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A Review of Routing Protocols for Delay Tolerant Networks

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Abstract— **Delay-tolerant networks have the great potential to connecting devices and regions of the world that are being presently under-served by current networks. A challenge for Delay Tolerant Networks is to determine the routes through the network without having an end to end connection at any given instant of time. The problem has an added constraint of limited size of buffers at each node. This situation limits the applicability of traditional routing techniques which categorize lack of path as failure of nodes and try to seek for existing end-to-end path.**
In this paper, an algorithm has been proposed for energy efficient by reducing the average number of messages forwarded from source to destination.The algorithm has focused on passing the messages to those nodes which are on the path away from the source node,and hence increases chances of delivering the message to the destination using the routing table.

Index Terms— **Delay Tolerant Networks,routing, Message Delivery, Simulation**

I. INTRODUCTION

Today's Internet has been very successful at connecting communicating devices round the globe. It has been made possible by using a set of protocols, which is widely known as TCP/IP protocol suite. Every device on the networks that comprise the Internet uses this protocol for transferring the data from source to destination with the minimum possible delay and high reliability. The underlying principle on which TCP/IP works is based on end-to-end data transfer using number of potentially dissimilar link-layer technologies. However, there are many regions where the assumptions of the internet cannot be upheld. If at any instant there is no path between the sources to destination, then TCP/IP fails to work properly or might even stop working completely. Because of such circumstances, a newer network has evolved which has independent end to end connectivity between nodes. This network is called as Delay Tolerant Networks (DTN). DTN is an intermittentlyconnected Network where the end-to-end paths may not existand communication routes may only be available through timeand mobility [1].

1.1 Need for Delay Tolerant Networks

***1)** Because of the characteristics mentioned below the need of DTN is felt in today's scenario.*

a) **Lack of Connectivity:**If at any moment, there is no end-to-end path between source and destination, thenend-to-end communication cannot take place using the TCP/IP protocols suite. Here DTN comes into picture.
b) **Irregular Delays:**The long propagation delays between transmitting nodes compounded with queuing delay at each node can topple the TCP/IP protocols which rely largely on quick return of acknowledgement of a sent data. This can be overcome using DTNs.
c) **Asymmetric Bidirectional Data Rates:**Moderate asymmetries of bidirectional data rate can be tolerated to an extent in conventional protocols. But if asymmetries are large, protocols can be defeated easily.

1.2Characteristics of Delay-Tolerance Networks:

Compared to traditional networks, DTN network have the following basic features [2]:

a) **Intermittent Connection:** As the node's mobility and energy are limited, DTN frequently disconnects, thus resulting in continues change in DTN topology. That is to say, the network keeps the status of intermittent connection and partial connection so that there is no guarantee to achieve end-to-end route.
b) **High delay, low efficiency, and high queue delay:** End-to-end delay indicates that the sum of the total delay of each hop on the route. The delay consist of waiting time, queuing time, and transmission time. 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. The queuing delay plays a main role in end-to-end delay and frequent fragmentations in DTN make queuing delay increases.
c) **Limited resource:**Node's computing and processing ability, communication ability and storage space is weaker than the function of an ordinary computer due to the constraints of price, volume and power. In addition, the limited storage space result in higher packet loss rate.
d)Limited Life time of node: In some special circumstances of the restricted network, the node is common to use the battery power in harsh conditions, which will cut the life time of node. When the power is off, then the node cannot guarantee normal work.*
e) **Dynamic topology: T**he DTN topology changes dynamically due to environmental changes, energy depletion or other failures, which results in dropping out of network. The requirements of entering DTN also change the topology.
f) **Poor Security:**In general, DTN is vulnerable to eavesdropping, message modification, routing spoofing, Denial of Service (DoS), and other security threats. due to the lack of specialized services and maintenance in real-world.
g) **Heterogeneous interconnection:**DTN is an overlay network for transmission of asynchronous message. Introducing the bundle layer, the DTN can run on different heterogeneous network protocol stacks and DTN gateway

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ensures the reliable transmission of interconnection message.

1.3 Architecture

A Delay Tolerant Network can be considered as an overlay on the existing regional networks. This overlay is called as the bundle layer. This layer is intended to function above the existing protocol layers and provide the function of a gateway when two nodes come in contact with each other. The main advantage of this kind of protocol is flexibility. It can be easily linked with the already existing TCP/IP protocol networks or can be used to link two or more networks together. The position of the bundle layer can be seen in the following fig. 1.

