Intermittent connection effect in the Message Ferry Delay Tolerant Network

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Abstract. Delay Tolerant Networks (DTN) give a base of communication that permits the delivery of data within harsh environments or even between networks without interconnection. The connection between networks happens when some nodes cross between them and carry information. Our model consists of the Message Ferry Mobility Model (MFMM) where all nodes in the network are confined to their village except one mobile node (the message ferry). In order to reduce the energy consumption the wireless interface is not always on. We aim to study how much does the on/off state of the wireless interface reduces the total connection time available in the MFMM. To answer this question, we created a simulator that uses the MFMM. The simulator generated mobility traces of all nodes and measured the contact time under different patterns of the on/off cycle. As expected the contact time are longer when the interface is active more often. However we found an unanticipated reduction in contact time vs active wireless interface ratio. Hence, we concluded that in the MFMM, the on/off duty-cycle of the wireless interface influences the total contact times.

Keywords: Delay Tolerant Network, DTN, mobility model, Message Ferry, metrics, wireless interface

1 Introduction

Places difficult to access in developing countries, harsh environments, space, wildlife watch, natural disaster zones are cases where full linked networks may not be feasible. In particular, connection between mobile equipment, or even internet access may not be possible all the time. Delay Tolerant Networks (DTN) approach this problem by giving the bases of communication to deliver messages or data even when there isn't a direct communication between source and destination. This is done through moving middle nodes that facilitate this contact, thus allowing the inter-exchange of data.

1.1 DTN

Wireless networks are getting more and more popular, allowing the carrier of a mobile device the capacity to connect from multiple places to the Internet. However, hot spots are not available everywhere. Even in if a hotspot is present, access to the information required may be delayed due to, e.g. the volume of users, short fails, small delay or low error rate. These problems belong to the "well behaved" cases when compared to the scenarios approached by Delay/Disruption Tolerant Networks (DTN). In DTN there isn't always end-to-end connection in real time, that can be caused by nodes mobility or short radio range, physical obstacles, scarce resources, etc [1]. There are limitations that the standard TCP/IP protocol won't be able to work with caused by special requirements such as: harsh environment, remote locations, frequent connection fail, long delay [2]. On the other hand, there could be limitations to the resources like: size, radio capacity, small memory, low bandwidth, low processing, millions of nodes, small batteries [2]. They can use exotic methods of communication, be military networks on hostile environment or war, environmental limitations, intentional interference, security [2]. These networks can still be influenced by delay, communication errors, security and confidence, reliability, etc [2].

DTN solve this kind of problems using a message exchange technique [3]: each node stores-and-forwards the messages he collects. In this way there is no need to have an end-to-end connection, since consecutive point-to-point connections will suffice. The creation of the bundle concept, the unit of transmission, and the inherent protocol were initially defined in 2 RFCs from 2007, RFC 4838 [4] and RFC 5050 [5]. The protocol describes a way to transfer custody of a message, priority, state report and security, among other information. There was also initially created a standard for the representation of numbers: the Self-Delimiting Numeric Values (SDNV) [6] that are able to represent huge numbers.

The radio wireless interface is the main mean of transmission in DTN, although other means of communication are supported. This resource spends energy essential to the mobile device, so all processes that can reduce the consumption of battery are important. The deactivation of this module can save much energy at the cost of making communication impossible for that period of time. Our motivation is the study of the implications of this temporary deactivation in the data transmission. The simulation is an easy way to explore scenarios and patterns of mobility for wildlife, people or vehicles, gathering the needed data and metrics.

1.2 Mobility models and metrics

Mobility models are simplified representations of reality that describe the pattern of movement of a known group. These models can always be empirical models of mobility.

There are innumerous mobility models ([7], [8]) so we choose to use one model that represents the principle of DTN, the Message Ferry Mobility Model (MFMM) also known as Mule Mobility Model [9]. There are many variations of this model but the basic one has some areas (villages) were the units ("villagers") move around based on the Random Waypoint Model [10]. The "villagers" never enter in contact with other villages. There is one other unit that moves between villages and enters in contact with the locals exchanging with them the messages received earlier. Then he sets of to the next village carrying the messages received. This is why he is also called the "Mule".

