Millimeter wave module for ns-3 network simulator

Sourjya Dutta, Menglei Zhang, Marco Mezzavilla,
Mustafa Riza Akdeniz, Sundeep Rangan

Electrical and Computer Engineering Department,
Polytechnic School of Engineering, New York University, Brooklyn, NY.

{sdutta, menglei, mezzavilla, akdeniz, srangan}@nyu.edu

ABSTRACT

In this work, we present a novel module developed for the simulation of millimeter wave based cellular networks with the ns-3 simulator. The main focus of this work is the modeling of customizable channel, physical and medium access control (MAC) layers of millimeter wave systems. The overall design and architecture of the model is discussed with emphasis on the customizability of the module. Finally, a simple simulation scenario and its results are discussed.

Keywords

Millimeter Wave, Network Simulator, ns-3.

1. INTRODUCTION

The ever increasing demand of wireless cellular data has motivated researchers to investigate the potentials of millimeter wave communication system. A substantial body of literature is currently available discussing physical measurements and formulations for millimeter wave channels [1], [2]. As a logical next step, we aim at studying how the upper layers of the communication stack work over millimeter wave physical channels. In this work we aim to develop the first millimeter wave module for the ns-3 network simulator that can be used to quantitatively analyze the performance of higher layer protocols over millimeter wave last-mile links, like the transmission control protocol (TCP) and the user datagram protocol (UDP), or applications like the hypertext transfer protocol (HTTP) and the file transfer protocol (FTP).

The simulation module described in this paper is designed to be a fully customizable model where the user can plug in various parameters, like bandwidth, frame length, etc., describing the physical behavior of the millimeter wave channel and devices. In fact, the aim of this work is to enable researchers to flexibly use this module for various scenarios. The rest of the article is organized as follows. In Section 2, we discuss the architecture of the mmW module. In Section 3, we show some results for a simple simulation scenario. Section 4 concludes the article.

2. THE MILLIMETER WAVE MODULE FOR NS-3

The mm-Wave module provides a basic implementation of millimeter wave user and infrastructure devices which include the propagation models, physical (PHY) and MAC. Inspired by the LTE module [3], this module has been designed to provide a completely customizable simulation tool for mm-Wave devices. The important features provided by the module are (i) a basic implementation of mm-Wave user devices and infrastructure devices (base stations), (ii) support for time division duplexing (TDD), a feature not implemented in the LTE module, (iii) a customizable OFDM based frame structure for data and control channels, (iv) support for downlink and uplink MAC scheduling, (v) a outdoor mmWave channel model based on [2] and (vi) customizable MIMO antenna system with beam forming at the user and infrastructure device.

The module is developed completely in C++. **Figure 1** shows a schematic diagram of the mmWave module.

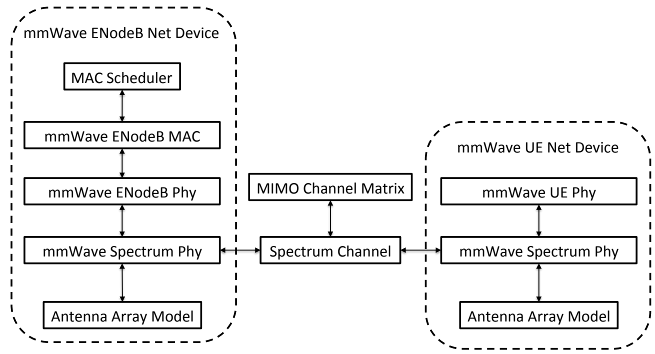

Figure 1: A schematic diagram of the mmWave device functionalities.

2.1 Channel Model

The mmWave spectrum channel handles path loss, small scale fading and beam-forming gain. Path loss is calculated according to distance and link scenario [2]. Small scale fading is characterized as 3 clusters formed by 20 paths. Beamforming gain is computed based on a 64×16 channel matrix and associated antenna weights, which are generated offline using MATLAB.

2.2 Physical Layer

The chief function of the physical layer is *i)* to transmit signals sent from the upper layers over the physical channel, *ii)* to process data and control signals received over the physical channel, and *iii)* send associated primitives to the upper layers. The mmWave module supports TDD, which is likely to be adopted in 5G cellular networks, mainly to better support relays.

