１５．SWIM 実証実験の報告と分析

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1. INTRODUCTION

With the rapid increase in local and global air traffic, the system-wide operational information exchange and life-cycle management technologies are required to improve the capacity, safety and efficiency of Air Traffic Management ATM. However, today's ATM system comprises a wide variety of applications with their own communication protocols, interfaces and self-contained information systems. Therefore, this point-to-point communication is difficult to upgrade with new technologies, information exchange is not globally harmonized, and information security is poor.

The System Wide Information Management (SWIM) concept is to change the conventional ATM information architecture from point-to-point data exchanges to system-wide interoperability, and to achieve life-cycle management of data, information, and service. The SWIM concept provide not only system architecture for the delivery of information services to support meeting the expectations of the ATM community in different key performance areas, but also a common understanding of different information domains. Therefore, implementation of the SWIM concept must address the challenge of creating an interoperability environment which allows the SWIM IT systems to cope with the full complexity of operational information exchanges [1][2].

The International Civil Aviation Organization (ICAO) has made efforts to promote the SWIM concept and establish the communication and information standards. Several exchange modes have been developed for some information domains, such as the aeronautical information exchange model (AIXM), the flight information exchange model (FIXM) and the weather information exchange model (WXXM) [2].

The research and development of SWIM concepts and solutions has been undertaken in different countries. ATM modernization programs such as Next Generation Air Transportation System (NextGen) [3][4] in the United States and Single European Sky ATM Research (SESAR) [5][6] in Europe both consider the implementation of SWIM as a fundamental element for future ATM systems.

The main objectives of SWIM is not only to achieve seamless integration among geographically distributed and heterogeneous systems in the air transportation field but also to enable seamless information sharing among the multiple stakeholders in the ATM domain. Therefore, Service Oriented Architecture (SOA) based SWIM will enable stakeholders to achieve high performance and low cost.

To research and validate SWIM concepts, the project of Mini Global Demonstration (MGD) has been conducted by the Federal Aviation Administration (FAA) to exchange air transportation information among different Air Navigation Service Providers (ANSPs) by using standard information exchange models. The first demonstration, Mini Global I, was held in September, 2014 and the second one, Mini Global II, was held in April, 2016. As a main member, Japan Civil Aviation Bureau (JCAB), being technically supported by Electronic Navigation Research Institute (ENRI), participated in these two demonstrations.

This paper is structured as follows. The next section describes the overview of MGD. In section 3, the development of local system, scenarios and performance analysis are presented. The paper is concluded in section 4.

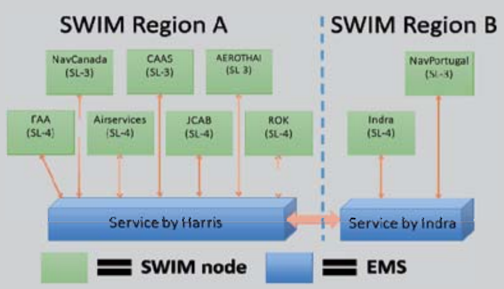
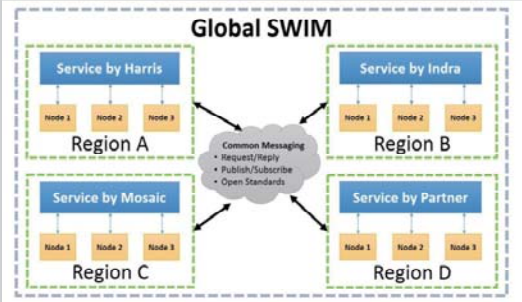
	Mini Global I	Mini Global II
Overview		
Platform	Global Enterprise Messaging Service (GEMS)	
Service Provider	Harris and Indra	Harris, Mosaic, Indra, NEC
Message Format	FIXM 2.0, AIXM 5.1, WXXM 1.1	FIXM 3.0.1, AIXM 5.1, IWXXM 1.0 (ICAO WXXM)
Messaging Protocol	Within Region: JMS, SOAP Between Regions: SOAP	Within Region: AMQP, JMS, SOAP Between Regions: AMQP, SOAP

Figure 1: Comparison of Mini Global I and Mini Global II

2. MINI GLOBAL DEMONSTRATION

The MGD is an ongoing international cooperation project to develop a global networked demonstration environment to research and validate SWIM concepts, the global exchange models, and the operational concepts outlined in Flight and Flow Information for a Collaborative Environment (FF-ICE) [7].

