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Improvement and implementation of Wireless Network Topology System based on SNMP protocol for router equipment

Hao Wang

Department of Experiment and Equipment Administration, Qufu Normal University, Rizhao 276826, China

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ABSTRACT

With the continuous expansion of computer network scale and the diversity of network equipment, the traditional single computer network maintenance and management method is no longer applicable. Therefore, in order to achieve efficient and accurate management of computer networks and ensure the stable operation of computer networks in various applications, computer network management software with superior performance and corresponding topology discovery technology become the key. In this paper, SNMP (Simple Network Management Protocol) network topology discovery algorithm is deeply analyzed in the laboratory computer network environment, and its shortcomings are pointed out. In view of the shortcomings of traditional SNMP algorithm, this algorithm is optimized and improved, and helps ICMP (Internet Control Message Protocol) detect the internal subnet, so as to discover the main network topology accurately and efficiently. In order to solve the heterogeneity of information storage modes in MIB (Management Information Base) libraries of different devices in laboratory network environment, this paper innovatively adds an optimized SNMP algorithm aiming at the heterogeneity of network devices, thus realizing the universality of network topology. Finally, the experiments show that the time dissipation of the proposed algorithm is less than 10 data points compared with the traditional algorithm under the same experimental conditions. The laboratory network environment based on the proposed system can achieve a fast and smooth laboratory network, which has obvious advantages compared with the traditional network management system.

1. Introduction

The rapid development of computer technology and network technology makes the network management and maintenance mode of traditional single-computer computer no longer applicable [1–3]. According to the continuous expansion of the current network scale, the diversity, heterogeneity and security brought by complex networks become the key and focus of new network management technology. The core technology of network management is to discover the main network topology structure in the network environment, which can realize the visual display of network operation, thus facilitating network managers to locate network faults accurately and quickly. However, the traditional computer network management technology is still inefficient and cannot solve the problem of heterogeneity of network equipment. Therefore, accurate and efficient computer network management technology has become an important research direction of computer network management. At the same time, solving the heterogeneity of computer network has become the top priority in its direction [4–6].

In order to achieve accurate and efficient management of large-scale computer networks, a large number of scholars and research institutions have carried out research and Analysis on them. American scholar [7] has proposed Mercator algorithm based on ICMP, which mainly uses the universality of the algorithm to discover the network layer topology, but this algorithm is still in the preliminary stage. When the scale of computer network is further expanded, its function is almost zero. Similar to Mercator algorithm, related scholars [8] proposed CNRG algorithm inspired by it. It starts with BGP (Border Gateway Protocol) routing information, and gradually finds routers in each domain and merges them. However, this algorithm is inefficient in the actual operation process. Cornell University and University of Southern California [9,10] propose a network layer discovery method based on SNMP. This method mainly collects MIB information base of network equipment to further extract network topology. However, traditional SNMP network management technology has no good effect on solving the problem of heterogeneity of device connection. Scholar Zhang C and Weng Y et al. [11,12] proposed an algorithm combining ICMP with SNMP, which is mainly based on the combination of active detection and passive detection. Corresponding computer technology companies such as Cisco, IBM and HP [12–16] have also developed their own computer network management technology, which has achieved certain results in different fields.

E-mail address: wanghao@qfnu.edu.cn.

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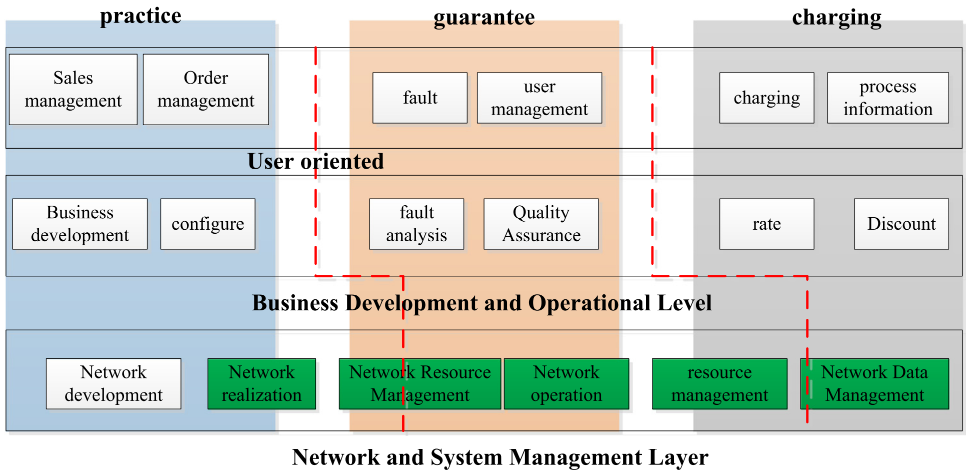

Fig. 1. Network management platform model of laboratory network topology.

