Traffic Offloading with Mobility in LTE HeNB Networks

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Abstract

In these years, the traffic is rapidly increasing in mobile communication networks. The increasing traffic seriously consumes the bandwidth of the core network. The 3GPP proposes a series of traffic offloading solutions in the Long Term Evolution-Advanced (LTE-A) system in which part of traffic from the core network is migrated to the Internet. Two traffic offloading methods are designed for the Home eNodeB (HeNB) networks: (1) Local IP Access (LIPA), which provides User Equipments (UEs) with the ability to communicate with other objects (e.g., UEs and servers) located in the same local HeNB network via HeNB without accessing the core network, and (2) Selected IP Traffic Offload at Local Network (SIPTO@LN), which provides UEs with the ability to connect to the Internet via HeNB without going to the core network. Several studies tried to improve 3GPP traffic offloading methods; however, those methods have no or little support of mobility.

In this paper, we propose two methods to offload the traffic in Local HeNB Network (LHN) with better mobility support than existing methods. The first method, Local Access Traffic Offload (LATO), enhances the LIPA function by providing UEs with the ability to hand over into and out of the LHN. The second method, Global Access Traffic Offload (GATO), enhances the SIPTO function by providing UEs with the ability to hand over between the LHNs.

Keywords: LTE-A, HeNB, LHN, Traffic Offload.

1. Introduction

In the LTE-A (*Long Term Evolution-Advanced*) system, various multimedia services generate huge amount of data traffic to the core network [6]. Thus the bandwidth of the core network is rapidly consumed and the traffic is congested in the core network [3]. To solve this problem, 3GPP adopts the traffic offloading technology in its specifications [7] [9]. The offloading technology sets the offloading points to reduce the transmission path or not to pass through the core network by selecting appropriate routes.

In LTE-A networks, the specification [8] introduces the offloading design for *Home eNodeB* (**HeNB**). In this specification the *Local-Gateway* (**L-GW**) in the PDN (*Packet Data Network*) acts as the **P-GW** (*PDN Gateway*) for exchanging the data packets in HeNB networks. In other words, the UE sends a packet to the L-GW for routing to the PDN, and the L-GW decides the route based on whether the packet belongs to the offloading services or not. [11] The offloading services include (1) *Local IP Access* (**LIPA**) service and (2) *Selected IP Traffic Offload at Local Network* (**SIPTO@LN**) service. For example, network printer, local file sharing, and local *Voice over IP* (VoIP) are LIPA services. Web page browsing and on-line video are SIPTO@LN services. The following figure illustrates the architecture of LTE HeNB networks.

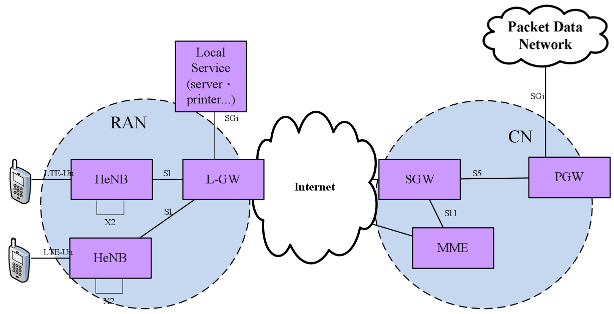

Figure 1. The Architecture of LTE HeNB network.

However, there are some issues in the specifications. First, the L-GW is the gateway for the UE in the HeNB networks, but the P-GW is the gateway for the UE in the macro-cell [10]. Therefore, the UE's PDN connections in the HeNB and that in the macro-cell are different. When the UE moves from a HeNB to a macro-cell, the P-GW instead of the L-GW serves the UE, and the PDN connection between the L-GW and the UE is broken [8]. In this case, the gateway is changed from the L-GW to the P-GW. The UE should be able to connect to the L-GW and the P-GW when the UE moves from the HeNB to the macro-cell. These issues limit the offloading technology to be applied in the mobility cases.

