

# Optimal Cluster Head in DTN Routing Hierarchical Topology (DRHT)

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**Abstract:** In delay tolerant networking (DTN), nodes are autonomous and behave in an unpredictable way. Consequently, a control mechanism of topology is necessary. This mechanism should ensure the overall connectivity of the network taking into account nodes' mobility. In this paper, we study the problem of data routing with an optimal delay in the bundle layer, by exploiting: the clustering, the messages ferries and the optimal election of cluster head (CH). We first introduce the DTN routing hierarchical topology (DRHT) which incorporates these three factors into the routing metric. We propose an optimal approach to elect a CH based on four criteria: the residual energy, the intra-cluster distance, the node degree and the head count of probable CHs. We proceed then to model a Markov decision process (MDP) to decide the optimal moment for sending data in order to ensure a higher delivery rate within a reasonable delay. At the end, we present the simulation results demonstrating the effectiveness of the DRHT. Our simulation shows that while using the DRHT which is based on the optimal election of CH, the traffic control during the TTL interval (Time To Live) is balanced, which greatly increases the delivery rate of bundles and decreases the loss rate.

**Keywords:** Ad hoc network, DTN network, Bundle, Hierarchical Cluster, Cluster Head Election, Delivery success probability.

## 1. Introduction

A delay tolerant networking (DTN), as described in [1] is a kind of MANET network Mobile Ad-hoc Networks. It consists of a set of self-organized stations fully decentralized, forming an autonomous network, dynamic and without pre-existing infrastructure. These stations communicate with each other through a radio interface. Only the elements that exist in the transmission range are able to communicate directly with each other. Otherwise, communication between the components takes place by connecting the close messages until the destination is reached. In this case, it is not easy to find an efficient routing between distant elements [2].

The mobility of stations and the lack of infrastructure have a significant impact on connectivity in such networks. Therefore, the topology of MANET network is rarely or never, connected and the message delivery must be tolerant to delay [3 - 7].

A DTN network is characterized by intermittent connectivity, asymmetric flow, high error rate, long or variable delivery delay, extensive networks and high mobility of nodes. This latter creates new problems such as frequent disconnection, low communication rate, modest resources and limited energy source. These factors make the network spread on a large-scale, and therefore the delivery delay is very long and the delivery rate is potentially low.

Thus, the need to develop optimal transmission systems to maximize the DTN network performance is then essential, in order to ensure a great autonomy to these networks which are

typically deployed in hostile or inaccessible areas. Furthermore, the unequal load of nodes can potentially cause, in some nodes, an early depletion of their batteries and their storage capacity, disrupting consequently the network connectivity and leading to the loss of data.

The objective of this work is to solve effectively this problem of delivering information between different nodes of the network. Some parameters must be taken into account in order to save the bandwidth, the scarce radio resources, etc. The designed protocol must adapt to the increased number of participants and their mobility, so that they can function correctly.

Our approach to this problem is first based on the regrouping of nodes in clusters, then the selection of a cluster head (CH) in each cluster and finally the communication between CHs through ferries. The selected CH is responsible for coordinating the communication with mobile nodes in the same cluster (intra-cluster) and with nodes of the other clusters (inter-cluster). The elected CH must take into account the determined characteristics such as the battery lifetime and the minimum average distance between the nodes of a subset and the CH in a given cluster. The conception of a cooperative control system in real time requires a good comprehension of the system in order to achieve the common goal, which is to maintain the system connectivity and to optimize the delivery delay as long as possible. For this, the problem of choosing a dynamic coordinator can be reduced to the problem of a CH election, which is a major problem of the mobile network. Furthermore, the solution proposed for the distributed system (e.g. WSN) cannot be applied in the DTN where the change in topology is frequent and links are intermittent [8-12]. Our work provides an effective intra-cluster communication due to an optimization on two levels: the optimal election of CHs and the communication between them via ferries in order to increase the QoS in the DTN networks. In other words, the proposed approach improves the delivery rate and the delivery delay compared to conventional approaches.

Indeed, a DTN network can be used to ensure reliable transmission in hostile networks with a very long delivery delay and intermittent connectivity. To facilitate communication and optimize the tasks that involve multiple nodes at once, a network organization is required. This organization is guaranteed by the establishment of a logical topology in the network that allows imposing rules and constraints governing the operation of the network and the collaboration between the different nodes, especially when the destination is not in the same region of the source.

It is noteworthy to mention that the rest of this article is organized as the following: In Section 2, we provide a preliminary on the store and forward mechanism, Custody transfer, the DTN routing protocols and message ferry (MF). Then, we present in Section 3 system model and problem statement. In Section 4, we describe the model of the DTN routing hierarchical topology (DRHT). In Section 5, we analyze our approach for obtaining the optimal cluster head (CH) in the DRHT. Section 6 is devoted to the model of the success probability of delivery for a bundle with specific TTL and the average duration of inter-contact. In Section 7, we describe the environment and the simulation parameters. In Section 8, we will present the obtained results to assess the performance of the used topology control DRHT compared to Maxprop protocols and Epidemic Spray and wait. Finally, in Section 9, we present a conclusion and we expose our future works.

## 2. DTN Preliminary

The DTN architecture implements a number of mechanisms mainly the store-and-forward technique by adding a new protocol layer called Bundle. In this section, we will briefly define the store-and-forward mechanism, Custody Transfer and the DTN routing protocols. Finally, we will define the message ferry.

### 2.1 Store-and-forward mechanism

The primary characteristic of the bundle layer is the support for in-transit storage. The received bundles from a sender are possible to be loaded in an intermediate node for an excessive amount of time (minutes, hours or even days) because of the store-and-forward technique (Figure 1). The network stack is mainly responsible for performing these storage operations, at the bundle layer, transparently to the application. The in-transit storage is the tool to overcome the delays and disruptions induced while a bundle goes hop by hop till its final destination; in order to avoid costly end-to-end retransmissions due to the high errors rate, the asymmetric flow or the long delivery delay; and also to permit exchanging data between two nodes that do not share any end to end communication path at any given moment, the bundle protocol defines a custody operation that allows an intermediate node to handle bundle delivery to final destination on behalf of a more distant sender [13].

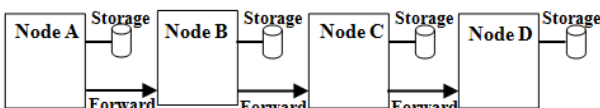


Figure 1. The principle of store-and-forward

### 2.2 Custody Transfer

Custody transfer is a mechanism enhancing the reliable message transmission and retransmission of the lost data using the transmission reliability hop-by-hop, whether one time or more. When there is no connectivity from end to end, custody transfer gives the responsibility of the reliable delivery to intermediate nodes called: custodians usually characterized by a very long lifetime and high storage capacity along a path from source to destination. In addition, custody transfer allows the source to delegate responsibility of retransmission and recovery of resources that are relatively related to the retransmission just after sending the message [14-16].