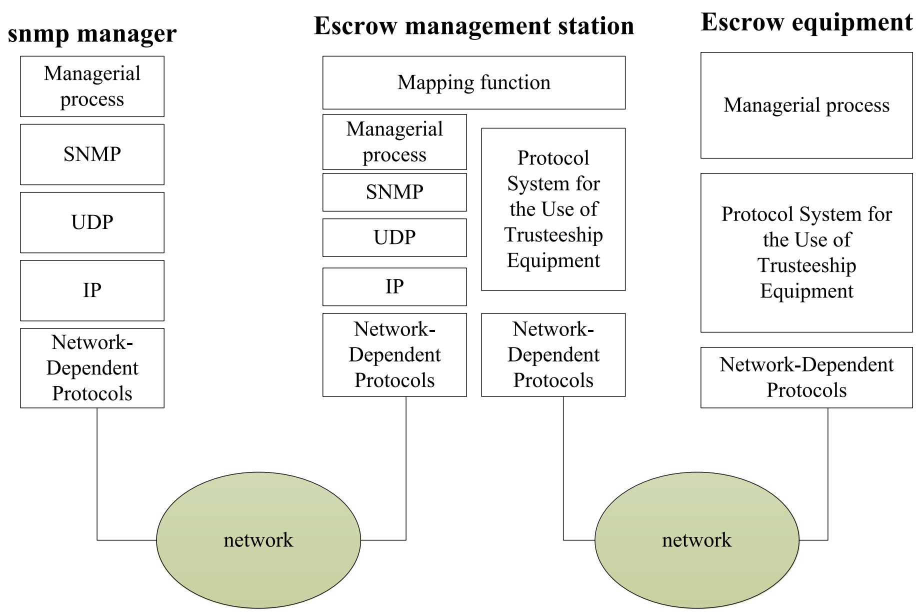

Fig. 2. The protocol hierarchy and structure of the network management protocol used in this paper.

Through the above analysis of the current research background and status, in order to further solve the problems of computer network management, this paper proposes an optimization algorithm of network topology system based on SNMP. In this paper, based on the laboratory computer network environment, the network topology discovery algorithm of SNMP is deeply analyzed and its shortcomings are pointed out. According to the shortcomings of traditional SNMP algorithm, this paper optimizes and improves the algorithm, and assists ICMP to detect the sub-net interior, so as to discover the main topology of computer network accurately and efficiently. In order to deal with the heterogeneity of information storage modes in MIB libraries of different devices in laboratory network environment, this paper adds an algorithm to optimize SNMP algorithm to deal with the heterogeneity of network devices, thus realizing the universality of network topology discovery algorithm. Finally, the experiment shows that the laboratory network environment based on the system proposed in this paper can achieve fast and smooth laboratory network, which has obvious advantages over traditional network management system.

This paper makes the following arrangements on the structure of the article: Section 2 of this paper will specifically study and build the overall system based on network topology discovery in the laboratory, mainly involving the corresponding hardware framework and interface design; Section 3 of this paper will specifically analyze and study the optimized SNMP network management technology, mainly involving the algorithm optimization and the solution algorithm of heterogeneous problems; Section 4 of this paper is mainly the whole. The realization of the system and system testing; finally, a summary of this paper will be made.

2. Overall design of laboratory network topology

This section will mainly analyze the overall design of the network topology structure of the laboratory, which involves the overall framework of the network management system of the laboratory and the interface design and analysis of the corresponding network topology discovery.

2.1. Overall architecture design of laboratory network management system

The overall architecture of the laboratory network management system is designed in this paper. The main network management architecture used in the actual system design is four-tier network architecture. The corresponding four-tier structure is as follows:

A. Network management platform. It mainly carries on the intelligent management to the network, its management scope includes the equipment quantity, the equipment performance analysis. At the same time, the platform also realizes the corresponding fault management and resource management, realizes the data sharing between the network layer and the layer, and grasps the operation of the whole network. The model selected at this level in this paper is shown in Fig. 1.

B. Network technology protocol. It is the core of the network management system. The network protocol used in this paper is SNMP network protocol, which has the advantages of high management level, high service quality and low operation cost. The SNMP used in this paper is composed of a large number of rules, protocols and related data structures. Its main components can be divided into three parts: the corresponding management information structure SMI, the management protocol SNMP and the corresponding management information base MIB. The corresponding SMI defines the framework and organization identification of the whole network management system, the corresponding MIB defines the set of management objects accessed through the network management protocol, and the SNMP defines the relevant application layer concretely. Agreement. As shown in Fig. 2, the protocol hierarchy and structure of the network management protocol used in this paper, in which the communication between the corresponding SNMP manager and agent is mainly based on the connectionless user datagram protocol for information transmission. The corresponding message format in SNMP transmission follows the SNMPv2 version. The corresponding SNMP message encoding is mainly expressed in abstract grammar. The standard adopted in this paper is ASN.1 standard. In terms of message delivery and reception, UDP (User Datagram Protocol) is used as the fourth layer protocol of SNMP communication to realize connectionless operation. Its main operation flow is: first, receiving the request sent by SNMP information, then converting the request into internal data format, then mapping MIB to local value, then performing the assignment and value operation of the request, and finally, re-formatting the corresponding data format. Convert it to an external format and send it out.

