# IPv6 in Cellular Networks

APNIC 44

Taichung - Taiwan

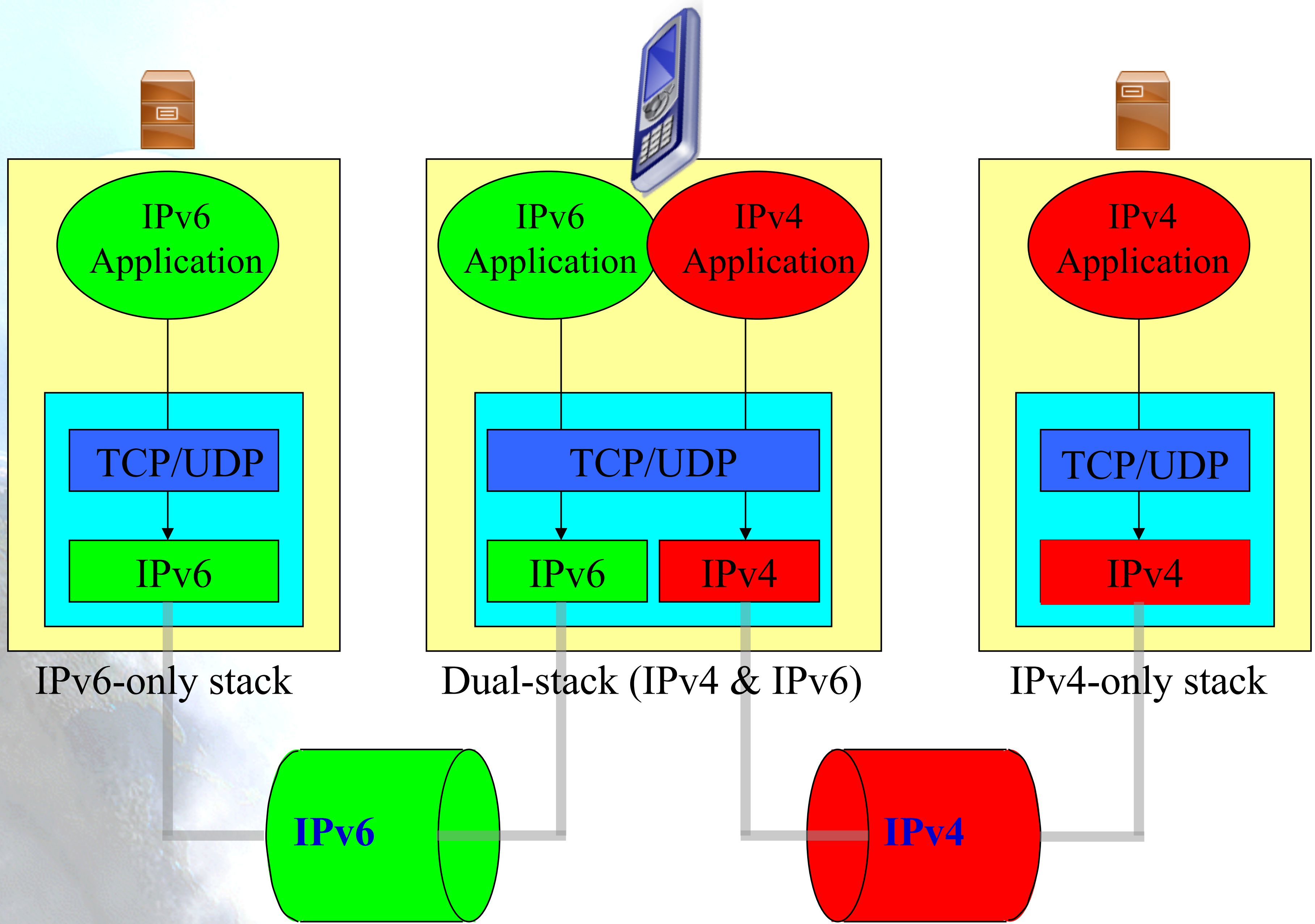
September 2017

**Jordi Palet (jordi.palet@theipv6company.com)**

# Need to support IPv6

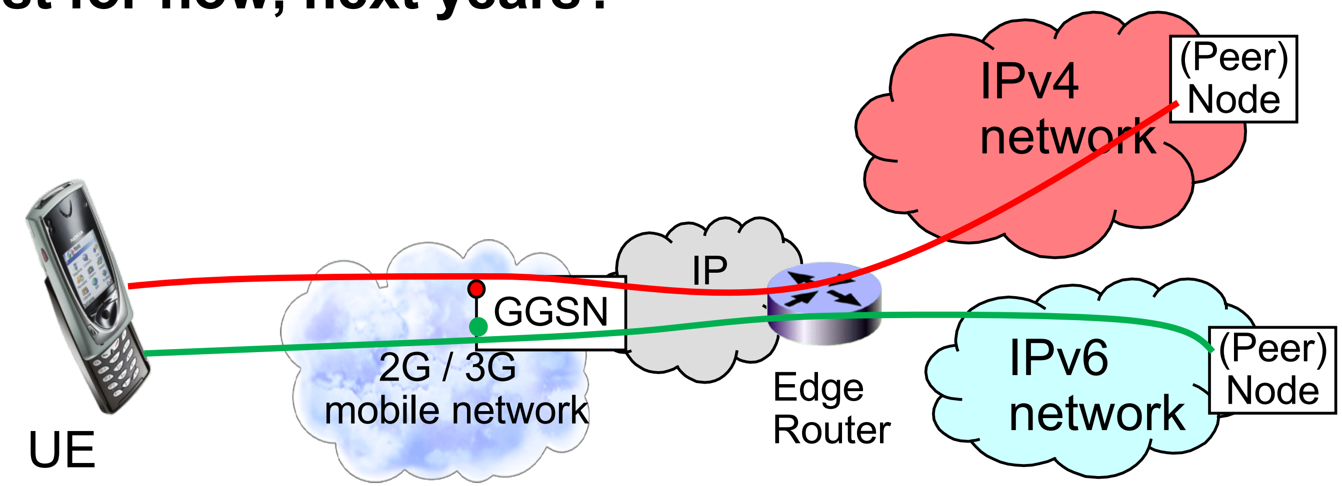
- IPv4 exhaustion
  - Sharing IPv4 (CGN) is not enough and is problematic
- Increase in number of users
- Increase in number of devices per user (and also tethering)
- Increase in number of addresses per device (VMs, other reasons)
- VoLTE/IMS
- IoT
- **LONG TERM STRATEGY**

# The best solution: Dual-Stack!



# Sure ?

- Do you have enough IPv4 addresses?
  - Not just for now, next years?




- O&M cost?
- Call-center impact?
- Performance?
- Licenses?
- Issues authenticating 2 addresses?

# Alternatives to Dual-Stack

- **IPv6-only**
- **IPv6-only with NAT64**
- **IPv6-only with NAT64 and DNS64**
- **464XLAT**
- **Other transition technologies**

# So … IPv6-only?

- **Many examples in content providers**
- **FaceBook is one of them**
- **Datacenters are IPv6-only**
  - Started in 2014, internal traffic was 90% IPv6
  - +100 Terabits per second
  - 100% IPv6 in June 2015
  - Allows using FaceBook in IPv6-only networks and clients
  - IPv4 (from Internet) terminated in the IPv6-only clusters
    - RFC1918 space for IPv4 BGP sessions
    - Later on use RFC5549
      - Advertising IPv4 Network Layer Reachability Information with an IPv6 Next Hop
    - IPv4 in IPv6 tunneling, for IPVS (IP Virtual Server)
    - IPv4 link-local (169.254.0.0/16) for Linux and switches

# IPv6-only in the cellular net

- Not an option today
- Users will be able to access IPv6-only contents and apps
  - However no access to IPv4-only ones
  - IPv4-only tethered devices will not work

# NAT64 (1)

- Problem: When ISPs only provide IPv6 connectivity or devices are IPv6-only (cellular)
  - but there are still IPv4-only contents/apps in Internet
- Similar idea as NAT-PT, but working better
- Several **IPv6-only** nodes share a public IPv4 address to access IPv4 Internet
- NAT64 is a mechanism to translate IPv6 packets to IPv4 and vice versa
- Translation is carried out in packet headers following the IP/ICMP Translation Algorithm [RFC7915][RFC6146]
- Current specification only defines how NAT64 translates unicast TCP, UDP, and ICMP packets

# NAT64 (2)

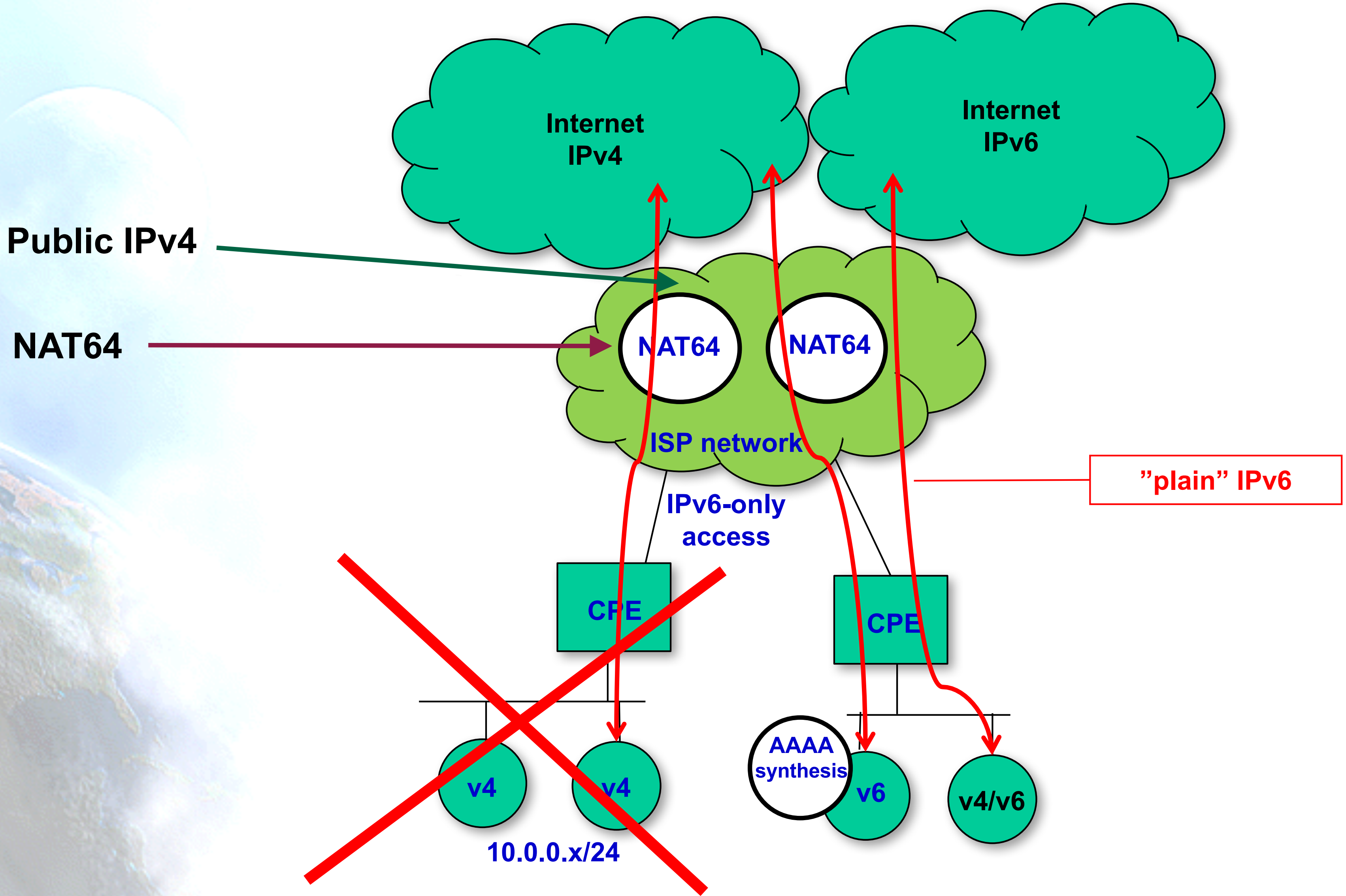
- IPv4 addresses of hosts is algorithmically translated to/from IPv6 addresses using a specific algorithm [RFC6052]
- It's based on statically configured information, including a well known prefix
- A well-known prefix is defined (64:ff9b::/96), another could be used

```
+--+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|PL| 0-------------32--40--48--56--64--72--80--88--96--104---------|
+--+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|32|     prefix    |v4(32)         | u | suffix                    |
+--+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|40|     prefix        |v4(24)     | u |(8)| suffix                |
+--+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|48|     prefix            |v4(16) | u | (16)  | suffix            |
+--+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|56|     prefix                |(8)| u |  v4(24)   | suffix        |
+--+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|64|     prefix                    | u |   v4(32)      | suffix    |
+--+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|96|     prefix                                    |    v4(32)     |
+--+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
```

