exercises-collection-rt-v04.docx
2022-12-21

# Collection of exercises (part 4)

<Quesito> 1

Consider a packet transfer in a POS (Packet Over Sonet) scenario, using MPLS over PPP. A flow of IP packets of length L bytes is transferred at a rate of R packets/s. Evaluate the ratio between the load at IP level and the load at PPP level.
The MPLS header is 4 bytes long, and the PPP PDU is shown below, assume that the protocol field is 16 bits and that the FCS is 16 bits (pay attention to count the Flag field only once!).

MPLS packet (Information field)

| Flag | Address | Control | Protocol | Information | Padding | FCS | Flag | Inter-frame Fill |
|---|---|---|---|---|---|---|---|---|
| 01111110 | 11111111 | 00000011 | 8/16 bits | * | * | 16/32 bits | 01111110 | or next Address |

Data:

| | | |
|---|---|---|
| L | 105 | bytes |
| R | 38 | pacch/s |

Answer:

Considering a packet of length L bytes at the IP level, we need add 4 bytes for MPLS, while at PPP level 1+1+1+2+2=7 bytes are added.

Therefore the ratio is :
$C_{IP}/C_{PPP} = L / (L+11)$

<Quesito> 2

Consider a stream of IP packets, which is controlled by a Two Rate Three Color Marker (trTCM), with parameters CIR, CBS, PIR, PBS. The IP packets have length L (at IP level). How many packets can be transmitted at the peak rate PIR (starting from the full bucket), being colored in green? (part 1)
Which is the maximum length M of IP packets [bytes], such that S packets can be transmitted at the peak rate colored in green? (part 2)

| | | |
|---|---|---|
| CBS | 21KB (kbytes) | |
| CIR | 3 MB/s | |
| PIR | 10 MB/s | |
| L | 1000 | bytes |
| S | 60 | packets |

Answer:

(part 1)
We assume that the “Committed” buffer at time zero is Tc(0)=21KB
The stream start transmitting packets at a rate PIR and the Committed bucket is being filled at a rate CIR . Therefore the Committed buffer is decreasing at a rate (PIR-CIR).
It will become empty at CBS/(PIR-CIR) [s].

21KB / 7 MB/s = 3 ms

When sending at peak rate, the packet rate R will be
R=PIR / L

If the peak rate is 10MB/s and each packet is 1000 bytes, the packet rate is 10000 packets/s.
R=10 MB/s / 1000 B = 10000 p/s = 10 p/ms

In 3ms, 30 packets will be sent.

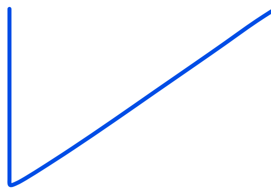
(part 2)

It is possible to send a burst of IP packet of size
B = PIR*3ms = 10 MB/s * 3 ms = 30 KB
Therefore, if 60 packets need to be sent at PIR, the size of each packet can be at most
M = B/60 = 500 Bytes

<Quesito> 3

Consider a stream of IP packets, which is controlled by a Two Rate Three Color Marker (trTCM), with parameters CIR, CBS, PIR, PBS.
It is needed to send a burst of N IP packets of length L at peak rate with “green” color. What is the required CBS [bytes]? (part1)
If CBS is set to S, what is the maximum IP packet length that allows transmitting N “green” packets at peak rate? (part 2)

| | | |
|---|---|---|
| CIR | 4 MB/s | |
| PIR | 16 MB/s | |
| N | 20 | packets |
| L | 800 | bytes |
| S | 6 | KB |



Answer:

(part 1)

When packets are transmitted at peak rate, the bucket empties at a rate
E = PIR-CIR
In order to transmit a burst of N IP packets of length L at peak rate, the following duration is needed:
Tb = N*L/PIR
The time needed for the token bucket to empty is
Te = CBS/(PIR-CIR)
Tb=Te => N*L/PIR = CBS/(PIR-CIR) =>

