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Recommendation

ITU-T Y.4486 (03/2023)

SERIES Y: Global information infrastructure, Internet protocol aspects, next-generation networks, Internet of Things and smart cities

Internet of things and smart cities and communities – Frameworks, architectures and protocols

Framework of cross edge decentralized service by using digital ledger technology and edge computing technologies for Internet of things devices

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Recommendation ITU-T Y.4486

Framework of cross edge decentralized service by using digital ledger technology and edge computing technologies for Internet of things devices

Summary

Decentralized services such as distributed ledger technology (DLT) service for Internet of things (IoT) devices are usually deployed in local area networks (LANs) or in core clouds. When only deployed in LANs, the decentralized services may be affected by the limited capabilities of storage, computation and communication of IoT devices. When only deployed in core clouds, the decentralized services may be affected by the communication capabilities between the IoT devices in LANs and the peers in core clouds. With the popularization of the use of edge computing, parts or all of functionalities of the decentralized services can be deployed in edge clouds.

Recommendation ITU-T Y.4486 introduces a cross edge decentralized service (CEDS) by using DLT and edge computing technologies, which supports seamless cross edge DLT services for IoT devices (fixed and mobile) by using DLT and edge computing technologies. The CEDS can take the advantages of edge computing to speed up the service efficiency of DLT services for IoT devices. In addition, the CEDS provides adaptive service management to match the dynamic changes of IoT devices.

This Recommendation provides relevant general characteristics and requirements of the decentralized service by using DLT and edge computing technologies, and also provides its functional framework, common capabilities and general procedures.

History

Edition	Recommendation	Approval	Study Group	Unique ID*
1.0	ITU-T Y.4486	2023-03-28	20	11.1002/1000/15485

Keywords

Decentralized service, distributed ledger technology (DLT), edge computing, framework, Internet of things (IoT).

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Framework of cross edge decentralized service by using digital ledger technology and edge computing technologies for Internet of things devices

1 Scope

This Recommendation introduces a cross edge decentralized service (CEDS) by using decentralized ledger technology (DLT) and edge computing technologies for IoT devices, and provides relevant general characteristics and requirements, a functional framework, common functionalities and general procedures.

The scope of this Recommendation includes:

– Introduction of the cross edge decentralized service by using DLT and edge computing technologies;

– General characteristics and requirements of the cross edge decentralized service by using DLT and edge computing technologies;

– Functional framework, common functionalities and general procedures of the cross edge decentralized service by using DLT and edge computing technologies.

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.4000] Recommendation ITU-T Y.4000/Y.2060 (2012), *Overview of the Internet of things*.

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 application [b-ITU-T Y.2091]: A structured set of capabilities, which provide value-added functionality supported by one or more services, which may be supported by an API interface.

3.1.2 core cloud [b-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).

3.1.3 decentralized system [b-ITU-T X.1400]: Distributed system wherein control is distributed among the persons or organizations participating in the operation of system.

3.1.4 device [ITU-T Y.4000]: With regard to the Internet of things, this is a piece of equipment with the mandatory capabilities of communication and the optional capabilities of sensing, actuation, date capture, data storage and data processing.

3.1.5 distributed ledger [b-ITU-T X.1400]: A type of ledger that is shared, replicated, and synchronized in a distributed and decentralized manner.

3.1.6 distributed ledger technology (DLT) [b-ITU-T X.1400]: Technology that enables the operation and use of distributed ledgers.

3.1.7 distributed ledger technology client (DLT client) [b-ITU-T X.1409]: A client to access the distributed ledger technology system.

3.1.8 distributed ledger technology system (DLT system) [b-ITU-T X.1400]: A system that implements a distributed ledger.

3.1.9 edge cloud [b-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.

NOTE 2 – 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 resource.

3.1.10 edge computing [b-ITU-T Y.3073]: This refers to a strategy to deploy processing capability at network edge where end terminals are connected, and to perform the processing of data which is derived from and fed to the end terminals.

3.1.11 Internet of things (IoT) [ITU-T Y.4000]: A global infrastructure for the information society, enabling advanced services by interconnecting (physical and virtual) things based on, existing and evolving, interoperable information and communication technologies.

NOTE 1 – Through the exploitation of identification, data capture, processing and communication capabilities, the IoT makes full use of things to offer services to all kinds of applications, whilst ensuring that security and privacy requirements are fulfilled.

NOTE 2 – In a broad perspective, the IoT can be perceived as a vision with technological and societal implications.

3.1.12 ledger [b-ITU-T X.1400]: Information store that keeps final and definitive (immutable) records of transactions.

3.1.13 multi-access edge computing (MEC) [b-ITU-T J.1303]: System which provides an IT service environment and cloud-computing capabilities at the edge of an access network that contains one or more types of access technology, and in close proximity to its users.

3.1.14 mobility [b-ITU-T Q.1743]: The ability for the user to communicate whilst moving independent of location.

3.1.15 node [b-ITU-T X.1400]: Device or process that participates in a distributed ledger network.

NOTE – A node can store a complete or partial replica of the distributed ledger.

3.1.16 peer [b-ITU-T X.1161]: Communication node on peer-to-peer (P2P) network that functions simultaneously as both "client" and "server" to the other nodes on the network.

3.1.17 service [b-ITU-T Y.2091]: A set of functions and facilities offered to a user by a provider.

3.1.18 thing [ITU-T Y.4000]: With regard to the Internet of things, this is an object of the physical world (physical things) or of the information world (virtual things), which is capable of being identified and integrated into the communication networks.

3.2 Terms defined in this Recommendation

This Recommendation defines the following terms:

3.2.1 distributed ledger technology service (DLT service): A decentralized service provided by a distributed ledger technology (DLT) system.

NOTE – DLT system can be deployed in core clouds and/or edge clouds.

3.2.2 cross edge distributed ledger technology service (cross edge DLT service): A distributed ledger technology (DLT) service for Internet of things (IoT) devices enabled by edge computing technologies, in which the IoT devices can get seamless service wherever they are roaming in different edge clouds.

NOTE 1 – A cross edge DLT service is performed by multiple DLT systems as deployed in related edge clouds and core clouds, and those DLT systems collaborate to provide the service for IoT devices.

