Activity 2.1.3 Protocols and Bandwidth Answer Key

Procedure

1. Greet your partner to practice professional skills. Set team norms for pair work.

   There is a human protocol for a business introduction. First impressions in business (as elsewhere) are lasting. People do infer personality and confidence from your introduction. A business introduction includes both a verbal introduction and a handshake and is done while standing. Read the following protocol, and then practice by exchanging an introduction with each member of your group.

   - The verbal introduction should give your full name and a title or context. Allie might say, “Hello, my name is Allie Trusting. I’m a sophomore at Washington High School.”
   - One person starts their verbal introduction and extends their hand a relaxed distance toward the other person. The handshake lasts 3–4 seconds with two or three shaking motions.
   - The handshake should be as firm as you would use to turn a door handle. The web between your thumb and index finger should meet your partner’s.

   In this activity, we dive into some of the details of how the Internet works. There is a high demand for employees in **computer system design**. These jobs are approximately equal in number to jobs in applications programming. These computer specialists create and maintain networks and the computer hardware on the networks. They work with the layers of abstraction at which data are exchanged among computers in a network. They might have one of the following job titles.

   - Computer Engineers and Research Scientists create new technology

     Teacher Only

     $101k

   - Computer Support Specialists troubleshoot users’ problems

     Teacher Only

     $46k

   - Computer Systems Analysts analyze an institution’s technology and recommend

improvements

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$78k

- Computer Network Architects design an institution's network

Teacher Only

$76k

- Computer Systems Administrators install and maintain networks

Teacher Only

$69k

2. Reference the Bureau of Labor Statistics (BLS) *Occupational Outlook Handbook* at `http://www.bls.gov/ooh/`. Select **Computer and Information Technology** from among the occupation groups.

- The five groups listed earlier are among the BLS information. Which of these occupation groups has the highest median salary?

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The 2010 median salaries (in thousands) of the five groups are listed above. Research scientists earn the most.

- Which of the five occupation groups needs the fewest years of education?

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Computer support specialists do not need a four-year degree.

Part I: Act out protocols and the TCP/IP handshake

3. Think of decisions that you or another person made that were compromises among competing objectives. Describe one of these decisions that stayed in effect for some time after the decision was made.

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Answers vary. Example: when you sign up for classes, you might compromise among difficulty, interest level, and being with friends. Once you sign up, you stick with it.

4. Create a playwrite-style script for a TCP handshake, similar to the one above, just using different numbers. Write it down.

Teacher Only

Answers vary. In this example, the 16 and 5008 could be any numbers. However, the 17 and 5009 must be in sequence with those numbers.

1. Client: "SYN 16"
2. Server: "ACK 17, SYN 5008"
3. Client: "ACK 5009"

6. What might be a disadvantage of agreeing that both ends will confirm receipt like this?

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It requires more messages passing back and forth, more processing time for the server, and more waiting time for the client.

Part II: Explain how the Domain Name System works

7. What domain is this name server in charge of?

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casos.cs.cmu.edu

8. Name servers delegate autonomous authority to servers below them. For example, the `.org` name server doesn't keep track of IP addresses for all computers using domain names within `.org`.

   Why is this delegation of authority necessary?

Teacher Only

Without delegation, a central server would become overloaded as the Internet grew.

9. The six computers involved in the diagram are listed A–F. Record who says each of the messages 1–8 below, and to whom.

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1. Your computer: Jane
2. Your name server: John
3. root name server: Mary
4. `.org` name server: Jacob
5. `example.org` name server: Devon
6. `www.example.org` web server: Trey

1. from A to B: What is the IP address of www.example.org?
2. from B to C: What is the IP address of www.example.org?
3. from C to B: Ask 204.74.112.1
4. from B to D: What is the IP address of www.example.org?
5. from D to B: Ask 93.184.216.119
6. from B to E: What is the IP address of www.example.org?
7. from E to B: The IP# of www.example.org is 93.184.216.119
8. from B to A: The IP# of www.example.org is 93.184.216.119

Part III: Get situated on a server

13. Review the vocabulary in the Lesson 2.1 Key Terms and examine the commands in Section 1 of the Lesson 2.1 Reference Card.

    One strategy to improve reading comprehension is to create a graphic organizer connecting the main ideas. Another strategy is to create a sentence describing the relationships that connect the main ideas. For example, write one or more sentences that describe how you use the command “pwd” and what it tells you, using the terms “operating system”, “application”, “shell”, and “command line interface.”

    Teacher Only

    The command `pwd` can be typed at a shell prompt. The shell is an application run by the Linux operating system. The shell provides a command line interface to the operating system. The command pwd tells you what directory is the current working directory in a particular shell.

Part IV: Examine how the NIC gets you onto the Internet

15. Identify three pieces of information from the output.
    - Recall that data on the Internet is always sent in numbered packets, sent from one IP address to another IP address. Version 4 of the IP address protocol uses “dotted decimal” notation: four decimals between 0 and 255, separated by dots. The output shown above says that the Ethernet card has the IPv4 address `172.17.27.123`.

      What is the IP version 4 address of the NIC your Cloud9 machine?