# NAT64 (3)

- It's known that there are things that doesn't work:
  - Everything out of TCP,UDP, or ICMP: Multicast, Stream Control Transmission Protocol (SCTP), the Datagram Congestion Control Protocol (DCCP), and IPSEC
  - Applications that carry layer 3 information in the application layer: FTP [RFC6384], SIP/H323
  - Some apps: online gaming, skype, etc.
    - Peer-to-peer using IPv4 "references"
  - Literal addresses
  - Socket APIs

# NAT64



Internet
IPv4
Internet
IPv6
Public IPv4
NAT64
NAT64
NAT64
ISP network
"plain" IPv6
IPv6-only
access
CPE
CPE
AAAA
synthesis
v4
v4
v6
v4/v6
10.0.0.x/24

# IPv6-only with NAT64

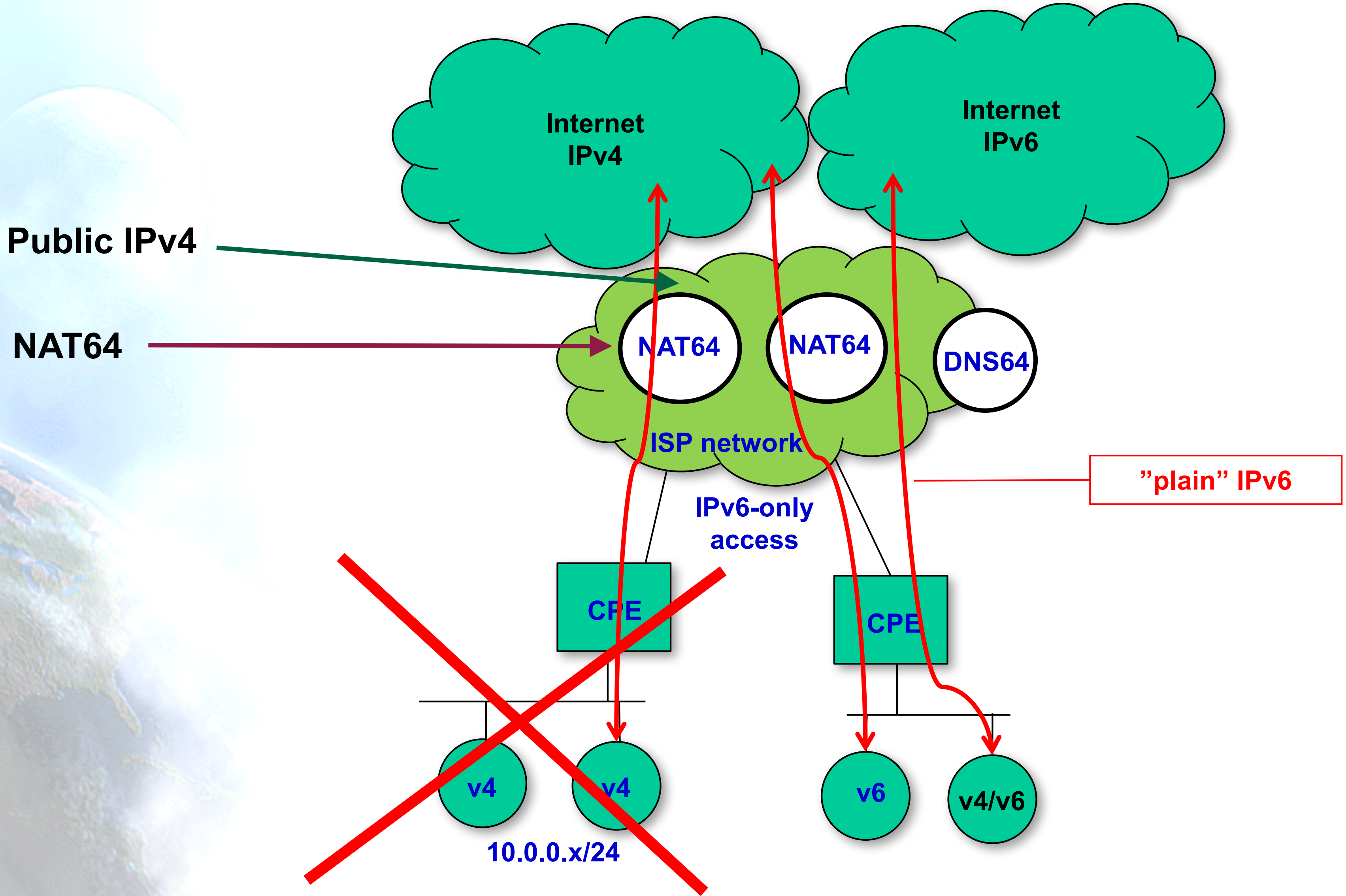
- Only valid if UE supports it
  - By means of "built-in" AAAA synthesis
    - RFC7050 (Discovery of the IPv6 Prefix Used for IPv6 Address Synthesis) + RFC6052 (IPv6 Addressing of IPv4/IPv6 Translators)
      - Happy Eyeballs v2 includes it

- For the rest of the cases
  - Users will be able to access IPv6-only contents and apps
    - However no access to IPv4-only ones
    - IPv4-only tethered devices will not work

# DNS64

- DNS64 is a mechanism to synthesize RRs of type AAAA from A RRs [RFC6147]
- IPv6 addresses in synthesized AAAA is generated from IPv4 address and the IPv6 prefix assigned to the NAT64 device [RFC6052]
- When there is an AAAA query, it asks outside for A and AAAA RRs. If only receives an A, converts it into an AAAA
- Hosts see the host as IPv6 reachable, with the synthesized IPv6 address

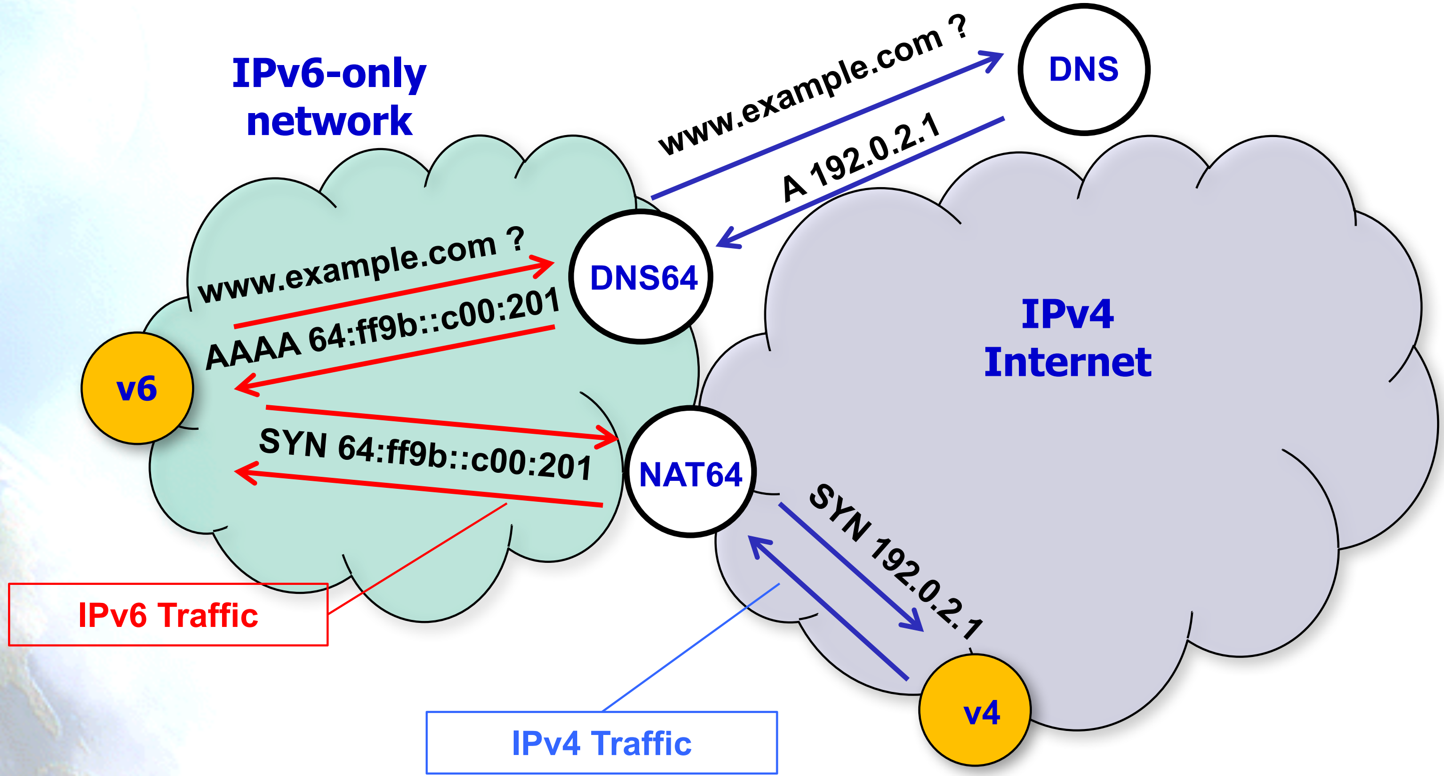
# NAT64+DNS64



Internet
IPv4
Internet
IPv6
Public IPv4
NAT64
NAT64
NAT64
DNS64
ISP network
"plain" IPv6
IPv6-only
access
CPE
CPE
v4
v4
10.0.0.x/24
v6
v4/v6

# Stateful NAT64

- Allow an IPv6-only network to connect to IPv4 Internet



# IPv6-only with NAT64+DNS64

- All good ?

