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A Protocol Design for Mobility Assisted Delay / Disruption Tolerant Network Nodes

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Abstract

The paper entitled "A Protocol Design for Mobility Assisted Delay / Disruption Tolerant Network Nodes" mainly intends in designing a disruption tolerant network useful for challenged internet areas lacking "always-on" setup, fewer expectations of end-to-end connection and node resources. Disruption Tolerant Networking (DTN) is a networking area which addresses challenges in disconnected, disrupted networks without end-to-end connection. Today's internet operated using highly successful architecture and supporting protocols (protocols in TCP/IP model) performs poorly in environments characterized by very long delay paths and frequent network partitions. These problems make end nodes having severe power or memory constraints perform poor. Many DTN networks use their own specialized protocols like Licklider Transmission Protocol (LTP), Bundle Protocol (BP) etc. In order to achieve interoperability between such networks, an overlay architecture is designed above the transport layers of the networks it interconnects provides important services such as in-network data storage and retransmission capability, interoperable naming, coarse-grained class of services and authenticated forwarding. A network with three node test setup is created which will demonstrate the working of delay/disruption tolerant network for asymmetric data rates, high error rates, long and variable delays and intermittent connectivity.

Keywords: Disruption Tolerant Networking, TCP/IP model, Terrestrial Mobile Networks, Bundle Protocol.

Introduction

The paper entitled "A Protocol Design for Mobility Assisted Delay / Disruption Tolerant Network Nodes" is an effort being put for efficient communication in areas with high error rates, disrupted environments and power and memory constraints. The design of Disruption Tolerant Network protocols is a novel way to improve communication in above mentioned areas as in [1].

The existing TCP/IP protocols fail to operate effectively in challenged internet because of a number of assumptions built in their architecture such as an end-to-end path exists between a data source and its destination(s), the maximum round-trip time is not large between any network node pairs, and the end-to-end packet drop probability is small. Lamentably, challenged networks, which may violate one or more of the assumptions of Internet protocols, are gaining priority and may not be well served by the current end-to end TCP/IP model.

Challenged networks arise mainly because of various forms of host and router mobility, disconnection due to power management or interference. The end-to-end connectivity principle has been one of the building blocks of the internet, but in case of real-world wireless scenarios, we find that end-to-end connection is often intermittent, which limits the performance of end-to-end transport protocols.

Consider Challenged networks such as Terrestrial Mobile Networks. Very often these networks may become unexpectedly partitioned due to node mobility or RF interference. In few cases, the network may never have an end to- end path connection and could be partitioned in a periodic and predictable manner. For example, consider a commuter bus acting as a store and forward message switch with only limited RF power communication capability. As it travels from place to place, it provides a form of message switching service to its nearby clients to communicate with distant parties it will visit in the future.

In this paper, we suggest general purpose message-oriented reliable overlay architecture as the appropriate approach to tie together networks which

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suffer from frequent network partitioning, forming "internetwork of challenged internets" as in [2].

The Disruption Tolerant Networking Model

To explain the disruption tolerant networking model we begin with the urban-rural area communication scenario of figure 1. This real-world situation is abstracted, according the DTN architecture discussed in section III. There are three methods used to transfer data between the urban and the rural areas:

- Low-earth orbit satellite links,
- Conventional modem links, and
- Mobile "commuter bus"

In the context of DTN, a mobile DTN router device has the ability to store-and-forward protocol data units, and acts as a data carrying entity. These data carrying "routers" are called *Data Mules*. This term originated to describe scenarios where some entity which is in motion (the mule) is providing storage for messages to provide transit connectivity. By taking figure 1 into consideration results are discussed for a three node test node, one each in urban and rural region and another node acting as a mobile bus.

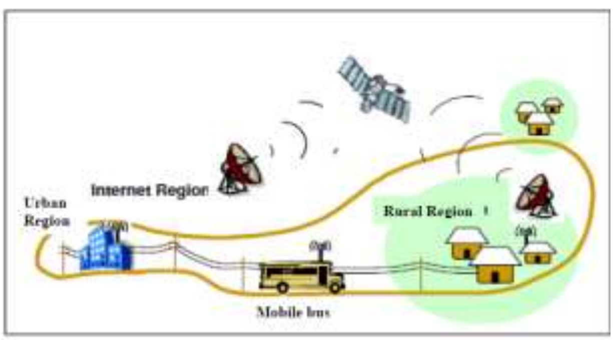

Fig 1: Example DTN network

Delay/Disruption Tolerant Networking Architecture

Aiming to overcome the problems associated with intermittent connections, long or variable delays, data rates that are asymmetric, and error rates that are high, as in [3] DTNs use

1. Store-and Forward Message Switching
2. Routing and Forwarding
3. Fragmentation and Reassembly
4. Custody based Re-transmission

A. *Store-and Forward Message Switching*

As described in figure2 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 (switch intersection) to a storage place on another node, along a path that reaches the destination.

