A Network Controller Supported Open Reconfigurable Technology

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Abstract. In open reconfigurable architecture, the network devices realize the separation of the control plane and data plane. This paper study the control center of entire open reconfigurable network device: control element. It provides independent exclusive platform for control plane resources, which can enhance its scalability, control ability and efficiency significantly. The hierarchical structure of reconfigurable network and architecture of control element software are discussed. Then, core components of control element, which include protocol middleware and the development of user operating management system are introduced in details. Experiments of middleware software are illustrated for running routing protocols, network management, interface test etc. The experiment results show the feasibility of the control element design.

Keywords: Control element · Open reconfigurable technology

1 Introduction

In open reconfigurable network, a NE (e.g., a router/switch) is systematically separated into a control plane and a forwarding plane, disperse the control and forwarding / switching functions into different processors in the physical network devices. With the expansion of the network, data plane can reach a large capacity through a multi-stage (whether Clos or Benes cascade), as control plane have independent exclusive platform , it is possible to enhance its expansion significantly, control ability and efficiency by independent upgrade, to solve the capacity contention issues for control plane and data plane in a single network device.

In term of the Network Service Provider, the central control unit can assemble those contained units in data plane which is departed in physical space, loosely-coupled into a logical entirety which can provide IP network service to the customers. At the same time, it can avoid various IP network service from scrambling the IP infrastructure resources as they are all coordinated by the central control unit.

Xbind [1] has studied a set a set of the distributed software components which is used to create, deployment and management of multimedia services on the ATM

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network early. Click software router project [2] [3]in MIT provides a modular and scalable network device structure. W.Louati [4] used the / proc file system in Linux as a communication mode between kernel and user to achieve dynamic configuration function in Click. I.Houidi[5] used the CORBA component model to realize Click. There are two open source programmable networking platform: Open Contrail[6], Open Daylight[7].ForTER[8] ,analyze and implement an open programmable router based on forwarding and control elements separation. Section 2 described the architecture of open reconfigurable network and CE . Section 3 presented the implementation details of key elements in CE. Section 4 introduced some experiments and tests result

2 Architecture

2.1 Hierarchical Structure of Reconfigurable Network

In reconfigurable network, management node and open reconfigurable router are important parts of it, its specific structure is showed in Figure 1, which has developed a set of software architecture specification for open reconfigurable router. Management node can be divided into the business layer and the service layer , open reconfigurable router can be divided into logical functional layer and the service layer . According to ForCES structure, open reconfigurable router can also be divided into a control element (referred to as CE) and forwarding element (referred to as FE). Service layer is consist of the service access unit, service management unit and other modules. Service access unit is mainly to complete the communication between the open reconfigurable router and management nodes, and service management unit is primarily responsible for the management of services, deployment of services (on the managed node) or configuration (on the open reconfigurable router) of LFC .The logical functional layer of open reconfigurable router mainly to complete the main resource management of LFC and support services can be reconstructed.

2.2 Software Architecture of the Control Element

In the CE software architecture which is based on ForCES middleware, the core is ForCES middleware and various third-party software. According to achieve different specific application services (such as: path discovery service, user management services, etc.),R & D personnel select the corresponding third-party software and design different application software abstract adaptation (eg: routing information management adaptation, user management adaptation)for each third-party software , the operating of application services via abstract adaptation unified transformation into standardized operating which is provided by reconfigurable component model. And multiple applications can use same abstract adaptation, such as OSPF, RIP, network management and other applications services can use interface management adaptation in the meantime. Figure 2 is the schematic of control element software architecture based on ForCES middleware.

