Considerations of Gradual IPv6-only Deployment in 5G Mobile Networks

draft-ma-v6ops-5g-ipv6only

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Background

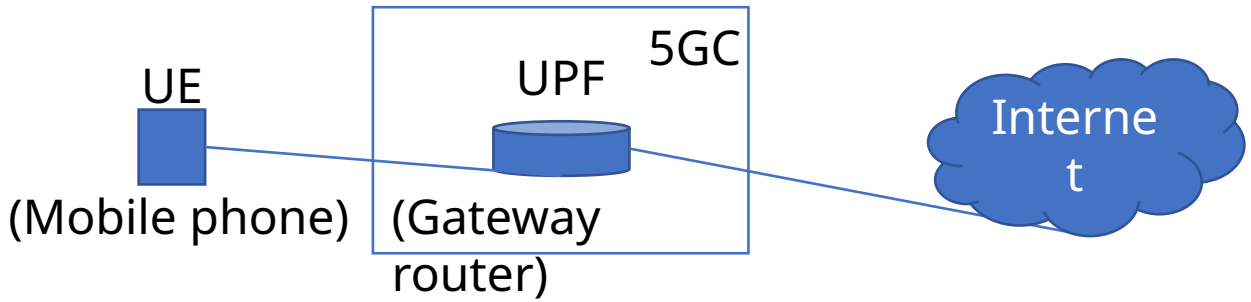
- IPv6 has been widely in mobile networks of operator, it has even gained the dominant position from the perspective of traffic especially in China.
  - Around 67.5% according to official data available at https://www.china-ipv6.cn/#/traffic/simpleInfo. And it maybe continue to show an upward trend.
  - Consider to migrate netwoks to IPv6-only

- Operators have begun experimenting with deploying IPv6-only approach in their mobile networks.
  - Most existing deployments utilize 464XLAT technology in cellular network.
  - T-mobile, EE, Sprint, Reliance Jio, Orange, etc.
  - No 5G deployment experience available here.

- This document describes the approach of gradually deploying 464XLAT based IPv6-only technology on user plane in 3GPP 5G networks.
  - 5GS IPv6-only Architecture on User Plane
  - Deployment Challenges
  - Deployment Solution

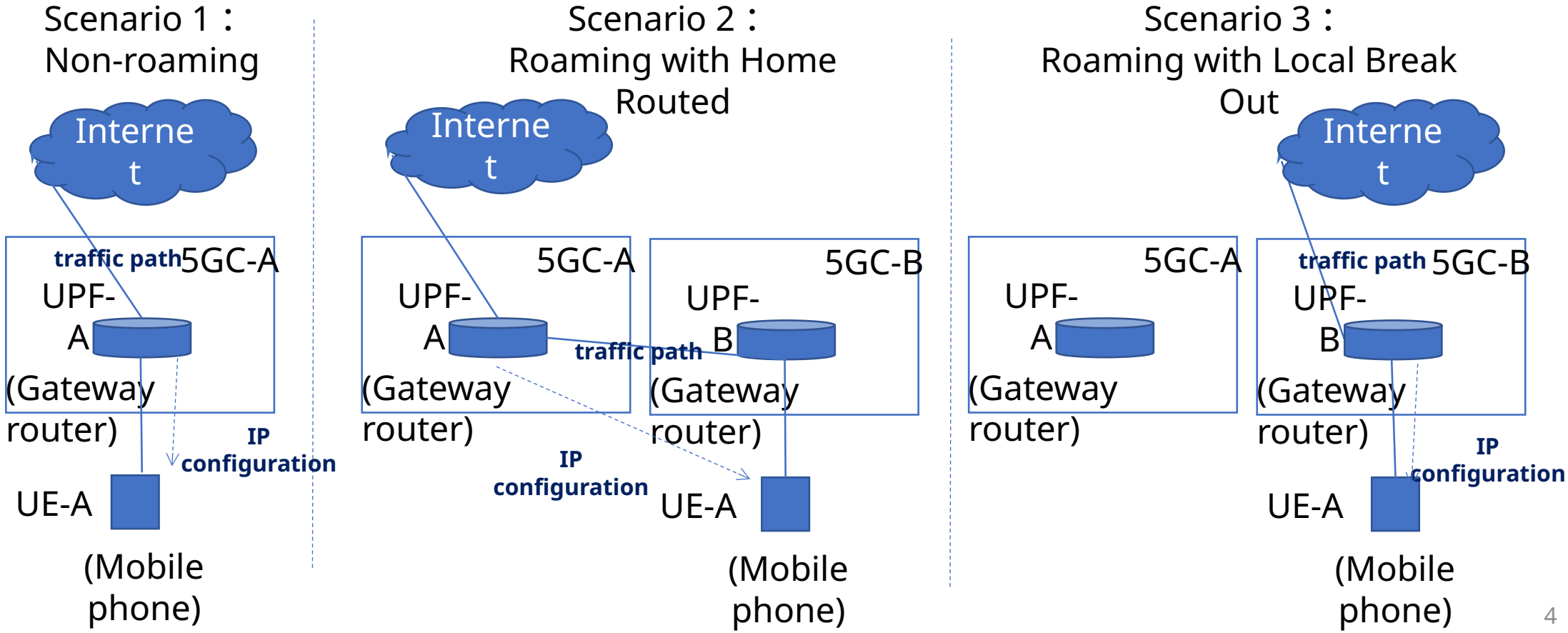
Simpified Terms (1/2)

- For a better understanding, use plain language to describe related terms in 5G systems, focusing on how things function like IP devices. Some functions are simplified.
- UPF
  - Definition: UPF (User Plane Function) is a critical component in 5G core networks (5GC) that handles user data forwarding and processing.
  - Simplified: Acts as a gateway between 5G devices and external networks (like the internet), including IPv4 address/IPv6 prefix assignment function.
- PDU session
  - Definition: A PDU (Protocol Data Unit) Session is the logical connection between a 5G device (UE) and a data network (e.g., internet, private cloud), enabling end-to-end data transmission.
  - Simplified: It’ the context of the connection. For example, If the PDU session type is IPv6, UPF assigns IPv6 prefixes to UE and UE using IPv6 to access Internet.



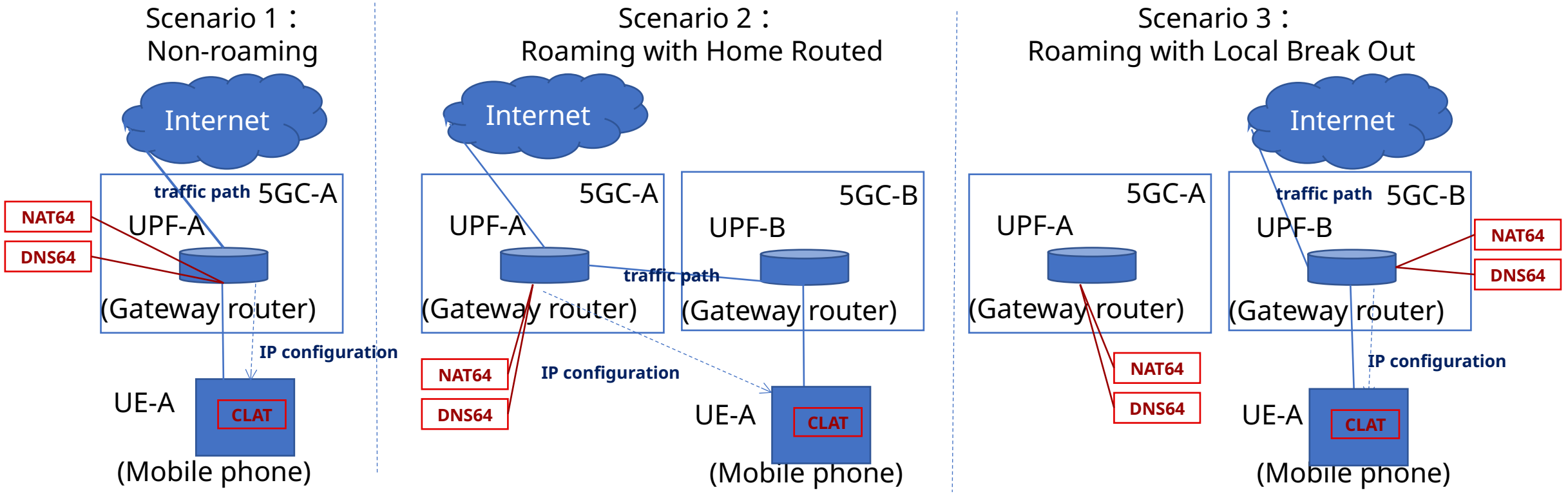
Simpified Terms (2/2)

- Roaming
  - Definition: Roaming allows a 5G device (UE) to connect to a visited network (different from its home network) while maintaining seamless service.
  - Simplified: 3 scenarios as shown below (For example, UE-A connect to home network 5GC-A, get IP configuration from home network 5GC-A, and access internet through 5GC-A.)



5GS IPv6-only Architecture on User Plane

- The following figures show the architecture of each scenarios.



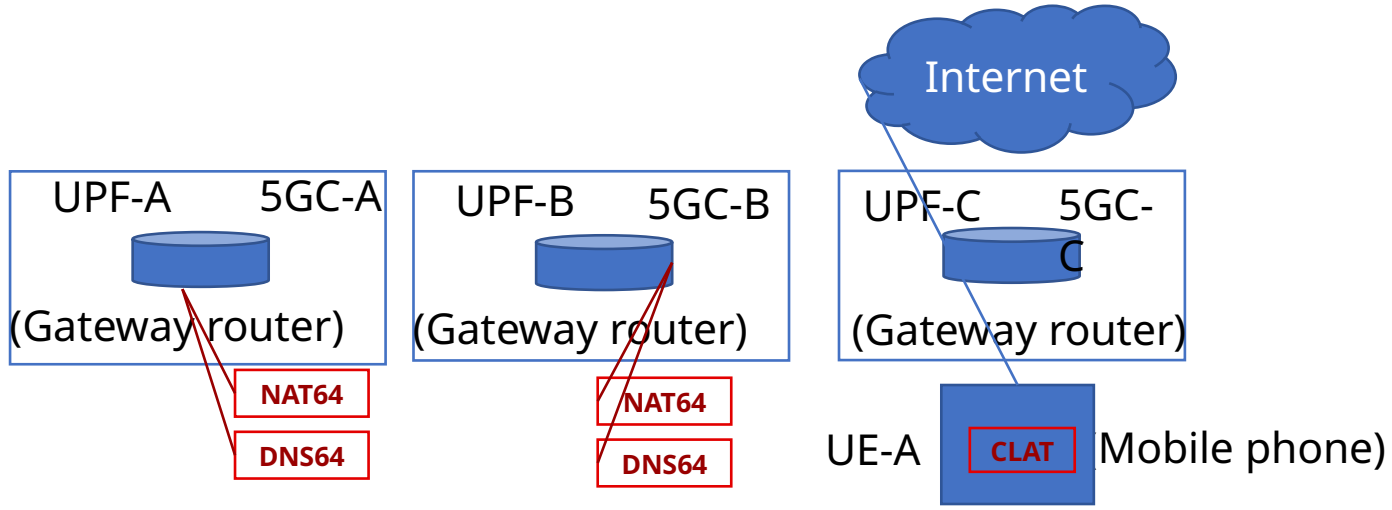
- The following table summarizes 5GC's network capabilities.

Scenarios	Non-roaming	Roaming with Home Routed	roaming with Local Braak Out
UE	CLAT	CLAT	CLAT
Home Network	NAT64, DNS64	NAT64, DNS64	NAT64, DNS64
Visited	\	\	NAT64, DNS64

Deployment Challenges (1/3)

- Roaming Challenge
  - Based on our practices, for large-size mobile network operators, it's very difficult for operators to deploy IPv6-only capabilities across the whole network at once. There is a transition period that the IPv6-only capability is deployed gradually.
  - No NAT64 and DNS64 functions in 5GC-C, some IPv4 service can't work.

