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Deploying IPv6 in Fixed and Mobile Broadband Access Networks

Tomás Lynch – Ericsson
Jordi Palet Martínez – Consulintel
Ariel Weher – LACNOG

Agenda (1/2)

- IPv6 in Broadband Networks – Where are we?
- IPv6 Transition Mechanisms for Broadband Networks
- IPv6 Prefix Assignment
- Deployment of IPv6 in Mobile Broadband Networks
- Deployment of IPv6 in PPPoE & IPoE Networks
- Deployment of IPv6 in Cable Networks

Agenda (2/2)

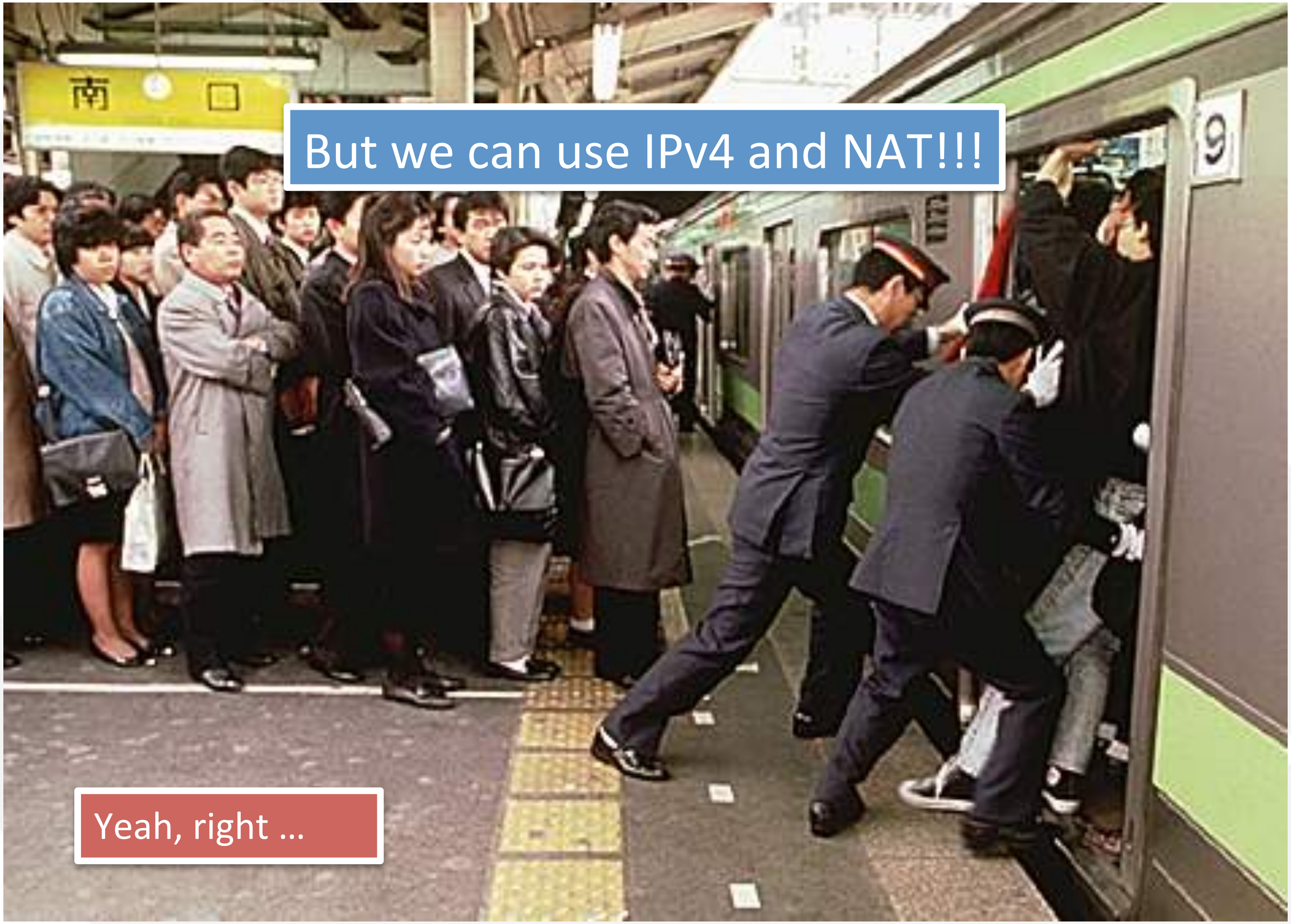
- Current IPv6 Deployments in Broadband Access Networks
- Other Systems Involved in IPv6 Deployment
- IPv6 Transition Planning
- Useful Documents
- Conclusions

IPv6 in Broadband Networks
Where Are We?

IPv4

Yes, the IPv4 pool

IPv4 with NAT



IPv6

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Why IPv6? Move to IPv6 Now!

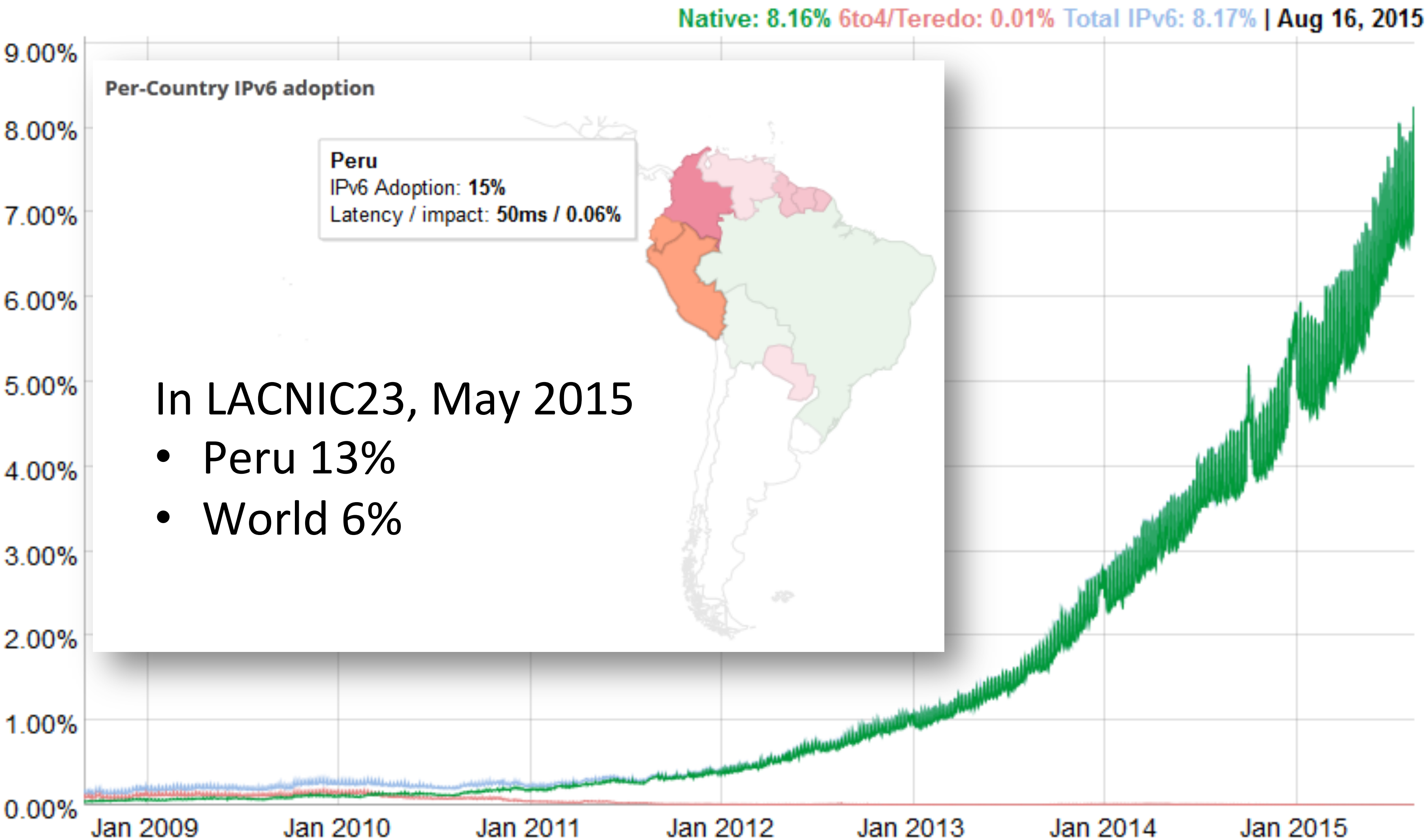
New Business Opportunities	Operational Needs
Allows continuous growth of Internet business	Simplify service providers operations
Ready for Cloud and M2M (moving towards 50 billion)	IPv4 Address Depletion
New business models	Increasing government regulations requiring IPv6 deployment

IPv6 Readiness – No Excuses!

› Laptops, pads, mobile phones, dongles, CPEs: Ready!

- –OS: 90% of all Operating systems are IPv6 capable
- –Browsers are ready!
- –Mobile devices: Android, IOS6, LTE devices are ready!
- –Mobile Apps: More than 85% with IPv6 support
- –CPEs: More than 45% support IPv6

IPv6 Traffic is Growing – No Excuses!



Source: Google IPv6 Statistics - 8/16/2015

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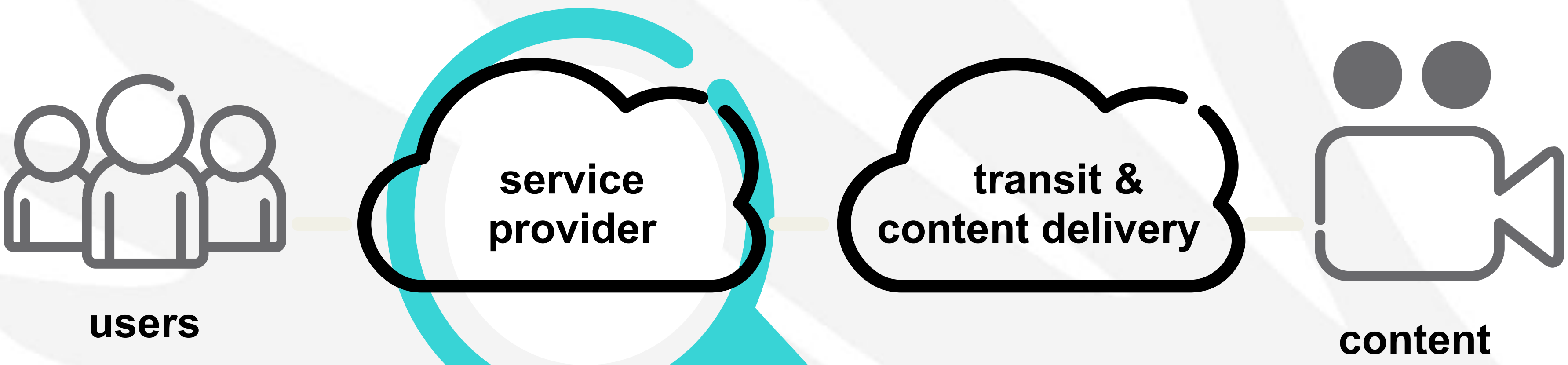
So ISP what are you doing?

- You may have IPv6 in your backbone:
  - Dual stack backbone, 6PE, 6VPE
  - Easy stuff!
    - Loopbacks, IGP (yes, ISIS is great), we love to configure BGP!
  - If not, what are you waiting for?

- What about your customers?
  - Mobile broadband: customers change their phone more quickly than their clothes, easy stuff but those GGSN licenses are killing me.
  - Fixed broadband: oh, no! those old IPv4 only CPE, there are millions of them! Worst than that,: NAT44 at each house.
  - Enterprise customers: do they know what IPv6 is?

IPv6 Transition Mechanisms For Broadband Networks

Transition to IPV6



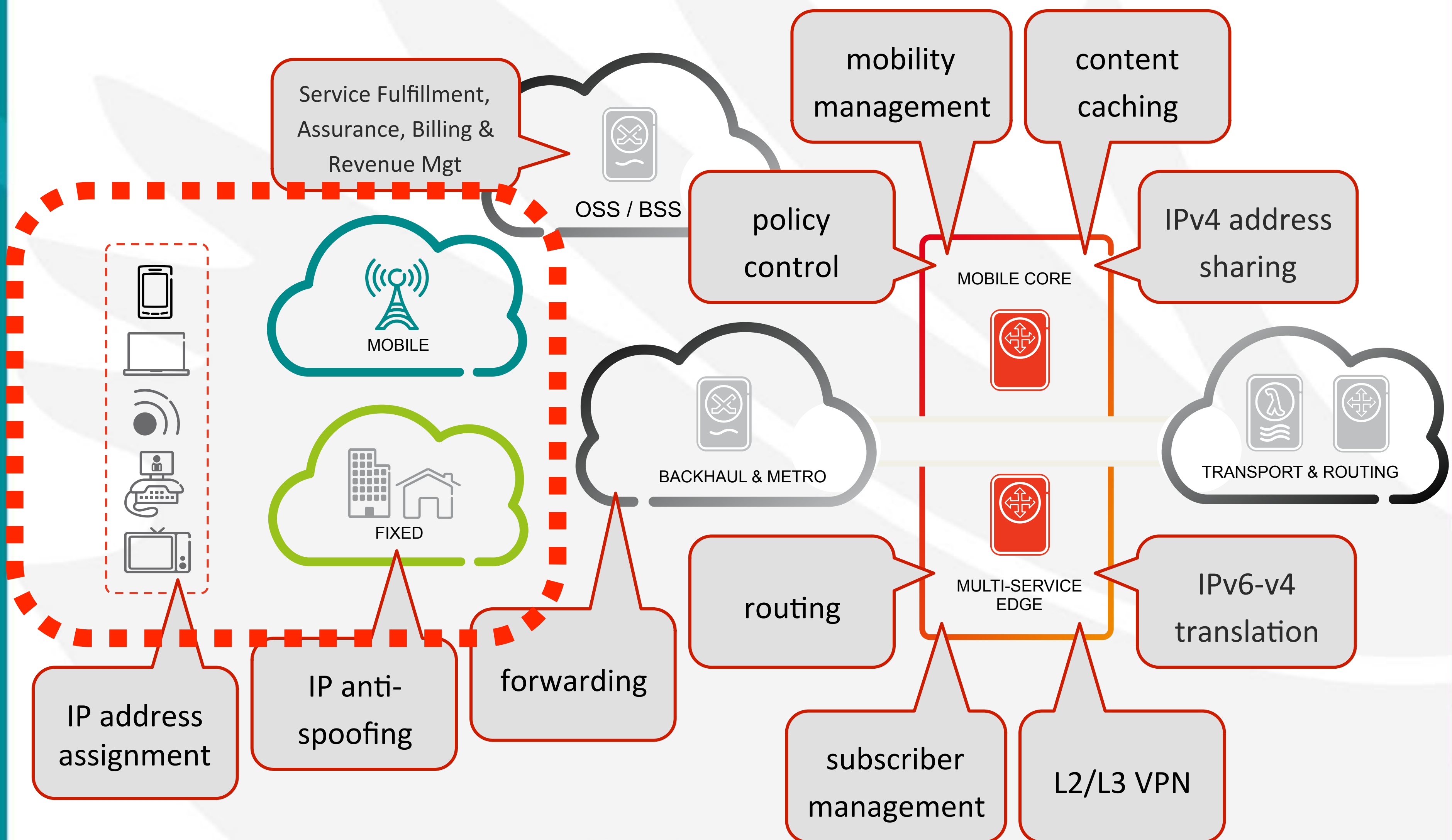
users
- ✓ operating systems
- ✓ applications
- ✓ programming environments

service provider
- ✓ address provisioning
- ✓ transport
- ✓ user database
- ✓ mobility management
- ✓ policy control
- ✓ firewall
- ✓ intrusion detection

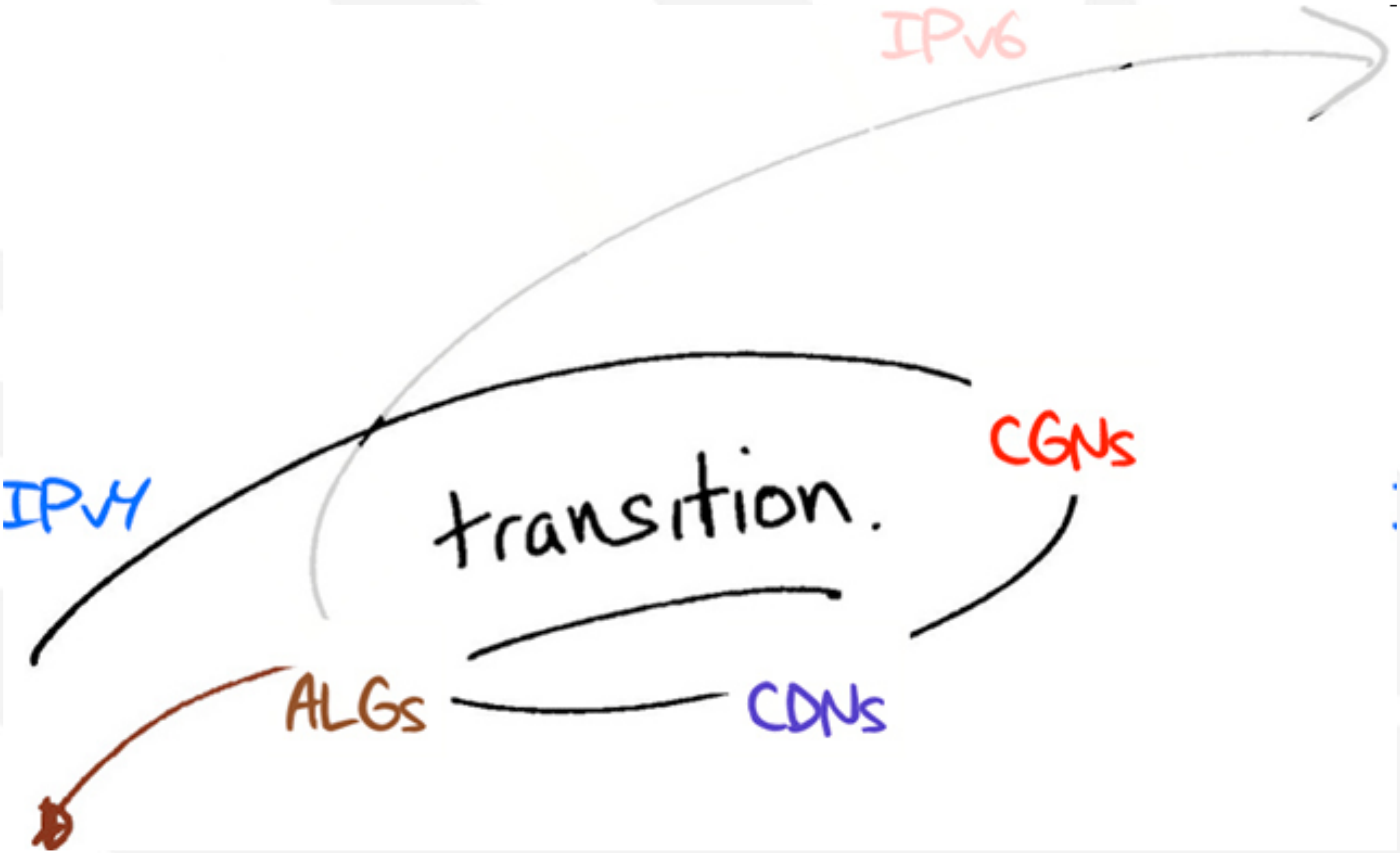
transit & content delivery
- ✓ routing
- ✓ transport
- ✓ traffic management
- ✓ caching

content
- ✓ server operating system
- ✓ applications
- ✓ load balancing
- ✓ DoS protection

Service Provider Perspective



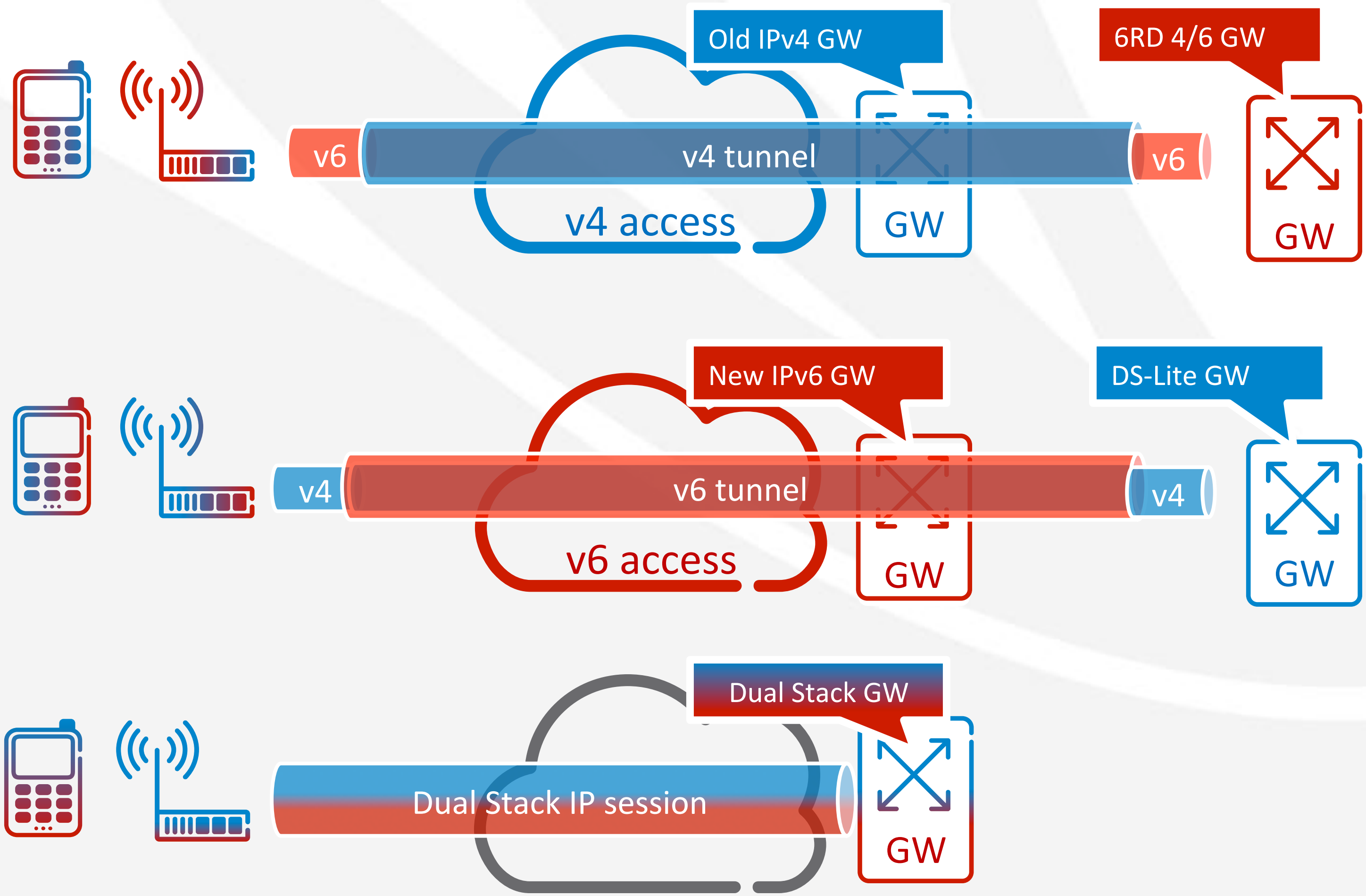
Transition Alternatives – What if...?



