Development of Simulation Experiments for the Curriculum of Data Communication and Computer Network

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Abstract. In order to make up for the deficiency of traditional actual experiments in the curriculum of data communication and computer network, we put forward an idea that network simulation technique should be applied to develop experiment items. The methods of developing simulation experiments by network simulator were disscued, and application examples were introduced in detail. The using effect shows that the proposed scheme can help students to combine recondite concepts and theories with pratice, and is also an efficient way to improve research abilities of students.

1. Introduction

Data communication and computer network is an important specialized curriculum for the major of electronic information engineering. Because the curriculum involves a lot of recondite concepts and theoretical analysis, such as various protocols and algorithms, layered structure, data encapsulation, calculation of network performance indicators, so it is difficult to make students adequately understanding the contents of teaching. Practical training by experiments is an efficient way to improve teaching effect [1].

However, building actual experiment systems have significant limitations, the reason of which can be summarized in two folds. First, because of the limitation of equipment, the scale of actual computer network is usually too simple to accomplish complex experiments. Further, the communication parameters in the process of messages transmitting can't be acquired, so performance indicators such as network throughput, end-to-end delay, channel utilization and packet loss rate can't be analyzed by actual experiment systems. On the other hand, random and independent behaviors of nodes make it difficult to build accurate theoretical model to analyze performance indicators of communication network.

In order to solve above problems, we present the scheme of developing simulation experiments by network simulator, which has two kinds: computer network design and configuration, and computer network performance testing.

2. Experiments of Computer Network Design and Configuration

Huawei ENSP (Enterprise Network Simulation Platform) or Cisco Packet Tracer can all be used to develop simulation experiments of computer network design and configuration [2, 3]. Experiment teaching should follow the principles from simple to complex, form easy to difficult, from part to whole. To this end, the following two kinds of experiments are developed:

(1) Single experiments

In single experiments, pre-constructed network topology by simulator is provided to students, which includes adequate subnets of LAN and WAN. The whole network configuration is divided into several single experiments, as shown in table 1.

(2) Comprehensive experiment

After finishing all single experiments, students have expertly mastered the methods of computer network configuration, and deeply understand the principle of data communication, on this basis, comprehensive experiment should be drawn into the curriculum's teaching. The comprehensive experiment requests students to structure a campus network based on multi-layer switching mode. The designed campus network must meet the needs of real services and capacity, and the technologies of virtual LAN (VLAN), network address translation (NAT), access control list (ACL), virtual private network (VPN) and firewall must be used to enhance the security and flexibility of designed campus network.

Tab 1: The developed single experiment items

number	experiment title	experiment content
1	the methods of computer network design and configuration	building network topology, configuration methods of router, switch and computer
2	subnet dividing and IP address assignment	subnet dividing, VLSM (Variable Length Subnet Mask), CIDR (Classless Inter-Domain Routing)
3	routing protocol	static routing, interior gateway protocol (RIP, OSPF, IGRP), external gateway protocol (BGP)
4	WAN configuration	ISDN configuration, PPP protocol, frame-relay protocol
5	virtual LAN (VLAN)	dividing a physical network into different virtual LANs
6	access control list (ACL)	standard access control list, extensional access control list
7	virtual private network (VPN)	the method of VPN configuration
8	network address translation (NAT)	two methods of NAT configuration

