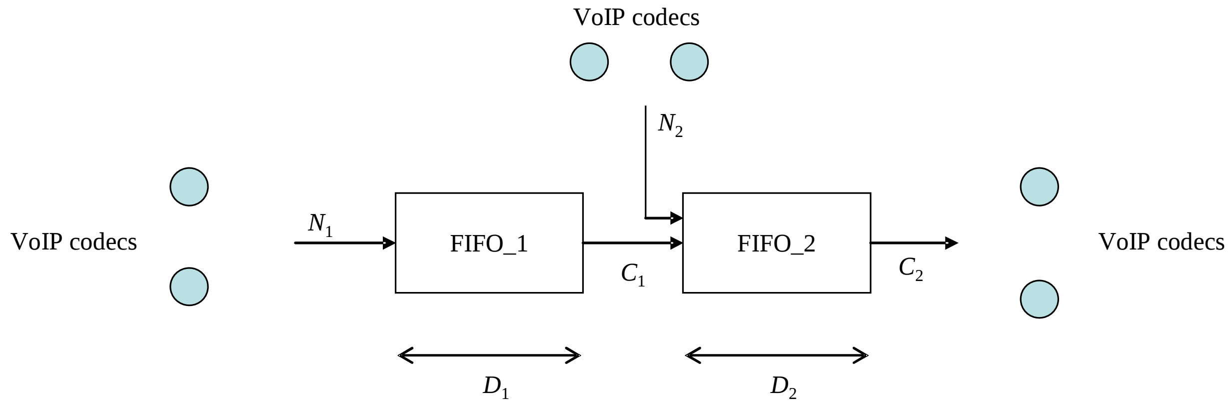
Sample exam

COGNOME	
NOME	
MATRICOLA	

Exercise 1.

In the network shown in the Figure, N_1 VoIP flows are multiplexed by a FIFO scheduler with transmission capacity equal to C_1. These flows are then multiplexed by another FIFO scheduler with other N_2 flussi VoIP; the capacity of the second FIFO scheduler is C_2.



The VoIP codec is the G.726 with Voice Activity Detection (VAD). The parameters are:

- λ (s^{-1}): transition rate from OFF state (silence) to ON state (voice);
- μ (s^{-1}): transition rate from ON state to OFF state;
- P (bit/s): coded speed, in the ON state (note that this is the application layer speed, it does not take into account protocol overheads);
- d_f (s): frame duration;
- d_a (s): algoritmic delay (only in the coding phase);
- d_p (s): playout buffer depth.

The protocol stack is RTP/UDP/IP/PPP. The total protocol overhead per packet is L (bit).

Calculate the probability density of the queuing delay in the FIFO buffer 1, and its average value D_1. D_1 does not include coding delay and the transmission time of VoIP packets.
Soluzione.
Length of VoIP packets:

$$L_{VoIP} = Pd_f + L \text{ (bit).}$$

Physical-layer peak transmission speed:

$$P_{phy} = \frac{L_{VoIP}}{d_f} = \frac{Pd_f + L}{d_f} \text{ (bit/s).}$$

Average transmission speed of one VoIP flow, at the physical layer:

$$r = \frac{\lambda}{\lambda+\mu} P_{phy} = \frac{\lambda}{\lambda+\mu} \frac{Pd_f + L}{d_f} \text{ (bit/s).}$$

Burst lebgth of one VoIP flow:

$$b = 2\frac{\mu}{(\lambda+\mu)^2} P_{phy} = 2\frac{\mu}{(\lambda+\mu)^2} \frac{Pd_f + L}{d_f} \text{ (bit).}$$

For N_1 flows:

$$R_1 = N_1 \frac{\lambda}{\lambda+\mu} \frac{Pd_f + L}{d_f} .$$

$$B_1 = N_1 2\frac{\mu}{(\lambda+\mu)^2} \frac{Pd_f + L}{d_f} .$$

Thus, the probability density of delay in the first scheduler is:

$$f_{D_1}(t) = 2\frac{C_1(C_1 - R_1)}{R_1 B_1} \exp\left(-2\frac{C_1(C_1 - R_1)}{R_1 B_1} t\right).$$

