Outdoor Demonstration of 5Gbps MHN Enhanced System

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Abstract—**In ETRI (Electronics and Telecommunication Research Institute), we have been designing and developing MHN–E (Mobile Hotspot Network - Enhanced) system, which supports up to 10Gbps downlink data transmission rate for fast moving group vehicle. Supported moving velocity is considered up to 500km/h. In this paper, we described the demonstration of 5Gbps outdoor road test of MHN-E system in Gangneung area with the running test bus during 2018 winter Olympic game period. We measured the real-time performance of MHN-E system while running the test bus which installed a test-bed mTE system. Furthermore we verified that the peak data rate of MHN-E system is over 5Gbps throughput without SFMF (Single Frequency Multi Flow) in outdoor environment.**

***Keywords*— Mobile Hotspot Network, SFMF, Millimeter.**

I. INTRODUCTION

Although 4th Generation LTE/LTE-A mobile communication systems are currently commercialized [1][2], it is sure that higher data transmission rate will be required. In order to meet the required data rate, specification working of NR (new radio) 5th generation mobile communication system [3-5] is under way and development is also in progress. It is also naturally considered to adopt millimeter wave band to use wider band to improve data transmission rate.

Especially in the group vehicle such as express trains, subways and buses, where there are many passengers who use smart phones and tablets, heavy data transmission will be required. Therefore, in order to support the same level of service as that at home in the moving group vehicle, next generation of wireless mobile backhaul which supports Gbps data transmission service is needed. In the public transportation, in order to overcome the problem of degradation of Wi-Fi service quality, it is necessary to lead development the millimeter based high speed wireless mobile backhaul technology. Furthermore, it is also necessary to acquire and verify the state of the art technology related high speed wireless mobile backhaul technology. There has been few system that considers both high data transmission rate and high-speed mobility. There is no wireless mobile backhaul system to cover these requirements. This initiated the development a wireless mobile backhaul system that is suitable for fast moving environment.

In ETRI, MHN system has been developed by Feb. 2016, which system supports maximum downlink data rate 1Gbps. MHN-E (MHN – Enhanced) system is the next version of previous MHN system. The peak data rate of MHN-E system is 10Gps and the supported maximum speed is about 500km/h. In this paper, some key features of MHN-E system are described and difference of MHN-E system and MHN system is shown. Furthermore, we demonstrated MHN-E system with a running test bus.

This paper is organized as follows. In section II, comparison between MHN-E system and MHN system are described in brief. Characteristics of MHN-E system is also described. In section III, special issues of road test of MHN-E system are shown. In section IV, simulation results of downlink data channel in MHN-E system are described. Finally, we concluded this paper in section V.

II. MHN-E SYSTEM

A. MHN-E System

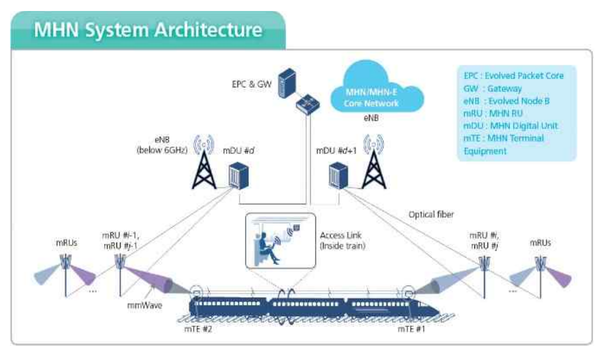

Figure 1. Architecture of MHN-E System

In this section, we compared MHN-E system with MHN system. MHN-E system is also based on TDD like MHN system. 10ms radio frame is consisted of 5 subframes. One 2ms duration subframe is composed of 8 slots, which means one slot is 250us duration. TTI (Transmission Time Interval) duration is 1/4 of LTE/LTE-A like MHN system. As applying 250us TTI, latency can be reduced.

