Performance Analysis of WAVE Communication for Emergency Broadcasting in Metro Environments

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***Abstract* - Recently, subway trains running underground have become an issue of passengers inconvenience and safety due to the failure of announcements in emergencies such as breakdown, train accidents and power outage in tunnels. Thus, there is a need to develop an emergency broadcasting system that can provide announcements to all passenger cars in any emergency on the railway route. WAVE communication technology based on IEEE 802.11p standard using 5.9GHz dedicated frequency band enables direct communication between terminals more than 200m without additional relay infrastructure. Especially, it is considered to be a suitable communication technology for the emergency broadcasting system of the urban subway, showing robust communication performance even in the tunnel area[1].**

In this paper, the applicability of various wireless communication technologies for the emergency broadcasting system through the measurement campaign was examined in Seoul metropolitan subway. The WAVE is a communication technology that can use 5.9GHz dedicated frequency band without charge and it is possible to communicate between terminals without the help of additional relay infrastructure. Especially, it confirms robust communication performance in a tunnel which is an operating environment of urban subway, and therefore, it is considered to be suitable as a communication method of a radio-connected emergency broadcasting system for an urban subway. It is also expected that it will be possible to develop the emergency broadcasting system capable of safe evacuation and emergency guidance to passengers using urban subway in any emergencies.

WAVE, IEEE802.11

I. Introduction

Recently, subway trains running underground have become an issue of passengers' inconvenience and safety due to the failure of announcements in emergencies such as breakdown, train accidents and power outage in tunnels. Thus, there is a need to develop an emergency broadcasting system that can provide announcements to all passenger cars in any emergency on the railway route.

However, although each urban railway operator is deploying an emergency broadcasting system using wireless communication techniques for the safety of passengers, the environmental conditions of underground tunnels makes it difficult to secure the performance of the wireless communication. In particular, the wireless communication environment of the Seoul metropolitan subway, South Korea's leading urban railway operator, includes more than 70 % of underground section. In addition, many frequencies and services exist, such as self-network wireless communication systems for safe operation of trains and mobile communication systems for the Internet services of passengers. This poor radio environment makes it difficult to deploy radio-based broadcasting systems to ensure the safety of passengers from train accidents.

Therefore, each urban railway operator in South Korea defines the following technical requirements for radio-connected emergency broadcasting system. Emergency broadcasting equipment shall provide for the announcement of safe evacuation of passengers in the event of an accident, such as a fire, collision, or power failure. Emergency broadcast equipment of all passenger cars must be capable of emergency calls with the cab or command office, so that emergency situations can be identified immediately. In addition, it should not interfere with other radio equipment installed on other trains or other external frequencies, and should operate independently from the radio communication network used in existing railways. In particular, robust communication performance should be ensured in tunnel areas, such as communication shadow zones. Finally, even if some of the passenger cars are lost during a train accident, the emergency broadcast equipment of all the remaining passenger cars must operate normally. For this, the direct communication distance between the terminals in the tunnel should be at least 200m without relay function.

II. Methods

Considering these requirements, it seems that LTE-R(Long Term Evolution-Railway)[2] or WAVE(Wireless Access in Vehicular Environments, ITS-G5)[3] using the dedicated band can be applied as candidates for radio-connected emergency broadcasting system. However, since the LTE-R

