Draft new Recommendation ITU-T Y.3552 (formerly Y.ecloud-reqts)

Cloud computing - Functional requirements of edge cloud

Summary

Edge cloud is defined in ITU-T Recommendation Y.3508 as cloud computing deployed to the edge of the network accessed by cloud service customers (CSCs) with small capacity resources enabling cloud service. In the edge cloud, the cloud service is provided in the form of lightweight cloud service by CSP. Lightweight cloud service refers to a portion of cloud service to reconfigure the functionality of cloud service to fit on edge cloud such as base station and gateway with small capacity resources. This Recommendation provides the overview of edge cloud, logical components, capabilities for lightweight cloud service and functional requirements of edge cloud through various use cases.

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Keywords

cloud computing, distributed cloud, edge cloud, lightweight cloud service

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II.4 Cloud gaming scaling among edge clouds 24

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Cloud computing - Functional requirements of edge cloud

1 Scope

This Recommendation provides functional requirements of edge cloud. Edge cloud is a cloud computing deployed to the edge of the network. It has small capacity resources enabling cloud service. It addresses the following subjects:

- Overview of edge cloud;
- Logical components of edge cloud;
- Capabilities to support lightweight cloud service;
- Functional requirements of edge cloud;
- Use cases of edge cloud.

2 References

The following ITU-T Recommendations and other references contain provisions, which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published.

The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

[ITU-T Y.3500] Recommendation ITU-T Y.3500 (2014), *Information technology – Cloud computing – Overview and vocabulary*.

[ITU-T Y.3502] Recommendation ITU-T Y.3502 (2014), *Information technology – Cloud computing – Reference architecture*.

[ITU-T Y.3508] Recommendation ITU-T Y.3508 (2018), *Cloud Computing – Overview and high-level requirements of distributed cloud*.

[ITU-T Y.3510] Recommendation ITU-T Y.3510 (2016), *Cloud Computing infrastructure requirements.*

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 cloud computing [ITU-T Y.3500]: Paradigm for enabling network access to a scalable and elastic pool of shareable physical or virtual resources with self-service provisioning and administration on-demand.

NOTE – Examples of resources include servers, operating systems, networks, software, applications and storage equipment.

3.1.2 cloud service [ITU-T Y.3500]: One or more capabilities offered via cloud computing invoked using a defined interface.

3.1.3 cloud service category [ITU-T Y.3500]: Group of cloud services that possess some common set of qualities.

3.1.4 cloud service customer [ITU-T Y.3500**]**: Party which is in a business relationship for the purpose of using cloud services.

NOTE – A business relationship does not necessarily imply financial agreements.

3.1.5 cloud service partner [ITU-T Y.3500**]**: Party which is engaged in support of, or auxiliary to, activities of either the cloud service provider or the cloud service customer, or both.

3.1.6 cloud service provider [ITU-T Y.3500**]**: Party which makes cloud services available.

3.1.7 core cloud [ITU-T Y.3508**]**: A cloud computing, which manages resource pools including resources in the edge of the network and enables cloud service.

NOTE – Enabled cloud service on the core cloud is provided by a cloud service provider (CSP).

3.1.8 distributed cloud [ITU-T Y.3508**]**: Distribution of cloud capabilities types to the edge of the network for enabling cloud services with low latency and real time processing on limited bandwidth by interworking among pools of physical or virtual resources.

3.1.9 edge cloud [ITU-T Y.3508**]**: A cloud computing deployed to the edge of the network accessed by cloud service customers (CSCs) with small capacity resources enabling cloud service.

NOTE 1 – Enabled cloud service on the edge cloud is lightweight cloud service provided by a cloud service provider (CSP) depending on cloud service category.

3.1.10 hypervisor [ITU-T Y.3510**]**: A type of system software that allows multiple operating systems to share a single hardware host.

NOTE – Each operating system appears to have the host's processor, memory and other resources, all to itself.

3.1.11 physical resource [b-ITU-T Y.3100]: A physical asset for computation, storage and/or networking.

NOTE – Components, systems and equipment can be regarded as physical resources.

3.1.12 regional cloud [ITU-T Y.3508**]**: A cloud computing hosted from core cloud to particular geographical regions.

NOTE – Enabled cloud service on the regional cloud is entire or partial cloud service of core cloud provided by a cloud service provider (CSP).

3.2 Terms defined in this Recommendation

3.2.1 edge device: A piece of hardware located at the edge of the network, providing physical resources for edge cloud.

NOTE – Hardware includes computing units (CPUs, memory, GPUs), storage devices (SSDs, hard disks), network equipment (routers, switches) and other physical computing components.

3.2.2 lightweight cloud service: a portion of cloud service to reconfigure the functionality of cloud service to fit on edge cloud.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

ASIC Application Specific Integrated Circuit

CC Core Cloud

CSC Cloud Service Customer

CSP Cloud Service Provider

FPGA	Field Programmable Gate Array
HDD	Hard Disk Drive
I/O	Input/Output
OS	Operating System
PC	Personal Computer
RAM	Random Access Memory
RC	Regional Cloud
SSD	Solid State Drive
vCPU	virtual Central Processing Unit
vGPU	virtual Graphic Processing Unit
VM	Virtual Machine

5 Conventions

The keywords "**is required to**" indicate a requirement which must be strictly followed and from which no deviation is permitted if conformance to this document is to be claimed.

The keywords "**is recommended**" indicate a requirement which is recommended but which is not absolutely required. Thus, this requirement need not be present to claim conformance.

6 Overview of edge cloud

An edge cloud is a cloud computing deployed to the edge of the network accessed by cloud service customers (CSCs) with small capacity resources enabling cloud service. The edge cloud requires specialized hardware resources on purpose; i.e., the resources in the edge cloud are constrained due to limitations of space or power. The edge cloud has different configurations of resources and cloud capabilities types with physical and virtual resources depending on a CSC's requirements of cloud services and conditions in the deployment environment. [ITU-T Y.3508]

The edge cloud has limited resources compared to the core cloud or the regional cloud. But the edge cloud provides lower latency, which is essential for real-time services such as autonomous vehicles, augmented and virtual reality experiences, and live streaming services. And the edge cloud processes data at the edge of network, minimizing the risk of data interception during transmission to the core cloud. The edge cloud reduces the potential threats from data transmission across the networks. On the other hand, security for data storage may be more vulnerable than core cloud.

To overcome the resource constraints in edge cloud, the lightweight cloud service is used in edge cloud. The lightweight cloud service is a portion of cloud service to reconfigure the functionality of cloud service to fit on edge cloud such as base station and gateway with small capacity resource.

The distributed cloud includes core, regional and edge clouds, which meet the cloud capabilities types described in [ITU-T Y.3500]. Cloud services are deployed to the core, regional and edge clouds, interwork with one another, and provide a single system view to the CSCs for location transparency [ITU-T Y.3508]. The distributed cloud is categorized into three distributed cloud models. The edge cloud is provided in distributed cloud model 2 and model 3 as shown Figure 6-1 and Figure 6-2.

