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

Next Generation Networks – Future networks

Generic requirements and framework of addressing, routing and forwarding in future, packet-based networks

Recommendation ITU-T Y.2612

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Recommendation ITU-T Y.2612

Generic requirements and framework of addressing, routing and forwarding in future, packet-based networks

Summary

Recommendation ITU-T Y.2612 describes the generic technical architecture, attributes and mechanisms of future, packet-based networks (FPBN) addressing, mapping, translation, routing, and forwarding based on Recommendations ITU-T Y.2601 and Y.2611. This Recommendation can be provided as a reference to the future design and implementation of the FPBN network.

Source

Recommendation ITU-T Y.2612 was approved on 23 January 2009 by ITU-T Study Group 13 (2009-2012) under Recommendation ITU-T A.8 procedure.

FOREWORD

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In this Recommendation, the expression "Administration" is used for conciseness to indicate both a telecommunication administration and a recognized operating agency.

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Generic requirements and framework of addressing, routing and forwarding in future, packet-based networks

1 Scope

This Recommendation describes the generic technical architecture, attributes and mechanisms of addressing, mapping, translation, routing, and forwarding within a future, packet-based network (FPBN), including:

- Transport stratum addresses
- Allocation methods for addresses
- Mapping between service stratum names and transport stratum addresses
- Translation between different transport stratum technologies and administrative domains
- Mechanisms of routing and forwarding within the transport stratum.

This Recommendation is restricted to describing some common technical requirements and framework of these above aspects. The specific technologies which can be used to implement these aspects are outside of the scope of this Recommendation.

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 G.805] Recommendation ITU-T G.805 (2000), *Generic functional architecture of transport networks*.

[ITU-T Y.2601] Recommendation ITU-T Y.2601 (2006), *Fundamental characteristics and requirements of future packet based networks*.

[ITU-T Y.2611] Recommendation ITU-T Y.2611 (2006), *High-level architecture of future packet-based networks*.

[IETF RFC 2328] IETF RFC 2328 (1998), *OSPF version 2*.
<http://www.ietf.org/rfc/rfc2328.txt>

[IETF RFC 2453] IETF RFC 2453 (1998), *RTP version 2*.
<http://www.ietf.org/rfc/rfc2453.txt>

[IETF RFC 4271] IETF RFC 4271 (2006), *A Border Gateway Protocol 4 (BgP-4)*.
<http://www.ietf.org/rfc/rfc4271.txt>

[IETF RFC 4291] IETF RFC 4291 (2006), *IP version 6 Addressing Architecture*.
<http://www.ietf.org/rfc/rfc4291.txt>

3 Terms and definitions

This Recommendation uses the following terms defined elsewhere:

3.1 **address**: See [ITU-T Y.2601].

3.2 **control plane**: See [ITU-T Y.2011].

3.3 **data plane**: See [ITU-T Y.2011].

3.4 **identifier**: See [ITU-T Y.2601].

3.5 **management plane**: See [ITU-T Y.2011].

3.6 **name**: See [ITU-T Y.2611].

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

ACL Access Control List

AP Access Point

BGP Border Gateway Protocol

CP Connection Point

DCE Data Circuit-terminating Equipment

DNS Domain Name System

DTE Data Terminal Equipment

FIB Forwarding Information Base

FIFO First In First Out

FP Flow Point

FPBN Future Packet-Based Network

GFP Generic framing Procedure

ICMP Internet Control Message Protocol

ID Identifier

IP Internet Protocol

MAC Media Access Control

NAT Network Address Translation

NGN Next Generation Network

OAM Operation, Administration & Maintenance

OSPF Open Shortest Path First

PBN Packet Based Network

QoS Quality of Service

RIP Routing Information Protocol

TCP Termination Connection Point

TFP Termination Flow Point

TTL Time To Live

URPF Unicast Reverse Path First

5 Conventions

In this Recommendation, the following conventions are used:

The keywords "**is required to**" indicate a requirement which must be strictly followed and from which no deviation is permitted, if conformance to this Recommendation is to be claimed.

