Name…………………………………..….ID………..………..Section……..……Seat No……..….

Sirindhorn International Institute of Technology
Thammasat University

Comment [SG1]: Check the comments in 2008 Final Exam questions. There are changes to be made.

Final Examination: Semester 1/2008

Course Title : ITS 323 – Introduction to Data Communications

Instructor : Dr Steven Gordon

Date/Time : Thursday 2 October 2008, 13:30 – 16:30

Instructions:

- This examination paper has __ pages (including this page).
- Condition of Examination
  - Closed book (No dictionary; a non-programmable calculator is allowed)
- Students are not allowed to be out of the exam room during examination. Going to the restroom may result in score deduction.
- Turn off all communication devices (mobile phone etc.) and leave them under your seat.
- Write your name, student ID, section, and seat number clearly on the answer sheet.
- The space on the back of each page can be used if necessary.
- Unless stated in the question, you can assume the speed of transmission is 3 x 10^8m/s
- Unless stated in the question, give IP addresses in dotted decimal notation.

Part A - Multiple Choice Questions [27 marks]

Select the most accurate answer (only select one answer). Each correct answer is worth 1.5 marks.

1. Four computers and a router are connected via full-duplex Unshielded Twisted Pair cables to a 100Mb/s Fast Ethernet switch. Assuming they all need to send equal amounts of data, what is the maximum amount of data a single computer can send and receive?
   a) 20Mb/s
   b) 25Mb/s
   c) 50Mb/s
   d) 100Mb/s
   e) 200Mb/s
   f) 400Mb/s
   g) 500Mb/s

2. With some adaptive routing protocols information about the network (e.g. topology, link costs) comes from *all nodes* and is updated on a *periodic* basis. For normal flooding, where does the information come from and how is it updated?

a)	All nodes	Periodic updates
b)	All nodes	Continuous updates
c)	All nodes	No updates
d)	No nodes	Periodic updates
e)	No nodes	Continuous updates
f)	**No nodes**	**No updates**
g)	Neighbor nodes	Periodic updates
h)	Neighbor nodes	Continuous updates
i)	Neighbor nodes	No updates

3. A disadvantage of circuit switching (versus datagram packet switching) is:
   a) It is difficult to guarantee performance for delivery of data
   b) Data is likely to be dropped at switches
   c) Switches are complex because they must process every piece of data
   d) A larger delay (than datagram packet switching) will always occur when transferring the same amount of data
   e) As new connections are requested they may be blocked

4. The TCP retransmission scheme follows the principles of:
   a) Stop-and-Wait ARQ
   b) Go-Back-N ARQ
   c) Selective-Reject ARQ
   d) Forward Error Correction
   e) Parity check error detection

5. An important motivation of internetworking protocols (such as IP) is:
   a) To allow users to communicate independent of the LAN or WAN technologies in use
   b) To allow a connection to be setup between two users in a network
   c) To allow multiple users to send data over a single link

d) To map user-friendly addresses to IP addresses that can be used by computers
e) None of the above

6. An Internet application may be considered as implementing three parts:
   a) Network layer, transport layer, application layer
   b) HTTP, communications protocol, user interface
   c) Communications protocol, user interface, application logic
   d) User interface, application logic, transport layer protocol
   e) TCP, IP and user interface
   f) Application logic, HTTP and data storage

7. In IP:
   a) Fragmentation may occur at the source host only, with re-assembly at the destination host only
   b) Fragmentation may occur at the source host and routers, with re-assembly at the destination host only
   c) Fragmentation may occur at the source host only, with re-assembly at the routers and destination host
   d) Fragmentation may occur at the source host and routers, with re-assembly at the routers and destination host
   e) Fragmentation and re-assembly is not implemented.

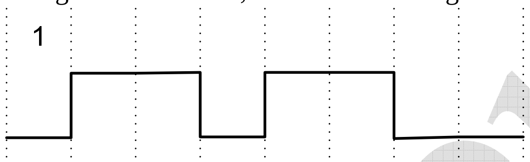
8. Email delivery in the Internet uses:
   a) SMTP for sending emails to servers, and MIME for delivering the email to destination user agent
   b) IMAP4 for sending emails to servers, and POP3 for a destination user agent to retrieve emails from servers
   c) MIME for sending emails to servers, and SMTP for delivering the email to destination user agent
   d) IMAP4 for sending emails to servers, and SMTP for a destination user agent to retrieve emails from servers
   e) SMTP for sending emails to servers, and POP3 for a destination user agent to retrieve emails from servers

9. Which medium access control (MAC) protocol involves computers transmitting if no other computer is transmitting, otherwise waiting a random amount of time before trying again to transmit?
   a) Round Robin MAC
   b) Contention-based MAC
   c) Reservation-based MAC
   d) TDM
   e) FDM
   f) Statistical Multiplexing

10. IP provides the following features:
   a) Ordered delivery, fragmentation and error control
   b) Error control, addressing, ordered delivery
   c) Connection management, addressing and multiplexing
   d) Multiplexing, addressing and error control
   e) None of the above

11. If a transmission system uses 32 voltage levels to transmit a digital signal, then how many bits does each signal level represent?
    a) 1
    b) 2
    c) 3
    d) 4
    e) 5
    f) 6
    g) 8

12. If the NRZI encoding scheme is used, then the remaining bits would be:



    a) 1101100
    b) 1001001
    c) 0010011
    d) 0100101
    e) 1011010
    f) 1101100

13. Using Pulse Code Modulation to encode analog data, according to the sampling theorem, a data rate of 6Mb/s is required. How many bits are used to represent each sample (code), if the highest frequency component of the analog data is 1MHz?
    a) 1 bit
    b) 2 bits
    c) 3 bits
    d) 4 bits
    e) 5 bits
    f) 6 bits
    g) 12 bits

