5G/6G Special Day I

International Conference

Samsung Research

# Evolution of Mobile Communication towards 6G

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# Evolution of Mobile Communications



- Every cellular generation enhanced user interactions and opened up new services

"Higher data rate and larger capacity"

| 1973 | 1980s | 1990s | 2000s | 2010s | 2020s |
|---|---|---|---|---|---|
| Start | 1G | 2G | 3G | 4G | 5G |
| April 3, 1973, Martin Cooper, the first call from a cell phone | Voice only<br>2 Kbps | Digital Message<br>64 Kbps | Mobile Data<br>2 Mbps | Mobile Broadband<br>100-1000 Mbps | Massive Broadband and IoT<br>>1 Gbps |

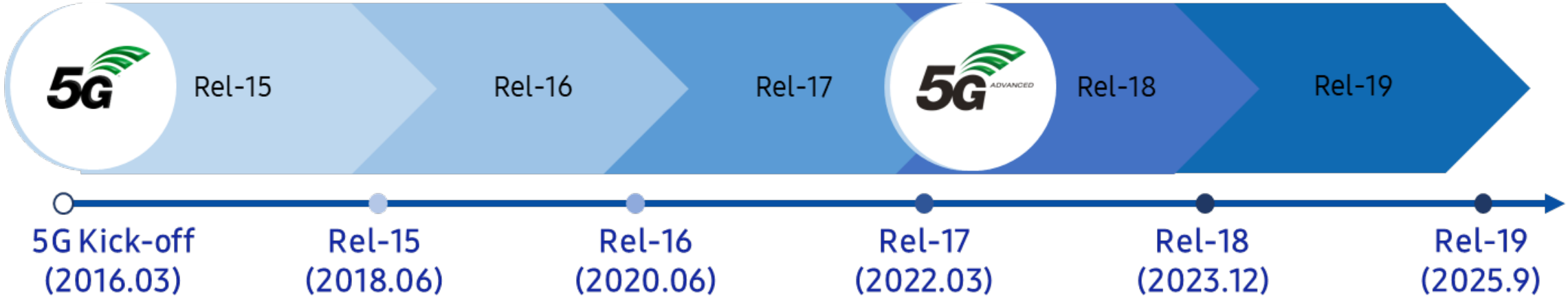





# Evolution of 5G Standards in 3GPP



- Rel-15: Introduction of 5G framework
- Rel-16: Expansion to vertical services and enhancement from Rel-15
- Rel-17: Full support of LTE services within 5G framework and enhancement from Rel-16
- Rel-18: 5G-advanced for the next phase of 5G evolution
- Rel-19: Completing 5G-advanced features and preparing 6G



# 5G-Advanced for the Next Phase of 5G Evolution

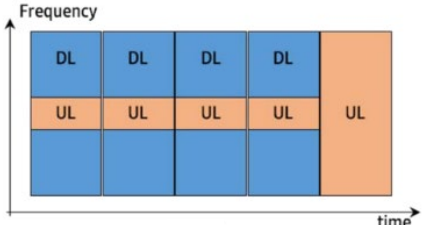


## Continued enhancements on existing 5G technologies

- MIMO evolution
- Multi-carrier enhancement
- Mobility enhancement
- Coverage enhancement
- Positioning enhancement
- Sidelink evolution

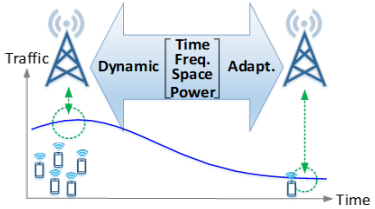
## New technologies for enhanced performance, sustainability, and cost reduction

- Duplex evolution

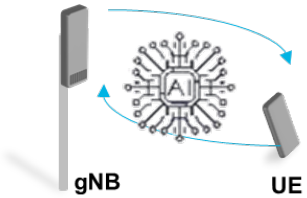



SBFD

- Network energy saving

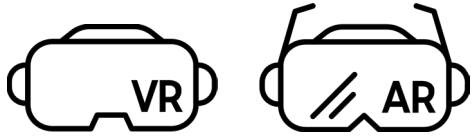



- AI/ML



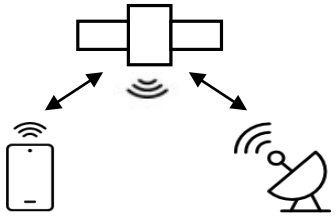

## Support of new services and new terminal types

- VR, AR, XR




- Uncrewed Aerial Vehicle

- Non-terrestrial network



# 5G in the eyes of consumers



Enhancement of performance alone is NOT enough anymore…

U.S. end-user is experiencing 5-10x throughput

5G customer satisfaction falls short of expectations

“5G speed is 5x faster than 4G”

“4G is good enough to watch videos”

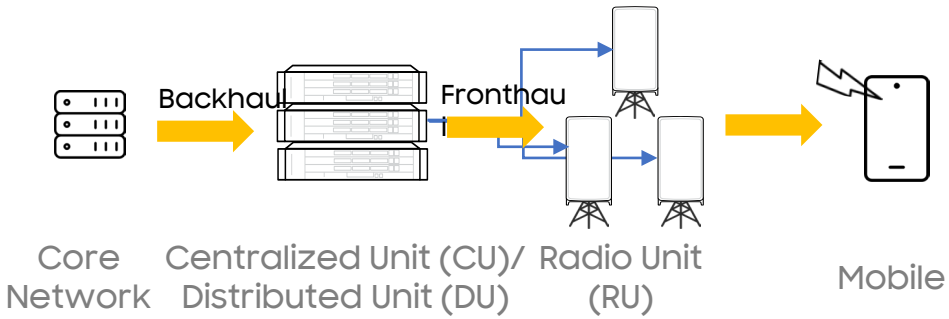
"5G connection drains the battery faster."

# Telecom Trend in Beyond 5G and 6G (B5G/6G)

## Virtualization, AI-Native

### Today

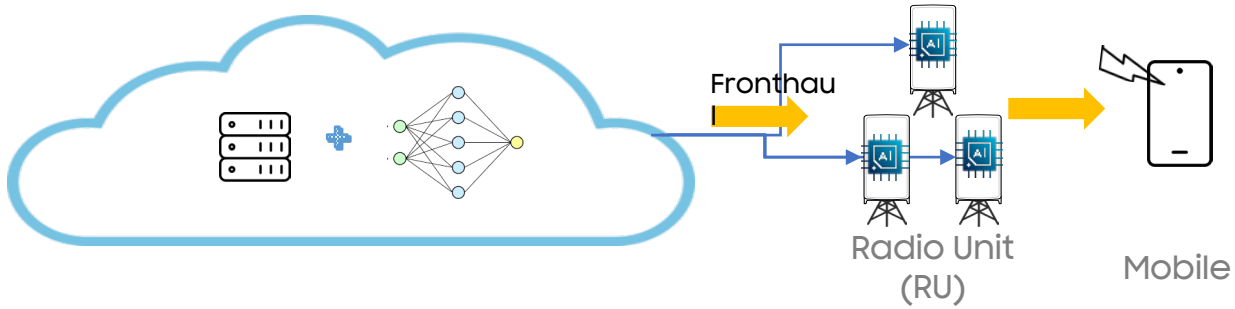
- Complex network with customized H/W
- High maintenance and upgrade costs




