Position-based Routing in Delay Tolerant Networks

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***Abstract*— Delay Tolerant Networks are networks where there are no permanent end-to-end connections. This type of network has a variable topology, with frequent partitions in the connections. Given the dynamic characteristics of these networks, routing protocols can take advantage of dynamic information, such as the node location, to route messages. Geolocation-based routing protocols choose the node that moves to the location of the message destination as the message carrier. In this work, the HybridDirGreedy geographical protocol was developed, using routing metric based on the node movement direction. In the initial phase, the protocol replicates a limited number of messages in the network and then, in the second phase, it uses the direction of movement of the nodes to route the messages in the known destination direction. In order to obtain the locations of nodes in the network, a localization system was created, called GeoLocation, in which each node in the network maintains a dictionary with the location information, movement direction and, speed of nodes with which it established contact. The performance of HybridDirGreedy has been compared with geographic and non-geographic protocols. A comparative analysis of the geographic protocols was made with an optimal scenario, where the nodes know the exact position of all the nodes in the network, and with a scenario in which the protocols use GeoLocation, knowing only the approximate position. The results show that the HybridDirGreedy protocol has a higher delivery rate and lower latency than the other evaluated protocols.**

Keywords- Intermittent Connectivity, Delay Tolerant Networks, Routing Protocols, Location System, Location-based routing

I. INTRODUCTION

Delay-Tolerant Networks (DTNs) [1] are networks with a variable topology over time, in which there is no permanent path between the source and the destination for data routing. The main particularities of this type of networks are: intermittent connectivity, long and variable delays, and high error rates in data transmission. Due to frequent network partitions, the usual routing protocols, such as Open Shortest Path First (OSPF), cannot find routes resulting in data transmission failures. The Routing in Delay Tolerant Networks, is done through cooperation between the nodes of the network. The Messages are stored in the nodes buffers and transported. When another node with better conditions to find the destination appears, the message is transferred, repeating the process until the destination of the message is eventually found.

One of the challenges of routing in DTNs is the development of routing metrics, that allow choosing the most appropriate node to which the messages are transferred. Since in DTNs, contact opportunities between nodes may be scarce, choosing the node carrying the message is important. The present work is about routing in DTNs based on the node location and navigation information. Due to the dynamic topology of DTNs, it is appropriate to use dynamic network information, such as node's location, in the protocols routing metrics.

The use of routing metrics based on location information requires that the node with the message knows its position, the position of the node with which it communicates, and the localization of the message's destination. Location information related to the nodes in contact can be obtained using the Global Positioning System (GPS) and exchanged during the communication period, but locating the message's destination requires a location system. Existing geographic protocols do have mechanisms to get the location information of the message's destination node. They assume that the network nodes know the exact location of the destination, not considering the associated delays with obtaining the information. And, if the destination is mobile, location information may be outdated due to mobility.

Another issue is that most geographical routing protocols, for DTNs, use their metric information from navigation systems, such as the node's destination or the estimated time to reach the destination. However, if it is common for mobile nodes to have GPS, it is not so common for them to have a navigation system and know their destination on the map, since it would require user action. There are also problems related to the reliability of the information, for instance by not following the route suggested by the navigation system or the route changing during the trip. Therefore, there is a high dependence of its protocols on the navigation system, which can affect its performance.

In this work is developed a location-based routing protocol, HybridDirGreedy, and a system for locating the nodes, GeoLocation. HybridDirGreedy is a hybrid protocol, which uses multiple and single copy protocols mechanisms. The protocol has two operation phases: in the first phase, it disseminates a limited number of copies of the messages in the network and, in the second phase, it makes location-based routing of the created copies of the messages. To obtain the location of the nodes in the network, it uses the GeoLocation system. GeoLocation is a localization system, where each node of the network maintains a dictionary with location information, direction of movement and speed of the network nodes. When

two nodes establish communication, they update their dictionaries through exchange.

The results of the performance evaluation, compared with geographic and non-geographic protocols for DTNs, show that the HybridDirGreedy protocol has a higher delivery rate and lower latency than the other protocols evaluated.

The rest of the paper is organized as follows. Section II describes some related work. Section III presents the proposed localization system for DTNs, GeoLocation. Section V presents the HybridDirGreedy routing protocol and its principles of operation. Section V focuses on the performance evaluation and results discussion of GeoLocation and HybridDirGreedy. Finally, Section VI concludes the study and considers future work.

