



FEDERATED LEARNING: CENTRALIZED vs MULTI-MASTER

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PROBLEM DESCRIPTION







1. Data often contains sensitive, private information that is subject to legal constraints, necessitating proper authorization or consent for usage.



2. Growing storage and computational capabilities of devices in distributed networks presents an opportunity to leverage local resources



SOLUTION DESIGN



Federated Learning

Instead of sharing raw local data, FL aggregates model parameters from local models. This approach enhances privacy, security, and the development of robust machine learning models.

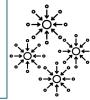
Centralized FL

A central server accumulates and aggregates model updates from all participating clients



Multi-Master FL

Multiple coordinators are responsible for a subset of clients.



Fully Decentralized

CASE STUDY: BINARY CLASSIFICATION IN THE HEALTHCARE SECTOR



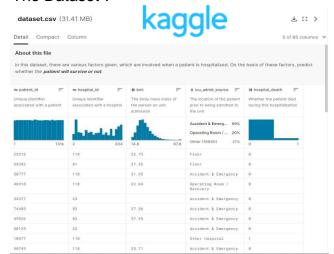
In the healthcare sector:

- data is fragmented to abide by stringent privacy requirements
- healthcare institutions maintain separate data silos

This fragmentation hinders the opportunity to leverage local resources.



The Dataset1:





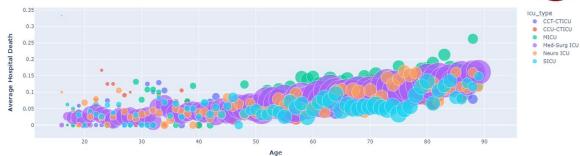
On the basis of medical information, our task is to predict whether the patient will survive or not.

¹ dataset loaded at the link https://www.kaggle.com/datasets/mitishaagarwal/patient

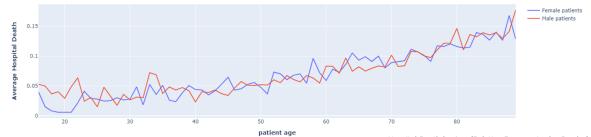
EXPLORATORY DATA ANALYSIS



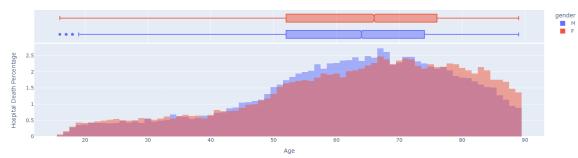




Average hospital death probability of patients

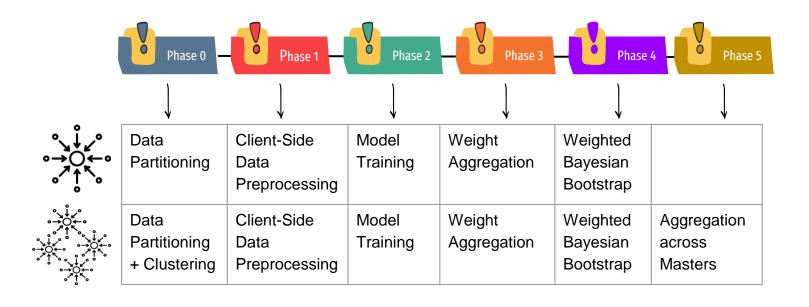


Hospital Death by Age (Relative Frequencies by Gender)



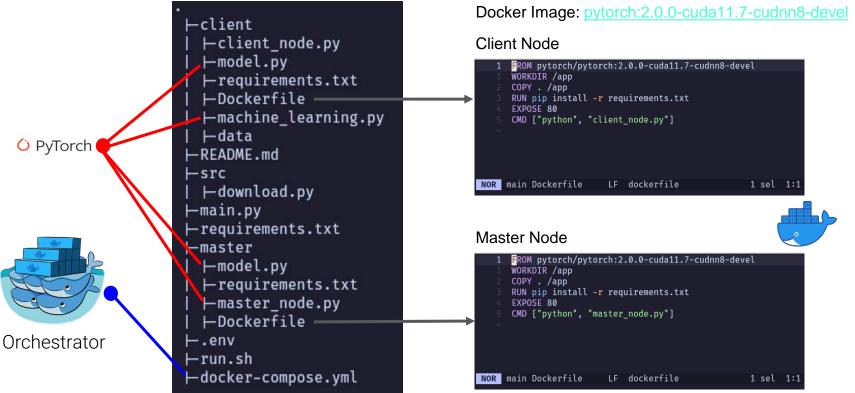
SOLUTION DESIGN (continue)





