International Civil Aviation Organization

The Tenth Meeting of System Wide Information Management Task Force (SWIM TF/10)

Bangkok, Thailand, 20 – 23 May 2025

Agenda Item 5: Updates on the assigned tasks by task leads/contributors, including progress report and issues

SIPG ACTION WS-1-4、WS-1-5: IMPROVEMENT OF THE HIERARCHICAL ARCHITECTURE FOR REGIONAL SWIM IMPLEMENTATION AND REQUIREMENTS FOR GATEWAY EMS

(Presented by China and Hong Kong China on behalf of the SWIM Implementation Pioneer Ad-Hoc Group)

SUMMARY

This paper presents the modified version of the hierarchical architecture for regional SWIM as well as the functional and non-functional requirements of Gateway EMS, aiming to address the issues highlighted in SWIM TF/9-WP/10 and promote the implementation of regional SWIM.

1. INTRODUCTION

1.1 To address the vulnerabilities of the hierarchical architecture as highlighted in SWIM TF/9 - WP/10 "Consideration on Guaranteed Message Delivery for Regional SWIM Architecture", members have further discussed the issues in SIPG WS/1 and agreed on a modified version of the hierarchical architecture and some further implementation of Gateway EMS.

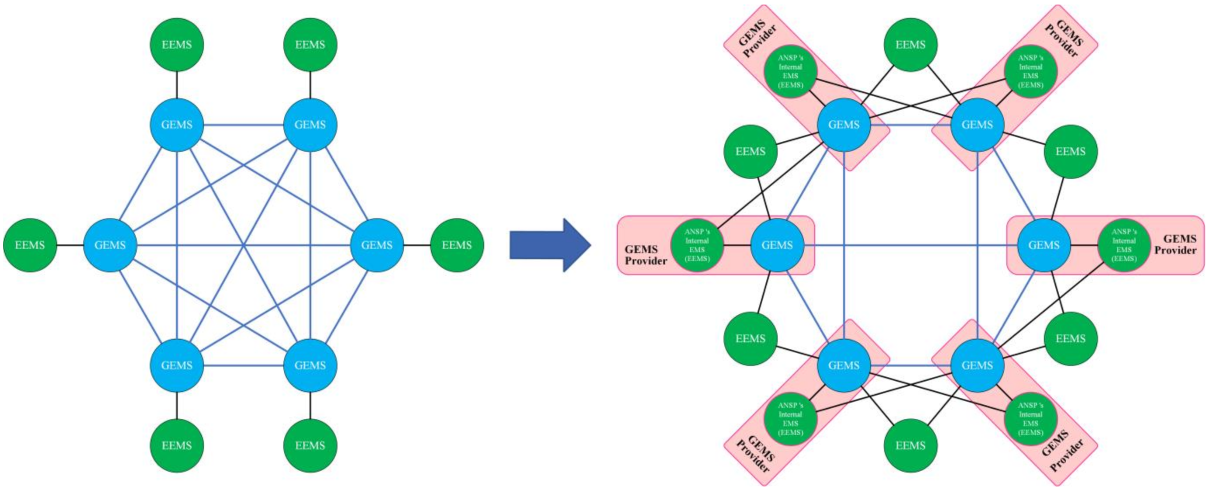
1.2 The SIPG WS/1 meeting concluded that a modified version of the hierarchical architecture would be most suitable for implementation within APAC, considering the various recommendations and solutions proposed and discussed. The meeting required that SIPG to propose to the SWIM TF/10 a modified version of the hierarchical architecture for regional SWIM implementation.

1.3 The need for specific performance requirements of the Gateway EMS was discussed during the meeting. The meeting deliberated on the requirements for the Gateway EMS and identified two categories: (i) the requirements for the Gateway EMS itself and (ii) the requirements for the Gateway EMS provider. The meeting required that SIPG to propose these requirements for the consideration of the SWIM TF/10.

2. DISCUSSION

Modified Version of the Hierarchical Architecture for Regional SWIM Implementation

2.1 A modified version of the hierarchical architecture is shown in the diagram below, with limited number of Gateway EMSes, optimized multi-connections between Gateway EMSes and redundant connections between Gateway EMS and Edge EMS. Most critically, ANSPs are required to deploy the Gateway EMS on a separate device from their internal EMS. This configuration is of utmost significance as it effectively transforms the ANSP’s internal EMS into an Edge EMS, thereby fundamentally altering its operational dynamics and ensuring the integrity and security of the overall system architecture.



