A Comparative Analysis of Well-known Drop and Buffer Management Policies in Delay Tolerant Networks

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Abstract —Delay Tolerant networks (DTN) are mobile networks that aim to bypass classic networks limits in difficult environments characterized by intermittent connectivity, power outages, and difficult topographies. Delay tolerant networks follow the Store-Carry-and-Forward mechanism. Hence, a node Stores messages in its own memory and carry it for long time until the rise of a delivery or forward opportunity, then it transmits it to the other node(s). In the present article, we are comparing famous DTN routing protocols to a set of buffer management policies and scheduling algorithms by changing TTL values and at the end of our simulations we analyze the results we obtained in terms of number of delivered messages, the network overhead and the average latency.

Index Terms—Delay tolerant network; drop policy; routing; scheduling; congestion

I. INTRODUCTION

The usual internet and tcp/ip network are based on the fact that the end-to-end path between source and destination is secure and have enough bandwidth. These criteria cannot be valid for some hard environments such as interplanetary or underwater networks which are characterized by lack of direct path between nodes, lot of power outages and intermittent connectivity. For those situations, new network architecture has been proposed which is named DTN (Delay Tolerant Networks).

This new model which have been proposed by Kevin Fall *et al*. [1] in 2003, is based on Store and Forward mechanism, thus, every DTN node has a local buffer where it carry the message for long periods until the raise of a forward chance to other node or to the destination. By carrying a large number of messages, the buffer memory becomes full and congested. In order to provide a solution for this issue, researchers have proposed buffer management policies also known as drop policies.

In the present work we are comparing a set of DTN drop policies in different circumstances with different routing protocols in terms of messages delivery rates and network overhead and then analyzing the results.

We have organized the remains of this paper as follows: Section II contains the state of the art where we give brief definition of Delay tolerant networks and routing mechanism. Section III describes the congestion control and buffer management policies in DTNs. Section IV summarizes our simulation results and analysis. Then finally, we reserved Section V for conclusion and future work.

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II. DESCRIBING DTN

By implementing a new layer (Bundle) over the transport layer and by deploying the main rule of the Store-and-Forward mechanism [2], DTN networks manage to overcome much of the problems that are result of internet limitations such as intermittent connectivity, the long or variable Delay, asymmetric data rates and the high error rate.

A. Bundle Protocols

The Bundle Protocol [3] is a shared framework for algorithm and application development in DTNs. This protocol defines groups of adjacent data blocks into bundles and transports them based on store-and-forward technique.

The DTN protocols that are using bundling leverage the application layer to transmit data blocks (bundles) across networks. As a result of the store-and-forward nature of DTN, the routing algorithms benefits from access to application layer information. Bundle protocols collect application data into bundles, which will be sent over a heterogeneous network configuration associated with a high-level service guarantee.

B. Routing

Transporting data and choosing the best route between source and destination is mandatory capability that every kind of communication network must have.

Ad-hoc networks routing protocols assumes that the direct path between nodes is guaranteed. Delay and tolerant networks (DTNs) are characterized by lack of end-to-end paths between source and destination nodes which make the application of standard Ad-hoc routing protocols impossible. To deal with that issue, researchers have proposed a new approach called "store and forward".

1) Store and forward

In Delay tolerant networks, the transportation of a message from source to a destination may take a while, and nodes don't meet very frequently with each other.

By applying a mechanism called "Store and forward" Fig. 1: Store and forward mechanism, each node owns a local memory where messages are stored and carried until the appearance of a new forward opportunity. While the memory size is limited, a node cannot carry infinity of messages.

By the growing number of carried messages, the storage memory become overfilled, and automatically every new coming message will be rejected. this fact will of course impact the delivery rate of the network negatively.

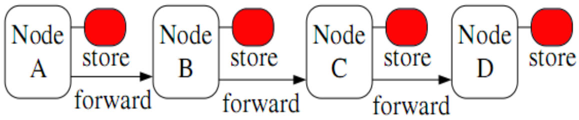

Fig. 1. Store and forward mechanism

Messages routing in DTN can be achieved in two methods Random or routing based on network topology information [4]. Researchers have proposed a set of several routing protocols and algorithms. For instance, Epidemic routing [5], Prophet [6], Spray and wait [7], MaxProp [8], Rapid [9], First Contact [10] and Direct Delivery [11] and many others.

