Centralized Dynamic Host Configuration Protocol and Relay Agent for Smart Wireless Router

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Abstract **— Serving a Dynamic Host Configuration Protocol (DHCP) request with some additional services package may cause a conventional wireless router consumes more memory resources. High memory usage would break the DHCP request process if the wireless router becomes busy. In this paper, the centralized DHCP servers is proposed to overcome this situation. In term of Cisco product there is Wireless LAN Controller that can solve that situation. In this research, we suggest an open source solution for this situation. The original master and backup algorithm are modified to reserve DHCP request. DHCP master server serves many connected network under the main router. The modification of original master and backup algorithm is located in resource allocation calculation in the main router. Computer agent checks the memory of the main router to decide a diversion of DHCP pool to the backup router. Run test results show that the proposed method has an acceptable lease time. It can handle 254 DHCP requests within only 0.6 seconds longer than the conventional method. Further, the number of client that could be reserved by the proposed method is better than the method used in OpenWRT router, which is about 100 more clients successfully receive their IP.**

Keywords - centralized, DHCP, lease time, master and backup algorithm, wireless router

I. Introduction

On a computer network, each device connected to the network has a unique address called IP (Internet Protocol) address. This IP address is needed to distinguish device in the network where the data package will be sent or received. Setting process of IP address can be done manually when the device joins a network. This process takes time and uncomfortable, especially when changing to different network since the configuration must be reset. In other hand, this arrangement can be done automatically by using DHCP (Dynamic Host Configuration Protocol) server technology. DHCP server provides IP automatically when a device joins a network.

On-campus networks, there are usually many sub-networks commonly called subnets. Subnets are formed when there are certain divisions that require network separation. This subnet can be connected using a router or gateway. If there are a lot of subnets, then many subnet configurations must also be created on the DHCP server. Therefore a DHCP relay agent is needed to forward DHCP requests from different subnets to predetermined centralized DHCP servers [1]

The usage of DHCP Hierarchical Failover in Virtual Private Network (VPN) campus network has been conducted in [2]. It was claimed that the proposed method successfully overcame the limitation on the number of failover servers as defined in DHCP-F protocol. DHCP-F protocol make several DHCP server in Virtual Machine environment that could backup the real physical server. The proposed method enhanced the available wireless routers with a selection mechanism. Selection mechanism is also considering the failover mechanism to back up the master router if memory utilization is near full. The operating system of the existing wireless router was modified by installing Open-WRT to make wireless router became bridge interface and so Wi-Fi router could forward the DHCP request to higher hierarchy of the router connected if the memory was not full [3].

Several studies have been done to improve the ability of DHCP Relay Agents by a caching method. In [4], the author modified the source code of the DHCP Relay Agent on an IBM AIX server by proposing a proxy on the source code. The proxy made every request of the DHCP Relay Agents could be stored in the database without having to ask the central DHCP server. The proposed method did not use a proxy system because each wireless router would be set as the successor of the package from the central router. This research also covered the usage of an alternative algorithm to improve round-robin and polling mechanism of searching for lower utilization of the router become a priority of selection.

Further use of the captive portal has been investigated in [5]. This study discusses a DHCP starvation attack that tries to use all existing IP resources so that the DHCP server could not serve a DHCP request anymore. Special ICMP packages were used to perform DHCP recovery by sending it to the "coova-chili" daemon, which was act as a captive portal. It was shown that, it is possible to carry out captive portal mechanisms to act as DHCP client interface [6].

DHCP flow could be detected using algorithms from watcher agent that automatically set up to understand the request [7] and restored the IP address from DHCP if there is an attack that interrupt DHCP flow [8]. DHCP packet also can be modified from ARP cache because there is an cache to understand the flow [9]. This research captured DHCP flow and made an action from that flow with open source program. Beside made an open source program, this research also tweaks operating system of the wireless router to make router become wireless bridge. Router could become a relay and find the best way to select optimal memory of which router was assigned as a server.

Another DHCP relay was designed and combined with a modern protocol based on SDN (Software Defined Networking) in [10]. It was stated that DHCP relay could act as a Bootstrap protocol that was always asked for every DHCP process. It was needed when sending messages between clients and servers. The process carried out in [10] was to create a Python program based on POX controller. It was used to determine the destination and source from DHCP. If there was a DHCP server in a subnet then it would be sent to the DHCP server. If there was no DHCP server in a subnet then it would not be forwarded to the DHCP relay.

It was possible to implement a server that uses OpenvSwitch and OpenFlow protocol as an SDN device. It was also shown the performance comparison between the proposed centralized DHCP system and the conventional DHCP. [11].

