

TCP/IP Visualization Systems with a Packet Capturing Function

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Abstract—This paper proposes four TCP/IP protocol visualization systems for students who intend to become computer and communication engineers. Because TCP/IP protocols are the fundamental technology underlying computer networks and the Internet, communication and computer engineers must learn these protocols. However, students cannot gain experience or fully understand the protocols by traditional learning methods, such as textbooks and lectures, since these methods cannot demonstrate the various communication procedures. To solve this problem, we have been developing systems to visualize the protocols of TCP/IP with a packet capturing function.

Index Terms—TCP/IP, visualization, packet capturing.

I. INTRODUCTION

TCP/IP protocols are the fundamental technology for computer networks and the Internet. Thus, students who intend to become computer and communication engineers must learn these protocols. However, it is difficult for students to learn the concepts of the protocols by traditional learning methods, such as textbooks and lectures, because these methods give routine communication patterns that are not as effective as using the protocols in reality. A packet capturing tool, such as Wireshark [1], is one solution. However, it is also difficult for students to use such tools because they are directed toward network engineers. In this paper, systems visualizing TCP/IP with a packet capturing function are proposed.

It is assumed that learning systems for computer networks are divided into three categories: showing effective information for protocol theories, showing effective information for constructing LANs, and providing a learning environment for constructing LANs.

Two systems were developed to teach the theories of TCP/IP for a communication and network course at a local university. One system teaches communication procedures and data formats with a packet capturing function [2][3]. The other system simulates control methods that rarely occur in real communication and also combinations of control methods [4].

Tajima et al. developed a system that provides teaching information on TCP/IP basic mechanisms for high school students with a packet capturing function [5]. Hayakawa et al. proposed a system that sets IP addresses and network cables in a virtual LAN [6]. Therefore, users can learn about the Internet and datalink layers. Toguro et al. developed a

simulator that constructs a virtual network to teach network configuration [7]. Nakagawa et al. proposed a system that provides a teaching environment for constructing computer networks using VMWare [8]. In addition, Network Simulator ns-2 [9] and OPNET [10] are well-known systems that simulate computer networks.

In this paper, four TCP/IP visualization systems with a packet capturing function for learning protocol theories are proposed.

II. VISUALIZATION SYSTEM FOR DATA STRUCTURE AND COMMUNICATION PROCEDURES

The first system demonstrates the communication procedures and data formats of TCP/IP. The system consists of one main window and several sub-windows. The system has the following functions.

- 1) *Packet monitoring*: The system can capture real communication packets that a student receives or sends on a personal computer (PC). First, the student selects an application protocol from SMTP, POP, HTTP, or telnet (Fig. 1. (1)). Then, the student clicks the start button and uses an application program such as email or an Internet browser that uses the application protocol selected by the student. The system captures packets until the student clicks the stop button (Fig. 1. (2)).
- 2) *Displaying brief information on a packet*: Fig. 1. (3) shows a table with information of the captured packets. Each packet is described in one row of the table.
- 3) *Displaying details of a packet*: In Fig. 1. (4), the system displays details, such as the name of the field and the value of a packet selected from the packet information table.
- 4) *Displaying communication procedures*: The system displays the communication procedures of the transport layer (Fig. 2. (1)) and the application layer (Fig. 2. (2)) by selecting the check buttons (Fig. 1. (5)).

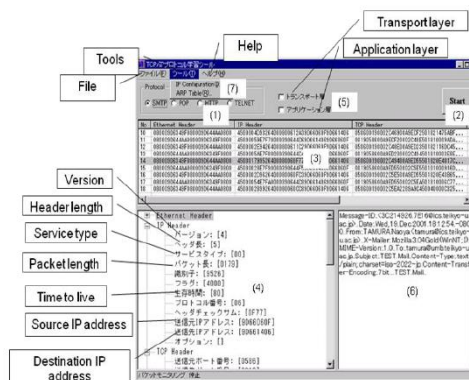


Fig. 1. Display of the data structure.

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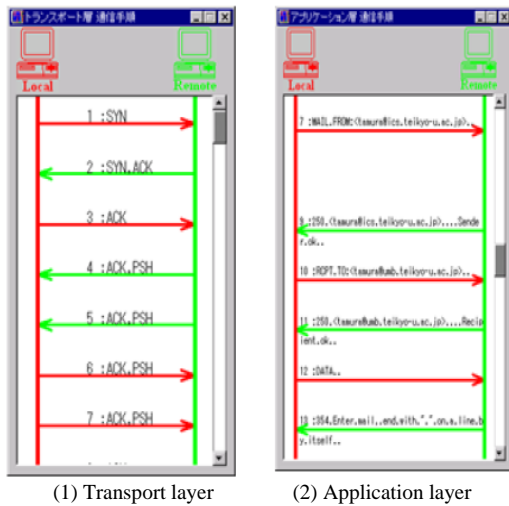


Fig. 2. Display of the communication procedure.

We used the system in an actual TCP/IP course at Teikyo University. One-hundred-five junior students in the Department of Computer Science took the course. After the students were done using the system in their class, we distributed a questionnaire for the students' evaluations of the system. Ninety-seven students answered the questionnaire. According to the results, the tool was useful for 91% of the students.

III. APPLICATION PROTOCOL VISUALIZATION SYSTEM

The system mentioned in Section 2 had the following problem: although it can visualize the communication procedures and data for the datalink, Internet, transportation, and application layers, a new learner may not be able to understand the information, particularly the meaning of messages, of the application layer in the network. Thus, in this section, we developed a new system that specializes in application protocols and visualizes the communication procedure and data for the application layer using a packet capturing function [11].

