Mini-Workshop: Deep-Space Communications - Today & Tomorrow
17 & 18th July 2006

Chairs: Leigh Torgerson, NASA/JPL, ltorgerson@jpl.nasa.gov
Manikantan Ramadas, Ohio University, mramadas@irg.cs.ohiou.edu

THEME

This workshop focuses on novel architectures, technology, protocols, and paradigms for effective communication in Deep-Space. We discuss the current state-of-the-art in deep-space communications infra-structure - the challenges faced and the lessons learnt, and active efforts for developing different aspects of the future deep-space communications infra-structure - such as the NASA and CCSDS efforts, and the work done under the auspices of the Delay Tolerant Networking Research Group. We expect the workshop to serve as a catalyst igniting more synergy between the space mission planners, engineers, and researchers and their counterparts from academia and industry.

AGENDA

Day 1: Monday, 17 July 2006

TIME	TOPIC	PRESENTER
9:30-10:00	Keynote: Overview of Current Space Network Activities	Adrian Hooke, NASA/JPL
10:00-10:30	Coffee Break	
10:30-11:00	Relay Operations for the Mars Exploration Rovers	Roy Gladden, NASA/JPL
11:00-11:30	DSN Arrays	Mark Gatti, NASA/JPL
11:30-12:00	LTP, Study of a Priority Paradigm for Deep-Space Applications	Manikantan Ramadas, Ohio University
12:00-1:30	Lunch Break	
1:30-2:00	Future Lunar Architecture	Keith Scott, MITRE

TIME	TOPIC	PRESENTER
2:00-2:30	Future Mars Architecture	Leigh Torgerson, NASA/JPL
2:30-3:00	DTN Lake Sensor Network	Stephen Farrell, Trinity College Dublin, Ireland
3:00-3:30	Tea Break	
3:30-4:00	Towards Interplanetary Grids	Laurent Lefevre, The French Institute for Research in Computer Science and Control, France Jean-Patrick Gelas, ENS Lyon, France
4:00-5:00	Integrated SharedNet and DTN Simulation Demo	Esther Jennings, NASA/JPL

Day II: Tuesday, 18 July 2006

TIME	TOPIC	PRESENTER
9:00-10:00	Asynchronous Messaging Service: Presentation & Demo	Amalaye Oyake, NASA/JPL
10:00-10:30	Coffee Break	
10:30-11:00	Deploying CFDP on MESSENGER: Lessons Learned	Christopher Krupiarz, JHU/APL
11:00-12:00	CFDP Telemetry Accelerator: Presentation & Demo	Jackson Pang, Joshua Schoolcraft NASA/JPL

TIME	TOPIC	PRESENTER
12:00-1:30	Lunch Break	
1:30-2:00	Frequency Plan, Sampling, and Quantization Effects in a Software Receiver Using Few Bits ADC	Chieh-Fu Chang, National Space Organization, Taiwan
2:00-2:30	Reconfigurable Protocol Sensing in an End-to-End Demonstration	Clayton Okino, Andrew Gray, Joshua Schoolcraft NASA/JPL
2:30-3:00	Agoric Architectural Styles for Deep-Space Exploration	Rohit Khare CommerceNet Labs
3:00-3:30	Tea Break	
3:30-4:15	Panel Discussion: Space Communication Research-ers & Mission Planners - Shall we talk?	
4:15-5:00	Informal Group Discussion	

ABSTRACTS

Day I: Monday, 17 Jul 2006

9:30 - 10:00 Overview of Current Space Network Activities
Adrian Hooke, NASA/JPL, adrian.j.hooke@jpl.nasa.gov

With the recognition that space networks are going to be a necessary element of future missions, several groups are investigating appropriate architectures for these endeavors. Among them are NASA's Space Communication Architecture Working Group (SCAWG), the CCSDS Cislunar Working Group, and NASA Constellation's Command, Control, Communication, and Information (C3I) effort. While all of these groups are addressing a similar subject, they each provide a unique perspective to the evolving space network architecture.

