# YouTrack Performance Task Report

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# Application setup

Two separate machines are used to host Service/Server and Load generator.

Server: MacBook Pro 2,3 GHz Quad-Core Intel Core i7 (Hyper-Threading enabled), 32GB RAM
Load Generator: MacBook Pro M3 (5 performance / 6 efficiency cores), 18GB RAM
YouTrack: ZIP installation

Second machine with ZIP installation was used for server since ARM arch is not supported (although it started successfully on Apple M3 chip ☺) and Docker installation on Mac is not easy to backup/restore due to filesystem access limitation.

# Users setup

99 users (as 1 user is reserved for admin and license limit is 100) created using k6 users.js script
https://github.com/yurysup/jetbrains-youtrack-test/blob/main/setup/users.js

Users data (username, email) are generated using Python Faker package https://faker.readthedocs.io/en/master/ in
https://github.com/yurysup/jetbrains-youtrack-test/blob/main/setup/fake_users_data.py

# Task #1: Issues upload

## Data parametrization

10.000 descriptions (up to 200 symbols) / summaries (up to 10 words) text prepared and stored in CSV format ensure data variety (e.g. search performance might be dramatically impacted by low data cardinality).

Same Faker package is used for data generation in https://github.com/yurysup/jetbrains-youtrack-test/blob/main/setup/fake_issues.py

## Creation scenario

Although issue creation scenario executed from UI (using web-browser) triggers bunch of different API calls (e.g. /drafts, /sprints, /issueWatchers, etc), there's a programmatic way to create a new issue using simple REST API call:

https://www.jetbrains.com/help/youtrack/devportal/resource-api-issues.html#create-Issue-method

**As far as task challenges us to 'upload 100k issues as fast as possible', we're going to stick to that simplistic scenario.**

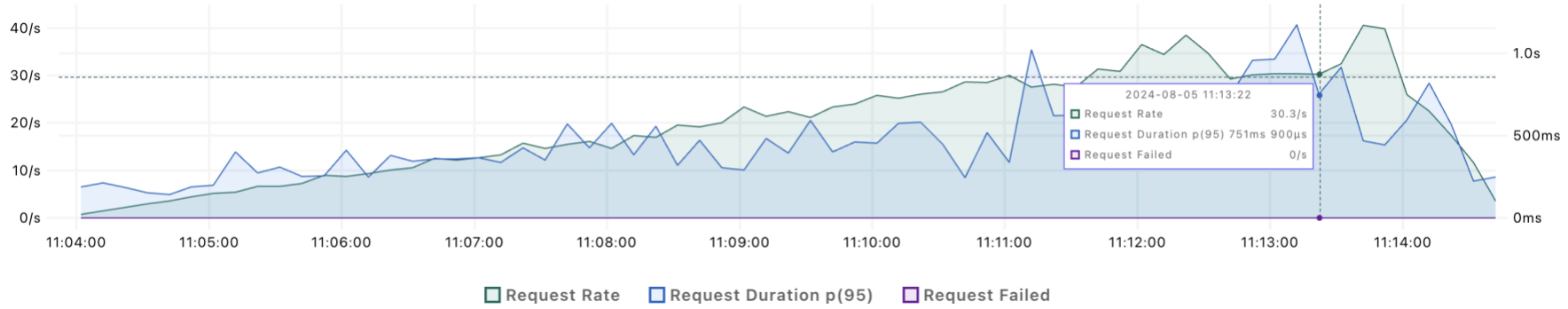
Please, note that real-world scenario would imply much more intensive load model to replicate browser behavior.

## Open vs Closed Load model

Since we need to ensure stability of issues creation (not to overload system causing failures), **closed load model better fits the case as it provides sort of back pressure mechanism** (each thread iteration will be delayed in case of service time degradation, stalling further requests initiation).

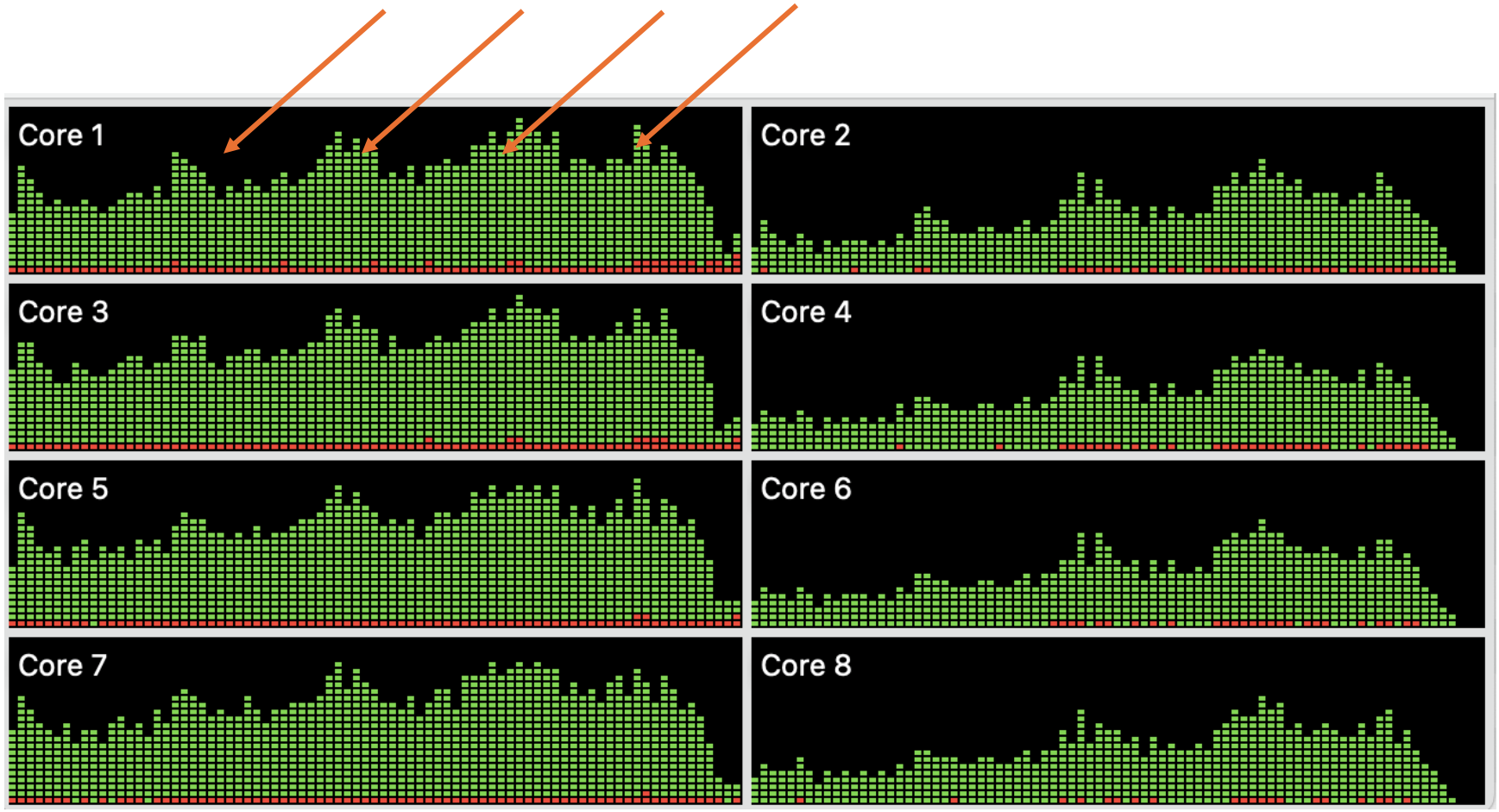
## Throughput

Ramp-up load test executed to check potential maximum throughout for issues creation.




Maximum throughput reached ~30rps, caused by CPU exhaustion. It may look not completely convincing due to CPU utilization ups & downs as there's a visible pattern of CPU spikes every ~1m or ~1.5m (potentially caused by some background scheduled task):

- Last 7m of the test:



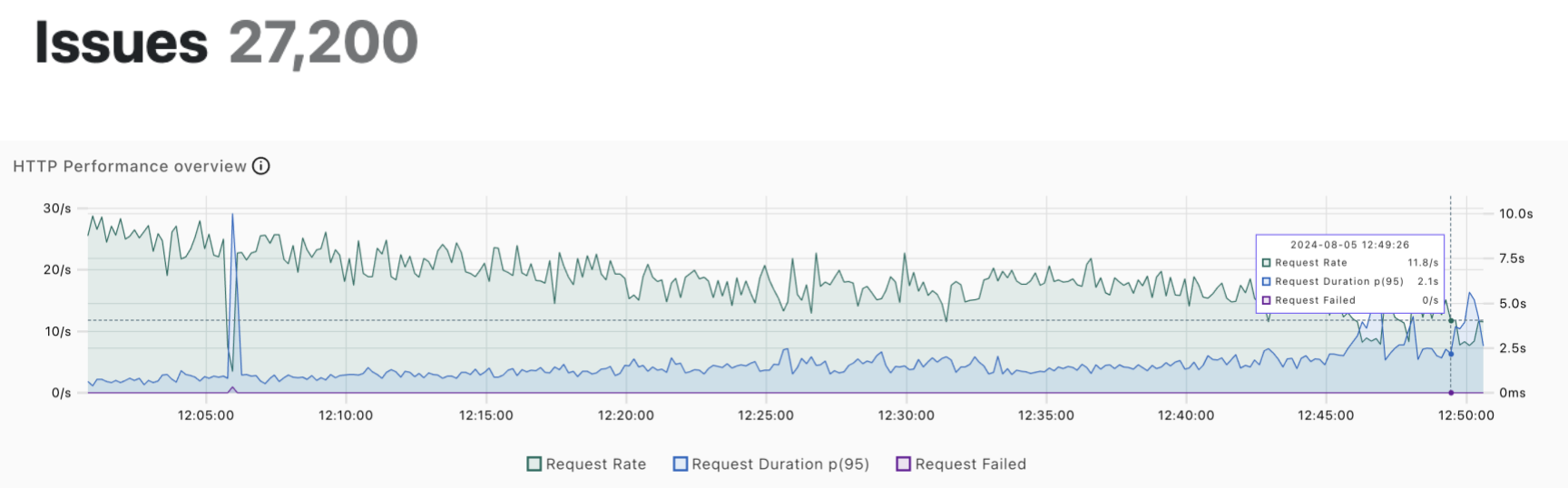

Thus, to ensure stable rate of issues creation (even during CPU spikes), we should stick to a rate of slightly less than **30rps**.
Note: there are 4 physical cores available on the server machine, however monitoring detects 8 vCPUs due to Intel's hyper-threading mechanism.

**Theoretical time** in that case would be 100_000 r / 30rps = 3333s ~= **1h**
However, there's no guarantee that system will demonstrate similar performance as number of issues in the system grows (e.g. indexes update and data insertion might become more expensive). Let's find it out by trying to create 100_000 issues.

## Upload 100_000 issues

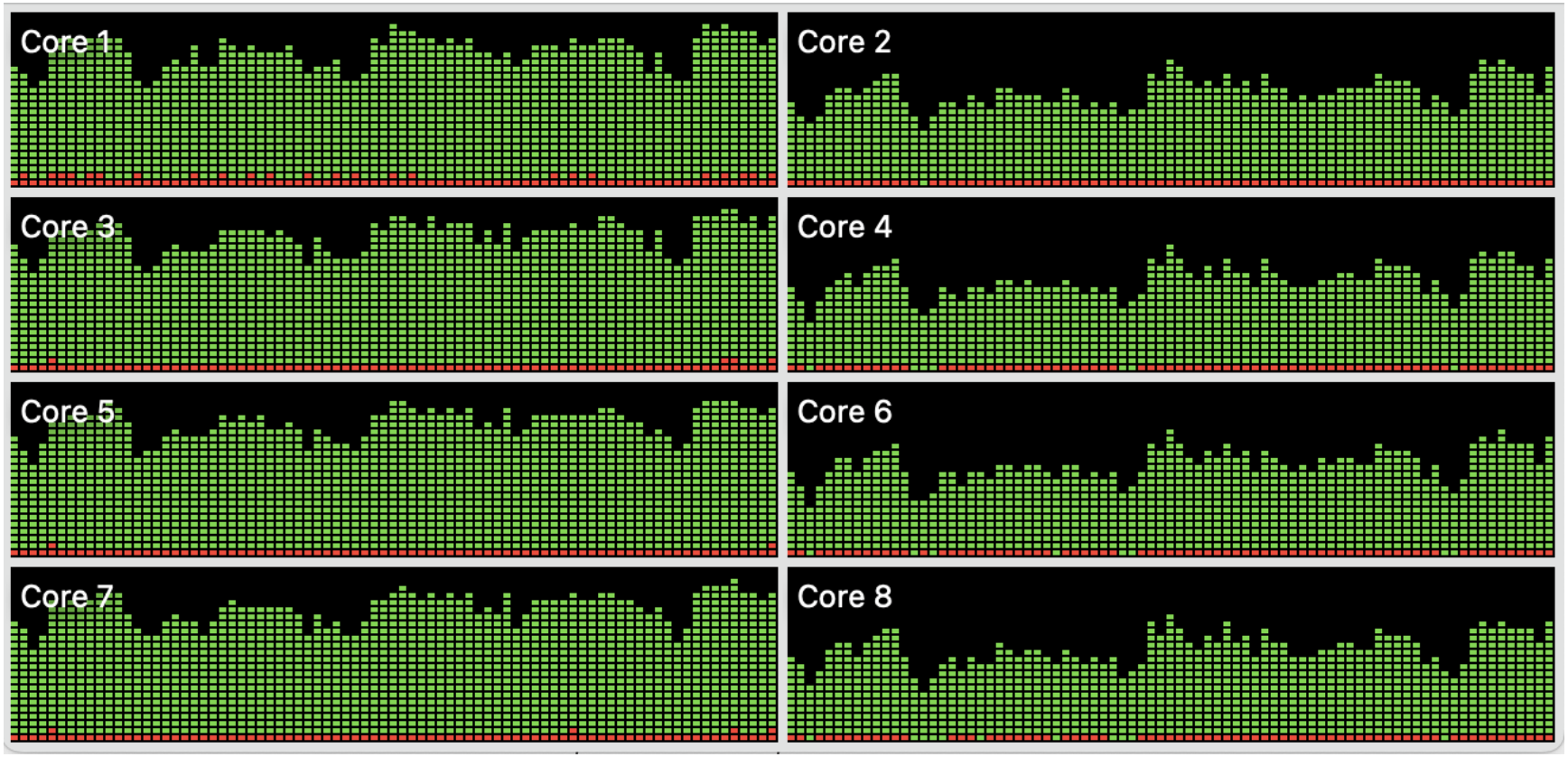
In order to create exactly 100k issues we're going use purpose-built k6 executor: https://k6.io/docs/using-k6/scenarios/executors/shared-iterations/ , see https://github.com/yurysup/jetbrains-youtrack-test/blob/main/setup/issues.js