14. A computer receives packets at the times shown in the table. What is the jitter at the receiver?

Packet Number	*Time sent [ms]*	*Time received [ms]*
1	0	3
2	4	8
3	5	9
4	7	11
5	14	19

a) 0.1ms
b) 0.5ms
c) 1.0ms
d) 3ms
e) 4ms
f) None of the above

15. An IP datagram is sent from host S to host D, via routers A then B. If all subnets between S and D are Ethernet then:
a) The header of the Ethernet frame from A to B contains the MAC address of B as destination
b) The header of the IP datagram from A to B contains the IP address of B as destination
c) The header of the Ethernet frame from A to B contains the MAC address of D as destination
d) The header of the Ethernet frame from A to B contains the MAC address of S as source
e) The header of the IP datagram from A to B contains the IP address of A as source

16. In a TCP segment sent from A to B, if the Window field is set to 2500 and Acknowledgement number is 100 and Sequence number is 4000, then we know that:
a) A is allowed to send a maximum of 2500 bytes of data to B
b) The segment contains 4000 bytes of data from A to B
c) A just received 100 bytes of data from B
d) A has 2500 bytes available space in its receive buffer
e) The Sequence number in the next segment sent from A to B will be 4100
f) The next segment sent from B containing data will have sequence number 4000

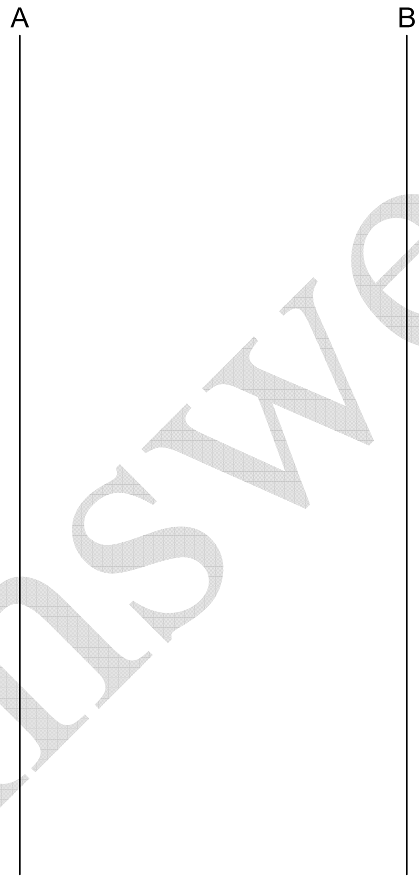
17. Consider a communications link with a signal-to-noise ratio of 31. What bandwidth would be required to transmit at the maximum theoretical data rate of 1Mb/s?
a) 32 kHz
b) 100 kHz
c) 200 kHz
d) 1 MHz
e) 5 MHz
f) 31 MHz

18. Which HTTP message most likely carries a username/password to access a file?
a) A HTTP request with Authorization header field
b) A HTTP response with Not Authorized status reason
c) A HTTP request using the GET method
d) A HTTP request using the POST method
e) A HTTP response with Forbidden status reason
f) A HTTP request with Accept header field

Part B – General Questions [73 marks]

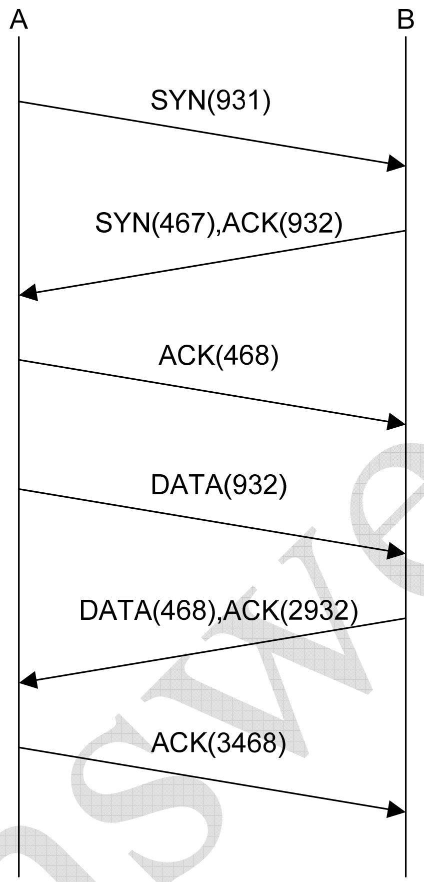
Question 1 [5 marks]

a) Draw a diagram to illustrate the TCP connection setup process between A and B. You must include the segment types as well as any other important information carried in the segments. Assume A chooses an initial sequence number of 931, and B chooses 467. [2 marks]



b) "Piggybacking" describes the process of including both DATA and an ACK in a single TCP segment. Assume, after the TCP connection setup between A and B, that A sends 2000 bytes of data in a single segment to B. Then B sends 3000 bytes of data in a single segment to A using piggybacking. Draw the complete data transfer (either on the diagram from part (a) or a new diagram on the back of this page), showing segment types and other important information. [3 marks]

Answer


A
B
SYN(931)
SYN(467),ACK(932)
ACK(468)
DATA(932)
DATA(468),ACK(2932)
ACK(3468)

Question 2 [10 marks]

