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Indian Institute of Technology Hyderabad

IIT HYDERABAD

WiSig Networks

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

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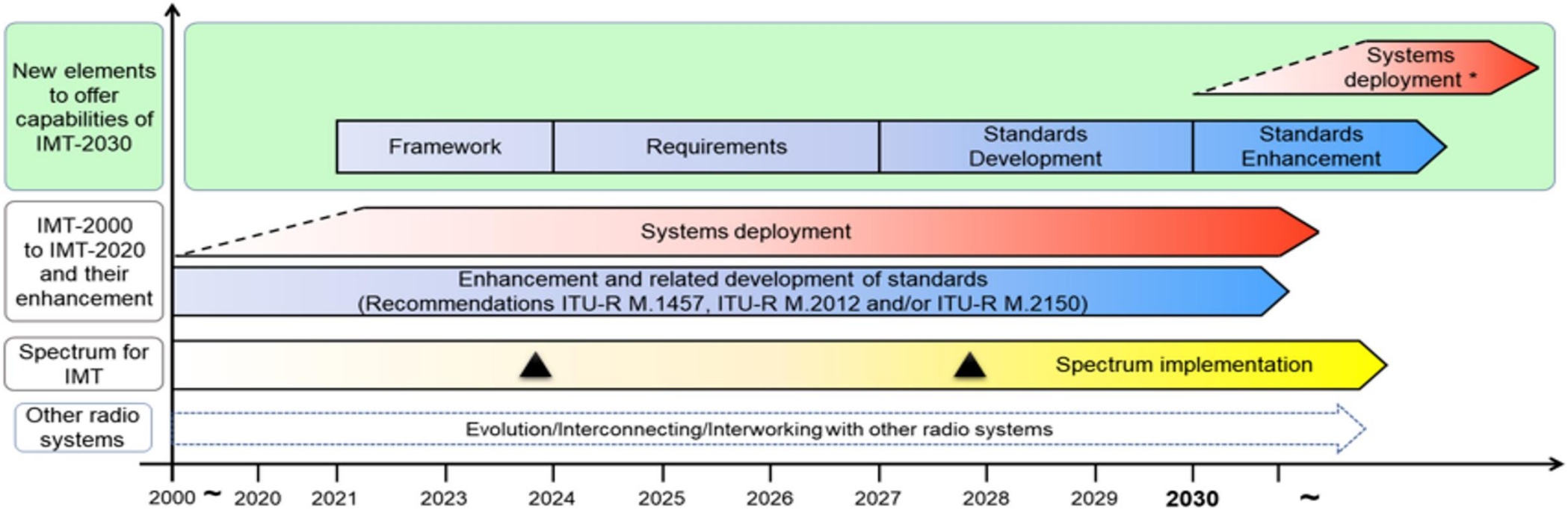
Founder, WiSig Networks

Relationships & Timelines: ITU WP 5D

- Roadmap for technology/standard development, deployment and spectrum
- In addition, enhancement of existing IMTs and relationship with other radio systems

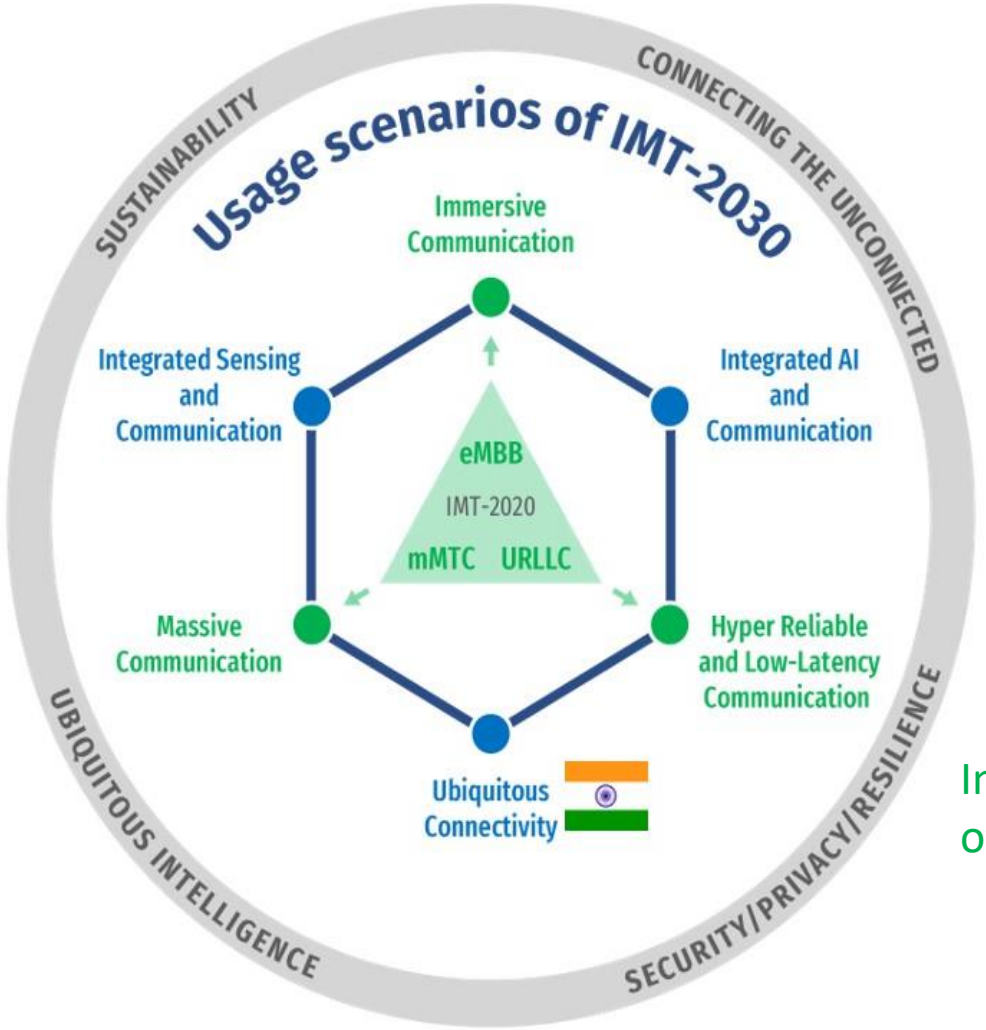


The sloped dotted lines in systems deployment indicate that the exact starting point cannot yet be fixed.

