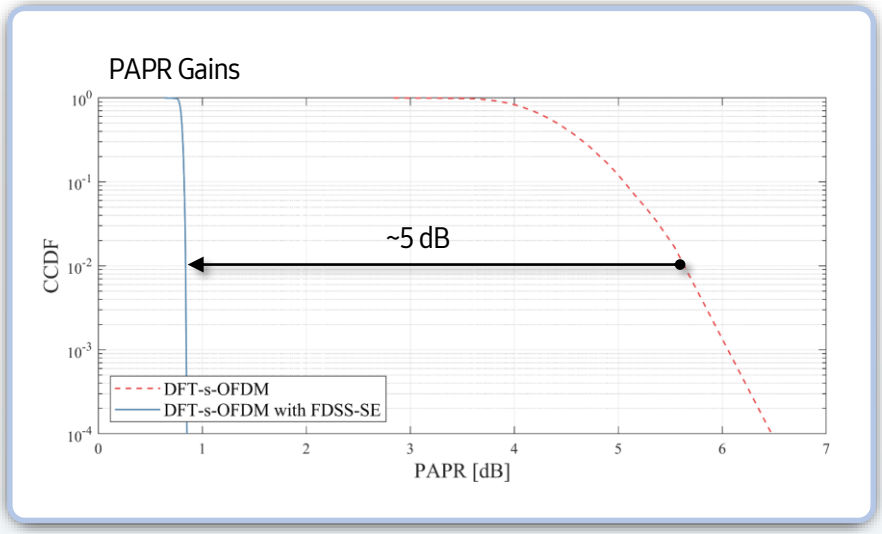
Waveform Enh.: Frequency-domain spectrum shaping for uplink coverage extension

- PAPR reduction ~5 dB → extended coverage





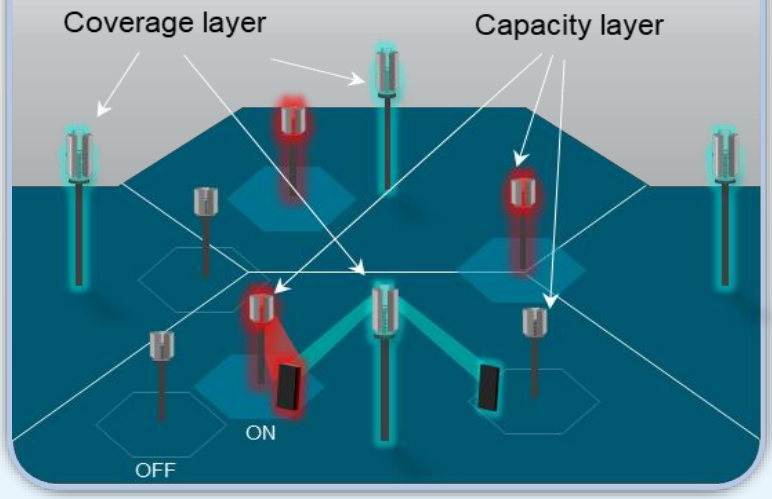




- New design expected to bring greater energy saving compared to 5G
- Key features in 6G Network Energy Saving (NES):

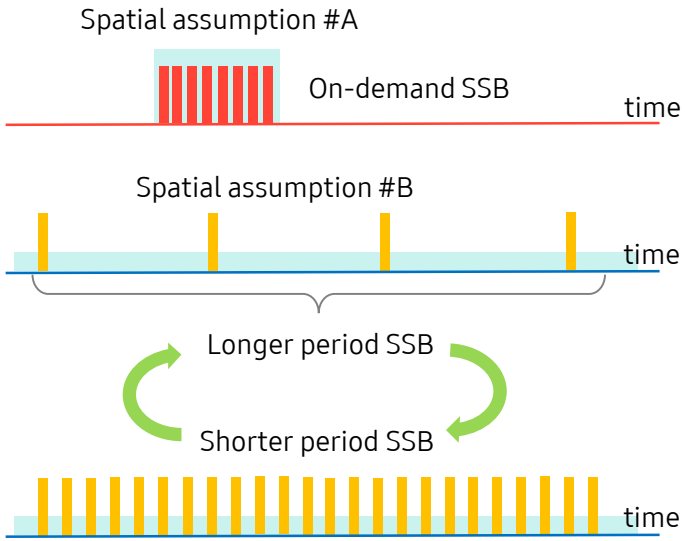
Carrier-dependent capabilities and characteristics

Coverage carrier supports to general operations and capacity carrier takes care of data boosting when available



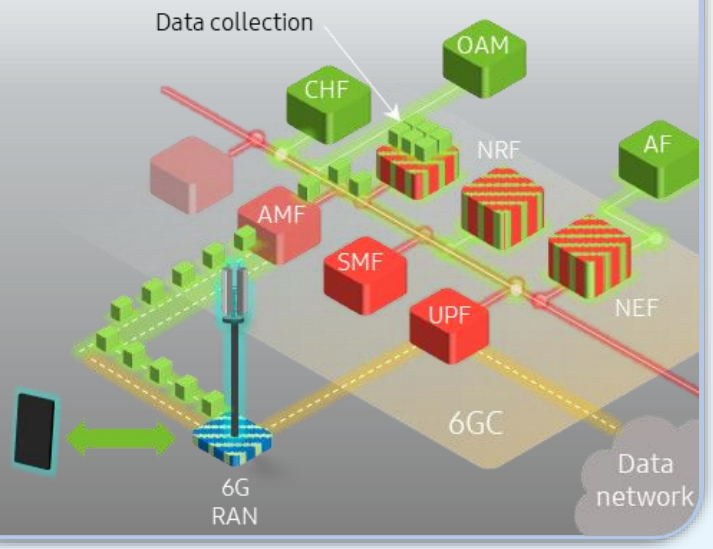
Less ON and more OFF

Design air interface from the scratch to make more sleep and less ON for both CA and non-CA cases



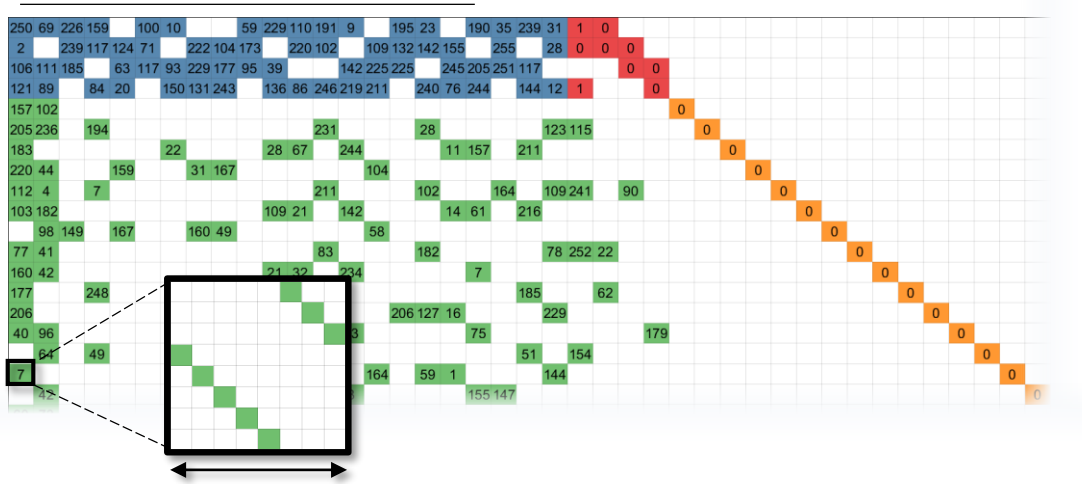
Energy-aware management and exposure

6G core network should support energy-aware and energy-oriented policy, management, charging, and exposure



- **Enhanced LDPC codes** (data) → High-throughput decoder-friendly structure (= energy efficiency)
- **Enhanced Polar codes** (control) → Large block support

5G NR LDPC code structure

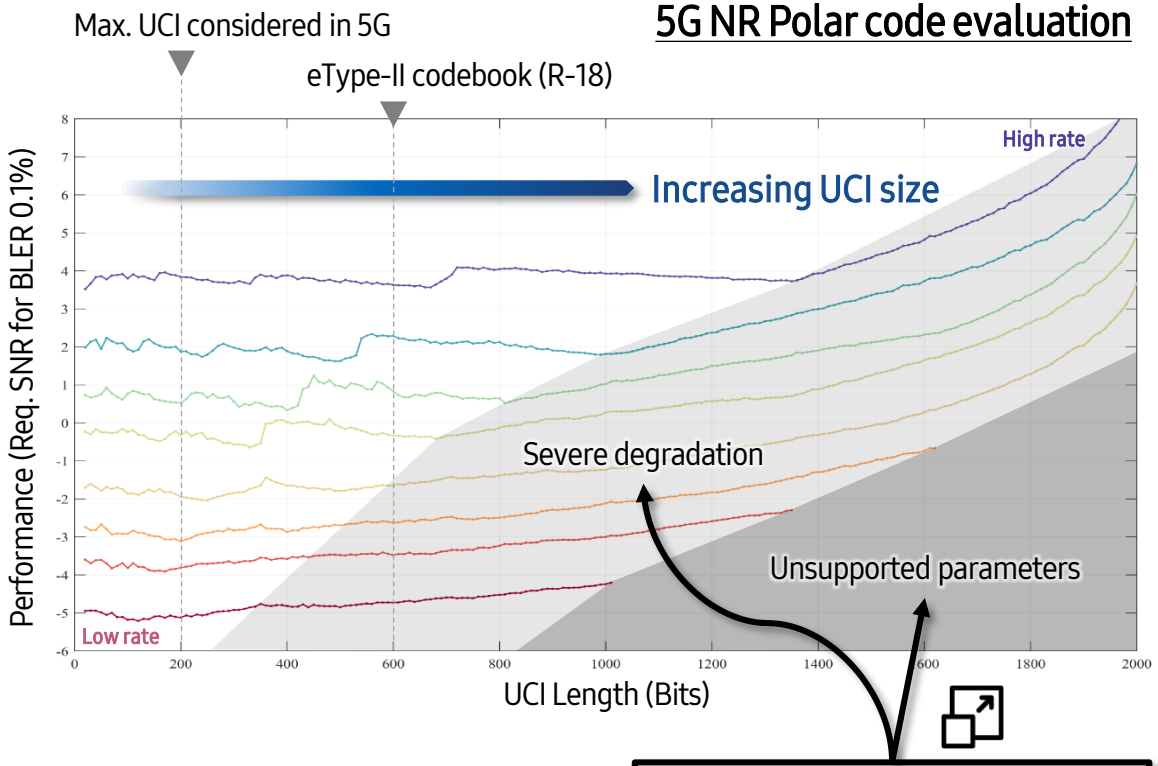


5G: Lifting size 384 → **6G: 2x larger lifting size** (e.g. 1024)

High-parallelizable LDPC code framework (for energy efficiency, high throughput)

+ Better BLER

5G NR Polar code evaluation

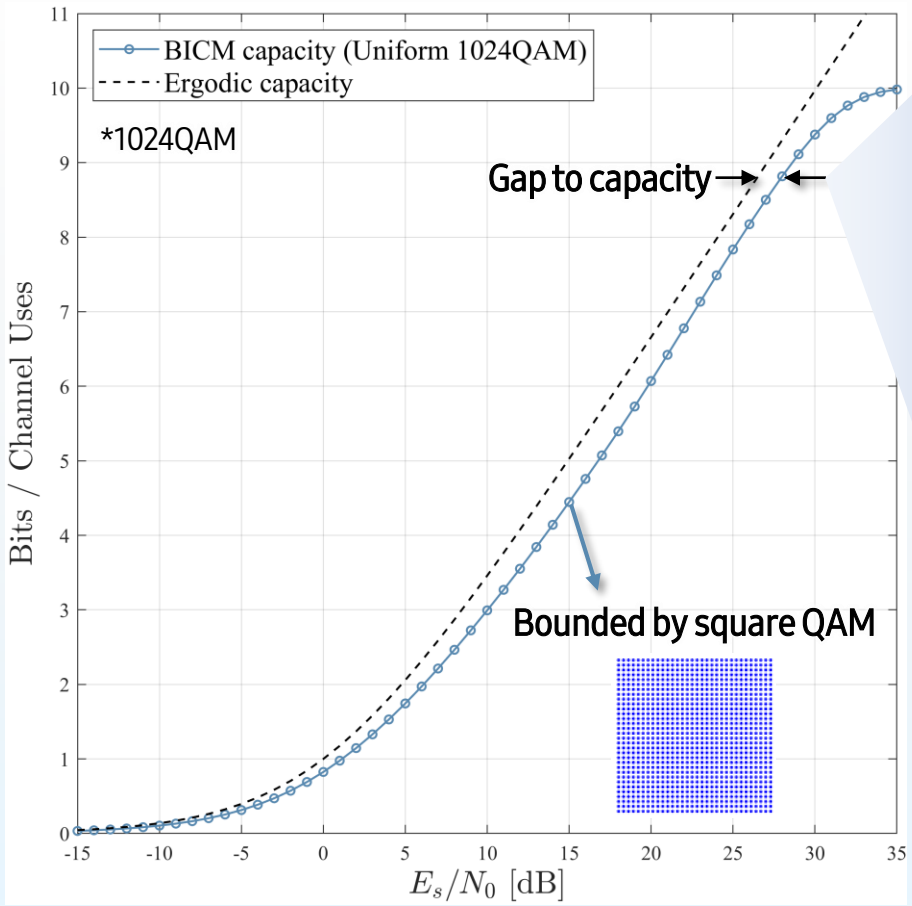


Better BLER +

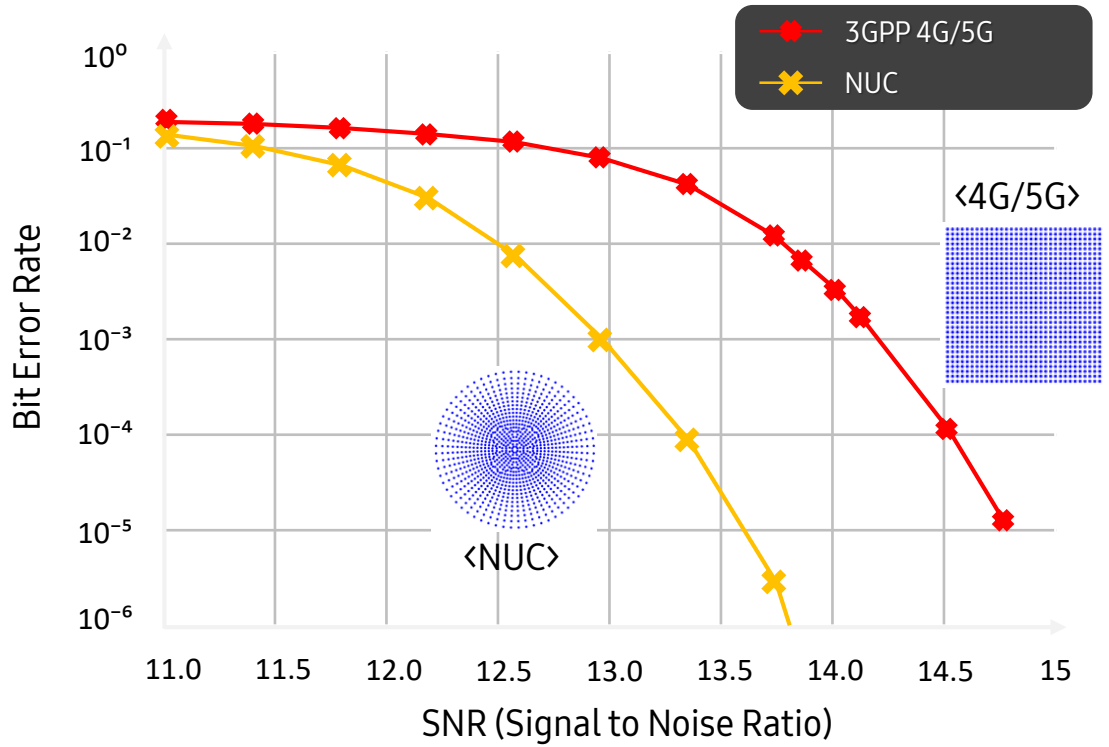
Large-block polar code design
New segmentation method

Possible approaches for enhanced modulation

- Constellation shaping (e.g., non-uniform constellation for higher order modulation)
- New combination with channel coding



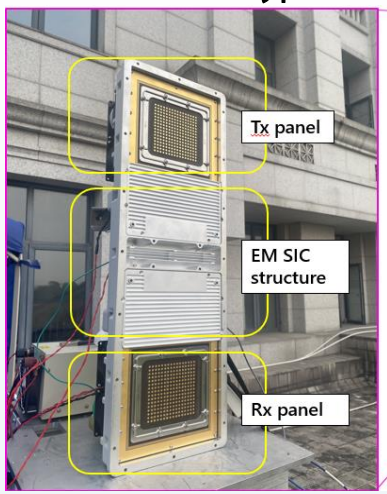
(Non-uniform constellation)



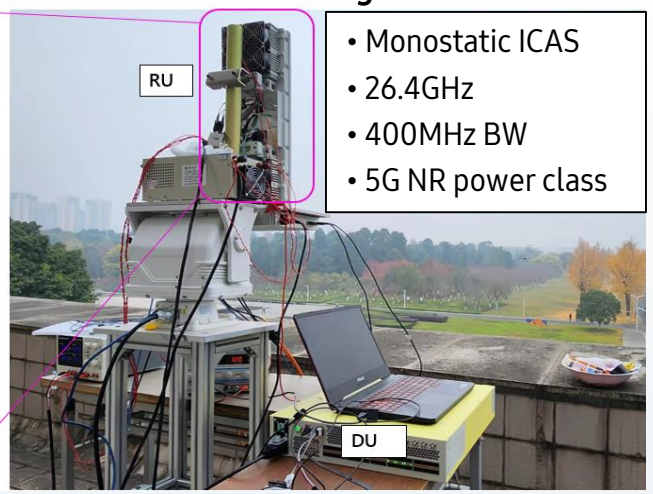
Integrated Sensing and Communication

- One of 6G usage scenarios defined by IMT 2030
- Leveraging cellular networks as a ubiquitous sensing framework
- Importance increasing in industry and standardization bodies with rise of applications (e.g., factory automation, environmental monitoring, etc.)

ISAC Prototype

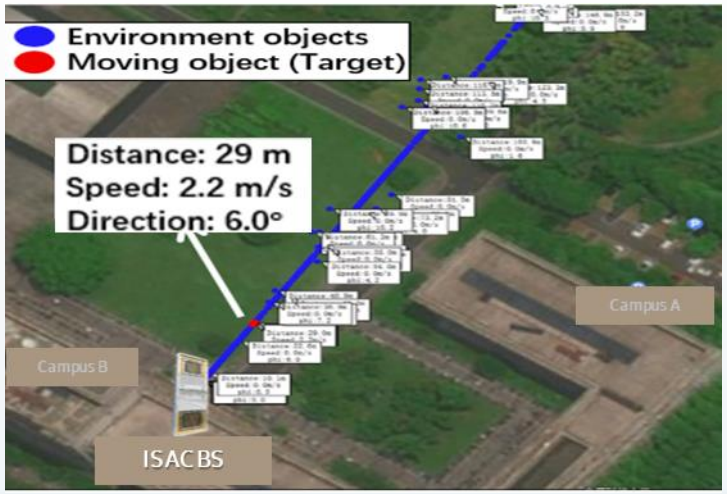


Settings



- Monostatic ICAS
- 26.4GHz
- 400MHz BW
- 5G NR power class

Field Test Scenario



Sensing Metric	State of The art	PoC Test Results
Ranging	5G FR2 CP coverage: ~100m	~ 1 km detected (beyond cell coverage)
Distance accuracy	5G positioning (decimeter level)	Decimeter level
Angular accuracy	5G FR2 beam measurement ~ 3° level	< 1°

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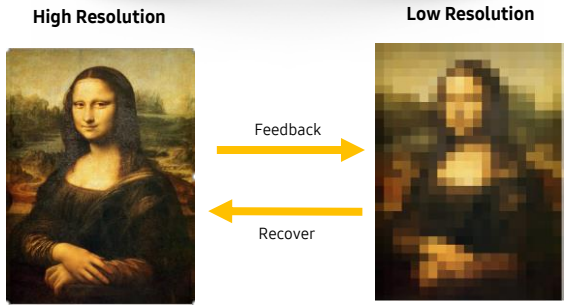
AI for Communications

AI for Future Telecom

- Wireless communication system could be automated end-to-end and optimally operated/managed using AI

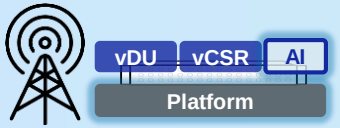
AI -native L1/L2 Radio



AI Channel Estimation & Prediction

AI Precoding & Scheduler

Cell Site

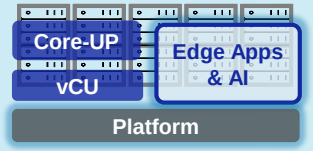


Network Optimization and Automation

Network Analytics

Network Parameter Optimization

Edge Unit

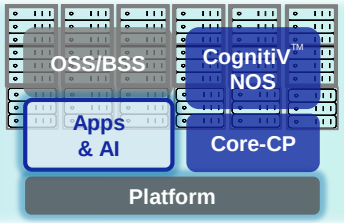


Telco LLM

AI-Agent for intent-based optimization

Other AI applications

Data Center

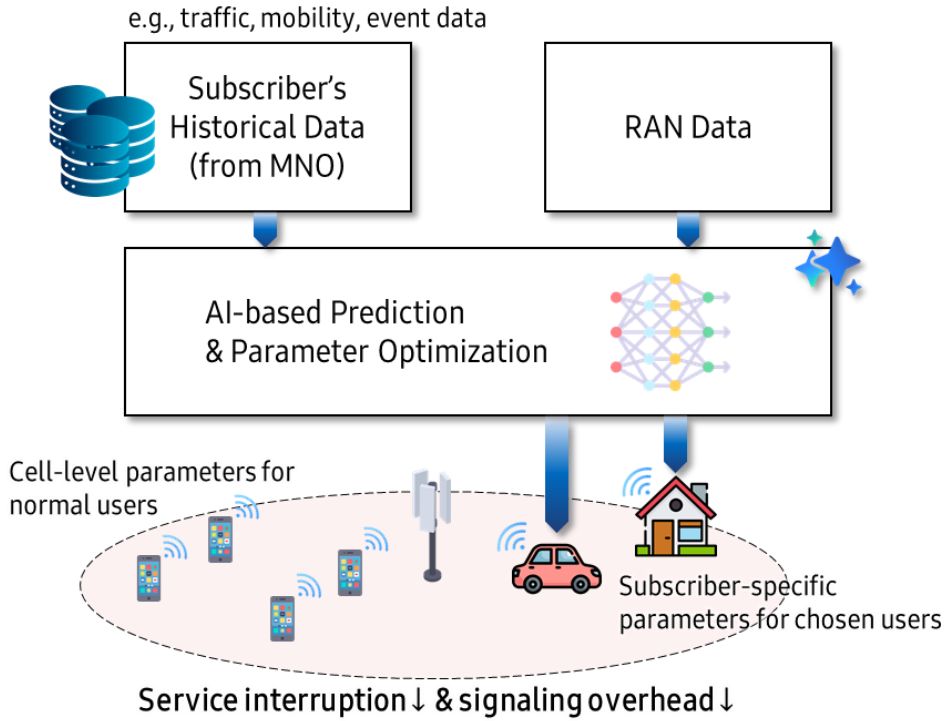


AI-based Network Optimization (SMO, RIC at Data Center)

Improvements in call quality, throughput, and reduction in signaling overhead

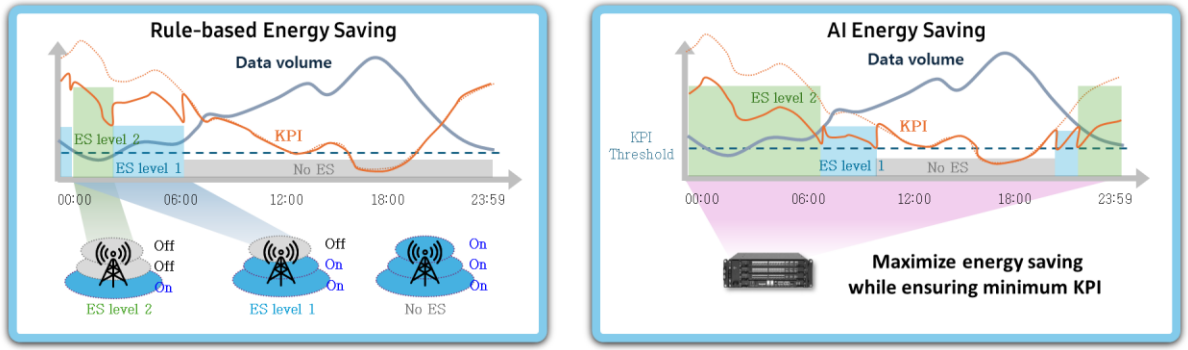
Subscriber-Specific AI Configuration

Subscriber-specific prediction and parameters optimization to reduce service interruption and signaling overhead



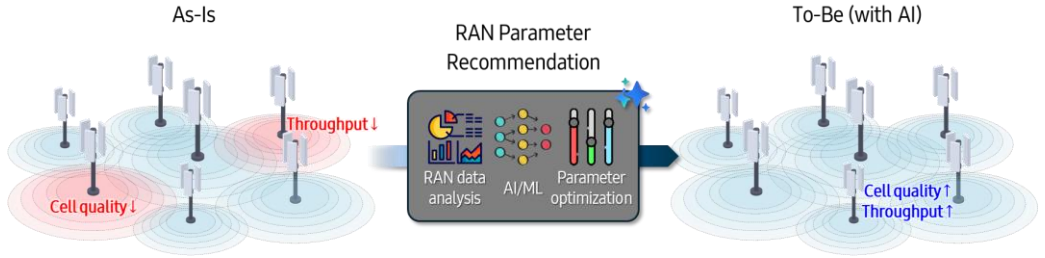
AI Energy Saving

AI-based traffic and KPI prediction to enhance energy saving



AI RAN Optimization

Optimal parameters recommend using data analysis and AI



7~10% Throughput gain with AI

AI-powered L1/L2 (Cell sites)

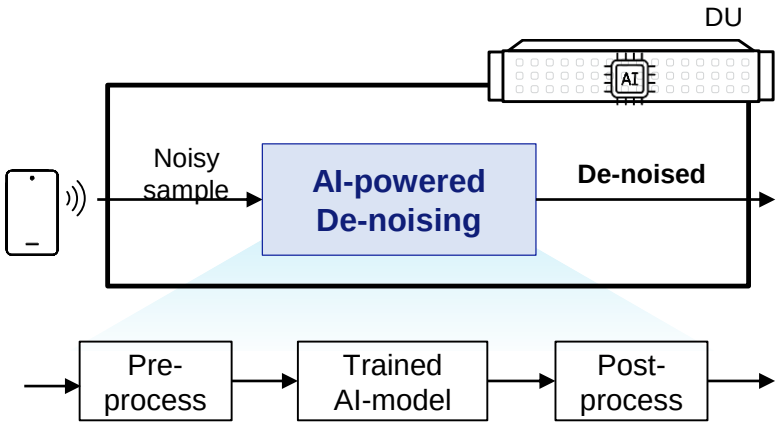
AI models to improve 5G and 6G RAN: One-sided model

Channel Estimation

AI-powered de-noising to improve channel estimation in weak RF conditions

AI PUSCH CE : >30% UL Tput gain for cell-edge users

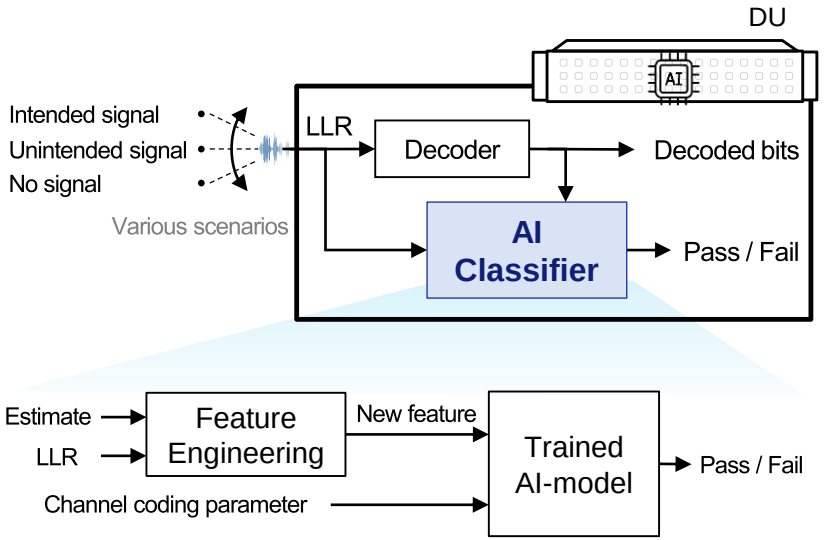
AI SRS CE: Up to 12% DL Tput gain over legacy PMI



UCI Validation

AI-powered binary classification to improve error-detection capability for small-size UCI

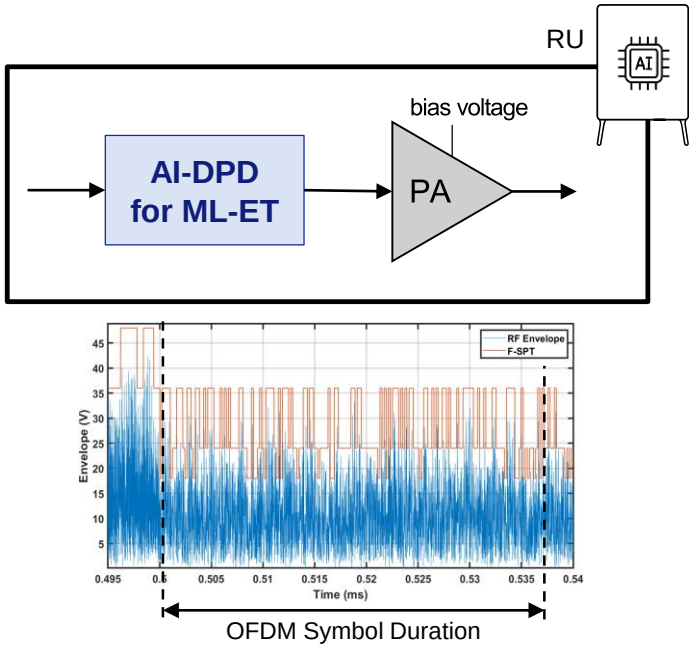
10x accuracy improvement



AI-DPD

AI solution to mitigate non-linearity caused by multi-level bias voltage transition within symbol to improve PA efficiency

30% power efficiency improvement



UCI: Uplink Control Information
LLR : Log Likelihood Ratio

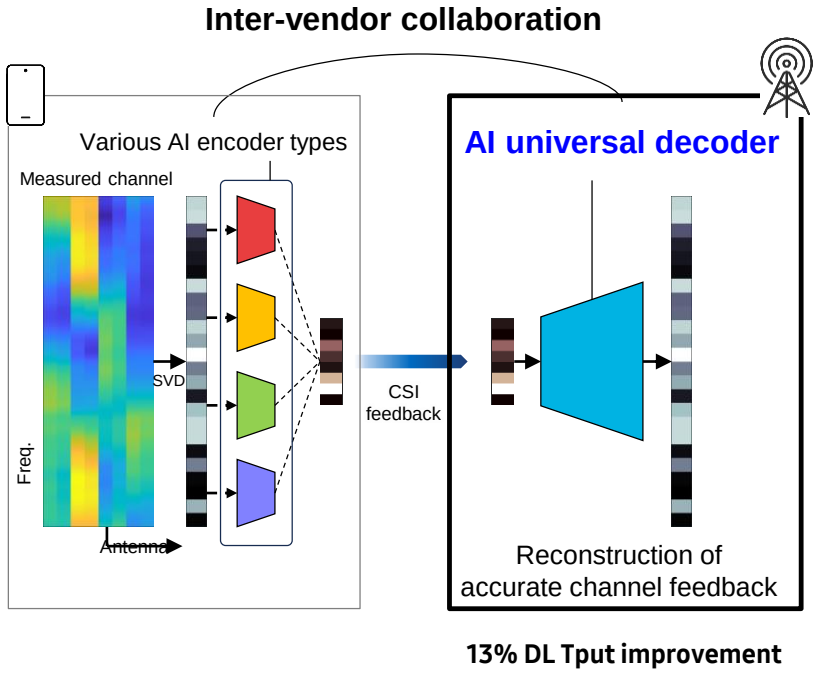
* DPD: Digital Pre-Distortion
* ML-ET: Multi-Level Envelop Tracking
* F-SPT: Faster-than-Symbol level Power Tracking

AI-powered L1/L2 (Cell sites)

AI model for 6G RAN: Two-sided and more

CSI Compression

AI universal decoder for CSI compression to support various UE encoders



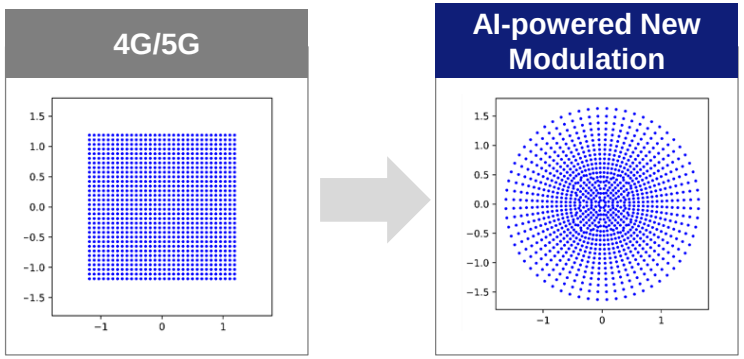
13% DL Tput improvement

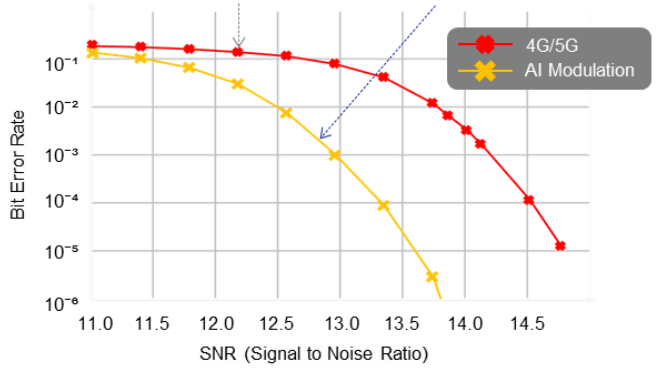
High-order Modulation

AI-powered constellation shaping for high-order modulation for higher spectral efficiency

1.2 dB (25%) Rx power reduction

1024-ary (10 bits per symbol)

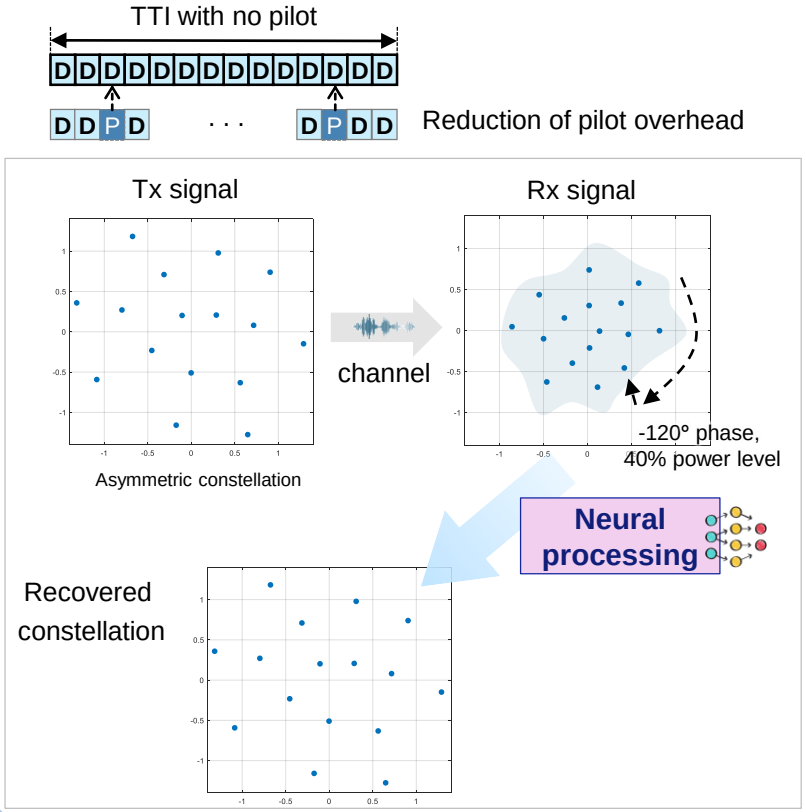




Pilot-less Communication

Neural receiver and asymmetric constellation without pilot overhead for higher throughput

0.8dB SNR gain compared to 5G 64-QAM



SVD: Singular value decomposition

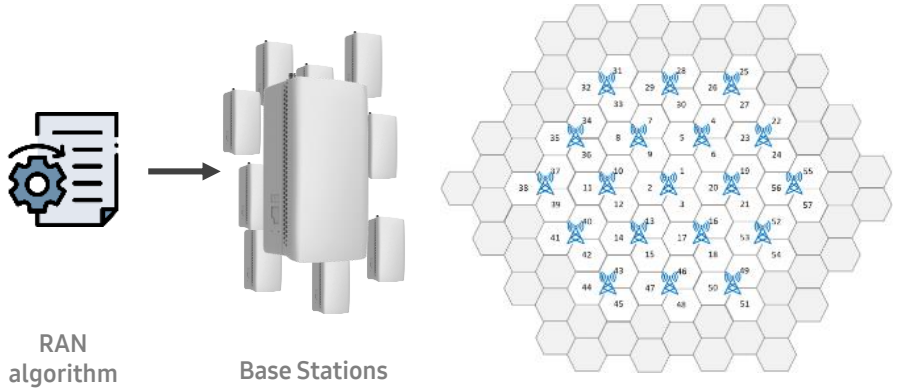
TTI: Transmit Time Interval

Self-learning B5G/6G network with AI

- Paradigm shift from one-size-fit-all to AI-based site-specific optimization
- AI life-cycle management: Lab training + on-site adaptation

