



**SINGLE BASE STATION LOCALIZATION  
ESTIMATION ALGORITHMS FOR INDOOR AND  
OUTDOOR MICROCELLULAR WIRELESS  
NETWORKS USING ANTENNAS**

by

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A thesis submitted in fulfillment of the requirements for the degree of  
Doctor of Philosophy

**School of Computer and Communication Engineering  
UNIVERSITI MALAYSIA PERLIS**

2018

## DEDICATION

Dedicated with love and gratitude to:

The soul of my dearest father (May Allah have mercy on him)

The spring that never stops giving, to my mother

My beloved wife (Aisha)

My beloved kids

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## ACKNOWLEDGMENT

All praises to Allah (subhanahuwata'ala) for giving me the strength, health, patience, and knowledge to complete this work.

First, I would like to express my deepest gratitude to my supervisor, Associate Professor Ir. Dr. Mohd Faizal Jamlos for his excellent guidance, motivation, caring, patience, and providing me with an excellent facilities and environment for doing this research. Without his continued support, I could not have completed this research project.

I would like to extend my profound gratitude to my co-supervisor Prof. Dr. Syed Alwee Aljunid, Dr. Ping Jack Soh, Dr. Adam Narbudowicz, and Dr. Siti Zuraidah Ibrahim for their mentorship and contribution to innumerable experiments and discussions on the different research projects that we worked on together.

I would like to thanks all my colleges at Advanced Communication Engineering Centre (ACE), School of Computer and Communication Engineering, UniMAP, for the help and sharing knowledge and ideas during working in my project.

I acknowledge, Hadhramout University (HU) and Universiti Malaysia Perlis (UniMAP) for their financial support.

And I would like to express my gratitude to the most important supporters, my family, I extend my greatest gratitude from the bottom of my heart to my mother. She is always there for me to help me endure the most difficult times and get out victorious. I also want to express tremendously thank you to my wife (Aisha Mubarak) for her love, patience and support during my graduate studies. To my beloved kids (Fatima, Aiman and Salem), my sisters and brothers, and all members of my family for their continued support, inspiration, patience and love.

Thanks goes to all my friends and to all those whoever has helped me either directly or indirectly in accomplishment of this research project.

I close this section by thanking all the people whom in one way or another have contributed to this great achievement from my childhood up to this point. Specially my family, friends and teachers during all these years, and for believing in me.

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## LIST OF ABBREVIATIONS

2D	Two Dimensional
3D	Three Dimensional
2G	Second Generation
3G	Third Generation
3GPP	Third Generation Partnership Project
4G	Fourth Generation
5G - WiFi	5 GHz Wi-Fi
ADS	Advanced Design System
AOA	Angle of Arrival
BS	Base Station
CDF	Cumulative Distribution Function
CST	Computer Simulation Technology
CPW	Coplanar Waveguide
dB	Decibel
dBm	Decibel of Measured power referenced to 1 milliwatt (mW)
E field	Electric field
GHz	Gigahertz
GPS	Global Positioning System
GSM	Global System for Mobile Communication
H field	Magnetic field
IEEE	Institute of Electrical and Electronics Engineering
LOS	Line of Sight
LAN	Local Area Network
LSE	Least Square Error
LTE	Long Term Evolution
LTE-A	Long Term Evolution-Advanced
MATLAB	Matrix Laboratory
mm	Millimeter
MS	Mobile Station

MT	Mobile Terminal
NLOS	Non Line of Sight
P	Power
PCS	Personal Communications Service
PDA	Personal Digital Assistant
Pr	Power received
QoS	Quality of Service
RP	Reflected Point
RF	Radio Frequency
RFID	Radio Frequency Identification
RMS	Root Mean Square
RMSE	Root Mean Square Error
RSS	Received Signal Strength
RSSI	Received Signal Strength Indicator
RT	Ray Tracing
Rx	Receiver
SBS	Single Base Station
$S_{ii}$	Reflection Coefficient (input from $i$ th element)
$S_{ij}$	Transmission Coefficient (from $j$ th to $i$ th element)
TDOA	Time Difference of Arrival
TOA	Time of Arrival
Tx	Transmitter
VSWR	Voltage Standing Wave Ratio
WCDMA	Wideband Code Division Multiple Access
WiMAX	Worldwide Interoperability for Microwave Access
WLAN	Wireless Local Area Network
WPAN	Wireless Personal Area Network

