Innovative Design and Implementation of New Practical Teaching Methods for Network Management Majors Comprehensively Using Multiple Virtualization Technologies

Ruifeng Yu[1] Jingna Cui[2] Wenhua Bai[3] Dezhi Niu[4] Jin Zhang[5]

[1,2,3,4,5] *College of Information and Communication, National University of Defense Technology, Wuhan, Hubei 430000, China*
[1] *Corresponding author. Email: yuruifeng123@nudt.edu.cn*

ABSTRACT
Network management majors mainly focus on practical teaching, and in the implementation of teaching, the requirements for the experimental environment of the computer room are high, the construction of teaching conditions directly affect the teaching effect, and the improvement of teaching methods under fixed teaching conditions can significantly improve the quality of teaching. The paper will address the current problems in the teaching of network management majors, with SNMP technology as the core, together with the use of VMware, eNSP, cloud desktop and other professional virtualization tools, to put forward a teaching method innovation design and practice application, so as to provide effective reference and basis for the actual relevant professional higher education and vocational education teaching staff.

Keywords: *Computer network management, Virtualization technology, Teaching method innovation.*

1. INTRODUCTION

In the context of rapid development of Internet technology, high growth of user base, rapid expansion of network scale, and birth of more kinds of network services, network management technology is also developing [1]. Network management-related majors or "network management and maintenance" majors have been established in institutions of higher learning one after another. Some of the courses in this major are also reflected in the network engineering major of the undergraduates and the cyberspace security major of the postgraduates. The study of network management professional courses has realistic teaching significance and meets the social employment demand. Currently, the professional courses of network management mainly contain "Computer Network", "Routing and Switching Technology", "Server Building Configuration and Management", "Computer Network Security", "Network Performance Testing", etc., and the teaching goal of the major is to train students with the professional ability to use network management tools, which can be used to discover abnormal network events, analyze network security risks and develop network security strategies [2]. The paper will take the vocational education network management and maintenance major of College of Information and Communication as an example, combine years of the teaching and teaching reform experience of network management teaching group, use a variety of virtualization technology integrated application to network management major practice teaching, and propose a teaching method innovation design and practice application, to solve the existing problems in current teaching, provide effective reference and basis for higher education and vocational education teaching staff of related majors in laboratory condition construction and teaching method innovation, and also provide reference ideas for the reform of teaching mode of next generation SDN network management majors.

2. PROBLEMS IN THE CURRENT NETWORK MANAGEMENT TEACHING

The network management majors mainly focus on practical teaching, which requires complex work such as managing a large number of routing and switching devices, simulating comprehensive networking relations, deploying and using network management systems, monitoring network operation status in real time, discovering abnormal network events, and formulating network security strategies in the teaching process. Therefore, the requirements for the experimental environment of the computer room are strict[3]. At present, the environment of the computer room of institutions of higher learning network management majors is basically fixed at the beginning of construction, and the computer network management structure is generally based on SNMP network management model with three main elements of manager-protocol-agent[4]. In the construction of traditional teaching conditions, a server will be built in the laboratory and the network management system will be assembled as the manager and a certain number of routers and switches will be used as managed devices to start the agent[5], and then specific management operations will be carried out on the real equipment and related teaching. However, the above-mentioned laboratory teaching environments all have several problems of difficult to guarantee teaching equipment and difficult to improve teaching effect, which are reflected as follows:

- High construction cost of computer room environment, long application transformation cycle, and slow update of existing equipment software and hardware;
- Average scale of deployable network topology connection relation, poor expansion ability, poor flexible networking ability and average teaching effect;
- Short hands-on time for students alone on the computer, generating the problem of many misoperations affecting the physical network environment, and network failures due to student operations may require a large number of classroom teaching hours, making teaching inefficient;
- The average cost of the advanced network management system is more than 100,000-300,000 yuan and the number of manageable nodes is limited, so it is difficult to guarantee the use of each student; when teaching, the network management system account is usually assigned to multiple students. Although this can guarantee students to experience the network management process at the same time, but students will interact with each other when operating on the computer, and lagging will occur in batch experiments, which is more dependent on server performance;
- The management operation records of students in different classes are stored centrally on the server where the network management station is located, which is not conducive to each student's calling data individually, analyzing and learning;
- Because there is only one network management station node, it is impossible to simulate a decentralized and hierarchical distributed network management structure.

