mmNets Workshop

Mobility Management for TCP in mmWave Networks

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Outline

- Introduction
- TCP in mmWave cellular networks
- Mobility management architectures
- Performance evaluation
  - ns-3 mmWave module
  - Results
- Conclusions

mmWave cellular networks

- Part of 3GPP New Radio
- PHY-layer issues impact the higher layers
  - Small cells
  - Beamforming
  - Blockage

Joint performance analysis of *transport layer* and *mobility* in mmWave cellular networks

TCP in mmWave cellular networks

- TCP – most used transport protocol (*so far..*)
- Loss-based congestion control

→ Performance on wireless networks has been investigated since the 90s

↓

mmWave cellular networks introduce new challenges

Challenges for TCP in mmWave

- Very high bandwidth
  - Issues with congestion window slow ramp-up
- Extended outages
  - Retransmission timeouts and resets
- LOS/NLOS link variability
  - **Bufferbloat**

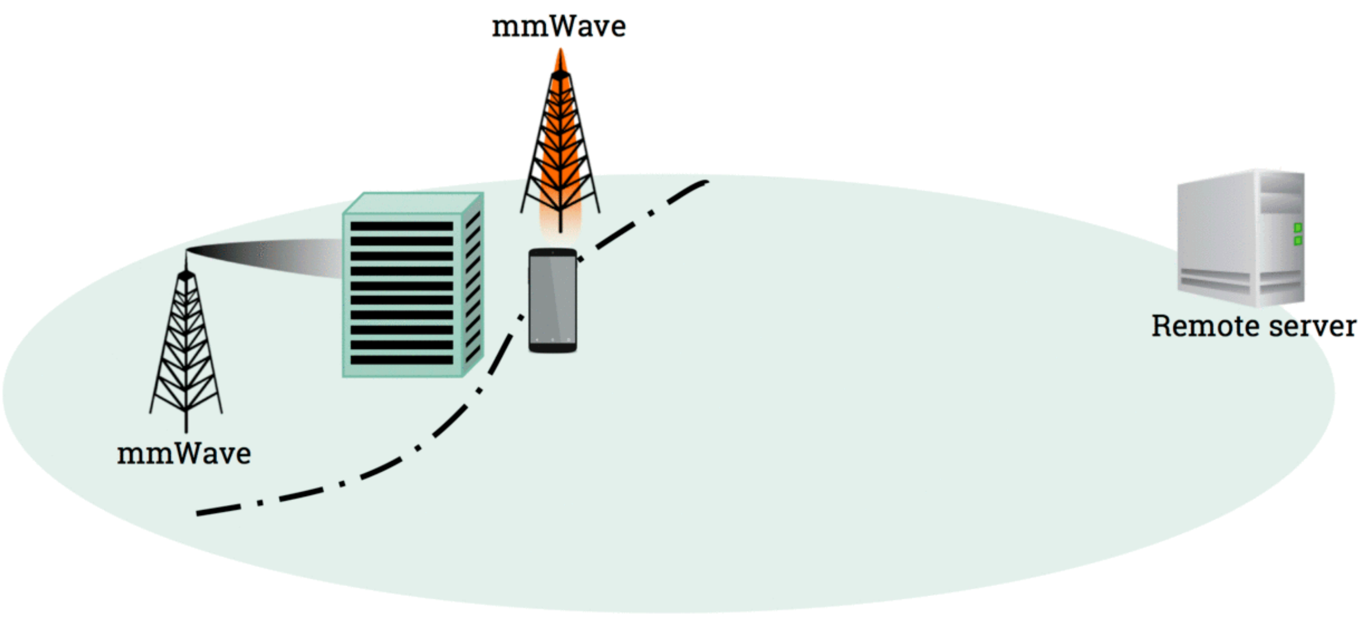
Cross-layer approaches? Multipath TCP?

Rely on smart network management?

