THE SPACECRAFT ONBOARD INTERFACE STANDARDIZATION ACTIVITY

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Abstract

The Consultative Committee for Space Data Systems (CCSDS) is an international organization of national space agencies (such as NASA in the United States) that is organized to promote the interchange of space related information. Now, CCSDS is branching out to provide new standards for the interchange of information, and the interconnection of subsystems and devices onboard of a spacecraft. This effort is know as Spacecraft Onboard Interface (SOIF). SOIF will publish standards that will allow for the enhanced reuse of spacecraft equipment and software. SOIF expects that these standards will be well known and used within the space community, and that they will be based on or similar to the well-known Internet protocols. This paper will provide a description of the SOIF work by reviewing this work with three orthogonal views. The first of these views is the Protocol view, which describes the protocols and services that are to be implemented in order to provide the users with the advantages of the SOIF architecture. The second of these views is the Services View, which describes the data communications services that are provided to the users. And finally, the Interoperability view provides a description to users how SOIF can be used to interchange between different spacecraft data busses. This paper will give the reader an excellent introduction to the work of the international SOIF team.

Introduction

The CCSDS P1K Subpanel for Spacecraft Onboard Interfaces (SOIF) is setting out to develop recommendations for spacecraft onboard interfaces. We firmly believe that these recommendations will profoundly effect the development of both the flight hardware and software of future spacecraft. This paper discusses the SOIF activity, detailing its scope, objectives, and the progress made so far.

The Scope of SOIF

SOIF addresses the electrical and communications interfaces onboard the spacecraft, and encompasses the electrical, software, and mechanical aspects of those interfaces. In order to limit the activity so that we can generate the first stable recommendations within two years, we are concentrating initially on the communication interfaces between flight units, which include the spacecraft onboard buses, and electrical interfaces to sensors, actuators devices, subsystems, and payload instruments. Our expectation is that, with recommendations on these aspects deployed, support for SOIF will grow and the activity will expand to address other areas, such as the more complex software aspects of these interfaces.

The results of the SOIF activity will be published in the form of CCSDS Blue Book recommendations containing the specifications for the interfaces. Since the scope of SOIF is so large, these recommendations will be published in several parts, and projects can elect to comply with one or more parts as appropriate. This allows us to promote a phased adoption of SOIF with some parts of the recommendation being available before others, to simplify project tailoring, and adapt to changes in the future.

The Need for SOIF

Standardizing the onboard interfaces, and producing well-structured and comprehensive recommendations should lead to:

- Reduced development costs and risks for onboard hardware and software,

- Shorter development times for the spacecraft flight element,
- Shorter spacecraft flight element integration times,
- Shared design and test documentation for spacecraft onboard systems,
- Increased potential for flight equipment re-use,
- Increased potential for flight software re-use,
- Increased potential for test equipment re-use,
- Potential for improved quality of flight and test equipment,
- Potential for development of standard components,
- Potential for second-sourcing of flight and test equipment,
- Better potential for secondary or "quick-ride" payload development,
- Easier adoption new and evolving technologies in the future, including hardware and software upgrades, autonomy and vehicle health management.

It is clear from this list that SOIF impacts just about all areas of the development of the flight element electronic systems, including both the electronics hardware and the software.

The Objectives of SOIF

The generation of internationally agreed recommendations and the realization of the benefits listed above are clearly the primary objectives of SOIF. However, there are a number of other objectives that must be considered.

Firstly, SOIF must not constrain the spacecraft implementer unnecessarily. This means, for example, that SOIF must not limit the implementers' choice of onboard bus, or constrain him to use a particular programming language or operating system. Also, while SOIF will recommend the use of certain communication protocols, and will define the implementation profiles of those protocols, it will not preclude the use of different protocols that can be integrated within the protocol stack.

Secondly, SOIF must be appropriate for several future generations of spacecraft. This means that it must accommodate the needs of the next generation of spacecraft, which can be determined fairly accurately, as well as the needs of spacecraft far in the future, which are much more difficult to determine.

