The Performance of DTN Routing Protocols: A Comparative Study

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Abstract: - The delay tolerant networks (DTN), which form the mobile and wireless ad hoc networks, are characterized by intermittent connectivity, asymmetric flow, high error rate and long or variable delivery time, especially when the destination is not in the same area as the source. The purpose of this paper is to compare two categories (flooding strategy and forwarding strategy) based on two-pronged strategy, mainly the replication strategy that refers to the following protocols: Epidemic, Spray and Wait. The expedition strategy associated with the following protocols: Prophet and MaxProp. In addition, our contribution is based on a combination of routing protocols DTNs and the model of bundle layer end-to-end retransmission (BLER) to improve routing in DTN networks and operating nodes that allow the distribution of information between the shared network. This study is performed on our simulator programmed in java based on Opportunistic Network Environment simulator (ONE) in order to evaluate the performance of routing protocols DTN. The results of the evaluation show that the performance of different protocols can benefit from optimizing the performance of DTN in terms of the delivery probability, average latency and overhead rates.

Key-Words: - Network, Ad Hoc, DTN, Epidemic, Spray and Wait, Prophet, MaxProp, BLER, ONE Simulator.

1 Introduction

Mobile and wireless networks fall into two categories: those with infrastructure (cellular models) and those without infrastructure or ad hoc networks. A mobile ad hoc network, commonly known MANET can be defined as a collection of mobile entities interconnected by wireless technology, forming a temporary network without the aid of any administration, neither for its configuration nor for its management [1].

The recent evolution of wireless communication has enabled some wireless calculating organs to take part in a network through a wireless communication interface. Mobile environments provide a great flexibility of use mobility criterion without any restriction of the communicating organs location. This mobility creates other problems such as: frequent disconnection, low flow of communication, modest resources and limited energy source. Contacts between the nodes in the ad hoc network occur very frequently. Consequently, the network topology is rarely, if never, connected and the message delivery must be tolerant to delay [1, 2].

Traditional MANET routing protocols such as DSR, AODV and OLSR, that require a network topology, are completely connected to route the messages, if there is not a complete route from source to destination when sending, routing will fail. For this reason, the conventional ad hoc routing protocols cannot be used in environments with intermittent connectivity [2, 3, 4].

To overcome this problem, researchers have designed an extension of ad hoc networks: the delay tolerant network (DTN) where node mobility is exploited to physically carry messages between disconnected parts of the network, communication model "Store and Foward" (Fig.1). In other words, when a node receives a message, it determines how to route it further, and whether it has connectivity to the next destination or not. In that case, the message is transferred forward. However, in case of connectivity loss or failure, the messages are not neglected, but stored until the connection is available. And so, once it is available, the transfer is resumed. This makes the conception of routing protocols DTN much more difficult [4, 5].

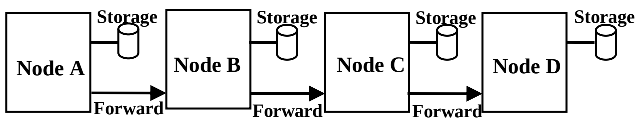

Fig.1: The Principle of Store-and-Forward.

In this study, we have analyzed the performance of four different DTN routing protocols (Epidemic, Spray and Wait, Prophet, MaxProp) depending on the combination of these four routing protocols and the model of BLER. These protocols have been analyzed using different performance metrics, namely: the delivery probability (delivery rate), the overhead rate, the average latency, etc. This work is conducted in three different areas.
The rest of this article is organized as follows. In the section 2 we review the DTN routing protocols. Afterwards, we present the BLER's model and one of transfer and Custody Transfer so as to achieve the desired contact. In the fourth section, we introduce and develop our contribution to improve the DTN routing. In the last two sections, we describe the environment of simulation and we summarize with the obtained results to evaluate the performance of the DTN protocols considered in this work.

2 DTN Routing Protocols

Routing protocols in DTN network are classified according to the type of information collected by the nodes and how to make the routing decision. We can divide the routing strategies proposed for DTNs into two main categories depending on the properties used to find the path upon which transmitting the data. The first property is replication (Flooding strategy), which means that the strategy creates multiple copies of a message to deliver it to a destination. The second property (Forwarding strategy) uses different mechanisms to select effectively the relay nodes and reinforce the probability of distribution in the case of limited resources and storage. They collect information about other nodes in the network to select the relay nodes [6, 7, 8].

