CCSDS Application Profiles for the Mars Environment

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Introduction

An application profile addresses the five layers of the CCSDS protocol stack applicable to space missions: physical, data link, network, transport, and application. The first step in establishing an application profile for a mission environment is to evaluate and choose which communication protocols and space data application standards are to be used by the asset classes (e.g., orbiters, landers, probes) defined within the enterprise. Once this list of standards has been chosen, the individual options within these standards need to be evaluated in order that a specific subset of these options can be chosen. The application profiles consisting of a list of specific options within an approved list of communication protocols and applications defines the project or program's communications policy for that specific environment. The advantage to this approach is that these profiles define the baseline communications capabilities for all the missions participating in a given enterprise. This will guide each individual mission to pick the right set of options when implementing the CCSDS recommendations for space data system standards.

It is envisioned that these application profiles for the Mars environment will consist of a coherent list of options within the CCSDS layered protocol stack for international Mars projects organized by asset class. The goal of these profiles is to enhance interoperability and cross support amongst the diverse set of missions, represented by these asset classes at Mars.

This paper will discuss considerations for the application profiles for current and planned future missions at Mars. These missions belong to the following three asset classes: small Mars bound assets (landers, rovers, probes), medium to large size rovers and landers, and relay and science orbiters.

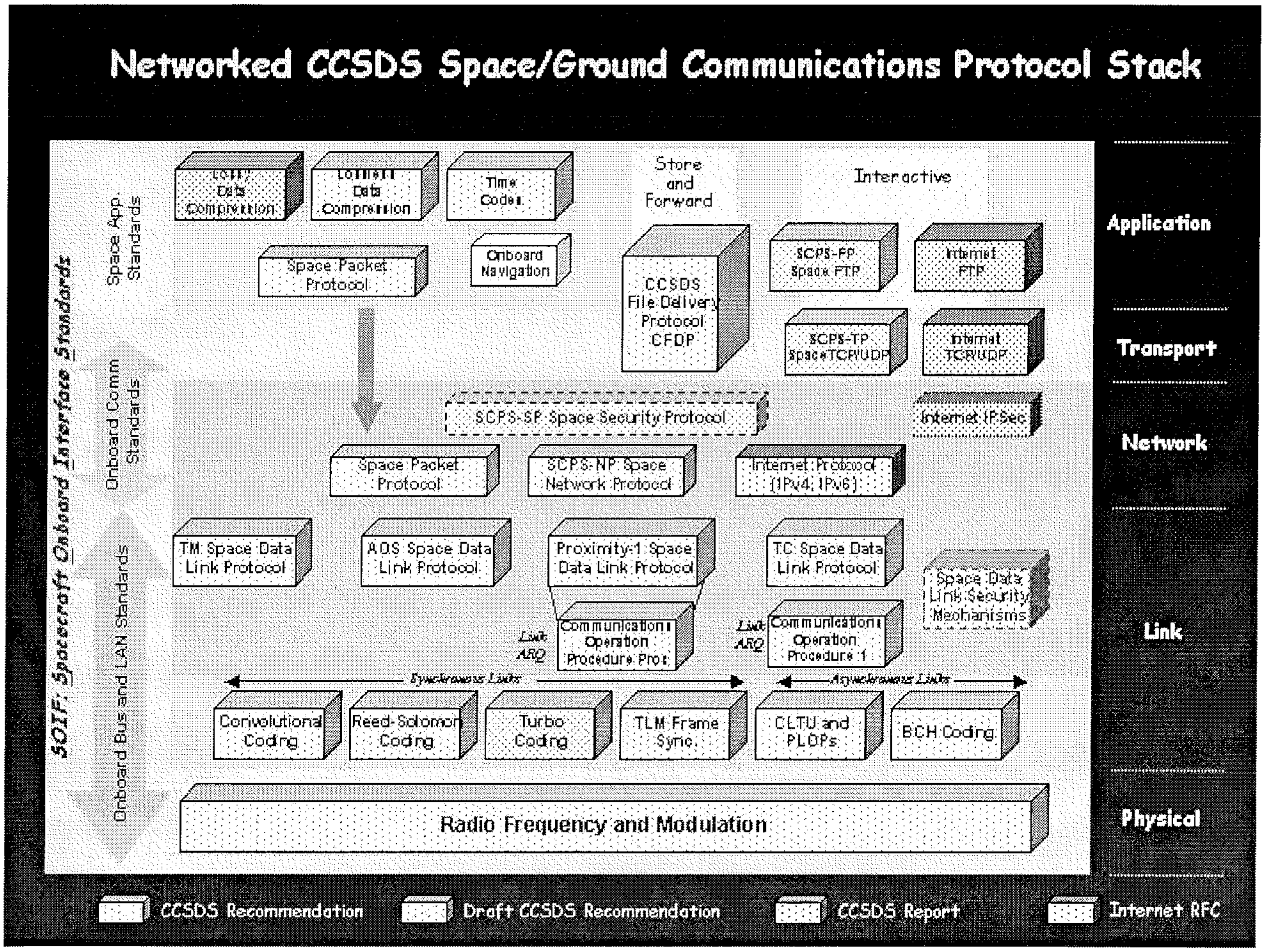

Figure 1: The CCSDS Layered Protocol Communications Model

Figure 1 shows the Consultative Committee for Space Data Standards (CCSDS) protocol stack, which provides the framework for both the space and ground link communications and application protocols used by a given enterprise. It is the task of a given enterprise, to determine which layers of the model are applicable for communication within that enterprise along with any requirements for interagency cross support. Once that is determined, the specific protocol within a given layer also needs to be determined. For example, on the deep space link, there are two possible link layer protocols that can be chosen: TM Space Data Link or AOS Space Data Link protocol. For deep space communication from Mars at high rate (> 1Mbps), the AOS Space Data Link protocol will be used. For bidirectional proximity communications between Mars bound assets and relay or science orbiters, Proximity-1 Space Data Link Protocol is used. Another choice that needs to be made is coding. CCSDS provides different coding options for synchronous vs. asynchronous links. At the network layer, the user has the choice between the CCSDS source packet, SCPS-NP datagrams, IPV4, or the encapsulation packet, which can encapsulate future network packets i.e., IPV6. At the transport and application layers, CFDP, the bidirectional file transfer protocol is envisioned to be used on all future Mars missions starting with the Mars Reconnaisance Orbiter (MRO) launching in 2005. It is also envisioned that CFDP will be used on both the forward (command link) and return (telemetry) link between Mars bound assets and relay/science orbiters starting with the Mars Science Laboratory lander and MRO and Mars Telecom Orbiter (MTO). CCSDS also provides application-based protocols such as lossless data compression, time code formats and is developing standards for on-board interfaces (SOIS) as well.

