

ASSIGNMENT 2 – LAB 4: SOCKET PROGRAMMING

MAIN TOPICS: MESSAGE-ORIENTED COMMUNICATION, TCP VS UDP, CLIENT SERVER MODEL, SOCKETS

Objective:

Write a Python script that opens a stream socket server listening on a given TCP port. For each new incoming connection, the server must store in a list the time elapsed since the previous connection setup (using at least millisecond precision). Then the server must store in another list the time elapsed since the previous data reception on that connection (again using at least millisecond precision). If a `--verbose` option is passed, the server must also print out the content of any data received from a client, decoded in text format. Before terminating, the server must print out the average inter-arrival time computed from both stored lists (connection setup time and data reception time). Tests must be run for both iterative and concurrent server modes.

As a client script, you can reuse the script developed in Assignment 1 (timestamp generator with different inter-event time distributions) after properly modifying it to send the timestamps through the stream socket instead of writing them to an output file. Also the client should print out the generated timestamps only if a `--verbose` option is passed. The client must always run in a multithreading concurrency mode.

Command line arguments:

The server-side script must allow these inputs from the command line:

- Server's IP address or hostname (optional, with a specified default value)
- Server's TCP port number (optional, with a specified default value)
- Choice between iterative and concurrent server mode (optional, with a specified default value)
- Verbose mode (optional, disabled by default)

The client-side script must allow these inputs from the command line:

- Number of workers to generate
- Number of inter-event intervals to generate
- Distribution of the inter-event time and related parameter(s), including at least:
 - deterministic (parameter: fixed inter-event time)
 - uniform within an interval $[0:T]$ (parameter: size of the interval)
 - exponential (parameter: mean event occurrence rate)
- Server's IP address or hostname to send the timestamps to (required)
- Server's TCP port number (optional, with a specified default value)
- Verbose mode (optional, disabled by default)

1ST ATTEMPT: MULTITHREADING FOR THE SERVER AND UNIFORM DISTRIBUTION FOR THE CLIENT

```
python3 ASSIGNMENT2_SERVER_done.py --port 55000 --concurrency-mode thr --verbose
```

```
python3 ASSIGNMENT2_CLIENT_done.py --workers 3 --intervals 5 --dist u --param 2.0 --
server 127.0.0.1 --port 55000 --verbose
```

```

PROBLEMS OUTPUT DEBUG CONSOLE TERMINAL PORTS

● mariapiabuonomo@MacBookAir esercizidistr % source /Users/mariapiabuonomo/Desktop/esercizidi
str/.venv/bin/activate
○ (.venv) mariapiabuonomo@MacBookAir esercizidistr % python3 ASSIGNMENT2_SERVER_done.py --por
t 55000 --concurrency-mode thr --verbose
Parsed CLI arguments: {'port': 55000, 'address': '', 'concurrency_mode': 'thr', 'verbose':
True}
The concurrent TCP server is ready to receive (PID = 95296)
[+] New server socket worker spawned for client 127.0.0.1:58177
Thread ID: 14714972 - PID: 95296 - PPID: 94794
[+] New server socket worker spawned for client 127.0.0.1:58178
Thread ID: 14714973 - PID: 95296 - PPID: 94794
[+] New server socket worker spawned for client 127.0.0.1:58179
Thread ID: 14714974 - PID: 95296 - PPID: 94794
Sentence "Worker 1 Event 1, Timestamp 1768823258707" received from 127.0.0.1:58179
Sentence "Worker 3, Event 1, Timestamp 1768823259886" received from 127.0.0.1:58178
Sentence "Worker 1, Event 2, Timestamp 1768823259914" received from 127.0.0.1:58179
Sentence "Worker 2, Event 1, Timestamp 1768823259917" received from 127.0.0.1:58177
Sentence "Worker 3, Event 2, Timestamp 1768823260026" received from 127.0.0.1:58178
Sentence "Worker 3, Event 3, Timestamp 1768823260068" received from 127.0.0.1:58178
Sentence "Worker 2, Event 2, Timestamp 1768823260823" received from 127.0.0.1:58177
Sentence "Worker 3, Event 4, Timestamp 1768823261184" received from 127.0.0.1:58178
Sentence "Worker 3, Event 5, Timestamp 1768823261376" received from 127.0.0.1:58178
[x] Connection closed for 127.0.0.1:58178
Sentence "Worker 1, Event 3, Timestamp 1768823261842" received from 127.0.0.1:58179
Sentence "Worker 2, Event 3, Timestamp 1768823262551" received from 127.0.0.1:58177
Sentence "Worker 1, Event 4, Timestamp 1768823262552" received from 127.0.0.1:58177
Sentence "Worker 2, Event 4, Timestamp 1768823263653" received from 127.0.0.1:58179
Sentence "Worker 2, Event 5, Timestamp 1768823264174" received from 127.0.0.1:58177
[x] Connection closed for 127.0.0.1:58177
Sentence "Worker 1, Event 5, Timestamp 1768823265363" received from 127.0.0.1:58179
[x] Connection closed for 127.0.0.1:58179
[ ]
```