SOLUTION IMPLEMENTATION





SOLUTION IMPLEMENTATION (continue)

```
A DOLLMAN
```

```
version: '3'
     services:
        master:
         image: master-node:latest
         environment:
           - CLIENTS=0
         ports:
          - "80:80"
         networks:
           - my_network
       client
         image: client-node:latest
         depends on:
          - master
          deplov
           replicas: 0
          restart policy:
          condition: on-failure
         volumes:
          - common data:/app/data
          networks:
          - my_network
     networks:
       my network:
      volumes:
     common data:
NOR main docker-compose.yml
                                LF yaml
                                            1 sel 30:1
```

```
#!/usr/bin/env bash

pip install -q -r requirements.txt

python ./src/download.py

docker build -t master-node ./master --rm
docker build -t client-node ./client --rm

docker swarm init

docker stack deploy -c docker-compose.yml my_stack

NOR run.sh LF bash 1 sel 13:1
```

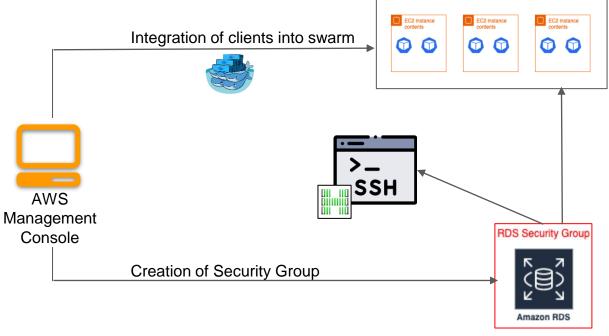
Procedure:

- 1) Create and start a python environment.
- 2) Run the run.sh script.
- Run the main.py script with the wanted number of clients.

AWS DEPLOYMENT

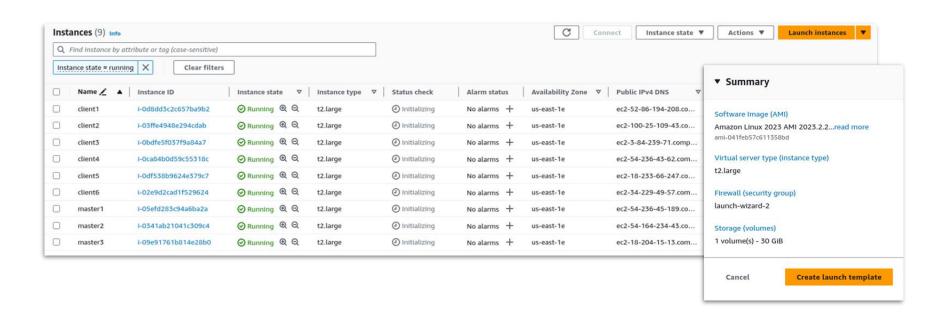






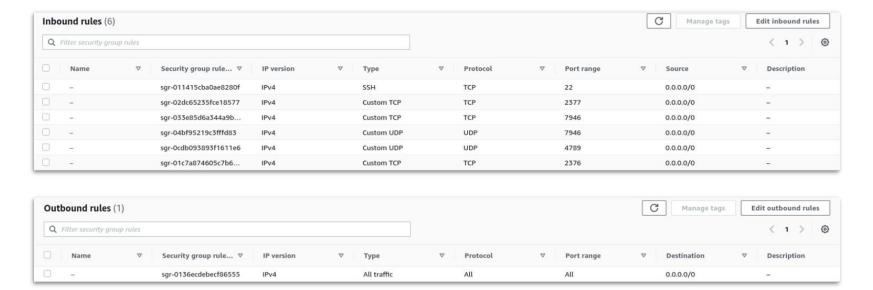
AWS DEPLOYMENT (EC2)





