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signet.dei.unipd.it

End-to-end full-stack evaluation

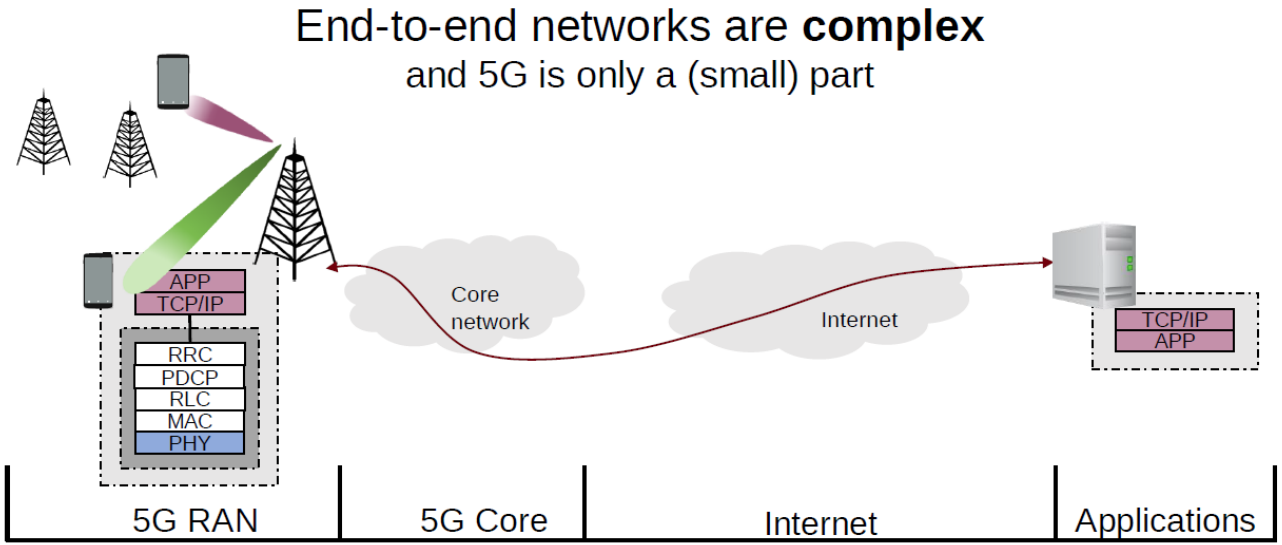
Panel presentation

Michele Zorzi, University of Padova
zorzi@dei.unipd.it
mmwave.dei.unipd.it

Our Approach

- End-to-End evaluation of mmWave systems
  - Protocols need to be tested in realistic conditions
  - Open-source 5G NR full stack simulator based on ns-3
- Channel models are key
  - Both stochastic and ray-tracing models are needed
- Key scenarios and applications for mmWaves
  - Vehicular (sidelink) communications (V2V)
  - Non-terrestrial networks (NTNs)
  - Integrated Access and Backhaul (IAB)

