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SERIES Y: GLOBAL INFORMATION INFRASTRUCTURE, INTERNET PROTOCOL ASPECTS AND NEXT-GENERATION NETWORKS

Next Generation Networks – Frameworks and functional architecture models

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Framework of vertical multihoming in IPv6-based next generation networks

Recommendation ITU-T Y.2056

ITU-T

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Recommendation ITU-T Y.2056

Framework of vertical multihoming in IPv6-based next generation networks

Summary

Recommendation ITU-T Y.2056 describes a framework for vertical multihoming in IPv6-based next generation networks (NGN). This Recommendation provides the definition, requirements, methods, functional architecture and applications of vertical multihoming in IPv6-based NGN.

History

Edition	Recommendation	Approval	Study Group
1.0	ITU-T Y.2056	2011-08-06	13

Keywords

IPv6, multihoming, NGN, vertical multihoming.

FOREWORD

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1 Scope

As heterogeneous access technologies have been developed, network nodes have been given the ability to simultaneously connect multiple access networks to support reliability, load sharing and mobility. These simultaneous multiple connections are established through multiple accesses to next generation networks (NGNs) using multiple access technologies, multiple network interfaces, multiple Internet Protocol version 6 (IPv6) addresses and multiple transport sessions.

To provide efficient simultaneous multiple connections, it is required to consider the impact from/on multiple access technologies, multiple network interfaces and multiple transport sessions. This Recommendation defines vertical multihoming as multihoming based on the characteristics of simultaneous multiple connections of several layers, which are managed vertically across several layers. This Recommendation describes a framework of vertical multihoming in IPv6-based NGN.

This Recommendation describes or defines:

– vertical multihoming;
– requirements of vertical multihoming;
– methods of vertical multihoming;
– functional architecture of vertical multihoming;
– applications of vertical multihoming.

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 published regularly. 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.2001] Recommendation ITU-T Y.2001 (2004), *General overview of NGN*.

[ITU-T Y.2011] Recommendation ITU-T Y.2011 (2004), *General principles and general reference model for Next Generation Networks*.

[ITU-T Y.2051] Recommendation ITU-T Y.2051 (2008), *General Overview of IPv6-based NGN*.

[ITU-T Y.2052] Recommendation ITU-T Y.2052 (2008), *Framework of multi-homing in IPv6-based NGN*.

[ITU-T Y.2701] Recommendation ITU-T Y.2701 (2007), *Security requirements for NGN release 1*.

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 IPv6-based NGN [ITU-T Y.2051]: This refers to NGN that supports addressing, routing protocols and services associated with IPv6. An IPv6-based NGN shall recognize and process the IPv6 headers and options, operating over various underlying transport technologies in the transport stratum.

3.1.2 IPv6 multihoming [ITU-T Y.2052]: A feature of an IPv6 host and/or IPv6 network that enables the host or network to be multihomed to networks through multiple network interfaces and multiple IPv6 addresses.

3.1.3 fault tolerance [b-ITU-T E.800]: The attribute of an item that makes it able to perform a required function in the presence of certain given sub-item faults.

3.1.4 load balancing [ITU-T Y.2052]: A scheme by which the traffic load could be separated and balanced to effectively utilize the network resources (e.g., link bandwidth).

3.1.5 network interface [ITU-T Y.2052]: A device to be used by a node to connect to a network.

3.2 Terms defined in this Recommendation

This Recommendation defines the following terms:

3.2.1 multihoming: Multiple links between an end-point and one or more transport networks. Multihoming may be used, for example, for load balancing or protection via diverse routes.

3.2.2 vertical multihoming: A feature of multihoming based on the characteristics of simultaneous multiple connections of several layers which are managed vertically across several layers.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

DCCP	Datagram Congestion Control Protocol
IP	Internet Protocol
IPv4	Internet Protocol version 4
IPv6	Internet Protocol version 6
MAC	Media Access Control
NACF	Network Attachment Control Functions
NGN	Next Generation Networks
OS	Operating System
PHY	PHYsical Layer
QoS	Quality of Service
RACF	Resource and Admission Control Functions
SCTP	Stream Control Transmission Protocol
TCP	Transmission Control Protocol
UDP	User Datagram Protocol

5 Conventions

None.

6 Description of vertical multihoming in IPv6-based NGN

IPv6-based NGN [ITU-T Y.2051], as one example of NGN, consists of a core network and heterogeneous access networks which allows flexible use of various interfaces. In addition, by using IPv6 multihoming capability [ITU-T Y.2052], a network and/or a network node are able to have multiple network connections via multiple network interfaces with multiple IPv6 addresses.