▲ : Possible spectrum identification at WRC-23, WRC-27 and future WRCs

• : Systems to satisfy the technical performance requirements of IMT-2030 could be developed before year 2030 in some countries.
: Possible deployment around the year 2030 in some countries (including trial systems)

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



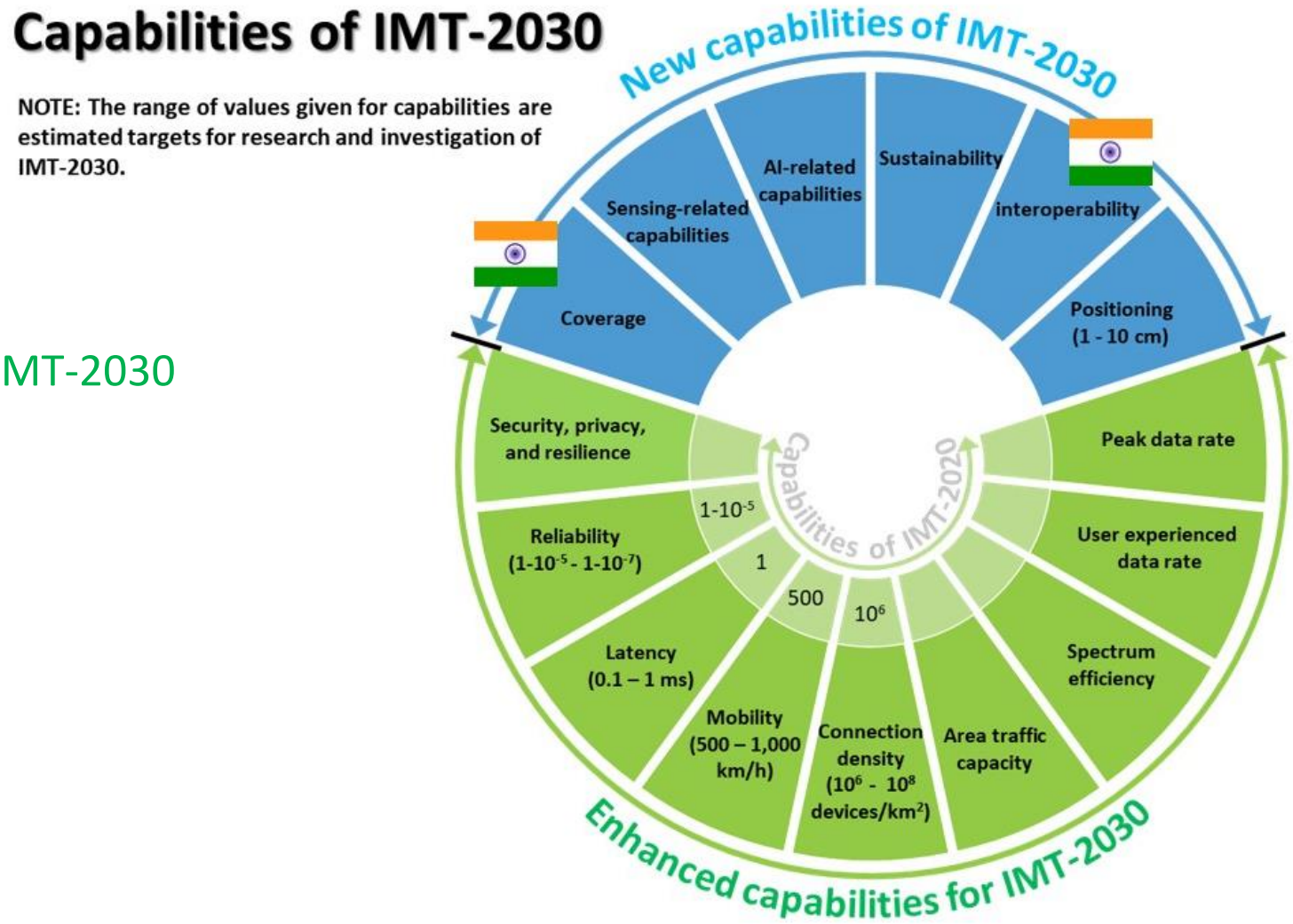
Focus on better serving the networked society in developed and developing countries

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

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



How to achieve Ubiquitous Connectivity?

There are four key ingredients

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

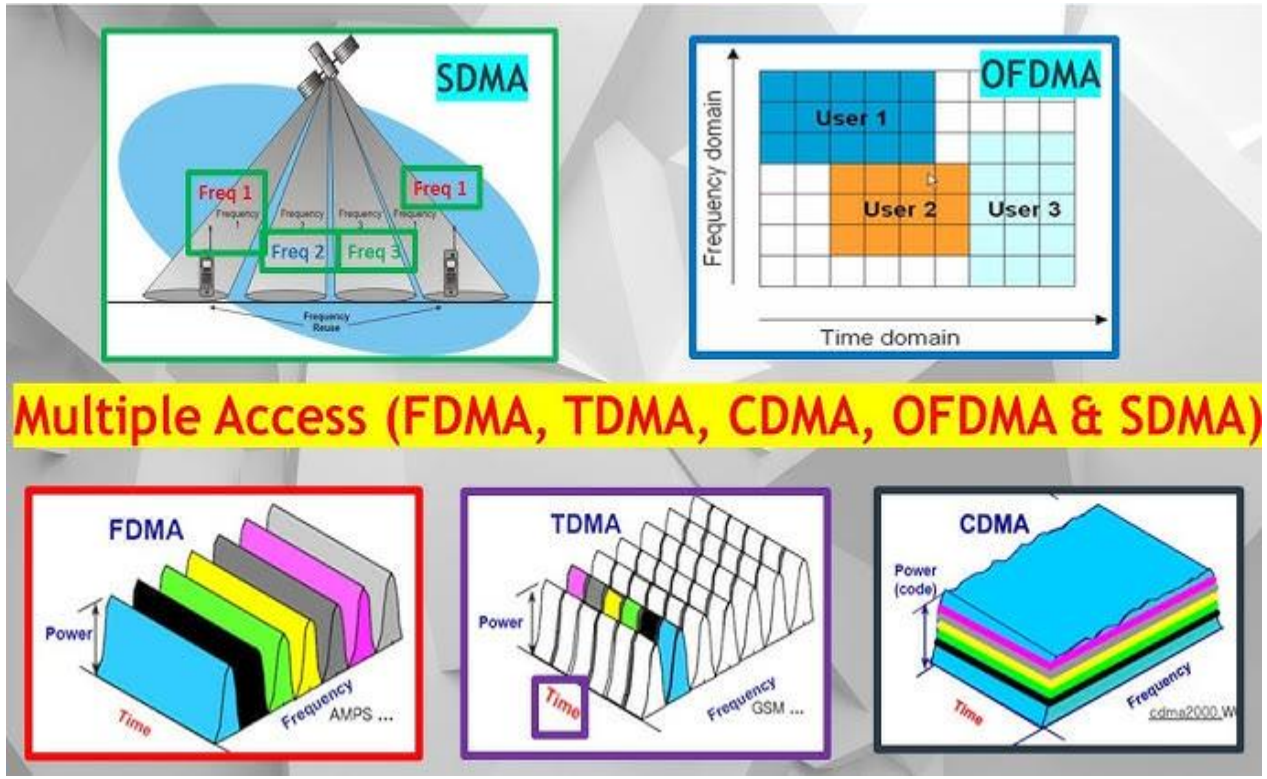
Tight Integration between Terrestrial and NTN

