

# 15213 Lecture 21: Network Programming

## Introduction

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This activity will motivate the structure of an interconnected network (internet). It will then introduce you to some common command-line tools, which you'll use to explore the global TCP/IP Internet's structure and protocols.

### Learning Objectives

- Describe the structure of a LAN (Local-Area Network), and compare with that of an internet.
- Recognize the mapping between human-readable domain names and IP addresses via DNS.
- Compare and contrast domain names and IP addresses.
- Identify the properties of a connection (point-to-point, full-duplex, reliable).
- Explain the role of ports in a connection and the mapping between ports and services.
- Explain the role of the HTTP protocol in the functioning of a Web browser.
- Outline the steps of a client-server network transaction.

## 1 Model 1: Network Structure

Conventional postal delivery systems (aka snail mail) are designed to carry written messages and packages from place to place. Mail carriers collect letters from several houses and drop them off at local post offices. Before the postal system was unified nationwide, post offices delivered local mail and transferred mail directly to other post offices.

1. A Local Area Network (LAN) is composed of a series of hosts, connected by switches, which are connected by routers. Write the postal entity whose role most closely corresponds to the given computer network component in a LAN (there are multiple acceptable answers). A word bank is provided.

Letter      Mailbox      House      Mail carrier      Postal relay box  
Local post office

Host \_\_\_\_\_  
Hub \_\_\_\_\_  
Switch \_\_\_\_\_

Today, post offices are linked by regional mail processing plants. Local post offices send their collected mail to mail processing plants, which then send the mail to one or more additional mail processing plants. The mail is then directed to the correct local post office and then given to a mail carrier for delivery.

2. An internet is composed of a series of LANs connected by one or more routers. Write the postal entity whose role most closely corresponds to the given computer network component in an internet (once again, there are multiple acceptable answers). A word bank is provided.

Letter      Mailbox      House      Mail carrier      Postal relay box  
                 Local post office      Mail processing plant

Host \_\_\_\_\_  
Switch \_\_\_\_\_  
Router \_\_\_\_\_

We will now use the command line tool `traceroute` to see this structure in action. Log into a shark machine. First, try running `traceroute` on a domain in the same network.

```
shark> traceroute shark.ics.cs.cmu.edu
```

3. How many routers were encountered in the route to another shark machine? Why?

Now, try running `traceroute cs.cmu.edu`. You will see a printout of the intermediate routers between your computer (in this case, the shark machine you're logged in to) and the destination server.

4. How many intermediate routers are there now? What do you observe about the names of all the intermediate routers? Why might this be?

## 2 Model 2: Network Protocol

Each host has a unique identifying *IP address*. IP addresses are mapped to a set of human-friendly *domain names*, which are maintained in a worldwide database called *DNS*, standing for Domain Name System. We will now explore DNS using a few common command line utilities.

The most basic way to find a domain name's IP address is through `nslookup`.

```
shark> nslookup cmu.edu
```

5. What is the IP address of `andrew.cmu.edu`? What about `cmu.edu`? What do you notice about these IP addresses?
6. Here, `andrew.cmu.edu` is a *subdomain* of `cmu.edu`. Try finding the IP address of a few more subdomains of `cmu.edu`, such as `cs.cmu.edu`, `csd.cs.cmu.edu`, and `ece.cmu.edu`. What do the IP addresses of these subdomains have in common? Why might this be?

The IP addresses of subdomains often share the highest-order 16 or 24 bits with each other and the parent domain. This is because both IP addresses and domain names are **hierarchical**.

7. Does the most significant (*least* fine-grained) piece of information come first or last in a domain name? What about in an IP address?
8. (*Advanced*) You can use `host` to do a reverse DNS lookup, where you find the domain name given an IP address. Use `hostname` to get the domain name of the machine you're currently logged in to and `hostname -i` to get its IP address. Try typing

```
shark> hostname -i
```

then entering the result into `host [IP_ADDRESS]`. What do you observe?