II. Related Work

There are several routing protocols for DTNs in the literature. Here are presented some of these protocols, which differ in the number of message copies in the network and the type of knowledge used to forward the messages. These protocols are: Greedy-DTN, MoVe, Epidemic, PRoPHET and Spray-and-Wait. The first two routing protocols use a single-copy strategy, meaning there is only one copy of each message on the network. While the remaining protocols use a multi-copy strategy, distributing multiple copies of the messages on the network.

The Motion Vector (MoVe) [2] is a geographic routing protocol, that leverages the knowledge of relative velocities of nodes to estimate the closest distance that they are predicted to get to the destination of the messages, following their current trajectories. The node whose estimated trajectory goes closest to the destination becomes the best forwarding node.

The Greedy-DTN protocol, as referred to in [3], is a geographic routing protocol that forwards the message to the node that is closest to the destination. The protocol is an adaptation, for DTNs, of the geographical routing protocol for Ad-Hoc networks, GPSR [4]. When the network is dense enough for connectivity, the message is forwarded hop-by-hop, to nodes that minimize distance to the destination. When a local maximum occurs, that is, there is no neighboring node, which is closer to the destination, than the node that holds the message, the node carries the message stored in its buffer, until there is a better contact opportunity.

Epidemic [5] is a replication routing protocol, which disseminates an unlimited number of messages on the network, so that one of the copies will eventually find the best path to the destination of the message. Nodes maintain a list, with the ID of messages stored in their buffer, called summary vector. When two nodes establish contact, they exchange their lists, so that each node only receives the messages, which are not yet stored in its buffer. The protocol is simple and fast, but it overloads the network quickly.

Spray-and-Wait [6] is a replication protocol that limits the number of message copies created to a configurable maximum value. The protocol has two distinct phases: the Spray phase and the Wait phase. In the Spray phase, for every message originating at a source node, L message copies are initially spread to L distinct relays. In wait phase, if the destination is not found in the spraying phase, each of the L nodes carrying a message copy will forward the message only to its destination. There are two different versions of the protocol, which differ in how the L copies of the message are spread. The simplest version is Source Spray-and-Wait, in which the source node forwards all L copies to the first L distinct nodes it encounters. The second version is Binary Spray-and-Wait, where any node that has $n > 1$ message copies (source or relay), and encounters another node with no copies, hands over $\lfloor n/2 \rfloor$ copies and keeps $\lceil n/2 \rceil$ copies for itself. When a node is left with only one copy, it switches to the wait phase.

PRoPHET [7] is a probabilistic routing protocol, that replicates message copies based on node's encounter history. The protocol uses the node's contact history to calculate a probabilistic metric called delivery predictability, which indicates how likely it is that a node will be able to deliver a message to the destination. When a contact opportunity occurs, the involved nodes exchange summary vectors, which contains the delivery predictability information stored at the nodes. The received information is used to update the delivery predictability summary vector. A message is replicated to another node if the delivery predictability of the destination of the message is higher at that node.

III. Location-Based System

In this section, we present the GeoLocation localization system. The system was designed for use in geographic routing in Delay Tolerant Networks.

A. GeoLocation Operation Principle

In DTNs, there is no connectivity and communication is made when contact opportunities occur, so the location requests responses can take a long time.

GeoLocation is a decentralized localization system based on operating principles of epidemic algorithms, which disseminate information in the network. Nodes maintain a dictionary with the information of all the nodes with which they meet and exchange it whenever a contact occurs. The set of information, belonging to a given node, consisting of node identification, position coordinates, direction angle of movement, speed and time at which the information was created is called GeoInfo and its structure is in Figure 2.

Nodes use a Global Positioning System (GPS) receiver to get their location and time information. The GeoLocation system obtains the data and uses it to also calculate the speed and nodes' movement direction angle. The direction angle is obtained from the direction coordinates, which is calculated as the difference between two successive coordinates of the nodes' position. The velocity is calculated by the quotient between the displacement of the node between two successive positions and the respective time interval.

Node's ID	Location Coordinates	Angle of the movement direction	Node's speed	Time information was generated

Figure 1 - GeoInfo's structure.

