UC San Diego
JACOBS SCHOOL OF ENGINEERING
Electrical and Computer Engineering

WCSNG
Wireless Communications
Sensing and Networking

mMobile: Building a mmWave Testbed to Evaluate and Address Mobility Effects

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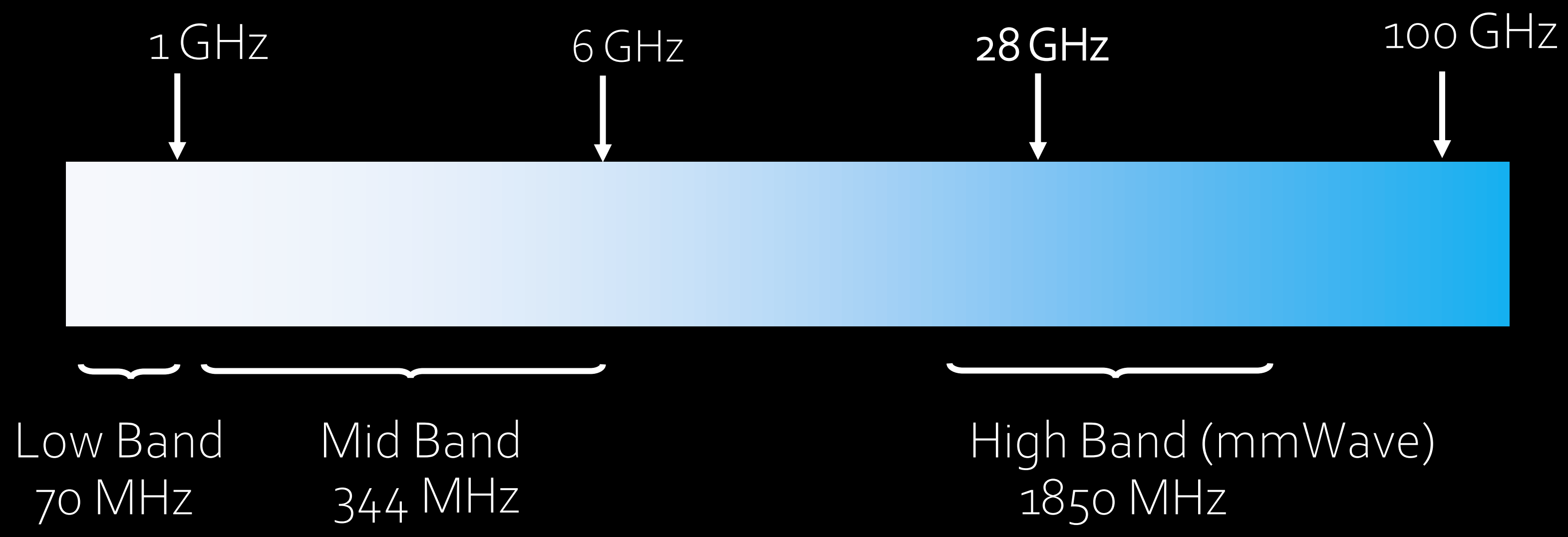
Mobicom Workshop: mmNets 2020

Why mmWave?


1 GHz
6 GHz
28 GHz
100 GHz
Low Band
70 MHz
Mid Band
344 MHz
High Band (mmWave)
1850 MHz

mmWave applications

V2X

VR/AR

The Big Challenge: Propagation and Mobility

- Mobility causes misalignment, loss of link throughput and reliability

Need practical testbeds to understand physical effects and evaluate solutions

Testbeds – Predominantly 60 GHz

2014	2016	2017	2019	2020
OpenMili 60 GHz	MIRA 24 GHz	X60 60 GHz	Millimetera 60 GHz	Mm-Flex 60 GHz

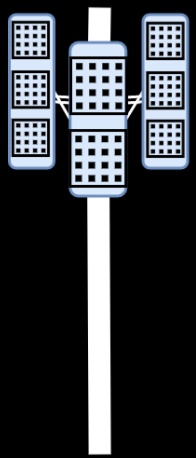
60 GHz mmWave	28 GHz mmWave
Limited adoption	Deployments Ramping up
IEEE 802.11ad	3GPP 5G-NR
High attenuation (O2 absorption)	Better propagation

Need testbeds at 28 GHz to keep up with current trends

mMobile: Testbed to Study Mobility @ 28 GHz

- A 28 GHz testbed primarily for mobility-based experiments
  - 5G NR complaint
  - Mobility support
  - Easy to replicate
- Demonstration of a low-complexity beam tracking algorithm
- Public dataset of channel measurements

Testbed requirements and challenges



gNB

- High Bandwidth (400 MHz)
- Efficient Beamforming
- NR-Compliant PHY
- Stringent RF requirements

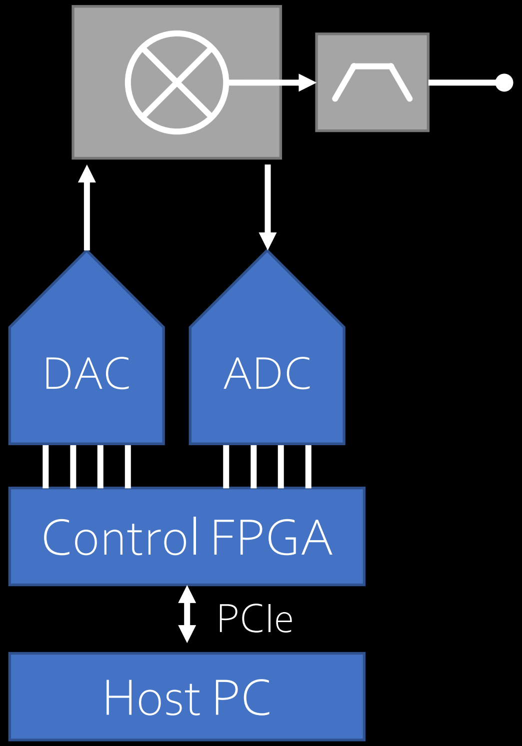
UE

- Lower Bandwidth (100 MHz)
- Small form factor
- Compact power supply

Testbed Design 1

High baseband processing gNB

- One giga-sample-per-second ADC/DAC to support 400 MHz bandwidth
- Opensource FPGA implementation
- 5G-NR waveforms streaming
- External mixer for baseband to intermediate frequency (IF)