3. Experiments of Computer Network Performance Testing

3.1 The developed process of experiments

The experiment development is based on Network Simulator 2 (NS2), which is a discrete event simulator. When running OTCL script in NS2, the events of data packet transmitting are recorded into trace files. Finally, we can use gawk data processing tool to analyze trace files, and calculate the performance indicators of network [4, 5]. The developed process of experiments of computer network performance testing is shown in figure 1.
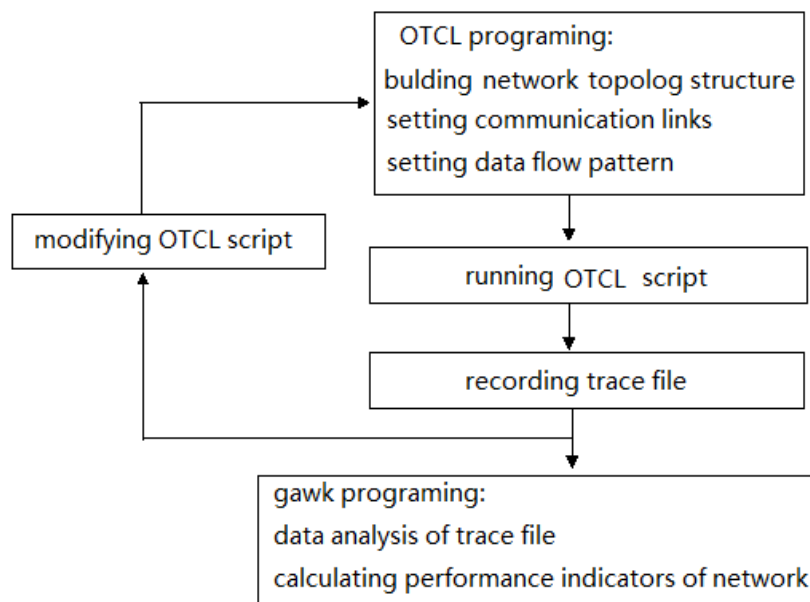

Figure 1: The developed process of experiments of computer network performance testing

We have developed several experiments to test computer network performance, including MAC layer channel contention algorithm, WLAN route protocols, TCP/UDP protocol, simulation model of video transmission, simulation model of Ad-Hoc network.

3.2 An example of computer network performance testing experiment

In MAC layer of IEEE 802.11e WLAN, EDCA (Enhanced Distributed Channel Access) protocol is used to perform channel access control. EDCA has four channel access categories (ACs), each AC employs CSMA/CA (Carrier Sense Multiple Access/Collision Avoidance) mechanism to competing wireless channels. CSMA/CA uses Binary Exponential Back off (BEB) algorithm to reduce the collision probability of channels. EDCA assigns higher priority AC with smaller CSMA/CA competition window and back off time, so that the higher the transmission priority, the better is the opportunity to compete wireless channels [6-8].

We develop EDCA simulation experiment to test network throughput and transmitting delay. Virtual network scenario building in OTCL script is as follows:

(1) 10 nodes are distributed on the area of 100m×100m, all nodes can communications with each other through single hop, wireless channel is ideal.

(2) Nodes incessantly send data frames with each other, the data frames include voice frames of AC3 queue, video frames of AC2 queue, UDP frames (Best effort frames) of AC1 queue, TCP frames (Background frames) of AC0 queue. The highest priority is AC3 queue, the lowest priority is AC0 queue.

(3) All data frames have the fixed length of 1000 bytes.

(4) Simulation duration time is 20 seconds.

After running OTCL script, we can obtain the trace file which records the packet events in the process of data transmitting, including packet sending, packet arrival, packet loss and packet timeout. The part of trace file is shown in figure 2, it records the events that node 1 sends ARP (Address Resolution Protocol) frame or CBR (Constant Bit Rate) frame to node 2, and node 2 sends back ARP response and ACK frame to node 1.

```
s 2.556838879 _1_ AGT --- 0 cbr 97 [0 0 0 0] ------- [1:0 2:0 32 0] [0] 0 0
s 2.556933879 _1_ MAC --- 0 ARP 71 [0 ffffffff 1 806] ------- [REQUEST 1/1 0/2]
r 2.557502150 _2_ MAC --- 0 ARP 28 [0 ffffffff 1 806] ------- [REQUEST 1/1 0/2]
s 2.558570148 _1_ MAC --- 0 cbr 1000 [f2 2 1 800] ------- [1:0 2:0 32 0] [0] 0 0
r 2.558781328 _2_ MAC --- 0 cbr 97 [f2 2 1 800] ------- [1:0 2:0 32 0] [0] 1 0
s 2.558791328 _2_ MAC --- 0 ACK 29 [0 1 0 0]
r 2.559023599 _1_ MAC --- 0 ACK 29 [0 1 0 0]
```

Figure2: The part contents of trace file

Further, we analyze trace file by gawk program, and then, calculate the performance indicators of saturated throughput and transmission delay. The results are shown in figure 3. From figure 3, we can clearly observe that high priority AC queue has better throughput and lower transmission delay, so their service requirements can adequately be ensured.

