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The Adaptation of Vehicle Assisted Data Delivery Protocol in IoV Networks

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Abstract: By their nature, richness and continuity; the growing IoV data sets will also inform research into areas as diverse as human behaviour and social sciences, urban design, national security, medicine and epidemiology, population dynamics, geo-political wealth distribution and economic development, meteorology, market responses to advertising and price setting, resource and utilities management, food retailing, modelling the spread of invasive plants, pathogens and pests, freight logistics, tourism trends, planning of education systems, analysis of media consumption and broadcasting, agricultural development, and the fundamental mathematics of complex dynamic systems. The implementation of the routing algorithms is a complex problem since the IoV environment is dynamic and evolves over time, which implies a frequent change at the level of the network topology in order to find an information routing protocol that guarantees the transmission of the packets using the best route, the shortest delay and the performance on dense routes. The protocol chosen is the Vehicle-Assisted Data Delivery (VADD) protocol. This work is focusing on adapting VADD routing protocol for IoV network.

Key Words: IoT; IoV; ITS; VADD

1. INTRODUCTION

The Internet of Vehicles (IoV) is an integration of three networks: an inter-vehicle network, an intra-vehicle network, and vehicular mobile Internet (Andrei Furda et al., 2011). Based on this concept of three networks integrated into one, we define an Internet of Vehicles as a large-scale distributed system for wireless communication and information exchange between vehicle2X (X: vehicle, road, human and internet) see Fig 1 according to protocol communications and data interaction standards (examples include the IEEE 802.11p WAVE standard, and potentially cellular technologies). It is an integrated network for supporting intelligent traffic management, intelligent dynamic information service, and intelligent vehicle control that representing a typical application of Internet of Things (IoT) technology in intelligent transportation system (ITS) (Chou, Li-Der, et al., 2011).

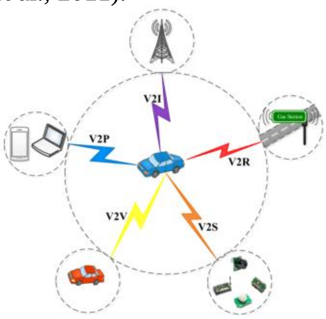

Fig. 1. The Five Types of Vehicular Communications of IoV

The convergence of technology encompasses information communications, environmental protection, energy conservation, and safety. To succeed in this emerging market, acquisition of core technologies and standards will be crucial to securing a strategic advantage. However, the integration of the IoV with other infrastructures should be as important as the building of the IoV technologies themselves. As a consequence of this, the IoV will become an integral part of the largest Internet of Things (IoT) infrastructure by its completion. Here, it must be emphasized as primary, that collaboration and interconnection between the transportation sector and other sectors (such as energy, health-care, environment, manufacturing, and agriculture, etc...) see Fig 2, will be the next step in IoV development (J. Gubbi, R. Buyya, S. Marusic, and M. Palaniswami, 2013).

Fig. 2. IoT Connecting "Anything, Anyone, Anytime, Anyplace"

The implementation of the routing algorithms is a complex problem since the IoV environment is dynamic and evolves over time, which implies a frequent change at the level of the network topology in order to find an information routing protocol that guarantees the transmission of the packets using the best route, the shortest delay and the performance on dense routes. The protocol chosen is the Vehicle-Assisted Data Delivery (VADD) protocol. It is unicast and adopts the idea of storage and transmission. For VADD, the routing mechanism is based on the current positioning of vehicles in the vicinity and the state of traffic in the road network. Based on the simulation results of the VADD routing algorithm, it has been observed that it is an efficient protocol on dense routes (J. Zhao and G. Cao, 2008).