However, in [8], the specification proposes an idea of *Local HeNB Network* (LHN). Multiple HeNBs are *grouped* to an **LHN** to increase the service area of the L-GW. The LHN improves the offloading service area. However, the offloaded traffic is still limited in the service area of the LHN. If the UE moves out of the service area of the LHN, the service will be *broken*. Therefore, the usage of the offloading technology will be significantly improved if the offloading traffic can hand over in/out the LHN.

The rest of this paper is organized as follows. Section 2 introduces the related solutions of the traffic offloading. The proposed LATO and GATO methods are elaborated in Section 3. The effects of the service ratio and handover ratio to the offloading ratio are provides in Section 4. Finally, the conclusion is given in Section 5.

2. The Related Traffic Offloading Solutions

We elaborate the related articles studying the traffic offloading solutions as follows.

[5] adds an element **TFT** (*Traffic Flow Template*) in the HeNB. The TFT classifies the packet to filter the specific traffic for offloading. The following figure demonstrates the network architecture of the TFT mechanism. The TFT is a strategy-based solution.

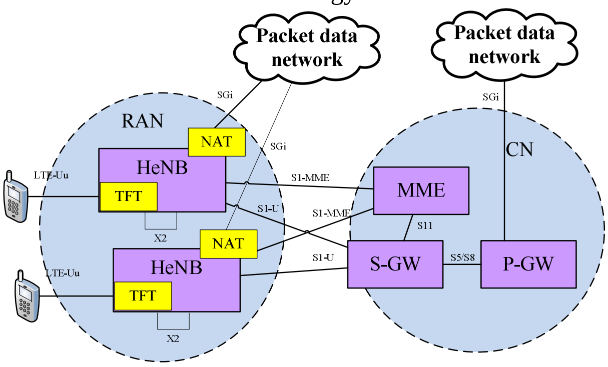

Figure 2. The Network Architecture of the TFT solution.

When the HeNB receives the *first* packet of a service, it classifies this packet by using **TFT**. Based on the classification result, the packet is assigned to an offloading strategy of the service. For local services, the packets are tagged to "**LIPA**", and the rest packets of the session will be served through the same "LIPA" strategy. On the other hand, for the Internet services, the packets are tagged with "**SIPTO**", which are served through the "SIPTO" strategy. Note that the traffic designated to the core-network (e.g., a telecom service) cannot be off-loaded. The packets belonging to the telecom service are tagged as "**core-network**" and are sent to core network without the offloading process on the HeNB.

The "SIPTO" offloading packets are translated by the NAT (*Network Address Translation*) device on the HeNB. The IP/port translation should be design for the case in which the UE moves from the HeNB to another HeNB or a macro eNB.

[4] proposes a design of **NoFs** (*Networks of Femtocells*), which adds an element **LFGW** (*Local Femto Gateway*). The LFGW acts as the local **MME** (*Mobility Management Entity*) to handle the *signaling traffic* and as the **SGW** (*Serving Gateway*) to process the *user data*. The network architecture is illustrated in Figure 3.

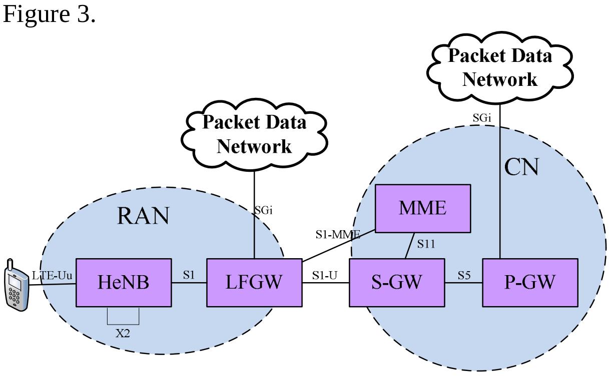

Figure 3. The network of NoF.