The keywords "**is recommended**" indicate a requirement which is recommended but which is not absolutely required. Thus this requirement need not be present to claim conformance.

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

Addressing, routing and forwarding mechanisms all play key roles respectively in the FPBN network. The addressing mechanism determines the topological location of each entity in the FPBN network. The routing mechanism distributes and collects topology-related information, calculates the routes, establishes and maintains the routing table, establishes and maintains the forwarding information base (FIB). The forwarding mechanism retrieves the FIB, and transfers the packets based on the results of the retrieval.

Although the mechanisms of addressing, routing and forwarding in different networks are different, there are still some common technical requirements and framework.

This Recommendation summarizes some generic requirements and framework according to the basic requirements ([ITU-T Y.2601]) and high level design of the FPBN network ([ITU-T Y.2611]).

This Recommendation can be provided as a reference to the future design and implementation of the FPBN network.

7 Addressing

An address is the location identifier for a specific entity (unicast) or a group of entities (multicast) or one of a group of entities (anycast) in layer networks of transport stratum. In the FPBN network, addressing mechanism is a set of actions to define the address structure, to specify the entities to be addressed, to clarify the allocation methods, and so on.

7.1 Address attributes

The layer networks that form the transport stratum are independent from one another; as a result, the addressing of these layer networks is recommended to be independent from one another within the transport stratum.

To satisfy the requirements of the FPBN defined in [ITU-T Y.2601], addresses in FPBN are required to have several desirable properties in their addressing domain. Some important attributes are listed as follows:

- Uniqueness: An address is required to be used reliably and deterministically for a single unique entity in one administrative domain. But an entity can have more than one address.

- Persistence: If the location of an entity does not change, the address of the entity is required not to be changed frequently.
- Structured: The address is required to be structured, with the purpose of aggregation. It can facilitate the routing and forwarding processes.

7.2 Structure of addresses

There are two kinds of structured addresses in a packet based network: flat and hierarchical.

- Flat addressing: Address allocation is random from the aspects of routing and forwarding. Routing and forwarding mechanisms work on the whole bits of target address in a packet header, rather than part of them in the address fields. Typical flat addressing is Ethernet MAC address.
- Hierarchical addressing: For the purpose of efficient routing and forwarding, address management follows a top down allocation process whereby intermediate levels can sub-allocate to lower levels, portions of the address that was assigned to them by a higher level. Routing and forwarding will only work on parts of bit of the whole address, rather than the whole address. Typical hierarchical addressing is IP address.

In the FPBN network, it is recommended to choose hierarchical addressing, and the hierarchical address can be divided into several parts, each part of the address carries its own information. For example, one part of address specifies the network ID, another part specifies the host ID.

Hierarchical address is required to support unicast and multicast, and recommended to support anycast.

7.3 Addressing objects

In FPBN, addressing objects can be a specific entity or a group of entities or one of a group of entities in layer networks of transport stratum, which are either DTE or DCE, such as network terminal(s), AP (access point), TCP (termination connection point), CP (connection point), FP (flow point), TFP (termination flow point) defined in [ITU-T G.805]. All of the addressing objects are required to be addressed to support unicast, multicast, and/or anycast communication.

As recommended in [ITU-T Y.2611], there are three planes (data plane, management plane and control plane) in the FPBN network and each plane is recommended to have its own address space. Each address space can be independent of the other address spaces, even if they use the same syntax or structure.

When involved in more than one plane, each addressing object is recommended to have an independent address for each plane correspondingly.

Control plane address identifies the location of the addressing object in FPBN control plane which exchanges control information (for example, topological information, QoS policy) between network entities.

Data plane address identifies the location of addressing object in FPBN data plane which transfers user packets among network terminals.

Management plane address identifies the location of the managed addressing object in the FPBN network which exchanges OAM information, and can be used to locate and access the addressing object by operators or other transport entities in the management plane.

