CARLETON UNIVERSITY
Department of Systems and Computer Engineering

SYSC5608 – Wireless Communications Systems Engineering – Winter 2018

TERM EXAM **15 March 2018 – Prof. Halim Yanikomeroglu**

Closed-book exam. A two-sided aid-sheet is permitted.
No smart phones, no internet access.
Write answers in the space provided on the question sheet. If necessary, use both sides of a page.
Write legibly, and state any assumptions that you make.
Time = 100 mins.

Name: **Student No:**
Carleton or uOttawa?: **E-mail:**

Question	Mark	out of
1		20
2		30
3		30
4		50
5		50
TOTAL		180

Q1 [20 pts] – Short Questions

Consider a cellular network with a fixed number of BSs. The operator upgrades the network from 3G with a reuse factor of 1/3, to 4G LTE with a reuse factor of 13/20. If everything else remains the same in the network, what percentage of capacity increase is achieved through this upgrade?
(Note: The reuse factor is the inverse of the cluster size.)

Q2 [30 pts] – Non-Terrestrial Networks

A terrestrial UE (user equipment) is in communication with a HAP (high-altitude platform) at an altitude of 20 kms at carrier frequency $f_{\text{UE-HAP}} = 30$ GHz.

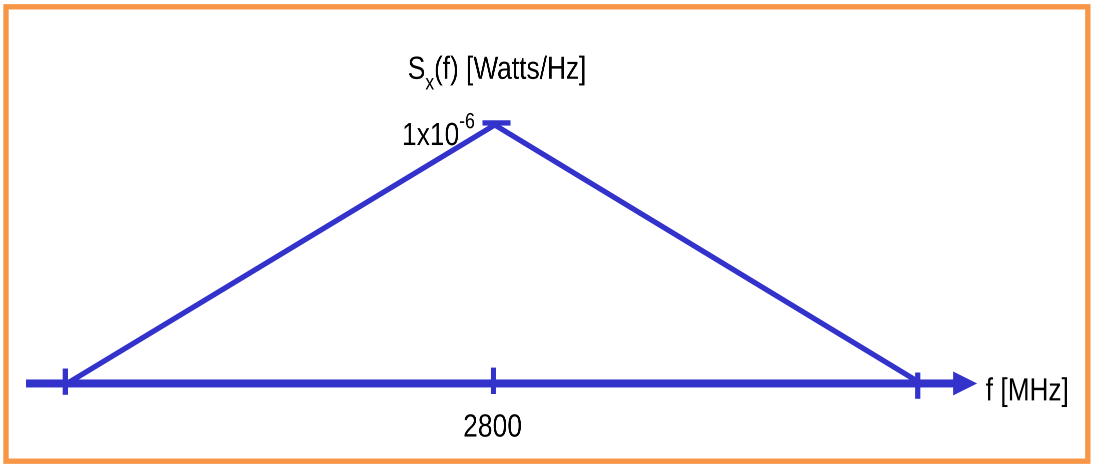
The UE is also in communication with a low earth orbit (LEO) satellite at an altitude of 2,000 kms at carrier frequency $f_{\text{UE-LEO}} = 3$ GHz.

Both links have the same bandwidth. Antenna gains of HAP and the LEO satellite are $G_{HAP} = 7$ dB and $G_{LEO} = 23$ dB. UE uses the same transmit power for both links. The propagation exponent is given as 2.

Consider the uplink; if $SNR_{HAP} = 11$ dB, obtain SNR_{LEO}.

