STRATEGIC WHITE PAPER

464XLAT in mobile networks

IPv6 migration strategies for mobile networks

To cope with the increasing demand for IP addresses, most mobile network operators (MNOs) have deployed Carrier Grade–Network Address Translation (CG-NAT). Introducing IPv6 in the mobile network reduces the CG-NAT bandwidth required by the mobile operator resulting in reduced CAPEX. This approach is supported by the increasing availability of websites and applications over IPv6 and the increasing support of IPv6 on SIM-based devices. An important benchmark to evaluate IPv6 transition technologies is the impact on the user experience, which should be minimized. The chosen transition technology should also result in minimal OPEX and CAPEX for the mobile operator. This whitepaper describes IPv4/IPv6 protocol translation (464XLAT)—an IPv6 transition technology—and compares it to other options available to mobile operators for the introduction of IPv6 in mobile networks.

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Introduction

IPv6 addressing is vital in today's mobile networks. IPv4 addresses are depleted so there is an insufficient number of addresses for the rapidly escalating number of mobile devices. Support for IPv6 on mobile network equipment, as well as on handheld user equipment (UE) is becoming more prevalent. MNOs now have multiple options to transition to IPv6 in their networks at a low cost. However, IPv4-only websites and applications still remain on the Internet, which require CG-NAT. The MNO's goal should be to minimize the traffic that has to pass CG-NAT. Or, to put it differently, the IPv6-to-IPv4 traffic ratio should be optimized as much as possible. To do this, the MNO must introduce IPv6 access to customer devices. As a result, network migration to IPv6 becomes a strategic decision that must be carefully considered.

IPv6 to 3GPP standards and mobile networks

The 3rd Generation Partnership Project (3GPP) maintains the standards for General Packet Radio Service (GPRS)-based 2G/3G wireless access networks and System Architecture Evolution (SAE) for LTE and LTE-Advanced wireless access. IPv6 was introduced into these standards with Release 99. However, it was not widely implemented by equipment vendors, nor was it extensively deployed by MNOs.

Most 3G network deployments today are based on Release 7, using the generic tunneling protocol (GTPv1). A separate bearer is required for IPv4 and IPv6 access. This has a scaling impact on the mobile core by significantly increasing the number of bearers on the GPRS Gateway Serving Node (GGSN). 464XLAT overcomes this issue, while also enabling the introduction of IPv6 for 3G networks without the need for a major network upgra mde.

For its part, Release 8 introduced Evolved-UMTS Terrestrial Radio Access (E-UTRA). E-UTRA is designed to provide a single evolution path for a wide range of radio access technologies. Release 8 defines the new Evolved Packet Core (EPC), which must be implemented when deploying LTE access. Release 8 also defines a single shared bearer for IPv4 and IPv6 for GTPv2 only (bearer of PDN-Type IPv4v6). Release 9 introduces support in GPRS (GTPv1) for dual-stack IPv4v6 PDP contexts on a single shared bearer, while Release 10 introduces DHCPv6-PD.

IPv6 migration strategies

MNOs have a number of strategic options when migrating to an IPv6 network. Each of these options is briefly discussed along with their advantages and disadvantages in Table 1.

Do nothing – IPv4 only

One strategy is to delay the introduction of IPv6 to a later date and remain an all-IPv4 network. Over the long term, this option will lead to problems and increased costs for the MNO. The MNO will need to resolve the problem of increased demand for IP addresses with CG-NAT. All traffic to and from the Internet will have to pass CG-NAT. In turn, growth in bandwidth demand can only be handled with increased CG-NAT capacity. This has a higher cost. As a result, the MNO is unable to benefit from the increasing ratio of IPv6-to-IPv4 Internet traffic. Bypassing CG-NAT, which IPv6 enables, will not be possible, leading to no reduction in costs. In addition, it is expected that, at some point, certain websites or applications on the Internet will only be available in IPv6. This will result in an inferior service for the operator's customers.

The traditional way – IPv4 and IPv6

Another strategy is the dual-stack approach—introducing IPv6 in the network next to IPv4. For the MNO, this approach is a less desirable option because dual-stack networks are more complex to deploy, operate, and manage. This option also requires an address management solution for both IPv4 and IPv6 addresses. 3GPP pre-release 8 3G networks require dual bearers for the dual-stack option. Dual bearers have a direct impact on the network; they reduce the scale of GGSN, require double accounting, and make roaming and QoS more complex. Release 9 overcomes these complexities but also requires a multiple component upgrade in the mobile core (e.g. SGSN) that has a huge cost impact on the MNO. With CG-NAT, the MNO is able to resolve the problem of the increased demand for IP addresses and, as a result, the MNO benefits from the increasing ratio of IPv6-to-IPv4 Internet traffic. Cost savings are reaped by bypassing CG-NAT, which IPv6 enables. This approach supports UE devices, websites, and applications that are IPv4- or IPv6-only, or dual stack. The end-user service experience is not compromised.

Drastic – IPv6 only

A third strategy is to introduce IPv6 in the network and remove IPv4 completely. For the MNO, this approach has benefits because IPv6-only networks are simpler to deploy, operate, and manage. An address management solution is required only for IPv6 addresses. And, as a result, there is no impact on scale, charging, and roaming because only a single bearer with a single stack is required. Moreover, the MNO need not invest in legacy IPv4 continuation (CG-NAT); nor does the MNO require any public IPv4 addresses. This results in savings in both CAPEX and OPEX. Even so, the problem with this approach is that many UE devices, websites, and applications still only work on IPv4. Moving to an IPv6-only network would lead to inferior service for MNO customers, resulting in dissatisfaction and raising the risk of churn.

Improved – IPv6 only + NAT64

The addition of NAT64 and DNS64 as an IPv4 continuation mechanism represents an improvement on the previous option. In this case, IPv4 is offered as a service over IPv6 for DNS-based applications. For the MNO, this approach has its advantages. IPv6-only networks are simpler to deploy, operate, and manage. An address management solution is required only for IPv6 addresses. In addition, there is no impact on scale, charging, and roaming as only a single bearer with a single stack is required. DNS64 also embeds IPv4 Internet destinations in IPv6 addresses. IPv6 packets are translated to IPv4 packets by a central CG-NAT64, deployed behind the packet gateway (PGW). As a result, the MNO benefits from the increasing ratio of IPv6-to-IPv4 Internet traffic. Cost savings are achieved by bypassing the CG-NAT64, which IPv6 enables. This mechanism works only for DNS-based applications; IPv4-only, non-DNS applications will be broken. This could result in inferior service for the operator’s customers, elevating the possibility of churn.

The smart way – IPv6 only + 464XLAT

The 464XLAT strategy is the preferred option, providing further improvement on all previous options. IPv4 is offered as a service over IPv6 for all applications (DNS and non-DNS). As in the case of the previous options, this approach has several advantages. IPv6-only networks are simpler to deploy, operate, and manage. An address management solution is required only for IPv6 addresses. Plus, there is no impact on scale, charging, and roaming because only a single bearer with a single stack is required. For IPv4-only, non-DNS applications, IPv4 packets are translated to IPv6 packets by the UE and translated back to IPv4 packets by a central CG-NAT64, which is deployed behind the PGW. MNOs benefit from the increasing ratio of IPv6-to-IPv4 Internet traffic. Cost reductions are achieved by bypassing the CG-NAT64, which IPv6 enables. This solution requires support of the customer translator (CLAT) on the UE device. An advantage is that the solution works with websites and applications that are IPv4-only, IPv6-only, or that support dual stack. The offered service is never inferior.

Table 1. IPv6 deployment options in mobile networks

	IPV4 ONLY	DUAL STACK	IPV6 ONLY	NAT64	464XLAT
OPEX impact	None	Increase	None	None	None
CAPEX impact	Increase	Increase	Small	Small	Small
Scale impact	None	Yes[1]	None	None	None
Impact Packet Core	None	High[2]	Low	Low	Low
Customer experience	Degraded	Good	Degraded	Degraded	Good
Future Proof	No	Yes	Yes	Yes	Yes
Deployable Today	Yes	Yes	No	No	Yes

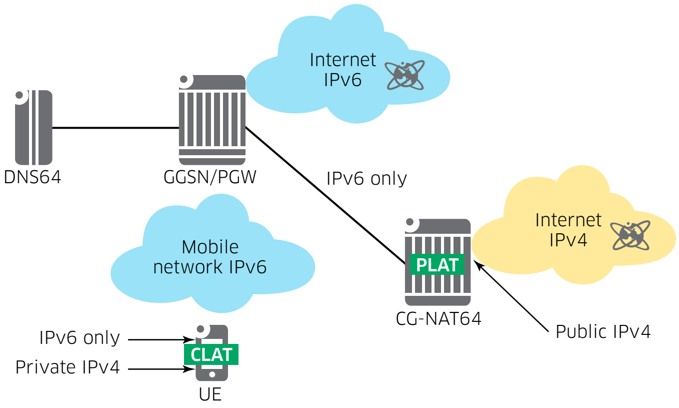
464XLAT in mobile networks

464XLAT, described in RFC 6877, is an architecture that provides IPv4 connectivity across an IPv6-only network by combining existing and well-known:

- Stateful protocol translation (RFC 6146) at CG-NAT64
- Stateless protocol translation (RFC 6145) at the UE
- DNS64 (RFC 6147) mechanisms at the DNS server
- IPv4 embedding into IPv6 addresses (section 2.2 of RFC 6052)

464XLAT is a simple and scalable technique to deploy IPv4 access service to mobile IPv6-only networks. Figure 1 illustrates the solution’s network elements. It should be noted that 464XLAT can also be used in wireline networks, but this discussion is beyond the scope of this paper.

Figure 1. 464XLAT in mobile networks



Native IPv6

A single IPv6/64 prefix is handed out to the UE on the mobile network. IPv6-enabled websites and applications are natively routed over the GGSN/PGW towards the IPv6 Internet.

[1] Scale impact is relevant when dual bearers are deployed. This is mandatory for pre-3GPP Release 9 mobile cores. Dual bearers will impact GGSN scale, require double accounting, as well as make roaming and QoS more complex.

[2] The impact on the packet core is high when a single bearer solution with dual stack is deployed. This requires an upgrade of multiple components in the mobile core (e.g., SGSN).

DNS64

DNS64 is a mechanism for synthesizing IPv6 address (AAAA) resource records from IPv4 address (A) records. If the AAAA query results in one or more AAAA records in the answer section, the result is returned to the requesting client, as per normal DNS semantics. If only an A record is available for the AAAA query, the DNS64 component embeds the IPv4 addresses from the A record in an IPv6 address to be used to respond the AAAA query. The IPv4 address is embedded in the IPv6 address. The IPv6 address always begins with an IPv6 prefix that belongs to the CG-NAT64. This prefix is referred to as “Pref64/n”. IPv6 packets that begin with Pref64/n are always routed towards the CG-NAT64.

CLAT

The customer-side translator (CLAT) component is a piece of software that runs inside the UE. It implements stateless protocol translation and offers a private IPv4 address and an IPv4 default route to IPv4-only applications on the UE. Traffic with an IPv4 destination is translated to IPv6 by the CLAT component. A dedicated /96 out of the /64 IPv4 prefix assigned to the UE is used for the source address. The source IPv6 address is constructed using the /96 prefix followed by the IPv4 address. The destination IPv6 address is constructed using the Pref64/n and the embedded destination IPv4 address.