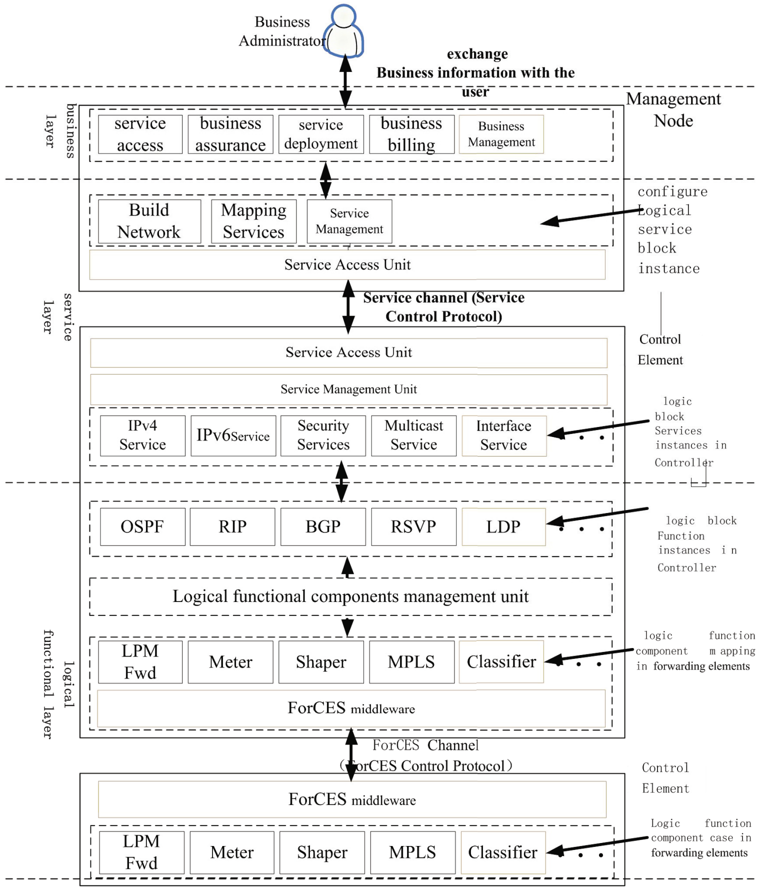


Fig. 1. Hierarchical structure of reconfigurable network

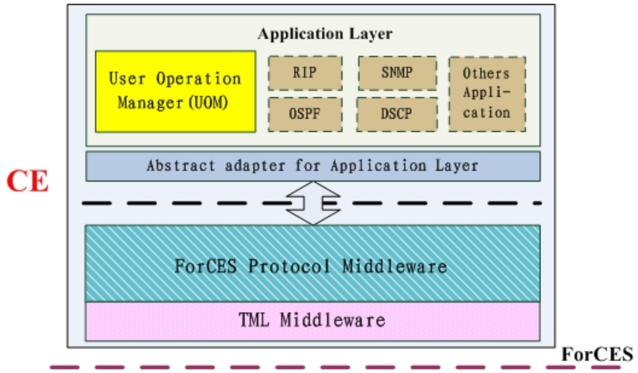


Fig. 2. Software architecture of reconfigurable control element based on ForCES middleware

In view of the present demand, mainly study the following four categories for business component abstraction adaptation layer :

- ✧ Research and design for the abstract adaptation layer of user central management.
- ✧ Research and design for the abstract adaptation layer of path finding based on third-party software
- ✧ Research and design for the abstract adaptation layer of network management based on third-party software
- ✧ Research and design for the abstract adaptation layer of service quality control and other value-added services based on third-party software

Adaptation layer component does not have to correspond with business component, that is: multiple business components can use one same abstract and adaptation layer component, the operating of business components via abstraction and adaptation components transform into a unified standard operating. Can be considered a unified abstract interface which is divided into the following categories: configure the interface, query interface, event reporting interfaces, packet redirection interface.

3 Core Components of Control Element

3.1 Protocol Middleware

The architecture of ForCES middleware products are showed in figure 3, ForCES protocol middleware contains Protocol Layer (PL) and Transport Mapping Layer (TML). All middleware should have the function of process and transmit control information, redirection of data, store and access data, and the interaction with the third-party software, FE topology discovery. ForCES middleware does good job on encapsulation of protocol data package and associated logic relationship which ForCES protocol need to complete, and lay a good foundation for the development of all types of network device which based on ForCES protocol. ForCES structure network products for different applications can use the same set of ForCES middleware, can avoid iterative development.

