DIRECTIVE MMWAVE CELLULAR NETWORKS: SCHEDULING, COEXISTENCE, NETWORK SLICING

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Motivation

DIRECTIVE MILLIMETERWAVE (mmWave) communication is one of the main novel technologies expected to be launched with 5G. It provides unprecedented large new spectrum and the possibility of wireless backhaul.

However, there are several **challenges** to be solved for directive mmWave to become a reality:

I. The ***multi-hop*** mmWave architecture, which effective scheduling, routing, congestion control and QoS differenciation of flows.

II. The frequent ***blockages*** in mmWave, which make heterogeneous mmWave/microWave networks worth to study.

III. The ***dense number of mmWave Base Stations*** per Mobile Operator (MO). Instead of each MO having its own infrastructure (high CAPEX,OPEX), Virtual Network Slices of infrastructure per MO need to be studied.

Thesis Objectives

I.A. Link *Scheduling*, Routing and Congestion Control algorithms for mmWave multi-hop cellular networks.

I.B. Proportional Flow *Delay Differentiation* algorithms for mmWave multi-hop cellular networks.

II. *Coexistence* between microWave and mmWave communications in an Heterogeneous architecture.

III. Multi-Operator Infrastructure *Network Slicing* with different levels of virtualization in mmWave cellular.

Research Plan

Theoretical approach in each objective:

I. *State of the Art* of related contributions.

II. Propose a *new scenario/problem* to study/solve. E.g., Link Scheduling, User Association.

III. Elaborate the *System Model*. Use mmWave channel models in literature.

IV. Develop a *novel algorithm*.

V. *Theoretical performance* of proposed algorithms. Stochastic Lyupanov Optimization, Matching Theory.

VI. Numerical *Simulations*.

Next Year Planning

Expect to finish current workload:

I. Publishing journal [2] in an IEEE Transactions or Conference.

II. Finishing and submiting ongoing work to an IEEE Transactions or Conference [4].

III. Writing thesis document and defense.

Results & Discussions

Journal I (*Published [1]*). We propose a ***fast*** and Throughput-Optimal link scheduling and routing algorithm to ***exploit*** the multi-hop mmWave cellular ***capacity region***. Utility-Optimality is also included via a Dual Congestion Controller at the sources. Several ***interference models*** (IF, AI and WI) are proposed for mmWave networks.

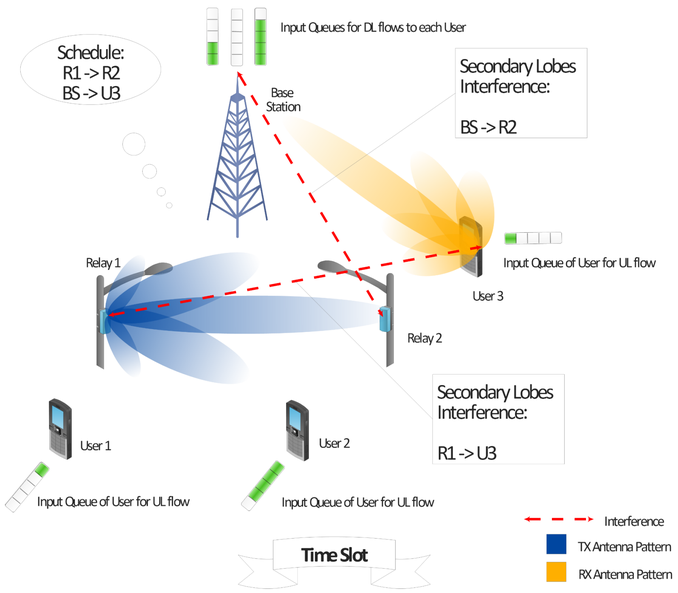
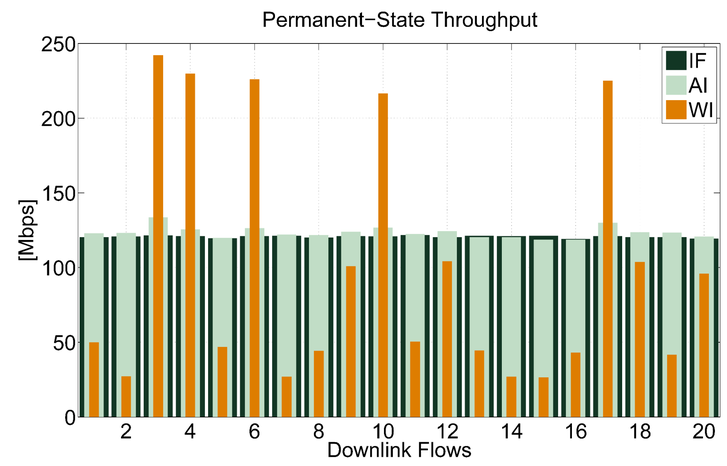
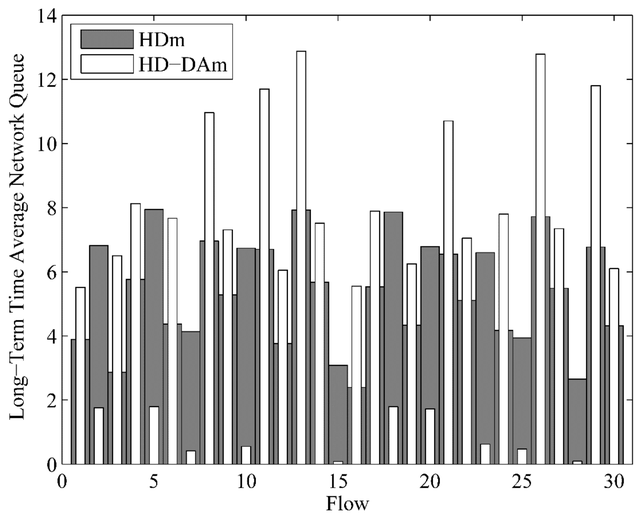


