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Chapter 4
16.
Answer:

Number the acquisition attempts starting at 1. Attempt i is distributed among 2^{i-1} slots. Thus, the probability of a collision on attempt i is $2^{-(i-1)}$. The probability that the first $k-1$ attempts will fail, followed by a success on round k is

$$P_k = (1 - 2^{-(k-1)}) \prod_{i=1}^{k-1} 2^{-(i-1)}$$

which can be simplified to

$$P_k = (1 - 2^{-(k-1)})\, 2^{-(k-1)(k-2)/2}$$

The expected number of rounds is then just $\sum kP_k$.

Chapter 5
14.
Answer:
Node H is three hops from B, so it takes three rounds to find the route.

15.
Answer:
The protocol is terrible. Let time be slotted in units of T sec. In slot 1 the source router sends the first packet. At the start of slot 2, the second router has received the packet but cannot acknowledge it yet. At the start of slot 3, the third router has received the packet, but it cannot acknowledge it either, so all the routers behind it are still hanging. The first acknowledgement can only be sent when the destination host takes the packet from the destination router. Now the acknowledgement begins propagating back. It takes two full transits of the network, $2(n - 1)T$ sec, before the source router can send the second packet. Thus, the throughput is one packet every $2(n - 1)T$ sec.

16.

Answer:

Each packet emitted by the source host makes either1, 2, or 3 hops. The probability that it makes one hop is *p*. The probability that it makes two hops is *p*(1 −*p*). The probability that it makes 3 hops is (1 − *p*)^2. The mean path length a packet can expect to travel is then the weighted sum of these three probabilities, or *p*2 −3*p* + 3. Notice that for *p* = 0 the mean is 3 hops and for *p* = 1 the mean is 1 hop. With 0 < *p* < 1, multiple transmissions may be needed. The mean number of transmissions can be found by realizing that the probability of a successful transmission all the way is (1 − *p*)^2, which we will call α. The expected number of transmissions is just

$$\alpha + 2\alpha(1-\alpha) + 3\alpha(1-\alpha)^2 + \cdots = \frac{1}{\alpha} = \frac{1}{(1-p)^2}$$

Finally, the total hops used is just $(p^2 - 3p + 3)/(1-p)^2$.

18.

Answer:

With a token every 5μsec, 200,000cells/sec can be sent. Each packet holds 48 data bytes or 384 bits. The net data rate is then 76.8 Mbps.

19.

Answer:

The naive answer says that at 6 Mbps it takes 4/3 sec to drain an 8 megabit bucket. However, this answer is wrong, because during that interval, more tokens arrive. The correct answer can be obtained by using the formula

S = *C/* (*M* −ρ). Substituting, we get *S* = 8*/*(6 – 1) or 1.6 sec.

23.

Answer:

The initial IP datagram will be fragmented into two IP datagrams at I1. No other fragmentation will occur.

Link *A-R1*:

Length = 940; *ID* = x; *DF* = 0; *MF* = 0; *Offset* = 0

Link *R1-R2*:

(1) *Length* = 500; *ID* = x; *DF* = 0; *MF* = 1; *Offset* = 0

(2) *Length* = 460; *ID* = x; *DF* = 0; *MF* = 0; *Offset* = 60

Link *R2-B*:

(1) *Length* = 500; *ID* = x; *DF* = 0; *MF* = 1; *Offset* = 0

(2) *Length* = 460; *ID* = x; *DF* = 0; *MF* = 0; *Offset* = 60

24

Answer:

If the bit rate of the line is *b*, the number of packets/sec that the router can emit is *b/*8192, so the number of seconds it takes to emit a packet is 8192*/b*.To put out 65,536 packets takes 2^29 */b* sec. Equating this to the maximum packet lifetime, we get 2^29 */b* = 10. Then, *b* is about 53,687,091 bps.

25.
Answer:
Since the information is needed to route every fragment, the option must appear in every fragment.

26.
Answer:
With a 2-bit prefix, there would have been 18 bits left over to indicate the network. Consequently, the number of networks would have been 2^18 or 262,144. However, all 0s and all 1s are special, so only 262,142 are available.

27.
Answer:
The address is 194.47.21.130.

28.
Answer:
The mask is 20 bits long, so the network part is 20 bits. The remaining 12 bits are for the host, so 4096 host addresses exist.