Source: "IPv6 Transitional Uncertainties", Geoff Huston, CircleID, available online, accessed on 09/12/2011, http://www.circleid.com/posts/ipv6_transitional_uncertainties/

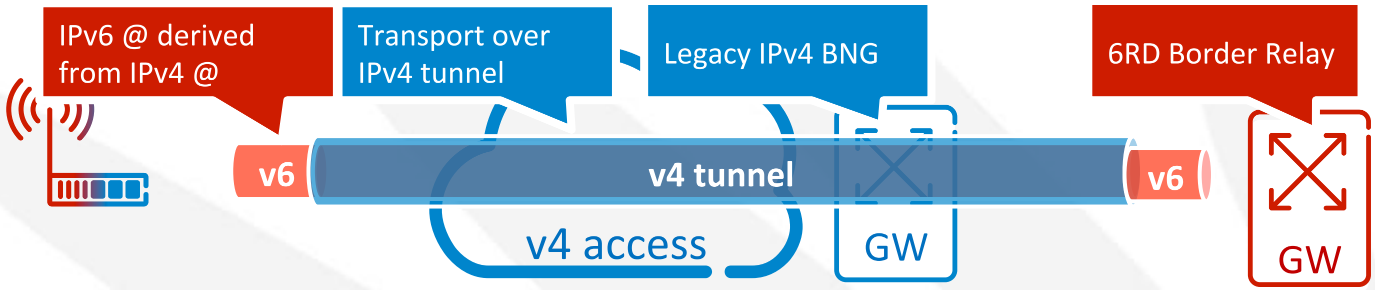
Some IPv6 Transition Options

1. 6RD
   RFC 5969
2. DS-Lite
   RFC 6333
3. Dual Stack
   RFC 4213



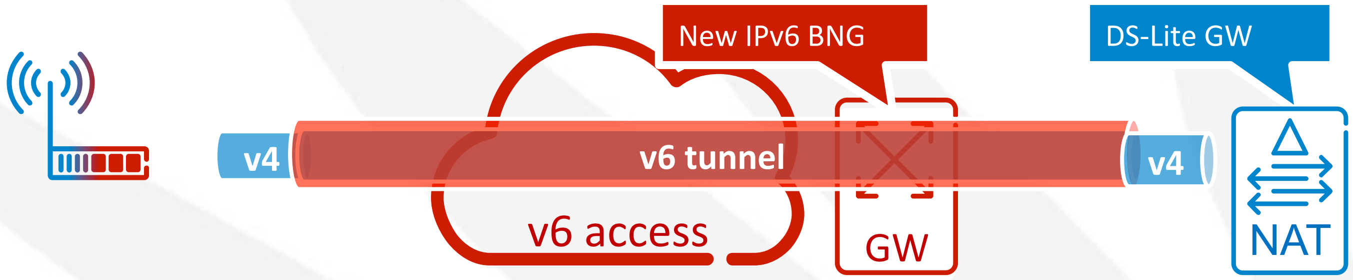
Plenty of more options: 6to4, 6over4, ISATAP, Teredo, 464XLAT, MAP-T, MAP-E, …

IPv6 Rapid Deployment (6RD)



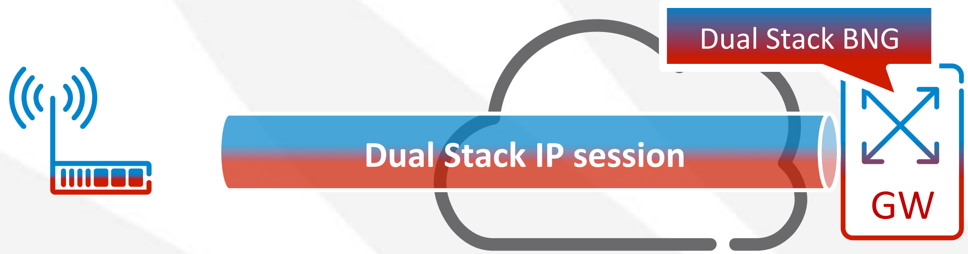
- Allows simple deployment of IPv6 by reusing IPv4 infrastructure
- But not a viable long terms solution
  - Overlay adds complexity – impacts operations
  - Centralization limits scaling – limited flexibility in content injection
  - Creates dependency on IPv4 plane – can't turn off IPv4 plane in the future
- Mostly appealing to operators that have a challenge to migrate their existing access infrastructure (DHCP based internet access)
  - Anti-spoofing mechanisms (IP/MAC association) and Option 82 insertion
- Must carefully consider alternative options
  - Gradual IPv6 introduction depending on access modernization
  - Alternate access model (i.e. use PPPoE dual stack or per subscriber VLAN)

Dual-Stack-Lite



- At the opposite of 6RD – DS-Lite is not looking at simplifying IPv6 introduction but rather on expediting IPv4 phase out
- Similar to 6RD it relies on v4 over v6 tunneling the traffic to a central NAT translation gateway.
- There is a limited incentive for deployment of DS-Lite for current carriers
  - Does not speed up or simplify by any mean the IPv6 introduction
  - Shares the same scaling and complexity issues with 6RD
  - Does not allow for a fast transition out of IPv4 either (many v4 functions – AAA, LI, addressing etc…) still require support on the GW
  - Difficult to introduce on legacy Access Node base (1st gen Ethernet, ATM)
- Main appeal is on the added flexibility for address translation
  - There are however simpler ways to address this

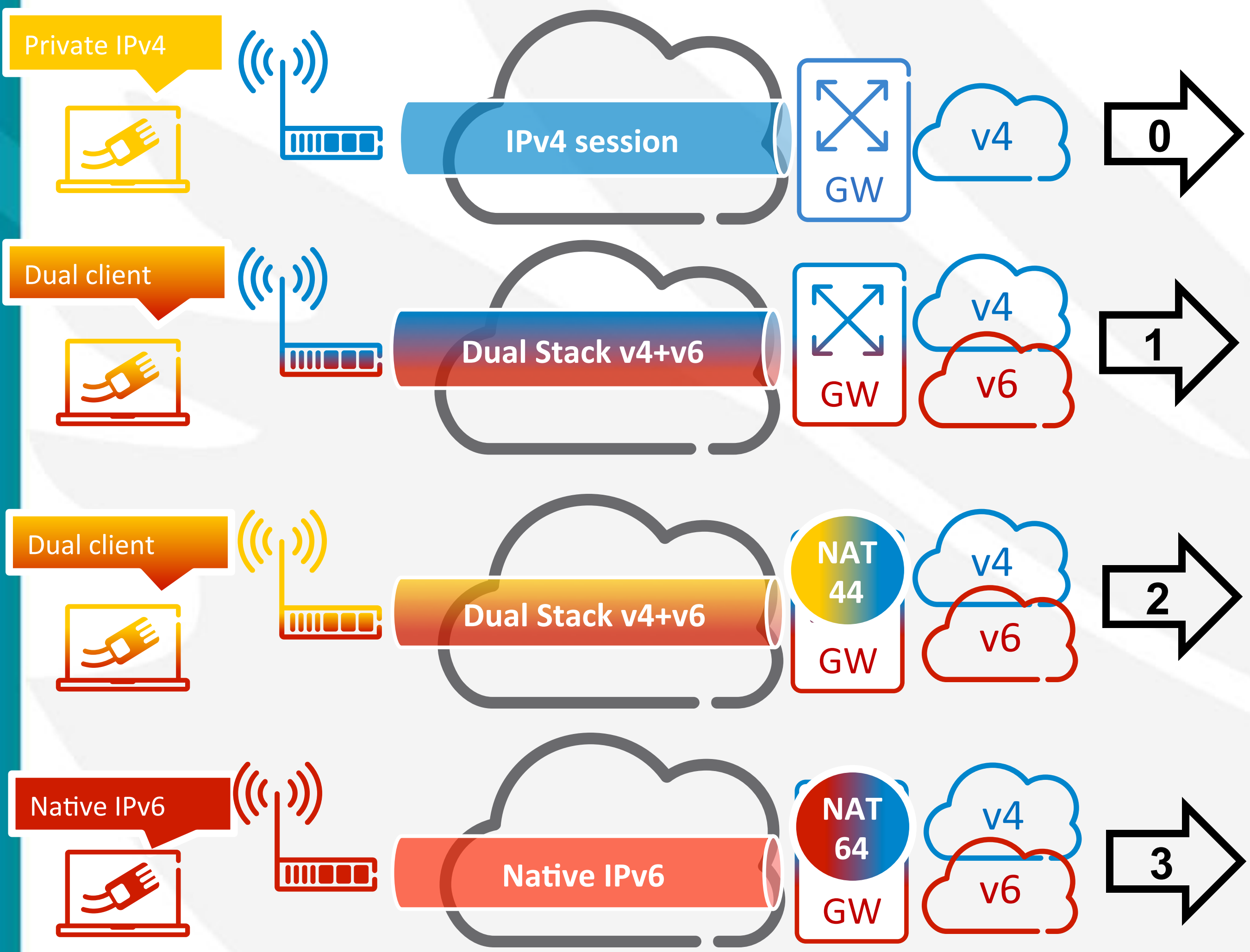
Dual Stack v4v6



- Simpler: Dual stack v4 & v6 follow the same connection logic and endpoints, no tunnel encapsulation, no specific tunnel setup procedures, no MTU issues
- Cheaper: Single box solution for v4 and v6 resources - soft resource transfer from v4 connectivity to v4+NAT then to v6+NAT then to full v6
- Having an IPv4 plane independent from IPv6 plane helps to decouple problems and introduction phase
  - Allows to introduce IPv4 / CGNAT if v4 depletion is an urgent issue
  - Allows to introduce IPv6 first without CGNAT if depletion is not a pressing issue
  - Can turn off IPv4 layer at a later stage without impact on the IPv6 plane
- Consistent approach with the Mobile domain – Dual Stack is defined as the standard 3GPP approach and supported natively in UE stacks.

Recommended IPv6 Transition steps

Ariel



Today

Dual Stack
No architecture change
Single session/bearer

Address IPv4 depletion
when / if required

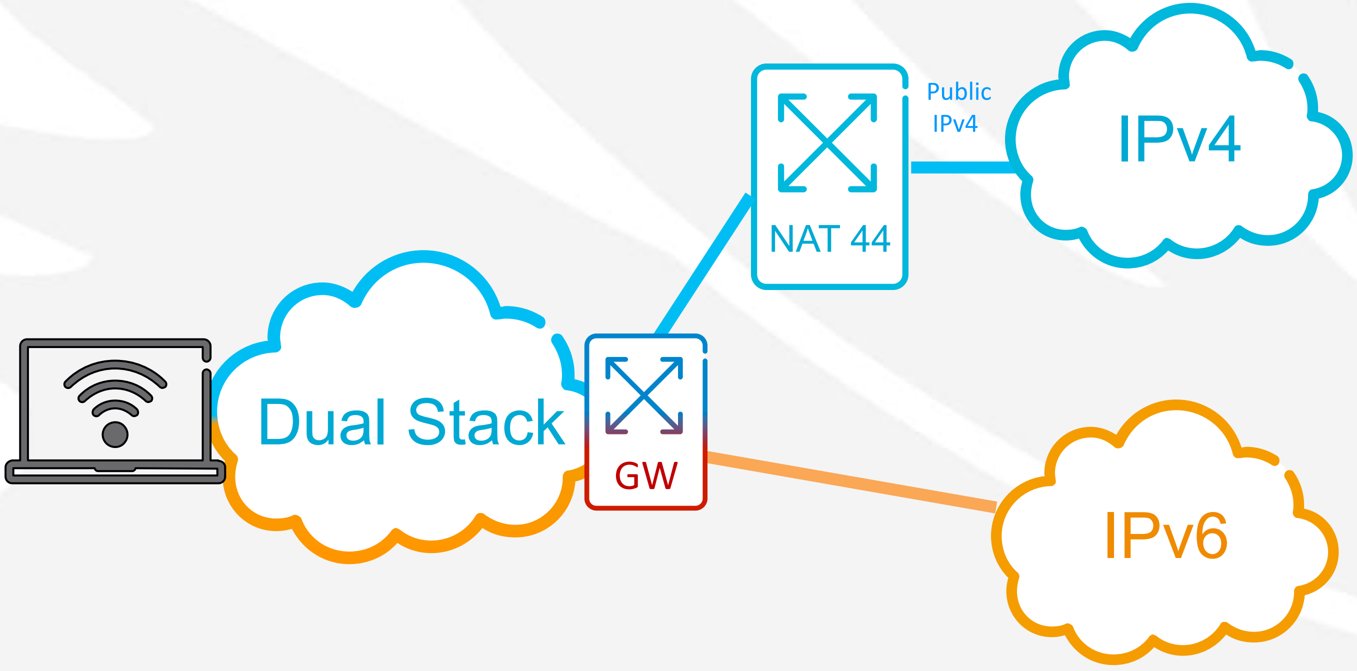
When v4 clients/services become marginal speed up native IPv6 via NAT 64:graceful IPv4 shutdown

Dual Stack or IPv6-only?

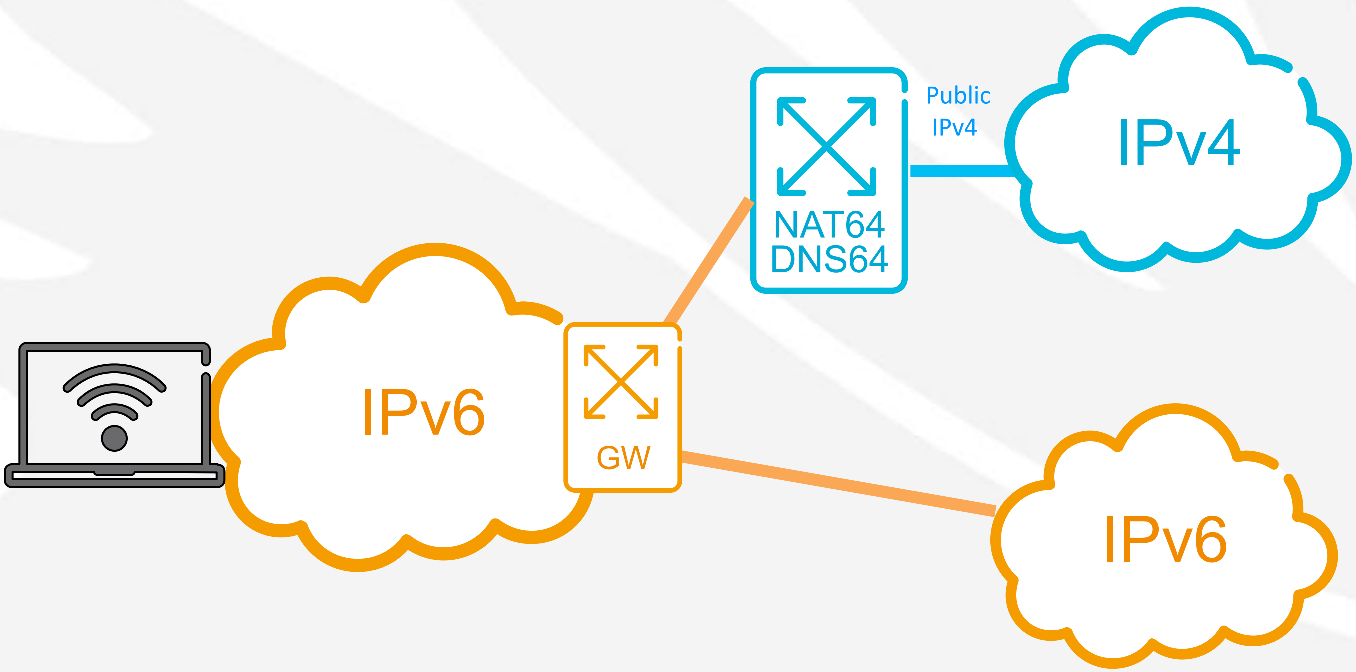
- Dual Stack is the option preferred by a majority of carriers
  - Deployment has zero downtime
  - IPv4-only equipment can share network resources
  - IPv4 depletion still a problem, then NAT44
  - Good for already running networks

- IPv6-only
  - IPv6 Internet traffic still represents less than 1%
  - UE must support IPv6
  - Network deployment include downtime
  - Needs NAT anyway
  - Good for new networks such as LTE

Dual Stack with NAT44



IPv6-Only with NAT64/DNS64

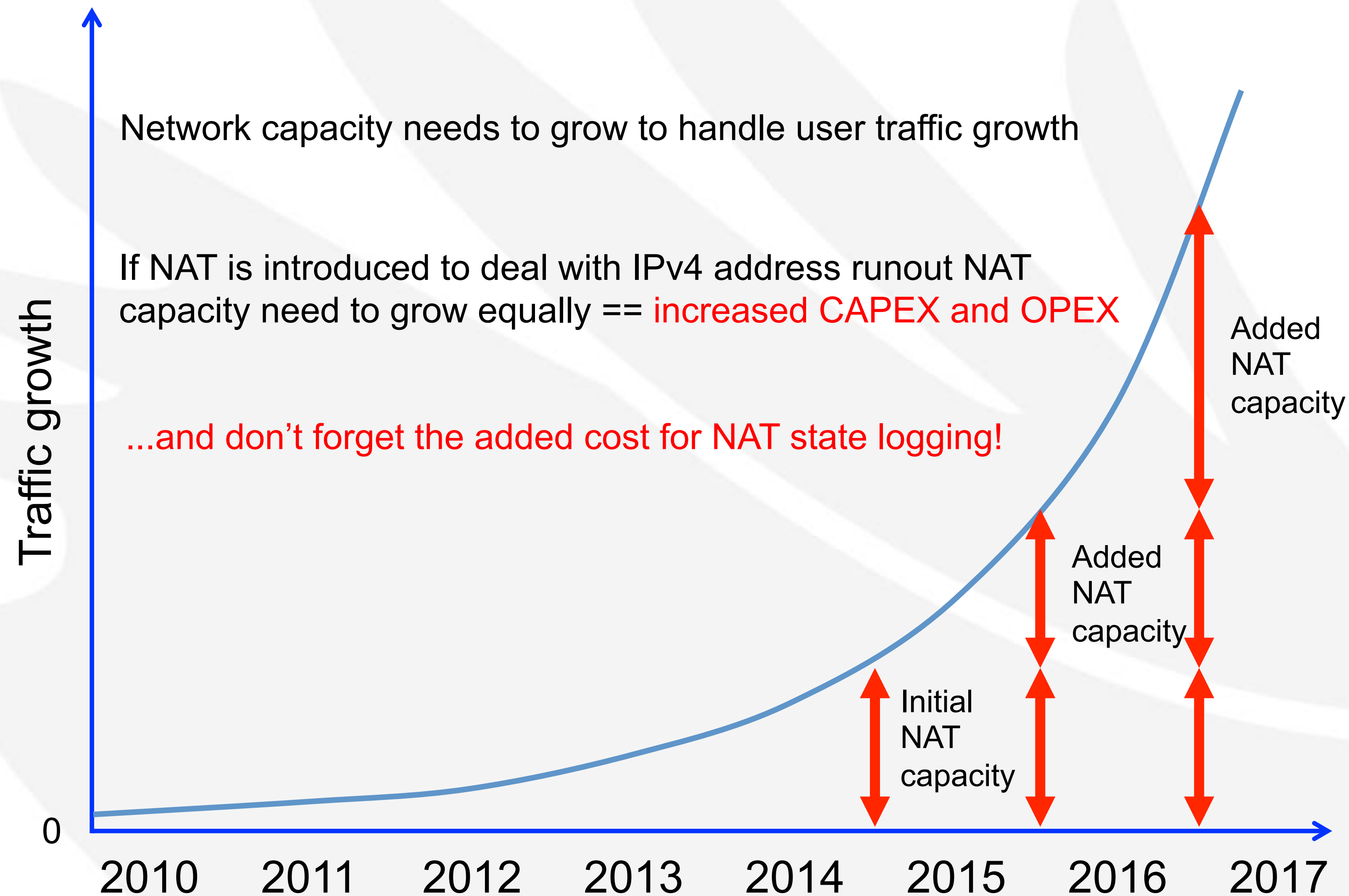


NAT, a Necessary Evil

- Some companies are sticking to NAT only
  - We are not going to deploy IPv6, it's like Y2K!
  - We have bought this nice CGNAT box that goes in front of our router!

- Other companies are planning their transition
  - Like it or not the future is IPv6
  - Meanwhile, let's mitigate some issues with NAT

IPv6 Business Case – Traffic Growth Impact on CGNAT



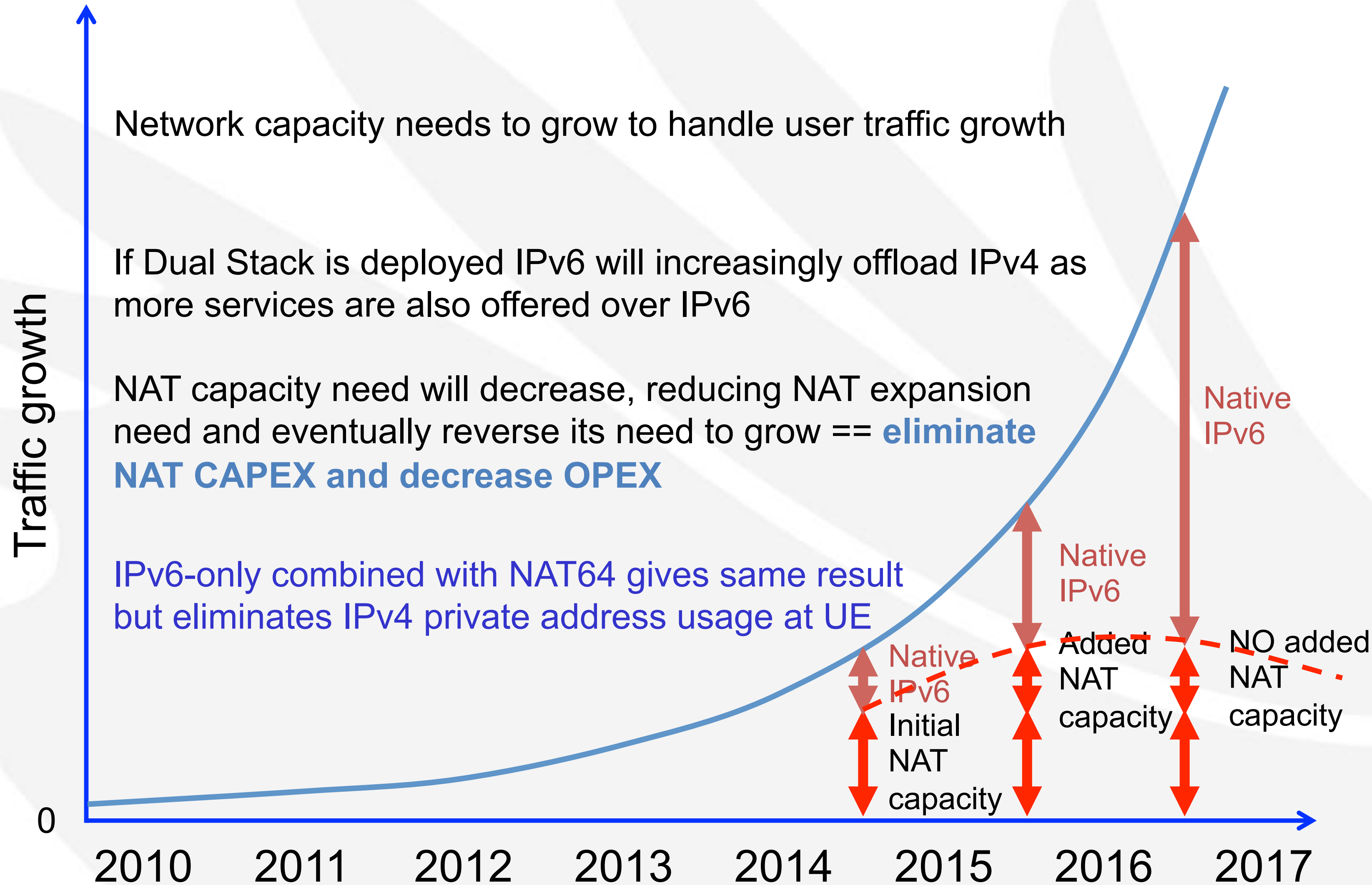
IPv6 Business Case – CGNAT with Dual Stack

Network capacity needs to grow to handle user traffic growth

If Dual Stack is deployed IPv6 will increasingly offload IPv4 as more services are also offered over IPv6

NAT capacity need will decrease, reducing NAT expansion need and eventually reverse its need to grow == **eliminate NAT CAPEX and decrease OPEX**

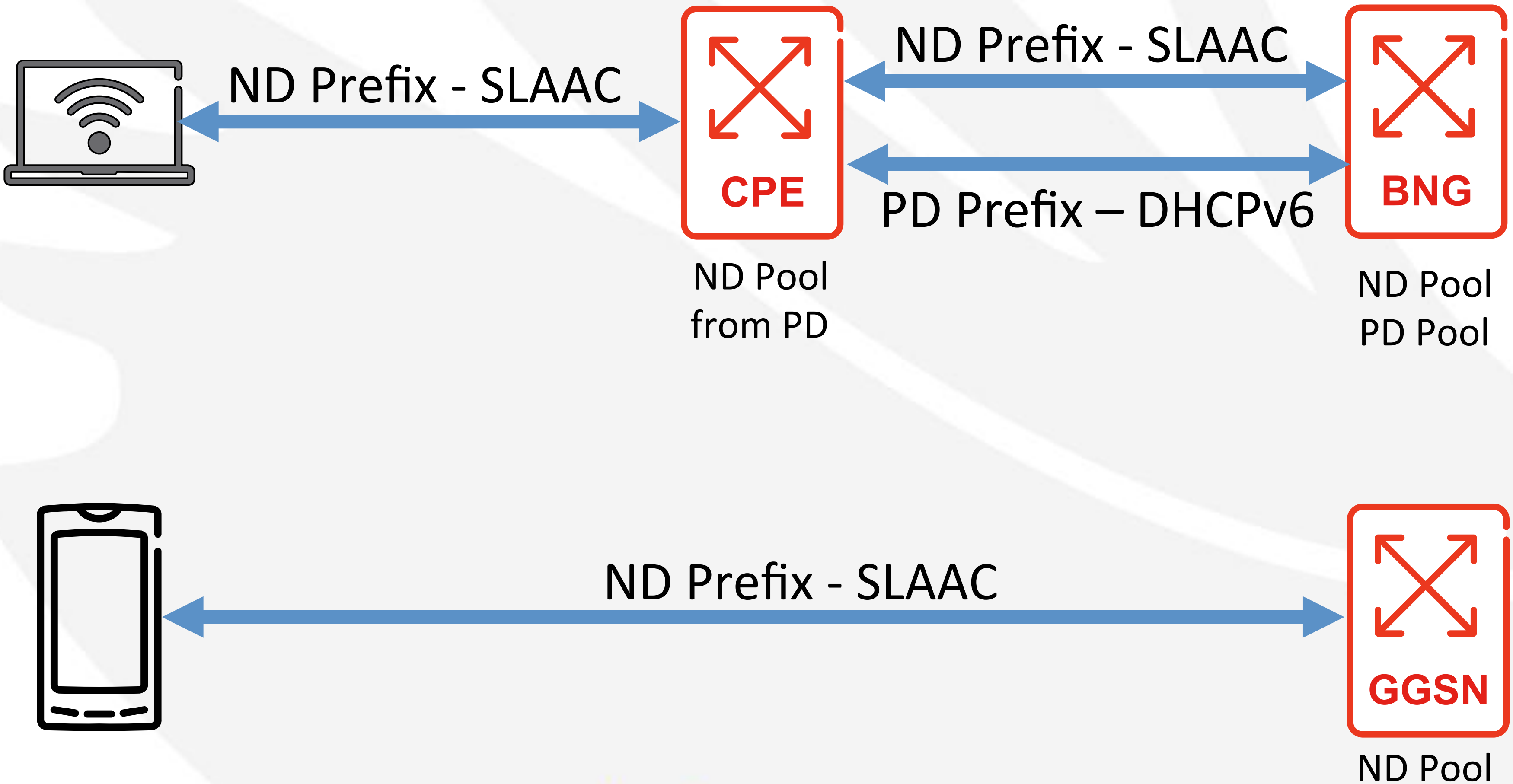
IPv6-only combined with NAT64 gives same result but eliminates IPv4 private address usage at UE



