Dynamically Authorized Remote Online Experiment Teaching System

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Abstract. With the outbreak of the COVID-2019 around the world, major colleges and universities have started online teaching. One of the most difficult problems to solve in online teaching is how to conduct practical courses that require laboratory equipment support online. Tianjin University's Mitsubishi Electric Automation Experiment encountered a similar problem when designing an online course. In response to this problem, a dynamic authorization remote online experimental teaching system was proposed, which assigns IP addresses to laboratory equipment and establishes access to and from the campus. The channel enables students to access on-campus laboratory resources outside the school, and automates management of the access rights of different users at different times to avoid resource access conflicts, improve resource operation efficiency, and reduce labor costs. At the same time, an appointment management system is provided to allow students to reserve laboratory equipment in advance. On this basis, the construction of a complete set of software and hardware system has been completed. Now the system has been running smoothly in Tianjin University and other institutions, continuously providing services for teachers and students, and has been successfully applied.

Keywords. online teaching; remote experiment; dynamic authorization; experiment reservation

1. Overview

The outbreak of the COVID-2019 in 2020 has quickly affected all walks of life around the world. Colleges and universities are crowded places. Under the influence of the epidemic, offline teaching cannot be carried out normally [1][2]. In order to allow students to continue to complete their studies, major colleges and universities have begun to teach online. Online teaching has a very positive effect on continuing teaching activities, but some courses cannot be directly converted to online courses, especially practical courses that require hardware equipment support, and it is difficult to achieve teaching effects through live broadcasts and other methods [3][4]. Practical courses are often the key courses to improve students' hands-on ability and accumulate experience. Therefore, it is necessary to design a new scheme so that students can operate experimental equipment at home and realize remote teaching of practical courses [5].

In this environment, Tianjin University's Mitsubishi Electric Automation Laboratory is in urgent need of a feasible solution that can support students' remote experiments. Under the traditional teaching situation, students enter the laboratory to operate the laboratory equipment according to the class schedule, and the whole process of the practical course needs to be completed by the students in the laboratory [6]. Under the epidemic, offline teaching of stu-

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dents cannot be achieved, resulting in the inability to carry out teaching activities. In addition, when there is no course arrangement in the laboratory, the equipment in the laboratory is often idle, which greatly reduces the utilization rate of the equipment. It is difficult for students to know which time period there is no course arrangement. Even if the equipment is idle, it needs to be managed. The coordination of staff in terms of time, the communication cost is extremely high [7][8].

In order to solve the above problems, it should design and develop a dynamic authorized remote online experimental teaching system, and successfully apply it to the teaching of Tianjin University Mitsubishi Electric Automation Laboratory, providing a strong guarantee for the development of practical teaching and the efficient use of laboratory resources under the epidemic.

The dynamic authorized remote online experimental teaching system provides the following functions.

(1) Remote access

Students can remotely access laboratory equipment through the Internet outside the school, perform experimental operations, and watch the experimental results.

(2) Exclusive access by time period

During the time period when students reserve the use of laboratory equipment, other students are prohibited from operating the equipment, ensuring that different students have exclusive access during their respective time periods.

(3) Dynamic fast switching

The system modifies the access rights regularly, and automatically switches the accessible users between different appointment time periods, without the need for administrator intervention to achieve dynamic and rapid switching.

(4) Authorized access

Students are assigned access rights during their respective access periods, and unauthorized students cannot access devices.

(5) Query appointment

Provide an appointment management system to facilitate students to inquire and reserve idle equipment.

2. System design

2.1 Overall structure

The dynamic authorized remote online experimental teaching system consists of reservation platform and VPN automatic management system.

The laboratory reservation platform is a web-based equipment reservation management platform. Through this platform, users can view the resource information that allows reservation access in the enterprise internal network, and make reservations for the use of equipment ac-

cording to personal needs and equipment availability. The reservation information includes reservation device information and reservation time information. After the user successfully reserves the device, within the reserved time period, the user can access the corresponding device in the local area network through the VPN system. The first core problem solved by the reservation platform is to provide users with a convenient and complete query reservation scheme, and control the first layer of access rights at the front desk level to provide users with highly available services. The second core problem solved by the reservation platform is to establish an information channel with the VPN automatic management system to provide data support for the automatic management of VPN.

