New Traffic Message Delivery Algorithm for a Novel VANET Architecture

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Abstract—**Traffic problems in the field of Intelligent Transport System (ITS) have always been an attraction in the researchers' eyes all over the world. To reduce traffic congestions, to save travel time, to decrease traffic accidents and to provide demanding information exchanges have become challenges of today and the future. Current research works focus on applying Car-to-Car (C2C) and Car-to-Infrastructure (C2I) approaches in infrastructure-less and flexible ad hoc networks environment. The routing problem has always been one of the most difficult problems in such dynamic environment network. This paper presents a novel, designed for routing purposes, traffic routing algorithm (TMDA) for a novel VANET architecture. The algorithm with the inclusion of urban traffic related routing information has been designed to be deployed in vehicles, e.g., cars and buses and aims to provide proper strategies for the utilization of travel information available in many of the vehicles traversing urban networks. The research investigates and compares communication performance of the communication system under TMDA and the other existing ad-hoc routing protocol (e.g., Ad hoc On-Demand Distance Vector) by a set of experiments with the NS-2 simulator. According to simulation-based performance evaluation, the proposed algorithm, TMDA, provides higher efficiency and reliability than a popular used broadcasting method for data dissemination.**

Keywords-ITS; C2C/C2I; ad hoc network; VANET; routing algorithm; NS-2 simulation

I. INTRODUCTION

In recent years, much more projects emerge in the field of Intelligent Transport System (ITS) because of the increasing traffic problems, such as traffic jam and fast accident notifications etc. Fast and reliable real-time traffic information is irreplaceable tool to build safe and efficient traffic environment. To achieve this goal, traffic objects should cooperate with each other by using Car-to-Infrastructure (C2I) and Car-to-Car (C2C) communication approaches, as the communication of information is the biggest unutilised fully factor in ITS for reducing traffic congestions, saving travel time, decreasing traffic accident, improving air pollutions, lowing energy consumption and also providing demanding information during travels.

Typical examples adding weight to this concept are C2X communications investigated in the following projects of the 6th EU Framework Programme for Research and Technological Development [1]: 60 million EU CVIS (Cooperative Vehicle-Infrastructure Systems) Integrated Project [2], targeting mobile traffic participants to provide wise interactions between mobiles and transport infrastructures for road safety; COOPER (CO-OPerative SystEms for Intelligent Road) project [3], aiming at cooperative traffic management by exchanging real-time traffic information among travellers and fixed roadside system to finally enhance road safety on motorways; and SAFESPOT integrated project [4], cooperating intelligent information exchanges between vehicles and roadside units to realize safe and efficient transportations. These projects attempt to integrate C2C and C2I applications while existing outcomes show that the focal point is C2I solutions, by utilizing the supports of roadside units (RSU), access points (AP) and cellular base-stations etc.

While the C2I architectures have been well developed nowadays, further problems about the cost of infrastructure deployment, the speed of connections and the volume of data are considered. Hence, more and more research work and projects pay attention to ad hoc networks, which are self-organized, dynamical and flexible for solving certain urgent social problems, e.g., emergency services and traffic information exchanges, etc. [5] with co-operations of other practical technologies.

In this paper, novel Vehicle Ad-hoc Network (VANET) architecture for city traffic communications is introduced. This framework will create an opportunity for investigation of the benefits of car-based acquisition and dissemination of traffic information as well as generation and distributed implementation of traffic control. For routing purposes, the system applies a new Traffic Message Delivery Algorithm (TMDA). The defining novelty in this algorithm is the presence and utilization of travel route information available in many of the vehicles presenting in the traffic e.g., all buses, cars using Sat-Nav devices etc.

Compared with real test-beds [6][7][8], simulations can save large expenses to construct a model and allow components to execute repeatable tests in diverse targeting scenarios. This paper discusses essential simulation issues via NS-2 and displays results for investigations of the new routing algorithm in the proposed VANET architecture.

The paper is structured as follows. Next section processes literature reviews on broadcasting techniques and introduces the new ideas about essential information being included in the transmission messages. Then newly VANET architecture with a proposed message delivery algorithm TMDA is introduced in details. There are a set of simulation experiments exhibited to evaluate communication performances with the innovative routing protocol. Finally, we conclude results and give a future vision.

