HANDOVER MANAGEMENT IN MOBILE WiMAX USING ADAPTIVE CROSS-LAYER TECHNIQUE

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ABSTRACT

The protocol type and the base station (BS) technology are the main communication media between the Vehicle to Infrastructure (V2I) communication in vehicular networks. During high speed vehicle movement, the best communication would be with a seamless handover (HO) delay in terms of lower packet loss and throughput. Many studies have focused on how to reduce the HO delay during lower speeds of the vehicle with data link (L2) and network (L3) layers protocol. However, this research studied the Transport Layer (L4) protocol mobile Stream Control Transmission Protocol (mSCTP) used as an optimal protocol in collaboration with the Location Manager (LM) and Domain Name Server (DNS). In addition, the BS technology that performs smooth HO employing an adaptive algorithm in L2 to perform the HO according to current vehicle speed was also included in the research. The methods derived from the combination of L4 and the BS technology methods produced an Adaptive Cross-Layer (ACL) design which is a mobility oriented handover management scheme that adapts the HO procedure among the protocol layers. The optimization has a better performance during HO as it is reduces scanning delay and diversity level as well as support transparent mobility among layers in terms of low packet loss and higher throughput. All of these metrics are capable of offering maximum flexibility and efficiency while allowing applications to refine the behaviour of the HO procedure. Besides that, evaluations were performed in various scenarios including different vehicle speeds and background traffic. The performance evaluation of the proposed ACL had approximately 30% improvement making it better than the other handover solutions.

ABSTRAK

Jenis-jenis protokol dan stesen pangkalan (BS) teknologi adalah media komunikasi utama antara kenderaan untuk Infrastruktur (V2I) komunikasi dalam rangkaian kenderaan. Semasa kelajuan tinggi pergerakan kenderaan, komunikasi terbaik adalah dengan kelewatan penyerahan yang lancar (HO) dari segi kehilangan paket dan jumlah lepas yang lebih rendah. Banyak kajian telah memberi tumpuan kepada bagaimana untuk mengurangkan kelewatan penyerahan semasa kelajuan kenderaan yang lebih rendah dengan pautan data (L2) dan rangkaian (L3) lapisan protokol. Walaubagaimanapun, kajian ini mengkaji Lapisan Pengangkutan (L4) protokol Stream Protokol Kawalan Penghantaran bergerak (mSCTP) yang digunakan sebagai protokol yang optimum dengan kerjasama Pengurus Lokasi itu (LM) dan Pelayan Nama Domain (DNS). Di samping itu, teknologi BS yang melaksanakan HO yang lancar menggunakan algoritma penyesuaian dalam L2 untuk melaksanakan HO mengikut kelajuan kenderaan semasa yang juga termasuk dalam kajian ini. Kaedah-kaedah yang diperolehi daripada gabungan L4 dan kaedah teknologi BS menghasilkan reka bentuk Penyesuaian Lapisan Silang (ACL) yang berorientasikan penyerahan skim pengurusan mobiliti yang bersesuaian dengan prosedur HO antara lapisan protokol. Pengoptimuman mempunyai prestasi yang lebih baik semasa HO kerana ia mengurangkan kelewatan imbasan dan tahap kepelbagaian serta sokongan mobiliti telus di antara lapisan dari segi kehilangan paket yang rendah dan jumlahlepas yang lebih tinggi. Semua metrik ini mampu menawarkan fleksibiliti dan kecekapan yang maksimum di samping membenarkan permohonan untuk memperbaiki tingkah laku prosedur HO itu. Selain itu, penilaian telah dijalankan dalam pelbagai senario termasuk kelajuan kenderaan dan latar belakang trafik yang berbeza. Penilaian prestasi ACL yang dicadangkan mempunyai kira-kira 30% peningkatan dan menjadikannya lebih baik daripada penyerahan penyelesaian yang lain.

