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Research Article

The QoS Indicators Analysis of Integrated EUHT Wireless Communication System Based on Urban Rail Transit in High-Speed Scenario

Xiaoxuan Wang [1], Hailin Jiang [2], Tao Tang [1], and Hongli Zhao [1]

[1] *State Key Laboratory of Rail Traffic Control and Safety, Beijing Jiaotong University, Beijing 100044, China*
[2] *National Engineering Research Center of Rail Transportation Operation and Control System, Beijing Jiaotong University, Beijing 100044, China*

Correspondence should be addressed to Xiaoxuan Wang; wangxiaoxuan@bjtu.edu.cn

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Nowadays, in urban rail transit systems, train wayside communication system uses Wireless Local Area Network (WLAN) as wireless technologies to achieve safety-related information exchange between trains and wayside equipment. However, according to the high speed mobility of trains and the limitations of frequency band, WLAN is unable to meet the demands of future intracity and intercity rail transit. And although the Time Division-Long Term Evolution (TD-LTE) technology has high performance compared with WLAN, only 20 MHz bandwidth can be used at most. Moreover, in high-speed scenario over 300 km/h, TD-LTE can hardly meet the future requirement as well. The equipment based on Enhanced Ultra High Throughput (EUHT) technology can achieve a better performance in high-speed scenario compared with WLAN and TD-LTE. Furthermore, it allows using the frequency resource flexibly based on 5.8 GHz, such as 20 MHz, 40 MHz, and 80 MHz. In this paper, we set up an EUHT wireless communication system for urban rail transit in high-speed scenario integrated all the traffics of it. An outdoor testing environment in Beijing-Tianjin High-speed Railway is set up to measure the performance of integrated EUHT wireless communication system based on urban rail transit. The communication delay, handoff latency, and throughput of this system are analyzed. Extensive testing results show that the Quality of Service (QoS) of the designed integrated EUHT wireless communication system satisfies the requirements of urban rail transit system in high-speed scenario. Moreover, compared with testing results of TD-LTE which we got before, the maximum handoff latency of safety-critical traffics can be decreased from 225 ms to 150 ms. The performance of throughput-critical traffics can achieve 2-way 2 Mbps CCTV and 1-way 8 Mbps PIS which are much better than 2-way 1 Mbps CCTV and 1-way 2 Mbps PIS in TD-LTE.

1. Introduction

With the rapid development of the city size, the urban rail transit becomes the main trip mode of human beings which could provide safe, punctual passenger services within urban areas and intercity. In order to release the traffic pressure in urban area, the transit speed and capacity need to be improved along with more and more urban population. So, an automated train control system called communication-based train control (CBTC), which uses high capacity and bidirectional train-wayside communication, becomes one of the key subsystems in urban rail transit systems to guarantee the safe operation of rail vehicles [1]. According to the open standards and available commercial-off-the-shelf equipment [2], the WLANs are often used as the train-wayside communication in urban rail transit, such as Singapore North-East Line from Alstom [3] and Beijing Metro Line 10 form Siemens. However, with the development of urban rail transit, such as high-speed operation and integrated services including CBTC information, train state monitor information, passenger information systems (PIS) video, closed-circuit television (CCTV) video, and emergency text, WLAN cannot meet the developed safety-critical and throughput-critical requirements of urban rail transit and QoS of wireless communication system due to increasing operation density.

Although TD-LTE obtains some improvement in communication performance comparing with WLAN, the performance of TD-LTE is degraded greatly in high-speed scenario around 300 km/h, such as reduced throughput and large communication delay [4]. Therefore, the existing technology can hardly guarantee the strict QoS requirements of urban rail transit systems in high-speed scenario over 300 km/h.

Hence, a new technology which can solve the problems in high-speed scenario needs to be sought. Fortunately, these problems can be addressed by a new technology named EUHT. EUHT is a novel wireless communication technology based on 802.11ac which can achieve the requirements of 5G [5]. The highest throughput of this system can reach 3.48 Gbps which is much larger than the TD-LTE. The analysis of throughput is described in Section 3. And the communication delay can be lower than 10 ms normally. Furthermore, other advantages of EUHT are set as follows:

(i) Frame length of EUHT can be configured according to different scenarios from 0.5 ms to 10 ms and EUHT designed configurable pilot for effective channel estimation for high speed scenario.

(ii) EUHT physical frame is the first to use the self-contained structure, that is, uplink and downlink resource allocation. downlink data transmission and the uplink acknowledgment transmission are completed in the same frame, which is considered to be one of the key technologies of 5G by Qualcomm. The self-contained frame structure can greatly reduce the system latency.

(iii) EUHT has designed a special sequence at the header of frame to enable the receiver to achieve a more efficient and reliable synchronization process. The receiver can perform frame detection, automatic gain control (AGC), and other operations based on the EUHT header without any other auxiliary synchronization sources (such as base station, GPS). Through the optimization design of the synchronization sequence, the receiver can achieve a reliable estimate of the large frequency deviation at low cost, thus greatly reducing the requirement of crystal performance to +/−20 ppm.

Due to these advantages, EUHT has a better performance than existing WLAN and TD-LTE technology in high-speed scenario up to 500 km/h.

At present, there are some researches about the communication system based on 802.111ac. Authors propose delayed dynamic bandwidth channel access scheme with virtual primary channel reservation in [6]. This scheme mitigates the performance bottleneck problem as well as a scalability problem. In [7], an antenna allocation scheme for a full-duplex communication is proposed in IEEE 802.11ac WLAN. A set of results from a performance evaluation study of wireless communication based on the IEEE 802.11ac standard are proposed to study the performances of IEEE 802.11ac communication system in [8]. These related works make some contributions on using the 802.11ac technology in public wireless communication networks, but they do not consider the integrated urban rail transit traffics in high-speed scenario.

Recently, substantial works have been done on the wireless communication issues in the railway environment. Authors of [9] use the cross layer Reliable Mobility Pattern Aware (RMPA) handover strategy to improve handover performance for broadband wireless communication in high-speed railway. Not only do He et al. in [10] test the broadband delay cluster performance at 2.4 GHz in subway tunnel, but also the analysis of the results are given. In [11], a field test has been done in Madrid subway to build the radio channel in tunnels at 2.4 GHz. The authors in [12] give us a cross-layer admission control scheme for high-speed railway communication system. Zhu et al. design a cross-layer handoff method for CBTC wireless communication system in [13].

Although these aforementioned works consider the CBTC performance under different railway wireless communication environment, few of them study the integrated urban rail transit traffics in the same environment. Moreover, the working frequency of related works is all based on 2.4 GHz or lower. There are few studies that consider the high working frequency communication system in high-speed scenario. In this paper, an integrated EUHT wireless communication system based on urban rail transit in high-speed scenario is designed, which works in the 5.8 GHz and includes all the traffics in CBTC systems.

In this paper, we firstly study the integrated EUHT wireless communication system based on urban rail transit in high-speed scenario, which works in the 5.8 GHz. Then, the theoretical calculation of communication delay without handoff, handoff latency, and throughput in EUHT wireless communication system based on urban rail transit are given. In order to get the real integrated EUHT wireless communication system performance, we set up an outdoor test scenario in Beijing-Tianjin High-Speed Railway. The test results show that the QoS performance of integrated EUHT wireless communication system based on urban rail transit not only satisfies the requirements of safety-critical traffics and throughput-critical traffics in high-speed scenario well, but also has greatly performance improvement comparing with TD-LTE system.

The remainder of this paper is organized as follows. Section 2 describes the integrated EUHT wireless communication system based on urban rail transit. In Section 3, the theoretical calculation of communication delay without handoff, handoff latency, and throughput are given. The test scenario in Beijing-Tianjin High-Speed Railway is introduced in Section 4. The the requirements of all the traffics in CBTC systems and test results are presented in Section 5. Finally, the conclusion is given.

2. The Integrated EUHT Wireless Communication System Based on Urban Rail Transit

As we can see in Figure 1, the integrated EUHT wireless communication system based on urban rail transit includes the

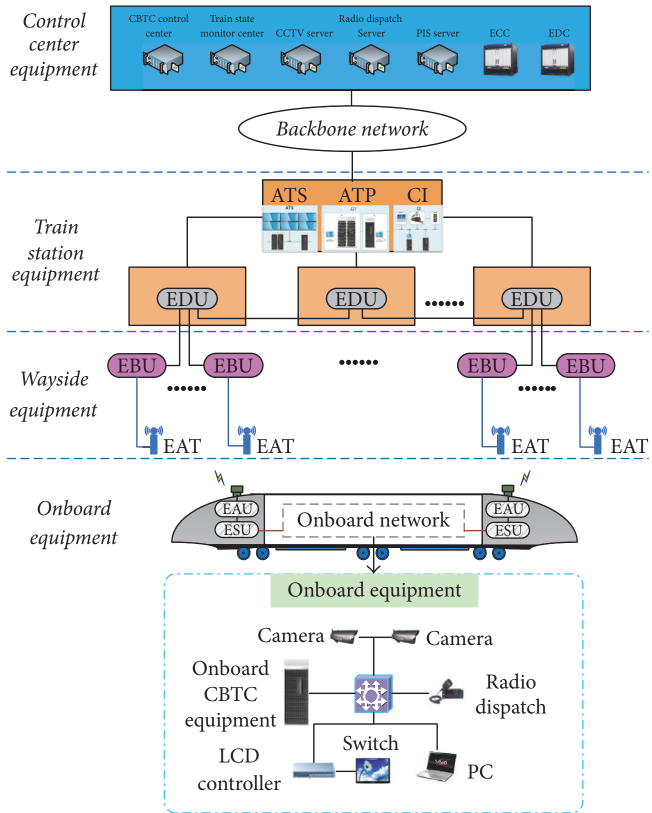

FIGURE 1: System architecture of EUHT wireless communication system based on urban rail transit.

control center subsystem, train station subsystem, trackside subsystem, and on-board subsystem.

