Spring term 2008
TELCOM 2321 - CS 2520
Wide Area Networks

Homework 5

Due date: Tuesday Feb 12, 2008

One-day late submissions will be accepted without penalties.

Problem 1

Explain the main differences between open-loop and closed-loop end-to-end congestion control schemes, discussing the two approaches adopted to solve the network congestion problem. Elaborate on a possible hybrid solution.

Problem 2

Recall from the textbook, Chapter 7, Section 7.2, the definition of mean value and variance of a continuous random variable x with probability density function $f(x)$. Show that a Pareto-distributed random variable $x \in [k, +\infty)\,, k > 0$ with density function

$$f(x) = \begin{cases} \frac{\alpha\, k^{\alpha}}{x^{\alpha+1}}\,, \quad \alpha > 0 & \text{when} \quad x \geq k \\ 0 & \text{when} \quad x < k \end{cases}$$

has finite mean when $\alpha > 1$ and finite variance when $\alpha > 2$.
Hint*: to prove the previous properties, recall that the following integral*

$$\int_{b}^{+\infty} \frac{1}{x^n}\, \mathrm{d}x\,, \quad b > 0$$

is convergent iff $n > 1$.

Problem 3

Consider a traffic source generating fixed-size packets at variable rate and being subject to an open-loop congestion control scheme. Assume a discrete time model such that the congestion control system changes its status at the end of fixed time intervals, meaning that we can approximate the system behavior considering arrival, departure and loss events occurred within a given interval as if they took place at the same instant. For instance, if during the n-th interval a packets arrive at a buffer with b packets already stored and d packets depart from the buffer, the buffer occupancy at the end of the n-th interval will be $B(n) = \min\{b + a - d, b_{\max}\}$, where $b_{\max}$ is the buffer size, while the number of dropped packets will be $L(n) = \max\{b + a - d - b_{\max}, 0\}$.

Now, assume that during the n-th interval the source generates $N(n)$ packets. Assume also that, for a given period of 14 intervals, the source generates packets as follows:

n	1	2	3	4	5	6	7	8	9	10	11	12	13	14
$N(n)$	3	4	7	3	2	4	7	3	3	0	2	0	0	0

1. In case the network applies a leaky bucket traffic policing mechanism with peak rate $\rho = 3$ packets per interval, show the value of the policed rate $R(n)$ (i.e. the number of packets admitted) and the number of packets lost/marked $L(n)$ for each $n = 1, 2, \ldots, 14$. Find the total number of packets lost/marked.

2. Now assume that the source itself applies a leaky bucket traffic shaping mechanism, still with peak rate $\rho = 3$. There is also a delay constraint that limits the bucket size to $\beta = 5$ packets. Show the value of the shaped rate $R(n)$, the bucket level $B(n)$ (i.e. the current number of packets in the bucket) and the number of packets dropped/marked $L(n)$ for each $n = 1, 2, \ldots, 14$. Assume an empty bucket at $n = 0$. Find the total number of packets dropped/marked and compare it with the value obtained in the previous point.

Suppose now that the source exhibits a burstier behavior, as follows

n	1	2	3	4	5	6	7	8	9	10	11	12	13	14
$N(n)$	3	4	10	3	2	4	10	3	3	0	2	0	0	0

3. Compute again $R(n)$, $B(n)$, $L(n)$ and the total number of packets dropped/marked when the source uses the same leaky bucket traffic shaping mechanism used in the previous point.

4. Find the minimum value of the shaping peak rate ρ to be used in order not to exceed the total number of dropped/marked packets found in point 2.

5. Finally, consider the same bursty source as in the previous two points subject to a token bucket shaping scheme, where the token generation rate is $\rho = 3$ tokens per interval, each packet transmission requires a token and the shaping buffer size is limited to $\beta = 5$ packets. Find the minimum value of the token bucket size σ such that no packets are dropped/marked in the observed period and show the value of the shaped rate $R(n)$, the bucket level $B(n)$ (i.e. the current number of tokens in the bucket) and the shaping buffer level $S(n)$ for each $n = 1, 2, \ldots, 14$. Assume a full bucket of tokens available at $n = 0$.

Problem 4

Consider an IP router with three network interfaces. An Ethernet interface (eth0) is directly attached to a LAN, while two PPP interfaces (ppp0 and ppp1) are connected to other two routers through point-to-point links. The IPv4 addresses assigned to the router's interfaces are:

- 137.204.57.253 to eth0
- 10.0.0.9 to ppp0
- 10.0.0.13 to ppp1

Assume the router executes lookups on the following forwarding table using a longest prefix match technique:

Forwarding table			
	Prefix	**Next-hop**	**Interface**
1	0.0.0.0/0	137.204.57.254	eth0
2	10.0.0.8/30	direct	ppp0
3	10.0.0.12/30	direct	ppp1
4	137.204.56.0/24	10.0.0.14	ppp1
5	137.204.57.0/24	direct	eth0
6	137.204.58.0/23	10.0.0.10	ppp0
7	137.204.121.0/24	10.0.0.14	ppp1
8	137.204.121.128/25	10.0.0.10	ppp0
9	192.168.8.0/22	10.0.0.14	ppp1

Find which network prefixes are used on the LAN and on the point-to-point links and tell which table entry is used when a packet must be routed with the following destination address:

- 137.204.57.31
- 137.204.56.28
- 137.204.59.18
- 137.204.121.200
- 137.204.121.20
- 10.0.0.17
- 192.168.11.254

Justify your answer.