Three-Dimensional (3-D) 28 GHz Channel Modeling and Measurements for Urban Cellular Mobile Propagation

A Proposal for project associated with the

NYU WIRELESS Industrial Affiliates program

To:

Jeongho Park

Rakesh Taori

[jeongho.jh.park@samsung.com](mailto:jeongho.jh.park@samsung.com)

rakesh.taori@samsung.com

Samsung DMC R&D Communications Research Team (CRT)

From:

Prof. Theodore S. Rappaport

NYU WIRELESS

Polytechnic Institute of New York University

New York University

[Ted.rappaport@nyu.edu](mailto:Ted.rappaport@nyu.edu)

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1. **Scope of work**

This proposal is for work in NYU WIRELESS in the area of 28 GHz 3-D propagation modeling, statistical modeling, and development of a new time-synchronized measurement system. As part of the NYU WIRELESS Industrial Affiliates program, this project has no overhead and is a best effort project. The project will involve one graduate student and one undergraduate researcher working with Prof. Ted Rappaport at New York University over the period of June 1, 2014 – May 31, 2015 to build on the extensive modeling and analysis already performed. Our new work will focus on 3-D modeling through propagation measurements to be performed with a new time-synchronized channel sounder.

During this project, the students and Prof. Rappaport shall perform the following research and activities at Improving the Statistical Spatial Channel Model (SSCM) for 28 GHz:

1. **Measurements and modeling of Elevation/3-D effects:**

Based on the extensive (more than 50 GB) measured 28 GHz propagation data from New York City (NYC) during the summer of 2012, NYU WIRELESS researchers Rappaport and Samimi have produced the world’s first Statistical Spatial Channel Model, capable of recreating the statistics of measured channels for an arbitrary antenna pattern. This omnidirectional SSCM that allows for considering propagation over all azimuth antenna pointing angles at TX and RX, thus allowing arbitrary antenna patterns and beamforming techniques to be used with the resulting SSCM. Early works in [1][2][3] have demonstrated that path loss is a function of distance, and that the outdoor environment in NYC is very reflective (making penetration into buildings difficult). Our early work also shows that a promising SSCM modeling approach for generating realistic scenarios for angle of arrivals (AOAs) and angle of departures (AODs) is to use the concept of lobes, and we have submitted a technical report to Samsung in 2Q 2014, and the first paper on this subject for IEEE Globecom 2014 based on the recently completed MS Thesis of Mathew Samimi [4][5].

One of the weaknesses of our current SSCM is that it is only a 2-D model, as there is not much data available for elevation angles, as our original 2012 measurements did not use many different elevation angles at the RX, and only one downtilt elevation at the TX. Also, our measurements during 2012 did not use an exact timing reference, requiring us to use manual ray tracing to create temporal statistics for a limited number of RX measurement locations. This technique, while suboptimal, was useful for producing a good SSCM [4][5].

In the 2014-2015 work, we shall conduct more measurements at 28 GHz in urban New York City, with a focus on elevation angles at the RX and RX. We shall design a measurement plan that ensures a wide range of TX and RX antenna pointing angles, so that multipath impulse response, as a function of 3-D pointing at both the TX and RX can be modeled. Unlike in 2012, we shall pick a few representative TX and RX locations, representative of typical future mmWave cellular systems, and we shall focus on a wide range of elevation angles for those locations.

1. **Small Scale Fading measurements and models:**

One of the relatively unknown areas of mmWave propagation is the correlation between multipath amplitudes and times of arrival. Without a time-synchronized measurement system, it is difficult to synthesize sufficient data to properly analyze correlation of amplitudes or time delays. In this year’s research program, we shall conduct measurements with the new channel sounder (see Item 3 below) to determine the correlation between times of arrivals and amplitudes of arrival, as well as Angles of Arrival. To perform this work, we shall investigate:

1. The correlation of multipath amplitudes over time delay, and over a spatial linear track, where each track increment is spaced out by half-wavelengths, while conducting AZ and EL sweeps at the TX and RX.

2. The correlation of multipath amplitudes in time delay for each linear track increment, for different AZ and EL sweeps at the TX and RX.