## 2.3 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 (figure 2). 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 [17-19].

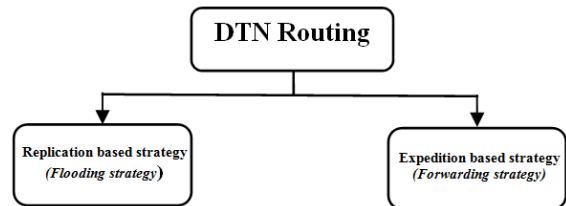


Figure 2. DTN routing strategies.

### 2.3.1 Epidemic protocol

Epidemic routing protocol 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 [20].

### 2.3.2 Spray and wait protocol

The routing protocol Spray and wait limits the replication strategy of blind Epidemic routing messages by combining an L number of messages indicating the maximum allowable copies of the message. The routing protocol spray and wait has two phases: Spray phase and wait phase. In the first phase, for each message generated at the source, L copies are distributed to L distinct relays (figure 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 second phase (figure 3, part b). The parameter L is selected depending on the density of the network and the desired average time [21].

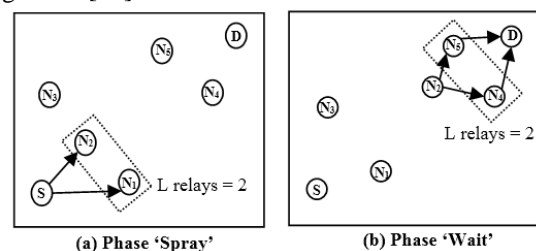


Figure 3. Spray and wait routing.

### 2.3.3 Maxprop protocol

Maxprop is a routing protocol based on forwarding strategy. In Maxprop routing each node maintains a vector called the

delivery probability. When two nodes meet, they exchange these vectors, and so that each node can calculate the shortest path to the destination. Maxprop uses a buffer memory ordered, which is divided into two parts based on an adaptive threshold. Maxprop gives a high priority to new messages and forward them firstly with low hop count and drops messages with the highest cost path when buffer is full. When nodes have small buffer sizes, Maxprop performance is poor owing to the adaptive threshold calculation. Maxprop has a better performance with large buffer size [22].

### 2.4 Message Ferry (MF)

Different approaches have been proposed during the recent years to defeat large-scale partitioning problem [23]. One of them, namely the system of Message Ferry (MF) [24], uses special nodes as ferries to transmit messages through the partitions of a DTN. With the MF system, despite the fact that normal nodes are partitioned, ferries allow the connection by moving from one partition to another [25, 26]. Information dissemination is carried out in two possible approaches:

- The approach initiated by the regular nodes (Node-initiated message ferrying): To transmit data, ferries follow a random movement pattern on known paths of regular nodes, which approach the path of a ferry when they want to send information to a destination.
- The approach initiated by ferry nodes (Ferry initiated message ferrying): Ferries adapt their movements according to the CHs wishing to send data to destination. A ferry node starts by periodically broadcast their position to CHs. Then, regular nodes interested in sending messages reply with a request. Once the request is received by a ferry, it adapts its path basing upon requests.

This method improves the performance of routing packets compared to other models. Indeed, by taking into consideration the different positions and by adapting these shifts to positions, latency for transporting a package from end-to-end can be reduced significantly, which seems advantageous when nodes are constrained in terms of energy and memory capacity, particularly in large-scale networks.

## 3. System model and problem statement

In this section, we present the network model considered in this study. Table 1 summarizes the main notations and some assumptions used in this paper. Finally, we describe the problem statement and the function objective.

### 3.1 Network model

Let a DTN composed of  $N + 1$  nodes, i.e. mobile nodes. Two nodes can communicate only when they enter the reciprocal communication range and we consider this as a "contact" between them in the network DTN. Let the interval of pairwise inter-contact between  $n_i$  and  $n_j$  denotes the time duration from the instant when they leave communication range of each other to the next instant when they enter it. To improve the performance of DTN in the existing analytical results, we use the same mobility model, in which the interval of pairwise encounter fulfills the exponential distribution with the same rate  $\lambda$ . This model has been widely supported in the literature [27, 28] because it is considered as

a good approximation for the interval of inter-contact in a significant number of realistic DTN networks [28].

### 3.2 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
$C_k$	Cluster of the network
$N_k$	Number of nodes in each area, with: $N = \sum_{k=1}^K N_k$
$F$	Message ferry
$v$	Speed of the ferry
$P$	Ferry route
$ P $	Length of a ferry route
$l_{ij}^p$	Distance between the node $n_i$ and $n_j$
$t_{w_{ij}}$	Time of wait to $n_i$ before being transmitted to the ferry
$t_{c_{ij}}$	time of carrying to the ferry before delivered to $n_j$
$d_{ij}^p$	Average delay to transmit a message of $n_i$ to $n_j$ .
$b_{ij}$	Average traffic between node $n_i$ and $n_j$ .

### 3.3 Hypotheses

The study of the performances of the DTN network is constraining because of its various characteristics, in particular the mobility of nodes, the bandwidth and the resources of energy. This leads us to an approximation of calculations by the means of certain assumptions on the network considered. In fact, we focus on the connection between the nodes, the nature of circulation of flows on the routes ferry linking the various regions, the transmission range, and the law of behavior managing the contact between the areas. Thus, we summarize these assumptions by:

- (H1): The nodes have the same range of transmission;  
(H2): The regions of the network forming a cluster;  
(H3): The movement of nodes is random between  $K$  regions;  
(H4): The traffic in the network is unpredictable;  
(H5): The range length of each cluster is strictly lower than the ferry route length;  
(H6): The contact between the two regions  $C_k$  and  $C_{k'}$  follows an exponential distribution of the parameter  $\lambda = \lambda_{k,k'}$ .

### 3.4 Problem statement

A DTN network can be considered as a set of time-varying contacts (a contact is defined as an opportunity to send data). The maximum amount of data that can be transmitted on a contact is called the delivery rate, and is defined as the product of the contact duration and the number of messages received during this period. A path is defined as a sequence of contacts. The path volume is the minimum volume of contact of all contacts of the path. Messages are transferred along a path in storage and forwarding mode (store-and-forward). If the next contact is not available, messages are buffered until the contact becomes available or messages have expired.

In order to assure connectivity between clusters, we need to determine the positions where the multiple MF must move in order to maximize the number of nodes covered. Movement

of the multiple MF must also ensure a connected DTN network. In addition to the effective coordination with the optimal CH in each cluster.