The core protocol SNMP in the above network management protocol is mainly divided into three parts: the SNMP managed device, the SNMP manager and the corresponding SNMP proxy device. The corresponding protocol environment diagram is shown in Fig. 3. From the diagram, it can be seen that the managed device is a node in the whole network, which is called network unit. Its corresponding specific devices are mainly routers, switches and bridges.

C. Network management interface XML. It mainly converts the topology information collected by the topology management system into corresponding XML documents, and integrates the information into a form which is beneficial to program reading and transfers it to the network management system.

D. Data communication network. It mainly realizes the transmission of network management information between managed equipment and network management system. It is mainly composed of switches and network lines.

2.2. Interface design of network topology discovery in laboratory

In this paper, SNMP and XML network management interfaces are mainly used in the experimental interface part. The corresponding managed network device interfaces are divided into three parts. The corresponding contents are as follows:

A. MIB library interface It is mainly used to store the collected real-time laboratory network management data and the configuration of network management data. In the actual laboratory MIB library, the network data related to the topology mainly exists in the table of interface.

B. UDP Lab Network Communication Interface: It is mainly responsible for receiving the configuration of external network management, viewing the network data management information commands of equipment network, and decoding the management PDU sent by the corresponding Manager. In addition, the interface also needs to encode the corresponding network management data with SNMP PDU and send it to the external gateway.

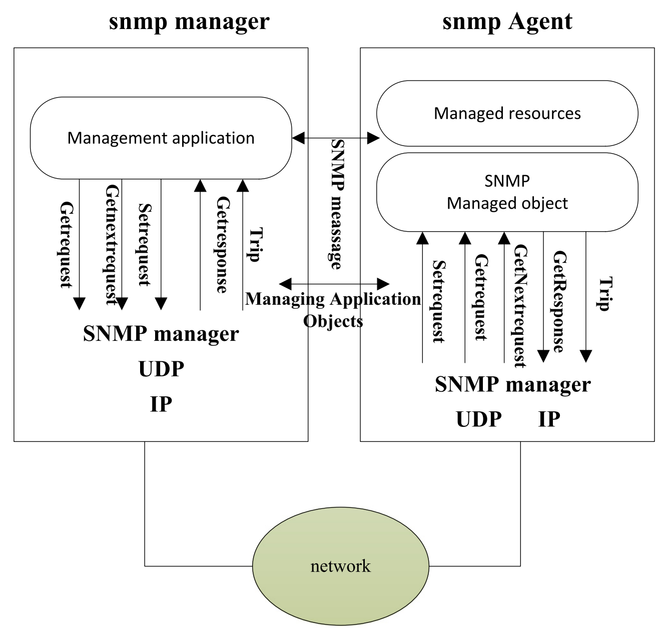

Fig. 3. NMP network protocol structure diagram.

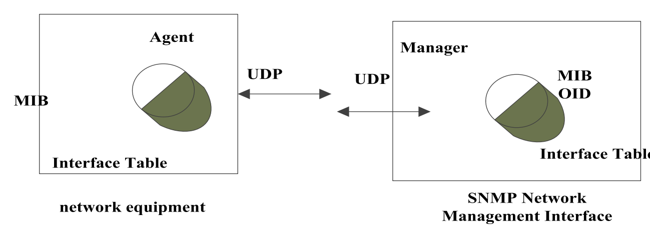

Fig. 4. Managed network interface architecture and management station system interface architecture.

Table 1
Objects in interface tables in MIB databases.

Object	Syntax	Access	Description
ifNumber	INTEGER	RO	numbers
ifTable	SEQUENCE OF ifEntry	NA	lists
ifEntry	SEQUENCE	NA	lists
ifIndex	INTEGER	RO	value
ifDescr	Display String	RO	information
ifType	INTEGER	RO	types

C. Corresponding Agent Data Interface: It is mainly responsible for setting and collecting network data, putting the data system into MIB database, and executing the received commands of the external network management system.

The corresponding managed network interface architecture and the management station system interface architecture are shown in Fig. 4.

In Fig. 4, the interface design of the corresponding network topology management system of the whole laboratory mainly includes the following four levels of interface, and the corresponding details are as follows:

(1) **OID (Object Identifier) tree in MIB database:** This library is a global library, which mainly stores and manages all the devices in the laboratory Internet environment, and finally stores the global OID of all managed devices in the form of a tree. Its main

Table 2
PDU Types of Laboratory Network Management System.

Types of PDU	Examples
0	Get request
1	Get next request
2	Set request
3	Set require
4	Trap

function is interface OID data table. The corresponding objects in the interface data table are shown in Table 1.

(2) **UDP network data communication interface:** It mainly carries on SNMP PDU coding processing to the Manager's network management command, and forwards the Manager's network management command to the network object agent. At the same time, it receives the network management information from the managed network equipment, and decodes the corresponding SNMP PDU.

(3) **Manager:** It mainly implements the topology management function of the whole laboratory system, and sends out the corresponding commands of topology data acquisition, and decodes, stores and collates the collected topology data.

