Available *online* at : http://jnte.ft.unand.ac.id/

Jurnal Nasional Teknik Elektro

| ISSN (Print) 2302-2949 | ISSN (Online) 2407-7267 |

Performance Evaluation of VoIP Service for Emergency Disaster Responses over WiMAX-WLAN Integrated Network

Prasetiyono Hari Mukti, Syaldi Kharisma Ananda and Gatot Kusrahardjo

Department of Electrical Engineering, Institut Teknologi Sepuluh Nopember, Jalan Arief Rahman Hakim, Surabaya 60111, Indonesia

ARTICLE INFORMATION

Received: October 24, 2021
Revised: October 10, 2022
Available online: November 30, 2022

KEYWORDS

Backhaul, Disaster response, VoIP, WiFi, WiMAX

CORRESPONDENCE

E-mail: prasetiyono@ee.its.ac.id

A B S T R A C T

As a very large archipelago country, Indonesia has a high intensity of the natural disaster. In many cases, the telecommunication infrastructure collapse during the disaster. Therefore, a prominent and robust emergency telecommunication network is required. In this paper, an implementation of VoIP services over the WiMAX-WLAN integrated network is proposed. The integrated network is designed to provide an alternative of the emergency network during the disaster response. The VoIP service is selected for the study case because this service can be used as a complementary of the telephony service. In this paper, the WiMAX network is designed based on the IEEE Standard 802.16-2004 with the frequency band of 3.5 GHz while the WLAN network is designed based on the IEEE Standard 802.11n. To support many scenarios of network topology, the proposed integrated network is designed in P2P and PMP topologies. Within these network topologies, the network performance is evaluated in terms of delay, jitter, throughput and packet loss, as well as MOS value. The network performance is evaluated over various background traffic. From the experimental evaluation, it shows that the network becomes worse when the network load that is represented by the background traffic exceeding 3 Mbps. In general, there is no significant performance different between P2P and PMP network topology.

INTRODUCTION

Indonesia as a very large archipelago country has a high intensity of disaster, including flood, landslide, volcanic eruption, and earthquakes that sometimes followed by tsunami. For example, Indonesian National Agency for Disaster Management (BNPB) recorded more than 20 events of tsunami in the last 100 years. The highly intensity of disaster in Indonesia is caused by the position of Indonesia that is lied on the junction of 3 (three) very large plates, that are Indo-Australian, Eurasia and Pacific Plate [1]. Besides that, Indonesia is also located on the Pacific Ring of Fire that causes the country is surrounded by the active volcano that can erupt at any time and followed by the subsequent disaster.

The disaster eventually causes many victims and damages. The damage caused by a disaster does not only happen to a private infrastructure such as house, but also to a public infrastructure such as streets, bridges and telecommunication infrastructures. The damage of the telecommunication infrastructures causes a communication disconnection both of in-going and out-going to/from the affected area. This disconnection causes a difficulty to exchange the information, especially about the victims conditions and logistic distribution to assists the victims and volunteers.

Therefore, an emergency telecommunication infrastructure that can be built quickly is required. Many telecommunication technologies have been used as an emergency infrastructure during the disaster response. Satellite communication system with Very Small Aperture Terminal (VSAT) services [2] and High Frequency (HF) communication systems [3] are the two among the technologies that are massively used in the last decades. Beside its advantages of very large bandwidth, VSAT services have also the disadvantage of vulnerability to the weather condition especially in the rainy condition and high implementation cost. For HF communication, eventhough it has a long-range distance, the HF system has a narrow bandwidth and vulnerability to the ionosphere changes [4]. A comprehensive comparison of the possible technology for the emergency disaster response is described in [5].

On the other hand, WiMAX technology offers a very large bandwidth and long-range distance in the non-Line-of-Sight (NLOS) conditions. Due to its advantages, many researchers have proposed the WiMAX technology as an emergency telecommunication infrastructure during disaster response in the last years. Pedro Neves in [7] proposed the use of WiMAX Technology to provide telecommunication services for the remote areas in Europe under the WEIRD Project. The offered services include environment monitoring and telemedicine.

https://doi.org/10.25077jnte.v11n2.963.2022

However, this project did not describe the use of the technology for the disaster response in which many disaster officers require very robust communication access. Another alternative use of WiMAX technology is as the backhaul link for the telecommunication networks [8]. To provide communication services to the users, the implementation of WiMAX network as a backhaul should be integrated with another access network, such as WLAN Technology.