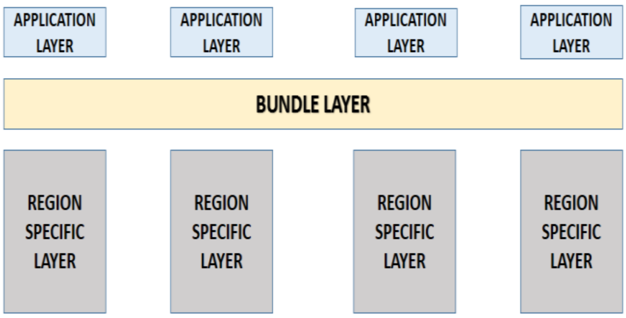

Fig 1: The position of the bundle layer

Bundles are also called as messages. The transfer of data from one node to another can be made reliable by storing and forwarding entire bundles between nodes. The bundles comprise of three things, source node's user-data, control information (e.g., source node ID, destination node ID, TTL etc.), and a bundle header.

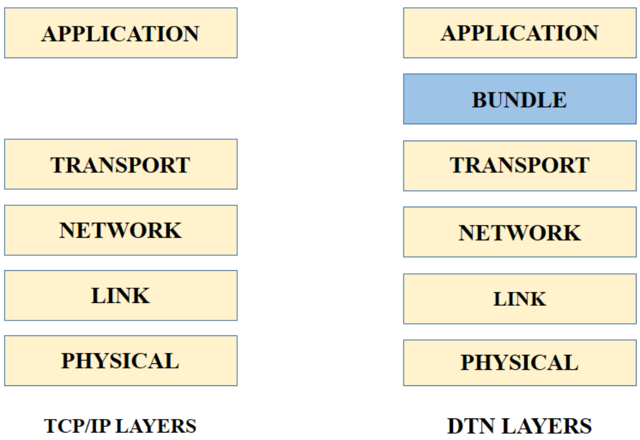

Fig 2: A comparison between TCP/IP layers and DTN layers

1.3.1 Bundle layer

The unit of information exchange in a DTN is a bundle. A DTN node is an entity with a bundle layer. A node may be a host, router, or gateway (or some combination) acting as a source, destination, or forwarder of bundles. A router forwards bundles within a single DTN region while a gateway forwards bundles between DTN regions.

In a typical network, applications on different nodes communicate using a common set of network layers (such as TCP and IP). In a DTN, the bundle layer is placed below the application layer and hides the actual network- or regionspecific communication layers, as depicted in Figure 1. A network-specific convergence layer is used underneath the bundle layer as to interface with each different network layer protocol used.

In DTNs, forwarding nodes (routers and gateways) can be authenticated. Also, the sender information is authenticated by forwarding nodes, so that network resources can be conserved by preventing the carriage of prohibited traffic at the earliest opportunity.The bundle protocol defines a custody operation which allows an intermediate node to handle bundle delivery to final destination on behalf of a more distant sender.

1.3.2 Design issues and concerns

The DTN architecture originates from the work on the Interplanetary Internet. It was then extended and popularized to include challenged networks in general [3]. The Bundle Protocol is considered as the single solution for all DTN scenarios [4]. As per authors of paper [5] the Bundle Protocol can be described as a complex extensible container format, with optionally secured payloads, carried by the supporting local network infrastructure.

1.4 Applications of DTN

There are many real-life applications where wireless nodes, mobile or stationary, are forced to undergo extreme operational conditions and/or wait for extended intervals of time that exceed traditional IP forwarding times (that are usually measured in milliseconds) before being able to forward their data to next hops.