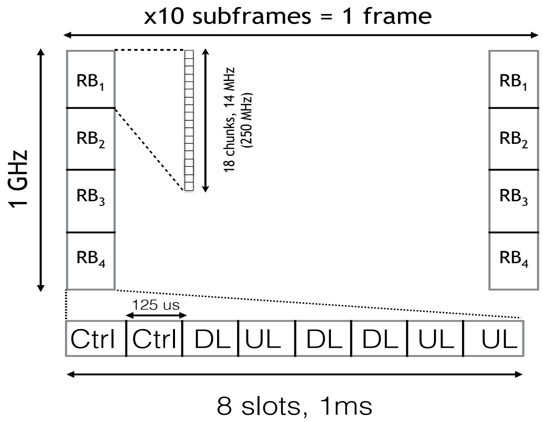

Figure 2: mmWave frame structure.

The physical layer is also in charge of computing the received signal-to-interference-noise ratio (SINR) for data signals taking into account the beam forming vectors of the transmit and receive antennae and the spatial matrices for the channel. Control signals are assumed to be ideally transmitted and received.

2.3 MAC layer

The MAC layer hosts the packet scheduler. The scheduler bases the scheduling decision on a TDD pattern, which determines the transmit-receive scheme to be used by each device. Based on a specified time granularity, the MAC and the PHY layers will interact and update the scheduling scheme. The infrastructure device will transmit the uplink scheduling information to the users in a control message.

3. SIMULATION AND RESULTS

As shown in Figure 2, we have 10 subframes, each of 1 ms, which define a frame. Each subframe is further split into 8 slots each of 125 μs. A bandwidth of 1GHz is used, which is split into 4 resource blocks (RBs) each of 250 MHz. The centre carrier frequency is 28 GHz. This is in accordance with the work presented in [4]. A simple round-robin scheduling algorithm is used for resource allocation at the MAC . We simulate the communication between 2 eNBs and 2 UEs over the millimeter wave channel. We can observe the SINR perceived by the users in **Figures [3,4]**. The variation of SINR across time and frequency includes both the long term ($\sim$ 100 ms) and the short term ($\sim$ 1 ms) variations due to channel statistics are captured in the figure. Due to applying adaptive modulation and coding (AMC) scheme, data rate is varying based on the channel conditions.

4. CONCLUSION

In this paper, a novel module for the simulation of millimeter wave cellular systems has been presented. The module is highly customizable, in order to let researchers use it flexibly to analyze different scenarios at varying configurations. A basic implementation of mm-wave devices, MAC layer, PHY layer and channel models have been developed. In the near future we plan to add several enhancements including the integration with higher layer modules (RLC, RRC) and the core network, a scheduling techniques, the integration of HARQ module, and so forth.

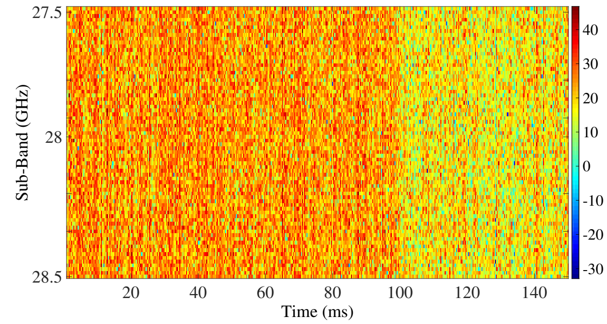

Figure 3: Signal to interference noise ratio (SINR) at UE1.

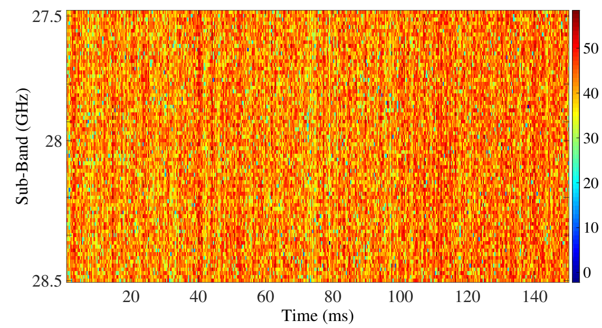

Figure 4: Signal to interference noise ratio (SINR) at UE2.

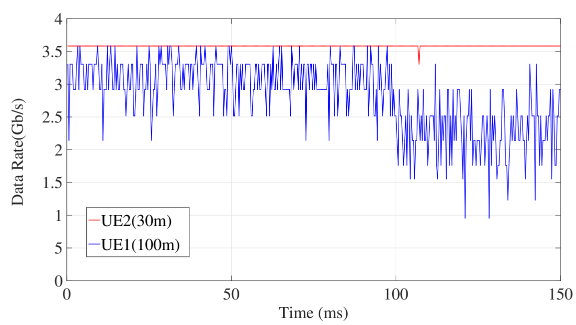

Figure 5: Data Rate(Gb/s) at UE1 and UE2.

5. REFERENCES

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