Network Programming

Lecture 01

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Homework

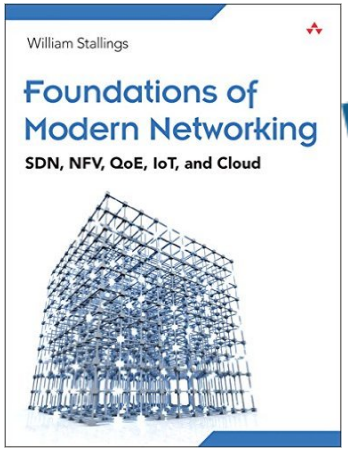
Topics

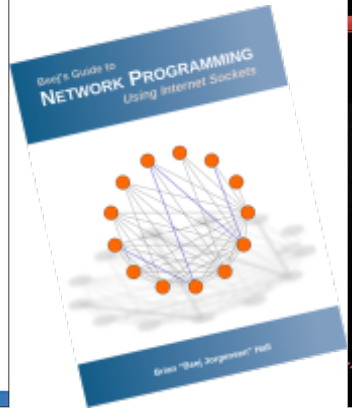
- TCP/IP Suite Review
- Unix/Linux Networking Basics
- IP4 and IP6
- Socket Programming (C++/Python)
- Client - Server Architecture Model
- Network Protocols and Services
- Network Routing Protocols
- SDN, NFV

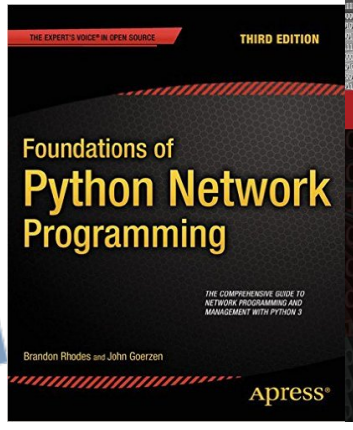
Lab

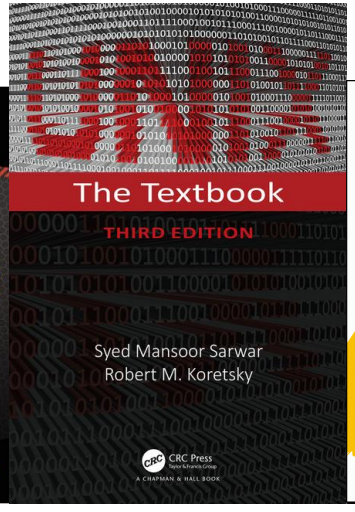
- Unix/Linux Networking Basics
- Socket Programming (C++/Python)
- Packet Capturing and Analysis (tcpdump/wireshark)
- Packet Tracer
- Mininet

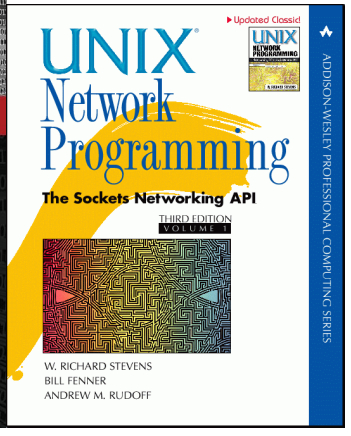
References


William Stallings
Foundations of Modern Networking
SDN, NFV, QoE, IoT, and Cloud


Network Programming
Using Internet Sockets


THIRD EDITION
Foundations of
Python Network
Programming
Brandon Rhodes and John Goerzen
Apress


The Textbook
THIRD EDITION
Syed Mansoor Sarwar
Robert M. Koretsky
CRC Press


UNIX
Network
Programming
The Sockets Networking API
THIRD EDITION
W. RICHARD STEVENS
BILL FENNER
ANDREW M. RUDOFF
ADDISON-WESLEY PROFESSIONAL COMPUTING SERIES

Marks

- 60 Marks - Final Exam
- 10 Marks - Oral Exam
- 10 Marks - Midterm Exam
- 10 Marks - Practical Exam
- 10 Marks - Project
- 100 Marks - Total

OFFICE HOURS

OPEN Most Days About 9 or 10

Occasionally as Early as 7,

But SOME DAYS As Late As 12 or 1

WE CLOSE About 5:30 or 6

Occasionally About 4 or 5

But Sometimes As Late as 11 or 12.

