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SERIES H: AUDIOVISUAL AND MULTIMEDIA SYSTEMS

Broadband, triple-play and advanced multimedia services – Ubiquitous sensor network applications and Internet of Things

Functional architecture for virtual content delivery networks

Recommendation ITU-T H.644.1

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Recommendation ITU-T H.644.1

Functional architecture for virtual content delivery networks

Summary

Recommendation ITU-T H.644.1 describes a functional architecture for a virtual content delivery network (VCDN). It specifies the overall functional architecture, domains and functional role relationships, functional blocks, reference points, relationships between physical resources, virtual resources and logically isolated network partitions (LINPs), functions and their mutual relationships, and security considerations. VCDNs can realize accurate infrastructure distribution and elastic resource scheduling. VCDNs can integrate the resources of a content delivery network (CDN), reduce construction costs and improve scalability.

History

Edition	Recommendation	Approval	Study Group	Unique ID*
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Content delivery network, streaming service, virtualization.

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Functional architecture for virtual content delivery networks

1 Scope

This Recommendation describes the functional architecture for virtual content delivery networks (VCDNs) and the scope of the document covers:

– domains and functional role relationship of VCDNs

– VCDN functional architecture

– reference points between functional blocks of VCDNs.

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 F.743.4] Recommendation ITU-T F.743.4 (2017), *Functional requirements for virtual content delivery networks.*

[ITU-T Y.1901] Recommendation ITU-T Y.1901 (2009), *Requirements for the support of IPTV services.*

[ITU-T Y.1910] Recommendation ITU-T Y.1910 (2008), *IPTV functional architecture.*

[ITU-T Y.2019] Recommendation ITU-T Y.2019 (2010), *Content delivery functional architecture in NGN*.

[ITU-T Y.3011] Recommendation ITU-T Y.3011 (2012), *Framework of network virtualization for future networks.*

[ITU-T Y.3012] Recommendation ITU-T Y.3012 (2014), *Requirements of network virtualisation for future networks.*

[ITU-T Y.3300] Recommendation ITU-T Y.3300 (2014), *Framework of software-defined networking*.

[ITU-T Y.3320] Recommendation ITU-T Y.3520 (2014), *Requirements for applying formal methods to software-defined networking.*

[ITU-T Y.3501] Recommendation ITU-T Y.3501 (2016), *Cloud computing – Framework and high-level requirements.*

[ITU-T Y.3512] Recommendation ITU-T Y.3512 (2014), *Cloud computing - Functional requirements of Network as a Service.*

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.

3.1.2 logically isolated network partition (LINP) [ITU-T Y.3011]: A network that is composed of multiple virtual resources which is isolated from other LINPs.

3.1.3 network virtualization [ITU-T Y.3011]: A technology that enables the creation of logically isolated network partitions over shared physical networks so that heterogeneous collection of multiple virtual networks can simultaneously coexist over the shared networks. This includes the aggregation of multiple resources in a provider and appearing as a single resource.

3.1.4 software-defined networking [ITU-T Y.3300]: A set of techniques that enables to directly program, orchestrate, control and manage network resources, which facilitates the design, delivery and operation of network services in a dynamic and scalable manner.

3.1.5 virtual content delivery network [ITU-T F.743.4]: A content delivery network using virtualisation technology that enables the allocation of virtual storage, virtual machines, and network resources according to vendors' requirements in a dynamic and scalable manner.

3.1.6 virtual resource [ITU-T Y.3011]: An abstraction of physical or logical resource, which may have different characteristics from the physical or logical resource and whose capability may be not bound to the capability of the physical or logical resource.

3.2 Terms defined in this Recommendation

None.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

AAA	Authentication, Authorization and Accounting
ACL	Access Control List
AF	Application Functions
API	Application Programming Interface
APP	Application
CDF	Content Delivery Functions
CDN	Content Delivery Network
CPU	Central Processing Unit
I/O	Input/Output
LINP	Logically Isolated Network Partition
OS	Operating System
QoS	Quality of Service
RAL	Resource Abstraction Layer
SDN	Software Defined Network
SLA	Service Level Agreement
VCDN	Virtual Content Delivery Network
VLAN	Virtual Local Area Network

VM Virtual Machine

VRCF Virtual Resource Control Functions

5 Conventions

In this Recommendation, the following conventions are used:

The keywords "is required" 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.