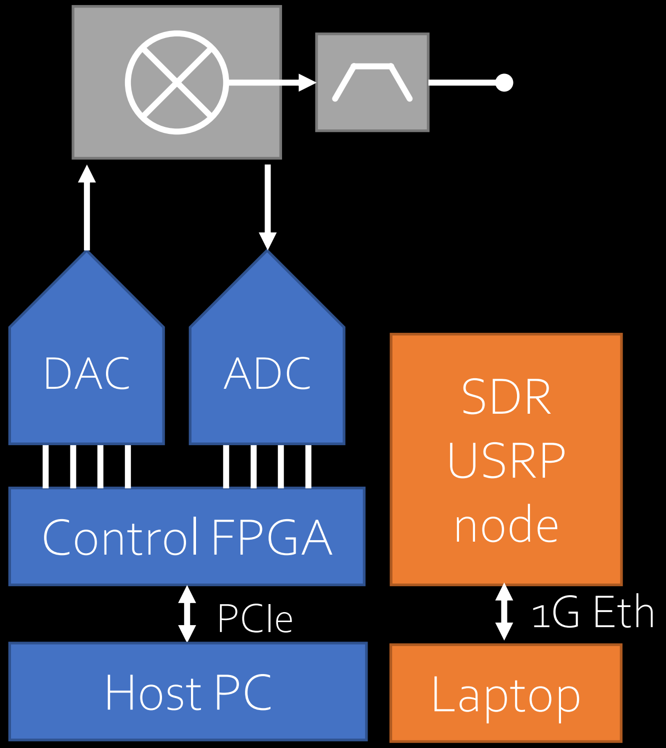


Testbed Design 2

High baseband processing gNB

Small Form-factor mobile node

- Software-Defined Radio (USRP X300) with 100 MHz bandwidth
- Modified USRP FPGA to support streaming on a laptop



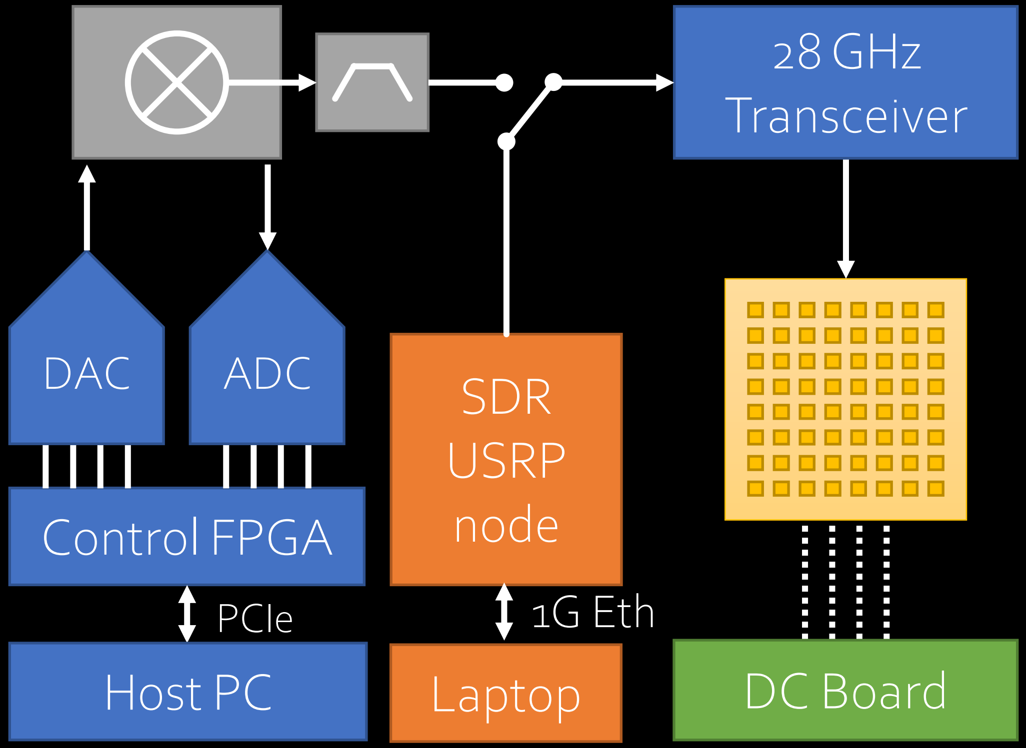
Testbed Design 3

High baseband processing gNB

Small Form-factor mobile node

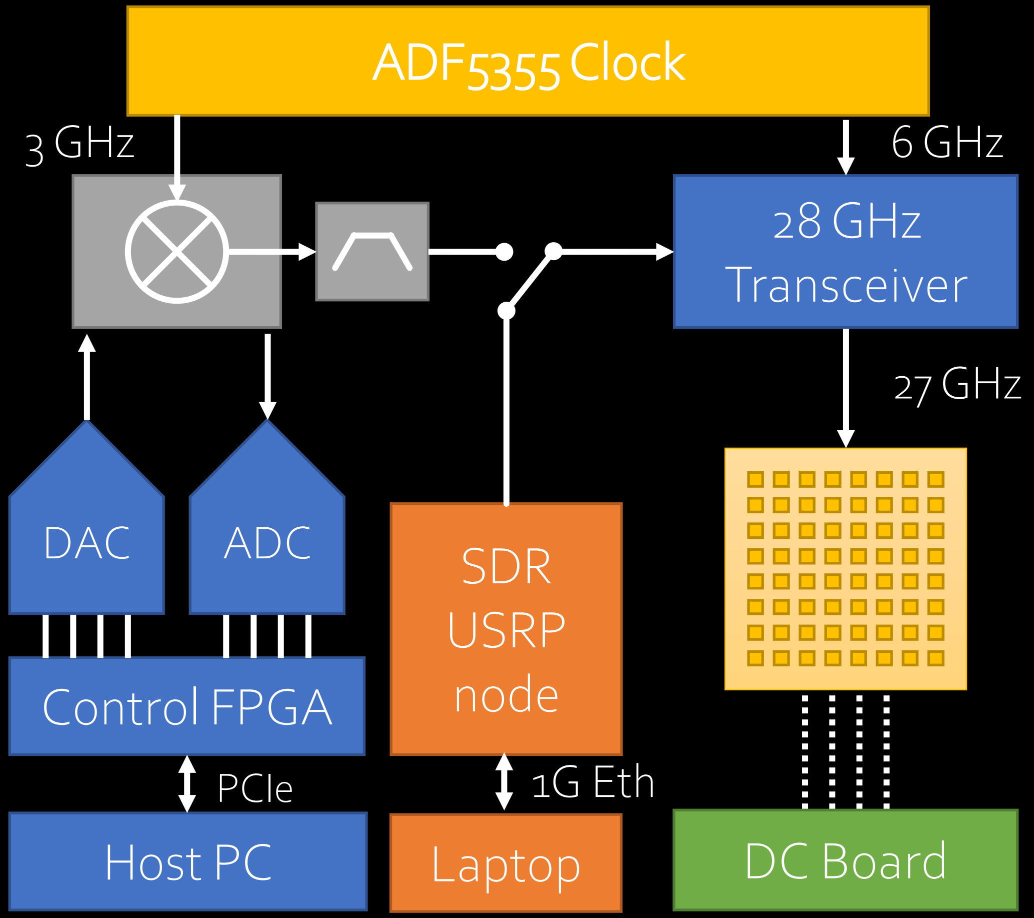
Phased array beamforming

- 64 element dual-polarized phased array
- Fast switching of beam pattern
- Integrated 28 GHz transceiver