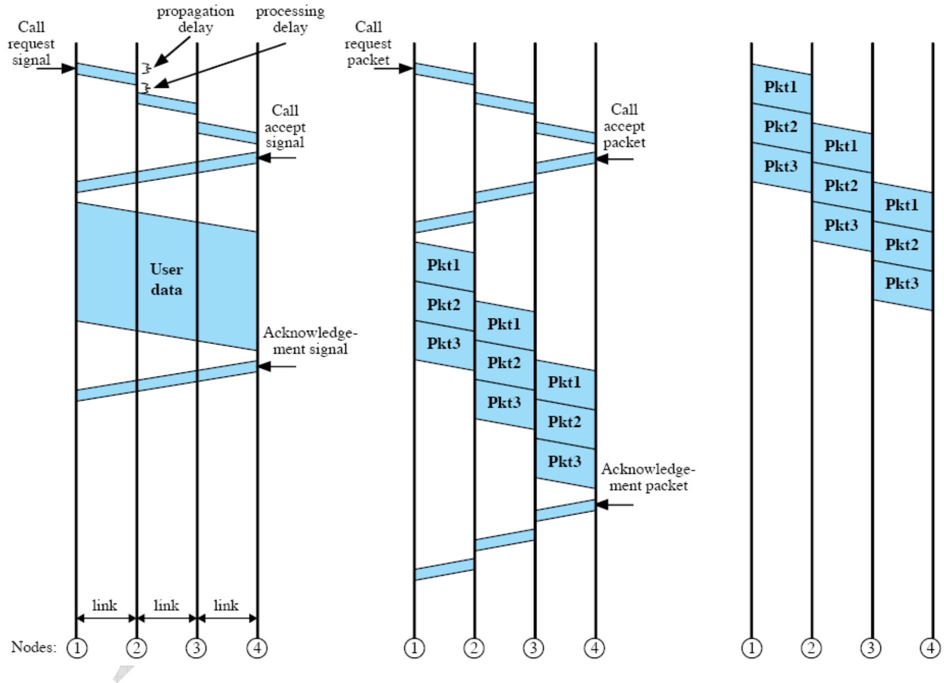
Consider the options of using Circuit Switching or Virtual Circuit Packet Switching in a network. Assume for both techniques the connection setup time and connection termination time are very small (that is, 0) compared to data transfer time. Under the following conditions, calculate the data transfer time for each technique:

- Total amount of data = 10 MBytes
- Date rate of each link = 2 Mbits/sec
- Propagation delay of each link = 10ms
- Number of hops from source to destination = 5
- Maximum amount of data a packet may carry (if needed) = 1000 Bytes
- Each packet (if needed) contains data plus a 125 Byte header

a) Data transfer time for Circuit Switching [3 marks]

Answer

Recall the differences between the techniques from the diagram:



Total transfer time for Circuit Switching

= DataSize / DataRate + NumberLinks * LinkDelay

= 80,000,000 / 2,000,000 + 5 * 0.01

= 40.05 sec

b) Data transfer time for Virtual Circuit Packet Switching [4 marks]

Answer

Total transfer time for Virtual Circuit Packet Switching
= #Packets * PacketSize / Rate + (NumberLinks – 1) * PacketSize / Rate + NumberLinks * LinkDelay

#Packets = 80,000,000 / 8,000 = 10,000 packets
PacketSize = 1000 B + 125 B = 9,000 bits

Total time
= 10,000 * 9,000 / 2,000,000 + (5 – 1) * 9,000 / 2,000,000 + 5 * 0.01
= 90,000,000 / 2,000,000 + 36,000 / 2,000,000 + 0.05
= 45sec + 0.018sec + 0.05 sec
= 45.068 sec

c) For the above scenario, which approach is fastest (less delay): Circuit Switching or Virtual Circuit Packet Switching? Explain why. [1 mark for explanation]

Answer

Circuit Switching. With circuit the data is not delayed at the switches (as soon as a signal is received it is sent to the next switch). With packet switching a switch must wait until it receives an entire packet before sending to the next switch. Also, with Circuit Switching headers are not needed, meaning less overhead (ignoring connection management).

d) If Datagram Packet Switching was used to transfer the same amount of data as in the above scenario, then (assume that the time for connection management is no longer very small):

i. The delay for Datagram Packet Switching will be

Larger Smaller Same as **Don't Know**

than the delay for Circuit Switching (circle one of the above answers) [1 mark]

ii. The delay for Datagram Packet Switching will be:

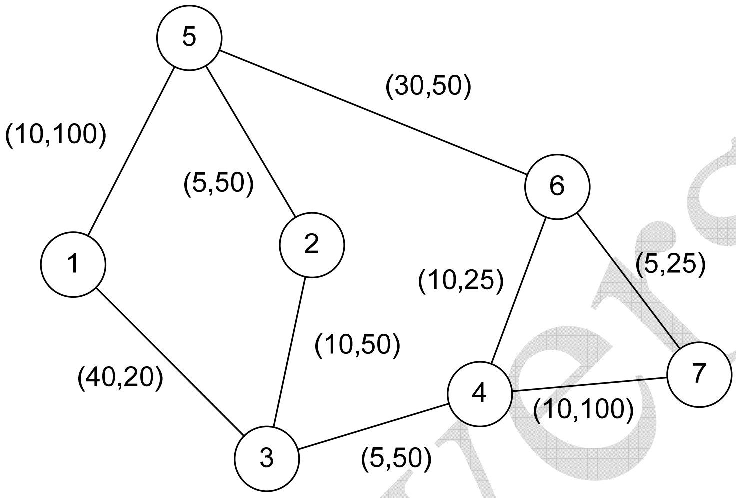
Larger **Smaller** Same as Don't Know

than the delay for Virtual Circuit Packet Switching [1 mark]

Note: "Don't Know" means, from the information in the question, you cannot determine which one is smaller.

Question 3 [8 marks]

Consider the network shown in the figure below. The delay (measured in milliseconds) and data rate (measured in Mbps) for each link are shown in the format: (delay, data rate).