Scenario 3：
Roaming with Local Break Out



Deployment Challenges (2/3)

- UE Challenge
  - Regarding UE challenge, a significant number of terminals have not enabled CLAT functionality. The vast majority of Android terminals support and have enabled the CLAT functionality.
  - Most new terminals like smart watch do not support this feature.
  - Moreover, Apple's iOS in China does not enable CLAT functionality. But it does support that function.
- UP Layer Challenge
  - When IPv6-only users access IPv4 sites, the actual address they reach is generated by the DNS64 server, which combines a special IPv6 prefix with the IPv4 site address to form an IPv6 address. Existing layer 3&layer 4 content billing rules based on IPv4 addresses will no longer be effective and will need to be adjusted to accommodate the IPv6 addresses formed by DNS64.

Deployment Challenges (3/3)

- DNS64 Configuration Challenge
  - After enabling the DNS64 functionality, there is an increase in the processing load due to the additional handling of IPv6 queries and the DNS64 conversion, which consumes some device performance. The extent of this performance demand increase depends on the scale of IPv6 queries.
  - Once the DNS64 functionality is enabled, DNS resolution requests from both IPv6-only and dual-stack users will be processed by the DNS64 server. Even IPv4 resolution requests from dual-stack users will be treated as if they were from IPv6-only users, which place a significant load pressure on the DNS server. This may futher impact the service logic of the existing dual-stack users.

Deployment Solutions (1/3)

- For Roaming , UE, and DNS64 challenges , A viable solution direction involves equipping networks with the functionality to allocate IPv6-only environments for IPv6-only users.

- IMEI Configuration at Network Side.
  - One solution is to enhance the core network's capability to configure IP addresses and DNS server addresses based on IMEI number ranges.
  - The IMEI is a unique sequence of 14 to 15 digits assigned to each mobile phone. It serves as a device identification number, enabling service providers to recognize the phone within the network.
  - The primary purpose of the IMEI is to uniquely identify each device, allowing the network to determine whether the UE supports CLAT functionality. By configuring a white list of IMEIs that support CLAT functionality in the network, the network can assign an IPv6-only environment to UEs listed in the white list.
  - Not in the scope of IETF

Deployment Solutions (2/3)

- Option 108
  - One possible solution is to use the option108 [RFC 8925] method, allowing UE to choose whether to join the IPv6-only environment.
  - Additionally, a method for configuring DNS64 server addresses needs to be considered.
  - However, in practical deployments, core network support for DHCPv4 functionality is optional and may not be applicable to all networks.

Deployment Solutions (3/3)

- Another possible solution is to transmit Pref64 and DNS64 address information through the RA option.
  - In 5G systems, RA is used to advertise IPv6 prefixes in the SLAAC, which is a mandatory functionality. Transmitting this information through RA is also a favorable option.
  - Currently, the IETF has produced two RFCs, namely [RFC 8106] and [RFC 8781]. In practical implementations, the mobile core network supporting IPv6-only environments (IPv6-only mode) should include these two options in the RA messages. Upon receiving this message, the UE can abandon the IPv4 interface and operate in IPv6-only mode.
  - In this solution, the core network does not need to be aware of the protocol stack ultimately used by UE.

Next Steps

- Solicit feedbacks and comments

- Develop the solution based on RFC 8106 and RFC 8781
  - RFC 8106 specifies IPv6 Router Advertisement (RA) options (called "**DNS RA options**") to allow IPv6 routers to advertise a list of DNS Recursive Server Addresses and a DNS Search List to IPv6 hosts.
  - RFC 8781 specifies a **Neighbor Discovery option** to be used in Router Advertisements (RAs) to communicate **prefixes** of Network Address and Protocol Translation from IPv6 clients to IPv4 servers (**NAT64**) to hosts.
  - **Using RA to deliver PREF64 and DNS64 address, and UEs shall be prioritized in determining attachment to IPv6-only networks.**

Thank You !