Workshop on

Standards-driven Research @ NCC 2024

28th February 2024

09:00 to 17:30 IST

IIT Madras

Workshop on Standards-driven Research @NCC 2024

Research Topics with a Potential for Standardization

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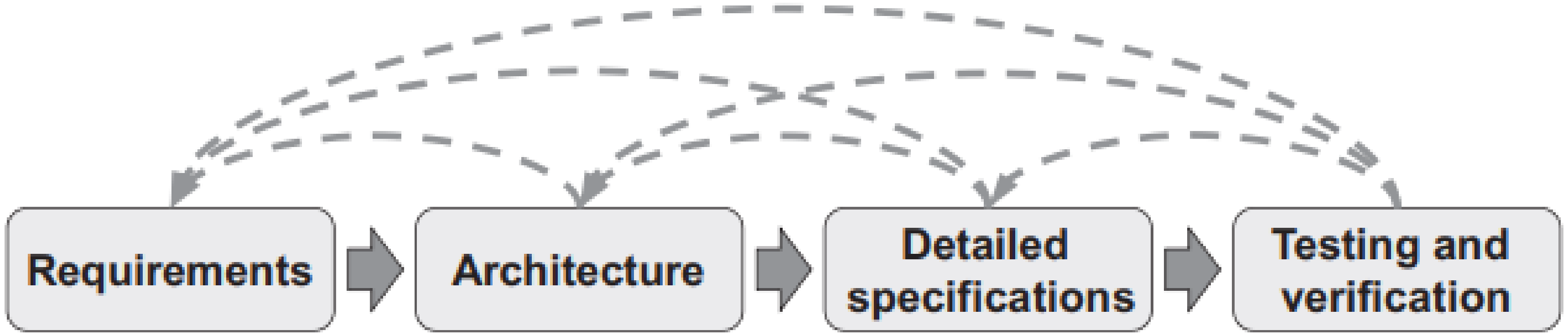
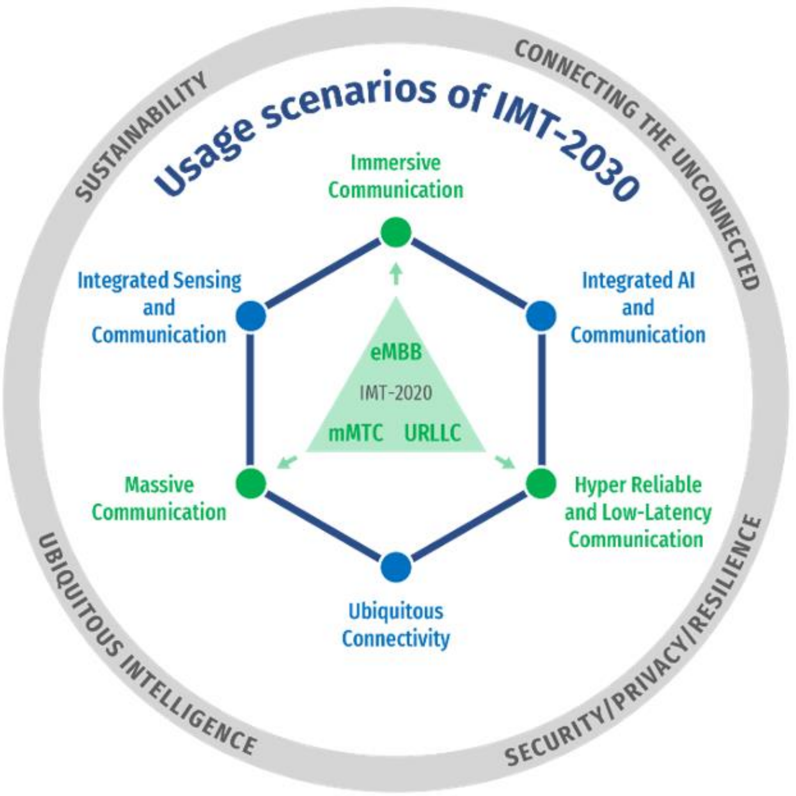
Standardization Paradigm

- Five decades: 1G 2G 3G 4G 5G …5G+ ……..6G
- Collective efforts from academia, research, industry, operators



Erik Dahlman, Stefan Parkvall, and Johan Skold. 2018. 5G NR: The Next Generation Wireless Access Technology (1st. ed.). Academic Press, Inc., USA.