I've started from ~27k issues in the system with a test of 35 virtual users (1s think time on each iteration), resulting in ~30rps:

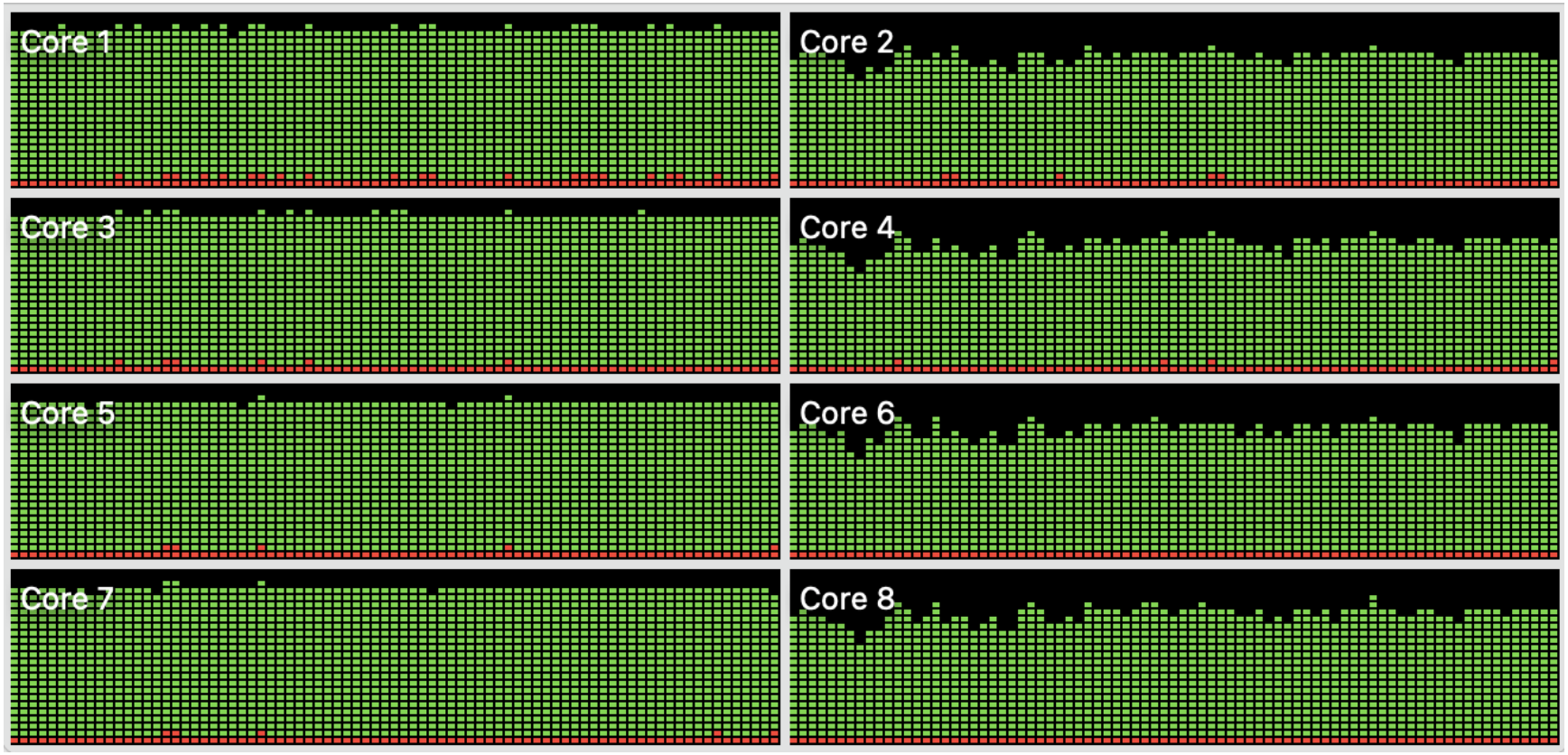



My initial assumption of **system degradation depending on data volume** was right. As we can see, service time increases linearly as data grows in the system (see issues throughput report). That means each issue creation operation becomes more and more CPU intensive:

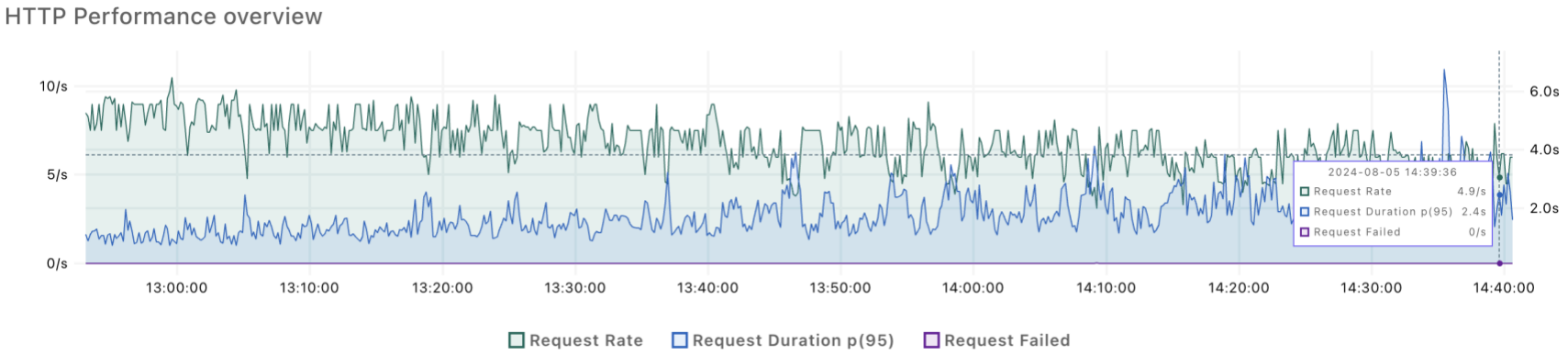
- How it started:




- How it ended:




So I was forced to stop the test and decrease number of virtual users to decrease pressure on the system (to avoid failures due to timeout and system outage):




Overall, we can see that **issue creation throughput has decreased** from **~30rps** when there were **27k issues** to **~5rps** when there were **127k issues**.

It took 50m + 110m = **160m in total to create 100k issues** (from 27k to 127k), which is almost 3 times higher than estimated based on initial throughput.


```
running (0h50m00.4s), 00/35 VUs, 55303 complete and 35 interrupted iterations
create_100k_issues ✗ [=====================>----------------] 35 VUs  0h50m00.4s/3h0m0s  055303/100000 shared iters
ERRO[3001] test run was aborted because k6 received a 'interrupt' signal
```

```
running (1h50m44.2s), 00/15 VUs, 44700 complete and 0 interrupted iterations
create_100k_issues ✓ [======================================] 15 VUs  1h50m44.2s/3h0m0s  44700/44700 shared iters
```

## Q&A

Q: How much it would take to 'upload' 100k issues?
A: It took **160m (2h40m)** due to **decreasing insert performance as data volume grows**.