II. RELATED WORK

Presently, a plethora of routing protocols is designed to adapt flexible and dynamic ad hoc networks. This paper will only concentrate on those studies being directly related to the proposed techniques and protocols.

A. Broadcasting in VANET

Broadcasting is a basic method used in ad hoc networks. The simplest and earliest broadcasting technique is flooding methods, as described in [9][10][11]. Each mobile node, which receives the packet for the first time, periodically broadcasts or rebroadcasts the packet to all neighbours; otherwise, the receiver will discard the packet due to redundant operations. Ho et al. [12] state that a simple flooding method provides minimal state and high reliability, particularly being suitable for highly mobility networks, such as MANET and VANET.

The main problem of the simple flooding, also known as blind flooding [13], is the high amount of redundant broadcasting messages. This is referred as broadcast storm. To solve the problem, a few of solutions have been proposed. For example, a probability-based method from [14] assumes that nodes rebroadcast the received packet depending upon the predetermined probability. If the probability reaches 100%, the scheme is identical to be pure flooding. Additionally, an IEEE802.11-based protocol named urban multi-hop broadcast (UMB) is designed in [15] to minimize the broadcast storm by allowing the farthest vehicles to receive and forward data and inform other nodes between original senders and itself. Meanwhile, it uses acknowledgment messages (ACK) to guarantee high reliability of packet delivery.

As Ros et al. [16] presented, uneven distributions and speeds of vehicles are particular characteristics in VANET networks. Due to these reasons, VANET has to deal with high number of disconnections which may impact on message exchanges. U. Lee et al. [17] introduced periodically broadcasting methods to neighbours. In this case, one-hop neighbours will be able to disperse the message via their mobility to more hops of retransmissions. Moreover, Kitani et al. [22] present a concept of 'message ferrying' in Inter-vehicle communications, introducing 'bus' as the ferry rather than 'car'. It proposes to improve efficiency of information sharing in sparse areas depending on buses which have regular routes and could collect more traffic information.

In this paper, our new algorithm attempts to improve communication performance by using strategic broadcasting mechanism with the inclusion of traffic route information in the algorithm.

B. The inclusion of essential information

In the traffic area, diverse and changeable communication demands and traffic problems can occur at any time. For these reasons, maximum and optimum information are expected to be included in communication protocols by many research and projects. Although there has not been any comprehensive and popular message delivery algorithm meeting the requirements yet, some researchers have proposed algorithms with the inclusion of particular traffic information, for example, the inclusion of the acknowledgments into the periodic beacons for high reliability [16] and the inclusion of vehicles' status and surrounding information in [18], etc.

So far, on the basis of studies in existing literatures, the concept of the inclusion of traffic route information has not been proposed and implemented. Certainly, many projects assume electronic devices such as GPS are installed in most of cars and mobile terminals. Hence, those devices could provide route information to car drivers or other traffic participants. However, this information cannot be easily shared with others unless they are included into the message routing protocols. For the proposed purpose, this research introduces designing a new message delivery algorithm with the inclusion of traffic route information based on a novel MANET architecture.

III. THE NOVEL MESSAGE DELIVERY ALGORITHM - TMDA

A. The proposed VANET architecture

Wu [6] introduced a VANET architecture that, based on the background of Car-to-Car/Car-to-Infrastructure communications, involves spontaneous wireless communications occurring within a group of wireless mobile nodes (Figure 1). The architecture integrates features of traditional ad hoc networking technologies and VANET technologies, being used in standalone mode or cooperative connections to the larger Internet [23].

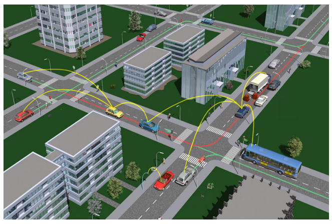

Figure 1. Novel ad hoc wireless mobile network architecture
Ref.: http://www.car-to-car.org/index.php

Being different from traditional ad hoc networks, this communication system utilizes vehicles for routing purposes via the inclusion of traffic route information. It recognises three types of ad hoc nodes - mobile, semi-mobile and static ad hoc nodes. To best exert the functionality of node when communications occur, the system specifies three types of nodes.

