

MULTICHANNEL ORTHOGONAL FREQUENCY DIVISION
MULTIPLEXING -ROF FOR WIRELESS ACCESS NETWORK

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To my beloved family and friends

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In the name of ALLAH, The Most Gracious and Most Merciful

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ABSTRACT

Current deployments of FTTH in Malaysia become an issue due to the installation of fiber under or inside the home. It becomes a major concern for the consumer because to subscribe the broadband from TM, their house needs to be drilled in order to install equipments and inserts fiber into the home. Sometimes massive hacking of concrete walls or floor tiling may cause permanent damages to their home premises. The objective of the research is to find other alternatives of deploying FTTH in Malaysia. In order to maintain reliable and consistency of high data rates and large bandwidth of FTTH, RoF technology and Photonic Access Point technology is the excellent approach to be applied. With combination of Multiple-Input Multiple-Output (MIMO) technology and Orthogonal Frequency Division Multiplexing (OFDM) is considered as the best solution to provide high data rates under frequency-selective fading channel. Hypothetical –Deductive method will be used as development methodology for this project. In order to complete development of this project, this method was chosen because it serves as the typical method in other successful researches conducted. The idea has been realized by designing and simulating the multichannel OFDM-RoF for wireless access network using OptiSystem software. The system is based on photonic access point technology and utilizing of MIMO antenna. The completed system is designed to accommodate Wireless Local Area Network (WLAN) 802.11n standard which is using data rate 130Mbps over carrier frequency 2.4GHz. Several analysis tools from Optisystem software has been used to analyzed the system's performances. The simulation results such as eye diagram and graphs have been discussed to determine the system performance.

ABSTRAK

Perlaksanaan FTTH di Malaysia sekarang menjadi isu disebabkan oleh pemasangan gentian fiber optik ke bawah atau ke dalam rumah. Ia menjadi kebimbangan utama bagi pengguna kerana untuk melanggan jalur lebar dari TM, rumah mereka perlu digerudi untuk memasang peralatan dan memasukkan gentian fiber optik tersebut ke rumah. Kadang- kala proses pengerudian besar ke dinding konkrit atau ke jubin lantai boleh menyebabkan kerosakan kekal pada premis kediaman mereka. Objektif kajian ini adalah untuk mencari alternatif lain melaksanakan FTTH di Malaysia. Dalam usaha untuk mengekalkan konsistensi kadar data yang tinggi dan jalur lebar besar bagi FTTH, teknologi ROF dan teknologi adalah pendekatan terbaik untuk diguna pakai. Dengan gabungan teknologi Multiple-Input Multiple-Output (MIMO) antena dan Orthogonal Frequency Division Multiplexing (OFDM) dianggap sebagai penyelesaian yang terbaik untuk menyediakan kadar data yang tinggi di bawah saluran frekuensi terpilih. Kaedah Hipotetikal-deduktif akan digunakan sebagai metodologi pembangunan untuk projek ini. Dalam usaha untuk menyelesaikan pembangunan projek ini, kaedah ini telah dipilih kerana ia berfungsi sebagai kaedah biasa yang diguna pakai dalam penyelidikan lain yang telah berjaya yang dijalankan. Idea ini telah direalisasikan dengan mereka bentuk dan mensimulasikan beberapa saluran OFDM-ROF untuk komunikasi tanpa wayar FTTH menggunakan perisian OptiSystem. Sistem ini adalah berdasarkan kepada teknologi Photonic Access Point dan menggunakan MIMO antena. Sistem yang lengkap direka untuk menampung Wireless Local Area Network (WLAN) 802.11n standard yang menggunakan 130Mbps kadar data dan frekuensi pembawa 2.4GHz. Beberapa alat analisis daripada perisian Optisystem telah telah digunakan untuk menganalisis pelaksanaan sistem ini. Keputusan simulasi seperti gambarajah mata dan graf telah dibincangkan untuk menentukan prestasi kesweluruhan sistem ini.

