ROUTING STRATEGY IN DELAY TOLERANT NETWORK

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Abstract: This paper provides an introduction to Delay Tolerant Networks (DTN) and would touch upon some basic features. Continuous connectivity is difficult in today's wireless world. The data preservation and security in challenged and intermittent network, is of paramount importance. In this paper, we will see how DTN provides an effective alternative. This will also try to explain basic architecture of DTN and routing techniques that can be incorporated for effective data forwarding. Security of data becomes important in disrupted networks; this paper would also discuss security concerns with DTNs. This paper also discusses possible applications and areas where DTN can be effectively used.

Keywords: Bundle Protocol, Contact Patterns, DTN, Flooding, Forwarding, Routing

1. Introduction

Internet has been successfully connecting communicating devices worldwide today. TCP/IP protocol suite plays most important role in achieving this effectively. Every device on the countless sub-networks that comprise the Internet makes use of this protocol for data transfers from source to destination with the minimal possible delay and high reliability. End to end data transfer is the basic principle on which TCP/IP is based on. However assumptions of internet cannot hold in many regions. If there instances where end-to-end connectivity is broken or intermittent, then TCP/IP may not work correctly and reliably, in many cases it can completely fail to transfer data from source to destination [1]. Basically internet (TCP/IP protocol) works based on certain assumptions:

- End-to-end path between source and destination exists for the duration of a communication session
- Retransmissions based on timely and stable feedback from data receivers is an effective means for repairing errors
- End-to-end loss is relatively small
- All routers and end stations support the TCP/IP protocols
- Applications need not worry about communication performance
- Endpoint-based security mechanisms are sufficient for meeting most security concerns
- Packet switching is the most appropriate abstraction for interoperability and performance
- selecting a single route between sender and receiver is sufficient for achieving acceptable communication performance

Such networks suffer from frequent temporary partitions which can be termed as Intermittently Connected Networks (ICNs).[3] This problem occurs mainly in remote areas, or villages that lack basic infrastructure to support internet. Due to such circumstances, a newer network has evolved which is independent of end-to-end connectivity between nodes. This network is called as Delay Tolerant Networks (DTN).Delay Tolerant Networking (DTN)[5] is an approach to computer network architecture that aims to address the technical issues in heterogeneous networks that experience lack of continuous network connectivity. Delay Tolerant Networks (DTNs) enable data transfer when mobile nodes are only intermittently connected. Since the connectivity is not expected to be consistent in DTN, it employs what is called a store-carry-and-forward routing mechanism. In this, the intermediate mobile nodes carry data packets when they receive it and forward it to the next node as and when contact is established. As DTN depends on mobile nodes to carry data, the performance of routing the data solely depends on whether the nodes come in contact with each other or not.

2. Delay Tolerant Network

Delay tolerant networks (DTNs) represent a class of wireless systems that virtually need minimum to none infrastructure and would support the functionality of networks experiencing frequent and long lasting partitions.[9] DTNs are intended to deal with scenarios involving heterogeneity of standards, intermittent connectivity between adjacent nodes, lack of *contemporaneous* end-to-end links and exceptionally high delays and error-rates. Also the mobile nodes available in challenged environments can be extremely limited in their resources; such as CPU processing power, memory and network capacity. As DTNs are expected to tackle such dared environments, they are usually intended to achieve interoperability and eventual connectivity to a range of complex applications that include:

- Wireless sensor networks (WSNs) deployed in wildlife tracking or in extreme regions (e.g. volcanic and underwater areas).
- Mobile Ad-Hoc networks connecting remote and rural communities via GPSs, cellular devices and portable storages.
- Exotic Media Networks (EMNs) interconnecting extra-terrestrial nodes such as satellites and deep space probes in Inter-Planetary Networks (IPNs).

Each of the potential field of applications mentioned above is intended to operate under stressful circumstances and in environments that are considered to be challenging for ordinary wireless nodes within a traditional network settings[3]. DTN architecture represents an attempt to extend the reach of networks. It promises to enable communication between instances of such challenged networks and to act as an integral platform between instances that originally adopt heterogeneous or inconsistent standards, even if they exist in territories lacking a proper communication infrastructure. The main purpose of the DTN approach is to provide a means for message delivery in such challenged settings.

