Study on Mobility Management Scheme of Moving Relay Nodes in LTE Network

LTE ネットワークにおける移動中継ノードの移動管理方式に関する研究

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Graduate School of Global Information and Telecommunication Studies
Waseda University

Wireless Communication System II

Battulga DAVAASAMBUU

Preface

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Abbreviations

2G	2nd Generation
3G	3rd Generation
3GPP	3rd Generation Partnership Project
5G	5th Generation
CAC	Call Admission Control
CAPEX	CAPital EXpenditure
CIO	Cell Individual Offset
E-UTRAN	Evolved Universal Terrestrial Radio Access Network
EPC	Evolved Packet Core
eNB	Evolved Node B
FDD	Frequency-Division Duplexing
FIFO	First In, First Out
FRN	Fixed Relay Node
GTP	GPRS Tunneling Protocol
HCDP	Handover Call Dropping Probability
HOF	Handover Failure
HPI	Handover Performance Indicator
HPP	Handover Ping-Pong
IMS	IP Multimedia Subsystem
LTE	Long Term Evolution
LTE-A	Long Term Evolution Advanced
MIMO	Multiple-Input and Multiple-Output
MME	Mobility Management Entity
MRN	Moving Relay Node
mMRN	main Moving Relay Node
NCBP	New Call Blocking Probability
NCHH	Network-Controlled Hard Handover
nRT	non-Real-Time
OFDM	Orthogonal Frequency-Division Multiple
OPEX	OPerating EXpenditure

P-GW	Packet Data Network Gateway
PCRF	Policy Control and Charging Rules Function
QoS	Quality of Service
RHP	Reference Handover Point
RLF	Radio Link Failure
RSS	Received Signal Strength
RSRP	Reference Signal Received Power
RT	Real-Time
RTP	Reference Trigger Point
S-GW	Serving Gateway
SINR	Signal to Interference plus Noise Ratio
SOHP	Self-Optimization of Handover Parameters
SON	Self-Organizing Network
sMRN	secondary Moving Relay Node
TDD	Time-Division Duplexing
TTT	Time-To-Trigger
UE	User Equipment
USIM	Universal Subscriber Identity Module
VPL	Vehicular Penetration Loss
VoIP	Voice over IP

Summary

In the past, cellular networks were primarily used for voice and short message services. Today, this has changed and these networks are mainly used for data transferring services such as live video streaming, online gaming, and social application data. Hence, the development of next-generation wireless networks focuses on addressing the increasing bandwidth usage and mobile data traffic in order to provide a good quality of service, low end-to-end latency, data reliability, efficient bandwidth management, and more secure connections. Achieving these goals is an important challenge cellular network operators need to overcome. The growth of the amount of mobile data traffic and the number of Internet-connected devices is presented in Cisco's Visual Networking Index [2014-2019] and the Ericsson Mobility Report (June 2015): (i) global mobile data traffic grew by 69 percent in 2014, which reflects the impact of smartphone and powerful operating systems. In addition, it is expected to increase nearly tenfold by 2019, reaching 24.3 Exabytes per month by 2019, (ii) the increasing number of devices connected to the Internet such as smartphones, tablets, laptops, game consoles, and portable devices, and (iii) the increase in the amount of sensitive data traffic, for example, mobile video traffic comprised 45 percent of mobile data traffic in 2014. (iv) on-board mobile devices generate a considerable amount of mobile data traffic. In addition, applications need to be targeted at mobile users and their devices.

One promising solution is to use a moving relay that focuses on the provision of high-quality service within trains as a new issue. Consequently, it is necessary to provide a good quality connection for the passenger that satisfies the wireless network configuration for high-speed scenarios. To address this need, moving relay nodes (MRN) were introduced in Release

12 (TS 38.836) of the LTE standard to support data services in fast moving environments. Furthermore, MRN is a feature enhancement and one of the typical solutions involving an indoor, mobile, small base station capable of supporting communication to users traveling on public transportation, providing a wireless backhaul connection via the base station by an outer antenna. This solution can bypass the following difficulties: vehicular penetration loss, increased the power consumption of user equipment, more handover frequency, and signaling overhead.

Although the MRN solution improves indoor coverage and performance, it also creates a single point of failure because, if MRN fails to handover, the connections of mobile users will be dropped. MRN architecture is designed such that passengers' devices do not execute the handover procedure; instead, only the MRN takes handover to the target cell via the outer antenna located on the front of the train. However, MRN mobility management used a conventional hard handover scheme without any changes in the handover preparation step. The problems associated with current mobility management schemes in fast-moving trains are increased Radio Link Failures (RLFs), more frequent handovers, service interruption, and a reduced handover success rate. This is because from the viewpoint of a core network, MRN handover triggering and decision-making is the same as that of regular UE,i.e., it is static and configured manually in LTE standards.

Our first study commences with an investigation of a handover scheme, parameters, and call admission control for MRNs in LTE networks. Specifically, we proposed an adaptive handover hysteresis scheme based on a cost function to influence handover triggering and to increase handover performance. The function effectively adjusts handover hysteresis as the main parameter of the handover procedure between cells in a homogeneous network. The cost function is based on important factors, namely the current speed of the vehicle relative to the MRN, the load on the candidate cells, and the service types of the active users. Moreover, the proposed handover can increase the duration of the handover procedure, including the time required by the security policy and data re-routing, during fast movement of trains and buses in the overlapping area

between neighboring cells. Second, the probability of handover call blocking is reduced by introducing a proposed call admission control scheme to support the radio resource reservation for handover calls that prioritizes MRN handover calls over UE handover calls and new calls. The proposed solution in which adaptive handover is combined with call admission control is evaluated by system level simulation. Our simulation results illustrate an increased handover success rate and reduced RLFs.

In our second study, we present the self-optimization of handover parameters that can autotune hysteresis and offset in order to reduce the number of RLFs and connection interruptions that occur during handover procedures. The two parameters are the current speed of the train based on automatic hysteresis and the handover performance indicator based on the individual offset of a macrocell. This scheme focuses on the handover performance and triggering that can define a starting point of the handover procedure at the correct time. Further, in order to reduce service interruption, we present a handover procedure with dual MRNs in which cooperative outer antennas are installed on the front of the train. Only one of these antennas, referred to as the main outer antenna, produces a measurement report for its handover decision by the serving cell. The other antennas begin a handover procedure that emulates the successful handover of the main antenna. In the simulation, the proposed self-optimization scheme was compared to that of a conventional handover scheme with manually configured parameters for high-speed environments. The simulation results show that the proposed scheme reduced handover delay, RLFs, and communication interruption.

Chapter 1

Introduction

In the past, cellular networks were primarily used for voice and short message services. Today, this has changed and these networks are mainly used for data transferring services such as live video streaming, online gaming, and social application data. These applications and services demand high-quality communication for real time sessions. The report ”Cisco Visual Networking Index (VNI) 2014-2019 help us to imagine the future of mobile data traffic, which is shown in Figure 1.1, whereas the Ericsson Mobility Report introduced an increased a number of future subscriptions, which are shown in Figure 1.2. Several factors of the next generation wireless network are presented:

(a) The growth of global mobile data traffic has experienced; it increased by 69 percent in 2014.In addition, it is expected to increase nearly tenfold by 2019, reaching 24.3 Exabytes per month by 2019 [1].

(b) The number of devices connected to the Internet, such as smartphones, tablets, laptops, and game consoles, are increasing. Today, the smartphone has become part of people’s daily lives; 497 million mobile devices were added in 2014, with a total of one billion

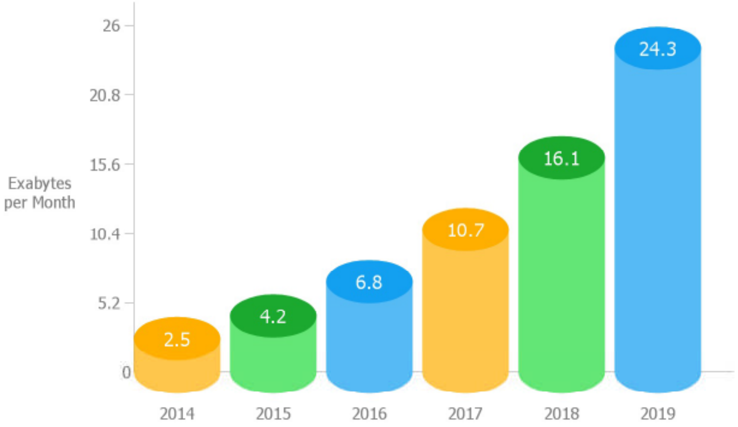


FIGURE 1.1: Cisco forecasts: 24.3 Exabytes per month of mobile data traffic by 2019., *Source: Cisco Visual Networking Index - Global mobile data traffic forecast update, June 2015 [1].*

devices connected to the Internet. The extent of this increase cannot easily be measured [1]. In addition, mobile broadband devices are expected to comprise 85 percent of all subscriptions by the end of 2020 [2].

(c) Social applications that generate high-speed bandwidth-intensive data traffic such as the high-definition video, chatting, image sharing, and online gaming when people are traveling. Hence, on-board mobile devices generating a lot of mobile data traffic.

(d) Mobile operator companies are developing the architecture required to improve the network performance and to meet customer requirements by offering unlimited data bundles.

In view of this expected growth in mobile traffic, the development of next-generation wireless networks focuses on addressing the increasing bandwidth usage and mobile data traffic in order to provide a good quality of service, low end-to-end latency, data reliability, efficient bandwidth management, and more secure connections. The achievement of these tasks is an important challenge mobile network operators need to consider. In addition, our online/cyber life is expanding and customers desire to remain connected anywhere, anytime by way of smartphone usage. Consequently, wireless technologies such as Long Term Evolution (LTE)

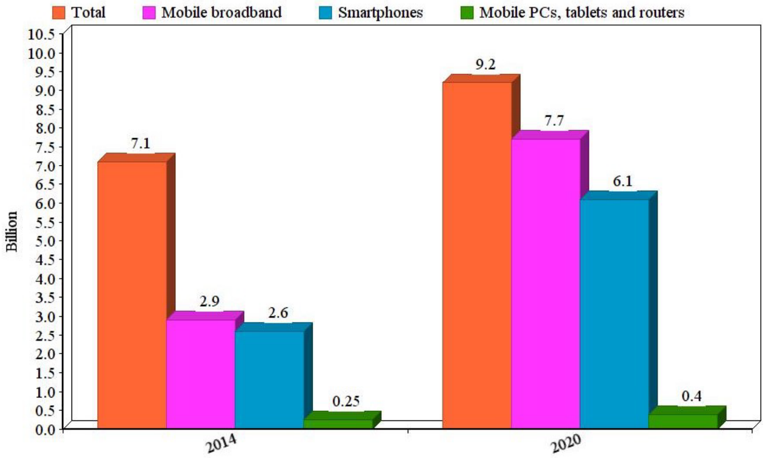


FIGURE 1.2: Number of subscriptions with the forecast, *Source: AB Ericsson Mobility Report June 2015 [2].*

and Long Term Evolution-Advanced (LTE-A) are emerging to satisfy both the growing requirements of both users and applications to be connected to the Internet.

Mobile network operators are attempting to address future network expectations and the growth of mobile data traffic by developing improvements such as the introduction of small cells, femtocells, vehicular networks, device-to-device connections, and fixed and moving relays. These developments have encouraged operator companies to build complex network architecture with new features. An overview of the new deployment scenarios of next-generation wireless technologies is shown in Figure 1.3.

One promising solution is to use a moving relay that focuses on the provision of high-quality service within trains as a new issue. Consequently, it is necessary to provide a good quality connection for the passenger that satisfies the wireless network configuration for high-speed scenarios. Different solutions are proposed to solve this issue, for example, the deployment of mobile small cell or femtocell networks for passengers (vehicular users) in high-speed mobility environments, as well as dense networks. Concerning research on the mobile small cell, many studies have focused on network architecture aspects, such as the development of optimal and indoor cellular coverage of the train, a powerful outdoor antenna for a wireless backhaul link for

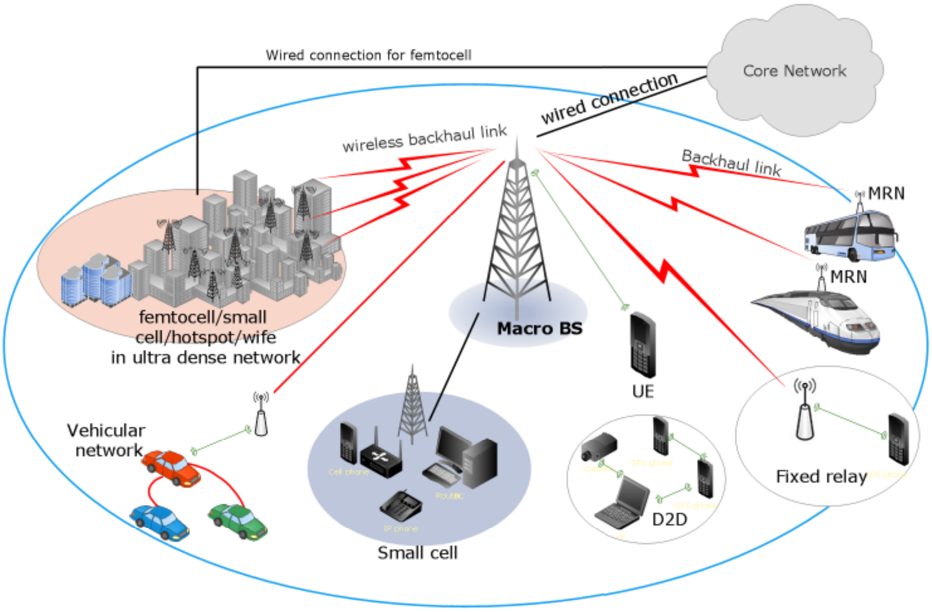


FIGURE 1.3: Illustration of the next-generation cellular wireless network: multi-tier, dense, and complex.

connecting a macrocell, and proxy/routing between antennas [3–6]. The Moving Relay Node (MRN) is an indoor, mobile, small base station that is deployed by the LTE standard working group to support data communication inside vehicles (such as in offices, subways, buses, and trains), that is the cellular coverage area is served by an inside antenna [7]. Thus, MRNs in the form of mobile small cells are changing the wireless network such that it is becoming dynamic and a promising solution for 5th Generation (5G) networks [8]. Figure 1.4 and 1.5 contain diagrams showing the MRN architecture.

In Figure 1.5, the MRN is connected as a regular terminal to donor Evolved Node B (eNB) via a wireless backhaul link (Un). Donor-eNB is a base station capable of supporting the backhaul link for MRN and providing a connection between passengers' terminals and MRN as regular terminals. Researchers have evaluated the performance of MRN in public transition scenarios with respect to interference, channel model, and radio resource assignment mechanisms for passengers' devices [4, 10, 11]. Other studies proposed mobile femtocells, with the

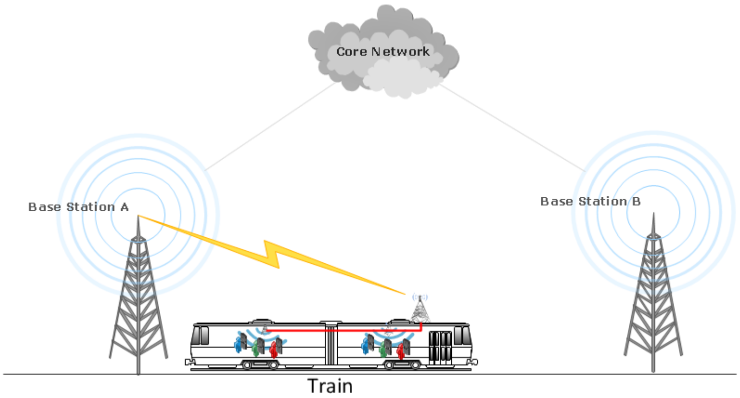


FIGURE 1.4: System model of the mobile relay node (MRN),
Adapted from "Adaptive Handover Hysteresis and Call Admission Control for Mobile Relay Nodes," by Author B.Davaasambuu, 2015, International Journal of Computer Networks and Communications (IJCNC), Volume 7(6), p87-98 [9].

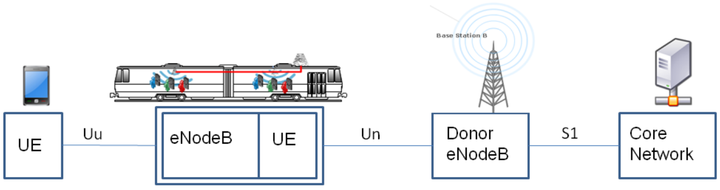


FIGURE 1.5: Architecture aspects of MRN.

aim of providing efficiency in terms of power consumption and signaling overhead, including spectrum usage and scheduling [12, 13].

As the deployment of mobile relays has the potential to enhance the mobile user's experience while traveling on public transit systems, we believe that the following factors motivate our thesis work:

1. On-board mobile devices generate a considerable amount of mobile data traffic, which is increasing due to the increased usage of smartphones and their applications such as Facebook and online games. These developments are affecting cellular network performance.

2. MRN has been proposed by the 3GPP standard and several researchers have proposed enhancements for both cellular coverage and the network capacity of public transit and moving vehicles. However, 3GPP defines the handover procedure of MRN without any changes in the preparation step of the handover procedure. The difference between MRN and regular user equipment (UE) in term of mobility management is the implementation of a path switch and synchronization methods in the execution step of the handover procedure.

3. The wireless backhaul link of MRN creates a single point of failure because, if MRN fails to handover, the connections of mobile users will be dropped.

1.1 Issues with MRN architecture

The key technical challenges for MRN architecture are the following: the inter-cell interference/outage probability, mobility management, Call Admission Control (CAC), and authentication/security. In this subsection, we discuss some of the issues related to MRN architecture. Comprehensive research in these areas is required to improve the efficiency of wireless networks with MRN. This thesis considers mobility management and CAC issues in LTE networks with MRN.

Inter-cell Interference and Outage Probability: A two-hop network is formed for MRN backhauling and overlaid on the coverage of eNB. Inter-cell interference can be addressed by providing (1) a direct macrocell link and MRN backhaul link from a neighboring macrocell and (2) an access link for the inside MRN antenna from nearby small cells (such as an MRN, femtocell). Different interference management solutions for networks with MRN have been proposed in which it was shown that the access link of an inside MRN antenna incurs minimal impact from outdoor wireless links [14]. In addition, higher Vehicular Penetration Loss (VPL) was used to reduce this impact.

In [15–17], the authors compared the outage probability of vehicular users connecting via MRN using a two-hop transmission and single-hop direct transmission (eNB). When the VPL is high, the outage probability is higher than for an MRN-assisted connection. In addition, the distance between the vehicle and eNB is an important factor to consider in regard to the outage probability.

