Assignment2:

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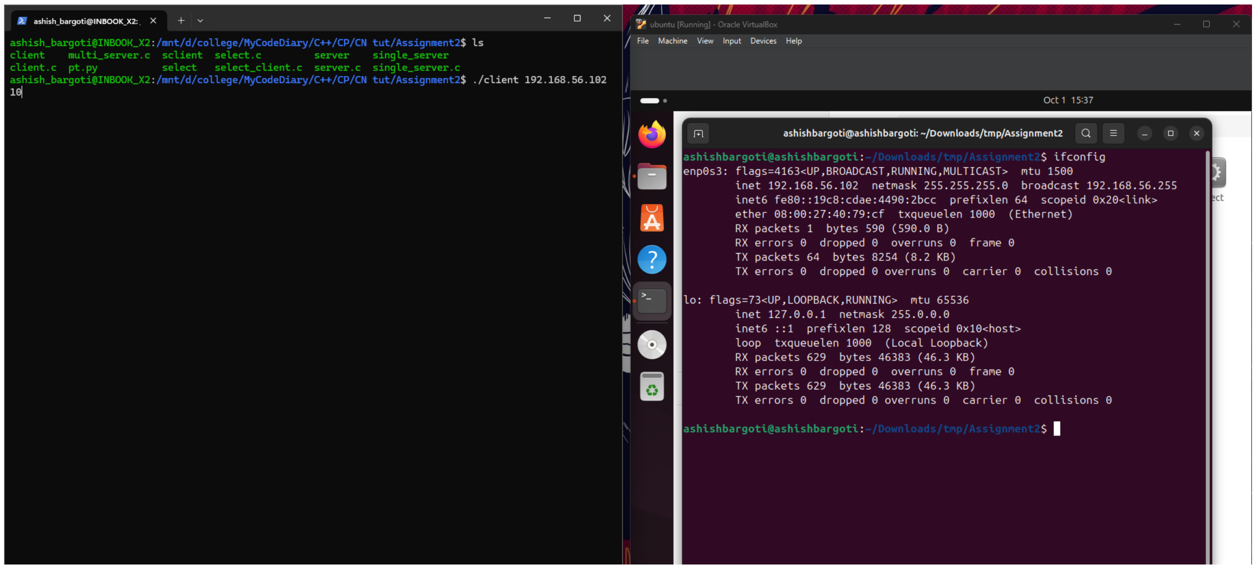
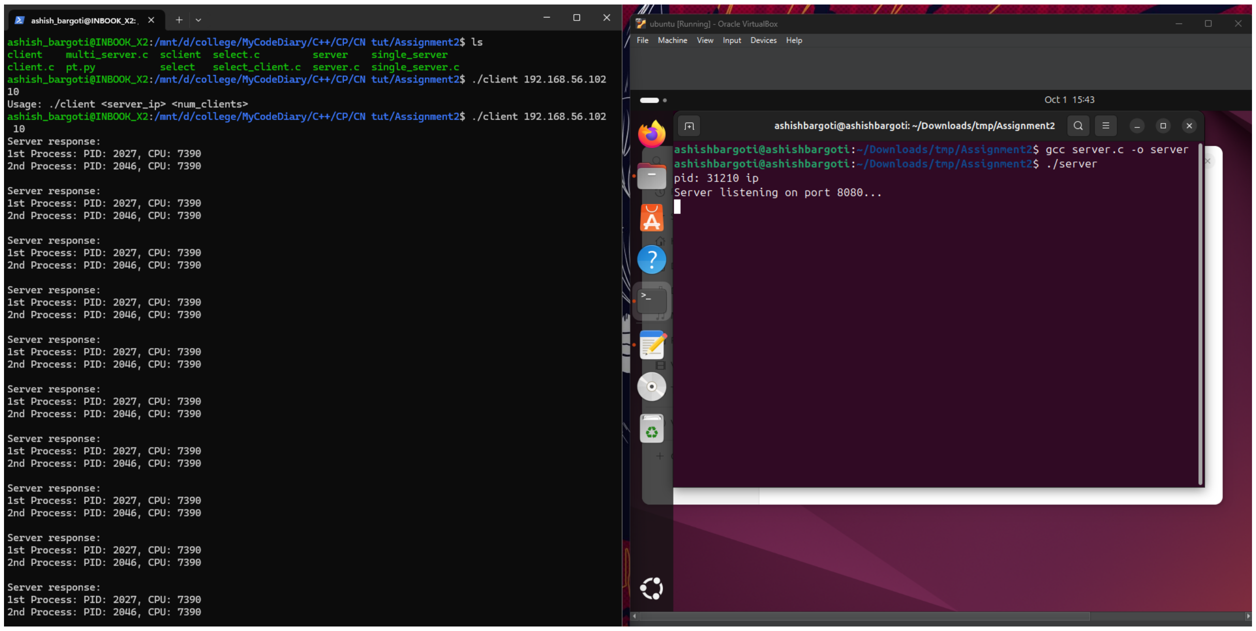
Q1:Client-Server Socket Program



ashish_bargoti@INBOOK_X2:
ubuntu [Running] - Oracle VirtualBox
File Machine View Input Devices Help
Oct 1 15:37
ashishbargoti@ashishbargoti: ~/Downloads/tmp/Assignment2

```
ashish_bargoti@INBOOK_X2:/mnt/d/college/MyCodeDiary/C++/CP/CN tut/Assignment2$ ls
client    multi_server.c  sclient  select.c         server    single_server
client.c  pt.py           select   select_client.c  server.c  single_server.c
ashish_bargoti@INBOOK_X2:/mnt/d/college/MyCodeDiary/C++/CP/CN tut/Assignment2$ ./client 192.168.56.102
10
```

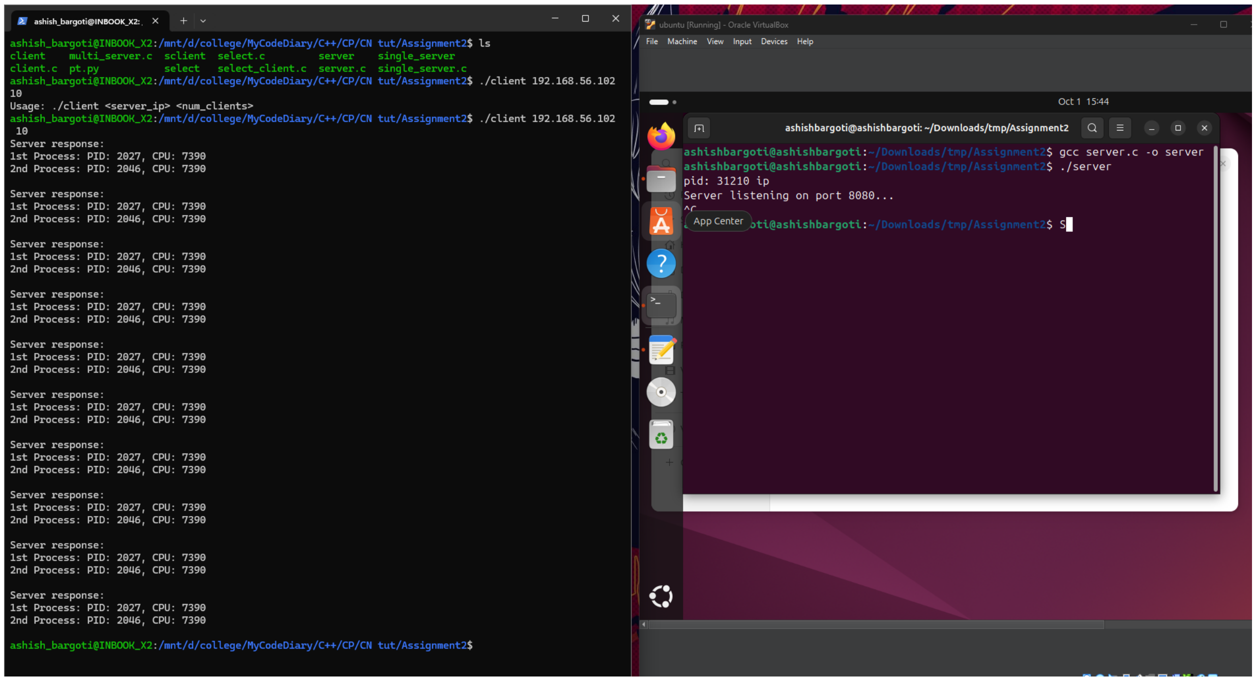
```
ashishbargoti@ashishbargoti:~/Downloads/tmp/Assignment2$ ifconfig
enp0s3: flags=4163<UP,BROADCAST,RUNNING,MULTICAST>  mtu 1500
        inet 192.168.56.102  netmask 255.255.255.0  broadcast 192.168.56.255
        inet6 fe80::19c8:cdae:4490:2bcc  prefixlen 64  scopeid 0x20<link>
        ether 08:00:27:40:79:cf  txqueuelen 1000  (Ethernet)
        RX packets 1  bytes 590 (590.0 B)
        RX errors 0  dropped 0  overruns 0  frame 0
        TX packets 64  bytes 8254 (8.2 KB)
        TX errors 0  dropped 0 overruns 0  carrier 0  collisions 0

lo: flags=73<UP,LOOPBACK,RUNNING>  mtu 65536
        inet 127.0.0.1  netmask 255.0.0.0
        inet6 ::1  prefixlen 128  scopeid 0x10<host>
        loop  txqueuelen 1000  (Local Loopback)
        RX packets 629  bytes 46383 (46.3 KB)
        RX errors 0  dropped 0  overruns 0  frame 0
        TX packets 629  bytes 46383 (46.3 KB)
        TX errors 0  dropped 0 overruns 0  carrier 0  collisions 0

ashishbargoti@ashishbargoti:~/Downloads/tmp/Assignment2$ 
```



```
ashish_bargoti@INBOOK_X2:/mnt/d/college/MyCodeDiary/C++/CP/CN tut/Assignment2$ ls
client    multi_server.c  sclient  select.c         server    single_server
client.c  pt.py           select   select_client.c  server.c  single_server.c
ashish_bargoti@INBOOK_X2:/mnt/d/college/MyCodeDiary/C++/CP/CN tut/Assignment2$ ./client 192.168.56.102
10
Usage: ./client <server_ip> <num_clients>
ashish_bargoti@INBOOK_X2:/mnt/d/college/MyCodeDiary/C++/CP/CN tut/Assignment2$ ./client 192.168.56.102
 10
Server response:
1st Process: PID: 2027, CPU: 7390
2nd Process: PID: 2046, CPU: 7390

Server response:
1st Process: PID: 2027, CPU: 7390
2nd Process: PID: 2046, CPU: 7390

Server response:
1st Process: PID: 2027, CPU: 7390
2nd Process: PID: 2046, CPU: 7390

Server response:
1st Process: PID: 2027, CPU: 7390
2nd Process: PID: 2046, CPU: 7390

Server response:
1st Process: PID: 2027, CPU: 7390
2nd Process: PID: 2046, CPU: 7390

Server response:
1st Process: PID: 2027, CPU: 7390
2nd Process: PID: 2046, CPU: 7390

Server response:
1st Process: PID: 2027, CPU: 7390
2nd Process: PID: 2046, CPU: 7390

Server response:
1st Process: PID: 2027, CPU: 7390
2nd Process: PID: 2046, CPU: 7390

Server response:
1st Process: PID: 2027, CPU: 7390
2nd Process: PID: 2046, CPU: 7390

Server response:
1st Process: PID: 2027, CPU: 7390
2nd Process: PID: 2046, CPU: 7390
```

```
ashishbargoti@ashishbargoti:~/Downloads/tmp/Assignment2$ gcc server.c -o server
ashishbargoti@ashishbargoti:~/Downloads/tmp/Assignment2$ ./server
pid: 31210 ip
Server listening on port 8080...
```

