# Graded Exercise 3

CSC317 Computer Networks

24 October 2016

1. Match the people with their achievements.

| **Person** | **Achievement** |
|---|---|
| Marc Andreesen | Ethernet |
| Tim Berners-Lee | packet switching, Internet's first node |
| Vint Cerf & Bob Kahn | routing algorithm |
| Len Kleinrock | TCP/IP |
| Bob Metcalfe | Web browser |
| Radia Perlman | World Wide Web |

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2. A shared communications channel has a bandwidth of 3 Mbps. Each subscriber requires a bandwidth of 150 kbps when using the channel. Each subscriber uses the channel only 10% of the time.

   This means that the capacity of the channel is sufficient to allow simultaneous communications by 20 subscribers.

   This means that the probability $p$ that any given subscriber is active at any given moment is 0.1.

   The probability that exactly $n$ of $N$ subscribers are simultaneously communicating when the probability that any individual subscriber is communicating is $p$ is:

$$P_p(n \mid N) = \frac{N!}{n!(N-n)!}(p)^n(1.0-p)^{N-n}$$

The probability that exactly n of 120 subscribers are simultaneously communicating is...

$$P_{0.1}(n \mid 120) = \frac{120!}{n!(120-n)!}(0.1)^n(1.0-0.1)^{120-n}$$

With the help of a calculator we can find the probability that 21 or more subscribers are active at once.

The online calculator displays input fields for "Probability of success on a single trial," "Number of trials," and "Number of successes (x)." Enter values of 0.1, 120, and 21 in these fields Click on the calculate button. Look for the probability that 21 or more subscribers are simultaneously active in the output field that is labeled "Cumulative probability: $P(X \geq 21)$."

(a) What is the probability that at any given moment 21 or more subscribers will be communicating?

(b) What happens in a packet switched network when subscribers request more bandwidth than the channel can provide.

(c) What can you infer from this result about an advantage of packet switched communications?

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(a) The probability that 21 or more subscribers will be active at any given time is a little less than 0.008. That is, subscribers will demand more bandwidth than is available less than 1% of the time.

(b) When users of a packet switched network demand more bandwidth than is available, the network queues some packets.

(c) A packet switched network might be able to serve more subscribers than can a circuit-switched network.

3. (a) How many bits are in an IPv4 address?

   (b) If all bits in an IPv4 address were available for specifying addresses of different machines on the Internet, how many hosts could the Internet connect?

   (c) The dotted decimal notation is a way of writing IPv4 addresses.

   Find the IPv4 address of `www.eonsahead.com` by typing:

   `nslookup www.eonsahead.com`

   Express the IPv4 address of `www.eonsahead.com` in dotted decimal notation.?

(d) The dotted decimal notation presents an address as four decimal numbers, each in the range of 0 to 255, and separated from one another by periods.

A number $x$ in the range of 0 to 255 can be expressed in hexadecimal notation with two hexadecimal digits.

- The first (most significant) digit is $x/16$. The division is integer division.
- The second (least significant) digit is $x \bmod 16$.
- Here is an example: $77_{10} \equiv 4D$ because...
  - $77/16 = 4$
  - $77 \bmod 16 = 13$
  - the hexadecimal digit that represents 13 is $D$

| **decimal** | **hexadecimal** | **decimial** | **hexadecmal** |
|---|---|---|---|
| 0 | 0 | 8 | 8 |
| 1 | 1 | 9 | 9 |
| 2 | 2 | 10 | A |
| 3 | 3 | 11 | B |
| 4 | 4 | 12 | C |
| 5 | 5 | 13 | D |
| 6 | 6 | 14 | E |
| 7 | 7 | 15 | F |

Express the address of `www.eonsahead.com` in hexadecimal notation.

(e) To translate a number from hexadecimal format to binary, replace each hexadecimal digit with the corresponding four bits bound in this table:

| **Hexadecimal digit** | **Binary equivalent** |
|---|---|
| 0 | 0000 |
| 1 | 0001 |
| 2 | 0010 |
| 3 | 0011 |
| 4 | 0100 |
| 5 | 0101 |
| 6 | 0110 |
| 7 | 0111 |
| 8 | 1000 |
| 9 | 1001 |
| A | 1010 |
| B | 1011 |
| C | 1100 |
| D | 1101 |
| E | 1110 |
| F | 1111 |

Express the IPv4 address of `www.eonsahead.com` in binary notation.

(a) 32 bits

(b) $2^{32} = 4,294,967,296$ hosts

(c) 45.40.136.115

(d) $2D$ 28 88 73

(e) 0010 1101 0010 1000 1000 1000 1111 0011

4. An IPv6 address contains 128 bits. With 128 bits, it is possible to represent $2^{128}$ addresses.

   (a) Look up the current population of the earth. What integer power of two most closely approximates this number?

