In the assignment, you will measure how much a multiprocessor can speed up a single program over single-processor execution. The skeleton program provided in the assignment contains func1() and func2(); measure their execution time under single-processor and multiprocessor execution. Adding OpenMP compiler directives can conveniently parallelize the main for loop in each function. A code example to use the directive is included at the end of this document. OpenMP directives can also specify the number of threads/cores to use for the program.

The execution time of a program can vary from run to run. As such, repeat each measurement 10 times and take the average; use the average time to compute speedup (i.e., speedup over single thread should be the average execution time under single-core execution divided by average execution time under multi-core execution).

IBM has kindly provided everyone in the class with a Power9 VM instance, each with 32 cores. Use the IBM VM to carry out the measurements. You will also reuse your VM for Programming Assignment 4.

There are three parts to this assignment.

Part A) Add OpenMP directives to func1() to parallelize the loop in the function. Measure the speedup over single-thread execution as you increase the number of threads to 2, 4, 8, 16, and 28. Print your answer as follows: "Part 1.a) 2T: <measured speedup>, 4T: <measured speedup>, 8T: <measured speedup>, 16T: <measured speedup>, 28T: <measured speedup>"

Part B) Repeat the above for func2() in the skeleton code.

Part C) For which of the two functions can the multiprocessor achieve higher speedup? Explain your answer.

<u>What to turn in:</u>

- Fill in the skeleton program with your new code and turn in the completed program.
- You will need to modify func1(), func2(), main(); a convenient way to time the functions multiple times is to call them in an added loop in main.
- The C code should also print your answers and explanations so that the grader can get all the answers to Part A, Part B, and Part C by running the C code.

<u>Advice:</u>

- When compiling your measurement program, turn off all compiler optimizations so that the binary executable behaves as closely as possible to the original C/C++ program.

OpenMP Code Example:

The following demonstrates the “#pragma omp parallel for” directive to execute the different iterations of a loop under different threads.

```
#include <omp.h>
#include <stdio.h>
#include <stdlib.h>

int main(int argc, char* argv[])
{
  omp_set_num_threads(4);
  printf("Num threads: %d\n", omp_get_max_threads());

  #pragma omp parallel for
  for (int i = 0 ; i < 8 ; i++) {
    int thread_id = omp_get_thread_num();
    printf("Thread %d executes iteration %d\n", thread_id, i);
  }
  return 0;
}
```

How to compile:

```
$ gcc openmp_helloworld.c -o omp -fopenmp
```

How to run:

```
$ ./omp
```

Output:

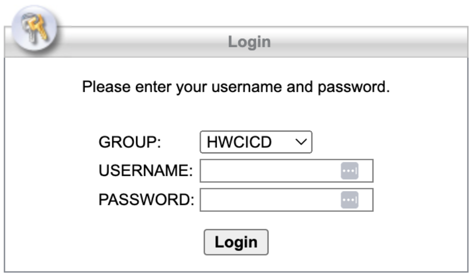
```
Num threads: 4
Thread 1 executes iteration 2
Thread 1 executes iteration 3
Thread 2 executes iteration 4
Thread 2 executes iteration 5
Thread 0 executes iteration 0
Thread 0 executes iteration 1
Thread 3 executes iteration 6
Thread 3 executes iteration 7
```

How to access the VM

VPN access to IBM resources is started with a standalone application: Cisco AnyConnect Secure Mobility Client.

The following instructions to download the software:

1. Go to the webpage: https://vpnisv.isv.ihost.com
2. Select HWCICD from the “Group” dropdown menu.
3. Enter the username and password sent to you via the email. You were sent two username and passwords. Use the VPN Username/Password.

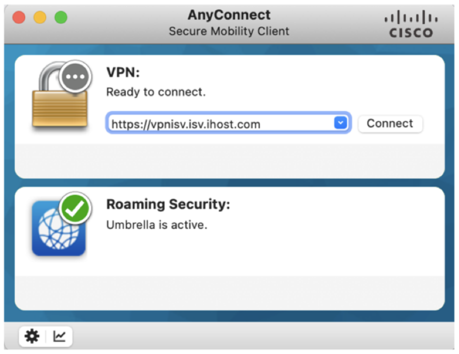


Login

Please enter your username and password.

GROUP: HWCICD
USERNAME:
PASSWORD:

4. Click on login and follow the instructions on the screen to lead you to the download page.
5. Install the AnyConnect application and start it
6. Type https://vpnisv.isv.ihost.com as the VPN address and click on “Connect”

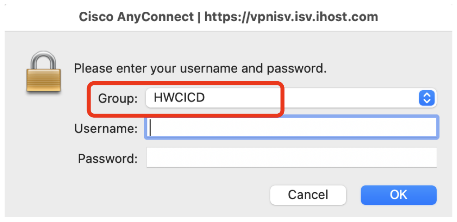


AnyConnect
Secure Mobility Client

VPN:
Ready to connect.
https://vpnisv.isv.ihost.com

Roaming Security:
Umbrella is active.

7. Then select HWCICD from the “Groups” dropdown menu and enter the same username and password you entered earlier to connect to the VPN



Cisco AnyConnect | https://vpnisv.isv.ihost.com

Please enter your username and password.

Group: HWCICD
Username:
Password:

8. Now you are connected to IBM’s network.
9. Next, use the VM Username/Password to ssh into the VM.
10. Once logged into the VM, execute the following commands:
    a. $ source .profile

b. $ export PATH=/opt/IBM/openxlC/17.1.1/bin/:$PATH
c. $ export PATH=/opt/freeware/bin:$PATH