Hi team, thank you for the constructive and motivating feedback. This gives me a glimpse of hope that I should not give up on this position! ☺

I just started deep-dive researching the world of asynchronous requests to better understand what is going under the hood. Although most of the materials I've come across were kind of lacking for me to connect the dots, then I came up with these 2 Part GitHub blogposts which kind of cleared the fogs a bit. I highly recommend them, in case you are interested in fun read:
https://bbc.github.io/cloudfit-public-docs/asyncio/asyncio-part-1
https://bbc.github.io/cloudfit-public-docs/asyncio/asyncio-part-2

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Feedback Review

After carefully reviewing your feedback, I believe most of the code had to be adjusted to address points on feedback. So, few points I've come up with to discuss the drawbacks of previous code and their improvements in new version:

- *Your server is waiting for all requests to finish before sending the first successful response. Beware that some requests can take a really long time and the "time" property in response does not correspond to the actual request duration.*

Apparently, the cause of this is **asyncio.gather()** function which waits to collect the given request results. As a result, the previous code was waiting for all the requests to be finished before sending the first successful response. But, as we want to process requests greedily as they are ready, we will use the loop over **asyncio.as_completed()** [https://bit.ly/as_compled]. As the name implies, it helps us to get the earliest next result among requests.

Also, in my last implementation, I was mistakenly considering time property in response from Exponea server as real time, and the code was working based on that time. In this new implementation, the code will work with time that is based on session rather than Exponea's response.

- *"Second and third requests are sent after the first request finishes instead of waiting 300ms since the request has been started."*

The cause, again is **asyncio.gather()** which waits the first request to finish. To address this, the closest I could come up with is to use **asyncio.wait_for()** with **asyncio.shield()** [https://bit.ly/wait_for_shield]. More about this is below.

- *You mentioned the possibility to run tests but you forgot to push them.*

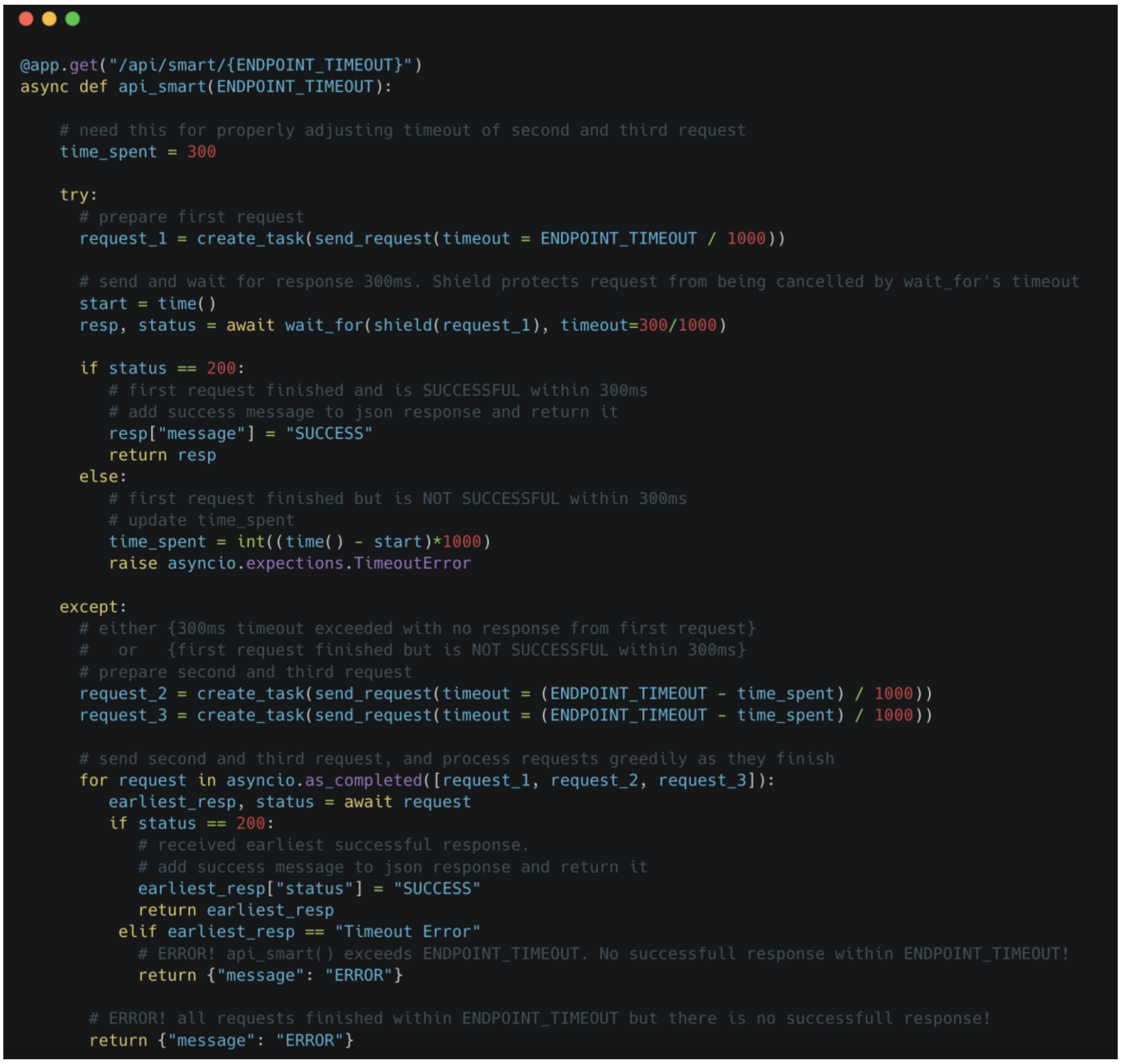
Added pytests into api_test.py script. The script runs tests and checks the possible cases.

- *We would love to see your discussion about the server’s performance. Feel free to run a performance benchmark and share your results with us. How many concurrent requests can the server handle? How would you protect the server against being overloaded?*

I used Apache JMeter for performance benchmarking and discussed the server behavior at the end of this report.

Code & Case studies

First, let’s explore the pseudo-code of our new approach. It is pseudo by means that I included the most essential parts for taking screenshot. Original code is just slightly different than this but they work the same way.

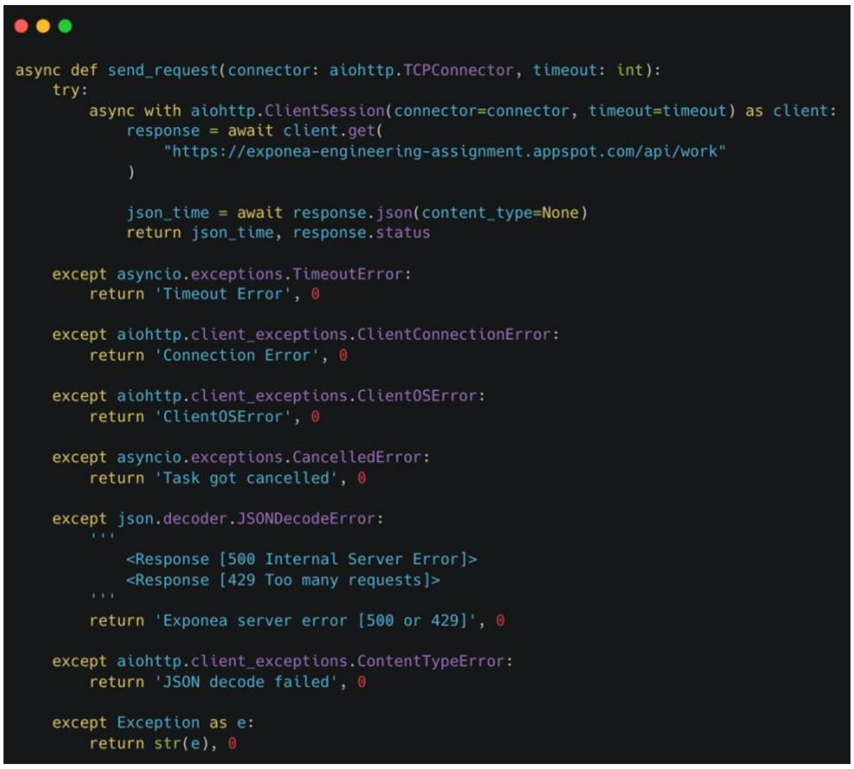


```
@app.get("/api/smart/{ENDPOINT_TIMEOUT}")
async def api_smart(ENDPOINT_TIMEOUT):

    # need this for properly adjusting timeout of second and third request
    time_spent = 300

    try:
      # prepare first request
      request_1 = create_task(send_request(timeout = ENDPOINT_TIMEOUT / 1000))

      # send and wait for response 300ms. Shield protects request from being cancelled by wait_for's timeout
      start = time()
      resp, status = await wait_for(shield(request_1), timeout=300/1000)

      if status == 200:
         # first request finished and is SUCCESSFUL within 300ms
         # add success message to json response and return it
         resp["message"] = "SUCCESS"
         return resp
      else:
         # first request finished but is NOT SUCCESSFUL within 300ms
         # update time_spent
         time_spent = int((time() - start)*1000)
         raise asyncio.expections.TimeoutError

    except:
      # either {300ms timeout exceeded with no response from first request}
      #    or   {first request finished but is NOT SUCCESSFUL within 300ms}
      # prepare second and third request
      request_2 = create_task(send_request(timeout = (ENDPOINT_TIMEOUT - time_spent) / 1000))
      request_3 = create_task(send_request(timeout = (ENDPOINT_TIMEOUT - time_spent) / 1000))

      # send second and third request, and process requests greedily as they finish
      for request in asyncio.as_completed([request_1, request_2, request_3]):
         earliest_resp, status = await request
         if status == 200:
            # received earliest successful response.
            # add success message to json response and return it
            earliest_resp["status"] = "SUCCESS"
            return earliest_resp
          elif earliest_resp == "Timeout Error"
            # ERROR! api_smart() exceeds ENDPOINT_TIMEOUT. No successfull response within ENDPOINT_TIMEOUT!
            return {"message": "ERROR"}

       # ERROR! all requests finished within ENDPOINT_TIMEOUT but there is no successfull response!
       return {"message": "ERROR"}
```