NOTE 2 – A cross edge DLT service needs to interact with entities in edge clouds to follow mobility information (such as location) of the connected IoT devices in order to provide seamless service when the IoT devices are roaming in different edge clouds.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

CCA-FC	Core-Core Agent Functional Component
CDA-FC	Core-DLT Agent Functional Component
CDM-FC	Core Data Migration Functional Component
CDS-FC	Core Data Synchronization Functional Component
CEA-FC	Core-Edge Agent Functional Component
CEDS	Cross Edge Decentralized Service
CSC	Cloud Service Customer
CSM-FC	Core Service Management Functional Component
CSP	Cloud Service Provider
CSS-FC	Core Service Synchronization Functional Component
CVM-FC	Core service Migration Functional Component
DLT	Distributed Ledger Technology
ECA-FC	Edge-Core Agent Functional Component
EDA-FC	Edge-DLT Agent Functional Component
EDM-FC	Edge Data Migration Functional Component
EDS-FC	Edge Data Synchronization Functional Component
EEA-FC	Edge-Edge Agent Functional Component
EMA-FC	Edge-MEC Agent Functional Component
ESM-FC	Edge Service Management Functional Component
ESS-FC	Edge Service Synchronization Functional Component
EVM-FC	Edge service Migration Functional Component
FC	Functional Component
IoT	Internet of Things
IoV	Internet of Vehicles
MEC	Multi-access Edge Computing
P2P	Peer-to-Peer
PII	Personally Identifiable Information

5 Conventions

The following conventions are used in this Recommendation:

– The keywords "is required to" indicate a requirement which must be strictly followed and from which no deviation is permitted, if conformance to this Recommendation 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 Introduction of the cross edge decentralized service by using DLT and edge computing technologies

Decentralized services such as distributed ledger technology (DLT) services for Internet of things (IoT) devices are usually deployed in local area networks (LANs) or in core clouds. When only deployed in LANs, the decentralized services may be affected by the limited capabilities of storage, computation and communication of IoT devices. When only deployed in core clouds, the decentralized services may be affected by the communication capabilities between the IoT devices in LANs and the peers in core clouds.

Typically, edge clouds are deployed in the edge of communication networks, which provide services only for IoT devices in specific areas. Decentralized services can be deployed in edge clouds. In general, storage volume and computation capabilities of an edge cloud are limited. Therefore, generally, a decentralized service deployed in edge cloud can only provide part of functionalities, and can only serve part of IoT devices in specific areas.

The cross edge decentralized service (CEDS) is one type of decentralized service, which provides seamless cross edge DLT services for IoT devices (fixed and mobile) by using DLT and edge computing technologies. A CEDS consists of one part in a core cloud (core CEDS) and multiple corresponding parts in edge clouds (edge CEDSs) (see Figure 6-1). Each part of a CEDS supports all or parts of functionalities of DLT services and collaborates with other parts to perform seamless cross edge DLT services for IoT devices.

In a CEDS, the core CEDS and multiple corresponding edge CEDSs include DLT systems (core DLT systems and corresponding edge DLT systems) respectively. The DLT systems of an edge CEDS, collaborating with the core CEDS and relevant core DLT systems, provide DLT services to IoT devices as connected to the edge cloud. Due to limited capabilities of storage and computation of edge clouds, full data of DLT services for IoT devices usually are stored in core CEDS and relevant core DLT systems, and the corresponding edge CEDSs and relevant edge DLT systems only store necessary and new data of DLT services of the connected IoT devices.

With the supports of CEDS, when an IoT device is roaming from one edge cloud to another edge cloud, related DLT services can be migrated to the target edge cloud simultaneously and seamlessly.

The CEDS can take the advantages of edge computing to speed up the service efficiency of DLT services for IoT devices. In addition, the CEDS provides adaptive service management to match the dynamic changes of IoT devices. When an IoT device accesses to a DLT service, the CEDS performs synchronization of data and services of the DLT service from corresponding core clouds, and provides the DLT service to IoT devices in edge clouds. In addition, when an IoT device moves from a LAN to another one which is served by different edge clouds, the CEDS can retrieve necessary information (such as mobility information) from the edge clouds and offer migration management of data and services in order to promote the DLT services for the IoT device.

Therefore, the CEDS can provide capabilities, collaborating with DLT services in core clouds and those in edge clouds, to perform all the functionalities and to serve all of the IoT devices.

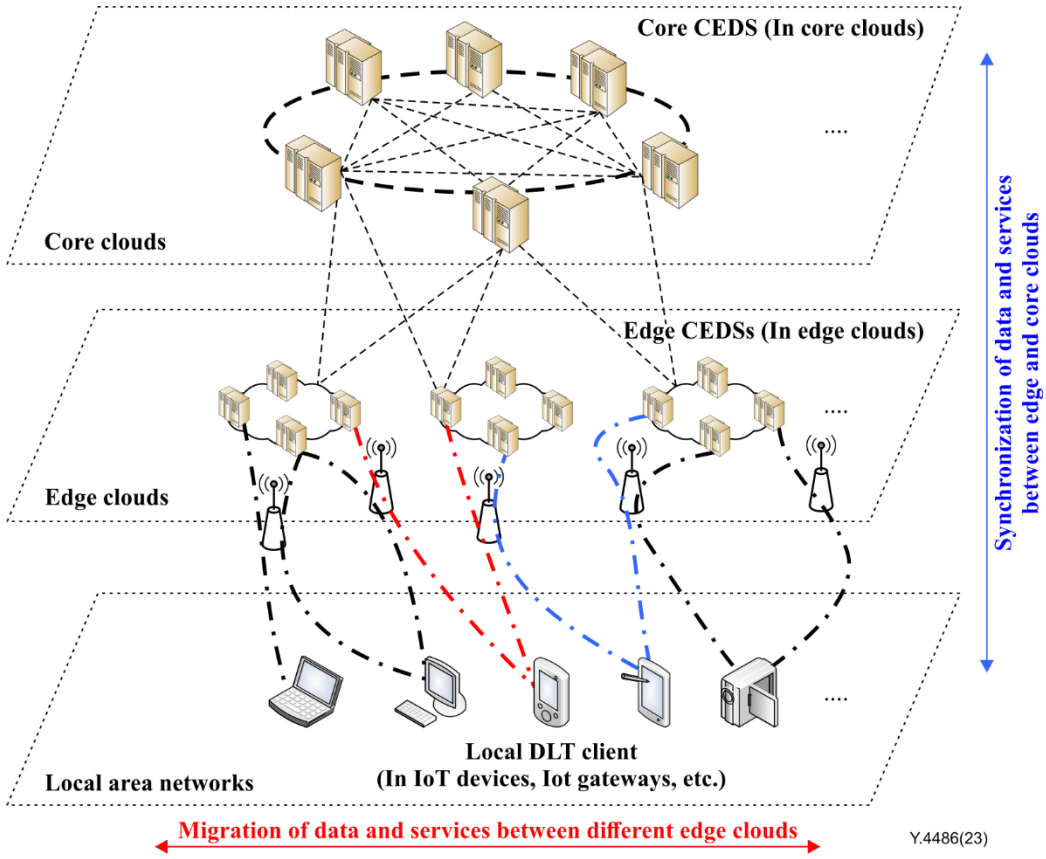

Figure 6-1 – Overview of CEDS

NOTE – CEDS can be deployed in multi-access edge computing (MEC) nodes in edge clouds, and can integrate functionalities exposed by MEC nodes, such as getting mobility information (e.g., location) of IoT devices from mobility services of MEC (see clause 8.3.1). [b-ITU-T Y.3073] and [b-ITU-T J.1303] provide more information about MEC and MEC nodes.

