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INFRASTRUCTURE, INTERNET PROTOCOL ASPECTS
AND NEXT-GENERATION NETWORKS

Next Generation Networks – Frameworks and functional
architecture models

Functional architecture for distributed service networking

Recommendation ITU-T Y.2080



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Recommendation ITU-T Y.2080

Functional architecture for distributed service networking

Summary

Recommendation ITU-T Y.2080 specifies the functional architecture for distributed service networking (DSN), taking into account the requirements and capabilities for DSN as described in Recommendation ITU-T Y.2206.

The main objective of this Recommendation is to provide guidance regarding the design of networks, services and applications making use of DSN.

History

Edition	Recommendation	Approval	Study Group
1.0	ITU-T Y.2080	2012-06-15	13

Keywords

Distributed service networking, DSN, functional architecture, functions, reference points.

FOREWORD

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The approval of ITU-T Recommendations is covered by the procedure laid down in WTSA Resolution 1.

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Recommendation ITU-T Y.2080

Functional architecture for distributed service networking

1 Scope

This Recommendation describes the functional architecture of distributed service networking (DSN) and its relationships with next generation networks (NGNs). This Recommendation provides a description of functions required for the support of the DSN and reference points between DSN functions.

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.2011] Recommendation ITU-T Y.2011 (2004), *General principles and general reference model for Next Generation Networks*.
- [ITU-T Y.2012] Recommendation ITU-T Y.2012 (2010), *Functional requirements and architecture of next generation networks*.
- [ITU-T Y.2206] Recommendation ITU-T Y.2206 (2010), *Requirements for distributed service networking capabilities*.

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

- 3.1.1 control plane** [ITU-T Y.2011]: The set of functions that controls the operation of entities in the stratum or layer under consideration, plus the functions required to support this control.
- 3.1.2 distributed service networking** [ITU-T Y.2206]: An overlay networking which provides distributed and manageable capabilities to support various multimedia services and applications.
- 3.1.3 DSN node** [ITU-T Y.2206]: A node used in DSN providing distributed functionalities, including distributed routing and distributed storage.
- 3.1.4 functional entity** [ITU-T Y.2012]: An entity that comprises an indivisible set of specific functions. Functional entities are logical concepts, while groupings of functional entities are used to describe practical, physical implementations.
- 3.1.5 hash function** [b-ITU-T X.810]: A (mathematical) function that maps values from a (possibly very) large set of values into a smaller range of values.
- 3.1.6 management plane** [ITU-T Y.2011]: The set of functions used to manage entities in the stratum or layer under consideration, plus the functions required to support this management.

3.1.7 overlay network [b-ITU-T Y-Sup.10]: A network of nodes and logical links that is built on top of the underlying, e.g., transport, network with the purpose of providing network service that is not available in the underlying network.

3.1.8 peer-to-peer (P2P) [ITU-T Y.2206]: A system is considered to be P2P if the nodes of the system share their resources in order to provide the service the system supports. The nodes in the system both provide services to other nodes and request services from other nodes.

NOTE – Peer is the node in a P2P system.

3.1.9 reference point [ITU-T Y.2012]: A conceptual point at the conjunction of two non-overlapping functional entities that can be used to identify the type of information passing between these functional entities.

3.2 Terms defined in this Recommendation

This Recommendation defines the following terms:

3.2.1 bootstrap node: The first node of the overlay network to which an enrolling node can connect.

3.2.2 buffer map: A map indicating the availability of chunks in a DSN node, which can be shared between DSN nodes.

3.2.3 chunk: A basic unit of data resulting from partitioning content into defined component parts.

NOTE – A DSN node may use a chunk as a unit of storage, advertisement and exchange among peers.

3.2.4 content delivery: In the context of the DSN functional architecture, the operation of sending and receiving content between the requested peer and the requesting peer or client.

NOTE – A client is a service consumer external to DSN. A peer is a node within DSN.

3.2.5 content distribution: In the context of the DSN functional architecture, the whole process of content sending from one or more content sources, and sharing among DSN nodes.

NOTE – During the content distribution process, content is often sent to appropriate intermediate nodes to enable subsequent delivery.

3.2.6 content ID: In the context of the DSN functional architecture, a global unique content name for identifying the content.

3.2.7 content node: A DSN node which can be used for media content distribution, storage and/or caching.

3.2.8 control node: A DSN node which provides service control functionalities.

3.2.9 distributed hash table (DHT): A hash table which is stored across a set of distributed peers.