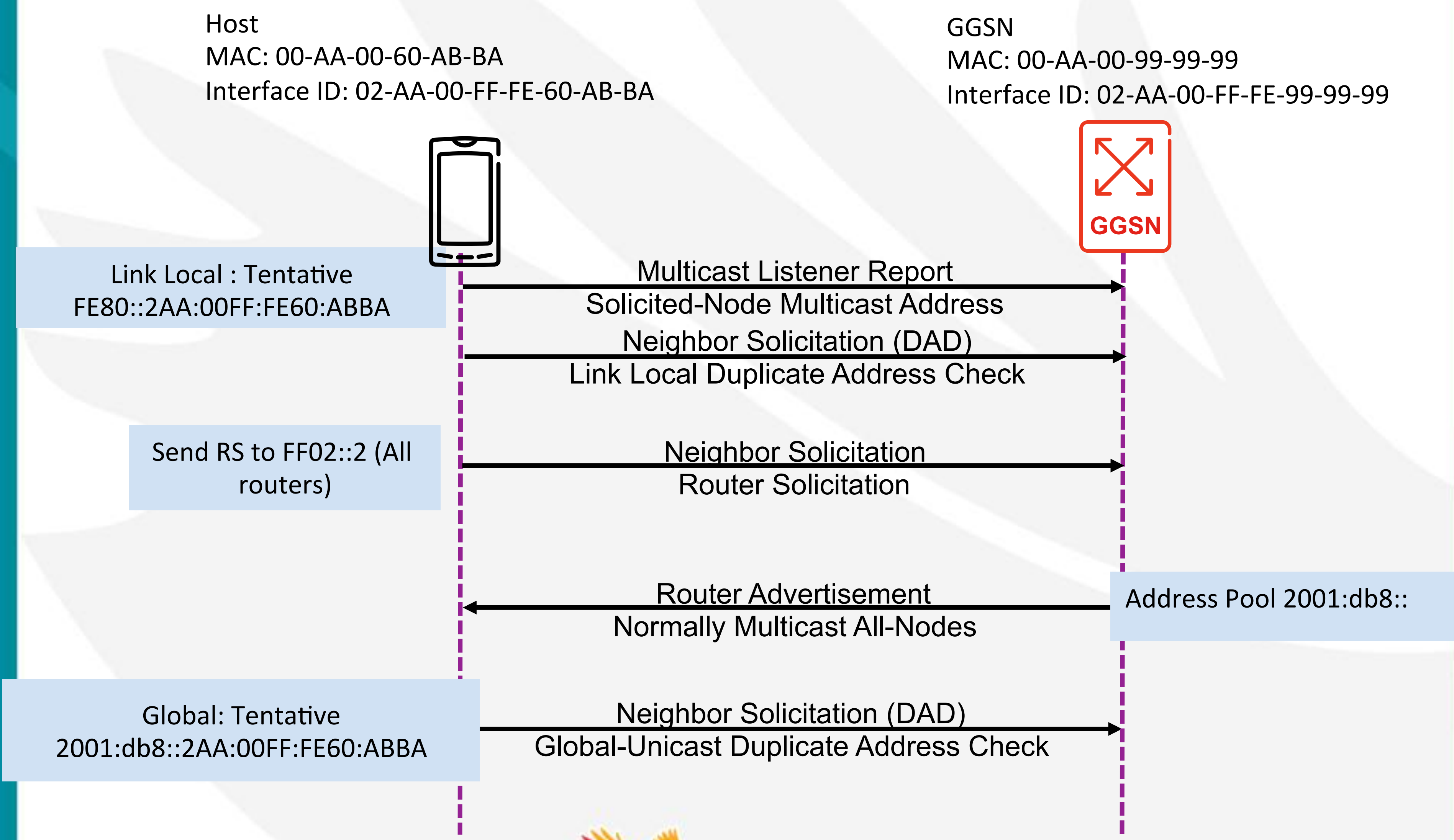
Jordi

IPv6 Prefix Assignment

IPv6 Prefix Assignment



IPv6 Stateless Address Autoconfiguration (SLAAC)



Interface Identifier using EUI-64

Take MAC Address

00-AA-00-60-AB-BA

Insert 0xff-fe between third and fourth bytes

00-AA-00-FF-FE-60-AB-BA

Complement the universal/local bit

02-AA-00-FF-FE-60-AB-BA

Have EUI-64 inserted in IPv6 Prefix

2001:db8::2AA:FF:FE60:ABBA/64

Interface Identifier using EUI-64

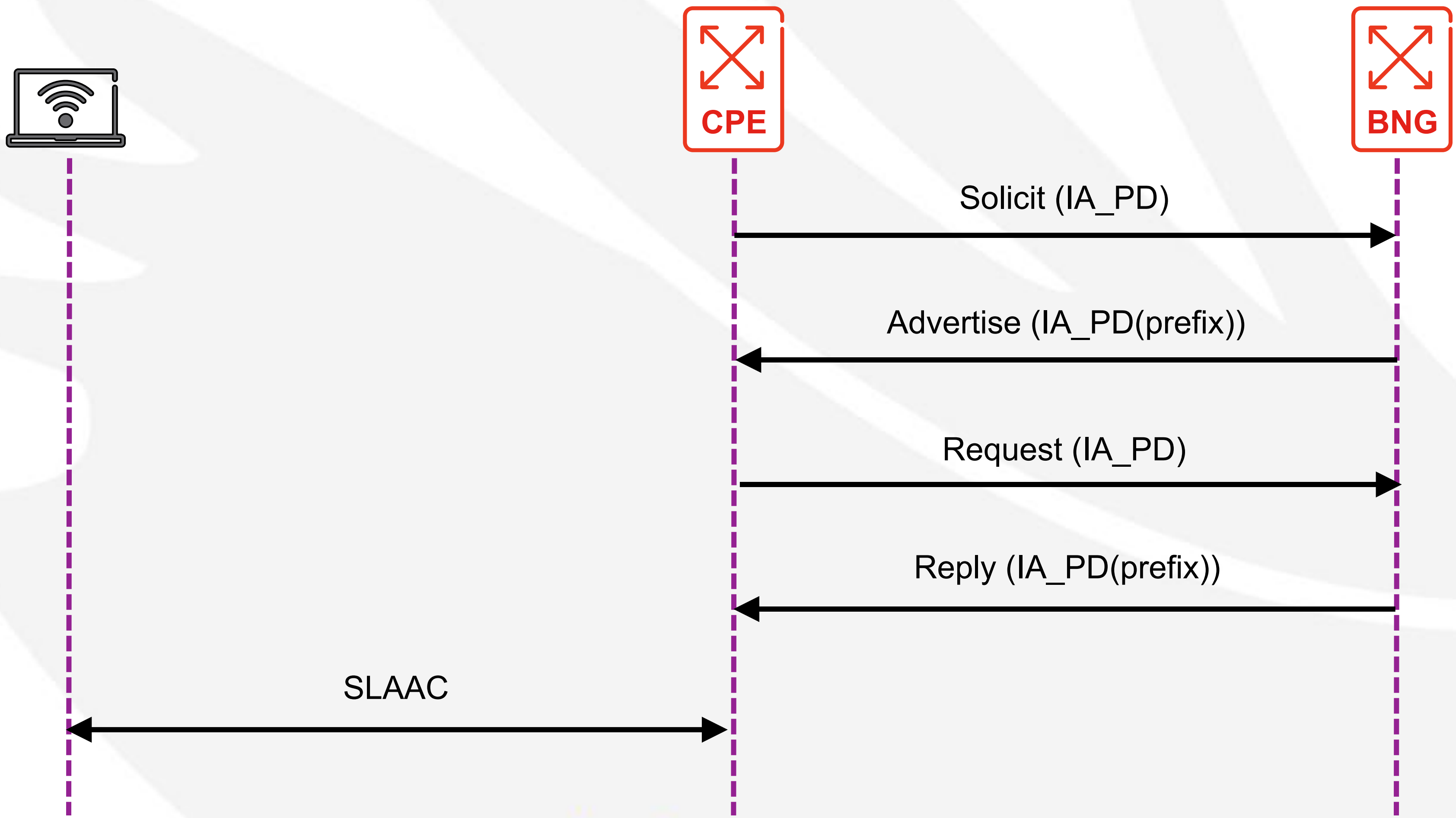
- MAC-based IDs have some security issues [1]:
  - Interface Identifiers do not vary over time, they allow correlation of host activities within the same network,
  - Resulting IPv6 addresses can be leveraged to track and correlate the activity of a host across multiple networks,
  - Interface Identifier leaks device-specific information

[1] Fernando Gont, RFC 7217 - A Method for Generating Semantically Opaque Interface Identifiers with IPv6 Stateless Address Autoconfiguration

Interface Identifier using RFC7217

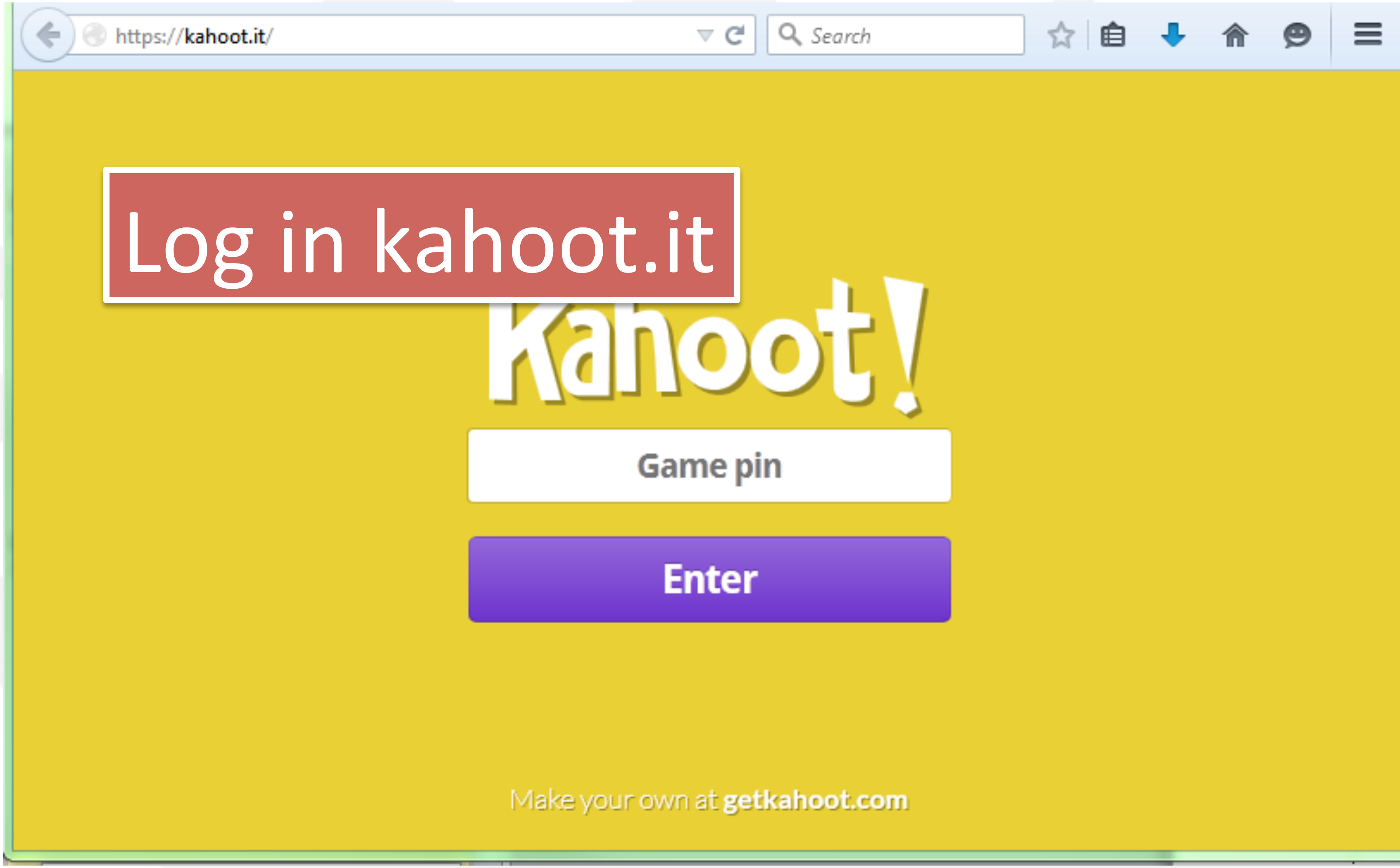
- Use a Random (but stable) Identifier:
  - Generates the same Interface Identifier when configuring an address (for the same interface) belonging to the same prefix within the same subnet.
- This ID is generated by a pseudorandom function using prefix, network interface, network id (optional), DAD counter, secret key

Prefix Delegation with DHCPv6



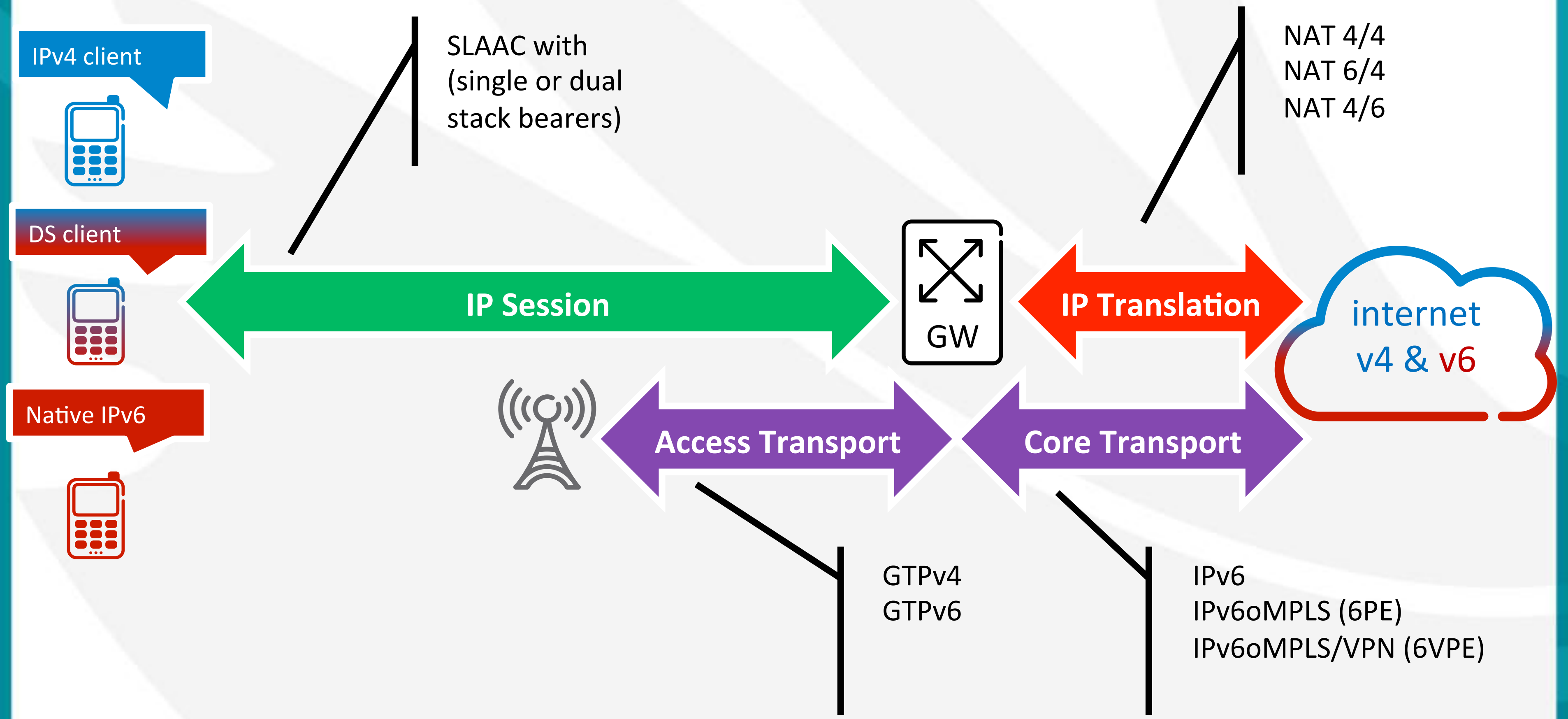
IPv6 Quiz 1

Tomás

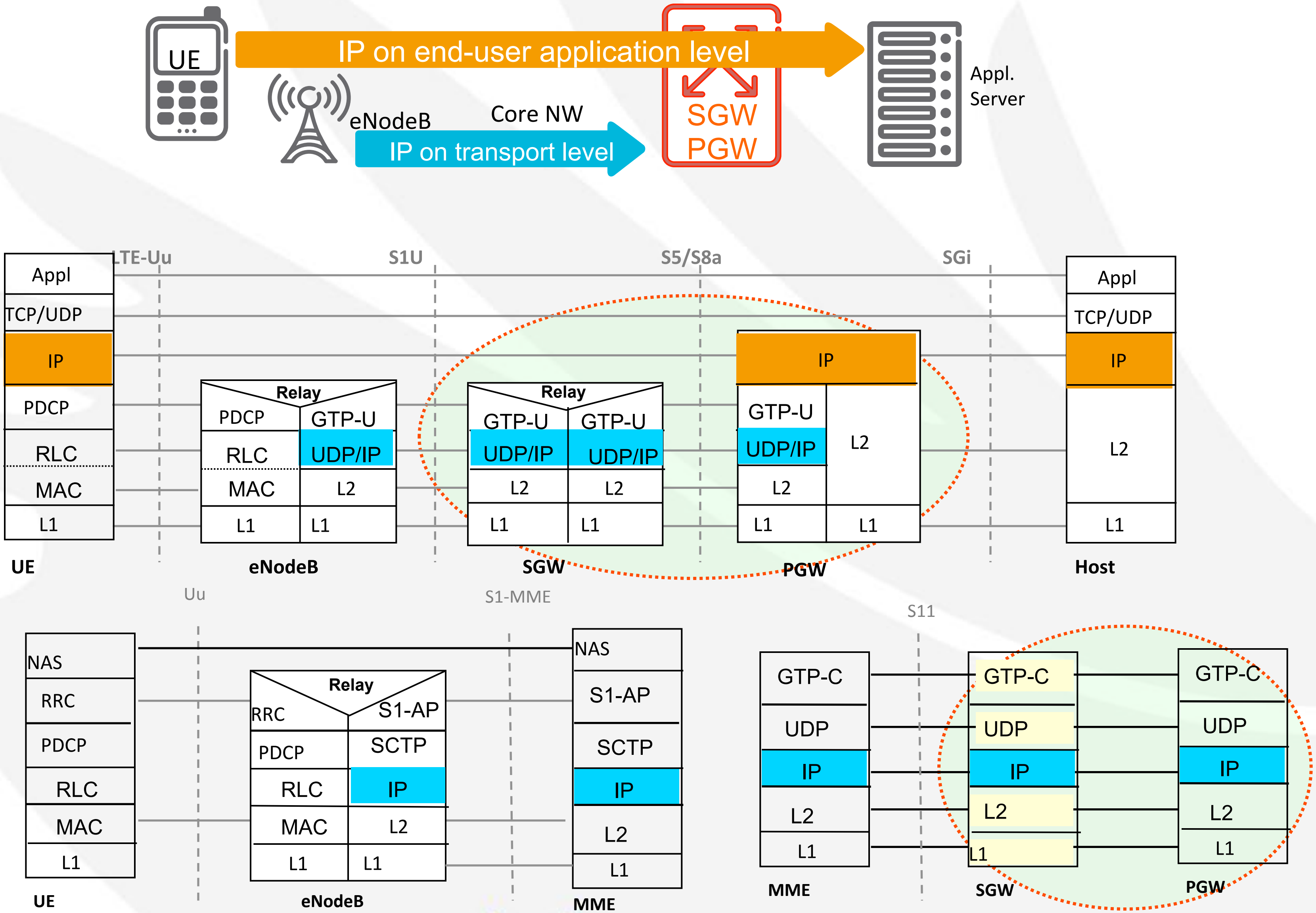


Deployment of IPv6 in Mobile Broadband Networks

IP in Mobile Packet Networks Architecture

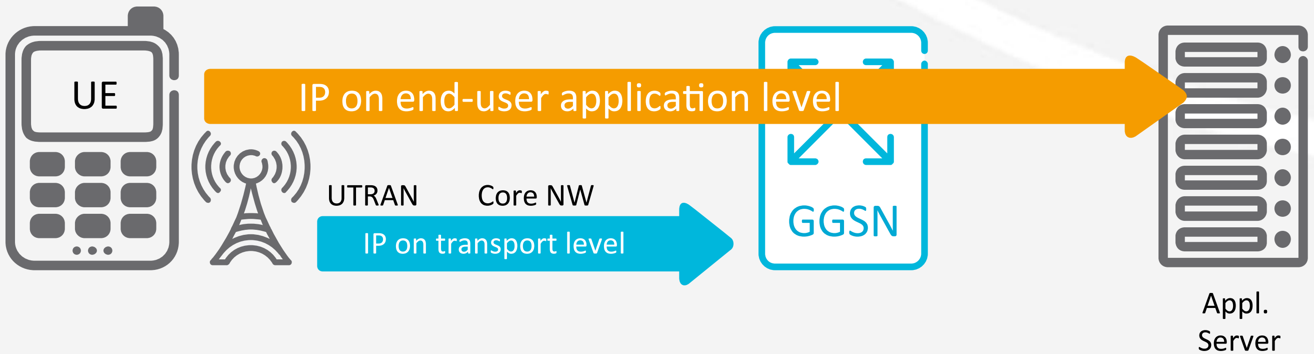


IP in Mobile Packet Networks – LTE call



Step-wise IPv6 strategy

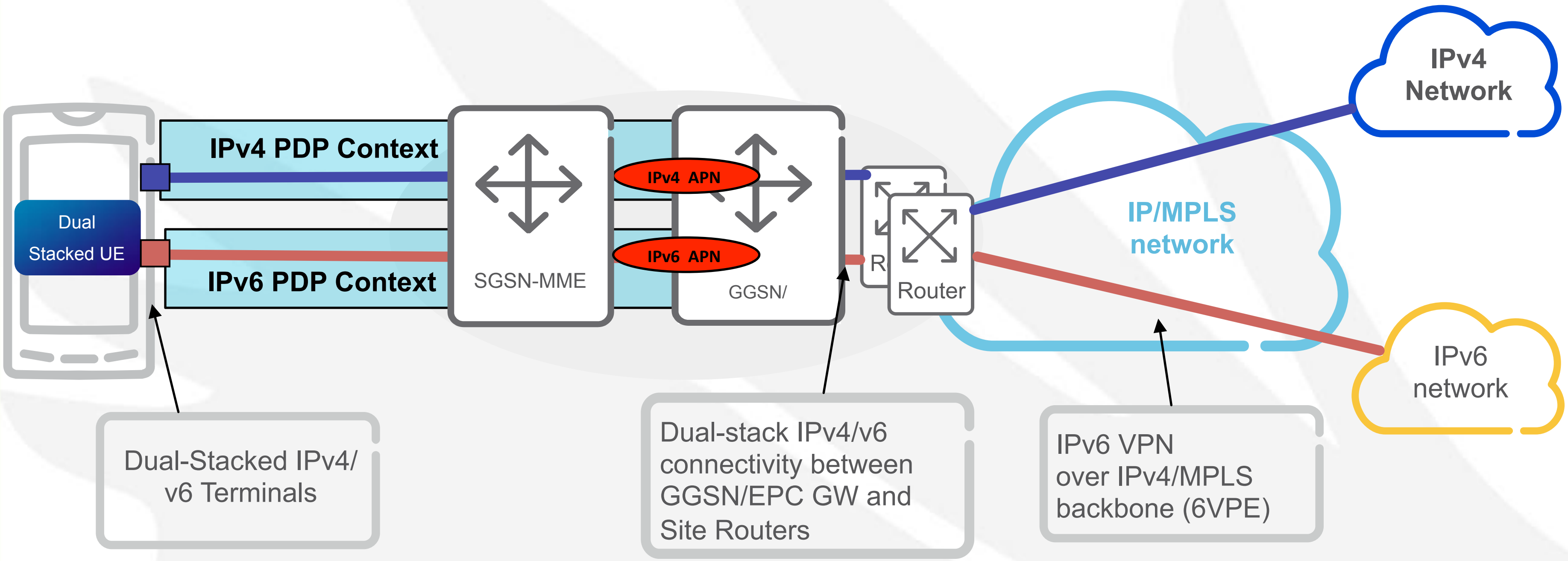
- Activate IPv6 first on the user plane (end user application level)
  - IPv6 addresses assigned to mobile terminals
  - IPv6 addresses assigned to Internet servers
  - Migration Scenarios with single/dual stack terminals and NAT64
- Then activate IPv6 on the transport plane (packet core level)
- IPv6 in Control Plane (mobile service nodes and signaling)
- IPv6 in O&M may be introduced in parallel with other phases



IPv6 in EPC

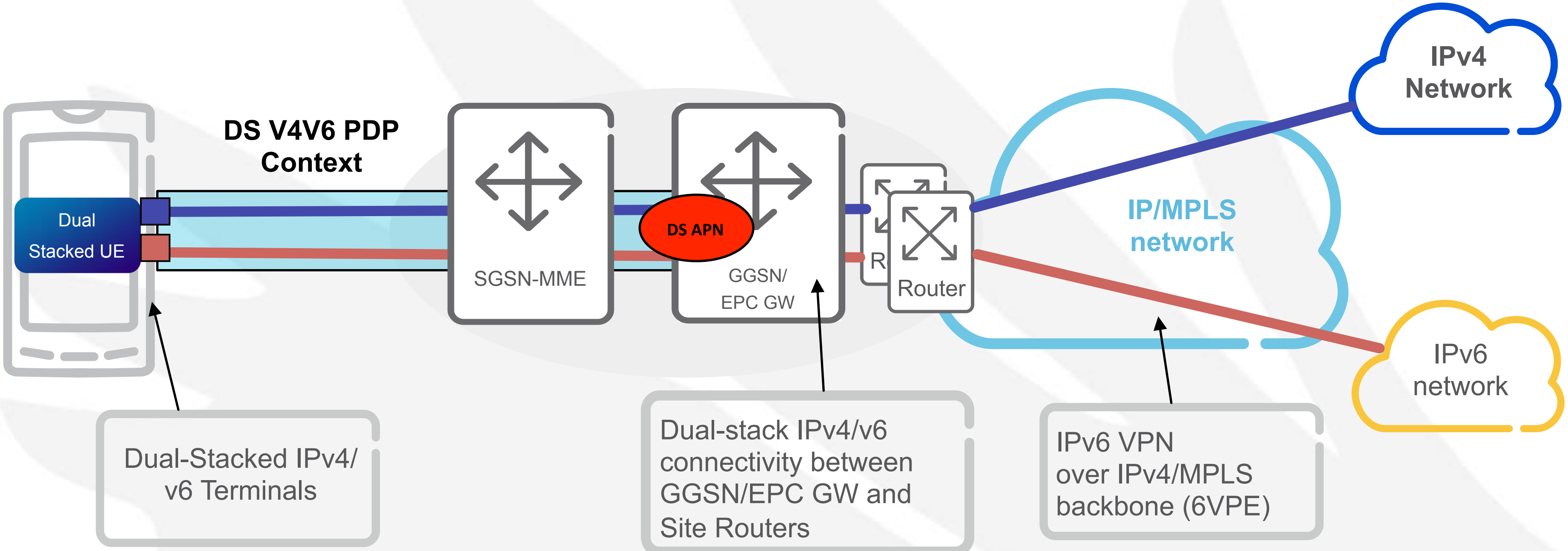
- The IPv6 address will be assigned to the UE at Attach (Always On), but assigning an IPv4 address is not mandatory.
- The UE will always get its IPv6 address by Stateless Address Autoconfiguration
- The PDN-GW will assign the the UE IPv6 prefix either from a local pool or via RADIUS/DIAMETER/DHCP
- A typical use-case benefits from separate QoS handling for
  - IPv6 IMS Signalling
  - IPv6 IMS Media Streams
  - IPv4 ”legacy applications”, Internet, i.e. Web browsing etc.