CBS = N * L * (PIR-CIR)/PIR = 20 * 800 * (12/16) = 16000 * (12/16) = 12000 bytes

(part 2)

If CBS = S = 6 KB, the time needed for the token bucket to empty is
Te = CBS /(PIR-CIR) = 6 KB/12MB/s = 0.5 ms
In the interval Te, the amount of bytes that can be sent at peak rate is:
Burst_size = PIR * Te = 16 MB/s * 0.5 ms = 8 KBytes.
Burst_size = n_packets * L = 20 * L
8 KBytes = 20 * L
L_max = 8KBytes / 20 = 4KBytes /10 = 400 bytes

<Quesito> 4

Consider an application that is sending a stream of IP packets, which is controlled by a Two Rate Three Color Marker (trTCM) with parameters CIR, CBS, PIR, PBS. The application is using a UDP connection. The length of IP+UDP headers is 28 bytes. The IP packet length is L=1500 bytes.
The application is able to adapt to the trTCM policer and shape the traffic accordingly. Assuming that the bucket is initially full, evaluate the time T1 needed to send a file of M Mbytes.
After the end of the file transmission, how much time (T2) is needed before the bucket become full again?
Assuming that the bucket is initially empty, evaluate the time T3 needed to send the same file.

CBS 200KB (kbytes)
CIR 2 MB/s
PIR 10 MB/s
M = 800 KB

Answer:
In order to send the file of size M [MB], the size at IP level Mip is
Mip = M / (1500-28) * 1500

Initially the file is transmitted at PIR, until the bucket becomes empty.
The time needed for the buffer to become empty is:
Te = CBS / (PIR-CIR)

During this time, the amount of the file transmitted (at IP level) is:
Mip1 = PIR * TE = CBS * PIR / (PIR-CIR)

The remaining part (Mip – Mip1) will be transmitted at rate CIR, taking a time
Tfin = (Mip – Mip1) / CIR

Therefore T1 = Te + Tfin

When the bucket is empty, the time T2 needed to become full again is
T2 = CBS/CIR

If the buffer is initially empty, the file will be sent at rate CIR from the beginning. The time needed to send the file is:
T3 = Mip / CIR.

<Quesito> 5

Consider a Two Rate Three Color Marker (trTCM) with parameters CIR, CBS, PIR, PBS that is controlling a stream of packets sent by an application.
The system is configured to drop the packets that exceed the CIR/CBS (marked in yellow).
Assume that a given time the CIR/CBS bucket is half full (Tc=CBS/2 [bytes])
An application starts sending IP packets at a rate corresponding to PIR/2.
Evaluate the time T1 during which the IP packets are sent without being dropped.
The length of IP packets is L. How many packets are transmitted during this interval T1?

Which is the packet loss ratio, after T1?

CBS 100KB (kbytes)
CIR 2 MB/s
PIR 10 MB/s
L = 800 Bytes

Answer:

When packets are transmitted at a rate PIR/2 the bucket empties at a rate Re
Re = PIR/2-CIR
If the bucket starts at CBS/2, the time to empty the buffer is

T1= CBS/2 / (PIR/2-CIR) = 50 KB / (5-2 MB/s) = 50 / 3000 [s] = 16.7 ms
The bytes transmitted in T1 are
T1*PIR/2 = 16.7 ms * 5 MB/s = 83.3 KB

Considering that the packet length is L bytes, the number of transmitted packets is
N= floor (83.3 KB / 800 B) = 104

After T1 the bucket is empty, so only a rate CIR can be transmitted as in-profile.
The application continues to send at a rate PIR/2, therefore the rate of packets that are marked out-profile is
R_out = PIR/2 – CIR = 5 -2 = 3 MB/s

The packet loss ratio is the ratio between the packets that are dropped and the total packets that are transmitted. We can evaluate it by considering the ratio between the rate of dropped packets and the rate of transmitted packets.

