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Network based Bonding solution for Hybrid Access
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Abstract

In order to address increasing bandwidth demands, operators are considering bundling of multiple heterogeneous access networks (Hybrid access) for residential and enterprise customers. This document describes a solution for Hybrid access and covers the use case scenarios.

Requirements Language

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in RFC 2119 [RFC2119].

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1. Introduction

To address the increasing demand of bandwidth by residential and enterprise customers, operators are looking for alternatives that can avoid rebuilding of the existing fixed access networks.

In Hybrid Access network, a Customer Premise Equipment (CPE) is connected to heterogeneous access networks (e.g. DSL, LTE etc) simultaneously. Traffic is distributed in flexible manner over these heterogeneous links thus increasing the bandwidth capacity of a residential or an enterprise customer.

This document describes a solution to implement the network based bonding Hybrid Access architecture. The solution is generic enough that it is applicable to fixed as well mobile nodes with multiple Access technologies.

2. Terminology

All mobility related terms are to be interpreted as defined in [RFC5213] and [RFC5844]. Additionally, this document uses the following terms

IFOM   IP flow mobility

NB-IFOM Network based IFOM

ePDG   Evolved Packet Data Gateway (defined in 3GPP [24.302])

RR   Routing Rule

HAG   Hybrid Access Gateway

PcRF   Policy and Charging Rules Function

NBF   Network based Bonding Function

MCP   Multi-path conversion point (defined in [NAMPTCP])

3. Reference Architecture

```
      +----+                   ------
      |    |                /          \
      |HOST|     +-----+   |  Wireless  +-----\+-----+
      |    +-----+     | +-+    3G/4G   |      |     |       *****
      +----+ Wireless  +-+  \          /       |     |     **     **
                 |     |       ------          |     |    *         *
      +----+     | CPE |                       | HAG +---*  Internet *
      |    |     |     |       ------          |     |    *         *
      |HOST+-----+     +-+  /          \       |     |     **     **
      |    |Wired|     | +-+            |      |     |       *****
      +----+     +-----+   |    Fixed   +-----/+-----+
                            \          /
                               ------
```

Figure 1 Network based bonding Hybrid Access Architecture

A CPE with HAG Figure 1 shows the network based bonding hybrid access architecture. In this architecture, HAG with network bonding function is deployed at the remote side of the CPE. The HAG receives the downstream traffic from internet and can apply the policies to distribute downstream traffic towards the CPE over available paths.

An in-band control protocol between the CPE and the HAG MAY be used to negotiate the traffic distribution policies for uplink traffic.

However, there SHOULD be flexibility to download the traffic distribution policies OUT-of-band.

Traffic distribution policies on CPE and HAG can have independent packet-based behavior.

Operators can have flexibility to distribute flows over multiple paths or associate affinity of flow to a particular access type. Traffic policies can also be applied taking into account the access networks link status such as latency, state etc.

Operator can also apply policy to fill one access link first before utilizing other (MAX-FILL). Affinity to one access MAY be due to cost or application characteristics. In this case the distribution of traffic is adjusted dynamically based on the load.

Behavior to adjust on moving around flows or packet is a matter of local policy.

4. Network Based Bonding Solution Overview

4.1. Separate BNG and PGW

```
       <--------Fixed Path-----> | <----- PMIPv6/GTP ---->|

                       +------+                 +------+

                       | AAA  |                 | PCRF |

                        +------+                 +------+
                           |                         |
                           |                         |
   +---+      _----_     +------+     _----_     +------+     ****
   |   |    _(Fixed )_   |      |   _(      )_   | HAG  |   **    **
   |CPE|<==(  Access  )==| BNG  |==( Operator )==|(NBF/ |==*Internet*
   +---+    (_      _)   |      |   (_Network_)  | PGW) |   **    **
      ^       '----'     +------+     '----'     +------+     ****
      |         DSL Access       PMIPv6/GTP Tunnel   ^
      |                                              |
      |                                              |
      |                                              |
      |                 Non-3GPP access              |
      |       ===================================    |
      |                  3GPP Access                 |
      |                +----+                        |
      |         +------|MME |----+                   |
      |         |      +----+    |                   |
      |         |                |                   |
      | S1-AP   |                | S11               |
      |         |                |                   |
      |       +---+           +-----+   S5-c         |
      +=======|eNB|============| SGW |===============+
              +---+   S1-u     +-----+   S5-u
                   <----GTP----> | <---PMIPV6/GTP--->|
```

Figure 2 Hybrid access service in Fixed mobile convergence

In Figure 2, CPE (either home or enterprise) is connected to internet via fixed access network using DSL as well as wireless access network using 4G cellular network.

