MinVisited: A Message Routing Protocol for Delay Tolerant Network

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MinVisited: A Message Routing Protocol for Delay Tolerant Network

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***Abstract*—We studied routing protocols for Delay Tolerant Networks devised to improve the message delivery performance in natural disaster scenarios. In this paper we propose the MinVisited protocol which during the transitive path to the message destination, selects the next node based on two features: (1) the most distant neighbor, and (2) the largest number of encounters with the destination node of the message. We compare our protocol with well-known protocols of the technical literature. The results show that the proposed protocol presents a low workload overhead with a number of hops lower than 2, and in average 95% of the messages are successfully delivered.**

***Keywords*-Delay Tolerant Networks; the ONE simulator.**

I. INTRODUCTION

The Delay Tolerant Networks (DTN) have been widely studied in the technical literature to enable communication in disaster scenarios which may lack of continuous network connectivity, specially between mobile devices. After large-scale natural disasters situations, it is important to maintain communication channels operating. In other words, it is important to have fault tolerant communication networks. A communication loss, either between communities, people or government entities, can delay sending medical assistance and also delays rescue operations. DTNs have been devised to re-establish the communication by using secondary channels. Examples of this kind of situations are common in Chile, a high-seismicity country with 111 earthquakes to date [8], with approximately 7,9 millions mobile devices reported until December 2016 and with 57% disapproval on telecommunication services in the earthquake in 2010 [9]. Other more recent situations are the earthquake in Mexico (2017), and the Irma hurricane which affected mostly Cuba and the United States.

In this work, we propose a new communication protocol, named MinVisited, for DTNs. Our proposal is designed to deliver a message to the farthest neighbor, so in this way we increase the possibility for a larger hop and therefore to reach the destination node faster. The goal is to reduce the number of hops in the transitive path to the message destination. We evaluate our protocol using the ONE (Opportunistic Networking Environment) Simulator which has been widely used in the literature to evaluate this kind of network protocols [7]. We compare our proposal with well-known protocols of the technical literature such as the Epidemic [3] and the Spray and Wait [4].

II. RELATED WORK

DTNs are typically categorized in two kind of protocols for message routing [1]. In the first one, named forwarding-based, only a single copy of a message exists in the network at any given time, which allows to reduce the wasteful of network resources [1]. An example is the First Contact protocol [2]. The second kind of protocols, named flooding-based [1], wastes more network resource as it tries to take advantage of the mobility of the nodes. The aim is to rout messages by hops and multiple copies are sent to the destination node. Some example are the Epidemic [3] and the Spray and Wait [4] protocols.

The protocols presented in the technical literature propose different algorithms for message routing. Those algorithms are based on special characteristics of the network and the history of the neighbor nodes. Some examples include:

- Epidemic, it is a flooding-based algorithm. It continuously delivers a message copy through the network to all reachable and newly discovered nodes [3].
- Spray and Wait, this protocol sets an upper bound on the number of copies per message allowed in the network. Later, it waits until each one of the nodes that have a message copy delivers the message in a direct way to the destination node [4].
- Probabilistic Routing Protocol using History of Encounters and Transitivity (PROPHET), this protocol maintains a set of probabilities for the successful delivery of the messages to known destination nodes in the network. This probability is calculated based on the encounter history of each neighbor [5].
- MaxProp, this protocol is devised to determine which packets should be deleted when buffers are low on space. This protocol prioritizes the fewer number of hops to the destination node [6].

Mobility models are an important factor affecting directly the performance and evaluation of routing protocols, and each model presents different behaviors as for example: random movements and more complex movements such as working days, evasion of obstacles, movements in the city, etc. In this context, it is important to use simulations tools

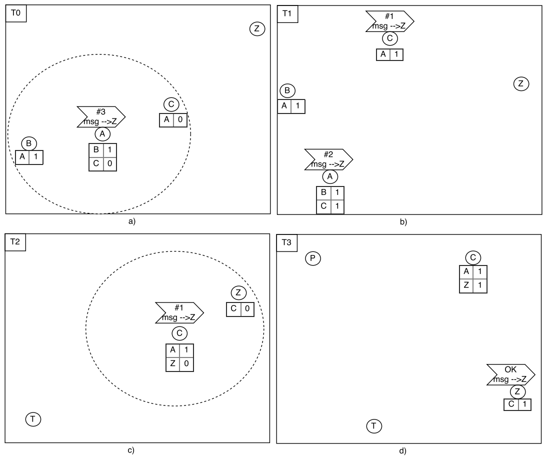


Figure 1. Sequence of steps executed to route a message.

