SWIM Common Registry: Concept, Architecture, and Implementation

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Abstract: In recent years, a new technological framework known as SWIM (System Wide Information Management) has emerged in EUROCONTROL and FAA as a viable model for Air Traffic Management (ATM) applications. SWIM addresses the communications and interoperability requirements of highly-distributed, loosely-coupled and platform-independent components by consistently applying the principals of Service-Oriented Architecture (SOA). The dynamic and intrinsically heterogeneous nature of SOA calls for establishing some form of a service registry that allows SOA-based services to efficiently discover and communicate with each other. As SWIM implementation has been expanded across international as well as organizational borders, new challenges have been introduced for SOA registry implementers, most noticeably in the areas of managing services metadata and establishing semantic interoperability among organizationally diversified service registries.

This paper, a product of current collaboration between the Single European Sky ATM Research (SESAR) and Next Generation Air Transport System (NextGen) programs, introduces the concept of a SWIM Common Registry (SCR) and reviews the technologies and approaches that lead to the development of this concept. It assesses different architectural options for SCR and describes the means for implementing possible solutions.

Keywords: *service-oriented architecture, SOA, service registry, SWIM, SCR*

1 Introduction

1.1 Background

SWIM (System Wide Information Management) aims to change the way information is provided and managed by Air Traffic Management (ATM) stakeholders. It does this by making available a wide range of capabilities through a common infrastructure of reusable and shared services. As defined in the International Civil Aviation Organization (ICAO) SWIM Concept Paper [1], SWIM consists of standards, infrastructure and governance enabling the management of ATM-related information and its exchange between qualified parties via interoperable services. A SWIM registry enables the discovery of these ser-

vices and related information (e.g., standards, common infrastructure specifications, list of qualified parties). The registry is an essential building block in the deployment of service-oriented architecture (SOA).

SWIM has been embraced on a global scale by a multitude of current ATM modernization programs (e.g., NextGen, SESAR, CARATS (Collaborative Actions for Renovation of Air Traffic Systems), and CNAS (China New Generation ATM System)), but their maturity varies from case to case and there is not yet a fully harmonized approach. In the near future, an increase in global coordination and collaborative development efforts is expected.

Recent collaboration [2] on SWIM between the US Federal Aviation Administration and EUROCONTROL has increased the need for sharing a common view of SOA assets and providing insight into both organizations' services. The joint work resulting in the creation of a common service description conceptual model (SDCM) [3] has been a first step. This paper continues that work by proposing a common approach for the exchange of information between registries.

Another contributing factor for this paper is the need for a system to support the governance of the ICAO ATM Information Reference Model (AIRM) as expressed in the NextGen-SESAR Data Model Coordination Group's (NSDMCG) ICAO AIRM Governance Considerations paper [4].

1.2 SWIM Common Registry

The registry is an important component of SOA and a key building block in the deployment of SWIM. As described in ICAO's SWIM Concept paper [1], SWIM enables the management of ATM information and its exchange between qualified parties via interoperable services that are described in the registry. A number of US and European programs are implementing SWIM according to their own schedules and specific needs, and it is expected that multiple registries will need to coexist in the future. Each registry will have information relevant to a specific community; however, information of common interest to different communities will need to be shared (e.g., list of services available across regions, list of prescribed standards).

The SWIM Common Registry (SCR) as conceived in this paper will enable the management and sharing of common information among registries. It will contribute to interoperability in SWIM by providing a common method for exchanging information between registry implementations. This method consists of a common registry information model that describes semantically and syntactically the information to be exchanged, and a common registry exchange interface that defines the operations that need to be supported by connected registries.

The SCR aims to improve visibility to consolidated information on assets of common interest to a group of SWIM communities. This includes an inventory of shared services, stakeholders (e.g., service providers), and news related to events of common interest. It will also support the collaborative management of those interoperability resources (e.g., standards) that have been selected to ensure interoperability in the implementation of SWIM between the various communities.

2 Purpose

The purpose of this paper is:

- To introduce the concept of the SWIM Common Registry (SCR) as a mechanism to share information between registries.
- To provide an overview of the SCR's expected capabilities from the perspective of its content and function.
- To describe the roles, processes and interactions among the SCR's components and stakeholders.
- To assess and compare alternative architectural options.
- To describe the required governance and activities that must be performed to complete the implementation of the SCR (e.g., interface specification, data exchange model, etc.).

3 SCR Concepts and Objectives

3.1 Concepts

This section introduces the main concepts of the SCR.

The SCR considers the existence of *SWIM Communities*. Each SWIM Community is a group of one more organizations, all of whom share a common SWIM governance and characteristics (e.g., members of the US SWIM Community share a common governance that is different from that of the EU SWIM Community). It is expected that each will implement SWIM and registries according to its needs. However, in order to achieve interoperability and benefit from the efficiencies of collaboration, these SWIM communities will need to share information.