Thirdly, the cost of compliance for early adapters must be kept to a minimum so that their cost of adoption will be lower than their added cost of adopting the standard. Obviously, the adoption of any standard will impose some cost penalties on the first projects to adopt the recommendations. To keep the costs of compliance as low as possible requires that early users get adequate support, and that component and instrument developers are encouraged to adopt the recommendations for their products.

Finally, SOIF must be compatible with other, existing standards that are used onboard spacecraft, such as the CCSDS Telemetry and Telecommand standards, and the ESA Packet Utilization Standard (PUS).

SOIF in Reality

The preceding sections have painted a rosy picture of the SOIF objectives, but making SOIF a reality, i.e. taking these objectives and turning them into a set of recommendations that can be understood and used in spacecraft projects, requires a well-chosen, pragmatic approach.

One of the main problems is that, because of its broad scope, SOIF is seen as many different things by many different people. For example, spacecraft onboard hardware developers are expecting to see detailed electrical specifications for onboard interfaces. Onboard software developers are looking for abstract interfaces that make it easier for them to access common services for data transfers, onboard time distribution, and device data acquisition and commanding. Spacecraft system engineers are looking for recommendations that will increase the ability to interoperate and to re-use flight components across different platforms. Project managers are looking for solutions that will save them schedule time and money on their projects, and reduce development risks.

All of these views, and many others, must be taken into account in the preparation of the SOIF recommendations, and we are putting a great deal

of effort into making the recommendation easily understood by these different communities. The solution that we have adopted is a careful structuring of the recommendation document tree.

Another problem that we face, again due to the broad scope of SOIF, is that within the sub-panel we have people with a broad range of skills and specializations. Many of these specializations have their own distinct way of looking at problems, and their own vocabulary for describing things. In order to get the most out of the individual participants on the sub-panel, we have divided the tasks up into key areas, each of which is addressed by a Special Interest Group, SIG, i.e. a small group of individuals with a special interest in that area. This has reduced the need for sub-panel members to become distracted by issues that they are not interested in, and has allowed work on the key areas to be carried out much more efficiently and in parallel with other activities.

The recognition of several views of the SOIF problem domain has been an important step in our standardization activities, and one that we are only just coming to terms with. Figure 1a shows three orthogonal views of the SOIF problem domain, and discussion of each of these views can give some insight into how the SOIF sub-panel is attempting to accommodate them.