Through the innovation of teaching methods of virtualization technology, it can realize single student for single computer, providing a smooth and stable experimental environment and reducing the use and maintenance costs. At the same time, the paper combines cloud desktop technology with virtualization technology to deploy the tools needed for classes to each PC in batches, and store the experiments done by students in different classes and by the same student in each class as snapshots in the form of time slices, thus well avoiding problems such as the loss of experimental data. What's more, individual students can study in groups with each other and experiments can be managed in a decentralized and hierarchical network within and between groups.

3. PROJECT DESIGN

3.1 Theory Basis and Design Ideas

At present, virtualization technologies can be broadly divided into three categories: virtual server, virtual desktop and virtual network technology. A virtual server is to virtually multiplex existing fixed number of physical servers into multiple servers using virtualization tools while fully utilizing their performance resources[6]. Most of the virtual desktop technologies use B/S remote access to do the functional computing and storage in the cloud. A virtual network technology is the interconnection between two and more real machines and virtual devices using a bridge protocol or software access without physical direct connection. These three virtualization technologies have been widely used

in enterprises and colleges and universities, initially realizing self-device office, remote office, mobile office, etc., which greatly improves work efficiency. Among them, for example, the famous VMware (server virtualization) as well as the Chinese Vesystem Next Generation Cloud Desktop (desktop virtualization) and Huawei Simulation Platform eNSP (network router virtualization) have been relatively mature and widely used. The paper will combine several virtualization tools in the above introduction to conduct comprehensive experiments.

This paper integrates both the manager and managed devices in the SNMP network management model into the local PC of individual students, while each PC is interconnected under the same switch, which ensures that the managed networks among individual students are relatively independent when being operated individually, and can be connected at any time when collaboration is needed. After connecting the virtual network to the real device through eNSP's cloud bridge function on the local PC, the teaching staff can use static route, ospf and other network protocols to expand the configuration of the virtual local area network in the virtual network built by eNSP to form a larger managed network according to the students' ability and class needs. At the same time, a VMware virtual machine is assembled in the local PC, a server system is installed in the virtual machine, then a network management station is deployed in the server system, and the virtual machine uses the bridge mode to allow the network management station to be connected to the local PC[7]. The network management station can then manage both the virtual devices independently and multiple small virtual local area networks, and analyze and study the performance indicators in the network. Then the network model among "manager-SNMP-agent" can be presented at the local PC, while the local PCs between students are connected to the same switch, constituting a relatively independent and interconnected large local campus network. As shown in "Figure 1", a schematic diagram of the simulation network topology of a single device is presented, where from right to left are:

- Assembling the network management station in Vmware, and using the virtual NIC bridge mode to connect local PC for network function configuration; this experiment uses VMware tool to install Server2008 operating system and H3C iMC (DEMO), an intelligent network management station from H3C;
- Referring related hardware performance indicators for student PC host: CPU i5 10th generation, RAM 16G, SSD 512G;
- Managed device R1, one listed here, can be extended according to the number of laboratory PC performance, virtually simulated by Huawei simulator eNSP; the use of the bridge function within the software can connect the virtual router R1 and its expansion devices with local PC.

Through the virtualization transformation of the above teaching methods, students can achieve the goals of flexible and rapid networking, batch deployment of network management systems, and interference-free independent work during the class, which basically solves the 6 problems in the current network management teaching as pointed out in the paper, and also provides a platform basis for the reform of the professional teaching mode of next-generation SDN network management.

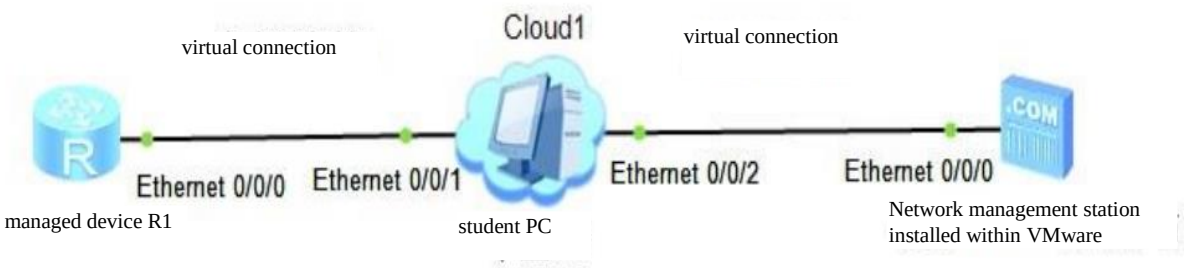

Figure 1 Schematic diagram of the simulation connection in a single local PC.