And its average value is:

$$E(D_1) = \frac{R_1 B_1}{2C_1(C_1 - R_1)} .$$

Now, calculate the probability density and average value of delay in the second scheduler.
Solution.
The available service in the first scheduler is $C_1 t$, thus, the variance of the traffic at the output of the first scheduler is equal to the variance of traffic at its input. Thus, at the input of scheduler 2:

$$R_2 = \left(N_1 + N_2 \right) \frac{\lambda}{\lambda + \mu} \frac{Pd_f + L}{d_f}.$$

$$B_2 = \left(N_1 + N_2 \right) 2 \frac{\mu}{\left(\lambda + \mu \right)^2} \frac{Pd_f + L}{d_f}$$

Thus:

$$f_{D_2}\left(t \right) = 2 \frac{C_2 \left(C_2 - R_2 \right)}{R_2 B_2} \exp\left(-2 \frac{C_2 \left(C_2 - R_2 \right)}{R_2 B_2} t \right)$$

$$E\left(D_2 \right) = \frac{R_2 B_2}{2 C_2 \left(C_2 - R_2 \right)}$$

Now, calculate the end-to-end average delay of traffic, including coding/decoding and transmission delay

Solution.

$$E\left(D_{1,tot}\right)=d_f+d_a+E\left(D_1\right)+\frac{L_{VoIP}}{C_1}+E\left(D_2\right)+\frac{L_{VoIP}}{C_2}+d_p$$

Si calculate the probability density of the delay $D_1 + D_2$.
Soluzione.

$$f_{D_1}(t) = 2\frac{C_1(C_1 - R_1)}{R_1 B_1}\exp\left(-2\frac{C_1(C_1 - R_1)}{R_1 B_1}t\right) = k_1 e^{-k_1 t}$$

$$k_1 = 2\frac{C_1(C_1 - R_1)}{R_1 B_1}$$

$$f_{D_2}(t) = 2\frac{C_2(C_2 - R_2)}{R_2 B_2}\exp\left(-2\frac{C_2(C_2 - R_2)}{R_2 B_2}t\right) = k_2 e^{-k_2 t}$$

$$k_2 = 2\frac{C_2(C_2 - R_2)}{R_2 B_2}$$

thus:

$$f_{D_1+D_2}(t) = \frac{k_1 k_2}{-k_1 + k_2}e^{-k_1 t} + \frac{k_1 k_2}{k_1 - k_2}e^{-k_2 t}$$

Exercise 2.

Let us consider a series of two schedulers, with 5 service classes for each scheduler. The first scheduler is Strict Priority, and it serves the traffic flows X1, X2, X3, X4, X5, with priority 1, 2, 3, 4 and 5, respectively. Each flow has parameters *m* (average rate), *b* (burst length) and *H* (Hurst parameter). The traffic flow X5, at the output of the first scheduler, is named Y5 and it is offered to a second scheduler, GPS, that serves also the fresh traffic flows Y1, Y2, Y3 e Y4. The weights of the traffic flows Y1, Y2, Y3, Y4 and Y5 are w1, w2, w3, w4 e w5, respectively. The capacity of schedulers 1 and 2 is C1 and C2, respectively. Calculate the probability that the delay of the flow Y5 in the second scheduler is larger than *d*.

Parameters:

- mx1=1x10^6 bit/s, bx1=1x10^6 bit, Hx1=0.95;
- mx2=2x10^6 bit/s, bx2=2x10^6 bit, Hx2=0.92;
- mx3=3x10^6 bit/s, bx3=3x10^6 bit, Hx3=0.89;
- mx4=4x10^6 bit/s, bx4=4x10^6 bit, Hx4=0.87;
- mx5=5x10^6 bit/s, bx5=5x10^6 bit, Hx5=0.85;
- my1=1x10^6 bit/s, by1=1x10^6 bit, Hy1=0.96;
- my2=2x10^6 bit/s, by2=2x10^6 bit, Hy2=0.94;
- my3=3x10^6 bit/s, by3=3x10^6 bit, Hy3=0.92;
- my4=4x10^6 bit/s, by4=4x10^6 bit, Hy4=0.90;
- w1=1/15, w2=2/15, w3=3/15, w4=4/15, w5=5/15;
- C2=45 Mbit/s
- d=0.05 s