The VPN automatic management system needs to be connected with the data sharing of the Web reservation management system to automatically handle functions such as user account management and authority division.

(1) Device access rights management

Manage the access rights of VPN users to the devices in the LAN, and only allow users to access the resources of the specified IP in the LAN.

(2) VPN user management

Receive the reservation information of the reservation system, and manage the account name, password, password aging, etc. of the VPN user as required.

(3) VPN usage management

Manage logged-in users according to the scheduled time, and allow specific users to access experimental resources at a specific time period. When the specified time is exceeded, the system will automatically disable the account and force the user to log off.

(4) VPN performance parameters

It supports controlled access of 100 devices and users, and the access delay is at the level of 1s.

The usage scenario of the system is shown in figure 1.

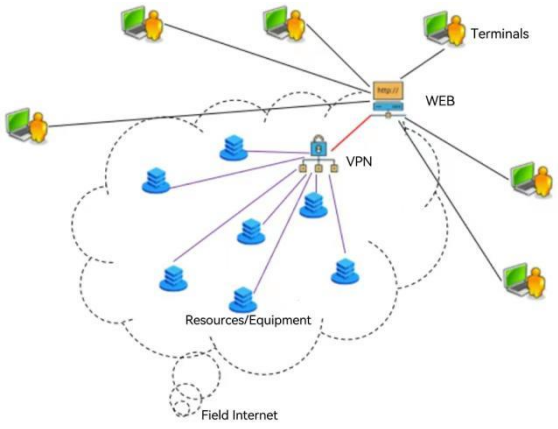

Figure 1. Dynamic authorization of the remote online experimental teaching system use scenarios

2.2 Appointment platform

The first core problem solved by the reservation platform is to provide users with a convenient and complete query reservation scheme, and to control the first layer of access rights at the front desk level to provide users with highly available services. The second core problem solved by the reservation platform is to establish an information channel with the VPN automatic management system to provide data support for the automatic management of VPN. The functional modules of the laboratory reservation system are shown in figure 2.

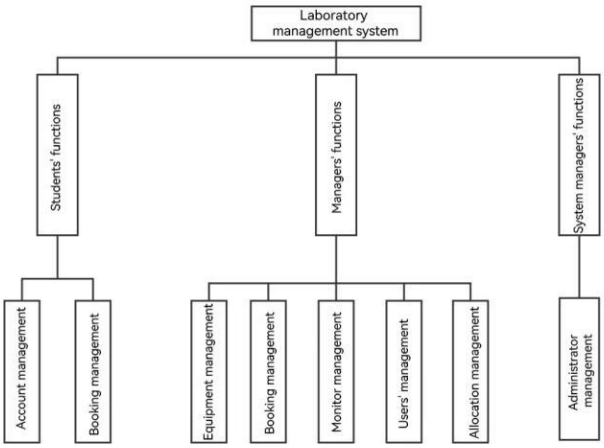

Figure 2. Function module of the reservation platform

The reservation management system distinguishes three user roles, including student, laboratory administrator, and system administrator. Different users have different system functions, the details are as follows.

(1) Student users

a. View laboratory information and laboratory equipment information

Students can view the information of the laboratory and the equipment in the laboratory through the reservation platform, including the name of the laboratory, the name of the equipment, and the time period that can be reserved.

b. Make an appointment for laboratory equipment

A student makes an appointment for a certain device and submits information such as the name of the device to be reserved, the time period for the appointment, the student number and name of the reserved student. After the student submits the appointment information, it should wait for the administrator's approval.

c. View the results of the appointment review

After submitting the appointment, students can view the results of the appointment review at any time. If the review is approved, a login password will be generated and displayed to the student together with the appointment information.

d. Modify the reservation information

Students can modify the reservation information after the reservation is successfully reviewed and before the experiment starts. Modifying the reservation information requires the administrator to review and confirm, the modification will take effect after the review is approved.

e. Cancellation of appointment

Students can cancel the reservation before the experiment starts after the reservation is reviewed successfully.