The fixed access network BNG is connected to the PGW using 3GPP s2b reference point [TS23401]. The 4G cellular network is connected to the same PGW using S5 reference point (GPRS Tunneling Protocol (GTP) or Proxy Mobile IPV6 (PMIPV6) [RFC5213]) as specified by the 3GPP system architecture [TS23401].

The 3GPP as well non-3GPP access is bonded in CPE and the HAG which consist of NBF and PGW function. The bonding at HAG is achieved by allocating the same "IP address" when LTE access is setup on s5 and fixed (DSL) access over s2b.

The packet distribution policies applied to the bonded session on the HAG and CPE. Policies applied on HAG helps steering downlink traffic on specific access type or distribute percentage of traffic across both access types on per flow basis or per packet basis. Similarly policies applied CPE helps steering uplink traffic on specific access type or distribute percentage of traffic on per flow basis or per packet basis.

4.2. Integrated BNG and SGW/PGW

```
        <----------------Fixed Path-------------->

                                 +-------+    +-------+

                                 | AAA  |     | PCRF |

                                  +-------+   +-------+
                                     |---------- |
                                                 |
   +---+      _----_     +---+     _----_     +-------+     ****
   |CPE|    _(Fixed )_   |   |   _(      )_   | HAG  |   **    **
   |   |<==(  Access  )==|SN |==( Operator )==|(S/PGW|==*Internet*
   +---+    (_      _)   |   |   (_Network_)  | BNG) |   **    **
      ^       '----'     +---+     '----'     +-------+     ****
      |    DSL Access         PMIPv6/GTP Tunnel
      |                                          ^ ^
      |                 Non-3GPP access          | |
```

```
      |       =================================  | |
      |                  3GPP Access             | |
      |                +-----+                   | |
      |         +------|MME |--------------------+ |
      |         |      +-----+      S11-c          |
      |         | S1-AP                            |
      |         |                                  |
      |       +---+                                |
      +=======|eNB|================================+
              +---+               S1-u
                      <------------GTP------------>
```

Figure 3 Integrated BNG,SGW,PGW with HAG

In Figure 3 , CPE is connected to internet through HAG by fixed and wireless access. HAG consist of BNG,SGW/PGW and NBF function.

HAG performs address assignment for all access types and acts as IP anchor point for IP services.

5. HAG Function

5.1. Address Assignment

```
         ========            ::::::::            =======

           CPE               LTE/DSL              HAG

         ========            ::::::::            =======
```

5.1.1. Separate BNG and PGW

Following are steps for address allocation when BNG and PGW are separate. HAG in this case performs the NBF and PGW function.

```
  [...CPE obtains LTE WAN IF address "A" during Pdp from HAG...]

     (...CPE performs LTE attach for IMSI "X" APN "Y"...)

     (...HAG allocates address "A" from APN.............)



  [...CPE obtains DSL WAN IF address "A" during PPPoE from HAG...]
```

```
(...CPE begins the PPPoE setup with BNG...................)

(...BNG authenticates the CPE ............................)

(...BNG receives all the 3GPP attributes from AAA server...)

(...BNG signals on s2b to HAG for address allocation.......)

(...HAG receives the s2b attach for APN "Y" with same IMSI.)

(...HAG finds session for IMSI "X" in APN "Y" RAT=LTE......)

(...HAG bonds the LTE session with s2b session.............)

(...HAG returns address "A" in S2b response to BNG.........)

(...BNG stitches the PPPoE session with s2b session .......)

(...BNG returns the address "A" in PPPoE/DHCP to CPE.......)
```

HAG performs Address assignment for all access type which acts as anchor point for IP services.

