TELKOMNIKA Indonesian Journal of Electrical Engineering
Vol. 13, No. 2, February 2015, pp. 352 ~ 359
DOI: 10.11591/telkomnika.v13i2.7036

Internet Access Using Ethernet over PDH Technology for Remote Area

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Abstract

There was still is gap among people living in city and in remote area to get information access, especially who lived in the Eastern part of Indonesia. People living in such remote area usually were isolated from town by natural condition like rivers, valleys, hills and so on. Therefore, telecommunication infrastructure for remote area using cooper was not effective and efficient way to build. The issue was how information and communication technology could penetrate such areas. This research aimed to propose technology that could be implemented to overcome the difficulties. Ethernet over Plesiochronous Digital Hierarchy (EoPDH) was one of many techniques that provided Ethernet connectivity over non-Ethernet networks. EoPDH was a standardized methodology for transporting native Ethernet frames over the existing established PDH transport technology. To provide last milefor the local people, use of Mesh Wireless Local Area Network was made and connected to internet gateway via Ethernet over PDH based microwave radio link. The test showed that The Ethernet frames were successfully transported to remote area with good quality of service such as throughput, response time, and transaction rate.

Keywords: *MWLAN, radio link, quality of service*

1. INTRODUCTION

Penetration of internet in Indonesia is still low. This is due to some constraints such as, the development of supported telecommunication infrastructure that are not sufficiently adequate, especially for the Eastern part of Indonesia. Recent report from Akamai showed that connection speed of internet in Indonesia in the third quarter of 2013, is 1.5 Mbps at average. This figure places Indonesia in the second rank from bottom among Asia–Pacific countries, and a little bit higher than India which is 1.4 Mbps at average. Other constraint is that cost of internet use is still expensive due to cost of international interconnection up to local interconnection (last mile), and low internet bandwidth as well. Result of World Summit on the Information Society – WSIS in 2003 and 2005, agreed that all countries around the world are expected to follow up the action plan of world development towards information society for the welfare of the mankind in making use of information and communication technology (ICT). The issue laid in the readiness of telecommunication infrastructure to access information that is supported by internet technology. People living in town might obtain information access easier than people who lived in remote area. Technology is also another issue that has also to be taken into account.

Actually, several rural telecommunication infrastructure technologies have already been implemented in some countries like United State of America, Zimbabwe, Ghana and so on. Here are description regarding the technologies implemented in such countries; Fiber To The Home (FTTH) is fiber optic based telecommunication infrastructure technology that is proposed to be implemented in rural areas in USA. FTTH is considered to be good solution in order to meet the demand of internet services and other multimedia applications. So FTTH is good solution to provide Triple Play which consist of data (Internet or Intranet), Voice over IP (VoIP), and video (TV and Multimedia) in one more practical infrastructure [1,4]. Deployment and installation of fiber optic is the most expensive part of its investment. Some installation method that have already been introduced, is influenced by several factors such as, budgeting, network topology, access technology, culture of surrounding, and esthetic. Generally rural areas in Indonesia have contour like mountains, hills and valleys beside people live sparsely therefore cost of installation for FTTH technology for remote areas in Indonesia will be expensive.

Received October 17, 2014; Revised December 7, 2014; Accepted December 28, 2014

Wireless Regional Access Network (WRAN) technology is based on cognitive radio technology. This radio is intelligent to be programmed and configured dynamically. This transceiver is designed to utilize the best wireless communication channel in its vicinity. And it automatically can change its reception or transmission parameters according with detected channel spectrum frequency. Zimbabwe is one of African countries that is the first to make experiments to use WRAN technology [7-8]. Their experiments succeed to connect the whole population in Cape Town where the use of TV frequency spectrum is very high [2].

GSM, UMTS, HSPA are technologies that have already been used widely in many European, African, and some Asian countries. The African country used as a test here is Ghana. Presently in cosmopolitan areas of sub-Saharan Africa, the Global System for Mobile Communications (GSM), the Universal Mobile Telecommunications Service (UMTS) and the High Speed Packet Access technologies (HSPA) family of mobile network technologies are ubiquitous. Other network technologies like Wi-MAX, Wi-Fi, and VSAT etc. are used in a small scale compared to the ubiquitous technologies. It is necessary to find out which technology if deployed will reduce the cost of access by the subscriber [3].

This research is aimed to solve a problem of digital divide as a gap among individuals, households, business, (or a group of people), and geographical area in certain level of different social economic in obtaining information access and use of internet for various activities of people living in remote areas in Indonesia.

2. Research Method

As mentioned above, the contours of many remote areas in Indonesia have the following characteristics such like mountains, forest, hills, rivers and so on. Therefore telecommunication infrastructures for remote area using cooper or fiber optics are not effective and efficient way to build. There exist broadband mobile technologies in Indonesia like GSM, UMTS, HSDPA but there are still many blank spot areas which have not been covered with these technologies. So it turns out with a research question how internet access can penetrate such remote areas where telecommunication infrastructures do not exist yet. Therefore, research method proposed here is to design last mile (local access) using Mesh Wireless Local Area Network (MWLAN) technology. This MWLAN is backhauled with transmission link to get connectivity to internet gateway that is usually located at Central Office (CO) in town. Transmission link design proposed for this purpose is Plesiochronous Digital Hierarchy (PDH) based digital microwave radio link. Actually this technology is mainly used in digital network for voice and data communication. In order to be able to deliver Ethernet frame from internet gateway to a remote area via microwave radio link, an Ethernet to PDH converter is made. It is a device to convert Ethernet frame signal to digital frame one and vise versa and is called Ethernet over PDH. PDH is technology used in telecommunications networks to transport large quantities of data over digital transport equipment such as fiber optic and microwave radio systems [10].

Ethernet over PDH (EoPDH) is a standardized methodology for transporting native Ethernet frames over PDH links such as T1, E1, or DS3. The technologies used in EoPDH include GFP frame encapsulation, Ethernet Mapping, Virtual Concatenation, Link Capacity Adjustment Scheme, and Management Messaging (OAM). Common practices in EoPDH equipment also include the tagging of traffic for separation This is good chance for incumbent Indonesian carrier to insert Ethernet services as their portfolio of their business without changing existing network into real Ethernet network because Ethernet has lake of supports for link monitoring, fault isolation, and diagnostic testing.

Sites for deployment and testing of MWLAN and microwave radio transmission link are necessary to be conducted. Therefore site survey must be conducted to obtain sites prior to radio link design. And the site should simulate a remote area in which there is not yet telecommunication infrastructure at all.

2.1. Microwave Radio Link Design

Design is the most important step among the other where requirement and technical specification has already to be defined. The design process involved link budget calculation and radio link simulation. To design radio link, it is necessary to have sites. Based on survey, two sites are proposed for the radio link design. The coordinate and site names are shown in Table 1 and Table 2 where Site Pakuhaji in one side and Site Politeknik Negeri Bandung (Polban) on the other side. Pakuhaji is situated in the Eastern part of Bandung while Polban is about 10 km a way from Pakuhaji as shown in Figure 1. These sites are chosen because they meet line of sight condition.

Table 1. Coordinate and altitude of Site Polban

Latitude	6° 52' 12.7" S
Longitude	107° 34' 13.4'' E
Altitude	855 meter above see level (ASL)

Table 2. Coordinate and altitude of Site Pakuhaji

Latitude	06° 50' 11.20 " S
Longitude	107° 32' 10.00" E
Altitude	966.5 meter ASL

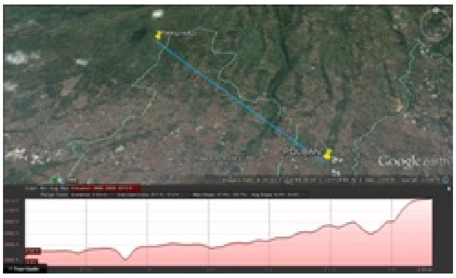


Figure 1. Two sites are shown on the google map for radio transmission link design

Antenna height in site Polban is 20 meter above ground level while in site pakuhaji is about 10 m high. The antennas are mounted on top of tower as shown in Figure 2 and 3.

Figure 2. Tower at site Polban

Figure 3. Tower at site Pakuhaji

2.1.1. Microwave Radio Link Design Requirement

The design shall fulfill the following requirements:

a) Satisfy Line Of Sight (LOS) condition with free obstruction at least 60% F1
b) Fade Margin > 40 dB
c) Received Signal Level (RSL) shoul be within -44 dBm up to -54 dBm
d) Link Quality : Bit Error rate (BER) < 10-9 at NORMAL atmosphere condition
e) Minimum availability = 99.995%

2.1.2. Microwave Radio Equipment Specification

Radio equipment used for this design is Radio link Alcatel 9413UX that has technical specification as follows:

a) Data rate : 2 x 8 Mbits/s (240 channels), standard E1 (2048 Kbps), CCITT PCM30, G.703
b) System Gain : 119 dB

c) Receiver Minimum Threshold Level = - 89 dBm @ BER 1x10-3untuk data rate 8x2Mbps
d) Modulation type : QPSK
e) Frequency Band : 13 GHz

2.1.3. Antenna Specification

Antenna used for the radio link is specified as follows;
a) Frequency band : 13 Ghz
b) Diameter of dish : 80 cm
c) Gain : 34 dBi
d) Return Loss : 26.4 dB

2.1.4. Link Budget Calculation

Radio Link budget has been calculated and the result is summarized in Table 3.

