Opportunistic Routing Protocol for Resource Optimization in Vehicular Delay-Tolerant Networks (VDTN)

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Abstract
VDTNs (Vehicular Delay-Tolerant Networks) are a breakthrough-based DTN solution for vehicular communications in difficult situations of long delays and intermittent connectivity. This technology uses the store-carry-and-forward model to enable in-transit bundles to arrive at their destination asynchronously, hop by hop, over moving vehicles fitted with short-range wireless devices. The VDTN architecture is based on out-of-band signalling with separate control and data planes, and it employs an IP over VDTN strategy. This paper presents an Opportunistic Routing Protocol called OPRNET, which works on the routing decisions based on global location data, and merges a hybrid technique between multiple-copy and single-copy approaches. It also improves the performance by minimized energy consumption in vehicular communication approach. The simulation results from our proposed approach suggest that OPRNET is feasible and can be viewed as a very important technology for vehicular communications, though it does include appropriated technologies for outline interferences and QOS support. OPRNET attempts to optimize network capacity such as storage, latency, and energy consumption while increasing distribution chance and reducing latency and overhead.

Keywords: DTN, ORPNET, Store-carry-forward, bundles drop ratio and total overhead.

I. INTRODUCTION

Traditional vehicular ad hoc networks (VANETs) routing and forwarding protocols attempt to provide end-to-end communication among network nodes and support end-to-end interfaces of existing transports and applications. As a result, they struggle to produce results, in sparse, irregular, partially connected, and opportunistic vehicular networks. To overcome these issues, vehicular networks should use the store-carry-and-forward (SCF) model of delay-tolerant networks (DTNs), which maximizes data distribution possibility, particularly in sparsely populated areas.

Vehicular delay-tolerant networking (VDTN) is a modern architecture that includes three groups of nodes: terminals, relays, and mobile nodes. Fixed or mobile computers (vehicles) that may be the source or endpoint of data are known as terminal nodes. They will operate as access points (APs) or servers once they have Internet access, offering valuable knowledge about road and weather conditions (e.g., traffic jams, entertainment, etc.). Relay nodes are stationary nodes with store-and-forward functionality that are positioned at crossroads. Mobile nodes (bikes, motorcycles, taxis, vans, and so on) are in charge of physically carrying and forwarding bundles from the source to the destination nodes. Therefore, proposing a novel routing protocol will improve the performance of the VDTN and communicates the message in an efficient ways and improves the life span of the network.

Objectives

The following objectives are recommended for the research work in order to increase the network's efficiency.

a) Suggest an opportunistic network principle (in which nodes are used geographically to carry information among vehicles) and the distribution of bundles based on the store-carry-and-forward principle, as well as produce a route decision using geographical location information given by positioned devices.

b) To introduce a multiple-copy routing system with a limit on the number of copies per bundle, as well as a forwarding routing approach, to increase data distribution efficiency and storage capacity across multi-hop vehicles by clearing bundles on hop nodes that have been distributed to destinations.

This study aims to assist network designers and administrators in choosing and designing routing protocols that are suitable for delay-tolerant applications. The remainder of this paper is structured in the following manner. In Section II, the DTN routing protocols' literature reviews and related work are presented in a sequential format. The proposed work and architecture discussed in the chapter III. Performances metrics, Simulation setup and the key issues of proposed OPRNET routing protocol are presented in Section IV. Finally, Conclusions are in the Section V.

II. RELATED WORK

Because of their high versatility and stable mobility trends, vehicular ad hoc networks (VANETs) vary from traditional wireless networks [2]. Owing to the lack of infrastructure and regular changes in the network, communication in VANETs is more difficult, but the essence of motion can be projected using roads and automated city maps [2]. The number and type of information used to make a routing decision are classified by DTN Routing Protocols. Each packet is given a unique ID that is associated with it and all of its copies before they are dropped or sent to their intended destination. The biggest disadvantage of Epidemic routing is that it consumes a lot of scarce resources including memory, power, and contact period.

[9] proposes the Probabilistic Routing Protocol with History of Interactions and Transitivity (PROPHET). The protocol calculates a metric called delivery predictability for each node. PROPHET provides partial guiding to the destination by tracing node contacts and assigning weights to these contacts, whether they were made directly or through intermediate nodes.

Blind-routing protocols [7],[8] aim at fast spreading of packets in the network. Since they don't use node selection criteria, these protocols don't accumulate information from other nodes. They differ in terms of how they disperse and how far they spread. The biggest disadvantage of Epidemic routing is that it consumes a lot of finite resources including memory, power, and contact period.

DTN employs the store-and-forward strategy [2]. On an IP network, the DTN network employs the package protocol. The Package protocol bundles data from applications and sends it to lower layers of the overlay network.