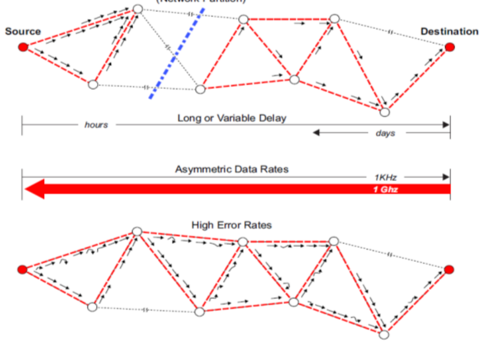
2.1 Architecture of Delay Tolerant Network

The architecture of DTN is designed in such a way that it counters most of the assumptions and conditions that traditional TCP/IP based networks are based on. DTN architecture is based on following design principles:

- Use variable-length (possibly long) messages (not streams or limited-sized packets) as the communication abstraction to help enhance the ability of the network to make good scheduling/path selection decisions when possible.
- Use a naming syntax that supports a wide range of naming and addressing conventions to enhance interoperability.
- Use storage within the network to support store-and-forward operation over multiple paths, and over potentially long timescales (i.e., to support operation in environments where many and/or no end-to-end paths may ever exist); do not require end-to-end reliability.

Provide security mechanisms that protect the infrastructure from unauthorized use by discarding traffic as quickly as possible.

- Provide coarse-grained classes of service, delivery options, and a way to express the useful lifetime of data to allow the network to better deliver data in serving the needs of applications



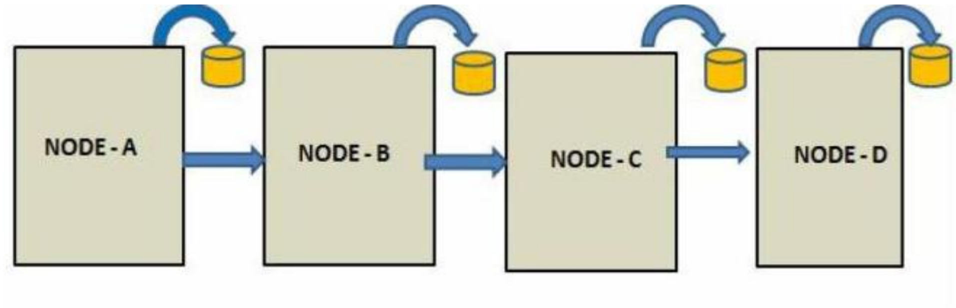
2.1.1 Concept of Bundle Protocol :

A Delay Tolerant Network can be considered as an overlay on the existing regional networks. This overlay is called as the bundle layer[2]. 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.

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.), a bundle header. Besides Bundle transfer, custody transfer is also done. The custodian node for a bundle keeps the message until it is successfully transferred to the next node and it takes the custody for that message or until the TTL of the message expires

2.1.2 Store and Forward Technique :

Delay Tolerant Networks have overcome the problems associated with the conventional protocols in terms of lack of connectivity, irregular delays, asymmetric bidirectional data rates etc. using the concept of store and forward. The method of store and forward is very analogous to the real life postal service. Every letter has to pass through a set of post offices, here it is processed and forwarded, before reaching the destination. Here the complete message or a chunk of it is transferred and stored in nodes successively until it reaches the destination. The following figure gives a rough graphical representation of how a message is propagated through a network.



2.1.3 Types of Contacts

Store and forward mechanism solely depends on whether or how the nodes make contact with each other. Contacts typically fall into one of several categories, based largely on the predictability of their performance characteristics and whether some action is required to bring them into existence. Following are major types of contacts that can be defined:

2.1.4 Persistent Contacts

Persistent contacts are always available (i.e., no connection-initiation action is required to instantiate a persistent contact). An 'always-on' Internet connection such as a DSL or Cable Modem connection would be a representative of this class.

2.1.5 On-Demand Contacts

On-Demand contacts require some action in order to instantiate, but then function as persistent contacts until terminated. A dial-up connection is an example of an On-Demand contact (at least, from the viewpoint of the dialer; it may be viewed as an Opportunistic Contact, below, from the viewpoint of the dial-up service provider).

2.1.6 Intermittent - Scheduled Contacts

A scheduled contact is an agreement to establish a contact at a particular time, for a particular duration. An example of a scheduled contact is a link with a low-earth orbiting satellite. A node's list of contacts with the satellite can be constructed from the satellite's schedule of view times, capacities, and latencies. Note that for networks with substantial delays, the notion of the "particular time" is delay-dependent. For example, a single scheduled contact between Earth and Mars would not be at the same instant in each location, but would instead be offset by the (non-negligible) propagation delay.

2.1.7 Intermittent - Opportunistic Contacts

Opportunistic contacts are not scheduled, but rather present themselves unexpectedly. For example, an unscheduled aircraft flying overhead and beaconing, advertising its availability for communication, would present an opportunistic contact. Another type of opportunistic contact might be via an infrared or Bluetooth communication link between a personal digital assistant (PDA) and a kiosk in an airport concourse. The opportunistic contact begins as the PDA is brought near the kiosk, lasting an undetermined amount of time (i.e., until the link is lost or terminated).