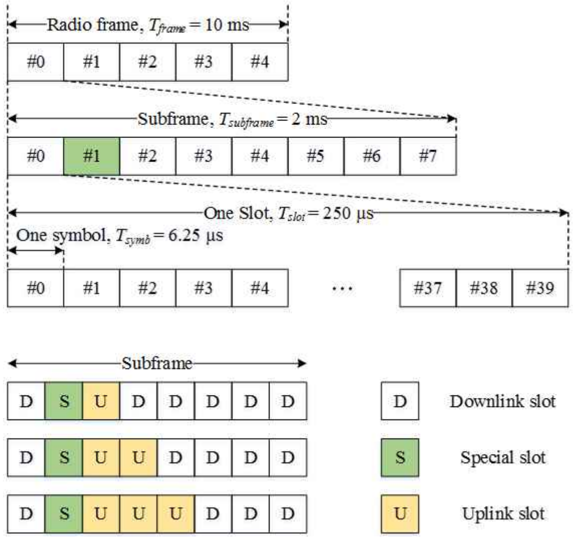

Figure 2. Frame Structure of MHN-E system

Similar to the MHN system, the basic bandwidth unit is 125MHz occupied one CC (Carrier Component). As expanding 8 times with applying CA (Carrier Aggregation), maximum 1GHz which is two times wider than MHN system can be used. Furthermore, in MHN-E system, adopting polarization antenna transmission technique, it is designed to attain 4 times transmission performance than that of MHN system. Backhaul transmission capacity that one mTE can receive can be extended to more than 5Gbps.

Carrier aggregation is not only the equipment to extend the bandwidth. One of the most important parts in designing MHN-E baseband is to enable to support proper handover. In case of MHN and MHN-E systems, as they both use millimeter wave band, in order to attain the enough coverage of beams, very sharp beams are used at the receiver and at the transmitter as well, which means that beamforming gain is very high. In this case, cell searching is very difficult because the power of received signals from the serving cell is much higher than that from the target cell before going through cell boundary, which is around 900m duration in figure 4. Therefore, the new frame structure, which is shown in figure 2, is designed and included in MHN-E physical layer specifications to support better neighbor cell searching and more proper handover in the very high speed mobile environment. Related to this frame structure, three types of frequency bands which are used in carrier aggregation are classified as follows.

- PCell (Primary Cell)
- SCell (Secondary Cell)
- TCell (Tertiary Cell)

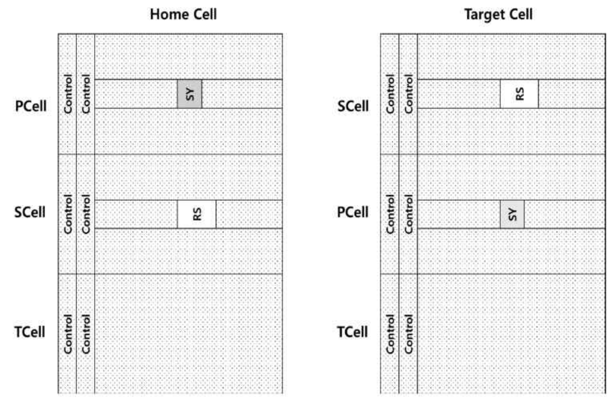

Figure 3. Radio Frame Structure of MHN-E system

In figure 3, horizontal axis is time axis, vertical axis means frequency. PCell, SCell, and TCell occupy 125MHz, respectively. In case of PCell, both synchronization signal and broadcasting signal are allocated in SY part. In case of SCell, a little wider area than SY part of PCell is allocated in RS part, at which part no signal is transmitted. In case of TCell, there is no SY and RS area. In case of all three cases, data are transmitted in all area except for RS, SY and control signals. By the way, as shown in figure 3, we can notice that the position of PCell frequency is interchanged between home cell and target cell. By doing this, mTE included in home cell cannot be interfered from home cell while receiving the synchronization signal and the broadcasting signal from target cell. In MHN-E system, as we can predict the direction of progress, we can allocate the position of PCell to intersect between two adjacent cells, which can make detect target cell in home cell stably.

Target performance of MHN-E system is as follows. The maximum data transmission rate of wireless mobile backhaul is 10Gbps, and handover interruption time is below 5ms, and the maximum frequency efficiency is 10bps/Hz (per train), and frequency efficiency at 500km/h high speed mobility is more than 6bps/Hz.

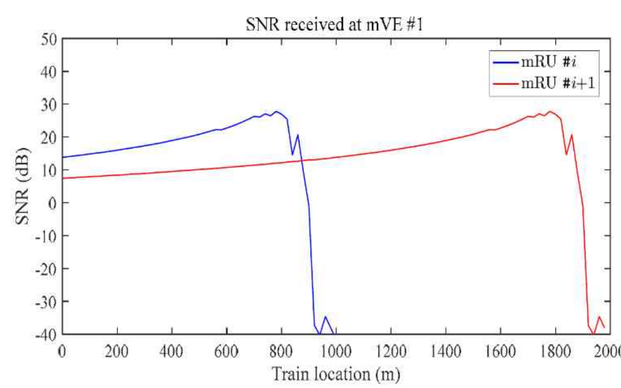

Figure 4. Characteristics of received signals of Serving Cell(#i) and Target Cell