Note that, for the sake of chosen implementation way, api_smart() only handles TimeoutError exception which is thrown by either of below:

- **by async.wait_for() if it exceeds 300ms**
- **by manually raising it**

The reason for this is that, on the other side, send_request() can handle all exceptions that may occur during the sessions and returns the respective response and status of requests back to api_smart(). This helps api_smart() to evaluate the requests according to their responses and statuses, and handle exceptions caused by sessions.



```
async def send_request(connector: aiohttp.TCPConnector, timeout: int):
    try:
        async with aiohttp.ClientSession(connector=connector, timeout=timeout) as client:
            response = await client.get(
                "https://exponea-engineering-assignment.appspot.com/api/work"
            )

            json_time = await response.json(content_type=None)
            return json_time, response.status

    except asyncio.exceptions.TimeoutError:
        return 'Timeout Error', 0

    except aiohttp.client_exceptions.ClientConnectionError:
        return 'Connection Error', 0

    except aiohttp.client_exceptions.ClientOSError:
        return 'ClientOSError', 0

    except asyncio.exceptions.CancelledError:
        return 'Task got cancelled', 0

    except json.decoder.JSONDecodeError:
        '''
            <Response [500 Internal Server Error]>
            <Response [429 Too many requests]>
        '''
        return 'Exponea server error [500 or 429]', 0

    except aiohttp.client_exceptions.ContentTypeError:
        return 'JSON decode failed', 0

    except Exception as e:
        return str(e), 0
```

Now, let's see how our server works. Once our API receives a GET request via endpoint, api_smart() starts with checking if endpoint received an integer and if it is below 300. If it is not integer, then we return message "Endpoint timeout parameter should be integer". If it is integer but is below 300, then we return message "Endpoint timeout parameter should be above 300". If it is integer and is above 300, then api_smart() continues with firing the first request with timeout=ENDPOINT_TIMEOUT and waiting for response 300ms:

1) If within 300ms, first request finishes and is successful within 300ms. (i.e., 200), then we return its response.
2) If within 300ms, first request finishes, but is not successful (i.e., !200), then we manually raise TimeoutError. Idea is that, as our first request failed, it is time to fire two other requests ***without waiting 300ms timeout***. Now, in order to handle the TimeoutError, code continues with "except" clause and fires two other requests and process all requests inside asyncio.as_completed() loop greedily as they finish and we return the earliest successful response. It is important to note that, although the first request is finished unsuccessfully, for the sake of chosen implementation way, we will still await its task during asyncio.as_completed() loop. Lets remember that its task is "finished task", and according to https://bit.ly/await_finished_task, awaiting the finished task returns its result immediately – so, we are okay. Now, if there is no any successful response out of second and third requests, loop will finish without returning, and we will continue with the next line which returns ERROR. On the other hand, if there is/are successful responses, the earliest one is returned during the loop.
3) If 300ms exceeds with no response from first request, wait_for() throws TimeoutError exception. Idea is that, we waited for first request's response for 300ms, but as it did not finish within 300ms, it is time to fire two other requests. Note that in this case, we are sure that first request did not finish within 300ms, because if it had finished within 300ms, it would be either case 1) or 2). It is also

important to note that we have to protect first request with asyncio.shield() in order for it not to be cancelled once wait_for() timeout occurs. Reason is that, even if 300ms timeout occurs, we still need the response of first request. Now, to handle the TimeoutError thrown by wait_for(), code continues with "except" clause. This is where we fire two other requests and process requests greedily as they finish using asyncio.as_completed() and return the earliest successful response. If there is no any successful response out of all three requests, loop will finish without returning, and we will continue with the next line which returns ERROR. On the other hand, if there is/are successful responses, the earliest one is returned during the loop.

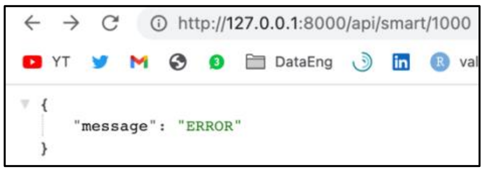
4) Last case is when during any of above cases, api_smart() execution time exceeds ENDPOINT_TIMEOUT. This is approximately addressed by allocating timeout for each request's session such that each session throws TimeoutError when api_smart() exceeds ENDPOINT_TIMEOUT. It is important to note that, this is an approximate implementation, and after studying the server's behavior, we see that sessions throw TimeoutError **almost at the same time with 10-30ms difference in-between**. Also, most of the time, first request's session is the earliest to throw TimeoutError. Please, refer to the code implementation for getting more insights on this topic. Finally, I also added **elif statement** into as_completed() loop which **returns ERROR** if any request's session threw TimeoutError – this is where we know if api_smart() execution time exceeds ENDPOINT_TIMEOUT.
   Moreover, this case also implicitly means that there is no successful response within ENDPOINT_TIMEOUT. Because, if there is/are successful responses within this ENDPOINT_TIMEOUT, it would have already been returned by 1), 2) or 3) case.

Empirical Studies

Apparently, most of the examples provided in the last report submission were wrong – because they were considering time property in Exponea server's response as real time. This has been resolved in new implementation. Lets try to replicate Case Studies above by sending requests to our implemented server.

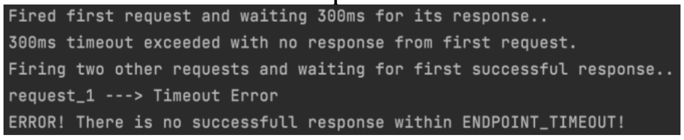
Note that, black screenshots below are taken from terminal after sending the requests. Please, checkout ***with_console_prints branch*** on github repository in order to print results to terminal. They helped a lot for studying & debugging the code, however, I noticed and also read in couple of posts on internet that print() statements to console slows down the server performance. Therefore, I created new branch from ***master branch*** for this purpose, and left master branch intact.

Example №1–№6 are when our server returns ERROR message as below. (i.e., when there is no successful response within ENDPOINT_TIMEOUT)



```
{
    "message": "ERROR"
}
```

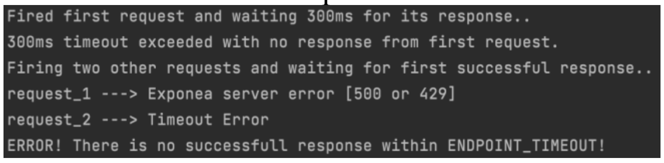
Example №1



```
Fired first request and waiting 300ms for its response..
300ms timeout exceeded with no response from first request.
Firing two other requests and waiting for first successful response..
request_1 ---> Timeout Error
ERROR! There is no successfull response within ENDPOINT_TIMEOUT!
```

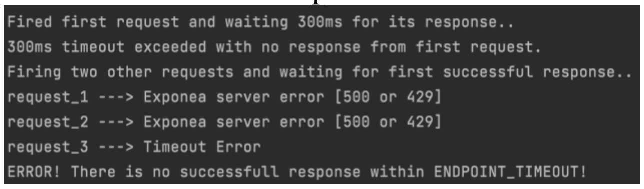
This starts as 3) case, but evolves as 4) case **from the Case Studies above**. while waiting for earliest response from all 3 requests inside as_completed() loop, we got "Timeout Error" response from request_1 which implies that api_smart() execution time exceeded ENDPOINT_TIMEOUT – so, our server returns {'message': 'ERROR'}.