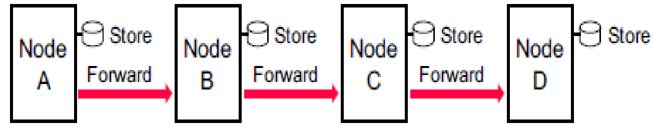

Fig 2: Store-and-Forward Message Switching

The storage places (such as hard disk) can hold messages indefinitely. These are termed as persistent storage in contradiction to very short-term storage provided by memory chips and buffers which store (queue) incoming packets for a few milliseconds while they are waiting for their next-hop routing table lookup and an available outgoing router port.

B. *Routing and Forwarding*

A DTN is described using a multigraph, wherein the vertices may be interconnected with more than one edge. Edges in this graph are time-varying with respect to their delay, capacity and transmission direction. Zero capacity edge is considered not to be connected. The period of time during which capacity is positive and delay can be considered constant is called contact. Intelligent routing and forwarding decisions can be made if contacts and their volumes (product of capacity and interval) are known prior.

C. *Fragmentation and Reassembly*

In order to improve the efficiency of bundle transfers by ensuring that contact volumes are fully utilized and avoid retransmission of partially forwarded bundles, DTN supports two forms of Fragmentation/ Reassembly- Proactive and Reactive.

Proactive Fragmentation is used when contact volumes can be predicted in advance. A block of application data is divided into multiple smaller blocks and each block transmitted as an independent bundle. The final destination(s) are accountable for reassembling incoming bundles into original large bundle and ultimately, the application data unit.

Reactive Fragmentation is used when a bundle is partially transmitted. The previous hop sender may learn that only a portion of the bundle has been delivered to the next hop and send the remaining portion when subsequent contacts become available. It requires certain level of support from underlying protocols.

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D. Custody based Re-transmission

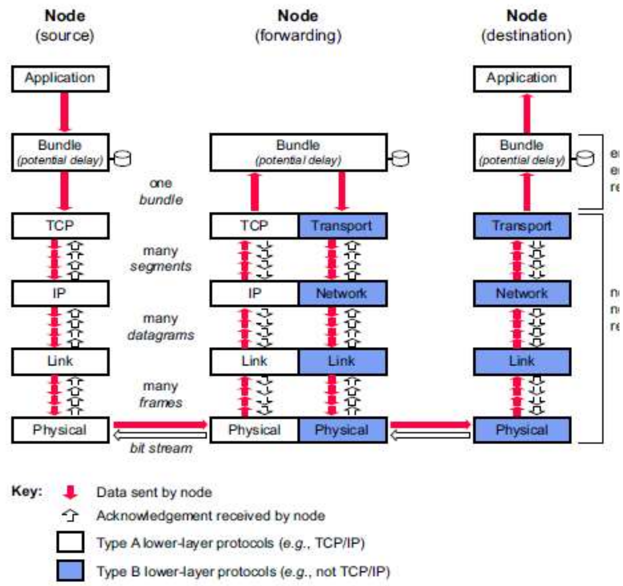

Fig 3: Custody based Re-Transmission

Node-to-node retransmission capability is supported by the bundle protocol by means of custody transfers arranged between the bundle-protocol agents of successive nodes, at the initial source application request. When the current bundle custodian sends a bundle to the next custodial node (not necessarily the next node in the path), it requests a custody transfer acceptance by that node and starts a time-to-acknowledge retransmission timer. If the next DTN node accepts custody, it returns a custody transfer success acknowledgment to the previous custodian. If no acknowledgment is returned before the custodian's time-to-acknowledge expires, the custodian retransmits the bundle. The value of time-to-acknowledge retransmission timer can be computed locally, based on past experience with a particular node or by using routing information as in [4].

The Bundle Protocol

In order to meet the requirements of DTN architecture discussed in section III, a DTN protocol called the Bundle protocol is implemented. This bundle protocol is present between the application and transport layer of the Internet protocol suite. The bundle protocol ties together the lower-layer protocols so that application programs can communicate across the same or different sets of lower-lower protocols under conditions that involve long network delays or disruptions as in [5].

Figure 4 illustrates the bundle-protocol overlay and figure 5 compares the Internet protocol stack (left) with a DTN protocol stack (right).

