Multi Agent Protocol for Cooperative Overtaking Assistance System

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Abstract—**Development of vehicular communication systems and multi agent system allow the use of active safety devices to have the ability cooperative like Cooperative Overtaking Assistance System (COAS). Some COASs on different vehicles can cooperate with a goal to improving safety and ride comfort indexes. COAS work by using the V2V communication which is WAVE (wireless access in vehicular environment). Data exchange between vehicles (agents) is governed by the multi agent protocol designed specifically for the implementation of the cooperative overtaking. This paper presents the multi agent protocol for the purposes of the COAS that are designed with the WAVE architecture environment. An efficient protocol shows that it can improve the safety index of COAS, length of overtaking time, and total time for data exchange.**

Keywords—cooperative overtaking assistance system, wireless access in vehicular environment, agent protocol

I. Introduction

Three important factors which are the cause of traffic accidents is human, vehicle, and environment. Human error is the main cause of 94% accidents that occur on the traffic [1]. The high number of traffic accidents caused by human error can be reduced by improving the vehicle technology. The use of safety technology and vehicle technology refinement in general proven can reduce the number of the accident [2].

By 2020 the Intelligent Driver Assistance Systems (IDAS) or Advanced Driver Assistance Systems (ADAS) who has the ability to be cooperative began to be used [3]. In the same year also estimated the driverless vehicle will start marketed [4]. Both of these technologies are expected to have a major contribution in reducing the number of casualties resulting from traffic accidents [5].

Cooperative IDAS can be realized due to the development of Vehicular Ad hoc Networks (VANET) that enables data exchange between vehicles every 20 ms with a radius of 1000 m [6]. VANET technologies allow a vehicle to infrastructure (V2I), vehicle to vehicle (V2V), and vehicle-to-pedestrian (V2P) communication. Much research has been conducted on VANET [7] and [8]. One of VANET architecture that is currently widely used in the development of IDAS is Wireless Access in Vehicular Environments (WAVE). Some WAVE researches has been conducted by [9] and [10].

II. Research Method

A multi-agent protocol has been developed is specifically to address cooperative overtaking process involving three agents (vehicles). The protocols were developed to obtain a more efficient protocol in time usage for communication among agents.

A. Overtaking in Connected Vehicles

Overtaking maneuver can be done by four techniques, namely accelerate/normal, flying, 2+, and piggy backing [11]. Phases of accelerative overtaking are approaching, tailgating, lane changing, passing, and lane returning. At the time of tailgating the driver will make the decision whether it can overtake or not. The calculation of the overtaking intention in the COAS will be done automatically by utilizing data from the sensor [12]. In COAS, the data for overtaking intention calculation are not only from the sensors, but also from a communication device which is the WAVE. The data exchanged via the WAVE are sourced from the GPS as illustrated in Fig. 1.

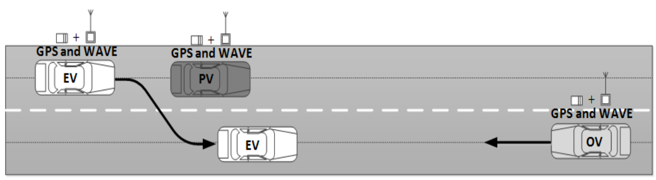

Fig. 1. Illustration of overtaking in connected vehicle environment

Through broadcast mode of WAVE, the vehicles are exchanging information containing: a vehicle ID, position, speed, acceleration, direction, and type of vehicle. Based on these data, the EV vehicle can calculate overtaking intention. If the value of overtaking intention is 1 the EV will overtake, but if the value is 0 then the EV will continue tailgating until there is a chance of overtaking.

B. Cooperative Overtaking

Cooperative overtaking is overtaking which is conducted through the mechanism of cooperation among several vehicles with the aim of improving the safety and ride comfort. Illustration of cooperative overtaking on the bidirectional road can be seen in Fig. 2. Ego Vehicle (EV) is the overtaker vehicle, Partner Vehicle (PV) is an overtaken vehicle, and Obstacle/Oncoming Vehicle (OV) is a vehicle coming from the opposite direction.