# Task #2: Users load scenario

## Load model

Based on task description, I'm going to use following operations distribution as a base (with only assumptions that 9/10 issue 'write' operations are updates and 1/10 is new issue creation, and for each viewed issue user navigates to Issues page first).

| Operation | requests #, 1 user / h | requests #, 100 users / hour | requests #, 100 users / min |
|---|---|---|---|
| Create issue | 1 | 100 | 2 |
| Update issue | 9 | 900 | 15 |
| View issue/issues | 30 | 3000 | 50 |
| Search | 10 | 1000 | 17 |

As each user spends major part of the time in idle, it's more efficient from load generator utilization standpoint to rely on requests throughput rather than number of users in the system (though, generally there're cases when we need to ensure total amount of concurrent user connections/session, especially in stateful services). Besides of that, it's easier to emulate expected load rates directly rather than adjusting think times. For a test task purpose I'm going to stick to throughput-based model.

Open load model executor provided by k6 https://k6.io/docs/using-k6/scenarios/executors/ramping-arrival-rate/ is a good fit to ensure specific load rate per operation.

Thus, reaching desired operations load rates will indicate that system can handle 100 users operating concurrently. We can also increase load rates linearly by using *X_LOAD* multiplicator (where x1 equals to 100 users) to find out system's capacity (additional buffer).

## Endpoints selection

Although the task clearly defines limited load model we should stick to, there's still a problem of endpoints selection to be included into a test scenario. Generally, it's easier to build load model based on business scenarios/actions rather than specific endpoints, but similar criteria could be applied to individual endpoints as well.

Usually there are several key factors to consider when creating a load model:

- **Frequency of occurrence**: most used operations/endpoints tend to make more performance impact;
- **Business criticality**: any business-critical actions should be load-tested to ensure normal product operation (e.g. if payment in online shop doesn't work, it makes almost no sense; thus, it should be checked). Examples of such operations in case of issue tracker may include, but not limited to, issue creation / update / view;
- **Load intensity**: some operations may cause heavy load impact on the system even if they are used not as frequently, e.g. reports & statistics generation.

However, there might be additional minor factors to keep in mind, such as:

- **Maintainability & complexity of the load script**: whenever we're trying to reach higher test coverage, we're increasing complexity of the script and decreasing it's maintainability. In the worst case, performance team may spend too much time during release cycles doing script updates rather than valuable work such as analysis & optimizations;
- **Operations/data "balance"**: some modifying actions made in the system should be counter-balanced by applying reverting actions to avoid malfunctioning, e.g. closing recently opened issues per user as users do not tend to open 1k+ issues tabs. Although it might be useful to know if such behavior can really lead to a system instability or outage, it makes load model unrealistic and it makes practical conclusions from tests harder to make (will such a problem ever

occur in production or not?). That means if we add recently opened issue we should probably close it later to avoid data collecting over test iterations;
- **Caching**: some resources (not only html/css/js static files) might be cached on client side (example – *GET /api/config*). For the systems where there aren't many 'fresh' users such calls might be skipped.

From a practical standpoint, we should balance between coverage and script maintainability/complexity with help of the key factors described above.

Let's try to apply that criteria and define crucial calls/endpoints within our main user operations in YouTrack (as it tends to send a bunch of API requests per each transaction/operation).

## Business criticality

Specific endpoints that are playing main role in user action should be included into a script.
Examples of such endpoints:

- *GET /api/sortedIssues, POST /api/issuesGetter* while viewing Issues page;
- *GET /api/issues/<issue_id>* while viewing/previewing particular issue;
- *POST /api/users/me/drafts, GET /api/users/me/drafts, POST /api/users/me/drafts/<id>, POST /api/issues?draftId=<id> for creating new issue;*
- *POST /api/commands?fields=issues(idReadable)* while applying commands;
- *PUT /api/issues/<issue_id>/draftComment, POST /api/issues/<issue_id>/draftComment, POST /api/issues/<issue_id>/comments* while commenting issues (or using commands);
- *GET /api/sortedIssues?query= , POST /api/issuesGetter* while doing search;

## Frequency of occurrence

YouTrack UI seems to send a bunch of different requests (and some of them are repeated multiple times) for every user action:

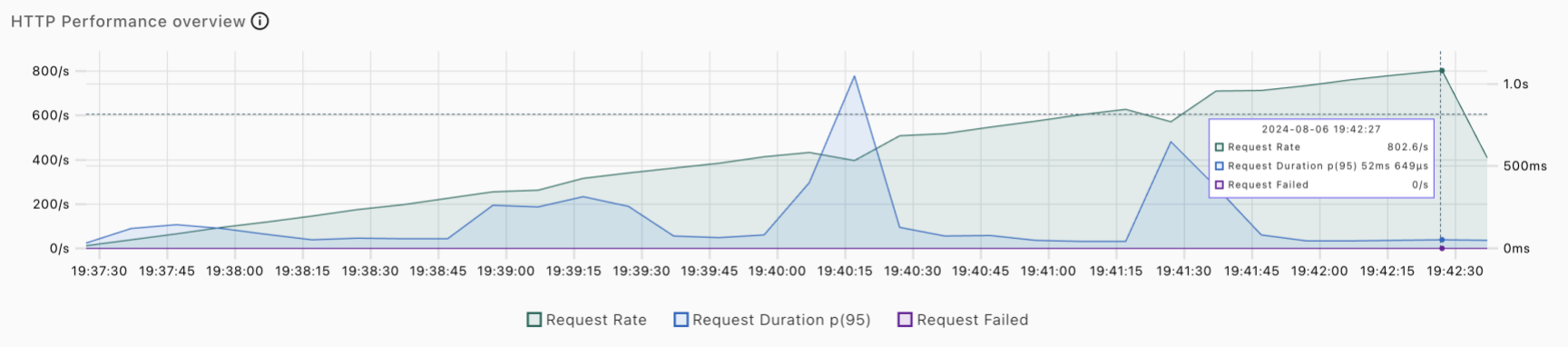
- *GET /api/issues/<issue_id>/sprints, GET /api/issues/<issue_id>/links, GET /api/issues/<issue_id>/activitiesPage, GET /api/issues/<issue_id>/issueWatchers, POST /api/issuesGetter, POST /api/users/me/recent/issues, POST /api/issuesGetter/counts* while viewing/previewing particular issue;
- *POST /api/search/assist* while doing search;
- *POST /api/commands/assist* while applying commands;

There are many other calls made from UI while doing user actions (some of them are triggered from different pages, e.g. *GET /api/inbox/folders, GET /api/permissions/cache, GET /api/filterFields/values, GET /api/users/me* and others. For the task solution purpose, I'm not going to include them, **but on real projects they still should be at least considered**. Even if every particular call doesn't seem to make any difference, it's the total amount of them which may impact performance. Generally, we can either check their load intensity by providing synthetic test with such calls, or we can increase load rates of other operations in test to counter-balance the fact of partially missing load/traffic.

## Load intensity

As mentioned above, let's try to assess an impact from some calls that seem to be neglectable. To do that, we can create a simple synthetic load test containing some of these calls to see how many of them system can handle:

- *GET /api/inbox/folders?$top=-1&fields=id,lastNotified,lastSeen,enabled&ignoreLicenseErrors=true&start=<timestamp>*
- *GET /api/permissions/cache?fields=global,permission(key),projects(id)*
- *GET /api/filterFields/project/values?$top=-1&fields=id,presentation,query&prefix=&query=&type=Issue*
- *GET /api/admin/widgets/general?fields=id,key,appId,description,appName,name,collapsed,indexPath,extensionPoint(),iconPath,appIconPath,expectedHeight,expectedWidth*




System can **easily handle >800rps** with such 'minor' calls. Given that 100 users are viewing issues with a rate of ~1rps, there should be hundreds of these calls per single view to make any impact, which **allows us to ignore them**.
Interestingly, an impact of presumably a background task running every ~1m I mentioned earlier is visible even on such test by impacted response times.

## Resulting scenarios

- View all issues: *GET /sortedIssues, POST /issuesGetter/count, POST /issuesGetter*;
- View particular issue: *GET /issues*;
- Create issue: *POST /users/me/drafts, POST /users/me/drafts/<draft_id>, POST /issues*;
- Update issue: *POST /commands/assist, POST /commands*;
- Search issues (both attribute & text): *POST /search/assist, GET /sortedIssues?query=, POST /issuesGetter*;

See https://github.com/yurysup/jetbrains-youtrack-test/blob/main/youtrack.js

In conclusion, I'd like to mention that I wasn't aiming to providing the most realistic/accurate load model, but rather tried to come up with a general framework of assessing endpoints/operations coverage. Simplistic resulting set is relevant for a test task purpose only.

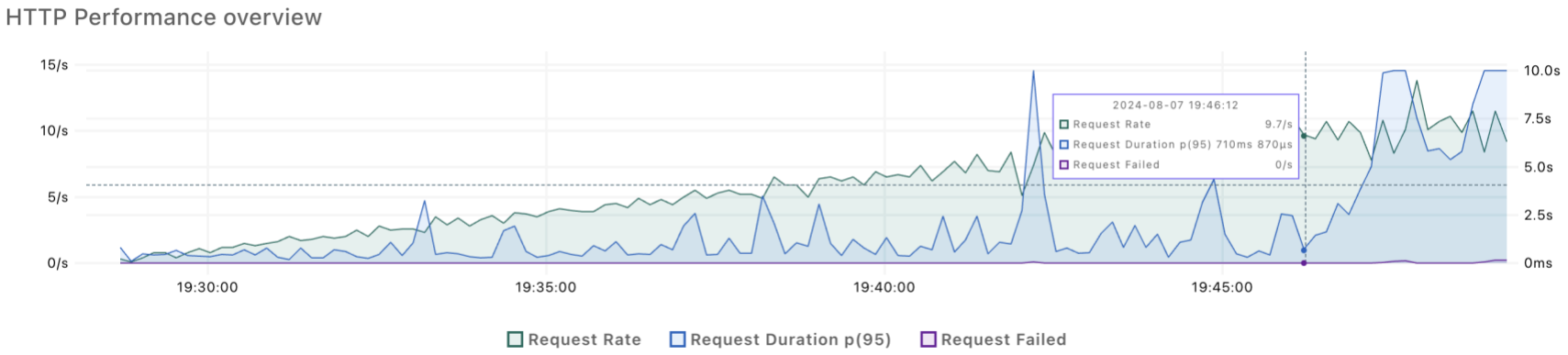
## Test execution

### Capacity

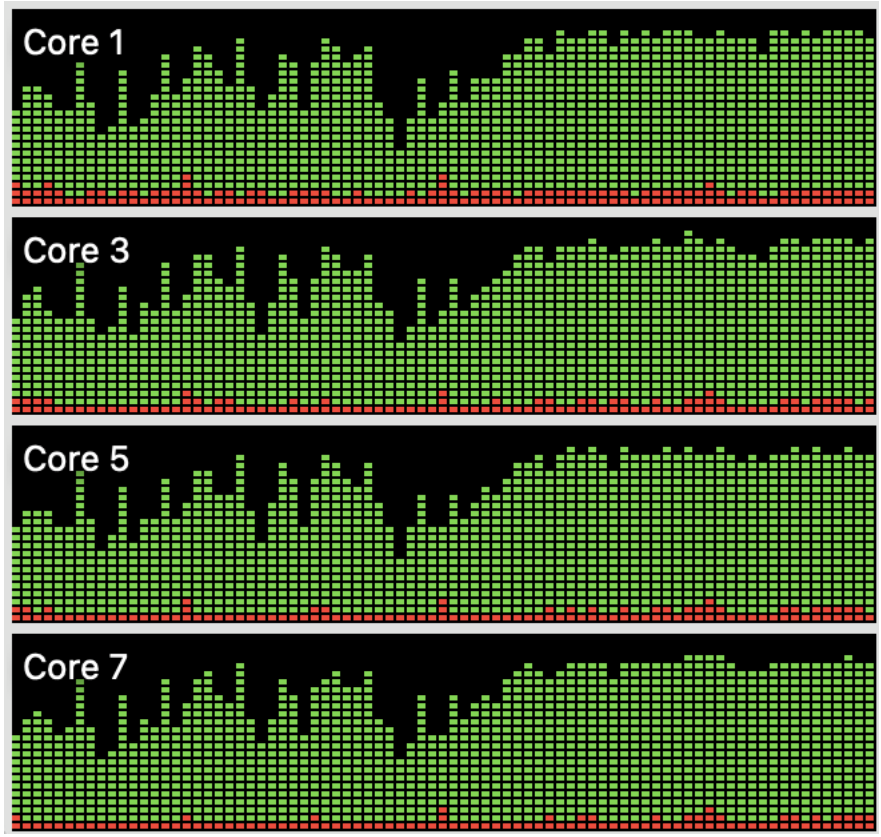
First, let's figure out the maximum capacity, e.g. find saturation point.
To do that, I'm going ramp the load up to X_LOAD=3 (equals to 300 concurrent users) over 30m and track response times/throughout/error rate.

```
scenarios: (100.00%) 4 scenarios, 160 max VUs, 32m30s max duration (incl. graceful stop):
         * create_issue: Up to 0.10 iterations/s for 32m0s over 3 stages (maxVUs: 20, exec: testCreateIssue, gracefulStop: 30s)
         * search_issues: Up to 0.85 iterations/s for 32m0s over 3 stages (maxVUs: 20, exec: testSearchIssues, gracefulStop: 30s)
         * update_issue: Up to 0.75 iterations/s for 32m0s over 3 stages (maxVUs: 20, exec: testUpdateIssue, gracefulStop: 30s)
         * view_issue: Up to 2.50 iterations/s for 32m0s over 3 stages (maxVUs: 100, exec: testViewIssue, gracefulStop: 30s)
```

After ~20m of the test run, I was forced to stop it as responses grew up to ~10s causing timeouts (set in k6 script):