Existing Waveforms/Multiple Access

1. TDMA
   - Time multiplexing of data, control demodulation reference sequence in one block (**called TDMA slot**)
   - Pulse shaping – SQRT RC – Bandlimited but not time limited
   - Low PAPR, High PA efficiency
   - Low Flexibility in frequency multiplexing multiple signals/users

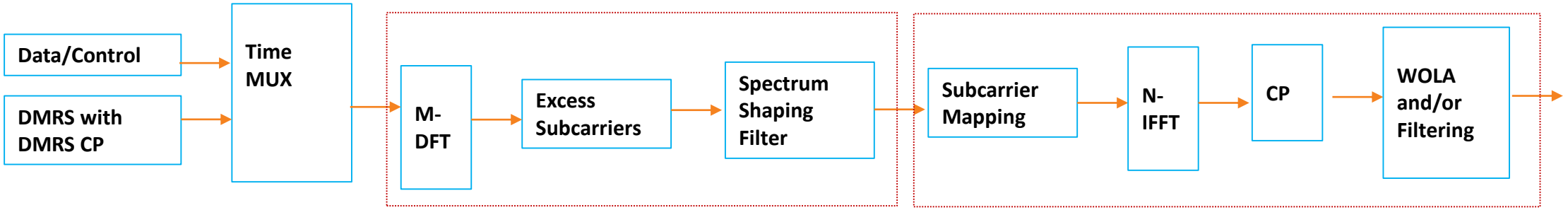
2. OFDM(A)
   - Allows frequency Multiplexing of multiple signals or users or channels
   - OFDM time limited to one OFDM symbol - Non-bandlimited
   - WOLA/filtering for spectral confinement
   - High PAPR, low PA efficiency

3. DFT-S-OFDM(A)
   - DFT precoding, Subcarrier Mapping and IDFT – same spectral properties as that of OFDM
   - But low PAPR
   - Data and DMRS occupy distinct OFDM symbols. In eMBB, one out of 7 symbols is reserved for DMRS transmission (DMRS overhead 1/7)



OTDM Offers the Combined Advantages of all the Above

Orthogonal Time Frequency Division Multiplexing (OTFDM)



Time Division Multiplexing in one Symbol

- Time multiplexing of Data and Control and 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

