Constructing an Innovative, Economical and Secure Wireless Mesh Network: Comparing OSPF and RIP

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Abstract. Since the invention of the internet, the number of users has been growing exponentially. The second largest continent regarding population in Africa, however, Africa is ranked fourth with the number of internet users that Africa has, despite being second in population and fourth in internet users, Africa is ranked last regarding the percentage of internet users to the population of Africa, which is 31.2%. The contribution of this paper regards to the raspberry pi, RIP and wireless authentication. In this paper, implementation of wireless mesh network using four raspberry pi's is presented. However, since there are two suitable routing protocols that use two different algorithms, OSPF and RIP, are analyzed to see which of the routing protocols is best suited to this papers' network. For the experiments, ping and fault tolerance was used to compare OSPF and RIP while also using different devices from different ends of the network. Though RIP has been sidelined by major companies and organizations, the experimental results show that RIP was best suited in the context of this papers wireless mesh network.

Keywords: Wireless mesh networks, Routing protocols, Network topology.

1 Introduction

The main aim of this paper is to be able to create an economical wireless mesh network, that would be suitable for an impoverished country. Since Africa has a total population of 1,246,504,865, however, their total internet users are only 388,376,491, which is only 31.2% of their total population [1]. From these statistics, Africa is in desperate need of some innovation to increase their internet population, so the wireless mesh network will be based on Africa, however, the network can be used for any impoverished country. [1,3,4] are reviewed to research how a wireless mesh network can be incorporated into a destitute country. A network is analysed to determine how to create a network that is best suited for a country that has low wealth, technical expertise and networking infrastructure. For the networks routing methodology, two routing protocols that use different algorithms are compared with ping and Fault Tolerance Recovery Link (FTRL) experiments. Wireless security and authentication are reviewed for the network, as well as displaying the implementation of the network. The first area that this paper contributes to is the Single Board Computer (SBC) raspberry pi, by detailing that using a raspberry pi is both economical and powerful, and is similar to a desktop

PC or a router. The second area that this paper contributes to is the routing protocol RIP (Routing Information Protocol), even though that RIP has been sidelined by major companies and organizations for Open Shortest Path First (OSPF). The third area that this paper contributes to is the wireless authentication, by detailing different ways of configuring wireless authentication within this papers' context.

2 Motivation

Since the invention of the internet, the number of users has been growing exponentially. Information for Internet World Stats are gathered from; United Nations Population Division, Nielsen Online, International Telecommunications Union (ITU) and Gesellschaft Fur Konsumforschung (GfK) to display the world internet usage and population statistics [1]. According to Internet World Stats, since 30th June 2017 the population of the internet has risen to 51.68% of the world population, the lowest internet usage comparing to the population in Africa with an infiltration rate of 31.2%, that use the internet [1]. The main area of research that this paper will delve into will be to conceive a network that is able to be used by an impoverished country with low technical expertise. Currently in the vast majority of Africa, there is both little network infrastructure and networking expertise [2], so building a network with both security and usability, provides its own problems. Apart from the network creation issues, there are other concerns regarding the individual countries. These concerns include; wealth of the country and per person, conflict, political instability and availability of communication infrastructure. Overall this paper will focus and solve both the network and country concerns, by conceiving a network that is able to be affordable, secure and user-friendly.

3 Literature Review

The first resource is a master thesis called 'Bandwidth Aggregation of Mobile Broadband Links on Raspberry Pi Based Access Point' [3]. Within this thesis, the raspberry pi was only used as a gateway to the internet, rather than the raspberry pi being used throughout the network. An experiment could have been created where there are multiple routes from the hosts, so a routing protocol will have to be integrated, instead of using a point-to-point connection protocol.

The second resource is a website blog called 'Building Beyond: A Trade School in Swaziland, Africa' [4], which details a trade school that was completed by a company called Architecture for Humanity Toronto within Swaziland.

The third resource is a conference paper called 'Experimental Results of a Raspberry Pi Based Wireless Mesh Network Testbed Considering TCP and LoS Scenario' [5], which presents an implementation of five raspberry pi's within a wireless mesh network. The major drawback of this conference paper is the hop count experiment, as the authors should have foreseen that as it is a wireless mesh network, every device would be one hop away.

4 Problem and Analysis

In order for a network to be established within an impoverished country, there are areas that need to be addressed. The main area that needs to be addressed with any impoverished country, is cost. Cost of a network can be broken down into the following segments; Transmission of data (either wired or wireless technologies) and Hardware (refer to; routers, switches, hubs, firewall and end devices). Wired technologies are far superior to wireless technologies, due to the following; almost zero interference, higher bandwidth speeds, higher throughput speeds and improved security. When dealing with an underprivileged country, performance can be sacrificed in order to achieve a cheaper, so for this network, wireless technologies are the way to go. The other reasons for choosing wireless technologies include; less technical expertise, unable to afford foreign technical expertise, wired technologies require more cables to be installed and maintained and have the ability to freely move devices around the network. With hardware, it is possible to locate cheap networking hardware; routers, switches, hubs and firewalls. However, an even cheaper option would be to use a raspberry pi which can act as; routers, switches, hubs and firewalls.