By deploying LFGW, both the signaling and the user data are off-loaded. Similar to the design of LHN, LFGW extends the service area from inside a HeNB to inter-HeNBs. Since the LFGW plays the role of the MME, the LFGW should interact with the MME in the core network when the UE moves from the FoNs to a macro eNB (i.e., outside the FoN). However, this article does not design the procedures for the UE moving between the NoF and the macro eNB.

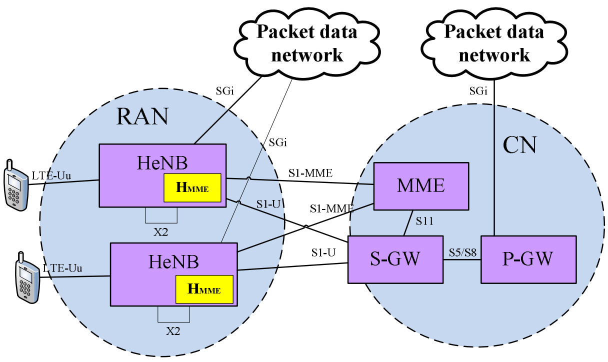

Figure 4. The network architecture of HMME.

[2] proposes an LIPA solution to improve the communication quality of the local VoIP (*Voice over IP*) services. Specifically, the solution adds an $\mathbf{H_{MME}}$ (*Home MME*) module on the HeNB to handling the *signaling message* exchanged between the UE and the HeNB.

In this solution, the HeNB utilizes the TFT to filter the offloading services and then establishes an extra DRB (*Data Radio Bearer*) between the UE and the HeNB for carrying the packets designated to local access. However, in this solution, the H_{MME} sniffs the **IMSI** (*International Mobile Subscriber Identity*) of the UE to obtain the $\mathbf{K_{ASME}}$ key from the HSS (*Home Subscriber Server*). This procedure breaks the security communications and increases the security issues.

The above articles propose the mechanisms and solutions for traffic offloading and improve the performance for local access. However, they have the issues and does not support full *mobility* functions. Thus, this paper proposes a novel method to provide traffic offloading with mobility in HeNB networks

3. System Design

Based on the architecture of LHN, this paper designs that multiple HeNBs are *grouped* as an LHN and connect to an L-GW (*Local Gateway*). The L-GW connects to the LTE core network. The group of HeNB forms a service area which provides *Local Access Traffic Offload* (**LATO**) and *Global Access Traffic Offload* (**GATO**) functions. Note that the mobility support is included in the LATO and GATO methods. The details are elaborated in the following subsections.

3.1. System Design

To support the offloading function with mobility support in the HeNB environments, this paper proposes to add several *lists* in the **HeNB** and **L-GW** to store the parameters for the on-going services. Specifically, this paper adds the *Bearer* List in the HeNB, and the *Bearer* List, the *Service* List and the *IP* List are added in the L-GW. The Bearer list records the applied policy of the bearer, and the Service and IP lists store the rules to filter the service types and UEs.

Since **S1-bearer** utilizes **GTP-U** (*GPRS Tunneling Protocol-User Data*) to carry the user data and GTP-U is not encrypted, the proposed system classifies the packets transmitted on S1 bearer to identify the offloading packets. The offloading point of these packets is the **L-GW**. The L-GW records the offloading information and controls the transmission and recipient for the traffic offloading. The traffic is off-loaded if the traffic is transmitted within an LHN (e.g., the LIPA traffic) or the traffic belongs to a non-QoS-guaranteed Internet service (e.g., the SIPTO traffic).

Based on the modifications, this paper divides the offload traffic into the *Local Access Traffic Offload* (LATO) and *Global Access Traffic Offload* (GATO). LATO modifies the L-GW in the *Radio Access Network* (RAN), and the GATO modifies the HeNB, L-GW and P-GW in the RAN and core network.

