LOCAL MULTIPOINT DISTRIBUTION SERVICES ARCHITECTURE BASED ON RAIN PROFILE EXTRACTED FROM METEOROLOGICAL RADAR

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Dedicated to my parents, brothers, wife and our beloved children Huda and Abdullah

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ABSTRACT

The growing demand for high-speed Broadband Wireless Access (BWA) applications has motivated the use of millimetre waves operation in Ka band, point-to-multipoint fixed cellular with a large bandwidth of 0.5–1.55 GHz. This service is also known as Local Multipoint Distribution Service (LMDS). It has the advantages of rapid installation, scalability, high capacity, ease of deployment and low initial infrastructure costs; and could be an attractive alternative to other broadband access technologies. However, the service is limited up to 8 km of coverage area due to line of sight constraints. Co-channel interference and rain attenuation are major limitation factors to system performance. This study is conducted to analyse LMDS performance based on local rain cell profile. The long-term cumulative rainfall rate was obtained from weather radar data. This data is compared with ITU-R recommendation and data from rain gauge network. The influence of rain length distribution probability to different rain rate thresholds had been studied from the database for an area size of 25 km^2. The target is to design LMDS that reaches up to 5 km of cell size service with good availability. Four architectures of fixed BWA were investigated in terms of a carrier to interference ratio (C/I) using three types of modulations which are QPSK, 16-QAM and 64-QAM. The rain cell profile results shows that higher rain rates experience shorter rain length. The rain rates at 0.01 percentage of time for radar data in UTM is 106.25 mm/hr and rain length was less than 0.46 km. Besides, during low rain rate events, the LMDS service coverage has better performance than clear sky. This is due to fact that the low rain rates present low attenuation to the desired signal but causes high attenuation to interfering base station signals, resulting in better C/I performance. During heavy precipitation, the effective service coverage area will reach to less than 2 km using QPSK in conventional architecture at 99.99% availability. In addition, the co-channel interference can be reduced by using certain design-rule for various architectures. Moreover, it was observed that by decreasing LMDS cell size, the service coverage performance would improve. Two methods had been proposed to improve the performance. One is to use different architectures namely conventional with 4 frequency reuse, simplex ring relaying and dual ring relaying. The second method is to reduce the LMDS service size, i.e. to determine appropriate cell size which offers 99.99% availability. It showed that, for conventional architecture, 3 km cell size was sufficient to reach the required availability based on local climate. In addition, 5 km service cell size for 99.98% availability can be achieved by using dual ring architecture. All the information are important to present BWA network architectures for Malaysian environment based on rain intensity distribution extracted from radar data.