7 General characteristics and requirements of the cross edge decentralized service by using DLT and edge computing technologies

7.1 General characteristics

This clause describes the general characteristics of CEDS.

7.1.1 Supporting seamless cross edge DLT services

The CEDS provides seamless cross edge DLT services. The CEDS can take the advantages of edge computing to speed up service efficiency of DLT services for IoT devices, and can overcome the challenges of capabilities limitation of storage and computation of edge clouds.

In order to overcome the limited storage and computation capabilities, each of the edge CEDSs of a CEDS only serves nearby IoT devices as connected to the relevant edge cloud, and it can synchronize the data and service of DLT services for IoT devices with its corresponding core CEDS of the CEDS, if needed.

The edge CEDS of a CEDS can follow the location of connected IoT devices. When an IoT device is roaming in a new edge cloud, the original edge CEDS can collaborate with the corresponding core CEDS and target edge CEDS of the CEDS to migrate the data and service of the DLT services to the target CEDS, in order to provide dynamic seamless services.

7.1.2 Supporting service management for IoT devices

The CEDS interacts with functional entities in edge clouds to track status (e.g., available capacity resources) of the edge clouds in order to make full use of the capabilities of edge clouds, such as dynamically managing resource consumptions of DLT services in edge clouds.

The CEDS interacts with functional entities (e.g., mobility services) in edge clouds to track status information (e.g., connection status, mobility information) of connected IoT devices, in order to select an appropriate edge CEDS to provide DLT services for IoT devices.

7.1.3 Supporting synchronization of data and services from core clouds

Parts or all of functionalities of DLT services as usually deployed in core clouds can be deployed in edge clouds. In this case, the CEDS provides a mechanism to synchronize data and service of DLT services between its core CEDS and corresponding edge clouds, in order to keep the consistency of data and service of DLT services for IoT devices.

7.1.4 Providing migration management of data and services among edge clouds

The CEDS can follow mobility information (such as location) of mobile IoT devices and provide migration mechanisms to keep the consistency of data and service of DLT services for IoT devices among different edge clouds.

7.1.5 Data security protection and PII privacy preservation

The CEDS provides multi-level data security protection and personally identifiable information (PII) privacy preservation support to the data and service of DLT services for IoT devices. In addition, the CEDS can comply with national and regional data regulations related to the DLT services.

7.2 General requirements

This clause provides general requirements of CEDS.

7.2.1 Cross edge service provision

The cross edge service provision related requirements of CEDS are as follows:

– It is required to provide dynamic seamless cross edge service of DLT services for IoT devices (fixed and mobile).

– It is recommended to provide adaptive resource mechanisms to allow DLT services to manage resource consumptions in edge clouds and in core clouds, such as resources for storage, computation and communication, etc.

– It is recommended to allow DLT services to interact with functional entities (e.g., mobility services of communication networks) in edge clouds to track status information of IoT devices (such as, connection status, mobility information, etc.).

– It is recommended to be compatible with different types of DLT services.

7.2.2 Synchronization management of data and services between edge and core clouds

The synchronization management related requirements of CEDS are as follows:

– It is required to support data and service synchronization of DLT services for IoT devices between the different parts of the DLT services in core clouds and in edge clouds, if requested, according to the policy of the CEDS.

– It is required to provide mechanisms to keep data consistent when synchronizing data and service for DLT services in core and edge clouds.

7.2.3 Migration management of data and services between different edge clouds

The migration management related requirements of CEDS are as follows:

– It is required to support seamless service and data migration of DLT services for IoT devices, when the IoT devices are roaming in different edge clouds, if requested, according to the location of the IoT devices and policy of the CEDS.

– It is required to provide mechanisms to keep data consistent when migrating data for DLT services in different edge clouds.

7.2.4 Data security protection and PII privacy preservation

The data security protection and PII privacy preservation related requirements of CEDS are as follows:

– It is recommended to provide mechanisms on data security protection and PII privacy preservation when interacting with functional entities (such as mobility systems) in edge clouds.

– It is required to provide mechanisms on data security protection and PII privacy preservation when synchronizing data and service of DLT services between core clouds and edge clouds.

– It is required to provide mechanisms on data security protection and PII privacy preservation when migrating data and services of DLT services between edge clouds.

– It is required to be able to comply with national and regional data regulations involved when synchronizing and migrating data and services of DLT services.

8 Functional framework of the cross edge decentralized service by using DLT and edge computing technologies

This clause provides a functional framework and common functionalities of CEDS according to the requirements listed in clause 7.

The CEDS works on the service support and application support layer of the IoT reference model specified in [ITU-T Y.4000]. Figure 8-1 is a schematic diagram of the functional framework of CEDS.