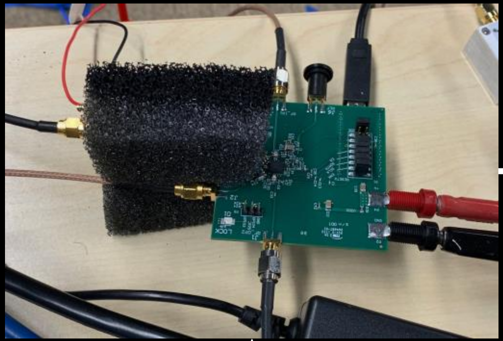
Testbed Design 4

- High baseband processing gNB
- Small Form-factor mobile node
- Phased array beamforming
- **Clock synchronization**
  - Need good phase noise and frequency stability performance
  - Single PLL supplied to IF and RF mixer
  - GPS Disciplined Oscillator synchronized

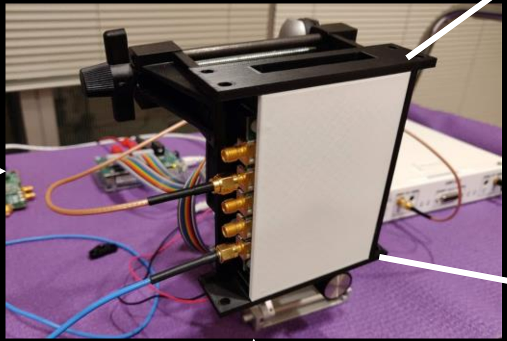


