CNTF - Containerized Network Testing Framework

Business Relevance

CNTF is a testing environment designed for developers to evaluate open-source 5G cores.

- For **developers**, CNTF offers valuable resources to enhance 5G core development and make informed comparisons of existing solutions. It will give valuable insights into these solutions, potentially reducing the cost of provisioning private 5G network(s) by taking advantage of open-source applications.

- For **enterprises**, CNTF provides assurance that they have selected the right 5G core for their specific needs.

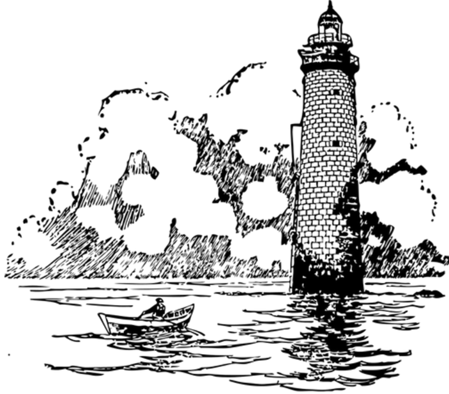
Project Refocus

Originally, this project aimed to build test frameworks around three different open-source 5G cores: Open5GS, Magma, and Free5GC. However, after thorough research, it became clear that only one was a viable option: Open5GS.

Review of Magma and Free5GC:

- Magma: Magma is no longer actively developed or supported by either Facebook or the Linux Foundation. Additionally, it relies on a deprecated version of Kubernetes.
- Free5GC: While potentially valuable, Free5GC proved challenging to integrate with Kubernetes due to its numerous dependencies, making it difficult to test effectively.

Customer Focus



Customer: LiveView

Main takeaways from conversations with LiveView:

- Desires for a 5G network:
  - Rapid UE Connections (< 60 seconds).
  - Consistent Upload Speeds (3MBps - 12MBps) regardless of network traffic.
- Other:
  - Automated Testing (Simulate VPN connections, latency, traceroutes, network connection times, cradlepoint reboots, and carrier change speed).
  - Real-time, observable network data.

Objective Key Results

Hypothesis: “Testing Open5GS for load, latency, and QoS will uncover its inadequacy in meeting the network requirements of our customer, LiveView."

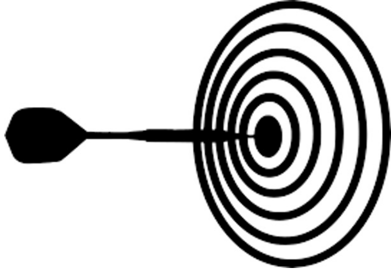
OKRs:

1: Create an automated process of deploying open-source 5G core(s), UERANSIM (test-suite), and out of the box tests.

2: Develop six reusable test cases focused on load, latency, and QoS, to evaluate Open5GS as a potential 5G core for LiveView.

3: Create three dashboards visualizing network data in real-time.

OKR Outcomes



OKR 1: 70%

- Successfully automated the deployment of infrastructure, apps, and test cases via Gitlab CI pipelines.
- Some test cases that LiveView had in mind were not accounted for, such as VPN connections and trace routing, speed of carrier changes, etc.

OKR 2: 75%

- Successfully developed five reusable test cases to evaluate the load and latency performance of Open5GS
- Could not test QoS because Open5GS does not support this functionality.

OKR 3: 85%

- Effectively visualized live test data by creating five Coralogix dashboards.
- The visualization of test data is near real-time but could be further optimized