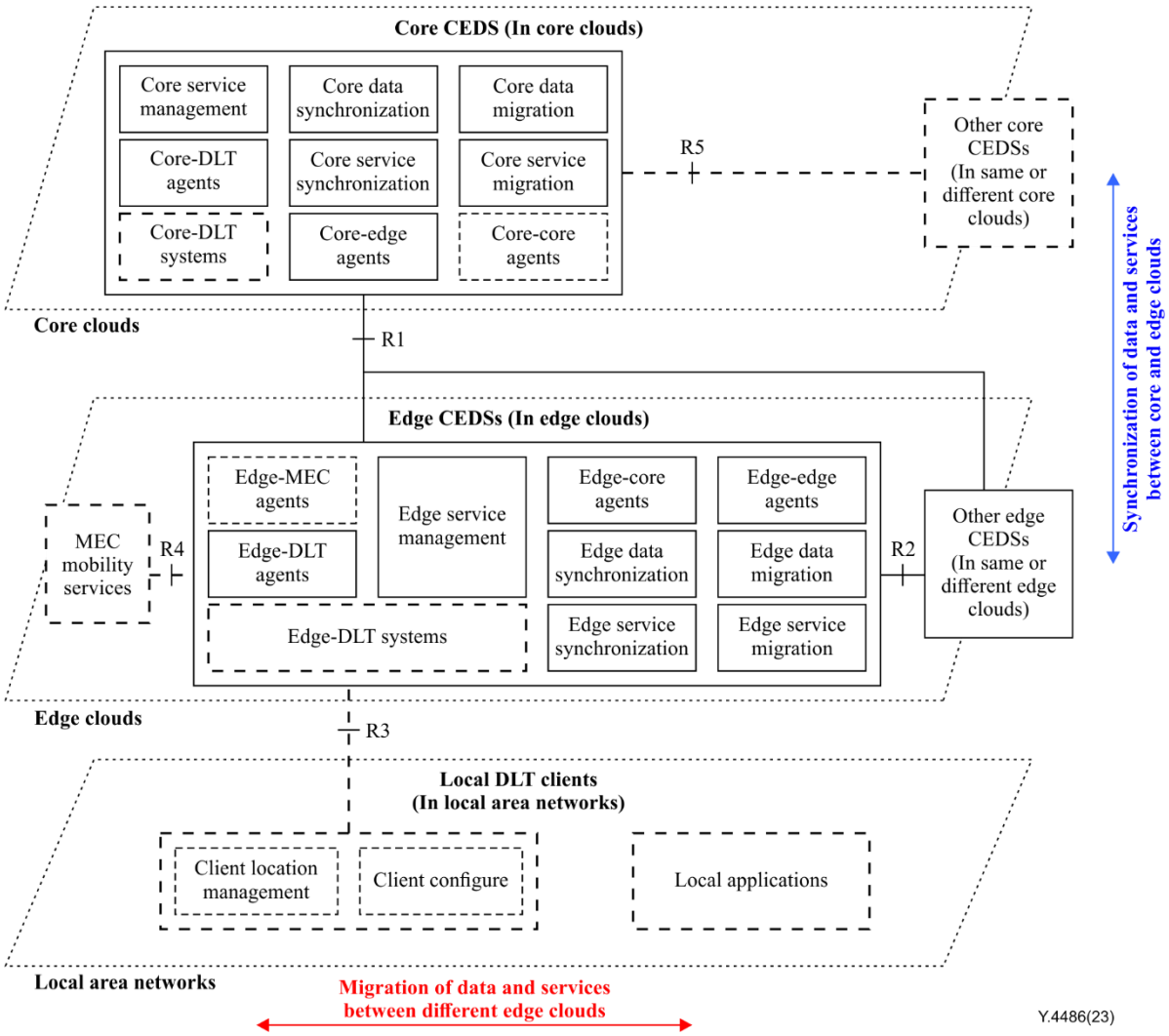

Figure 8-1 – Functional framework of CEDS

CEDS mainly consists of two parts, one core CEDS and multiple corresponding edge CEDSs. Each of them includes groups of logical functional components (FCs):

– edge CEDS: The FCs of each edge CEDS include edge service management, edge data synchronization, edge service synchronization, edge data migration, edge service migration, groups of agents (edge-MEC agents, edge-edge agents, edge-core agents and edge-DLT agents), and edge DLT systems.

– core CEDS: The FCs of core CEDS include core service management, core data synchronization, core service synchronization, core service migration, core data migration, and groups of agents (core-edge agents, core-core agents and core-DLT agents), and core DLT systems.

Edge CEDS, in collaboration with corresponding core CEDS, provides cross edge DLT services to IoT devices. Edge CEDS interacts with local DLT clients in IoT devices. Local DLT clients in IoT devices can notify edge CEDS of location information of their host IoT devices. Additionally, edge CEDS can interact with MEC mobility services (see clause 8.3.1) to follow location-related information of connected IoT devices.

Edge CEDSs and corresponding core CEDS keep synchronization of data and services when it provides cross edge DLT services to IoT devices. Additionally, edge CEDSs in the same or different edge clouds can collaborate to provide dynamic seamless cross edge DLT services to mobile IoT devices.

CEDS exposes a group of reference points R1 to R5 (see clause 8.4) to facilitate internal interactions of the CEDS, and external interactions between the CEDS and other entities, such as MEC mobility services in edge clouds, and local DLT clients in LANs, etc.

8.1 Functional components of core CEDS

8.1.1 Core service management functional component (CSM-FC)

The CSM-FC of core CEDS collaborates with corresponding edge CEDSs to manage cross edge DLT services, including data, services and resources in core clouds and information of IoT devices, etc.

The CSM-FC of core CEDS provides functionalities as below:

– Collaborating with corresponding edge CEDSs to manage cross edge DLT services;

– Managing the profiles and policy of synchronization and migration of cross edge DLT services;

– Supporting data and service synchronization of cross edge DLT services with corresponding edge CEDSs;

– Supporting data and service migration of cross edge DLT services among corresponding edge CEDSs in the same or different edge clouds;

– Collaborating with core DLT systems to provide core part of functionalities of cross edge DLT services in core clouds;

– Providing and managing resources (such as storage, computation, communication, etc.) for cross edge DLT services in core clouds;

– Supporting interaction with other CEDS in the same or different core clouds.

8.1.2 Core data synchronization functional component (CDS-FC)

The CDS-FC of core CEDS supports data synchronization between core CEDS and corresponding edge CEDSs, according to the profiles and policy of CEDSs and relevant national and regional data regulations.

The CDS-FC of core CEDS provides functionalities as below:

– Collaborating with corresponding edge CEDSs (EDS-FCs, see clause 8.2.2) to synchronize data of cross edge DLT services, including:

  • Receiving data from corresponding edge CEDSs on demand;

  • Dispatching data to corresponding edge CEDSs on demand;

– Collaborating with CSM-FC and core DLT systems to manage the data for synchronization of cross edge DLT services, including:

  • Storing relevant data into core DLT systems;

  • Retrieving relevant data from core DLT systems;

  • Keeping relevant data consistent between core CEDS and the core DLT systems.

8.1.3 Core service synchronization functional component (CSS-FC)

The CSS-FC of core CEDS supports dynamic seamless service synchronization between core CEDS and corresponding edge CEDSs, according to the profiles and policy of CEDSs and relevant national and regional data regulations.

The CSS-FC of core CEDS provides functionalities as below:

– Collaborating with corresponding edge CEDSs (ESS-FCs, see clause 8.2.3) to synchronize dynamic and real-time service information of cross edge DLT services, including:
  - Receiving relevant information from corresponding edge CEDSs on demand;
  - Dispatching relevant service information to corresponding edge CEDSs on demand;
– Collaborating with CSM-FC and core DLT systems to manage dynamic and real-time service information for synchronization of cross edge DLT services, including:
  - Storing relevant information into core DLT systems;
  - Retrieving relevant information from core DLT systems;
  - Keeping relevant information consistent between core CEDS and the core DLT systems.

8.1.4 Core data migration functional component (CDM-FC)

The CDM-FC of core CEDS supports data migration between corresponding edge CEDSs on demand, according to the profiles and policy of CEDSs and relevant national and regional data regulations.

The CDM-FC of core CEDS provides functionalities as below:

– Collaborating with corresponding edge CEDSs (EDM-FCs, see clause 8.2.4) to migrate data of cross edge DLT services, including:
  - Validating the data migration requests;
  - Supporting the transferring of data from one corresponding edge CEDS to other corresponding edge CEDS(s) on demand;
– Collaborating with CSM-FC and core DLT systems to manage the data for migration of cross edge DLT services, including:
  - Storing relevant data into core DLT systems;
  - Retrieving relevant data from core DLT systems;
  - Keeping relevant data consistent between core CEDS and the core DLT systems.

8.1.5 Core service migration functional component (CVM-FC)

The CVM-FC of core CEDS supports dynamic seamless service migration between corresponding edge CEDSs on demand, according to the profiles and policy of CEDSs and relevant national and regional data regulations.

