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DT-AODV: An On-Demand Routing Protocol based DTN in VANET

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Abstract: Vehicular Ad Hoc Networks (VANET) as a fundamental part of the future intelligent, which constitutes by communication between cars, cars and roadside node use a unified wireless communication network, it can transmit auxiliary driving or real-time information to avoid accidents, and can provide the operating convenience and security with people's travel, so VANET routing protocols is crucial, especially the packet delivery ratio in protocol. Firstly, the traditional routing protocols in MANET is researched and the actual real movement of vehicles on the road is built for network simulation, all aspects of the performance of the AODV, DSDV and DSR routing protocols is analyzed in VANET environment, the result showed that the three classic routing protocols are not suitable for VANET with the characteristic of low packet transmission rate, high normalized routing load and large delay in the average end to end. Then, according to delay tolerant network (DTN) network topology can change dynamically over time to determine the appropriate case transmission path, and it can more effectively sends the packet to the destination, so the stored - carry - forwards mechanism as a design basis, the on-demand routing protocol DT-AODV based DTN is proposed, taking into account the variability of VANET when connected, a directed graph model is built in VANET modeled, and finally the detailed protocol is descripted. Experimental comparison shows that, DT-AODV is more suitable for VANET than other classical routing protocol in MANET.

Keywords: VANET, Delay Tolerant Network, DT-AODV, Routing Protocol, SUMO

1 Introduction

1.1 VANET routing protocols

With the rapid development of transportation, the number of road vehicles was increased beyond imagination; road traffic safety situation has become increasingly serious [1]. Over the past 10 years, a lot of research is committed to driving through the development of auxiliary systems to solve the problem of traffic safety, this system can sense the surrounding traffic and vehicles, and accurate remind drivers when in danger [2]. A vehicular ad hoc network (VANET) uses moving cars as nodes in a network to create a mobile network [3]. A VANET turns every participating car into a wireless router or node, as cars fall out of the signal range and drop out of the network, other cars can join in, connecting vehicles to one another so that a mobile Internet is created. So the cars can communicate with each other for safety purposes, and the network can provide entertainment, network access and other services [4]. A typical application with VANET is showed in Fig. 1

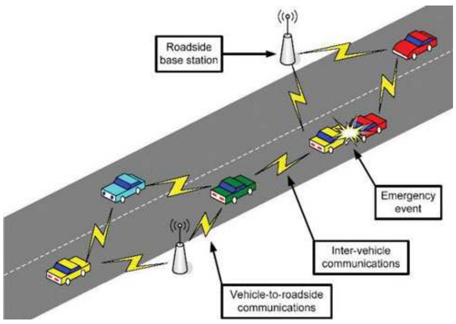

Fig. 1: Application Diagram of VANET

Most of the concerns of interest to mobile ad hoc networks (MANETs) are of interest in VANETs, but the details differ [5]. Rather than moving at random, vehicles tend to move in an organized fashion. The interactions with roadside equipment can likewise be characterized fairly accurately [6][7]. And finally, most vehicles are

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restricted in their range of motion, for example by being constrained to follow a paved highway. But network topology change more frequently with fast moving nodes in VANET, and density of network is uneven [8][9], network status easily affected by the factors such as time, space, etc., details is shown in Table. 1, so routing protocols in MANET need to be reassessed in VANET scenarios.

Table 1: VANET Compares with MANET

Attribute	VANET	MANET
Node	Vehicles	mobile devices
Movement speed	Express (vehicle)	slow (people)
Topological variability	High	Low
Routing directions	Road path	Random shapes
Resource implications	High	Low
Coverage	Large	Small
Connection maintain	Difficult	Easy

Based on the above research, in VANET, when using traditional routing protocols in MANET [10][11] (such as AODV and DSR, DSDV, etc.), the success of the packet transmission rate does not exceed 50%, and with the large delay and delay jitter intense.

