

Computer Networks - Midterm

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Duration: 1:45 hours, closed book.

Please write your answers on these sheets in a *readable* way. Poorly written answers will *not* be corrected. Use extra sheets if necessary (put your name on them).

You may write your answers in English or in French.

The total number of points is 40.

This document contains 16 pages.

Full Name (Nom et Prénom):

SCIPER No:

Division: \Box Communication Systems \Box Computer Science \Box Other (mention it):

Year: \Box Bachelor Year 2 \Box Bachelor Year 3 \Box Other (mention it):

(answers to the questions are shown in italic and blue)

1 Short questions

(5 points)

For each question, please circle a single best answer.

- 1. Sort the following physical media based on their maximum throughput, from lowest to highest.
 - (a) Twisted Pair Category 5, IEEE 802.11g, Fiber Optic
 - (b) Twisted Pair Category 5, Fiber Optic, IEEE 802.11g
 - (c) IEEE 802.11g, Twisted Pair Category 5, Fiber Optic *CORRECT*
 - (d) Fiber Optic, IEEE 802.11g, Twisted Pair Category 5
- 2. Packet-switching versus circuit-switching: Which of the following is correct?
 - (a) Packet-switching is more flexible, circuit-switching is more robust to link failures
 - (b) Packet-switching is more secure, circuit-switching is more efficient
 - (c) Packet-switching and circuit-switching offer the same bandwidth guarantees
 - (d) Packet-switching allows more users to access the network, circuit-switching provides qualityof-service guarantees *CORRECT*
- 3. Consider the following Java code:

```
1: try {
2:
        ServerSocket ss = new ServerSocket (2011);
3:
       Socket s1 = ss.accept();
4:
       Socket s2 = ss.accept();
5:
       DataInputStream is = new DataInputStream(s1.getInputStream());
       DataOutputStream os = new DataOutputStream(s2.getOutputStream());
6:
7:
        while (true) {
8:
            os.writeByte(is.readByte());
9:
        }
10: } catch (Exception e) {
11:
      // crash!
12: }
```

What does this code do?

- (a) Does not compile, because the ServerSocket constructor takes no parameters.
- (b) Always crashes in line 4, because you can only call accept () once.
- (c) Creates an "echo" program that responds to the client with the exact same bytes he sent.
- (d) Creates a "relay" program that sends the bytes received from one client to another client. *CORRECT*
- 4. An organization's Web server and mail server:
 - (a) can have exactly the same alias for a hostname (for example, foo.com). *CORRECT*
 - (b) cannot have exactly the same alias for a hostname (for example, foo.com).
 - (c) must run on the same machine.
 - (d) can run on the same machine only if they share one DNS record.

5. Assume that the following lines are inserted at the DNS server:

(midterm.edu, service1.edu, CNAME) (midterm.edu, service2.edu, MX) (service1.edu, 8.11.11.101, A) (service2.edu, 8.11.11.104, A)

As a consequence, when you open midterm.edu in your browser:

- (a) the request is served by the server with IP 8.11.11.101. CORRECT
- (b) the request is served by the server with IP 8.11.11.104.
- (c) the request is served by the server with IP 8.11.11.101 or 8.11.11.104, depending on the current server load.
- (d) the DNS server cannot hold two records for midterm.edu.
- (e) none of the above.
- 6. Which of the following regarding UDP is true?
 - (a) UDP would work perfectly for applications such as Email and File Transfer.
 - (b) UDP segments have a smaller packet header size as compared to TCP segments. CORRECT
 - (c) UDP requires an explicit connection establishment using three-way handshake protocol.
 - (d) An application using UDP can never have reliable data transfer.
- 7. In a Go-Back-N (GBN) protocol, if the last correctly received (and delivered to the upper layer) segment has sequence number 5 and the receiver next receives a segment with sequence number 7, it does the following:
 - (a) Buffers segment 7 and sends an ACK for segment 5.
 - (b) Buffers segment 7 and sends an ACK for segment 7.
 - (c) Discards segment 7 without sending any ACK.
 - (d) Discards segment 7 and sends an ACK for segment 5. CORRECT
- 8. In TCP, a sender performs a fast retransmit (re-transmitting a lost segment before the timeout event) in the following event:
 - (a) It received three duplicate ACKs for the same data. CORRECT
 - (b) The RTT (Round Trip Time) of the last ACK was greater than the average RTT.
 - (c) Data in the sender's TCP buffer exceeds a threshold value.
 - (d) None of the above.