The ForCES middleware includes three parts: protocol layer, application function layer and control element manager.

Protocol layer (ForCES Protocol Layer, PL): mainly complete the functions such as building the chain of ForCES , maintaining the link state of ForCES, the operations of packing and unpacking for ForCES protocol messages.

Application Function Layer (,AFL): Saving all information of LFB and attribution in FE.

CE managers (ForCES Control Element Manager, CEM): mainly to complete the related startup parameters configuration of TML and PL in CE, such as: all FEID controlled by CE.

Concrete block diagram of ForCES architecture which based on middleware is showed in Figure 2

3.2 Develop User Operating Management System in Control Element

User operating management system (UOM) is an important part of supporting open reconfigurable generic network equipment control element , which is essentially a special third-party software application. Its main purpose is to provide users with a common graphical operating management, so as to bring convenience for the user in the management of open reconfigurable device.

The main functions of UOM

1) Verification for login of user, and supports the three levels management authority of user.
2) Use tree as resource overview map in the network device which allow users to deployment management property of nodes in a tree .
3) Topology management is not only convenient for the user to view the distribution of resources in the FE, but also supports online reconstructed network resources , and thus meet the rapid escalation of network resources and deployment needs.
4) Supports view, add , delete routing table, and deployment management RIP, OSPF and other routing protocols.
5) Filter provide deployment management of security policies and security associations for the application layer.
6) Open third-party software management interface, support integration of routing software (Zebra, Xorp etc.) and SNMP network management software.

3.2.1 Internal Structure of UOM

As shown in Figure 3, UOM adopt B / S mode, the overall is divided into server and client : the former relying on Tomcat , the latter is runned by downloading in the IE browser , can be flexibly deployed on Linux and Window platforms . In UOM, the data layer reflect on the underlying layer of ForCES middleware , UOM is divided into four layers , graphical user interface (GUI) layer, message management layer, and background processing layer and plug-in layer, each function is as follows:

1. Graphical user interface (GUI) layer , provides a graphical user operating interface .
2. Message management layer , in the B / S mode, the message communication layer between client and server, now encrypt http object flow data interaction form is used to guarantee the security of the system.
3. Background processing layer, according to message information, control the movements of background data , and its business operating.
4. Plug-in layer , set up a bridge between the UOM and ForCES middleware, to achieve seamless between the two.

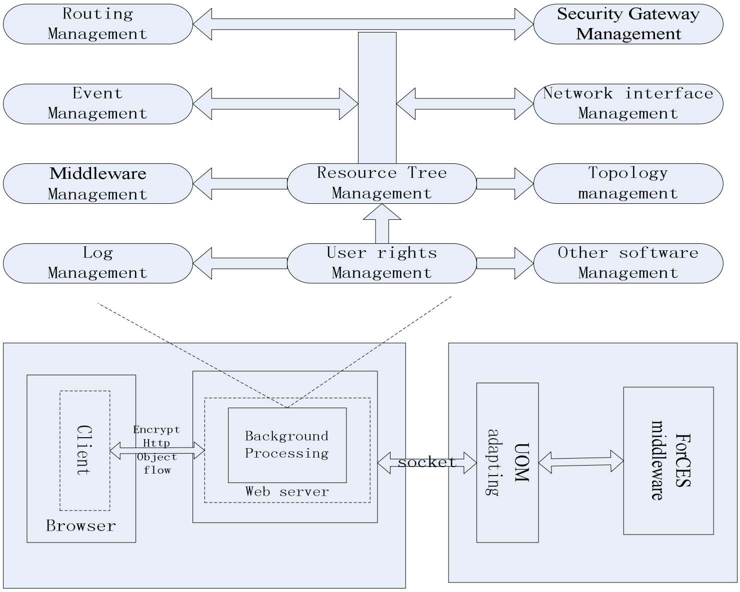


Fig. 3. Internal structure of UOM

3.2.2 UOM Interface Design

UOM main interface include eight major areas ,in particular: 1.the main menu area ; 2.tree operating area ; 3 .node property configuration and topology display area ; 4.tab page; 5.event notification area ; 6.the operating results prompt area ; 7 .login display ; 8.the progress bar. UOM main interface is shown in Figure 4.