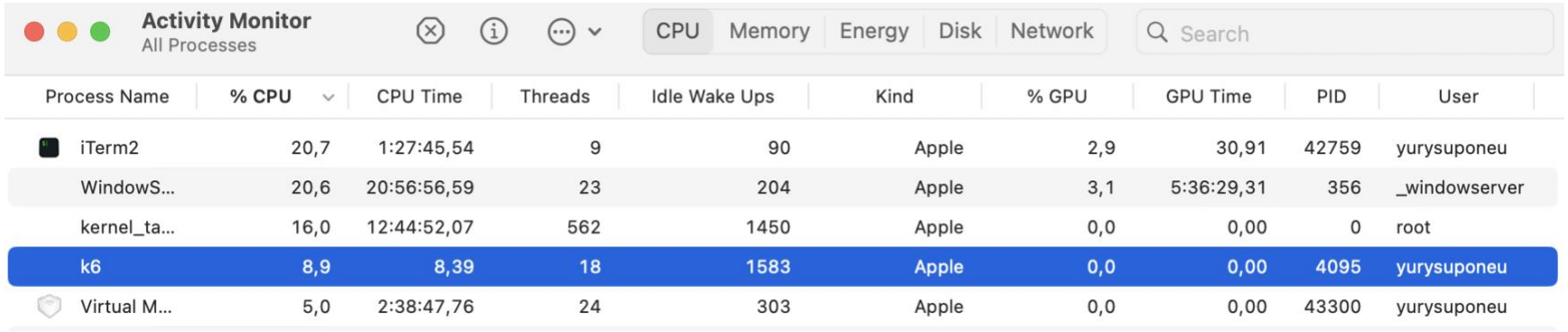


Saturation point seems to be reached ~ at 19:46 (**17m** after test start) as responses start to grow rapidly due to CPU resource exhaustion (last 7m of the test):




As test was ramping up from 0 to 300 users within 30m, 17m of the test indicates **~170 users as a maximum throughput** (capacity). It gives us ~70% of safety buffer in terms of load system can handle (see capacity report).

Meanwhile, load generator machine was hardly loaded:

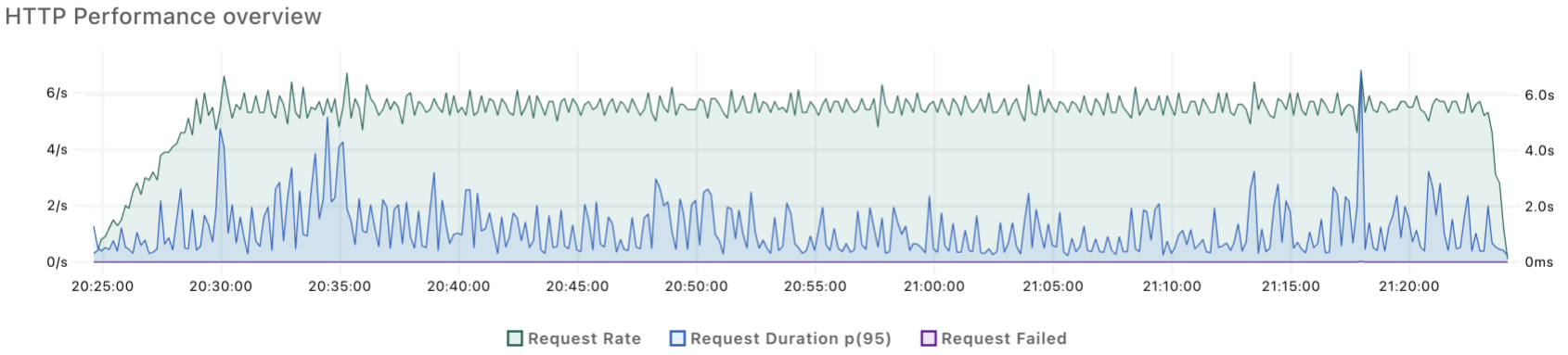



| Process Name | % CPU | CPU Time | Threads | Idle Wake Ups | Kind | % GPU | GPU Time | PID | User |
|---|---|---|---|---|---|---|---|---|---|
| iTerm2 | 20,7 | 1:27:45,54 | 9 | 90 | Apple | 2,9 | 30,91 | 42759 | yurysuponeu |
| WindowS... | 20,6 | 20:56:56,59 | 23 | 204 | Apple | 3,1 | 5:36:29,31 | 356 | _windowserver |
| kernel_ta... | 16,0 | 12:44:52,07 | 562 | 1450 | Apple | 0,0 | 0,00 | 0 | root |
| k6 | 8,9 | 8,39 | 18 | 1583 | Apple | 0,0 | 0,00 | 4095 | yurysuponeu |
| Virtual M... | 5,0 | 2:38:47,76 | 24 | 303 | Apple | 0,0 | 0,00 | 43300 | yurysuponeu |

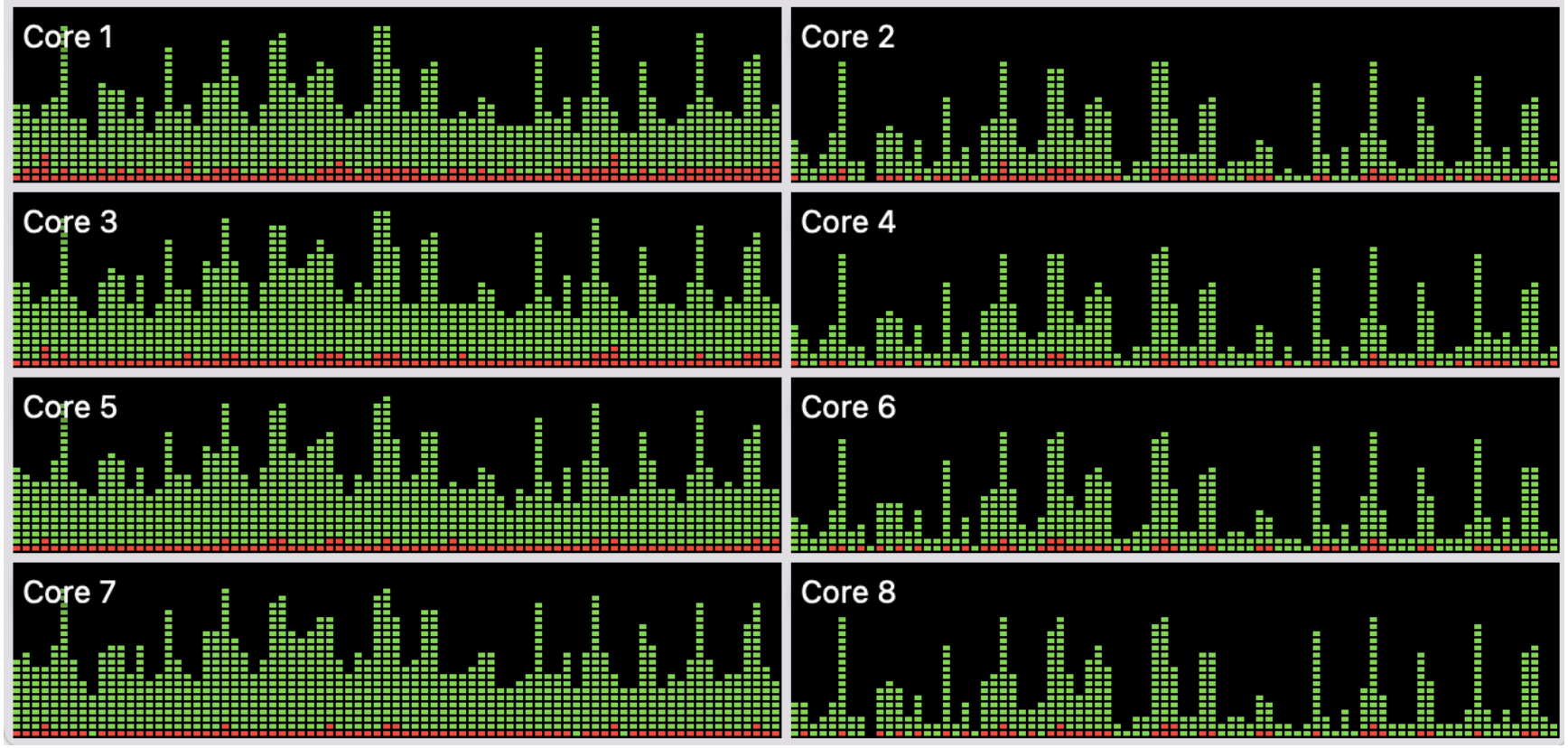
Which double-confirms that the **bottleneck is on application side**.