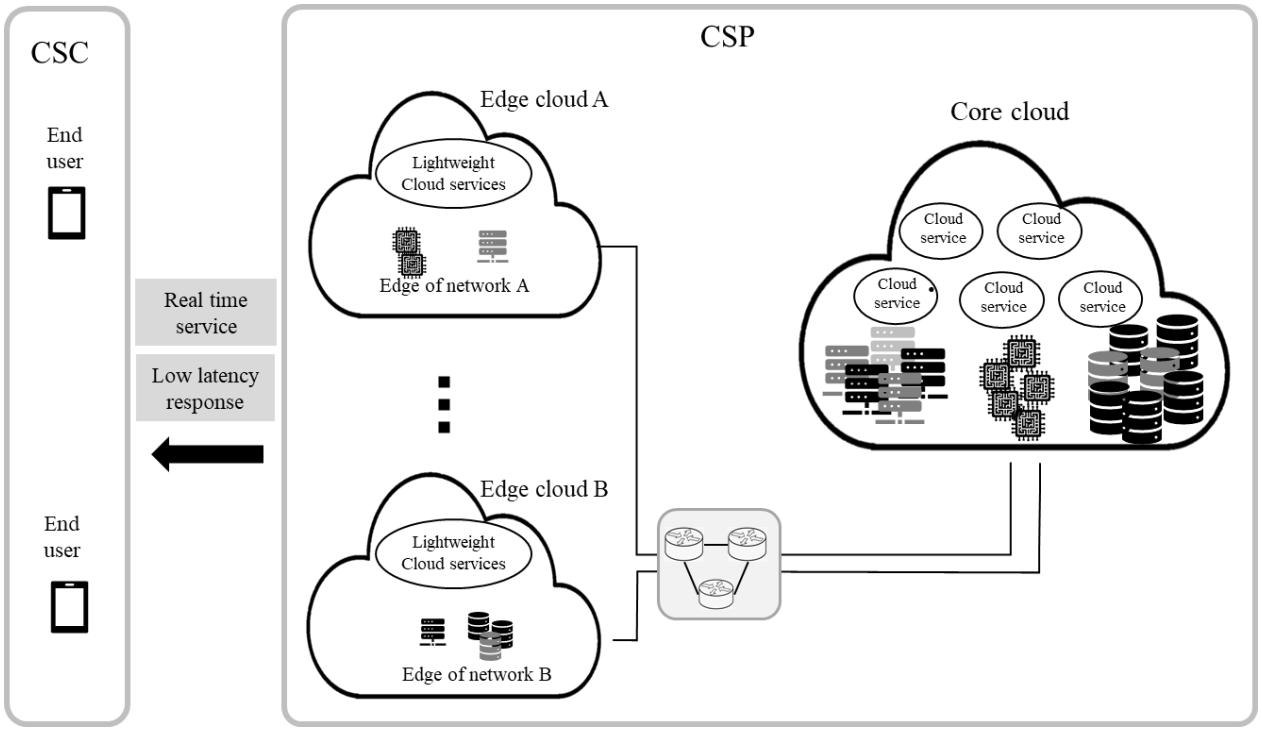


Figure 6-1 – General configuration of edge cloud in distributed model 2

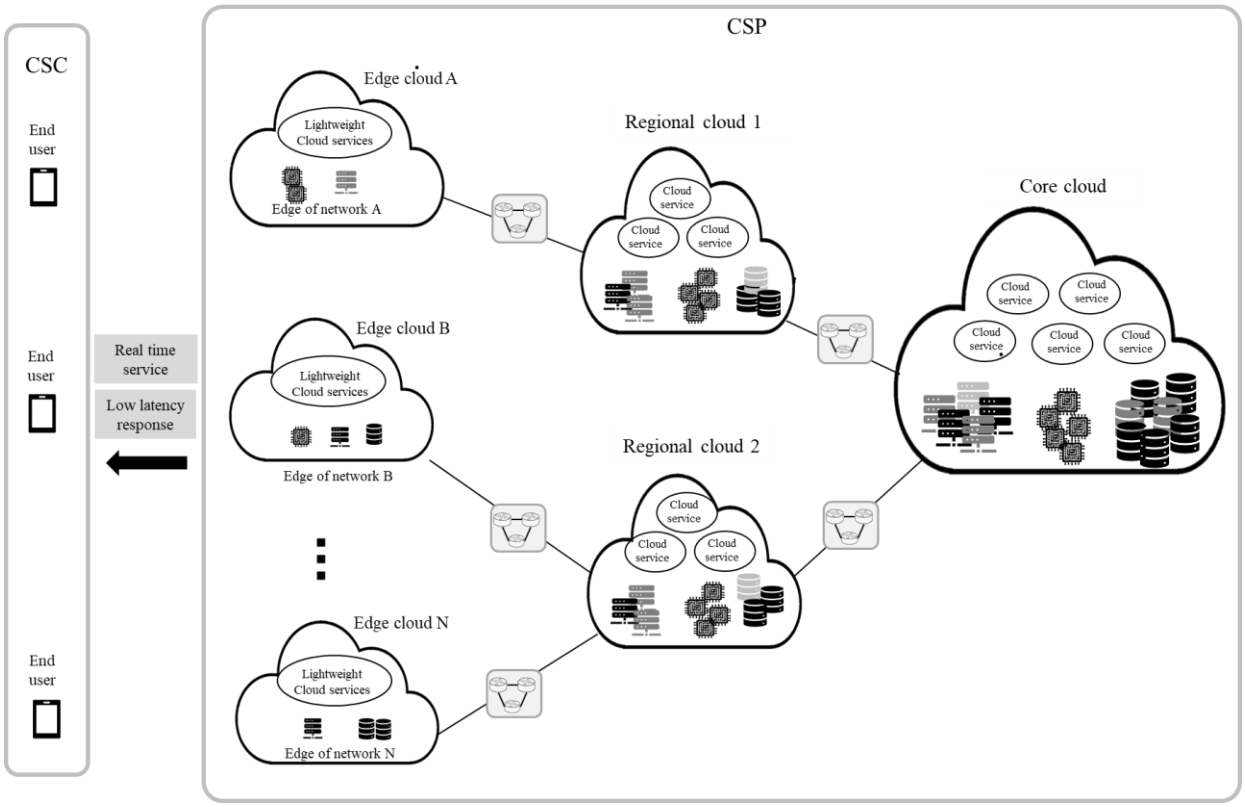


Figure 6-2 – General configuration of edge cloud in distributed model 3

In distributed cloud model 2, edge clouds and a core cloud are configured together and a cloud service is functionally reconfigured and is executed on both edge cloud and core cloud by interworking [ITU-T Y.3508]. In distributed cloud model 3, edge clouds, regional clouds and a core cloud are configured together. [ITU-T Y.3508].

The edge cloud is a collection of specialized hardware in edge devices to provide the cloud services to the CSC. The edge cloud provides lightweight cloud services depending on the CSC's requirements and the physical resource in edge cloud.

The CSP maintains information about the resources and lightweight cloud services of edge cloud. The information is updated in cooperation with the edge cloud.

7 Logical components of edge cloud

The logical component of the edge cloud includes three parts: physical resources, resource pool and lightweight cloud services.