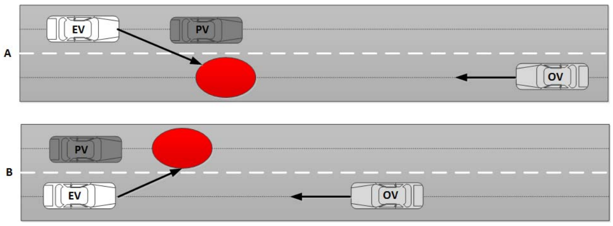

Fig. 2. Overtaking on bidirectional road

Figure 2(A) shows when the EV has decided to overtake the PV, then the EV starts lane changing, but the OV increase speed. If the increased Speed of the OV is not taken into account when calculating the overtaking intention, the EV can be failed to overtake and collided with OV or PV. Through the cooperation mechanism, the EV can request to the OV to maintain or reduce speed so that the EV is able to overtake PV safely.

In Figure 2(B) shows the situation when the EV is going to go back to the original lane. At the time when the EV is passing by the PV, the PV may increase the speed. If this situation is not taken into account when calculating the overtaking intention by the EV, the EV can be failed back to the original lane because it is obstructed by the PV and the EV could be colliding with the OV. The mechanism of cooperation can address this issue by the asking the PV not to add the speed so that the EV can go back to the original lane safely without colliding with the OV.

Cooperation between vehicles in an overtaking process can be done at the calculation of the overtaking intention or when the overtaking maneuver is executed [13]. In this study, we designed a protocol that is used during the execution of the overtaking maneuver.

C. Message Spreading through WAVE

The dissemination of the message in WAVE is done in two modes, namely a broadcasting mode and a unicasting mode. In the broadcasting mode, the delivery of traffic information in general will be periodically, such as the location of other vehicles [14]. Illustration of the broadcasting mode can be seen in Fig. 3 [15].

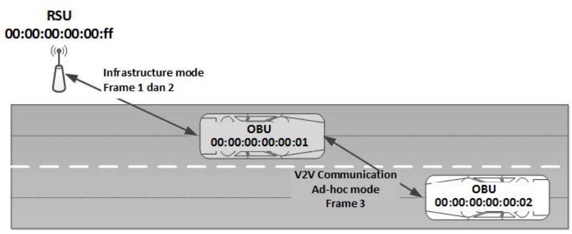

Fig. 3. Broadcast mode in WAVE

In broadcast mode the message contains information as shown in the Table I. This message is sent every 20 ms in 50 Hz data rate [16]. 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 Adaptive Cruise Control (CACC) [17].

TABLE I 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

D. Protocol Design

The protocol was designed referring to the protocol which is used in the cooperative multi agent system (CMAS) environment. In the CMAS environment, the agents communicate using a language known as an 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 [18]. We have developed special predicates and arguments used in vehicle agents such as: maneuver=passing, sequence=behind, and cooperative=slower. The design of the protocol for cooperative overtaking can be seen in Fig 4.

In conventional protocol, the EV will go back into the original lane after the PV and OV agrees to keep the speed. The situation is becoming very dangerous when there is a delay in communications so that the EV will be late return to the lane and very likely collided with the OV. In efficient protocol, the EV is allowed to be back into the original lane if the condition already permits, even the approval messages from PV and OV are not yet accepted by EV.

An example of the use of ACL in the protocol that we have designed can be seen in Table II.