Dual Stack Support Pre 3GPP R8



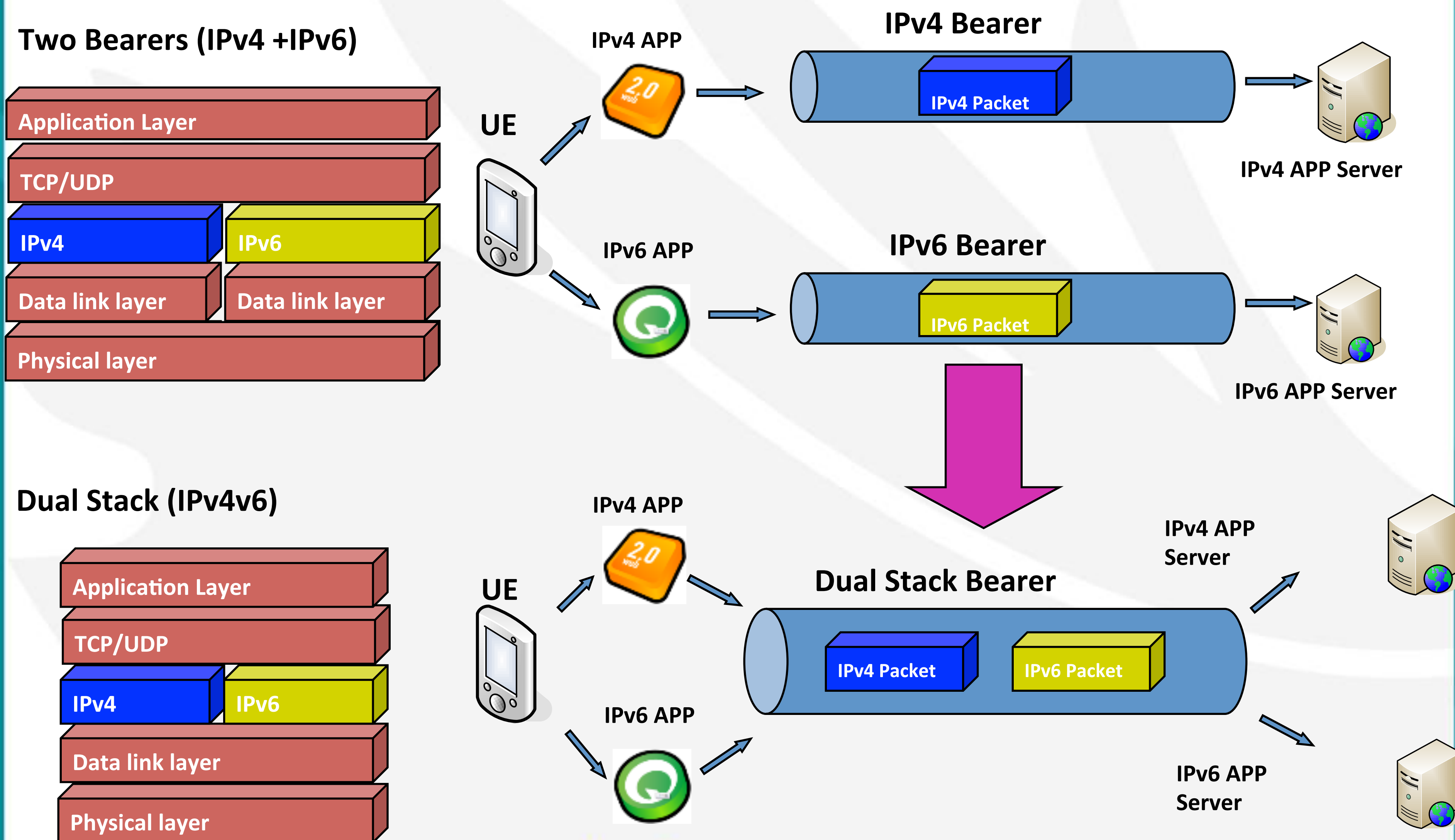
- 3GPP PRE-RELEASE 8
  - Dual Stacked UE using single stack PDP context.
  - Dual bearers required (2 PDP contexts)
  - Logical separation in GGSN for V4 and V6 APNs

Dual Stack Support 3GPP R8

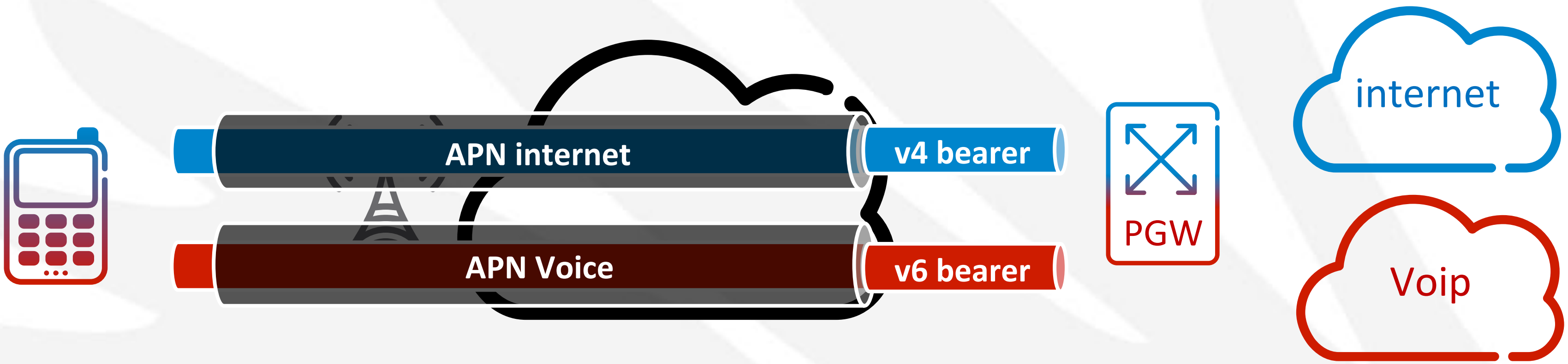


- 3GPP Release 8 and Beyond
  - Dual Stacked UE using Dual Stack v4v6 PDP context.
  - End-to-end User Plane IPv4v6 dual stack support
  - Single bearer required per user (1 PDP context)
  - DS connectivity on GGSN/EPC GW.

Dual Stack Bearer Comparison

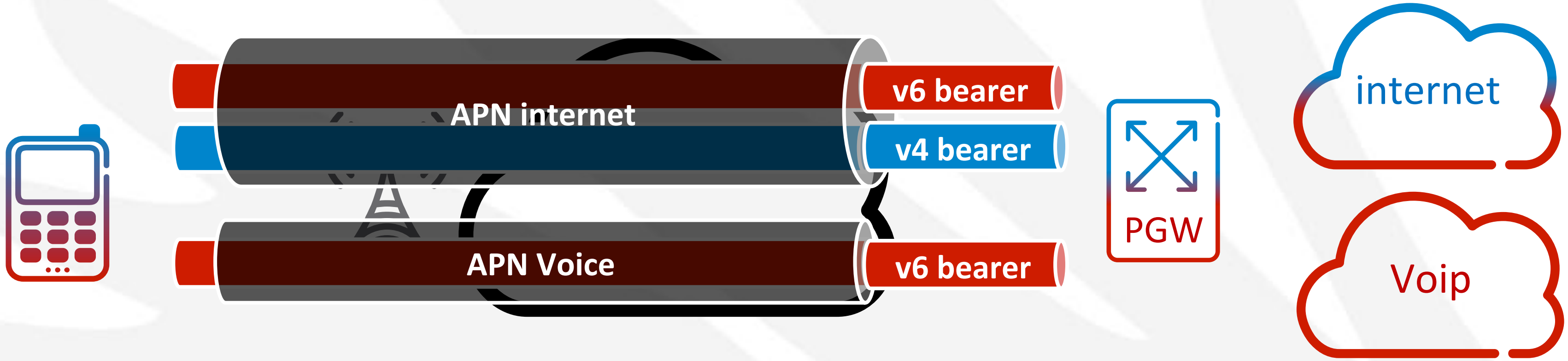


EPS Dual Stack variations – Using Separate APN



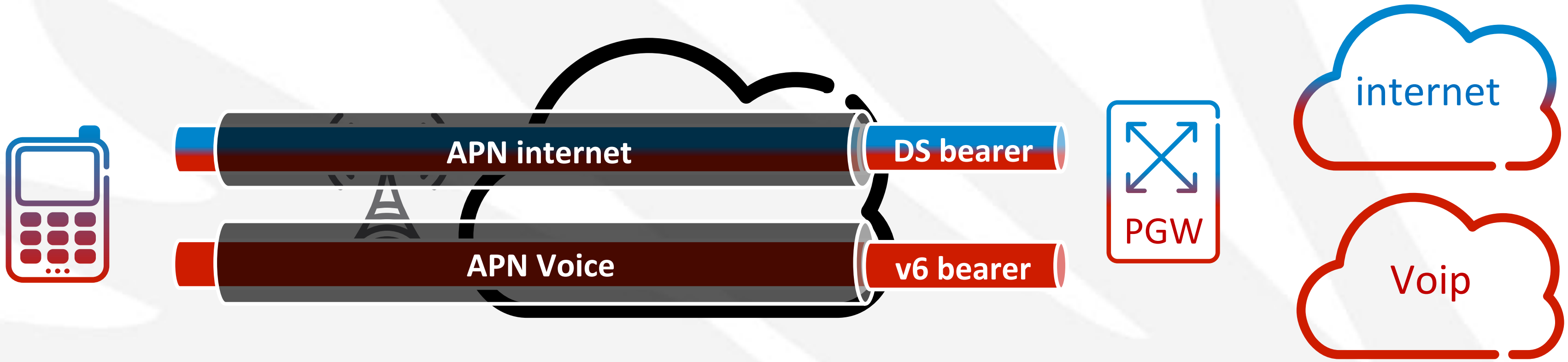
- New IPv6 applications can be overlaid on top of current ipv4 applications
- VoLTE is an ideal candidate for managed application
- Typically isolated into different VPN contexts

EPS Dual Stack variations – Using Separate Bearers



- A single APN can support both IPv4 and IPv6 bearers
- Allows dual stack application access to a service – i.e. typically to dual stack internet (can't predict what a specific application will access)
- It can however creates unnecessary overhead
  - Why maintaining different bearer states for the same service
  - Do you have to make a choice for the default bearer?

EPS Dual Stack variations – Dual Stack Bearer



- A recommended solution is to support a dual stack capable bearer to simplify dual stack applications and services deployment
- In complement with dedicated bearers
  - Legacy IPv4 only application to coexist in the long run
  - New IPv6 only applications to be introduced

EPS Bearer

- One EPS Bearer per version
  - May lead to resource waste (licenses, memory) when is likely that most parameters in the connection are the same across IP versions
  - Duplicate the need for signaling for connection setup, movements, QoS, filter updates, etc.
  - Debugging is harder: two connections, possibly two different gateways, two resets needed to restore the situation, etc.

- Dual stack EPS Bearer solve these problems

IPv6-only APN Configuration – Juniper

```
[edit services epg pgw]
apn ipv6only {
      pdp-context {
                  pdp-type ipv6;
                  ipv6-address {
                    2001:db8:db8::/48;
          }
      }
      ipv6-name-server {
                    2001:db8::3434;
                    2001:db8::3435;
      }
}
```

Dual Stack APN Configuration – Ericsson

```
(config-ManagedElement=1,Epg=1,Pgw=1)
Apn = dualstack
    pdpContext = 1
        pdpType = ipv4v6
                Address = 192.0.2.128/25
                Ipv6Address = 2001:db8:db8::/48
    NameServer = 192.0.2.3
        Priority = 1
    NameServer = 192.0.2.5
        Priority = 2
    Ipv6NameServer = 2001:db8::3434
        Priority = 1
    Ipv6NameServer = 2001:db8::3435
        Priority = 2
```

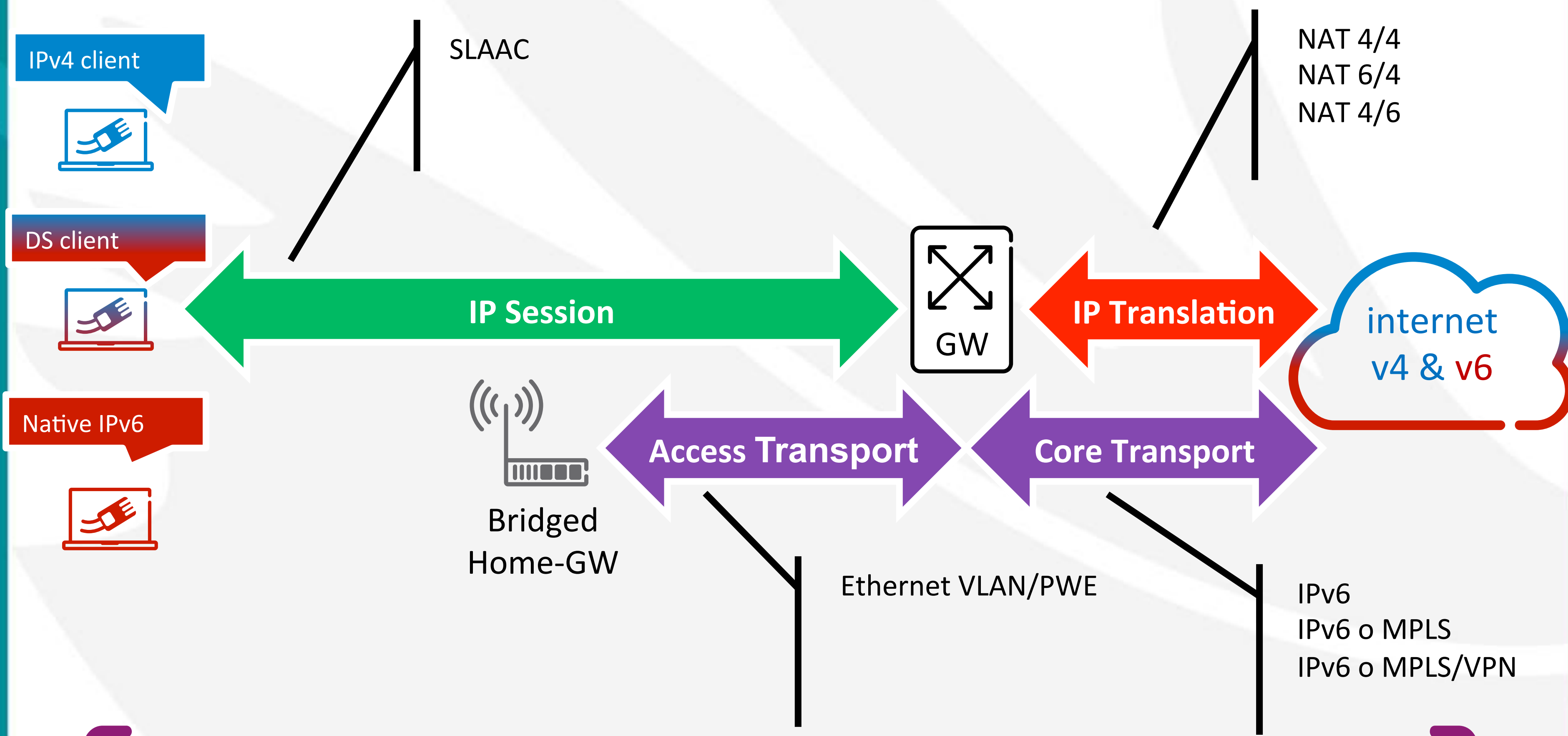
Ariel

Deployment of IPv6 in PPPoE & IPoE Networks

Fixed Broadband Access

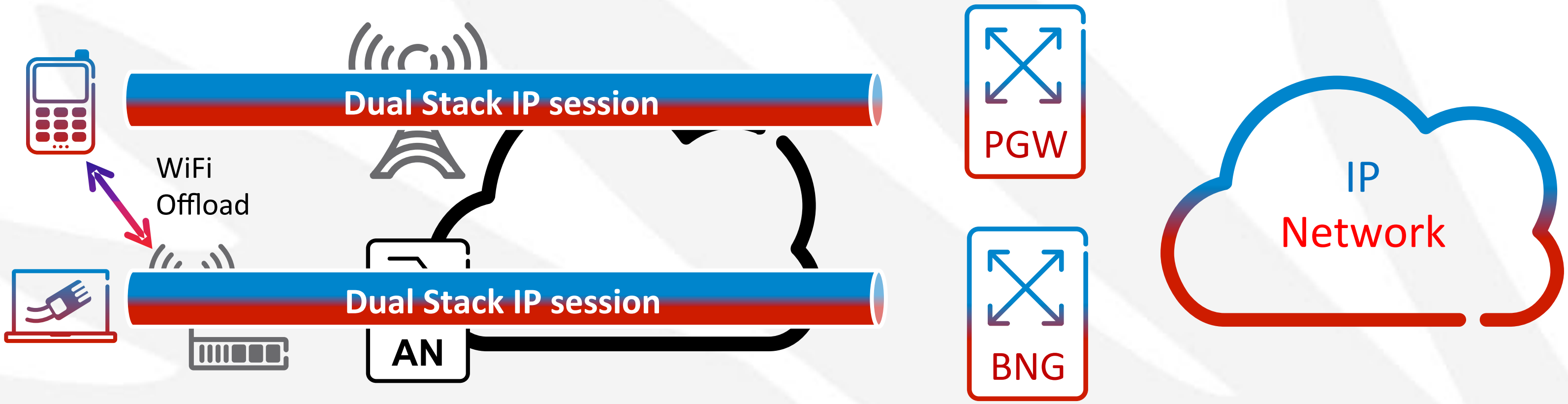
- CPE types
  - Bridged CPE
  - Routed CPE
- Access types
  - PPPoE
  - IPoE

IPv6 Components – Bridged HGW



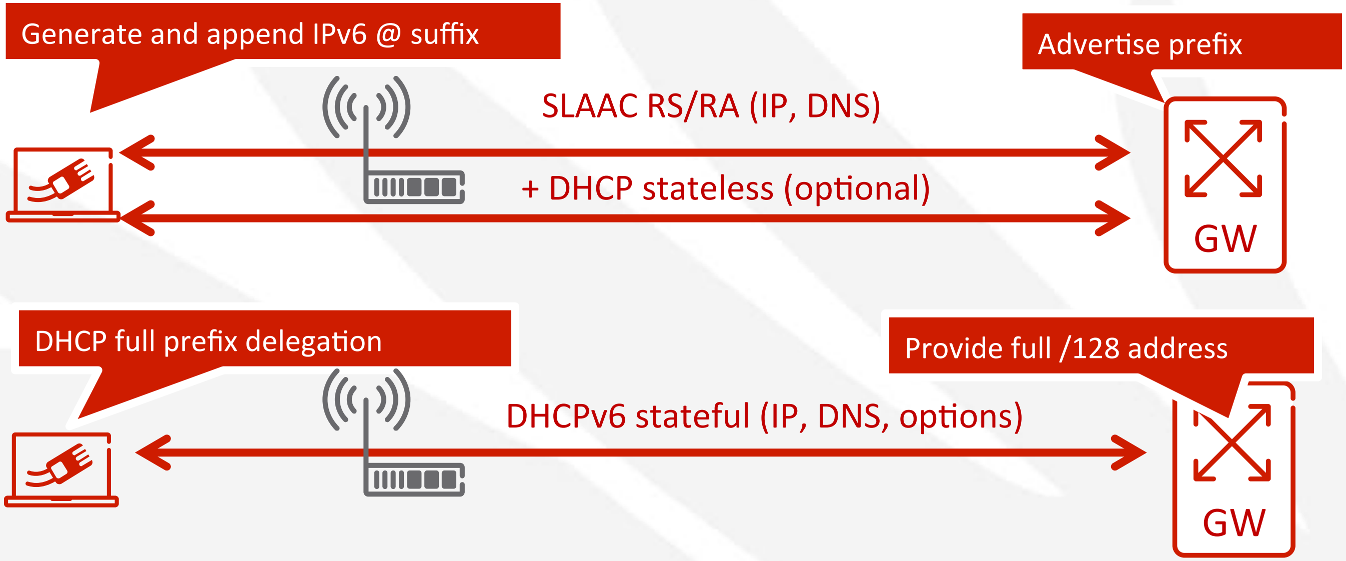
Simplified model with limited implementation options

Aligned Fixed & Mobile Architecture



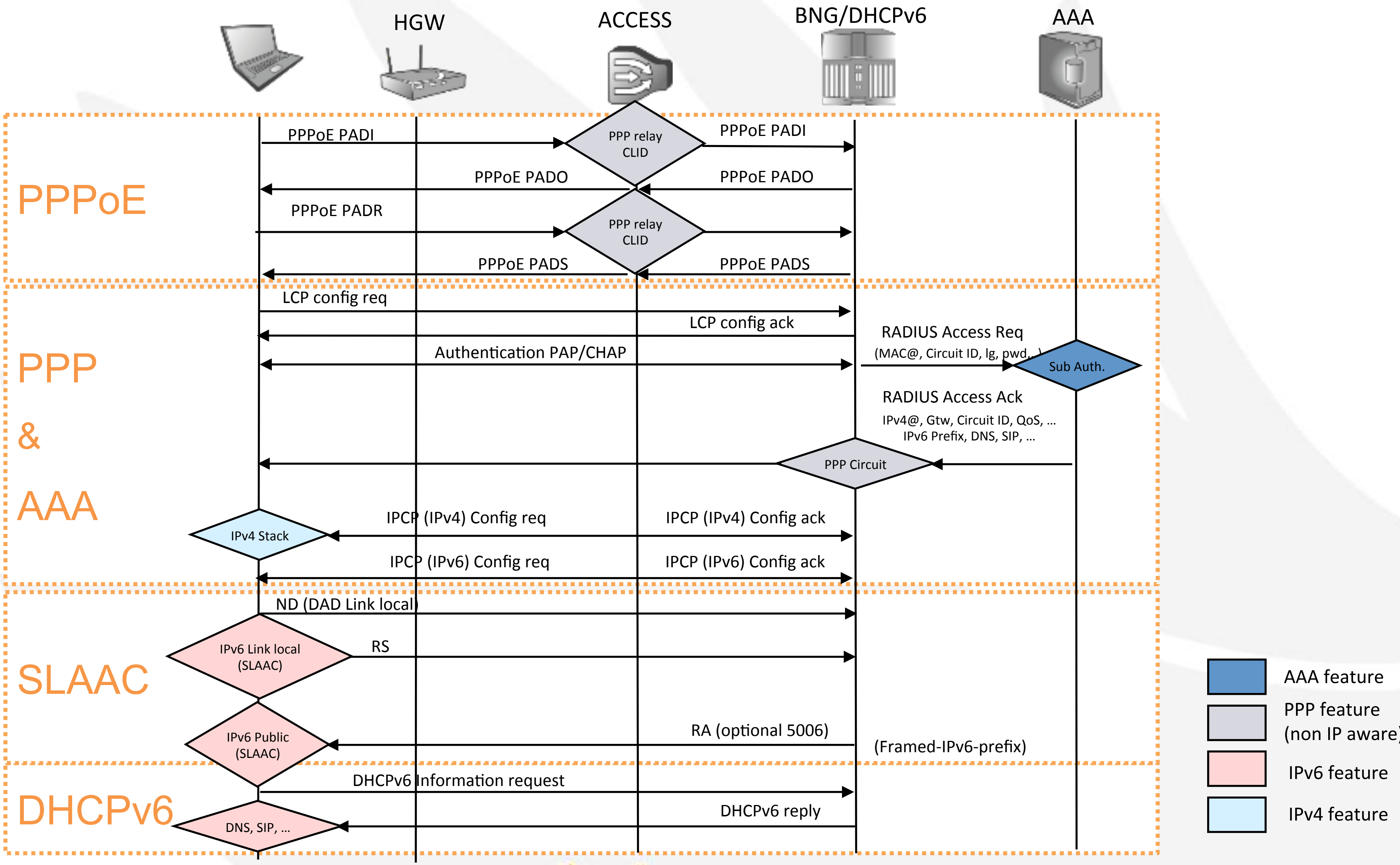
- With a bridge HGW model operators will be able to provide a per device individualized session & services
  - This models fully align fixed & mobile deployment use case and allow to define portable service models across both domains
  - This also simplifies the access network by providing a flat service architecture (removes the Home gateway hierarchy)
- HGW bridging architecture are however typically deployed for service specific functions – such as managed voice or video – making deployment more challenging