The integration of WiMAX network and WLAN network is considered due to some reasons, that are (1) the ability of the WiMAX network to provide a very large bandwidth in the long-range distance and (2) many premise devices at the users support WLAN network. Besides that, the implementation of WiMAX technology and WLAN technology for the emergency disaster response have been examined in [5]. Both technologies comply with technology requirements for disaster response, as described in [6]. Those requirements include Rapid deployment, Robustness and reliability, Voice and Data support, Scalability, Interoperability, Cost.

There are numerous reports in the literature about integration of the WiMAX and WLAN technology [9]-[11]. In [9], Gracias integrates the WiMAX and WLAN Technologies in the testbed platform. In this report, Gracias uses the WLAN technology based on the IEEE standard 802.11a/g/n. The channel bandwidth that is used in this report is about 967.5 Kbps. In [10], Pentikousis reports the implementation of Speex based VoIP services and Video based on H.264/AVC in the testbed of the WiMAX-and WLAN integration network. The WLAN technology that is used in this report is based on IEEE Standard 802.11g which has an average data rate of about 54 Mbps. In [11], Peh reports the implementation of the VoIP based on G.711 and G.729 in the integrated network of WIMAX and WLAN.

All the aforementioned reports do not describe the implementation of the services for the emergency service during disaster response. Therefore, this paper proposes the network integration between WiMAX and WLAN technology for the use as an emergency network during the disaster response. In this paper, WiMAX technology based on IEEE Standard 802.16d and WLAN technology based on IEEE Standard 802.11n are used. To support the communication between the officers in the affected disaster area, this integration network is evaluated to deliver VoIP service. The VoIP service is selected due to this service can be considered as a complementary of the telephony service which is the most common voice-based service used by the users. It is also related to the ITU Recommendation which is stated that the fundamental method of telecommunication in a disaster emergency is a voice-based service [12].

The rest content of the paper is organized as follow. In the subsequent section, an overview of the WiMAX and WLAN technology is elaborated. In this section, the characteristic of each network technology is compared. Furthermore, the proposed integration of the network architecture between WiMAX and WLAN is described. It followed with an explanation of the network performance evaluation. This paper ends with conclusion in the last section.

OVERVIEW OF WIMAX AND WLAN TECHNOLOGY

In this section, an overview of the WiMAX and WLAN technology will be described. The description does not only cover the characteristic of each technology, but also the comparison between the two technologies.

Worldwide Interoperability Microwave Access (WiMAX) is a trademark of the Broadband Wireless Access (BWA) technology that is developed by WiMAX Forum which refers to the family of IEEE Standard 802.16 and operate in the framework of Metropolitan Area Network (MAN) [13]. Beside the ability of providing the fixed and mobile communication services, this technology has the advantages including (1) high data rate up to 70 Mbps, (2) long-range transmission up to 50 km (3) adaptive modulation system and (4) high capacity with the aid of OFDM technique [14]. In terms of service quality, WiMAX technology can accommodate several Quality of Service (QoS), that are (1) *Unsolicited Grant Service* (UGS), (2) *Real-Time Polling Service* (rtPS), (3) *Non-Real-Time Polling Service* (nrtPS), dan (4) *Best Effort* (BE) [15].

Furthermore, another technology that is used in this work is WLAN. This technology is often called WiFi, which is stand for Wireless Fidelity. WiFI is another trademark of wireless access technology that is developed based on the family of the IEEE Standard 802.11. This technology is usually operated to support the implementation of Local Area Network (LAN). One of the variants that is utilized in this paper is IEEE Standard 802.11n. This standard offers an advantage that is Multiple-Input-Multiple-Output (MIMO) systems which provides the possibility to implement spatial diversity [16]. With the implementation of the spatial diversity, this variant offers high data rate transmission up to 74 Mbps. The comparison between WiMAX and WLAN technology is provided in Table 1.