Assuming least-cost routing is used to find a path from 1 to 7, indicate the path *and* total cost if the cost metric was:

a) Number of hops [1 mark]

Path: ________________________ Total Cost: ___________________

Answer

Path: 1-5-6-7 (3 hops) or 1-3-4-7 (3 hops)

b) Link delay [1 mark]

Path: ________________________ Total Cost: ___________________

Answer

Path: 1-5-2-3-4-7 (40)

c) $\dfrac{100\text{ Mb/s}}{\text{Link data rate}}$ [2 marks]

Path: ________________________ Total Cost: ___________________

Answer

Path: 1-5-6-7 (7)

d) Adaptive, link-state routing protocols often use flooding to distribute link-state packets on a regular basis.

i. What information should be included in link state packets? [2 marks]

Answer

A node should include the nodes that it has links to, as well as the cost of those links. (Other information such as sequence numbers and hop limits may also be included)

ii. What is an advantage of increasing the frequency at which link-state packets are distributed? [1 mark]

Answer

An advantage is that other nodes will have more accurate knowledge of the current state of the topology.

iii. What is a disadvantage of decreasing the frequency at which link-state packets are distributed? [1 mark]

Answer

A disadvantage is that the overhead (amount of routing information or number of link state packets) of the routing protocol will increase, leaving less time for real data to be sent through the network.

Question 4 [9 marks]

Consider an internet containing seven DNS Servers (shown in Figure 1) and several hosts. Each DNS Server maintains a list of registered domain names, cached domain names, as well as a list of DNS Servers (parent and children) that it is aware of. Each Host maintains a list of cached domain names, as well the IP address of its local DNS Server.

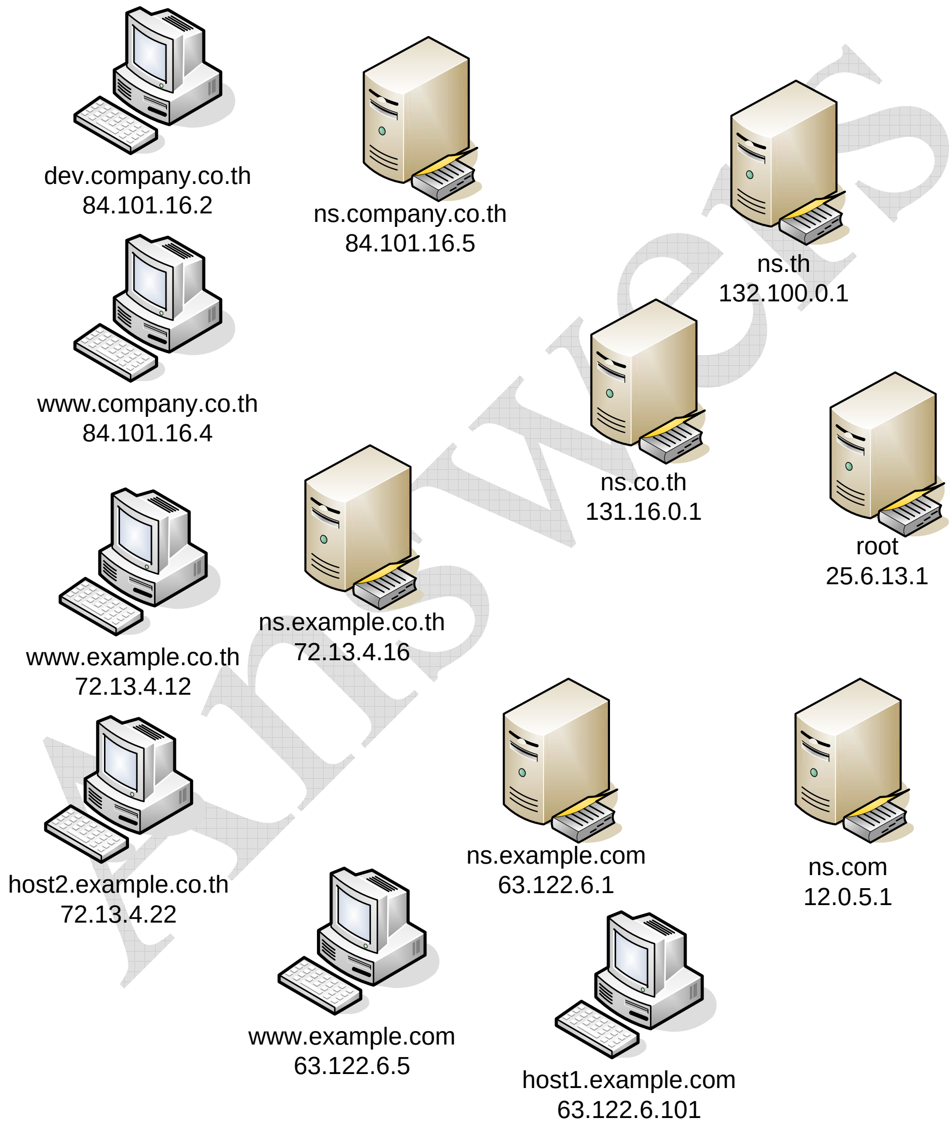


Figure 1

a) For DNS Server `ns.company.co.th`, indicate the list of (write 'none' if there are no relevant entries in the list):

   i. Registered domain names [0.5 mark]

Answer

dev.company.co.th
www.company.co.th

ii. Parent/children DNS Servers [0.5 mark]

Answer

ns.co.th

b) For DNS Server `ns.co.th`, indicate the list of:

i. Registered domain names [0.5 mark]

Answer

none

ii. Parent/children DNS Servers [0.5 mark]

Answer

ns.th
ns.company.co.th
ns.example.co.th

c) For DNS Server `root`, indicate the list of:

i. Registered domain names [0.5 mark]

Answer

none

ii. Parent/children DNS Servers [0.5 mark]

Answer

ns.th
ns.com

d) If an application on `dev.company.co.th` has data to send to `www.example.com`, explain the steps that DNS would take to find the IP destination address. You must indicate all computers that query/response would pass via (in order). Assume the cached domain names are currently empty. [3 marks]

Answer

The query would pass from
dev.company.co.th -> ns.company.co.th -> ns.co.th -> ns.th -> root -> ns.com -> ns.example.com
ns.example.com should have the IP address for www.example.com. The response will pass the reverse path.

e) If, shortly after the request in part (d), an application on `host2.example.co.th` has data to send to `www.example.com`, explain the steps that DNS would take assuming caching was used on all DNS servers and hosts. [3 marks]

Answer

The query would pass from
Host2.example.co.th -> ns.example.co.th -> ns.co.th
Ns.co.th should have the IP address for www.example.com cached, and the response will be returned.