initiating 10 client requests



```
ashish_bargoti@INBOOK_X2:/mnt/d/college/MyCodeDiary/C++/CP/CN tut/Assignment2$ ls
client    multi_server.c  sclient  select.c         server    single_server
client.c  pt.py           select   select_client.c  server.c  single_server.c
ashish_bargoti@INBOOK_X2:/mnt/d/college/MyCodeDiary/C++/CP/CN tut/Assignment2$ ./client 192.168.56.102
10
Usage: ./client <server_ip> <num_clients>
ashish_bargoti@INBOOK_X2:/mnt/d/college/MyCodeDiary/C++/CP/CN tut/Assignment2$ ./client 192.168.56.102
 10
Server response:
1st Process: PID: 2027, CPU: 7390
2nd Process: PID: 2046, CPU: 7390

Server response:
1st Process: PID: 2027, CPU: 7390
2nd Process: PID: 2046, CPU: 7390

Server response:
1st Process: PID: 2027, CPU: 7390
2nd Process: PID: 2046, CPU: 7390

Server response:
1st Process: PID: 2027, CPU: 7390
2nd Process: PID: 2046, CPU: 7390

Server response:
1st Process: PID: 2027, CPU: 7390
2nd Process: PID: 2046, CPU: 7390

Server response:
1st Process: PID: 2027, CPU: 7390
2nd Process: PID: 2046, CPU: 7390

Server response:
1st Process: PID: 2027, CPU: 7390
2nd Process: PID: 2046, CPU: 7390

Server response:
1st Process: PID: 2027, CPU: 7390
2nd Process: PID: 2046, CPU: 7390

Server response:
1st Process: PID: 2027, CPU: 7390
2nd Process: PID: 2046, CPU: 7390

Server response:
1st Process: PID: 2027, CPU: 7390
2nd Process: PID: 2046, CPU: 7390

ashish_bargoti@INBOOK_X2:/mnt/d/college/MyCodeDiary/C++/CP/CN tut/Assignment2$
```

```
ashishbargoti@ashishbargoti:~/Downloads/tmp/Assignment2$ gcc server.c -o server
ashishbargoti@ashishbargoti:~/Downloads/tmp/Assignment2$ ./server
pid: 31210 ip
Server listening on port 8080...
^C
oti@ashishbargoti:~/Downloads/tmp/Assignment2$ S
```

1. Server Setup (TCP Socket)

- **TCP Socket Creation**: The server uses the `socket()` function to create a TCP socket. The server binds the socket to a specific IP and port using `bind()`. It then listens for incoming client connections using `listen()`.

- **Multithreaded Server**: Upon accepting a connection from a client using `accept()`, the server creates a new thread for handling the client using the `pthread` library. This allows the server to handle multiple clients concurrently while continuing to listen for new connections on the main thread.
- **4-Tuple Socket Info**: The new socket created upon accepting a client connection has 4-tuple information (server IP, server listening port, client IP, and client port).

2. Handling Multiple Clients

- **Threading Mechanism**: The server creates new threads for each client connection. Each thread handles the client connection independently using the `pthread_create()` function. The main thread keeps the server listening for new client connections.
- **Concurrency**: This multithreaded approach allows multiple clients to be connected simultaneously, with each thread performing specific tasks for its respective client.

3. Client Setup

- The client also creates a socket and uses the `connect()` function to establish a TCP connection with the server.
- **Concurrent Client Requests**: The client can initiate multiple concurrent connections based on the value of `n` (the number of clients), which is passed as a command-line argument. This allows for stress-testing the server's multithreading capabilities.

4. Fetching Top CPU-Consuming Processes

- Once the connection is established, the client sends a request to the server to fetch details of the top two CPU-consuming processes.
- **Server Process Data**: The server reads the `/proc/[pid]/stat` files in the `/proc` filesystem to gather information about each process, such as its name, PID, and CPU usage (user + kernel mode CPU time). The `/proc/[pid]/stat` file

contains critical performance statistics, which are parsed to obtain the desired data.

- The server computes the top two CPU-consuming processes based on user and kernel mode CPU times.

5. Transmitting Data to the Client

- After gathering the information, the server sends the details (process name, PID, and CPU usage in clock ticks) back to the client through the connected socket.
- The data is sent as a formatted message, which includes information about the two most CPU-intensive processes at that time.

6. Client Output and Connection Termination

- Upon receiving the server's response, the client processes the received data and prints the details (process name, PID, and CPU usage).
- The client then closes the connection.

Server Code (server.c)

The server code handles socket creation, connection acceptance, and multithreading.

Key sections:

- **Socket Creation and Binding**:

```
int server_fd, new_socket;
struct sockaddr_in address;
int opt = 1;
int addrlen = sizeof(address);

server_fd = socket(AF_INET, SOCK_STREAM, 0);
setsockopt(server_fd, SOL_SOCKET, SO_REUSEADDR | SO_REUSEP
ORT, &opt, sizeof(opt));
```

```
address.sin_family = AF_INET;
address.sin_addr.s_addr = INADDR_ANY;
address.sin_port = htons(PORT);

bind(server_fd, (struct sockaddr *)&address, sizeof(addres
s));
listen(server_fd, 3);
```

- **Handling Multiple Clients with Threads**:

```
pthread_t thread_id;
pthread_create(&thread_id, NULL, handle_client, (void *)&n
ew_socket);
pthread_detach(thread_id);
```

- **Fetching CPU Information**:
  - Read from `/proc/[pid]/stat` to parse the CPU usage for all processes and find the top two CPU consumers.
- **Sending Data to Client**:

```
send(new_socket, buffer, strlen(buffer), 0);
```

Client Code (client.c)

The client code initiates a connection to the server and sends requests.