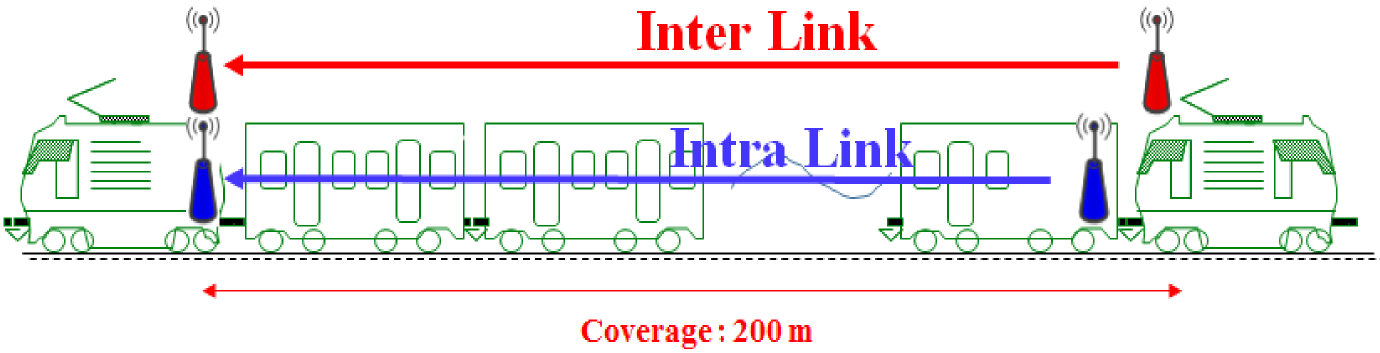


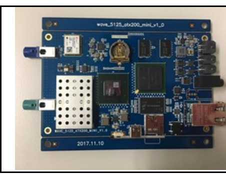
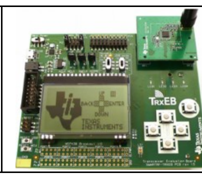
Figure 1. Communication Link

communication technology does not support direct communication between terminals, it is limited to apply to an emergency broadcasting system.

On the other hand, WAVE communication technology based on IEEE 802.11p standard using 5.9GHz dedicated frequency band enables direct communication between terminals more than 200m without additional relay infrastructure. Especially, it is considered to be a suitable communication technology for the emergency broadcasting system of the urban subway, showing robust communication performance even in the tunnel area. Therefore, in this paper, we evaluate the performance of WAVE technology, which is used as the next generation ITS communication technology, in actual urban railway service area. And then, the analysis of results will review its applicability as a radio communication technology for emergency broadcasting systems. In addition, SUB-1GHz communication technology, which is widely used in IoT(Internet of Thing) and smart metering in 920MHz ISM band, is also compared and analyzed. Table 1 shows differences within WAVE and SUB-1 wireless communication technologies.

Table 1. Setting Information of WAVE, SUB-1 GHz Modules

	WAVE	SUB-1 GHz
Frequency	5.9 GHz	920 MHz
Tx. Power	100 mW	16 mW
EIRP (Omni-directional Ant.)	29 dBm	16 dBm
EIRP (Directional Ant.)	33 dBm	26 dBm
Data Rate	3 Mbps	50 Kbps
Modulation	BPSK	FSK
Coding Rate	1/2	-
Packet Length	100 or 1000 Bytes	-
Sensitivity	-99 dBm	-109 dBm
Manufacturer	KETI	TI (CC1120)[4]

Module		

Seoul metropolitan subway in South Korea is the most widely used rapid railway transport system in the world, featuring ten subway lines. The system serves nearly ten million inhabitants of the capital city, Seoul, and the provinces of Gyeonggi, Incheon and northern Chungnam. The total length of the subway line is about 287km (179.4 miles) of which 70% is underground. The subway has 291 stations. This measurement campaign is conducted for the lines 2 and 3 of Seoul metropolitan subway, and it is performed from the subway depot to the main sections of lines 2 and 3 while going through the round trip. Figure 1 shows the line 2(green-line) and 3(yellow-line) of Seoul metropolitan subway. In particular, communication performance is evaluated by stopping for up to two minutes in areas with severe bending rates or communication shadow area. The speed of train is up to 80 km/h, and the measurement campaign runs continuously, including all test scenarios. Here, the evaluation criteria targets throughput, coverage, PER(Packet Error Rate), RSSI(Received Signal Strength Indicator), and the like.

