

An Interactive Interface for Information Exchanging between QualNet and Virtual Machine for IP Based Network

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Abstract—Recently, the hardware-in-the-loop simulation for protocol design, software testing, and device model testing has been widely considered for the IP-based communication network owing to a higher authenticity and accuracy. However, as the number of real devices increases, a huge testing cost becomes inevitable. In this paper, an interactive approach for information exchanging between network simulator and virtual machine for IP based network simulation is proposed. Together with the interactive interface, the data packets generated by the network software or the model of real network device, which is needed to be tested and is installed on the virtual machine, are transmitted from the corresponding node to the target node in QualNet based virtual network. Based on the proposed interactive approach, a large-scale network emulator, which effectively reduce the testing cost, can be composed by the network simulator and the virtual machine together with the network device image and software. Simulation results demonstrate that the interactive interface can realize the information exchanging between network simulator, i.e., QualNet, and virtual machine, with an acceptable delay and rare packet loss.

Keywords— interactive interface, IP based network, QualNet, virtual machine, emulation

I. INTRODUCTION

Owing to a higher authenticity and accuracy by considering physical or real devices in the simulation environment, hardware-in-the-loop simulation has been widely considered for the feasibility and the reliability evaluation of network protocol, network software as well as prototype of device in communication network [1].

In [2], a hardware-in-the-loop simulation interface based on OPENT for realizing the protocol mapping from external simulation member to simulated nodes was presented. In [3], an interactive real-time interface had been designed to transmit simulation data to the external device based on QualNet. In [4], an emulation based on QualNet is built to simulate the tactical data link. However, the real communication device and virtual communication node has to be pre-assigned as a pair. As a result, when the scale of

network simulation expands, e.g., large scale network simulation with a great number of real routers, too much hardware resource cost is required for above system. Instead, the virtual machine can be considered as a substitution of real device. In [5], virtual machines were used to replace real devices for network security attack and defence experiment. In [6], the virtual machines coordinated with the virtual network to verify the secure framework for trusted service chain. Although the methods of virtual machine was proposed in the above paper, how to combine virtual machine with the network simulator in network simulation has not been studied. Thus, the interactive interface for information exchanging between network simulator, e.g., QualNet, and virtual machine is valuable to be designed.

In this paper, an interactive interface that supports information exchanging between QualNet and virtual machine for IP based network simulation is addressed. According to the interactive interface, the tested software or the model of real device, which is installed on the virtual machine, generates data packets and transmits them via wired links to the network simulator. Network simulator can reassemble real packets into virtual packets and inject them into virtual wireless network at the corresponding virtual node based on the simulation protocol. Together with the proposed interactive interface, an efficient network emulator can be composed of network simulator and virtual machine with network software and network device image. This emulator can realize the exchanging information, e.g., video streaming, between network simulator and virtual machine with an acceptable delay of less than 1 millisecond.

The paper is organized as following. Section II introduced the architecture as well as the implement of interactive interface. Section III describes the experiment environment and shows the simulation results. The conclusions are drawn in Section VI.