3.2 Experimental Content

Teaching staff can use a variety of virtualization tools to simulate a small network on a local PC, and then manage the virtual network with a network management station in a virtual server on the local PC. After multiple PC devices interconnect, they have the ability to build a campus-level simulation network, and each virtual device can be interconnected with the support of network protocols[8].

- Interconnection between the virtual server and the managed virtual router, using the network management station to add and manage the virtual network devices;
- Generating connection relations for virtual networks and allowing management of their topology;
- Monitoring performance indicators of on-net devices;
- Analyzing and processing the generated alarm faults by observing and recording the network status;

4. IMPLEMENTATION STEPS

4.1 Assigning Addresses

Here, a local PC node is used as an example and the experimenter can configure and improve the IP within the same structure according to their own laboratory room network configurations.

- VMware virtual server (i.e., H3C iMC network management station location): 192.168.6.22 16
- Local PC: 192.168.5.22 16
- Virtual router R1: 192.168.5.122 16

4.2 SNMP Manager Configuration

- Installing VMware on the local PC, installing Server2008 operating system on the created virtual machine, and installing H3C iMC (DEMO) on that operating system in the next step; the virtual machine needs to allocate at least 6 cores, 4G memory, and 40G storage space. A bridge mode is used to connect to the local PC within the virtual machine.
- The local PC with VMware, H3C iMC, and eNSP installed is used as the super administrator, and then the cloud desktop tool is used to promote the release of the LAN; this experiment uses the Vesystem cloud desktop tool, and the hosts in the laboratory are in an incremental consistent state after the promotion of the release, and there may be IP address conflicts in the servers in VMware, and manual changes are required if conflicts are encountered. Here, the server address is configured as 192.168.6.22 16.

4.3 Agent Startup of Managed Devices

- (1) Using eNSP to create a virtual router, create a virtual cloud, and connect the virtual router to the local PC virtual link[9], as shown in "Figure 2".

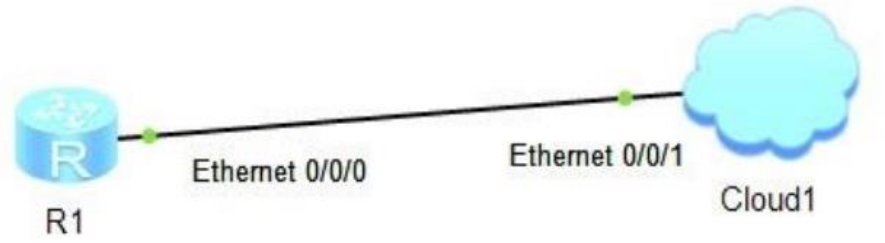

Figure 2 Local PC is connected to the virtual router.

- (2) Configuring Cloud1 to enable the local PC to establish port bi-directional channel mapping with virtual router R1 in eNSP, as shown in "Figure 3".