- 9. Suppose within your Web browser you click on a link to obtain a Web page. The IP address for the associated URL is not cached in your local host, so a DNS lookup is necessary to obtain the IP address. Suppose that n DNS servers are visited before your host received the IP address from DNS; the successive visits incur an RTT of $RTT_1, ..., RTT_n$. Further suppose that the Web page associated with the link contains exactly one object, consisting of a small amount of HTML text. Let RTT_0 denote the RTT between the local host and the server containing the object. Assuming zero transmission time of the object, how much time elapses from when the client clicks on the link until the client receives the object?
 - (a) $RTT_1 + RTT_2 + ... + RTT_n + RTT_0$
 - (b) $RTT_1 + RTT_2 + \ldots + RTT_n + 2RTT_0$ CORRECT
 - (c) $2(RTT_1 + RTT_2 + ... + RTT_n) + RTT_0$
 - (d) $2(RTT_1 + RTT_2 + ... + RTT_n + RTT_0)$

2 The Web

(10 points)

A student sequentially visits two different websites that use the same advertisement provider to include online advertisements into the content of their webpages. The generated traffic was captured with Wireshark and simplified traces (trace 1 corresponding to website 1 and trace 2 to website 2) are given in Figure 1, Figure 2, Figure 3, Figure 4, Figure 5 and Figure 6. By analyzing the given traces, answer the following questions:

	F	ilter:	http		•	Expression	Clea	ar Appl	У	
	No.	Time		Source	Destination	Protocol	Info		A	1
I	4	0.1	35657	128.178.151.105	207.126.123.20	HTTP	GET /o	d/foodblog	gs/Food_and_Cooking_Blogs.htm HTTP/1.1	1
	13	0.4	34711	207.126.123.20	128.178.151.105	HTTP	HTTP/1	.1 200 OK	(text/html)	
I	19	0.7	99800	128.178.151.105	209.85.148.165	HTTP	GET /p	agead/show	<pre>w_ads.js HTTP/1.1</pre>	
	25	0.8	16715	209.85.148.165	128.178.151.105	HTTP	HTTP/1	.1 200 OK	(text/javascript)	
Ш	33	1.8	35682	128.178.151.105	209.85.148.165	HTTP	GET /p	agead/js/	r20110928/r20110914/show_ads_impl.js HTTP/1.1	1
U	- 50	1.8	68917	209.85.148.165	128.178.151.105	HTTP	HTTP/1	.1 200 OK	(text/javascript)	1
1	54	2.2	10796	128.178.151.105	209.85.148.165	HTTP	GET /p	agead/ren	der_ads.js HTTP/1.1	1
I	55	2.2	27434	209.85.148.165	128.178.151.105	HTTP	HTTP/1	.1 200 OK	(text/javascript)	1
I	62	2.4	89540	128.178.151.105	209.85.148.156	HTTP	GET /p	agead/ads'	client=ca-about-radlink&output=js&1mt=1317980573#_ads=0&max_ra	1
Ш	66	2.8	00012	209.85.148.156	128.1/8.151.105	HTTP	HTTP/1	.1 200 OK	(text/javascript)	1
	٠								•	1
Ш	⊞ FI	rame	4: 559) bytes on wire (4	472 bits), 559 by	es captu	ured (4	472 bits)		1
I		ther	net II	, Src: Usi_6d:19:e	3 (00:1a:6b:6d:19	:e3), Ds1	t: Cisc	o_ff:fc:50) (00:08:e3:ff:fc:50)	1
I	• II	nter	net Pro	otocol, Src: 128.1	78.151.105 (128.1)	78.151.10	05), Ds	t: 207.120	5.123.20 (207.126.123.20)	
I	⊞ TI	ransi	missio	n Control Protocol	, Src Port: 57515	(57515)	, Dst P	ort: http	(80), Seq: 1, Ack: 1, Len: 505	1
I	🗆 Hy	per	text Ti	ransfer Protocol						
I	۲	GET	/od/fo	odblogs/Food_and_C	ooking_Blogs.htm	HTTP/1.1	.\r\n			4
I		Acce	ept: ap	plication/x-ms-app	lication, image/j	peg, app	licatio	on/xam1+xm	l, image/gif, image/pjpeg, application/x-ms-xbap, application/x-sho	2
I		Acce	ept-Lan	guage: en-US\r\n						
I		User	-Agent	: Mozilla/4.0 (con	patible; MSIE 8.0	; Window	IS NT 6.	.1; WOW64;	Trident/4.0; SLCC2; .NET CLR 2.0.50727; .NET CLR 3.5.30729; .NET C	-
I		ACCE	ept-Enc	oding: gzip, defla	ite\r\n					
I		Host	t: home	cooking.about.com	\r\n					
1		Conr	iection	: Keep-Allve\r\n						
1		/r,/t	1							
		Conr \r\r	nection N	: Keep-Alive\r\n						