Using draft-ietf-behave-nat64-discovery-heuristic, the CLAT discovers the Pref64/n. The CLAT component sends an AAAA query to the DNS64 for the well-known IPv4-only name “ipv4only.arpa”. The Pref64/n is derived from the received AAA response. The CLAT determines the used address format by searching the received IPv6 addresses for the well-known IPv4 addresses (192.0.0.170 or 192.0.0.171).

PLAT

PLAT is a provider-side translator (XLAT) that implements well-known stateful protocol translation. It translates N:1 global IPv6 addresses to public IPv4 addresses, and vice versa. The PLAT holds the Pref64/n prefix. All traffic towards this IPv6 prefix must be routed to the PLAT. The PLAT derives the destination IPv4 address from the destination IPv6 address.

The PLAT implements Application Layer Gateways (ALG) to allow certain protocols to traverse the CG-NAT component. Examples of these protocols include: FTP, SIP, RTSP and PPTP. The PLAT also implements a scalable logging mechanism to log all CG-NAT64 bindings for legal purposes. Examples of logging mechanisms include: Syslog, SNMP, Radius, or IPFIX.

The Alcatel-Lucent 7750 Service Router (SR) supports the PLAT function. In addition to CG-NAT with high-session scalability and system reliability. The PLAT function can be deployed on the 7750 SR with inter-chassis redundancy by using anycast addressing for the Pref64/n IPv6 prefix. This mechanism is preferred where the standby PLAT only advertises the Pref64/n prefix and the public IPv4 addresses upon detecting that the primary PLAT has become inactive. This way the same public IPv4 addresses can be used on both the active and standby PLAT.

Conclusion

464XLAT is an IPv6 transition technology and deployment option for providing IPv4 services over an IPv6-only network. The technology has become relevant especially because UE Operating System (OS) support for CLAT has increased. Today, Android and Windows Phone both support CLAT. As described in this paper, the Alcatel-Lucent IP/MPLS toolkit supports the PLAT component with industry-leading throughput and session scale. For MNOs, transitioning their networks to IPv6 using 464XLAT offers several advantages. IPv6-only networks are simpler to deploy, operate, and manage, which reduces OPEX. The 464XLAT also delivers reductions in CAPEX because it benefits from the increasing ratio of IPv6-to-IPv4 Internet traffic, lowering CAPEX for CG-NAT. And, for the end customer, the offered service is never compromised.

Acronyms

3GPP	3rd Generation Partnership Project
ALG	Application Layer Gateway
CAPEX	Capital Expenses
CG-NAT	Carrier Grade–Network Address Translation
CLAT	Customer-side translator (XLAT)
DNS	Domain Name System
EPC	Evolved Packet Core
E-UTRA	Evolved-UMTS Terrestrial Radio Access
FTP	File Transfer Protocol
GGSN	Gateway GPRS Support Node
GPRS	General Packet Radio Service
IPFIX	IP Flow Information eXport
LTE	Long Term Evolution
MNO	Mobile Network Operator
OPEX	Operational Expenses
PD	Prefix Delegation
PDP	Packet Data Protocol
PGW	Packet Gateway
PLAT	Provider-side translator (XLAT)
PPTP	Point-to-Point Tunneling Protocol
RA	Router Advertisement
RS	Router Solicitation
RTSP	Real Time Streaming Protocol
SAE	System Architecture Evolution
SGSN	Serving GPRS Support Node
SIP	Session Initiation Protocol
SLAAC	Stateless Address Auto-Configuration
SNMP	Simple Network Management Protocol
UE	User Equipment
UMTS	Universal Mobile Telecommunications System

References

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- RFC6145: IP/ICMP Translation Algorithm
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- RFC 6147 DNS64: DNS Extensions for Network Address Translation from IPv6 clients to IPv4 Servers
- RFC 6877 464XLAT: Combination of Stateful and Stateless Translation
- draft-ietf-behave-nat64-discovery-heuristic
- 3GPP Release 99
- 3GPP Release 7
- 3GPP Release 8
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- 3GPP Release 10