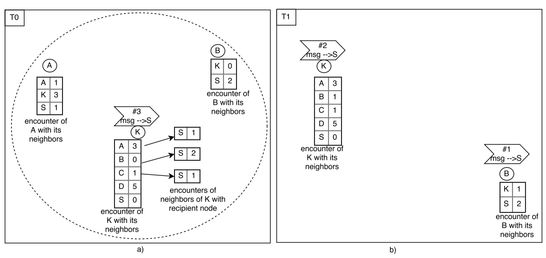


Figure 2. Example of the "confirmation" step.

which help to evaluate the routing protocols for DTN. The ONE Simulator [7] allows to evaluate a group of metrics for those protocols using different mobility models.

III. MinVisited protocol

Our proposed protocol aims to spread messages as far as possible from the origin node, so in this way it has a higher possibility to reach out-of-range destination nodes. The distance is defined as the number encounters between nodes, i.e., while fewer encounters are recorded between two nodes, the farther they are.

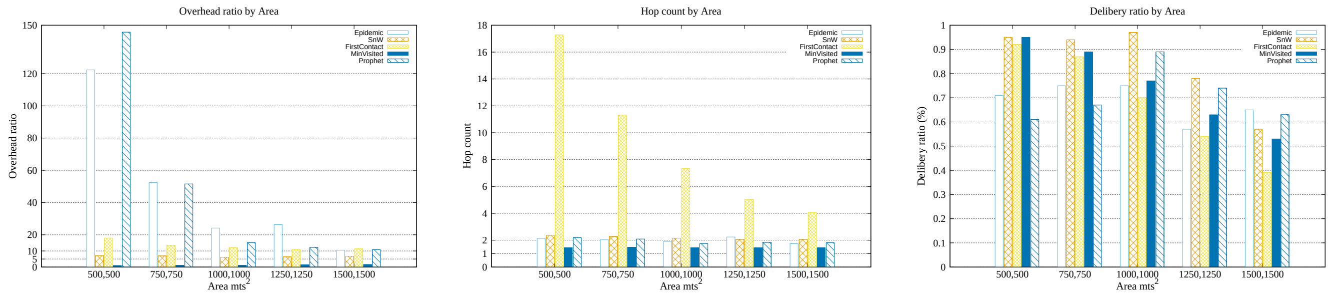
The protocol follows these six rules:

- All the messages have a fixed number of copies. This number is updated as messages are successfully delivered either to the destination node or to an intermediate node.
- During each time interval (or window time) the message can be replicated on a limited number of neighbors.
- Each node has an encounter vector -a hash table with two descriptors (key; value)- used to store the number of encounters between the node and its neighbors.
- When a node must replicate a message it selects the neighbor with fewer encounters. We call this node candidate intermediate node. In the Figure 1, we show the sequence of steps used to route messages between nodes. At the instance time T0 (Figure 1.(a)), the node A starts to send a message to node Z. The number of copies is set to "#3". However, the node Z is not within the covering radius of node A, which is represented by a dotted circle. Each node holds a hash table with previous encountered nodes. In the transitive path to the message destination, the node A finds the nodes B and C, being C the farthest node, because it has fewer previous encounters with A -actually none- unlike the node B which has one previous encounter with the node A. Therefore, C is selected as the candidate intermediate node to send the message.
- After selecting a candidate intermediate node, the algorithm has to confirm that the selected node is the best choice to send a copy of the message. To this end, the algorithm verifies whether the intermediate node has a greater or equal number of encounters with the destination node than the origin node. If so, the origin node confirms the selection of the intermediate node and delivers a copy of the message. After this confirmation, in Figure 1.(b) and Figure 1.(c), as the time advance (T1 and T2) the hash tables are updated as well as the number of copies of the message in the node A (it is updated to "#2" in T1). In T2, the node C is encountered with the node Z and, in Figure 1.(c), it sends the message to the destination node.
  Figure 2 shows an example of the "confirmation" step. In this example, the node K sends a message to the node S, based on its covering radius. At time T0, the node K encounters the nodes A and B within its covering radius, and selects the node B as a candidate intermediate node since it has fewer encounters with K (none). To confirm this selection, the algorithm verifies that the candidate intermediate node B has more encounters with the destination node S than the origin node K. Due to the condition is fulfilled, the node K sends a copy of the message to the node B.
- Finally, in case a node has a single copy of the message, the node waits until it encounters the destination node. That is, the node holding the message does not search for an intermediate node.