APN "Y" on HAG is configured with property of "bonding" so that it can accept request from another access type for the same IMSI within same APN for same Pdp type. This helps in bonding the session with another access type session instead of treating it as handover.

BNG performs authentication of CPE. As part of authentication, it also receives the 3GPP attributes like IMSI, APN and HAG information from AAA server. It uses (3GPP) S2b reference point in [TS23402], specified by the 3GPP system architecture to get IP address from HAG and stitches the fixed access (PPPoE/IPoE) session with the s2b session both in control plane and data-plane.

The CPE remains unchanged as it uses standard method of IP address management for IPv4 and IPv6, on LTE link as well as DSL link.

5.1.2. Integrated BNG and SGW/PGW

Following are the steps for address allocation when BNG, SGW and PGW function is integrated along with the HAG function

[...CPE obtains LTE WAN IF address "A" during Pdp from PGW/HAG...]

(...CPE performs LTE attach for IMSI "X" APN "Y"...)

(...HAG allocates address "A" from APN............)

[...CPE obtains DSL WAN IF address "A" during PPPoE from BNG/HAG..]

(...CPE begins the PPPoE setup with on BNG................)

(...BNG authenticates the CPE ....)

(...BNG receives all the 3GPP attributes from AAA server...)

(...BNG/HAG finds session for IMSI "X" in APN "Y" RAT=LTE..)

(...BNG bonds the PPPoE session with LTE session..........)

(...BNG returns the address "A" in PPPoE/DHCP to CPE.......)

Address assignment is done in the HAG for all access type which acts as anchor point for IP services.

APN "Y" on HAG is configured with property of "bonding" so that it can accept request from another access type for the same IMSI within same APN for same Pdp type. This helps in bonding the session with another access type.

BNG performs authentication of CPE. As part of authentication, it also receives the 3GPP attributes like IMSI, APN and PGW information from AAA server. BNG detects that the PGW is local and hence internally bonds the fixed (PPPoE/IPoE) session with the LTE session with the same IMSI and APN. As part of bonding it uses the same IP allocated for the LTE session and sends back in PPPoE response or waits for DHCP to request for the address in the DHCP response. Traffic distribution policies are applied to the bonded LTE and fixed (PPPoE/IPoE) session to distribute the traffic.

The CPE remains unchanged as it uses standard method of IP address management for IPv4 and IPv6, on LTE link as well as DSL link.

5.2. Setup and Tunnel Management

There is no extra tunnel apart from the link tunnels representing each access used in this solution.

Any link can be setup first. The link that sets up access tunnel first gets the IP address from HAG. The link which comes later is bonded in HAG with the control plane to the existing access tunnel and the same IP address is returned to the later tunnel setup.

BNG stitches the fixed (PPPoE/IPoE) tunnel to the s2b tunnel setup towards the HAG. As part of it, it maps the setup and tear down event of the fixed (PPPoE/IPoE) tunnel to the s2b tunnel and vice versa.

5.3. Traffic distribution policies

As mentioned in earlier section, traffic distribution policies for upstream traffic is applied at CPE where as the downstream policies are applied at HAG. Given that single IP is allocated to all access type in this solution, it greatly helps to do flow mobility within the accesses.

Traffic distribution can be done on per flow basis, per MP-TCP sub-flow basis or on per packet. Flow based traffic distribution avoids out-of-order packets resulting out of differential latencies on each access tunnel and doesn't require buffering resources at the CPE or HAG to re-order the packets.

Policies applied in CPE can be downloaded out-of-band using ANDSF mechanism. Some CPEs are capable of sending initial uplink traffic on access type using random hashing but are able to move the flow to the access type chosen by network for the downlink traffic of that flow. Such CPEs need zero to minimal traffic policy configuration.

Traffic distribution policies applied at HAG for downlink traffic distribution can help in distributing flows or packets using hashing.

