Optimized Traffic Breakout and Mobility Support for WLAN and Cellular Converging Network

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Abstract. In order to cope with the traffic exploding, operators are looking for offloading solutions which can efficiently offload high-volume Internet traffic from not only mobile access but also mobile core network. WLAN requires no expensive network planning and leverages unlicensed spectrum to add capacity. To expand the reach of revenue-generating services and applications, operators can make use of already-existing WLAN networks. The paper presents a new product concept of Wireless Access Broker (WAB) as well as the innovation solution on how to provide network-based IP flow mobility support and Internet traffic breakout. In contrast with current solutions, this new solution enables the legacy UE to support selective IP flow offloading to the WLAN network. Unlike the IFOM solution defined in 3GPP, our solution does not require the UE to install DSMIPv6 stack and related interacting module. Serving as a breakout point, WAB enables the Internet traffic directly bypass through the fixed access network while bringing no effect on other network elements.

Keywords: WLAN · Convergence · Selective IP flow mobility · Internet breakout

1 Introduction

Due to the ever growing mobile data (including mobile Internet) in the network, the operators are looking for offloading solutions which can efficiently offload high-volume Internet traffic from not only mobile access but also mobile core network.

Wi-Fi has provided tangible data offload benefits to its main proponents, which has helped offload the growth in mobile data traffic from the radio access network at low cost. The technology can also offer an improved user experience, through faster, less congested connectivity and improved indoor coverage [1]. Major operators (AT&T, Verizon, CT, CMCC. etc.) are starting to explore integrated cellular-WLAN solutions. However, the major challenge for operators is how to integrate WLAN into operator's network and maintain the services continuity while the UE moving between the cellular and WLAN network [12].

This paper presents a new product concept of Wireless Access Broker (WAB) as well as the innovation solution on how to construct a telecom WLAN network in operator's network. WAB is designated for the purpose of integrating WLAN into

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operator's network to extend network coverage, add Wi-Fi mobility to the network, and also offload cellular traffic from both mobile access network and mobile core network.

The remainder of this paper is organized as follows. Section 2 introduces some related research and standardization activities in the area of WLAN & 3G/LTE network interworking, especially on the handover and IP flow mobility support. A brief introduction of WAB is presented in Sect. 3. Enhanced IP flow mobility solution and optimized upstream traffic breakout mechanism are provided in Sects. 4 and 5 respectively. Section 6 gives the performance analysis of our approach, followed by the conclusion Sect. 7.

2 Related Work

The 3rd Generation Partnership Project (3GPP) standard is specifying architectures for the WLAN and 3GPP networks interworking [2–4]. The interworking between WLAN and 3GPP systems is provided by connecting WLAN to the EPS through an ePDG (evolved Packet Data Gateway) or directly by connecting the UE through WLAN to the P-GW as depicted in the Fig. 1 below

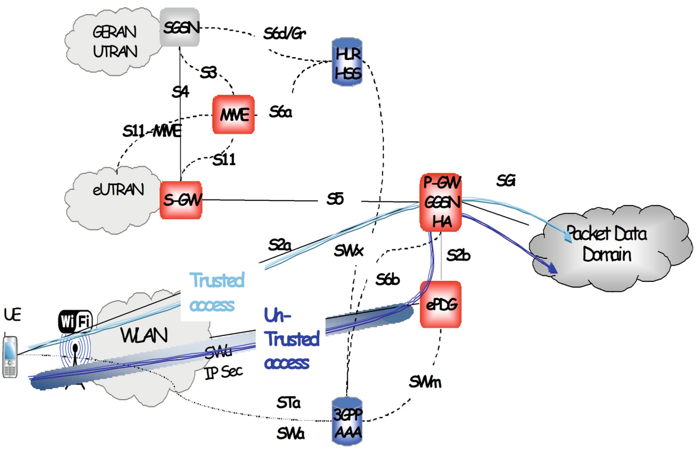


Fig. 1. WLAN/3GPP interworking architecture

Currently, 3GPP is also standardizing support for IP flow mobility and seamless WLAN offload [8] building the solution on Dual-stack Mobile IPv6 [6], multi-homing [7], and flow-based mobility handling [10] using traffic selectors [11]. The goal is to provide mobile data offload support for LTE networks allowing multimode terminals to move certain flows to WLAN hotspots when overlapping coverage is available in the proximity of the terminal.