In this paper, the study limits the DHCP relay scenario based on available network equipment using Cisco 2960 switches. DHCP server devices using Cisco router series 1721 and IBM x3100 servers as an alternative. The wireless router devices that were tested were the TP-LINK WR-940ND series and the Linksys E1200 series. On each wireless router, Open-WRT firmware was installed as an open-source operating system that made the wireless router became a DHCP relay with LAN interface. Focus of the first step is to apply DHCP technology to routers and wireless router devices.

The main contribution of this research is to design an agent that acts as a DHCP monitoring server and sends network command automatically when a DHCP packet is passing through the router in term of open source system. This research design alternative solution that overcome the DHCP problem in wireless device with some additional resource selection mechanism. A modification is conducted in the existing DHCP server-selecting algorithm. Polling algorithm is used to forward DHCP requests to all DHCP servers. The DHCP clients select the DHCP server from which the first DHCP reply comes. If the DHCP router that replies DHCP request is from the same router then the load of one router may become very heavy. However, if the real traffic is known in the router that serves DHCP, the traffic can be distributed more wisely.

The rest of this paper is arranged as follows. Section II discusses the proposed centralized DHCP for smart wireless router. Section III deals evaluation procedures of the proposed method. It presents a testing scenario of DHCP relay using the testing script and also a real user of the Wi-Fi DHCP. In Section IV, some conclusions and further development of DHCP server and relay agent are presented.

II. Centralized DHCP for Smart Wireless Router

The proposed system consists of three parts. First part is a router as a DHCP server and relay.

A. Router as DHCP server and relay

Routers reserve some IP pool to be assigned to the client that wants to connect. The router also reserves a routing mechanism that connects all of the nodes of DHCP. This is an example configuration to make DHCP pool in Cisco interface:

```
R1(config)#ip DHCP pool "name"
R1(dhcp-config)#network 192.168.20.0 255.255.255.0
R1(dhcp-config)#dns-server 192.168.20.1
R1(config)#ip dhcp excluded-address 192.168.20.1
```

In one router could be made several DHCP pools. One router could be assigned as a center DHCP server to make several DHCP pools. To make router become DHCP relay is needed to set DHCP helper-address on every interface that needs DHCP. DHCP helper address could be set to the IP address of the gateway in the higher hierarchy of router. The example of relay router configuration in Cisco interface:

```
Relay(config)#interface fastEthernet 0/0
Relay(config-if)#ip helper-address 192.168.10.1
```

B. Server Agent to monitor DHCP traffic

The second part is an agent to monitor DHCP traffic. The agent is a server with Python script to check every packet that passed through the master router. Tcpdump library is used to get information that filtered from the raw packet gained from the listening interface. Tcpdump filters DHCP packet with parameter (udp port 67) and (udp[247:4] = 0x63350103). The magic number 63350103 is examined from Wireshark in Fig. 1.

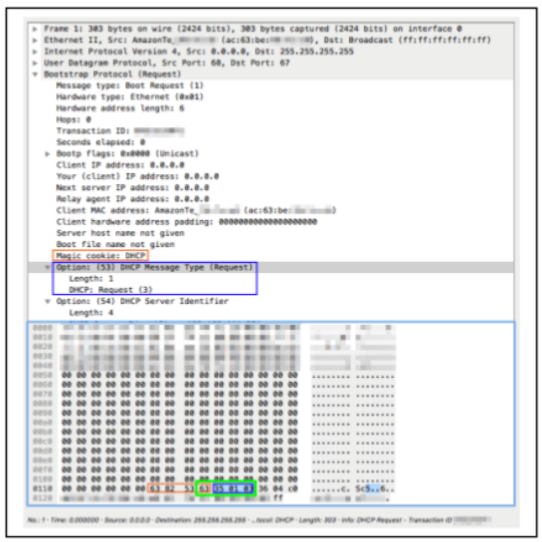

Fig. 1. Magic Number from DHCP discover packet.

Beside Tcpdump library there is also another library to scripting command to router interface using telnet mechanism, which is named Pexpect. Pexpect could detect every prompt command mode in telnet mode. Pexpect detects prompt command mode with some special character like "#" in privileged EXEC and global configuration mode in the Cisco interface. Pexpect could also detect a special case with using a regular expression to detect a combination of the character.

C. OpenWRT Wi-Fi DHCP relay

The third part of the system is a Wi-Fi router available on the market. In this research, we used a TP-LINK series WR-940ND and Linksys series E1200. The original operating system of the Wi-Fi is changed with the custom open-source OS which is named OpenWRT. OpenWRT could improve the functionality of the Wi-Fi router by adding Linux package support to the device. OpenWRT changes the router become LAN repeater like in a Wi-Fi repeater functionality. OpenWRT could make the router become a bridge interface that doesn't serve a DHCP service. Fig. 2 shows the overall system of DHCP management.

