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An Experimental Connectivity Performance of Simple Wireless Mesh Implementation Using Wireless Distribution System (WDS)

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Received June 7, 2017 Revised July 27, 2017 Accepted August 8, 2017 Available online August 14, 2017 Keywords Wireless, WDS, Connectivity Performance	Today wireless technology grows rapidly, especially in the field of telecommunications and communications. Computer networks now widely utilizes wireless. Wireless Mesh Network is one of the method which is use to communicate computer wirelessly. One important factor in application of wireless network is how to extend wireless signal coverage. Wireless Distribution System is one way to expand the wireless network by mean of wireless interconnection of access point on the network IEEE 8022.11. This study suggests how to build a simple wireless computer network using WDS technology and describes connectivity performance and its signal coverage. The test result of connectivity performance shows that the connectivity was not success in multichannel testing. Furthermore the test result of coverage shows that the range of wireless signal coverage reaches 39 meters with different circumstance room.

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1. Introduction

Advances in wireless technology growing rapidly around the world, especially in the field of telecommunications and data communications. Wide coverage is an important factor in wireless technology. One way to extend the range of the signal is to use WDS technology.

WDS technology is a technology extending wireless network by means of wireless interconnection of access points in the IEEE 802.11 network. With WDS technology, expanded wireless networks using multiple access points without the need for a wired backbone to connect.

Several previous studies discussing the implementation of wireless mesh with WDS. One study on the wireless network using WDS was stated by Babangida Zubaira. In the paper, he developed WDSN (Wireless Distribution System Network) use WDS to demonstrate WLANs, OPNET simulated then measure its performance parameters. The measured parameter is the response time, throughput, and delay [1].

Jutamas Kongtep suggests research in a paper on adaptive frequency hopping scheme for WDS in WLANs. And the result of his research is a signals lingering at predefined frequency for the short period of time in each channel all the time that protects noise with neighbors channels and avoids Intruders roommates Resolves a problem in the general form of WDS is vulnerable considering the attacks or interferences diligence to perpetually use same frequency channel [2].

Another study about WDS presented by Alpatov, et.al about evaluation performance of wireless network for mobile user [3]. Research on Wds for mobile nodes carried by Ridwan Riesta is to implement its WDS bridge mode to support data services on the mobile node [4]. Alif Subardono presented his research in 2011 on performance analysis wireless distribution system configuration star and mesh for hotspot area. In his research it was found that throughput in star configuration is better than mesh configuration [5]. Another research about WDS for hotspot is presented by Wiwin Sulistyo, et.al. research about implementation and analysis of use dd-wrt firmware to establish wireless distribution system network in hotspot network [6]. Deer Li present his research about the performance MPEF-4 AVC video streaming over IEEE. 802.11 WDS [7].

Based on all research explaining above, we present an experimental of simple WDS. The purpose of this research is to build a wireless Mesh Network as simple as connecting the two pieces of the access points. In addition to experiment with performance wireless mesh parameter measurements include reliability, connectivity, connectivity Multichannel Multi SSID and signal range on the system.

2. Theory

2.1. Wireless and Wireless Network Mesh

The wireless network is a wireless network that uses air as the transmission medium to conduct electromagnetic waves [8]. Based on its coverage, there are several type of wireless networks (Figure 1).

- 1. Wireless Personal Area Network (WPAN) is a wireless network with range of small area for example infrared.
- 2. Wireless LAN (WLAN) is a wireless coverage larger than WPAN.

- 3. Wireless MAN (WMAN) is wireless network that connect multiple network WLAN, for example WiMAX.
- 4. Wireless WAN (WWAN).
- 5. WWAN is a wireless network that reaches a large area such as connecting headquarters and branches across province.

Wireless mesh network (WMN) is a wireless network consisting of mesh routers and mesh clients. Mesh routers have at least minimal mobility and form the backbone WMN. WMN can be integrated with other networks such as the Internet, cellular, IEEE 802.11, IEEE 802.15, IEEE 802.16, sensor networks and so forth. Figure 1 shows the shape of WMNs [9].