Terminal Device IPv6 Session

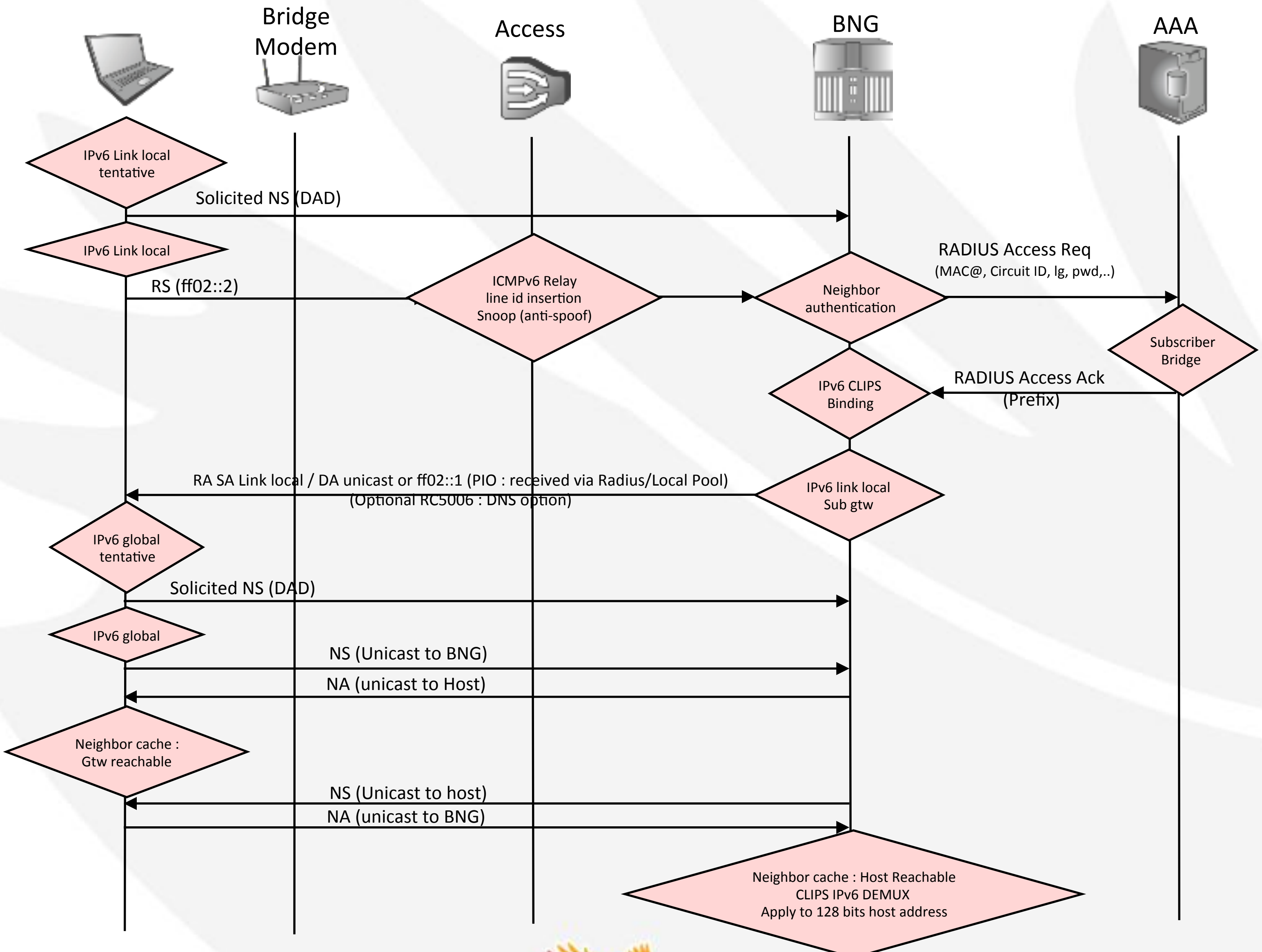


- It is recommended standardizing end device support through SLAAC as it is a minimum subset supported across devices on fixed & mobile
  1. Stateless Address Auto-Configuration
     - Minimal support to carry complementary information such as DNS info
  2. Stateless DHCP complements SLAAC by providing additional options
  3. Stateful DHCP supplement SLAAC as an alternative addressing method

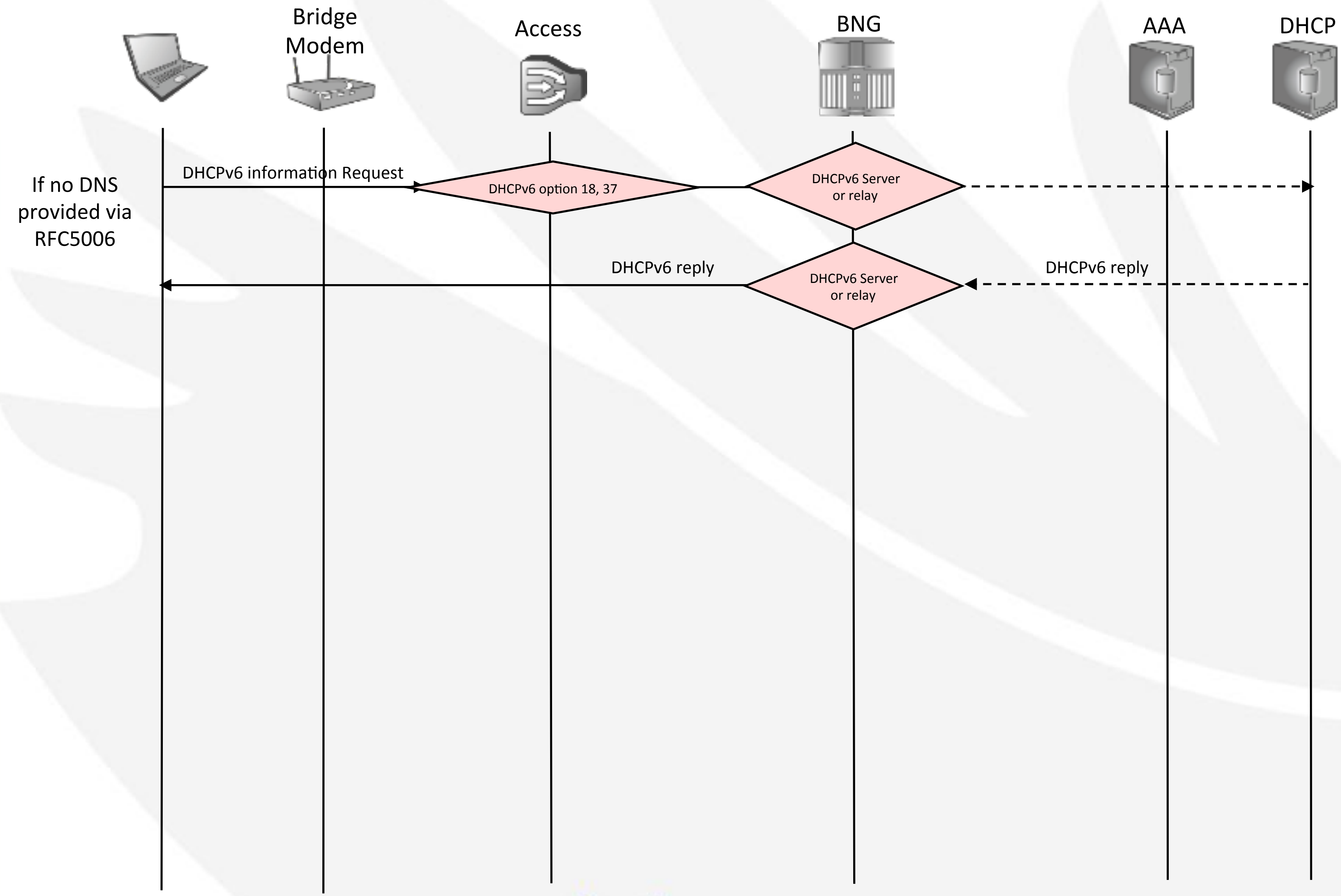
Bridged HGW - PPPoE Attachment Process



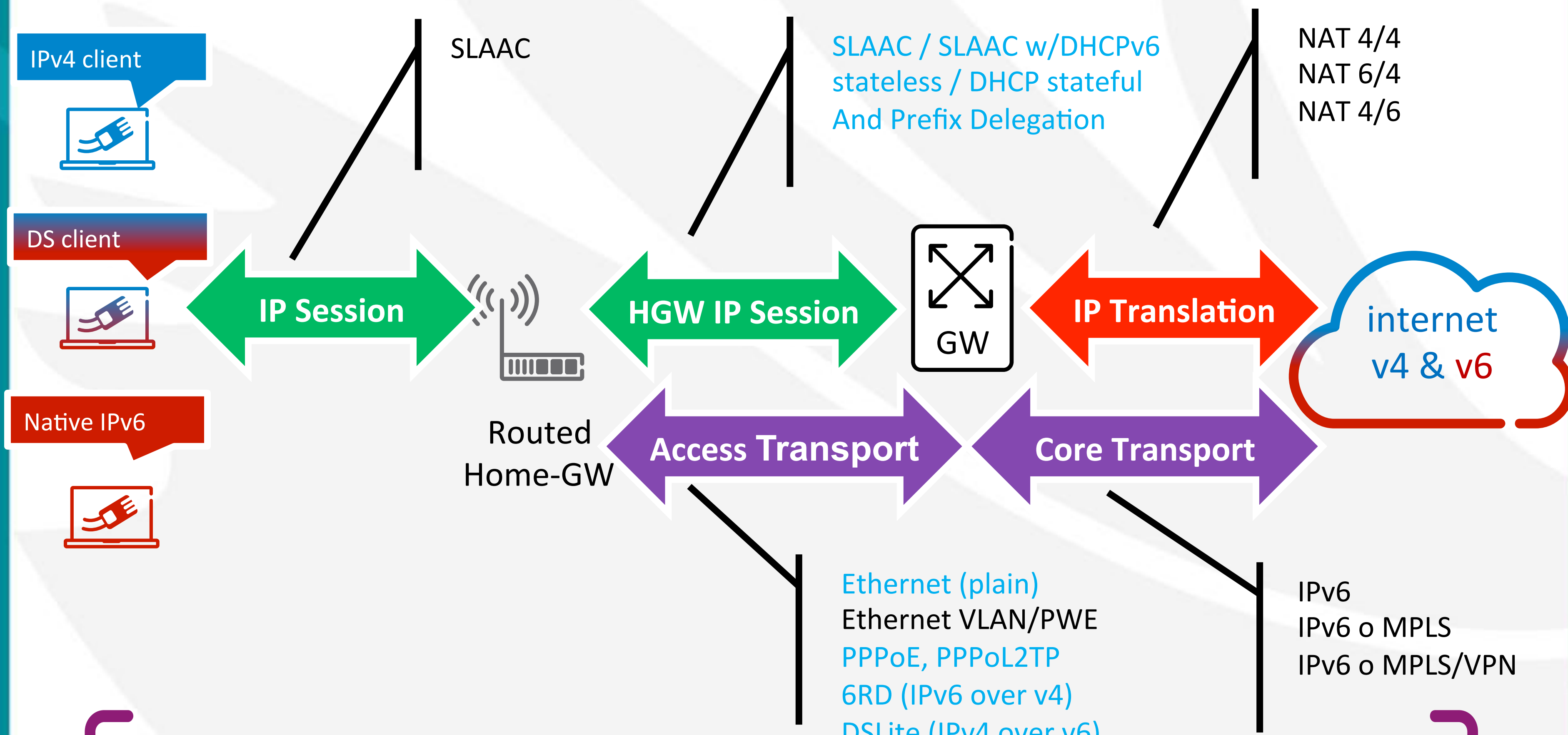
Bridged HGW : IPoE Attachment Process (1)



Bridged HGW : IPoE Attachment Process (2)

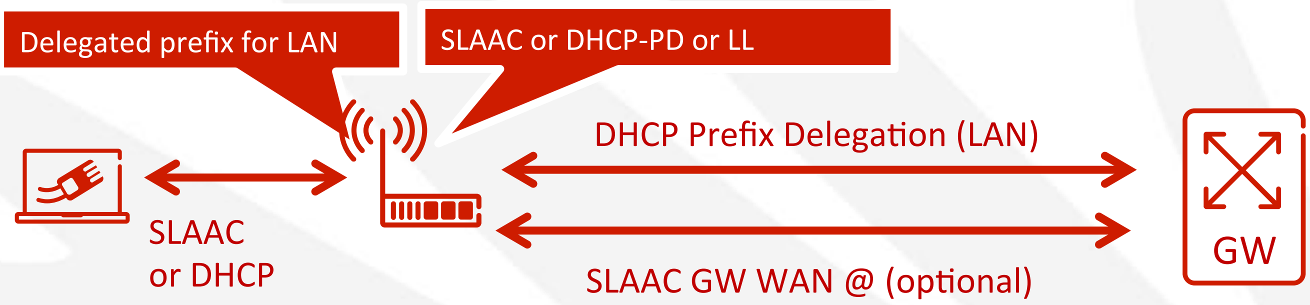


IPv6 Components – Routed HGW



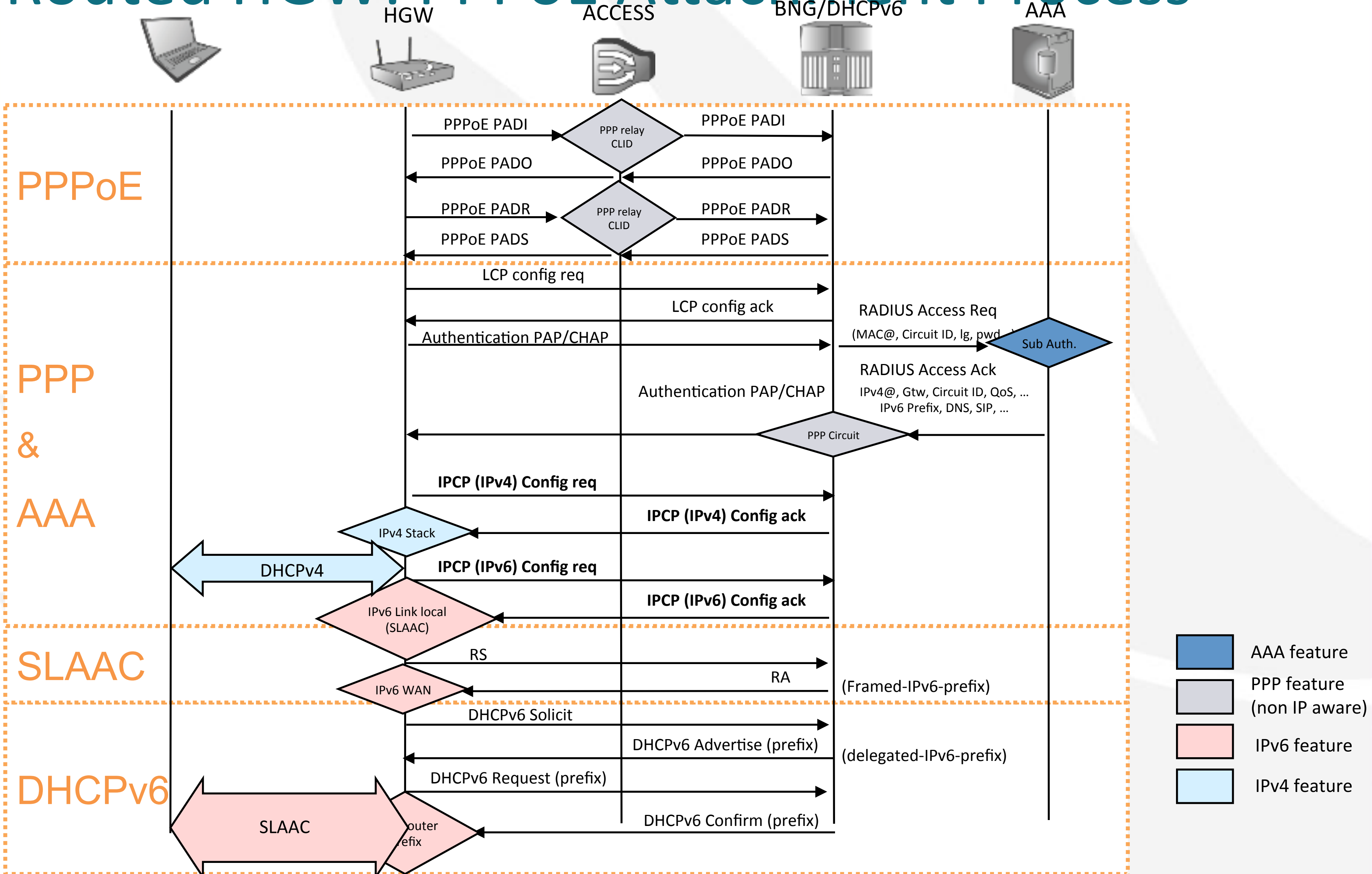
Many more options to consider for the broadband sessions

Home GW IP Prefix Delegation



- A routed home-GW deployment is introducing a layer of hierarchy in addressing
  - IPv4 deployment typically only allow a single public IP per home forcing at NAT translation mode between inner & outer segment
  - DHCP prefix delegation allows to distributed a prefix for GW LAN
- DHCP-PD can be used in complement to SLAAC/DHCP stateful
  - Provide additional prefix for LAN
- Or subsume HGW addressing function
  - Only provide PD – let the HGW extract an address out of the prefix for its own use (Management, voice service etc…)

Routed HGW: PPPoE Attachment Process



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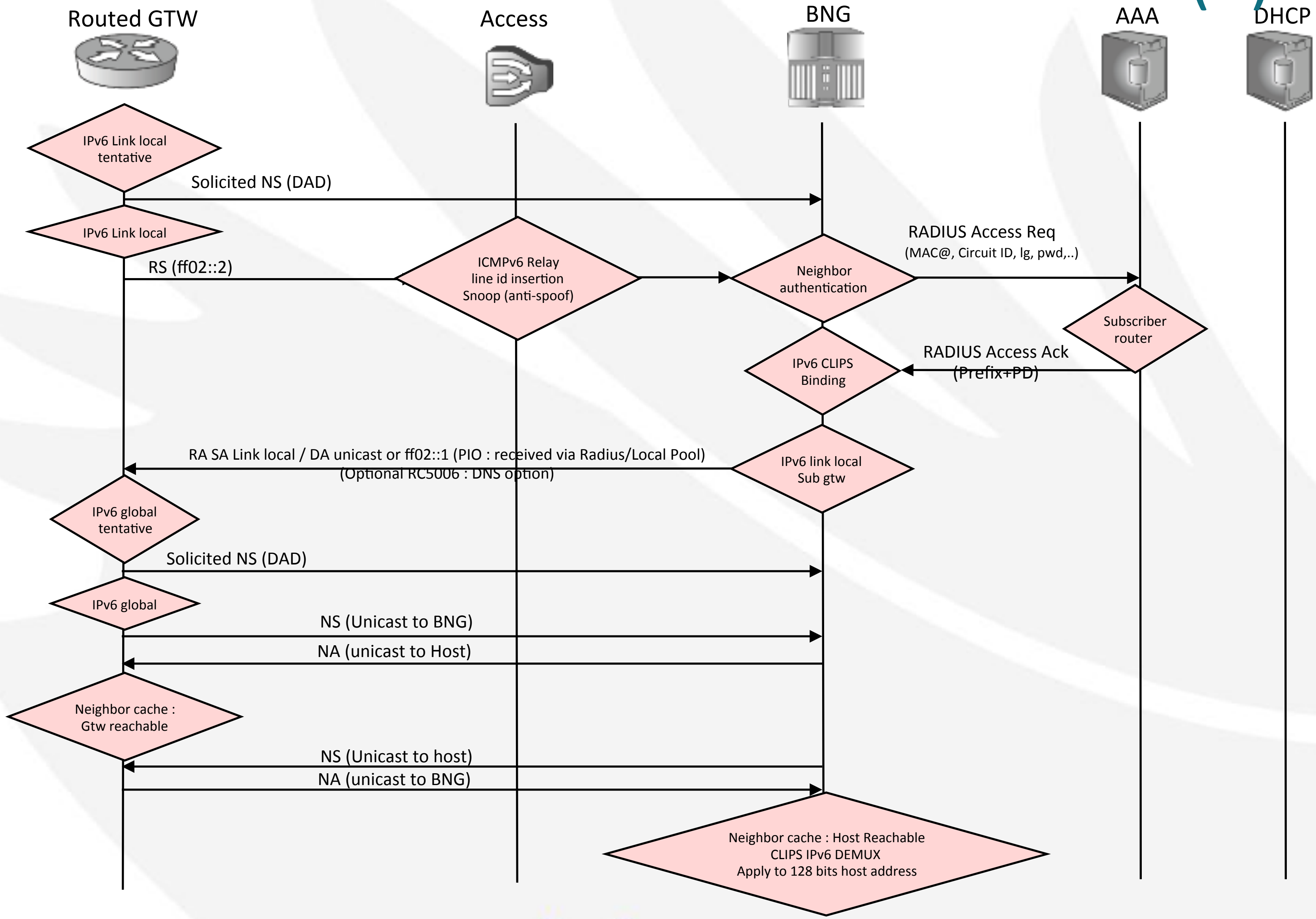
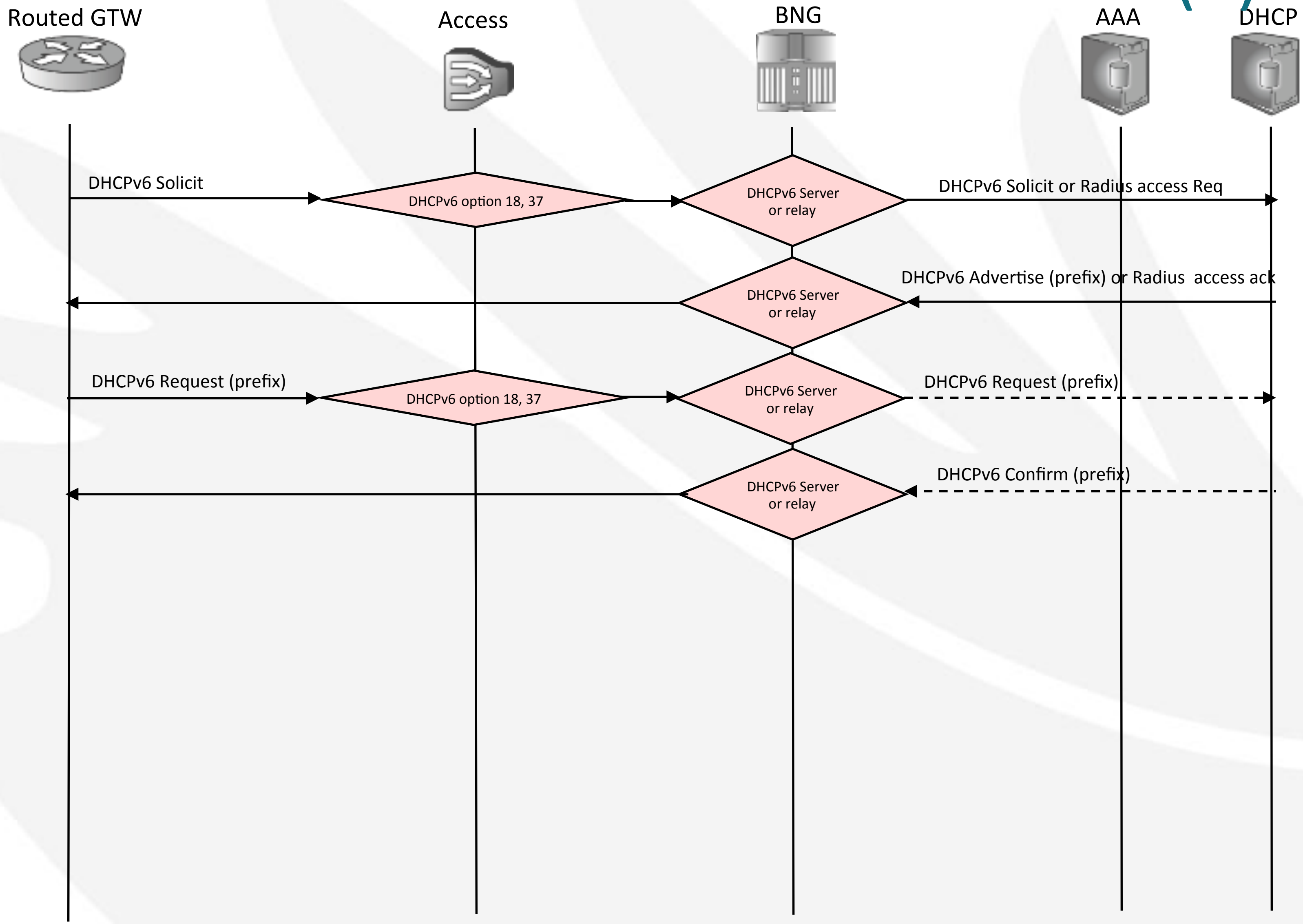
Routed HGW: IPoE Attachment Process (1)



Routed HGW: IPoE Attachment Process (2)



Configuration Example

```
interface pool multibind
 ip address 192.0.2.1/24
 ipv6 address 2001:db8:db8::1/56
 ip pool 192.0.2.0/24
 ipv6 pool 2001:db8:db8:2::/64 2001:db8:db8:ff::/64
 ipv6 pool dhcpv6 2001:db8:db8:1100::/56 2001:db8:db8:ff00::/56
!
subscriber default
 ip address pool
 ip source-validation
 ipv6 framed-pool
 ipv6 delegated-prefix maximum 1
 ipv6 source-validation
```

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Deployment of IPv6 in Cable Networks

IPv6 en Redes de Cable

- Motivos para Implementar IPv6
- DOCSIS & IPv6
- Consideraciones para el despliegue
- Estrategias para comenzar

Motivos para Implementar IPv6

- Agotamiento IPv4 para CPE (público):
  - Estamos en FASE 2 de Agotamiento de IPv4: hasta un /22 cada 6 meses.
  - Algunos operadores pueden tener direcciones disponibles por un par de años pero muchos no.
  - Debemos implementar IPv6 para asegurar conectividad extremo a extremo lo mas transparente posible.