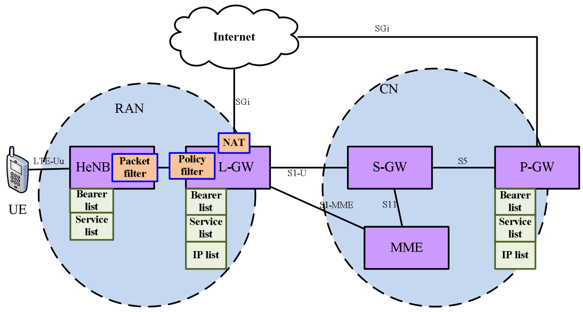

Figure 5. The network architecture of LATO and GATO.

Figure 5 illustrates the proposed system architecture. To classify the packets, this paper proposes to add a *packet filter* on the HeNB, a *policy filter* and a *NAT* on the L-GW.

The packets are classified into four services, namely "**New**", "**LATO**", **GATO**" and **Telecom**". The offloading services and tags are described in Table 1.

Table 1. The Offloading Services and Tags.

Tags	Service
New	When the service is not assigned by the L-GW, the tag of the bearer is assigned to "New" by the HeNB.
LATO	When the L-GW decides to perform LATO, the HeNB is informed to tag the bearer to "LATO".
GATO	When the L-GW decides to perform GATO, the HeNB is informed to tag the bearer to "GATO".
Telecom	When the traffic is sent to the telecom's core network, the HeNB is informed to tag the bearer to "Telecom".

When the L-GW receives a packet without a tag, it starts to perform the packet classification. If the packet is classified as "New", "LATO", "GATO" or "Telecom" the following steps are executed.

Step 1. Record the source IP and destination IP addresses, the S1 bearer TEID, the QoS level, and the HeNB identity.

Step 2. Use the above identities to decide whether the packet should be off-loaded.

Step 3. If "LATO" is decided, the **L-GW** forwards the packet within the LHN. If the "GATO" is decided, the L-GW forwards the packet to the **NAT**.

Step 4. On the other hand, if the "Telecom" is decided, the packet is forwarded to the core network.

The HeNB maintains the bearers and services lists for the UEs that are registered to the HeNB. The HeNB utilizes the Bearer list and Service list to decide whether the service on the bearer should be off-loaded and which strategy should be applied. The L-GW and the P-GW maintains the Bearer list, the Service list and the UEs' IP list. The Bearer list, Service list and IP list provide the offloading information to the L-GW. The parameters of the lists are shown in Table 2 and described as follows.

Table 2. Bearer, Service and IP Lists.

Bearer List	Service List	IP List
PDN address TEID Policy tag Z` level Service	Source IP address Destination IP address Policy tag Uplink TEID Downlink TEID QoS level	IP address HeNB ID IP@NAT

The eNB/HeNB informs the L-GW to set the bearer policy during *handover*, *tracking area update*, *attach procedure* and *request PDN connectivity*. When the eNB/HeNB is requested to build a new bearer, it informs the L-GW to insert the newly created PDN connection into the bearer list. The bearer list records identities including the PDN type/address, TEID, policy tag, QoS (*Quality of Service*) level and service of the payload.

3.2. Operation Procedures of LATO and GATO

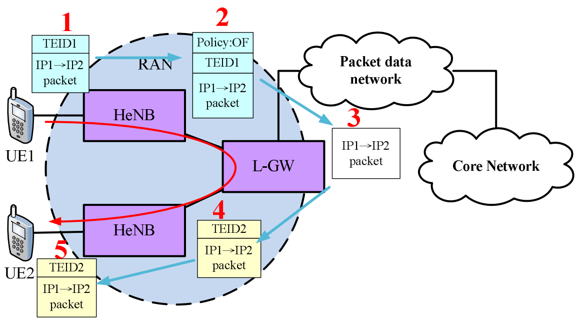

Figure 6. LATO Operations.

