

End-to-End Research Platform for Public Safety Millimeter Wave Communications

PSIAP STAKEHOLDER MEETING, CHICAGO

JULY 10TH 2019





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4G LTE & Public Safety





A GLOBAL INITIATIVE

2004: First proposed by NTT DOCOMO

2007: First live demo by Ericsson

2010: Commercialization

2012: Congress created FirstNet

2013: Rel. 12 includes mission critical technology

Proximity Service

Group call enablers

2017: FirstNet signed a contract with ATT







Beyond conventional cellular..



COW = Cell On Wings

FAA approves Flying Cow drones to restore Puerto Rico cell network

https://www.zdnet.com/article/faa-approves-drones-to-restore-puerto-rico-cell-reception/







INTRODUCTION

Fully intertwined with 5G!





From E. Kalantari et al., "Backhaul-aware robust 3D drone placement in 5G+ wireless networks".





INTRODUCTION

Google trends



VIRELESS

public+safety+5g Search term		public+safety+4g Search term		+	Add comparison			
Worldwide 🔻	6/1/17 - 6/1/19 ▼ All o	categories 💌	Web Search 💌					
Interest over time	0					<u>+</u>	<>	\leq







Why mmWave?





4G spectrum cannot accommodate the increasing mobile broadband demand



		mot decommodate the meredang mobile broadband demand	
		MMWAVE SPECTRUM ———	
3	28		300

Frequency (GHz)

the mmWave spectrum is vast and largely unused!



MMWAVE

4G - Omnidirectional









MMWAVE

4G - Omnidirectional

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5G mmWave - Directional









MMWAVE

5G mmWave - Directional





<u>CHALLENGING RADIO PROPAGATION</u> bouncing off obstacles (walls, trees, humans)





MMWAVE

Initial search











Reconnection











Faster access

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[1] Barati, Hosseini, Mezzavilla, et al "Initial Access in Millimeter Wave Cellular Systems" IEEE TWC 2016.





MMWAVE

More robust





[2] Herranz, Zhang, Mezzavilla et al, "A 3GPP NR Compliant Beam Management Framework to Simulate End-to-End mmWave Networks, ACM MSWiM 2018.













Thrust 1: Measure dynamic directional channels in Public Safety (PS) scenarios.

Our mission

- □ Thrust 2: Prototyping new ultra-low latency MAC and synchronization algorithms likely to be used in the PS links.
- Thrust 3: Provide the first scalable realtime emulation of complex mmWave channels in PS settings.
- Thrust 4: Development and integration of PS specific scenarios in end-to-end mmWave network simulator.



OVERVIEW



Human-Body Blockage







C. Slezak, V. Semkin, S. Andreev, Y. Koucheryavy, S. Rangan, "Empirical Effects of Dynamic Human-Body Blockage in 60 GHz Communications", IEEE Communications Magazine Nov. 2018.



THRUST 1: CHANNEL SOUNDING



Aerial mmWave





G. Bielsa, M. Mezzavilla, J. Widmer, S. Ranga, "Performance Assessment of Off-the-Shelf mmWave Radios for Drone Communications", IEEE WoWMoM 2018.



THRUST 1: CHANNEL SOUNDING





Indoor office

- Measurements were performed in the NYU WIRELESS office space
- TX was raised to ceiling height using a light stand, RX was kept at ground level
- Maximum separation is approx. 8 meters due to cables running between TX and RX
- Blockers walk close to RX, distances varying from 20 to 100 cm
- Various mechanical rotations done at TX and RX (situation dependent)







Prototyping effort

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THRUST 2: SOFTWARE DEFINED RADIO

Emulated 3GPP channels









THRUST 3: CHANNEL EMULATION

End-to-end mmWave ns-3



Open source

- □ 3GPP channel models / scenarios
- Mobility (including vehicular / hi-speed transportation / drones)
- Customizable 3GPP NR frame structures, frequency bands, OFDM numerologies, schedulers
- 3GPP NR beam management
- **E2E** performance evaluation including:
- □ TCP/IP, S2/X1, PDCP, RLC, MAC/PHY metrics
- □ RRC signaling, RLC buffers, HARQ procedures
- Coexistence with other radio technologies (e.g., IEEE 802.11, LTE)
- Dual connectivity, carrier aggregation, IAB, ..



Mezzavilla et al , "End-to-end simulation of 5G mmWave networks", IEEE COMST 2018



Aerial mmWave control





W. Xia, M. Polese, M. Mezzavilla, G. Loianno, S. Rangan, M. Zorzi, "Millimeter Wave Remote UAV Control and Communications for Public Safety Scenarios", IEEE SECON 2019.



THRUST 4: END-TO-END NETWORK SIMULATION



Robotic mmWave control





Huaijiang Zhu, Manali Sharma, Marco Mezzavilla, Sundeep Rangan and Ludovic Righetti, "Reliably Balancing Legged Robots with Locally Assisted Remote Control via Edge Computing", CAFR 2019.



THRUST 4: END-TO-END NETWORK SIMULATION



Integrated Access and Backahaul

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M. Polese, M. Giordani, A. Roy, D. Castor, M. Zorzi, "Distributed Path Selection Strategies for Integrated Access and Backhaul at mmWaves", IEEE GLOBECOM, 2018.
M. Polese, M. Giordani, A. Roy, S. Goyal, D. Castor, M. Zorzi, "End-to-End Simulation of Integrated Access and Backhaul at mmWaves", IEEE CAMAD, 2018.
M. Polese, M. Giordani, T. Zugno, A. Roy, S. Goyal, D. Castor, M. Zorzi, "Integrated Access and Backhaul in 5G mmWave Networks: Potentials and Challenges", submitted to IEEE Communications Magazine



THRUST 4: END-TO-END NETWORK SIMULATION

Motivation: FR 5 FR 8 mmWave BS 2+ .FR 3

- reference scenarios implemented in ns-3
- □ Key contribution:
 - **□** Evaluation of the performance of mmWave communications in three realistic PSC scenarios

Provide to the community 800 mmWave BS 4 FR 7

60

Y [m]





Chemical plant explosion scenario with remote wheelbarrow robot operations & HQ video stream

M. Polese, T. Zugno, M. Zorzi, "Implementation of Reference Public Safety Scenarios in ns-3", WNS3 2019





THRUST 4: END-TO-END NETWORK SIMULATION

Simulated PSC scenarios





M. Rebato, M. Polese, and M. Zorzi, "Multi-Sector and Multi-Panel Performance in 5G mmWave Cellular Networks", IEEE Globecom 2018.

Need to accurately model directional propagation in realistic deployment scenario

- □ Key contribution:
 - Implementation of multiple sectors at the base stations and multiple panels at the UE
 - □ End-to-end performance evaluation



Multi-Sector / Multi-Panel





Latency

andom walk UE mobility





- We have conducted several mmWave measurements (aerial, blockage, outdoor), and <u>NEXT STEPS</u>: plan to run indoor-office p2p measurements
- □ We have spun out a fully-digital mmWave transceiver board for **prototyping**, and <u>NEXT STEPS</u>: plan to integrate a network stack on top of it
- □ We have integrated 3GPP channel models in the **emulator**, and <u>NEXT STEPS</u>: plan to connect it to our prototyping board
- □ We have implemented a number of additional features to our ns-3 mmWave **simulator**, and <u>NEXT STEPS</u>: plan to improve the channel abstraction and add more PSC-related options







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Come back for the **Next Session**3:30 PM