Graded Exercise 3

Nam Phan

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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?

(a) The probability that at any given moment there will be 21 or more subscribers communicating is 0.00794

(b) Packet delays and packet lost.

(c) Packet switching networks can handle more host and allocate bandwidth.

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) IPv4 uses 32-bit (four-byte) addresses

(b) If all bits in an IPv4 address were available for specifying addresses of different machines on the Internet, there would be around 4 billions ($4 \cdot 2^{10} \cdot 2^{10} \cdot 2^{10}$) hosts in the Internet

(c) 45.40.136.115

(d) 2d.28.88.73

(e) 00101101.00101000.10001000.01110011

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 $x/3$: $2^{40} \approx 10^{40/3}$.

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

(a) The current population of the earth is almost 7.5 billions, which is equal to $7.5 \cdot 2^{10} \cdot 2^{10} \cdot 2^{10}$, which is less than $2^3 \cdot 2^{10} \cdot 2^{10} \cdot 2^{10} = 2^{33}$

(b)

$$\begin{aligned}
2^{128} &= 2^8 \cdot 2^{120} = 2^8 \cdot (2^{10})^{12}\\
&\approx 256 \cdot (10^3)^{12} = 256 \cdot 10^{36} \approx 100 \cdot 10^{36} = 10^{38}
\end{aligned}$$

(c) $\frac{2^{128}}{2^{33}} = 2^{95} = 32 \cdot 10^{27}$ IPv6 addresses for each 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?

   (a) These addresses blocks are reserved for a private network or a realm with private addresses, such as the home network.
   (b) $2^{24} = 16,777,216$ addresses.
   (c) $2^{16} = 65,536$ addresses.
   (d) IP address: 10.101.6.4

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?

Port numbers are used to identify the processes that the programs in the application layer want to address.

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?

   (a) Medium access control (MAC) address.
   (b) This address, also known as a link-layer address, identifies network interfaces for communications on the physical network segment. For most LANs (including Ethernet and 802.11 wireless LANs), the MAC address is 6 bytes long.

(c) $16^{12} = 2^{48} = 48$ bits

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

(a) Port numbers.

(b) IP addresses.

(c) 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*?

(a) DHCP allows a host to obtain (be allocated) an IP address automatically. It also provides the host related configuration information such as the subnet mask and default gateway.

(b) DHCP is suited to situations where there are many users coming and going, and addresses are needed for only a limited amount of time. DHCP is similarly useful in residential ISP access networks.

(c) DHCP clients use UDP port number 67 to find servers, and port 68 to find clients.

(d) Since several DHCP servers can be present on the subnet, the client may find itself in the enviable position of being able to choose from among several offers. Each server offer message contains the transaction ID of the received discover message, the proposed IP address for the client, the network mask, and an IP address lease timethe amount of time for which the IP address will be valid. It is common for the server to set the lease time to several hours or days.

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

(a) Port numbers are meant to be used for addressing processes, not for addressing hosts used by NAT.

(b) Routers are supposed to process packets only up to layer 3

(c) The NAT protocol violates the so-called end-to-end argument; that is, hosts should be talking directly with each other, without interfering nodes modifying IP addresses and port numbers.

(d) We should use IPv6 to solve the shortage of IP addresses, rather than recklessly patching up the problem with a stopgap solution like NAT.

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?

(a) Between hostnames and IP addresses.

(b) Between MAC addresses and IP 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?

(a) Link Layer

(b) 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 ∞ 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?

(a) The number represents the least cost from a source node to a specific node in the network.

(b) The label represents the previous node in the shortest path to the current node.

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?

(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?

(a) A protocol that obtains reachability information from neighboring ASs (autonomous systems) and propagates the reachability information to all routers internal to the AS.
(b) Inter-AS routing
(c) 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?

(a) The receiver can know about what bit was altered by counting the number of ones in each row and column. Thus, it can figure out the exact position of the error by matching the column and the row that have odd number of ones.

(b) The receiver can just flip the bit in the position that it detects 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?

(a) E goes up when d_{prog} goes down and E goes down when d_{prog} goes up.

(b) E goes up when d_{tran} goes up and E goes down when d_{tran} goes down.

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?

(a) Router
(b) Switch
(c) Switch
(d) Router
(e) Switch

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							
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												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) This subtraction is using exclusive or (XOR) between the dividen and the divisor.

(b) It sends both Data D and R = 0100

(c) The CRC can detect the error with a block of bits in the Data