When the L-GW decides to perform **LATO** method to the packets, the L-GW removes the original header of the S1 bearer and adds the header for the UL/DL bearer. Then, the L-GW forwards the packet to the HeNB of the target UE based on the DL header of the S1 bearer. The detailed operations of the packet transmission are described as follows.

Step 1. UE sends a packet to the HeNB through the bearer.

Step 2. When the HeNB receives the packet, it changes the header into the S1 header, and the packet filter adds a *policy tag* based on the Bearer list. The packet is forwarded to the L-GW.

Step 3. Upon receipt of the packet, the L-GW processes the packet based on the policy rules.

Step 4. The L-GW classifies that the packet belongs to LATO service and adds the UL/DL header to the bearer based on the *Service list*. Then the packet is forwarded to the HeNB of the target UE.

Step 5. When the HeNB receives the packet from the L-GW, it forwards the packet to the target UE.

According to the above operations, the packet classified to LATO service does not enter the core network and the packet is processes based on the pre-defined policy rules. Note that the operations does not change the service operations to the UE and the core network. The LATO method does not modify the core network. Thus, the transmission will not be dropped when the UE leaves a LHN.

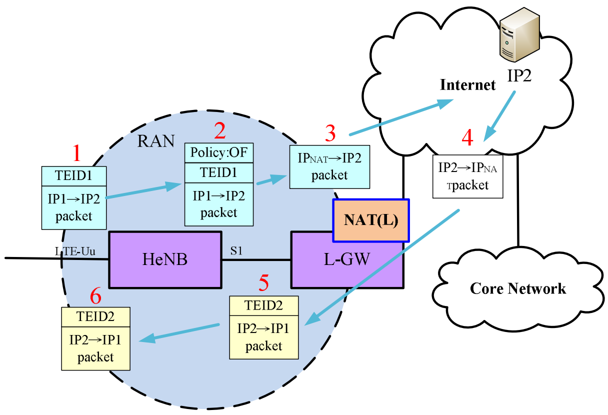

Figure 7. GATO Operations.

When the L-GW decides to perform **GATO** method to the packet incoming from the LHN, the L-GW removes the S1 bearer header and forwards the packet to the NAT. The NAT translates the IP address and then sends the packet to Internet. When the L-GW decides to perform GATO to the packet incoming from Internet, the NAT translates the IP address based on the *IP* list and then the packet is added an S1 header by the L-GW. The packet is forwarded to the HeNB of the target UE. The proposed GATO operations are described as follows.

Step 1. UE sends a packet to the HeNB through the bearer.

Step 2. Upon receipt of the packet, the HeNB changes the header to the S1 bearer header and the packet filter adds the policy tag based on the Bearer list. The packet is forwarded to the L-GW.

Step 3. Upon receipt of the packet, the L-GW processes the packet based on the policy rules. When the L-GW classifies the packet into **GATO** service, it forward the packet to the **NAT** for the IP/port translation. After the translation, the packet is forwarded to Internet.

Step 4. When the L-GW receives a packet incoming from Internet, it request the NAT to perform the IP/port translation. The L-GW forwards the packet to the HeNB based on the translated IP address.

Step 5. The L-GW adds the header for the DL bearer and forwards the packet to the HeNB of the target UE.

Step 6. Upon receipt of the packet sent from the L-GW, the HeNB forwards the packet to the target UE.

According to the above description, the packet does not enter the core network for Internet access. However, the above operations does not include mobility in the offloading scenario. To solve this problem, the P-GW, which is the gateway of user data between the core network and Internet, is proposed to be modified. The P-GW should obtain the records the UE of the LHN, the UE's bearer, and the on-going service. Based on these records, the P-GW can forward the packets designated to the target UE to the L-GW. If the UE moves out of the HeNB, the L-GW forwards the packet to the P-GW and the P-GW sends the packet to the UE.