A. Outline of the System

Fig. 3 shows the main window of the system and an execution result of HTTP. The window has a combination box (Fig. 3. (1)), a start button (Fig. 3. (2)), and four subwindows (Fig. 3. (3)-(6)). The computers that execute the system are referred to as local computers, and the computers that communicate with the local computers, such as Web servers, are referred to as remote computers.

First, a user selects the application protocol from the combination box shown in Fig. 3. (1). Next, the user clicks on the "START" button shown in Fig. 3. (2), and then the system begins to capture packets.

The four subwindows show messages appropriate to the application protocol selected in the combination box. Application messages consist of requests or comments, additional information, and attached files. Fig. 3. (3) shows the requests that the local computer using a web browser requested for a server (right arrow "→"), and the responses that the local computer received from the server computer (left arrow "←"). If the user selects one line in Fig. 3. (3), the system gives an explanation of the request or comment, as

shown in Fig. 3. (4). Similarly, information about the attached files is shown in Fig. 3. (5), and additional information is shown in Fig. 3. (6).

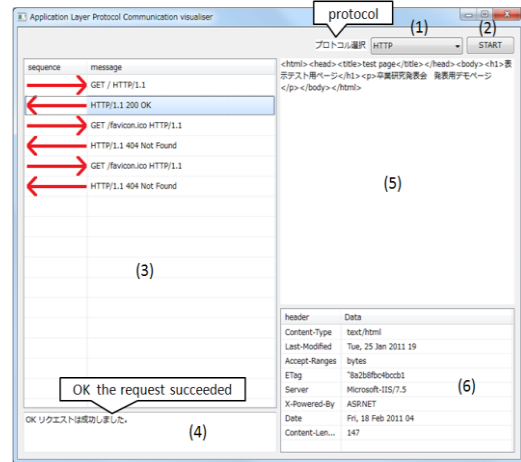


Fig. 3. Display of the application protocol information.



Fig. 4. Tree structure of XML tags used in the system.

B. Application Protocol Definition XML Data

This system has XML data files for defining each application protocol. If new application protocols are proposed or the present application protocols are updated, the system can be updated by defining new XML data. Fig. 4 shows the XML tag tree structure used in the system. All XML tags are defined within the protocol tag and are classified into three categories: fundamental information (general), message analysis (analyse), and explanation (exp).

IV. VISUALIZATION SYSTEM FOR THE CONTROL METHOD OF THE PACKET ARRIVAL ORDER

We assume that the traditional methods for explaining the control method of the packet arrival order have the following problems:

- 1) Textbooks about learning the control method show that the sequence number and the acknowledge number are incremented one by one. The numbers, however, are incremented according to the byte size of the sending or receiving data; and

- 2) Students cannot recognize the relationship between the sequence number and the acknowledge number.

To solve these problems, we developed a new visualization system for the control methods of the packet arrival order [3]. Fig. 5 shows the main window of this system.

The system has the following functions.

- 1) *Packet monitoring*: The system can capture real communication packets that the user sends or receives on a PC. First, the user selects an application protocol from SMTP, POP, HTTP, or the input port number (Fig. 5. (1)). Then, the user clicks on the start button and uses an application program such as email or an Internet browser that uses the application protocol selected by the user.
- 2) *Displaying details of a packet*: The system displays details, such as the name of the field and the value of a packet selected in the packet information table (Fig. 5. (2)).
- 3) *Displaying details of the packet arrival order*: The system displays the IP addresses, the sequence numbers, the acknowledge numbers and the data size (Fig. 5. (3)). Therefore, the user can visually recognize the control method of the packet arrival order.



Fig. 5. Display of the control method of the packet arrival order.

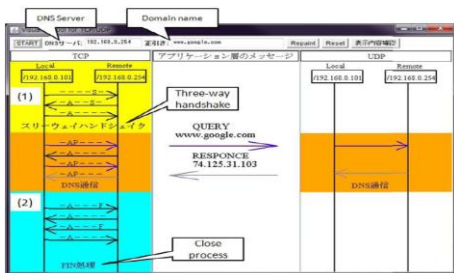


Fig. 6. The display for visualizing the difference between TCP and UDP.

V. VISUALIZATION SYSTEM TO SHOW THE DIFFERENCE BETWEEN TCP AND UDP

We assume that it is difficult for students to understand why TCP is more reliable than UDP. To address this problem, we are now developing a visualization system that shows the difference between TCP and UDP. Fig. 6 shows the main window for the system.

The system has the following characteristics.

- 1) *Displaying TCP and UDP in parallel*: The system captures real communication packets of the DNS. TCP and UDP data that the user sends or receives on a PC are shown in parallel.

- 2) *Displaying three-way handshake and close process of TCP*: The system displays the three-way handshake and close process of TCP (Fig. 6. (1), (2)).
- 3) *Displaying TCP flags*: The system displays TCP flags such as acknowledge, synchronize, push, fin, and so on (see Fig. 6 A, S, P, F) for the control method of error correction.

VI. CONCLUSION

In order to learn TCP/IP theories, we proposed TCP/IP visualization systems with a packet capturing function that showed the following: the data structure and the communication procedure, the application protocol, the control method of the packet arrival order, and the difference between TCP and UDP. In an actual TCP/IP class at one university, 91% of the students stated that these were useful tools. We plan to further evaluate the system(s) through practical use in actual classes.

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