International Civil Aviation Organization

The Tenth Meeting of System Wide Information Management Task Force (SWIM TF/10) and Second Working Session of SIPG

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Agenda Item 5: b) SWIM Infrastructure

ENHANCING RELIABLE MESSAGE DELIVERY IN HIERARCHICAL ARCHITECTURE FOR APAC SWIM IMPLEMENTATION

(Presented by JAPAN/ENRI)

SUMMARY

Based on discussion within the SWIM Implementation Pioneer Group (SIPG), the hierarchical architecture has been proposed for APAC SWIM implementation, in comparison to centralized and decentralized approaches. Therefore, certain concerns regarding reliable message delivery in a hierarchical architecture need to be addressed and clarified. This working paper proposes an approach for constructing the hierarchical architecture, analyzes methods to enhance reliable message delivery for APAC SWIM implementation, and identifies the required functionalities for Gateway and Edge Enterprise Messaging Services (EMSs).

1. INTRODUCTION

1.1 In the APAC region, the Common aeRonautical Virtual Private Network (CRV) has been established as a secured, aviation centric IP network to address potential security prior to a unified, endorsed ICAO trust framework. As a result, the CRV is a strong candidate for supporting APAC SWIM implementation.

1.2 Based on discussion within the SWIM Implementation Pioneer Group (SIPG), the hierarchical architecture has been proposed for APAC SWIM implementation, in comparison to centralized and decentralized approaches. This hierarchical approach avoids the issue of having a single point of failure present in the centralized model while at the same time avoiding the issue of a very complex topology in the decentralized model.

1.3 However, concerns regarding reliable message delivery within a hierarchical architecture have been identified. To ensure reliable message delivery remains a key challenge that need to be addressed and clarified. This working paper proposes an approach for constructing the hierarchical architecture, analyzes methods to enhance message delivery reliability for APAC SWIM implementation, and identifies the required functionalities for Gateway and Edge Enterprise Messaging Services (EMSs) to support reliable message exchange.

2. DISCUSSION

2.1 As shown in Figure 1, the hierarchical architecture consists of multiple EMSs, which are key components in constructing the APAC SWIM Technical Infrastructure (TI). These EMSs are categorized into Gateway EMS and Edge EMS and are connected to form sub-communities. A Gateway

EMS serves as an interconnecting broker between different sub-communities and provides message routing functions. An Edge EMS provides connectivity service for SWIM-enabled users and routes SWIM messages between the upper-level Gateway EMS and SWIM-enabled users. In addition, the Edge EMS offers connectivity to external IP-based networks, including the Internet, allowing approved aviation partners who cannot directly connect to the CRV to provide existing and emerging SWIM information services (e.g., MET information services).

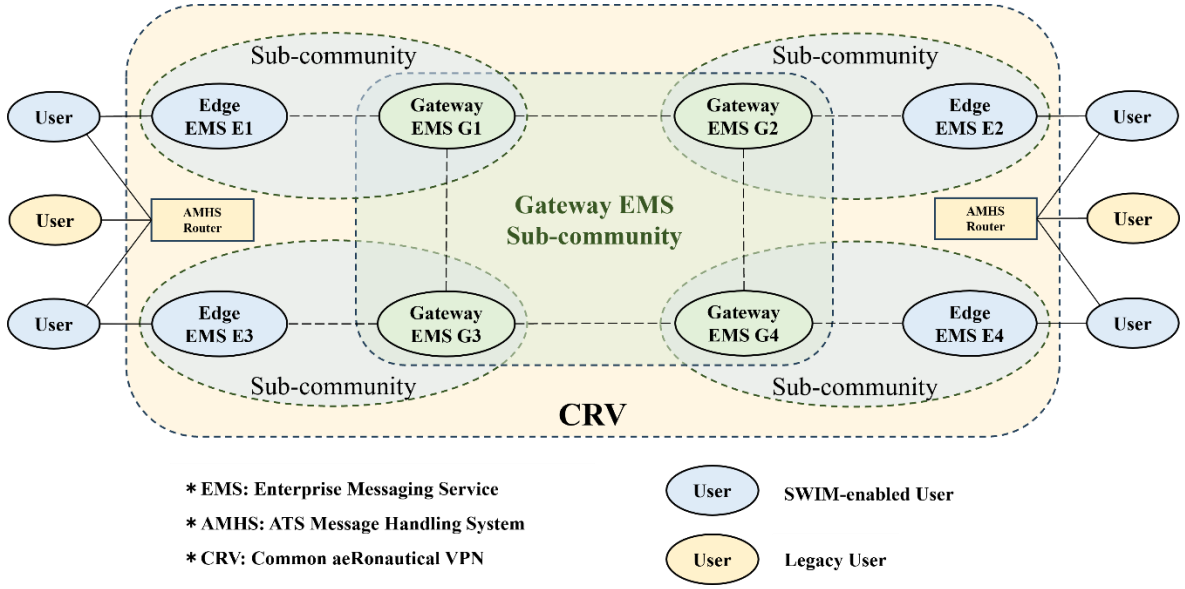

Figure 1. Hierarchical Architecture for APAC SWIM Implementation

2.2 Based on different implementation levels, the hierarchical architecture is considered an appropriate option for APAC SWIM to satisfy different requirements of member States and achieve interoperability during the transition. Figure 1 also shows the image of coexistence of AMHS and SWIM systems. These two systems operate independently, and the transition between them is not required. This option is regarded as the most suitable during the initial stage or throughout the transition period. Given the existing regional AFTN/AMHS network connections, one possible approach is to designate member States facilitating ATN Backbone Sites as Gateway EMS and Edge EMS service providers. As a Gateway EMS or Edge EMS service provider, it must provide connectivity between the CRV and the SWIM TI, while supporting SWIM message exchange.

