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STUDY OF VDTN ROUTING PROTOCOLS PERFORMANCES IN SPARSE AND DENSE TRAFFIC IN THE PRESENCE OF RELAY NODES

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Vehicular Delay Tolerant Networks (VDTN) are growing challenging field of Delay Tolerant Networks (DTN) containing mobile nodes (vehicles) that communicate using the paradigm of store carry and forward. In this model, nodes store the bundle waiting for the opportunity to transfer it to another node in the same transmission range, and in a limited duration. VDTN enables communications in a sparse network characterized by low density, high mobility of nodes, intermittent connectivity, no end-to-end communication and no information on the path of nodes, which make routing in such cases difficult and challenging. This paper studies the performances of some well-known VDTN routing protocols in sparse and dense traffic. The proposed scenario considers stationary nodes representing sensors measuring different types of data to be transferred to stationary destination nodes through the VDTN network (vehicles). The destination nodes are the only part of the network that is connected to the Internet. The transmission of collected data is also made by fixed nodes representing stationary relays such as audio-signal traffic lights, placed in the crossroads of Rennes city streets. The map of Rennes has been used and the position of the stoplights has been carried out using Open Data. The aim of our simulation is to study the impact of mobile nodes and stationary relays on the routing protocols performances in dense and sparse traffic.

Key words: Vehicular Delay-Tolerant Networks, Routing, Relay, Performance Evaluation, ONE

1 Introduction

Vehicular delay tolerant network (VDTN) is a class of networks that extends the features of delay tolerant network (DTN) to the vehicular environment [1][2]. It was the subject of many researchers in the recent decade because of its potential applications such as safety related information, information advertisement, multimedia sharing content, weather reports and email access[3][4]. VDTN enables communications in a network characterized by intermittent connectivity, no end to end path between

communicating nodes, high change of network topology, high error rate, limited duration of nodes contact [5] for these reasons, routing in such environment is a challenging task. Indeed, routing protocols for such networks should be designed to guarantee message transmission even when the traffic is very low. VDTN is characterized by its paradigm of store carry and forward that motivate the use of opportunistic routing protocols. The idea behind this concept is that, the node store message called bundle in its buffer size till they find the opportunity to transfer it to its destination[5]. In this paper we study the performance of some well-known VDTN routing protocols, in the case of dense and sparse traffic. Our previous work [6] studied the suitability of VDTN routing protocols to collect data in smart cities and focused on the impact of various parameters on the routing protocols performances. The current work is the continuity of the previous one where we want to get closer to real cases. For this reason, we have used for our simulations, the map of the city of Rennes and its traffic information provided by open data. The study focuses on stationary nodes collecting data and transferring it to other stationary nodes connected to the Internet. The transmission of data is made through mobiles nodes that are vehicles, and stationary relays representing audio-signal traffic lights. The main goal is the study of the impact of those parameters on the routing protocols performances.
The remainder of this paper is organized as follows. Section 2 is an introduction to DTN, its architecture, VDTN and the routing protocols used in both DTN and VDTN. Section 3 describes the scenario used in the current study with its different parameters. Section 4 contains the results of the simulations and the interpretations of graphs. Section 5 concludes the paper.

2 Background

2.1 Delay Tolerant Network (DTN)

Delay tolerant network is an opportunistic network[7] which has attracted large attention in the last few years[8]. This kind of network is characterized by intermittent connectivity, high error rates, long and variables delays/latencies, and high node mobility [9][10]. It was designed for the first time in 1998 in partnership with Nasa's Jet Propulsion Laboratory[11] to establish communication between different nodes located in the solar system[12]after the failure of the traditional routing protocols used in the internet communication because of the frequent disruptions, and the excessive propagation delays. The project was named interplanetary networking (IPN), and then it spread to different challenging applications as wireless sensor networking and the vehicular networking [12].

To deal with the new situation where the traditional routing protocols are not suitable anymore, the group of research DTN (DTNRG), which has taken part of Internet Research Task Force (IRTF) had proposed new architecture designed to DTN [13]. The aim was to support new routing protocols, features related to DTN, and also to provide structure dealing with the heterogeneity of different communicating regions, by the addition of a layer between the transport and the application layer named bundle layer (figure 1). It connects the specific lower layers so that application programs can communicate across several regions of different natures. The bundle layer also stores and relays the bundles/messages hop by hop between nodes[14].