Illustration of a directional multi-hop mmWave celular network



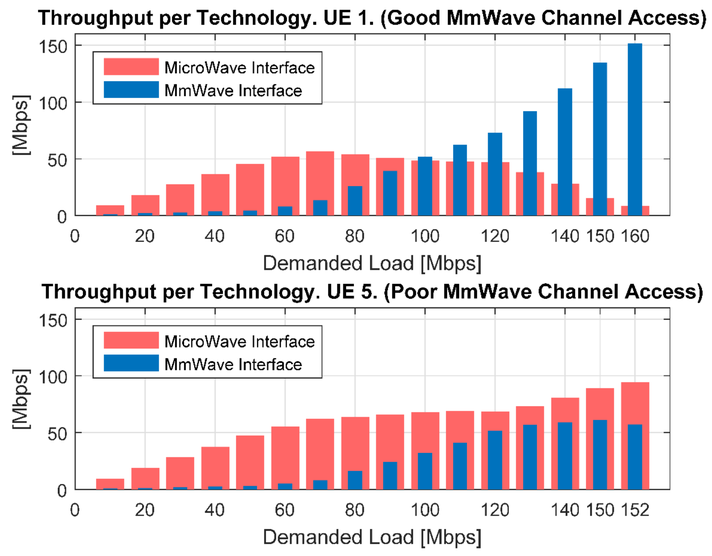
Throughput performance results with three interference models proposed: Actual Interference (AI), Interference-Free (IF) and Worst-Interference (WI)

Journal II (*Submitted [2]*). In this work we define a class of Delay-Aware link scheduling and routing policies, termed as DA. We propose an optimization framework for proportional ***flow delay differentiation*** in multi-hop networks. We define BP-DA, BPE-DA and HD-DA algorithms, which are Throughput-Optimal. In addition, HD-DA minimizes Average Network Delay within the class of DA policies. Resulting policies are suitable for mmWave networks.



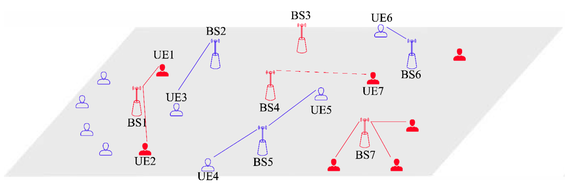
Delay flow differentiation with the proposed HD-DAm policy in a rectangular-grid topology

Conference I (*Accepted [3]*). In this paper we propose an heterogeneous architecture for 5G systems, where ***mmWave*** and ***microWave*** network-slices ***coexist*** and mutually back each other to enhance network capacity, delay, inter-arrival times and reliability. In addition, traffic splitting efficiently balances the load among mmWave and microWave interfaces.

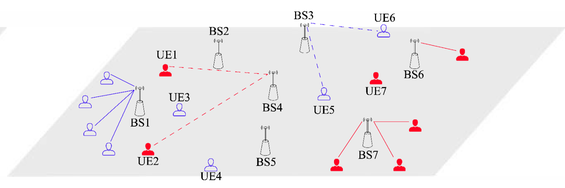


Load balancing among mmWave and microWave network slices. Comparison between a UE with good mmWave channel and a UE with poor mmWave channel

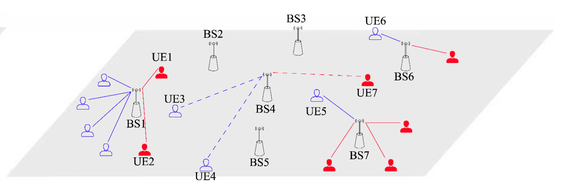
Journal III (*Ongoing [4]*). Increasing bandwidth in mmWave may be useless due to blockage. In this paper we study the scenario where multiple Virtual Service Providers (VSPs) share a common mmWave infrastructure creating a ***Network Infrastructure Slice per VSP***. We develop distributed matching-based algorithms to solve the proposed problem, finding ***stable*** and ***optimal*** network slices. Rigorous proofs are presented. Results show the impressive advantages of network slicing for VSPs in mmWave.



Fixed Infrastructure per VSP



Network Infrastructure Slice with LoV = 1



Network Infrastructure Slice with LoV = 2

References

1. J. García-Rois, F. Gómez-Cuba, F. J. González-Castaño, J. C. Burguillo-Rial, M. R. Akdeniz, S. Rangan and B. Lorenzo, "On the Analysis of Scheduling in Dynamic Duplex Multi-Hop mmWave Cellular Systems", *IEEE Trans. Wireless Communications*, June 2015.
2. J. García-Rois, F. J. González-Castaño, B. Lorenzo and J. C. Burguillo-Rial, "Delay-Aware Optimization Framework for Proportional Flow Delay Differentiation in Multi-Hop Wireless Networks", *submitted to IEEE Trans. on Communications*, 2017.
3. J. García-Rois, B. Lorenzo, F. J. González-Castaño and J. C. Burguillo-Rial, "Heterogeneous Millimeter-wave/Micro-wave Architecture for 5G Wireless Access and Backhauling", *IEEE European Conference of Networks and Communications*, 2016.
4. J. García-Rois, B. Lorenzo, F. J. González-Castaño and Jinsong-Wu, "Millimeter-Wave Infrastructure Network Slicing for Multiple Virtual Service Providers: A User Association Perspective with Heterogeneous QoE", *ongoing*, 2017.
5. T. S. Rappaport *et al*., "Millimeter Wave Mobile Communications for 5G Cellular: It Will Work!," in *IEEE Access*, 2013.