- NOT really …
  - Will break if apps use:
    - Literal addresses
    - Socket APIs
  - IPv4-only tethered devices will not work

# NAT64 breaks …

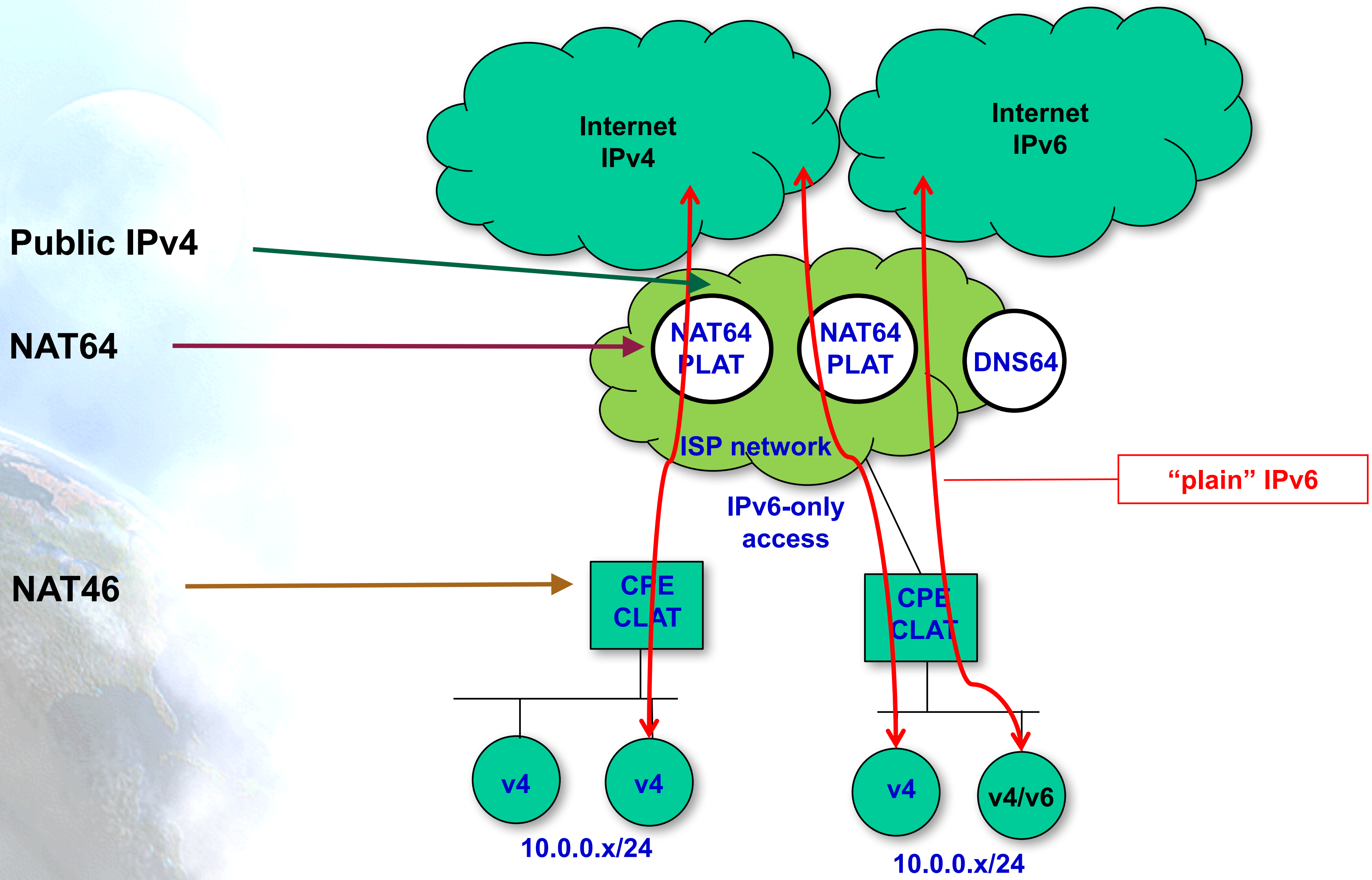
| App Name | Functionality | Version | 464XLAT Fixed |
|---|---|---|---|
| connection tracker | Broken | NA | NA |
| DoubleTwist | Broken | 1.6.3 | YES |
| Go SMS Pro | Broken | NA | YES |
| Google Talk | Broken | 4.1.2 | YES |
| Google+ | Broken | 3.3.1 | YES |
| IP Track | Broken | NA | NA |
| Last.fm | Broken | NA | YES |
| Netflix | Broken | NA | YES |
| ooVoo | Broken | NA | YES |
| Pirates of the Caribean | Broken | NA | YES |
| Scrabble Free | Broken | 1.12.57 | YES |
| Skype | Broken | 3.2.0.6673 | YES |
| Spotify | Broken | NA | YES |
| Tango | Broken | NA | YES |
| Texas Poker | Broken | NA | YES |
| TiKL | Broken | 2.7 | YES |
| Tiny Towers | Broken | NA | YES |
| Trillian | Broken | NA | YES |
| TurboxTax Taxcaster | Broken | NA | |
| Voxer Walkie Talkie | Broken | NA | YES |
| Watch ESPN | Broken | 1.3.1 | |
| Zynga Poker | Broken | NA | YES |
| Xabber XMPP | Broken | NA | |

***T-Mobile**

# 464XLAT

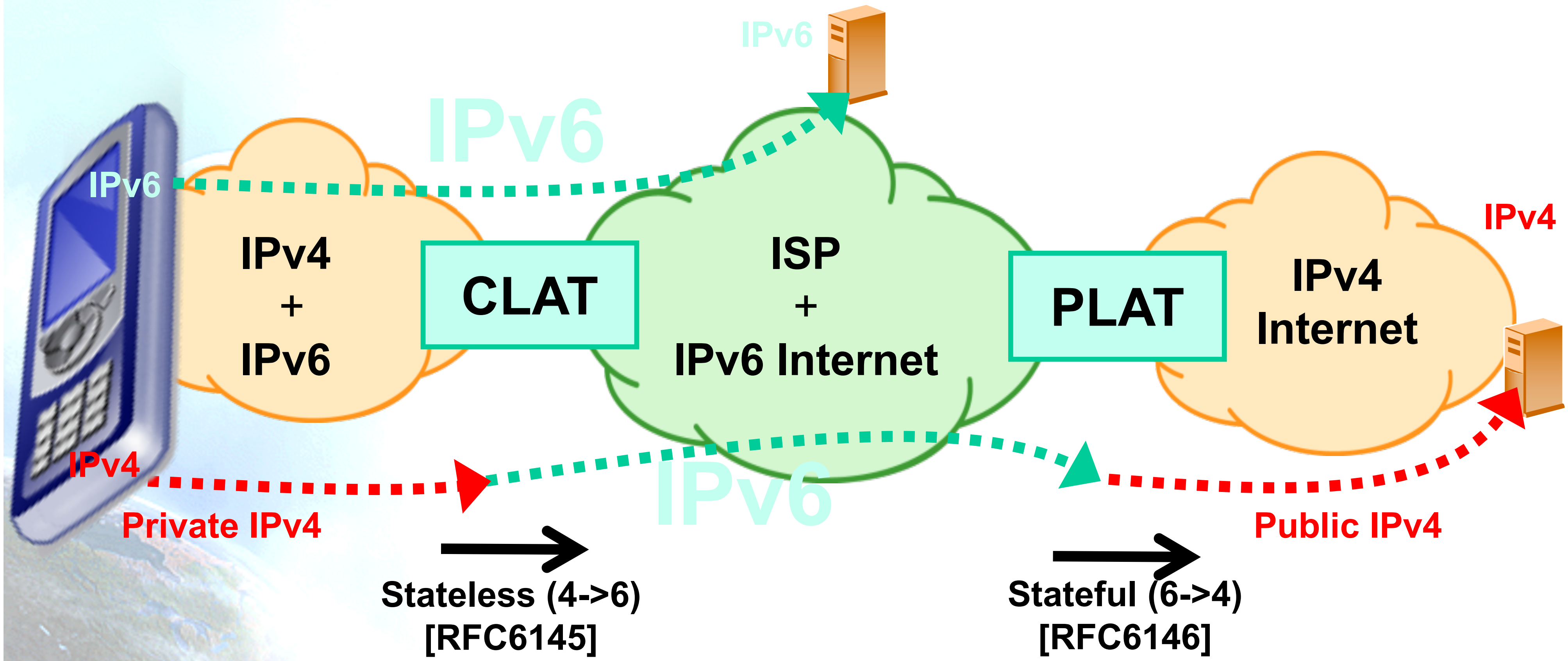
- 464XLAT (RFC6877): RFC6145 + RFC6146
- Very efficient use of scarce IPv4 resources
  - N*65.535 flows per each IPv4 address
  - Network growth not tied to IPv4 availability
- IPv4 basic service to customers over an-IPv6 only infrastructure
  - **WORKS** with applications that use socket APIs and literal IPv4 addresses (Skype, etc.)
- Allows traffic engineering
  - Without deep packet inspection
- Easy to deploy and available
  - Commercial solutions and open source