II. PROPOSED INTERACTIVE INTERFACE

A. Architecture of Proposed Interactive Interface

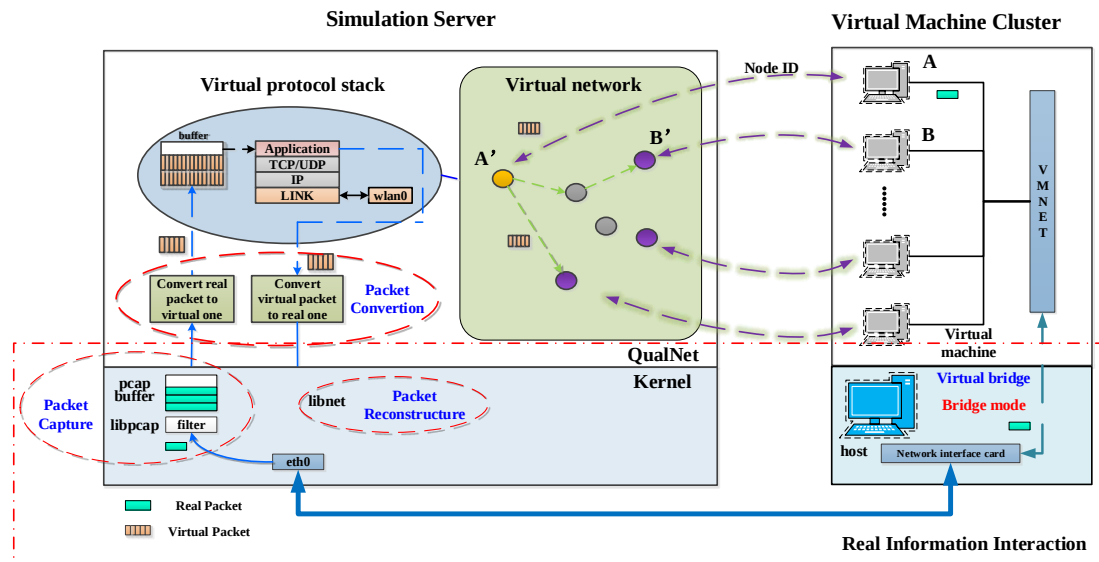


Figure 1. Emulation architecture of QualNet and virtual machine

The emulation architecture of QualNet and virtual machine is shown in Figure 1. QualNet is utilized to generate the network topology of communication nodes. Network software or device models are running on the virtual machines created by VMware. According to the interactive interface, each virtual machine is assigned a virtual communication node simulated in QualNet as a pair, and each of them is given a unique identification (ID).

Here, an example of information exchanging process of the proposed interactive interface between QualNet and virtual machine is given as following. It is assumed that a device model or software running on virtual machine A generates message and will send it through the virtual network simulated by QualNet to a device model or software running on virtual machine B. When a message is generated on virtual machine A, it is packetized in a standard format and sent over a virtual bridge to the host network interface card, and then transmitted to the simulation server via the wired link. The simulation server captures all packets that passing through it at the network interface card, i.e., eth0 by calling packet capture library, i.e., libpcap, and filters those packets from virtual machine A according to the format. QualNet obtains the information including source node ID, target node ID, message type, etc. by parsing packets received in the network interface card, and injects them into the virtual wireless network from the application layer of source node A' as the virtual packets. In the QualNet based simulation scenario, the virtual packets are sent and received according to the simulated routing protocol until they reach the target node, i.e., B'. The information is then extracted at the application layer and reconstructed as the real packets. The simulation server takes out the data packets from the application layer of target node B' and calls the libnet library to send them, which is

received and possessed by the software running on target virtual machine B. It's noted that a virtual bridge is utilized to connect the host network interface card to the virtual switch VMnet. Therefore, the IP of virtual machine and the simulation server must be in the same network segment [7].

B. Implement of Information Interaction

The transmission of real data packets between the simulation server and the virtual machine is accomplished based on the data distribute service (DDS) middleware via wired link based on IP transmission protocol. The transmission mechanism is shown as Figure 2. The virtual communication node simulated in QualNet and each virtual machine work in the same domain as a pair of independent domain participants.

To complete the information transmission, two different topics are needed at least. One is data transmission of simulation server topic (Data_S_Transmission Topic), another one is data transmission of virtual machine topic (Data_V_Transmission Topic). Once a message is sent from the virtual machine to the simulation server, an instance of Data_V_Transmission Topic will be immediately created including source node ID, target node ID, and other information in a form of string, and will be published to the corresponding domain through Data_Transmission writer. For the simulation server, it subscribes to the Data_V_Transmission Topic from the domain. In another word, as long as an instance of Data_V_Transmission Topic is published to the domain, the simulation server will get the instance through the Data_Reception reader. In addition, when the simulation server has a message to send to virtual machine, the process is performed as the same as that, except another topic (Data_S_Transmission Topic) is utilized.