   (b) What is the integer power of ten that most closely approximates $2^{128}$? Here are some relationships that you might find helpful.

$$
\begin{aligned}
2^{10} &\approx 1000 = 10^3 \\
2^{20} &= 2^{10} \cdot 2^{10} \approx 10^3 \cdot 10^3 = 10^6 \\
2^{30} &= 2^{10} \cdot 2^{10} \cdot 2^{10} \approx 10^3 \cdot 10^3 \cdot 10^3 = 10^9 \\
2^{40} &= 2^{10} \cdot 2^{10} \cdot 2^{10} \cdot 2^{10} \approx 10^3 \cdot 10^3 \cdot 10^3 \cdot 10^3 = 10^{12}
\end{aligned}
$$

   In general, if $2^x = 10^y$, then $y$ is approximately equal to $x/y$: $2^{40} \approx 10^{40/3}$.

   (c) How many IPv6 addresses would each person on earth have if the addresses were evenly distributed?

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(a) The population of the earth is about 7.28 billion people. That is approximately $2^3 3$ people.

(b) $2^{128} \approx 10^{38}$

(c) $2^{128}/2^{33} = 2^{95}$ addresses per person.

5. Hundreds of millions of IPv4 addresses are reserved.

   (a) For what purposes are the CIDR address blocks 10.0.0.0/8 and 192.168.0.0/16 reserved?

   (b) How many addresses are in the 10.0.0.0/8 block?

(c) How many addresses are in the 192.168.0.0/16?

(d) Use the `ifconfig` command to determine the IP address of one of the Linux machines in our laboratory. What is the address of the computer?

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(a) They are reserved for local communications within a private network.

(b) There are $2^{24} = 16,777,216$ addresses in the 10.0.0.0/8 block.

(c) There are $2^{16} = 65,536$ addresses in the 192.168.0.0/16 block.

6. Port numbers are 16 bit addresses. A 16 bit address is large enough to specify any one of 65536 different ports. What is a programmer addressing when a programmer specifies a port number?

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The port number corresponds to a process on a host.

7. Here is an address: d4:9a:20:0a:49:00

   (a) The format of this address matches the format of what kind of address?

   (b) What does the address identify?

   (c) The address contains 12 hexadecimal digits. How many bits are needed to specify this kind of address?

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(a) This a MAC address. This kind of address is also sometimes called a LAN address or a physical address.

(b) The address identifies the network interface of a host or router.

(c) 48 bits are needed to specify a MAC address.

8. What kinds of addresses to the headers in each of these kinds of packets contain? (Your choices are IP addresses, MAC addresses, and port numbers.)

   (a) Transport layer segments

   (b) Network layer datagrams

(c) Link layer Ethernet frames

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(a) Transport layer segments contain port numbers.

(b) Network layer datagrams contain IP addresses.

(c) Link layer Ethernet frames contain MAC addresses.

9. DHCP is a client-server protocol.

   (a) What does this service provide to clients? (It may provide more than one item.)

   (b) Under what circumstances is a DHCP service especially useful?

   (c) Which transport level protocol and which port number is used by a host to discover a DHCP server?

   (d) DHCP uses an IP address that is reserved for broadcast. A host that joins a network is a client. The exchange between a DHCP client and a DHCP server begins when the client broadcasts a *discover message*. The client broadcasts this message because it does not yet know any addresses (including most particularly the address of the DHCP server) in the network. The server responds by broadcasting an *offer message*.

   Why does the server also broadcast the *offer message*?

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(a) DHCP provides clients with an IP address and additional information that may include a subnet mask, the IP address of a first-hop router, and the IP address of a local DNS server.

(b) DHCP is especially useful for networks in which people connect and disconnect their computers frequently at different locations within the network. This happens, for example, in networks on college campuses.

(c) The *discover message* is broadcast via UDP on port 67.

(d) A client asks DHCP for an IP address because it does not yet have an address! The server cannot direct a response to a particular client until after it has offered that client an IP address and the client has accepted the address.

10. What are several possible objections to the use of NAT?

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(a) The protocol requires that routers process messages at level 4, rather than just at levels 3 and 2. This does not respect the separation of functions in the design of the Internet protocol stack.

(b) NAT requires a router between two hosts to mediate their communication. This is inconsistent with a design principal that calls for direct communication between hosts.

(c) NAT uses port numbers to specify hosts. Port numbers were invented as a way of specifying processes, not hosts.

(d) A better way of coping with the shortage of IPv4 addresses than the use of NAT will be the adoption of IPv6 address.

11. DNS and ARP both translate between two kinds of addresses.

(a) Between which two kinds of addresses does DNS translate?

(b) Between which two kinds of addresses does ARP translate?