B. Dictionary update

The algorithm of dictionary exchange between nodes is shown in Figure 2. It is considered that all the nodes of the network have the GeoLocation system implemented. First, each node updates its dictionary, so that information is deleted at very advanced ages, because due to the mobility of the nodes, it is too outdated. This saves the data storage space of the nodes, which is a limited resource. The maximum value of the information age is a configurable parameter. Nodes in contact should update their GeoInfo and place it in their dictionary. Then, the nodes exchange their dictionaries. When a node receives its neighbor dictionary, updating its dictionary is done as follows: for each GeoInfo associated with a given node, in the dictionary received, it is verified whether the information is already present in the dictionary. If the information is in its dictionary, it should only update it if the time of acquisition of the information in the dictionary of the neighboring node is more recent. If the information is not present, it adds it to its dictionary.

Algorithm for updating dictionaries

- Delete GeoInfos from dictionary with very old information
- Get current GeoInfo and put in dictionary
- Send my dictionary to neighbor node
- Receive the neighbor's Dictionary
- For each node ***i*** in the neighbor's dictionary whose ID is different from my ID
    - If ***i*** is in my dictionary
        - If neighbor's information is more recent, update ***i***
    - Else
        - Add ***i*** to my dictionary

Figure 2 - Algorithm for exchanging dictionaries between nodes when a contact occurs.

IV. HYBRIDIRGREEDY ROUTING PROTOCOL

HybridDirGreedy is a geographic routing protocol for Delay Tolerant Networks that uses the routing strategy of multiple copy protocols and single copy protocols. The HybridDirGreedy protocol employs the Spray phase concept of the Binary Spray-and-Wait protocol, in which a predetermined quantity of copies of the message is disseminated in the network. According to the authors in [6], the binary version of the Spray-And-Wait algorithm is the one with the best mechanism to minimize the time of distribution of the copies of the messages in the Spray phase. However, in the second phase of operation, instead of waiting to find the messages destination, as done in Spray-and-Wait, it forwards the message to a node that moves towards the destination of the message.

A. Protocol principle of Operation

The HybridDirGreedy protocol has two phases of operation:

1st stage - Spray)

In the Spray phase, the node source of the message places the maximum number of copies of the message in the message header. The number of copies of the message determines the maximum number of times the message can be replicated. Any node that has more than one copy of the message and finds another node that has no copies, delivers half the copies to it and has half to itself. If the message is not delivered in this first phase and the node is left with only one copy, it changes to the second phase of the protocol.

2nd phase - Search)

In the second phase, nodes that have only one copy of the message, route it geographically to the destination node. To do this, whenever they establish contact with a neighboring node, they must evaluate if it is going in a direction closer to the destination than itself. If so, they transfer the message to that neighbor. Since the nodes are in contact, they are relatively close, since the DTN network is sparse, it will be preferable to forward the message to the node that is going further towards the destination. If both nodes have the same angle of the direction of movement relative to the destination, the node, which minimizes the distance to the destination, is selected to stay with the message. It was preferred to be greedy in order to take advantage of the multi-hop communication opportunities if they exist, which are expected to have lower latency, than the message is simply carried by the node.

B. Direction of movement calculation

In calculating the nodes movement direction angle relative to the destination, it is considered the location of the node, its movement direction, and the location of the destination. Given the Node **X's** movement direction vector $\vec{v}_X$, and the vector $\overrightarrow{XD}$ *originating from the node* **X** to the known location of the target **D**, the direction of the movement angle of **X** relative to **D** is

$$\theta = \cos^{-1}\left(\frac{\overrightarrow{XD}.\overrightarrow{v_X}}{|\overrightarrow{XD}||\vec{v}|_X}\right) \quad (1)$$

C. Protocol Algorithm

The protocol algorithm is in Figure 3 , it describes the sequence of actions that the protocol performs always when contact is established between two nodes. It is considered, to exemplify, that a given node **X** initiates a contact with a neighboring node **Y**.

The node **X** and **Y** begin to exchange the respective location dictionaries. Then, node X accesses its list of stored messages and verifies if there is any message whose destination is the node **Y** to be delivered. The next phase (Spray) is to verify the messages stored with the number of copies greater than one, to be replicated to the node **Y**. Node **X** updates the copy number property in the message header to half the present value and creates a copy to deliver to node **Y**. Finally, in the Search phase, it verifies the remaining messages with number of copies equal to one, to evaluate if **Y** is a better carrier of the message. The

node **X** calculates its movement direction angle and its distance relatively to the message destination. Next, the node **X** performs the same calculations for the node **Y**. The message must be delivered to the node **Y** if its movement direction angle relative to the destination is less than the angle of the node **X**. If a situation occurs where nodes have equal angles, the message is only delivered to node **Y** if its distance from the destination is less than that of node **X**. Messages forwarded to the node **Y** must be cleared from the node **X's** buffer, when it receives confirmation that the delivery of the message was successful.

