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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

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# Virtual content delivery network: Network virtualization

Recommendation ITU-T H.644.2

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# Recommendation ITU-T H.644.2

## Virtual content delivery network: Network virtualization


### Summary

Recommendation ITU-T H.644.2 specifies the functional architecture, related functions and functional blocks, and high-level reference points which implement content delivery network (CDN) virtualization by utilizing networking virtualization technologies. Based on the functional architecture and functions, this Recommendation also introduces the various technical solutions of the CDN nodes virtualization utilizing current network virtualization technologies, such as network function virtualization and software-defined networks.



### History

| Edition | Recommendation | Approval | Study Group | Unique ID* |
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| 1.0 | ITU-T H.644.2 | 2019-11-29 | 16 | 11.1002/1000/14111 |

### Keywords

Content delivery network, network virtualization, software-defined network, virtualization.


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## Virtual content delivery network: Network virtualization

### 1 Scope

This Recommendation specifies the functional architecture, related functions and functional blocks, and high-levelled reference points which support content delivery network (CDN) virtualization by utilizing networking virtualization technologies. This Recommendation also describes the various technical solutions of the CDN nodes virtualization utilizing current network virtualization 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 H.644.1] Recommendation ITU-T H.644.1 (2019), *Functional architecture for virtual content delivery networks*.

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

[ITU-T Y.3302] Recommendation ITU-T Y.3302 (2017), *Functional architecture of software-defined networking*.

### 3 Definitions

#### 3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

**3.1.1 content delivery network** [b-ITU-T Y.2084]: A content delivery network (CDN) is a system of distributed servers that deliver content (e.g., web pages, files, videos and audio) to users based on pre-defined criteria such as the geographic locations of users, the status of the content delivery server and the IP network connection.

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

**3.1.3 network virtualization** [b-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** [b-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 manners.

**3.1.6 virtual resource** [b-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

This Recommendation defines the following term:

**3.2.1 network virtualization system**: A software platform or the logical functions collection which can provide the capability of network resource virtualization. Its physical system components can be deployed in a centralized way or geographically distributed way.

## 4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

| | |
|---|---|
| BSS | Business Support System |
| CDN | Content Delivery Network |
| CP | Content Provider |
| GSLB | Global Server Load Balance |
| LINP | Logically Isolated Network Partition |
| MANO | Management and Orchestrator |
| OSS | Operation Support System |
| RCF | Resource Control Functions |
| RF | Resource Functions |
| RP | Reference Point |
| SDN | Software Defined Network |
| SP | Service Provider |
| VCDN | Virtual Content Delivery Network |
| VN | Virtual Network |
| VNAM | Virtual Network Application Management (VNAM) |
| VNRC | Virtual Network Resource Control |

## 5 Conventions

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 document is to be claimed.

– The keywords "is prohibited from" 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.

– The keywords "is not recommended" indicate a requirement which is not recommended but which is not specifically prohibited. Thus, conformance with this specification can still be claimed even if this requirement is present.

– 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 Introduction

The target of a conventional CDN is to improve the service QoE by pushing the content to the server node which is nearest to the end user. However, the efficiency of a CDN will be affected by various factors, such as loading balance status, bandwidth changing, network traffic and the underlay network topology. The current network is fixed, non-service aware and hard to be replaced. For some CDN solutions, CDN nodes may have the capability to detect and retrieve the network status periodically for service optimizing. But the problem is, the retrieved network information is unreliable, which may reduce the CDN service efficiency. On the other hand, it is difficult for the service provider to quickly create and distribute a new service based on the fixed network hardware and configuration.

Therefore, as the fundamental element of CDNs, network innovation brings a great benefit to the service provider or CDN operator to optimize their CDN service. A flexible, programmable and service-aware network would give an opportunity to solve the problem mentioned above and reduce the cost of CDN service investment and maintenance.

Figure 6-1 shows the functional component that relates to network virtualization in the virtual content delivery network (VCDN). The functional architecture can be found in [ITU-T H.644.1].

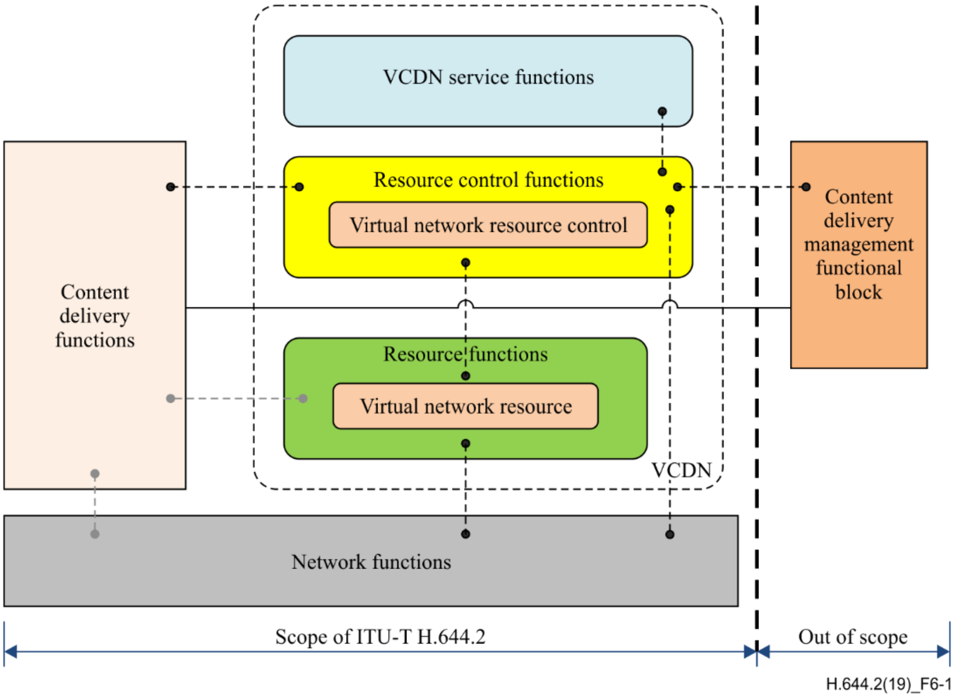


**Figure 6-1 – Functions related to network virtualization in VCDN architecture**

Figure 6-1 presents the basic idea of network virtualization related functions within the scope of VCDNs.

The physical network resource in network functions, such as routers and switches, can be abstracted in the resource function and be orchestrated and managed by the resource control functions (RCF). The orchestrator and management can be implemented in the VN MANO (virtual network management and orchestrator) functions which could be integrated with the RCF. Alternatively, the VN MANO functions can be separated from the RCF and act as third party functions. In this case, the communication between the RCF and third party MANO can be realized through a standard interface.

The network resource control may be based on the request from the content delivery management functional block or be dynamically modified according to the network information from the under layer network.

Resource functions (RF) will provide an abstract resource infrastructure based on the physical resource from the content delivery functions (CDF) and create the required virtual resource by the instructions of the RCF.

# 7 Functions and functional blocks related to network virtualization under VCDN architecture

Resource control functions and resource functions handle the core functionalities of CDN virtualization. The following clauses specify the functions and functional blocks within those two functions which relate to the scope of network virtualization.