Hardware-centric Telecom Network

### Future

- AI, Virtualization and Cloudification for scalability & flexibility
- Low maintenance costs and flexible upgrades




AI-Native Virtualized Network in Cloud

# B5G/6G Use Cases and Services

Bringing 'the next hyper-connected experience' to every corner of life

## Enhancement of Mobile Broadband

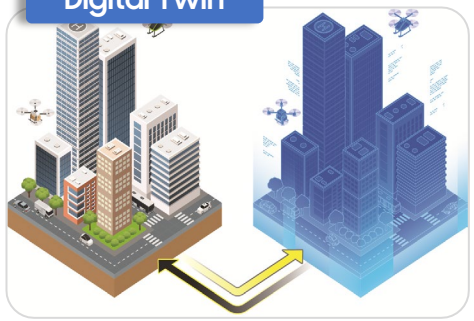
Broadband & AI Innovations


## Emerging Use Cases

Support emerging use cases and services

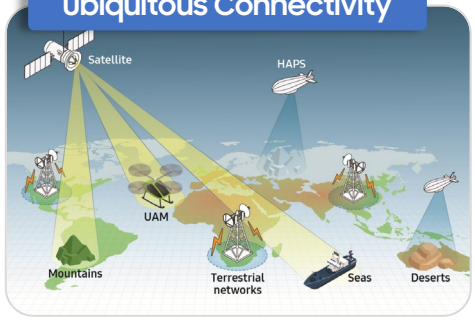
Immersive XR

Digital Twin

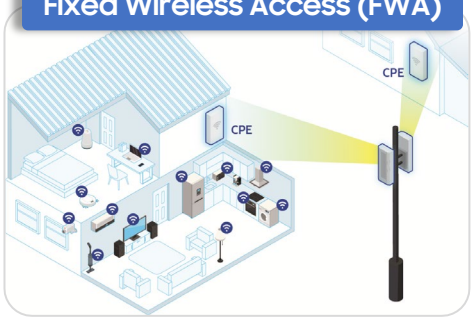


Massive Communication

Ubiquitous Connectivity




Fixed Wireless Access (FWA)

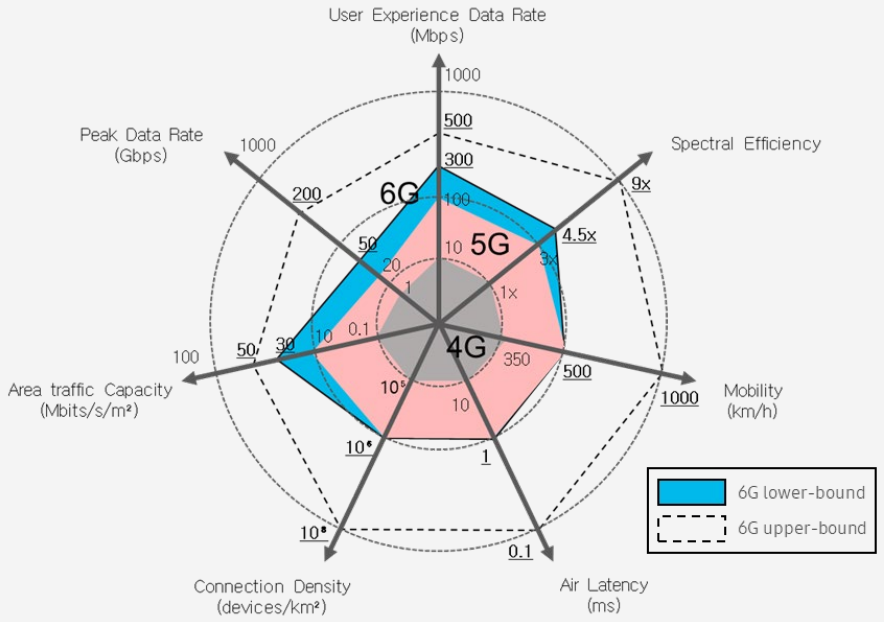


# Shape the Future of B5G/6G

## 6G requires 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



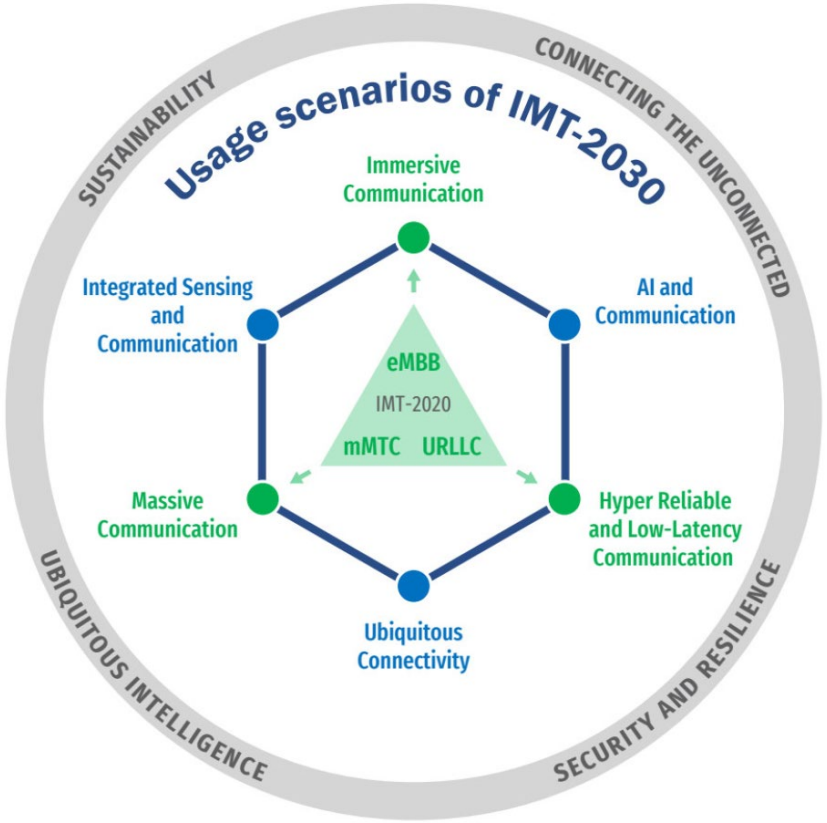

※ ITU-R IMT-2030 Framework

### 6G New Attributes

Future-proof and sustainable user experience

# Use Cases and Requirements for 6G (IMT-2030)

## Continue to identify & generate use cases for future 6G




**IMT usage Scenario Evolution from 5G to 6G**

- 5G/IMT-2020: eMBB, mMTC, URLLC
- 6G/IMT-2030: extension from IMT-2020 and 3 new use cases