SOME DAYS OR Afternoons,

We Aren't Here At All, and Lately

I've Been Here Just About All The Time,

Except When I'm Someplace Else,

But I Should Be Here Then, Too.

Let's Get Started!

Following content is based on
http://www.cubrid.org/blog/dev-platform/understanding-tcp-ip-network-stack/

Understanding TCP/IP Network Stack

- Understand how data is transfered

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  - improve performance through tuning

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Understanding TCP/IP Network Stack

- Understand how data is transfered
  - improve performance through tuning
  - improve performance through troubleshooting
  - introduction to a new technology

Objectives of TCP/IP

Objectives

- Transmit data quickly
- Keep data order
- Without any data loss

Key characteristics of TCP/IP

- Connection-Oriented
- Bidirectional Byte stream
- In-order Delivery
- Reliable through ACK
- Flow Control
- Congestion Control

Connection-Oriented

- First, a connection is made between two endpoints (local and remote)
- and then data is transferred.
- "TCP connection identifier" is a combination of addresses of the two endpoints, having

```
<local IP address, local port number,
   remote IP address, remote port number>
```

Bidirectional Byte Stream

Bidirectional data communication is made by using byte stream.

In-order Delivery

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- To mark the order, 32-bit integer data type is used.

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- When a sender did not receive ACK from a receiver after sending data, sender TCP re-sends the data.
- Therefore, sender TCP buffers unacknowledged data from receiver.

Flow Control

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- Sender sends as much data as the size of bytes that receiver's receive window allows.

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  - BIC
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- Sender sends as much data as the size of bytes that the receiver's congestion windows allows by using a variety of algorithms, such as
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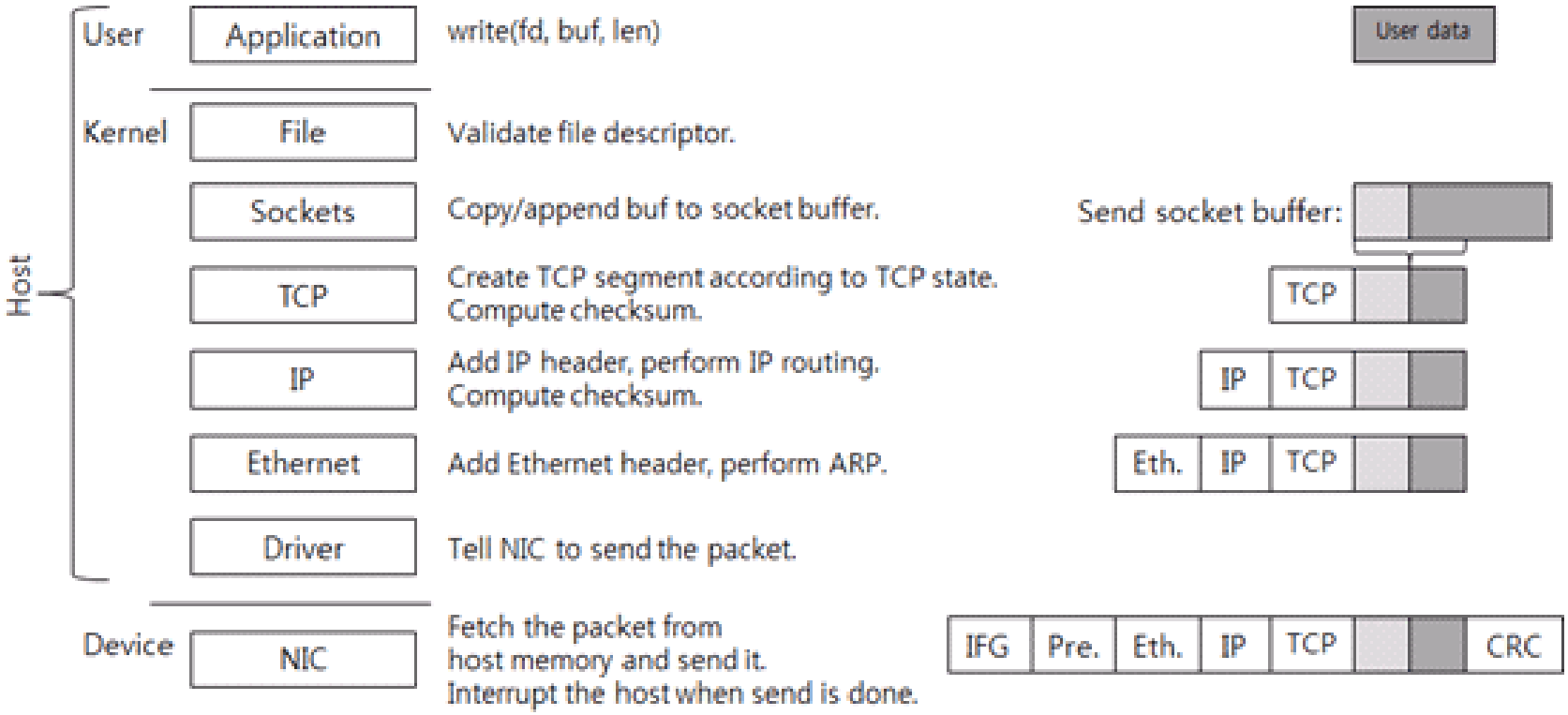
- Different from flow control, congestion control is implemented by the sender only.