The SCR defines *common information* as the one shared between the registries of various communities, and distinguishes two types: 1) Information that is owned and managed exclusively by one SWIM Community and shared with the rest (e.g., list of services managed by one community) and 2) Information owned and managed collaboratively between several communities (e.g., list of data exchange models).

Figure 1. SCR vs. Collaboration vs. Community

The SCR is implemented in support of *collaboration* between SWIM communities. A concrete collaboration specifies the scope of the SCR by determining which information is shared and among which communities. As an example, the SCR could be used to implement a SWIM Global Registry of Services in support of a worldwide collaboration between SWIM ATM stakeholders with the objective of creating a common global view on services. The flexibility of the SCR concept enables a community to contribute to two different SCR implementations (e.g., EUROCONTROL in collaboration with global ATM partners contributes to a global SCR and, as part of a second collaboration with European organizations, contributes to a European SCR).

From a registry interoperability perspective, three different types of registries are considered whose purpose and interactions are key to understanding the SCR concept.

Figure 2. Independent vs. Affiliated vs. Common

The concept of ***Independent Registry*** describes a system that:

- Addresses the need to improve accessibility to information on SWIM assets (e.g., services) that are relevant to a specific SWIM community.
- Does not include a common interface with other registries for the exchange of information. This implies that in most of the cases:
  - Information owned by the community of an independent registry is not shared with another community's registry (even if this is of interest to this community).
  - Information that is collaboratively managed with another community is not managed in the registry (e.g., data exchange models).

The concept of ***Affiliated Registry*** describes a system that:

- Addresses the need to improve accessibility to information on SWIM assets (e.g., services) that are relevant to a specific SWIM community. In this respect it is similar to an independent registry; however, an affiliated registry contains information published in other registries.
- Uses a common interface:
  - To obtain Information managed by other communities in their respective registries.
  - To provide information to other registries.
- Does not support the collaborative management of assets with other communities.

The concept of ***Common Registry*** describes a system that:

- Addresses the need to share information on SWIM assets (e.g., services) that are relevant to multiple SWIM communities.
- Uses a common interface to obtain information from the registries of participating communities.
- Supports the collaborative management of assets by the participating communities. It becomes the source of reference for commonly managed assets.
- Addresses the need to complement specific registries without replacing them.

3.2 Objectives

The objectives of the SCR are:

- To enable the exchange of information between registry implementations based on a common method.
- To improve visibility of consolidated information on assets of common interest to a group of SWIM communities. This includes:
  - Service Instances managed by a community become discoverable by a larger list of consumers from other communities (e.g., Europe's Flight Plan Filing Service described in the European registry becomes discoverable in the FAA registry to US Airlines).
  - The organizations belonging to a particular SWIM Community become discoverable by members of other communities (e.g., US service providers become discoverable by European consumers in the European SWIM registry).
  - News and announcements on events managed by a community reach a wider audience including members of other communities (e.g., SESAR Large Scale Demonstrations).
- To support the collaborative management of SWIM assets adopted by multiple SWIM Communities. This includes:
  - The lists of adopted interoperability resources (e.g., standards) that enable interoperability among the SWIM implementations of multiple communities. These are either external to the participating communities (e.g., list of selected ISO standards) or owned by them (e.g., data exchange models).

4 SCR Content and Application

4.1 Content

The SCR provides access to consolidated information that supports the collaboration among different SWIM Communities. This information is referred to as the content of the SCR and is described in this section.

Figure 3. Global Information Assets

There are different types of *information assets* in the scope of the SCR:

- Service Instances: These are descriptions of implemented services that are provided by a SWIM stakeholder (i.e., service provider). These are typically bound to the governance requirements of a specific SWIM community and are required to be registered in the community's specific registry. A SWIM community shares a description of its services with another community via the SCR.
- Interoperability Resources: This is the agreed-upon list of resources that enable the implementation of interoperable solutions among the various SWIM communities involved. These resources are either owned by these communities (e.g., ATM Information Model) or are simply references to resources owned by external third parties (e.g., ISO Standards). Among the types of resources to be considered are:
  - ATM Information Reference Model. This is made up of information constructs relevant to ATM with the objective of providing a common semantic reference. It ensures that exchanged information shares the same meaning at its origin and its destination. It will enable systems to easily combine and process information from multiple sources.
  - Data Exchange Models. These are the data structures that support the exchange of information (e.g., Aeronautical Information Exchange Model (AIXM)).
  - Service Reference. This establishes a common approach to building services. It includes service description models that enable multiple providers to share a common logical definition of their implemented services (e.g., SESAR-NextGen SDCM [3]). It enables determining whether two service implementations are equivalent at the logical level.

