CHAPTER 1: INTRODUCTION

17. In some networks, the data link layer handles transmission errors by requesting damaged frames to be retransmitted. If the probability of a frame's being damaged is p, what is the mean number of transmissions required to send a frame? Assume that acknowledgements are never lost.

p = probability that a frame is damaged
$q = 1 - p$ = probability that a frame is not damaged

The probability that a frame is successfully sent after k transmissions is the same as the probability that the frames are damaged in the first $k - 1$ transmissions:

$$P_k = p^{k-1} q^{k-(k-1)} = p^{k-1}(1-p)$$

Thus, the mean number of transmissions (expected value) is $\sum_{k=1}^{\infty} kP_k = \frac{1}{1-p}$.

$$\begin{aligned} E(X) &= \sum_{k=1}^{\infty} kP_k \\ &= \sum_{k=1}^{\infty} kp^{k-1}(1-p) \\ &= (1-p)\sum_{k=1}^{\infty} kp^{k-1} \\ &= (1-p)\left[\frac{1}{1-p} + \frac{p}{(1-p)^2}\right] \\ &= 1 + \frac{p}{1-p} \\ E(X) &= \frac{1}{1-p} \end{aligned}$$

Sum of arithmetic-geometric series:

$$a + (a+d)r + (a+2d)r^2 + \cdots = \frac{a}{1-r} + \frac{rd}{(1-r)^2}$$

For $a = 1$, $d = 1$, and $r = p$:

$$\begin{aligned} \sum_{k=1}^{\infty} kp^{k-1} &= 1 + 2p + 3p^2 + 4p^3 + \cdots \\ &= 1 + (1+1)p + (1+2\cdot 1)p^2 + \cdots \\ &= \frac{1}{1-p} + \frac{p \cdot 1}{(1-p)^2} \end{aligned}$$

20. A system has an n-layer protocol hierarchy. Applications generate messages of length M bytes. At each of the layers, an h-byte header is added. What fraction of the network bandwidth is filled with headers?

Message	M
Layer 1	$M + h$
Layer 2	$M + h + h = M + 2h$
Layer 3	$M + 2h + h = M + 3h$
…	
Layer n	$M + (n - 1)h + h = M + nh$

The total number of header bytes with n-layers and h bytes per header is nh. The fraction of the network bandwidth filled with headers is $\frac{nh}{M + nh}$.

21. List two ways in which the OSI reference model and the TCP/IP reference model are the same. Now list two ways in which they differ.

Both the OSI and TCI/IP reference models are based on the concept of a stack of independent protocols. Also, both models have an application, transport, and network layer; and the layers up to and including transport layer provide reliable end-to-end transport service.

On the other hand, the OSI and TCI/IP have several differences. The OSI model has explicit distinctions between the concepts of service, interface, and protocol; whereas the TCI/IP model has no such distinction. The OSI model has 7 layers; the TCI/IP has only four (does not have a presentation and session layer). The OSI model supports both connectionless and connection-oriented communication in the network layer and connection-oriented communication in the transport layer; the TCI/IP model only supports connectionless communication in the network layer and both modes in the transport layer.

28. An image is 1024 × 768 pixels with 3 bytes/pixel. Assume the image is uncompressed. How long does it take to transmit it over a 56-kbps modem channel? Over a 1-Mbps cable modem? Over a 10-Mbps Ethernet? Over 100-Mbps Ethernet?

1024 × 768 pixels = 1024 × 768 × 3 bytes = 1024 × 768 × 3 × 8 bits = 18,874,368 bits

Over 56-kbps modem: $\frac{18{,}874{,}368 \text{ bits}}{56 \times 10^3 \text{ bits/s}} \approx 337 \text{ s} = 5.62 \text{ min}$

Over 1-Mbps cable modem: $\frac{18{,}874{,}368 \text{ bits}}{10^6 \text{ bits/s}} \approx 18.87 \text{ s}$

Over 10-Mbps Ethernet: $\frac{18{,}874{,}368 \text{ bits}}{10^7 \text{ bits/s}} \approx 1.887 \text{ s}$