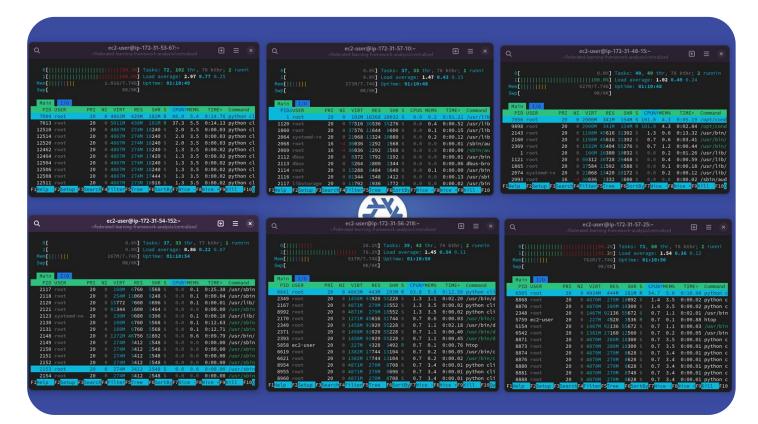
AWS DEPLOYMENT (Security Group)





AWS DEPLOYMENT (SSH + HTOP)





Task Results

Epoch 29: 100% 2/2 [00:00<00:0 my_stack_client.3.k28avy9wkj03@nixos	90, 2.19it/s, v_num=0, val_ Restoring states from the o	checkpoint path at /app/lightnin
		loss=0.474, val_lacc=0.903]tning
	l [00:00<00:00, 37.70it/s]	
my_stack_client.3.k28avy9wkj03@nixos my_stack_client.3.k28avy9wkj03@nixos	Test metric	DataLoader 0
ny_stack_client.3.k28avy9wkj03@nixos ny_stack_client.3.k28avy9wkj03@nixos	test_acc	0.9677419866429138
uy_stack_client.3.k28avy9wkj03@nixos uy_stack_client.3.k28avy9wkj03@nixos	test_loss	0.24648040533065796
ny_stack_client.9.xqmg1jgiua1e@nixos ny_stack_client.9.xqmg1jgiua1e@nixos	`Trainer.fit` stopped: `max Restoring states from the o	x_epochs=30` reached. checkpoint path at /app/lightni
y_stack_client.3.k28avy9wkj03@nixos poch 29: 100% 2/2 [00:01<00:0	200 	loss-0 888 val lacc-1 8881tnin
[esting DataLoader 0: 100%] 1/3	l [00:00<00:00, 64.33it/s]	1005-0.000, Var_tace-1.000[till]
ny_stack_client.9.xqmg1jgiua1e@nixos	New York Company of the Company of t	2010/2010/2010/2010
y_stack_client.9.xqmgljgiuale@nixos	Test metric	DataLoader 0
y_stack_client.9.xqmg1jgiua1e@nixos y stack client.9.xqmg1jgiua1e@nixos		1.0
y_stack_ctient.9.xqmgijgiuale@nixos y_stack_client.9.xqmgijgiuale@nixos	test_acc test_loss	0.0
y_stack_client.9.xqmgljgiuale@nixos		