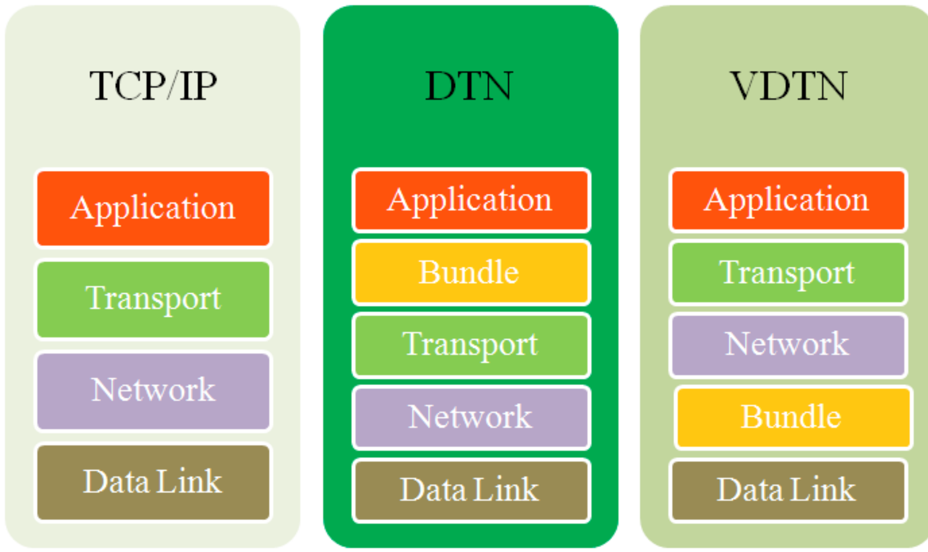

Figure 1: Difference between TCP/IP and DTN architecture

2.2 The Approach of Store-Carry and Forward

Contrary to the approach used in the Internet, which relies on the store and forward principle, the DTN use the paradigm of store, carry and forward implemented in its new architecture.

This approach allows the intermediate nodes to store the bundles in their buffers for remarkable amount of time that can be minutes, hours, or even days; waiting for the opportunity to get in touch with the next node until the messages reach their final destinations or their time to live (TTL) expires.[15].

2.3 Vehicular Delay Tolerant Network (VDTN)

The Vehicular Delay Tolerant Network (VDTN) is a growing field of DTN that has, recently, led to numerous research works (figure 2). It extends the principle of VANETs, by using the characteristics and the capabilities of DTN in order to deal with the intermittent connectivity, the high error rates, and the high mobility of nodes[13]…etc. It is considered one of the most challenging applications of DTN.

There are many applications of VDTN, ranging from road safety improvement to the traffic flow and road capacity optimization. For more details related to VDTN applications, one can consult one of the comprehensive surveys in the literature [13].

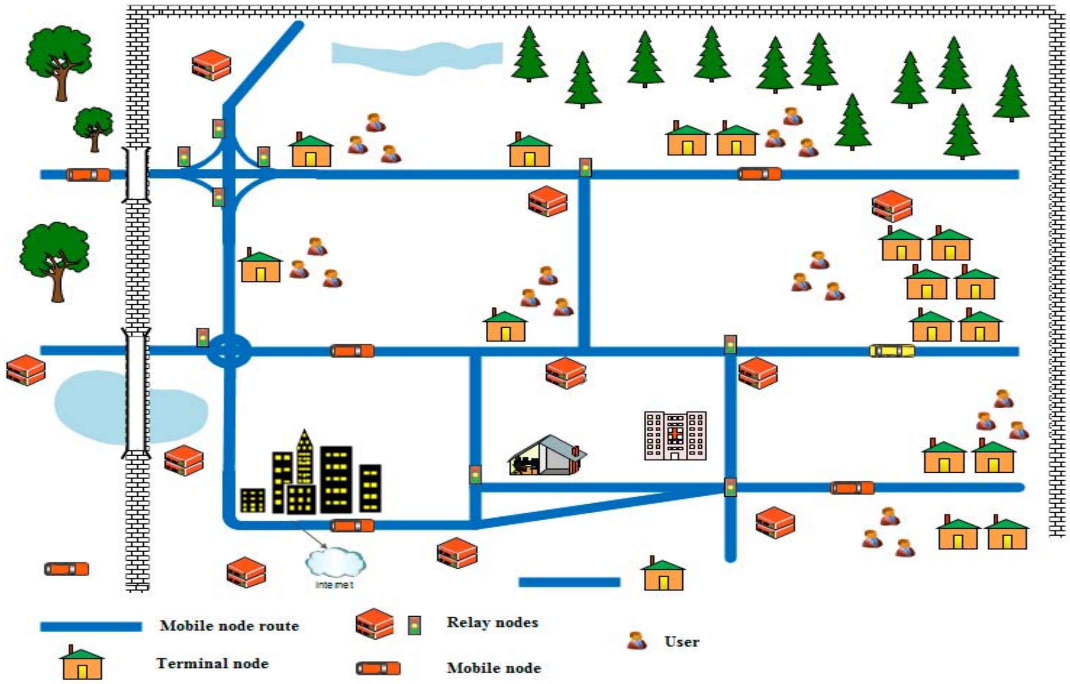

Figure 2 : Example of VDTN scenario

2.4 Routing Protocols

First Contact is a single copy DTN routing protocol, i.e. only one copy of each message exists in the network. In this protocol, a message is transmitted along a single path by selecting the node randomly from the available links. If the connections do not exist, nodes store data, and transmit it to the first contact available. However, this node will not delete the message directly transferred, but it will remove the old data when it is stored entirely[16][17].

Direct Delivery is a single copy DTN routing protocol. Its simplicity lies in the fact that a given source node can deliver its own message. In the strategy of direct delivery, the source node stores the message and sends it directly to the destination node; it always chooses the route between the source and destination. If the buffer is full and the message has not been sent, it will be dropped[16].

In the epidemic routing protocol [18], which is based on the flooding strategy, the node replicates the message and transfer it to every node that gets in touch with and that doesn’t have the message.

Its strategy decreases the delay of delivery and increases the hop count and the overhead ratio because of the number of resources used.

Contrary to epidemic, Spray And Wait routing protocol [19] uses n-copies to transfer the messages. This protocol contains two phases: (1) Spray phase, where the message spread from the source nodes to the others nodes until the n copies get exhausted, (2) Wait phase, where the nodes that receive the message transfer it to its final destination [20]. This protocol had two versions, the normal one, where the node gives one copy to every contacted node, and the binary one which is considered as an improvement of this protocol and consists on transferring half of the messages to every contacting node[21].