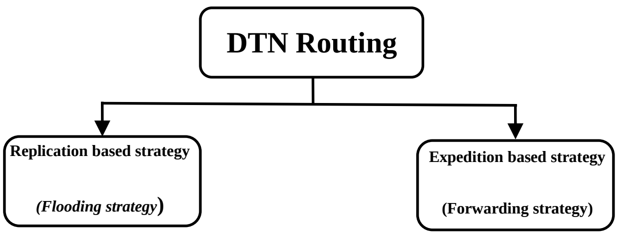

Fig.2 : DTN Routing Strategies.

Routing strategies in DTNs must balance between different factors: the data delivery rate, the impact on network resources and the time delivery.
In the following, a brief overview of the DTN routing protocols, namely Epidemic, Spray and Wait, Prophet and Maxprop, will be provided.

2.1 Epidemic protocol

Epidemic routing protocol [9] is historically the first DTN routing protocol. It is based on the replication strategy in nature. In Epidemic, each node continuously replicates and transmits messages to newly discovered nodes that do not already possess a copy of the message, in order to ensure that the message reaches its destination. Epidemic routing protocol allows the transmission of the messages and guarantees its delivery regardless of latency, storage space, etc. However, it has the disadvantage of consuming a lot of network resources. Furthermore, the message continues its propagation through the network even after being delivered. This is the main reason behind network congestion.

2.2 Spray and Wait protocol

The routing protocol Spray and Wait [10] limits the replication strategy of blind Epidemic routing messages by combining an number L of messages indicating the maximum allowable copies of the message. In the spray phase, for each message generated at the source, L copies are distributed to L distinct relays as it shown in Fig.3, part a). If the destination is not reached during the first phase, each of the L relays spreads in turn the message to their neighbors until the attainment of the destination, which is the task of the wait phase (Fig.3, part b). The parameter L is selected depending on the density of the network and the desired average time.

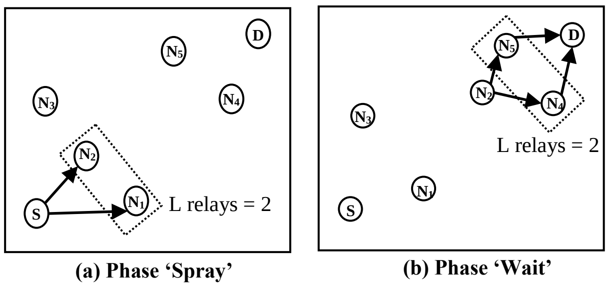

Fig.3: Spray and Wait Routing.

2.3 Prophet protocol

Epidemic and Spray and Wait protocols, justly described in the previous paragraph, are considered to be the optimal solution if and only if the bandwidth of the various contacts established between the various nodes DTN is endless and that the size of the storage units of which is also endless [11]. However, many constraints on resources such as bandwidth, capacity storage units and energy of different nodes can be faced. The routing protocol PROPHET (Probabilistic Routing Protocol using History of Encounters and Transitivity) [11] is just one of the routing algorithms that have been proposed to use these resources properly. PROPHET introduces a metric $P(.,.) \in [0\,,1]$ called PROPHET Delivery Predictability. This metric is computed by each node A of the DTN network and that for every known destination B and it would be used so as to decide what are the messages to be exchanged whenever two nodes meet. In this case, the two nodes update their delivery probability and then, the two nodes exchange their list of delivery predictability using the following equations (1)-(3) :

(i) When the node A meets the node B, then the delivery probability is updated:

$$P(A,B) = P(A,B)_{old} + (1 - P(A,B)_{old}) \cdot P_{init} \quad (1)$$

$P_{init} \in [0,1]$, is the initialization vector.

(ii) If the two nodes A and B do not meet each other for a period while, the node A updates the probability distribution to the node B using the following equation:

$$P(A,B) = P(A,B)_{old} \cdot \gamma^k \quad (2)$$

$\gamma \in [0,1]$ is the constant aging, and k is the number of time units that have elapsed since the last time the metric was aged.

(iii) If A meets B and B meets C, then C has a good probability of transfer to A. To calculate it,

$$P(A,C) = P(A,C)_{old} + (1 - P(A,C)_{old}) \cdot P(A,B) \cdot P(A,C) \cdot \beta \quad (3)$$

$\beta \in [0,1]$ is the constant transitivity that reflects the impact of the transitivity on the delivery probability. For more details about this equations see [11].

2.4 MaxProp protocol

MaxProp is a routing protocol based on forwarding strategies. It introduces a metric called the estimation of the delivery probability f_j^i which reflects the probability that the node i would be connected to the node j, defined as follows [12]:

$$f_j^i = \frac{1}{|S| - 1} \ , for\ i \neq j \quad (4)$$

Bearing in mind that S is the total number of nodes in the network.

The idea is that each node maintains a vector called the delivery probability, which is obtained by using the average incremental. When two nodes meet, they exchange these vectors, and so that each node can calculate the shortest path to the destination. Each node has a renormalized vector $F^i = (f_1^0 \ldots f_{j-1}^i)$. The sum of elements is equal to 1. When a node j meets the node i the value of f_j^i is incremented by 1, and then all the elements of the vector are divided by 2, using the following relationships [13, 14]:

$$f_j^i = \begin{cases} \left(\left(f_j^i\right)_{old} + 1\right)\Big/2 & , if\ the\ node\ met = j \\ \left(f_j^i\right)_{old}\Big/2 & , if\ the\ node\ met\ \neq j \end{cases} \quad (5)$$

where

$$\sum_{all\ j} f_j^i = 1\ , for\ i \neq j \quad (6)$$

Vector values f_j^i are used to calculate the cost of a path (through intermediate nodes $i, i+1, \ldots$) towards the node d, the desired destination. Each node transmits messages via the lowest cost way. We use the following relationship [12]:

$$c(i, i+1, \ldots, d) = \sum_{x=i}^{d-1} [1 - (f_{x+1}^x)] \quad (7)$$

MaxProp uses a buffer memory ordered, which is divided into two parts based on an adaptive threshold. MaxProp assigns a higher priority to new messages and transmits the first one with a small number of hops, and drops a message with the highest cost path when the buffer is full. MaxProp has poor performance when nodes have small buffer sizes because of the adaptive threshold calculation. MaxProp performance is better with a large buffer size.

After presenting the DTN routing protocols, our objective to ameliorate the performance of the different protocols, using the Bundles transmission models namely : BLER and Custody transfer models.

3 Transfer Model

The main idea is to build a topology of routing in a DTN partitioned network. The dominant character of such network is the number of nodes that circulate throughout the path of diffusion to reach the nodes situated in two different regions. Therefore, we will present two models for the data transfer: BLER and Custody Transfer models.

3.1 Custody Transfer

The bundle layer includes an option called custody transfer that provides a reliable hop-by-hop to the final destination. Depending upon the mechanism of custody transfer, the packets are transmitted in a "Store-and-forward" technique, while the responsibility of a reliable transfer is delegated to the next node in the route to the final destination.

The node that receives custody of a bundle is called custodian. This latter must forward the bundle to a neighboring node requesting custody transfer. The neighboring node will reply either with a custody acceptance or custody refusal signal, according to its admission control policy. The ability to forward the bundle to its final destination before time-to-live (TTL) expiration and the resource availability, are the basic criteria upon which each receiving node is evaluated. In cases where the custodian node does not receive a reply within a specific time interval, a timer triggers the bundle's retransmission through a new route. The custodian shall store the bundle until the reception of custody acceptance signal or until the expiration of bundle's lifetime.

Therefore, there is only one custodian node in a DTN which is responsible for the delivery of the specific bundle, and if this custodian node becomes unavailable to the network, there is a high probability that the bundle will never be delivered and that the data will be lost [15, 16, 17].

3.2 BLER Mechanism

The lack of end-to-end monitoring of data transmission makes the custody transfer mechanism insufficient to guarantee the reliability of transmission and retransmission of data at certain cases, especially in shared networks. Bearing in mind the scenario where the custodian node is not able to forward the bundle before the expiration of the TTL due to unexpected events (e.g., lack of mobility between areas) after accepting its custody but before forwarding the message to another node especially in shared networks. Consequently, the existence of a mechanism that could handle effectively the transmission of bundles in networks that are partitioned into several areas seems to be indispensable.

The principal idea of this model [17] consists on acting to the operations of shared networks to find a satisfactory solution to the transmission of bundles between different areas of the network and provide a guaranteed data transfer. Consequently, the aim is to ensure that the bundles reach their final destination in a minimum period of time, especially if the source and destination are not in the same area, provided that carriers have intended movements between different areas. In this model and in order to provide an end-to-end communication, the nodes which can act as carriers must have the following characteristics:

- A high probability.
- A sufficient transmitter power.
- A high storage capacity.
- The intended movements.

Our acknowledgment mechanism that is applied to BLER model between the different regions is made according to the used by the model of Custody Transfer with the aid of carriers.

4 Our Contribution to DTN Routing Protocols

4.1 Problematic

Delay tolerant networks are characterized by intermittent connectivity, asymmetric flow, high error rate and a long and variable delivery time. Therefore, the use of end-to-end routing protocol is prohibited. However, the end-to-end functionality should be included in the bundle layer to provide a reliable end-to-end service. In this context, the bundle layer is the dominant layer in DTN networks especially partitioned into multiple areas that are generally based on regular links between different parts of the considered network. In this case, communication between zones network depends only on the movement of certain nodes (carriers) between the zones. The choice of such nodes is very important in order to maximize the chances that at least one message reaches its destination and minimize the resources used in the network, such as bandwidth, the capacity of storage devices and the energy of the different nodes in an environment characterized by frequent disconnections due to low density and node mobility on the one hand, and lack of energy on the other. (Fig.4).

We have conducted a comparative study of routing protocols DTNs (Epidemic, Spray and Wait, Prophet and MaxProp) in combination with BLER model and using similar mechanisms (custody transfer and flooding) to operate certain nodes as carriers of messages in the shared network.

The main issues solved through this contribution are:

- Choice of nodes that can act as carriers of messages between the partitioned network.
- Selection of nodes wich increase the probability that a message reaches its destination while minimizing the time from

end to end, and save the consumed resources.
- Minimization of error rate.

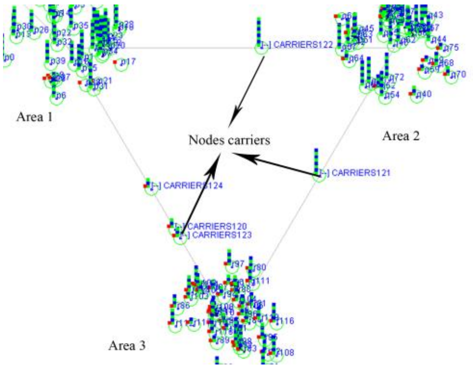

Fig.4 : Transfer of some messages by mobile nodes moving between three areas each of which has few nodes.

In the following section we are interesting to a theoretical approach (probabilistic) to model the contact between nodes or areas. After defining a set of all considered parameters and the constraints linked to contact, we give some assumption with are usefully used to describe our phenomenon.

4.2 Modeling

In this section we focus on modeling the distribution of nodes in a different regions shared network, depending upon on stochastic geometry tools such as those of probabilistic graph theory.
For DTNs, which form the general framework of our study, we define the network and its components: regions and arcs that connect them. Then we mention some specific characteristics of the nodes, known as carriers, which ensure the connection between two regions.
The problem of selecting carriers will be modeled by calculating the probability that a node in a given region will be present in another region. In this case, the connection between these regions will be established, and therefore, many problems due to the network performance arise, namely:

- The likelihood of delivery.
- The time of delivery.
- The latency.
- The storage space.
- The overhead.

The study of this problematic requires the introduction of some notations and assumptions.

4.2.1 Notations

For the rest of this work, we consider the following notations:

TABLE 1. NOTATIONS USED FOR MODELING

Notations	Definition
N	Total number of nodes of the shared network
K	number of regions forming the network
k	An area of the network
N_k	Number of nodes in each area, with: $N = \sum_{k=1}^{K} N_k$
c	Specific characteristics of a node
$n_i = n_i(c)$	The node i in the network
$n_{k,i} = n_{k,i}(c)$	The node i of the region k
$n_{k,i,k'} = n_{k,i,k'}(c)$	The carrier going from the region k to the region k'
$P_{k,i,k'}$	Probability of the contact between the two regions k and k'

4.2.2 Hypothesis

The study of the performance of DTN network, their comparisons and their optimizations, is banded by different characteristics, in particular, node mobility, bandwidth and energy resources. The answer to such questions forms always-tricky problems. This leads to an approximation of calculating using some assumptions on the considered network. Indeed, we focus on the link between nodes $n_{k,i}$, the nature of circulating flows on the arcs connecting different regions, the transmission range and the constitutive law governing the contact between regions. Therefore, we can summarize these assumptions as the following:
(H1): The nodes have the same range of transmission.
(H2): The regions of the network form an oriented graph.
(H3): The movement of nodes is random between K regions.
(H4): The contact between the two regions k and k' follows an exponential distribution of the parameter $\lambda = \lambda_{k,k'}$.
After that, we consider the concept of contact between nodes carriers, for describing the link in our DTN network.

4.2.3 Contact modeling

A contact is the ability to transmit data through an arc; it is about a specific link, a time interval during which the capacity of the link is strictly positive. In this section, we focus on modeling a persistent contact between several regions in a shared network by means of special nodes $n_{k,i,k'}$, that are generally identifiable by the specific characteristics cited below:

- The power of transmission.
- The node’s lifetime.
- The storage space.

– The mobility model.

These characteristics provide the nodes $n_{k,i,k'}$ the capacity to ensure an end to end communication between different areas of the network, they are useful in emergencies following a disaster or a military situation and can be used also where infrastructure is absent or inaccessible on the one hand, and for differentiating the nodes of the shared network on the other hand.

The following figure shows a DTN network partitioned into regions, connected by means of nodes $n_{k,i,k'}$, in the form of a graph:

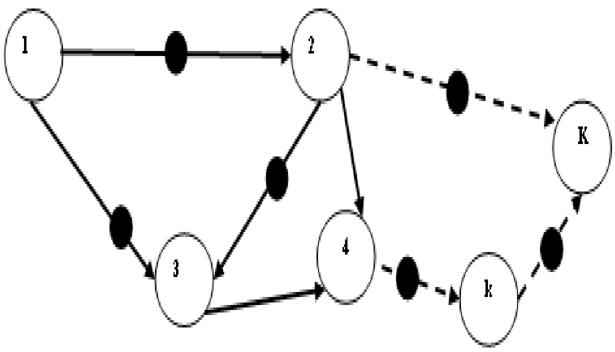

Fig.5 : Modeling graph of the shared network DTN

Using probabilistic graph theory, we can interesting with the probability of the contact between the two regions k and k' via the node $n_{k,i,k'}$ denoted by $P_{k,i,k'}$. It depends on several characteristics related to the energy of a node, especially the life of the bundle, the power of transmission, the storage capacity, the mobility model and the routing protocol with which nodes are circulating in the shared network. To calculate the probability that represents the contact between the two regions k and k' in a K regions shared network, it is necessary to know how to organize links and nodes $n_{k,i,k'}$ between the different regions. Therefore, we relied on the assumptions noted above, particularly (H3) and (H4).

Depending upon this modeling, we calculate $P_{k,i,k'}$ the probability of the contact between the regions k and k' taking into account the considered characteristics. The obtained result will guide us in the selection of carriers $n_{k,i,k'}$ among the nodes $n_{k,i}$ of the shared network, which is usually characterized by a very long lifetime and high storage capacity all along the road linking source to destination, especially in shared networks. Our contribution aims at optimizing the consumption of energy in a DTN network and increasing the probability of data delivery in a suitable delivery time in a shared network. In our measurements, we focus on reducing the number of carriers $n_{k,i,k'}$ in a several zones partitioned network. With all this consideration, and in order to compare the DTN protocols we are implemented our contribution based in ONE simulator making a count the effect of the contact probability and some other parameters as a TTL.

5 Simulation

In this section, we will present the operating principle of the used simulation tools, the used process of simulation, the performance metrics and finally the configuration of our simulation.

5.1 Stimulation used tool

Observing that they do not rely on analytical models, the exact evaluation of certain aspects of these protocols is very difficult. This is the reason that leads us to make simulations to study its performance. Our simulation is performed depending upon the simulator ONE [18, 19]. It allows generating a classification of the different routing protocols studied using performance metrics.

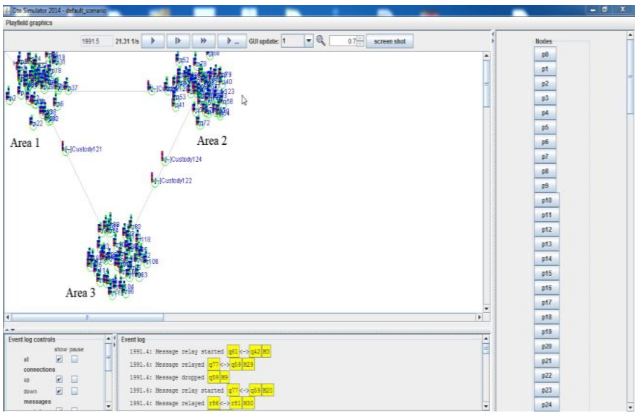

Fig.6 : Screenshot of our simulator

5.2 Simulation procedure

Evaluating the routing protocols DTN in the simulator described above, it is necessary to implement the routing algorithm and execute it in the DTN simulated environment. During the execution of the simulation, the different types of network performance metrics are collected and stored for analysis, further interpretation and therefore to have the outcomes. In this paragraph, we have taken into consideration the various inputs and outputs that are relevant to assess the DTN routing protocol as well as to provide a simple conceptual model, as we can see:

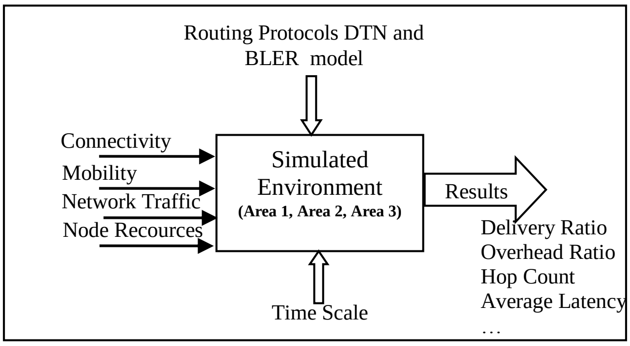

Fig.7 : Assessment Model of a DTN routing protocol.

5.3 Metrics performance

Comparing networks routing protocols DTNs, several parameters must be tested. These parameters can describe the simulation results in terms of the performance metrics, variables or input data of simulation such as models of nodes mobility, nodes resources etc, in a surface of simulation where the network is set up. Among these metrics we can cite [20]:

5.3.1 Delivery ratio (Delivery probability)

It is the ratio of the total number of messages delivered to the destination and the total number of messages created at the source node.

$$Delivery\ Ratio = \frac{D}{C} \tag{8}$$

Bearing in mind that:
D: Number of messages delivered to the destination.
C: Number of messages created at the source.

5.3.2 Overhead Ratio

This metric will allow us to evaluate the effectiveness of the bandwidth and interpret the number of copies created by a delivered message (it simply reflects the cost of transmission in a network). In other words, the number of replication required performing a successful delivery. For this purpose, we always look for algorithms that would minimize the value of overhead ratio.

$$Overhead\ Ratio\ = \frac{(R-D)}{D} \tag{9}$$

Taking into account:
R: Number of successful transmissions between nodes (This metric reflects the transmissions that took place).
D: Number of messages delivered to the destination.

5.3.3 Average latency

The latency measured here is the time that elapses between the creation of a message and its delivery at its destination.

5.3.4 Average buffer time

This is the average time that messages spend during its transit in the buffer nodes. This is not a metric of time spent in the buffer by the messages delivered, but it is the average of the time spent by all messages delivered and abandoned or stranded in the buffers of intermediate nodes.

5.3.5 Hop count

Number of hops is a metric in DTN assessments which denotes the number of nodes by means of which the message must pass between the source and the destination node, it helps understanding how messages, along a path, must pass from the source to the destination or how the network resources have been used, etc. Thus, the information of the average number of hops tells us about the use of network resources.

5.4 Simulation parameters

Table 2 summarizes the simulation configuration used to analyze the DTN routing protocols. Our scenario is stimulated into three regions (Fig.6).

TABLE 2. PARAMETERS OF SIMULATION

Parameter	Value
Total Simulation Time	5h
World Size	4500 X 3400 m
Routing Protocol	Epidemic, Spray and Wait, Prophet, Maxprop
Node Buffer Size	5M
No of Nodes	125
Interface transmit Speed	2 Mbps
Interface Transmit Range	10 meters
Message TTL	60 minutes
Node Movement Speed	Min=0.5 m/s Max=1.5 m/s
Message Creation Rate	One message per 25-35 sec
Message Size	50 KB to 150 KB

6 Results and Discussion

In the simulated environment, we focused on comparing the performance in terms of the metric defined in section 5.3. Running simulations based on the parameters defined in table 2 obtain the results presented here.

6.1 Delivery probability

Table 3 shows the delivery probability including the maximum number of messages delivered in relation to the amount of messages generated during the simulation that has a value of 608 messages.

TABLE 3. DELIVERY PROBABILITY

	Created Msg	Delivered Msg	Not delivered Msg	Delivery Probability
MaxProp	608	595	13	97.86%
Prophet	608	519	89	85.36%
Spary and Wait	608	495	113	81.41%
Epidemic	608	408	200	67.11%

The graph below shows a comparison of the delivery probability chosen in chart 3.

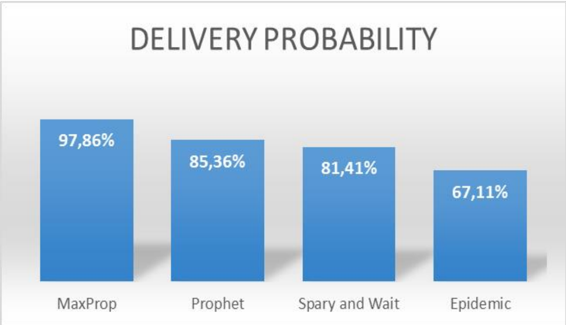

Fig.8 : Delivery probability of the evaluated protocols.

