A Survey of Deep Space Networks and Protocols

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Abstract - **Exploration of space has expanded further away from Earth. As this distance increases the difficulty to relay messages between Earth to other spacecrafts and satellites increases as well. The creation of an interplanetary space network is imperative for the continuation of deep space exploration and studies. Although there are many difficulties with setting up such a complex relay network system in the vast unknown that is space. This survey proposes to analyze current Deep Space Network solutions and problems as well as address the current difficulties when setting up a communication relay system for the Solar System.**

General Terms

Protocol, DSN, Survey, Interplanetary Internet, Deep Space Protocols**,** Deep Space Networks

Keywords

CCSDS, DTN, LTP, BP,

I. Introduction

COMMUNICATION systems utilized geo-satellite relay systems to send and receive messages around the world. Society currently only inhabits Earth, with rare exceptions of human space travel and ISS agents in orbit. However, with plans to transport humans to Mars and even longer plans to colonize the red planet, the need for an interplanetary internet system is essential.

Deep Space Networks - DSN for short - are, generally, arrays of large radio dishes used for interplanetary and spacecraft communication. One such system is NASA's JPL Deep Space Network which operates many of the agency's interplanetary robotic space missions . This network works by using three massive satellites placed and using telemetry to ping a spacecraft and transmit a message [4]. As space travel advances further away from Earth the need to find more reliable and efficient methods for deep space communication grows.

A popular proposed solution is to place satellite in planetary orbit around other celestial bodies to help relay messages. This solution although feasible in theory is expensive in price.

There is no way to speed up the rate at which data travels, in regards to wave speed, as it is limited to the speed of light. However, using new and improved protocols designed specifically for interplanetary internet conditions could help reduce transfer time and prevent package loss due to delays or disruptions.

With this new proposed computer network in space communication comes a need for new protocols and technology. These protocols and technology need to be able to withstand the large delays and error due to the long interplanetary distances. This lends interplanetary internet to the method of store and forward. Where a message is sent and kept for an extended period of time before it is in range to relay to another node.

The Committee that readily discusses space networks and sets protocols is the Consultative Committee for Space Data Systems (CCSDS). Within this committee, majority of the following protocols have been decided upon for feasibility within a interplanetary internet system.

II. Delay and Disruption Tolerant Networks

A delay/tolerant network (DTN) is designed, using the following protocols, to address technical issues such as a lack of continuous network connectivity. **[[add somewhere else: The main funder of this research is the Defense Advanced Research Projects Agency (DARPA) [16].]]** The problem with standard Internet Protocols(IP) and TCP, is that they require a continuous end-to-end connection during the duration of the transfer with minimal change from packet to packet. The type of environments that the DTN and its protocols were designed for typically have long propagation delays due to the speed of light or long queuing delays.

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III. Protocols

A. NASA's Delay/Disruption Tolerant Protocol

NASA's solution to long distance communication with its spacecraft is its Delay/Disruption Tolerant Networking Protocol Suite(DTN). The DTN is a computer networking model and a system of rules for transmitting data [14]. Where normal Internet Protocols(IP) fail, DTN is suited for all scenarios including those where long light times or frequent link disruptions (E.g, satellite goes behind a planet). DTN is utilized in environments where error rates are high and frequent disruptions occur. This notable feature extends the terrestrial internet capabilities into deep space environments.

Figure 1: Interplanetary Network Structure

As notable in the above photo (Figure 1, follow from middle left to lower right), the DTN will use nodes to store data during a delay/disruption. The DTN will assure delivery of data using the store-and-forward method. Store-and-forward is a method of storing data in a intermittent node until it is able to be sent to the next node or to its destination. This is efficient as each datum at any arbitrary node only needs the next link to be available to be forwarded. DTN also includes network management, security, and quality of service(priority levels).

B. Bundle Protocol

A bundle is a protocol data unit. It is located within the bundle node's local memory. Each node separates into three different parts: a bundle protocol agent, none or multiple convergence layer adaptors, and an application agent [10]. Bundle Protocol (BP) supports end-to-end network services by forming a store-and-forward network.

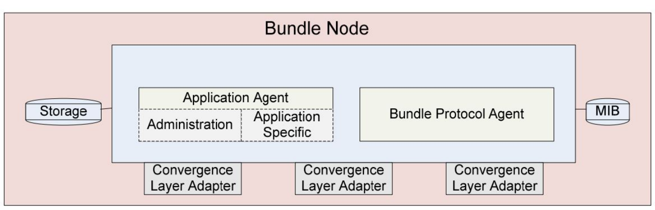

Figure 2: Bundle Node Structure

When Bundle Protocol moves bundles of data it could commence a registration, terminate a registration, switch between an Active and Passive state, transmit a bundle to an endpoint, cancel a requested transmission, poll a passive state registration, deliver a received bundle, or report the bundle's status.