4. Simulation and Comparison

This study simulates the traffic of various service in the LHN to obtain the offloading ratios. The input parameters include the service ratio and the handover ratio. This paper discuss the offloading ratio under different services or different mobility scenarios. The following table lists the parameters for simulation:

Table 3. Simulation Parameters

Parameters	**Values**
Number of UEs	200
Simulation Time	60 Minutes
Number of Service for each UE	4
Ratio of Mobile UE	10% - 50%
Ratio of Ide UE	10%
Ratio of Local Service	10%, 25%, 40%
Ratio of Local Comm.	10%, 25%, 40%
Ratio of Global Service	40%, 25%, 10%
Ratio of Global Comm.	40%, 25%, 10%

4.1. The Effect of Handover Ratios to the Offloading Ratios

When the service ratio is **75%** (local service 75% and Internet service 25%), this paper compares the offloading ratios for different solutions. The results in Figure 8 show that the proposed solution (i.e., LATO and GATO) maintains almost **60%** offloading ratio even when the handover ratio is *high* (i.e., 50%). The reason is that the existing solutions only reduce the traffic load oriented from the HeNB.

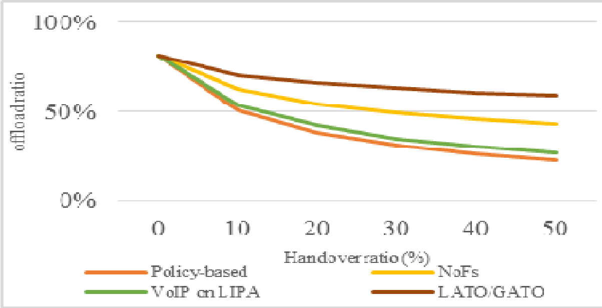

Figure 8. The Effect of Handover Ratios to the Offloading Ratios

The related solutions provides little offloading or no offloading function if the traffic is initiated from the LHN. The proposed solution provides the offloading function for the traffic inside or outside the LHN. Therefore, the gap difference increases with the handover ratio increases.

4.2. The Effect of the Service Types on the Offloading Ratios

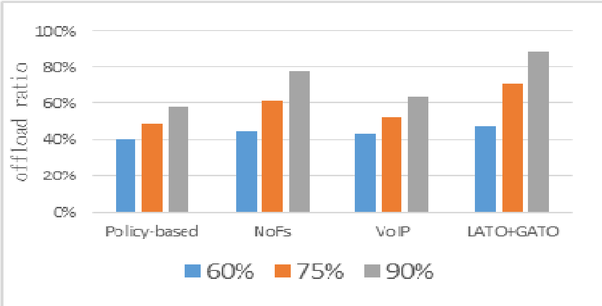

Figure 9. The Effect of the Service Types on the Offloading Ratios

Figure 9 is simulated when the handover ratio is 10%. This paper compares the offloading ratios of the policy-based solution, the NoFs solution, the VoIP-LIPA solution and the proposed solution. Obviously, when the ratio of local service increases, the offloading ratios of all solution increase. Among these solutions, the proposed solution outperforms the other solutions in all scenarios (i.e., ratios of local service are 60%, 75% and 90%). The reason is that the offloading service initiated outside the LHN still works in the proposed solution when the UE moves into the LHN. However, the other three solutions do not support this case and the offloading services are broken.

5. Conclusion

The existing work focuses on studying the offloading case within only one HeNB but does not design for the complete telecom architecture. In addition, the HeNB is assumed not easy to modify in the previous articles. To reduce the traffic load of the core network, this paper proposes a solution that consider the whole network architecture and adds the lists on the HeNB, L-GW, and P-GW to provide offloading with mobility. This solution offers the offloading service to the UE that can moves in or out of the LHN. In these cases, the service continuity is still kept and the traffic does not goes to the core network.

In the future work, we would like to design an offloading solution with minimal or without modification to the core network for the global Internet services. In this way, the traffic load of the core network can be further reduced. In addition, we will find a fast and efficient classification mechanism for the L-GW and the HeNB to improve the forwarding speed and reduce the classification load.

6. Acknowledgements

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