Average Loss	Average Accuracy
0.1745	0.9512

Final weights

2023-10-22 09:00:44.032 - INFO - {'age': 0.4218870371207209, 'bmi': 0.0017469028377932012, 'elective surgery': -8.546808610487613, 'ethnicity:Caucasian': -0.5094642714811735, 'ethnicity:Hispanic': -1.1176496082840794, 'gender': -0.358246 9575345104, 'height': 0.09624113133147756, 'icu_admit_source:Accident & Emergency': -1.7589837001557567, 'icu_admit_source:Floor': 4.723181868092635, 'icu_admit_source:Operating Room / Recovery': -3.926008291371521, 'icu_id': 0.101920504 53491938, 'icu type:Med-Surg ICU': 2.184667445595778, 'pre icu los days': 1.2012566652708747, 'weight': -0.12909385570209495, 'apache 2 diagnosis': -0.08059139071931654, 'apache 31 diagnosis': -0.06370006936873897, 'apache post operative : -0.5708895217071789, 'arf_apache': 5.651092464161899, 'gcs_eyes_apache': -1.8612991543486985, 'gcs_motor_apache': -2.0994811009700447, 'gcs_unable_apache': 9.8396559284514, 'gcs_verbal_apache': -1.3575329216097651, 'heart_rate_apache 0.0834432215610339, 'intubated apache': 9.568955489012586, 'map apache': 0.0028019364198478757, 'resprate apache': 0.004260757527601763, 'temp apache': -0.28095491296174074, 'yentilated apache': 8.427622559985879, 'dl diasbo max': 0.13 243250237479887, 'dl_diasbp_min': -0.16644887629413813, 'dl_diasbp_noninvasive_max': 0.23508030814267913, 'dl_diasbp_noninvasive_min': -0.12313057173886867, 'dl_heartrate_max': 0.12724182447567198, 'dl_heartrate_min': -0.1006680476502766 , 'dl_mbp_max': -0.11055543392027249, 'dl_mbp_min': -0.22409153260535994, 'dl_mbp_noninvasive_max': 0.055496727339368446, 'dl_mbp_noninvasive_min': -0.10914568927302926, 'dl_resprate_max': 0.3503375799168295, 'dl_resprate_min': 0.254608 61385010464, 'dl_spo2_max': 0.004139776975072803, 'dl_spo2_min': -0.4406005043913603, 'dl_sysbp_max': -0.07469340319293195, 'dl_sysbp_min': 0.028298425556500573, 'dl_sysbp_moninvasive_max': -0.09091138859509104, 'dl_sysbp_moninvasive_min : -0.013818575023301985. 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'hl diasbp noninvasive_min': -0.05718541548051344, 'h1_heartrate_max': -0.1953667740104318, 'h1_heartrate_min': 0.16426152496410948, 'h1_mbp_max': -0.003578846371670395, 'h1_mbp_min': -0.08806853302371277, 'h1_mbp_noninvasive_max': 0.0854058407639 8693, 'hl_mbp_noninvasive_min': -0.14867375470365576, 'hl_resprate_max': 0.19062347004599342, 'hl_resprate_min': 0.7719268580874573, 'hl_spo2_max': -0.0254425104420282, 'hl_spo2_min': -0.02574877578941983, 'hl_sysbp_max': 0.0755117950547 0769, 'hl_sysbp_min': 0.010656552326919292, 'hl_sysbp_noninvasive_max': -0.018821079848284704, 'hl_sysbp_noninvasive_min': -0.1595632185075495, 'dl_glucose_max': -0.0033774305248458524, 'dl_glucose_min': -0.042754494617379644, 'dl_potass ium max': 0.8342337702817949, 'dl_potassium_min': 0.4657111668131292, 'apache_4a_hospital_death_prob': 16.7997397275226, 'apache_4a_icu_death_prob': 17.433240905650347, 'aids': -4.042394664903847, 'cirrhosis': 7.109314043279745, 'diabete s mellitus': -2.516350453356222, 'hepatic failure': 6.188869473184748, 'immunosuppression': 7.436833706134749, 'leukemia': 13.930501161257403, 'lymphoma': 1.3361426431658456, 'solid tumor with metastasis': 10.092355189482538, 'apache 3j bodysystem:Cardiovascular': 0.20394961993396196, 'apache 3i bodysystem:Gastrointestinal': -2.9175553868953457, 'apache 3i bodysystem:Genitourinary': -9.58500612001569, 'apache 3i bodysystem:Hematological': 5.717031681989869, 'apache 3i bodysystem: odysystem:Metabolic': -3.5407995019187637, 'apache 3i bodysystem:Musculoskeletal/Skin': -3.0679455275054868, 'apache 3i bodysystem:Neurological': 2.7342419093000943, 'apache 3i bodysystem:Respiratory': -1.6124628029342478, 'apache 3i bodysystem:Neurological': 2.7342419093000943, 'apache 3i bodysystem:Respiratory': -1.6124628029342478, 'apache 3i bodysystem:Neurological': 2.7342419093000943, 'apache 3i bodysystem:Respiratory': -1.6124628029342478, 'apache 3i bodysystem:Neurological': 2.7342419093000943, ysystem:Sepsis': 3.2507405836495913, 'apache_3j_bodysystem:Trauma': 2.445504857468429, 'apache_2_bodysystem:Cardiovascular': 1.0595829301959514, 'apache_2_bodysystem:Gastrointestinal': -2.892267691448451, 'apache_2_bodysystem:Haematologi ': 5.618709733272075, 'apache_2_bodysystem:Metabolic': -3.5476895401990816, 'apache_2_bodysystem:Neurologic': 2.776607897231498, 'apache_2_bodysystem:Renal/Genitourinary': -10.641580670964899, 'apache_2_bodysystem:Respiratory': -1.54684 41105688442, 'apache_2_bodysystem:Trauma': 2.4327838874987564, 'apache_2_bodysystem:Undefined diagnoses': -1.4712010915501632, 'linear.bias': 0.026528888296127137, 'ethnicity:African American': 0.6259360388076014, 'apache_3i_bodysystem:G necological': -8.177893375369166, 'apache_2 bodysystem:Undefined Diagnoses': -5.213283467226857, 'ethnicity:Asian': 3.370969717928638, 'icu_admit_source:Other Hospital': 9.114968234315509, 'ethnicity:Native American': 8.161711713492384 'icu type:SICU': -2.4009952809439232, 'ethnicity:Other/Unknown': -4.941105993184711, 'icu admit source:Other ICU': 23.02419391480629, 'icu type:CCU-CTICU': -1.8215129375457764, 'icu type:CTICU': -6.860136032104492, 'icu type:MICU': 3.54 562152862549, 'icu type:Neuro ICU': 4,6999382972717285}