2.3 Since metadata-based message routing also depends on network connections between systems, the current network connections for AMHS message routing between different sites should be considered. If all ATN Backbone Sites can serve as Gateway EMSs, the existing network topology can be reused. If not, a connection policy based on adjacent Flight Information Region (FIR) or air traffic volume priorities can be used to establish connections between Gateway EMSs, as well as between Gateway and Edge EMSs,. For example, if Gateway EMS G(i) (or Edge EMS E(i)) and G(j) belong to adjacent FIR(i) and FIR(j), then G(i) (or E(i)) connects to G(j); otherwise, G(i) (or E(i)) connects to G(k) in FIR(k), which has the highest air traffic volume with FIR(i). The advantages of this policy are as follows.

- Establish connections that consider both flight operation requirements and technical capacities;
- Enhance the efficiency and reliability of massage exchange between Gateway and Edge EMSs within the same sub-community belonging to adjacent FIRs;

- Reduce the message forwarding between sub-communities and improve the message routing efficiency between Gateway EMSs.

2.4 However, concerns regarding reliable message delivery within a hierarchical architecture have been identified and discussed at previous meetings. The problems, use cases and corresponding solutions for enhancing the reliability of message delivery are summarized in Table 1. It is required to establish a collaborative environment where all Gateway and Edge EMS service providers agree on a common set of functions and settings to provide reliable, secure and efficient message exchange service for SWIM-enabled end users.

Table 1. Considerations for Reliable Message Delivery in Hierarchical Architecture

Problem	Use Case	Solution
1. Priority messaging cannot be applied based on the importance of the information.	Surveillance messages caused queue overflow and loss of FF-ICE messages.	· Deliver surveillance messages using a separate queue and logical network · Set a message TTL for surveillance messages
2. Guaranteed message delivery is disrupted if a message broker malfunctions within the message delivery chain.	When the message broker reaches the maximum number of messages, it drops subsequent messages.	· Set up a persistent or replicated message queue · Support automatic failover and failback
3. Compensation transactions cannot be performed to recover from transaction failure in the message delivery chain.	The publisher is not aware of failures that occurred in the EMS afterwards.	· Implement retry logic for failed message deliveries · Record Forward Failure List for traceability
4. Message rerouting is not possible in the event of a failure within the message delivery chain.	The publisher is not able to change delivery responsibility even if the publisher recognizes a failure in the message delivery chain.	· Set a backup EMS for each publisher and Edge EMS · Each Gateway EMS has at least two connections to other Gateway EMS
5. The edge node cannot know which message to resend when message loss occurs.	In the case of a missing message that occurs in a subsequent EMS, the publisher cannot specify the message and try to resend it.	· Publish the Forward Failure List, making it accessible to publishers · Subscriber responds “Submission Response” to the publisher

2.5 To ensure reliable message delivery in the hierarchical architecture, the required functionalities for Gateway and Edge EMSs are listed in Table 2. The at-least-once delivery configuration is always applied to support retry and redelivery policies. Since at-least-once delivery may result in duplicate messages, SWIM information services should be idempotent, ensuring that processing a message multiple times does not cause any issues.

Table 2. Required Functionalities for Gateway and Edge EMSs

Functionality	Description
Message Persistence	· Ensure messages are stored reliably until they are successfully delivered · Support durable (replicated) queues and persistent message storage
Acknowledgment & Confirmation	· Implement publisher acknowledgments to confirm message reception · Support consumer acknowledgments to confirm message subscription
Retry & Redelivery Policies	· Support automatic message retries upon failure · Implement exponential backoff and dead-letter queues for failed messages
High Availability & Redundancy	· Deploy in a clustered mode to avoid a single point of failure · Ensure failover/failback mechanisms and redundant EMSs for resilience
Routing & Security	· Support metadata-based message routing between EMSs · Support Transport Layer Security (TLS) encryption for secure communication
Monitoring & Logging	· Provide real-time monitoring for message status and EMS health · Enable logging and auditing for troubleshooting and compliance
Network Failure Handling & Auto-Recovery	· Detect network failures and re-establish connections automatically · Implement message deduplication to prevent duplicate processing

3. ACTION BY THE MEETING

3.1 The SWIM TF/10 is invited to:

- Note and review the content of this working paper;
- Discuss any relevant matters as appropriate; and
- Agree to provide this document to the related Working Groups/Task Forces for further deliberation.

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