HybridDirGreedy's protocol Algorithm

- **X** establishes communication with **Y**

/** GeoLocation dictionary exchange between **X** and **Y **/**

- **X** Updates its GeoInfo in the dictionary with its current data and sends to **Y** its GeoLocation dictionary
- **X** Receives GeoLocation dictionary and updates its dictionary with the latest received information

/** Delivery of messages whose destination is **Y **/**

- For each message stored in **X**'s buffer and destined for **Y**
  - **X** delivers to **Y** and deletes it from its buffer

/** Replication/forwarding of remaining messages **/

- For each message ***i*** in **X**'s buffer
  - If ***i***'s number of copies (**L**)> 1
    - **X** delivers to **Y L/2** copies of ***i***
  - Else
    - **X** accesses its Geolocation dictionary to get its GeoInfo, **Y**'s GeoInfo and destination node's GeoInfo.
    - if destination GeoInfo is in the dictionary
      - **X** calculates its distance and the angle of the direction of its movement relative to ***i's*** destination
      - **X** calculates **Y**'s distance and the angle of the direction of **Y**'s movement relative to **i**'s destination
      -
      - if **Y**'s angle is smaller than **X**'s angle
        - **X** delivers ***i*** to **Y** and deletes it from its buffer
      - else
        - if **X**'s angle is equal to **Y**'s angle and **Y**'s calculated distance is smaller than **X**'s distance
          - **X** delivers ***i*** to **Y** and deletes it from its buffer
    - else **X** keeps ***i*** in its buffer and moves on to the next message

Figure 3 - HybridDirGreedy algorithm when contact occurs between node X and Y.

V. PERFORMANCE EVALUATION

In this section, it is presented the scenarios and the results of the simulations, for the GeoLocation and for the routing protocols. The simulations were done in the ONE (Opportunistic Network Environment)[8] simulator.

The map of the city of Helsinki, with dimensions of 4.5 km and 3.4 km, was used.

A. GeoLocation

A set of simulations was made to analyze the error associated with the data in the nodes dictionaries. The aim is to evaluate the speed of information acquisition, the age of the present information in the nodes dictionary, the position error, the relative speed error, and the direction of movement error. For each metric evaluated, it was calculated the average value with the data collected from all the nodes present in the simulation. Samples were collected at 15-minute intervals over 15000 seconds (4 h).

1) Performance metrics

The dictionary size, as a function of time, is the amount of GeoInfos in the node's dictionary, it allows to know how the information propagates in the network. The age of information allows us to know how long ago the information was created and how outdated it is. It is about the difference between the current time and the time when the information was generated, given in seconds. The position error is the distance between the position in the dictionary and the actual position of the node, which is given in meters. The speed's relative error is given in percent, and allows analyzing the error associated with speed information present in the dictionaries. The direction error, in degrees, is the module of the difference between the actual value of the node's angle direction and the direction angle value in the dictionary of a given node.

In the GeoLocation evaluation, there were considered three scenarios with different node densities: with 50 nodes, with 150 nodes and with 300 nodes. The nodes speed movement varies in the interval from 2.7 $m.s^{-1}$ to 3.9 $m.s^{-1}$. The movement model is SPMBM (Shortest Path Map-Based Movement), present in the ONE simulator, nodes randomly choose a destination and move to the location by the shortest path.

2) Results

In Figure 4, is presented the results of the average dictionaries size as a function of time. In the three scenarios, at 900s, the nodes dictionaries are almost filled with information about the nodes of the network. The information diffusion is fast and, after 15 minutes, the nodes have location information of all the other nodes of the network in their dictionaries. The high speed of the vehicles increases the frequency of contact between the nodes in the network, which increases the information diffusion speed in the network.

In Figure 5 are the results for the average age of the information present in the nodes dictionaries. Comparing the graphs, it is verified that the information is more outdated in scenarios of lower node density. The node dictionary is updated whenever contact occurs between two nodes. In low-density nodes environments, contact opportunities are rarer than in denser nodes environments, so information in the dictionary is not updated as often as in low density network.

Observing Figure 6, Figure 7 and Figure 8, respectively corresponding to the average location error, the average relative error of speed and the average error of direction of movement, it is found that the average error is lower in the higher density scenarios. Given that, in denser scenarios the information is more recent than in less dense scenarios, where the information has less error. The average error of the angle of the movement direction has more variations, because the nodes move based on a road map in an urban scenario, reason they frequently change direction in the intersections.