2. PROTOCOL VADD

The VADD is a position-based unicast routing protocol designed to handle the problems of frequent disconnections and extreme mobility of the vehicular network. It implements the "storage and forwarding" strategy when a node moves, at the same time it stores the packets until a new node arrives at its region and transmits the stored packets to it. This protocol is made for the mobility of nodes that is based on two factors: network traffic density and the type of route; which allow a node to discover the next transmission node. The most important problem is to choose a transmission path with the shortest delay of transmission.The VADD protocol usually sends packets for these three reasons (J. Zhao and G. Cao. G., 2006):

- Continue to use the available wireless channel;
- Send the packet to the node with the highest speed in the transport way ;
- Since IoV is a high-mobility environment, it is difficult to estimate packet transmission by a predefined optimal path, which may lead to continue discovering a new optimal route for transmitting packet.

To avoid the routing loop, each node adds information about its old skip / hop before forwarding the packet, which also contains its own information as an old hop: Once the packet is received by a node, the node looks at the information about previous hops to avoid retransmitting them and tries to find other available hops, so that it can avoid the looping problem at the routing level (Jiang, Ji-Han, Shih-Chieh Shie, and Jr-Yung Tsai, 2014).

2.1. Transmission Mode of Packets for VADD

The VADD protocol uses three modes of packets transmission: intersection mode, straightway mode, and destination mode, based on the location of the packet holder (i.e. the vehicle that is carrying the packet). Passing between these modes, the packet carrier chooses the best packet transfer path (Kang, Hyunwoo, et al., 2015).

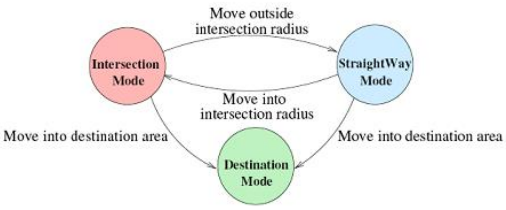

Fig. 3. Different Transmission Mode of Packets in VADD

- **Intersection mode:** Optimizes the routing direction of packets.
- **Straightway mode**: Geographical transmission of packets to the next target intersection.
- **Destination mode**: Broadcast packets to the destination.

Among the three modes, the intersection mode is the most critical and the most complex one. As vehicles have more choices at the intersection. Data transmission in straightway mode is much simpler than the intersection scenario, since the traffic is usually bidirectional. For this mode, we can simply specify the coming intersection, which is connected by the current route, as the target, and then we apply the GPSR protocol for the location of the target. For the straightway mode, if there is no vehicle available to receive the packet and retransmit it, the current packet carrier continues to transmit the packet (Karp, Brad, and Hsiang-Tsung Kung., 2000).

Certainly, there may have better solutions. For example, when a vehicle transmitting a package, it will find another vehicle in the opposite direction. The estimated delay from the current position of the vehicle may be different when the other vehicle in the other direction receives the packet. The packet transmission changes to the destination mode when its distance to the destination is less than a predefined threshold. The location of the destination becomes known and the GPSR protocol will be used to deliver the packet to the final destination (Leontiadis, Ilias, and Cecilia Mascolo, 2007).

2.2. Packet Transmission Mechanism for VADD

To transfer a packet, the VADD protocol implements four different methods (M. A. Feki, F. Kawsar, M. Boussard, and L. Trappeniers, 2013):

- First Probe (L-VADD): it allows delivering the packet to the node closest to the destination without taking into account the direction of the movement. The disadvantage in this method is the loop problem at the routing level.
- Direction first Probe (D-VADD): The next hop selection is based on the node that has the same direction of travel as the destination, which may help to avoid the loop at the routing level.
- Multi-Path Direction First is the VADD Probe (MD-VADD): it offers a multiple path rather than just one path, but it consumes bandwidth because of redundancy packets.
- Hybrid Probe VADD (H-VADD): This is a hybrid system that takes the advantages of L-VADD and D-VADD, to deliver a package, it first uses L-VADD, but if a routing loop is identified, it changes to D-VADD. Therefore, this system works better than the L-VADD and D-VADD methods.

The routing mechanism is based on the current position of vehicles in the neighborhood and on the state of traffic density. In VADD, the densest routes are considered as the optimal paths for routing packets.

