Marketing Report

MR-436

Introduction to Automated Intelligent Management (AIM)

Issue: 1

Issue Date: August 2022

Revision History

Issue Number	Approval Date	Publication Date	Revision Editor	Changes
1	16 August 2022	16 August 2022	Ken Kerpez, DZS	Original

Comments or questions about this Broadband Forum Marketing Report should be directed to info@broadband-forum.org.

Editor Ken Kerpez, DZS

Work Area Director(s) Bruno Cornaglia, Vodafone

Mengmeng Li, China Mobile

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Executive Summary

The Broadband Forum has defined specification TR-436 [1], Access and Home Network O&M Automation and Intelligence, for Automated and Intelligent Management (AIM). TR-436 defines a framework that applies recent technology trends to enable data driven automation networks which includes:

1) Automatically identifying typical anomalies and faults appearing in the network segments involved in the E2E service delivery based on Machine Learning (ML), Artificial Intelligence (AI) algorithms and expert/cognitive experience that facilitate rapid troubleshooting, root-cause identification and autonomic behaviour thus reducing false alarms and improving the customer experience.

2) Perform predictive analysis based on ML and AI to achieve preventive Operations and Maintenance (O&M) and self-healing in case of failure.

This Marketing Report presents business motivations and then presents a brief overview of the AIM management architecture and interfaces.

1 Business Motivations

Over the past decade, growth in the Telco industry’s revenue has never outpaced growth in Operational Expense (OPEX). As the scale of a network increases, OPEX increases with it. Therefore, it is becoming vital to reduce OPEX. Moreover, for broadband services, most network trouble issues are driven by complaints, which challenges network operation efficiency. Furthermore, the O&M of Telco networks rely heavily on human experience and skills. For the maintenance of the same number of network devices, many more engineers and technicians are required in the Telco industry compared to the IT industry. For the workload of home and access networks, O&M occupies more than half of the entire workload of the High Speed Internet (HSI) E2E service O&M. Therefore, it is strongly recommended to manage access and home networks with automation and intelligence, to achieve higher O&M efficiency and lower OPEX. The main challenges and requirements needed to accomplish this recommendation are listed below:

- Maintenance efficiency requirements - Reducing the customer complaints and the work orders for on-site maintenance are the main factors to reduce OPEX.
- Network operation efficiency challenges - How to predict the network reliability and status; how to automatically operate the network using dynamically scalable controllers. Typical domains are:
    - Access: PON fault root cause analysis. The manual analysis typically used today causes difficulties in troubleshooting, and so automation and intelligence are needed.
    - In-home: Wi-Fi optimization to reduce interference. Interference is becoming the top problem in Wi-Fi deployment with un-licensed spectrum. Using automation and intelligence for selection of optimal resources (e.g., appropriate channel and bandwidth, band selection) can improve Wi-Fi performance.

  TR-436 was originally scoped to access and in-home networks, however, AIM also applies to additional domains.

    - Transport: Backhaul link failures or suboptimal performances that impact the customer service particularly with increasing packet loss, jitter, or latency.
    - Core and Peering: Suboptimal link termination due to issues appearing on a 3rd party network, capacity issues, fast and automated steering of traffic according to service objectives.
    - Content Distribution Networks (CDN): Poor E2E customer experience while watching a video or listening to music due to network buffering, or due to variations in network congestion in peak hours or planned and unplanned special media events, etc.

Meanwhile, recent technology trends enable data driven automation networks. Various means of data collection, such as telemetry, accelerate massive network operations. Some ongoing projects, e.g., ETSI ISG ENI [2], are working on a set of use cases and generic technology independent architectures, providing a means of big data analysis with AI. There are well-known SDN projects all over the world, most of which are designed for automation of network element installation, service delivery, and routing. But there are still gaps in automation of network planning, maintenance, and operations.

Automated and Intelligent Management (AIM) addresses the business drivers and technical readiness discussed above. TR-436 [1] defines a closed loop automation framework for E2E HSI service O&M based on data collection, big data analysis, decision making, and execution. The AIM framework adopts the concept of hierarchical closed loop described in ETSI GANA [5] and the concept of ML Pipeline described in ITU-T Y.3172 [6], combined with a Service Based Architecture (SBA) approach to further specify the pipeline components, their functions, and how they are orchestrated into a pipeline or a hierarchy of pipelines.