mMobile Implementation

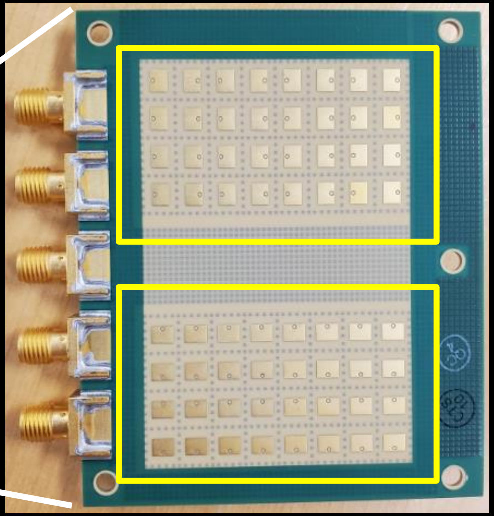
Qorvo IF mixer



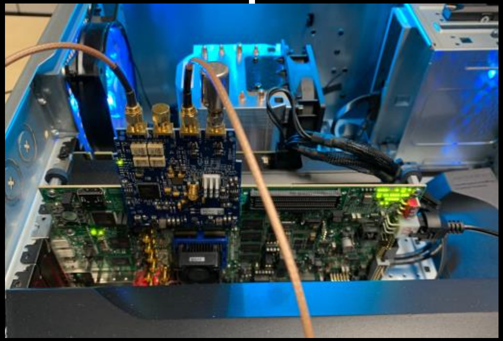
64 element Phased Array



32 element H-channel



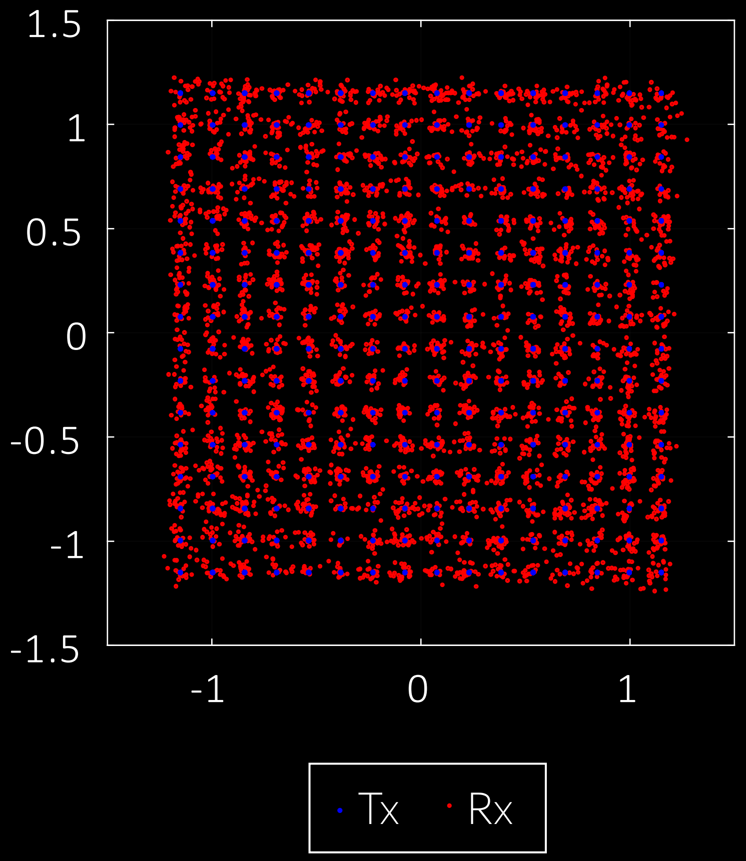
32 element V-channel

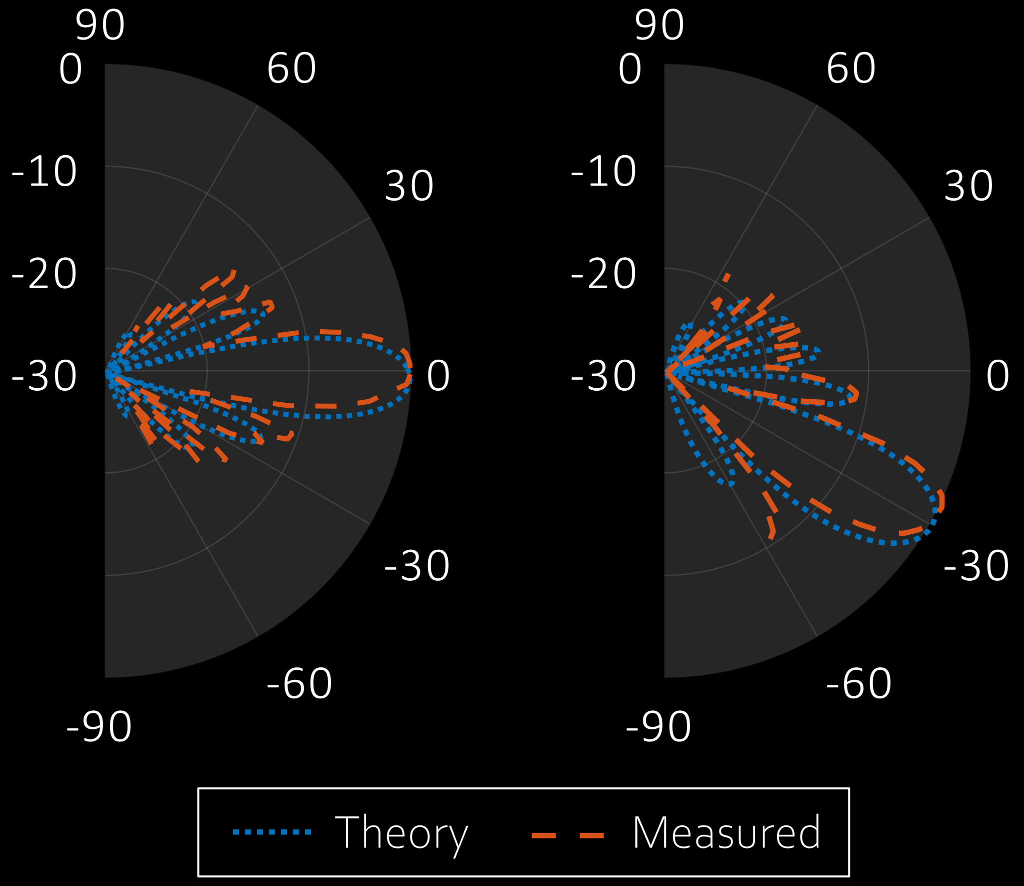


KCU105 FPGA

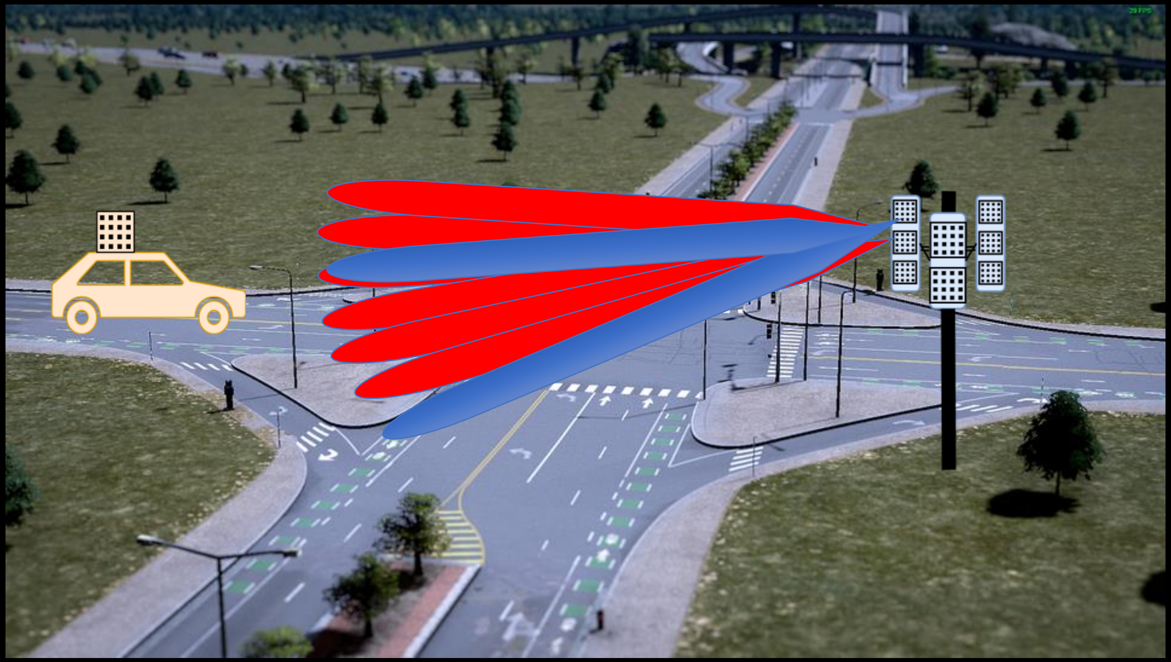
USRP X300 (with CBX120 daughter card)

