Physical Layer Modem Implementation for Movable Wireless Backhaul System

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***Abstract*—In this paper we present the physical layer implementation structure and verification environment of the movable wireless backhaul system MBH(Mobile Backhaul) to deploy backhaul system and provide mobile communication infrastructure to the communication disaster area.**

Keywords—millimeter wave, mobile backhaul, unscrewed aerial vehicle

I. Introduction

In mobile communication based on 3GPP LTE (Long Term Evolution), especially 5G NR(New Radio) using mmWave(Millimeter Wave), the deployment of a large number of small cells is required to reduce non-service areas. In addition, wireless backhaul is being studied and surveyed for efficient matching between macro base stations, small cells, and core networks[1][2]. We proposed OFDM(Orthogonal Frequency Division Multiplexing) based fixed high-capacity wireless backhaul system in the E band. It was confirmed the possibility of deployment mobile communication network infrastructure using fixed high-capacity wireless backhaul implementing and demonstrating a wireless backhaul system of 25 Gbps capacity[3]. In this paper, we introduce MBH system in section II, implementation and validation environment with result in section III and conclude in IV.

II. MBH System

A. System description

MBH system is used the mmWave with carrier frequency of range 26.5 to 27.3 GHz and 400 MHz bandwidth per FA (Frequency Assignment) corresponding to one backhaul link. For modulation, it was employed the OFDM being validated applying to wireless backhaul in [3]. TABLE I. shows system parameters of MBH.

TABLE I. System Parameters

Variable	Value
System bandwidth[MHz] per FA	400
Subcarrier spacing[kHz]	120
FFT size[sample]	4096
Number of subcarrier	3072
Occupied bandwidth[MHz]	368.64
OFDM symbol duration[us]	8.33
CP length long/short[sample]	544/288
CP duration long/short[us]	1.11/0.59
Number of OFDM symbol per Slot	14
Slot duration[us]	125
Subframe duration[ms]	1
Midframe duration[ms]	2
1Radio frame duration[ms]	10

To operate in mmWave need sufficiently wide subcarrier spacing, it was adapted the Numerology 3 of 3GPP 5G NR[4] to the radio frame of MBH, a frame of 10 ms length is composed of 10 subframes, a subframe is 8 slots, and 14 OFDM symbols per 1slot. The TDD slot format has a structure of DL:UL(Downlink:Uplink) = 4:1 within one midframe composed of two consecutive subframes. Each slot has a structure of either Type-A or Type-B, and Type-A for transmitting synchronization signals and control information is located only in the first midframe of 1 radio frame. Fig. 1 shows one radio frame structure and slot format configuration.

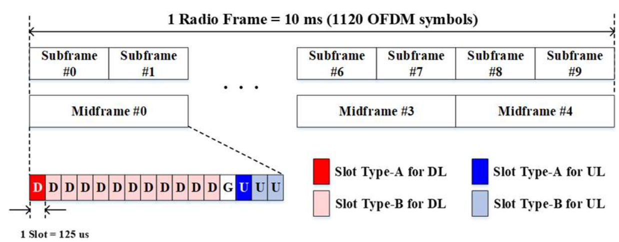

Fig. 1. Radio frame structure and Slot format configuration

B. Physycal layer

Physical channel includes CCH (Control Channel) for transmitting control information and SCH (Shared Channel) for data transmission, and DMRS (Demodulation Reference Symbol) to estimate channel status is allocated to the first symbol of each slot. PTRS (Phase Tracking Reference Signal) to compensate for common phase error is uniformly assigned to the time domain. In the first slot of the frame, SSB (Synchronization Signal Block), PRACH (Physical Random Access Channel) and SRS (Sounding Reference Signal) are located for initial synchronization acquisition and ranging.

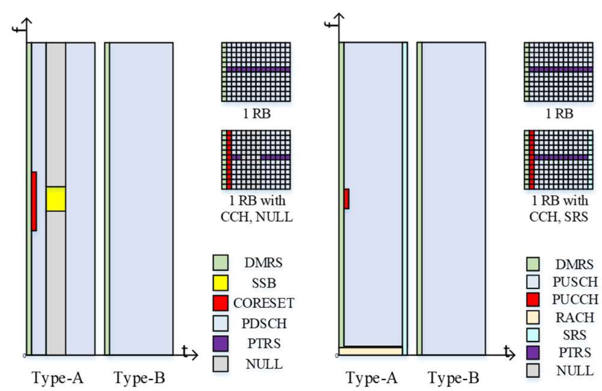

Fig. 2. Physical Resource Allocation of DL(left) and UL(right)

III. Implementation And Field Test

To achieve throughput performance of 1 Gbps per link at a distance of 2.5 km and 250 Mbps at a distance of up to 10 km, we investigated power over distance and throughput over MCS(Modulation and Coding Schemes) simulating path loss and estimating maximum throughput, as shown in Fig. 3 and TABLE II.

