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Delay Tolerant Network

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Abstract:
The evolution of wireless devices along with the increase in user mobility has created new challenges such as network partitioning and intermittent connectivity. These new challenges have become apparent in many situations where the transmission of critical data is of high priority. The challenge of establishing communication between devices where end to end connectivity is not possible has led to an evolutionary form of networks called Delay Tolerant Networks (DTNs). Networks with frequent and long duration partitions prevent common Internet protocols from working successfully. This occurs in situations in which no stable infrastructure exists that can guarantee permanent link connectivity. The Internet protocols are not useful for DTNs because link disruptions are not properly handled, causing protocols to timeout and abort. For reliable communication, DTNs use store and forward approach thus routing hop by hop. DTNs use replication and knowledge based protocols for routing. Epidemic routing protocol discussed has least message delivery delay but uses more number of redundant message copies. We propose a protocol which is an improvement over epidemic routing by drastically reducing the number of redundant message copies with appreciable delay.

1. Introduction

In the 1970s, spurred by the micronization of computing, researchers began developing technology for routing between non-fixed locations of computers. While the field of ad-hoc routing was inactive throughout the 1980s, the widespread use of wireless protocols reinvigorated the field in the 1990s as mobile ad-hoc networking (MANET) and vehicular ad-hoc networking became areas of increasing interest. Concurrently with (but separate from) the MANET activities, DARPA had funded NASA, MITRE and others to develop a proposal for the Interplanetary Internet (IPN). Internet pioneer Vint Cerf and others developed the initial IPN architecture, relating to the necessity of networking technologies that can cope with the significant delays and packet corruption of deep-space communications. In 2002, Kevin Fall started to adapt some of the ideas in the IPN design to terrestrial networks and coined the term delay-tolerant networking and the DTN acronym. A paper published in 2003 SIGCOMM conference gives the motivation for DTNs. The mid-2000s brought about increased interest in DTNs, including a growing number of academic conferences on delay and disruption-tolerant networking, and growing interest in combining work from sensor networks and manets with the work on DTN. This field saw many optimizations on classic ad-hoc and delay-tolerant networking algorithms and began to examine factors such as security, reliability, verifiability, and other areas of research that are well understood in traditional computer networking. The ability to transport, or route, data from a source to a destination is a fundamental ability all communication networks must have. Delay and disruption-tolerant networks (DTNs), are characterized by their lack of connectivity, resulting in a lack of instantaneous end-to-end paths. In these challenging environments, popular ad hoc routing protocols such as AODV and DSR fail to establish routes. This is due to these protocols trying to first establish a complete route and then, after the route has been established, forward the actual data. However, when instantaneous end-to-end paths are difficult or impossible to establish, routing protocols must take to a "store and forward" approach, where data is incrementally moved and stored throughout the network in hopes that it will eventually reach its destination A common technique used to maximize the probability of a message being successfully transferred is to replicate many copies of the message in the hope that one will succeed in reaching its destination. This is feasible only on networks with large amounts of local storage and internode bandwidth relative to the expected traffic. In many common problem spaces, this inefficiency is outweighed by the increased efficiency and shortened delivery times made possible by taking maximum advantage of available unscheduled forwarding opportunities. In others, where available storage and internode throughput opportunities are more tightly constrained, a more discriminate algorithm is required.

2. Delay Tolerant Network

Delay Tolerant Networking (DTN) is an approach to computer network architecture that seeks to address the technical issues in heterogeneous networks that may lack continuous network connectivity.

- THE CONCEPT OF DTNs
  A Delay Tolerant Network (DTN) is a network of regional networks. It is an overlay on top of regional networks, including the Internet. DTNs support interoperability of regional networks by accommodating long delays between and within regional networks, and by translating between regional network communications characteristics. In providing these functions, DTNs accommodate the mobility and limited power of evolving wireless communication devices. [1]. The wireless DTN technologies may be diverse, including not only radio frequency (RF) but also ultra-wide band (UWB), free space optical, and acoustic (sonar or ultrasonic) technologies. [1]

3. Today's Internet

Communication on the Internet is based on packet switching. Packets are pieces of a complete block of user data (eg: pieces of an email messages or a web page) that travel independently from source to destination through a network of links connected by routers. The source, destination, and routers are collectively called nodes. [1]Each packet that makes up a message can take a different path through the network. If one link is disconnected, packets take another link. Packets contain both application program user data (the payload part) and a header (the control part). The header contains a destination address and other information that determines how the packet is switched from one router to another. The packets in a given message may arrive out of order, but the destination's transport mechanism reassembles them in correct order. The usability of Internet depends on some important assumptions:

- Continuous, bidirectional end-to-end path: A continuously available bidirectional connection between source and destination to support end-to-end interaction.
- Short round trips: Small and relatively consistent network delay in sending data packets and receiving the corresponding acknowledgement packets.
- Symmetric data rates: Relatively consistent network delay in both directions between source and destination.
- Low error rates: Relatively little loss or corruption of data on each link

4. Literature Survey

Many evolving and potential networks do not conform to the Internet's underlying assumptions. These networks are characterized by:

- **Intermittent Connectivity**: If there is no end-to-end path between source and destination, called network partioning. End-to-end communication using the TCP/IP protocols does not work.

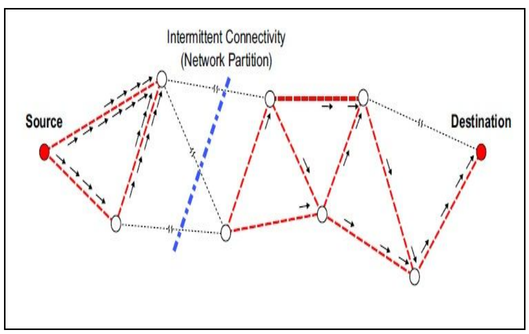

Figure 1: Intermittent connectivity

The intermittent connectivity is represented by the blue line as shown in figure 1. It occurs due to high mobility of nodes.

- **Long or variable delay**: In addition to intermittent connectivity, long propagation delays between nodes and variable queuing delays at nodes contribute to end to end path delays that can fail the working of applications that rely on quick return of acknowledgements or data. [1] Earth & Mars are at 4 light minutes at closest approach and 20 light minutes when they are at farthest point. If we consider data packet transfer from Earth to Mars using existing TCP/IP based protocols, it takes hours together just to initiate 3 way hand shake, hence the delay could become in terms of hours or days as shown.
- **Asymmetric data rates**: The Internet supports moderate asymmetries of bidirectional data rate for users with cable TV or asymmetric DSL access. But if asymmetries are large, they interrupt proper operation of protocols.

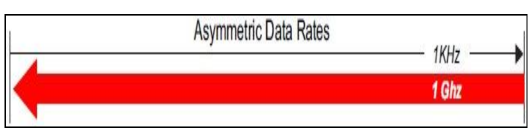

Figure 2: Asymmetries data rate

The figure 2 shows the data rate asymmetries in uplink and downlink.

- **High error rates**: Bit errors on links require correction (which requires more bits and more processing) or retransmissions of the entire packet (which results in more network traffic). For a given link error rate, fewer retransmissions are needed for hop-by-hop than for end-to-end retransmission (linear increase v/s exponential increase).

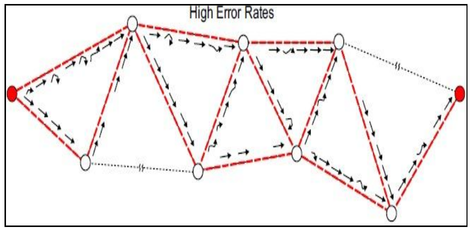

Figure 3: Bit errors at intermediate nodes

As we can see in the figure 3,that bit errors occur at intermediate nodes, retransmission of same packet from source increases congestion in network.

DTNs overcome the problems associated with intermittent connectivity, long or variable delay, asymmetric data rates, and high error rates by using store-and-forward message switching. Whole messages (entire blocks of application program user data) or pieces (fragments) of such messages are moved (forwarded) from a storage place on one node to storage space on another node, along the path that eventually reaches the destination. The storage places (such as hard disk) can hold messages indefinitely. They are called as 'persistent storage', as opposed to very short term storage provided by memory chips [5]. Internet routers use memory chips to store (queue) incoming packets for a few milliseconds while they are waiting for their next hop routing and an available outgoing router port.

DTN routers need persistent storage for their queues for one or more of the following reasons:

- A communication link to the next hop may not be available for a long time.
- A node in a communicating pair may send or receive data much faster or more reliably than the other node.
- A message, once transmitted, may need to be retransmitted if an error occurs at a node or link, or if a node declines acceptance of a forwarded message.

By moving whole messages (or fragments thereof) in a single transfer, the message switching technique provides network nodes with immediate knowledge of the size of messages, and therefore the requirements for immediate storage space and retransmission bandwidth.