- Agotamiento de espacio de direccionamiento de gestión (privado):
  - Normalmente se utiliza direccionamiento privado [RFC 1918] para gestión de CM/STB/eMTA.
  - Al llegar a puntos de alto nivel de consumo es necesario subnetear redes ya asignadas lo que complica el esquema.

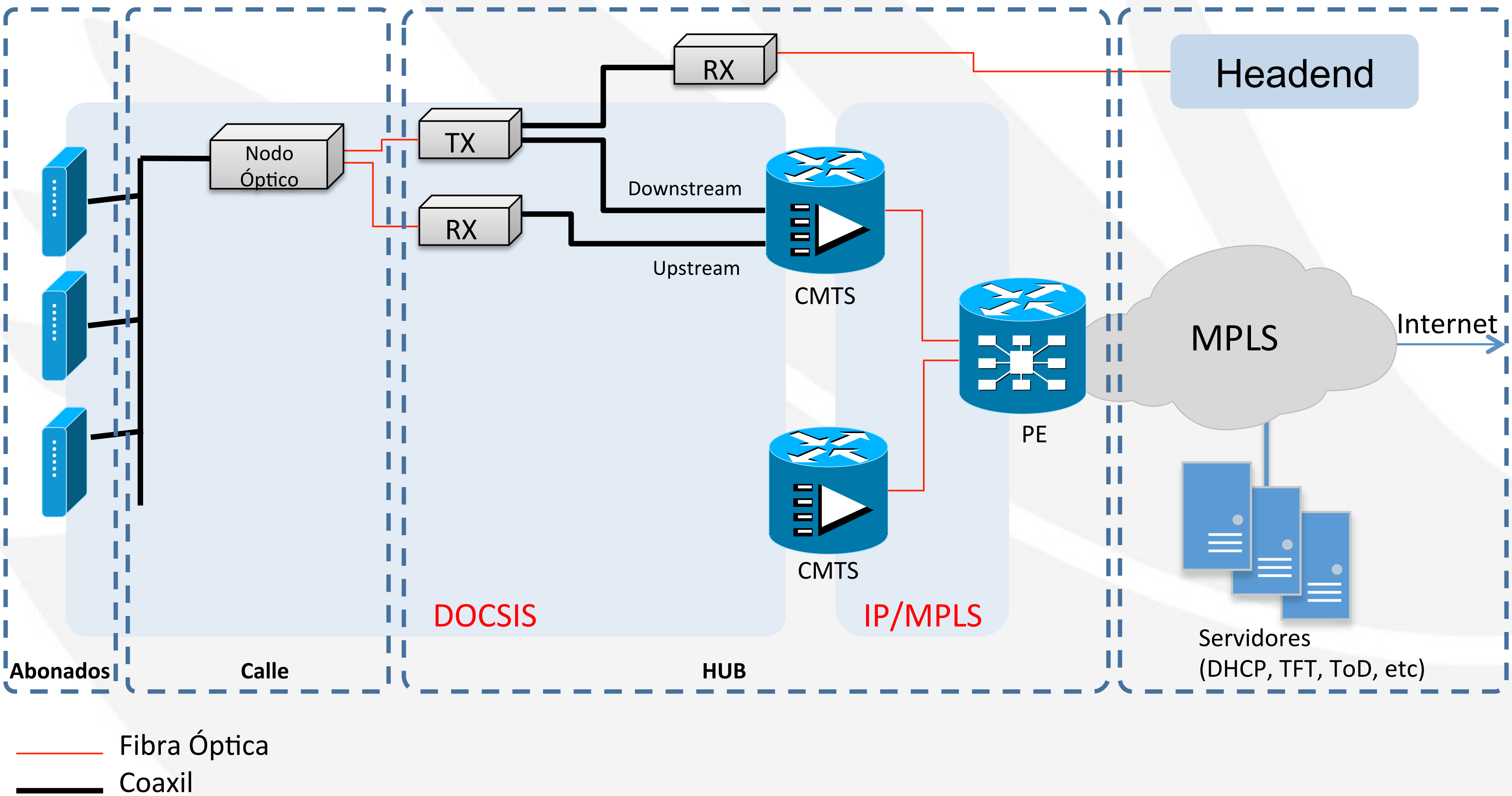
- Requerimiento de IPv6 por parte de clientes:
  - Los que mas puedan solicitar el servicio seguramente serán clientes corporativos y si bien son pocos respecto a la cantidad de residenciales, son muy importantes.

- Menos carga en CGN:
  - Al tener IPv6 nativo con Dual-Stack en los CPEs, el dimensionamiento de la plataforma de Carrier Grade NAT baja considerablemente.

DOCSIS & IPv6

- Esquema Red HFC
- Pre-requisitos para IPv6
- Requerimientos en CMTS
- Escenarios de IPv6 en DOCSIS 3.0
- Requerimientos para CM Modo Bridge
- Requerimientos para CM Modo Router
- IPv6 para el eRouter
- IPv6 en Management de CM

Esquema de Red HFC



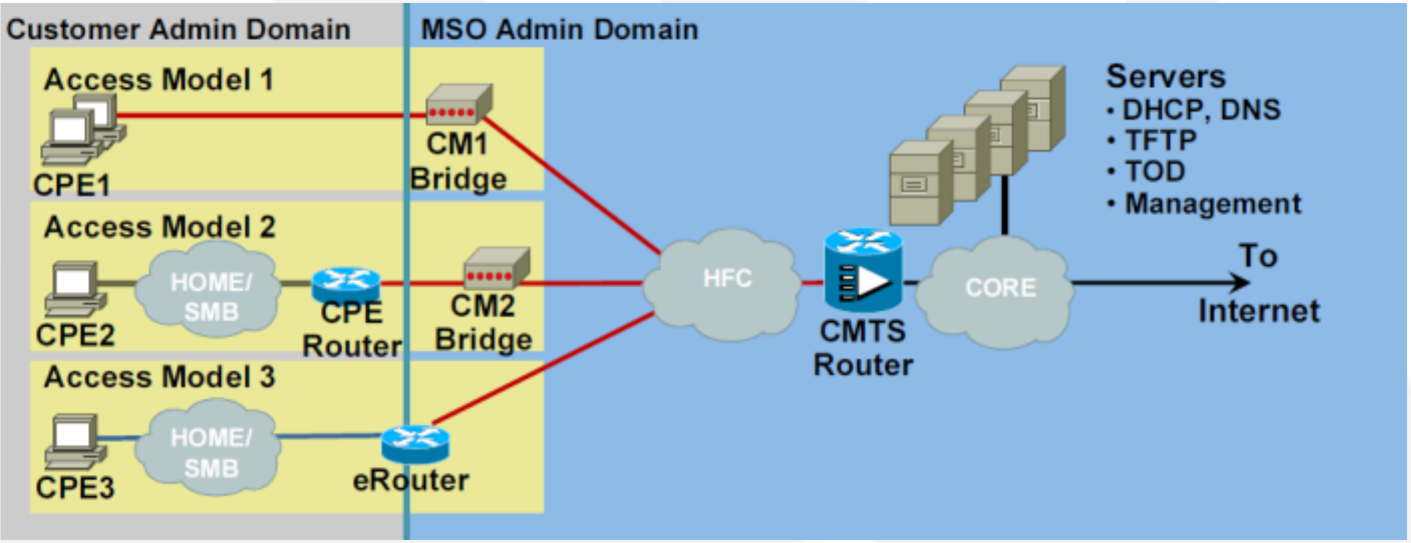
Pre-requisitos para IPv6

- Soporte para el transporte de Dual-Stack en todo el Backbone.
- IPv6 en Sistemas de Monitoreo y Aprovisionamiento:
  - DHCP Server con soporte DHCPv6 y Prefix-Delegation.
  - El sistema de monitoreo debe poder consultar directamente a la IPv6 de los CMs.
- Disponibilidad de CMs D3.0 o D2.0+.
- Esquema de asignación de direcciones IPv6 para abonados residenciales y corporativos.
- Deseable: DNS con IPv6 (puede ser el/los actuales de IPv4 en DS) y que responda registros AAAA.

Requerimientos en CMTS

- Dual-Stack configurado en el CMTS.
  - Si utilizan un OSPF como IGP para el anuncio de redes entre el CMTS y el router de distribución, ambos tendrían que soportar OSPFv3
- Relay-Agent para DHCPv6.
  - Al igual que en IPv4, el CMTS deberá soportar actuar como Relay Agent para los mensajes de DHCPv6.
- Soporte Multicast para NS/NA y RS/RA.
- Envío de RAs a través de la red HFC.
- Capacidad de seguir soportando versiones anteriores de DOCSIS al mismo tiempo.

Escenarios de IPv6 en DOCSIS 3.0



- Modelo 1 – CM Bridge:
  - CM: Se puede dar IPv6 al CM.
  - Hosts: IPv6 provisto directamente.
- Modelo 2 – CM Bridge – CPE Router:
  - CM: Se puede dar IPv6 al CM.
  - CPE router: IPv6 /64 de WAN + IPv6-PD.
  - Host: IP de sub-prefijo /64.
- Modelo 3 – CM eRouter:
  - CM: Se puede dar IPv6 al CM.
  - eRouter: IPv6 /64 de WAN + IPv6-PD.
  - Host: IP de sub-prefijo /64.

Requerimientos para CM en Modo Bridge (Modelo 1 y 2)

- Soporte de asignación IPv6 para gestión del CM.
  - Soporte de Modos APM y Dual-Stack.
- Gestión utilizando SNMP a la dirección IPv6.
- Soporte forwarding de tráfico Multicast
  - MLDv1 y MLDv2 (Multicast Listener Discovery).
  - NDP (Neighbor Discovery Protocol)
- Permitir forwarding de tráfico IPv6 de CPEs sin importar el método de aprovisionamiento.
- Router: Cumplir con RFC7084 - Basic Requirements for IPv6 Customer Edge Routers

Requerimientos para CM en Modo Router (Modelo 3)

- Función DHCPv6 Client para:
  - IPv6 lado WAN
  - PD para lado LAN
- Función DHCPv6 server y SLAAC para asignación a hosts.
- Firewall IPv6.
- Soporte de queries de ND (NS/NA) y RS desde los dispositivos hogareños.
- Envío de información de DNS vía DHCPv6 u opción Recursive DNS Server en RA [RFC 6106].
- eRouter: Cumplir con RFC7084 - Basic Requirements for IPv6 Customer Edge Routers

IPv6 en Management de CM

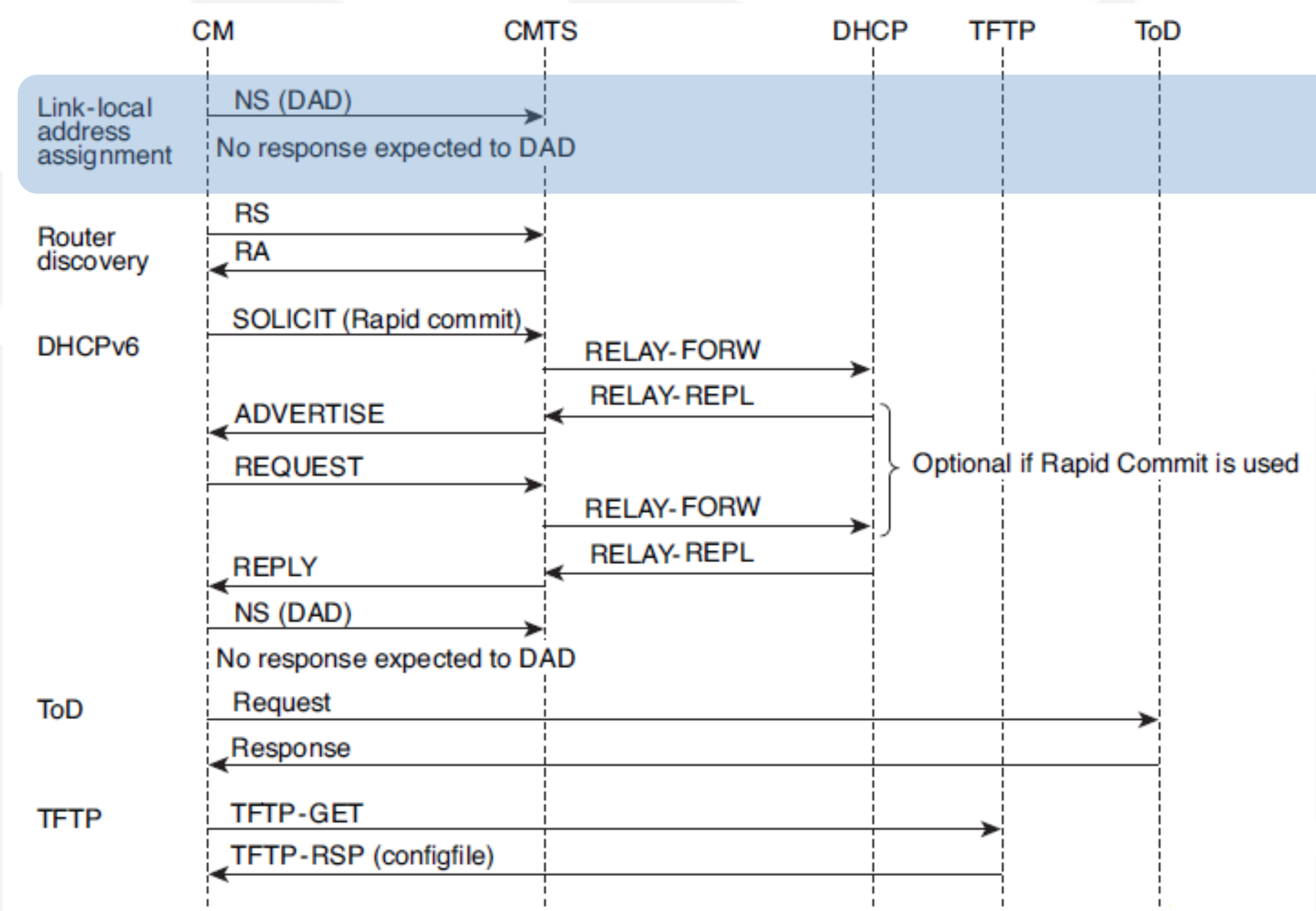
- Mensaje MDD (Mac Domain Descriptor):
  - Pertenece a DOCSIS 3.0. Si no está este mensaje, los CMs funcionan en D2.0.
    - Primary Downstream Channel
    - MAC Domain Downstream Service Group
    - MAC Domain Upstream Service Group
    - IP Provisioning Mode
    - Etc
  - IP Provisioning Mode: Campo dentro del MDD que determina si el CM se va a aprovisionar con IPv4 o IPv6 y puede tener uno de los siguientes valores:

    0 = Solo IPv4

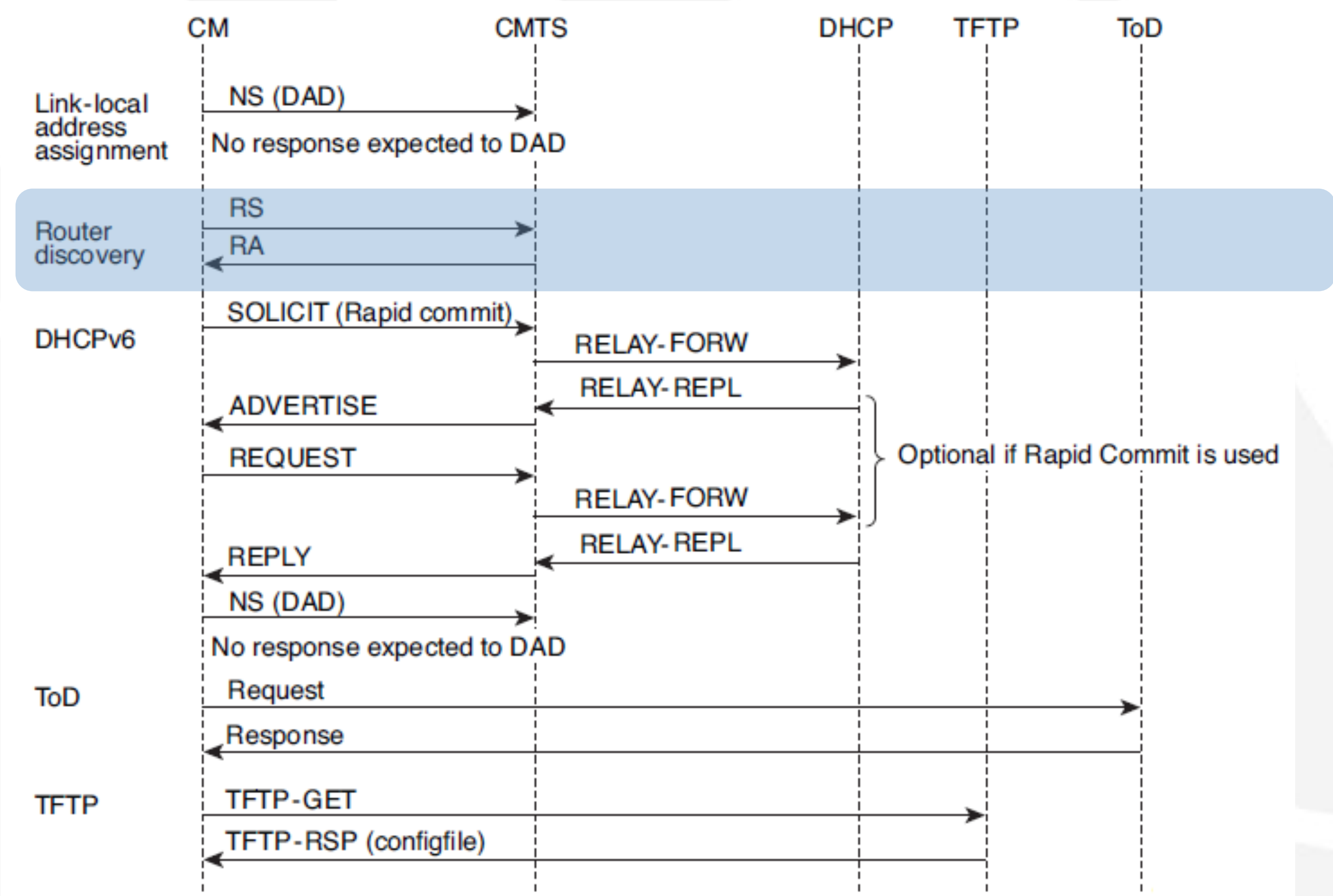
    1 = Solo IPv6

    2 = Alternate Provisioning Mode (APM) – Intenta aprovisionarse con IPv6, si no obtiene respuesta se aprovisiona con IPv4

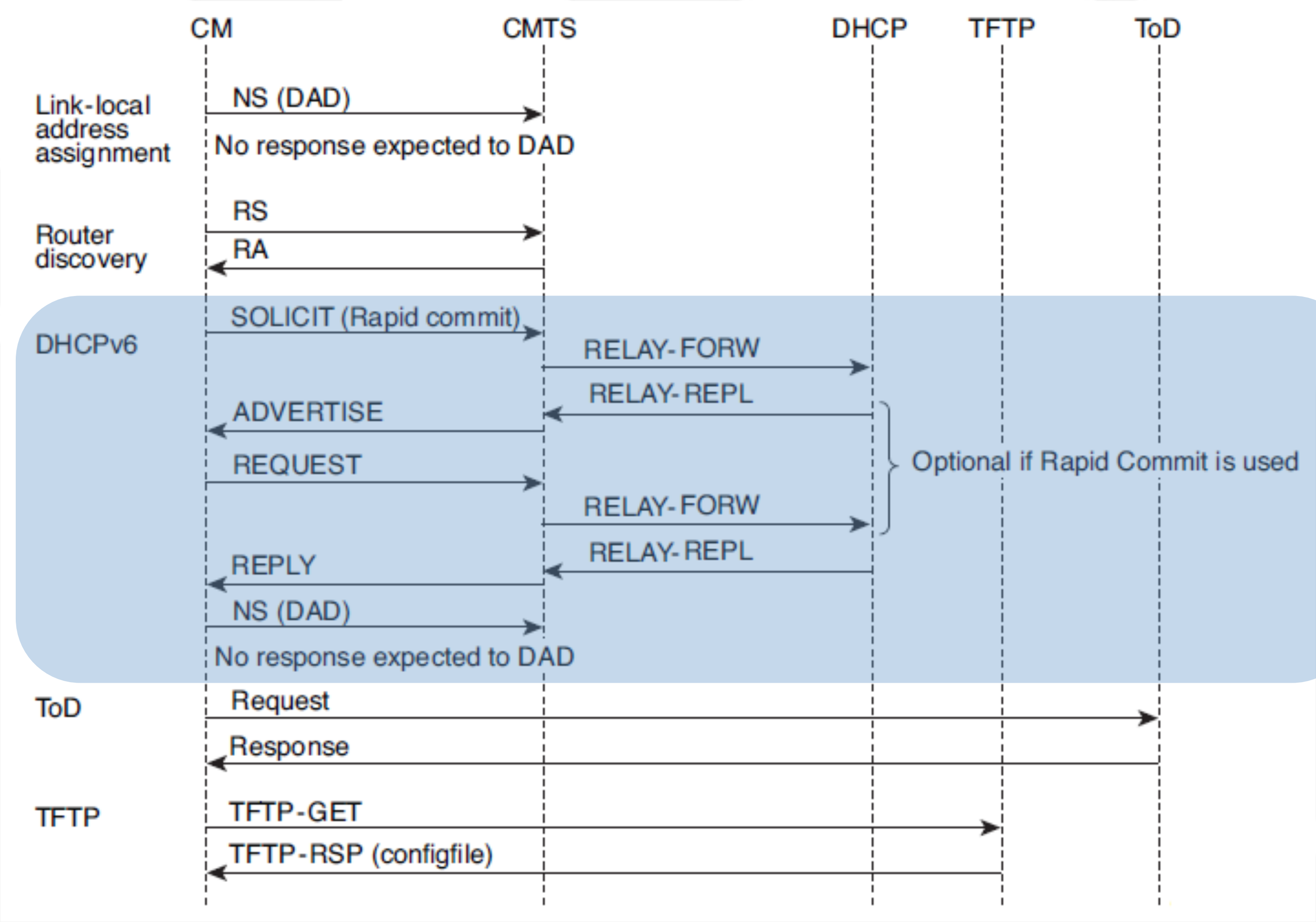
    3 = Dual-Stack Provisioning Mode (DPM) – Útil durante el proceso de transición. Primero utiliza DHCPv6 para adquirir IPv6 y luego DHCPv4 para IPv4.



Dirección de Link-Local: El CableModem envía un mensaje de Neighbor Solicitation(NS) con su dirección de link local (LLA), el cual inicia el proceso de detección de dirección duplicada (DAD) para esa LLA. El CM no se queda esperando respuesta.

