STANDARD USER DATA SERVICES FOR SPACECRAFT APPLICATIONS

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ABSTRACT

The Consultative Committee for Space Data Systems (CCSDS) is an international organization of national space agencies that is branching out to provide new standards to enhanced reuse of spacecraft equipment and software. These Spacecraft Onboard Interface (SOIF) standards will be based on the well-known Internet protocols. This paper will review the SOIF standards by looking at the services that are being proposed for SOIF. These services include a Command and Data Acquisition Service, a Time Distribution Service, an Instrument & Subsystem "Plug & Play Service, a Message Transfer Service, a File Transfer Service, and a CCSDS Packet Service. This paper will describe each of these services, and how they may be used.

KEYWORDS

Standard spacecraft interfaces, Standard data services, Standard communications services, Spacecraft user services, Standard user services, Spacecraft plug and play

INTRODUCTION

The CCSDS work area for Spacecraft Onboard Interface (SOIF) Services is setting out to develop recommendations for spacecraft onboard interfaces [1] [2]. We firmly believe that these recommendations will profoundly affect the development of both flight hardware and software of future spacecraft. This paper will expand on a SOIF overview paper [3], by providing a description of the SOIF user services. These are the services that the users can and will expect to use to access the advantages of SOIF.

THE SOIF REFERENCE MODEL

The SOIF Services Working Area has developed a SOIF Reference Model. Within the SOIF Working Area, we are using this model to describe and document our work, both for ourselves, and to others.

Figure 1 shows the SOIF Reference Model [1]. This figure shows how the SOIF layers relate to each other, and where the SOIF communications services fit within these layers. The access points for these SOIF services are shown in this figure as the ellipses at the top of the Communications Services box [3]. The Reference Model also shows the SOIF applications services that are located in the Space Applications layer.

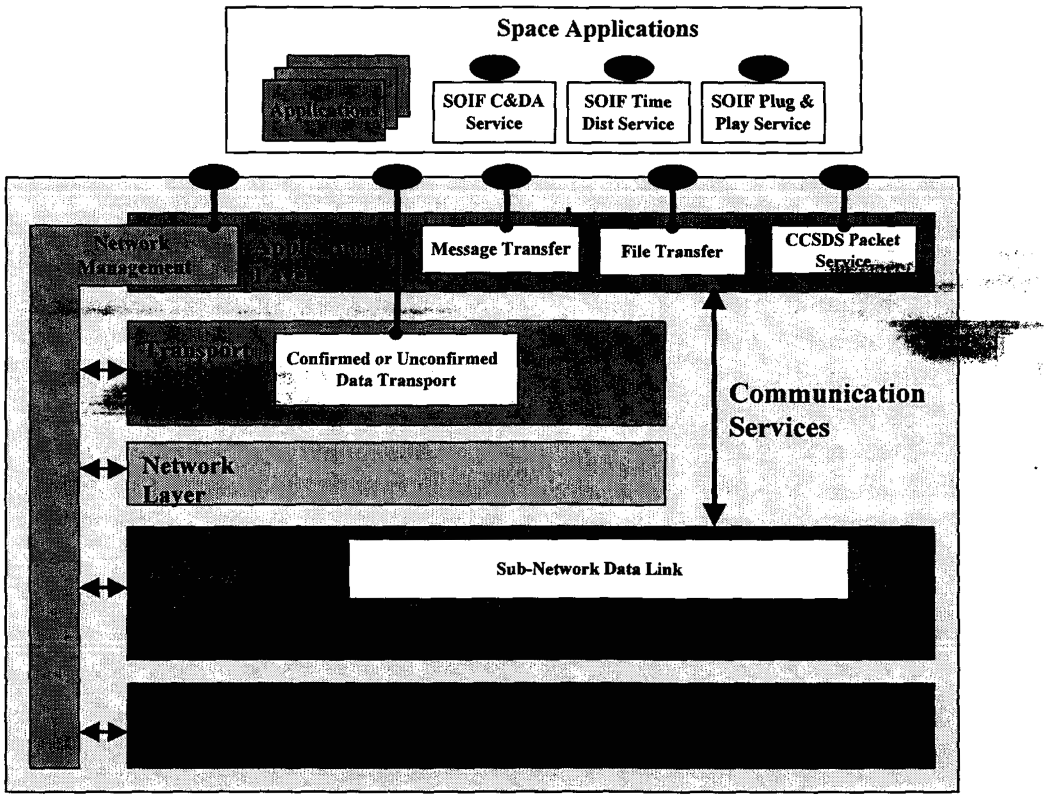

Figure 1: The SOIF Reference Model

THE SOIF SERVICES

We are going to be introducing these services by the layer in the protocol stack, as shown in Figure 1. The services are located in the Transport Layer, the Applications Layer and in the Space Applications Layer. There are seven (7) SOIF services that are presently defined and are available to the users, and they provide access to three different SOIF layers.