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(a) DNS translates between domain names and IP addresses.

(b) ARP translates between IP address and MAC addresses.

12. (a) The MTU (Maximum Transmission Unit) defines a limit at which layer of the Internet protocol stack?

(b) The MSS (Maximum Segment Size) defines a limit at which layer of the Internet protocol stack?

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(a) The MTU defines a limit at the link layer.

(b) The MSS defines a limit at the transport layer.

13. The link-state algorithm associates a number and a label with each node in a network. The algorithm assigns an initial value of $\infty$ to the number and $NULL$ (unknown) to the label. It updates these values in the course of its execution.

(a) What does the number denote?

(b) What does the label denote?

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(a) The number associated with a node $a$ represents the distance from the sender to $a$ along the shortest path.

(b) The label associated with a node $a$ identifies the node $b$ that lies just before $a$ on the shortest path from the sender to $a$.

14. The Bellman-Ford equation describes a relationship that is the basis of the distance-vector routing algorithm.

    Combine the following mathematical expressions (found in the first column of the table) to produce the Bellman-Ford equation.

| **expression** | **meaning** |
|---|---|
| $d_x(y)$ | distance from $x$ to $y$ along shortest path between the two nodes |
| $c(x, v)$ | length of edge that connects node $x$ to node $v$ |
| $d_v(y)$ | distance from $v$ to $y$ along shortest path between the two nodes |
| $\{\cdots\}$ | a set |
| $\min_v$ | minimum value in collection of values that depend upon $v$, for all values of $v$ |

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$$d_x(y) = \min_v\{c(x, v) + d_v(y)\}$$

15. The distance-vector routing algorithm is...

    (a) iterative or recursive?

    (b) asynchronous or synchronous?

    (c) centralized or distributed?

    (d) self-terminating or terminated by a special signal?

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(a) iterative

(b) asynchronous

(c) distributed
(d) self-terminating

16. The Border Gateway Protocol (BGP) facilitates inter-AS routing.
    (a) What is inter-AS routing?
    (b) Is scalability a more important concern in intra-AS routing or in inter-AS routing?
    (c) Is performance (for example, the selection of the shortest route) a more important concern in intra-AS routing or in inter-AS routing?

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(a) An AS is an autonomous system. It is a network that belongs to a single organization. That organization might be a company, a university, or an Internet service provider (ISP), for example. Inter-AS routing moves packets from one autonomous system to another.
(b) Scalability is more important in inter-AS routing.
(c) Performance is less important in inter-AS routing (more important in intra-AS routing).

17. In the following table, the first four elements of the first four rows are data. The fifth element in each of the first four rows is a parity bit computed for that row. The elements of the fifth row are parity bits computed for the columns.

    The parity bits have been chosen to make the number of ones in a row (or column) even. For example, only one of the data bits in the first row is a one. Making the parity bit a one makes the total number of ones in the row even.

| | | | | |
|---|---|---|---|---|
| 0 | 0 | 0 | 1 | 1 |
| 1 | 0 | 0 | 1 | 0 |
| 0 | 1 | 1 | 0 | 0 |
| 0 | 1 | 0 | 0 | 1 |
| 1 | 0 | 1 | 0 | 0 |

Now suppose that noise in the communication line alters a bit during the transmission of this table. The receiver sees this table:

| | | | | |
|---|---|---|---|---|
| 0 | 0 | 0 | 1 | 1 |
| 1 | 0 | 0 | 1 | 0 |
| 0 | 1 | 0 | 0 | 0 |
| 0 | 1 | 0 | 0 | 1 |
| 1 | 0 | 1 | 0 | 0 |

(a) What can the receiver know?

(b) What can the receiver do?

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(a) The receiver can determine the presence and location of the error (if the receiver assumes that only a single error occurred).

(b) The receiver can correct the error.

18. This problem is about a CSMA/CD network.

- Let $d_{prog}$ be the upper bound on the time required for front edge of a signal to travel (propagate) between two network adapters (interfaces).
- Let $d_{tran}$ be the time required to transmit the largest frame.
- Let $E$ be the efficiency of the network. "Efficiency" means the fraction of time (computed over a long run) in which frames are passing between adapters without collision. Assume that there are many adapters with many frames to send.

$$E \approx \frac{1}{1 + 5 \cdot \frac{d_{prog}}{d_{tran}}}$$

Here is an analogy: Imagine a large school. There are many rooms. A single hallway connects the rooms. At unpredictable times, groups of students in one room pass through the hall to another room. A group of art students might move from the studio to the library. Another group of students might later move from the chemistry laboratory to the gymnasium. After that, a third group of students might walk from their English class to the nurse's office.

A rule forbids more than one group of students to be in the hall at once. If the chemistry students open the door and see the art students in the hall, they must duck back into their laboratory, check the hallway for traffic again at a later time, and proceed only when the see at that the hallway is empty.