Paket loss ratio = R_out / (PIR/2) = 3 / 5 = 60%

<Quesito> 6

Consider a Two Rate Three Color Marker (trTCM) with parameters CIR, CBS, PIR, PBS that is controlling a stream of packets sent by an application.

The application is using UDP and needs to send a set of IP packets of total size M [MB] every 4 seconds (M is measured at IP level). The packets need to be marked green and the application is able to adapt its rate to the (trTCM) needs. The requirement is to complete the transmission of the file of size M in T1 ms.
The maximum PIR that can be configured is PIRmax. If there is no limitation to the CBS, choose the couple (CBS, CIR) in order to minimize the CIR. (Part 1). (NB: Start with the bucket full).

(Part 2) Assume that the maximum CBS is CBSmax. Choose the minimum CIR that can meet the requirement (complete the transmission of the file in T1 ms). Only provide the equation that need to be solved to find the minimum CIR.

PIRmax 10 MB/s
M 5 MB
T1 800 ms
CBSmax 2MB

Answer:

Part 1 :
If there is no limitation in the CBS, you can set the CBS so that all the file is sent at PIRmax. The CIR need to be set in order to match with the average rate produced by the application: M bytes every cycle time T = 4 sec.

Ravg = M / T = 1.25 MB/s
CIR = Ravg = 1.25 MB/s
When sending the packets at the PIRmax rate, the bucket empties at rate (PIRmax-CIR), therefore we can set CBS :
M/PIRmax = CBS/(PIRmax-CIR)
CBS = M (PIRmax-CIR) / PIRmax = M (8.75/10) = 4.475 MB

Part 2

Now we have to use a smaller CBS with respect to part 1, the new CBS is CBSmax=2MB. Using this CBS it is not possible to send all M bytes at PIRmax.

The transmission of the file starts at PIRmax until the bucket empties, for a duration
Te = CBSmax / (PIRmax-CIR)
The amount of bytes transmitted at IP level in this interval is:
Me = PIRmax * Te = CBSmax * PIRmax/ (PIRmax-CIR)

In order to transmit all the packets at PIR rate we can set CIR by solving
M = CBSmax * PIRmax/ (PIRmax-CIR)
In this case it will take a time
T = M / PIRmax = 5 MB / 10 MB/s = 500 ms

This is NOT the minimum CIR
As T < T1 we can select a smaller CIR, so that the first part of the packets will be sent at PIRmax for a duration Te, and the remaining part of the packets will be sent at CIR.
Te = CBSmax / (PIRmax-CIR)

The remaining bytes are transmitted at CIR, in a time
Tcir = (M-Me) / CIR

The condition to be verified to send the packet in time is
Te + Tcir < T1
CBSmax / (PIRmax-CIR) + (M-Me) / CIR < T1

Replacing Me which was evaluated above, the minimum CIR is found by solving this equation:
T1 = CBSmax / (PIRmax-CIR) + (M - CBSmax * PIRmax/ (PIRmax-CIR)) /CIR

(NB the numerical solution hereafter is NOT required in the exercise!)

0.8 s = 2MB / (10MB/s – CIR ) + M /CIR – 2MB / (10MB/s-CIR) * 10MB/s /CIR

Everything is in MB, MB/s, s !
CIR == x

0.8 = 2 / (10 – x ) + 5/x – 2 / (10 - x) * 10/x

we multiply both sides by x, x<>0
0.8 x = 2x / (10 –x) + 5 – 20 / (10 - x)

we multiply both sides by (10-x), 10-x <>0
(10 –x)* 0.8 x = 2x + 5(10-x) – 20
8x – 0.8 x^2 = 2x +50 – 5x -20
-0.8x^2+11x-30=0

x1 = 3.75 MB/s    (x2 = 10 MB/s root not acceptable)

CIR = 3.75 MB/s

<Quesito> 7

A voice signal is sampled with a frequency F (khz) and converted to digital with a M bit converter. The digital stream is compressed with a coder, let q be the compression factor (ratio between the original bit rate and compressed bit rate).
If the coder produces packets of length L (bytes), which is the rate ($s^{-1}$) of the compressed packets ?