III PROPOSED WORK

VDTNs are defined by short node-to-node connections and a highly complex network topology, with routing being an especially difficult problem. Routing protocols that must share control information during communications in order to upgrade routing tables or other databases usually have less time to pass data packages.

Routing protocols that do not keep such control details, on the other hand, are forced to make more bundle copies in order to achieve the same distribution efficiency. Furthermore, directly applying the store-carry-forward method to vehicular networks may result in a large number of packet replications, which can create data congestion, especially when vehicles are dense. Data transmission speeds, data transfer time between source and destination, energy efficiency, and bandwidth utilisation are also critical factors to consider when designing routing protocols.

3.1 VDTN Routing Protocols

As previously stated, routing protocols in VANETs are designed to provide end-to-end connections between network nodes, as opposed to the delay tolerant setting. However, the bundle protocol, which is the foundation of DTN, does not fix routing issues since no routes between nodes are defined.

3.2 NETWORK MODEL

We consider a city-wide network of pedestrians and cars roaming along predefined pathways that serve city streets as nodes. The number of nodes is N. As these nodes come into contact range with one another, they are linked by wireless links. They are said to be in contact if anything happens.

Sender (Sc), Receiver (Rc), Time (tc), and Length (Dc) are the four attributes of a communication c, as discussed below:

Sender: The node whose buffer holds the messages that will be sent to the other node.

Receiver: The node that is expected to receive the messages that are sent by the other node.

Time: When the two nodes are within contact range of each other and begin exchanging control packets, this is the moment.

Duration: The amount of time that two nodes are in contact with each other and can send and receive messages. Each of the n€N nodes has its own message buffer. The buffer of a node has two properties: The below are the capacity and occupancy attributes:

Capacity B_n: The maximum number of messages that node n's buffer will hold.

Occupancy b_n: The number of messages in node n's buffer at the start of the communication.

As discussed below, each message m has four attributes: source, destination, transmission time, and TTL.

Source: The message's source is the node that created it.

Destination: The message's destination is the node to which it should be sent.

Transmission time d_m: During a contact, the transmission time dm is the time it takes to send m from one node to another.

Lifetime L_m: The Time-To-Live TTL, or the lifespan of message m, in which the message is no longer useful and should be discarded. We'll use the terms 'path' and 'route' interchangeably in the document, as well as the terms 'packet' and 'message'.

3.3 PERFORMANCE METRICS

The following three metrics are used to assess the success of the various protocols:

Delivery ratio, DR: the ratio of the packets delivered to those generated in the network during the simulation time

$$DR = \frac{\sum_{n \in N} (P_{dv})_n}{\sum_{n \in N} (P_g)_n} \quad \text{-------(3.1)}$$

where $(P_{dv})_n$ is the number of packets transmitted to node n's destination, and $(P_g)_n$ is the number of packets produced at node n's source. Simply put, the distribution ratio is the proportion of packets transmitted to packets produced in the network during the simulation period.

Delivery cost, DC:

$$DC = \frac{\sum_{n \in N} (P_r)_n - \sum_{n \in N} (P_{dv})_n}{\sum_{n \in N} (P_{dv})_n} \quad \text{-------(3.2)}$$

where $(P_r)_n$ is the number of packets received by node n. The cost of delivering one packet to the routing protocol in terms of redundant packets is denoted by DC.

Average packet delay, Del:

$$Del = \frac{\sum_{n \in N} \sum_{p \in DV_n} d_p}{\sum_{n \in N} (P_{dv})_n} \quad \text{-------(3.3)}$$

Performance Overhead: When the network expands, so does the volume of routing traffic. The cumulative number of routing packets sent over the network, calculated in bits per second or packets per second.

Throughput: Throughput is defined as the ratio of the total amount of data sent by a sender to the time it takes for the recipient to receive the last packet.

3.4 Improved Opportunistic Routing Protocol (OPRNET)

The OPRNET protocol proposed in estimates a node metric, P(a,b), similar to PROPHET routing protocol. When two nodes meet, they improve their link by adding a constant to the protocol, which is set to 1. The two nodes then split their delivery predictability for all nodes, including each other, by 1+ α, resulting in a total delivery predictability of 1.

P(a,b) = P(a,b) + 1 direct contact between a and b

P(a,c) = P(a,c)=(1 + α) c is every other node including b
where £ [0,1] is the upgrading constant, that is set to 1.