Furthermore, another routing protocol has gained much attention by researchers in DTN field. This is Probabilistic Routing Protocol using History of Encounters and Transitivity routing protocol (Prophet), which is based on the strategy of forwarding. This routing protocol calculates probabilistic metric named delivery predictability, to estimate which node has the higher probability to be the best node for transferring the message to its final destination with less latency[22] [23].

MaxProp routing protocol tries to transfer all the messages not retained by the other nodes when they are in the same transmission range, to guarantee successful transfer of the messages. This protocol manages the buffer size of nodes by using the acknowledgements to clear the copy of messages remaining in the other nodes when they are transferred to their destinations. In this protocol, nodes exchange messages by depending on the delivery likelihood to a destination to give the priority to a specific node between others[24]. Table 1 summarizes different routings protocols in VDTN.

Routing Protocols	**Type**	**Type of Copy copy**	**Estimation based**	**Description**
Direct Delivery	Direct	Single	No	Source moves and delivers the bundle directly
First Contact	Random	Single	No	Use any available contact
Epidemic (ER)	Flooding	Unlimited-copy	No	Rapid propagation of data
Spray & Wait	Controlled flooding	n-copy	No	Sets a limit on the number of copies
PROPHET	Probabilistic	Unlimited-copy	Yes	Probabilistic
MaxProp	flooding	Unlimited-copy	Yes	use of the delivery likelihood as a cost assigned to each destination

Table 1 Summarization of different routing protocols known in VDTN

2.5 About One Simulator

Opportunistic Network Environment (ONE) is a Java-based open source simulator used for the implementation and testing of routing protocols. The main functions of the ONE simulator are the modelling of node movement, inter-node contacts using various interfaces, routing, message handling and application interactions [25]. It was designed especially for delay tolerant network. By the use of its Graphic User Interface (GUI), ONE allows the visualization of nodes movement during the simulations, which facilitates the understanding of the simulation [26]. Results collection and analysis are done through visualization, reports and post-processing tools [25]. The six routing protocols mentioned above, are implemented by default in ONE Simulator. Also it uses the map of Helsinki city and contains different models of mobility such as random way point model, map based movement model, and shortest path map based movement.

3 Performance Assessment

In this section, we define the scenarios of our comparative study of the well known routing protocols in VDTN: Epidemic, Spray And Wait, Prophet, and Maxprop. We did not compare Direct Delivery and First Contact because they are not suitable for our study.

Moreover, we compare the routing protocols using four performance metrics. Delivery Probability, which is the percentage of successfully, delivered bundles among the bundles sent. Average latency, which defines the time between the generation of the bundles and their delivery. The overhead ratio, which measures how many transfers are needed for each bundle delivery. And finally, the contacts per hour, which defines the number of contacts per hour for the relay nodes.

3.1 Network Setting

In the current study, we did not use the default map of ONE. Indeed, the network scenario is based on a part of the city of Rennes (France) as shown in fig.3. Ten stationary sources nodes and ten stationary destinations nodes are placed on the extremities of the map. The coordinates of these nodes are not arbitrary, but in accordance with the information provided by the open data related to the city of Rennes. The aim is to transfer bundles from those sources, representing sensors, to destinations representing gateways connected to the Internet. This communication is enabled through mobile nodes representing vehicles and relay nodes representing auto signal traffic light that we get from the traffic information of the city of Rennes. The aim is to simulate VDTN routing protocols using real data.

In the first set of simulations, the number of mobile nodes is 30 to specify sparse network, then we change it to 80 nodes to simulate the case of dense network. The number of relay nodes deployed in the network was changed from 0 to 14 nodes to show their impact on the performances. The position of all nodes is shown in figure 4.