4.1 Network Topology

Table 1. The most well-known network topologies, [6]

Topology	Methodology	Expansion	Reliability
Star	All nodes connected to central node.	Point-to-Point connection to the central node.	If the central node goes down, the whole network goes down.
Bus	All nodes are directly connected to a half-duplex link.	For large networks, packet collisions increases.	If the main link (bus) fails, the whole network goes down.
Ring	All nodes connect to two other nodes.	The topology has to be broken to expand.	If one node fails, information will travel the other way.
Mesh	All nodes are in a mesh design.	The network is not disrupted.	If one node fails, the network will not be affected.

For an impoverished country with no ability to either develop their own network administrators through education or from foreign countries, their network topology will have to withstand maintenance. By comparing, Star, Ring and Mesh topologies, for an impoverished country with no constant network administrator maintaining the wireless network, the mesh topology is best suited.

4.2 Routing Protocol

In order to route traffic between each network, a routing protocol will need to be configured into each raspberry pi. RIP is an Interior Gateway Protocol (IGP) designed to distribute routing information within an Autonomous System (AS). As a standardized Distance Vector protocol, designed to be used on smaller networks, it uses a Bellman-Ford Distance Vector algorithm and hop count as its distance metric. For more information about RIP, [7]. The advantages of RIP include, easy to configure and router discoverability. The disadvantages of RIP include; no authentication between routers, slow to converge and hop count.

OSPF, like RIP, is an IGP, designed to distribute routing information within an AS. As the most well-known Link-State protocol, it uses Dijkstra's algorithm, generates link-state packets that contain local information for each router. For more information about OSPF, [8]. The advantages of OSPF include; requires authentication, fast to converge and cost metric. The disadvantages of OSPF include; more complex to setup and requires more memory.

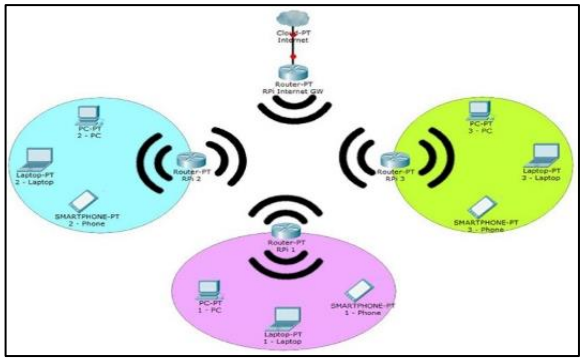
Enhanced Interior Gateway Routing Protocol (EIGRP) is an IGP, designed to distribute routing information within an AS. As a proprietary Distance Vector protocol from Cisco System, based on Diffusing Update Algorithm (DUAL) [9]. In order for EIGRP to calculate a route's cost, EIGRP uses; Bandwidth, Load, Delay and Reliability into its cost calculation.

OSPF and RIP appear to be suitable for a wireless mesh network with little network administration. A comparison test will be done to determine which routing protocol, OSPF or RIP, is superior in the context of an improvised wireless mesh network with little network administration.

4.3 Security & Authentication

As the network will be completely wireless, security will need to be configured to the network. The wireless security of the mesh wireless network will be Wi-Fi Protected Access II (WPA2) which was developed by Wi-Fi Alliance. Unlike Wired Equivalent Privacy (WEP) and WPA, WPA2 uses Advanced Encryption Standard (AES) instead of Rivest Cipher 4 (RC4) [10]. Authentication ensures the device is who they claim to be. By using authentication services it allows the opportunity that if an attacker is able to get into the network and set up a rogue device, they will have to make sure that they have got the right authentication key with that specific device or the attacker will not get a hold on any information of the network.

5 Design



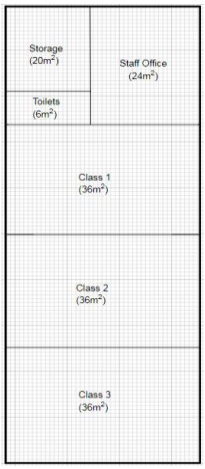


Fig. 1. (a) Wireless Mesh Network Design
(b) Initial School Design for Swaziland [4]

By using the African continent as a basis for an impoverished country that could benefit from a wireless mesh network and using the initial school design for Swaziland (see Fig. 1(b)) as a basis for an impoverished school. To develop the network, raspberry pi's will need to be used, specifically for this paper the raspberry pi 3 model B will be used, at the time of writing this paper, it was the preferred option.
The overall design of the network in Fig. 1(a), portrays the four raspberry pi's connected to the same wireless mesh network between raspberry pi's, while RPi-1, 2 and 3, each have their own Local Area Network (LAN), which the end device's connects to the raspberry pi wirelessly. However, in Fig. 1(a), it illustrates RPi-GW using an Ethernet cable to connect to the internet, this is dependent on the individual country whether that country uses Ethernet or wireless technology to communicate to the internet.