In view of the existing three types of routing protocols, there is not a routing protocol entirely suitable for vehicular ad hoc networks [12][13], this paper proposed DTN-based on-demand routing protocol DT-AODV, in the protocol, new data forwarding mechanism is designed with store and carry forward, and the new data storage forwarding algorithm SFFA (Store and forward flooding algorithm) is proposed, the problem of communications and chain scission can be solved in VANET routing, and packet delivery success rate is improved and the standard routing load is reduced with lower latency.

2 Classic routing protocol in MANET Research in VANET

This section will first use OpenStreetMap maps files to build the actual real road network as a simulation scenario, and then simulate the communication between moving vehicles based on SUMO, MOVE and NS2 [14], the performance of PDR, NRL and AEL will be tested at different vehicle densities with AODV, DSDV and DSR which are three classical MANET routing protocol in VANET, finally a theoretical of the experimental results will be analyzed.

2.1 Build Experimental Environment

As the characteristics of urban road environment are varied speed of vehicle, communications affecting by buildings or obstructions, roads relatively fixed, so VANET routing algorithm in urban road environment has great significance.

In this paper, first use electronic map of San Francisco bay which is open source map posted on the website OpenStreetMap, then build real urban road and node movement simulation model by the SUMO, and simulate the correct vehicle trajectory. In order to test the performance of different routing protocols, it is necessary to the simulation of vehicle information exchange between the nodes. Then write Tcl scripts of the model into NS2, finally, generate trace files through analysis. The performance of AODV (Ad hoc On-Demand Distance Vector Routing) [15], DSDR (Destination Sequenced short Vector) and DSR (Dynamic Source routing) are investigated with different vehicle density On PDR (Packet Delivery Ratio), and NRL (Normalized Routing Load), AEL (Average end-to-end Delay).

2.1.1 Install SUMO

Preparation:
1)Gcc
2)G++
3)Gdal proj xerces-c
4)Libfox-1.6-dev
5)Libgdal 1.7.0
Install:
1)Start SUMO and execute configure

```
/configure
  --with-fox-includes=/usr/include/fox-1.6
  --with-gdal-includes=/usr/include/gdal
  --with-proj-libraries=/usr
  --with-gdal-libraries=/usr
  --with-proj-gdal
```

2) Make
3) Make install
Because the paper is to use MOVE software, so this paper chose SUMO with 0.12.3 version.

2.1.2 Processing maps

Log in OpenStreetMap, map-tailored like Fig. 2:

Download the corresponding Osm file and convert them:

```
netconvert --osm-files download.osm.xml
           -o download.net.xml
```

2.1.3 Import maps

SUMO run the modified map file imported as shown in Fig. 3:
Large map can see specific traffic lights, drive, etc., as shown in Fig. 4:

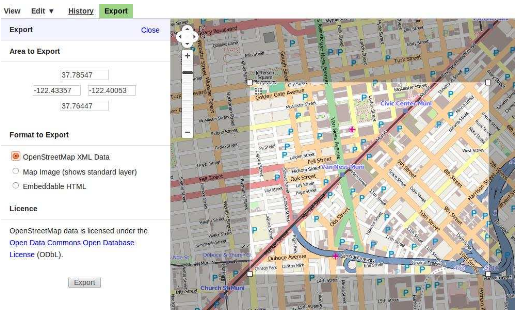

Fig. 2: Tailored map from OpenStreetMap

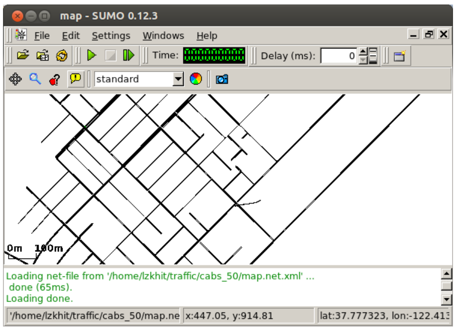

Fig. 3: Import map with SUMO

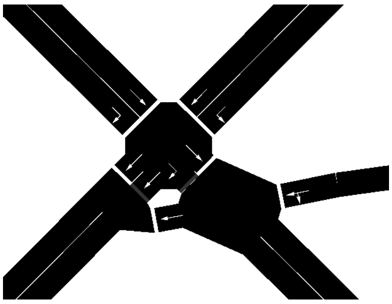

Fig. 4: The large type map in SUMO

2.1.4 Path generation

Map file with vehicle mobile trace is generated according to the detailed design of randomTrips.Py file and DUAROUTER script.

```
/randomTrips.py -n cabs.net.xml -r cabs.rou.xml
```

Get the corresponding trips files, and then constitute the corresponding routes file. When the map is not integrity by generated path, the repair parameters and ignores the error is needed to add in back.