2) Epidemic Routing

The Epidemic algorithm is a replication based routing protocol. In this protocol the source node generates multiple copies of the same message and sends them to all nodes of the network. Those nodes keep the message in the internal buffer until the appearance of a connection to the destination. When two nodes meet each other, all carried messages are exchanged. This mechanism can guarantee a fast and high delivery rate of messages and optimized latency. Unfortunately, this spread causes an overhead of the bandwidth and very high consumption of the network resources.[4]

3) Probabilistic Routing(ProPHET)

In order to reduce some of the epidemic approach weaknesses, for example, to mitigate the spread of messages, a new routing concept has been introduced as an alternative to the previous one. It is called ProPHET Protocol. [12]

Two nodes, which meet each other very frequently, are more probably to get in touch again. With ProPHET, this probability of re-contact is used to measure which nodes have the right predictability for the next message destination.

4) Spray \& Wait Router(SnW)

Spray and wait protocol merges the high delivery ratio of replication based routing (Epidemic) and the optimization of resource consumption of forward-based protocols. During the Spray phase, the source node transmits one copies of the message to L intermediate nodes it encounters (relay nodes), then every relay keeps the message copy until it meets the destination or the TTL is reached. The L constant is to define at the beginning of the simulation.

C. Nodes Mobility

Mobility models define how nodes are moving inside the area of th simulation. For some models, nodes are walking in arbitrary way, like the case of Random walk or Random Waypoint. Other models are based on traces collected from real situations such as ZebraNet or DakNet. Finally, DTN supports also some map-based movement models.

The Shortest Path Map-Based movement is the model we chose for our simulation. It combines at the same time the advantages of map-based movement and the intelligence of Dijkstra algorithm.

1) Other mobility models

a) Randomwalk

In this mobility model, every node chooses a random angle between 0 and 2π, and a random speed between V_{min} and V_{max}. The node keeps walking for a specified time (t) or distance (d) and then it chooses another angle and speed. According to [20], this scheme was at first mathematically described by Einstein on 1926.

b) RandomWayPoint

RandomWayPoint used at first by Johnson & Malts [21] to evaluate the DSR routing protocol for AdHoc networks. In this model, the node chooses randomly a destination point with the location (x,y) in the simulation area and a speed between V_{min} and V_{max}. The node walks to the destination with the chosen speed. At the destination, the node may take a pause before choosing the next target point.

III. Buffer Management in DTN

By storing lot of messages, the node buffer becomes full and new message are no more accepted. To bypass this buffer overload issue, a set of buffer management policies has been developed. Every policy is suitable for some environments and conditions (traffic density, area size, buffer size, TTL ...).

A. Drop Policies

In this section we are presenting brief definitions of some existing DTN drop policies:

1) Last In First Out (LIFO)

By applying this drop policy in the DTN network, the messages in the buffer are scheduled in LIFO manner. Hence, the last message arrived to the node, will be the first to be dropped. [13]

2) First in First Out (FIFO)

In opposite of LIFO, the messages here are organized as First In First Out. So, The message which arrived first to the node's buffer is the first message to be dropped. [13]

3) Drop Youngest (DY)

Contrary to SHLI, the messages which will be chosen to remove here is the one with the highest TTL values, which is obviously the youngest message of the group. [13]

4) Drop Largest (DL)

Of course in DTN as well as every other communication network every message has different size. For this policy, the message which occupies more memory is the message we remove first.[13]

5) Shortest Lifetime First (SHLI)

Every message has much information about its source, its destination, the nodes it traversed as well as the Time to Live (TTL) value. With this drop policy, the oldest message which has the shortest TTL value will be dropped first. [14]

6) Most Forwarded First (MOFO)

Every DTN node keeps a history about how many nodes a message has been forwarded to. With MOFO drop policy, the message which has been forwarded to the most number of nodes is the message to be rejected first. [15]

IV. Simulation and Results

A. The ONE Simulator

The simulator we used in our work is ONE: Opportunistic Network Environment (ONE) Fig. 2. Unlike other DTN simulators, which usually focus only on simulating routing protocols, the ONE combines mobility modeling, DTN routing and visualization in one package that is easily extensible and provides a rich set of reporting and analyzing modules [16].