Figure 1: Wireshark trace 1 - The first HTTP request

Filt	er:	http		-	Expression	Clear	Apply	
No.	Time	e	Source	Destination	Protocol	Info		A
4	40.1	13777	128.178.151.105	184.106.62.180) HTTP	GET / HT	TP/1.1	
68	31.9	39545	184.106.62.180	128.178.151.10	05 HTTP	HTTP/1.1	200 OK	(text/html)
222	213.	816677	128.178.151.105	209.85.148.164	4 НТТР	GET /pag	ead/show_	_ads.js HTTP/1.1
223	313.	833552	209.85.148.164	128.178.151.10	DS HTTP	HTTP/1.1	304 Not	Modified
227	/ 14.	429172	128.178.151.105	209.85.148.164	4 HTTP	GET /pag	ead/expar	insion_embed.js HTTP/1.1
24:	314.	49/438	209.85.148.164	128.1/8.151.10	DS HTTP	HTTP/1.1	200 OK	(text/javascript)
250	J 15.	547406	200 85 148 156	209.85.148.150		GET /page	ead/ads/o	CTTENT=Ca-pub-6464516566245894&output=ntm1&n=90&sTotname=5224/
257	15.	24/490 240623	209.85.148.150			CET /pag	200 OK	(LEXL/IILII)
260) 15	876438	200 85 148 96	128 178 151 10	15 HTTP	HTTP/1 1	302 Eou	(CIE802)
261	15	893744	128 178 151 105	209 85 148 156	Б НТТР	GET /pag	ead/view	throughconversion/1070643593/2label=ledXCKfUShC188L-Aw&guid=ON
•		000111	12011/011511205	2007.007.110110		III	eady viren	ten oughtonver 5 ton, tor ou 1555) Haber - reakent obresoot Anagara-on
⊞ Fra	ame 4	4: 520 k	oytes on wire (416	0 bits), 520 by	tes capture	ed (4160 b	its)	
🗉 Eth	nerne	et II, S	Src: Usi_6d:19:e3	(00:1a:6b:6d:19	:e3), Dst:	Cisco_ff:	fc:50 (0	00:08:e3:ff:fc:50)
🗉 Int	erne	et Proto	col, Src: 128.178	.151.105 (128.1	78.151.105)	, Dst: 18	34.106.62	2.180 (184.106.62.180)
🗉 Tra	insm	ission (Control Protocol,	Src Port: 58696	(58696), D	st Port:	http (80	0), Seq: 1, Ack: 1, Len: 466
🗉 Нур	erte	ext Trar	nsfer Protocol					
🗆 G	ET /	′ HTTP/1	.1\r\n					
۲	[Ex	pert In	fo (Chat/Sequence)	: GET / HTTP/1.	1\r\n]			
	Req	uest Me	thod: GET					
	Req	uest UR	[: /					
	Red	uest ve	rsion: HIIP/1.1					incer(-if incer(since explication(), monthem explication(), etc.
A	ccep	t: appi	TCation/x-ms-appi	ication, image/	jpeg, appin	cation/xa	mi+xmi,	<pre>image/gir, image/pjpeg, application/x-ms-xbap, application/x-sno</pre>
1 0	cor-	Agent .	Mozilla/ 4.0 (comp	atible MSTE 8 (). Windows	NT 6 1 · W	0W64 • Tr	nident/4 0. SICC2. NET CLP 2 0 50727. NET CLP 3 5 30720. NET C
	ccen	t-Encod	ing: gzin deflat	e r n	, windows		0104, 11	Tuent/4.0, SECC2, MET CER 2.0.30727, MET CER 3.3.30723, MET C
l Ĥ	ost.	www.im	notobsessed com\r	\n				
l c	onne	ction:	Keen-Alive\r\n	···				
1 1	r\n							
,								

Figure 2: Wireshark trace 2 - The first HTTP request

Question 1: What are the URLs of the visited Web pages?