2.1.5 Generate configure file

```
<configuration>
    <input>
      <net-file value="/home/map.net.xml"/>
      <route-files value="/home/cabs.rou.xml"/>
      <additional-files value=""/>
      <junction-files value=""/>
    </input>
    <output>
      <netstate-dump value="/home/cabs.sumo.tr"/>
      <tripinfo-output value="output-tripinfos.xml"/>
      <emissions-output value="output-emissions.xml"/>
      <vehroute-output value="output-vehroutes.xml"/>
    </output>
    <time>
      <begin value="0"/>
      <end value="25"/>
      <time-to-teleport value="-1"/>
      <srand value="23423"/>
      <route-steps value="-1"/>
    </time>
    <reports>
       <print-options value="false"/>
    </reports>
</configuration>
```

In XML file, the input domain defines the map file, the location of the network and vehicle routes. The Output domain defines the trace file and the location of all kinds of info file after the running, as well as the time and reports domain.

2.1.6 Start simulate

Run the configure file in 2.1.5, can get the simulation project, and enlarge to the corner as shown in Fig. 5: Since there is no communication between vehicles, so the

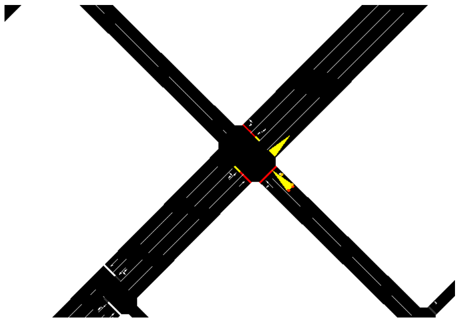

Fig. 5: Simulation Screenshot

simulation environment to build modules only vehicle flow process which laying the groundwork for subsequent simulation.

2.2 Simulation

2.2.1 Control the number of vehicles

In introducing to the SUMO configure file, we talked about the time of the document domain. Here, we can control the simulation time to control the number of vehicles indirectly. The rules of simulation written TCL are generate several vehicles nodes within1s.

2.2.2 Control communication routing protocol

The different routing protocols can be changed by Tcl script with changing the rp (routing protocol) key. Specific routing protocol implementation methods are detailed in NS2 system configuration files.

2.2.3 Write TCL scripts respectively

Network test parameters are shown in Table. 2:

Table 2: VANET Compares with MANET

Index	Parameter
Channel type	Channel/WirelessChannel
Radio-propagation model	Propagation/TwoRayGround
Network interface type	Phy/WirelessPhy
MAC type	Mac/802.11P
Interface queue type	PriQueue and CMUPriQueue
Link layer type	LL
Antenna model	Antenna/OmniAntenna
Max packet in ifq	50
Number of mobilenodes	255075100
Routing protocol	AODVDSDV and DSR
Map area	San Francisco Bay
NS2 version	Ns 2.35
Car model	carFollowing-Krauss

According to the specific grammar TCL scripting, complete vehicle movement and the process of communication between vehicles.

2.2.4 Run the script trace files respectively

After running the script through NAM tool (NAM is an NS2 simulation tool which results can be displayed in visual) to visually communicates the vehicle movement and manifested, as shown in Fig. 6:

Three types of routes with four vehicle densities are analyzed, 12 trace files is generated with PDR, NRL and AEL parameters. To reduce the accidental errors, each experiment was repeated ten times, and averages the results of the experiment.