The following benefits are available from using AIM:

- For a service provider: provide high quality broadband to customer and reduce OPEX by proactively and autonomously fixing network issues. Measure the actual customer experience and how it evolves over time (customer experience accounting)
- For an equipment manufacturer: identify opportunities to provide better networking testing to enable end-to-end (E2E) network function and performance verification. Decouple O&M functionalities from the hardware to expose performance in the cloud and become hardware/vendor agnostic by adopting standard interfaces and data models
- For a component manufacturer: further improve the components according to new requirements and performance tests
- For a test company: certify devices, follow the test plan, and provide additional benefits. Improve their development processes by adopting a best-of-breed approach selecting each AIM component from the best supplier
- For a system integrator: provide a reference design/product to help operators improve the Quality of Experience (QoE) of customers
- For a customer: benefit from an improved overall E2E experience

The Broadband Forum's CloudCO demonstrations show how the AIM framework is applied to CloudCO by demonstrating monitoring and troubleshooting of the home network's Wi-Fi and the network connectivity for the subscriber's HSI service.

2 Automated Intelligent Management Architecture and Interfaces

Automated and Intelligent Management (AIM) empowers management and control functionalities and processes with automation capabilities based on intelligent decision making.

Figure 1 shows logical subsystems within the AIM architecture. The AIM architecture broadly aligns with ETSI NFV Management and Orchestration (MANO) and Broadband Forum Cloud CO. The standardized architecture shown here supports interoperability to maximize cross-industry fertilization and minimize costs.

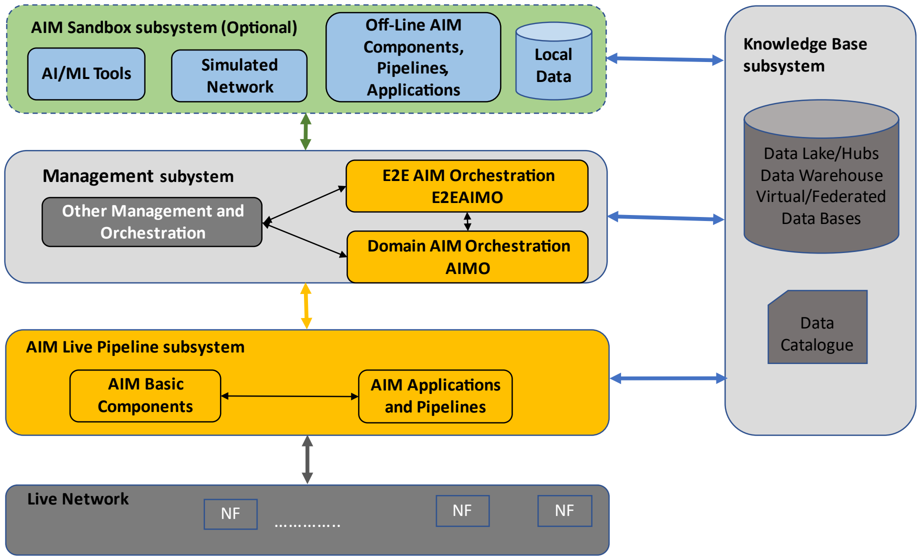

Figure 1: AIM Architecture Logical Subsystems

The AIM Sandbox is an optional subsystem. Model training, testing and evaluation are done in the AIM Sandbox logical subsystem independently (i.e., off-line) of the live network.

The Management subsystem contains the AIM Orchestrator (AIMO) which orchestrates AIM logical subsystems and the End-to-End AIM Orchestrator (E2EAIMO) which provides orchestration across AIM domains. The AIMO and/or the E2EAIMO oversees the instantiation of the AIM components, set-up of the AIM pipelines and run-time monitoring of the AIM applications.

An AIM Live Pipeline is deployed and running on an operator's environment within the operational infrastructure. It can span multiple domains to pinpoint the specific root cause of the issue affecting the E2E customer experience. Within the AIM live pipeline subsystem, an AIM application is a complete software application that may include a set of pipelines with all types of AIM basic components (SRC, CF, PPF, MF, PF, DF,SINK) or just few of them (e.g., SRC, MF, DF). By building hierarchical pipelines, even negative feedbacks from domain-specific control loops become valuable information to the holistic approach offered by the AIM framework.