DSMIPv6 [6] is used to provide mobility between 3GPP and I-WLAN with service continuity e.g. IP address preservation for the UE. The Home Agent may be co-located with GGSN or PDG and terminates the DSMIPv6 signaling within the network. This signaling is transparent to GGSN and PDG. The UE needs to be enhanced by a DSMIPv6 Client to enable the DSMIPv6 based signaling towards the Home Agent. The UE has to initiate DSMIPv6 specific signaling towards the Home Agent to create a binding in the HA and to register its care-of-address. This will, on one side, establish the DSMIPv6 tunnel between the HA and the UE, and on the other side, ensure that mobile terminated traffic is routed by the HA towards the correct access network.

Since the UE registers to the HA and builds DSMIPv6 tunnel to it, all the traffic from UE need to be transported to the HA through this tunnel no matter which access network the UE is connecting. Unlike the MIPv4 protocol [5], there is no other mobility anchor (FA, Foreign Agent) to enable the upstream traffic breakout. For the large amount of Internet or other 3rd party application services, this solution is not efficient enough due to the aggregation point locating at the mobile core network.

IP Flow Mobility (IFOM) defined in 3GPP Rel-10 [4] introduces the concept of treating IP flows individually within a PDN connection. It specifies that the mobility of a PDN connection is handled per IP flow. This means within a PDN connection the following operations can be performed:

(1) Establishment of IP flows over multiple accesses.
(2) Selective removal of IP flows from an access system.
(3) Selective transfer of IP flows between access systems.
(4) Transfer of all IP flows from a certain access system.

This requires some DSMIPv6 extensions to allow the registration of multiple addresses simultaneously [7]. More specifically, the extensions defined for DSMIPv6 have the capability to register multiple local addresses (i.e., CoAs) to a single permanent address (i.e., HoA), and also the capability to bind different IP flows (i.e., HTTP, Video, VoIP, etc.) to different CoA(Care-of address) or directly to HoA (Home-of address) (Fig. 2).

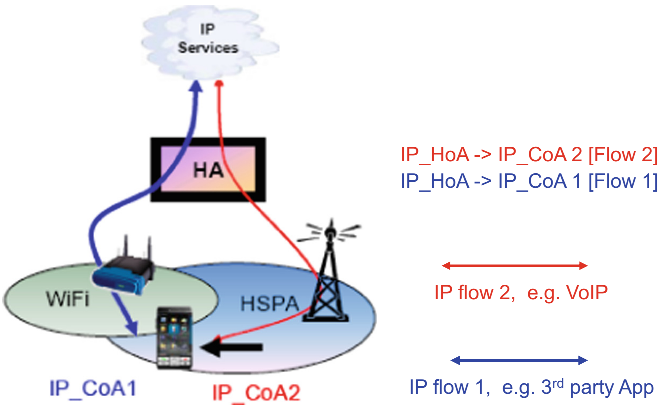


Fig. 2. IFOM solution

3 Wireless Access Broker

The product concept of Wireless Access Broker (WAB, shown in Fig. 3) is proposed to integrate WLAN networks into telecom network and interwork with mobile core network. It relieves cellular network from heavy traffic load while bypassing Internet traffic. In handover scenario, it acts as a mobility anchor and breakout upstream data traffic directly which can efficiently reduce the data flow to the mobile core network.