The main task of control center subsystem is to use plenty of equipment such as EUHT Control Center (ECC), EUHT Data Center (EDC), CBTC control center, train state monitor center, CCTV server, radio dispatch server, and PIS server to control and manage the integrated CBTC system. Moreover, the backbone network is used to provide the wired communication link between control center subsystem and train station subsystem. As there are trains operating in the management area of any train station, the train station subsystem will charge the communication with all trains. The track-side subsystem consists of the EUHT Base-Station Unit (EBU) and EUHT Antenna (EAT). The EBU is the base station of the EUHT system and connected to EAT using optical fiber. The EAT exchanges the information with on-board subsystem through air interface. The on-board subsystem can be divided into EUHT Access Unit (EAU), EUHT Service Unit (ESU), PIS screens, CCTV cameras, onboard CBTC equipment, train radio dispatch equipment, and train state sensors. All these types of equipment are connected by switches.

Moreover, in order to verify whether the integrated EUHT wireless communication system can satisfy the QoS requirements of different traffics in urban rail transit, the theoretical analysis is shown in Section 3 and the details about test scenario and procedure are presented in Section 4.

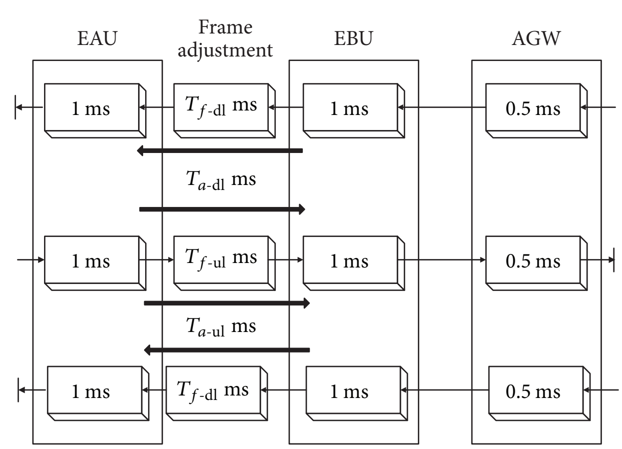

FIGURE 2: Transmission delay without handoff.

3. The Theoretical Analysis of Integrated EUHT Wireless Communication System

In this section, the theoretical analysis of communication delay, handoff latency, and throughput are analyzed.

3.1. Communication Delay without Handoff. The communication delay without handoff is shown in Figure 2, where $T_{a\text{-dl}}$ and $T_{a\text{-ul}}$ are the downlink and uplink average Automatic

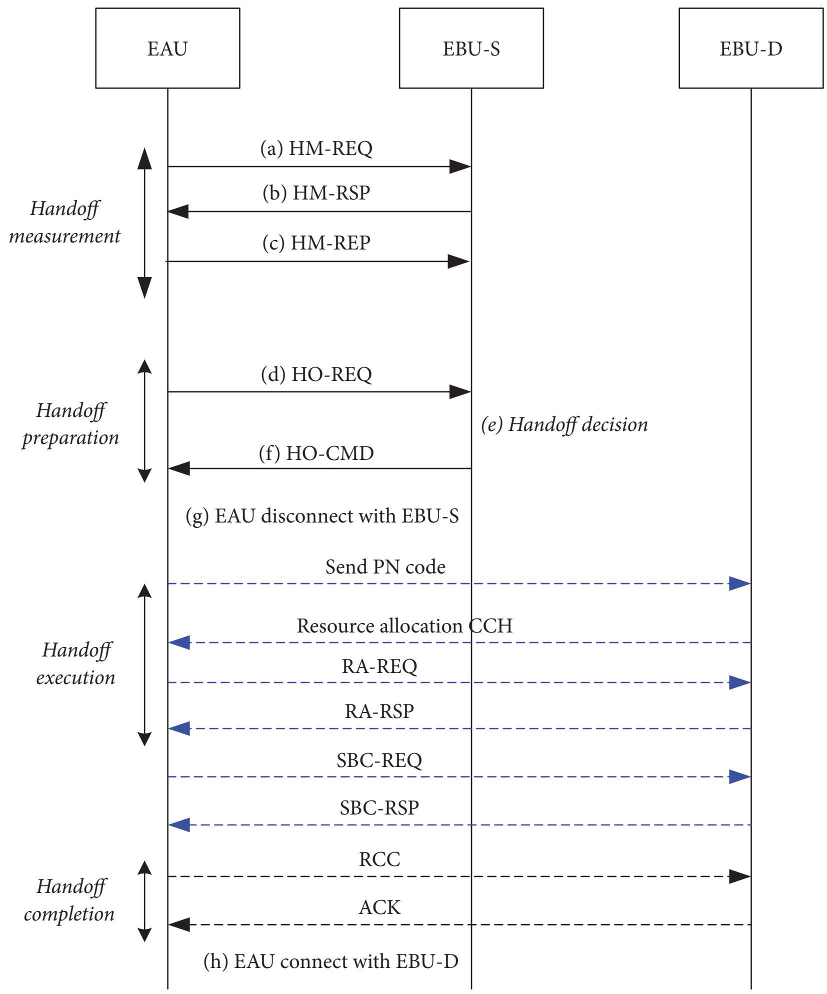

FIGURE 3: The handoff procedure of EUHT system.

