An Algorithm and Implementation of Network Topology Discovery Based on SNMP

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***Abstract*—A network topology algorithm based on SNMP was put forward and implemented. This algorithm could confirm the connection between ports and improve the efficiency of discovery through combining the topology discovery of the network layer and the link layer. It could solve the problem of subnet information redundancy and incomplete information of address forwarding table during the discovery. The experimental results show that this algorithm could find accurate network topology and the efficiency of topology discovery was improved.**

Keywords-SNMP; network layer; link layer; subnet; address forward table

I. INTRODUCTION

With the expanding size and increasingly complex structure of network, grasp the entire network topology structure become the precondition of network management and it's increasingly difficult to manage the topology rely on artificial. Therefore, network topology discovery has become a very important function in the network management.

In order to solve this problem, workers have carried out relevant research at home and abroad. Paper [1] put forward a topology discovery algorithm based on SNMP [2]. This method has the advantage of small overhead, good real-time performance and accurate results, but cannot solve the problem of subnet connection and multi-ip of router. Paper [3] put forward an improved SNMP topology algorithm which could solve the problem of multi-ip through the method of MAC address binding, but it can't apply to multi-subnet topology. Paper [4] put forward an algorithm based on ICMP, sending ICMP echo request packets and traceroute packets to discover through ping-command. Yuri Breitbart from Bell Labs put forward a topology algorithm based on address forwarding table [5], concluding a direct-connect theorem using the data from BRIDGE-MIB [6] to judge the connection relationship between two devices. The algorithm can accurately find the physical connection between the equipment, but this method is limited because of the high requisition in integrity of address forwarding table.

Network topology discovery is divided into two levels, the network layer topology discovery and the link layer topology discovery. The network layer discovery can find the logical connection relationship but not the physical connection through analyzing the route information from network equipment. The link layer discovery is based on the second layer of the OSI model; it can find the physical connection relationship with the information of device. This paper put forward an improved algorithm with the combination of network layer and link layer discovery. This algorithm can accurately find the backbone and subnet of network; solve the problem of subnet information redundancy, incomplete of address forwarding table, etc. This method has improved the accuracy and efficiency of topology discovery.

II. NETWORK TOPOLOGY DISCOVERY ALGORITHM

A. Algorithm Based

Definitions:

MAC address set A : MAC address that appeared at the address forwarding table of a specific port of switch and router. $A_{\alpha i}$ is the MAC address Set of port i of the switch(router) α .

Port-port relation set E : connection relationship between ports. The form is binary group $< S_{\alpha i}, S_{\beta j} >$. $< S_{\alpha i}, S_{\beta j} >$ represents port i of device S_α and port j of device S_β are connected.

Port-device relation set T : connection relationship between port and device. The form is binary group $< S_{\alpha i}, S_\beta >$. $< S_{\alpha i}, S_\beta >$ represents that the MAC address of device S_β has appeared at the address forwarding table of port i of device S_α .

Since SNMP is network layer protocol, it couldn't get the information of device which worked on data link layer. This paper presented two theorems used to determine the positions of devices worked on data link layer.

Theorem 1 M is the MAC address of host H , if M is the only element of $A_{\alpha i}$, host H is connected with port i of device S_α .Otherwise host H and device S_α is connected through a hub.

Theorem 2 If $A_{\alpha i} \bigcup A_{\beta j} = U$ (U is the set of all the switches and routers in this subnet) and $A_{\alpha i} \bigcap A_{\beta j} = \varnothing$, then $S_{\alpha i}$ and $S_{\beta j}$ is connected directly, otherwise they are connected through a hub [7].

