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Design and Application of OSPF Protocol Training Program Under Project-Based Teaching

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Abstract: Aiming at the problems of "abstract theory and disconnected practice" in OSPF protocol teaching of computer network and related majors, this paper designs a set of OSPF protocol training programs combined with the concept of project-based teaching. With "building a multi-area local area network (LAN) for university buildings" as the core project, the program is divided into five stages: "demand analysis - topology design - configuration implementation - troubleshooting - acceptance evaluation". The training environment is built through eNSP simulation software, covering core knowledge points such as OSPF configuration, area division, route summarization, and fault handling.

Keywords: Project-based teaching; OSPF protocol; Training program; eNSP simulation

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1. Introduction

OSPF (Open Shortest Path First), a widely used dynamic routing protocol, features fast route convergence. It can automatically calculate and generate most routes without manual intervention, greatly simplifying network management. When the network topology changes, OSPF can respond quickly and update routing information automatically to ensure network connectivity and communication efficiency [1]. OSPF uses the Link-State Routing algorithm to determine the optimal path. It forwards network topology information to all connected routers, and then calculates the shortest path tree to determine the best path to the target network [2]. However, traditional teaching mainly relies on "theoretical explanation + single case demonstration," leading to a common dilemma for students: "being able to understand but unable to configure."

Training teaching is a key link connecting theory and practice, which is a student-centered, project-driven, and progressive experimental teaching process [3]. However, current OSPF training faces two major pain points: first, vague training goals, mostly focusing on "single router configuration" and lacking simulation of real network scenarios; second, rigid teaching models, where teachers dominate operational demonstrations and students passively imitate, resulting in a lack of continuity, comprehensiveness, and interest. This makes it difficult for students to systematize and integrate what they have learned, which not only reduces their learning interest but also restricts the improvement of their problem-solving ability and the cultivation of innovative awareness [4]. Project-based teaching takes "practical projects" as the carrier, allowing students to master theoretical knowledge and operational skills in the process of completing projects through “task-driven, student-led, and teacher-guided” methods.

Therefore, this paper designs an OSPF protocol training program under project-based teaching. Through the real scenario project of “network training room LAN”, OSPF knowledge points are integrated into the whole process of project implementation. With Huawei’s eNSP network simulation platform, a graphical operation interface is adopted to select various Huawei devices, then draw the network topology diagram, simulate configuration commands of various devices, and finally verify business requirements. It allows users to conduct network experiments and learn network technologies without real devices, verifying the effectiveness of the program to make up for the deficiencies of traditional training network devices [5].

2. Design of OSPF protocol training program under project-based teaching

2.1. Program design principles

2.1.1. Scene authenticity

Taking “building a multi-area LAN for university buildings” as the project background, it simulates network interconnection needs, covering real application scenarios such as OSPF area division, route summarization, and default route announcement, avoiding “fragmented training divorced from reality.”

2.1.2. Tool adaptability

Considering the limited hardware resources of colleges and universities, eNSP simulation software is used to build the training environment.

2.2. Training program framework

The training project is divided into five stages, with the specific framework as follows.

2.2.1. Stage 1: Project demand analysis

A router is deployed at the Internet exit, and both the router and the core switch of the data center use the OSPF routing protocol. Corresponding VLANs are divided, and Layer 3 intercommunication is realized through VLANIF. Link aggregation is configured on the aggregation layer switch, which is interconnected with the access switch through two physical lines.

2.2.2. Stage 2: Network topology design

Draw the topology diagram using eNSP [6–8]. The designed network must include the following devices:

(1) 1 router (R1: data center router), 7 switches (SW1: data center core switch, SW2: data center core switch, SW3: data center core switch, SW4: Hongde Building access switch, SW5: Siyuan Building access switch, SW6: Qihang Building access switch, SW7: Huyang Building access switch);

(2) SW1 is connected to the data center router; SW1, SW2, and SW3 are interconnected with each other;

(3) 10 PCs belong to 10 network segments, respectively, for connectivity testing.