## LIST OF SYMBOLS

$\Omega$	Ohm
$\eta$	Efficiency
$\varepsilon$	Permittivity
$\mu$	Permeability
$\sigma$	Conductivity
$\Gamma$	Reflection Coefficient
$f$	Frequency
$C$	Light Speed in Free Space
$\lambda$	Wavelength
$Z$	Impedance
$d$	Distance
$G_r$	Receiver antenna gain
$G_t$	Transmitter antenna gain
$P_r$	Receiving power
$P_t$	Transmitting power
$\gamma$	Path Loss Exponent
$\beta_1$	Incidence angle
$\beta_2$	Reflected angle
$\tau$	Multipath delay spread
$\theta$	Elevation angle

# **Algoritma-algoritma Anggaran Penyetempatan Stesen Pangkalan Tunggal untuk Rangkaian Mikrobersel Tanpa Wayar Dalam dan Luaran Menggunakan Antena**

## **ABSTRAK**

Anggaran penyetempatan adalah faktor penting dalam rangkaian tanpa wayar di masa akan datang yang digunakan dalam kebanyakan aplikasi mudah alih, navigasi kenderaan dengan kenderaan yang lain, menyelamatkan kehidupan kita terutama dalam situasi kecemasan. Walaupun menggunakan teknologi Sistem Kedudukan Sejagat (GPS) dalam bidang sistem lokasi sejak berdekad yang lalu, permintaan untuk membangunkan teknik penyetempatan berskala, tepat, cekap dan berkost rendah adalah wajar dengan menggunakan kawasan liputan Frekuensi Radio (RF) dari antena stesen pangkalan yang ada berbanding satelit. Dua algoritma berbeza yang menggunakan Stesen Pangkalan Tunggal (SBS) untuk pencapaian isyarat pada Garis Penglihatan (LOS) dan Bukan Garis penglihatan (NLOS) dicadangkan dalam kerja-kerja penyelidikan ini untuk sistem anggaran penyetempatan luaran dan dalaman. Pendekatan sistem anggaran penyetempatan luaran (OLES) telah dicadangkan dengan menggunakan pengetahuan sedia ada tentang koordinat geometri daripada beberapa halangan tetap yang mengelilingi stesen Mudah Alih (MS) dan SBS. Maka, jarak yang berselerak dikira dengan menggunakan kedua-dua kombinasi iaitu teknik Ketepatan Masa (TOA) dan Sudut Ketibaan (AOA) untuk mengenal pasti lokasi MS. Laman asrama mahasiswa UniMAP dipilih sebagai lokasi kajian di mana ianya menunjukkan bahawa 70% daripada lokasi pelanggan yang telah dikenalpasti dalam lingkungan 125 meter<sup>2</sup> lebih memuaskan berbanding piawai Suruhanjaya Komunikasi Persekutuan (FCC) iaitu sebanyak 67%. Sistem anggaran lokasi penyetempatan dalaman (ILES), yang mempunyai komponen laluan pelbagai yang kuat dan kesan-kesan kabur di mana GPS tidak boleh digunakan. Oleh itu, algoritma penyetempatan dalaman tiga dimensi (3D) telah dicadangkan bergantung kepada analisis kekuatan isyarat yang diterima (RSS), yang diukur menggunakan beberapa antena yang telah diselidik. Dua tetapan pengukuran yang berbeza telah dipilih untuk ILES bergantung kepada jenis antena samada arah keliling atau searah. Beberapa jenis antena arah keliling dan searah telah direka dimana ianya merupakan fokus kerja yang kedua bagi Evolusi-Maju Jangka Masa Panjang (LTE-A), Rangkaian Tanpa Wayar Setempat (WLAN), dan aplikasi 5G Wi-Fi. Bagi tetapan pertama antena arah keliling, antena dua polar beserta slot Y telah direkabentuk dan digunakan sebagai alat penerima, dimana ianya beroperasi pada jalur frekuensi pelbagai. Bagi alat penghantar, antena pandu gelombang planar bersama (CPW) telah direkabentuk bersama sel unit bahan meta bagi meningkatkan lebar jalur dan ciri-ciri gain yang tinggi. Walau bagaimanapun, bagi kes tetapan kedua, antena satu arah disambungkan dengan secara fizikal pada 72 darjah antara muka beralih daripada rekabentuk jalur lebar lima antara muka meter pantul (5PR) untuk mengalirkan pada senario terpilih di ruang siswazah ACE di UniMAP. RSS yang dikumpulkan dianalisis dalam dua kategori termasuk jarak dan arah fasa bagi MS yang dikenalpasti. Sebanyak 80% pengguna dilokalisasikan dalam lingkungan atau kurang dari julat ralat 0.7 meter dengan melaksanakan algoritma dalaman yang dicadangkan sedangkan 19% MS dapat dicapai tepat di lokasi sebenarnya. Tambahan pula, ralat yang dianggarkan pada sudut ketinggian antara lokasi anggaran dan sebenar dicatatkan pada tahap lima darjah atau kurang bagi 96% daripada jumlah pengguna. Cadangan OLES dan ILES adalah cekap untuk aplikasi perkhidmatan berkualiti tinggi (QoS).

