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Implementing OLSR and Wireless VoIP as Low-Cost Infrastructure Telephony for Rural Area

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Abstract

Communication is one of essential elements in this life, including the people who live at rural areas. However, telecommunications in rural area especially in Indonesia have many constraints like expensive infrastructure, difficult terrain and electrical problem. This led to a lot of areas that uncovered by telecommunication access. In this paper, we proposed a design and architecture of mobile wireless communication based on modified openWRT as a solution for low-cost communication and telephony infrastructure in rural areas. The design combines VoIP over mesh ad-hoc network as a potential solution for cheap calls and use modified embedded device to save electrical resources as a node to connect each other with multi hop transmissions. With this approach, we get many advantages such as high mobility, easy to use, scalable, low-cost implementation, and low power consumption. This paper presents the measurement result of performance to provide access telecommunication in several conditions. In addition, this paper also shows benchmarking results and lifetime of the node that we use in this prototype. The results show that our node can provide telecommunications access in terms of making calls with good quality using wireless LAN. To sum this up, The OpenVoice node is expected to contribute bridging digital divide in rural areas.

***Keywords**: OpenVoice, VoIP, Rural Area, Mesh Ad-hoc*

1. Introduction

Communications is one of the essential elements in human life. As a developing country, the availability of telecommunications services in Indonesia will be very influential in national development aimed to provide prosperity and easy access to information for our people as Indonesian's constitution no.36 in 1999 subsection 3 about telecommunication and universal declaration human rights subsection 19 and 26. But in fact, today there are still many remote areas that have not been touched by the telecommunications services which have an impact on lack of the local population development to grow, either socially or economically. It makes big digital discrepancy between our people in rural and urban area. In 2011 data from Ministry of communication and information technology state there were 66,778 villages in Indonesia and only about 36 percent (24,000) of them covered by telecommunications services. Not only that, distribution of the frequency band dominated by Java Island with 50.4% instead Maluku-Papua just only have 1.5% [22] which indicate that the telecommunication infrastructure have not been spread evenly.

However, there are many challenges and constraints so there are still many areas left untouched by telecommunication services. These challenges like high cost infrastructure development, power grid resources, difficult terrain, and immediate returns on investment (ROI) problems from provider. It makes service provider unwilling to invest for telecommunication infrastructure in remote areas because of what is invested by service provider is not comparable with that will be earned. It is more like business factor from service provider.

OpenVoice Project is conducted to cope with it and make an inexpensive telecommunications and can be used by many people even if at remote areas. By combining VoIP technology as a potential solution to make cheap calls [1] and wireless mesh-ad hoc network, we can get many advantages such as scalable network, mobility, self-forming and configuration, self-healing, fault tolerance, low-cost and easy deployment which make the openvoice as one of the solution to solve the issue of telecommunications in remote areas as mentioned before. Moreover, using modified openWRT firmware and embedded device using

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MR-3020 in implementation as a node for link access in our design makes this prototype has other advantages such as low power consumption, and low-cost in development and implementation. Furthermore, the utility of openvoice is not limited to telecommunications in remote areas but openvoice also offers many other purposes such as ad hoc military communications, search and rescue, e-learning, spread internet access and also communication after disaster.

This paper describes the design from openvoice prototype like architecture and components. More to the point, we also take several measurements like quality of service from this prototype in terms making calls in small scale area, benchmarking hardware, multi hop communication, energy consumption and node lifetime. The measurements conducted to determine preliminary results from our prototype for future development.

The remainder of the paper is organized as follows. Section II presents related work from this research. Section III described OpenVoice architecture and components. Section IV discusses the design for basic implementation from this project. Section V presents preliminary result from several measurements that we conducted. Finally, section VI concludes the paper.

2. Related Work

There are many researches and other projects were conducted by researcher in the entire world. The main goal is providing internet access and cheap telecommunications for rural or remote areas which are shown in Table 1. Most of project using inexpensive off-the-shelf hardware devices in their implementation such as VillageTelco project [3], Digital Gangetic Plains in Kanpur [9], Wray Project in England [4], Fractel Project in India [10], AirJaldi Network in India [5], Pebbles Valley Mesh Network in South Africa [6] and the LinkNet wireless network in Zambia [11]. Others include the Tegola Mesh [8] and Sengerema Mesh Network [7]. Other research about optimization performance VoIP network using wireless mesh network [12], research about MobiMesh which is provide mesh network with mobility [13]. Using OLSR protocol to enhancement mobility and flexibility of the system [14] and using mobile adhoc network and wireless mesh in military for tactical communications [15, 16]. Survey about rural wireless mesh network conducted in [17].

