Multi Agent Protocol for Cooperative Intersection Collision Avoidance System

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Abstract: One of the safety devices embedded in autonomous vehicles is the Intersection Collision Avoidance System (ICAS). In connected vehicle environment, ICAS can be developed into cooperative ICAS (CICAS), namely ICAS which has the ability to cooperate with other vehicles. CICAS can be realized using V2V communication, among others, with Wireless Access in Vehicular Environment (WAVE) technology. Data exchange between vehicles equipped with CICAS is governed by a special protocol. This paper presents the multi agent protocol for the purposes of the CICAS that are designed with the WAVE architecture environment. Simulation results demonstrate that the proposed protocol can improve the safety index of CICAS, length of intersection passing time, and total time for data exchange.

1 INTRODUCTION

The emergence of WAVE (Wireless Access in Vehicular Environments) encourages cooperative vehicle development, namely vehicles that can work together to improve safety and driving comfort. Through the WAVE between vehicles can communicate by exchanging important data such as the position, speed, and direction of the vehicle. These important data can then be used by drivers, Advanced Driver Assistance Systems (ADAS) (Basjaruddin, et al., 2018), or autonomous vehicles to choose the right maneuver so that the vehicle can avoid accidents and / or inconvenience.

Intersection Collision Avoidance System (ICAS) is a device that can help the driver to avoid accidents at intersection. ICAS uses sensors that can alert or braking vehicles suddenly when they will collide with other vehicles that will cross the intersection. Weakness of ICAS is a very limited operating area, when the vehicle is near the intersection. Sudden braking due to working ICAS certainly reduces passenger comfort.

The weakness of ICAS is overcome by the development of ICAS which has cooperative capability or known as Cooperative Intersection Collision Avoidance System (CICAS). CICAS allows multiple vehicles to work together when crossing the intersection so safety is guaranteed. The wider scope of the CICAS area is also useful for maintaining the comfort of passenger vehicles.

Research in the development of ICAS is carried out in (Basma, et al., 2011) , (Yang, et al., 2016), and (Elleuch, et al., 2017). Basma,et.al. (2011) develops the intersection collision avoidance (ICA) using telematics and wireless sensor networks (WSN) to monitor approaching traffic, detect possible collision, and then transfer information to drivers, warning them of high collision probability. Cooperative driving model for unsignalized intersections developed by Yang, et.al. (2016). In this research model was developed with reduplicate dynamic game theory. Elleuch, et al. (2017) study cooperative intersection collision avoidance based on V2V communication and real-time databases.

This paper will discuss the design of the protocol which serves to regulate the exchange of data between vehicles so that passing the intersection can be carried out safely. The protocol design was then tested with a simulator program developed with a cooperative multi agent system approach using BDI (belief desire intention) agents (Basjaruddin, et al., 2015).

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2 RESEARCH METHOD

In a connected vehicle environment between vehicles can exchange information on speed, acceleration, heading, position, and other attributes periodically every 20 ms. This information exchange can be done using WAVE technology. In addition to periodic data exchange, each vehicle can also exchange special data related to special conditions such as notifying that the vehicle will cross a intersection. Periodic data exchange is carried out by broadcast, while special data exchange is carried out by unicast. Unicast mode in WAVE can be used to support cooperative technology.

2.1 Wireless Access in Vehicular Environments

Wireless Access in Vehicular Environments (WAVE) is the operating mode used by IEEE 802.11 devices to work on Dedicated Short Range Communications (DSRC) bands. DSRC is the name of the 5.9 GHz band allocated for communication in the Intelligent Transportation System (ITS) (Weigle, 2008).

WAVE architecture can be seen in Figure 1. WAVE consists of 5 layers and refers to the OSI (Open Systems Interconnection) model that layer occupies layers 1-4 and a combination of layers 5, 6, and 7. At the top layer, the application layer, IPv6 supports access internet wirelessly via TCP (Transmission Control Protocol). IP-based communication allows vehicle users to access the internet from vehicles. Communication services that are not IP based are supported by the WAVE Short Message Protocol (WSMP). This communication service is generally used to develop active safety or ITS system (Baccelli, et al., 2010).

The WAVE architecture supports multi-channel operations that support control channels (CCH) and service channels (SCH) to transmit data in general and data in the form of WAVE Short Messages (WSMs). WSMs are transmitted to CCH, especially if they contain information related to safety, both are event-driven messages and beacon-driven messages. Even-driven messages will warn drivers of hazardous situations, such as accidents and generally have high priority. While beacon-driven messages will send traffic information in general and periodically, such as the location of other vehicles (Ghandour, et al., 2014). Even-driven messages are distributed unicastically, while beacon-driven messages are distributed broadly. Illustration the broadcast mode can be seen in Figure 2.