7.4 Allocation methods

In FPBN, the allocation method is required to support one of the following options: provider-preference and geography-preference. Provider-preference and geography-preference are not mutually exclusive. In certain circumstances, the address space can be first allocated by an address

allocation authority to the network provider, and then it can be further allocated according to the regional locations in the network provider.

Provider-preference implies that address space can be allocated by an address allocation authority to the network providers, not to a country or a region. Each network provider can apply and be assigned a part of address space which can be distinguished by different address prefix. Network providers can independently decide how to allocate addresses in their own network. The current IP address allocation method is a typical example of provider-preference.

Geography-preference implies that network addresses can be allocated according to the national or regional locations. Each nation or region has its own address space with a different address prefix, and can independently allocate addresses by its own rule.

8 Mapping and translation

There will be several independent addressing mechanisms existing in the different layers. For example, IP address and MAC address belong to different layers in the transport stratum. Even in the same layer network of the transport stratum, it is also possible that different addressing mechanisms are used in the different administrative domains. For example, private IPv4 addresses can be used in enterprise network, while IPv6 or public IPv4 addresses can be used in the access and/or core network.

The mapping mechanisms are required between different layers within an FPBN, and the translation mechanisms are required at the boundary of the different administrative domains in the FPBN network. The mapping and translation mechanisms are required within the data plane, control plane and management plane in the FPBN network.

8.1 Mapping

Mapping is to make a logical connection between two entities which belong to the different layers, for example, the logical connection from domain name to IP address or reversely, or the logical connection from IP address to MAC address or reversely.

The mapping results can optionally be stored in a mapping table, a central database, or a distributed database. In order to enhance the efficiency, the mapping results are recommended to be cached in memory.

It is required to support at least one of the three types of mapping mechanisms: to be assigned statically by the management plane, to be informed with or without inquiry, or to be calculated by some algorithms. For example, the mapping from IPv6 address to MAC address can be configured statically, or inquired by ICMPv6, or calculated by Internet protocol version 6 (IPv6) addressing architecture [IETF RFC 4291]. The mapping is required to have a lifetime, which can be temporary or permanent.

Some mapping results are only available locally, for example, the mapping information between IPv6 and MAC address. Some mapping results can be accessible globally, for example, the mapping results from the DNS record. In the FPBN network, the two conditions can be both taken into consideration.

There are four kinds of mapping, one-to-one, one-to-many, many-to-one and many-to-many. The FPBN network is required to support the first three at least.

8.2 Translation

Translation is to make a logical connection between different addresses when the entity belongs to different addressing spaces, such as to make a logical connection between IPv4 address and IPv6 address or to make a logical connection between private IP address and global IP address.

The translation results can optionally be stored in a translation table, central database, or distributed database.

It is required to support at least one of the three translating mechanisms: to be assigned statically from the management plane, to be informed with or without inquiry, or to be calculated by some algorithms. The translation is required to have a lifetime, which can be temporary such as NAT, and can also be permanent such as global address of intranet web server.

In the FPBN network, one-to-one translation is required to be performed by the gateway devices.

9 Routing

Routing is the process of distributing and collecting topology-related information, calculating the routes, establishing and maintaining the routing table in the FPBN network, establishing and maintaining the FIB based on the routing table.

9.1 Distributing/collecting topology information

Topology information distributing/collecting are procedures that routing entities propagate/collect, with or without solicitation, network topology information or route items within its routing domain.

In the FPBN network, the network topology information can optionally include the link connectivity information, routing entity's status information, link cost information, or the route items calculated by the sender, etc.

A routing domain is a group of entities which run the same routing protocol in the same administrative domain. Within a routing domain, the objectives to which the network topology information is distributed can be different in different routing protocols such as the topology information can be sent to the neighbours of the same link in the routing information protocol (RIP), [IETF RFC 2453], the topology information can be flooded to all of entities in the same area in the open shortest path first protocol (OSPF), [IETF RFC 2328], the topology information can also be sent to the peers of the routing process in the border gateway protocol (BGP), [IETF RFC 4271]. In the FPBN network, the modes mentioned above can optionally be supported.