ABSTRAK

Permintaan yang semakin meningkat untuk aplikasi yong menggunakan Akses Jalur Lebar Wayarles (BWA) berkelajuan tinggi telah mendorong penggunaan gelombang milimeter beroperasi pada jalur Ka, iaitu selular talian tetap titik ke pelbagai titik dengan lebar jalur yang besar. Perkhidmatan ini juga dikenali sebagai Servis Pemancaran Pelbagai Titik Tempatan (LMDS) yang mempunyai pemasangan yang pantas, kebolehan untuk diskala, berkapasiti tinggi, kemudahan penempatan dan kos infrastruktur awal yang rendah dan boleh menjadi satu alternatif menarik kepada teknologi akses jalur lebar lain. Tetapi, perkhidmatan ini terhad sehingga 8 km dari kawasan liputan kerana kekangan garis sesaluran penglihatan. Gangguan saluran bersebelahan dan gangguan hujan adalah faktor utama yang menghadkan prestasi sistem. Maka, kajian telah dijalankan untuk menganalisa prestasi LMDS berdasarkan profil sel hujan tempatan. Kadar kumulatif hujan jangka panjang telah diperoleh daripada data radar cuaca. Data ini dibandingkan dengan syor ITU-R dan data dari rangkaian tolok hujan. Pengaruh taburan kebarangkalian panjang hujan ke atas kadar hujan yang berbeza telah dikaji dari pangkalan data bagi saiz kawasan seluas 25 km2. Sasaran adalah untuk mereka bentuk perkhidmatan LMDS yang mencapai sehingga 5 km dengan ketersediaan baik. Empat seni bina BWA tetap telah dilakukan berdasarkan nisbah pembawa kepada gangguan (C/I) menggunakan tiga jenis modulasi QPSK, 16-QAM dan 64-QAM. Sel hujan profil hasil kajian menunjukkan kadar tinggi hujan mempunyai saiz hujan pendek. Kadar hujan pada 0.01 peratus masa untuk data radar UTM adalah 106.25 mm/jam dan saiz hujan untuk kadar ini adalah kurang daripada 0.46 km. Tambahan pula, semasa kadar hujan rendah, liputan perkhidmatan adalah lebih baik berbanding keadaan tanpa hujan. Ini kerana kadar hujan yang rendah memberi kesan minimum kepada isyarat yang diingini tetapi menyebabkan rosotan yang besar kepada isyarat gangguan dari stesen asas yang memberikan prestasi yang C/I lebih baik. Semasa hujan lebat, kawasan liputan perkhidmatan berkesan akan menjadi kurang dari 2 km menggunakan QPSK dalam seni bina konvensional pada ketersediaan 99.99%. Sehubungan itu, gangguan saluran bersebelahan boleh dikurangkan dengan menggunakan peraturan reka bentuk tertentu untuk pelbagai seni bina. Tambahan pula, dengan mengurangkan LMDS saiz sel prestasi liputan perkhidmatan akan bertambah baik. Dua kaedah telah dicadangkan untuk meningkatkan prestasi. Satu adalah dengan menggunakan seni bina yang berbeza iaitu konvensional dengan 4 frekuensi guna semula, geganti gelung simpleks dan geganti gelung duaan. Kaedah kedua adalah mengurangkan saiz perkhidmatan LMDS, iaitu dengan menentukan saiz sel yang sesuai yang menawarkan ketersediaan 99.99%. Didapati bahawa bagi senibina konvensional, 3 km adalah saiz sel yang sesuai untuk mencapai ketersediaan yang diperlukan berdasarkan iklim tempatan. Di samping itu, saiz sel perkhidmatan 5 km pada ketersediaan 99.98% boleh dicapai dengan menggunakan seni bina gelung duaan. Semua maklumat ini adalah penting untuk seni bina rangkaian BWA mengikut iklim Malaysia berdasarkan pengagihan keamatan hujan yang diekstrak daripada data radar.

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LIST OF SYMBOLS

A	-	Rain Attenuation
ACI	-	Adjacent channel interference
AIP	-	Acceptance interference probability
Ar0.01	-	Attenuation at 0.01 of time
BS	-	Base Station
C	-	Area coverage
CCI	-	co-channel interference
C/I	-	Carrier to Interference ratio
CIR	-	Carrier to Interference ratio
C/N	-	Carrier to noise ratio
CNR	-	Carrier to noise ratio
dB	-	Decibel unit
Fr	-	Frequency reuse
HS	-	Hub Station
I/N	-	Interference to Noise Ratio
ICI	-	Inter-cell Interference
ISI	-	Inter-symbol interference
km	-	Kilometer
PL	-	Path Loss
R	-	Rain Rate
Rth	-	Rain Rate threshold
R0.01	-	Rain Rate at 0.01 percentage of time
RF	-	Radio Frequency
γ_s	-	Specific Attenuation
TS	-	Terminal Station

LIST OF ABBREVIATIONS

BWA	-	Broadband wireless access
CDF	-	Cumulative Distribution Function
CPE	-	Customer Premise Equipment
DBA	-	Dynamic Bandwidth Allocation
EIRP	-	Effective Isotropic Radiating Power
FBWA	-	Fixed broadband wireless access
FCC	-	Federal Communications Commission
FSL	-	Free Space Path Loss
GHz	-	Giga hertz
LAN	-	Local Area Network
LMDS	-	Local Multipoint Distribution Services
LOS	-	Line of sight
MCMC	-	Malaysian Communications and Multimedia Commission
mm/hr	-	Millimetre per hour
PDF	-	Probability Density Function
ITU-R	-	International Telecommunication Union - Radio communications
IEEE Std	-	International of Electrical and Electronic Engineering Standard
P-MP	-	Point to Multipoint Fixed Service
P-P	-	Point to Point Fixed Service
PPI	-	Plan Position Indicator
QAM	-	Quadrature Amplitude Modulation
QPSK	-	Quadrature Phase Shift Keying
RHI	-	Range Height Indicator
Z	-	Radar Reflectivity Factor