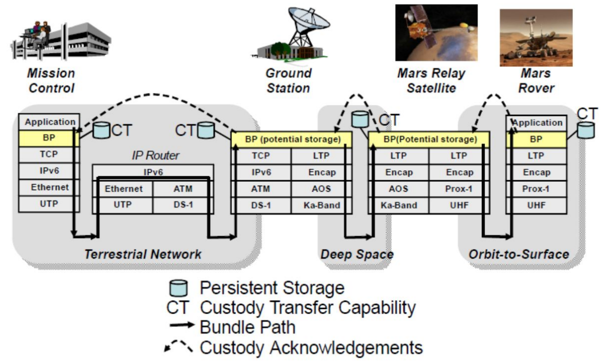

Figure 3: BP Used in DSN

These services allow the relay of vital information throughout the network while preventing data loss. It accounts for adapting to different receiver and signal protocol types. The ability for BP to cope with intermittent connectivity by taking advantage of not only scheduled, but situational connectivity helps it's efficiency. With the security provided from checking the authentication of the transmitting entity, which is referred to as "hop-by-hop" security, BP is able to maintain a secure network. BP also utilizes "end-to-end" security within the end-to-end network to maintain confidentiality and integrity of the bundles.

C. Delay Tolerant Convergent Layers

(further correction/research needed)

D. Licklider Transmission Protocol

Licklider Transmission Protocol (LTP) assists in communications over a single link hop. It is inbetween the Data Link and the Network Layers of the ISO stack. Although LTP has multi-hop capabilities, it is recommended that it is terminated at the end of long-delay, error-prone, or disruption prone link in a multi-hop path.

LTP moves blocks of data between LTP engines. The two engines are solely connected by a space link because they reside in separate data systems. There are two parts in each block, the 'red-part' and the 'green-part'. The red-part is transported reliably while the green part is data transmitted unreliably. The LTP Client Service Instance controls what data is in which block. The data in the red block needs to be picked up by the receiver while the data in the green block could be ignored. Thus this creative solution reduces the prices of retransmissions when sending data in deep space which improves performance overall.[15]

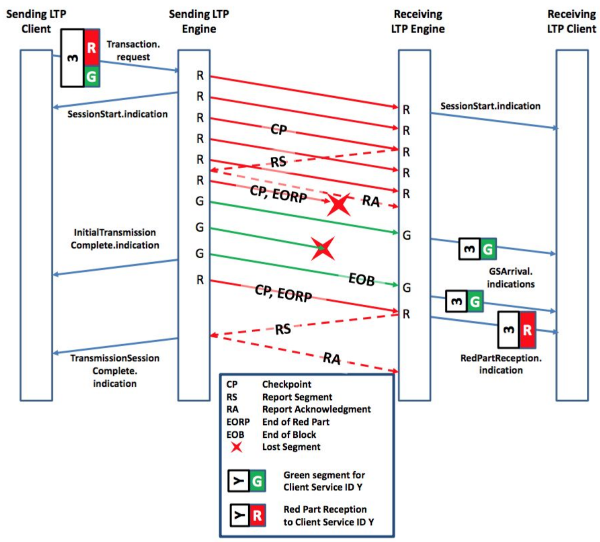

Figure 3: LTP Sending and Receiving Example

E. Saratoga

Saratoga is a a file transfer protocol for DTN bundles. Saratoga is designed to send packets our as fast as possible. This is due to the fact it is a single hop transfer system.

Although Saratoga was developed prior to LTP, the advantages of utilizing it are: it is simpler, faster, and easy to implement. The draft is half of the size in Saratoga making it much less complex. Since Saratoga is only intended to be utilized for one hop it's much faster. Finally, since it's headers fit into C structs majority of the libraries are easy to access and do not need conversions to use. Some of the more smaller feature Saratoga offers over LTP is it is capable of directory listings selection pull, it can include metadata, it offers object integrity checksums in MD5, and is a beacon for discovery and automated transfers.

F. Deep Space TCP (DS-TP)

G. Delay Tolerant Transfer Protocol(DTTP)

(further correction/research needed)

H. Adaptive Rate Control Protocol

(further correction/research needed)

I. TP Planet

(further correction/research needed)

J. CCSDS File Delivery Protocol (CFDP)

The CCSDS CFDP provides the ability to transfer files to and from spacecraft mass memory. Although it was designed for the purpose of file transportation, it was built as an abstract 'virtual filestore' because CFDP does not define exactly what a 'file' is allowing the transfer of data between repositories that may not look like file systems.

When compared to it's terrestrial counterpart, the CFDP has many unique characteristics. It is efficient over simple,half-duplex, and full-duplex links. It has time disjoint connectivity giving it the ability to transfer to ground station contracts as well as multiple ground stations. It is still highly effective during highly unbalanced link bandwidths and does not have a lot of link traffic. CFDP minimizes the use of onboard memory requirements through buffer sharing. CFDP operates through multi-hops. CFDP also has end-to-end accountability even through multiple automatic store-and-forward intermediaries and operations. It stores and forwards before the file is completely received at the forwarding entity. These features make CFDP very effective in spanning low Earth orbit and deep space.

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