## 7.1 Functions and functional blocks in resource control functions

Resource control functions handle the orchestration and management of the virtual network resource abstracted from the resource functions. It also creates and manages the networking related application instances to meet the VCDN operator's requirements. With the combination of these components, the RCF is able to control the virtual network resource creation, allocation and release.

Figure 7-1 shows the functions and functional blocks in the RCF.

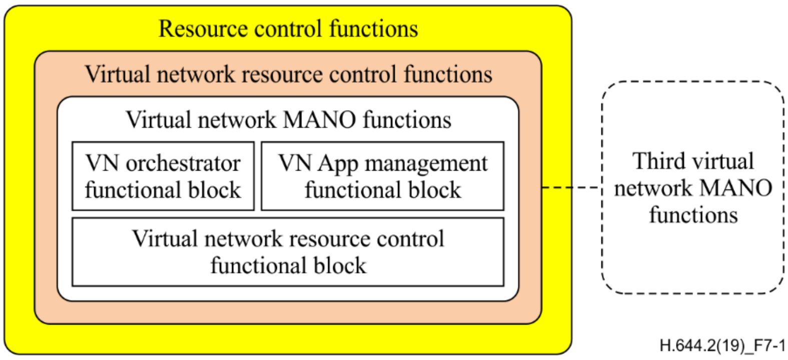


**Figure 7-1 – Functional blocks in resource control functions related to virtual network instance**

NOTE – The architecture of the virtual network resource control functions (VN-RCF) in this Recommendation covers the instantiation of the virtual network. But it could cover the instantiation of virtual storage and virtual computing as well.

### 7.1.1 Virtual network MANO functions

Virtual network MANO (VN-MANO) functions handle the lifecycle of the VCDN service, VNAF and the virtualized network resource control corresponding to the VCDN service request. It is composed of an orchestrator, VN application management and VN resource control functional blocks.

It is noted that VN-MANO functions are alternatively exited out of the RCF as third party functions. The examples of communication between VN-RCF and the third party VN-MANO can be referenced to [b-ETSI GS NFV 002].

#### 7.1.1.1 Virtual network orchestrator functional block

The orchestrator functional block is responsible for the lifecycle management of the VN service, the coordination of VN applications management in the VCDN and the orchestration of the VN resource.

### 7.1.1.2 Virtual network application management functional block

The virtual network application management (VNAM) functional block is responsible for the instantiation and lifecycle management of the VN application related to a VCDN service. It is noted that the VNAM functional block is possibly composed of many independent instances.

### 7.1.1.3 Virtual network resource control functional block

The virtual network resource control (VNRC) functional block is responsible for the control and management of the virtual network resource from the resource functions.

## 7.2 Functions and functional blocks in resource functions

Resource functions handle the physical resource maintenance, especially the network resources in this Recommendation, and the resource virtualization. The virtualized network resource can be utilized by the resource control function. With the combination of these components, the RF is able to create the logical network resource partition for different uses under the control of the RCF.

Figure 7-2 shows the functions and functional blocks that are contained in the RF.

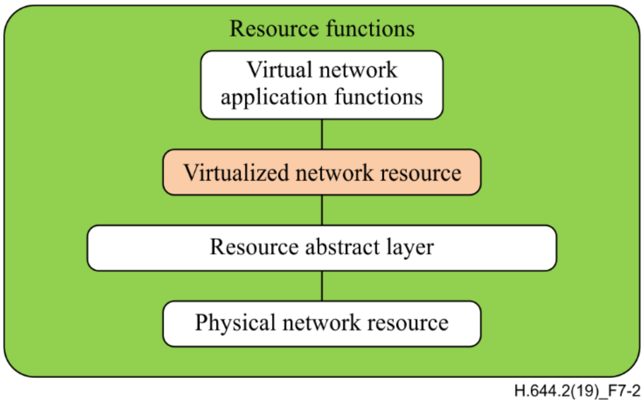


**Figure 7-2 – Functional blocks in resource functions related to virtual network instance**

NOTE – The physical resource here is in the scope of the resource function. In fact, the physical resource entity comes from different geographical locations.

### 7.2.1 Virtual network application functions

Virtual network application (VNA) functions enable the resource control function (RCF) to implement the CDN service logical functional components as instances based on virtualized network resources, e.g., an APP implements CDN service functionalities as virtualized CDN nodes.

### 7.2.2 Virtualized network resource

Virtual network resource (VNR) functions are a logical representation of the physical network resource. These virtualized network resources are created and assigned by the request from the RCF according to the specific capability of an application or a service.

### 7.2.3 Resource abstract layer

The resource abstract layer (RAL) interacts with the physical network resource to provide the abstraction of the physical network functions. With this abstraction, the physical network resource can be reassigned as many logical network resource partitions, and be presented as the available virtual network resource.

### 7.2.4 Physical network resource

Physical network resource is composed of the physical network elements, such as routers and switches. In a general point of view, the CPU and hard-disk can also be regarded as the physical network elements. They have different capabilities and characteristics. Those network elements can be located in one data centre or can be distributed in the broad geographic locations.

# 8 Network virtualization for VCDN

With the network virtualization technologies, VCDNs can be built in a flexible, programmable and service-sensitive network environment. The different network virtualization technologies enable the VCDN to work for different purposes with the corresponding solutions. The following clauses introduce some potential solutions by taking advantage of network virtualization technologies.

## 8.1 CDN function virtualization coupled with SDN-based solution

The following subclauses introduce the possible solutions of adopting SDN into CDN function virtualization. According to the purpose of CDN capability design, the two different SDN-based solutions could be selected: tight coupled SDN-based solution and loose coupled SDN-based solution.

### 8.1.1 Tight coupled SDN-based network virtualization

The tight coupled network virtualization means most data routing functions in the CDN, especially the network transport and traffic control related functions, can be coordinated with the SDN service and the rest of the CDN service logic remains in the CDN functions. VCDN functions need to receive the request from CDN functions to create its own service logic and control the resource usage directly. The benefit of adopting the tight coupled network virtualization is the improvement of the CDN distribution and delivery efficiency. Data transport and processes can be directly executed under the control of the virtualized network elements in the VCDN.

The SDN-based VCDN solution provides an opportunity to integrate the CDN functions with the SDN functional architecture. Figure 8-1 shows how the SDN functional architecture can be integrated with CDN functions within the VCDN scope.

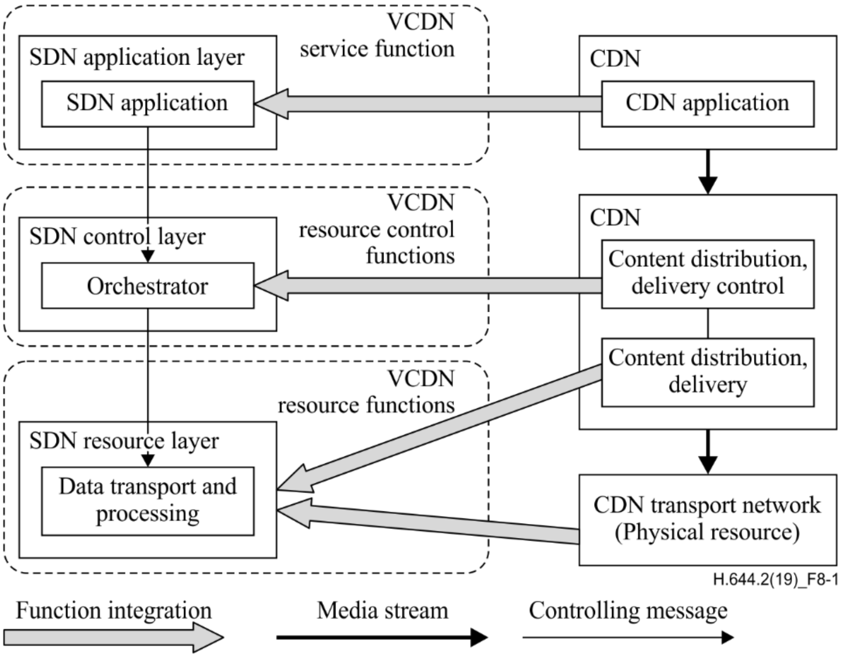


**Figure 8-1 – Tightly-coupled SDN-based network virtualization solutions**

Basically, there are three parts in the CDN are recommended to be coordinated with SDN layers:

– The CDN application function is integrated with SDN application.

– The CDN control functions, i.e., content distribution control function and content delivery control function are integrated with the SDN controller.

– Content distribution, content delivery and the physical network resource, such as switcher, router, gateway or any device which supports SDN transport protocols, are integrated with the SDN resource layer (more precisely, the data transport and processing function).

With the integration, when the SDN application layer receives the service request from the CDN application, it creates the resource acquiring information and service orchestrating information based on the request. Then that information will be used to create the resource reservation request. The request is then sent from the application layer to the SDN control layer.

The SDN control layer allocates the CDN resource required according to the above-mentioned resource reservation requirement. It also generates a content route table for data transporting, according to the network load balance and routing policy. Then the SDN control layer generates the L2/L3 (data link layer/network layer) forwarding table based on the content routing table and sends this table to the SDN resource layer.

The data transport and processing function in the SDN resource layer is responsible for the data transporting for content distribution and content delivery. When the request of content distribution and content delivery are received, the SDN resource layer invokes the related resource from the CDN physical network to execute the functions of distribution and delivery for implementing the service application, according to the L2/L3 forwarding table.

From the above conceptual progress, the CDN is able to request, allocate, occupy and release the network resource dynamically by taking advantage of tight coupled SDN-based network virtualization.

### 8.1.2 Loose coupled SDN-based network virtualization

Loose coupled network virtualization means the most of CDN functions, i.e., the application, distribution and delivery, can be migrated into an SDN-based VCDN and only a few functions still remain in the CDN functions, e.g., user request redirect. When the VCDN receives the request redirected from the CDN or other request sources, it implements its own service logic and controls the resource usage directly under the VCDN software environment. In this case, the VCDN node is almost separated from the physical dedicated CDN node. The benefit of adopting the loose coupled network virtualization is flexible CDN functions deployment. CDN nodes can be created as a software module based on a universal hardware and operation system, where other application programs are managed in parallel. It is easily managed by operators and can reduce the hardware and software investment.

Figure 8-2 shows how CDN functions are migrated in the SDN functional architecture within the VCDN scope.

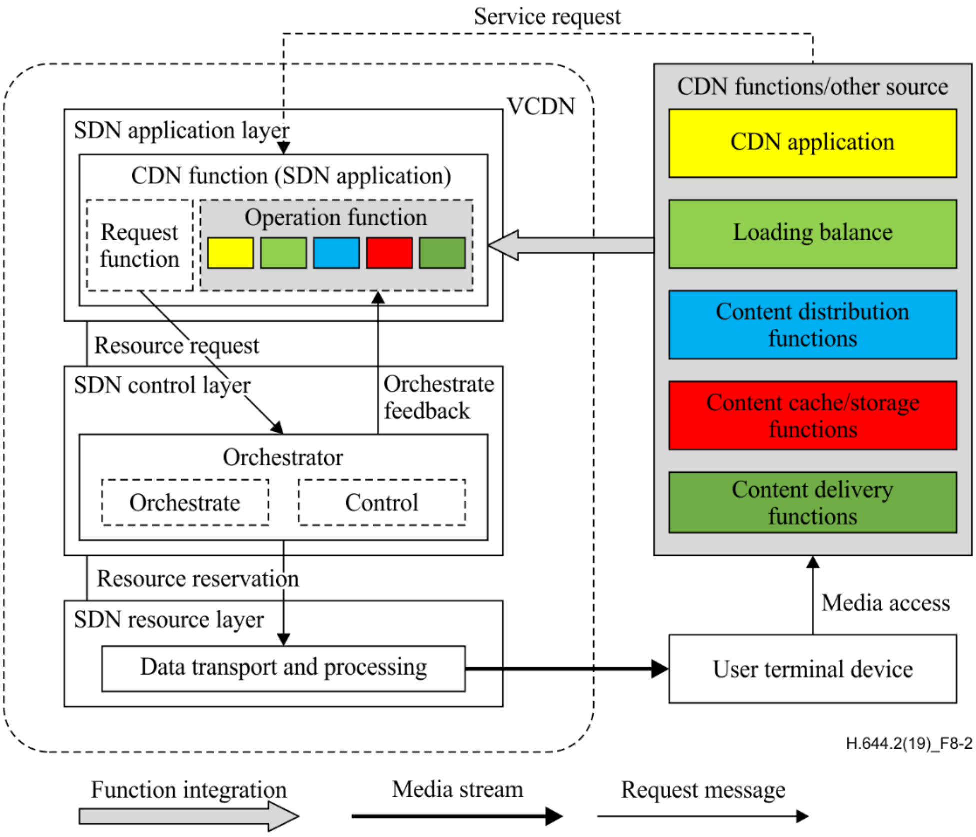


**Figure 8-2 – Loose coupled SDN-based network virtualization solutions**

– SDN application layer – CDN function (SDN application)

CDN logical functions could be migrated into the SDN application layer as an SDN application. To implement CDN service logical operations, the CDN function needs to implement at least 2 functional modules:

○ Request function

This functional block is used to add the integrated CDN service logical functions into the SDN application layer. Moreover, it receives the CDN service request and then sends the request of resource requiring and service orchestrating to the orchestrate function in the orchestrator in the SDN control layer.

○ Operation function

The major CDN functions, e.g., CDN application, content distribution and delivery, content storage and load balance, can be migrated into the operation function which handles the logical procedure of the CDN service. When the feedback information of resource reservation is received, the operation function implements the logical operation based on the content distribution or media accessing request.

– SDN control layer – Orchestrator functions

The orchestrator provides control and management of the network resource, as well as the coordination of requests from the SDN application layer (referenced from [ITU-T Y.3300]). To process the request from the SDN application layer, the orchestrator is recommended to implement 2 functional modules:

○ Orchestrate function

The orchestrate function can be further composed of two functional blocks:

1 Resource coordination: This is used to receive the request of resource requiring and service orchestrating and to process the service orchestrating according to the SDN

network information. Then it sends the request of required resource reservation to the control function.

2 Orchestrate feedback: When the resource reservation has been completed, it returns the feedback to the CDN function with the resource reservation information.

○ Control function

The control function is used to allocate the resource required by the CDN service, according to the resource reservation request. After the resource allocation, the control function will determine the routing path for content distribution and delivery, combining with the condition of load balance and routing status in the network. It also creates the data link layer/network layer (L2/L3) forwarding tables based on the control policy of the SDN controller layer and then sends these tables to the data transport and process function. Moreover, it also needs to return the information of resource reservation to the orchestrate function.

– SDN resource layer – data transport and processing functions

The data transport and processing function entity involves many network devices which support SDN transport protocols. They are used for storing data based on the allocated resource related to the CDN function. Furthermore, it executes data transporting correspond with the logical operation in the CDN function, according to the L2/L3 forwarding tables determined by the control function.

### 8.2 CDN node virtualized with the support of network virtualization system

The following subclauses introduce the solution of creating a virtualized CDN node with the support of a network virtualization system.

#### 8.2.1 High-level functional architecture of CDN node virtualization

The typical service components of the CDN include the CDN operation and maintenance system, content distribution system, delivery system, content location and routing system. These systems are composed of many logical functions and are implemented in the various types of CDN node. According to the VCDN solution, these logical functions are required to be virtualized and be reorganized as the one or various virtual applications running in one or multiple virtual machines. These virtual applications are recommended to be created by the network virtualization system.

The diagram in Figure 8-3 shows the high-level functional architecture of a virtualized CDN node.

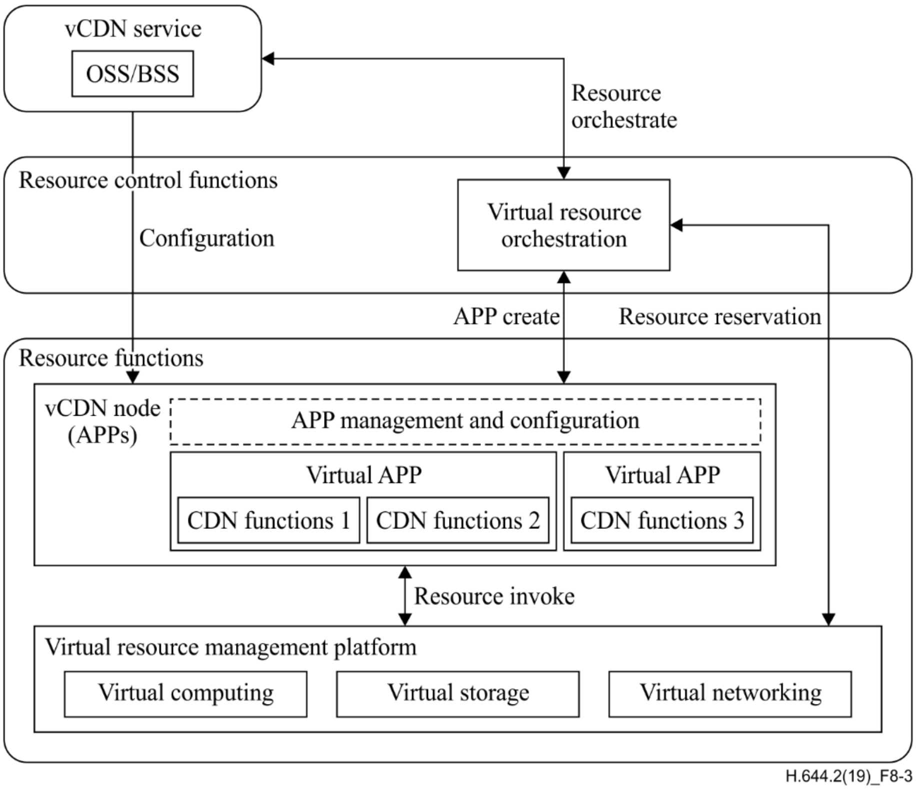


**Figure 8-3 – CDN node virtualized with network virtualization system**

In the VCDN ecosystem, the creation of a virtual CDN node will mainly rely on the network virtualization system. Typically, a network virtualization system can be composed of a virtual resource orchestration system and virtual resource management system (resource pool).

The virtual CDN node should be created by the intention of the VCDN customer. The intention will be decomposed and be reprogrammed as the computing request in the VCDN service system, typically, in the OSS/BSS. The virtual resource orchestration system receives the request and then orchestrates the related resource for a target VCDN node(s). The resource reservation request is sent to the virtual resource management system for resource allocation and reservation. With the response of the resource reservation, the virtual resource orchestration system created the instance of the VCDN node as one or couples of software apps. Furthermore, once the VCDN nodes have been created, the VCDN nodes information should be updated in the OSS/BSS or GSLB and can be used in the entire CDN ecosystem.

### 8.2.2 The functional components within network virtualization system

The network virtualization system in Figure 8-3 is composed of several functional components: the virtual resource orchestrator, virtual resource management platform, virtual applications and the related management system.

#### 8.2.2.1 Virtual resource orchestrator

The virtual resource orchestrator receives the VCDN service creation request from the OSS/BSS in the VCDN service functions. The service creation request contains the VCDN node description information. Based on the description information, the logical VCDN node functions and the resources for VCDN node creation are orchestrated and the related virtual applications which represent the CDN functions are created and performed on the physical hardware, i.e., virtual machine(s).

It is noted that the resource orchestration request could also come from the GSLB if the GSLB determines to modify the node capacity by inspecting the CDN node topology.

The resource orchestrator can be further composed of the following subfunctions:

– ***Orchestrating function:*** Receives the VCDN nodes creation request and orchestrates the related resource based on the VCDN node logical functions. In an optional way, a preconfigured resource orchestration template can be stored in advance for quick CDN node virtualization.

– ***Virtual resource reservation function:*** Sends the resource request to the virtual resource management platform and reserves the related virtual resources.

– ***Virtual application management function:*** With the reserved virtual resource, the virtual application management system creates the instances of VCDN logical functions, i.e., virtual apps. The lifecycle of virtual apps is also managed by the virtual application management functions.

#### 8.2.2.2 Virtual resource management platform

The virtual resource management platform is regarded as a resource pool which provides the abstract resource to the resource orchestrator. The virtual CDN apps are able to be deployed in the hardware and software environments provided by the virtual resource management platform. In addition, the virtual resource can be adjusted in the future if the VCDN node functions need to be modified.

The logical virtual resource can be integrated in one virtual machine or be provided by multiple separate virtual machines.

#### 8.2.2.3 Virtual application

The virtual application is the instance of the virtual CDN functions. By invoking the reserved virtual resource portion, these applications are created and managed by the virtual resource orchestrator. The logical functions of a virtualized CDN node can be made up of one or many virtual applications. According to the functional requirements, the virtual CDN node can be performed as different types, such as the centre node and edge node:

The virtual application for the centre node may contain a content pro-process function, content ingestion function, content distribution function, storage/cache function, GSLB function, SLB function and OSS/BSS functions.

The virtual application for the edge node may contain a content delivery function, delivery control function, SLB function, storage/cache function, content process function and OSS/BSS functions.

In addition, some network devices, such as a virtual switch, may also be created as one or more apps.

The application is recommended to be configurable after it has been created. The parameters of CDN node functions are usually determined by the CDN OSS/BSS according to the VCDN customer's intention. An app management and configuration system can be used to execute the CDN node app configuration.

## 8.3 CDN node virtualized with the support of network virtualization system and SDN controller

The following subclauses introduce the solution of creating a virtualized CDN node with the support of a network virtualization system and an SDN controller.

In this case, the networking sources virtualization and allocation are under the control of SDN controller functions, which can be performed as a dedicated physical device.

### 8.3.1 High-level functional architecture of CDN node virtualization with SDN controller

The primary intention of this solution is to leave the network resource to be orchestrated by the SDN, precisely, the SDN controller layer. In this solution, most procedures of the creation of a virtual CDN node are the same as the description given in clause 8.2.1. The only difference is that the network resource orchestration request will be forward to the SDN controller. The SDN controller controls reservation and management of the virtual network resource.

The other functional components and the related functions are very similar to the components mentioned in clause 8.2.1. But in the resource control functions, the physical network devices are recommended to be able to support the interaction between the virtual resource orchestration functions and the SDN controller functions.

The diagram in Figure 8-4 shows the high-level functional architecture of CDN node virtualization with an SDN controller.

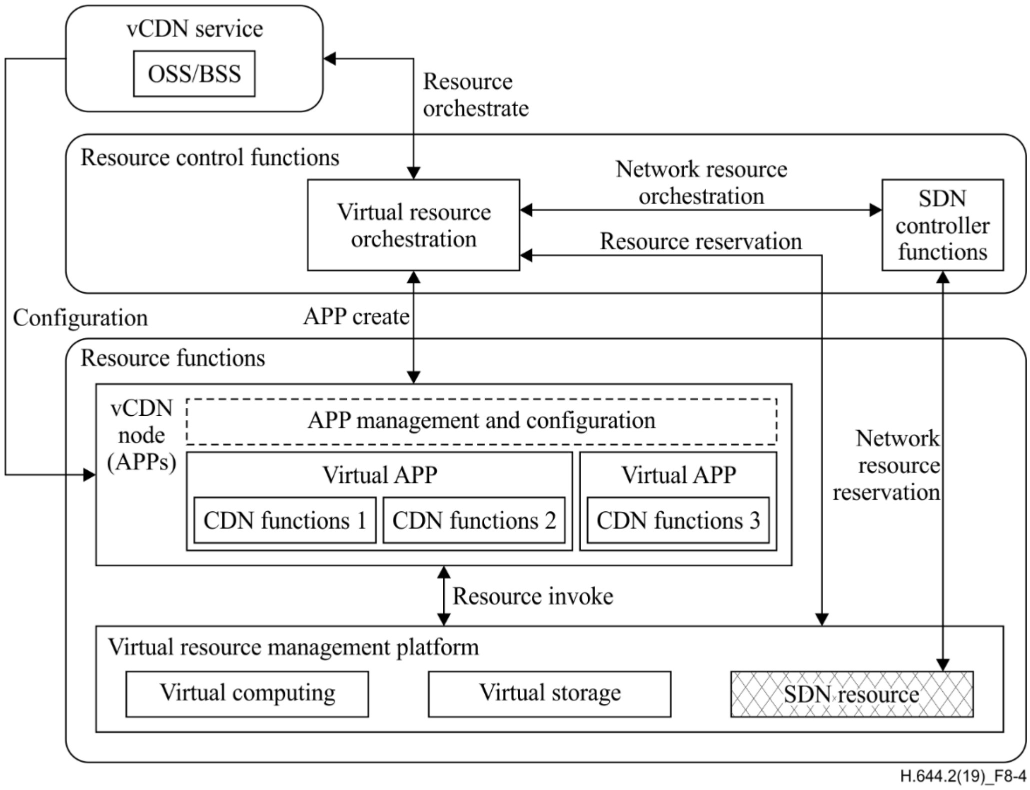


**Figure 8-4 – CDN node virtualized with network virtualization system (cooperated with SDN controller)**

Logically, the SDN controller functions are recommended to be separated from the virtual resource orchestrator and to deal with the network resource orchestration specifically. It receives the network resource orchestrate request from the virtual resource orchestrator through a standard interface, e.g., the northbound interface. The reservation of management of network resources is controlled by the SDN controller by through another standard interface, e.g., the southbound interface. The implementation of these interfaces may have many solutions. For example, [ITU-T Y.3300] defines the interfaces and their functions in clause 11.5.

### 8.3.2 The functional components within network virtualization system and SDN controller

Most of the functional components and the functional requirements in this case are the same as those of the previous case. Considering the requirement of supporting the SDN controller, the functional components in the network virtualization system may have some new features.

#### 8.3.2.1 Virtual resource orchestrator cooperated with SDN controller

The primarily functions of the virtual resource orchestrator can be referenced from clause 8.2.2.1.

In this solution, after the virtual resource orchestrator receives the VCDN service request, the network resource orchestration request will be separately forwarded to the SDN controller. The virtual network resource will be orchestrated by the SDN controller based on the real-time transport network information.

Therefore, the virtual resource orchestrator should be performed as a logical SDN application. The interface between the virtual resource orchestrator and the SDN controller is recommended to be compliant with the SDN northbound interface requirements. The SDN northbound interface definition can be referenced from [ITU-T Y.3300], clause 11.2.

In an optional way, a proxy server can be performed as the protocol interpreter between the virtual resource orchestrator and the SDN controller, if the virtual resource orchestrator does not support the SDN northbound interface definition. That proxy server can be physical equipment or a software app.

#### 8.3.2.2 Virtual resource management platform

The primary functions of the virtual resource orchestrator can be referenced from clause 8.2.2.2.

What is different from the description in clause 8.2.2.2 is that the virtual resource management platform is recommended to be able to respond to the network resource control request from the SDN controller. The request can be delivered through an interface between the virtual resource management platform and the SDN controller, which is recommended to be compliant with the SDN southbound interface requirements. The SDN southbound interface definition can be referenced from [ITU-T Y.3300], clause 11.2.

The physical network resources managed by this platform, such as routers, are required to support SDN protocols.

#### 8.3.2.3 Virtual application

The primary functions of the virtual resource orchestrator can be referenced from clause 8.2.2.3.

#### 8.3.2.4 SDN controller functions

In this case, SDN controller functions are separated from the virtual resource orchestrator. They orchestrate and reserve the network resource based on the available network resource under their control. The detailed functions of the SDN controller can be referenced from [ITU-T Y.3300] and [ITU-T Y.3302].

It is noted that the physical SDN controller device can be deployed separately from the resource control function (physical platform) in the real implementation, while the SDN controller functions act as a software application.

## 8.4 CDN node virtualized with the support of network virtualization system and virtual SDN controller

The following subclauses introduce the solution of creating a virtualized CDN node with the support of a network virtualization system and an SDN controller.