Although a network and/or a network node have multiple network connections with IPv6 multihoming, generally, it uses only one network connection at one time. Other network connections remain to prepare for a secondary (backup) connection and are used for special cases such as fault tolerance, providing higher bandwidth, load balancing, and mobility. There is a difference between providing multiple network connections and providing simultaneous multiple network connections with respect to how many network connections are being utilized at a given moment.

As heterogeneous access technologies are widely deployed in NGN, an NGN node can have the ability to connect various access networks simultaneously [ITU-T Y.2001] and [ITU-T Y.2011]. In multiple network connections due to heterogeneous access networks, many layers are used to establish multiple network connections.

From the point of view of the physical (PHY)/media access control (MAC) layer, there may be multiple network interfaces/MAC protocols which are directly related to each access technology, and these multiple network interfaces/MAC protocols may be simultaneously used. So, in PHY/MAC layer, there are multiple link layer connections to communicate with other nodes.

From the network layer's aspect, there may be multiple IPv6 addresses/IPv6 prefixes which are simultaneously used to establish multiple communication paths. So, in the network layer, there are multiple network layer connections to communicate with other nodes.

From the transport layer's aspect, there may be multiple transport layer sessions which are simultaneously used.

When considering how multiple network connections are established, each layer has a specific role for multiple network connections. Multiple network connections are made with the help of each layer and there is no interaction or relationship between the layers. However, to make efficient multiple network connections and manage these connections, it is required to consider the interaction and the relationship between layers. To do this, the concept of 'vertical multihoming' is used. In vertical multihoming, each layer has its specific multihoming features, which should be harmonized between layers. Figure 1 shows the multihoming of each layer and vertical multihoming. This Recommendation defines vertical multihoming as multihoming based on the characteristics of simultaneous multiple connections of several layers, which are managed vertically across several layers.

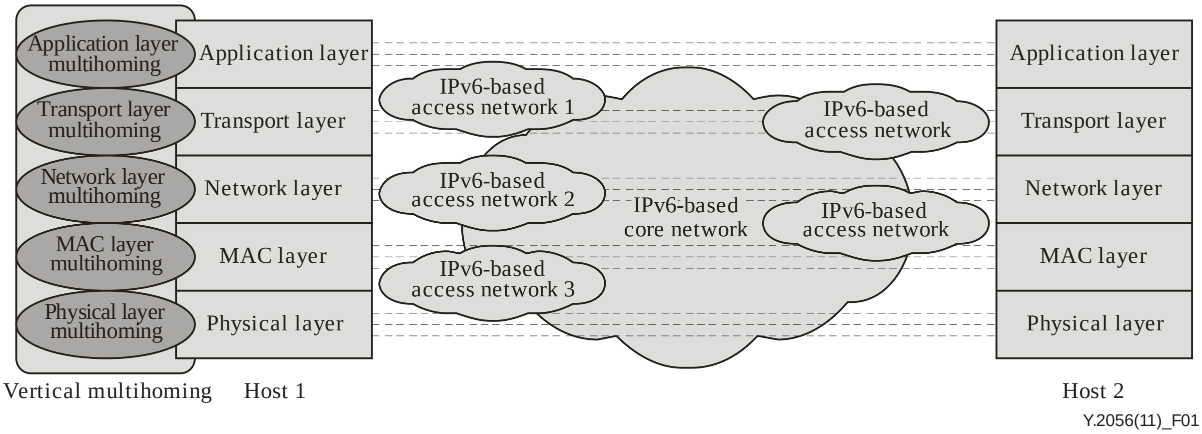

Figure 1 – Concept of vertical multihoming

In vertical multihoming, each layer has multihoming features and many network resources are used to establish multiple network connections. In PHY/MAC layer, multiple access technologies, multiple network interfaces, and multiple radios are network resources. In the network layer, multiple IPv6 addresses and multiple IPv6 prefixes are network resources. In the transport layer, multiple transport sessions are network resources. To establish multiple network connections and manage network resources efficiently, an integrated and harmonized network management is needed.

7 Requirements of vertical multihoming in IPv6-based NGN

With regard to the requirements of multihoming for IPv6-based NGN, the general, site specific, and host specific requirements are described in [ITU-T Y.2052]. As vertical multihoming is based on characteristics of multiple connections, which are simultaneously used, supported by several layers, and managed vertically across the layers, the requirements specific to the vertical multihoming involve not only the network layer but also other layers. This clause first describes aspects of each layer for vertical multihoming. Then, it describes the requirement of interaction across several layers. Because vertical multihoming is related to several layers, which have their own resources, management of the resources is one of the important topics to be considered for vertical multihoming.

7.1 Multihoming features and requirements of each layer

Generally, IPv6 multihoming means that a feature of IPv6 hosts and/or an IPv6 network enables the host and/or network to be multihomed to networks through multiple network interfaces and multiple IPv6 addresses. To provide multiple network connections, it is not only IPv6-multihoming, but also multihoming features of other layers that play an important role.

