Roadmap for IPv6 Migration from NGN Operators’ Perspectives

The objective of this draft recommendation is to give guidelines for NGN operators on how to migrate from IPv4-based NGN to IPv6-based NGN step by step.

Keywords
IPv6, IPv6 migration, NGN, IPv6-based NGN, NGN operator

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Roadmap for IPv6 Migration from NGN Operator’s Perspectives

1 Scope

The objective of this draft recommendation is to give guidelines for NGN operators on how to migrate from IPv4-based NGN to IPv6-based NGN step by step. This draft recommendation first identifies the IPv6 migration phases for NGN operators. Then, this draft recommendation describes IPv6 migration strategies in each phase for NGN operators. The strategies are how NGN operators may deploy the different combinations of existing transition mechanisms in their NGN.

- Identification of IPv6 migration phases for NGN operators
- IPv6 migration strategies and scenarios of each phase for NGN operators

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.

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1. Host [ITU-T Y.1540]: A computer that communicates using the internet protocols. A host implements routing functions (i.e. it operates at the IP layer) and may implement additional functions including higher layer protocols (e.g. TCP in a source or destination host) and lower layer protocols (e.g. ATM).

3.1.2. Router [ITU-T Y.1540]: A host that enables communication between other hosts by forwarding IP packets based on the content of their IP destination address field.

3.1.3. IPv6-based NGN: An NGN which 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.

3.1.4. DNS (Domain Name Service): A resolving service that translates domain names into IP addresses. An IPv6 DNS shall translates domain names into IPv6 addresses.

3.2 Terms defined in this Recommendation

This Recommendation uses the following terms:

3.2.1 IPv6 operator: An entity that provides IPv6 network connection. It provides and maintains IPv6-based network infrastructure in NGN. The services that allows IPv6 user to access IPv4 networks may also be provided.

3.2.2 CGN (Carrier Grade NAT): a NAT device deployed in carrier network. It translates packets between different IP address namespaces. It may be integrated with tunnel functions too.

[Editor note: future discussion on the definition of CGN is needed. Dual-stack and Dual-stack NGN should be described.]

4 Abbreviations

This Recommendation uses the following abbreviations.

IETF Internet Engineering Task Force
IPv6 Internet Protocol version 6
NGN Next Generation Network
NAT Network Address Translation
CGN Carrier Grade NAT
5 Features of IPv6 migration in NGN

The primary purpose of IPv6 migration solutions is to allow NGN operators providing IPv6 network and IPv6-based services while keeping IPv4 network and IPv4-based services continuously available. It also allows IPv4 and IPv6 networks to communicate with each other.

5.1 Communication scenarios in IPv6 migration for NGN operators

During the IPv6 migration period, NGN operators need to support the following communication scenarios, in addition to some basic IPv6 communications. Some of these scenarios may be optional during different migration phases.

- Scenario A: A legacy IPv4 host communicates with a legacy IPv4 host or an IPv4 application on a dual stack host. It should be consistently supported till Phase 4 – Complete IPv6-based NGN. The basic function requires IPv4 routing and forwarding.

- Scenario B: An IPv6 only host communicates with an IPv6 only host or an IPv6 application on a dual stack host. It should be supported during every Phases from the beginning of IPv6 migration, Phase 1. The basic function requires IPv6 routing and forwarding.

- Scenario C: A legacy IPv4 host communicates with a legacy IPv4 hosts or an IPv4 application on a dual stack host through IPv6 network. It should be supported in Phase 3, and may be supported in Phase 2. The basic function requires IPv4 over IPv6 tunneling.

- Scenario D: An IPv6 only host communicates with an IPv6 only host or an IPv6 application on a dual stack host through IPv4 network. It should be supported in Phase 1, and may be supported in Phase 2. The basic function requires IPv6 over IPv4 tunneling.

- Scenario E: An IPv6 only host communicates with an IPv4 only host. It should be supported in Phases 1, 2, 3 and 4. The basic function requires translation on addresses and protocols.