In this case, the SDN controller is not a dedicated piece of hardware but a virtual app created dynamically by a specific request.

### 8.4.1 High-level functional architecture of CDN node virtualization with virtual SDN controller

The primary intention of this solution is very similar to the intention of clause 8.3.1. The only difference in this solution is the network resource will be orchestrated by a virtual SDN controller, which is created by the network virtualization system as a virtual app. Therefore, the network virtualization system manages the lifecycle of the virtual SDN controller, as well as the virtual CDN functions simultaneously.

The diagram in Figure 8-5 shows the high-level functional architecture of CDN node virtualization with the virtual SDN controller.

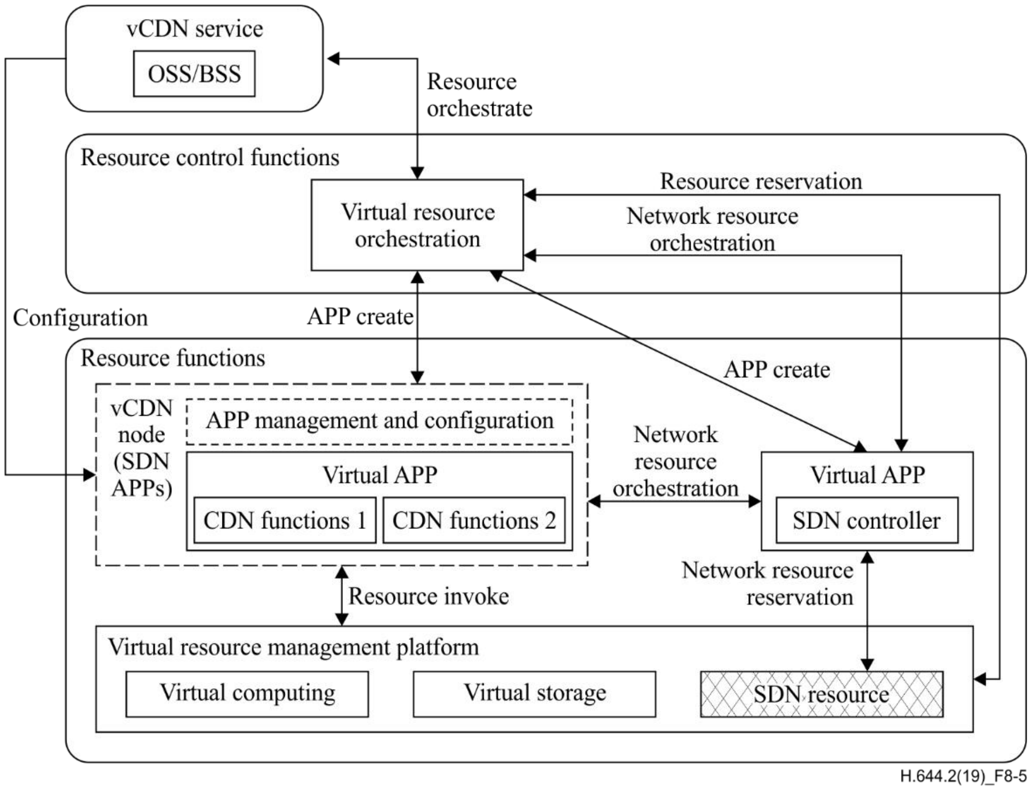


**Figure 8-5 – CDN node virtualized with network virtualization system (cooperated with virtual SDN controller)**

As an alternative solution, the procedure of the creation of a virtual CDN node is the same as the procedure description in clause 8.3.1. The only difference is the SDN controller here is a virtualized app to which the network resource orchestration request will be forwarded. The functions of a virtual SDN controller is almost the same as that of a physical SDN controller.

This case is expected to be suited to a CDN which is composed of virtual nodes completely.

### 8.4.2 The functional components within network virtualization system and virtual SDN controller

Most functional components and functional requirements in this case are the same as those in clause 8.3.2.

#### 8.4.2.1 Virtual resource orchestrator cooperated with a virtual SDN controller

The primary functions of the virtual resource orchestrator can be referenced from clause 8.2.2.1.

In this case, after the virtual resource orchestrator has received the VCDN service request, the network resource orchestration request is separately forwarded to the virtual SDN controller. The virtual SDN controller will orchestrate the virtual network resource based on the transport network information.

As noted in clause 8.3.2.1, the virtual resource orchestrator should be performed as the logical SDN application. The interface between the virtual resource orchestrator and the virtual SDN controller is recommended to be compliant with the SDN northbound interface requirements.

In an optional way, a proxy server can be performed as the protocol interpreter between the virtual resource orchestrator and the virtual SDN controller, if the virtual resource orchestrator does not support the SDN northbound interface definition. That proxy server can be a physical piece of equipment or a software app.

### 8.4.2.2 Virtual resource management platform

The primary functions of the virtual resource management platform can be referenced from clause 8.3.2.2.

### 8.4.2.3 Virtual application

The primary functions of the virtual application can be referenced from clause 8.3.2.3. In this case, the virtual SDN controller or the virtual network device running the SDN protocol is created as a virtual application, as well as the creation of the other functions mentioned previously.

### 8.4.2.4 Virtual SDN controller

The virtual SDN controller in this case is separated from the virtual resource orchestrator and be virtualized by the network virtualization system, as a virtual app. It orchestrates and reserves the network resource based on the network resource under its control. The detailed functions of the SDN controller can be referenced from [ITU-T Y.3300] and [ITU-T Y.3302].

As a virtual app, the virtual SDN controller can be created and released by request dynamically and be managed by a network virtualization system, after the CDN service request has been received. Like other virtual applications, the resources for creating the virtual SDN controller are orchestrated and managed by the virtual resource orchestrator as well. Different from the physical SDN controller or the third party SDN controller, the virtual SDN control may only control the limited network resource which is provided by a specific CDN service provider, instead of the entire resource from all networks. Moreover, the virtual SDN controller can work as an individual server or together with the other SDN controllers to share the information between them as a logical SDN controller function.

## 9 Reference points

The diagram in Figure 9-1 presents the high-level reference points between the functions within the VCDN service scope defined in [ITU-T H.644.1].