SOIF TRANSPORT LAYER SERVICES

The users will have the ability to directly access the Transport Layer. The services available at the Transport Layer will be a reliable (acknowledged) and unreliable (unacknowledged) transport service. In the Internet protocols, these services could be provided by the well know TCP/UDP protocols. The designer may also wish to use an alternate protocol, such as the Space Communications Protocol Standards (SCPS) [4], which has been optimized for the space-ground communications link.

While the Transport Layer interfaces will be available to the user, it is assumed that this will not be a popular interface. Not all implementations will require the use of the Transport and Network Layers. For example, if a spacecraft has only a single subnetwork, then the functionality of these two layers may not be required, and they will not be implemented or available. If some implementations do not use the Transport Layer, and therefore do not have these Transport Layer Services available, then it is not possible to use these services as a generic interface.

SOIF APPLICATIONS LAYER SERVICES

As we can see in Figure 1, there are three other data services in the Applications Layer. The Space Applications and the SOIF Space Applications services can use these services to move data around the spacecraft as needed.

Because the Applications Layer services will isolate the details of the underlying data bus from the users and SOIF services in the Space Applications layer, these three services will be the most important aspect of the SOIF recommendations. For these three services, among other things, do provide for this isolation. In a later section of this paper we will show how these services in the Applications Layer will provide this isolation.

Message Transfer Service [5], is used to move messages around the spacecraft, where the user can define the quality of service provided by the service. The use of a single message transfer service interface hides network/interface differences from higher application functions. When this standard interface is used, the application can use all the services provided by the protocol otherwise the applications either need to supply the service themselves (e.g. reliability, routing, multi-link transparent transport), or do without the service. Furthermore, without using this standard interface, when the underlying bus changes, then the effects will ripple up into the applications. Some applications, particularly those that directly interface with low level sensors or effectors, might require direct link level access, either due to latency or the need for direct control of some critical interface such as a pyro device or propulsion control valve. However, for most applications the use of these higher level interfaces will provide significant benefits in terms of portability, functionality, and isolation from changes at the physical level.

The interface supports both peer to peer and client server interaction models, and provides primitives that can be used to construct basic publish / subscribe interaction pattern if such is desired. The basic elements of this include: name and address resolution, connection establishment, synchronous and asynchronous message transfer mechanisms, and synchronization mechanisms for cooperating processes. Mechanisms are also provided to enable discovery of available level of service (LoS), to select LoS, and for error reporting and service monitoring suitable for operation in a space environment.

File Transfer Service is used to move files between users onboard or within the vicinity of the spacecraft. These users will again have a single interface to use, just as discussed above in the case of the Message Transfer Service. And this single interface will have the same advantage in hiding the network/interface differences from the higher application functions. Furthermore, this service will allow users to send complete files between themselves, in the case where this is the preferred data structure. This data structure would be preferred in a number of cases, such as a complete set of related scientific observations (telemetry), a set of commands to a particular destination, or a patch or update to the flight software for a particular instrument or subsystem.

The ***CCSDS Packet Service*** is the final of the three data format that is used to move data around the spacecraft at the Applications Layer, as required by the users. This format is particularly useful because some Space Applications Layer services are specifically designed to operate with data in this format. The European Packet Utilization Standard (PUS) [6] is perhaps the most popular of these Space Applications Layer users, even to the point that a standard for this service has been created for use by the European Space Agency.

SOIF SPACE APPLICATION LAYER SERVICES

And in Figure 1, we can also see that there are three other SOIF services in the highest of the layers, the Space Applications Layer. The Space Applications Layer services use the Applications Layer services to move data around the spacecraft. In this way, the Applications Layer services will be just as useful to the SOIF Space Applications Layer services as they are to the user applications in hiding the effects of the networks/interfaces from both the users and the SOIF Space Applications Layer services.

Command and Data Acquisition Service (C&DA), which will provide low overhead access to read data from spacecraft sensors and to also provide low overhead commands to spacecraft actuators. A central aspect of this service is that it will be able to provide its functionality to any sensor or actuator, no matter where on the spacecraft (relative to the user) that the sensors or actuators are located relative to the user.

There are six capability sets that make up the functionality of the C&DA service, and they are as follows:

- Device Access: where the logical address of the device can be converted into a network address, that allows the device to be accessed from anywhere in the network.

- Engineering Unit Conversion: which will convert the digital number from reading of the device into the engineering units of the measurement. In other words, the by using this capability, the user will be reading a temperature, voltage, or pressure, instead of receiving a number in which the user must make this conversion.