D. Network Scenario

Fig. 2 shown that R1 was a master router. R1 has interconnection with PC/server "PC-1". If R1 memory utilization is below 75% then all request is directed to R1. R2 and R3 become a relaying router that forwards DHCP request to R1 if in router configuration there is no DHCP pool command initialized. R2 and R3 could become the relaying router by automatically trigger Cisco command from telnet connectivity when utilization of R1 is full. R2 and R3 configured to add DHCP pool from server agent. R2 and R3 become destined master router after add DHCP pool. When the router of the network that needs DHCP is added with DHCP pool configuration then the client does not search the DHCP center master router again.

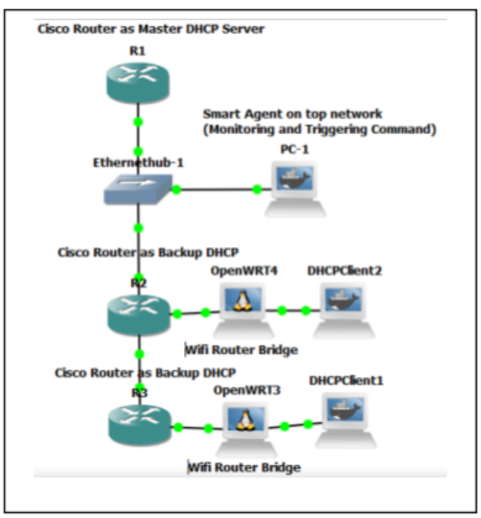

Fig. 2. DHCP Centralization Scenario.

E. DHCP server original selection mechanism

DHCP relay agent supports the polling and master-backup DHCP server selecting algorithms. In Cisco small enterprise router such as the 1700 series, there is no specific configuration of DHCP algorithm. DHCP relay agent uses polling algorithm by default. Polling algorithm forwards DHCP requests to all DHCP servers. DHCP clients select the DHCP server from which the first received DHCP reply comes.

Different from the polling algorithm, master-backup algorithm forwards DHCP requests to the master DHCP server first. If the master DHCP server is not available, the relay agent forwards the subsequent DHCP requests to a backup DHCP server. If the backup DHCP server is not available, the relay agent selects the next backup DHCP server, and so on [13]. If no backup DHCP server available, it repeats the process starting from the master DHCP server [14].

F. Proposed Method for Smart DHCP

The method proposed in this research is to modify the mechanism of the master backup algorithm. The router manages many services such as routing mechanism. The reason behind the router's memory is full is could not suspect directly. Suspicious activity could also overload the router memory.

Modification of the algorithm has been done to overcome the unsuspected activity by checking the memory resource allocation. Modification of algorithm could also be applied in a practical manner by modification of router default OS and make server to manage router automatically from that unsuspected activity.

The algorithm is implemented using Python programming language by using "subprocess", "fcntl", "os", "re", "pexpect" and "getpass" library. Subprocess is a library to call the default OS program by command. Fcntl is a library to detect several key pressed. OS is a library to call OS function. Pexpect is a library to check the expected character in command line interface [15]. Getpass is a library to make pass mechanism to the router. Fig. 3 shows the flowchart of modified master and backup algorithm.

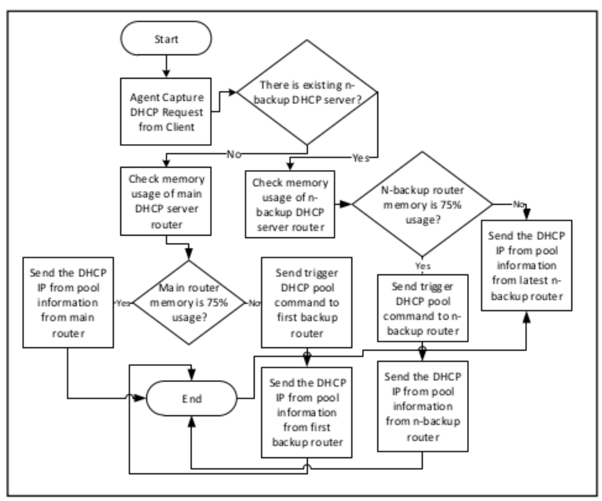

Fig. 3. DHCP Centralization Scenario.

