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Performance of Efficient Routing Protocol in Delay Tolerant Network: A Comparative Survey

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Abstract

Nowadays, the research and application about delay-tolerant network (DTN) have become more and more popular. A communications network that is capable of storing packets temporarily in intermediate nodes, until the time an end-to-end route is re-established or regenerated is known as a delay tolerant network/s, in short, DTN.Routing of the packets in DTN is based on store-carry-and forward paradigm. When a node receives a message but no availability of paths towards destination node, the message should be buffered in the current node and wait for opportunities to encounter other nodes. This paper aims to detail basic & general aspects specific to information needs in DTN routing and present classification chart. We discuss some detail of routing issues and classifications of routing protocols. Routing is one of the major issues affecting the overall performance of DTN networks in terms of resource consumption, data delivery. Over the past few years a number of routing protocols have been proposed for DTN networks. In this paper mainly three DTN routing protocols Epidemic, PROPHET and Spray and Wait Routing protocols are discussed.

Keywords: *Delay tolerant network, Routing in DTN, routing protocol*

1. Introduction

Communication network realize straightforward thing recently, but it is still very difficult to transmit data in some networks in presence of delay and interruption. To avoid the issue many researchers have proposed many solutions over the last few years. However, such approaches are all try to address the issue based on the traditional network protocols so that these schemes are not feasible in some specific cases, which resulted in a concept of DTN. A communications network that is capable of storing packets temporarily in intermediate nodes, until the time an end-to-end route is re-established or regenerated is known as a delay tolerant network/ disruption tolerant networks i.e. DTN [1]. Delay-tolerant networking (DTN) is an attempt to expand the reach of networks. It promises to enable communication between "challenged" networks [2], which includes deep space networks, outer-space networks, under-water networks, sensor networks, vehicular networks, mobile ad-hoc networks, military networks, inter-planetary networks [3], and low-cost networks. The basic aim of networks to reach information of any form, from source to destination .DTN is wireless networks in which for any given time instance, the connectivity of the network is maintained by nodes only when they come into the transmission ranges of each other. A node stores the message until an appropriate communication opportunity arises.

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In a standard network senario, the nodes are connected most of the time; the routing protocol forwards the packets. The cost of links between nodes are mostly known or easily estimated so that the routing protocol computes the best path to the destination in terms of cost and tries to send the packets over predefined path. Moreover, the packet is only sent to a single node because the reliability of paths is assumed relatively high and mostly the packets are successfully delivered. In case of DTN like networks, routing becomes challenging because the nodes are in transit and connectivity rarely maintain. The transient network connectivity needs to be of primary concern in the design of routing algorithms for DTNs. Therefore, routing of the packets is based on store-carry-and forward paradigm [4]. When a node receives a message but no availability of paths towards destination node, the message should be buffered in the current node and wait for opportunities to encounter other nodes.

The remainder of paper is organized as follows. Sections 2 discuss features of Delay Tolerant network; Section 3 discovers routing issues of DTN. Section 4 is about Classification of routing protocols and Section 5 discuss the popular DTN routing protocols.

2. Features of Delay Tolerant Network

i) **Intermittent connectivity**
Due to limitation of mobility and energy of nodes, DTN frequently disconnected, thus resulting in continue change in DTN topology. Meaning to say, the network keeps the status of intermittent connectivity [12] and partial connection so that there is no guarantee to achieve end-to-end route.

ii) **Limited resource**
The nodes in DTNs are mobile and thus, they have limited resources. . For example, to forward packets to the next node, the data should be safely stored within the current node until the connectivity to the next node is available and establish. However, new data can be received and collected which occupy another part of the buffer space. Therefore the limited memory capability will restrict the data buffering.

iii) **High delay, low data rate**
End-to-end delay indicates that the sum of the total delay of each hop on the route. Each hop delay might be very high due to the fact that DTN intermittent connection keeps unreachable in a very long time and thus further leading to a lower data rate and showing the asymmetric features in up-down link data rate.