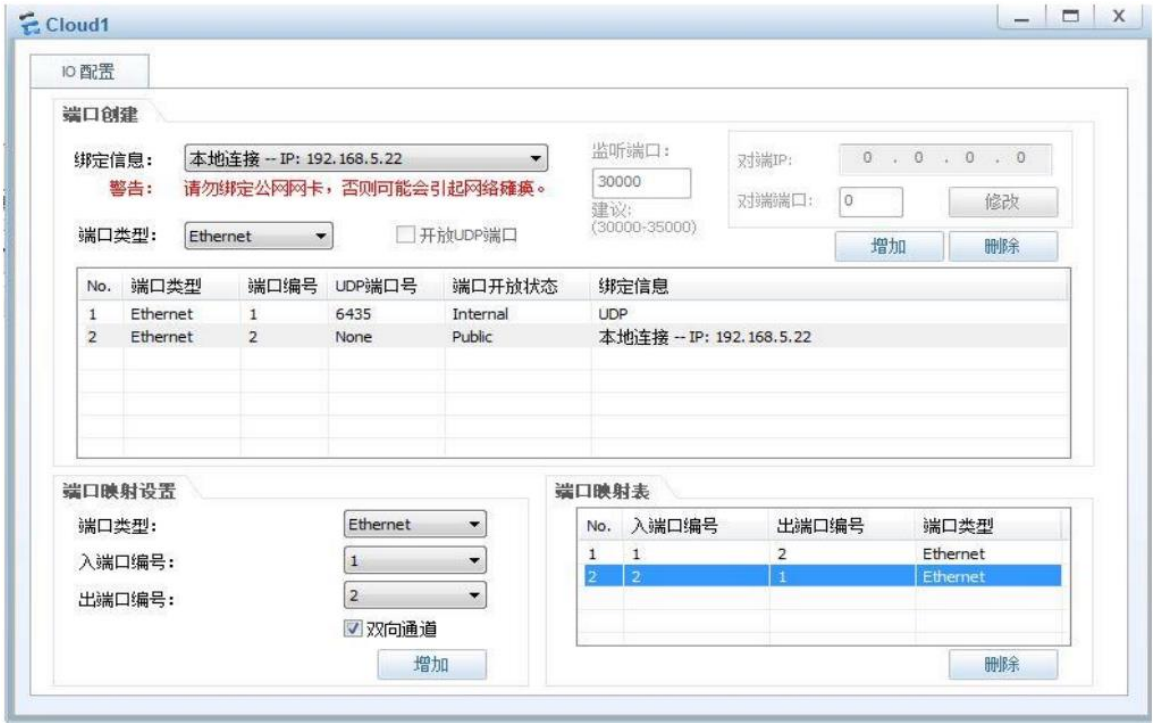

Figure 3 Cloud1 configuration parameters.

- (3) Configuring the virtual router R1 network address, and testing the connection with the host; the main command lines are as follows:

[R1]interface Ethernet0/0/0

[R1-Ethernet0/0/0]ip address 192.168.5.122 16

[R1-Ethernet0/0/0]ping 192.168.5.22

The server in Vmware performs the connection test on the local PC and virtual router R1, as shown in "Figure 4".

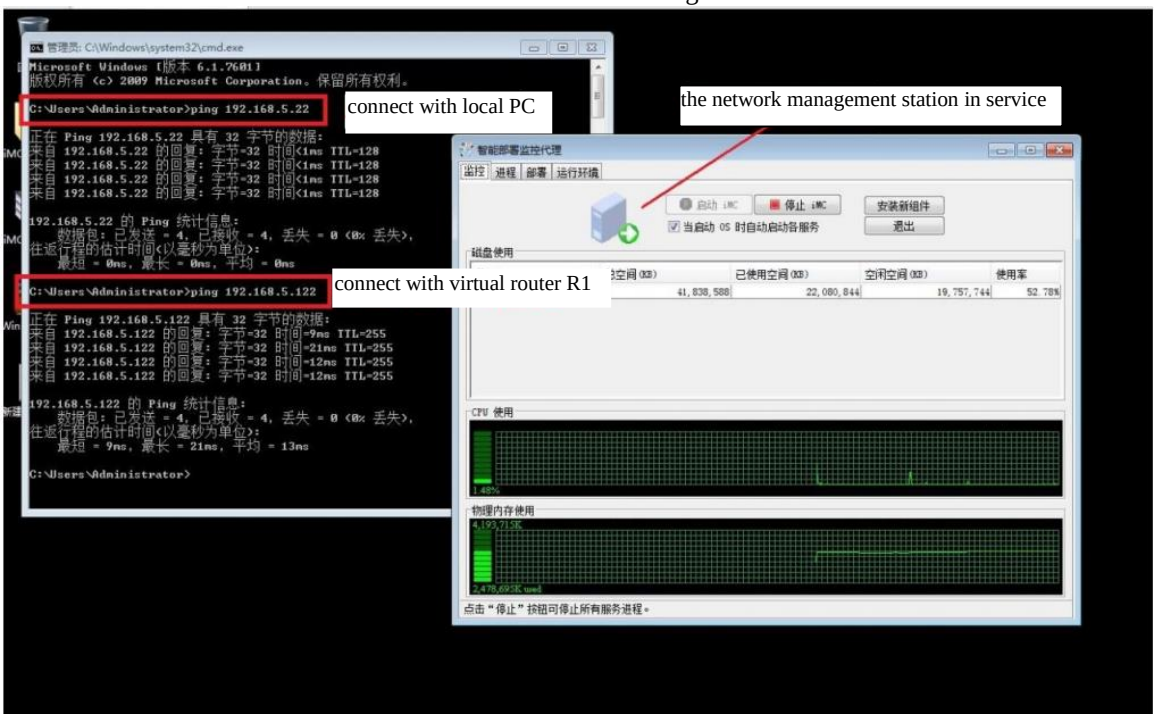

Figure 4 Server connection test between local PC and virtual router.