Data Transmission



Operation Process by Each Layer of TCP/IP Network Stack for Data Transmission.

Data Transmission

There are several layers that are briefly classified into three areas:

- User area
- Kernel area
- Device area

host vs. device

host vs. device

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- here, device is NIC that sends and receives packets
- NIC is more accurate term than "LAN card"

User Area

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- Assume **fd** has been created. When system call is called, the area is switched to kernel area.

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- File layer executes a simple examination and calls the socket function by using the socket structure connected to file structure.

Kernel Socket

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1. One is the **send socket buffer** for sending
2. And the other is the **receive socket buffer** for receiving

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- data in the user area is copied to the kernel memory
- and then added to the end of the send socket buffer
- This is to send the data in order
- Then, TCP is called

TCP Control Block

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  - **receive window**
  - **congestion window**
  - **sequence number**
  - **resending timer**
  - **etc**

```
ESTABLISHED, SYN_SENT, SYN_RECV, FIN_WAIT1, FIN_WAIT2,
    TIME_WAIT, CLOSE, CLOSE_WAIT, LAST_ACK, LISTEN, CLOSING,
     UNKNOWN
```

Connection States

- **ESTABLISHED** The socket has an established connection.
- **SYN_SENT** The socket is actively attempting to establish a connection.
- **SYN_RECV** A connection request has been received from the network.
- **FIN_WAIT1** The socket is closed, and the connection is shutting down.
- **FIN_WAIT2** Connection is closed, and the socket is waiting for a shutdown from the remote end.
- **TIME_WAIT** The socket is waiting after close to handle packets still in the network.

Connection States (contd.)

- **CLOSE** The socket is not being used.
- **CLOSE_WAIT** The remote end has shut down, waiting for the socket to close.
- **LAST_ACK** The remote end has shut down, and the socket is closed. Waiting for acknowledgement.
- **LISTEN** The socket is listening for incoming connections. Such sockets are not included in the output unless you specify the –listening (-l) or –all (-a) option.
- **CLOSING** Both sockets are shut down but we still don't have all our data sent.
- **UNKNOWN** The state of the socket is unknown.

