Integrating Space Communication Network Capabilities via Web Portal Technologies

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We have developed a service portal prototype as part of an investigation into the feasibility of using Java portlet technology as a means of providing integrated access to NASA communications network services. Portal servers provide an attractive platform for this role due to the various built-in collaboration applications they can provide, combined with the possibility to develop custom inter-operating portlets to extent their functionality while preserving common presentation and behavior. This paper describes various options for integration of network services related to planning and scheduling, and results based on use of a popular open-source portal framework. Plans are underway to develop an operational SCaN Service Portal, building on the experiences reported here.

I. Introduction

Among the challenges of automated space network operations is that of providing user tools for estimating, planning and forecasting, developing and managing service agreements, and all the associated activities which these entail. There are significant efforts required on the part of end users as well as the network providers, especially as capabilities and requirements evolve over time. With the popularity of the web has come a multitude of disparate systems, tools, sites, and servers, often requiring different user sign-ons, which the user has to navigate to gather and effectively use the necessary information. These vary depending on mission phase and type of mission, adding to the cost for both users and network providers.

This paper describes a project undertaken at JPL to assess and prototype the use of standardized web portal technology (JSR-168, JSR-286: Portlet Specification 2.0) as a mean to integrate software tools and systems, from the perspectives of different users. Such an approach leverages commercial developments in enterprise level portals that provide extensive built-in functionality (for example: document management, wikis, message boards, search, security). We have investigated, designed, and implemented 'portlets' of various types to demonstrate selected capabilities specifically relevant to space mission design, communications requirements and capabilities, and space network planning and scheduling. Among the functions we have demonstrated as conveniently integrated in a portlet container are:

- communications service profile creation and management, including review and approval workflows
- link analysis calculations driven directly from service profile parameters
- long-range planning requirements and forecasting
- schedules and mission scheduling requirements
- scheduling process information (deadlines, notifications, etc.)

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In addition, the implementation of discrete capabilities as portlets allows for customization and mixing and matching as necessary. For example, a portlet that displays the current network schedule can be used on a mission scheduler's dashboard, as well as that of a user monitoring the overall process, or one seeking opportunities for network tests. Further, portlets offer a mechanism for inter-portlet communication, thus allowing for interoperating portlets to be assigned to a single view with all the associated synergy that this provides.

In this paper we discuss: the variety of portlet integration strategies that we have investigated; security and the integration of portal role management with LDAP and OpenAM for authentication and authorization; inter-portlet communication and its use to develop loosely-coupled families of portlets; and lessons learned that may be useful for others considering adopting portal technology for similar purposes. We also describe how this work is planned to be extended in the future.

II. Overview of SCaN Network Integration and Service Portal

The National Aeronautics and Space Administration (NASA) Space Communications and Navigation (SCaN) program is responsible for providing communications and navigation services to space flight missions located throughout the solar system. The SCaN Program provides flight missions with services like transmitting data to and from space vehicles and deriving information from transmitted signals for tracking, position determination, and timing. These services are provided by the three existing network elements, the Near Earth Network (NEN), the Space Network (SN), and the Deep Space Network (DSN).

Recently, over a period of several years, numerous trade studies and analyses have led to the definition and plan of an overall Integrated Network Architecture[1], to be realized in phases[2,3]. The NASA integrated space communications network is intended to unify NASA's three existing network elements into a single network. Figure 1 illustrates the "should-be" architecture to be realized at the conclusion of this integration effort.