Each message has a time to live inside each node. Once the time to live has expired, the message is deleted from the node. Additionally, the number of selected intermediate nodes (neighbors), is a parameter of the protocol. This parameter can be adjusted to increase the reachability of the protocol or to reduce the traffic communication.

IV. Experiments

In this section, we show the experiments performed to evaluate the proposed protocol for DTN using the ONE Simulator. We set the parameters for the simulations according to [7]. The experiments were executed on a computer with a processor Intel Core i73630QM CPU 2.40GHz, Memory 8GB and hard disk of 1TB.



(a) (b) (c)

Figure 3. (a) Overhead ratio by area. (b) Hop count by area. (c) Delivery ratio by area.

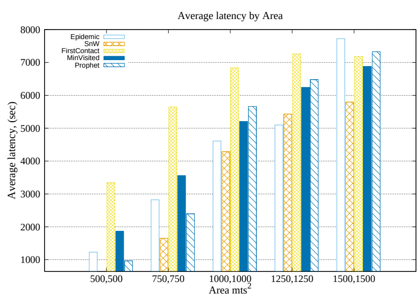


Figure 4. Average latency by area.

We evaluate the performance of our protocol with two criteria using the parameters of Table I. We simulate a total of 12 hours and 50 nodes using the Random Way Point mobility model because it has been widely used in the literature for evaluation of this kind of protocols [1]. The first criteria used to evaluate the protocols focuses on the behavior of the protocol with respect to the dimensions of the area where the nodes move. The second evaluation criteria focuses on the behavior of the protocol according to storage buffer size. We compare our protocol with the First Contact, the Epidemic, the Binary Spray and Wait and the Prophet protocols. Table II summarizes the parameters used to evaluate these protocols.

Table I
EXPERIMENT PARAMETERS.

Parameters	Value
Simulation Time	12 hours
Number of nodes	50
Transmission speed	250KB
Transmission range	10 meters
Message weight	between 50KB - 1MB
Time To Live (TTL)	5 hours
Message Generation Interval	30-60 sec
Mobility Model	RandomWaypoint

A. Area Evaluation

Figure 3.(a) shows the overhead ratio per square meter reported by all the networks protocols. The x-axis shows the square meter, e.g. 500×500 which gives a total of 250000 square meter. The Prophet and the Epidemic protocols tend to report the highest overhead ratio. In other words, these protocols produce a high number of message copies in the network. Meanwhile, our proposal keeps the lowest overhead, outperforming the results presented by the First Contact and the Spray and Wait (SnW) protocols.

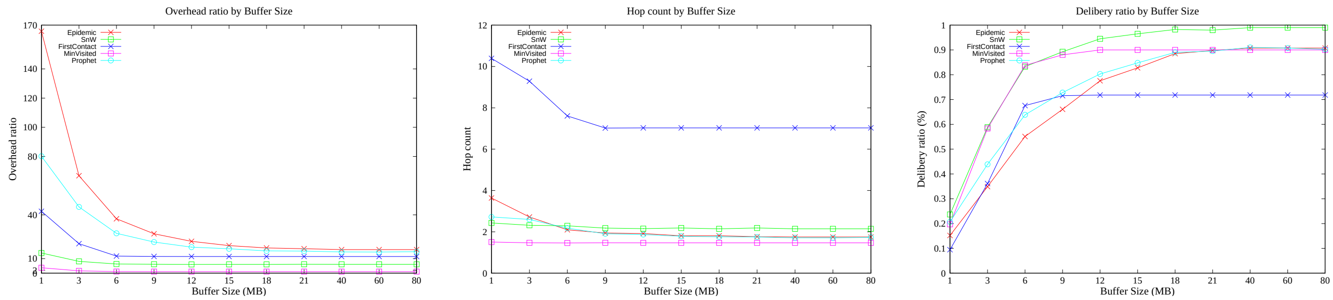
Table II
PARAMETERS USED FOR EACH PROTOCOL.