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LIST OF ABBREVIATIONS

ADC	- Analogue-To-Digital Converter
AWG	- Arrayed Waveguide
AWGN	- Additive White Gaussian Noise
BBGP	- Broadband To The General Population
BER	- Bit Error Rate
BIDI	- Bidirectional
BPON	- Broadband Passive Optical Network
BS	- Base Station
CBS	- Central Base Station
CD	- Compact Disc
CO	- Central Office
CW	- Continuous-Wave
DAC	- Digital-To-Analogue Converter
DMT	- Discrete Multi-Tone Modulation
DPSK	- Differential Phase-Shift Keying
DQPSK	- Differential Quadrature Phase-Shift Keying
DSL	- Digital Subscriber Line
DSSS	- Direct Sequence Spread Spectrum
DW	- Double Weight
EDW	- Enhanced Double Weight Optical Code Division Multiple
OCDMA	Access

EPON	- Ethernet Passive Optical Network
FDM	- Frequency-Division Multiplexing
FFT	- Fast Fourier Transform
FHSS	- Frequency Hopping Spread Spectrum
FTTH	- Fiber To The Home
GPON	- Gigabit Passive Optical Network
GUI	- Graphical User Interface
HR/DSSS	- High-Rate Direct Sequence Layer
HSBB	- High Speed Broadband
ICI	- Causing Inter-Carrier Interference
IPTV	- Internet Protocol television
ISI	- Inter-Symbol Interference
ITU-R	- International Telecommunication Union Recommendation
LAN	- Local Area Network
LiNb MZM	- Lithium Niobate Mach-Zehnder Modulator
LOS	- Line Of Sight
MAC	- Medium Access Control
MCS	- Modulation And Coding Scheme
MFH	- Modified Frequency Hopping
MFN	- Multi-Frequency Broadcast Networks
MIMO	- Multiple-Input Multiple-Output
MLD	- Maximum Likelihood Detector
MMSE	- Minimum-Mean-Squared-Error
MPDU	- MAC Protocol Data Units
MS	- Mobile Station
MSDU	- MAC Service Data Units
NRZ	- Non Return To Zero
O/E	- Optical-To-Electrical
OFDM	- Orthogonal Frequency Division Multiplexing
OLT	- Optical Line Terminal
ONT	- Optical Network Terminal
ONU	- Optical Network Units
OSP	- Outside Plant

P2P	- Point-To-Point
P2MP	- Point-To-Multipoint
PAP	- Photonic Access Point
PAPR	- Peak-To-Average Power Ratio
PBRs	- Pseudo-Random Bit Sequence
PER	- Packet-Error-Rate
PHY	- Physical Layer
PON	- Passive Optical Network
PSK	- Phase-Shift Keying
QAM	- Quadrature Amplitude Modulation
RF	- Radio Frequency
RoF	- Radio Over Fiber
RS	- Remote Station
S2P	- Two-Port Network S-Parameter
SCM	- Subcarrier Multiplexing
SFN	- Single-Frequency Networks
SDM	- Space Division Multiplexing
SDMA	- Space Division Multiple Access
SNR	- Signal To Noise Ratio
STBC	- Space-Time Block Codes
STC	- Space Time Coding
STTC	- Spacetime Trellis Codes
TM	- Telekom Malaysia
WDM	- Wavelength Division Multiplexing
WLAN	- Wireless Local Area Network
VoiP	- Voice Over Internet Protocol

CHAPTER 1

INTRODUCTION

1.1. Background Study

Developed country is based on the successful connectivity to a reliable telecommunication network and Malaysia is progressively moving towards this stage. As part of its ongoing efforts to support the nation's call for higher broadband speeds, Telekom Malaysia Berhad (TM) have launched the new fibre-to-the home (FTTH) broadband access solution by the mid year of 2011, which has offered users the beginning step towards the digital home experience.

FTTH is an end-to-end fiber optic connection for the deployment of high-speed broadband services to homes. The technology is capable of supporting up to 1Gbps of data transmission in both direction but in early stage of Malaysia deployment, TM was targeting of providing from 10Mbps up to 100Mbps onwards to users' homes. Contrast from Asymmetric Digital Subscriber Line (ADSL), this previous technology only capable of providing service from 1.5 Mbps to 8 Mbps to the end

user. Although it offers higher speeds and better throughput quality compared to copper wires, its distance limitation of up only to 5km from the exchange still incomparable to FTTH technology which able to cover between 10 to 20km in distance service. With expected increasing number of user in broadband services, it is very crucial for the government to provide access network with high bit rate and low cost.