The information in the dictionaries has low accuracy. As an example, in Figure 5, the scenario with 300 nodes has 850m position error, for information with an average age of 5 minutes. This will have effects on the routing protocols, which can be very significant, if they are based on very outdated information.

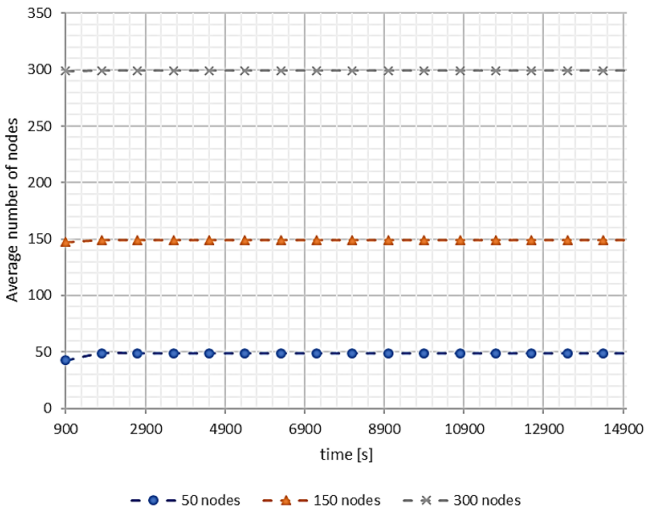

Figure 4- Average dictionary size.

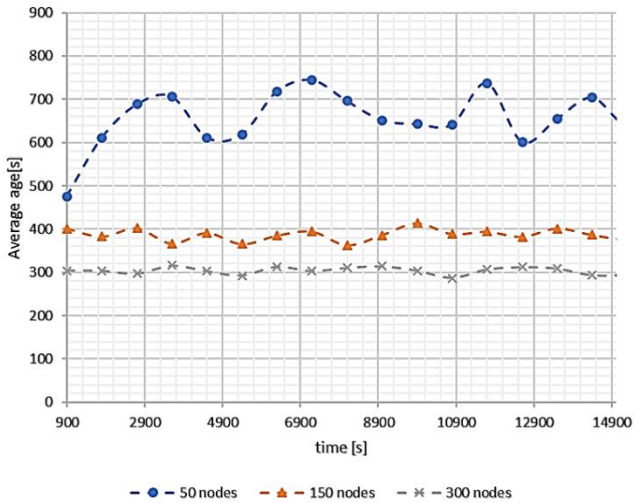

Figure 5- Average age of information, in seconds.

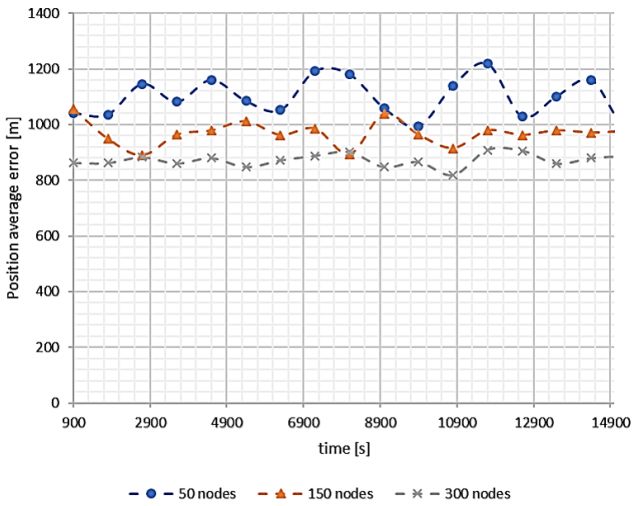

Figure 6- Average error of position, in meters.

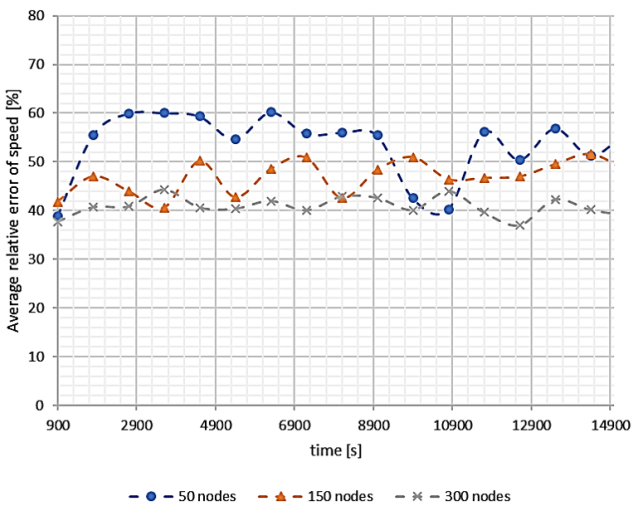

Figure 7- Average relative error of speed, in percent.