The data storage structure used in the introduction of algorithm is described as below:

(1)Collecting information table

```
Struct Detect_list
{
        int ipForwarding;
        vector<string> ipAdEntAddr;
        vector<string> ipAdEntNetMask;
        vector<string> ipRouteNextHop;
        vector<string> ipRouteType;
        vector<string> ipRouteDest;
        vector<string> ipRouteMask;
        vector<string> TpFdbAddress;
        vector<string> TpFdbPort;
}
```

(2)Device information table

```
Struct Device
{
        string Descr;
        vector <string> SubnetList;
        string ip;
        string MAC;
        int dot1dStpPriority;
        map<string,string> TpFdbTable;
}
```

(3)Connection queue

```
Struct Switch
{
        map <string,string> switch_link;
        map <string,string> switch_port;
        map <string,string> host_port;
}
```

B. Algorithm Description

In this topology discovery algorithm, three lists are needed, i.e., IpList, DeviceList, and DetectedList to store a list of IPs to be detected, a list of device information and a list of detected IPs. Firstly the topology discovery algorithm based on SNMP is used for the network layer topology discovery to obtain all network devices and their logical connection relationship. Then ICMP echo request packets are sent to all found subnet segments to confirm the active host. Then marker nodes are selected according to StpPriority (Spanning Tree Priority), and from that point on, the address forwarding table of each device is analyzed to determine the physical connection relationship.

The topology discovery algorithm is described as follows:

1) Network layer topology discovery
   a) Take out the first IP of IpList. Read the MIB information of the corresponding device and store the data in accordance with the type of Detect_list data structure. Judge whether ipForwarding value is 1. If yes, it indicates that the device has routing function.
   b) Take out the first route from the routing table, query the value of ipRouteType; if the value is 3 (direct), it indicates that the route is pointing to a subnet; if the value is 4 (indirect), it indicates that the route is pointing to another routing and switching equipment.
   c) Match the subnet IP address range obtained from operation of ipRouteDest and ipRouteMask that pointed to the subnet with the subnet address range at the port; if the ranges are successfully matched, add the information into the device subnet list. Add ipRouteNextHop that points to the routing and switching equipment not repeatedly to IpList.
   d) Repeat steps (b) and (c) until the routing table is traversed.
   e) Add the device to the Switch List. When the current IP is added to the DetectedList, take out the next IP from the IpList for detection.
   f) Repeat steps (a) – (e), until IpList is null.
2) Link layer topology discovery
   a) Sort all devices by priority according to their values of dot1qStpPriority, and select the device with the highest priority as a marker node.
   b) When the SwitchList is not null, take out device S_1 with the highest priority, and send the ICMP echo request packets to the IP addresses contained in all subnets to confirm the active host. Obtain address forwarding table set A_{1i} , traverse set A_{1i}, and then add the ports that have the MAC addresses of other routing and switching equipment into set $T<S_{1i},S_{\beta}>$; for the remaining MAC addresses, determine the connection relationship between the host and the devices inside the subnet according to Theorem 1.
   c) Remove device S_1 from the SwitchList.
   d) Repeat steps (b) (c) until the address forwarding table information of all devices has been processed.
   e) Process set T. Integrate two pairs of elements in $<S_{\alpha i},S_{\beta}>$ and $<S_{\beta j},S_{\alpha}>$ into $<S_{\alpha i},S_{\beta j}>$, and add them into set E , and then remove these two pairs of elements.
   f) If the same port $S_{\alpha i}$ has several corresponding ports $S_{\beta j}$ and $S_{\chi k}$, it can be judged that $S_{\beta j}$ and $S_{\chi k}$ are connected with port $S_{\alpha i}$ through a link-layer switch according to Theorem 2.
   g) Repeat step (e) until set T is null.
   h) Determine the uplink and downlink ports[7] of all devices level by level in accordance with their priorities and generate the entire network topology.

C. Algorithm flow chart

According to the algorithm, the flow chart is shown in Figure 1.