First: homecooking.about.com/od/foodblogs/Food_and_Cooking_Blogs.htm *Second:* www.imnotobsessed.com

Question 2: What is the size of the first HTTP GET request in trace 1? 505B, noted in the Len field of the TCP packet details.



Figure 3: Wireshark trace 1 - The first HTTP response

Question 3: Is there a domain for which the first visited website can track the student's subsequent browsing behavior? Justify your answer.

Yes, on the domain about.com. Set-Cookie headers in the first HTTP response message indicate that the first website has placed cookies in the student's browser for the domain about.com. Unless the student deletes cookies, for subsequent visits the website will recognize the student as a returning visitor.



Figure 4: Wireshark trace 1- The second HTTP request

Question 4: Which mechanism is used to include ads into the content of visited Web pages? Which server is contacted for inclusion of ads? To which organization does that server belong? What is its IP address?

From the second HTTP GET request: Host: pagead2.googlesyndication.com. The server belongs to Google and the website includes Google ads via show_ads.js javascript. IP of the server is: 209.85.148.165.

Question 5: When the student's browser communicates with the ad provider, does the ad provider know which webpage the student is visiting? Justify your answer.

Yes, based on the value of the Referer field (e.g., in the second HTTP GET request: http://homecooking.about.com/od/foodblogs/Food_and_Cooking_Blogs. htm).

Question 6: Can the second website know that the student has previously visited the first website? Justify your answer.

No, because the student has independently entered the URL of the second website thus the referer field is empty. Also, the websites belong to different domains and cookies are not shared between these two websites.

Question 7: Can the second website know that the student has previously been served ads from the same ad provider? Justify your answer.

No. For the second website to learn this information, the cookies for the domain of the ad provider would have to be shared with the second website, which is not the case (i.e., the domain of the second website is different from the domain of the ad provider).