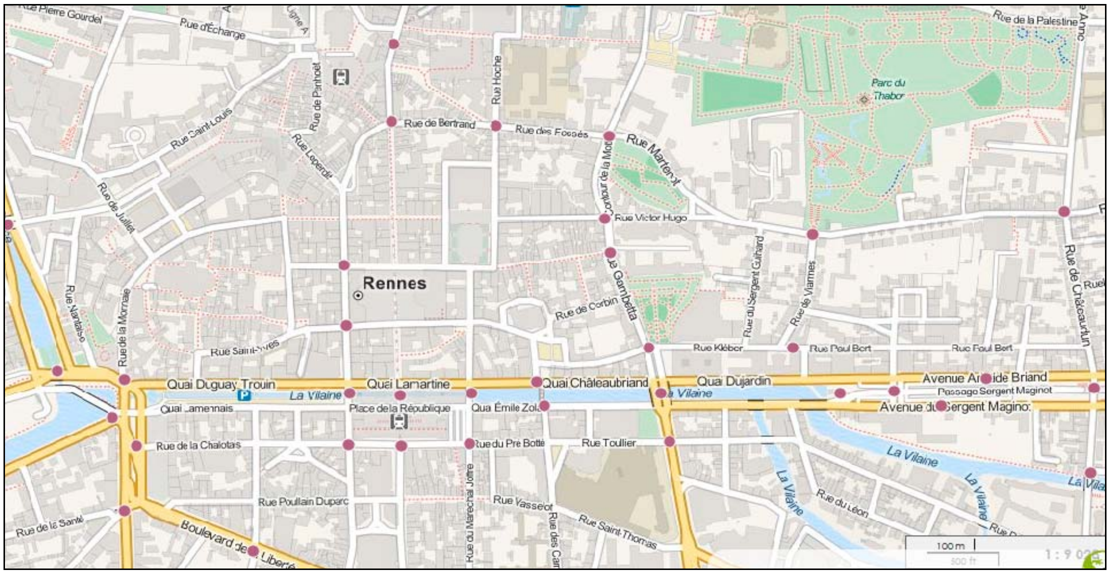

Figure 3 The part of Rennes's city map

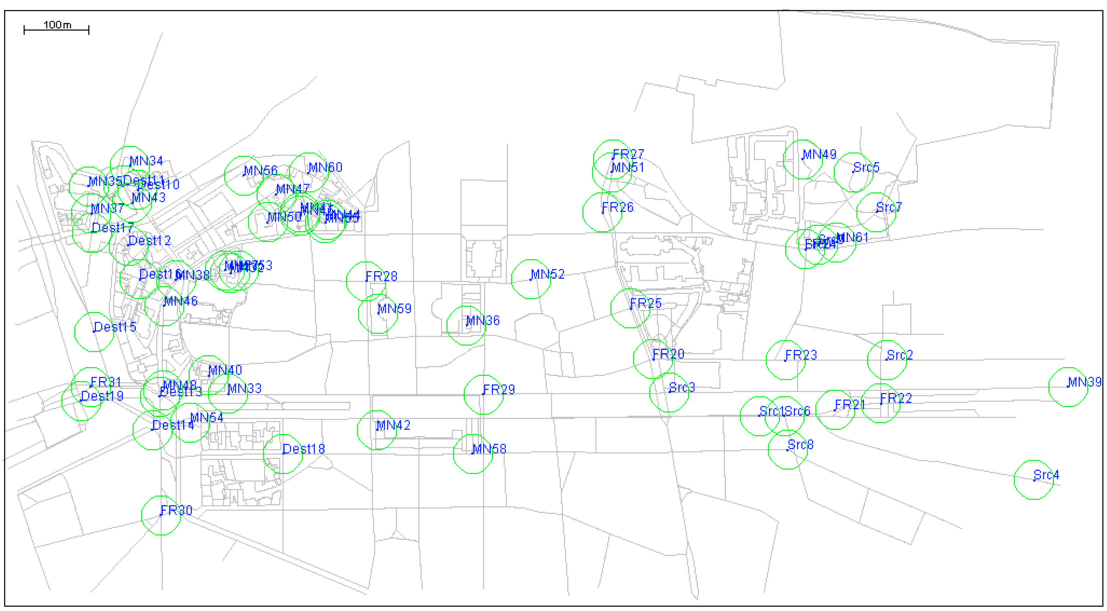

Figure 4 Position of all nodes before the start of simulation

The time of simulation is 12 hours. All nodes in the network have a 5M in their buffer size. The group of mobile nodes (vehicles) moves along the map roads, with a speed ranging from 10 km/h to 50 km/h by using shortest path map based movement model. Data bundles are originated at specific stationary source nodes and are destined to specific stationary terminal nodes. No random transmissions have been used in all simulations. Furthermore, we have used external event generator to create 1000 messages with sizes varying from 100KB to 1MB. These messages are created in an interval time between the start of the simulation and 900s. The TTL was fixed 60min for all simulations. All nodes in the network use wifi802.11, with transmission range of 30 meters and transmission speed of 11Mbps. Table 2 summarizes the different parameters used in our study.

Simulation time	43200 secondes
Buffer size	5 M
Movement model	Shortest Path Map Based Movement
Time to live (TTL)	60 min (1h)
Routing Protocols	[MaxProp; Epidemic; Prophet; Spray And Wait]
Interface type	Simple Broadcast Interface
Number of nodes	Sources nodes : 10 nodes Destinations nodes : 10 nodes Mobiles nodes : [30;80] nodes Relay nodes : [0;5;14] nodes
Speed of mobile nodes	10-50 km/h
Size of bundles	100KB, 1MB
The event genertor used	External Event Queue
Size of map	10000,10000
Transmission range	30 meters
Transmission speed	11 Mbps
Number of copies (L)	15, the binary mode = true

Table 2 Different parameters used in the scenario configuration

We ran the simulations several times using different seeds for each protocol, and then we calculate the average of all results to reach the confidence interval. The simulation takes in average 30 to 40 min when the number of nodes in the network is small, contrary to the case when the number is more important. It also depends on the protocol used because some routing protocols take more time than the others. After the end of simulation, ONE provides the possibility of viewing the path of different messages from their sources to their destinations. In figure 5, we illustrate an example of messages path from sources Src3 and Src6 to destinations Dest10, Dest11, Dest13, and Dest18.