### 3.5 Function objective

The objective function of the average delivery delay, for all the traffic in a given ferry route  $P$ , is defined as:

$$\Delta_d = \frac{\sum_{1 \leq i, j \leq N} b_{ij} d_{ij}^P}{\sum_{1 \leq i, j \leq N} b_{ij}} \quad (1)$$

The original problem of the ferry route is defined in [26] with two basic hypotheses, which are: firstly the nodes are fixed and their position is known, and secondly the average traffic  $b_{ij}$  between the node  $n_i$  and the node  $n_j$  can be estimated before calculating the route. However, as we have assumed according to the hypothesis (H4)  $b_{ij}$  cannot be determined in advance. Furthermore, when  $F$  (ferries) are dynamic, the delivery delay from one point to another is not fixed. Therefore, we need to change the objective-function of the average delivery delay for all the traffic, which is determined as follows:

Let's suppose that, in the time period  $(0, t)$ , there are  $M$  messages to be transmitted by ferries  $F$ . The message size ( $1 \leq i \leq M$ ), its source and its destination cluster are designated by  $\mu_i$ ,  $s_i$  and  $d_i$  respectively.

The objective-function of the average delivery delay in the DRHT, for all the traffic in a given ferry route, is defined as:

$$\Delta_{DRHT} = \frac{\sum_{i=1}^M \mu_i d_{ij}^P}{\sum_{i=1}^M \mu_i} \quad (2)$$

The main challenge in DTN networks is how to improve the performance of data delivery in large-scale networks. Our goal is to find an optimal route for the ferry in order to minimize the objective function.

The performance of the proposed topology is linked to parameters relating to the external environment such as: the mobility, the DTN protocols, the connectivity, the number of participating nodes, the generated traffic, the energy, the election of CH, etc. This will be the subject of the next section, in which we try to analyze the topology behavior particularly the methodology for electing a CH.

## 4. DTN Routing Hierarchical Topology (DRHT)

### 4.1 Description of the construction DRHT

The main idea is to build a topology of routing in a large-scale DTN network. The dominant character in the DRHT is the number of nodes (MF) that cross the diffusion paths to ensure connectivity between clusters. The choice of data carrying nodes (MF) is an important step in the construction of the set of clusters. In addition, each cluster is identified by three categories of nodes:

1. The cluster head (CH) is a dominant node, it is the head of the cluster;
2. The center of the cluster (CC) is a point of exchange at which messages can exchange data between different CHs via MF within each cluster;
3. The ordinary node (ON) are not dominating nodes.

Consider a DTN network of  $N$  mobile nodes and  $F$  ferries, each one with a value of communication range equals to  $r$ . Supposing that the network is partitioned into  $K$  components, each one forms a cluster the chief of which is

the cluster head CH. To simplify the problem, we limit the movement of a CH in a circular area. The center of the cluster  $C_k$  is noted as a point of CC.

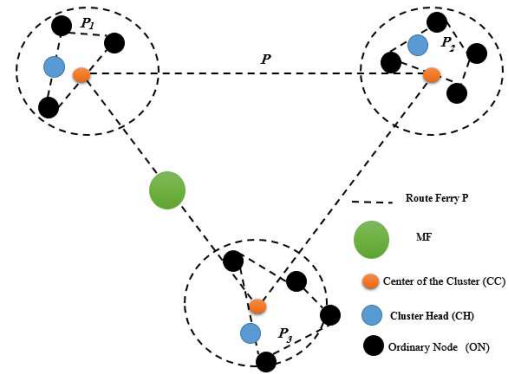


Figure 4. Diagram of the DRHT.

Here is a description of the different stages of the DRHT algorithm that is divided into five phases:

1. The network partitioning;
2. The choice of the broadcaster node;
3. The scope and density of clusters;
4. The calculation of the ferry cluster route. For each cluster, ferry route can be calculated by the algorithm proposed in [25, 29];
5. The calculation of the global ferry route. Along the direction of the route  $P$ , the global ferry route can be obtained by connecting the CH position of each cluster.

### 4.2 Routing phases in the DRHT

The DRHT divides the routing of data into two parts: intra-cluster and inter-cluster. Each cluster-head is responsible for communication within its cluster and maintains the information of routing that allows joining the other ordinary nodes. Moreover, since the other cluster-heads are not directly connected, multiple MF are also used to ensure communication between cluster-heads located in two different clusters.

#### 4.2.1 Intra-cluster routing phase

This phase allows to a source node to reach a node recipient inside the cluster. It is the CH that has a total knowledge of the cluster, it checks the presence of the node recipient there. Thus, any message must obligatorily pass by it.

#### 4.2.2 Inter-cluster routing phase

This phase allows a source node (or intermediate) to reach a destination node located in a different cluster via MF, if a ferry stops at CC, it would be able to communicate with the CH cluster  $C_k$ . A simple contact between the ferry and CH is enough to deliver messages to other members.

These multiple MF allow reducing the number of duplicated messages by lessening the traffic flowing through the network, and furthermore reducing the energy of consumption. Moreover, the transmission of data to other clusters through a single MF becomes almost impossible when the extent of the network increases. To solve this problem, routing of multiple MF is the communication mode adopted to transmit data between the different clusters.

Furthermore, once the nodes of different clusters are connected, we can use conventional protocols such as

Epidemic, Prophet, Spray and wait and Maxprop for communication between the CH and the other members. It is noteworthy to mention that the delivery delay required for transmission of messages within a cluster  $C_k$  (intra-cluster communication) is much shorter than between different  $C_k$  clusters (inter-cluster communication), and it is less relevant for the ferry route. However, the two have a high importance in the communication process especially in the DRHT.

### 4.3 Analysis of delivery delay in the DRHT

Depending upon many works in this field [24, 25], this section we will present basic concepts to model and analyze the delivery delay introduced by the DRHT, following certain scenarios in which nodes  $n_i$  and  $n_j$  are located in different position. When  $F$  crosses node  $n_i$ , a message destined to the node  $n_j$  is produced. The delivery delay of this message is analyzed as follows:

- The time of wait in  $n_i$  before being transmitted toward  $F$  is:

$$t_{w_{ij}} = \frac{|P|}{2v} \quad (3)$$

- The time of carrying of the ferry of  $n_i$  to  $n_j$  is:

$$t_{c_{ij}} = \frac{l_{ij}^P}{v} \quad (4)$$

- The delay between the instants to generate the message in the node  $n_i$  and to deliver the message in the node  $n_j$  is:

$$d_{ij}^P = t_{w_{ij}} + t_{c_{ij}}$$

$$\rightarrow d_{ij}^P = \frac{|P|}{2v} + \frac{l_{ij}^P}{v} \quad (5)$$

#### 4.3.1 When nodes $n_i$ and $n_j$ are in the same cluster

The delay of single ferry routing is:

$$d_{ijF}^P = \frac{|P|}{2v} + \frac{l_{ijF}^P}{v} \quad (6)$$

In the DRHT, let  $P_k$  be the ferry route for cluster  $C_k$  and let  $l_{ij}^{P_k}$  be the distance between node  $n_i$  and node  $n_j$  in route  $P_k$ .