# 464XLAT



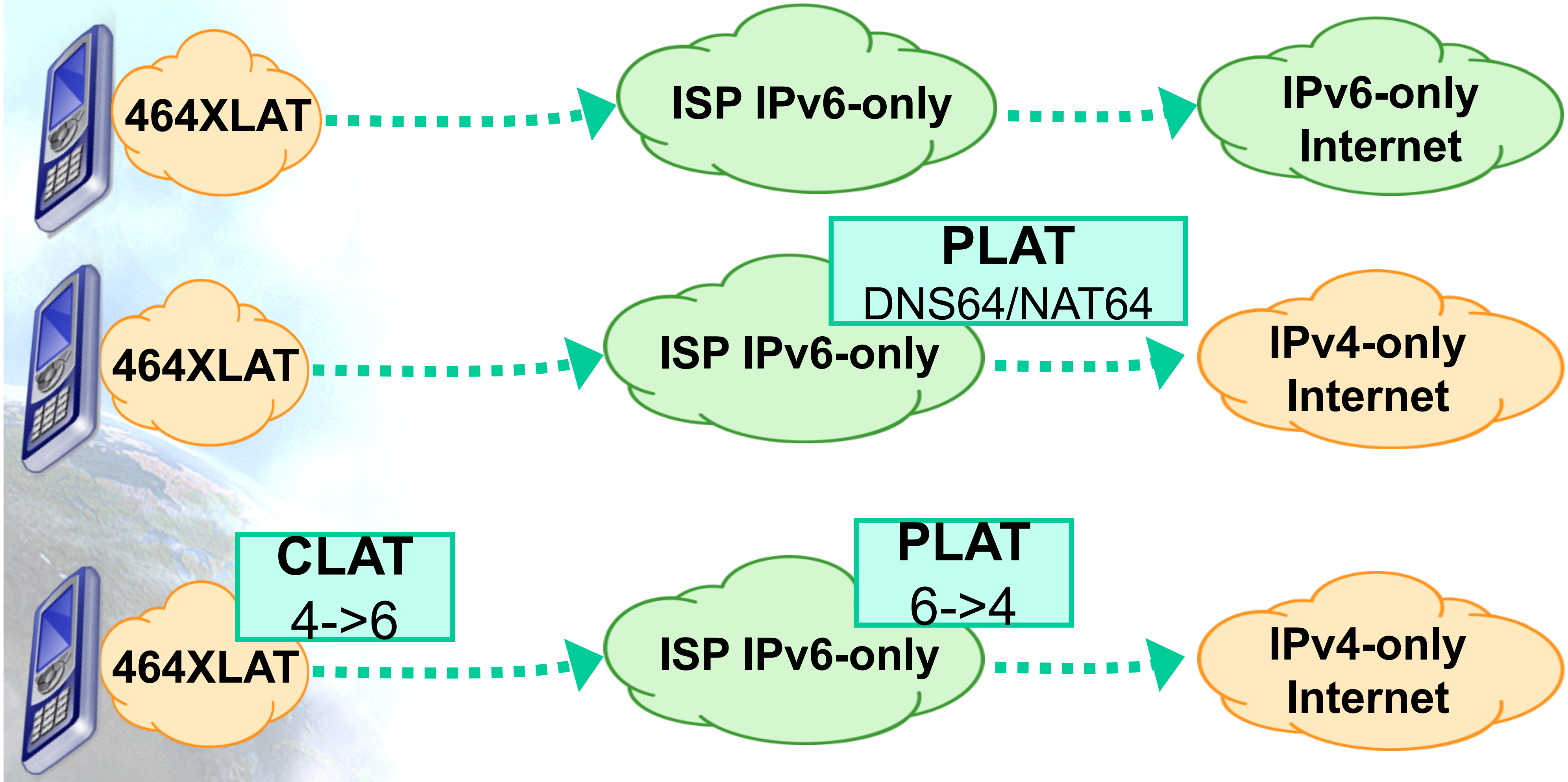
Internet
IPv4
Internet
IPv6
Public IPv4
NAT64
NAT64
PLAT
NAT64
PLAT
DNS64
ISP network
"plain" IPv6
IPv6-only
access
NAT46
CPE
CLAT
CPE
CLAT
v4
v4
10.0.0.x/24
v4
v4/v6
10.0.0.x/24

# How it works 464XLAT?

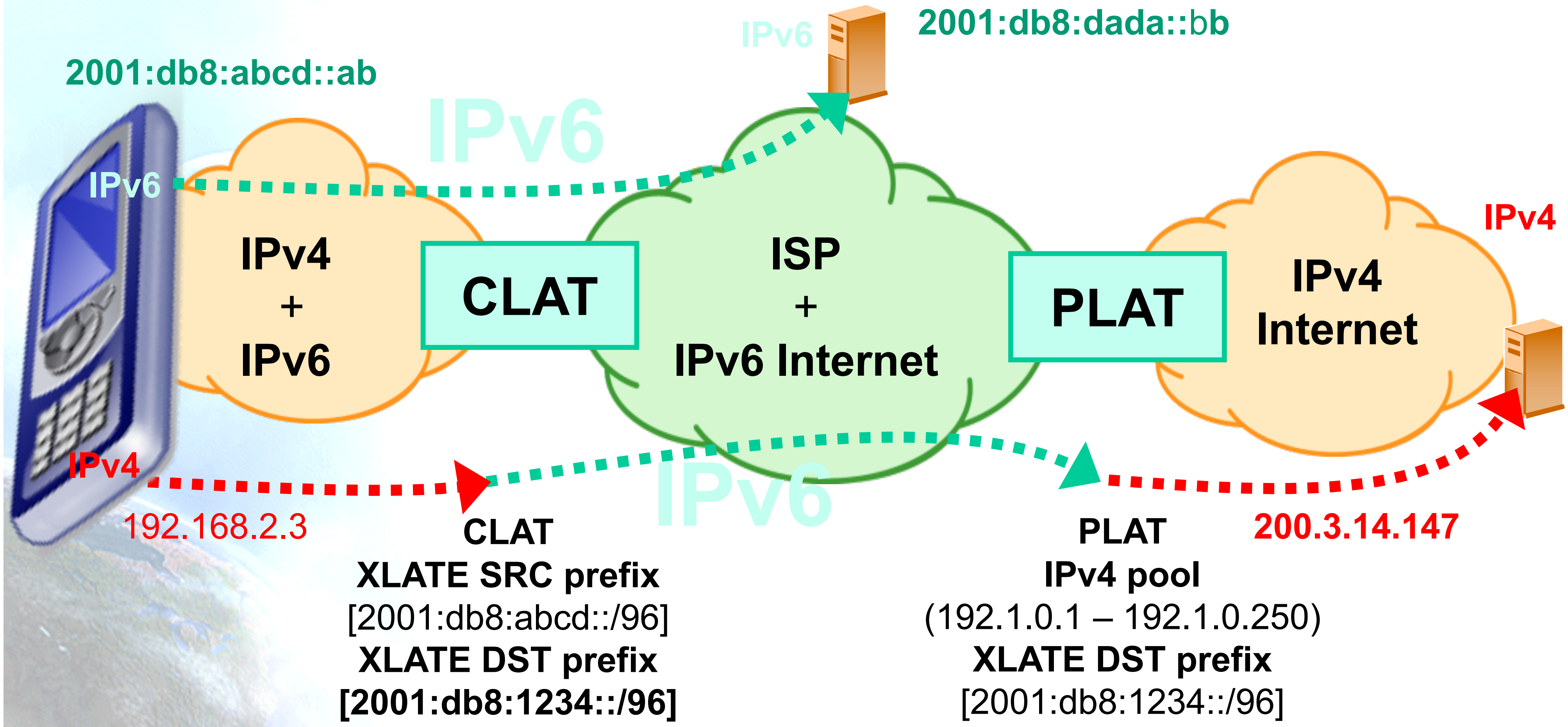



CLAT: Customer side translator (XLAT)
PLAT: Provider side translator (XLAT)

# Possible "app" cases



# 464XLAT Addressing




**IPv4 SRC**
192.168.2.3
**IPv4 DST**
**200.3.14.147**

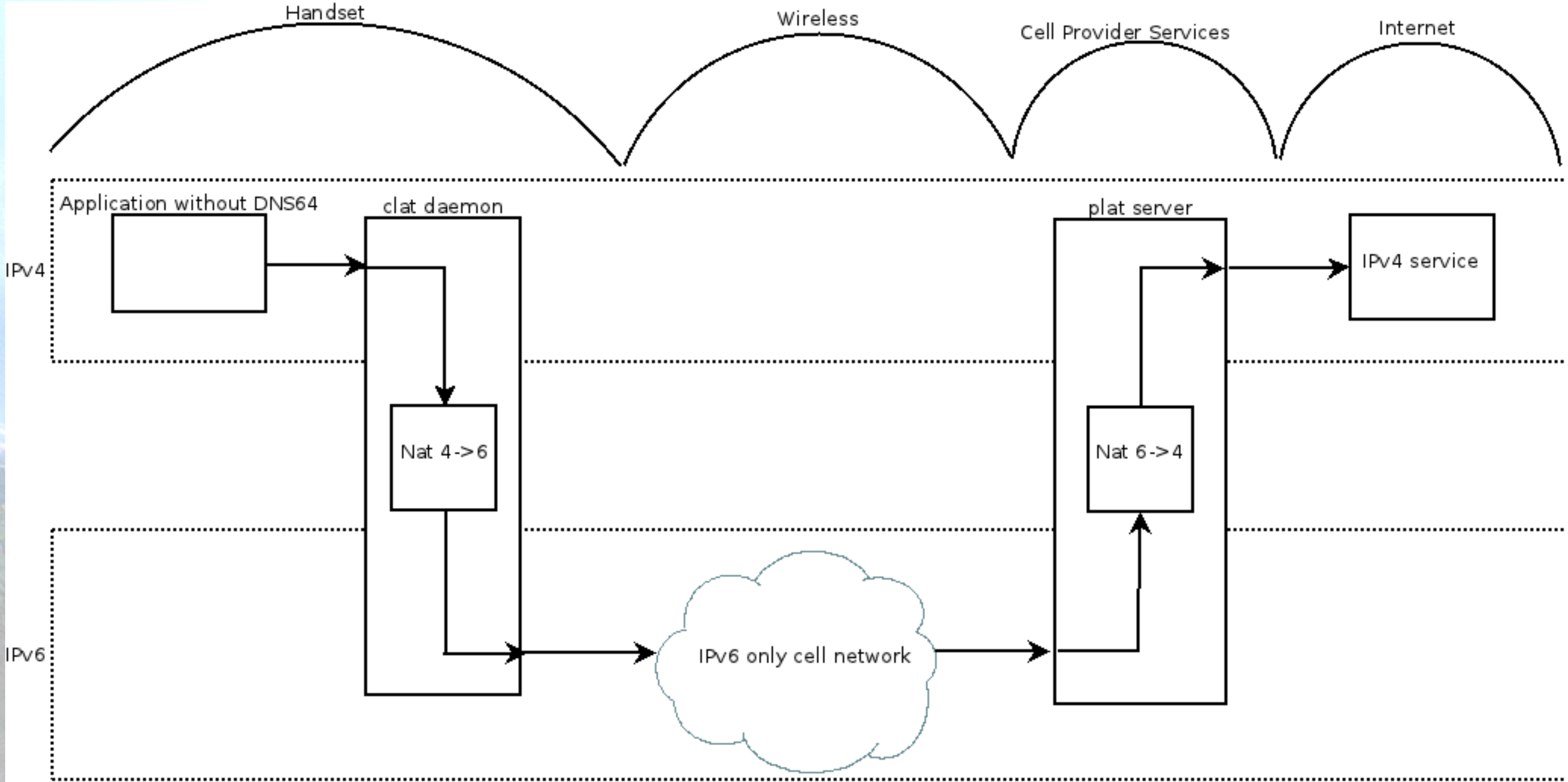
→ **Stateless** XLATE **[RFC6145]**

**IPv6 SRC**
2001:db8:abcd::192.168.2.3
**IPv6 DST**
**2001:db8:1234::200.3.14.147**

→ **Stateful XLATE [RFC6146]**

**IPv4 SRC**
192.1.0.1
**IPv4 DST**
**200.3.14.147**

# Simplicity




* Dan Drown

# Availability and Deployment

- NAT64:
  - A10
  - Cisco
  - F5
  - Juniper
  - NEC
  - Huawei
  - Jool, Tayga, Ecdsys, Linux, OpenBSD, …
- CLAT
  - Android (since 4.3)
  - Nokia
  - Windows
  - NEC
  - Linux
  - Jool
  - OpenWRT
  - Apple (sort-of, is Bump-in-the-Host [RFC6535] implemented in Happy Eyeballs v2) - IPv6-only since iOS 10.2
- Commercial deployments:
  - T-Mobile US: +68 Millions of users
  - Orange
  - Telstra
  - SK Telecom
  - …
  - Big trials in several ISPs