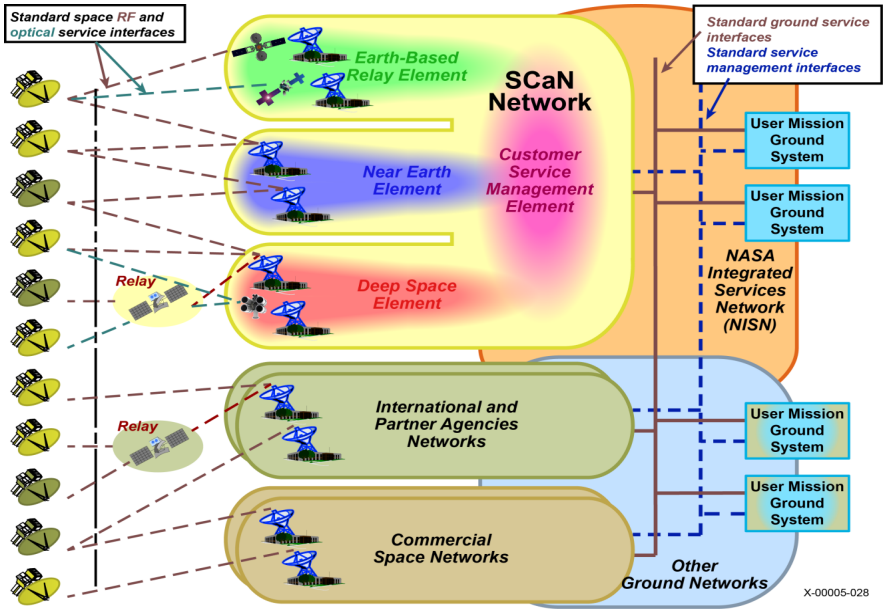


Fig. 1 - The NASA Integrated Network Architecture around the 2018 era — a notional illustration[2]

As one of the first steps in moving to the integrated architecture, the SCaN program has determined that a Service Portal must be built to provide the primary access point for user missions to interface with the NASA Integrated Network. The Service Portal, from the view of user missions, is a web-based system facilitating service management activities such as:

- access to the Integrated Network services catalog, services catalog for each network element, and user's guides for each network element
- interfaces with the Integrated Network for submitting spacecraft trajectory file
- interfaces with the Integrated Network for submitting spacecraft link configuration files
- access to RF link analysis tool(s) for performing the link design
- access to the all the network schedule products

The Service Portal is to provide a single access point for user missions for performing network planning functions, including development of service agreements that involve one or more of the constituent networks.

III. Standards-Based Portal Containers

There is broad demand across many industries for web portal functionality such as that envisioned for the SCaN Service Portal. Since the late 1990s, vendors have been providing "enterprise portals" incorporating toolkits for enterprises to develop and deploy their own customized portals, for internal and external use. Efforts to standardize and provide for interoperability between portal servers and 'portlets' (pluggable user interface software components that are managed and displayed in a portal) led to an initial Java standard designated JSR-168 in 2003 [4]. A subsequent update of that standard was published as JSR-286 (Portlet 2.0) in 2008 [5]. At this time, numerous vendors provide portal servers with a wide range of built-in functionality, and the technology is well established — there are 16 vendors with products supporting the Portlet 2.0 specification, including both open source and proprietary systems. Among the basic capabilities provided by portal servers or containers are the following:

- **single sign-on** — requires a user to authenticate only once in order to access various services provided though the portal
- **integration** — the connection of functions and data from multiple systems into new components/portlets/web parts with an integrated navigation between these components
- **customization** — users can customize the look and feel of their portal views, in some cases building their own custom pages or sites with tailored functionality
- **access control** — the ability for portal to limit specific types of content and services users have access to
- **search** — provide integrated search encompassing all portal content

In addition, many portal products provide build-in portlet applications that can be incorporated along with custom portal content, to provide a full-featured enterprise information portal. At an early stage of the project reported here, we assessed the available portal offering and settled on the open source Liferay[6] portal as the basis for our investigation. The bundled applications with the Liferay product are typical of those provided by other vendors, and include:

- **wikis**: collaborative user editable documentation
- **content management**: web content definition and management, include workflows for staging and publishing
- **document management**: storage and metadata for documents, also including workflows and versioning
- **blogs** and blog aggregation
- **message boards**
- **alerts** and **announcements**, including **RSS news feeds**
- shared and private **calendars**

Portals have been developed and deployed in a variety of space science and operations contexts, including geophysics[7], remote sensing[8], and for the NASA System Engineering Body of Knowledge (SEBoK)[9]. Numerous commercial instances are in active use[6].

IV. Custom Portal Content

While the portal portlet applications described in Section III are essential to build rich portals for applications like the SCaN Integrated Network, there are additionally a variety of custom functions needed. These require development of Java portlets that run in the same portal environment, and integrate seamlessly with built-in applications and with other custom portlets. The remainder of this section describes a variety of these functions and the conclusions drawn from our feasibility investigations.

A. Integration with external authentication systems

Liferay provides a built-in authentication mechanism, through which users can register, specify their passwords and email addresses, security questions, profiles, etc. However, in the context of an enterprise application where user identity is managed external to the portal, as will be the case for the SCaN Service Portal, it is essential to integrate with external authentication servers. To evaluate this, we integrated a Liferay instance with two different external authentication servers, using LDAP and OpenAM for this purpose. In this way, user authentication is managed via a standard external service, while permissions to access various portions of the portal itself are managed using the portal's own access control mechanisms.

