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On the feasibility of monitoring DTN: Impacts of fine tuning on routing protocols and the user experience

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Abstract—The “machine to machine” communication paradigm will become a central element for mobile networks. This paradigm can be easily constructed by a contact-based network, notably a disruption/delay tolerant networks (DTN). To characterize a DTN, we can use the Inter-contact time among the nodes. The better understanding of inter-contact time (ICT) has practical applications on the tuning of forwarding strategies, and hence in the quality of the User Experience. Nevertheless, the fine tuning of those parameters is tight to a set of assumptions about the regularity of movement or periodicity of patterns in an usually non complete and cumbersome statistical analysis. That is why in a dynamic environment where we cannot assume any previous information the tuning of parameters is usually overestimated. In this work we study how monitoring can help to adapt those parameters to give a better understanding of both natural evolution of the network and non periodical events.

Keywords-Monitoring, Characterization, Measurement, DTN

I. INTRODUCTION

The capabilities of information processing, storage and communication of next generation mobile systems will not only strengthen the ability of these systems to autonomously realize tasks but also to coordinate themselves to achieve cooperative activities. The “machine to machine” communication paradigm thus becomes a central element for mobile networks. This new kind of communication paradigm offers a new way to communicate without the need of infrastructure network but with the cost of frequent disconnection. These type of networks, known as disruption/delay tolerant networks (DTN), allow to easily exchange message-based data. Examples of such data can be subway newspapers, advertisement, public information, time tables or warning information.

This kind of networks can be easily constructed just by proximity contacts. However, the difficulty of this approach is the diffusion of information. This makes the big difference with wireless networks which need deployment of infrastructure, but offer direct connectivity among nodes. In order to spread information over a DTN the network connectivity must be characterized. Previous studies [1] showed that the best way is to assess the inter-contact law between nodes.

Having this characterization allows to select both the right algorithm (such as epidemic routing [2], Spray and Wait [3] and PROPHET [4]) and the right configuration parameters (for instance: vaccines, TTL, number of replicates) to diffuse the information on the network.

Furthermore, these parameters need to be precisely tuned as they heavily impacts on the quality of experience of the user in terms of delivery ratio, memory usage, energy consumption. The main challenge in order to improve the quality of experience is the tuning of these parameters. Today the tuning of those parameters is tight to a set of assumptions about the regularity of movement or existence and periodicity of patterns. That is why in a dynamic environment where we cannot assume any previous information usually the tuning of parameters is overestimated.

However, The problem of evaluating inter-contact time among the nodes is not trivial. Today, the common way to perform such evaluation is to drive a statistical analysis of collected inter-contact time data during a certain period of time between the nodes. Usually this process is cumbersome and not scalable with the increasing number of nodes in DTNs. Furthermore, the statistical analysis is an averaged view of the network during a given period. Hence, we need a dynamic light way to assess the inter-contact among the nodes.

Monitoring over a DTN network would allow/propose a fair trade-off between the complexity and the scalability of the characterization of the inter-contact. The natural temporal sampling of monitoring provides a method to reduce the significant amount of data that is needed to construct the approximate network characterization.

However, in a dynamic ambient like DTNs several questions arise. First we need to determine if it is possible to select a set of representative DTN nodes. Given the mobility of nodes, we need to define where to monitor and how the monitors should behave in relation with other nodes movement. We also need to assess the sampling time duration and estimate the relative error when the sampling period is too short.

Hence, monitoring and adapting those parameters over time can help to address a better understanding of both

natural evolution of the network model and non periodical events, providing a bigger resilience to changes.

In this work, we discuss on the feasibility of perform such monitoring based on the random waypoint movement (RWP) model. Basically, we weight up the trade-off between the complete statistical analysis and the approximation given by the monitoring model and study the impact of this characterization over the fine tuning of the most important routing protocols available on DTN.

II. MODEL BASICS

In this section we present the model basics to characterize the inter-contact time. We define some basic notation and then explain how monitoring to create the approximate characterization of the inter-contact time.

For each pair of nodes (i, j) we denote their k -proximity contact as (c_k^s, c_k^f) , where c_k^s, c_k^f are the start and end time respectively. The inter-contact time is usually characterized as a frequency table ICT_k for each pair of nodes (i, j) as:

$$ICT_k = \{(t_1, f_1), (t_2, f_2), \dots, (t_{n_k}, f_{n_k})\} \quad (1)$$

Where t_l is the time elapsed between the end of the last contact c_{r-1}^f to the start of a new contact c_r^s between the nodes (i, j)

$$t_l = \begin{cases} c_{r-1}^f - c_r^s & r > 0 \\ 0 & \sim \end{cases} \quad (2)$$

and f_l the number of repetitions of t_l over time.