The CVM-FC of core CEDS provides functionalities as below:

– Collaborating with corresponding edge CEDSs (EVM-FCs, see clause 8.2.5) to migrate service of cross edge DLT services, including:
  - Validating relevant service migration requests;
  - Supporting the transferring of relevant information from one corresponding edge CEDS to other corresponding edge CEDSs on demand;
– Collaborating with CVM-FC and core DLT systems to manage the dynamic service information for migration of cross edge DLT services, including:
  - Storing relevant information into core DLT systems;

- Retrieving relevant information from core DLT systems;
- Keeping relevant information consistent between core CEDS and the core DLT systems.

8.1.6 Core-edge agent functional component (CEA-FC)

The CEA-FC of core CEDS, collaborating with edge core agent functional components (ECA-FCs) of corresponding edge CEDSs (see clause 8.2.7), supports interactions between core CEDS and corresponding edge CEDS on demand.

The CEA-FC of core CEDS provides functionalities as below:

– Supporting interactions between core CEDS and corresponding edge CEDSs for synchronization and migration of data and services of cross edge DLT services;

– Supporting service management of data and services of cross edge DLT services.

8.1.7 Core-core agent functional component (CCA-FC)

The CCA-FC of core CEDS supports collaborations with the core CEDSs of other CEDSs in the same or different core clouds.

NOTE – Collaborations between core CEDSs of different CEDSs in core clouds are out of scope of this Recommendation.

8.1.8 Core-DLT agent functional component (CDA-FC)

The CDA-FC of core CEDS supports interactions between core CEDS and core DLT systems (see clause 8.1.9) in core clouds.

The CDA-FC of core CEDS provides functionalities as below:

– Supporting interactions between components of core CEDS and core DLT systems for cross edge DLT systems, including management for relevant data and services;

– Supporting the maintenance of consistent data and services of cross edge DLT services.

8.1.9 Core DLT system

The core DLT systems deployed in core clouds and corresponding edge DLT systems (see clause 8.2.10) under the supporting of CEDSs (core CEDS and corresponding edge CEDSs), provide cross edge DLT services for IoT devices. Core DLT systems interact with components of core CEDS by using core-DLT agent functional component (CDA-FC).

NOTE – Core DLT system itself is out of scope of this Recommendation.

8.2 Functional components of edge CEDS

8.2.1 Edge service management functional component (ESM-FC)

The ESM-FC of edge CEDS collaborates with corresponding core CEDS to manages cross edge DLT services, including data, services and resources in edge clouds and information of IoT devices, etc.

The ESM-FC of edge CEDS provides functionalities as below:

– Collaborating with corresponding core CEDS to manage cross edge DLT services;

– Managing the profiles and policy of synchronization and migration of cross edge DLT services;

– Supporting data and service synchronization of cross edge DLT services with corresponding core CEDS;

– Supporting data and service migration of cross edge DLT services among corresponding edge CEDSs in the same or different edge clouds;

– Collaborating with edge DLT systems to provide edge part of functionalities of cross edge DLT services in edge clouds;
– Providing and managing resources (such as storage, computation, communication, etc.) for cross edge DLT services in edge clouds;
– Collaborating with multi-access edge computing (MEC) mobility services (see clause 8.3.1) in edge clouds to follow mobility information of IoT devices (such as location) for cross edge DLT services.

8.2.2 Edge data synchronization functional component (EDS-FC)

The EDS-FC of edge CEDS supports synchronizing data of cross edge DLT service with corresponding core CEDS for IoT devices on demand, according to the profiles and policy of CEDSs and relevant national and regional data regulations.

The EDS-FC of edge CEDS provides functionalities as below:

– Collaborating with corresponding core CEDS (CDS-FC, see clause 8.1.2) to synchronize data of cross edge DLT services, including:
  - Receiving data from corresponding core CEDS on demand;
  - Sending data to corresponding core CEDS on demand;
– Collaborating with edge service management functional component (ESM-FC) and edge DLT systems to manage the data for synchronization of cross edge DLT services, including:
  - Storing relevant data into edge DLT systems;
  - Retrieving relevant data from edge DLT systems;
  - Keeping relevant data consistent between edge CEDS and the edge DLT systems.

8.2.3 Edge service synchronization functional component (ESS-FC)

The ESS-FC of edge CEDS supports dynamic seamless service synchronization of cross edge DLT services with corresponding core CEDS, according to the profiles and policy of CEDSs and relevant national and regional data regulations.

The ESS-FC of edge CEDS provides functionalities as below:

– Collaborating with corresponding core CEDS (CSS-FC, see clause 8.1.3) to synchronize dynamic and real-time service information of cross edge DLT services, including:
  - Receiving relevant information from corresponding core CEDS on demand;
  - Sending relevant service information to corresponding core CEDS on demand;
– Collaborating with ESM-FC and edge DLT systems to manage dynamic and real-time service information for synchronization of cross edge DLT services, including:
  - Storing relevant information into edge DLT systems;
  - Retrieving relevant information from edge DLT systems;
  - Keeping relevant information consistent between edge CEDS and the edge DLT systems.

8.2.4 Edge data migration functional component (EDM-FC)

The EDM-FC of edge CEDS supports data migration of cross edge DLT services between corresponding edge CEDSs, according to the profiles and policy of CEDSs and relevant national and regional data regulations.

The EDM-FC of edge CEDS provides functionalities as below:

– Collaborating with corresponding edge CEDSs to migrate data of cross edge DLT services, including:
  - Validating the data migration requests;
  - Supporting the transferring of data from one corresponding edge CEDS to other corresponding edge CEDS(s) on demand;
– Collaborating with ESM-FC and edge DLT systems to manage the data for migration of cross edge DLT services, including:
  - Storing relevant data into edge DLT systems;
  - Retrieving relevant data from edge DLT systems;
  - Keeping relevant data consistent between edge CEDS and the edge DLT systems.

8.2.5 Edge service migration functional component (EVM-FC)

The EVM-FC of edge CEDS supports dynamic seamless service migration between corresponding edge CEDSs on demand, according to the profiles and policy of CEDSs and relevant national and regional data regulations.

The EVM-FC of edge CEDS provides functionalities as below:

– Collaborating with corresponding edge CEDSs to migrate service of cross edge DLT services, including:
  - Validating relevant service migration requests;
  - Supporting the transferring of relevant information from one corresponding edge CEDS to other corresponding edge CEDS(s) on demand;
– Collaborating with ESM-FC and edge DLT systems to manage the dynamic service information for migration of cross edge DLT services, including:
  - Storing relevant information into edge DLT systems;
  - Retrieving relevant information from edge DLT systems;
  - Keeping relevant information consistent between edge CEDS and the edge DLT systems.

8.2.6 Edge-MEC agent functional component (EMA-FC)

The EMM-FC of edge CEDS interacts with the external MEC mobility service of a communication network in an edge cloud (see clause 8.3.1), to dynamically retrieve mobility information (such as location) of IoT devices.

NOTE – Edge-MEC agent and the methods to interact with MEC mobility services in edge clouds are out of scope of this Recommendation.