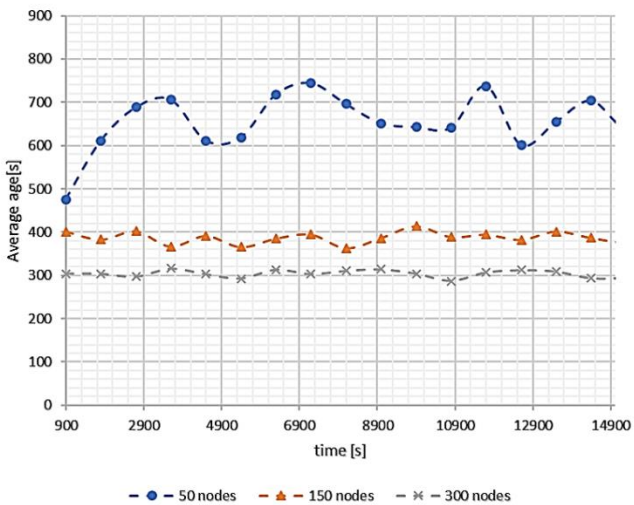

Figure 8- Average error of direction of movement, in degrees.

B. Routing Protocols

This section describes the simulation scenarios and the evaluation of the routing protocols.

The evaluation of the HybridDirGreedy protocol was done with three replication protocols, implemented in the ONE simulator, which do not use geographic information such as routing metric and two geographic protocols. The protocols are: Epidemic, PRoPHET, Spray-and-Wait, MoVe, and Greedy-DTN. The results will be presented first in the optimal environment, where the nodes have exact knowledge of the position of all the nodes in the network. Then, it is presented the results of a real scenario, where the nodes, not knowing where exactly the message destinations are, use the GeoLocation system to have the latest known location.

1) Simulation setup and Performance metrics

The simulation takes place during the period of 12h, in a scenario with a total of 150 nodes, of which 105 are cars and 45 are public vehicles. The cars have a buffer size of 20MB and move on roads, according to the SPMBM model. The speed of movement of the cars varies between 10 $km.h^{-1}$ and $50km.h^{-1}$, with pauses in the range of 0s to 120s. The public vehicles have a buffer size of 50 MB and moves on pre-programmed routes, according to the RMBM (Route Map Based Movement) movement model. Its speed of movement varies in the interval between $25km.h^{-1}$ to $36km.h^{-1}$, with pause intervals in the range of 10s to 30s. The wireless communication interface of the nodes has a range of 30m and a transmission rate of 4.5Mbs^{-1}. The nodes randomly generate messages for a random destination node, with an interval ranging between 25s to 35s. The size of the generated messages range between 500kB and 1MB. All the intervals are randomly distributed variables with uniform distribution.

The parameters of the PRoPHET protocol (P_{init}, β e γ) are according to the proposed in [15]. Spray-and-Wait and HybridDirGreedy use the binary scheme with the number of copies equal to six. It was chosen to limit message replication to a maximum of six copies to avoid overloading the network. The buffer management policy used by the routing algorithms is the First In, First Out (FIFO), which is implemented in the simulator. Thus, the first messages to be discarded when buffer congestion occurs are the oldest messages.

The simulations were done by varying the value of TTL (Time to Live) parameter of the messages, to vary the load on the network. The TTL determines the period of validity of a message in the network, that is, when the set value ends, the message is deleted from the node's buffer. The values chosen for the TTL were: 60 minutes, 120 minutes, 180 minutes, 240 minutes, and 300 minutes. The metrics used to evaluate the protocols were: Delivery Ratio, Average Delay, Overhead and Average number of hops. Each simulation was executed 8 times using different random seeds. The presented results are the average values of the performance evaluation metrics and the respective 95% confidence intervals.