^{^C}The server is terminating

Average connection inter-arrival time: 0.30 ms

Average data inter-arrival time: 1033.52 ms

Because these threads share the same memory space, the overhead for managing new connections is minimal, resulting in an extremely low average connection inter-arrival time of 0.30 ms. The observed average data inter-arrival time of 1033.52 ms aligns closely with the theoretical 1000 ms mean of the uniform distribution used by the client workers, proving that the threaded server can keep up with the data flow without introducing significant latency.

2ND ATTEMPT: MULTIPLE CLIENTS IN CONCURRENCY MODE (multiprocessing for the server)

```
python3 ASSIGNMENT2_SERVER_done.py --port 55001 --concurrency-mode proc --verbose
python3 ASSIGNMENT2_CLIENT_done.py -w 2 -n 4 -d d -p 1.0 -s 127.0.0.1 -P 55001 -v
python3 ASSIGNMENT2_CLIENT_done.py -w 3 -n 5 -d u -p 2.0 -s 127.0.0.1 -P 55001 -v
python3 ASSIGNMENT2_CLIENT_done.py -w 4 -n 6 -d e -p 0.5 -s 127.0.0.1 -P 55001 -v
```

CLIENT:

```

source /Users/mariapiabuonomo/Desktop/esercizidistr
● mariapiabuonomo@MacBookAir esercizidistr % source /Users/mariapiabuonomo/Desktop/esercizidistr/.venv/bin/activate
○ (.venv) mariapiabuonomo@MacBookAir esercizidistr % python3 ASSIGNMENT2_CLIENT_done.py -w 3 -n 5 -d u -p 2.0 -s 127.0.0.1 -P 55001 -v
Starting 3 threads connecting to 127.0.0.1:55001...
[Worker 3] Connected. Server says: Hello! You are connected to the server.
[Worker 1] Connected. Server says: Hello! You are connected to the server.
[Worker 2] Connected. Server says: Hello! You are connected to the server.
[Worker 1] Sending: Worker 1, Event 1, Timestamp 1768823630665
[Worker 2] Sending: Worker 2, Event 1, Timestamp 1768823630665
[Worker 3] Sending: Worker 3, Event 1, Timestamp 1768823630665
[Worker 1] Sending: Worker 1, Event 2, Timestamp 1768823630667
[Worker 2] Sending: Worker 2, Event 2, Timestamp 1768823630667
[Worker 3] Sending: Worker 3, Event 2, Timestamp 1768823630667
[Worker 1] Sending: Worker 1, Event 3, Timestamp 1768823630674
[Worker 2] Sending: Worker 2, Event 3, Timestamp 1768823630674
[Worker 3] Sending: Worker 3, Event 3, Timestamp 1768823630674
[Worker 1] Sending: Worker 1, Event 4, Timestamp 1768823630677
[Worker 2] Sending: Worker 2, Event 4, Timestamp 1768823630677
[Worker 3] Sending: Worker 3, Event 4, Timestamp 1768823630677
[Worker 1] Task completed and connection closed.
[Worker 2] Task completed and connection closed.
[Worker 3] Task completed and connection closed.
All workers have finished.
(.venv) mariapiabuonomo@MacBookAir esercizidistr %
(.venv) mariapiabuonomo@MacBookAir esercizidistr %
(.venv) mariapiabuonomo@MacBookAir esercizidistr %
[Worker 2] Sending: Worker 2, Event 5, Timestamp 1768823630682
[Worker 1] Task completed and connection closed.
[Worker 2] Task completed and connection closed.
[Worker 3] Task completed and connection closed.
All workers have finished.
(.venv) mariapiabuonomo@MacBookAir esercizidistr %
(.venv) mariapiabuonomo@MacBookAir esercizidistr %
[Worker 2] Task completed and connection closed.
[Worker 1] Sending: Worker 1, Event 6, Timestamp 1768823630699
[Worker 3] Sending: Worker 3, Event 5, Timestamp 1768823630705
[Worker 1] Sending: Worker 1, Event 5, Timestamp 1768823630705
[Worker 2] Sending: Worker 1, Event 5, Timestamp 1768823630705
[Worker 3] Sending: Worker 3, Event 5, Timestamp 1768823630705
[Worker 1] Task completed and connection closed.
[Worker 2] Task completed and connection closed.
[Worker 3] Task completed and connection closed.
All workers have finished.
(.venv) mariapiabuonomo@MacBookAir esercizidistr %
(.venv) mariapiabuonomo@MacBookAir esercizidistr %
[Worker 2] Task completed and connection closed.
[Worker 1] Sending: Worker 1, Event 6, Timestamp 1768823630719
[Worker 3] Sending: Worker 3, Event 5, Timestamp 1768823630719
[Worker 1] Sending: Worker 1, Event 5, Timestamp 1768823630719
[Worker 2] Sending: Worker 1, Event 5, Timestamp 1768823630719
[Worker 3] Sending: Worker 3, Event 5, Timestamp 1768823630719
[Worker 1] Task completed and connection closed.
[Worker 2] Task completed and connection closed.
[Worker 3] Task completed and connection closed.
All workers have finished.
(.venv) mariapiabuonomo@MacBookAir esercizidistr %
(.venv) mariapiabuonomo@MacBookAir esercizidistr %
[Worker 2] Task completed and connection closed.
[Worker 1] Task completed and connection closed.
[Worker 3] Task completed and connection closed.
All workers have finished.
[ ]
```

SERVER

```
mariapiabuonomo@MacBookAir esercizidistr %
python3 ASSIGNMENT2_SERVER_done.py --port 55001 --concurrency-mode proc --verbose
Sentence "Worker 2, Event 2, Timestamp 1768823631667" received from 127.0.0.1:58246
Sentence "Worker 1, Event 2, Timestamp 1768823631670" received from 127.0.0.1:58245
Sentence "Worker 1, Event 1, Timestamp 1768823631732" received from 127.0.0.1:58249
Sentence "Worker 4, Event 1, Timestamp 1768823631817" received from 127.0.0.1:58254
Sentence "Worker 2, Event 1, Timestamp 1768823632448" received from 127.0.0.1:58247
Sentence "Worker 3, Event 1, Timestamp 1768823632552" received from 127.0.0.1:58250
Sentence "Worker 2, Event 3, Timestamp 1768823632672" received from 127.0.0.1:58246
Sentence "Worker 1, Event 3, Timestamp 1768823632674" received from 127.0.0.1:58245
Sentence "Worker 1, Event 1, Timestamp 1768823632716" received from 127.0.0.1:58252
Sentence "Worker 3, Event 1, Timestamp 1768823633108" received from 127.0.0.1:58255
Sentence "Worker 3, Event 2, Timestamp 1768823633174" received from 127.0.0.1:58250
Sentence "Worker 2, Event 2, Timestamp 1768823633280" received from 127.0.0.1:58247
Sentence "Worker 1, Event 2, Timestamp 1768823633590" received from 127.0.0.1:58249
Sentence "Worker 2, Event 4, Timestamp 1768823633677" received from 127.0.0.1:58246
[x] Connection closed for 127.0.0.1:58246
Sentence "Worker 1, Event 4, Timestamp 1768823633679" received from 127.0.0.1:58245
[x] Connection closed for 127.0.0.1:58245
Sentence "Worker 3, Event 2, Timestamp 1768823633715" received from 127.0.0.1:58255
Sentence "Worker 3, Event 3, Timestamp 1768823634035" received from 127.0.0.1:58250
Sentence "Worker 3, Event 3, Timestamp 1768823634179" received from 127.0.0.1:58255
Sentence "Worker 2, Event 3, Timestamp 1768823634456" received from 127.0.0.1:58247
Sentence "Worker 3, Event 4, Timestamp 1768823634666" received from 127.0.0.1:58250
Sentence "Worker 4, Event 2, Timestamp 1768823635126" received from 127.0.0.1:58254
Sentence "Worker 1, Event 3, Timestamp 1768823635498" received from 127.0.0.1:58249
Sentence "Worker 4, Event 3, Timestamp 1768823635712" received from 127.0.0.1:58254
Sentence "Worker 4, Event 4, Timestamp 1768823636079" received from 127.0.0.1:58254
Sentence "Worker 3, Event 5, Timestamp 1768823636114" received from 127.0.0.1:58250
[x] Connection closed for 127.0.0.1:58250
Sentence "Worker 2, Event 4, Timestamp 1768823636169" received from 127.0.0.1:58247
Sentence "Worker 4, Event 5, Timestamp 1768823636377" received from 127.0.0.1:58254
Sentence "Worker 2, Event 5, Timestamp 1768823636852" received from 127.0.0.1:58247
[x] Connection closed for 127.0.0.1:58247
Sentence "Worker 3, Event 4, Timestamp 1768823636873" received from 127.0.0.1:58255