Example №2


```
Fired first request and waiting 300ms for its response..
300ms timeout exceeded with no response from first request.
Firing two other requests and waiting for first successful response..
request_1 ---> Exponea server error [500 or 429]
request_2 ---> Timeout Error
ERROR! There is no successfull response within ENDPOINT_TIMEOUT!
```

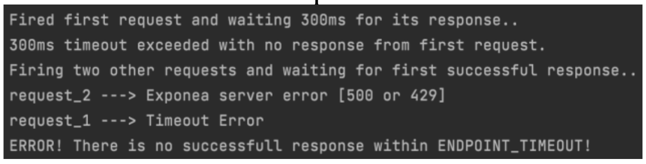
Again, starts as 3) case, but evolves as 4) case, but different from Example №1. This time, while waiting for earliest response from all 3 requests inside as_completed() loop, first earliest response was “Exponea server error” from request_1. Loop continued by awating next earliest response, and got “Timeout Error” response from request_2 which implies that api_smart() execution time exceeded ENDPOINT_TIMEOUT – so, our server returns {‘message’: ‘ERROR’}.

Example №3


```
Fired first request and waiting 300ms for its response..
300ms timeout exceeded with no response from first request.
Firing two other requests and waiting for first successful response..
request_1 ---> Exponea server error [500 or 429]
request_2 ---> Exponea server error [500 or 429]
request_3 ---> Timeout Error
ERROR! There is no successfull response within ENDPOINT_TIMEOUT!
```

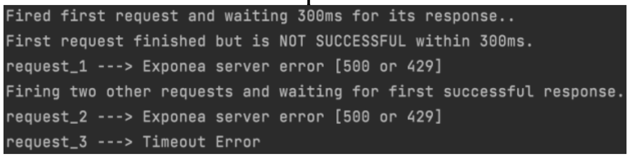
Again, starts as 3) case, but evolves as 4) case, but different from both Example №1 and Example №2. This time, while waiting for earliest response from all 3 requests inside as_completed() loop, first earliest response was “Exponea server error” from request_1, and next earliest response was “Exponea server error” from request_2. Finally, in last iteration of loop, we got “Timeout Error” response from request_3 which implies that api_smart() execution time exceeded ENDPOINT_TIMEOUT – so, our server returns {‘message’: ‘ERROR’}.

Example №4


```
Fired first request and waiting 300ms for its response..
300ms timeout exceeded with no response from first request.
Firing two other requests and waiting for first successful response..
request_2 ---> Exponea server error [500 or 429]
request_1 ---> Timeout Error
ERROR! There is no successfull response within ENDPOINT_TIMEOUT!
```

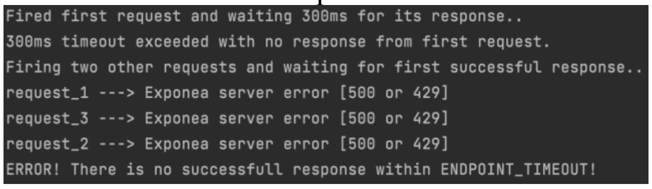
Again, starts as 3) case, but evolves as 4) case, but different from previous examples. This example proves that responses from requests are being collected greedily as they come inside as_completed() loop – so, as shown on screenshot, request_2 was first earliest response, but as it was “Exponea server error”, the loop continued by waiting the next earliest response which is “Timeout Error” from request_1. It implies that api_smart() execution time exceeded ENDPOINT_TIMEOUT – so, our server returns {‘message’: ‘ERROR’}.

Example №5


```
Fired first request and waiting 300ms for its response..
First request finished but is NOT SUCCESSFUL within 300ms.
request_1 ---> Exponea server error [500 or 429]
Firing two other requests and waiting for first successful response.
request_2 ---> Exponea server error [500 or 429]
request_3 ---> Timeout Error
```

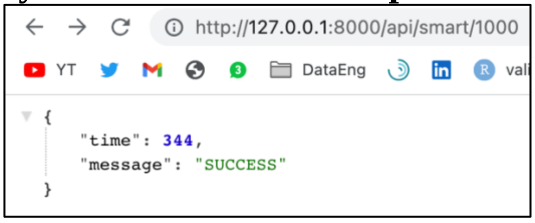
This starts as 2) case, but evolves as 4) case. Its interesting one. As shown on screenshot, first request finished within 300ms but it was not successful because its response was “Exponea server error”. Technically, as soon as we got this reponse from first request, we manually raised TimeoutError in order to jump to “except” clause and fire two other requests. Then while waiting for earliest response inside as_completed() loop, first earliest response was “Exponea server error” from request_1. This is because, although the first request is finished up until now, for the sake of implementation, we still have to **await** it, and as previously explained in Case Studies above – awaiting finished task returns **immediately** – so, the first earliest response had to come from request_1. But still, the loop continued by waiting for the next earliest response because response of request_1 did not have status code 200. Then we get next earliest response as “Exponea server error” from request_2, and loop again continues by waiting for the next earliest response because of same reason – response did not have status code 200. Finally, in last iteration of loop, we got “Timeout Error” response from request_3 which implies that api_smart() execution time exceeded ENDPOINT_TIMEOUT – so, our server returns {‘message’: ‘ERROR’}.

Example №6


```
Fired first request and waiting 300ms for its response..
300ms timeout exceeded with no response from first request.
Firing two other requests and waiting for first successful response..
request_1 ---> Exponea server error [500 or 429]
request_3 ---> Exponea server error [500 or 429]
request_2 ---> Exponea server error [500 or 429]
ERROR! There is no successful response within ENDPOINT_TIMEOUT!
```

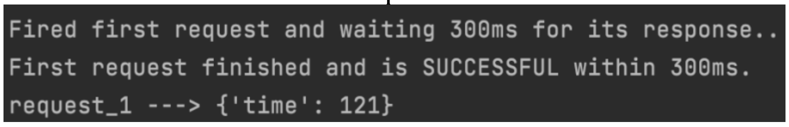
This is 3) case. *NOTE: this is the only example case where the code runs down until the last return statement inside api_smart().* Reason why api_smart() returns ERROR in this example, is different from all previous examples. In previous Examples №1–№5, we returned ERROR because api_smart() execution time exceeded ENDPOINT_TIMEOUT. But in this example, its execution finished within ENDPOINT_TIMEOUT, but all 3 response were “Exponea server error” – so, our server returns {‘message’: ‘ERROR’}. This is rather a rare case, because all requests finished but they finished unsuccessfully, and all these happened within ENDPOINT_TIMEOUT. Note: to catch this case, I set ENDPOINT_TIMEOUT=2000 to allow each request a reasonable time to finish. 1000ms was not enough.

Example №7–№20 when our server returns SUCCESS message along with payload received from Exponea server such as:



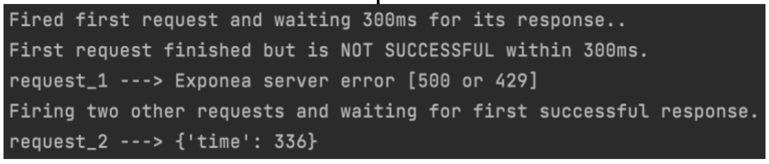
```
{
    "time": 344,
    "message": "SUCCESS"
}
```

Example №7


```
Fired first request and waiting 300ms for its response..
First request finished and is SUCCESSFUL within 300ms.
request_1 ---> {'time': 121}
```

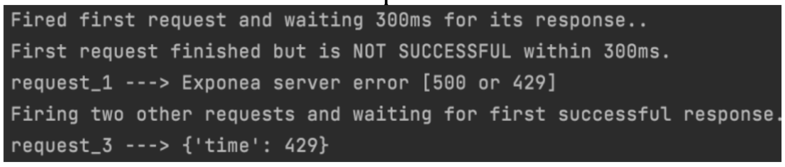
This is 1) case. First request finished within 300ms and as it was successful (response status 200), we returned it. So, our server returns {‘time’: 1221, ‘message’: ‘SUCCESS’} json.