Testbed performance

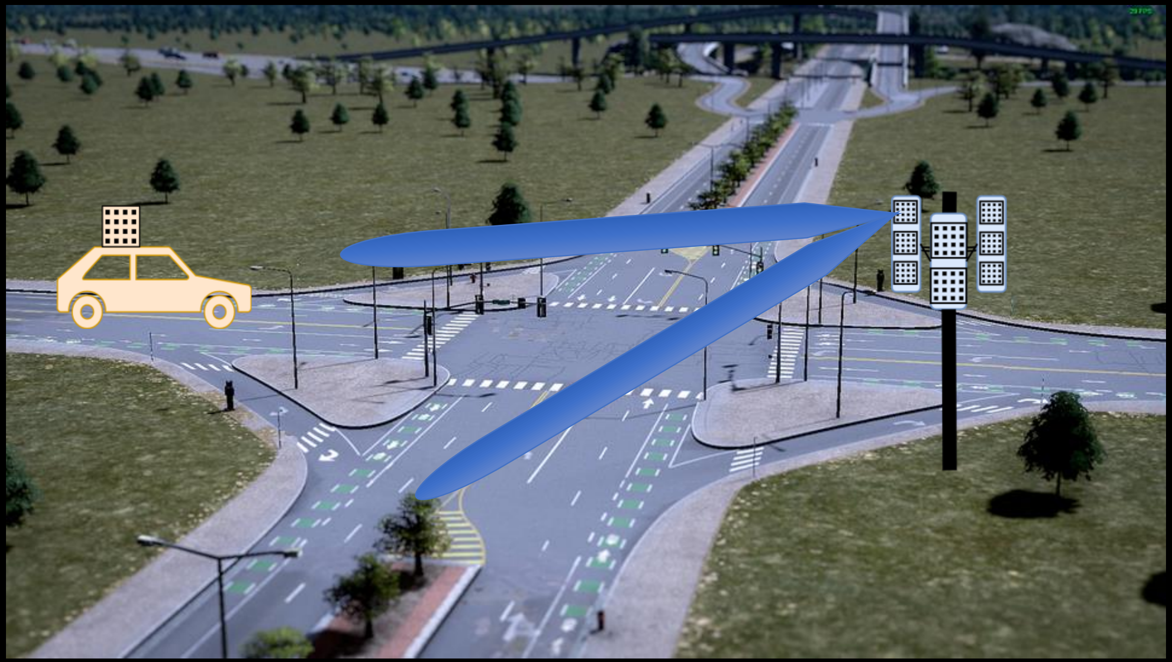




Beam tracking Demonstration



High-overhead Beam
scanning

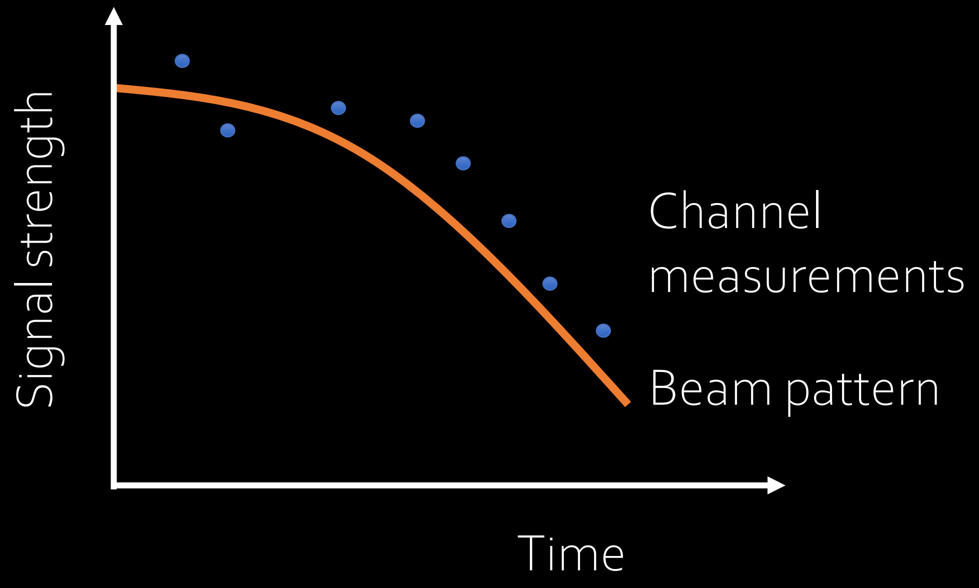


Smart Beam
tracking

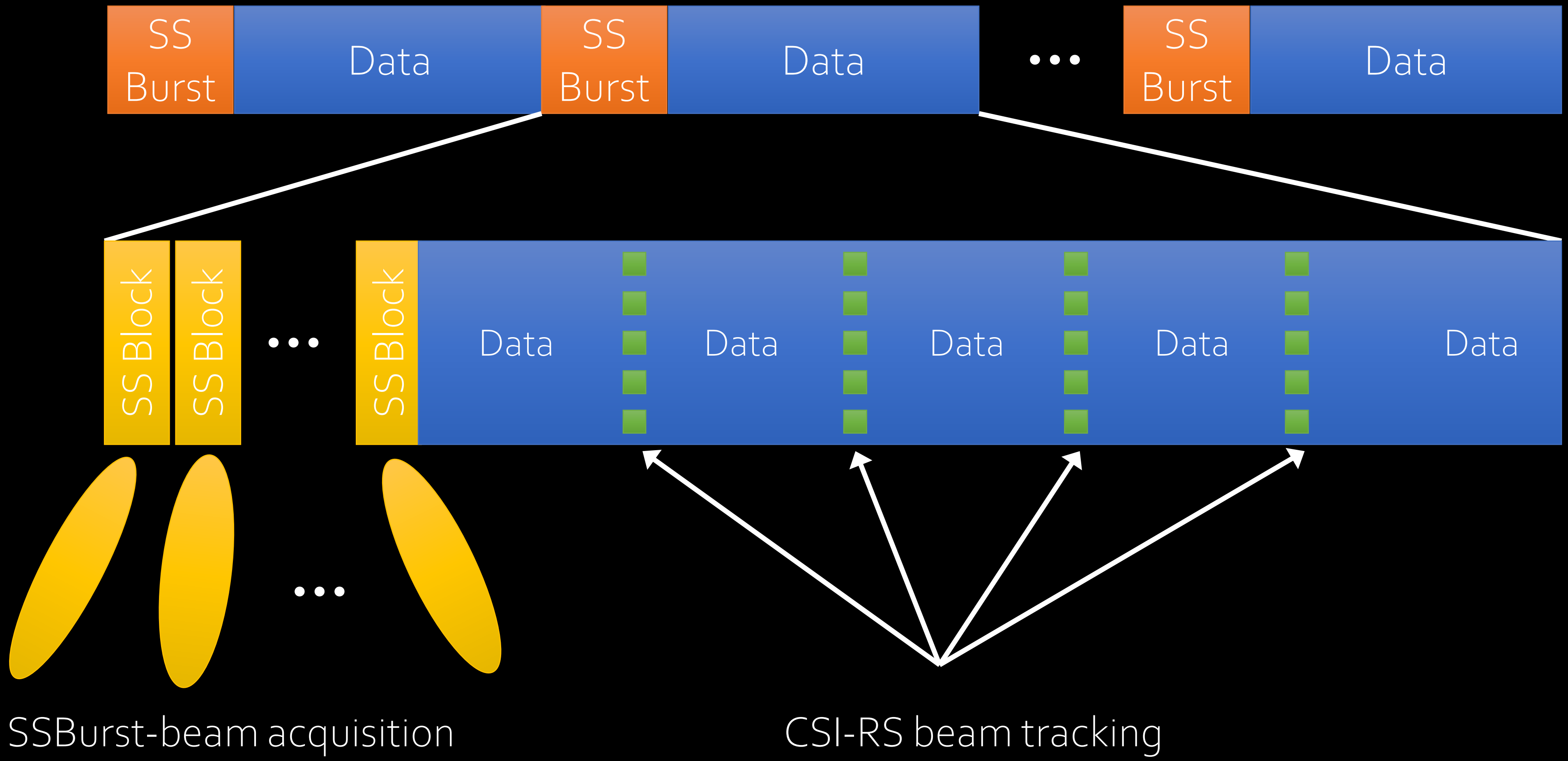
Beam tracking Literature

History-based	Sensor-based	Wide-beam-based	Channel-based
• Select a set of 'good' beams during initial acquisition and reuse them.	• Use location-assisted sensors such as GPS or IMU	• Use a wide beam to reduce misalignment due to user mobility	• Only relays on wireless channel measurements for tracking