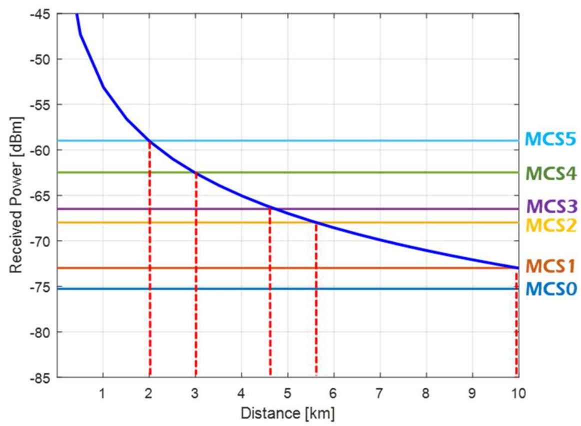

Fig. 3. Received power over distance

TABLE II. Throughput for MCS

MCS index	Modulation Order	Throughput[Mbps]	
		Downlink	Uplink
0	QPSK	113.26	28.31
1		238.34	59.30
2	16QAM	391.41	97.75
3		562.42	140.34
4	64QAM	635.97	158.83
5		1051.72	262.68

A. Implementation of baseband modem

Baseband modem of MBH is composed of PS(Processing System) to control baseband modem and PL(Programmable Logic) and was used Xilinx Zynq RF SoC(ZU48DR) for implementation. L1 and L1 control part of baseband modem were designed and implemented in Verilog and C++ respectively by our own source code. To process 400 MHz bandwidth at 491.52 MHz system clock, it is simultaneously processed 4 OFDM symbols with 122.88 Mhz clock as described later.

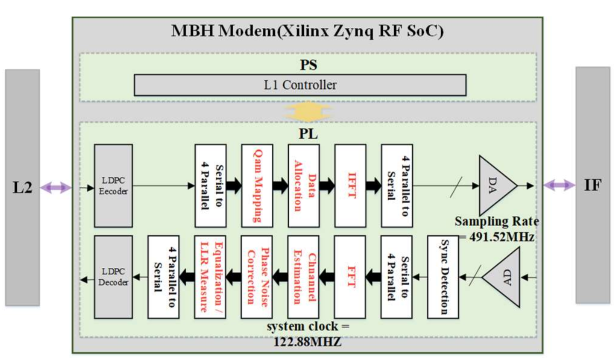

Fig. 4. Block diagram of MBH baseband modem

Fig. 4 shows a block diagram of MBH baseband modem. Modulator was designed with 4 path streams to meet a slot time 125 us processing IFFT(Inverse Fast Fourier Transform), QAM(Quadrature Amplitude Modulation) mapping and physical resource mapping. Demodulator has 4 parallel stream structure from FFT(Fast Fourier Transform) to LLR(Log-Likelihood Ratio) being similar to the modulator. Time synchronization signal for DL is consisted of PSS(Primary Synchronization Signal) to detect coarse timing synchronizing and SSS(Secondary Synchronization Signal) to search cell ID and the tracking is performed with DMRS. It is adopted PRACH to synchronize timing for UL, the 10 ms length radio frame is composed of 5 midframes and each midframe has 1.626 us length downlink period and 374 us length uplink period. In order to be up to 10 km maximum distance between hub and terminal, the guard time of PRACH is been 50 us corresponding to 6 OFDM symbols[5]. Fig. 5 shows the shape of the platform with the IF(Intermediate Frequency) module installed on the evaluation module board(ZCU208) with the Zynq chip embedded and the L2 board(ZCU111) connected with the AURORA interface. IF module was designed to be able to control received gain and transmitting power and up-convert to 3.3 GHz the baseband signal. The utilization of logic resource for PL is shown in TABLE III. .

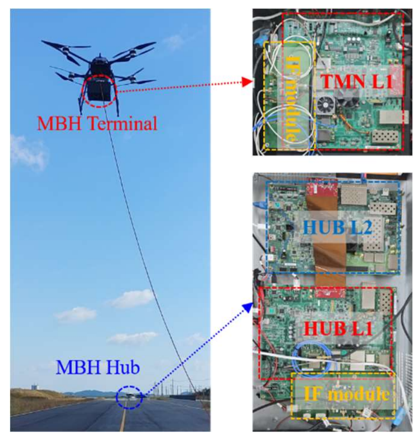

Fig. 5. MBH link test environment(left) and Plaform structure of Terminal(upper right) and Hub(bottom right)