Table 1 Performance comparison of WiMAX and WLAN [9]

Parameters	WLAN	WiMAX
Implementation complexity	Easy and cheap	Difficult and expandable
Access characteristic	Pedestrian	~ 120 km/h
Coverage	250 m	50 km
User capacity	13	150
Data rate	288,90 Mbps	100 Mbps
Typical Used	Access Point	ISP network

METHODS

In this section, a research methodology that is used to develop the proposed network is described. The proposed network is developed with the following steps:

1. Design an integrated network topology
2. Configure the proposed integrated network
3. Testing of the proposed integrated network.

https://doi.org/10.25077jnte.v11n2.963.2022

The Proposed Integrated Network Topology

In this section, the proposed integration network topology will be described. In general, the proposed network topology in this paper follows the possible network topology offered by WiMAX technology for backhaul network. The offered backhaul network topology are Point-to-Point (P2P) and Point-to-multipoint (PMP). The PMP topology is proposed to handle in case multiple Subscriber Station is required due to nature obstacles. The proposed topologies are illustrated in Figure 1. In general, the proposed network architecture consists of 3 (three) segments, that are (1) WiMAX core network, (2) Backhaul link and (3) WiFi Access network.

The WiMAX core network is built to act as an ISP-like to deliver the VoIP Service. Besides that, this core network can also be built to provide an ad-hoc network during the disaster response activities. The next segment that is built is a backhaul link that gives a connection between WiMAX core network and WiFI access network. The last segment that is built is a WiFi access network that provides the VoIP Services to the end-user by using WiFi Access Point (AP). The WiFi AP received a radio link signal from the WiMAX Subscriber Station (SS).

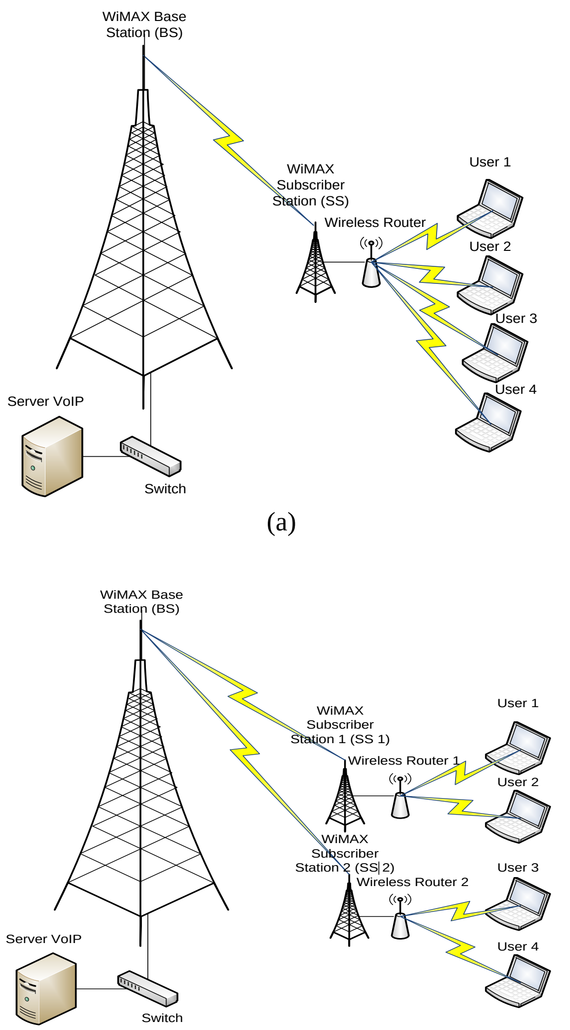

Figure 1 Network topology for (a) single subscriber station (b) multi subscriber stationsex

Configuration of the Proposed Integrated Network

The next step after defining the topology of the proposed network is configuring the network to operate as expected. In general, there are 3 (two) steps of configuration, that are (1) configuring the WiMAX equipments, (2) configuring the WLAN equipments, and (3) configuring the user equipments.

WiMAX Equipment that is used in this work is a WiMAX testbed facility at the Department of Electrical Engineering, ITS. This equipment consists of a RedMAX *Base Station Transceiver* (BS) as a transmitter that operates in the frequency band of 3.5 GHz and RedMAX *Subscriber Units* as a receiver. The power transmit from the BS is set to 0 dBm or 1 mW to avoid an interference to satellite services around the testbed location. Moreover, the channel bandwidth of the RedMAX BS is set to 7 MHz. Meanwhile, the transmission data rate of the backhaul link to communicate with the RedMAX SS of about 2 Mbps for both downlink and uplink sides. For the services access, this system is set to use a scheduling scheme of Best Effort which means that all users have the same priority to access the network. A detail specification of the testbed system is summarized in Table *2*.