TCP State

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- If current TCP state allows for data transmission, a new TCP segment is created.

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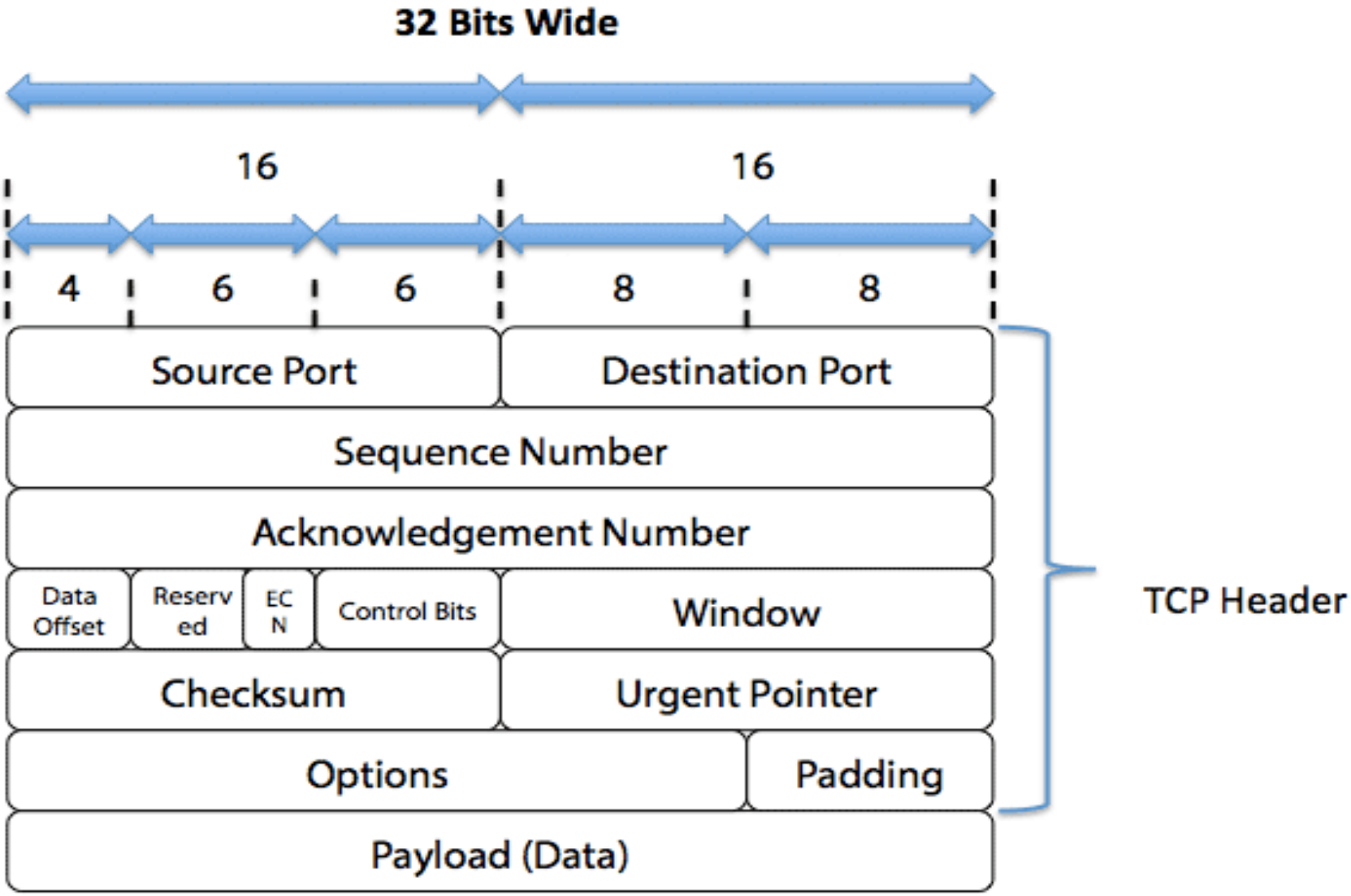
- If data transmission is impossible, due to flow control or such a reason, the system call is ended here and then mode is returned to user mode (control passed to the application)

There are two TCP segments:

1. TCP header
2. Payload

TCP Frame Structure



Payload

Payload

- Payload includes data saved in the unacknowledged send socket buffer.