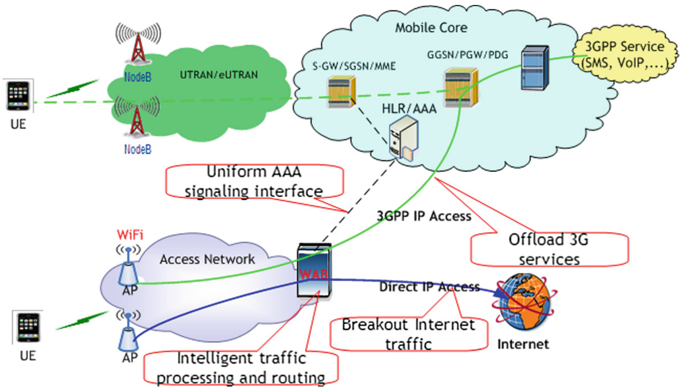


Fig. 3. WAB solution

Providing standard data and signaling interface to cellular network, WAB enables dual mode UE to access 3GPP services through WLAN network. With intelligent traffic processing and routing mechanism, WAB can breakout Internet traffic while bypassing the macro RAN and mobile core. Providing the NAT function, WAB maintains multiple global IP address to setup backhaul to different network domain. UE only obtains a local IP address from WAB, so there is no requirement for UE to maintain different IP address to access different services. WAB can distinguish the different destination of traffic from UE, and routes it to different network domain. Since the traffic is bypassed from WAB, the accounting function is also implemented in the WAB with the signaling interface to the 3GPP core network. Other charging and management functions (e.g. lawful interception) are also supported by WAB for the operation purpose.

Current definition of IFOM requires the UE to support DSMIPv6 stack and other interacting module which may be a hurdle for its deployment. The WAB provides an enhanced mechanism to implement IP flow mobility in cellular & WLAN converging network.

(1) It provides network-based mobility support for IPv4-enabled UE to register its CoAs and routing filter. Through this new mechanism, the legacy UE can support IP flow mobility without any requirements on DSMIPv6 stack and register module.

(2) The mobility anchor in the WAB maintains the CoA address for each UE while the UE only configures one IP on its dual network interfaces.
(3) The mobility anchor in the WAB serves as a pseudo UE to perform HA discovery and binding update. It also interacts with the HA for routing policy transfer.
(4) Serving as a breakout point, WAB enables the Internet traffic breakout through the fixed access network while bringing no effect on other network elements.

In handover scenario, the WAB acts as a mobility anchor and breakout upstream data traffic directly which can efficiently reduce the data flow to the mobile core network. A new routing module in WAB performs package interception and flow control to breakout the upstream Internet traffic. This routing module captures the upstream data package from UE and identifies the real destination address. According to the destination information, WAB decides whether the package is to be encapsulated and transported to mobile core network. If the destination IP address indicates that the package need to be delivered to the Internet or other 3rd party applications domain, this routing module in WAB directly bypasses the package without any tunnel encapsulation through the fixed wireline network.

4 Enhanced Mobility Mechanism for Selective IP Flow

3GPP/WLAN mobility using DSMIP as per 3GPP Rel-8 provides a solution for seamless WLAN offload where all traffic is offloaded to the WLAN. However, it may be desired that in some scenarios only some traffic is moved to the WLAN while other IP flows are maintained over the 3G access. This requires some DSMIPv6 extensions to allow the registration of multiple addresses simultaneously. These protocol extensions, known as IP Flow Mobility (IFOM), are part of 3GPP Rel-10 [4] and introduce the capability to move selective IP traffic – a new dimension in flexibility. This definition of IFOM requires the UE to support a DSMIPv6 stack and related interacting functions which may be a hurdle for its deployment.