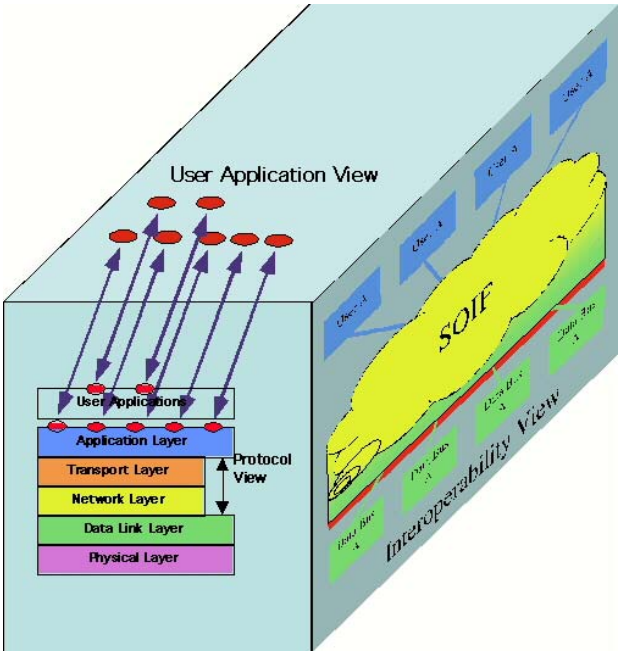

Figure 1a: Three Orthogonal Views of SOIF

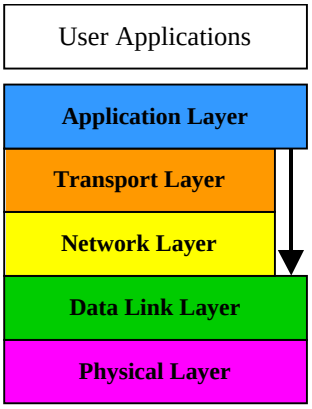

Figure 1b: The Protocol View of SOIF

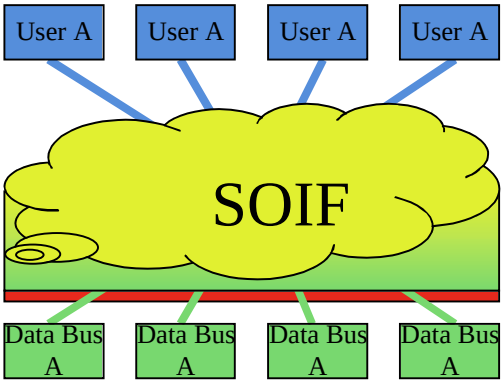

Figure 1c: The Interoperability View of SOIF

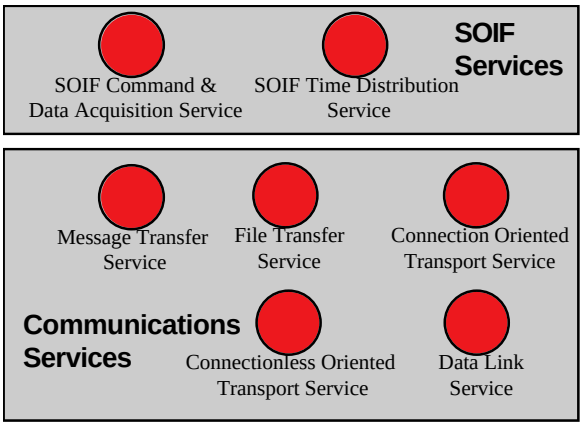

Figure 1d: The Services View of SOIF

The first view can be called the protocol view, and is shown in more detail in Figure 1b. This sees the SOIF problem as being similar to that addressed by classical communication architectures like the ISO OSI 7-layer reference model, or the Internet protocol stack. Under this view, the solution to the problem is seen as a set of hierarchically ordered

services. The key to meeting the SOIF goals of being able to tailor and scale the solution for different situations, and to allow evolution and development in the future, is in the relationships between the services, which are determined by the definition of the service interfaces.

The vocabulary associated with this view is that of OSI and the internet community, and includes words and phrases such as *service*, *hierarchy*, *service access point* (SAP), *grades of service*, and so on.

This view is natural to many of the sub-panel members, particularly those who have been involved in protocol design and communication system engineering in the past. It is quite likely that the protocol view will be that seen by the implementers of SOIF, i.e. the engineers responsible for providing SOIF services on a given spacecraft. However, this view is not intuitive to many of the potential users of SOIF, particularly software application developers who write the flight application software, and hardware designers who make hardware interface components.

The second view to consider is the user applications view. This is the view of software engineers and programmers developing flight applications for a spacecraft. Since these are one of the most important 'customers' for SOIF, we need to fully understand their view. Typically, application developers see a set of application programming interfaces (APIs), i.e. a set of procedure and function calls that they can bind with their applications to access the services offered by SOIF.

From the user application view, the underlying hierarchy is not only not visible, but not of interest. Users see only a set of APIs that are uniformly accessible from each application. These APIs correspond to the service access points exposed by the SOIF stack. The vocabulary associated with this view includes expressions such as *API*, *bind*, *procedure call*, *function call*, and so on. This services view of SOIF is shown in Figure 1d.

The third view that is considered here is the interoperability view. This view doesn't even consider the services that are provided, but is concerned with how a SOIF compliant device or subsystem can be attached to any supported underlying bus with a minimal amount of change. This is shown in Figure 1c as the ability to change out the bus without effects on the protocols (in the protocol views) or the provided services (in the User Applications view). Implementation of this view will also allow the SOIF compliant spacecraft to easily implement gateways between different types of data busses, if this is required.

This last view is the view generally adopted by the avionics hardware engineers, who are concerned with the implementation of the avionics data bus, and how the data bus can be changed to meet the needs of the particular mission.

