Enhancement of Binary Spray and Wait Routing Protocol for Improving Delivery Probability and Latency in a Delay Tolerant Network

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Abstract. In this paper, we enhanced the Binary Spray and Wait (B-S&W) routing protocol and create two versions of Spray and Wait (S&W-V1 and S&W-V2) and evaluate and compare their performance in a Delay Tolerant Network (DTN). The network is created from pedestrians, cars and buses of public transport, equipped with smart devices that move and exchange information in an urban area in Tirana city, Albania. Different simulations are conducted to evaluate the performance of the enhanced protocols. Simulations are done using the Opportunistic Network Environment (ONE) simulator. We use the delivery probability and average latency as evaluation metrics. Based on simulation results, we found that our proposed versions S&W-V1 and S&W-V2 improve the delivery probability and average latency.

1 Introduction

Delay Tolerant Networks (DTNs) enable communication where connectivity issues like sparse connectivity, long delay, high error rates, asymmetric data rate, and no end-to-end connectivity exists. In DTNs, mobile nodes can send and receive data, carry data as relays and forward data in opportunistic way upon contacts. In order to handle disconnections and long delays, DTNs use store-carry-and-forward approach.

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Smart devices equipped with different communication interfaces like Bluetooth and WiFi are the main computing and communication platform nowdays. These smart devices can be used to carry and forward messages in DTNs.

DTNs are occasionally connected networks, characterized by the absence of a continuous path between the source and destination [1,2]. DTN is the "challenged computer network" approach that is originally designed from the Interplanetary Internet, and the data transmission is based upon the store-carry-and-forward protocol for the sake of carrying data packets under a poor network environment such as space [1]. Different copies of the same bundle can be routed independently to increase security and robustness, thus improving the delivery probability and reducing the delivery delay. However, such approach increases the contention for network resources (e.g., bandwidth and storage), potentially leading to poor overall network performance.

DTNs get around the lack of end-to-end connectivity with an architecture that is based on message switching. It is also intended to tolerate links with low reliability and large delays. The architecture is specified in RFC 4838 [3].

Bundle protocol has been designed as an implementation of the DTN architecture. A bundle is a basic data unit of the DTN bundle protocol. Each bundle comprises a sequence of two or more blocks of protocol data, which serve for various purposes. In poor conditions, bundle protocol works on the application layer of some number of constituent Internet, forming a store-and-forward overlay network to provide its services.

In order to handle disconnections and long delays in sparse opportunistic network scenarios, DTN uses store-carry-and-forward approach. A network node stores a bundle and waits for a future opportunistic connection. When the connection is established, the bundle is forwarded to an intermediate node, according to a hop-by-hop forwarding/routing scheme. This process is repeated and the bundle will be relayed hop-by-hop until reaching the destination node.

There are different research works with focus on routing in DTNs. In [4–21] authors deal with routing in DTNs.

In this paper, we enhanced Binary Spray and Wait (B-S&W) protocol. For the simulations we use the Opportunistic Network Environment (ONE) [22] simulator. This simulation environment can generate different movement models and offers various DTN routing algorithms. Its graphical user interface visualize both mobility and message passing in real time. The simulation results show that for the proposed versions of protocol, the delivery probability and average latency is improved.

The remainder of this paper is as follows. Spray and Wait protocol and its enhanced versions are presented in Sect. 2. The simulation system design and simulation scenarios are described in Sect. 3. In Sect. 4 are shown the simulation results. Finally, the conclusions and future work are presented in Sect. 5.

2 Spray and Wait Routing Protocol and Its Enhanced Version

2.1 Spray and Wait Routing Protocol

Spray and Wait (S&W) [17] is a routing protocol that attempts to gain the delivery ratio benefits of replication-based routing as well as the low resource utilization benefits of forwarding-based routing. The S&W protocol is composed of two phases: the spray phase and the wait phase. When a new message is created in the system, a number L is attached to that message indicating the maximum allowable copies of the message in the network. During the spray phase, the source of the message is responsible for "spraying", or delivery, one copy to L distinct "relays". When a relay receives the copy, it enters the wait phase, where the relay simply holds that particular message until the destination is encountered directly.