Repeat Request-Round Trip Time (ARQ-RTT), respectively, and $T_{f\text{-dl}}$ and $T_{f\text{-ul}}$ are the average downlink and uplink frame adjustment time, respectively. With the analysis, the EUHT communication delay $\text{Comm}_{\text{delay}}$ is shown as follows:

$$\text{Comm}_{\text{delay}} = 1 + T_f + 1 + p * T_a, \quad (1)$$

where T_a and T_f are the average ARQ-RTT and frame adjustment time.

For our test, the theoretical calculation result with typical parameters of communication delay without handoff and retransmission is 4–8 ms. However, there is no ideal wireless environment of the high speed scenario around 300 km/h. Therefore, the real communication delay is greater than this result.

3.2. Handoff Latency. In order to make the best of the frequency resources and eliminate the intercell interference, the Interfrequency Handoff (IFHO) is selected by EUHT. The theoretical analysis of it is set below.

As is shown in Figure 3, the handoff procedure includes handoff measurement, handoff preparation, handoff execution, and handoff completion. The handoff measurement and preparation phases are performed without EBU-Destination (EBU-D), so that the messages in these two phases are directly exchanged among the EAU and the EBU-Service (EBU-S). At the beginning, when the Radio Signal Strength Indicator (RSSI) of EBU-S has been lower than the measurement threshold for a certain period set before, the EAU will send the Handoff Measurement Request (HM-REQ) to EBU-S to apply to starting the handoff measurement. Then, when the EAU receives the Handoff Measurement Response (HM-RSP), it will measure the RSSI of ESU-S and EBU-D and report the information to EBU-S using a Handoff Measurement Report (HM-REP). When RSSI of the EBU-D has been stronger than that of the EBU-S for a certain period, the EAU will decide to execute handoff and initiate the handoff preparation phase by sending a Handoff Request (HO-REQ) to the EBU-S. A HO-REQ includes EAU context information, QoS parameters, and the information of EBU-D candidates. EBU-S selects an EBU-D from the candidates and replies to the EAU with a Handoff Command (HO-CMD). Therefore, the latency for the handoff preparation phase is represented as follows:

$$T_{\text{HO-Prep}} = 2 * T_{\text{EAU-EBU-S}} + T_{\text{con1}} + T_{\text{dec1}}, \quad (2)$$

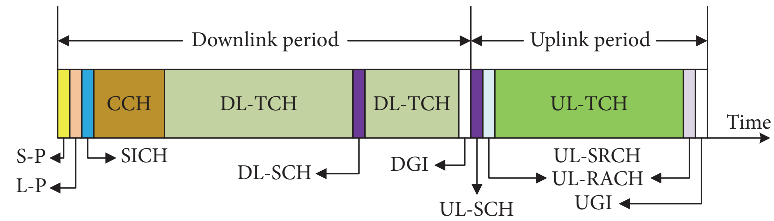

Figure 4: The frame structure of EUHT system.

where $T_{\text{EAU-EBU-S}}$ indicates the transmission delay between the EAU and EBU-S, T_{con1} is the latency of the measurement frequency conversion of EAU, and T_{dec1} represents the processing delay of the EBU-S, where T_{dec1} includes the processing of EBU-D selection and handoff decision.

The handoff execution phase is most critical on the handoff performance due to the handoff interruption/disconnection that occurs. The handoff execution phase is triggered by the EBU-S sending a HO-CMD to the EAU. Upon reception of the HO-CMD, the EAU disconnects from the EBU-S and changes the working frequency to be the same as EBU-D. Then, EAU sends Pseudo-Noise (PN) code to the assigned EBU-D through the Random Access Channel (RACH) and attempts to initiate the Random Access (RA) process. Next, As the EBU-D receives the PN code, it will allocate the Control Channel (CCH) resources for EAU and EAU will send RA-REQ message through the CCH. After receiving RA-REQ message and RAU MAC, the EBU-D will reply the RA-RSP to EAU. Then, in order to inform EAU capability parameters to EBU-D, EAU sends the Station Basic Capability (SBC-REQ) to EBU-D. As EBU-D receives the request, it will compare the capability parameters of EAU and EBU-D and reply the SBC-RSP which includes the capability parameters supported by EBU-D, the allocated EAU ID, and scheduling information to EAU. The latency for the handoff execution phase $T_{\text{HO-Exe}}$ is represented as

$$T_{\text{HO-Exe}} = 6 * T_{\text{EAU-EBU-D}} + T_{\text{con2}} + T_{\text{dec2}}, \tag{3}$$

where $T_{\text{EAU-EBU-S}}$ indicates the transmission delay between the EAU and EBU-D, T_{con1} is the latency of the measurement frequency conversion of EAU, and T_{dec1} represents the processing delay of the EBU-S, where T_{dec1} includes the processing of EBU-D selection and handoff decision.