- Scenario F: A legacy IPv4 host communicates with an IPv6 only host. It should be supported in Phases 1, 2, 3 and 4. The basic function requires translation on addresses and protocols.

5.2 Available Transition mechanisms for NGN operators deployment

5.2.1 Available Transition mechanisms

ITU-T Y.2053 “Functional Requirements for IPv4/IPv6 Migration in NGN” has described three basic approaches for interworking and migration: dual IP layer (dual stack), configured tunneling, network address translation and protocol translation. Additionally, application level gateway or proxy server can be adopted based on each application. These basic transition mechanisms meet different requirements and scenarios during the migration phases. NGN operators may deploy the different combinations of these existing transition mechanisms in their NGN according to their requirements in each phase.

Furthermore, the exhaustion of global public IPv4 addresses is getting closer and closer. Many network operators already start to suffer the shortage of global public IPv4 addresses. Many NAT devices have been deployed so that private IPv4 addresses are used widely. The usage of private IPv4 addresses does not solve the address exhaustion issue. It may slow the exhaustion but with many side effects and issues. However, during the IPv6 migration, private IPv4 addresses may be used to provide IPv4 access services. CGN can be deployed in the NGN so that public IPv4 address can be shared.
5.2.2 Combination transition mechanisms for NGN operators deployment

The combination of existing transition mechanisms can be deployed in the NGN to simplify the operation of end user services during the IPv4/IPv6 migration phases. The functions can be integrated with CGNs and deployed on the network side and managed/maintained by NGN operators.

In Phase 1 and 2, as shown in Figure 5-1, IPv6 tunneling over IPv4 may be integrated with CGN and translation function between IPv6 and IPv4. The integrated devices can be deployed at the border between the IPv4-based NGN and the IPv6-based NGN. When a dual-stack CGN receives a data packet from a dual-stack host, it firstly checks whether the packet is a normal IPv4 packet or an IPv6 over IPv4 tunnel packet. For a normal IPv4 packet, the CGN translates packet source address from a CGN-scoped private IPv4 address into a public IPv4 address, and then send it to IPv4-based NGN. The CGN should record v4-v4 address mapping information for inbound packets, just like normal NAT does. For an IPv6 over IPv4 tunnel packet, the CGN needs to decapsulate it into the original IPv6 packet and then sends it to IPv6-based NGN. If the destination address of the original IPv6 packet is IPv4-embedded address, this IPv6 packet is forwarded to translation function between IPv6 and IPv4; after translation, new IPv4 packet(s) is sent to IPv4-based NGN.

Figure 5-1: Combination of v6-over-v4 tunnel, v4-v4 CGN and IPv6/IPv4 translation

In Phase 2 and 3, as shown in Figure 5-2, IPv4 tunneling over IPv6 may be integrated with CGN and translation function between IPv6 and IPv4. The integrated devices can be deployed at the border between the IPv4-based NGN and the IPv6-based NGN. When a dual-stack CGN receives a data packet from a dual-stack host, it firstly checks whether the packet is a normal IPv6 packet or an IPv4 over IPv6 tunnel packet. For a native IPv6 packet, the CGN simply forwards it to IPv6-based NGN. For a IPv4 over IPv6 tunnel packet, the CGN first decapsulates it obtaining the original IPv4 packet, then translates packet source address from a CGN-scope private IPv4 address into a public IPv4 address, and then sends it to IPv4-based NGN. The CGN should record both IPv4 over IPv6 tunnel information and v4-v4 address mapping information for inbound packets. If the destination address of the original IPv4 packet points to translation function between IPv6 and IPv4, after translation, new IPv6 packet(s) is sent to IPv6-based NGN.
The subsistent NGN are based on IPv4. Also, all subsistent user access requirements are based on IPv4. In the near future these networks would be replaced by IPv6-based NGN. However, giving the enormous scale of the current Internet, the migration period from the legacy IPv4-based NGN to all IPv6-based NGN is expected to be long. Hence, a prudent approach is to deploy IPv6 incrementally while keeping IPv4 access available. During the transition period, IPv6 migration would start from relevant small areas first, then, stretch into the core of the Internet; and at the same time, IPv4 network will become smaller and smaller, till vanish at the end.