Example №8


```
Fired first request and waiting 300ms for its response..
First request finished but is NOT SUCCESSFUL within 300ms.
request_1 ---> Exponea server error [500 or 429]
Firing two other requests and waiting for first successful response.
request_2 ---> {'time': 336}
```

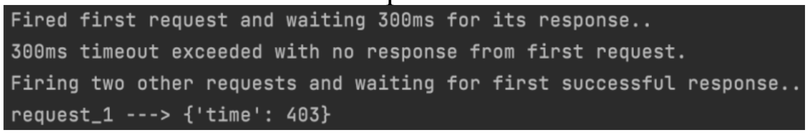
This is 2) case. First request finished within 300ms but it was not successful because its response was “Exponea server error”. As soon as we got this reponse from first request, we manually raised TimeoutError in order to jump to “except” clause and fire two other requests. Then while waiting for earliest response inside as_completed() loop, first earliest response was from request_2. And as it was also a successful response, we returned it. So, our server returns {‘time’: 336, ‘message’: ‘SUCCESS’} json.

Example №9


```
Fired first request and waiting 300ms for its response..
First request finished but is NOT SUCCESSFUL within 300ms.
request_1 ---> Exponea server error [500 or 429]
Firing two other requests and waiting for first successful response.
request_3 ---> {'time': 429}
```

This is 2) case. First request finished within 300ms but it was not successful because its response was “Exponea server error”. As soon as we got this reponse from first request, we manually raised TimeoutError in order to jump to “except” clause and fire two other requests. Then while waiting for earliest response inside as_completed() loop, first earliest response was from request_3. And as it was also a successful response, we returned it. So, our server returns {‘time’: 429, ‘message’: ‘SUCCESS’} json.

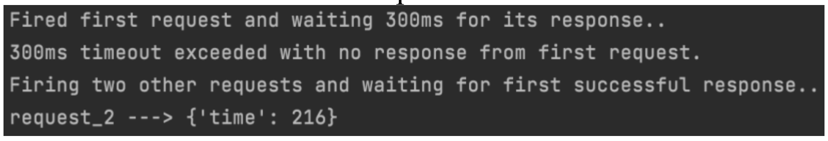
Example №10



```
Fired first request and waiting 300ms for its response..
300ms timeout exceeded with no response from first request.
Firing two other requests and waiting for first successful response..
request_1 ---> {'time': 403}
```

This is 3) case. As said on screenshot above, 300ms timeout exceeded with no response from first request, so, wait_for() threw TimeoutError exception and code continued with “except” clause where it fired two other requests and got response from request_1 as earliest successful response. Note that, response of request_1 is also the earliest response besides being earliest successful response. Our server returns {‘time’: 403, ‘message’: ‘SUCCESS’} json.

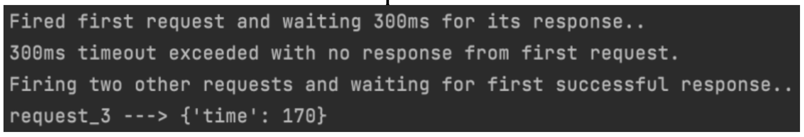
Example №11



```
Fired first request and waiting 300ms for its response..
300ms timeout exceeded with no response from first request.
Firing two other requests and waiting for first successful response..
request_2 ---> {'time': 216}
```

This is also 3) case. Its difference from previous Example №10 is that, this time the earliest successful response comes from request_2. Again, note that, response of request_2 is also the earliest response besides being earliest successful response. Our server returns {‘time’: 216, ‘message’: ‘SUCCESS’} json.

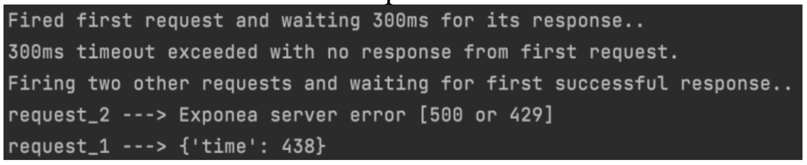
Example №12



```
Fired first request and waiting 300ms for its response..
300ms timeout exceeded with no response from first request.
Firing two other requests and waiting for first successful response..
request_3 ---> {'time': 170}
```

Also 3) case. This time, the earliest successful response among 3 reqests is request_3. Again, note that, response of request_3 is also the earliest response besides being earliest successful response. Our server returns {‘time’: 170, ‘message’: ‘SUCCESS’} json.

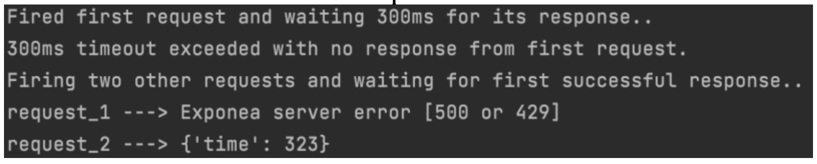
Example №13



```
Fired first request and waiting 300ms for its response..
300ms timeout exceeded with no response from first request.
Firing two other requests and waiting for first successful response..
request_2 ---> Exponea server error [500 or 429]
request_1 ---> {'time': 438}
```

Also 3) case. The earliest successful response comes from request_1. Note that, response of request_2 was the first earliest response but as it was not successful, as_complete() loop continued by waiting the next earliest response. Our server returns {‘time’: 438, ‘message’: ‘SUCCESS’} json.

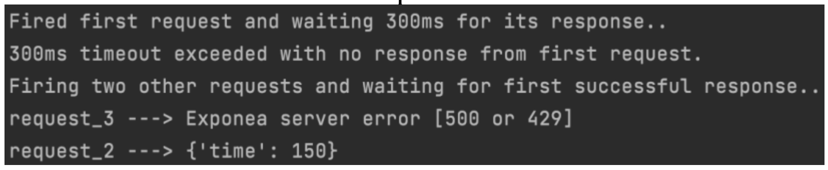
Example №14



```
Fired first request and waiting 300ms for its response..
300ms timeout exceeded with no response from first request.
Firing two other requests and waiting for first successful response..
request_1 ---> Exponea server error [500 or 429]
request_2 ---> {'time': 323}
```

Also 3) case. The earliest successful response comes from request_2. Note that, response of request_1 was the first earliest response but as it was not successful, as_complete() loop continued by waiting the next earliest response. Our server returns {‘time’: 323, ‘message’: ‘SUCCESS’} json.

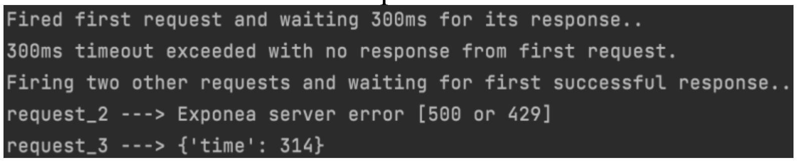
Example №15



```
Fired first request and waiting 300ms for its response..
300ms timeout exceeded with no response from first request.
Firing two other requests and waiting for first successful response..
request_3 ---> Exponea server error [500 or 429]
request_2 ---> {'time': 150}
```

Also 3) case. The earliest successful response comes from request_2. Note that, response of request_3 was the first earliest response but as it was not successful, as_complete() loop continued by waiting the next earliest response. Our server returns {‘time’: 150, ‘message’: ‘SUCCESS’} json.

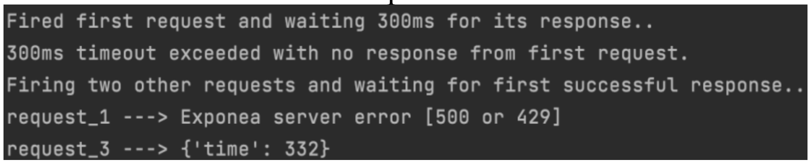
Example №16



```
Fired first request and waiting 300ms for its response..
300ms timeout exceeded with no response from first request.
Firing two other requests and waiting for first successful response..
request_2 ---> Exponea server error [500 or 429]
request_3 ---> {'time': 314}
```

Also 3) case. The earliest successful response comes from request_3. Note that, response of request_2 was the first earliest response but as it was not successful, as_complete() loop continued by waiting the next earliest response. Our server returns {‘time’: 314, ‘message’: ‘SUCCESS’} json.

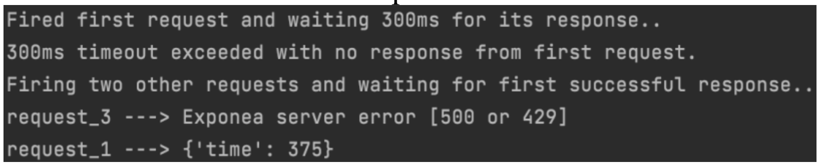
Example №17



```
Fired first request and waiting 300ms for its response..
300ms timeout exceeded with no response from first request.
Firing two other requests and waiting for first successful response..
request_1 ---> Exponea server error [500 or 429]
request_3 ---> {'time': 332}
```

Also 3) case. The earliest successful response comes from request_3. Note that, response of request_1 was the first earliest response but as it was not successful, as_complete() loop continued by waiting the next earliest response. Our server returns {‘time’: 332, ‘message’: ‘SUCCESS’} json.

