PoC Reference:
Reference Implementation Model for the Area Management Security Use Case

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[RIM AM-S PoC Reference]

Legal

Contents

List of Figures

1. Introduction

The Innovative Optical and Wireless Network Global Forum (IOWN GF) has defined the Cyber Physical System Area Management Security Use Case (AM Security UC) [IOWN GF CPS UC] and developed the Reference Implementation Model (RIM) for it (hereafter, the AM-S RIM) [IOWN GF AM-S RIM]. This PoC Reference provides guidelines for conducting the Proof of Concept (PoC) of the AM-S RIM to prove the validity and efficacy of the AM-S RIM.

1.1. Purpose

To deliver specifications for IOWN technologies satisfying markets demands in a rapid and efficient manner, IOWN GF is taking an iterative approach of

- developing a RIM based on the IOWN GF Use Cases,
- executing PoCs for evaluating the RIM using a defined Benchmark Model, and
- providing outputs of the executed PoCs for developing specifications and feeding back to the next version of the RIM.

As the first attempt at developing a RIM, the AM-S RIM document [IOWN GF AM-S RIM] defines:

- The Benchmark Model for AM Security UC-Metrics for evaluating implementation models, i.e., system cost and system power consumption. (see 1.2 and A.1 in [IOWN GF AM-S RIM] for the Benchmark Model and implementation models)
- The initial AM-S RIM that yields the best evaluation results for the Metrics defined in the Benchmark Model.

Based on the AM-S RIM document above, this document provides guidelines for conducting PoCs for AM Security UC to evaluate the AM-S RIM using the defined Benchmark Model in the middle of the iterative approach to validate the IOWN technologies as enablers of low-cost and low-power consumption of AM Security UC.

1.2. Objectives

Toward the purpose stated in 1.1, this document defines the objectives of the PoC for AM Security UC as follows:

- to aid for developing the specifications of IOWN technologies satisfying the market's demand in a rapid and efficient manner by accelerating through the iterative approach with PoCs for AM Security UC for evaluating the AM-S RIM,
- to implement critical parts of the AM-S RIM, which have difficulty to be realized economically with the current technologies,
- to measure the Metrics related to the cost and energy consumption in a quantitative manner, and
- to find potential technical improvements and provide feedback to future releases of IOWN technologies and AM-S RIM studies.

1.3. Scope

To achieve the objectives shown in 1.2, this document defines the following PoC scopes to include critical parts of the AM-S RIM, PoC-1 for Sensor Data Aggregation and Ingestion (SDAI) and PoC-2 for Data Hub and Live 4D Map.

- PoC-1: Sensor Data Aggregation and Ingestion (SDAI)

- Scope: Local Aggregation node (N1)-Ingestion node (N3) until the process on Ingestion node (N3) generates labeled objects.

- PoC-2: Data Hub and Live 4D Map
  - Scope: Data Hub (N5)-Intelligence Application (N8) from receiving the labeled objects by Data Hub (N5) to processing them by Live 4D Map on Intelligence Application (N8).

The scopes of both PoC-1 and PoC-2 are shown in Figure 1 in the context of the full AM-S RIM, which is slightly simplified from Figure 5.2-1 of the AM-S RIM document for explanatory purpose.

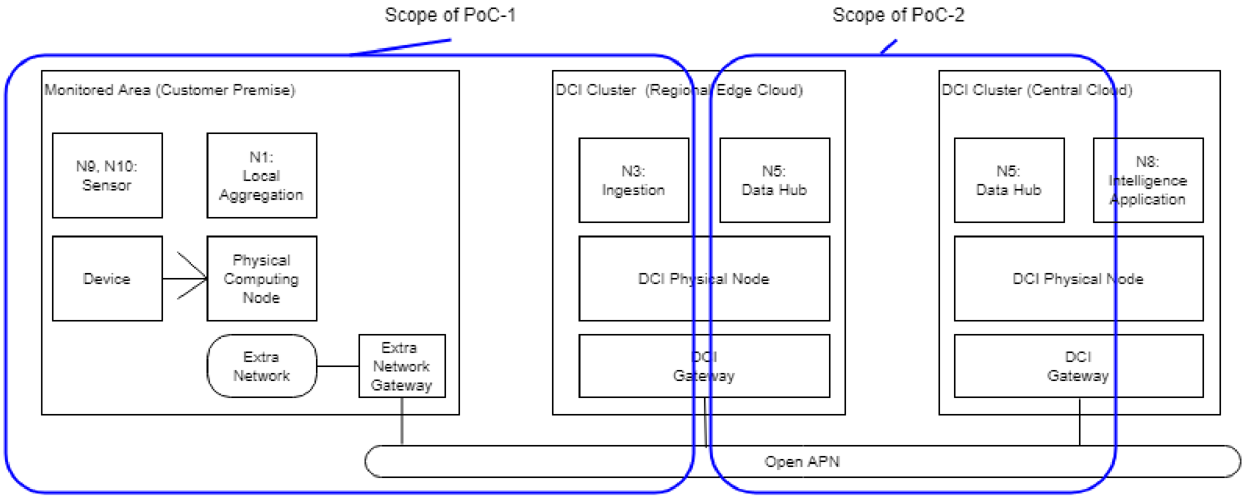

Figure 1: Scopes of PoCs for AM Security UC to evaluate the AM-S RIM

This document provides an overview of the PoC, selected features, advanced optional features, and the expected benchmark in sections 2 and 3 for PoC-1 and 2, respectively.

2. PoC-1: Sensor Data Aggregation and Ingestion (SDAI)

This section describes PoC-1, Sensor Data Aggregation and Ingestion (SDAI). The overview of PoC-1 is provided in 2.1. Selected features for the PoC of the SDAI are discussed in 2.2. All the SDAI reported in PoC Reports at least needs to cover the features in 2.2. Then, the advanced optional features for PoC are highlighted in 2.3. Finally, the expected benchmark of the PoC and other considerations the PoC Team should take into account are described in 2.4 and 2.5, respectively.

