Report

on

Intra-Datacenter Load Balancing in a Federated Cloud with Throttled Algorithm

Course Code

CSL7510

submitted by

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1. Problem Statement

The project addresses **uneven load distribution** within datacenters in a federated cloud environment, leading to reduced Quality of Service **(QoS)** and Service Level Agreement **(SLA)** violations. Federated clouds aggregate resources from multiple cloud providers but struggle with intra-datacenter load imbalance, causing inefficient resource utilization and delayed response times. This issue is critical in cloud computing as effective load balancing ensures optimal performance, scalability, and cost-efficiency while meeting user demands.

2. Literature Review

Several research studies have explored various load balancing techniques for cloud environments:

- **Hybrid Load Balancing Algorithms:** For example, a hybrid algorithm (**MMRR**) [1] that combines maximum-minimum and round-robin methods was proposed to improve response times. However, while effective in reducing overall response time, it may not adequately consider dynamic VM states during high-load periods. **HAMM** [2] algorithm is hybrid of min-min and max-min algorithms. Achieved 89.6% makespan and 89.5% resource utilization but lacked AI integration.

- **Nature-Inspired Approaches:** Research has also explored nature-inspired [3] methods (e.g., genetic algorithms, honeybee-inspired strategies) to optimize load distribution. These approaches can be more adaptive but often require complex parameter tuning and additional computational overhead.
- **Throttled Load Balancing Algorithm:** The throttled algorithm [4] serves as the basis for the current work. Previous studies using throttled approaches have shown promise in dynamically allocating tasks based on real-time availability of resources. However, limitations were observed in its direct application to federated environments without further adaptation.
- **Comparative Reviews of Cloud Simulators:** Evaluations of different simulation tools (like CloudAnalyst, CloudSim) provide context on how load balancing techniques are modeled and benchmarked, highlighting the importance of simulation-based validation.

These references collectively highlight that while several algorithms exist, each has limitations in either adaptability or resource management that the proposed intra-datacenter load balancing algorithm aims to address.

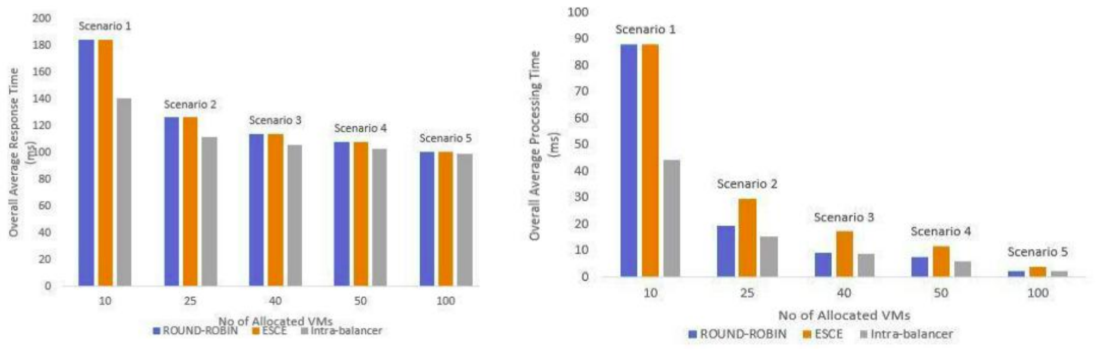
3. Existing Results

Previous studies and simulation benchmarks provide a context for evaluating load balancing algorithms. The research report presents detailed test cases comparing the proposed intra-balancer with established methods (Round-Robin and ESCE). Two key test scenarios were implemented:

- **Test Case 1:**
  Varying the number of available VMs (from 10 to 100) resulted in a commensurate decrease in both response time and processing time. For instance, with 100 VMs, the intra-balancer achieved an average response time of **98.93 ms** and a processing time of **2.26 ms**.

Scenario ID	**Scenario**	**Overall Average Response Time (milliseconds)**	**Overall Average Processing Time (milliseconds)**
Scenario 1	2 VMs in DC 1, 4 VMs in each DC 2 and DC 3	140.98	44.53
Scenario 2	5 VMs in DC 1, 10 VMs in each DC 2 and DC 3	111.91	15.20
Scenario 3	10 VMs in DC 1, 15 VMs in each DC 2 and DC 3	105.54	8.94
Scenario 4	10 VMs in DC 1, 20 VMs in each DC 2 and DC 3	102.69	6.17
Scenario 5	20 VMs in DC 1, 40 VMs in each DC 2 and DC 3	98.93	2.26

Table 1. Intra-balancer results (Case 1)