IP address planning: The network is divided into 10 VLANs (10 network segments), among which the IP addresses of the data center router and core switches are planned separately. Currently, the number of available IP addresses for terminal devices is planned to be 2530, and 2277 IP addresses are reserved for terminal devices in the later stage, totaling 4807 terminal devices that can be used simultaneously.

The data center is located in the Information Building (10.1.100.0/24, 10.1.200.0/24 network segments); the building groups are located in Hongde Building (10.1.10.0/24, 10.1.20.0/24 network segments), Siyuan Building (10.1.30.0/24, 10.1.40.0/24, 10.1.50.0/24 network segments), Qihang Building (10.1.60.0/24, 10.1.70.0/24 network segments), Huyang

Building (10.1.80.0/24, 10.1.90.0/24, 10.1.100.0/24 network segments); other building groups are reserved for later expansion (10.1.110.0/24 - 10.1.190.0/24 network segments, 2277 IP addresses).

Requirements:

(1) Network interconnection between the data center and building groups.

(2) Configure the CSR interface IP and OSPF process.

(3) Configure the CSW interface IP and OSPF process.

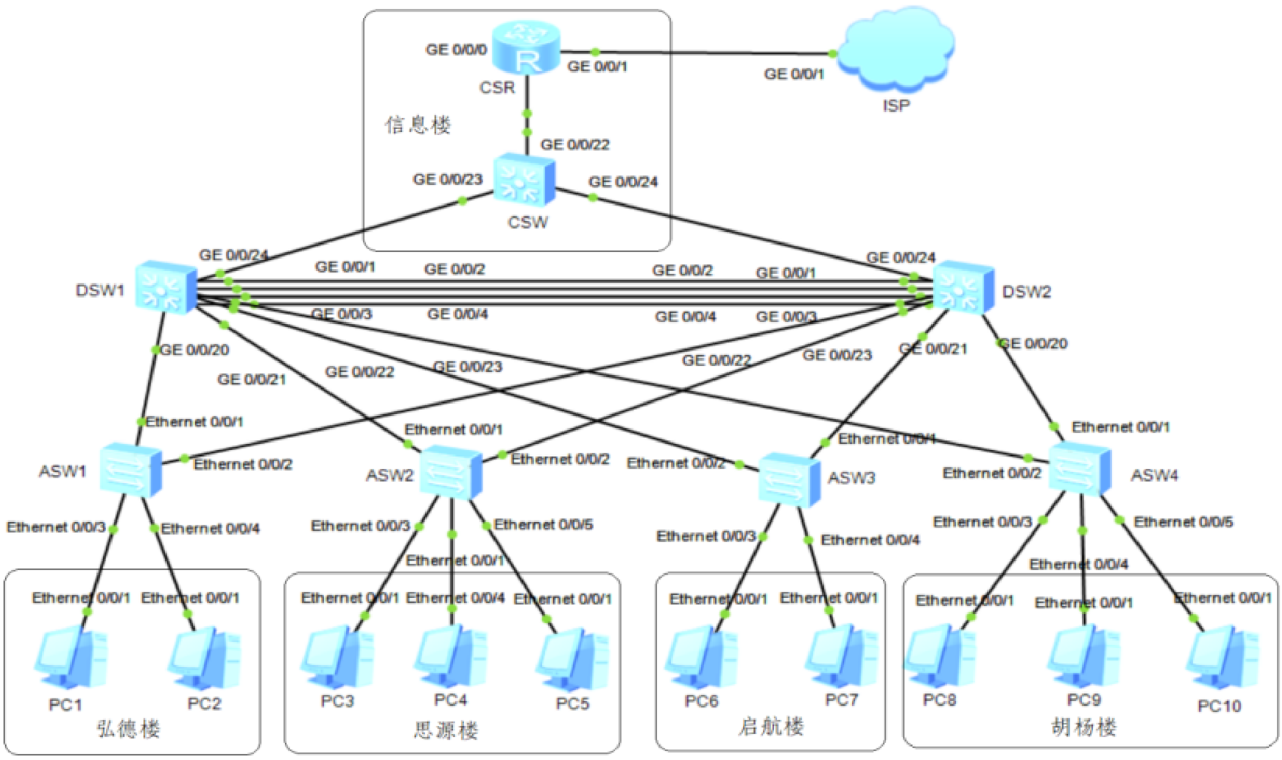

Figure 1. Network topology design.