In PHY/MAC layer, there may be many PHY entities (e.g., physical interfaces, radios or channels) and many MAC entities (e.g., MAC protocols). If it is assumed that the connection on the PHY/MAC layer is a link layer connection, then there are many link layer connections due to heterogeneous access networks. As heterogeneous access technologies and access networks have been deployed in IPv6-based NGN, a host can use multihoming features of the link layer such as multiple radios, multiple channels, multiple interfaces and multiple MAC protocols. Using these multihoming features makes it possible to establish multiple link layer connections. For vertical multihoming, multiple link layer connections are required to be provided and these multiple link layer connections are required to be simultaneously enabled and utilized. And these multiple link layer connections are required to be harmonized with above network layer connections.

In the network layer, for multihoming features, multiple IPv6 addresses and multiple IPv6 prefixes are used. By using this IPv6 multihoming, multiple network connections are established at the network layer. For vertical multihoming, multiple network layer connections are required to be provided and these multiple network layer connections are required to be simultaneously enabled and utilized. Also, these multiple network layer connections are required to be harmonized with link layer connections and transport layer connections.

In the transport layer, for multihoming features, multiple transport streams and ports are used. By using these multihoming features, multiple transport connections are established at the transport layer. For vertical multihoming, these multiple transport layer connections are required to be provided and these multiple transport layer connections are required to be simultaneously enabled and utilized. These transport layer connections are also required to be harmonized with link layer connections and network layer connections.

7.2 Interaction across several layers

Generally, the layer concept (e.g., Transmission Control Protocol (TCP)/IP Protocol suites) simplifies design, implementation, and testing by partitioning the overall communications process. Protocols in each layer can be designed separately from those in other layers. The layer concept provides flexibility for modifying and evolving protocols and services without having to change layers above or below. Typically, the architecture and services of the Internet have been developed based on this layer concept and operated properly.

In NGN environments, where a host has the capability to connect to heterogeneous access networks and simultaneously use multiple connections, there is a strong need to modify the current layer concept. For example, a cross-layer mechanism could redesign the layer concept by interconnecting the layers. It could include the creation of new interfaces, the merging of adjacent layers, and designing coupling without new interfaces. Similarly, for vertical multihoming, interaction across several layers is needed.

Figure 1 depicts multihoming for each layer: physical layer multihoming, MAC layer multihoming, network layer multihoming, transport layer multihoming and application layer multihoming. If the multihoming of each layer is not managed in an integrated fashion, it would seem that the synergy effects of multihoming of each layer is not good. For example, if there are multiple link layer connections at the PHY/MAC layer and multiple network layer connections at the network layer and there is no interaction between two adjacent layers, the network layer would not know how many link layer connections are provided for them. Without knowing the below link layer connection characteristics, it would be difficult to efficiently utilize network layer connections. Similarly, multiple transport connections are required to interact with below network layer connections and link layer connections to ensure efficient utilization. So, for vertical multihoming, the interaction across several layers is required.

7.3 Resource management of vertical multihoming

Vertical multihoming is related to several layers; the PHY/MAC layer, network layer, transport layer, and application layer. In each layer, there are specific network resources. In the PHY/MAC layer, wired/wireless interfaces, radios and channels are included. In the network layer, IPv6 address and IPv6 prefix are network resources. In the transport layer, transport streams and port numbers are network resources. If the legacy layer concept is considered, network resources at each layer do not directly affect other network resources at an adjacent layer. But, in vertical multihoming, due to the interaction across several layers, network resources at one layer affect other adjacent layers. So, it is required to manage network resources in different ways.

As described in clause 7.2, in vertical multihoming, interaction between adjacent layers is required and network resources in adjacent layers affect other layers. In vertical multihoming, network resources are required to be managed in an integrated fashion, which differs from the legacy layer concept. Also it is required to consider the effect of using network resources in one layer on an adjacent layer.

7.4 Other requirements for vertical multihoming

For vertical multihoming, the following requirements are required to be satisfied in order to handle multiple network interfaces and multiple network connections efficiently.

– Routing optimization through multiple network connections over multiple interfaces: Routing optimization focuses on choosing the data path on multiple network connections for forwarding data efficiently in terms of diverse application requirements.

– Quality of Service (QoS) based connection selection over multiple network connections: In heterogeneous environments, each network interface technology has different transmission capabilities. Hence, the multihomed host can forward data through different routing paths with different transmission capabilities over multiple network connections established with multiple network interfaces. Also, dividing data streaming among different network interfaces can increase transmission capabilities through simultaneous usage of multiple network interfaces.

– Bandwidth utilization over multiple network connections: Bandwidth utilization is to provide better transmission stability, reliability and performance. Hence, the issues affecting bandwidth utilization are how to separate data streams and how to recombine data streams over multiple network connections.