2.1. Overview

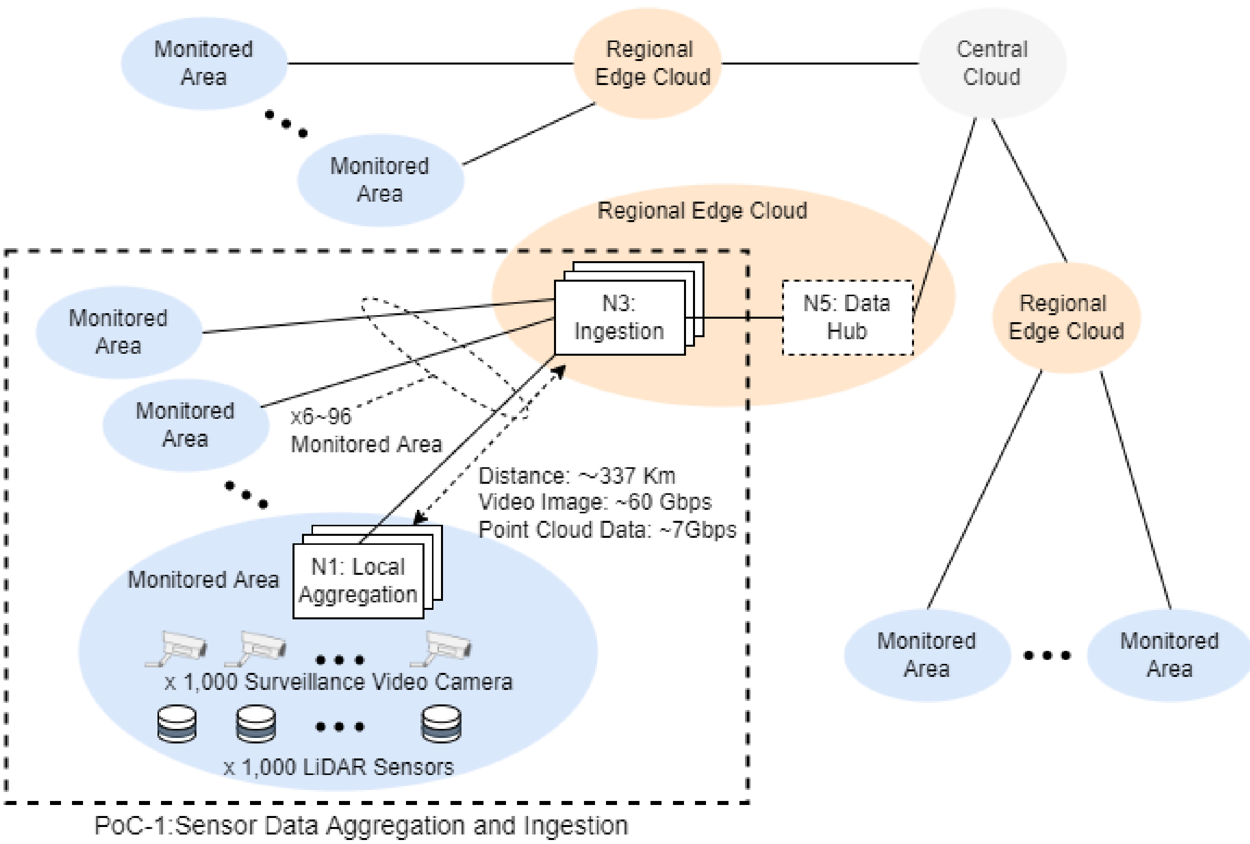

Figure 2: An overview of PoC-1: Sensor Data Aggregation and Ingestion

As one of the most critical parts of the RIM for the AM Security UC, the AM-S RIM for short, [IOWN GF AM-S RIM] in terms of the data volume, computing workloads, and energy consumption, this PoC Reference focuses on the SDAI.

Figure 2 shows an overview of the SDAI in the AM-S RIM. The SDAI corresponds to the front part of the processing flow 1 "Detection of Suspicious Persons or Activities" in the AM-S RIM document (see Figure 3.1-2 in [IOWN GF AM-S RIM]) and consists of an Ingestion node (N3) and its subordinate Local Aggregation nodes (N1). The SDAI is responsible for collecting data from a large number of geographically distributed sensor devices with a large volume of data, e.g., video cameras and LiDAR sensors, and converting the collected data into appropriate forms for further use in many Intelligence Application nodes. According to the deployment example described in the AM-S RIM document [IOWN GF AM-S RIM] (Annex E), the coverage area size for one SDAI reaches a radius of several hundred km, which may contain up to about 200,000 sensor devices in total. In addition, this data conversion process involves computingintensive CNN-based AI inference to produce necessary events or labeled objects in which many Intelligence Application nodes are commonly interested. As a result, the SDAI becomes the most resource and energy-consuming part of the AM-S RIM.

The AM-S RIM document described a promising solution set leveraging IOWN technologies to reduce the processing and energy overhead of data transfers and data conversion in the SDAI without needing to resort to hardware over-provisioning [IOWN GF AM-S RIM] (5.2, 5.3.1, and 5.3.2). The aims of this PoC-1 are to verify the applicability and effectiveness of the solution set to the SDAI and to prove the SDAI with IOWN technology can be a building block for the realization of the Area Management Security Use Case in an environmentally friendly manner.

2.2. Selected Features

This subsection describes the selected features of the SDAI to fulfill the aims of PoC-1. As mentioned in the previous subsection, the aims of this PoC are not to implement complete feature sets and conduct performance testing for prototyping but to examine the applicability of IOWN technologies to the target use cases and to prove their effectiveness. Although the scope of this PoC is narrowed to the SDAI, there are still many functional and non-functional features described in the AM-S RIM document [IOWN GF AM-S RIM]. In addition, an Ingestion node is expected to accommodate traffic from multiple monitored areas, where each monitored area is supposed to have 2,000 sensor devices. Therefore, it is recommended that PoC Teams start with a small-scale system of SDAI with the selected feature set because a full-scale production system of SDAI is too large and may be too much effort for some PoC Teams.

The following subsections describe the selected features for the PoC. First, features for sensor devices, local aggregation nodes, ingestion nodes, communication between sensor device and local aggregation node, and communication between local aggregation node and ingestion node, are listed in 2.2.1 to 2.2.5. The lists include features that need to be implemented in the PoC and their requirements with references to the corresponding parts of the AM-S RIM document. The lists also show some notes that may not be described in the AM-S RIM document but should be taken into consideration in the PoC. Then, the latency and scalability requirements for the PoC are discussed in 2.2.6 and 2.2.7.