The delay introduced by DRHT is  $d_{ij}^{P_k}$  :

$$d_{ij}^{P_k} = \frac{|P_k|}{2v} + \frac{l_{ij}^{P_k}}{v} \quad (7)$$

According (6) and (7), we note that  $d_{ij}^{P_k} < d_{ijF}^P$  since  $|P_k| < |P|$  and  $l_{ij}^{P_k} < l_{ijF}^P$ . That means that when the node  $n_i$  and the node  $n_j$  belong to the same cluster, the delay of routing of DRHT is lower to the single message ferry.

#### 4.3.2 When nodes $n_i$ and $n_j$ are situated in different clusters $k$ and $k'$

The delay of routing of the single message ferry when the nodes  $n_i$  and  $n_j$  are located in different clusters is the same that when the node  $n_i$  and the node  $n_j$  are in the same cluster.

Based on the figure 4, the delivery delay consists of three parts in the DRHT.

- Let  $d_{ij}^{P_1}$  be the delivery delay in cluster 1.

$$d_{ij}^{P_1} = \frac{|P_1|}{2v} + \frac{l_{ij}^{P_1}}{v} \quad (8)$$

- The delivery delay is the time of waiting of the ferry and the time of carrier of the ferry in the point CC before delivering it to the cluster 2:

$$d_{ij}^{P_{CC}} = \frac{|P_{CC}|}{2v} + \frac{l_{ij}^{P_{CC}}}{v} \quad (9)$$

- Let  $d_{ij}^{P_2}$  be the delivery delay in cluster 2 :

$$d_{ij}^{P_2} = \frac{|P_2|}{2v} + \frac{l_{ij}^{P_2}}{v} \quad (10)$$

Therefore, the total delivery delay of the message is  $d_{ij}^{P_{all}} = d_{ij}^{P_1} + d_{ij}^{P_{CC}} + d_{ij}^{P_2}$  and one writes:

$$\begin{aligned} & \frac{|P_1|}{2v} + \frac{l_{ij}^{P_1}}{v} + \frac{|P_2|}{2v} + \frac{l_{ij}^{P_2}}{v} + \frac{|P_{CC}|}{2v} + \frac{l_{ij}^{P_{CC}}}{v} \\ &= \frac{(|P_1| + |P_{CC}| + |P_2|)}{2v} + \frac{l_{ij}^{P_1} + l_{ij}^{P_{CC}} + l_{ij}^{P_2}}{v} \end{aligned} \quad (11)$$

From figure 4, we see that  $|P_1| + |P_{CC}| + |P_2| < |P|$  and  $l_{ij}^{P_1} + l_{ij}^{P_{CC}} + l_{ij}^{P_2} < l_{ijF}^P$ .

## 5. Optimal cluster head election in the DRHT

### 5.1 Optimal cluster head election

The cluster head in the DRHT has a major impact within its substructure. Each CH acts as data temporary carrier within its cluster and communicates with other CHs. Cluster head (CH) election is the process to select a particular node among specific nodes within the cluster. Generally, the role of the CH is to manage the nodes of its own cluster and to communicate with other clusters. It is able to communicate with other clusters directly through the respective CH or through intermediaries as the case of the DRHT, this is by sending and receiving the data, compressing the data and transmitting it to other CHs.

Electing a specific node as a cluster head is not an easy task. Depending on different factors, such as geographical location of the node, stability, mobility, energy, storage capacity, etc. The selection criteria may vary in order to confide the coordinating responsibility to the CH.

This section provides an optimization of delivery rate of bundles and the delivery delay in the DRHT by the optimal check point of CHs within the cluster. The objective of our approach is to reduce the cost of locating optimal position of specific nodes in a cluster. The selection criteria of the objective -function are based on the residual energy, intra-cluster distance, node degree and head count of probable cluster heads.

Let  $\Sigma = \{p_1, p_2, \dots, p_N\}$  the set of all the specific nodes considered for the DRHT in each cluster. If there are  $n$  specific nodes in the DRHT, then each specific node possesses a position vector  $x_i$  and a velocity vector  $v_i$ , given by:

$$x_i = (x_{i1}, x_{i2}, \dots, x_{im})^T \quad (12)$$

$$v_i = (v_{i1}, v_{i2}, \dots, v_{im})^T \quad (13)$$

In which  $i = 1, 2, \dots, n$ , and  $m$  symbolizes the dimension. Moreover,  $x_{ij}(t)$  and  $v_{ij}(t)$  signifie the  $i^{th}$  specific node position and the velocity in  $j^{th}$  dimension during the time instant  $t$ . To track the global best positioning,  $C_k$  maintains the local best positions of specific nodes in the  $\sigma = \{p_1, p_2, \dots, p_N\}$  which contains the best positions of all the specific nodes ever visited.

In addition to that, the optimal local position of  $i^{\text{th}}$  specific node and the best global location (with respect to all specific nodes in a cluster) at time  $t$  are denoted by  $p_i(t)$  and  $p_g(t)$  respectively.

$$p_i(t) = \arg \min_t f_i(t) \quad (14)$$

$$p_g(t) = \arg \min_t f(p_i(t)) \quad (15)$$

## 5.2 Objective function for the election of CH

In this section, we define our proposed objective function for effective execution of the election of the CH in the DRHT based on the Custody Transfer. The main goal of the objective function is to optimize the combined effect of average distance between nodes in a cluster, residual energy, node degree and head count of probable cluster heads (ie . the number of times a specific node served as a cluster head). The objective function, represented as  $f(x_i(t))$  for the  $i^{\text{th}}$  specific node is specified in the following equation:

$$f(x_i(t)) = \text{optimize } (\beta_1\chi_1 + \beta_2\chi_2 + \beta_3\chi_3 + (1 - \beta_1 - \beta_2 - \beta_3)\chi_4) \quad (16)$$

