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Handover Enhancement in LTE-Advanced Relay Networks

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***Abstract*—LTE and IEEE 802.16 WiMAX are competing access network technologies in 4G wireless networks. LTE is one of 3GPP standards while 802.16 WiMAX is standardized by IEEE. Although WiMAX already commercially operates in Taiwan, it is limited to the independently new system that cannot compatible with current 3G system. Hence, the cost of system construction is higher and cannot be popularized fast. On the other hand, LTE is developed by 3GPP which is organized by telecommunication manufactories and operators. Moreover, LTE is backward compatible with 3G/UMTS cellular systems. The LTE specifications define how user equipments (UEs) connect and communicate with base stations (eNBs). The enhanced version, LTE-Advanced, add a new entity called relay node (RN) to enlarge service coverage. The architecture is changed and becomes more complicated when RN is added. This paper focuses on handover procedure in LTE-Advanced networks and proposes a smart forwarding mechanism to improve handover performance.**

Keywords- 4G, LTE, LTE-Advanced, Relay

I. INTRODUCTION

Wireless networks are rapidly evolving from GSM telephony networks to 3G and beyond. Following the blooming markets of cellular phone network and Internet services, mobile high-bandwidth data communication is becoming a new promising business niche. Users want to access network services in any place and at any time via their mobile devices. IEEE 802.11 wireless technology is developed to fit user's mobility requirement. However, IEEE 802.11 suffers from smaller serving coverage, interfered with obstructers and indoor use only. Therefore, IEEE 802.11 needs higher deployment density to provide stable connectivity. IEEE 802.16 WiMAX [1][2] can offer larger serving coverage and provide more technologies to enhance performance. The usage and service are restricted because of limited base station deployment.

Compares to the development of the IEEE wireless technologies, the telecom manufactories and vendors also begun providing network communication services on mobile phones in the last decade. The newest technology is Long Term Evolution (LTE) [3][4] which is competing access network technologies in 4G wireless networks with WiMAX. LTE can use OFDM, OFDMA or SC-FDMA access technologies. It also can use 2×2 or 4×4 MIMO (Multi-Input Multi-Output) antenna systems and provide FDD or TDD mode. Moreover, LTE not only can offer traditional voice telephony service, but also can provide cost effective broadband communication services. 3GPP (Third Generation Partnership Project) formally approves the LTE to be the standard technology for the wireless communication. Since LTE is defined by telecom vendors and is backward compatible with GSM/UMTS cellular systems, this makes LTE deployment much easier than WiMAX.

In the enhanced LTE version, LTE-Advanced [4], the transmission bandwidth has been further increased. The transmission rate can up to 1Gbps if UEs are in low mobility status. Even when UEs are in high mobility status, the transmission rate still can reach 100Mbps. Therefore, ITU has been certified that LTE-Advanced conformed to the requirements of IMT-Advanced for 4G.

The major difference between 3GPP Release 10 LTE-Advanced [4] and original LTE is a new entity called relay node (RN) introduced in LTE-Advanced. An eNB can extend its serving coverage by using RN. However, the network architecture is changed and becomes more complicated when RN is added. [5] defines four different alternates within two different architectures. In this paper, we will describe those four alternates and propose a smart forwarding mechanism to improve handover performance.

The remainder of this paper is organized as follows. Section II briefly introduces LTE technology and LTE-Advanced relay architectures. Section III shows the proposed smart forwarding scheme. The performance analysis is presented in Section IV. Finally, we conclude this paper in Section V.

II. LTE AND LTE-ADVANCED ARCHITECTURE

A. LTE

LTE inherits current telecommunication network architecture and is backward compatible with GSM or UMTS cellular systems. Thus, operators only need to upgrade their traditional Node B (NB) equipment to eNB system in order to support LTE. Upgrading eNBs are much easier than system fully reestablishment. Thus LTE gains from system deployment benefit. Furthermore, LTE can combine OFMDA, MIMO and HARQ technologies [6]. This makes LTE be able to dynamically configure its bandwidth according to available frequencies and can support highly mobility environment. This is a desirable solution for high speed rail which moves at speed up to 350 km/h.

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Although LTE is developed by telecom manufactories and operators, it has been designed to support all IP packet-switching services. The radio access system is called Evolved-UTRAN (E-UTRAN) 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 Evolved Packet Core (EPC) which includes the following entities:

- PDN Gateway (P-GW)
- Serving Gateway (S-GW)
- Mobility Management Entity (MME)

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

There are two types of handover procedures: X2 handover and S1 handover. When an UE moves and switches between two eNBs which are still managed by same operator, the X2 handover procedure is triggered. However, when an UE switches between two eNBs without X2 interface between them or two eNBs are managed by different operators, S1 handover procedure is needed.