Table 3. Link Budget Summary

Free Space Loss, FSL	129.2018 dB
Received Signal Level, RSL	-43.958 dBm
Effective Isotropic Radiated Power, EIRP	85.25 dBm
Fade Margin, FM	45,042 dB
Worst Month Availability	99.9999983%
Annual Availability	99.99999947%
Worst Month Outage Time	0.000444362 seconds

2.1.5. Simulation

To evaluate if radio path profile design has satisfied Line Of Sight (LOS) condition, simulation of radio path profile is also conducted by using Radio Mobile Deluxe software application. The program use digital terrain elevation data as shown in Figure 4.

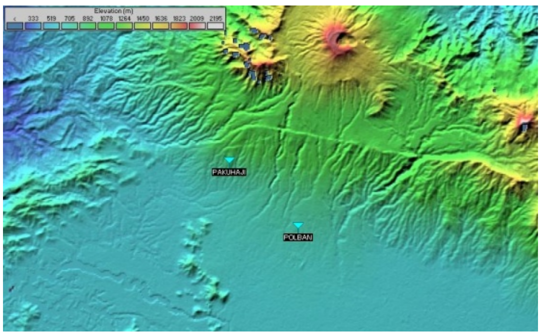


Figure 4. Mapping of site Pakuhaji and Site Polban

With the following setup parameters;

Transmit Power :+24 dBm
Antenna Gain : 32 dB_i
Distance : 7 km

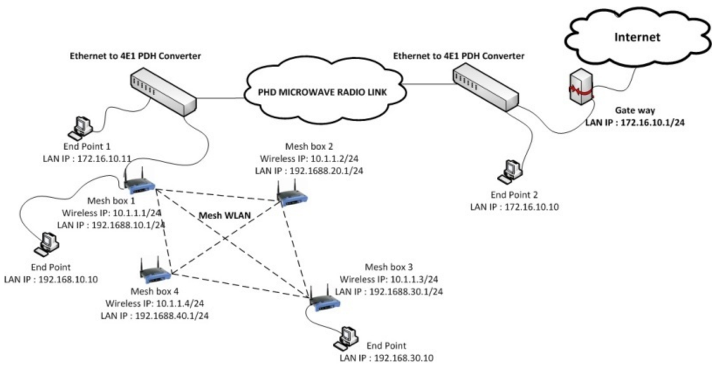
Simulation result is shown in Figure 5, and some values are generated as follows:
a) Received Signal Level (RSL) = -48 dBm
b) Fade Margin = 40,9 dB

So the results above confirmed that generally, radio link has fulfilled the design requirement.

Figure 5. Display of simulation result using Radio Mobile Deluxe

2.2. Mesh WLAN Design

Mesh WLAN is intended to provide last mile or internet access for people living in such remote area with no support of telecommunication infrastructure. Hardware required for the network implementation is wireless router with IEEE 802.11 g standard. In this case Linksys WRT54GL is chosen as shown in Figure 7. This router has first to be upgraded with suitable firmware so that it can be used for mesh network application. The firmware that is chosen is Freifunk version 1.7.4 with embedded Optimized Link State Routing (OLSR) protocol. This routing protocol falls under the class of proactive routing protocol, hence the routes are always available immediately when needed [10]. Implementation of Mesh WLAN which is connected to internet gateway by Ethernet over PDH based radio microwave link is shown in Figure 6.



.Figure 6. Mesh WLAN connected to internet gateway via Ethernet over PDH based radio link

Figure 7. Linksys WRT 54GL Router

There are some principles that have to be considered in Mesh WLAN design, namely;

a) Each routers have to be configured in ad-hoc mode.
b) ESSID and BSSID shall have the same name
c) BSSID has to use MAC address of one of any routers.
d) The frequency channel of all routers have to be the same.

3. Result and Analysis

Result of the research is a test and measurement data of the followings; Bit Error Rate (BER), Error Performance Rec ITU, and end point performance.

3.1. BER Test

This test measures bit errors of every 2 Mbps tributaries or line rate of 2048 kbps of digital radio link using QPSK modulation type. In this measurement only 4 out of 8 tributaries are measured. Test setup is shown in Figure 8. And the test result is given in Table 4.