- Main menu area

In the main menu area users can complete all operating except for the tree operating. Specifically includes : System Login / Logout , deployment management of PL and TML , subscribe / cancel / view for LFC events , LFC topology management , third-party software management (support routing software (Zebra and Xorp) and multiple SNMP agent) , the routing table management, network interfaces management, security gateway management, log management , user privilege management.

- Node property configuration and topology display area

When the user double-click a node on the tree operating area, it will show attribute information of node in detail in this area , then you can modify attribute according to the actual situation and click "Apply" button to take effect. In addition, this area also displays LFC topology .Shown in Figure 5.

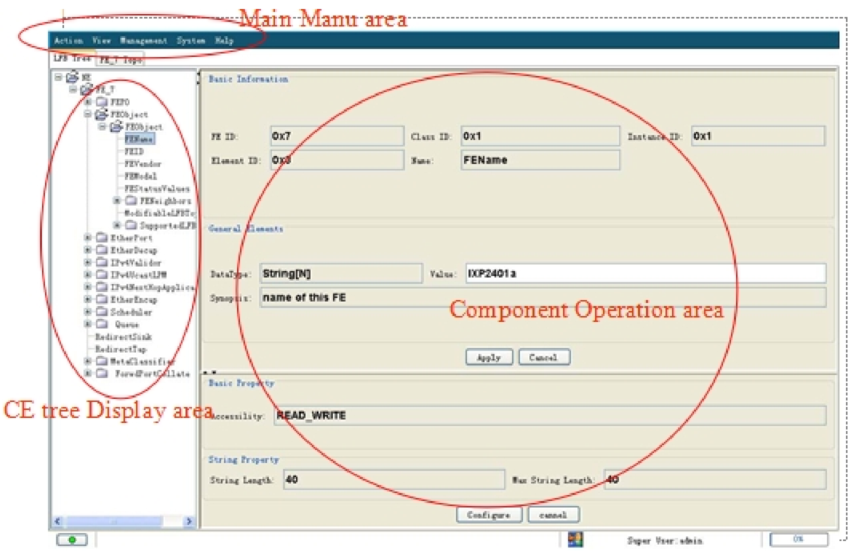


Fig. 4. Software interface of user management platform

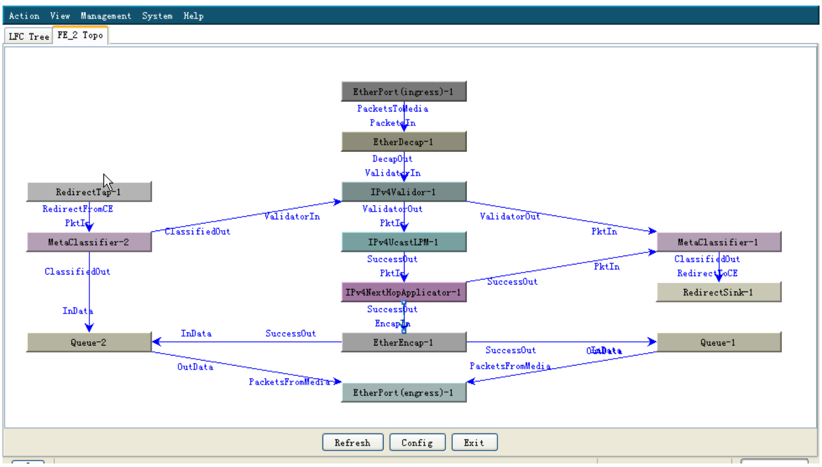


Fig. 5. Component topology management interface

4 Experiment

4.1 Test Environment

Support the open reconfigurable control element software apply to open reconfigurable router system, open reconfigurable router connected directly by a single control element (CE) and more than one forwarding elements (FE) through the switch, while running middleware software in CE and FE .its test environment as follows:

- CE hardware environment: PC machine;
- CE software environment: Red hat 9.0
- LFC type in FE: FE Object, FEPO, Ether Port, Ether Decap,IPv4 Next Hop Aplication, IPv4 Validor, IPv4 Ucast LPM, Meta Classifier, Scheduler, Queue, Ether Encap, Redirect Sink, Redirect Tap, Forwd Port Collate;

Executable filename of compiled core code in CE : ce; executable filename of FE named: fe_test, CE and FE use script files to realize startup. Control element of open reconfigurable routers provide web services, which can access open reconfigurable router through web terminal. Hardware configuration of open reconfigurable router and reconfigurable are showed in figure 6.