Some benefit characteristic of WMN are increased reliability, low installation cost, large coverage area, and automatic network connectivity [10].



Figure 1 Type of Wireless Network Based on Coverage

2.2. Wireless Distribution System

WDS is a technology extending wireless network without having to build a wired network backbone as the interconnection between the bridges. The example of WDS is shown in Figure 2. Access Point is connected by Mac Address [1].



Figure 2 Wireless Distribution System

3. Analysis and Design

To build a Wireless Mesh Network using WDS then the required hardware and software can be showed in Table 1.

Table 1 Hardware and Software

Hardware	Software
Access Point 2 Pieces Linksys WRT54GL v1.1	DD-WRT Firmware version 24
Two laptops are used for end user	

Construction of the system is done in stages with the following stages:

1. Configure the network according to the topology as follows in figure 3. Topology used is a simple wireless computer network that consists of 2 pieces of computer and access point as in figure 4.



Figure 3 Topology of WDS

- 2. To install DD-WRT firmware. DD-WRT is a Linux-based firmware for various wireless routers of different brands.
- 3. Perform wireless mesh configuration with WDS.
- 4. Perform wireless mesh network connectivity.
- 5. To test the reliability of wireless mesh.
- 6. Perform WDS Network Coverage Testing.

4. Implementation and Testing

4.1. Implementation

The results of the analysis and design then implemented physically. After designing the topology to be implemented then perform the installation and configuration of the DD-WRT firmware by entering the username and password as in Figure 4.

Then configure the wireless mesh with WDS. For the selection of the channel using the insider as a helper application to view the wireless channel is in the area to be used. Figure 5 shows that channel 1 will be used to implement this WDS.



Figure 4 DD-WRT Configuration

inSSDer	Street a Distant of Station					ALC: U.S. 199	
File View W-Fi Help							
Radio + ESSID FILTERS: SSO							
	CHANNE		SIGNAL (dBm) 🔻			SEC MIN DATA RATE	
Connectify-me			-51		b, g, n	1.0	144.4
@wifi.id 0-0	6, 11, 153, 15	7, 161				1.0	300.0
flashzone-seamless	6, 11, 153, 15	7, 161			b, g, n	1.0	300.0
TelkomUniversity		5, 9				1.0	144.4
					b, g, n	1.0	144.4
www.arispugud.com	153		-77			6.0	144,4
~death to all drug smugglers!!!!					b, g, n	1.0	150.0
T-Flash			-80		b, g, n	1.0	130.0
MasihCariJodoh?					b, g, n	0 1.0	144.4
Nouby Hotspot (08221-7005-938)			-86			1.0	150.0
TelkomUniversity_Cisco					b, g, n	1.0	216.7
1							
-30 -40 -50 -50 -50 -50 -50 -50 -50 -50 -50 -5	Connectify-me Flag #wifi.idless fity-rsfieldi.id all drug smugglesstiff by purtworty						-30 -40 -50 -50 -50 -50 -50 -50 -50 -90
1 2 3 4 5 6 7	8 9 10 11	36 44 52 60		100 108	116 133	140 149 157 1	65

Figure 5 DD-WRT Configuration

The next step is to configure the network by entering the IP and DHCP Gateways on the access point 1 and 2. Then select the AP mode and select the channel to be used. In configuration mesh WDS, it must turn off security. Figure 6 and 7 show the configuration of Access Point 1 and Access Point 2.