2) Results

Figure 9 a) shows the graphics related to the average message delivery rate. The HybridDirGreedy protocol has the highest average delivery rate for the various TTL values. The second protocol with the highest average delivery rate is the Spray-and-Wait protocol. The two protocols have an equal dissemination phase, in which they place multiple copies of the messages circulating in the network, increasing the probability that eventually one of these copies will find the destination of the message. However, in the second phase of operation Spray-and-Wait waits until it finds the destination to deliver the message, while HybridDirGreedy forwards the copies of the messages to the nodes that are moving towards the destination. The delivery rate of the Greedy-DTN and MoVe routing protocols grow with the increase of the messages TTL. Since these are protocols where there is only a single copy of each message in the network, with more time to deliver the messages, the right path to the destination is more likely to be found. The Epidemic and PRoPHET protocols have different behavior from the remaining protocols with the TTL variation. In this case, the number of copies circulating in the network is unlimited, so increasing TTL results in increased congestion and increased message dumping, which results in a lower delivery rate. In Figure 9 b) it is observed that the average message delivery rate of the HybridDirGreedy protocol, when using GeoLocation differs from its average delivery rate in an optimal scenario, only for the 60 minutes of TTL, remaining practically the same for the remaining TTL values. As for the MoVe and Greedy-DTN protocols, the difference between the average delivery rates in the optimal scenario and the scenario using GeoLocation are more significant. For example, for the 60-minute TTL, the difference in the MoVe average delivery rate is equal to 24.4%. HybridDirGreedy distributes a limited number of copies of the messages in the network and then forwards the copies using geographic routing metrics, while MoVe retains only one copy of the message circulating on the network. GeoLocation is a decentralized location server, so the information present in the node dictionary and associated errors are not the same. Therefore, the various copies of the messages circulating in the network are subject to different circumstances imposed by GeoLocation.

In Figure 9 c), there are the graphics referring to the latency in the delivery of the messages. In general, with the increase of the TTL there is an increase in the latency of the protocols, due to the increase of congestion in the network. Single-copy protocols, Greedy-DTN and MoVe, have higher latency than replication protocols. Because replication protocols distribute multiple copies of messages on the network, it is more likely that one of these copies will reach the destination by a fast route. It is possible to verify that HybridDirGreedy is the protocol with the lowest latency, which is due to its hybrid nature. Its Spray phase allows to distribute a limited number of copies of the message to explore different paths and its Search phase routes the messages towards the destination.

In Figure 9 d), there are graphics referring to the latency in the scenario using GeoLocation. The three geographic routing protocols have higher latency when using GeoLocation. The Inaccurate node location information causes more latency in message delivery. In the optimal scenario, the metrics are calculated by always considering the current position, so the message is being transported towards the destination. In the scenario using GeoLocation, the message suffers more deviations when it is transported to outdated positions.

Observing Figure 9 f), it is verified that the replication protocols are those that have higher overhead, except for Spray-and-Wait. The Spray-and-Wait only generates 6 copies of each message in the Spray phase. When entering the Wait phase, the number of transmissions is very close to this value. Epidemic and PRoPHET generate unlimited copies, resulting in higher overheads. The geographic protocols have a Greedy behavior, so they always transmit to any node that is closer to the destination, increasing the number of transmissions. In Figure 9 g) it is observed that the overhead of geographic routing protocols increases when using GeoLocation. Since the protocols have higher latency, messages circulate for longer period on the network, causing more transmissions.

VI. Conclusions and Future Work

This paper proposed a geographic routing protocol called HybriDirGreedy and a location system called GeoLocation for routing in DTNs. HybridDirGreedy makes routing decisions based on geographical location information and moving direction of nodes. The GeoLocation provides the information of nodes location used by the protocol.

The results showed HybridDirGreedy is the protocol that performs best among the evaluated protocols. The protocol has the highest average delivery rate and the lowest average latency, in the optimal scenario and in the scenario using GeoLocation.

The hybrid strategy used by the protocol allows it to get good results. HybridDirGreedy performs better than single-copy geographic routing protocols, because in the first phase (Spray) it does controlled replication of messages. Consequently, there are several copies of a message circulating in the network, exploring different ways to find the destination. This has the effect of increasing the likelihood of finding the destination. In the second phase (Search), the forwarding of copies of a message to the nodes that moves toward the destination, improves its latency compared to replication protocols.