2.2.5 The experimental results and analysis

(1)PDR (Packet Delivery Ratio)
In Fig. 7, AODV routing protocol which combine DSDV and DSR routing protocol reference step-by-step routing

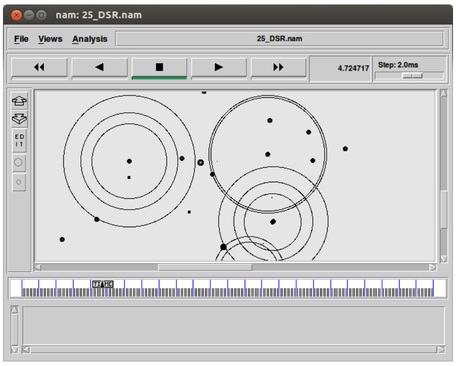

Fig. 6: NAM runs screenshot

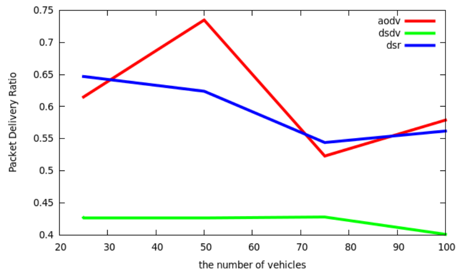

Fig. 7: PDR chart

and regular maintenance from DSDV and discovery strategy from DSR, so PDR in AODV is higher, but PDR will decline with the larger density of vehicles, vehicle intensification of the conflict between the wireless collision. In topology environment with motion dramatic changes, DSDV as a table-driven routing protocols need to constantly update the routing tables, so the data packet PDR is low because routing links often interrupt.
(2)NRL (Normalized Routing Load)

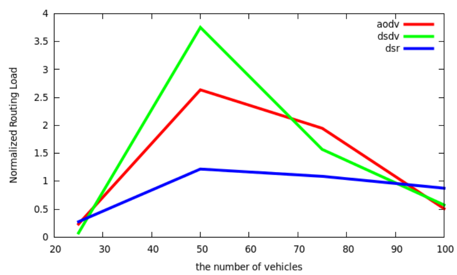

Fig. 8: NRL chart

Fig. 8 shows that NRL in DSDV protocol is highest, AODV is higher, DSR is lowest. With the increase in the number of vehicles, NRL should increase in theoretically, but number of vehicles is limited in the simulation

experiments, so a NRL has phenomenon with Flatten out when increased to a certain degree in result. DSDV as a table-driven routing protocol need for regular broadcast routing link information, increase the network packet traffic, so the routing load is higher. AODV routing protocol reference periodic maintenance in DSDV, so routing load is lower. DSR is the lowest.
(3)AEL (Average End-to-end Delay)

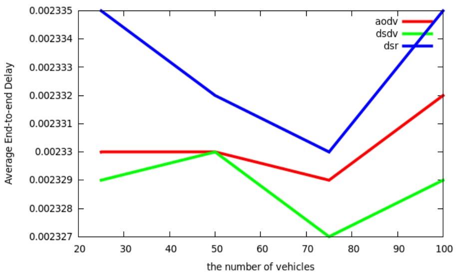

Fig. 9: AEL chart

In Fig. 9, the experimental results are basically the same in many times between AODV and DSDV, increase the number of experiments afterwards only get a slight gap as shown above. The delay of DSR is highest, AODV and DSDV is lower. Since DSR is source routing which need for route discovery strategy, so the delay is highest. Similar reasons, AODV which learn this strategy is lower, DSDV is the lowest.

2.2.6 Conclusions of this section

From section 2.2.5 of the line chart with the specific routing protocol implementation principle, we have come to Table. 3:

Table 3: VANET Compares with MANET

Routing Protocol	PDR	NRL	AEL
AODV	High	Medium	Medium
DSR	Medium	Small	Poor
DSDV	Low	Large	Better

Based on the above research, in VANET, when using traditional routing protocols in MANET (such as AODV and DSR, DSDV, etc.), the success of the packet transmission rate does not exceed 50%, and with the large delay and delay jitter intense. From the table above, the existing several typical routing protocols have their own advantages, but also have a fatal weakness. Balance the pros and cons, three routing protocols are not the best for VANET routing protocol scheme.