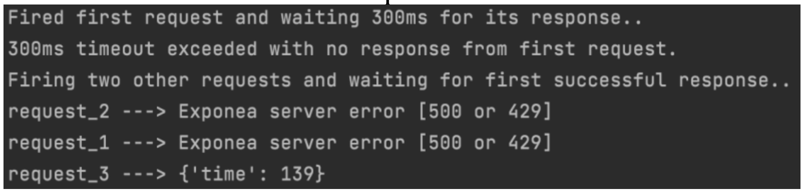
Example №18



```
Fired first request and waiting 300ms for its response..
300ms timeout exceeded with no response from first request.
Firing two other requests and waiting for first successful response..
request_3 ---> Exponea server error [500 or 429]
request_1 ---> {'time': 375}
```

Also 3) case. The earliest successful response comes from request_1. Note that, response of request_3 was the first earliest response but as it was not successful, as_complete() loop continued by waiting the next earliest response. Our server returns {‘time’: 375, ‘message’: ‘SUCCESS’} json.

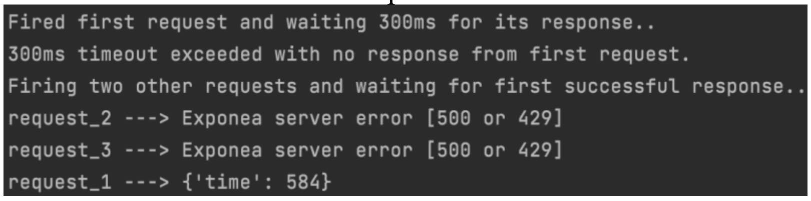
Example №19



```
Fired first request and waiting 300ms for its response..
300ms timeout exceeded with no response from first request.
Firing two other requests and waiting for first successful response..
request_2 ---> Exponea server error [500 or 429]
request_1 ---> Exponea server error [500 or 429]
request_3 ---> {'time': 139}
```

Also 3) case. The earliest successful response comes from request_3. Note that, response of request_2 was the first earliest response but as it was not successful, as_complete() loop continued by waiting the next earliest response. Then response of request_1 was the second earliest response but it was also not succesful, so as_complete() loop continued to the last iteration where it got response of request_3 as successful. Our server returns {‘time’: 139, ‘message’: ‘SUCCESS’} json.

Example №20



```
Fired first request and waiting 300ms for its response..
300ms timeout exceeded with no response from first request.
Firing two other requests and waiting for first successful response..
request_2 ---> Exponea server error [500 or 429]
request_3 ---> Exponea server error [500 or 429]
request_1 ---> {'time': 584}
```

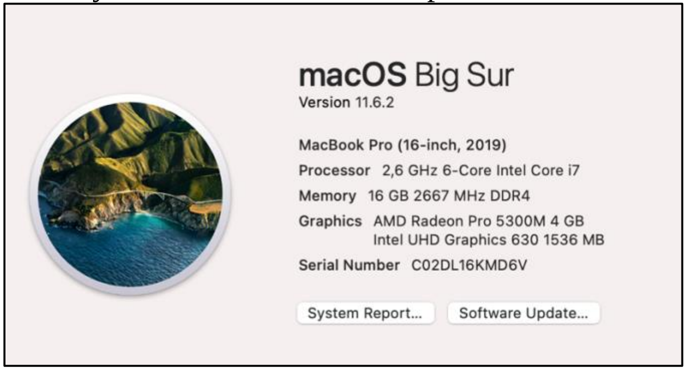
Also 3) case. The earliest successful response comes from request_1. Note that, response of request_2 was the first earliest response but as it was not successful, as_complete() loop continued by waiting the next earliest response. Then response of request_3 was the second earliest response but it was also not succesful, so as_complete() loop continued to the last iteration where it got response of request_1 as successful. Our server returns {'time': 584, 'message': 'SUCCESS'} json.

Performance Benchmark

Actually, finding the proper tool for performance benchmarking took a bit of time. The most mentioned open source tool on discussions was Apache Benchmark, and apparently, it is installed on macOS by default. So, I went with it. Although, it was pretty straightforward and easy to use via terminal, it just enough just for simple tests, and I couldn't predict the performance boundaries of the server in terms of concurrency and number of requests per second. Besides from Apache Benchmark, also tried to use open source tools such as Artillery and wrk, but had some issues during installation, then I finally found out about **Apache Jmeter**, went with it. It is a cool tool. It was a bit hard to understand parameters at first, but it gradually made sense.

Note: I was getting **OSError: too many open files** during initial tests. It was resolved by running **ulimit -n unlimited** command on terminal.

Also, I am running the server on my local machine with the specs as below:



macOS Big Sur
Version 11.6.2

MacBook Pro (16-inch, 2019)
Processor 2,6 GHz 6-Core Intel Core i7
Memory 16 GB 2667 MHz DDR4
Graphics AMD Radeon Pro 5300M 4 GB
Intel UHD Graphics 630 1536 MB
Serial Number C02DL16KMD6V

For performance benchmarking on Apache Jmeter, these will be the parameters that we will play with:

- Number of threads (users)
- Ramp-up period (seconds)
- Loop count (number of iterations per thread/user)

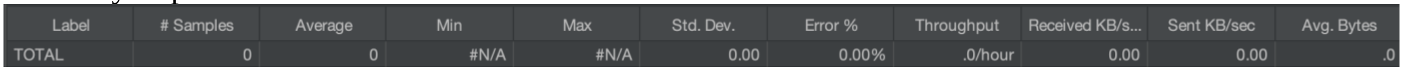
Ramp-up period is an interesting one. According to official user's manual, it tells how long to take to "ramp-up" to the full number of threads(users) chosen. Also, a comment on this stackoverflow post https://bit.ly/jmeter_ramp_up helped better understand its purpose:

"Useful for testing auto-scaling - e.g. for most websites, it's unlikely that you're going to go from 0 to 100 concurrent users instantly. It's more likely that concurrent users will gradually increase (and thereby give the auto-scaling system time to respond). Ramp-up enables this scenario to be tested. – Jon Burgess"

Note that, we will evaluate the tests by checking "**Summary Report**", "**Response Time Graph**" and "**Graph Results**" listeners.

Summary Report summarizes important results of the test on the table. Response Time Graph will help us check response times throughout the test. Finally, we will use Graph Results for checking throughput requests/sec.

Summary Report:



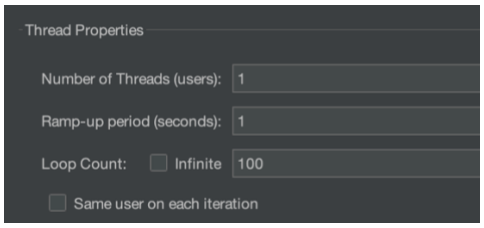
Label	# Samples	Average	Min	Max	Std. Dev.	Error %	Throughput	Received KB/s...	Sent KB/sec	Avg. Bytes
TOTAL	0	0	#N/A	#N/A	0.00	0.00%	.0/hour	0.00	0.00	.0

- Samples: number of total requests sent
- Average/Min/Max: is regarding the response time. Response time is the elapsed time from the moment when a given request is sent to the server until the moment when the last bit of information has returned to the client.
- Error%: Percent of requests with errors.
- Throughput: number of requests processed per second/minute/hour by the server. The larger, the better.
- KB/Sec: amount of data downloaded from server during the performance test execution. It is the throughput measured in kilobytes per second.

For all the tests below, we set ENDPOINT_TIMEOUT=1000 ms.

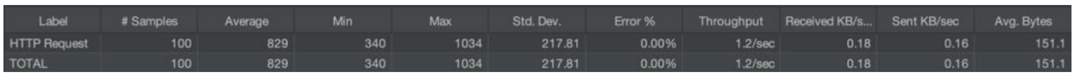
Test №1

Lets start with very simple case where we have 1 user, 100 iteration per user and ramp-up 1 sec. For this and the rest of the tests, we will clear out the box of “Same user on each iteration” – this will allow us to have different users in each iteration, which means that requests will be sent by separate users. We get the below results on **“Summary Report”** listener.