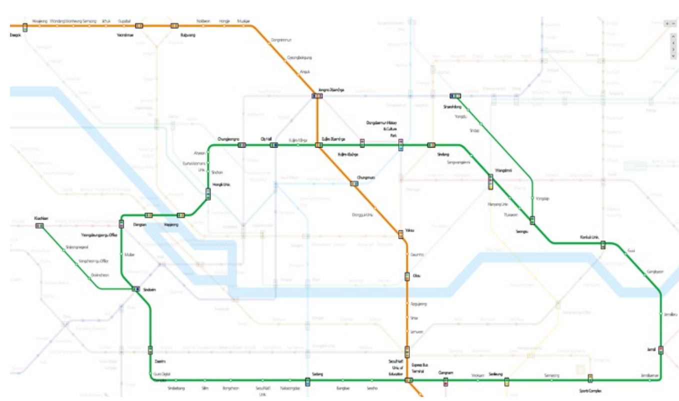


Figure 2. The line 2(green-line), 3(yellow-line) of Seoul metropolitan subway

Table 2. The Environment of Measurement campaign

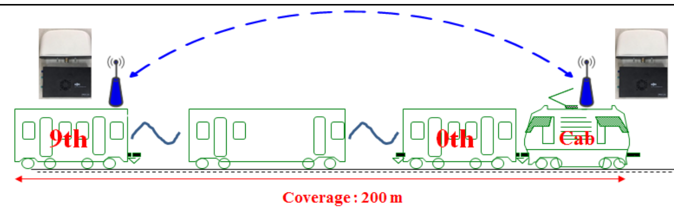
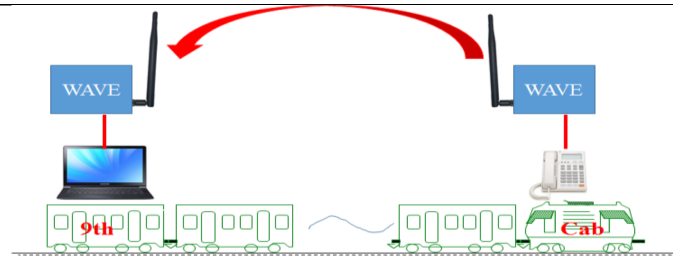
<table>
<tr><th>Scenario</th><th>Comm. Module</th><th>Evaluation Criteria</th><th>Test Environment</th></tr>
<tr><td rowspan="2">Intra-link Test</td><td>WAVE</td><td>PER, throughput, coverage, RSSI</td><td rowspan="2"></td></tr>
<tr><td>SUB-1 GHz</td><td>ER, coverage, RSSI, omni-directional/directional antenna</td></tr>
<tr><td rowspan="2">Inter-link Test</td><td>WAVE</td><td>PER, throughput, coverage, RSSI, omni-directional/directional antenna</td><td rowspan="2"></td></tr>
<tr><td>SUB-1 GHz</td><td>PER, coverage, RSSI</td></tr>
<tr><td>VoIP Test</td><td>WAVE</td><td>Audio quality</td><td></td></tr>
</table>

Table 3. Results of Measurement Campaign[5]

<table>
<tr><th colspan="3" rowspan="2">Scenario Information</th><th colspan="2">Throughput [Kbps]</th><th colspan="2">RSSI [dBm]</th><th colspan="2">Average PER [%]</th><th colspan="2">Coverage [m]</th></tr>
<tr><th>SUB1</th><th>WAVE</th><th>SUB1</th><th>WAVE</th><th>SUB1</th><th>WAVE</th><th>SUB1</th><th>WAVE</th></tr>
<tr><td rowspan="3">Line 3</td><td rowspan="2">Stop</td><td>Gupabal</td><td>-</td><td>2,279</td><td rowspan="2">-84</td><td>-65</td><td rowspan="2">43</td><td rowspan="3">0.8</td><td rowspan="6">Under 80</td><td rowspan="6">Over 200</td></tr>
<tr><td>Anguk</td><td>-</td><td>2,238</td><td>-82</td></tr>
<tr><td>Move</td><td>Jichuk ->Yaksu</td><td>-</td><td>2,182</td><td>-</td><td>-68</td><td>-</td></tr>
<tr><td rowspan="3">Line 2</td><td rowspan="2">Stop</td><td>City-hall</td><td>-</td><td>2,385</td><td rowspan="2">-61</td><td>-63</td><td rowspan="2">47</td><td rowspan="3">0.5</td></tr>
<tr><td>Hongik Univ.</td><td>-</td><td>2,400</td><td>-61</td></tr>
<tr><td>Move</td><td>Seungsu ->Sindorim</td><td>-</td><td>2,304</td><td>-</td><td>-66</td><td>-</td></tr>
</table>

