

IEEE Standard for Edge/Fog Manageability and Orchestration

IEEE Communications Society

Developed by the
Edge, Fog, Cloud Communications with IOT and Big
Data Standards Committee

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STANDARDS

IEEE Standard for Edge/Fog Manageability and Orchestration

Developed by the

Edge, Fog, Cloud Communications with IOT and Big Data Standards Committee
of the
IEEE Communications Society

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Abstract: With the innovation of mobile applications and the arrival of the fifth generation of telecommunication, edge computing has become a popular scheme due to its geographical proximity to end users. The overall architecture has the advantage of lower latency and improved user experience. However, because of physical limitations, management and orchestration in the edge system is necessary to maintain operations, common functions, and application lifecycle. Accordingly, a standardized, orchestration-wise design to simplify the process and offer better system performance and user experience was introduced by the IEEE P1935 working group. The framework, architecture, and procedures of the edge/fog system as well as its application lifecycle management are involved in this standard.

Keywords: edge computing, IEEE 1935, management and orchestration

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Introduction

This introduction is not part of IEEE Std 1935-2023, IEEE Standard for Edge/Fog Manageability and Orchestration.

With the innovation of mobile applications and the arrival of the fifth generation of telecommunication, edge computing has become a popular scheme due to its geographical proximity to end users. The overall architecture has the advantage of lower latency and better user experience. However, because of physical limitations, management and orchestration in the edge system is necessary in order to maintain operations, common functions, and application lifecycle. Accordingly, the IEEE P1935 working group introduced a standardized, orchestration-wise design to simplify the process and offer better system performance and user experience. This standard involves the framework, architecture, and procedures of the edge/fog system as well as its application lifecycle management.

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IEEE Standard for Edge/Fog Manageability and Orchestration

1. Overview

1.1 Scope

This standard specifies management and orchestration framework and mechanisms for edge/fog computing systems. It describes the edge/fog platform management procedures and edge/fog application management procedures.

1.2 Word usage

The word *shall* indicates mandatory requirements strictly to be followed in order to conform to the standard and from which no deviation is permitted (*shall equals is required to*).^{6,7}

The word *should* indicates that among several possibilities one is recommended as particularly suitable, without mentioning or excluding others; or that a certain course of action is preferred but not necessarily required (*should equals is recommended that*).

The word *may* is used to indicate a course of action permissible within the limits of the standard (*may equals is permitted to*).

The word *can* is used for statements of possibility and capability, whether material, physical, or causal (*can equals is able to*).

1.3 Introduction

Edge computing is an emerging technology that can host the mobile applications closer to its users, provides lower latency, more efficient bandwidth and service delivery, as well as better user experience quality. Innovative mobile applications, such as augmented reality, facial detection, and interactive applications, evolve with mobile devices and attract great attention due to their ability to bring convenience and spice up people's lives. With a core concept similar to edge computing's placing the computing capacity at the local area network, fog computing is more often used in industrial internet of things (IIoT) scenarios. Edge/fog computing is a brand-new and promising paradigm offering an environment characterized by low latency and necessary resources for mobile devices to liberate them from computing-intensive and real-time applications.

⁶The use of the word *must* is deprecated and cannot be used when stating mandatory requirements; *must* is used only to describe unavoidable situations.

⁷The use of *will* is deprecated and cannot be used when stating mandatory requirements; *will* is only used in statements of fact.

Although edge devices are closer to their users to provide the advantages described above, their reduced capacities of computation and storage compared to cloud computing is a fatal issue in practice. Edge/fog systems are responsible for maintaining common operations, handling application lifecycle, providing a corresponding environment for mobile services, performing storage and traffic control, and supporting service mobility. To meet these requirements, the management and orchestration of the edge/fog computing system become key topics in modern scenarios of networking and service delivery, aiming to leverage constrained resources more efficiently and coordinately.

The management and orchestration mentioned in this standard indicate the manual and automated configuration, control, and coordination of the edge/fog system and its services. The unified management and orchestration—such as regulating message transmission, controlling and allocating resources of the edge devices, and monitoring and arranging the mobile application lifecycle—can satisfy the mentioned needs and ensure better availability, flexibility, reliability, scalability, stability, service mobility, and performance. It means that the system shall be easy for multiple types of users to operate and configure, reliable while facing different challenges, and as efficient as possible. The edge/fog system—especially the orchestrator level in the three-level architecture that will be explained in later clauses—contains multiple entities and components responsible for executing the related management mechanism and coordinating the interaction among them. With a comprehensive management and orchestration scheme on top of it, the edge/fog system can handle multiple edge applications with various customers and scenarios.