Requirements for TCP and mobility

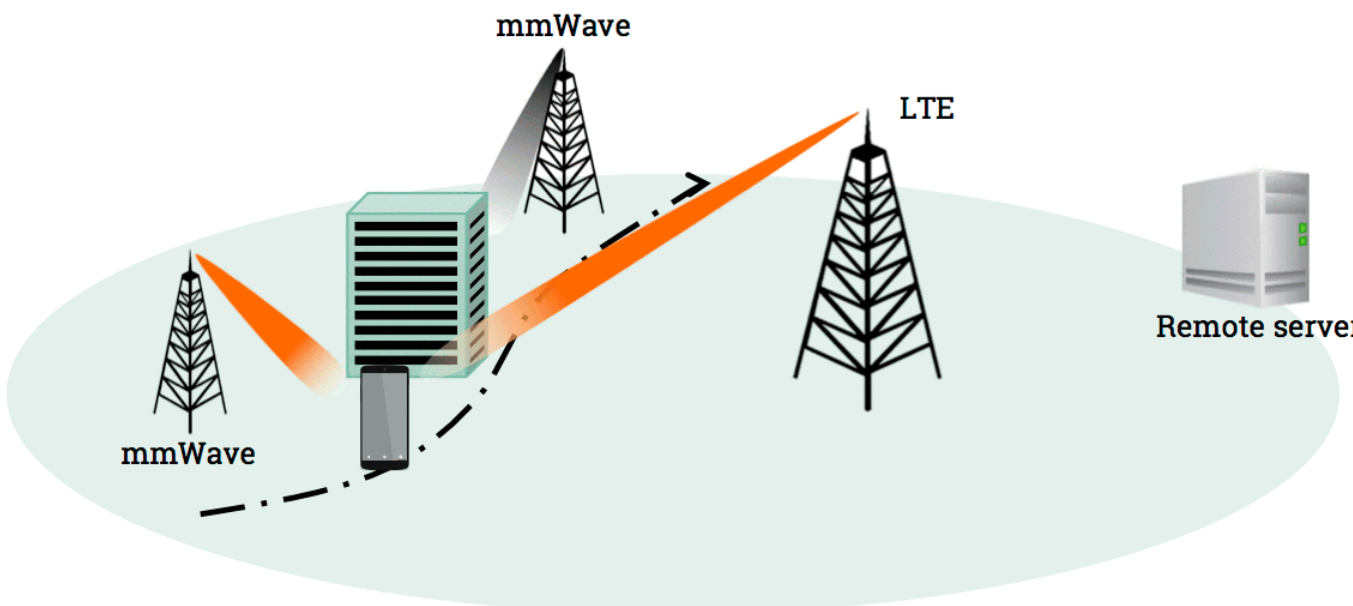
- Prompt reaction to channel updates
- Continuous coverage
  - Availability of multiple beams
- Minimize
  - Packet loss
  - Handover interruption time
- Low end-to-end latency

Mobility management in mmWave



- Stand-alone
  - Single connectivity
  - Traditional Hard Handover (HH)

Mobility management in mmWave



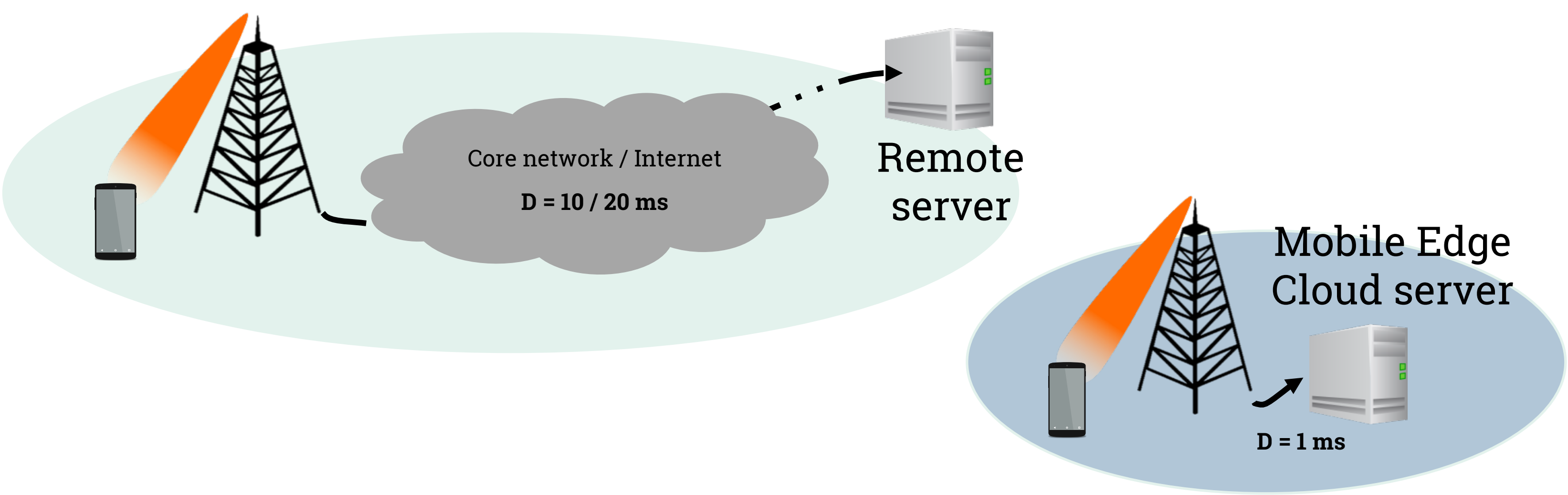
- Dual-connectivity
  - LTE overlay + mmWave base station
  - Fast switch + faster secondary cell handover