A routing entity usually distributes the topology information periodically. In order to improve the convergence performance of the routing, a routing entity can send related information triggered by certain events. In some cases, the routing entity can damp the sending procedure for the sake of network stability, or to avoid routing flap. In the FPBN network, the modes mentioned above are required to be supported.

9.2 Calculating the routes

Calculating the routes is a procedure that the routing entity can calculate the best path (route) by certain routing protocols according to the topology information and route items it receives.

Taking the requirements of traffic engineering and routing policy into consideration, the procedure is recommended to be combined with some route constraint conditions in the FPBN network.

In the connection-oriented transmission mode of the FPBN network, the end-to-end path is required to be established with consideration of the attributes of QoS, parameters of network resource, and so on.

In the FPBN network, the routes can optionally be statically configured or be calculated dynamically. There are several types of dynamic routing algorithm available, such as distance vector algorithm, link state algorithm, path vector algorithm.

9.3 Establishing/maintaining the routing table

A routing table is an electronic file or a database object which is stored in a routing entity or other specific place(s) in a FPBN network.

Establishing/maintaining the routing table is a procedure that the routing entity can build the routing table and insert/delete/modify the route items in the routing table according to the results of the routing calculation or the demand of the management plane.

In the FPBN network, a routing table is recommended to consist of four information fields as below:

- Source address in the connectionless transmission mode or input label in the connection-oriented transmission mode
- Destination address in the connectionless transmission mode or the output label in the connection-oriented transmission mode
- Input interface
- Output interface

A routing table can optionally include other information fields, such as netmask, next hop address, route precedence, route metric, etc.

In the connection-oriented transmission mode, input label and output label are used for packet forwarding. While in the connectionless transmission mode, source address and destination address are required for the packets forwarding.

In order to improve the stability, reliability and security, the control plane and data plane are required to be built separately in the routing entities.

9.4 Establishment and maintenance of the FIB

The FIB is established and maintained based on the routing table. The FIB is usually a subset of routing table, although it is possible to take full set of it. For example, there can be multiple routes to the same destination in the routing table, but only the most preferable route is required to be installed in the FIB.

In the FPBN network, the items of FIB are required to include the necessary information for packet transferring.

In the connectionless transmission mode, the FIB is required to include at least the destination network address (prefix), the output interface(s) and/or the next hop(s).

In the connection-oriented transmission mode, the FIB is required to include at least the input label, the input interface, the output label(s) and the output interface(s).

NOTE – For unicast, the output interface generally includes only one interface; for multicast, the output interface generally includes multiple interfaces.

There can optionally be more information to be added into the FIB if some forwarding control policies are applied. For example, in the connectionless transmission mode, if URPF (unicast reverse path first) is enabled, the input interface is recommended to be added into the FIB.

10 Forwarding

Forwarding is the process of transferring packets from an input interface to output interface(s) based on the FIB.

10.1 Input procedure

Input procedure includes integrity checking, input queue management, congestion control and others.

In the FPBN network, network entity is recommended to store the incoming packets in a buffer firstly, and then implement the integrity checking. After that, network entity forwards those valid packets to their destination ports, and drops those invalid packets.

10.2 Enquiring the FIB

By enquiring the FIB, the entity in the FPBN network can determine which output interface(s) a packet will be switched to.

In the connection-oriented transmission mode, the keyword(s) enquired is recommended to include the input interface and label.

In the connectionless transmission mode, the keyword(s) enquired is recommended to include the destination address in the packet header.

Other information fields can optionally be included in the keyword(s) enquired, if necessary.

10.3 Switching

According to the result of the enquiry, the entity in the FPBN network can switch the packet from the input interface to the output interface(s).

For unicast, a packet is required to be copied to one certain output interface. For multicast, a packet is required to be copied to multiple output interfaces.

10.4 Output procedure

In the FPBN network, output procedure is recommended to support framing, output queue management, and shaping.

Bibliography

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[b-ITU-T Y.2011] Recommendation ITU-T Y.2011 (2004), *General principles and general reference model for next generation networks*.

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