2.2.1. Sensor Device

- Device type: surveillance video camera [IOWN GF AM-S RIM] (2.1.3)
    - This PoC Reference focuses only on video cameras as sensor devices since they are the most commonly used device and have a higher data volume requirement than other types of sensors.
    - Video cameras can be substituted with video delivery servers for PoC evaluation.

Note: The use of LiDAR sensors is not included in the selected feature set. It is treated as one of the advanced optional features in 2.3.

- Properties of video images:
    - Frame size: Full HD [IOWN GF AM-S RIM] (2.1.4) or higher
    - Frame rate: 15 fps [IOWN GF AM-S RIM] (2.1.4) or higher

Note: The AM-S RIM document does not define the compression scheme for video image streams from video cameras since it depends on the deployment environment of the monitored area. But the AM-S RIM document recommends Motion JPEG for data transferring from a Local Aggregation node to an Ingestion node [IOWN GF AM-S RIM] (5.2), so if there is no strong reason to choose a different implementation, Motion JPEG should be applied to this communication section.

2.2.2. Local Aggregation Node

- Functional features
    - Accepting and aggregating video image streams from one or more sensor devices [IOWN GF AM-S RIM] (5.3.1)
    - Hardware-based data transmission of aggregated video image streams to the peered Ingestion node [IOWN GF AM-S RIM] (5.1.6, 5.3.1)
        - See also the "Communication Protocol" in 2.2.5.

2.2.3. Ingestion Node

- Functional features
    - Hardware-based data reception of video image streams from one or more peered Local Aggregation nodes [IOWN GF AM-S RIM] (5.1.6, 5.3.2)
        - See also the "Communication protocol" in 2.2.5.
    - Data replication and delivery of accepted video image streams to multiple data consumers [IOWN GF AM-S RIM] (5.3.2)
    - Video decoding and CNN-based image recognition to produce labeled objects in a real-time manner [IOWN GF AM-S RIM] (5.3.2)
- Non-functional features
    - Data-plane accelerated by hardware-based data transfer [IOWN GF AM-S RIM] (5.3.2)
        - Data transfer over intra-node/inter-node should have less impact on CPU usage by using hardware-based and kernel bypassing acceleration techniques. As described in the AM-S RIM document, DMA/RDMA between host memories and functional cards can be candidate solutions.
    - Utilization of heterogeneous accelerators optimal for each portion of the workload [IOWN GF AM-S RIM] (5.3.2)

Note 1: For example, logical servers created from sets of CPUs, RDMA capable NICs, and GPGPUs, or sets of DPUs and GPGPUs will be appropriate for the Ingestion node.

Note 2: PoC Teams might want to consider utilizing reports of the data-centric-infrastructure-as-a-service PoC [IOWN GF DCIaaS].

2.2.4. Communication between Sensor Device and Local Aggregation Node

- Network type: Network type is not specified but PoC Teams should take the following points into account.
    - Example network types are Ethernet, SDI (Serial Digital Interface), etc.
    - To allow the heterogeneous networking environments of the monitored area, the AM-S RIM document assumes that sensor devices are connected via the best available network for the monitored area [IOWN GF AM-S RIM] (5.2).

- Communication distance: Communication distance is not specified but PoC Teams should take the following points into account.
    - In a deployment option in the AM-S RIM document, the communication distance can be up to 1km [IOWN GF AM-S RIM] (Annex E).
    - Evaluation in a local experiment environment is acceptable since the sensor devices are connected with Local Aggregation nodes in the same monitored area.
- Communication protocol: Communication protocol is not specified but PoC Teams should take the following points into account.
    - Example communication protocols are RTP, HTTP, QUIC, etc.

2.2.5. Communication between Local Aggregation Node and Ingestion Node

- Network type: Network type is not specified but PoC Teams should take the following point into account.
    - It is recommended to apply Open APN, extra network gateway, and DCI gateway to the underlying network. The extra network gateway and DCI gateway should support Flexible bridging Service [IOWN GF AM-S RIM] (3.1.2).
- Communication distance: Communication distance is not specified but PoC Teams should take the following points into account.
    - In a deployment option in the AM-S RIM document, the communication distance can be up to 337 km [IOWN GF AM-S RIM] (Annex E))
    - It is recommended to evaluate the changes in performance with respect to changes in distance. The communication distance may be emulated by network emulators.
    - To evaluate the basic performance of the SDAI, evaluation in a local experiment environment is also acceptable.
- Communication protocol: RoCEv2 (RDMA over Converged Ethernet v2) (UDP/IP/Ethernet) should be applied, at least, to the data transfer of video image streams.
    - The AM-S RIM document recommends RDMA as a communication protocol for inter-node interconnect since its protocol stack can be fully offloaded to hardware on the NIC [IOWN GF AM-S RIM] (5.1.6, 5.3.2).

Note 1: It is recommended that the PoC Report include a comparative performance analysis between RDMA and conventional software-based communication protocol stacks (e.g., TCP/IP, RTP, QUIC, HTTP, gRPC, etc.).

Note 2: PoC Teams might want to consider utilizing reports of the RDMA over Open APN PoC [IOWN GF RDMA over Open APN].

2.2.6. Latency

The mandatory E2E response time of the AM Security UC is expected to be less than 1 sec [IOWN GF AM-S RIM] (2.1.7). Therefore, the latency of the SDAI should be kept around hundreds of milliseconds. Please also see 2.4.1 for a detailed definition of the latency of the SDAI.

2.2.7. Scalability

Conducting a PoC by building a system of the production size as described in the AM-S RIM document is not feasible. Therefore, this PoC Reference does not put restrictions on the scale of the PoC (e.g., the number of sensors per monitored area and the number of monitored areas). However, the PoC Team shall choose an implementation strategy that scales well, and the PoC Team shall choose an implementation size for the PoC that is sufficiently large to allow extrapolation of the required system resources and the system cost to the size of an actual production system. For this purpose, this PoC Reference describes scalability-related KPIs and a consideration item in 2.4 and 2.5 respectively.