## Single Base Station Localization Estimation Algorithms for Indoor and Outdoor Microcellular Wireless Networks Using Antennas

### ABSTRACT

Localization estimation is a critical factor in future wireless network to be used in most of mobile applications, vehicle-to-vehicle navigation and saving our lives especially in emergency situations. Despite the use of Global Positioning System (GPS) technology in the field of location system in the past decades, the demand for developing a scalable, accurate, efficient and low-cost localization technique is highly desirable using the Radio Frequency (RF) coverage area of the available base station antennas instead of using satellite. Two different algorithms using Single Base Stations (SBS) for Line-of-Sight (LOS) and Non-Line-of-Sight (NLOS) RF propagated signals are proposed in this research work for outdoor and indoor localization estimation system. Outdoor localization estimation system (OLES) approach has been proposed by utilizing a prior knowledge about the geometrical coordinates of some fixed obstacles surround the Mobile Station (MS) and the SBS. Hence, the scattering distance is calculated by utilizing the combination of both, Time of Arrival (TOA) and Angle of Arrival (AOA) techniques to identify the MS location. A site of UniMAP students' hostel is chosen as a case study where the result shows that 70% of the subscribers location identified within 125 meter<sup>2</sup>, which is more satisfactory compared Federal Communications Commission (FCC) standard of 67%. Indoor Localization Estimation System (ILES), which suffers forceful multipath component and fading effects where GPS is unreliable. Therefore, Three-Dimensional (3D) indoor localization algorithm has been proposed depending on the analysis of Received Signal Strength (RSS), which is measured using several investigated antennas. Two different measurement setups have been selected for ILES depending on omnidirectional and directional antennas. Few omnidirectional and directional antennas are designed which are secondary focus of this work for Long Term Evolution-Advanced (LTE-A), Wireless Local Area Network (WLAN) and 5G Wi-Fi applications. For the first setup using omnidirectional antennas, Y-slot loaded dipole antenna is designed and used as a receiver, which is operating in multiple frequency bands. As for the transmitter antenna, Coplanar Waveguide (CPW) antenna is designed associated with proposed metamaterial unit cell to facilitate enhanced bandwidth and high gain characteristics. However, for the case of second setup, designed directional antennas are connected with the physically 72 degree shifted ports of designed symmetric wideband Five Port Reflectometer (5PR) to sectorize the indoor selected scenario at ACE graduate room in UniMAP. The collected RSS is analyzed in two categories including distance and phase direction of the identified MS. 80% of the users are localized within or less than 0.7 meter error range by implementing the proposed indoor algorithm whereas 19% of MSs are achievable exactly in their actual location. Furthermore, the error in estimated elevation angle between the actual and estimated location is recorded in the level of five-degrees or less for 96% of the total users. The proposed OLES and ILES are efficacious for high quality of service (QoS) applications.

## CHAPTER 1 : INTRODUCTION

### 1.1 Background

In the recent years, the demand of wireless communications systems has been grown significantly. Therefore, Smart Mobile Phones (SMP), Personal Digital Assistance (PDA) and Radio Frequency Identification (RFID) have been an essential part of our daily life. These developments allow the people and things to communicate easily with each other where plenty of mobile services have been required. Mobile localization, also known as mobile positioning, is one of the most necessary services in wireless networks, since most of the mobile applications totally depending on the previous knowledge of the device location. Emergency rescue calling, handover process, mobile healthcare, Vehicle-to-Vehicle (V2V) navigation and weather tracking are several examples of applications and systems that cannot work properly without clearly identify the accurate user location.