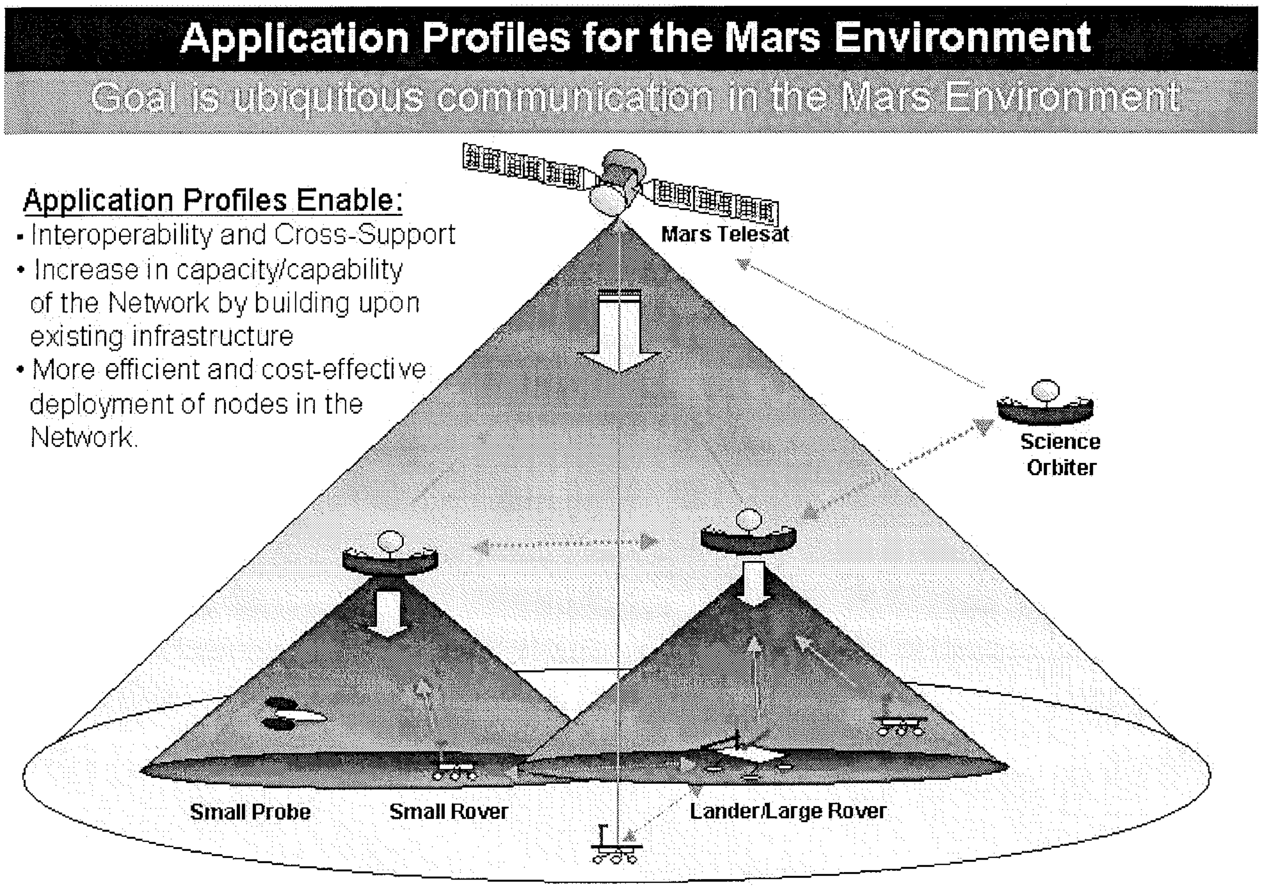

Figure 2: Need for Application Profiles at Mars

The ultimate communications goal at Mars is to establish a Mars Network, in which nodes have the capability of communicating amongst themselves in a seamless manner. Application profiles are an enabler towards a network centric approach at Mars. The benefits of using a common set of communications protocols and agreeing upon a standard set of options within these protocols are: 1) interoperability and cross-support between space agencies at Mars; 2) the capability of increasing the capacity/capability of the Mars Network by building upon existing infrastructure; 3) More efficient and cost effective deployment of nodes in the Network.

The first demonstration of interoperability at Mars between the NASA MER landers and the ESA Mars Express Orbiter occurred in February 2004 with the use of the CCSDS Proximity-1 Space Link protocol. Both commands as well as telemetry were transferred successfully and robustly using the reliable data transfer service within Proximity-1. As NASA and ESA continue to send more spacecraft to Mars, the importance of using each others assets for communication purposes will become of greater utility than this initial demonstration has proven. Currently, Proximity-1 is the established link layer protocol at Mars and transceivers in development such as the NASA/JPL ELECTRA transceiver to be flown on the NASA/JPL MRO and MTO orbiters is planned to be Proximity-1 compliant. Indeed by flying common protocols and transceivers amongst space agencies, money can be saved in development and test of these capabilities.

Drivers	RF & Coding	Link Layer	Network/Transport/Application
Testing at Earth	Regulatory limits	N/A	Connectivity
Round Trip Delays /Use of ARQ	Non-use of ARQ requires lower FER	Go-back N desirable with short delays	Selective Repeat desirable with long delays