Over 100-Mbps Ethernet: $\frac{18{,}874{,}368 \text{ bits}}{10^8 \text{ bits/s}} \approx 0.1887 \text{ s}$

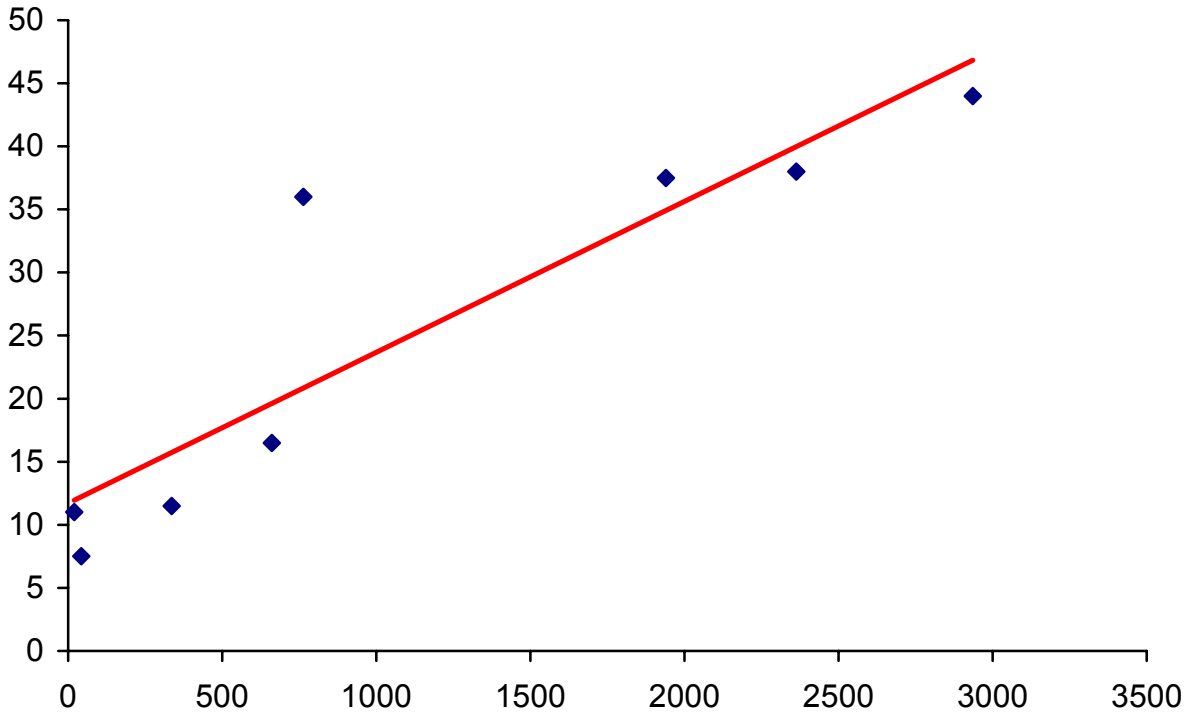
35. The *ping* program allows you to send a test packet to a given location and see how long it takes to get there and back. Try using *ping* to see how long it takes to get from your location to several known locations. From these data, plot the one-way transit time over the Internet as a function of distance.

For this problem, I will made assumptions:

1. The server that I am pinging is located on the campus of the respective school.
2. The distance information (obtained through Mapquest.com) from my house to the respective campus is accurate (or at least close enough).

Below is a table of the summarizing the ping results and distances. The average one-way transit time was obtained taking half of the average round trip time.

Campus	**Address**	**Average Time**	**Distance**
Stanford University	stanford.edu	11 ms	20 mi
UC Berkeley	berkeley.edu	7.5 ms	43 mi
UCLA	ucla.edu	11.5 ms	336 mi
Oregon State University	oregonstate.edu	16.5 ms	661 mi
University of Utah	utah.edu	36 ms	764 mi
Princeton University	princeton.edu	44 ms	2936 mi
University of Iowa	uiowa.edu	37.5 ms	1940 mi
Michigan State University	msu.edu	38 ms	2363 mi



The graph pretty much follows a linear pattern; time varies directly with distance. There is a outlier, namely the University of Utah with a distance of 764 mi and a one-way transit time of 36 ms. I did a trace route for utah.edu and found that there is a delay from hop 10 to hop 11. I then searched the DNS registries for several IP addresses and found that IP 209.124.176.33 belongs to a company in Washington. My assumption is that my ISP is routing the ping request to Washington which in turn routes it to Utah. It would explain why it takes 30 ms to get to 209.124.176.33 and an additional 30 ms to get to Utah (map distance from CA to WA is approximately the same as from WA to UT). This is just a hypothesis though, I really don't know if Gigapop's router is *really* in Washington.