3. Routing Issues in Delay Tolerant Network

i) **Buffer space**
Due to Intermittent connectivity, messages must be buffered for long periods. This means that intermediate routers require enough buffer space to store all the messages that are waiting for future communication opportunities. Hence, intermediate routers require sufficient buffer space to store all pending messages as demanded.

ii) **Energy**
In DTN, because of mobility of nodes and the complexity of connection to power station, the nodes have usually low level of energy. During sending, receiving and storing & computation of messages, nodes required sufficient energy. Therefore the energy-efficient design of routing protocols is of importances.

iii) Reliability

In DTNs, for reliable delivery of data any routing protocol should have some acknowledge, which ensure successful and stable delivery of data. For example, when a message correctly reaches to a destination, some acknowledge messages should be sent back from destination to sources for later use.

iv) Processing Power

One of the goals of delay-tolerant networking is to connect devices that are not performed by traditional networks. These devices may be very small having small processing capability, in terms of CPU and memory. These nodes will not be capable of running complex routing protocols. The routing strategies presented here could still be used on more powerful gateway nodes, in order to connect the sensor network to a general purpose delay-tolerant network.

v) Security

For any network either traditional or DTN, Security is always a significant problem. A message may pass through intermediate hosts randomly before reaching its final destination. Depending on the security requirements of applications, users may require secure guarantees about the authenticity of a message. The cryptographic techniques may be beneficial for secure intermediate routing.

4. Classification of Routing Protocols

The existing routing protocols in DTNs are classified with respect to their strategies for controlling message copies and making the forwarding decision [5] shown in Figure 1.

- **Number of destination**

  According to the number of destination nodes of a message, routing protocols can be classified into three categories: unicast routing, multicast routing, and broadcast routing.

i) Unicast routing: Single destination for each message.
ii) Multicast routing: Group of destination nodes for each message.
iii) Broadcast routing: All the nodes in the network are destination nodes for each message.

- **Number of copy**

  Depending on the number of message copies utilized in the routing process, protocols can be classified into two categories [6, 7]: single-copy and multiple-copy.

i) Single-copy routing protocols: only a single copy for each message exists in the network at any time.
ii) Multiple-copy routing protocols: multiple copies of same message can be generated and distributed into the network.

   Moreover, multiple copy routing protocols can be further divided into flooding-based and quota based.

   a) Flooding-based routing protocol: dissemination a copies of each message to as many nodes as possible.
   b) Quota-based routing protocol: intentionally limit the number of message copies.

- **Available Network knowledge**

  In addition, according to whether the forwarding decision is based on the knowledge derived from the nodes' encounters or not, protocols can as well be classified into two categories: Deterministic and Non-deterministic (Opportunistic) [13].

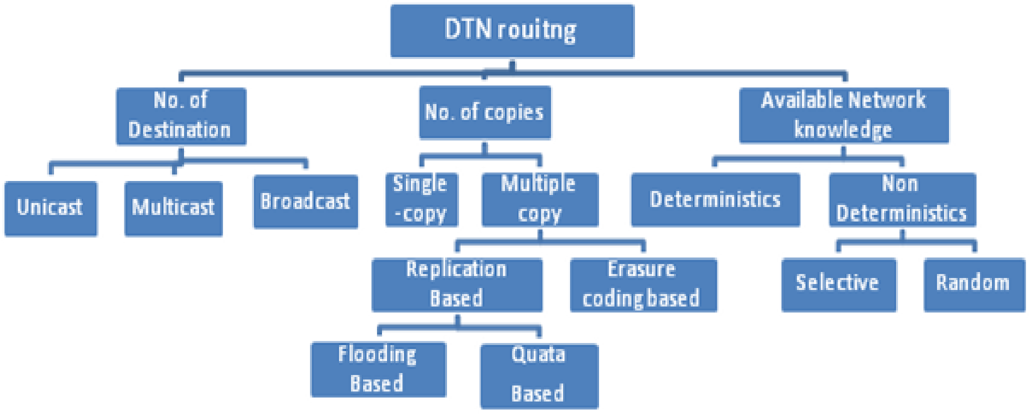

Figure 1. Classification of DTN Routing Protocols

i) Deterministic routing protocol: Complete knowledge of node trajectories, encounter probability of nodes and node meeting times and period to make the forwarding decision.

ii) Non-deterministic routing protocols: Zero knowledge of pre-determined path between source and destination.