III. Implementation and The Road Test

The final performance goal of MHN-E system is to attain 10Gbps throughput. This goal can be achieved with the following key techniques. CA (Carrier Aggregation) up to 1GHz bandwidth, FD-MIMO and SFMF (Single Frequency Multi Flow). Currently, MHN-E system which satisfies three characteristics above has been developed. Therefore, maximum data transmission rate shows downlink 10Gbps. It is scheduled to demonstrate the result of MHN-E system on the road in Gangneng city during 2018 winter Olympic game period. In order to show SFMF, mRU should be installed in both way, however, this is not easy. Because of the budget problem, we had to install mRUs in one way. Therefore, we demonstrate the performance of one way MHN-E system, which means 5Gbps downlink transmission data rate. We demonstrated the performance with the test bus in figure 5. Throughout many tests, it was successful to demonstrate 5Gbps data rate with running bus installed mTE test-bed system. SFMF environment was configured with installation of mRUs in both ways around the playground of ETRI. We demonstrated the 10Gbps downlink data transmission rate with SFMF in ETRI. We verified the feasibility of usage of SFMF technology.

Figure 5 shows the test bus and we can see the mTE system installed inside the test bus in figure 6. Figure 7 shows the mRU system installed on top of the building in the test route of system demonstration. Maximum transmit power of mRU is 100mW.

Figure 5. The Test Bus of MHN-E system

Figure 6. mTE system installed inside the test bus

Figure 7. mRU system installed on top of a building

Figure 8 depicts the snapshot of downlink data rate which supports 5Gbps during running a bus in the route of demonstration. We can see the maximum data rate is over 5Gbps and the constellation is 64QAM.

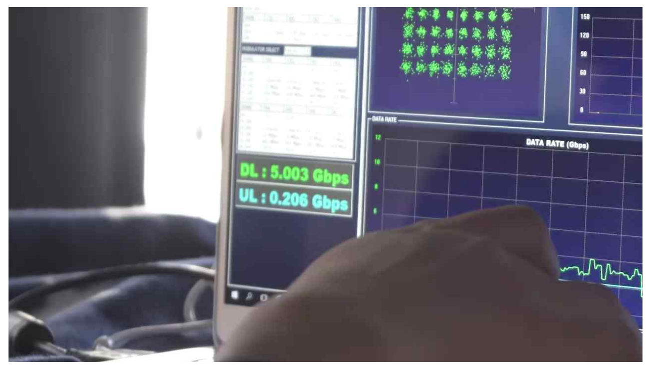

Figure 8. Snapshot of downlink 5Gbps data rate during running a bus

Bus demonstration of MHN-E system is performed in Gangneung area in South Korea during winter Olympic game period. As shown in figure 6, total length of this demonstration area is 821m, and 2 RUs are installed. 1st RU is installed at mRU#1 site which is about 400m away from the start point and the second RU is installed at mRU#2 site which is about 820 m away from the start point. Installed mRUs are shown in figure 7. Although this street route for demonstration looks like a straight lane, as there are a lot of running cars including big vehicles such as buses and trucks, and a lot of road signs, channel environment is not good condition. During the demonstration, the maximum speed of the test bus is under 100km/h. The degree of beamforming in both mRU and mTE is the same 12 degree. The road of start point is a downhill road. Therefore, the direction of mTE antenna is not directly heading to the mRU antenna, which makes downlink system performance degrade. From the first mRU position, the road is flat, which makes the performance better. While running the test bus, antenna position is fixed.