3.2.10 hash table: A data structure that uses a hash function for mapping input values to their associated attributes. A hash function is applied to map the input values (typically a large range of them) to a smaller range of index values that are spread in an equal probability distribution in its range statistically. The resulting index values point to the tables which manage the attributes associated to the original input values.

NOTE – In a common implementation, the first step (index calculation) is installed in any nodes enquiring for the associated attributes and the second step (attribute table) is installed in a dedicated node.

3.2.11 overlay algorithm: An algorithm which forms and maintains a topology of interconnections among the peers, and determines the peers for storing a particular piece of data in the overlay (i.e., independent from the underlying network) and locates the peers in order to find a piece of data.

3.2.12 relay node: A DSN node which relays data packets in order to improve node reachability and QoS by changing the original route of the packets. The data can be voice data, video data, etc.

3.2.13 resource: In the context of the DSN functional architecture, data or an instance of service logic residing in DSN nodes. A resource in DSN is accessible by authorized DSN nodes only.

NOTE 1 – Examples of resource in DSN include user profile data, content, relay, session control or other service capability.

NOTE 2 – In the DSN environment, resources can have multiple replicas residing in different DSN nodes.

3.2.14 user profile: In the context of the DSN functional architecture, a collection of information that specifies the subscribed services and access privileges related to a DSN service user. The data in the user profile is called user profile data.

NOTE – A user profile may include the following attributes: user ID and other data related to authentication and authorization, user preferences, service status, service class, usage and/or contribution information, or subscriber accounting characteristics, etc.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

AF	Application Function
CDF	Content Delivery Function
CPU	Central Processing Unit
CSAF	Content Service Application Function
DHT	Distributed Hash Table
DSN	Distributed Service Networking
EF	End-user Function
ID	Identifier
MF	Management Function
NAT	Network Address Translation
NEF	Node Enrolment Function
NGN	Next Generation Network
P2P	Peer-to-Peer
PSTN	Public Switched Telephone Network
RF	Relay Function
RLF	Resource Location Function
SCF	Service Control Function
TOCF	Traffic Optimization Control Function
UE	User Equipment

5 Conventions

The following conventions apply:

- 1) The meaning of functions is as follows.

functions: In the context of the DSN functional architecture, "functions" are defined as a functional group composed of functional entities. It is represented by the following symbol:

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Functions

2) In this Recommendation:

The keywords **"is required to"** and **"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 adherence to 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 means the vendor may not choose to provide the feature (and an operator may choose not to offer it) but still claim conformance with the Recommendation.

In the main body of this Recommendation and its annexes, the words "shall", "shall not", "should", and "may" sometimes appear, in which case they are to be interpreted, respectively, as "is required to", "is prohibited from", "is recommended" and "can optionally". The appearance of such phrases or keywords in an appendix or in material explicitly marked as informative are to be interpreted as having no normative intent.

3) In this Recommendation:

DSN network means the network constructed based on DSN.

DSN service means the service provided by the DSN network.

DSN service provider means service provider that makes use of the DSN network in order to provide services and applications to its users.

6 Characteristics of the DSN functional architecture

In a DSN environment, resources, including data and instances of service logic, are distributed throughout the whole network. In addition, DSN nodes may or may not be active at any given time.

The DSN functional architecture supports the following characteristics.

- **Multiple services:** The DSN functional architecture supports the capabilities to construct an overlay network for each service. DSN nodes participating in the same service constitute an overlay network. A DSN node may participate in more than one overlay network.
- **Dynamic self-organization of nodes:** The DSN functional architecture provides mechanisms that ensure the stability and robustness of DSN service by supporting self-organization by the DSN nodes even when a node providing a resource or service joins or leaves the DSN network.
- **Distributed resource management:** The DSN functional architecture defines capabilities to locate, manage and utilize the distributed resources which are spread across the DSN network.
- **Traffic optimization:** The DSN functional architecture provides functions for network status monitoring and reporting, which supports traffic optimization. Traffic optimization is based on the monitored network information and the policies of the DSN service provider.