Q3 [30 pts] – Power Spectral Density

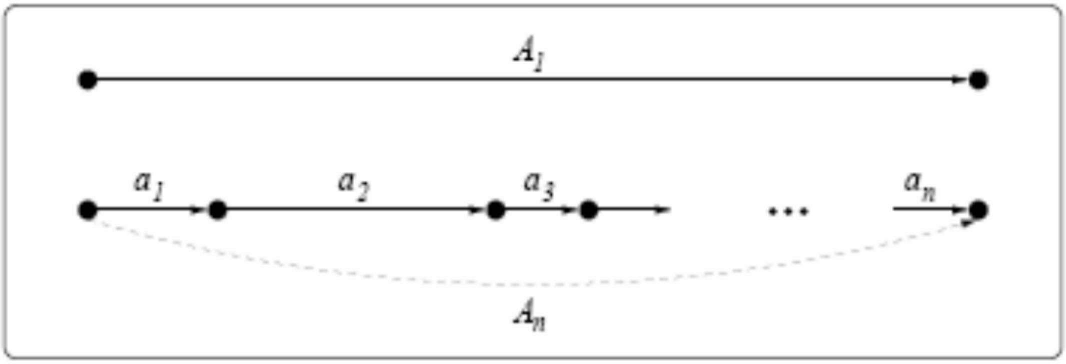
The double-sided power spectral density, $S_x(f)$, for a digital signalling scheme is given below. PSD is symmetric with respect to the $f = 0$ Hz vertical axis; the left part is not shown.



$BW_{90\%}$ (90%-bandwidth) is defined as the frequency region in which 90% of the total power is confined to. If $BW_{90\%}$ = 20 MHz, find the absolute BW.

Q4 [50 pts] – Spectral Efficiency of Multihop Links

We would like to determine when it is efficient to use a multihop link in a relay network. Consider a potential n-hop replacement of a single-hop link as shown in the below figure.



Without loss of generality, we consider the "time" as the channel. As it can be observed from the above figure, the n-hop link uses n time channels while the single-hop link uses only one such channel.

We consider the worst case scenario (in the sense of efficiency) where no channel reuse is allowed. In other words, in the n-hop link all the n time channels are orthogonal to each other (that is, first the transmission in hop-1 occurs, then hop-2 transmission takes place, and so on; in other words, there is no concurrent transmission).

This is a time-division multiplexed system with half-duplex operation. If a bandwidth of B Hz is available for the single-hop link, all of that bandwidth becomes available in each hop in the n-hop case.

In the above figure, the spectral efficiency (in bits/sec/Hz) of the single-hop link is denoted by A_1. The spectral efficiencies of the individual hops in the n-hop link are denoted by a_1, a_2, a_3, …, a_n.

You are asked to find the equivalent spectral efficiency of the n-hop link, A_n, in terms of $\{a_i\}_{i=1}^{n}$. Obtaining A_n is important because it will be worth to replace the single-hop link with the n-hop link only if $A_n > A_1$.

In your formulation, omit all the possible overhead data that can be incurred in a realistic implementation of the n-hop link (such as the addressing information for multi-hop routing).

Hint: One way of approaching to this problem is to consider the total time it will take to send a data packet (say, M bits) from the source to destination.

[*Extra space for Q4*]

Q5 [50 marks] – Link Budget

Assume that Canada is auctioning spectrum for wireless 4G cellular services. Frequency bands can be leased at three different carrier frequencies (denoted by options A, B, and C) by the potential operators. The spectrum leasing cost (LC) for option B is given as $30 million per MHz; you are asked to determine the leasing costs for the other two options:

Carrier Frequency A: f_A = 800 MHz	→	Leasing Cost: LC_A = **?**
Carrier Frequency B: f_B = 1.8 GHz	→	Leasing Cost: LC_B = $30 M/MHz
Carrier Frequency C: f_C = 3.4 GHz	→	Leasing Cost: LC_C = **?**

Here are some figures from the operator specifications:

- BS transmit power: P_{TX} = 15 W
- Transmitter (BS) antenna gain: G_{TX} = 8 dB
- Receiver (terminal) antenna gain: G_{RX} = 10 dB
- Path loss: $PL = (4\pi f/c)^2 d^{3.4}$, where
  - Distance between BS and a terminal: d
  - Speed of light: $c = 3\text{x}10^8$ m/sec

The spectrum leasing costs should be related to how large an area one base station (BS) can provide radio coverage; note that a larger coverage area for a BS means more customers per BS, which in turn means more revenue per BS.

Let us consider the downlink (from BS to the terminals). The coverage region of a BS is the area in which the received power for a signal sent by that BS is greater than a threshold value (that threshold is the same for all the three options).

Here is the rule to determine the spectrum leasing costs: If option i allows a BS to serve an area u times larger in comparison to option j, then $LC_i = u\, LC_j$. Determine LC_A and LC_C.

[*Extra space for Q5*]