**Lessons Learnt from the 5G Experience**

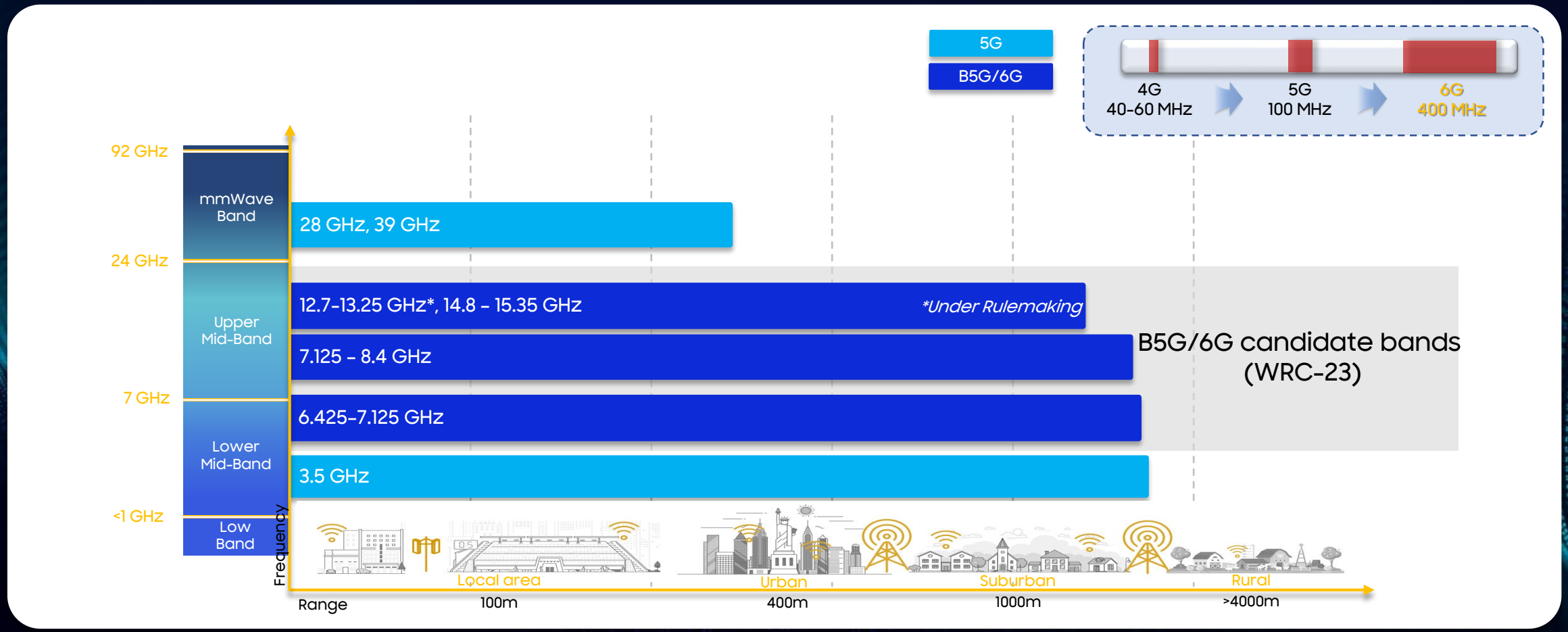
- Gap between IMT-2020 vision and market reality
- 6G needs market-driven approach toward use case ideation and technology development

※ Source: ITU-R IMT-2030 Framework and Objective

# Candidate Spectrum Bands for 6G



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



## E2E optimization of network performance & operation

### Current 5G AI Applications

**Network planning**
e.g., optimization of site locations

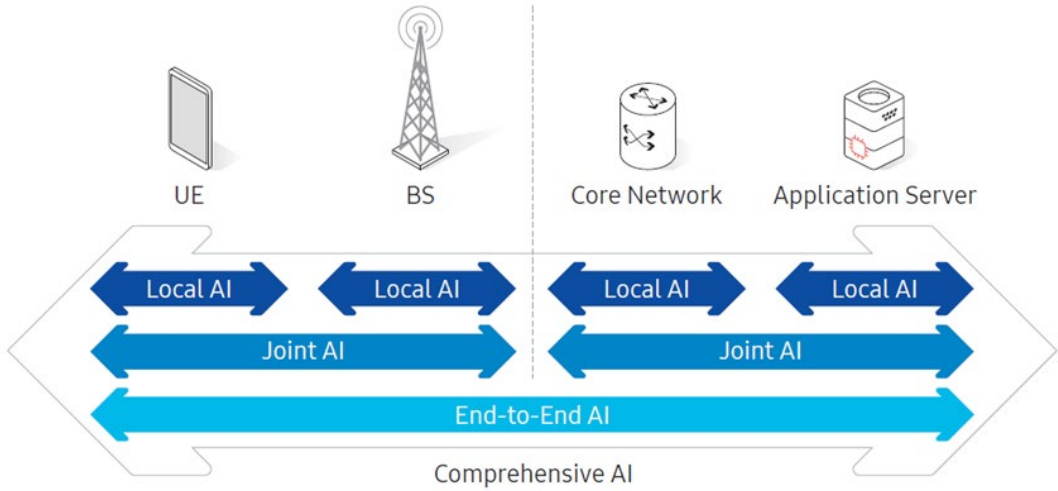
**Prediction, detection, and self-healing of network anomalies**

**Network management**
e.g., configuration automation, power consumption minimization

**Performance improvement**
e.g., handover optimization and scheduler enhancement

### Comprehensive 6G AI

- Local/joint AI for global awareness
- Joint optimization across functions and layers
- Handling nonlinearity and long-term correlations