Payload

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- Maximum length of Payload is the maximum value among the receive window, congestion window, and maximum segment size (MSS).

TCP Checksum

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- Then, TCP checksum is computed.

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  - IP addresses
  - segment length
  - protocol number

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- Then, TCP checksum is computed.
- Pseudo header information that are included are:
  - IP addresses
  - segment length
  - protocol number
- One or more packets can be transmitted according to the TCP state.

Checksum Offload

- TCP checksum is computed by NIC, not by the kernel.
- Why?

IP Layer

- The created TCP segment goes down to the IP layer, that does:
  - Adds IP header to the TCP segment
  - Performs IP routing

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- The created TCP segment goes down to the IP layer, that does:
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  - Performs IP routing
  - **IP routing** is a procedure of searching the next hop IP in order to go to the destination IP.

Ethernet Layer

Ethernet Layer

- Searches for the MAC address of the next hop IP by using the ARP.
- It then adds the Ethernet header to the packet.
- Host packet is completed by adding the Ethernet header.

NIC

- After IP routing is performed, the transmit interface (NIC) is knows as the result of IP routing.
- The interface is used for transmitting a packet to the next hop IP and the IP.
- Therefore, the **transmit NIC driver** is called.
- At this time, if a packet capture program such as tcpdump or wireshark is running, the kernel copies the packet data onto the memory buffer that the program uses.
- In that way, the receiving packet is directly captured on the driver.
- Generally, the traffic shaper function is implemented to run on this layer.

NIC Driver

- NIC driver requests packet transmission according to the driver-NIC communication protocol defined by the NIC manufacturer.
- After receiving the **packet transmission request**, NIC copies the packets from the **main memory** to **NIC memory** and then sends it to the network line.
- At this time, by complying with the Ethernet standard, it adds the Inter-Frame Gap (IFG), preamble, and CRC to the packet.
  - IFG and preamble are used to distinguish the start of the packet (framing).
  - CRC is used to protect the data
- Packet transmission is started based on the physical speed of the Ethernet and the condition of Ethernet flow control.

NIC Interrupts

- When NIC sends a packets, NIC generates interrupts to the host CPU.
- Every interrupt has its own interrupt number, and the OS searches an adequate driver to handle the interrupt by using the number.
- The driver registers a function to handle the interrupt (an interrupt handler) when the driver is started.
- OS calls the interrupt handler and then the interrupt handler returns the transmitted packet to the OS.

However

- So far, we have discussed the procedure of data transmission through the kernel and the device when an application performs write.
- However, without a direct write request from the application, the kernel can transmit a packet directly calling TCP.
- For example ?!!

However

- So far, we have discussed the procedure of data transmission through the kernel and the device when an application performs write.
- However, without a direct write request from the application, the kernel can transmit a packet directly calling TCP.
- For example ?!!
- When an ACK is received and the receive window is expanded, the kernel creates a TCP segment including the data left in the socket buffer and sends the TCP segment to the receiver.

Next Week InchALLAH

Next Lecture

- Data Receiving
- Data Structure
- Following Code

Next Lab

- Review TCP/IP Suite (Solve selected Qs)
- Qs can be found at `http://technologyeye.weebly.com/uploads/9/6/1/4/9614102/interview_question_networkingrajkumar.pdf`

Homework

- Study this lecture (very well)
- Prepare for the Next Lecture
- Check some Kernel code (mainly Networking Subsystem)


YOU GO
NOW!