2.3. Advanced Optional Features

Subsection 2.2 describes the selected features for the PoC of SDAI. Actually, there are several other advanced features discussed in the AM-S RIM document [IOWN GF AM-S RIM]. To make the PoC more appealing to the Industry, PoC Teams are encouraged to implement additional features described in the AM-S RIM document and demonstrate them. Examples of such features include:

- Workload optimization with an event-driven approach among Local Aggregation node and Ingestion node [IOWN GF AM-S RIM] (Annex D).
- Utilization of heterogeneous accelerators with accelerator pooling and auto-scaling [IOWN GF AM-S RIM] (3.1.2).
- Advanced AI analysis employing sensor fusion techniques with multiple types of sensor devices [IOWN GF AM-S RIM] (C.3.3).
    - e.g., a combination of video cameras and LiDAR sensors

One of the objectives of this PoC is to find potential technical improvements toward Release 2 of the AM-S RIM document. PoC Teams are welcome to suggest new features to support potential technical solutions, incorporate them into their PoC, and evaluate their benefits. Examples of such potential technical solutions include:

- Application of XPU to XPU RDMA [IOWN GF RDMA over Open APN] to communication between Local Aggregation node and Ingestion node or internal communication within a Local Aggregation node or Ingestion node.
- Remapping of functions to geographically distributed computing resources.

2.4. Expected Benchmark

This subsection identifies the benchmark that PoC Teams are expected to evaluate. The key KPIs for the benchmark defined in this PoC Reference are latency, system resources and configuration, throughput, and energy efficiency. The PoC Report should include the evaluation results in terms of the four KPIs. Each KPI is outlined in 2.4.1, 2.4.2, 2.4.3, and 2.4.4, respectively.

2.4.1. Latency

- Scope: latency
    - from the time when a Local Aggregation node finishes receiving the whole data of a frame
    - to the time when the Ingestion node completes to produce labeled objects from the frame
- Metrics: millisecond.

- Measuring Method: TBD (This is determined by the PoC Teams and documented in their PoC Reports.)

2.4.2. Required System Resources and Configuration

- Scope: The overall system resources and configuration for the PoC of the SDAI.
- Metrics: Describe the environment used for the evaluation
  - Network and system configuration, including devices, servers, and networks
  - Properties of video streams (e.g., resolution, frame rate, compression scheme, and bit rate) from cameras
- Measuring Method: Provide a list of the system configuration, such as the number of devices, number of CPUs, memory size, and bandwidth.

2.4.3. Throughput

- Scope: The maximum number of cameras the SDAI can accommodate
- Metrics: the number of cameras or fps
- Measuring Method:
  - Change the number of camera streams input to the SDAI, and check the maximum number of camera streams the SDAI can process without significantly increasing the latency and error occurrence. At least, the latency should not exceed the E2E response time (1 sec).

2.4.4. Energy Efficiency

- Scope:
  - The total energy consumption of the system resources for the PoC of the SDAI
    - The energy consumption of the Local Aggregation node and Ingestion node should be measured.
    - The measurement of the energy consumption of sensor devices and network equipment is optional since they might be emulated.
  - The energy consumption required for processing a single video stream from a camera
- Metrics:
  - Total energy consumption (Wh)
  - Energy consumption per camera (Wh/camera)
- Measuring Method: TBD (This is determined by the PoC Teams and documented in their PoC Reports.)

2.5. Other Considerations

The PoC Reports should include considerations regarding the following items:

- Provide qualitative and quantitative analysis by comparing IOWN technologies with existing technologies.

- Scalability
  - Consider applicable methods to ensure scalability (e.g., scaling up/out) when adapting to all of the requirements in the AM-S RIM document [IOWN GF AM-S RIM].
  - Describe any benefits, challenges, or concerns with the methods for ensuring scalability described above.

3. PoC-2: Data Hub and Live 4D Map

This section describes PoC-2, Data Hub and Live 4D Map, with leveraging the IOWN Data Hub (hereinafter referred to as IDH). The overview of PoC-2 is provided in 3.1. Implementation models to be tested are explained in 3.2. Selected features for the PoC are discussed in 3.3. PoC Reports for Data Hub and Live 4D Map at least needs to cover the features in 3.3. Then, the advanced optional features for PoC are highlighted in 3.4. Finally, the expected benchmark of the PoC and other considerations the PoC Team should take into account are described in 3.5 and 3.6, respectively.

3.1. Overview

As described in the AM-S RIM document [IOWN GF AM-S RIM], a data pipeline that supports both real-time data movement and ad hoc/event-driven data movement has to be built between the regional edge cloud and the central cloud. Also, in the central cloud, the Live 4D Map has to be built so that an intelligence application can analyze the situation with short latency.

When developing such a mechanism with today’s technologies, we will definitely face many issues, such as lack of real-time-ness and the burden of costs. These issues come from the design principles of today’s data management technologies, including cloud-based ones, which are explained in the IOWN Data Hub Functional Architecture (hereinafter referred to as the IDH document) [IOWN GF IDH FA] document (4.1, 4.2, and 4.4). It means that each existing data management service focuses on scalability first, so it provides only a limited set of capabilities and doesn't support real-time data processing, as described in the IDH document [IOWN GF IDH FA] (5.2.6). A limited set of capabilities of each service also imply that we have to combine multiple services to build the system, so many data movements have to occur. It means that data has to be pulled by the consumer application rather than pushed. This situation further reduces real-time-ness, increases the system cost, and consumes a lot of energy, especially when there is a necessity to run a complex query/shuffling job to retrieve the required data.

The IDH solutions are developed so that the above issues are solved/mitigated on top of APN and DCI architecture. It means that each IDH service class not only provides higher performance but also provides richer functionality without sacrificing scalability.

In this PoC, we will compare today’s implementation model and the IDH-based implementation model, especially around Message Broker, Key-Value Store (KVS), and Converged DB service classes, to build the data pipeline and Live 4D Map to confirm the benefits of IDH described above.

3.2. Implementation Models to be evaluated

As described in section 3.1, today’s implementation model and one or a few IOWN GF implementation models have to be compared during the benchmark. In this section, candidates for such implementation models are described.

3.2.1. Today’s Implementation Model for the scope of PoC-2

The first thing to do with PoC is to look at the performance limits of today's implementation models.

The following Figure 3 shows an example of such implementation models with today's technology.