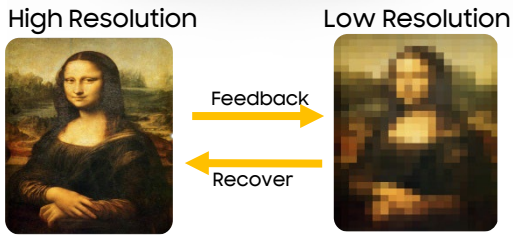


# AI-Native : AI for End to End Future System



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

## AI for L1/L2 Radio




- AI Channel Estimation & Prediction
- AI Precoding & Scheduler

## AI for Network Automation

- Network Analytics
- Network Parameter Optimization

## Telco LLM

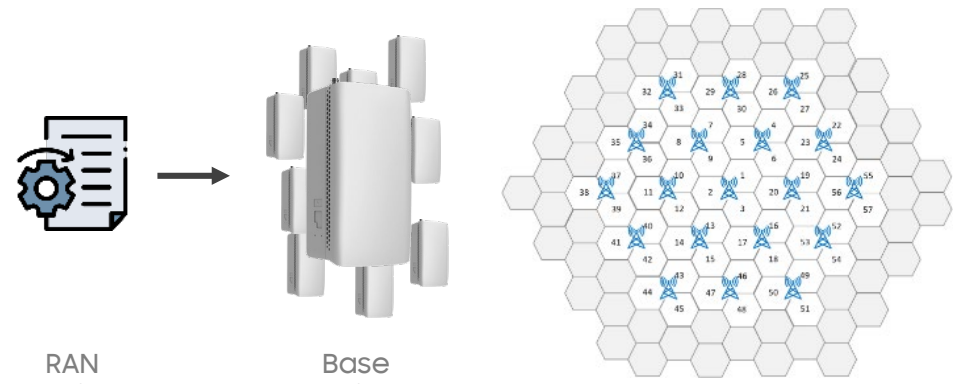

- Intent-based Optimization
- Multi-tenancy LLM

# AI-Native : Self-learning B5G/6G network with AI

## AI enables customized design for each cell with site-specific optimization

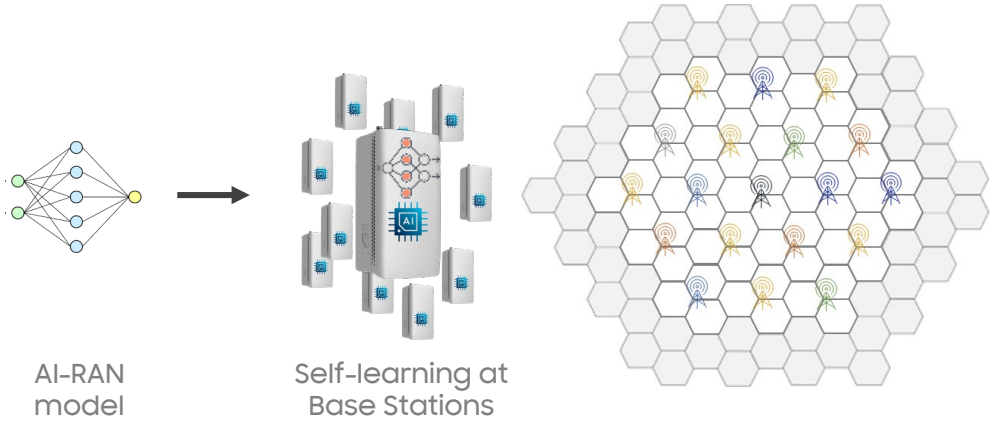
### Today

One solution for millions of base stations



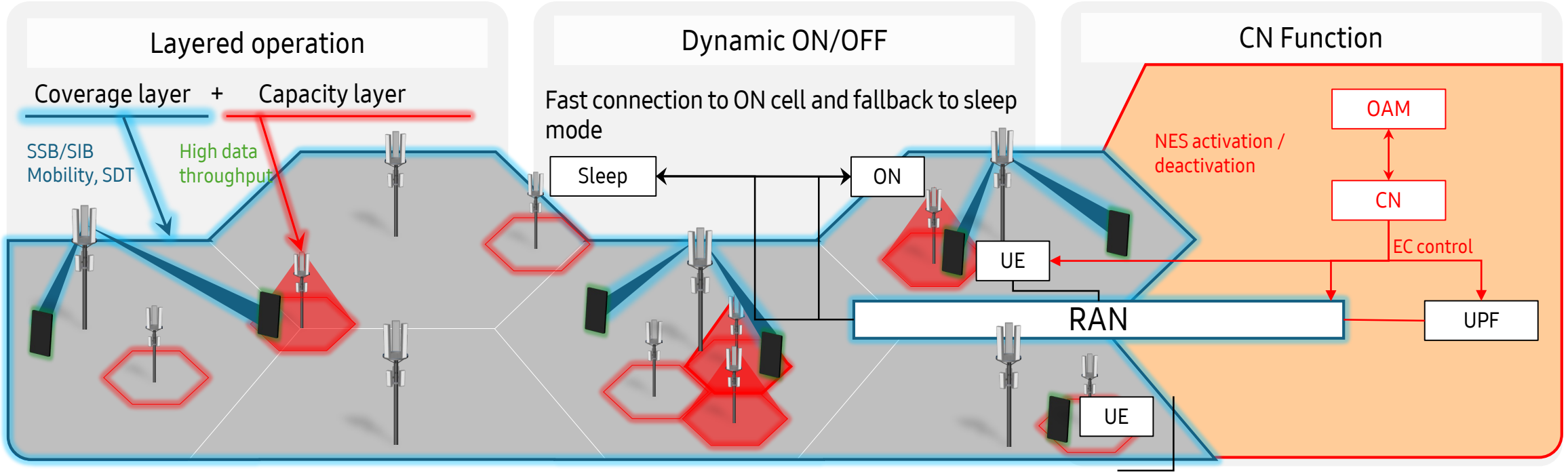

### Future

A million solutions for a million base stations



# Sustainable Network : Network Energy Saving

## New design expected to bring greater energy saving compared to 5G



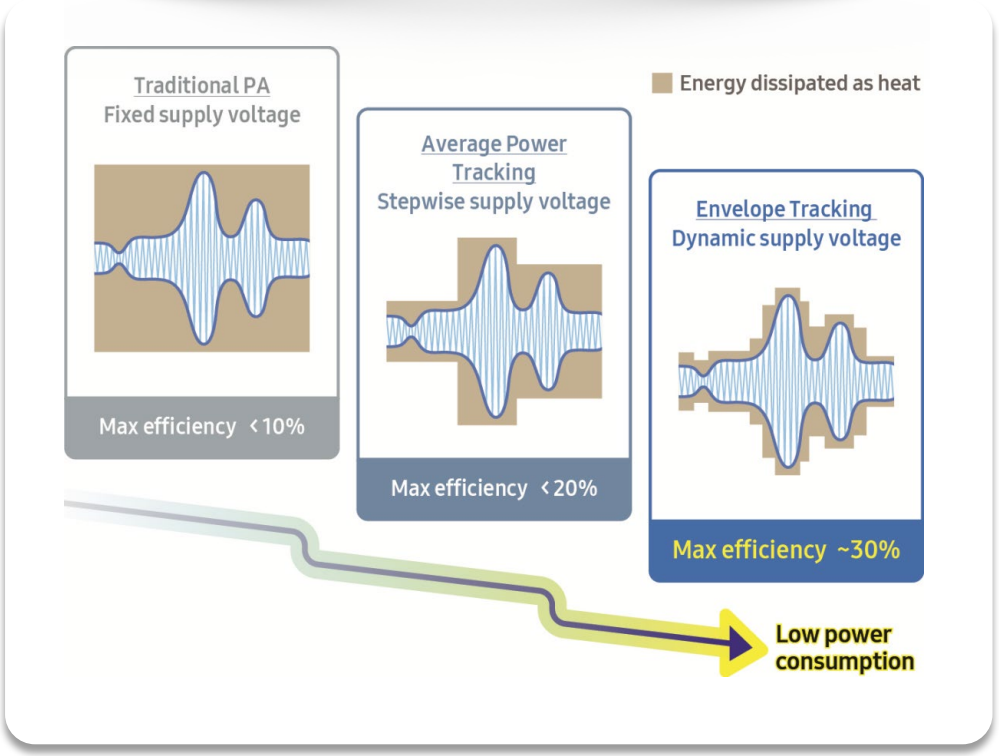

- Layered operation: coverage layer for general (connection/mobility) operations and capacity layer for data boosting (when needed)
- Dynamic ON/OFF: joint NW and UE operations to enable dynamic cell ON/OFF with support of on-demand operations, seamless handover and aligned DRX operations between NW and UE
- New CN function: ES data collection, policy update, and activation/deactivation of ES mode

# Sustainable Network : Energy-Efficient Hardware



- Improve PA efficiency through e.g. envelope tracking (ET)
- Advanced modem algorithms + high-performance SoC to reduce digital power consumption