– Recovery scheme for network interface failure: When the original network interface used for data transmission fails because of the link disconnection problem in the link layer or the routing problem in the network layer, the multihomed host is required to perform a fast connection recovery by using any available network interface in the multihomed host.

– Network interface selection: Network interface selection defines which network interfaces to use and when to change them, depending on the network interface selection algorithm and policy. The selection takes into account chosen parameters such as signal strength, transmission rate, service stability and reliability.

8 Methods of vertical multihoming

This clause introduces several methods of vertical multihoming in terms of how network addresses correspond to interfaces and to what extent the relevant capabilities of layers are involved.

8.1 Methods of vertical multihoming in terms of correspondence between IPv6 address and interface

In a vertical multihoming environment, there are two different methods for establishing multiple network connections according to the number of IPv6 addresses as follows:

– Multiple network connections through a unique IPv6 address per interface.

– Multiple network connections through a shared IPv6 address per interface.

In the first method, where the multihomed host is assigned the unique IPv6 address per interface, the multihomed host can send and receive packets simultaneously over the multiple network connections established with a network host through the unique IPv6 address assigned to an interface. As shown in Figure 2-a, this method shows that the multihomed host is able to create multiple connectivity via multiple network interfaces and uses multiple network interfaces simultaneously for sending and receiving packets without a particular IPv6 stack support. Since a particular application which wants to establish multiple network connections contacts a network host by creating a client-local TCP/User Datagram Protocol (UDP) socket of the transport layer with a unique IPv6 address assigned to multiple network interfaces, that is, from the application's perspective, there may exist multiple network connections between the multihomed hosts.

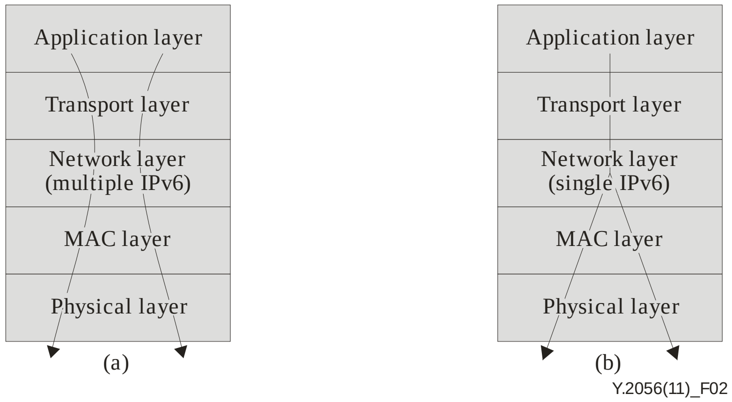

Figure 2 – Multiple network connections through (a) a unique IPv6 address per interface and (b) a shared IPv6 address per interface

In the second method, the multihomed host is assigned the shared IPv6 address across multiple network interfaces. Although this method makes only one IPv6 address visible to the application, the multihomed host is able to access heterogeneous networks through multiple network interfaces. Therefore, it uses multiple network resources which can be accessed by multiple network interfaces. However, in this method, although a particular application in the multihomed host wants to establish multiple network connections with a network host, the application is not able to establish multiple network connections. Since the application does not know how to support multiple network interfaces, a particular function for the establishment of multiple network connections is needed in the IPv6 stack. Here, the function may perform the flow assignment for an application flow to be serviced on a particular network interface.

8.2 Methods of vertical multihoming in terms of supporting layers

To support vertical multihoming in an IPv6-based NGN, not only the IPv6 network layer but also other layers/stratums are to be considered. To provide optimal vertical multihoming, it is better to ensure all layers/stratum have multihoming capabilities. However, in reality, this is difficult to achieve. Vertical multihoming is related to several layers and each layer may have different capabilities to support vertical multihoming. This clause classifies the methods of vertical multihoming in terms of supporting layers.

If the methods of vertical multihoming are classified as the multihoming capabilities of each layer, there are the following methods for providing vertical multihoming:

– multiple network connections through the multihoming capabilities of the PHY/MAC layer;

– multiple network connections through the multihoming capabilities of the PHY/MAC and network layers;

– multiple network connections through the multihoming capabilities of the PHY/MAC, network and transport layers;

– multiple network connections through the multihoming capabilities of the PHY/MAC, network, transport and application layers.