10:30 - 11:00 Relay Operations for the Mars Exploration Rovers
Roy Gladden, NASA/JPL, roy.e.gladden@jpl.nasa.gov

The Mars Exploration Rovers (MER) have been highly successful in the use of relay operations in achieving the goals of the MER mission. With close to 95% of science data transmitted via relays, the current Mars communication infrastructure has been instrumental in MERs continued operations on the red planet. Mars Odyssey is the primary asset in this configuration, although the rovers have also made use of the Mars Global Surveyor as well as Mars Express, which, in particular, demonstrates the usefulness of international standards.

11:00 - 11:30 DSN Arrays
Mark Gatti, NASA/JPL, mark.s.gatti@jpl.nasa.gov

The DSN currently supports space science missions telecommunications needs with a variety of large aperture antennas (ranging from 26m to 70m) located at three approximately equidistant places on the earth. These assets are managed and operated locally at each site with coordination from the Space Flight Operations Center at JPL. To meet future requirements, which suggest that downlink/telemetry capability increase by as much as a factor of 400, the DSN Array Project proposes to create the next generation DSN consisting of arrays of many smaller antennas. Significantly, the operations concept proposed by the Project includes maximum automation at the remote sites and centralized control from a single center at (or near) JPL. This talk will describe the basic Project concept, a more modern operations concept, and the expectations for both the ground and space based telecommunications equipment.

11:30 - 12:00 LTP / A Priority Paradigm for Deep-Space Applications
Manikantan Ramadas, Ohio University, mramadas@irg.cs.ohiou.edu

We introduce LTP: Licklider Transmission Protocol aka Long-haul Transmission Protocol, designed as a reliable datalink protocol optimized for long-haul deep-space datalinks. It is stateful, has no negotiations or hand-shakes, is capable of handling link disruptions, and does retransmissions of lost data with the selective repeat ARQ paradigm. In the DTN protocol stack, it is the deep-space convergence layer. It is specified in three internet drafts (Motivation/Specification/Extensions) and is on its way to being published as an experimental RFC. We then discuss our study on a Priority Paradigm for deep-space applications with two dimensions: Immediacy (a measure of how important the timely delivery of data is) and Intrinsic Value (a measure of how important the reliable delivery of data is).

1:30 - 2:00 Future Lunar Architecture
Keith Scott, MITRE, kscott@mitre.org

The Consultative Committee for Space Data Systems (CCSDS) is developing an architecture to enable interpretability across space system elements as well as their respective international organizations through the work performed the CCSDS Cislunar Working Group. The impetus for this work is the increasing reliance on networked communications that will be required by NASA's Vision for Space Exploration, ESA's Aurora program, and other space-faring countries' efforts to explore the Moon and beyond. With the large number of missions, an interoperable networked architecture will reduce the burden of the increasingly complex task of managing the return of science data, command and control, and communication necessary to support human exploration. The Cislunar Work Group architecture will provide a recommended suite of protocols based upon current CCSDS efforts as well as terrestrial communication protocols.

2:00 - 2:30 Future Mars Architecture
Leigh Torgerson, NASA/JPL, ltorgerson@jpl.nasa.gov

As part of the Mars Technology Program being managed by the NASA Jet Propulsion Laboratory, a joint team of researchers at the NASA Jet Propulsion Laboratory (JPL) and the Johns Hopkins University Applied Physics Laboratory (JHU/APL) are studying protocols that fall under the umbrella of Delay Tolerant Networking for use in a next generation Mars protocol architecture. The team is developing flight software versions of the Bundle Protocol and Licklider Transmission Protocol (LTP) as defined in DTN as well as creating various scenarios to be modeled and simulated through a JPL developed network test suite - Multimission Advanced Communications Hybrid Environment for Test and Evaluation (MACHETE). A mission scenario involving two landers, two relay orbiters, ground stations and a ground system is simulated using MACHETE to verify the feasibility of using DTN in future missions.

2:30 - 3:00 DTN Lake Sensor Network
Stephen Farrell, Trinity College Dublin, stephen.farrell@cs.tcd.ie

LTP is primarily designed for high latency space communications, but as it turns out also offers advantages for some terrestrial applications. This talk describes one such implementation with an emphasis on how LTP's delay tolerant traits are helpful even running over UDP and when using wireless LAN based link layers. In addition to being a practical LTP demonstration, the work has also given rise to a proposal for some possible extensions to LTP which will also be covered.

