ENHANCING LOCATION ESTIMATION ACCURACY USING COOPERATIVE RELAY STATION IN WIMAX

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I dedicate this research work to my dear supervisor, Dr. Azmi bin Awang Md Isa who has taught and guided me throughout this whole year and to my family who supports me both financially and mentally.

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ABSTRACT

Location and Positioning (L&P) based services plays an important role in wireless communication system. Many researches were done to enhance the location estimation accuracy, but much improvements are yet to be done to satisfy the requirement of Federal Communications Commission (FCC). In wireless communication system, location estimation accuracy can be increased by utilizing more base stations (BS), however there are some restrictions such as high building cost of BS. In this project, a novel technique is developed, where through the usage of relay station (RS) in Worldwide Interoperability for Microwave Access (WiMAX) network, the location estimation accuracy can be enhanced by using only one BS and two RSs. An algorithm including four main parts for locating the coordinates of BSs, RSs and mobile stations (MS), time of arrival (TOA) estimation based on two non-light-of-sight (NLOS) error calibration method, generating the NLOS error using Circular Disk Scatterer Model (CDSM), and calculating the location estimation error using Linear Least Square (LLS) and Non Linear Least Square (NLLS) method. An algorithm to select the suitable RS location is developed as well. Simulation results shown that the location estimation accuracy for the deployment of one BS and two RSs is the best among all the cases. The result obtained will lead to a major development to the location estimation technologies in WiMAX network.

ABSTRAK

Perkhidmatan pengenalpastian lokasi dan kedudukan memainkan peranan yang penting dalam sistem komunikasi tanpa wayar. Walaupun banyak kajian telah dijalankan untuk meningkatkan ketepatan lokasi, namun penambahbaikan masih perlu dilakukan untuk memenuhi keperluan *Federal Communications Commission* (FCC). Dalam sistem komunikasi tanpa wayar, ketepatan lokasi boleh ditingkatkan dengan menggunakan lebih banyak stesen pangkalan, namun halangan-halangan seperti kos pembinaan stesen pangkalan yang tinggi tetap wujud. Melalui projek ini, satu teknik baru telah dibangunkan melalui penggunaan stesen geganti untuk rangkaian *Worldwide Interoperability for Microwave Access* (WiMAX). Ketepatan lokasi boleh dipertingkatkan menggunakan hanya satu stesen pangkalan dan dua stesen geganti. Pengekodan telah dihasilkan dan dibahagikan kepada empat bahagian utama iaitu mencari koordinat stesen pangkalan, stesen geganti dan stesen mudah alih, menggunakan kaedah *time of arrival* (TOA) berdasarkan dua cara penentukuran ralat laluan penglihatan yang dihalang, seterusnya menjana ralat laluan penglihatan yang dihalang menggunakan *Circular Disk Scatterer Model* (CDSM), dan akhirnya mengira ralat anggaran lokasi menggunakan kaedah *Linear Least Square* (LLS) dan *Non Linear Least Square* (NLLS). Algoritma pemilihan lokasi stesen geganti yang sesuai juga dibangunkan. Keputusan simulasi menunjukkan bahawa ketepatan anggaran lokasi untuk penggunaan satu stesen pangkalan dan dua stesen geganti adalah terbaik antara semua kes. Keputusan yang diperolehi akan meningkatkan pembangunan teknologi pengenalpastian lokasi dan kedudukan untuk rangkaian WiMAX.

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LIST OF ABBREVIATIONS

L&P	-	Location and Positioning
BS	-	Base Station
MS	-	Mobile Station
GDOP	-	Geometric Dilution of Precision
TOA	-	Time of Arrival
NLOS	-	Non-line of Sight
RS	-	Relay Station
WiMAX	-	Worldwide Interoperability for Microwave Access
LBS	-	Location based Services
PSAP	-	Public Safety Answering Point
QoS	-	Quality of Service
3G	-	Third Generation
WLAN	-	Wireless Local Area Network
IP	-	Internet Protocol
MIMO	-	Multiple Input Multiple Output
AMC	-	Adaptive Modulation and Coding
LOS	-	Line of Sight
RF	-	Radio Frequency
GPS	-	Global Positioning System
A-GPS	-	Assisted Global Positioning System