B. Custom portlets for integrated data display

Fig. 2 shows an overview diagram of the variety of different types of custom portlet data flow, storage, and presentation options that we have evaluated using the Liferay platform as portal server. The portal architecture is based on a presumption of network accessible services provided by the individual NASA network elements. Some of these services will likely be new, or have new interface servers, and so can be specified to use e.g. RESTful HTTP interfaces with appropriate security protocols. However, some services are expected to be provided via 'legacy' interfaces, which are too costly or too great an impact to change. Such services still need to be accessible to the

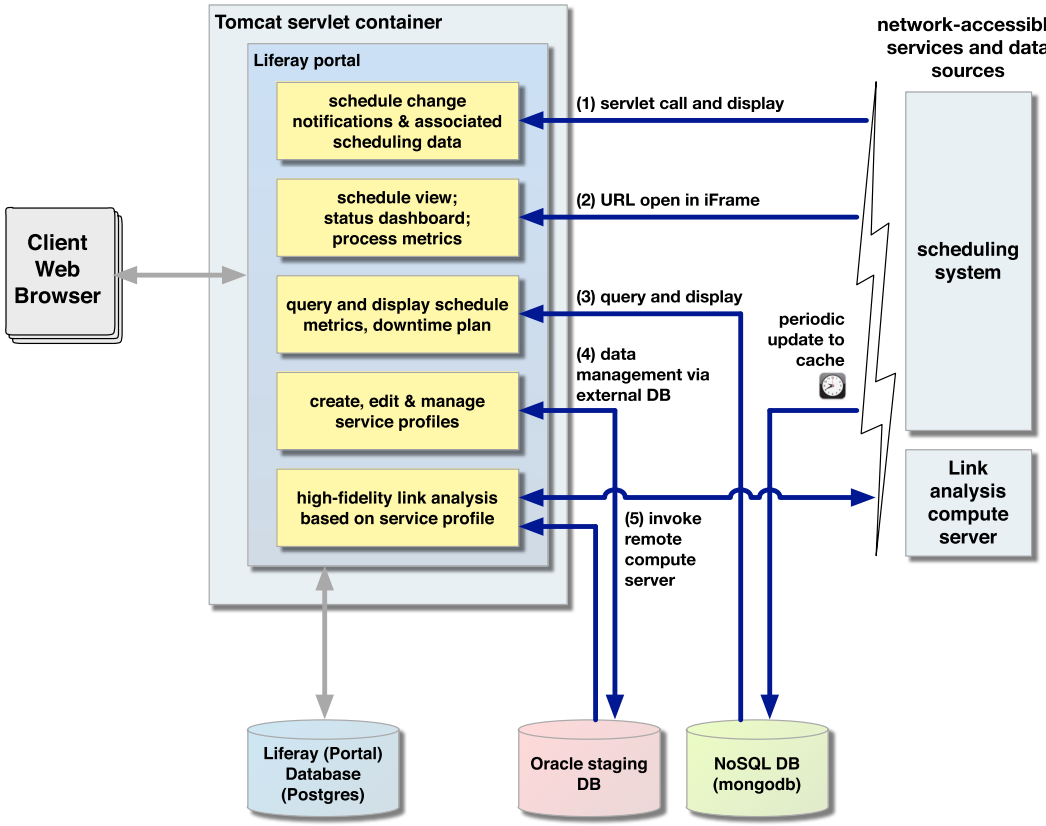


Fig. 2: A variety of portlets types indicating data flow and presentation options

SCaN Servide Portal, possibly wrapped in proxy services that provide specialized access to the underlying data or services.