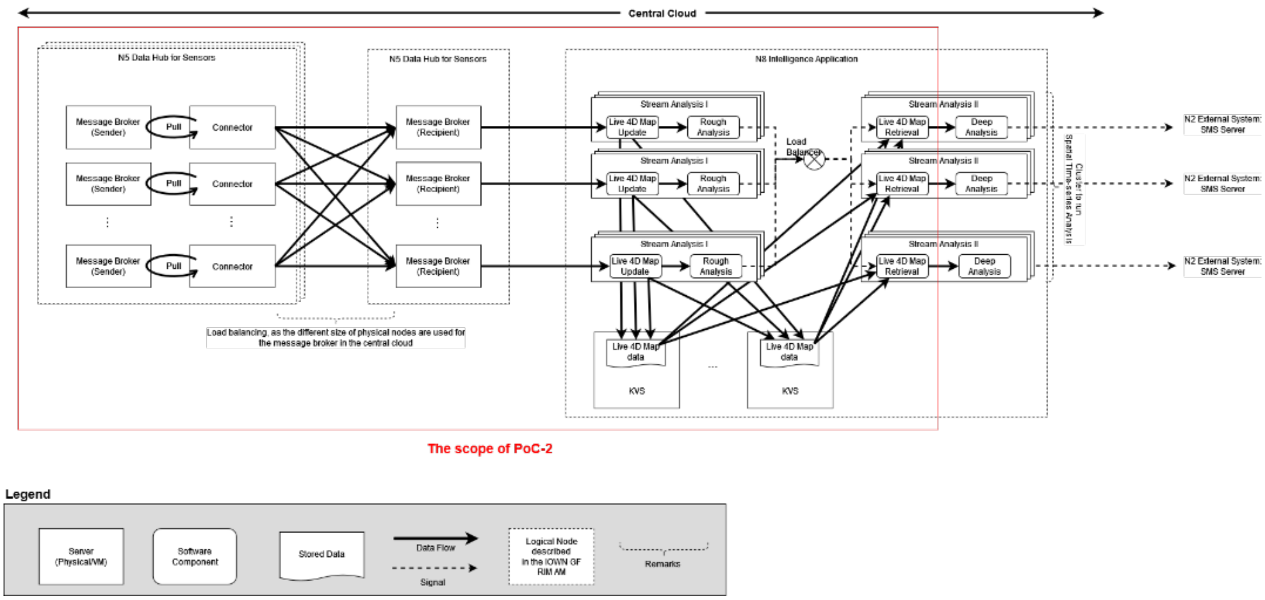

Figure 3: Example of implementation models with today's technology

The role and key requirements of components and elements described above are as follows:

- Message Broker (Sender)
  - Accept data ingestion from the Ingestion logical node (N3) with short latency; data is temporarily stored in the order data is received, with a focus on fast and stable data ingestion.
  - Guarantee the data persistency; data is written to the storage and replicated across multiple message broker physical nodes, to ensure that data is not lost and service continues when any single node fails.
  - Pass data to the connector physical node in response to a pull request from it. Note: The relationship between the message broker physical node and the connector physical node is generally 1: 1 or 1: N, depending upon the amount of workload that the connector nodes need to support. In this PoC, the connector nodes just forward the data to the appropriate Message Broker (Recipient) based on the content of the data, their workload will not be so high, and N would be 1 or 2.
- Connector
  - Pull data from the assigned message broker physical node.
  - Transmit data to the message broker physical nodes in the central cloud equally by using, for instance, the hash value of the data ID as soon as possible.
- Message Broker (Recipient)
  - Accept data ingestion from the connector physical nodes in the central cloud with short latency; thus, data is temporarily stored in the order it receives.
  - Guarantee the data persistency; thus, data is written to the storage and replicated across multiple physical nodes.

  - Pass data to the stream analysis physical node in response to a pull request from it. Note: The relationship between the message broker physical node and the stream analysis I physical node is generally 1: 1 or 1: N.

- Stream Analysis I
  - Pull data from the assigned message broker physical node.
  - Verify data, and convert data as required.
  - Store the converted data to the Live 4D Map physical nodes. Note: Depending upon the content of data, data is stored in the different nodes.
  - Roughly analyze received data that falls in the last N second time window. Note1: the last N-second data can be held in memory and thus can analyze quickly at a low cost. Note2: to detect suspicious behaviors of people, last 10 second data or so may be required, because nothing can be confirmed from a momentary snapshot data.
  - Notify one of the Stream Analysis II nodes by considering those workload statuses so that it can start a deep analysis process to investigate the situation

- Live 4D Map (KVS)
  - Record and manage various kinds of data received. Note: Data in the CPS AM Security system has various structures depending on its contents. For instance, machine learning inference results will be semi-structured data because it has various attributes, and data like object coordinates will be structured data because the number of attributes to be managed is fixed. KVS will be used in today's implementation model for such a mixture of data because it can handle such different kinds of data together.
  - Manage a large amount of data in a distributed manner with multiple physical nodes. Note: Data distribution across physical nodes will be determined by criteria such as location, etc.
  - Group (partition) and/or index data based on time and space to make it easier to access the data.
  - Link relevant data records so that the deep analysis is accelerated.
  - Respond data to the stream analysis II node in response to a query request from it. Note: The relationship between the Live 4D Map nodes and the stream analysis II nodes is generally N: M. Given the largest KVS and analytical cluster deployments today, this N: M can be as high as a few hundred to a few hundred.

- Stream Analysis II
  - Receive the deep analysis request from the Stream Analysis I nodes, through a load balancer that considers the workload status at Stream Analysis II.
  - Query the relevant data required for the deep analysis from the Live 4D Map nodes. Note: This query can be iterated as required for analysis.
  - Run the deep analysis process to detect dangerous/suspicious situations. Note: This deep analysis process itself is out of scope in this PoC.
  - Depending upon the quality of the rough analysis executed in Stream Analysis I, the number of nodes to run Stream Analysis II will vary. For instance, if the rough analysis detects 5 situations per second

that need to be analyzed in detail, and if a single node in Stream Analysis II can execute one detailed analysis per second, then the required number of Stream Analysis II nodes becomes 5.

As shown above, even with the current implementation model and technologies, the scope of PoC-2 in the CPS AM Security system can be functionally constructed. However, there are periodic pull-based data accesses, and essentially the same data is repeatedly transferred and stored. Such data processes increase end-to-end latency, system cost, and energy consumption, so the use case requirements cannot be fulfilled. For example, considering a typical IoT system reference case, the end-to-end latency requirement of 1 second, ideally 100 msec, in the scope of PoC-2 would not be met, and the suspicious person will run away before alerts are issued in today's implementation model.