Filter:	http			▪ Exp	ression	Clear	Apply	y	
No Time		Source	Destination	Bro	tocol In	fo			
4 0.13	5657	128,178,151,105	207.126.123.20) HT	TP G	ET /od/	foodblog	as/Food and Cooking Blogs.htm HTTP/1.1	
13 0.43	4711	207.126.123.20	128.178.151.10)5 HT	TP H	TTP/1.1	200 OK	(text/html)	
19 0.79	9800	128.178.151.105	209.85.148.165	HT	TP G	ET /pag	ead/show	v_ads.js HTTP/1.1	=
25 0.81	.6715	209.85.148.165	128.178.151.10)5 HT	TP H	TTP/1.1	200 OK	(text/javascript)	
331.83	5682	128.178.151.105	209.85.148.165	HT	TP G	ET /pag	ead/js/r	20110928/r20110914/show_ads_impl.js HTTP/1.1	
50 1.86	8917	209.85.148.165)5 HT	TP H	TTP/1.1	200 OK	(text/javascript)	
55 2 22	7/3/	120.1/0.101.100	128 178 151 10		TP G	ET /pag TTD/1 1	200 or	(text/javascript)	
62 2 48	9540	128 178 151 105	209 85 148 156	HT	TP G	FT /pag	ead/ads?	<pre>?client=ca-about-radlink&output=is&lmt=1317980573#_ads=0&max_r;</pre>	
66 2.80	0012	209.85.148.156	128,178,151,10)5 НТ	TP H	TTP/1.1	200 OK	(text/javascript)	-
•								•	
Frame 66:	128 by	rtes on wire (1024 b	oits), 128 bytes o	apture	d (1024	bits)			
Ethernet 1	II, Sro	: Cisco_ff:fc:50 (0	0:08:e3:ff:fc:50)), Dst:	Usi_6d	:19:e3 ((00:1a:6b	:6d:19:e3)	
Internet F	rotoco	ol, Src: 209.85.148.	156 (209.85.148.1	L56), D	st: 128	.178.151	L.105 (128	8.178.151.105)	
Transmissi	ion Cor	trol Protocol, Src	Port: http (80),	Dst Po	rt: 575	23 (5752	23), Seq:	1393, Ack: 1256, Len: 74	
[Reassemb	led TCF	Segments (1466 byt	.es): #64(1380), #	¥65(12)	, #66(7	4)]			
Hypertext	Transf	er Protocol							
HIIP/1.1	200 0	K\r\n "http://googloads	a doubleclick pet	(02002)	l/acn n		cn "cun	PA ADMA DEVA TATA DEAA DEDA OUD TND UNT DUD TNT DEM ETA DDE COM NAV OTC 1	IOT
Content-	Type	= nttp://googleaus. text/javascript: ch	g. doublectick.net	/payeau	i/gcn_ps	spxiii i	, CP= CUR	KA ADMA DEVA TATO PSAO PSDO OUR IND UNI PUR INT DEM STA PRE COM NAV OTC P	IOI
Set-Cook	ie: id	=227b9519180100c211	t=1298645995 et=7	30 cs = 0)02213fr	d485f9fa	7841a3fd7	720: expires=Sun, 24-Feb-2013 14:59:55 GMT: nath=/: domain=.doubleclick.r	net'
X-Conten	t-Type	-Options: nosniff\r	\n	50105-0				zo, and new ban, in the rout interior and participation of the rout rection of the	
Content-	Dispos	ition: attachment\r	\n						
Content-	Encodi	ng: gzip\r\n							
Date: Fr	i, 07	Oct 2011 09:42:54 G	MT\r\n						
Server:	cafe\r	\n							
Cache-Co	ntrol:	private\r\n							
Content-	Length	: 816\r\n							
LConter	nt leng	jth: 816]							
X-XSS-Pr	otecti	on: 1; mode=block\r	\n 4 CMT\ n\ n						
Expires:	Fri,	07 OCT 2011 09:42:5	4 GMT \r \r						
Content-	encode	d entity body (azin): 816 bytes -> 2	615 bvt	es				
Line-based	text	data: text/javascri	ipt	015 Oy					
		, j							

Figure 5: Wireshark trace 1 - The fifth HTTP response

	Filter:	http			▼ E	xpression	Clear	Apply	
No.	Time	9	Source	Destination		Protocol	Info		A
	4 0.1	13777	128.178.151.105	184.106.62.1	L80	HTTP	GET / HTT	P/1.1	
	681.9	39545	184.106.62.180	128.178.151.	105	HTTP	HTTP/1.1	200 OK	(text/html)
2	22 13.	816677	128.178.151.105	209.85.148.1	105	HTTP	GET /page	ad/show	_ads.js HTTP/1.1
2	23 ± 3 .	833552	209.85.148.164	128.1/8.151.	105	HITP	HTTP/1.1	304 NOT	Modified
2	43 14	429172	209 85 148 164	128 178 151	105	HTTP	HTTP/1 1	200 OK	(text/javascript)
2	50 15.	392232	128.178.151.105	209.85.148.1	56	НТТР	GET /page	ad/ads?	lient=ca-pub-6464516566243894&output=html&h=90&slotname=32247
2	57 15.	547496	209.85.148.156	128.178.151.	105	HTTP	HTTP/1.1	200 OK	(text/html)
2	5915.	849683	128.178.151.105	209.85.148.9	96	HTTP	GET /page	ead/conv	ersion/1070643593/?label=ledXCKfUShCJ88L-Aw&guid=ON&script=0 H
2	60 15.	876438	209.85.148.96	128.178.151.	105	HTTP	HTTP/1.1	302 Fou	nd (GIF89a)
2	61 15.	893744	128.178.151.105	209.85.148.1	L56	HTTP	GET /page	ead/view	throughconversion/1070643593/?label=ledXCKfUShCJ88L-Aw&guid=ON <
•									•
⊞F	rame 2	250: 131	1 bytes on wire (10488 bits), 1	1311	bytes ca	ptured (1	0488 bit	s)
ΞE	therne	et II, S	rc: Usi_6d:19:e3	(00:1a:6b:6d:	19:e	3), Dst:	Cisco_ff:	fc:50 ((0:08:e3:ff:fc:50)
	nterne	et Proto	COI, STC: 128.1/8	5nc Dont: 527	.1/8.	(151.105) (2744)	, DST: 20	9.85.140 http://80	.150 (209.85.148.150)
	vnerte	avt Tran	sfer Protocol	SIC PUIL. 30/	44 (.)0/44), L	St POPL.), Seq. 1, Ack. 1, Leff. 1237
	ftrun	cated]	GFT /pagead/ads?c	lient=ca-pub-6	54645	16566243	894&output	=html&h	=90&slotname=3224796578&w=728&lmt=1317983002&flash=10.0.32.18&ur
-		runcated] Expert Info (Ch	nat/Sequence):	GET	/pagead/	ads?clien	t=ca-pul	-6464516566243894&output=html&h=90&slotname=3224796578&w=728&lm
	Req	uest Met	hod: GET						
	Req	uest URI	[truncated]: /pa	agead/ads?clie	nt=c	a-pub-640	6451656624	3894&ou	put=html&h=90&slotname=3224796578&w=728&lmt=1317983002&flash=10
	Req	uest ver	Sion: HIIP/1.1	insting image	. /				imper/sif imper/since emlisation/u me uhan emlisation/u she
	Dofor	or htt	n://www.imnotobse	sed com/\r\n	s/ Jbe	y, appri	Cat TOTT/ Xall	1+XIII1,	Tillage/gff, Tillage/pjpeg, apprication/x-lis-xbap, apprication/x-shc
	Accen	t-Langu	age: en-US\r\n	SSec. com/ (r (n					
	User-	Agent:	Mozilla/4.0 (comp	atible: MSIE 8	3.0:	Windows	NT 6.1: WO	0W64: Tr	ident/4.0: SLCC2: .NET CLR 2.0.50727: .NET CLR 3.5.30729: .NET C
	Accep	t-Encod	ing: gzip, deflat	e\r\n			,,		
	Host:	google	ads.g.doubleclick	.net\r\n					
	Conne	ction:	Keep-Alive\r\n					_	
	Cooki	e: id=2	27b9519180100c2 ⁻	t=1298645995 e	et=73	0 cs=002	213fd485f9	9fa7841a	3fd720; _drt_=NO_DATA; PREF=ID=d6888570f97977b4:TM=1317980578:LM
	\r\n								

Figure 6: Wireshark trace 2 - The fourth HTTP request

Question 8: Can the ad provider know that the student has visited the first website before visiting the second website? Justify your answer.

Yes. In the fifth HTTP response in the first trace (packet 66, Figure 5) the ad provider sets a cookie in the student's browser (Cookie id=227b9519180100c2 t=1298645995 et=730 cs=002213fd485f9fa7841a3fd720) for the domain .doubleclick.net. When the following requests are sent to the same domain, the browser includes this cookie (second trace, fourth HTTP GET request, packet 250, Figure 6). Thus, the ad provider "recognizes" the student and can link the requests from the first and second trace with the same student. Based on the Referer field of the requests the ad provider learns which websites the student has visited.

Question 9: After visiting the first website, is there any domain at which the ad provider can track the student's subsequent browsing behavior? Justify your answer.

The ad provider has placed a cookie for the domain .doubleclick.net in the student's browser. This means that the student's browser will send this cookie to doubleclick ad servers with each request to this domain. This enables the ad provider to link these requests with the student and track his behavior on this domain. However, since each of these requests contain Referer field that informs the ad provider which page the student is currently visiting, in practice the ad server will know all the pages that the student has browsed that include ads from this ad provider.

Question 10: When visiting the second website, what does the code 304 of the second HTTP response message (packet 223, Figure 2) signify?

304 code of the HTTP message means that the conditional HTTP GET was sent. Since the object has not been modified, it was not downloaded again from the server but from the cache. The object was cached after being downloaded when the student has visited the first Web page.

3 Network Delays

(7 points)

Consider a route in the Internet connecting hosts A and B. The route is composed of n links. The *i*th link has length d_i meters, propagation speed v_i m/s, and throughput r_i bps. Unless stated otherwise, assume that routers incur no processing or queueing delay. Assume that the routers work in a store-and-forward fashion: A packet has to be fully received before the router can start to retransmit it.

Question 1: What is the propagation delay from A to B for this route?