Some of these applications are listed below: [6-8]

a) **Wildlife Monitoring:** This application is concerned with gathering data about wild faunae species and their habitats. Monitoring is conducted by attaching a sensing device to each animal (i.e. mobile node). These devices may contain microcontrollers, global positioning systems (GPS), and orientation and temperature sensors.

b) **Forestry and Underwater Sensors:** Using forestry and underwater sensors Measurements regarding temperature, air pressure, intensity of natural lighting, chemical contamination in the soil or the water, fire hazards, radiation levels and other measurements can be gathered.

c) **Village Networks:** Village networks represent a very promising public application for DTNs, especially in secluded areas lacking communication infrastructure.

d) **Inter-planetary Networks:**The massive distances separating terrestrial artificial objects and the need for these objects to exchange data among each other or with base-stations on earth –or perhaps other planets-represent an extreme case of DTN communication.

e) **Military Applications:** In military, as in the case of wildlife monitoring, there is a need to monitor extended geographical planes their objects and inhabitants – i.e. soldiers-who would be equipped with wireless sensors in order to indicate their locations.

II. Literature Survey

Delay Tolerant Networks are wireless networks in which a fully connected path from source to destination is unlikely to exist. Therefore, in these networks, message delivery relies on opportunistic routing where nodes use store-carry-and-forward paradigm to route the messages. The different routing Algorithms& Data delivery Mechanisms are presented in the following section.

2.1 Data delivery mechanisms

In this section, we have classified routing schemes for DTNs into a different categories based on their characteristics.

2.1.1 Epidemic routing schemes

One of the earliest and probably the simplest protocols proposed for data delivery in DTNs is epidemic routing [9]. The idea is whenever two nodes encounter one another they will exchange all the messages they currently carry with each other. At the end of the encounter, both will possess the same set of messages. As this process continues, eventually, every node will be able to send information to every other node. So the packets are basically flooded through the network much like the spread of a viral epidemic. This represents the fastest possible way in which information can be disseminated in a network with unlimited storage and unlimited bandwidth constraints. This scheme requires no knowledge about the network or the nodes. However, in most practical scenarios, such a scheme will result in inefficient use of the network resources such as power, bandwidth, and buffer at each node. Moreover, messages may continue to exist in the network even after they have been delivered to the destination. Epidemic routing serves as the baseline for comparison for most of the DTN routing schemes.

In paper [10] the basic epidemic scheme is improved with the introduction of single-copy routing for enforcing reliable transmission. This routing is appropriate for energy-constrained and bandwidth-constrained applications in DTN networks. The routing scheme of single-cop is based on the DTN connectivity graph and the greedy tree. During a period of time, a DTN connectivity graph is constituted by the edged and the nodes, and the degree sequence of vertices of DTN connectivity graph is achieved, which is the greedy tree.This scheme improve the reliable delivery ratio when there are some disability nodes and selfish nodes in the networks and the message is transmitted successfully.

The improvement in a bandwidth overhead and resource usage of the entire network due to the continuous spread of message, in Epidemic routing is shown in [11]. Prophet Protocol (Probabilistic Routing Protocol using a History of Encounter and Transitivity) was introduce to solve the problem.

The Prophet approach is based on the delivery predictability metric which is calculated at each node. This metric is calculated so that a node with a higher value for certain destination is estimated to be a better candidate for delivery a bundle to the destination. When two nodes meet each other, they exchange the value of the metrics for different known destinations. The researcher focus on the improvement of the Prophet routing protocol through a new algorithm by implementing the predictability optimization factor. Compare to Prophet, Epidemic it has improvement in the amount of aborted transmission between nodes, dropped messages, the buffer time and the hop count state.

2.1.2 Direct-contact schemes

This data delivery scheme is one of the simplest possible where a source delivers a packet to a destination when it comes in direct-contact. In other words, the source waits till it comes in radio range of the destination and then directly delivers the packet to the same. This scheme does not consume any additional resources and makes no additional copies of the data. However, the major limitation is that the delivery delay can be extremely large and in many cases the source and the destination may never come in direct-contact of each other.

In the context of vehicular networks, the authorspropose the employment of the direct-contact based data delivery in [12]. They present comparative performance of a family of replication strategies that determine the number of replicas for a given data item based on its popularity.

2.1.3 One-hop relay schemes

In this scheme, the source delivers a packet to an intermediate node, which in turn delivers the same to the destination. Compared to direct-contact, this scheme only incurs an overhead of one additional copy of a packet. A large number of application scenarios have employed this scheme for successful data delivery. The mobility of the relay node may be controlled or random.