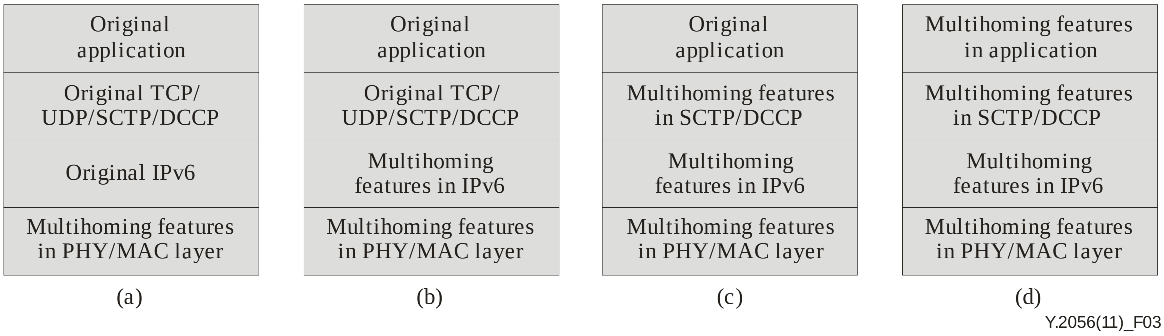

Figure 3 – Multiple network connections through the multihoming capabilities of each layer

In the first method, the host adopts multihoming features in the PHY/MAC layer such as multiple interfaces, multiple channels, multiple radios, and multiple MAC protocols, but other layers do not support multihoming. Due to the overheads and cost of modification of the original network layer, the transport layer and application layer, it is difficult to modify other layers all at once, to support multihoming at each layer. For specific applications and/or a specific operating system (OS), it may be difficult to modify them to support vertical multihoming. In this method, the host must have a capability to handle multihoming features in the PHY/MAC layer even though the original network layer and transport layer do not support multihoming features in the PHY/MAC layer.

In the second method, the host adopts multihoming features in the PHY/MAC layer and network layer but other layers such as the transport layer and application layer are not aware of the existence of multihoming features in the PHY/MAC layer and network layer. In this method, the host must have a capability to effectively combine multihoming features in the PHY/MAC layer and multihoming features in the network layer. Also, a host must have a capability to handle multihoming features in the PHY/MAC layer and network layer even though the original transport layer and application layer do not support multihoming features in the PHY/MAC layer and network layer.

In the third method, the host adopts multihoming features in the PHY/MAC layer, network layer, and transport layer but the application layer is not aware of the existence of these multihoming features in the other layers. It seems that existing TCP/UDP could not have the capability to support multihoming features and it seems that Stream Control Transmission Protocol (SCTP) [b-IETF RFC 2960]/Datagram Congestion Control Protocol (DCCP) [b-IETF RFC 4340] could have the capability to support multihoming features. In this method, the host must have a capability to effectively combine multihoming features among the PHY/MAC layer, network layer, and transport layer. Also, a host must have a capability to handle multihoming features in the PHY/MAC layer, network layer, and transport layer even though the original application layer does not support multihoming features in other layers.

In the fourth method, the host adopts multihoming features in every layer and it is the ultimate vertical multihoming. So, there are multiple connection characteristics of each layer and these characteristics may be simultaneously utilized and managed vertically across several layers. In this method, a host must have a capability to interact multihoming features across several layers and a resource management scheme for vertical multihoming.

9 Functional architecture of vertical multihoming

As described in clause 7, the requirements of vertical multihoming in an IPv6-based NGN include the requirements of multihoming in an IPv6-based NGN as described in [ITU-T Y.2052]. As vertical multihoming is based on IPv6 multihoming, the requirements of vertical multihoming are also based on the requirements of IPv6 multihoming in IPv6-based NGNs.

Also, the functional architecture of vertical multihoming is related to the functional architecture of multihoming in IPv6-based NGNs. Many functions and functional entities described in [ITU-T Y.2052] can be referred to, to provide vertical multihoming.

In the functional architecture described in [ITU-T Y.2052], the main function and functional entities for multihoming in an IPv6-based NGN are located on the network side such as the network attachment control function (NACF), access network function, edge function, and core transport function.

The functions for vertical multihoming on the network side are also related to functions for vertical multihoming on the host side. As the primary purpose of vertical multihoming is to provide efficient multiple connections by considering the multihoming characteristics of each layer, the functions for vertical multihoming on the host side is basically responsible for providing vertical multihoming and the functions for vertical multihoming on the network side assist the functions on the host side.

9.1 Functional architecture of vertical multihoming on the host side

To consider the requirements of vertical multihoming, most requirements are related to the host side.

The required functions for vertical multihoming are as follows:

– identifying resources on each layer;

– resource management;

– recognizing network status and adjust resources;

– interaction across several layers.

To provide these functions for vertical multihoming in IPv6-based NGN, these functions may be located on both the host side and the network side. This clause describes the required functions for vertical multihoming on the host side. As shown in Figure 1, multihoming features exist in each layer and vertical multihoming functions are related to multihoming features in each layer.

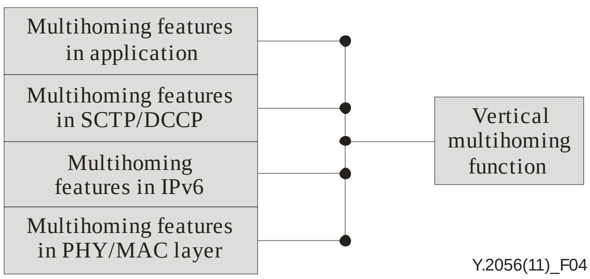

Figure 4 – The relationship between vertical multihoming functions and multihoming features in each layer

For vertical multihoming, the resource identifying function, resource management function, network status recognize and adjust function, and interaction across layer functions are tightly coupled and interact closely. The basic capability of each function is as follows:

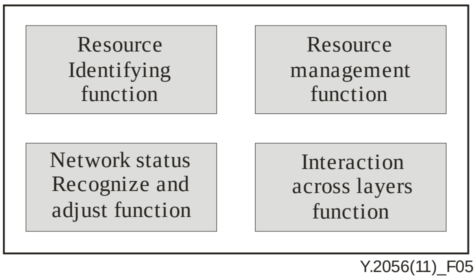

Figure 5 – Functions for vertical multihoming

– Resource identifying function: For vertical multihoming, there are many resources in each layer. It is important to identify what kind of resources are related to vertical multihoming and what kind of attribute of each resource has an influence on vertical multihoming. The resource identifying function identifies resources on each layer for vertical multihoming and gathers necessary information for resource management.

– Resource management function: In vertical multihoming, a resource in one layer is closely related to resources in another layer. The role of the resource management function for vertical multihoming is to control and manage resources in each layer in an integrated fashion.

– Network status recognize and adjust function: Because vertical multihoming deals with interactions between all layers and relates to the resources in each layer, it is important to precisely recognize the status of each layer. To satisfy the requirement of a specific service (such as guaranteeing end-to-end performance, guaranteeing minimum bandwidth for some applications), vertical multihoming is required to have the capability to adjust resources on each layer.

– Interaction across layer function: For vertical multihoming, one specific layer must collaborate with other layers. The interaction across layer function manages the interaction between different layers for vertical multihoming.

9.2 Overall architecture of vertical multihoming on the network side

In clause 9.2 of [ITU-T Y.2052], the functional architecture to support multihoming is described. To provide functions for vertical multihoming on the network side, existing functional entities can be used to provide functions for vertical multihoming. In contrast to the functional architecture which is defined in [ITU-T Y.2052], the resource and admission control function (RACF) [b-ITU-T Y.2111] is required to participate in providing vertical multihoming. The following figure shows the overall architecture related to vertical multihoming on the network side.