3:30 - 4:00 Towards Interplanetary Grids
Laurent Lefevre, The French Institute for Research in Computer Science and Control, laurent.lefevre@inria.fr
Jean-Patrick Gelas, ENS Lyon, jpgelas@ens-lyon.fr

This presentation describes how to integrate the Disruption Tolerant Networking protocols with Active Grids in order to design Delay Tolerant Grids. These Grids will provide the basic set for the future deployment of interplanetary grids.

4:00 - 5:00 Integrated SharedNet and DTN Simulation Demonstration
Esther Jennings, NASA/JPL, Esther.H.Jennings@jpl.nasa.gov

In space-based networks, the use of SharedNet middleware may allow spacecrafts to collaboratively utilize shared assets/resources more effectively, robustly, with lower operation cost and risk. In this demonstration, we show the use of SharedNet to service mission applications with QoS-aware transmission over a network simulator running Delay-Tolerant Network protocol (Bundle Protocol, BP). The experiment scenario consists of a Mission Operation Center (MOC), a Deep Space Network ground station, an orbiter, and two rovers. Both rovers produce science data at various priorities; currently, BP supports three priority levels. The orbiter subscribes to all data from the landers and creates high priority derived data. It also provides storage and relay services for data. The MOC subscribes to high priority data and commands the orbiter and landers. This experiment shows the interaction of SharedNet with simulated DTN where there are link outages of the proximity links (between landers and orbiter) and deep space link (between orbiter and DSN station).

Day II: Tuesday, 18 Jul 2006

9:00 - 10:00 Asynchronous Messaging Service: Presentation & Demo
Amalaye Oyake, NASA/JPL, amalaye.oyake@jpl.nasa.gov

The increasing complexity of mission systems based on communication among subsystem modules tends to increase the chance of systems failure, since the success of those systems become increasingly critical to the achievement of mission objectives. Some measures that can minimize the chance of failure of complex systems are: exhaustive regression testing and configuration management, flight rules constraining the exercise of unproven system capabilities, and the introduction of improvements. These steps increase mission cost if they are taken and increase risk if they are not. These considerations have led to the present recommendation for the use of software standards. One such recommendation is a standard system of communication - messaging - among mission software modules. The objective of this proposed messaging standard is to reduce mission cost and risk by confining much of the complexity of modern mission systems to relatively static and proven reusable infrastructure.

AMS is a "middleware" messaging specification that defines wire protocol bits and basic communication handshake. It enables applications to exchange information typically across a network. As such, it relies on the capabilities of underlying Transport layer protocols to accomplish the actual copying of a message from the memory of the sending node to the memory of the receiving node. It additionally relies on those capabilities to accomplish the transmission of meta-AMS (or MAMS) messages to and from registrars and configuration servers that enables the dynamic self-configuration of AMS message spaces.

Thus AMS is a modular specification that allows it to take advantage of multiple transport layer protocols that deal with the network, thus making it well suited for heterogeneous environments. The simple demonstrations will show AMS test benchmarking tests and very simple message exchange between two computers.

10:30 - 11:00 Deploying the CCSDS File Delivery Protocol on MESSENGER: Lessons Learned
Christopher Krupiarz, JHU/APL, Christopher.Krupiarz@jhuapl.edu

The Consultative Committee on Space Data Systems (CCSDS) developed the CCSDS File Delivery Protocol (CFDP) to provide a standard protocol for transmission of files to and from spacecraft. CFDP is tuned for operation in the deep space environment where bandwidth is scarce and significant round trip light times exist. For the past two years, the MESSENGER mission to Mercury has returned thousands of files via this method. While the deployment has been largely successful, several lessons learned have been recorded in order to help future missions deploy CFDP.