Question 5 [14 marks]

Assume a web browser is executing in Host A and a web server executing on Host B in an internet. Assume the following about the network and applications:

- HTTP is used.
- The IP address of Host A is 62.16.4.2
- The IP address of Host B is 74.2.2.1, which has the registered domain name of www.example.com.
- Every HTTP request contains 200 bytes of headers (including the start line and any blank lines).
- Every HTTP response contains 200 bytes of headers (including the start line and any blank lines).
- The web browser does not use caching or proxies.
- The processing time at the web server is 2 ms.
- The processing time at the web browser is 0ms.
- The propagation time from browser to server is 50ms (and the same in opposite direction).
- The average data rate over the internet is 100kbytes/sec.
- The required Domain names exist in the local cache (you can ignore the time it takes to obtain the IP address)
- Ignore the operations and overheads of protocols at layers other than application layer (that is, only consider HTTP)
- There are no errors in transmission

The files stored at the web server (and their size) are:

`/index.html`	5000 bytes
`/contact.html`	2000 bytes
`/images/logo.jpg`	10000 bytes
`/images/steve.jpg`	20000 bytes
`/images/pic.jpg`	50000 bytes

`index.html` has two images embedded (`/images/logo.jpg` and `/images/pic.jpg`), and `contact.html` has two images embedded (`/images/logo.jpg` and `/images/steve.jpg`). `index.html` has a link to `contact.html`, and `contact.html` has a link to `index.html`.

a) The user types in the URL `http://www.example.com/index.html` into their web browser (at time 0sec). Draw a diagram that illustrates the HTTP data transfer. You must clearly label the HTTP message types, showing the Start Line of each message. [3 marks]

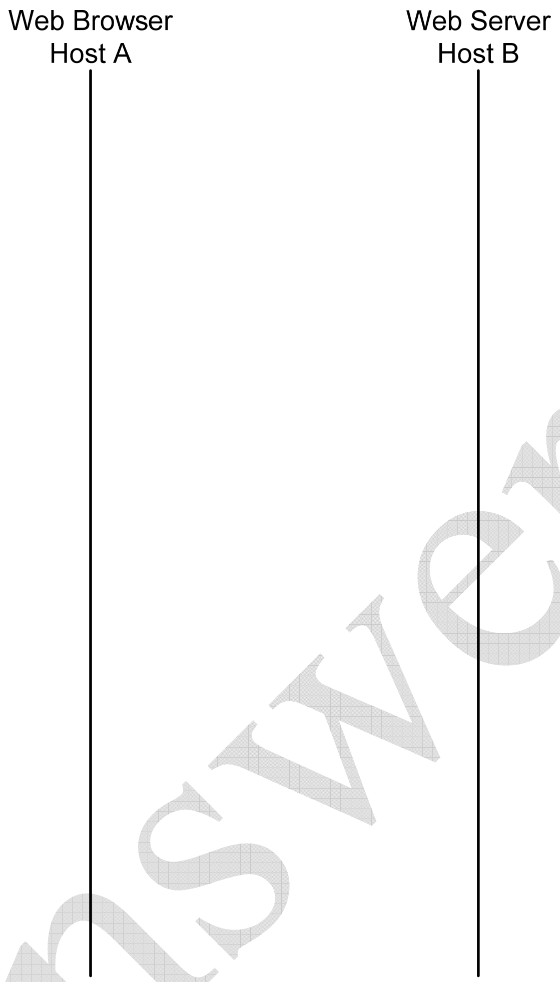
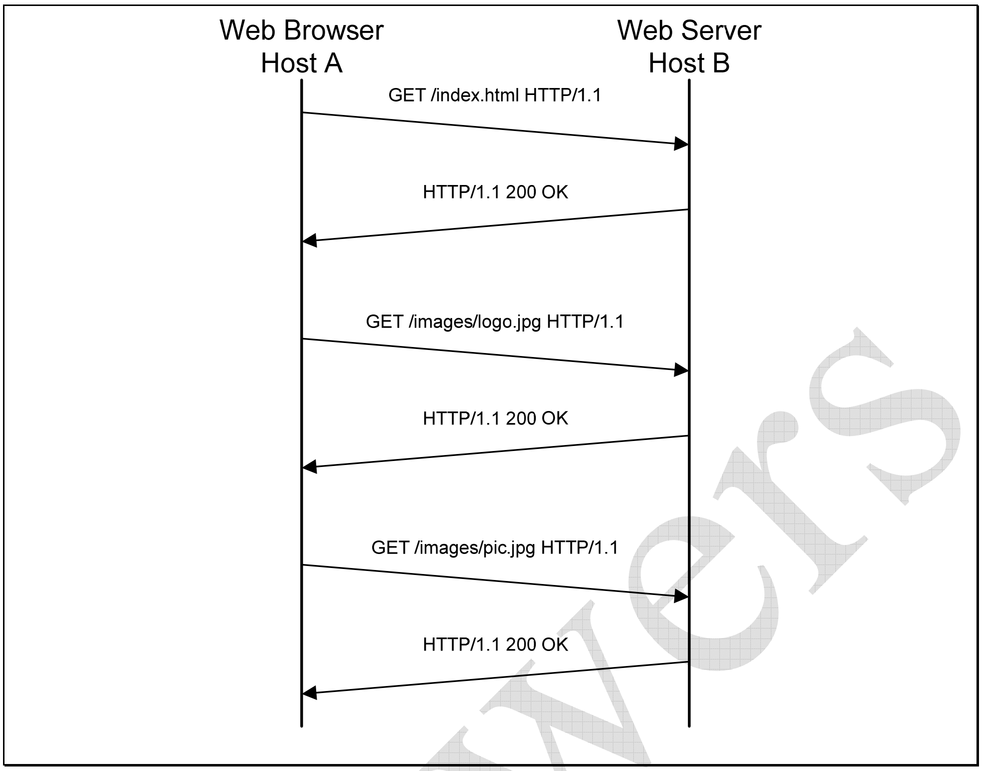