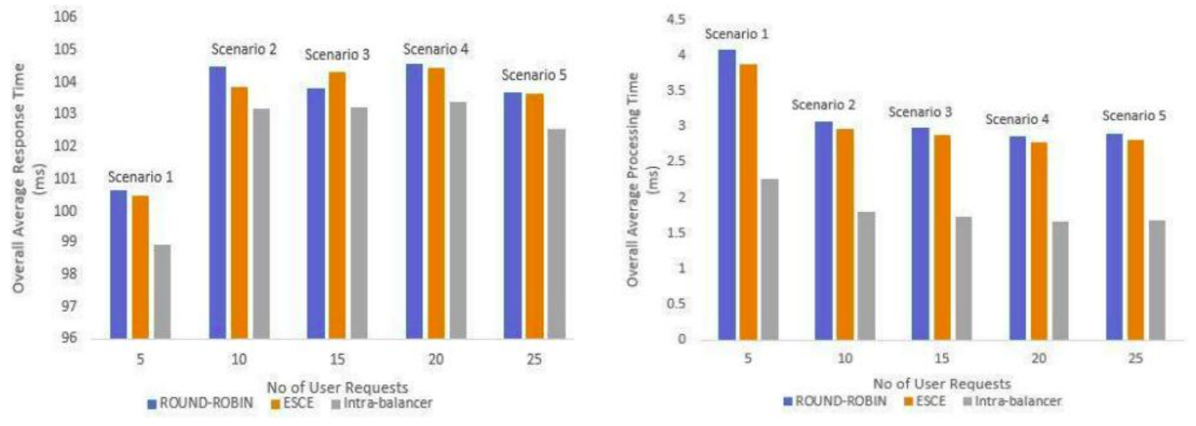
(a) (b)

Fig. 1. Case 1 Comparison of Round-Robin, ESCE, and Intra-balancer in terms of (a) Response Time, and (b) Processing Time

- **Test Case 2:**
  By varying the number of requests per user base while keeping the total number of VMs constant (100 VMs), the intra-balancer consistently maintained response times around **98–103 ms** and processing times near **1.7–2.3 ms**.

Scenario ID	Requests Per Hour	Overall Average Response Time (milliseconds)	Overall Average Processing Time (milliseconds)
Scenario 1	5	98.94	2.27
Scenario 2	10	103.17	1.80
Scenario 3	15	103.40	1.73
Scenario 4	20	103.40	1.67
Scenario 5	25	102.54	1.69

Table 2. Intra-balancer results (Case 2)



(a) (b)

Fig. 2. Case 2 Comparison of Round-Robin, ESCE, and Intra-balancer in terms of (a) Response Time, and (b) Processing Time

These benchmarks, summarized in tables and graphical figures, demonstrate that the adapted throttled algorithm (Intra-balancer) outperforms other traditional algorithms by efficiently allocating requests to available VMs.

4. Our Implementation

The implementation of the intra-datacenter load balancing algorithm was carried out using the CloudAnalyst simulation toolkit. The following step-by-step process was followed:

1. **Environment Setup:**
    - **Installation of Java SDKs** to support the simulation environment.
    - **Installation of a Java IDE** to develop and run the simulation project.
    - **Downloading of CloudAnalyst**
    - **Importing the CloudAnalyst Project** into the IDE.
2. **Algorithm Adaptation:**
    - The standard throttled algorithm was adapted to focus on intra-datacenter balancing. The algorithm continuously monitors the state of each VM (Available vs. Busy) in real time.
    - A table of VMs is maintained and updated, allowing the load balancer to select the first available VM for each incoming request. If no VM is free, the request is queued until a VM becomes available.
3. **Simulation Execution:**
    - The adapted algorithm was simulated on CloudAnalyst, **testing various scenarios** by altering the number of VMs and user request rates.
    - Performance metrics such as response time and processing time were recorded.
4. **Validation:**
    - The simulation results were compared with those obtained from Round-Robin and ESCE algorithms to evaluate improvements in load balancing efficiency.

5. Our Results

The implementation of the intra-datacenter load balancer yielded the following outcomes:

- **Improved Latency:** The algorithm achieved an average response time as low as **98.03 ms** in high resource scenarios, indicating faster request processing.