TABLE II 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(keepSpeed)
ACL	*(request* *:sender (00:00:00:00:00:01)* *:receiver (00:00:00:00:00:02)* *:content* *"cooperation (keepSpeed)"* *:language fipa* *)*

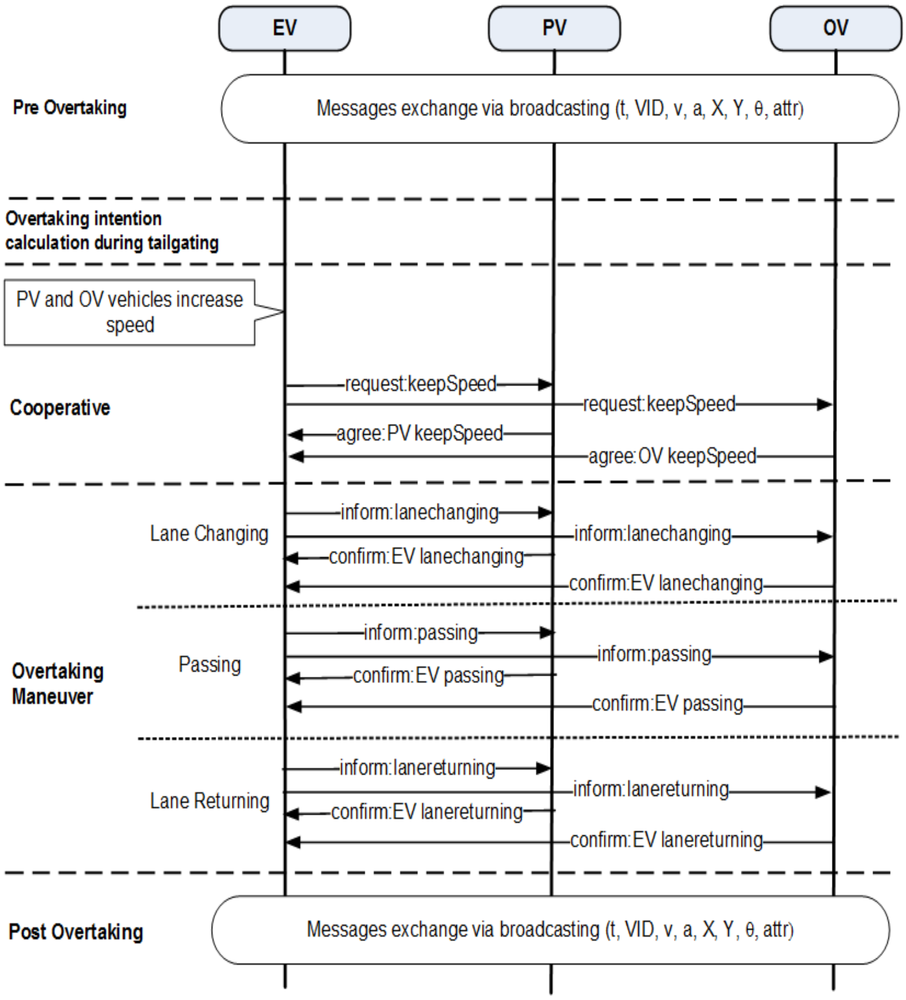

Fig. 4. Protocol for cooperative overtaking

III. Results and Analysis

Protocol testing is performed using the simulator, which was developed specifically using BDI agent-based programming. We define the protocol total time (PTT) which means the entire time, which is used for data exchange for overtaking and is calculated by (1).

$$PTT = Nbc.Cbc + Nuc.Cuc \quad (1)$$

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

Testing protocol performed on two conditions, namely small delays (under the maximum latency of WAVE, 100ms) and large delays (above maximum latency of WAVE). The effect of small and large delays on safety index (SI) can be seen in Fig. 5 and Fig. 6. In Fig. 7 and Fig. 8, the effect of large delays on the PTT and the length of overtaking time (LOT) can be seen.

In the span of a small delay, it can be seen that the safety index is not affected by the delay either IOS uses protocols efficiently or inefficiently. If the delay is above 1 second, it can cause of impairment of the SI and can harm the process of overtaking. The influence of large delays can be overcome with efficient protocol. Fig. 7 shows that the PTT value of the efficient protocol has lower value than the PTT value of the inefficient protocols. In addition to raising the safety index on efficient protocols, they can also shorten the length of overtaking time as shown in Fig. 8.

