Optical and Transport Networks

Prof. Stefano Bregni **I Exam 2018-19 – 17 January 2019**

Last and first name: *(capital letters)*

(signature)

Matriculation number:

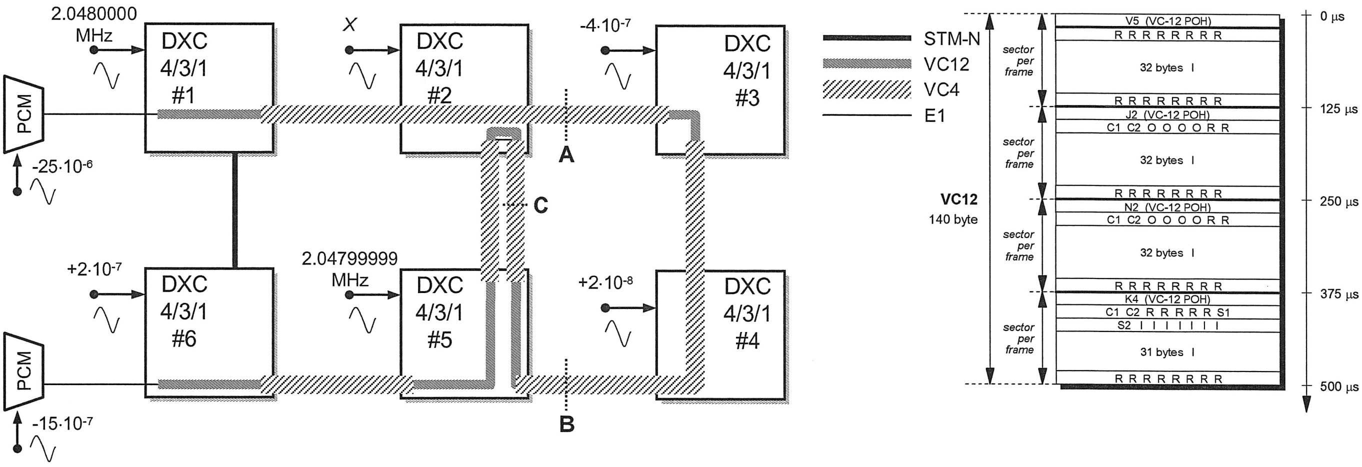
NB: In any exercise, any answer not justified adequately, even with few words, will not be considered.

Problem 1

(Solve on this sheet in the space provided) (8 points)

Consider the network of DXC 4/3/1 elements in figure below, where all links are bidirectional. Links between DXCs are STM-4 (f_0 = 622.080 Mbit/s). Each Network Element (NE) is synchronized by an external reference, of which either the fractional frequency deviation from the nominal value f_0 = 2.048 MHz or directly the absolute frequency is given. For your convenience, the asynchronous mapping scheme of E1 into VC12 is also given.

Two PCM multiplexers, synchronized by autonomous references, are connected by a bidirectional E1 link (f_0 = 2.048 MHz), which follows the path indicated with the black thin line in figure. The E1 circuit is transported (asynchronous mapping) via the VC12 path indicated with the grey line in figure (1-2-3-4-5-2-5-6). The VC12 path is transported in its turn via VC4 paths indicated with wider grey lines in figure (1-2-3, 3-4-5, 5-2, 2-5, 5-6)



a) Compute the justification ratio ρ (as fraction of justification opportunity bits occupied by dummy bits) in the VC12 terminated at the desynchronizer of the E1 interface of DXC #1. *(1 point)*

$2{,}048 \text{ Mb/s } (1-15\cdot10^{-7}) = (1025-2\rho)\cdot 2000\cdot(1+2\cdot10^{-7}) \text{ bit/s}$

$\rightarrow \rho = 0{,}5008705$

b) What would be the difference in the result of question a), if the VC12 path would be routed on the direct link DXC #1 – DXC #6? *(1 point)*

0

c) Compute every how many seconds TU12 pointer justifications do happen at interface A (i.e., the inter-justification period), in the direction from DXC #3 to DXC #2, specifying also their sign (POS/NEG) *(2 points)*

In the VC12 pointer processor in #3: $\Delta f \simeq f_{VC12}(+6 \cdot 10^{-7}) =$

$= +1344$ bit/s

$\Rightarrow$ 1 TU12 just. every

$\frac{8 \text{ bit}}{1344 \text{ bit/s}} \simeq 5{,}95$ sec (NEG)