5. DTN Architecture

The DTN architecture implements store-and-forward message switching by overlaying a new protocol layer called the 'bundle layer' on top of heterogeneous region specific lower layers. The bundle layer ties together the region specific lower layers so that application programs can communicate across multiple regions.[1,2] Application layer messages are divided into chunks called bundles. The bundle layer stores and forwards entire bundles (or bundle fragments) between nodes. A single bundle layer protocol is used across all networks (regions) that make up a DTN. By contrast, the layers below the bundle layer (the transport layer and below) are chosen for their appropriateness to the communication environment of each region.

The figure 4 below illustrates the bundle overlay (top) and compares Internet protocol layers with DTN protocol layers (bottom).

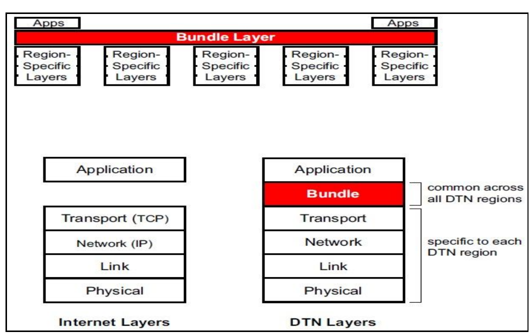

Figure 4: Comparison of Bundle and Internet layers

Bundles consist of three things: (1) A source application's user data, (2) Control information, provided by the source application for the destination application, describing how to process, store, dispose of, and otherwise handle the user data, and (3) A bundle header, inserted by the bundle layer. Like application program user data, bundles can be arbitrarily long. A bundle layer breaks whole bundles into fragments, just as an IP layer may break whole datagrams into fragments. If bundles are fragmented, the bundle layer at the final destination reassembles them.

DTNs support node-to-node retransmission of lost or corrupt data at both the transport layer and the bundle layer. However, because no single transport layer protocol (the primary means of reliable transfer) operates end-to-end reliability can be implemented only at the bundle layer. The bundle layer supports node-to-node retransmission by means of custody transfers. Such transfers are arranged between the bundle layers of successive nodes, at the initial request of the source application. When the current bundle layer custodian sends a bundle to the next node, it requests a custody transfer and starts a time-to-acknowledgement retransmission timer. If the next hop bundle layer accepts the custody, it returns an acknowledgement to the sender. If no acknowledgement is returned before the sender's time-to-acknowledgement expires, the sender retransmits the bundle. The value assigned to the time-to-acknowledge retransmission timer can be either be distributed to nodes with routing information or computed locally, based on past experience transmitting to a particular node.

A bundle custodian must store a bundle until either (1) Another node accepts custody, or (2) Expiration of the bundle's time-to-live, which is intended to be much longer than a custodian's time-to-acknowledge. However, the time-to-acknowledge should be large enough to give the underlying transport protocols every opportunity to complete reliable transmission. The Custody transfers do not provide guaranteed end-to-end reliability. This can be done only if a source requests both custody transfer and return receipt. In that case, the source must retain a copy of the bundle until receiving return receipt and it will retransmit if it does not receive return receipt.

The bundle layer uses reliable transport layer protocols together with custody transfers to move points of retransmission progressively forward toward toward the destination. The advance of retransmission points minimizes the number of potential retransmission hops, the consequent additional network load caused by retransmissions, and the total time to convey a bundle reliably to its destination[5]. This benefits networks with either long delays or very lossy links. For paths containing many lossy links, retransmission retransmission requirements are much lower for hop-by-hop retransmission than for end-to-end retransmission.

6. Results

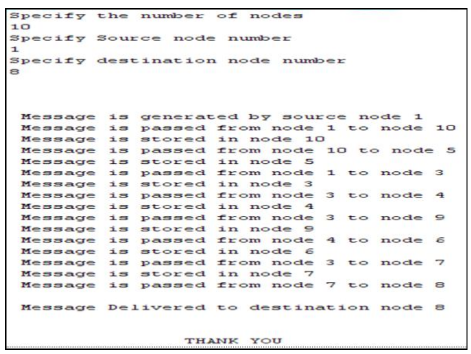

Figure 5: simulation result

The figure 5 shows the simulation result for source message node number one is passed to destination node number eight with least delay time

7. Conclusion

NDMR protocol achieves the objective of routing with less number of message copies with a delivery delay which is invariant to number of nodes.For higher communication radius, delay and number of message copies decrease exponentially, interestingly the delay becomes equal to that of least delay protocol (Epidemic Routing Protocol).NDMR protocol smartly chooses the next carrier node depending not only on node density but also on remaining battery power level.

8. References

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