Comparative Analysis of WAVE and 5G Mobile Communication Performance for Advanced V2X Communication

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***Abstract*— In this paper, we investigate how the swift evolution of wireless communication technology has led to the rapid emergence of 5G mobile communication as a transformative force in the domain of Vehicle-to-Everything (V2X) communication. The study delves into assessing the influence of 5G's performance on the advancement of V2X communication. Additionally, we explore the trajectory of V2X communication's development, elucidating its objectives. Moreover, through the selection of fundamental test components related to V2X, generating scenarios, and conducting practical measurements, we confirm the most effective technology to be adopted in the V2X technological approach.**

***Keywords*—5G Communication Technology, V2X, WAVE**

I. Introduction

In the rapidly evolving modern transportation landscape, the quest for sustainable mobility solutions grounded in safety and efficiency is propelling innovation. Intelligent transport systems(ITS) stand as transformative forces that facilitate these changes, orchestrating interactions among vehicles, infrastructure, and even pedestrian safety. Furthermore, the adoption of high-performance wireless technology has gained significance as global automakers and regulators strive to establish an intelligent transportation communication framework for the comprehensive integration of connected vehicles. At the core of this transformative shift lies V2X communication. The concept of V2X communication emerged from the necessity to address diverse challenges arising from the escalating complexity of contemporary transportation networks. As urban areas grow denser and traffic congestion amplifies, existing transportation solutions encounter limitations in terms of both safety and efficiency. V2X communication seeks to surmount these constraints by fostering an interconnected environment where vehicles and transportation infrastructure engage in real-time collaboration. The vehicle to everything (V2X) concept uses the latest generation of information and communication technology to realize omnidirectional vehicle to vehicle (V2V), vehicle to infrastructure (V2I), vehicle to pedestrian (V2P), and vehicle to network/cloud(V2N/V2C) network connections [1] [2].

Furthermore, V2X communication has already exhibited its potential in augmenting road safety, streamlining traffic flow, and curbing carbon emissions. This potential is substantiated by research and standardization efforts spanning decades in the realms of wireless technology, safety enhancements, and traffic efficiency.

In this paper, we explore the potential opportunities arising from the convergence of 5G communication technologies to enhance the functionality of V2X communication. Additionally, we present performance test scenarios that are crucial for verification when integrating 5G communication technology into V2X solutions, by conducting a comprehensive comparison and analysis of the performance of V2X communication, WAVE communication, and 5G communication.

II. Proposed Scheme

The convergence of 5G communication technology and V2X communication presents a promising avenue to enhance and extend the capabilities of the V2X communication system. These opportunities are poised to usher in safer, more efficient, and highly intelligent transportation systems, thus facilitating autonomous driving within smart cities. Ensuring reliability and enhancements through performance evaluations from the developmental phase are pivotal for the optimized functioning of the 5G-based V2X communication system. Hence, this paper outlines a suitable test scenario for assessing the performance of the V2X communication system, followed by a performance comparison between the existing WAVE communication and the convergence communication of WAVE with 5G.

A. Communication Error Rate Measurement Scenarios

As a validation test to confirm the secure delivery proficiency of V2X messages, packets were dispatched from a stationary test support vehicle, and subsequently, the rates of packet reception and communication errors were gauged. For this examination, two V2X communication terminals were employed, and the communication error rate was determined by collecting message receptions from the receiving terminal across an average of 10,000 packet transmission and reception instances.

TABLE I. Communication Error Rate Test Conditions

Test Conditions	Value
Channel	178
Data Rate	6Mbps
TX Power	20dBm
Interval	10ms
Count	10,000

B. Communication Delay Measurement Scenarios

In order to assess the effectiveness of Communication Delay V2X messages, a series of WAVE/5G communication tests were conducted. In the WAVE communication delay test, a packet was transmitted from a designated test support vehicle (referred to as A) to another test support vehicle (referred to as B). After receiving the packet, vehicle B swiftly retransmitted it back to vehicle A, allowing for the measurement of the time required for both transmission and reception.

For this assessment, two vehicles and a V2X communication system were employed. The communication delay was calculated by averaging the results obtained during measurements while the two vehicles were stationary in close proximity. Additionally, the delay in 5G communication was validated through a ping test executed using a domestic server.

TABLE II. WAVE COMMUNICATION LATENCY MEASUREMENT TEST CONDITIONS

Test Conditions	Value
Channel	178
Data Rate	6Mbps
TX Power	20dBm
Interval	10ms
Packet Length	400

C. Multiple Communication Support Validation Scenarios

To validate the feasibility of transmitting V2X messages using WAVE, LTE, and 5G communication methods, a comprehensive test was conducted. This test encompassed multiple communication scenarios, involving the transmission of WSM (Wave Short Message) through the WAVE communication interface, as well as a ping test to the Google DNS address via the LTE/5G interface.

The experiment was executed separately for WAVE+LTE and WAVE+5G configurations. This thorough testing approach confirmed the capability of V2X communication through all three modes: WAVE, LTE, and 5G.

TABLE III. 5G COMMUNICATION LATENCY MEASUREMENT TEST CONDITIONS

Test Conditions	Value
Interval	1s
Packet Count	60
Packet Length	400

III. MEASUREMENT RESULT

To assess the efficacy of the proposed scenario, practical tests were conducted on actual roadways. The initial outcomes of the communication error rate test are presented as follows:

In order to assess the performance of the proposed scenario, practical tests were carried out on actual roads. Initially, during the communication error rate test, a total of 10,000 packets were transmitted at intervals of 10 ms, and all 10,000 packets were received successfully. This outcome verifies that the communication error rate was 0%.