The Knowledge Base (KB) logical subsystem is used for storing knowledge and data in various types of repositories and is accumulated over time. The KB is implemented according to each Operator's database integration strategy, it supports strong data governance mechanisms. The KB encompasses distributed data sources and other resources like data catalogs. The KB facilitates sharing of information among AIM Components and among Hierarchical control loops. This is particularly true when the control loops span across multiple federated domains.

The systematic architecture and repositories for AIM pipelines allow reusability and lower costs.

While the required capabilities and characteristics to be provided by the AIM framework are described in TR-436 [1], the logical building blocks of the AIM Framework are:

- Loop Automation
- Hierarchical Automated Loops
- Domain Federation
- AIM Degrees of Intelligence
- Information Models

The functional building blocks of the AIM Framework are:

- E2E AIM Orchestrator
- Domain AIM Orchestrator
  - Distribution Function
  - Policy Function
- Decision Element
  - Collection Function
  - Pre-processing Function
  - Model Function

The following sections briefly describe the logical and functional building blocks. Further details can be found in TR-436 [1].

2.1 Logical Building Blocks

2.1.1 Loop Automation

Loop automation is central for implementing Automated Intelligent Management (AIM). The concept of loop automation was originally advanced by the European Telecommunications Standards Institute (ETSI) Generic Autonomic Network Architecture (GANA) [2]-[5] and is now incorporated in AIM. Loop Automation (LA) operates on a logic involving one or more Managed Entities (MEs) and Decision Elements (DEs).

A **Managed Entity** is a managed resource or a set of managed resources, such as mechanisms hosted in a network element (NE).

A **Decision Element** is a logical component that implements decision-making capabilities via some degree of intelligence and reasoning over inputs mainly received from the associated Managed Entities (MEs). DEs can make use of information sources (data lakes, inventories) to enhance their decisions. A DE generates, as its main output, recommendations, that are either automatically converted into actions on the MEs (Closed Loop Automation) or supervised by a human for decision (Open Loop Automation). Closed loop automation is a very effective tool for minimizing OPEX.

The simplest example of an automated loop with one Managed Entity (ME) and one Decision Element (DE) is shown in Figure 2.

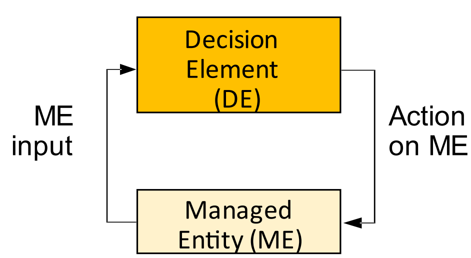

Figure 2: Simple Closed Loop Automation

The Decision Element (DE) can be realized with any number and combination of the AIM functional blocks Collection Function (CF), Pre-Processing Function (PPF) and Model Function (MF) chained together and orchestrated to form a pipeline. A DE includes at least one Model Function.

In a real-world network, automation is based on much more complex interactions and automated loops. Automated loops can operate among multiple DEs and MEs, can be nested, and organized hierarchically.

2.1.2 Hierarchical Automated Loops

While multiple functional blocks may be chained within a pipeline to create complex DEs, any pipeline that starts with a source of data (SRC) and ends with a target for its outcome (SINK) implements a control loop. Closed Loop Application (CLA) and/or Open Loop Application (OLA) may be implemented by a single control loop or by nested hierarchical control loops that may share their outcomes to implement a cognitive behaviour.