Routing Protocol	Parameter	Value
Prophet Router	Second unit	30
Epidemic Router	N/A	N/A
Binary Spray And Wait	Number of Copies	8
First Contact	N/A	N/A
MinVisited	Number of Copies (nc)	2
MinVisited	Neighbors (nv)	1
MinVisited	Number of Copies per Encounter	1

The average number of hops performed to deliver a message is presented in Figure 3.(b). Our proposed protocol reports the lowest hop count for reaching the destination node. It keeps the hop count lower than 2 for all studied cases. Unlike one of its closest competitor, the Epidemic protocol, our proposal avoids performing unnecessary hops.

In Figure 3.(c), we present the results achieved with the successful delivery rate metric. These results show that our proposed model has a good performance, due to in an area up to 1000×1000 square meters our proposal reports a delivery ratio between 95% and 77%. With a larger area size of 1250×1250 and 1500×1500 square meters, the delivery ratio tends to fall abruptly to 63% and 53% respectively.

In Figure 4 we present the average time delay for delivering a message to the destination node. As expected and for all protocols, the delay time of sending a message increases with a larger area size. The First Contact protocol reports the highest delivery delays for almost all area size. Only with the largest area size the Epidemic protocol reports the highest delivery delays. Moreover, with a larger area size the differences reported by all protocols tend to minimize. This is because as we increase the area size, the protocols reduce the possibility of spreading the message, and therefore, it is more probable to deliver the message directly.



(a) (b) (c)

Figure 5. (a) Overhead ratio by buffer size. (b) Hop count by buffer size. (c)Delivery ratio by buffer size.

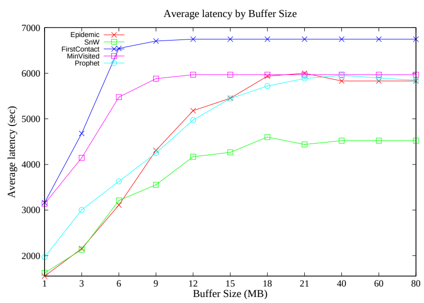


Figure 6. Average latency by buffer size.

B. *Buffer Size Evaluation*

In Figure 5.(a), we show the overhead ratio using buffers with different size, ranging from 1MB to 80 MB. The y-axis is in logarithmic scale. Results show that the overhead for the Epidemic, the Prophet and the First Contact protocols start very high, but then it tends to stabilize at around 18MB. The proposed protocol present the lowest overhead for the entire spectrum of buffer sizes.

In Figure 5.(b) we show the hop count as the buffer size is increased. The First Contact protocol reports the highest number of hops. The remaining protocols present similar results, and our proposed protocol, the MinVisited, has the smaller hop count. Therefore, it overcome the other protocols in the whole range of buffer sizes.

The probability of successfully delivering the messages for the different buffer sizes is presented in the Figure 5.(c). In this case, the proposed protocol presents a low performance for a small buffer size, however it presents a similar behavior as the other protocols.

In Figure 6 we show the average delivery time for the messages. Most of the protocols tend to report a stable percentage of delivery time for a buffer size of 40MB.

V. Conclusion

In this work, we proposed a new protocol of message routing for DTNs. The proposal is based on the delivery of the message to the farthest neighbor and which has, at the same time, a greater number of encounters in respect to the destination node. This protocol was evaluated using different metrics and against well-known protocols of the technical literature. Results show that our proposal reports the smallest average number of hops required to deliver a message -lower than 2-, with the lowest work overload and it also presents a successful message delivery rate around 95% in the smallest studied area, and 90% when the storage buffer size is greater or equal than 12MB.

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