To optimize this mobility solution, a mobility anchor is proposed to support the legacy UE with IFOM function. The mobility anchor is located in the WLAN network and help UE to register the CoA and routing filter to the HA/P-GW. The UE only obtains the HoA address from EPS/P-GW when it performs the initial PDN connection establishment through the 3GPP air interface. The conventional UE may configure it on the dual network interfaces. This is called one address on two interfaces. The UE uses the HoA address to access the WLAN network all along since only the HoA address is configured on the Wi-Fi interface of the UE. In contrast with the DSMIPv6 solution defined in Rel.10, our solution does not need to configure one or more CoA addresses for each UE which can significantly save the address resource. Through the WLAN connection procedure, the mobility anchor obtains the HoA/HA address of the UE and performs the HA discovery as well as the DSMIPv6 bootstrapping process substituting for the UE.

When the conventional UE connects to the WLAN and completes the WLAN link establishment with the HoA address obtained cellular network, the mobility anchor serves as a pseudo UE to send BU message which is used to register the CoA and routing filter to the HA/P-GW. The CoA address may be a local address or the IP address of the mobility anchor itself, which can be routed from the HA. The mobility anchor maintains the CoA address for each UE while the UE does not need to configure this IP address. The mobility anchor request the HA to store routing filters so that one or more flows can be associated to a registered CoA. Furthermore, the HA needs to identify individual flows, then it can route a particular flow through a particular access. The work procedure is shown in Fig. 4. The mobility anchor performs the package encapsulate/de-encapsulate function when the traffic arrives.

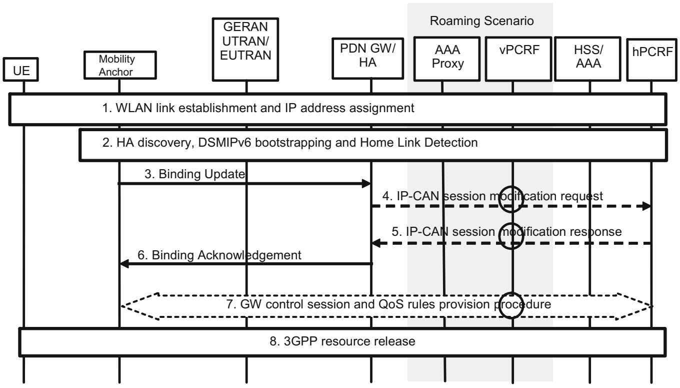


Fig. 4. Work procedure of IFOM support for the legacy UE

This solution can be utilized to enhance the S2c interface in Rel-8 EPS mobility architecture so that it supports this flow level granularity (i.e. flow binding). The IETF extension to DSMIPv6 introduces a new Flow Identification mobility option [9], which is included in the BU message and can be used to distribute routing filters to the recipient of the BU. Using the Flow Identification mobility option, the mobility anchor can bind one or more flows to a CoA while maintaining the reception of other flows on another CoA. Requesting the flow binding can be decided based on local policies within the WLAN network, e.g. link characteristics, types of applications running at the time, etc.

In order to allow the WLAN network elements indicate the HA/P-GW through which access technology PDN connections/IP flows are expected to be routed, inter system routing policies are introduced. Such policies can be defined per APN, per IP flow class under any APN or per IP flow class under a specific APN and can be provided to the UE either through ANDSF [3] or by means of static pre-configuration. The interacting module in the mobility anchor extends DSMIPv6 basic support to allow it to specify policies associated with each binding and even to each flow through individual routing filters. The routing filters are unidirectional and can be different for uplink and downlink traffic. A policy can contain a request for a special treatment of a particular IP flow, e.g. QoS.

We note that there are some concerns about the difference between our method and the Proxy MIP mechanism. We would like to make some clarifications. Firstly, the Proxy MIP is adaptive for the use case that the mobile node makes handover between different access points with one network interface. The PMIP can substitute for the mobile node to de/encapsulate the MIP packets while the mobile node needs to do noting and just keeps the IP address unchanged on the network adapter. In cellular & WLAN converged network, the mobile nodes would have two network interfaces. Basically the mobile nodes would obtain two different IP addresses for accessing the two networks separately. If we use the PMIP mechanism here, the session would be disrupted because the IP address has changed. Secondly, the PMIP is designed for the one interface scenarios. Even with our method that one address is configured on dual interfaces, the PMIP cannot support the selective IP flow mobility. Because the PMIP protocol only supports fully handover between different access points, all the IP flows would be transferred to the destination access point when the handover occurs. Thirdly, the PMIP cannot support the multiple CoAs maintained for one mobile node. So it can not differentiate the service class between multiple IP flows of one mobile node. Our solution help one mobile node to register multiple CoAs which facilitates the differentiation of multiple IP flow classes even these IP flows are over the same the accesses and the same APN manner. The PMIP mechanism cannot support this feature.