Data contained in broadcast messages can be seen in Table 1. This message is sent every 20 ms in 50 Hz data rate (Liu, 2012). The unicast mode is used for special purposes, namely for the delivery of messages related to safety. One example of the use of this mode for active safety device is sending safety messages in the Cooperative Overtaking System (CACC) (Ploeg, et al., 2011).

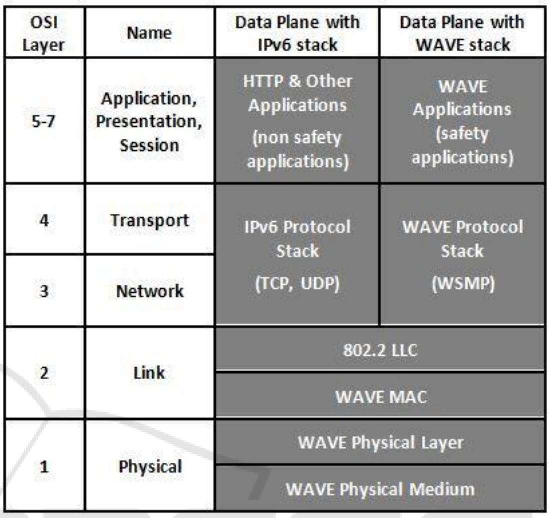

Figure 1: WAVE Architecture.

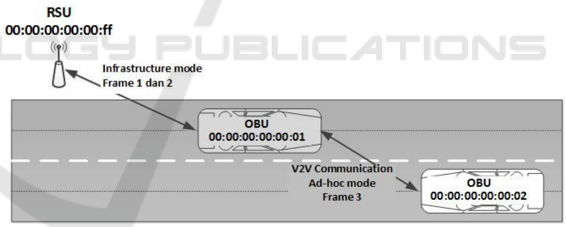

Figure 2: Sending messages in broadcast mode on WAVE.

Table 1: Format and Data Source.

Field	Format	Data source
Time	hhmmss.sss	GPS (UTC)
VID	00:00:00:00:00:00	MAC OBU
Position	xxx.xxxxxx:yyy.yyyyyy	GPS (DD format)
Speed	ss.ss	GPS (m/s)
Heading	hhh.hh	GPS (degree)
Attribute	vv	MAC OBU

WAVE specifications are as follows (Armstrong, n.d.):

- special frequency range in the 5.9 GHz band (5.860 GHz - 5.920 GHz)
- data rates of 6-27Mbits / s.

- 7 licensed channels
- Dual stack protocol namely Transmission Control Protocol (TCP) and WAVE Short Message Protocol (WSMP)
- support operations in range up to 1000 meters
- Supports high speed of the vehicle (~ 500 km / h relative speed)
- support communication on the On Board Unit (OBU) and Road Side Unit (RSU) and between OBU.
- Command-response & peer to peer

2.2 Intersection in Connected Vehicle Environment

Illustrations of intersection in connected vehicle environments can be seen in Figure 3 and Figure 4. Figure 3 shows how connected vehilce works at intersections with traffic lights (signalized intersection). Each vehicle has an On Board Unit (OBU) and a Road Side Unit (RSU) is installed in a traffic light system. In this situation there is an exchange of data between RSU and OBU also between OBU and other OBUs. At the intersection without traffic lights (unsignalized intersection) there is a data exchange between the OBU and OBUs in other vehicles. See Figure 4.

2.3 Cooperative Intersection Collision Avoidance System

CICAS is the development of ICAS. ICAS utilizes a proximity sensor so that it has weaknesses in the working range. Communication technology between vehicles enables the development of CICAS.

CICAS devices function to prevent collisions at intersection, especially at intersections without traffic lights. Between vehicles that have been equipped with OBU communication devices will exchange information such as speed, position, and direction periodically every 20 ms. This data exchange allows each vehicle to decide whether it is safe to cross the intersection or not. If one vehicle gets priority crossing then another vehicle will cooperatively maintain speed or reduce speed so that the vehicle that gets priority will be safe crossing the intersection.

In Figure 5 two vehicles with the same relative speed will cross the intersection in different directions. Vehicle A drove from West to East (W2E), while vehicle B was from South to North (S2N). The distance of vehicles A and B to the intersection is relatively the same, $d_A = d_B$. Similarly, the speed of the two vehicles is also relatively the same, namely $v_A = v_B$.