Answer

Let Fp ($s^{-1}$) be the rate of the compressed packets.
The compressed bit rate is Fp * L * 8

Original bit rate / compressed bit rate = q
Original bit rate = q * compressed bit rate

F * 1000 * M = q * Fp * L * 8

Fp * L * q * 8 = F * 1000 * M
Fp = F * 1000 * M / (L * q * 8) = F * 125 * M / (q * L)

F * 125 * M / (q * L) $[s^{-1}]$

<Quesito> 8

Let us consider two voice flows encoded using G.729 (8 kb/s) and G.723 (5.3 kb/s). Evaluate the bit rate at IP level considering a packetization interval of 20ms and 40ms for G.729 and 30ms and 60 ms for G.723. The IP, UDP and RTP headers are respectively 20, 8 and 12 bytes.

Answer :

The encoded stream is divided into packets according to the packetization interval.
If the encoded bit rate is Re, and the packetization interval is Tp, the size of an encoded packet is Le = Re * Tp [bit]

The Length at IP level is
Lip = Le + (20 + 8 + 12)*8 = Le + 320 [bits]

The bit rate at IP level Rip equals to the IP level packet length multiplied by the packet rate
Rip = Lip * (1/Tp) [bit/s]

G.729, Tp=20ms : Rip = 24 kb/s
G.729, Tp=40ms : Rip = 16 kb/s

G.723, Tp=30ms : Rip = 15.967 kb/s
G.723, Tp=60ms : Rip = 10.633 kb/s

<Quesito> 9

Consider a set of N voice flows encoded using G.729 (8 kb/s) with a packetization interval of 40ms. The flows are transmitted using Silence Suppression (SS), which reduces the bit rate to 40% of the bit rate without SS. Evaluate the average bit rate and the maximum bit rate at the IP level of the aggregate of the N flows. The IP, UDP and RTP headers are respectively 20, 8 and 12 bytes.

N = 30

Answer :

The packetization interval is Tp = 40ms, Re = 8kb/s
The size of an encoded packet is Le = Re * Tp [bit] = 320 [bit]

The Length at IP level is
Lip = Le + (20 + 8 + 12)*8 = Le + 320 [bit] = 640 [bit]

The bit rate at IP level without SS Rip_base is:
Rip_base = Lip * (1/Tp) [bit/s] = 16 kb/s

The average bit rate of a flow considering SS is:
Rip_avg = Rip_base * 0.4 = 6.4 kb/s

The total average bit rate for the N flows, considering SS is
Rtot_avg = N * Rip_avg = 192 kb/s

The total maximum bit rate is
Rtot_max = N * Rip_base = 30 * 16 = 480 kb/s

<Quesito> 10

The traffic flowing on a Gigabit Ethernet network link interconnecting two routers is captured for a duration of 2 seconds (the capture has been performed only in one direction of the link). The analysis shows N IP packets of size Lip, carrying RTP payload that are assumed to be VoIP flows. There are M different UDP source/destination ports pairs, therefore M different VoIP flows (we assume that no flow is setup or terminated during the 2 seconds interval that has been captured). Assuming that Silence Suppression (SS) is used and that the SS reduces the bandwidth to 40% of the value without SS, estimate the packetization interval and the bit rate of the VoIP flows at the codec level (i.e., before silence suppression). The IP, UDP and RTP headers are respectively 20, 8 and 12 bytes.

N = 18750
Lip = 80 bytes
M = 1406

Answer :

For each flow, we want to evaluate the packet rate Rp before the silence suppression. The silence suppression reduces the bandwidth to 40% of the value without SS.
We consider the number of packet per each flow in one second and divide it by 0.4.