Traffic policies MUST have the flexibility to configure the amount of percentage of traffic to be steered over a given access type. This allows addressing the use case where operator MAY want to send a particular type of traffic over a specific access type (Video over DSL). In this case a video rule with affinity of DSL access can be set to steer 100 percent of traffic over DSL link whereas traffic matching any-any rule can be set to steer 50% over DSL and 50 % over LTE.

Traffic policies MUST allow asymmetric affinity association of access type for upstream and downstream traffic which allows splitting of a flow in upstream and downstream direction. Applying

such polices operators can use LTE for uplink where as fixed (DSL) for downlink. Studies of such configuration have shown application performance improvement over use same access for an application.

For the use case where a desired access link bandwidth is filled first (MAX-FILL) and use of second link is for the bandwidth overflow, one can use flow based or packet based approach for traffic distribution. The desirability of preferred access can be due to cheap access path or link characteristics for the given application.

To fulfill this requirement, two rate Three color marker (trTCM) can be used. Each access link uses token buckets to meter the packets as per configuration both at CPE and the HAG. Colored based policy is applied at CPE and HAG to steer packets to an access based on color. For ex. Green packets are steered to DSL if that is the preferred access, whereas yellow packets are steered over LTE access.

If flow based distribution is used, then on reaching certain thresholds there MUST be flexibility to move the flows from preferred access (say DSL) to another (LTE) by changing the percentage distribution. However, moving of FAT flows MAY result in under utilization of preferred access link. Similarly once the threshold drops, the traffic can be move back to preferred access by reverting the percentage distribution.

To avoid FAT flow distribution issues, packet based traffic distribution can be used to fully utilize the preferred access. Packets sent over different access for the same flow can reach out-of-order at the receiving end, due to differential transport latencies. Hence receiving end needs buffering and re-ordering capabilities to deliver flow packets correctly to an application.

5.4. Path Management

This solution relies of existing mechanism of Path management for wireless (LTE) and fixed (PPPoE/IPoE) tunnels.

In case of failure of any access tunnel the traffic MUST be switched to the alternate available access tunnel based on the traffic distribution policies.

5.5. Backward compatibility

This solution does not introduce any new protocol extensions. In this solution the CPE uses ANDSF routing rules to do the traffic distribution downloaded off-band in the CPE.

The policies at the HAG are either local configured or downloaded from PCRF. The existing service (ex. IPTV traffic MUST remain on DSL access) remains untouched by configuring appropriate traffic distribution policies. The exact configuration of those policies is outside the scope of this document.

6. Applicability in Mobile networks

A mobile node (MN) (also called User Equipment UE) connected to a 3GPP access network specified by the 3GPP system architecture [TS23401] is connected over the S5 reference point (Proxy Mobile IPV6 (PMIPV6) [RFC5213] or GPRS Tunneling Protocol (GTP)) to the PGW where the mobile node's session is anchored.

The (3GPP) S2b reference point in [TS23402], specified by the 3GPP system architecture defines a mechanism for allowing the mobile node (MN) attached to an "untrusted" non-3GPP IP access network to securely connect to a 3GPP network and access IP services. In this scenario, the mobile node establishes an IPSec ESP tunnel [RFC4303] to the security gateway called evolved packet data gateway (ePDG) and which in turn establishes a GPRS Tunneling Protocol (GTP) [TS23402] or Proxy Mobile IPV6 (PMIPV6) [RFC5213] tunnel to the packet data gateway (PGW) [TS23402] where the mobile node's session is anchored.