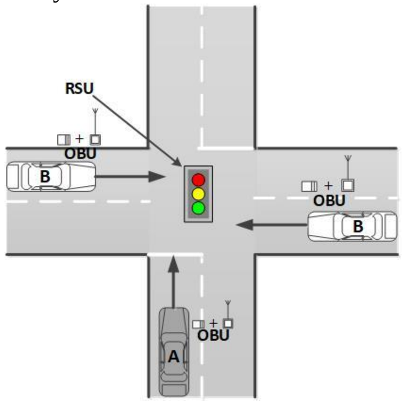

Figure 3: Signalized intersection in connected vehicle environment.

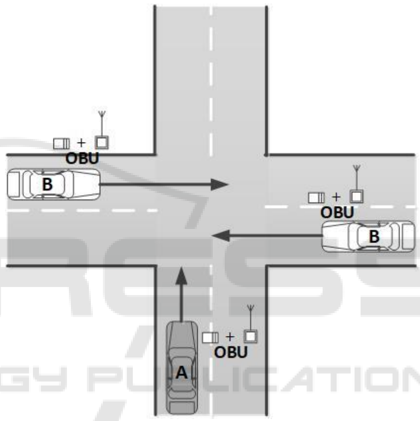

Figure 4: Unsignalized intersection in connected vehicle environment.

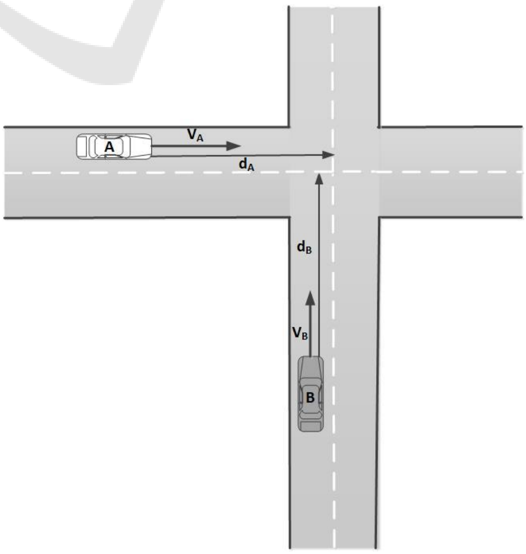

Figure 5: An illustration of the studied intersection.

2.4 Protocol Design

The function of the cooperative algorithm on a cooperative vehicle system is to regulate information exchange and cooperation mechanisms. Algorithms that function to regulate information exchange are known as application protocols. The developed protocol refers to protocol which is used in the cooperative multi agent system (CMAS) environment. The language commonly used in multi agent systems is agent communication language (ACL). Almost all ACLs are developed from the speech act theory, such as The Knowledge Query and Manipulation Language (KQML) and The Foundation for Intelligent Physical Agents (FIPA) ACL (Vasudevan, 1998). We have developed special ACL used in vehicle agents such as: maneuver = crossing, sequence = behind, and cooperative = slower. The design of the protocol for cooperative intersection crossing can be seen in Figure 6.

