3GPP NR Release 15

Analog Vs. Digital mmWave Radios: Directional Synchronization and Network Performance Comparison

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Problem

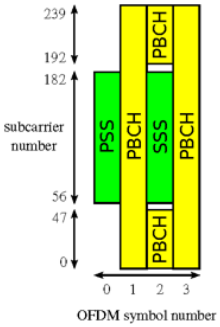
- In order to overcome the high isotropic loss at mmWave bands, base stations and portable devices will be equipped with multiple antennas which can focus the energy in a specific direction and thus expand their communication range.
- This technique is called *beamforming* and represents a fundamental component of 5G mmWave systems. However, directionality is not the only challenge. Due to the susceptibility to blockage events, operating in the mmWave bands requires advanced techniques known as *beamtracking*.
- As a consequence, *beam management* is one of the key items in 3GPP, the standard body that is defining the guidelines upon which 5G New Radio (NR) will be built.

Goal

- Evaluate the reactiveness of network layers at varying *beam management* logics, i.e., synchronization interval duration, periodicity and reporting mechanisms, along with different beamforming architectures, namely, analog and fully digital.
- In particular, we show the greater system performance achieved with digital transceivers, as a direct consequence of radios that can better track the best transmit-receive direction.

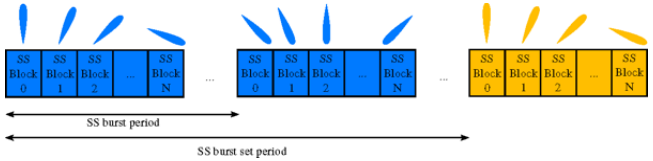
3GPP Synchronization Model

The novelty in NR with respect to Long Term Evolution (LTE) is that Synchronization signals (SS) transmission is *beamformed* to support scanning in the mmWave regime.



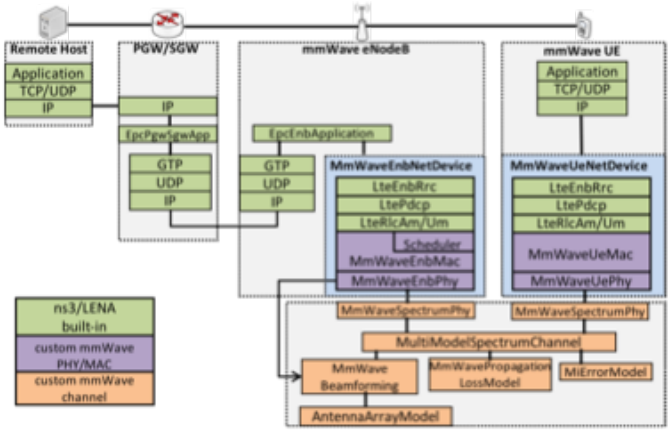
The SS structure consists of the primary and secondary SS (PSS, SSS), occupying 1 OFDM symbol and 127 subcarriers each.
The physical broadcast control channel (PBCH) spans across symbols 2 to 4 and 240 subcarriers but leaving an unused part in the middle of symbol 3 for SSS. This 4-symbol-long structure is best known as **SS/PBCH block**. The periodicity of the **SS/PBCH block** is configured by the network and the time locations where **SS/PBCH block** can be sent are determined by the sub-carrier spacing (SCS).

SS/PBCH blocks within a half-frame constitute an **SS burst**, and one or more **SS bursts** constitute an **SS burst set**.



Each **SS block** is *beamformed* towards one direction. Directions are sequentially shifted to beam sweep in azimuth and elevation. Beamforming pattern is restarted every **SS burst set** period.

Simulation Framework

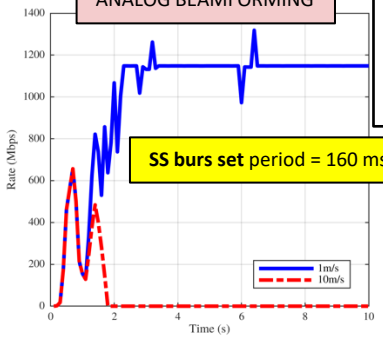


Simulation based on ns-3

- Performance evaluation of analog vs digital beamforming architecture , leveraging the ns-3 end-to-end 5G mmWave simulation framework.
- Impact of the **SS burst set periodicity** on the ability of the system to *beamtrack* a mobile user.
- Measurement reports based on **SS block** measurement.
- Beam tracking assessment in LOS and LOS-NLOS-LOS condition.

Results

ANALOG BEAMFORMING



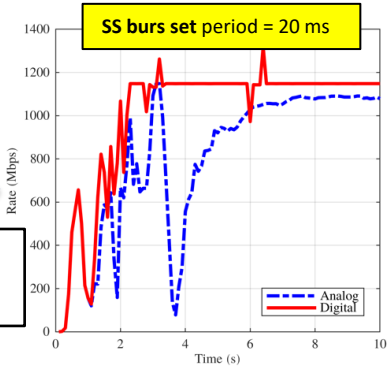
SS burs set period = 160 ms

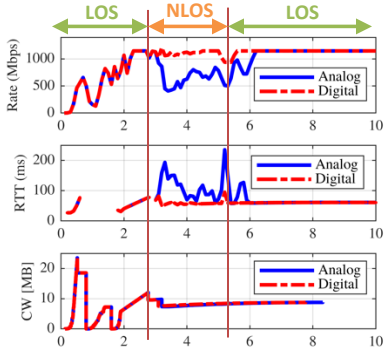
With long SS burst set periodicities, analog architectures can track UEs at a pedestrian speed, but fail when the UE moves faster because beam updates are not performed in time.

LOS SCENARIOS

With shorter **SS burst set** periodicities, digital architectures in outperform analog beamformers.

SS burs set period = 20 ms





LOS-NLOS-LOS SCENARIO

UE speed = 10 m/s

- Throughput and Round-Trip-Time (RTT) penalty with analog beamforming in the NLOS area.
- Higher degradation with higher UE speed.