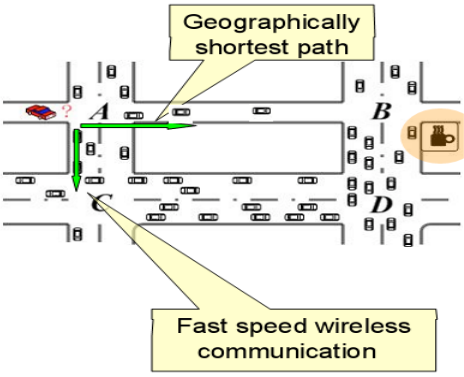

Fig. 4. Routing Mechanism Using the VADD Protocol

Let's suppose a driver approaches intersection I_a and sends a request to the cafe located in the corner of intersection I_b to make a reservation. The transmission of the request through A → C, C → D and D → B would be faster than by A → B even if the latter provides the geographically shortest path. The reason is that, in case of disconnection, the package must be carried by other vehicles. However, it is not always possible to know in advance the change in behavior of vehicles as well as changes in traffic conditions in a road network. The nodes can change direction and leave the path at any time and for this reason, the vehicle must keep the packet and look for a retransmitted node capable of successfully delivering the packet (M. H. Eiza, T. Owens, Qiang Ni, Qi Shi, 2015).

Algorithm for transmitting packets in right path mode in what follows; we will study this protocol in right path mode (S. Zeadally, R. Hunt, Y. S. Chen, A. Irwin, A. Hassan, 2012). The notation used in this section is explained in Tab.1.

Table 1. Terms Used in the Algorithm

Term	Explanation
V_Src	Source Vehicle
D_fx	The destination
D_sd	The distance between the source and the destination
R	The communication range
V_vd	The direct Neighbors

2.2.1. Hypothesis for Straightway or Straightway Mode

Each vehicle knows the position of its neighbors by the exchange of beacon messages.

- A "beacon" message contains:
  - -The speed of vehicles
  - -Vehicle management
  - -The position of the vehicles

-Each vehicle knows the route information and the statistics of the traffic from a digital map.

2.2.2. Description of the Packet Transmission Algorithm in Mode Straightway

Procedure 1: When a vehicle wishes to send a message, such as a booking message for a restaurant, it first compares the distance remaining to the restaurant and the range of communication. If this distance is less than the communication range then it sends the packet directly to the destination (Vahdat, Amin, and David Becker, 2000).

Procedure 2: In the opposite case and if the distance is greater than the communication range then the vehicle is looking for a direct neighbor from the exchange of beacon messages. If it finds a direct neighbor and before sending the packet to it, it must first check at its routing table if that neighbor's identifier is registered like an old hop (Venkatesh; Indra; A. and Murali. R., 2012):

- If this neighbor is registered as an old hop then the vehicle continues to carry the packet, look for another neighbor or carry the packet to the destination in case no neighbor is found.

- If the direct neighbor is not registered then the vehicle registers its ID as older hop and sends it the packet.

  Procedures 1 and 2 will be repeated until receipt of the packet by the destination.

Algorithm for sending the packet "DATA" in the routing protocol VADD in right path mode or "Straightway"

Start
parameters Initialization:
Input parameters:
The packet type "DATA".
A fixed destination (coffee shop, restaurant, station ... etc)
Sending "DATA" packet from V_Src to D_fx:
D_sd is the distance between the source and the destination
R is the communication range
If d_sd<R then we change from right path mode to destination mode
{
Send the "DATA" packet directly from V_Src to D_fx
}
If not
{
Store the packet and look for the direct neighbor V_vd
If the direct neighbor V_vd exists (1)
{
Update the routing table
Repeat (1) until the packet is received by destination D_fX
}
If not
{
Store and transport the packet to the destination
Update the routing table
}
End

2.3. Propagation Model for the VADD Protocol

The propagation model for the VADD protocol is the model "Shadowing" (model shadow). This model does not take into account the unpredictable phenomena that may be occurred the network because it does not require the existence of a direct path between the transmitter and the receiver. The phenomenon "Shadowing" consists of two sub models, the first is the model loss of journey. For this model the average power of the signal received at a distance *d* noted P_r ($d0$) is (Y. Fangchun, W. Shangguang, L. Jinglin, L. Zhihan, and S. Qibo, 2014) :

$$\left[\frac{\overline{P_r(d)}}{P_r(d_0)}\right]_{dB} = -10\beta \log\left(\frac{d}{d_0}\right) \qquad (1)$$