This scenario is frequently used in sensor networks to recover data and remote villages like in the projects RuralKiosk[11] and Wizzy Digital Courier [12].

1.3 Objectives:

The aim of this study is to discover how much does the on/off state of the wireless interface reduces the total connection time available in the Message Ferry Mobility Model. To this end it was created a simulator, patterns of duty-cycle to the wireless interface and a wireless interface component to evaluate the contact time metric and total contact time with the generated traces of units.

In the next section we describe the methodology used, followed by the results obtained. The discussion and the conclusions end this document.

2 Methodology

With the reduction of active wireless interface time it is expected to reduce the time of contact between the units. From the many metrics available to analyze the impact of the patterns created we chose the metric total contact time. This metric is the sum of all the contact times between units and should only sum the contact time between A and B and not accumulate both times. This is the time the units have to transfer data so it is an important measure.

The patterns' usage are based in an automatic on/off state of a wireless interface so they were thought for the 1/3, 2/3 and 1/6 spare of battery time. The first pattern (duty-cycle) is the base of comparison ("always on") (a), 180s off followed by 120s on (b), 180s off followed by 60s (c) on, 360s off followed by 120s on (d), 360s off followed by 60s on (e), and random (f).

For these duty-cycles, all units are on or off at the same time and for the last one (f) each unit uses a uniform distribution function to calculate the on/off times with a maximum of 10% of the simulation time for each phase.

Before initiating the collection of data it was necessary to determine the simulation area and the total simulation time. Usually researchers choose areas of simulation close to squares of 1000m [13-16] and some hours for the simulation time. In this case we choose 3600s of simulation time [17].

The number of units to use in each simulation is suggested to be in the order of 40 units [16,18]. This value permits almost the coverage of all simulation area making most units interconnected with each other all the time. Since this is not one of the characteristics of the DTN networks we defined a 10 unit limit so 1/3 of all simulation space could be covered at max.

Since the number of possibilities increase at each parameter to control, we set the maximum speed of the village units to be 10% of the message ferry unit. The speed function is calculated using the speed and direction defined by the model.

The coverage area of each antenna was set to 100m and after this range there is no contact. It isn't considered the possibility of better signal and better transfer rates at closer range.

The units are initially placed randomly inside their village area and the ferry starts from the center of one village.

Random numbers are generated using the uniform distribution.

The mobility model chosen (Message Ferry Mobility Model) was initialized with 3 villages with 3 inhabitants each.

Two scenarios were created: one scenario with the message ferry unit circulating at a maximum speed of 20m/s; and a second scenario where the unit is set to a maximum speed of 30m/s (close to a car speed limit). This way the units in the villages will be at a speed of 2m/s or 3m/s which is closely the walking speed.

3 Results

The platform developed was based in the client-server architecture and presents a page for the user to choose the parameters for the simulation and to receive the generated results. There are parameters for: speed; size of simulation area; mobility model to process; number of units; time of simulation; etc. (see Fig. 1). the browser should support the Adobe SVG plugin for the movement to be generated.

The platform was created in PHP and all the processes are executed in parallel. It supports batch executions for long simulations with different parameters.

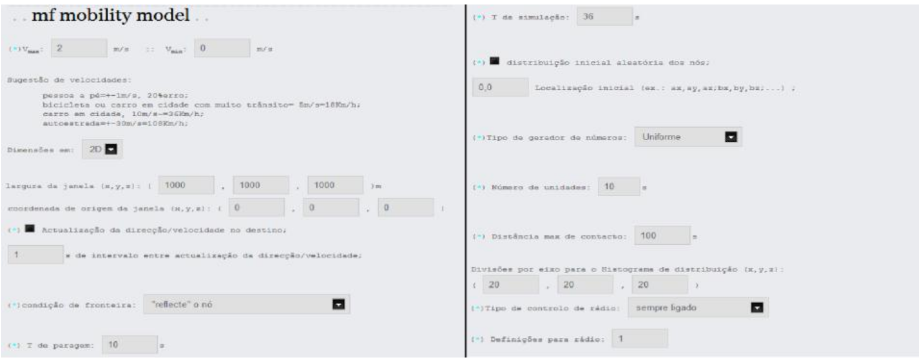

Fig. 1. Window of parameters from the simulator (snapshot).