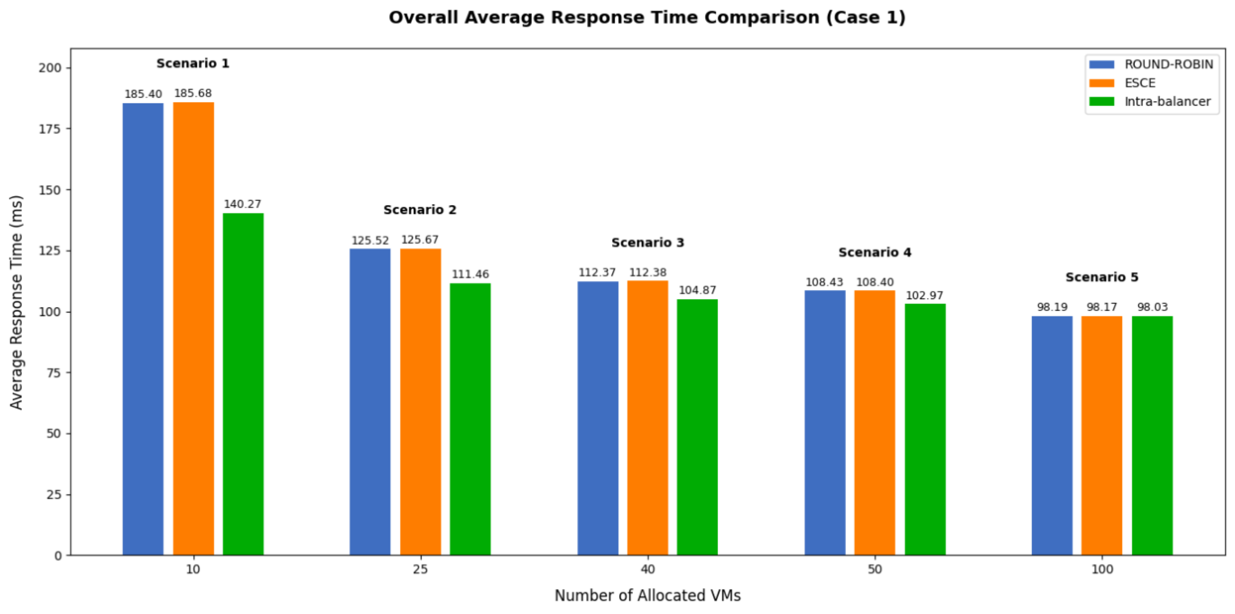
- **Enhanced Processing Efficiency:** Processing times reached as low as **2.12 ms**, highlighting the algorithm's ability to quickly assign tasks to VMs.

- **Scalability:** As the number of VMs increased, both response and processing times improved, demonstrating the algorithm's scalability in federated cloud environments.

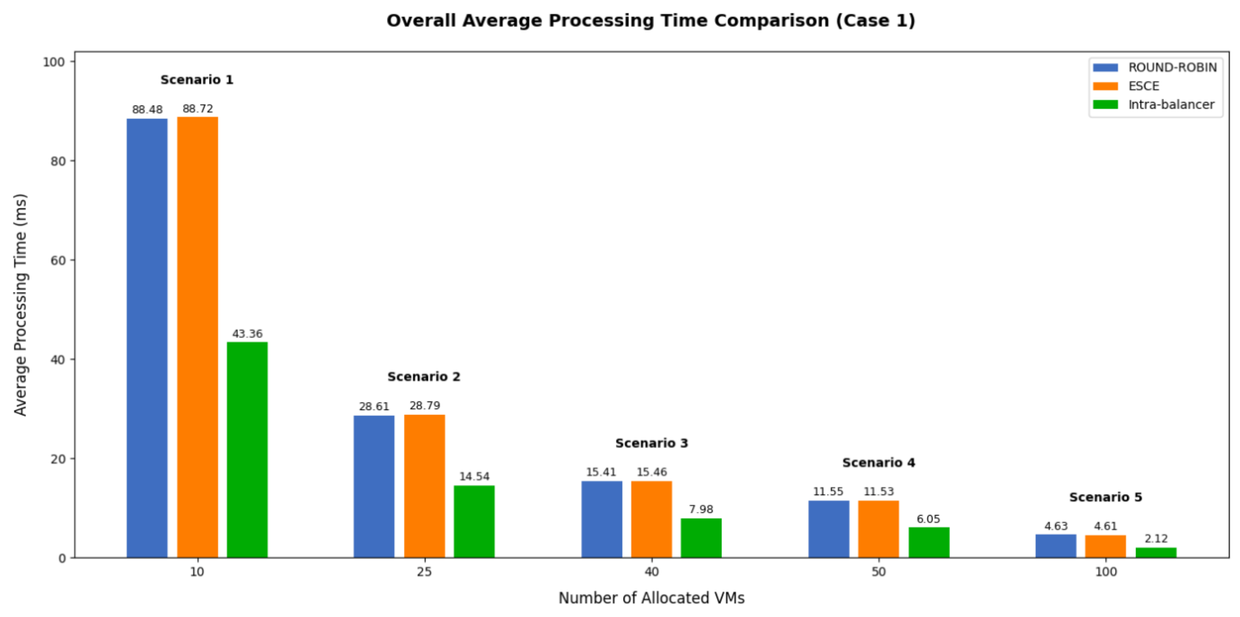
- **Test Case 1:**
  Varying the number of available VMs (from 10 to 100) resulted in a commensurate decrease in both response time and processing time. Table 3 and Fig. 3 denote this.