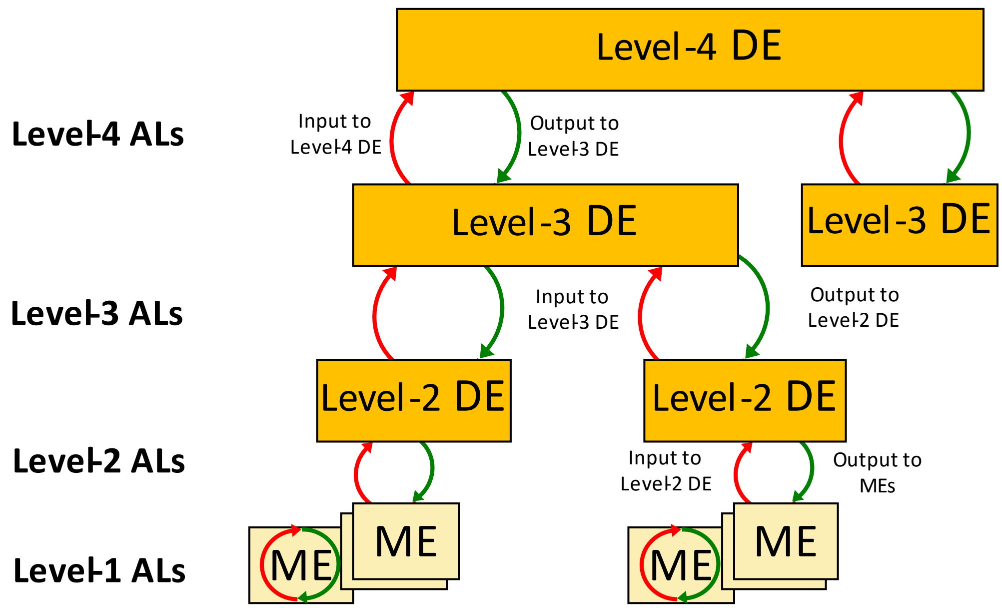

Figure 3: Hierarchical Automated Loops (ALs)

The Domain AIM Orchestrator (AIMO) orchestrates the nested control loops in the hierarchy. The AIM functional blocks are agnostic with respect to what control loop they belong to, and control loops are agnostic with respect to the CLA/OLA hierarchy they belong to.

2.1.3 Domain Federation

AIM domains are best defined as a grouping of AIM components under the same administrative and security control. The Operator may decide to organize its business and operational workflows based on network and technology domains (Access, Transport, Core etc.) and/or business domains (Sales, Assurance, Engineering etc.) or any other organizational structure they design for.

The concept of domain federation consists in the implementation of cross-domain interfaces between domain specific DEs (Dom1-DE and Dom2-DE in Figure 4) whereby the decision process of Dom1-DE is then based not only on the inputs from Dom1-MEs but also on inputs received from Dom2-DE and vice-versa. AIM implements domain federation via an orchestration element (the E2E-AIMO) hierarchically higher than Dom1-DE and Dom2-DE.

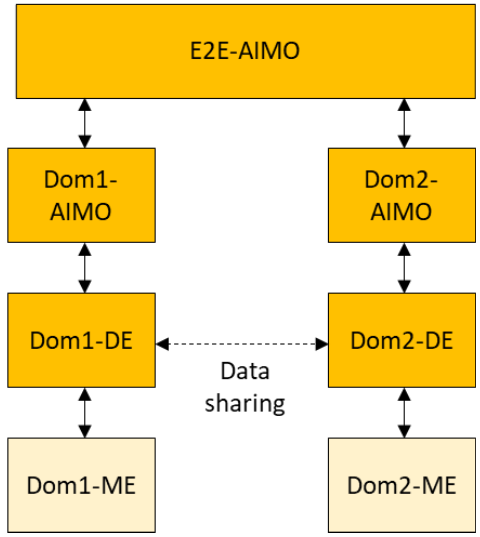

Figure 4: Domain Federation

2.1.4 AIM Degrees of Intelligence

With the advent of Artificial Intelligence (AI) and Machine Learning (ML) techniques, combined with easier access to considerable computational power, a strong focus is placed on applications with intelligent capabilities and fast decision-making that simulate human-like reasoning.

The AIM framework in TR-436 [1] encompasses various degrees of intelligence to help network operators and service providers operating and managing their network and services by enabling and improving automation, optimization, and rapid processes. AI/ML types include:

ML AI - Trained (supervised or unsupervised) rather than explicitly programmed rules and models. Rules and models are derived from the statistical structure of the training set. In case of deep learning, models are derived from a multi-layer representation of the training set.

Rule-based AI - Hardcoded rules crafted by programmers that do not involve any learning. Expert knowledge intelligence based on generally reusable solutions and actions in response to specific conditions or known and identified problems. Includes predefined logics (e.g., equational, semantic, syntactic) or constraints (physics, SLAs, etc.). Uses a sufficiently large set of explicit rules for manipulating knowledge.

The AIM framework supports DEs that implement ML AI or Rule-based AI or both.