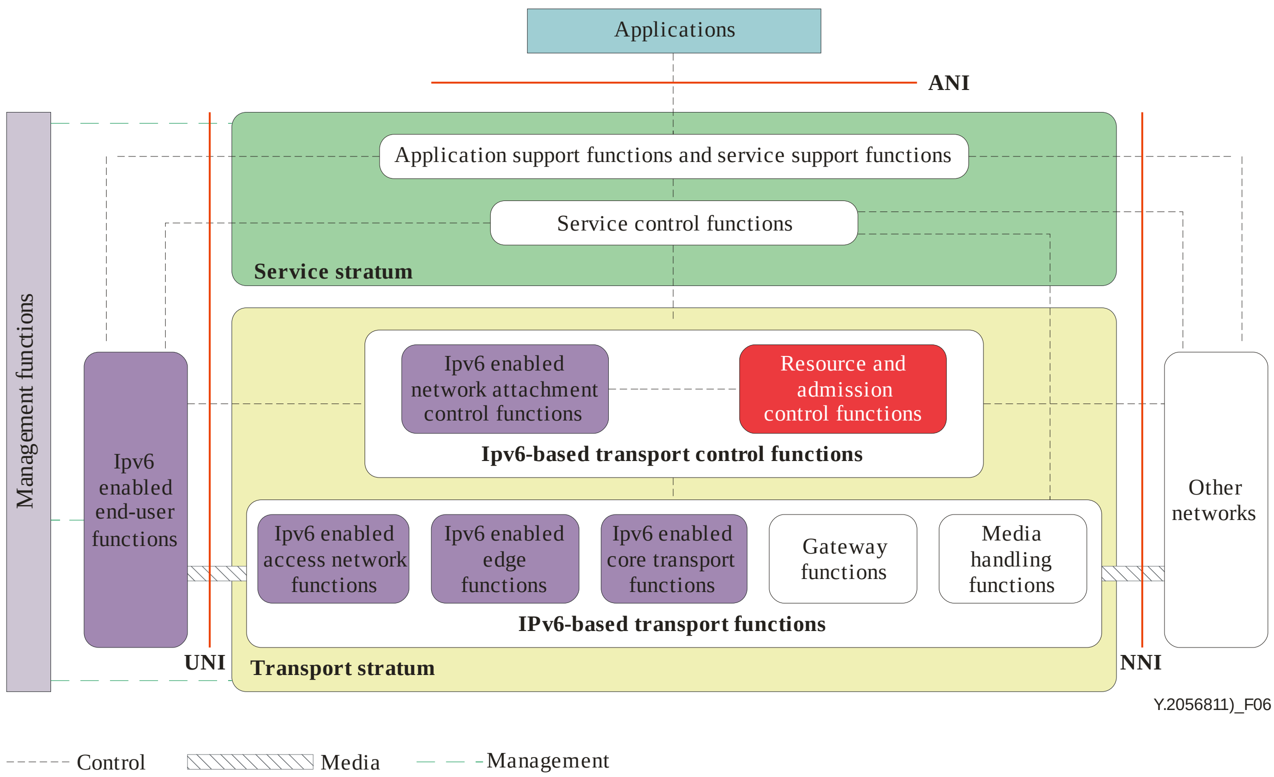

Figure 6 – Overall architecture of vertical multihoming on the network side

10 Applications of vertical multihoming

In IPv6-based NGN, NGN users will benefit from always-on connectivity, load sharing, traffic engineering, fault tolerance with redundancy, and session continuity with the help of IPv6 multihoming [ITU-T Y.2052]. With vertical multihoming, these use cases are also applied to IPv6-based NGN. Besides these use cases, vertical multihoming has additional use cases as follows.

– use cases related to lower layer (e.g., PHY layer, MAC layer);

– use cases related to upper layer (e.g., transport layer, application layer).

10.1 Use cases related to lower layer

Generally, a legacy user terminal utilizes one network interface for communication at a time. Even though it has multiple network interfaces, it does not utilize multiple network interfaces simultaneously. The reason why it uses a single interface at a time may be in compliance with the traditional TCP/IP layer concept and there is no need to use multiple interfaces simultaneously.

In the traditional TCP/IP layer concept, typically, one network interface is directly related to one IP address. Even though IPv6 is widely deployed, this situation does not change. The big difference between IPv6 and Internet Protocol version 4 (IPv4) is that there is a greater number of IPv6 addresses available to the network entities for use. It is possible to use multiple IPv6 addresses per single network interface and multiple network interfaces in a host. So, it is possible to utilize multiple network connections using an abundant number of IPv6 addresses and multiple network interfaces. The benefit of IPv6 multihoming, usage of multiple network connections with multiple IPv6 addresses and multiple network interfaces is not increased as expected due to the inefficient relation between one IPv6 address and a single network interface.

If a host has multiple interfaces and multiple IPv6 addresses, the relationship between them may exist in various ways and it may be dynamically changeable. Among multiple interfaces, some of them may be utilized (connected to an access network) and some of them may not be utilized (is not connected to an access network). Among multiple IPv6 addresses, some of them may be utilized (there is a routing path to communicate) and some of them may not be utilized (there is no routing path to communicate). If a host can recognize the existence of multiple interfaces and multiple IPv6 addresses and the utilized conditions of each interface and each IPv6 address, the host may find the optimal association between the network interface and IPv6 address.

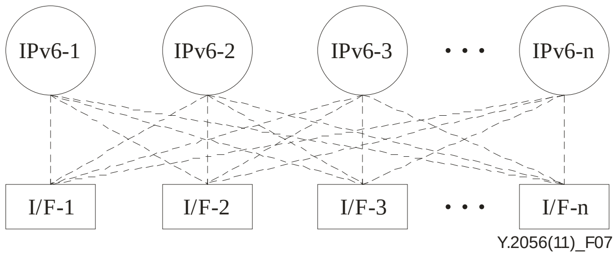

Figure 7 – An example of the relationship in the multiplicity of network interfaces and IPv6 addresses

For example, in the traditional TCP/IP layer concept, one specific interface and one specific IPv6 address is combined at a starting time of communication. The selection of one IPv6 address among multiple IPv6 addresses and the selection of one network interface among multiple interfaces are completely independent. Even though there are lots of advantages of this independent layer concept, this complete independent layer concept cannot utilize the benefit of the existence of multiple interfaces and multiple IPv6 addresses. As there is no specific rule for combining a network interface and an IPv6 address and one IPv6 address and one network interface is selected for communication, there is no guarantee to select the optimal association between a network interface and an IPv6 address.

After communication between the nodes start, the combination between specific network interfaces and specific IPv6 addresses cannot be modified. In communication mechanisms based on the traditional TCP/IP layer concept, the combination between a network interface and an IPv6 address should be used for the entire time of communication. During communication, if the relation combination between a network interface and an IPv6 address is modified, the communication is disrupted.