(4) **XML interface:** It is mainly used to facilitate the reading and writing of programs in network system. It can realize the information integration of applications across platforms. The corresponding programs of network devices can achieve fast loading and data analysis. In this paper, the laboratory network management system mainly uses MySQL database to convert the corresponding data into XML format and output it. The XML interface mainly plays an image display function of network topology structure in the whole laboratory network management system. It can call the network topology information in the database, then integrate it and send the data in XML format to the UI module of the network management system for further processing.

3. Optimum design of laboratory network topology algorithm based on SNMP

This section will mainly analyze and discuss the optimization module of the laboratory network topology discovery algorithm and the solution to the heterogeneity problem. In the optimization module, it mainly involves the improvement of data acquisition mode of laboratory network system, the improvement of IP address processing mode of router, the improvement of system topology level and the improvement of three-layer switch.

3.1. Optimization of lab network topology discovery algorithms

In order to further optimize the laboratory network topology discovery system, this section will optimize and improve it according to the disadvantages of traditional algorithms in four aspects: the improvement of data acquisition mode of laboratory network system, the improvement of router IP address processing mode, the improvement of system topology level and the improvement of three-layer switch.

3.1.1. Improvement of data acquisition method in laboratory network system

As shown in Fig. 5, the message format of SNMP used in this paper is composed of three parts: SNMP header, Get/Set header or Trap header and corresponding variable binding.

In this message format, the corresponding PDU type corresponds to the Table 2.

From the above message information, we can see that the inefficiency of the corresponding traditional laboratory network management system is mainly due to the structure of the traditional message format. Specific analysis is as follows:

In fact, for the whole topology discovery system, reducing additional network traffic and improving the speed of network topology discovery are the key to improve the efficiency of the whole experimental network. One of the main constraints to improve the speed of network discovery is the speed of data acquisition in laboratory network. Essentially, the fundamental method to solve the speed of network data acquisition is the command of data acquisition related to SNMP messages. From the above message, it can be seen that in traditional SNMP, when MIB data acquisition is carried out, the data acquisition request of Getnext needs to be sent continuously to complete the data acquisition work, which makes the whole data acquisition efficiency extremely low and increases the additional flow of the whole system. In order to improve the above problems, this paper introduces GetBulkrequest message operation command in data acquisition, and its corresponding PDU format is shown in Formulas (1) and (2). The core of this command is that it can acquire successive variable values of multiple variables in the binding list continuously. At the same time, it can detect a large amount of data by one-time binding, which greatly improves the efficiency of the operating system and reduces the additional traffic.

$$PDUType, \text{Request-}id, Non\text{-}repeated, \max\text{-}repetitions, Variable\text{-}bindings \tag{1}$$

$$OidName\text{-}1, OidValue\text{-}1, OidName\text{-}2, OidValue\text{-}2, \ldots \tag{2}$$

In the above formula, the first two fields of Getbulk's message replace the err-status and err-index fields of the original traditional message. At the same time, n in the no-repeaters in the new message represents that the first n variables in the variable binding list are each performed a Getnext operation, and the next variable is returned. If no next variable is found, the original variable is returned. The remaining variables perform the mth Getnext loop defined by the max-repetitions value. The corresponding operational formulas are shown in Formulas (3)–(6).

$$non\text{-}repeaters \rightarrow n \rightarrow Getnext \tag{3}$$

$$\begin{aligned} &non\text{-}repeaters \rightarrow error\text{-}status \\ &\max\text{-}repetitions \rightarrow error\text{-}index \end{aligned} \tag{4}$$

$$non\text{-}repeaters \rightarrow N \rightarrow endOfMibview \tag{5}$$

$$\max\text{-}repetitions \rightarrow m \rightarrow m(GetNext) \tag{6}$$

3.1.2. Improvement of router IP address processing

In the laboratory network management system, the corresponding router is a multi-port device, which has many IP addresses. Therefore, if the new IP address of the router cannot be effectively judged in the traditional network topology discovery system, it will cause the system to misjudge the topology structure, which will also cause a lot of time waste. In traditional systems, different addresses in iprouteTable are usually processed and represented by iproutenexthop. Considering that variables in MIB database will provide the current IP address of network data, the corresponding ipAddrtable corresponds to each behavior ipAddrentry, which corresponds to the address information of the corresponding interface. The corresponding expression of address interface and address information is shown in Formula (7).

$$ipAddrTable \rightarrow MIB \rightarrow ipAddrEntry \tag{7}$$

Based on the above analysis, the laboratory network management system in this paper has been optimized and improved on the router IP address. Firstly, it traverses all the IP addresses in the ipAddrTable, and then matches the IP address of the subsequent router with the current IP address library, so as to further confirm whether the currently discovered router address is the newly discovered router address, and