(2) Lab administrator user

a. View appointment information

Administrators can view the appointment information submitted by users, including those that have passed the review, those that have not been approved, and those that have been cancelled by the user.

b. Review appointment information

The administrator can review the reservation information, and if the review is passed, a password for logging in to the VPN will be generated for the user to log in to the VPN during the experiment.

c. Laboratory equipment management

Equipment management includes the addition, modification and deletion of laboratory equipment information.

d. User account management

Basic information about user accounts can be managed.

e. Monitoring management

Monitor the information of users using the reservation system.

(3) System administrator user

A system administrator is a type of management account that manages administrator accounts. The system administrator can add, modify, and delete accounts.

2.3 VPN automation management system

The VPN automation management system is built based on Openconnect VPN (OCServ), which is an open source VPN server software. The project research team builds on the OCServ and further develops the following functions.

(1) Enriched account management functions.

As an open source VPN server software, the traditional OCServ only has the most basic user account management functions, including adding and deleting users, checking the online status of users, and stopping users. And the above functions need to be implemented in the server through corresponding instructions. This method of user management cannot meet the requirements of the online experimental teaching system based on dynamic authorization and

controllable equipment at all. Therefore, the research team carries out in-depth secondary development based on OCServ to enrich its account management functions.

The research team developed a user account management system to realize the function of automatically generating specific user accounts. This function can automatically generate a specific user name and password according to the requirements of the website of the online experimental teaching system based on dynamic authorization and controllable equipment, and add it to the OCServ system. On this basis, the user account management system can also automatically delete related users according to website requirements.

Through the development of the user account management system, the functions of OCServ are expanded, the management methods of OCServ are enriched, and the use requirements of the online experimental teaching system based on dynamic authorization and controllable equipment are met.

(2) Improve the VPN usage policy.

Due to the needs of teaching, an online experimental teaching system based on dynamic authorization and controllable devices must be able to control the time when users use accessible teaching resources. For example, student A makes an appointment to use the corresponding laboratory hardware resources from 8:00 am to 10:00 am, while student B makes an appointment to use the same teaching resource from 10:00 am to 12:00 am. If the system is not controlled, student A may not finish the use of resources at 10:00, or student B may start to use teaching resources earlier than 10:00, which will cause conflicts and may seriously damage the experimental equipment. The traditional OCServ does not have the corresponding time-limited access function, so the research team has developed a corresponding management module, which can strictly control the use of resources according to the reserved time. When the appointment time is reached, the system will automatically stop or enable the corresponding user's permission to ensure that the user can normally use the system to complete the teaching work.

Extend VPN functionality. Although traditional OCServ has the ability to establish VPN access channels, it does not have control over the permissions of external computers to access devices. Once an external computer is mapped to the internal network through VPN, it can access all resources of the internal network. The demand for access to the online experimental teaching system of controllable equipment does not match. Therefore, the research team carries out in-depth development on the basis of OCServ, and builds a VPN connection with limited access through technologies such as IP masquerading.

After users enter the intranet through the VPN system developed by the project team, they can only access network resources pre-limited by the administrator, and unauthorized resource users cannot. Through this setting, the security and controllability of the VPN connection are greatly improved, and the functions of the VPN are expanded.

3. Key technology

3.1 Characterization

Access control of resources needs to establish the characteristics of users and resources, and then restrict them according to characteristics. The solution of this subject is to realize the access control of resources through IP matching. It can set the IP address of the resource to be be preset. However, it is difficult to determine the IP address of any user. A user name and password can be given, and it can establish a dynamic unique mapping between user names and IP addresses, which is one of the difficulties of the project.

3.2 High-frequency dynamic establishment and cancellation of a large number of link paths

The subject takes the university laboratory equipment reservation and VPN access management as the usage scenario, designs and develops the automatic programmable VPN gateway system. The subject innovatively proposes the function of time-sharing access according to equipment resources and needs, and opens up the channel between users and local area network resources. The traditional VPN gives the user an intranet IP address and has the right to access various resources in the local area network. On this basis, it needs to control access to resources, establish links to resources that have access, and disconnect links to resources that do not have access. With the passage of time, the number of links to be controlled is very large. The number of links for M resources and N users is M×N. It is difficult to dynamically establish and cancel these links at any time according to user needs.