Key sections:

- **Socket Creation and Connection**:

```
struct sockaddr_in serv_addr;

sock = socket(AF_INET, SOCK_STREAM, 0);
serv_addr.sin_family = AF_INET;
serv_addr.sin_port = htons(PORT);
```

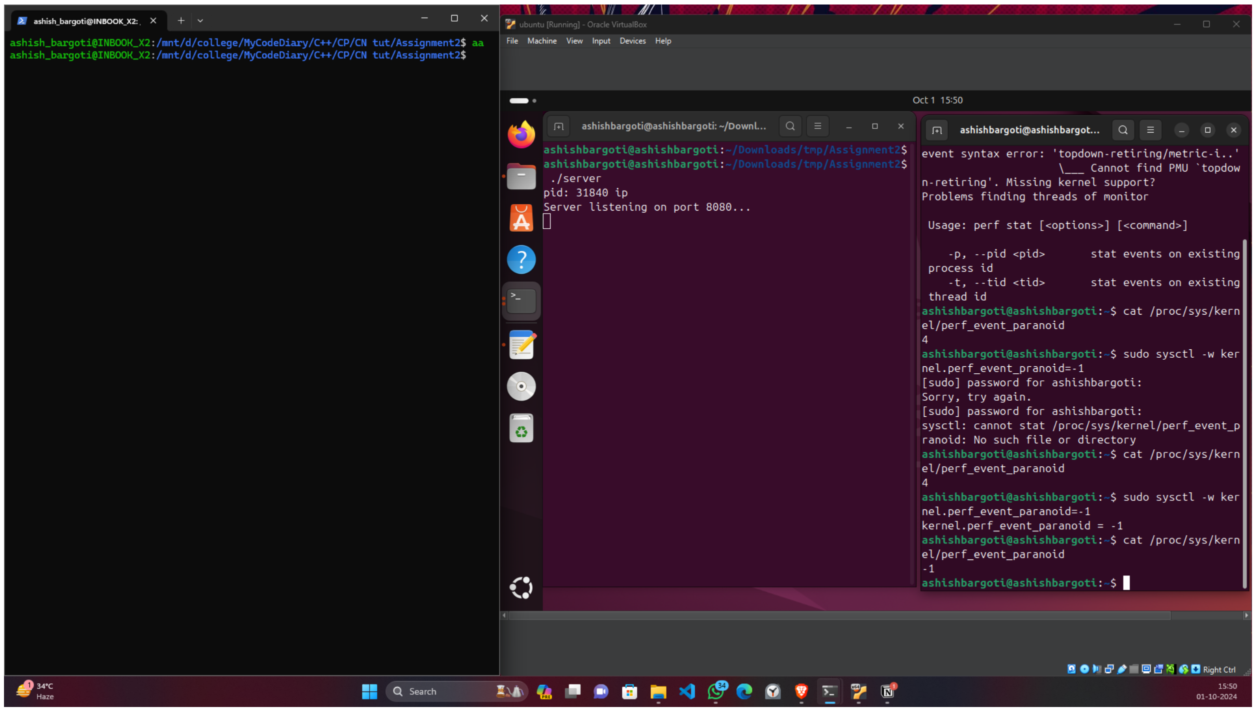
```
connect(sock, (struct sockaddr *)&serv_addr, sizeof(serv_a
ddr));
```

- **Sending and Receiving Data**:

```
send(sock, request, strlen(request), 0);
read(sock, buffer, 1024);
```

- **Taskset Usage**: `taskset` is used to pin both the client and server processes to specific CPU cores. This ensures that the performance of the processes can be measured in isolation from other processes running on the same system.

Q2:



```
ashish_bargoti@INBOOK_X2:/mnt/d/college/MyCodeDiary/C++/CP/CN tut/Assignment2$ aa
ashish_bargoti@INBOOK_X2:/mnt/d/college/MyCodeDiary/C++/CP/CN tut/Assignment2$
```

```
ashishbargoti@ashishbargoti:~/Downloads/tmp/Assignment2$
ashishbargoti@ashishbargoti:~/Downloads/tmp/Assignment2$
 ./server
pid: 31840 ip
Server listening on port 8080...
```

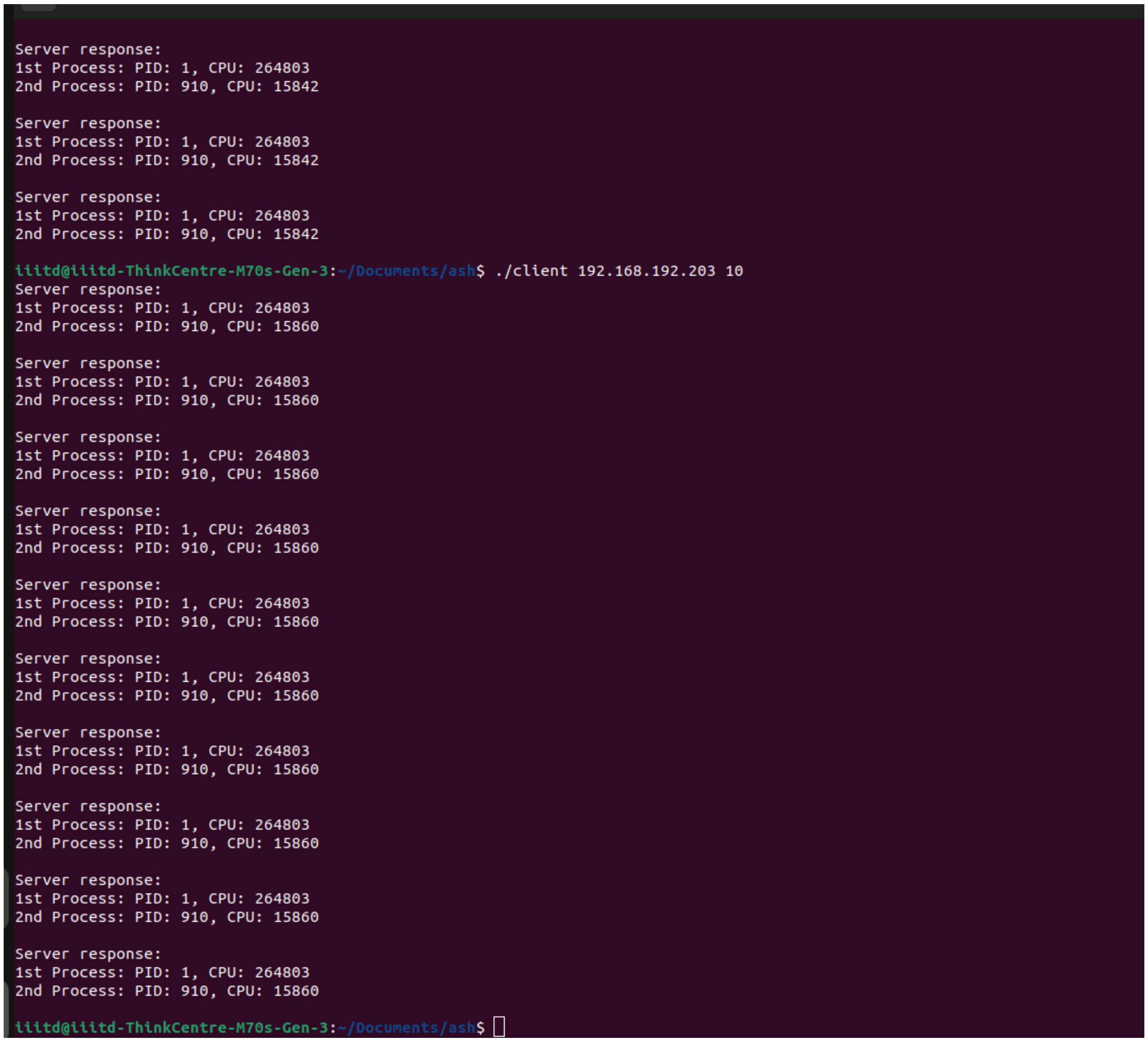
```
event syntax error: 'topdown-retiring/metric-i..'
                     \___ Cannot find PMU `topdow
n-retiring'. Missing kernel support?
Problems finding threads of monitor

 Usage: perf stat [<options>] [<command>]

    -p, --pid <pid>       stat events on existing
 process id
    -t, --tid <tid>       stat events on existing
 thread id
ashishbargoti@ashishbargoti:~$ cat /proc/sys/kern
el/perf_event_paranoid
4
ashishbargoti@ashishbargoti:~$ sudo sysctl -w ker
nel.perf_event_pranoid=-1
[sudo] password for ashishbargoti:
Sorry, try again.
[sudo] password for ashishbargoti:
sysctl: cannot stat /proc/sys/kernel/perf_event_p
ranoid: No such file or directory
ashishbargoti@ashishbargoti:~$ cat /proc/sys/kern
el/perf_event_paranoid
4
ashishbargoti@ashishbargoti:~$ sudo sysctl -w ker
nel.perf_event_paranoid=-1
kernel.perf_event_paranoid = -1
ashishbargoti@ashishbargoti:~$ cat /proc/sys/kern
el/perf_event_paranoid
-1
ashishbargoti@ashishbargoti:~$
```

ubuntu [Running] - Oracle VirtualBox
File Machine View Input Devices Help
Oct 1 15:50
Right Ctrl
15:50
01-10-2024

Q2:

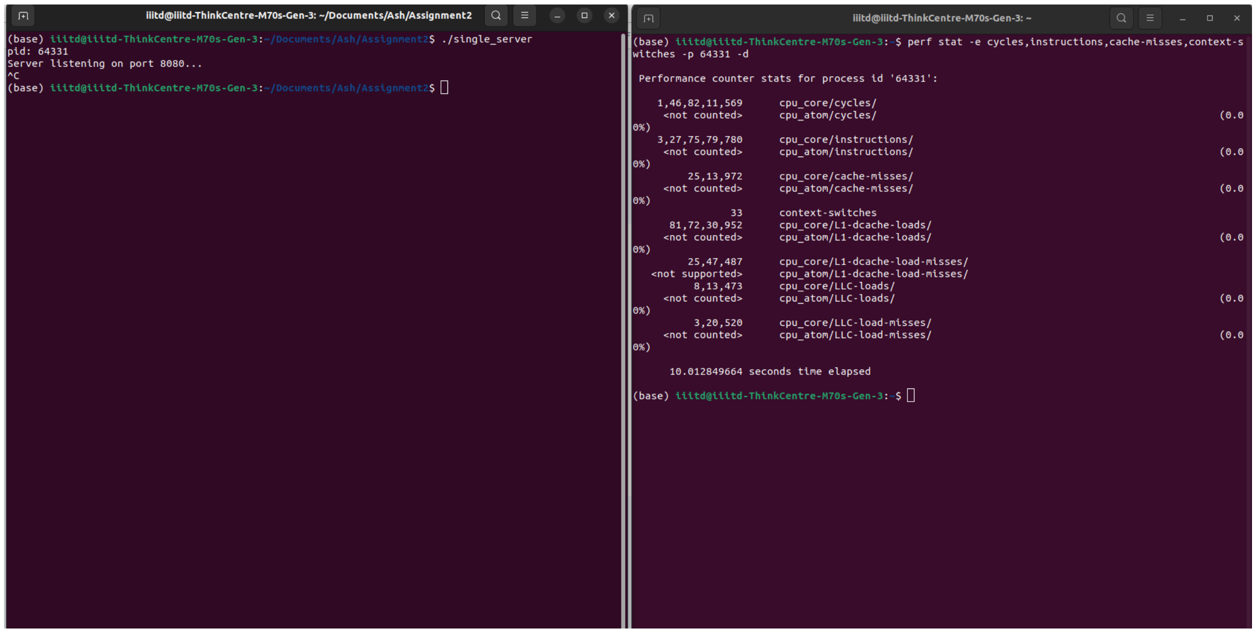
(a) Single-threaded TCP client-server

Client:



```
Server response:
1st Process: PID: 1, CPU: 264803
2nd Process: PID: 910, CPU: 15842

Server response:
1st Process: PID: 1, CPU: 264803
2nd Process: PID: 910, CPU: 15842

Server response:
1st Process: PID: 1, CPU: 264803
2nd Process: PID: 910, CPU: 15842

iiitd@iiitd-ThinkCentre-M70s-Gen-3:~/Documents/ash$ ./client 192.168.192.203 10
Server response:
1st Process: PID: 1, CPU: 264803
2nd Process: PID: 910, CPU: 15860

Server response:
1st Process: PID: 1, CPU: 264803
2nd Process: PID: 910, CPU: 15860

Server response:
1st Process: PID: 1, CPU: 264803
2nd Process: PID: 910, CPU: 15860

Server response:
1st Process: PID: 1, CPU: 264803
2nd Process: PID: 910, CPU: 15860

Server response:
1st Process: PID: 1, CPU: 264803
2nd Process: PID: 910, CPU: 15860

Server response:
1st Process: PID: 1, CPU: 264803
2nd Process: PID: 910, CPU: 15860

Server response:
1st Process: PID: 1, CPU: 264803
2nd Process: PID: 910, CPU: 15860

Server response:
1st Process: PID: 1, CPU: 264803
2nd Process: PID: 910, CPU: 15860

Server response:
1st Process: PID: 1, CPU: 264803
2nd Process: PID: 910, CPU: 15860

Server response:
1st Process: PID: 1, CPU: 264803
2nd Process: PID: 910, CPU: 15860

iiitd@iiitd-ThinkCentre-M70s-Gen-3:~/Documents/ash$ 
```

server:

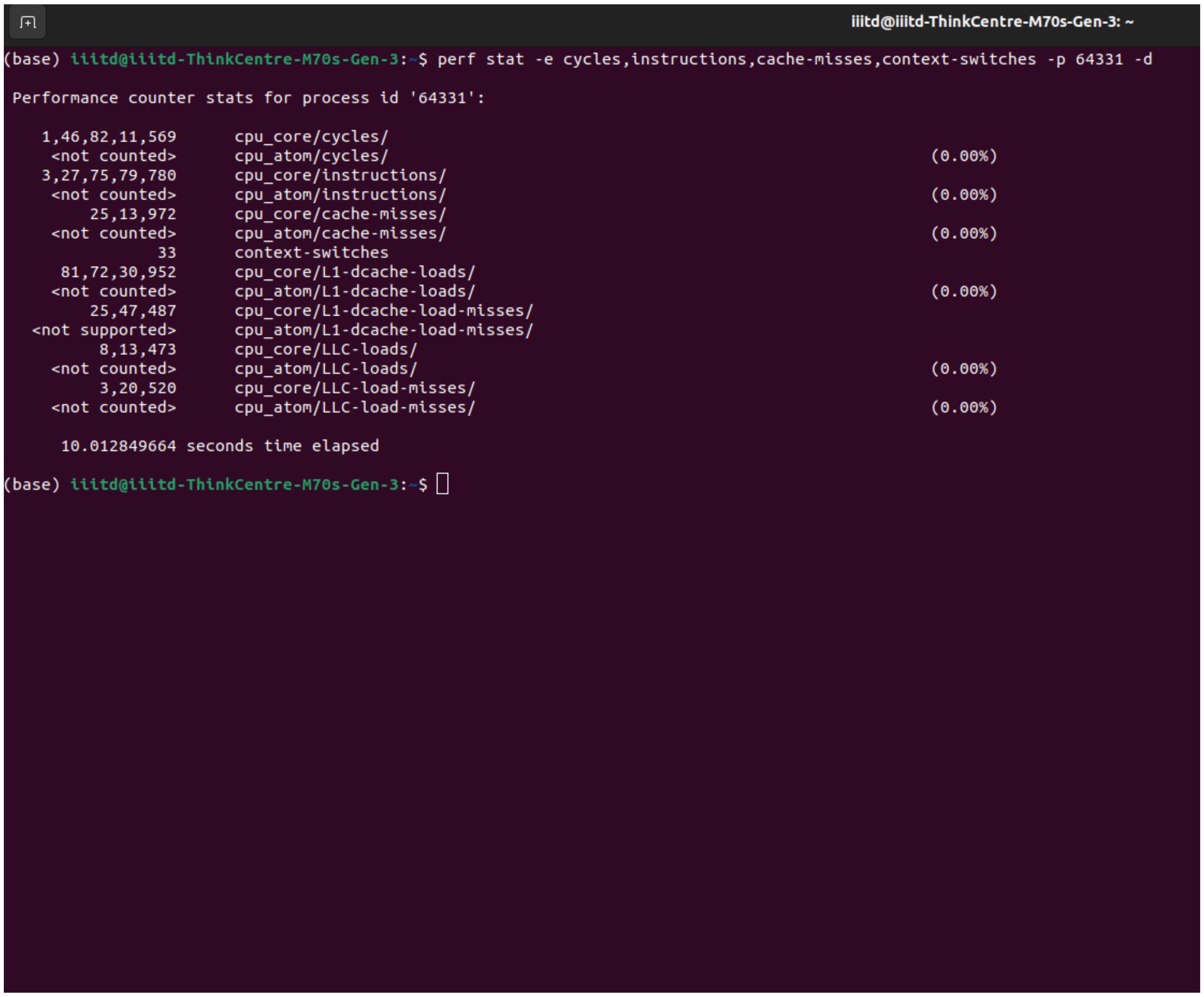


iiitd@iiitd-ThinkCentre-M70s-Gen-3: ~/Documents/Ash/Assignment2

```
(base) iiitd@iiitd-ThinkCentre-M70s-Gen-3:~/Documents/Ash/Assignment2$ ./single_server
pid: 64331
Server listening on port 8080...
^C
(base) iiitd@iiitd-ThinkCentre-M70s-Gen-3:~/Documents/Ash/Assignment2$ 
```