- Data Product Acquisition: where data from multiple sensors can be read from a single access, and simple calculations can be made from these multiple readings.

- Data Monitoring: the requested data is monitored against declared limits (for example red-line and yellow-line limits) and only reported to the user when the data goes outside the limits.

- Device Virtualization: devices are read and controlled using a virtual generic device image, or model. Models can also be used to control more complex devices, such as a reaction wheel.

- Data Pooling: where the Data Pooling function performs a periodic read of the sensor data, and places the most recent into a data pool (data base). The user can access the periodic data from the sensor data pool or data base, and will access the most recent data.

As sensor and actuator devices are attached or initialized to the onboard spacecraft data bus, they will need to be declared with a discovery capability, so that they will be known to be available to the C&DA Service. This discovery capability will need to be developed at two different levels. The Data Link Layer will need to be used to discover the actual devices that are attached to the bus. Then at the Space Applications Layer, it will be necessary to have another discovery capability for the functionality of the sensors and actuators. This will allow the users to know what sensors are available to the users.

Time Distribution Service, which is used for distribution of time from a central spacecraft clock to the distributed clocks, located in different elements of the spacecraft avionics. These services keep various spacecraft clocks properly synchronized, and then provide a standard interface to all users where they can receive the correct spacecraft time. The methods that are used to keep the central spacecraft time synchronized to the ground or control center are beyond the scope of this SOIF Time Distribution Service.

Plug and Play Service, is a capability to provide a set of standard interfaces for the space application, or the space user. The standard interfaces for that would be available to the space application would be such capabilities as commanding, telemetry, fault protection (FDIR), mission and science planning and scheduling, control and monitor, and other interfaces as defined.

As subsystems, instruments, and other processors attached or initialized to the onboard spacecraft data bus, they will need to be declared with a discovery capability, so that they will be known to be available to the Plug and Play Service. This discovery capability will need to be developed at two different levels. The Data Link Layer will need to be used to discover the actual processors that are attached to the bus. Then at the Space Applications Layer, it will be necessary to have another discovery capability for the functionality of the subsystems, instruments, or processor. This will allow the users to know what services are available to the users.

ACCESS TO THE DATA LINK LAYER

Figure 1 shows the SOIF Reference Model, and we have briefly discussed how the services in the SOIF Application Layer can be used to isolate the user applications from the underlying data bus. This is further shown in Figure 2, that there are two different paths to access the Data Link Layer.