Figure 2 presents the class model of the created platform. The main class creates an area of simulation with the defined parameters, sets the clock of simulation and creates one or more Mobility Units (MU), its attributes and associated to this MU the chosen mobility model and radio pattern. Then it starts by calling the method *proxposicao* from class *modelo* in each MU to create the movement for each unit until the simulator time expires. Each MU can be a process executing in parallel.

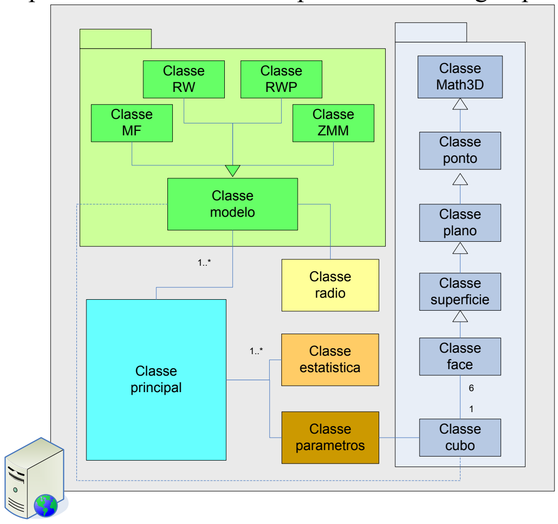

Fig. 2. Class Diagram for the simulator prototype.

After the creation of the traces, the main class launches processes to get the statistics needed. This task may take a long time. In the following figure (Fig. 3) we present 2 histograms of positions taken from the 100 simulations of data generated.

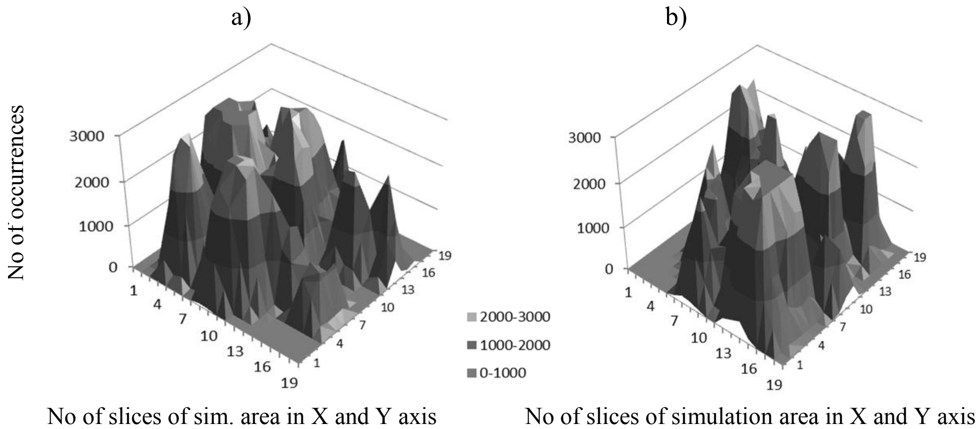

Fig. 3. Histogram showing the 100 simulations for the message Ferry model with the MF moving at 20m/s (a) and at 30m/s (b) in an 1s interval (scenario 1).

In the following picture (Fig. 4) there is a snapshot of the application showing a 360s of one of the simulations. We can see clearly the 3 villages and some occupants moving around. This is a typical movement in the message ferry model.

