ISSN 1816-6075 (Print), 1818-0523 (Online)
Journal of System and Management Sciences
Vol.12 (2022) No.1, pp.241-253
DOI:10.33168/JSMS.2022.0117

High-Precision Position Protocol for Vehicle to Pedestrian using 5G Networks

Moon-ki Cho[1], Yang-ha Chun[2]

[1] Hanyang University, Sangnok-gu, Ansan, Gyeonggi-do, Korea.

[2] Yongin University, Cheoin-gu, Yongin-si, Gyeonggi-do, Korea.

yangha00@yongin.ac.kr

Abstract. In a 5G environment, it is possible to provide various services that have not been experienced before based on high-speed, ultra-low latency, high reliability, and ultra-connectivity infrastructure. In particular, intelligent convergence technology that provides high-quality services requires precise location measurement data with a very low error range. This includes high-precision data positioning in self-driving cars. Such a positioning data will enable driverless vehicles to run in a safer and more stable manner. At present, it is possible to measure the exact position of a vehicle through sensors and communication among cars using Global Positioning System (GPS) but it is still difficult to figure out the position between vehicles and pedestrians. Therefore, this paper proposes a communication protocol for Vehicle to Pedestrian (V2P) services using 5G networks. This protocol may identify distances between the vehicle and the pedestrian by using signals to identify distances between the vehicle and the repeater, the repeater and the pedestrian, and the pedestrian and the pedestrian. And if you calculate the direction angle using triangulation, you can know the exact location. Based on this location information, the relationship that predicts the time when an accident occurs according to the change in the speed of the vehicle and the walking speed of the pedestrian was analyzed through simulation. According to the simulation results, it was confirmed that the speed of the vehicle and the speed of the pedestrian had a great influence on the time when the accident occurred. Therefore, it also affects the time when a warning message or warning sound should be sent to both the vehicle and the pedestrian, which means that it can actively respond to collisions between the vehicle and the person. In particular, it will be more useful if it is used with sensors when it is difficult to secure visibility due to low-speed intersections, crossings, child protection areas, and fog, and accidents will be reduced if the above-mentioned cases are prevented. In summary, this paper developed a protocol for high-precision positioning of pedestrians to prevent emergencies that may occur with pedestrians in autonomous driving based on the 5G communication network reflecting the structure of SDN. In addition, the correlation between the speed of the vehicle and the time when an emergency situation occurs according to the change in the walking speed of the pedestrian was analyzed through a simulation.

Keywords: Position, Measurement, Vehicle to Everything(V2X), Autonomous driving, 5G.

1. Introduction

Today, mobile communications have evolved rapidly over decades, mainly focusing on coping with the burgeoning data demands from the 2G to 5G network technology (Bae KY, Cho MK, 2020). Autonomous driving, which has recently emerged as a social issue, calls for innovation in automotive technology as well as solving various technical problems related to 5G network technology. In addition, innovations in various business models such as HD Map, infotainment services including video calls, media streaming, in-vehicle payments, and robotic taxis and car sharing services that can be delivered through autonomous driving are expected to take place extensively. The mobility innovation that occurs through self-driving cars is expected to make many changes to the ecosystem of social infrastructure and related industries. There are still many technical challenges to overcome to realize self-driving cars that will have a great impact on society. Video recognition and machine learning technologies, which have drawn the most attention due to the rise of self-driving cars, are accelerate the realization of self-driving cars due to the rapid development of deep learning technologies, but they still lack much reliability and accuracy. Self-driving technology using artificial intelligence is difficult to make a self-driving car as a current technology because it does not collect and process information at the same level as humans. There is also a constraint that sensors fitted to self-driving vehicles cannot be utilized in areas beyond vision. Therefore, a method has recently been proposed to solve the limitation of self-driving reliability that cannot be increased only by autonomous driving technology using in-vehicle autonomous driving control by expanding the recognition range of autonomous vehicles using V2X communication and C-ITS.

Thus, in the late 2000s, efforts were made to receive information from outside the vehicle, including in-vehicle sensors to integrate with autonomous driving. Along with the development of automobile technology, various IT services are continuously upgraded into the transportation infrastructure used by automobiles to build an intelligent road infrastructure. Based on this market need, Wireless Access in Vehicle Environment (WAVE) communication systems defined by IEEE 802.11p wireless communication standards and IEEE 1609.2-4 protocol specifications emerged in the United States in 2010. WAVE communication system is a V2X communication technology designed to exchange information between vehicles and infrastructure, and between vehicles and vehicles through direct communication.