During the handoff completion phase, when the EAU completes the RA process, the EAU informs the EBU-D by sending a RA Connection Complete (RCC) and the EBU-D replies to the EAU with an ACK. Finally, the EAU connects with EBU-D and transmits traffics through the Uplink/Downlink-Transmission Channel (UL/DL-TCH). The handoff completion latency is expressed as

$$T_{\text{HO-Comp}} = 2 * T_{\text{EAU-EBU-D}} + T_{\text{ACK}}, \tag{4}$$

where T_{ACK} is the processing delay of the EBU-D, which includes the processing of RRC and sending ACK.

So, the total handoff latency is presented below:

$$\begin{aligned} T_{\text{HO}} &= 2 * T_{\text{EAU-EBU-S}} + 8 * T_{\text{EAU-EBU-D}} + T_{\text{con1}} + T_{\text{con2}} \\ &\quad + T_{\text{dec1}} + T_{\text{dec2}} + T_{\text{ACK}}. \end{aligned} \tag{5}$$

In our test, given the typical parameters, the handoff latency without failure is about 20 ms, and with high speed scenario reaching up to 300 km/h and complex environment in the field test, the real handoff latency is greater than this.

3.3. Throughput. In this subsection, the throughput with overhead needs to be calculated at first. According to the characteristic of 802.11ac [14], the single cell throughput of EUHT system mainly depends on system bandwidth, length of OFDM symbol, and Modulation and Coding Scheme (MCS). Thus, the peak data rate is

$$\text{Throughput} = \frac{N_{\text{DBPS}}}{L}, \tag{6}$$

where N_{DBPS} is the number of data bits per symbol and L is the length of OFDM symbol, which is 14.4 μs. Moreover, N_{DBPS} is represented as

$$N_{\text{DBPS}} = N_{\text{BPSCS}} * R * N_{\text{SS}} * N_{\text{subcarrier}}, \tag{7}$$

where N_{BPSCS} indicates the modulation order, R is the code rate, N_{SS} represents the number of spatial streams, and $N_{\text{subcarrier}}$ is the number of subcarrier.

However, as is shown in Figure 4, the transmission frame of EUHT system consists of Short-Preamble (S-P), Long-Preamble (L-P), System Information Channel (SICH), CCH, UL/DL-TCH, Uplink/Downlink-Search Channel (UL/DL-SCH), Uplink/Downlink-Guard Interval (U/D-GI), Uplink-Scheduling Request Channel (UL-SRCH), and Uplink-RACH (UL-RACH). Because UL/DL-TCH can only be used to transmit train-ground communication traffics in one transmission frame, the uplink and downlink peak throughput need to be calculated with data bits of carrying without overhead which contains S/L-P overhead, SICH overhead, CCH overhead, UL/DL-SCH overhead, U/D-GI overhead, UL-SRCH overhead, UL-RACH overhead, and pilot frequency (PF) overhead, over a single wireless frame time.

In this paper, the length of one frame is 2 ms, which totally have 139 OFDM symbols and the UL/DL configuration is 1 : 1.2. Moreover, in our test, S/L-P, SICH, CCH, UL/DL-SCH, U/D-GI, UL-SRCH, UL-RACH, and PF occupy 2, 1, 4, 2, 8,