TABLE III. Utilization of PL

Resource	Utilization(%)	Available
LUT as memory	178798(42.04%)	425280
LUT as logic	110742(51.85%)	213600
BRAM	1031(95.46%)	1080
FF	323774(38.07%)	850560
DSP	340(7.96%)	4272

B. Field test

To confirm test environment as tracking performance of hub antenna and gimbal, MAT(Modem Analysis Tool) and characteristics of wireless channel, we conducted P2P fixed link test at relatively close distance in ground before aerial test mounted MBH system on UAV. The aerial test mounted on UAV was conducted at UV Land in Taean, Chungcheongbuk-do, Rep. of Korea to secure sufficient distance and LOS(Line of Sight). The following test results were conducted at a bridge 2.5 km and 4.5 km away from UV land, and although there were obstacles such as utility poles in not a perfect LOS, predicable results were obtained for each distance.

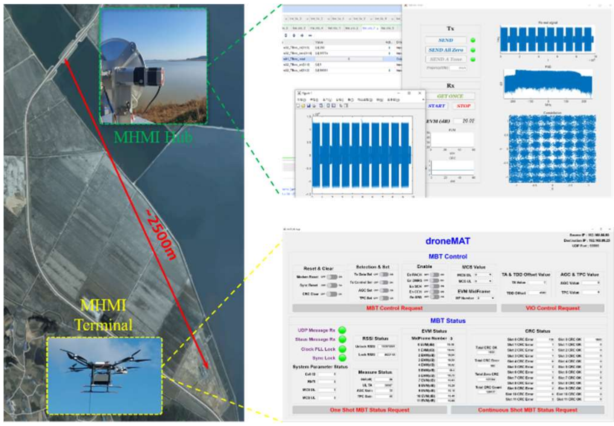

Fig. 6. MBH link test at 2.5 km distance

Fig. 6 shows link test result and test environment of 2.5 km distance between MBH hub and terminal. In according to Fig. 3, performance at 2.5 km was expected to support up to MCS4, but in practice MCS5 was possible, with an EVM(Error vector magnitude) of approximately 20 dB and error rate of less than 0.01% both DL and UL.

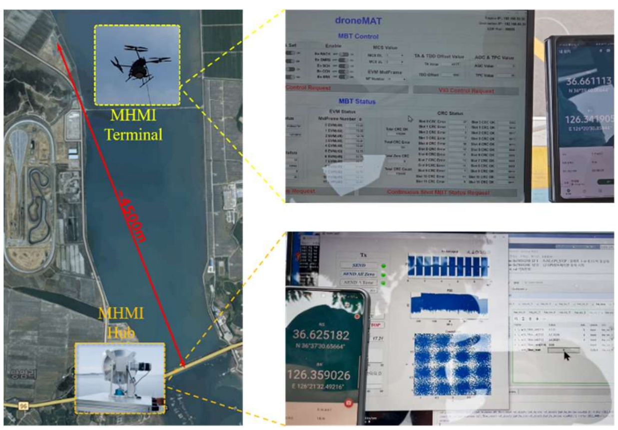

Fig. 7. MBH link test at 4.5 km distance

Fig. 7 shows link test result and test environment of 4.5 km distance between MBH hub and terminal. It was performed at 4.5 km distance with EVM of 17 dB at MCS3 and below 0.1% error rate both DL and UL.

IV. Conclusion

In this paper, we presented MBH system and the physical layer implementation structure and result of test. Currently, the implementation and test for P2P using one UAV of the 2.5 km, 4.5 km distance between the hub and terminal have been completed, and the implementation of P2MP are in progress. Further, integrating between Core-network and FBS(Flying Base Station) transmitting FHD(Full High Definition) streaming and data of up to 500 Mbps by connecting three UE devices are being conducted at 4.5 km distance as shown in Fig. 8, finally, we plan on demonstrating service scenarios for disaster situations. The results of this study are expected to contribute to the rapid provision of mobile communication infrastructure in the event of a disaster or accident in mountainous or remote areas.

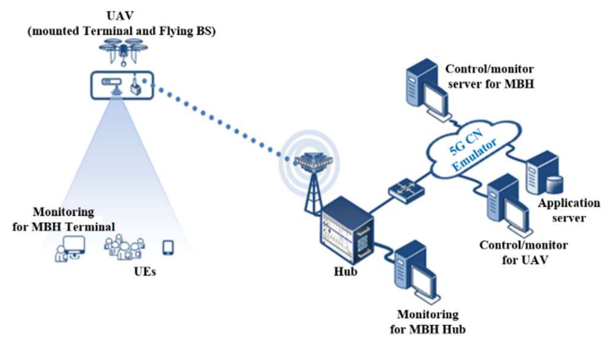

Fig. 8. MBH system integration P2P test

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