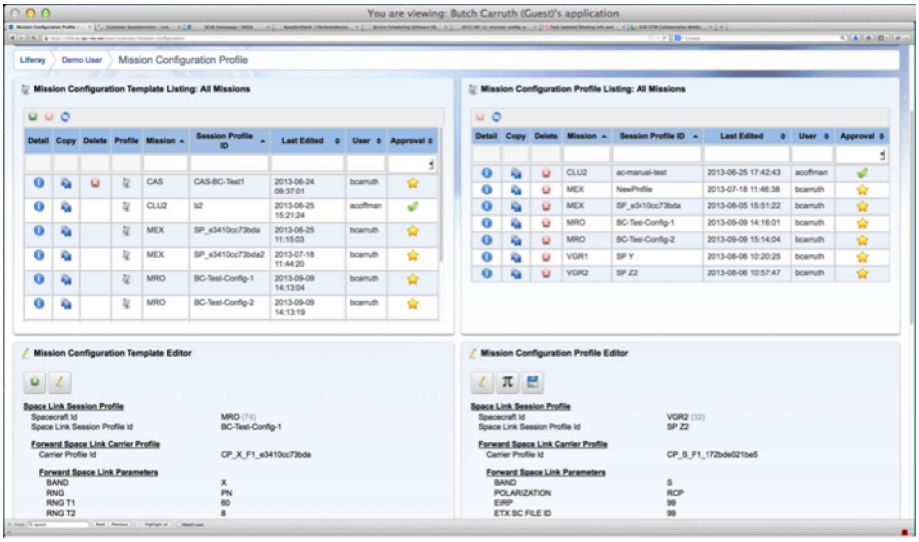
- **(1) Servlet call and display** — a common pattern that can be made to work for many web services is for the portlet — which is essentially a Java servlet that follows certain conventions — to make an HTTP request, and then process the response to generate HTML that is displayed to the user. This allows for the provided HTML to include all of the functionality of web pages that are available outside the portlet environment (Javascript, AJAX, DOM manipulation, etc.) Such a pattern also makes it possible to use portal server authentication to prevent the user from having to sign on multiple times, though this depends on the nature of the service being called. Among the services prototyped in this way were:
  - schedule (graphical Gantt views and tabular grids) from an instance of the DSN scheduling software
  - notifications of schedule change proposals, shared schedules, and other updates
- **(2) URL opened in iFrame** — an alternative approach to a custom portlet presentation is to open an existing web page as an iFrame (inline frame) in a portlet designed for just this function. This allows the display of essentially any web page or set of pages that can be run in the browser, but in a portlet instead. The drawback of this approach is that the portlet display is isolated and cannot interact with other portlets on the same page, and, if authentication is required, cannot make use of currently active sign-ons. Still, this is an attractive option for certain legacy pages or web applications. Among the services demonstrated in this way were:
  - a Confluence wiki for use by scheduling personnel
  - the DSN Service Preparation Subsystem web portal
- **(3) Query and display from database** — this approach is similar to (1) above in that the portlet provides the user interface, but the data comes from querying a local or network database. Such a database can be populated specifically for portal use, or be a staging area for data extracted elsewhere and cached for quick display to a user. As indicated in Fig. 2, one of our example portlets was driven by schedule data updated periodically from the source server, then cached in a local MongoDB database. Among the services demonstrated in this way were:
  - the current real-time schedule display for a selected mission

- schedule process metrics
- planned DSN antenna downtime

C. Custom editors for configuration profiles

Among the data types to be managed by a SCaN service portal are service profiles, such as those designated *SpaceCommunicationServiceProfile* in the CCSDS Service Management specification[10]. These profiles are described by XML schema, so as part of an investigation of automating the creation and management of them, we have developed a tool that processes the XML schema to automatically generate 1) HTML editor forms, 2) validation of form entries, 3) help text based on schema annotations, and 4) database table definitions for profile instance persistence. This mechanism offers a great deal of flexibility in the face of changes to the schema in the future, since all of these related items can be kept synchronized. Fig. 3a shows a snapshot of a portal page with portlets for listing profile templates and instances, along with portlet editors for editing profile templates and instances. The corresponding data is kept externally to the Liferay database, in an Oracle database, in order to provide greater control over profile data management.

(a)



(b)

Fig. 3 (a) example portal page illustrating profile and instance listing and editor portlets; (b) a portal page illustrating portlets for editing profiles and invoking link analysis tools

D. Integration with Link Analysis Tools via Inter-Portlet Communications

One of the most important capabilities to be provided by the Integrated Network Service Portal is that of access to link analysis tools. Such analyses are prerequisite to formulating service agreements with any of the NASA networks. As part of our investigation of how to best provide this capability, we prototyped networked invocation of a remote telecom predict analysis tool that has been developed and used at JPL on numerous missions. This tool, called Telecom Forecast Predictor[11,12] (TFP) is written in Matlab; for our study, a wrapper script was developed for remote execution. TFP takes as input a set of telecom parameters, derived from the service configuration set described above. Running TFP involves gathering appropriate parameters from the service profile, formulating them (along with any default values) as an HTTP request, and invoking the service URL. The result is returned to the calling portlet as a JSON string, from which plots can be generated for the user to evaluate. Fig 3b illustrates an example of the portlets that implement this process.