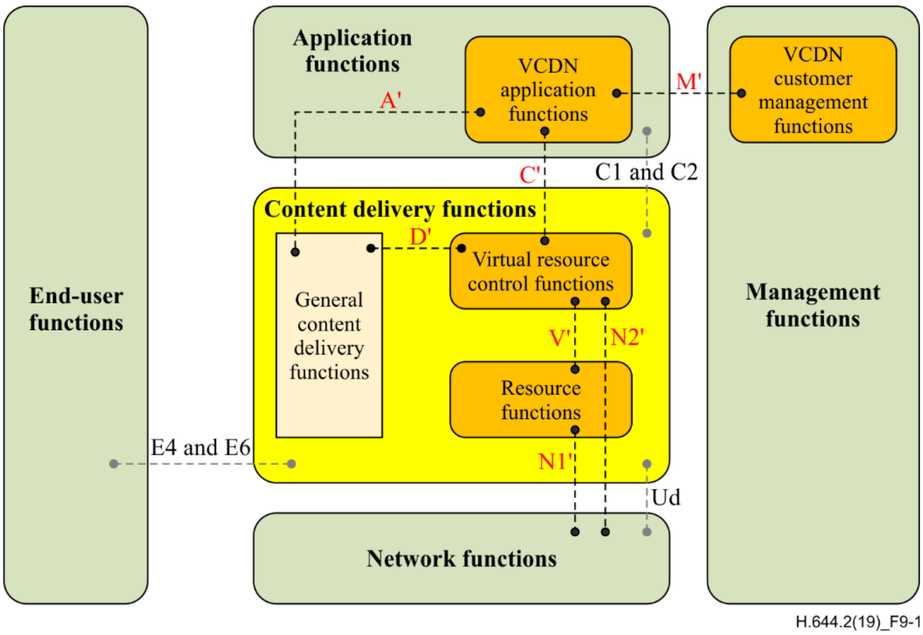


**Figure 9-1 – Reference points of VCDN architecture**

The reference point defined in this document is recommended to be compliant with the general reference point definition in clause 9 of [ITU-T H.644.1]. By considering the usage of network virtualization technology in a VCDN, the reference point and the information carried on it can be extended as follows, based on the general definitions mentioned in [ITU-T H.644.1].

### 9.1 Reference point M'

In this document, VCDN application functions receive the service request from the customer management functions on behalf of a certain SP or CP, by RP-M'.

The service request includes the service creation and delete request, service requirements request and other types of requests.

### 9.2 Reference point C'

The virtual resource control functions receive the required service related resource orchestration request from the VCDN application functions, by RP-C'. In the scenarios mentioned in this document, the requests refer to the orchestration of resources which enable the creation of logical function entities or apps of virtualized CDN nodes.

While the virtual service is created, the feedback information can be returned by this RP.

### 9.3 Reference point V'

Resource functions receive the resource reservation, allocation and other resource management requests from the virtual resource control functions, by RP-V'.

While the virtual app is created, the app management request is also delivered from this RP.

### 9.4 Reference point N1'

The general RP-N1' definition can be found in [ITU-T H.644.1]. The VCDN data, especially L2/L3 data, can be transferred or forwarded by this RP.

### 9.5 Reference point N2'

The general RP-N2' definition can be found in [ITU-T H.644.1]. This RP can be particularly used by the SDN controller if the SDN technology is used together with the other network virtualization technologies in the VCDN service.

The following reference points can be used in the situation of coexistence of the VCDN and physical CDN nodes.

### 9.6 Reference point A'

The application-level request is transmitted from the VCDN application functions to the general content delivery functions, by RP-A'. The general content delivery functions, as the software collection, can be implemented in the dedicated CDN hardware or virtualized in the common virtual machines.

The general RP-A' definition can be found in [ITU-T H.644.1].

### 9.7 Reference point D'

Generally, this RP-D' is used to exchange the information of physical CDN hardware/software resources between the content delivery functions and the virtual resource control functions, which can be found in [ITU-T H.644.1].

In this Recommendation, this RP-D' would also be used to transfer the virtual network resource orchestration request from the content delivery functions to the virtual resource control functions where the SDN controller is placed, especially under the situation of coexistence of the VCDN and physical CDN nodes.

# Appendix I

## Use cases of network virtualization supporting VCDN services

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

Legacy telecommunication services, such as IPTV, is usually deployed on the telecommunication operator's dedicated network. The CDN is also a distribute network overlay with the legacy transport network. But in current markets, the CDN is expected to be designed for an integrated service in an open network environment. Integrated services may be run on different platforms or networks with their own service logic. According to the features of the integrated service, network virtualization is a prospective approach to improve the CDN capability to use the network resource with higher efficiency and flexibility by ignoring the difference of hardware/software.

So the network virtualization for VCDN is considered to have the following use cases.

### I.1 Virtualized CDN node deploy dynamically and flexibly

In general, CDN nodes deployment depends on many factors such as geographical location, target user density, etc. Usually the deployment purpose and node device should be determined by CDN operators. Once the CDN nodes are deployed, the configuration and maintenance for CDN nodes are usually kept stable. But in this situation, if one CDN node capability has exceeded its limitation by the rapid increase of user requests at a peak time, it is difficult to add a new CDN node in time. Also a deployed CDN node resource may not be used efficiently in normal time. The VCDN approach is able to create a new logical CDN node when there is a network device supporting network virtualization through a resource control request and to release the resource when the peak time has passed.

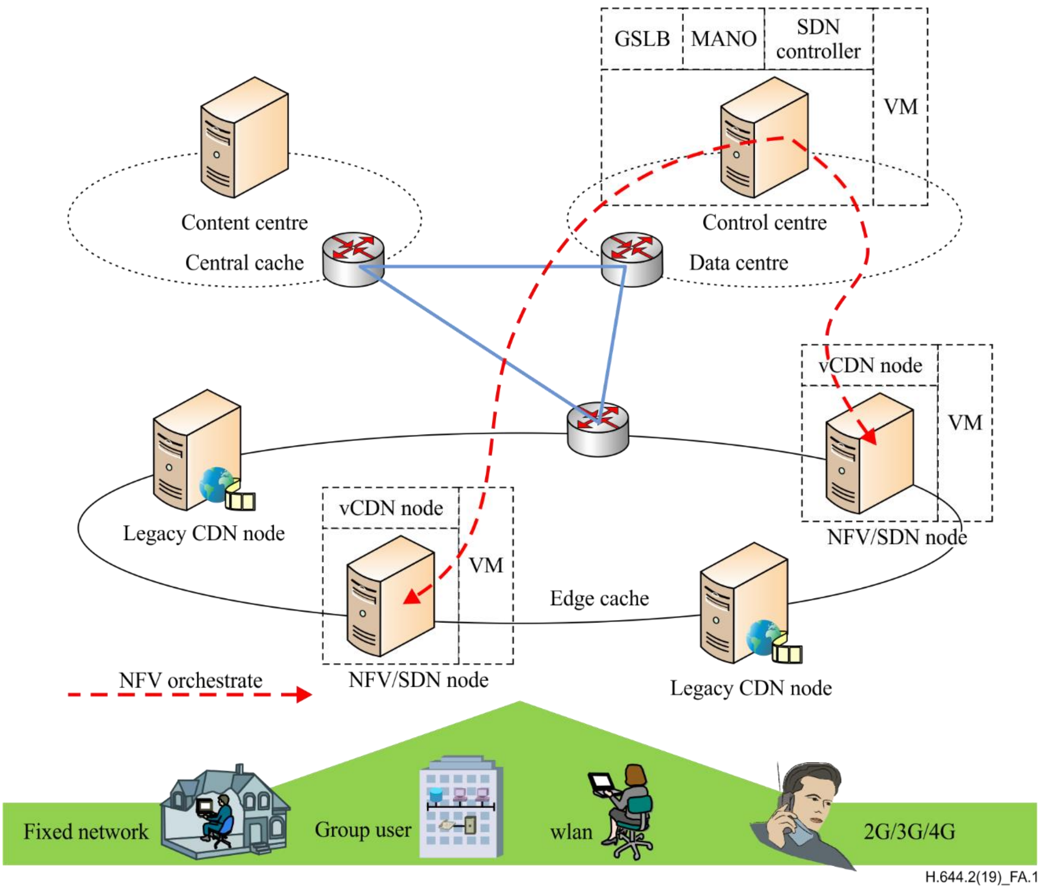


**Figure I.1 – VCDN nodes deploy dynamically**

As Figure I.1 shows, a VCDN node can be created and deployed by the service request. The functionality of a CDN node can be virtualized and programmed on the virtual machine in a server located in a data centre or any device which supports NFV/SDN functions.