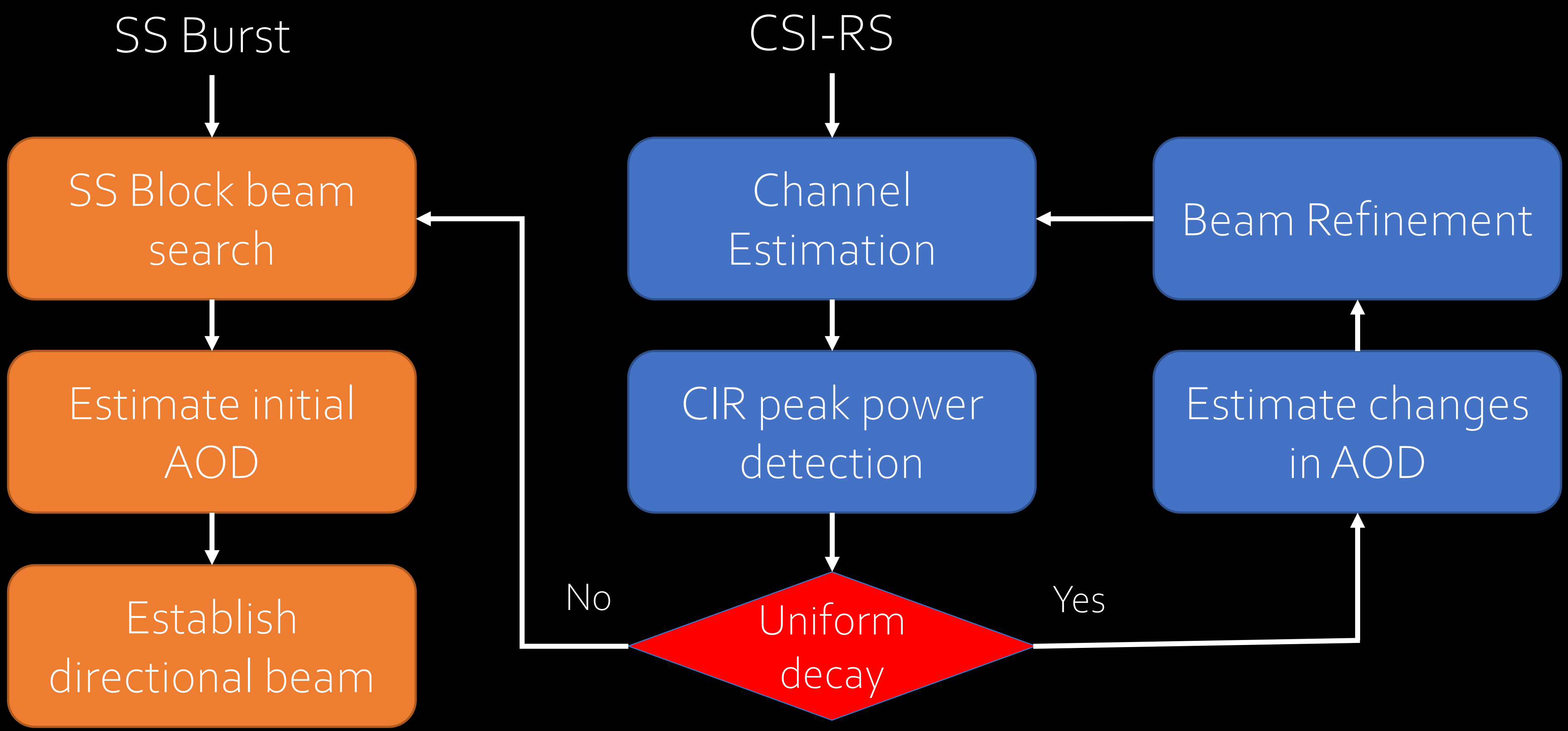
Channel-based Beam Tracking



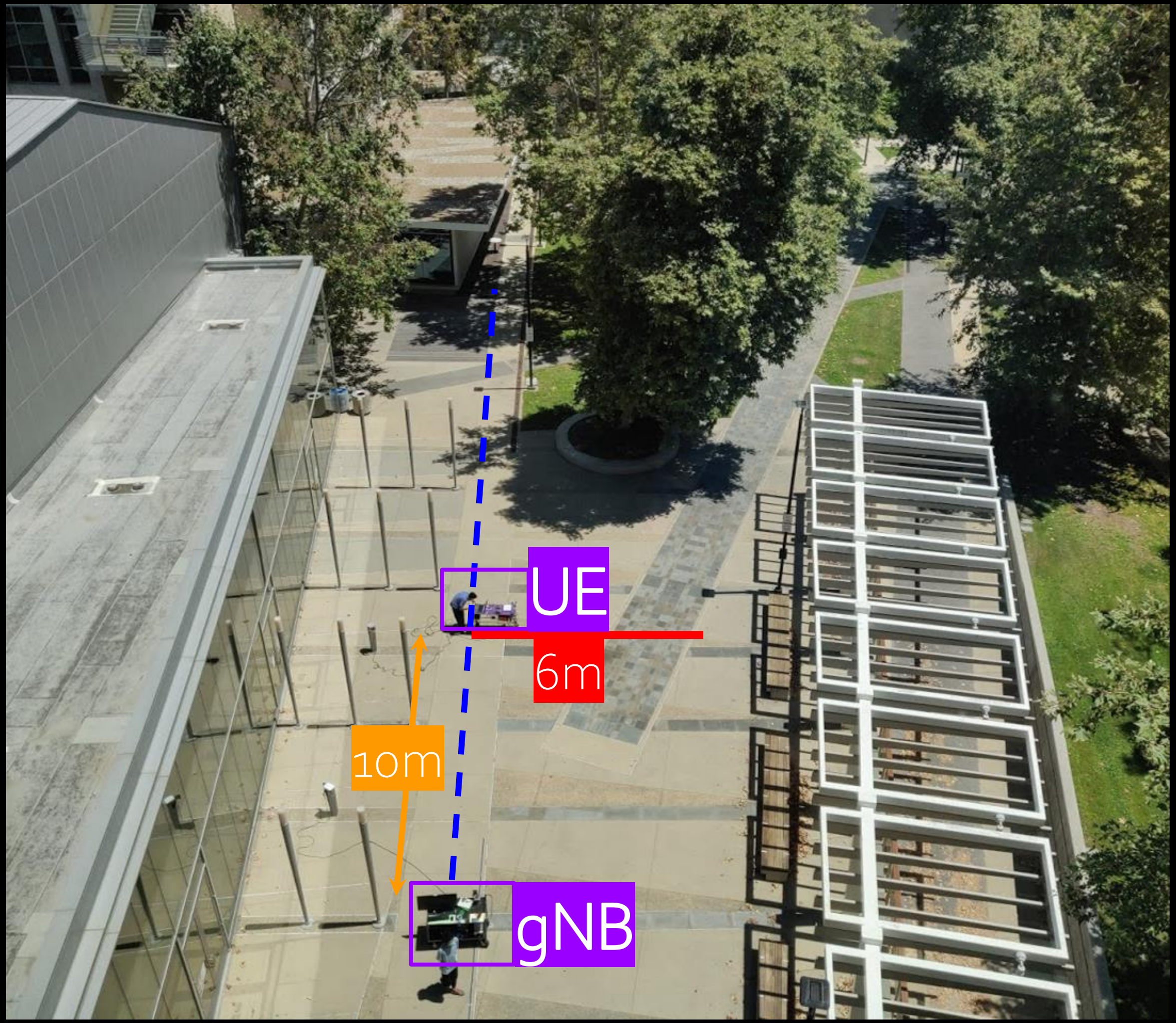
Implementing Beam Tracking with 5G-NR



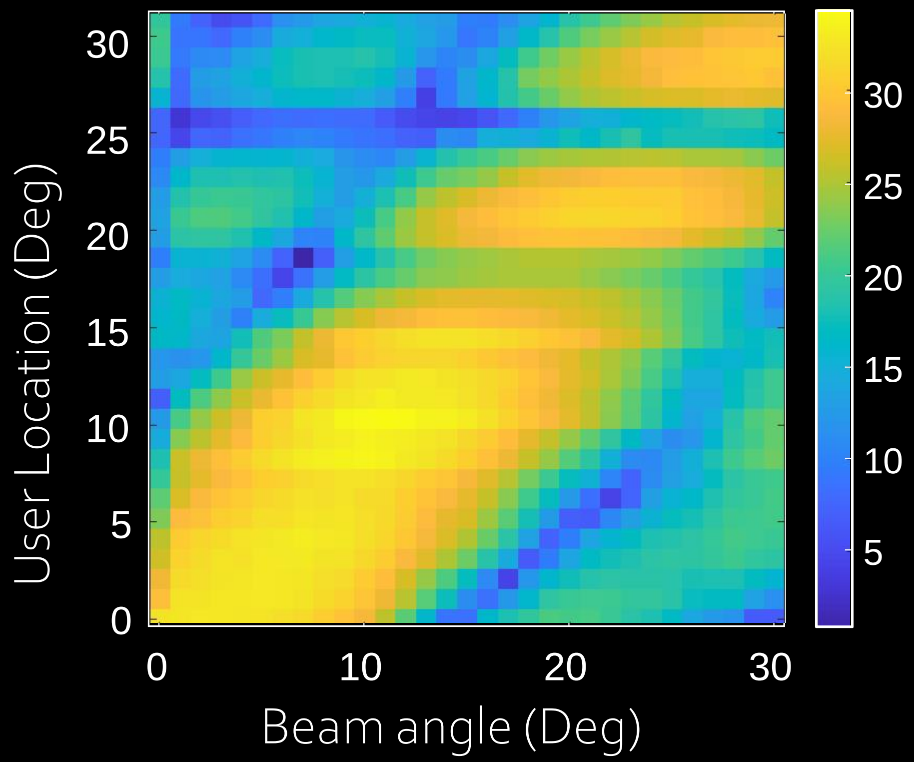
Beam Tracking Overview