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AN •	00:	D3:	/39	4A:	529	20		
Disable 🔻	00:	00:	00:	00:	00 :	00		
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a options							(Defects Die	- 11- 2
izy wus			0	Enabl	e 🖲	Disable	(Default: Dis	able)

Figure 6 WDS Access Point 1 Configuration

LAN		C8:	B3:	73 :	44:	2E:	7A	
Disable		00:	00:	00 :	00:	00:	00	
Disable	T	00:	00:	00 :	00 :	00:	00	
Disable		00:	00:	00 :	00:	00:	00	
Disable	•	00:	00:	00:	00:	00:	00	
Disable	•	00:	00:	00:	00:	00:	00	
Disable	۲	00:	00:	00 :	00:	00:	00	
Disable	•	00:	00:	00 :	00:	00:	00	
Disable	۲	00:	00:	00 :	00:	00:	00	
Disable	•	00:	00:	00 :	00:	00:	00	

Figure 7 WDS Access Point 2 Configuration

4.2. Testing System

Simple wireless mesh using WDS is tested by these stages:

- 1. Connectivity Testing,
- 2. Reliability Testing,
- 3. Multi SSID Testing,
- 4. Multichannel Testing,
- 5. Coverage Testing.

C:\Windows\system32\ping.exe		23
Pinging 192.168.1.1 with 32 bytes of data: Reply from 192.168.1.1: bytes 32 time=1ms TIL=64 Reply from 192.168.1.1: bytes 32 time=2ms TIL=64 Reply from 192.168.1.1: bytes 32 time=1ms TIL=64		* III

Figure 8 Access Point 1 Connectivity

C:\\	Vindow	s\system32\ping.exe	2		
Reply Reply	from from	192.168.1.3: 192.168.1.3:	bytes=32 bytes=32	time=54ms TTL=64 time=84ms_TTL=64	*
Reply Reply Reply	from	192.168.1.3 192.168.1.3 192.168.1.3	bytes=32 bytes=32 butes=32	time=1ms ITL=64 time=23ms ITL=64 time=49ms TTL=64	
Reply	from	192.168.1.3: 192.168.1.3:	bytes=32 bytes=32	time=77ms TTL=64 time=1ms TTL=64	
Reply Reply Reply	from from	192.168.1.3: 192.168.1.3: 192.168.1.3:	bytes=32 bytes=32 butes=32	time=32ms TTL=64 time=60ms TTL=64 time=82ms TTL=64	
Reply	from from	192.168.1.3: 192.168.1.3:	bytes=32 bytes=32	time=1ms TTL=64 time=33ms TTL=64	
Reply Reply Reply	from from from	192.168.1.3 192.168.1.3 192.168.1.3	bytes=32 bytes=32 bytes=32	time=bbms IIL=b4 time=90ms TTL=64 time=1ms TTL=64	
Reply Reply	from from	192.168.1.3: 192.168.1.3:	bytes=32 bytes=32	time=40ms TTL=64 time=66ms TTL=64	
Reply Reply Reply	from from from	192.168.1.3 192.168.1.3 192.168.1.3	bytes=32 bytes=32 bytes=32	time=95ms IIL=64 time=1ms TTL=64 time=49ms TTL=64	
Reply	from from	192.168.1.3: 192.168.1.3:	bytes=32 bytes=32	time=74ms TTL=64 time=1ms TTL=64	
Reply	from	192.168.1.3:	bytes=32 bytes=32	time=1ms IIL=64 time=55ms TTL=64	*

Figure 9 Access Point 2 Connectivity

Testing connectivity between the client and the access point 1 and the access point 2 is done by pinging between client and access point connectivity. The test results are presented in Figure 8 and 9. The results showed that the image of connectivity for successful wireless mesh can be seen from the results of ping to the access point 1 and 2 so that the second access point access point can be connected.

Mesh network reliability testing is done by turning one access point and then try its mesh network. Results of testing the reliability of the mesh network shown in the Figure 10, 11 and 12. The test results showed that the client can not access to the access point 1, but still connected to the access point 2 proves that wireless mesh has good reliability.

