Beam Management Frameworks for 3GPP New Radio at mmWave Frequencies

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OVERVIEW

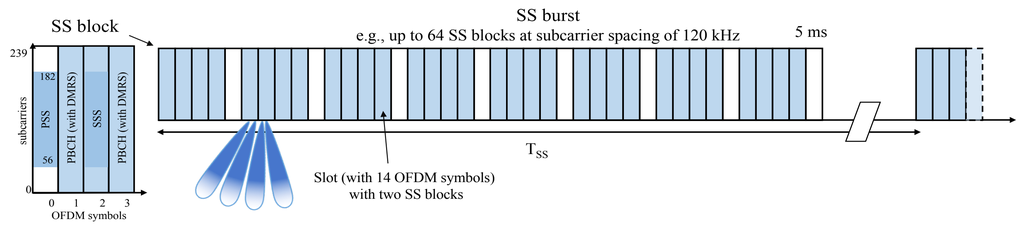
- 5G is currently undergoing standardization in 3GPP as New Radio (NR) with support for mmWave frequencies → huge rates but unstable propagation
- Need for fine and durable **alignment** of the beam pair
- Need to TRACK and MONITOR the channel quality → BEAM MANAGEMENT

GOAL: *Definition of mmWave-aware initial access (IA) strategies*

3GPP NR BEAM MANAGEMENT

1. *Beam sweeping:* covering a spatial area with a set of beams
2. *Beam measurement:* evaluate the quality of the received signal
3. *Beam determination:* the selection of the suitable beam based on measurements
4. *Beam reporting:* feedback of transceiver decision in the beam determination phase

- *Synchronization Signal (SS)* block and burst to estimate the channel and select the best gNB to attach to

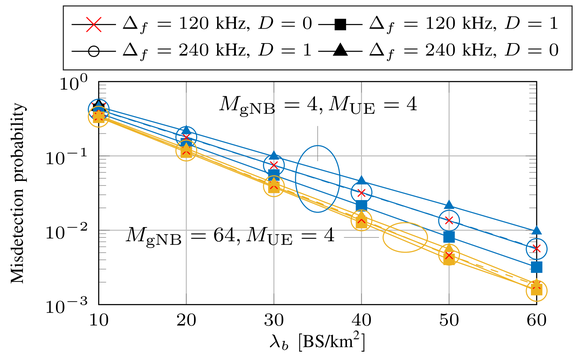


- *Standalone*. UE connects only to an NR gNB at mmWave frequencies
- *Multi-connectivity*. UE maintains multiple possible signal paths to different cells at different frequencies (i.e., mmWaves and sub-6 GHz)
- *Downlink*. The gNBs transmit synchronization signals via SS blocks
- *Uplink*. The UEs transmit Sounding Reference Signals (SRSs)

Parameter	Δ_f	D	N_{SS}	T_{SS}	K_{BF}	M	λ_b
Accuracy	✓	✓	x	x	✓	x	✓
Reactiveness	✓	x	✓	✓	✓	✓	x
Overhead	✓	✓	✓	✓	✓	✓	x

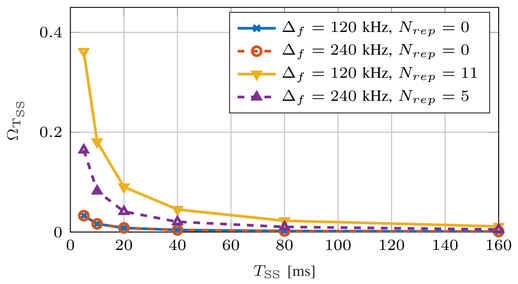
- Δ_f = {120, 240} KHz: subcarrier spacing
- D: Frequency diversity (data or repetition)
- N_{SS} = {8, 16, 32, 64}: max. number of SS blocks in a burst
- T_{SS} = {5, 10, 20, 40, 80, 160} ms: SS burst periodicity
- M: antenna elements (and number of steering directions)
- λ_b: gNB density

RESULTS and DISCUSSION



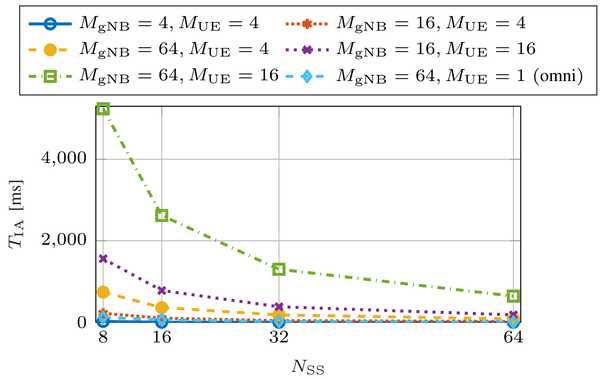
Accuracy (misdetection probability)

- Better accuracy for dense networks
- Better accuracy with narrow beams
- Better accuracy with frequency diversity and narrowband communication

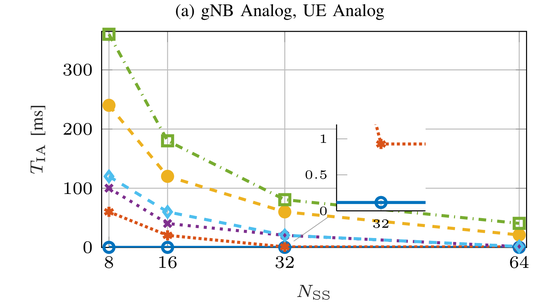


Overhead (initial access resources)

- Impact of SS block configuration
- Impact of subcarrier spacing
- Frequency diversity needs more resources



(a) gNB Analog, UE Analog



(b) gNB Analog, UE Digital (DL-based configuration)

Reactiveness (initial access delay)

- Impact of SS block configuration
- Digital BF enables faster IA operations
- Better reactiveness with larger beams
- Analog gNB / Analog UE leads to very large IA delays

SUMMARY of RESULTS

- It is better to use a configuration that completes the beam sweep in a single SS burst, by appropriately selecting N_{SS}, the beamforming and the antenna array architectures
- The adoption of a frequency diversity scheme increases the detection accuracy at the expense of an increased overhead
- With low network density, larger antenna arrays enable the communication with farther users, and provide a wider coverage, but, as the gNB density (λ_b) increases, it is possible to use a configuration with wide beams for SS bursts
- Standalone and multi-connectivity frameworks mainly differ when accounting for the impact of *beam reporting*:
  - Standalone enables fast IA operations (if a single SS burst is enough for all the steering directions)
  - Multi-connectivity may be preferable for (i) fast radio link failure recovery and (ii) robustness

[1]: 3GPP, "Study on New Radio (NR) Access Technology – Physical Layer Aspects – Release 14," TR 38.802, 2017.
[2]: 3GPP, "NR – Physical channels and modulation – Release 15," TS 38.811, 2017.