

**ICAO***International Civil Aviation Organization***THE ELEVENTH MEETING OF SYSTEM WIDE
INFORMATION MANAGEMENT TASK FORCE
(SWIM TF/11)***Bangkok, Thailand, 25 – 29 May 2026***Agenda Item 4: b) SWIM Infrastructure****HIERARCHICAL SWIM ARCHITECTURE TO ACHIEVE
MESSAGE EXCHANGE PATTERNS IN THE APAC REGION**

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SUMMARY

In accordance with the decision of the SWIM Task Force, a hierarchical architecture has been adopted for the APAC SWIM implementation. Therefore, the approaches to achieving the different message exchange patterns defined in the Manual on SWIM Implementation based on this architecture need to be discussed and clarified. This working paper clarifies the application requirements for these message exchange patterns, and discusses technical approaches for achieving them through coordination among Edge and Gateway Enterprise Messaging Services (EMSs).

1. INTRODUCTION

1.1 The SWIM Task Force has decided to adopt a hierarchical architecture for the implementation of SWIM in the APAC region. This architecture consists of Edge and Gateway Enterprise Messaging Services (EMSs), which are key components of the APAC SWIM Technical Infrastructure (TI). 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 users. The SWIM Implementation Pioneer Group (SIPG) has established a test platform based on this architecture over the Common aeRonautical Virtual Private Network (CRV) to evaluate its functional and non-functional capabilities.

1.2 To ensure the utilization of various information services, the Manual on SWIM Implementation (ICAO Doc 10203) defines several message exchange patterns (MEPs), including synchronous and asynchronous request/reply, publish/subscribe and one-way. These MEPs are expected to be supported by the SWIM TI. However, the practical implementation of these patterns within the APAC SWIM hierarchical architecture requires further discussion and clarification.

1.3 In particular, the coordination between Edge and Gateway EMSs introduces specific technical and operational considerations that need to be addressed to ensure interoperability and consistency across States. This working paper aims to clarify the application requirements for different MEPs, and discuss technical approaches for implementing these patterns through coordination among Edge and Gateway EMSs.

2. DISCUSSION

2.1 The messaging capability is the most important function of the SWIM TI, as it ensures message exchange between information services and consumers to support the implementation of defined operations. As shown in Table 1, four MEPs with different processes and constraints are defined in the ICAO Doc 10203 to ensure technical interactions between information services and consumers.

Table 1. Processes and Constraints of MEPs

MEP	Process	Constraint
Synchronous Request/Reply	The consumer initiates a request to an information service; the service processes the request and generates a reply to the consumer.	During the period of waiting for this response, the consumer cannot send or receive any other requests or responses.
Asynchronous Request/Reply	The consumer initiates a request to an information service; the service processes the request and generates a reply to the consumer.	This pattern requires that the consumer be able to receive messages at any time and correlate them with prior requests.
Publish/Subscribe	Push: The consumer initiates a subscription request to an information service, and the information service sends necessary updates (publish) to the consumer.	This pattern requires that the consumer can receive messages at any time.
	Pull: The consumer initiates a subscription request to an information service, and the information service would keep necessary updates available to the consumer.	This pattern requires that the consumer send requests to the information service to receive the updates.
One-way	The consumer initiates a message to an information service without expecting any response from the information service.	This MEP is particularly useful at the lower application layer, where message responses are not required.

2.2 Considering technical interoperability, system expandability and implementation consistency, the Advanced Message Queuing Protocol (AMQP) is adopted for asynchronous request/reply and publish/subscribe patterns, while the Hypertext Transfer Protocol (HTTP) is used for synchronous request/reply pattern. The adoption of a hierarchical architecture introduces coordination requirements that do not exist in a flat or centralized topology. In particular, the following challenges require further clarification.

- Message routing across Edge and Gateway EMSs: Messages originating from an Edge EMS must be properly routed to the intended recipient, which may be connected to another Edge EMS through one or more Gateway EMSs.
- Pattern-specific protocol handling: Given the fundamental differences in connection and session models between AMQP and HTTP, Edge and Gateway EMSs must bridge or proxy these protocols appropriately.

2.3 Since the one-way pattern is the most commonly used pattern at the lower application layer, and approaches for other MEPs can be utilized for its implementation, the remaining three patterns are discussed in the following paragraphs.

2.4 Asynchronous Request/Reply

2.4.1 The asynchronous request/reply pattern temporally decouples the request from the reply. The consumer sends a request without blocking for a response, while the information service processes the request independently and sends a reply to a designated destination. This pattern is suitable for non-time-critical and correlated message exchanges where processing latency may be variable.

2.4.2 Within the APAC SWIM TI, AMQP 1.0 is mandated as the communication protocol for this pattern. It is recommended that the following AMQP header properties be included in messages to improve reliability and efficiency in a multi-hop delivery environment.

Table 2. AMQP Header Properties

Property	Type	Default	Description	Recommendation
durable	boolean	false	Whether the message is durable (must be stored persistently by brokers).	true: survives broker restart
priority	uint8	4	Message priority (0~9). Brokers with priority queues will deliver high-priority messages first.	8 for FF-ICE messages
ttl (time-to-live)	milliseconds	no expiry	Message expiration time. Prevents stale messages from circulating indefinitely in a mesh.	3,600,000 for FF-ICE messages
first-acquirer	boolean	false	Whether the recipient is the first to acquire the message. Can help with routing logic or preventing re-processing in some topologies.	true
delivery-count	uint32	0	Count of delivery attempts. Used to detect duplicates or retries; important in multi-hop delivery.	10 within the APAC region

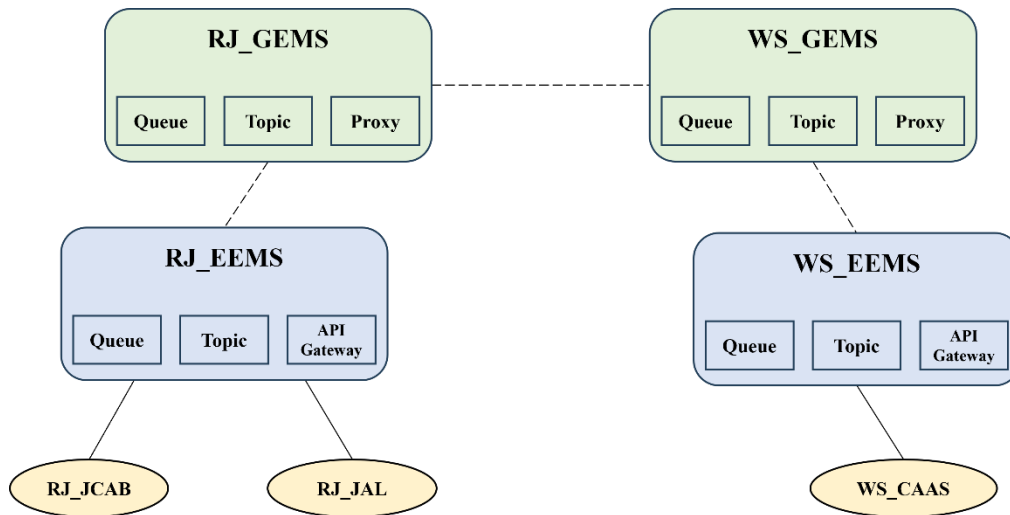


Figure 1. Hierarchical SWIM Architecture for Multiple MEPS

2.4.3 To ensure that messages are correctly routed to their intended recipients, message-header (metadata) based routing is considered an appropriate approach for implementation in a multi-hop delivery environment. Furthermore, the effectiveness of this approach for FF-ICE message exchange has been validated through multiple international demonstrations. The following message headers are required to support message routing across Edge and Gateway EMSs (EEMS and GEMS) in the APAC region. The naming convention for source, recipient and system identifiers should follow the format: (ICAO Indicator Prefix)_(Abbreviation of Organization or System Name), e.g., RJ_JAL, WS_CAAS, and RJ_GEMS.

- APAC_SOURCE: Name of message sender or information service provider, e.g., RJ_JAL
- APAC_RECIPIENT_LIST: Name list of recipients, e.g., RJ_JCAB,WS_CAAS
- APAC_TIMESTAMP: Timestamp of the message out or in the system (the format is epoch time, the type is milliseconds), e.g., RJ_EEMS_IN:1753337616725, RJ_EEMS_OUT:1753337617735

2.4.4 According to the hierarchical topology shown in Figure 1, when RJ_JAL submits an FF-ICE FILED_FLIGHT_PLAN message to RJ_JCAB and WS_CAAS, the following routing approach is applied across EEMSs and GEMSs.