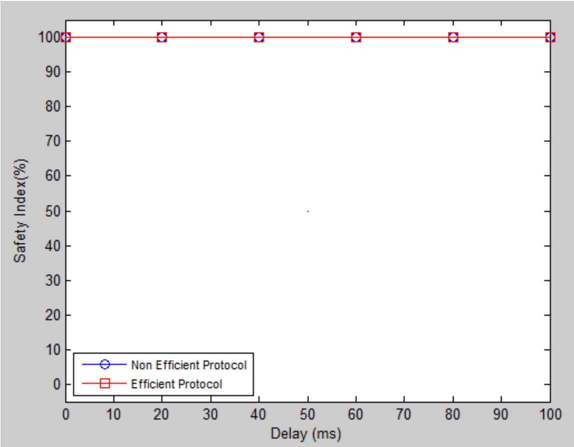

Fig. 5 Effect of Small Delays on SI

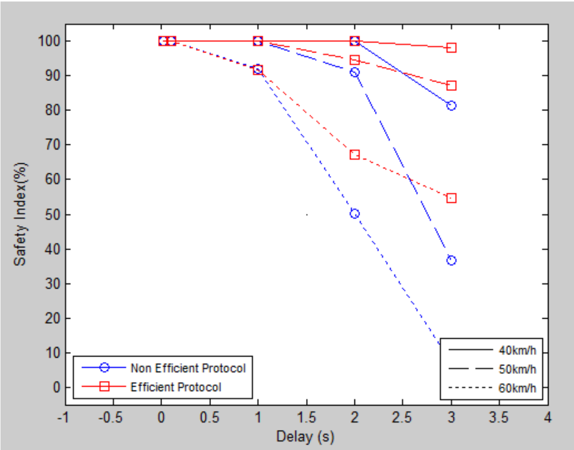

Fig. 6 Effect of Large Delays on SI

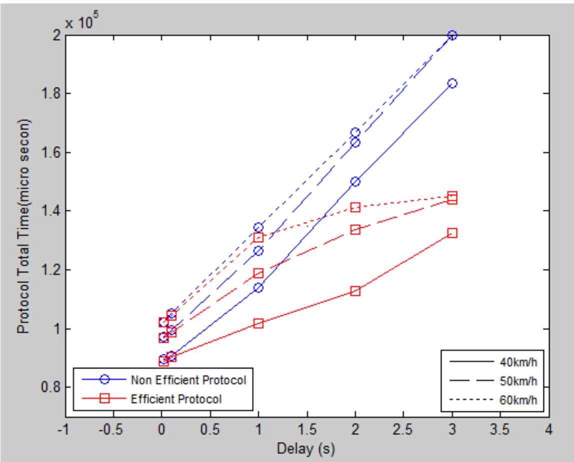

Fig. 7 Effect of Large Delays on PTT

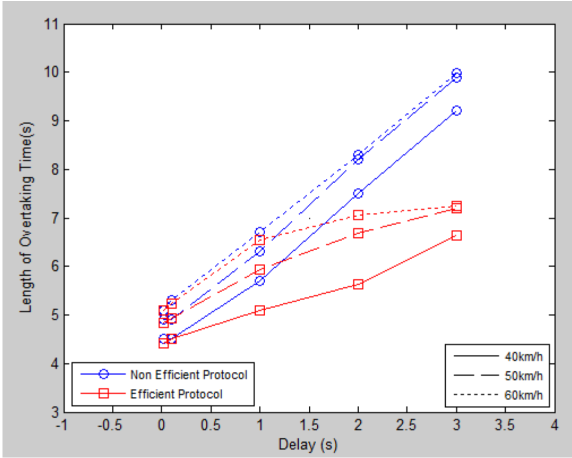

Fig. 8 Effect of Large Delays on LOT

IV. CONCLUSION

In general the small delays have no effect on COAS performance, while the large delays greatly affect to the COAS performance on the safety index (SI), protocol total time (PTT), and length of overtaking time (LOT). The effect of large delays on the COAS performance can be reduced with the use of efficient protocols.

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