Mobile nodes, such as cars, are defined as traditional ad hoc nodes without pre-conceived route with functions of routing and transmitting messages. They could be a major group to request traffic information and fast forward

 ISBN: 978-1-61208-203-5

messages. Indeed, if the car equips high capability electronic devices for message storages, they could carry messages anywhere and exchange to others anytime due to the nature of arbitrariness. However, most of drivers do not accept to spend money on these devices. Hence, car behaviors have to be relatively simplified, e.g., broadcasting only.

Alternatively, bus-nodes, considered as semi-mobile nodes – having predetermined route onto which they are currently traveling, integrate routing, transmitting and gateway altogether to provide a possibility of interconnection among other types of networks, e.g., Internet. Although they could not move everywhere as cars do, they are able to equip powerful devices to offer more communication capabilities than other common vehicles. Typical examples are the energy of transmission, the range of communications, as well as the storage of messages. These are possible to compensate discontinuous delivery occurring between car communications. Moreover, buses and bus-lanes present some particularities in urban scenarios. Most of cities specify lanes for buses priority to guarantee unimpeded travels for the public, even in peak time.

As far as static ad hoc nodes are concerned, they will cooperate with other two types of nodes to provide more reliable and specific information if exchanges of a message between first two kinds of nodes does not meet users' requirements. In this research, static nodes belong to a kind of ad hoc nodes; however, the essence is similar as roadside units. The nodes are expected to provide access for larger scale of information exchanges.

B. TMDA overview

Traffic Message Delivery Algorithm (TMDA) is a novel traffic routing algorithm designed for improving communication performance of a particular VANET network described in Section A. The difference as compared to another routing protocol is that TMDA does not only implement single broadcasting approach, such as the simple flooding, probability-based method, area-based method and neighbourhood-based conception [19], but also adopts intelligent routing strategies by utilizing the pre-existing travel information for message delivery at any given moment. It means that the algorithm with the inclusion of traffic route information will be embedded in each communication mobility node with current advanced information adaptation devices and provide optimization routes to messages between the source and the destination.

TMDA utilizes features of each type of nodes for efficient and reliable traffic communications. For example, it does not only take advantage of arbitrariness of car-nodes, but also exploits the benefits of controllable, scheduled, and predicted bus-nodes; it does not only allow simple broadcasting behaviours of cars, but also make uses of higher capability of bus-nodes for properly storing and forwarding the messages. Furthermore, TMDA is prone to regional message delivery and does not exclude the possibility of Internet access via static nodes to spread messages widely.

C. Algorithm details

TMDA could be divided into two sections: sending and receiving. Procedures are relatively simple for sending the message that nodes carry on periodic broadcasting via IEEE 802.11 within a certain expiry; whereas more considerations occur in terms of receiving a message. Algorithm I is showing the pseudo-code of TMDA in message receiving section.

ALGORITHM I. PSEUDO-CODE OF TMDA IN MESSAGE RECEIVING

```
Event: the message has been received
if msg_id is not in check_list then
|   receives the message
else
    discard the message

Event: the message received from NB or S
if R = src then
|   discard the message;
else
  if R = dst then
  | inform others to stop broadcasting;
  else
    if P_s is on I-Routes then
    | if P_r  is on I-Routes then
    | | when T_c = T_d1, farthest nb forward message;
    | | inform others between <S,R> to stop broadcast;
    | | message is stored longer in this node R;
    | else
    |   if D_r = D_s then
    |   | when T_c = T_d2, farthest NB forward message;
    |   else
    |     when T_c = T_d3, farthest NB forward message;
  else
    if P_r is on I-Routes then
    | when T_c = T_d1, farthest nb forward message;
    | inform others between<S,R> to stop broadcast;
    | message is stored longer in this node R;
    else
      when T_c = T_d1, farthest nb forward message;
```

Actually, above steps implement a selective forwarding mechanism by utilising additional urban traffic related information. The overall aim is to address broadcast storm problems. Two main parts are involved in the mechanism.