Security	Spread Spectrum, Encryption	Authentication, Encryption	Access to Space (Router Issue), store & forward, file encryption
Emergency Modes	Omni vs pointing, Coding vs Uncoded	ARQ vs best efforts or none	N/A
Missions: Power/ Energy/Duration limited	X-band .5 m HGA + 12 dB UHF on shared platform	Two 4.2 m HGA + Multiple Access phased array	1 m HGA + 12 dB UHF on shared platform
Relay data rates	Ability to transmit/receive & decode	Ability to do ARQ	Ability to do Select Repeat and prioritize data for return
Operational Issues: Routing, Prioritization, Demand Access	Demand access signaled over physical layer	Simple routing and prioritization	Move to more sophisticated protocols as network grows
Simultaneous multiple links?	CDMA/FDMA/ TDMA	Simultaneous ARQ sessions	Greater data management & control issues

Table 1: Key Application Profile Considerations

What are the issues that one should consider when constructing application profiles? The table above examines some of the drivers involved in application profile construction in general. The purpose of such a table is to evaluate the key issues associated with an application profile both within each protocol layer as well as across each applicable layer. For example, what is the best method of utilizing ARQ on the proximity link for a given asset class within the Mars environment? Or whether ARQ should be used on this link at all? Should a selective repeat protocol be used or would a simpler to implement Go-back-N scheme suffice? The ARQ scheme used by the Proximity-1 Space Link protocol is the Command Operations Procedure - Proximity (COP-P), which employs a Go-back-N scheme. This scheme is compatible with short (up to a second or so) delays, whereas the selective repeat protocol that CFDP employs is compatible with longer delays, but is more complicated to implement. Clearly, knowledge of the round trip light time delay is one of the key parameters that are required to resolve this trade-off.