6G: Requirements



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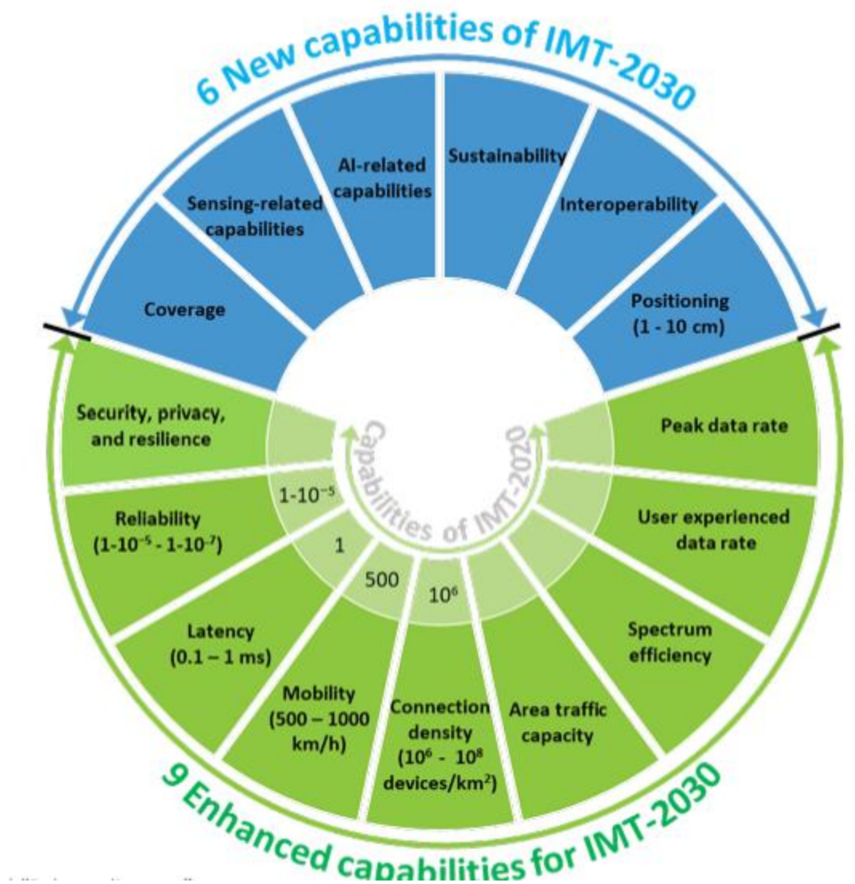

Research Topics

- Waveforms
- Design of physical signals
- Efficient channel coding techniques
- Channel modeling
- Codebook design
- Multiplexing Multiple access enhancements
- Signal processing Enhancements
- AI/ML
- Signaling Enhancements

New Waveforms for future generations !

Requirements of a Waveform

- Spectral efficiency
- Energy efficiency
- Time frequency localization
- Less Out Of Band (OOB) emissions
- Low complexity
- Easier extension to MIMO

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OFDM and DFT-s-OFDM won the race in 4G and 5G

Waveforms for future generations

Diverse expectations due to varied applications

- Communication at very high frequencies
- High mobility scenario
- Integrating Sensing applications
- Wake Up Signal design/ IoT applications

Waveforms for future generations

Diverse expectations due to varied applications

- Very high frequencies (single carrier waveforms)
  - DFT-s-OFDM, SC
- High mobility (waveforms with channel hardening)
  - Orthogonal Time Frequency Space (OTFS)
- Integrating Sensing applications (waveforms with chirp pattern)
  - OCDM/AFDM/LFM
- Wake Up Signal design/ IoT applications (waveforms that enable low complex receiver)
  - SC-OOK

Waveforms for future generations

OFDM may still be the base waveform

- Most waveforms may be seen as overlay on OFDM

Support multiple waveforms and select one based on need

- Selection techniques
- User multiplexing
- Signaling exchanges

Frame structure definitions

- Grid in time-frequency: define positions of different channels/signals

- Definition of suitable grid structure in other domains !
  - OTFS: Delay-Doppler domain

- Enable low latency

- Simple frame structure for IoT applications ?

- Guard (band/duration) requirements for sensing applications ?

Design of physical signals

Synchronization signal design

Pilot (Reference Signals) design

Synchronization signals

- Synchronization signals (SS): first signals seen by user equipment (UE)
- SS in 4G/5G: PSS and SSS
  - Detect cell ID, time-frequency synchronization
- SS design to suit different waveforms
- Simplified SS for IoT devices
- SS packing for huge number of beams

Reference Signal Design

- Channel estimation
  - Demodulation, beam management, channel quality measurements, positioning,….