The main functions of the ONE simulator are the modeling of node movement, inter-node contacts, routing and message handling. Result collection and analysis are done through visualization, reports and post-processing tools. The elements and their interactions are shown in Fig 2 [16].

A detailed description of the simulator, the ONE simulator project and the source code are available in [16], [17] and [18] respectively.

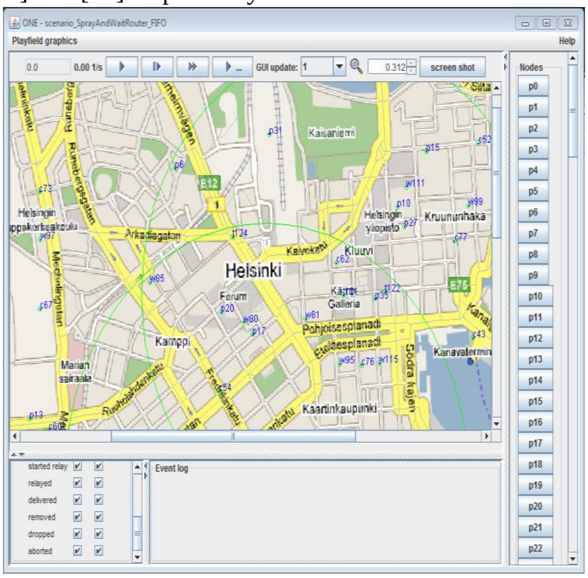

Fig. 2. Screenshot: The ONE simulator GUI

B. Metrics for Performance Evaluation

The following metrics are commonly used when evaluating scenarios related to DTN protocols. [19]

1) Delivery rate

Suppose that M be the set of all messages created in the network and M_d be the set of all messages delivered. Then, the delivery ratio is computed as:

$$M_d / M \quad (1)$$

2) Overhead ratio

The Overhead is the average number of copies of the same message that are created during the simulation.

Let r_i be the number of replications of any message $m_i \in M$. Then the overhead ratio is determined as:

$$\sum_{i=1}^{M}(r_i - M_d) / M_d \quad (2)$$

3) Latency average

Latency is the average time between message creation and deliverance. Now let the i[th] delivered message was created at time c_i and delivered at time d_i. Then the average message delivery latency is computed as:

$$\sum_{i=1}^{M_d}(d_i - c_i) / M_d \quad (3)$$

C. Simulation Environment

In our simulations, we have experienced multiple environments by switching between different parameters like routing protocols, TTL value and drop policies while other parameters are fixed for all simulations such as area size, movement model and buffer size..., The Table I summarizes the important parameters of our simulations

TABLE I: ENVIRONMENT PARAMETERS OF OUR SIMULATIONS

Parameter	Value
Movement Model	Shortest Path Map Based Movement
Router	Epidemic - ProphetV2 - SprayAndWait
Buffer Size	5M
Drop Policy	FIFO - LIFO - DL - DY - SHLI - MOFO
Message TTL (in minutes)	60 - 120 - 180 - 240 - 300
World Size (meters)	4500, 3400

D. Delivery Rate

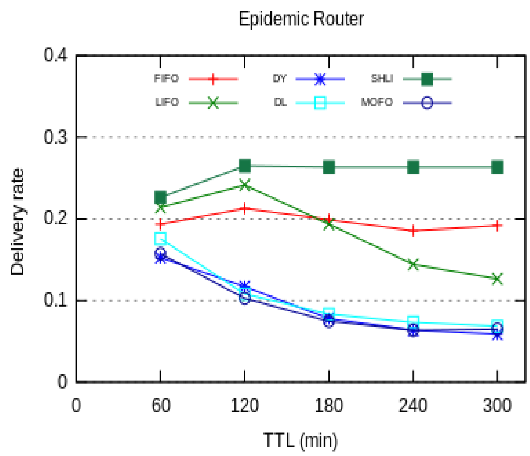

Fig. 3. Delivery rate of epidemic router

For the epidemic routing, the best drop policies are SHLI and FIFO the delivery rate is high and almost stable by the increment of the TTL While

Other policies keep decreasing. This result is normal while Epidemic protocol is not suitable for long time simulations