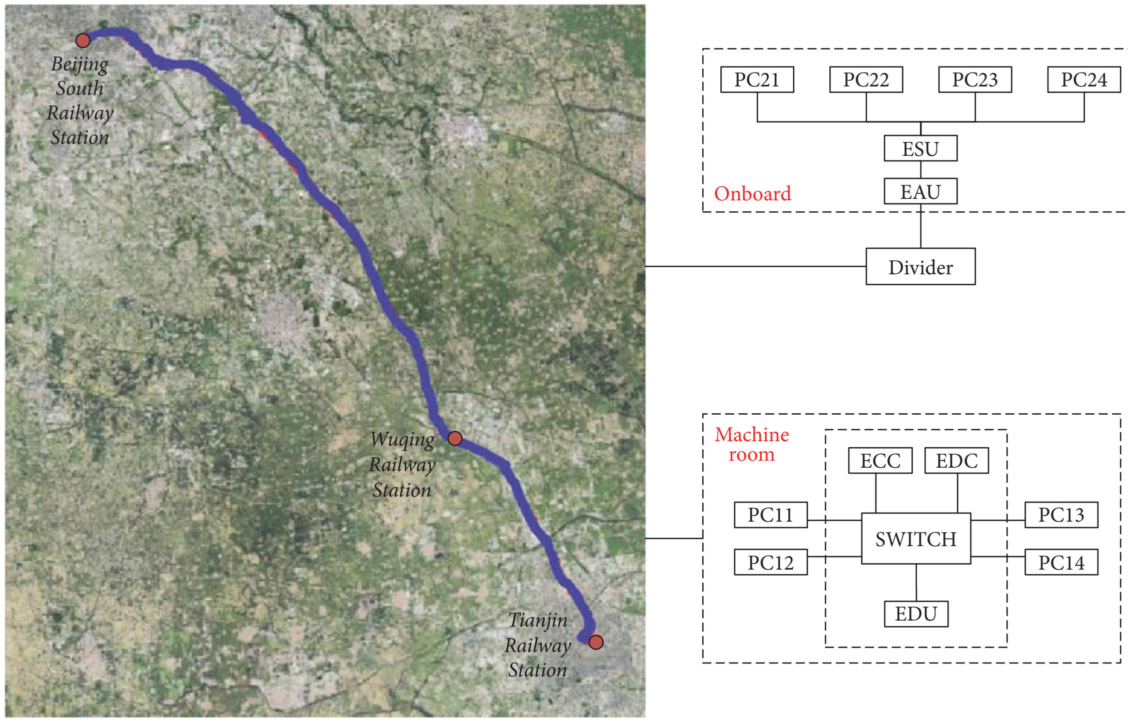

Figure 5: Test scenario of Beijing-Tianjin High-Speed Railway.

1, 2, and 9 OFDM symbols in one frame, respectively. So, the total overhead is 29 OFDM symbols in one frame. The total overhead of EUHT system in one frame is represented as

$$\begin{aligned}\mathrm{OH}_{\text{total}} = {} & \mathrm{OH}_{\text{S/L-P}} + \mathrm{OH}_{\text{SICH}} + \mathrm{OH}_{\text{CCH}} \\ & + \mathrm{OH}_{\text{UL/DL-SCH}} + \mathrm{OH}_{\text{U/D-GI}} + \mathrm{OH}_{\text{UL-SRCH}} \\ & + \mathrm{OH}_{\text{UL-RACH}} + \mathrm{OH}_{\text{PF}}.\end{aligned} \tag{8}$$

According to the analysis in this subsection, the downlink throughput of EUHT which does not include the overhead can be shown as

$$\text{Throughput}_{\text{DL}} = \text{Throughput} * \left(1 - \mathrm{OH}_{\text{total}}\right) * \frac{1.2}{2.2}. \tag{9}$$

The uplink throughput of EUHT without overhead can be written as

$$\text{Throughput}_{\text{UL}} = \text{Throughput} * \left(1 - \mathrm{OH}_{\text{total}}\right) * \frac{1}{2.2}. \tag{10}$$

For our field test, the bandwidth and maximum MCS are 80 MHz and 21. So, the maximum uplink and downlink throughput are 179.06 Mbps and 214.87 Mbps, respectively. But with high speed scenario reaching up to 300 km/h and complex environment in the field test, the real throughput is lower than this.

4. Test Scenario and Parameters

In this section, a field test scenario has been done in the Beijing-Tianjin High-Speed Railway to make the testing results more accurate than that in the laboratory. The test scenario is made up of three parts, obviously, the high-speed railway, machine room plant, and on-board space. As is shown in Figure 5, the Beijing-Tianjin High-Speed railway is located between Beijing and Tianjin and has a length of 115.2 km. It starts from Beijing South Railway Station and ends at Tianjin Railway Station by way of Wuqing Railway Station. The high-speed railway is made up of elevated railway except the area around railway station. So, in most area of the railway, there is no tall building which can affect the wireless transmission.

In this field test, in order to guarantee the Quality of Coverage (QoC), 109 EBUs are deployed along the railway in total. The distance between every two EBUs is about 1 km. So, the average RSSI received by onboard EAU is above −90 dBm which can meet the demand of urban rail transit wireless communication system. Moreover, every adjacent EBU works at different frequency point due to IFHO. Thus, to make the different traffics meet the QoS requirement described in Table 2, we allocate 160 MHz for the whole system. Half of the EBUs run in 5560 MHz–5640 MHz frequency band, and others run in 5725 MHz–5805 MHz frequency band. These two frequency bands are all possibly used for high-speed railway and urban rail transit system. Furthermore, because of less use of the frequency resources in 5.6 GHz–5.8 GHz, there is little wireless interference in this frequency band along the railway. So, the radio free wave is used in wireless communication system instead of leaky cable and leaky waveguide. What is more, Table 1 shows the other configurations of this test scenario.

Table 1: The configurations in Beijing-Tianjin High-Speed Railway.

Parameters	Value
EBU TX power	17 dBm
Track-side antenna gain	17 dB
Frequency point	120 (5600 MHz), 153 (5765 MHz)
Working bandwidth	80 MHz
Handoff model	IFHO (interfrequency handoff)
Wireless coverage	Free wave
Maximum train speed	300 km/h
Onboard antenna height	3 m
Track-side antenna height	5 m

As we can see in Figure 5, in the machine room, ECC is used for controlling the EUHT network. All the data are analyzed and processed by EDC. The EDU is connected to the wayside equipment with optical fiber. Four PCs are the analog servers for CBTC, train state monitor, PIS, CCTV, and emergency text, respectively. There are also EAU used for onboard network access and ESU used for analyzing and processing the data received by EAU, and four PCs connected with ESU are the analog on-board servers for CBTC, train state monitor, PIS, CCTV, and emergency text, respectively. Therefore, one-way CBTC traffic (200 Kbps), two-way CCTV traffic (2 Mbps), one-way PIS traffic (8 Mbps), one-way emergency text traffic (200 Kbps), and one-way train state monitor traffic (200 Kbps) are set to be transmitted between the PCs located at the machine room plant and on-board space.