- Different RS designs to suit different waveforms
  - OTFS RS pattern (For ex.)
    - Sparse in time
    - Same RS for multiple measurements

  - Single Carrier waveforms (For ex.)
    - Variations in Phase Noise (PN) Tracking Reference Signal patterns

  - Different RS patterns for high frequencies
    - Nearly LOS channel, higher PN effects

- New predefined RS patterns
  - Terrain, mobility, use case requirements

Enhancements in channel coding

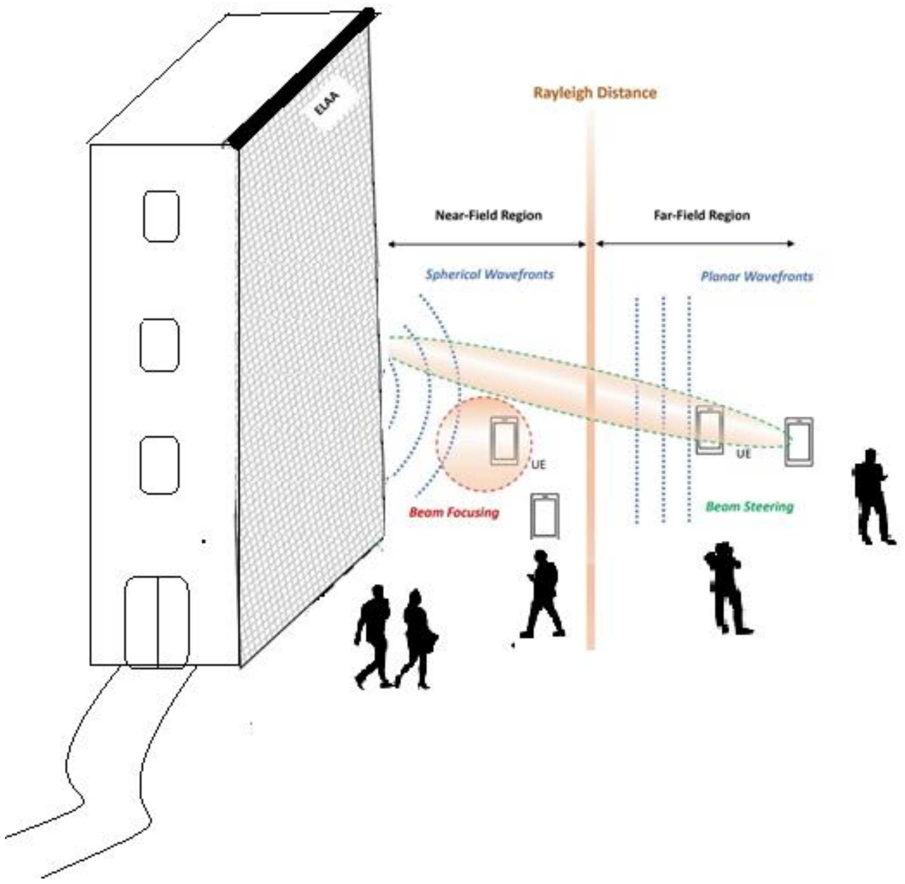
- Immersive comm
  - High throughput, low latency
  - Streaming codes ?
- HRLLC
  - Ultra low latency and hyper reliability (BER of order of 10^{-7})
- Low complexity decoding
- Different codes for large block sizes and small block sizes

Channel modelling: study and evaluate

Channel modelling for upper mid-band

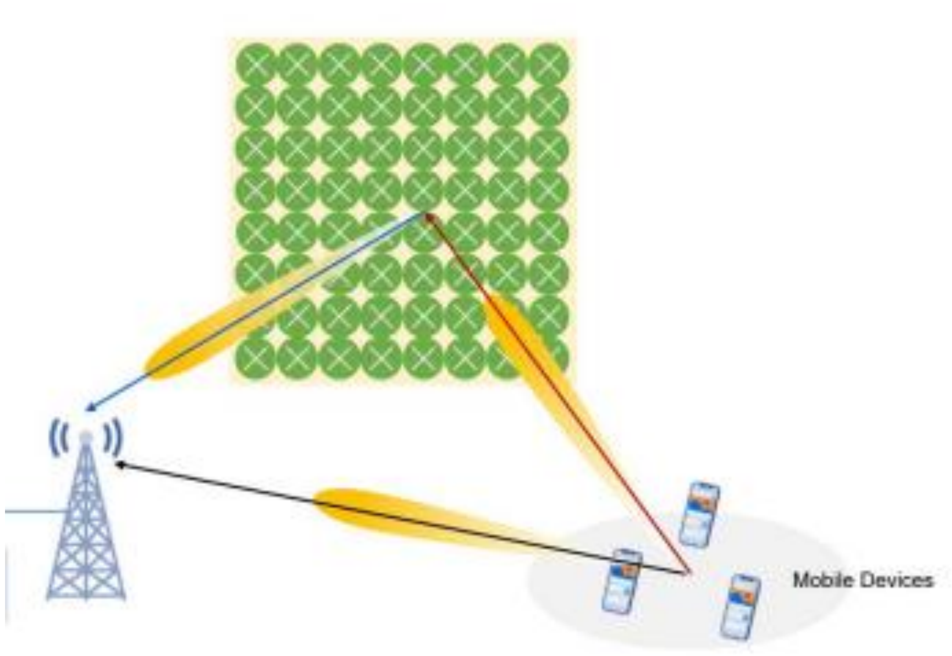
- 3GPP TR 38.901 : 5G SCM channel model
  - Channel model up to 100GHz
  - Modeling for upper mid band based on interpolation
  - Validation and study on clusters

