Achieving mmWave Beam Tracking Within 3GPP New Radio Release 15

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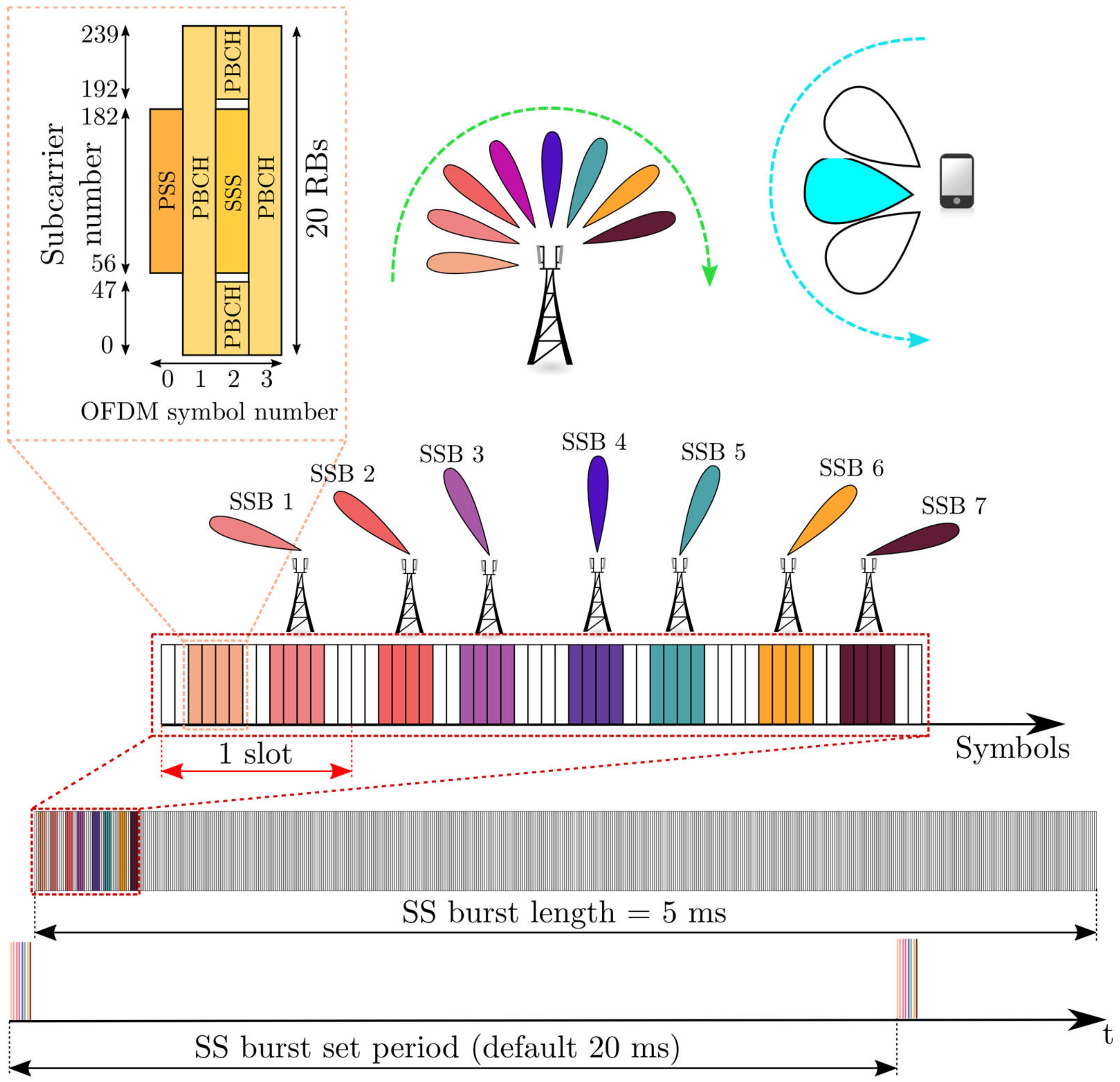
Problem

3GPP New Radio (NR) permits operation in the millimeter wave (mmWave) band. Operation at mmWave are known to suffer deep signal fluctuations due to blockages.
To overcome signal losses in mmWave, multiple antenna elements must be equipped in transmitters and receivers so they can beamform the signal on a given direction.
NR UEs acquire initial beam information after successfully synchronizing with a serving cell. However, **the initial beam information may get obsolete very quickly in mobility scenarios**.
The success of mmWave networks depends on the ability to adapt to beam changes and always find the optimum pair (TX and RX) of beams.