The test tool used for test is Ixchariot software which can simulate different urban rail transit traffics. There are also different IP and traffics set for different pair of PCs. PC11 and PC21 are for CBTC traffic. PC12 and PC22 are for train state monitor traffic. PC13 and PC23 are for CCTV traffic. PC14 and PC24 are for PIS traffic and emergency text traffic.

5. Test Results and Discussions

As is shown in our previous works, the requirements of all the traffics in CBTC systems, such as communication delay, handoff latency, and throughput, are much stricter than that in public wireless networks. Thus, the communication delay and handoff latency must be stipulated less than the train-wayside communication period which is 200 ms in the traditional CBTC systems; otherwise the trains may experience some serious accidents [15]. Furthermore, the throughput is related to the performance of the high throughput demand traffics, such as PIS and CCTV.

Table 2 shows the different requirements for different traffics in integrated urban rail transit [16]. Therefore, in order to ensure the safe operation of the trains on the line, the transmission delay of safety-critical traffics, such as CBTC information, train state monitor, and emergency text, should be stipulated less than 150 ms through wireless and wired transmission whether the handoff happens or not. And the latency requirement of the other nonsafety critical traffics is less than 500 ms. In the requirement of throughput, at least 100 kbps should be allocated to CBTC traffic both in uplink and in downlink due to the bidirectional transmission of it. And according to the unidirectional transmission of train state monitor and emergency text, there are total 200 kbps allocated to these two traffics. Furthermore, the throughput-critical traffics, such as PIS and CCTV, are required 8 Mbps in downlink and 4 Mbps in uplink at least, respectively.

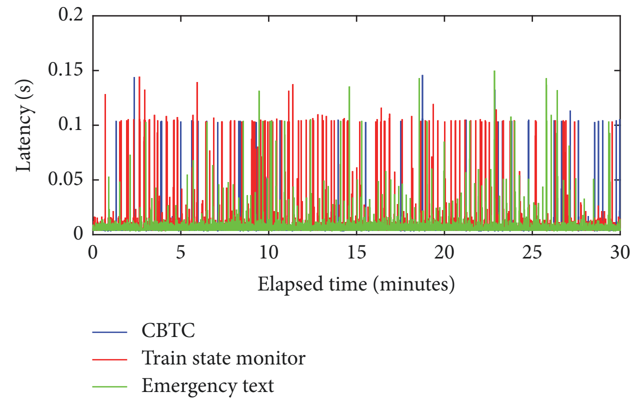

Figure 6: Test result of communication delay and handoff latency based on EUHT.

Therefore, in this section, some testing results about communication delay, handoff latency, and throughput are shown to describe whether the integrated EUHT system can satisfy the requirements of CBTC system in high-speed scenario firstly. As we know, the most important QoS parameter for safety critical traffics is transmission delay which include communication delay without handoff and handoff latency. Figure 6 shows the communication delay without handoff and the handoff latency performance for these traffics. As we can see, when handoff does not happen, the average communication delay without handoff is 5 ms, 5 ms, and 6 ms for CBTC, train state monitoring traffic, and emergency text, respectively. The maximum values are 33 ms, 55 ms, and 103 ms for them, respectively. Therefore, the communication delay without handoff of safety-critical traffics can satisfy the requirements shown in Table 2 very well in high-speed scenario.

Moreover, as is shown in Figure 6, comparing with the communication delay without handoff, the maximum handoff latency of CBTC, train state monitoring, and emergency text can reach 146 ms, 144 ms, and 150 ms. Even so, all the handoff latency still satisfy the requirement of CBTC safety critical traffics in high-speed scenario.

Figure 7 describes the throughput testing results of throughput critical traffics. In our test, 2-way CCTV analogue videos, 2 Mbps for each, and 1-way 8 Mbps PIS analogue video are transmitted in this integrated system. Thus, as is shown in Figure 7, because of the handoff, there are some fluctuations in the throughput results of CCTV and PIS, but the average value of CCTV and PIS all stabilize around the throughput requirements presented in Table 2.

Something needs to be pointed out; when handoff happens, the EAU will be disconnected with EBU. During this period, the data cannot transmit between EAU and EBU. As is shown in Figure 7, the throughput will be decreased during

Table 2: The requirement of different traffics in integrated urban rail transit.