Test Cases

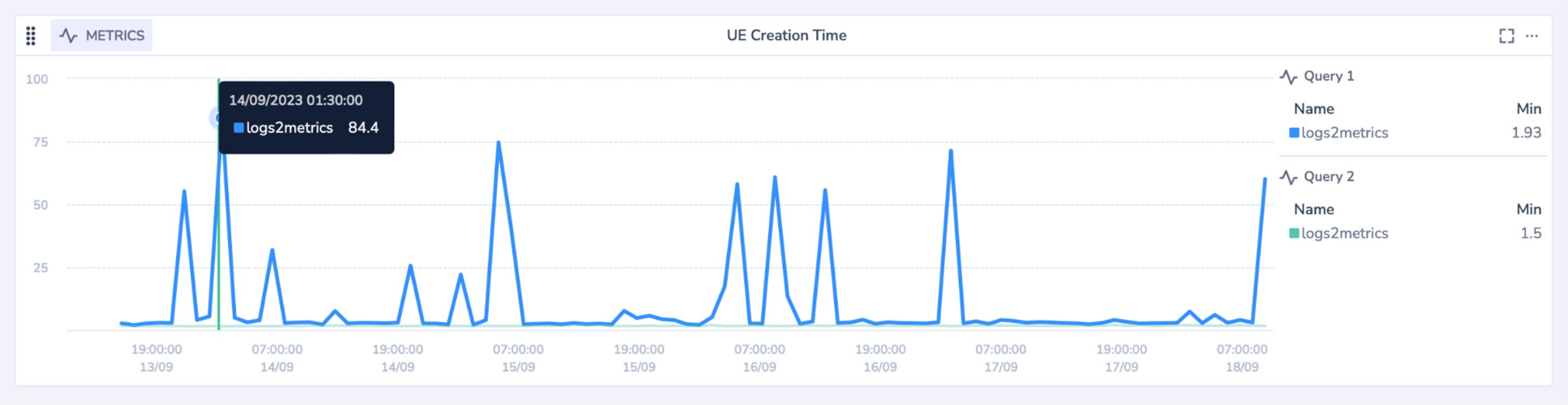
Methodology

CNTF test cases were crafted and executed using bash scripts and UERANSIM. Originally designed for Open5GS, with minor adjustments, they can also run on other open-source networks that support UERANSIM integration and containerized environments with bash shells.

UERANSIM
5G SOLUTIONS

Test Case - UE Subscription Test

- **Description:** Connect new user equipment (UE) devices to Open5GS every five minutes.
- **Purpose:** Evaluate Open5GS's response to continuous new connections and its ability to meet LiveView's requirement of connecting to a new network in under 60 seconds.
- **Outcomes:**
  - Open5GS inconsistently subscribed UEs in under 60 seconds.
  - Open5GS limits its simultaneous UE connections to approx. 3,000 devices. After that, its database blocks new connections.