Table 1. Listing Telecommunication Project for Remote Areas

Project Nama	Coverage	Mesh Node	Power Resource	User	Routing Protocol
DGP	80 KM	Soekris	ST/SP/B	N/A	Static
Wray Mesh	2 KM^2	MeshBOx LUmesh	GS	200	AODV OLSR
Macha Mesh	250 KM^2	Linksys WRT54GL	GS/BSP	150	OLSR
Tegola Mesh	19 KM	Avila GW2348-4	GS/W/SP	500	OSPF
AirJaldi	41 KM	Linksys WRT54G	SP/B/UPS	10K	OLSR
Pebble Mesh	15 KM^2	Linksys WRT54G	GS/B/SP	700	OLSR
Sanggarema Mesh	3 KM^2	Linksys WRT54GL	GS/B/SP	400K	OLSR
Village Telco	2 KM^2	Mesh Potato	B/SP	200	BATMAN

Note. SP: Solar Panel, GS: Grid Supply, B: Battery, ST: Stabilizer, UPS: Uninterrupted Power Supply, N/A: Not Available

3. OpenVoice Prototype Design

OpenVoice is one of many projects about telecommunication in rural areas or remote areas. The main goal from this project is to make a cheaper or a free telecommunication for every people. OpenVoice combining VoIP technology is a potential solution to make cheap calls with Mesh network that can make reliable communications. This combination put into one embedded device as a node such as router or other commercial off the shelf to gain low-cost development and low power consumption. In this chapter we will describe about OpenVoice design from the components to network architecture.

3.1. OpenVoice Prototype Component

This openvoice prototype is built with combining several component software and hardware consist of modified MR-3020 board, modified OpenWRT, Asterisk and OLSR protocol into one platform which is ready to implementation with several scenarios.

Figure 1. MR3020 Board a) Original Board b) MR3020 Modified

The first is MR-3020 board, MR3020 board is a tiny AP/router showed in Figure 1(a) which is powerful although have small dimension. This router comes with processor AR7240 support openWRT System on chip (SoC) with speed 400 MHz, Spansion S25FL032P flash rom 4MiB and modified become 16 MiB in this research, Windbond W9425G6JH SDRAM 32 MiB and modified into 64 MiB in this research. Chipset Wi-Fi controller AR9331 IEEE 802.11n 1x1 2.4 GHz System on chip (SoC) integrated in single chip. Not only that, to operate this router we just use 5V/1A power and it means even though using power bank we can operate this router. Table 2 lists the comparison of power consumption between original firmware and openWRT firmware [21]. With these specifications, MR-3020 is suitable to use in this research. Figure 1(b) shows MR3020 board which has been modified to gain optimal results.

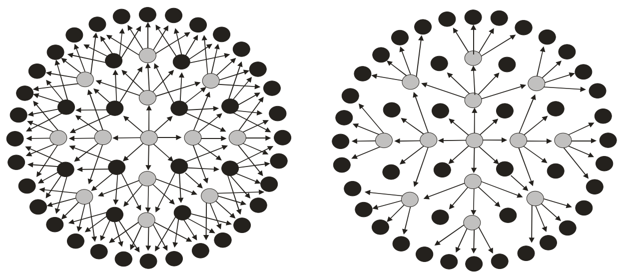
The second is OpenVoice based on OpenWRT firmware [18]. As explained above, OpenWRT is low-level distribution or special firmware that supports for many routers in the entire world. With this firmware, we can make router become mini Linux box which has many advantages if compared with original firmware. OpenWRT makes our router become multifunctional device like Mobile SIP server, mini box penetration tester, file sharing, telemetry, robotic, automation and many more. Now, OpenWRT supports more than 3000 applications and library in their repository include several routing protocol for mesh ad-hoc network like BATMAN and OLSR. OpenWRT reliability has been proven and has been used in several large projects related to communication in remote areas as mentioned earlier at related work. In this research we modified this firmware with eliminating some of services that we do not need in our application. This is conducted to achieve lightweight and efficient firmware for limited resources. Beside that, we added smart queue management feature to this firmware for implementing in large scale which can handle more services.

Table 2. Power Consumption Comparison Between Original Firmware and OpenWRT Firmware

Condition	Original FW	OpenWRT FW
Boot	150 mA	100 mA
Idle	125 mA	68 mA
Idle + LAN	155 mA	108 mA
Idle + WLAN	125 mA	105 mA
Idle + LAN + WLAN	155 mA	148 mA
Idle + LAN + WLAN + USB	210 mA	205 mA
Active download + LAN + WLAN + USB	260 mA	255 mA
AP + Monitor + Dump on USB + LAN + WLAN + USB	N/A	230 mA

Note. FW: Firmware, N/A: Not Available

The third is asterisk. Asterisk is open source software that was reserved for operational of PBX phone. In this prototype asterisk works as a soft switch like MSC and BSC in GSM architecture to routing calls from user to another user over mesh ad-hoc network. Asterisk has many features like voice mail, teleconference, VoIP, video call, messaging and many more. The small size form this application allows to run in embedded system like OpenVoice design and make router become VoIP server with many codec support like GSM, alaw, ulaw, and speex.