5 Optimized Breakout for Upstream Traffic

In current 3GPP defined interworking solution, as dashed line shown in Fig. 5, when the UE accesses to the cellular network and wants to communicate with the correspondent node in the Internet, the destination IP address of the upstream packages is the correspondent node's IP (162.105.203.16). While the UE is roaming to the WLAN network, it obtains a CoA address (172.24.149.166) and notifies the HA of the new binding information. A DSMIPv6 tunnel is built between the UE and the HA and all the upstream packages from the UE are transmitted through the tunnel no matter whether the correspondent node locates in the mobile core network or not. The UE encapsulates the original packages with the destination IP address set as the HA addresses and delivers through the DSMIP tunnel. When the HA receives the upstream packages from the tunnel, it decapsulates the packages and routes the original packages to the correspondent node. For the large amount of Internet or other 3rd party

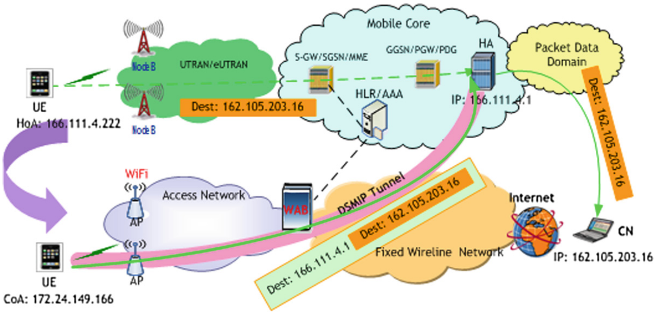


Fig. 5. Current DSMIP mechanism

application services, this solution is not efficient enough due to the aggregation point (HA) locating at the mobile core network.

To optimize this mobility solution, a new routing module is introduced in the WAB which is designated for the purpose of integrating WLAN into operator's network and offloading cellular traffic from cellular network. This routing module performs package interception function and makes en/decapsulation on the packages substituting for the UE. WAB has the capability to identify the destination address of the original data packages transmitted from the legacy UE which does not support DSMIPv6 protocol. It substitutes for the legacy UE to perform MIP signal processing and interworking with HA for the purpose of mobility support. According to the destination information in the upstream package, the WAB decides whether the package is delivered through fixed wireline network directly. If the destination IP address indicates that the correspondent nodes locates in the 3GPP network domain, this routing module will encapsulate the package with DSMIPv6 head and set the HA IP address as the destination address. On the other hand, as the red line shown in Fig. 6, the original package to the correspondent node which locates in the Internet will be offloaded directly by the WAB through the fixed wireline network.

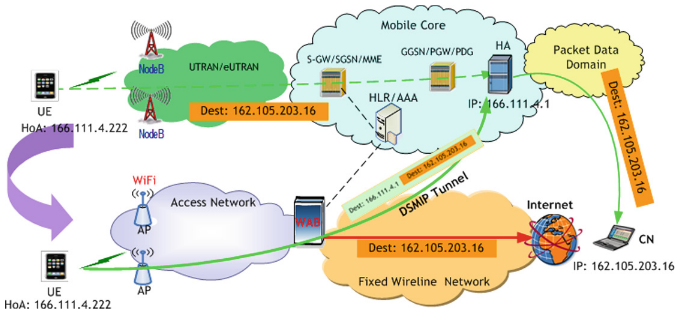


Fig. 6. WAB-based routing mechanism (Color figure online)

With this package interception and traffic processing function, WAB can offload the upstream Internet traffic in mobility scenario which efficiently relieves the traffic load of the mobile core network. As for the downstream traffic, the routing module in the WAB performs the decapsulation accordingly. It provides network-based mobility support for the legacy UE that has not installed DSMIPv6 stack and related interacting modules. Serving as a breakout point, WAB enables the Internet traffic breakout while bringing no effect on other network elements.