(1st experiment)



Centralized FL

We run the model with incremental number of instances to see how the KPIs change.

In the last model, 1 instance is assigned to the master-node, 8 to worker-nodes..

- One instance → baseline model
- Five instances → load distribution over more CPU capacity
- Nine instance → max number of instances allowed to us



Multi-Master FL

The Multi-Master model is designed by accounting three masters.

In this model, 3 instances are assigned to master-nodes, 6 to worker-nodes

 We deployed nine instances in order to compare this implementation with the most performing one of the centralized type.

EXPERIMENTAL DESIGN (2nd experiment)



Centralized FL

We run the model with incremental number of clients to see how the KPIs change:

In the last model, 1 instance is assigned to the master-node, 8 to worker-nodes.

- Nine instance → max number of instances allowed to us
- Three executions where there are a master and respectively 10 clients, 60 clients and 120 clients.



Multi-Master FL

The Multi-Master model is designed by accounting three masters.

In this model, 3 instances are assigned to master-nodes, 6 to worker-nodes

- Nine instance → max number of instances allowed to us
- Three executions where each master has 3-4 clients, 20 clients and 40 clients.

EXPERIMENTAL DESIGN(Metrics and Monitoring)





Key Performance Indicators

CPU Utilization Percentage
CPU Costs
Network Packets
Status Check failures

This metric measures the extent to which the CPU (Central Processing Unit) of your AWS instance is utilized

CPU Costs represent the expenses associated with the CPU usage of your AWS resources. It reflects the cost incurred due to the allocation of CPU resources to your instances or services.

Network Packets are the units of data transmitted over the network. Monitoring network packets helps you understand the volume of data being sent and received by your AWS instances or services.