2.1.5 Information Model

In order to create synergies and to make data available to be consumed within the same organization but also to be shared with business partners, the creation of a data catalog and common vocabulary for all the data hosted in various data stores becomes paramount. The AIM framework supports an information model based on such shared data catalogs and a common vocabulary.

The use of a common and shared information model introduces a reference standard to support heterogeneous IT landscapes and business definitions, in a logical way, that is based on inherent properties of the information itself rather than on any physical data storage structures.

2.2 Functional Building Blocks

The AIM pipeline is a set of the basic AIM components integrated by the chaining mechanism that enables the flow of information and control. An AIM pipeline containing all basic components is shown in Figure 5, but not all components need to be included. The Source and SINK may be the same single ME or may involve multiple entities.

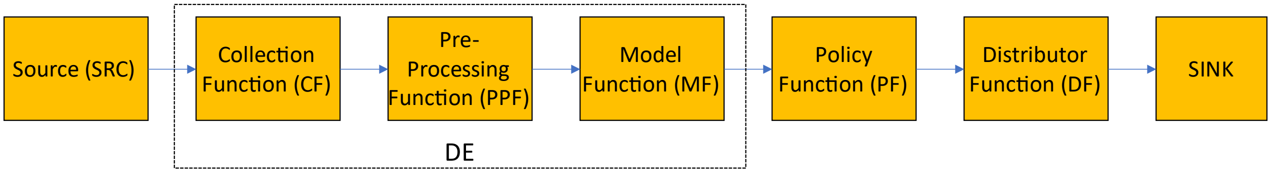

Figure 5: AIM pipeline

Table 1 briefly describes the AIM functional components and their functions. Further details can be found in TR-436 [1].

Table 1: Functional AIM Components

Collection Function (CF)	A CF is responsible for collecting data from one or more SRC logical nodes. A CF may have the capability to configure SRC logical nodes. For example, a CF may be used to control the nature of data, its granularity and periodicity from the SRC.
Pre-processing Function (PPF)	A PPF is responsible for cleaning data, aggregating data or performing any other pre-processing needed for the data to be in a suitable form so that the AIM Model Function can consume it.
Model Function (MF)	An MF is a model, in a form which is usable in an AIM Live Pipeline.
Policy Function (PF)	A PF enables the application of policies to the output of the MF node. This node can be used to monitor model performances. Moreover, this node may govern the impact of the output to a live operational environment or to other systems thanks to specific rules that can be put in place by a network operator.
Distributor Function (DF)	A DF is responsible for identifying the SINK(s) and distributing the output of the MF and PF nodes to the corresponding SINK nodes. It may have the capability to configure SINK nodes.
Domain AIMO	The Domain AIMO implements the DF and PF functions. Its main responsibility is to orchestrate the CF, PPF and MF components into a pipeline. It also delivers the necessary Service Abstraction Layer, hiding the internal operations of the AIM from the NBI.
E2E AIMO	The E2E AIMO resolves multiple accesses to the AIM resources including the sharing of information by granting applications access to the Knowledge Base (KB). The scope spans across multiple AIM Domains. Its function is key to providing home to the AIM NBI towards the customer management layer, and as such, in collaboration with the Domain AIMO, it delivers the necessary multi-domain Service Abstraction Layer, hiding the internal operations of the AIM from the NBI.

The operation of the AIM Framework can be very briefly summarized: the Domain AIMO receives a declarative intent from the E2E AIMO and creates an AIM pipeline that conforms to the specification and requirements of an AIM order sent to the E2E AIMO by the customer management layer application. A pipeline is realized by instantiating AIM components (e.g., CF, PPF, MF) and its source and target (SRC, SINK) and taking into account the requirements/attributes of the intent and the capabilities of the underlying infrastructures. The Domain AIMO allows flexible placement, distribution, chaining, and execution of its components to facilitate the implementation of complex AIM Pipelines.

2.3 AIM Interfaces

WT-486 is currently being written to specify the AIM interfaces described in TR-436 [1], their functions and Data Models (DM) that allow the interactions between the AIM components and subsystems. WT-486 follows the Service Based Architecture (SBA) principles, that define what services and DMs are exposed, and what protocol requirements are supported by the specific AIM component.