One aspect of the invocation mechanism worthy of note is that it makes use of the inter-portlet communication mechanism that is part of the Portlet 2.0 specification. This mechanism allows a portlet to publish a message, described in XML, that other portlets on the same page can subscribe to, and then respond appropriately when received. In this case, the service profile editor includes a "calculate" button (Greek letter *pi* in Fig. 3b), which, when triggered, publishes a message to the TFP display portlet to request and display the TFP calculation results. Such inter-portlet communication linkages provide a good way to develop loosely-coupled set of portlets that work together to provide more functionality in the aggregate than any individual portlet can readily provide alone.

E. Workflow

One feature essential to the smooth operation of the planned service portal is that of workflow: users progress through a set of steps, orchestrated by the service portal, that include developing documentation, running tools, interacting with service portal and the individual network's personnel, eventually leading to the development of service agreements and the later stages of service management. Liferay provides an integrated workflow engine that fits well with this notion of stepwise progression, and the Liferay permissions and roles allows for a flexible assignment of individuals to the different approval stages.

Figure 4 illustrates an illustrative 2-stage approval process for mission service profiles, from creation through publication as final. This involves one approval cycle by network commitment office personnel, followed by a second cycle for final release. We have implemented this workflow in Liferay and verified that the gates and notifications behave as indicated. Real workflows for the service portal will be more involved, but are expected to follow the same principles.

F. Form Data — Entry and Management

Development of service agreements with the networks, and the associated prerequisite documentation, requires a mechanism to enter, edit, and manage form data. Such data can be seen as document-like with free text, diagrams, etc., while at the same time providing common fields for data that needs to be queried for other purposes. XForms[13] is evolving W3C standard for forms that can describe both purpose and presentation of a form. We investigated a commercial XForms-based product[14] for applicability to the types of forms commonly used in the SCaN network commitment processes.

The forms processor we evaluated provided some very powerful functionality in terms of usability:

- wizard-based forms entry
- save/restore of partially filled forms
- field validation and tooltip help
- jump-to-error diagnostics when forms do not validate
- automated generation of PDF documents from filled-in form

Forms can be subject to workflow along the lines described above, and so can go through approval processes,

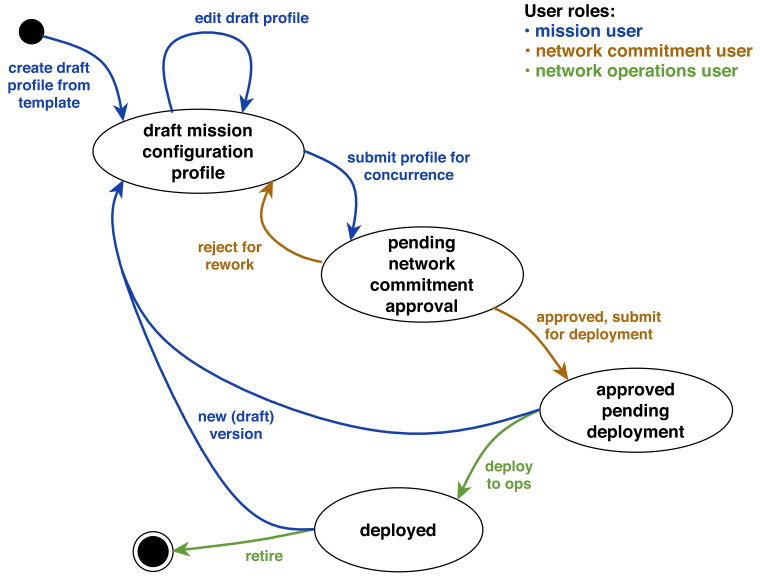


Fig. 4: Workflow example illustrating a two-stage approval process for service profiles

versioning, etc. Data entered into the form can be extracted for further manipulation, including querying and reporting.

V. Conclusions and Future Work

The conclusion of our investigation is that portal functionality such as that provided by the Liferay open source platform, and other vendors, can provide an effective basis for the infrastructure needs of the integrated network service portal. Key requirements related to modularity and scalability can be addressed by the portlet architecture and the possibility to cluster and load balance large scale portal deployments. Custom portlets can be developed that interoperate via inter-portlet communication, to improve the user's experience. All of the functionality of HTML5 and web applications are available to the portlet developer, along with a variety of powerful built-in portlet applications that support collaboration and information exchange. Integration with a wide range of network services, via mechanisms such as those described in Section IV, provides data sources that can be made available to portal users in an integrated fashion, much more conveniently than going to each of the networks separately.

At this time, the first increment of the SCaN service portal is starting development, building on the results of trade, feasibility, and pilot studies done not just at JPL, but also at the NASA Glenn Research Center.

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