RAPID : Resource Allocation Routing for DTN Paradigm

Disruption or Delay Tolerant Network is a new approach to handle data communication in challenged network. This network approach is used extensively in Inter-Planetary Network

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Project Details

1.   Introduction

1.1   Objective

We are attempting to explore an efficient way to deliver data in a challenged network using DTN paradigm.

1.2   Problem Description

A challenged network is the one that does not provide any reliability. Some of the typical reason for disruption could be: -

- Multiple disabilities
- Very high delay rate
- Temporary disconnection
- Asymmetrical bidirectional data-rate
- Mobile intermediate nodes

Communication has been an important tool of exploration and development of modern world. However, due to physical disabilities, it is difficult to provide reliable network in all the subsystems. With the exponential growth in wireless communication, connecting heterogeneous networks has become a serious challenge. Additionally, the quest to explore interplanetary network also demands advancement in the field of data communication.

Our existing protocols depend upon the assumptions that the network is reliable, has high good-put and a transmission delays are low. Clearly, it does not address or expects the challenge faced by modern communication. Hence, we need to develop new methods to tackle such problems. This includes writing new algorithm that specifically handles a challenged network.

Most of the algorithms currently in used for DTN routing are based on successful delivery of the data. Since the cost of sending the data is tremendous, these algorithms have only incidental effect on routing matrix. We indent to improve the efficiency of data transmission over DTN by considering routing as a resource allocation problem. This is essentially done by improving the routing matrix that is considered as a per packet utility.

1.3   Scope of Investigation

We are basically concerned with the improvement of specific routing matrix instead of concentrating on overall throughput. Also, with this project, we attempt to deploy a standard DTN2 infrastructure developed by DTN research group. However, since the infrastructure is open source, the documentation is not up-to-date. In case we are unable to deploy the infrastructure on time, we would attempt to simulate store and send custody transfer network. Later on, we would develop our routing algorithm on either of the infrastructure.

2.   Literature Review

2.1   Definition of the Problem

The electronic communication of TCP/IP protocol is characterized by relative small signal propagation latencies (on the order of milliseconds) and a continuous end-to-end connection. Moreover, the Internet routing system enables routers to choose the best paths for packet forwarding. However, such assumptions may not be appropriate when modelling existing and recently emerging wireless networks, especially those deployed in extreme environments (e.g. battle fields, volcanic regions, deep oceans, deep space, developing regions, etc.) where they suffer challenging conditions (e.g. military wars and conflicts, terrorist attacks, earthquakes, volcanic eruptions, floods, storms, hurricanes, severe electromagnetic interferences, congested usage, etc.) resulting in excessive delays, severe bandwidth restrictions, remarkable node mobility, frequent power outages and recurring communication obstructions. Nonetheless, enabling the proper operation and functionality under these challenging conditions pushed researchers to propose a new networking paradigm referred to in the open literature as a Delay- or Disruption-Tolerant Networking.

2.2   Theoretical Background of the Problem

Over the past few years, a new communication architecture called delay/disturb-tolerant networking (DTN) has been developed to combine the long link delay and frequent link disruptions that generally characterize space communications. DTN adopts a store-and forward custody transmission mechanism to deal with challenging environments. Each DTN node keeps a copy of every data packet sent until receiving an ACK confirming the packet has been received successfully from the next node in the end-to-end path. This ensures that no data packets are lost even if a router is temporarily out of sight due to occultation or rotation in space.

2.3   Related Research to Solve the Problem

There is lots of work on DTN routing algorithms. One of the simplest approaches is to let the source or a moving relay node carry the message all the way to the destination.

A faster way to perform routing in DTN is Epidemic routing. The basic idea of Epidemic routing is to select all nodes in the network as relays, say Epidemic routing being flooding based in nature, as nodes continuously replicate and transmit messages to newly discovered contacts that do not already possess a copy of the message. However, as messages are flooded to all other nodes, it is extremely wasteful of resources, such as batteries energy.

SprayAndWait is a routing protocol that attempts to gain the delivery ratio benefits of replication-based routing as well as the low resource utilization benefits of forwarding-based routing.