Mobility Management: This can be used to support seamless connectivity for terminals moving from a cell to a neighboring cell. Mobility management involves selecting an appropriate handover scheme. LTE systems only support a hard handover, known as Network-Controlled Hard Handover (NCHH), which is a break-to-make method, in which the old link between UE and the source eNodeB is released before the new link (between the UE and the target eNB) is established [18].

In the case of MRN, enhanced handover management is necessary to allow, for example, the handover procedure to finish before MRN leaves the area covered by the serving cell. Thus, if the handover fails, MRN and its connected UE will be dropped.

The call admission control: CAC functions to manage radio resources, as well as call blocking or acceptance. When admitting calls, CAC can either process a new call or handover call based on the availability of resources in the target cell. The target cell should provide the resources for the MRN and its connected UE during the handover procedure and cell residence time. The typical call admission is able to reserve the radio resources for handover calls and new calls. Insufficient radio resource utilization can lead to dropped handover calls. This can be prevented by providing the radio resource reservation with priority for MRN by redesigning CAC in LTE.

Security In an LTE network system, the base station is directly connected to the operator's core network, thereby reducing potential security problems. This ensures that MRN is part of the access network of the LTE system. In addition, authentication and registration can be used to provide safety and security in the homogeneous network.

1.2 Problem Statement and Thesis Contribution

Mobility management of MRN is a new paradigm in cellular networks. In a system that utilizes MRN, the mobile devices connect to the inside antenna of MRN and do not execute the handover procedures between macrocells; instead, only the outside antenna of MRN executes the handover procedure to the target cell [4, 7]. However, in the current version of MRN architecture, the Mobility Management Entity (MME) reuses the conventional NCHH [7]. However, conventional NCHH is more reliable in the general sense in low-mobility environments, in which the UE incur a high ping-pong handover ratio and a low Radio Link Failures (RLFs) ratio. These problems could be solved by defining a value of Time-To-T (TTT) for the LTE standard capable of reducing the number of ping-pong handovers. On the other hand, NCHH is not reliable for direct use in a high-speed mobility environment. The advantage of using high-speed mobility in the overlap area is a reduced ping-pong handover ratio, but it also imposes disadvantages resulting from reduced handover performance such as an increased RLF ratio, service interruption, and a reduced handover success rate. In addition, from the viewpoint of the core network, handover triggering and the decision steps of the MRN are the same as those of NCHH of regular UEs as similarly defined in the preparation phase of the handover procedure. However, in this case the handover is defined with some differences, namely the path switch steps and synchronization method in the execution and completion phrase of the handover procedure. Hysteresis is the main parameter that can manage handover triggering and increase the handover performance. An enhanced handover scheme is, therefore, crucial to solving these problems. Enhancement of this scheme would enable a reduction in RLF, commencement of the handover procedure at the correct time, and an increase in the handover success rate in a high-speed mobility environment.

In wireless networks, typical CAC schemes can reserve the radio resources for handover calls and new calls (two classifications) in the target cell [19–22]. From the point of view of the target cell, the handover call of an MRN is the same as the handover calls of the UE because the serving cell begins the handover procedure only for the outside antenna. The CAC scheme would need to support the MRN and its connected devices. This need could be addressed by enhancing and modifying the CAC capability to reserve the radio resources for MRN and its connected UE.

In this thesis, we consider a network scenario involving MRN, in which the MRN is installed in a train traveling between macrocells. Our focus is on ensuring that the handover is triggered at the correct time such that the RLFs are reduced and the handover performance is increased. The main contribution of this thesis is a detailed study of handover triggering for LTE networks and MRNs. Hence, our main contributions are the following.

1) An investigation of the MRN handover procedure and associated problems in the high-speed mobility environment. First, we propose a cost-based adaptive hysteresis scheme and an enhanced CAC scheme that optimize MRN deployment for two different network objectives: the reduction of both RLFs and the dropping of handover calls during the handover procedure. The normalized function of the proposed cost function is load, speed, and services with the aim of selecting the optimal candidate base station, and to optimize hysteresis related to the current speed of the train. Then we classify calls according to three types: MRN handover calls, UE handover calls, and new calls. In addition, we assign a high priority to MRN handover calls because it is necessary for the CAC scheme to reserve the radio resources for MRN and its connected devices. Our proposed CAC is designed to meet these requirements: it can reserve the radio resources for MRN and its connected UEs with high priority.

2) An investigation of the Handover Performance Indicators (HPI). In this case, we propose a self-optimization handover parameter scheme comprising two main features: (i) speed-based handover hysteresis optimization for handover triggering and decision-making; and (ii) HPI-based offset optimization for the reduction of RLFs. Next, we propose a dual MRN architecture to reduce the duration of communication interruptions of passenger devices. We conduct a simulation study to analyze and validate the performance efficiency of our proposed schemes.

1.3 Organization of the Thesis

The rest of this thesis is organized in several chapters as follows. We proceed by providing an overview of the background topics related to the thesis in Chapter 2. At first, I introduced the LTE network architecture. Then, MRN architecture and handover procedure are presented.

Chapter 3 investigates design and elaboration of the proposed an adaptive hysteresis scheme and CAC for MRN. We investigate an adaptive handover hysteresis scheme based on the cost function to increase the handover performance of hard handover in LTE. The cost function is based on important factors, namely the speed of the vehicle relative to the MRN, the load on the system and the service types of the active users. Then, we reverse the radio resources for the handover calls of MRN, in order to reduce the HCDP.

In Chapter 4, we analyze the potential performance of self-optimization scheme of handover parameters and the handover procedure with Dual MRNs. We first proposed to optimize the handover parameters: a) hysteresis, which is the main parameter associated with the handover triggering and b) CIO; which provide radio resource and signal quality management of each cell and the main parameter associated with reduced RLFs. Then, we proposed the handover management for the dual MRNs in order to reduce the data interruption time. In addition, only main antenna completes the measurement procedure for its handover decision by the serving cell. After this handover is completed, a secondary MRN begins a handover procedure that emulates the successful handover procedure of the main antenna.

Chapter 5 summarizes and concludes the work in this thesis, and outlines some potential future work.

Chapter 2

LTE Networks, MRN architecture and Handover

This chapter presents background material related to the work in this thesis. It starts with an overview of LTE network in Section 2.1. MRN architecture and handover procedure are overviewed in Sections 2.2 and 2.3, respectively. The handover parameter optimization presented in Section 2.4 Related works are presented in Section 2.5.

2.1 Introduction to LTE

LTE is a wireless technology that was developed by the 3rd Generation Partnership Project (3GPP) and which contributed to the development of the fourth generation mobile network. LTE can support the requirements and high data rates of multimedia traffic such as video streaming, video call, online conference, Voice over IP (VoIP), and gaming over wireless networks for access anytime and anywhere. Furthermore, LTE supports the MIMO (Multiple-Input and Multiple-Output) technology and OFDM (Orthogonal Frequency-Division Multiple), as well as

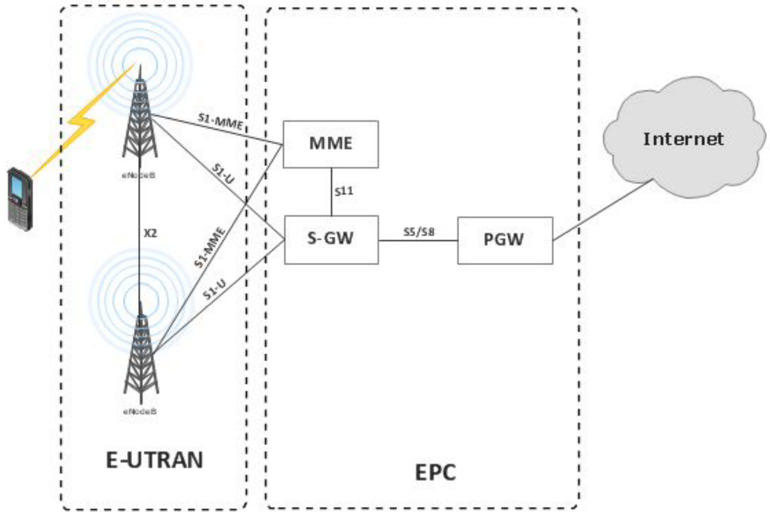


FIGURE 2.1: LTE network architecture (3GPP Release 2008).

FDD (Frequency-Division Duplexing) and TDD (Time-Division Duplexing) modes. The basic components of LTE are shown in Figure 2.1.

From a network design point of view, LTE network comprises many interconnected eNBs, which is the component of the Evolved Universal Terrestrial Radio Access Network (E-UTRAN). eNBs are connected to MME, Serving Gateway (S-GW), and Packet Data Network Gateway (P-GW) in the Evolved Packet Core (EPC) network to support various kinds of services, such as signaling, handover, and security [23]. Apart from providing cost-effective broadband communication services, LTE provides the improved capacity, higher throughput, increased spectrum efficiency, lower latency and improved coverage [24]. LTE has been superseded by its enhancement, which is known as LTE-A. It includes new capabilities, which offer sufficient performance to support high-quality IP-based video streaming and other multimedia services over IP to a large number of customers simultaneously [24].

2.1.1 E-UTRAN

The E-UTRAN is a part of LTE network that is a radio access network based on a packet-switched technology. An LTE network comprises many interconnected the base station, called eNodeB, which are the main component of the E-UTRAN and in order to provide the radio links to UEs.In addition, the eNodeB is a provider to UEs by the wireless, cellular coverage in the geographical area.

The functions run in eNodeB that can provide the radio resource management and data traffics. Example: a packet scheduler to manage the packet queue of upload and download procedures of all connected UEs, and the resource allocation to manage the channels for admitting calls.Moreover, an interface called X2 to transfer control/data messages between the neighbor eNodeBs and S1 interface to make a connection with the EPC's functions.

A part of E-UTRAN is UE which is devices with LTE module such as a smartphone, tablet, and other mobile devices. In other hands, UE is the USIM (Universal Subscriber Identity Module) installed devices. The USIM/LTE module provides a good quality connection between eNodeB and UE over a radio link called Uu. Also, it stores data that is a subscriber identity number and its related key for security functions such as authentication, longer encryption, data integrity and an address book. The USIM is an application that can support the billing, roaming, monitoring and other application level functions.

2.1.2 EPC

The EPC is core network of LTE. Its components are P-GW, S-GW, and MME.

P-GW is main routing point to the external network. The element of the network which serves as a router for connection to the external network. In IP networks, router service is responsible for allocation of IP address to the UE and the connection with operator's IP services such as IP Multimedia Subsystem (IMS). The IP address assigned by P-GW is used for internet access and service provisioning over control interface SGi. The P-GW facilitates enforcement of QoS and flow-based charging rules of Policy Control and Charging Rules Function (PCRF). It also filters the downlink user packet into respective QoS-based bearers and functions as a mobility anchor for other non-3GPP technologies.

S-GW is a local anchor for mobility when UEs moves between the eNodeBs. Its functions are the re-routing, path switch, buffer, and synchronization. Generally, the S-GW relays data transmission from serving eNodeB to P-GW and path switching of GPRS Tunneling Protocol (GTP) tunneling between source and target eNodeBs during handover procedure.

MME is the main control point of LTE access network and mobility (S1-MME interface is shown in Figure 2.1). The two major functions are the location management and handover management. In tracking area level, the location management stores the location information for each user and then selects the appropriate gateway for data transmission. The handover management to control handover preparing, triggering, execution and etc. The important role of MME is a seamless connectivity by a combination of these functions. The MME also can provide the handover signaling between LTE, 2nd Generation (2G), 3rd Generation (3G), and other wireless networks (in heterogeneous networks).

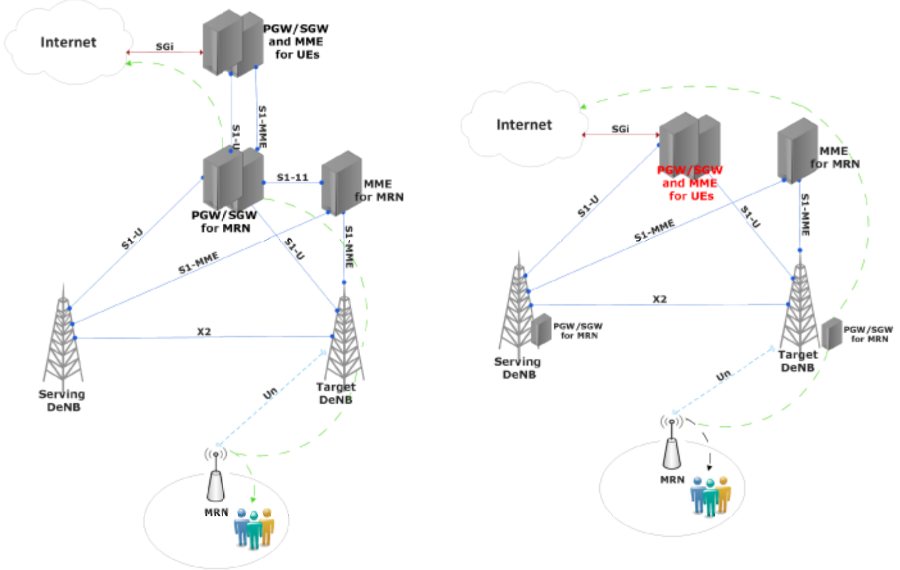
2.2 MRN architecture

A relay node architecture increasing the capacity of the system and the radio coverage area [4, 25]. In LTE/LTE-A standards, Fixed Relay Node (FRN) and MRN have been considered [3, 4, 7, 25]. Using this network architecture with MRN, mobile network operators can achieve high data rates to support a good quality connection and multimedia applications over wireless networks for vehicular users on the high-speed move. It is a part of the newly aim of the mobile network operators. In addition, MRN is one of the feature enhancements and the enabled solutions in the next-generation wireless networks.

From a technical point of view, MRN similar to the FRN, that is connected to the donor-eNodeB via backhaul link Un for the data transmission. Donor-eNB is the eNodeB of mobile network operator's access network that the relay technology enabled. Moreover, the MRN exchanges control information for the MME and S-GW for UE's leave and enter process over the serving donor-eNB. In addition, the UE is connected to an antenna of MRN located inside in the in the public transportation vehicles, such as bus, car or train.

FRN and MRN are the advanced relay technology that can buffer packets and check errors when forwarding data to UE. Two main concepts of relay defined by LTE standards (see Figure 2.2). In LTE release 10, a baseline architecture is Alternatives 2 (called Alt 2) relay that like as the proxy node in order to provide QoS and improved coverage area of donor eNB [3, 5, 7]. In this architecture, routing network functions (S-GW and P-GW) are located on donor eNB that can transfer control and data signaling through Un link to relays. Alternatives 1 (called Alt 1) relay is the full layer-3 relay and the transparent for the serving donor eNB. Also, network functions separated from the serving donor eNB [3, 5, 7]. In this architecture, when MRN execute a handover procedure, separated S-GW/P-GW can anchoring for mobility MRN and its user devices.

Advantages of MRN architecture: Using the MRN, vehicular users can to bypass the difficulties: VPL by the inside, outside antennas and functions (router or proxy), increased power consumption and QoS of UEs in because MRN's inside antenna has the optimum and fixable signal strength more than direct to UE from eNodeB, and the reduction connection failures of UE's because the poor radio link conditions. Moreover, Only MRN's execute handover procedure instead of its connected UEs when the vehicle entering to the overlap area between donor-eNBs. It can be reduced the signaling overhead such as the communication path switch to the new cell, and a number of handover procedure in the same condition. Researchers showed the comparison



(a) Alt.1 architecture

(b) Alt.2 architecture

FIGURE 2.2: Type 1 and type 2 relay architectures.

and performance results of MRN usage for downlink and uplink accesses [6, 26, 27]. The data transmission rate of the vehicular users is increased with higher transmission power and MIMO technology from powerful outside antenna. In addition, authors [28] showed the improvement of onboard users' throughput by the simulation result of comparison of the direct transmission and cooperative MRNs.

Disadvantages of MRN architecture: For architecture, the main issue is the radio link quality and reliability of backhaul link that is *the single point of failure*. In addition, the data packet scheduler of donor-eNB is an open issue.

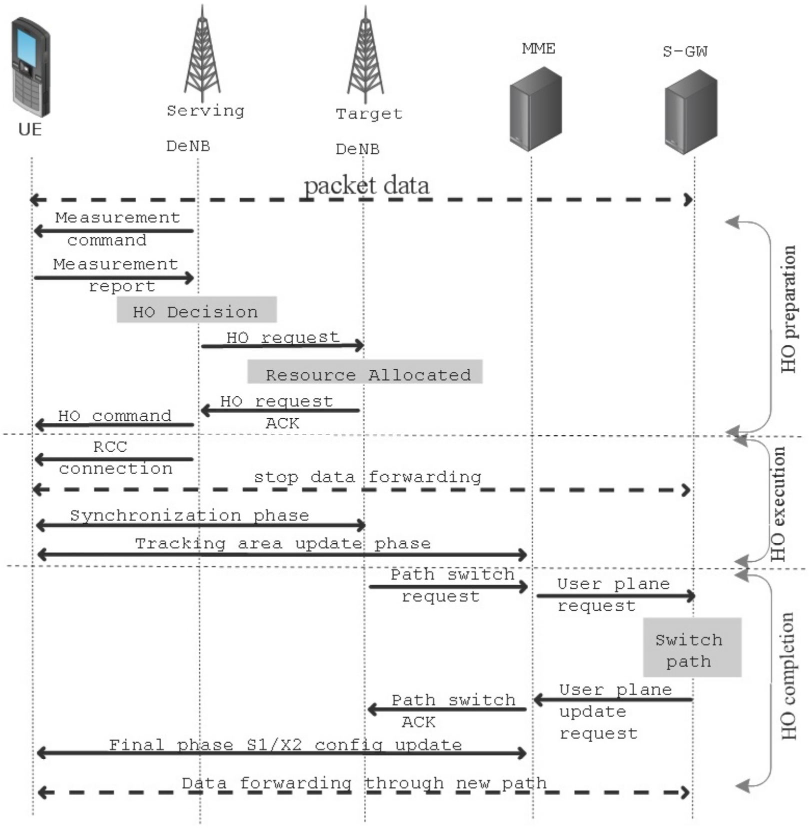


FIGURE 2.3: Signaling of existing handover procedure between the eNBs.

2.3 Handover procedure and parameters

2.3.1 Handover procedure

handover management is a major task that supports continuous transmission for a mobile terminal moving across the different radio coverage areas. The working group of LTE standards defined handover management based on the NCHH [7]. NCHH is a ”break-before-make” method; that is, a connection between UE and the serving eNB is broke, before a new connection is established between the UE and the target eNB. The conventional handover procedure includes three phases: handover preparation, execution, and completion [29]. Figure 2.3 depicts the existing NCHH of the LTE.