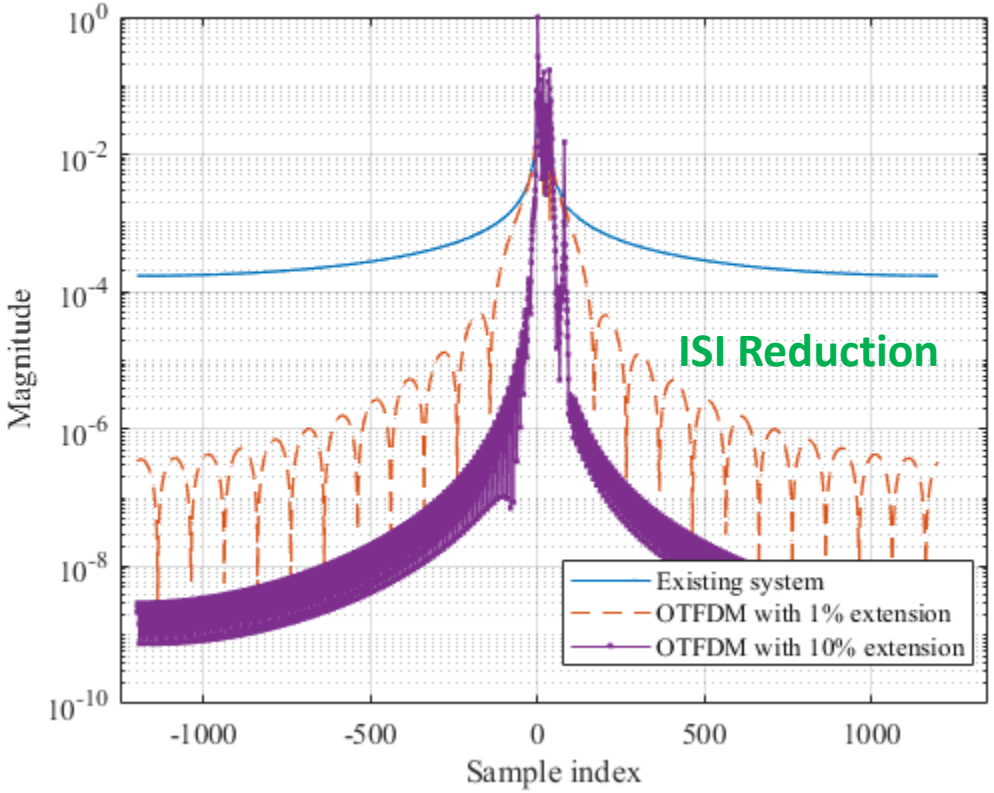
Standard OFDM Operations

- 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

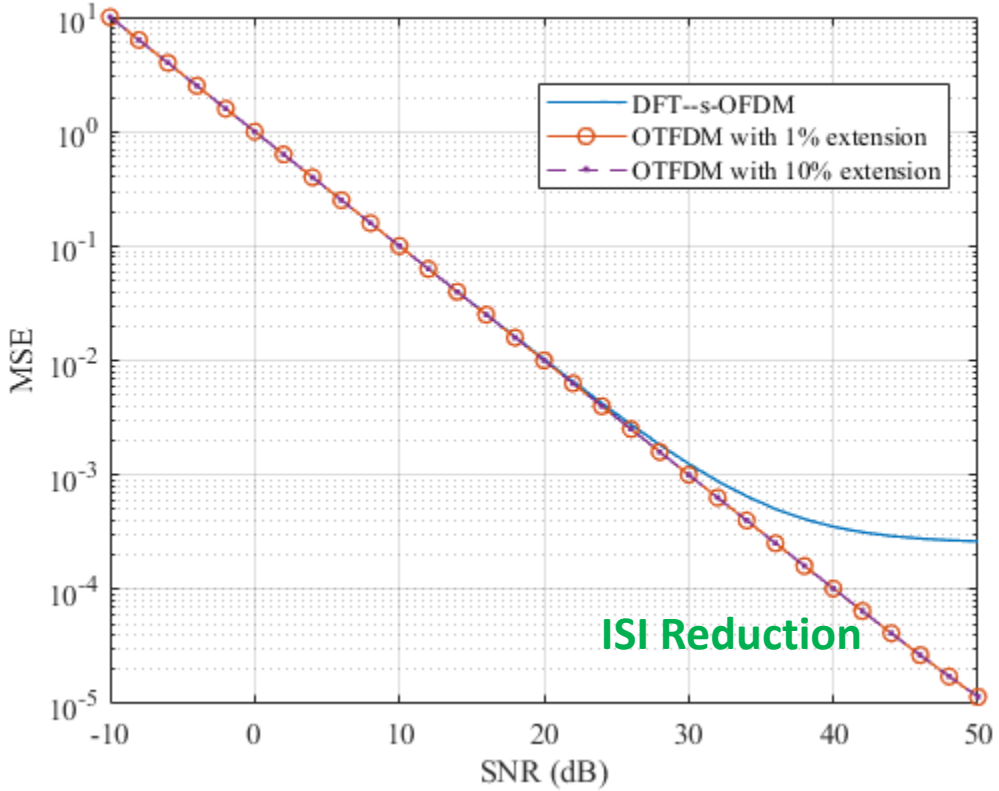
OTFDM achieves the targets: low PAPR, Hyper low-latency

Performance

Time domain channel with the effect of pulse/spectrum shaping



Channel estimation Mean squared error performance



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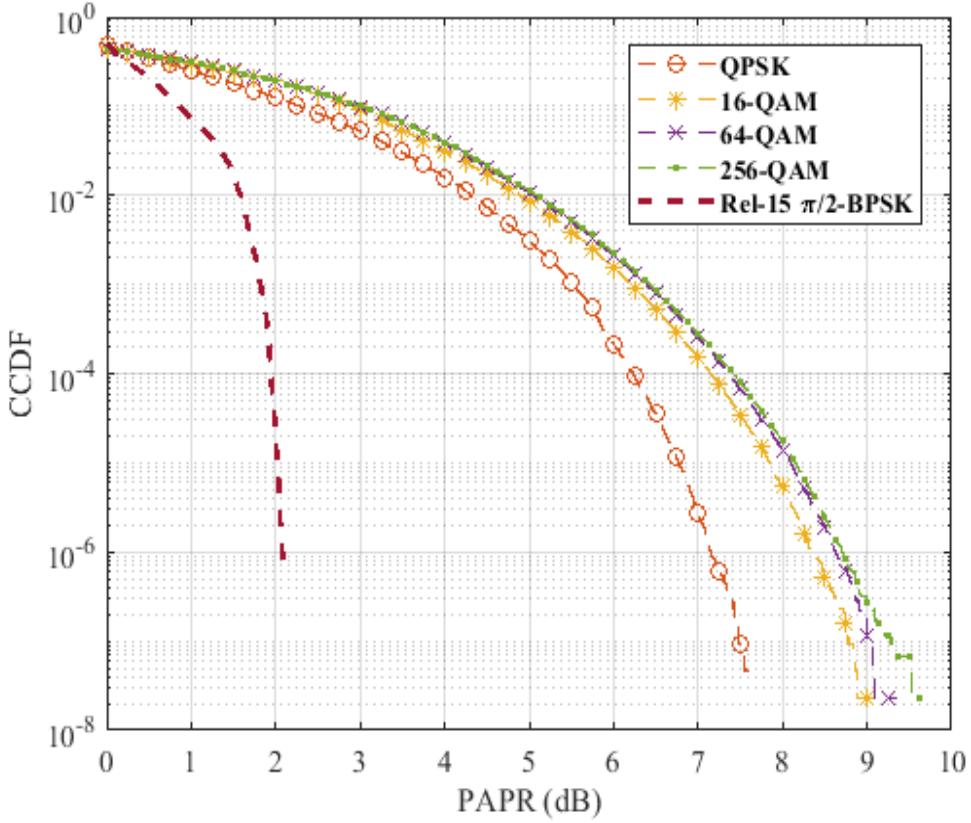
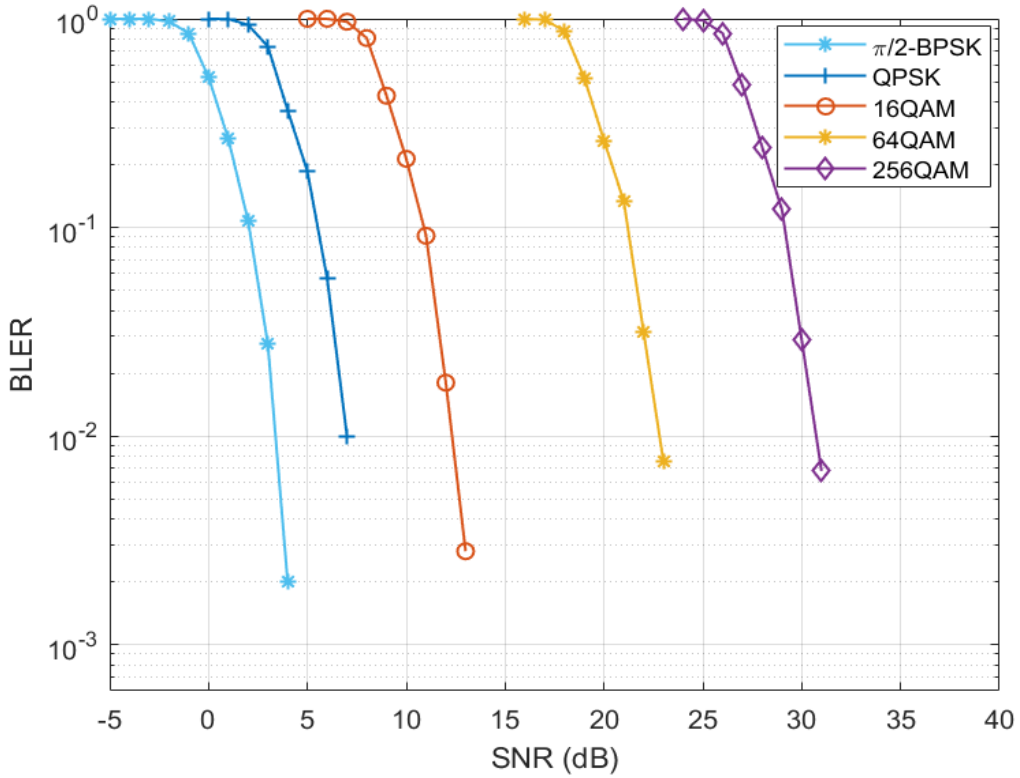
PAPR performance