Figure 2

Answer



b) What is the web page response time (that is, the time from when the request is made until the time at which the page *and* any images are displayed)? [5 marks]

Answer

Request for /index.html	
Request size = 200 Bytes	
Data Rate = 100,000 Bytes/sec	
Transmission Time =	2ms
Propagation Time to Server	50ms
Server processing time =	2ms
Response for /index.html	
Response size = 200 + 5000 = 5200 Bytes	
Transmission Time =	52ms
Propagation Time to Browser =	50ms
Request for /images/logo.jpg, Trans. Time =	2ms
Propagation Time to Server	50ms
Server processing time =	2ms
Response, Trans. Time =	102ms
Propagation Time to Browser =	50ms

Request for /images/pic.jpg, Trans. Time =	2ms
Propagation Time to Server	50ms
Server processing time =	2ms
Response, Trans. Time =	502ms
Propagation Time to Browser =	50ms
Web Page Response Time =	968ms

c) From the page requested in part (a), 1 minute after receiving the `index.html` page (and images), the user clicks on a link to `/contact.html`. What is the web page response time for `contact.html` (and images)? [3 marks]

Answer

Using the same approach as part (b):

Response time for contact.html =	22ms
Response time for logo.jpg =	102ms
Response time for steve.jpg =	202ms
Web Page Response Time =	638ms

Consider the web transfer from parts (a), (b), and (c) again, however this time assuming that the web browser caches the pages and images it receives. If a file to be requested by the web browser is available in the cache, then the web browser includes the header "If-Modified-Since" in the request for that file. If the web server indicates the file has not been modified, the web browser will use the cached copy of the file.

Assume the web browser cache is initially empty. Then, at time 0, the user types in the URL as in part (a). Then, 1 minute after receiving the `index.html` page (and images), the user clicks on a link to `/contact.html`.

d) Assuming no pages are modified on the web server, what is the web page response time for `contact.html` (and images)? [3 marks]

Answer

After the first request (for index.html), the web browser will have the following files in cache:
index.html
logo.jpg
pic.jpg

In the second request (contact.html), everything is the same as in part (c), except that the request for logo.jpg will include the "If-Modified-Since" header field. When the web server receives the request, it checks that the logo.jpg file has not been modified, and returns a 301 Not Modified response. The file logo.jpg is not included in the response (the web browser will use the cached copy).

Hence, the only different to part (c) is that the response time for the logo.jpg request will be 2ms, not 102ms.

Web Page Response Time = 538ms

Question 6 [13 marks]

Consider TCP implementing the following rules:

- TCP sender sends a DATA segment when it has at least 180 Bytes of data from the application layer.
- TCP sender will send a maximum of 180 Bytes in one DATA segment.
- TCP receiver uses cumulative acknowledgements: a single ACK is sent immediately after every *second* DATA segment is received.
- TCP receiver has initial advertised window of 2^{16}-1. As the buffer size at the receiver is very large, you may ignore the effects of flow control in this question.

Assume the following about the network and applications:

- No options (or padding) are used in the TCP header (see Figure 3)
- The processing time at both hosts is 0. There are no queuing delays.
- The propagation time between Host A and Host B is 10ms.
- The average data rate over the internet is 10,000 Bytes/sec.
- There are no errors in transmission.
- TCP connection setup has been completed: both A and B chose an Initial Sequence Number of 0.

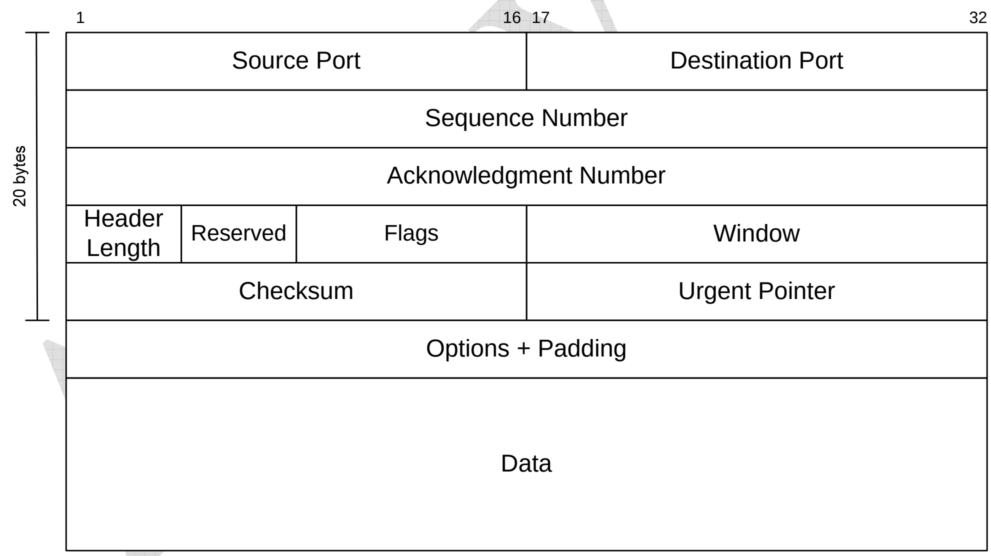


Figure 3

The application on Host A writes data at the following times:

- At time = 0, application writes 360 Bytes
- At time = 50ms, application writes 540 Bytes
- At time = 130ms, application writes 180 Bytes

a) What is the transmission time of a TCP segment containing DATA? [1 mark]

Answer

DATA segment is 180 + 20 = 200 Bytes
Transmission time of a DATA segment @ 10,000 B/s = 20ms

b) What is the transmission time of a TCP segment containing only an ACK? [1 mark]

Answer

ACK segment is 20 bytes
Transmission time of an ACK segment is 2ms

c) On the diagram below, illustrate the exchange of TCP segments between A and B to complete the data transfer. Show the types of TCP segments, sequence and acknowledgement numbers (where necessary). Your diagram does not have to be to scale (although for answering subsequent parts of this question it will be easier if it is close to scale). The dashed lines represent 20ms intervals. [4 marks]

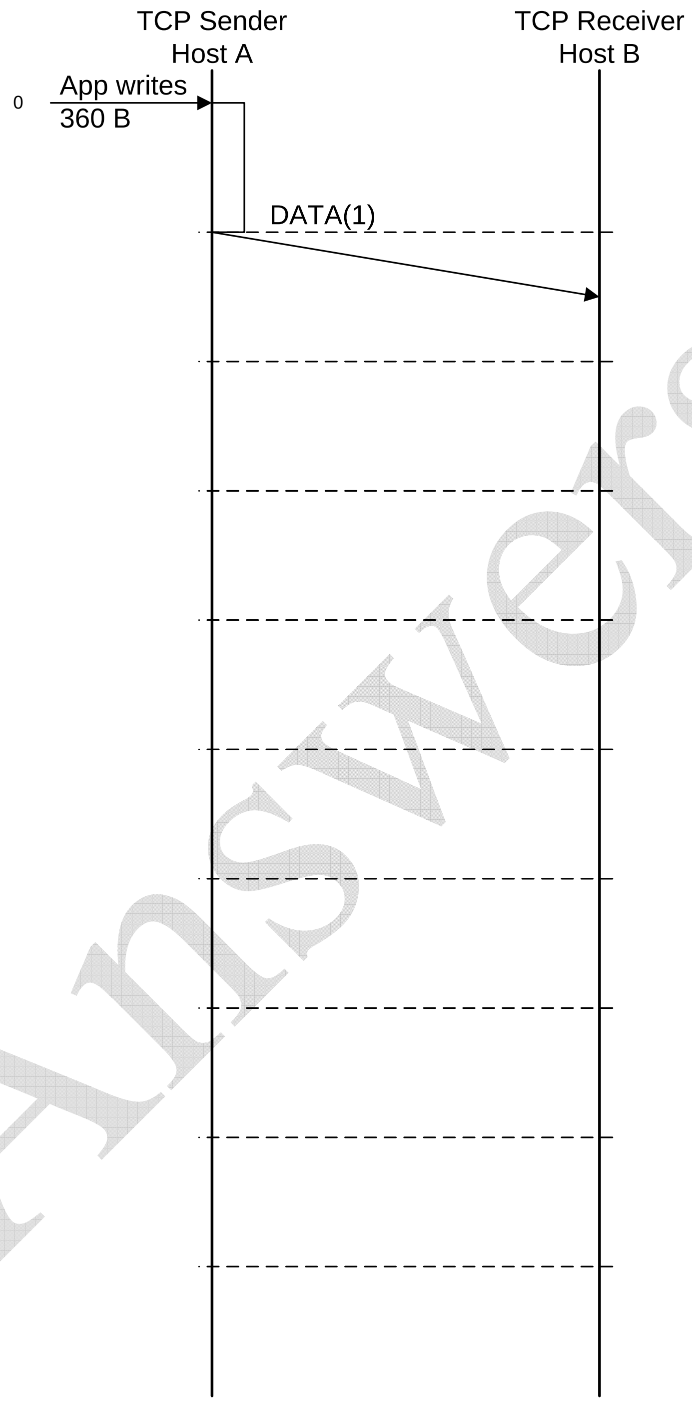
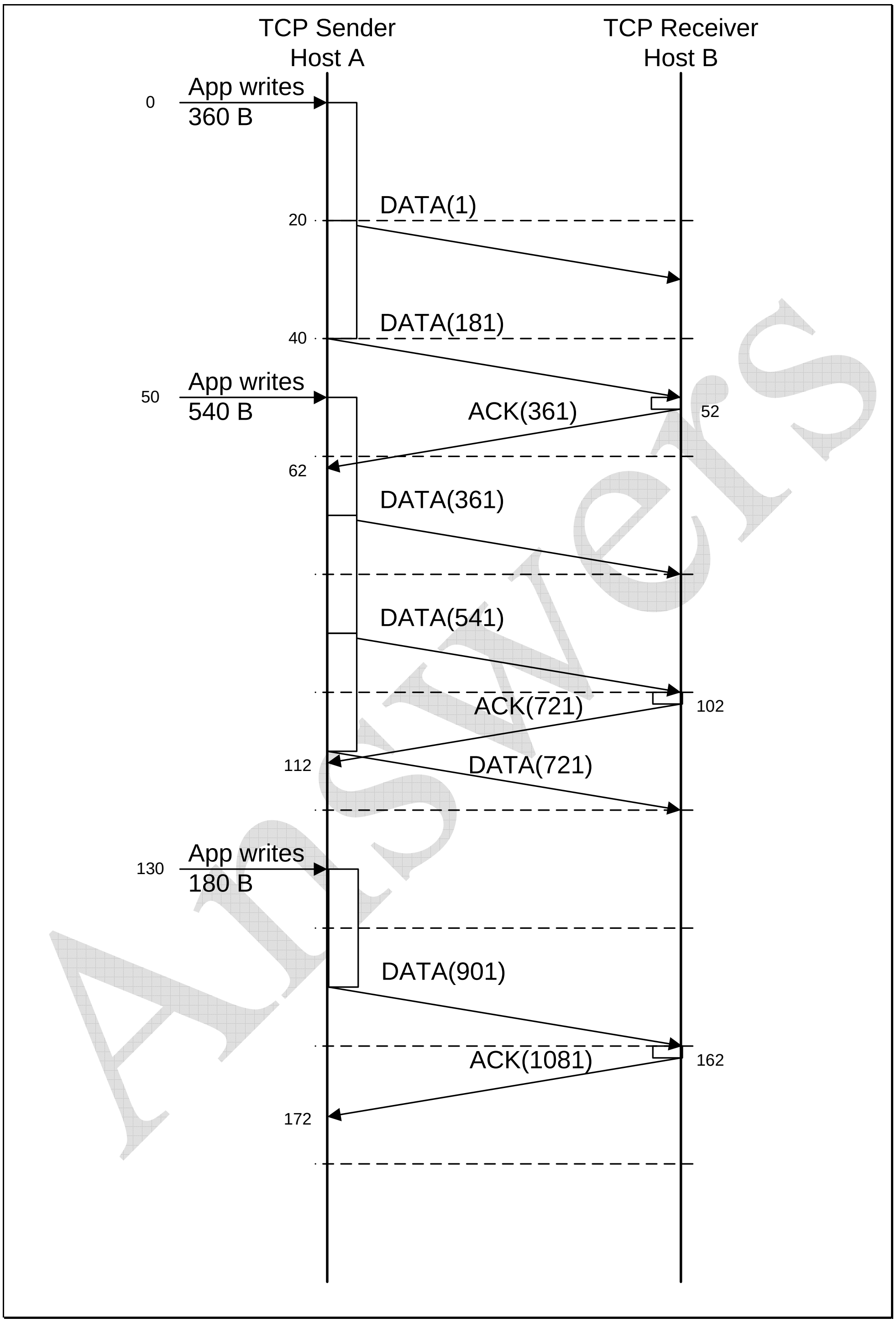