## Envelope tracking for PA efficiency improvement




13 GHz MMU power consumption

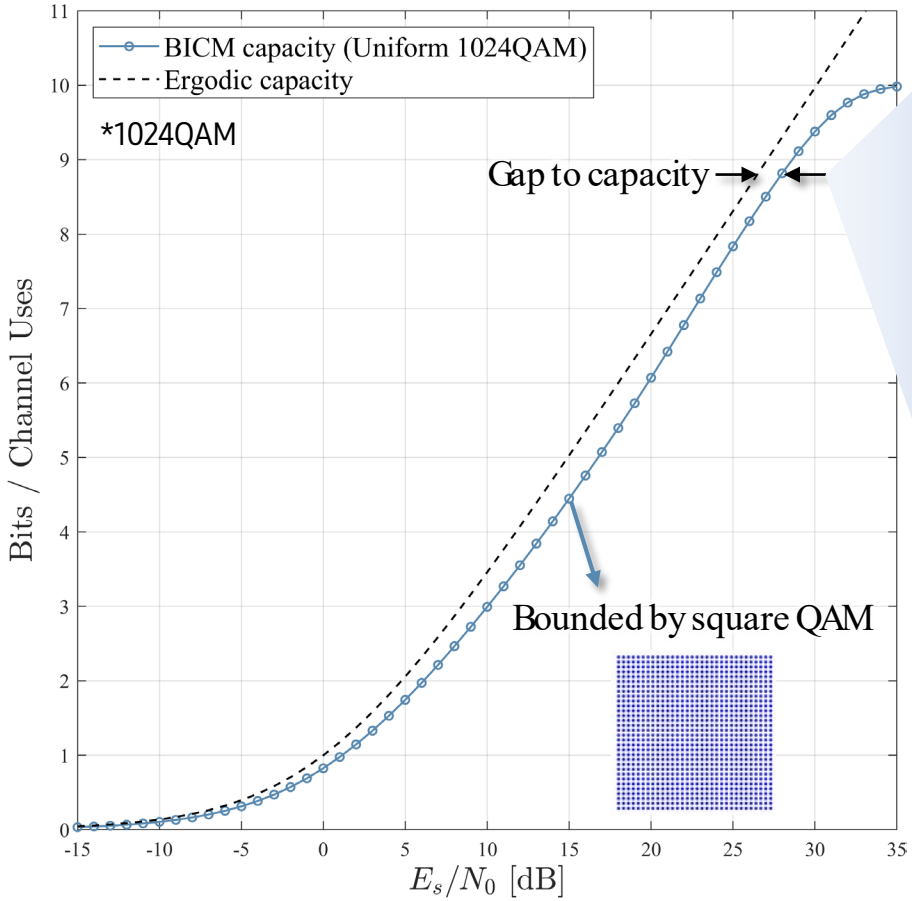
| | Today | To-be |
|---|---|---|
| PA efficiency at 9 dB Back-off | 5% | 30 % |
| Total PA power consumption | 2.4 kW | 0.4 kW |
| Total digital power consumption | 2.4 kW | 0.8 kW |
| Total MMU power consumption | 4.8 kW | 1.2 kW |

75%↓

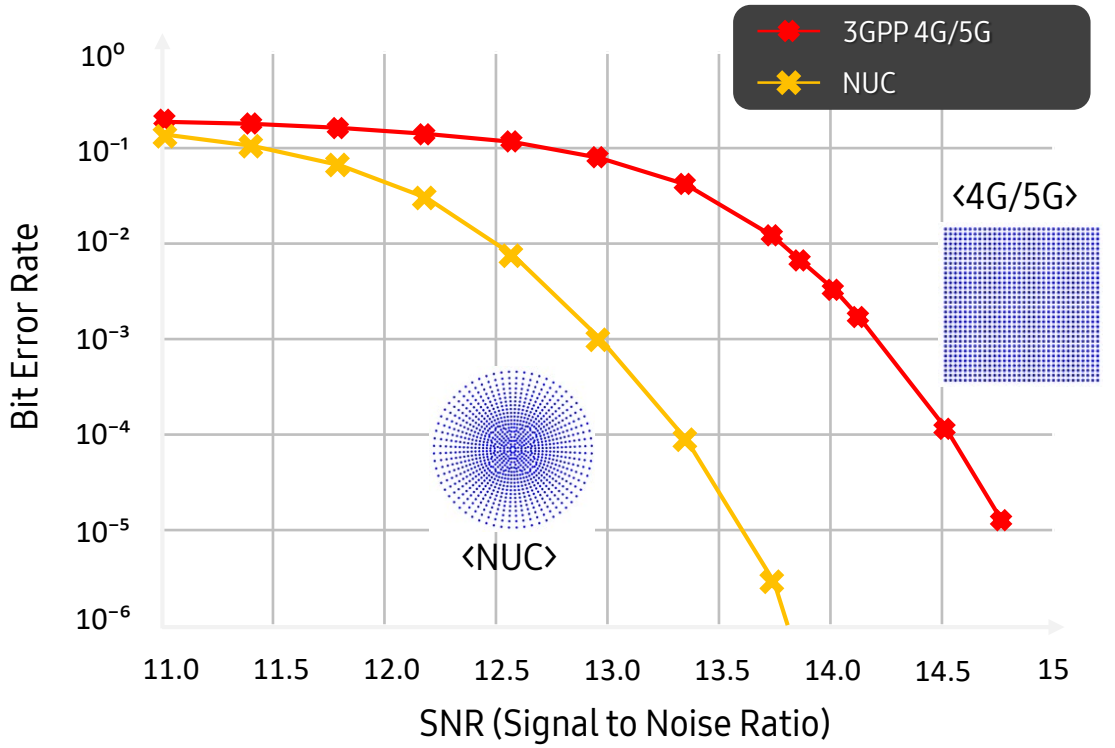
# Sustainable Network : Energy-Efficient Modulation



## Constellation shaping (e.g., non-uniform constellation for higher order modulation)




(Non-uniform constellation)