BLER performance



Pi/2 BPSK allows operation at PA Saturation Level
Higher Order Modulation Modes Requires a PA Back-off
High Speed user mobility up to 750 Kmph can be supported at 7GHz

Hyper Low Latency

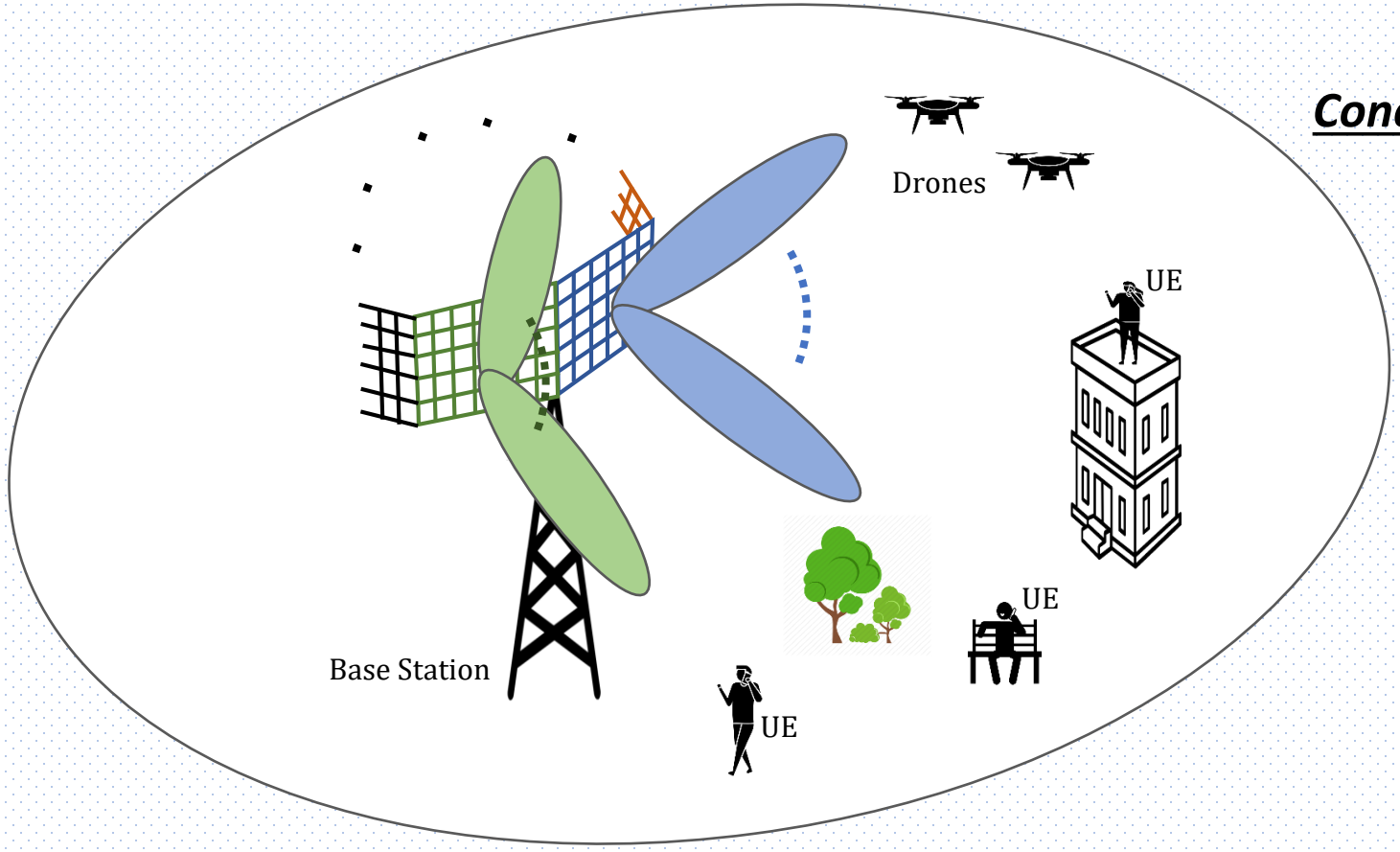
TTI duration for different Subcarrier spacings:

Subcarrier spacing	30 KHz	60 KHz	120 KHz	240 KHz	Units
System bandwidth	100	200	400	800	MHz
FFT size	4096	4096	4096	4096	
Sampling time	8.138	4.069	2.0345	1.01725	n Seconds
Symbol duration	33.33	16.67	8.33	4.167	μ Seconds
CP duration	2.344	1.172	0.586	0.293	μ Seconds
TTI (symbol + CP duration)	35.677	17.839	8.919	**4.459**	μ Seconds

Transmission Time Interval (TTI) is a fundamental building block of a system that determines Latency