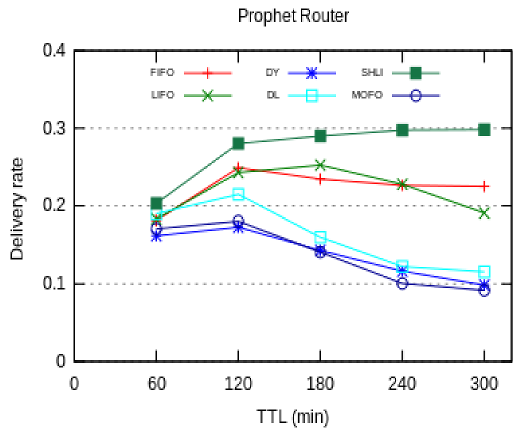

Fig. 4. Delivery rate of prophet router

For the prophet router, the result is approximately the same as the one before, and the growth of TTL value impacts negatively all policies aside from SHLI and FIFO. We can also notice for this Routing protocol that the delivery rate is a little bit higher.

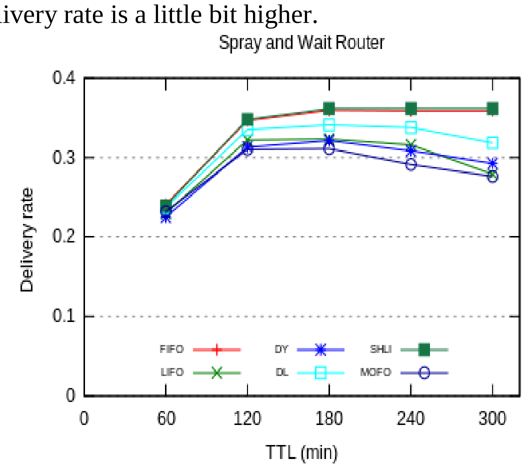

Fig. 5. Delivery rate of spray and wait router

In our simulations, the Spray and wait router gives the best rate of deliverance and this rate is impacted positively by the increase of the TTL value.

E. Overhead Ratio

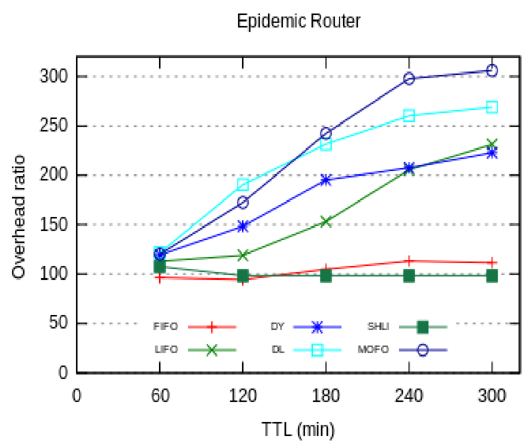

Fig. 6. Overhead ratio of Epidemic router

Again the two policies FIFO and SHLI provides the best result among other policies for the Epidemic router this time, the metric we are analyzing is the overhead ratio.

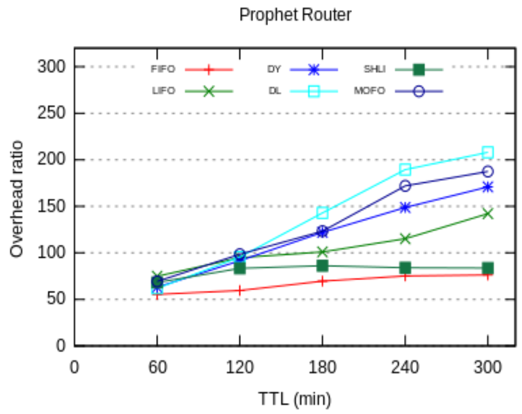

Fig. 7. Overhead ratio of prophet router

The behavior of drop policies with Prophet router is not much different from Epidemic. However, the range of the overhead is lower this time, the minimum is 50 and the maximum is 200 while it's between 100 and 300 for the previous router.

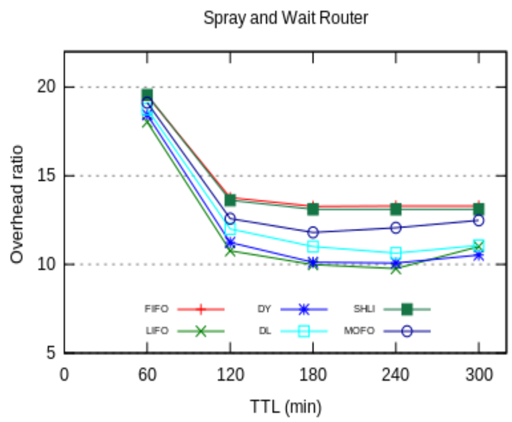

Fig. 8. Overhead ratio of spray and wait router

In the case of Spray and Wait protocol, all policies behave the same and in the opposite of the two previous protocols, the Overhead ratio keeps lessening with the increase of TTL. And also this ratio is very minor comparing two other, it maintain the range of 10 to 20 message copies.