2.2 The modified version of the hierarchical architecture could address the issue of “Detouring cannot be performed if a failure occurs in the message delivery chain” highlighted in SWIM TF/9-WP/10 by the following approaches.

a) Clustered servers could be setup for publisher, Edge EMS and Gateway EMS to provide redundancy.

b) Each Gateway EMS should have multiple connections to multiple Gateway EMSes.

c) Each Edge EMS should have two connections to two different Gateway EMSes.

2.3 The potential improvement brought by the modified version of hierarchical architecture are listed below:

a) By separating the Gateway EMS from ANSP’s internal EMS, the complexity of the Gateway EMS will be reduced. Management of the ANSP’s internal EMS can be done independently, without affecting the core functions of the Gateway EMS focusing on message exchange.

b) By limiting the number of Gateway EMS, the complexity of the regional SWIM backbone network will be reduced. This helps to accelerate the initial setup and ease the management and maintenance of the regional SWIM architecture.

c) With multi-connections between Gateway EMSes and redundant connections between Edge EMS and two different Gateway EMSes, single point of failure can be avoided.

Gateway EMS Requirements in the Hierarchical Architecture

2.4 Gateway EMSes are an important component of the APAC SWIM TI and, therefore, with requirements to be met (for details of SWIM TI, please refer to SWIM TF/9 – WP/09 Revision of APAC SWIM Technical Infrastructure Profiles). The requirements of a Gateway EMS include both functional and non-functional requirements such as performance and maintenance requirements to suit various operational scenarios.

2.5 Functional Requirements of Gateway EMS - in general, they include message processing, security protection, control and management of the operation of the Gateway EMS itself, etc. These requirements should align with the functional requirements in the SWIM TI. Given that, the important role of the Gateway EMS as the core node in the hierarchical architecture, the following requirements need to be emphasized:

a) Message processing should support data transmission protocols (such as AMQP, RESTful API, and WCS/SOAP) as predefined. Gateway EMS should support as many protocols as possible and preferably with support for protocol conversion.

b) The Gateway EMS' message routing should be easily modifiable based on business scenarios, with possible routing methods including maintained static routing tables and/or dynamic routing tables for message delivery, load balancing, or bypassing faulty nodes.

c) If Gateway EMS provides AMHS/SWIM conversion capabilities, including protocol conversion, data model transformation, address mapping, service level adaptation, and security-related conversions, it can better serve the connected stakeholders.

2.6 Non-functional Requirements of Gateway EMS - they include performance, reliability, and non-functional security provisions. Since the Gateway EMS needs to provide services for multiple Edge EMSes, particular attention should be given to QoS metrics such as **Availability**, **Latency**, and **Throughput**. With reference to the metric information of ATM-related services and systems (for details, please refer to Attachment A: Investigation of QoS metric recommended values for ATM Systems), we and hereby provide the following suggestions:

Metrics	Recommended values
Availability	⩾99.9% (annual allowable unplanned downtime of 8.76 hours)
Latency	For operational use cases: In the order of seconds. For post-operational or non-operational use cases: In the order of minutes.
Throughput	depends on the Edge EMSes connecting to the Gateway EMS, data size, and data update rate，and can be measured in two primary units（KB/unit time or messages/unit time）

a) The availability metric requires balancing between benefits and costs. Each additional "9" in availability (e.g., from 99.9% to 99.99%) poses exponential challenges across hardware, software, testing, and operations, necessitating higher technical expertise, more rigorous governance, and substantial resource allocation. The resource investment grows exponentially as the availability level increases.

b) The latency of Gateway EMS is part of the end-to-end SWIM latency, which includes delays from Gateway EMS, Edge EMS, and CRV. The latency of Gateway EMS is primarily determined by system hardware and software performance. Through comprehensive analysis of latency in multiple scenarios such as surveillance data transmission, flight plan updates, and meteorological information sharing, it is recommended to define the individual Gateway EMS processing delay on the order of seconds for operational use cases and on the order of minutes for post-operational or non-operational use cases.

c) In technical terms, throughput refers to the total volume of data processed or transferred within a specified time frame. The throughput of a Gateway EMS is heavily dependent on operational scenarios, requiring consideration of number of targets to be updated (related to the Edge EMSes connecting to the Gateway EMS), data size (determined by the data schema) and update rate (dictated by data source characteristics and scenario requirements)

<u>The requirements for the Gateway EMS Provider</u>

2.7 The Gateway EMS and the ANSP's internal EMS shall be kept independent. That is, Gateway EMS providers also need to operate their own Edge EMS and establish connections with multiple Gateway EMSes, including their own Gateway EMS.