      Teacher Only

      Answers vary.

    - Every network interface card has a Media Access Control address (**MAC address**, no special relationship to Macintosh computers) built into the card hardware when it is manufactured. Most NICs connect to the Internet by Ethernet over copper wires. Ethernet uses one or more shorter packets called frames to send each IP packet to the other devices connected to the copper wires, and the frames include the sender’s MAC address and the target recipient’s MAC address. Each MAC address has six 2-digit hexadecimal numbers separated by colons. The MAC address shown in the output above is `02:42:ac:11:1b:7b`.

      What is the MAC address of the NIC on your Cloud9 machine?

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Answers vary.

- There were only `256·256·256·256` addresses possible with IP version 4. (Can you explain why?) In 2012, the Internet ran out of addresses. For that reason, gradually, Internet traffic is shifting to IP version 6, and most NICs can use either version. IPv6 addresses are written in colon-hexadecimal notation: eight 4-digit hexadecimal numbers separated with colons. Leading zeros are left out, so a number like 0c4f is written as c4f. If one or more of the 4-digit numbers is zero, the 0 or 0's are replaced with a double colon. The output above shows that the Ethernet NIC has IPv6 address `fe80::42:acff:fe11:1b7b`, which is shorthand for `fe80:0000:0000:0042:acff:fe11:1b7b`.

  What is the IPv6 address of the NIC on your Cloud9 machine?

Teacher Only

Answers vary.

Part V: Use the domain name system to look up IP addresses

17. Use `nslookup` to find the IP address for the web server of your favorite web page. Simply type `nslookup` followed by the domain name of your favorite website.

    ```
    c9username:~/workspace $ nslookup www.coolsite.com
    ```

    Record your information here. URL of favorite website:
    _____

Teacher Only

Answers vary. Example: www.pandora.com

IP address of favorite web server:
_____

Teacher Only

Example for pandora: 208.85.40.50 and 208.85.40.20

18. To see the work of the authoritative DNS servers, use the `dig` (domain information groper) program with the `+trace` option as shown below.

    ```
    c9username:~/workspace $ dig www.example.org +trace
    ```

    …lots of output and finally the output:

    ```
    www.example.org.  4697    IN   A    93.184.216.119
    ```

    There is much more output from the dig program than shown here. First, the recursive DNS server reports the domain name of one or more root servers. The recursive server asks one of the root servers for the IP address of `www.example.org`. That root DNS server responds with the domain names (and IP addresses, though not shown in the output) for the `.org` name servers. The `NS` records refer to other name servers, while the `A` record shown above finally gives the address.

    How many separate machines are serving DNS for the top-level `.org` domain?

Teacher Only

6. Answer may vary, but six machines serve .org name service as of early 2016.

Part VI: Measure latency and bandwidth

The `ping` command is another commonly used tool to see behind the curtain in a computer network, on both Windows and UNIX-like systems. The command uses a simple protocol: one host sends a packet asking for an echo, and the target host responds. The ping command repeats the process for many iterations. It reports how long the round trips took and whether any packets were dropped. Use Ctrl-c to **kill** the `ping` **process**. A process is a program or distinct thread of a program. Killing a process tells the operating system to stop executing it.

19. Execute the command with your own choice of domain name in place of `www.example.org`. The last line of output is shown below.

    ```
    c9username:~/workspace $ ping www.example.org
    rtt min/avg/max/mdev = 17.385/17.439/17.585/0.108 ms
    ```

    This output shows that the packets traveled round trip from `pltwcs.org` to `www.example.org` in `17.439 ms`, on average. A signal can travel one million feet of copper wire in `1 ms`!

    Try a few domains; what is the fastest response you can find?

Teacher Only

60 ms or less is reasonable for a web server. Students might find responses faster than 20 ms.

23. Given the download speed you measured, calculate how long it would take to download a 450 kb file. Show your work.

Teacher Only

$$450\,\text{kB} = 450\,\text{thousand bytes} = 3600\,\text{thousand bits}$$

$$3600000\,\text{bits} \bullet \frac{1\,\text{second}}{(\text{download speed from above, e.g., 1.68 million bits})} = (\text{varies, e.g., 2.1 sec})$$

Part VII: Observe that IP packets travel multiple paths

24. Use `whatsmyip.org` in a new browser tab to identify the IP address of your computer. (This might be your school's router's IP address. ipconfig would find your computer's IP address, but it might be only internal to the school network. We'll ignore these complications.)

    Record the IP address from the top of the page.

Teacher Only

Answers vary, but all students will get similar addresses and perhaps one single address. Part b below uses `63.152.11.159`.

To find the paths from the Cloud9 server to the computer that you are using, you need the tracepath utility.

25. First, install tracepath on the Cloud9 machine using the following command.

```
c9username:~/workspace $ sudo apt-get install iputils-tracepath
```

The `sudo` command lets you execute any other command as the "superuser" with unlimited rights. The `apt-get` program is the advanced packaging tool, and it takes two arguments: a command like `install` and a package like `iputils-tracepath`.

You should see lots of output.