M. Polese, M. Giordani, M. Mezzavilla, S. Rangan and M. Zorzi, "Improved Handover Through Dual Connectivity in 5G mmWave Mobile Networks," in IEEE Journal on Selected Areas in Communications, vol. 35, no. 9, pp. 2069-2084, Sept. 2017

Performance evaluation

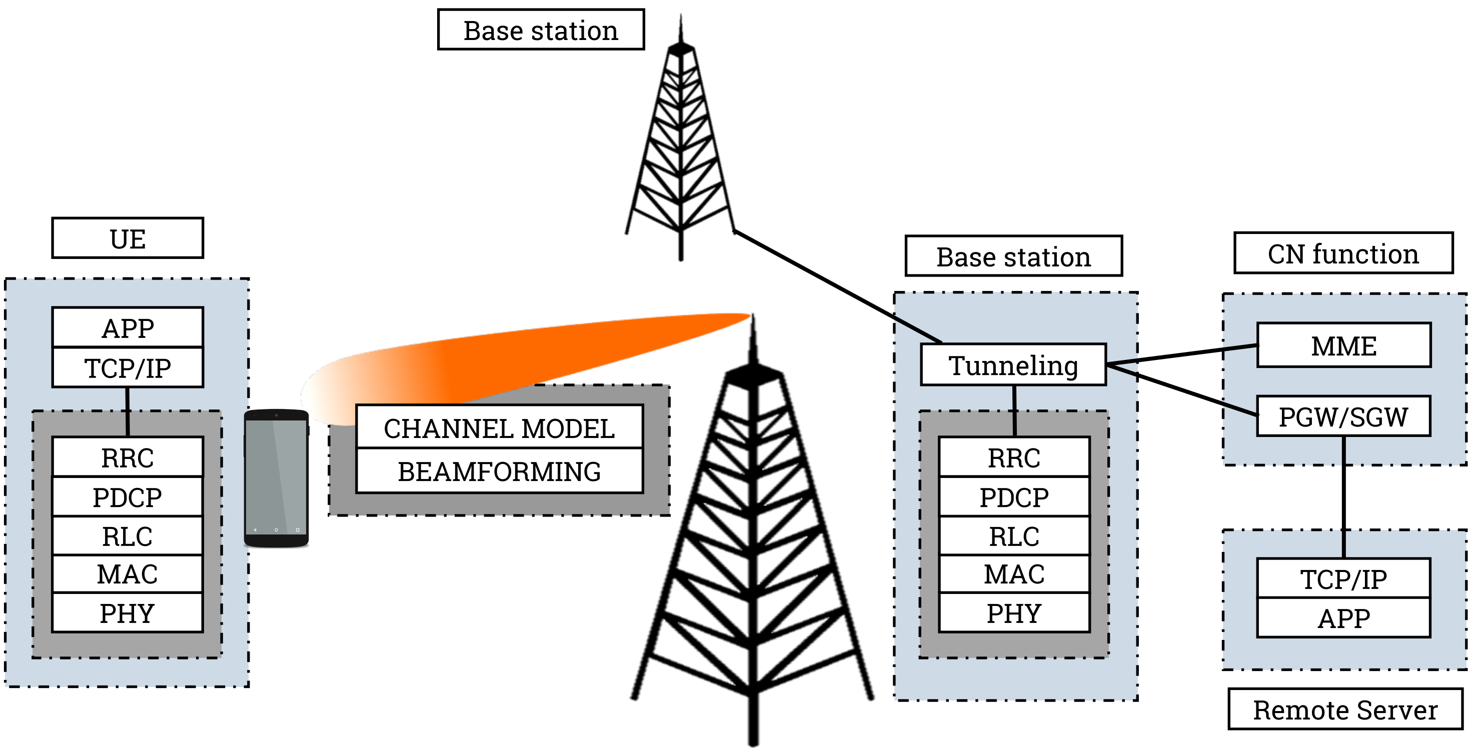
- Comparison of
  - Single base station scenario (no handover)
  - Single Connectivity with Hard Handover
  - Dual Connectivity