3 The Design of DT-AODV protocol in VANET

Based on the above analysis, the traditional MANET routing protocol cannot meet VANET, recent years, researchers from various countries conducted extensive research on mobile self-organized network transmission problem, through analyzing the design and ideas of mobile ad hoc network transmission control protocol elements, some ideas of practical value and programs designed for transmission Control Protocol VANET have reference. But the current studies lack in the mobile self-organized network with particular special in VANET. Delay or disruption-tolerant network (DTN) is an emerging concept which concerned in research field of wireless networks recent years, it refers to reasons such as mobile nodes without stable end transmission paths, and even most of the time in the interrupt status of a class of networks. Compared with traditional networks, topology in delay tolerant network changes dynamically between nodes without a stable transmission path, and may even have no one complete transmission path at any time, making those Ad hoc network routing mechanism which rely on traditional stable transmission path is difficult to play a role. Thus, packet transmission is often based store-carry-forward way to complete in delay tolerant networks. And the active mobile model oriented routing algorithm in DTN can take advantage of the node mobility to assist in the network packet transmission. In general, these algorithms are mainly collaborations between nodes mobile route planning active mobile node under the condition of the known partial node deployment, but how to analysis the algorithm in-depth theoretical which quantify the optimization goal and allows it to have a certain quality of service, we found that the active mobile model with forwarding strategy oriented routing protocol can solve the routing problem of VANET.

3.1 The design of DT-AODV

DT-AODV is designed based on ad-hoc on-demand routing algorithm with store-carry-forward strategy. Taking into account the variability of VANET when connected, and because the vehicle VANET node has great links with the map, so VANET modeled which is a directed multi-graph model is designed, the model is shown as Fig. 10: Graph nodes can be connected to multiple edges, representing different physical connection. Each node j forwards the packet routing, has limited storage capacity (bj). One advantage is that the parameter of the source and destination nodes with a capacity (c (t)) and the delay function (d (t)). Each side is expressed as en = ((u, v) n, c (t), d (t)), where, u, v represent the edge of the source node and the destination node, c (t) represents the link capacity function, d (t)

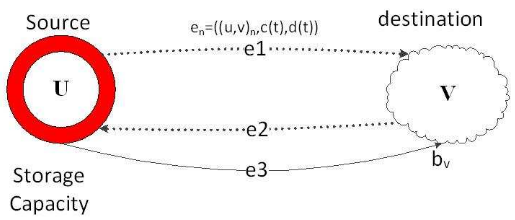

Fig. 10: VANET direction multi-graph model

represents delay function. In addition, set the dynamic topology of the network and traffic demand as abstract knowledge (knowledge: an abstract description of network conditions). Design knowledge set into four kinds of types which are contact with summary, contacts, queuing and traffic needs, each type reflecting a different amount of knowledge, the model is build according to the described above. For vehicle nodes in VANET, the nodes in protocol with transition mode are designed to three states which are destination state, the straight state and intersection state. Vehicle node status is shown as Fig. 11: Through these mode switch between vehicles, the node

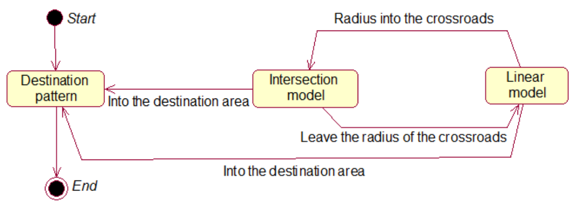

Fig. 11: State diagram of the vehicles

will carry the packet has the best path forward. In these three modes, the intersection point mode is the most critical and most complex, because the vehicle at the intersection has more choices.