However, while both WAVE and C-V2X are capable of providing basic safety services as outlined in Table 1, it is difficult to meet the requirements of services requiring low-latency, high-capacity data transmission (Lee SW, Lee JS, 2020).

Table 1: Comparison of V2X technology WAVE and C-V2X

Sortation	WAVE	C-V2X
Data rate	UP to 27Mbps	Up to 100 Mbps
Reliability	98~99%	95~99%
Latency	<100ms	<100ms
Density	hundreds of units	hundreds of units
Mobility	Max. 200 km/h	320km
Coverage	250~300m	1km
V2I & V2N	possibility	Good

Based on these V2X communication technologies, existing intelligent transport systems and services (ITS) are being transformed into C-ITS. Starting with the Ministry of Land, Infrastructure and Transport's smart highway construction project in 2007, Korea has expanded the C-ITS to support autonomous driving by combining it with vehicle control technology. The C-ITS system can provide additional services such as intersection collision prevention, accident avoidance, pedestrian collision prevention, and emergency vehicle assistance, with expanded sensor concepts such as rapid collection of information from roads only. However, the current situation lacks the infrastructure of the network, and there are many problems such as hacking, risk of information leakage, and frequency interference. In particular, at this point when infrastructure construction of communication and transportation environments is not completed, it is difficult to use wireless communication reliably even with V2X technology, and significant load on the network is expected. Therefore, it is necessary to build on the Software Defined Network (SDN) structure, a network technology that can support high-quality service flexibility while efficiently responding to dynamic changes in traffic.

Among the various fields of V2X, safety is the most important in autonomous driving. In particular, the quality of data on the location between vehicles and pedestrians is a critical information. However, the Global Positioning System (GPS), which is currently being used for location measurements, has problems identifying the location of mobile devices. Accurate position measurement is difficult because errors of up to 50 meters occur. Therefore, in this paper, we propose a communication protocol for V2P using 5G networks. The protocol can prevent pedestrian collisions by reducing the error range by high-precision measurements of pedestrians' mobile locations. In other words, 5G networks allow pedestrians and vehicles to exchange information with each other, resulting in a warning system on both sides when the distance between the vehicle and the pedestrian is close. In particular, this service is thought to be useful if visibility is difficult due to low-speed intersections, crossings, child protection zones, and fogs, and accidents can be reduced if only the above-mentioned cases are prevented.

2. Literature review

2.1. 5G

2G mobile communication technology, which had implemented voice call and text service digitally, has continued to innovate as it evolved into 4G mobile communication technology. This is because higher performance is required in terms of latency and transmission capacity in various services such as games, medical, transportation, and national defense. In order to meet the demands of the times, the 3rd Generation Partnership Project (3GPP) specification 38 series announced the 5G NR(New Radio) standard in June 2018, and from 2019, major developed countries around the world, led by South Korea, began commercializing 5G services in earnest (Cho SJ, 2019).

The 5G network technology is an enhanced mobile broadband technology (eMBB) capable of over 20Gbps high-capacity transmission services and high-confidence/ultra-latency communication (URLLC) for remote control and control of autonomous vehicles or as part of its core technologies (Cho MK, Bae KY, 2021). Due to these technological characteristics, 5G networks can be used to facilitate rapid, ultra-low latency, high-capacity services such as VR technology, which is actively being studied, and hologram, which will become a reality in the near future. One technology for this is to separate one physical network into multiple logical virtual networks with network slicing, enabling each virtual network to implement independent services (Lee SI, Shin MK, 2016). At this point, each network slice is virtualized and acts like an independent network, so even if an error or problem occurs on a particular slice, it does not affect the other slice, enabling independent service implementation for each slice.

In conventional 4G networks, only voice communication and data communication were provided. At this time, some differentiated services were provided in the case of voice communication, but only the same service was provided in the case of data communication, increasing the transmission speed in all service areas. However, unlike in 4G networks, in 5G networks, network slicing technology has been applied, allowing differential service to be provided in the data domain according to service characteristics. For example, slices implementing self-driving services can implement services to minimize latency, and slices requiring high-quality video information to be transmitted using virtual reality (VR) technology can be implemented to enable high-capacity transmission. Since network slicing technology can guarantee independence between slices, it is mainly used in the private sector to implement customized services.