Subject to:

$$\chi_1 = \sum_{\substack{\forall n_j \in C_k \\ x_i \in C_k}} \left\{ \frac{\|n_j x_i\|}{|C_k|} \right\} \quad (17)$$

$$\chi_2 = \frac{\sum_{\substack{i=1 \\ x_i \in C_k}}^N E(p_i)}{\sum_{\substack{j=1 \\ n_j \in C_k}}^{|C_k|} E(n_j)} ; E_{\min} \leq E(n_j) \leq E_{\max} \quad (18)$$

$$\chi_3 = N_{\text{deg}}(p_i) ; 0 < \beta_1, \beta_2, \beta_3 < 1 \quad (19)$$

$$\chi_4 = \frac{1}{H(p_i)} ; H(p_i) \geq 1 ; \beta_1 \leq \beta_2 \leq \beta_3 \quad (20)$$

As mentioned above,  $\beta_1, \beta_2, \beta_3$  are the weightage parameters. In our optimization function we provide comparatively valuation to the residual energy associated with the specific node  $p_i$ . The node  $n_j$  must have its energy level within the interval  $[E_{\min}, E_{\max}]$ , or else this node filtered out and hence not selected for the comparison with the specific node  $p_i$ . Moreover,  $E(p_i)$ ,  $N_{\text{deg}}(p_i)$  and  $H(p_i)$  denote respectively the energy, the node degree and the head count of probable cluster heads, associated with the specific node  $p_i$ . Also,  $n_j$  is the  $j^{\text{th}}$  node of the  $k^{\text{th}}$  cluster ( $C_k$ ) and  $|C_k|$  denotes the total number of nodes in the respective cluster.

The Euclidean distance between the node  $n_j$  and the specific node  $p_i$  is represented by the notation  $n_j; x_i$ . It is clear, from the equation, that  $\chi_1$  is the average distance between the specific node  $p_i$  and all other nodes in the cluster and  $\chi_2$  is the energy measure of the specific node compared to the other nodes. The  $\chi_3$  parameter refers to the degree of the node associated to the specific node  $p_i$ . This criterion helps to select, around the specific node, the node with highest degree. The node that is connected to more number multiple of nodes reflects greater efficiency in receiving more bundles easily.  $\chi_4$  is the probability of choosing the specific node  $p_i$  on the basis of its head count the head count of probable CHs.

The head count of probable CHs is basically the frequency of a specific node of becoming cluster head. As the head count of probable CHs increases, the probability of the selection of a specific node as cluster head decreases by certain magnitude.

As a final point, at the end of each tour (i.e. on completion of  $T_{\max}$  number of generations), the specific node whose attributes optimize the objective function, is chosen as the best global position for the head cluster. The specific node nearest to the optimal global location is elected as the CH for the current tour. The selected node acts as CH until its energy drops (parachutes) beyond a particular level, after which the current CH informs  $C_k$  to initiate the next tour of the cluster head selection.

## 5.3 Optimal forwarding instant of the CH

To solve the problems of synchronized collisions and the imbalance of the traffic control (overhead) on the bundle layer, we propose a solution based on theories of decision and probability. These two theories answer the following question: "Is it more appropriate to send my message now or delay its sending? And how long do I delay it if that's the case? "

In this section, we give a model the problem concerning the optimal instant for sending a message via a CH by a Markov decision process (MDP) which evolves in space and time. The objective of a CH is to maximize the percentage of the message reception by sending it while the bundle layer is free or little busy. While the bundle layer is free, forwarding maximizes certainly the chances of message reception, but can also greatly extend its delivery delay if the links are broken. A compromise must be found between the reception rate of a message and the additional time induced by its delay, in order not to overload the bundle layer by informations that are no longer relevant.

### 5.3.1 Markov Decision Process (MDP) Formulation

The selected decision of the optimal moment of sending represents a compromise between the final gain; which is the reception rate, and the cost related to the potential delay. The resolution of this problem is obtained through a Markov decision process (MDP) modeling. The TTL lifetime of an information is limited and the delay tolerated for its forwarding too. Thus, we propose a set  $T$  of  $N$  periods in time included only in the TTL interval, of each  $t$  duration, during which CH can send its message or decide to delay it until the next period of time.

The set of time periods for the transmission of a message are:  $T = \{T_1, \dots, T_N\}$  with  $N = \frac{V}{t}$ , such as:

$$T_{i+1} - T_i = t + \eta T_{\text{service}} + v T_{\text{guard}}; \text{ where } i < N$$

where :

$$\eta = \begin{cases} 1 & \text{At the meeting of Service interval} \\ 0 & \text{if not} \end{cases}$$

$$v = \begin{cases} 1 & \text{At the meeting of the guard interval} \\ 0 & \text{if not} \end{cases}$$

Our MDP model is composed of a set  $S$  of possible states for the system, actions  $A_s^{T_i}$ , rewards and costs  $R(s^{T(i+1)}, s^{T_i})$  that depend on two process states, and finally transition probabilities  $P(s^{T(i+1)} | a, s^{T_i})$  between the two states  $s^{T(i+1)}$  and  $s^{T_i}$ , which are separated in time  $(T_{(i+1)} - T_i)$ , when the selected action is  $a$ .

#### (a) States

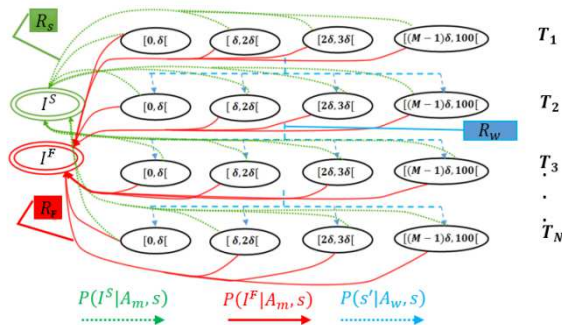
The set  $S$  of the process states includes two parts, the states  $C$  which relate to the occupation percentage of the bundle layer going from 0% to 100% for each period  $T_i$  of the information TTL. In addition to the two absorbing states  $I$

which represent the successful or failed forwarding status of a message. These states are achieved when a CH sends its message. This set of states is illustrated in figure 5. All these states are connected by transition probabilities, which result in costs  $R_f$  and  $R_w$  or rewards  $R_s$ .

$$T = \{S_0^{T_i}, S_1^{T_i}, S_2^{T_i}, \dots, S_j^{T_i}, \dots, S_{M-1}^{T_i}\}; \quad 0 < i \leq N$$

Where  $M = \frac{100}{\delta}$  and  $S_j^{T_i} = [j\delta\%, (j+1)\delta\%]$ ,  $\delta$  is the precision chosen for the intervals of the states  $C$ .