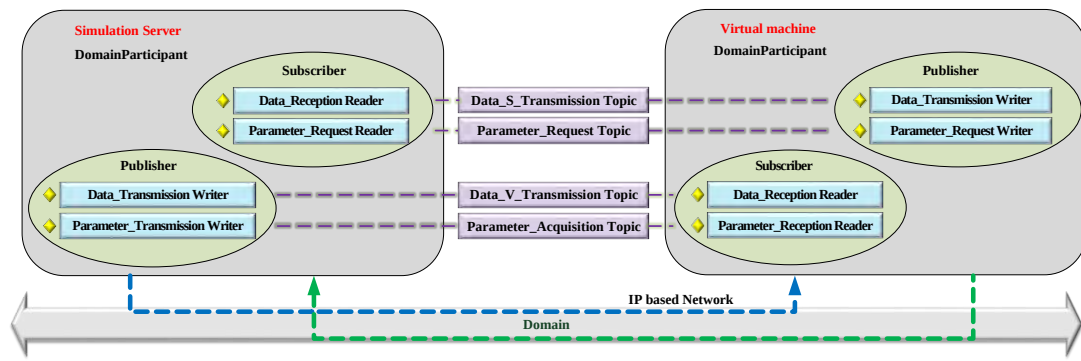


Figure 2. Information exchanging mechanism between simulation server and virtual machine based on DDS

This interaction can also support the display of parameters and statistics realization during the simulation. The process is similar to the transmission of data, but the definition of topic is different. Once the virtual machine sends the request of specified node to the simulation server, the QualNet will packetize the corresponding parameters and the statistical data back to the virtual machine via a `Parameter_Transmission Topic`. All topic structures are known to both simulation server and virtual machines. And the topic structure used by the publisher for sending is consistent with the topic structure used by the subscriber for receiving.

III. EXPERIMENT AND RESULTS

In the experiment, a wire-wireless hybrid network model is simulated by QualNet and each of the simulated nodes is assigned a corresponding virtual machine as a pair. On each virtual machine, a software with functions, e.g., video stream sending and playing, parameter acquisition and parameter control, is used to generate and receive data information for testing. The basic transmission process is from the virtual machine through the virtual network to another virtual machine.

A. Experiment Environment

The architecture of experiment is shown in Figure 3, which includes one simulation server, one VMware server and one notebook. The parameters of devices are shown in Table 1. QualNet is running on the simulation server. Virtual machine server installs vSphere 6.7 system, where three virtual machines are created. The notebook is used as a real network device for the performance comparison.

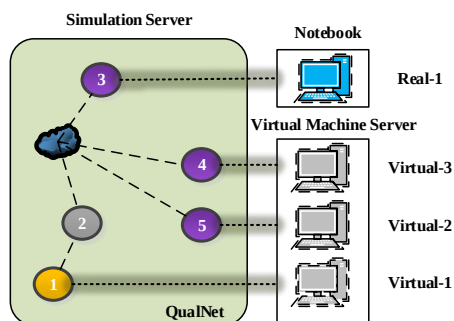


Figure 3. Architecture of experiment

TABLE 1. PARAMETER OF DEVICES

Name	CPU	Memory	Disc space	System
Simulation server	CPU Core i5-6400	128GB	120GB	Ubuntu 12.04
VMware server	CPU Inter Xeon E5-2620 V4	128GB	2TB	vSphere 6.7
Notebook	CPU Inter Xeon E5-2620 V4	8GB	1TB	Windows 7
Virtual-1	CPU Inter Xeon E5-2620 V4	8GB	32GB	Windows 7
Virtual-2	CPU Inter Xeon E5-2620 V4	8GB	32GB	Windows 7
Virtual-3	CPU Inter Xeon E5-2620 V4	8GB	32GB	Windows 7