The figure below shows the hybrid access figure where the mobile node is connected to 3GPP and non-3GPP access simultaneously getting access to IP services via a PGW.

```
      <---------- IKEv2/IPsec ------> | <------ PMIPv6/GTP ----->|

                       +------------+
                       |    ePDG    |
                       | +--------+ |
   +---+     _----_    | | IPsec  | |    _----_    +-----+    ****
   |MN |   _(      )_  | | Module | |  _(      )_  | HAG/|  **    **
   |   |<=( Internet )=| +--------+ |=( Operator )=|(PGW)|-*Internet*
   +---+   (_      _)  |     :      |  (_Network_) +-----+  **    **
      ^      '----'    | +--------+ |    '----'        ^      ****
      |    IPsec Tunnel| | GTPv2  | |PMIPv6/GTP Tunnel |
      |                | |  MAG   | |                  |
      |                | +--------+ |                  |
      |                +------------+                  |
      |                 Non-3GPP access                |
      |       ======================================= |
      |                  3GPP Access                   |
      |                +----+                          |
      |         +------|MME |----+                     |
      |         |      +----+    |                     |
      |         |                |                     |
      | S1-AP   |                | S11                 |
      |         |                |                     |
      |       +---+            +-----+   S5-c          |
      +=======|eNB|============| SGW |=================+
              +---+   S1-u     +-----+   S5-u
               <------GTP-------> | <---PMIPV6/GTP--->|
```

Figure 4 Hybrid access service in Mobile network

In the hybrid access architecture, an User equipment (UE) is connected to multiple access technology at the same time. It MAY connect to same network or different IP network based on the operator service. A mobile node with Third Generation Partnership Project (3GPP) access technology such as LTE, UMTS and non-3GPP access such as WIFI having simultaneous network connections is a use case of hybrid access in mobile networks.

As shown in Figure 4, the LTE access is bonded with the WIFI access and the same IP address is allocated on s2b as well as s5 3gpp reference point. As discussed above, traffic distribution policies can be applied to steer traffic over specific access type or distribute over both access type to increase the bandwidth for the mobile node.

In some mobile networks, WIFI is preferred access since it's cheap, in that case policies described in MAX-FILL can be applied.

In some mobile networks, mobile nodes are configured to prefer WIFI access as local break out policy. However it's been observed that if mobile node has LTE access as well WIFI access available and if the mobile node connects to WIFI access over the s2b reference point to the same PGW, the PGW treats it as 3GPP to non-3GPP access handover and disconnecting the LTE access. But since mobile node is configured to be always connected over LTE access, mobile node reconnects over LTE and the PGW treats it as non-3GPP to 3GPP access handover disconnecting the WIFI access. This results in ping-pong effect. Since both accesses are simultaneously connected, in this solution, it helps in addressing the ping-pong issue as well.

7. Inter-working with MP-TCP

When used flow based hashing, it is possible that a FAT flow may cause to over congest the access link. To address FAT flow issues operator can deploy a MCP with the NBF. Operator in that case can apply policy to ensure the FAT flow traffic is split among small multi-path flows which can be seamlessly moved between the access types based on traffic distribution policies.

Inter-working helps operators in using MP-TCP for selective traffic thus ensuring effective utilization of buffering resources both at CPE as well as at MCP.

8. Security Considerations

The security considerations applicable while deploying the access types independently remains same while deploying network based bonding hybrid access architecture. This specification does not introduce any new security vulnerabilities.

9. IANA considerations

10. References

10.1. Normative References

[RFC2119] Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels", BCP 14, RFC 2119, March 1997.

[RFC4303] Kent, S., "IP Encapsulating Security Payload (ESP)", RFC 4303, December 2005.

[24.008] 3GPP, "Technical specification Group Core Network and Terminals: Mobile radio interface Layer 3 specification; Core network protocols; Stage 3"

[24.301] 3GPP, "Technical specification Group Core Network and Terminals: Non-Access-Stratum (NAS) protocol for Evolved Packet System (EPS); Stage 3"

[NAMPTCP] M.Bouchadair et al. "draft-nam-mptcp-deployment-considerations-00", (work in progress), October 2016

10.2. Informative References

[RFC5213] Gundavelli, S., Leung, K., Devarapalli, V.,Chowdhury, K., and B. Patil, "Proxy Mobile IPv6", RFC 5213, August 2008.

[RFC5844] Wakikawa, R. and S. Gundavelli, "IPv4 Support for Proxy Mobile IPv6", RFC 5844, May 2010.

[TS23402] 3GPP, "Architecture enhancements for non-3GPP accesses", .

[TS23401] 3GPP, General Packet Radio Service (GPRS) enhancements for Evolved Universal Terrestrial Radio Access Network (E-UTRAN) access.

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