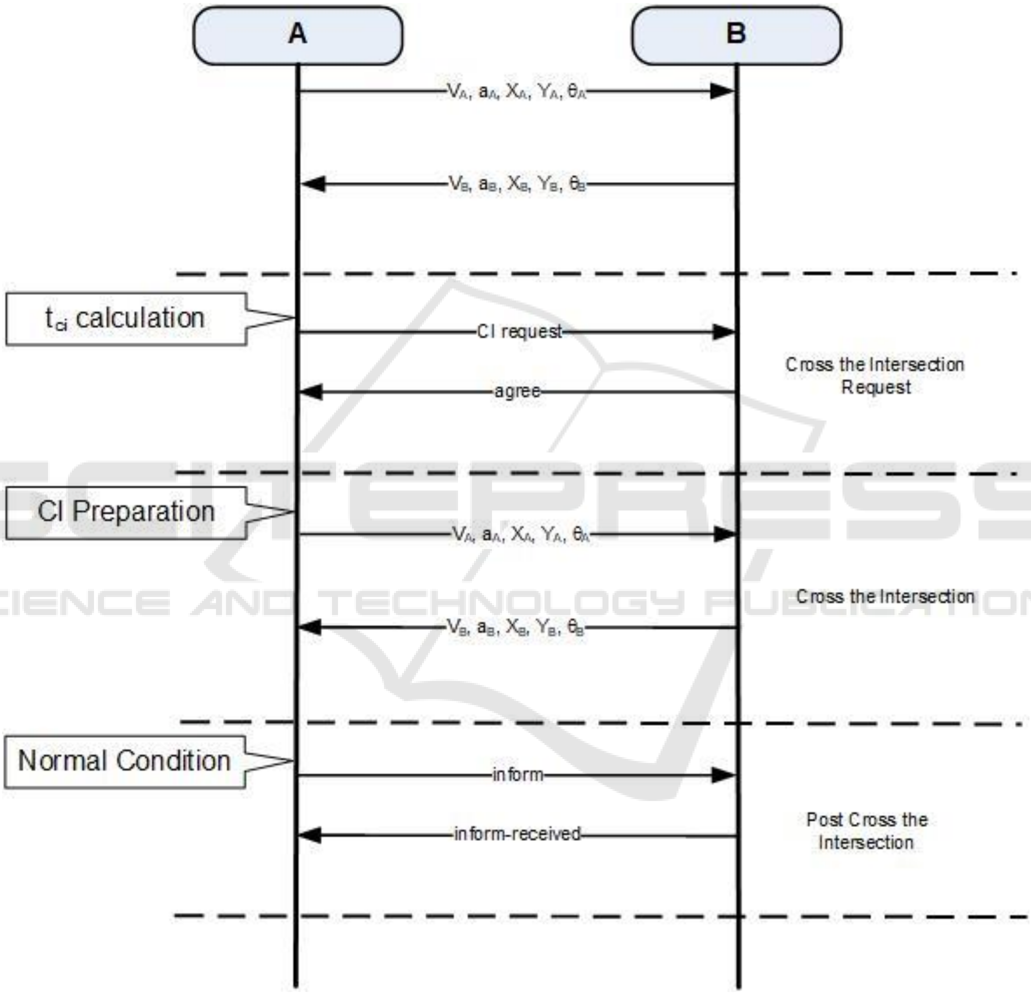

Figure 6: Protocol for cooperative overtaking.

An example of the use of ACL in the protocol that we have designed can be seen in Table 2. In proposed protocol the information exchange process devide into three phases, namely the Intersection Passing Request (IPR), Intersection Passing Action (IPA), and Intersection Passing Confirmation (IPC).

When two vehicles A and B approach the intersection the two vehicles periodically exchange information on speed, acceleration, position and direction. The distance to the intersection and the speed of the two vehicles are relatively the same. According to traffic rules in Indonesia vehicle A will get priority to cross the intersection compared to vehicle B. The first step A will send an IP request to B (IPR). Then B replies the request from A by sending ‘agree’ message. If ‘agree’ message has been received by A, then vehicle A will cross the intersection (IPA). After finishing crossing the intersection vehicle A will send a message to B containing information that A has finished crossing the intersection (IPC).

Table 2: An Example of The Use ACL in Protocol.

Sender	00:00:00:00:00:01
Receiver	00:00:00:00:00:02
Performative	request
Content	cooperation(intersectionPass)
ACL	*(request* *:sender (00:00:00:00:00:01)* *:receiver (00:00:00:00:00:02)* *:content* *"cooperation (*intersectionPass*)"* *:language fipa* *)*

3 RESULTS AND ANALYSIS

The developed protocol was tested using software developed using a multi agent system approach. Protocol performance is determined by calculating the Protocol Total Time (PTT) which means the entire time is used for data exchange for intersection crossing and is calculated by Eq. (1).

$$PTT = Nbc.Cbc + Nuc.Cuc \tag{1}$$

where,

Nbc : number of broadcast messages
Cbc : average message delivery time in broadcast communication
Nuc : number of unicast messages
Cuc : average message delivery time in unicast communication

Safety Index (SI) represents the percentage of simulation episodes that result in the success of the vehicle reaching the target without collision with other vehicles. The safety index is expressed in Eq. (2) (Yen & Pfluger, 1995), (Cang, 1999), and (Ngai & Yung, 2011).

$$\bar{c} = m/k \tag{2}$$

with m is the total simulation episode without collision and k is the number of all simulation episodes.

We define the Length of Intersection Passing Time (LIPT) is the time needed by the vehicle to cross the intersection from a distance of 100 meters to the intersection. If the vehicle speed is considered to be fixed at v m / s, LIPT is obtained as shown in Eq. (3)

$$LIPT = 100 / v \tag{3}$$

In the simulation program, LIPT is calculated from the time taken by the vehicle to cross the intersection from a distance of 100 m. This is to approach a more realistic situation because there is no guarantee that the speed of the vehicle will remain.

Protocol testing is done by observing PTT, SI, and LIPT for cooperative and non-cooperative situations. In non-cooperative situations it is assumed that the vehicle does not have ICAS devices and the algorithm works on autonomous vehicles.

