A Proposal of Routing Strategy to DTNs Considering Application Service Targets in Environment with Nodal Heterogeneity and Constrained Resources

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***Abstract*—This research work presents studies developed aiming at the overcome of the tradeoff that would presumably exist in opportunistic routing of DTNs. Published papers show that is too difficult, if not impossible, to simultaneously achieve high delivery rate and low delivery delay in DTNs comprising heterogeneous node populations and constrained resources. To meet concomitant demands for both services under these conditions, we propose to adopt strategies that are: setting more than one routing scheme for the same node, buffer/queue management policies and numbers of message copies according to the corresponding application's service targets. Our study shows that the set of strategies reduces the total number of transmissions, ensures the reliability of delivery and yet reduces delays for those messages that need to be delivered within a relatively strict deadline.**

***Index Terms*— DTN, routing, service target.**

I. Introduction

In Delay/Disruption Tolerant Networks (DTNs) in which devices are mobile, researchers have proposed a variety of opportunistic routing schemes to ensure communication services. Such routing schemes are based on the inherent mobility of the participating nodes to store and carry messages until an opportunity of communication. Upon opportunistic encounters, independent local decisions for routing messages are taken so that the message may finally reach its destination. This technique is known in the literature as store-carry-forward.

Face to the questions still open in relation to the opportunistic routing, this research work presents studies developed aiming at the overcome of the tradeoff that would presumably exist in these types of routing, as the authors of [1] conjecture. They state that it is too difficult, if not impossible, to simultaneously achieve high delivery rate (D_R) and low delivery delay (D_D) in DTNs comprising heterogeneous node populations with the following characteristics: a) unavailability of network knowledge, b) storage and power constraints and c) the possible existence of several applications running concurrently, some of them requiring 100% of D_R (e.g., e-mails) and others, low D_D, because their data can become useless if not delivered within a (relatively) strict deadline (e.g., telemetry data).

II. Problem and approach

The tradeoff is due to the fact that to achieve low D_D it's necessary to distribute multiple copies of a message through the network in the hope that at least one of them reaches the destination within the deadline. This attitude would involve some risks, in the sense that some of these copies can be delivered to the network nodes with little likelihood of delivery, leading to waste of energy and storage.

On the other hand, if you have multiple copies being introduced to the network through multiple transmissions, storage spaces can be recovered discarding messages whose deliveries have been confirmed. However, the considerable consumption of energy can quickly result in shut down of device due to power outage. The 'death' of the device would cause the loss of all stored messages, resulting in a significant reduction in the rate of delivery. Therefore, to achieve high D_R there should be a higher efficiency in energy consumption by limiting the number of copies to the minimum possible. For this purpose, messages marked as D_R would require wise decisions in the sense that the forwarding of copies of messages occurs for those neighbors with most likely delivery.

Hence, this research work resumes relevant evaluation of DTN routing algorithms in a DTN scenario with a heterogeneous population of nodes as presented in [2]. However, unlike that paper, this research work also admits demanding applications regarding the delivery rate, D_R, like the other desired service target of an application DTN. We considered that in DTN, messages with requests to one or another type of desired service coexist.

III. A proposal of routing strategy

To meet concomitant demands for D_R and D_D services (without loss of one over the other) in DTNs comprising heterogeneous nodes and constrained resources, this research work proposes and presents results of a set of strategies employed to overcome the mentioned tradeoff. We adopt strategies that are: setting more than one routing scheme for the same node; buffer/queue management policies according to the corresponding application's service targets; L_{DR} and L_{DD} copies for D_R and D_D messages, such that $L_{DR} < L_{DD}$.

This research work evaluates the performance of DTNs whose nodes usually go less or more often out of their communities, roam around the network and return to their community (roaming nodes) are configured with two routing schemes. These schemes use some utility function for choosing relay nodes, and each scheme is in charge of trying to reach the service target it has been responsible for. Therefore, in the roaming nodes the routing decision of D_R and D_D messages is made by different algorithms. In addition, the messages are stored in separate areas of the buffer, so that, input/discard management of a type of message does not affect other messages stored in the other area.