Sentence "Worker 1, Event 4, Timestamp 1768823637128" received from 127.0.0.1:58249
Sentence "Worker 1, Event 5, Timestamp 1768823637165" received from 127.0.0.1:58249
[x] Connection closed for 127.0.0.1:58249
Sentence "Worker 1, Event 2, Timestamp 1768823637599" received from 127.0.0.1:58252
Sentence "Worker 2, Event 1, Timestamp 1768823637599" received from 127.0.0.1:58253
Sentence "Worker 1, Event 3, Timestamp 1768823638107" received from 127.0.0.1:58252
Sentence "Worker 1, Event 4, Timestamp 1768823639409" received from 127.0.0.1:58252
Sentence "Worker 1, Event 5, Timestamp 1768823640319" received from 127.0.0.1:58252
Sentence "Worker 4, Event 6, Timestamp 1768823640679" received from 127.0.0.1:58254
[x] Connection closed for 127.0.0.1:58254
Sentence "Worker 1, Event 6, Timestamp 1768823641533" received from 127.0.0.1:58252
[x] Connection closed for 127.0.0.1:58252
Sentence "Worker 3, Event 5, Timestamp 1768823642741" received from 127.0.0.1:58255
Sentence "Worker 3, Event 6, Timestamp 1768823646954" received from 127.0.0.1:58255
[x] Connection closed for 127.0.0.1:58255
mariapiabuonomo@MacBookAir esercizidistr %
python3 ASSIGNMENT2_SERVER_done.py --port 55001 --concurrency-mode proc --verbose
Parsed CLI arguments: {'port': 55001, 'address': '', 'concurrency_mode': 'proc', 'verbose': True}
The concurrent TCP server is ready to receive (PID = 97364)
[+] New server socket worker spawned for client 127.0.0.1:58245
Thread ID: 14725386 - PID: 97466 - PPID: 97364
[+] New server socket worker spawned for client 127.0.0.1:58246
Thread ID: 14725387 - PID: 97467 - PPID: 97364
[+] New server socket worker spawned for client 127.0.0.1:58250
Thread ID: 14725495 - PID: 97556 - PPID: 97364
[+] New server socket worker spawned for client 127.0.0.1:58249
Thread ID: 14725494 - PID: 97555 - PPID: 97364
[+] New server socket worker spawned for client 127.0.0.1:58247
Thread ID: 14725493 - PID: 97554 - PPID: 97364
Sentence "Worker 1, Event 1, Timestamp 1768823630665" received from 127.0.0.1:58245
Sentence "Worker 2, Event 1, Timestamp 1768823630666" received from 127.0.0.1:58246
[+] New server socket worker spawned for client 127.0.0.1:58252
Thread ID: 14725616 - PID: 97647 - PPID: 97364
[+] New server socket worker spawned for client 127.0.0.1:58253
Thread ID: 14725617 - PID: 97648 - PPID: 97364
[+] New server socket worker spawned for client 127.0.0.1:58255
Thread ID: 14725619 - PID: 97650 - PPID: 97364
[+] New server socket worker spawned for client 127.0.0.1:58254
Thread ID: 14725618 - PID: 97649 - PPID: 97364
[x] Connection closed for 127.0.0.1:58253
^CThe server is terminating
Average connection inter-arrival time: 261.69 ms
```