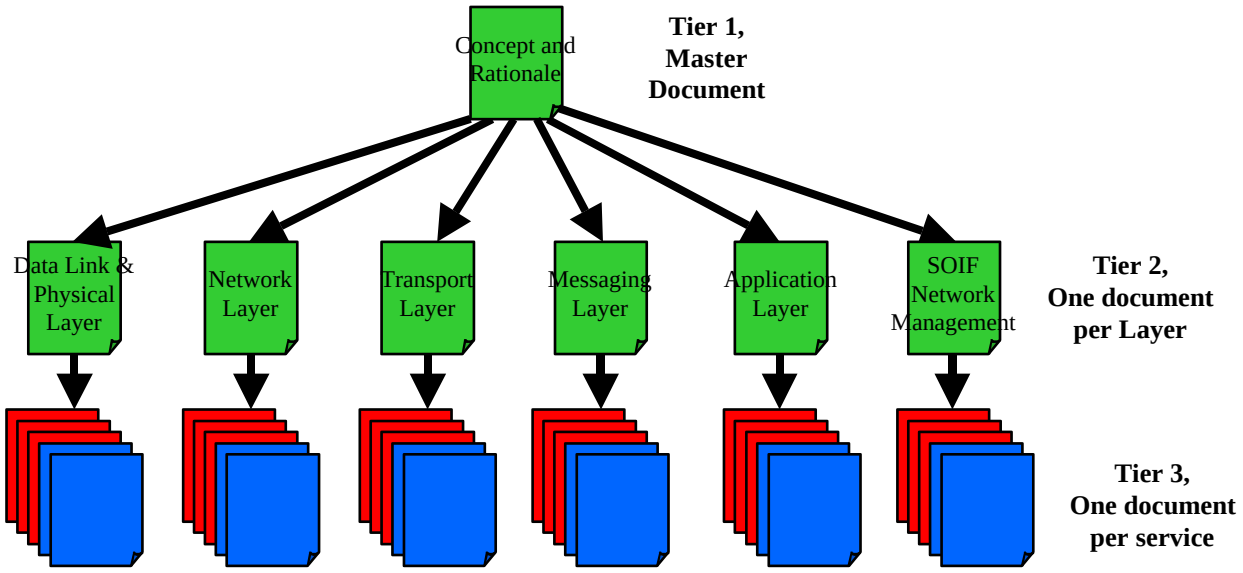

Figure 2: The SOIF Document Tree

All of these views are important, and all of them are now being taken into account in SOIF. Since SOIF is ultimately deployed as a recommendation, or in fact as a set of recommendations, the document tree that is shown in Figure 2 is extremely important. This structure determines how easily different potential users can understand SOIF, and how readily they can adopt the elements of the recommendation that are appropriate to them. The principal documents published by CCSDS are green and blue books. Green books describe concepts and rationale, and are informative. Blue books contain the actual recommendations, and are therefore the normative documents of CCSDS. Prior to being finalized and approved, blue books are published as red books. The proposed structure of the SOIF document tree is shown in Figure 2. Under this scheme, a single green book called the SOIF Concept and Rationale describes the basic concepts behind SOIF and explains how SOIF can be used on a project. Beneath this there is a series of green books describing the concepts of the key components of SOIF in more detail. Finally, beneath these are the red (draft recommendations) and blue books that make up the normative part of the recommendation.

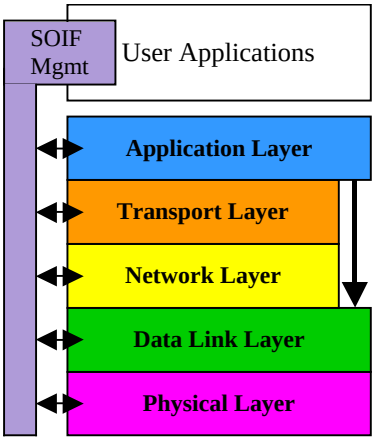

Figure 3: The SOIF Architectural Reference Model

The SOIF Architectural Model

The SOIF architectural reference model is layered according to the principles of the ISO OSI Reference Model, and is depicted in Figure 3.