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LIST OF ABBREVIATIONS

ACL	-	Adaptive Cross- Layer Design
ASCONF	-	Association Configuration
ASCONF-ACK	-	Association Configuration Acknowledgement
BS	-	Base Station
BU	-	Binding Update
CLD	-	Cross-Layer Design
CN	-	Correspondent Node
CoA	-	Care of Address
CWND	-	Congestion Window
DAD	-	Duplication Address Detection
DAR	-	Dynamic Address Reconfiguration
DHCP	-	Dynamic Host Configuration Protocol
DNS	-	Server Name Domain
DL MAP-IE	-	Down Link Medium Access Protocol – Information Entity
F-BAck	-	Fast Binding Acknowledgement
FBSS	-	Fast Base Station Switching
FBU	-	Fast Binding Update
FHMIPv6	-	Fast Hierarchical Mobile Ipv6
FMIPv6	-	Fast Handover Mobile Ipv6
FNA	-	Fast Neighbor Advertisement
HA	-	Home Agent

HACK	-	Handover Acknowledgement
HHO	-	Hard Handover
HI	-	Handover Initiation
HACK	-	Handover Acknowledgement
HMIPv6	-	Hierarchical Mobile Ipv6
HO	-	Handover
ITS	-	Intelligent Transportation System
L1	-	Physical Layer
L2	-	Data Layer
L3	-	Network Layer/IP Layer
L4	-	Transport Layer
LBACK	-	Local Binding Ack
LBU	-	Local Binding Update
LM	-	Location Management
LM	-	Location Manager
MAC	-	Medium Access Control
MANET	-	Mobile Ad Hoc Network
MAP	-	Mobility Anchor Point
MDHO	-	Macro-Diversity Handover
MIPv6	-	Mobile IPv6
MM	-	Mobility Management
MN	-	Node Mobile
MOB_NBR-ADV	-	Neighbour Advertisement Message
mSCTP	-	Mobile Stream Control Transmission Protocol
NAR	-	Access Router New
NBR_Sol	-	Neighbor Solicitation
NEMO BS	-	Network Mobility Basic Support Protocol
OSI	-	Open System Interface
PAR	-	Previous Access Router
PHA	-	Permanent Home Address

PKI	-	Public Key Infrastructure
PLCoA	-	Previous On-Link CoA
PrRtAdv	-	Proxy Router Advertisement
QoS	-	Quality of Service
REG.REQ/RSP	-	Registration Request/ Response
RSSI	-	Received Signal Strength Indicator
RtSolPr	-	Router Solication Proxy
SAA	-	Stateless Address Auto-Configuration
SBS	-	Serving Base Station
SCTP	-	Stream Control Transport Layer Protocol
SIGMA	-	Generalized Mobility Architecture IP Seamless
SIP	-	Section Initiation Protocol
SNR	-	Signal to Noise Ratio
TBS	-	Target Base Station
TCP	-	Transport Control Protocol
V2I	-	Vehicle to Infrastructure
V2V	-	Vehicle to Vehicle
VAN	-	Vehicular Area Network
VANETs	-	Vehicular Ad Hoc Networks
VoIP	-	Voice Over IP
WiMAX	-	Worldwide Interoperability for Microwave Access
WLAN	-	Wireless Local Area Network

LIST OF SYMBOLS

T_{MA}	-	The delay between MAP and access router,
T_{MT}	-	The measuring time for average delivery delay,
T_{CM}	-	The delay between CN and MAP
ld	-	Wired link delay
Wd	-	Wireless link delay
T_{frame}	-	Frame time
T_{synch}	-	Synchronization time
z	-	Handover area
v	-	Vehicle speed
t	-	Handover time
x	-	Overlapping area
c	-	Cell radius
r	-	Coverage BS area radius
R	-	Factor relates speed and threshold
D	-	Hythersys factor
TH_{drop}	-	Dropping threshold
TH_{HO}	-	Handover threshold