# DNSSEC Considerations

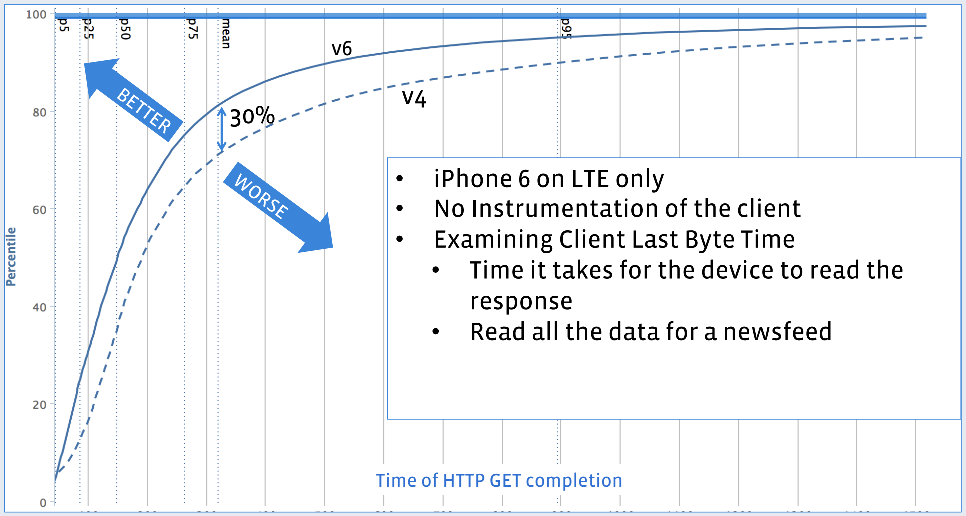
- DNS64 modifies DNS answers and DNSSEC is designed to detect such modifications, DNS64 can break DNSSEC
- In general, DNS servers with DNS64 function, by default, will not synthesize AAAA responses if the DNSSEC OK (DO) flag was set in the query. In this case, as only an A record is available, it means that the CLAT will take the responsibility, as in the case of literal IPv4 addresses, to keep that traffic flow end-to-end as IPv4, so DNSSEC is not broken
- Today no apps in cellular that use DNSSEC, but you should be ready for that
  - Consider apps used by means of tethering
  - Very relevant for non-cellular networks

# Other Transition Technologies

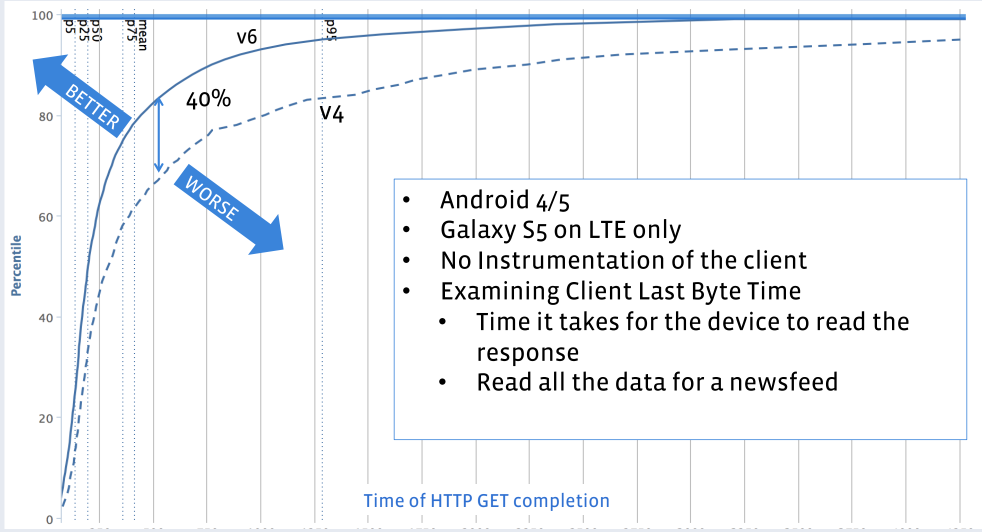
- 6RD
- DS-Lite
- MAP-E or MAP-T
- …
- No way!
  - Not implemented in smartphones
  - Require using lots of IPv4 addresses
  - Heavy setup and network overhead, require DHCP
  - Take less advantage of “multiplexing” IPv4 addresses & ports, than stateful NAT64

# Performance

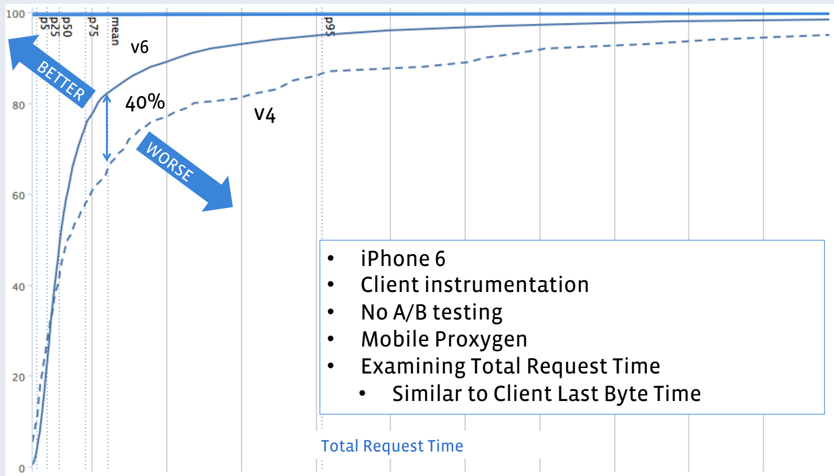
## US Mobile Performance – Dual Stack Provider iOS




## US Mobile Performance – Dual Stack Provider Android




## US Mobile Performance – Dual Stack Provider iOS




***FaceBook data**

(17/3/2015)

The IPv6 Company

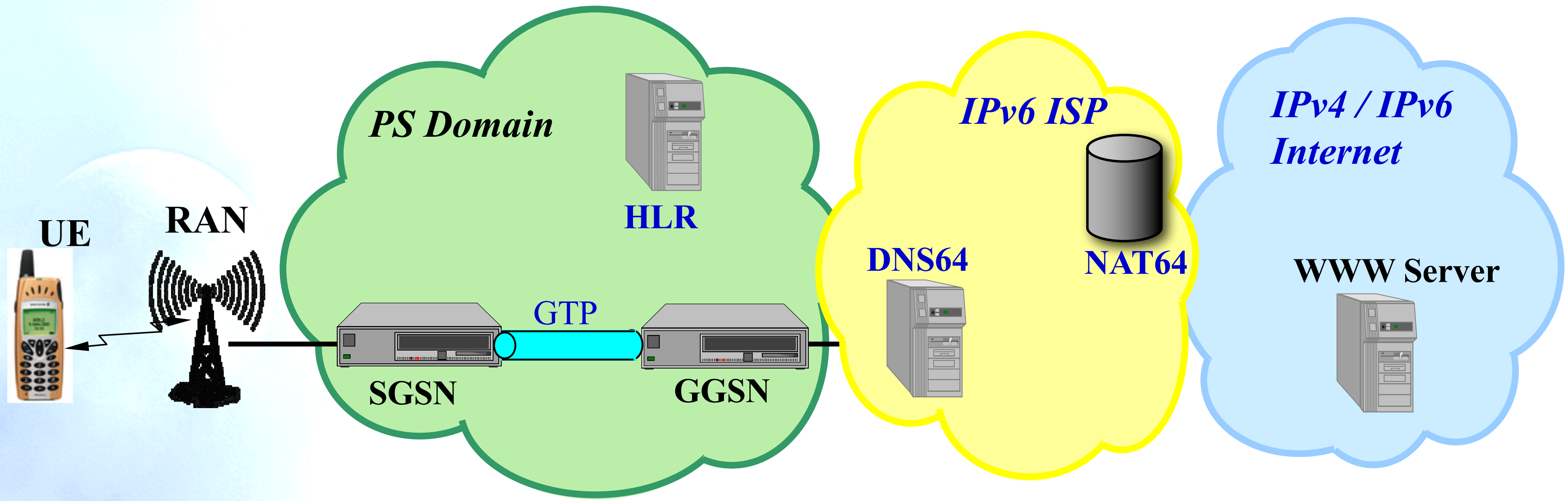
# Cost ?

- No CapEx/OpEx
  - No need to buy CGN
    - NAT64 scales better, you have open source solutions, lower cost
  - No need to buy IPv4
- Progressive deployment:
  - New phones
  - Not impacting existing users
  - Naturally increase your IPv6 traffic
    - Decrease IPv4 one
- Billing
  - Trunking IPv6 adresses in CDRs
  - Hash IPv6 addresses in IPv4 records

# Roaming

- Use PCRF (Policy and Charging Control Function) to selectively enable IPv6 in roaming customers sessions
  - Depending on “roaming partner”
- RFC7445
  - Analysis of Failure Cases in IPv6 Roaming Scenarios