β is the exponent of the weakening of the path.
The second sub model is the variation of the signal strength received at a certain distance. The whole "Shadowing" model is represented by [16]:

$$\left[\frac{\overline{P_r(d)}}{P_r(d_0)}\right]_{dB} = -10\beta \log\left(\frac{d}{d_0}\right) + X_{dB}(2) \qquad (2)$$

2.4. VADD Delay Model

To formally define the packet-delivery delay, we need the following notations (Y. Sun, H. Song, A. J. Jara, and R. Bie, 2016).

- r_{ij}: the road from I_i to I_j;
- l_{ij}: the Euclidean distance of r_{ij};
- ρ_i: the vehicle density on r_{ij};
- v_{ij}: the average vehicle velocity on r_{ij};
- d_{ij}: the expected packet-forwarding delay from I_i to I_j.

We assume that the intervehicle distances follow an exponential distribution, with a mean distance equal to $1/\rho_{ij}$.

$$d_{ij} = \left(1 - e^{-R.\rho_{ij}}\right).\frac{l_{ij}.c}{R} + e^{-R.\rho_{ij}}.\frac{l_{ij}}{v_{ij}} \qquad (3)$$

Thus; where R is the wireless transmission range, and c is the average one-hop packet transmission delay. Equation (1) indicates that the intervehicle distances are smaller than R on a portion of $1-e^{-R.\rho_{ij}}$ of the road, where wireless transmission is used to forward the packet. On the rest of the road, vehicles are used to carry the data. Apparently, a larger traffic density makes up a small portion completed by vehicle motion.

3. SIMULATION ENVIRONNEMENT

To analyze the performance of the VADD routing protocol, we used the SUMO-O.15.0 traffic simulator and the OMNET ++ 4.2.2 network simulator. We used the Veins-2.0 Framework (Vehicles in Network Simulation) which ensures the meeting of the OMNET ++ and SUMO simulators. The VADD Protocol is evaluated in an urban environment. From the analysis of the results obtained during simulations of the VADD protocol, it is retained that in order to have a maximum transmission rate of the packets and a shorter delay, it is necessary to work in a dense medium in terms of vehicles.

Table 2. Properties of the Simulation Environment

Settings	Values
Network simulator	OMNET ++ 4.2.2
Road Traffic Simulator	SUMO-O.15.0
Propagation models	Shadowing
Number of nodes	30, 50, 150
Simulation time	100s
Transmission range	300m
Simulation Area	1200m*1200m
vehicles Speed	20 m / s
Number of packets	40
Packets size	1024 bits
Message beacon Interval	0.5 s

3.1. Packet delivery ratio

We also evaluated the accuracy of routing to collect the application data. The packet delivery ratio is a network performance metric, is defined as the ratio between the number of data packets successfully delivered to the destination and the number of packets transmitted by the source (including re-transmissions)

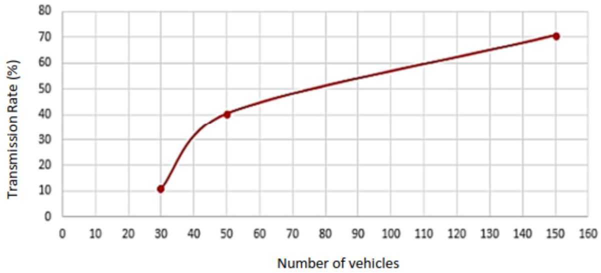

Fig. 5. Transmission rate of 40 packets for 30, 50 and 150 nodes.

Fig 5 shows that the delivery ratio of 40 packets sent increases when the number of vehicles is increased. For the first simulation of 30 vehicles, we note that the transmission rate is around 10% while for 150 vehicles the transmission rate is 70%.
This increase proves that the VADD protocol is more efficient in dense environments, ie, the more the number of vehicles increases, and the more the transmission rate increases.