UE Creation Time

14/09/2023 01:30:00
🟦 logs2metrics 84.4

Query 1

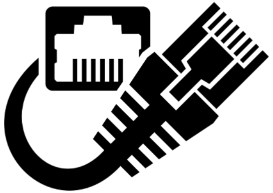
Name	Min
🟦 logs2metrics	1.93

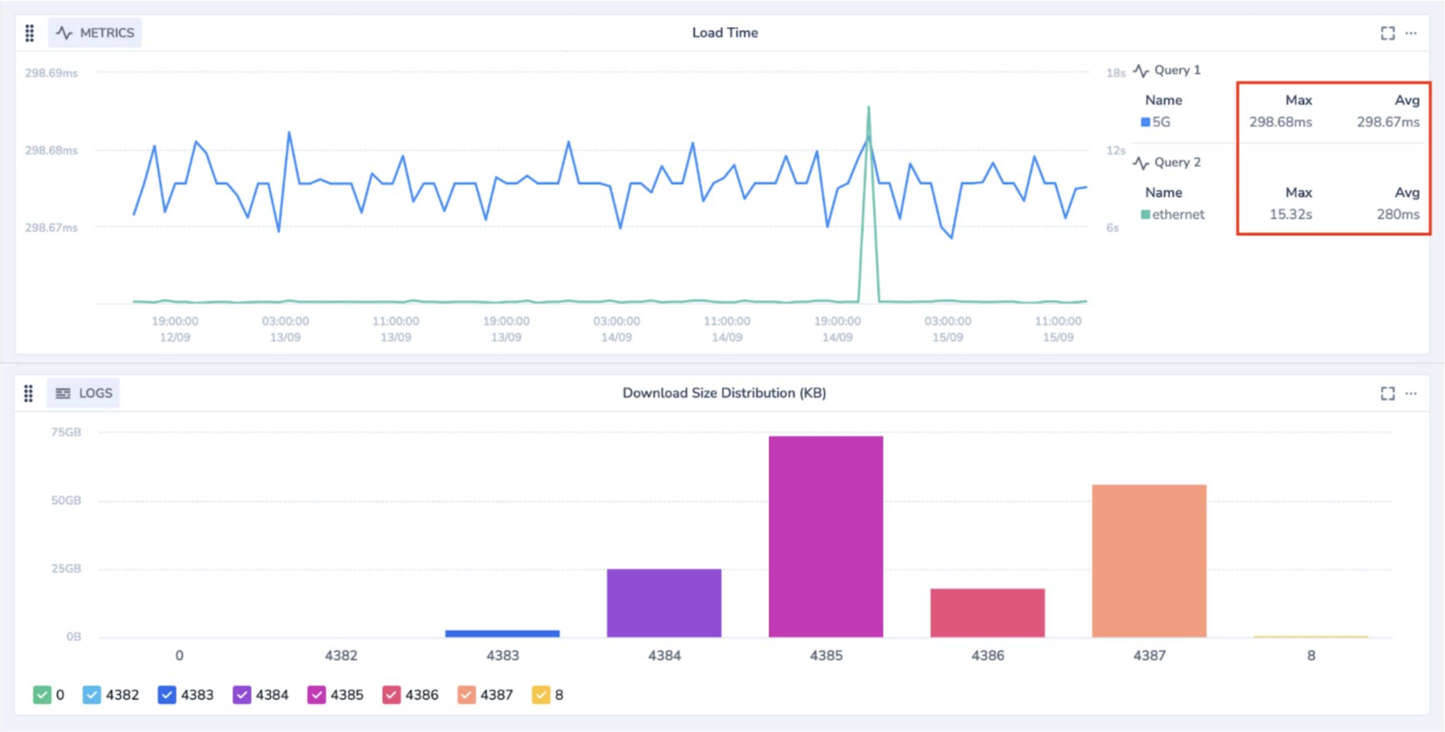
Query 2

Name	Min
🟩 logs2metrics	1.5

Test Case - Smoke Test

- **Description:** Compare the speed of Open5GS to the internet by simultaneously executing curl commands over 5G network interfaces and an ethernet interface.
- **Purpose:** Evaluate Open5GS's baseline latency performance.
- **Outcome:** Open5GS consistently showed slightly higher latency compared to the internet when accessing websites.



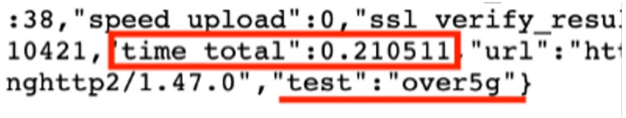


Query 1

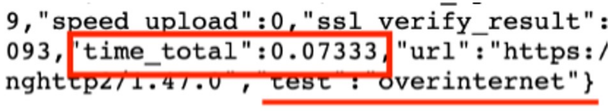
Name	Max	Avg
5G	298.68ms	298.67ms

Query 2

Name	Max	Avg
ethernet	15.32s	280ms



```
:38,"speed upload":0,"ssl verify_resul
10421,"time total":0.210511,"url":"ht
nghttp2/1.47.0","test":"over5g"}
```