One is the idea of I-Route. This is a critical route, e.g., bus lanes, used to determine next operations of nodes. Briefly, if messages reach I-Routes, they will be faster forwarded following the pre-configured directions of the I-Routes; otherwise, they are based on developed broadcasting strategies only. The nodes on I-Route, regardless the real type, are treated as buses. On the basis of I-Route, another concept is about 'farthest node first send' (FNFS). Once a sender delivers a message to all neighbours, the farthest one within the transmission range will deal with the message following the priority over others. The priority level is set by delays introduced in the following pseudo-code of TMDA. The idea is beneficial to control data collisions to a certain degree.

Message receiving function is divided into two events. From line 1 to 5, when a receiver *R* obtains a message with the id *msg_id*, *R* should firstly check whether it receives a redundant message. Each VANET node has a *check_list* to store received *msg_id*. Thus if the *msg_id* is found in the list, *R* discards the message; otherwise, continues the steps of another event (line 6 to 29).

When *R* receives the message from its neighbours *NB* or source *S*, it needs to make sure that the message dose not loop back. Then if *R* is the destination node, it simply broadcasts back to all neighbours with a stop instruction. Alternately, if *R* is an intermediate node only, steps from line 13 to line 29 are focused on. To judge when to forward the message to neighbours, *r* needs to know *nb*'s or *s*'s position (x, y) and its own position. This helps to check whether they are on *I-Routes* or not. If both of *S* and *R* are on *I-Routes*, then *R* forwards the message at T_{d1} which consists of current_time (*Tc*) and a waiting delay d_1. Within the transmission range, the delay d_1 will be reduced accompanying with the increase of distance between <*S, R*>. That is, the farthest *R* will forward message firstly. Additionally, if *S* is on the *I-Route* but *R* is not, the moving directions of *R* and *S* become important. Same direction of *R* and *S* $(D_r = D_s)$ makes the forward occur at T_{d2} while the message is broadcast at T_{d3} for different directions of *R* and *S*. The value of T_{d2} or T_{d3} is different but both consist of a current time *Tc*, a delay according to the distance d_1 and a pre-configured delay d_2 setup by the algorithm. The value order is $T_{d1} < T_{d2} < T_{d3}$.

IV. SIMULATION ISSUES

NS-2 is selected as a well-suitable simulation tool in this paper. It uses Tcl (Tool Command Language) to organize script files for setting up traffic patterns such as scenarios and movements and also communication patterns, e.g., transmission issues.

A. A City scenario

In terms of traffic patterns, the focus at this stage is #-shaped city scenario (Figure 2). Compared with T-shaped patterns in a previous paper [6], this scenario contains more traffic situations.

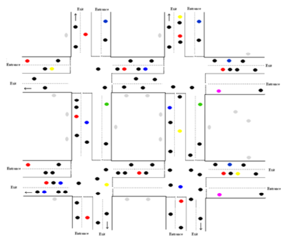

Figure 2. #-shaped traffic pattern

#-Shaped city scenario (Figure 2) – a medium scale network with possible traffic units consists of intersections, horizontal and vertical roads. It can be useful to investigate some issues that whether I-Route areas provide efficient decisions for message delivery; whether different types of nodes work properly to provide high reliability in various densities of networks etc.

Nodes – The term density represents as the number of nodes over the network. This paper presents four dense levels (Figure 3), from very low to high.

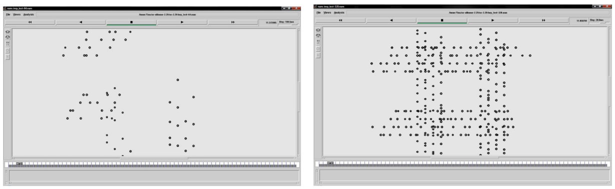

Figure 3. Simulation models for example densities of networks

I-Route – This is a term for a set of special routes integrated in our established ad hoc wireless mobile communication system. On I-Routes, message transmissions obey special strategies and they are expected to support for performance improvements. Therefore, I-Routes should have a capability to centralize more mobile nodes so that strategies can be best used. According to features of buses mentioned in previous sections, I-Routes are pre-set to be bus lanes in this paper. This point will be further investigated and validated. Current simulation models adopt the following I-Route patterns, drawn as two lines with arrows in Figure 4. Future more I-Routes could be identified by buses or be pre-configured by control centres due to the different purposes.