(a) (b)

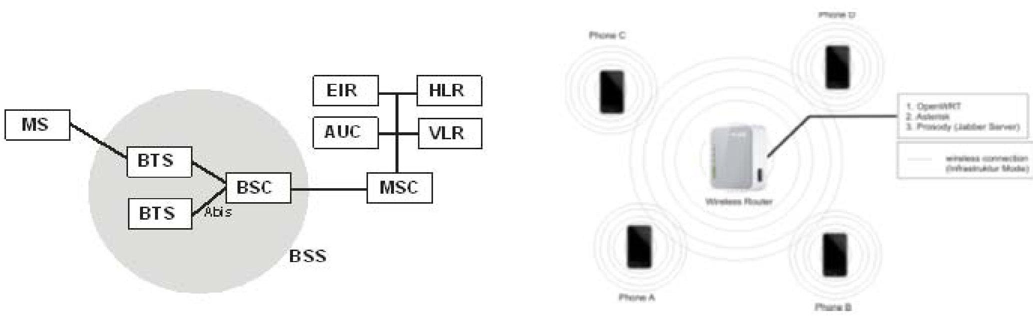
Figure 2. Flooding mechanism, a) Link State b) MPR flooding

The last is OLSR or Optimized Link State Routing. OLSR is a proactive protocol commonly used to build mesh adhoc network. OLSR works using routing table that regularly updated to keep topology information so it can be used to determine path in data transmission [2]. OLSR is an optimization from link state protocol with using multipoint relays (MPR) mechanism to reduce overhead flooding to all nodes in the network that are shown in Figure 2. In this prototype, we use OLSRD [19] which is an implementation from OLSR with fish eye mechanism and ETX in our node by adding several plug-in to make easy to using this daemon.

3.2. OpenVoice Architecture and Basic Topology

Figure 3 point (a) illustrates GSM architecture which has two main parts such as BSC and MSC. BSC and MSC have a basic function to route a call to internal network or external network and save user database. Figure 3 point (b) describes the architecture model which implemented in OpenVoice prototype in this research. BSC and MSC function is replaced by asterisk as a soft switch to route a call and save user database. This asterisk embedded into router wireless was modified with our modified firmware. With this approach, we can route a call both in internal network and external with VoIP technology using frequency 2,4 GHz ISM Band for access link and using frequency 5 GHz for backbone link.

All nodes are interconnected to each other on the same Wi-Fi channel and operate in two modes simultaneously using bridge connections. Ad-hoc mode is needed to interact with others nearby node in order to make mesh networks. Infrastructure mode is used to interact with user as a client to gain communication access or internet access in the network. We use this design to make client can use their phone with any brand without any specialized configuration for as we know smart phone that available today do not recognize an ad hoc mode.



(a) (b)

Figure 3. Telecommunication Infrastructure Architecture (a) GSM Architecture
(b) OpenVoice Architecture

In the user side, we can use handheld with Android, iOS or windows based operating system with zoiper -soft phone application- that already installed. This soft phone is free and available in Google play, app store or windows store. Furthermore, the most important thing is handheld has to be equipped with Wi-Fi interface because we using Wi-Fi connection to connect to SIP server through mesh networks with multi hop transmissions.

3.3. OpenVoice Basic Implementations

In Figure 4, we can see an illustration of OpenVoice basic implementation for communication at remote areas. This implementation is the development of architecture as described in Figure 3. For implementation scenario which is depicted in Figure 4, we can use multiple transmission bands to get connections for long distance communication by using 5 GHz band for the backbone and using 2.4 GHz band for access link to client. Obviously, the equipment that we used such as antennas, Nano stations or similar low-cost hardware will increase if we want extends the range of the mesh network. Moreover, Wireless mesh network for long distance always has a challenge to get maximal results due to a wireless channel condition is always changing and get interference from the environment that may happen during connections. It can reduce the end-to-end VoIP quality. However, for this research we focused implementation in access link only using OLSR as shown in Figure 5.