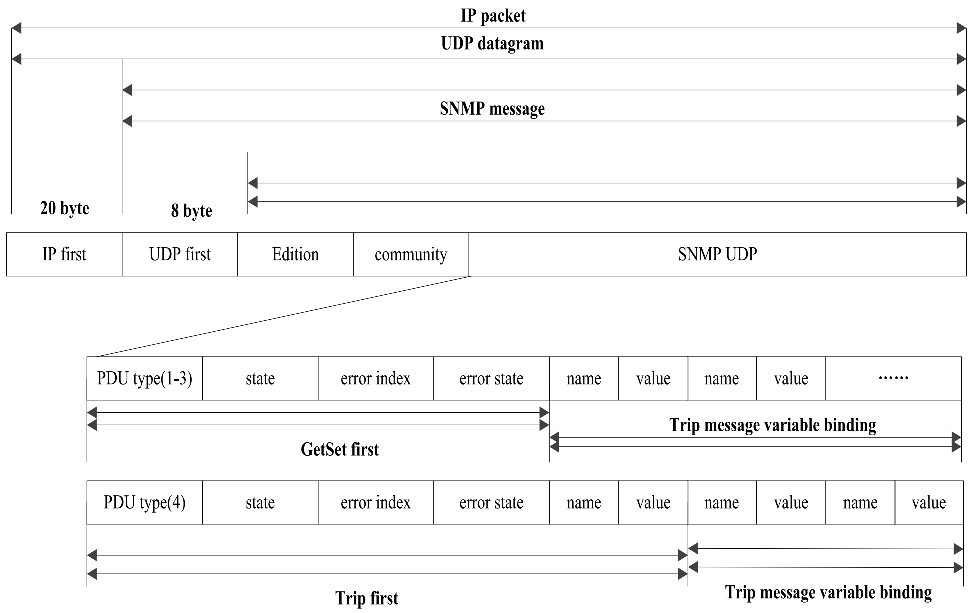

Fig. 5. SNMP message format of laboratory network management system.

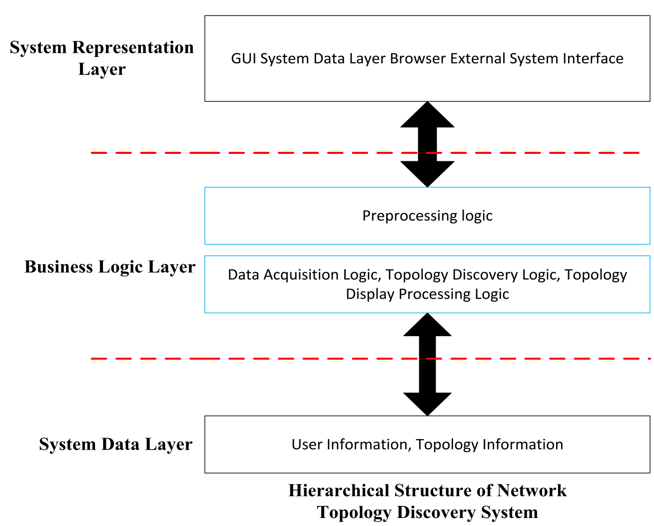

Fig. 6. Lab network management system topology hierarchy diagram.

then judge whether the router is a new router address. Whether it is a newly discovered router or not, the problem of multi-address of router is finally solved.

3.1.3. Improvement of system topology level

In this paper, we abandon the traditional topological level in the system topological level and adopt a simpler topological structure. The corresponding topological structure is shown in Fig. 6. From the graph, we can see that the corresponding topological level is divided into three layers, namely, the system presentation layer, the business logic layer and the system data layer. In the system presentation layer, the functions of data management, data query and monitoring management are mainly included. The core technology of the system is GUI and other technologies. Business logic layer is the core of the system, which mainly includes network topology discovery, data acquisition logic, topology display logic and other functions. The data layer of the system mainly contains all the data information found by the system, including data acquisition information and user rule permission files.

The corresponding system topological structure design diagram is shown in Fig. 7.

3.1.4. Optimal improvement of layer 3 switches

The traditional network management system has the phenomenon of information loss in the three-layer switch technology. This paper makes the following improvements and optimizations for this purpose:

When the system completes each inspection of the current device, it immediately resolves all the IP addresses in the ARP table, including the IP addresses of other routing devices connected to the routing device and the IP addresses of active hosts in the direct subnet. The corresponding OIDs are 1.3.6.1.2.1.4.22.1.1, respectively. Then the ifnumbei of these devices corresponding to the IP address is judged. When ifnumber >2, the corresponding device is the routing device. The corresponding expression formula is shown in Formula (8).

$$ifnumber \rightarrow OID(1.3.6.1.2.1.4.22.1.1) > 2 \rightarrow \text{Router equipment} \tag{8}$$

3.2. Solution of heterogeneity problem in lab network topology discovery

In order to solve the problem of heterogeneous network discovery in laboratory network management system, this paper proposes a heterogeneous processing module for network topology discovery, which is mainly used as the core component of network layer and link layer calls. It is mainly responsible for discovering the topological information of different vendors and types of network devices in heterogeneous network environment. When optimizing the heterogeneous processing module in practice, the main idea of the algorithm is as follows:

1. Create a separate ArrayList object for various vendor devices that have been analyzed and processed

2. Define the corresponding OIDArrayList, which is used to store the MIB data information group of each manufacturer to provide program calls for topology discovery

3. Use the value of OID to get the required information

4. If the required topological information does not exist under the standard OID node or the information under the node is incomplete, the SysObjectID of the device and the identification of the device private OID node are needed to determine the type of device manufacturer.

