Design of Terahertz Wireless Communications Simulator for Future Wireless Internet

Seongman Min, Wonjung Kim, Taewon Song, and Sangheon Pack
School of Electrical Engineering
Korea University, Korea
{pobi1020, abcxxxx, crazytb, shpack}@korea.ac.kr

ABSTRACT
Terahertz (THz) waves can offer high transmission rates due to the ultra-broad bandwidth. So THz communications are recently received attention. However, due to the absence of a proper simulator, a diversity of attempts are not performed on THz communications. In order to alleviate this problem and to contribute the improvement in the performance of THz communication, we describe the design of THz simulator in this paper. Specifically, the design of PHY layer and MAC layer are handled in detail.

Keywords
terahertz, simulator, PHY layer, MAC layer

1. INTRODUCTION
Future wireless communications systems, which supports ultrahigh data rates, is expected to apply a variety of field that need more 10GHz. Conventional WLAN, WPAN, and UWB systems use the bandwidth between multi-MHz and multi-GHz. Therefore, these have limited in the requirement of future wireless communication systems. To address this limitation, terahertz (THz) technologies have recently gained momentum in the area of research and development. As THz region covers 100-10000 GHz range, THz waves support much more bandwidth than millimeter waves. Due to its characteristic, THz communication systems with several tens of Gbps data rates can be applied to many applications such as wireless extension of high-speed wired local networks, wireless data center networks, and high-definition and ultra-high-definition television (HDTV & UHDTV) [1].

In addition to ultra-high bandwidth, THz waves have several other characteristics. Firstly, THz waves are inherently more directional than millimeter waves due to less free space diffraction of the waves. Consequently, THz communication systems are typically line-of-sight (LOS) systems. Secondly, THz waves are severely attenuated along the propagation path. When the propagation distance or the carrier frequency becomes double, the attenuation increases 6dB. Finally, in outdoor condition, THz waves are significantly influenced by weather condition (i.e., rain, snow, fog, etc.) because they are mainly absorbed in water-vapor [2]. And the degree of attenuation is different depending on frequency band, so there are available bandwidths satisfying a standard point [3]. On the contrary, in indoor condition, the weather condition does not affect on THz waves but obstacles (i.e., wall, furniture, human, etc.) absorb or reflect them [4].

Many research projects on THz are being performed reflecting these characteristics in the industry and academia. Most of them evaluate a performance of proposing schemes by relying on experiments. However, it is hard to perform a diversity of attempts on THz communications because the method, relying on experiments, has limitations of time, space, and cost. If we use the THz communications simulator, we can predict the performance of proposing schemes by simulations ahead of experiment and perform a diversity of attempts at the lowest cost. However, there is no a simulator on THz region yet. Therefore, in this paper, we address the development of a methodology for THz communications simulator.

2. THz COMMUNICATIONS SIMULATOR
In the design of the THz communications simulator, we consider two things; PHY layer and MAC layer. As figure 1 presents a brief architecture of THz communications simulator, MAC and PHY layer consist of three modules, respectively. In our PHY layer, THz waves propagation model is used to predict the received signal power of each packet. Using this propagation model, the simulator takes into account the effects of transmission distance, absorption and reflection due to obstacles, atmospheric conditions, and directionality of THz waves. In the MAC layer, the simulations measure the performance at MAC layer such as throughput, average delay, and packet loss metrics. Since there is no standard of wireless communications on THz region yet, we use the MAC layer of IEEE 802.11ad [5]

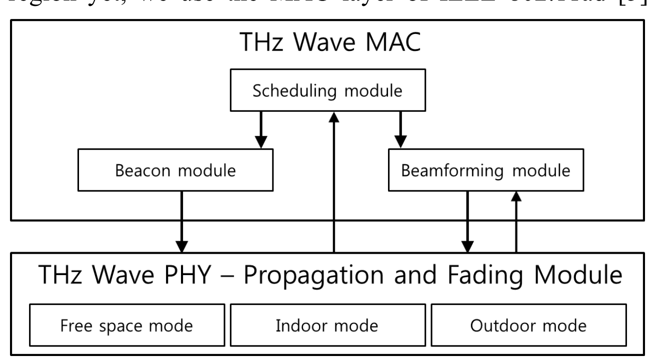

Fig. 1. THz Communications Simulator Architecture.

which is a standard of WLAN on 60GHz whose characteristics are similar to THz waves. In our MAC layer, as network architecture, we consider personal basic service set (PBSS) which is newly defined in IEEE 802.11ad to decrease power consumption of mobile terminals and to support directional transmission. In PBSS, there is PBSS central point/AP (PCP/AP) which supports QoS and manages the frequency spectrum.