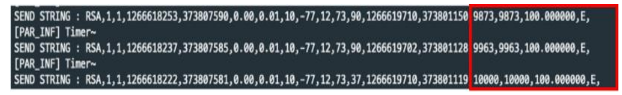

Fig. 1. Communication error rate transmission/reception log

Moving on to the measurement of communication delay times, the obtained results are as follows:

For WAVE communication, the average delay time was calculated using the formula (receiving time - transmitting time) / 2, resulting in a value of 1.9315 ms.

In contrast, 5G communication exhibited distinct delay characteristics:

Furthermore, the average communication delay time for 5G was determined to be 34.012 ms. It is apparent that the expected performance has not yet been achieved, likely due to significant interference originating from the surrounding environment. WAVE can prioritize messages, however, in dense and high load scenarios the the troughput is decreases while the delay is increasing significantly[7].

Packet count	Transmission time	Receiving time	Communication Latency
1	20220927.005218.873	20220927.005218.878	2.5
2	20220927.005218.973	20220927.005218.977	2
3	20220927.005219.073	20220927.005219.077	2
4	20220927.005219.173	20220927.005219.177	2
5	20220927.005219.273	20220927.005219.276	1.5
⋮			
996	20220927.005358.373	20220927.005358.377	2
997	20220927.005358.473	20220927.005358.477	2
998	20220927.005358.573	20220927.005358.577	2
999	20220927.005358.673	20220927.005358.677	2
1000	20220927.005358.773	20220927.005358.777	2

Fig. 2. WAVE Communication Delay Measurement log

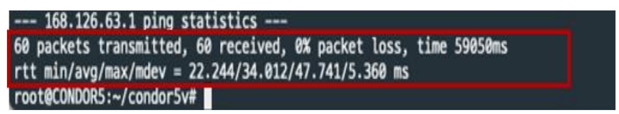

Fig. 3. 5G Communication Delay Measurement log

The outcome of the multi-communication support verification is as follows: The test results from the ping test demonstrated that both the WAVE+LTE and WAVE+5G configurations effectively support a total of two distinct types of communication.

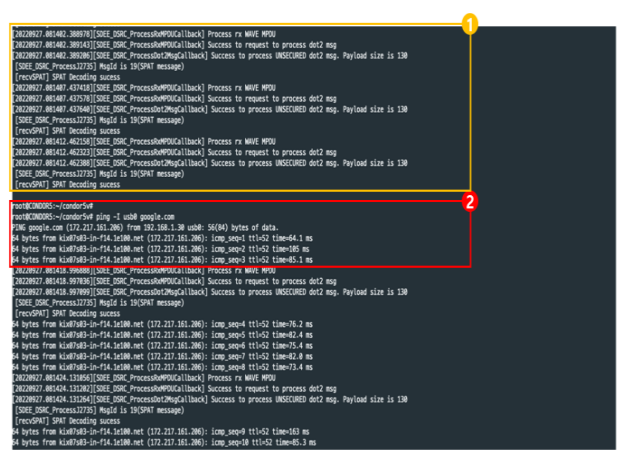

Fig. 4. WAVE+LTE Communication Support Log

In this context, "Number 1" refers to the reception log of the J2735 message set via WAVE communication, while "Number 2" signifies the log of the ping test conducted using the usb0 LTE communication interface with the Google DNS address. The results conclusively demonstrate that WAVE+LTE communication is indeed feasible.

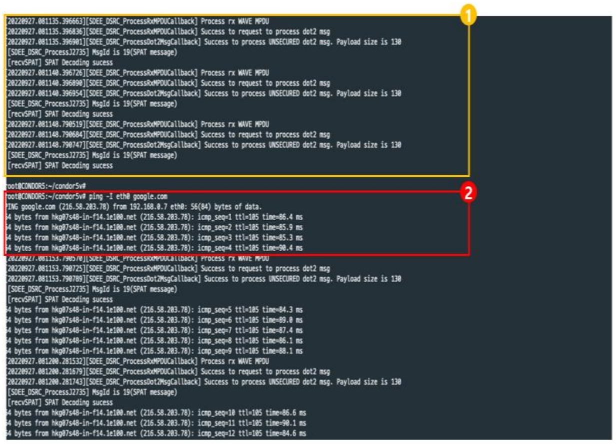

Fig. 5. WAVE+5G Communication Support Log

In this context, "Number 1" corresponds to the reception log of the J2735 message set achieved through WAVE communication, while "Number 2" pertains to the log of the ping test conducted using the Eth0 5G communication interface with the Google DNS address. The results provide conclusive evidence that WAVE+5G communication is indeed achievable.

IV. Conclusion

This paper is anticipated to establish the foundational framework for unveiling new horizons by harnessing the capabilities of 5G in the realm of intelligent transportation. Presently, a competition between C-V2X and WAVE (DSRC) persists to determine the V2X standard within the global V2X market. Notably, in 2020, the United States became the second country after China to embrace C-V2X as the sole standard, leading to the global standardization of C-V2X. Meanwhile, Korea is actively engaged in parallel research endeavors, navigating through the associated challenges. With the research findings of this paper juxtaposing the WAVE and 5G methodologies, the aspiration is that a superior standard technology will be embraced. This, in turn, is expected to pave the way for a safer, more efficient, and sustainable mobility solution to be realized through innovative advancements within the transportation system.

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