- (4) Starting the agent program of the virtual router R1, configuring the reading/writing of Community String, allowing the versions passed and trap to send address[10], and noting that the trap message should be sent to the network management station, i.e., 192.168.6.22; the main command lines are as follows:

[R1]snmp-agent

[R1]snmp-agent community read 123

[R1]snmp-agent community write 321

[R1]snmp-agent sys-info version all

[R1]snmp-agent target-host trap address udp-domain 192.168.6.22 params securityname 123

4.4 Network Management Using the Network Management Station

4.4.1 Adding Devices and Viewing Topology

In the local PC, the browser is used to visit http://192.168.6.22/imc:8080, open the network management station interface, and add the virtual router using the manual add device method, reading Community String 123 and writing Community String 321.After successful addition, one can manage the managed virtual device R1. At this point, other local PCs can perform the same configuration as above, and virtual routers created by other PCs in the same network segment can be searched and added in the network management station. After adding other devices successfully, one can see the virtual routers created by other local PCs after using the topology view function of the network management station, as shown in "Figure 5".

Figure 5 Other virtual routers viewable on the network management system.

4.4.2 Expandable Network Structure

When building the topology in step 4.3-(1) above, one can continue to add virtual routers at the left end of "Figure 2" and use the routing protocol to expand the connection. "Figure 6" shows the topology after the expansion of the left end of the virtual router in a PC. After connection, the

expanded virtual device is connected using the ospf protocol, with the specific address design as in "Figure 6". The connection is tested and added to the network management station, which can successfully present the topology and perform network management. The switches and PCs in the eNSP topology on the right side of "Figure 6" need to start the agent for these devices if they want to be presented in the iMC network management system, as shown in 4.3-(4), which is not repeated here.

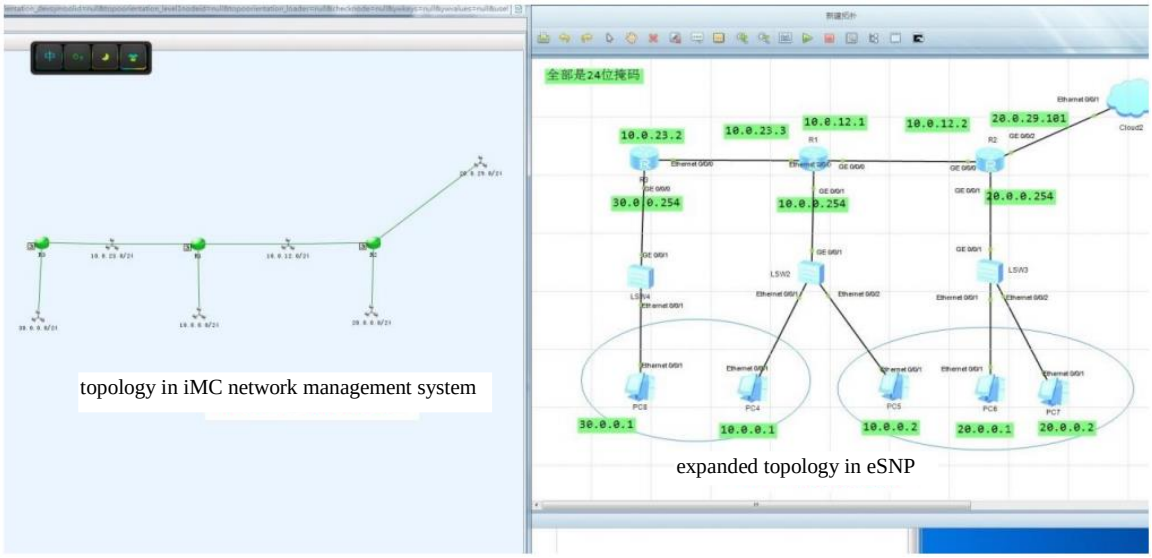

Figure 6 Expanded topology viewable on the network management system.

4.4.3 Monitoring Performance Indicators of On-net Devices

The performance management of virtual devices is carried out through the network management station, which is designed as follows:

- Monitoring the performance of the whole network, including four indicators of CPU utilization rate, memory utilization rate, device unreachability ratio, and device response time, and the monitoring view is presented.
- Creating a real-time performance monitor to perform real-time performance detection of memory utilization of virtual router devices with a polling time of 5 seconds.
- Modifying the primary and secondary thresholds of memory utilization to 80%-important and 90%-urgent, respectively.