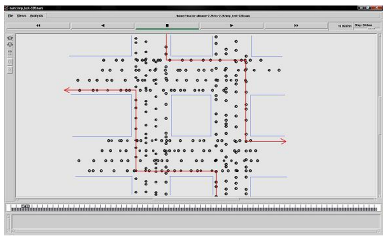

Figure 4. Simulation model with I-Routes

B. Transmissions

Following points, such as transmission range and nodes distance etc. are essentially to impact on the design of simulation models.

Distance – The distance of a node-pair varies because of simulation initializations and node densities. In our designs, the nodes are distributed following the shape of urban lanes and the distance between two nodes is chosen randomly but between 10 to 150 meters. Actually, the value is decided particularly in this research because of real traffic considerations. Meanwhile, the transmission range is set as the same value.

Speed – Regarding to the real world conditions, the speed of vehicles should be different according to transportation conditions, such as the traffic flows, the speed of front nodes and the traffic rules etc. Therefore, the speed of nodes is assigned randomly when nodes are running with different directions.

Time - Total simulation time for above models is set to 300 seconds. Message sending time is randomly chosen by

 ISBN: 978-1-61208-203-5

NS-2 within the total simulation time. We assume that the maximum expire time of message is no more than 60 seconds for non-emergency messages.

Message **–** Message contains three elements: message size, message id and other information, such as source node, destination node, current sender, the position of senders, the speed of senders, the direction of senders, the message expiry and current timestamp. It assumes that only one message is transmitted between a pair of nodes each time and the minimum number of message over the network at the time is 1 while the maximum value is 10 in this paper.

V. RESULTS EVALUATION AND ANALYSIS

A. Network communication performance metrics

End-to-End Delay Time (EDT) **-** It refers to the duration of a message sent from source to destination over the network [21]. Note that the equation (1) is used for calculating single-pair of nodes' delay (EDT). Te stands for the end time of a packet delivery and T_0 means the start time; (2) solves the average delays (ΔEDT) by using the sum of single delays (Σ(EDT)) and the number of tests (n).

$$EDT = Te - T_0 \quad (1)$$

$$\Delta\, EDT = \Sigma\, (EDT)\ /\ n \quad (2)$$

The acceptable maximum delay time is limited as 60 seconds for non-emergency messages. If the delay time is over 1 minute, then packet loss is recorded.

Message Delivery Ratio (MDR) **–** It represents a ratio of successful message deliveries. In equation (3), a single rate is calculated using the number of successful receives (n_r) and the number of original sends (n_s). The final evaluation of this paper will follow the results obtained via equation (4) which shows the average value of the testing delivery ratios.

$$MDR = (\ n_r\ /\ n_s\ ) * 100 \quad (3)$$

$$\Delta\, MDR = \Sigma\, (MDR)\ /\ n \quad (4)$$

B. The Comparison of routing protocols

AODV – Wireless Ad hoc On-Demand Distance Vector (AODV) routing protocol concerns on mobile ad hoc networks (e.g., MANETs) nowadays. It is a reactive routing protocol which creates a route for nodes only when they demand it, being one of common broadcasting routing protocols used currently for both unicast and multicast routing. The serious problem is the broadcasting storm, which attempts to be avoided and reduced in the proposed routing protocol TMDA.

TMDA – Traffic Message Delivery Algorithm delivers messages depending on the concept of pre-configured routes (I-Routes) in the city scenarios. On the basis of general broadcasting methods, TMDA reduces broadcast storms via selective forwarding mechanism, coupled with geographic information.

Table I shows advantages and disadvantages of AODV, which have been proposed and validated for long years. Following that, the anticipated features of TMDA, being given in advance, will be investigated by simulation results in later sections.