The Paper Message Ferries [13] captures a more generalized scenario where the movement of the ferries can be controlled to carry data from a source node to a destination node. The initial proposal for ferries assumed that the nodes had limited resources, were stationary, and consequently were not burdened with the routing functionality. However, in follow-up works, the authors [14] extend the scheme to networks with mobile nodes and multiple ferries. This scheme requires online collaboration between the ferries and mobile nodes. The nodes need to proactively move so as to intersect with the path chosen by the ferries to transfer data to the latter. This assumption in turn was relaxed in a recent study where the message ferry routes were designed based on the mobility model of the nodes and probabilistic node locations [15].

2.1.4Routing based on knowledge oracles

[16] The paper presents a family of algorithms for routing in delay tolerant networks based on the presence of knowledge oracles. They model the DTN as a directed multigraph with time-varying edge costs, based on propagation delay and edge capacity. The various knowledge oracles considered provide information about the following:

(a) All future contacts of nodes such as time of contact, duration of contact, bandwidth available for information exchange during contact,

(b) The future traffic-demand of the nodes,

(c) The instantaneous queue sizes at each node.

Using information from one or more oracles, various algorithms have been designed to send data from a source to a destination along a single path using either source-routing or local-per-hop routing. The authors have extended Dijkstra’s shortest path algorithm to use time-varying edge costs. The performance of algorithms has been evaluated via simulations using a discrete-event simulator. The authors also present a linear programming formulation that uses all the oracles to determine the optimal routing for minimizing average delay in the network. The solution to this optimization serves a base-line optimum. The results indicate that as algorithms are fed more knowledge from the oracles, they provide better performance.

2.1.5 Location-based schemes

In certain scenarios, the nodes may be aware of their location which can be used for opportunistic forwarding in DTNs. The location information may be known in either a physical (from GPS devices attached to nodes or through a location service) or a virtual coordinate space (designed to represent network topology taking obstacles into account). On an encounter, a node forwards data to another node only if it is closer to the destination.

The author proposes a framework for routing in DTNs, called MobySpace, where each node is represented by a point in a multi-dimensional Euclidean virtual space [17].

Routing is done by forwarding messages toward nodes that have mobility patterns that are more and more similar to the mobility pattern of the destination. The authors demonstrate the feasibility of this framework through an example in which each dimension represents the probability for a node to be found in a particular location.

2.1.6 Gradient-based schemes

In gradient-based routing, the message follows a gradient of improving utility functions toward the destination thereby delivering the packet with a low delay and using minimal system resources.

Gradient based routing is also sometimes called adaptive routing since the metrics used for routing decisions essentially capture the context information of the nodes such as the rate of change of connectivity of a host and its current energy level [18].

Gradient-based routing schemes suffer from a slow-start phase. Sufficient number of encounters must happen before the nodes develop meaningful metrics for each destination. This scheme initially forwards the message picking a neighbor at random until the metric utility value reaches a certain threshold [19]. Thereafter a gradient-based approach may be employed to deliver the message to the destination.

2.1.7 Controlled replication schemes

Compared to traditional epidemic routing based schemes and its variants that rely on reducing the consumption of network resources, Spray and Wait presents a novel way to achieve efficient routing in DTNs [20]. The idea is that it reduces the number of copies of a given message, and hence the number of transmissions for a given message to a fixed valuethat can be tuned in accordance with the delivery delay requirement. The scheme ‘sprays’ a number of copies of a message into the network to distinct relays and then ‘waits’ till one of these relays meets the destination.

2.1.8 Network coding based schemes

As opposed to the traditional model of forwarding in DTNs where nodes may forward the entire copy of the message to encountered relays, an alternate approach is to employ network coding based schemes. The authors provide an erasure-coding based approach to forward data in DTNs [21]. The idea is that the source node encodes a message and generates a large number of code blocks guided by a replication factor (*r*). The generated code blocks are then equally split among the first $k \cdot r$ relays, for some constant *k*, and those relays must deliver the coded blocks to the destination directly. The original message can be decoded once $1/r$ coded blocks have been received. Such a scheme is more robust to failures of a few relays or some bad forwarding choices. The authors demonstrate via simulation evaluation with both synthetic and real world traces that this scheme achieves better worstcase delay performance that existing approaches with a fixed overhead.