2.8 The connections between Gateway EMSes need to be redundant. One Gateway EMS should be connected to at least 2 - 3 other Gateway EMSes, and ensure network connectivity and real-time monitoring.

2.9 The Gateway EMS Provider shall be able to support 7×24-hour monitoring and maintenance to ensure the stability and continuity of the Gateway EMS operation.

2.10 The Gateway EMS Provider needs to have necessary security protection capabilities and measures to ensure network security and data security.

2.11 The Gateway EMS Providers should establish collaborative emergency response procedures among themselves and its downstream Edge EMSes. In case of necessity, they should be able to carry out fault transfer and emergency response in a timely manner.

2.12 The Gateway EMS Provider should preferably provide AMHS/SWIM conversion capability to ease the expected AMHS to SWIM transition.

2.13 The implementation of the functional and non-functional requirements for Gateway EMS ensures the guaranteed delivery of messages. It helps prevent message exchange failures resulting from a single Gateway EMS node and enables the resolution of some of the issues related to Gateway EMS as mentioned in SWIM TF/9 - WP/10.

2.13.1 <u>Priority messaging is not possible depending on the importance of the information</u>

a) Different queues can be setup according to the nature and/or importance of the information, e.g. surveillance data is separated from FF-ICE message.

b) Priority segregation could be applied at the messaging level by assigning AMQP priorities.

2.13.2 Guaranteed message delivery is destroyed when malfunctioning of a message broker occurs in the message delivery chain

a) Critical messages which require a guaranteed message delivery could be configured with message durability and persistence in the message broker.

b) Concept of staging database between incoming queue and outgoing queue could be implemented to act as a buffer for reliable messaging.

2.13.3 Compensation transactions cannot be performed to compensate transaction failure in the message delivery chain

a) Retry logic for failed message deliveries could be implemented.

b) A record forward failure list could be used for traceability.

Information Service Requirement in the Hierarchical Architecture

2.14 It should be noted that while the modified hierarchical architecture and Gateway EMS requirements effectively enhance the message delivery success probability, message loss remains unavoidable. Therefore, it is necessary for both providers and consumers of SWIM Information Services to incorporate compensation mechanism during design and implementation.

2.14.1 The edge node does not know which message to resend when message loss occurs

a) A mixed use of publish-subscribe pattern and request-reply pattern could supplement information gap when message loss has occurred.

b) Message acknowledgement could be used to notify the publisher that a message was successfully delivered to the consumer, such as response messages used in FF_ICE.

3. ACTION BY THE MEETING

3.1 The meeting is invited to:

a) note the information contained in this paper;

b) deliberate on the proposed suggestions to guide SIPG's next steps in its work; and

c) discuss any relevant matter as appropriate.

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APPENDIX A

Investigation of QoS metric recommended values for ATM Systems

A thorough search was conducted for QoS metrics (Availability, Latency, and Throughput) associated with ATM systems, and meanwhile, the definitions and calculation methodologies of the QoS metrics for Gateway EMS were presented as below.

1. Availability

1.1 Definition and calculation of availability

Availability refers to the proportion of time a system is in an operational state under specified conditions, calculated as Availability = MTBF / (MTBF + MTTR). MTBF is the mean time between failures, and MTTR is the mean time to repair. A 99.9% availability corresponds to an annual downtime of approximately 8.76 hours (365 days × 24 hours × 0.1%). A99.99% availability corresponds to an annual downtime of approximately 52 minutes.

1.2 ATM Systems standards and practices for availability

The availability metric requires balancing security, cost, and technical feasibility. Each increment in the availability level by an additional “9” (99.9% to 99.99%) inevitably leads to an exponential escalation of redundant resources. ICAO and various civil aviation administrations (such as FAA, EUROCONTROL, and CAAC) have not set uniform requirements for system availability. The establishment of availability metrics takes into account technical needs, safety regulations, industry standards, and cost-effectiveness. Some air traffic control systems’ availability indicators are as follows：

Authorities	Performance Requirement Statement / Comment	Availability Threshold
ICAO	ICAO recommends PBCS equipment to support two availability tiers: 99.9% and 99.99%.[1].	99.9% / 99.99%
FAA	FAA mandates national airspace system facilities and services shall achieve a minimum availability of 99.5%[2].	99.5%
CAAC	The availability requirement of aviation control automation equipment is greater than 99.97% [3].	99.97%
EUROCONTROL	EUROCONTROL requires ATM surveillance system to meet a minimum availability of 99.98% [4].	99.98%
HKCAD	ATC system shall be at least 99.99%.	99.99%

2. Latency

2.1 Definition and calculation of latency

Processing latency denotes to the time incurred during the system's internal processing. For Gateway EMS, this latency comprises CPU scheduling overhead, algorithm execution time, and data I/O operations (e.g., disk/network read/write), among others. It is influenced by hardware specifications (e.g., CPU architecture, memory capacity, storage performance) and software implementation factors —such as algorithmic time complexity, multithreading efficiency, context-switching overhead, and concurrency control mechanisms (e.g., locking protocols).