- Different server deployment scenarios

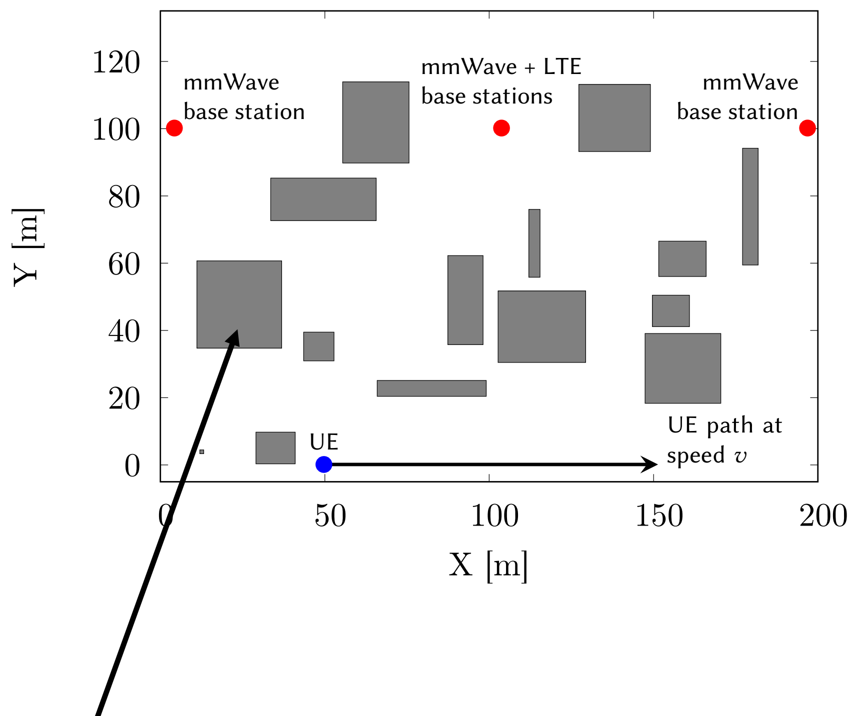


ns-3 mmWave module

- Based on ns-3 + LTE module
- End-to-end performance analysis
- 3GPP mmWave channel implementation