iiitd@iiitd-ThinkCentre-M70s-Gen-3: ~

```
(base) iiitd@iiitd-ThinkCentre-M70s-Gen-3:~$ perf stat -e cycles,instructions,cache-misses,context-s
witches -p 64331 -d

 Performance counter stats for process id '64331':

    1,46,82,11,569      cpu_core/cycles/
     <not counted>      cpu_atom/cycles/                                                      (0.0
0%)
    3,27,75,79,780      cpu_core/instructions/
     <not counted>      cpu_atom/instructions/                                                (0.0
0%)
         25,13,972      cpu_core/cache-misses/
     <not counted>      cpu_atom/cache-misses/                                                (0.0
0%)
                33      context-switches
      81,72,30,952      cpu_core/L1-dcache-loads/
     <not counted>      cpu_atom/L1-dcache-loads/                                             (0.0
0%)
         25,47,487      cpu_core/L1-dcache-load-misses/
   <not supported>      cpu_atom/L1-dcache-load-misses/
          8,13,473      cpu_core/LLC-loads/
     <not counted>      cpu_atom/LLC-loads/                                                   (0.0
0%)
          3,20,520      cpu_core/LLC-load-misses/
     <not counted>      cpu_atom/LLC-load-misses/                                             (0.0
0%)

      10.012849664 seconds time elapsed

(base) iiitd@iiitd-ThinkCentre-M70s-Gen-3:~$ 
```



iiitd@iiitd-ThinkCentre-M70s-Gen-3: ~

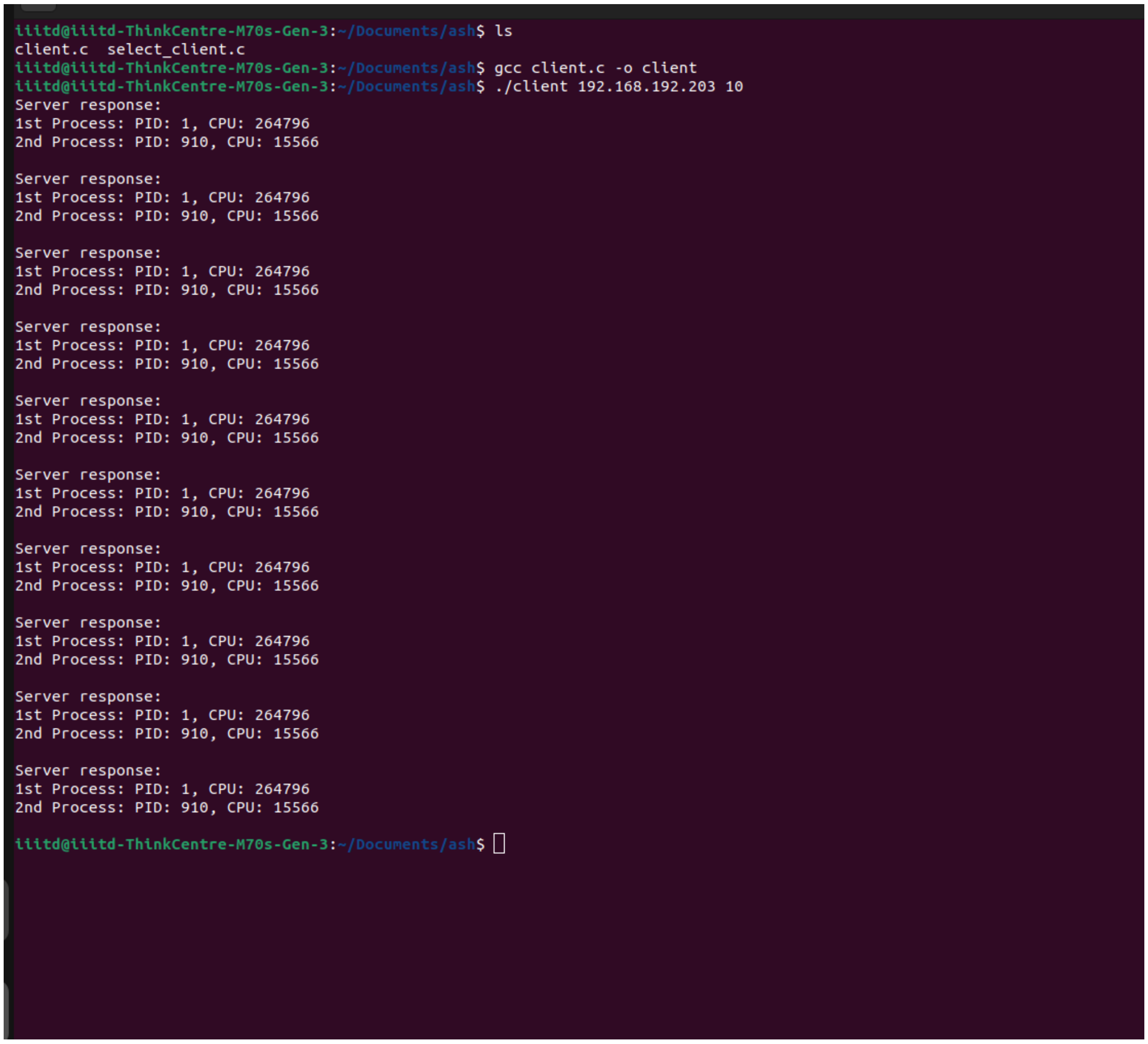
```
(base) iiitd@iiitd-ThinkCentre-M70s-Gen-3:~$ perf stat -e cycles,instructions,cache-misses,context-switches -p 64331 -d

 Performance counter stats for process id '64331':

    1,46,82,11,569      cpu_core/cycles/
     <not counted>      cpu_atom/cycles/                                                      (0.00%)
    3,27,75,79,780      cpu_core/instructions/
     <not counted>      cpu_atom/instructions/                                                (0.00%)
         25,13,972      cpu_core/cache-misses/
     <not counted>      cpu_atom/cache-misses/                                                (0.00%)
                33      context-switches
      81,72,30,952      cpu_core/L1-dcache-loads/
     <not counted>      cpu_atom/L1-dcache-loads/                                             (0.00%)
         25,47,487      cpu_core/L1-dcache-load-misses/
   <not supported>      cpu_atom/L1-dcache-load-misses/
          8,13,473      cpu_core/LLC-loads/
     <not counted>      cpu_atom/LLC-loads/                                                   (0.00%)
          3,20,520      cpu_core/LLC-load-misses/
     <not counted>      cpu_atom/LLC-load-misses/                                             (0.00%)

      10.012849664 seconds time elapsed

(base) iiitd@iiitd-ThinkCentre-M70s-Gen-3:~$ 
```

- **CPU Cycles and Instructions**:
    - The output shows a high count of CPU cycles (`1,46,82,11,569`) and instructions (`3,27,75,79,780`).
    - This suggests that the server is doing a lot of work in processing requests
    - The number of cycles divided by the number of instructions us gives an indication of how effectively the CPU executes instructions. A high value indicates that it takes more CPU cycles to execute each instruction, which can happen due to cache misses, CPU stalls, or other bottlenecks.
- **Cache Misses**:
    - **L1-Dcache-load-misses** (`25,47,487`) and **LLC-load-misses** (`3,20,520`) indicate how often requested data was not available in the corresponding cache level.
    - The cache misses suggest that the server code might not be making efficient use of the cache. This can happen if:
        - There are too many context switches, causing data to be evicted from the cache.
        - The data access pattern is irregular, which often happens in single-threaded implementations handling multiple requests one after another.
        - The data being accessed doesn’t fit well in the cache, leading to frequent misses.
- **Context Switches**:
    - The **context switches** count is relatively low (`33`), which makes sense for a single-threaded implementation since it is only handling one client at a time.
    - This low count indicates minimal multitasking or parallel processing, which is a characteristic of single-threaded servers. In a single-threaded approach, fewer context switches mean that the server doesn't need to

save and load different tasks often, which is good for latency but limits scalability.