These algorithms either forward the messages randomly or prediction based (Probabilistic based).

5. DTN Routing Protocols

I. Epidemic Routing Protocol

Epidemic routing algorithm published by Vahdat and Becker et al. (2000), & proposed as a flooding-based forwarding algorithm [8]. The main goals of Epidemic Routing are to: i) maximize message delivery rate ii) minimize message latency and iii) minimize the total resources consumed in message delivery.

In DTNs routing scheme, the node receiving a message, forwards a copy of it to all nodes it encounters. Thus, the message is spread throughout the network by mobile nodes and finally all nodes will have same data. Although no delivery guarantees are provided. This algorithm can be seen as the best-effort approach to reach the destination. Each message and its unique identifier are stored in the node's buffer.

The list of them is called the summary vector. Whenever two adjacent nodes get contact with each other, they exchange and compare their summary vector to identify which messages they do not have and subsequently request them. When the counter of a packet reaches zero, the packet is discarded. Another approach is to set Time-To-Live (TTL) for each packet as in Epidemic routing. The packet will keep on getting copied from one node to the other node till its *TTL* expires. The scheme of message delivery is shown in Figure 2.

Such routing type will result in inefficient use of the network resources such as power due to forwarding of multiple copies of the same message, bandwidth and costly in terms of energy consumption and memory**.** Here, one can easily notice that Epidemic Routing provides the fastest spread of copies in the network which of course yields the optimum delivery time. However, flooding causes a huge number of control packets in control channels, which can result in network congestion.

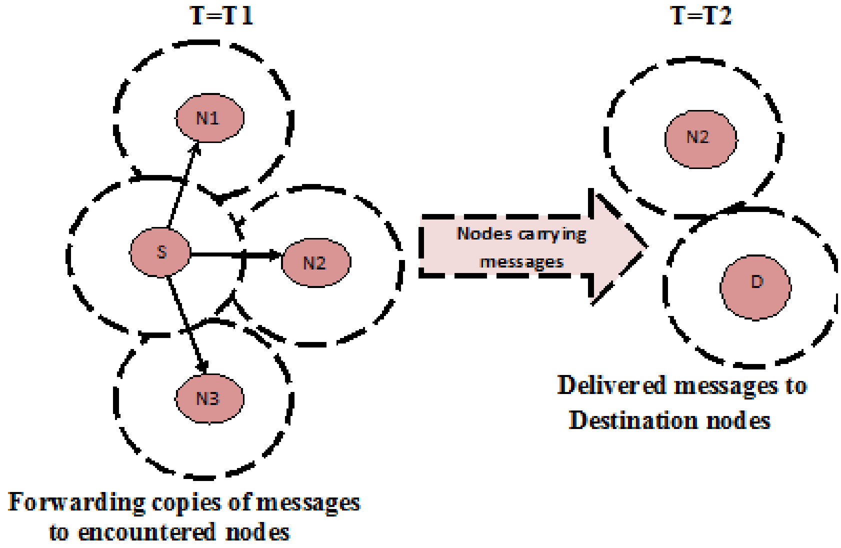

Figure 2. Epidemic Routing Protocol Method

The epidemic routing has been suggested to use in those conditions when there are no better algorithms to deliver messages. It is especially useful when there is lack of information regarding network topology and nodes mobility patterns [14].

II. PROPHET Routing Protocol

The probabilistic routing protocol using history of encounter and transitivity (PROPHET) is a probabilistic routing protocol developed by Lindgren *et al.*, (2003).The basic assumption in the PROPHET is that node's mobility is not a random but it is a repeating behavior. In the PROPHET scheme, it is assumed that the mobile nodes tend to pass through some locations more than others, implying that passing through previously visited locations is highly probable. As a result, the nodes that met each other in the past are more likely to meet in the future [9, 10]. Routing protocol PROPHET proposed for improve the delivery probability and reduce the wastage of network resources in Epidemic routing.