To achieve the flexibility, scalability, security, and ability to manage its services and resources, it is necessary for an edge/fog system to follow the related specification consistently. Aside from the regular concepts and requirements, the edge/fog system and its components, as well as the management and orchestration designs, need to fulfill the demands and requirements listed below to achieve practicality:

- a) It shall be possible to deploy the edge/fog system in various positions in the wired, wireless, and mobile network, as well as the data center of the edge service operators and edge service providers.
- b) It shall be possible to deploy the components, including the edge/fog orchestrator (EFO), edge/fog control nodes, and edge/fog compute nodes, on the various hardware devices.
- c) The edge/fog system shall fit in and communicate with the wireless communication network, dealing with the corresponding traffic routing to the correct components.
- d) The edge/fog system shall be able to provide edge services and edge applications, as well as the corresponding environment for them.
- e) The edge/fog system shall support the communications between the components and edge services and edge applications if authorized. This may include the different applications on different edge/fog compute nodes.
- f) The edge/fog system shall support the full lifecycle and related operations of edge applications, such as hosting, onboarding, instantiation, operating, and termination.
- g) The edge/fog system shall support edge service operators to manually and dynamically access the edge services and edge applications on their needs.
- h) The edge/fog system shall be able to decide the service homing.
- i) The edge/fog system shall support the compatibility with the authorized third-party entities, including processing the corresponding requests.
- j) It shall be possible to deploy edge applications on different edge/fog compute nodes without specific arrangement.
- k) The edge/fog system shall be able to authorize and authenticate the user requests about the edge applications.

- l) The edge/fog system shall support the service mobility, that is, keeping connectivity while the user equipment (UE) is moving from the coverage of one edge/fog control node to another.
- m) The edge/fog system shall utilize the related network information to improve its own performance in various matrices.
- n) The edge/fog system shall support the edge service to declare its own availability during service discovery.
- o) The edge/fog compute nodes shall be able to provide computing, networking, and storage resources.

This standard specifies the related components, requirements, procedures, and other necessary parts of management and orchestration in the edge/fog system. The following clauses illustrate and describe these specifications in detail. The framework and elements of the edge/fog system, as well as their functionalities and communication, are introduced in [Clause 3](#). The ways to manage and orchestrate the platforms and related resources in edge/fog system are explained in [Clause 4](#). The procedures and necessary formal files involved in launching and deploying the services and applications on the edge/fog system are elaborated in [Clause 5](#). The concept of communication among multiple edge/fog systems are described in [Clause 6](#).

2. Definitions, acronyms, and abbreviations

2.1 Definitions

For the purposes of this document, the following terms and definitions apply. The IEEE Standards Dictionary Online should be consulted for terms not defined in this clause.⁸

application context: Application context, or simply *context*, involves all the files that contain the custom information operators need, such as user information and statistical data.

application management element: The entity managing and coordinating the operation of edge applications, such as edge platform.

application package: One of the files that is involved in the application onboarding procedures. The application package is hierarchical, containing the necessary data and information of the application and its components, like virtual function (VF) images. An application package can be considered an installation file that will be deployed to a compute node to launch a specific edge application.

artifact: All the files that are generated by the edge app designer component and are distributed to the other components in the edge/fog orchestrator (EFO). They are the descriptor files for the components in the EFO.

attribute: The additional information of the resource.

blueprint file: A file that includes the orchestration rules, resource lifecycle management designs, etc. This file is used to configure the components in the edge/fog orchestrator (EFO).

compute node: One entity in the computer level that can handle the computing tasks on its own.

computer level: the bottom layer of the edge system that is composed of one or more compute nodes dealing with the computing tasks.

context: *See:* **application context**.

⁸IEEE Standards Dictionary Online is available at: <http://dictionary.ieee.org>. An IEEE account is required for access to the dictionary, and one can be created at no charge on the dictionary sign-in page.

controller level: The middle layer of the edge system that is composed of one or more control nodes responsible for management and coordination of computer level.

control node: One entity in the controller level for management of the related compute nodes.

data plane: The functional entity that handles the traffic routes.

edge app: The applications running on the edge system.

edge app designer: A component in the edge/fog orchestrator (EFO) handling the application design and onboarding.

edge inventory manager: A component in the edge/fog orchestrator (EFO) for the management of the inventory in the edge system.

edge platform manager: An entity managing the edge platform.

edge platform: A platform that handles purposed computing tasks.

edge resource: The resources created in the edge system. This resource can be further sliced as the resource quota.

edge service operator: The service operator dealing with the management and operation of edge applications.

edge service provider: The designer and onboarder of edge applications.

edge/fog orchestrator (EFO): An orchestrator of the whole edge system. *Syn:* **edge orchestrator**.