2.2 Binary Spray and Wait Routing Protocol

In Binary Spray and Wait (B-S&W), the source of a message initially starts with L copies. Any node A that has $n > 1$ message copies (source or relay), and encounters another node B (with no copies), hands over to B $n/2$ and keeps $n/2$ for itself. When it is left with only one copy, it switches to direct transmission.

2.3 Enhanced Versions of Spray and Wait Routing Protocol

In the enhanced versions of Spray and Wait the changes are done only in the spray phase. Different from B-S&W where the sending node sprays to the encountered node $n/2$ and keeps $n/2$ for itself, in order to improve delivery probability we changed the value for S&W-V1 to $3n/5$ and keeps $3n/5$ and for S&W-V2 to $7n/10$ and keeps $7n/10$. When it is left with only one copy, it switches to direct transmission. The algorithm of S&W-V1 and S&W-V2 is shown in Fig. 1.

3 Simulation System and Scenarios

The simulation is realized for a part of Tirana city in Albania by importing the map from Open Street Map (OSM) [23] as presented in Fig. 2. Simulations are carried out using the ONE simulator. We create a DTN with 200 nodes. In our simulated scenario, there are 75 cars, 75 pedestrians and 50 buses, all equipped with a smart device that move according to map-based movement model and exchange information among them. The simulation time is 4 h. In Fig. 3 is shown the initial position of all nodes.

All network nodes use a transmission range of 10 m. The buffer size varies from 1 MB to 6 MB. The event generator is responsible for generating bundles with sizes uniformly distributed in the ranges [500 kB, 1 MB]. The data bundles ttl is set 300 min. The simulation parameters are shown in Table 1.

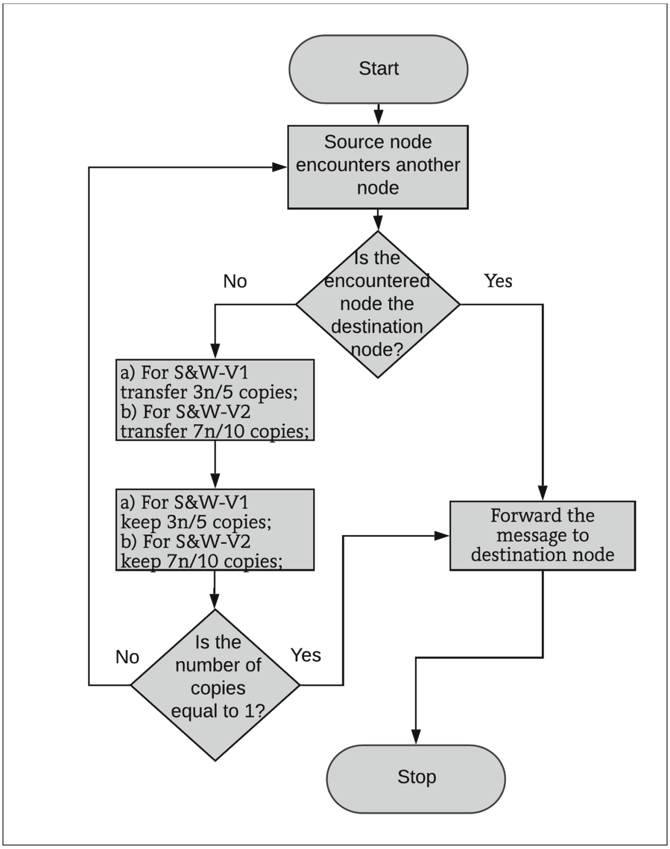

Fig. 1. Algorithm of S&W-V1 and S&W-V2.