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CHAPTER 1

INTRODUCTION

1.1 Background

The rapid growth of services with higher data rate and their increasing demands in wireless networks motivate new communication technologies to accommodate broadband wireless access. Various wireless network technologies have been developed with special characteristics in terms of bandwidth, range, mobility support and Quality of Service (QoS) [1-4]. Wireless data networks allow users with wireless enabled mobile devices to access the core network and benefit Internet connectivity, or to interact with other devices in their proximity spaces as depicted in Figure 1.1. However, in mobile wireless communications one of the crucial issues is handover (HO) as it needs to provide seamless services without any disruption during user’s movement from one network to another. An emerging technology, Worldwide Interoperability for Microwave Access (WiMAX), as an alternative to the wired broadband access, eases the delivery of end point wireless [1-2, 4-8]. Specifically, WiMAXs is operating based on IEEE 802.16e among the IEEE 802.16 standards, which provides mobility support mainly through the admission control, buffering and service scheduling. Handover requirements in WiMAX, are negotiated at the initiation of the session and mapped on the HO parameters in the IEEE 802.16 MAC layer [4, 9-17] and both soft and hard handover mechanisms are supported. The mobile node (MN) users’ movement between the subnets in the same network domain (micro-mobility) and between two different network domains (macro-mobility) is controlled by the handover procedure. WiMAX is increasingly popular as a wireless broadband solution that many types of mobile devices have already been equipped with WiMAX interfaces.

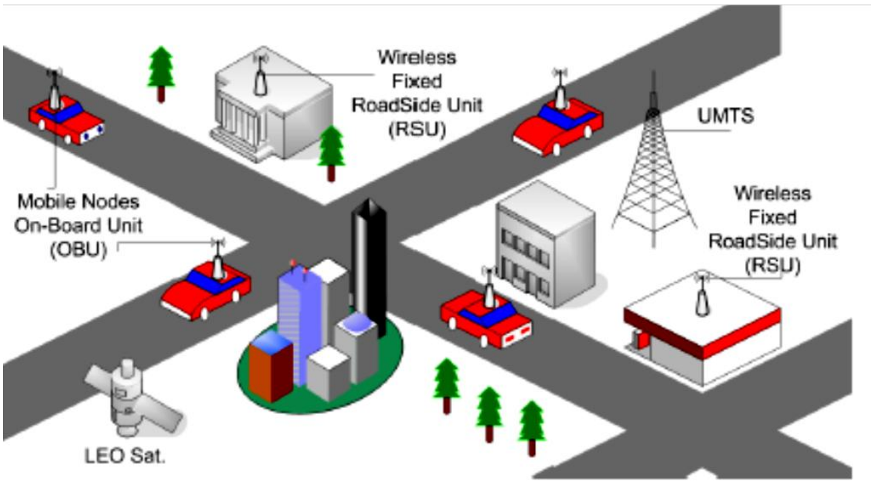

Figure 1.1 Wireless Networks Along the Roads

Typically, handover occurs when signals transmitted on the radio channel are weak and unstable in the boundary of the coverage area of the BSs. When channel quality degrades, the signalling messages and data packets are about to being lost or delayed. Furthermore, the user mobility plays an important role in the handover process while the user moves at a higher velocity leading to severe degradation of the radio channel quality due to the Doppler frequency shift. The handover latency is more critical for users with higher mobility since the overlapping area is limited between adjacent BSs. With the aim of supporting mobility, these issues become challenging and has to be tackled in different ways [2, 6, 9, 12, 18-22]. Recently, a wide area of research has been performed to deal with the mobile WiMAX's HO delay. They attempt to choose the best target base station (BS) through tracking the MN movement, detecting the signal level from BSs or analysing the QoS information of neighbour BSs [9, 22-24]. Many researches explore checking and improving the handover performance from the point of view of the protocol layers: data link layer (L2) or the network layer (L3))), and few of them in transport (L4)) and physical (L1) layers.

