Principles of Computer Networks

Tutorial 4

Problem 1

The total amount of time to get the IP address is

$$RTT_1 + RTT_2 + \cdots + RTT_n .$$

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

$$2RTT_o + RTT_1 + RTT_2 + \cdots + RTT_n$$

Problem 2

a) Consider a distribution scheme in which the server sends the file to each client, in parallel, at a rate of 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.

b) 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 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 $F/d_{\min}$.

c) From Section 2.6 we know that

$$D_{CS} \ge \max \{NF/u_s, F/d_{\min}\} \quad \text{(Equation 1)}$$

Suppose that $u_s/N \le d_{\min}$. Then from Equation 1 we have $D_{CS} \ge NF/u_s$. But from (a) we have $D_{CS} \le NF/u_s$. Combining these two gives:

$$D_{CS} = NF/u_s \text{ when } u_s/N \le d_{\min}. \text{ (Equation 2)}$$

We can similarly show that:

$$D_{CS} = F/d_{\min} \text{ when } u_s/N \ge d_{\min} \text{ (Equation 3).}$$

Combining Equation 2 and Equation 3 gives the desired result.

Problem 3

a) Define $u = u_1 + u_2 + \ldots.. + u_N$. By assumption

$$u_s \le (u_s + u)/N \qquad \text{Equation 1}$$

Divide the file into N parts, with the i^{th} part having size $(u_i/u)F$. The server transmits the i^{th} 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 $(N\text{-}1)r_i$. We have

$$(N\text{-}1)r_i = (N\text{-}1)(u_s u_i)/u <= u_i,$$

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

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

$$r_i + \sum_{j<>i} r_j = u_s$$

Thus each peer receives the file in F/u_s.

b) Again define $u = u_1 + u_2 + ... + u_N$. By assumption

$$u_s >= (u_s + u)/N \qquad \text{Equation 2}$$

Let $r_i = u_i/(N\text{-}1)$ and

$$r_{N+1} = (u_s - u/(N\text{-}1))/N$$

In this distribution scheme, the file is broken into $N+1$ parts. The server sends bits from the i^{th} part to the i^{th} peer (i = 1, ..., N) at rate r_i. Each peer i forwards the bits arriving at rate r_i to each of the other N-1 peers. Additionally, the server sends bits from the $(N+1)^{st}$ part at rate r_{N+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

$$r_1 + ... + r_N + N\, r_{N+1} = u/(N\text{-}1) + u_s - u/(N\text{-}1) = u_s$$

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

$$(N\text{-}1)r_i = u_i$$

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

$$r_i + r_{N+1} + \sum_{j<>i} r_j = u/(N-1) + (u_s - u/(N-1))/N = (u_s + u)/N$$

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

(For simplicity, we neglected to specify the size of the file part for $i = 1, ..., N+1$. We now provide that here. Let $\Delta = (u_s+u)/N$ be the distribution time. For $i = 1, ..., N$, the i^{th} file part is $F_i = r_i \Delta$ bits. The $(N+1)^{st}$ file part is $F_{N+1} = r_{N+1} \Delta$ bits. It is straightforward to show that $F_1 + \ldots + F_{N+1} = F$.)

c) The solution to this part is similar to the previous question. We know from Section 2.6 that

$$D_{P2P} >= max\{F/u_s, NF/(u_s + u)\}$$

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