- Employing large arrays
  - Rayleigh distance: $2D^2/\lambda$ comparable to inter-site distances
    - Near field effects: spherical wavefronts
  - Spatial non stationarity



Channel modelling for RIS

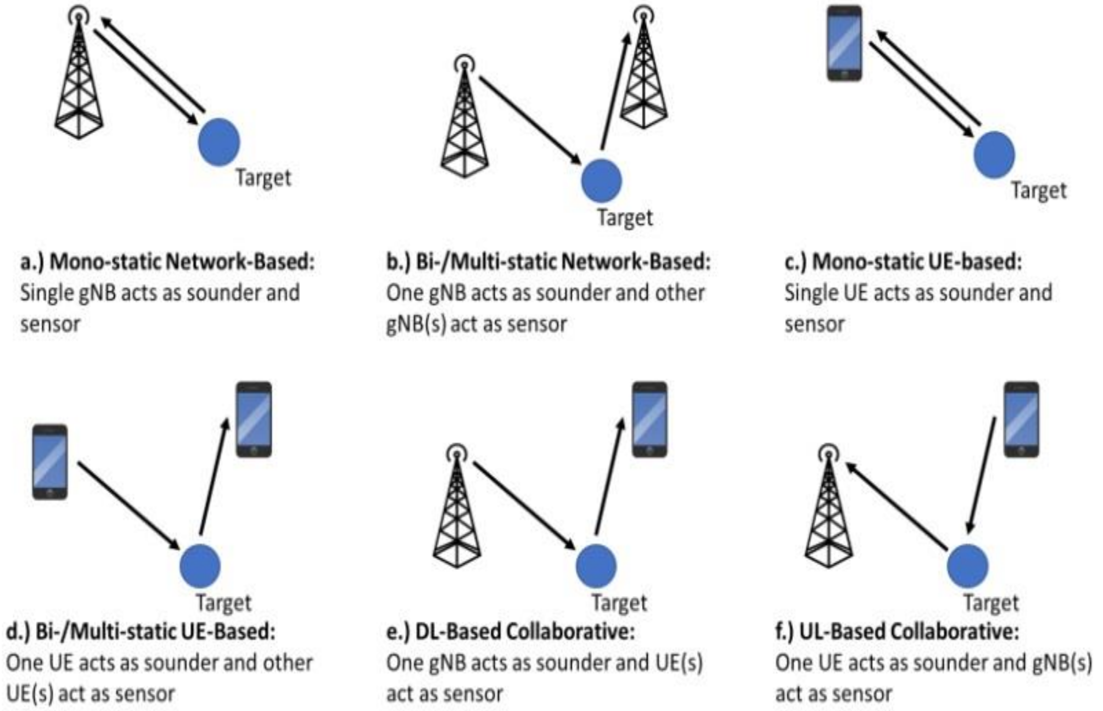
- Reflective Intelligent Surfaces (RIS) are planar surfaces with meta elements
- Phase shits of meta elements adjusted to provide coverage to a certain region
- Channel model for two paths



Zhao, Yajun & He, Jiguang. (2023). RISTA - Reconfigurable Intelligent Surface Technology White Paper (2023). 10.12142/RISTA.202302002.