Furthermore, the comparative analysis of the performance of the geographical routing protocols, between the optimal scenario and the scenario using GeoLocation, showed that the inaccuracy of the GeoLocation information has more impact on the single-copy geographic protocols. As each node in the network maintains its own GeoLocation dictionary, the information present in each dictionary and the associated errors

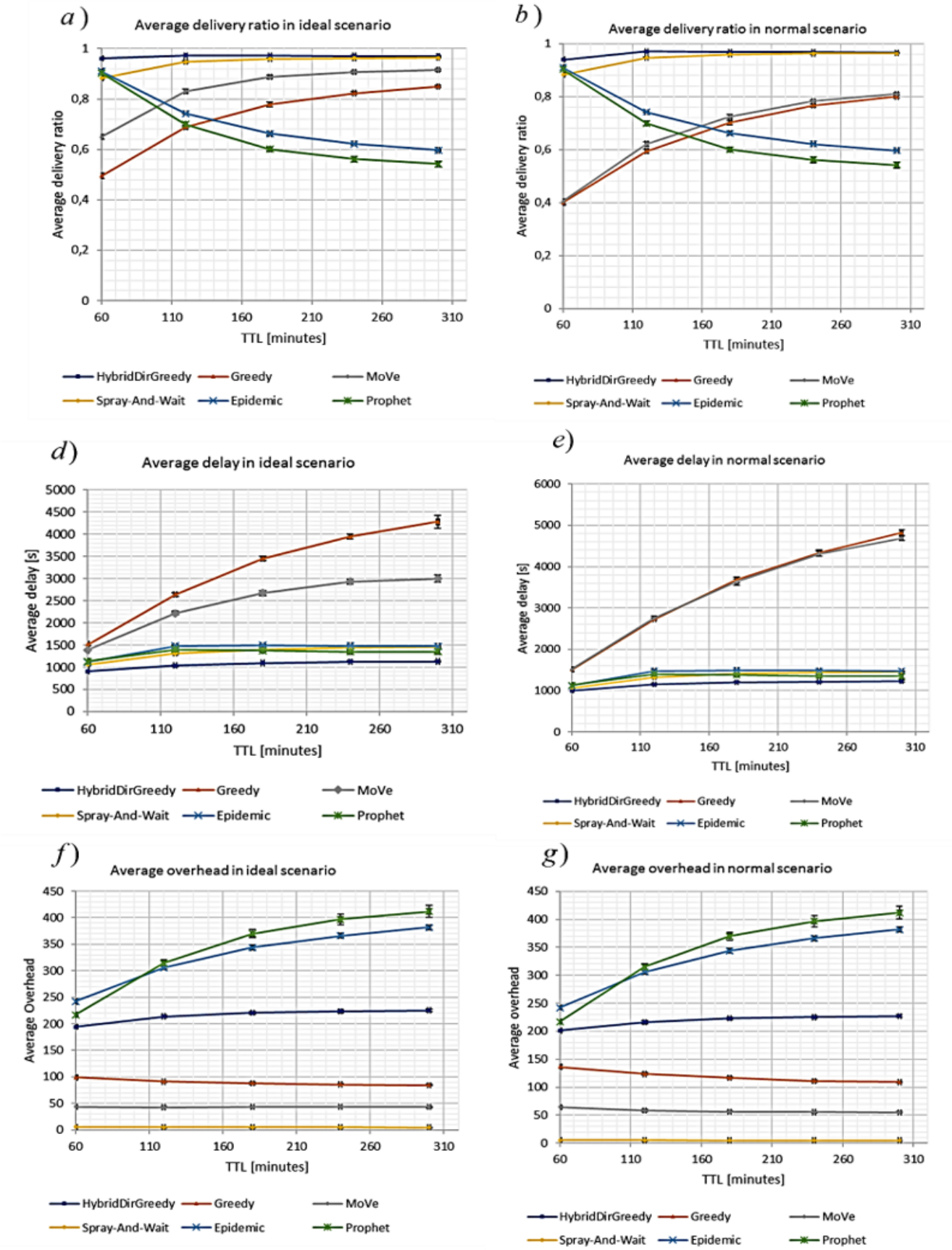

Figure 9 - Results of the simulations in an ideal scenario and in a real scenario.

are not the same. The only time it is the same is when there is a contact between two nodes and they update their dictionaries. Therefore, the various copies of the messages circulating in the network are subject to different contexts.

As for future work, further studies of the performance of the protocol in other scenarios (different node densities, nodes speed and other city map) will be conducted to study the scalability of the protocol and the location system under different scenarios. Also, the integration of GeoLocation with maps will improve the quality of information provided. The accuracy of the position coordinates estimation will be improved, since GPS only allows estimating the current position if the speed and direction of movement do not change.

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