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CHAPTER 1

INTRODUCTION

1.1 Introduction

There is a growing interest of using broadband wireless access (BWA) service, because it provides reliable transmission of information such as data and video (Ahamed, 2009). BWA utilizes large bandwidth and has low error rates for acceptable performance service to consumers, as compare to copper telephone wires or coax cable (Agne and Telenor, 2000).

However, attenuation due to rain is a major limitation for terrestrial and slant path links especially at shorter wavelengths. The rain attenuation might cause temporary loss of signal therefore it is an important parameter in the design of telecommunication systems which relies on wavelengths above 1 GHz (Crane, 1996).

Reliable estimates of rain attenuation can be obtained through measurements taken from radar data (Adhikari et al., 2011; Akuon and Afullo, 2011; Yeo et al., 2012). Direct measurements like rain gauge or microwave link are not convenient for use, because of infrastructure and time constrain (Olsen, 1982; Seed et al., 1990; Lahaie et al., 1993). In addition, it is sometimes complicated to transfer the outcomes to other sites. Thus, there is growing interest in using indirect measurement techniques such as radar data.

Radar (Radio detection and ranging) utilizes electromagnetic waves to “remote-sense” the location, determine velocity, and determine characteristic of targets. The primary reason for utilizing radar is the ability of this instrument to detect with great spatial detail of precipitation over large area in real time and with single installation. Radar data can be used principally to evaluate the propagation impairments through simulations (Battan, 1973), which is due to hydrometeors for any length of ground paths, any kind and complexity of radio system and for any frequency. However, the shortcoming is the radar reflectivity (Z), that is fundamental measurement for the meteorological target which can not be directly used, its conversion to rain intensity and depends mostly on Drop Size Distribution (DSD) (Capsoni and Caboni, 2003).

With rapid growth of information technology (Murdock et al., 2012), there is a trend of using local Multipoint Distribution Service (LMDS) applications and evolution (Ahamed, 2009; Panagopoulos et al., 2007; Dimitris et al., 2011). This has led to the utilization and exploitations of high wavelengths band such as Ka band (20/30 GHz) and above. The spectrum at Ka band is essential for BWA services. This is so; due to relatively unused spectrum with essentially no congestion problem, that provides greater bandwidths, and ability of frequency reuse comparing with lower band frequency.

There are two kinds of interference in LMDS; first type is interference from other communication systems known as "inter-system interference" such as interference from other Ka-band communication systems (Bose et al., 2001). This can be solved with proper licensing of spectrum band. The second interference is known as "intra-system interference". This is essentially interference produced by the system itself, including adjacent channel interference (ACI) and co-channel interference (CCI). ACI could be resulted from signals which are adjacent within the frequency for that desired signal. CCI is the major concern in LMDS cellular architecture; the biggest problem is the consequence of interference of a single cell on others throughout heavy rain because of frequency reuse (Hakegard, 2000). Similarly, CCI sometimes happens due to crosstalk from two different radio transmitters using the same frequency which is unquestionably the worst issue in the coexistence. This study is devoted to CCI effect only.

A modified rain models (ITU-R P.837-6, 2012; ITU-R P.530-14, 2012) according to local radar data measurements was used to identify the rain rate and rain attenuation distribution. In this work, the performance of LMDS has been evaluated in terms of carrier-to-interference ratio C/I under different rain conditions. Rain attenuation and inter cell interference (ICI) play a very important factor in LMDS planning techniques.

1.2 Problem statement

Wireless telecommunication world is very competitive; in view of that, power budget and fade margin requirements need to be studied extensively in designing Local Multipoint Distribution Service (LMDS). In any engineering discipline, pre-implementation analysis is very much required for reliability. Predictions of reliable local rain attenuation and path loss are necessary for service availability and quality of service. Previous researchers demonstrated that rain is the principal reason for system outage and service unavailability (Baldotra and Hudiara, 2004; Chu and Chen, 2005). The knowledge of rain attenuation at the frequency of operation is extremely required for design of reliable terrestrial and earth space communication link at particular location.