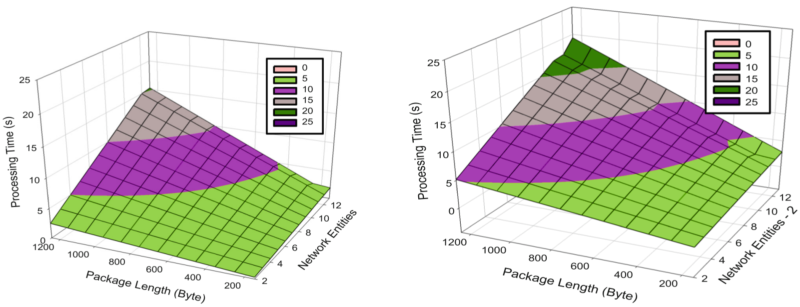
6 Performance Analysis

This section gives some performance analysis on our new approach. In our simulation, we estimate the upstream traffic from the UE and give the contrast result between our approach and 3GPP approach.

We assume that there are 1000 APs (Access Points) in the WLAN network and 10 active UEs under each AP on average. In the simulated scenario, each active UE transmits Internet upstream data with the rate of 100 packages per second, and we suppose that there are at least 2 more network entities (e.g. router, switch, gateway) the upstream packets need to be transmitted through when these packages are transported via the mobile core network than they are offloaded through fixed access network directly. In our assumption, each intermediate network entity is equipped with 1Gbps interface which is used to process the traffic.

For a standard IPv6 package, the package head of IP layer is 40-bytes in length. Since the WAB would encapsulate the DSMIP package head with the original package when transmitting it to the mobile core network, there are 40 bytes more data for each package to be transmitted through the mobile core network than the fixed access network. We investigate the total processing time when the upstream Internet packages are transmitted through two different paths and define it as the transportation cost. In our contrast test, we calculate the total transportation cost under two variable quantities. The one variable quantity is the average package length of UE's upstream traffic. The other factor is the intermediate network entities that the packages are transmitted through.

The two charts below give the simulation result of our WAB-based solution and 3GPP solution respectively (Fig. 7).



WAB Solution 3GPP Solution

Fig. 7. Transportation cost of two solutions

In the above figure of 3GPP solution, it needs to note that the actual amount of network entities is 2 more than the described value in the X axis. In order to contrast the two mechanisms efficiently, we keep the X-axis value aligned in two figures. As we mentioned before, we assume that there are at least 2 more entities the upstream packages need to be transmitted through in the 3GPP mechanism than our mechanism.

Since the routing module in WAB directly bypasses the upstream Internet traffic through the fixed wireline network, our solution can efficiently relieve the cellular network from heavy traffic load. Due to the less intermediate entities and shorter package length, WAB solution also evidently reduces the processing time and network delay as well. The contrast figures show that the transport cost of 3GPP solution is obviously higher than our WAB solution.

7 Conclusion

This paper introduces an efficient routing mechanism to support mobility between cellular network and WLAN network. In contrast with the DSMIPv6 solution, our solution offloads the upstream Internet traffic through the fixed wireline network which can efficiently relieve the cellular network from heavy traffic load. Serving as a mobility anchor, the network-based mobility support is provided by the WAB in the WLAN network. It helps the UE to send BU message which is used to register the CoA and routing filter to the HA/P-GW. Through this new mechanism, the conventional UE can support selective IP flow offloading to the WLAN network, while maintaining connectivity to the same PDN connection via the 3GPP radio interface.

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