Optical fiber is medium of choice in wide, metro, access, and local area (wired) networks. PONs technology might be viewed as final frontier of optical wired networks interfacing with a number of wireless technologies. One interesting approach to integrate optical fiber networks & wireless networks are so-called radio-over-fiber (RoF) networks. RoF is a wireless communication technology where radio signals sent by equipment to base stations modulate a light and transmitting optical data. The data moves through fiber to access telecommunications hubs. Returning signals coming in the other direction go through the base station, which emits radio waves for equipment to pick up. In simple words, radiofrequencies (RFs) are carried over optical fiber links to support various wireless applications. RoF makes use of the concept of a Remote Station (RS). In this project, the RS is referred as Photonic Access Point (PAP). This station usually consists of optical-to-electrical (O/E), optional frequency up or down converter, amplifiers, and antenna.

Frequency division multiplexing (FDM) is a technology that transmits multiple signals simultaneously over a single transmission path, such as a cable or wireless system. Each signal travels within its own unique frequency range (carrier), which is modulated by the data such as text, voice, and video. As for Orthogonal FDM's (OFDM), spread spectrum technique distributes the data over a large number of carriers that are spaced apart at precise frequencies. OFDM is an FDM modulation technique for transmitting large amounts of digital data over a radio wave. OFDM works by splitting the radio signal into multiple smaller sub-signals that are then transmitted simultaneously at different frequencies to the receiver. OFDM reduces the amount of crosstalk in signal transmissions. For example 802.11a WLAN, 802.16 and WiMAX technologies use OFDM.

Integrating Multiple-Input Multiple-Output Orthogonal Frequency Division Multiplexing (MIMO-OFDM) in the PAP will increase the data rates received at the users. The combination of MIMO-OFDM will be the best solution to provide high data rates under frequency-selective fading channels. The combination also will increase the diversity gain in the system capacity by exploiting spatial domain. Through modeling, simulations, and broad experiments, the behavior and performance of a RoF downlink employing MIMO-OFDM was investigated.

permanent damages to their concrete walls. Moreover, for certain customer premise with underground fiber deployment, this would sometime involve massive hacking of concrete walls or floor tiling.

A part from paying high cost of fiber installation and drilling works, they also need bear in mind for additional cost to repair the premises if damages occur. With the current deployment of FTTH to consumer premise, it may affect huge number of potential subscribers who are very concern with their premises market values. Even small damages to the premises may give huge impact to its market values.

From interview session conducted with several subscribes of FTTH in Malaysia, it is hard for them to endure high cost of installation service and also additional cost to repair their premise. Some potential subscribers also said they may consider put on hold their thought to subscribe the broadband due to current installation process. Interview sessions also have been done with a colleague from TM who is involved directly with Malaysian High Speed Broadband (HSBB) project. He also agreed it would be huge advantage if providers able to eliminate high cost of installation and also get rid of works to penetrate the subscriber's concrete walls.

All of them said it would be very helpful if other alternatives of deploying FTTH could be done. A wireless approach would be a good implementation to be applied. To maintain reliable and consistency of high data rates and large bandwidth, RoF technology and Photonic Access Point technology would be excellent alternatives to be considered. With combination of Multiple-Input Multiple-Output (MIMO) technology and Orthogonal Frequency Division Multiplexing (OFDM) is considered as the best solution to provide high data rates under frequency-selective fading channel.

1.3. Project Objective

The main objective of this project is to design and simulate wireless FTTH application by utilizing multichannel OFDM-RoF based Photonic Access Point with MIMO antenna. It is purposely designed to reduce cost of FTTH deployment in Malaysia. Higher data rate for wireless FTTH will be maintained by utilizing 2x2 MIMO antenna with higher level modulation scheme of 64-QAM. The access point will be operating at 2.4GHz using 802.11n standard.