In NCHH procedure, firstly the serving eNB sends a ”measurement command” to a UE if radio link quality and signal strength are reduced. On receiving the measurement control command, UE starts the measurement procedure for make list of the available eNBs and consequently sends a ”measurement report” to the serving eNB. The serving eNB then makes the handover decision and selects the target eNB based on the measurement report from the UE. The preparation phase is thus completed.

If handover procedure is necessary, the serving eNB sends the ”handover request” to the selected target eNB via X2 interface (if inter-EPC) or S1 interface (if intra-EPC). The target eNB accepts and prepares the handover request if radio resources are available (resource allocation and control functions), and replies with the ”handover request ACK” to the serving eNB. Then, the serving eNB sends ”handover command” and ”RCC connection” to the UE includes the necessary information of the target eNB. Upon receiving a thus command, the UE disconnects a connection with the serving eNB and make a connection with the target eNB.

After an RCC connection, the serving eNB stops data forwarding to UE. In the same time, UE synchronizing to target eNB, and sends ”tracking area update phase” to MME. The target eNB sends a ”path switch request” to MME for a new connection. After MME accepts it, MME sends a ”user plane request” to S-GW for re-routing. S-GW replies after switch path and MME replies an accept command ”path switch ACK”. Finally, if the handover procedure is successful, the MME and UE updates X2/S1 configuration and data forwarding through a new path over the target eNB.

2.3.2 Handover triggering and parameters

If network configured condition is satisfied, the serving eNB starts the handover procedure based on a measurement report. This handover trigger is based on events, conditions are defined in the LTE specification [18]:

- **Event A1**: Serving becomes better than the threshold.
- **Event A2**: Serving becomes worse than the threshold.
- **Event A3**: Neighbor becomes offset better than serving.
- **Event A4**: Neighbor becomes better than the threshold.
- **Event A5**: Serving becomes worse than one threshold and neighbor becomes better than another threshold.

Figure 2.4 illustrates the entering condition to the target cell based on Event A3 in the LTE network that is a relative condition for parameters of the serving and target cells. Other conditions are based on the configured threshold.

Equation (2.1 and 2.2) defines the conditions for Event A3:

Entering condition of Event A3

$$M_n + Of_n + Oc_n - Hys_{A3} > M_s + Of_s + Oc_s + off_{A3} \tag{2.1}$$

Leaving condition of Event A3

$$M_n + Of_n + Oc_n + Hys_{A3} < M_s + Of_s + Oc_s + off_{A3} \tag{2.2}$$

where

- M_n and M_s denote the measured Received Signal Strength (RSS) of the target eNB and serving eNB, respectively.
- Of_s and Oc_s are the cell specific offset values of the serving eNB. Expressed in dB.

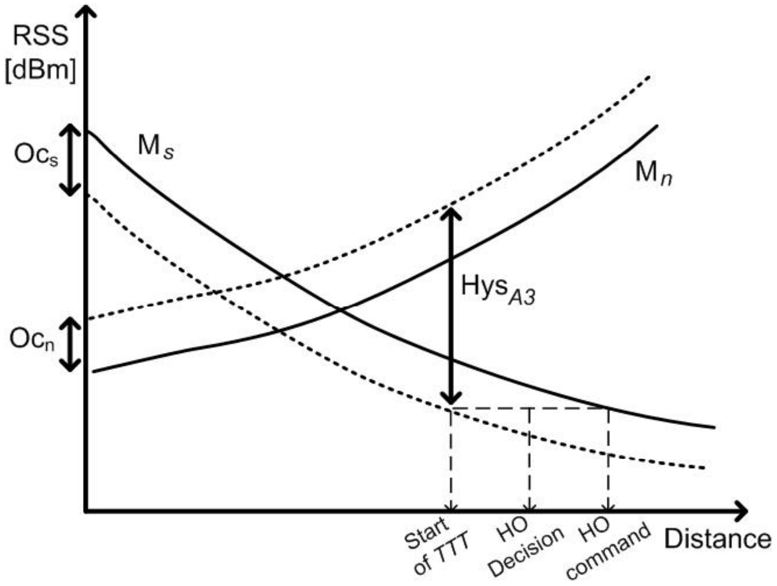


FIGURE 2.4: Handover parameters
Adapted from "Self-Optimization of Handover Parameters for Long-Term Evolution with Dual Wireless Mobile Relay Nodes," by Author B.Davaasambuu, 2015, MDPI Future Internet, Volume 7(2), p196-213 [30].

- Of_n and Oc_n are the cell specific offset values of the target eNB. Expressed in dB.
- Hys_{A3} denotes hysteresis for this event, expressed in dB.
- and off_{A3} is the offsets for this event, expressed in dB, configured by the operator.

In the handover procedure [18], the presented handover parameters are hysteresis, TTT, and offsets.

hysteresis is defined as an integer between 0 and 10 dB in steps of 0.5dB, used within the entry and leave condition.

time-to-trigger: If Event A3 is satisfied, the serving eNB begins the timer (called TTT). After the timer is finished, if the condition is satisfied, the serving eNB initiates the handover procedure. The TTT are defined in the LTE specification, the possible values are: 0, 40, 64, 80, 100, 128, 160, 256, 320, 480, 512, 640, 1024, 1280, 2560 and 5120 ms.

offset: cell specific offset parameter is the applicable to a specific neighbor eNB or serving eNB. Value is dB-24 (-24 dB), dB-22 (-22 dB) and so on. Otherwise, if it is equal to zero, the departing or entering range of the cell is set as the measurement result. Cell Individual Offset (CIO) is offset configured by the serving cell for the target cell.

2.4 Parameter optimization

In current wireless networks, the optimum selection of the handover parameters is not easy, moreover, it can lead to network performance. Poorly configured handover parameters can diminish the performance of the network because the unsuccessful handover and RLFs. Also, manual configuration is not the only method for selection of handover parameters. In order to solve the problem of parameter selection and configuration, the Self-Organizing Networks (SON) defined in LTE Releases 11 [31]. The SON functions can manage and auto-tunes the parameters of radio access network based on real-time management mechanisms. This functions is self-* management functions; the self-configuration, self-optimization and self-healing [31–34].

Optimizing handover mechanisms concern both the self-configuration and the self-optimization. handover parameter optimization is one of SON functions. This function auto-tunes the handover parameters in order to provide the seamless mobility and increased handover performance for any scenarios [35]. The self-configuration can change the handover parameter setup of the network. In addition, context information of terminal (velocity, load, location, direction and others) and information of a current state of the network is used for improving SON functions. The results of handover parameter optimization are reduced numbers of ping-pong handovers, too early handovers, too late handovers, RLFs and a wrong cell selection in the limited radio resource on the target cell. The handover optimization related works is introduced in next section.

2.5 Related Works

2.5.1 Related Works on CAC

Wireless networks based on a CAC scheme have been described and studied in many papers. In [19], the authors analyzed the adaptive resource allocation scheme for two cases, namely with both non-priority and guard-channel schemes for the adaptive handover scheme, and the corresponding simulation results showed that adaptive schemes are able to reduce the dropping probability of handover connections. In [20], the authors introduced an adaptive CAC algorithm to complement the resource reservation mechanism with a bandwidth reallocation policy. The proposed scheme was shown to significantly reduce the new call blocking and handover call dropping. The self-optimization of the CAC is being investigated in the SOCRATES (Self-Optimisation and self-ConfiguRATion in wirelEss networkS) project for LTE and next generation mobile networks [21]. These schemes only focus terminals such as UEs. CAC scheme must to support the wireless backhauling if the target cell enabled. Authors in Zhou and Ai [36] introduced the admission control scheme that utilizes and prioritized the knowledge of the overlap area between cells and the speed/location information of the train. Statistical and dynamic versions can decrease the CDRs of video application to 38 percentage and data to 16 percentage, respectively. Also, proposed scheme can increase the resource utilization ratio to higher than the traditional scheme.

2.5.2 Related Works on Handover Optimization

Many studies on the 3GPP LTE system have focused on SON to minimize CAPital EXpenditure (CAPEX) and OPerating EXpenditure (OPEX) and to maximize operator revenue through automatic network management [32]. This self-configuration and self-optimization comprise dynamic networks. Note that the handover procedure in the network-controlled handover of the 3GPP LTE system is closely connected to the self-optimization that collects measurement information from the UE and eNB; it then automatically tunes the configuration data to optimize the network. The handover parameter optimization is part of self-optimization. The SON automatically optimizes handover parameters to increase handover performance. Thus, self-optimization schemes can dynamically choose handover parameters in wireless networks [33, 37, 38]. In addition, to minimize the oscillations of the handovers by the TTT and handover hysteresis, parameters are optimized in [35]. Another oscillation-focused scheme is also proposed in [39]. The proposed scheme adjusts the TTT and handover hysteresis to minimize the number of RLFs. Further results are presented in [40], authors analyzed on the effects of handover hysteresis and TTT parameters. In different traffic and speeds cases, handover hysteresis is an effective more than TTT for LTE optimization. Resulting, handover hysteresis is the main parameter for handover optimization and the reduction of handover failures. However, optimization scheme to monitor a selection of TTT. To address it, in [41], an algorithm that finds the best handover hysteresis and TTT combination, which serves to improve the handover performance, is presented. In the proposed algorithm, a weighting HPI function that includes the ping-pong handover, handover failures, and dropped calls is defined. The handover parameters of individual HPIs are also weighted in order to reduce the number of Handover Failures (HOF), Handover Ping-Pong (HPP) and RLFs [42]. In [43], the focus is on UE speed-based mobility robustness optimization, which involves optimized HH and classified UE speed. Simulation results are presented for cases in which TTT and CIO are constant for all users; however, each cell has its own CIO.

2.5.3 Related Works on Handover schemes of train system

The handover for MRN is introduced similarly to a regular UE handover (which is named NCHH) in 3GPP Technical Report 36.836 [7]. Researchers introduced a handover scheme for relay-based networks. The RSRP-based handover was introduced between the serving donor-eNB and the target donor-eNB for LTE relay architecture alternatives, Alt1 and Alt2 [3]. In [44], authors introduced a cell selection mechanism for mobile relay operations based on the geometric boundary of the cell and the obtained location of the UE. In addition, the analysis and simulation results presented in [4] are related to moving relays and mobility optimization for the relay enhanced networks. The authors in [45] introduced a relay assisted handover schemes for the train system. In this scheme, a repeater relay located in the overlap area, and this relay to control the power and to provide the data transmission during the handover procedure. Also, train control system to support a handover by a context information. The authors in [46] present the modified handover of LTE standard based on reference points for MRN mounted on the top of the train. Two reference points are Reference Trigger Point (RTP) for periodically measurement report and Reference Handover Point (RHP) for the handover execution phrase. During the preparation phrase, bi-casting is also introduced to realize seamless handovers. In the results, the handover delay reduced to about 50 ms when the velocity is higher than approximate 200km/h. Focus on the probability of handover triggering, authors in [47] introduced an adaptive handover trigger scheme. In this scheme, when the train is arrival at a midpoint of overlap area for the adaptive periodically measurement report. Periodically report based handover triggering is the main idea of this scheme in order to increase handover triggering probability. In [48], authors proposed handover scheme with two external antennas (front and rear) and bi-casting for High-speed train. For seamless connection, in order to provide non-interruptive connection, front antenna execute the handover procedure, then starts the bi-casting for data forwarding by serving and target base stations. After the rear antenna executes handover, bi-casting will stop by the serving base station. The antennas execute all phrase of the handover procedure. This is may increase the signaling overhead. In simulation results, two antennas can provide the improved handover performance and reduced interruption probability. In addition, handover schemes with bicasting solutions have been proposed to increase system throughput by other researchers [49–51].

2.5.4 Related Works on Parameter Optimization of High-speed Environment

In [52], two handover schemes that adjust handover parameters to improve network performance are proposed. The first scheme is a rapid handover algorithm based on UE velocity. In this scheme, the handover hysteresis and TTT are adjusted to ensure the handover success rate and communication quality at velocities between 0 km/h and 350 km/h. The second scheme focuses on TTT optimization. In [53], an LTE-based cell array solution that supports high throughput and continuous multimedia service is proposed. This scheme prepares a cell array based on the mobility direction and speed of the train. In [54], a handover scheme that utilizes coordinated multi-points for moving vehicular femtocell networks is presented. In this scheme, several external antennas are installed on the train. When the train reaches an overlap area, all external antennas send measurement reports to the serving cell. Firstly, an external antenna with weak RSS from the serving cell begins the handover. Then, other external antennas execute the handover. A similar scheme is presented in [48, 55]. The authors in [56] introduced the improvement of A3 event algorithm of LTE to adapt to the high-speed scenarios. In this scheme, TTT replaced by a threshold (static) for the reduction of RLFs and affect to the handover triggering. In system level simulation, a combination of hysteresis and proposed threshold can reduce the probability of RLFs below 10 percentage.

Chapter 3

Adaptive Handover Hysteresis and Call Admission Schemes For MRNs

3.1 Introduction

The fast moving of the train, possibly at a very high speed in the area in which two cells overlap, could cause the network to suffer from a reduced handover success rate and, hence, increased Radio Link Failures (RLF)s. The combined impact of these problems is service interruptions to vehicular users. The handover schemes are crucial in solving these problems. The two main problems associated with the handover procedure of Moving Relay Node (MRN) are that: (1) they require radio resources to be reserved for the handover call of MRN, and (2) they need to be instructed on how to finish the handover procedure of MRN before losing the signal of the serving cell.

The main part of mobility management is the handover scheme that can be used to support seamless connectivity for a mobile terminal moving into the overlap area. The aim of proposed adaptive hysteresis scheme, which is based on the speed of the vehicle with MRN, is to influence the handover triggering condition. Moreover, the proposed scheme can increase the time for the handover procedure, including the time required by the security policy and data re-routing, when the speed of the vehicle is high in the overlap area. In LTE systems, Call Admission Control (CAC) to manage radio resources, as well as call blocking or acceptance. When admitting calls, CAC can either process a new call or a handover call based on the availability of radio resources of the target cell in order to provide the efficient utilization, and QoS in terms of UE requirements is satisfied. In addition, the target cell should provide resources for MRN and its connected UE during the handover procedure and cell residence time.

In the typical CAC schemes, reservation scheme defined the handover call of MRN same as UE. Therefore, our proposed CAC scheme is required to realize radio resource reservations for three call types (a new call, UE handover call, and MRN handover call) and to minimize the dropping of MRN handover calls. After CAC dropped a handover call, the serving donor-eNB would have to re-initiate the handover procedure for MRN to the other target donor-eNBs. This, in turn, requires more time for handover, and as a result, a further delay and increased handover failure rate are introduced.

In this work, we first proposed an adaptive hysteresis scheme capable of dynamically tuning handover hysteresis based on the speed of the train. Hysteresis is the main parameter that can manage the starting point of handover procedure in the preparation step. Second, the Handover Call Dropping Probability (HCDP) is reduced by introducing a modified CAC scheme to support radio resource reservation for handover calls that prioritizes handover calls of MRN over the other calls. The proposed solution in which adaptive hysteresis is combined with CAC is evaluated by system level simulation. Our simulation results illustrate an improved handover performance and reduced RLFs. The scheme and results described in this chapter have been published as *"A Cost-Based Handoff Hysteresis Scheme in Wireless Mobile Relay Node," by Author B.Davaasambuu, 2014, Proceeding of IEEE Vehicular Technology Conference (VTC Fall) [57]* and *"Adaptive Handover Hysteresis and Call Admission Control for Mobile Relay*

Nodes," by Author B.Davaasambuu, 2015, International Journal of Computer Networks and Communications (IJCNC), Volume 7(6), p87-98 [9].

3.2 Cost Function Based Handover Hysteresis Scheme

This section presents the cost function and the adaptive handover hysteresis for encouraging hard handover procedure. In order to minimize handover failures in the high-speed environment, the purpose of adaptive hysteresis scheme is to select the most appropriate target donor-eNB and to calculate hysteresis based on the result of cost function, as well as to support the handover procedure. The proposed cost function is based on three important factors that can affect the handover performance, simultaneously. Factors that namely the speed, load, and service. In other words, the serving donor-eNB is assigned the order of the target donor-eNBs by normalized value of the load using the measurement report from the MRN and information of the neighbor cells. Also, the serving donor-eNB runs the cost function in order to select suitable a hysteresis related to speed of the train when a measurement report arrives. We presented the cost function, factors and its normalized functions in the next sections.

3.2.1 Cost Function

In heterogeneous networks, the handover schemes based on the cost function have been introduced. In [58], authors proposed the vertical handover decision algorithm based on the cost function with a combination of the prediction of SINR (signal to interference plus noise ratio) in heterogeneous wireless networks. A cost function was introduced on the basis of multi-attribute QoS, and an approach for optimal network selection was introduced. In [59], authors proposed a handover enhancement for a relay enhanced LTE network. The proposed scheme is a handover scheme based on a cost function, including signal cost and throughput on LTE cellular relay networks, and compared their scheme with conventional NCHH of an LTE network. However, the previous studies only focused on target cell or network selection. Moreover, these scheme were created for regular UE and low mobility environment. In contrast, the scheme presented in this chapter is created for MRN and high-speed mobility environment. From a cost function perspective, it is used in vertical handover heterogeneous networks that is provided as a weighted sum of normalized functions by many factors[58, 60]. Factors are the Signal to Interference and Noise Ratio (SINR), user preference, user traffic cost and the available bandwidth of the access network. For an adaptive hysteresis scheme, we need to consider the factors related to the handover procedure, MRN mobility and network performance. When changing the cost function f_H that is applied in the LTE network with MRN, it uses the following three factors: the load difference between the neighbor donor-eNBs, the speed of the train containing the MRN and service type of active users (passengers). Our scheme is presented as follows 3.1:

$$f_H = w_l * N_{load} + w_v * N_{speed} + w_s * N_{service} \tag{3.1}$$

where normalized functions (N) calculate the adjustment value by the natural logarithm based on the context information of MRN and the load difference of neighboring cells. The weights (w) are for use by the normalized function to define the priority of factors. In our research, speed is a high priority; therefore, speed was assigned a larger weight than the other two parameters ($w_l + w_v + w_s$ must be one). The $load$ is the difference of the available bandwidth between the serving and target cells; $speed$ is a speed of the train containing the MRN; and $service$ is the service type of passengers (devices connected to the inside antenna of MRN). The parameters N_{load}, N_{speed} and $N_{service}$ of Equation 3.1 are presented in the next subsections.