Rp = 18750 /2 / 1406 / 0.4 = 16.669 pckt/s

The estimated packetization interval is
Tp = 1/Rp = 59.9 ms

The bit rate at codec level for each flow (before silence suppression) is
Rcodec = Rp * Lvoip

Lvoip = Lip – (20+8+12) = 40 bytes

Rcodec = 16.669 * 40*8 = 5.33 kb/s

<Quesito> 11

Consider a single token bucket with Rate R=10 MB/s and bucket size B=50 MB

An IP flow of constant bit rate Fr= 20 MB/s (at IP level) is received by the token bucket (the bucket is initially full).

Calculate the duration of the interval in which all the bytes of the flow can be transmitted “in-profile”. Calculate how many bytes are transmitted in this interval (at IP level).

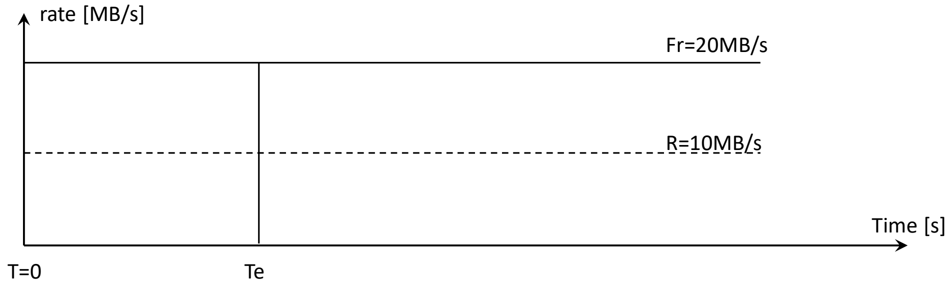
Answer:

The bucket starts full, then it decreases its tokens with a rate of (Fr-R) [MB/s].
The flow will be transmitted “in-profile” until the bucket will become empty.
Let Te be the time when the bucket becomes empty

Te = B / (Fr-R) = 50 / (20-10) = 5 [s]

During this interval, the transmitted bytes S_in are:

S_in = Te * Fr = 5 * 20 = 100 MB [


<Quesito> 12

Consider a single token bucket with Rate R=10 MB/s and bucket size B=50 MB

Assume that an IP application sends a burst of S = 400 MB of data (at IP level) at a rate Fr = 40 MB/s.

Evaluate if the burst can be transmitted in-profile. If not, assume that the token bucket is acting as a marker and will mark out-of-profile packets. Evaluate how many bytes are transmitted in profile and how many bytes are transmitted and marked out-of-profile.

Answer:

The bucket starts full, then it decreases its tokens with a rate of (Fr-R) [MB/s].
The flow will be transmitted “in-profile” until the bucket will become empty.
Let Te be the time when the bucket becomes empty

Let Tb the time needed to transmit the burst
$Tb=S/Fr$ [s] $= 400 / 40 = 10$ s

If $Te >= Tb$ all the burst will be transmitted as in-profile
If $Te < Tb$ the first part of the burst will be transmitted as in-profile, the second part of the burst will be transmitted as out-of-profile

$Te = B / (Fr – R) = 50 / (40-10) = 1.667$ [s]
$Te < Tb$

The size of the initial part that is transmitted in-profile is

$Se = Te * Frr = 1.667 * 40 = 66.67$ MB

The remaining part is transmitted and marked as in-profile for a rate of R MB/s, while a rate of Fr-R is marked as out-profile.

$S2\_in = (Tb-Te) * R = 8.333 * 10 = 83.33$ MB

$S2\_out = (Tb-Te) * (Fr -R) = 8.333 * 30 = 250$ MB (total bytes marked as out-profile)

In total, the bytes that are transmitted as in-profile are:
$S\_in = Se + S2\_in = 66.67 + 83.33 = 150$ MB