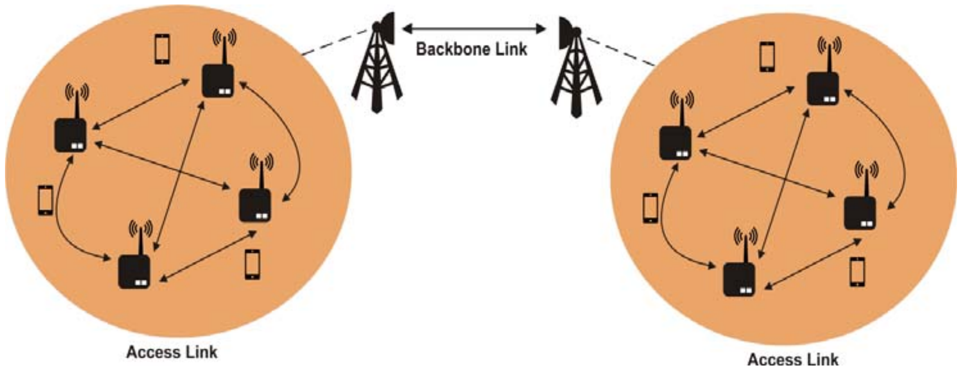


Figure 4. OpenVoice System Implementations using Dual Band Connection

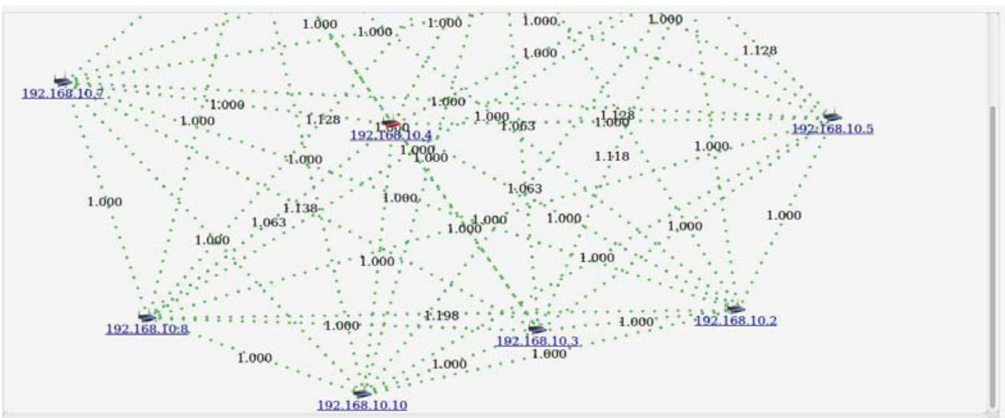


Figure 5. Visualization Mesh-Adhoc Network with OLSR at link access

4. Measurements and Discussions

In this chapter, we present several result of the simulations from openvoice prototype such as preliminary result about ability to provide communication access for small scale, multihop communication, hardware benchmarking and node life-time using smart power management.

4.1. Communication Access for Small Area

This simulation is conducted to investigate the ability of this prototype to connect users in the network so they can communicate each other without service provider or internet connections. In this simulation, it also shows QoS (Quality of Service) parameters that occurred during the simulation. This simulation is held in two buildings (B and AJ Building) of electrical engineering department ITS that illustrated in Figure 7 with 6 users and 5 node openvoice prototypes.

The simulation use six smart phones from various brands, with zoiper is used as soft phone that already installed to make calls for approximately 5 minutes. Measurements QoS are using call quality feature from the soft phone. Furthermore, we use parameters and components as listed in Table 3.

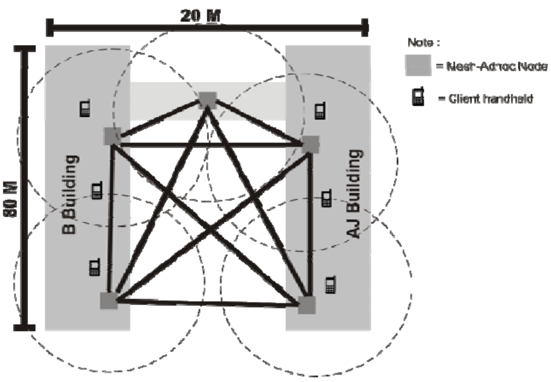


Figure 7. Testing Area

Table 3. Simulation Paramater

Parameter	Description
Codec	GSM FR 8 Khz
Sampling Rate	8 Khz
Bit Rate	13 kb/s
Signaling	SIP
Transport	UDP over RTP
Softswitch	Asteriks 18
Routing Protocol	OLSRv1
Softphone	Zoiper
Platform	MR3020 with OpenVoice Firmware
Power Resource	Solar Power Bank

Results from the simulation as listed in Table 4 below indicates this prototype can be used to communicate between users in coverage area network. The measurement result from the simulation shows the average packet loss and jitter received enough low according ITU-T standard [20]. It is indicated this prototype can provide VoIP services with good quality in small scale.