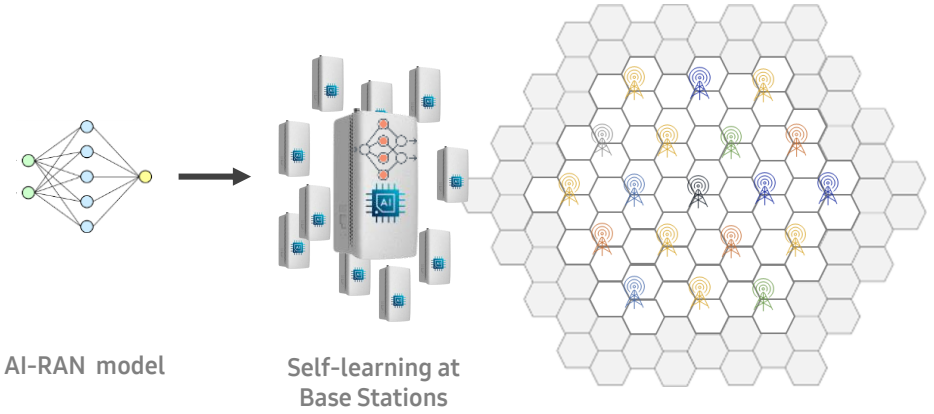
Today

One solution for millions of base stations

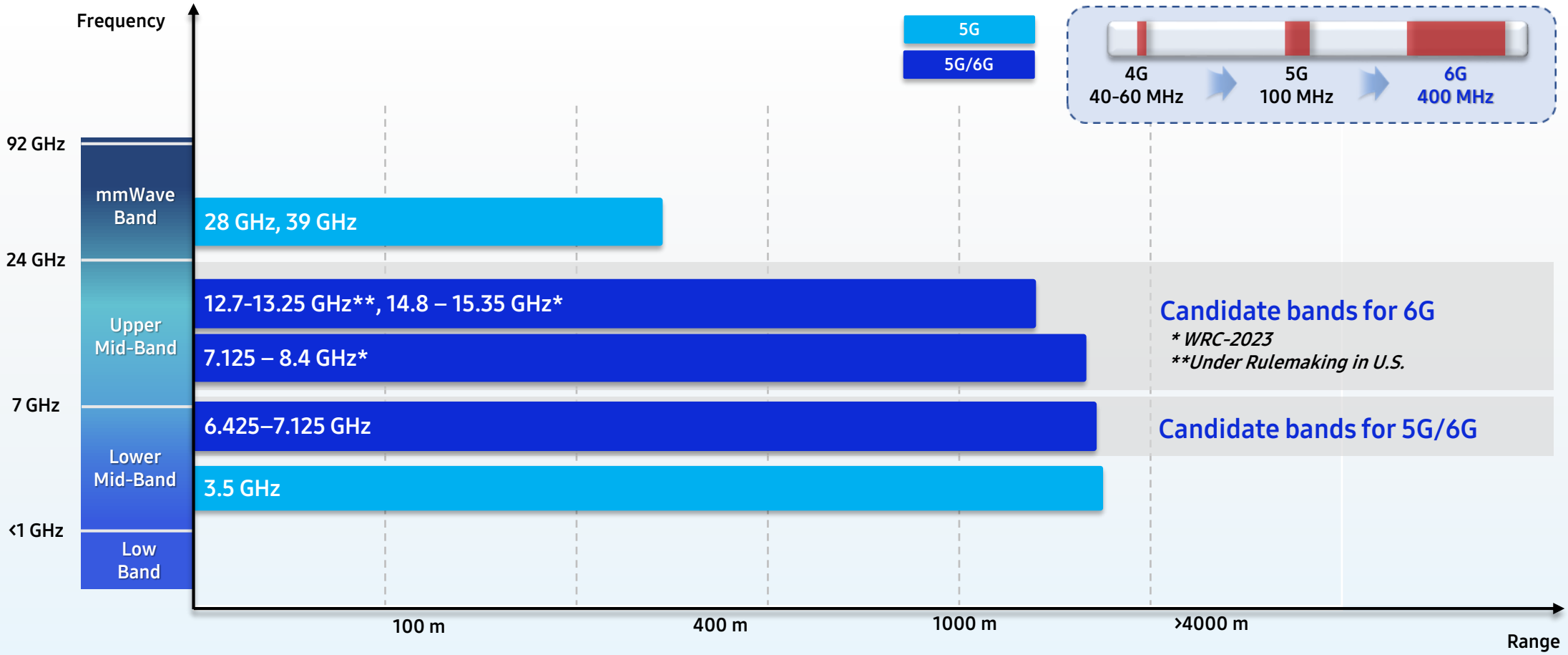


Future

A million solutions for a million base stations

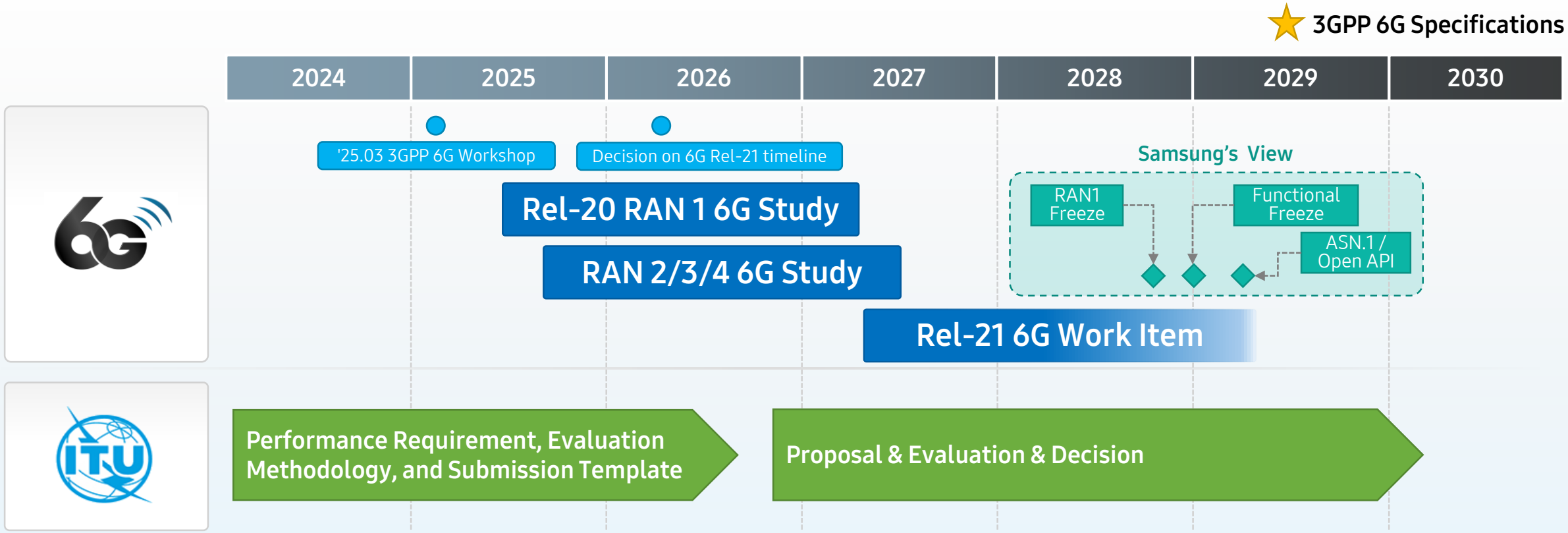


Bandwidth per operator: 4G 40-60 MHz → 5G 100 MHz → 6G 400 MHz



3GPP Discussion for 6G Journey Starts in 2025

Samsung actively contributes to 3GPP and ITU (2 chairs and 4 vice chairs in 3GPP, 1 chair in ITU-R)



Outcome of 3GPP 6G Workshop

*March 10-11, 2025, Incheon Korea,~100 companies participated

“Day 1” objectives: TCO reduction, and new revenue beyond eMBB

* Total Cost of Ownership

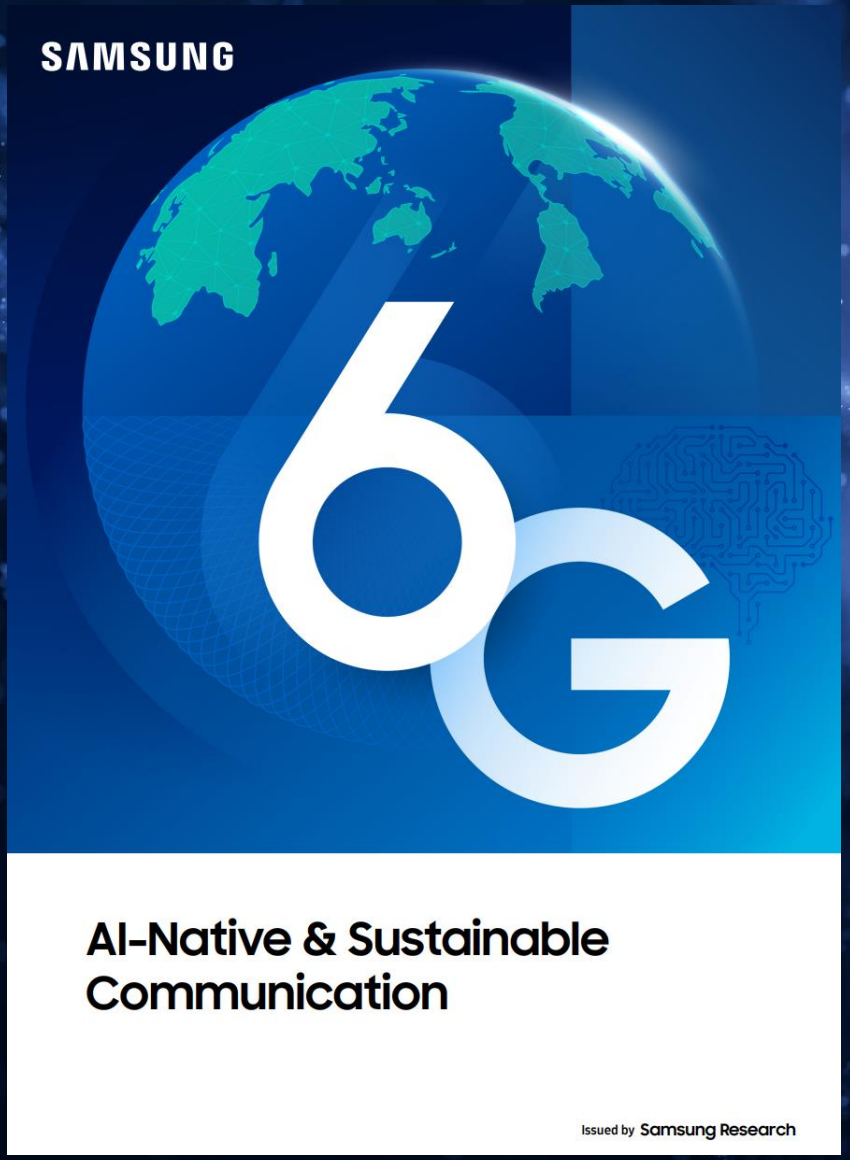
- TCO reduction by
  - Spectral Efficiency Enhancements, Network Energy Savings, RAN simplification (compared to NR), Coverage/cell-edge enhancements
- New revenue examples
  - FWA, NTN and NTN/TN coexistence, LPWA (e.g. replace eMTC, 6G RedCap), ISAC, Robot, etc.

Not in “Day 1”: Full duplex, Repeaters (e.g. NCR, IAB, RIS), Sidelink/V2X, unlicensed spectrum, Terahertz, multicast

NCR: Network Controlled Repeater, IAB: Integrated Access Backhaul, RIS: Reconfigurable Intelligent Surface, LPWA: Low Power Wide Area

Samsung Research

Thank you



Samsung 6G White Paper