$\sum_{i=1}^{n} \frac{d_i}{v_i}$

Question 2: Assume that you send a packet of L bits from A to B. What is the transmission delay for link i?

Question 3: Give the total delay of transmitting an L bit packet from A to B over this route.

$$\sum_{i=1}^{n} \left(\frac{d_i}{v_i} + \frac{L}{r_i}\right)$$

 $\frac{L}{r_i}$

For the following questions, assume that you are logged in at host A. You can launch pings with a packet of chosen size, and obtain the round-trip time for each ping. Try not to launch excessive pings.

Question 4: Assume that all links have propagation speed $v_i = v$ (for this question only). Discover the total length of the route in meters. What pings do you launch and what computation do you perform? (Recall that we assume no processing or queueing delays, and try to be as precise as possible.)

 $\begin{array}{l}t_1 = ping \ B \ with \ packet \ size \ L \ bits.\\t_2 = ping \ B \ with \ packet \ size \ 2L \ bits.\\From \ Question \ 3, \ we \ know \ that \ t_1 = 2\sum_{i=1}^n \left(\frac{d_i}{v} + \frac{L}{r_i}\right) \ and \ t_2 = 2\sum_{i=1}^n \left(\frac{d_i}{v} + \frac{2L}{r_i}\right)\\Hence: \ d = 0.5(2t_1 - t_2)v\end{array}$

Question 5: Assume that all n links have throughput $r_i = r$. Discover the value of r. What pings do you launch and what computation do you perform? (Recall that we assume no processing or queueing delays.)

 $t_1 = ping B$ with packet size L bits. $t_2 = ping B$ with packet size 2L bits. From Question 3, we know that $t_1 = 2\left(\sum_{i=1}^n \frac{d_i}{v_i} + \frac{Ln}{r}\right)$ and $t_2 = 2\left(\sum_{i=1}^n \frac{d_i}{v_i} + \frac{2Ln}{r}\right)$ Hence: $r = \frac{nL}{0.5(t_2-t_1)}$

Question 6: Assume that link j has a significantly lower throughput than all the other links. Discover the approximate throughput of this link (r_j) . What pings do you launch and what computation do you perform? (Recall that we assume no processing or queueing delays.)

Is your approximation a lower-bound or an upper-bound? What is the maximum error (relative or absolute) that you can make with this approximation when trying to estimate the throughput of the link with lowest throughput?

 $t_1 = ping B$ with packet size L bits. $t_2 = ping B$ with packet size 2L bits. Approximation: $r_j = \frac{L}{0.5(t_2-t_1)}$ This is a lower-bound. The relative error is

$$\frac{\sum_{i \neq j} r_i^{-1}}{\sum_{i=1}^n r_i^{-1}}$$

which takes the maximal value $\frac{n-1}{n}$ when all links have the same throughput.

Question 7: Assume now that queueing delays cannot be neglected. Discover the (approximate) average queueing delay for this route. What pings do you launch and what computation do you perform? (We assume no processing delays.)

We launch N pings with size L and get RTTs t_k We approximate the queueing delay $t_{queue} = 0.5(mean\{t_k\} - min\{t_k\})$

4 Peer-to-Peer

(4 points)

Consider distributing a file of F bits to N peers using a client-server architecture. Assume a fluid model where the server can simultaneously transmit to multiple peers, transmitting to each peer at different rates, as long as the combined rate does not exceed the upload rate u_s of the server's access link. Denote the download rate of the *i*-th client's access link by d_i and d_{min} is the download rate of the client with the lowest download rate, i.e., $d_{min} = \{d_1, d_2, \dots, d_N\}$.

Question 1: Suppose that $u_s/N \le d_{min}$. Specify a distribution scheme that has a distribution time of NF/u_s .

Consider a distribution scheme in which the server sends the file to each client, in parallel, at a rate of u_s/N . Note that this rate is less than each of the client's download rate, since by assumption $u_s/N \le d_{min}$. Thus each client can also receive at rate u_s/N . Since each client receives at rate u_s/N , the time for each client to receive the entire file is $F/(u_s/N) = NF/u_s$. Since all the clients receive the file in NF/u_s , the overall distribution time is also NF/u_s .

Question 2: Suppose that $u_s/N \ge d_{min}$. Specify a distribution scheme that has a distribution time of F/d_{min} .