3.2.2 Normalized Functions

Target cell selection and normalized function of load: We now introduce the N_{load} function of Equation 3.1. In order to select the target donor-eNB, the serving donor-eNB calculates the normalized value of neighbor cells. After MRN replied a measurement command of serving donor-eNBs, in order to select target donor-eNBs, the serving donor-eNB sends a request ”load” to all candidate donor-eNBs that are listed in the measurement report of MRN. When receiving a reply, serving donor-eNB estimates the normalized value of a load of all candidates and to resort by load in order to select the target donor-eNB. Note that a cell lower load is optimal choose in the cost function.

The N_{load} function that is defined the difference between normalized values of the target and serving donor-eNBs,

$$N_{load} = ln(L_{serving}) - ln(L_{target}) \tag{3.2}$$

where L_{target} and $L_{serving}$ are the load information of target donor-eNB (top one in order) and serving donor-eNB, respectively. When a load of target donor-eNB is lower than serving donor-eNB, N_{load} is positive and a result of cost function will increase.

Normalized function of speed: Second, we now calculate that N_{speed} experiences handover when the train moves at high speed, *i.e.*, the distance per unit time is greater. If the speed of the train containing the MRN is high at a starting point of overlap area between cells, it is necessary to decrease the hysteresis value in order to start the handover procedure early. Therefore, we defined a summarized N_{speed} function, which is formulated as Equation 3.3.

$$N_{speed} = \log_{Hys_{A3}} \frac{(V_{max} - V_{current} + \alpha)}{V_{max}} \tag{3.3}$$

where $V_{current}$ is the current speed of train or bus, Hys_{A3} is the default fixed value of hysteresis (configured manually for regular UEs), α is weight and V_{max} is the maximum speed. If $V_{current}$ were to reach maximum speed, N_{speed} would be equal to $minimum$ value of hysteresis(defined in the next subsection). Thus, the handover decision (or time-to-trigger TTT parameter in Figure 2.4) would shift depending on the speed of MRN.

Normalized function of service type: We now introduce $N_{service}$ function with different QoS values that classify two service types: Real-Time (RT) and non-Real-Time (nRT) in LTE systems. In addition, an RT service has a higher priority than nRT services. In MRN utilized system, the handover procedure of MRN is important when the number of passengers with RT service prevails over the nRT service. Because, when MRN fails to handover, all UEs attached to an inside antenna of MRN will drop. Then, all UEs re-initial session to server after MRN is connected to the nearby cell. For example, MRN's inside UE using VoIP service lost a connection after the long connection interruption time when data transferring failed via MRN to the server because MRN cannot connect to the target cell. After MRN connect to the nearby cell, UE re-connect to the VoIP server like as a new connection and make a new session with a peer. Therefore, we presented the function by Equation 3.4 below.

$$N_{service} = \frac{ln(N_{RT}) - ln(N_{nRT})}{2} \tag{3.4}$$

where N_{RT} is the number of passengers using RT service and N_{nRT} is the number of passengers using nRT service.

3.2.3 Adaptive Hysteresis

We now introduce an adaptive hysteresis that can change the fixed hysteresis value based on the result of proposed cost function. When MRN reaches the cell boundary of the serving

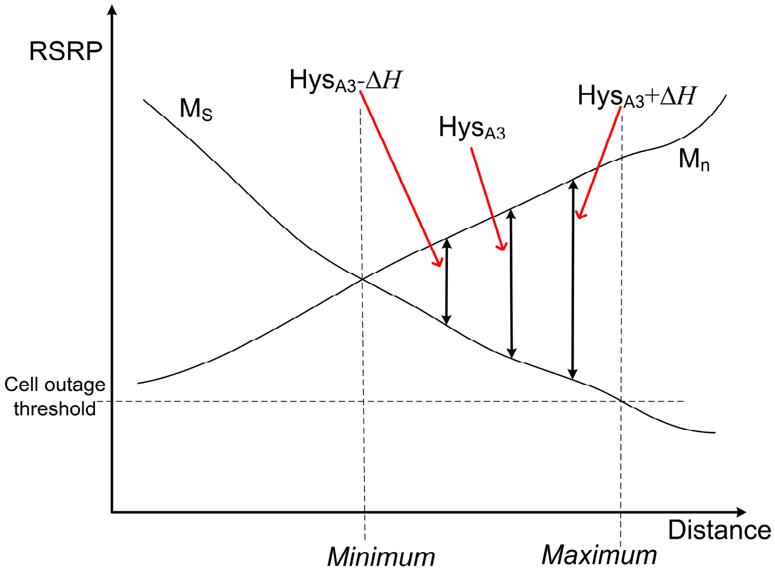


FIGURE 3.1: Hysteresis calculation, minimum, maximum and default values when an MRN moves to the target donor-eNB.

donor-eNB or a measurement command received, the measurement is performed and reply to the serving donor-eNB.The list of candidate donor-eNBs in this measurement report are related to the serving donor-eNB by utilizing the interface (namely X2 in Figure 2.1) to estimate the load of each candidate cell and then to generate a priority list based on load. Note, the cell boundary is the starting point of overlap between the neighbor cells.

Figure 3.1 shows the calculation of hysteresis value when an MRN moves to the neighbor M_n donor-eNB from M_s donor eNB. In this calculation of hysteresis value, Hys_{A3} is the default hysteresis value configured manually by the system, $\triangle H$ denotes the adjusted value of hysteresis calculated by a function, $minimum$ is the possible minimum hysteresis and $maximum$ is the possible maximum hysteresis. If the calculated hysteresis exceeds $maximum$, the serving donor-eNB directly start a handover procedure of MRN to M_n donor-eNB. The point at which the RSRP value of M_n donor-eNB exceeds the value of M_s donor-eNB is named minimum hysteresis ($minumum$).

In the proposed scheme, the hysteresis (H) value is automatically adjusted and calculated by Equation 3.5. This adaptive hysteresis can manage a starting point of handover procedure related to factors of MRN in the preparation step and to affect the handover performance.

$$H = Hys_{A3} - \triangle H \tag{3.5}$$

where Hys_{A3} is the default hysteresis and $\triangle H$ denotes weighted result of the cost function. Moreover, when the triggering condition represented below (Equation 3.6) satisfied, the handover procedure of MRN begins by the serving donor-eNB to the target donor-eNB.

$$M_s - M_n \geq H \tag{3.6}$$

where M_n and M_s denote the Reference Signal Received Power (RSRP) of target donor-eNB and serving donor-eNB, respectively.

In Equation 3.7, $\triangle H$ is expressed by:

$$\triangle H = \alpha * f_H \tag{3.7}$$

where α is weight for cost function (randomly selects less than $maximum$-Hys_{A3}). The value of $\triangle H$ increases as α is increase, in which case it would be more agreeable to find the best hysteresis for the handover procedure of MRN. f_H is a function that presented in the Section 3.2.1.

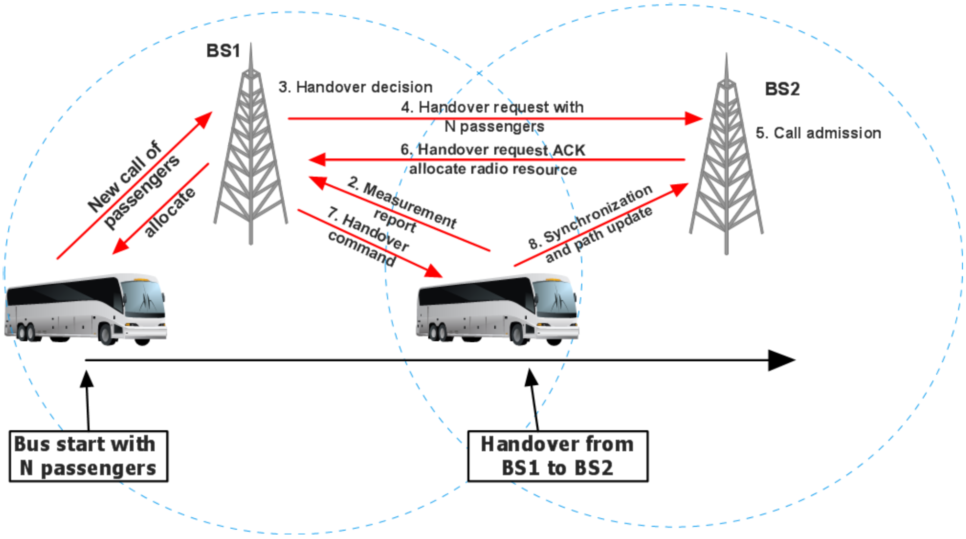


FIGURE 3.2: The handover procedure between the serving BS1 and target BS2, handover request and call admission control

3.3 Call Admission Control Scheme

The radio resources of a cell are efficiently managed by the Call Admission Control (CAC). When MRN is newly initiated within the nearby cell, the MRN sends a new call for a connection of outside antenna. Then, MRN transfer the new call for each passenger when the passenger's device is changed from idle to active. On the other hand, when handover triggering condition is satisfied during the TTT (time-to-trigger presented in Figure 2.4, Section 2.3.2) of the handover procedure, the serving BS1 send a ”handover request” with passengers (step 4) to the target BS2 for the handover procedure of MRN, shown as Figure 3.2. This request includes the number of outside antennas and the number of MRN's passengers using any services (with the established sessions). After handling the ”handover request” on the target BS2, the CAC scheme (step 5) allocates a radio resource for the received request. And, the target donor-eNB reply by ”handover request ACK” message (step 6).

The main parts of CAC are the efficient utilization of power and a channel allocation strategy. The utilization of power controls the transmission power of the target donor-eNB and

MRN. And, utilization of channel allocation strategy manages the limited radio resources. The typical CAC denotes the process of admitting a new call or a handover call, based on the availability of resources in a cell. Moreover, some calls are blocked or lost on target cell, because the utilization and limitation of the radio resources. Two important factors of call blocking are the new call blocking and handover call dropping in CAC. The first type refers to failure of the new call, whereas second type refers to drop of handover call by the target cell. In addition, if the available resources are insufficient in the target cell for accepting the calls, the target cell will drop them. The result of this is the increased unsuccessful handover ratio. The typical CAC schemes can reserves the radio resource for two call type on the target cell. At this point, the handover call of MRN is same as the handover calls of regular UEs.

In the proposed CAC scheme, calls are classified according to three types: handover call of MRN, handover call of UE and new call.

New call: The new call is the initial call connection establishment when a status of devices has changed from $idle$ to $active$. In addition, MRN will send the initial call for only outside antenna when MRN's status has changed from $idle$ to $active$. If accepted, inside antenna of MRN serve to the vehicular UE (passengers). Note that when passengers send a new connection request, MRN transfer it to the serving cell, it is same as new call of regular UEs.

Handover call of UE: The handover call of UE is a request to transfer in-service call when UE moves from one cell to another. The serving cell sends to target cell in LTE network. If dropped, the serving cell runs a cell selection process again or re-start the handover procedure.

Handover call of MRN: The handover call of MRN is a request to transfer in-service calls of passengers when MRN moves from one cell to another. The serving cell sends this request to target cell in LTE network. Passengers that are vehicular users served by MRN and to transferring data via MRN to macrocell and core network. In addition, the serving cell re-initiate the handover procedure after handover call of MRN is dropped, and send ”handover request” to the other target donor-eNBs.

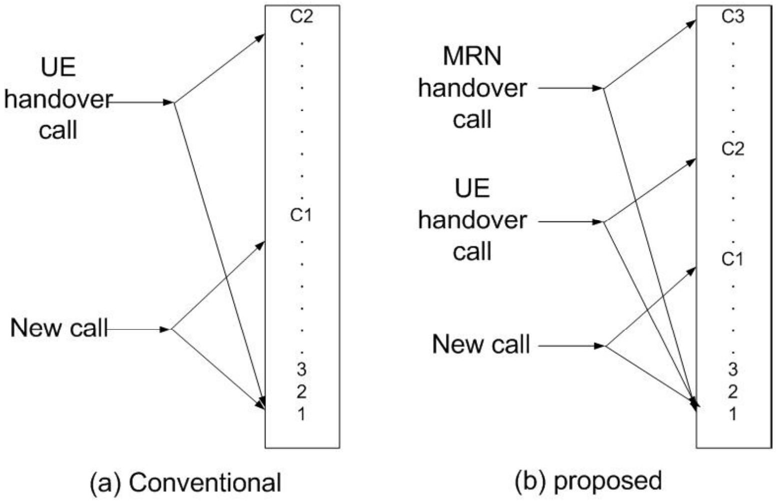
Additionally, when handover call of MRN in received, CAC of target donor-eNB need reserve the radio resources for an outside antenna of MRN and the devices connected to an inside antenna of MRN. Moreover, we propose a priority algorithm for CAC, which gives the highest priority to the handover call of MRN over the handover call of UE and new call. The focus of the proposed CAC scheme is to reserve the radio resources for handover call of MRN with high priority in order to reduce the handover call dropping.

3.3.1 Guard Channel based Call Admission

In the proposed scheme, the total channels of the target cell are divided into three parts by guard channels, handover call of MRN, handover call of UE and new call. The system models of a conventional and our proposed schemes are shown in Figure 3.3.

In conventional CAC, the received calls reserved below C1 guard channel. When the unavailable channels exceeds the C1, only handover calls are reserved up to C2 guard channel. C2 means the number of measured available channels. Thus, our proposed scheme reserve the new calls below C1 guard channel, similarly a conventional scheme. And, the channels between C1 and C2 guard channels are reserved for handover calls of UEs, the channels between C2 and C3 guard are reserved for handover calls of MRN and passengers. When the calls are received, proposed CAC runs the call admission algorithm, shown in Figure 3.4.

Consider a call request that arrives at time t, and C_{total} is the total channels of the cell. Denote by C_{req} the required channel of arriving call, by C_{busy} the number of already accepted active calls (channels are not available), $C_{busy_{C2-C3}}$ is the number of already accepted active calls between C2 and C3 guard channels, $C_{busy_{C1-C3}}$ is the number of already accepted active calls between C1 and C3 guard channels. The purpose of C1 and C2 channel is to prioritize



(a) Conventional (b) proposed

FIGURE 3.3: System model; (a) conventional CAC with two guard channels, (b) proposed CAC with three guard channels
Adapted from "Adaptive Handover Hysteresis and Call Admission Control for Mobile Relay Nodes," by Author B.Davaasambuu, 2015, International Journal of Computer Networks and Communications (IJCNC), Volume 7(6), p87-98 [9].

the handover calls. When a new call arrives, and the total needed channels C_{busy}+C_{req} is larger than C1, the call is blocked. In this way, guard C1 makes sure that channels between C1 and C3 is reserved for all handover calls. If an arriving new call passes the test which involves C1, it is accepted. When a handover call of UE arrives, and the total needed channels C_{busy}+C_{req} is larger than C2, the call is blocked. In this way, guard C2 makes sure that channels between C2 and C3 is reserved for handover calls of MRN. If an arriving handover call of UE passes the test which involves C2, it is accepted. When a handover call of MRN arrives, and the proposed algorithm following steps:

Step 1. when the total needed channels $C_{busy_{C2-C3}}$+C_{req} is smaller than C3, call is accepted.

Step 2. if call is dropped, next criteria is that the total needed channels $C_{busy_{C1-C3}}$+C_{req} is smaller than C3, call is accepted.

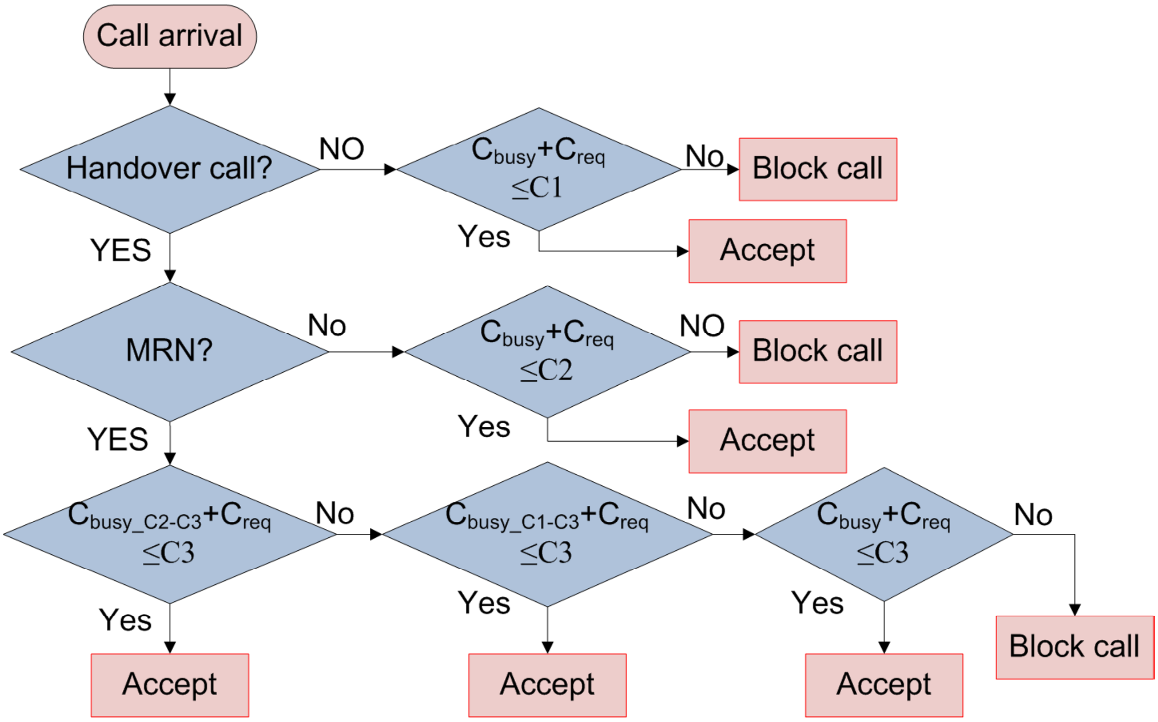


FIGURE 3.4: Flowchart of the proposed call admission algorithm

Step 3. if call is dropped, the total needed channels C_{busy}+C_{req} is larger than C3 (C_{total}), the call is blocked. In other hand, call is accepted.