Teacher Only

```
No student artifact. If part c works, then part b was successful.
Output should look like:
Reading package lists... Done
Building dependency tree
Reading state information... Done
Suggested packages:
traceroute
The following NEW packages will be installed:
iputils-tracepath
0 upgraded, 1 newly installed, 0 to remove and 37 not upgraded.
Need to get 32.6 kB of archives.
After this operation, 115 kB of additional disk space will be used.
Get:1 http://us-central1.gce.clouds.archive.ubuntu.com/ubuntu/ trusty
Fetched 32.6 kB in 0s (34.9 kB/s)
Selecting previously unselected package iputils-tracepath.
(Reading database ... 75370 files and directories currently installed
Preparing to unpack .../iputils-tracepath_3%3a20121221-4ubuntu1.1_amd
Unpacking iputils-tracepath (3:20121221-4ubuntu1.1) ...
Processing triggers for man-db (2.6.7.1-1ubuntu1) ...
Setting up iputils-tracepath (3:20121221-4ubuntu1.1) ...
update-alternatives: using /usr/bin/traceroute6.iputils to provide
/usr/bin/traceroute6 (traceroute6) in auto mode
```

26. Now, execute the `tracepath` command on the server, followed by your computer's IP address. Ctrl-c will stop the tracepath program early if desired. Use your IP address instead of `63.152.11.159` as in the example below.

    Packets contain the maximum number of hops that can be sent, known as the time-to-live (TTL). When an Internet host forwards a packet, it **decrements** the TTL. If the TTL reaches 0, the packet is dropped and an error message is sent back to the sender's IP. The tracepath program sends IP packets that will survive only one hop, two hops, or three hops, and so on, so it can receive error messages from the machines along the way to the destination, revealing their IP addresses. Some machines won't send back an error message if they get a packet that has run out of hops, resulting in "no reply".

    How many hops does it take to reach you? As an example, one line of output is shown below, indicating that a packet sent to `63.152.11.159` that was set to expire after five hops had reacher of hop #5 is shown below.

```
c9username:~/workspace $ tracepath 63.152.11.159
mi
rtt
5:  PR01.LAX03.google.com (206.223.123.21) 17.827ms
```

Teacher Only

Answers vary. This example shows that packets from Cloud9 to a Qwest customer travel

through five hops and that the third hop has already gotten a packet to a Qwest router:

```
c9username:~/workspace $ tracepath 63.152.11.159
1?: [LOCALHOST]                                         pmtu 1460
1:  172.17.0.1                                            0.099ms
1:  172.17.0.1                                            6.046ms
2:  209.85.143.191                                       19.874ms asymm
3:  cer-edge-17.inet.qwest.net                           15.239ms asymm
4:  cdrr-agw2.inet.qwest.net                             15.973ms asymm
5:  209-181-211-86.cdrr.qwest.net                        16.412ms asymm
6:  no reply
7:  no reply
^C
c9username:~/workspace $
```

Part VIII: Infrastructure and Organizations

28. How much faster is Gigabit Ethernet than the bandwidth you observed in Step 21 using speedtest.net?

Teacher Only

Answers vary. Example: The randomness of the waiting time.

29. Create one group with the entire classroom and repeat the procedure above. What changes?

Teacher Only

Answers vary. Example: Mostly, it's collisions with the large group.

What, if any, do the limitations of this protocol seem to be?

Teacher Only

It works with a limited number of hosts on a single network.

30. Use the Internet to find a web page or article about international issues regarding the Internet and governmental programs for monitoring civilian communication.

Teacher Only

An example is available at http://www.usatoday.com/story/tech/2013/12/01/tech-firms-counter-nsa-data/3495995/

31. Skim the article to determine what it is about.

Teacher Only

This particular article is about tech firms competing to provide their users with privacy.

32. Summarize what you learned from the article.

Teacher Only

Answers vary.

33. For each of the following listed entities, use the Internet to determine their responsibilities to the Internet:
    - IETF

Teacher Only

The Internet Engineering Task Force develops standards and protocols for the Internet such TCP/IP and DNS.

    - W3C

Teacher Only

The World Wide Web Consortium develops standards for the web, such as as HTTP and HTML.

    - ICANN

Teacher Only

The Internet Corporation for Assigned Names and Numbers coordinates the assignment of IP numbers and domain names.

Conclusion Questions

1. Match each protocol on the left with its purpose on the right.

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◦ IP b	1. How to request Web content
◦ TCP c	2. How to address and route packets
◦ DNS d	3. How to sequence packets and verify accuracy
◦ HTTP a	4. How to get the IP address for `retailer.com`

2. Why are protocols necessary?

Teacher Only

Without protocols two machines would have no way to assign meaning to the 0s and 1s transferred between them. The machines wouldn't know what voltages or light intensities are represented by 0s and 1s nor how to send them.

3. Why do protocols get outdated?

Teacher Only

Circumstances change. Hardware can send, receive, and process information faster. Larger systems raise new issues with scaling, security, and privacy.

4. How do governmental agencies, corporations, and non-governmental organizations affect the development and functioning of the Internet?

Teacher Only

They all invest in infrastructure, agree on standards and protocols, and develop new

technologies.