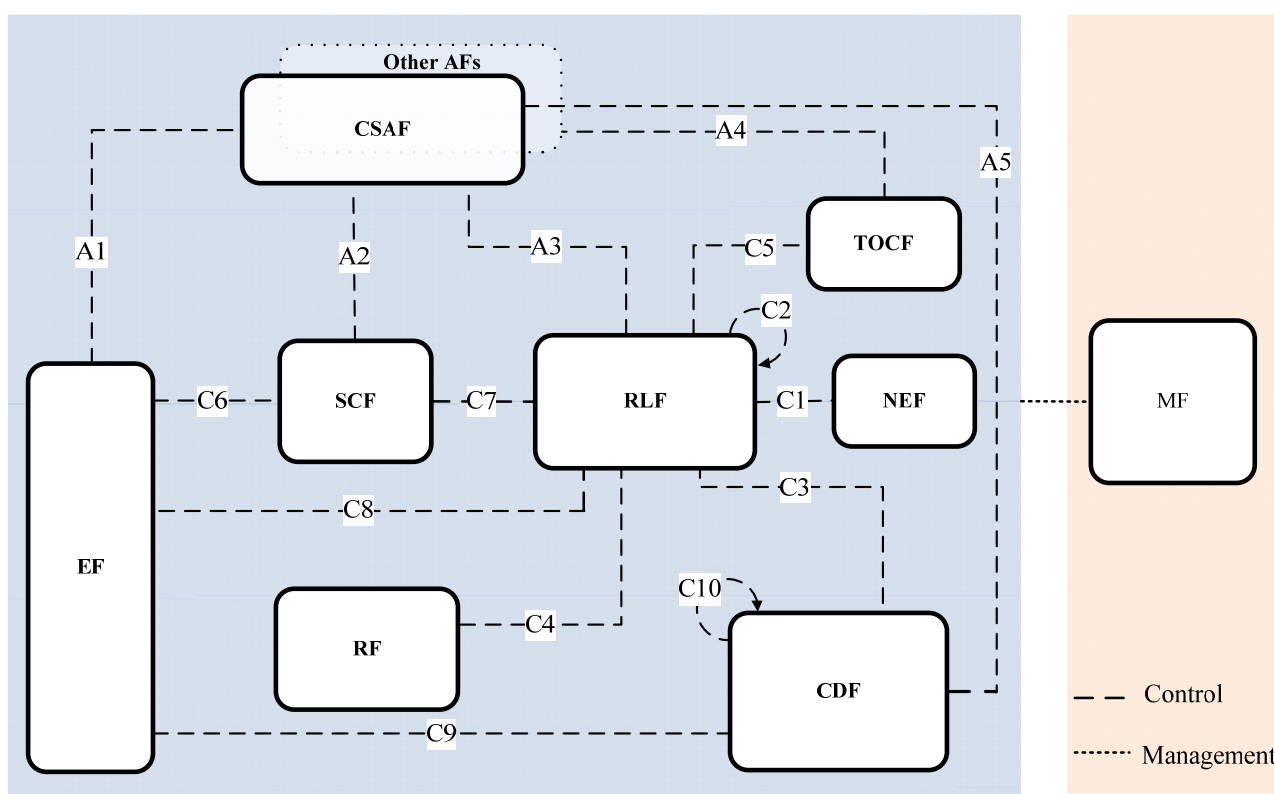
Implementing the DSN functional architecture is beneficial for avoiding single points of failure, deploying resources to optimal locations and utilizing the capabilities of various nodes, including user DSN nodes.

7 DSN functional architecture

This clause describes the DSN functional architecture by defining its functions and their logical interfaces called "reference points". The reference points are required to support both resource management, including resource location and selection, and traffic optimization, which is required to maintain the quality of service. Clause 7.1 describes the functions of the DSN functional architecture while clause 7.2 provides details about relevant reference points of the DSN functional architecture. The relationship of the DSN functional architecture with the NGN functional architecture can be found in Annex A, while detailed information flows explaining how to use the DSN functions and reference points are provided in Appendix I.

7.1 DSN architectural functions

Figure 7-1 shows the functions and reference points of the DSN functional architecture.



NOTE – This figure shows the interfaces for the control plane only. Media data transmission and transmission control are conducted through media interfaces depicted in Figure A.1.

Figure 7-1 – DSN functional architecture

As shown in Figure 7-1, the DSN functional architecture covers functions in the control plane and management plane.

The DSN functional architecture consists of several functions that interwork to provide DSN related services and capabilities. These functions include:

- node enrolment functions (NEFs);
- resource location functions (RLFs);

- relay functions (RFs);
- content delivery functions (CDFs);
- traffic optimization control functions (TOCFs);
- service control functions (SCFs);
- end-user functions (EFs);
- management functions (MFs);
- application functions (AFs).

This Recommendation only specifies the content service application functions (CSAFs), which is one kind of AF.

The descriptions of these DSN functions are provided in the following subclauses.

7.1.1 Node enrolment functions (NEFs)

When DHT is used to construct a DSN network, every DSN node is required to enrol in the DHT-based DSN network. In the DHT-based DSN network, the NEF checks the validity of the enrolling DSN node, provides initial configuration information for the DSN node and tracks the registered DSN node.

