- [P1 (5 points)] Try to use traceroute and other tools to find:
  1. A destination host on the Internet so that the route from your laptop/desktop to the destination has the largest number of hops that you can find. Please list the hops. What is your strategy to find such a host?
  2. A destination host on the Internet so that the route from your laptop/desktop to the destination traverses the largest number of ISPs. You can get full credit if it has at least 5 different ISPs, but we encourage you to try to find a longer one. What is your strategy to find such a host?

1. 通过尝试多种网站，可以看到 hop 有 9—16 个各种情况，下图是 hop 最多的一个网站。
策略：用各种网站去尝试，然后选取 hop 数最多的一个

```
hadoop@ubuntu:~$ traceroute -I www.tsinghua.edu.cn
traceroute to www.tsinghua.edu.cn (166.111.4.100), 30 hops max, 60 byte packets
 1  _gateway (192.168.116.2)  0.312 ms  0.283 ms  0.263 ms
 2  192.168.0.1 (192.168.0.1)  2.570 ms  2.553 ms  2.538 ms
 3  1.184.30.117.broad.xm.fj.dynamic.163data.com.cn (117.30.184.1)  21.325 ms  2
1.304 ms  21.306 ms
 4  117.30.25.45 (117.30.25.45)  8.291 ms  8.276 ms  8.255 ms
 5  61.154.236.13 (61.154.236.13)  8.239 ms  8.534 ms  8.634 ms
 6  202.97.109.137 (202.97.109.137)  30.422 ms  24.205 ms  27.574 ms
 7  202.97.98.149 (202.97.98.149)  41.706 ms * *
 8  * * *
 9  101.4.117.109 (101.4.117.109)  49.621 ms  53.323 ms  53.290 ms
10  101.4.116.65 (101.4.116.65)  54.607 ms  65.222 ms  65.535 ms
11  101.4.113.201 (101.4.113.201)  57.686 ms  47.505 ms  50.607 ms
12  tjn3.cernet.net (202.112.38.2)  47.145 ms  46.735 ms  53.650 ms
13  118.229.4.74 (118.229.4.74)  49.083 ms  50.751 ms  50.241 ms
14  118.229.2.66 (118.229.2.66)  45.438 ms  45.686 ms  47.066 ms
15  118.229.8.6 (118.229.8.6)  47.103 ms  46.448 ms  46.681 ms
16  www.tsinghua.edu.cn (166.111.4.100)  48.723 ms  46.874 ms  47.002 ms
```

2.选取第 1 题曾经试过的网站，根据 ip 找 isp 的个数

```
hadoop@ubuntu:~$ traceroute -I www.hupu.com
traceroute to www.hupu.com (113.96.156.248), 30 hops max, 60 byte packets
 1  _gateway (192.168.116.2)  0.366 ms  0.331 ms  0.289 ms
 2  192.168.0.1 (192.168.0.1)  4.953 ms  4.937 ms  4.922 ms
 3  1.184.30.117.broad.xm.fj.dynamic.163data.com.cn (117.30.184.1)  4.896 ms  4.
877 ms  4.857 ms
 4  117.30.25.41 (117.30.25.41)  8.139 ms  8.206 ms  8.282 ms
 5  61.154.236.25 (61.154.236.25)  6.464 ms * *
 6  * * *
 7  219.128.190.106 (219.128.190.106)  34.027 ms  31.616 ms  31.580 ms
 8  183.59.4.14 (183.59.4.14)  34.796 ms  37.247 ms  37.228 ms
 9  14.215.65.242 (14.215.65.242)  41.569 ms  51.841 ms  37.550 ms
10  14.215.88.174 (14.215.88.174)  37.795 ms  37.989 ms  38.673 ms
11  113.96.156.248 (113.96.156.248)  31.027 ms  31.173 ms  34.459 ms
```

| | |
|---|---|
| IP 地址: | 117.30.25.41 |
| IP Long: | 1964906793 |
| 归属地(纯真数据): | 福建省厦门市 电信 |
| 归属地(ipip): | 中国 福建 厦门 - |
| 归属地(淘宝数据): | 中国 福建 厦门 电信 |
| 归属地(IP2REGION): | 中国 福建省 厦门市 电信 |

| | |
|---|---|
| IP 地址: | 219.128.190.106 |
| IP Long: | 3682647658 |
| 归属地(纯真数据): | 广东省汕头市 电信 |
| 归属地(ipip): | 中国 广东 佛山 - |
| 归属地(淘宝数据): | |
| 归属地(IP2REGION): | 中国 广东省 汕头市 电信 |