TTFF	-	Time to First Fix
MSR	-	Mobile Scan Report
RSSI	-	Received Signal Strength Indication
RTD	-	Round-trip Delay
RD	-	Relative Delay
D-TDOA	-	Downlink Time Difference of Arrival
U-TDOA	-	Uplink Time Difference of Arrival
CSN	-	Connectivity Service Network
CPE	-	Customer Premises Equipment
NMS	-	Network Management Systems
OFDMA	-	Orthogonal Frequency Division Multiple Access
QAM	-	Quadrature Amplitude Modulation
BPSK	-	Binary Phase Shift Keying
SNR	-	Signal to Ratio
MAC	-	Media Access Control
MCS	-	Modulation and Coding Scheme
DOA	-	Direction of Arrival
OPEX	-	Operational Expenditure
QoE	-	Quality of End-user
TCO	-	Total Cost of Ownership
NGMN	-	Next Generation Mobile Network
CINR	-	Carrier to Interference and Noise Ratio
MR	-	Multihop Relay
TDOA	-	Time Difference of Arrival
RSS	-	Received Signal Strength
AOA	-	Angle of Arrival
LLS	-	Linear Least Square
NLLS	-	Non Linear Least Square
ARS	-	Ad hoc Relay Station
CDSM	-	Circular Disk Scatterer Model
SSSD	-	Stationary Signal Strength Difference

PD	-	Pseudorange
PL	-	Position Location
WINNER	-	Wireless World Initiative New Radio
EM	-	Electromagnetic
PDP	-	Power Delay Profile
CDP	-	Cumulative Distribution Probability
FCC	-	Federal Communications Commission
RMSE	-	Root Mean Square Error

CHAPTER 1

INTRODUCTION

1.1 Introduction

Due to the significant growth of wireless networks, Location & Positioning (L&P) techniques act as an important role as this techniques are required to be carried out before a connection can be established. L&P method relies on availability and the coverage region of base station (BS) locations as well as the mitigation of propagation effects [1]. The ability of a mobile station (MS) to send and receive signal as well as determining their location depends greatly on the BS [2]. It is however, the location accuracy suffers from poor geometric dilution of precision (GDOP) caused by BS location as the orthodox algorithms result in large GDOP values which correspond to poor geometrical topology [3]. Furthermore, a large error in time of arrival (TOA) reading occurs as a result of non-line of sight (NLOS) effect [4]. The reception of an area becomes poor due to obstruction and random fading or may even turn outs to be a dead zone, hence affecting MS estimation

accuracy [5]. Relay station (RS) is used to extend the coverage of a single BS [6]. A MS can connect to a BS by transmitting signal to RS first, then RS will relay the signal to the BS. Besides enhancing the throughput, RS can also be used for positioning purposes.

In this project, fixed relay station based on Worldwide Interoperability for Microwave Access (WiMAX) cellular network architecture is used to extend the coverage of a single BS and to enhance the location estimation accuracy. A novel mobile location method based on assistance of relay stations using TOA measurements to mitigate the effect of NLOS in a WiMAX network is proposed. The main contribution of this project is a proposed algorithm that allow significant improvement in location estimation accuracy without additional base station on network architecture.

1.2 Problem Statement

Poor GDOP caused by BS location will lower the location estimation accuracy. GDOP is a metric to determine the geometric effect on the accuracy of location estimation for the MS. A high value of GDOP will degrade the performance of location estimation [3]. Besides, NLOS effect in the coverage region deteriorates the location estimation accuracy. NLOS effect is common where obstacles present between the BS and MS such as forests, hills and buildings [4]. Apart from this, the building cost of BS is very high due to the high cost to pay for antenna space, the wired backhaul connection and the digital and radio frequency equipment [7]. Moreover, the design of BS is more complex than RS as it has more functionality [8]. However, in this case the main aim is to extend the coverage range of a BS and enhance the location estimation accuracy. Hence, building a RS is enough.

In this project, a single base station is used. Relay stations serve as base station to mobile station and to be a mobile station for base station. By replacing base stations with several relay stations, the functionalities can still work and the cost will be lower under comparison.