$f_{VC12} = \frac{35 \cdot 8 \text{ bit}}{125 \mu s} = 2{,}240$ Mb/s

d) Compute every how many seconds TU12 pointer justifications do happen at interface B (i.e., the inter-justification period), in the direction from DXC #5 to DXC #4, specifying also their sign (POS/NEG) *(2 points)*

In the VC12 p.p. in #5: $\Delta f = f_{VC12}\left(+2 \cdot 10^{-7} - \left(\frac{2{,}04799999}{2{,}048} - 1\right)\right) =$

$= +0{,}459$ bit/s

$\Rightarrow$ 1 TU12 just every

$\frac{8 \text{ bit}}{0{,}459 \text{ bit/s}} = 17{,}43$ sec (NEG)

e) Be informed that TU12 pointer justifications at interface C, in the direction from DXC #2 to DXC #5, happen once every 5 minutes and are negative. Then, compute the fractional frequency deviation $X = \Delta f / f_0$ from the nominal value f_0 of the reference synchronizing DXC #2. *(2 points)*

In the VC12 p.p. in #2: $\Delta f = f_{VC12}(2 \cdot 10^{-7} - X)$

To have 1 TU12 just (NEG) every 300 sec: $\Delta f = + \frac{8 \text{ bit}}{300 \text{ sec}}$

$\Rightarrow X = +1{,}881 \cdot 10^{-7}$

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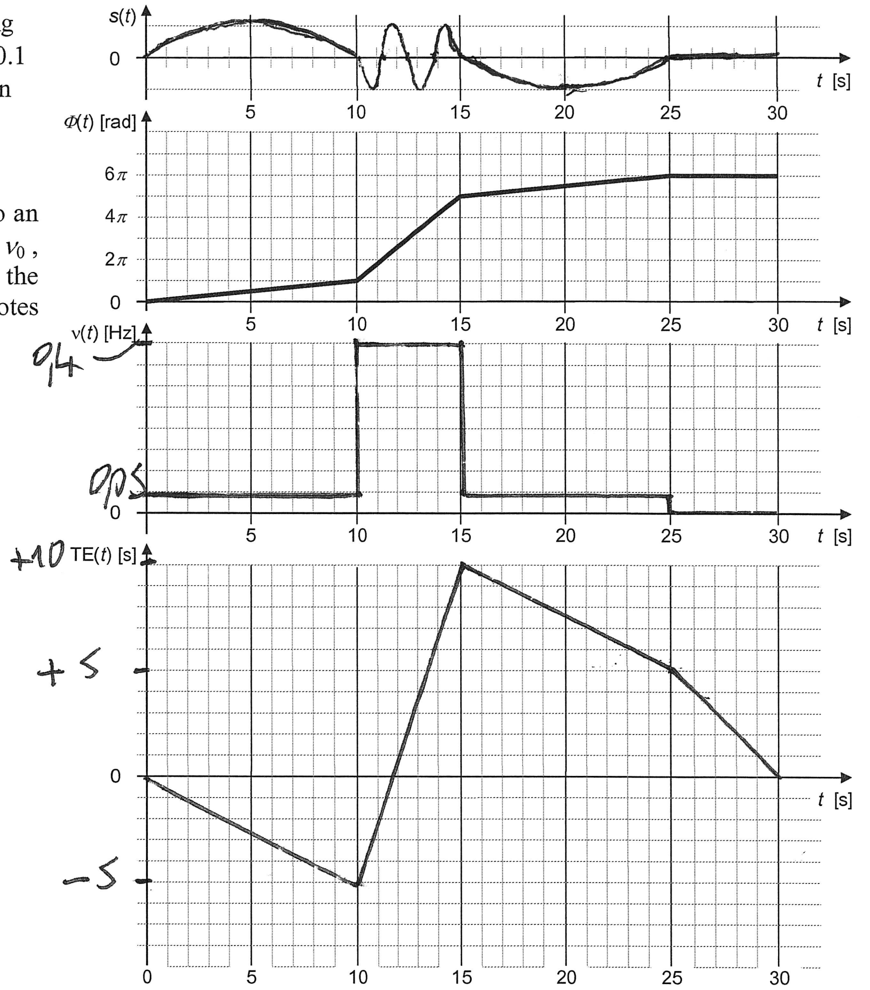
Problem 2

(Solve on this sheet in the space provided) (6 points)

a) Let $s(t)$ be a pseudo-sinusoidal timing signal with nominal frequency $\nu_0 = 0.1$ Hz and *Total Phase* $\Phi(t)$ as plotted in figure. Plot on the graphs at right:

- the timing signal $s(t)$;
- the instantaneous frequency $\nu(t)$;
- the *Time Error* TE(t) with respect to an ideal timing signal with frequency ν_0, starting from TE(0)=0, with the convention that positive TE denotes time advance.