In this clause, migration period is divided into three phases. In each phase, NGN operators would structure their networks differently from IPv4/IPv6 point of view. This document also provides recommendations on how NGN operators should strategize their IPv6 migration in different phases.

6.1 Phase 0: NGN with IPv6

The subsistent NGN is IPv4-based. IPv4 plays an essential role. There has no IPv6 networks deployed. In this phase, as shown in Figure 6-1, there is no IPv6 services provided at all. Correspondently, operator networks do not adopt any IPv6 functions.
In this phase, IPv6 may be deployed in some customer networks locally. IPv6-based NGN islands may also be linked to each other through IPv6-over-IPv4 tunneling or protocol translation technologies. However, since operators’ networks do not provide IPv6 connectivity services, these IPv6 islands are totally isolated from NGN operators' perspectives. The NGN is still completely IPv4-based.

6.2 Phase 1: Connecting IPv6-based NGNs across IPv4-based NGN

At the early stages of IPv6 co-exists with native IPv4 environment, there would be only a few and isolated IPv6-based NGN, like islands, floating around IPv4-based ocean, as shown in Figure 6-2. The initial focus of this phase is on the migration and transition techniques, rather than dealing with traffic volume.

In this phase, the most important IPv6 functional requirement for operators’ networks is to support IPv6 tunnels in IPv4 network. There may be limited number of IPv6-only hosts, but they should be able to communicate with legacy IPv4-only hosts, and also with each other through IPv4-based NGN, e.g., with 6PE support across IPv4-MPLS backbone.
6.3 Phase 2: Connecting IPv6-based NGNs and IPv4-based NGNs across dual-stack NGN

With increased IPv6 adoption, backbone routers would be upgraded to dual stack routers and form IPv4 and IPv6 logical dual-plane, where there exists a separate operation for IPv4 and IPv6, respectively, in data plane, control plane and management plane, and IPv4 and IPv6 run in the same physical network.

In this phase, as shown in Figure 6-3, IPv4 and IPv6 logical planes are isolated from each other mutually. However, the same NGN devices may be used for both IPv4 and IPv6 logical planes. According to traffic situation, resources may be dynamically adjusted between IPv4 and IPv6 logical planes.
6.4 Phase 3: Connecting IPv4-based NGNs with IPv6-based NGN

The IPv4 address exhaustion will eventually result in large scale adoption of IPv6 and thus IPv6-only NGN, as shown in Figure 6-4. In this phase, vast majority of business applications have moved to IPv6 network. Core backbone only supports IPv6. Sporadic small-size IPv4-based NGN may distribute around the large IPv6-based NGN. IPv4-over-IPv6 tunnels are required to support IPv4/IPv4 communication through IPv6-based NGN. Protocol translation would still be needed to allow IPv4 hosts access to IPv6 services.

![Figure 6-4: Phase 3-IPv4 Islands with IPv6-based NGN](image)

6.5 Phase 4: Completed IPv6-based NGN

Finally, as shown in Figure 6-5, IPv6 will replace IPv4 totally. NGN will become pure IPv6-based. In this phase, there is no IPv4 connectivity service provided by NGN operators. Correspondently, operator networks do not adopt any IPv4 functions.

![Figure 6-5: Phase 4-Completed IPv6-based NGN](image)

In this phase, IPv4 may still exist in some customer network locally. IPv4-based NGN may also be linked to each other through IPv4-over-IPv6 tunnels or protocol translation mechanisms. However,
since operators’ networks do not provide IPv4 connectivity service, these IPv4 islands are totally isolated from the NGN operators’ perspective. The NGN is completely IPv6-based.