Table 2 Specification of the proposed system configuration.

Paramater	Specification
Base Station	RedMAX AN-100U
Subscriber Station	RedMAX SU-O
Frequency Band	3.5 GHz
Channel Bandwidth	7 MHz
PHY	WiMAX 802.16d 256 OFDM FDD
BS Tx Power	0 dBm

Furthermore, the WLAN equipments are configured to operate in the same network as WiMAX Equipment. The configuration includes setting the IP subnet and IP assignment mode. In this case, the IP subnet of 192.168.0.1/24 and DHCP mode are used. Moreover, setting up the user equipment (in this case, it is implemented on a PC) is conducted. This set up includes installing the required software to support the implementation of VoIP service. The software includes (1) Jitsi as a VoIP service emulator, (2) Wireshark as a tool to analyze the network protocol, (3) TfGen and netpersec generate and monitor the network traffic. The protocol that is used for the VoIP service in this case is G.711 [18].

After the network is ready to deliver the VoIP service, futher step that needs to be prepared is performance evaluation of the VoIP service over the proposed integrated network. The performance is conducted with the following steps:

1. Connection test using Mini Speeedtest
2. Traffic test using TfGen and netperSec
3. User perception test using E-Model and MOS.

RESULTS AND DISCUSSIONS

The last step that is important to be done after designing the network architecture is a network performance testing. The performance testing is conducted by delivering the VoIP services over the proposed network architectures. As mentioned in the previous section, the proposed network architectures in this paper include Point-to-Point (P2P) and Point-to-multipoint (PMP) topologies. In P2P topology, all users (4 users) access the same SS. While in the PMP topology, two SS' are involved which of each is accessed by 2 (two) users through 1 (one) access point.

The network performance is evaluated in terms of delay, jitter, throughput and packet loss. This performance evaluation is conducted by using a software of *WireShark* which is installed on each client terminal to capture data packet of VoIP communication. In addition, the network performance is also evaluated in terms of Mean Opinion Score (MOS) to measure a user perception to the network performance. MOS evaluation is conducted based on the ITU-T E-Model [19].

Before evaluating the network figure of merits, it is necessary to have an overview of the maximum data rate in the full capacity condition. The data rate measurement is conducted with the aid of the application of Mini Speedtest that has been installed on the PC server which is connected to the BS. This application is then accessed by the user at the SS. The measurement result is depicted in Figure *2*. From this figure, it is shown that the core network has a maximum data rate of about 1.94 Mbps and 2.04 Mbps for its downlink and uplink. The difference between downlink and uplink is caused by the different signal modulation technique for downlink and uplink. Besides that, the difference is also caused by a different power transmit from BS and SS.

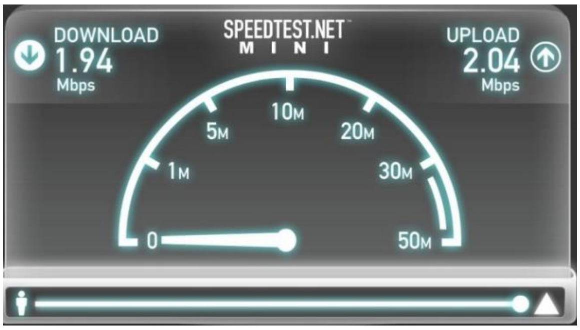

Figure 2 Measurement result for downlink and uplink of WiMAX network

After having a general overview of the system capability, the network performance when delivery the VoIP services is evaluated. In general, during the network performance evaluation the amount of data load that is generated to represent the traffic variation of 0, 1 Mbps, 2 Mbps, 3 Mbps and 4 Mbps. These loads will be used for all test parameters.

The first parameter that is evaluated is throughput. Throughput on the network can be defined as a ratio between the successfully received data and the transmitted data in a certain duration. This parameter is usually represented in bit per second. Figure 3 shows the measurement result of the network performance in terms of throughput over various background traffic.

In general, from Figure 3 it can be inferred that throughput decreases proportionally with the increment of the background traffic. This is due to congestion in the network and when the packet is not proceeded, it causes a packet discharge. This condition causes a throughput becomes low when the background traffic increases.