2.4   Advantage/Disadvantage

There are three major cases, classifying the level of mobility in the network. First, it is possible that there are no mobile entities. In this case, contacts appear and disappear based solely on the quality of the communication channel between them. For instance, in interplanetary networks, large objects in space, such as planets, can block communicating nodes for a set period of time. Second, it is possible that some, but not all, nodes in the network are mobile. These nodes, sometimes referred to as Data Mules, are exploited for their mobility. Since they are the primary source of transitive communication between

two non-neighboring nodes in the network, an important routing question is how to properly distribute data among these nodes. Third, it is possible that the vast majority, if not all, nodes in the network are mobile. In this case, a routing protocol will most likely have more options available during contact opportunities, and may not have to utilize each one. Advantages and disadvantages of some of the existing protocols in use are as follows:

Epidemic Routing Algorithm

Advantages:

- Epidemic Routing supports the eventual delivery of messages to arbitrary destinations with minimal assumptions regarding the underlying topology and connectivity of the underlying network.
- Epidemic Routing achieves eventual delivery of 100% of messages with reasonable aggregate resource consumption

Disadvantages:

- There is a tradeoff between memory and network resources allocated to Epidemic Routing and maximizing the percentage of delivered messages.
- There is a long latency delay because of replication at all nodes.

SprayAndWait

Advantages:

- Spray and Wait bounds the total number of copies and transmissions per message without compromising performance.
- Under low load, Spray and Wait results in much fewer transmissions and comparable or smaller delays than flooding-based schemes.
- It is highly scalable, exhibiting good and predictable performance for a large range of network sizes, node densities and connectivity levels; what is more, as the size of the network and the number of nodes increase, the number of transmissions per node that Spray and Wait requires in order to achieve the same performance decreases
- It can be easily tuned online to achieve given QoS requirements, even in unknown networks
- Under high load, it yields significantly better delays and fewer transmissions than flooding-based schemes

Disadvantages:

- Only source node is allowed to spray copies. Thus, it incurs considerable Delay.

2.5 Our Solution

Up till now, the routing algorithms designed for DTN has an Incidental effect on some of the routing matrix like worst-case delivery or fraction of packets delivered. Unfortunately, the burden of finding single path is so great that it has only an incidental effect on the routing matrix. We intend to present a solution that treats network routing as a resource allocation problem. We will be considering this matric as a "**per packet utility**" so that we can control the replication of individual packets.

3. Hypothesis

A resource allocation problem can deliver all data packages from the source to the destination with a feasible schedule of packet transfers, where feasible means that the total size of packets transferred during each opportunity is less than the size of the storage constraints.

4. Methodology

4.1 How to Generate/Collect Input Data

The following information will be given as input to the system: -

- Network Topology in form of network configuration files (.conf). This will generate a network graph that we eventually be routed as a graph routing problem.
- Test Data will be random raw bytes. This payload will be sent over DTN using store and send protocol as a custodial bundle.
- Contact Points will be given to the system to dynamically switch the graph according to node availability

4.2 Algorithm Details

Following is the algorithm details that we will implement using C++ programming language. We will use DTN2 infrastructure as a DTN network. We may try to simulate our own infrastructure in case the DTN2 doesn't provide facilities that we may need.

For minimizing average delay of packets, utility U_i of packet i is the negative of the expected delay to deliver i

$$T_{over} + T_{estimated} = Total\ Delay$$
$$\mathbf{U_i = -D(i)}$$

Let δU_i denote the increase in U_i by replicating i and S_i denote the size of i present in buffer.
Packet replication is in order of MAX($\delta U_i/S_i$) (highest marginal utility). In general, U_i = expected contribution of i to the given routing metric. Accordingly, the utility of a packet is its expected delay. Thus, rapid is a heuristic based on locally optimizing marginal utility, rapid replicates packets in decreasing order of their marginal utility at each transfer opportunity.