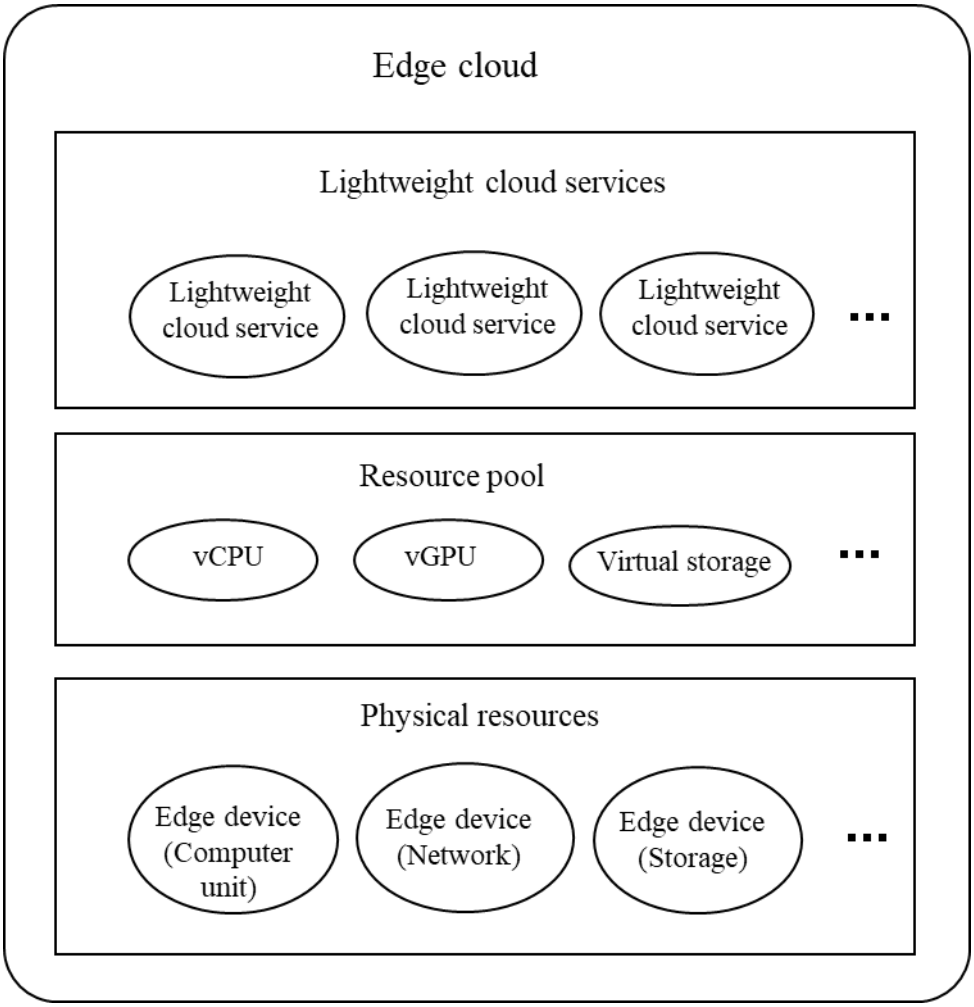


Figure 7-1 – Logical component of edge cloud

7.1 Physical resources

Physical resources provide the computing, network and storage resources and other physical computing infrastructures in edge devices. The physical resource is provided by CSP or CSC. For more information on physical resource, see [ITU-T Y.3502], [ITU-T Y.3510].

7.2 Resource pool

A resource pool is an aggregate collection of physical resources, and is accessed by lightweight cloud services. The resource pool provides various types of virtual resources. The followings are example of virtual resources in the resource pool:

- Computing resources:
  - vCPU (virtual central processing unit): a vCPU is the virtualized instances of physical CPU cores. vCPUs are allocated to virtual machines or containers to perform computational tasks;
  - vGPU (virtual graphics processing unit): a vGPU provides graphical processing power to virtual machines or containers;
  - vRAM (virtual random-access memory): a vRAM is the abstraction of physical RAM allocated to virtual machines or containers;
- Network resources:
  - Virtual network: a virtualized network enables communication between VMs and containers;
  - Subnetwork: a subnetwork is a logically visible subdivision of an internet protocol (IP) network. Subnetwork allows an organization to create multiple logical networks within a single physical network.
- Storage resources:
  - Virtual storage: virtualized instances of physical storage devices such as SSDs and HDDs for scalable and flexible data management solutions;
- Specialized hardware:
  - ASICs, FPGAs, and other custom hardware.

7.3 Lightweight cloud service

Lightweight cloud service is designed to operate within the constrained resources of edge cloud. A lightweight cloud service involves reconfiguring the functionality of cloud service to ensure cloud service fit within constrained resources of edge cloud. Despite the reduction in resource consumption, the functionality of lightweight cloud service is equivalent with cloud service by CSP. Creating a lightweight cloud service involves reconfiguring functionality of existing cloud service using various capabilities to ensure they operate in edge cloud. The lightweight cloud service aims to reduce resource consumption while providing essentially the same functionality.

8 Capabilities to support lightweight cloud service

This clause provides several capabilities such as lightweight hypervisor, container, service decomposition, modular design, and interworking to support lightweight cloud service.

8.1 Lightweight virtualization

The lightweight virtualization provides resource usage while minimizing the overhead associated with resource-intensive virtualization such as full virtualization, hypervisor. The lightweight virtualization involves several key capabilities, but are not limited to:

- **Lightweight hypervisor:** offers virtualization capabilities with minimal resource overhead. It focuses on providing essential functionalities needed to run virtual machines.
- **Container**: utilizes OS-level virtualization to run multiple isolated user-space instances on a single OS kernel. Container shares the host system's kernel, avoiding the need for

separate operating systems for each application. Containers reduce resource consumption allowing more applications to run on the same resources

8.2 Pre-defined cloud service

Pre-defined cloud service provided by CSP refers to cloud service that can be easily deployed on edge cloud. From an edge cloud perspective, a pre-defined cloud service is designed to be selectively applicable, providing the essential functionalities of each cloud service within the constraints of available resources. A pre-defined cloud service operates as a portion of the cloud service within the edge cloud, using capabilities such as service decomposition and modular design.

- **Service decomposition**: dividing cloud service into smaller, manageable components that is independently deployed. Service decomposition allows the cloud service to be tailored to specific edge cloud.

  NOTE 1 – Service decomposition involves analysing the cloud service to identify distinct functionalities and creating independent modules.

  NOTE 2 – Functionality are provided by a cloud service and the functionality is classified into different cloud capability types, such as application capabilities, infrastructure capabilities, and platform capabilities. [ITU-T Y.3500]

  NOTE 3 – Decomposed cloud service refers to divided cloud service into smaller, manageable components.

- **Modular design**: creating service components by dividing them into independent modules. Each module performs a specific function and operates independently. This design enables the selective activation of functionalities based on resource availability in the edge cloud.

8.3 Interworking

The interworking among core, regional, and edge cloud provides collaboration among edge clouds and regional or core clouds. Modules deployed at the edge cloud interwork with modules deployed in the regional cloud and the core cloud to provide cloud services to CSC. Service decomposition and modular design allow independent modules to exchange data seamlessly across edge, regional, and core clouds.

- **Storage tiering:** refers to optimization of storage by moving data between different storages based on predefined criteria such as data usage, access frequency, and performance requirements.

  NOTE – The storage tiering has a role in edge cloud to manage storage resources within the limited capacities of storage in edge clouds. The frequently accessed and critical data is stored on storage in edge cloud, and less frequently accessed data is moved to lower-cost, higher-capacity storage in regional or core clouds using storage tiering. The CSP monitors data usage patterns to decide frequently accessed data in edge cloud.

9 Functional requirements

9.1 Functional requirements for physical resources

1) It is required that the CSP (edge cloud) provide inventory management of physical resources in edge devices.

   NOTE 1 – Inventory management involves tracking and managing all physical hardware components, their specifications, and statuses within the edge devices.

2) It is required that the CSP (edge cloud) provide configuration management of physical resources in edge devices.

NOTE 2 – Configuration management involves maintaining and updating the settings and configurations of hardware to ensure they operate correctly and efficiently.

3) It is required that the CSP (edge cloud) provide status checks of physical resources in edge devices.

4) It is required that the CSP (edge cloud) provide fault recovery for physical resources in edge devices.

NOTE – Fault recovery involves detecting hardware failures and initiating predefined recovery actions to minimize downtime.

5) It is recommended that the CSP (edge cloud) provide upgrade the software including firmware to operate hardware in edge device.

6) It is required that the CSP (edge cloud) provide resource pool of physical resource in edge device to cloud service partner (CSN) and CSC.

9.2 Functional requirements for resource pool

9.2.1 Functional requirements of resource allocation

1) It is required that the CSP (edge cloud) provide load balancing of virtual resource across lightweight cloud services to ensure efficient utilization of virtual resource.

2) It is recommended that the CSP (edge cloud) provide dynamic resource allocation to lightweight cloud services based on resource usage pattern.

3) It is required that the CSP (edge cloud) provide predictive analysis to forecast resource demands and adjust allocations based on resource usage patterns.

4) It is required that the CSP (edge cloud) provide automatic scaling to adjust resource allocation in response to changing demands.

NOTE – The automatic scaling to adjust resource allocation allows dynamic resizing of resources (upscaling or downscaling) without service interruption.

9.2.2 Functional requirements of network

1) It is recommended that the CSP (edge cloud) provide bandwidth control of network according to cloud service category from edge device.

