Lecture Notes in Electrical Engineering 309

James J. (Jong Hyuk) Park · Yi Pan · Cheon-Shik Kim · Yun Yang *Editors*

**Future Information Technology**

The new multimedia standards (for example, MPEG-21) facilitate the seamless integration of multiple modalities into interoperable multimedia frameworks, transforming the way people work and interact with multimedia data. These key technologies and multimedia solutions interact and collaborate with each other in increasingly effective ways, contributing to the multimedia revolution and having a significant impact across a wide spectrum of consumer, business, healthcare, education, and governmental domains. This book aims to provide a complete coverage of the areas outlined and to bring together the researchers from academic and industry as well as practitioners to share ideas, challenges, and solutions relating to the multifaceted aspects of this field.

Electrical Engineering

ISBN 978-3-642-55037-9

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# Design of Mobile Relay Architecture for Traffic Offloading Support in LTE-Advanced Network

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**Abstract.** Recent years, LTE-Advanced is a mobile communication standard and high wireless bandwidth technology, formally submitted as a candidate 4G solution in the world. The major difference between 3GPP Release 10 (Rel-10) LTE-Advanced and the original LTE (Rel-8) is a new entity called relay node (RN) introduced in Rel-10. Due to the radio backhaul link in RN, Mobile Relay (MRN) is a hot and important issue in 3GPP LTE-Advanced standard forum. The demand of traffic offloading is increased as the number of UEs under a Mobile Relay increases. It's suggested to consider the aspect of offloading in determining a suitable architecture for MRN. This paper proposes the supporting of LIPA and SIPTO for MRN and a basic comparison analysis among MRN architecture alternatives is presented.

**Keywords:** LTE, LTE-Advanced, Mobile Relay, Offloading, LIPA, SIPTO.

## 1 Introduction

*LTE (Long Term Evolution)* is developed by telecom manufacturers and operators, it has been designed to support all IP packet-switching services. The radio access system is called *E-UTRAN* (as lower part of Fig. 1) in LTE. User devices such as mobile phones, iPads or hand-held devices are named *User Equipments* (*UEs*) while the base stations are called *Evolved Node B (eNBs)*. The non-radio access rear system is called *Core Network* (*CN*) or EPC which includes *PDN Gateway (P-GW)*, *Serving Gateway (S-GW)* and *Mobility Management Entity (MME)*.

The eNBs are normally interconnected with each other by *X2* interface, and connect to MME/S-GW by *S1* interface.

In the enhanced LTE version, Each eNB has a limited serving area. But it is more difficult to deploy a new eNB since residents have health concerns in regards to the electromagnetic waves emitted. Thus, the idea of signal relaying by a smaller entity

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James J. (Jong Hyuk) Park et al. (eds.), *Future Information Technology*,
Lecture Notes in Electrical Engineering 309,
DOI: 10.1007/978-3-642-55038-6_23, © Springer-Verlag Berlin Heidelberg 2014

called RN has been proposed and becomes an LTE-Advanced specification. As illustrated in Fig. 1, an eNB (called *Donor eNB*, *DeNB*) can expand its serving area by using RN to relay signal coverage.

RN firstly connects to an eNB in order to enlarge an eNB's serving area. The eNB that's connected with RN is called DeNB since it needs to provide more functionality for serving both UE and RN. The interface used between RN and DeNB is called *Un* as shown in Fig. 1. The RN has S1 and X2 interfaces since it acts as a regular eNB for UE. Furthermore, an RN is similar to a UE (*Un* interface in the center of Fig. 1) that is running with *RRC* (*Radio Resource Control*) and *NAS* (*Non Access Stratum*) functionalities.

The standard [1][2] classifies RN functionalities into two different architectures: Architecture A and Architecture B. The Architecture A is further divided into 3 different alternates. Alt.2 of Architecture A has been chosen to be the standard in LTE-Advanced Release 10 specification [1].

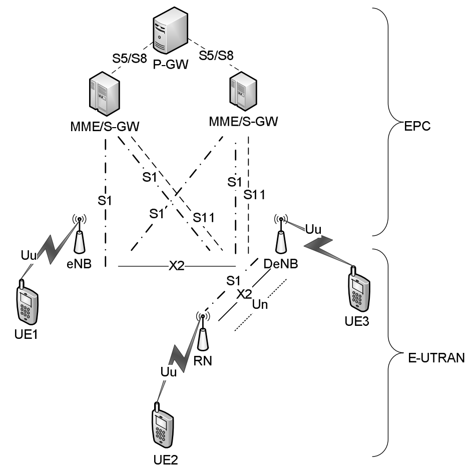


**Fig. 1.** LTE-Advanced network architecture

LTE-Advanced (LTE-A) [1], the RN architectures design supporting mobility were still discussed. To enhance coverage and capacity of existing radio access networks is the major target of fixed RN [2][3], it is also already standardized in 3GPP Rel-10. MRN refers to the scenario that RN would move like a UE with its served UEs.