9. (*Advanced*) Unfortunately, reverse DNS lookup is rarely so straightforward. Try using `host` to look up the domain names of the IP addresses you found of `cmu.edu` and its subdomains. You can also look up domain names of IP addresses neighboring those. What is different about the domain names returned by a reverse DNS lookup?

### 3 Model 3: Client-Server

We will now explore the `ping` tool, which sends messages (called packets) to a server under a given domain name and waits for a response. Type

```
shark> ping -c 5 cs.cmu.edu
```

This is a very basic example of a client-server transaction. The client (the shark machine) is sending a request to a server somewhere, which processes the request and sends a response.

10. `ping` prints the time taken for a response to be received. Try `ping`-ing the CS programs of CMU (`cs.cmu.edu`), MIT (`csail.mit.edu`), and the National University of Singapore (`comp.nus.edu.sg`). How do the ping response times compare?

### 4 Model 4: Ports and Services

We have seen that IP addresses uniquely identify host machines.

11. Imagine that this were the most specific level of addressing. What limitations would this impose?

To address (no pun intended) this shortcoming, connection requests contain an additional port number appended to the IP address, which allows the client and server to route their requests to the appropriate service or process.

You can view a listing of services with their associated ports and protocols in the `/etc/services` file. Type

```
shark> head -n 100 /etc/services
```

12. Do you recognize any of the service names? What port number does `ssh` use? What about `http`? What are their associated protocols?

## 5 Model 5: Connection Properties

In this model, you will reinforce the properties of a network connection. You may be familiar with SMS messaging, also known as text messaging. Like a network connection, SMS messaging is **point-to-point**; that is, it connects a pair of recipients, rather than broadcasting to multiple recipients.

SMS messaging is also not necessarily **reliable**, which means that the sender receives no indication that messages are received, if they are received at all. Nor is SMS messaging particularly **ordered**; there is no guarantee that successive messages will be received in the order they were sent. However, network connections are reliable, meaning messages received are acknowledged by the recipient. Network connections are also ordered, meaning that messages will be received in the order they are sent.

Consider the following text message exchange, where Alice and Bob are discussing a time to meet. Alice sees:

Alice	Bob
Can we meet at 7:00 pm?	
If not, I'm also available at 8:00 pm.	
	Sure, that sounds good.

However, when Alice arrives at 8:00 pm, she finds that Bob had arrived at 7:00 pm and was waiting for her.

13. What went wrong? What does Bob's messaging history look like?

Now consider the next text message exchange. Alice sees

Alice	Bob
I'm free at 7:00 pm.	
We can meet at 8:00 pm?	
	Let's do the first one.

This time, Alice arrives at 7:00 pm, but Bob shows up an hour later.

14. What went wrong here? What does Bob's messaging history look like?
15. (*Advanced*) You can use the `netstat` utility to see a printout of the current network connections, but it prints out a lot of information. Run (on a shark machine)

```
shark> netstat --tcp
```

to only see the connections using the TCP protocol. Can you pick out the `ssh` connection with your local host name? Run `netstat --tcp` (you may have to run `netstat -p tcp` instead) on your local machine. Can you pick out the `ssh` connection? What port is that process using on your local machine (the client), and what type of port is this?

## 6 Model 6: HTTP Protocol

You will now use the `telnet` tool to explore sending HTTP requests to a Web server and receiving a response. Establish a connection to `cs.cmu.edu` on port 80 (the port associated with the HTTP service) by typing

```
shark> telnet cs.cmu.edu 80
```

Send an HTTP GET request to `cs.cmu.edu` by typing `GET /~213/index.html`.

16. What does the server response contain? What is this document?

This is an example of another client-server interaction, where the client is sending (via `telnet`) an HTTP GET request to the Web server of `cs.cmu.edu`, which processes the request and sends a response with the requested webpage.

17. How might you access the office hours page? What about the staff page?
18. (*Advanced*) On the staff page, you'll find the paths to pictures of the course staff. Try using `telnet` to send an HTTP request for one of those images. What happened? Can you think of a reason why?