| | |
|---|---|
| IP 地址: | 183.59.4.14 |
| IP Long: | 3074098190 |
| 归属地(纯真数据): | 广东省惠州市 电信 |
| 归属地(ipip): | 中国 广东 惠州 - |
| 归属地(淘宝数据): | |
| 归属地(IP2REGION): | 中国 广东省 广州市 电信 |

| | |
|---|---|
| IP 地址: | 14.215.65.242 |
| IP Long: | 248988146 |
| 归属地(纯真数据): | 广东省佛山市 电信 |
| 归属地(ipip): | 中国 广东 潮州 - |
| 归属地(淘宝数据): | 中国 广东 佛山 电信 |
| 归属地(IP2REGION): | 中国 广东省 潮州市 电信 |

| | |
|---|---|
| IP 地址: | 113.96.156.248 |
| IP Long: | 1902157048 |
| 归属地(纯真数据): | 广东省潮州市 电信IDC机房 |
| 归属地(ipip): | 中国 广东 潮州 - |
| 归属地(淘宝数据): | 中国 广东 广州 电信 |
| 归属地(IP2REGION): | 中国 广东省 潮州市 电信 |

一共有 5 个 isp（外网其实会更多但是算了不太敢）

策略：由于 ip 属于不同的 isp，要想 isp 数量较多就需要找 ip 数量相对较多的网站，然后根据 ip 去查对应的 isp

- [P2 (10 points)] Suppose the number of people at XMU is 60000. Determine the number of external phone lines that XMU will need in order to achieve a call blocking percentage of 1%. Assume that each person at XMU makes one external phone call per day, and each such phone call lasts on average 3 minutes, with the memoryless distribution.

P2 解：由每人每天一个电话，则一天一共 $60000\times1=60000$（个）$\Rightarrow \lambda=\frac{60000}{24\times60\times60}=\frac{25}{36}$ /s

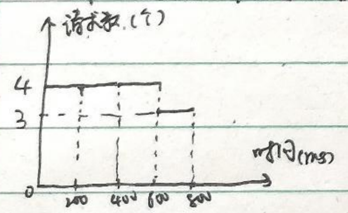
又平均一个电话三分钟 $\Rightarrow \mu=\frac{1}{3\times60}=\frac{1}{180}$ /s $\Rightarrow \frac{\lambda}{\mu}=125$

而 $P_0=\frac{1}{1+\frac{1}{1!}(\frac{\lambda}{\mu})+\frac{1}{2!}(\frac{\lambda}{\mu})^2\cdots} \cancel{=\frac{1}{e^{\lambda/\mu}}=\frac{1}{e^{125}}}$

又 $P_N=\frac{1}{N!}(\frac{\lambda}{\mu})^N P_0=\frac{1}{N!}\times125^N\times P_0=0.01 \Rightarrow N\approx102$

[P3 (10 points)] Suppose that you are designing a Web server for your startup. You have acquired a single machine with a quad-core processor. Assume that CPU is the bottleneck. You anticipate that Web requests arrive (memoryless) at a rate of 15 requests/second, and benchmarking shows that it takes a core on average 200 ms to serve a Web request. What is the average service time that each Web request experiences? If it is a dual-core processor, what happens? You need to draw the state diagram when working on this problem.

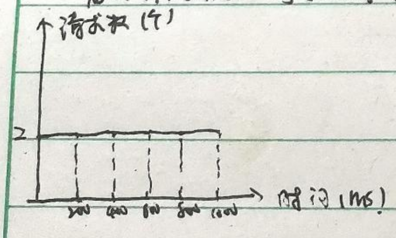
P3 解：由题意，单机为四核，则可以同时处理4个请求




由图可知 共需 $200\times4+400\times4+600\times4+800\times3 = 7200$ ms

则平均时间：$\frac{7200}{15} = \cancel{\frac{60}{3}}$ ms. 480ms.

若只有两核，则可以同时处理两个请求




则1s只能处理10个请求，到达的15个请求中有5个请求不能在1s内完成，同时1s后又会有15个请求到达，导致出现请求的堆积。

- [P4 (5 points)] This elementary problem explores propagation delay and transmission delay, two central concepts in data networking. Consider two hosts, A and B, connected by a single link of rate *R* bps. Suppose that the two hosts are separated by *m* meters, and suppose the propagation speed along the link is *s* meters/sec. Host A is to send a packet of size *L* bits to Host B.