5. Through the above steps, we can obtain the most network device topology information, otherwise we need separate analysis and processing.

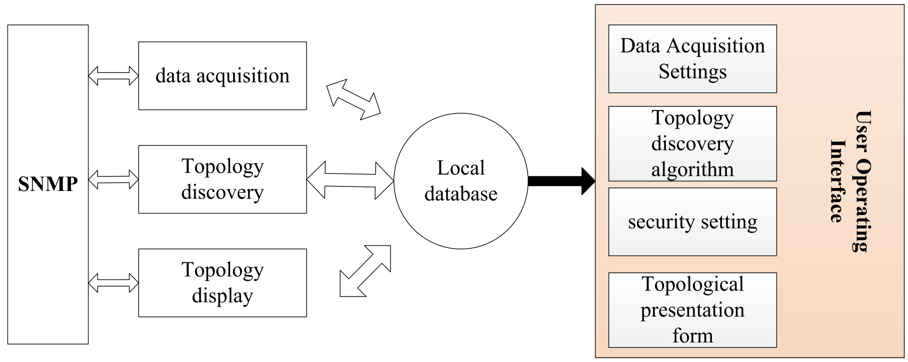

Fig. 7. Topology structure design of laboratory network management system.

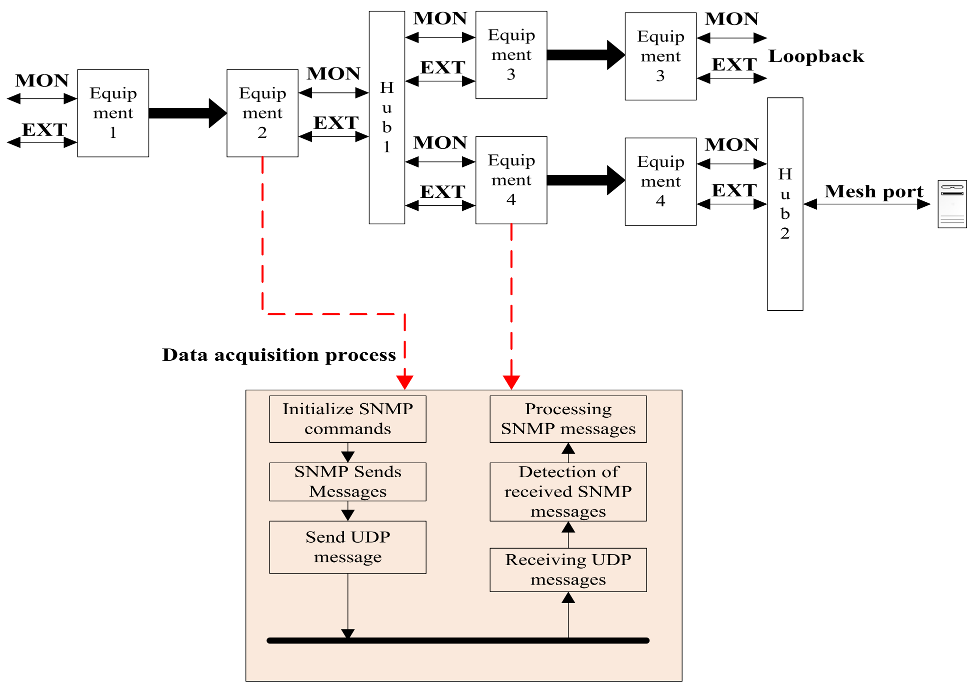

Fig. 8. The architecture of laboratory network management system proposed in this paper.

4. System implementation and system test analysis

Based on the analysis and research of the third section above, this section will design and test the software of the laboratory network management system and compare it with the traditional network management system in recognition speed and accuracy.

First of all, the laboratory network management system in this paper is mainly based on Borland Developer Studio 2006 platform. The computer language used is Pascal language and assists the development of software with Microsoft database. The corresponding network architecture of the whole system is shown in Fig. 8.

According to the system architecture diagram, the corresponding algorithm flow chart based on SNMP is shown in Fig. 9.

Start the whole system first, then read and analyze the network LSA (Link-State Advertisement), and judge and classify the network type during this period. When the network is judged as the path LSA, four classification algorithms should be carried out and integrated into the SNMP algorithm for processing and analysis, and finally complete the algorithm.

Based on the above architecture and flow chart, this paper will verify the superiority of the system based on the above experimental environment. Fig. 10 shows a comparison of the TCP (Transmission Control Protocol) information obtained by the two algorithms and the speed required to obtain the information. From the graph, we can see that the TCP information obtained by the proposed algorithm is more detailed and comprehensive, which involves the UDP protocol network packet volume, traffic, false guarantee and packet loss information. At the same time, compared with the traditional system, the proposed algorithm can obtain more TCP information at the same time faster than the traditional system for the same network environment.