End-to-end simulation

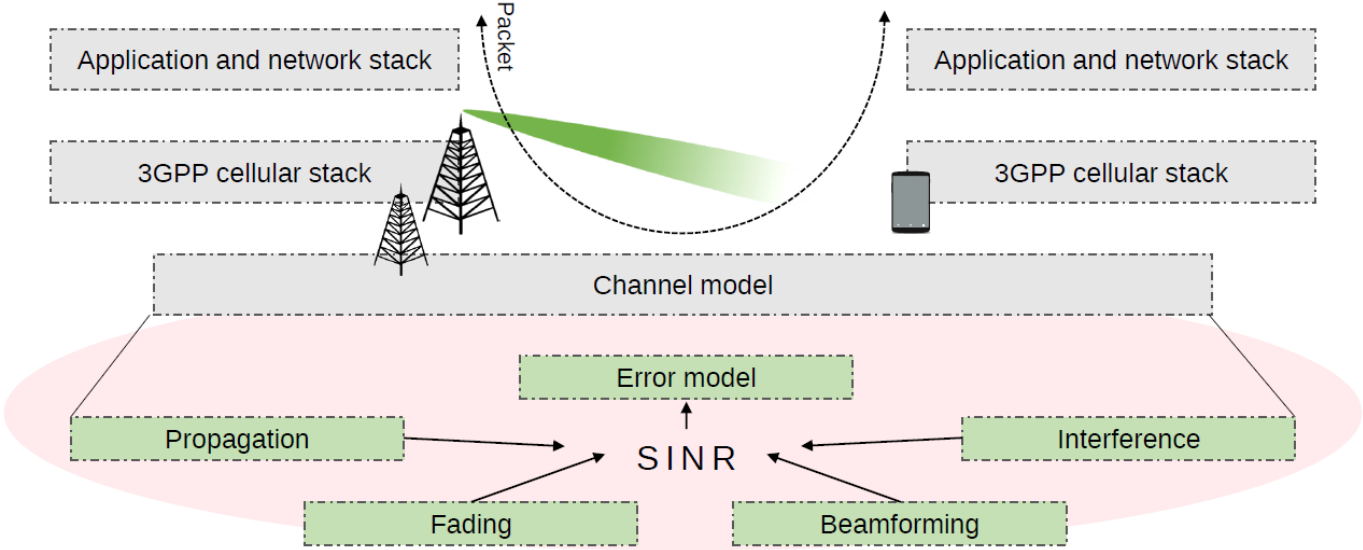


The user quality of experience depends on the interaction of these elements

M. Mezzavilla, M. Zhang, M. Polese, R. Ford, S. Dutta, S. Rangan, M. Zorzi, "End-to-End Simulation of 5G mmWave Networks", in IEEE Communications Surveys & Tutorials, vol. 20, no. 3, pp. 2237-2263, Third quarter 2018.

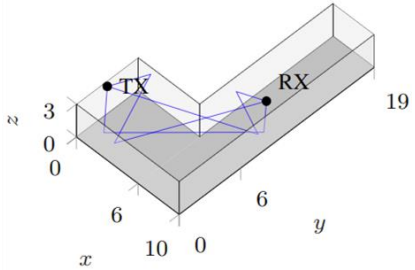
ns-3 simulator

- Packet-level simulator
- Open source, very advanced wireless and TCP/IP models

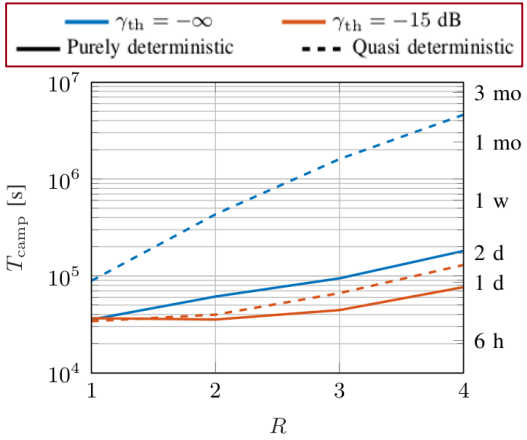


Channel Modeling

- Accurate channel models needed for protocol testing



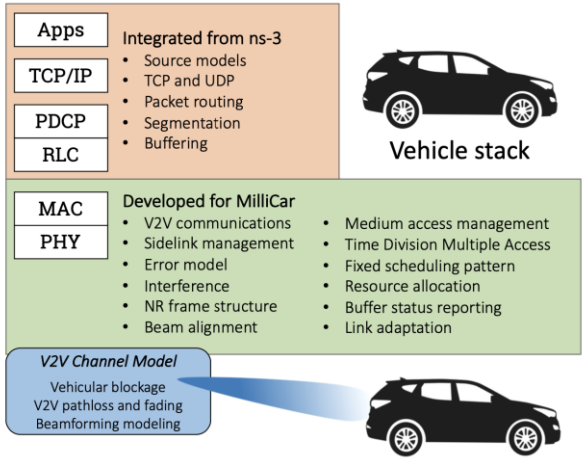
- Stochastic channels
  - ✓ Useful for generic evaluations
  - ✓ Quick
  - ✗ Not realistic
- Ray-tracing[1]
  - ✓ Realistic
  - ✓ Evaluation of target scenario
  - ✗ Slow → Need optimization!



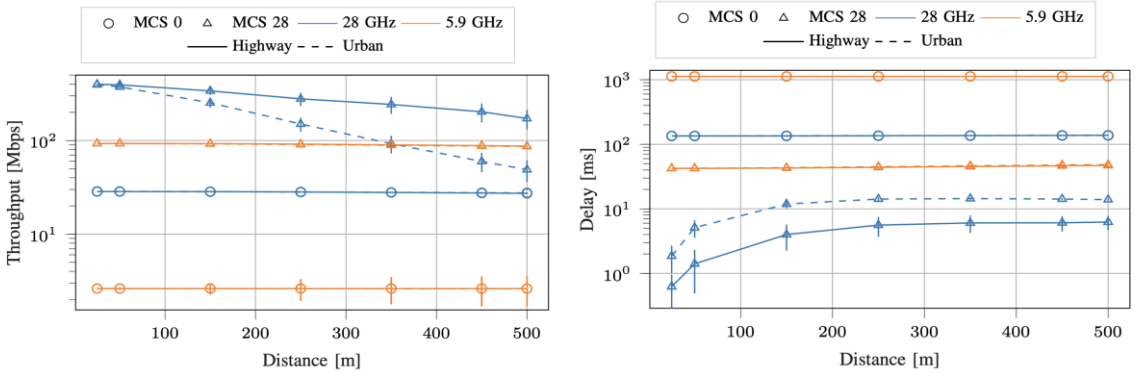
[1] Available open-source implementation: https://github.com/wigig-tools/qd-realization
M. Lecci, P. Testolina, M. Polese, M. Giordani, M. Zorzi, "Accuracy vs. Complexity for mmWave Ray-Tracing: A Full Stack Perspective.' submitted to IEEE Trans. Wireless Comm., 2020, arxiv.org/abs/2007.07125

Key Scenarios – V2V

- We developed the first 3GPP-like ns-3 module to simulate **sidelink** V2V operations at mmWaves (`https://github.com/signetlabdei/millicar`).