The above three steps are successfully experimented, as shown in "Figure 7".

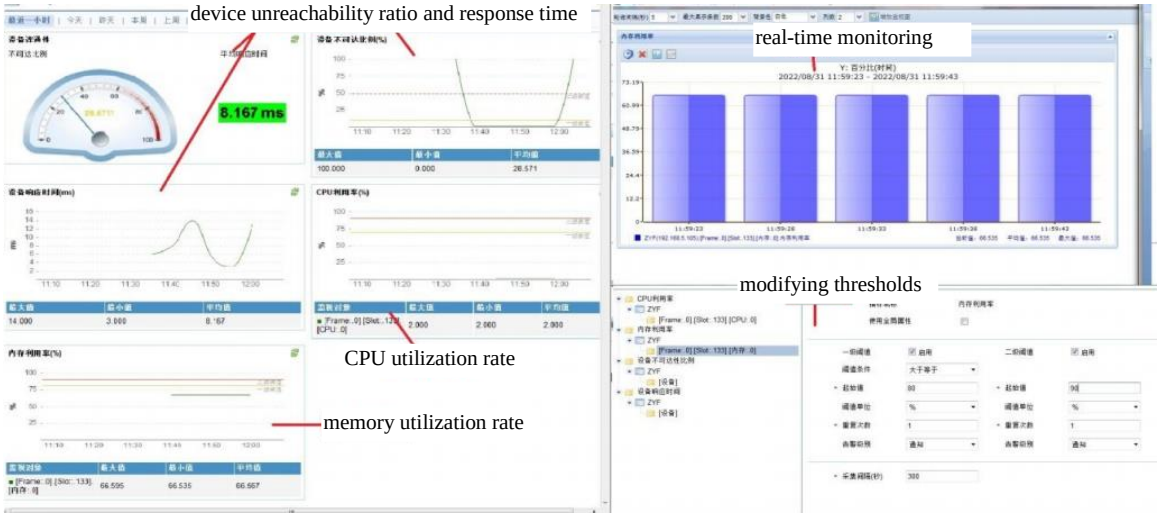

Figure 7 Performance management of managed virtual devices by network management system.

4.4.4 Viewing and Disposal of Fault Alarms of Managed Devices

As the virtual managed devices generally don't actively generate alarms, in teaching, one can design to actively create alarm information and use the shutdown command in the managed virtual router R1 to shut down the interface connected to the virtual router and the local host, return to the iMC network management station and use the real-time alarm function to monitor the alarm generation of this device, confirm and restore the alarm information, re-enter the configuration interface of this device in eNSP, use the undo shutdown command to turn on the interface connected with the local host, and use the ping command to test the gateway to complete an experimental effect of the alarm disposal, as shown in "Figure 8".

Figure 8 The network management system disposes of alarms for the managed virtual devices.

5. CONCLUSION

According to the teaching needs of the network management and maintenance major in the institution where the authors work, this paper proposes a new teaching method with SNMP technology as the core with a combination of various virtualization technologies. This teaching method realizes the comprehensive use of desktop virtualization, server virtualization and network virtualization, and implements four types of management for virtual devices, including device, topology, performance and alarm, and also has the function of expanding network. The final improvements are now further summarized in two aspects:

On the one hand, virtualizing each PC as a server reduces the burden of the original server and ensures the hands-on requirement of each computer for each student. This enables each each student to have exclusive access to a server and complete network management function experiments independently, avoiding the original problems of conflicting class management resources, experimental chaos, and overloaded servers. It can also comprehensively enhance each student's intuitive experience of network management and favorably improve classroom teaching efficiency.

On the other hand, the use of virtual network technology to build an expandable network topology relation can achieve the flexible networking needs in the implementation of teaching. In conjunction with the interaction between students, this also enables mutual management within and between groups, and also provides the possibility of decentralized and hierarchical network management, which can give students complex and variable network management challenges and facilitate their growth in practice.

AUTHORS' CONTRIBUTIONS

Ruifeng Yu is responsible for experimental design, Jingna Cui analysed data, Wenhua Bai wrote the manuscript, Dezhi Niu and Jin Zhang contributed to revising and editing.

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