3.3.2 Call Blocking and Dropping Probability

In order to evaluate the performance of proposed CAC in minimizing the handover call dropping of MRN during the handover procedure, the handover call dropping probability (HCDP) will be analyzed. In the CAC system model, the arrival of calls is represented by a Poisson function with the arrival rate of new calls denoted by λ_n, handover calls of UEs by λ_{ue}, and handover calls of MRNs with devices of passengers by λ_{mrn}. λ_{mrn} denotes a required channel number of MRN and the connected devices of passengers. In other words, the proposed CAC reserve the radio resource equal to the number of connected devices when handover call of MRN is received. The call holding time for all three types of call is exponentially distributed with 1/μ, 1/η and 1/β, respectively. Let ρ=(λ_n+μ)(λ_{ue}+η)(λ_{mrn}+β) be the total arrival rates of calls to the target cell. If the target cell has n channels, let P_n be the probability. The probability P_n that n channels are busy is:

$$P_n = \begin{cases} \left(\frac{\rho^n}{n!}\right) P_0 & 0 \leq n \leq C1 \\ \rho^{C2} \left(\frac{{\lambda_{ue}}^{n-C2}}{n!}\right) P_0 & C1 \leq n \leq C2 \\ \rho^{C3} \left(\frac{{\lambda_{mrn}}^{C2-C3}}{n!}\right) P_0 & C2 \leq n \leq C3 \end{cases} \tag{3.8}$$

where:

$$P_0 = \left[\sum_{n=0}^{C1} \frac{\rho^n}{n!} + \rho^{C2} \sum_{n=C1+1}^{C2} \frac{{\lambda_{ue}}^{n-C2}}{n!} + \rho^{C3} \sum_{n=C2+1}^{C3} \frac{{\lambda_{mrn}}^{C2-C3}}{n!} \right]^{-1} \tag{3.9}$$

Following which, the HCDP of MRN is calculated by using the following:

$$P_{l_{mrn}} = \rho^{C3} \sum_{n=C2+1}^{C3} \frac{{\lambda_{mrn}}^{C2-C3}}{n!} + \rho^{C2} \sum_{n=C1+1}^{C2} \frac{{\lambda_{mrn}}^{C1-C2}}{n!} + \rho^{C1} \sum_{n=1}^{C1} \frac{{\lambda_{mrn}}^{1-C1}}{n!} \tag{3.10}$$

3.3.3 Priority Policy

Our proposed algorithm is shown in Figure 3.4. In fact, on the arrival of handover calls of MRN simultaneously, which request with the different type of service, one gives the priority for the RT service.

In order to provide the prioritization, we investigate a priority policy scheme that to provide the lowest possible dropping ratios for the handover calls of MRN. When the number of radio resources available in cell is insufficient to provide the ongoing calls, the arrival handover calls of MRN will await the acceptance by storing them in specific queue order by the passengers.

The calls with a similar number of passengers will be treated differently because service type of passengers depends importantly. Thus, we propose a queue for handover call of MRN with a similar number of passengers. In proposed policy, the calls in queue will resort based on the number of passengers who are using RT services. In other words, the call that has the delay intolerant services will be treated first because of the streaming services are limited to the delay variation of end-to-end flow. However, if the available resources in a cell lower that the requested, the cell will drop this call and will be treated next the handover call of MRN in the queue.

3.4 Performance Analysis and Simulation Results

We first presented the performance analysis of proposed adaptive hysteresis and CAC schemes. Then, simulation results are introduced. First, we simulated the proposed hysteresis scheme in the homogeneous network scenario. Second, we compared CAC schemes, the conventional and the proposed CAC schemes.

3.4.1 Performance Analysis of Adaptive Hysteresis

When the train moves from serving cell s to target cell *t*, it sends measurement reports periodically to the serving cell. At train location x, when the signal strength from the target cell Pr_t exceeds that from the serving Pr_s by a hysteresis H (see Section 2.3), the handover procedure should begin. This handover criterion is given by

$$Pr_t - Pr_s > H \tag{3.11}$$

where Pr_s and Pr_t denotes the signal strength received at the train from serving and target cells, respectively. H is hysteresis. The signal strength received from serving and target cells by the outside antenna, defined as Pr_s and Pr_t in dB, can be calculated as

$$Pr_s = P_{eNB} - 10\gamma \log_{10} D_s \ + 10\log_{10} sh_s^2 \tag{3.12}$$

$$Pr_t = P_{eNB} - 10\gamma \log_{10} D_t \ + 10\log_{10} sh_t^2 \tag{3.13}$$

where s is serving cell, t is target cell, D_s is the distance between train and serving cell, D_t the distance between train and target cell, P_{eNB} is the transmit power of cells, $10\gamma \log_{10} D_s$ is path-loss (dB) between serving cell s and location x, $10\gamma \log_{10} D_t$ is path-loss (dB) between target cell t and location x, $10\log_{10} sh_s^2$ denotes shadow fading (dB) at location x of serving cell s, which obeys Gaussian distribution with mean 0 and standard deviation σ and $10\log_{10} sh_t^2$ denotes shadow fading (dB) at location x of target cell t, which obeys Gaussian distribution with mean 0 and standard deviation σ.

According to Equation (3.11)-(3.12), the handover probability that the condition is satisfied at location x can be obtained as

$$\begin{aligned} P_x &= P\left\{Pr_t - Pr_s > H\right\} \\ &= P\left\{-10\gamma \log_{10} D_t \ + 10\log_{10} sh_t^2 + 10\gamma \log_{10} D_s \ - 10\log_{10} sh_s^2 > H\right\} \end{aligned} \tag{3.14}$$

Therefore, the handover probability can be derived as follows:

$$P_x = P\left\{10\gamma\log_{10}\frac{D_s}{D_t} + SD \geq H\right\} = Q((H - 10\gamma\log_{10}\frac{\sqrt{x^2 + {d_s}^2}}{\sqrt{(D-x)^2 + {d_s}^2}})/\sigma) \tag{3.15}$$

where d_s denotes the distance between the rail path and serving cell location, Q is Q function.P_x can be seen that the handover probability is determined by the train's current location x. $Q(x)$ is the probability that a normal (Gaussian) random variable will obtain a value larger than x standard deviations above the mean. The received signal strength is measured and reported by MRN periodically. At (k)th sample interval, the distance between serving cell s and k is $D_{s\_k} = \sqrt{{x_k}^2 + {d_s}^2}$, the distance between target cell t and k is $D_{t\_k} = \sqrt{(D - x_k)^2 + {d_s}^2}$, $x_k = x_o + k * v * T_s$, x_o is the initial location, T_s is the measurement report period.

We now define the handover triggering probability at the train's location x_k. Handover is triggered and completed before the train leaves the coverage of the serving cell s, and a high handover triggering probability is needed in order to reduce communication interruptions and the radio link failures during the handover procedure. Handover triggering probability is the probability of that the handover trigger condition is satisfied at a location of the train. Thus the handover triggering probability at location x_k , which is the sum of handover probability at between cell boundary (starting point of overlap area) and the $k+1$ decisions, is given by

$$P_{triggering} = \sum_{i=0}^{k} Q((H - 10\gamma\log_{10}\frac{\sqrt{(x_o + i * v * T_s)^2 + {d_s}^2}}{\sqrt{(D + x_o - i * v * T_s)^2 + {d_s}^2}})/\sigma) \tag{3.16}$$

where $x_k = x_o + k * v * T_s$, x_o is the initial location, T_s is the measurement report period.

We now define the handover success probability. The cell outage probability occurs when the received signal of the serving cell is weak or lost. Thus, the handover success probability is the probability of that the cell outage doesn't occur before the handover triggering. The cell outage probability refers to the probability that received signal quality is too weak to be properly decoded and leads to link interruption. It is assumed that when the signal to interference and noise ratio (SINR) of the received signal is smaller than a threshold γ (dB) [3GPP TS 36.101 V10.0.0], the outage happens:

$$P_{out} = SINR_x < \gamma \tag{3.17}$$

where $SINR_x$ is the SINR while the train stays at location x. In the handover schemes, there is main solution for handover success is that handover happens before outage probability.

$$P_{suc} = P_x * \sum_{y=0}^{x} (1 - P_{out}\left[SINR_{(s,y)} < \gamma\right]) \tag{3.18}$$

where x is the location of the train, s is the serving cell, $SINR$ denotes SINR, γ is the threshold for signal quality (dB).

We defined the Radio link failures ratio that is the ratio of number of radio link failures to the number of handovers that were completed to target cell.

$$RLF_{ratio} = \frac{Radio\,link\;failures}{Handover\;completed} \tag{3.19}$$

3.4.2 Analysis of the Proposed Handover

Our proposed cost function-based adaptive hysteresis scheme is simulated and verified on the open source LTE-sim [61]. The LTE-sim is open source framework, including the

TABLE 3.1: Simulation parameters. 5 Macrocells with 1km radius

Parameter	Value
Number of Donor eNBs	5 cell sites, urban area
Radius of cell	1 kilometer
Overlap area between two cells	300 m
Cell Tx power	43 dBm
Carrier frequency	2.6 GHz
Path loss model	128.1 + 37.6 $\log_{10} d$, [62]
Shadow fading deviation	4 dB
System bandwidth	10 MHz
Transmission time interval	1 ms
T	IP and data
MRN speed	Interval [120 km/h,350 km/h]
MRN measurement interval	50 ms

E-UTRAN and EPC that can support multi-cell environments, heterogeneous and two-tier network, user mobility, handover procedures, and applications.

3.4.2.1 Simulation Setup

For simulation purposes, a connection manager application was used to modify and implement in order to control connection quality between the serving donor-eNB and the MRN. In addition, we have to modify and add the donor-eNBs for calculating the load of donor-eNBs by considering sending a request to the neighbor donor-eNBs to receive the necessary information and to repeat the sorting of the target donor-eNBs according to their load. Table 3.1 lists all of the parameters of simulation.

Figure 3.5 shows the scenario we used for our simulation. It consists of a homogeneous network with urban cells (the radius is 1 km) that includes five LTE eNBs, the MRN-installed vehicle (a train) and its connected UEs in the interval [10,50]. The MRN is equipped with a

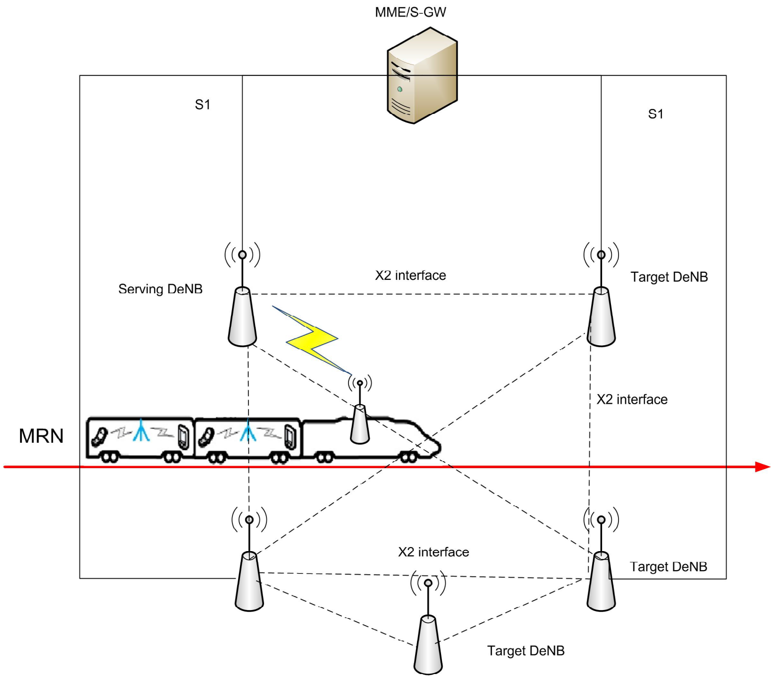


FIGURE 3.5: Homogeneous network scenario
Adapted from "A Cost Based Handoff Hysteresis Scheme in Wireless Mobile Relay Node," by Author B.Davaasambuu, 2014, Proceeding of IEEE Vehicular Technology Conference (VTC Fall) [57].

transparent router between the outside and inside antennas. The cell boundary and overlap of neighboring cells is 300 meters. At the beginning of simulation, the MRN is connected to the serving donor-eNB. At the starting point of overlap area, the MRN makes a measurement report for handover and send to the serving donor-eNB. After received this report, the serving donor-eNB calculates the hysteresis and to run a cell selection scheme based on the load of candidate donor-eNBs. However, the serving donor-eNB controls the power of received signal of the serving and target donor-eNBs by the measurement report of MRN. When the handover triggering condition is satisfied, the serving donor-eNB begins the handover procedure for outside antenna of MRN. A simulation can effectively show the difference between the static hysteresis based hard handover (defined in [7]) and the proposed adaptive hysteresis scheme with dynamically changed hysteresis based on the context information of the train.

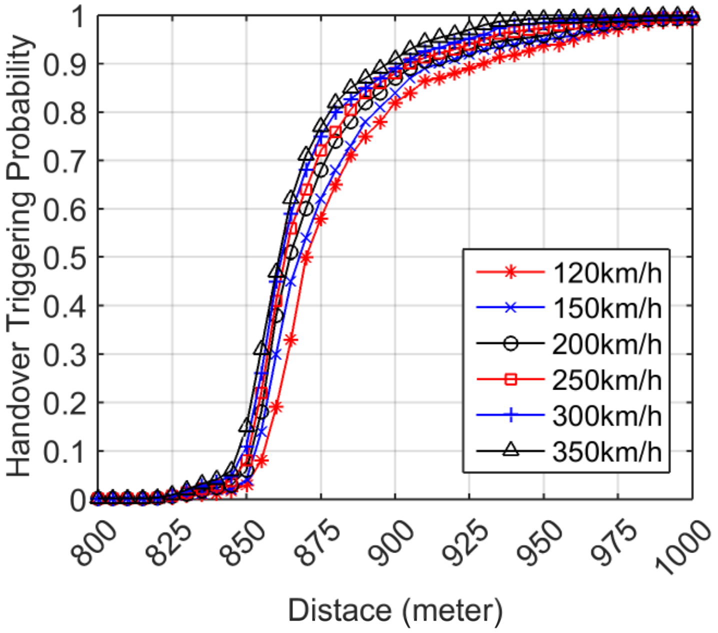


FIGURE 3.6: Handover triggering probability of different speeds
Data adapted from "Adaptive Handover Hysteresis and Call Admission Control for Mobile Relay Nodes," by Author B.Davaasambuu, 2015, International Journal of Computer Networks and Communications (IJCNC), Volume 7(6), p87-98 [9]

3.4.2.2 Simulation Result

Figure 3.6 illustrates the simulation results of the handover triggering probability with the location of the train and current speed of train is 120km/h, 150km/h, 200km/h, 250km/h, 300km/h and 350km/h. The maximum speed is 350 km/h. The x-axis denotes the distance between the train location with the MRN and the serving donor-eNB. Starting from the location x = 840 meters, RSRP of the target donor-eNB starts to overbear RSRP of the serving donor-eNB. The resulting handover triggering probability increases from the location x = 850 meters, and the speed is typically higher rather than lower. Further, the triggering probability increases abruptly up to 90 percent of the distance between the locations x = 875 meters and x = 925 meters. Thus, our proposed handover scheme is capable of triggering the probability based on

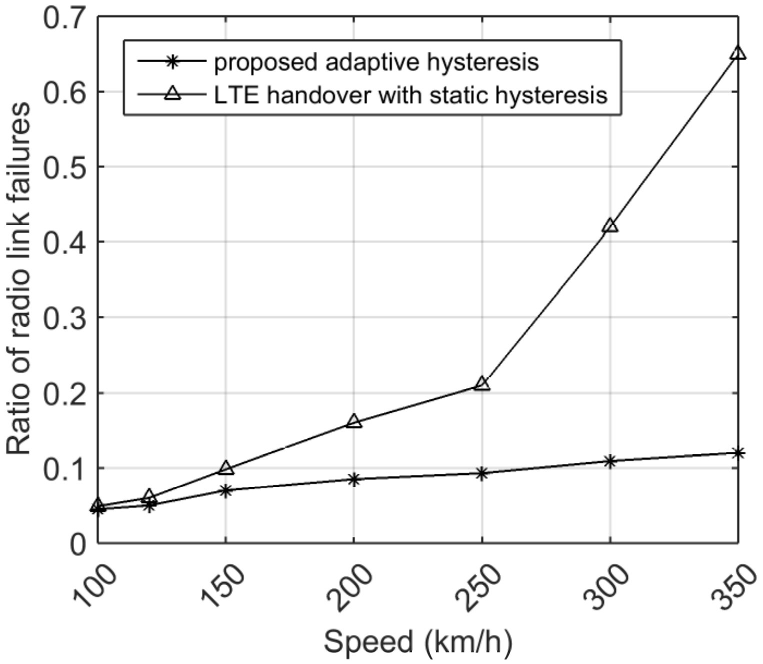


FIGURE 3.7: The radio link failure (RLF) comparison between proposed and hard handover with different speed
Data adapted from "Adaptive Handover Hysteresis and Call Admission Control for Mobile Relay Nodes," by Author B.Davaasambuu, 2015, International Journal of Computer Networks and Communications (IJCNC), Volume 7(6), p87-98 [9]

speed by using the cost function. At the location x = 840 meter, the signal quality of target donor-eNB is sufficient to meet the communication requirement. In addition, the proposed handover scheme can provide the handover decision, and the starting time satisfies the high-speed mobility environment. Note that the handover triggering probability shows result after the cell selection and the passengers attached to an inside antenna of MRN are fixed. Also, we can see the influence of adaptive hysteresis from Figure 3.6 clear.

Figure 3.7 shows the ratio of radio link failures with different MRN speeds in the interval [120,350]. In Figure 3.7, our proposed handover scheme with adaptive hysteresis compares hard handover with the RSRP based scheme that employs regular UE's handover based on static parameters, as defined by the 3GPP standard, which has been reused for MRN [7]. In a low mobility environment, the two schemes behave similarly. However, when the MRN runs at high speed, only proposed scheme can provide the low ratio of radio link failures. It is also observed that as the speed increases, the proposed scheme to decrease the hysteresis value. This is because in the proposed scheme the train with high-speed required smaller hysteresis value than the user devices with low-speed. As a result, the handover procedures start too early. If the train leaves from the coverage area of serving donor-eNB before the handover procedure was completed, the number of RLFs increase. Because, RLFs has dropped handover calls before the handover procedure was completed if the train leaves the coverage area of serving donor-eNB. Then, the MRN makes a new connection with the available cell. In other hands, the handover procedure failed (not RLFs), MRN must re-connect to the serving donor-eNB and start the new handover procedure.

Figure 3.8 shows the handover success probability in the overlap area. We compared our proposed scheme and the hard handover scheme that is defined in [7]. From the figure, the distance from serving cell is less than 850 meters, the handover success probability of two schemes has little difference. At location 850 meters, the handover success probability of our proposed scheme is increased, because of proposed scheme changed a cell outage probability and hysteresis that is a factor of the handover probability calculation (see Equation 3.15). Also, the proposed scheme can provide the reduced RLFs, and increased number of performed handovers in the overlap area. Moreover, the available radio resources, mobility management, and security policy are irrelevant to this result. Note that Figure 3.8 shows result of simulation when the target donor-eNB is selected and the number of passengers attached to inside antenna is randomly selected between 0 and 50.

