Graded Exercise 3

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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

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) p=0.00794119224839296

(b) When more bandwith is requested than can be provided, a bottleneck occurs, and the queueing delay for packets increases, possibly to the point where the queue is filled and packets begin to be dropped.

(c) Given the rather low probablility of more subscribers being active simultaneously than the system can handle, packet switch communications in this example can provide each subscriber as much bandwith as they need most of the time.

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) There are 32 bits in an IPv4 address, divided into 4 8 byte segments.

(b) If every bit was available, there could be a total of 4,294,967,296 IP addresses.

(c) The IP address of `www.eonsahead.com` is 45.40.136.115

(d) `www.eonsahead.com`'s hexadecimal address is 2D.28.88.73

(e) `www.eonsahead.com`'s binary address is 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/y: $2^{40} \approx 10^{40/3}$.

   (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 between 2^{32} and 2^{33} people.

(b) 2^{128} is around three hundred and forty undecillion addresses.

(c) Every person would be able to have a very large number of addresses, approximately 47 octillion apiece.

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) 10.0.0.0/8 and 192.168.0.0/16 are reserved for private networks.

(b) There are 16,777,216 addresses in the 10.0.0.0/8 block.

(c) There are 65,536 addresses in the 192.168.0.0/16 block.

(d) The address of a computer in the lab is 10.101.6.3

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?

A port number defines which network application a segment is being delivered to, as an added layer of specificity over the IP 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) This address is formatted as a MAC address.

(b) A MAC address is a link-layer address which uniquely identifies a link-layer adapter.

(c) 48 bits are needed for a 12 digit hexadecimal number.

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) IP Address
(b) Port Number
(c) MAC Address

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 assigns an IP address to a host and provides its subnet mask, the address of the first router packets will visit upon leaving the host, and the address of the local DNS server.
(b) DHCP is particularly useful for networks where users are constantly connecting and disconnecting and do not need to keep the same IP address for an extended period of time.
(c) DHCP discovery messages are sent by UDP to port 67.
(d) The server broadcasts the offer message because it is possible for the request to reach and be returned by multiple DHCP servers. Because a client is not guaranteed to choose that particular DHCP server, it waits to open the connection and send an ACK until after the offer message gets a response.

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

(a) Port numbers are meant to address processes, not hosts.
(b) Routers are only supposed to process packets up to layer 3.
(c) NAT violates the idea that hosts should talk directly to each other.
(d) If we switched to IPv6, NAT would be unnecessary.

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) DNS translates between IP addresses and hostnames.
(b) ARP translates between IP addresses 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?

(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 denotes the cost of the least-cost path to reach the node

(b) The label denotes the node which will be passed through directly before reaching the destination node on the least-cost path from the source.

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

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) Inter-AS routing provides each autonomous system with a means to obtain subnet reachability from neighboring ASs, distriubte that information to all routers within the AS, and determine "good" routes to subnets based on the information and policies.

(b) Scalability is more important in inter-AS routing.

(c) Performance is 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?

(a) The receiver can know that there is an error.

(b) The receiver can tell which bit the error is in and 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?

(a) As d_{prog} decreases, E increases.

(b) As d_{tran} increases, E increases.

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) The subtraction has no borrows or carrys, and uses XOR instead of traditional math operators.

(b) The sender transmits a number which is exactly divisible by a predetermined generator.

(c) The receiver can detect all burst errors up to the length of the generator string, as well as most longer burst errors. In addition, any odd number of errors can be detected no matter how many there are.