Accordingly, it is evident that the delivery probability of the routing protocol MaxProp in the considered scenario is higher than that of Prophet, Spray and Wait and Epidemic. The delivery probability of Prophet and Spray and Wait is almost identical; these results, which provide a quite high probability in almost all routing protocols studied, can be explained by the use of BLER model.

6.2 Overhead ratio

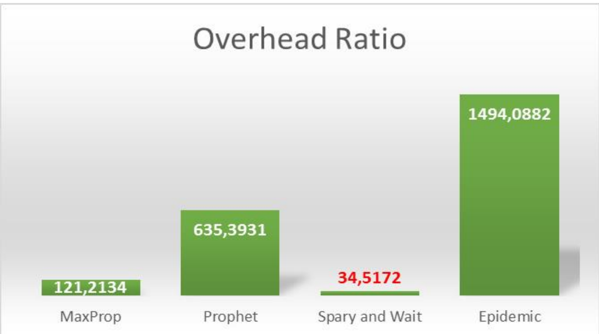

Fig.9 : Overhead ratio of different evaluated protocols.

We know that Overhead Ratio depends largely on the type of data diffusion techniques used for each DTN routing protocol. Looking at Fig.9, Spray and Wait is the best performing followed by MaxProp, while the overhead of routing protocols of Epidemic and Prophet have the highest values, especially the Epidemic one, which is characterized by the highest number of replications. However, the other protocols have low replication rates. That can be explained by the role of the BLER mechanism that allows them making an effective selection of the nodes among the existing ones.

6.3 Average latency

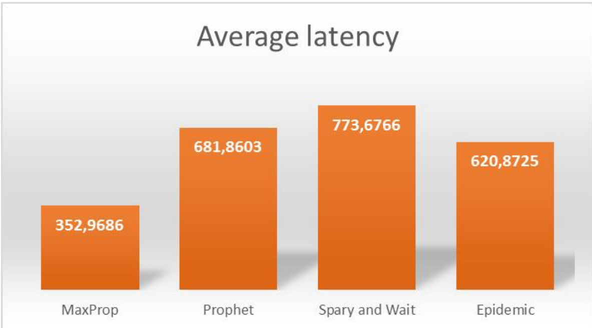

Fig.10 : Average latency of different evaluated protocols.

According to the last figure, it is evident that the average latency supported by a message in all the four routing protocols is considerable. This is because the message must wait ever more in the buffer before either being delivered to or eliminated due to the lifetime expiration. Thus, we find that the routing protocol MaxProp remains the most powerful among the four routing protocols objects of this study. This will allow MaxProp minimizing the transit time between the source and the destination.

6.4 Hop count

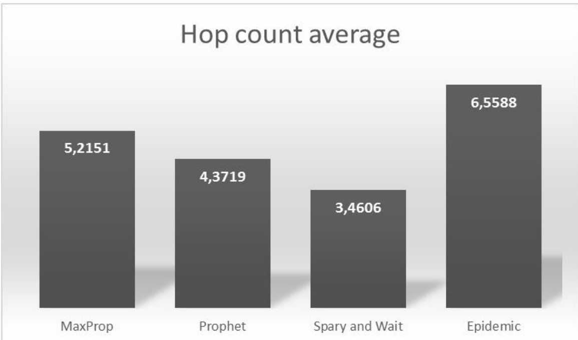

Fig.11: Hop count of different evaluated protocols.

The average hop count is an important metric for the interpretation and analysis of the routing performance according to the delivery rate and delivery time. From Fig.11, it is clear that Spray and Wait and Prophet routing protocols have a maximum number of hop count in the proposed scenario, compared to the MaxProp and Epidemic protocols. But, in terms of the delivery rate and the delivery time, MaxProp protocol is the most effective in relation to the three protocols namely: Prophet, Spray and Wait and Epidemic.

7 Conclusion

Research in the field of mobile ad hoc networks and especially DTN networks is booming. DTN several routing protocols have been developed in recent years. In this article, we have seen some DTN routing algorithms in order to compare it basing on the custody transfer and BLER models. Also, we found it useful to make an overview of the metrics used in this field. We consequently we have achieving our comparative study by evaluating a simulation code based on ONE simulator, in term of some DTN performances like as deliveries rate and time, hop count and overhead ratio.

Following this work, we intend to propose a contact model in order to describe some metrics in DTN network, according to the weakness considered assumptions. And then, the optimization problem well be formulated and evaluated by a developed simulating code.

References:

[1] T. Poongothai and K. Duraiswamy, Cross Layer Intrusion Detection System of Mobile Ad Hoc Networks using Feature Selection Approach, International Journal of WSEAS Transactions On Communications, Vol.13, 2014, pp. 71-79.