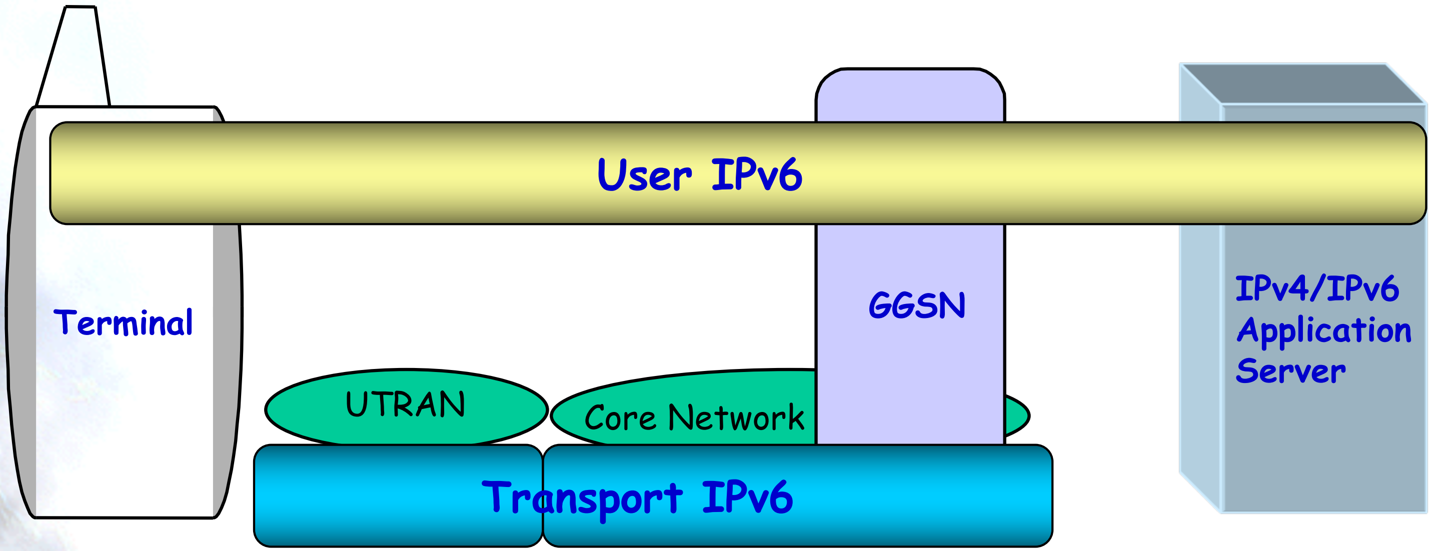
# Overall IPv6 3G/4G Architecture




- RFC6459: IPv6 in 3rd Generation Partnership Project (3GPP) Evolved Packet System (EPS)
- UE: User Equipment
- RAN: Radio Access Network (UTRAN, LTE, …)
- SGSN/MME: Serving GPRS Support Node/Mobility Management Entity
  - Acts as a “switch”
- GTP: GPRS Tunneling Protocol
- HLR: Home Location Register
- GGSN/EPG: Gateway GPRS Support Node/Evolved Packet Gateway
  - Acts as a “router”

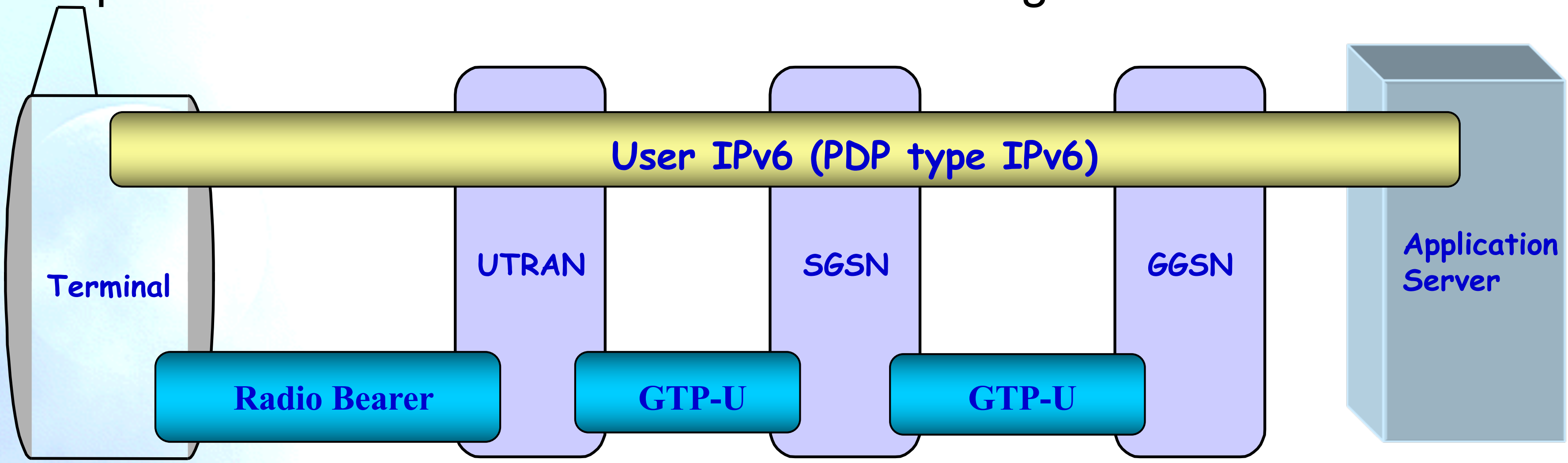
# User plane vs. transport plane

- User and transport planes are completely independent:
  - –The transport plane can run on a different IP version than the user plane
- RAN and Core Network transport can also run on different IP versions



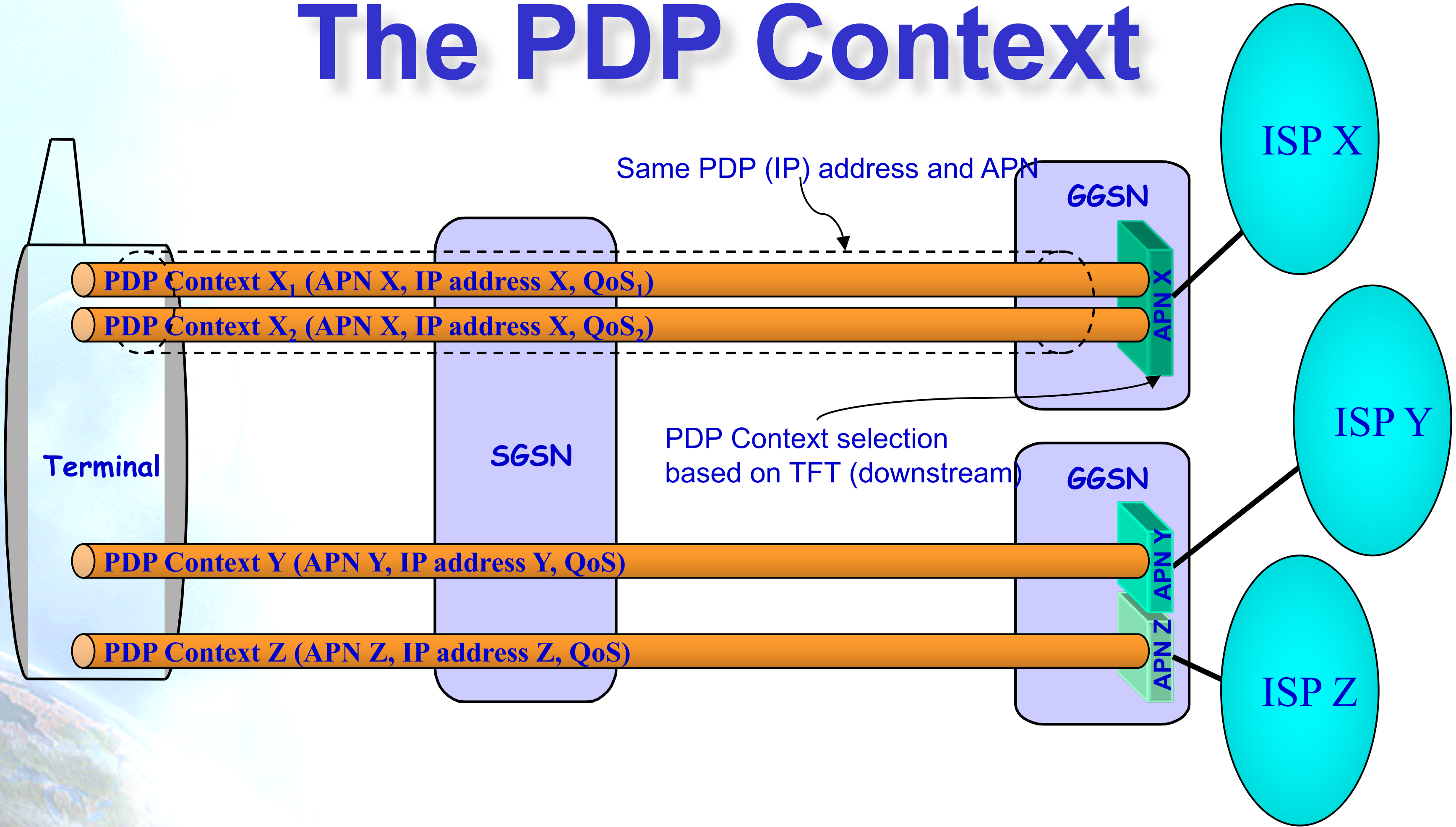
# Transport of user IP packets

- IP packets to/from the UE are tunneled through the cellular network.




- When an UE attaches to the Network, the SGSN creates a Mobility Management context containing information pertaining to e.g., mobility and security for the MS.
- At PDP Context Activation (PDP - Packet Data Protocol), the SGSN and GGSN create a PDP context, containing information about the session (e.g. IP address, QoS, routing information , etc.).
- Each Subscriber may activate several PDP Contexts towards the same or different GGSNs.
- When activated towards the same GGSN, they can use the same or different IP addresses.

# The PDP Context

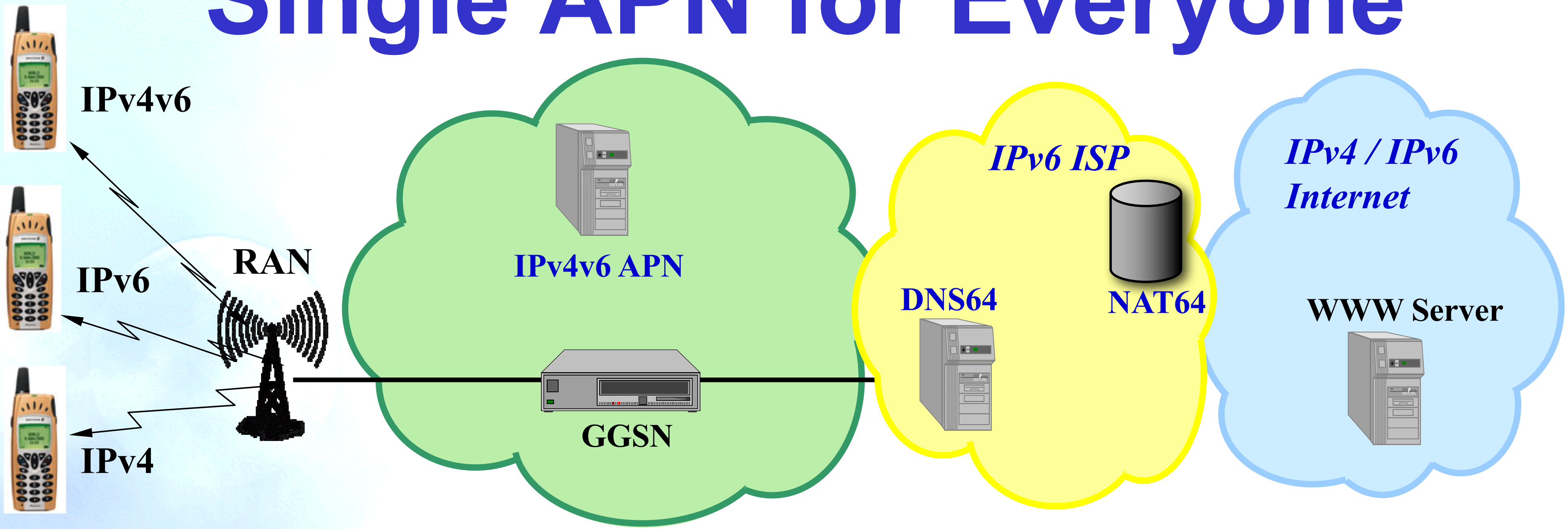



- PDP context can be IPv4-only (IPv4), IPv6-only (IPv6) or dual-stack (IPv4v6)
- Dual-stack could also be provided with two PDP contexts (one each protocol, however it means 2 PDP context licenses)
- 464XLAT works with IPv6-only PDP context (long-term strategy)

# The Access Point Name - APN

- The APN is a logical name referring to a GGSN. The APN also identifies an external network.
- The syntax of the APN corresponds to a fully qualified name.
- At PDP context activation, the SGSN performs a DNS query to find out the GGSN(s) serving the APN requested by the terminal.
- The DNS response contains a list of GGSN addresses from which the SGSN selects one address in a round-robin fashion (for this APN).