OTFDM Meets Hyper Low Latency Targets Set by ITU WP 5D

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*

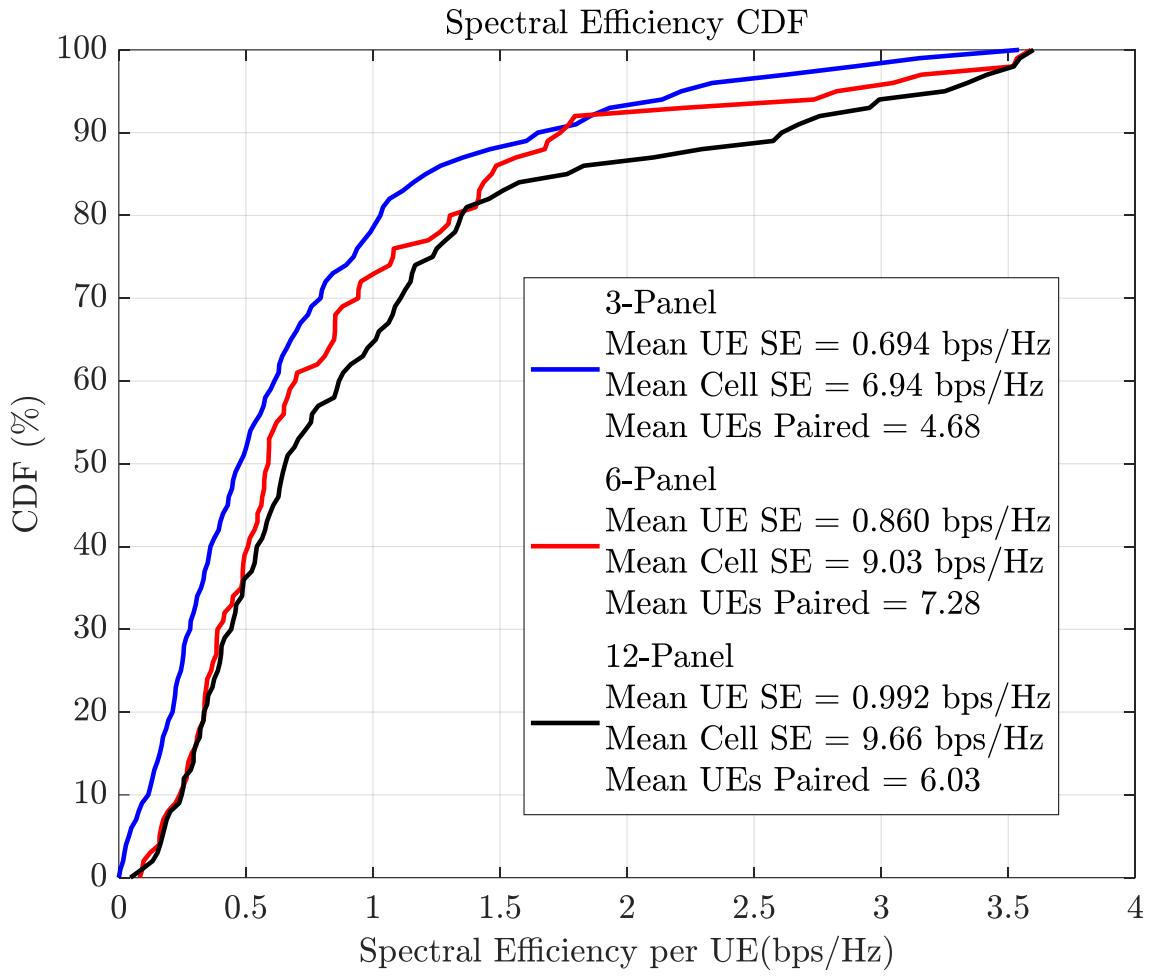
Existing systems are limited by limited directivity associated with each antenna port

S-MIMO: Spectrum Creation

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 he possibility of reaching 100 Bits/Sec/Hz target