$$I = \{I^S, I^F\}$$



**Figure 5.** Markov decision process of the transmission on Bundle layer.

### (b) Actions

Two actions  $A_s^{T_i}$  can be chosen during a period of time  $T_i$  and for a states  $\in C$ . The first action  $A_m$  consists in sending the message immediately; the second action  $A_w$  delays it for a period of time. A message is delayed until it meets a decision of immediate sending or until the expiry of its validity.

$$A_s^{T_i} = \begin{cases} \{A_w, A_m\} & \text{if } s^{T_i} \in C \text{ and } i < N \\ A_m & \text{if } s^{T_i} \in C \text{ and } i = N \end{cases}$$

### (c) Rewards and costs

Each decision is taken in order to maximize a final gain; this latter represents the reception rate for a sent message. Its calculation depends on the  $R(s'^{T(i+1)}, s^{T_i})$  obtained during transitions between states; they can represent allotted rewards or deducted costs. A reward  $R_s$  is allotted when a message is sent successfully, whereas a cost  $R_f$  is inflicted when the sending fails. The cost induced by the adjournment of a message for a period of time,  $R_w$ , is the third parameter taken into account in the decision making.

The reward  $R_s$  is always positive, to motivate CHs to send their message. Whereas the costs related to the sending failure and the additional time delay are either negative or equal to zero. The value of each of these parameters can be weighted to the access category (AC) of the message to send.

$$R(s'^{T(i+1)}, s^{T_i}) = \begin{cases} R_s & \text{if } s'^{T(i+1)} = I^S, s^{T_i} \in C, a = A_m \\ R_f & \text{if } s'^{T(i+1)} = I^F, s^{T_i} \in C, a = A_m \\ R_w & \text{if } s'^{T(i+1)}, s^{T_i} \in C, a = A_w, i < N \end{cases}$$

### (d) Transition probabilities

Finally, a MDP model includes transition probabilities  $P(s'^{T(i+1)}|a, s^{T_i})$  for each action  $a$  chosen between two states of the process. When the chosen action is to delay the message  $A_w$ , the transition probabilities are the same as those concerning the occupation of the bundle layer at the time  $T_{(i+1)}$ .

To have representative probabilities, each CH saves its local history of the occupation rate in the bundle layer during  $\alpha$  TTL intervals. It then calculates the average percentage of occupation in time for each period of the TTL interval.

When the selected action is that of the sending;  $A_m$ , two probability are possible, either a successful forwarding or a failed one. One complements the other, they are calculated on the basis of the occupation percentage of the bundle layer at the sending time; let the state  $s$ , and the reception efficiency at this same period of time  $E^{T_i}$ . The efficiency is the ratio between the occupation time which was used for the successful reception of a number of messages  $NM^{T_i}$ , with an average size  $Size$  and a flow  $D$ , and the total occupation time of the bundle layer at this same period  $T_i$ , its calculation is given in the equation (21). These two parameters of occupation and efficiency of the bundle layer are weighted, in the sending probabilities with success or failure, by the variable  $\rho \in [0, 1]$ .

$$E^{T_i} = \frac{NM^{T_i} \times \frac{Size}{D}}{\frac{\delta \times s}{100} \times t} \quad (21)$$

$$P(s'^{T(i+1)}|a, s^{T_i}) = \begin{cases} P(s'^{T(i+1)}) & \text{if } s^{T_i}, s'^{T(i+1)} \in C, a = A_w \\ P(s'|a, s^{T_i}) & \text{if } s^{T_i} \in C, s' \in F, a = A_m \\ 0 & \text{if not} \end{cases}$$

where

$$P(I^S|A_m, s^{T_i}) = \rho \frac{\delta \times s}{100} + (1 - \rho) E^{T_i}$$

$$P(I^F|A_m, s^{T_i}) = 1 - P(I^S|A_m, s^{T_i})$$

### 5.3.2 The Problem's Solution

The solution to this problem is an optimal policy  $\pi^*$  of actions for each occupation state of the bundle layer  $S$  and period of time  $T_i$ . A policy  $\pi$  is associated with a matrix  $V(T_i, s)^\pi$ , to save the maximum future gain for all the possible combinations between the period of time  $T_i$  and the occupation state of the bundle layer  $s$  of a CH.

In order to determine  $\pi^*$ , we use the dynamic programming, which consists in making iterations as many as necessary to obtain the convergence of the results, the decisions taken for each combination are fixed and their corresponding final gain can vary only by an insignificant  $v$ . We consider as negligible the convergence time of data because the number of possible combinations is a finite number, in the same way; we consider as important the capacities of a CH processor.

### 5.3.3 Resolution Algorithm

These steps are described in the Algorithm 1, where we initialize, during the *Phase 0*, all decisions of our policy  $\pi(T_i)$  at those of the sending  $A_m$  and all final gains  $V(T_i, s)^\pi$  at 0. We add a premium matrix  $V'(T_i, s)^\pi$  to which we will refer us to verify the convergence of the results.

During the *Phase 1*, we first save the old matrix values of final gains in the premium matrix in order to perform a comparison at the end of the iteration. Then, during the *Phase 1.a*, we calculate the gains  $V_m$  and  $V_w$  for each combination linking the time parameter  $T_i$  and the bundle layer state  $s$ . Both values,  $V_m$  and  $V_w$ , correspond to the gains of the immediate sending action  $A_m$  and that of the adjournment action  $A_w$ , respectively.  $V_m$  is the sum of both probabilities of success and failure for a message sending, each of these probabilities is multiplied by the corresponding reward or cost, and the last gain value obtained for the same combination. The gain  $V_w$  is calculated from the sum of transition probabilities, at the next period of time, to all possible occupation states of the bundle layer; represented

bys', this transition takes place when the CH decides to delay sending its message. The sum of all these probabilities is multiplied by the cost inflicted by our model for each period of adjournment and the previous gain value for the same combination.

We compare in the *Phase 1.b* the gain generated by the two actions, let  $V_m$  and  $V_w$ . We save for each combination the maximum gain in the matrix  $V(T_i, s)^\pi$  and the corresponding decision in the policy  $\pi(T_i)$ . When the difference of gains between two successive iterations is minimal, ie less than  $\nu$ , we stop the iterations and we save the latest version of actions policy, this latter is considered as the optimal policy and marks the end of the *Phase 2*.

A message is sent only when the CH reaches a combination of time and state of occupation of the bundle layer, that has as optimal decision the action of sending  $A_m$ . Otherwise, the CH delays by one, two, or  $N$  periods of time the sending its message, in order to maximize the chances of successfully sending, this provided it does not exceed the lifetime of the information.