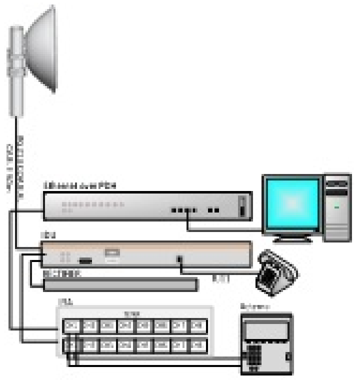


Figure 8. BER Test setup

BER Results			
Total second(s) 21600			
Line rate	2047921		<totals>
Code er ratio 0.000E 0		Code errs 0	
Bit rate	63997	Total bits	1.382E 9
Bit err ratio	7.23E-10	Bit errors	

Table 4 BER Test result

Bit Error Rate (BER) is a measure of digital transmission quality. And based on the measurement, error rate, r is 7.2 X 10^{-7}. This result can be analyzed in the presence of additive noise, with the following expression:

$$\tau = \frac{1}{2} erfc \sqrt{\frac{C}{N_o x D}}$$

To calculate the error rate as a function of the power level C of the carrier modulated at the significant instant, the noise density N_o and the digital rate D [11]. Based on design and simulation result the following orders of value are obtained:

a) Received Signal Level, C = -44 dBm.
b) D = 16 Mbps = 72 dB
c) No = 10log KT + 7dB = - 174dBm + 7 = - 167dBm

From the above expression, the signal to noise ratio can be calculated as follows;

$$10 \log \frac{C}{No\ x\ D} = -44\ dBm - (-167\ dBm + 72{,}041\ dB) = 50\ dB.$$

When $10 \log \frac{C}{No\ x\ D}\ exceeds\ 15\ dB,$ the error rate becomes practically zero. In order to determine the consequences of the orders of value, consider the effect of imposing that error rate r must never drop below 10^{-3} when C reaches a minimum as a result of accidental attenuation due to fading of the flat type (not selective). And the radio link is said to be outage when BER falls to 10^{-3} [11]. So this analysis has confirmed the BER measurement result.

3.2. Error Performance Measurement.

Using the same measurement setup as shown in Figure 8, error performance of radio link has also to be measured. Error performance parameters are derived from the following events:

Errored second (ES): It is a one-second period in which one or more bits are in error or during which Loss of Signal (LOS) or Alarm Indication Signal (AIS) is detected.

Severely errored second ratio (SESR): The ratio of SES to total seconds in available time during a fixed measurement interval. The test result of error performance is given in Table 5.

Table 5. Error performance test result.

Nomor Tributary	Errored Free Seconds	Error Seconds	Severe Error Seconds
1	600 100%	PASS 0 0%	PASS
2	598 99.6667%	PASS 2 0.333%	PASS
3	600 100 %	PASS 0 0 %	PASS
4	592 98.6667%	PASS 8 1.333%	PASS

According to ITU-T Recommendation G.821 revised by ITU-T Study Group 13 (2001-2004) and approved under the WTSA Resolution 1 procedure on 14 December 2002, The performance objectives for an international ISDN are shown in Table 6. It is intended that international ISDN connections should meet all of the requirements of Table 6. The connection fails to satisfy the objective if any of the requirements is not met [12]. Based on the test result, it showed that error performance measurement has met G.821 – Error performance objectives for international ISDN connections.

Table 6. G.821 Error performance objectives for international ISDN connections

Performance classification	Objective
Severely Error Second Ratio	<0.002
Errored Second Ratio	<0.08

NOTE – The ratios are calculated over the available time. The observation time has not been specified since the period may depend upon the application. A period of the order of any one month is suggested as a reference.

3.3. End Point Performance Measurement

This measurement is Quality of Service (QoS) of Ethernet frame signal which is conversion result from PDH digital signal. Basically there are three parameters to be measured, namely throughput, response time, and transaction rate. End point measurement is conducted using software tool called **NetIQ Charriot** which shall be installed in PC terminals at both end points. The end point measurement result is shown in Table 7. The measurement is conducted with 2 Mbps Tributaries and use TCP dan UDP protocol for various service quality such as G.711. G.723.1 for voice application and, H261CIF, H261QCIF for video application. According to FCC broadband speed guide, it implies that for activities such as phone calls (VoIP), the minimum download speed should be less than 0.5 Mbps and for Standard streaming videos is less than 0.7 Mbps. So based on the test result in Table 7, it has complied the FCC broadband speed guide.

Table 7. End point to End point performance test result

Protocol	Service Quality	Throughput Average (Mbps)	Transaction Rate Average (s)	Response Time Average (s)
TCP	G723.1	0.7	0.034	0.29
	G711	0.8	0.101	0.93
	G729	0.5	0.039	0.25
	H261CIF	1.885	2.358	0.42
	H261QCIF	1.885	2.358	0.42
UDP	G723.1	0.4	0.031	0.32
	G711	0.7	0.099	0.10
	G729	0.7	0.033	0.29
	H261CIF	1.827	2.287	0.43
	H261QCIF	1.827	2.287	0.43

4. Conclusion

Telecommunication infrastructure using backhaul radio link Ethernet over PDH based technology has already been successfully designed and implemented and satisfied BER and error performance objective.

Ethernet end to end measurement result depend on the transmission quality and performance and availability of radio link.

Throuhput of Ethernet signal resulting from conversion process is less than bit rate of transmission rate of PDH signal. This is because some bytes are used as over head for Ethernet framing process.

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