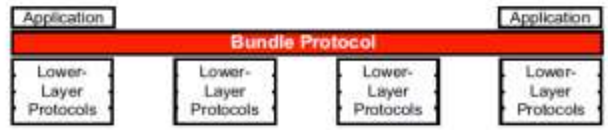

Fig 4: The Bundle-protocol overlay

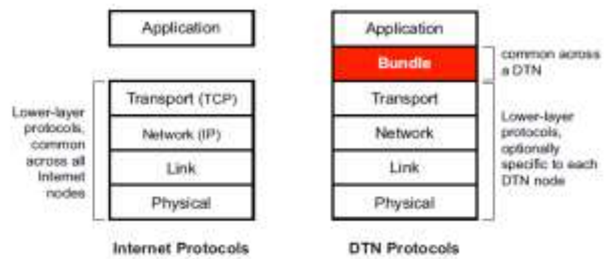

Fig 5: Internet protocol stack versus DTN protocol stack

The bundle protocol provides the following services

- Authentication: The method of digital signature used to verify the sender's identity and the integrity of the message.
- Delivery Priority: Bulk, Normal, or Expedited.
- Bundle Return Receipt: Confirmation to the source, or its reply to entity, that the bundle has been received by destination application.
- Custody Acceptance Notification: Notification to the source, or its reply to entity, when a node accepts a custody transfer of the bundle.
- Bundle Forwarding Report: Notification to the source, or its reply to entity, whenever the bundle is forwarded to another node.
- Custody Transfer Success/ Failure Acknowledgement: Delegation of retransmission responsibility to a node which have enough resources to accept custody of a protocol data unit. The accepting node sends custody transfer success acknowledgement to the previous custodian.

Results

The results for a three node setup DTN are obtained using ModelSim simulator and the code is written in VHDL. In the result shown in figure 6, each DTN node in urban or rural areas can hold up to four unacknowledged bundles. Ram number indicates which ram number is currently in use for storing

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bundles. In the simulation result shown in figure 6 user data to be sent (ex: HELLO= x"48 45 4C 4C 4F") is taken from the application, its size is decoded and stored in temporary memory (user_ramstore in figure 6) until the bundle header is formed. The complete bundle to be sent is stored in persistent storage and transmitted along with a predefined pattern at the beginning when outgoing link is available to the commuter bus.

Figure 6: DTN Transmitter node sending bundle header and user data from application

The commuter bus stores in its memory as shown in figure 7, the bundle received from sending DTN node of either urban area or rural area and delivers it to the destination DTN node from either urban area or rural area. Only the required amount of memory is written, rest is left unused (denoted by XX).

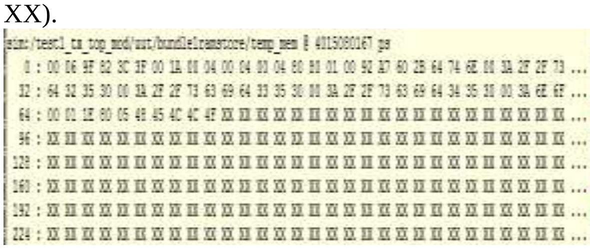

Figure 7: Persistent storage at commuter bus

The receiver DTN node decodes the bundle received (serial_in_line signal in figure8) and determines if the bundle is destined for itself or not. If the bundle's destination id matches with the receiving DTN node id, then it extracts the user data and delivers it to the receiving application using uart transmission (shown by signal uart_tx_out) as shown in figure 8.

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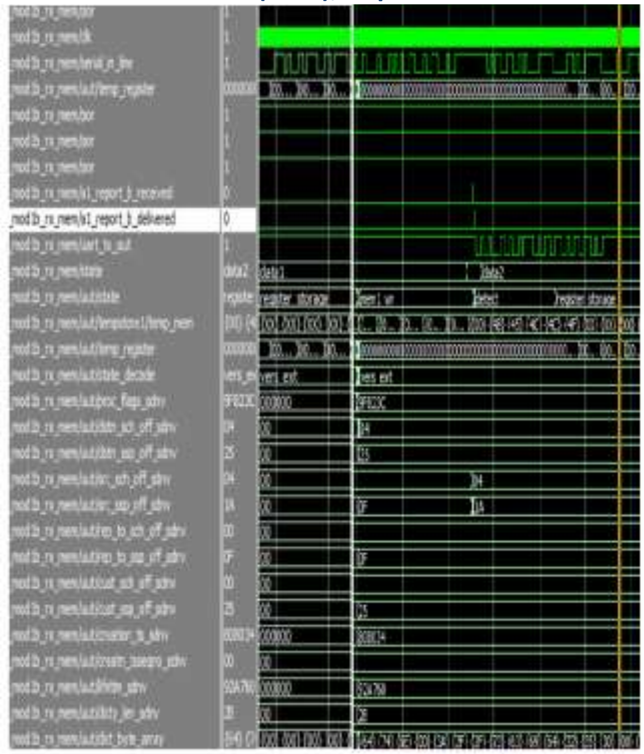

Conclusion

A network tolerant to delay and disruption has been designed and tested. It works well in the presence of long time scale delays because of persistent storage and custody based retransmission method which was adopted. Hence even in case of "Challenged Internet" in areas with high error rates, disrupted environments and power and memory constraints efficient communication can take place with the design of bundle protocol and DTN architecture discussed in this paper.

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