3.2 Vehicles model design

To nearest real-life vehicle model, the carFollowing-Krauss model which has the most detailed parameters was selected. The parameters are shown in Table. 4:
(1) Attributes on the table speedFactor and speedDev used for sampling a vehicle and deviations from the mean speedFactor normal distribution speedDev specific choices SpeedFactor. Use speedFactor = 1, speedDev = 0.1 will result in the velocity distribution, of which 95% of the legal speed limit of 80% and 120% of the vehicle driver. For flows, each vehicle will be drawn into the single chosenSpeedMultiplier. Maximum resulting value of 0.1, in order to prevent extreme dawdle. The vehicle

Table 4: CarFollowing-Krauss Model parameters

Attribute	Value Type	Description
id	id(string)	The name of the vehicle type
accel	float	The acceleration ability
decel	float	The deceleration ability
sigma	float	The driver imperfection
tau	float	The drivers reaction time
length	float	The vehicle's netto-length
minGap	float	Empty space after leader
maxSpeed	float	Vehicle's maximum velocity
speedFactor	float	Vehicles lane speed limits
speedDev	float	Deviation of the speedFactor
color	RGB	vehicle type's color
vClass	class	An abstract vehicle class
emissionClass	emission	An abstract emission class
guiShape	shape	How this vehicle is rendered

maintains its chosenSpeedMultiplier edge speed multiplied throughout the simulation to calculate the actual speed driving on the edge. Thus, the vehicle speed can exceed the edge. However, the vehicle speed is still subject to the type of vehicle MAXSPEED.
(2)As far as possible the simulation model car chase real data, the Gaussian model uses two values to describe car lengths. Length-attribute attribute describes the length of the vehicle itself. Furthermore, minGap-attribute describes the shortest distance between vehicles. See Fig. 12:

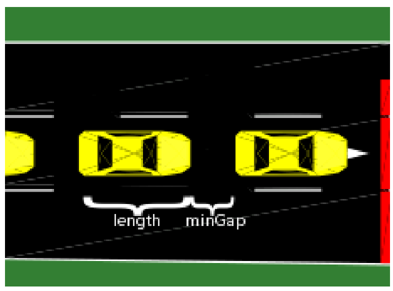

Fig. 12: Vehicle model

3.2.1 Set the parameters for the vehicle model

CarFollowing-Krauss model which is car chase model was used in experiment. In this model, the vehicle speed by the speed of the vehicle traveling ahead in the constraints of the vehicle-collision, when the vehicles speed in mind we call a safety speed and do vsafe. Specific safety speed analytic formulas can be expressed as equation (1):

$$vsafe(t) = vt(t) + \frac{g(t) - vt(t)\tau}{\frac{\bar{v}}{b(\bar{v})} + \tau} \quad (1)$$

$$
\begin{aligned}
&Where\\
&v_{safe} - vehiclesafetyspeed\,(m/s)\\
&v_t\,(t) - aheadvehiclespeedattimet\,(m/s)\\
&\bar{v} - averagespeedbetweenthetwovehiclesaround\,(m/s)\\
&g\,(t) - thedistancefromthevehicleinfrontattimet\,(m)\\
&\tau - driver'sreactiontime, typicallylessthan1s\,(s)\\
&b\,(t) - adecelerationfunctionaboutt\,\left(m/s^2\right)
\end{aligned}
$$

Be practical environmental constraints, and finally the ideal vehicle maximum speed as shown in Equation (2):

$$vdes(t) = \min[vsafe(t), v(t) + a, v\max] \tag{2}$$

$$
\begin{aligned}
&Where\\
&v_{safe} - thesafetyspeed\,(m/s)\\
&v\,(t) + a - real - timespeed\,(m/s)\\
&v_{max} - Roadspeedlimit\,(m/s)\\
&a - maximumvehicleacceleration\,\left(m/s^2\right)
\end{aligned}
$$