    1. Express the propagation delay, $d_{prop}$, in terms of *m* and *s*.
    2. Determine the transmission time of the packet, $d_{trans}$, in terms of *L* and *R*.
    3. Ignoring processing and queuing delays, obtain an expression for the end-to-end delay.
    4. Suppose Host A begins to transmit the packet at time $t = 0$. At time $t = d_{trans}$, where is the last bit of the packet?
    5. Suppose $d_{prop}$ is greater than $d_{trans}$. At time $t = d_{trans}$, where is the first bit of the packet?
    6. Suppose $d_{prop}$ is less than $d_{trans}$. At time $t = d_{trans}$, where is the first bit of the packet?
    7. Suppose $s = 2.5 \times 10^8$, $L = 120$ bits, and $R = 56$ kbps. Find the distance *m* so that $d_{prop}$ equals $d_{trans}$.

P4 解：(1) 由题意 $d_{prop} = \frac{m}{s}$ s

(2) 由题意 $d_{trans} = \frac{L}{R}$ s

(3) 由题意 ~~[illegible]~~ 不计排队延迟和处理延迟

则 $d_{end\text{-}to\text{-}end} = d_{prop} + d_{trans} = \frac{m}{s} + \frac{L}{R}$ s

(4) 由从 $t=0$ 开始发送分组，则 $t = d_{trans}$ 时，最后1个bit单从主机A发送刚离开主机A

(5) 由 $d_p > d_t$，则第1个比特在物理链路 A→B 上，距A距离按物理传播计算

$D_1 = s d_t = \frac{sL}{R}$

(6) 由 $d_p < d_t$，则第1个比特在距A距离按传输计算

$D_2 = R d_t = L$. 此时第1个比特到达主机B

(7) 由 $d_p = d_t$. $\Rightarrow \frac{m}{s} = \frac{L}{R}$ 又 $s = 2.5 \times 10^8$ m/s. $L = 120$ bit $R = 56$ kbps

$\Rightarrow m = \frac{75}{14} \times 10^5$ m $\approx 5.36 \times 10^5$ m.

- [P5 (10 points)] Suppose two hosts, A and B, are separated by 20,000 kilometers and are connected by a direct link of $R$ = 2 Mbps. Suppose the propagation speed over the link is $2.5 \cdot 10^8$ meters/sec.

    1. Calculate the bandwidth-delay product, $R \cdot d_{prop}$.
    2. Consider sending a file of 800,000 bits from Host A to Host B. Suppose the file is sent continuously as one large message. What is the maximum number of bits that will be in the link at any given time?
    3. Provide an interpretation of the bandwidth-delay product.
    4. What is the width (in meters) of a bit in the link? Is it longer than a football field?
    5. Derive a general expression for the width of a bit in terms of the propagation speed $s,$ the transmission rate $R,$ and the length of the link $m$.

P5 解：(1) 由题意 $m=2\times10^4$ km. $s=2.5\times10^8$ m/s $\Rightarrow d_{prop}=\frac{m}{s}=\frac{2\times10^7}{2.5\times10^8}=\frac{2}{25}$ s

则 $R\cdot d_{prop}=2\times10^6$ bps $\times\frac{2}{25}$ s $=1.6\times10^5$ bits

(2) 由输送是持续的，则输送的最大比特与 dprop 有关，又 R=2Mbps，

则最大比特数即(1)的带宽时延积，$1.6\times10^5$ bits（总是大于该值）

(3) 带宽时延积，是一种网络性能指标，在数据通信中指的是一个数据链路的能力与来回通信延迟的乘积，即给定时刻链路中字节的最大值.

(4) 由(2)，则 width: $\frac{2\times10^7}{1.6\times10^5}=125$ m. >120m. 比足球场长.

(5) 由题意. 由 $m = R\cdot d_{prop}\cdot width$ ~~$m\times width=R\cdot d_{prop}$~~ $= R\cdot\frac{m}{s}\cdot w \Rightarrow width=\frac{s}{R}$

- [P6 (10 points)] In this problem, we consider sending real-time voice from Host A to Host B over a packet-switched network (VoIP). Host A converts analog voice to a digital 64 kbps bit stream on the fly. Host A then groups the bits into 56-byte packets. There is one link between Hosts A and B; its transmission rate is 2 Mbps and its propagation delay is 10 msec. As soon as Host A gathers a packet, it sends it to Host B. As soon as Host B receives an entire packet, it converts the packet's bits to an analog signal. How much time elapses from the time a bit is created (from the original analog signal at Host A) until the bit is decoded (as part of the analog signal at Host B)?