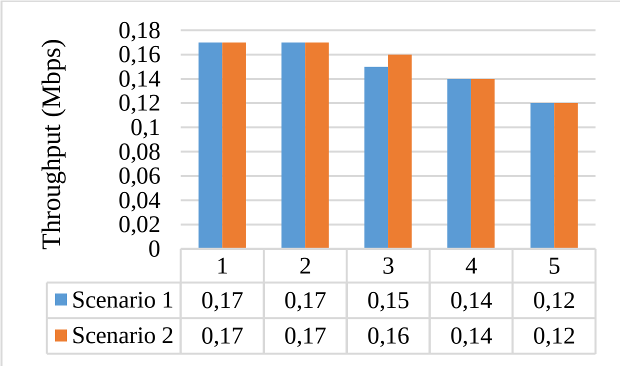

Figure 3 Measurement result of throughput over different load

The next parameter that is also important to be evaluated to measure the network performance is a delay. Delay can be defined as a time that is used by the packet to travel and wait for a processing. In the communication network, delay becomes a parameter that is used to measure a service quality to operate properly. Based on the QoS standard, a delay up to 150 ms can still be acceptable [20]. This value is also required the ITU-T Recommendation G.114 which is stated that the minimum delay for one-way end-to-end voice transmission is 150 ms [21].

The measurement result of delay parameter in the end-to-end data communication in the testbed network is revealed in Figure 4. From this figure, it can be inferred that the delay increases proportionally with the increment of the background traffic. From the figure, it also can be observed that delay is still below 150 ms and therefore it can be still tolerable. The increasing of the delay is caused by the processing delay time due to the queueing of the data processing in the network.

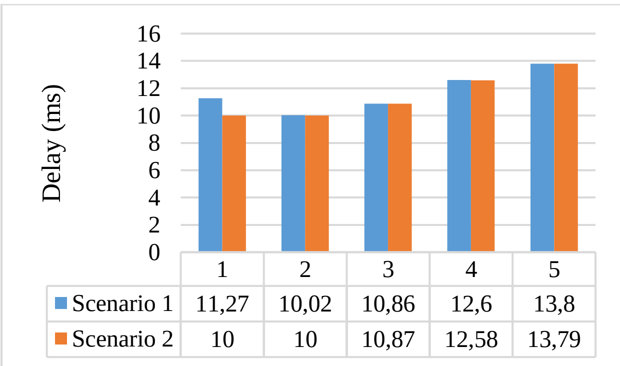

Figure 4 Measurement result of delay over different load

Furthermore, a jitter parameter on the proposed network architecture is measured. Jitter can be defined as a delay variation of the data arrival due to a different condition of the network during the data transmission. A measurement result of the network performance in terms of jitter parameter over various background traffic is shown in Figure *5*.

From this figure, it can be inferred that the jitter parameter increases proportionally with the increment of the background traffic. Similar to the delay parameter, it also happens due to the

https://doi.org/10.25077jnte.v11n2.963.2022

queueing of data processing in the network. As shown in the figure, the jitter value is still acceptable and complied to the network performance which requires a maximum jitter of 100 ms [20].

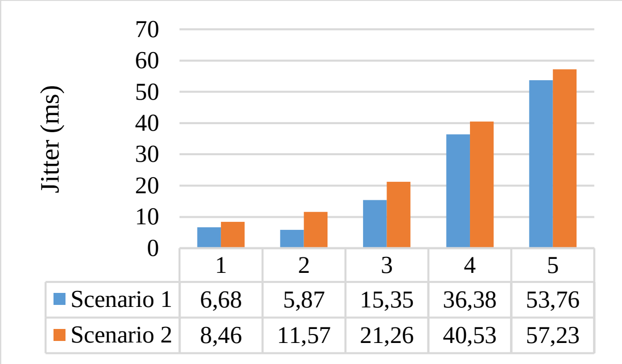

Figure 5 Measurement result of jitter over different load

The last network parameter that is also important to be measured is a packet loss of the transmitted data in network. The measurement of the packet loss is conducted to support the measurement of the throughput. Packet loss is a measurement parameter that is obtained by comparing the amount of the packet loss and all transmitted packets. The packet loss is caused by the exceeding of the live time of a packet due to a busy traffic in the network.