Fig. 11 shows the UDP information comparison between the proposed scheme and the traditional one. From the figure, we can see that the proposed system can get more data packet connection failure information, security gateway error reporting and failure information than the traditional system. At the same time, we can also see the corresponding TCP error information. Similarly, it is found that in the same network environment, the network management system proposed in this paper is faster than the traditional system to obtain information.

Fig. 12 shows a comparison of trip information between the proposed scheme and the traditional one. From the figure, we can see that in the same network environment, the network management system proposed in this paper is faster than the traditional system to obtain information.

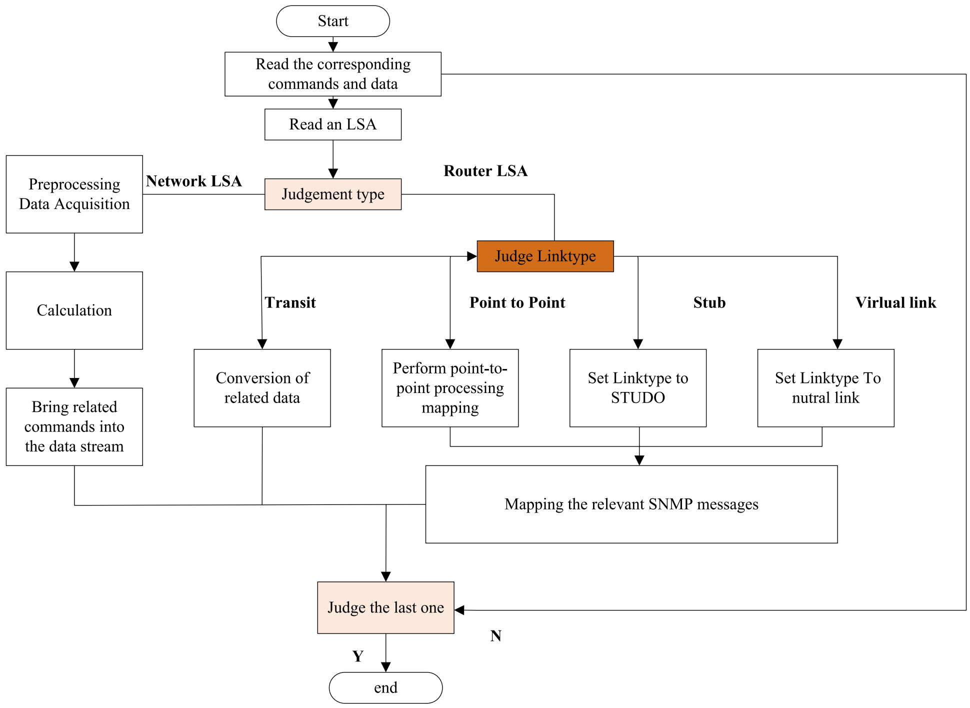

Fig. 9. The algorithm flow chart of laboratory network management system proposed in this paper.

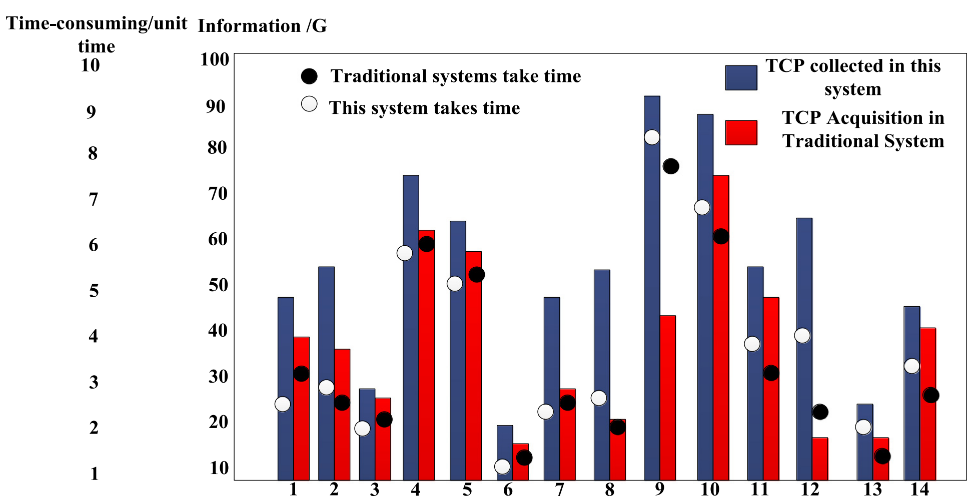

Fig. 10. Comparisons between two schemes for TCP information acquisition.

In order to facilitate the reproducibility of the experiment, the experimental code based on the laboratory data platform is given as shown in Fig. 13.

5. Conclusion

This paper mainly analyzes the drawbacks of the current traditional computer network management system, and puts forward an optimization solution for the corresponding drawbacks, which involves the improvement of the data acquisition mode of the laboratory network system, the improvement of the router's IP address processing mode, the improvement of the system's topology level and the improvement of the three-tier switch. In order to solve the problem of heterogeneity in laboratory network management, this paper also innovatively proposes a module to solve the problem of heterogeneity. In order to further verify the superiority of the computer network management system proposed in this paper, based on the same network environment, this paper proposes to compare it with the traditional computer network management system. The test results show that the computer network management system proposed in this paper has obvious advantages. In the latter part of this paper, we will focus on the application of algorithms in LANS (Local Area Network Server), and point out the corresponding risk assessment.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

CRediT authorship contribution statement

Hao Wang: Writing - original draft.