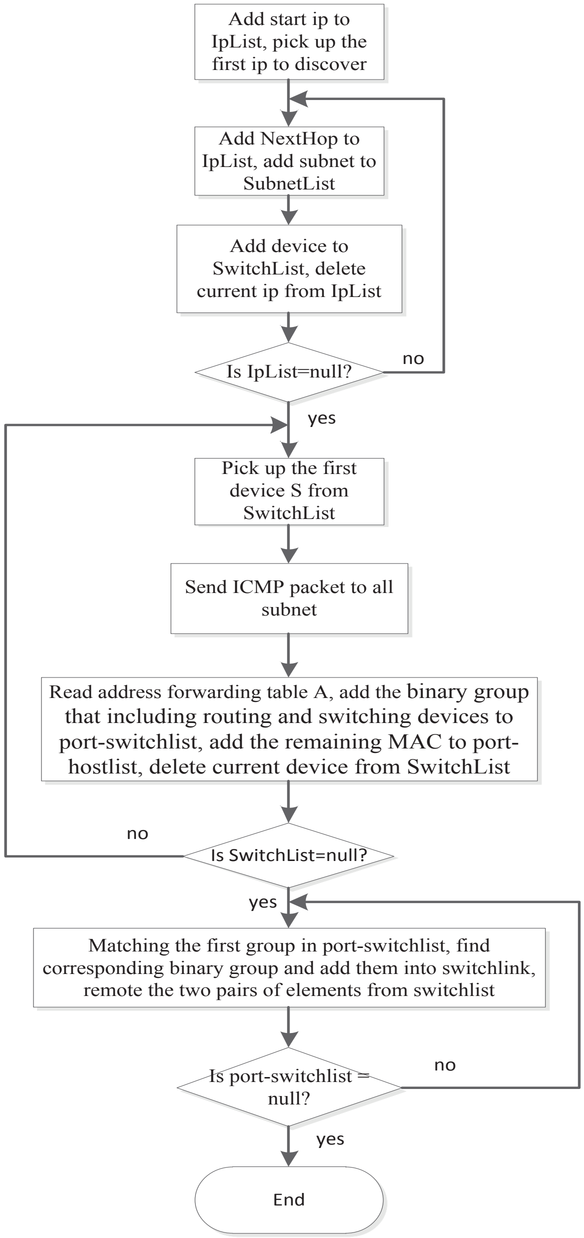

Figure 1. Algorithm flow chart.

III. ALGORITHM ANALYSIS

A. Subnet Information Redundancy Problem

The routing table is a basis for a device forwarding a data packet. However, a lot of redundant data exist in the routing table, this will increase the network load during topology discovery process, affecting the efficiency of topology discovery, and thus it is necessary to process the data in the routing table to exclude redundant information. This paper presents a method for filtering routing information. With this method, the system conducts transposition and operation of ipRouteDest and IPRouteMask in the direct routes, and adds subnet address a_n obtained into set A . Then the system conducts transposition and operation of ipAdEntAddr and ipAdEntNetMask, and adds subnet b_n where a port locates into set B , and take out $S = A \cap B$, set S is valid subnet information. This can exclude a large number of invalid subnet segments, and improve the efficiency of confirmation of active host inside the subnet and topology discovery.

B. VLAN division affect the accuracy of topology discovery

In real networks, routing and switching equipment has divided a large number of VLANs, while in the MIB-II, the MAC address information of a device in general is the MAC address of a default VLAN. Therefore, it cannot determine the exact physical port information based on the MAC address appeared in the address forwarding table. This paper has adopted a bilateral matching method based on binary group information, which integrated the information in the address forwarding table according to the corresponding mode of port-MAC address, determined the port number that showed the MAC address of the peer side, and added the ports to binary group set A . The bilateral matching is performed to sets A_1 and A_2 for two devices, thus discovering a connection relationship between the ports. Since the MAC address of the default VLAN only acts as intermediate information to match the interconnected ports of the two devices, i.e., it only played the role of device identification during the matching process; therefore, VLAN division does not affect the confirmation of the connection relationship between the ports. In this way, the interference of VLAN division on physical topology discovery can be avoided.