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******** TRANSCRIPT OF TRACERT SESSION ***********

C:\Documents and Settings\admin>tracert utah.edu

Tracing route to utah.edu [155.97.155.159]over a maximum of 30 hops:

  1     *        *        *     Request timed out.
  2     9 ms    10 ms     *     GE-1-3-ur01.santaclara.ca.sfba.comcast.net
                                 [68.87.198.97]
  3    11 ms     *       17 ms  68.87.226.185
  4     *        *        *     Request timed out.
  5    11 ms    11 ms    11 ms  12.127.32.33
  6    30 ms    31 ms    30 ms  tbr2-p013701.sffca.ip.att.net [12.123.13.177]
  7    35 ms    35 ms    33 ms  tbr1-cl10.st6wa.ip.att.net [12.122.12.114]
  8    32 ms    30 ms    36 ms  12.122.82.241
  9    31 ms    45 ms    30 ms  prs1-wes1-ge-0-1-0-801.pnw-gigapop.net
                                 [209.124.179.42]
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 10    31 ms    35 ms    31 ms  ccar2-wes-ge-0-0-0-0.pnw-gigapop.net
                                 [209.124.176.33]
 11    60 ms    59 ms    60 ms  frgp.client.pnw-gigapop.net [209.124.179.102]
 12    73 ms    73 ms    79 ms  192.43.217.157
 13    72 ms    73 ms    73 ms  205.124.244.177
 14    78 ms    72 ms    82 ms  205.124.244.2
 15    71 ms    72 ms    71 ms  205.124.249.118
 16     *        *        *     Request timed out.
 17     *        *        *     Request timed out.
 18     *        *        *     Request timed out.
 19     *        *        *     Request timed out.
 20     *        *        *     Request timed out.
 21     *        *        *     Request timed out.
 22     *        *        *     Request timed out.
 23     *        *        *     Request timed out.
 24     *        *        *     Request timed out.
 25     *        *        *     Request timed out.
 26     *        *        *     Request timed out.
 27     *        *        *     Request timed out.
 28     *        *        *     Request timed out.
 29     *        *        *     Request timed out.
 30     *        *        *     Request timed out.

Trace complete.
```

********PARTIAL TRANSCRIPT OF PING SESSION ***********

```
Microsoft Windows XP [Version 5.1.2600]
(C) Copyright 1985-2001 Microsoft Corp.

C:\Documents and Settings\admin>ping berkeley.edu

Pinging berkeley.edu [169.229.131.92] with 32 bytes of data:

Reply from 169.229.131.92: bytes=32 time=15ms TTL=50
Reply from 169.229.131.92: bytes=32 time=15ms TTL=50
Reply from 169.229.131.92: bytes=32 time=17ms TTL=50
Reply from 169.229.131.92: bytes=32 time=14ms TTL=50

Ping statistics for 169.229.131.92:
    Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
Approximate round trip times in milli-seconds:
    Minimum = 14ms, Maximum = 17ms, Average = 15ms

C:\Documents and Settings\admin>ping stanford.edu

Pinging stanford.edu [171.67.20.37] with 32 bytes of data:

Reply from 171.67.20.37: bytes=32 time=25ms TTL=49
Reply from 171.67.20.37: bytes=32 time=15ms TTL=49
Reply from 171.67.20.37: bytes=32 time=25ms TTL=49
Reply from 171.67.20.37: bytes=32 time=23ms TTL=49

Ping statistics for 171.67.20.37:
    Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
Approximate round trip times in milli-seconds:
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    Minimum = 15ms, Maximum = 25ms, Average = 22ms

C:\Documents and Settings\admin>ping arizona.edu

Pinging arizona.edu [128.196.128.233] with 32 bytes of data:

Request timed out.
Request timed out.
Request timed out.
Request timed out.