**3. Verification of 3-D SSCM using time-synchronized rubidium standards.**

To ensure that accurate propagation time is recorded, the NYU WIRELESS channel sounder will implement a timing mechanism to trigger the recording of a PDP at the RX with the exact timing of the start of a PN sequence at the TX. GPS time provides an option for triggering the TX and RX to record accurate absolute propagation time of transmitted signals. In the future measurement campaign, we will employ the NI (National Instruments) PN clock at both the TX and RX, which can be integrated into the chassis and operated using FPGA (Field Programmable Gate Array) programs. Combining GPS and FPGA, accurate timing will be realized, allowing us to record absolute time of arrival.

Phase-locking is necessary to obtain the phase information of the I and Q channels. This can be achieved by slaving channel sounder frequency sources (e.g. IF and LO on both TX and RX) in the measurement system to the same highly stable 10 MHz reference source. We are currently working on locking the channel sounder frequency sources onto a 10 MHz output of a GPS disciplined oscillator at both the TX and RX. Proper recording of I and Q is crucial to obtain phase information.

We will perform measurements in different types of weather (e.g. rain) to study the effects of such weather conditions on the propagation of mm-waves, because a reliable SSCM must account for weather changes. In particular, we believe polarization diversity will be impacted by rain and moisture of buildings and streets, so our measurements will measure during wet and dry conditions to determine changes in polarization discrimination and reflection coefficients of typical materials.

To verify the SSCM, and to ensure proper use in a “blind’ field test, additional measurements shall be recorded in Summer 2015, using a variety of different beamwidth antennas at both TX and RX. We will use 24.5 dBi and 15 dBi horn antennas to take more measurements investigating AOD statistics (e.g. angle pointing configuration 10, TX sweeping the azimuth plane while RX remains fixed) and AOA statistics to complement and add on to our summer 2012 measurements, in order to verify, improve and enhance the accuracy of our new 3-D SSCM model. The correlation between antenna beamwidth and time delay shall be determined to complement the accuracy of the SSCM.

1. **Create a software simulator that recreates the 3-D SSCM for use by the research community**

A software simulator is capable to reproduce multipath channel PDPs (e.g. impulse responses) using the statistical models developed based on the NYC measurements. Such a tool will allow the prediction of arriving signals by convolving transmitted signals with the statistically generated impulse responses. These predictions are important during the engineering design process in assessing the viability of a communication link.

1. **Cost:** This Statement of Work shall be part of the Samsung Industrial Affiliates fee of $100,000 per year, which is treated as gift funding with no overhead charged. Because no overhead is charged, deliverables cannot be guaranteed, and this is best effort.
2. **REFERENCES**

[1] Samimi, M., Wang, K., Azar, Y., Wong, G. N., Mayzus, R., Zhao, H., Schulz, J. K., Sun, S., Gutierrez, F., Rappaport, T. S., “28 GHz Angle of Arrival and Angle of Departure Analysis for Outdoor Cellular Communications using Steerable Beam Antennas in New York City,” to appear in the 2013 IEEE Vehicular Technology Conference (VTC), June 2~5, 2013.

[2] Azar, Y., Wong, G. N., Wang, K., Mayzus, R., Schulz, J. K., Zhao, H., Gutierrez, F., Hwang, D., Rappaport, T. S., “28 GHz Propagation Measurements for Outdoor Cellular Communications Using Steerable Beam Antennas in New York City,” to appear in the 2013 IEEE International Conference on Communications (ICC), June 9~13, 2013.

[3] Zhao, H., Mayzus, R., Sun, S., Samimi, M., Schulz, J. K., Azar, Y., Wang, K., Wong, G. N., Gutierrez, Jr., F., Rappaport, T. S., “28 GHz Millimeter Wave Cellular Communication Measurements for Reflection and Penetration Loss in and around Buildings in New York City,” to appear in the 2013 IEEE International Conference on Communications (ICC), June 9~13, 2013.

[4] M. K. Samimi, T. S. Rappaport, “'Ultra-Wideband Statistical Channel Model for Non Line of Sight Millimeter-Wave Urban Channels,” submitted to IEEE Global Communications Conference, December 2014, Austin, TX.

[5] M. K. Samimi, “Characterization of the 28 GHz Millimeter-Wave Dense Urban Channel for Future 5G Mobile Cellular,” M. S. Thesis, NYU WIRELESS, May 2014.