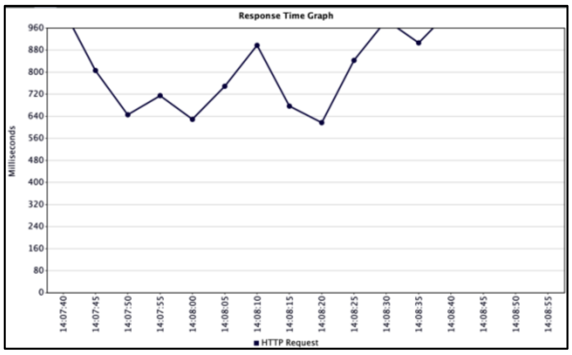


Thread Properties

Number of Threads (users):	1
Ramp-up period (seconds):	1
Loop Count: ☐ Infinite	100
☐ Same user on each iteration	



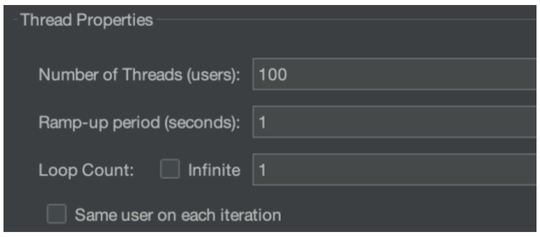
Label	# Samples	Average	Min	Max	Std. Dev.	Error %	Throughput	Received KB/s...	Sent KB/sec	Avg. Bytes
HTTP Request	100	829	340	1034	217.81	0.00%	1.2/sec	0.18	0.16	151.1
TOTAL	100	829	340	1034	217.81	0.00%	1.2/sec	0.18	0.16	151.1



We see average response time is 829ms. This means that, on average, our server responded within ENDPOINT_TIMEOUT (1000ms). This can also be seen from Response Time Graph above. Also, sometimes we got some responses such as max. response with 1034ms, which is slightly above the time the server is supposed to respond to a single request. The reason for this can be either server’s approximate implementation (discussed in case studies) or the transport latency(?). As per https://bit.ly/request_latency, transport latency + processing time = response time, so, this can also be the case. Finally, summary report indicates that all requests were successful, as we have Error 0.00%.
Also, note that the Throughput rate on summary report corresponds to last throughput rate, not the average.

Test №2

For this and following tests, we will gradually increase the load to server, and see how the server will behave under the load. Now, 100 users, 1 iteration per user and ramp-up 1 sec. This means that all the threads/users will start within 1 second. So, the server will be loaded with total of 100 requests from 100 users within short period of time.



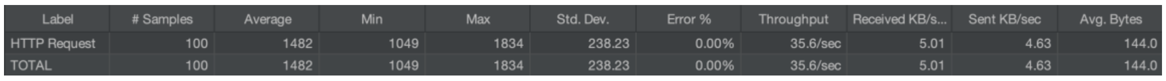
Thread Properties

Number of Threads (users): 100

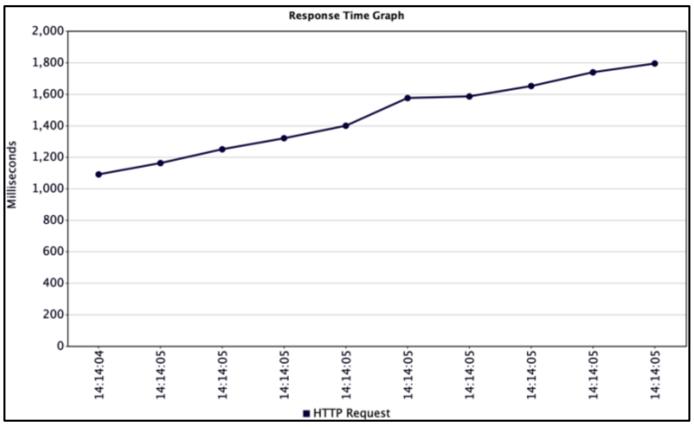
Ramp-up period (seconds): 1

Loop Count: ☐ Infinite 1

☐ Same user on each iteration



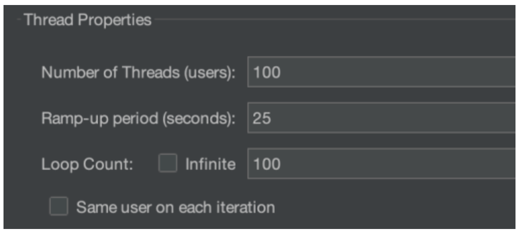
Label	# Samples	Average	Min	Max	Std. Dev.	Error %	Throughput	Received KB/s...	Sent KB/sec	Avg. Bytes
HTTP Request	100	1482	1049	1834	238.23	0.00%	35.6/sec	5.01	4.63	144.0
TOTAL	100	1482	1049	1834	238.23	0.00%	35.6/sec	5.01	4.63	144.0



We see that all request finished successfully under the load, having Error 0.00%. However, all requests' response time exceeded endpoint's timeout parameter. Note that, X-axis of graph shows the timestamp when the each requests are sent – so, in this example, we see that within couple of seconds, the server were able to respond to all 100 request successfully. However, all response times were above endpoint timeout.

Test №3

Now, lets try to further increase the load by changing the parameters. We will set number of users to again 100, ramp-up period to 25 sec, and loop count to 100. This means that we will have a total of 100*100 = 10,000 requests to the server but with 25 sec ramp up.



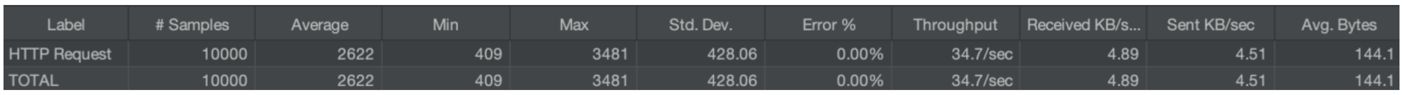
Thread Properties

Number of Threads (users): 100

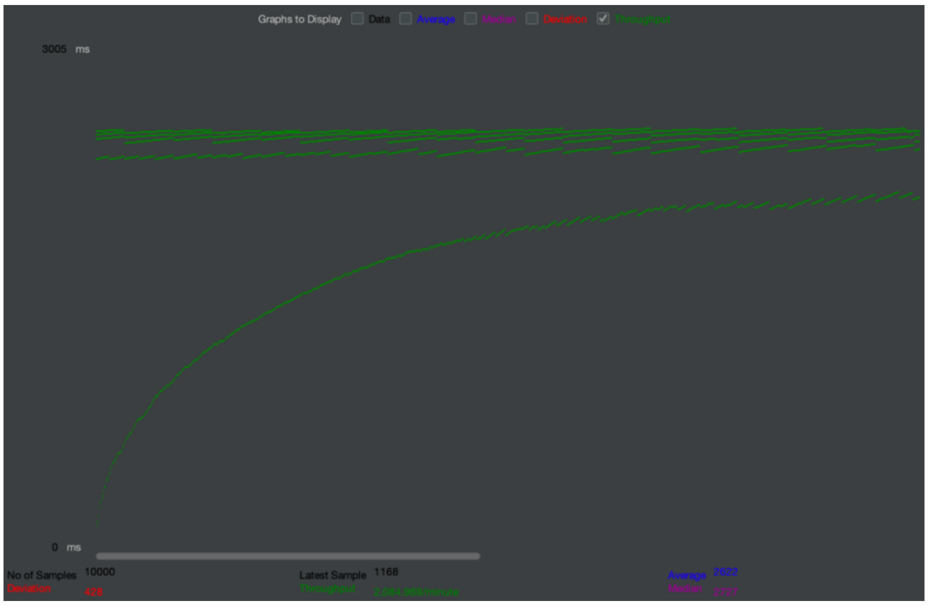
Ramp-up period (seconds): 25

Loop Count: ☐ Infinite 100

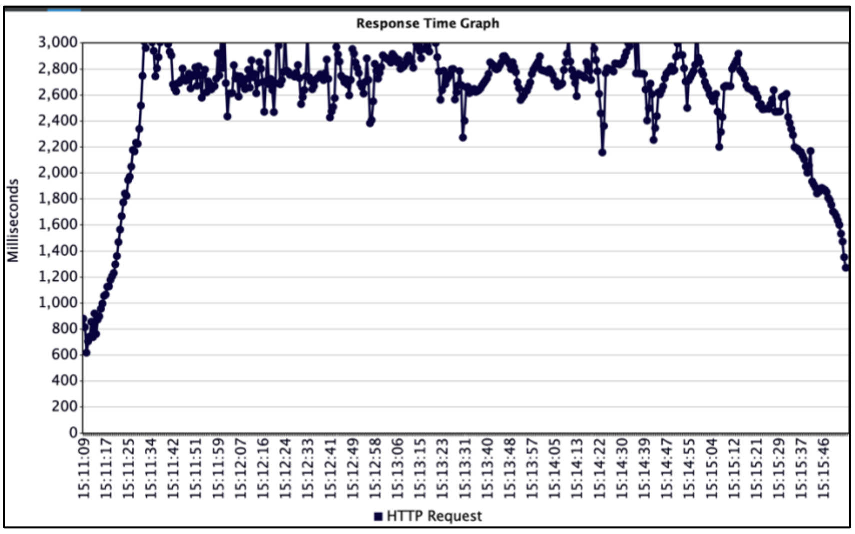
☐ Same user on each iteration



Label	# Samples	Average	Min	Max	Std. Dev.	Error %	Throughput	Received KB/s...	Sent KB/sec	Avg. Bytes
HTTP Request	10000	2622	409	3481	428.06	0.00%	34.7/sec	4.89	4.51	144.1
TOTAL	10000	2622	409	3481	428.06	0.00%	34.7/sec	4.89	4.51	144.1