2.2.3. Stage 3: Configuration implementation and testing

This stage is the core of the training, following the steps of "basic configuration - advanced configuration - connectivity testing" [9–12].

2.2.3.1 Basic configuration

(1) Configure the router hostname as CSR, and set the interface IP addresses: GigabitEthernet0/0/0 to 10.1.200.254/24 and GigabitEthernet0/0/1 to 115.115.115.2/24.

```
interface GigabitEthernet0/0/0
 ip address 10.1.200.254 255.255.255.0
#
interface GigabitEthernet0/0/1
 ip address 115.115.115.2 255.255.255.0
```

Figure 2. IP addresses configuration.

(2) Configure the data center core switch hostname as CSW. VLANIF interfaces are used to realize intercommunication between different VLANs, and configure IP addresses and gateways for all PCs in sequence [13,14].

(3) Configure OSPF: Announce interfaces to the corresponding area, start the OSPF process with process number 10,

and specify the router ID as 1.1.1.1 for this OSPF process. The Router-ID is unique in the OSPF network, serving as the identity of the OSPF router in the network to distinguish different routers during neighbor relationship establishment and link state information exchange.

Specify that subsequent network announcements belong to the OSPF backbone area (Area 0) through “area 0.0.0.0”. OSPF adopts a hierarchical architecture, and the backbone area is the core of the entire OSPF network, responsible for transmitting routing information between different non-backbone areas. This hierarchical division helps reduce the size of routing tables, lowers the overhead of routing information transmission, and enhances network scalability and stability, making routing management of large-scale networks more efficient.

Announce that the network segment belongs to the management scope of the current OSPF process through “network”, meaning that interfaces within this network segment will participate in OSPF routing information interaction (including sending and receiving link state advertisements, etc.). Through network announcement, OSPF can discover neighbor routers within the network segment, establish neighbor relationships, exchange link state information, and finally generate a complete routing table to realize routing reachability between network segments.

```
ospf 10 router-id 2.2.2.2
 area 0.0.0.0
  network 10.1.10.0 0.0.0.255
  network 10.1.20.0 0.0.0.255
  network 10.1.30.0 0.0.0.255
  network 10.1.40.0 0.0.0.255
  network 10.1.50.0 0.0.0.255
  network 10.1.60.0 0.0.0.255
  network 10.1.70.0 0.0.0.255
  network 10.1.80.0 0.0.0.255
  network 10.1.90.0 0.0.0.255
  network 10.1.100.0 0.0.0.255
  network 10.1.200.0 0.0.0.255
```

Figure 3. CSW-OSPF configuration.

```
ospf 10 router-id 1.1.1.1
 area 0.0.0.0
  network 10.1.200.0 0.0.0.255
```

Figure 4. CSR-OSPF configuration.

2.2.3.2. Advanced configuration

Configure a default route on the CSR pointing to the ISP, and import the default route into the OSPF process.

“ip route-static” is a command used to configure static routes. “0.0.0.0 0.0.0.0” indicates that the destination network is any network (i.e., default route; when the device cannot find a specific destination network route in the routing table, it will use this default route to forward data packets). “115.115.115.10” is the next-hop address, that is, the IP address of the next device to which the data packet is forwarded.

Force the OSPF process to always advertise the default route to its neighbor routers through “default-route-advertise always”. The default route plays a “fallback” role in the network; when the router cannot find a specific route to the target network in its own routing table, it will forward data packets according to the direction of the default route.

By advertising the default route, other routers can still forward data packets in the absence of specific routing information, improving network connectivity and routing simplicity. The “always” parameter ensures that the default route is continuously advertised regardless of whether the local router itself has a default route, enhancing the stability and predictability of network routing [15].

```
ospf 10 router-id 1.1.1.1
 default-route-advertise always
 area 0.0.0.0
  network 10.1.200.0 0.0.0.255
```

```
ip route-static 0.0.0.0 0.0.0.0 115.115.115.10
```

```
ospf 10 router-id 1.1.1.1
 default-route-advertise always
 area 0.0.0.0
  network 10.1.200.0 0.0.0.255
```

Figure 5. CSR-OSPF configuration.