11:00 - 12:00 CFDP Telemetry Accelerator: Presentation & Demo
Jackson Pang, NASA/JPL, jackson.pang@jpl.nasa.gov
Joshua Schoolcraft, NASA/JPL, joshua.schoolcraft@jpl.nasa.gov

The Protocol Test Lab presents its state-of-the art hardware implementation of the CCSDS File Delivery Protocol testbed along with the usage of CFDP and DTN that make up the Next Generation Mars Protocol Suite. In this exhibit, PTL demonstrates the high-speed CFDP file transfer using the Channel Simulator that fluctuates the link condition and delay. The Next Generation Mars Protocol Suite demonstration will emphasize on the benefit of using CFDP and DTN to increase the data return and reduce costs associated with file transfer scheduling for the future Mars network.

1:30 - 2:00 Frequency Plan, Sampling and Quantization Effects in a Software Receiver Using Few Bits ADC
Chieh-Fu Chang, National Space Organization,Taiwan, jeffchang@nspo.org.tw

Software receivers draw more and more attention because of their flexibility to demodulate a number of distinct RF transmissions and the removal of several analog components at RF band. When implementing a software receiver, fewer bits quantization is usually chosen at analog-to-digital-converter (ADC) in order to reduce the required resource. The major disadvantage of using fewer bits is the degradation of signal-to-noise-ratio (SNR). In this paper, we investigate the degradation performance regarding carrier frequencies, sampling rate and quantization effect, separately and jointly. Quantitative results are provided in order to help people plan frequency, design sampling and quantization scheme using a software receiver with limited resource.

2:00 - 2:30 Reconfigurable Protocol Sensing in an End-to-End Demonstration
Clayton Okino, Andrew Gray, Joshua Schoolcraft
[clayton.okino | andrew.gray | joshua.schoolcraft]@jpl.nasa.gov

In this work, we present sensing performance using an architecture for a reconfigurable protocol chip for space-based applications. Toward utilizing the IP packet architecture, utilizing data link layer framing structures for multiplexed data on a channel are the targeted application considered for demonstration purposes. Specifically, we examine three common framing standards and present the sensing performance of these standards and their relative de-correlation metrics. Some analysis is performed to investigate the impact of lossy links. Finally, we present results on a demonstration platform that integrated reconfigurable sensing technology into the Ground Station Interface Device (GRID) for End-to-End IP demonstrations in space.

2:30 - 3:00 Agoric Architectural Styles for Deep Space Exploration
Rohit Khare, CommerceNet Labs, rohit@commerce.net

As future space networks become increasingly complex, elements of that network will depend upon ad-hoc cooperation between missions as well as various agencies and countries. An architecture that can work independently from the ground operations can enable increased usage of resources on various nodes of a space network, multicasting of messages via different routes both locally and to Earth, and coordinated scientific observations amongst elements. One solution to these decentralized applications is agoric computing which applies market discipline for allocating resources dynamically among coalitions of mission elements in space.

Keynote Speaker Biography

Adrian Hooke serves dual roles within the CCSDS, both as Chairman of the CCSDS Engineering Steering Group (CESG) and as Manager of the NASA Data Standards Program. Currently, he is on the staff of the Interplanetary Network Directorate at NASA's Jet Propulsion Laboratory.

From 1966-1969 Adrian worked in US industry as a member of the Kennedy Space Center launch team for the Apollo 9, 10, 11 and 12 Lunar Modules. Joining JPL in 1969, he was a member of the flight control teams for the Mariner 9 and 10 missions to Mars, Venus and Mercury. After working on the Voyager onboard data system and leading the design of the SEASAT end-to-end data system, he became a staff member of the European Space Agency in 1976 to work on the flight operations architecture for the Shuttle-SpaceLab program. Rejoining JPL in 1977, he focused on the development of new technology in the area of standardized space data communications protocols. He is one of the founders of the CCSDS and has led the development of international standards for Packet Telemetry, Packet Telecommand, Advanced Orbiting Systems and the "SCPS" extension of the terrestrial Internet protocol suite into space. He also chairs the US Technical Advisory Group to ISO TC20/SC13, "Space Data and Information Transfer Systems".

Adrian holds a B.Sc. (Honours) in Electronic and Electrical Engineering from the University of Birmingham, England. He is registered as a Chartered Engineer (C.Eng.) with the IEE in London and as a European Engineer (Eur. Ing.) with FEANI in Paris. He has been awarded two NASA Exceptional Service Medals.