TABLE I. COMPARISONS OF ROUTING PROTOCOLS

Routing Protocol	Advantages	Disadvantages
AODV [20]	1) On-demand 2) Destination sequence numbers to find latest route 3) Small control and data packet requires few bandwidth 4) Link broken response fast 5) High reliability in medium and large networks	1) stale entries 2) Multiple RREP packets to a single RREQ packet causes big control overhead 3) Battery and bandwidth consumptions
TMDA	***Anticipated:*** 1) Simple broadcasting mechanism 2) No network topology maintenance 3) No complex route discovery algorithm 4) I-Routes are set up for controlling packet forwards 5) Reduction of broadcast storm	***Anticipated:*** 1) Bear with a certain delays if nodes are not on pre-configured routes 2) Not good for emergency message exchanges in sparse networks

C. Results in various dense networks

Figures 5, 6, 7 and 8 compare EDT and MDR results by applying Traffic Message Delivery Algorithm (TMDA) and implementing Ad hoc On-Demand Distance Vector (AODV) routing protocol in very low, low, medium and high density of networks separately. There is an assumption in the experiments that the acceptable delivery time for non-emergency message is no more than 60 seconds, and random source-to-destination pairs are allowed to exchange various amount of messages (from 1 to 10) per randomly testing time. The overall aim is to investigate whether TMDA leads to less EDT and higher MDR in various scenarios rather than an another existing routing protocol; how degree the amount of messages impact on communication performance; and how the trend of EDT and MDR changes in different network conditions.

1) High & Medium density

Figure 5 represents the average EDT and Figure 6 shows the trend of MDR in the dense and moderate dense network respectively. According to above line charts, TMDA exhibits smaller EDT from 1 message to 10 messages per testing time, reflecting on the below lines in Figure 5 and higher MDR from the above lines in Figure 6 than those obtained from AODV protocols.

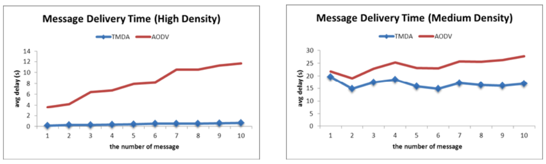

Figure 5. Delays in the high & medium density of networks

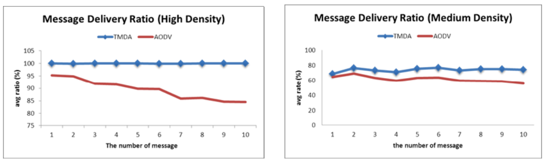

Figure 6. Rates in the high & medium density of networks

For AODV, the trend of the average EDT in both networks goes up accompanied with increases of the message number shown in Figure 5; conversely, the ratio displays as decreasing status in Figure 6. Therefore, the number of nodes over the network and the number of transmission messages have significant impacts on the transmission delays and reliability. However, the trends of average EDTs and MDRs are relatively stable when TDMA is used for message deliveries. Particularly in the dense VANET, the average value of EDTs is very small, presenting a distinguished gap between the line of AODV and the line of TMDA. Oppositely, the trend of average MDRs in TMDA keeps in a high level (e.g., 80%-100%) while AODV experiences decreasing values when increasing the message number from 1 to 10.

Compared to the results in moderate density of networks, the results are notably better in the high density network. One of drawbacks inherited from AODV is the broadcast storm which is also considered as a major reason of packet loss. If 10 messages are transmitting over the network, more nodes mean higher possibility to generate data collisions over the network. As introduced earlier in the paper, TMDA adopts delay strategies to reduce broadcast storm and the results prove that the packet loss is relatively less prominent.

Certainly, when the nodes are reduced, both routing algorithms are influenced, reflecting on the increasing delays and the declining packet ratios, e.g., those in medium density of networks. It is understandable that the condition of re-send becomes frequent.

2) Low & Very low density

Figure 7 and Figure 8 display average EDT and MDR in low and very low density networks respectively. TMDA provides better results than those of AODV. For example, EDT lines of TMDA in both networks are lower than those of AODV with smaller average delays. Meanwhile, the above MDR lines which represent higher successful packet deliveries are from TMDA.