2.2.3.3. Connectivity testing

Use the ping command to test cross-segment connectivity. Use “display ospf peer” to view neighbor relationships, and “display ip routing-table protocol ospf” to view the routing table.

```
Ping 10.1.100.250: 32 data bytes, Press Ctrl_C to break
Request timeout!
From 10.1.100.250: bytes=32 seq=2 ttl=127 time=141 ms
From 10.1.100.250: bytes=32 seq=3 ttl=127 time=125 ms
From 10.1.100.250: bytes=32 seq=4 ttl=127 time=141 ms
From 10.1.100.250: bytes=32 seq=5 ttl=127 time=125 ms

--- 10.1.100.250 ping statistics ---
  5 packet(s) transmitted
  4 packet(s) received
  20.00% packet loss
  round-trip min/avg/max = 0/133/141 ms
```

Figure 6. Network connectivity test between the PC in Hongde Building and the PC in Huyang Building.

```
       OSPF Process 10 with Router ID 1.1.1.1
             Neighbors

Area 0.0.0.0 interface 10.1.200.254(GigabitEthernet0/0/0)'s neighbors
Router ID: 2.2.2.2          Address: 10.1.200.253
  State: Full  Mode:Nbr is  Master  Priority: 1
  DR: 10.1.200.253  BDR: 10.1.200.254  MTU: 0
  Dead timer due in 29  sec
  Retrans timer interval: 5
  Neighbor is up for 00:08:50
  Authentication Sequence: [ 0 ]
```

Figure 7. CSR - view neighbor relationships.

```
Public routing table : OSPF
         Destinations : 10       Routes : 10

OSPF routing table status : <Active>
         Destinations : 10       Routes : 10

Destination/Mask    Proto   Pre  Cost      Flags NextHop         Interface

      10.1.10.0/24  OSPF    10   2           D   10.1.200.253    GigabitEthernet
0/0/0
      10.1.20.0/24  OSPF    10   2           D   10.1.200.253    GigabitEthernet
0/0/0
      10.1.30.0/24  OSPF    10   2           D   10.1.200.253    GigabitEthernet
0/0/0
      10.1.40.0/24  OSPF    10   2           D   10.1.200.253    GigabitEthernet
0/0/0
      10.1.50.0/24  OSPF    10   2           D   10.1.200.253    GigabitEthernet
0/0/0
      10.1.60.0/24  OSPF    10   2           D   10.1.200.253    GigabitEthernet
0/0/0
      10.1.70.0/24  OSPF    10   2           D   10.1.200.253    GigabitEthernet
0/0/0
      10.1.80.0/24  OSPF    10   2           D   10.1.200.253    GigabitEthernet
0/0/0
      10.1.90.0/24  OSPF    10   2           D   10.1.200.253    GigabitEthernet
0/0/0
     10.1.100.0/24  OSPF    10   2           D   10.1.200.253    GigabitEthernet
0/0/0
```

Figure 8. CSR - view OSPF routing table.

```
Public routing table : OSPF
         Destinations : 1        Routes : 1

OSPF routing table status : <Active>
         Destinations : 1        Routes : 1

Destination/Mask    Proto   Pre  Cost      Flags NextHop         Interface

        0.0.0.0/0   O_ASE   150  1           D   10.1.200.254    Vlanif200
```

Figure 9. CSW - view OSPF routing table.

3. Conclusion

The OSPF protocol training program under project-based teaching, designed in this paper, integrates OSPF knowledge points through the real project of "building a multi-area LAN for university buildings." Relying on eNSP simulation tools, it realizes a low-cost and high-simulation training environment, cultivating students' practical operation ability and their understanding of "the correlation between protocol principles and faults", enabling them to "know not only what but also why."

In the future, the program will be optimized from three aspects: first, expand project scenarios to improve students' comprehensive application ability in different scenarios; second, introduce a "virtual-real combination" training model, integrating eNSP simulation with real device operations to further enhance training authenticity; third, organize competitive competitions to extend training effects and learning fun.

Disclosure statement

The author declares no conflict of interest.

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