P6 解 主机A产生所有比特所需时间：$\frac{56\times8}{64\times10^3}=7$ ms

由 R=2Mbps. $d_{trans}=\frac{L}{R}=\frac{56\times8}{2\times10^6}=2.24\times10^{-4}$ s $=0.224$ ms

又由题意. $d_{prop}=10$ ms $\Rightarrow$ 总用时：$7+0.224+10=17.224$ ms

则一共花费 17.224ms.

- [P7 (5 points)] Suppose you would like to urgently deliver 40 terabytes data from Boston to Los Angeles. You have available a 100 Mbps dedicated link for data transfer. Would you prefer to transmit the data via this link or instead use FedEx over-night delivery? Explain.

P7 解：由题意，共传输数据 40TB $= 40\times2^{40}$ B $= 40\times2^{40}\times8$ bit $= 5\times2^{46}$ bit.

又 $R = 100$ Mbps $\Rightarrow d = \frac{L}{R} = \frac{5\times2^{46}}{100\times10^6} = \frac{2^{45}}{10^7} \approx 3518437$ s

又一天为 $24\times60\times60 = 86400$s 远远小于计算结果，FedEx over-night delivery 更快，因此选择 over-night delivery.

- [P8 (10 points)] Consider an application that transmits data at a steady rate (for example, the sender generates an N-bit unit of data every k time units, where k is small and fixed). Also, when such an application starts, it will continue running for a relatively long period of time. Answer the following questions, briefly justifying your answer:

    1. Would a packet-switched network or a circuit-switched network be more appropriate for this application? Why?

    2. Suppose that a packet-switched network is used and the only traffic in this network comes from such applications as described above. Furthermore, assume that the sum of the application data rates is less than the capacities of each and every link. Is some form of congestion control needed? Why?

P8. 解：(1) 电路交换网络更适合. 由题意可知传输速率已知且波动不大，则带宽不会有浪费. 又会话是长期的，则建立和拆除会话的开销不算浪费，因此电路交换网络更适合.

(2) 不需要. 由于数据速率总和小于每个链路的容量，则最坏情况下每条链路也能处理所有数据. 因此不会发生拥塞现象，就不需要控制机制.

- [P9 (10 points)] Suppose users share a 3 Mbps link. Also suppose each user requires 150 kbps when transmitting, but each user transmits only 10 percent of the time. (You can refer to the discussion of packet switching versus circuit switching in Section 1.3.2. of the textbook, if you want.)

    1. When circuit switching is used, how many users can be supported?
    2. For the remainder of this problem, suppose packet switching is used. You can use either our queueing analysis in class or direct binomial distribution analysis. Find the probability that a given user is transmitting.

3. Suppose there are 120 users. Find the probability that at any given time, exactly *n* users are transmitting simultaneously.
4. Find the probability that there are 21 or more users transmitting simultaneously.

P9. 解：(1) 由用户共享带宽，则 数量：$\frac{3Mbps}{150kbps} = \frac{3\times10^6}{150\times10^3} = 20$ 个

(2) 由题意，每个用户仅有10%时间在传输，因此任意时刻某用户~~传输~~传输概率为10%

(3) 由题意，当共120个用户，其中恰好有n个用户同时传输概率

$$P = p^n \times (1-p)^{120-n} \times C_{120}^{n}$$

(4) 由(1)，最多能供给20个用户，则21个及以上用户同时使用可能性为0

- [P10 (10 points)] In modern packet-switched networks, including the Internet, the source host segments long, application-layer messages (for example, an image or a music file) into smaller packets and sends the packets into the network. The receiver then reassembles the packets back into the original message. We refer to this process as *message segmentation*. The figure below illustrates the end-to-end transport of a message with and without message segmentation. Consider a message that is $8\times10^6$ bits long that is to be sent from source to destination in the figure below. Suppose each link in the figure is 2 Mbps. Ignore propagation, queuing, and processing delays.

1. Consider sending the message from source to destination *without* message segmentation. How long does it take to move the message from the source host to the first packet switch? Keeping in mind that each switch uses store-and-forward packet switching, what is the total time to move the message from source host to destination host?
2. Now suppose that the message is segmented into 800 packets, with each packet being 10,000 bits long. How long does it take to move the first packet from source host to the first switch? When the first packet is being sent from the first switch to the second switch, the second packet is being sent from the source host to the first switch. At what time will the second packet be fully received at the first switch?