2) It is required that the CSP (edge cloud) provide load balance of network traffic to distribute traffic across multiple network paths.

3) It is required that the CSP (edge cloud) provide monitoring of network status of edge cloud.

NOTE – Network status includes latency, bandwidth usage, packet loss, and connection stability.

9.2.3 Functional requirements of storage

1) It is recommended that the CSP (edge cloud) provide storage tiering for effective usage of storage.

2) It is recommended that the CSP (edge cloud) provide policy management of storage tiering.

NOTE – The policy includes criteria for data movement, retention periods, and performance thresholds.

3) It is recommended that the CSP (edge cloud) provide data compression to reduce the amount of storage space in resource pool.

4) It is recommended that the CSP (edge cloud) provide data encryption for stored data to ensure the protection of data.

9.2.4 Functional requirements of monitoring

1) It is required that the CSP (edge cloud) provide monitoring the status of resource pool.

NOTE 1 – The status of the resource pool includes total resource capacity, current resource usage, resource availability, and performance metrics.

NOTE 2 – Monitoring objects of cloud service and resources includes but not limited to cloud service load, resource load (e.g. CPU usage, CPU load, memory usage, I/O, etc.).

2) It is recommended that the CSP (edge cloud) provide report of a resource usage pattern to CSC and CSP (core cloud).

NOTE 3 – Resource usage pattern reflect the number of resources used at specific period of time.

3) It is required that the CSP (edge cloud) provide information of edge cloud to the CSP (core cloud).

NOTE 4 – Information of edge cloud includes detailed information about the resources and lightweight cloud services in edge cloud.

4) It is required that the CSP (core cloud) provide management of information of edge cloud.

9.3 Functional requirements for lightweight cloud services

1) It is recommended that the CSP (core cloud) provide pre-defined cloud service customized for the edge cloud.

NOTE 1 – A pre-defined cloud service refers to a cloud service that is defined in advance to use by CSP. A pre-defined cloud service operates as a portion of the cloud service in the edge cloud, using capabilities such as service decomposition and modular design.

2) It is recommended that the CSP (core cloud) provide functionality specification of cloud service to CSC and CSN.

NOTE 2 – The functionality specification includes interfacing, defining, and documenting the various capabilities, features, and functions that the cloud service offers.

3) It is recommended that the CSP (core cloud) provide decomposed clous service components that is independently deployed and managed.

4) It is recommended that the CSP (core cloud) provide interfaces for decomposed cloud service components.

NOTE 3 – The interface refers to a set of standardized methods, protocols, and tools that allow different decomposed cloud service components to communicate and interact with each other.

5) It is recommended that the CSP (core cloud) provide modularization of cloud service.

NOTE 4 – Modularization involves designing and creating cloud services that are independently created, operable, modified, replaced, or exchanged.

6) It is recommended that the CSP (core cloud) provide packaging decomposed cloud service with container.

NOTE 5 – In edge cloud, bundles a decomposed cloud service with all the files and libraries it needs to run on any infrastructure in edge cloud are provided in forms of container package.

10 Security considerations

It is recommended that the security framework for cloud computing described in [b-ITU-T X.1601] be considered for the edge cloud. [b-ITU-T X.1601] analyses security threats and challenges in the cloud computing environment and describes security capabilities that could mitigate these threats and meet security challenges.

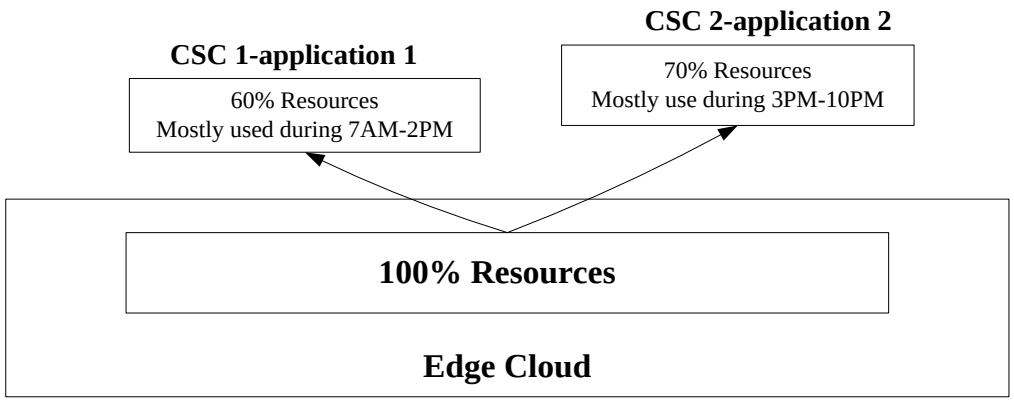
It is recommended that the guidelines for the operational security of cloud computing described in [b-ITU-T X.1642] be considered for the edge cloud. [b-ITU-T X.1642] clarifies the security responsibilities between CSPs and CSCs, and analyses the requirements and categories of security metrics of operational security for cloud computing.

Appendix I
Use case of edge cloud development

(This appendix does not form an integral part of this Recommendation.)

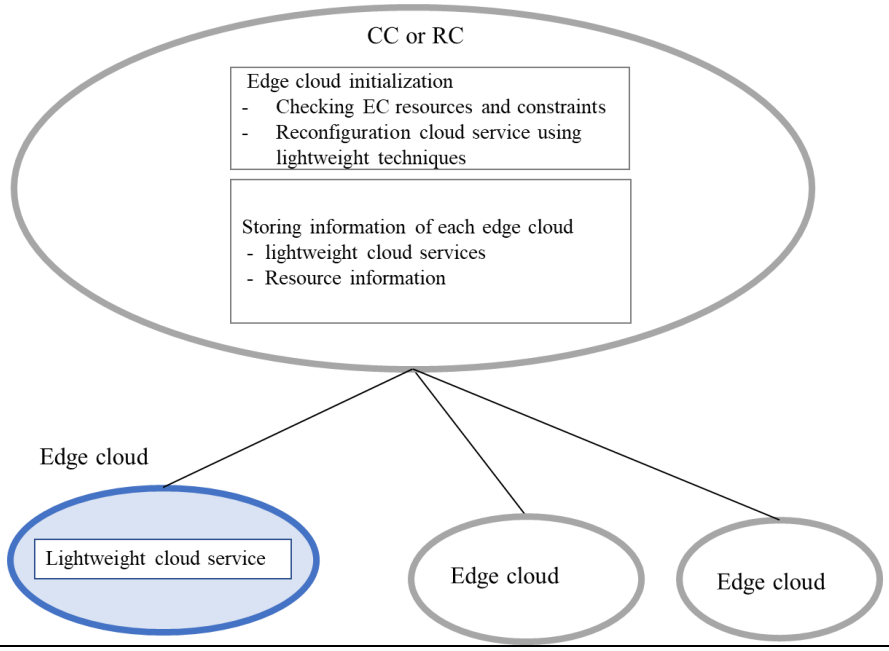
The cloud service capabilities in edge cloud are inherited from core cloud or regional cloud. And in the use case, core cloud and regional cloud are represented as clouds that play the same role. That is, in the use case, core cloud and regional cloud are expressed as CSP (CC/RC).