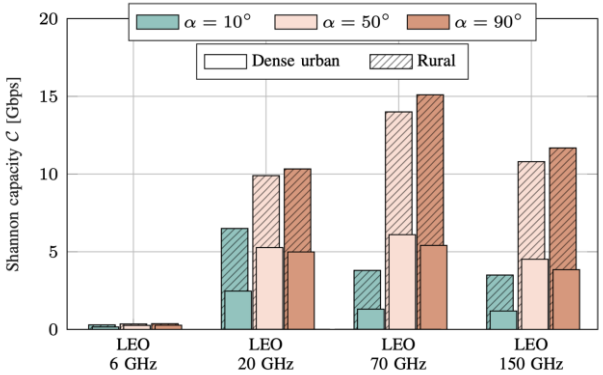
mmWaves can support orders of magnitude **higher throughput** and **lower latency** (a critical requirement in V2V applications).



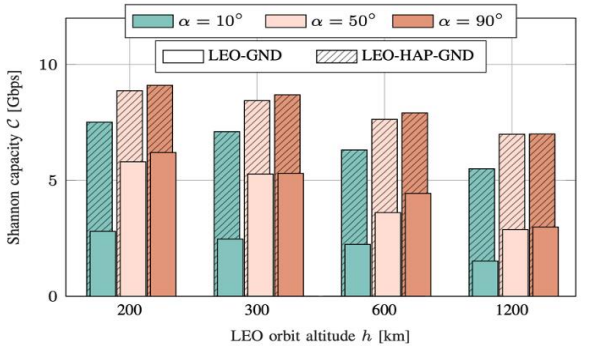
M. Drago, T. Zugno, M. Polese, M. Giordani, M. Zorzi, "MilliCar - An ns-3 Module for mmWave NR V2X Networks", in ACM WNS3, June 2020.

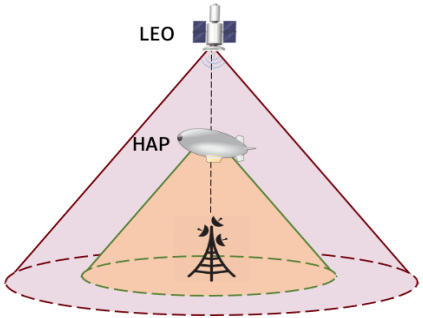
Key Scenarios – NTNs

- Today, mmWaves on satellites support services like home delivery, meteorology, television broadcasting, remote sensing, and navigation.
- mmWaves can be used to support **high-capacity communications**.



The potential of **multi-layer hybrid integration**



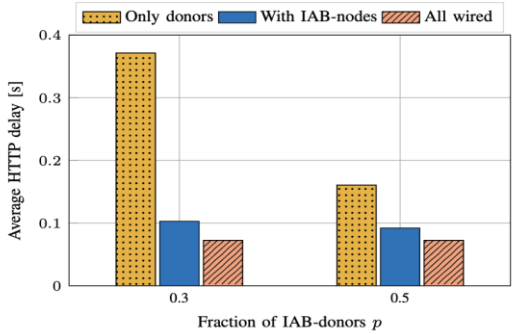


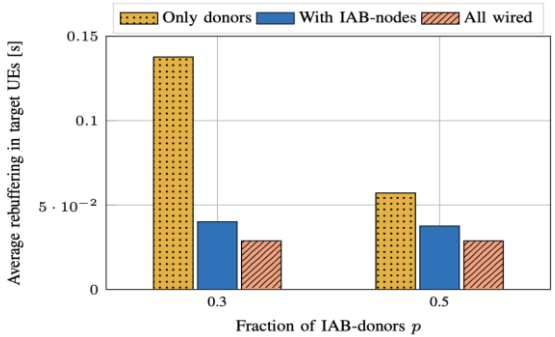
M. Giordani, M. Zorzi, "Non-Terrestrial Networks in the 6G Era: Challenges and Opportunities," IEEE Network, March 2021.

Key Scenarios – IAB

- LTE (sub-6 GHz): rigid partitioning of the access and backhaul resources.
- 5G/6G (mmWaves): the huge available capacity can be exploited for self-backhauling solutions, to provide both access and backhaul.
- We developed the first 3GPP-like ns-3 module to simulate IAB operations at mmWaves (https://github.com/signetlabdei/ns3-mmwave-iab).

IAB decreases the deployment and management costs with sustainable performance degradation.





M. Polese et al., “Integrated Access and Backhaul in 5G mmWave Networks: Potential and Challenges,” IEEE Commun. Mag., March 2020.