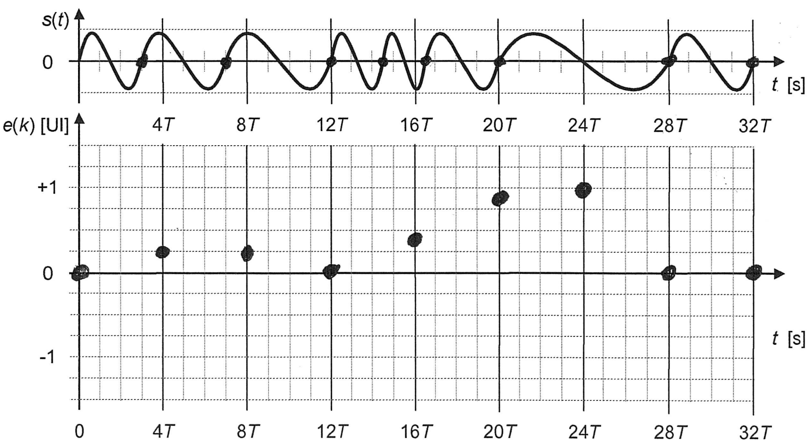
$$T(t) = \frac{\Phi(t)}{2\pi \nu_0}$$



b) Let $s(t)$ be the pseudo-sinusoidal timing signal $s(t)$ plotted in figure and with nominal frequency $\nu_0 = 1/(4T)$ Hz.

- What is its average frequency over the interval $(0, 32T)$?

$$\frac{8 \text{ cycles}}{32T} = \frac{1}{4T}\text{ Hz} = \nu_0$$



- Plot on the graph the jitter values $e[k]$ measured in [UI], at significant instants $t_k = k(4T)$ of the ideal timing signal with frequency ν_0, starting from the initial point $e[0] = 0$, with the convention that positive jitter denotes time advance.

Problem 3

(Solve on this sheet in the space provided) (5 points)

100 persons make a call, or attempt to call, on the average once every 4 hours at random Poisson times using their mobile phones. The duration of calls is random, with unknown distribution and average 3 minutes. Telephones are all connected to the same radio base station, linked to the network by a backhaul link carrying m lines (single telephone circuits).

a) What probability distribution would you use to evaluate the probability that a call is rejected? How is it called this probability, Call Congestion or Time Congestion? In the present case, have the two the same value or not?

$$B_m(A_0) = \frac{A_0^m / m!}{\sum_{i=0}^{m} A_0^i / i!}$$

b) How many lines are needed, in order to make the probability that a call is rejected lower than 1%?

$$A_0 = 100 \cdot \frac{3}{240} = \frac{5}{4}$$

m	$B_m(A_0)$
1	0,555
2	0,258
3	0,097
4	0,0294
5	0,0073 $\Rightarrow m \geq 5$

c) How many lines are needed, instead, if the number of users is reduced to half?

$$A_0 = \frac{5}{8}$$

m	$B_m(A_0)$
1	0,385
2	0,107
3	0,0219
4	0,0034 $\Rightarrow m \geq 4$

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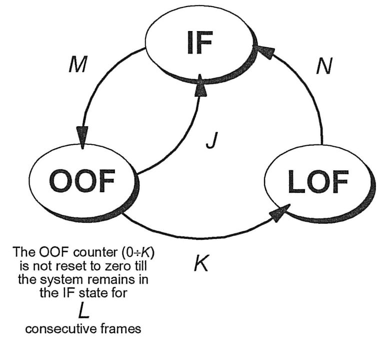
Problem 4

(Solve on this sheet in the space provided) (5 points)

Consider the standard SDH frame alignment algorithm, represented by the diagram below. The frame aligner operates on a test STM-1 framed signal at input, with random content everywhere in all frames except the alignment word, which consists of X bits during hunting and 8 bits during maintenance. The test signal is affected by random transmission errors on the line, uncorrelated and with rate $\varepsilon = 10^{-5}$.