I.1 Use case of resource dynamic allocation

Title	Resource dynamic allocation
Description	Edge clouds usually have limited resources. It would happen that multiple CSCs want to use resources in the same edge cloud. Under this condition, the CSP should figure out how to provide the limited resources to as many as CSCs, and how to improve the resource utilization. One solution to achieve this is that edge cloud support resource dynamic adjustment. Once a CSC applied for resources in edge cloud, the CSP could monitor the resource utilization of CSC's application. Based on the monitoring data, CSP can summarize a resource usage pattern to indicate spare time and busy time of the application. During the application's spare time, the resource utilization rate of this application would be low, and the spare resources can be orchestrated to other applications.
Role/Sub-role	
Figure (optional)	
Pre-conditions (optional)	
Post-conditions (optional)	
Derived requirements	– Clause 9.2.1 item 2) – Clause 9.2.1 item 3) – Clause 9.2.1 item 4)

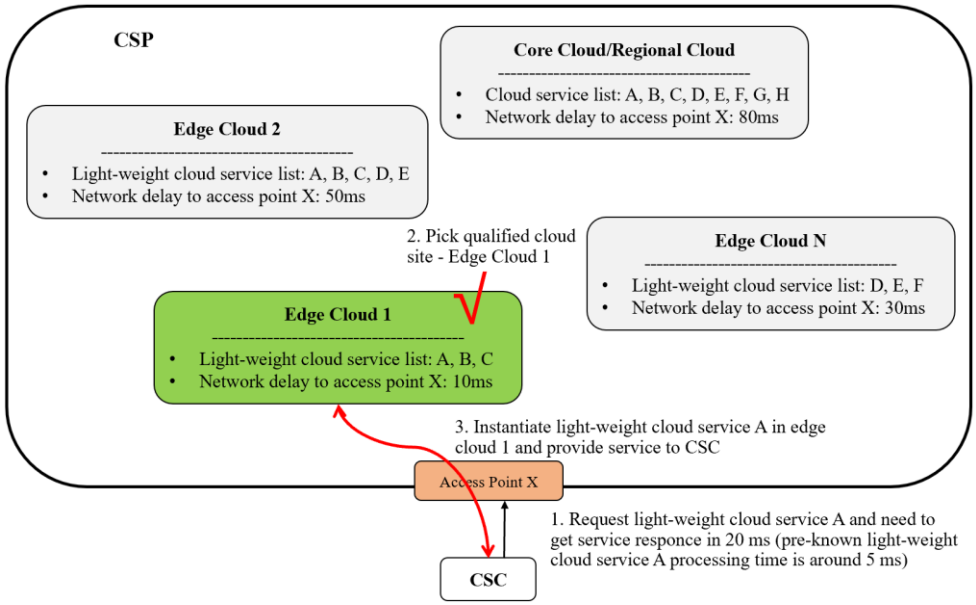
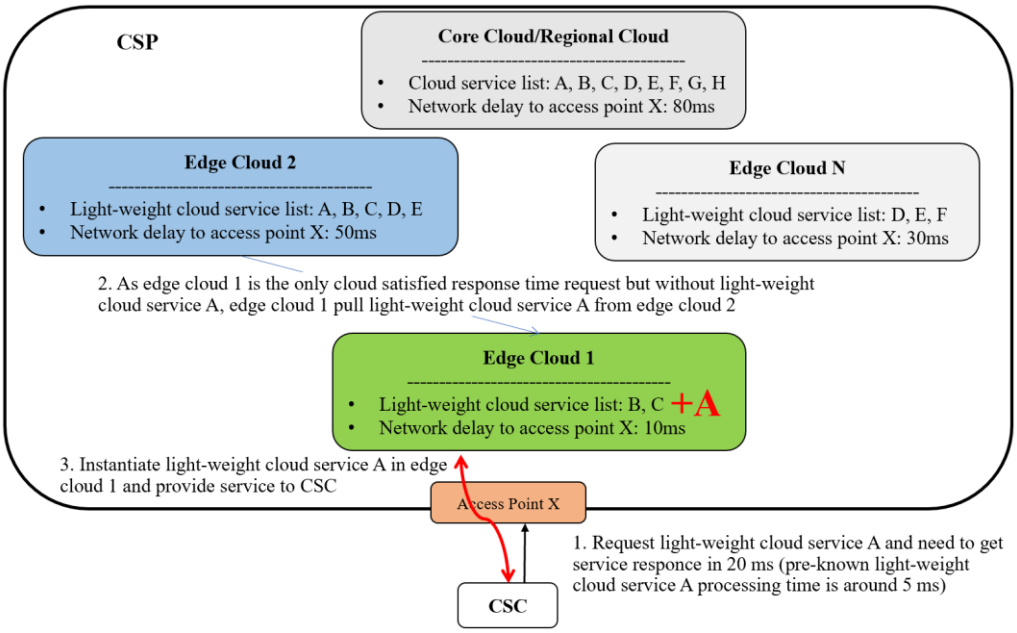
I.2 Edge cloud initialization and registration

Title	Edge cloud initialization and registration
Description	This use case shows a process of initialization and registering a new edge cloud with a cloud service provider (CSP). Edge cloud initialization and registration are performed by the CSP (CC or RC). The initialization and registration procedure for the new edge is as follows. 1) Requirement analysis: A CSP (CC or RC) analyze the requirements and determine the needed cloud services to be provided by the edge. 2) Hardware and networking configuration: The CSP (CC or RC) set up the necessary hardware and network infrastructure for building the edge cloud and establish network connectivity between the CSP (CC or RC) and edge. 3) The CSP (CC or RC) checks the resource status of the equipment (e.g. server, device) to install the edge cloud. 4) The CSP (CC or RC) configure appropriate resources for cloud services that will run the cloud service, taking into account factors such as processing power, memory and storage capacity. 5) The CSP CC or RC) install the necessary software components, such as the operating system, virtualization technologies, container, networking, and security solutions. 6) The CSP (CC or RC) deploy and manage the required cloud services on the initialized edge cloud. This encompasses data storage, computing resources, infrastructure management, and monitoring. 7) The CSP (CC or RC) perform testing and validation to ensure that the edge cloud operates correctly. This includes performance testing, security validation, and testing user scenarios. 8) The CSP (CC or RC) creates a profile about the new edge cloud and register in to catalogue which is located in CC or RC. The profile includes information about the edge cloud's available resources, physical information (ex, location information) and service capabilities. 9) The CSP (edge Cloud) monitors status of resources and checks availabilities of edge cloud services in edge cloud. And the CSP (edge cloud) inform that information to the CSP (CC or RC)
Roles	CSC, CSP

Figure (optional)	
Pre-conditions (optional)	
Post-conditions (optional)	
Derived requirements	– Clause 9.1 items 1), 2), 3), 4), 5), 6) – Clause 9.3 items 1), 2), 3), 4) – Clause 9.2.4 item 3) – Clause 9.2.4 item 4)