In PROPHET scenario, initially estimate the probabilistic metric called delivery predictability (a,b) $\in$ [0,1] at every node A for each known destination B.Whenever a node encounter with other nodes in the network, they exchange summary vectors as it is in epidemic routing. Summary vector contain the delivery predictability values for destinations known by each node. The operation of the PROPHET protocol could be calculated by delivery predictabilities and then forwarding strategies.

The calculations of delivery predictabilities of nodes have three parts. Nodes update their delivery predictability metrics whenever meet each other. Visiting more nodes results in higher delivery predictability values. This calculation is shown below, where Pinit ∈ [0, 1] is an initialization constant.

$$\mathbf{P\ (a,b) = P(a,b)old + (1 - P(a,b)old) \times Pinit}$$

On the other hand, if two nodes do not meet each other for a long time, they exchange message with low probabilities. Thus the delivery predictability values must *age*, being reduced in the process. The aging equation is shown below, where, γ ∈ [0*;* 1), represent the aging constant, and *k* is the number of time units that have elapsed since the last time the metric was aged. The time unit used can differ, and should be defined based on the application and the expected delays in the targeted network.

$$\mathbf{P\ (a,b) = P\ (a,b)old \times \gamma\text{^}k}$$

The delivery predictability has transitive property meaning that if node A frequently encounters node B and node B frequently encounters node C, then node C probably is a good node to forward messages destined for node A. This equation shows how this transitivity affects the delivery predictability, where β ∈ [0, 1] is a scaling constant that decides how large impact the transitivity should have on the delivery predictability.

$$\mathbf{P(a,c) = P(a,c)old + (1 - P(a,c)old) \times P(a,b) \times P(b,c) \times \beta}$$

Unlike conventional routing protocols that base their forwarding decisions and selection of a path to a given destination on some simple metrics such as the shortest path or the lowest cost, forwarding strategy in the PROPHET is more complicated. Whenever node receives a message and has no path to the destination stores the message in buffer and forwards it whenever another node is encountered. When a node meets a neighbor with low delivery predictability, there is no guarantee that it would meet another node with a higher delivery predictability value during the message life time.

The basic difference of Prophet than Epidemic Routing is its forwarding strategy. When two nodes meet, Prophet allows the transfer of a message to the other node only if the delivery predictability of the destination of the message is higher at the other node.

III. SPRAY and WAIT Routing Protocol

Spyropoulos *et al.*, (2005) proposed the spray and wait routing protocol to control the level of spreading of messages throughout the network. Similar to the epidemic routing, the spray and wait protocol assumes no knowledge of network topology and mobility pattern of nodes. It simply forwards multiple copies of received messages using flooding technique. The difference between spray and wait protocol and epidemic routing scheme is that it only spreads L copies of messages. The author in [11] proved that minimum level of L to get the expected delay for message delivery depends on the number of nodes in the network and independent of the size of network and transmission range.

Spray and Wait routing consists of two phases:

i) Spray phase: In this phase, a limited number of copies (L) of messages are spread over the network by the source and some other nodes which later receives a copy of the message.

ii) Wait phase: After the spreading of all copies of the message is done and the destination is not encountered by a node with a copy of the message in the spraying phase, then each of these nodes carrying a message copy tries to deliver its own copy to destination via direct transmission independently (*i.e.*, will forward the message only to its destination).

To facilitate performance of the algorithm Spyropoulos *et al.*, (2005) purposed the binary spray and wait scheme. This method provides the best results if all the nodes' mobility patterns in the network are independent and identically distributed (iid) with the same probability distribution. According to binary spray and wait, the source node creates L copies of the original message and then, whenever the node is encountered, communicate half of them to it and keeping the remained copies. This process is continued with other relay nodes until only one copy of the message is left. When this happens the source node waits to meet the destination directly to carry out the direct transmission.

In general, different methods limiting the number of distributed messages and reduce resource consumption in intermediate nodes but often better performance result compared to the epidemic routing protocol.

6. Conclusion

In this paper, we introduced delay tolerant network with their features such as intermittent connectivity, resource limitation and high delay. We also introduced the open routing issues in Delay Tolerant Network's security. The existing routing protocols in DTNs are classified to their strategies for controlling message copies and making forwarding decision. We have made a depth study in performance of efficient routing protocols.

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