There are there major components of RAPID algorithm: -

- A *selection* algorithm - determine which packets to replicate if an opportunity is observed.
- An *inference* algorithm - estimate the utility of a packet given
- A *control channel* (We have already talked about this)

Each node X maintains a separate queue of packets Q destined to each node Z sorted in decreasing order of T(i) or time since creation

RAPID Protocol

rapid(X, Y)

1. *Initialization*: Obtain metadata from Y about packets in its buffer and metadata Y collected over past meetings.
2. *Direct delivery*: Deliver packets destined to Y in decreasing order of their utility.
3. *Replication*: For each packet i in node X's buffer
   - I.   If i is already in Y 's buffer (as determined from the metadata), ignore i.
   - II. Estimate marginal utility, δU_i, of replicating i to Y.
   - III. Replicate packets in decreasing order of $\delta U_i/S_i$

Termination: End transfer when out of radio range or all packets replicated
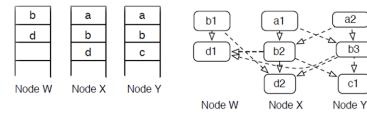
Algorithm Estimate Delay(X, Q,Z):

Node X with a set of packets Q to destination Z estimates the time, A(i), until packet i $\in$ Q is delivered to Z as follows:
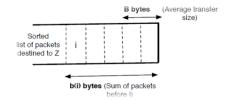
- Sort packets in Q in decreasing order of T(i). Let b(i) be the sum of sizes of packets that precede i, and B the expected transfer opportunity in bytes between X and Z (refer Figure 1).
- X by itself requires $[b(i)/B]$ meetings with Z to deliver i. Compute the random variable (Meeting Time between x and y) $M_X(i)$ for the corresponding delay as
  $M_X(i) = M_{XZ} + M_{XZ} + \ldots [b(i)/B]$ times (4)
- Let X1, . . . ,Xk $\supseteq$ X be the set of nodes possessing a replica of i. Estimate remaining time a(i) as
  $a(i) = \min(M_{X1}(i), \ldots ,M_{Xk}(i))$ (5)
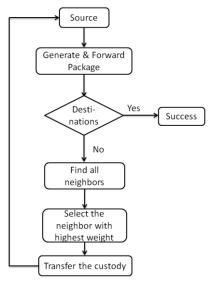- Expected delay D(i) = T(i) + E[a(i)]

(a) Packet destined to Z buffered at different nodes

(b) Delay dependancies between packets destined to node Z

Pic. 1 Illustration of RAPID protocol
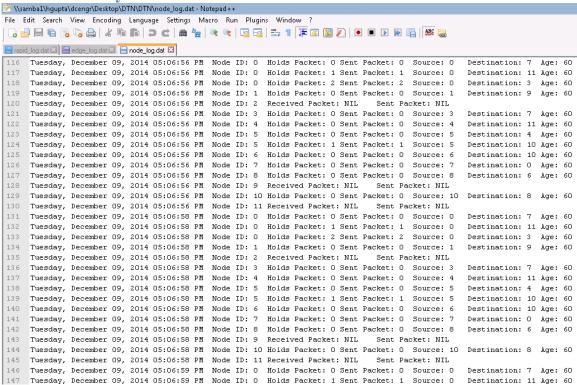
5.   Implementation

For source code, please refer to the code in the Appendices part, including all the source files and the header files.
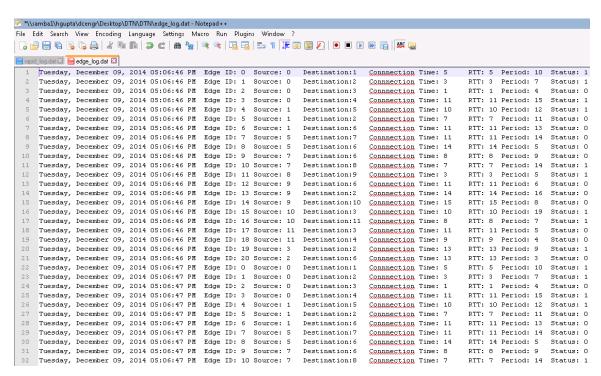