C. Requirements of integrity of address forwarding table

The topology discovery algorithm based on the address forwarding table has a high demand for the integrity of the address forwarding table of the routing and switching equipment. If a user under a subnet has no network access behavior that crosses network segments in a long time, it would be lack of address forwarding information of an uplink port of a gateway switch. In this paper, we combined the network layer discovery algorithm with the link layer discovery algorithm. For the network configured with static routes, we have implemented a communication process of the whole network based on the network layer topology discovery process; in this way, the address forwarding tables of uplink and downlink ports of every device are integral. In addition, ICMP packets are sent to all subnets, so as to ensure the integrity of the address forwarding table.

IV. ALGORITHM IMPLEMENTATION

The topology program has run on the internal network of an Academy. The depth of topology is 3. The results of topology are shown in Figures 2, 3. Figure 2 is topology of the whole internal network. Figure 3 is subnet topology of exchange-management domain:

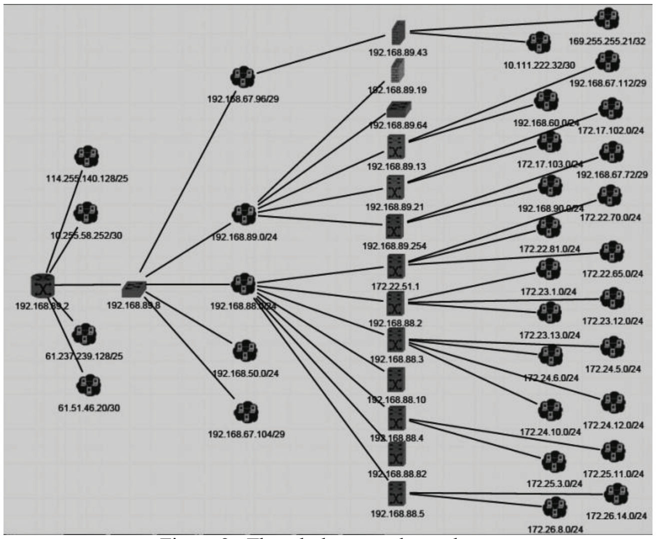

Figure 2. The whole network topology.

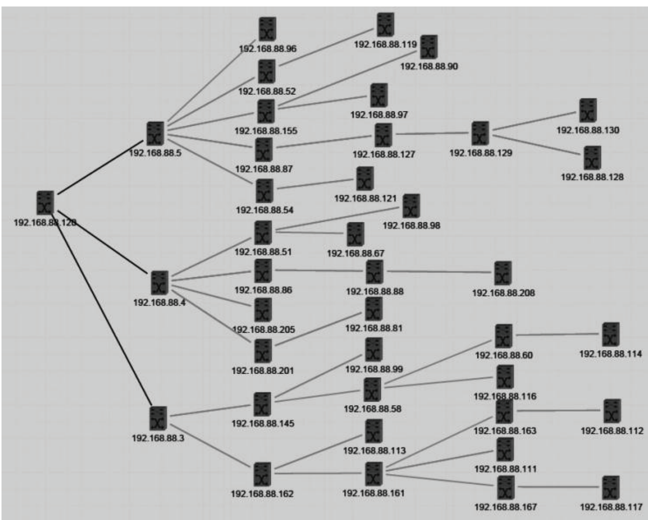

Figure 3. The subnet topology.

Figure 2 shows that the topology result has discovered 33 effective devices, 77 links and the time of this process is 2 minutes and 40 seconds. Compared with the actual network, there two links are repeated because of the same configuration of two switches. 2 switches and 1 firewall do not support automatically discover because of shutting down SNMP service. Figure 3 show that the exchange-management domain has discovered 68 switches and 66 links. The experimental results show that this algorithm can realize the discovery of target network effectively and the port information is accurately.

V. CONCLUSION

This paper introduces a kind of network topology discovery algorithm based on SNMP which can discover the topology of target network completely and accurately through combining the topology discovery of network layer and link layer. The results can be accurate to the connection relationship between port and port and it can solve the problem of discovery on link layer switches. But there are many different manufactures and kinds of equipment in the network, every manufacture have its own support on SNMP. The impactive of heterogeneity problem at topology discovery is what we should carry on next.

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