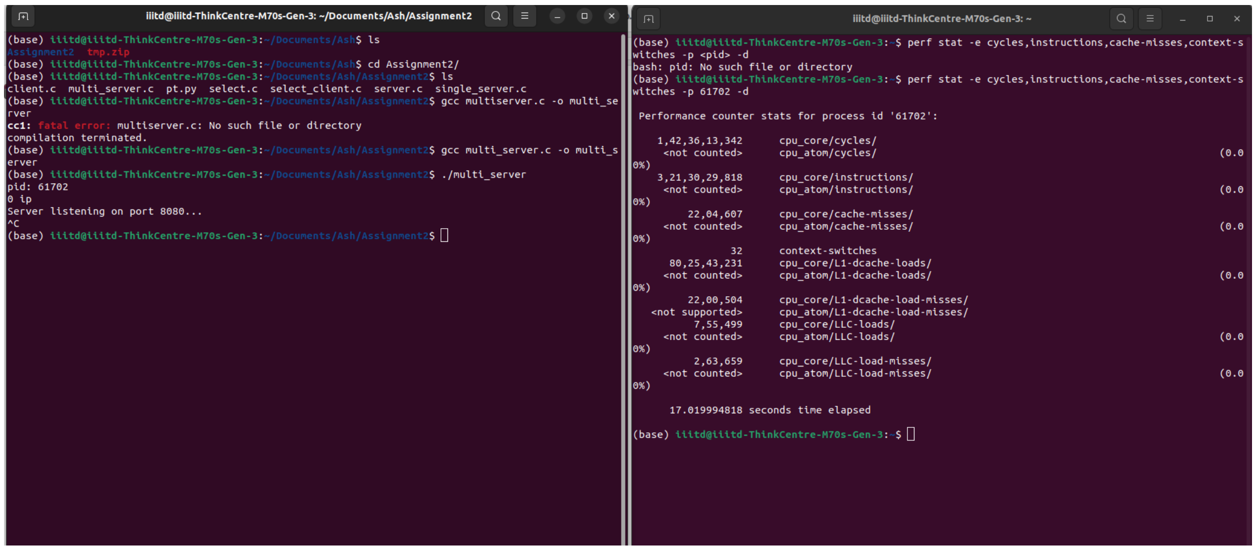
(b) Concurrent TCP client-server

Client:



```
iiitd@iiitd-ThinkCentre-M70s-Gen-3:~/Documents/ash$ ls
client.c  select_client.c
iiitd@iiitd-ThinkCentre-M70s-Gen-3:~/Documents/ash$ gcc client.c -o client
iiitd@iiitd-ThinkCentre-M70s-Gen-3:~/Documents/ash$ ./client 192.168.192.203 10
Server response:
1st Process: PID: 1, CPU: 264796
2nd Process: PID: 910, CPU: 15566

Server response:
1st Process: PID: 1, CPU: 264796
2nd Process: PID: 910, CPU: 15566

Server response:
1st Process: PID: 1, CPU: 264796
2nd Process: PID: 910, CPU: 15566

Server response:
1st Process: PID: 1, CPU: 264796
2nd Process: PID: 910, CPU: 15566

Server response:
1st Process: PID: 1, CPU: 264796
2nd Process: PID: 910, CPU: 15566

Server response:
1st Process: PID: 1, CPU: 264796
2nd Process: PID: 910, CPU: 15566

Server response:
1st Process: PID: 1, CPU: 264796
2nd Process: PID: 910, CPU: 15566

Server response:
1st Process: PID: 1, CPU: 264796
2nd Process: PID: 910, CPU: 15566

Server response:
1st Process: PID: 1, CPU: 264796
2nd Process: PID: 910, CPU: 15566

Server response:
1st Process: PID: 1, CPU: 264796
2nd Process: PID: 910, CPU: 15566

iiitd@iiitd-ThinkCentre-M70s-Gen-3:~/Documents/ash$ 
```

In the above image the program client.c is compiled via the command gcc client.c -o client. Then we ran the compiled client program by connecting it to a server at 192.168.192.203 and initialized the number of clients to 10



```
(base) iiitd@iiitd-ThinkCentre-M70s-Gen-3:~/Documents/Ash$ ls
Assignment2  tmp.zip
(base) iiitd@iiitd-ThinkCentre-M70s-Gen-3:~/Documents/Ash$ cd Assignment2/
(base) iiitd@iiitd-ThinkCentre-M70s-Gen-3:~/Documents/Ash/Assignment2$ ls
client.c  multi_server.c  pt.py  select.c  select_client.c  server.c  single_server.c
(base) iiitd@iiitd-ThinkCentre-M70s-Gen-3:~/Documents/Ash/Assignment2$ gcc multiserver.c -o multi_se
rver
cc1: fatal error: multiserver.c: No such file or directory
compilation terminated.
(base) iiitd@iiitd-ThinkCentre-M70s-Gen-3:~/Documents/Ash/Assignment2$ gcc multi_server.c -o multi_s
erver
(base) iiitd@iiitd-ThinkCentre-M70s-Gen-3:~/Documents/Ash/Assignment2$ ./multi_server
pid: 61702
0 ip
Server listening on port 8080...
^C
(base) iiitd@iiitd-ThinkCentre-M70s-Gen-3:~/Documents/Ash/Assignment2$
```

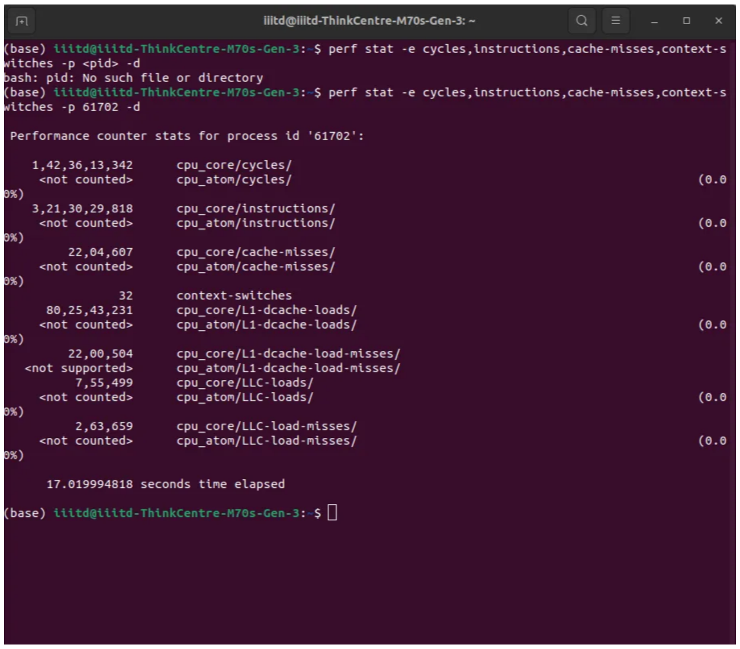
```
(base) iiitd@iiitd-ThinkCentre-M70s-Gen-3:~$ perf stat -e cycles,instructions,cache-misses,context-s
witches -p <pid> -d
bash: pid: No such file or directory
(base) iiitd@iiitd-ThinkCentre-M70s-Gen-3:~$ perf stat -e cycles,instructions,cache-misses,context-s
witches -p 61702 -d

 Performance counter stats for process id '61702':

    1,42,36,13,342      cpu_core/cycles/
     <not counted>      cpu_atom/cycles/                                                     (0.0
0%)
    3,21,30,29,818      cpu_core/instructions/
     <not counted>      cpu_atom/instructions/                                               (0.0
0%)
         22,04,607      cpu_core/cache-misses/
     <not counted>      cpu_atom/cache-misses/                                               (0.0
0%)
                32      context-switches
      80,25,43,231      cpu_core/L1-dcache-loads/
     <not counted>      cpu_atom/L1-dcache-loads/                                            (0.0
0%)
         22,00,504      cpu_core/L1-dcache-load-misses/
   <not supported>      cpu_atom/L1-dcache-load-misses/
          7,55,499      cpu_core/LLC-loads/
     <not counted>      cpu_atom/LLC-loads/                                                  (0.0
0%)
          2,63,659      cpu_core/LLC-load-misses/
     <not counted>      cpu_atom/LLC-load-misses/                                            (0.0
0%)

      17.019994818 seconds time elapsed

(base) iiitd@iiitd-ThinkCentre-M70s-Gen-3:~$
```

Server Initialization:

In the above image the server program is started and is listening to port 8080,the server's process ID(PID) is 31840, showing that its's ready to accept connections form the client.

Using perf tool:

Perf tool is used to monitor the server's performance.



```
(base) iiitd@iiitd-ThinkCentre-M70s-Gen-3:~$ perf stat -e cycles,instructions,cache-misses,context-s
witches -p <pid> -d
bash: pid: No such file or directory
(base) iiitd@iiitd-ThinkCentre-M70s-Gen-3:~$ perf stat -e cycles,instructions,cache-misses,context-s
witches -p 61702 -d

 Performance counter stats for process id '61702':

    1,42,36,13,342      cpu_core/cycles/
     <not counted>      cpu_atom/cycles/                                                     (0.0
0%)
    3,21,30,29,818      cpu_core/instructions/
     <not counted>      cpu_atom/instructions/                                               (0.0
0%)
         22,04,607      cpu_core/cache-misses/
     <not counted>      cpu_atom/cache-misses/                                               (0.0
0%)
                32      context-switches
      80,25,43,231      cpu_core/L1-dcache-loads/
     <not counted>      cpu_atom/L1-dcache-loads/                                            (0.0
0%)
         22,00,504      cpu_core/L1-dcache-load-misses/
   <not supported>      cpu_atom/L1-dcache-load-misses/
          7,55,499      cpu_core/LLC-loads/
     <not counted>      cpu_atom/LLC-loads/                                                  (0.0
0%)
          2,63,659      cpu_core/LLC-load-misses/
     <not counted>      cpu_atom/LLC-load-misses/                                            (0.0
0%)

      17.019994818 seconds time elapsed

(base) iiitd@iiitd-ThinkCentre-M70s-Gen-3:~$
```

The concurrent server code (
`multi_server.c`) includes multi-threading with `pthread`, allowing it to handle multiple clients simultaneously.