S-MIMO: Network Simulation



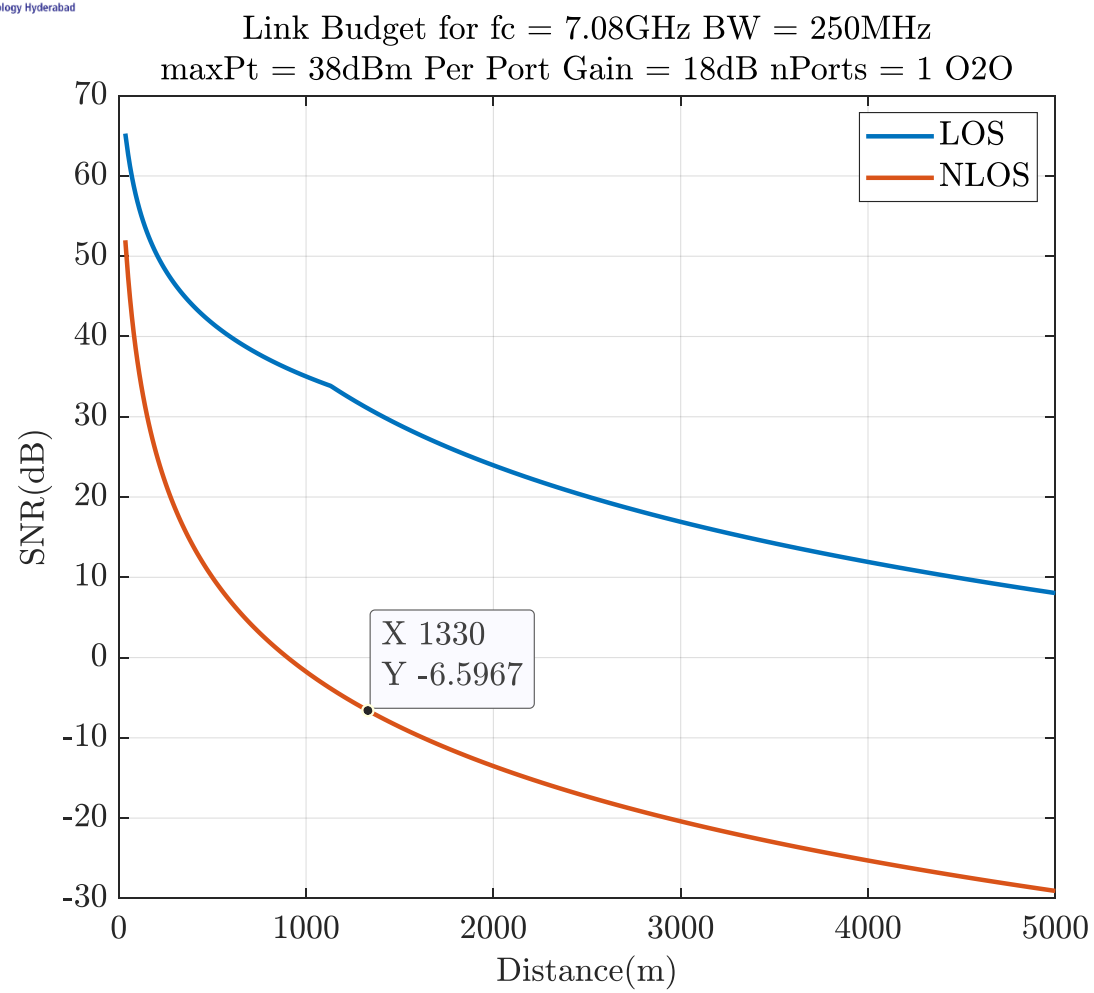
SE numbers in bps/Hz

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

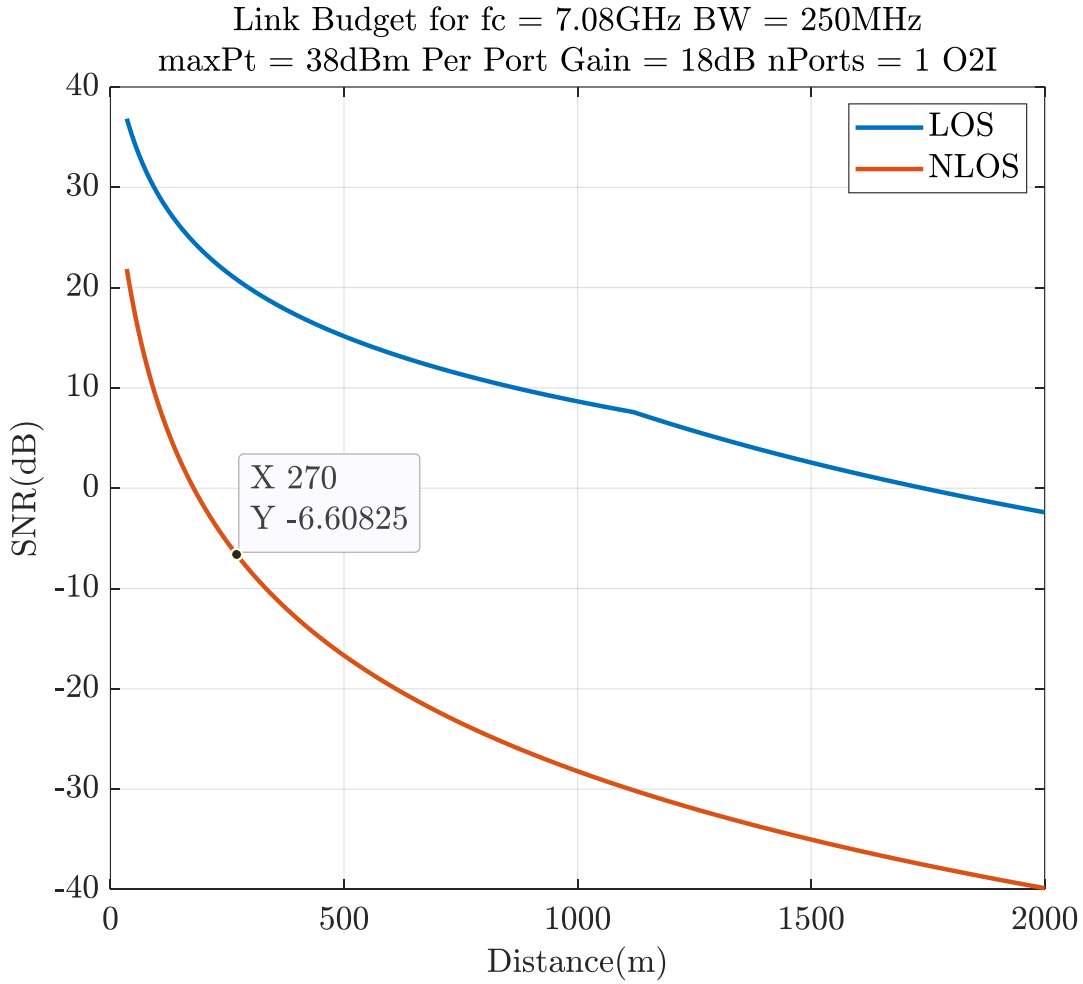
DL S-MIMO MU MIMO SE with multiple antenna panels – Mid-band