NOTE – In some service scenarios, the DSN node can join a DSN network which is not based on DHT, so it does not need to interact with the NEF. In content service, for example, only resource registration of content is needed. Enrolment for a DSN network which is not based on DHT is implementation specific and not specified in this Recommendation.

NEF allocates a globally unique node ID to each enrolling DSN node, provides bootstrap information for the DSN node to join to the DHT-based DSN network, and maintains the node profile.

NEF performs the following functions.

- Authenticate and authorize a new enrolling DSN node for the DHT-based DSN network. The NEF then establishes the identity and starts a profile of the enrolling node in the DHT-based DSN network.
- Assign a globally unique node ID to the enrolling DSN node. The ID value may be at random, based on the physical location of the node or based on the load situation of DHT-based DSN network. The node ID describes the logical position of the DSN node in the DHT-based DSN network and the resources it is responsible for.
- Configure the enrolling node with parameters and information for enrolling the DHT-based DSN network, including the algorithm for network construction and maintenance, and the position of the bootstrap node.

7.1.2 Resource location functions (RLFs)

In order to execute services, required resources residing somewhere in the DSN network must be located. The RLF maintains resource-related information and finds the required resources when enquired. RLF performs the following functions.

- Resource registration: Based on resource registration procedure activated by resource-holding DSN nodes, the RLF accepts the resource registration and maintains locations of the resources. Besides the location, the RLF stores resource information reported during registration.

NOTE 1 – Resource location is the DSN node ID or address where the required resource resides.

NOTE 2 – Resource information is the meta-data of the resource.

- Resource locating: Resource locating is the procedure to find the required resource in the DSN node(s). When enquired, the RLF locates the enquired resources.

- Resource location maintenance: Resource location maintenance is the procedure to update the location of a resource when a new DSN node joins or a resource-holding DSN node leaves the DSN network.
 - Resource information maintenance: Resource information maintenance is the procedure to update the resource information when there is any change.
 - Node status information maintenance: Node status information maintenance is the procedure to record status of the DSN nodes which have resources registered in the RLF.
 - Retrieve optimization information from the TOCF for optimal resource selection in the RLF.
 - Provide candidate node list to the TOCF for optimal resource selection in the TOCF.
- NOTE 3 – Optimal resource selection can be executed either in the RLF or in the TOCF.

7.1.3 Relay functions (RFs)

When a DSN node or UE is behind a NAT/firewall or is affected by traffic overloads, it may not be able to use or provide DSN services. In order to handle such cases, the DSN functional architecture is required to provide functions for NAT/firewall traversal or redirection to avoid the congested point of the network. The RF relays particular application traffic for the DSN nodes to achieve NAT/firewall traversal and QoS improvement.

RF performs the following functions.

- NAT or firewall traversal: The RF can be used for traversing the NAT and firewall. DSN nodes and UE can send and/or receive packets over NAT/firewalls using intermediate DSN nodes with the RF.
 - Traffic relay: The RF relays traffic for DSN nodes and UE when a direct data path does not provide the required QoS.
 - Relay node status monitoring and report: The RF maintains status information of the relay node in which it resides for further reporting to the RLF.
- NOTE 1 – Status information includes CPU usage, memory usage, disk usage, network interface usage, etc.
- Event monitoring and report: The RF reports event related information (e.g., the node status) to the RLF when an event occurs.
- NOTE 2 – Examples of events monitored by the RF include the case where the load of the relay node in which the RF resides reaches a given threshold.
- Flow monitoring and report: The RF maintains and reports the flow statistics information of the relay node in which the RF resides to the management functions (MFs) for accounting or node/resource contribution statistics.

7.1.4 Content delivery functions (CDFs)

CDF stores, processes, and delivers content to DSN nodes or UE. It performs the following functions.

- CDF caches, stores and processes (e.g., transcoding, encryption) content.
- CDF delivers content to other CDFs or end-user functions (EFs).
- CDF initiates content registration to the RLF.
- CDF maintains and reports content related information to the RLF (which includes but is not limited to: content availability, content popularity, etc.).
- CDF requests the RLF for content location information when it needs to pull content from other CDFs.
- CDF provides buffer map information to other CDFs and EFs.