Consider a distribution scheme in which the server sends the file to each client, in parallel, at a rate of d_{min} . Note that the aggregate rate, $N \cdot d_{min}$, is less than the server's link rate u_s , since by assumption $u_s/N \ge d_{min}$. Since each client receives at rate d_{min} , the time for each client to receive the entire file is F/d_{min} . Since all the clients receive the file in this time, the overall distribution time is also F/d_{min} .

5 Transport Layer Error Recovery

(8 points)

Consider a Selective Repeat (SR) error recovery protocol with a window size N of 3 and valid sequence numbers ranging from 0 to 8. Assume that there is no re-ordering of segments possible on the channel, but segments can be lost. Answer the following questions:

Question 1: If the receiver is expecting segment with sequence number 3 (i.e., $recv_base = 3$) at time instant t and if it receives segments with sequence numbers 2, 0 and 1 (in that order), which segments have been lost, assuming that any segment in the network can be lost at most once? What is the response of the receiver on receiving each of these segments 2, 0 and 1? You are expected to answer this question by completing the sequence diagram below by clearing showing the segment exchanges between the sender and the receiver, including the lost segments and ACKs, the timeout events and the sender/receiver windows when segments (including ACKs) are received by the sender/receiver.



Figure 7: Selective Repeat (SR) Protocol (Solution to Question 1).

Question 2: Assume that the window size (N) is the same as in the previous question, i.e., 3, but the sequence number range is now only from 0 to 3. The receiver is expecting segment with sequence number 3 (i.e., $recv_base = 3$) at time t, but it receives a segment with sequence number 0 instead. Does the receiver treat this segment as a new segment or a re-transmitted segment? Please justify your answer.

The receiver cannot decide if this segment is a new segment or a re-transmission of an old segment. There are two situations when this can happen. The sender can send a segment with sequence number 0 because all the previous acknowledgments (from the receiver) were received correctly and is thus moving its window from 0,1,2 to 3,0,1. The sender can thus send a new segment with sequence number 0 in this window. Another situation in which the sender sends a segment with sequence number 0 is when it does not receive the acknowledgement of the segment 0 sent when the window was 0,1,2. In the latter case, this segment is a re-transmission of the previously sent segment. The receiver is not able to distinguish between these two cases. This problem arises because the size of the congestion window in the protocol is too large as compared to the range of sequence numbers.

6 TCP Connection Management

(6 points)

A client initiates a TCP connection with a server, exchanges some data and then closes the connection. Assume that the communication channel can lose segments but cannot re-order segments. Answer the following questions:

Question 1: Figure 8 shows the TCP three-way handshake protocol used by the client to initiate a TCP connection with the server. Complete Figure 8 by filling in the missing SYN flags, SEQ numbers and ACK numbers of the segments exchanged between the client and the server.



Figure 8: TCP connection setup: Three-way handshake protocol (Solution to Question 1).

Question 2: Assume that the server reserves memory for TCP buffers at the time instant the connection is granted (before sending the ACK). If the server has limited memory, how can a malicious client run the server out of TCP buffer memory using the TCP three-way handshake protocol? Explain.

The malicious client can send a large number of TCP SYN segments (on different port addresses), without completing the third handshake step. The attack can be amplified by sending the SYN segments from multiple sources. Soon the server will run out of available (free) TCP buffer space and will not be able to accept additional TCP requests. Such a type of Denial of Service (DoS) attack is called a SYN flood attack.

Question 3: Figure 9 shows the TCP connection closing protocol (initiated by the client). During this connection closing, what will happen if the last ACK is lost? Show the next steps of the protocol by drawing on Figure 9. You can assume that no more segments will be lost.



Figure 9: TCP connection close (Solution to Question 3).

Question 4: What behavior do you expect if client closes connection immediately after sending the final ACK, i.e., the *Timed wait* time interval is zero? Is this good or bad? Explain why?

If the client immediately closes connection after sending the final ACK and destroys the client socket on the associated port, and the client ACK is lost (as shown in Figure 9), then the server will never know that the client closed the TCP connection. Further re-transmissions of the FIN from the server (after time-out) will be immediately dropped by the client because there is no longer a TCP socket running on that port. This is not good. The server will keep transmitting FINs expecting the client to reply with ACK. Moreover, if there is piggybacked data with the server FIN, that data will be lost.