Pic. 2 Design Flow Chart

The Pic.2 shows our design flow chart. The source send the message packets out to all the connectted nodes and make the package finnaly arrive at the destination. The destination send the acknowledge out to all the nodes. In the meantime, the destination will compare the current routing withe the former routing stored. If it is a better routing, the routing information will update.
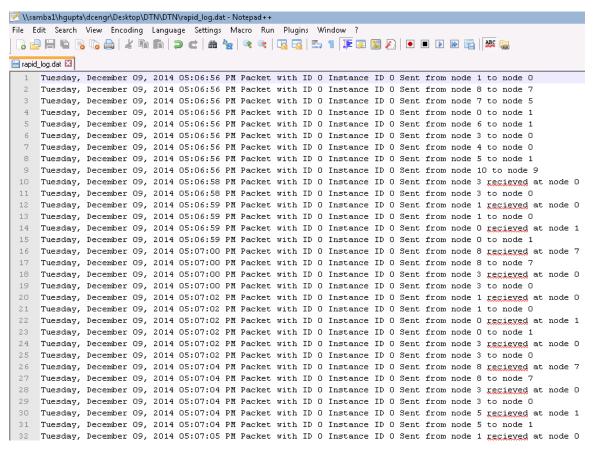
6. Data Analysis and Discussion

Pic. 3 Output of the nodes information

Pic. 4 Output of the edge information

Pic. 5 Output of the RAPID information

7.   Conclusion and Recommendations.

7.1 Conclusions
DTN Infrastructure was implemented successfully.

7.2 Recommendations for future Work
POSIX compliance interface for Persistence.

Usage of DTNRG instead of

8. Bibliography

[1] Khabbaz, Maurice J., Chadi M. Assi, and Wissam F. Fawaz. "Disruption-tolerant networking: A comprehensive survey on recent developments and persisting challenges." Communications Surveys & Tutorials, IEEE 14.2 (2012): 607-640.

[2] Jain, Sushant, Kevin Fall, and Rabin Patra. Routing in a delay tolerant network. Vol. 34. No. 4. ACM, 2004.

[3] Balasubramanian, Aruna, Brian Levine, and Arun Venkataramani. "DTN routing as a resource allocation problem." ACM SIGCOMM Computer Communication Review 37.4 (2007): 373-384.

[4] Wang, Ruhai, Scott C. Burleigh, Paavan Parikh, Che-Jen Lin, and Bo Sun. "Licklider transmission protocol (LTP)-based DTN for cislunar communications."IEEE/ACM Transactions on Networking (TON) 19, no. 2 (2011): 359-368.

[5] Wang, Ruhai, Xuan Wu, Tiaotiao Wang, Xueguan Liu, and Liulei Zhou. "TCP convergence layer-based operation of DTN for long-delay cislunar communications." Systems Journal, IEEE 4, no. 3 (2010): 385-395.

[6] Samuel, Hany, Weihua Zhuang, and Bruno Preiss. "DTN based dominating set routing technique for mobile ad hoc networks." In Proceedings of the 5th International ICST Conference on Heterogeneous Networking for Quality, Reliability, Security and Robustness, p. 9. ICST (Institute for Computer Sciences, Social-Informatics and Telecommunications Engineering), 2008.

[7] Warthman, Forrest. "Delay-tolerant networks (DTNs): A tutorial." (2003).

[8] Keränen, Ari, and Jörg Ott. "DTN over aerial carriers." In Proceedings of the 4th ACM workshop on Challenged networks, pp. 67-76. ACM, 2009.

[9] Jain, Melissa Ho, and Robin Patra. "Implementing delay tolerant networking." (2003).

[10] Itani, Wassim, Ayman Tajeddine, Ayman Kayssi, and Ali Chehab. "Slow but certain wins the race: authenticated bundle communication in delay tolerant networks." In Proceedings of the 6th ACM workshop on QoS and security for wireless and mobile networks, pp. 90-97. ACM, 2010.

[11] Spyropoulos, Thrasyvoulos, Rao Naveed Rais, Thierry Turletti, Katia Obraczka, and Athanasios Vasilakos. "Routing for disruption tolerant networks: taxonomy and design." Wireless networks 16, no. 8 (2010): 2349-2370.

[12] Wang, Ruhai, Tarik Taleb, Abbas Jamalipour, and Bo Sun. "Protocols for reliable data transport in space Internet." Communications Surveys & Tutorials, IEEE 11, no. 2 (2009): 21-32.0

[13] Rahul C. Shah, Sumit Roy, Sushant Jain, and Waylon Brunette. Data MULEs: Modeling a Three-tier Architecture for Sparse Sensor Networks. In Proc. IEEE SNPA Workshop, May 2003

9. Appendices