No of Samples 10000
Deviation 428
Latest Sample 1168
Throughput 2,084.969/minute
Average 2622
Median 2727



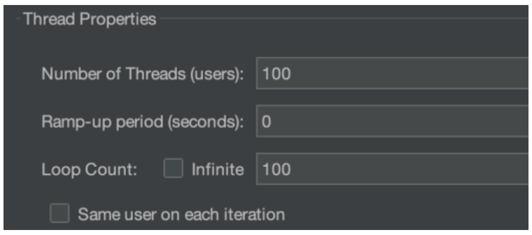
00:04:47 ⚠ 0 0/100

We see that, test execution finished within 4:47 minute, and Summary Report shows that all 10,000 requests were successful with Error 0.00%. Graph Results (with green lines) show that Throughput rate kind of reached to its maximum of 2,084 requests /minute → 2,084/60 = 34,7 requests/sec towards the end of the test. This is also shown on Summary Report as 34.7 requests/sec. Finally, from both Summary Report and Response Time Graph, we see average response time is around ~2600 ms. Also, response graph indicates that at the beginning of test, the application got **gradually** loaded as the ramp-up time was is 25 sec.

To conclude, with the given initial configurations, we can conclude that server handles all 10,000 requests (coming from separate users) successfully with average response time of ~2600ms which is 1600ms more than ENDPOINT_TIMEOUT=1000ms, and it also reaches maximum throughput of ~34.7 requests/sec.

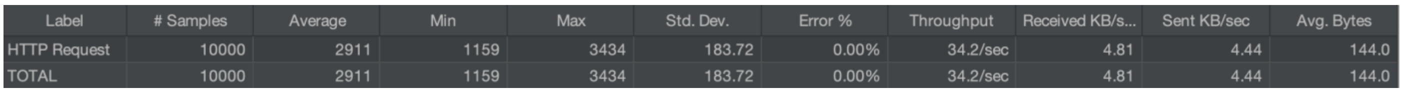
Test №4

Now, with same configurations excepts this time ramp-up = 0 seconds. This will lead all 100 threads/users being created at the same time at the beginning of the test. Also, it will keep the application under more strees compared to previous test, because of ramp-up being 0.

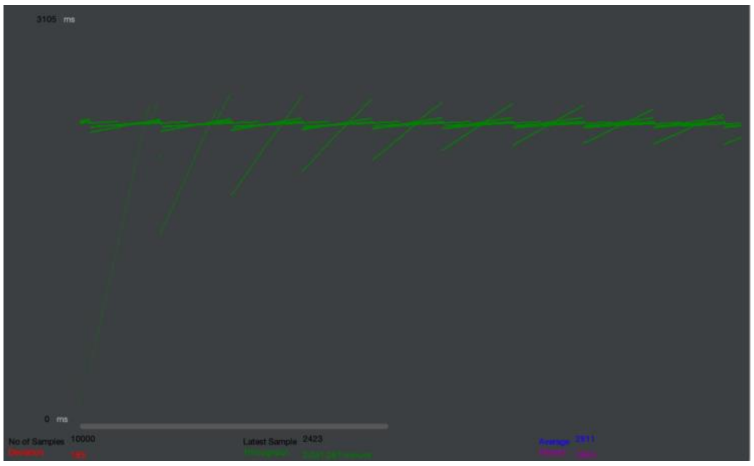


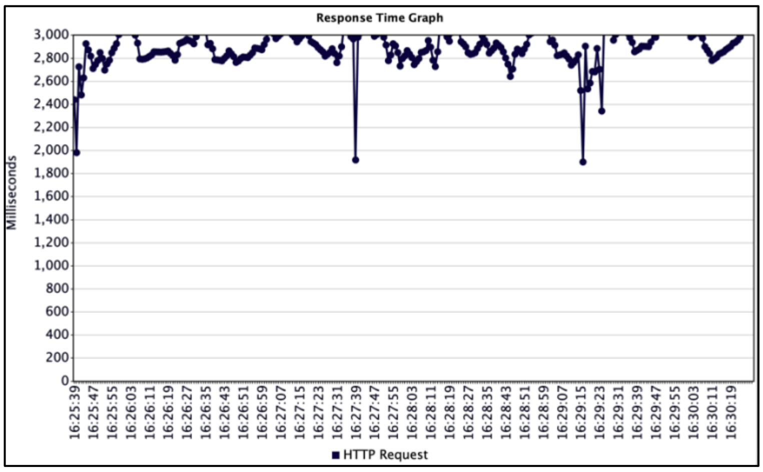
Thread Properties

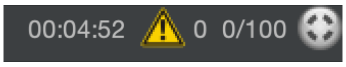
Number of Threads (users):	100
Ramp-up period (seconds):	0
Loop Count: ☐ Infinite	100
☐ Same user on each iteration	



Label	# Samples	Average	Min	Max	Std. Dev.	Error %	Throughput	Received KB/s...	Sent KB/sec	Avg. Bytes
HTTP Request	10000	2911	1159	3434	183.72	0.00%	34.2/sec	4.81	4.44	144.0
TOTAL	10000	2911	1159	3434	183.72	0.00%	34.2/sec	4.81	4.44	144.0







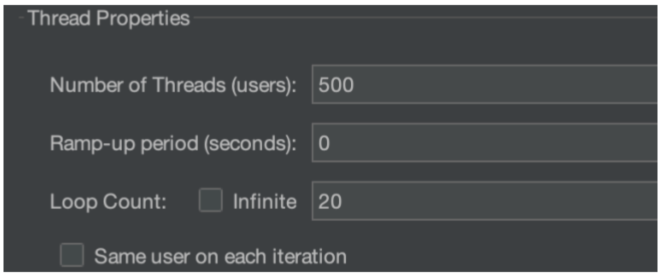
00:04:52 ⚠ 0 0/100

We see that, test execution finished within 4:52 minute, and Summary Report shows that all 10,000 requests were successful with Error 0.00%. Throughput on Summary Report shows as 34.2 requests/sec. From both Summary Report and Response Time Graph, we see average response time is around ~2900 ms.

When we compare these results with previous test results, we see that decreasing ramp-up time down to 0 caused the server to be loaded more quickly at the beginning of the test (also during the test). However, the server could still handle all requests successfully with average response time being close to previous test’s average response time.

Test №5

Now, we will change parameter a bit again. We will still have total of 10,000 requests, but in this time, they will be coming from 500 users with 20 being loop iteration. We keep ramp-up = 0 so that we can compare this test's results with previous one's and see how the increase in number of users will affect the server behaviour.