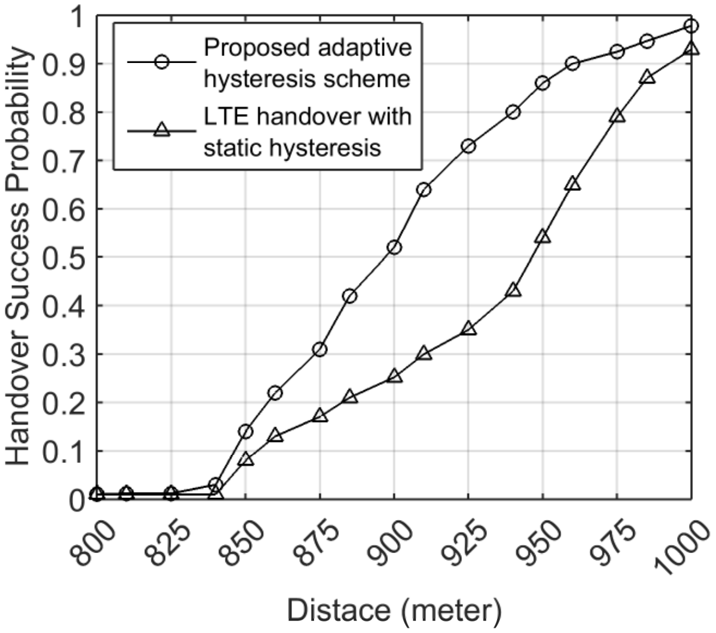


FIGURE 3.8: Comparison of handover success probability of different schemes.

3.4.3 Analysis of the CAC Scheme

In this section, we present our analysis of the effectiveness of the proposed CAC, which performs the task of reducing the handover call dropping of MRN. We compared the performance of our proposed CAC scheme with the priority policy and the performance of a conventional CAC with the ”first received first served” algorithm. In proposed CAC, we consider three priority classes in the homogeneous system by proposed priority policy (defined in Section 3.3.3). The result of simulation shows the new call blocking and handover call dropping probability that are calculated by Equation 3.6.

3.4.3.1 Simulation Setup

In our simulation analysis, the call arrivals are generated based on Poisson process with a mean arrival rate of λ (calls/second). The network setup is considered for the Table 3.1

presented in this section. The other parameters for call admission process are considered Table 3.2. The performance of proposed CAC is evaluated using the following performance metrics:

The new call blocking probability (NCBP) is defined as the probability of that new calls are blocked by the target cells because of a lack of available channels below a guard channel for the handover calls;

The handover call dropping probability (HCDP) is defined as as the probability of that the attempted handover calls of MRNs are blocked because of all channels being unavailable.

3.4.3.2 Performance of Handover Call Dropping Probability

The performance of proposed CAC is discussed in this subsection. In the proposed CAC, the arrival of calls is represented by a Poisson function with the arrival rate of new calls denoted by λ_n, handover calls of UEs by λ_{ue}, new calls of UEs attached to MRN by $\lambda_{UE_{new}}$, and handover calls of MRNs with devices of passengers by λ_{mrn}. λ_{mrn} denotes a required channel number of MRN and the connected devices of passengers. The call holding time for new call of UE, handover call of UE and new call of UE attached to MRN and handover call of MRN with μ, η, κ and β, respectively. Let ρ=(λ_n+μ)(λ_{ue}+η)($\lambda_{UE_{new}}$+κ)(λ_{mrn}+β) be the total arrival rates of calls to the target cell.

The probability of handover call of MRN that is similarly with Equation 3.10. In addition, the priority policy that can affect the probability. If the target cell has n channels, let P_{mrn} be the probability of that handover call of MRN with passengers. The probability P_n that n channels are busy is:

$$P_{mrn} = \sum_{C2}^{C3} P_{mrn} + \sum_{C1}^{C2} P_{mrn} + \sum_{1}^{C1} P_{mrn} \qquad (3.20)$$

TABLE 3.2: Parameter values used for the parameters of CAC scheme and priority policy. 1km radius

Parameter	Parameter Value	Parameter Defination
C_{total}	120	Total number of channels
$C3$	81 to 120	Guard channel C3 Number of channels reserved for MRN handovers below the guard channel C3
$C2$	41 to 80	Guard channel C2 Number of channels reserved for UE handovers below the guard channel C2
$C1$	1 to 40	Guard channel C1 Number of channels available for new calls below the guard channel C1
λ_n	Poisson process	New call of passengers arrivals are modeled according to the Poisson process, respectively.
λ_{MRN}	Poisson process	handover call of MRN arrivals are modeled according to the Poisson process.
$UE_{passenger}$	Random between 0 and 50	The number of passengers in each MRN, using any service.
$RT_{service}$	Random between 0 and $UE_{passenger}$	The number of passengers using RT service (VoIP or video)
$nRT_{service}$	$UE_{passenger}$-$RT_{service}$	The number of passengers using nRT service (data)
μ, η, κ and β	120 second	The call holding time

In addition, P_n is the handover call dropping probability is the probability of that handover call of MRN is dropped when the channels are busy between the guard channels. The probability of new calls of UEs attached to MRN is the probability of that channels are busy between the first channel and guard channel $C1$, similarly the new call blocking probability in Equation 3.9.

If the target cell has n channels, let $P_{UE_{new}}$ be the probability of that new call of UEs attached to MRN. The probability P_n that n channels are busy is:

$$P_{UE_{new}} = \sum_{n=0}^{C1} \frac{\rho^n}{n!} \tag{3.21}$$

3.4.3.3 Simulation Result

To compare the performance of the proposed priority and non-priority schemes, it is assumed that one resource units are assigned to one passenger in the non-priority scheme. In the results, ”non-priority” denotes the new call blocking probability of non-priority CAC scheme, ”proposed priority” denotes the new call blocking when the serving cell sends the new call for an outside antenna of MRN and the new calls of UEs attached to an inside antenna of MRN before/after the handover procedure. The y-axis represents the new call blocking probability. The non-priority based conventional CAC scheme is not considered the channel reservation scheme for handover calls. In other words, conventional CAC use FIFO (First In, First Out) algorithm and will drop calls (both new calls and handover calls) if all channels are busy. The proposed CAC scheme gives the lower priority to the new calls. We also consider the number of passengers, to show the effect of priority policy resource allocation in the proposed priority.

Figure 3.9 shows the effect of handover call arrival rate (train) on the handover call dropping probability (HCDP) of the train. The handover call arrival rate denotes the handover requests with context information (the number of passengers) from the serving cell to target cell when bus moving to the target cell, shown in Figure 3.10. Compared with the non-priority scheme without guard channel, HCDP in the proposed priority scheme can be reduced by two guard channels for handover of MRNs. From Figure 3.9, it can be also seen that proposed priority scheme can reduce HCDP even compared with the non-priority scheme with one guard channel. This is because the proposed priority scheme fairly allocates the radio resource units

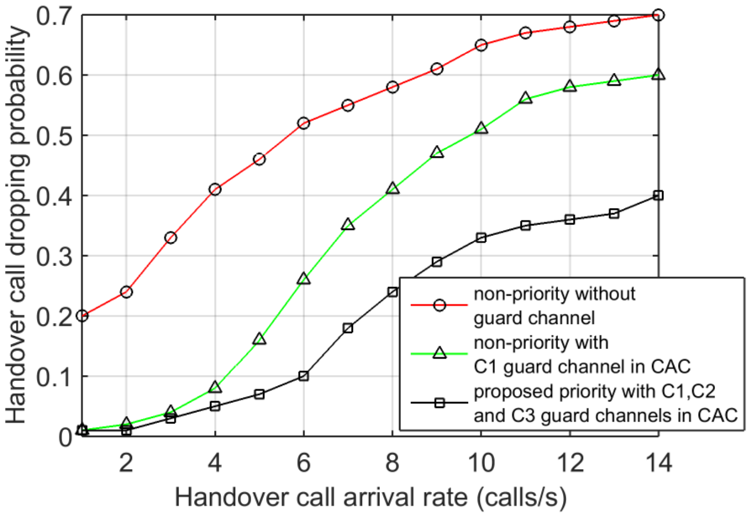


FIGURE 3.9: Effect of the handover calls on the HCDP of MRN.

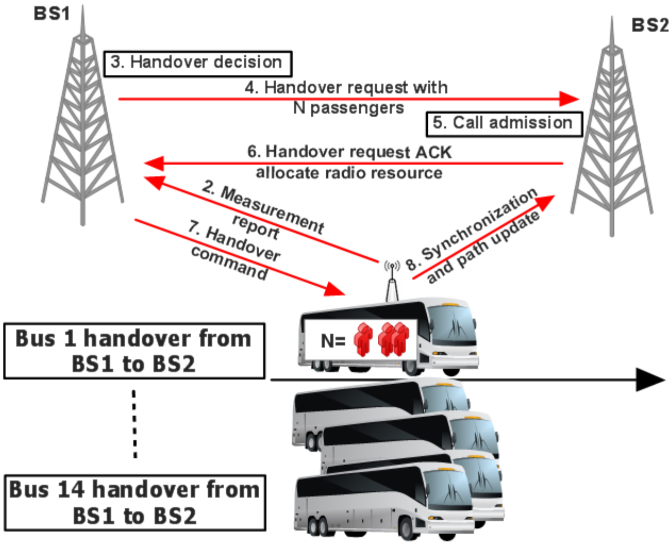


FIGURE 3.10: Handover request for MRNs from the serving BS1 to target BS1.

depending on the number of passengers in the train as group request and using the priority policy. But, the non-priority scheme allocates the radio resource unit for each passenger as the pedestrian users. In addition, the proposed priority scheme has lower HCDP than the non-priority scheme with guard channel. This is because the queue policy and second guard channel can reserve the radio resource for handover of MRN. This indicates that proposed priority scheme can provide better QoS to train passengers than the non-priority scheme in handover scenarios.

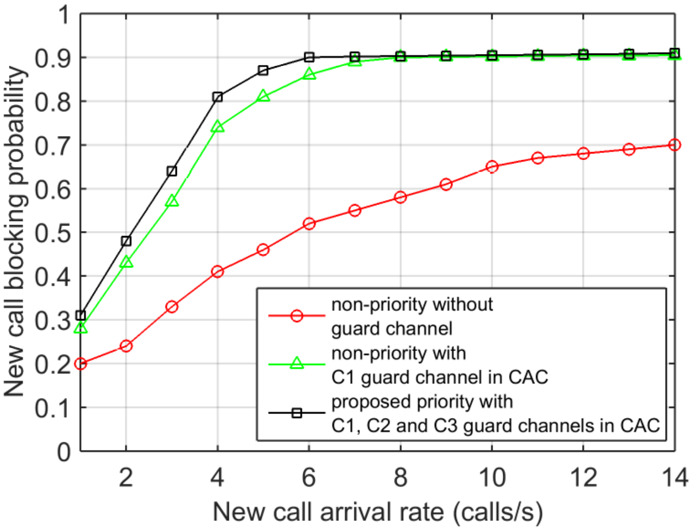


FIGURE 3.11: Effect of the new call arrival on the NCBP of MRN.

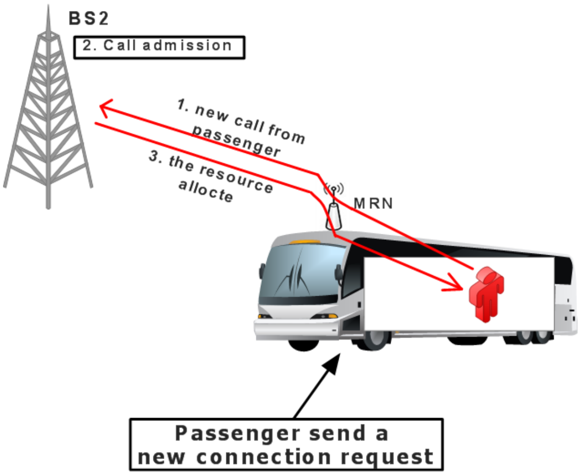


FIGURE 3.12: New call from passenger via MRN to the base station BS2.

Even though the two guard channels are effective to reduce the handover call dropping probability of the train, it can increase the new call blocking probability (NCBP) of the train and passengers. The new call arrival rate denotes the new call requests from passengers via MRN to the serving cell, shown in Figure 3.12. After a new call allocated, a passenger can transfer data via the MRN to the serving cell. As shown in Figure 3.11, the non-priority scheme with guard channel has higher NCBP than the non-priority scheme without the guard channel. Due to the same reason, the proposed priority scheme has higher NCBP than the non-priority scheme without guard channel.

On the contrary, it can be seen that NCBP of the proposed priority scheme and the non-priority are no different when the new call arrival rate more than 7. If the new call arrival rate more than 7, there are much handover of MRN in the cell area and thus more resource units are used by the handover of MRN. Therefore, less resource units can be used by new calls and NCBP of the proposed priority and non-priority with guard channel schemes is higher when handover call arrival rate is very high although guard channels are set for handover call. Note that, in the proposed priority scheme, when the passenger's device changed a status from idle to active, MRN can acquire additional radio resources by sending a new call to the serving cell during the cell residence time. But, MRN cannot send a new call for passenger during the handover procedure. This is because of the serving cell cannot establish a new session for the new call after a handover command sent and break a connection of MRN when passenger sent a new calls. Also, the target cell only admits the new calls of passengers after the handover procedure of MRN is completed.

The results of the proposed CAC can be explained by the processes of proposed scheme: radio resource reservation, three call classification and giving higher priority to handover calls of MRN in the admission step. In addition, our proposed scheme prioritizes handover calls of MRN over handover calls of UEs and new calls (handover calls of MRN are high, handover calls of UEs are medium, and new calls are low). The handover calls of MRNs were the same as the handover calls of UEs in the conventional CAC scheme. From this point of view, conventional CAC can reserve one radio resource for MRN. Therefore, the CAC scheme would need to support MRN and its connected devices. To address this need, our proposed CAC reserved the radio resources for MRN and its connected UEs.

3.5 Conclusion

This chapter presented a cost function based on an adaptive hysteresis scheme and CAC for MRN in LTE network. First, we introduced the handover with an adaptive hysteresis scheme based on the context information of cells and MRN in the LTE network. There are two novel contributions in the proposal of proposed adaptive hysteresis scheme. We compared our proposed scheme with the hard handover with static hysteresis in terms of the handover triggering probability, RLFs ratio, and the handover success probability. The proposed scheme can affect to the handover triggering that can be used to select suitable hysteresis for the train (with MRN) at different speeds by using a cost function. In high-speed scenario, the proposed handover can increase the time required for the handover procedure when the mobility speed in the overlap area is increasing. This is due to increasing the number of handover procedures completed before losing the signal and leaving the coverage area of the serving cell. The second contribution is the automatic tuning of hysteresis can increase the handover success probability. Second, we introduced the call admission control (CAC) with priority policy. We compared the performance of proposed CAC scheme and conventional CAC scheme. Our proposed CAC scheme was shown to reduce the handover call dropping probability. In addition, the proposed scheme can reserve the radio resources for MRN and its passengers.

We believe proposed handover scheme will significantly contribute not only in the area of high-speed scenario but also in low-speed scenario.

Chapter 4

Self-optimization of Handover Parameters for LTE with Dual MRNs

4.1 Introduction

In this chapter, we present our proposed Self-Optimization of Handover Parameter (SOHP) and dual MRNs network model for high-speed moving vehicle. Two main concepts are presented: (i) in order to affect to the handover triggering and performance, we proposed an optimization scheme for the hysteresis and offset parameters; the SOHP selects a suitable hysteresis and changes the CIO of each cell to facilitate a handover decision step of handover process when the train is moving at a high speed; and (ii) we outline our proposed dual MRNs network model and its handover procedure. The proposed model provides seamless mobility and uses the co-operating dual MRNs to reduce the connection interruption. The results of simulations conducted in which the performance of proposed SOHP was compared to that of LTE handover show that the proposed scheme can reduce the number of RLFs and service interruption during handover procedures. The scheme and results described in this chapter have been published as *MDPI Future Internet, Volume 7(2), 2015, p196-213 [30].*.

4.2 Backgrounds

In this section, we look at RLFs, HPI related work on self-optimization handover parameters.

4.2.1 Radio Link Failures

In some cases, the general configuration of handover parameters is unsuitable. If the serving eNB does not initiate the handover at the correct time, a handover that is too early or too late occurs, which results in an increase in the number of RLFs and unsuccessful handover. Moreover, the radio link must be re-established to the serving eNB, which causes the handover procedure to restart. Figure 4.1 illustrates late and early handovers with two UEs and high-speed movement between cells.

Before the handover procedure finishes, if the signal quality of serving cell is inadequate for the data communication requirement, a late handover occurs. Otherwise, if handover procedure has already been completed when the signal quality of target cell becomes inadequate for the communication requirement, a handover that is too early occurs. In other cases, an increase in the number of RLFs is due to ineffective the target cell selection by the handover decision algorithms.