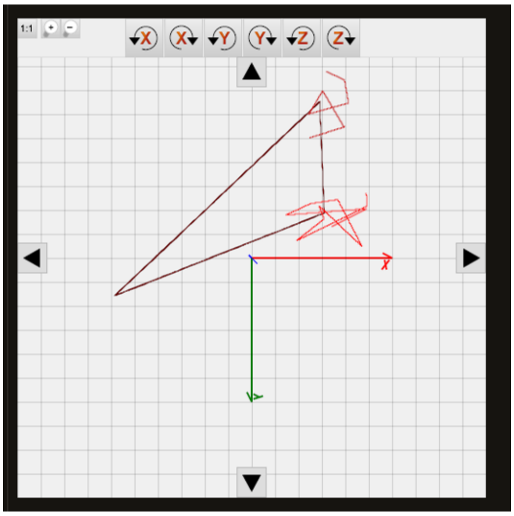

Fig. 4. Simulator showing a typical 360s movement of the Message Ferry Model.

The following table (Table 1) contains the contact time and intercontact time that is, the time between contacts for the simulations. Each column subdivides in the 2 scenarios created. It indicates the minimum and maximum for the 100 simulations, the sum, average and standard deviation. This table indicates that in average, the contact time between units in MF 20/2 is approximately 2min. this is the time available to transmit data between mobile units. If we change to the MF 30/3 there is a slight reduction in the average time.

Table 1. Contact time and intercontact time for the 2 scenarios with some statistical values.

	Contact time (seconds)		Time without contact (seconds)	
Vmax (m/s) of MF and village units	**20 and 2**	**30 and 3**	**20 and 2**	**30 and 2**
Minimum	1	1	1	1
Maximum:	1691	1758	3581	3083
Sum	293398	333746	421265	507667
Average	128,01	104,04	210,32	163,98
Standard deviation	175,00	144,40	322,66	287,03

The next two tables (Table 2 and 3) indicate the deviation of the contact time if we apply the duty-cycles on the wireless interface. The parameters from the previous table were maintained.

Table 2. The contact time (in seconds) for various automatic patterns applied to the wireless interface (scenario 1).

	Always on (a)	**180s off 120s on (b)**	**180s off 60s on (c)**	**360s off 120s on (d)**	**360 off 60 on (e)**	**random (f)**
Minimum	1	1	1	1	1	1
Maximum	1691,0	121	61,0	121,0	61,0	281
Average	133,8	59,73	38,5	55,8	36,8	45,98
Sum	293398	151354	62329	62266	29154	45581
No of contacts	2292	2567	1636	1135	805	998
Standard deviation	170,6	41,51	20,7	39,5	20,3	46,77

Table 3. The contact time (in seconds) for various automatic patterns applied to the wireless interface (scenario 2).

	Always on (a)	**180s off 120s on (b)**	**180s off 60s on (c)**	**360s off 120s on (d)**	**360 off 60 on (e)**	**random (f)**
Minimum	1	1	1	1	1	1
Maximum	1758,0	121	61,0	121,0	61,0	284
Average	109,9	53,53	35,7	50,8	35,9	41,87
Sum	333746	171412	70866	71085	33553	47214
No of contacts	3208	3292	2015	1448	950	1165
Standard deviation	140,0	39,24	20,5	37,6	20,0	40,42

The next table (Table 4) resumes the last ones indicating the loss of total contact time in percentage for each scenario. The pattern is indicated on top.

Table 4. Percentage of lost contact time.

	180s off 120s on. (b)	**180s off 60s on (c)**	**360s off 120s on (d)**	**360s off 60s on (e)**	**Random (f)**
Ratio	**2/3**	**1/3**	**1/3**	**1/6**	~1/2
MF 30m/s and villagers at 3m/s	**48,64%**	**78,77%**	**78,70%**	**89,95%**	**85,85%**
MF 20m/s and villagers at 2m/s	**48,41%**	**78,76%**	**78,78%**	**90,06%**	**84,46%**

4 Discussion

The mobility model chosen has a big concentration of units in specific zones, called villages. We can see on Fig. 4 the typical example of this situation and in Fig. 3 the over-position of all simulations.