Application	Throughput uplink	Throughput downlink	Delay	Handoff latency	Reliability
CBTC	100 kbps	100 kbps	150 ms	150 ms	High
Train state monitor	100 kbps	None	150 ms	150 ms	High
Emergency text	None	100 kbps	150 ms	150 ms	High
CCTV	4 Mbps	None	500 ms	500 ms	Medium
PIS	None	8 Mbps	500 ms	500 ms	Low

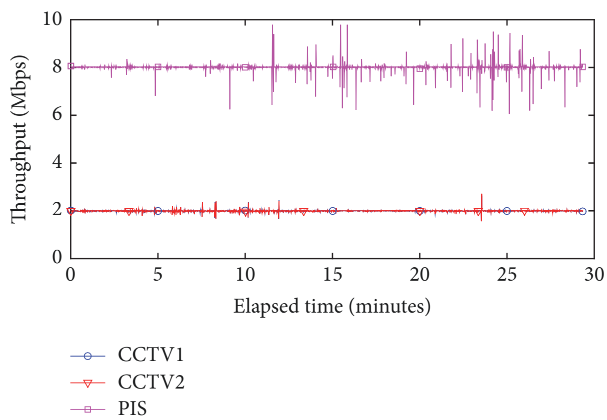

Figure 7: Test result of throughput of PIS and CCTV based on EUHT.

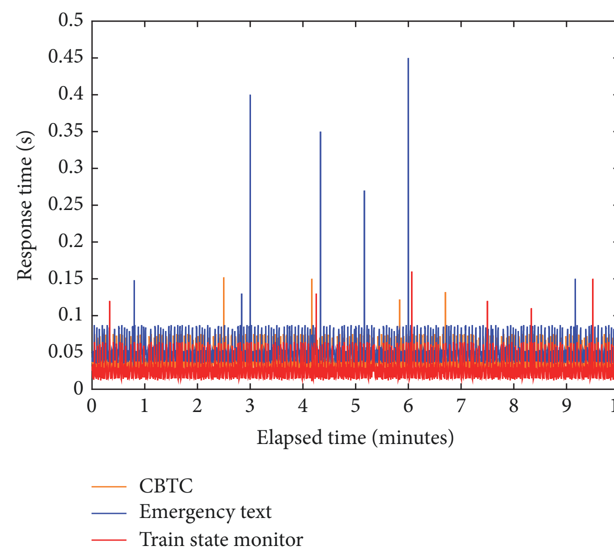

Figure 8: Test result of communication delay and handoff latency based on TD-LTE.

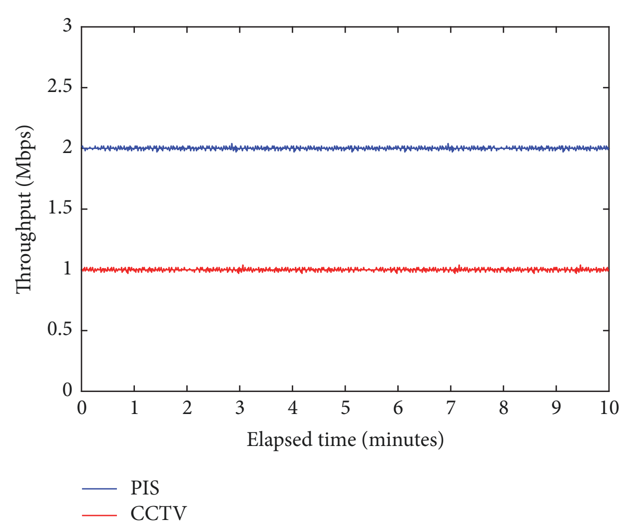

Figure 9: Test result of throughput of PIS and CCTV based on TD-LTE.

the handoff procedure. When the EAU completes the IFHO procedure, it connects with new EBU. The untransmission data will be transmitted in a short period. The throughput will be increased after the IFHO.

After the analysis of EUHT test results, we will show the comparison with the TD-LTE test results which we get in the Circular Railway Experiment Station of China Academy of Railway Sciences [16, 17]. Figures 8 and 9 are the test results of TD-LTE under the scenario with 200 km/h. As we can see, the maximum handoff latency of safety-critical traffics can reach 225 ms which is much larger than the requirement in Table 2. Moreover, the throughput results can only satisfy the requirements with 1-way 1 Mbps CCTV analogue videos and 1-way 2 Mbps PIS analogue video.

Therefore, compared with TD-LTE, the integrated EUHT wireless communication system can achieve better performance in safety-critical and throughput-critical traffics in high-speed scenario.

6. Conclusion

In this paper, we first detailed presented the structure of integrated EUHT wireless communication system based on urban rail transit and described all the traffics of traditional CBTC system. Then, the theoretical values including communication delay without handoff, handoff latency, and throughput were calculated in ideal condition. In order to get the real EUHT wireless communication system performance, an outdoor test scenario in Beijing-Tianjin High-Speed Railway was set up. Plenty of test results and the comparison with TD-LTE were shown in this paper. As we can see, not only can the QoS performance of integrated EUHT wireless communication system based on urban rail transit satisfy the requirement of safety critical traffics and throughput critical traffics in high-speed scenario well, but also it has better performance than TD-LTE in the high-speed scenario.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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