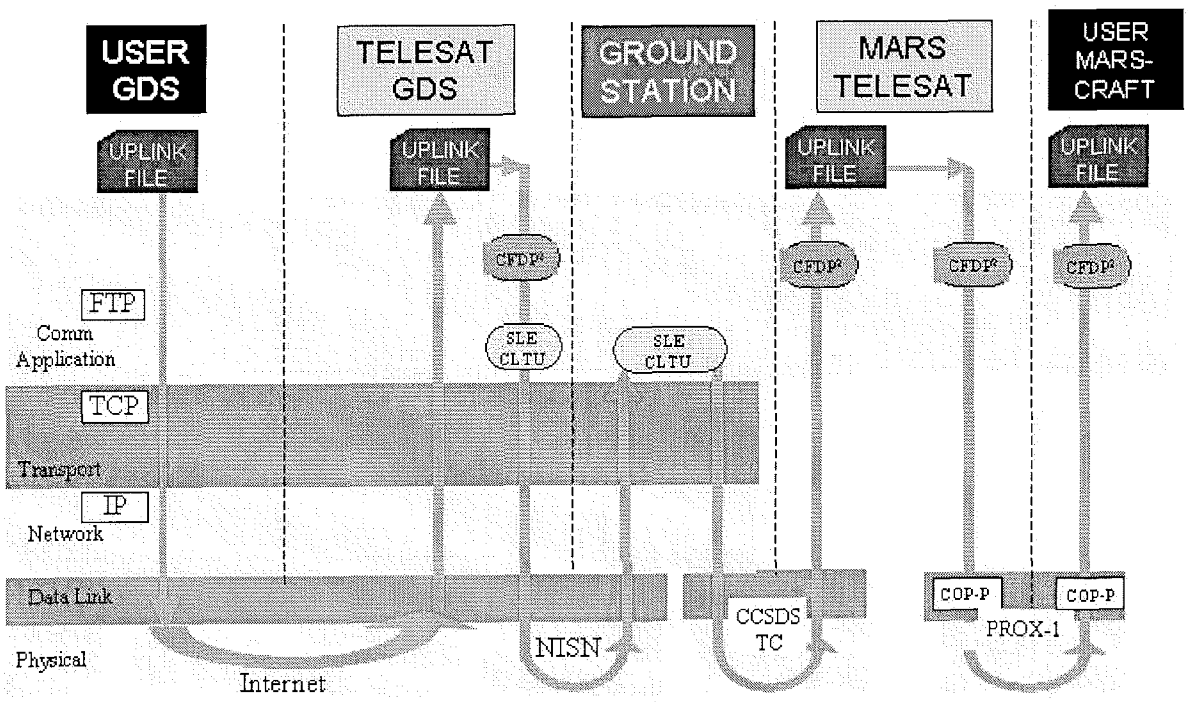

Figure 3: Forward Link Communications Protocol Stack

Figure 3 shows how an uplink file (representing commands/ flight software upload/ star map) is transferred across the layered protocol stack to the Mars bound spacecraft. The file is first transferred by means of the Earth's terrestrial Internet to the relay orbiter's GDS, in this case the Mars Telesat GDS. There, the file is segmented into CFDP protocol data units (PDUs) and sent across to the ground station using the Space Link Extension (SLE) Command Link Transmission Unit (CLTU)

Service. The ground station radiates these CLTUs which are composed of Telecommand (TC) frames each containing a CFDP PDU as the payload. On board the Mars Telesat, the uplink file is reconstructed by the on-board CFDP process and stored on-board. When a relay opportunity presents itself, the uplink file is transferred to the Marscraft using CFDP over Proximity-1. This link could be closed i.e., run reliably either at the data link layer using Proximity-1 or at the application/transport layer using CFDP.