## 100 users fixed-load test

Now let's figure out if system can stay stable at expected peak load of **100 concurrent users** over longer time – **1h** as suggested by the task (see fixed-load report).



Response times were stable throughout the test apart from a few peaks (correlated with CPU peaks):



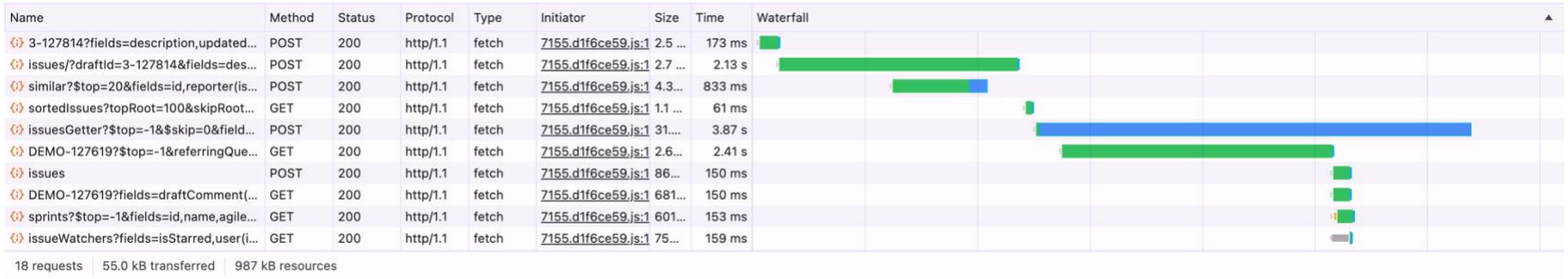

Let's assess **summary statistics**:

```
  checks.............................: 0.00%  ✓ 0        ✗ 0
  ✓ { name:main_calls_status_200 }...: 0.00%  ✓ 0        ✗ 0
  data_received.....................: 3.1 GB 853 kB/s
  data_sent.........................: 34 MB  9.5 kB/s
  http_req_blocked..................: avg=520.76µs min=1µs     med=9µs      max=500.22ms p(90)=13µs     p(95)=15µs
  http_req_connecting...............: avg=510.44µs min=0s      med=0s       max=500.08ms p(90)=0s       p(95)=0s
  http_req_duration.................: avg=299.54ms min=4.18ms  med=97.11ms  max=10s      p(90)=650.27ms p(95)=1.32s
    { expected_response:true }......: avg=299.03ms min=4.18ms  med=97.11ms  max=9.73s    p(90)=650.17ms p(95)=1.32s
  ✓ { name:GET /issues }............: avg=146.13ms min=12.42ms med=84.58ms  max=1.67s    p(90)=337.77ms p(95)=435.58ms
  ✓ { name:GET /search/assist }.....: avg=158.88ms min=11.41ms med=89.75ms  max=1.91s    p(90)=369.87ms p(95)=497.21ms
  ✓ { name:GET /sortedIssues }......: avg=126.96ms min=5.81ms  med=40.29ms  max=4.9s     p(90)=341.79ms p(95)=439.04ms
  ✗ { name:POST /commands }.........: avg=368.53ms min=36.84ms med=85.55ms  max=5.97s    p(90)=1.01s    p(95)=1.49s
  ✓ { name:POST /commands/assist }...: avg=107.01ms min=5.71ms  med=58.89ms  max=1.54s    p(90)=260.08ms p(95)=314.48ms
  ✗ { name:POST /issues }...........: avg=3.41s    min=1.19s   med=3.13s    max=10s      p(90)=4.91s    p(95)=5.6s
  ✗ { name:POST /issuesGetter }.....: avg=778.8ms  min=5.58ms  med=437.27ms max=7.13s    p(90)=2.03s    p(95)=2.59s
  ✓ { name:POST /users/me/drafts }...: avg=296.92ms min=39.47ms med=175.86ms max=1.58s    p(90)=666.75ms p(95)=825.9ms
✓ http_req_failed...................: 0.00%  ✓ 1        ✗ 18923
  http_req_receiving................: avg=134.16ms min=0s      med=532µs    max=6.32s    p(90)=373.55ms p(95)=727.1ms
  http_req_sending..................: avg=89.91µs  min=8µs     med=65µs     max=3.6ms    p(90)=229µs    p(95)=270µs
  http_req_tls_handshaking..........: avg=0s       min=0s      med=0s       max=0s       p(90)=0s       p(95)=0s
  http_req_waiting..................: avg=165.29ms min=4.13ms  med=50.46ms  max=10s      p(90)=356.01ms p(95)=572.51ms
  http_reqs.........................: 18924  5.247204/s
  iteration_duration................: avg=4.13s    min=47.83ms med=3.78s    max=15.35s   p(90)=7.02s    p(95)=7.81s
  iterations........................: 4788   1.327606/s
  vus...............................: 1      min=0      max=16
  vus_max...........................: 160    min=160    max=160
```

Thresholds were set to p90:1000ms for all POST requests and p90:500ms for all GET requests.
As we can see, multiple POST requests have significantly crossed the expected SLA:

- POST /commands – apply commands 1.01s;
- POST /issues – create issue **4.91s**;
- POST /issuesGetter – receive list of issues **2.03s**;

It may seem like we've chosen saturation point too high and gave wrong capacity evaluation, but in fact it's **caused by general slowness of respective endpoints due to high data volume**. It's visible even on idle system with single (1) user interaction, which means system will exceed SLAs in that case as well:



| Name | Method | Status | Protocol | Type | Initiator | Size | Time | Waterfall |
|---|---|---|---|---|---|---|---|---|
| 3-127814?fields=description,updated... | POST | 200 | http/1.1 | fetch | 7155.d1f6ce59.js:1 | 2.5 ... | 173 ms | |
| issues/?draftId=3-127814&fields=des... | POST | 200 | http/1.1 | fetch | 7155.d1f6ce59.js:1 | 2.7 ... | 2.13 s | |
| similar?$top=20&fields=id,reporter(is... | POST | 200 | http/1.1 | fetch | 7155.d1f6ce59.js:1 | 4.3... | 833 ms | |
| sortedIssues?topRoot=100&skipRoot... | GET | 200 | http/1.1 | fetch | 7155.d1f6ce59.js:1 | 1.1 ... | 61 ms | |
| issuesGetter?$top=-1&$skip=0&field... | POST | 200 | http/1.1 | fetch | 7155.d1f6ce59.js:1 | 31.... | 3.87 s | |
| DEMO-127619?$top=-1&referringQue... | GET | 200 | http/1.1 | fetch | 7155.d1f6ce59.js:1 | 2.6... | 2.41 s | |
| issues | POST | 200 | http/1.1 | fetch | 7155.d1f6ce59.js:1 | 86... | 150 ms | |
| DEMO-127619?fields=draftComment(... | GET | 200 | http/1.1 | fetch | 7155.d1f6ce59.js:1 | 681... | 150 ms | |
| sprints?$top=-1&fields=id,name,agile... | GET | 200 | http/1.1 | fetch | 7155.d1f6ce59.js:1 | 601... | 153 ms | |
| issueWatchers?fields=isStarred,user(i... | GET | 200 | http/1.1 | fetch | 7155.d1f6ce59.js:1 | 75... | 159 ms | |