Performance Observations for Concurrent TCP Client-Server

1. **CPU Cycles and Instructions**:
    - **Cycles**: `1,42,36,13,342`
    - **Instructions**: `3,21,30,29,818`

    Analysis:

    - Compared to the single-threaded version, the number of CPU cycles and instructions has decreased slightly, but they are still quite significant. The reason is that the concurrent server handles multiple client connections in parallel using threads. Each thread processes a client independently, which can lead to better CPU utilization.

Cache Misses:

- **L1-Dcache-load-misses**: `22,00,504`
- **LLC-load-misses**: `2,63,659`

Analysis:

- The **L1-Dcache-load-misses** have decreased (`25,47,487` to `22,00,504`) compared to the single-threaded version, indicating better utilization of L1 cache.
- Context switches would increase significantly if the server is handling more concurrent connections or if there is more competition for CPU resources.

Context Switches:

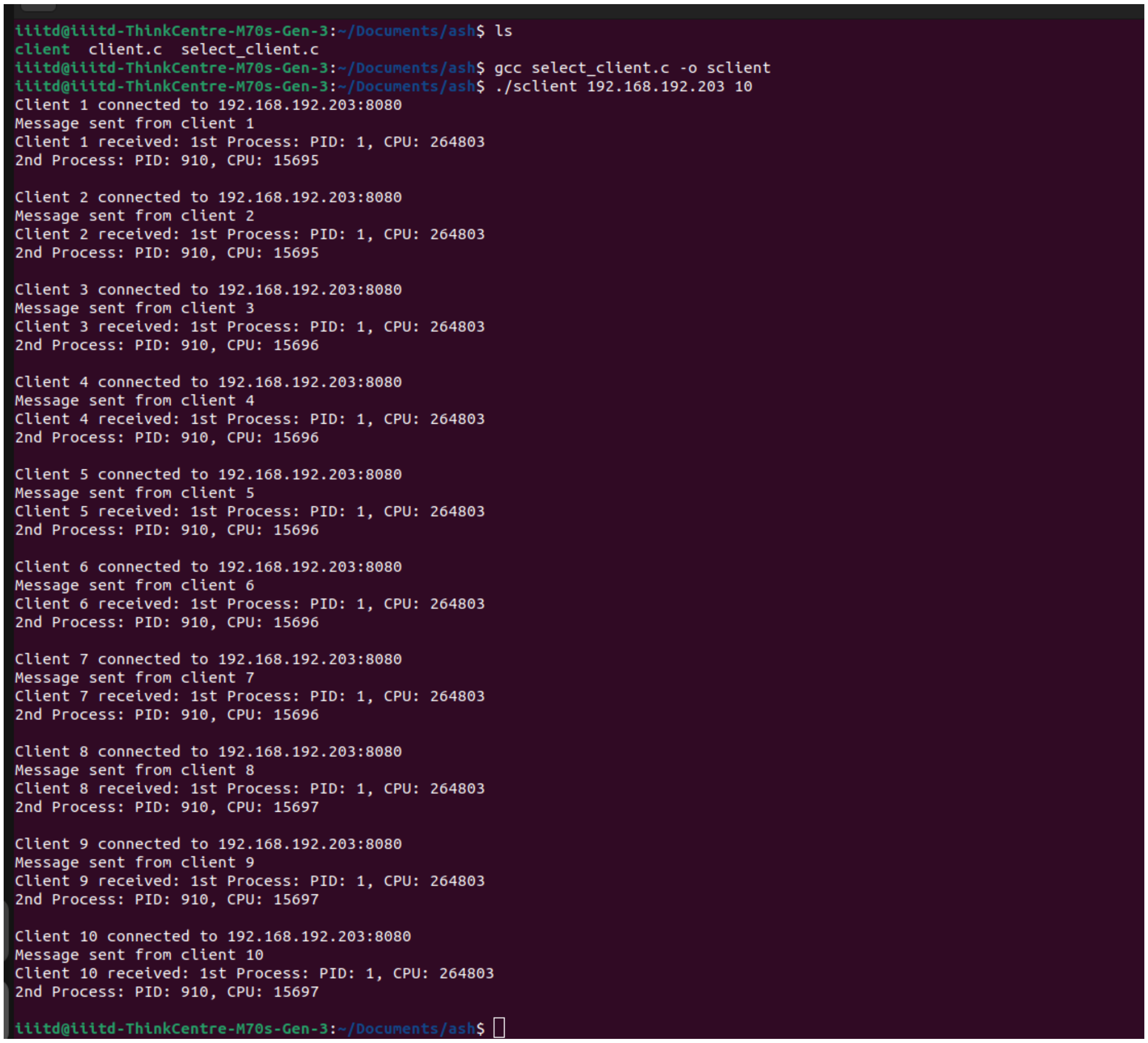
- **Context Switches**: `32`

Analysis:

- The number of context switches (`32`) is similar to the single-threaded version (`33`). One would expect a concurrent server to have higher context switches, given that multiple threads are involved.

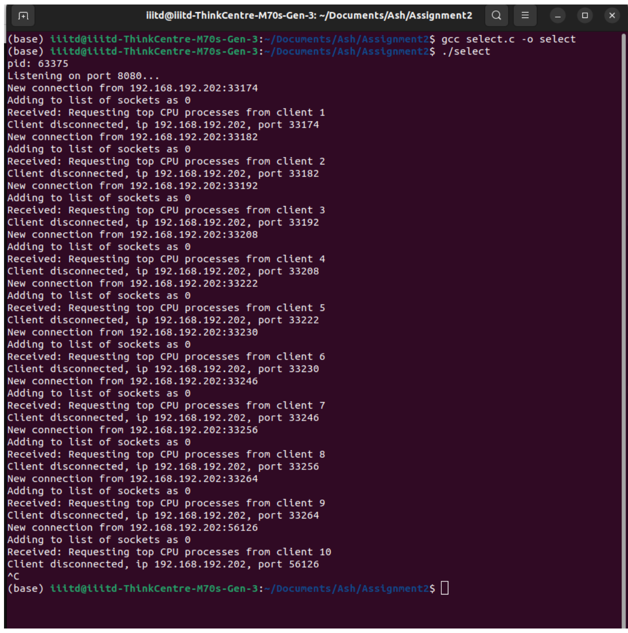
(c) TCP client-server using "select"

client:

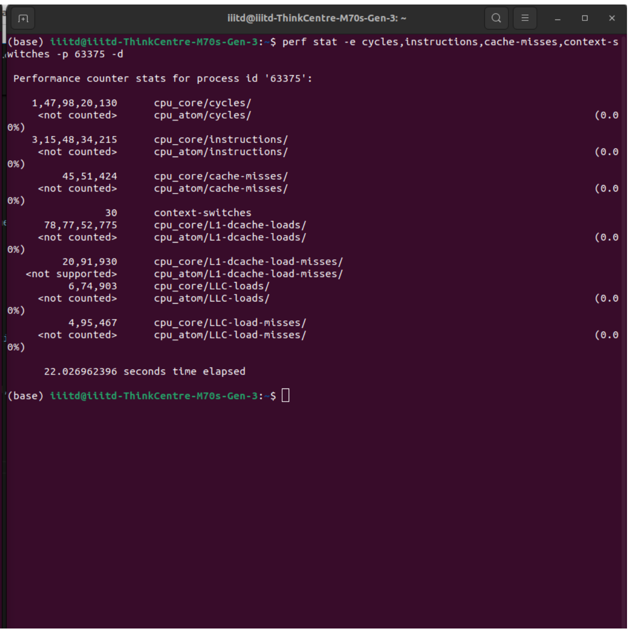


```
iiitd@iiitd-ThinkCentre-M70s-Gen-3:~/Documents/ash$ ls
client  client.c  select_client.c
iiitd@iiitd-ThinkCentre-M70s-Gen-3:~/Documents/ash$ gcc select_client.c -o sclient
iiitd@iiitd-ThinkCentre-M70s-Gen-3:~/Documents/ash$ ./sclient 192.168.192.203 10
Client 1 connected to 192.168.192.203:8080
Message sent from client 1
Client 1 received: 1st Process: PID: 1, CPU: 264803
2nd Process: PID: 910, CPU: 15695

Client 2 connected to 192.168.192.203:8080
Message sent from client 2
Client 2 received: 1st Process: PID: 1, CPU: 264803
2nd Process: PID: 910, CPU: 15695

Client 3 connected to 192.168.192.203:8080
Message sent from client 3
Client 3 received: 1st Process: PID: 1, CPU: 264803
2nd Process: PID: 910, CPU: 15696

Client 4 connected to 192.168.192.203:8080
Message sent from client 4
Client 4 received: 1st Process: PID: 1, CPU: 264803
2nd Process: PID: 910, CPU: 15696

Client 5 connected to 192.168.192.203:8080
Message sent from client 5
Client 5 received: 1st Process: PID: 1, CPU: 264803
2nd Process: PID: 910, CPU: 15696

Client 6 connected to 192.168.192.203:8080
Message sent from client 6
Client 6 received: 1st Process: PID: 1, CPU: 264803
2nd Process: PID: 910, CPU: 15696

Client 7 connected to 192.168.192.203:8080
Message sent from client 7
Client 7 received: 1st Process: PID: 1, CPU: 264803
2nd Process: PID: 910, CPU: 15696

Client 8 connected to 192.168.192.203:8080
Message sent from client 8
Client 8 received: 1st Process: PID: 1, CPU: 264803
2nd Process: PID: 910, CPU: 15697

Client 9 connected to 192.168.192.203:8080
Message sent from client 9
Client 9 received: 1st Process: PID: 1, CPU: 264803
2nd Process: PID: 910, CPU: 15697

Client 10 connected to 192.168.192.203:8080
Message sent from client 10
Client 10 received: 1st Process: PID: 1, CPU: 264803
2nd Process: PID: 910, CPU: 15697

iiitd@iiitd-ThinkCentre-M70s-Gen-3:~/Documents/ash$ 
```