However, it is difficult to commercialize all services. This is because it does not provide all users with the required bandwidth, and 5G requires a number of base stations to prevent signal path loss because it has very short reach and objects such as trees and buildings cause severe signal interference (Sulyman Al et al., 2014). Therefore, a complete rollout of 5G can potentially take years.

2.2. SDN

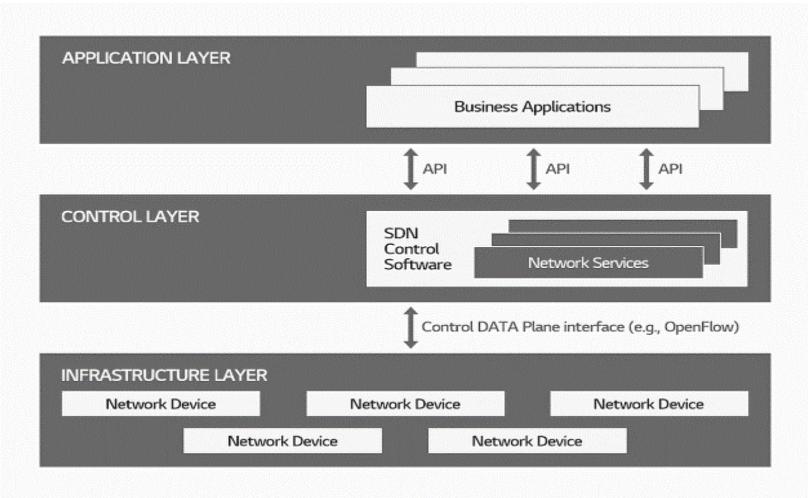
The SDN is separated into a control plane and a data plane in the network equipment (Kim JG, Kwon TW, 2020). disconnected control part is integrated into one controller and the controller controls each equipment that has only transmission functions excluding the control part. These next-generation data centers utilizing SDNs and The Cloud will be SDNs implemented as network fabrics. Network fabric refers to an environment in which services in a network are closely fused to related devices. This environment enables IT administrators to manage all network environments, such as I/O devices, routers, cloud services, network cards, switches, and more, from a single screen. In addition, network environments that were scattered in each area, such as servers and storage, are integrated and managed as one under the network fabric, eliminating boundaries between networks. Networks that are key to implementing IT infrastructure are vendor-specific user interfaces, network operating systems, and protocols, resulting in poor interoperability and operational efficiency. However, SDN is a bridge between software and networks that have evolved around hardware by separating the network control layer from the data layer.

Figure 1 expresses the typical logical structure of SDN (ONF, 2012). SDN has a structure in which all control functions of the network equipment are integrated into the SDN Controller. In other words, SDN Controller is the core of SDN, corresponding to the brain of the network, and all information is concentrated on SDN Controller, which performs a function of coordinating the entire network. In addition, we provide a South-bound API (API) to communicate with other network equipment, as well as a North-bound API (API) to enable communication with other operational tools and to develop applications of various functions (Kang SH et al., 2013). NFV and SDN, which introduced the concept of software in the hardware-centric network market, enabled the implementation of advanced infrastructure in environments such as 5G, cloud, virtual reality, and the Internet of Things.

2.3. V2X

Autonomous driving means driving a vehicle to a designated destination with a technology that assists or replaces the driver's operation through an algorithmized system. This autonomous driving requires communication with all applicable forms of road and vehicle. Vehicle to Everything (V2X) refers to the technology in which a vehicle communicates information through wired and wireless networks with objects built on infrastructure such as vehicles and roads, such as V2V (Vehicle to Vehicle), V2I (Vehicle to Nomadic Device) and V2P (Vehicle to Pedestrian (E. Uhlemann, 2017). The V2V communication supports smooth cooperative driving by exchanging information such as vehicle location, speed, and traffic conditions with nearby vehicles. It also assists the vehicle in safe driving by informing the driver of the vehicle in the event of a collision and lane change, and if blind spots appear or the weather causes poor front visibility. The V2P communication is a communication between a vehicle and a human smartphone, which can prevent accidents by exchanging information on nearby pedestrians. The V2I communication means communication between vehicle and infrastructure, and V2N communication means communication between vehicle and network.