1.4. Scope of Project

To establish a guideline for the whole project, we have come out with several scope of study. This is important to ensure the project always keep on track of the main objective it want to achieve. For this project, it will concentrate on implementing multichannel OFDM-RoF technology for the wireless access network. The system will utilize Photonic Access Point technology and MIMO antenna.

For antenna design, the project will focus on implementing spatial multiplexing of 2x2 antennas. A carrier frequency of 2.4GHz will be operated to modulate the information signal before it can be transmitted over the fiber. The downlink system start from Optical Line Transmission (OLT) up to the end user will be designed and simulated using OptiSystem Software.

Scope of project also will be based on case study conducted on FTTH implementation in Malaysia. Telekom Malaysia will be the reference for the FTTH service provider.

1.5. Thesis Outline

This thesis contains of seven chapters and arranged as follows:

Chapter 1 describes a brief introduction to this project. The introductory part of this thesis explained the background study of this project together with problem statement, objective, scope of work and followed by thesis outline.

Chapter 2 contains literature reviews for this project. This chapter has described the FTTH architectures and its implementation in Malaysia. A part from that the overview of RoF technology, OFDM, MIMO and MIMO-OFDM in WLAN also being studied in this chapter. Related research about MIMO-OFDM technology is presented at the end of this chapter.

Chapter 3 explained the methodology conducted through the whole process of completing the project. Briefly, after literature reviews are done, designing and simulating the system are realized using OptiSystem software. Prior to the designing and simulating the system, a specific parameter needed to be determined. As the simulation succeeded, the results are analyzed using various analysis tools available and has been discussed.

Chapter 4 presents the system model for our proposed wireless FTTH application. This chapter briefly explained each part involved in designing the system using a diagram for better understanding. Here also discussed current FTTH deployment being done by Telekom Malaysia. Several diagrams are shown for clearer view about current FTTH practice.

Chapter 5 discussed about the whole system design and its simulation. Each parts of the system are explained and discussed in details. From main signal processing in Central Base Station (CBS), then transmitted through optical fiber and received at Photonic Access Point (PAP) before being transmitted to the end user using wireless medium. Basically the system is simulated from OLT up to end user.

1.2. Problem Statement

High speed data and fast internet connections are very important in a lot of industries and individual daily lives for the past decade. Every single person extremely depending on reliable and efficient internet connection to run their everyday life for example business operation, make communications, for leisure and also entertainment. If the level of connectivity were not fulfill the users need and requirement, it may affect their production in business and also give difficulties for them to make communication such as making video conference call and transferring large volume of data to one another. Therefore, until today we have seen a lot of development in the internet technologies. It began as computer network of ARPA (ARPAnet) and keep develop to todays various kind of PON technology which have leads to very reliable and efficient internet connection such as FTTH.

Almost 15 million consumers now use direct fiber optic connections worldwide, about 3 millions consumers in United States and more than 10 million in Japan. Although Malaysia still at the early stage of implementing the FTTH, but the communities subscribing it are flourishing. This happened due to FTTH capabilities of providing the optimal solution of broadband connection with more bandwidth and more flexibility than other alternatives, at an affordable price. For Malaysia current situation, FTTH is the only technology that will deliver enough bandwidth, reliably and at a low enough cost, to meet the consumer demands of the next decades to come.

However, with fast development and penetration of FTTH in Malaysia, several issues has arise that keep consumers attention. For example, current deployments of FTTH in Malaysia become an issue due to the installation of fiber under or inside the home. It becomes a major concern for the consumer because to subscribe the broadband from TM, their house needs to be drilled in order to install equipments and inserts fiber into the home. With poor skills set of drilling works, it may cause

Chapters 6 enlighten the results obtained after simulation from several analysis tools in OptiSystem software. The tools such as Electrical Constellation Visualizer, RF Spectrum Analyzer, Optical Spectrum Analyzer and Eye Diagram Analyzer are used in order to analyze the whole system's performance. All the results has been analyzed and discussed in details through this chapter.

Chapter 7 concludes the whole project. This chapter summarized the findings and provides a few recommendations for future work to develop and modify the system.

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