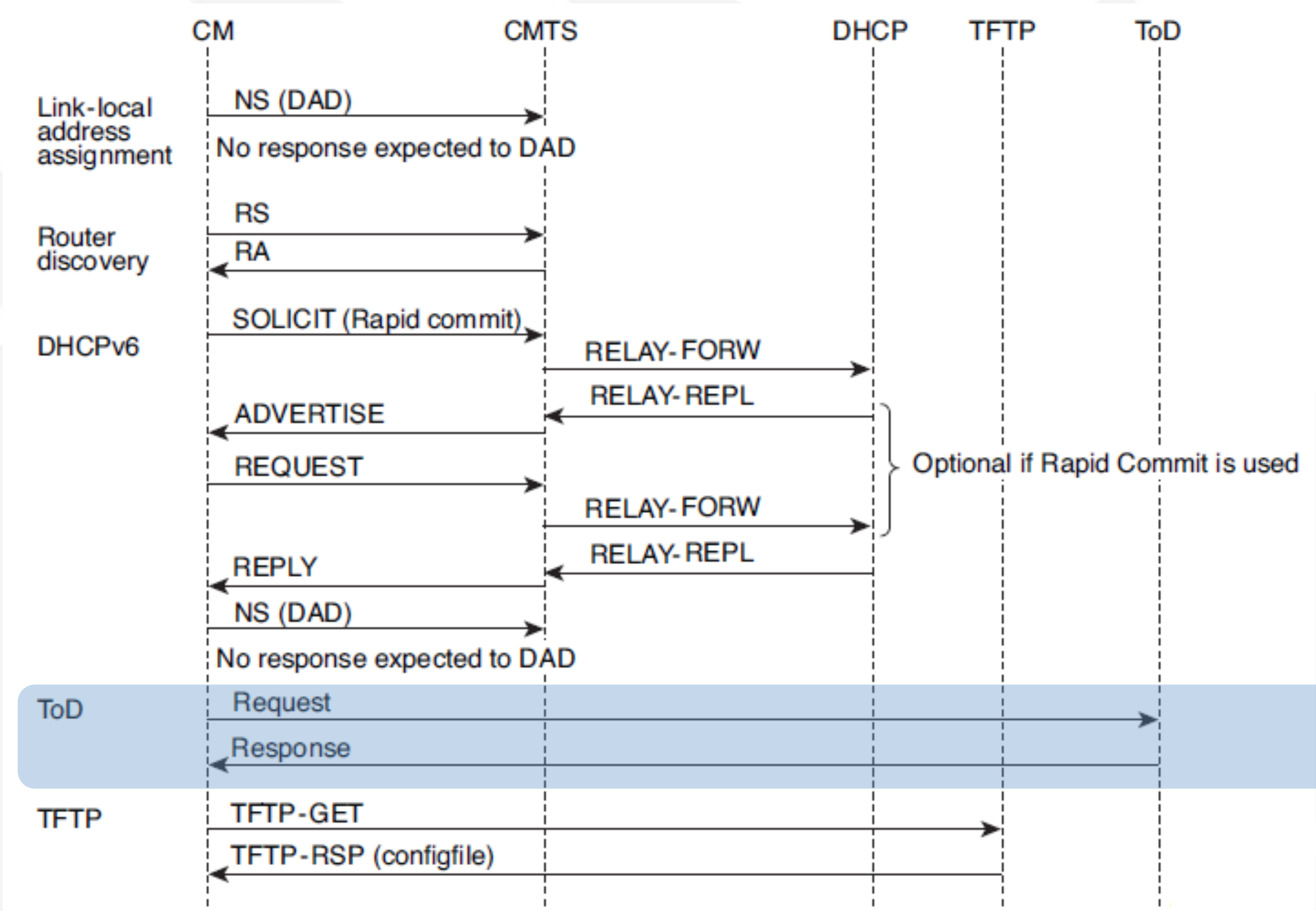


- <u>Router Discovery:</u>
  - Envío de Router Solicitation (RS) para buscar al router en el link.
  - El CMTS responde con un mensaje de Router Advertisement (RA) con los Bits M y O en 1 indicando que el método de asignación es DHCPv6.
    - Flag M (Managed): Con esto le decimos al CPE que sólo tome IPv6 por DHCPv6 (no puede utilizar SLAAC).
    - Flag O (Other Configuration): Utilizar DHCPv6 también para otros parámetros como DNS, NTP, etc.

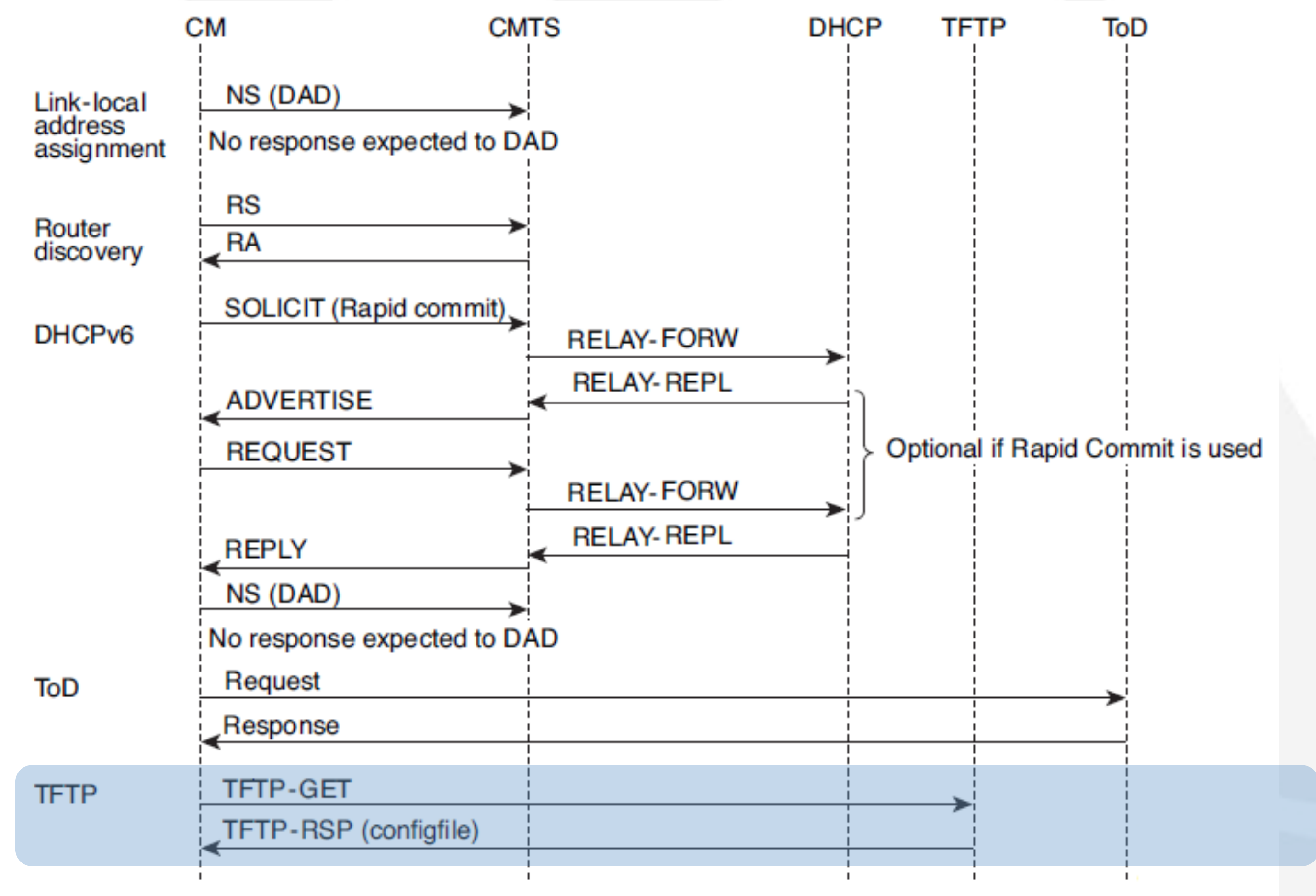


DHCPv6: El CM envía un mensaje DHCPv6 Solicit al CMTS. El CMTS reenvía esta solicitud al servidor DHCPv6. Este último responde con un Advertise indicando su disponibilidad. Si no se utiliza Rapid-Commit, el CM responde con un Request, luego el DHCP Server responde con la confirmación.

Después inicia el proceso de DAD para verificar que no haya IP duplicada.



Time of Day (ToD): Al tener ya conectividad, el CM solicita información de clock al ToD Server.



TFTP: Para finalizar el CM envía una solicitud al Servidor TFTP para descargar su archivo de configuración.

IPv6 para el eRouter

- Definir el modo de aprovisionamiento por TLV 202 del archivo de configuración:
  - 0: Disabled
  - 1: IPv4 Protocol Enable
  - 2: IPv6 Protocol Enable
  - 3: Dual IP Protocol Enable

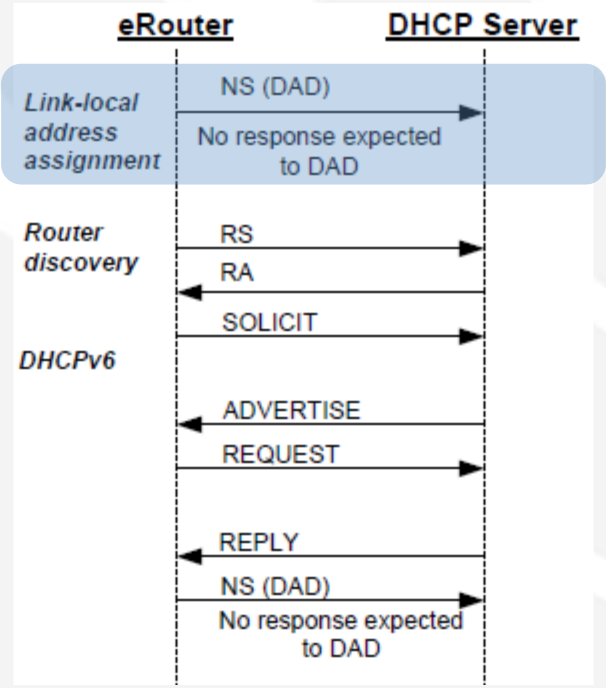
Mode	IPv4	IPv6
Disabled	CM bridges all traffic per MULPI spec.	CM bridges all traffic per MULPI spec.
IPv4 Protocol Enabled	eRouter forwards IPv4 traffic with NAPT.	eRouter does not forward IPv6 traffic.
IPv6 Protocol Enabled	eRouter does not forward IPv4 traffic.	eRouter forwards IPv6 traffic.
Dual IP Protocol Enabled	eRouter forwards IPv4 packets using NAPT.	eRouter forwards IPv6 packets.

```
GenericTLV TlvCode 202 TlvLength 3 TlvValue 0x010103; /* dual IP */
```

IPv6 para el eRouter

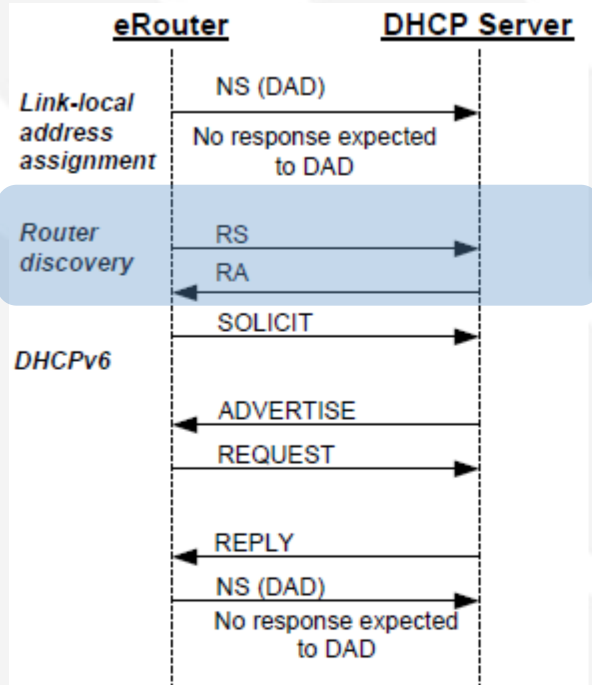
- Luego de quedar aprovisionado el CM comienza el proceso de obtención de IP del eRouter.
- Si el Modo de Aprovisionamiento es 2 o 3 el eRouter utilizará DHCPv6 para obtener su dirección IPv6 [RFC3315].
- A continuación el Flujo de Mensajes para aprovisionamiento de IPv6 en eRouter.

IPv6 provisioning Message Flow



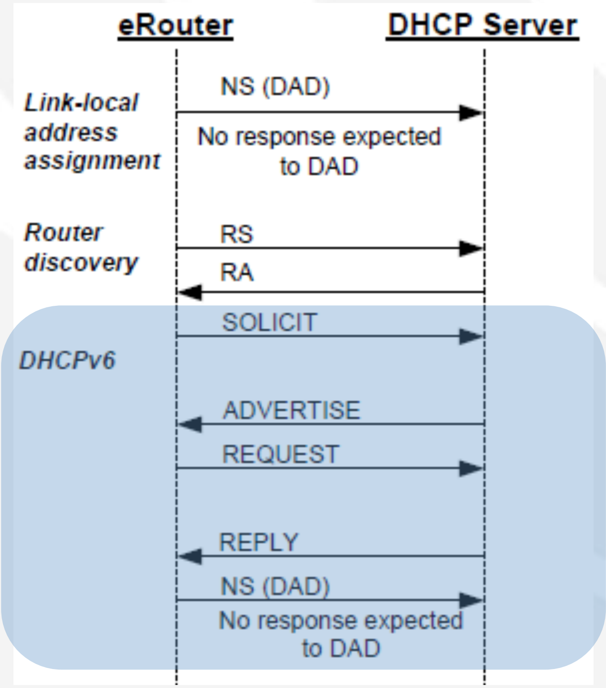
- Link-Local:
  - El eRouter envía un mensaje de Neighbor Solicitation (NS) con su dirección de link local (LLA) e inicia el proceso de detección de dirección duplicada (DAD) para esa LLA. El eRouter no se queda esperando respuesta.

IPv6 provisioning Message Flow



- Router Discovery:
  - Envío de Router Solicitation (RS) para buscar al router en el link.
  - El CMTS responde con un mensaje de Router Advertisement (RA) con los Bits M y O en 1 indicando que el método de asignación es DHCPv6.
    - Flag M (Managed): Con esto le decimos al CPE que sólo tome IPv6 por DHCPv6 (no puede utilizar SLAAC).
    - Flag O (Other Configuration): Utilizar DHCPv6 también para otros parámetros como DNS, NTP, etc.

IPv6 provisioning Message Flow



- <u>DHCPv6:</u>
  - Envío de mensaje DHCPv6 Solicit que debe incluir la opción de PD. El CMTS reenvía esta solicitud al servidor DHCPv6.
  - Este último responde con un Advertise indicando su disponibilidad. Si no se utiliza Rapid-Commit, el CM responde con un Request, luego el DHCP Server responde con la confirmación.
  - Después inicia el proceso de DAD para verificar que no haya IP duplicada.

Direccionamiento IPv6 en D3.0

- WAN (DHCPv6):
  - Management CM. Ej: /64 ULA por cada CMTS. (fc00::/7)
  - eRouter. Ej: /64 por cada CMTS
  - PD para LAN de eRouter. Ej: /44 por cada CMTS (65536 /60)
- Lado cliente:
  - Asignación de sub-prefijos /64 en Interfaces L3 lado-cliente.
  - Delegación de sub-prefijos en CPEs.
- Consideraciones:
  - Si el prefijo es /64 no se puede asignar un sub-prefijo y las interfaces lado cliente comparten el mismo prefijo.
  - El prefijo debe ser mayor a /64 para poder delegar un sub-prefijo a un router interno del cliente.
  - Prefijo /60, genera sub-prefijos /62. El primero para interfaces y el resto para delegar.

Configuración Básica en CMTS

- Habilitar IPv6 en la configuración global:

```
ipv6 unicast-routing
ipv6 cef
```

- Interfaces de Uplink y Loopback:

```
interface TenGigabitEthernetX/Y/Z
 ipv6 address FC00:XXXX:XXXX:XXXX::X/126
 ipv6 enable
 ipv6 nd ra suppress
 ipv6 ospf network point-to-point
 ipv6 ospf 2 area 1
!
interface Loopback0
 ipv6 address FC00:YYYY:YYYY:YYYY::Y/128
!
ipv6 router ospf 2
 router-id FC00:YYYY:YYYY:YYYY::Y/128
 summary-prefix 2800:XXXX:XXXX::/48
 redistribute connected
 redistribute static
!
```

Configuración Básica en CMTS

- Interface Bundle:

```
interface Bundle1
 ipv6 address 2800:ZZZZ:ZZZZ:ZZZZ::Z/64
 ipv6 enable
 ipv6 nd managed-config-flag
 ipv6 nd other-config-flag
 ipv6 nd ra interval 5
 ipv6 dhcp relay destination FC00:ZZZZ:ZZZZ:ZZZZ::Z
```

- Interface Cable:

```
interface cable 5/0/0
 cable ip-init [apm | dual-stack | ipv4 | ipv6]
```

  - Esto es para la IP del CM.

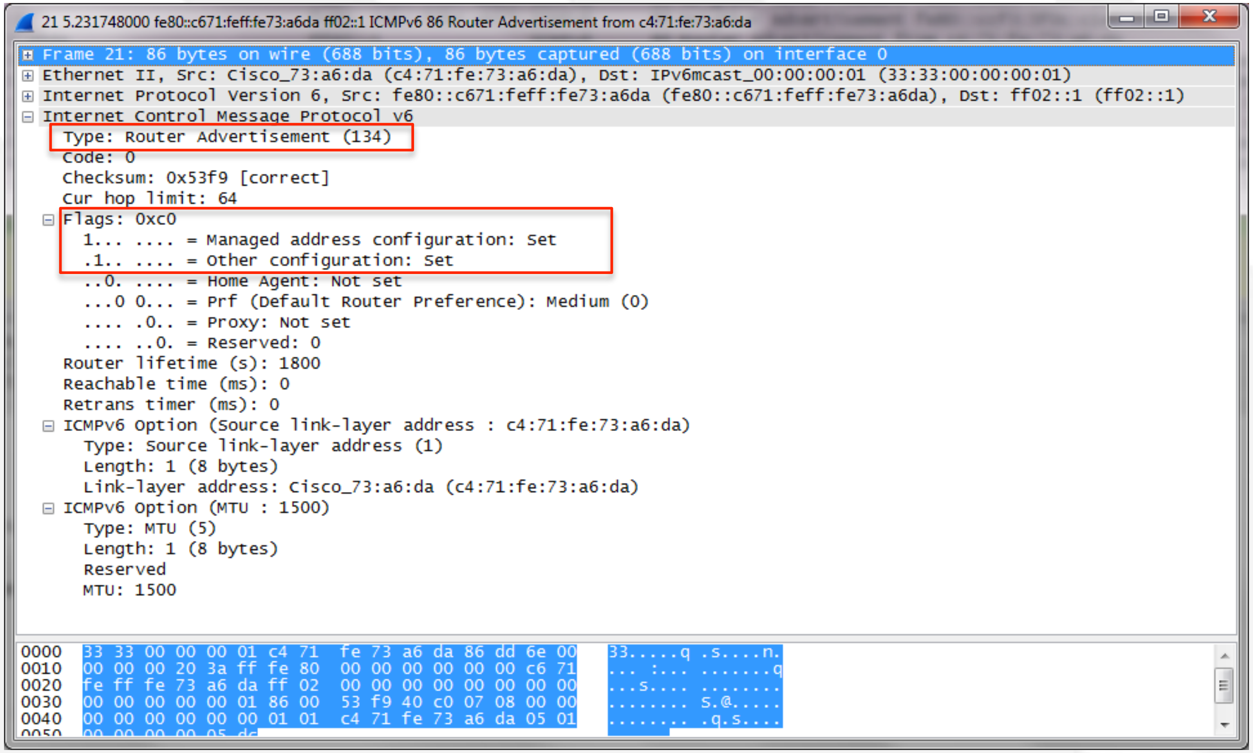
- Observaciones:
  - Interfaces Uplink y Loopback de CMTS con direccionamiento de ULA (Unique Local Address).
  - DHCP server también con IPv6 de ULA.

Configuración Básica en CMTS

En el CMTS:

```
CMTS#sh cable modem 38c8.5cb3.54c0 ipv6 cpe
MAC Address    IP Address
38c8.5cb3.54c4 2800:810:400:FFFE:D904:664:44E0:71A7

CMTS#
CMTS#sh cable modem 38c8.5cb3.54c0 ipv6 prefix
Device Type: B - CM Bridge, R - CM Router
IP Assignment Method: D - DHCP

MAC Address    Type IPv6 prefix
38c8.5cb3.54c4 R/D  2800:810:401:10::/60

CMTS#
BR-CMTS#sh ipv6 interface bundle 1 prefix
IPv6 Prefix Advertisements Bundle1
Codes: A - Address, P - Prefix-Advertisement, O - Pool
       U - Per-user prefix, D - Default
       N - Not advertised, C - Calendar

PD default [LA] Valid lifetime 2592000, preferred lifetime 604800
AD 2800:810:400:FFFE::/64 [LA] Valid lifetime 2592000, preferred lifetime 604800
CMTS#
CMTS#sh ipv6 route 2800:810:401:10::/60
Routing entry for 2800:810:401:10::/60
  Known via "static", distance 1, metric 0
  Redistributing via ospf 4
  Route count is 1/1, share count 0
  Routing paths:
    FE80::3AC8:5CFF:FEB3:54C4, Bundle1
      Last updated 4d04h ago
```

Router Advertisement



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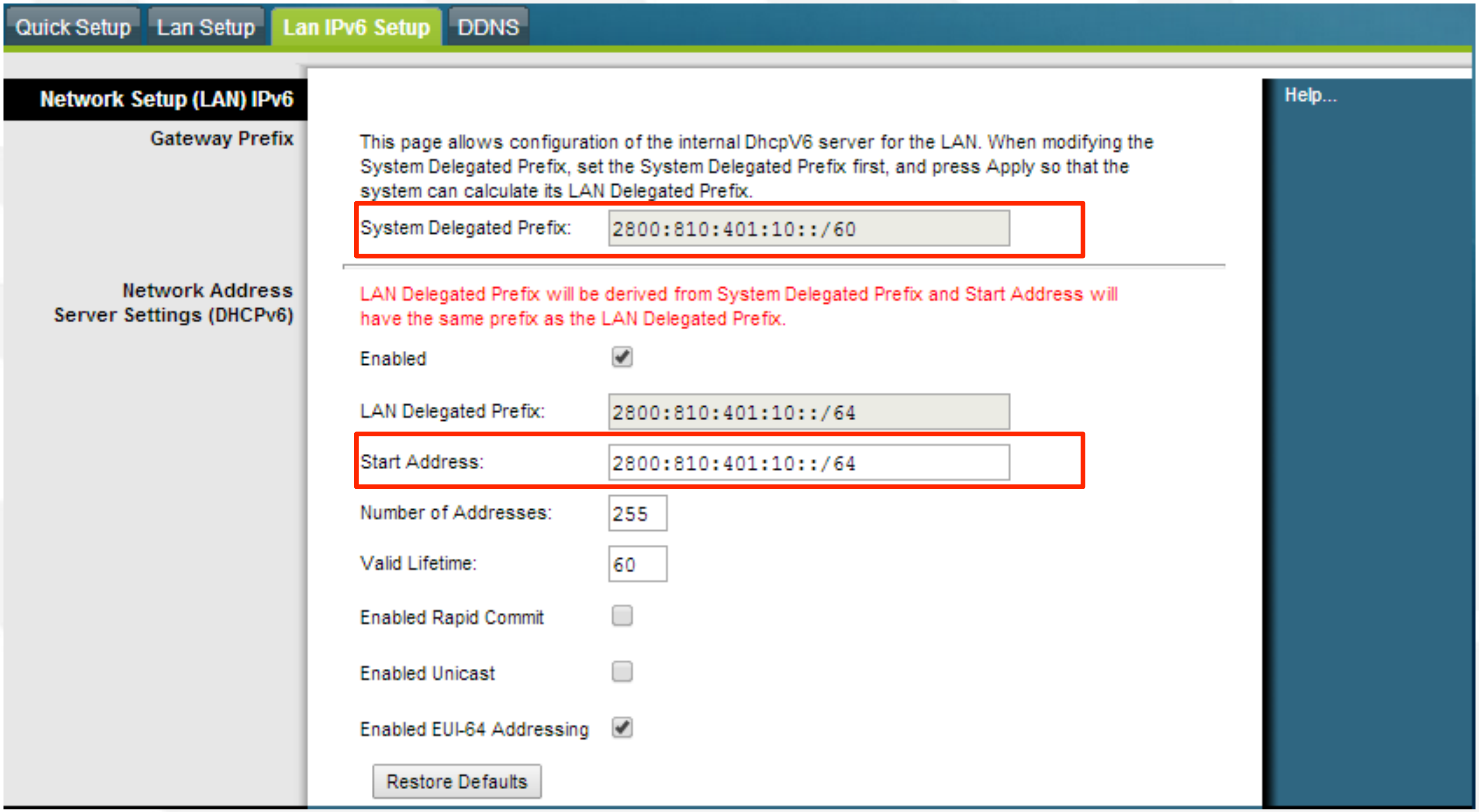
IPv6 en eRouter



Consideraciones para el despliegue

- Compatibilidad de dispositivos.
- Sistemas de Monitoreo y Gestión.
- Sistema de Aprovisionamiento.
- CRM y Billing
- DPI

Compatibilidad de Dispositivos

- IPv6 no es compatible con IPv4.
  - No podemos simplemente cambiar el servicio de nuestros clientes con IPv4 y moverlos a uno con IPv6. Lleva tiempo.
- Modelos de CM:
  - CM DOCSIS 1.0, 1.1, 2.0 desplegados sin soporte IPv6.
  - Homologación de IPv6 en todos los modelos nuevos y actualmente en uso de CM. Modo Bridge y Modo Router.
  - Ideal: CMs con todos los servicios básicos integrados (eRouter, eMTA – Embedded Multimedia Terminal Adapter, WiFi)
- Dispositivos propiedad del abonado sin soporte IPv6.
  - Considerar que el cliente puede tener equipamiento (ej. Router WiFi) sin soporte IPv6.
  - Recordar: la transición debe ser totalmente transparente para el abonado.

Sistema de Monitoreo y Gestión

- Es para IPv6 en Gestión del CM, eMTA.
- Sistema de Monitoreo:
  - Plataforma SNMP con Stack de IPv6.
  - Bases de Datos: actualizar para almacenar tanto IPv4 como IPv6 en Direccionamiento de los dispositivos.
- Gestión de CMs:
  - Accesibilidad desde Operaciones:
  - Administración remota vía Web, ssh, telnet, etc. de CMs
  - Considerar Routers, Firewalls internos, acceso desde VPN.

Sistema de Aprovisionamiento

- Previamente determinar si se va aprovisionar IPv6 en gestión.
  - Definir el número de IPs de la solución completa.
- Componentes:
  - DHCP Server:
    - Soporte IPv4, IPv6 e IPv6-PD.
    - Calcular cantidad de leases para dimensionamiento de servidor y licencias.
  - TFTP Server: Conectividad IPv6 contra los CMs.
  - Time Server: Idem TFTP Server.
  - Syslog: Idem.
  - Base de Datos de Leases: Si los Leases de DHCP se almacenan en una DB, considerar modificación de estructura de la misma.
  - Aplicación de Provisioning:
    - Conectividad IPv6 con los componentes.
    - Soporte asignación IPv6 en gestión de CM, eRouter y Prefix-Delegation.