Because there are multiple network interfaces and multiple IPv6 addresses for communication, a host can utilize multiple network interfaces and multiple IPv6 addresses simultaneously. But in the traditional TCP/IP layer mechanism, a host cannot utilize these multiplicities of network interfaces and IPv6 addresses.

If vertical multihoming is used, it is possible to utilize these multiplicities of network interfaces and IPv6 addresses. Vertical multihoming can recognize the existence of multiple network interfaces and IPv6 addresses and coordinate them. One-to-one mapping between a network interface and an IPv6 address in traditional TCP/IP layer concept is enhanced to multi-to-multi mapping between them. The host can find optimal mapping between network interfaces and IPv6 addresses and dynamically update the combination between them to adapt to a changeable exterior environment.

10.2 Use cases related to upper layer

Generally the upper layer of IPv6 is the transport layer and application layer. In the traditional TCP/IP layer the concept, there is no relationship between IPv6 multihoming and upper layer operations. Even though so many IPv6 addresses and network interfaces exist, they do not directly affect the operations of the upper layer. Also, upper layer protocols such as TCP/UDP do not utilize the advantage of IPv6 multihoming and the multiplicity of multiple interfaces. If SCTP and multi-path TCP are utilized in the transport layer, the relationship between IPv6 multihoming and the upper layer should be enforced.

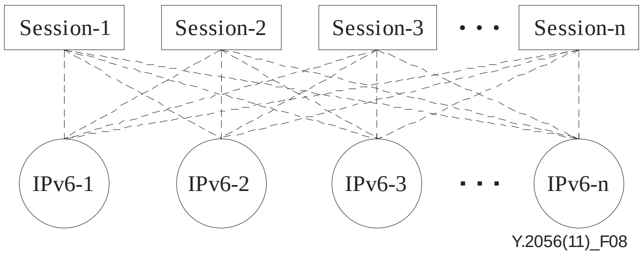

Figure 8 – An example of the relationship in the multiplicity of IPv6 addresses and sessions in transport layer

In the traditional TCP/IP layer concept, typically, one TCP/UDP session is directly related to one IP address and it does not change even though IPv6 is widely deployed. If one TCP/UDP session could use multiple IPv6 addresses (and also multiple network interfaces), there any many benefits. If a host has multiple IPv6 addresses and multiple transport sessions, the relationship between them may exist in various ways and it may be dynamically changeable. From the point of the transport layer, among multiple IPv6 addresses, some of them may be utilized (to make an end-to-end connection) and some of them may not be utilized (there is no routing path to communicate). If a host can recognize the existence of multiple IPv6 addresses and multiple transport sessions and the conditions of each IPv6 addresses and transport sessions, the host may find the optimal association between the IPv6 address and transport session.

For example, in the traditional TCP/IP layer concept, one specific IPv6 address and one specific session/port number are combined when the communication starts. The selection of an IPv6 address among multiple IPv6 addresses and the selection of a session/port number among multiple session/port numbers are completely independent. Even though there are lots of advantages of this independent layer concept, this complete independent layer concept cannot utilize the benefit of the existence of multiple IPv6 addresses and multiple session/port numbers. As there is no specific rule for combining an IPv6 address and session/port number and one IPv6 address and one session/port number is selected for communication, there is no guarantee to select the optimal association between an IPv6 address and a session/port number.

After communication between the nodes start, the combination between a specific IPv6 address and a specific session/port number cannot be modified. In communication mechanisms based on the traditional TCP/IP layer concept, the combination between an IPv6 address and a session/port number should be used for the entire time of communication. During communication, if the relationship of the combination between an IPv6 address and a session/port number is modified, the communication is disrupted. To solve the modification of an IPv6 address, it is possible to use another mobility management protocol such as Mobile IPv6 [b-IETF RFC 3775] and Proxy Mobile IPv6 [b-IETF RFC 5213].

As there are multiple IPv6 addresses and multiple session/port numbers for communication, a host can use multiple IPv6 addresses and multiple session/port numbers simultaneously. But in the traditional TCP/IP layer mechanism, a host cannot utilize these multiplicities of IPv6 addresses and session/port numbers.

As shown in Figure 8, in vertical multihoming it is possible to utilize these multiplicities of IPv6 addresses and session/port numbers. Vertical multihoming can recognize the existence of multiple IPv6 addresses and session/port numbers and coordinate them. One-to-one mapping between an IPv6 address and a session/port number in the traditional TCP/IP layer concept is enhanced to multi-to-multi mapping. The host can find optimal mapping between an IPv6 address and a session/port number and dynamically update the combination between them to adapt to a changeable exterior environment.

For the application layer, vertical multihoming can coordinate between IPv6 addresses and session/ port numbers and dynamically control the necessary QoS features.

11 Security considerations

This Recommendation does not require any specific security considerations and aligns with the security requirements in [ITU-T Y.2701].

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