B. *LTE-Advanced Relay Architecture*

Each eNB has a limited serving area. But it is more difficult to deploy a new eNB since residents have much healthy concern about the electromagnetic wave. Thus, the idea of signal relaying by a smaller entity called relay node (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.

There are two different RN types depending on its functionalities. Type 1 RN has the OSI layer 3 functionality that act as a regular eNB for UE and act like an UE for DeNB. Type 2 RN just operates at OSI layer 2 functionality that provides messages decoding and forwarding mechanisms and is transparent to both UE and DeNB. The system management becomes more complicated if the operators deploy different types of RN. Although the architecture and signaling among DeNB and RN are still under discussion and design, RN relaying mechanism already becomes a key technology of LTE-Advanced. How to gain the benefit from RN, fit the QoS requirements and reducing total cost of ownership are the significant research topics.

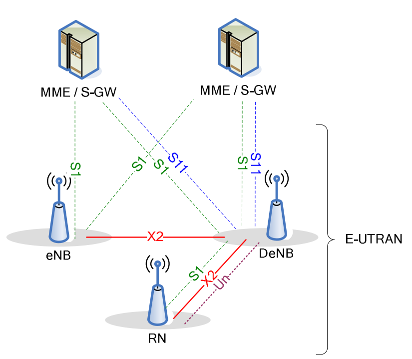

Figure 1. LTE-Advanced network architecture

An RN firstly connects to an eNB in order to enlarge eNB's serving area. The eNB that connected with RN is called Donor eNB (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 act as a regular eNB for UE. Furthermore, an RN is similar to a UE (Un interface in Fig. 1) that is running with RRC (Radio Resource Control) and NAS (Non Access Stratum) functionalities.

[3] classifies RN functionalities into two different architectures: Architecture A and Architecture B. The Architecture A is further divided into 3 different alternates

III. Proposed Smart Forwarding Scheme

Alt 2 of Architecture A has been chosen to be the standard in LTE-Advanced Release 10 specification [4]. The downlink traffic that sent from Source DeNB will be buffered in Source RN before completing the handover procedure. After the UE handover completed, the Source RN forwards its buffered packets to Source DeNB. The packets then pass via the Target DeNB which manages Target RN from Source DeNB to the Target RN. Finally, the Target RN forwards received packets to UE. Obviously, there is a duplicated transmission path that results in a poor transmission performance. The downlink transmission still has duplicated path even if the UE handoffs from RN to an eNB directly.

If somehow we can buffer downlink packets at the cross point i.e. DeNB in Fig. 2, the transmission performance can be improved. Therefore, the idea of smart forwarding scheme is proposed in this paper. Before UE initializes handover procedure, the RN issues a control message to its serving DeNB by which the RN demands that the serving DeNB begins buffering received packets destined to a specified UE. The serving DeNB only need to forward the buffered packets to new eNB or DeNB after UE finishing handover procedure. The detailed signaling flow of proposed smart forwarding scheme is illustrated in Fig. 3.