Fig. 1: Structure of SDN[1]



The V2X communication is essential for stable and efficient autonomous driving. Therefore, V2X communication is expected to develop in conjunction with 5G services that feature high-speed, ultra-low latency, and ultra-connectedness. Figure 2 presents a V2X conceptual diagram.

3. Research method

3.1. V2P protocol model and procedure

This chapter proposes a protocol for high-precision positioning of pedestrians for V2P communication in a 5G communication network. When the location of the vehicle and pedestrian is checked in real time and entered within a range where a safety accident may occur, a safety message or a warning sound may be generated to

[1] https://blog.naver.com/hyun0524e/221838513601V2X

prevent the accident.

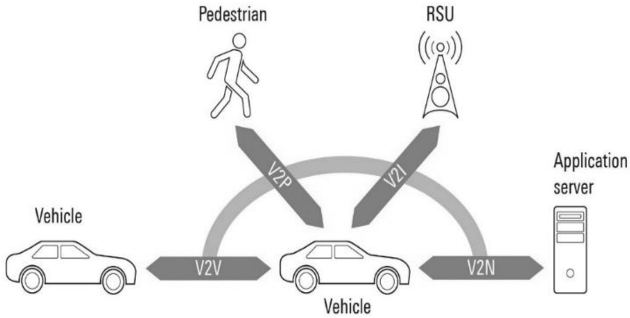


Fig. 2: V2X[2]

First, in order to measure the distance and direction between the vehicle and the pedestrian, the distance is calculated using the departure time and arrival time of the radio wave. However, using only the distance, pedestrians can exist at all the same distances of the 360-degree turning radius around the vehicle, making it impossible to specify the location. Therefore, the exact position of the pedestrian can be measured only when the angle is calculated using triangulation and the direction is known. This is expressed by the figure and equation as follows.

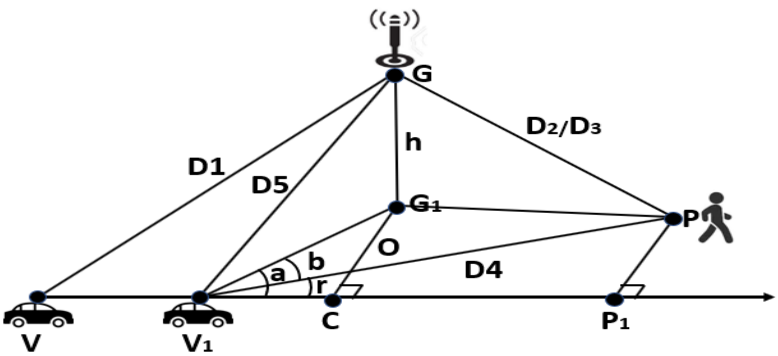


Fig. 3: Algorithms for mobile location identification

$$\text{Cos r} = \text{Cos (a-b)} = \text{Cos a} * \text{Cos b} + \text{Sin a} * \text{Sin b}$$

$$\text{Cos a}=\frac{V1C}{G1V1}=\frac{\sqrt{D5^2-h^2-O^2}}{\sqrt{D5^2-h^2}}$$

$$\text{Cos b}=\frac{D5^2-h^2+D4^2-D3^2+h^2}{2D4\sqrt{D5^2-h^2}}=\frac{D5^2+D4^2-D3^2}{2D4\sqrt{D5^2-h^2}}$$

V = Current location of the vehicle.

V_1 = Where the vehicle has moved

G = The location of the repeater.

[2] https://www.autoelectronics.co.kr/article/articleView.asp?idx=3449

G_1 = Ground position under the repeater
P = The current location of pedestrians
P_1 = Where the pedestrian has moved
D1 = T * (GAT - VDT) : distance between V and G
D2 = T * (PAT - GDT) : distance between G and P
D3 = T * (GAT - PDT): distance between P and G
D4 = T * (VAT - PDT): distance between P and V1
D5 = T * (VAT – GDT) : distance between G and V1
T : propagation speed
GAT : Reactor arrival time
GDT: Intermediate departure time
VAT : Vehicle Arrival Time
VDT: Vehicle Departure Time
PAT : Arrival time of person
PDT: Departure time for people
$\overline{G_1P} = \sqrt{D3^2 - h^2}$
$\overline{G_1V_1} = \sqrt{D5^2 - h^2}$
$\overline{V_1C} = \sqrt{D5^2 - h^2 - O^2}$

3.2. Protocol Procedures

Figure 4 represents the procedure in the protocol.

The vehicle (1) sends a Beacon signal and waits to receive the signal from the SDN repeater. (1) Beacon is a message periodically sent by the vehicle to determine the distance from the current vehicle to the repeater. This header consists of the following.

- Location of vehicle: Provide current vehicle location
- Vehicle Speed: Current Vehicle Speed
- Vehicle zone: the area where the current vehicle is located in the SDN structure network.
- IP address of the vehicle: IP address of the vehicle
- Vehicle Departure Time: Time the vehicle sent a Beacon signal

The repeater calculates the distance of D1 using the arrival time received the Beacon signal of (1). (2) Beacon is a message periodically sent to know the distance between pedestrians and pedestrians. (1) Add D1 distance to the header received from Beacon and the time at which the signal is generated from the SDN repeater.

- Location of vehicle: Provide current vehicle location
- Vehicle Speed: Current Vehicle Speed
- Vehicle zone: the area where the current vehicle is located in the SDN structure network.
- IP address of the vehicle: IP address of the vehicle
- Distance between vehicle and repeater: T * (GAT - VDT)

- Departure time from repeater: time the repeater sent Beacon signal

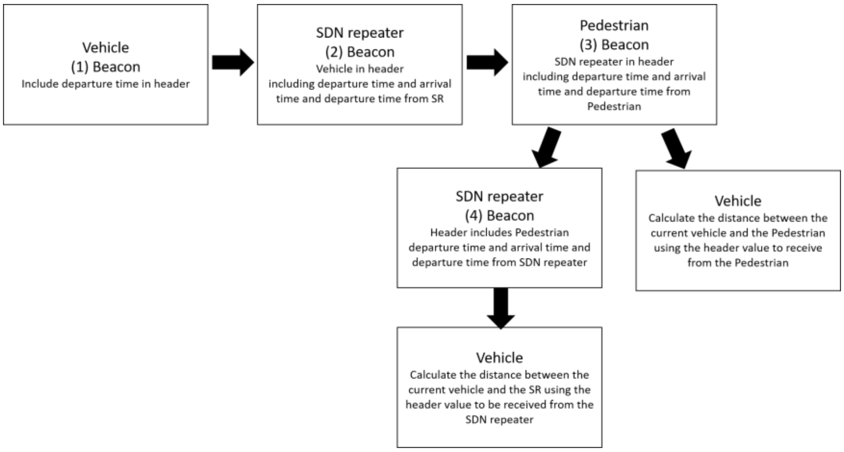


Fig. 4: V2P Protocol Procedure

Pedestrians who receive the Beacon signal in (2) calculate the distance D2 using the arrival time. (3) Beacon is a message sent periodically to know the distance between SDN repeater and pedestrian and pedestrian. (2) Add the distance information of D1 and D2 to the header received by Beacon and the time at which the signal is generated.

- Location of vehicle: Provide current vehicle location
- Vehicle Speed: Current Vehicle Speed
- Vehicle zone: the area where the current vehicle is located in the SDN structure network.
- IP address of the vehicle: IP address of the vehicle
- Distance between vehicle and repeater: T * (GAT - VDT)
- Distance between repeater and Mobile: T * (PAT - GDT)
- Departure time at Mobile: Time when Mobile sent Beacon signal

After receiving the Beacon signal of (3), calculate the distance D4 using the arrival time. At the same time, the SDN repeater, which received the Beacon signal of (3), calculates the distance of D3 using the arrival time. (4) Beacon is a message that is sent periodically to know the distance from the moving Vehicle 1, or Vehicle 1. (3) The header received from Beacon consists of adding the distance information of D1, D2 and D3 along with the time the signal is generated, and Vehicle1 received in this message can be obtained using the time received.