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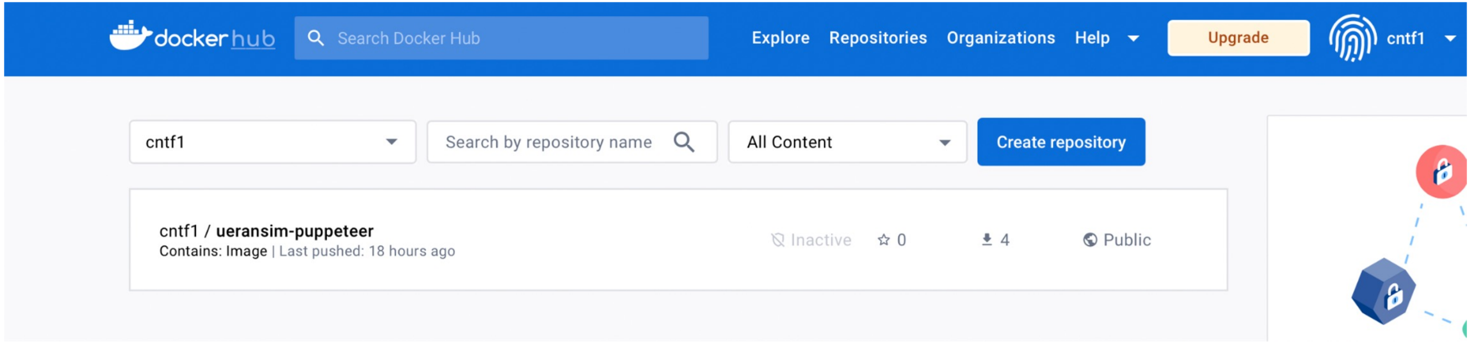
9,"speed upload":0,"ssl verify_result":
093,"time_total":0.07333,"url":"https:/
nghttp2/1.47.0","test":"overinternet"}
```

UERANSIM Customization

UERANSIM + Puppeteer

Description: Customized the UERANSIM test suite to enable UEs to perform various user activities (e.g. watching YouTube, browsing websites, etc.). This was achieved by enhancing UERANSIM's Docker image with Chromium, Node.js and unique JavaScript files.



cntf1 / **ueransim-puppeteer**
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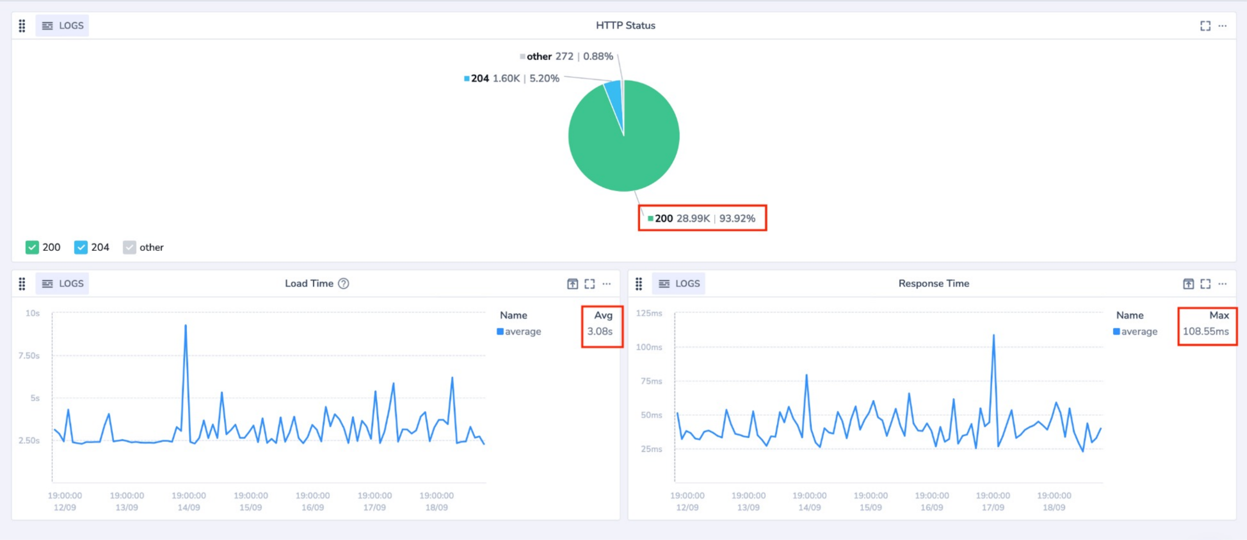
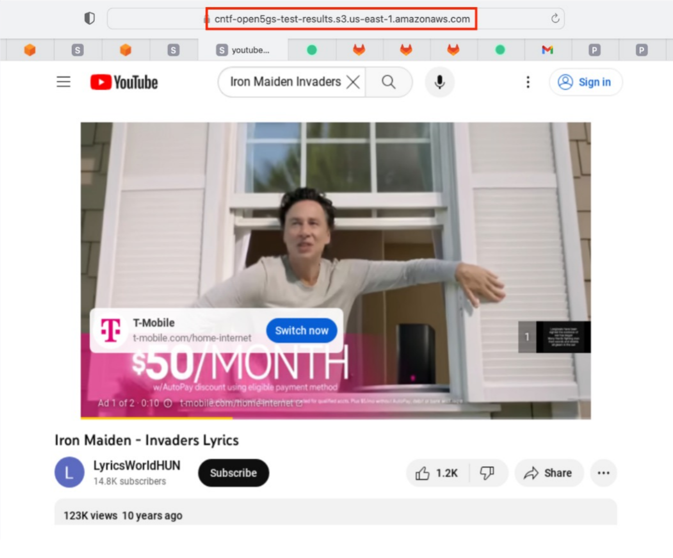
Inactive ☆ 0 ⬇ 4 Public

Test Case - YouTube Test

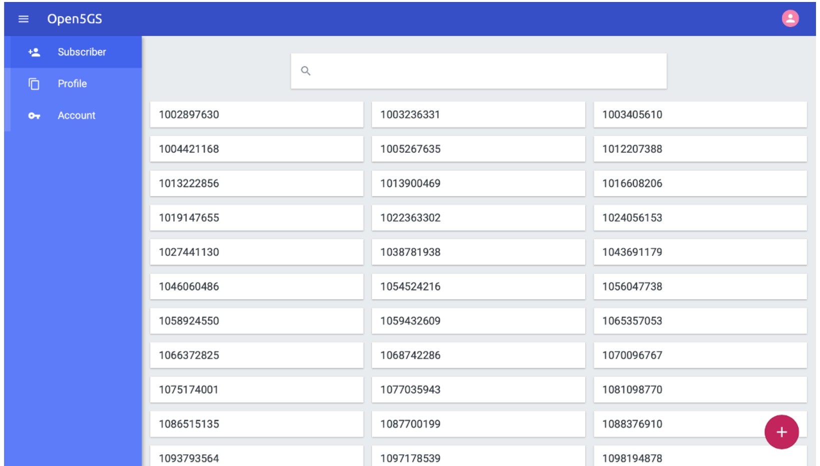
- **Description:** Simulate a UE watching a YouTube video while connected to the 5G network.
- **Purpose:** Determine how well Open5GS supports data streaming activities on a UE (e.g. video playback).
- **Outcome:** Open5GS demonstrated good video streaming performance with minimal HTTP errors and consistent response/load times.
- **Metrics:**
    - screenshot of video
    - total test load time