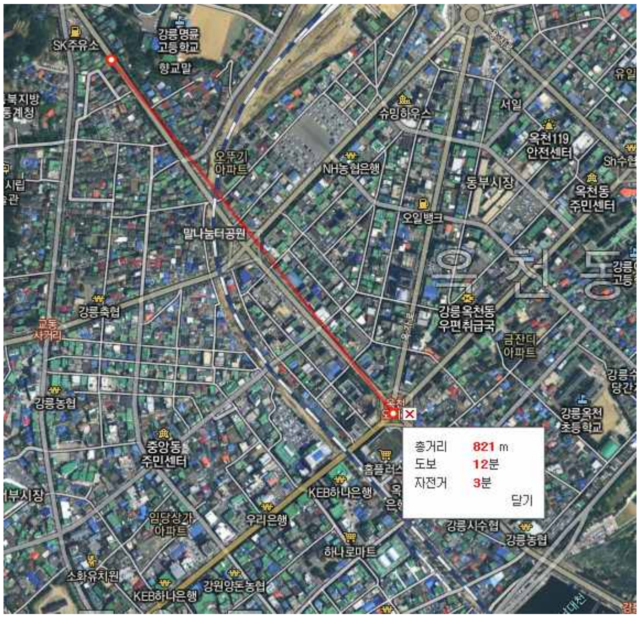

Figure 9. Test area of Gangneung in South Korea

Transmitted beam from mRU can reach all area regardless of the position of mTE. However, performance of the system is deeply related to the degree, the height and the direction of mTE antenna. According to the position of mTE, the receiving performance can be different. From this phenomenon, it is necessary to adopt beam switching among several beams to improve the performance henceforth, especially in mTE. In mRU, beam switching is not necessary.

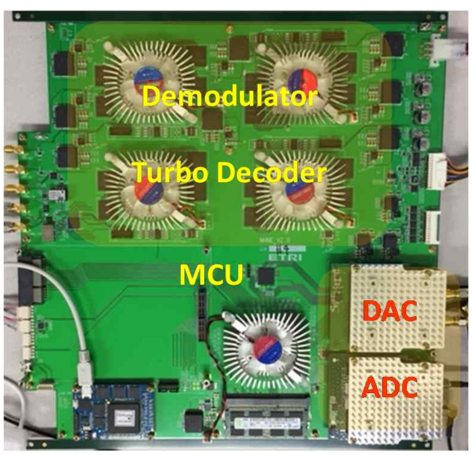

Figure 10. Flat-form of mTE and mDU

Figure 10 shows the flat-form mTE and mDU test-bed system. One of key features of modem development is the selection of FPGA. Xilinx UltraScale XCKU115 is used for modulation, demodulation and turbo decoder. One XCKU115 is used to match using PCIe, DAC/ADC, DDR3 and interface. 4 XCKU115 are used to implement modulation and demodulation, where each FPGA supports 1.25Gbps data rate processing through 4 decoders, respectively. Central MCU is ARM CPU (model : STM32F746NGH6), which is used to control L1 layer.

IV. Simulation Results

Figure 6 depicts the BER performance of data channels. Table I shows MHN-E system simulation parameters.

TABLE I. Simulation Parameters

Parameters	*Setting*
Channel model	*Multipath-cluster channel model with Rician fading channel*
K-factor	*20dB*
Cross Polarization Discrimination (XPD)	*0dB, 50dB*
Carrier frequency	*26GHz*
Velocity	*100km/h, 300km/h, 500km/h*
Code rate	*0.8*
Modulation order	*QPSK, 16-QAM, 64-QAM*
Transmission scheme	*2x2 single-frequency multi-flow (SFMF)*
TM for each mTE*	*TM1, TM2, TM3*
Receiver	*AFC for Doppler compensation, Turbo decoder*

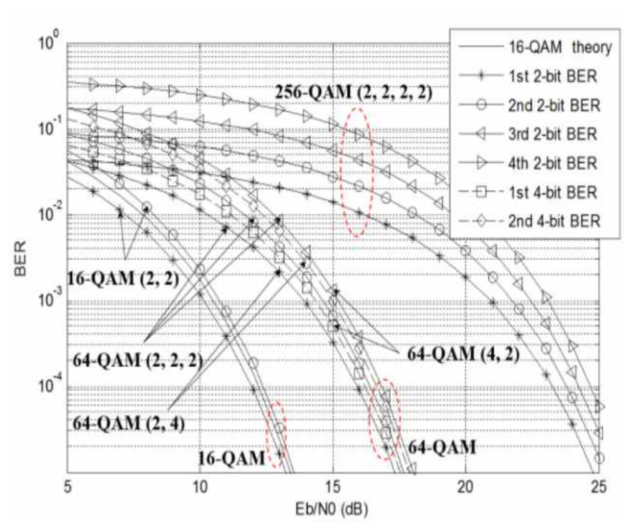

Figure 11. Performance of M-DSCH

V. Conclusions

In this paper, we described the MHN-Enhanced mobile backhaul system, which can support 10Gbps downlink data rate and mobile speed up to 500km/h. Furthermore, we demonstrated 5Gbps downlink data rate during running a bus where the MHN-E system is installed.

ACKNOWLEDGEMENT

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[10] MHN-E PHY PLP, ETRI

[11] MHN-E PHY MCC, ETRI

[12] MHN-E PHY PCM, ETRI