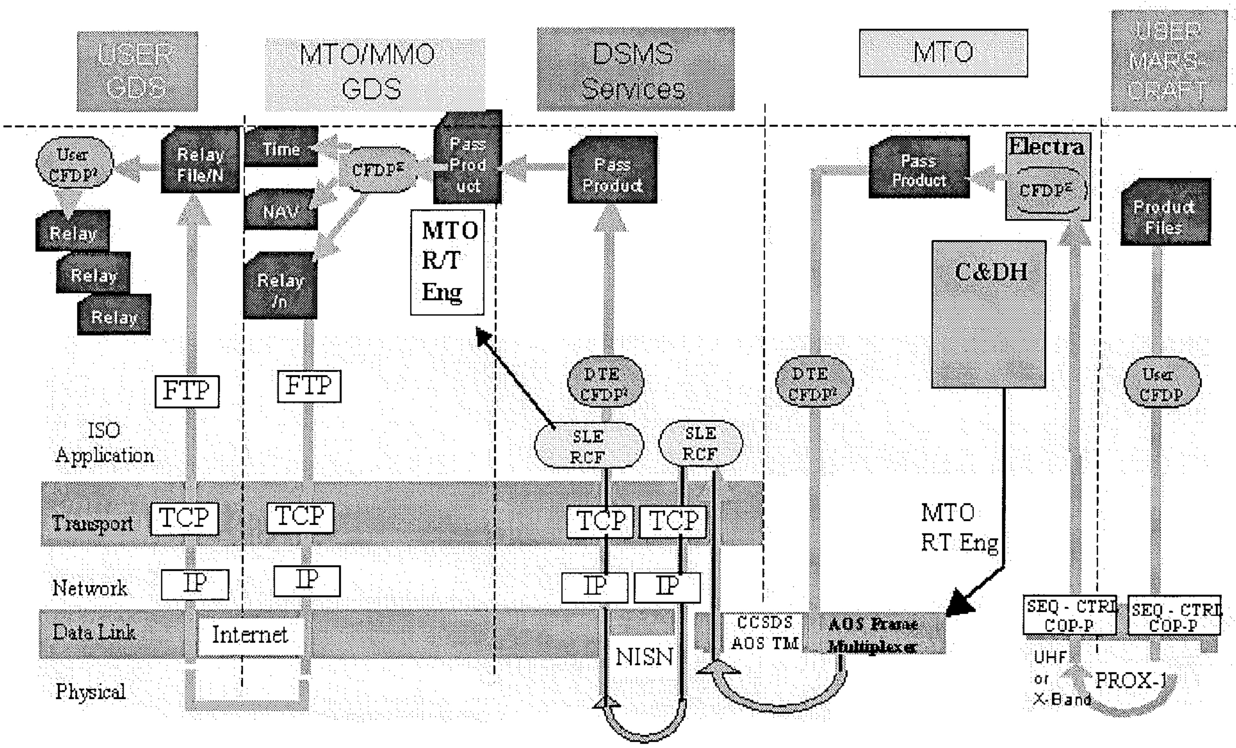

Figure 4: Return Link Communications Protocol Stack

Figure 4 shows how a downlink file set (representing multiple downlink products) is transferred across the layered protocol stack to the end user GDS. CFDP is used to segment the product files and Proximity-1 is used to transfer these PDUs reliably across the proximity link. The ELECTRA transceiver outputs a pass product which consists of the data collected from the Marscraft as one file, multiplexed with additional data products that the ELECTRA transceiver creates such as a Doppler and/or Time correlation files. This pass product maybe parsed on-board by the C&DH into separate files and downlinked separately to Earth using CFDP. Alternatively, the entire pass product can be transmitted as one entity and reconstructed into separate files by the CFDP process within the Multi-

Mission Operations (MMO) GDS. Figure 4 shows the option in which MMO splits apart the multi-mission Doppler and Timing files, but leaves the relay conglomerate file in tact. The user's GDS breaks this file into its component parts using CFDP, assuming individual files were not sent from the relay orbiter.

Summary

Application Profiles define which protocols and space application standards are to be assigned to the asset classes within a given enterprise. For the Mars environment, a preliminary set of protocols has been established. These include: Proximity-1 at the physical and data link layers, CFDP at the transport and application layers. For the space link extension (SLE) between the tracking stations and the Project Operations Control Center (POCC) this includes SLE RCF, RAF and CLTU services. Within this defined list of standards/applications, it is the task of the enterprise to evaluate and choose specific options within these standards for deployment. Once a set of specific options within these standards has been chosen, the enterprise implements this profile throughout their mission set to enhance interoperability within it's mission set and interoperability amongst space agencies.

Acknowledgement

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