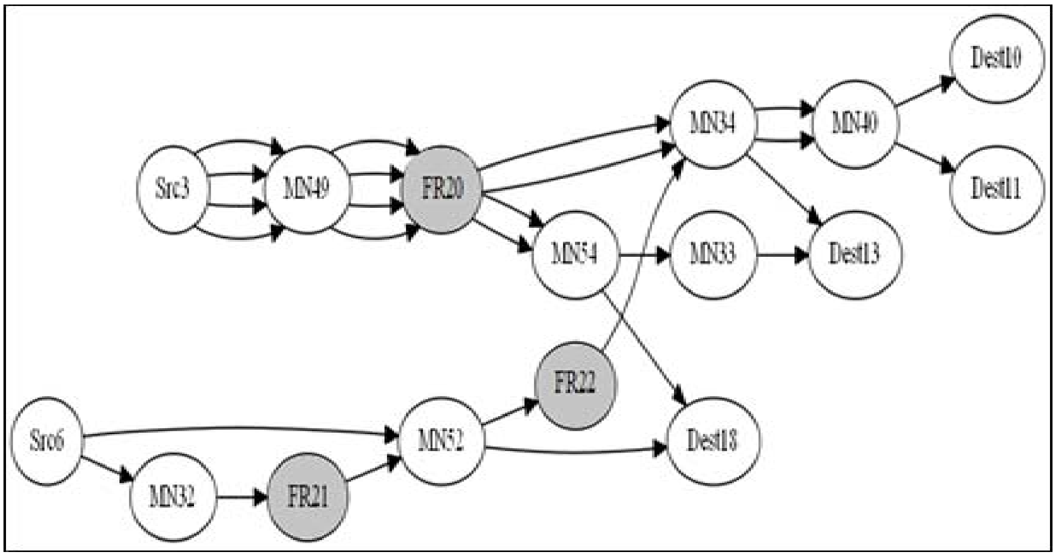

Figure 5 Example of paths messages from sources nodes to destinations nodes

Maxprop offers the best chance of delivery through its buffer management mechanisms of the queue, acknowledgments, followed by spray and wait. Epidemic does not provide good results in terms of the delivery probability because it creates an unlimited number of messages, the same for prophet, because of its calculated probability, which can cause message loss due to expiration of its TTL before its transmission.

4 Results And Discussion

4.1 Simulation Scenario With 30 Mobile Nodes

We start our evaluation by simulating a scenario with 30 mobile nodes. The delivery probability increases with the number of relays because if we have more stationary relays we will have more possibility that the message reaches its destination because it plays the role of intermediary between nodes especially in the case where density is very small (Figure 6). In addition, the latency decreases when increasing the number of fixed relays because there is more chance that the message arrives promptly (Figure7).

At average latency, Maxprop is not very efficient because, the transmission of the message requires more time to choose the shortest path to the message, but the Epidemic protocol transmits the message promptly because, by creating an unlimited number of messages, it explores all available paths in order to convey the message with minimal delay.

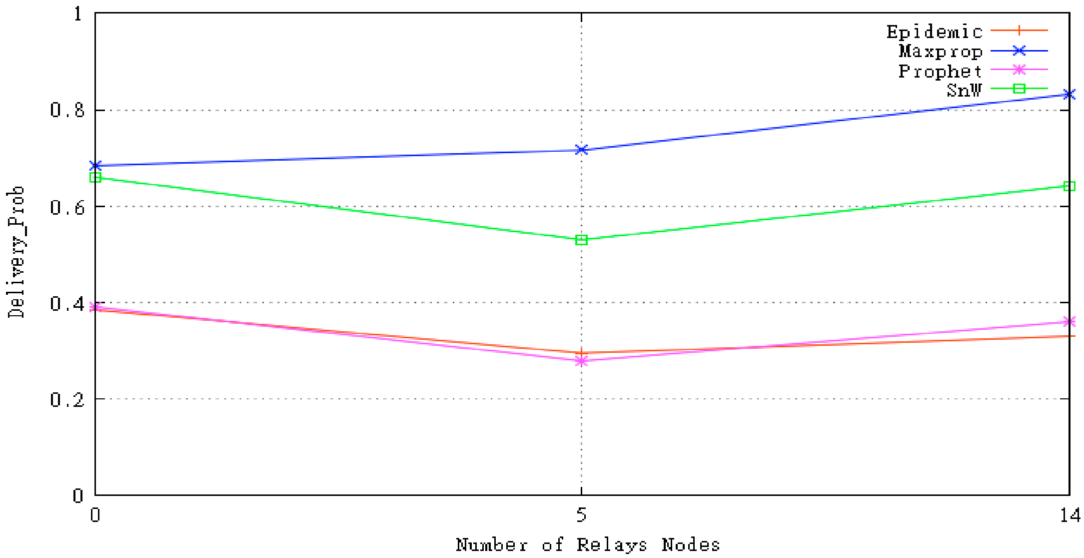

Figure 6 Delivery probability depending on relay nodes in sparse traffic

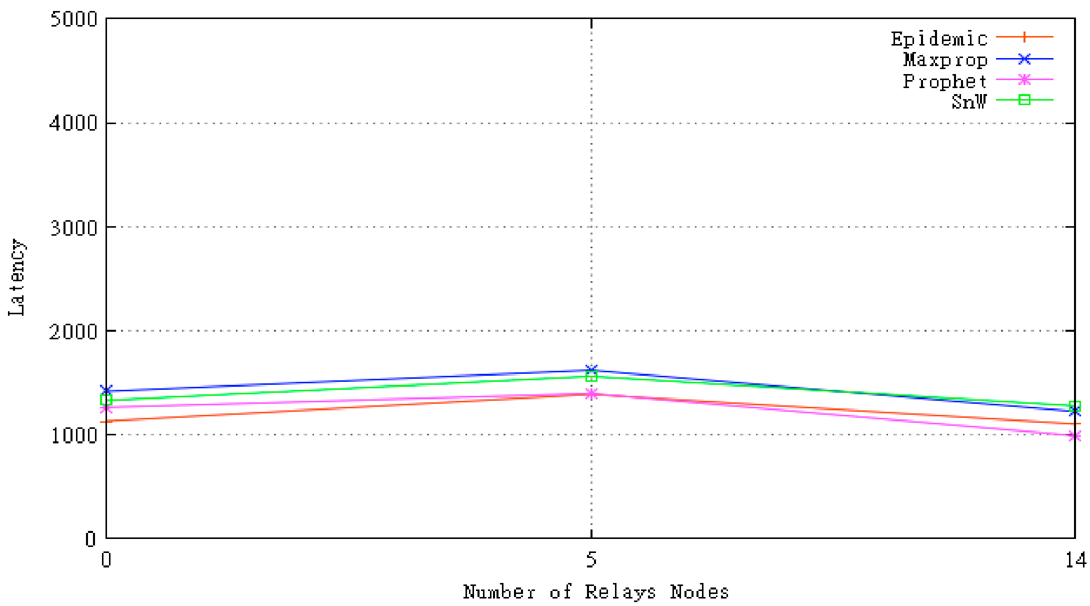

Figure 7 Average latency depending on relay nodes in sparse traffic

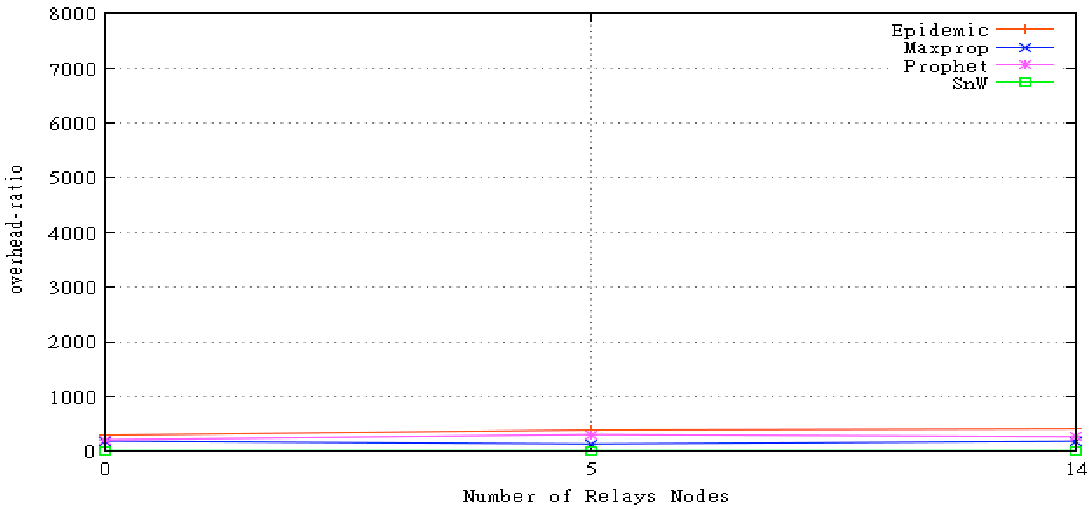

Figure 3 Overhead ratio depending on relay nodes in sparse traffic

The multitude of copies in Epidemic justifies valuable overhead ratio with this protocol. With spray and wait this amount of overhead ratio is very small because this protocol created a limited number of copies that can optimize the use of bandwidth. (Figure 8)

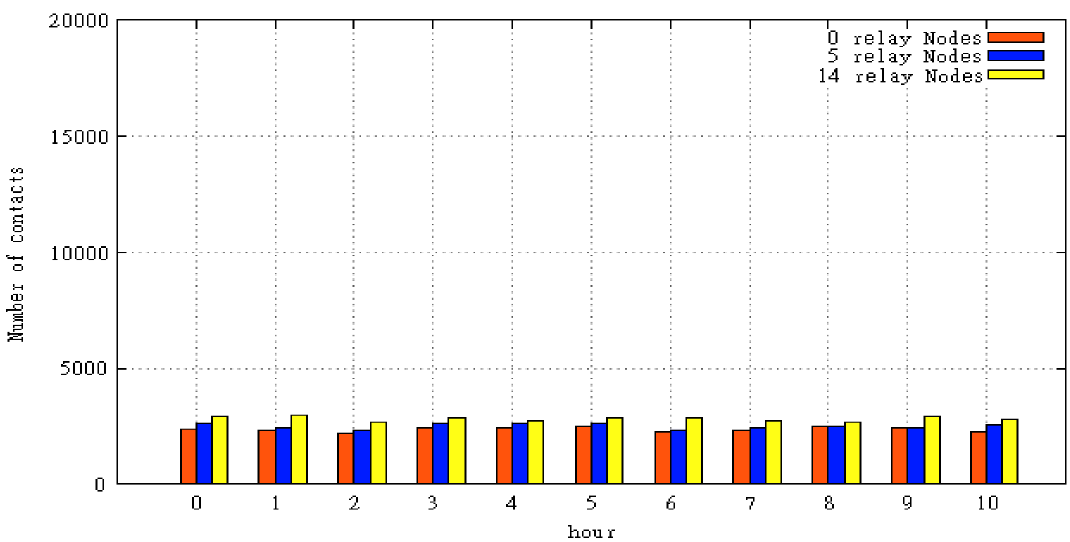

Figure 9 Number of contacts per hour in sparse traffic

The number of contact time increases when the number of relays increases, as the relay function is to act as an intermediary between two or more mobile nodes, it receives a message from a node and forwards it to another which causes an increase in the number of contacts. (Figure 9)