Ping statistics for 128.196.128.233:
    Packets: Sent = 4, Received = 0, Lost = 4 (100% loss),

C:\Documents and Settings\admin>ping ucla.edu

Pinging ucla.edu [169.232.55.135] with 32 bytes of data:

Reply from 169.232.55.135: bytes=32 time=27ms TTL=49
Reply from 169.232.55.135: bytes=32 time=27ms TTL=49
Reply from 169.232.55.135: bytes=32 time=20ms TTL=49
Reply from 169.232.55.135: bytes=32 time=20ms TTL=49

Ping statistics for 169.232.55.135:
    Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
Approximate round trip times in milli-seconds:
    Minimum = 20ms, Maximum = 27ms, Average = 23ms

C:\Documents and Settings\admin>ping princeton.edu

Pinging princeton.edu [128.112.128.81] with 32 bytes of data:

Reply from 128.112.128.81: bytes=32 time=105ms TTL=46
Reply from 128.112.128.81: bytes=32 time=81ms TTL=46
Reply from 128.112.128.81: bytes=32 time=83ms TTL=46
Reply from 128.112.128.81: bytes=32 time=86ms TTL=46

Ping statistics for 128.112.128.81:
    Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
Approximate round trip times in milli-seconds:
    Minimum = 81ms, Maximum = 105ms, Average = 88ms

C:\Documents and Settings\admin>ping uiowa.edu

Pinging uiowa.edu [128.255.56.76] with 32 bytes of data:

Reply from 128.255.56.76: bytes=32 time=79ms TTL=46
Reply from 128.255.56.76: bytes=32 time=76ms TTL=46
Reply from 128.255.56.76: bytes=32 time=73ms TTL=46
Reply from 128.255.56.76: bytes=32 time=73ms TTL=46

Ping statistics for 128.255.56.76:
    Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
Approximate round trip times in milli-seconds:
    Minimum = 73ms, Maximum = 79ms, Average = 75ms

C:\Documents and Settings\admin>ping msu.edu
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```
Pinging msu.edu [35.8.10.26] with 32 bytes of data:

Reply from 35.8.10.26: bytes=32 time=73ms TTL=236
Reply from 35.8.10.26: bytes=32 time=74ms TTL=236
Reply from 35.8.10.26: bytes=32 time=69ms TTL=236
Reply from 35.8.10.26: bytes=32 time=91ms TTL=236

Ping statistics for 35.8.10.26:
    Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
Approximate round trip times in milli-seconds:
    Minimum = 69ms, Maximum = 91ms, Average = 76ms

C:\Documents and Settings\admin>ping utah.edu

Pinging utah.edu [155.97.155.159] with 32 bytes of data:

Reply from 155.97.155.159: bytes=32 time=72ms TTL=241
Reply from 155.97.155.159: bytes=32 time=72ms TTL=241
Reply from 155.97.155.159: bytes=32 time=73ms TTL=241
Reply from 155.97.155.159: bytes=32 time=72ms TTL=241

Ping statistics for 155.97.155.159:
    Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
Approximate round trip times in milli-seconds:
    Minimum = 72ms, Maximum = 73ms, Average = 72ms

C:\Documents and Settings\admin>ping ku.edu
Ping request could not find host ku.edu. Please check the name and try again.

C:\Documents and Settings\admin>ping www.ku.edu

Pinging kuprdwb.cc.ku.edu [129.237.33.6] with 32 bytes of data:

Request timed out.
Request timed out.
Request timed out.
Request timed out.

Ping statistics for 129.237.33.6:
    Packets: Sent = 4, Received = 0, Lost = 4 (100% loss),

C:\Documents and Settings\admin>ping unr.edu

Pinging unr.edu [134.197.1.173] with 32 bytes of data:

Request timed out.
Request timed out.
Request timed out.
Request timed out.

Ping statistics for 134.197.1.173:
    Packets: Sent = 4, Received = 0, Lost = 4 (100% loss),
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