Furthermore, the heterogeneous networks, which include various kinds of wired and wireless systems (Y.-B. Lin & Chlamtac, 1996), will interoperate among each other and among the users' terminals due to its ability to identify their location. In the early stage of the wireless network systems development, the demand for mobile localization technology is generated mostly in a Wireless Wide Area Network (WWAN). Hence, Global Positioning System (GPS), as a navigation system using several number of satellites, has been developed to realise this purpose whereas a wide geographic area can be covered by using this system (Parkinson, 1996). However, it is only work for outdoor environments and inappropriate for large-scale deployment because of its drawbacks in terms of cost and power consumption (Paz-Soldan et al., 2014). In addition, it is

unreliable for indoor scenarios. Meanwhile, the demand for an alternative approach in wireless networks becomes very important.

Recently, mobile localization estimation systems are more sophisticated based on the Digital Cellular Networks (DCN), Wireless Local Area Network (WLAN) and Wireless Sensor Network (WSN), which can be applied for indoor (H. Liu, Darabi, Banerjee, & Liu, 2007) and even underwater (Ian F Akyildiz, Pompili, & Melodia, 2005), however, this feature is not available in GPS. Nowadays, the developed mobile localization estimation techniques have been depending on the measured sent/received radio signal between a group of nearby base stations (BSs) and the mobile stations (MS) within the antenna BS coverage area. Therefore, the mobile user position can be estimated based on the previous knowledge about the BS location and prospective measurements where the numerous received signals by the BS antenna will be processed using a certain kind of algorithms to estimate the MS location. The mobile localization performance can be affected by the radio signal measurements precision, localization estimation method and reliability of the antenna BS (D. Liu, 2010). Consequently, unexpected mobile location might be determined because of signal time delay at receiver side in BS antennas. One of the reason for this delay is because of the antenna itself, due to this reason more efficient antennas are also required for better localization in modern world. Currently, antennas BS have to achieve various operations for various wireless technologies.

Antennas in localization systems are one of the most critical elements that can either enhance or constrain system performance. Depending on the system, application antennas for localization system can be directional or omni-directional. Directional antennas have the advantage of reducing the effects of interference and in extending the communication range of the system; however, the coverage area is limited. Using omni-

directional antennas enables coverage of all the directions equally; therefore, they are highly preferred.

Future wireless devices will require to integrate the antenna units with the rest of electronics to minimize size and manufacturing cost. Printed antennas are the ideal candidates among different types of antenna for these applications due to their planar structure and compatibility with the printed circuit fabrication techniques (Stutzman & Thiele, 2012). Printed antennas are more flexible to design; the most common ones are microstrip patch antennas (David M Pozar, 1992), printed dipole antennas (Edward, 1987), printed monopole antennas and their variants (Soras, Karaboikis, Tsachtsiris, & Makios, 2002). The major drawback of planar antennas is their narrow bandwidth, which restrict their use in many applications. Extensive studies have been done to solve this issue including usage of aperture coupling (Targonski & Pozar, 1993), parasitic elements (Rambabu, Alam, Bornemann, & Stuchly, 2004), stacked patch configuration (Lee & Yang, 2000).

According to IEEE 802.11 WLAN standardize the demanded frequencies allocated at 2.4 GHz, 5 GHz, 5.2 GHz and 5.8 GHz (Raj, Joseph, Aanandan, Vasudevan, & Mohanan, 2006). Recently, 5G Wi-Fi becomes popular in current wireless communications with higher data rates and Quality of Service (QoS). Its operating frequency band within the range of (5.15 - 5.875) GHz (Lai & Wong, 2015). However, LTE-A has arisen a great concern for fourth generation (4G) at 3.5 GHz, it is developed by Third Generation Partnership Project (3GPP) (Ian F. Akyildiz, Gutierrez-Estevez, & Reyes, 2010).

In wireless communication systems, both indoor and outdoor BS antennas are extremely desired to transmit high data rate in long or medium range, where lower gain antenna can't be satisfied. However, Indoor antennas suffer a significant challenge due