8.2.7 Edge-core agent functional component (ECA-FC)

The ECA-FC of edge CEDS, collaborating with CEA-FCs of corresponding core CEDS (see clause 8.1.6), supports interactions between edge CEDS and corresponding core CEDS on demand.

The ECA-FC of edge CEDS provides functionalities as below:

– Supporting interactions between edge CEDS and corresponding core CEDS for synchronization and migration of data and services of cross edge DLT services;

– Supporting service management of data and service synchronization of cross edge DLT services.

8.2.8 Edge-edge agent functional component (EEA-FC)

The EEA-FC of edge CEDS, collaborating with other components of edge CEDS and corresponding core CEDS, supports dynamic seamless service migration between edge CEDSs on demand.

The EEA-FC of edge CEDS provides functionalities as below:

– Supporting the migration of data and services to target corresponding edge CEDS(s) for cross edge DLT services, dynamically and seamlessly;

– Supporting the migration of data and services from other corresponding edge CEDS(s) for cross edge DLT services, dynamically and seamlessly;

– Supporting service management of data and service migration of cross edge DLT services.

8.2.9 Edge-DLT agent functional component (EDA-FC)

The EDA-FC of edge CEDS supports interactions between edge CEDS and edge DLT systems (see clause 8.2.10) in edge clouds.

The EDA-FC of edge CEDS provides functionalities as below:

– Supporting interactions between components of edge CEDS and edge DLT systems for cross edge DLT systems, including management for relevant data and services;

– Supporting the maintenance of consistent data and services of cross edge DLT services.

8.2.10 Edge DLT system

The edge DLT systems deployed in edge clouds and corresponding core DLT systems (see clause 8.1.9) under the supporting of CEDSs (core CEDS and edge CEDSs), provide cross edge DLT services for IoT devices. Edge DLT systems interact with components of edge CEDS by using EDA-FC.

NOTE – The edge DLT system itself is out of scope of this Recommendation.

8.3 External entities

8.3.1 MEC mobility services of communication network in edge clouds

The MEC mobility services of the communication network in edge clouds provide mobility information (such as location) of IoT devices on demand.

8.3.2 Local DLT clients in local area networks

The local DLT clients deployed in local area networks provide cross edge DLT-related functionalities in IoT devices, such as client location management, client configure, etc.

8.4 Reference points

The CEDS exposes a group of reference points (R1 to R5) to support interactions between its core CEDS and corresponding edge CEDSs, and interactions with other functional components and entities, including:

– R1: exposed by CEA-FC of core CEDS, to support interactions with ECA-FCs of corresponding edge CEDSs for cross edge DLT services, including supports of:

- Service management of cross edge DLT services for IoT devices;
- Service and data synchronization between core CEDS and corresponding edge CEDSs;
- Service and data migration between corresponding edge CEDSs.

– R2: exposed by EEA-FC of edge CEDS, to support service and data migration with other corresponding edge CEDS in the same or different edge clouds for cross edge DLT services for mobile IoT devices, including supports of:

  • Service management of cross edge DLT services for IoT devices.

  • Service and data migration between corresponding edge CEDSs.

– R3: exposed by edge DLT systems in edge clouds, for edge CEDS to interact with local DLT clients to provides cross edge DLT services to IoT devices in local area networks.

– R4: exposed by EMA-FC of edge CEDS, for edge CEDS to interact with MEC mobility service in edge clouds to follow mobility information of IoT devices in local area networks.

– R5: exposed by EEA-FC of core CEDS, for core CEDS to interact with other core CEDSs in the same or different core clouds to exchange information of IoT devices for cross edge DLT services.

NOTE – Reference points R3, R4 and R5 are out of scope of this Recommendation.

9 General procedures of the cross edge decentralized service by using DLT and edge computing technologies

This clause provides general procedures of CEDS.

9.1 Synchronization of data and service of DLT services between core cloud and edge cloud

This procedure shows how a given CEDS performs data and service synchronization of a cross edge DLT service for an IoT device between its core CEDS and edge CEDS.

The main steps reflecting a normal situation are described below (see Figure 9-1):

Step 1 A local DLT client hosted by an IoT device in a LAN (LAN A) requests access to a DLT service provided by an edge DLT system (edge DLT system A of edge CEDS A).

The request is sent to the edge DLT system (edge DLT system A).

Step 2 The edge DLT system (edge DLT system A) forwards the request to related FCs of edge CEDS (edge CEDS A).

The edge DLT system (edge DLT system A) collaborates with the related FCs of the edge CEDS (edge CEDS A) to manage the DLT service for the local DLT client.

Step 3 The related FCs of the edge CEDS (edge CEDS A) negotiates with a relevant MEC mobility service in the same edge cloud (edge cloud A) to validate mobility information (such as location) of the DLT client.

The local DLT client may be in the edge cloud (edge cloud A) already, or may be roaming in this edge cloud (edge cloud A) from other edge cloud.

If the local DLT client is already in the same edge cloud (edge cloud A), then it goes to step 5, otherwise, it goes to step 4.

Step 4 If the local DLT client is roaming from other edge cloud (such as edge cloud B), and then performs the procedures of data and service migration of DLT service between the two edge clouds (see clause 9.2).

Step 5 The FCs of edge CEDS (edge CEDS A) sends a request to FCs of core CEDS for synchronizing data and service of the DLT service.

Step 6 The FCs of core CEDS collaborate with related core DLT system to manage the DLT service inside of the core cloud.

If not accepted by the core CEDS, it goes step 9 to stop the request of the local DLT client.

Step 7 If accepted by the core CEDS, then the edge CEDS (edge CEDS A) synchronizes data and service of the DLT service.

The data and service of the DLT service may be from other edge CEDS.

Step 8 Similar to step 2, FCs of the edge CEDS (edge CEDS A) collaborate with the edge DLT system (edge DLT system A) to manage the DLT service for the local DLT client.

Step 9 and 10 The edge DLT system (edge DLT system A) provides the DLT service to the local DLT client accordingly, and synchronizes the data and service of the DLT service with the core CEDS.