To be more realistic, we continue to introduce new variable which is the human factor coefficient, because the driver cannot always keep focused state. Plus a non-negative rate, the actual speed of the vehicle Equation (3):

$$v(t) = \max[0, rand[vdes(t) - \varepsilon a, vdes(t)] \tag{3}$$

3.3 DT-AODV Protocol detailed design

Based on the analysis above, AODV protocol in MANET is more mature, but it is not applicable in VANET. We first draw in the basic strategy in AODV when design DT-AODV protocol in this paper, and then add the storage to carry forward thinking, the final completion of specific agreements DT-AODV, and key part of the protocol described in detail as follows:

```
AODV::sendRequest(nsaddr_t dst) { //send RREQ
aodv_rt_entry *rt = rtable.rt_lookup(dst);//
  add a route to the destination node , the route is
   unavailable at this time , invalid
void AODV::sendError(Packet *p, bool jitter) {
  // If the link is interrupted, need to send RERR,
  notify all affected nodes
Save(p&rt_dst) //temporary storage routing
void AODV::sendHello() //carry information and
   periodically sends Hello packets to detect the
  connectivity of neighbors
void AODV::recvAODV(Packet *p) //call different
   functions based on packet type , as follows:
  case AODVTYPE_RREQ    recvRequest(p);
  case AODVTYPE_RREP:   recvReply(p);
  case AODVTYPE_RERR:   recvError(p);
  case AODVTYPE_HELLO:    recvHello(p);
void AODV::recvRequest(Packet *p) {//  received
  RREQ
if(rq->rq_src == index)   Packet::free(p); //
  discard the RREQ
if (id_lookup(rq->rq_src, rq->rq_bcast_id))
  Packet::free(p);
id_insert(rq->rq_src, rq->rq_bcast_id);//
  etermine whether the received RREQ
  void AODV::sendReply(nsaddr_t ipdst,
  u_int32_t hop_count, nsaddr_t rpdst, u_int32_t
  rpseq, u_int32_t lifetime, double timestamp) //
  Fill RREP content
  void AODV::recvReply(Packet *p) // find
  whether there is a route to the destination node ,
   there is established or updated
  RERRvoid AODV::recvError(Packet *p)  //
  received RERR, check which path is interrupted due
   to the impact of the link , update RERR content
  to affected node sends the content.
```

4 DT-AODV Performance Evaluation

This section will be used the experimental environment in Chapter 2, the, build the actual real road network as a simulation scenarios which use OpenStreetMap map file, simulate the moving vehicles based on both SUMO, MOVE and NS2, and simulate the communication between the vehicles, testing the performance of the DT-AODV emphatically, and compared with AODV, DSDV and DSR, analyzed four kinds of vehicle density parameters (25,50,75,100) under the PDR, NRL and AEL. To increase the reliability of the experiment, each experiment was repeated ten times, and averages the results.

(1)PDR (Packet Delivery Ratio)

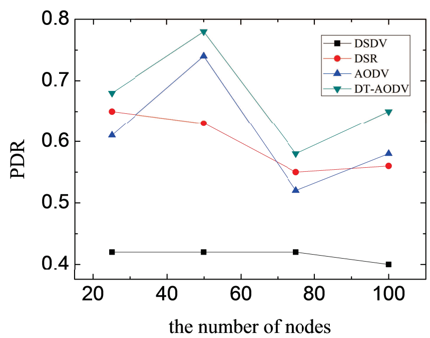

Fig. 13: Packet Delivery Ratio chart

In Fig. 13, the packet transfer rate of success in DT-AODV protocol which draws DTN store-carry-forward mechanism is better than AODV.

(2)NRL(Normalized Routing Load)

In Fig. 14, when the node is sparse, routing load standardization in DT-AODV is the highest, but as density increases, DT-AODV packet delivery rate increased, the standardized routing load will be reduced.

(3)AEL(Average End-to-end Delay)

In Fig. 15, when the node is sparse, the Average End-to-end Delay in DT-AODV is the highest, but as density increases, DT-AODV packet delivery rate increased and the Average End-to-end Delay will decreases accordingly.