CRM y Billing

- No es necesario que tengan IPv6.
  - La conectividad con el resto de los sistemas y la red puede seguir operando con IPv4.
- Soporte para conocer IPv6 asignada en CM, eRouter.
- Reserva de Direccionamiento IPv6.
- Capacitación a Call Center e Instalaciones.

DPI

- Tampoco es necesario actualizar direccionamiento de gestión de sus componentes (collector, subscriber manager, etc).
- Soporte completo de IPv6 en Hardware.
  - Detección y clasificación de tráfico IPv6.
  - Aplicado de políticas sin impacto adicional en rendimiento.

Estrategias para comenzar

- Definir esquema de transición:
  - Esquema simple y con mayor compatibilidad:
    - Dual-Stack Nativo en acceso e Interconexiones.
    - NAT44 / NAT444
  - Esquema de Asignación de Direcciones.
- Despliegue en la Red:
  - Backbone (Core, Distribución, ITXs)
  - CMTS
- Servicios de aprovisionamiento:
  - DHCP
  - TFTP
  - DNS IPv6
- Homologar CableModems
- Integrar con provisioning de producción, monitoria, CRM, etc.

IPv6 Quiz 2

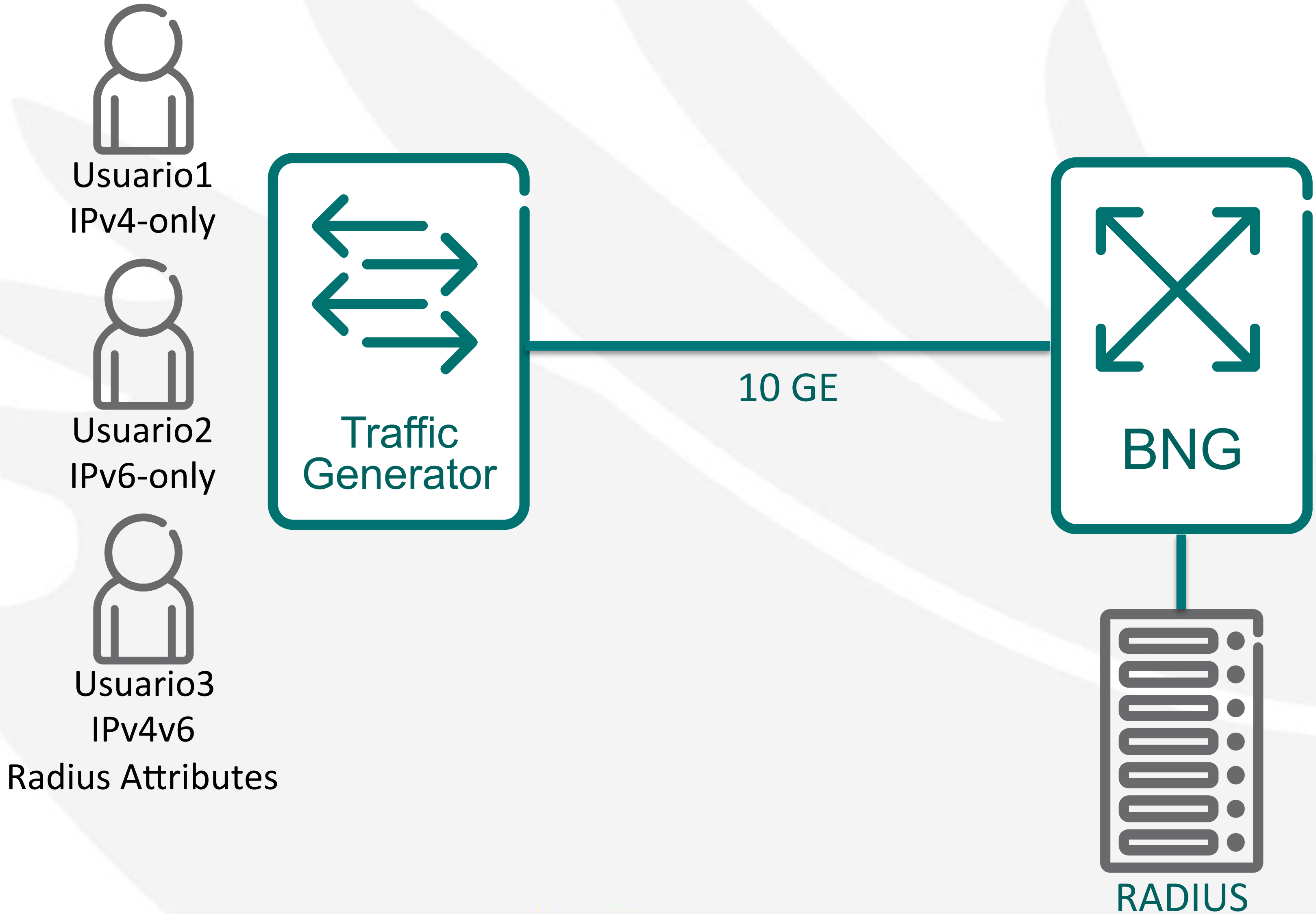
Tomás

PPPoE Demo

PPPoE Demo Objectives

- Connect different subscribers using IPv4-only, IPv6-only and Dual Stack
- Verify that IPCP and IP6CP of PPP are independent
- Play!

PPPoE Lab Topology



BNG Configuration 1/2

```
 interface pool multibind
  ip address 192.0.2.1/24
  ipv6 address 2001:db8:db8::1/56
  ip pool 192.0.2.0/24
  ipv6 pool 2001:db8:db8:2::/64 2001:db8:db8:f::/64
  ipv6 pool dhcpv6 2001:db8:db8:1100::/56 2001:db8:db8:ff00::/56
!
 subscriber default
   ip address pool
   ip source-validation
   dns primary 8.8.8.8
   ipv6 framed-pool
   ipv6 delegated-prefix maximum 1
   dns6 primary  2001:db8::1
   ipv6 source-validation
```

BNG Configuration 2/2

```
port ethernet 1/1
 no shutdown
 encapsulation dot1q
 dot1q pvc 200 encapsulation 1qtunnel
  dot1q pvc 200:201 encapsulation pppoe
   bind authentication pap chap context local
  dot1q pvc 200:202 encapsulation pppoe
   bind authentication pap chap context local
  dot1q pvc 200:203 encapsulation pppoe
   bind authentication pap chap context local
```

(Ericsson SmartEdge 1200, OS Version SEOS-12.1.1.6-Release)

RADIUS Configuration

```
usuario1@local User-Password := "*"
        Service-Type = Framed-User,
        Framed-Protocol = PPP,
        Framed-IP-Address = 255.255.255.254

usuario2@local User-Password := "*"
        Service-Type = Framed-User,
        Framed-Protocol = PPP,
        Framed-IP-Address = 255.255.255.254

usuario3@local User-Password := "*"
        Service-Type = Framed-User,
        Framed-IPv6-Prefix = 2001:db8:db8:fa::/64,
        IPv6-DNS =
"1=2000::106:a00:20ff:fe99:a998,2=2000::106:a00:20ff:fe99:a995",
        Framed-Protocol = PPP,
        Framed-IP-Address = 255.255.255.254

(FreeRADIUS Version 2.1.10, for host i486-pc-linux-gnu)
```

PPPoE Results – Usuario1

```
usuario1@local
        Session state Up
        Circuit   1/1 vlan-id 200:201 pppoe 86
        Internal Circuit   1/1:511:63:31/1/2/32
        Interface bound  pool
        Current port-limit unlimited
        Protocol Stack IPV4
        ip pool  (applied)
        ip source-validation 1 (applied from sub_default)
        dns primary 8.8.8.8 (applied from sub_default)
        ip address 192.0.2.87 (applied from pool)
        Framed-IPV6-Pool  (not applied from sub_default)
        Ipv6 source-validation 1 (not applied from sub_default)
        Ipv6-ND-Profile TEMPLATE (not applied from sub_default)
        Delegated Max Prefix 1 (not applied from sub_default)
        Ipv6-DNS  primary 2001:db8::1  (not applied from
sub_default)
```

PPPoE Results – Usuario2

```
usuario2@local
        Session state Up
        Circuit   1/1 vlan-id 200:202 pppoe 88
        Internal Circuit   1/1:511:63:31/1/2/33
        Interface bound  pool
        Current port-limit unlimited
        Protocol Stack IPV6
        ip pool  (not applied)
        ip source-validation 1 (not applied from sub_default)
        dns primary 8.8.8.8 (applied from sub_default)
        Framed-IPV6-Pool  (applied from sub_default)
        Ipv6 source-validation 1 (applied)
        Ipv6-ND-Profile TEMPLATE (applied)
        Delegated Max Prefix 1 (not applied from sub_default)
        Ipv6-DNS  primary 2001:db8::1  (applied from sub_default)
        Framed-IPV6-Prefix  2001:db8:db8:5::/64 (applied from pool)
```

PPPoE Results – Usuario3

```
usuario3@local
        Session state Up
        Circuit   1/1 vlan-id 200:203 pppoe 87
        Internal Circuit   1/1:511:63:31/1/2/34
        Interface bound  pool
        Current port-limit unlimited
        Protocol Stack Dual
        ip pool  (applied)
        ip source-validation 1 (applied from sub_default)
        dns primary 8.8.8.8 (applied from sub_default)
        ip address 192.0.2.88 (applied from pool)
        Framed-IPV6-Prefix  2001:db8:db8:fa::/64 (applied)
        Ipv6-DNS  primary 2000::106:a00:20ff:fe99:a998  (applied)
        Ipv6-DNS secondary 2000::106:a00:20ff:fe99:a995 (applied)
        Framed-IPV6-Pool  (not applied from sub_default)
        Ipv6 source-validation 1 (applied)
        Ipv6-ND-Profile TEMPLATE (applied)
        Delegated Max Prefix 1 (not applied from sub_default)
```

Current IPv6 Deployments in Broadband Access Networks

IPv6 Market Trends

1. Continue to grow internet business
2. Continue to grow subscriber base
3. Modernization and transformation of network
4. Comply with Regulations
5. Roaming support

ISP	Actions Taken
S	• **Fixed:** Dual stack solution with no CGNAT / NAT64 functionality
A	• **Mobile:** Deploying Dual Stack infrastructure in 2012 as part of LTE/EPC • **Fixed:** Started with 6RD, but considered too expensive so moved to Dual Stack using CGNAT
V	• **Mobile:** Deploying Dual Stack infrastructure as part of LTE/EPC Network • **Fixed**: Dual Stack PPP and Dual Stack DHCP
C	• Cable network started with DS-Lite, but found too difficult to manage, shut it down in January 2011 • Now using Dual Stack

Fixed Broadband Networks Trend

IPv6 access	IPv4 depletion
6RD and/or Dual-Stack DHCP	CGNAT
Dual Stack PPP	CGNAT
Dual Stack LNS & DHCPv6	DS-Lite
Dual Stack PPP & LNS	No plans
Dual Stack PPP & LNS	TBD
Dual Stack PPP + DHCP	CGNAT+DSLite
Dual Stack PPP, DHCP, LNS	CGNAT+DSLite
Dual Stack PPP + DHCP	CGNAT
Dual Stack PPP + LNS + DHCP	TBD looking at CGNAT
Dual Stack DHCP	DS-Lite (as backup)
Dual Stack PPP	IPv4 release
Dual Stack PPP & LNS	TBD
DualStack PPP & LNS, DHCP	TBD
Dual Stack PPP	No issue foreseen
DS-Lite(target) DSPPP (backup)	DS-Lite/CGNAT
Dual Stack PPP & DHCP & LNS	TBD
Dual Stack PPP & DHCP	TBD
Dual Stack PPP	CGNAT
Dual Stack PPP & LNS	TBD
Dual Stack PPP	CGNAT
Dual Stack LNS	TBD
Dual Stack PPP & LNS	CGNAT
Dual Stack PPP	CGNAT

Mobile Broadband Networks Trend

- Most operators are planning for Dual-stack deployments but also targeting IPv6-only
  - M2M and capable handsets/appliances may use IPv6-only combined with DNS64/NAT64 when accessing IPv4-only services
- LTE launches a trigger for IPv6
  - LTE Terminals are day one including IPv6
  - Part of major operators launches or planned launches
- IPv4 depletion announcement trigger/drive live deployment
- Node IP transport within Packet Core and RAN stay on IPv4 with a few exceptions.

Mobile Operators Deployment Options (1)

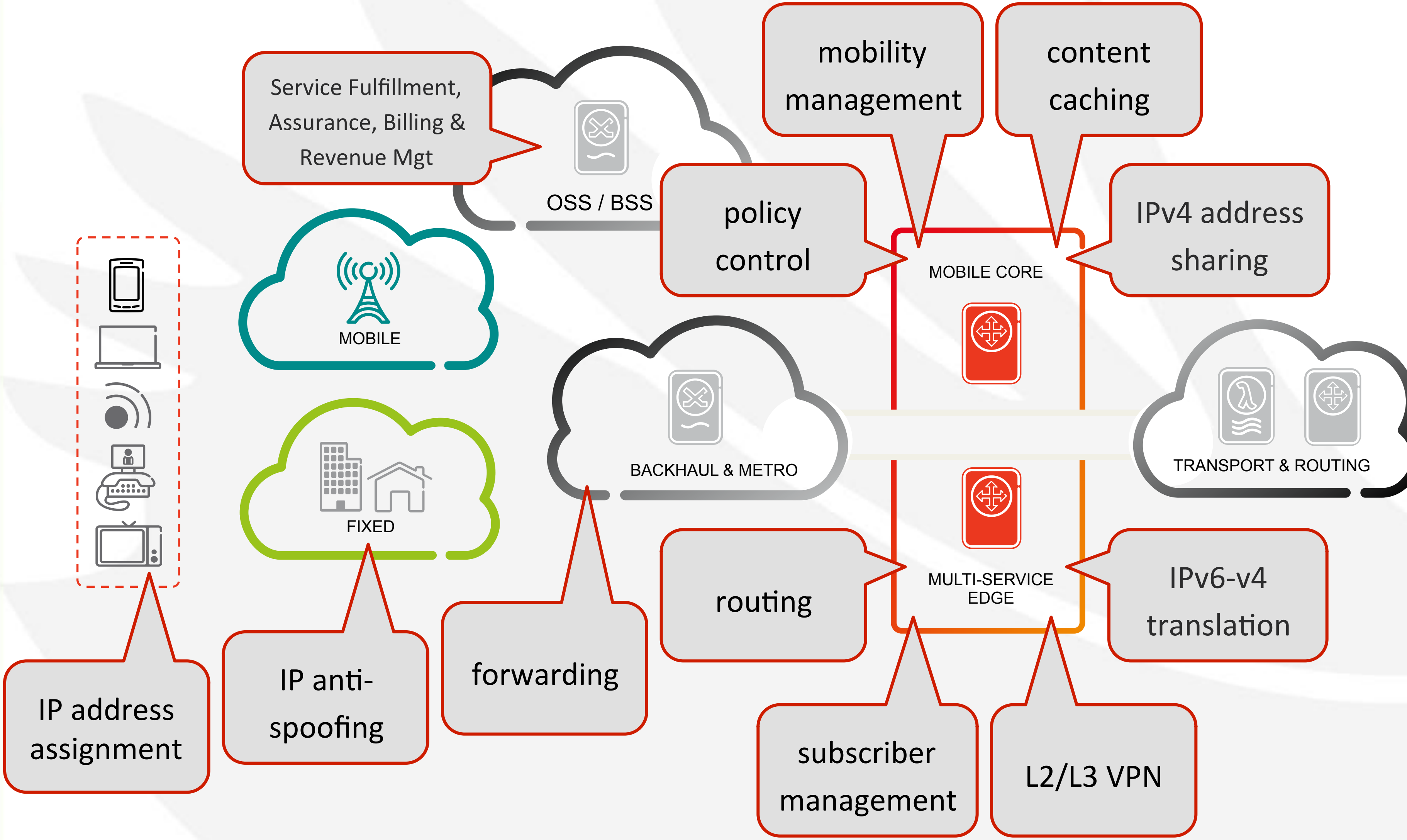
Country	Operational since	Main Driver	Solution	Other applications	Comments
Australia	2012	IPv4 depletion	Dual Stack PDP context	M2M IPv6-only	
France	Trials since 2010	IPv4 depletion	Dual Stack PDP context	M2M IPv6-only	Evaluating NAT64
Norway	2012	IPv4 depletion & LTE deployment	IPv6-only w/NAT64 and dual stack		IPv6 in 3G and LTE
Slovenia	2011	IPv4 depletion	IPv6-only w/NAT64 and dual stack		Self-provisioning IPv6
Sweden	2012	IPv4 depletion	Dual Stack PDP context		Provisioning by help desk backed by NAT64

Mobile Operators Deployment Options (2)

Country	Operational since	Main Driver	Solution	Other applications	Comments
Sweden	2012	IPv4 depletion	Two PDP contexts	M2M IPv6-only	Evaluating NAT64
Switz.	Limited since 2011	World IPv6 day	Two PDP contexts	M2M IPv6-only	Evaluating NAT64
USA	2012	IPv4 depletion & LTE deployment	Dual Stack PDP context		
USA	2010	IPv4 depletion & LTE deployment	Dual Stack PDP context	IMS IPv6-only	Moving transport plane to IPv6
USA	2012	IPv4 depletion & LTE deployment	IPv6-only w/NAT64 and IPv4-only w/ NAT44		Testing NAT64, DPI, etc.

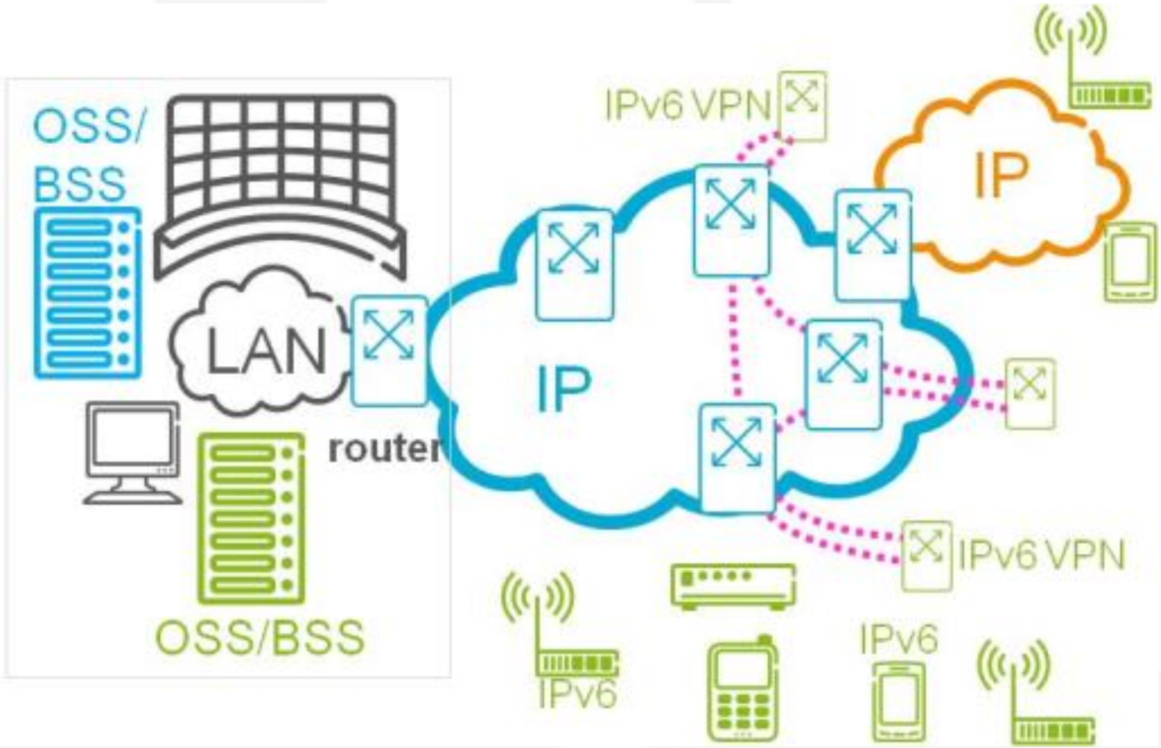
Other Systems Involved in IPv6 Deployment

Service Provider Perspective



Operational Considerations for IPv6

- Operational process
- Training
- OSS/BSS
- DCN



Any function, process, OSS or BSS that utilizes IP addresses are potentially impacted by IPv6 and needs to get operational support for IPv6 in place prior to deployment to ensure smooth rollout and ramp up.

IPv6 Operations Potential Process Impacts

Fulfillment

- Service Configuration and Activation
- Resource Provisioning
- Inventory & Allocation to Service Instance (e.g., IP Address Management

Assurance

- Service Problem Mgt.
- Service Quality Analysis Action & Reporting
- Fault, Root Cause Analysis
- Resource Data Collection, Analysis & Control

Billing & Revenue Management

- Charging
- Service Guiding and Mediation
- Resource Mediation and Reporting

› Understand impact of IPv6 on key functions to ensure support and update process changes

› Understand need to operate both IPv4 and IPv6 for different devices and in different parts of network

› Configuration, diagnostic testing

IPv6 Transition Planning

IPv6 Transition Planning

- IPv6 transition does not happen overnight, but rather over a gradual process
  - Analyze your current network for short and long term plans
- There are multiple paths towards IPv6 that are dependent upon your network and services
  - Some network situations do not face urgent needs as others, so multiple options exist

IPv6 Transition Checklist (1/2)

- **Prioritize end-user service** over operator internal infrastructure
- **Survey the network**. Understand which systems use IPv6 and which ones deal with IPv6 (billing, subscriber management).
- **Plan the Transition**. Priorities based on survey.
- **Start small**. Use closed groups or trials.
- **Start training** early.

Source: Korhonen et al., *Deploying IPv6 in 3GPP Networks*, John Wiley and Sons, 2013

IPv6 Transition Checklist (2/2)

- **Grow as service matures**.
- **Participate in Network Operators Groups**.
- **Try it out!** Hands-on experience, ask your providers for proof of concepts, labs, etc.
- **Start today!**
  - Transition is going to be difficult
  - The earlier the problems are found, the quicker can be solved

Source: Korhonen et al., *Deploying IPv6 in 3GPP Networks*, John Wiley and Sons, 2013

Useful Documents

Useful Documents 1/2

- Google IPv6 Report http://www.google.com/intl/en/ipv6/
- Global IPv6 Deployment Progress Report http://bgp.he.net/ipv6-progress-report.cgi
- Toward an IPv6 World In Mobile Networks – Ericsson White Paper http://bit.ly/1Fl6tLz
- IPv6 Transition In Fixed And Mobile Environments – ALU White Paper http://bit.ly/17fFgLQ
- Ahmed, Adeel and Salman Asadullah, *Deploying IPv6 in Broadband Access Networks*, John Wiley and Sons, 2009
- Korhonen, Savolainen and Soininen, *Deploying IPv6 in 3GPP Networks*, John Wiley and Sons, 2013

Useful Documents 2/2

- Data-Over-Cable Service Interface Specifications:
  http://www.cablelabs.com/wp-content/uploads/specdocs/CM-SP-eRouter-I10-130808.pdf
- CableLabs' DHCP Options Registry:
  http://www.cablelabs.com/wp-content/uploads/specdocs/CL-SP-CANN-DHCP-Reg-I10-130808.pdf
- IPv6 on Cable:
  http://www.cisco.com/c/en/us/td/docs/ios/cable/configuration/guide/12_2sc/Cisco_CMTS_Layer3_Bundle_Interface/cmts_ipv6.html
- Dual-Stack IPv6 Architecture Technical Report:
  http://www.cablelabs.com/wp-content/uploads/specdocs/PKT-TR-DS-IP6-V01-110825.pdf
- Cisco CMTS Router Layer 3 and Bundle Interface Features Configuration Guide
  http://www.cisco.com/c/en/us/td/docs/cable/cmts/config_guide/b_CMTS_Router_Layer3_BundleInterface.pdf

RFCs

- RFC 3315 - Dynamic Host Configuration Protocol for IPv6 (DHCPv6)
- RFC 3633 - IPv6 Prefix Options for Dynamic Host Configuration Protocol (DHCP) version 6
- RFC 3769 - Requirements for IPv6 Prefix Delegation
- RFC 4213 - Basic Transition Mechanisms for IPv6 Hosts and Routers
- RFC 4862 - IPv6 Stateless Address Autoconfiguration
- RFC 5969 - IPv6 Rapid Deployment on IPv4 Infrastructures (6rd) -- Protocol Specification
- RFC 6106 - IPv6 Router Advertisement Options for DNS Configuration
- RFC 6144 - Framework for IPv4/IPv6 Translation
- RFC 6333 - Dual-Stack Lite Broadband Deployments Following IPv4 Exhaustion
- RFC 6586 - Experiences from an IPv6-Only Network
- RFC 7217 - A Method for Generating Semantically Opaque Interface Identifiers with IPv6 Stateless Address Autoconfiguration (SLAAC)
- RFC 7021 - Assessing the Impact of Carrier-Grade NAT on Network Applications
- RFC 7084 - Basic Requirements for IPv6 Customer Edge Routers
- Internet Draft - Recommendation on Stable IPv6 Interface Identifiers draft-ietf-6man-default-iids-03

Conclusions & Questions

Conclusions

- IPv6 traffic today represents 8% of the total IP traffic. This almost three times the traffic a year ago.
- IPv6 allows continuous growth of Internet business.
- Most fixed and mobile operators are choosing dual stack as their transition plan.
- IPv6 transition has to be carefully planned.
- Don’t wait until doomsday!

IPv6 Deployment Survey

Log in kahoot.it

Where Would You Like To Be?

IPv4 with NAT444444444

IPv6