The measurement result of the packet loss parameter is depicted in Figure 6. From this figure, it can be observed that the packet loss is rose when a background traffic of 3 Mbps is provided. After this point, the packet loss also increases proportionally with the increment of the background traffic. This behavior also happens during the measurement of the throughput in network. When background traffic of 1 Mbps and 2 Mbps is injected to the network, the throughput is still the same. However, when the background traffic of 3 Mbps is injected, the throughput performance starts to decrease as the increment of the background traffic. It is reasonable because the more packet losses, the less throughput.

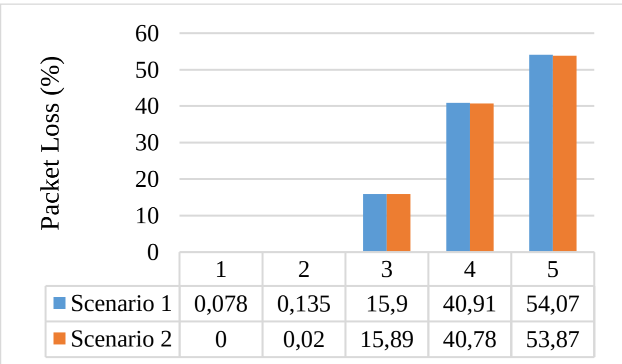

Figure 6 Measurement result of packet loss over different load

Moreover, besides the use of the network parameter, the quality of service can also be evaluated based on ITU-T E-Model [19]. ITU-T E-Model is a method to evaluate the data transmission objectively based on the quality parameters that have been obtained. The result of the performance evaluation with this method is represented in terms of Mean Opinion Score (MOS). Due to the evaluation process that uses a measurable parameter, the result is called objective MOS. Based on the ITU-T Recommendation P.107 [19], the value of MOS can be obtained by firstly calculating an R-factor as follow:

$$R = 94.2 - I_d - I_{ef} \quad (1)$$

where,

$$I_d = 0,024d + 0,11(d - 177,3)H_{(d-177,3)} \quad (2)$$

and

$$I_{ef} = 7 + 30\ln(1 + 15e) \quad (3)$$

with I_d as a factor of quality degradation influenced by a delay (d). Meanwhile, I_{ef} is a factor of quality degradation due to a compression technique and packet loss (e). Whilst, H is a step function with the following condition:

$$H = \begin{cases} 0 & \text{if } x < 0 \\ 1 & \text{if } x \geq 0 \end{cases} \quad (4)$$

With the calculated *R-factor* the MOS value can be calculated with the correlation as follow [22]:

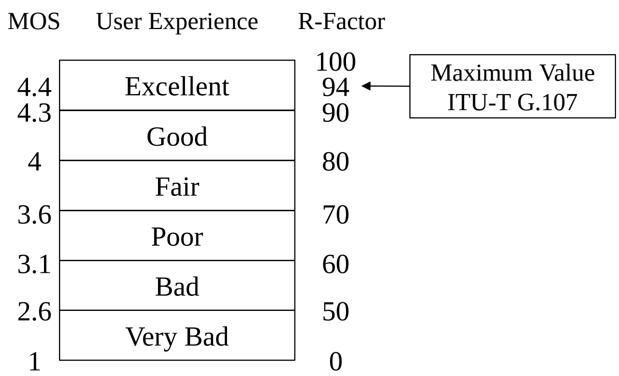

Figure 7 Relation between MOS and R-Factor

Besides the objective MOS calculation, the MOS value can also be obtained subjectively by conducting a satisfactory survey to a group of respondents to evaluate their experience or perspective during accessing the services. This scheme is used in this paper. This method is derived based on the correlation between objective and subjective calculation as described in [22]. The objective of this survey is to measure the satisfaction level of the user when they use the designed VoIP service. The survey is conducted by giving a questioner to 10 (ten) respondents. The respondents have the opportunity to make a voice call with a VoIP service. Each call is conducted 5 (five) times which of each call is injected with various background traffic. The background traffic is generated by using TfGen software as described for the previous parameters. The result of this measurement is depicted in Figure 8.

From this figure, it can be seen that the subjective MOS remains constant when the network is injected with the background traffic up to 2 Mbps. However, starting from the injection of background traffic of 3 Mbps, the subjective MOS becomes lower as the background traffic increases. Considering the aforementioned network quality parameters, it is understandable because when the background traffic increases, all of the network quality parameters become worse.