<pre>ply from 192.168.1.208: quest timed out. quest timed out. quest timed out. quest timed out. squest timed out. quest timed out.</pre>	Destination Destination Destination Destination Destination	host host host host	unr unr unr	Reply Reply Reply Reply Reply Reply Reply	fron fron fron fron fron fron	192.168.1.3: 192.168.1.3: 192.168.1.3: 192.168.1.3: 192.168.1.3: 192.168.1.3: 192.168.1.3:	hytes=32 hytes=32 hytes=32 hytes=32 hytes=32 hytes=32	time=65ms TTL=64 time=93ms TTL=64 time=1ms TTL=64 time=20ms TTL=64 time=77ms TTL=64 time=17ms TTL=64
rquest timen out. sply from 172.168.1.208: aquest timed out. sply from 172.168.1.208: aquest timed out. sply from 172.168.1.208: aquest timed out. sply from 172.168.1.208: aquest timed out. aquest timed out. aquest timed out.	Destination Destination Destination Destination	host host host	แกร แกร แกร	Reply Reply Reply Reply Reply Reply	fron fron fron fron fron	192.168.1.3 192.168.1.3 192.168.1.3 192.168.1.3 192.168.1.3	bytes=32 bytes=32 bytes=32 bytes=32 bytes=32	time=93ms IIL=64 time=1ms IIL=64 time=20ms IIL=64 time=77ms IIL=64 time=1ms IIL=64
ppy from 192.168.1.208: quest timed out. pply from 192.168.1.208: quest timed out. pply from 192.168.1.208: quest timed out. pply from 192.168.1.208: quest timed out. quest timed out. quest timed out.	Destination Destination Destination Destination	host host host	แกะ แกะ แกะ	Reply Reply Reply Reply Reply	fron fron fron fron	192.168.1.3: 192.168.1.3: 192.168.1.3: 192.168.1.3: 192.168.1.3:	hytes=32 hytes=32 hytes=32 hytes=32	tine=1ns IIL=64 tine=20ns IIL=64 tine=77ns IIL=64 tine=1ns IIL=64
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equest timed out. equest timed out.				Reply	fron	192.168.1.3:	bytes=32	time=1ms TTL=64
equest timed out.				Reply	fron	192.168.1.3:	bytes=32	time=28ms IIL=64
1				Reply	fron	192.168.1.3:	bytes=32	time=74ms IIL=64
ply from 192.168.1.208:	Destination	host	unr	Reply	fron	192.168.1.3:	bytes=32	tine=1ms TTL=64
equest timed out.				Reply	fron	192.168.1.3:	bytes=32	tine=1ms TTL=64
ply from 192.168.1.208:	Destination	host	unr	Reply	fron	192.168.1.3:	bytes=32	time=25ms IIL=64
equest timed out.				Reply	fron	192.168.1.3:	bytes=32	time=73ms IIL=64
ply from 192.168.1.208:	Destination	host	unr	Reply	fron	192.168.1.3:	bytes=32	time=102ms ITL=64
equest timed out.				Reply	fron	192.168.1.3:	bytes=32	tine=1ns TTL=64
equest timed out.				Reply	fron	192.168.1.3:	bytes=32	time=33ms TIL=64
equest timed out.				Reply	fron	192.168.1.3:	bytes=32	time=77ms IIL=64
ply from 192.168.1.208:	Destination	host	unr	Reply	fron	192.168.1.3:	bytes=32	time=1ms TTL=64
quest timed out.				Reply	fron	192.168.1.3:	bytes=32	time=1ms TTL=64
ply from 192.168.1.208:	Destination	host	unr	Reply	fron	192.168.1.3:	bytes=32	time=28ms IIL=64

Figure 10 Access Point Reliability Test

← → 🗙 🗋 192.168.1.1		
	This webpage is not available	
	ERR_CONNECTION_TIMED_OUT	
	Reload	Details