Table 4. Measurement Results

Parameter	Value
Receive packet	16183
Received bytes	1.34 MB
Received bytes payload	521.0 KB
Current receive bitrates	33 kb/s
Average received bitrates	34 kb/s
Sent packets	16220
Sent bytes	1.35 MB
Sent bytes payload	522 kB
Current sent bitrates	33 kb/s
Average sent bitrates	34 kb/s
Current packet loss	4,3 %
Current received jitter	18,83 ms
Throughput	0,0328 Mbit/sec

Moreover, we have been successfully implementing OLSR protocol to established Mesh ad-hoc topology, where each node connected each other and become relay for another node. With this topology, which means wherever we are, we still can use this VoIP service as long as we are in coverage area.

The Figure 8 below shows VoIP call graph analysis from session initiation protocol that we used during our simulation. From that graph it can be seen that we use UDP as transport over RTP as media session established by SDP for multimedia session. For codec or payload, we use GSM FR in this simulation. Moreover, from Figure 8 we can conclude that we have been successful implementing basic VoIP in embedded device.

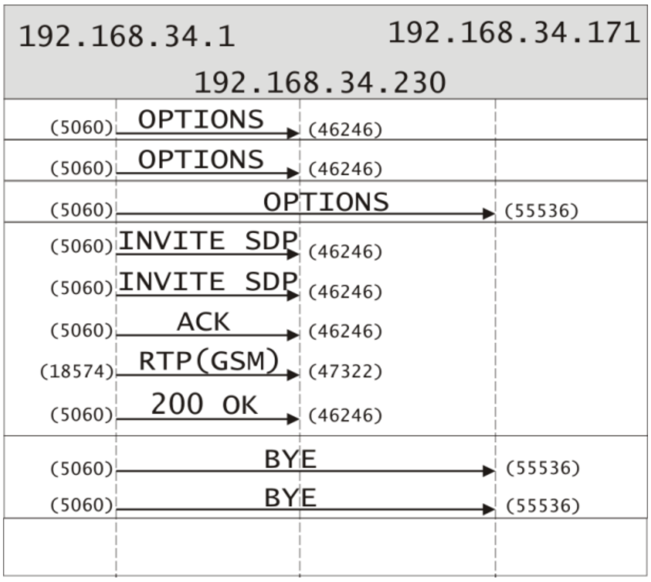


Figure 8. SIP Flow Diagram from Simulation

4.2. Multi Hop Communication Mode

In this section we will show the measurement result from multi hop communication using OLSR as routing protocol in our system. We use multi hop communication in our system with a purpose to extend our network, so we can provide communication access service in larger area. This measurement was performed by putting our node on a line at certain distance as shown as Figure 9. We arrange it this way in order to make sure our transmitted data must go through expected node to the destination using multi hop system.

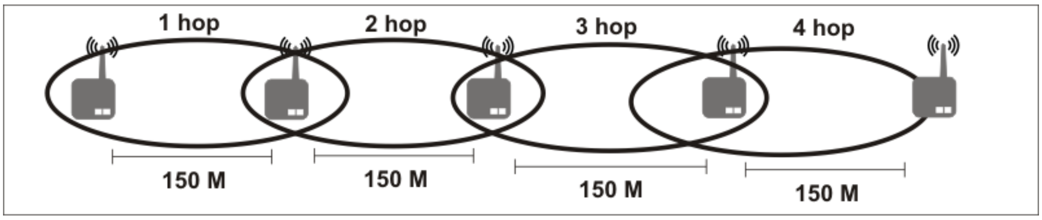


Figure 9. Multi Hop Scenario Measurement

In this measurement we use Iperf as traffic generator that installed at our smart phone and zoiper to make a phone call. We use throughput, jitter and packet loss as our parameter during the simulation process.

From Figure 10 below, we can conclude that adding hops can decrease performance from our network. These occur because we use wireless channel so the data that we send through our network suffer loss from unstable link between the node and noise from environment. Besides that, our node has only one antenna for transmitting and receiving data from other node so the data that has been sent is not been improved on the receiver side another case if we use MIMO technology with diversity technique that can improve received signal.

