# HW2 Solutions

### Problem 7

The total amount of time to get the IP address is

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Once the IP address is known,  elapses to set up the TCP connection and another  elapses to request and receive the small object. The total response time is



### Problem 8



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1. Persistent connection with pipelining. This is the default mode of HTTP.



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Persistent connection without pipelining, without parallel connections.



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### Problem 9

1. The time to transmit an object of size L over a link or rate R is L/R. The average time is the average size of the object divided by R:

Δ = (850,000 bits)/(15,000,000 bits/sec) = .0567 sec

The traffic intensity on the link is given by βΔ=(16 requests/sec)(.0567 sec/request) = 0.907. Thus, the average access delay is (.0567 sec)/(1 - .907) ≈ .6 seconds. The total average response time is therefore .6 sec + 3 sec = 3.6 sec.

1. The traffic intensity on the access link is reduced by 60% since the 60% of the requests are satisfied within the institutional network. Thus the average access delay is (.0567 sec)/[1 – (.4)(.907)] = .089 seconds. The response time is approximately zero if the request is satisfied by the cache (which happens with probability .6); the average response time is .089 sec + 3 sec = 3.089 sec for cache misses (which happens 40% of the time). So the average response time is (.6)(0 sec) + (.4)(3.089 sec) = 1.24 seconds. Thus the average response time is reduced from 3.6 sec to 1.24 sec.

### Problem 23

1. Consider a distribution scheme in which the server sends the file to each client, in parallel, at a rate of a rate of *us*/*N*. Note that this rate is less than each of the client’s download rate, since by assumption *us*/*N* ≤ *d*min. Thus each client can also receive at rate *us*/*N*. Since each client receives at rate *us*/*N*, the time for each client to receive the entire file is F/( *us*/*N*) = *NF/ us.* Since all the clients receive the file in *NF/ us*, the overall distribution time is also *NF/ us.*
2. 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* *d*min, is less than the server’s link rate *us*, since by assumption *us*/*N* ≥ *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*.*
3. From Section 2.6 we know that

*DCS* ≥ max {*NF/us, F/d*min} (Equation 1)

Suppose that *us*/*N* ≤ *d*min. Then from Equation 1 we have *DCS* ≥ *NF/us .* But from (a) we have *DCS* ≤ *NF/us .* Combining these two gives:

*DCS* = *NF/us* when *us*/*N* ≤ *d*min. (Equation 2)

We can similarly show that:

*DCS* =*F/d*min when *us*/*N* ≥ *d*min (Equation 3).

Combining Equation 2 and Equation 3 gives the desired result.

### Problem 24

1. Define u = u1 + u2 + ….. + uN. By assumption

us <= (us + u)/N Equation 1

Divide the file into N parts, with the ith part having size (ui/u)F. The server transmits the ith part to peer i at rate *r*i = (*u*i/*u*)*u*s. Note that *r*1 + *r*2 + ….. + *r*N = *u*s, so that the aggregate server rate does not exceed the link rate of the server. Also have each peer i forward the bits it receives to each of the *N-1* peers at rate *r*i. The aggregate forwarding rate by peer i is (N-1)ri. We have

(*N-1*)*r*i = (*N-1*)(*u*s*u*i)/*u* <= *u*i,

where the last inequality follows from Equation 1. Thus the aggregate forwarding rate of peer i is less than its link rate ui.

In this distribution scheme, peer i receives bits at an aggregate rate of



Thus each peer receives the file in F/us.

1. Again define *u* = *u*1 + *u*2 + ….. + *u*N. By assumption

*u*s >= (*u*s + *u*)/*N* Equation 2

Let *r*i = *u*i/(*N-1*) and

*r*N+1 = (*u*s – *u*/(*N-1*))/*N*

In this distribution scheme, the file is broken into *N+1* parts. The server sends bits from the ith part to the ith peer (i = *1, …., N*) at rate ri. Each peer i forwards the bits arriving at rate ri to each of the other N-1 peers. Additionally, the server sends bits from the (*N+1*) st part at rate rN+1 to each of the *N* peers. The peers do not forward the bits from the (*N+1*)st part.

The aggregate send rate of the server is

*r*1+ …. + *r*N + *N* *r*N+1 = *u*/(*N-1*) + *u*s – *u*/(*N-1*) = *u*s

Thus, the server’s send rate does not exceed its link rate. The aggregate send rate of peer i is

(*N-1*)*r*i = *u*i

Thus, each peer’s send rate does not exceed its link rate.

In this distribution scheme, peer i receives bits at an aggregate rate of



Thus each peer receives the file in NF/(us+u).

(For simplicity, we neglected to specify the size of the file part for i = 1, …., N+1. We now provide that here. Let Δ = NF/(us+u) be the distribution time. For i = 1, …, N, the ith file part is Fi = ri Δ bits. The (N+1)st file part is FN+1 = rN+1 Δ bits. It is straightforward to show that F1+ ….. + FN+1 = F.)

1. The solution to this part is similar to that of 17 (c). We know from section 2.6 that



Combining this with a) and b) gives the desired result.