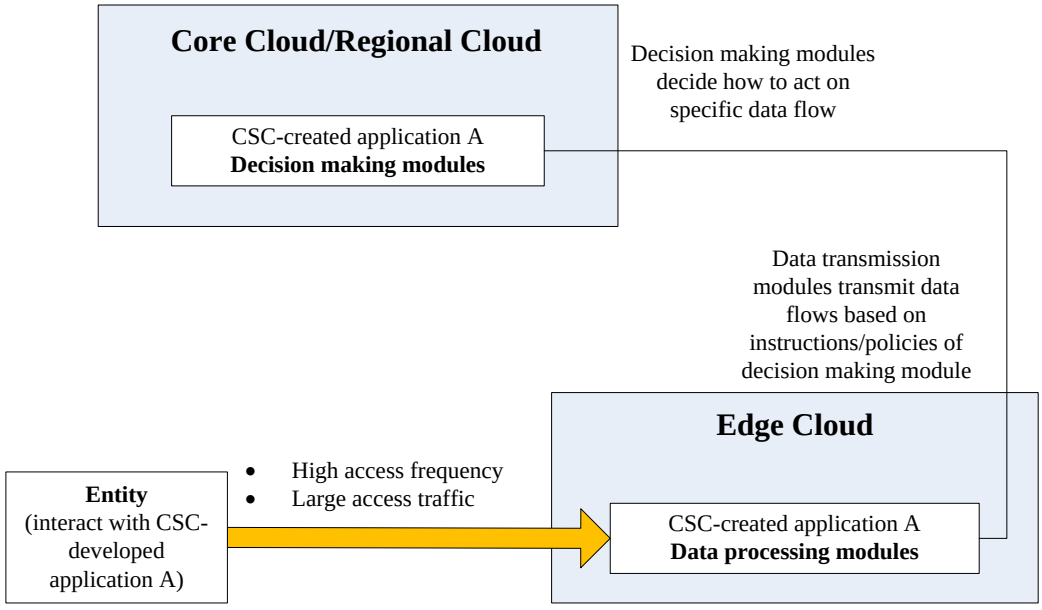
I.3 Using cloud services on edge cloud

Title	Using cloud services on edge cloud
Description	As edge clouds are usually close to CSC, they provide CSC with low network latency. When CSC requesting a light-weight cloud service from CSP with low latency, CSP will firstly check whether there is an edge cloud site that acquire requested lightweight cloud service as well as meeting the low latency requirements. There two possible situations: According to figure I.3-1, there is an edge cloud 1 of CSP acquiring CSC requested lightweight cloud service A. Then, edge cloud 1 will provide cloud service A to CSC by instantiating light-weight cloud service A and setting up all configurations. According to figure I.3-2, there is no qualified edge clouds but with only edge cloud 1 can meet low latency requirements. In this situation, CSP will check cloud sites that have lightweight cloud service A, which is edge cloud 2. Edge cloud 1 will clone lightweight cloud service A from edge cloud 2 by pulling images and configuration files of lightweight cloud service A. After the clone action, edge cloud 1 becomes the qualified cloud site that can provide light-weight cloud service A and meet the low latency requirements. Then, edge cloud 1 will provide light-weight cloud service A to CSC by instantiating light-weight cloud service A and setting up all configurations.

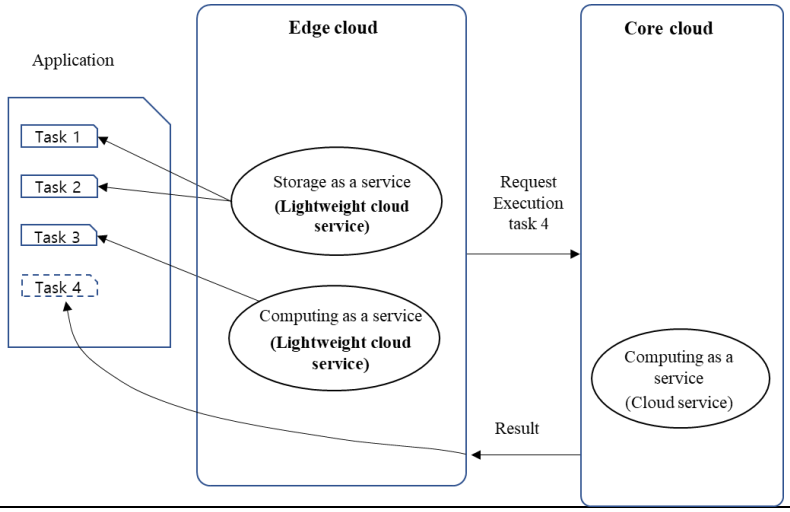
Roles	CSC, CSP
Figure (optional)	 (a) A qualified edge cloud provides required light-weight cloud service  (b) No qualified edge cloud provides required light-weight cloud service
Pre-conditions (optional)	1. CSC get access to the network through Access Point X 2. All core clouds, regional clouds, edge clouds are connected to Access Point X through well-constructed network of CSP 3. All core clouds, regional clouds and edge clouds are connected to each other through well-constructed network of CSP CSP acquire CSC-requested light-weight cloud services
Post-conditions (optional)	
Derived requirements	– Clause 9.3.1 item 1) – Clause 9.2.4 item 1) – Clause 9.2.4 item 3)

	– Clause 9.2.4 item 4)

I.4 Network traffic processing

Title	Network traffic processing
Description	This use case shows the CSP (edge cloud) provides network traffic processing capability. For a cloud application developed by CSC able to be deployed within distributed cloud, CSC usually deploy the application's decision make modules in one core cloud or regional cloud, while deploy application's data processing modules in several edge clouds. This helps other CSC to gain low network latency when other entities accessing cloud based application at the edge. As data transmission modules usually process huge amount of data, CSP should ensure strong network traffic processing capability of edge cloud.
Roles	CSC, CSP
Figure (optional)	 Figure-1: Access CSC-created application in distributed cloud
Pre-conditions (optional)	
Post-conditions (optional)	
Derived requirements	– Clause 9.2.2 item 1) – Clause 9.2.2 item 2) – Clause 9.2.2 item 3) – Clause 9.2.3 item 1) – Clause 9.2.3 item 2)

I.5 Use case of offloading in edge cloud

Title	Use case of offloading in edge cloud
Description	This use case shows offloading through the edge cloud and core cloud. In this use case, user request application based on edge cloud to the edge cloud. The edge cloud sends resource-intensive computational tasks to the core cloud during the requested tasks. In this use case, there are four tasks comprising the application. And the edge cloud utilizes its own cloud services to handle tasks. However, one of the tasks is complex and resource-intensive. The edge cloud is not suitable for efficiently handling the complex task. Therefore, the complex task is offloaded to the core Cloud. This process involves application partitioning, offloading decision making, and execution of distributed tasks Following are key features for offloading. 1. Task identification: Identifying tasks that are computationally intensive and evaluating their suitability for offloading. 2. Resource utilization monitoring: Monitoring of the CPU, memory, and storage utilization on edge devices is essential. 3. Decision algorithm: Determine which tasks should be offloaded.
Roles	CSC, CSP
Figure (optional)	
Pre-conditions (optional)	
Post-conditions (optional)	
Derived requirements	– Clause 9.3 item 2) – Clause 9.3 item 3) – Clause 9.3 item 4) – Clause 9.3 item 6)

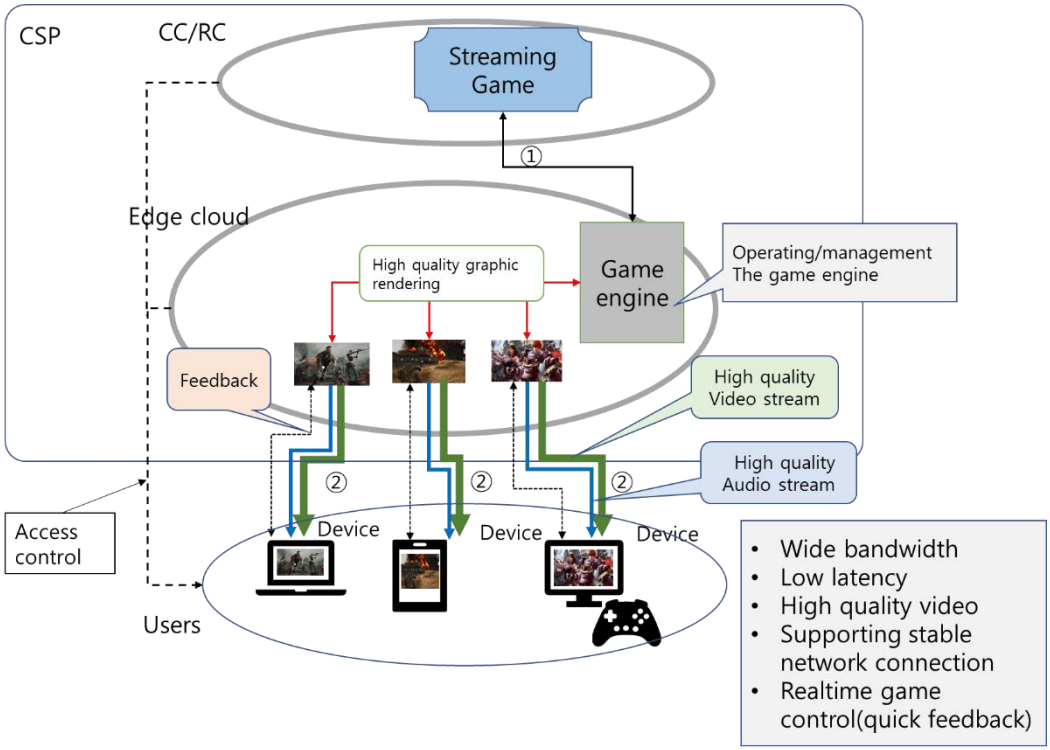
Appendix II
Use cases of edge cloud application

(This appendix does not form an integral part of this Recommendation.)