OPRNET's biggest contribution is its buffer control. As a result, OPRNET prefers packets with fewer hops to scatter across the network. The OPRNET protocol parameter is given in table -1. The procedure for OPRNET is given below

Procedure 3: Improved OPRNET Routing Protocol

```
1.  Procedure Name: OnContact
2.  Input: a,b and contact duration      /* a and b are nodes*/
3.  Discard Expired (a,b) /* Drop packets in both nodes whose lifespan has expired */
4.  Share Summary Vector(a,b)
5.  Update Delivery Predictability()
6.  if Contact Duration > 0 then
7.  pkt=GetPacket(a)
8.  if pkt then
9.      if NotReceivedBefore(pkt,b) then
10.         if IsDestination(pkt,b) then
11.             SendPacket(pkt,a)
12.             ConsumePacket(pkt,b)
13.         else
14.             DPn1=DeliveryPredictability(pkt,a)
                DPn2=DeliveryPredictability(pkt,b)
15.         if DPn2 > DPn1 then
                SendPacket(pkt,a)
                    StorePacket(pkt,b)
16.         end if
17.     end if
18.         Contact Duration=Contact Duration-size(pkt)
19.  end if
20. end if
21. end if
```

PROTOCOL	PARAMETER	VALUE
OPRNET	Initialization count	0.70
	Transitivity constant	0.20
	Aging constant	0.90
	Initial number of copied	5

Table 1: Protocol Parameters

IV SIMULATION RESULTS

Since OPRNET did not mention their queuing strategy in their job, we introduced a First-in-First-out (FIFO) scheme. Each point in the results figures is the average of ten repetitive experiment results with a degree of confidence 0.95. Delivery ratio, Delivery cost, and Average packet delay are the three metrics we consider for evaluating the OPRNET's performance. The metrics are explained in Section 3.3

We conducted five set of experiments to study the impact of the following parameters:

- Packet lifetime or time-to-live (TTL),
- Buffer Capacity,
- Traffic load by changing the packet generation rate, and
- Node density by changing the number of nodes in the network

Table 1 lists the values used in both of the tests for protocol parameters, while Table 2 lists the network parameters.

PARAMETER	PEDESTRIANS	VEHICLES
#Hosts	5,20,30,40,55	5,10,15,25,30

Speed 2,7-13.9 m/s	0.5-1.4 m/s	2,6-13.9
Movement	Shortest Path Map Based Movement	
Buffer capacity	2-10 Mbytes	
Packet TTL	Packet TTL	
Average Packet Inter-generation time	10,30,60,300,600 seconds	
Transmission speed	5 Mbps	
Simulation time	Simulation time	

Table 2: Network Parameters

Table 3 gives a rundown of the findings from the various studies. The number of packets sent is counted, and the total delivery time is calculated in minutes. In terms of distribution percentage, protocols are ranked from highest to lowest, and in terms of other metrics, they are ranked from lowest to highest.

IMPACT OF	BUFFER	TTL	N	TL
Delivery ratio	0.40-0.81	0.64-0.82	0.80-0.85	0.26-0.95
Comments	**Numbers shown are the minimum and maximum values. Ordered from high to low. The higher the better.**			
Delivery cost	3.0-3.5	2.8-3.5	3.7-6.5	20-28
Comments	**Numbers shown are the minimum and maximum values. Ordered from low to high. The lower the better.**			
Average delay	70-75	45-72	23-70	36-82
Comments	**Numbers shown are the minimum and maximum values. Ordered from low to high. The lower the better**			

Table – 3 Summary of Performance of OPRNET Routing Protocol

The simulation results of impact of changing buffer capacities on delivery ratio can be represented as Fig 1 impact of changing packet TTL on average packet delay can be represented as Fig 2 and Impact of changing packet TTL on cost of packet delivery represented as fig 3