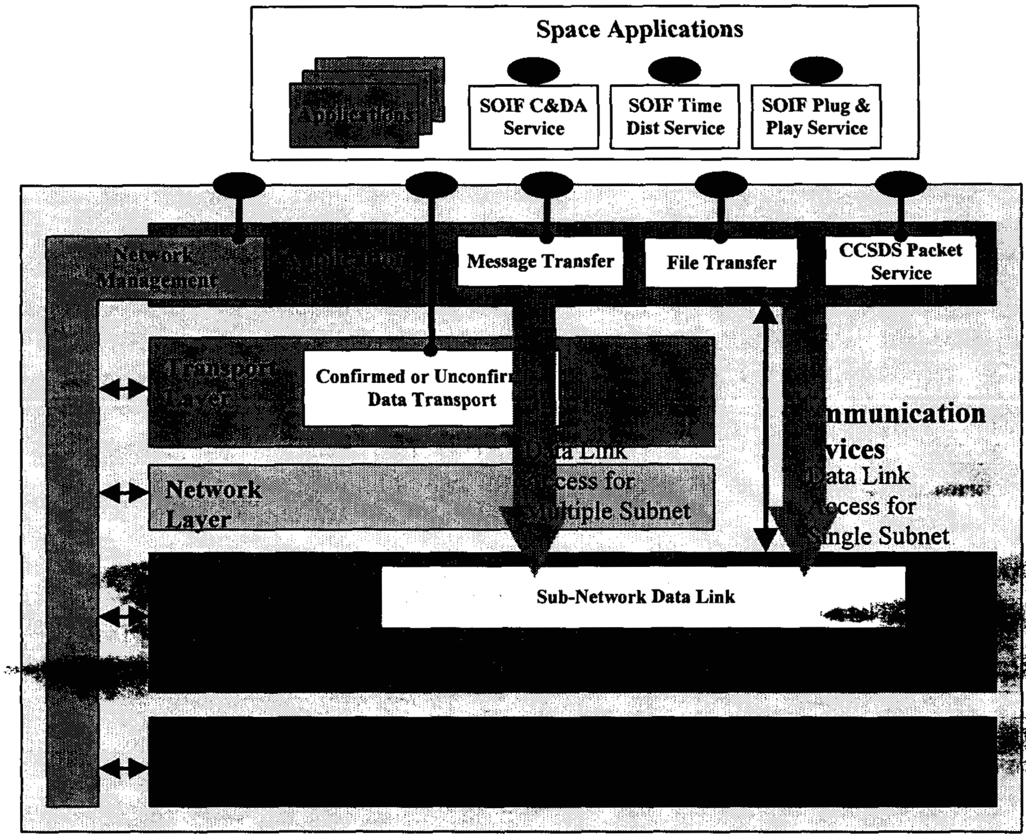

FIGURE 2: TWO PATHS TO ACCESS THE DATA LINK LAYER

For this discussion, we will assume that all users from the Space Applications Layer will access the lower layer communications by way of one of the three Application Layer services: the Message Transfer, File Transfer, or CCSDS Packets services.

As is shown in Figure 2 there are two paths to the Data Link Layer. The path of the arrow on the right shows the case when there is only one subnetwork (data bus) onboard the spacecraft. This means that there is not only one type of subnetwork, but there is only one physical subnetwork on the spacecraft.

The other case is shown by the arrow on the left in Figure 2, for the case when there are multiple subnetworks available to the spacecraft. In this case, it will be necessary to implement the Transport and Network Layers provide the ability to route the messages to the proper location on the proper subnetwork. In this case, there can be several subnetworks on the spacecraft, and they can even be of different types. It is even possible that a spacelink subnet (RF) can be used to connect two different spacecraft, if they are close enough for the Transport and Network Layer protocols to still work.

In the multi-subnetwork case, when all of the SOIF users are using one of the three Application Layer services (Message Transfer, File Transfer, or CCSDS Packet Services) then it will be transparent to the users which of these two paths are in use. This means that using the Applications Layer services will insulate the user (in the Space Application Layer) from the Data Link Layer or Layers that are used.

The implication of this discussion is that SOIF will be able to deliver on its promise for interoperability. With all of the users (be they subsystems, instruments, or hardware devices) using the SOIF Applications Layer Services, the users can be interchanged at will. Similarly, it will be possible to change out the underlying data bus without any effect on the users. Or, it will be possible to move a user from one spacecraft (for example if it has only one data bus) to another spacecraft, (even if it has multiple data busses, and none of them use the same data bus technology as the first spacecraft) without effecting the user implementation.

CONCLUSIONS

Therefore, the Applications Layer services are the key to the SOIF implementation, in preserving the implementation of the users when there is a change in the underlying data bus, and in giving the users a small set of standard interfaces with which to interface.

Ultimately, this flexibility of SOIF to operate in any number of different interoperability scenarios will be very important in the ultimate acceptance of SOIF in the larger spacecraft community. As these capabilities are diffused throughout the industry, we can expect that SOIF will start to bring increased levels of cost savings and reduced risk to a large number of different missions. Indeed, we in the SOIF Work Area believe that once SOIF is well known and understood, these recommendations and their successors will be the dominant spacecraft interface technology for the next few decades.

ACKNOWLEDGEMENTS

SOIF is a collaborative activity involving many individuals from different countries and organizations throughout the world. We gratefully acknowledge all of the contributions of the SOIF work area members during the twice-yearly face-to-face meetings, and the numerous teleconferences and e-mail exchanges that have brought us so far.

Some of the work described in this paper was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration.

REFERENCES

[1] Spacecraft Onboard Interfaces – Concept and Rationale, Consultative Committee for Space Data Systems, Green Book CCSDS 830.0-G-0.4, 2002

[2] Web site of the Consultative Committee for Space Data Systems, http://www.ccsds.org

[3] Introduction to Standardized Spacecraft Onboard Interfaces, by J. F. Smith, C. Plummer, and P. Plancke, ITC 2003, Las Vegas, NV, October 2003

[4] Web site for the Space Communications Protocol Standards, http://www.scps.org

[5] A Message Transfer Service for Space Applications, by Peter Shames, SpaceOps 2002 Conference, Houston, TX, October 2002

[6] Ground Systems and Operations – Telemetry and Telecommand Packet Utilization (Packet Utilization Standard), European Cooperation for Space Standardization Secretariat, ESA-ESTEC, Noordwijk, Netherlands, ECSS-E-70-41, Draft 5.3, 5 April 2001

ACRONYM LIST

C&DA:	Command and Data Acquisition
CCSDS:	Consultative Committee for Space Data Systems
FDIR:	Fault Detection, Isolation, and Recovery
LoS:	level of service
PUS:	Packet Utilization Standard
RF:	Radio Frequency
SCPS:	Space Communications Protocol Standards
SOIF:	Spacecraft Onboard Interface
TCP:	Transmission Control Protocol
UDP:	User Datagram Protocol