2.1 System Structure

In the domain level point-to-point exchange is still common but a growing number of Air Navigation Service Providers (ANSPs) are adopting SWIM infrastructures enabling them to have a more efficient messaging architecture within their own domain. As ANSPs complete their domain-level SWIM adoption, point-to-point messaging architecture will still exist between the ANSPs. Under this situation, ANSPs need to work out the governance among each other to establish trust and data exchange. To resolve this issue, a global networked environment with trusted governance policies among ANSPs as a whole enterprise umbrella is required.

To promote interoperability through integration of Global SWIM stakeholders, the Global Enterprise Messaging Service (GEMS) has been constructed to interconnects the SWIM regions by using a common set of standards (e.g. messaging protocol, data exchange model, security protocol, etc.). In the MGD, GEMS providers provide SWIM service connections to ANSPs around the globe that allows for the safe, efficient, and timely sharing of flight, weather, and aeronautical related data.

The comparison of GEMS solutions between Mini Global I and Mini Global II is shown in Figure 1. Mini Global I contained two GEMS providers: Harris and Indra. The initial Mini Global I demonstration successfully demonstrated interoperability between these two GEMS Providers' EMSs. The GEMS service by Harris and the GEMS service by Indra implemented an EMS to EMS adaption service utilizing the Simple Object Access Protocol (SOAP) Web Service (WS) messaging protocol as the common messaging protocol. Using this architecture, the GEMS Providers provided connectivity to multiple local ANSP SWIM nodes using the Java Messaging Service (JMS) and SOAP messaging protocol forming a SWIM region (Figure 1).

For Mini Global II, there were multiple GEMS Providers, Harris, Indra, Mosaic ATM and NEC providing Global SWIM interconnectivity between the GEMS Providers' EMSs. The GEMS Providers in Mini Global II are charged to enforce the use of the standardized aeronautical, flight and weather exchange models (AIXM, FIXM and IWXXM) with the updated versions for each of their SWIM nodes to ensure the interoperability of the exchanged information. The standard to exchange messages between GEMS Providers for publish/subscribe messaging is Advanced Messaging Queuing Protocol (AMQP) protocol, and the standards for request/reply WS messaging are SOAP and Representational State Transfer (REST) protocols. In addition, GEMS Providers also adapt their local users' messaging protocols to the GEMS standards and vice versa, allowing ANSPs to continue to use their established messaging standards and expand their communications to additional GEMS regions and SWIM nodes.

2.2 GEMS Governance

In the loosely coupled SWIM environment where services are provided and consumed by a number of entities, governance is essential. Governance establishes the processes to assure that appropriate rules, policies, and standards are followed. Within the domain of GEMS, governance refers to defining the business rules which define where, when, and how a message is transported from its source to its destination as well as the enforcement of those rules.

Due to the local and regional specific operational requirements, defining the scope of governance enforcement at the GEMS level requires a review of existing local and regional governance. Therefore, in the Global SWIM environment, governance is enforced at local, regional and global levels.

- Local governance refers to a local system or service in an EMS. This local governance at the system/service level controls how the information is generated. This is set by the local organization or ANSPs.
- Regional governance refers to data sharing agreements between two EMS systems inside of a SWIM region. The regional level of governance is the agreement between the organizations and their GEMS Provider.
- The global level of governance encompasses the agreements between GEMS Providers for the exchange of message between the two GEMS systems.

Depending on the level of data sharing agreements, global governance could include both local and regional governance agreements. If local and regional governance rules concern GEMS Providers when there is a need to transmit this protected local data between GEMS. At that point, all GEMS Providers involved in transmitting the restricted data have to take steps to safeguard that data.

3. System Development

In Mini Global II, ENRI not only cooperated with NEC to construct a Global EMS for GEMS-to-GEMS message exchange, but also developed a Local EMS for information generation and management. In this demonstration, not only the semi-live flight data in FIXM 3.0.1 of practical operation system was shared among the partners, but also the simulated data based scenarios with standardized information exchange models between different partners were demonstrated.

3.1 NEC GEMS

In Mini Global II, there are multiple GEMS providers that facilitate data sharing between a variety of partners, tools, and applications. As shown in Figure 2, there are four GEMS providers, Service by Harris (SBH), Service by Indra (SBI), Service by Mosaic (SBM) and Service by NEC (SBN). Each GEMS Provider tailors its EMS to interconnect to one or more ANSPs and/or other partners' services or applications by using a common set of interoperable messaging protocols.