For the considered parameters we evaluate the performance of 3 different versions of S&W protocols: B-S&W, S&W-V1 and S&W-V2.

We use the following metrics to measure the performance of different routing protocols: delivery probability and average latency.

- **Delivery probability** is the ratio of number of delivered messages to that of created messages.
- **Average latency** is the average time elapsed from the creation of the messages at source to their successful delivery to the destination.

4 Simulation Results

In Fig. 4 are shown the simulation results of delivery probability vs. message creation interval. Increasing the message creation interval will increase also the

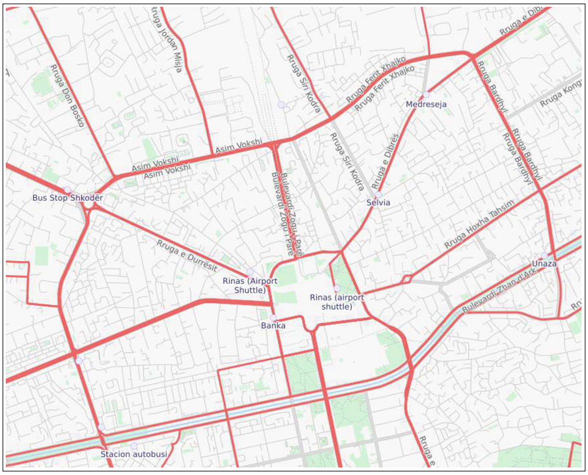

Fig. 2. Tirana city map imported from OSM.

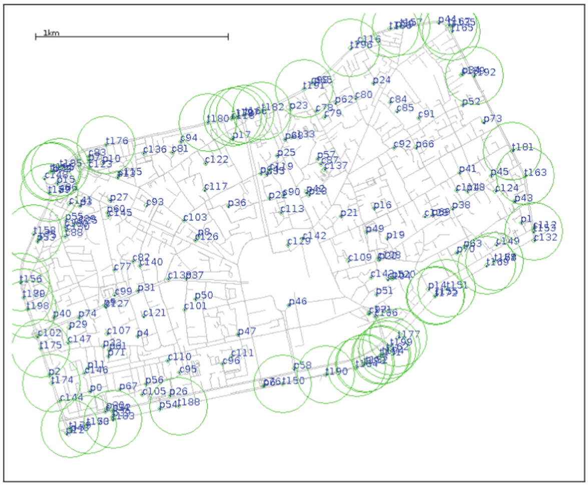

Fig. 3. Nodes initial positions.

delivery probability of all protocols. The enhanced version of S&W perform better than B-S&W.

In Fig. 5 are shown the simulation results of the average latency vs. message creation interval. From the results we can notice that the enhanced versions perform better than B-S&W because more copies of the messages are created in the network and they can reach faster the destination.

In Fig. 6 are shown the simulation results of delivery probability vs. buffer size. The increase of buffer size have a positive effect on the delivery probability

Table 1. Simulation parameters and their values.

Parameters	Values
Number of mobile nodes	200
Simulation time	14400 s
Map size	2.5 km × 2.5 km
Buffer size	1, 2, 3, 4, 5, 6 MB
Interface type	Bluetooth/WiFi
Interface Transmission Speed	2 MBps
Interface Transmission range	10 m
Message TTL	300 min
Pedestrians speed	1.8–5.4 km/h
Cars speed	5.4–27 km/h
Buses speed	25.2–36 km/h
Message size	500k, 1M
Warm up time	100 s
Message creation interval	[25–35], [55–65], [85–95], [115–125] s

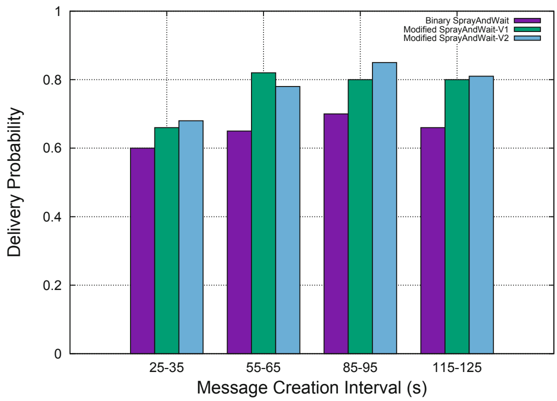

Fig. 4. Results of delivery probability vs. message creation interval.

for all versions of S&W. The enhanced versions S&W-V1 and S&W-V2 perform better in terms of delivery probability.