7 Functional requirements of IPv6 migration for NGN operators

[Editor Note] This clause intends to discuss the functional requirements of IPv6 migration for NGN operators, also enumerate available mechanisms that meet these functional requirements. (Note: this document does not intend to develop any new mechanisms, only cite existing mechanisms.) Functional requirements are different in different migration phases. Further contributions are invited at the next Question meeting.

7.1 General functional requirements to support IPv6 migration for NGN operators

Requirements for IPv6 migration for NGN operators include operational transparency, service continuity, smooth transition, no network or service degradation, etc.

IPv6 migration requires NGN operators to provide basic IPv6 network access while keeping the IPv4 services continuously available. The minimum is to provide IPv6 users to access IPv6 services. The maximum is to provide IPv4/IPv6 users to access any IPv4 or IPv6 services. Some initial IPv6 functional requirements include the following:

- IPv6 routing and forwarding: the fundamental function supports IPv6 packets delivered from their source hosts to destination host.
- IPv6 address assignment function: the fundamental function provides and manages IPv6 addresses and prefixes to networks and hosts.
- IPv6 DNS: the function provides resolving services between domain names and correspondent IPv6 addresses.
- IPv6 network management: the functions are relevant to the operation, administration, maintenance, and provisioning of IPv6-based NGN.

7.2 Functional requirements of each IPv6 migration phase for NGN operators

7.2.1 Functional requirements of IPv6 migration phase 1 for NGN operators

During the IPv6 migration phase 1, the NGN operators may choose to support part of the abovementioned functional requirements with chosen combination of transition mechanism.

In this phase, the IPv4-based NGN could remain unchanged at all. There is no extra function requirement for operators that maintain the IPv4-based NGN. However, the disadvantages are the IPv4-based NGN and its users does not aware the existing of IPv6 NGN and cannot launch the connection to it.

In the IPv6-based NGN, operators should provide basic IPv6 functions, including IPv6 routing and forwarding, IPv6 address assignment, IPv6 DNS and IPv6 network management, in the scope of its own IPv6-based NGN. Depends on whether there are v4 users in the IPv6-based NGN and the availability of IPv4 public addresses, the combination of v4-over-v6 tunnel, v4-v4 CGN and IPv6/IPv4 translation, described in the Section 5.2.2, may be deployed.

The router located between the IPv6-based NGN and IPv4-based NGN should provide two services: translation services, which translate IPv6 packets into IPv4 packets and vice versa; and configure tunnels, which encapsulate IPv6 packets into IPv4 packets and forward them to another IPv6-based NGN. If there are more than two IPv6-based NGN connected together by the tunnels, IPv6 routing
information should be provided in order to choose which tunnels IPv6 packets should be pushed into.

7.2.2 Functional requirements of IPv6 migration phase 2 for NGN operators

During the IPv6 migration phase 2, the NGN operators may choose to support part of the abovementioned functional requirements with chosen combination of transition mechanism.

In this phase, the IPv4-based NGN could remain unchanged if there is no requirement to connect to IPv6 NGN at all. If there are IPv6 connectivity requirements and there are no enough public IPv4 addresses, the combination of v6-over-v4 tunnel, v4-v4 CGN and IPv6/IPv4 translation, described in the Section 5.2.2, may be deployed.

In the IPv6-based NGN, operators should provide basic IPv6 functions, including IPv6 routing and forwarding, IPv6 address assignment, IPv6 DNS and IPv6 network management, in the scope of its own IPv6-based NGN. Depends on whether there are v4 users in the IPv6-based NGN and the availability of IPv4 addresses, the combination of v4-over-v6 tunnel, v4-v4 CGN and IPv6/IPv4 translation, described in the Section 5.2.2, may be deployed.