Figure 11 Access Point 1 Accessible

dd-wrt.c	omcontrol panel	Fir Time: 00:19:1	mware: DD-WRT v24- 7 up 19 min, load aver	up2 (10/10/09) mic age: 0.00, 0.00, 0.0 WAN IP: 0.0.0
Setup Wireless Ser	vices Security Access Restrictions NAT/C	oS Administration	Status	
Basic Setup DONS MA	C Address Clone Advanced Rasting VLANs Netw	orking		
WAN Setup			Help	more
WAN Connection Type			Automatic Configu	ration - DHCP:
Connection Type	Automatic Configuration - DHCP V		This setting is most of	commonly used by
STP	Fnable Tisable		caste operators.	
			Host Name:	
Optional Settings			ISP.	provided by your
Router Name	Access Point 2		Demain Names	
Host Name			Enter the domain nar	me provided by
Domain Name			your ISP.	
NTU	Auto * 1500		Local IP Address:	
			This is the address of	f the router.
Network Setup			Subnet Mask:	
Router IP			This is the subnet ma	ask of the router.
Local IP Address	192. 168. 1. 3		DHCP Server:	
Subnet Hask	255, 255, 255, 0		Allows the router to	manage your IP
Gateway	192, 168, 1, 3		aggresses.	
Local DNS	o lo lo lo		Start IP Address:	
			The address you wou with.	id like to start

Figure 12 Access Point 2 Accessible

Testing wireless mesh connectivity with multi SSID is done by adding one new SSID on both the access point and client enter a new SSID and try the connectivity. Results of testing multi SSID shown in the Figure 13 and 14. The test results show both the access point and create a new SSID second access point can be connected.

Basic Settings Radus Wireless Security MAC Filter Advanced Settings WDS Wireless Physical Interface wlo Physical Interface wlo - SSID [MESH PA] HWAddr [C8:B3:73:44:2E:7A] Wireless Mode AP ▼ Wireless Network Mode Mixed ▼ ▼ Wireless Network Mode Mixed ▼ ▼ Wireless Network Mode Mixed ▼ ▼ Wireless Network Name (SSID) MESH PA ■ Wireless SSID Broadcast ● Enable ◎ Disable ○ Sensitivity Range (ACK Timing) 2000 (Default: 2000 meters) Network Configuration © Unbridged ● Bridged ■ Wireless SSID Broadcast ● Enable ◎ Disable ■ Wireless SSID Broadcast ● Enable ◎ Disable ■ Mireless SSID Broadcast ● Enable ◎ Disable ■ AP ■ Enable ◎ Disable ■	Setup	etup Wireless Services Security Access Restrictions NAT / Qo5							Administ
Wireless Physical Interface wlo Physical Interface wlo - SSID [MESH PA] HWAddr [C8:B3:73:44:2E:7A] Wireless Mode AP Wireless Network Mode Mixed Wireless Network Mode Mixed Wireless Network Mode Mixed Wireless Network Name (SSID) MESH PA Wireless SSID Broadcast ® Enable Disable Disable Sensitivity Range (ACK Timing) 2000 Vertual Interfaces Unbridged Wireless SSID Broadcast ® Enable Virtual Interfaces Disable Wireless SSID Broadcast ® Enable Wireless SSID Broadcast ® Enable Virtual Interfaces Disable Wireless SSID Broadcast ® Enable Wireless SSID Broadcast ® Enable Disable AP AP Unbridged Bridged Network Configuration Wireless SSID Broadcast ® Enable Disable Network Configuration	Basic Sett	ings Rad	lius Wirele	ss Security	MAC Filter	Advanced S	ettings	WD5	
Physical Interface wID - SSID [MESH PA] HWAddr [C8:B3:73:44:2E:7A] Wireless Note AP Wireless Network Mode Mixed Wireless Network Mode Mixed Wireless Network Mode SSID) MESH PA Wireless SSID Broadcast Exact Benable Disable Sensitivity Range (ACK Timing) 2000 (Default: 2000 meters) Network Configuration Unbridged Bridged Virtual Interfaces Virtual Interfaces WID.1 SSID [Mesh PA 2] Wireless SSID Broadcast Exact Exact Disable Virtual Interfaces Disable AP Virtual Interfaces Benable Disable AP Isolation Enable Disable Network Configuration Unbridged Bridged Add Remove	Wireles	s Physica	I Interface	w10					
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Wireless Network Name (SSID) Mesh PA 2 Wireless SSID Broadcast	Virtual Inte	erfaces wl0.	1 SSID [Mesh	PA 2]					
Wireless SSID Broadcast	Wireless	Network Nam	ie (SSID)	Mesh PA 2					
AP Isolation © Enable © Disable Network Configuration © Unbridged ® Bridged Add Remove	Wireless	SSID Broadca	ast	Enable	Disable				
Network Configuration Unbridged Bidged Add Remove	AP Isolati	ion		Enable	Oisable				
Add Remove	Network (Configuration		O Unbrid	ged 🖲 Bridg	ged			
				Ad	d Remove				
Save Apply Settings Cancel Changes			Save	Apply 5	ettings	Cancel Change	s		