By running the server in "proc" mode, each new client connection is isolated into its own dedicated child process, which provides better fault isolation and allows the system to utilize multiple CPU cores for true parallelism. In this scenario, three separate client instances using Deterministic, Uniform, and Exponential distributions are launched at the same time. Despite the complexity of handling different traffic patterns at once, the server maintains an efficient average connection inter-arrival time of 261.69 ms. The terminal output shows a chaotic interleaving of messages from different workers, which confirms that the server is successfully processing multiple data streams in parallel.

3RD ATTEMPT: TWO CLIENTS AND ITERATIVE SERVER

```
python ASSIGNMENT2_SERVER_done.py --port 55002 --concurrency-mode iter --verbose
python ASSIGNMENT2_CLIENT_done.py -w 2 -n 4 -d u -p 1.0 -s 127.0.0.1 -P 55002 -v
python ASSIGNMENT2_CLIENT_done.py -w 3 -n 3 -d d -p 0.5 -s 127.0.0.1 -P 55002 -v
```

```
(.venv) mariapiabuonomo@MacBookAir esercizidistr % python A
SSIGNMENT2_SERVER_done.py --port 55002 --concurrency-mode iter --verbose
Parsed CLI arguments: {'port': 55002, 'address': '', 'concurrency_mode': 'iter', 'verbose': True}
The server is ready.
[+] New connection from 127.0.0.1:58299
Sentence "Worker 1, Event 1, Timestamp 1768827695037" received from 127.0.0.1:58299
Sentence "Worker 1, Event 2, Timestamp 1768827695401" received from 127.0.0.1:58299
Sentence "Worker 1, Event 3, Timestamp 1768827696112" received from 127.0.0.1:58299
Sentence "Worker 1, Event 4, Timestamp 1768827696827" received from 127.0.0.1:58299
[+] Closing connection from 127.0.0.1:58299
[+] New connection from 127.0.0.1:58300
Sentence "Worker 2, Event 1, Timestamp 1768827697489" received from 127.0.0.1:58300
Sentence "Worker 2, Event 2, Timestamp 1768827697937" received from 127.0.0.1:58300
Sentence "Worker 2, Event 3, Timestamp 1768827698315" received from 127.0.0.1:58300
Sentence "Worker 2, Event 4, Timestamp 1768827698388" received from 127.0.0.1:58300
[+] Closing connection from 127.0.0.1:58300
[+] New connection from 127.0.0.1:58303
Sentence "Worker 1, Event 1, Timestamp 1768827698894" received from 127.0.0.1:58303
Sentence "Worker 1, Event 2, Timestamp 1768827699400" received from 127.0.0.1:58303
Sentence "Worker 1, Event 3, Timestamp 1768827699900" received from 127.0.0.1:58303
[+] Closing connection from 127.0.0.1:58303
[+] New connection from 127.0.0.1:58304
Sentence "Worker 2, Event 1, Timestamp 1768827700403" received from 127.0.0.1:58304
Sentence "Worker 2, Event 2, Timestamp 1768827700908" received from 127.0.0.1:58304
Sentence "Worker 2, Event 3, Timestamp 1768827701414" received from 127.0.0.1:58304
[+] Closing connection from 127.0.0.1:58304
[+] New connection from 127.0.0.1:58305