1. RJ_JAL submits the FILED_FLIGHT_PLAN message, including metadata (APAC_SOURCE: RJ_JAL; APAC_RECIPIENT_LIST: RJ_JCAB, WS_CAAS; etc.) to RJ_EEMS.
2. RJ_EEMS routes the message based on the APAC_RECIPIENT_LIST. For local recipients, the message is placed in the corresponding queues (e.g., the RJ_JCAB.OUT queue for RJ_JCAB). For external recipients, the message is forwarded to RJ_GEMS.
3. Upon receiving the FILED_FLIGHT_PLAN message from RJ_JAL, the Filing Service of RJ_JCAB sends a SUBMISSION_RESPONSE message, including metadata (APAC_SOURCE: RJ_JCAB; APAC_RECIPIENT_LIST: RJ_JAL; etc.) to RJ_EEMS.
4. Upon receiving the SUBMISSION_RESPONSE message form RJ_JCAB, RJ_EEMS places the message in the RJ_JAL.OUT queue.

5. In parallel, RJ_GEMS forwards the FILED_FLIGHT_PLAN message to WS_GEMS based on the APAC_RECIPIENT_LIST and the routing table, which is determined by routing policies and connected GEMSs.
6. WS_GEMS resolves the APAC_RECIPIENT_LIST and forwards the message to the downstream WS_EEMS.
7. As the WS_CAAS is a local recipient, WS_EEMS places the message in the corresponding queue.
8. Then the Filing Service of WS_CAAS sends the SUBMISION_RESPONSE message, including metadata (APAC_SOURCE: WS_CAAS; APAC_RECIPIENT_LIST: RJ_JAL; etc.) to WS_EEMS.
9. The SUBMISION_RESPONSE message form WS_CAAS is routed back via WS_GEMS and RJ_GEMS to RJ_EEMS, which then places the message in the RJ_JAL.OUT queue.

2.4.5 A hierarchical architecture of Edge and Gateway EMSs is a multi-hop and multi-path environment. In this environment, when using message-header based routing, loops or retransmissions can occur. Therefore, duplicate handing should consider the combination of header-based prevention, EMS-level detection and application-level protection. The following approaches are recommended for implementation.

- Use message-id that is a unique identifier for the message included in AMQP message properties for duplicate detection.
- Use APAC_SOURCE message header to prevent messages returning to origin and enable loop detection.
- Use APAC_TIMESTAMP message header as routing path history to detect routing loops.
- For Edge EMSs, only use one active connection to a Gateway EMS, backup connection activated on failure.
- Use a deterministic routing table based on the connection topology and do not send a message back to the node it came from.
- Implement idempotency at consumer level.

2.5 Publish/Subscribe

2.5.1 The publish/subscribe pattern enables publishers to disseminate information to an arbitrary number of subscribers without direct knowledge of the subscriber population. This pattern is central to SWIM's information-centric model and serves as the primary mechanism for disseminating operational aeronautical and meteorological information, such as NOTAM and SIGMET messages.

2.5.2 Within the APAC SWIM TI, AMQP 1.0 is used to support this pattern. Topics are modelled as AMQP node addresses. Publishers establish a sender link to a topic node, while consumers establish receiver links. The EMS is responsible for the fan-out of messages received on a topic link to all attached receiver links.

2.5.3 Topics are structured as hierarchical address strings using a defined delimiter convention. A consistent topic naming convention is essential to enable topic relay and filtering among Edge and Gateway EMSs. Therefore, the following topic naming convention is recommended for use in the APAC SWIM environment.

- Topic naming convention: <region name>.<icao indicator prefix>.<abbreviation of service provider>.<service category>.<service name>.<category version>.<message type>
- Example for publish: apac.rj.jcab.aeronautical.digital-notam.axim-5-1-1.notam;
Example for subscribe: apac.rj.#

2.5.4 Within the hierarchical architecture, the following approaches are required to support topic relay among Edge and Gateway EMSs.

- Each user connects to a local Edge EMS for message publication and subscription.
- Each Edge EMS connects to its upper-level Gateway EMS to publish messages originating from local users and subscribe to messages from external users.
- Each Gateway EMS subscribes messages from other connected Gateway EMSs (logic multicast).

2.5.5 In the hierarchical topology shown in Figure 1, when RJ_JCAB publishes a NOTAM message to all subscribers (RJ_JAL and WS_CAAS subscribe all published messages by RJ_JCAB), the following routing approach is applied across EEMSs and GEMSs.