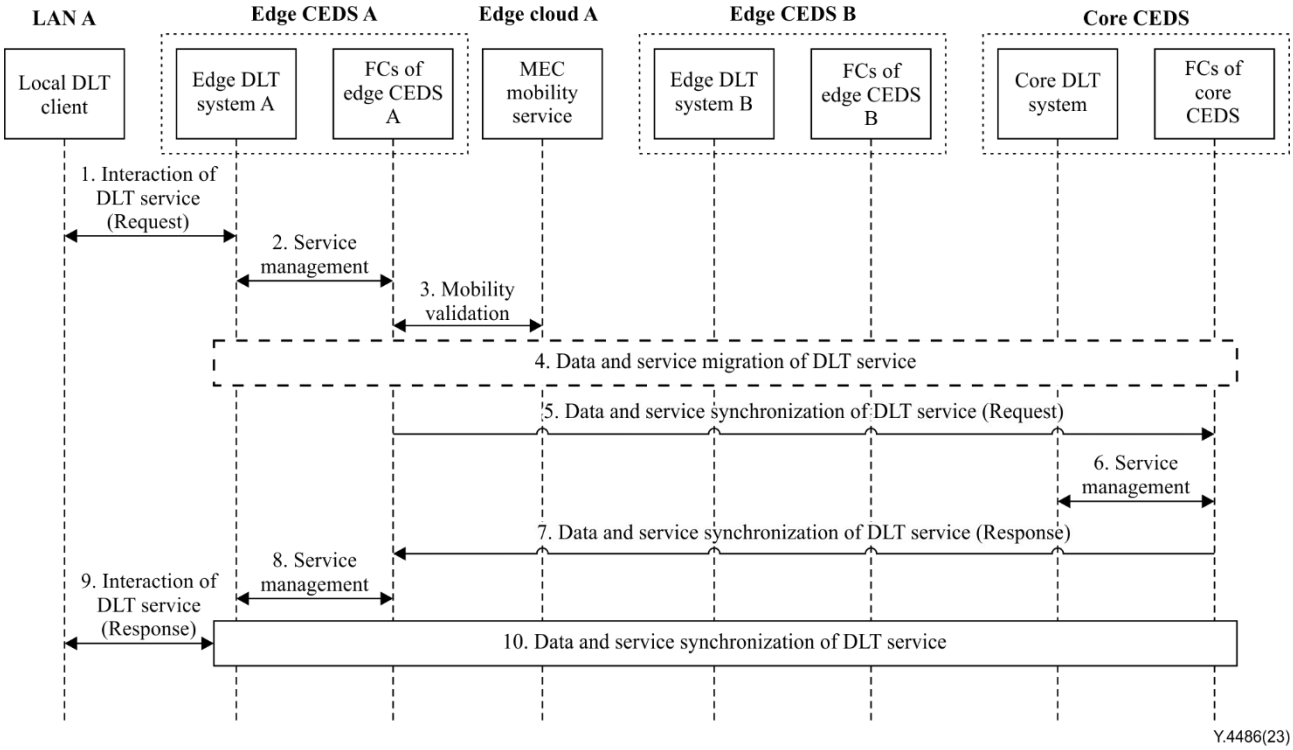

Figure 9-1 – Flow for data and service synchronization of cross edge DLT services

9.2 Migration of data and service of DLT services between edge clouds

This procedure shows how a given CEDS performs data and service migration of cross edge DLT service for an IoT device between different edge CEDSs.

The main steps reflecting a normal situation are described below (see Figure 9-2):

Step 1 A local DLT client hosted in an IoT device firstly in a LAN (LAN A) accesses a DLT service performed by an edge DLT system (edge DLT system A).

Afterwards when, the local DLT client roams to a new edge cloud (such as edge cloud B), the local DLT client will manage to continuously access the DLT service.

Step 2 The local DLT client manages to access the DLT service via edge CEDS in the new edge cloud (edge cloud B), and sends a request to the new target edge DLT system (edge DLT system B).

Step 3 The new target edge DLT system (edge DLT system B) forwards the request to related FCs of the edge CEDS (edge CEDS B).

The new target edge DLT system (edge DLT system B) collaborates with related FCs of the edge CEDS (edge CEDS B) to manage the DLT service for the local DLT client.

Step 4 The related FCs of the edge CEDS (edge CEDS B) negotiates with a relevant MEC mobility service in the same edge cloud (edge cloud B) to validate mobility information of the local DLT client.

If the local DLT client is already in the same edge cloud (edge cloud B), then it goes to step 8, otherwise, it goes to step 12.

Step 5 and 6 The related FCs of the edge CEDS (edge CEDS B) negotiates with related core CEDS, and notifies the related core CEDS of the roaming information, and requests to provide the DLT service to the local DLT client.

The edge CEDS (edge CEDS B) collaborates with the related core CEDS to decide whether to provide the relevant DLT service to the local DLT client.

If not accepted, then it goes to step 12.

Step 7 The local DLT client stops accessing the DLT service via the old edge CEDS (edge CEDS A), then the old edge CEDS (edge CEDS A) collaborates with the related core CEDS to synchronize data and service of the DLT service for the IoT device (see clause 9.1).

Step 8,9,10 and 11 If the new target edge CEDS (edge CEDS B) accepts the request of the local DLT client, it sends a request to the old edge CEDS (edge CEDS A) to migrate data and service of the DLT service.

The edge DLT system and FCs of the old edge CEDS (edge CEDS A) check the request. If not accepted, it goes to step 12.

If accepted, the old edge CEDS (edge CEDS A) interacts with the new target edge CEDS (edge CEDS B) to migrate the data and service of the DLT service.

Step 12 and 13 The new target edge DLT system (edge DLT system B) provides the DLT service to the local DLT client accordingly to synchronize the data and service of the DLT service with the core CEDS.