The test results of the developed protocol can be seen in Table 2. It can be seen that in cooperative mode PTT is required which is greater than in non cooperative mode. This is because during cooperative mode there is unicast exchange of information between vehicle A and B. In cooperative mode there is a significant increase in the safety index. On the contrary LIPT dropped. More shorter LIPT amounts show smoother traffic and greater fuel savings can be obtained.

In Figure 7 can be seen a simulator view is created specifically to test the CICAS protocol.

Table 3: Simulation results.

Mode	PTT (µs)	SI (%)	LIPT (s)
Non Coop	82,2	47	5,2
Cooperative	99,4	99	4,5

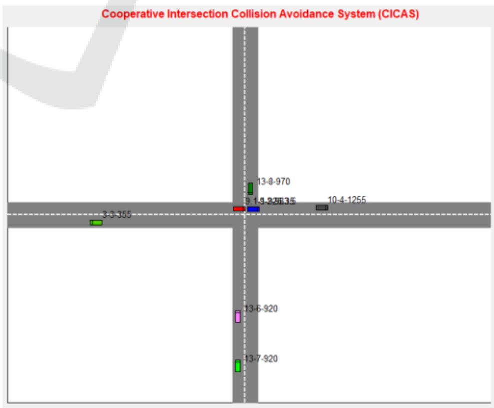

Figure 7: Display of the CICAS protocol simulator.

4 CONCLUSIONS

The cooperative properties used in ICAS can increase the safety index and shorten the passage time of crossing. Both parameters indicate that the use of communication between vehicles will improve the level of safety and smooth traffic.

REFERENCES

Armstrong, L., n.d. *Dedicated Short Range Communications at 5.9 GHz*, s.l.: s.n.

Baccelli, E., Clausen, T. & Wakikawa, R., 2010. *IPv6 Operation for WAVE - Wireless Access in Vehicular Environments.* Jersey City, NJ, s.n., pp. 160-165.

Basjaruddin, N. C., Kuspriyanto, Priyana, Y. & Husni, E., 2015. Modeling and simulation of overtaking maneuver using BDI agent. *International Review on Modelling and Simulations*, Vol 8(4), pp. 458-465.

Basjaruddin, N. C. et al., 2018. Hardware Simulation of Advanced Driver Assistance Systems Based on Fuzzy Logic. *International Review on Modelling and Simulations (I.RE.MO.S.)*, Vol 11(1), pp. 24-31.

Basma, F., Tachwali, Y. & Refai, H. H., 2011. *Intersection Collision Avoidance System Using Infrastructure Communication*. Washington, DC, USA, 14th International IEEE Conference on Intelligent Transportation Systems.

Cang, Y., 1999. *Behavior-based fuzzy navigation of mobile vehicle in unknown and dynamically changing environment.* Pokfulam: The University of Hong Kong (Pokfulam, Hong Kong).

Elleuch, I., Makni, A. & Bouaziz, R., 2017. *Cooperative Intersection Collision Avoidance Persistent System Based on V2V Communication and Real-Time Databases.* Hammamet , 14th International Conference on Computer Systems and Applications.

Ghandour, A., Di Felice, M., Artaila, H. & Bononib, L., 2014. Dissemination of Safety Messages in IEEE 802.11p/WAVE Vehicular Network: Analytical Study and Protocol Enhancements. *Pervasive and Mobile Computing*, Volume 11, pp. 3-18.

Liu, C., 2012. *Design of Efficient In-Network Data Processing and Dissemination for VANETs*, Houghton, Michigan: s.n.

Ngai, D. & Yung, N., 2011. A Multiple-Goal Reinforcement Learning Method for Complex Vehicle Overtaking Maneuvers. *IEEE Transactions on Intelligent Transportation Systems,*Vol 12(2).

Ploeg, J., Serrarens, A. F. & J.Heijenk, G., 2011. Connect & Drive: design and evaluation of cooperative adaptive cruise control for congestion reduction. *Journal of Modern Transportation*, September.19(3).

Vasudevan, V., 1998. Comparing Agent Communication Languages. *Object Services and Consulting, Inc.*

Weigle, M., 2008. *Standards: WAVE / DSRC / 802.11p*, s.l.: s.n.

Yang, Z., Huang, H., Yao, D. & Zhang, Y., 2016. *Cooperative Driving Model for Non-Signalized Intersections Based on Reduplicate Dynamic Game.* Rio de Janeiro, Brazil, 19th International Conference on Intelligent Transportation Systems (ITSC).

Yen, J. & Pfluger, N., 1995. A Fuzzy Logic Based Extension to Payton and Rosenblatt's Command Fusion Method for Mobile Robot Navigation. *IEEE Transactions on Systems, Man, and Cybernetics*, Vol 25, pp. 971-978.