1.2 Problem Statement

In the context of handover management, many research activities proposed a wide range of solutions in terms of network protocols. Currently available handover algorithms are designed to reduce handover delay in L2 and L3 of BSs and MN respectively in a wireless network. Each particular solution has different performance in terms of handover latency and packet loss levels. Especially the soft-handover algorithms present good performance in terms of the above mentioned parameters [12, 18, 25-28]. However, relying on only one protocol layer to convey the handover procedure presents several shortcomings as long HO delay. In certain circumstances none of the current protocol layers may be able to provide alone the required handover delay time that supports high vehicle moving speed. This is due to the distance, highway limited number of BSs or network availability [26-27, 29-30].

In IEEE 802.16e the L2's HO procedure of wireless networks is the most important where it supports HO to embrace mobility [14, 27, 31]. However, the long HO delay causes service disruption for some applications especially when the vehicle is in high velocity since the vehicle and the BS had to scan and modify (with high velocity scanning of the best target BS depends on the signal strength) the connection periodically [32-33]. These schemes demand more capacity and multiple channels in terms of bandwidth efficiency, which give rise to wireless resource waste. Thus, implementing the traditional handover algorithms will find difficulties to select an appropriate BS and maintain the expected handover time.

To complete HO procedure, the cooperation of entities (i.e. Base Stations) of the wireless network and the network protocol must be efficiently designed. Mobile IPv6 and its extension as network protocol can support mobility and fast HO, however it has several problems and may cause a long delay [34-35]. For instance, it requires home agent (HA) to manage the current location of the MN and it is a single point of failure, packet redundant routing, duplicate address detection (DAD) delay and other network delays. Most researches believed the handover performance from the point of view of the L2 or L3, but no sufficient attention is paid to L4 or L1.Therefore, a lot of mobility support can be found better in upper layers.

On the other hand, using only one protocol layer for HO management may leave valuable layers therefore communication resources are underutilized just because they do not provide the required handover parameters. Therefore, aggregating the network parameters of handover from multiple network layers and adapting with the current dynamic network environments, a general cross-layer design is able to provide necessary exchange the control information messages between layers. Furthermore, most existing HO algorithms and cross-layer techniques proposed for the user communications in wireless networks do not consider HO for high mobility users.

1.3 Research Objectives

The mobility management in vehicular networks should promise the global reachability to mobile nodes in a vehicular network as well as the reachability to the correspondent node (CN) in the Internet. Hence, the requirements for mobility management has confined as the main goal of the work is to design a seamless mobility, fast handover, IP support, high mobility speed and movement detection. These goals categorize in the following steps:

1) To reduce L2 handover delay to a minimum value that suitable for the high speed movement vehicle, since upper layers can complete handover in a short time respectively.

2) To optimize the transport layer time of handing off related to traditional protocol design Stream Control Transport layer Protocol (SCTP) for optimal IP diversity and global mobility management of L4.

3) To make L4 communication to the CN continuous without interruption by adapting to rapid changes of L2 handover parameters in case of high speeds.

4) To reduce overall handover delay of vehicle related to L2, L3 and L4 by designing an ACL design between the protocol design and mobile WiMAX base station.

This design efficiently handles these challenges using transport layer protocol SCTP and obtained information from the data link layer as Radio Signal Strength (RSSI), Signal to Noise Ratio (SNR) and speed.

1.4 Research Scope

This research mainly focuses on mobility management in WiMAX network with moving users. This is reducing handover delay in a scenario of a user's vehicle that access to the Internet by communicating with WiMAX network on a highway. The vehicle is moving with high speed (70-140 km\hr) along the highway using an efficient protocol to access to the base station that gives minimum handover delay with respect of high moving speed.

In this work, integration and exchanging the information from multiple protocol layers to improve performance of mobility management schemes. For this reason, a cross-layer design in a scenario of the vehicle move from serving BS (SBS) to the target BS (TBS) communicating to the Internet performing soft handover between mobile WiMAX BSs was designed.