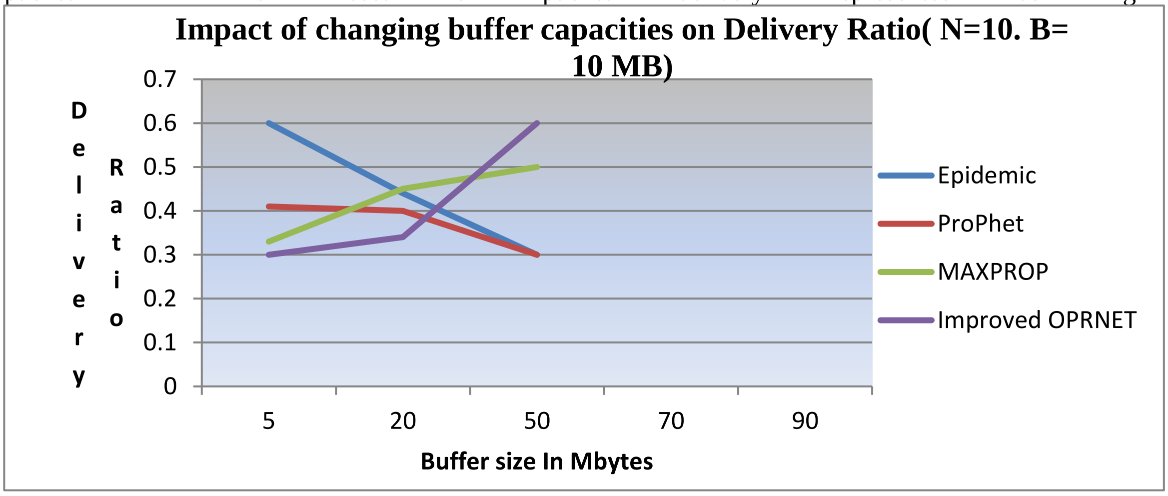

Fig 1. Impact of modifying the buffer capacities on Delivery Ratio

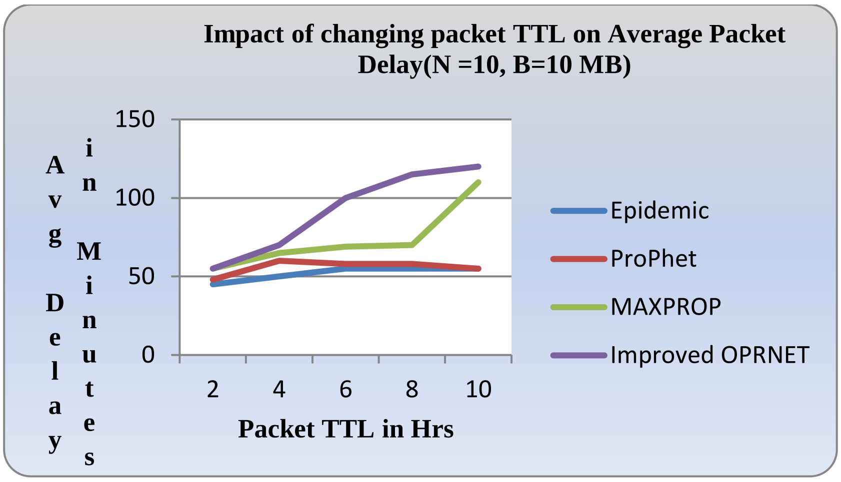

Fig 2. Impact of modifying the packet TTL on Average Packet Delay

Although transmissions and receptions increase with the higher values of TTL, delivered packets also increased. Therefore, packet delivery cost is found to be almost constant as shown in Figure 3

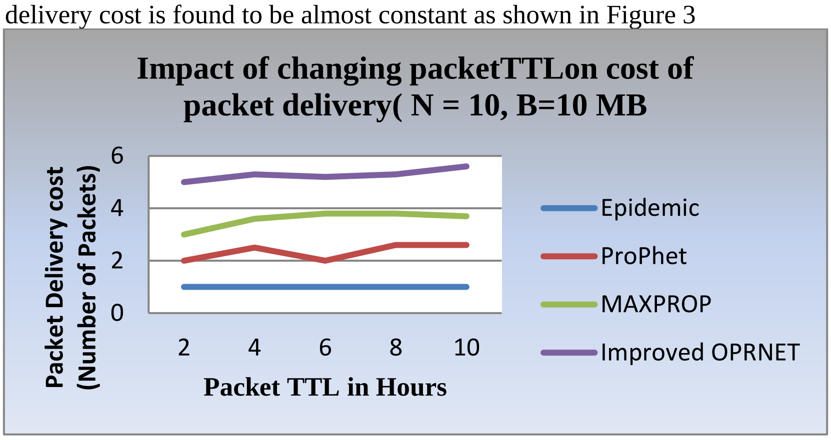

Fig 3. Impact of changing packet TTL on cost of packet delivery

V SUMMARY AND CONCLUSIONS

DTN routing protocols change as indicated by the measure of data they procure to take the directing choice. Conventional routing protocols don't gather any data about the network and, in this manner; they don't have a node selection mechanism. They simply dispersed the packets in the expectation that one of the copies would arrive at the intended location. When the packet spreading is limited, the efficiency improves. By selecting relay nodes, OPRNET looks for potential ways to overcome objections, improving the distribution ratio. End-to-end delays can be reduced by using a packet selection mechanism. A buffer management system aids in the expansion of the buffer space available for newly created and arriving packets. We introduced Results show the out performance of OPRNET in conveyance cost. To achieve the best results, an effective routing protocol should combine node selection, packet selection, and buffer management mechanisms. Likewise, it is seen that, resources present in the network is enhanced because of the best performance of our proposed OPRNET convention.

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