Channel modelling for sensing

- Integrated sensing and communications
  - Share same h/w, same signal
- Two way channel
  - Transmitter to target and target to receiver
- Presence of clutter in environment
- Radar Cross Section (RCS) varies with different targets
- Sensing modes to be considered
  - BS to BS / BS to UE / UE to BS / UE to UE
  - Mono static / bi static
- Use case based channel model



Precoder design

- Precoders for effective transmission
- Separate users in Multi user - MIMO system
- Codebook (CB) based and non CB based precoders are supported in specifications
- Codebook for multiplexing users in near field region
  - spherical waves exhibit non-linear phase characteristics leading to complicated signal processing
- Codebook design for RIS

Multiplexing and Multiple access enhancements

Multiplexing enhancements

- 4G/5G: multiplex different users in time-frequency gird
- Multiplex different waveforms for different applications
  - Interference study
  - Guard definition

New multiple access schemes

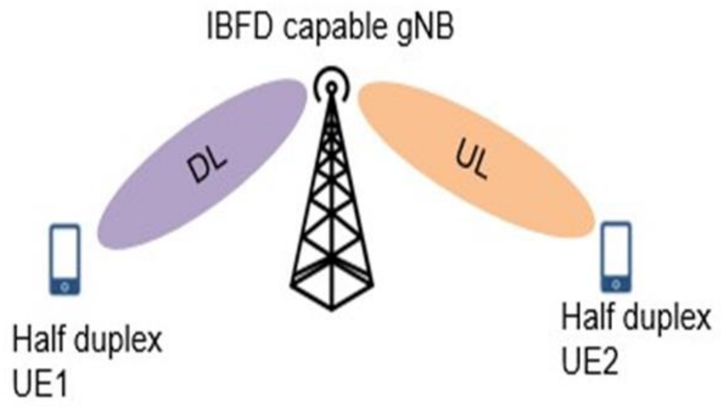
- Traditional schemes: orthogonal
  - Time/frequency/space/code
- Non orthogonal methods: improve spectral efficiency
  - Non Orthogonal Multiple Access (NOMA)
    - Power domain
    - Code domain
- Multiplex numerous users in a given set of resources (IoT applications)
  - Segregate users in grant free transmissions

Signal processing enhancements

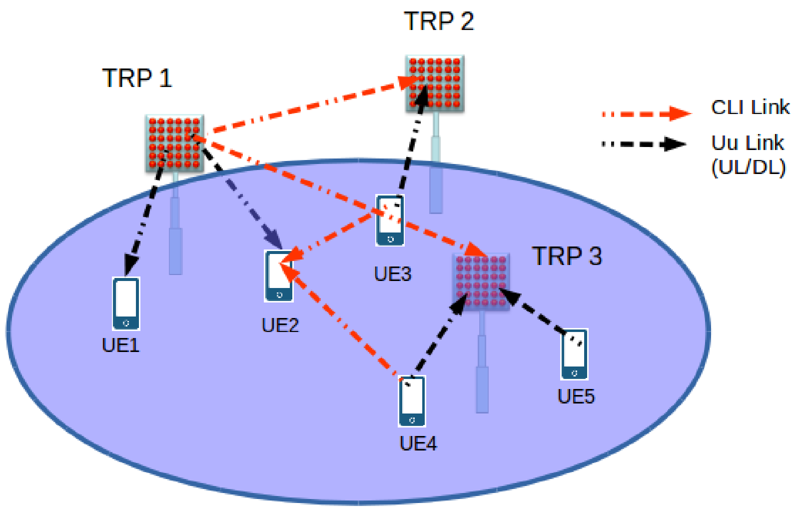
Need for new algorithms

- Channel estimation
  - Extreme MIMO: Large antenna arrays
  - RIS
- Interference mitigation (Full Duplex (FD) systems)
  - Self Interference (SI)
    - Antenna/beam separation
    - Analog domain cancellation
    - Digital cancellation
  - Cross Link Interference (CLI)
    - Scheduling enhancements, RS pattern tweaking

SI in FD systems



CLI in FD systems



Need for new algorithms

- New positioning methods
  - Carrier phase positioning
  - Schemes with lesser bandwidth requirements ??!
- New sensing algorithms
  - Clutter removal: delay line algorithms
  - Object identification

Algorithms define requirement on RS patterns !

Role of AI/ML in cellular

AI/ML in Rel. 18

- Beam management

  Study for different beam sets, different scenarios, UE speeds,

- CSI compression

- Positioning

Future trends in AI/ML

- Pilot less transmission
- Reduced control channel overhead
- SON for energy efficiency
- Coder-decoder design based on AI/ML

Signaling mechanisms

- Information exchange between entities

- Different levels of signaling
  - Radio Resource Configuration (RRC) : semi static
  - MAC-CE : dynamic
  - Control channel Information (DL/UL): dynamic

- Capability
  - Waveforms supported, MIMO order, Duplexing capabilities

- Data channel related
  - Codebook information, MCS, MIMO scheme, beam related information

- Measurements and reporting

Conclusions

- Vision of future generations
  - Variety of applications with diverse expectations
- Challenges are analysed and solutions are investigated
- Relevant research topics are their impact are looked into

Thank You

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