4.2 Simulation Scenario with 80 Mobile Nodes

The second scenario has 80 mobile nodes in the network, in an environment with medium density Spray and Wait is the best in terms of delivery probability followed by Maxprop. Identically to the other case where the traffic is sparse, Epidemic is not very effective at this metric compared to other protocols. (Figure 10)

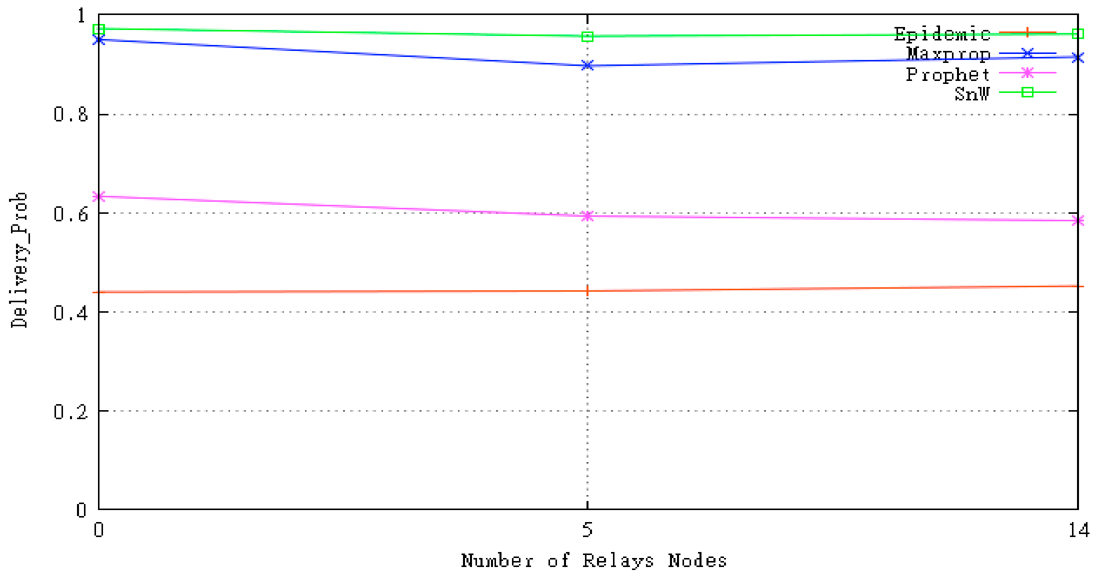

Figure 10 Delivery probability depending on relay nodes in dense traffic

In this environment, the message in Maxprop take less time to reach the destination compared to the others routing protocols, as opposed to spray and wait protocol that offers the greatest time for the transmission of messages. (Figure 11)

Figure 12 shows that the overhead is very large in this case with epidemic routing protocol, which uses very large memory resources followed by the prophet protocol given the number of copies used by the first and the exchange of predictability vectors used by the second. Unlike spray and wait protocol that uses fewer resources because of the limited number of bundle copies being generated.

As mentioned earlier, the number of contacts increases when the relay nodes are present in the network because of their role. Moreover, the simulations shows that in dense traffic the contacts between nodes increase remarkably, as a result of the number of nodes moving in the network. (Figure 13)