3.2. Packet transmission delay

We define the Packet transmission delay as average time necessary for an application message from a source node reach the final destination.

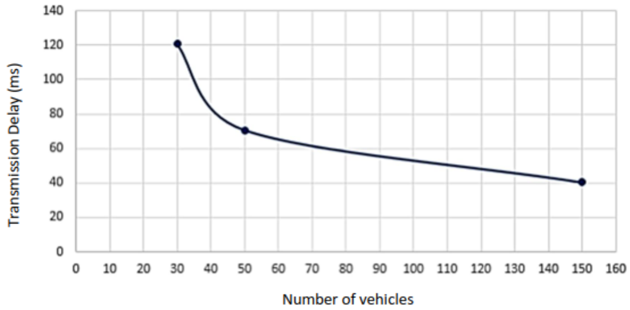

Fig. 6. Transmission delay of 40 packets for 30, 50 and 150 nodes

Fig 6 shows the variation of the transmission delay for the 40 packets sent. The delay decreases from 120 ms for the first simulation of 30 vehicles to 70 ms for the second simulation of 50 vehicles. For the third simulation of 150 vehicles, the Transmission delay is 40 ms. So we notice that each time we increase the number of vehicles, the time required to transmit packets between the source and the destination decreases. We conclude then that to have a minimum delay of transmission, it is always necessary to choose the densest roads in terms of the number of vehicles.

3.3. Packet loss rate

Packet loss rate is defined as the fraction of the total transmitted packets that did reach the final destination.

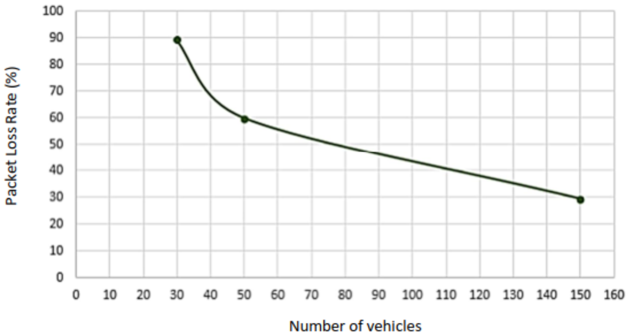

Fig. 7. Packet loss rate for 30, 50 and 150 nodes

For Fig 7, if we compare the rate of packet loss between the three scenarios, we note that there is a remarkable decrease between the first (30 nodes) and the third scenario (150 nodes). The packet loss rate decreases more than 50% between simulation with 30 vehicles (loss rate is 89%) and simulation with 150 vehicles (loss rate is 29%). These results show that packet loss increases when the number of vehicles, this may be due to the short duration of connectivity especially when the density of vehicles is very weak as in the case of the first simulation. In order to lower the rate of loss of packets, you need a deployment of several nodes relays or access points along the route, which would allow the retransmission of information over long distances.

4. CONCLUSION

Routing in IoV network's is a very difficult problem since the environment is scalable and dynamic, which implies a change frequent in the topology of the network. Routing is in a way the key mechanism of vehicular networks. It is thanks to the routing mechanism that the vehicles have the opportunity to communicate with each other. In order to guarantee transmission continuous messages in the vehicular network, it would be necessary that the routing protocol take into consideration the characteristics of vehicular networks. To do this, we studied in this paper the routing protocol VADD which is a unicast routing protocol adopting the idea of storage and transmission. For VADD, the routing mechanism is based on the current vehicle positioning in the vicinity and the state of the traffic in the road network. From the analysis of the results obtained during the simulations of the protocol VADD, it is retained that to have a maximum rate of transmission of packets and a less time, it is necessary to work in a dense environment in terms of vehicles. The performance evaluation of the VADD routing protocol was performed in this chapter. In view of the different results of the simulations, we found that the simulation with 150 vehicles has a considerable advantage in terms of transmission, loss rate and transmission delay, proving that our choice of routing protocol that guarantees packet transmission using the best route, least delay and performance on dense routes was successful.

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