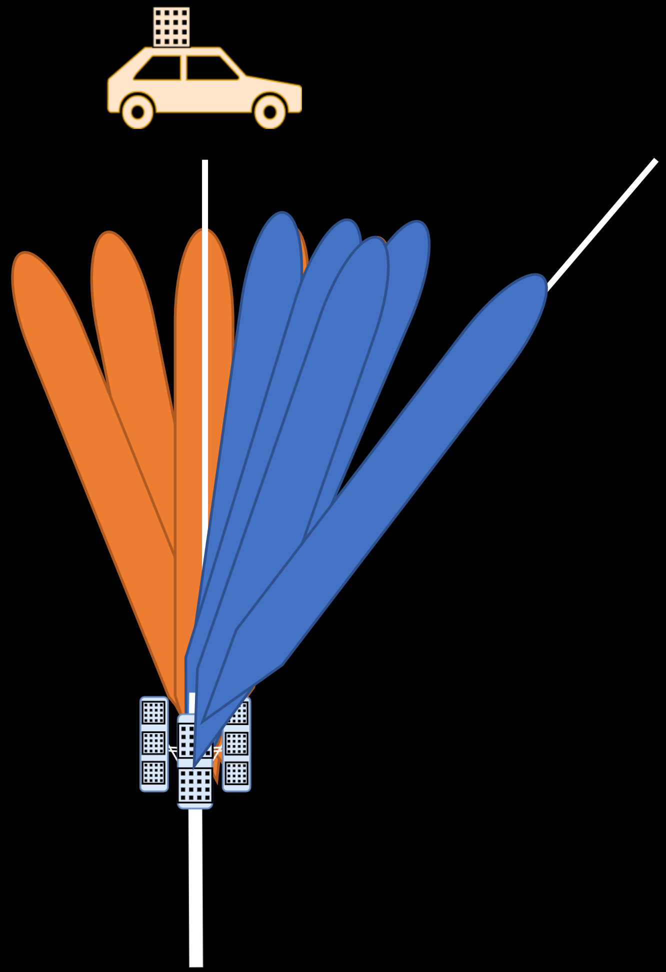
Mobility Dataset

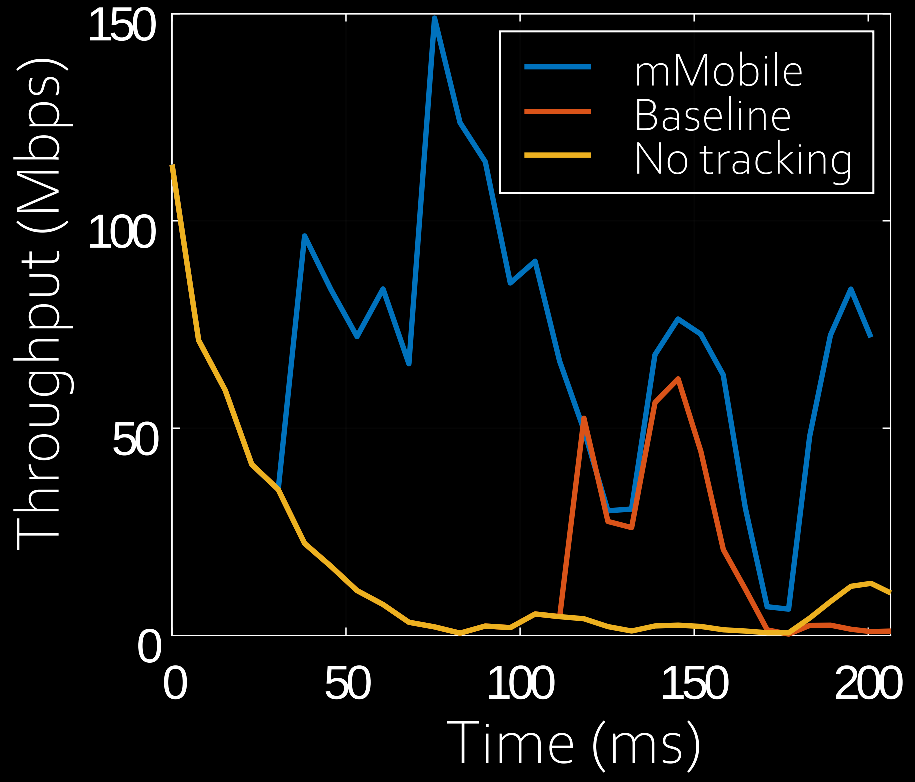


- Channel state information data with 1-degree movement resolution

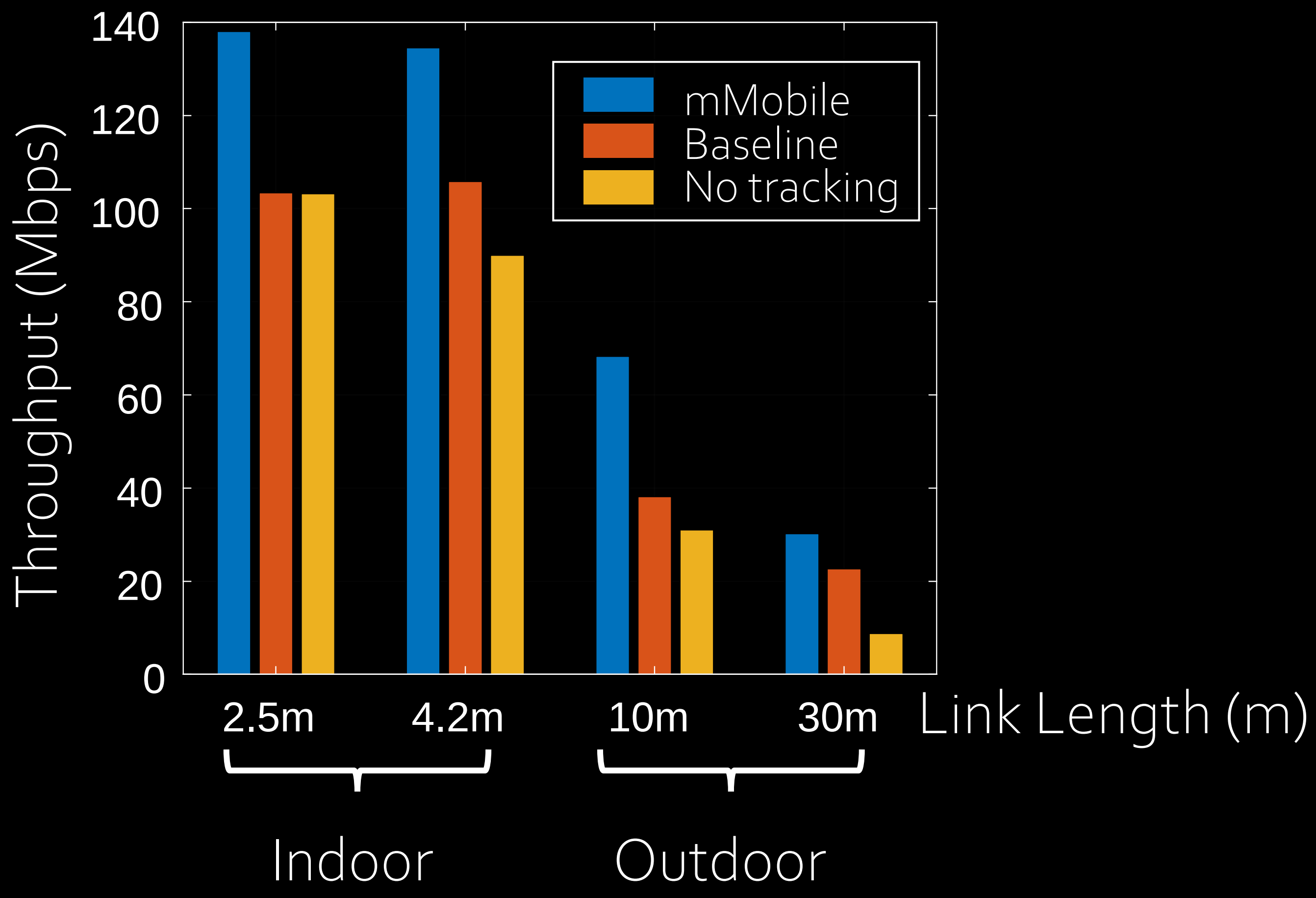


Results: Higher Throughput





Results: Average Throughput Performance



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Dataset and code available online
http://wcsng.ucsd.edu/mmobile/