a) Compute the probability P_1 that the system, being correctly aligned, moves to the state Out-of-Frame within 625 μs due to the random transmission errors.



$$P_1 = \left[1-(1-\varepsilon)^8\right]^5 \cong (8\varepsilon)^5 = 3{,}28\cdot 10^{-21}$$

b) Let P_2 be the probability that the system, being in state Loss-of-Frame, gains correct alignment (IF) within 3 ms due to simulation of the alignment word by the random payload. Compute the number of bits X, which are necessary to have $P_2 < 10^{-120}$.

$$P_2 = \left(\frac{1}{2^X}\right)^{24} \qquad \frac{1}{2^{24X}} < 10^{-120} \qquad 24X \log 2 > 120 \qquad \Rightarrow X \geq 17$$

c) Explain pros and cons of having a short vs. long alignment word during the phases of hunting and maintenance.

d) Explain the concepts of *forced loss of alignment* vs. *real loss of alignment*.

Problem 5

(Answer on this sheet in the space provided) (12 points)

NB: In any exercise, any answer not justified adequately, even with few words, will not be considered.

1) Consider a Passive Optical Network reaching 64 users at variable distances in range 0 to 10 km from the OLT. A single splitter 1×64 is located at the OLT. *(4 points)*

- What is burst-mode receiver? What is the maximum variation of power between consecutive bursts at the input of the burst-mode receiver at the OLT (consider the attenuation coefficient of fibres used in PONs)? Why a burst-mode receiver is not needed at the ONU?
- Illustrate the mechanisms commonly adopted to counteract security threats in the following cases:
  - avoid that user A receives information sent by the OLT to other users;
  - avoid that user A receives information sent by other users to the OLT;
  - avoid that user A jams the PON by transmitting continuously with high power (who is affected?)

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2) Outline the *Wilkinson's Method* (a.k.a. Equivalent Random Traffic method). In particular: *(4 points)*

- describe what is its purpose, what are its input data, what is its output;
- outline the algorithm (it is not necessary to write the exact formulas); is there any challenge to face in computing results in practical cases, say for a number of lines on the order of 10^5? how to get rid of that, if you have to write a program implementing the method?

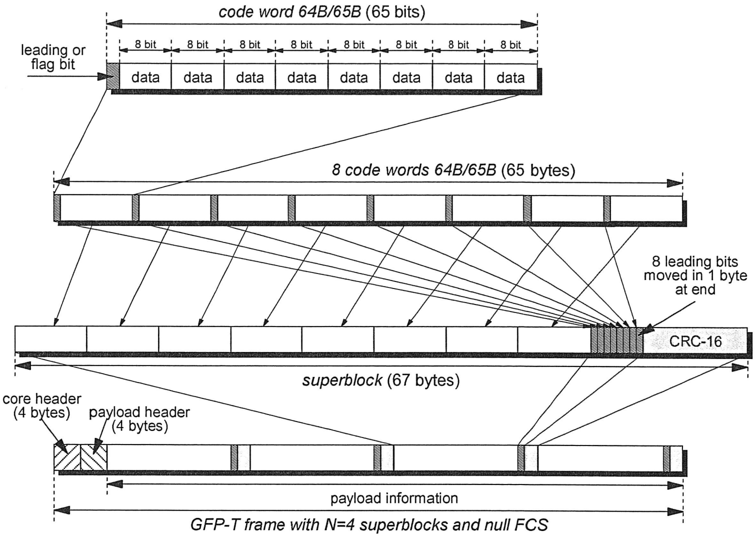
3) Consider the transport of a 1 Gb/s Ethernet signal via the standard GFP-T mapping (without FCS and null extension header). What is the limit rate of the resulting GFP-T signal for $N \to \infty$? *(2 points)*

$$\rho(N) = 1000 \frac{\cancel{65}}{64} \frac{67}{\cancel{65}} \frac{N67+8}{N67}$$

(rate of GFP-T signal)

$$\lim_{N \to \infty} \rho(N) = 1000 \frac{67}{64} \text{ Mb/s} =$$

$$= 1046{,}875 \text{ Mb/s}$$



4) Outline the principles of one-way vs. two-way schemes for synchronization over packet-switched networks. Are they suitable for frequency and/or time synchronization? *(2 points)*