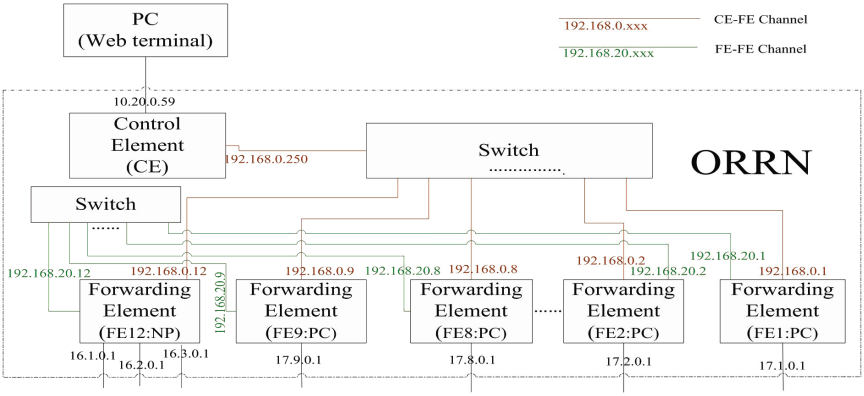


Fig. 6. Router topology of open reconfigurable

4.2 Interaction of OSPF Protocol Stack and the Generation of Routing Table

We specifically list the purposes of the experiment we have made based on middleware software as follows:

(1)To see the feasibility of data packet redirection function in ForCES protocol,
(2)To see the feasibility of the receive, interpretation, packaging and sending for redirect message

Its test ID is 1.4, and the test configuration description is showed in figure 7.

Test process(operation / signal flow):

(1)Connect a port (FE12 here in Port 2)of open reconfigurable router with the port 2 (SMB1-2)of SmartBits network tester's LAN-3321A module gigabit mouth;

(2)According to the testing requirements configure corresponding IP address for test equipment, use Tera Routing Tester test simulated network topology (IP address starts with 200 for each IP network segment), start SmartBits internal OSPF protocol;

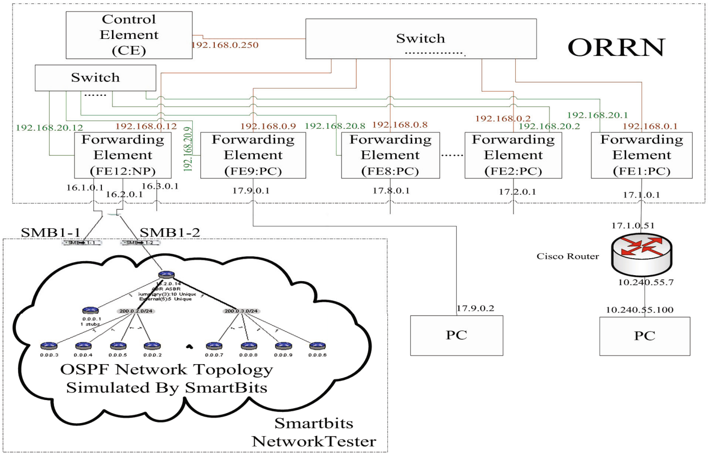


Fig. 7. Description of the test configuration

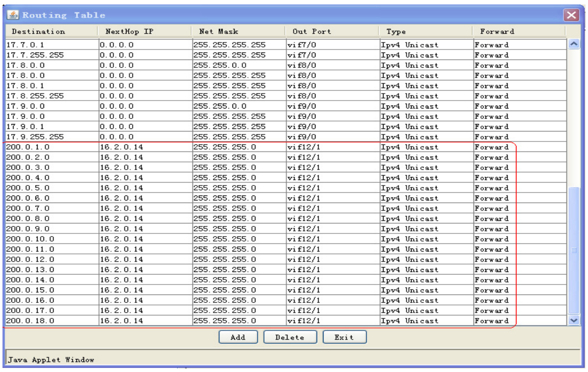
(3) Run OSPF on a port of FE12 (IP address: 16.2.0.1)in CE, starts OSPF protocol in the CE;