The SOIF ***application layer*** contains user-oriented services that are presented to SOIF users that reside outside of the model. Typically a SOIF user is an onboard application that makes use of the SOIF services to access other onboard applications, and onboard sensors and actuators. The SOIF application layer is equivalent to the application layer of the OSI 7-layer model.

The SOIF ***transport layer*** contains services that enable end-to-end transfer of messages between users. The SOIF transport layer contains the transport layer of the OSI 7-layer model.

The SOIF ***network layer*** contains services that control the operation of the underlying sub-networks and enable data to be routed throughout the spacecraft network. This layer corresponds directly with the network layer of the OSI 7-layer model.

The SOIF ***data link and physical layers*** contains services that implement the onboard sub-network and interfaces to other onboard devices, subsystems, and instruments. Typically, onboard sub-networks comprise onboard buses as well as point-to-point links between flight units. The SOIF data link and physical layers corresponds to the data link layer and the physical layer of the OSI 7-layer model.

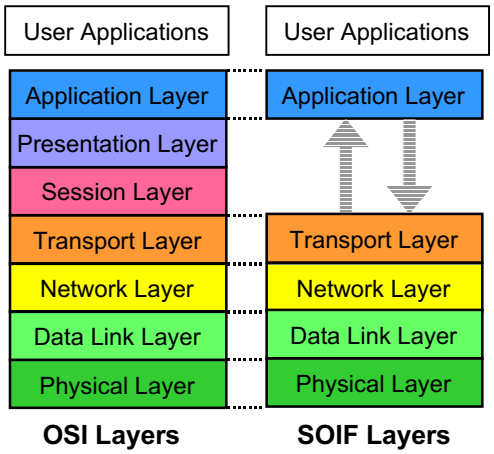

Figure 4: Correspondence between OSI and SOIF Protocol Layers

The SOIF ***management service*** provides the capability of managing the SOIF stack. Because this service is accessed as a user application, and controls the configuration of each layer, it is represented as another user application connected to a vertical slice spanning all of the layers of the

reference model in accordance with accepted OSI convention.

are needed onboard a typical spacecraft. These are shown in Figure 5.