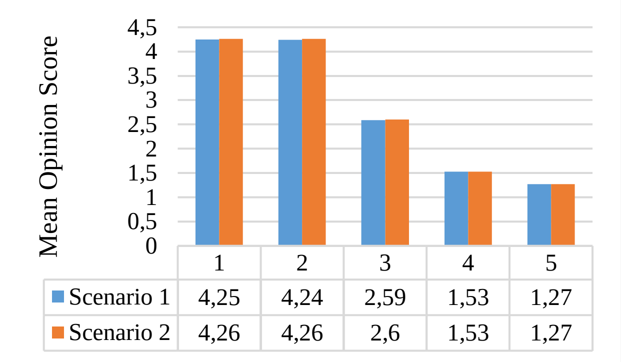

Figure 8 Measurement result of mean opinion score over different load

The network performance of the proposed integrated network can be compared to the available networks described in the literature. The comparison is described in Table 3.

Table 3 Network Comparison

Ref.	Underlying Technology	Applications
[7]	WiMAX technology	Environment monitoring and telemedicine in a remote area
[8]	WiMAX technology	backhaul
[9]	Integrated WiMAX and WLAN Technology	Integrated network testbed
[10]	Integrated WiMAX and WLAN Technology	VoIP in the testbed environment
[11]	Integrated WiMAX and WLAN Technology	VoIP G.711
This work	Integrated WiMAX and WLAN Technology	VoIP service for Emergency Disaster Response with MOS evaluation

CONCLUSIONS

In this paper, an implementation of VoIP services over the WiMAX-WLAN integrated network has been described. The integrated network uses a WiMAX network of IEEE standard 802.16-2004 with the frequency band of 3.5 GHz and WLAN network of IEEE standard 802.11n. The proposed integrated network is designed in P2P and PMP topologies. Within these network architectures, the network performance is evaluated in terms of delay, jitter, throughput and packet loss, as well as MOS value. The network performance is evaluated over various background traffic.

From the performance evaluation, it shows that the network becomes worse when the network load that is represented by the background traffic exceeding 3 Mbps. In general, there is no significant performance different between P2P and PMP network topology.

As the network performance parameters are still acceptable based on the respective parameter requirements, the proposed network is possible to be used as a emergency telecommunication network infrastructure during the emergency disaster response. The rapid deployment and scalability become the advantages of this proposed integrated network.

ACKNOWLEDGMENT

The authors would like to thanks to PT Aplikanusa Lintas Artha for their support by providing a WiMAX Testbed Network in the scheme of Program Hibah CSR Pendidikan Generasi Muda Berbasis ICT.

REFERENCES

[1] G.R. Thompson and J. Turk, *Introduction to Physical Geology*, Saunders College, US: 1998

[2] N. Suematsu, H. Oguma, S. Eguchi, S. Kameda, M. Sasanuma and K. Kuroda, "Multi-mode SDR VSAT against big disasters," in *the proceeding of 2013 European Microwave Conference* (EuMC), 2013, pp. 842-845.

[3] E.N. Koski, "Use of HF for extended-range Combat Net Radio (CNR) communications," in *the proceeding of 10th IET International Conference on Ionospheric Radio Systems and Techniques* (IRST 2006), 2006., pp.38-42.

[4] G.R. Kadambi, K. Krishnan and B.R.Karthikeyan, “HF Channel Estimation for MIMO System Based on Particel Filter Technique”, *Journal of Communication*, Vol. 5, No.9, Oct. 2010

[5] A. Carreras-Coch, J. Navarro, C. Sans, A. Zaballos, "Communication Technologies in Emergency Situations", in *Electronics*, Vol. 11, No. 7, Apr. 2022.

[6] R. B. Dilmaghani and R. R. Rao, "On Designing Communication Networks for Emergency Situations," in *2006 IEEE International Symposium on Technology and Society* (ISTAS), 2006, pp. 1-8

[7] P. Neves, P. Simões, A. Gomes, L. Mario, S. Sargento, F. Fontes, E. Monteiro, T. Bohnert, "WiMAX for Emergency Services: An Empirical Evaluation," *in the proceeding of The 2007 International Conference on Next Generation Mobile Applications, Services and Technologies* (NGMAST 2007), 2007. pp.340,345.

[8] Pentikousis, K., Pinola, J., Piri, E., Fitzek, F., 2008 “An Experimental Investigation of VoIP and Video Streaming over Fixed WiMAX”, in *the proceeding of 6th International Symposium on Modeling and Optimization in Mobile, Ad Hoc, and Wireless Networks and Workshops* (WiOPT 2008) pp.564-578.