    - network requests (Records load times for individual network requests during the test, with a focus on critical requests among the approximately 50 made during YouTube video playback)


LOGS
HTTP Status
other 272 | 0.88%
204 1.60K | 5.20%
200 28.99K | 93.92%
☑ 200 ☑ 204 ☑ other
LOGS
Load Time
10s
7.50s
5s
2.50s
19:00:00 12/09
19:00:00 13/09
19:00:00 14/09
19:00:00 15/09
19:00:00 16/09
19:00:00 17/09
19:00:00 18/09
Name
average
Avg
3.08s
LOGS
Response Time
125ms
100ms
75ms
50ms
25ms
19:00:00 12/09
19:00:00 13/09
19:00:00 14/09
19:00:00 15/09
19:00:00 16/09
19:00:00 17/09
19:00:00 18/09
Name
average
Max
108.55ms


cntf-open5gs-test-results.s3.us-east-1.amazonaws.com
youtube...
YouTube
Iron Maiden Invaders
Sign in
T-Mobile
t-mobile.com/home-internet
Switch now
$50/MONTH
w/AutoPay discount using eligible payment method
Ad 1 of 2 · 0:10
Iron Maiden - Invaders Lyrics
LyricsWorldHUN
14.8K subscribers
Subscribe
1.2K
Share
123K views 10 years ago

Test Case - Load Test

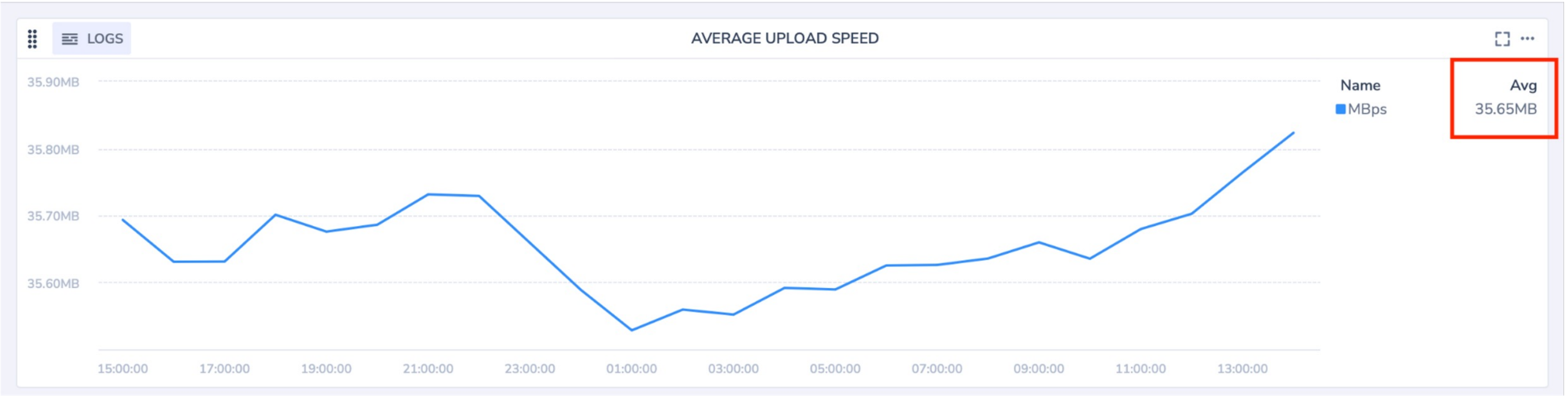
- **Description:** Load Open5GS with thousands of UEs to simulate heavy network traffic.
- **Purpose:** Determine the impact heavy network traffic has on Open5GS (e.g. do NF’s scale?, how many UE subscriptions can be made?, etc.) .
- **Outcome:**
    - Open5GS subscribes up to approximately 3,000 UEs