Table 2. Network Cost

	Raspberry Pi	**SD Card (8GB)**	**Ethernet Cable (1m)**	**Wi-Pi USB**
Amount	4	4	1	3
Price	£32.00	£4.98	£2.30	£8.00
	£128.00	£19.92	£2.30	£24.00
			Total Price	£174.22

Network Cost table (see Table 2.) displays the individual costs of the required materials to create the network illustrated in Fig. 1(a). By creating a network that is completely wireless, it allows the end users to be able to freely move their devices around the network range. A routing protocol will be required for Fig. 1(a), a comparison test will need to be done between RIP and OSPF.

5.1 Security

One way to stop attackers from constantly accessing the wireless network is to regularly alter two passwords. The first password to change is the LAN password, which each end device requires in order to connect to the raspberry pi. The second password to change is the intercommunication of the raspberry pi's. Both passwords will automatically change every seven hours as an average school day is roughly seven hours. With the LAN password, the staff of the school will be notified of the new password through their Android phones by using notify. However, with the second password, no one will be notified of the change, it will be done automatically. Both passwords will be a random 13 character bit password. In order to ensure security is upheld when the passwords are conveyed between destinations, port numbers of SSH and notify will only be open when required. The port number for SSH is 22 [11], while for the app notify is 3000 [12].

6 Implementation

In order to implement Fig. 1(a) certain configuration and software will need to be installed, these include; hostapd, dnsmasq, IP forwarding and Quagga. In order to implement the wireless security for the password changes, SCP, SSH and Cron will be used within a bash script. SCP transfers files securely between a designated SCP server to an SCP client. For its encryption, SCP relies upon the fundamental underlying of the SSH protocol. Cron is a time-based scheduler for Linux operating systems.

7 Testing

The network design has been implemented, but before traffic can be routed, a comparison test will be done to determine which routing protocol is superior. The way the experiment will be carried out is by completing the following:

1. Ping: Phone-2-Phone: Two phones acting as end devices, will connect to a separate Wireless LAN (WLAN) and ping each other 15 packets. The way this is achieved is by using an app called 'PingTools', which is downloaded on both phones.
2. Ping: PC-2-Phone: The PC and phone acting as end devices, will connect to separate WLAN's and ping each other 25 packets. The way this is achieved on the PC end, is by using Windows Command Prompt, which is part of Windows 10.
3. Ping: Network-2-Network: 25 packets will be sent from one gateway IP address of a WLAN to another WLAN gateway IP address.
4. Ping: Network-2-Phone: Similar to third experiment, however destination is a phone.

For the FTRL experiments, the above experiments will be done, however one of the Wi-Pi's will be physically withdrawn from one of the raspberry pi's. In order to test the wireless security bash scripts, two different experiments will be executed.

8 Results

Table 3. Ping[1] and FTRL[2] test results – milliseconds (ms)

Source	Destination	OSPF[1]	RIP[1]	OSPF[2]	RIP[2]
Phone	Phone	260.2	215.2	138	114.8
PC	Phone	240.8	207	156.2	167.6
Network	Network	6.698	4.255	3.646	3.235
Network	phone	172.4	171.253	224.363	151.617

By comparing OSPF and RIP with a wireless network, it is clear to see that RIP is the superior routing protocol when it comes to the context of this papers' network, (see Table 3).

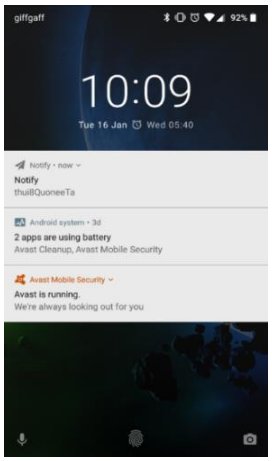


Fig. 2. Updated Password has been notified to the Android device by using app Notify

9 Conclusion

The main aim of this paper was to be able to create an economical wireless mesh network, which would be suitable for an impoverished country. With the wireless mesh network, the SCB raspberry pi was suitable in the context of this paper. Within the paper, two routing protocols that use different algorithms, OSPF and RIP, are compared by pinging different devices at different ends of the network and performing the FTRL experiment. With both routing protocols they were configured, with no added features, while both routing protocols were easy to configure, RIP required less information to be able to configure RIP. By analyzing the results, within the context of this paper, RIP was quicker to converge onto the destination in all the test than OSPF. For wireless security, WPA2 was used for the entire wireless mesh network. For authentication, SCP was used to transfer a file to another device by encrypting the file with SSH. SSH was also used to generate a private RSA key pair, in order to authenticate each file between devices. The notify app was used in order to transfer the updated password to all the teachers, that have an Android phone. For increased security, the port numbers for SSH and notify were only opened when required.

10 Future Work

If any future work was going to be done on this paper, one area would be to implement both RIP and OSPF into a larger scaled network with a higher density of wireless connections, by comparing the routing protocols to see if there is a difference between the routing protocols when in a larger scaled wireless mesh network.

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