This appendix describes use cases and scenarios of edge cloud applications

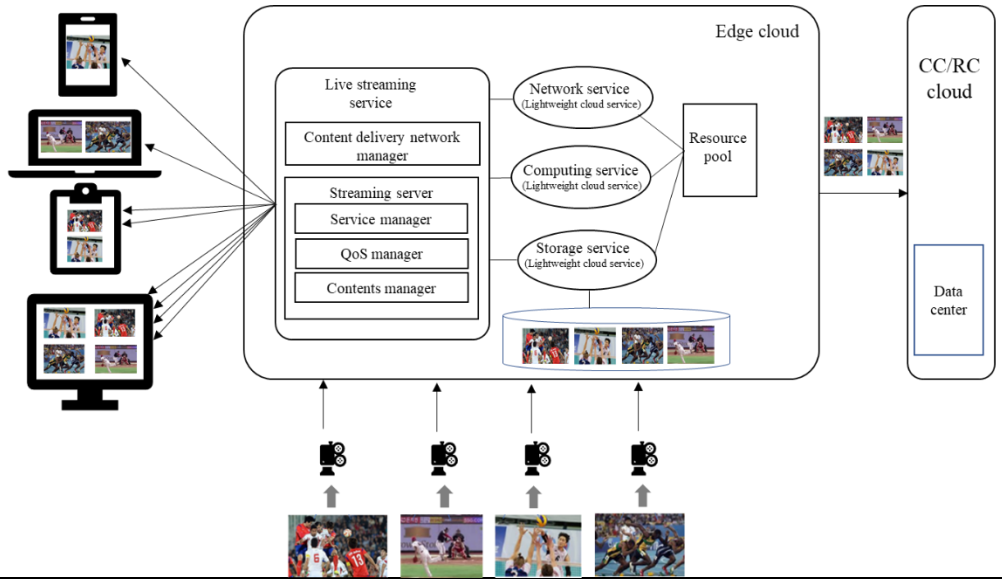
II.1 Edge cloud-based streaming game

Title	Edge cloud-based streaming game
Description	The use case for edge cloud based streaming game highlights a transformative approach to delivering high-performance gaming experiences to users without the need for dedicated, high-end hardware. The configuration and operation of this use case are as follows. 1. **Game configuration and streaming:** Games configured in the edge cloud are streamed to user's devices, such as smartphones, tablets, or even low-performance PCs, via wired or wireless networks. This approach allows users to play games without needing consoles or high-performance PCs. 2. **Edge cloud deployment:** To ensure gameplay with minimal latency, the game engine and necessary components are transferred and installed on an edge cloud. This is located closer to the user compared to core cloud (CC) or regional cloud (RC) data centres. 3. **High-quality rendering:** The CSP (edge cloud) utilizes its resources to perform high-quality graphic rendering and other processing tasks required for the game. The processed game visuals are then streamed to the user's device, enabling high-end gaming experiences on devices that would normally lack the necessary computing power. The key consideration of this use case are followings: 1. **Wide bandwidth and latency:** The critical factors for cloud-based gaming are bandwidth and latency. The edge cloud addresses these by situating processing power closer to the end-user, thus providing wider bandwidth support and reducing latency to ensure smooth gameplay. 2. **Interworking with core cloud:** The edge cloud needs to work in conjunction with central cloud (CC/RC) to access the game engine, settings, character information, and other necessary data. This setup ensures that the latest game content and updates are available for edge-based streaming. 3. **Stable network support**: To deliver a stable gaming service, a stable and fast network connection up to the user's device is essential. This includes monitoring network conditions periodically and maintaining low latency to prevent disruptions during gameplay.
Roles	CSC, CSP

Figure (optional)	
Pre-conditions (optional)	
Post-conditions (optional)	
Derived requirements	– Clause 9.2.2 item 1) – Clause 9.2.2 item 2) – Clause 9.2.2 item 3) – Clause 9.2.3 item 1) – Clause 9.2.3 item 2)

II.2 High-definition live streaming service in edge cloud

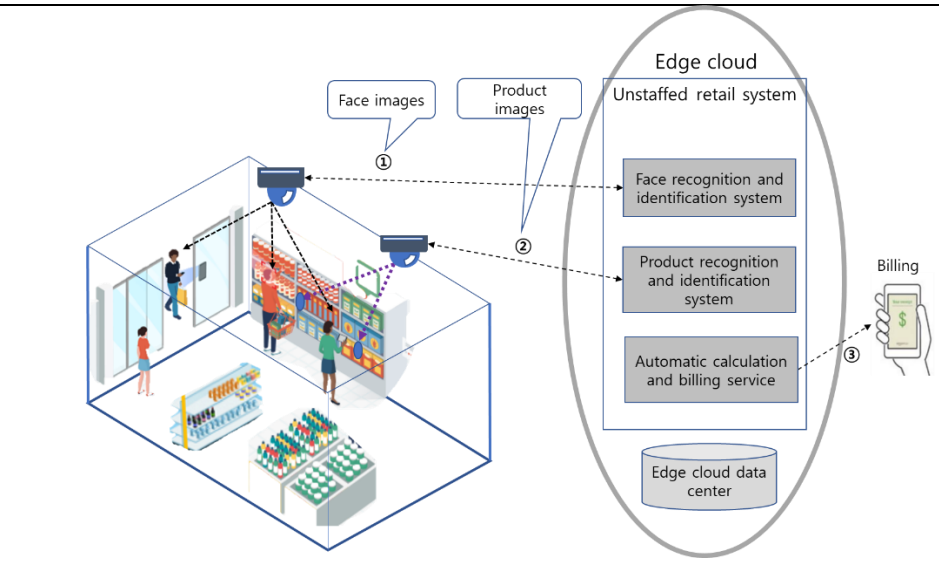
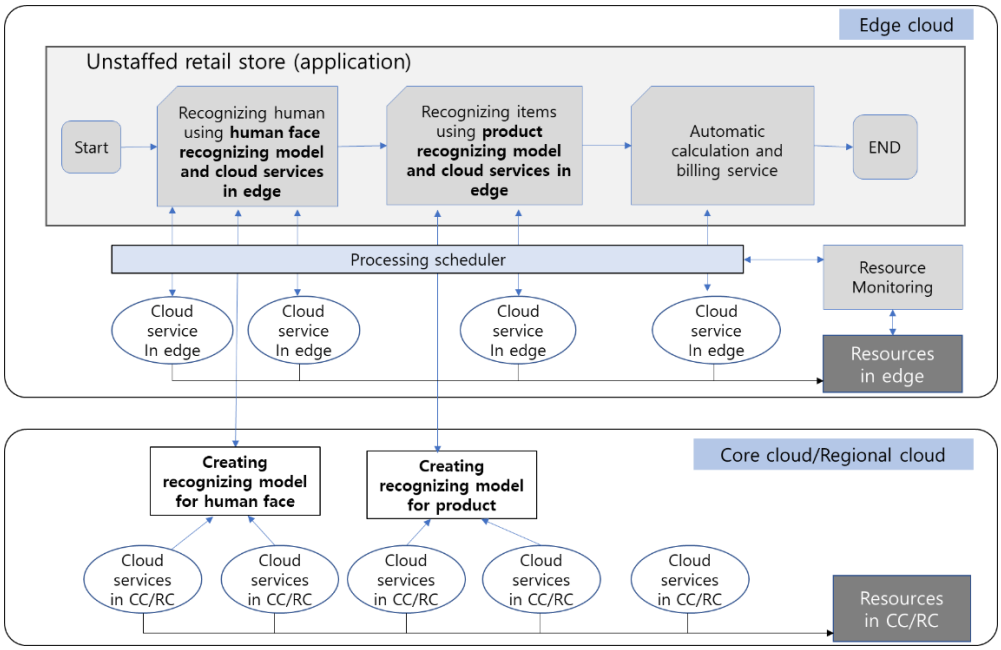
Title	High-definition live streaming service in edge cloud
Description	This use case shows that high-definition live streaming service is provided in the local area when various sports events are held simultaneously in the local area. In this use case, numerous cameras generate and provide high-definition contents in real time to local users. To support these services, considerations for high-bandwidth and low-latency connections between users and the cloud are essential. It necessitates the setup of a live streaming service on the edge cloud, configured to enable many local users to receive high-definition live streaming services efficiently. Followings are essential for deploying a high definition live streaming service.