With all the pairs we construct the global frequency table that leads to the empirical distribution function. An important remark is that the set defined by (i, j) is not necessarily the same defined by (j, i) . This is due the inherent behavior of some wireless protocols or by measuring problems. For the purpose of this work we assume that the pairwise distribution is the same.

Hence the global inter-contact time is defined as

$$ICT = \cup_k ICT_k \quad (3)$$

Where the union represents the sum of the frequency when the time index t_l is equal. We can see that to characterize the global ICT_k we need to know all the pairwise ICT_k distributions. Due to the difficulty to gather all the pairwise distributions, we propose to select a subset of nodes that can approximate the global ICT distribution.

Selecting the right placement of monitors in space and time is key to approximate the global ICT distribution. For instance, in Figure 1 we can see a typical static picture of a DTN. Let us assume that each monitor (depicted in blue in the figure) can connect at the same time with all the nodes at a given distance (usually the maximum distance is defined by the underlying wireless connectivity). We can see that each monitor define an area of monitoring as the subset of nodes that are monitored at that time (depicted by the red

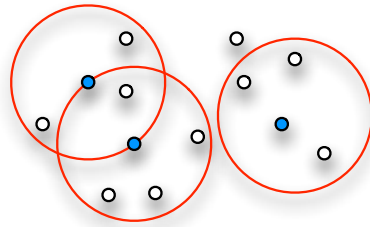


Figure 1: Monitor sampling scenario

circle in the figure). We observe the following cases: (i) a node is inside the range of the monitor, (ii) a node is inside the range of one or more monitors or (iii) a node is outside of any monitored area. Notice that also can be the case that monitors are in contact are able to share information. If we add that DTN are inherently rapid time changing, we have to also determine how our monitors should move along the space.

III. SIMULATIONS

In order to explore and answer some questions related to the feasibility and positive impact that monitoring can have under the fine tuning of DTN routing protocols, we perform an evaluation of several scenario. We run simulations in the well known The One simulator [5]. We use the random waypoint movement (RWP) model for both normal nodes and monitors. We setup the density of nodes to reflect a usual day scenario in a medium size city with $100 \text{ nodes}/m^2$. In order to determine the impact of the number of monitors spread among the normal nodes we define a series of scenarios with increasing number of monitors from 1% of the sample to 10%. Finally, to determine the impact of the time window used to sample we perform increasing runs from 1 minute to 1 hour (increasing in 1 minute each time).

Our initial results indicate that the ICT probability distribution function is similar for every scenario (with different parameters though). The smaller the monitoring period, the smaller the number of contacts, which provides a coarse-grained ICT estimation from the monitors. If we increase the number of monitors, the number of contacts increase accordingly, which results in an improved ICT estimation. As overall conclusion: In the random waypoint scenario, we can monitor a group of nodes using a subset of monitors. The key parameter to take into account is the number of contacts, that can be regulated either increasing the time sampling or by increasing the number of nodes in the space.

IV. RELATED WORK

Guerrieri et al. [6] present an extension off well known aggregation algorithms for connected networks. Specifically the notion of pairwise averaging and populations protocols

to the DTN scenario. However this work does not provides a mean to measure the error of the estimation. Instead the estimation is just performed by a given amount of time or by a given number of contacts desired, assuming that the more contacts you have, the better the estimation will be.

Noticeably, [7], [8] showed that the global inter-contact time distribution for real human traces follows a power law with an exponential decay. This impacts on the possibility to deliver a message and gives a superior bound for the expected packet delivery.

Most of the works that characterize a DTN are based in the global estimation of inter-contact time. Passarella et al. [9] present an analytical model which derives from pairwise inter-contact time distribution the aggregated distribution of the group. Remarkably, this study shows that there is no exact mirror between the pairwise connection with the aggregated distribution. If we assume that pairwise distributions follows an exponential law, then the aggregated distribution will follow a power law.

Pheneau et al. present a fine grained inter-contact time characterization in [10]. The main idea is to add an extra level of connectivity based in favorable inter-contact by n -hops of distance. The trace analysis under this model reveals new communication opportunities. Later, [11] present a vicinity study to characterize the behavior of the DTN. In this work is present the concept of k -vicinity as all the nodes that are at most at k hops from a given node and the k -inter-contact which is the time while a node left and come back to a given k -vicinity. Trace analysis shows that k -vicinities inter-contact time follows power laws with a exponential decay after a given time. Moreover, the k -vicinity of size $k=\{2,3\}$ gives already enough awareness to a node of its surrounding. This assumption is supported in the existence of groups in the node movements.

V. CONCLUSIONS

In this work we present a first study on the feasibility of perform monitor over a DTN network and its impact in the user experience. This impact is measured by the fine tuning that it is possible to perform over certain routing algorithms.

As future work we plan to extend our experiments with real traces such as those available on Crowdad. We also will explore different ways to measure the estimated error of the approximation. Also we will try different mobility models for both nodes and monitors.

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