Directional Synchronization

NR reorganized the synchronization signals (SS) into the so called SS Block. The time and frequency locations of these signals within the NR radio frame are well defined and depends on the numerology.
In mmWave, up to 64 SS Block transmission occasions within the 5 ms time window called **SS burst** [TS 38.213].
SS burst are periodically repeated. 10, **20 (default)**, 40, 80 or 160 ms.
Base stations and UEs **beamsweep** to find the **best pair of beams**.



Achieving Beam Tracking

Beam tracking with SS Blocks is possible:

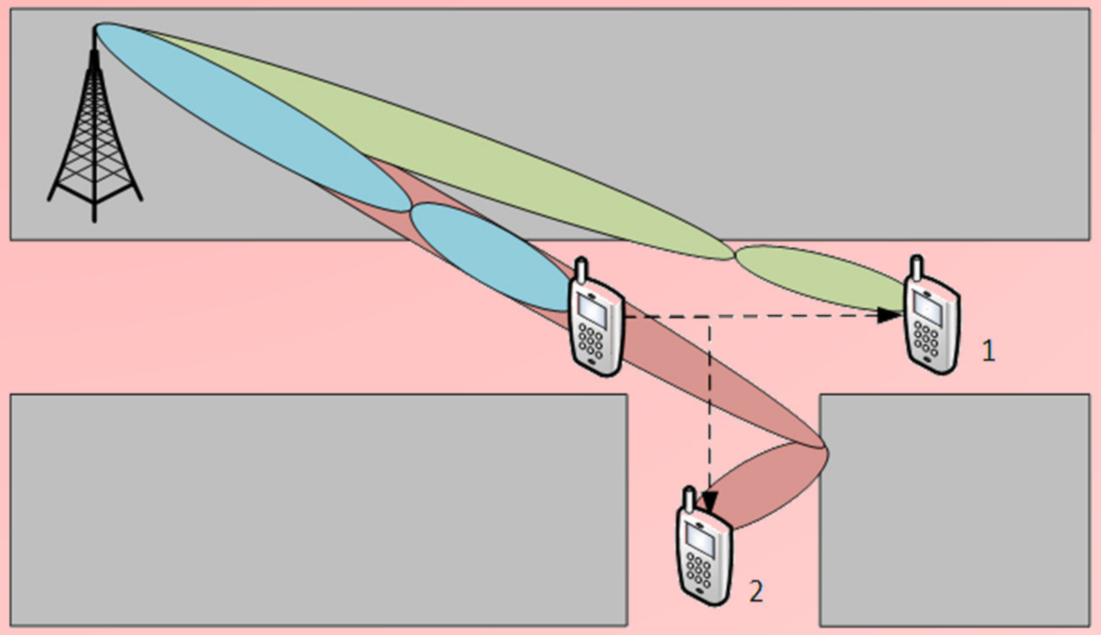
- Each SS Block is transmitted on a single beam.
- Beams out of predefined codebooks.

Channel information updates scale with the number of beam pairs → **Long channel updates delays**

Solution: SS Block + Channel State Indicator Reference Signal (CSI-RS).