The keywords "can optionally" indicate an optional requirement which is permissible, without implying any sense of being recommended. This term is not intended to imply that the vendor's implementation must provide the option and the feature can be optionally enabled by the network operator/service provider. Rather, it means the vendor may optionally provide the feature and still claim conformance with the specification.

6 VCDN domains and functional role relationship

Figure 6-1 shows the main domains and function roles that are involved in the provision of a VCDN service. The content is delivered from the content domain to the end-user domain, passing by the service domain and network domain.

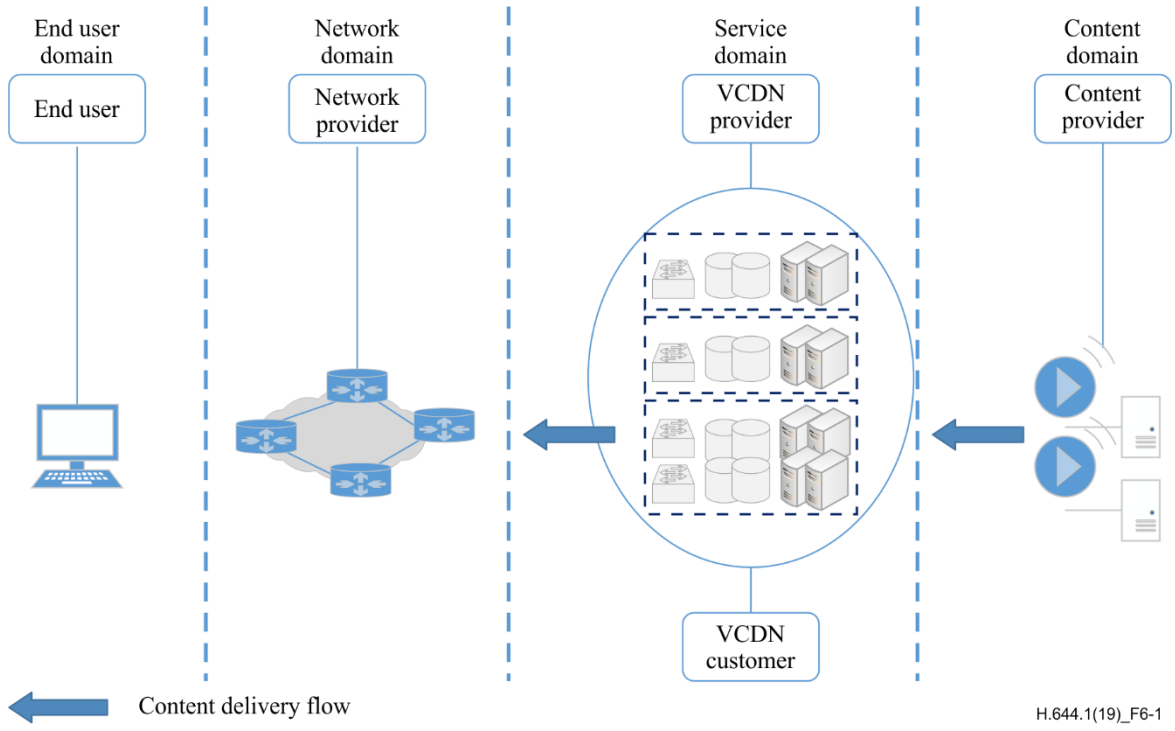

Figure 6-1 – VCDN domains and functional role relationship

The functional roles in Figure 6-1 are described as follows:

– **Content provider** [ITU-T Y.1910]: the entity that owns or is licensed to sell content or content assets.

– **VCDN service provider**: the entity that provides and maintains VCDN services to the VCDN consumers.

NOTE 1 – A VCDN provider can optionally also act as VCDN customer.

– **VCDN customer**: the entity that consumes VCDN services within a contract with a VCDN service provider.

– **Network provider**: the organization that maintains and operates the network components required for VCDN functionality.

NOTE 2 – A network provider can optionally also act as a VCDN service provider.

– **End user** [ITU-T Y.1910]: the actual user of the contents or services.

7 VCDN functional architecture

Figure 7-1 illustrates the VCDN functional architecture framework and its position by taking the IPTV functional architecture defined in [ITU-T Y.1910] as a basic implementation example.

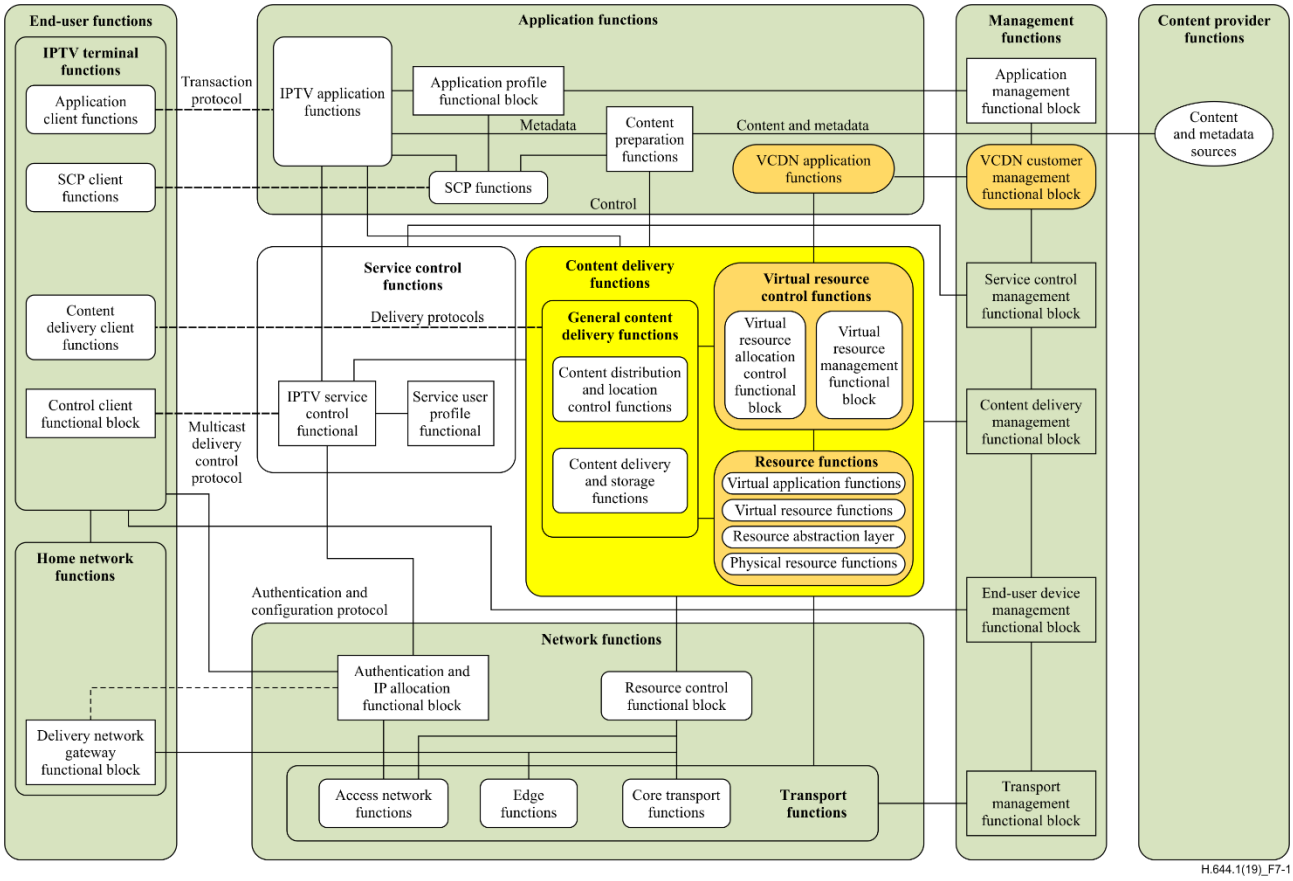

Figure 7-1 –VCDN functions involved in IPTV functional architecture

A VCDN implements content delivery functions described in [ITU-T Y.1910]; these are shown as a yellow rounded rectangle.

There are three functions in the content delivery functions: general content delivery functions, virtual resource control functions and resources functions. The application of virtual resource control functions and resource functions rely on virtual CDN resources. Content delivery functions defined in [ITU-T Y.1910] involve the traditional CDN functions, including basic CDN functions, such as content storage, distribution and delivery.

In comparison with virtual CDN functions using virtual CDN resources, the conventional CDN functions are enabled by physical CDN resources. VCDN concepts involve the basic CDN functions which rely on both physical CDN resources and virtual CDN resources. The entire VCDN functions

are implemented by taking advantage of the cooperation of virtual CDN functions and general CDN functions.

A VCDN is enabled with some new functional blocks described in [ITU-T Y.1910], which are shown as orange blocks, including VCDN application functions in application functions and VCDN customer functions in management functions. Both virtual resource control functions and resource functions are new functions added into content delivery functions.

A VCDN has the relationships with other functions described in [ITU-T Y.1910], which are shown as green blocks, including content provider functions, end-user functions and network functions.

The following clauses give descriptions for each functional group.

7.1 The primary functions

The primary functions involved in VCDNs implement the main functions of VCDNs.

7.1.1 Content delivery functions

The content delivery functions (CDF) described in [ITU-T Y.1910] receive content from the content provider functions. They store, process and deliver the content to the end-user functions by using the capabilities of the network functions under the control of the VCDN application functions.

7.1.2 VCDN application functions

The VCDN application functions (AF) are responsible for VCDN providers providing VCDN services to VCDN customers, by establishing a service portal for VCDN customers. With this portal VCDN customers can utilize some specific APIs to programme the services they need. Then the VCDN AF is able to deliver the requirements of VCDN customers to the CDF and virtual resource control functions for system configuration and resources allocation. In addition, the VCDN AF can also use the abstracted visual status report of the virtual resources which are provided by the VRCF.

VCDN application functions also provide authentication, authorization and accounting (AAA) function to VCDN customers.

7.1.3 Virtual resource control functions

Virtual resource control functions are responsible for managing resource functions, including physical resources and their abstracted sets or virtualized resources.

According to the request from the VCDN AF, an LINP is created by means of virtual resources. The allocation of a specific set of virtual resources to a specific LINP is under the control of a VRCF.

According to the configuration of each LINP, the VRCF requests network functions and resource functions to allocate resources and provide network capacities for the content delivery service.

VRCFs are composed of two functional blocks, which are shown in Figure 7-2.

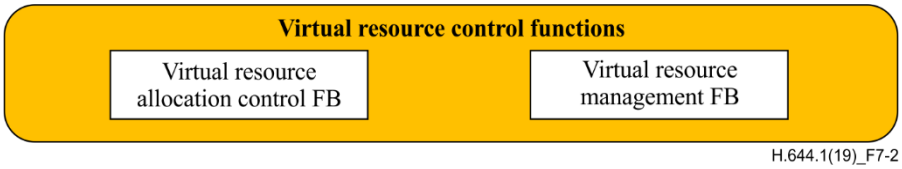

Figure 7-2 – VCDN resource control functions

7.1.3.1 Virtual resource allocation control functional block

The virtual resource allocation control functional block is responsible for selecting the most appropriate virtual resource from the resource functions. The resource selection is based on a virtual resource allocation policy and requirements from VCDN application functions, such as the feature or metadata of content to be stored, distribution policy, content ingest protocol, etc. With abstract sets

provided by the virtual resource management functional block, the virtual resource allocation control functional block is able to obtain the most appropriate resources corresponding to the VCDN customer's requirements.

7.1.3.2 Virtual resource management functional block

The virtual resource management functional block is responsible for managing the abstract sets of the virtual resource which are provided by the resource functions. Based on the VCDN customers' requirements, the virtual resources can be divided into different logical partitions. VCDN customers can manage their own partition by APIs provided by VCDN application functions.

7.1.4 Resource functions

Resource functions are used to provide essential capabilities for content delivery services and to support other system capabilities such as resource abstraction and control, management, security and monitoring.

Resource functions include physical resource functions and virtual resources functions. Physical resource functions support physical resource virtualization. Physical resources can be abstracted into virtual machines (VMs), virtual storage and virtual switches. The abstracted resources are isolated to an LINP. An LINP can be controlled to meet VCDN service customers' needs.

Resource functions are composed of four functions, as shown in Figure 7-3.