    - Network interface provisioning for UEs exhibited sporadic behavior
    - No scaling of network functions was identified



1002897630 1003236331 1003405610
1004421168 1005267635 1012207388
1013222856 1013900469 1016608206
1019147655 1022363302 1024056153
1027441130 1038781938 1043691179
1046060486 1054524216 1056047738
1058924550 1059432609 1065357053
1066372825 1068742286 1070096767
1075174001 1077035943 1081098770
1086515135 1087700199 1088376910
1093793564 1097178539 1098194878

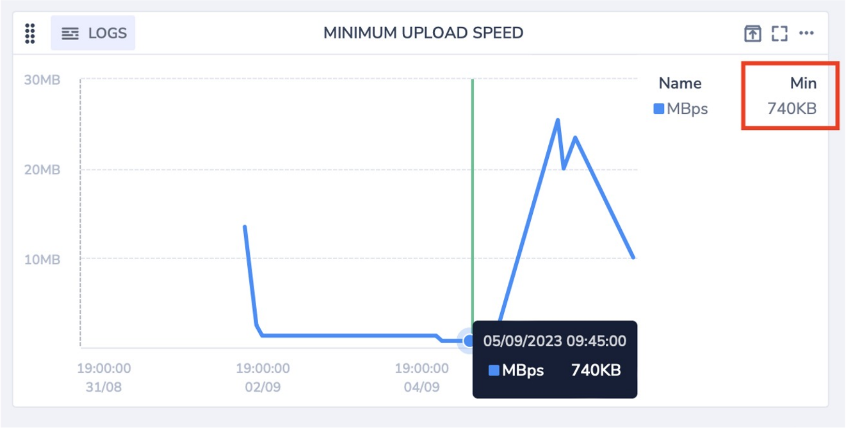
Test Case - Stress Test

- **Description:** Upload data to a webserver while Open5GS handles thousands of UE connections. Calculated the estimated maximum upload speed per second with a unique formula.
- **Purpose:** Evaluate Open5GS's ability to meet LiveView's minimum upload speed requirement of 3MBps-12MBps under network traffic.
- **Outcomes:**
  - With minimal traffic, Open5GS consistently supports upload speeds of approximately 35 MBps.
  - With heavy traffic, (approx. 3,000 UEs) there was a point in time where upload speeds dropped to 740 kB/s.



AVERAGE UPLOAD SPEED

Name	Avg
■MBps	35.65MB



MINIMUM UPLOAD SPEED

Name	Min
■MBps	740KB

05/09/2023 09:45:00
■MBps 740KB

Coralogix Dashboards

Methodology:

1. Captured logs and metrics from tests run in Open5GS/UERANSIM pods and stored them locally via bash scripts.

2. Utilized Python to transform local files into S3 objects within a dedicated bucket.

3. Set up a Lambda function to continuously transfer data from S3 bucket to Coralogix.

4. Parsed and converted logs into metrics to facilitate the creation of dashboards displaying data from test runs.

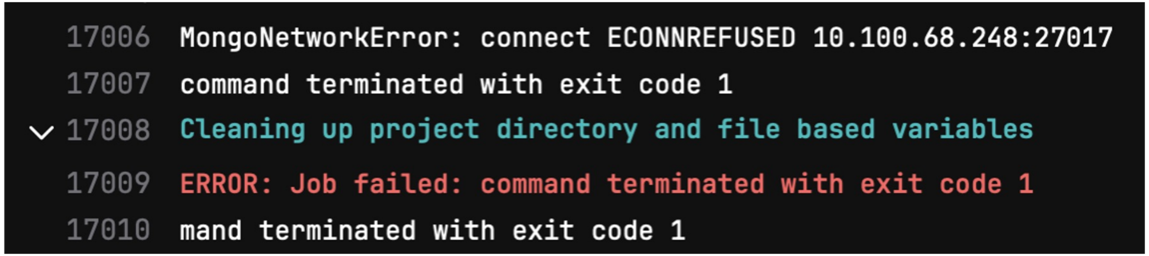
Conclusion

Hypothesis: “Testing Open5GS for load, latency, and QoS will uncover its inadequacy in meeting the network requirements of our customer, LiveView."

Conclusion: "After completing our test cases, it is evident that Open5GS does not meet LiveView's customer requirements."

Conclusion

1. Open5GS inconsistently subscribed UEs in under 60 seconds.
2. Upload speeds did not meet the 3MBps requirement when the network faced heavy traffic.
3. The database for Open5GS (MongoDB) consistently had network errors which greatly impacted the efficiency of connecting UEs to the 5G core.



```
MongoNetworkError: connect ECONNREFUSED 10.100.68.248:27017
command terminated with exit code 1
Cleaning up project directory and file based variables
ERROR: Job failed: command terminated with exit code 1
mand terminated with exit code 1
```