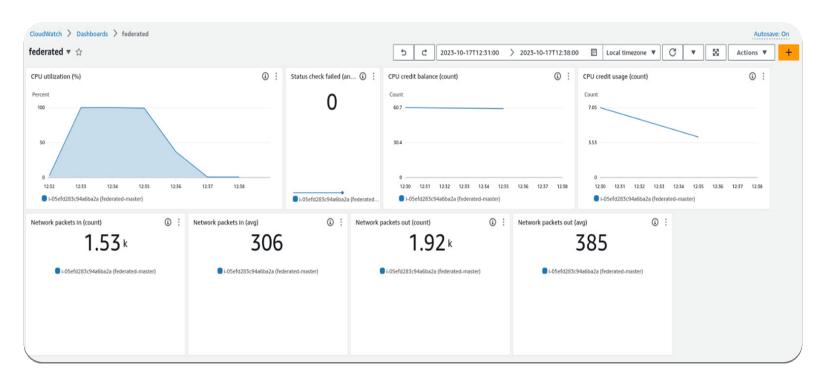
Status Check Failures indicate the number of times these checks have failed. These failures can be related to underlying hardware issues, network problems, or other instance health concerns



*We could not make use of automatic scaling

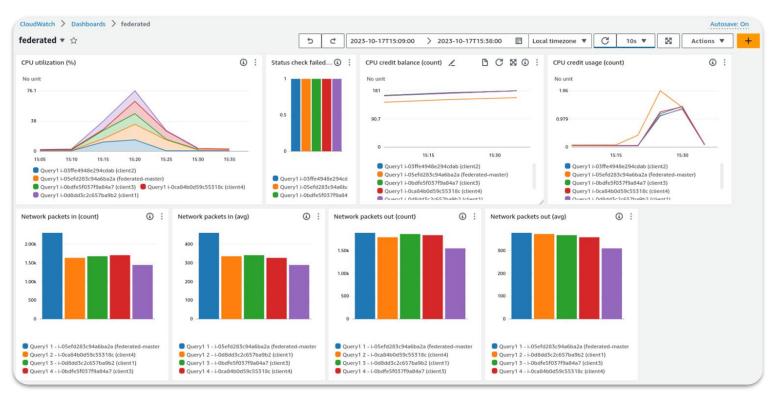
EXPERIMENTAL RESULTS (Centralized)(only 1 instance - 10 clients)





EXPERIMENTAL RESULTS (Centralized)(4 instances - 10 clients)





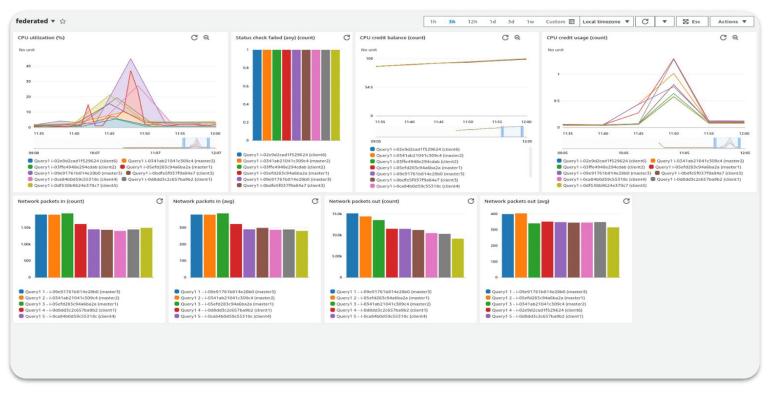
EXPERIMENTAL RESULTS (Centralized)(9 instances - 10 clients)





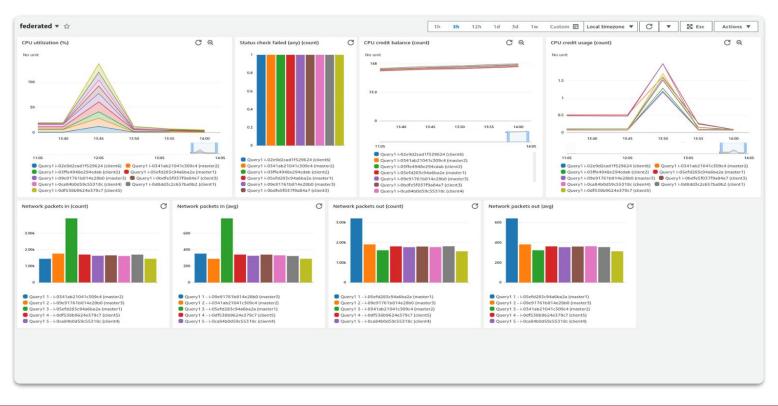
EXPERIMENTAL RESULTS (Multi-Master) (9 instances - 10 clients)