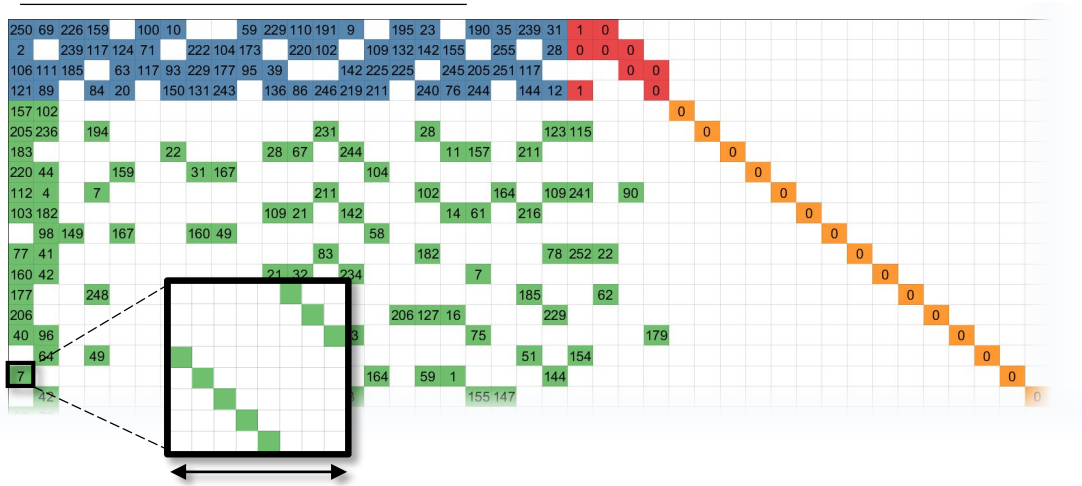


# Sustainable Network : Energy-Efficient Channel Coding



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

## 5GNR LDPC code structure

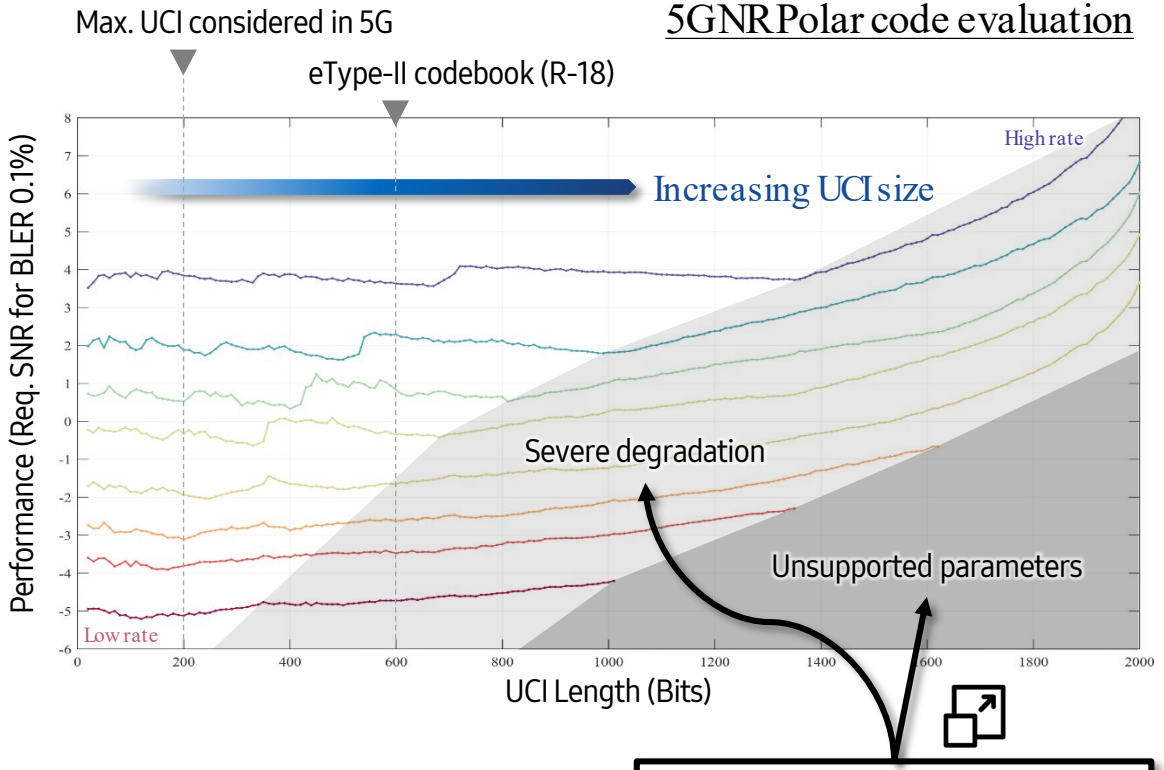


5G: Lifting size 384 → **6G: 2x larger lifting size** (e.g. 1024)

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

**+ Better BLER**

## 5GNR Polar code evaluation

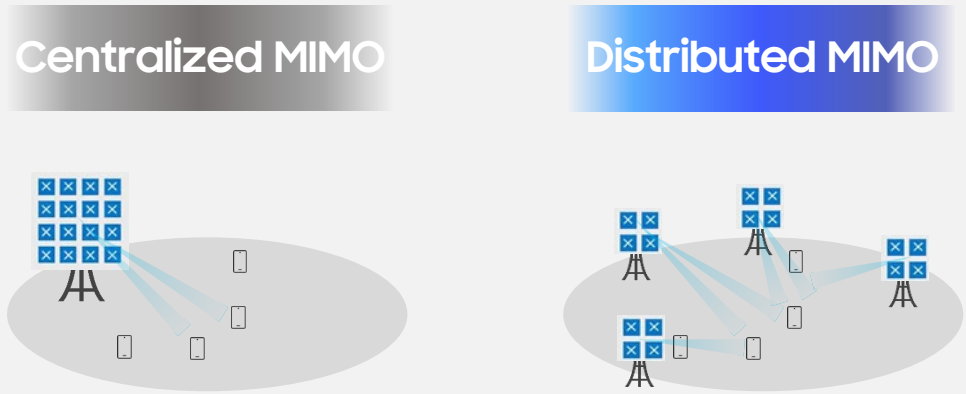



**Better BLER +**

**Large-block polar code design**
**New segmentation method**

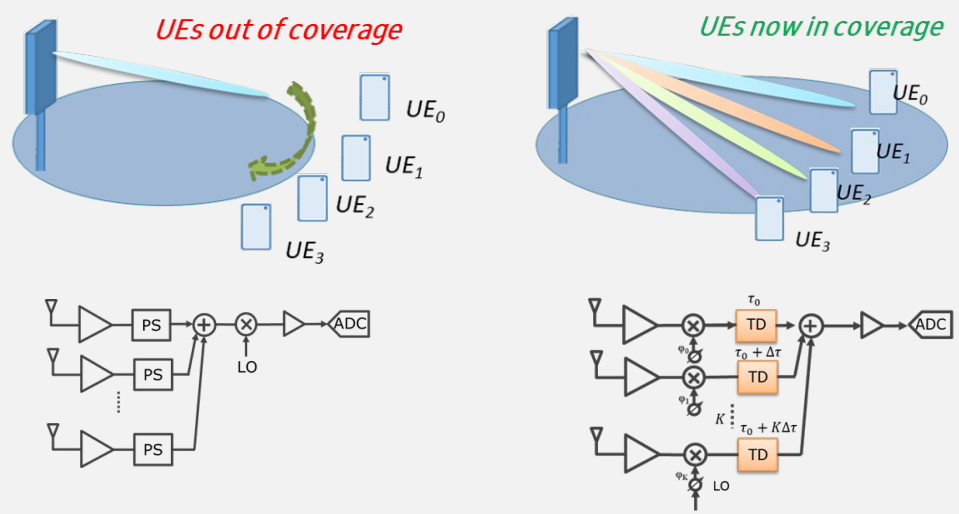
# Ubiquitous Coverage

## Distributed MIMO (FR1, sub-3.5 GHz)




- Spatial diversity and additional beamforming gain enabled by the joint use of multiple TRPs
- Better coverage, capacity (up to 50% gain)