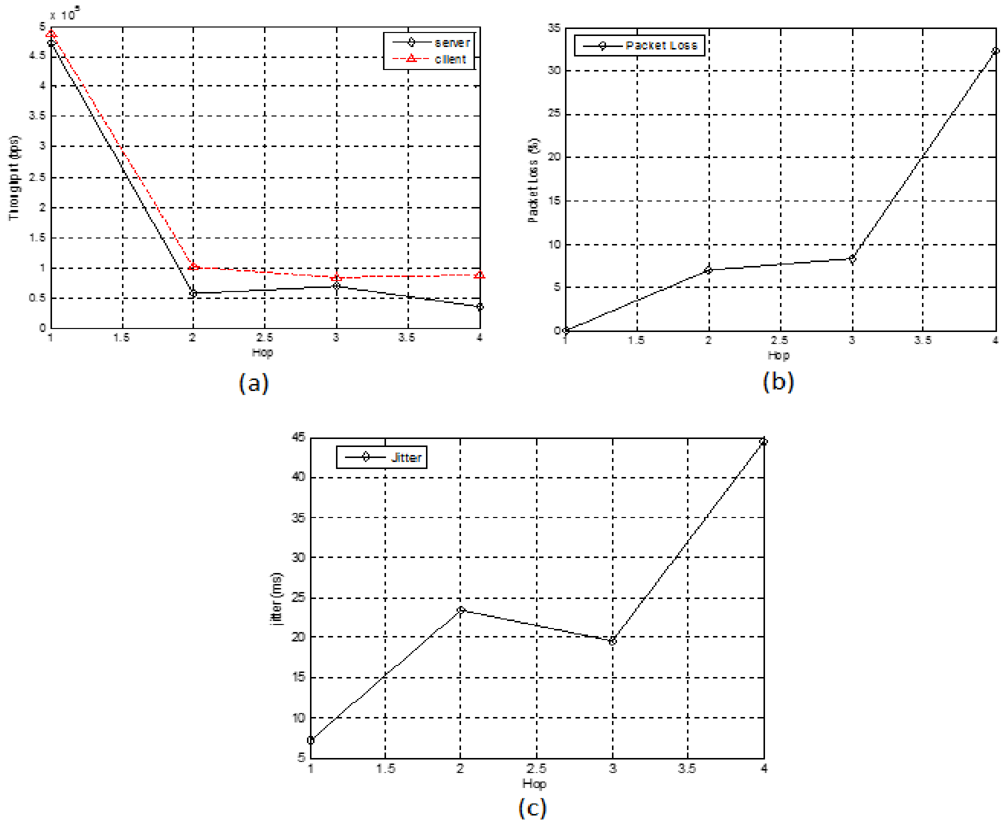


Figure 10. Measurement Results : (a) Throughput Result, (b) Packet Loss Result, (c) Jitter Result

4.3. Hardware Benchmarking

Performance of the hardware that we used indirectly will influence the performance from our system and our telecommunication service. Therefore, hardware benchmarking is very necessary to determine how powerful device we use in our research. This benchmark provides a rough estimate of how performance our devices with giving a task to compute and execute an algorithm (from the simplest one to the more complex algorithm) like AES 256 using Open-SSL software. In this research, we benchmarking our node by comparing the result of original openWRT firmware and our modified firmware on the same device.

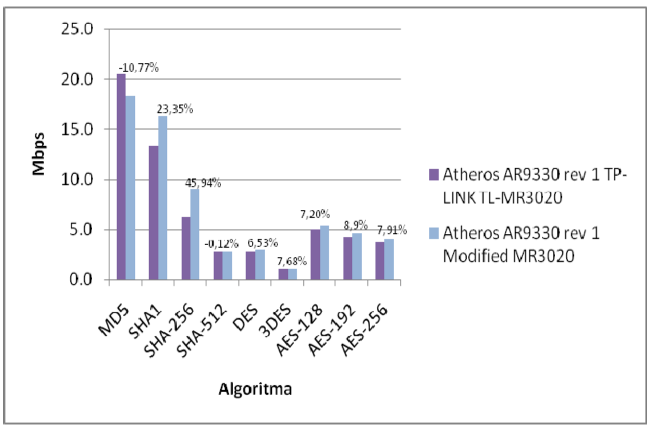


Figure 11. Benchmarking Result

In general, from benchmarking result as shown in Figure 13, we can see an improvement around 6,53% until 45,94% if we use our modified firmware compared with openWRT original firmware. This improvement occurred because we are using lightweight firmware by eliminate unnecesarry services which are having impact to processor performance when execute more data every second. It means our node is more powerful to handle traffic from our telecommunication services like voice, short messaging system and video call.

4.4. Power Consumption and Node Lifetime

This research is telecommunication project with a goal to provide telecommunication access in rural area. One of the biggest problems as mentioned above is electrical problem. Power awareness is very important if we want implemented our system in remote areas and this is why we take a measurement for power consumption and lifetime from our node.