3.2.2. IOWN GF Implementation Model for the scope of PoC-2 - Pattern I

The goal of the IOWN Global Forum implementation model is to eliminate/mitigate the above issues by leveraging the IOWN Global Forum APN, DCI, and Data Hub architectures and technologies.

However, as the AM-S RIM document [IOWN GF AM-S RIM] (5.3.3 and 5.3.5) describes the high-level structure of the expected system only, there are still various options to determine its physical structure. Figure 4 below shows one of such possible physical structures of the system.

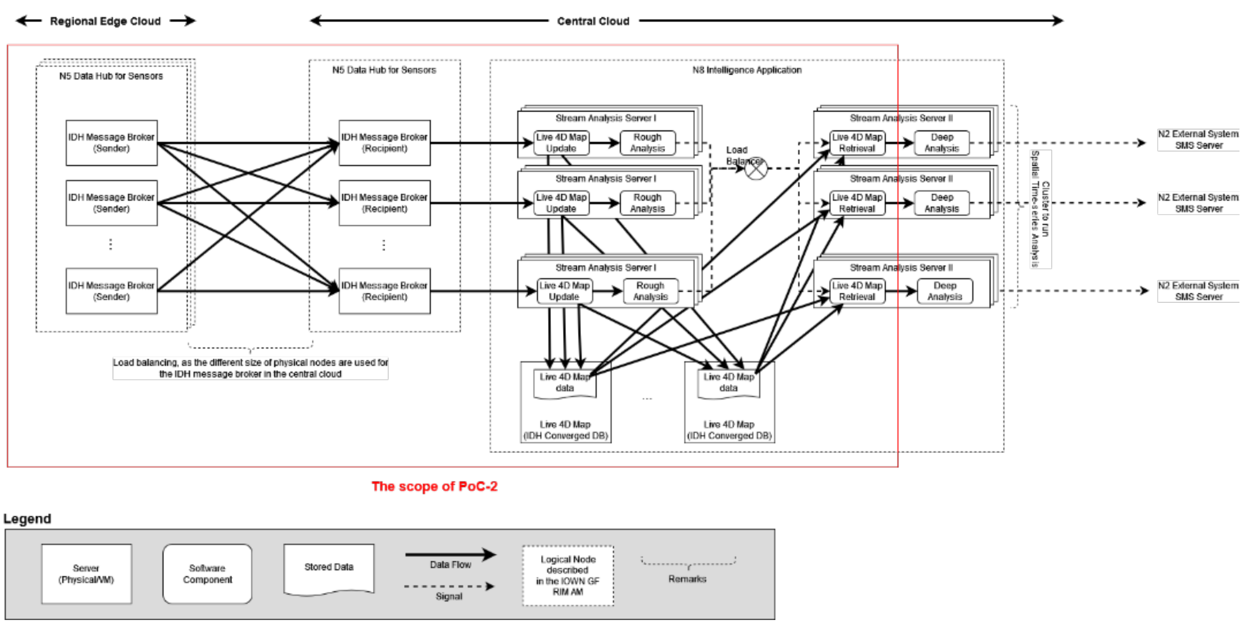

Figure 4: One of the possible physical structures for the scope of PoC-2 based on IDH

This IOWN GF-based implementation model has the following differences compared to today's implementation model:

- IDH Message Broker (Sender)
    - In IOWN GF Implementation Model, we leverage the IDH Message Broker described in the IDH document [IOWN GF IDH FA] (5.2.4).
    - In today's implementation model, the message broker nodes do not provide push capability, but IDH Message broker nodes do so.
    - To forward/shuffle data to the adequate recipient, connector nodes are required in today's implementation model. IDH Message broker is intelligent and multi-functional, so it can forward/shuffle data to the adequate recipient by itself in a push-process.

  - IDH Message broker can control data transfer based on the content of data and defined rules. For example, labeled objects that give us an overview of the situation can be transferred immediately, and raw data such as images can be transferred on a request basis or in a regular batch job.
  - IDH message broker uses system resources wisely and also provides strict resource control. This is because it is necessary to perform data push and pull operations without degrading the performance of data ingestion. That is, a certain amount of CPU time is reserved for the data ingestion process. Conditional pushes are based on the attributes of the data, which are expanded in memory, while data contents (payloads) are written to storage so that IDH Message Broker can accommodate a large amount of data for a while.

- Live 4D Map (IDH Converged DB)
  - In IOWN GF Implementation Model, we leverage the IDH Converged DB described in the IDH document [IOWN GF IDH FA] (5.2.6).
  - In today's implementation model, KVS is used because of its flexibility and scalability. However, KVS takes a position that it doesn't know the data structure until the data is stored, so there is overhead, and it is not always optimal. On the other hand, with IDH Converged DB, the Live 4D Map is more fine-tuned. It means that optimization is done depending on the kind of data stored. By storing various kinds of data in an optimized way in one place, it is possible to speed up advanced data processing that requires data integration.

- Inter-node interconnect
  - In today's cloud-based implementation model, inter-node interconnects are based on the Ethernet and the TCP/IP protocol. Especially in today's cloud environment, network performance is not good for multi-tenancy due to oversubscription, many routers/switches that packets have to go through, and non-VLAN-based SDN controls that look up the mapping table to translate virtual IP address to corresponding physical IP address and vice versa at all endpoints to establish virtual networks. In the IOWN Global Forum implementation model, these overheads are largely eliminated, so the expected inter-node interconnect performance is very high.

3.2.3. IOWN GF Implementation Model for the scope of PoC-2 - Pattern II

The above implementation model is a straightforward physical interpretation of the implementation model described in the AM-S RIM document [IOWN GF AM-S RIM] (5.3.3 and 5.3.5) and also follows the IoT system design practices commonly found today. However, as is clear from Figure 4, essentially, the same data is repeatedly stored and transferred over multiple hops between multiple servers, still. This is not lean. This increases the latency of data processing, the system cost, as well as energy consumption.

Such inefficiency can be solved by the node provisioning flexibility made available in the DCI architecture. An example of such designs is given in Figure 5 below. This other implementation model lets the message broker recipient node and the Live 4D Map data management node co-exist on the same physical node, assuming good isolation of resources and security contexts are made and these converged nodes are interconnected via RDMA so that memory space is shared; thus, data movement and extra data write operations to guarantee the data persistence are reduced.