Figure 4

Answer



d) At what time is the first ACK segment received by Host A? [1 mark]

Answer

62ms

e) What is the acknowledgement number in the first ACK segment received by Host A? [1 mark]

Answer

361

f) At what time is the third (3rd) DATA segment fully received by Host B? [1 mark]

Answer

80ms

g) At what time is the last DATA segment fully received by Host B? [1 mark]

Answer

160ms

h) What is the sequence number in the last DATA segment received by Host B? [1 mark]

Answer

901

i) What is the total time from when the first byte is sent, until the last DATA segment is acknowledged? [1 mark]

Answer

172ms

j) From TCP at Host A's perspective, what is the throughput? [1 mark]

Answer

Throughput = 1080 Bytes / 172ms = 6279 Bytes/sec

Question 7 [7 marks]

In this question, assume Classful IP addressing is used.

a) For a host with IP address 162.127.0.1:

i. What is the class? [1 mark]

Class: ____________________

Answer

Class B (since first two bits are 01)

ii. What is the directed broadcast address for the network of the host? [1 mark]

Broadcast: _______________________

Answer

162.127.255.255

iii. How many computers (including this one) may be located on this network? [1 mark]

Number of computers: ______________

Answer

2^{16}-2 = 65534

b) For a router with IP address 64.16.1.254:

i. What is the address of the network that the router is attached to? [1 mark]

Network: ________________________

Answer

64.0.0.0

ii. What is the local broadcast address that this router will use? [1 mark]

Local broadcast: ___________________

Answer

255.255.255.255

iii. How many computers (including this one) may be located on this network? [1 mark]

Number of computers: _______________

Answer

2^{24}-2 = 16777214

iv. How many networks of the same size of that in part (i) can be in an internet? [1 mark]

Number of networks: ________________

Answer

7 bits for network portion of address, however two values are reserved, allowed 126 networks.

Question 8 [7 marks]

In this question, assume classless IP addressing is used.

a) For host A with IP address 64.16.8.101/11:

   i. How many computers (including this one) may be located on this network? [1 mark]

Number of computers: _______________

Answer
2^{21}-2 = 2097150

   ii. What is the address that another host on another network would use to send to all hosts on the same network as host A? [1 mark]

Address: _________________________

Answer
64.31.255.255/11

   iii. What is the network address for host A? [1 mark]

Network: _________________________

Answer
64.0.0.0/11

b) For host B with IP address 102.72.225.13 and network address 102.72.192.0:

   i. What is the subnet mask, in dotted decimal notation, for Host B? [1 mark]

Mask: _________________________

Answer
/18 = 255.255.192.0

   ii. What is the directed broadcast address for Host B? [1 mark]

Broadcast: _________________________

Answer

102.82.255.255

c) Host C has IP address 31.3.77.1. A router on the same network as C has IP address 31.3.76.1:

   i. If host D on a different network to C, but with the same subnet mask, has IP address 31.3.72.15, then what is a possible subnet mask of C? [2 marks]

Mask: ________________________

Answer

C   31.3. 01001101 . 1
R   31.3. 01001100 . 1
D   31.3. 01001000 . 15
Since C and R are on the same network, they must have the same network portion, e.g. /23 or /22 or /21 or …
However D must have a different network portion, e.g. /22 or /23.
Hence the answer is /22 or /23.