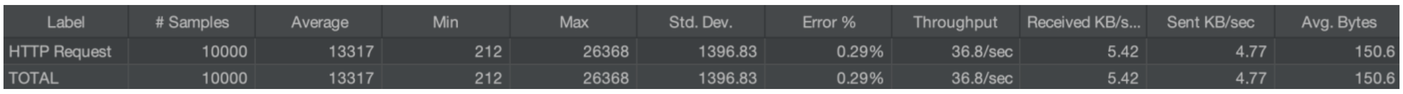

Thread Properties

Number of Threads (users): 500

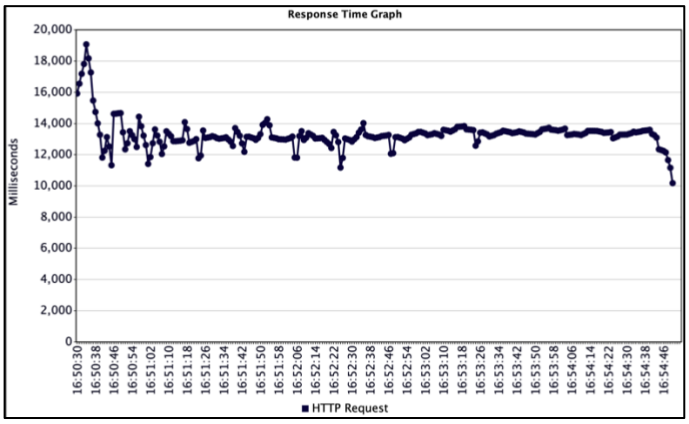
Ramp-up period (seconds): 0

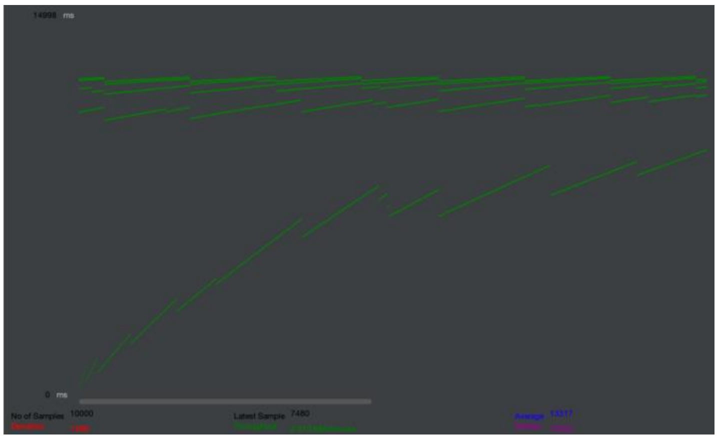
Loop Count: ☐ Infinite 20

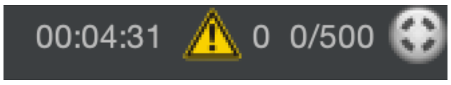
☐ Same user on each iteration



Label	# Samples	Average	Min	Max	Std. Dev.	Error %	Throughput	Received KB/s...	Sent KB/sec	Avg. Bytes
HTTP Request	10000	13317	212	26368	1396.83	0.29%	36.8/sec	5.42	4.77	150.6
TOTAL	10000	13317	212	26368	1396.83	0.29%	36.8/sec	5.42	4.77	150.6



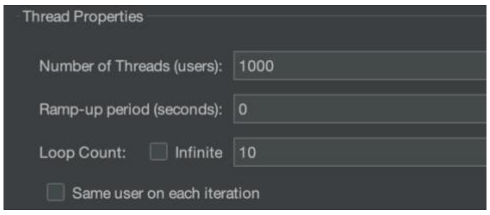




We see that, test execution finished within 4:31 minute – earlier than previous case. Summary Report shows that all Error 0.29%. So, this means that server failed to handle 29 requests out of 10,000. Throughput on Summary Report shows as 36.8 requests/sec. We also see from both Summary Report and Response Time Graph that average response time is around ~13,300 ms. So, when comparing with previous case, increase the thread size up to 500 lead the slower server response. Also, Response Time Graph shows that, when the test is initiated, the server had the highest load due to the sudden requests from 500 users (because ramp-up is 0). But eventually, server could stabilize request handling.

Test №6

Now, we will still have total of 10,000 requests, but in this time, they will be coming from 1000 users with 10 being loop iteration. We again keep ramp-up = 0.



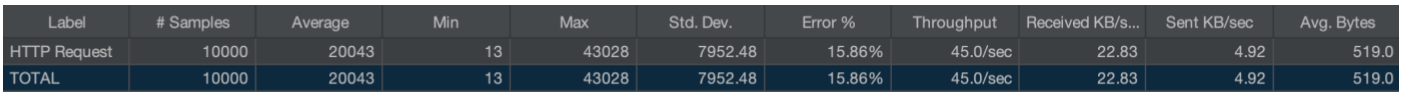
Thread Properties

Number of Threads (users): 1000

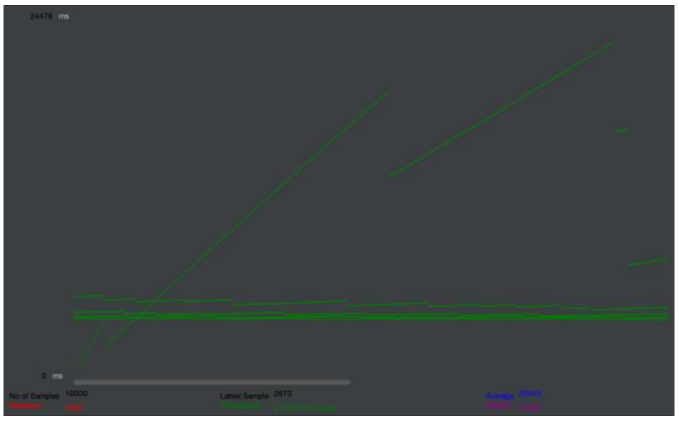
Ramp-up period (seconds): 0

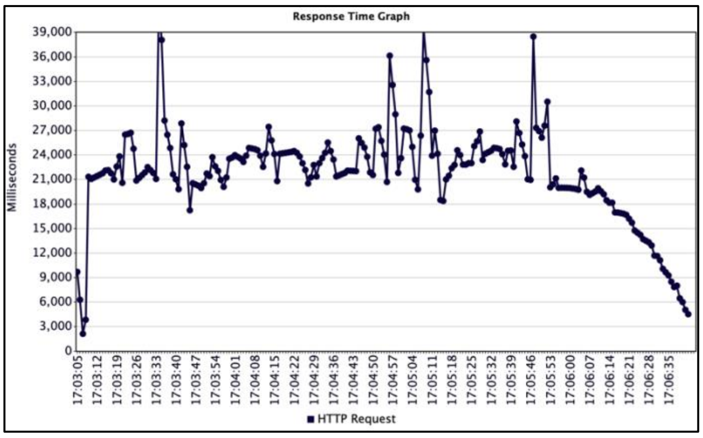
Loop Count: ☐ Infinite 10

☐ Same user on each iteration



Label	# Samples	Average	Min	Max	Std. Dev.	Error %	Throughput	Received KB/s...	Sent KB/sec	Avg. Bytes
HTTP Request	10000	20043	13	43028	7952.48	15.86%	45.0/sec	22.83	4.92	519.0
TOTAL	10000	20043	13	43028	7952.48	15.86%	45.0/sec	22.83	4.92	519.0





We see that, test execution finished within 3:41 minute – earlier than previous two cases, but Summary Report shows that all Error 15.86%. So, around 1,586 of 10,000 requests failed. Throughput on Summary Report shows highest among other tests – 45.0 requests/sec. We also see from both Summary Report and Response Time Graph that average response time is around ~ 20,043 ms. This means that, increasing the thread/user size up to 1000 lead even slower server responses. So, server is not performing very well in this kind of scenario – higher ramp-up seconds can lead to scenario where server performs better.

Along the way

You may notice that the script has got a different shape compared to first submission. Main reason is that there were lots of different obstacles that emerged every time I tried to add a new piece of code, so I had to adjust along the way to address those exceptions/errors. Few points along the way:

- As mentioned at the beginning of report, asyncio.gather() is actually working different than I was thinking. So, in order to implement the assignment correctly, I had to look for other options - asyncio.wait_for(), asyncio.shield(), asyncio.as_completed() helped to address this.
- At one point, I had to switch from httpx to aiohttp**,** because httpx were throwing *RuntimeError: The connection pool was closed while 1 HTTP requests/responses were still in-flight* that I wasn't able to resolve. You may refer to recent discussion around the error on https://bit.ly/httpx_runtime_error.
- At one point after switching to aiohttp, I was getting *aiohttp.client_exceptions.ClientConnectorCertificateError*. Installing certifi and using its certificates addressed the issue on https://bit.ly/aiohttp_certifi.
- Then I was getting *aiohttp.client_exceptions.ContentTypeError*, this was addressed by https://bit.ly/aiohttp_content_type. I set response.json(content_type = None) and introduced exception handling for ContentTypeError.
- Also had to put "except" clause in send_request() function to handle other possible exceptions such as when task gets cancelled, or in case of clients connection error, or client OS error.

Final notes

Big thanks to the team for this interesting assignment. It was a fun ride. I absolutely loved every step of it, be it code development/engineering/case studying or performance benchmarking of the server. I got to say, I was happy seeing the performance during the benchmarking, considering it's my first backend server building ☺ I'd much appreciate hearing your feedback on pros/cons of it.