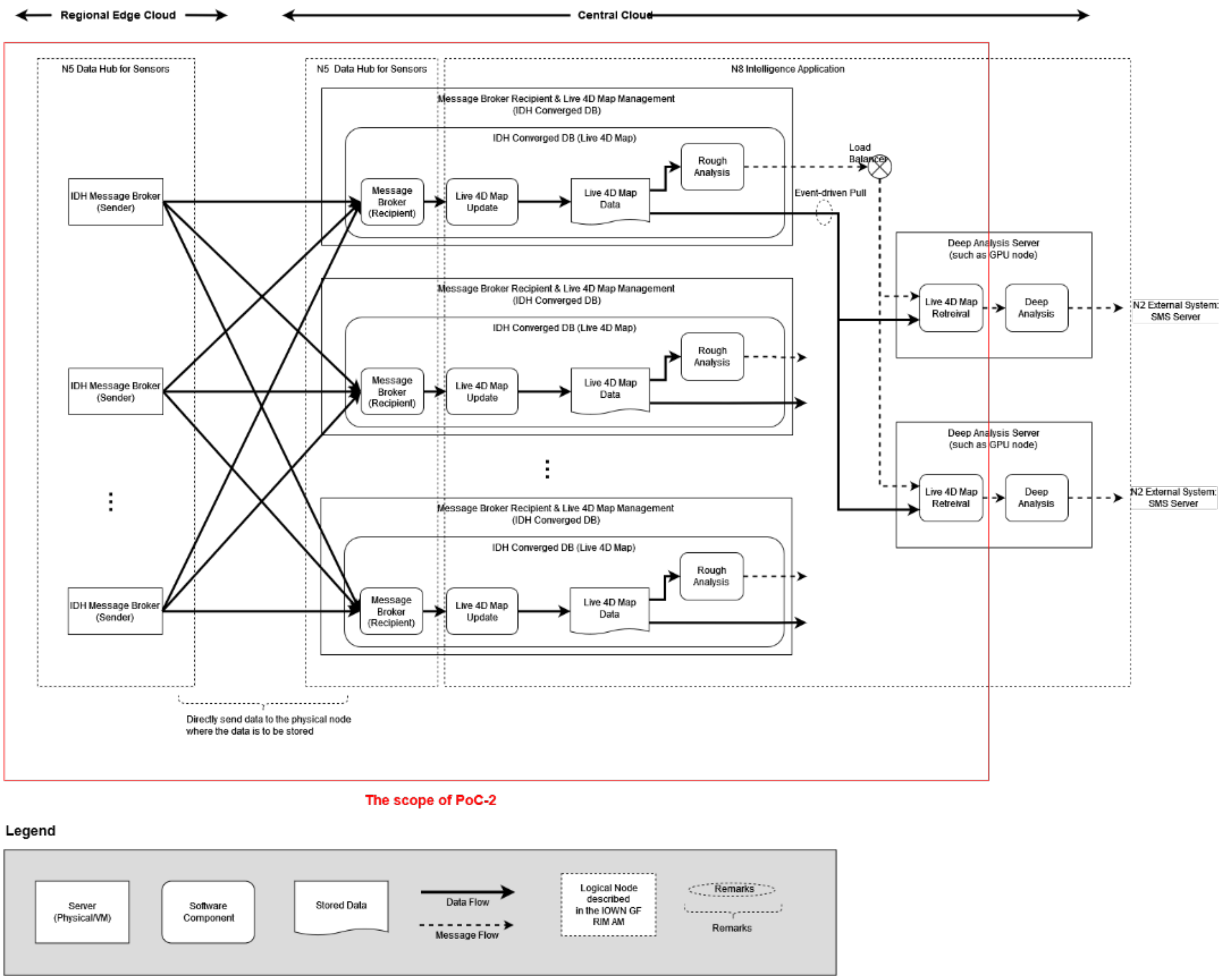

Figure 5: The other option of the possible physical structures for the scope of PoC-2 based on IDH with DCI

To make this implementation model feasible, there are additional requirements to be covered, which are described below:

- Live 4D Map has to accept the data ingestion with short latency and high throughput.
- Live 4D Map has to enable flexible data processing to run stream analysis I in the above models within the Live 4D Map. Such data processing may be mathematical/analytical, so it has to support the famous mathematical/analytical library, as well as the user's custom codes.
- Once data is ingested into the buffering area (message broker role) within the Live 4D Map, it shall trigger the data processing immediately.
- Live 4D Map has to execute the data processing with very short latency. Various techniques need to be supported for that. For instance, it shall support the following techniques:
    - in-DB data processing based on the shared buffer that eliminates data movement necessity
    - data processing based on the low overhead language such as C/C++, or ahead-of-time compilation of data processing code written in languages such as Java, Python, etc.
    - secure and light-weight environment to run the user code

- Live 4D Map has to implement more strict resource control, as there are various kinds of processes. High-priority processes must not be affected by low-priority processes.

- The Live 4D Map has to scale well without sacrificing performance. More data than usual may occur depending on the conditions of the monitored area. In such cases, the Live 4D Map must be scaled well.

    - For example, it is required to flexibly provision high-performance storage and/or decouple storage and compute so that more compute resources can be adjusted in response to load fluctuations without data movement.

    - As online scale-out/in requires data movement, so not only online scale-out/in but also online scale-up/down have to be supported. The disaggregated computing platform and virtualization technologies running on top of it have to be designed accordingly.

- To realize such a Live 4D Map, we leverage the full potential power of the IDH Converted DB described in section 5.2.6 of the Data Hub Functional Architecture document.

By introducing such new technology, it will be possible to implement a system with lower end-to-end latency at a lower cost and with less power consumption.

3.3. Selected Features

The upcoming PoC shall test Data Hub logical node (N5) and/or Live 4D Map in the Intelligence Application logical node (N8). Features of the Data Hub logical node (N5) and Live 4D Map are explained in section 3.2. It should be noted that it is not necessary to include the deep analysis within the Intelligence Application logical node (N8) but the data retrieval feature to extract the data from the Live 4D Map shall be included in the PoC.