(4)DV(Delivery Ratio) Delivery ratio under different storage capacity cache data as shown in Fig. 16:

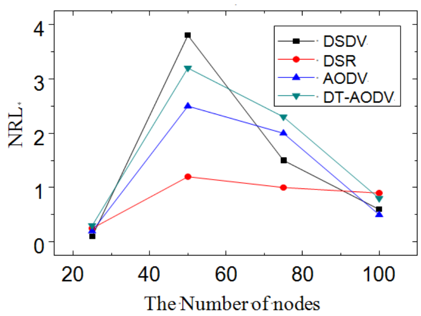

Fig. 14: Normalized Routing Load chart

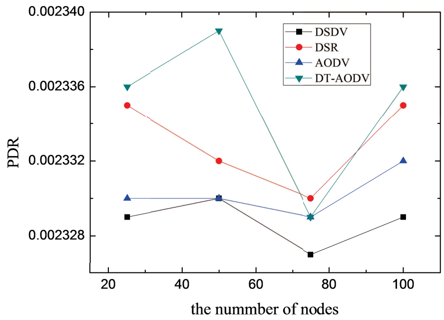

Fig. 15: Average End-to-end Delay chart

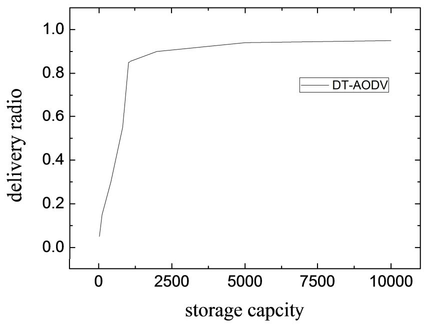

Fig. 16: Delivery ratio under different storage capacity chart

The figure can be seen that increasing the storage buffer capacity of the vehicle can increase transfer data arrival rate, but once over 5000kb storage capacity, the transmission rate is increased less and may even lead to difficulties in looking for packets addressed, and could waste of time to find the address of data packet. So we recommend the vehicle node carry a reasonable storage capacity. In conclusion, put the store and forward mechanism in DTN into AODV protocol and applied to VANET can improve the PDR, NRL and AEL, especially in the timeliness, and when under different storage capacity cache, the resulting data delivery rates are different, so set reasonable storage node cache can improve the arrival rate of data transmission.

5 Conclusion

In this paper, OpenStreetMap map files was used to build the actual real road network as simulation scenarios, simulate the moving vehicles based on both SUMO, MOVE and NS2, and simulate the communication between the vehicles. To illustrate what kind of routing protocols suitable for vehicular ad hoc networks which have peculiarity of packet transmission rate, normalized routing load is high and large average end to end delay, the authors tested the performance of PDR, NRL and AEL at different vehicle densities with three classic route protocol which are AODV, DSDV and DSR, analysis shows that the existing several typical routing protocols have their own advantages and disadvantages. Balance the pros and cons, three routing protocols are not entirely suitable for vehicular ad hoc networks routing protocol scheme. However, DTN network which topology changes dynamically over time, in order to effectively sends the packet to the destination, the messages when determine the appropriate transmission path are often based on the store-carry-forward mechanism, so VANET routing protocols can be designed by characteristics of DTN, DT-AODV protocol was proposed draw-demand MANET routing protocols AODV for VANET, DT-AODV significantly increased the data delivery rate for node characteristics which are distribution of high-density, high-speed mobile, after design, experiments with different density vehicles was proceeded and finally compared with AODV, DSR and DSDV, comparisons show that the new protocol with store-carry-forward the data storage mechanism is more suitable for VANET in terms of data delivery ratio higher forwarding, greater probability in packet reaches the destination node, and DT-AODV is a better solution for the actual traffic situation. However, due to join the store-carry-forward mechanism, leading to improved route cost, delay in DT-AODV is larger than the AODV, but overall still under control, optimize data forwarding algorithm to reduce the routing overhead will be the next research goal.

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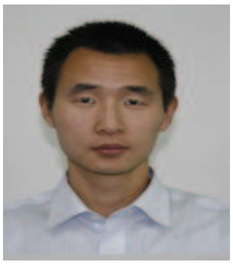

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