Scenario

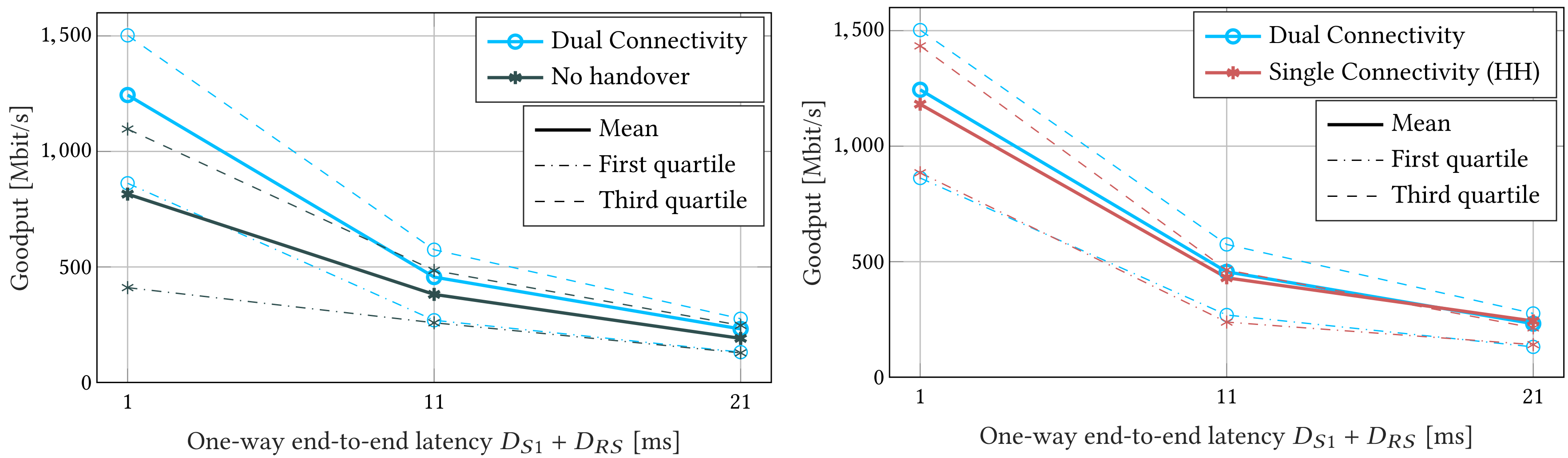


Randomly generated in each run (5 or 15 obstacles)

Parameter	Value
mmWave carrier frequency	28 GHz
mmWave bandwidth	1 GHz
LTE carrier frequency (DL)	2.1 GHz
LTE bandwidth	20 MHz
3GPP Channel Scenario	Urban Micro
mmWave outage threshold Ω	-5 dB
mmWave max PHY rate	3.2 Gbit/s
X2 link latency D_{X2}	1 ms
S1 link latency D_{S1}	1 ms
PGW to remote server latency D_{RS}	[0, 10, 20] ms
RLC buffer size B_{RLC}	1 MB
RLC AM reordering timer	1 ms
S1-MME link latency D_{MME}	10 ms
UE speed v	5 m/s
Number of obstacles N_{obs}	[5, 15]
TCP Maximum Segment Size	1400 byte