III. Results

The measurement campaign is divided into two test types. Figure 2 represent two test types. First, the communication performance test was divided into intra-link and inter-link according to the location of the transmission and reception antennas on the train. First, the intra-link antenna is installed in the passenger car, and the inter-link antenna is mounted on the roof of train. In this measurement campaign, performance evaluation is carried out according to ground/underground tunnels, directional/omni-directional antenna types, communication shadow area, bending rate, and the movement of train conditions. Next, VoIP(Voice over IP, based G.729[6]) based voice call test was performed using WAVE communication technology. In this test, voice data is transmitted in an IP packet via a WAVE terminal, and the result is evaluated based on the quality of voice data received normally. Table 2 shows the verification environments for each test scenario.

The test results are shown in Table 3 based on the evaluation indexes. First, as a result of performing intra-link performance evaluation, the WAVE satisfied the communication distance defined in the requirement when the connection door is open. On the other hand, in case of SUB-1 GHz, the communication distance between the terminals was about 100m despite using the hyper-directional antenna with high gain. On the other hand, if the connection door is closed, both WAVE and SUB-1 cannot secure a communication distance of 200m. This is probably because of the shadowing effect of the train structure including the connecting door. Furthermore, when a passenger actually rides, the communication distance is expected to be further shortened due to the abrupt fluctuation of the radio-wave level and frequency interference.

Next, the performance evaluation result of the inter-link will be described. In the case of WAVE, all evaluation indexes were satisfied even in the case of running at maximum speed in a communication shadow area such as City-hall station and Shindorim station. In addition, the WAVE showed excellent communication performance results for the poor propagation environment of underground tunnels, such as the propagation interference due to the train moving in the opposite direction, as well as the section with a high bending rate. However, in case of SUB-1 GHz, it does not satisfy all the performance evaluation indexes. Especially, it can be confirmed that the RSSI value drops drastically when entering the tunnel.

III. Conclusions and Contributions

In this paper, the applicability of various wireless communication technologies for the emergency broadcasting system through the measurement campaign was examined in Seoul metropolitan subway. The WAVE is a communication technology that can use 5.9GHz dedicated frequency band without charge and it is possible to communicate between terminals without the help of additional relay infrastructure. Especially, it confirms robust communication performance in a tunnel which is an operating environment of urban subway, and therefore, it is considered to be suitable as a communication method of a radio-connected emergency broadcasting system for an urban subway. It is also expected that it will be possible to develop the emergency broadcasting system capable of safe evacuation and emergency guidance to passengers using urban subway in any emergencies.

Acknowledgment

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References

[1] Liu Y, Ghazal A, Wang C-X, et al. Channel measurements and models for high-speed train wireless communication systems in tunnel scenarios: a survey. SCI China Information Sciences, 2017.

[2] Fraga-Lamas, P.; Fernández-Caramés, T.M.; Castedo, L.Towards the Internet of Smart Trains: A Review on Industrial IoT-Connected Railways. Sensors 2017, 17, 1457.

[3] IEEE Computer Society (2012) IEEE standard for information technology-Telecommunication and information exchange between system - Local and metropolitan area networks-Specific requirements part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications.

[4] http://www.ti.com/product/CC1120/technicaldocuments

[5] P. Unterhuber, et al., "A Survey of Channel Measurements and Models for Current and Future Railway Communication Systems," Mobile Information Systems, vol. 2016, p. 14, 2016.

[6] https://www.avanzada7.com/en/productos/centralitas/centralitasaccesorios/g729codec