3. How long does it take to move the file from source host to destination host when message segmentation is used? Compare this result with your answer in part (a) and comment.
4. In addition to reducing delay, what are reasons to use message segmentation?
5. Discuss the drawbacks of message segmentation.

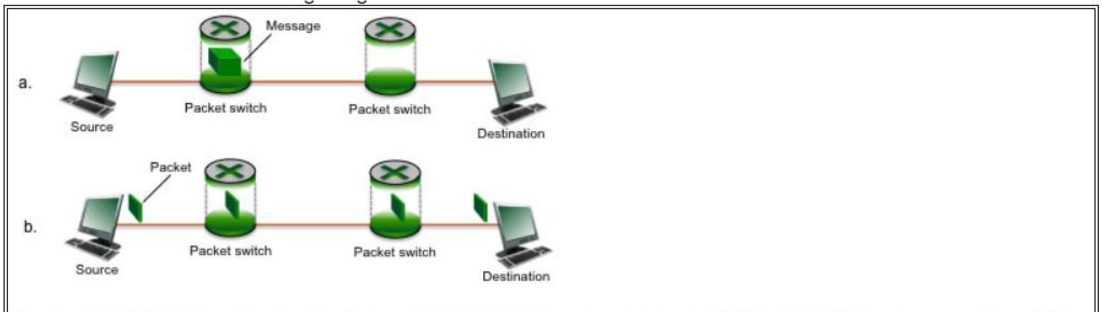



**Figure for P10:** End-end message transport: (a) without message segmentation; (b) with message segmentation.

P10 解：(1) 由题意 $d_{tran} = \frac{L}{R} = \frac{8\times10^6}{2\times10^6} = 4s$ 忽略其他延迟.

则从源主机到第一个交换机的时间为4s

又每个链路R相同，每个交换机使用存储和转发分组交换. 共3条链路

则总时间 $4s\times3=12s$

(2) 由一个分组为10000 bits. 则第一个分组到第一个交换机时延：$\frac{10^4}{2\times10^6}=0.005s=5ms$

又第一个分组发往第二个交换机时. 第二个分组发往第一个交换机. 两个分组一样大

则第一分组被第二交换机全部接收时第二个分组被第一个交换机全部接收.

时间：$5ms\times2=10ms$

(3) 由(2)一共有800个分组. 每个分组发送间隔为5ms, 则正要发送最后一个分组时.

总时间为 $799\times5$ (ms), 最后一个分组全部被目标主机接收需 $3\times5ms$.

总时长：$799\times5+3\times5=4010ms=4.01s$. 远小于(1)中的12s.

(4) 如果不进行分组，大文件中已传输的数据被迫要等待所有数据传输成功.会增加很多不必要的浪费，若分组则可以做到n个分组数据同时传播，减少时延.

(5) ①分组必须按一定顺序发送接收 ②多出的分组过程可能会有较高的开销.

- [P11 (10 points)] Consider sending a large file of *F* bits from Host A to Host B. There are three links (and two switches) between A and B, and the links are uncongested (that is, no queuing delays). Host A segments the file into segments of *S* bits each and adds 80 bits of header to each segment, forming packets of $L$ = 80 + $S$ bits. Each link has a transmission rate of $R$ bps. Find the value of $S$ that minimizes the delay of moving the file from Host A to Host B. Disregard propagation delay.

P11 解：由题意 一个分组通过一个 link 所需时间 $\frac{L}{R} = \frac{80+S}{R}$

又一共 F bits，则共有 $\frac{F}{S}$ 个分组．同时可知有3条link 两个交换机

则所需时间为 $(\frac{F}{S} - 1) \times \frac{80+S}{R} + \frac{80+S}{R} \times 3 = \frac{1}{R} \times (80+S) \times (\frac{F}{S}+2)$

$= \frac{1}{R} \times (\frac{80F}{S} + 160 + F + 2S)$ 若 d delay 最小 则对S求导为0

则 $\frac{d\,delay}{dS} = -\frac{80F}{R} \times \frac{1}{S^2} + \frac{2}{R}$ 为 0 $\Rightarrow S = \sqrt{40F}$

则 delay 最小时 S 为 $\sqrt{40F}$

- [P12 (5 points)] Skype is a software that allows you to make a phone call from a PC to an ordinary phone. This means that the voice call must pass through both the Internet and through a telephone network. Discuss how this might be done.

P12 解：当从PC端打出电话时，语音数据通过互联网发送到和由该网络的连接处，对语音进行处理后发送到电话交换网络．同理，从 ordinary phone 发出的数据也是在连接处处理后通过互联网发给PC端．