CS 465 – Fall 2018 – Homework 1
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Team Allowed: maximum of two per team. The members of a team must be from the **same** CS 465 section.

State clearly the team member names and GMU IDs as comments in each page of the submitted report.

IMPORTANT:

(1) Start to work on the homework early.
(2) If you plan to do the homework with a classmate, make a determination early on that your teammate is responsive.
(3) The explanation for your answers is required. **You will not get credit without explanation.**
(4) Use a word processor to type your answers and generate a pdf file from it.
(5) **Do not share your solutions or partial solutions** on Piazza or any other platforms (electronic or otherwise) before the deadline. This assignment is individual to a group. If you want to ask questions about your solution, please ask the TAs or me.

Late submissions are not accepted.

How to submit: A PDF file answering all questions. The submission will be made via a blackboard link available to you. For team projects, only one member of the team should submit the PDF file with all the answers and the other should submit a one-page PDF file stating the names of both members of the team. If you fail to submit the one-page PDF file you will not get any credit for the homework.

Question 1 [40 points]: Consider a heterogeneous computer architecture that has two types of processors: a powerful processor (of which there is only one) and p small capacity processors (called small processors heretofore). Consider that a program P can be broken down into two parts: a sequential part (which is executed by the powerful processor) and a parallelizable part that is processed in parallel by the p small processors. The sequential and parallel parts of the computation <u>start at the same time</u> and the program ends when both parts end (i.e., when the part that takes the longest time ends).

Assume the following notation:

T: total execution time of program P assuming it only uses CPU (i.e., the program does not do any I/O)
I: total number of instructions executed by P

f: fraction of the instructions of P that have to be executed by the powerful processor, i.e., the sequential part of P's instructions

CPI_S: average CPI of the part of the program executed on the powerful processor

CPI_P: average CPI of the part of the program executed on each small processor

f_S : clock frequency of the powerful processor

f_P : clock frequency of each small processor

(a) [6 points] Give an expression for the CPU time of the sequential part of the program

(b) [6 points] Give an expression for the CPU time of the parallel part of the program

(c) [8 points] Give an expression for the total execution time T

(d) [2 points] Give an expression for T when $f = 0$

(e) [2 points] Give an expression for T when $f = 1$

(f) [12 points] Assume that $I = 2 * 10^{10}$, f_S = 3.5 GHz, f_P = 1.8 GHz, CPI_S = 1.5, CPI_P = 3.0. Use Excel to draw a graph of T vs *p* (the number of small processors). Your graph should show 5 curves for the following values of *f*: 0, 0.15, 0.25, 0.5, and 1. The values of *p* should go from 1 to 50 in increments of 5. Use a x-y scatter plot type in Excel. Make sure to properly label the y and x axes.

(g) [4 points] What conclusions do you draw from the graph?

Question 2 [30 points]: A computer system S can be decomposed into three subsystems: processor, memory, and I/O. S has a failure rate equal to λ failures/sec. The processor accounts for a fraction f_p of the total failures, the memory accounts for a fraction f_m of the total failures, and the I/O subsystem accounts for a fraction $f_{i/o}$ of the total failures. (Note that $f_p + f_m + f_{i/o} = 1$)

(a) [7.5 points] What is the reliability improvement index (RII) of system S if the failure rates of the processor, memory, and I/O subsystem are improved by factors P_p, P_m, and $P_{i/o}$, respectively (i.e., the failure rates are reduced)?

(b) [4.5 points] Compute the RII assuming that $f_p = 0.25$, $f_m = 0.35$, and $f_{i/o} = 0.4$ and $P_p = 2$, $P_m = 3$, and $P_{i/o} = 1.5$.

(c) [7.5 points] Assume that there is a cost to improve the reliability of each of the subsystems. This cost is not the same for each subsystem. Assume the following notation:

C_p: cost per unit of reliability improvement for the processor. So, the cost of improving the reliability of the processor by a factor of P_p is $C_p \times P_p$.
C_m: cost per unit of reliability improvement for the memory subsystem. So, the cost of improving the reliability of the memory by a factor of P_m is $C_m \times P_m$.
$C_{i/o}$: cost per unit of reliability improvement for the I/O subsystem. So, the cost of improving the reliability of the I/O subsystem by a factor of $P_{i/o}$ is $C_{i/o} \times P_{i/o}$.

Give an expression for the metric K defined as the total improvement cost divided by the RII.

(d) [4.5 points] Consider the numerical values of item (b) above and compute K when Cp = $5000, Cm = $10,000, and Ci/o = $25,000.

(e) [6 points] Describe how K varies as the improvement factors vary.

Question 3 [20 points]: A program has a CPI equal to 2.0 when running a program P on a machine that has a clock frequency equal to 3 GHz. The hardware designer was asked to modify the hardware so that the CPU time of P becomes 1/3 of the original CPU time. The machine's ISA should stay the same. The designer first reduced the CPI of P to 1.0 by changing the implementation of the instructions.

(a) [14 points] What changes should the designer make to the clock frequency to get to the 1/3 reduction? Assume that changes in the clock frequency will not affect the CPI.

(b) [6 points] What was the resulting percentage change in the processor's dynamic power as a result of the change in item (a) above assuming there was no change in the capacitive load nor on the voltage.