III. Evaluation Procedures

The DHCP lease time performance is the first test conducted in this research. This test is taken to examine the lease time affected by how many relays that must be passed from the client to master router. TABLE I shows the comparison of lease time between the original DHCP and the proposed method for 11 trials that comes from single request and multiple requests. In this case two relays are used and multiple requests are 254 requests since the DHCP is set within class C subnet. The testing scenario is handled by Python script that makes multiple requests from the client to the next router.

TABLE I. COMPARISON OF LEASE TIME BETWEEN THE ORIGINAL DHCP AND THE PROPOSED METHOD.

Trial	Single Request		254 Requests	
	Original DHCP (s)	**Proposed (s)**	**Original DHCP (s)**	**Proposed (s)**
1	2.136	2.113	33.424	32.461
2	2.113	2.114	33.078	31.740
3	2.111	2.120	36.434	33.708
4	2.013	2.115	35.891	33.023
5	2.124	2.112	35.096	33.732
6	2.114	2.116	32.349	32.586
7	2.015	2.113	32.137	34.801
8	2.114	2.124	35.017	34.753
9	2.114	2.110	34.789	36.340
10	2.019	2.113	35.212	32.339
Mean	**2.087**	**2.115**	**34.343**	**33.548**
S.Dev.	**0.0501**	**0.0039**	**1.4918**	**1.4138**

TABLE I shows that there are no significant difference of lease time between the original DHCP and the proposed method, for single and multiple requests. These demonstrate that implementation of the proposed method in the DHCP relay will not take more time to forward the request to the master router. The multiple requests testing was also conducted to ensure that all requests could be handled by DHCP relay with the same time allocation respectively. From mean and standard deviation values, it can be verified that the difference of lease time between the original DHCP and the proposed method are below one second. It means that the proposed method has an acceptable lease time.

The second test related to the lease time and the number of client that could be handled by the system. The test was conducted by comparing the proposed DHCP relay to the simulated OpenWRT environment that acted as the original DHCP Wi-Fi router. The proposed DHCP relay consisted of two Cisco router that acted as a main router and backup router. The main and backup router connected to OpenWRT Wi-Fi router that acted as a bridge interface. Comparison of the lease time and the number of served client between the proposed method and the original DHCP server are listed in TABLE II. In this case, the original DHCP server is represented by single OpenWRT router.

TABLE II. COMPARISON OF LEASE TIME (S) AND NUMBER OF SERVED CLIENT (PCS) BETWEEN THE REAL OPENWRT WI-FI ROUTER AND THE PROPOSED METHOD.

Trial	OpenWRT		Proposed	
	Lease time (s)	**Served client (pcs)**	**Lease time (s)**	**Served client (pcs)**
1	60.571	150	32.461	254
2	58.147	150	31.740	254
3	59.292	153	33.708	254
4	59.593	153	33.023	254
5	66.254	150	33.732	254
6	59.616	152	32.586	254
7	59.405	155	34.801	254
8	57.003	151	34.753	254
9	58.948	150	36.340	254
10	58.302	158	32.339	254
Mean	**59.713**	**152**	**33.548**	**254**
StdDev	**2.4984**	**2.6583**	**33.420**	**0**

TABLE II shows that there is a significant difference between proposed lease time and real Wi-Fi router component simulated by OpenWRT. A lease time of OpenWRT take twice time slower than the proposed method. Table 2 also shows that there is more client, which have successfully received DHCP in the proposed method than in OpenWRT. The client not successfully connected, after about 160 connections although there is some memory free in the router. OpenWRT router must be reset to get the router running well again.

Memory usage of DHCP services in OpenWRT router is larger than in the proposed method. OpenWRT used about 124 KB of memory. The proposed method in Cisco router only used about 20KB of memory for DHCP services. Although the memory of RAM and processor not fully utilized in OpenWRT, the process of burst DHCP requests simultaneously could freeze the router. Different from OpenWRT, Cisco router could handle DHCP request better without freeze from many requests. Although the testing is happened in simulation, it is could be implied that DHCP request sometimes not reliable in real Wi-Fi router environment that handled DHCP requests itself. So it is needed to use centralized DHCP with a modified algorithm that was proposed to get a better result.

IV. CONCLUSION AND FUTURE WORK

We have proposed a modified algorithm of the original master and backup algorithm for smart wireless router. Run test results shows that the proposed method has an acceptable lease time and is able to serve more clients than OpenWRT that act as DHCP server directly. The difference of lease time between the proposed method and the normal DHCP for 254 requests is about 0.6 seconds. The number of client that can be reserved by the proposed method is about 100 more which successfully receive the IP.

Future work will be implementing the proposed method onto the hardware of selected wireless router.

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