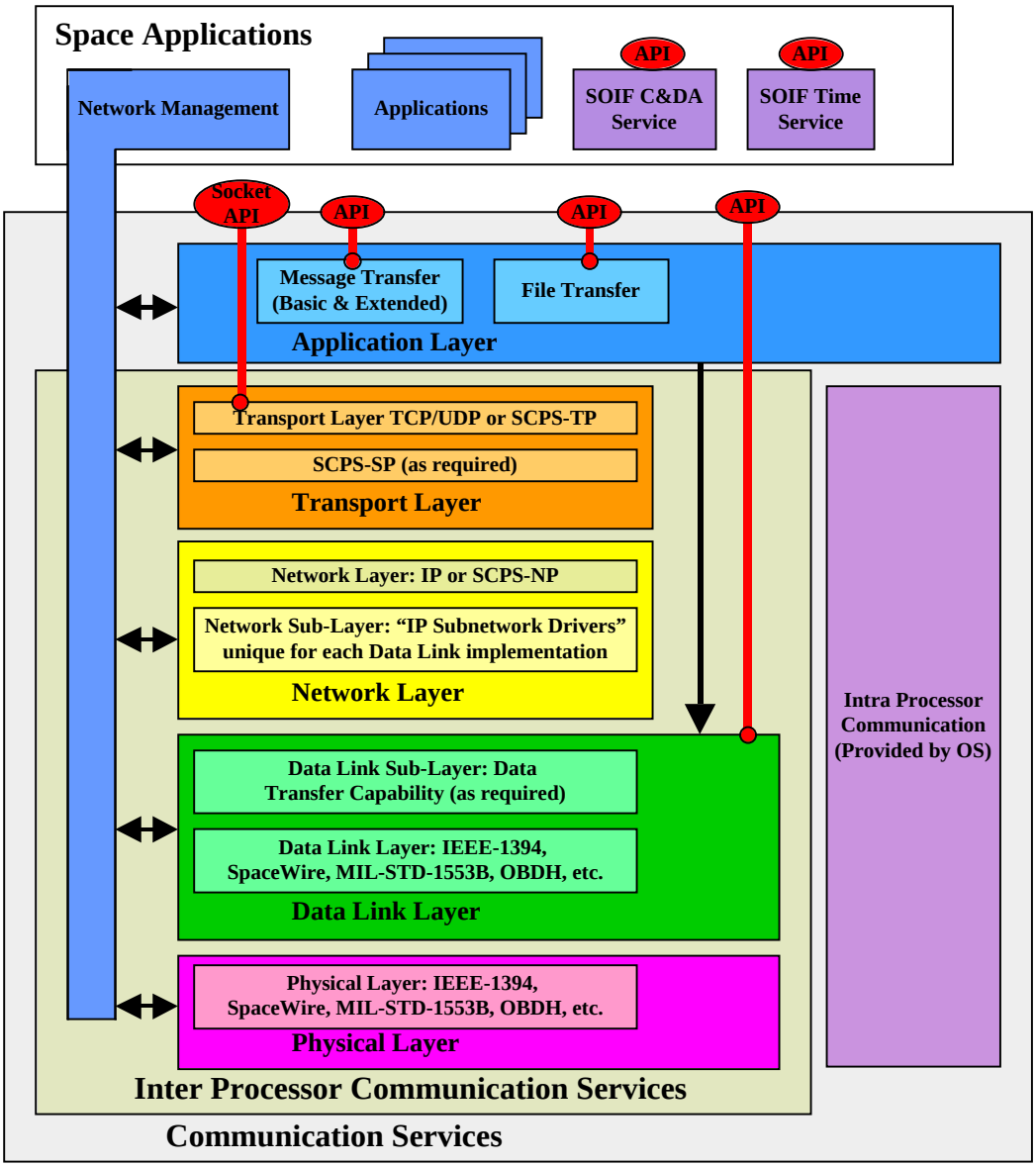

Figure 5. SOI Services and Protocols

The SOIF reference model layers differ from the actual layers named in the OSI reference model because we have chosen to combine certain layers. The correspondence between the SOIF layers and the OSI layers is shown in Figure 4.

SOIF Services

Having established the SOIF layers, these have now been populated with a number of services that

There are six (6) SOIF services available to the users that are presently defined. In the Space Applications layer, these services are:

- 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 effectors.

- Time 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.

In the Applications Layer, there are two other data services that are used by the Spacecraft Applications and the SOIF C&DA and Time services to move data around the spacecraft as needed. These services are:

- Message Transfer Service, which is used to move messages around the spacecraft, where the user can define the quality of service provided by the service, and
- File Transfer Service that is used to move files for the users.

The users can also directly access in the Transport Layer:

- Reliable (acknowledged) and unreliable (unacknowledged) transport service. In the internet protocols, these services could be provided by the well know TCP or similar protocol.

And finally, for legacy users who have applications that are designed to directly access the Data Link Layer of the underlying data bus, there is one final service:

- A Data Link Service which allows the legacy user to operate without changes

However, the CCSDS SOIF subpanel cannot recommend this Data Link Service. Using this service means that this application will not be able to take advantage of many of the SOIF capabilities.

Conclusions

SOIF is a very active, international initiative by the CCSDS and fully supported its sponsoring agencies and industry to define standards for spacecraft onboard interfaces. This work has a very broad scope, and is likely to have a beneficial effect on many aspects of spacecraft onboard systems in the future. Within the space of this short paper we have only been able to give a brief introduction to SOIF and its progress so far.

We apologize to many of our SOIF colleagues for not having featured some of their activities, particularly relating to the SOIF messaging service and network management aspects. This has been due only to a shortage of space. These and other aspects of the SOIF work will be published in the future.

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 sub-panel members during the twice-yearly face-to-face meetings, and the numerous teleconferences and e-mail exchanges that have brought us so far.

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