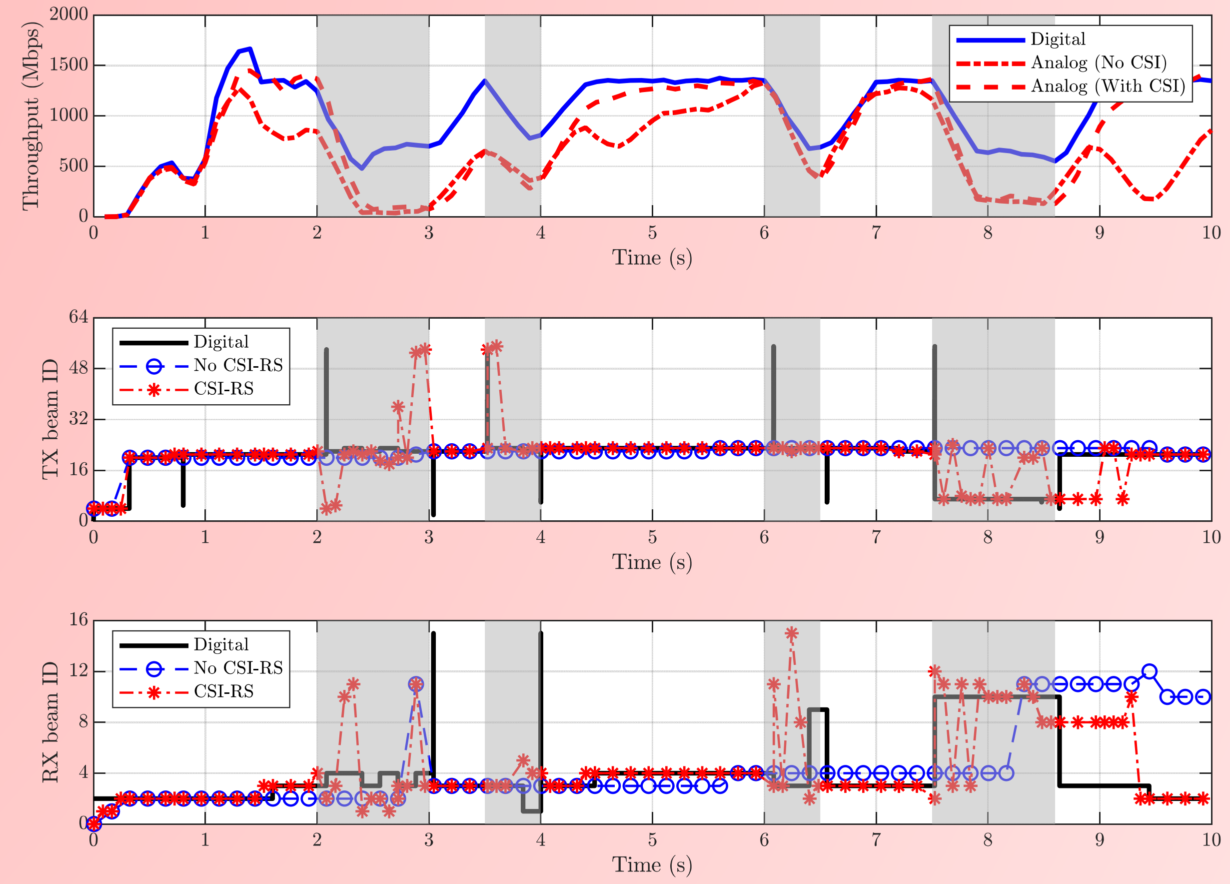
- CSI-RS has smaller periodicity than SS Blocks
- **Tracking up to 8 TX beam** [TS 38.214]
- Allows enlarging SS burst periodicity → Thr gain [1].
- Number of CSI resources does not affect TCP traffic [1].

Question: Network provisions a list of candidate beams to track (similar to neighbor cells list) but what beams should a given UE track?



Starting strategy: Tracking contiguous beams around the optimal pair of beams [1].

- Good for LOS conditions. Analog beamforming architectures can reach digital's performance figures.
- In NLOS, wrong beams in the list → significant rate drops.



List of candidate beams is extremely important to notify transitions to NLOS
Tracking must be aware of the UE environment
We will analyze two approaches

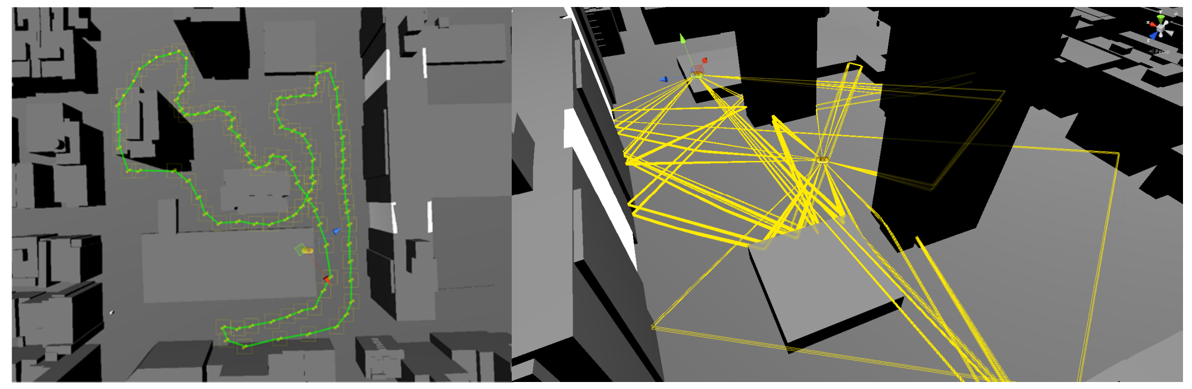
[1] C. Herranz et. al. "New Radio Beam Management in Release 15." Submitted to IEEE Communication Standards Magazine in Oct 2018.

Alt. 1: Fingerprinting

- We will simulate a realistic scenario with accurate propagation conditions from a well-calibrated ray tracing tool working at 28 GHz.
- We divide the scenario in a grid of 1 meter long squares
- In each square, we rank the pair of beams and select the top **N** combinations.
- Finally, we will add some real noise such as location deviations (i.e. GPS location error), rotation of the device and in-movement vehicles.

Alt. 2: Machine Learning

With the well-calibrated ray tracer working obtain several UE walks around the mmWave transmitter.



The collected data will be pre-processed and fed into a machine learning / artificial intelligence algorithm.
This supervised classification problem will make predictions on which pair of beams to include in the list of candidate beams.