[9] M. Gracias, V. Knezevic, A. Esmailpour. 2011. "Interoperability between WiMAX and WiFi in a testbed environment," in *the proceeding of 24th Canadian Conference on Electrical and Computer Engineering* (CCECE). pp.1144-1148

[10] Pentikousis, K., Pinola, J., Piri, E., Fitzek, F., 2008 “A Measurement Study of Speex VoIP and H.264/AVC Video over IEEE 802.16d and IEEE 802.11g”, in *the proceeding of IEEE Symposium on Computers and Communications* (ISCC). pp.19-24.

https://doi.org/10.25077jnte.v11n2.963.2022

[11] E.W.C. Peh, W.K.-G. Seah, Y.H. Chew, Y.Ge. 2008. "Experimental Study of Voice over IP Services over Broadband Wireless Networks," in *the proceeding of 22nd International Conference on Advanced Information Networking and Applications* (AINA). pp.834-839.

[12] *Framework(s) on network requirements and capabilities to support emergency telecommunications over evolving circuit-switched and packet-switched networks*, Recommendation ITU-T Y.1271, July 2014

[13] Sarmonikas, George. 2006. "WiMAX Deployment Workshop". Telefocal Asia. Singapore.

[14] WiMAX Forum, "WiMAX's Technology for LOS and NLOS Evirontments," Agustus 2004

[15] G. Wibisono and G.D. Hantoro. *WiMAX : Teknologi BWA Kini dan Masa Depan (in Indonesian),* Penerbit Informatika. Bandung, 2007.

[16] *IEEE Standard for Information technology-- Local and metropolitan area networks-- Specific requirements-- Part 11: Wireless LAN Medium Access Control (MAC)and Physical Layer (PHY) Specifications Amendment 5: Enhancements for Higher Throughput*, IEEE Std. 802.11n-2009, October 2009.

[17] B.I. Judiesanto, *Teknologi IEEE 802.11n (in Indonesian)*, available in http://ilmukomputer.org/ (accessed on 4 July 2014).

[18] *Pulse Code Modulation (PCM) of voice frequencies,* ITU-T Recommendatino G.711, Nov. 1988

[19] *The E-model: a computational model for use in transmission planning*, ITU-T Recommendation G.107, July 2015

[20] TIPHON, "Telecommunications and Internet Protocol Harmonization Over Networks (TIPHON) General aspects of Quality of Service (QoS)", DTR/TIPHON-05006, 1999

[21] *One-way transmission time*, ITU-T Recommendation G.114, May 2003

[22] *Methods for subjective determination of transmission quality*, ITU-T Recommendation P.800, August 1996

AUTHOR(S) BIOGRAPHY

Prasetiyono Hari Mukti, was born in Bandung, Indonesia. He received the bachelor degree in Electrical Engineering from Institut Teknologi Bandung (ITB), Bandung, Indonesia, in 2008. Afterwards, he received joint M.Sc degree from Institut Teknologi Bandung (ITB), Bandung, Indonesia, and Delft University of Technology (TU Delft), The Netherlands, in 2012. From 2013 he joined the Department of Electrical Engineering, Institut Teknologi Sepuluh Nopember (ITS), Surabaya, Indonesia as a Faculty Member. In 2022 he received the PhD degree in Microwave Engineering from Graz University of Technology, Austria. During his doctoral study in 2017, he also received Young Scientist Award from URSI. His areas of interest include wireless communication system, antenna and microwave circuits.

Syaldy Kharisma Ananda, was born in Sumbawa, Indonesia. He received a Bachelor Degree in Electrical Engineering in 2015 from Institut Teknologi Sepuluh Nopember (ITS) Surabaya. During his study, he served as a laboratory assistant for several courses. His field of interest is Data Communication and Wireless Communication System.

Gatot Kusrahardjo, was born in Bandung, Indonesia. He received his Bachelor Degree and Master Degree in Electrical Engineering from Institut Teknologi Sepuluh Nopember in 1985 and 1999, respectively. Since 1987, He joined the Department of Electrical Engineering, Institut Teknologi Sepuluh Nopember as a Faculty Member. His field of interest includes data communication, internet network and broadband access services.