Figure 13 Creating New SSID



Figure 14 New SSID Connection

Testing connectivity with multi-channel wireless mesh done by replacing the channel on one of the access point and test the connectivity. Results of testing multi SSID contained in the Figure 15, 16, 17, 18 and 19. In this test, a second access point has different channels so that both the access point can't connect to each other even if WDS is already in the configuration.



Figure 15 Access Point 1 Accessible Multi SSID



Figure 16 Access Point 2 Accessible Multi SSID



Figure 17 Channel Selection on Access Point 1



Figure 18 Make Channel 6 at Access Point 2

C:\Windows\s	\system32\ping.exe				C:\Windows\system32\ping.exe
keply from 1 keply from 1	$\begin{array}{c} 192.168.1.268\\$	Destination h Destination h	ost unreach ost unreach	able. able.	Request timed out. Reply from 192.168.1.3: hytes=32 time=188ms THL=64 Reply from 192.168.1.3: hytes=32 time=387ms THL=64 Reply from 192.168.1.3: hytes=32 time=287ms THL=64 Reply from 192.168.1.3: hytes=32 time=287ms THL=64 Reply from 192.168.1.3: hytes=32 time=287ms THL=64 Reply from 192.168.1.3: hytes=32 time=183ms THL=64 Reply from 192.168.1.3: hytes=32 time=163ms THL=64 Reply from 192.168.1.3: hytes=32 time=163ms THL=64 Reply from 192.168.1.3: hytes=32 time=113ms THL=64 Reply from 192.168.1.3: hytes=32 time=143ms THL=64 Reply from 192.168.1.3: hytes=32 time=53ms THL=64 Reply from 192.168.1.3: hytes=32 time=53ms THL=64 Reply from 192.168.1.3: hytes=32 time=30ms THL=64

Figure 19 Test Result of Multichannel Connection

Testing wireless mesh measurement range is done by testing the connectivity and change the placement position between the access point and client. Change of position is based on the distance and space. Results of testing wireless mesh range shown in the Table 2. The results of the testing range wireless mesh can be seen that the largest range of WDS that is as far as 39 meters.

Table 2 Test Re	sult of Wire	less Coverage
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Connectivity between AP 1 and API 2	Position of AP 1 and API 2	Distance between AP 1 and 2
Connectivity work properly	Access Point 1 and Access Point 2 in same Room	< 3 m
Connectivity work properly	Access Point 1 and Access Point 2 in same Room	< 10 m

Connectivity between AP 1 and API 2	Position of AP 1 and API 2	Distance between AP 1 and 2
Connectivity work properly	Access Point 1 and Access Point 2 in same Room	< 20 m
Connectivity work properly	Access Point 1 and Access Point 2 in different Room	< 5 m
Connectivity work properly	Access Point 1 and Access Point 2 in different Room	<10 m
Connectivity work properly	Access Point 1 and Access Point 2 in different Room	<20 m
Connectivity work properly	Access Point 1 and Access Point 2 in different Room	< 30 m
Connectivity work properly	Access Point 1 and Access Point 2 in different Room	< 39 m
Connectivity Bad	Access Point 1 and Access Point 2 in different Room	> 39 m

5. Result

The connectivity of simple wireless mesh network using WDS can work properly by using single SSID and Multi SSID but the connectivity cannot work properly on different channel. The signal range wireless mesh network using WDS can reach 39 meters with the position of each access point is located in a different room.

In the future, this research can be done on more complex configuration of WDS with different topologies with performance measurements on each topology. Performance measurement can be made on the throughput of each topology and compare the result.

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