B. Simulation Scenario

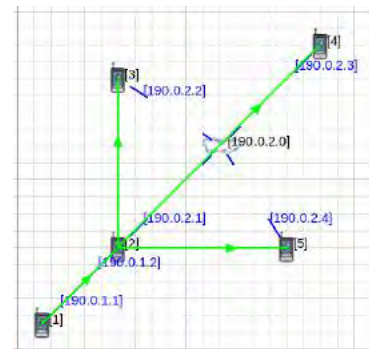


Figure 4. Qualnet based wireless-wired hybrid network topology

The simulated network scenario is shown as in Figure 4. In this scenario, the distance from node 2 to node 3 is the same as that from node 2 to node 5, both of which are 1 kilometer, and the distance from node 2 to node 4 is about 1.7 kilometers. The channel path-loss model is set as free space. For the wireless subnet, the physical layer protocol is Abstract, the mac layer protocol is time division multiple access (TDMA) and the application layer routing protocol is Adhoc On-

demand Distance Vector Routing (AODV). Nodes 1, 4 and 5 are connected to virtual machines, while node 3 is connected to a real machine. Node 2 plays as a relay station to broadcast the received data to other nodes. We mainly focus on the data transmission from virtual-1 to virtual-2, virtual-3, and real-1 via node 2.

C. Experiment Results

After the simulation starts, the software running on the Virtual-1 sends video stream and plays it locally as comparison. When the video stream passes through the virtual network and is transmitted to Virtual-5, the software gets video information and decodes to play immediately. The performance of video streams of Virtual-1 and Virtual-5 are shown in Figure 5, which implies that the information exchanging between QualNet and virtual machine can be successfully supported via the proposed interactive interface.



Figure 5. Performance of video transmission between Virtual-1 and Virtual-5

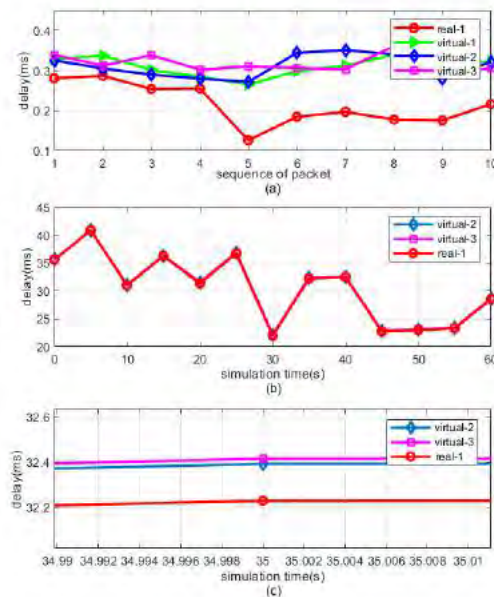


Figure 6. The delay of information interaction. (a) The transmission delay from QualNet to devices. (b) End-to-end delay from Virtual-1 to other devices. (c) Partial curve of the End-to-end delay.

The transmission delay of video streaming from QualNet to devices is shown in Figure 6(a). Since the message transmitted from the network interface card to the virtual machine needs to pass through the virtual bridge, the transmission delay from simulation server to virtual machine is higher than that to real device, thus, a 0.2 milliseconds difference can be observed. The end-to-end delays from Virtual-1 to other devices are shown in Figure 6 (b) and (c). The end-to-end delay of Virtual-3 is slightly larger than that to Virtual-2, because the distance from node 2 to node 4 is larger than that from the distance from node 2 to node 5. Together with the results of Figure 6 (a) and (b), we can know that the end-to-end delay is mainly determined by the transmission delay in virtual network in QualNet, and the proposed interactive interface has rare influence on the simulator.

IV. CONCLUSIONS

In this paper, the interactive interface for information exchanging between QualNet and virtual machine is designed and implemented. Together with the proposed interactive interface, the message generated by software or device model running on virtual machine can be efficiently realized by the network simulator, e.g., QualNet. The experiment results demonstrate that the information exchanging between the virtual network and virtual machine with software or device model can be successfully achieved with an acceptable delay. Furthermore, since the delays of virtual machine and real network device are similar to each other, the proposed interactive interface can be considered as a suitable substitution for large scale network testing with great number of real network devices without much loss of simulation authenticity and accuracy.

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