The proposed mobility management system mitigates the delay and enhances the performance in different aspects. The proposed design consists of three different aspects:

a) L2 handover delay of base station has to adapt the vehicle speed when it is very high. This can achieve using speed adaptation technique.

b) The L4 protocol delay has to reach a minimum value during handovers.

c) L4 delay of handover in high speed case can maintain by taking information on speed or another parameter affected by high speed from lower layers.

d) Last aspect is to reduce handover delay, packet loss accordingly higher throughput using cross-layer to update the upper layers of the vehicle protocol with the high mobility vehicle case in lower layer which hold the information.

1.5 Significance of the Research

This research proposed a handover management solution which efficiently exploits all the protocol layers and available communication resources. Thus, providing smooth and adaptive handover process high QoS levels, and most importantly consider transport layer efficiency by involving specific protocol in the decision making process. Providing an efficient with handover delay low packet loss and high throughput of wireless resources is also among the goals of this research work.

Also, this research offers a solution to remove high handover delay based on the network layer protocol by using a transport layer protocol of SCTP that recommend independent mobility management possibility. An SCTP feature of Multi-homing provides a foundation for mobility support as it allows a mobile user to add the new IP address, while holding the old IP address already assigned to it so it can prevent triangular transmission delay.

Also, by reducing high handover delay and packet loss rate in transport layer resulting of high mobility vehicle by adapting upper protocol layers and lower layers with the speed. Finally, joint these two approaches can obtain an efficient protocol. This goal can be achieved via a cross-layer design with mobile WiMAX messages

L2 and protocol messages L4 will minimize the total delay time for high speed vehicles on a highway, resulting in optimization of all systems.

1.6 Contributions

This thesis and the research activity performed to provide the following contributions to the advancement of the current state of the art:

1- The design of adaptive algorithm, a novel handover management algorithm, which

- Produce a new algorithm in L2 to update the protocol layers with different speeds of vehicles and signal degradation during handover.

- Performs adaptive handover using RSSI and SNR parameters.

- Makes an efficient handover scheme in wireless network communication.

2- A new mobility-aware transport layer design for high handover rates in wireless networks, a novel design can:

- Introduces an IP diversity protocol that globally manages and aware mobility management.

- Supports integration of mSCTP and DNS for global addressing of the vehicle.

- Provides integration of handover management, awareness of movement and IP diversity into a single vehicle modular architecture.

3- Introduction of Cross-Layer Scheme (CLS), a new design, which

- Is comprehensive and flexible metric combining L2, L3, L4 and adaptive algorithm of the handover and the vehicle's speed as well as adaptive cross-layer design (ACL).

- Represents a cross-layer messages with a high level of flexibility in terms of the protocol layer messages.

- Was tested for handover with background traffic on the highway.

The results of this research activity were properly disseminated and accepted by the international research community through book chapters, journal papers and conference papers.

1.7 Thesis Organization

The thesis was structured in six chapters as follows.

Chapter 1 introduces the motivation of the research activity conducted, the problem statement is exposed and then a brief overview of the solution is presented. The contributions to the advancement of the state of the art are detailed as well.

Chapter 2 discusses the background technologies related to Vehicular network communications in terms of mobility management in V2I. Secondly, mobile

WiMAX BS handover and messages flow mention in details. Network layer and transport layer protocols that support mobility mention clearly, all these being related to the subject investigated.

Chapter 3 presents the system design in details as the main idea of this work depends on the block diagrams and network scenarios of the idea. The simulation models and scenarios are presented. The testing results are detailed and the better performance of adaptive algorithm and a comparison has been made against other designs.

Chapter 4 introduces the adaptive algorithm of handover under the concept of intra handover optimization and discusses its flow and parameters. Each parameter is presented separately and its mathematical formula is introduced. Also, the transport layer mobility support scheme using to support high mobility speed of the vehicle. The ACL architecture and related algorithms presents accordingly. The message flow of the proposed protocols is described in different ways between network nodes. At the end the discussion of ACL performance and analysis of the results will describe in terms of background traffic of vehicles and compares the results with other systems.

Chapter 5 concludes the thesis and presents possible future work directions.

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