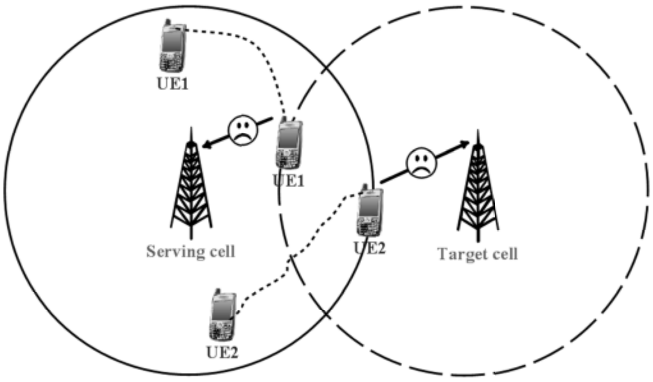


FIGURE 4.1: Handover started too early for UE1, handover started too late for UE2 *Adapted from "Self-Optimization of Handover Parameters for Long-Term Evolution with Dual Wireless Mobile Relay Nodes," by Author B.Davaasambuu, 2015, MDPI Future Internet, Volume 7(2), p196-213 [30].*

4.2.2 Handover Performance Indicators

The Handover Performance Indicator (HPI) serves to monitor the performance of handover procedures by each cell. The total HPI is a summation of HOF, HPP and RLF indicators (Equation (4.1)).

$$HPI = HPI_{HOF} + HPI_{HPP} + HPI_{RLF} \tag{4.1}$$

In [42], the following definitions are defined:

1. HPI_{HOF}: If the handover procedure fails when the UE connects to the target cell, the UE must re-establish the connection to the serving cell and begins a new handover procedure. If UE moves out of a coverage of serving cell, the re-establishment process also fails. It is added to the RLFs. The failed HPI is the ratio of number of handover failures (HO_{failed}) to the total number of handovers (HO_{total}). HO_{total} signifies the total number of handover attempts.

$$HPI_{HOF} = \frac{HO_{failed}}{HO_{total}} \tag{4.2}$$

2. HPI_{HPP}: The ping-pong HPI is the ratio of number of ping-pong handovers ($HO_{ping-pong}$) to the total number of handovers:

$$HPI_{HPP} = \frac{HO_{ping-pong}}{HO_{total}} \tag{4.3}$$

3. HPI_{RLF} is the number of handover calls that were dropped (by the network) before the handover procedure was finished, if the signal quality was not enough for the data communication requirement, and the UE moves out of a coverage of serving cell. In this scenario, the UE drops handover procedure and sends a new connection request to the nearest available cell (based on measurement). HPI_{RLF} is the ratio of number of radio link failures $HO_{dropped-handover}$ to the number of handovers that were completed to target cell:

$$HPI_{RLF} = \frac{HO_{dropped-network}}{HO_{accepted}} \tag{4.4}$$

4.3 Proposed Parameter Optimization

In this section, we describe how the hysteresis and offset parameters are calculated. The hysteresis, threshold, offset, and time-to-trigger parameters are discussed in [18]. Our self-optimization scheme focuses on the hysteresis and Cell Individual Offset (CIO) parameters. First, we present the calculation for hysteresis, which is the main parameter associated with the triggering of hard handover (Event A3 condition, defined in Section 2.3.2). For example, in a typical hysteresis adjustment scheme, a large hysteresis value is used for the Event A3 handover. Otherwise, if the difference between the signal quality of neighboring cells and that of the serving cell is high, and MRN is at the cell boundary of serving cell, MRN handover may begin late, in which case, hysteresis should be decreased. However, if a small hysteresis value were being used up to that point, then the hysteresis value should be increased.

Our proposed speed based hysteresis adjustment value is defined in Equation (4.5). If the speed of a vehicle is high, the starting time of handover procedure may be too late. Therefore, we must reduce the hysteresis of LTE system. Otherwise, if hysteresis is set too small, a handover procedure decision will be made too early compared with when the default hysteresis of LTE system is set.

$$H = Hys_{A3} - \frac{(V_{max} - V_{current} - \alpha)}{w * V_{max}} \tag{4.5}$$

where Hys_{A3} denotes the default hysteresis for all UEs, V_{max} is the maximum speed of a vehicle, and $V_{current}$ is the current speed of a vehicle, which includes vehicle context information. The maximum speed of a high-speed train. w and α are weights for current speed and maximum speed, respectively. According to Equation (4.5), if speed of the train increases, the hysteresis will decrease. Otherwise, if speed of the train decreases, hysteresis will incur minimal changes.

Let us now look at the CIO calculation for the serving donor-eNB based on HPI. The CIO parameter provides radio resource management for each cell. To monitor the performance of handover procedures, we compute the HPI as the ratio of sum of dropped handovers, handover failures, and handovers that are too late to the total number of handovers. The total number of handovers is the sum of all of handovers that are triggered in the target cell. Equation (4.6) defines the HPI for our proposed CIO adjustment scheme.

$$HPI_{late} = \frac{HO_{dropped} + HO_{failure} + HO_{late}}{HO_{total}} \tag{4.6}$$

where $HO_{dropped}$, $HO_{failure}$ and HO_{late} are the number of dropped handovers, failed handovers and late handovers, respectively. The unsuccessful handovers are added to these indicators when the procedure has failed, because of the radio link quality.

If CIO of neighboring cells is high, MRN handover may begin early. A handover that is too early must be controlled. Equation (4.7) shows the calculation carried out for an HPI that is too early.

$$HPI_{early} = \frac{HO_{ping-pong} + HO_{early}}{HO_{total}} \tag{4.7}$$

where $HO_{ping-pong}$ and HO_{early} are the number of ping-pong handovers and early handovers, respectively.

The SOHP scheme controls the hysteresis and CIO parameters for Event A3. The optimization algorithm is outlined in Algorithm 1. If CIO of neighboring cells is low, MRN handover may start too late. Consequently, the MRNs incur a connection loss if the serving cell cannot provide a consistent and sufficiently high-quality signal for the MRN. Therefore, SOHP scheme increases the CIO of neighboring cells. Otherwise, if the number of RLFs in the neighboring cells is more than the threshold, we increase the number of CIOs in the neighboring cells to reduce the number of RLFs. Finally, the Event A3 condition changes are summarized in Equation (4.8).

$$M_n + Oc_n - Hys_{A3} > M_s \tag{4.8}$$

where M_n denotes the measured RSRP of target eNB, M_s denotes the RSRP of serving eNB, Oc_n is the CIO configured by the target donor-eNB based on HPI and Hys_{A3} is the calculated hysteresis based on the speed of a vehicle.

Algorithm 1 handover parameter optimization algorithm [30].

```
Collect of context information
Collect of RLFs, CIO of Neighbor Cells, HOP and HPP
Calculate hysteresis adjustment value
$HPI_{late} \leftarrow Calculate\ HPI\ Too\ Late\ Handover$
$HPI_{early} \leftarrow Calculate\ HPI\ Too\ Early\ Handover$
$HPI_{threshold} \leftarrow threshold\ of\ HPIs$
$H_{adj} \leftarrow calculated\ hysteresis\ adjustment\ value$
$H \leftarrow handover\ hysteresis\ for\ UEs\ (same\ as\ hardhandover)$
$\Delta \leftarrow adjustment\ value\ of\ CIO$
if $HPI_{late} > HPI_{threshold}$ then
  $H \leftarrow H - H_{adj}$
  for $Neighbor\ Cell\ ID \rightarrow Neighbor\ Cell\ List$ do
    if $count\ RLF\ of\ Neighbor\ Cell\ ID > 0$ then
      $CIO\ of\ Neighbor\ Cell\ ID \leftarrow CIO\ of\ Neighbor\ Cell\ ID + \Delta.$
    end if
  end for
end if
if $HPI_{early} > HPI_{threshold}$ then
  $H \leftarrow H + H_{adj}$
  for $Neighbor\ Cell\ ID \rightarrow Neighbor\ Cell\ List$ do
    if $count\ RLF\ of\ Neighbor\ Cell\ ID > 0$ then
      $CIO\ of\ Neighbor\ Cell\ ID \leftarrow CIO\ of\ Neighbor\ Cell\ ID - \Delta.$
    end if
  end for
end if
```

4.4 Dual MRNs architecture

In this section, we outline the proposed network model with dual MRNs, illustrated in Figure 4.2. A main Moving Relay Node (main MRN) and a secondary Moving Relay Node (secondary MRN) are located at the front of a vehicle (without distance). The benefit of this model is that main MRN performs the SOHP scheme and represents it for the secondary MRN. The dual MRN-based network architecture focuses on broadband wireless communication and is intended for passengers of high-speed vehicles. The passengers connect directly to a small

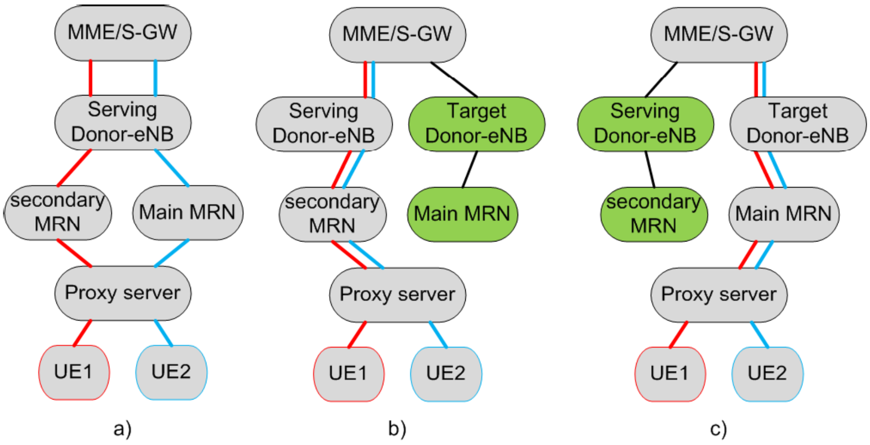


FIGURE 4.2: The dual MRNs architecture, a) Cell residence time, b) handover procedure of main MRN is started, c) handover procedure of secondary MRN is started.

cell installed inside the vehicle. This small cell connects to the donor-eNBs of LTE network by proxy server, which employs the cooperative dual MRNs on the outside of a vehicle. In addition, inside small cell collects data that are sent to the donor-eNBs by the established two path during the cell residence time (Figure 4.2a).

The dual MRNs simultaneously execute the handover from the serving donor-eNB to the target donor-eNB, which is the same for each user. However, MRNs execute the handover procedure sequential. Two main concepts in the SOHP scheme enable changes: (i) during the handover procedure, the MME introduces information about the MRNs connecting to the serving donor-eNB and target donor-eNB, and (ii) the S-GW utilizes a multipath method and saves the various data transmission routing paths serving the donor-eNBs and target donor-eNBs.

When the serving donor-eNB sends a measurement control message, only the main MRN replies with a measurement report. The measurement report comprises context information (including the speed and trajectory) associated with the vehicle to the serving donor-eNB. Main MRN stop the data forwarding and all passengers are served by only secondary MRN (Figure 4.2b). Further, the serving donor-eNB makes the handover decision based on the measurement

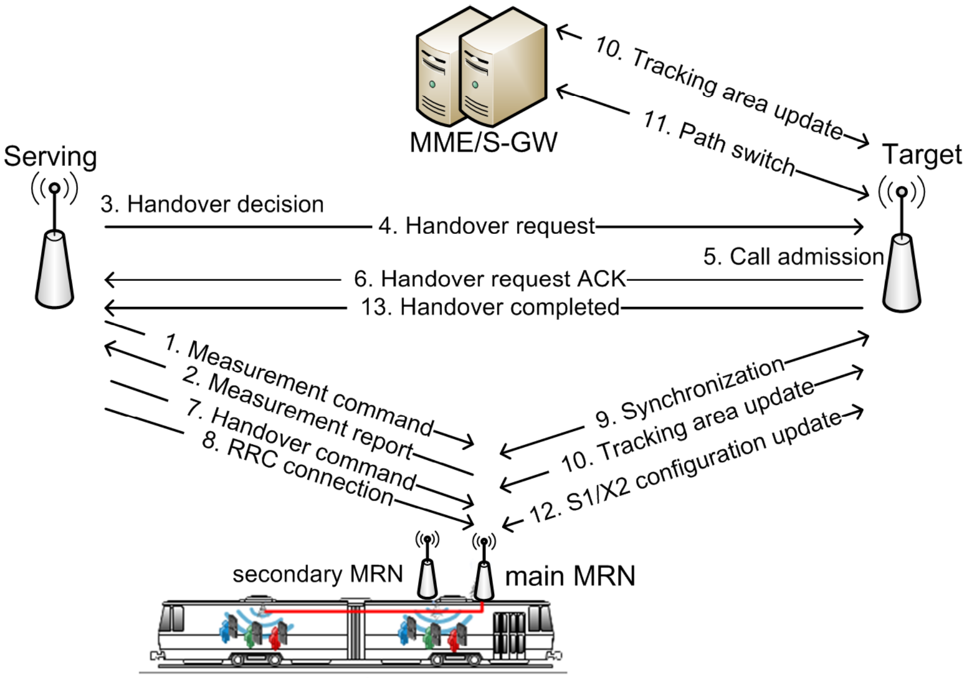


FIGURE 4.3: Handover procedure of main MRN between the serving and target cell.

report from the main MRN. The serving donor-eNB calculates a hysteresis and to check a handover triggering condition. When the handover is necessary, the serving donor-eNB can start the handover procedure of main MRN. After the handover of main MRN is finished, main MRN start the data forwarding through the target cell and the serving cell start the handover procedure of secondary MRN (Figure 4.2c).

4.4.1 Handover Procedure of main MRN

In this subsection, we outline the handover procedure of main MRN. Figure 4.3 depicts the procedure used in the SOHP scheme. The phases comprising the handover procedure are outlined below.

1. This phase begins when the serving donor-eNB send a measurement command (1).

2. Main MRN reply that is a measurement report (2) to the serving donor-eNB.
3. On receiving the report, the serving donor-eNB calculates the handover parameters using the proposed SOHP scheme. And the serving donor-eNB decides that the main MRN must perform the handover (3).
4. if handover is necessary, the serving donor-eNB send a handover request (4) to the target donor-eNB. The handover request sent contains the handover parameters and context information for the target donor-eNB to prepare the call admission (5).
5. After preparing the radio resource, the target donor-eNB accepts all MRNs and replies with a handover request ACK (6) containing parameters for the serving donor-eNB and the handover procedure.
6. A handover request ACK is received, serving donor-eNB sends the handover command (7) and radio resource control (RRC) connection reconfiguration (8) to the main MRN.
7. Then main MRN make a synchronization (9) with the target donor-eNB, In this phase, the donor-eNB stops forwarding data to the main MRN; it does not serve data to the UEs inside of train during the handover procedure. Until the handover procedure of main MRN has been completed, only the secondary MRN serves the UEs. On successfully synchronizing with the target donor-eNB, the main MRN makes the tracking area update (10) with the MME via the target donor-eNB, which the MME uses to update a location of main MRN.
8. The target donor-eNB switches the routing path to the main MRN by the path switch update (11) with the MME. In the final, the main MRN updates its interfaces (namely S1 and X2) configuration (12). Then, the target donor-eNB and S-GW begin forwarding data along the new path to the main MRN. At this point, the handover procedure is complete and the target donor-eNB sends a handover completed (13) message.

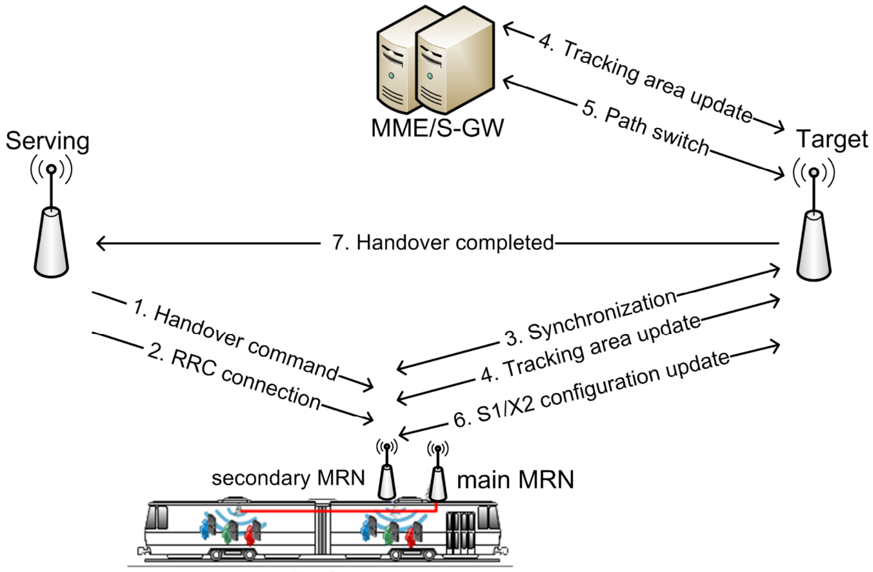


FIGURE 4.4: Handover procedure of secondary MRN between the serving and target cell.

4.4.2 Handover Procedure of secondary MRN

On completion of main MRN handover procedure, the serving donor-eNB places the secondary MRN in a wait state if the following conditions occur:

- The speed of vehicle has decreased or the vehicle has stopped. In this case, the handover procedure of main MRN is complete, and UEs have been served. The secondary MRN continues connecting with the serving donor-eNB and served UEs.
- The trajectory of vehicle has changed. If possible, the main MRN makes a new measurement report to update candidate cells.
- The RSRP of target donor-eNB has decreased or the RSRP of another candidate donor-eNB is better than that of target donor-eNB.

If the serving donor-eNB decides that the secondary MRN must perform handover, the handover procedures are initiated by the handover command of the serving donor-eNB. The secondary MRN does not need to make a measurement report for the handover procedure. The handover in secondary MRN procedure comprises the following phases, shown in Figure 4.4:

1. The handover procedure of secondary MRN begins by the handover command (1) and RRC connection (2) of the serving donor-eNB.
2. After the secondary MRN receives the handover command and the RRC connection, the serving donor-eNB stops forwarding data to the secondary MRN; the UEs are not served during the handover procedure. The secondary MRN will then try to synchronize with the target donor-eNB by the synchronization process (3).
3. Tracking area update phase (4): If the secondary MRN has successfully synchronized with the target donor-eNB, the secondary MRN make the tracking area update (4) with the MME via the target donor-eNB. After the path switch (5), the secondary MRN updates its S1/X2 configuration (6). Then, the target donor-eNB and S-GW start forwarding data along the new path to the secondary MRN, and the secondary MRN can complete its handover procedure. Finally, the target cell sends the handover completed message (7).

4.5 Simulation Results

4.5.1 Simulation Setup

We simulated and verified our proposed SOHP scheme and the dual MRNs network model using LTE-sim [61]. LTE-sim is an open source framework for simulating LTE networks. It contains several aspects of LTE networks, such as single and multi-cell environments, user mobility at different speeds and LTE hard handover procedures. For simulation, it has new call blocking and acceptance processes to control QoS-based call admission. A connection manager application modifies and implements MRN time control received signal strength of the serving

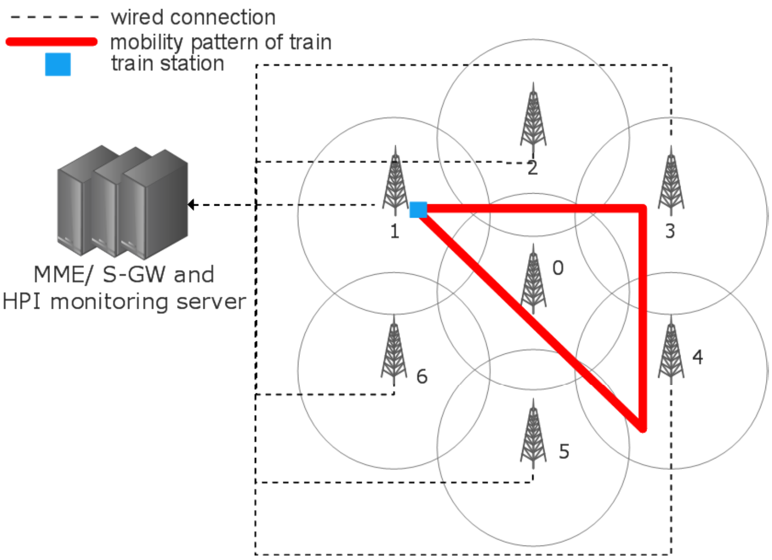


FIGURE 4.5: Train mobility patterns for simulation, 7 macrocells, HPI monitoring server located in MME.

cell. We compared the performances of proposed scheme and the LTE handover of LTE-sim via simulations.