F. Latency Average

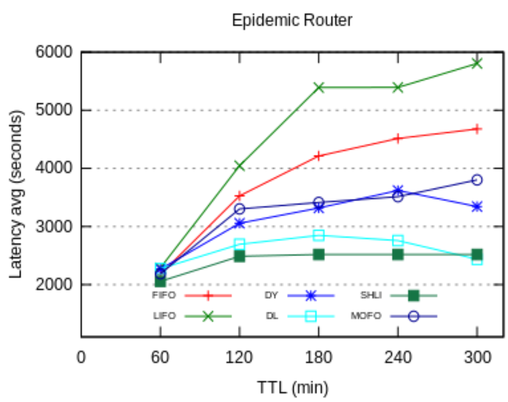

Fig. 9. Latency average of Epidemic router

The average latency is growing with TTL for all drop policies except from SHLI and drop largest where it remains almost steady near to 2500 seconds whatever the TTL value is. LIFO policy has the worse latency.

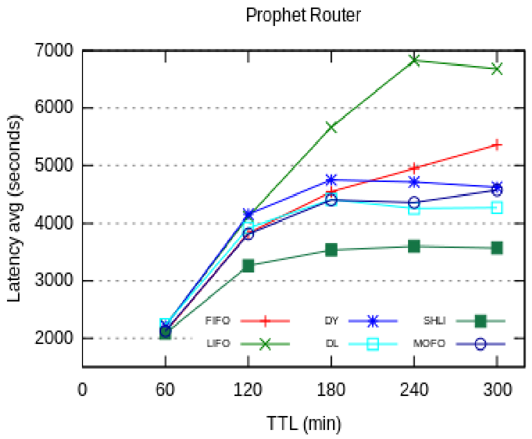

Fig. 10. Latency average of prophet router

For Prophet we perceive that result is almost the same, always the best latency is obtained by SHLI and the worse is provided by LIFO. The little difference here is that the average latency for SHLI is between 3000 and 4000 which is higher than Epidemic.

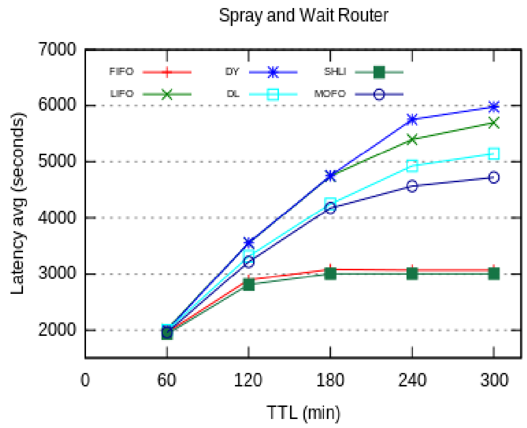

Fig. 11. Latency average of Spray and wait router

The latency for Spray and Wait protocol is a bit inferior to the two previous routers. The average range starts from near 2000 seconds which is about 1000 seconds lower. Again, SHLI drop policy beats other policies and FIFO joined it.

V. Conclusions

Conforming to the result shown before, we notice that the Spray and Wait routing algorithm and the Shortest Lifetime drop policy (SHLI) are the best combination for our simulation environment. The delivery rate obtained by this couple is noticeably higher than all others, while the overhead ratio and the average latency are lower. However, in term of energy consumption, this may not be the optimal choice.

During the current article we just concentrated on comparing a couple of well-known DTN routing protocols and a set of buffer management policies in a typical simulation environment. Then we analyzed the obtained results in term of delivery probability, overhead ratio and latency average.

In our future works, we plan to focus on two concepts:

- Trying to combine and optimize both Spray and Wait router and SHLI drop policy in order to improve messages deliverance and other important metrics.
- Working on the drop policy which will be applied in ambiguous situation, where for example two messages have the same TTL value, we have to make the right decision to choose the best message to drop.

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