2.1 Design of PHYSICAL layer

Depending on channel characteristics, PHY layer model is divided into three modes; free space, outdoor, and indoor. The free space mode simulates the ideal condition, which assumes a LOS path between transmitter and receiver. In the free space mode, free space attenuation is only considered as a parameter. Therefore, THz waves are attenuated by the distance between transmitter and receiver and the carrier frequency based on Friis' law.

The outdoor mode simulates the realistic condition which considers atmospheric condition in addition to free space attenuation. Therefore, water-vapor and atmospheric gases are also considered as parameters in the outdoor mode. In the near field wireless communication (under 10m), since the free space attenuation is much higher than the attenuation due to atmospheric condition, we can predict the attenuation only considering free space attenuation. The indoor mode simulates the realistic condition in a building or house. In an indoor condition, THz waves are reflected by obstacles (i.e., wall, ground, ceiling, furniture, human, etc.). As reflection coefficients depend on material of obstacles, significant reflected waves, which are once or twice reflected to any materials having low reflection coefficients, affect on the fading. Therefore, the indoor THz communication channel can be modeled by free space attenuation and power delay profile (PDP) [1], [4]. The PDP refers to the path length difference between the direct LOS and once or twice reflected waves. Its important parameters are mean delay and root mean square (RMS) delay spread. Since RMS delay spread significantly affects on inter-symbol interference (ISI) so it has a strong influence on bit-error-rate (BER) of communication system.

2.2 Design of MAC layer

In our MAC layer, three modules are defined; beacon module, beamforming module, and scheduling module. The beacon module is used to manage every associated terminals and connections. And it defines a structure of beacon frame and the information included in a beacon frame. Based on it, PCP/AP broadcasts a beacon frame to every associated terminals periodically.

The beamforming module is used to control the direction and width of antenna beam. Since THz waves are highly directional, the antenna direction of terminal should be adjusted to target terminal for communicating each other. Also, the beam width of antenna has to be tuned to decrease power consumption and to reduce interferences. The scheduling module is used to manage the sequence of connections and to allocate the resource. Data transfer time period in a beacon period consists of contention-based access periods (CBPs) and service periods (SPs). PCP/AP allocates CBPs and SPs, and it schedules the sequence of connections on SPs.

3. CONCLUSIONS

In this paper, we present the design of THz communications simulator with PHY layer channel models and MAC layer modules. We are currently working on reflecting THz channel characteristics in ns-3 simulator and implementing MAC layer protocol by using ns-3 simulator. THz simulator would allow for further investigation of the performance of THz communications systems at the low cost.

4. ACKNOWLEDGMENTS

This research was supported in part by the KCC, Korea, under the R&D program supervised by the KCA (KCA-2011-08913-04002), in part by the MKE, Korea, under the ITRC support program (NIPA-2012-H0301-12-4004) supervised by the NIPA.

REFERENCES

[1] J. Federici, , and L. Moeller, "Review of terahertz and subterahertz wireless communications," *J. Appl. Phys*., vol. 107, pp. 111101-1-111101-22, 2010.

[2] Recommendation ITU-R P.676-7, "Attenuation by Atmospheric Gases," 2007.

[3] Saunders, S. R., "Antennas and Propagation for Wireless Communication Systems," *Wiley John & Sons, Inc*., June 1999.

[4] R. Piesiewicz, R., Jemai, J., Koch, M., and Kürner, T., "THz channel characterization for future wireless gigabit indoor communication systems," *SPIE Intl. Symp. on Integrated Optoelectronic Devices, Terahertz and Gigahertz Electronics and Photonics IV*, Vol. 5727, pp. 166-176, San Jose USA, January 2005.

[5] IEEE P802.11ad/D0.1, Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications – Amendment 6: Enhancements for Very High Throughput in the 60GHz band, June. 2010.