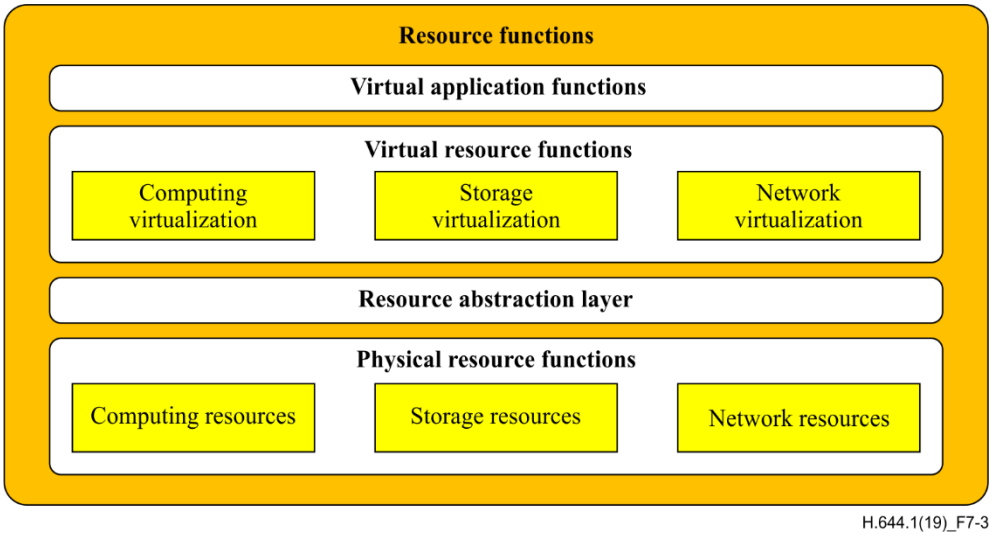

Figure 7-3 – VCDN resource functions

7.1.4.1 Virtual application functions

Virtual application functions create virtual applications by instancing the virtual resource provided by virtual resource functions. The virtual applications implement the required CDN functions while enabling VCDN customers to deploy their content consuming services.

7.1.4.2 Virtual resource functions

7.1.4.2.1 Computing virtualization functional block

The computing virtualization functional block is responsible for mapping the physical computing resources into a virtual machine resource pool. The physical computing resources pool is composed of many independent virtual machines. The capability of virtual machines is determined by the number of CPU, memory, I/O speed and so on, which form the main composition of virtual machines. The computing virtualization functional block can allocate relevant computing resources into the virtual machine pool. Moreover, it can allocate relevant CPU, memory and I/O resources to every

virtual machine. The allocation policy is based on the requirements of VCDN vendors and it is recommended to be able to be modified dynamically.

The computing virtualization functional block is recommended to isolate computing resource environments for each operating system. And it is recommended to support the migration of virtual machines within the computing resource pool.

Once the computing resource is reserved, the virtual computing resources provide service functions of the CDF, such as media service, load balance service and statistical service.

7.1.4.2.2 Storage virtualization functional block

The storage virtualization functional block is responsible for mapping the physical storage resources into a virtual storage resource pool. The virtual storage resource pool is composed of physical storage resources from at least one or more storage nodes. The size of the virtual storage resource pool is recommended to be preconfigured according to the VCDN costumer's requirement and it is recommended to be able to be modified dynamically.

For the case of content storage by VCDN service, according to the storage allocation policy and the content feature or metadata from the virtual resource allocation control functional block, the storage virtualization functional block obtains the storage resources according to the content feature or metadata from a virtual storage resource pool corresponding to the storage allocation policy.

Once the storage resource is reserved, the virtual resource allocation control functional block works with the CDF to store/read the content into/from a physical storage node corresponding to the storage resources.

7.1.4.2.3 Networking virtualization functional block

The networking virtualization functional block is responsible for allocating the network resources to the VCDN LINP in one CDN node. The network resources are specified an intranet network which is applied to access and interconnect servers in one CDN node, instead of a backbone network which is connected to other CDN nodes. A networking virtualization functional block provides network functions such as IP address allocation, VLAN allocation and virtual switching allocation, etc.

The networking virtualization functional block is recommended to support the dynamic migration of virtual machines. The related resources of virtual machines can be migrated with virtual machines migration. The service cannot be interrupted during virtual machine migration.

The networking virtualization functional block is recommended to support the mapping of a public IP address and private IP address in order to support dynamic migration of virtual machines addressing for different virtual machines.

The networking virtualization functional block is recommended to support the security policies for particular virtual machines to isolate the logical network among virtual machines, such as the establishment of a VLAN, ACL and firewalls.