Chapter 6

15.
Answer:
No. IP packets contain IP addresses, which specify a destination machine. Once such a packet arrived, how would the network handler know which process to give it to? UDP packets contain a destination port. This information is essential so they can be delivered to the correct process.

16.
Answer:
It is possible that a client may get the wrong file. Suppose client *A* sends a request for file *f1* and then crashes. Another client *B* then uses the same protocol to request another file *f2*. Suppose client *B*, running on the same machine as *A* (with the same IP address), binds its UDP socket to the same port that *A* was using earlier. Furthermore, suppose *B*'s request is lost. When the server's reply (to *A*'s request) arrives, client *B* will receive it and assume that it is a reply its own request.
17.
Answer:
Sending 1000 bits over a 1 Gbps line takes 1 μsec. The speed of light in fiber optics is 200 km/msec, so it takes 0.5 msec for the request to arrive and another 0.5 msec for

the reply to get back. In all, 1000 bits have been transmitted in 1 msec. This is equivalent to 1 megabit/sec, or 1/10 of 1% efficiency.

18.
Answer:
At 1 Gbps, the response time is determined by the speed of light. The best that can be achieved is 1 msec. At 1 Mbps, it takes about 1 msec to pump out the 1024 bits, 0.5 msec for the last one to get to the server, and 0.5 msec for the reply to get back in the best case. The best possible RPC time is then 2 msec. The conclusion is that improving the line speed by a factor of 1000 only wins a factor of two in performance. Unless the gigabit line is amazingly cheap, it is probably not worth having for this application.

19.
Answer:
Here are three reasons. First, process IDs are OS-specific. Using process IDs would have made these protocols OS-dependent. Second, a single process may establish multiple channels of communications. A single process ID (per process) as the destination identifier cannot be used to distinguish between these channels. Third, having processes listen on well-known ports is easy, but well-known process IDs are impossible.

22.
Answer:
The default segment is 536 bytes. TCP adds 20 bytes and so does IP, making the default 576 bytes in total.

30.
Answer*:*
The first bursts contain 2K, 4K, 8K, and 16K bytes, respectively. The next one is 24 KB and occurs after 40 msec.

31.
Answer:
The next transmission will be 1 maximum segment size. Then 2, 4, and 8. So after four successes, it will be 8 KB.

32.
Answer:
The successive estimates are 29.6, 29.84, 29.256.

33.
Answer:

One window can be sent every 20 msec. This gives 50 windows/sec, for a maximum data rate of about 3.3 million bytes/sec. The line efficiency is then 26.4 Mbps/1000 Mbps or 2.6 percent.

34.
Answer:
The goal is to send 2^32 bytes in 120 sec or 35,791,394 payload bytes/sec. This is 23,860 1500-byte frames/sec. The TCP overhead is 20 bytes. The IP overhead is 20 bytes. The Ethernet overhead is 26 bytes. This means that for 1500 bytes of payload, 1566 bytes must be sent. If we are to send 23,860 frames of 1566 bytes every second, we need a line of 299 Mbps. With anything faster than this we run the risk of two different TCP segments having the same sequence number at the same time.

36.
Answer:
A sender may not send more than 255 segments, i.e., 255 × 128 × 8 bits, in 30sec. The data rate is thus no more than 8.704 kbps.

39. Answer:
2× 10^19 bytes. A 75-Tbps transmitter uses up sequence space at a rate of 9.375 × 10^12 sequence numbers per second. It takes 2 million seconds to wrap around. Since there are 86,400 seconds in a day, it will take over 3 weeks to wrap around, even at 75 Tbps. A maximum packet lifetime of less than 3 weeks will prevent the problem. In short, going to 64 bits is likely to work for quite a while.

41.
Answer:
The speed of light in fiber and copper is about 200 km/msec. For a 20-km line, the delay is 100 µsec one way and 200µsec round trip. A 1-KB packet has 8192 bits. If the time to send 8192 bits and get the acknowledgement is 200µsec, the transmission and propagation delays are equal. If B is the bit time, then we have 8192B = 2 × 10^-4 sec. The data rate, 1/B, is then about40 Mbps.

42.
Answer: