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 LGW. 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 provided 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 packet filter to tag 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.](image)

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 offloaded. 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.](image)

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.](image)

[2] proposes an LIPA solution to improve the communication quality of the local VoIP (Voice over IP) services. Specifically, the solution adds an HsMME (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 HSS sniffs the IMSI (International Mobile Subscriber Identity) of the UE to obtain the K_Auth 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 SIP 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 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>
<thead>
<tr>
<th>Tags</th>
<th>Service</th>
</tr>
</thead>
<tbody>
<tr>
<td>New</td>
<td>When the service is not assigned by the L-GW, the tag of the bearer is assigned to “New” by the HeNB.</td>
</tr>
<tr>
<td>LATO</td>
<td>When the L-GW decides to perform LATO, the HeNB is informed to tag the bearer to “LATO”.</td>
</tr>
<tr>
<td>GATO</td>
<td>When the L-GW decides to perform GATO, the HeNB is informed to tag the bearer to “GATO”.</td>
</tr>
<tr>
<td>Telecom</td>
<td>When the traffic is sent to the telecom’s core network, the HeNB is informed to tag the bearer to “Telecom”.</td>
</tr>
</tbody>
</table>

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 L-GW to insert the newly created PDN connection
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>
<thead>
<tr>
<th>Bearer List</th>
<th>Service List</th>
<th>IP List</th>
</tr>
</thead>
<tbody>
<tr>
<td>PDN address</td>
<td>Source IP address</td>
<td>IP address</td>
</tr>
<tr>
<td>TEID</td>
<td>Destination IP address</td>
<td>HeNB ID</td>
</tr>
<tr>
<td>Policy tag</td>
<td>Policy tag</td>
<td>IP@NAT</td>
</tr>
<tr>
<td>Z’ level</td>
<td>Uplink TEID</td>
<td></td>
</tr>
<tr>
<td>Service</td>
<td>Downlink TEID</td>
<td></td>
</tr>
<tr>
<td>QoS level</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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

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 6. LATO Operations.](image)

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.

![Figure 7. GATO Operations.](image)

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
The handover ratio is maintained almost constant. Therefore, the gap difference increases with the handover ratio. This paper discusses the offloading ratios under different service types or different mobility scenarios. The following table lists the parameters for simulation:

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of UEs</td>
<td>200</td>
</tr>
<tr>
<td>Simulation Time</td>
<td>60 Minutes</td>
</tr>
<tr>
<td>Number of Service for each UE</td>
<td>4</td>
</tr>
<tr>
<td>Ratio of Mobile UE</td>
<td>10% - 50%</td>
</tr>
<tr>
<td>Ratio of Idc UE</td>
<td>10%</td>
</tr>
<tr>
<td>Ratio of Local Service</td>
<td>10%, 25%, 40%</td>
</tr>
<tr>
<td>Ratio of Local Comm.</td>
<td>10%, 25%, 40%</td>
</tr>
<tr>
<td>Ratio of Global Service</td>
<td>40%, 25%, 10%</td>
</tr>
<tr>
<td>Ratio of Global Comm.</td>
<td>40%, 25%, 10%</td>
</tr>
</tbody>
</table>

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.

4.2. 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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7. References

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