EFO controllers: The components in the edge/fog orchestrator (EFO) responsible for coordinating and configuration of virtual network functions and related resources.

end user app: An interface for all end users.

end user proxy: A component in the edge/fog orchestrator (EFO) as an interface between the EFO and the end user app.

end users: All users that access the edge/fog orchestrator (EFO) via the end user apps.

external API: In the edge/fog orchestrator (EFO), it is provided for the edge service operators or other entities to access the functionalities of the EFO.

filtering rule: The restrictions and conditions to narrow down the search results.

infrastructure manager (IM): *See:* **virtualization infrastructure manager**.

inventory: The network information, topology, and metadata that are about the edge system environment and are stored in the edge inventory manager component.

lifecycle manager enabler: A component in the edge/fog orchestrator (EFO) that is responsible for the management of the application lifecycle.

manifest file: The files used in the application onboarding procedures containing an application package and a blueprint file.

network infrastructure: *See:* **virtual network infrastructure.**

orchestrator level: The top layer of the edge system for management and orchestration of the whole system, including controller level and computer level.

physical resource: The physical hardware of the edge system, for example, the physical servers.

property: The characteristics of the resource.

resource configuration: A part at the end of the resource creation operation.

resource creation: The operation used to create new resources in the edge system.

resource deletion: The operation used to delete resources in the edge system.

resource discovery: The operation used to search and return the list of resources matching the filtering rules.

resource management element: The entity managing the resources in the edge system, such as infrastructure manager/virtualization infrastructure manager (IM/VIM).

resource quota: After resource creation, the edge resources will be created and configured. In the configuration process or the resource reconfiguration operation later, the edge resource can be sliced into resource quota.

resource reconfiguration: The operation used to modify the information of resources. There are two types of this operation: resource replacement and resource update.

resource replacement: One of two types of modification operation that replaces whole information of the resource.

resource status query: The operation used to get the current information of the target resource.

resource update: One of two types of modification operation that only updates partial information of the resource.

resource URL (uniform resource locator): The unique addresses of the resources for the edge system to locate.

resource: The physical and virtual assets that can be leveraged by the edge system.

rule framework: A component in the edge/fog orchestrator (EFO) dealing with all conditions, requirements, and reaction policies.

VF (virtual function) image: The virtual functions providing an executing environment for the edge application. An application package is composed of one or more virtual functions called *VF images*.

virtual function management and orchestration (VF M&O): A component in the edge/fog orchestrator (EFO) responsible for the start-up and operation of the application.

virtual network infrastructure (VNI): The virtualized and non-virtualized resources that enable network operations.

virtual resource: The non-physical resources in the edge system, including computing resources, networking resources, storage resources, etc.

virtualization infrastructure manager (VIM): An entity managing the infrastructure resources named virtual network infrastructure that can be virtualized or non-virtualized.

2.2 Acronyms and abbreviations

AAA	authentication, authorization, and accounting
AME	application management element
CID	connectivity/interoperability domain
EAD	edge app designer
EFO	edge/fog orchestrator
EIM	edge inventory manager
EUA	end user application
EUP	end user proxy
IM	infrastructure manager
LCM	lifecycle manager
RME	resource management element
SAD	service and application domain
SLA	service level agreement
URL	uniform resource locator
VF	virtual function
VF M&O	virtual function management and orchestration
VIM	virtualization infrastructure manager
VNI	virtual network infrastructure
VNF	virtual network function

3. Architecture and framework for edge/fog manageability and orchestration

3.1 Introduction

In the edge/fog system, there are three levels responsible for different functionality and various entities in each level. This clause describes the overall edge/fog architecture and the responsibility of each entity and component. The interfaces between each entity are presented as well.

3.2 Edge/fog manageability and orchestration framework overview

Figure 1 is the basic architecture of the edge/fog system framework. The term *framework* here refers to the full architecture of the system and the components and entities in it. The entities refer to the elements, either inside the system or outside the system (e.g., some third-party software), and may be composed of one or more components. The system can be classified into three levels: orchestrator level, controller level, and computer level, and the more detailed information of the components introduced here can be found in 3.3. The orchestrator level includes the edge/fog orchestrator (EFO) as the main management and orchestration entity, and it is responsible for interacting with “users,” that is, end users, edge service providers, and edge service operators. The end users can call all the users accessing the system via the end user app, which is another entity in the edge/fog system. The edge service providers are the designers and onboarders of edge applications. The

edge service operators provide the edge/fog system functionalities and infrastructures and are responsible for managing and operating these applications properly. The controller level may include one or more edge/fog control nodes, which oversee the edge/fog compute nodes and manages the related resources. The edge platform manager and the (virtualization) infrastructure manager are at this level. The computer level may include one or more edge/fog compute nodes as well, which are responsible for the practical computing tasks. The edge platform, the edge application, and the (virtual) network infrastructure are at this level. The edge/fog compute nodes, as the most common and the most widely distributed entity in the system, can also be called *edge nodes* as an abbreviation.⁹ All these entities and components will be described in detail in the following clauses.