**Algorithm 1.** Dynamic programming for resolution of the MDP.

**Data :**  $i \in \{1, \dots, N\}$ ,  $s \in C$   
**Phase 0:**  
 $V(T_i, s)^\pi = \{0\}$ ;  
 $V'(T_i, s)^\pi = \{0\}$ ;  
 $\pi(T_i) = \{A_m\}$ ;  
**Phase 1 :**  
**repeat**  
 $V'(T_i, s)^\pi = V(T_i, s)^\pi$ ;  
**while**( $i < N$ )**do**  
  **while**( $s \in C$ )**do**  
    **Phase 1.a:**  
       $V_m = P(I^S | A_m, s^{T_i}) \times (R_s + V[T_i, I^S]^\pi) +$   
       $P(I^F | A_m, s^{T_i}) \times (R_f + V[T_i, I^F]^\pi)$ ;  
       $V_w = \sum_{s'} P(s'^{T_{i+1}} | A_w, s^{T_i}) \times (R_s + V[T_i, s']^\pi)$ ;  
    **Phase 1.b:**  
    **if**( $V_w < V_m$ )**then**  
       $\pi[T_i] = A_m$ ;  
       $V[T_i, s]^\pi = V_m$ ;  
    **else**  
       $\pi[T_i] = A_w$ ;  
       $V[T_i, s]^\pi = V_w$ ;  
  **until**( $V'(T_i, s)^\pi - V(T_i, s)^\pi < \epsilon$ );  
**Phase 2 :**  
 $\pi(T_i)^* = \pi(T_i)$ ;

## 6. The probability of success to deliver a bundle with specific TTL

The probability of success to deliver a bundle is an important metric for the evaluation of data delivery quality in the DRHT under our approach of the election of the CH.

In this section, we try to determine the relations between the probability of delivery success and the TTL of bundles, which can help us to configure a reasonable TTL in order to improve the probability of delivery success of bundles. To do this, we will initially model the time of inter-contact between the reception of the  $n^{th}$  and the  $(n+1)^{th}$  bundle then we will model the probability of success under the constraint of TTL [30].

### 6.1 Modeling of the inter-contact time

The inter-contact time is a property of the mobility, defined as the time passed between two successive contact windows for a given pair of nodes. This latter can exert a considerable influence on the latency in partially connected networks.

In this paragraph we study the transfer time of a bundle in a DTN network and the distribution of the necessary time before that two nodes may (again) communicate. In other words, it is the time during which two nodes are in mutual vicinity. The duration of contact is the duration from which a contact finishes and the next one starts. Thus, it determines how many times a communication is possible. We use stochastic formulas to calculate the intensity of inter-contact  $\lambda$  and to analyze the duration of inter-contact between two nodes  $n_i$  and  $n_j$ . Consequently, we define the following proposal:

#### 6.1.1 Proposition 1

Let  $\{T_n, n = 1, 2, \dots\}$  be a punctual process with a counting function  $X(t)$ . Then the process  $\{T_n, n = 1, 2, \dots\}$  is a Poisson process with rate  $\lambda$  if and only if:

- (i).  $X(0) = 0$
- (ii). The process  $\{X(t), t > 0\}$  is with independent increments;
- (iii). For any  $0 \leq s < t$ , the random variable  $X(t) - X(s)$  follows a Poisson distribution with parameter  $\lambda(t - s)$ .

Let  $\{T_n, n = 1, 2, \dots\}$  be a Poisson process. By convention we put  $T_0 = 0$  and we assume that the first arrival occurs at  $T_1$ . We define the  $n^{th}$  inter-contact  $\tau_n$  as the duration passed between the  $n^{th}$  and the  $(n+1)^{th}$  contact, let:

$$\tau_n = T_n - T_{n-1}, n = 1, 2, \dots$$

with  $T_0 = 0$

The sequence  $\{T_n, n = 1, 2, \dots\}$  is called the sequence of inter-contact times. Inter-contact time is a very important property that characterizes the Poisson process; we define the following proposal:

#### 6.1.2 Proposition 2

The punctual process  $\{T_n, n = 1, 2, \dots\}$  is a Poisson process with rate  $\lambda$  if and only if random variables  $\tau_n = T_n - T_{n-1}, n = 1, 2, \dots$  are independent and identically distributed according to an exponential law with parameter  $\lambda$ ;  $\lambda$  is the intensity of inter-contact.

We conclude this paragraph by calculating the average duration of inter-contact, which can be given using the following formula:

$$E(\tau_n) = \frac{1}{\lambda} \quad (22)$$

A shorter inter-contact time means that two nodes  $n_i$  and  $n_j$  meet themselves quite often. In other words, if two nodes  $n_i$  and  $n_j$  have a short inter-contact time, this means that we can wait the next contact to send data directly. Thus, the more enormous  $\lambda$  is, the more reduced the average duration of inter-contact per unit time is. The number of these contacts and the distribution of average durations of inter-contact are two main factors in determining the capacity of opportunist networks. They give an overview of data quantity that can be transferred in each contact opportunity.



## 6.2 Probability of successful delivery

We take again the proposals (1) and (2), it is observed that the contact between nodes is distributed exponentially. We use these proposals to model the metrics of performance in the context of the DTN routing system. We use the delivery rate of bundles, the delivery delay and the buffer memory occupation, which are among the principal metrics of performance. Thereby, for a message entering the bundle layer at  $T_n$  time, let  $\tau_n$  be the time of inter-contact between the  $n^{th}$  and the  $(n+1)^{th}$  bundle. The probability that the bundle is delivered before the TTL expires is calculated using the following formula:

$$P_r(T_n \leq t_{TTL}) = 1 - e^{-\lambda t_{TTL}} \quad (23)$$

## 7. Simulation

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

### 7.1 Stimulation tools used

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 thanks to the ONE (Opportunistic Network Environment) simulator [31], which allows generating a classification of the different routing protocols studied using performance metrics.

### 7.2 Simulation procedure

In order to evaluate the DTN routing protocols 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 further analysis, interpretation and therefore to have the outcomes. In this paragraph, we consider the different inputs and outputs that are relevant to assess a DTN routing protocol as well as to provide a simple conceptual model, as the following:

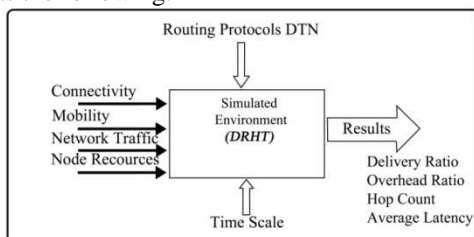


Figure 6. Assessment model of the DRHT.