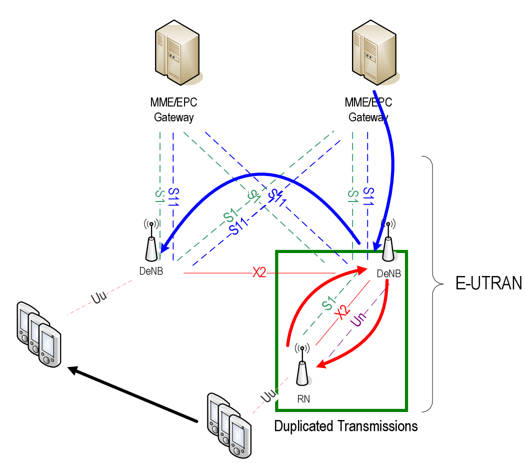

Figure 2. Downlink transmission path and buffering when UE handover occurs

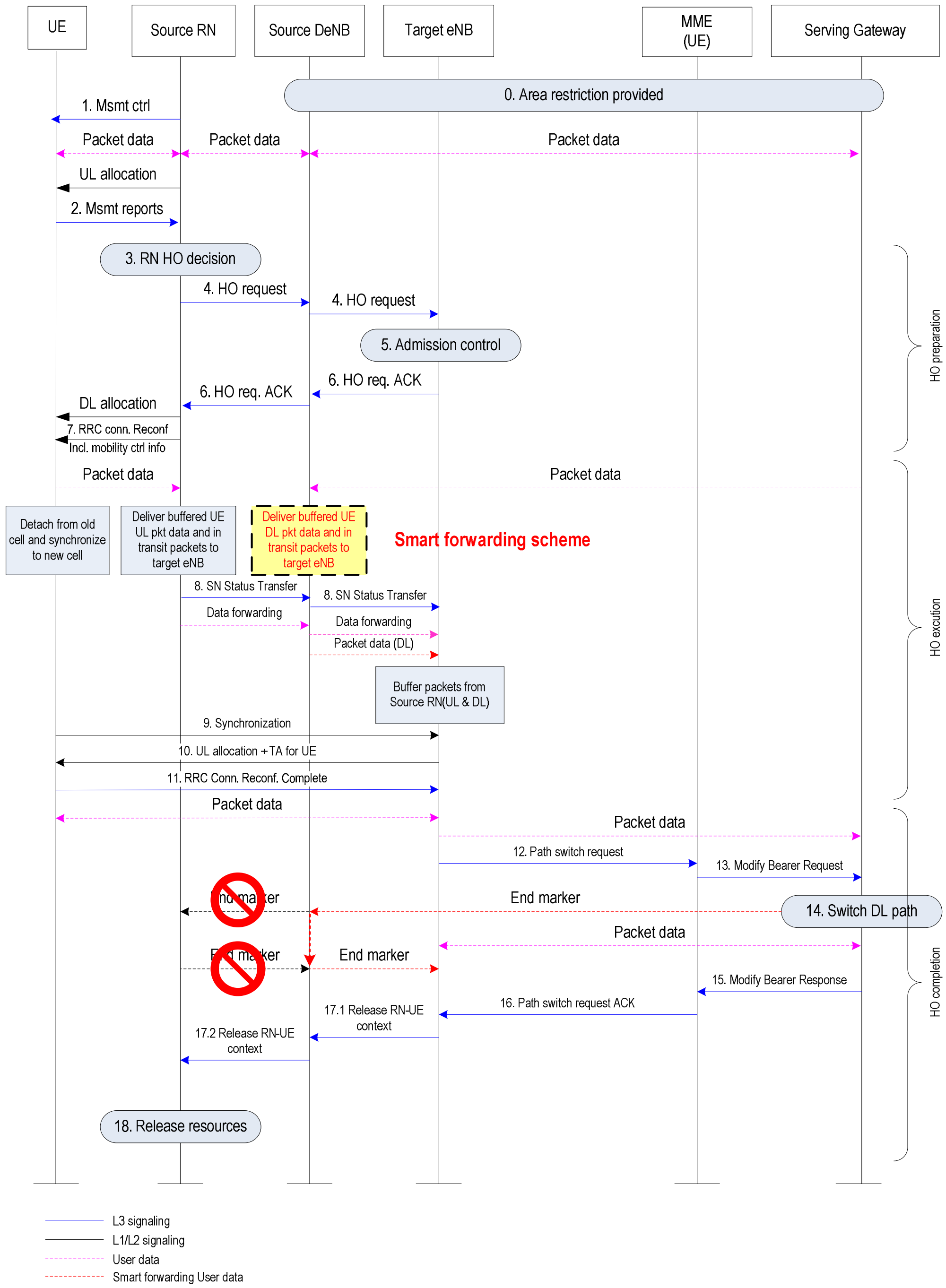

Figure 3. Signaling flow of proposed smart forwarding scheme when UE handoffs between RNs managed by different DeNB

If UE handoffs between RNs served by same DeNB, the downlink path is similar to the case in Fig. 2 based on standard specification. The proposed smart forwarding scheme can still be used to improve system performance. By using the proposed smart forwarding scheme, we can reduce routing path in downlink to improve forwarding efficiency. Moreover, the end marker signal can also benefit from the shorter path as shown in Fig. 3.

IV. PERFORMANCE ANALYSIS

Since UE supports only hard handover scheme in LTE-Advanced environment, UE has to disconnect with source RN/eNB and then reconnect with RN/eNB among its handover procedure. By using the forwarding mechanism can reduce the opportunity of packet loss. In order to analyze forwarding cost, we define the transmission cost in each link listed as follows:

H_{PGW_SGW}: the hop count between P-GW and S-GW
H_{SGW_DeNB}: the hop count between S-GW and DeNB
H_{Inter_DeNB}: the hop count between Source DeNB and Target DeNB
H_{Radio_RN}: the hop count between DeNB and RN
H_{Radio_UE}: the hop count between RN and UE
$P\_Time_{handover}$: the percentage of handover period in UE
$Cost_{data\_trans}$: the end-to-end transmission cost in EPC and E-UTRAN

Regular transmission cost

$$Cost_{data\_trans} = P\_Time_{handover} \times (H_{PGW\_SGW} + H_{SGW\_DeNB} + 3H_{Radio\_RN} + H_{Inter\_DeNB}) + (1 - P\_Time_{handover}) \times (H_{PGW\_SGW} + (H_{SGW\_DeNB} + H_{Radio\_RN} + H_{Radio\_UE})$$