2.1.8 Intermittent - Predicted Contacts

Predicted contacts are based on no fixed schedule, but rather are predictions of likely contact times and durations based on a history of previously observed contacts or some other information. Given a great enough confidence in a predicted contact, routes maybe chosen based on this information.

3. Routing in DTN:

Routing has to find a good path to a designated endpoint, but concurrently to deal with a resource shortage[6]. In an optimal case, all data can be delivered and the protocol finds the fastest and shortest path between the two involved nodes. In the real world or even in simulations restrictions occur, or are defined and therefore initiate the need for economical usage of resources. Depending on the application using the DTN, it can be useful to drop packets and free buffers quite early to give newly sent packets a good
chance to be delivered in time while, on the other hand, it may be important to deliver as many packets as possible, no matter how long it lasts.[12]

In the next few sections, we briefly discuss some currently used techniques for routing in DTNs followed by some analysis comparing the different techniques studied. We briefly discuss some currently used techniques for routing in DTNs followed by some analysis comparing the different techniques studied.

4. Routing Techniques

4.1 Direct delivery:

In this technique [9,10] the source waits until it comes into contact with the destination before forwarding the data. This technique uses minimal resources since each message is transmitted at most once.

4.2 First contact:

In this technique [8], a message is forwarded along an edge chosen randomly among all the current contacts. If all edges are currently unavailable, the message waits for an edge to become available and is assigned to the first available contact.

4.3 Message ferries [MF]:

In this technique [12], MF, the network devices are classified as *message ferries* (or *ferries* for short) or *regular nodes* based on their roles in communication. Ferries are devices which take responsibility of carrying messages among other nodes, while
regular nodes are devices without such responsibility. With knowledge about ferry routes, nodes can adapt their trajectories to meet the ferries. By using ferries as relays, nodes can communicate with distant nodes that are out of range.

4.4 Throw boxes:

In this technique [1], small and inexpensive devices equipped with wireless interfaces and storage are used. Throw boxes are stationary, thus when two nodes pass by the same location at different times, the throw box acts as a relay, creating a contact opportunity where none existed before. Throw boxes are most useful for routing algorithms that use multi-path routing and when nodes follow structured mobility patterns. Throw box deployment that incorporates knowledge about contact opportunities perform better than deployment that ignores this knowledge.

4.5 Forwarding approach

In this technique, single copy of the message packet is routed and transmitted during the communication process. The message packet is forwarded by routing towards a reliable relay node, avoiding duplication of message packets.

4.6 Seek and Focus*:*

This technique [4], adopts utility-based/application based as well as randomized routing. By this, they can overcome the slow-start phase and routing jamming by local maximization of utility. The initial step involves discovery of a potential relay neighbor by using the utility-based approach. This helps to avoid being struck for a long time at local maximum of utility, randomized routing is applied in the re-seek phase.

4.7 Moby Space:

This technique [13] utilizes a generic routing scheme, using high dimensional Euclidean space. The main routing idea is that the packet should be forwarded to the node having mobility pattern similar/matching to packet's destination. Since in the Moby Space, the mobility pattern of a node provides its coordinates, its Moby Point, routing is done by forwarding bundles toward nodes that have their Moby Point closer and closer to the Moby Point of the destination.

4.8 Epidemic Routing:

In this technique [6], when a message is sent, it is placed in the local buffer and tagged with a unique ID. When two nodes connect, they send each other the list of all the messages IDs they have in their buffers, called the summary vector. Using the summary vector, the nodes exchange the messages they do not have. When this operation completes, the nodes have the same messages in their buffers. This provides a large amount of redundancy since all nodes receive every message, making this strategy extremely robust to node and network failures. Additionally, since it tries every path, it delivers each message in the minimum amount of time if there are sufficient resources.

4.9 Prophet (Probabilistic Routing Protocol using a History of Encounters and Transitivity):

In this technique [3], when a message arrives at a node which does not have an available contact with other node, it must be stored in the buffer until the node encounters with another node. It only admits that a node can receive the message when its delivery
probability exceeds the threshold.

4.10 Spray and Wait*:*

In this technique [14], in spray phase, spread L message copies to L distinct relays and in wait phase; wait until one of the L relay finds the destination(i.e. direct transmission). It significantly reduces the transmission overhead of flooding-based scheme. The minimum number of copies needed for Spray and Wait to achieve an expected delay is independent of network size and transmission range and depends on number of nodes.