First step, we take measurement about power consumption from our node with compared factory firmware and our modified firmware using USB voltage current meter with several conditions. Measurement results showed improvement if we use our modified firmware around 7% - 20% as we can see in the Table 5 below:

Table 5. Power Consumption Measurement

Condition	OpenWRT FW	OpenVoice FW	Improvement
Boot	150 mA	120 mA	20%
Idle + OLSR	125 mA	100 mA	20%
Idle + OLSR + USB	180 mA	160 mA	11,11 %
File Transfer + OLSR + USB	260 mA	240 mA	7,69%

We also take lifetime estimation and compared it with real time measurements to determine lifetime from our node with two conditions, first scenario we use battery as single power resource. The second, we use smart power management contains 24.300 mAh Polymer Lithium Ion Battery that equipped with mini solar panel as an energy supply which is shown in wiring diagram at the Figure 14.

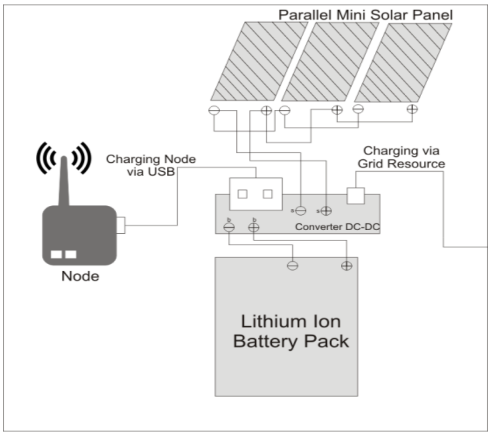


Figure 12. Power Management Wiring Diagram

4.4.1. Estimation of Node Lifetime

For lifetime estimation of our node, we use PSIM as simulator software to find out how much energy contribution if our node use power management equipped with mini solar panel. From the simulation, we can obtain energy estimation from mini solar panel for a day with ideal condition. The results that obtained from first scenario of lifetime estimation can be used to calculate how long our node can last if we combined battery and mini solar panel as a power resources. From calculation using previous data that we obtained, we can see the result like Figure 15.

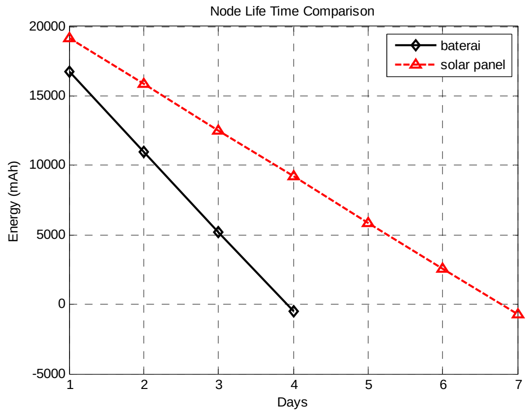


Figure 13. Node Life Time Measurement Result

From that figure, we can see comparison of lifetime from our node. When we only use battery as power resource, our node can only last less than 4 days or about 3 days 22 hours. However, our node can last much longer than before if we use a combination from battery and mini solar panel for less than 7 days or about 6 days 17 hours.

4.4.2. Real Time Measurement

We take two measurements using SNMP protocol and cacti from our node in real time. First measurement we use battery as single power resource and the second we use combination of mini solar panel and battery as power resource with condition like handling VoIP traffic with traffic generator. As a result, our node can run as well as using grid power for 2 days 14 minutes and 5 days 15 hours using combination power source as indicated at Figure 16 and 17.

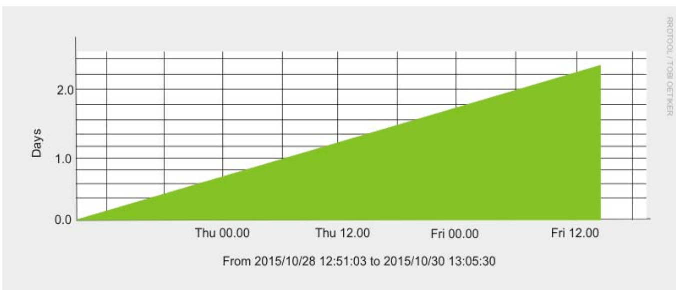


Figure 14. Node Life with Battery Only

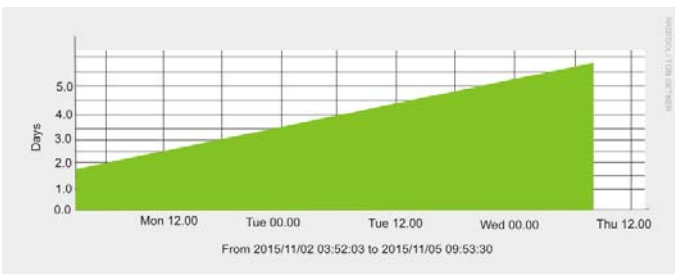


Figure 15. Node Life with Battery and Mini Solar Panel

5. Conclusion

In this paper we have introduced openvoice project for low-cost mobile wireless communication and telephony infrastructure for remote areas based on modified openWRT. This research combines OLSR and wireless VoIP as one framework called OpenVoice. This project conducted to provide communication access for rural areas with low-cost implementation, easy development, flexible systems and bridging digital divide in rural areas.