2.2 ATM Systems standards and practices for latency

Latency requirements for the system vary across scenarios such as surveillance data transmission, flight plan updates, and meteorological information exchange. Latency specifications for data in different operational contexts are defined by respective aviation authorities (e.g., ICAO, FAA, EUROCONTROL) for their target systems. Detailed requirements are outlined in the table below.

Data Type	Performance Requirement Statement / Comment	Latency Threshold
Surveillance	EUROCONTROL classifies surveillance system latency and accuracy requirements, e.g., horizontal position latency ⩽0.5 seconds [4].	⩽0.5S
	US mandates ADS-B data latency shall not exceed 2 seconds [5].	⩽2S
	CAAC specifies secondary surveillance radar data latency ⩽2 seconds [6].	⩽2S
Flight plans	CAAC requires DCL system to process individual flight plan messages within 1 second (including reception and processing time) [7].	⩽1S
Meteorological information	ICAO Doc 8896 emphasizes meteorological data shall be disseminated with minimal latency to ensure operational relevance [8].	timely

3. Throughput capacity

3.1 Definition and calculation of throughput

Throughput refers to the data volume that a system can handle within a unit of time. It can be measured in two main ways: messages per unit time (e.g., messages/second, messages/hour) or data volume per unit time (e.g., KB/second, KB/hour), depending on whether the focus is on message count or data size. A Gateway EMS processes multiple data types—such as surveillance data, flight plan messages, and meteorological data， within its coverage area which includes the corresponding Edge EMSes. For modeling purposes, we define the following parameters for each data type:

- N:The target quantity per unit of time during peak hours(unit: targets/second or targets/hour)
- f: Data update frequency per target (unit: messages/target)

- *S*: Size of a single data entry (unit: KB/message)

Assuming steady-state operation, the total throughput $T_{data\ volume}$ is calculated as the product of three factors: $T_{data\ volume} = N \times f \times S$ .This formula quantifies the system's capacity to process data under peak conditions, with units of KB/unit time reflecting the total data volume handled per unit time. For message throughput $T_{messages}$， we use a simpler formula:$T_{messages} = N \times f$, with units of messages/unit time .

3.2 Take Sanya FIR as an example for throughput calculation

The parameters for calculating the surveillance data throughput of Sanya FIR international flights are as follows:

Variable	Value	Unit
N	186	flights/second
f	1	updates/second
S	1.1	KB

The calculated throughput *T* of the monitoring data is approximately 1.64Mbps or 186 messages/second. The throughput of flight plans and meteorological information are calculated similarly.

3.3 Gateway EMS throughput calculation recommendations

It must be emphasized that when calculating the throughput of China's Gateway EMS, all international flights associated with this Gateway EMS ought to be encompassed. Nevertheless, in the present analysis, only the international flights traversing Sanya FIR are factored in. The data used for calculation includes surveillance information (TRACK_RAW format), flight plans (FF-ICE PFP, PS, FFP, FS, and SR messages), and some meteorological messages (METAR and TAF). Gateway EMS operators are encouraged to conduct calculations by taking their specific operational scenarios into account.

4. Reference

[1] ICAO Doc 9869 Performance-based Communication and Surveillance (PBCS) Manual.
[2] M. Hecht and J. Handal. An Analytical Model for Predicting the Impact of Maintenance Resource Allocation on Air Traffic Control System Availability, Annual Reliability and Maintainability Symposium. 2001 Proceedings. International Symposium on Product Quality and Integrity, Philadelphia, PA, USA, 2001, pp. 46-52.
[3] Civil Aviation Communication, Navigation and Surveillance System Operation and Maintenance Procedure of China, AP－115－TM－2016－01.
[4] EUROCONTROL Specification for ATM Surveillance System Performance (Volume 2 Appendices).
[5] https://www.ecfr.gov/current/title-14/chapter-I/subchapter-F/part-91/subpart-C/section-91.227
[6]Technical specification of ATC secondary surveillance radar, MH/T 4010-2024.
[7] Data link departure clearance service, MH/T 4035—2012.
[8] ICAO8896: Manual of Aeronautical Meteorological Practice.