The NEC GEMS is a highly-reliable platform that provides GEMS services for both regional and international partners. Other GEMS providers connect to the NEC GEMS via an access point for all GEMS-to-GEMS communications. NEC's adapter allows FIXM, AIXM, and IWXXM information to be exchanged between SBN participants and between external partners connected to other GEMS providers. And SBN provides routing service to ensure only authorized subscribers receive the flight data.

3.2 Local EMS

In Mini Global II, each user connected its own demonstration system to one of the GEMS providers by using the Virtual Private Network (VPN) over Internet. As a regional user, JCAB connected to the NEC GEMS and its demonstration system was constructed on the ENRI local EMS (Figure 2). There is a set of services and applications developed by ENRI that support both semi-lve flight data and simulated data for use in the scenarios.

- The Globally Unique Flight Identifier (GUFI) is a key component of flght object management. The Local GUFI Serivce provides the functionality of generating and tracking GUFIs.
- The Flight Object Manager maintains an up-to-date version of all subscribed flight data. The flight data is orgnized into flight objects by GUFI and then stored in a database for continuous updates and queries.
- The Flight Data Validation provides validation and reporting on FIXM 3.0.1 conformance to schema and set of business rules that participants need to be in compliance with before they exchange messages with any other ANSP or across the GEMS. It also monitors FIXM messages and provides near real-time status (valid or invalid) to users on any findings related to non-conformance of schema and non-compliance to business rules.

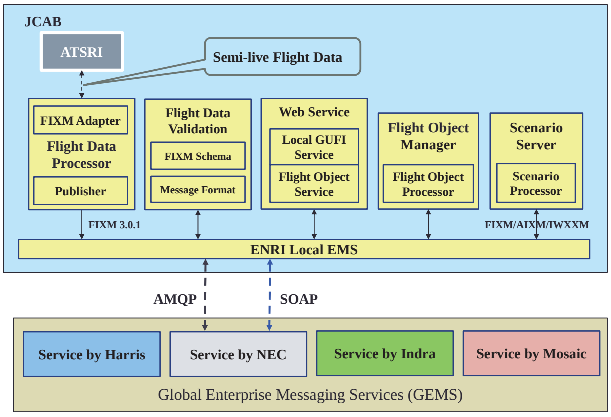


Figure 2: Local EMS Architecture

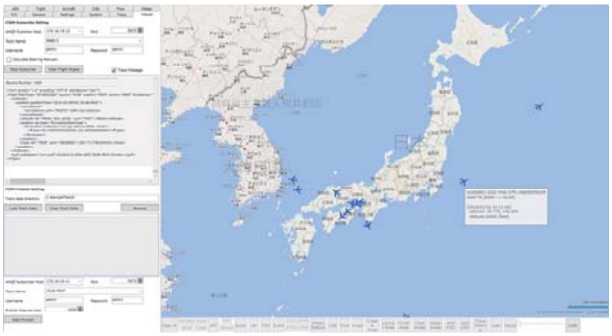


Figure 3: Semi-live Flight Data

- The Flight Data Processor converts the semi-live flight data provided by Air Traffic Service Research Institute (ATSRI) from local format to FIXM 3.0.1 format and publishes FIXM messages to the local EMS.
- The Scenario Server generates FIXM, AIXM and IWXXM messages based on the simulated data for use in the scenarios. It also supports the flight data visualization on a geospatial map (Figure 3).

The ENRI local EMS supports both AMQP for publish/subscribe messaging and SOAP for request/reply web service messaging. The semi-live flight data and simulated data for demonstrations are automaticly routed to NEC GEMS and local applications.

3.3. Scenarios

Built upon Mini Global I, to develop and execute complex use cases such as coordination between ANSPs and Flight Information Regions (FIR) is also

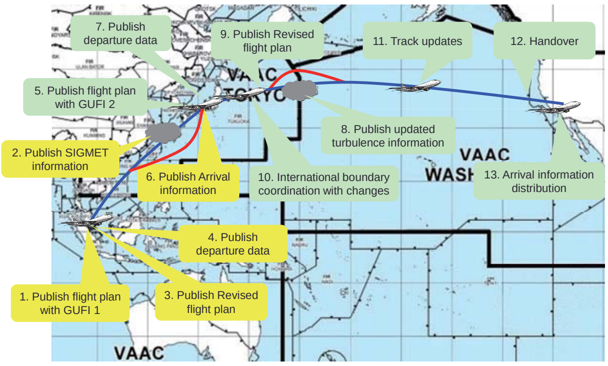


Figure 4: Scenario of Pacific Transit

one main objective of Mini Global II. The main scenario proposed by JCAB is Pacific Transit to demonstrate regional cooperation and global harmonization (Figure 4).