1. RJ_JCAB publishes the NOTAM message (apac.rj.jcab.aeronautical.digital-notam.axim-5-1-1.notam) to the topic address on RJ_EEMS (apac.#).
2. Since RJ_JAL has registered wildcard topic patterns (apac.rj.# and apac.ws.#) with RJ_EEMS, RJ_EEMS delivers the NOTAM message to RJ_JAL.
3. In parallel, RJ_EEMS forwards the NOTAM message to RJ_GEMS using the same topic address.
4. As WS_GEMS subscribes to all messages from the RJ domain (apac.rj.#), it receives the NOTAM message upon arrival.
5. WS_GEMS evaluates all registered topic subscriptions and forwards the message to WS_EEMS, which also subscribes to all messages from the RJ domain (apac.rj.#).
6. Since WS_CAAS has registered a wildcard topic pattern (apac.rj.#) with WS_EEMS, WS_EEMS delivers the NOTAM message to WS_CAAS.

2.5.6 As a Gateway EMS may be reachable via multiple paths, duplicate suppression should be implemented to support topic relay. Therefore, the following approaches for duplicate handling are recommended.

- Edge EMS should publish only messages originating from its local domain and subscribe to messages from external domains via the upper-level Gateway EMS.
- Each Gateway EMS should register distinct interest domains with connected Gateway EMSs and use AMQP filter expressions or address matching rules to prevent duplicate subscriptions.
- The end users should use the AMQP message-id properties for duplicate detection.

2.6 Synchronous Request/Reply

2.6.1 The synchronous request/reply pattern allows a requester to issue a request and block until a response is received within a defined timeout. This pattern is appropriate for transactional operations, real-time queries, and service invocations where the requester cannot proceed without a response.

2.6.2 Within the APAC SWIM TI, HTTP/HTTPS is the designated protocol for synchronous exchange, aligning with the RESTful, resource-oriented information service interface. HTTPS shall be

used for all inter-EMS and cross-domain traffic. Mutual TLS (mTLS) should be applied for machine-to-machine service invocations across EMS domains.

2.6.3 Unlike AMQP-based patterns, HTTP/HTTPS does not support brokered intermediary routing. Implementation approaches have been discussed by SIPG Task 3. A hybrid approach via the coordination between Edge EMS and Gateway EMS is recommended. An API Gateway deployed at the Edge EMS level provides centralised management for local service requests. The following key functions should be considered.

- Service registry and endpoint resolution: Maps logical SWIM information service to physical backend URIs.
- Authentication and authorisation enforcement: Validates OAuth 2.0 tokens, mTLS and client certificates before forwarding requests.
- Rate limiting and throttling: Protects downstream services from overload.
- Request/response transformation: Adapts message formats where necessary for legacy or heterogeneous services.
- Load balancing: Distributes traffic across multiple instances of a service.

2.6.4 Where deployment of a full API Gateway is not necessary, a reverse proxy at the Gateway EMS level may be used to provide transparent forwarding of HTTP requests from connected local Edge EMS to service hosted on remote Edge EMSs. In this pattern, the following URI naming convention is recommended to support path-based routing.

- `http://{api-gateway-host}:{api-gateway-port}/{region-name}/{country-code}/{abbreviation-of-service-provider}/{service-name}/{category-version}/{resource}?{query-parameters}`
- For example, when a CAAS user accesses the JCAB's SWIM Discovery Service, the request sent to CAAS's API Gateway should be as follows: `https://caas-api-gateway:port/apac/jp/jcab/smxs/sds-2-0-0/discovery-service`

2.7 The following coordination principles apply across all three MEPs and should be adopted in APAC SWIM TI implementations.

- Federation links: AMQP federation links between Edge and Gateway EMSs should use persistent, durable connections with automatic reconnect logic to handle network interruptions.
- Naming convention governance: A shared, registry-maintained topic/URI naming convention must be established and governed by the SWIM Task Force to prevent conflicts and ensure interoperability in APAC region.
- Failover and redundancy: Gateway EMS nodes should be deployed in active-active or active-standby pairs; Edge EMS nodes should support automatic failover to alternate Gateway EMS connections.

CONCLUSION

2.8 This working paper describes technical approaches for implementing SWIM MEPs within the APAC SWIM hierarchical architecture. The proposed approaches leverage established open standards and provide a basis for consistent implementation across the APAC region. The practical validation and evaluation have been conducted through SIPG activities.

3. **ACTION BY THE MEETING**

3.1 The SWIM TF/11 is invited to:

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