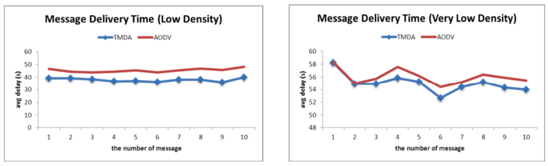

Figure 7. Delays in the low & very low density of networks

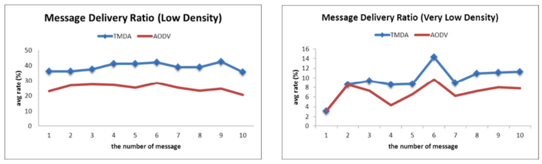

Figure 8. Rates in the low & very low of networks

Usually, a problem of disconnection seriously occurs in sparse networks. This is because nodes are not enough to forward messages and they are not distributed evenly. The problem causes transmission failures as high possibility of packet loss within an expiry. If the transmission fails within the expiry, AODV provides a sequence of procedures such as packet requesting, replying and repairing etc. to deal with these failures. However, the mechanism suffers more delays because senders should wait reply packets from the destination nodes and then judge if they need to re-send again or stop sending. For TMDA, it allows senders to continually broadcasting the message within the expiry unless they receive a redundant message or they receive an instruction included in the message to stop broadcasting. This approach saves the time for senders to wait the response and also each sender needs not to keep a list to record paths for replying packets.

Moreover, TMDA contains I-Route information. Nodes on the I-Routes are allowed to have longer storage time than nodes on the common lanes. This strategy helps to improve the ratio of message deliveries, particularly in sparse networks. One of cases in the experiments as follows: suppose a source node and a destination node are far from each other and a bus running on the I-Route could pass over each other in a certain time range. AODV allows the bus to re-broadcast the message within T and the distance takes t for the bus to connect with the receiver. Due to $T<t$, the packet will be dropped. Instead, TMDA allows the bus to extend re-broadcast time to be T1 ($T1 > T >= t$), then the message could be received. Certainly, in specific cases, the delivery time will be very long by using TMDA, but it could be accepted with a tolerance limit. In our experiments, we set maximum expiry for non-emergency messages to be 60 seconds. That is, any delay time more than 60 seconds will be regarded as final packet loss.

Besides the above features of I-Routes, they could direct message towards assigned directions. If both source and destination nodes are on 'I-Route', the delay could be very small because nodes on 'I-Route' have the high priority of forwarding actions. As in AODV, it lets the message be sent with the same rights of broadcasting requests, replies and forwarding to all one-hop neighbours. Certainly, if the source-to-destination pair is not on the I-Route or not all on the I-Route, the transmission time could be at least the similar as AODV results. Generally, the average message delivery time, seen in Figure 7, are smaller by using TMDA from 1 message to 10 messages.

VI. CONCLUSION AND FUTURE WORK

This paper presented the comparisons of communication performance by using different routing protocols in a novel VANET architecture. AODV is a published protocol used commonly in ad hoc networks, whereas, TMDA is a newly created algorithm. It not only adopts principles based on existing broadcasting algorithms but also incorporates urban traffic route information into the algorithm, utilizing the concept of 'I-Route' available in vehicles. The aim of these new routing strategies is to alleviate the impact of the problems caused by previous routing protocols and also best service for the particular implementation background. We design a VANET architecture which contains three types of ad hoc communication objects - mobile, semi-mobile and static ones.

So far, investigations indicate that TMDA generally shows better results than the others one in terms of packet delivery time and successful packet delivery ratio in dense, moderate dens, sparse and very sparse networks. The future work will concentrate on applying the algorithm in a real city scenario (e.g., Nottingham city) to further investigate above results of simulations. Meanwhile, static nodes are considered to be integrated into the architecture for collaboration studies.

ACKNOWLEDGMENT

The authors wish to thank all members of the Wireless Communications Simulation Modelling group of Nottingham Trent University, including Dr. Taha Osman, Dr. Richard Germon, Dr. Xiaoqi Ma, Postgraduate Researcher Emad Gamati and all other colleagues.

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