WT-486 adopts interface specifications published by the Broadband Forum and other Standards Development Organizations. WT-486 addresses both NETCONF/YANG interfaces (defined in referenced Broadband Forum TRs) and several other protocols in order to cover traditional FCAPS functions and also management functions for the orchestration of AIM Pipelines and integration among AIM logical subsystems.

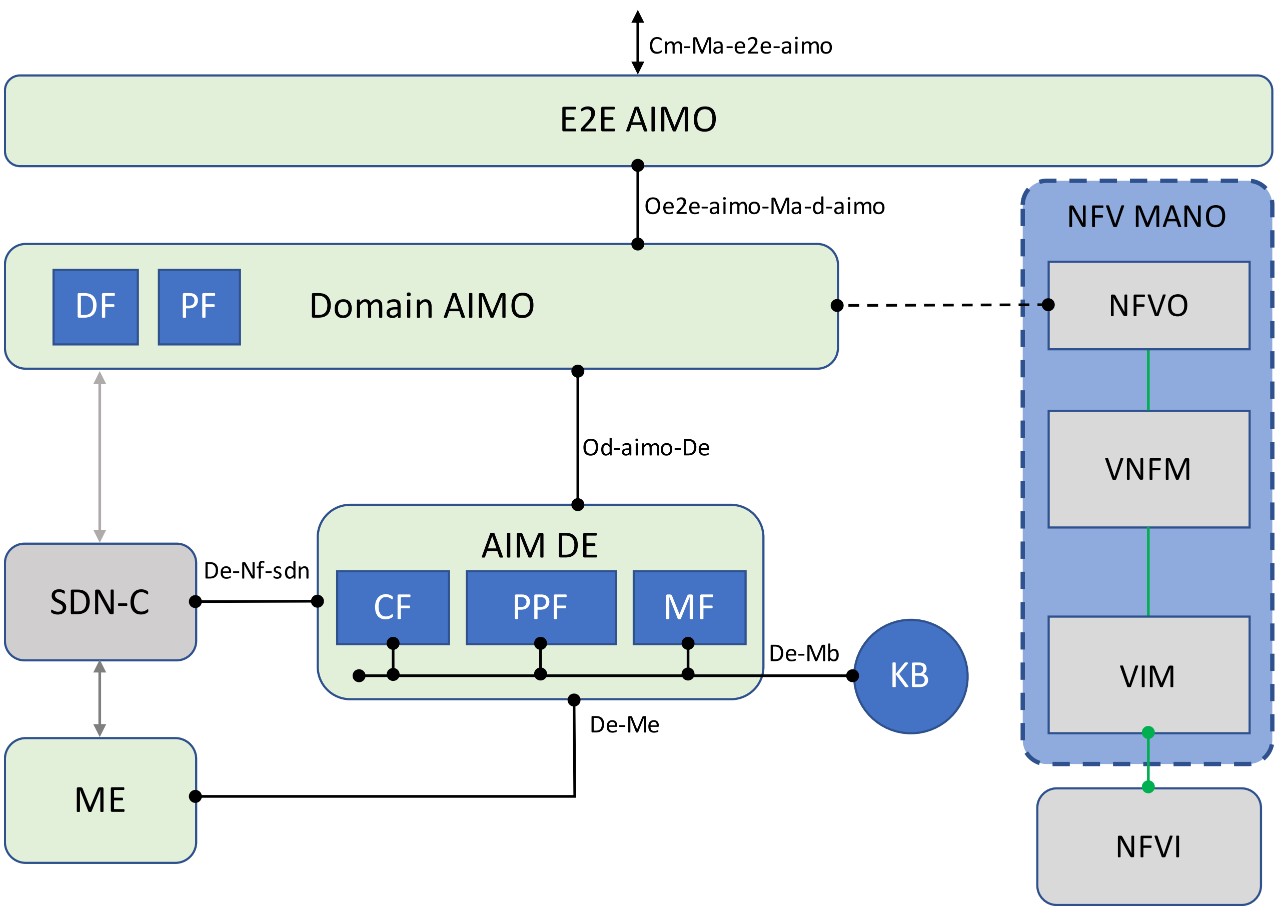

Figure 6: AIM Interfaces

Figure 6 shows AIM components or functional blocks and the interfaces between them, where the light green boxes denote AIM-specific components. As shown in Figure 6, the AIM solution relies on the NFV infrastructure and ETSI NFV MANO components that enable flexibility and scalability in the lifecycle and consumption of AIM components and pipelines. The SDN Controller (SDN-C) controls the physical infrastructure as well as all associated virtual/physical functions (PNF/VNF). Interfaces are:

- **Cm-Ma-e2e-aimo**: located between the Customer Management Layer and the AIM E2E Orchestrator; allows an abstracted view of the AIM Domain resources to the Customer Management layer.
- **Oe2e-aimo-Ma-d-aimo:** located between the E2EAIMO and the AIMO, allows an abstracted view of the AIM Domain resources to the E2EAIMO.
- **Od-aimo-De:** the interface for the AIMO to configure, manage and orchestrate the AIM functional blocks.
- **De-Nf-sdn:** the reference point for the AIM DE to interact with the SDN-C. Recommendations from the AIM DE are generally sent to the SDN-C, then to the Managed Entity.
- **De-Me:** the reference point for the collection function of the AIM DE to collect data from the Managed Entities (ME).
- **De-Mb:** is the reference point to exchange information between DEs, between components within a DE and with the Knowledge Base.

The interfaces denoted in Figure 6, and the information models for these interfaces, are currently being defined in WT-486. WT-486 also defines component functionality and management capabilities. The actual interface data models and messaging should be specified in WT-486 in the future. Standardized AIM interfaces engender an interoperable ecosystem that enhances the usability and industry growth of AIM.

3 Terminology

3.1 References

The following references are of relevance to this Marketing Report. At the time of publication, the editions indicated were valid. All references are subject to revision; users of this Marketing Report are therefore encouraged to investigate the possibility of applying the most recent edition of the references listed below.

A list of currently valid Broadband Forum Technical Reports is published at www.broadband-forum.org.

Document		Title	Source	Year
[1]	TR-436	Access & Home Network O&M Automation/Intelligence	Broadband Forum	2021
[2]	GS ENI 005 V1.1.1	Experiential Networked Intelligence (ENI);System Architecture	ETSI	2019
[3]	TR 103 473 v1.1	Autonomicity and Self-Management in the Broadband Forum (BBF) Architectures	ETSI	2018
[4]	TS 103 195-2 (v1.1.1)	Autonomic network engineering for the self-managing Future Internet (AFI); Generic Autonomic Network Architecture; Part 2: An Architectural Reference Model for Autonomic Networking, Cognitive Networking and Self-Management	ETSI	2013

[5]	White Paper No 16	GANA - Generic Autonomic Networking Architecture – Reference Model for Autonomic Networking, Cognitive Networking and Self-Management of Networks and Services	ETSI	2016
[6]	Y.3172	Architectural framework for machine learning (ML) in future networks including IMT-2020.	ITU-T	2019

3.2 Definitions

The following terminology is used throughout this Marketing Report.

Term	Definition
AI	Artificial Intelligence
AIM	Automated and Intelligent Management
AIMO	Automated and Intelligent Management Orchestrator
AL	Automated Loop
CDN	Content Distribution Network
CF	Collection Function
CLA	Closed Loop Automation
DE	Decision Element
DF	Distributor Function
DL	Deep Learning
DM	Data Model
E2E	End to End
ETSI	European Telecommunications Standards Institute
FCAPS	Fault, Configuration, Accounting, Performance, Security
GANA	Generic Autonomic Network Architecture
HSI	High Speed Internet
MANO	Management and Orchestration
MDU	Multiple Dwelling Unit
ME	Managed Entity
MF	Model Function
ML	Machine Learning
MR	Marketing Report
NBI	Northbound Interface
NE	Network Element

NF	Network Function
NFV	Network Functions Virtualization
NFVI	Network Function Virtualization Infrastructure
NFVO	Network Function Virtualization Orchestrator
O&M	Operations and Maintenance
OLA	Open Loop Automation
ONU	Optical Network Unit
OPEX	Operational Expense
PF	Policy Function
PNF	Physical Network Function
PON	Passive Optical Network
PPF	Pre-processing Function
QoE	Quality of Experience
SBA	Service Based Architecture
SDN	Software Defined Network
SDN-C	Software Defined Network Controller
VIM	Virtual Infrastructure Manager
VNF	Virtual Network Function
VNFM	VNF Manager
WLAN	Wireless Local Area Network.

End of Broadband Forum Marketing Report MR-436