(4)Wait for internal interaction of Smartbits network with open reconfigurable routers through by OSPF ;

(5)Based on web terminal interface in 2.2 section, click on View / Routing table to open the route lookup dialog box to view the dynamic routing tables generated by the CE;

(6)Log in a FE HyperTerminal, enter "route-n" command to view if the dynamic routing being added correctly.

1) View the dynamic routing table which generated by CE on routing query dialog box:



Routing Table

Destination	NextHop IP	Net Mask	Out Port	Type	Forward
17.7.0.1	0.0.0.0	255.255.255.255	vif7/0	Ipv4 Unicast	Forward
17.7.255.255	0.0.0.0	255.255.255.255	vif7/0	Ipv4 Unicast	Forward
17.8.0.0	0.0.0.0	255.255.0.0	vif8/0	Ipv4 Unicast	Forward
17.8.0.0	0.0.0.0	255.255.255.255	vif8/0	Ipv4 Unicast	Forward
17.8.0.1	0.0.0.0	255.255.255.255	vif8/0	Ipv4 Unicast	Forward
17.8.255.255	0.0.0.0	255.255.255.255	vif8/0	Ipv4 Unicast	Forward
17.9.0.0	0.0.0.0	255.255.0.0	vif9/0	Ipv4 Unicast	Forward
17.9.0.0	0.0.0.0	255.255.255.255	vif9/0	Ipv4 Unicast	Forward
17.9.0.1	0.0.0.0	255.255.255.255	vif9/0	Ipv4 Unicast	Forward
17.9.255.255	0.0.0.0	255.255.255.255	vif9/0	Ipv4 Unicast	Forward
200.0.1.0	16.2.0.14	255.255.255.0	vif12/1	Ipv4 Unicast	Forward
200.0.2.0	16.2.0.14	255.255.255.0	vif12/1	Ipv4 Unicast	Forward
200.0.3.0	16.2.0.14	255.255.255.0	vif12/1	Ipv4 Unicast	Forward
200.0.4.0	16.2.0.14	255.255.255.0	vif12/1	Ipv4 Unicast	Forward
200.0.5.0	16.2.0.14	255.255.255.0	vif12/1	Ipv4 Unicast	Forward
200.0.6.0	16.2.0.14	255.255.255.0	vif12/1	Ipv4 Unicast	Forward
200.0.7.0	16.2.0.14	255.255.255.0	vif12/1	Ipv4 Unicast	Forward
200.0.8.0	16.2.0.14	255.255.255.0	vif12/1	Ipv4 Unicast	Forward
200.0.9.0	16.2.0.14	255.255.255.0	vif12/1	Ipv4 Unicast	Forward
200.0.10.0	16.2.0.14	255.255.255.0	vif12/1	Ipv4 Unicast	Forward
200.0.11.0	16.2.0.14	255.255.255.0	vif12/1	Ipv4 Unicast	Forward
200.0.12.0	16.2.0.14	255.255.255.0	vif12/1	Ipv4 Unicast	Forward
200.0.13.0	16.2.0.14	255.255.255.0	vif12/1	Ipv4 Unicast	Forward
200.0.14.0	16.2.0.14	255.255.255.0	vif12/1	Ipv4 Unicast	Forward
200.0.15.0	16.2.0.14	255.255.255.0	vif12/1	Ipv4 Unicast	Forward
200.0.16.0	16.2.0.14	255.255.255.0	vif12/1	Ipv4 Unicast	Forward
200.0.17.0	16.2.0.14	255.255.255.0	vif12/1	Ipv4 Unicast	Forward
200.0.18.0	16.2.0.14	255.255.255.0	vif12/1	Ipv4 Unicast	Forward

Add Delete Exit

Java Applet Window

From the results, after the interaction, CE has been properly learned Smartbits dynamic routing table.