4.   Conclusions

In order to make up for the deficiency of traditional actual experiments, we present the scheme that developing simulation experiments for the curriculum of data communication and computer network. In these experiments, the experiments of computer network design and configuration can help students combine teaching contents with practice, and enhance their interest in curriculum learning. The experiments of network performance testing can help students understanding recondite concepts and theories, and improving their research ability. These developed experiment items have been used in the process of teaching, and good effects have been achieved.

As our further work, we will develop more innovation-oriented experiment items. Besides, we will attempt to combine simulation experiments with actual equipment experiments in the processing of curriculum teaching.
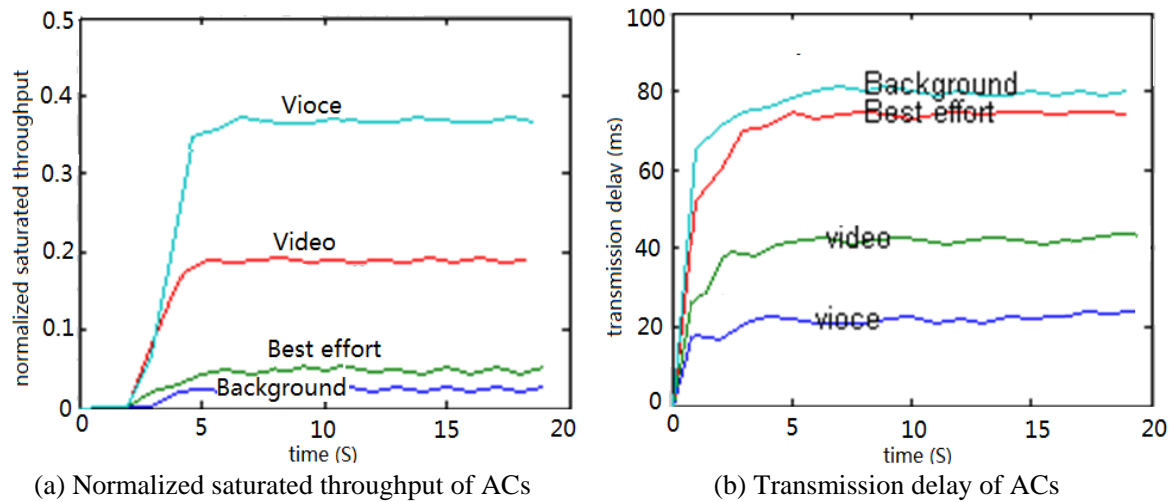
(a) Normalized saturated throughput of ACs　　　(b) Transmission delay of ACs

Figure 3: Performance analysis results of EDCA simulation experiment

Acknowledgements

References

[1] Xiren. Xie: *Computer Network* (Publishing House of Electronics Industry, China 2014). (In Chinese)

[2] Karen. Webb: *Building Cisco Multi-layer Switched Network* (Cisco Press, United States 2003).

[3] Information on http:// edu.51cto.com/course/course_id-3155.html

[4] Hua-ji. Huang: *NS Simulations of Network and Protocol* (Posts and Telecom Press 2010). (In Chinese)

[5] Lian-bo. Zhang, Xu-ming. Fang: *Journal of Southwest Jiaotong University*, vol. 39 (2002), p.660-664. (In Chinese)

[6] Zhi-heng. Ke, Rong-xiang. Cheng, De-jun. Deng: *NS2 Simulation Experiments- Multimedia and Wireless Communications* (Publishing House of Electronics Industry, China 2009). (In Chinese)

[7] IEEE Std. 802.11: *Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specification* (2007).

[8] Jian-bing. Mao, Yu-ming. Mao, Su-peng. Leng, Xiang. Bai: *Journal of Software*, vol. 4 (2010), p.750−770. (In Chinese)