Solution

$$E\left(X_1(t)\right)=m_{X_1}t \quad \operatorname{var}\left(X_1(t)\right)=m_{X_1}b_{X_1}t^{2H_{X_1}} \quad E\left(Y_1(t)\right)=m_{Y_1}t \quad \operatorname{var}\left(Y_1(t)\right)=m_{Y_1}b_{Y_1}t^{2H_{Y_1}}$$

$$E\left(X_2(t)\right)=m_{X_2}t \quad \operatorname{var}\left(X_2(t)\right)=m_{X_2}b_{X_2}t^{2H_{X_2}} \quad E\left(Y_2(t)\right)=m_{Y_2}t \quad \operatorname{var}\left(Y_2(t)\right)=m_{Y_2}b_{Y_2}t^{2H_{Y_2}}$$

$$E\left(X_3(t)\right)=m_{X_3}t \quad \operatorname{var}\left(X_3(t)\right)=m_{X_3}b_{X_3}t^{2H_{X_3}} \quad E\left(Y_3(t)\right)=m_{Y_3}t \quad \operatorname{var}\left(Y_3(t)\right)=m_{Y_3}b_{Y_3}t^{2H_{Y_3}}$$

$$E\left(X_4(t)\right)=m_{X_4}t \quad \operatorname{var}\left(X_4(t)\right)=m_{X_4}b_{X_4}t^{2H_{X_4}} \quad E\left(Y_4(t)\right)=m_{Y_4}t \quad \operatorname{var}\left(Y_4(t)\right)=m_{Y_4}b_{Y_4}t^{2H_{Y_4}}$$

$$E\left(X_5(t)\right)=m_{X_5}t \quad \operatorname{var}\left(X_5(t)\right)=m_{X_5}b_{X_5}t^{2H_{X_5}}$$

$$\operatorname{var}\left(S_{X_5}(t)\right)=\operatorname{var}\left(X_1(t)\right)+\operatorname{var}\left(X_2(t)\right)+\operatorname{var}\left(X_3(t)\right)+\operatorname{var}\left(X_4(t)\right)$$

$$\operatorname{var}\left(Y_5(t)\right)=\max\left(\operatorname{var}\left(X_5(t)\right),\operatorname{var}\left(S_{X_5}(t)\right)\right)$$

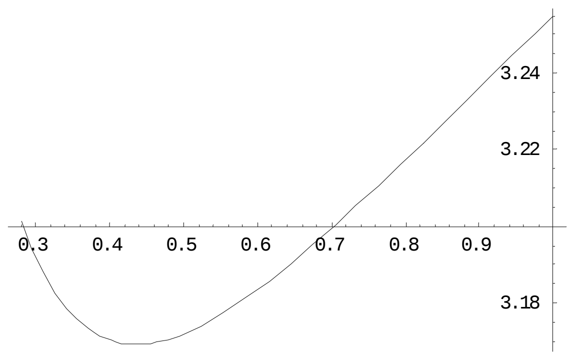
$$E\left(Y_5(t)\right)=E\left(X_5(t)\right)$$

$$E\left(S_{Y_5}(t)\right)=w_5C_2t+\sum_{j=1}^{4}\frac{w_5}{\sum_{k=1\ldots 5,k\neq j}w_k}\left(w_jC_2t-E\left(X_j(t)\right)\right)$$

$$\operatorname{var}\left(S_{Y_5}(t)\right) = \sum_{j=1}^{4} \left(\frac{w_5}{\sum_{k \neq j} w_k} \right)^2 \operatorname{var}\left(X_j(t)\right)$$

$$\alpha(t) = -\frac{E\left(Y_5(t)\right) - E\left(S_{Y_5}(t+d)\right)}{\sqrt{\operatorname{var}\left(Y_5(t)\right) + \operatorname{var}\left(S_{Y_5}(t+d)\right)}}$$

Numerically



$p = \exp(-3.17^2/2)$.

Exercise 3.

Explain how applications can be mapped onto PHBs in a Diffserv network. Which kinds of PHBs are properly selected for each application?