2) After logging into the FE3 super terminal, FE3 kernel routing table shows:

```
[root@f3 root]# route -n
Kernel IP routing table
Destination     Gateway         Genmask         Flags Metric Ref    Use Iface
200.0.12.0      192.168.20.12   255.255.255.0   UG    0      0        0 eth1
200.0.13.0      192.168.20.12   255.255.255.0   UG    0      0        0 eth1
200.0.14.0      192.168.20.12   255.255.255.0   UG    0      0        0 eth1
200.0.15.0      192.168.20.12   255.255.255.0   UG    0      0        0 eth1
192.168.20.0    0.0.0.0         255.255.255.0   U     0      0        0 eth1
200.0.8.0       192.168.20.12   255.255.255.0   UG    0      0        0 eth1
200.0.9.0       192.168.20.12   255.255.255.0   UG    0      0        0 eth1
200.0.10.0      192.168.20.12   255.255.255.0   UG    0      0        0 eth1
192.168.0.0     0.0.0.0         255.255.255.0   U     0      0        0 eth2
200.0.11.0      192.168.20.12   255.255.255.0   UG    0      0        0 eth1
200.0.4.0       192.168.20.12   255.255.255.0   UG    0      0        0 eth1
200.0.5.0       192.168.20.12   255.255.255.0   UG    0      0        0 eth1
200.0.6.0       192.168.20.12   255.255.255.0   UG    0      0        0 eth1
200.0.7.0       192.168.20.12   255.255.255.0   UG    0      0        0 eth1
200.0.16.0      192.168.20.12   255.255.255.0   UG    0      0        0 eth1
200.0.1.0       192.168.20.12   255.255.255.0   UG    0      0        0 eth1
200.0.17.0      192.168.20.12   255.255.255.0   UG    0      0        0 eth1
200.0.2.0       192.168.20.12   255.255.255.0   UG    0      0        0 eth1
200.0.18.0      192.168.20.12   255.255.255.0   UG    0      0        0 eth1
200.0.3.0       192.168.20.12   255.255.255.0   UG    0      0        0 eth1
```

From the chart, CE in open reconfigurable router learned new routing table through OSPF, and issued to the FE3, realize dynamic update of routing tables.

Results 1 and 2 shows data packet redirection between CE and FE correctly, containing receiving, interpretation, packaging and sending of reception message.

4.3 Support Management Functions for Open Reconfigurable Control Element Software and Interface Test

To see the feasibility of providing all the trees in FE and all interface to query information of LFC. Its test id is 2.1, and test configuration description is OSPF test configuration diagram remove configuration in the dashed box in the lower left.

Testing process (operation / signal flow): view the Web terminal in LFC Tree Domain . Test results:

1) Report LFC ability and display information: figure 4 show user management platform software interface

Tree structure shows the LFC in FE and details of each LFC.

(2)Topology information of LFC in FE: figure 5 component topology management interface

This topology shows the connection relationship between FE7 of each LFC.

From the above results, support ForCES protocol connection negotiation process which is realized by open reconfigurable network generic equipment control element software , and in the link stage, the connection messages are received ,interpreted, sending and package correctly.

5 Conclusion

In this paper, we introduced the hierarchical structure of reconfigurable network and architecture of control element software. Then, core components of control element, which include protocols middleware and the development of user operating management system are introduced in details.

Experiments of middleware software are illustrated for running routing protocols, network management, interface test etc. More importantly, the experiments have, as a result, actually illustrated the feasibility of control element.

Generic network devices which support open reconfigurable in this paper has been used in the development of open reconfigurable routing products, established two application demonstration in Shanghai Broadband Technology Center and the IETF ForCES working group during the project period, and the system has been deployed and tested in the application demonstration.

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