2.2 Comparison between Data Delivery Mechanism

Table 1: Comparison of various Data Delivery Scheme

Algorithm Scheme	Advantages	Disadvantages
Epidemic routing Scheme	Easiest, Simple, Flooding technique	No knowledge about the network or the nodes, Inefficient use of power, bandwidth & buffer at each node
Direct-Contact routing Scheme	Simple, Do not consume additional resources & makes no additional copies of data	Delivery delay can be extreme large
One-hop Relay routing Scheme	Successful delivery of data	High cost of data delivery delay
Routing based on knowledge Oracle Scheme	Presence of knowledge oracles, Better performance	Large storage constraints required
Location Based routing Scheme	Aware of location of nodes in the network	suffer from a local minima phenomenon
Gradient based routing Scheme	Improving utility function, Delivery packet with low delay & using minimal system resources.	Slow start phase
Controlled-replication routing Scheme	Reducing the consumption of network resources	Wait for the destination
Network-Coding based routing Scheme	Encoding & decoding of message, Robust to failures of a few relays.	receiver reconstructs the original message

2.3 Issues

There are several issues in delay tolerant network that needs to be addressed. Some of them are described as per below:

a) **Encounter Schedule:** In order to send the data from source to destination, the node can wait till it encounters the destination node and after that directly deliver the packet to the destination. However, this approach may take a long time and may not even happen. But the encounter schedule is very crucial factor, because the delivery of messages depends upon the schedule of the encounter.

b) **Network Capacity:** Generally, the duration of an encounter as well as the bandwidth of the network, are the main factors that tells the amount of packets that can be transferred from one node to another node. But the capacity of underlying network is also a vital factor for determining the amount of data that can be delivered. If during an encounter multiple nodes tries to forward data, the network may become congested. Thus, this factor determines whether a message needs to be fragmented or not in order to send it from source to the destination.

c) **Energy:** The transmission of packets as well as the computation carried out at nodes, consumes a significant amount of energy. In some cases, such as battery operated wireless sensor networks, the resources may be highly constrained where it is important to take into account the residual energy of a node while determining whether to exchange data during an encounter. So the energy is an important issue in delay tolerant networks that needs to be considered. However, in case of vehicular ad-hoc networks, the constraint on power may not be as severe as in case of delay tolerant network.

d) **Storage Capacity:** The storage capacity of nodes is limited. Whenever an encounter occurs, the nodes try to exchange all the data they currently carry with them. Therefore, if the nodes are storage constrained, the node buffers will overflow and it will result into packet loss.
Therefore, the approach of exchanging all the data during an encounter may not be applicable in all the applications. Certain intelligent schemes are needed that restrict the number of copies of the packets, as well as the schemes that delete the data that has already been delivered to the destination.

III. Proposed Algorithm

The Algorithm focusses mainly on energy efficiency by reducing the average number of messages forwarded from source to destination. It is assumed that the nodes are mobile in 100cm by 100cm area.

Algorithm :
1.Each node has to maintain a table which contains the details about the nodes which are currently in contact and the nodes which were in contact previously. The entries in the table are as follows (node id, node availability, last contact time, list of nodes in contact with this node). 2.From row in table entry of source node(S), the node (N) with shortest distance is selected. 3. If this node N is destination then Stop else go back to step 2.

The proposed algorithm has the following Tradeoff:
a) Table size which is stored in every node occupies space.
b) Updation of table is dynamically due to change in location of the node.

IV. Simulator

The Opportunistic Network Environment (ONE) is a Java based simulator targeted for research in Delay Tolerant Networks (DTNs). Apart from letting a user to simulate different scenarios quickly and in a flexible manner, it also provides an easy way to generate
Statistics from the simulation performed. The ONE
simulator could be run on Linux, Windows, or any other platform supporting Java [22].
The ONE is a simulation environment that is capable of

a) Generating node movement using different movement models.

b) Routing messages between nodes with various DTN routing algorithms and sender and receiver types.

c) Visualizing both mobility and message passing in real time in its graphical user interface.

V. Conclusion

In this paper, we have studied various routing protocols for DTNs. Choosing the correct routing schemes and combining them to the suitable routing method,improves the performance of DTN. And also various real life applications are mapped on major DTN routing schemes according to some influential network attributes and characteristics that are related particularly to the type of application. The algorithm considering the shortest route node in the mobile node scenario is presented along with the tradeoffs.

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