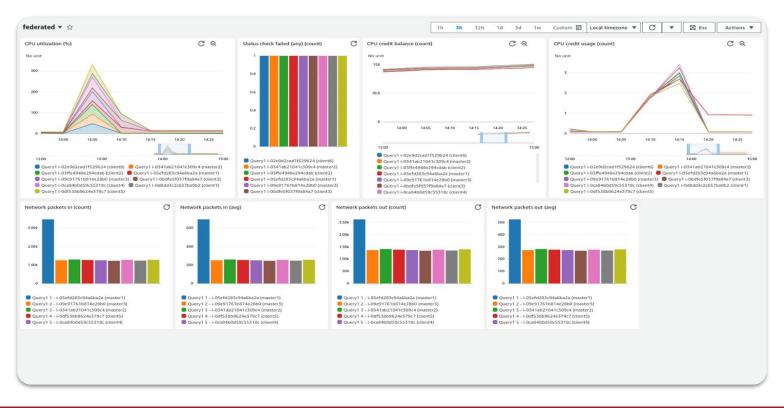
EXPERIMENTAL RESULTS (Centralized) (60 clients)





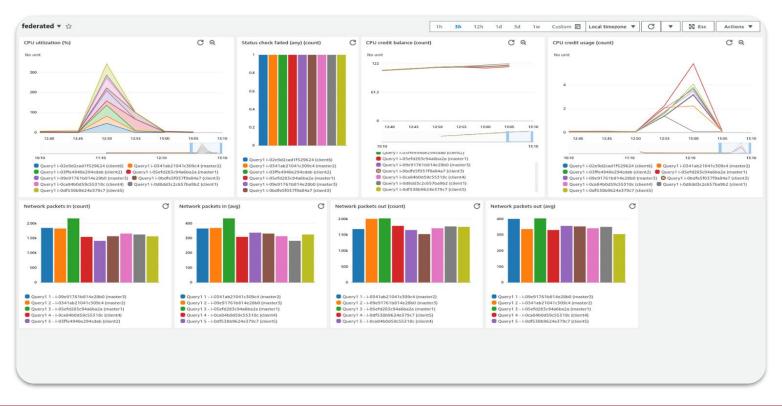
EXPERIMENTAL RESULTS (Centralized) (120 clients)





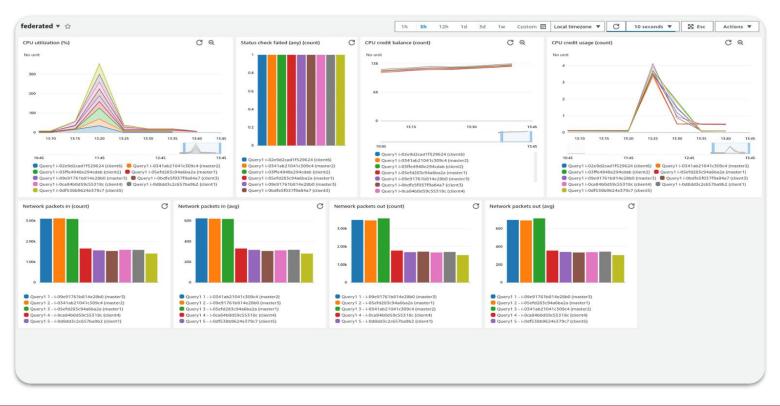
EXPERIMENTAL RESULTS (Multi-Master) (60 clients)





EXPERIMENTAL RESULTS (Multi-Master) (120 clients)







THANK YOU