# Single APN for Everyone




- Single APN
  - Supporting Dual-Stack and Single-Stack
  - Cellular IPv6 deployment is easy because the network supports whatever the UE ask.
  - Progressive deployment, as slow or fast as you want
    - One new phone, all new phones, then OTA old ones
- DNS supporting RFC7050
  - Discovery of the IPv6 Prefix Used for IPv6 Address Synthesis

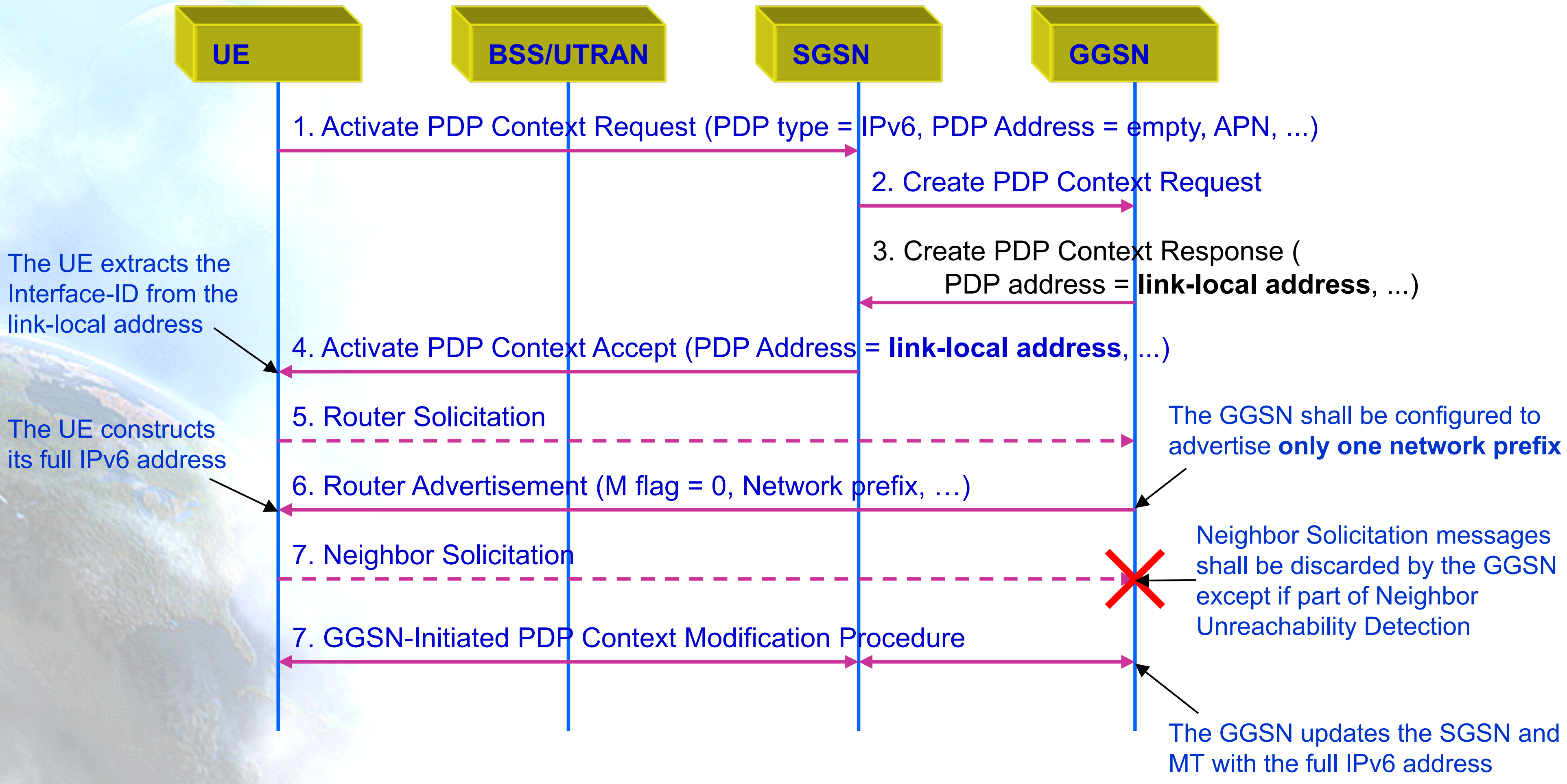
# IPv6 Address Allocation Methods

- Stateless Address Autoconfiguration
  - Default, /64 for each PDP context
  - Introduced in GPRS R'99

- Stateful Address Autoconfiguration
  - DHCPv6 client in the terminal
  - Requires DHCPv6 relay agent in the GGSN

- GPRS-specific Address Configuration
  - Static Address Configuration
    - The UE provides its statically configured IPv6 address at PDP context activation
  - Dynamic Address Allocation
    - The IPv6 address is provided by the GGSN at PDP context activation

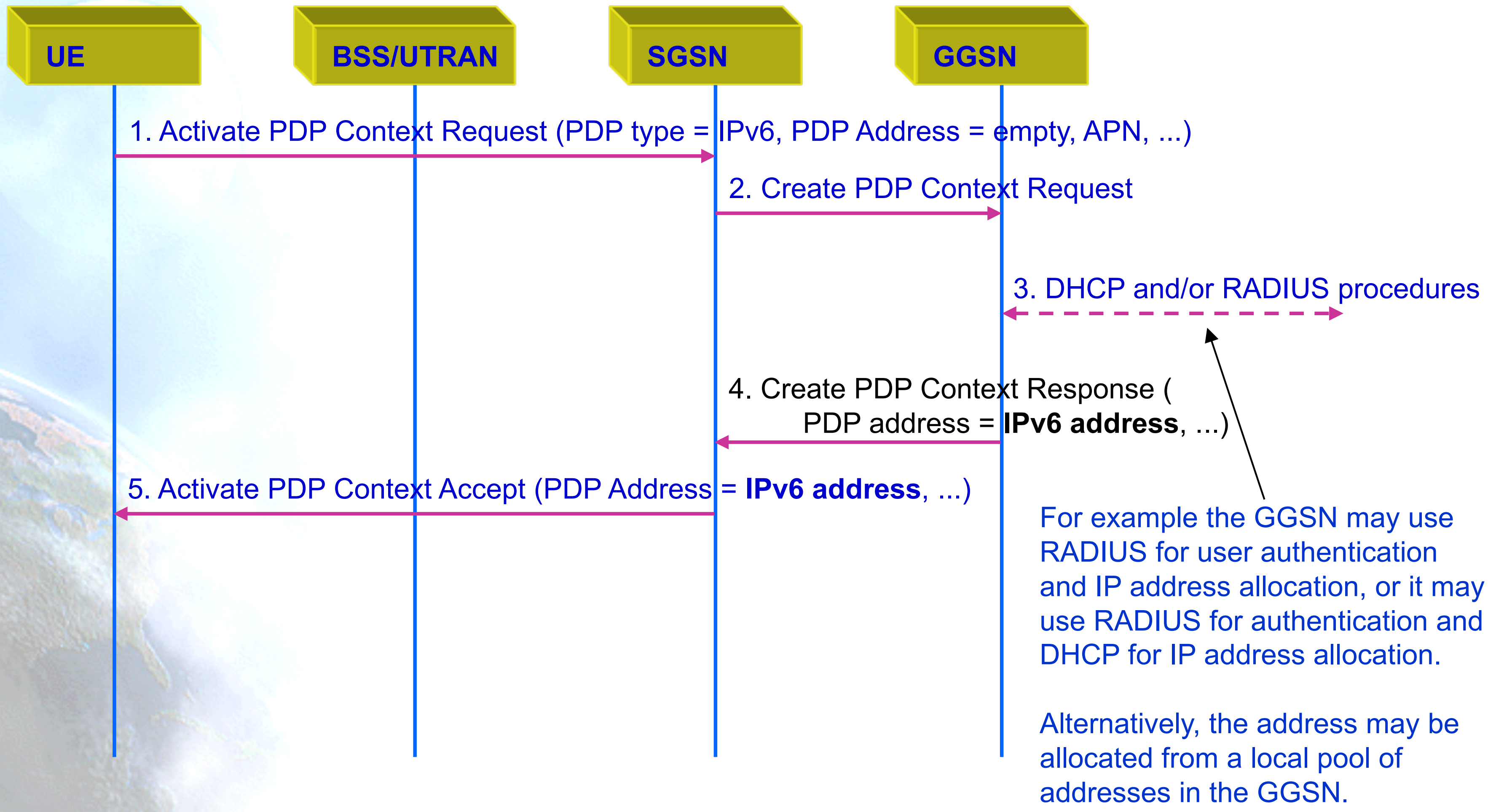
# Stateless Address Auto-configuration



# Tethering

- RFC7278
  - Extending an IPv6 /64 Prefix from a Third Generation Partnership Project (3GPP) Mobile Interface to a LAN Link
  - The UE is switched from an IPv6 host mode to an IPv6 router-and-host mode
- If the UE is also a CLAT, it provides IPv4 service with private addresses to the “tethered” devices