The histogram shows both zones with high density with abrupt reductions and zones clearly empty near the borders. In this case there is a great possibility of having long life contacts.

This model doesn't have border issues (units don't try to leave the simulation area) since the units are limited to their zone of activity and the Random Waypoint (RWP) and message ferry don't permit this action.

4.1 Patterns (duty-cycle) on/off

To the 100 simulations in the Message Ferry Mobility Model (MF) it is clear that there is a reduction of contact time when we reduce the active time of the wireless interface. For 2/3 of reduction of active time the loss is close to 50% and to a reduction of 1/3 the loss is close to 80%.

The size of the contact time block is close to the average which suggests that the speeds don't have interference in the size of these blocks.

The slow movement of the units in the village may justify why the maximum time connected is the same as the active state. This slow movement may justify why the average is always bigger in scenario 1.

Looking to the number of contacts these are always higher in scenario 2. The speed makes the units move faster, making them break contact more often but increases the likelihood of having a contact. This is a very important factor to the DTN networks because it increases the possibility of delivering the messages since it is more likely to contact with everyone in the network.

The total contact time is always higher in scenario 2 so this may have some relation with the number of contacts. The speed may reduce the average contact time but the possibility of another contact adds more time to the total time and optimizes the usage of the active time.

The patterns (c) and (d) in Table 2 and 3 are both 1/3 of the time active, but the active time is the double from the first to the second. The objective was to see if there was a significant difference between active times with the same ratio. Clearly all the values from Tables 2 and 3 are closely the same with the exception of the number of contacts. This metric is always inferior in the case of (d) but almost half in the scenario 2. It seems that the speed greatly affects this pattern so it would be better to use short active times than long ones.

For the random pattern only the maximum contact window is greater than any other statistical value. All the patterns make the interface active at the same time so all the units in the vicinity can be contacted during the active phase. In the case of the random pattern, one unit may have their interface active but the other unit passing by may not. This behavior seems to clearly reduce the performance of the pattern.

In Table 4 the values are very close so there is no clear best result from the data collected. From the results obtained it seems that the random pattern isn't the right choice for this mobile model. The best values were collected by the 2/3 pattern although they presented a 48% loss in contact time.

4.2 Simulation platform

The created platform permits the easy inclusion of new mobility models by just extending the class *modelo* and the implementation of the function *proxposicao*. This function is called at each simulation unit of time.

Each simulation has only one parameter changed so it was a good way to obtain the greatest number of statistics in the same computational time. This has the drawback of not being possible to analyze the interactions between parameters. The choice of 2 speeds allowed to reducing the number of simulations to 100 in a short period of time.

The wireless interface was created independently of the mobility model class to permit the abstraction of all models. This has 2 advantages: the movement was created to each simulation and afterwards all the patterns were applied to the same movement without the need to repeat the simulation; and in the generation of the statistics it is possible to query the state of the interface at a given time.

5 Conclusions

The work developed allowed the creation of a simulation prototype to which it can be added any mobility model and calculate the metrics shown with the added option of choosing the duty-cycle of the radio interface.

We can conclude from the data collected that there is a big influence of the patterns used on the total contact time in the mobility model chosen. The random pattern isn't a good choice but the 2/3 pattern reduces the total contact time to roughly 50% but it may allow significantly energy savings in every mobile unit of this model.

5.1 Limitations

The study limits the range of the wireless interface abruptly and for now it does not include obstacles or models with obstacles.

Although the two chosen speeds allow generating faster results it is not possible to see the interaction between the metrics and the speed variation.

Furthermore the data collected does not take into account the startup of the interface and the exchanged protocols so, the connections of 1s may produce one contact but do not permit the transaction of messages.

5.2 Future work

This study need to be extended in order to get more generalized results and include more models to be analyzed.

The data have to be further processed to apply statistical tests and prove mathematically the results.

Furthermore the platform is capable of generating movement in 3D and can be integrated with geographical maps. The integration with other simulators like the NS2 [19] may permit the inclusion of protocol issues to the study.

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