- Infrastructure Reference. This is the list of specifications that enable interoperability at the infrastructure level. It contains the agreed-upon list of infrastructure protocols to be used for the exchange of information in SWIM.

- Communications: These are messages that a particular community shares with others (e.g., SWIM implementation milestone achievements, demonstration events, conferences, availability/unavailability of an information asset).
- Stakeholders: These are ATM organizations and points of contact points within them.

The semantic and syntactic description of the above information assets will be described in the common registry information model. This model will be used for both exchange of information between registries as well as its storage in the SCR.

In order to facilitate the management and understanding of the SCR information, it will be necessary to classify information based on common registry taxonomies.

4.2 Processes

There are two main types of processes to be distinguished related to the registration of information in the SCR:

- Sharing Process: This enables a specific SWIM community to share its own information with other communities. The publication of this information in the SCR requires no formal acceptance by the other communities as it is currently applicable only to the publishing community. However, its publication in the SCR improves its potential reuse and enhances the visibility of what is done by a specific community (e.g., publishing a list of local services of interest to other communities).
- Collaborative Management Process: This enables SWIM communities to agree on and manage a common set of information assets. In this process, information assets are proposed by a community to be commonly managed, and require the acceptance of the other communities (e.g., registering a new version of the Flight Information Exchange Model (FIXM) that will become the common reference to be used by the various communities).

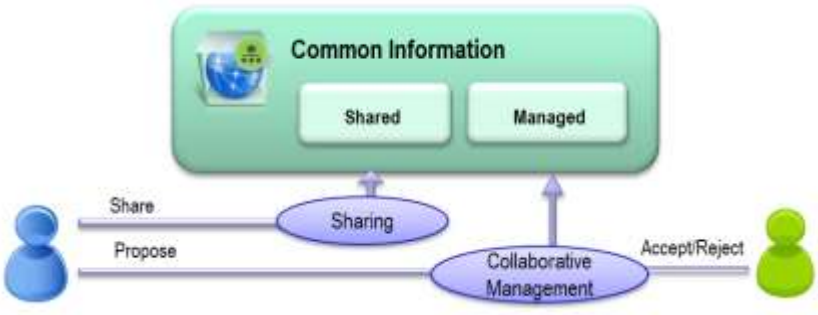


Figure 4. Common Registry Processes

4.3 Operations

The previously described processes require the following operations:

- Share: This enables information specific to a registry affiliate to become shared and commonly available to those participating in the SCR.
- Propose: This enables information specific to a registry affiliate to potentially become collaboratively managed. Until the information becomes commonly accepted, it is just a candidate.
- Approve: This enables the approval decision of a registry affiliate user to become known in the SCR.

4.4 Interfaces

The operations and information required to enable interoperability between registries and the SCR will be specified by the *common exchange interface.*

This interface is based on the *common registry information model* for the description of information.

The following aspects need to be considered in the implementation of this interface:

- Globally managed unique identifiers (e.g., URLs of common resources like AIXM).
- Master-slave relations between registries related to data ownership.
- Propagation of information updates.

4.5 Roles

- An SCR User is an entity belonging to a SWIM community that interacts with the registry. An SCR user represents a person or system.
  - An SCR User has “read” access to all information in the SCR.
- A SWIM community is represented in the SCR by a group of SCR users named SCR Community Managers. There is one group per community that participates in the SCR.
  - SCR Community Managers have the right to publish new information related to their own community.
  - Information previously published by a specific community can only be updated by its SCR Community Managers.
  - SCR Community Managers are able to propose information to be collaboratively managed.
  - SCR Community Managers can approve information proposed by other communities.

5 SCR Architecture

This architecture section describes possible deployment options for the SCR. The table below provides an overview to the two main options and their most significant differences.

	 **Distributed**	 **Centralized**
Description	This implementation of the SCR requires no additional systems to be implemented. It only requires an additional integration layer that is embedded in the participating registries (affiliates). It is a network of equals where all nodes communicate between each other (mesh).	This implementation of the SCR requires the deployment of an additional registry system. SCR common information is stored centrally at the SCR registry system. Information comes from the interface with affiliated registries or direct user input to the SCR registry system.
Benefits	It requires no additional infrastructure. It has no single point of failure. Canceling one affiliated registry has a limited impact for the common registry.	Those communities with no specific registry or no capability to build an automated interface to it are still able to contribute to the SCR based on the user interface to the SCR. Once in place, it lowers the barriers of entry to any SWIM community. It has a simplified communication model where all affiliated nodes communicate with just one other system. It enables the collaborative management of SWIM assets.
Disadvantages	It requires a higher number of connections. Every affiliated registry requires a connection to every other registry (needs to maintain locally a list of all registries' addresses). Those communities with no specific registry or no capability to build an automated interface have no means	It requires additional infrastructure to be set up upfront with a corresponding non-negligible cost. Deploying and operating a common infrastructure requires a common procurement and planning with a balanced allocation of resources between participating communities and organizations. This rep-

	to participate in the SCR. It does not enable the collaborative management of SWIM assets (as this would be over-complicated in a distributed architecture).	resents the biggest challenge for this architecture option. The considerable difficulty of deploying a centralized system by multiple communities becomes a significant entry barrier. Canceling the SCR system represents a single point of failure for sharing registry information among the participating communities.