The dual-stack NGN has both IPv6 plane and IPv4 plane. It provides both basic IPv6 functions, including IPv6 routing and forwarding, IPv6 address assignment, IPv6 DNS and IPv6 network management; and basic IPv4 functions, including IPv4 routing and forwarding, IPv4 address assignment, IPv4 DNS and IPv4 network management. Translation services may be deployed in order to connect IPv6-only hosts and IPv4-only hosts.

The router located between the IPv6-based NGN and IPv4-based NGN should provide translation services, which translate IPv6 packets into IPv4 packets and vice versa; and configure tunnels, which encapsulate IPv6 packets into IPv4 packets and forward them to another IPv6-based NGN. If there are more than two IPv6-based NGN connected together by the tunnels, IPv6 routing information should be provided in order to choose which tunnels IPv6 packets should be pushed into.

The router located between the dual-stack NGN and IPv6-based NGN may provide translation service. The router located between the dual-stack NGN and IPv4-based NGN may provide translation service.

7.2.3 Functional requirements of IPv6 migration phase 3 for NGN operators

During the IPv6 migration phase 3 the NGN operators may choose to support part of the abovementioned functional requirements with chosen combination of transition mechanism.

In this phase, the IPv4-based NGN could remain unchanged if there is no requirement to connect to IPv6 NGN at all. If there are IPv6 connectivity requirements and there are no enough public IPv4 addresses, the combination of v6-over-v4 tunnel, v4-v4 CGN and IPv6/IPv4 translation, described in the Section 5.2.2, may be deployed.

In the IPv6-based NGN, operators should provide basic IPv6 functions, including IPv6 routing and forwarding, IPv6 address assignment, IPv6 DNS and IPv6 network management, in the scope of its own IPv6-based NGN. Depends on whether there are v4 users in the IPv6-based NGN and the availability of IPv4 addresses, the combination of v4-over-v6 tunnel, v4-v4 CGN and IPv6/IPv4 translation, described in the Section 5.2.2, may be deployed.

The dual-stack NGN has both IPv6 plane and IPv4 plane. It provides both basic IPv6 functions, including IPv6 routing and forwarding, IPv6 address assignment, IPv6 DNS and IPv6 network management; and basic IPv4 functions, including IPv4 routing and forwarding, IPv4 address
assignment, IPv4 DNS and IPv4 network management. Translation services may be deployed in order to connect IPv6-only hosts and IPv4-only hosts.

The router located between the IPv4-based NGN and IPv6-based NGN should provide two services: translation services, which translate IPv4 packets into IPv6 packets and vice versa; and configured tunnels, which encapsulate IPv4 packets into IPv6 packets and forward them to another IPv4-based NGN. If there are more than two IPv4-based NGN connected together by the tunnels, IPv4 routing information should be provided in order to choose which tunnels IPv4 packets should be pushed into.

The router located between the dual-stack NGN and IPv6-based NGN may provide translation service. The router located between the dual-stack NGN and IPv4-based NGN may provide translation service.

7.2.4 Functional requirements of IPv6 migration phase 4 for NGN operators

During the IPv6 migration phase 4 the NGN operators only need to support IPv6 access and forwarding.

In the IPv6-based NGN, operators should provide basic IPv6 functions, including IPv6 routing and forwarding, IPv6 address assignment, IPv6 DNS and IPv6 network management, in the scope of its own IPv6-based NGN. Since there is no IPv4-based NGN any more, translations services is not needed any more.

8 IP6 migration strategies from NGN operators’ perspectives

The NGN operators are recommended to deploy IPv6 in NGN according to the sequential order of the 4 phases introduced in clause 6.

[Editor Note] This clause intends to give the NGN operators recommendation on the strategies in each migration phase. Based on the different function requirements discussed in clause 7, the NGN operators may choose to support chosen combination of transition mechanism that are enumerated in clause 7 too.

[Further contributions are invited at the next Question meeting.]

9. Security Considerations

[Editor Note] Further contributions are invited at the next Question meeting.