This scenario demonstrated the coordination of flight data, including GUFI, on a flight with two segments (legs). The flight of ANA77A departed from Singapore and arrived in Tokyo first and then departed from Tokyo to Los Angeles (LAX). This scenario also demonstrated the sending and receiving of multiple weather notifications that impacted operations. A JCAB issued SIGMET (Significant Meteorological Information) was taken into account when the flight plan was filed by CAAS (Civil Aviation Authority of Singapore) for the Singapore to Tokyo segment of the flight. After the flight departed Tokyo, JCAB received SIGMET information about turbulence en route to LAX and used that information to amend the route to avoid turbulence on the second segment of the flight.

Moreover, as ANA77A approached the boundary between FUKUOKA and OAKLAND FIR, JCAB initiated the boundary coordination process by first publishing an Advanced Boundary Information (ABI) message. As the flight progressed towards the boundary crossing point, JCAB published a Current Plan (CPL) message. The FAA responded to the JCAB published CPL message with a Coordination Negotiation (CDN) message. This message requested a change to the altitude at the boundary crossing point. JCAB evaluated this request and responded with an Accept (ACP) message.

This scenario demonstrated not only the operational benefits of real time distribution of weather information through IWXXM, thus providing Airspace Users (AUs) with the ability to optimize flight plans to avoid weather constraints, but also efficient boundary coordination of SWIM-based automatic negotiation with FIXM messages.

3.4. Analysis

The network and messaging infrastructures are key components for SWIM construction. And to assure SWIM-enabled applications, the performance, interoperability, fault tolerance, maintainability and security are required for core technologies. Based on the demonstration system, several common and open technologies are analyzed and evaluated. As shown in Table 1, number 3 means good, 2 is general, and 1 is not good.

With the advancement of IP network, the web service over Internet can meet most requirements of ATM applications. Howerver, it is difficult to assure high-performance communications in a large-scale distributed environment. Therefore, the EMS over VPN is an alternative approach that can satify real-time and high-performance exchanges in an EMS and between EMSs.

For publish/subscribe messaging protocols, AMQP is a wire level messaging standard that can be implemented by multiple vendors and platforms to provide seamless support for multiple protocols with the common security model. JMS is a Java message oriented middleware API for message exchange between Java-based systems. It requires proprietary solutions for cross-platform interoperabiltiy. Data Distribution Service (DDS) is data-centric middleware standard to provide scalble and high-performance data exchange. However, the current standard does not support security at protocol level and the cofiguraton is more complex than other protocols.

Table 1. Evaluation

Technologies / Requirements	Network Infrastructure		Messaging Infrastructure					
			Publish / Subscribe			Request / Reply		
	WS + Internet	EMS + VPN	AMQP	JMS	DDS	SOAP	REST	WFS
Performance	1	2	2	2	3	2	2	2
Interoperability	3	2	3	1	3	3	3	3
Fault Tolerance	3	2	2	2	3	2	3	2
Maintainability	2	3	3	3	2	3	3	2
Security	2	3	3	2	1	2	1	2

For request/reply messaging protocols, SOAP is an XML-based, widely-used web service protocol with a large number of supporting standards for security, reliability and transactions. While the large message size due to protocol overhead could be a concern in some SWIM applications, SOAP is still widely used in business-to-business systems. REST is an architectural style of request/reply messaging over HTTP with little overhead. Even REST is not a formal standard, it is widely used in industry since it can work with both XML and JSON (JavaScript Object Notation). Web Feature Service (WFS) is a standard protocol for serving geographic features across the web. The utilization of this standard is limited by its complexity and requirement to use a specific interface.

As above analysis, the AMQP and SOAP protocols are utilized for GEMS-to-GEMS communincations

4. Conclusions

How to construct a global messaging exchange infrastructure to support SWIM-based applications is a main objective of MGD. In this paper, the implementations of Mini Global I and Mini Global II are compared. Moreover, the development of Global EMS and Local EMS to demonstrate information sharing with standard information exchange models between JCAB and other ANSPs is described. Finally, the several network and messaging technologies are analyzed for GEMS implementation.

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