5.1 Architecture Components

This section explains the main components of the different architecture deployment options.

Disconnected Registries Architecture (Before SCR)

Independent registry system

This represents a registry system with no knowledge of other registries. It includes a local data store and provides the mechanisms to manage its own information. It is not connected to any other registry.

It includes:

- Specific SWIM Registry System with no interfaces to other registries.

Distributed Architecture

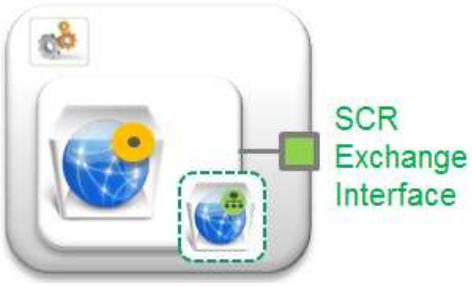
This architecture consists of a mesh network of affiliated registries. Each of them communicates with the rest based on a common exchange interface. It is a virtual implementation of the SCR concept.

Affiliated registry system

This represents a registry system with the configuration required to participate in the SCR.

It includes a specific independent registry system plus:

- SCR Exchange Interface
- SCR Data Store (Optional)



SCR Data Store

This component represents the need to host common registry data coming from other registries.

Its physical deployment depends on the implementation choice done for each independent registry. E.g., some registries will deploy a different data store than the one used for managing its own specific data, others will integrate the common data within the existing specific data store.

SCR Exchange Interface

Interface required by an independent registry system in order to become affiliated to the SCR.

It allows a specific registry to contribute and interoperate with other registries participating in the SCR.

Centralized Architecture

This architecture consists of a hub-and-spoke network where affiliated registries communicate with a single SCR node. The communication is based on a common exchange interface.

Affiliated registry system

It represents a registry system with the configuration required to participate in the SCR.

It includes a specific independent registry system plus:

- SCR Exchange Interface

SCR Exchange Interface

Interface required by an independent registry system in order to become affiliated to the SCR.

It allows a specific registry to interoperate with the SCR.

SCR Central Registry System

It represents the central node where all common information is stored.

It is an independent registry system that includes a:

- SCR Data Store
- SCR Exchange Interface

SCR Exchange Interface

Interface implemented by the SCR to exchange information with the affiliates.

SCR Data Store

Required by the SCR to persist common information contributed by the affiliates.

6 Managing SCR Design, Implementation, and Operation

This section describes the collaborative processes required to jointly manage the design, implementation, and operation of the SCR.

6.1 Design

There needs to be a commonly agreed-upon design of the global registry. The design includes:

- The SCR Information Model
- The SCR Exchange Interface Model

The design evolution will be managed by a *Design Change Board* where all participating communities should be equally represented.

6.2 Implementation

Due to the dependencies created between different registry systems, the deployment and update of their interfaces will need to be coordinated.

In the case of a centralized architecture, the implementation of the global registry system will require strong coordination among the involved partners for all phases of the project (e.g., procurement, development follow-up, deployment).

The SCR implementation requires the setup of an *Implementation Coordination Board* that ensures the overall implementation is coordinated among the participating communities.

6.3 Operational Support

As information is exchanged between various systems, the availability of a system needs to be known by the others.

The resolution of issues related to a common interface or system (in the case of centralized architecture) needs to be coordinated and managed.

The setup of an *Operational Coordination Team* is required for this purpose.

7 References

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8 Abbreviations

AIRM	ATM Information Reference Model
AIXM	Aeronautical Information Exchange Model
ATM	Air Traffic Management
CARATS	Collaborative Actions for Renovation of Air Traffic Systems
CNAS	China New Generation ATM System
FIXM	Flight Information Exchange Model
ICAO	International Civil Aviation Organization
NextGen	Next Generation Air Transport System
NSDMCG	NextGen-SESAR Data Model Coordination Group
SCR	SWIM Common Registry
SDCM	Service Description Conceptual Model
SESAR	Single European Sky ATM Research
SOA	Service-Oriented Architecture
SWIM	System Wide Information Management