[2] G.Yasin, S.F.Abbas and S.R.Chaudhry, MANET Routing Protocols for Real-Time Multimedia Applications, International Journal of WSEAS Transactions On Communications, Issue.8, Vol.12, August 2013, pp. 386-395.

[3] Y. Wang, H. Dang, and H. Wu, A Survey on Analytic Studies of Delay-Tolerant Mobile Sensor Networks: Research Articles, Wireless Comm. Mobile Computing,vol. 7, no. 10, 2007, pp. 1197-1208.

[4] G.Voyiatzis, A survey of delay – disruption tolerant networking applications, Journal of Internet Engineering, Vol.5, No.1, June 2012, pp.331-343.

[5] M.C.Chuah, P.Yang, B.D.Davison and L.Cheng, Store-and-Forward Performance in a DTN, Vehicular Technology Conference, Melbourne, Vic, Vol.1, 7-10 May 2006, VTC 2006-Spring. IEEE 63rd, pp.187 - 191.

[6] S.Maia, E.Silva, P.Guardieiro, A New Optimization Strategy Proposal for Multi-Copy Forwarding in Energy Constrained DTNs,Communications Letters, IEEE, Vol.PP, Issue.99, 07 August 2014, pp.1.

[7] R.S.Mangrulkar, M.Atique, Performance evaluation of delay tolerant routing protocol by variation in Buffer Size, Advances in Engineering, Science and Management (ICAESM), 2012 International Conference on IEEE, 30-31 March 2012, pp.674-678.

[8] Y.K.Ip, W.C.Lau, O.C.Yue, Forwarding and Replication Strategies for DTN with Resource Constraints,Vehicular Technology Conference, 2007. VTC2007-Spring. IEEE 65th, Dublin, 22-25 April 2007, pp.1260 - 1264.

[9] A. Vahdat and D. Becker, Epidemic Routing for Partially Connected Ad Hoc Networks, Technical Report CS-200006, Duke University, Durham, April 2000.

[10] T.Spyropoulos, K.Psounis and C.Raghavendra, Spray and wait: an efficient routing scheme for intermittently connected mobile networks. in Proceedings of the 2005 ACM SIGCOMM workshop on Delay-tolerant networking. 2005: ACM.

[11] A.Lindgren, A.Doria and O.Schelen, Probabilistic routing in intermittently connected networks. SIGMOBILE Mob, Comput. Commun. Rev. Vol.7, No.3, 2003, pp.19-20.

[12] J. Burgess, B. Gallagher, D.Jensen and B. N. Levine, MaxProp: Routing for Vehicle-Based Disruption-Tolerant Networks, Proceedings of 25th IEEE International Conference on Computer Communications, Barcelona, Spain, April 2006, pp.1-11.

[13] J.Karvo and J.Ott, Time Scales and Delay-Tolerant Routing Protocols, n Proc.c of the ACM MobiCom Workshop on Challenged Networks(CHANTS), Septempbre 2008, pp.33-40.

[14] K.Mistry, S.Srivastava, R.B.Lenin, Buffer Aware Routing in Interplanetary Ad Hoc Network, Communication Systems and Networks and Workshops, 2009. COMSNETS

2009. First International,IEEE, 5-10 January 2009, pp.1-10.
[15] Y.Yu, X.Chen,Performance evaluation of custody transfer in Mars-to-Earth DTN communications, Signal Processing, Communication and Computing (ICSPCC), 2013 IEEE International Conference on, KunMing, 5-8 August 2013, pp.1-5.
[16] K.Fall, W.Hong and S.Madden, Custody Transfer for Reliable Delivery in Delay Tolerant Networks, Technical Report, Intel Research, Berkeley, 2003.
[17] E.Koutsogiannis, F.Tsapeli and V.Tsaoussidis, Bundle Layer End-to-end Retransmission Mechanism, Internet Communications (BCFIC Riga), 2011 Baltic Congress on Future, Riga, 16-18 February 2011, IEEE, pp.109-115.
[18] A. KerAnen, opportunistic network environment simulator. Special assignment report, Helsinki University of technology, Department of Communications and Networking, May 2008.
[19] Tkk/Comnet. Project page of the ONE simulator. [Online]. Available: http://www.netlab.tkk.fi/tutkimus/dtn/theone, 2009.
[20] H.S.Bindra and A. L. Sangal, Performance Comparison of RAPID, Epidemic and Prophet Routing Protocols for Delay Tolerant Networks, International Journal of Computer Theory and Engineering, Vol.4, No.2, April 2012, pp.314-317.