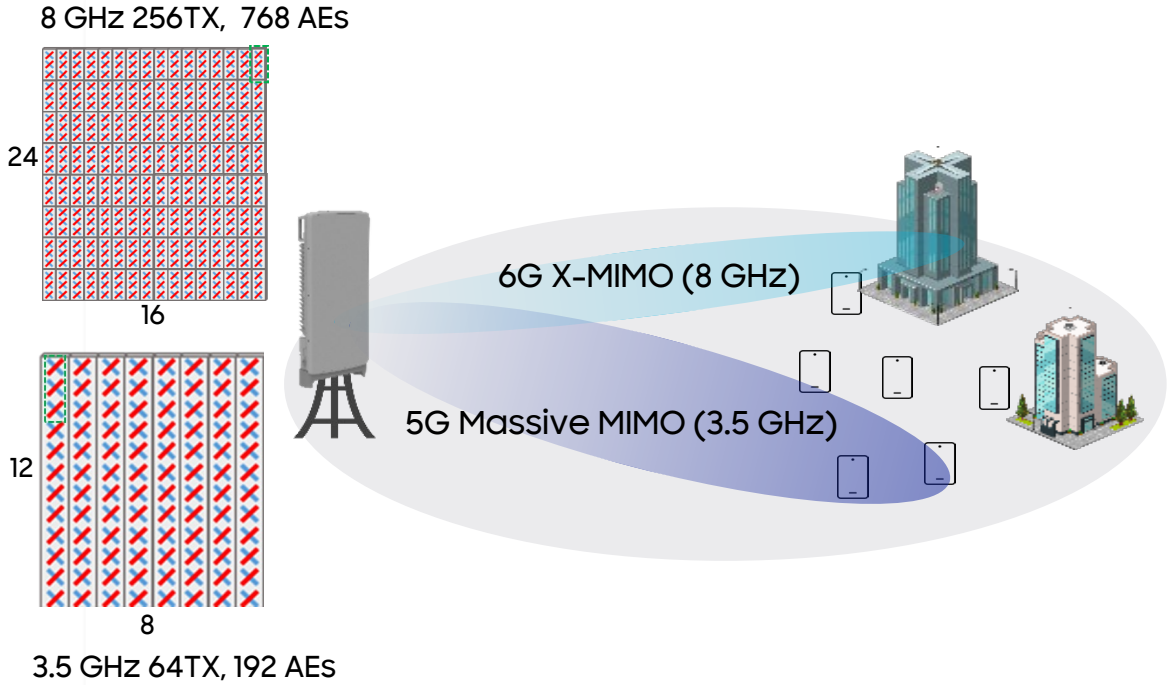
## Joint Phase and Time Array (FR2, mmWave)




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

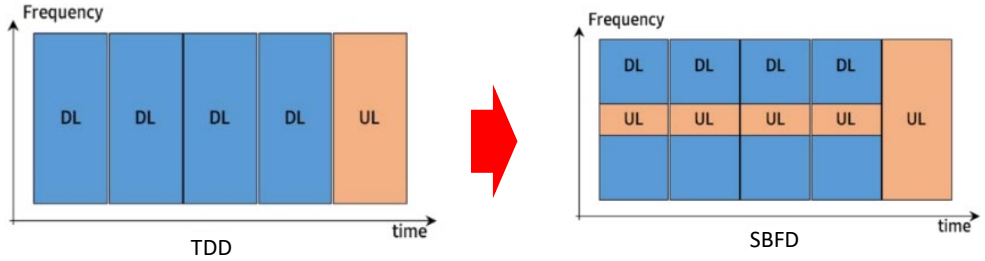
# Ubiquitous Coverage

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



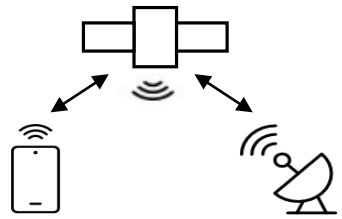

- Extremely large dimensional MIMO technology
- More antennas can be packed within the same area for the higher carrier frequency
- Better beamforming gain can be achieved with more antennas

## Duplex Evolution - SBFD




- SBFD (Sub-Band non-overlapping Full Duplex) for UL coverage extension (Rel-19 5G-Advanced in 3GPP)
- Further enhancement of SBFD for 6G

## Non-Terrestrial Networks

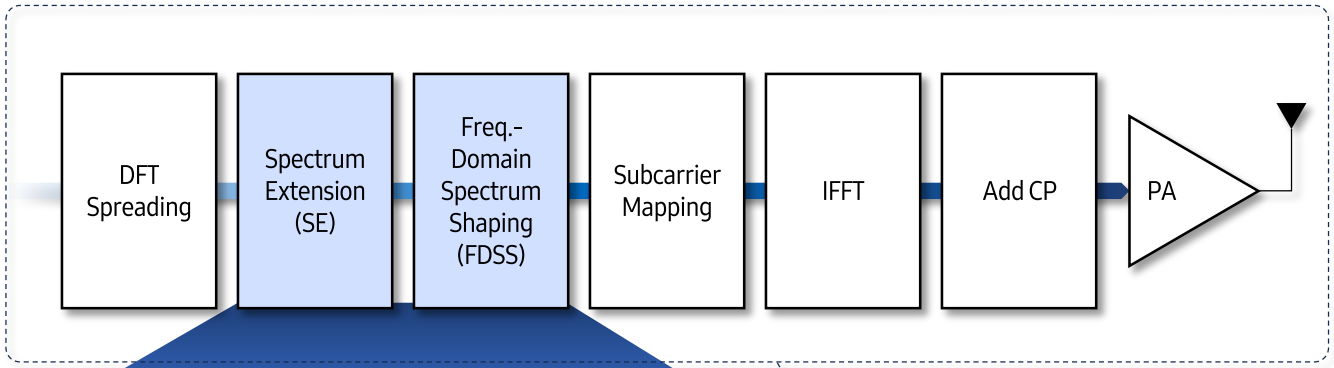


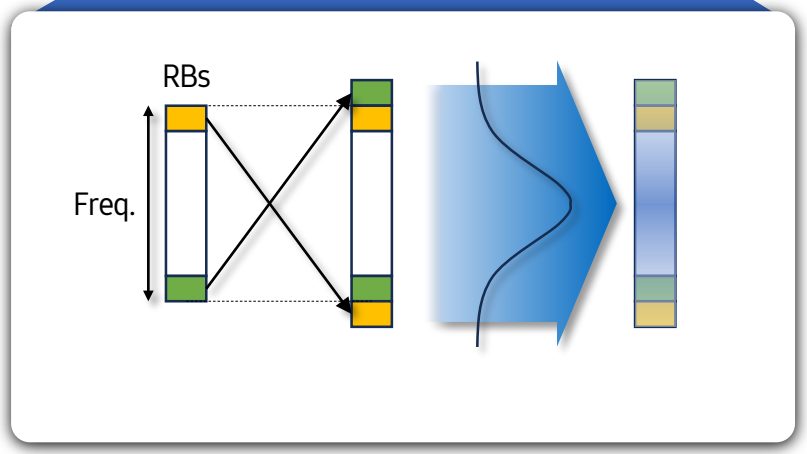
Provide ubiquitous coverage even in the areas where there is no terrestrial network (TN)

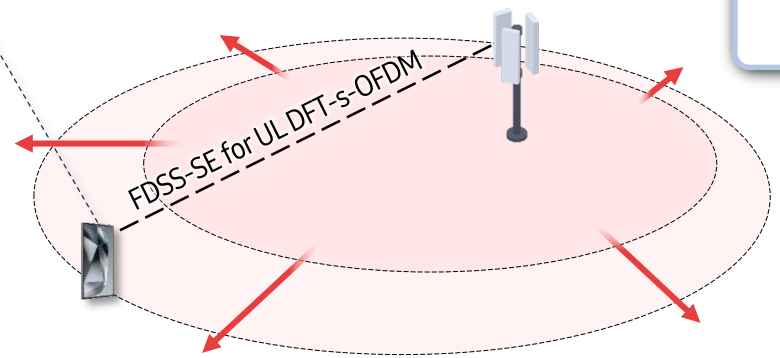
# Ubiquitous Coverage : Waveform Enhancement