	– High-speed and low-latency network connections are crucial for providing high-definition live streaming services – Data storage for live streaming content should be located within edge regions to enable fast access. The following are the features that the edge cloud provides for a high definition live streaming service. – The CSP (edge cloud) has real time monitoring tool of the resource utilization of resource pools. – The CSP (edge cloud) has dynamic resource allocation method. – The CSP (edge cloud) release idle or unutilized resources back to the pool for allocation to other services.
Roles	CSC, CSP
Figure (optional)	
Pre-conditions (optional)	
Post-conditions (optional)	
Derived requirements	– Clause 9.2.3 item 1) – Clause 9.2.3 item 2) – Clause 9.2.3 item 3) – Clause 9.2.3 item 4)

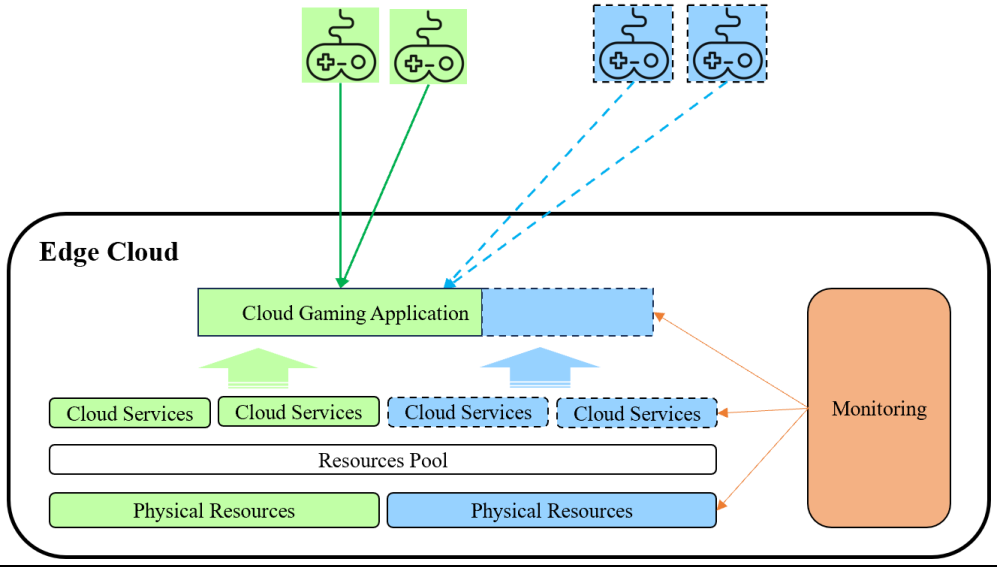
II.3 Unstaffed retail store using edge cloud

Title	Unstaffed retail store using edge cloud
Description	This use case shows the unstaffed retail store system that automatically recognizes a person's face, identifies a purchased product and automatically calculates and bills them to a CSC directly at an edge cloud.

	The following systems are required for the smooth operation of the unstaffed store. 1. Face recognition and identifying system 2. Product recognition and identification system 3. Automatic calculation and billing service In order for each system to operate, the following detailed works are required. <Face recognition and identification> When a guest enters the store, the Face recognition and identification system start to recognize and identify the guest. The camera located in the store captures the face of the guest and sends it to the face recognition and identification system. And then the system starts to identify and recognize the guest using the image. For identification, information about guests must be stored in advance. The system analyses the captured image and looks for the guest in the stored database. In order to perform face recognition and identification, a trained model for face recognition is needed. A trained model is made through a learning task (ex, machine learning) using stored face images. The learning task requires a lot of computing resources and time. Therefore, it is advantageous to do the learning task in the core cloud rather than in the edge cloud with limited resources. (Offloading) After the model is complete, it is used to identify people. But the task of recognizing and identifying people in real-time using the provided train rules is also not simple, because the captured image does not exactly the same as the stored image and it takes on various angles and shapes. Therefore, it is appropriate to perform such face recognition and identification in the edge cloud. <Product recognition and identification> Product recognition and identification are also performed in real-time as soon as the customer selects products. The trained model for identifying produce is provided from the core cloud/regional cloud. <Automatic product calculation and billing> Automatic calculation automatically sums up the values of purchased products and charges the guest for the amount. In this use case, the edge cloud needs to cooperate with CC/RC for getting trained model for face identification and product identification. Figure (b) shows the collaborating process between the edge cloud and CC/RC. The edge cloud sends stored face data and product data to CC/RC and requests trained model for recognition and identification.
Roles	CSC, CSP

Figure (optional)	 (a) Unstaffed retail system  (b) Collaborating edge cloud and CC/RC
Pre-conditions (optional)	
Post-conditions (optional)	
Derived requirements	– Clause 9.2.1 item 1) – Clause 9.2.1 item 2) – Clause 9.2.1 item 3) – Clause 9.2.1 item 4) – Clause 9.2.4 item 2)

II.4 Cloud gaming scaling among edge clouds

Title	Cloud gaming scaling among edge clouds
Description	Cloud gaming is one of the most popular ways that game companies provide game service to game players. Through cloud, game companies do not need to buy and maintain any physical or virtual resources by itself to run its cloud gaming applications but use cloud service provided by CSP instead. To ensure better game experience, cloud gaming applications are preferred to be deployed close to game players, which is usually edge cloud. As game playing action showing tidal effects, the game access traffic and workload of cloud gaming applications will also be heavy and vacant from time to time. When there are huge among of game players, more cloud gaming application instances are required, while less instances are required when there are only few players. To better save cost, game companies usually want to rent more cloud services during busy time while rent less cloud services during vacant time. This also helps both CSP and game companies (played as CSC in this use case) to improve resource usage rate. In this case, edge cloud should support scaling of applications deployed within it. To know whether the application want to scale in or scale out, edge cloud monitors the application workload, the application accessing traffic, as well as the resources and cloud services used by application. When monitoring heavy accessing traffic, heavy load of application, and high usage of resources and cloud services, it is necessary to scale out resources and cloud services used by the application. By scaling out, edge clouds will firstly select corresponding vacant cloud services and resources, configure those cloud services and resources, and update application configuration to use the newly added resources and cloud services. Edge cloud will monitor the newly created application instances as well as corresponding resources and cloud service. Then, edge cloud will redirect a certain percent of accessing traffics from original application instance to new application instances, which can be achieved by edge cloud traffic broker. After scaling out, edge cloud will continuously monitor the application workload of application, and load of resources and cloud services. If the workload and usage rate stay low for a certain amount of time, then edge cloud will update the application configuration to use fewer resources and cloud services, and relief those released resources and cloud services for future usage.
Roles	CSC, CSP
Figure (optional)	

Pre-conditions (optional)	
Post-conditions (optional)	
Derived requirements	– Clause 9.1 item 3) – Clause 9.2.1 item 1) – Clause 9.2.1 item 2) – Clause 9.2.1 item 4) – Clause 9.2.4 item 1)

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Bibliography

[b-ITU-T X.1601] Recommendation ITU-T X.1601 (2015), *Security framework for cloud computing*.

[b-ITU-T X.1642] Recommendation ITU-T X.1642 (2016), *Guidelines for the operational security of cloud computing*.

[b-ITU-T Y.3100] Recommendation ITU-T Y.3100 (2017), *Terms and definitions for IMT-2020 network.*

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