In order to reduce traffic load of core networks, offloading approaches such as LIPA (Local IP Access) and SIPTO (Selected IP Traffic Offload) [4] proposed, the basic offloading structure as Fig. 2. However, those technologies are developed for traditional LTE environment or LTE Femtocell system mainly, some research articles are discussed such as LTE-A without RN [5], Femtocell [6], and LTE M2M architecture [7]. To add the RN device in LTE-A network, the offload technologies need to be redesigned for MRN environment. This paper proposes the architectural design to support LIPA and SIPTO for LTE-A Mobile Relay, in which the deployment of L-GW (Local Gateway) for the UEs under Mobile Relay is the key in the design of proposed architecture, the name is called L-GW@MRN in LTE-A MRN network.

The remainder of this paper is organized as follows. Section 2 shows the proposed architectures to support LIPA and SIPTO for LTE-A MRN. Quantitative analysis between proposed architectures is shown in Section 3. Finally, we conclude this paper in Section 4.

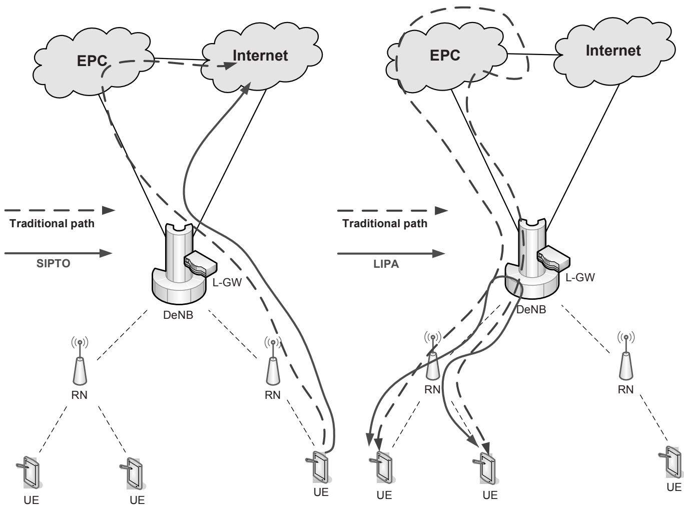


**Fig. 2.** Concept structure of LIPA and SIPTO in LTE-A

## 2 L-GW Deployment in LTE-A

Over the proposed designs, UE's L-GW is equipped with *SGi* interface to the Internet except in the MRN as L-GW@MRN, whose SGi is located at MRN's L-GW. UE's L-GW is used for PDN connectivity-based LIPA and SIPTO, but *DPI (Deep Packet Inspection)* based LIPA and SIPTO can also be performed by UE's L-GW. Moreover, the deployment of UE's L-GW has to fit in the infrastructure of LTE-A MRN. There are two alternatives for MRN architectures proposed in 3GPP TR 36.836 [8], in which two major ones are considered in this paper: Alt.1 and Alt.2 as Table 1 (also applicable to the enhancements). In the following paragraphs, we present the proposed deployments with associated signaling procedures in Alt.2 and Alt.1.

**Table 1.** Deployments of L-GW for LIPA and SIPTO

| MRN architecture / UE's L-GW deploy. | **Alt.2** | **Alt.1** |
|---|---|---|
| **UE_L-GW@MRN:**<br>1. LIPA breakout at UE's L-GW<br>2. Two-stage SIPTO breakout: UE's L-GW and MRN's L-GW | 1. UE's L-GW at MRN<br>2. MRN's L-GW collocated with MRN's P-GW at the Initial DeNB | 1. UE's L-GW at MRN<br>2. MRN's L-GW collocated with the standalone MRN's P-GW in EPC |

## 2.1 UE_L-GW@MRN

Basic features for this deployment are listed as follows:

(1) UE's L-GW is collocated at MRN.
(2) UE establishes LIPA session and SIPTO session with its L-GW.
(3) For LIPA, UE's L-GW extracts the coming IP packet's destination address and finds the corresponding UE's radio bearer to carry the packet to a local UE.
(4) For SIPTO, two-stage breakout is implemented by UE's L-GW and MRN's L-GW. UE's SIPTO traffic (in the case of uplink) reaches UE's L-GW and is tunneled by MRN's bearer from MRN to MRN's L-GW, where the traffic is routed to the Internet through SGi interface.