## I.2 Smart traffic control

In general, the quality of media content distribution and delivery in the CDN is usually restricted to bandwidth, traffic congestion and network jitter. The routing path and transport control cannot be easily predicted in the legacy CDN because of a lack of sensing for the low layer network status. In the VCDN approach, the traffic control can be centralized in a transport controller, e.g., an SDN controller, and the profile of the network can be obtained by the VCDN management node. Before the content transmission, the VCDN will plan a shortest (may not the shortest in geography) and efficient distribution/delivery path, according the profile of the network status. Moreover, the traffic control may adjust the bandwidth for media transmission during the peak time and release the bandwidth afterwards.

As Figure I.2 shows, the media content data can be distributed to the different edge nodes with an optimized path while the traffic congestion is detected. In addition, a virtualized switch/router can be created for adjusting the bandwidth temporarily.

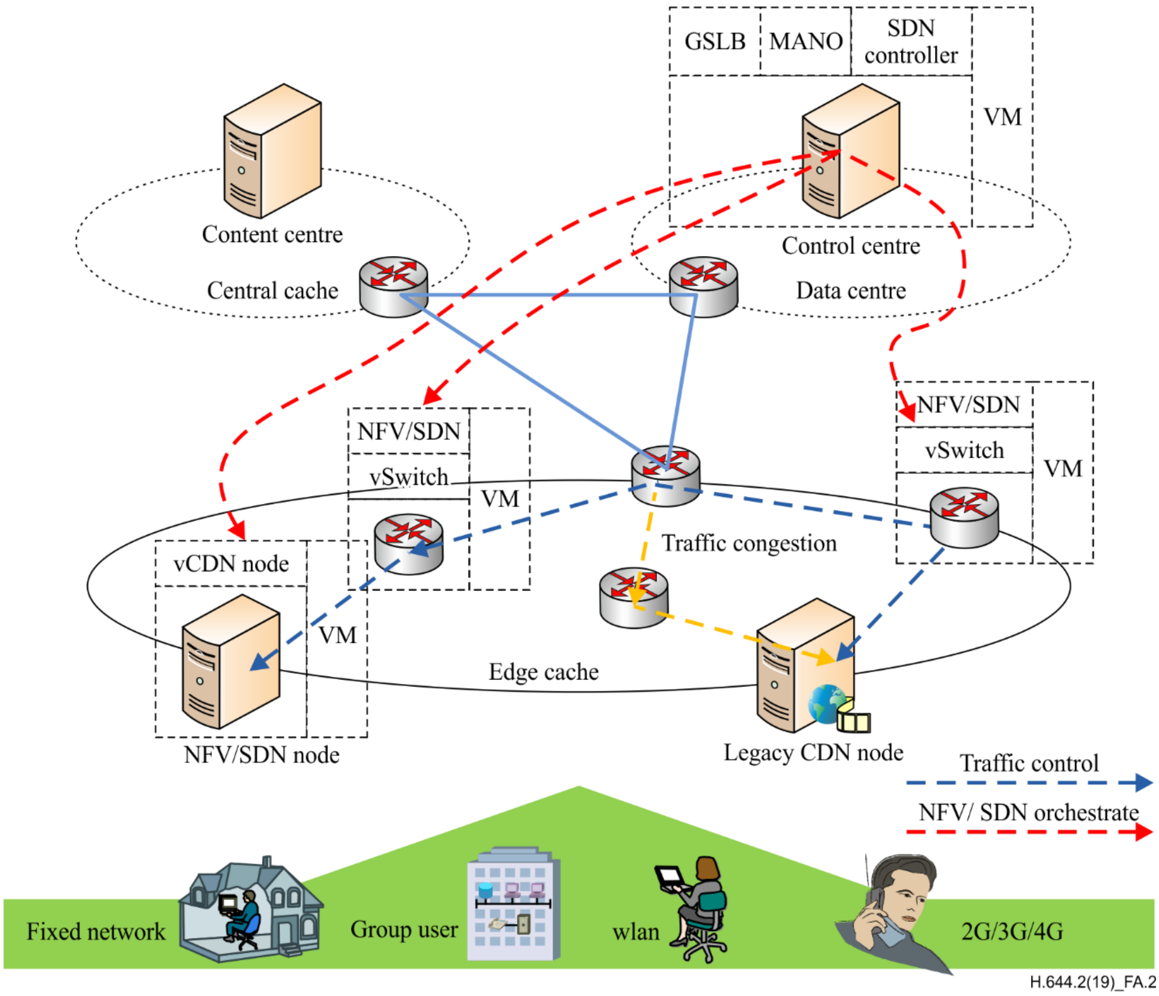


**Figure I.2 – Smart traffic control in VCDN**

## I.3 Rapid service deployment

In the current market, with the development of transport networks, service platforms and terminal devices, more and more services are being designed rapidly with multiple service types. But with traditional platforms, services usually run in a closed ecosystem. Service design and deployment may take a couple of months. They may require to be run on special hardware and software. Service configuration and maintenance are difficult because the network resources that the service requires cannot be easily reserved and allocated while the service needs to be distributed over a large-scaled network.

In the VCDN, a virtualized CDN node provides a network resource abstraction with the common hardware/software resource. A new service can be programmed and installed into the operator's service platform quicker than in the legacy way. Also, the visualization of network resources, information collection and network policy would help the operator to deploy the new service into each node in a very short period of time (usually a couple of months before, but only a few days now). The configuration will also be automatically completed in a short time by taking advantage of network resource virtualization.

### I.4 Unified configuration and management

In the traditional CDN ecosystem, many CDN equipment from different manufacturers may be deployed in a telecommunication operator's premises side-by-side. These CDN nodes are usually designed for different purposes and rely on the dedicated hardware or software. Any changes such as system/equipment updates and new service creation, may affect the operation for each node in the whole CDN topology correspondingly. Therefore, the differentiation of dedicated hardware/software increases the complexity of configuration, management and operation investments.

The VCDN approach provides an opportunity to separate the logical control layer from the dedicated physical equipment and be redesigned as a unified control centre. The unified control centre can interact with network elements in L2/L3 layer, such as a switch or router, through a standard interface. Moreover, with the virtualization of CDN functions, the unified control centre is able to configure and manage the logical CDN nodes for different purposes based on the resource allocated in a general infrastructure, even where the resource may physically come from different data centres. The resource can be added, adjusted, shared and migrated according to the CDN operator's purpose and time allocation.

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