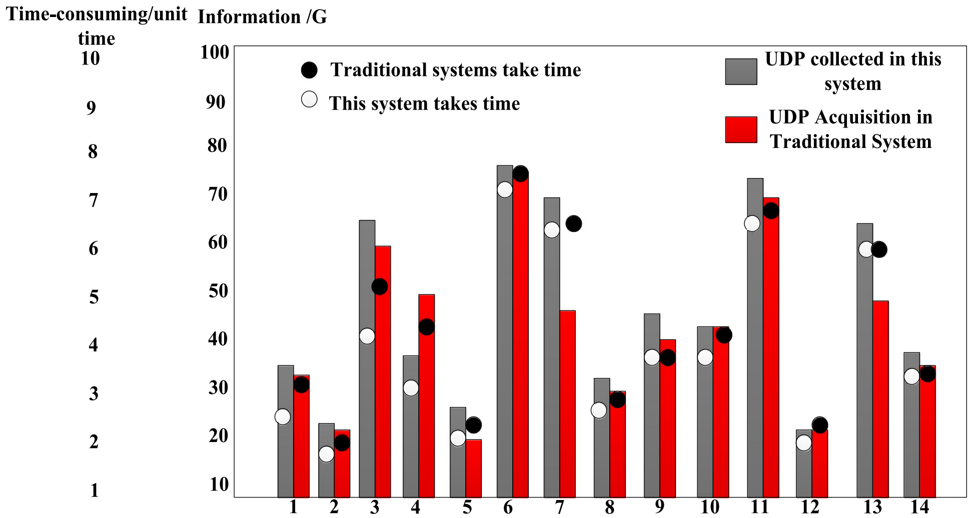

Fig. 11. Comparisons of UDP information acquisition for two schemes.

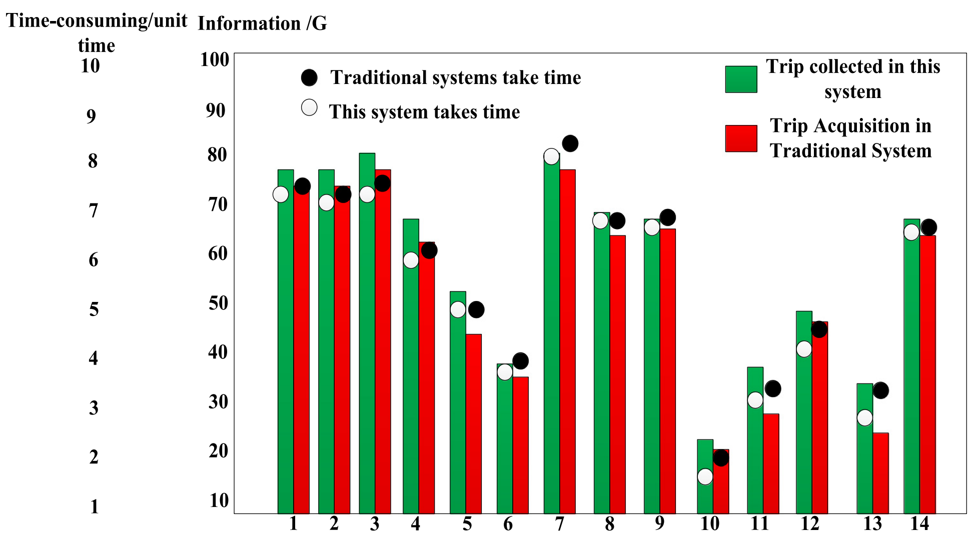

Fig. 12. Trip information acquisition comparison polygraph of two schemes.

```
Initializes the class weight factor. For example: 1.36 = 1/73.63%.
The final category weight factor restores the original distribution.
   Balanced_ratio: Balanced ratio, which gradually returns to the original distribution as iterations
increase.
 Number of cycles.
Maximum cycle.
  Current weight factor.
-------------------------------------------------------------------
  Balaanced_weights: [1.36, 14.37, 6.63, 40.23, 49.6]    // / Initialize the weight factor.
  Count: 0                                               // initialization iteration is 0.
  While count < max_epoch
      Alpha: balanced_ratio//
      Class_weight: balanced_weight*alpha/final_balanced_weight
      Count: count + 1                                   // Next cycle
      Prepare_train_data (class_weight)                  // Initialize the data according to the weight
factor.
      Train ()                                           // for the next round of training

  End while
```

Fig. 13. The code of laboratory part based on laboratory data platform.

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Hao Wang was born in 1980 in Shandong, China. He graduated from Qufu normal university with a bachelor's degree in 2005 and a master's degree in 2011. Since 2005, he has been teaching in Qufu normal university. Published 5 papers on laboratory construction and management. E-mail: wanghao@qfnu.edu.cn.