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- CDF supports content access check.
NOTE 1 – Access check means verifying whether the content requestor has the authority to download the content.
- CDF provides content chunking and reassembly of chunks.
- CDF provides integrity check and error recovery in content delivery.
- CDF provides delivery of content with flow control.
- CDF maintains status information of the content node in which it resides to be reported to the RLF.
NOTE 2 – Status information includes: CPU usage, memory usage, disk usage, network interface usage, etc.
- CDF reports event related information (e.g., the node status) to the RLF when an event occurs.
NOTE 3 – Examples of events include that the load of the content node in which the CDF resides reaches a given threshold.
- CDF optionally maintains and reports the flow statistics information to the MF for accounting or contribution statistics.

7.1.5 Traffic optimization control functions (TOCFs)

TOCF monitors and analyses network information and provides guidance to DSN nodes in order to make the delivery and distribution of application traffic in the DSN network more efficient and cost-effective.

TOCF performs the following functions:

- network information (including topology and traffic information) collection;
- traffic policy enforcement;
- provides location service to the DSN nodes (DSN nodes can query the TOCF about its geographic location in the network. DSN nodes can also query the TOCF for its network topology information, when necessary);
- provides network topology and traffic related information to the RLF and CSAF;
- provides preferred DSN node(s) from a set of candidate nodes that provide desired services (the TOCF provides a ranking service of DSN nodes based on the traffic information or topology information for traffic optimization; candidate nodes are provided by the RLF);
- provides specific traffic event notification function (the applications can subscribe to specific events such as the change of access bandwidth).

7.1.6 Management functions (MFs)

In order to use resources more efficiently and to manage services based on DSN, management functions for the DSN network and for the DSN service are needed. The MF inherits the functions of the MF in [ITU-T Y.2012], including:

- fault management;
- configuration management;
- accounting management;
- performance management;
- security management.

Specifically, the MF performs the following functions:

- records the statistics and accounting information generated by the RF and CDF which relates to usage and contribution of DSN services;

- supports scalable network management;

NOTE 1 – The DSN network may contain tens of thousands of network entities in a single administrative domain and the number of network entities may continuously increase after initial deployment. This requires a scalable and distributive design of the MF in the DSN. The capacity of the MF should increase as the network size increases.

- minimizes the impact of DSN node churn;

NOTE 2 – DSN nodes may frequently join and leave the DSN network. Maintaining long-term links from the MF to every DSN node becomes impossible. Therefore, a mechanism for dynamically setting up relationships between DSN nodes and the MF is needed. The mechanism enables the MF to discover the right DSN node and the DSN node to discover the right MF when a given management task needs to be performed. Furthermore, ungraceful leave (i.e., leave without normal leaving procedure) of DSN nodes may incur management information inconsistency. Thus, the management information should be stored in multiple MF/DSN nodes and synchronized when DSN nodes leave or join the DSN network.

- supports the redistribution of resources and functions.

NOTE 3 – DSN resources and network functions are no longer tied to specific nodes. Resources may move between DSN nodes and the role of a DSN node may change dynamically. Therefore, management tasks may need to be attached to the target resource or functions instead of specific DSN nodes so that management tasks can move with the resources or functions between different DSN nodes.

7.1.7 Service control functions (SCFs)

In the DSN, the SCF defined in NGN architecture [ITU-T Y.2012] is reused for service control.

NOTE – the DSN SCF interacts with DSN functions which are not defined in [ITU-T Y.2012] for resource location, application support, etc. The specification of reference points between the DSN SCF and other DSN functions may not be identical to that of the NGN.

7.1.8 End-user functions (EFs)

EF is a function of the DSN UE, which supports access to a DSN network and service.

NOTE – Besides the EF, UE may include other functions, such as the CDF and RF. When UE provides the capabilities of those functions, the contribution of the UE to the DSN network may be recorded and taken into account in the accounting. Which functions UE can support depends on the capability of the UE and the decision of the end user and DSN service provider. Refer to Appendix II for further information.

7.1.9 Content service application functions (CSAFs)

CSAF is an application function responsible in the DSN functional architecture for the provision of content-related services to the EF.

NOTE 1 – As shown in Figure 7-1, AFs different from the CSAF can be defined in the future for the provision of services other than content-related services.

CSAF performs the following functions:

- executes service logic based on the user profile and other information such as terminal capability, etc.;
- interacts with the SCF for user authentication and service authorization;
- interacts with the RLF to locate content resources for UE/applications;
- enables the EF to discover, select and purchase content;
- content preparation, which includes content naming, advertisement insertion, content slicing, trans-coding, encryption, etc.;
- pushes content to CDFs for distribution.

NOTE 2 – The CSAF pushes content to the root CDF. After content pushing, content can be distributed from the root CDF to other CDFs or end users.