From the measurements we can conclude that in small scale, this prototype can provide telecommunication access in the rural areas as well as for other application such as communication after disaster, communication at battlefield or search and rescue activity without service provider and only using electrical resources from Polymer Lithium Ion Battery equipped with mini solar panel with good quality at packet loss and jitter value. Moreover, we successful implement OLSR to make mesh ad-hoc network and expand coverage area with multi hop communication.

In the future, we will investigate our system for link stability with deep measurements in large scale using many node, many users and large areas with the integration of backbone system. Furthermore, we will investigate with less lightweight firmware, more efficient system and hardware to obtain maximum results from this prototype.

References

[1] Butcher, David, Xiangyang Li, Jinhua Guo. Security challenge and defense in VoIP infrastructures. *Systems, Man, and Cybernetics, Part C: Applications and Reviews, IEEE Transactions on.* 2007; 37(6): 1152-1162.
[2] Clausen, Thomas, et al. Optimized link state routing protocol (OLSR). 2003.
[3] Adeyeye, Michael, Paul Gardner-Stephen. The Village Telco project: a reliable and practical wireless mesh telephony infrastructure. *EURASIP Journal on Wireless Communications and Networking.* 2011; 2011(1): 1-11.
[4] Ishmael, Johnathan, et al. Deploying rural community wireless mesh networks. *Internet Computing, IEEE.* 2008; 12(4): 22-29.
[5] Surana, Sonesh, et al. Beyond Pilots: Keeping Rural Wireless Networks Alive. *NSDI*. 2008; 8.
[6] Johnson, David Lloyd, Kobus Roux. *Building rural wireless networks: Lessons learnt and future directions.* Proceedings of the 2008 ACM workshop on Wireless networks and systems for developing regions. ACM. 2008.
[7] Lenoir M. Building a Wireless Mesh Network in Sengerema, Tanzania. 2008.
[8] http://www.iicd.org/articles/launch-of-wireless-internet-in-sengerema-tanzania. 2015
[9] Bernardi, Giacomo, Peter Buneman, Mahesh K Marina. *Tegola tiered mesh network testbed in rural Scotland*. Proceedings of the 2008 ACM workshop on Wireless networks and systems for developing regions. ACM. 2008.
[10] Raman, Bhaskaran, Kameswari Chebrolu. Experiences in using WiFi for rural internet in India. *Communications Magazine, IEEE.* 2007; 45(1): 104-110.
[11] Chebrolu, Kameswari, Bhaskaran Raman. *FRACTEL: a fresh perspective on (rural) mesh networks*. *Proceedings of the 2007 workshop on Networked systems for developing regions*. ACM. 2007.
[12] Matthee K, et al. Bringing connectivity to rural zambia using a collaborative approach. 2007.
[13] Ganguly, Samrat, et al. Performance optimizations for deploying voip services in mesh networks. *IEEE Journal on Selected Areas in Communications.* 2006; 24(11): 2147-2158.
[14] Capone, Antonio, Stefano Napoli, Alberto Pollastro. Mobimesh: *An experimental platform for wireless mesh networks with mobility support.* Proc. of ACM QShine 2006 Workshop on" Wireless mesh: moving towards applications. Waterloo (Canada). 2006.
[15] Hafslund, Andreas, et al. *Secure Extension to the OLSR protocol*. Proceedings of the OLSR Interop and Workshop. San Diego. 2004.
[16] Plesse, Thierry, et al. OLSR performance measurement in a military mobile ad hoc network. *Ad Hoc Networks.* 2005; 3(5): 575-588.
[17] Shen, Wei-Liang, et al. Autonomous Mobile Mesh Networks. *IEEE Transactions on Mobile Computing.* 2014; 13(2): 364-376.
[18] Ajayi, Ayomide, et al. *A survey of rural Wireless Mesh Network (WMN) deployments*. Wireless and Mobile, 2014 IEEE Asia Pacific Conference on, IEEE. 2014.
[19] OpenWRT Firmware. http://www.openwrt.org. 2015.
[20] Tønnesen, Andreas. Implementing and extending the optimized link state routing protocol. Master's thesis. Norway: University of Oslo; 2004.
[21] G.114, ITU-T. http://www.itu.int/rec/T-REC-G.114/en. 2014.
[22] Argus's Lab. https://apollo.open-resource.org/lab:argus. 2015.
[23] Ibnugraha, Prajna Deshanta, Tora Fahrudin. Persebaran Layanan dan Infrastruktur Telekomunikasi Provinsi Papua. *Jurnal INFOTEL.* 2014; 6(1).