We created a simulation network topology comprising the 7 macro cells with the mobility pattern of train and the HPI monitoring server in LTE-sim, as shown in Figure 4.5. Table 4.1 lists the parameters used in the simulation. Also, the pedestrian users (UEs) are randomly placed in the simulation area initially and moves with random walk model, speeds of 3 km/h. In this section, “LTE handover” denotes the existing static hysteresis scheme [7], when MRNs do not use the proposed handover procedure, and “proposed SOHP scheme” denotes the our proposed SOHP scheme with the handover procedure of dual MRNs.

On the macrocells, the whole procedure of auto-tuning hysteresis scheme taken by MRN to transmit a measurement report message is described in Figure 4.6 (a).

1. when a measurement report is received, the serving cell auto-tunes a hysteresis by the proposed hysteresis scheme based on the speed of train.

TABLE 4.1: Simulation parameters. donor-eNBs, donor Evolved Node Bs; HPI, handover performance indicator; main MRN, main mobile relay node.

Parameters	**Value**
Train speed	up to 350 km/h
Carrier frequency	2.6 GHz
Operating bandwidth per UE	10 MHz
Tx power of donor-eNBs	25 dBm
Threshold for HPI	4%
Hysteresis of Event A3	3 dB
Time-to-trigger (TTT)	256 ms
Path loss model	128.1 + 37.6log10d, d is distance between main MRN and donor-eNB
Number of macro eNB	7
Cell radius	1 km
handover overlap area	300 m
main MRN measurement interval	50 ms
Transmission time interval	1ms
pedestrian UEs	100, with the random walk mobility model
UE speed	3 km/h
Adjustment value of CIO (Δ)	1 dB

2. If handover is necessary, the serving cell begins the handover procedure of MRN to the target cell and go to 3). if not, the serving cell resend a ”measurement command” to MRN and to restart the handover preparation.

3. If MRN fails to handover, the serving cell and target cell sends the handover information to HPI monitoring service located in the mobility management of LTE network. Then, go to 1) and the serving cell begins a new handover procedure. 1) to 3) is repeated until handover procedure of MRN finishes or the train leaves the coverage area of serving cell. If the handover procedure of MRN in completed, the serving cell finish a connection to MRN and reset the radio resources.

The HPI monitoring server located at the mobility management entity of LTE that runs the proposed handover parameter optimization Algorithm 1, in order to optimize the CIO parameter of target cell, shown as Figure 4.6 (b). This self-optimization and configuration process runs after handover procedure that is failed.

1. When the handover information is received, monitoring service select a cell that is the target cell from the handover information.
2. If HPI between the serving cell and target cell greater than threshold, go to 3); if not, go to 1).
3. the proposed CIO calculation scheme increase the CIO value of target cell by adjustment value. The monitoring service reconfigure the CIO parameter by the increased value. and go to 1).

4.5.2 Simulation Results

To compare the performance of proposed SOHP scheme and LTE handover with fixed parameters, it is manually configured that fixed hysteresis and offsets are used to the different speed scenarios of the train in LTE handover. Figure 4.7 shows the ratio of RLFs for the number of handovers. In the LTE handover case the optimization algorithm and HPI monitoring are disabled, the hysteresis and offset parameters are fixed in each cell and adjusted respectively to 3dB and 0dB. In the optimization case the proposed SOHP scheme reduces the number of radio link and handover failures.

At the beginning of simulation (before 50 handovers) little difference between the LTE handover and SOHP schemes are visible because of proposed adaptive hysteresis scheme optimizes a hysteresis for each handover procedure of MRN and HPI monitoring server is changing

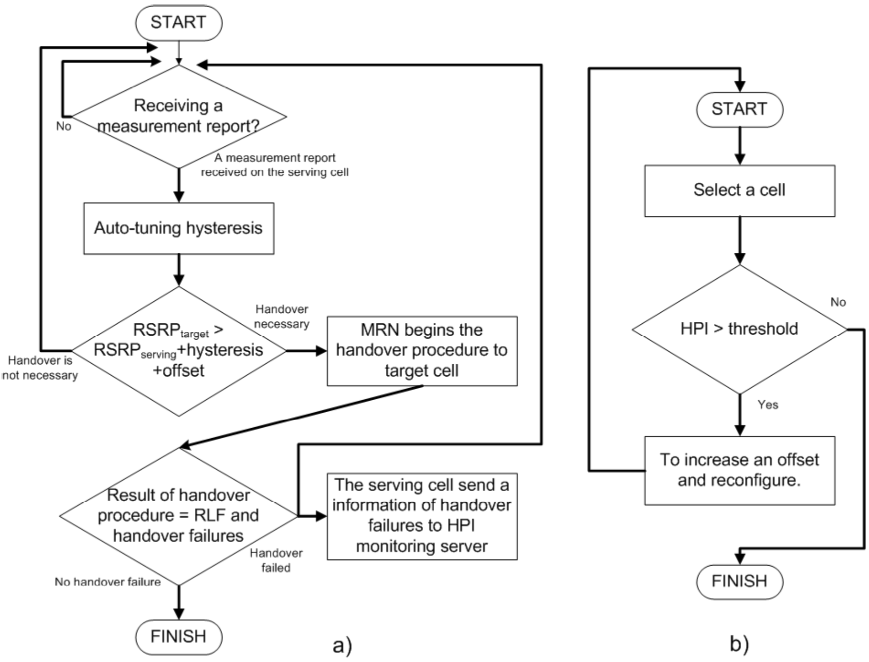


FIGURE 4.6: Flowchart of Self-optimization procedure, (a) Auto-tuning hysteresis and HPI collection, (b) Self-optimization and configuration of offset by HPI monitoring service

the offset of cells based on the result of the handover procedure. Also, no handover failures and dropped handovers are observed. When speed is higher, the ratio of RLFs and greater than lower speed one in the two schemes. And, the result of LTE handover shows a high peak and continuous increase as the number of handovers increases. During the optimization steps (between 55 and 75 handovers) drastically reduced ratio of RLFs than the LTE handover scheme are observed in the case the proposed SOHP scheme is activated. Hence the offset optimization actions of HPI monitoring are triggered after first handover in the proposed SOHP scheme and different speed scenarios. This effect can be explained by the initial offset optimization that has to be reconfigure after a handover failure information has received and the HPI exceed over the threshold. After this the proposed SOHP scheme is changed the handover parameters of all cells and the curves of RLF ratio significant performance gain until the end of simulation. However, when speed is high, the ratio of RLFs shows a higher than low-speed one in the proposed SOHP scheme is activated. This difference is caused by the handover triggering and wrong

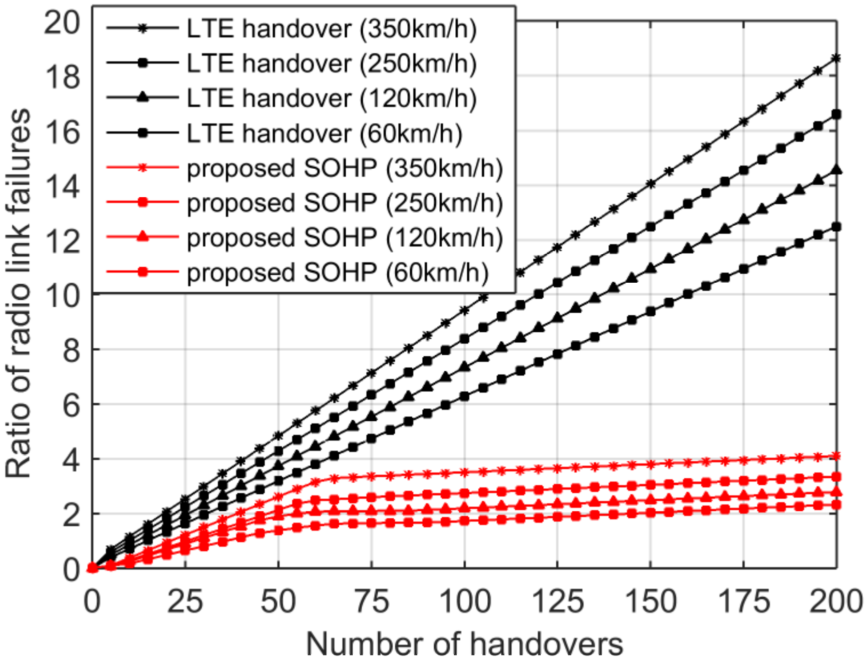


FIGURE 4.7: Performance comparison of proposed SOHP scheme with dual MRNs and the static hysteresis scheme (fixed train mobility). Ratio of radio link failures (RLFs).

cell selection that has the handover failures increased. In addition, the proposed SOHP scheme continuously improves the handover performance in the network.

We shows that compared result of LTE handover and SOHP schemes in terms of communication interruption time. The results are shown in Figure 4.8. The time consumption of all messages of handover procedure is defined in [63], We define the communication interruption time as the time interval from the MRN receiving the last packet from the serving donor-eNB to its receipt of the first packet from the S-GW through the target donor-eNB. In addition, only hard handover is supported in the LTE system. Therefore, the communication interruption of hard handover is defined by the path switch phase of handover procedure or the time interval in which MRNs do not transfer user data to base station.

Compared with the LTE handover scheme without dual MRNs, the service interruption

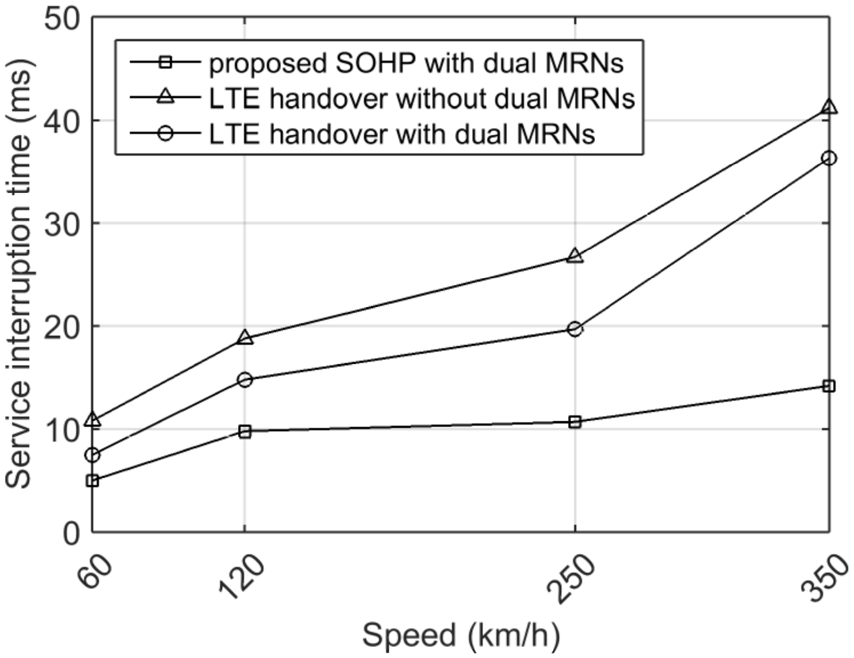


FIGURE 4.8: Interruption time during handover procedure of the train, comparison of LTE handover and proposed SOHP schemes with dual MRNs.

time in the proposed SOHP scheme can be reduced by dual MRNs and its handover procedure. From Figure 4.8, it can be also seen that the proposed SOHP scheme can reduce the service interruption time even compared with the LTE handover scheme in the dual MRNs. The SOHP scheme reduced communication interruption time by approximately 10.2 ms at 250 km/h, which is sufficient for the provision of QoS for passengers. Further, the communication interruption time of proposed SOHP scheme with dual MRNs was less than that for the LTE handover scheme on the high-speed environment. This is because the proposed SOHP scheme optimizes the parameters of handover procedure depending on the current speed of train and the handover performance. But, the LTE handover scheme manually configured the hysteresis and offset for handover procedure by the fixed value. Note that each MRN reply a measurement command of the serving cell and executes the handover procedure in the LTE handover scheme. This simulation result shows that the proposed SOHP scheme with dual MRNs can provide better

QoS to train passengers during the handover procedure.

4.6 Conclusion

Self-optimizing handover parameters can reduce wireless backhaul link (between the MRN and donor-eNB) failures during the handover procedures on high-speed environments. In this chapter, we proposed a self-optimizing hysteresis and CIO parameters with dual MRNs for LTE networks. The proposed SOHP scheme comprises two main features: (i) hysteresis optimization based on the speed of the vehicle; and (ii) a CIO optimization scheme for RLFs. the proposed SOHP scheme with dual MRNs is superior to the conventional static scheme with fixed parameter values. This is because a fixed parameter setting is adequate for general cases and UEs, but in the high-speed environment, a more flexible scheme is necessary. Our proposed SOHP scheme automatically tunes parameters based on the handover performance and speed; therefore, the hysteresis and CIO can be set to more appropriate values that are in line with changes in data communication. We also introduced the handover procedure of dual MRNs based network model in terms of data communication quality for train passengers. The results of simulations conducted, in which we compared the existing LTE handover and proposed SOHP schemes, showed that the proposed scheme reduces the number of RLFs and service interruptions during the handover procedures. This result can be explained by the following processes: (i) the passengers of the train are served by the secondary MRN during the handover procedure of main MRN; (ii) if the handover procedure of main MRN has failed, only main MRN starts the new handover procedure; and (iii) the dual MRNs execute the handover procedures by the powerful outside antennas of the train. In this scenario, outside antennas can use the MIMO that can provide the QoS of backhaul link to the donor-eNBs.

Chapter 5

Conclusion and Scope of Future Work

This dissertation considered mobility management and the MRN handover procedure by analyzing their impact on network performance. This thesis presents two novel handover schemes to improve the handover performance for the MRN wireless backhaul link. The first scheme is an adaptive hysteresis scheme, which is based on a cost function, with call admission for LTE networks in high-speed scenarios. This scheme selects suitable hysteresis based on the current speed of the train and reserves radio resources for MRN handover calls and the devices connected to it. The results of the simulation showed that the proposed scheme has increased handover performance and that it has the ability to reduce handover call dropping in a homogeneous network. The second proposed scheme is a self-optimization scheme of hysteresis and offsets designed for the MRN handover procedure in LTE networks. This scheme can monitor and optimize the hysteresis and offset of a cell in order to reduce the radio link failures and improve handover performance. We also introduced a network model based on a dual MRN handover procedure for enhanced data communication quality for train passengers.

The proposed handover schemes and the optimization solution developed for the wireless backhaul link of MRN and high-speed mobility scenarios are also scalable for implementation in heterogeneous networks and other scenarios. The required modification involves the re-definition of the handover parameters so as to overcome the effect and problems associated with low-speed mobility scenarios. In addition, re-definition of the cell selection mechanism with different cell sizes and network configurations is required. Based on this finding, the following guidelines are proposed in order to optimize the handover procedure:

1. Assign a higher priority to the load and service functions of the cost function than the speed function. In addition, reconfigure and optimize the weights for low-speed mobility scenarios.

2. Design the cell selection mechanism by considering the cell residence time and load balancing functions to select a suitable cell.

3. Consider early handover calculation and re-optimization when designing the proposed offset optimization algorithm. The only required changes are the re-definition of the early handover performance indicators.

5.1 Scope of Future Work

In future, there is scope for improving the proposed self-optimization schemes on 5G and heterogeneous networks. Besides, there is scope for re-designing the proposed schemes for software-defined mobile networks (SDNs for mobile environments) and other solutions. Apart from this, the open issue that still needs to be addressed is the handover for transferring the UE between different MRNs when the vehicle arrives at the station.

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List of achievement

Category (subheading)	[Paper/Article] Author(s), “Paper Title”, Conference/Journal Title, Issue number and page numbers, Presentation/Publication Date [Work] Author(s), Category, “Title”, Role in creating the work (Competition/Art Festival Name, Place of Showing, Date of Award-winning/Publication, Award Type)
Articles in refereed journals	○ Battulga Davaasambuu, Keping Yu and Takuro Sato, ”Self-Optimization of Handover Parameters for Long-Term Evolution with Dual Wireless Mobile Relay Nodes”, MDPI Future Internet 2015, vol.7, 196-213; doi:10.3390/fi7020196 ○ Battulga Davaasambuu, Frank Semaganga and Takuro Sato, ”Adaptive Handover Hysteresis and Call Admission Control for Mobile Relay Nodes”, International Journal of Computer Networks and Communications (IJCNC), vol.7, No.6, November 2015; doi:10.5121/ijcnc.2015.7606

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International Conference Proceedings	○ Battulga Davaasambuu and Takuro Sato, ”A Cost Based Handoff Hysteresis Scheme in Wireless Mobile Relay”, IEEE Vehicular Technology Conference 80th, 14-17 September 2014, Vancouver, Canada Battulga Davaasambuu, Nam Nguyen and Takuro Sato, ”Context-aware Handoff optimization for Wireless Mobile Base Station”, AsiaSim and JSST 2014, 26-30 October 2014, Kitakyushu, Japan Battulga Davaasambuu and Takuro Sato, ”Analyzing the Handoff Call Blocking Probability in Wireless network with mobile base station”, International Conference on Simulation Technology, JSST-2013, 11-13 September 2013, Tokyo, Japan.
Presentations at domestic conferences	Battulga Davaasambuu and Takuro Sato, ”Performance Analysis of QOS-aware Scheduling Scheme for Moving Base Station in LTE Networks”, IEICE General Conference 2014, 18-21 March 2014, Niigata University, Japan.
Co-authored papers	Nam Nguyen, Battulga Davaasambuu and Takuro Sato, ”Simulation of Dynamic WLAN Selection for Mobile Data Offloading”, AsiaSim and JSST 2014, 26-30 October 2014, Kitakyushu, Japan.

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Others (presentations)	Battulga Davaasambuu and Takuro Sato, ” Handoff Scheme for High Speed Vehicles”, Exchange Seminar between Waseda University and Hanyang University, 9 November 2013. Battulga Davaasambuu and Takuro Sato, ”Analyzing the Handoff Call Blocking Probability in Wireless network”, Exchange workshop betweeb KDDI and Waseda University, 14 November 2013. Battulga Davaasambuu and Takuro Sato, ”Analyzing the Handoff Call Blocking Probability in wireless network with Mobile base station”, Exchange workshop between Waseda University and Fujitsu, 5 December 2013.
Award	IEEE VTS Japan 2014 Young Researcher’s Encouragement Award, IEEE 80th VTC2014- Vehicular Technology Conference (VTC2014-Fall), 14 September 2014.