Sentence "Worker 3, Event 1, Timestamp 1768827701916" received from 127.0.0.1:58305
Sentence "Worker 3, Event 2, Timestamp 1768827702422" received from 127.0.0.1:58305
Sentence "Worker 3, Event 3, Timestamp 1768827702924" received from 127.0.0.1:58305
in/activate
● mariapiabuonomo@MacBookAir esercizidistr % source /Users/mariapiabuonomo/Desktop/esercizidistr/.venv/bin/activate
(.venv) mariapiabuonomo@MacBookAir esercizidistr % python A
SSIGNMENT2_CLIENT_done.py -w 3 -n 3 -d d -p 0.5 -s 127.0.0.1 -P 55002 -v
Starting 3 threads connecting to 127.0.0.1:55002...
[Worker 1] Connected. Server says: Hello! You are connected to the server.
[Worker 1] Sending: Worker 1, Event 1, Timestamp 1768827695
037
[Worker 1] Sending: Worker 1, Event 2, Timestamp 1768827695
401
[Worker 1] Sending: Worker 1, Event 3, Timestamp 1768827696
112
[Worker 1] Sending: Worker 1, Event 4, Timestamp 1768827696
827
[Worker 1] Task completed and connection closed.
[Worker 2] Connected. Server says: Hello! You are connected to the server.
[Worker 2] Sending: Worker 2, Event 1, Timestamp 1768827697
094
[Worker 2] Sending: Worker 2, Event 2, Timestamp 1768827699
400
[Worker 2] Sending: Worker 2, Event 3, Timestamp 1768827699
900
[Worker 2] Task completed and connection closed.
[Worker 3] Connected. Server says: Hello! You are connected to the server.
[Worker 3] Sending: Worker 3, Event 1, Timestamp 1768827700
403
[Worker 2] Sending: Worker 2, Event 2, Timestamp 1768827700
908
[Worker 2] Sending: Worker 2, Event 3, Timestamp 1768827701
414
[Worker 2] Task completed and connection closed.
[Worker 3] Connected. Server says: Hello! You are connected to the server.
[Worker 3] Sending: Worker 3, Event 1, Timestamp 1768827701
917
[Worker 3] Sending: Worker 3, Event 2, Timestamp 1768827702
422
[Worker 3] Sending: Worker 3, Event 3, Timestamp 1768827702
924
[Worker 3] Task completed and connection closed.
All workers have finished.
○ (.venv) mariapiabuonomo@MacBookAir esercizidistr % []
```

^{^C}The server has stopped.

Average connection inter-arrival time: 1659.44 ms

Average data inter-arrival time: 476.03 ms

To the left: server and then the two clients.

Unlike the previous models, the iterative server is restricted to processing only one connection at a time, meaning that any secondary connection attempts are blocked until the current client session is completely finished and closed. This serial constraint causes a massive bottleneck, as seen in the average connection inter-arrival time, which skyrockets to 1659.44 ms. The server logs clearly show that the second client only begins transmitting data after the first client has disconnected, proving that the lack of concurrency prevents the server from scaling effectively when faced with multiple simultaneous requests.