While roaming node are responsible for forwarding messages of both D_R and D_D, fixed nodes and community nodes (moving only within their own community) can only forward D_D messages. This distinct behavior is because these no roaming nodes have only one routing scheme exclusive of decision making for forwarding of D_D messages. For these nodes, the both messages occupy the same area of the buffer.

Thus, the source node of a D_R message can replicate copies of the message only to relays of roaming types. Differently, the source node of a D_D message may use any type of network node to forward copies. Regarding the exchange of message copies between relays, the router of node can only "talk" to its similar router installed on the other node. Hence a roaming relay can exchange copies of D_D messages with another no-roaming relay and vice versa; roaming relay can only exchange copies of the D_R messages with another roaming relay.

IV. Simulations and Results

From evaluations of the simulation results, PRoPHETv2 routing scheme [3] was chosen for routing of D_D messages. This version of PRoPHET defines a new transitive update equation and direct encounter update equation. Simulation evaluations show that PRoPHETv2 presents a better performance in relation to the delivery rate and delivery delay than the old PRoPHET routing scheme to scenarios consisting of heterogeneous and mobile nodes. The scheme Most-Social-First (MSF) [2] is the scheme used by routing decisions of D_R messages. MSF takes into account the sociability of the node, which is related to the number of unique node IDs encountered for a given time interval. This strategy to set MSF and PRoPHET in roaming nodes is defined in this research work as M&P strategy.

We simulated a scenario of heterogeneous DTN in the same configuration used in [2]. We compare the results of improved performance of the hybrid routing strategy M&P and the PRoPHET and MSF 'pure' schemes to the Spray and Wait (SW) scheme. The metrics used to compare performances are the reduction in forwarded messages and delivery delay, and levels of the delivery rate for each message type.

Some of the results of the simulations carried out are shown in Fig. 1 and 2. For these results, the queue management policy adopted was always the FIFO, the rule adopted for spraying of copies of the messages was the binary spray [2], which adopts a binary tree to equally spray the messages copies.

As can be noticed, the hybrid strategy M&P presents a

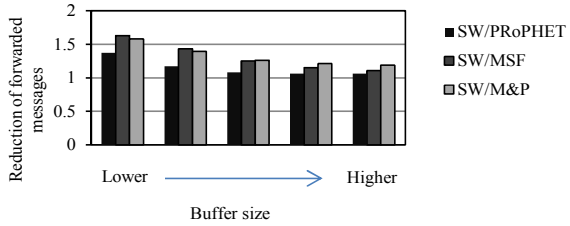

Fig. 2. Reduction of forwarded messages of PRoPHET, MSF and M&P over SW.

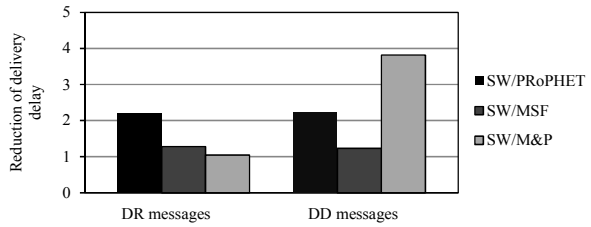

Fig. 1. Sample of delay reduction to D_R and D_D messages of PRoPHET, MSF e M&P over SW considering an average capacity of storage.

reduction of forwarded messages similar to that obtained by MSF 'pure', but it offers an improvement in the reduction of delivery delay of D_D messages for all storage capacities used. The M&P strategy presents the best performances especially in situations of greater constraint of storage. Performances which can be even more improved if, for example, queue management policies are more judicious than the FIFO are used. These findings may be reasserted from the other results described in this research work.

V. Conclusion and Future Works

In this research work, we assume that in DTNs can occur simultaneously some applications requiring for high delivery rate, D_R, and others for low delivery delay, D_D. In order to meet these both requirements of service targets, we propose that some special nodes (roaming nodes) have a routing scheme, buffer/queue management policy and distinct copy number of messages for each service target. The simulation results show that the proposal to use this set of strategies allows exploiting the system's resources better, such as the energy consumption by reducing forwarded messages. Possible direction for future work includes adopting strategies based on Bayesian game theory to aid in decision-making of a node with respect to generation and forwarding copies of a given message.

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