The simulation results of the average latency vs. buffer size are presented in Fig. 7. For small buffer size 1 MB and 2 MB, B-S&W performs better than two other versions. For bigger buffer size, best performance is achieved from enhanced versions.

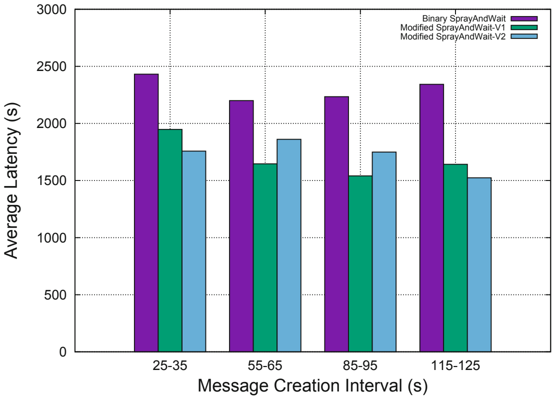

Fig. 5. Results of average latency vs. message creation interval.

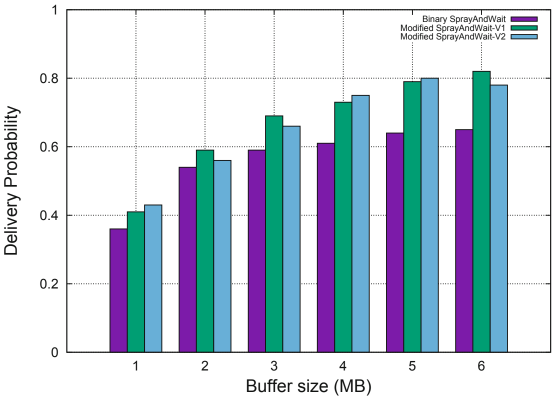

Fig. 6. Results of delivery probability vs. buffer size.

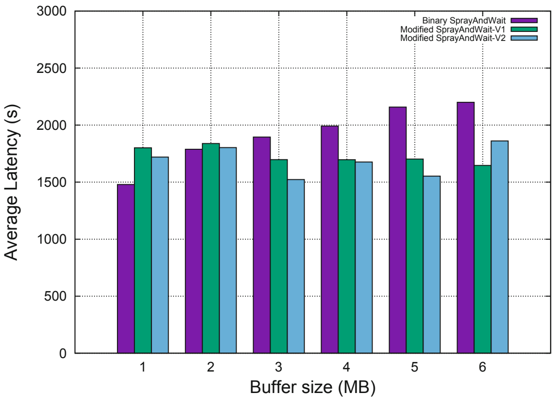

Fig. 7. Results of average latency vs. buffer size.

5 Conclusions

In this work, we enhanced the B-S&W routing protocol in the spray phase by increasing the number of copies the sending node sprays to the encountered node and the number of copies it keeps. Then, we evaluated and compared the performance of B-S&W routing protocol with its enhanced version S&W-V1 and S&W-V2 in a DTN based on Tirana city. For evaluation we considered delivery probability and average delay. Simulation results showed that the proposed versions of protocol have better delivery probability and lower average latency compared with B-S&W.

In the future, we would like to improve the performance of the S&W routing protocol in terms of overhead ratio. We also would like to create an energy-aware S&W routing protocol for DTNs evaluate its performance and compare with different routing protocols considering different scenarios and parameters.

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