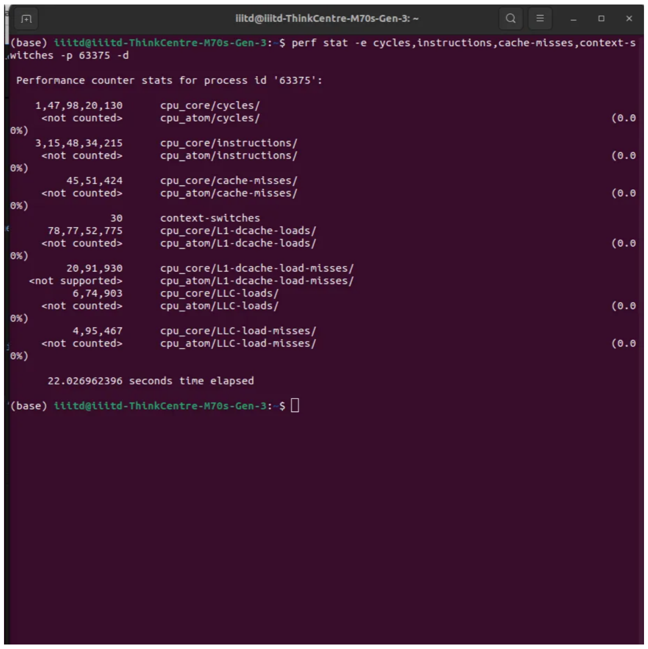
server



```
(base) iiitd@iiitd-ThinkCentre-M70s-Gen-3:~/Documents/Ash/Assignment2$ gcc select.c -o select
(base) iiitd@iiitd-ThinkCentre-M70s-Gen-3:~/Documents/Ash/Assignment2$ ./select
pid: 63375
Listening on port 8080...
New connection from 192.168.192.202:33174
Adding to list of sockets as 0
Received: Requesting top CPU processes from client 1
Client disconnected, ip 192.168.192.202, port 33174
New connection from 192.168.192.202:33182
Adding to list of sockets as 0
Received: Requesting top CPU processes from client 2
Client disconnected, ip 192.168.192.202, port 33182
New connection from 192.168.192.202:33192
Adding to list of sockets as 0
Received: Requesting top CPU processes from client 3
Client disconnected, ip 192.168.192.202, port 33192
New connection from 192.168.192.202:33208
Adding to list of sockets as 0
Received: Requesting top CPU processes from client 4
Client disconnected, ip 192.168.192.202, port 33208
New connection from 192.168.192.202:33222
Adding to list of sockets as 0
Received: Requesting top CPU processes from client 5
Client disconnected, ip 192.168.192.202, port 33222
New connection from 192.168.192.202:33230
Adding to list of sockets as 0
Received: Requesting top CPU processes from client 6
Client disconnected, ip 192.168.192.202, port 33230
New connection from 192.168.192.202:33246
Adding to list of sockets as 0
Received: Requesting top CPU processes from client 7
Client disconnected, ip 192.168.192.202, port 33246
New connection from 192.168.192.202:33256
Adding to list of sockets as 0
Received: Requesting top CPU processes from client 8
Client disconnected, ip 192.168.192.202, port 33256
New connection from 192.168.192.202:33264
Adding to list of sockets as 0
Received: Requesting top CPU processes from client 9
Client disconnected, ip 192.168.192.202, port 33264
New connection from 192.168.192.202:56126
Adding to list of sockets as 0
Received: Requesting top CPU processes from client 10
Client disconnected, ip 192.168.192.202, port 56126
^C
(base) iiitd@iiitd-ThinkCentre-M70s-Gen-3:~/Documents/Ash/Assignment2$
```



```
(base) iiitd@iiitd-ThinkCentre-M70s-Gen-3:~$ perf stat -e cycles,instructions,cache-misses,context-s
witches -p 63375 -d

 Performance counter stats for process id '63375':

    1,47,98,20,130      cpu_core/cycles/
     <not counted>      cpu_atom/cycles/                                                      (0.0
0%)
    3,15,48,34,215      cpu_core/instructions/
     <not counted>      cpu_atom/instructions/                                                (0.0
0%)
         45,51,424      cpu_core/cache-misses/
     <not counted>      cpu_atom/cache-misses/                                                (0.0
0%)
                30      context-switches
      78,77,52,775      cpu_core/L1-dcache-loads/
     <not counted>      cpu_atom/L1-dcache-loads/                                             (0.0
0%)
         20,91,930      cpu_core/L1-dcache-load-misses/
   <not supported>      cpu_atom/L1-dcache-load-misses/
          6,74,903      cpu_core/LLC-loads/
     <not counted>      cpu_atom/LLC-loads/                                                   (0.0
0%)
          4,95,467      cpu_core/LLC-load-misses/
     <not counted>      cpu_atom/LLC-load-misses/                                             (0.0
0%)

      22.026962396 seconds time elapsed

(base) iiitd@iiitd-ThinkCentre-M70s-Gen-3:~$
```



```
(base) iiitd@iiitd-ThinkCentre-M70s-Gen-3:~$ perf stat -e cycles,instructions,cache-misses,context-s
witches -p 63375 -d

 Performance counter stats for process id '63375':

    1,47,98,20,130      cpu_core/cycles/
     <not counted>      cpu_atom/cycles/                                                      (0.0
0%)
    3,15,48,34,215      cpu_core/instructions/
     <not counted>      cpu_atom/instructions/                                                (0.0
0%)
         45,51,424      cpu_core/cache-misses/
     <not counted>      cpu_atom/cache-misses/                                                (0.0
0%)
                30      context-switches
      78,77,52,775      cpu_core/L1-dcache-loads/
     <not counted>      cpu_atom/L1-dcache-loads/                                             (0.0
0%)
         20,91,930      cpu_core/L1-dcache-load-misses/
   <not supported>      cpu_atom/L1-dcache-load-misses/
          6,74,903      cpu_core/LLC-loads/
     <not counted>      cpu_atom/LLC-loads/                                                   (0.0
0%)
          4,95,467      cpu_core/LLC-load-misses/
     <not counted>      cpu_atom/LLC-load-misses/                                             (0.0
0%)

      22.026962396 seconds time elapsed

(base) iiitd@iiitd-ThinkCentre-M70s-Gen-3:~$
```

The select-based server code (
`select.c`) uses the `select` system call to handle multiple client connections concurrently in a single-threaded manner.

Performance Observations for TCP Client-Server Using `select`

1. **CPU Cycles and Instructions**:
    - **Cycles**: `1,47,98,20,130`
    - **Instructions**: `3,15,48,34,215`

    Analysis:

    - The number of **cycles** and **instructions** for the select-based server is higher compared to both the single-threaded and concurrent (multi-threaded) servers.
    - This indicates that the select-based server is spending a considerable amount of CPU cycles monitoring multiple sockets and processing data. Since all clients are handled in a single thread, the server needs to continuously poll multiple connections, leading to increased work per instruction.

L1-Dcache-load-misses are lower compared to the single-threaded server but slightly higher than the concurrent server. This indicates that the select-based server's memory access is reasonably efficient and falls between the two approaches.

Select-Based Server: The **context switch count** is relatively low (`30`) compared to the expectation for a multi-client server. This reflects the fact that the server was handling multiple clients concurrently in a single-threaded context, reducing the need for frequent context switching that would otherwise occur with multi-threading.