1.3 Project Objective

The objective of this project are listed below:

1) To propose a novel RS technique to improve the conventional L&P algorithms by considering the geometric effect on location estimation accuracy.
2) To develop algorithm for simulation of the proposed technique.
3) To incorporate the developed algorithm into WiMAX specification and evaluate the performance of the algorithm.

1.4 Project Scope

In this project, several scopes have been identified. First and foremost, a RS system model is being developed. After that, the coverage and location estimation accuracy of a BS region is being tested. Next, an algorithm is produced using MATLAB. After that, the ideal location to build RS is determined. The number of relay station to be installed is also analyzed. Different parameters are tested to minimize the system's limitation. The results will be shown in MATLAB software. Hardware is not available.

1.5 Contributions of Project

This project is focused on the enhancement for determination of the MS's location, based on WiMAX technology, by employing the usage of RS. The contribution of this project can be summarized as follows:

- Introduction of a novel RS technique to improve the conventional L&P algorithms by considering the geometric effect on location estimation accuracy.
- Development of algorithm for simulation based on geometrical approach and statistical approach by using TOA as range measurements to enhance location estimation in various NLOS conditions.
- Incorporation of the developed technique into WiMAX specification.
- Evaluation for the performance of the algorithm.

1.6 Structure of Project

The remainder of this thesis is organized as follow. Chapter 2 comprise of the literature review which presents the background knowledge for the main contributions of this thesis. Generally, in Chapter 2, the WiMAX technology and L&P are reviewed. Several features of WiMAX that can be used are also highlighted. The geometric and statistical approach used are presented as well. Besides, the effect of NLOS propagation is presented. Finally, the chapter reviews and compares the current existing technology to enhance location estimation accuracy.

Then, Chapter 3 provides the methodology and the steps involved in developing the algorithm of the proposed technique. A novel technique using RS to enhance the location estimation accuracy based on different propagation scenarios is demonstrated. The specification of WiMAX employed to form the algorithm through a measurement model which then includes TOA data fusion and existing linear least square (LLS) calculation are presented.

Next, Chapter 4 explains the result and discussion from the evaluation of simulations. Lastly, Chapter 5 concludes the project and proposes some recommendations for future work.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this chapter, literature reviews that are related to the project's objective will be discussed. In order to complete this project, various journals and articles were studied and reviewed, including the existing location and positioning techniques and relay station based WiMAX cellular network architecture. Several journals of previous research project which are related with this project's purpose and objective were discussed and compared.

2.2 Overview of WiMAX standards

Location based services (LBS) have evolved into a vital features for most wireless networks. There are significant demand for LBS such as navigation, assets tracking, public safety wireless location, location sensitive billing, fleet operations, intelligent transportation, mobility management, lawful interception, battle against cellular phone fraud, wireless system design, efficient radio resource management and emergency services such as E911, where the location of users are reported to the public safety answering point (PSAP) and emergency rescuers are dispatched to that specific location [9][10][11].

WiMAX, known as Worldwide Interoperability for Microwave Access, is based on the IEEE802.16 standard. The members of WiMAX forum oversees the promotion of WiMAX through activities such as implementing bandwidth licensing policies and testing to ensure interoperability between equipment from different vendors [8]. Research in wireless broadband networks has also gaining more attentions in many fields including allocation of resources, placement of relays, handover between cells, Quality of Service (QoS) and others. Dozens or even hundreds of pilot networks are deployed worldwide to test drive the WiMAX technology [12]. WiMAX wireless technology may be complementary to existing 3G, WLAN and wired broadband networks. In some perspectives, WiMAX technology has the potential of threatening existing markets [13].

Location based services helps to determine and deliver users' location to applications on the network or device, which can in turn add value by personalizing services for their subscribers [10]. The three main usage categories for location services in WiMAX are:

a) Commercial LBS, connected with applications providing value-added services to the subscribers of those services through knowledge of the MS location. These applications sums up to two types:
   i. Push type services, in which location request is started by an entity on network side, such as local advertisements.
   ii. Pull type services, where a request for location is activated by an application on the MS side, such as an MS request for local places.