In this case, $d_{prog}$ is a measure of how fast the students walk, and $d_{tran}$ is a measure of how much time it takes to get a group of students through a classroom door into the hall. The amount of time that a group spends in the hall is a function both of how fast the students walk and how many students are in the group.

Efficiency is the fraction of time during which there are students in the hallway moving between rooms.

(a) Does $E$ increase when $d_{prog}$ is increased or when it is decreased?

(b) Does $E$ increase when $d_{tran}$ is increased or when it is decreased?

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(a) $E$ increases when $d_{prog}$ decreases. (That is, when the students walk faster, efficiency is greater.)

(b) $E$ increases when $d_{tran}$ increases. (That is, when the groups of students are smaller and/or when the teacher pushes the groups through the door faster, efficiency is greater.)

19. Both routers and switchs store and forward packets. Routers execute layer 3 protocols. In layer 3, IP addresses determine where packets go. Switches execute layer 2 protocols. In layer 2, MAC addresses determine where packets go. Even so, network administrators can often choose to connect two networks using a router instead of a switch (or vice versa). Network adminstrators need to know the advantages and disadvantages of each kind of device.

    (a) Hierarchical addressing and an easier avoidance of cycles (an attractive characteristic) is a property of which kind of device: router or switch?

    (b) "Plug-and-play" (an attractive characteristic) is a property of which kind of device: router or switch?

    (c) Faster processing of packets (an attractive characteristic) is a property of which kind of device: router or switch?

    (d) The option of choosing from a greater variety of topologies (an attractive characteristic) follows from the selection of which kind of device: routers or switches? A greater variety of topologies means freedom from the constraint of avoiding multiple links between elements in a network. The network need not be a spanning tree, but can be a more general kind of graph.

    (e) Susceptibilty to broadcast storms (an unattractive characteristic) is a property of which kind of device: router or switch?

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(a) IP addresses are hierarchical. MAC addresses are flat. It is easier to avoid cycles with **routers** (at layer 3).

(b) **Switches** are plug-and-play devices.

(c) Switches process packets at layer 2. Routers process packets at layers 2 and 3. **Switches** filter and forward packets at higher rates.

(d) A network built with **routers** need not be a spanning tree.

(e) Networks built with **switches** are susceptible to broadcast storms.

20. Here is a computation for a cyclic redundancy check.

$$D = 1010101010$$
$$G = 10011$$

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 0 |
| 1 | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| | | | | | 1 | 0 | 0 | 1 | 1 | | | | | | | | | |
| | | | | | | 0 | 1 | 1 | 0 | 0 | | | | | | | | |
| | | | | | | 0 | 0 | 0 | 0 | 0 | | | | | | | | |
| | | | | | | | 1 | 1 | 0 | 0 | 1 | | | | | | | |
| | | | | | | | 1 | 0 | 0 | 1 | 1 | | | | | | | |
| | | | | | | | | 1 | 0 | 1 | 0 | 0 | | | | | | |
| | | | | | | | | 1 | 0 | 0 | 1 | 1 | | | | | | |
| | | | | | | | | | 0 | 1 | 1 | 1 | 1 | | | | | |
| | | | | | | | | | 0 | 0 | 0 | 0 | 0 | | | | | |
| | | | | | | | | | | 1 | 1 | 1 | 1 | 0 | | | | |
| | | | | | | | | | | 1 | 0 | 0 | 1 | 1 | | | | |
| | | | | | | | | | | | 1 | 1 | 0 | 1 | 0 | | | |
| | | | | | | | | | | | 1 | 0 | 0 | 1 | 1 | | | |
| | | | | | | | | | | | | 1 | 0 | 0 | 1 | 0 | | |
| | | | | | | | | | | | | 1 | 0 | 0 | 1 | 1 | | |
| | | | | | | | | | | | | 0 | 0 | 0 | 0 | 1 | | |
| | | | | | | | | | | | | | 0 | 0 | 0 | 0 | 0 | |
| | | | | | | | | | | | | | | 0 | 0 | 1 | 0 | 0 |
| | | | | | | | | | | | | | | 0 | 0 | 0 | 0 | 0 |
| | | | | | | | | | | | | | | | 0 | 1 | 0 | 0 |

$$R = 0100$$

(a) The computation is a long division. As in any long division, the computation requires subtractions of multiples of the divisor. How does the method of subtraction differs from ordinary subtraction?

(b) What is the bit string that the sender will transmit?

(c) What kinds of errors can the receiver detect?

(a) Subtraction is computed without borrows by means of the exclusive OR of corresponding bits.

(b) $D + R = 10101010100100$

(c) The receiver can detect any error in which 4 or fewer consecutive bits have been changed.