- Location of vehicle: Provide current vehicle location
- Vehicle Speed: Current Vehicle Speed
- Vehicle zone: the area where the current vehicle is located in the SDN structure network.
- IP address of the vehicle: IP address of the vehicle

- Distance between vehicle and repeater: T * (GAT - VDT)
- Distance between repeater and Mobile: T * (PAT - GDT)
- Distance between Mobile and repeater: T * (GAT - PDT)
- Departure time from repeater: time the repeater sent Beacon signal

Variable h is the vertical height from G (intermediate) to G1 (ground), and the distance from G1 to C at right angles to the road is also the fixed value.
The triangular measurements allow us to calculate the distance to V1G1, G1C, and V1C, which allows us to calculates the angle a of the right triangle. The distance to V1G1, G1P, and V1P can be calculated, where the b angle of the triangle can be calculated. Finally, the angle of r, which is a-b, can be obtained to accurately measure the direction and distance of the current pedestrian.

4. Research results

4.1. Conditions and consequences

The simulation condition assumes that the vehicle speed is between 10 and 200 km/h, and the pedestrian speed is between 1 and 20 km/h. The size of small cells in the 5G network was 100 m, assuming a 50 m radius of small cell environment. It is also assumed that the speed of 5G, up to 20Ghz, is sufficiently high to provide sufficient transmission speed to receive information about vehicles and pedestrians without errors. If the vehicle is said to move from V1 position to P1 position and from P1 position to P1, the simulation was carried out assuming that the distance of V1P1 is 100 m and the distance of PP1 is 10 m. The simulation results, in Figure 5, indicate the time it takes to travel 100 meters at the vehicle's speed. Figure 6 indicates the time it takes to travel 10 meters according to the walking speed of a pedestrian. Figure 7 indicates the time of accident at point P1 depending on the speed of the vehicle and the walking speed of the pedestrian. It can be seen that the pedestrian's walking speed is 1 km/h and the vehicle is 10 km/h, and it is encountered at point P1 after 36 seconds. If you look at the average walking speed of 4 km/h, you will encounter the vehicle at point P1 after 9 seconds if the vehicle speed is 40 km/h. The time taken depends on each speed, so if the vehicle and the person are warned by sending a warning message or a warning tone considering the speed, the emergency situation can be prevented.

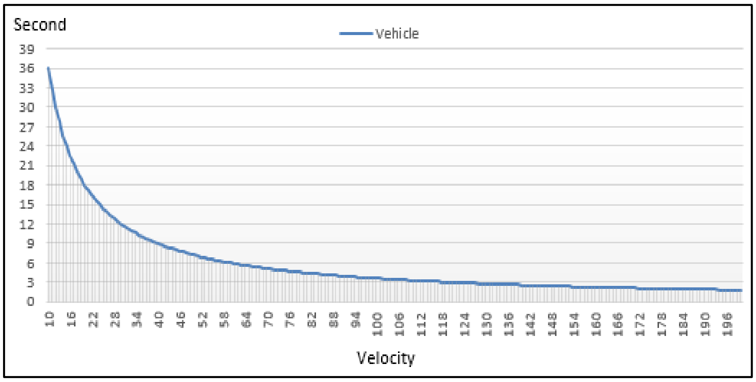


Fig. 5: P1 arrival time according to vehicle speed

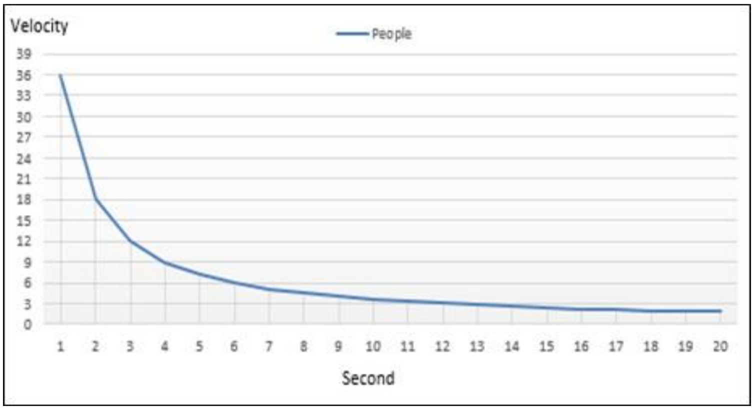


Fig. 6: P1 arrival time according to walking speed

5. Conclusion

The significance of this study is as follows. First, a protocol for high-precision positioning of pedestrians capable of overcoming the shortcomings of GPS was proposed based on the 5G communication network reflecting the structure of SDN. This protocol may identify distances between the vehicle and the pedestrian by using signals to identify distances between the vehicle and the repeater, the repeater and the pedestrian, and the pedestrian and the pedestrian. Also, it is possible to locate the exact position by calculating the direction angle using triangulation.