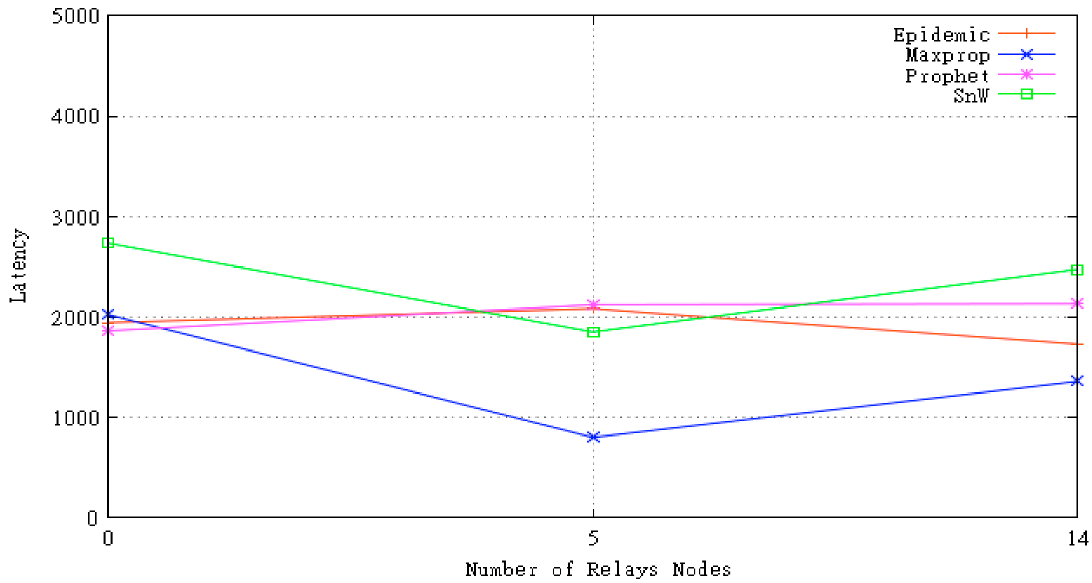

Figure 41 Average latency depending on relay nodes in dense traffic

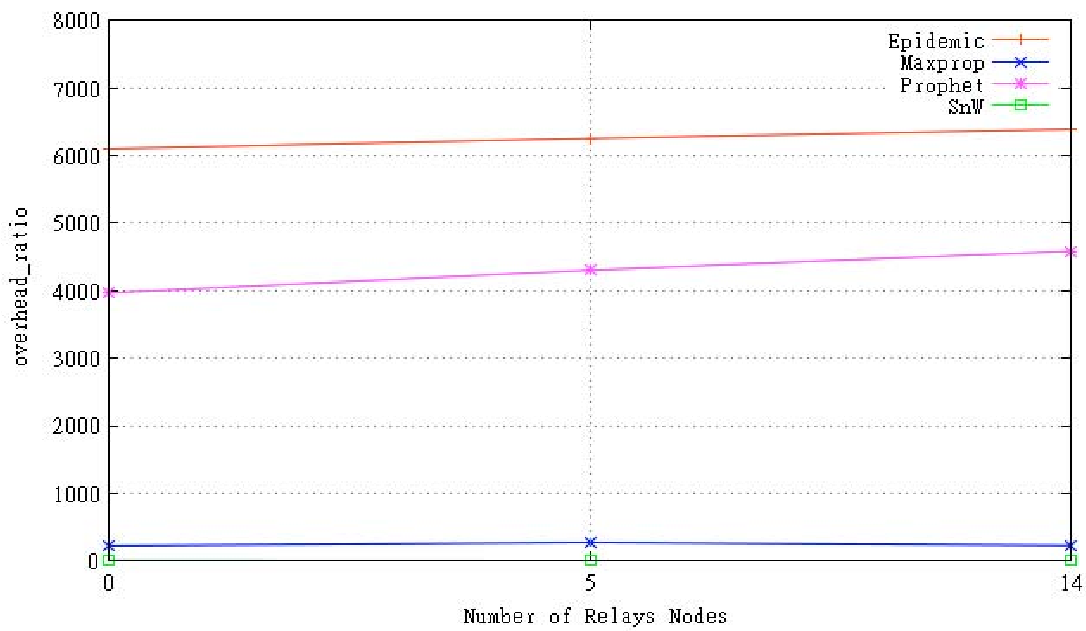

Figure 5 Overhead ratio depending on relay nodes in dense traffic

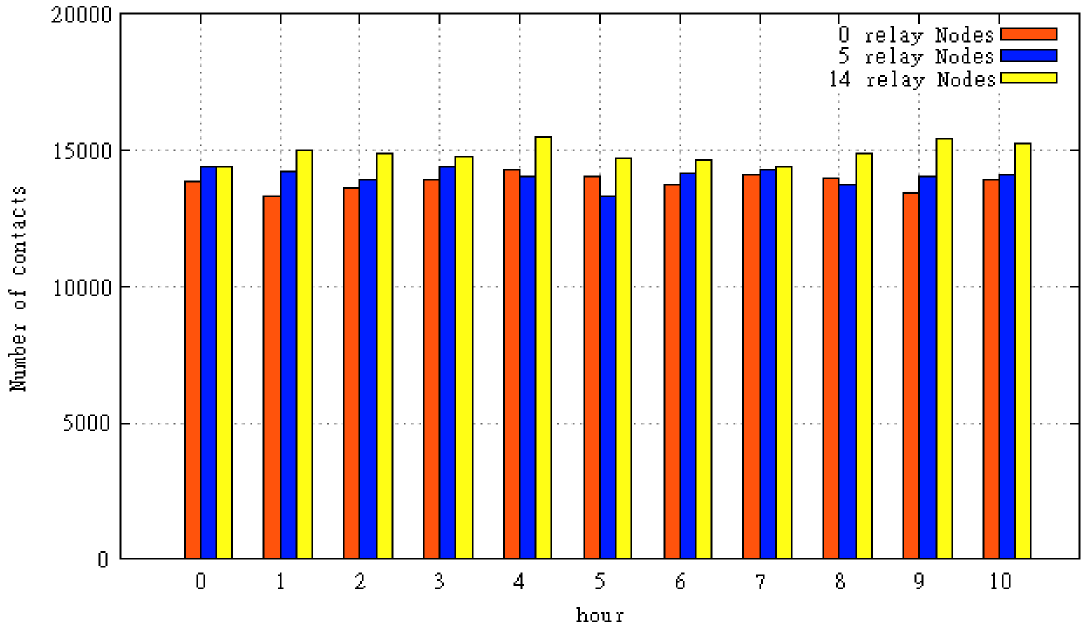

Figure 6 Number of contacts per hour for dense traffic

5 Conclusion

This study compared the performances of different VDTN routing protocols in sparse and dense environment and with different values of relay nodes. Our goal was to compare between various routing protocols using real data of the city of Rennes in order to bring out the impact of relay nodes in such environment.

In this paper, we have used the ONE simulator for our simulations. The results demonstrate that there is no best routing protocol suitable for all cases, and all metrics; indeed each protocol has its strengths and weaknesses depending on the scenario under consideration, which includes the density of the traffic.

The use of relay nodes in this study demonstrates their important role as intermediates between mobile nodes to store the bundles for a maximum amount of time, especially when the number of nodes in the network is very small.
From the analysis of the routing protocols in our study, we conclude that it is necessary to develop and design a robust routing protocol that could be more efficient in various situations and can be easily implemented.

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