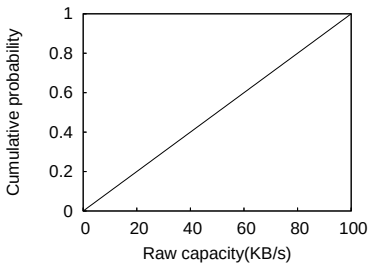

Figure 1: The cumulative capacity distribution of a BitTorrent swarm.

Fun modeling BitTorrent swarms (25 points). Suppose a BitTorrent swarm has a cumulative distribution of raw bandwidth capacity r as shown in Figure 1. That is:

$$P\{r \leq x\} = x/100$$

For simplicity, assume a BitTorrent client with a capacity r has a fixed size active set $active(r) = 4$. A BitTorrent client optimistically unchokes one peer every 30 seconds. Suppose all clients have symmetric access links, and the access links are the bottleneck links. All other assumptions such as representative distribution, uniform sizing, no steady state, high block availability are the same as in the BitTyrant paper. Answer the following questions.

1. (1 point) What's the equal split rate of a client P with upload capacity 80KB/s?

2. (1 point) What's the equal split rate distribution of the swarm?

3. (3 points) Suppose a client P with upload capacity 80KB/s unchokes a peer Q with upload capacity 20KB/s. What's the reciprocation probability? (Hint: under what circumstances will Q unchoke P?)

4. (3 points) What's the reciprocation probability if Q unchokes P instead?

5. (2 points) What's the expected reciprocation probability for the client P with capacity 80KB/s when averaged over all peers?

6. (3 points) What's the expected download rate of the client P?

7. (2 points) What's the expected download rate of the client Q?

8. (5 points) The client P runs on Ben Bitdiddle's computer. Ben is frustrated by the slow downloading rate. Alissa Ageek told Ben that he can increase his client's download rate by increasing the active set size from four to seven. Explain why. What's the expected download rate for Ben's client after the increment?

9. (3 points) (**Hard**) Ben made the modification and saw the improvement. He's excited by the result, and increased the active set size to 50. Will the client's download rate increase? Explain why. (Ignore TCP effects.)

10. (2 points) (**Hard**) Will your conclusion to the above question change if the swarm's capacity distribution is different? Explain why.