Different LMDS architectures are proposed in this study. The performance was based on local rain cell profile which indicates that, each architecture has its own coverage limitations. For that, it is necessary to analyze and estimate the optimum distance for LMDS during heavy rain. Base on this analysis changing the service cell size coverage or system architecture is required to improve the link reliability.

LMDS systems could offer high order modulation schemes such as 64-QAM which possess greater bandwidth efficiency (Lee et al., 1998). However, due to high interference in Multicell LMDS, 64-QAM is useful for limited coverage area, where it requires high data rate transfer close from the base station site (Ranjan Bose, 2004). Therefore, it is necessary to increase the coverage range area by switching to a lower modulation plan like 16-QAM and QPSK. Furthermore, careful cell planning and antenna placement are required to enhance the coverage area with maximum scheme time available and reduce the interference.

The proposed architectures for LMDS in this study includes: simplex and dual ring relay, which have already been applied in satellite but not performed yet in LMDS.

1.3 Research objectives

The problem discussed earlier was the main challenge and focus in this research work. The objectives of this research could be divided into the followings:

i. To estimate rain rate, and rain attenuation distribution for different path lengths by employing radar data obtained from Malaysian Meteorological Department.

ii. To determine the optimum required separation distance for LMDS cell in Malaysia, to ensure system reliability.

iii. To propose LMDS architectures based on local rain profile, which leads to higher LMDS availability.

1.4 Scope of work

In order to achieve the objectives, the research scope is as follows:

i. In this work, meteorological radar data has been utilized. The collected data from Kluang meteorological radar station which is located with latitude 2.020o and longitude 103.320o in Johor, Malaysia. This radar concerns the southern part of peninsular Malaysia. However, only data for the area which concerns was UTM-Skudai and Johor Bahru was considered in this study.

ii. Duration of data collection lasted one year data (November 2006 – December 2007). The study focused on terrestrial path; because of that, only 0.5o plan position indicator (PPI) scan elevation angle was considered. The available range bin sizes were 500 m, 1000 m, and 2000 m. However, in order to obtain more detail cell profiling, the 500 meter range bin resolution was selected.

iii. It is common to apply conventional architecture in LMDS (Chu and Chen, 2005; Panagopoulos et al., 2007; Charilas et al., 2011). For this work four LMDS architectures had been investigated namely; conventional, conventional with 4 frequency reuse, simplex ring relay and dual ring relay.

iv. In order to evaluate the performance of different LMDS architectures, the C/I of each architecture is considered.

1.5 Contributions to knowledge

Through this thesis, there are number of contributions present in FBWA field. These contributions are summarized as follows:

i. Significant study based on local weather radar data has been performed to obtain rain intensity profiling and rain attenuation. The results were comparable with ITU-R model and rain gauge network, which validate the use of radar data for this study.

ii. Four different LMDS architectures scenarios namely; conventional, conventional with 4 frequency reuse, simplex ring relay and dual ring relay architectures had been presented, and evaluated in terms of C/I ratio.

iii. The optimum LMDS cell size for different architectures in Malaysia had been identified. It had been obtained that, the proposed architectures offer larger coverage area than conventional and conventional with 4 frequency reuse architectures.

1.6 Structure of the study work

This thesis is divided into six chapters. The first chapter is the introduction, problem statement, research objectives, scope of work, along with the layout of the thesis. The second chapter contains the literature review, on meteorological radar, rain attenuation, LMDS configuration, and contains LMDS performance results from previous studies. The third chapter describes the procedure used to evaluating rain profile, the proposed LMDS architecture, and performance evaluations. The fourth chapter includes the results analysis for local rain rate and rain attenuation which will be used in chapter five. The fifth chapter essentially uncovers the optimum separation distance suitable for LMDS cells by employing local rain profile. It analyzes different scenarios to determine the LMDS performance. The last chapter presents the overall conclusions, the key contributions factors of the project and recommendations for future work.

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