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

Link Budget for 7GHz (UMa): EIRP = 56dBm

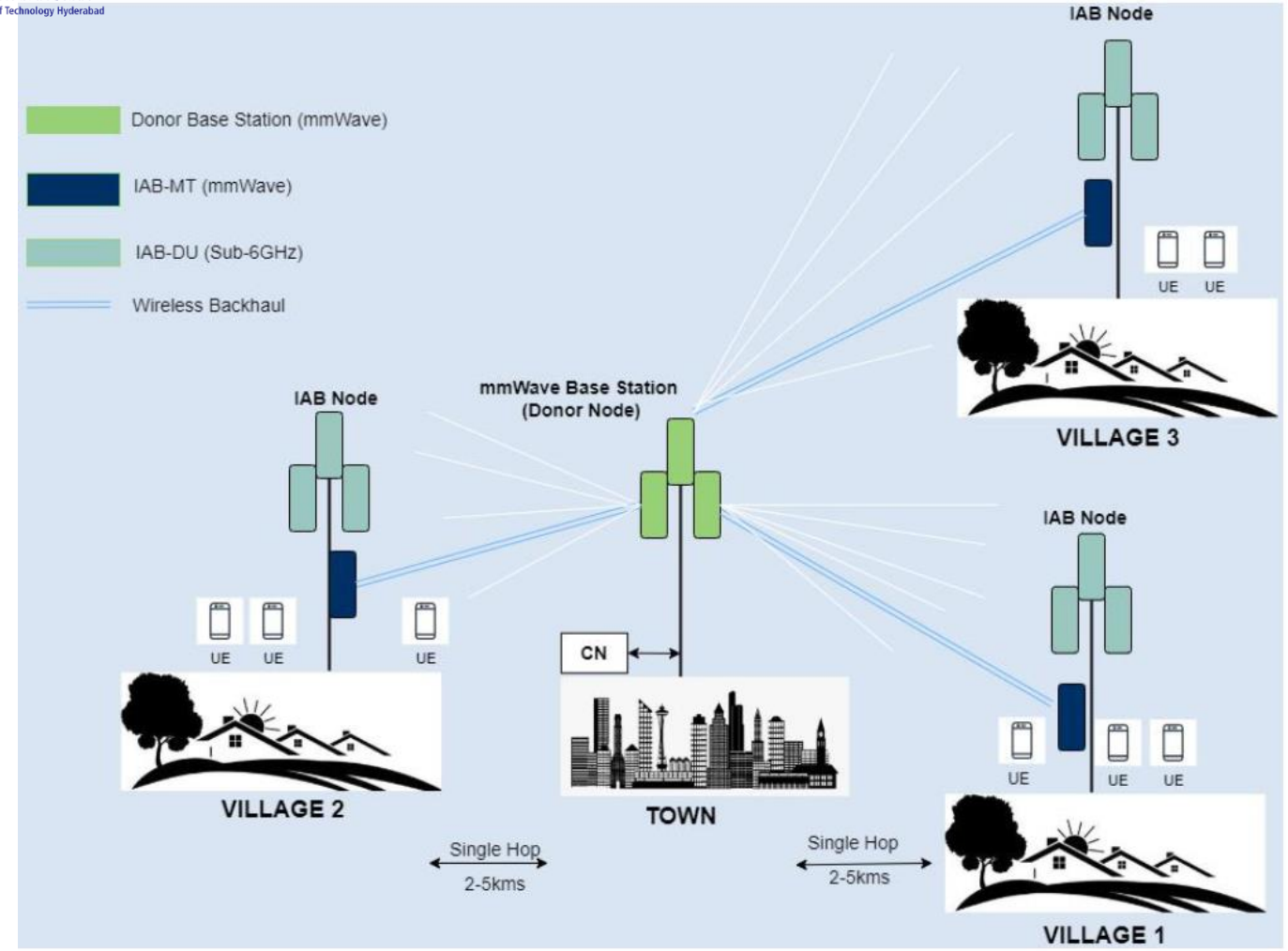


Outdoor UEs



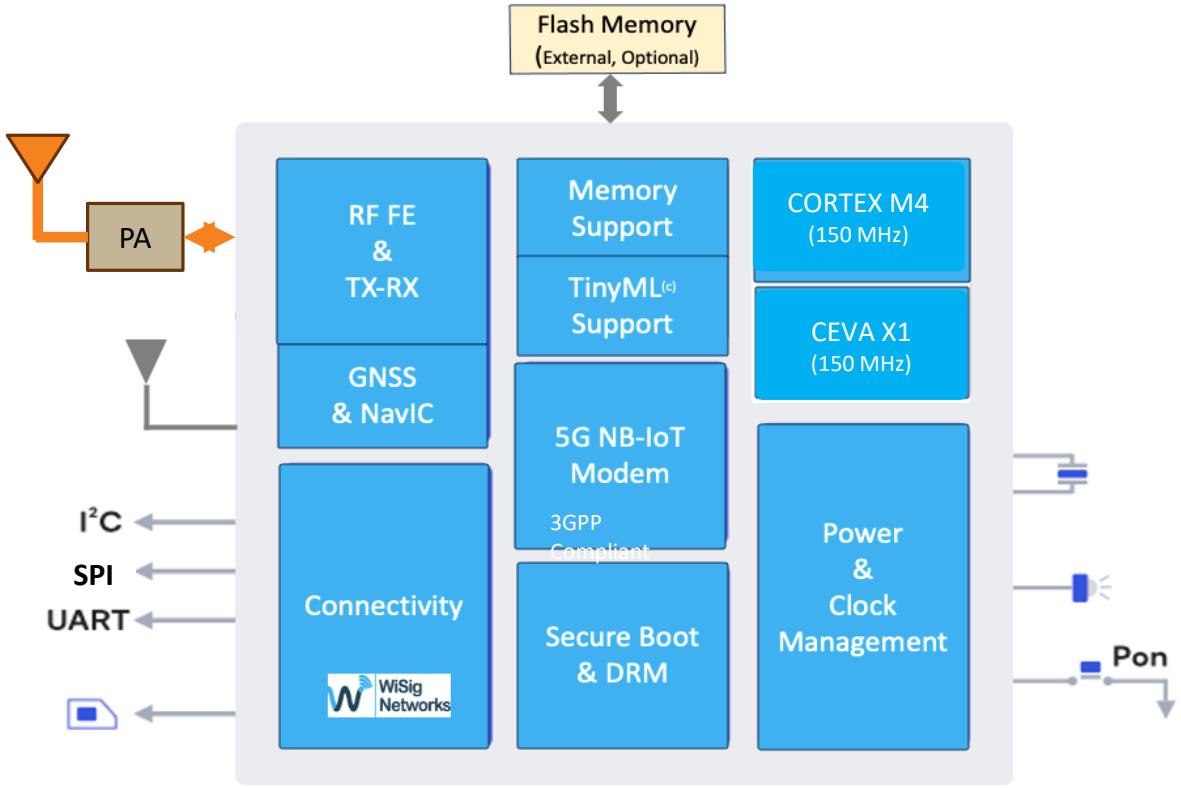
Indoor UEs

Chain of Relays

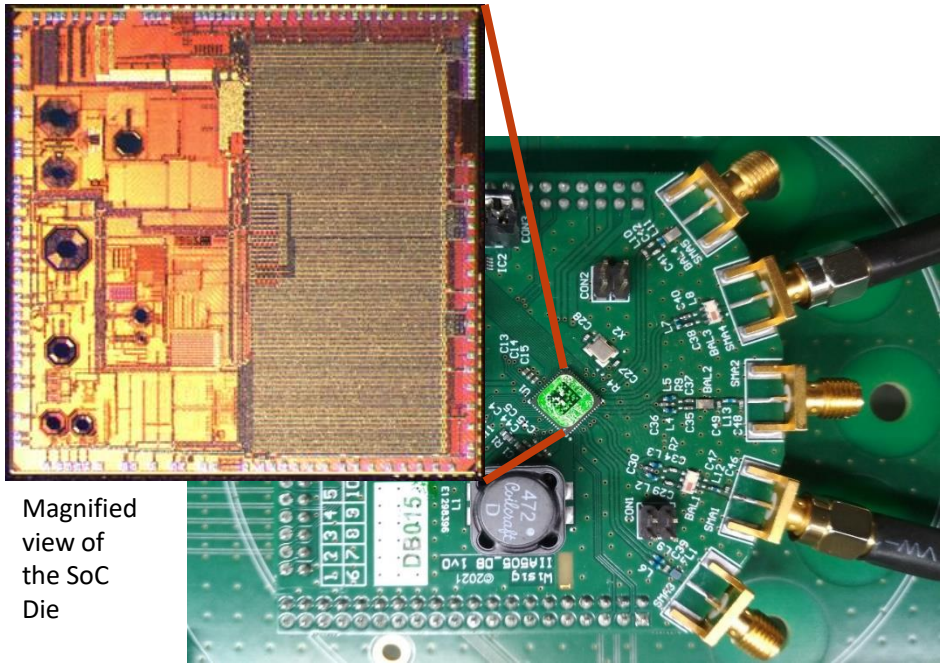


- **Optimize techniques for multi-hop relaying –long-range links**
- Low Latency IAB – fundamental PHY enhancements in baseband and RF
- Low-cost Relay UE and Relay Base Station
- Mix of FR1, FR2 and FR3

Koala 6G Modem
combines NB-IoT, Satcom Connectivity & Enables TinyML Support



Koala EDGE-ML(c) Modem



Magnified view of the SoC Die

Application Board

Unique Differentiator:

Software Defined Modem enables integration of **Terrestrial & Satellite** connectivity along with powerful enough MCU & DSP to run **TinyML** workloads

Conclusion

IMT 2030 sets ambitious targets for radio network performance

Potential technologies that meet the 6G radio KPIs

- OTFDM
- Structural MIMO
- Chain of Relays

Convergence of 6G and AI/ML Enabled Devices offer great promise

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Thank You !!

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