# Dynamic Address Allocation



# Prefix Exclude Option

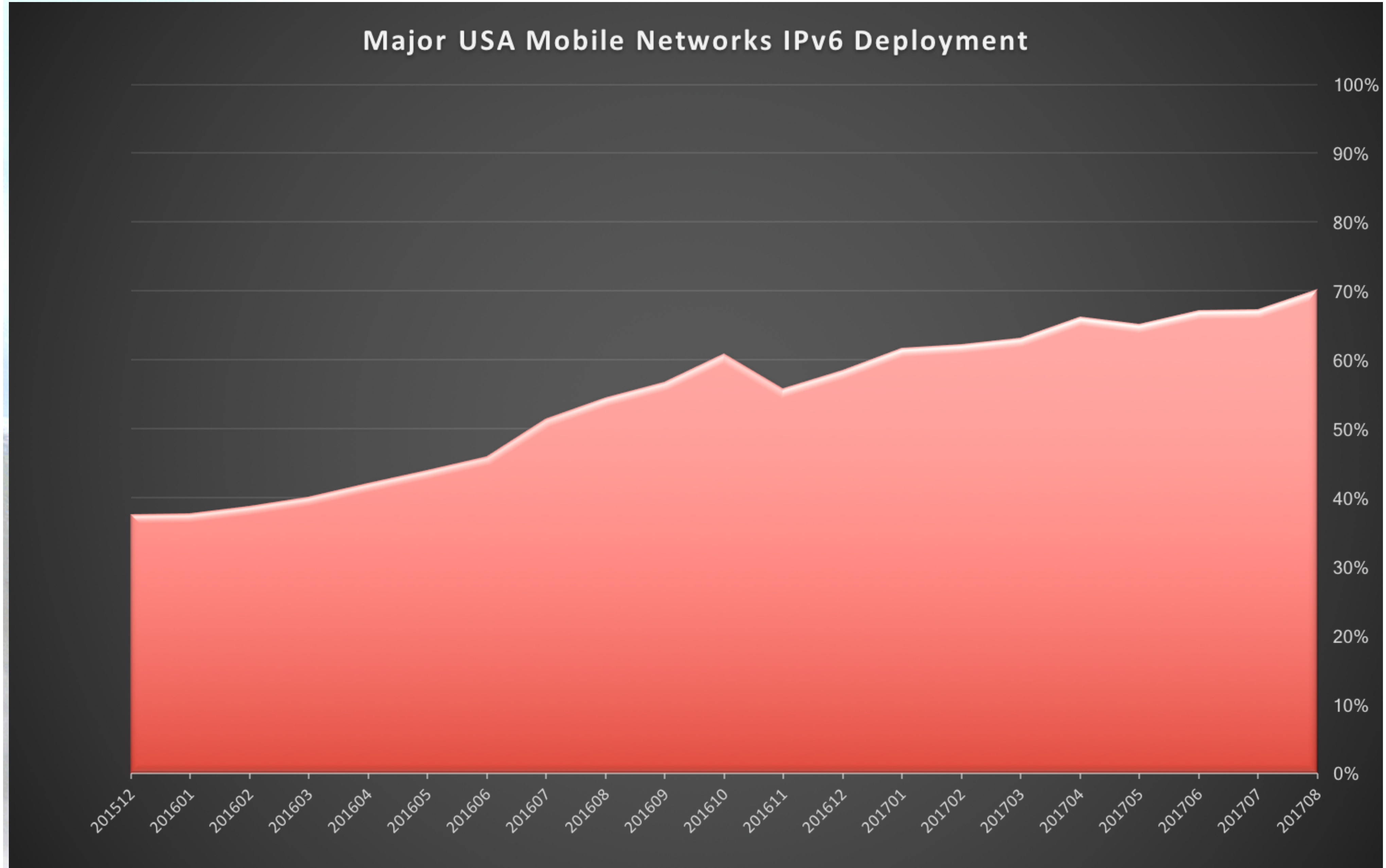
- If DHCPv6 is used, it may be interesting a single aggregated route/prefix for each customer, instead of using one prefix for the link between the delegating router and the requesting router and another prefix for the customer network.

- RFC6603
  - Prefix Exclude Option for DHCPv6-based Prefix Delegation

# Declare Success

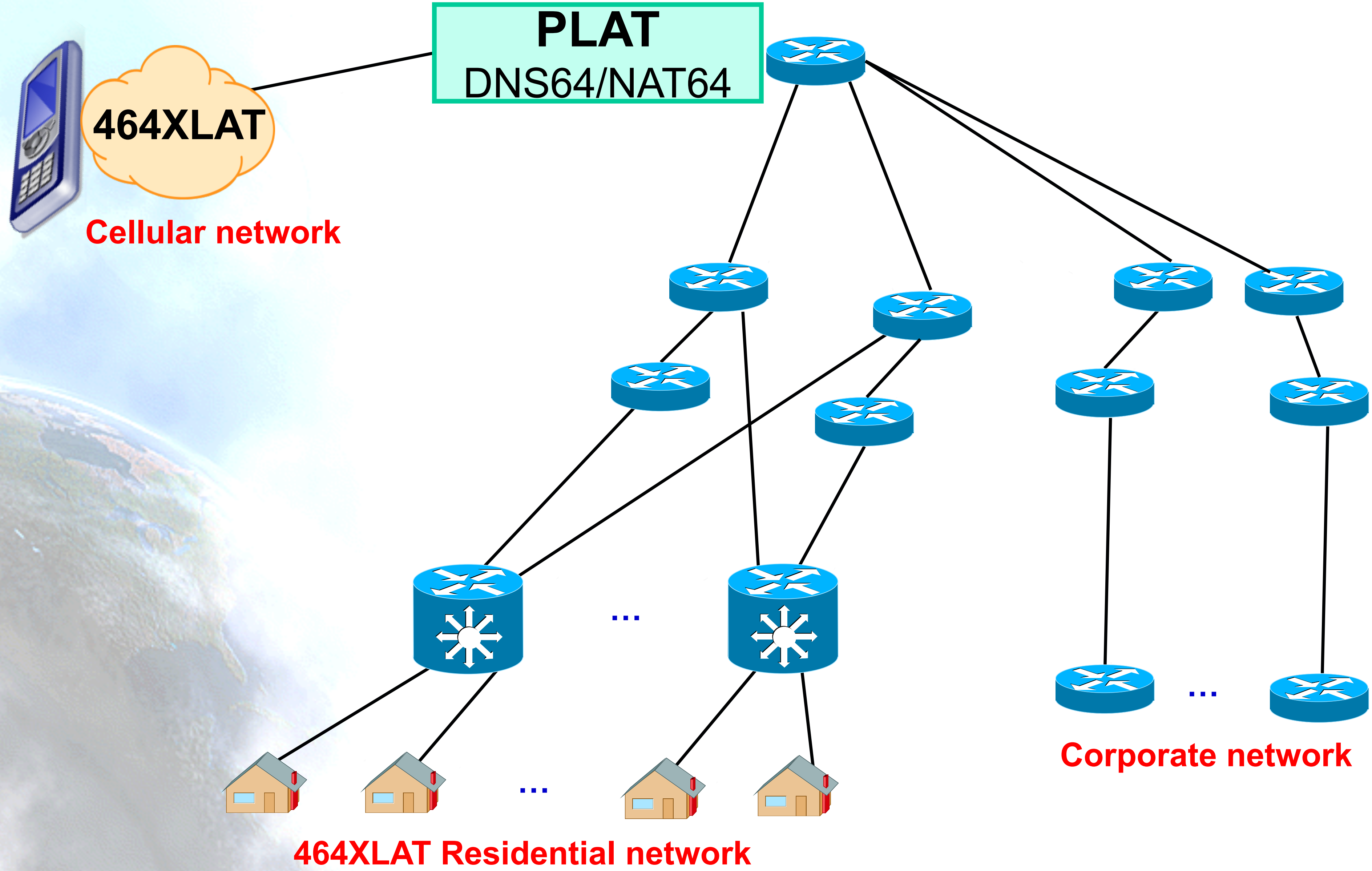
- Traffic moves from IPv4 to IPv6
- Customers never notice anything changed

# IPv6 in Cellular/US

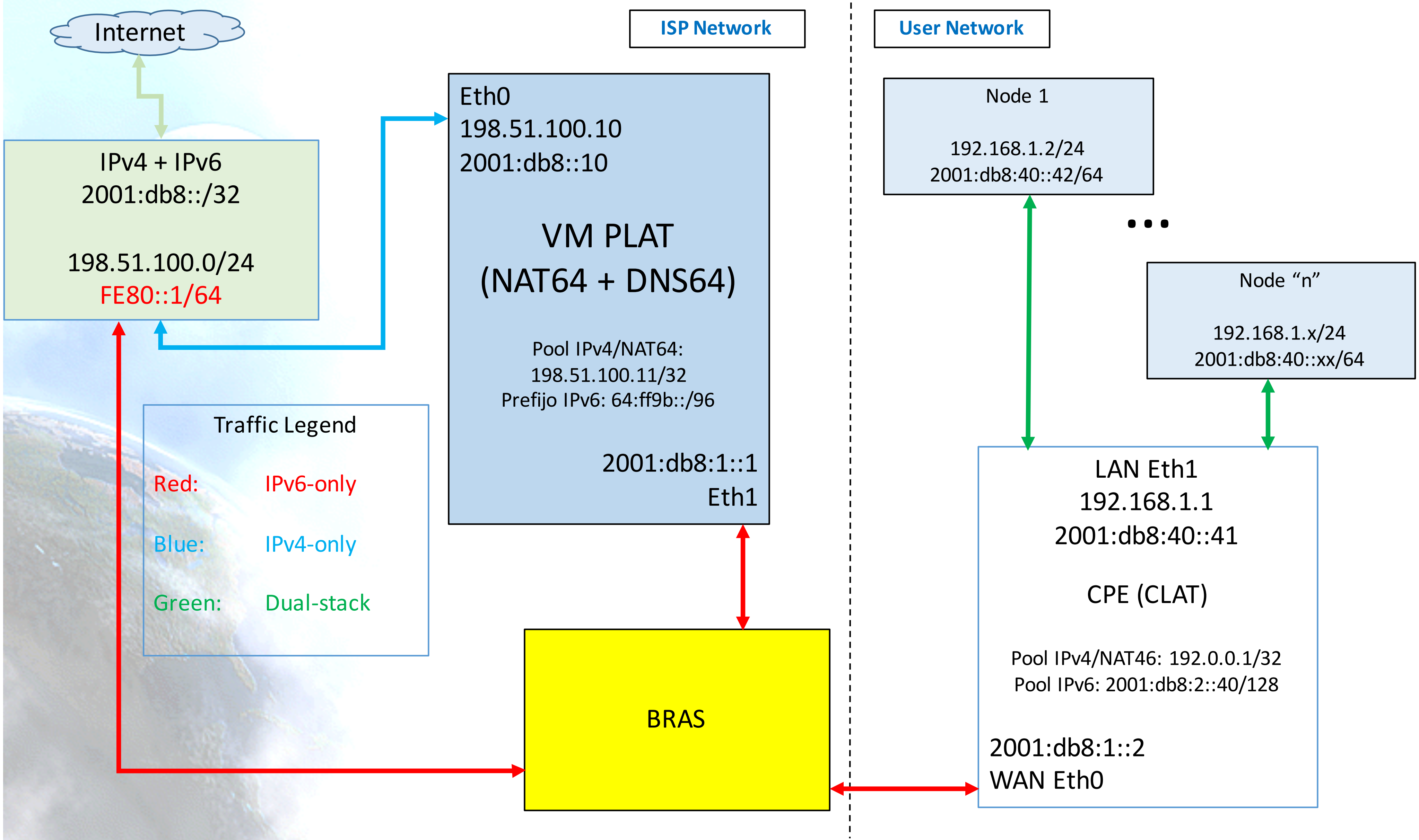



*ISOC/World IPv6 Launch data

# Multiservice Network



# Example Residential Customer



# Thanks!

## Contact:


– **Jordi Palet:** jordi.palet@theipv6company.com