4.10 Spray and Focus:

This technique [15] aims at improving the protocol of Spray and Wait for mobile users with localized mobility. The difference between them is that the message carrier in Spray and Focus will forward the copy to another suitable neighbor if they have not encountered the destination for a long time.

4.11 Simple replication*:*

In this technique [11], identical copies of the message are sent over the first r contacts, with r known as the replication factor. Only the source of the message is permitted to transmit/sends multiple copies, while the relay nodes are allowed to send /forward only to the destination; they cannot forward it to another relay. This makes a mixture between direct delivery and flooding.

4.12 History based simple replication:

In this technique [11,16], the source creates "*r*" identical copies of a message, which are then delivered to the "best" *r* nodes, where quality is determined by history. The intermediate nodes will then individually carry out Direct Delivery.

4.13 Erasure Coding:

In this technique [17], first encode the message at the source and generate a large number of code blocks. The generated code blocks are then equally split among the first *kr* relays, for some constant *k*, r is replication factor. The message can be decoded at the destination if $1/r$ of the generated code blocks is received. Since code blocks are divided equally among *kr* relays, the message can be decoded as soon as any *k* relays deliver their data if we assume that no code blocks are lost during transmissions to and from a relay.

4.14 EBEC (Estimation-based erasure coding):

In this technique [18]**,** message is divided into K blocks. For each message, the source takes a replication factor R and erasure codes R x K equal sized blocks. When two nodes encounter, these message blocks are re-dispatched between them according to their estimation values. The message can be fully decoded at the destination if at least K generated blocks is received. Note that since each message block is 1/K of the size of the original message, it generates the same overhead as simply replicating R copies of the message.

4.15 Island Hopping:

In this technique [19], routing protocol relies on the clusters in network. Through the analysis of mobility trace, the authors introduce a novel model with stable Concentration Points (CP) in which the nodes are assumed to communicate only in same CP. The routing algorithm first discovers the whole graph collaboratively in order to employ a sequence of CPs to forward message. The discovery of such a graph consists of two steps: vertex labeling, which can identify each CP that needs to be stitched and edge discovery that can estimate the edge, sets of possible CP graph. After each node knows the graph and respective position – trace or connecting-the-dot, an approach called Last Encounter Table is used to estimate the position of destination. Then the next CP is decided by taking advantage of the shortest path between the source and destination. During the message forwarding, message copies at each CP followed by one hop acknowledgment scheme makes sure the reliability of transmission. At the same time, the suppression mechanism works when an earlier copy appears in the same CP. The foundation of this algorithm is based upon a stable topology of concentration points (CP's). In an unstable topology, or where group movement of nodes is involved, the performance of such algorithm suffers.

4.16 Mobile vehicle routing:

In this technique [20], the routing decision is based on finding a peer having maximum probability of visiting the region of the destination. Both the source and the selected node try to perform Direct Delivery to the destination, this act results in slightly higher resource consumption than Direct Delivery alone.

4.17 Maxprop:

This technique [7], attempts to forward the message to any device in the network having maximum probability of delivering the message to destination. Maxprop process involves calculating the path for each message at each transfer opportunity using a modified Dijkstra algorithm with history as pivotal criterion. Maxprop defines its own way of computing history to dictate the channel path computation. Further it assumes that the network topology on which it is operating does not consume bandwidth. It also incorporates a fancy mechanism of message queuing at peer level that prefers the newly born messages and degrades the priority of messages based on the number of hops they have traveled and the delivery probability [13]. Even without the computational complexity of erasure coding, Maxprop is hungry for processing resources as the maintenance of the local queue is expensive for mobile devices under high message counts.

4.18 Earliest Delivery:

In this technique [8], path of a message is computed using modified Dijkstra algorithm, where the link costs represent the waiting time for the next contact between the vertices. It assumes a contact oracle, which has perfect foresight of future node encounters, equivalent to knowing the time-varying DTN multigraph. This algorithm is bound to perform better than all of the others because it has the unrealistic knowledge of the future, BUT NOT NECESSARILY TRUE. A message may still fail to reach the destination due to complete lack of a path to destination or congestion.

5. Conclusion

In this paper we have describe different routing techniques; leading to identification of critical & explicit parameters of each of the technique studied and described in some detail.. This is followed by an executive summary of the various routing techniques/schemes studied along with parameter details like mobility models, application environment and protocols captured Mobility model based on simulation depicts the movement patterns of mobile nodes; data. In this paper we have tried to provide the architecture and routing protocols of DTN in a brief manner which will provide the basic knowledge to the reader about the DTN.

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