Table 1: Simulation parameters

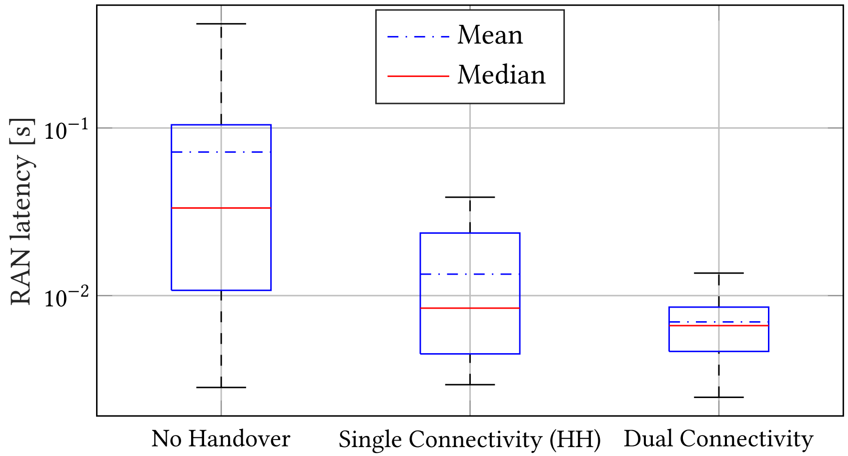
Goodput



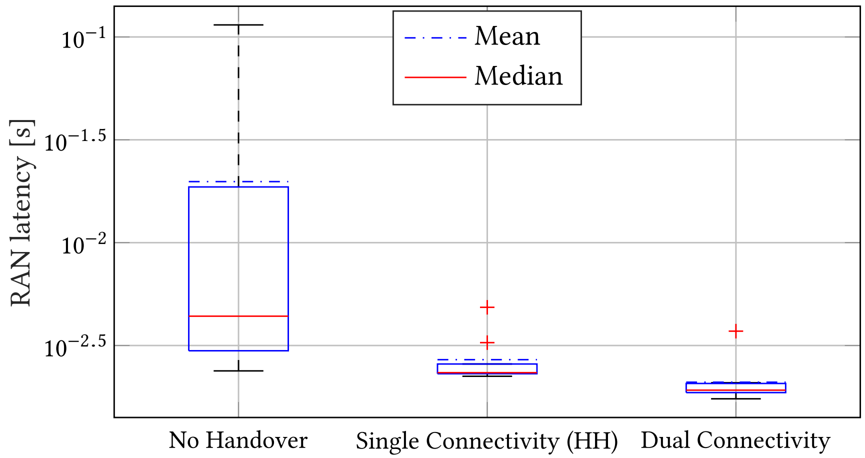
15 obstacles

- Dual and single connectivity -> better than no handover
- Impact of end-to-end latency **(edge server)**

Latency



15 obstacles



5 obstacles

- No handover -> **bufferbloat**
- **Dual connectivity** (fast handovers – no service interruption) -> lowest RAN latency

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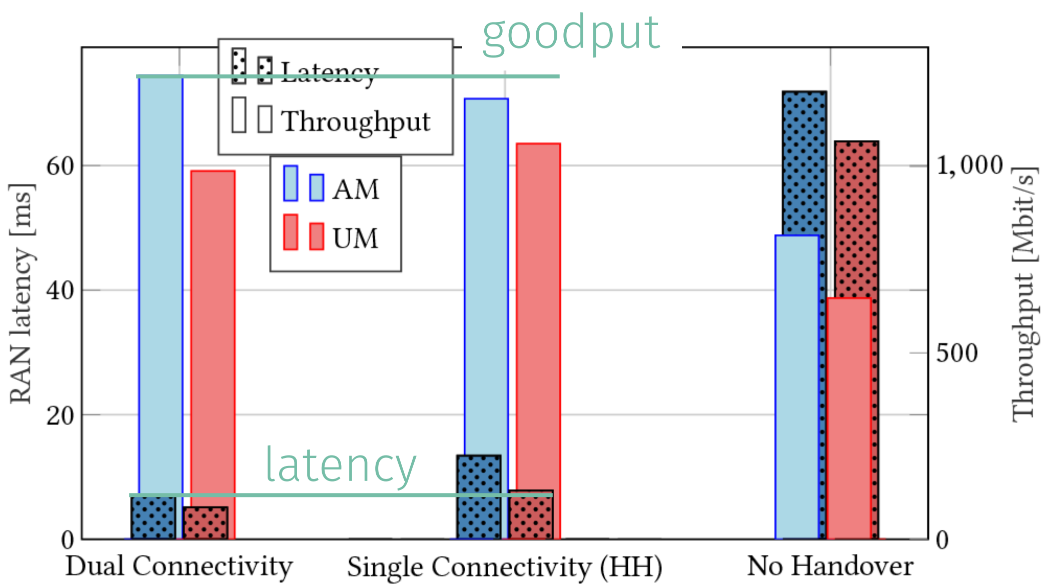
Edge server: RLC AM or UM?



- DC with RLC AM -> highest goodput and smallest latency

Conclusions

- End-to-end evaluation of TCP, mmWave, mobility
- Multiple base stations + fast handover procedures improve both *goodput* and *latency*
  - No bufferbloat!
  - Edge server gives the best goodput performance
  - Dual connectivity allows to reduce latency
- Next steps:
  - TCP proxy -> improve TCP reactiveness
  - Cross-layer approaches
  - Real testbed

Useful resources

- ns-3 mmWave module
  - https://github.com/nyuwireless-unipd/ns3-mmwave (branch new-handover for DC)
- mmWave cellular + vehicular research @ UNIPD
  - http://mmwave.dei.unipd.it
- NYU Wireless
  - http://wireless.engineering.nyu.edu

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