ELET 6302/4397: Advanced Wireless Networks

Assignment 1

Due March 11, 11:59 pm (before midnight)

Consider a mobile system consisting of a single base station and M mobile stations. The rate/resource allocated by the base station to i^{th} mobile station is given by r_i. Each mobile station has its own utility function $U_i(r_i)$ that corresponds to the type of traffic being handled by it. The objective is to determine the rate the base station should allocate to the different mobile stations to achieve optimality. To represent real-time applications running on mobile stations, use the normalized sigmoid utility function

$$U_i(r_i) = c_i\Big(\frac{1}{1+e^{-a_i(r_i-b_i)}} - d_i\Big), \tag{1}$$

where $c_i = \frac{1+e^{a_ib_i}}{e^{a_ib_i}}$ and $d_i = \frac{1}{1+e^{a_ib_i}}$. So, it satisfies $U(0) = 0$ and $U(\infty) = 1$. Additionally, to represent delay-tolerant applications running on mobile stations, use the normalized logarithmic utility function

$$U_i(r_i) = \frac{\log(1+k_ir_i)}{\log(1+k_ir_{max})} \tag{2}$$

where r_{max} is the maximum required rate for the user to achieve 100% utilization and k_i is the rate of increase of utilization with allocated rate. So, it satisfies $U(0) = 0$ and $U(r_{max}) = 1$. Consider the utility proportional fairness objective function given by

$$\prod_{i=1}^{M} U_i(r_i), \tag{3}$$

where M is the number of mobile stations. The goal of this assignment is to allocate the resources at the base station to mobile stations and maximize the total system utility in equation (3). To achieve this goal, solve the utility proportional fairness resource allocation problem given by:

$$\begin{aligned} \max_{\mathbf{r}} \quad & \prod_{i=1}^{M} U_i(r_i) \\ \text{subject to} \quad & \sum_{i=1}^{M} r_i \leq R \\ & 0 \leq r_i \leq R, \qquad i = 1, 2, ..., M. \end{aligned} \tag{4}$$

where $\mathbf{r} = \{r_1, r_2, ..., r_M\}$ and R is the total rate at the base station covering M mobile stations. Use the method of Lagrange multipliers to solve the optimization problem in equation (4).

Write a code using any programming language of your preference, e.g. MATLAB, C++, Java, Python, etc., to do the following:

(a) plot two normalized logarithmic utility functions with $k = 15$ and $r_{max} = 50$, and $k = 0.1$ and $r_{max} = 50$.

(b) plot two normalized sigmoid utility functions with $a = 5$ and $b = 10$, and $a = 0.5$ and $b = 20$. What is the change to the function with increase in the value of a? and increase in the value of b?

(c) use Levenberg–Marquardt algorithm for curve fitting the two functions in (b) to the normalized logarithmic utility functions, find the fitting parameters k and r_{max}. Plot the functions in (b) and new generated normalized logarithmic utility functions in the same figure.

(d) plot the allocation rates, bids and shadow price for the two utility functions in (a) and the two utility functions in (b) with time (iterations) for a total rate $R = 100$.

(e) plot the allocated rates, bids and shadow price for the two utility functions in (a) and the two normalized logarithmic utility functions in (c) with time (iterations) for a total rate $R = 100$.

(f) calculate the objective function in equation (3) for the optimal allocated rates in (d) and in (e). Plot side by side using a bar chart.

(g) let $M = 10$ mobile stations, generate 5 random values of $a = [1, 3]$, $b = [10, 20]$, $k = [1, 10]$ and $r_{max} = [30, 50]$. Use these values to generate $M_S = 5$ normalized sigmoid utility functions and $M_L = 5$ normalized logarithmic utility functions to represent applications running on mobile stations.

(h) using functions in (g), repeat (d), (e) and (f) for $R = 200$.

(i) using $M = 50$, $M_S = 25$, and $M_L = 25$, repeat (f) for $R = 500$.

(j) using $M = 100$, $M_S = 50$, and $M_L = 50$, repeat (f) for $R = 800$.

Please upload your assignment with the required figures and answers to the questions to Blackboard. Additionally, upload your source code used to plot these figures to Blackboard.

Note that you can refer to the following papers for more details on resource allocation optimization algorithms.

- A. Abdel-Hadi and T. Clancy, A Utility Proportional Fairness Approach for Resource Allocation of 4G-LTE, IEEE ICNC Workshop CNC, 2014. (pdf)

- A. Abdel-Hadi and T. Clancy, A Robust Optimal Rate Allocation Algorithm and Pricing Policy for Hybrid Traffic in 4G-LTE, IEEE PIMRC 2013. (pdf)