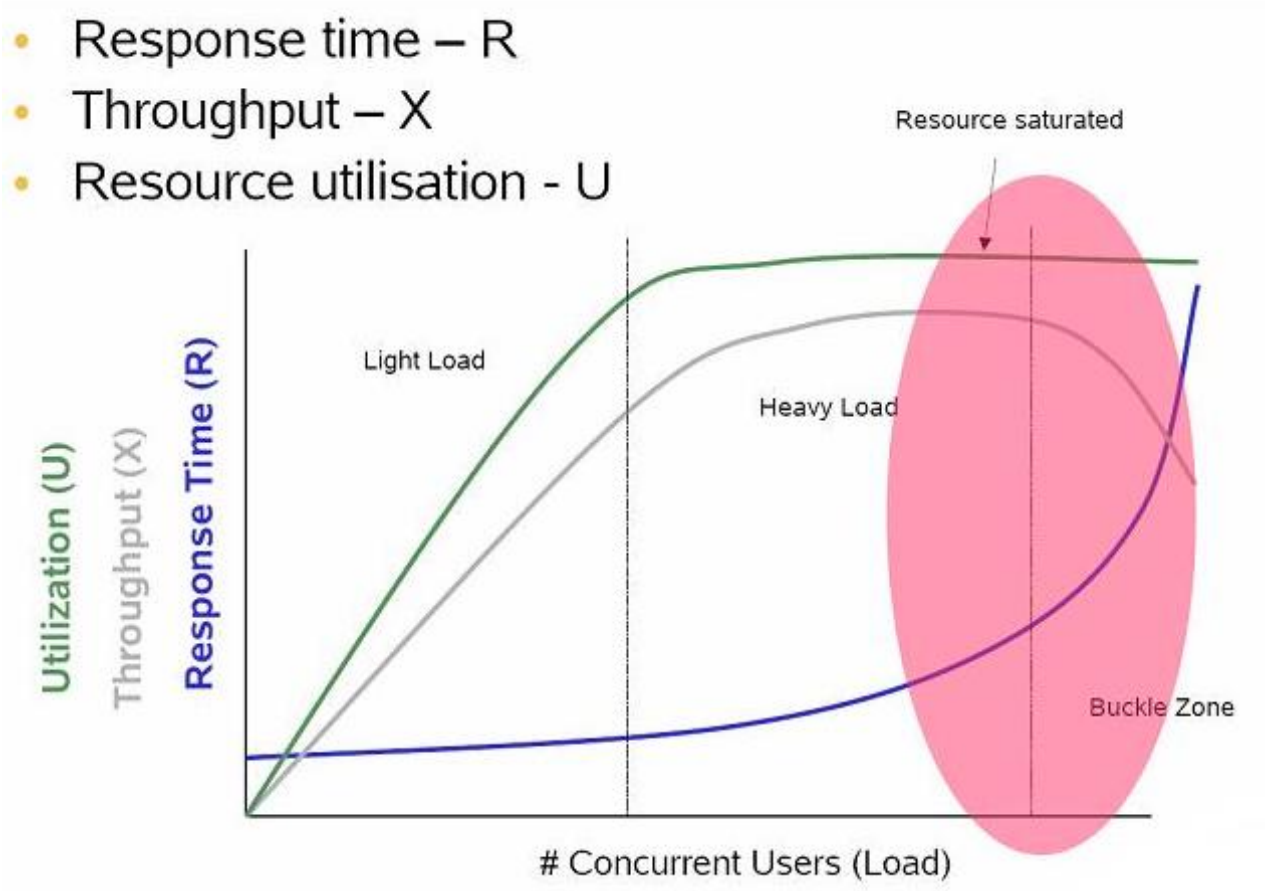
18 requests | 55.0 kB transferred | 987 kB resources

Single user test over 10 iterations:

✗ { name:POST /issues }.....: avg=2.82s min=1.59s med=2.62s max=4.87s **p(90)=3.68s** p(95)=4.27s

✗ { name:POST /issuesGetter }.....: avg=850.92ms min=11.43ms med=601.17ms max=4.81s **p(90)=1.68s** p(95)=2.28s

Although task explicitly declares 1000ms/500ms for POST/GET requests respectively, saturation point can't be defined by SLA only. General definition of saturation point:




That's the method I applied when identifying maximum capacity. Although **there's a correlation between response time and capacity, it can't be defined by specific threshold only**.
Generally, such **high response times need to be investigated/profiled to make API calls faster** (e.g. check traces if available, investigate underlying SQLs if any, etc). It may decrease pressure on the system, and lead to capacity increase (although it's not guaranteed and depends on type of the bottleneck). Capacity limitation due to CPU resource can be investigated using Java profilers.

## Q&A

Q: Can YouTrack tracker handle 100 concurrent users?
A: Yes, it **can handle more than 100 concurrent users** without significant degradation;

Q: What endpoints are crucial for load testing and what are not?
A: See **Endpoint selection** and **Resulting scenarios sections**;

Q: How much of safe-buffer system has in terms of load (capacity without significant degradation)?
A: System demonstrates **capacity of ~170 concurrent users** in current setup, however, is affected by some responses spikes;

Q: Can saturation point be detected in current setup or something is preventing us from doing it?
A: **Saturation point was successfully identified**, although it's not absolutely accurate due to spikes/deviations. However, SLA thresholds were crossed from the very beginning of the test, which means system doesn't demonstrate desired performance in terms of how fast it operates from user perspective.

# Additional Questions

## Q&A

Q: In case of load generator and service sharing same server, how can performance impact be mitigated? What system resources are they sharing?
A: For **Docker installation**, **specific resources can be provisioned per container** - https://docs.docker.com/config/containers/resource_constraints/ (*docker run –cpus <cpu_count> --memory <memory_amount>*), while for **ZIP installation native OS mechanisms should be used**, e.g. *ulimits* & *cgroups* (which I assume are implicitly used by docker as well);

Q: In case of load generator and service being set on separate servers, how performance degradation of the service can be justified?
A: By **providing telemetry both for service and load generator** (see Test execution section);

Q: In case of Cloud installation, can in-built telemetry from admin console be used for performance degradation justification?
A: I haven't used Cloud installation, but I used **admin telemetry endpoint** for ZIP installation (https://www.jetbrains.com/help/youtrack/devportal/resource-api-admin-telemetry.html) and it **doesn't seem to provide much of useful data for bottleneck localization**


```
{
  "textIndexSize": "130.5 MB",
  "blobStringsCacheHitRate": "78.64%",
  "usedMemory": "980.1 MB",
  "databaseBackgroundThreads": 1,
  "pendingAsyncJobs": 0,
  "databaseQueriesCacheHitRate": "25.04%",
  "requestsPerSecond": "0.13",
  "$type": "Telemetry"
}
```