7.1.4.3 Resource abstraction layer

The resource abstraction layer (RAL) interacts with the physical network resources to provide the abstraction of the physical network functions. Abstraction of physical resources are essential means to achieve on-demand and elastic characteristics of VCDNs. Physical resources can be abstracted into virtual machines (VMs), virtual storage and virtual networks. The abstracted resources are controlled to meet VCDN service vendors' needs.

7.1.4.4 Physical resource functions

Physical resources are used to provide essential capabilities for VCDN services and to support other system capabilities such as resource abstraction and control, management, security and monitoring.

Physical resources are classified into three categories: computing resources, storage resources and network resources.

Physical resources can be abstracted as several virtual resource units, such as a computing machine, a virtual storage space and a virtual network switch. The capability of a virtual resource unit is typically expressed in terms of hardware configuration, availability, scalability, manageability and energy consumption.

A set of physical resources are in an administrative domain. Physical resource management enables the configuration of physical resources which includes all physical resources used in the VCDN, such as storage, computing servers and network equipment used by different VCDN vendors. The requirements for the physical resource management are below.

The physical resources requirements include:

– It is recommended to support physical resource virtualization.

– It is recommended to support horizontal scalability (e.g., adding more computing servers or storage spaces) and vertical scalability (e.g., adding more resources with a computing servers or network equipment).

7.1.5 VCDN customer management functions

VCDN customer management functions request VCDN application functions to access VCDN services. VCDN customer management functions provide creating or deleting VCDN services, querying service logs, checking bills and allocating an LINP to support VCDN customer's need.

VCDN customer management functions request the content provider function to ingest the content of VCDN customer delivery to end users into CDF.

7.2 The other functions related to VCDN

The other functions related to VCDNs are in relationship with the management functions and the content provider functions, which are shown in the green colour block in Figure 7-1.

7.2.1 Content provider functions

Content provider functions are described in [ITU-T Y.1910]. They are provided by the entity that owns or is licensed to provide (i.e., sell, rent or give free usage permission) content or content assets (i.e., owner of the content, metadata and usage rights).

7.2.2 Network functions

The network functions are described in [ITU-T Y.1910]. They provide backbone network connectivity between the VCDN nodes located in different places and the end users. The network functions are shared across all services delivered by IP to end users.

The network functions contribute to the provision of the quality of service (QoS) and service required by VCDN services.

In terms of the requirements of VCDN customers which are dynamic, network functions are recommended to support software defined networks (SDNs) for dynamic reconfiguration.

7.2.3 End-user functions

End-user functions are described in [ITU-T Y.1910]. The end-user functions perform mediation between the end users and the VCDN infrastructure.

8 Reference points

The diagram in Figure 8-1 presents the high levelled reference points between the functions within the VCDN service scope.

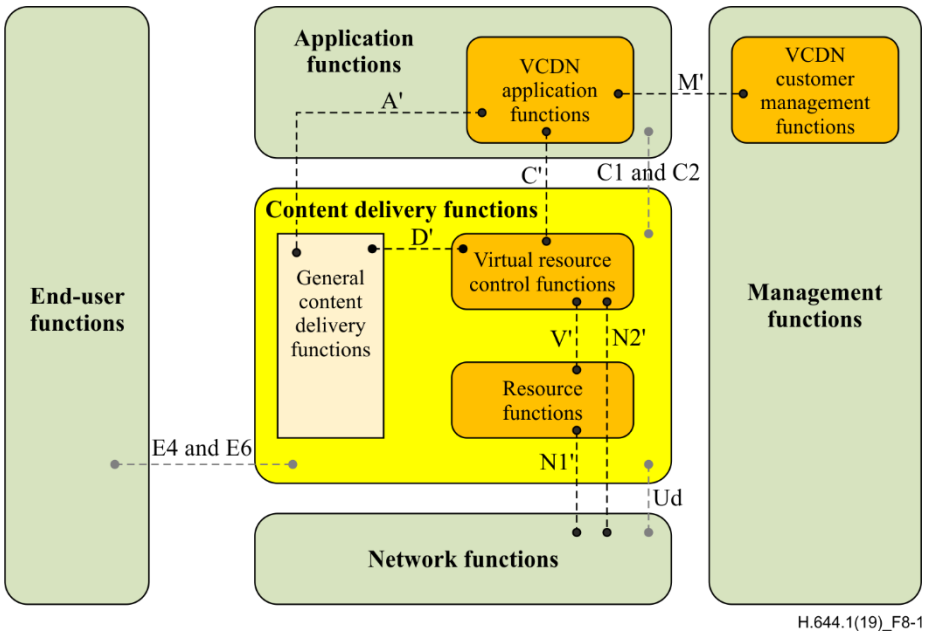

Figure 8-1 – Reference points of VCDN architecture

This Recommendation uses the existing C1, C2, E4, E6 and Ud reference points defined in [ITU-T Y.1910] which are related to content delivery functions and defines new reference points which are C', V', M', N', N2', D' and A' as follows.

The existing reference points are shown as dashed lines with black letters and new reference points are shown as solid lines with red letters.

8.1 Reference point M'

The M' reference point carries the information exchanged between the VCDN customer management functions and VCDN application functions. By M' reference, VCDN customers can optionally manage VCDN services and receive the service request from VCDN application functions.

The service request includes:

– service creation and deletion request
– service requirements request
– service log request
– service management request
– billing request.

8.2 Reference point C'

The C' reference point carries the information exchanged between VCDN application functions and virtual resource control functions. By C' reference point, the VCDN provides a series of APIs to the VCDN application functions. The APIs are related to implementing virtual resources allocation and deployment according to VCDN customers' requirements.

The service request includes:

– virtual resources orchestration request
– virtual resources template recalling request
– LINP (logical isolated network partition) configuration request.

8.3 Reference point A'

The A' reference point carries the information exchanged between VCDN application functions and general content delivery functions. By A' reference point, the VCDN provides a series of APIs to VCDN application functions. The APIs are related to implementing content delivery policy according to VCDN customers' requirements.

The service request includes:

– content delivery area configuration request

– content delivery scheduling configuration request

– content delivery log request.

8.4 Reference point V'

The V' reference point carries the information exchanged between virtual resource control functions and resource functions. An LINP is built from virtual resource functions which is an aggregation of virtual resources in all the nodes. Resource functions includes physical resources and virtual resources, which are abstracted to an LINP. By V' reference point, virtual resource control functions send service requests to manage and control resource functions.

The service request includes:

– resource allocation request

– resource reservation request

– resource adjust request

– resource release request

– virtual APP management request while virtual APP was created.

8.5 Reference point N1'

The N1' reference point carries the information exchanged between network functions and resource functions. By N1' reference point, virtual CDN data can be transported or forwarded among the physical network equipment in network functions.

8.6 Reference point N2'

The N2' reference point carries control information between virtual resource control functions and network functions if the network functions support the software defined networking (SDN) function. By N2' reference point, the virtual resource control functions send service requests to network functions according to VCDN customers' requirements.

The service request includes:

– network performance guarantee request

– network QoS guarantee request

– network optimize routing request

– expanding bandwidth request.

8.7 Reference point D'

The D' reference point carries the information exchanged between content delivery functions and resource functions. By D' reference point, VCDN resource functions can collect the information of physical hardware/software resources and add them as the logical resource pool.

The information includes:

– server loads status

– storage capacity status
– link traffic status.

9 Security considerations

The introduction of a multiple vendors in the overall service provided by means of virtual resources inevitably raises security challenges. Every vendor can manage their own LINP. An LINP has some network virtualization properties, such as flexibility, configurability, network abstraction and so on. So those kinds of properties would lead to the unexpected security and privacy issues.

To make sure that all the LINPs are logically independent, virtual resources allocated to each LINP have to be isolated from each other. From the viewpoint of security, isolation of virtual resources is essential in preventing users from unauthorized access or influence.

The following security issues should be considered to mitigate some of the potential security problems. Security and privacy issues should be considered during planning and designing network virtualization solutions. In addition, it is desirable that abnormal use of virtual resources can be detected by a collaborative mechanism of physical resource monitoring and fault management functions, virtual resource monitoring and fault management functions, and LINP monitoring and fault detection functions.

The issues contain the security and privacy requirements of VCDN vendors, VCDN providers and end users. In order to stop malicious access, the AAA functions are essential to operate LINPs. In addition, it is necessary to keep monitoring the security and privacy of data and applications that are implemented and deployed in VCDN LINPs.

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