As described in the AM-S RIM document [IOWN GF AM-S RIM] (2.1.7), the targeted end-to-end response time of the assumed use case is less than 1 sec, ideally 100 milliseconds. Of course, the component-level latency must be much smaller to meet this requirement. In the PoC, the team shall achieve less than 100 milliseconds latency from data ingestion to data usage in the Data Hub logical node (N5) and also in the Live 4D Map included in the Intelligence Application logical node (N8).

In addition, the PoC should be conducted based on an environment designed to scale well to provide the required throughput described in the AM-S RIM document [IOWN GF AM-S RIM] (Annex E). This means the Data Hub logical node (N5) and the Live 4D Map in the Intelligence Application logical node (N8) must scale well to support the required throughputs describe below. This allows us to estimate the cost and energy consumption of the production system while keeping the PoC size comparably small.

- Throughput of the Data Hub logical node (N5)
  As described in the AM-S RIM document [IOWN GF AM-S RIM] (Annex E), the data flow rate for the labeled objects sent from the Data Hub logical node (N5) in one regional edge covering 96 monitored areas is about 349 Gbps, and the data flow rate flows into one central cloud is around 2.4 Tbps.

- Throughput of the Live 4D Map in the Intelligence Application logical node (N8)
  Similarly, as described in the AM-S RIM document [IOWN GF AM-S RIM] (Annex C and E), the number of labeled objects sent to the Intelligence Application logical node (N8) is about 100 million per second. As all of these objects are reflected in the Live 4D Map, so, the Live 4D Map has to accommodate at least 100 million ingestions per second. In addition, within the Intelligence Application logical node (N8), associations between objects and tagging of objects will be made frequently. And finally, a set of relevant data will be retrieved at some frequency for detailed analysis. In summary, we assume that the Live 4D Map in the Intelligence Application logical node (N8) shall support 100 million ingestions per second, 10 million updates per second, and 1 million reads per second.

3.4. Advanced Optional Features

3.4.1. IDH Features described in the IDH Document

Today's implementation models of data hub technologies focus on scalability, so individual data hub services are kept intentionally simple. As a result, many data transfers among data hub services and repeated data storage in each data hub service have to occur, resulting in deterioration of system performance.

As described in the IDH document [IOWN GF IDH FA] (Chapter 5), IDH service classes are designed to address this issue by developing new data management services that implement multiple functions in an effective manner. Therefore, it is desirable to evaluate the value of such functions when being used as a part of a larger system. IOWN GF Implementation Model for the scope of PoC-2 - Pattern II described in section 3.4 is an example of such evaluation. As such, the PoC Team is encouraged to evaluate various features, which are described in the IDH document [IOWN GF IDH FA] but not mandated by this PoC Reference document.

3.4.2. Availability and Security Features

In addition, availability and security are also important factors in production systems. Therefore, it is desirable that PoC be done in consideration of these. For example, it is conceivable to build Data Hub and Live 4D MAP logical nodes with multiple physical nodes and configure them so that a quick failover can be conducted in the event of a node failure for availability. It is also conceivable to encrypt data-in-transit and data-at-rest with a strong algorithm. By considering these, the technology can be evaluated more correctly.

3.5. Expected Benchmark

This subsection identifies the benchmark that PoC Teams are expected to conduct.

To determine a better implementation model as described in the AM-S RIM document [IOWN GF AM-S RIM] (5.3.3 and 5.3.5), at least one or ideally a few implementation models that incorporate IOWN technology shall be compared with today's implementation model. References to such implementation models are explained in 3.2.

To compare the models, latency, amount of system resources, energy consumption, and throughput are measured. The KPIs to be measured are outlined in 3.5.1, 3.5.2, and 3.5.3, respectively.

3.5.1. Latency

As described in the AM-S RIM document [IOWN GF AM-S RIM] (4.2.2), the end-to-end response time target is 1 sec, ideally 100 msec. So, the latency to transfer the data through Data Hub logical node (N5), populate to the Live 4D Map, and retrieve data from the Live 4D Map by querying in the Intelligence Application logical node (N8) shall be up to one or two hundred msec, ideally less than ten or twenty msec. Therefore, the PoC Team must measure these latencies during the PoC.

3.5.2. Required System Resources

Another important KPI is the amount of system resources, because it is desirable to build the system with less resources while meeting the throughput requirements. Therefore, the PoC Team must estimate the required resources of the production system by considering the resources used and the throughputs achieved in the PoC.

3.5.3. Energy Efficiency

The same applies to energy efficiency. Therefore, the PoC Team must estimate the energy consumption of the production system by considering the energy consumed and the throughputs achieved during the PoC.

3.6. Other Considerations

The PoC Reports should include considerations regarding the following items:

- Provide qualitative and quantitative analysis of IOWN technologies by comparing IOWN GF technologies with existing technologies.

- Provide qualitative and quantitative analysis of the IOWN GF implementation model(s) by comparing IOWN GF implementation models with the existing implementation model(s).

4. Summary

This document defines the PoC scopes to include critical parts of the AM-S RIM, which are PoC-1 for Sensor Data Aggregation and Ingestion (SDAI) and PoC-2 for Data Hub and Live 4D Map. In each PoC scope, selected features, advanced optional features and expected benchmark are explained. In the benchmarks, the key KPIs are defined, such as, latency, system resources and configuration, throughput, and energy efficiency.

IOWN GF is looking forward to receiving PoC Reports for this PoC Reference. The experiences in these reports will be reviewed and used to improve and guide the further development of the IOWN GF CPS Area Management Reference Implementation Model and related specifications of IOWN technologies.

Reference

[IOWN GF CPS UC]	IOWN Global Forum, “Cyber-Physical System Use Case Release-1,” 2021.
[IOWN GF AM-S RIM]	IOWN Global Forum, “Reference Implementation Model (RIM) for the Area Management Security Use Case,” 2022.
[IOWN GF RDMA over Open APN]	IOWN Global Forum, “RDMA over Open APN PoC Reference,” 2022.
[IOWN GF DCIaaS]	IOWN Global Forum, “Data-centric-infrastructure-as-a-service PoC Reference,” 2022.
[IOWN GF IDH FA]	IOWN Global Forum, “Data Hub Functional Architecture,” 2022.

Note: The above documents are available on https://iowngf.org/.

History

Revision	Release Date	Summary of Changes
1.0	August 29, 2022	Initial Release