### 7.3 Metrics performance

In order to compare DTN routing protocols in the simulated environment, several parameters must be tested. These parameters can describe, on the one hand, the inputs data of simulation such as models of nodes mobility, nodes resources, etc, in a surface of simulation where the network is established, and on the other hand, the simulation results (outputs) that are the performance metrics. Among these metrics we can cite [32]:

- **Delivery probability**

It is the total number of messages delivered to the destination under the constraint of TTL compared to the total number of messages created at the source node.

- **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 reflects the cost of transmission in a network). In other words, it is the required number of replications needed to perform a successful delivery. For this purpose, we always look for algorithms that would minimize the value of overhead ratio.

- **Average latency**

It is the time that elapses between the creation of a message and its delivery at its destination.

- **Hop count**

It is the number of nodes through which the message must pass from the source node to the destination node. It helps to understand how messages are delivered from the source until the destination and therefore how network resources have been used. Consequently, the average number of hops informs us on the use of network resources.

### 7.4 Simulation parameters

Table 2 summarizes the simulation settings used to analyze the different DTN routing protocols in the simulated environment.

Table 2. Parameters of simulation

Parameter	Value
Total Simulation Time	12h
World Size	4500 X 3400 m
Routing Protocol	Maxprop, Prophet, Epidemic.
Node Buffer Size	5M
No of Nodes	10, 30, 40, ..., 100
Interface transmit Speed	2 Mbps
Interface Transmit Range	10 meters
Message TTL	60 minutes
NodeMovement 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

## 8. Results and discussion

In the simulated environment, we focused on comparing the performance in terms of the metrics defined in the section 6.3, particularly the following two metrics: the delivery probability and the average duration of inter-contact.

### 8.1 The delivery probability

The successful delivery of bundles is the main task of a DTN routing protocol. Therefore, the probability of successful bundles delivery is the most important parameter when comparing the different DTN routing protocols. This metric characterizes how complete, correct and efficient a routing protocol is. It describes how many bundles were lost, as well as the maximum number of bundles that the network can support.

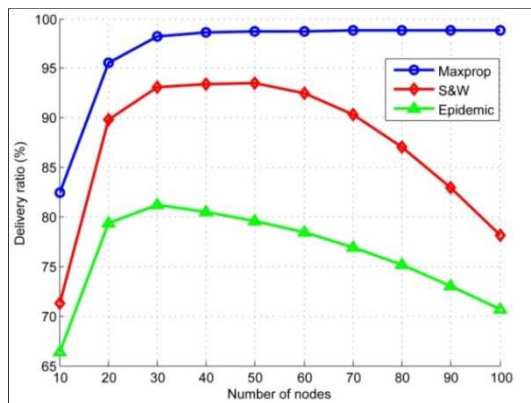


Figure 7. Variation of the delivery probability depending upon the number of nodes.

In figure 7 we show the ratio of delivery of bundles for each protocol by the number of nodes in the network. We noted that for a weak density (equal to 10 nodes) the three DTN protocols gave a low rate of bundles delivered. In fact, since the network's connectivity is weak because the density is weak, protocols do not find any path to reach some destinations, particularly after bundles' TTL expires. For medium density (between 20 and 25 nodes), the three protocols had a high ratio of bundles delivered. This is quite an interesting ratio and is much higher than 90% of sent bundles. However, an observed drop with increasing density follows this ratio's increase. This drop is noticed for every protocol except Maxprop, which keeps a constant ratio for all values of density considered by all scenarios (until 100 nodes). In addition, for Epidemic and Spray and wait protocols, at high density, each node must be able to forward more traffic. This traffic increases the rate of collision, interferes with the data's traffic and therefore increases the loss of bundles. Because of its low traffic of control at high density, Maxprop keeps a constant ratio of delivered bundles. These results, which offer a fairly high delivery rate in the DRHT, can be explained by the use of multiple MF and an optimal CH in each cluster.

## 8.2 Average duration of inter-contact

A shorter average life of contacts corresponds to a more dynamic topology of the network. In fact, great values of  $\lambda$  are reflected in shorter contact and inter-contact times and then an increase in contact opportunities. The bundles can benefit from it and their delivery probability increases when  $\lambda$  grows. Conversely, a very great instability of contacts and a lack of connection between nodes tend the delivery probability of bundles towards 0 because there are less contacts lasting in time.

The figure 8 shows clearly that, for a low density, the average duration of inter-contact of the three protocols is quite large because the distances separating nodes increase. We can also note that the average duration of inter-contact of the protocols decreases when nodes density increases. These results are explained by the increment of nodes average degree. Consequently, the end-to-end time becomes minimal. However, for Epidemic and Spray and Wait protocols with high density, each node is held to generate more traffic of control (overhead). This traffic of control increases the rate of collision and disturbs data traffic, and consequently the average duration of inter-contact increases. Thus, we note that Maxprop protocol remains the most efficient among the three routing protocols studied in terms of average duration

of inter-contact, which will allow it to minimize the delay of delivery between the source and the destination.

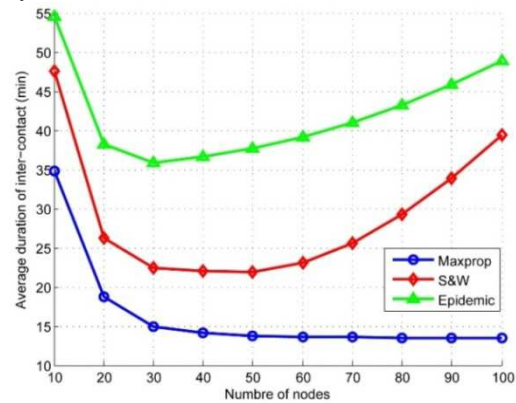


Figure 8. Average duration of inter-contact of different protocols evaluated depending upon the number of nodes.

## 9. Conclusion

In this research paper, we presented a proposition of a DTN hierarchical routing topology based on four fundamental notions: multiple MF, ferry routes, the clustering and the election of a CH. By the superposition of these four notions, we are able to improve the performance of DTN routing in the case of large-scale networks. In fact, the DRHT uses multiple ferry messages to make the whole network connected. Furthermore, the election of a dynamic CH in the DRHT has a major impact on the delivery rate and the delivery delay, by allowing the reduction of network resources. This election is based on specific criteria, among which we retain: the residual energy, the intra-cluster distance, the node degree and the headcount of probable CHs. In order to evaluate the performance of our proposition, we implemented it in the case of the simulator; ONE and we compared its performance with the performance of Maxprop, Spray and Wait and Epidemic protocols. The results show that Maxprop offers excellent performance in terms of the delivery rate and the delivery delay of bundles.

Following this work, we intend to tackle the optimization problem of one of the DTN metrics to optimize network resources by giving the simulation of this latter based on the simulator ONE, which evaluates the routing of networks DTN and validate the proposed model.

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