Smart forwarding transmission cost

$$Cost_{data\_trans} = P\_Time_{handover} \times (H_{PGW\_SGW} + H_{SGW\_DeNB} + H_{Radio\_RN} + H_{Inter\_DeNB}) + (1 - P\_Time_{handover}) \times (H_{PGW\_SGW} + H_{SGW\_DeNB} + H_{Radio\_RN} + H_{Radio\_UE})$$

TABLE I. PARAMETERS OF TRANSMISSION COST

Parameter	Hop count value
H_{PGW_SGW}	2~5
H_{SGW_DeNB}	5~10
H_{Inter_DeNB}	1~5
H_{Radio_RN}	1
H_{Radio_UE}	1
$P\_Time_{handover}$	2%~10%

Based on the transmission cost listed above, we can easily compare the difference between regular transmission cost and the cost with proposed smart forwarding scheme. Fig. 4 shows the comparison of end-to-end transmission cost between regular and proposed schemes while Fig. 5 shows the comparison of radio access portion only between regular and proposed schemes. Analytical parameters are listed in Table 1.

As shown in Fig. 4, the end-to-end transmission cost becomes larger as probability of handover increases. However, the proposed scheme adopts the smart forwarding mechanism resulting in lower transmission cost than regular approach

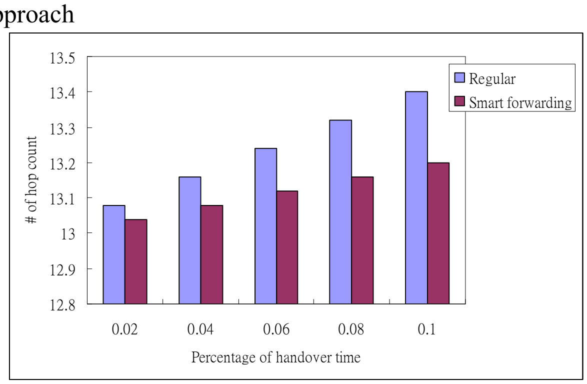

Figure 4. End-to-end transmission cost

Since the radio wireless channel is one of system important resources, reducing radio channel usage can also improve system efficiency. The analytical results shows that proposed forwarding scheme can substantially reduce the wireless channel utilization as shown in Fig. 5.

V. CONCLUSIONS

Both LTE and LTE-Advanced are backward compatible with 3G/UMTS cellular systems. They are considered having more future prospect and also gaining more opportunity of becoming 4G standard. The LTE-Advanced adds a new entity called relay node (RN) to enlarge service coverage. This paper focuses on handover procedure in LTE-Advanced networks and proposes a smart forwarding scheme to improve handover performance. Performance analysis shows that the proposed scheme can efficiently reduce forwarding cost as well as wireless channel usage during handover.

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REFERENCES

[1] IEEE Std 802.16-2009, IEEE Standard for Local and Metropolitan Area Networks Part 16: Air Interface for Broadband Wireless Access Systems, May 2009.

[2] IEEE Std 802.16j-2009, IEEE Standard for Local and Metropolitan Area Networks Part 16: Air Interface for Broadband Wireless Access Systems Amendment 1: Multiple Relay Specification, Jun. 2009.

[3] 3GPP TS 36.300, Evolved Universal Terrestrial Radio Access (E-TRA) and Evolved Universal Terrestrial Radio Access Network (E-UTRAN) Overall description; Stage 2, Rel. 8, v8.5.0, May 2008.

[4] 3GPP TS 36.300, Evolved Universal Terrestrial Radio Access (E-UTRA) and Evolved Universal Terrestrial Radio Access Network (E-UTRAN), Rel. 10, v10.2.0, Dec. 2010.

[5] 3GPP TR 36.806, Evolved Universal Terrestrial Radio Access (E-UTRA) Relay architectures for E-UTRA (LTE-Advanced); Rel. 9, v9.0.0, Mar. 2010.

[6] S. Sesia, I. Toufik, and M. P. J. Baker, LTE – The UMTS Long Term Evolution, Wiley, Apr. 2009.

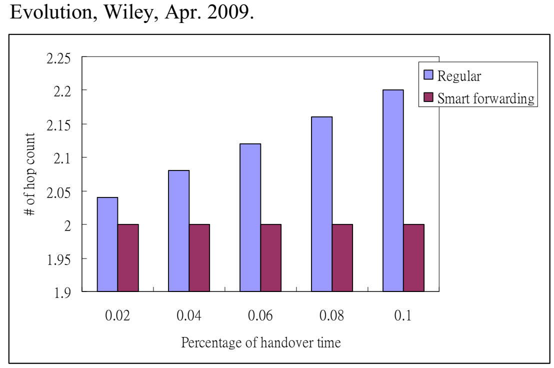

Figure 5. Transmission cost in E-UTRAN