### 2.1.1 UE_L-GW@MRN in Alt.2

To fit the deployment in Alt.2, MRN's L-GW is collocated with MRN's P-GW at the Initial DeNB, which is the first DeNB MRN attaches to. The overall architecture of the deployment is illustrated in Fig. 3. Signaling procedure for setting up LIPA and SIPTO session is displayed in Fig. 4. Steps in the signaling procedure are explained in the following.

**A. Procedure of LIPA PDN Connection Establishment (ref. Fig. 4)**

(1) UE initiates and sends PDN Connectivity Request (Step 1) to UE's MME to establish a PDN connection for LIPA. UE's MME performs LIPA authorization to decide whether the UE is allowed to use LIPA or not according to the UE subscription data and the LIPA capability of the UE's eNB (i.e. MRN). The MME might reject the PDN Connectivity Request if the LIPA authorization fails. After successful LIPA authorization, UE's MME uses the appropriate L-GW address provided in S1-AP signaling to select the L-GW collocated with eNB (i.e. MRN). Optionally, the PDN Connectivity Request can be triggered by UE's MME with PDN Connectivity Setup Indication (Step 0).
(2) UE's MME performs the Create Session process and sends Create Session Request to UE's L-GW by way of UE's S-GW (Step 2 & Step 3). The process is finished when UE's MME receives Create Session Response from UE's L-GW (Step 4 & Step 5).
(3) Upon reception of Create Session Response, UE's MME sends S1-AP Bearer Setup Request along with the message of PDN Connectivity Accept to MRN acting as UE's eNB (Step 6). The messages of RRC Connection Reconfiguration and RRC Connection Reconfiguration Complete are exchanged between MRN and UE for establishment of the default radio bearer and dedicated bearer(s) (Step 7 & Step 8), and MRN sends the S1-AP Bearer Setup Response message to UE's MME (Step 9).
(4) UE sends Direct Transfer message to MRN (Step 10), and MRN sends the message of PDN Connectivity Complete to UE's MME (Step 11).
(5) Finally, the messages of Modify Bearer Request and Modify Bearer Response are exchanged between UE's MME and UE's S-GW (Step 12 & Step 13), and the procedure of LIPA PDN connectivity establishment is finished.

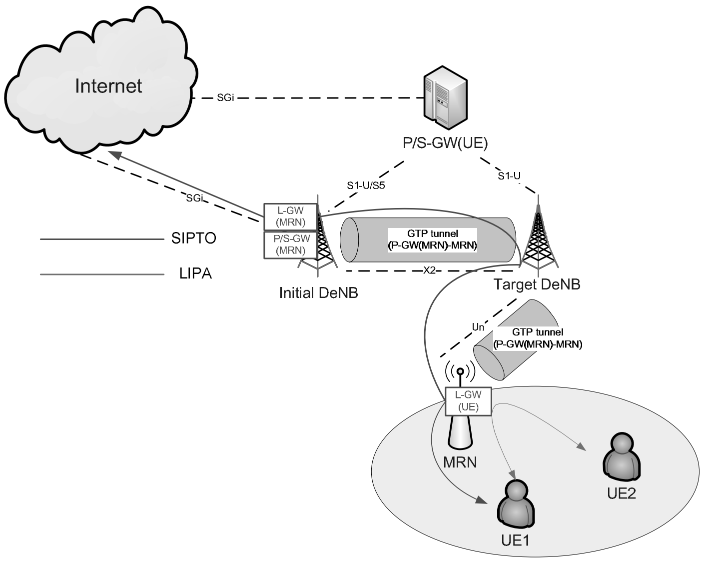


**Fig. 3.** L-GW@MRN in Alt.2

**B. Procedure of SIPTO PDN Connection Establishment (ref. Fig. 4)**

The procedure for SIPTO PDN connection establishment for the most part is the same as the procedure for LIPA presented in Section 2.1.1-A. The only difference is the additional steps of Step 3.1 and Step 3.2. In the case of SIPTO, UE's L-GW requests MRN (Step 3.1) to setup PDN Connectivity or GTP tunnel with MRN's L-GW to provide virtual SGi interface. The procedure for MRN acting as a UE to set up PDN connection with MRN's L-GW is the same as described in Section 2.1.1-A.

### 2.1.2 UE_L-GW@MRN in Alt.1

To fit the deployment of L-GW@MRN in Alt.1, MRN's L-GW is collocated with MRN's P-GW in EPC. The overall architecture, and signaling procedure are displayed in Fig. 5 and Fig. 6. Rather than collocated at the Initial DeNB in Alt.2, MRN's P-GW is a standalone device in Alt. 1, but the procedure of PDN connection establishment for both LIPA and SIPTO is the same as in Alt.2. Moreover, both Procedures of LIPA and SIPTO PDN connection establishment are the same as Section 2.1.1-A and Section 2.1.1-B (ref. Fig. 6) respectively.

## 3 Quantitative Comparison Analysis

The two proposed approaches, Alt.2 and Alt.1, have different advantages and disadvantages. Table 2 shows the comparison between Alt.2 and Alt.1. Based on Table 2's results, our proposed Alt.2 might have better performance.

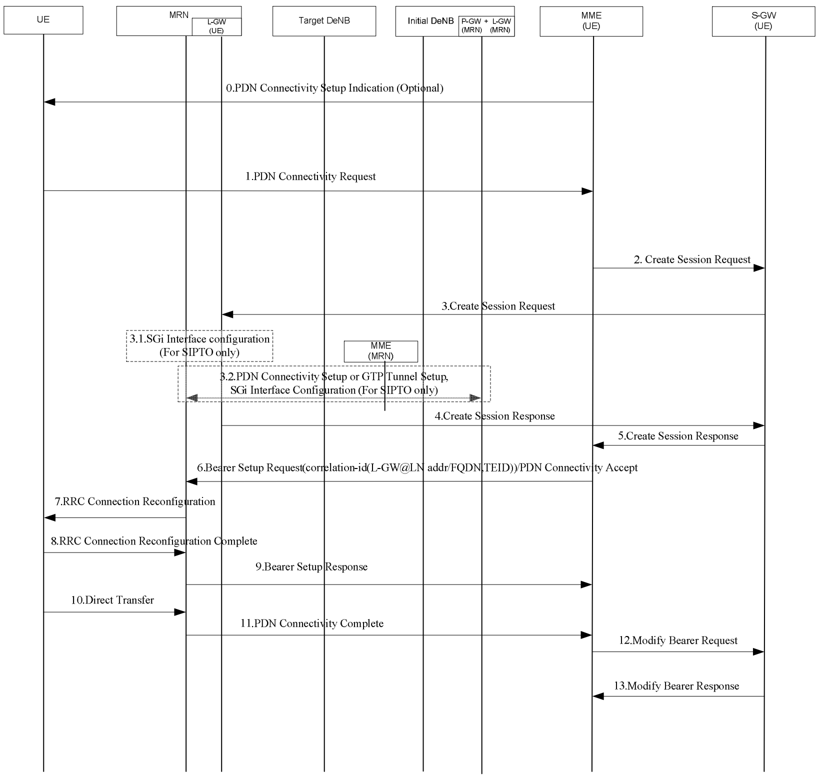


**Fig. 4.** L-GW@MRN in Alt.2: Signaling Procedure

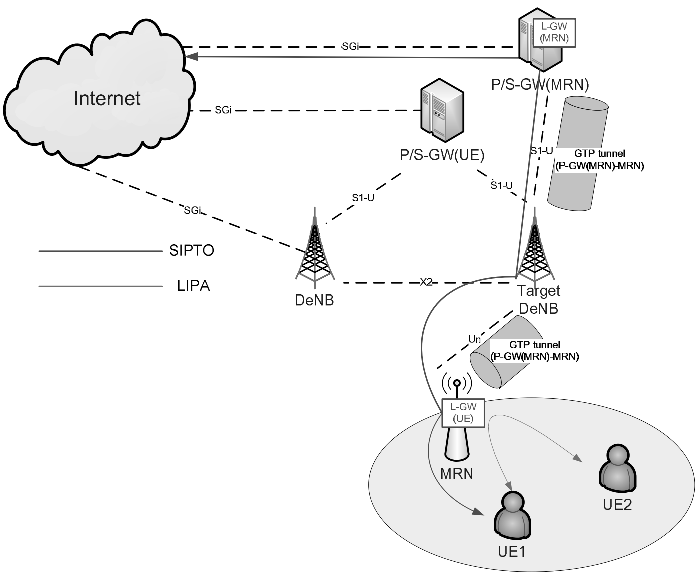


**Fig. 5.** L-GW@MRN in Alt.1

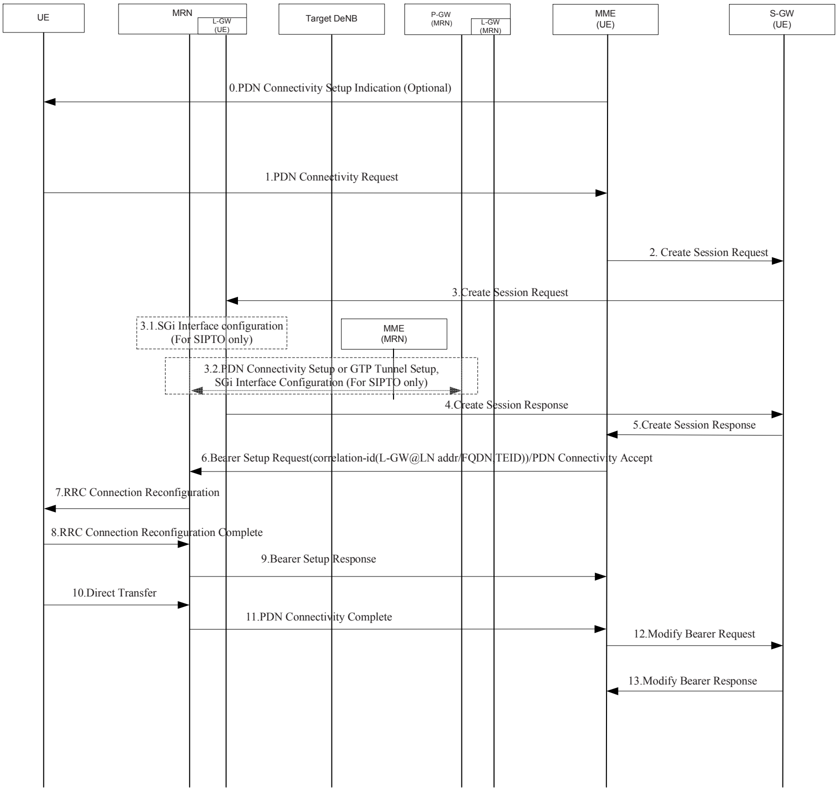


**Fig. 6.** L-GW@MRN in Alt.1: Signaling Procedure

**Table 2.** Quantitative comparison between Alt.2 and Alt.1

| **Metric** | **Alt.2** | **Alt.1** |
|---|---|---|
| Deployment cost | Low<br>(L-GW function at MRN) | Low<br>(L-GW function at MRN) |
| LIPA efficiency<br>(Note 1) | High<br>(UE--MRN) | High<br>(UE--MRN) |
| SIPTO efficiency<br>(Note 2) | Medium<br>(UE--MRN--<br>TargetDeNB--<br>InitialDeNB) | Low<br>(UE--MRN--<br>TargetDeNB--<br>MRN_P_GW) |
| Group mobility support<br>(Note 3) | Yes | Yes |
| Standardization effort<br>(Note 4) | No impact | Medium |

Note 1: Considering the path length for LIPA traffic (uplink). Shorter path makes higher efficiency.

Note 2: Considering the path length for SIPTO traffic (uplink). Shorter path makes higher efficiency.

Note 3: Does it require re-connection of UE's LIPA/SIPTO PDN connection when MRN moves to a new DeNB?

Note 4: Reference baseline is R-10.

# 4 Conclusions

Both LTE and LTE-Advanced are backward compatible with 3G UMTS cellular systems. They are considered the front runners when it comes to gaining the opportunity in becoming the 4G standard of wireless telecommunication networks. Considering radio resource utilization, the LTE-A's RN adds a functionality of traffic offloading to decrease the transmission overhead in EPC. This paper tries to design a workable architecture by which MRN is able to provide LIPA and SIPTO functionality to offload local and global traffic by local gateway. Furthermore, we also propose two different architectures as Alt.1 and Alt.2 with detailed signaling flow in this paper. Thus, analysis results have shown that our proposed structures can let the UEs' transition achievable in the LTE-A network. It is also a useful MRN architecture for traffic offloading support in LTE-A.

**Acknowledgments.** This work was supported in part by the Taiwan Mobile Co., Ltd., Taiwan, R.O.C., under grant no. TWN10200737.

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