3.3 Feedback communication between software components

A Web reservation management system has been established, and there are frequent interactions between the Web system, Linux commands, and OpenConnet. To ensure reliable communication, mutual cooperation, and seamless integration between the Web system, Linux commands, and OpenConnet, and finally complete the system's dynamic allocation capability, security assurance capability, and time-sharing access control capability for resource access, which is difficult to develop.

3.4 Efficiently forward data

The VPN device developed is a proxy between users and local area network resources. There is a lot of data communication between users and resources. In the case of adding access control, forwarding efficiency is a difficult point. The current target is on the order of 100 users and devices with a delay of 1s.

VPN automatic management system technology uses the VPN service based on Openconncet VPN Server to complete the basic network establishment of VPN. Openconnect VPN Server is an SSL VPN server that can perform complex user management and control. OpenConnect server provides the user management interface and back-end management necessary for enterprise environments, as well as security features such as client isolation. Openconnect server supports multiple authentication methods, including PAM and certificate authentication. An authenticated user is assigned an unprivileged worker process that maintains a network device and gets an IP address assigned from an address pool. Once authenticated, the Openconnect

server provides the client with an IP address and a routing table that it can access. To ensure high-speed transmission, the server does not process or filter packets. Openconnect server can also manage users in groups.

3.5 Resource permission control is implemented using iptables technology

Iptables is an excellent and completely free packet filtering-based firewall tool that comes with the unix/linux system. It is very powerful and flexible to use, and can control the data packets flowing in, out and through the server. Especially it can run very well on a very low configuration. Iptables is a service integrated in the linux2.4 and 2.6 kernels. Its functions and security are much more powerful than the older generation ipfwadm and ipchains. It is generally believed that iptables works on the seventh, second, third, and fourth layers of OSI. The biggest advantage of iptables is that it can configure stateful firewalls, an important feature that neither ipfwadm nor ipchains provided before. A stateful firewall can specify and remember the state of a connection established to send or receive packets. The firewall can obtain this information from the connection tracking state of the packet. This state information used by the firewall can increase its efficiency and speed when deciding on new packet filtering.

4. System test

This system test work includes function test and performance test. The functional test verifies the correct realization of the system functions to ensure that the final functional presentation of the system meets the project requirements and actual teaching needs. The functional testing work is carried out in two stages. The first one is before the system goes online. All functions of the reservation platform and VPN automation management system are tested in black box, and core functions are tested in white box. The second stage is the first semester of operation after the system goes online. A special person will accompany the class to monitor the operation of the system functions during the class at all times, and solve problems in a timely manner. After two stages of testing, the system functions fully meet the needs of remote experiments and are correctly implemented.

The performance test verifies the system's response speed, carrying capacity and other experiences to ensure that the system can eventually provide stable services under a large number of usage frequencies, duration and certain concurrency. The performance test is also divided into two phases, before the launch and the first semester after the launch. In the pre-launch phase, the system is subjected to stress testing and load testing through automatic testing tools. The test results show that when 100 people use the system at the same time, the system can still provide stable services, and there are very few cases of request errors and data loss. When the concurrency reaches 200, the system has obvious request errors and data loss. Considering that the number of most laboratory equipment is less than 100, the performance of the system is sufficient to meet the needs of laboratory teaching.

5. Conclusion

This paper designs and implements a dynamic authorized remote online experimental teaching system. Through this system, students can reserve laboratory resources, and exclusively access

laboratory resources remotely in their respective reserved time periods, conduct online experiments, and automatically conduct online experiments during class time. Switching the account that can be logged in achieves the purpose of remote teaching in the laboratory. This system breaks the limitations of time and space. Students do not need to go to the laboratory in person, but can conduct classroom experiments in any place with an Internet connection. Combined with the reservation platform, idle equipment can be reserved at any time, which effectively improves the utilization rate of laboratory resources. The management system can switch the accessible user accounts by itself, without the need for special personnel to wait, which greatly reduces labor costs. This system has been popularized and operated in some colleges and universities. After practical verification, this system can provide strong support for the remote teaching work in colleges and universities, and has great economic and social value.

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Design and Implementation of Automatic Programmable VPN Gateway

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