## UL waveform for large coverage and energy efficiency

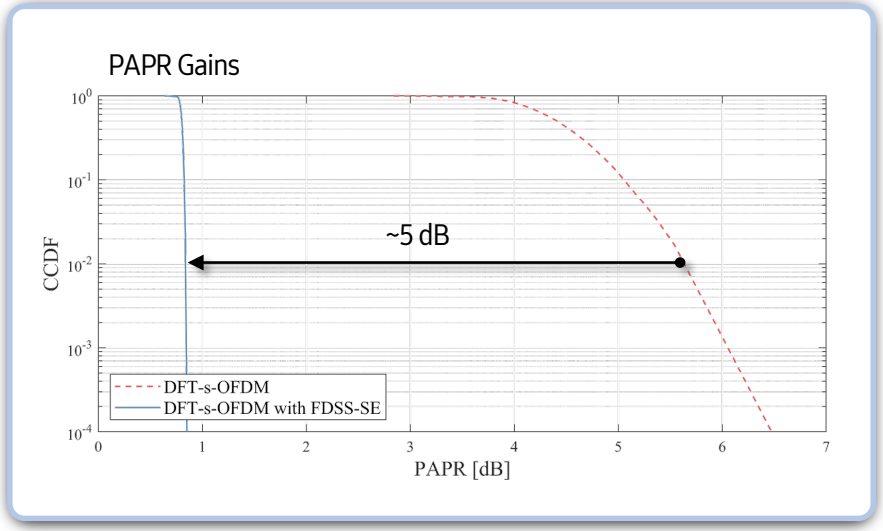
- Frequency-domain spectrum shaping technique for PAPR reduction
- PAPR reduction ~5 dB → extended coverage, better PA efficiency



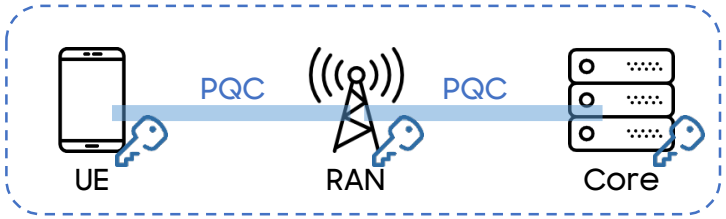




Coverage extension (UL)



# Secure & Resilient Network

## Post-Quantum Cryptography



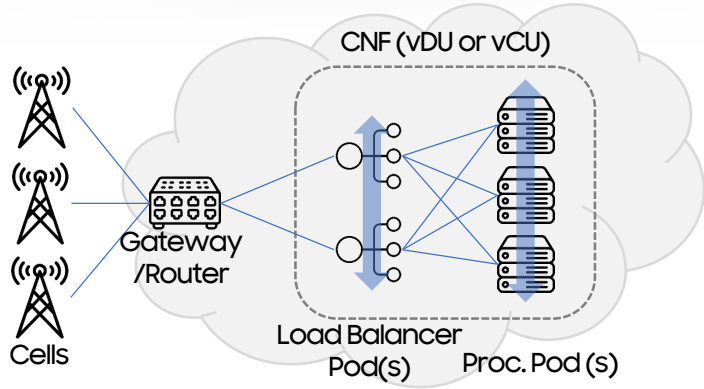

Hacker with quantum computer

- Advances in quantum computing technologies may motivate research on post-quantum cryptography (PQC)
- Monitor and evaluate how security threats evolve and to prepare suitable security technologies for 6G

## Zero Trust Architecture


- To mitigate security threats in open networks, applies the concept "Never trust, always verify"
- All entities in the network are continuously monitored to detect if any entity performs abnormal behavior

## Reliable Cloud vRAN



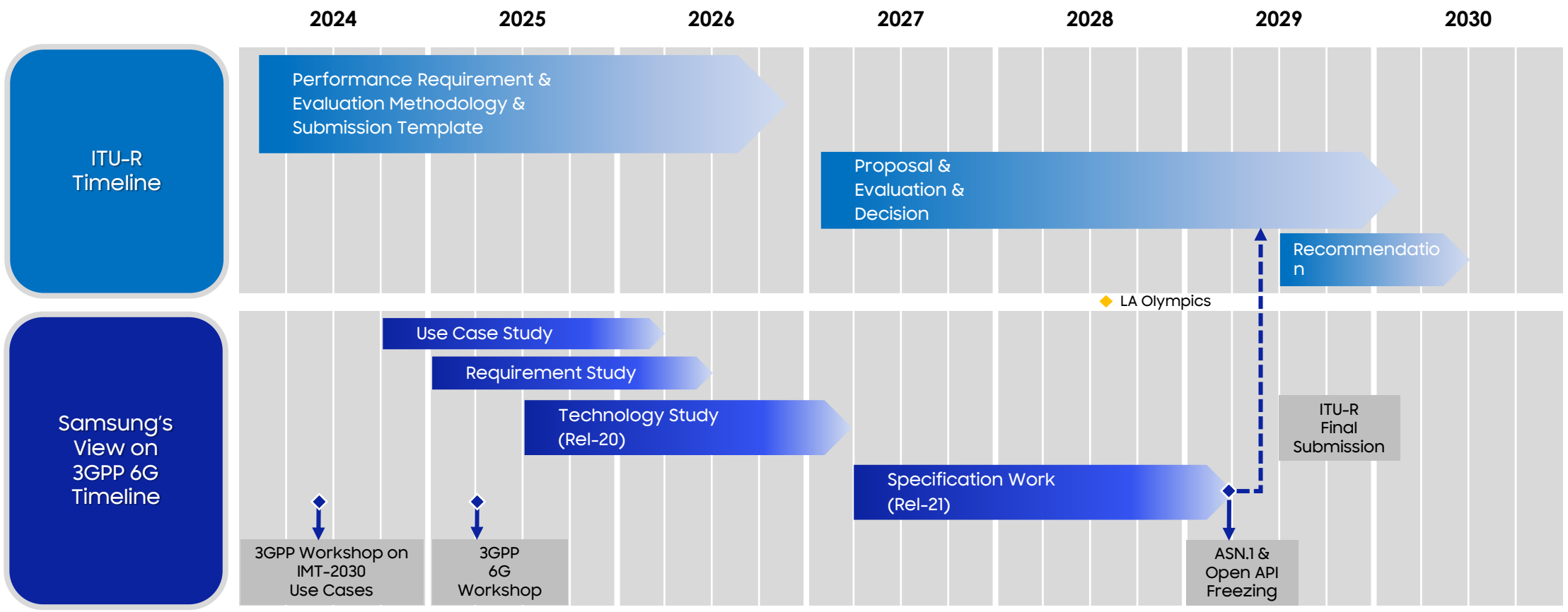

Example of all-active and scalable vRAN

- All-active architecture of pods with load balancer makes vRAN to be more reliable even if one of pods happens to fail.
- All vRAN pods should be scaled to prevent system overloads with high traffic demands.

# Overall Timeline for 6G



## ITU-R 6G timeline and Samsung's view on 3GPP 6G timeline



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# Thank you!