Secondly, based on this location information, the relationship that predicts the time when an accident occurs according to the change in the speed of the vehicle and the walking speed of the pedestrian was analyzed through simulation.

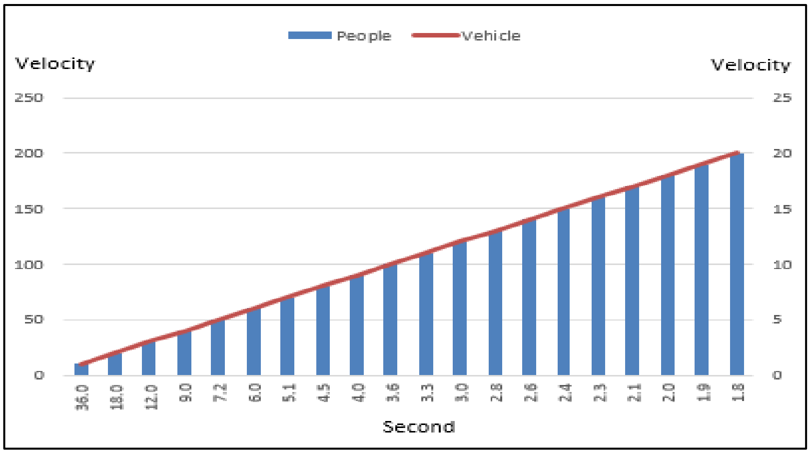


Fig. 7: P1 arrival time according to vehicle speed and walking speed

According to the simulation results, it was confirmed that the speed of the vehicle and the speed of the pedestrian had a great influence on the time when the accident occurred. Therefore, it also affects the time when a warning message or warning sound should be sent to both the vehicle and the pedestrian, which means that it can actively respond to collisions between the vehicle and the person.

In particular, it will be more useful if it is used with sensors when it is difficult to secure visibility due to low-speed intersections, crossings, child protection areas, and fog. Accidents will be reduced if the above-mentioned cases are prevented.

Looking at the limitations of this study, it was not possible to proceed by exchanging information between pedestrians and vehicles in the actual 5G network. In addition, it tracks changes in the location of vehicles and pedestrians to prepare for the risk of the accidents, which is affected by the distribution and quantity of vehicles and the distribution and quantity of pedestrians, but it did not reflect this. Therefore, in the future, research through actual implementation should be conducted in consideration of the above variables, and further research should be conducted to increase the accident prevention effect by finding various patterns using the analyzed data.

References

Bae KY, Cho MK. (2020). SANET-CC: Zone IP Allocation Protocol for Offshore Networks. *Journal of Intelligence and Information Systems*, 26(4), 87-109.

Cho SJ. (2019). The Status and Related Policy Trends of 5G Technology in Major Countries. NIPA Issue Report 2019, 27.

Cho MK, Bae KY. (2021). Edge to Edge Model and Delay Performance Evaluation for Autonomous Driving. *Journal of Intelligence and Information Systems*, 27(1), 191-207.

E. Uhlemann. (2017). Initial Steps Toward a Cellular Vehicle-to-Everything Standard. *IEEE Veh. Tech. Magazine*, 12(1), 14-19.

Kim JG, Kwon TW. (2020). Efficient Load Balancing Technique Considering Data Generation Form and Server Response Time in SDN. *The Journal of the Korea institute of electronic communication sciences*, 15(4), 679-686.

Kang SH., Kim YH., and Yang SH. (2013). SDN Core Technology and Evolutionary Outlook Analysis. *The Journal of The Korean Institute of Communication Sciences*, 30(3), 3-8.

Lee SW, and Lee JS. (2020). V2X image transfer protocol using 5G network. *The Journal of Korean Institute of Communications and Information Sciences*, 45(7), 1314-1321.

Lee SI, Shin MK. (2016). 5G Network Slicing Technology. *OSIA S&TR Journal*, 29(4).

ONF. (2012). Software-Defined Networking: The New Norm for Networks. ONF White Paper.

Sulyman Al, Nassar AT, Samimi MK, MacCartney Jr GR, Rappaport TS, Alsanie A, et al. Radio Propagation Path Loss Model for 5G Cellular Networks in the 28GHz and 38GHz Millimeter-Wave Bands. *Communications Magazine IEEE*. 52(9), 78-86.