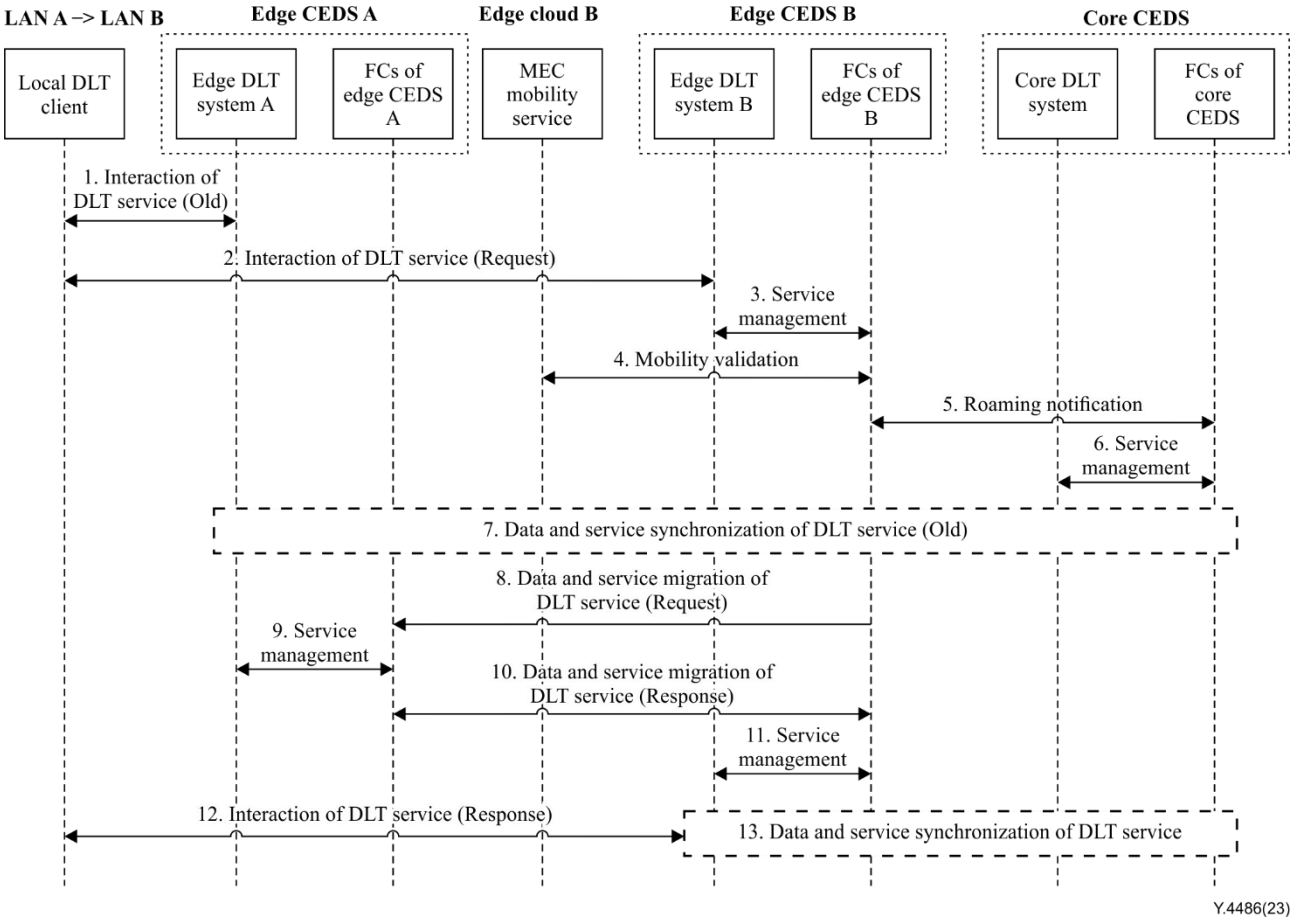

Figure 9-2 – Flow for data and service migration of cross edge DLT services

10 Security considerations

The data of IoT resources might be exposed to many security attacks, and third parties may exploit the data for illegal IoT services. To prevent these situations, the data should be secured during the interactions between users and service providers. The CEDS is responsible for the security of data during the synchronization and migration procedures from security threats (e.g., tampering of the communication, replay attack, distributed denial of service). The data security procedure should also follow local laws and regulations.

Appendix I

Use case of the cross edge decentralized service for IoT devices by using DLT and edge computing technologies

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

This appendix provides a use case to illustrate the concept of the cross edge decentralized service for IoT devices by using DLT and edge computing technologies.

I.1 Cross edge traffic information sharing of Internet of vehicles enhanced by CEDS

This use case shows Internet of vehicles (IoV) using DLT-based IoV services enhanced by a given CEDS to share traffic information in cross edge environments.

Without going into specifics, the core CEDS of the CEDS is deployed in the core cloud, and there is one edge CEDS of the CEDS in each of the edge clouds (see Figure I.1). The core CEDS and each of the edge CEDSs of the CEDS include a DLT-based IoV service. All of the DLT-based IoV services collaborate with each other to provide and speed up the seamless cross edge service for the IoV to share traffic information.

When the IoV moves from one local area network (LAN) to other LANs, the DLT-based IoV services in the target edge clouds can obtain the mobility information of the IoV from the edge nodes of communication networks using the supports of the corresponding edge CEDSs, and can then prepare the service environment for the IoV, including migration of data and services of the DLT-based IoV services from the original edge CEDS. In this way the IoV can get seamless and uninterrupted service such as sharing traffic information provided by the DLT-based IoV services when it is roaming in different edge clouds.

When the IoV shares traffic information in one edge cloud using the supports of the CEDS, the entities of DLT-based IoV services in the core cloud and in the edge clouds can synchronize data and services of the DLT-based services for the IoV in order to speed up the sharing operations.

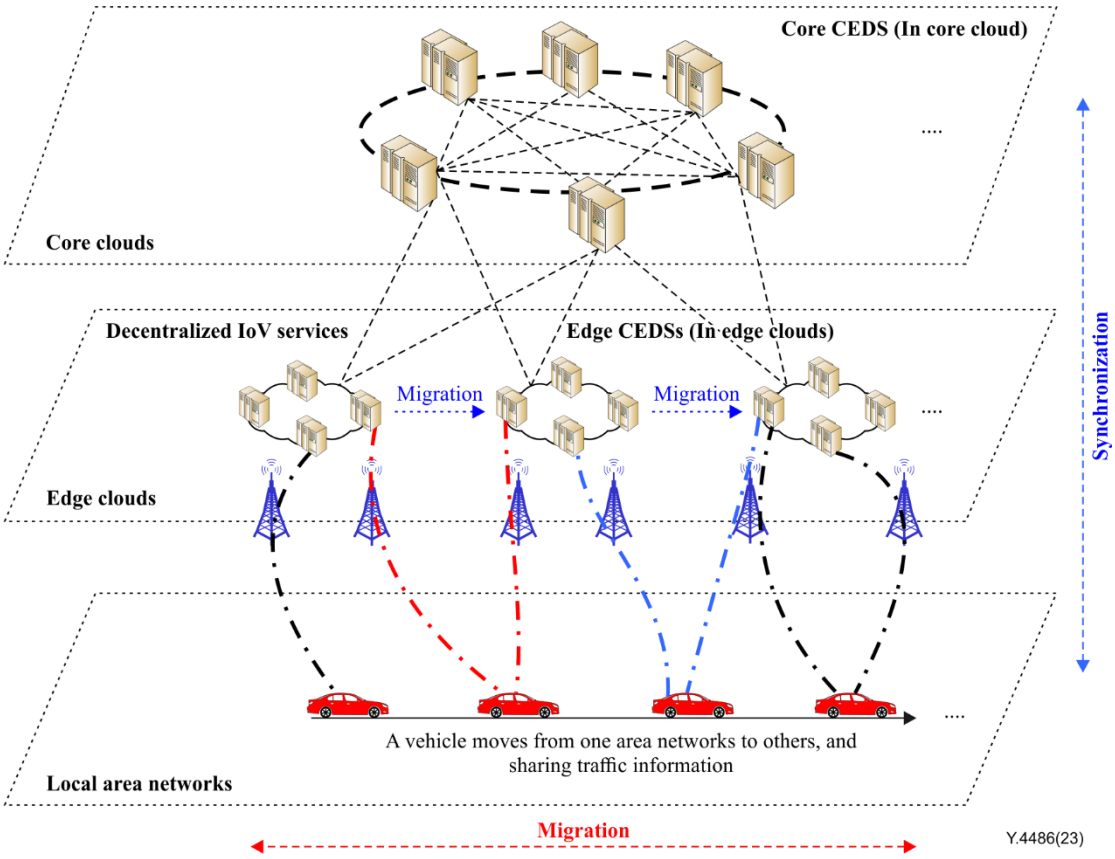

Figure I.1 – Use case of cross edge traffic information sharing of Internet of vehicles enhanced by CEDS

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