Table 1 gives some brief descriptions and the related clause to each entity mentioned in Figure 1, as well as the terms used in Clause 3.

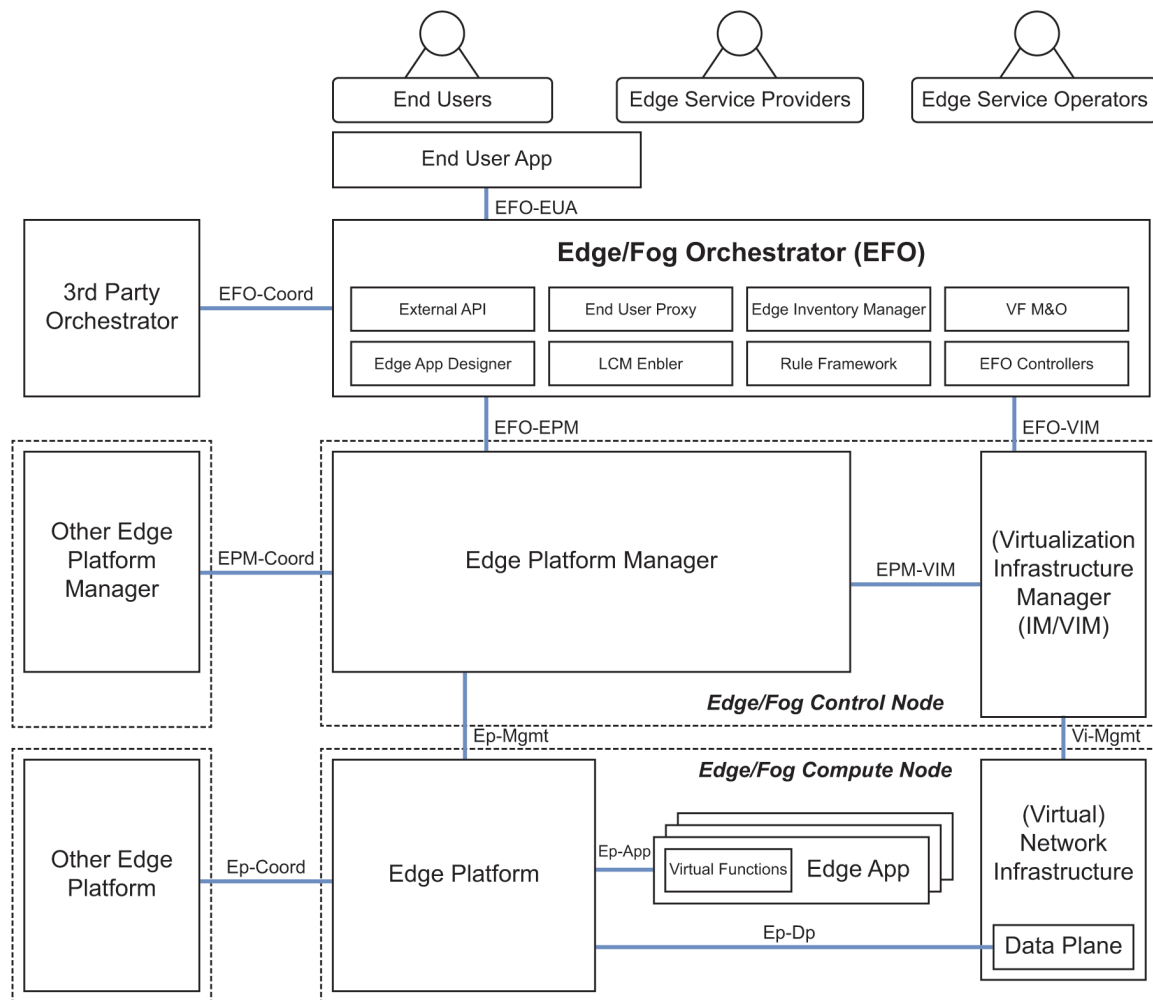


Figure 1—The basic architecture of the edge/fog system framework

⁹For ease of reading and description, we abbreviate the term *edge/fog* to *edge* in the remaining clauses of this standard. These terms refer to completely the same things. For example, an *edge/fog control node* can also be written as an *edge control node*.