Scenario ID	Scenario	Overall Average Response Time (milliseconds)	Overall Average Processing Time (milliseconds)
Scenario 1	2 VMs in DC 1, 4 VMs in each DC 2 and DC 3	140.27	43.36
Scenario 2	5 VMs in DC 1, 10 VMs in each DC 2 and DC 3	111.46	14.54
Scenario 3	10 VMs in DC 1, 15 VMs in each DC 2 and DC 3	104.87	7.98
Scenario 4	10 VMs in DC 1, 20 VMs in each DC 2 and DC 3	102.97	6.05
Scenario 5	20 VMs in DC 1, 40 VMs in each DC 2 and DC 3	98.94	2.12

Table 3. Intra-balancer results (Case 1)



(a)



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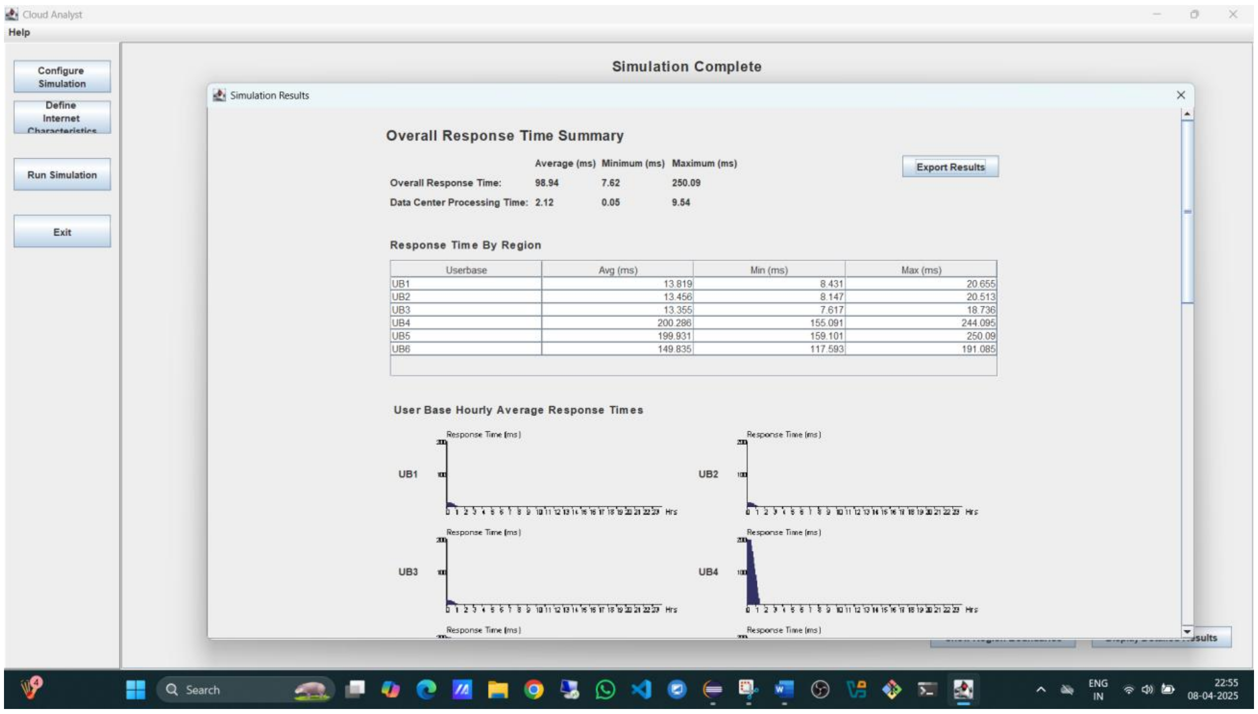


Simulation Complete

Overall Response Time Summary

	Average (ms)	Minimum (ms)	Maximum (ms)
Overall Response Time:	98.94	7.62	250.09
Data Center Processing Time:	2.12	0.05	9.54

Response Time By Region

Userbase	Avg (ms)	Min (ms)	Max (ms)
UB1	13.819	8.431	20.655
UB2	13.456	8.147	20.513
UB3	13.355	7.617	18.736
UB4	200.286	155.091	244.095
UB5	199.931	159.101	250.09
UB6	149.835	117.593	191.085

User Base Hourly Average Response Times

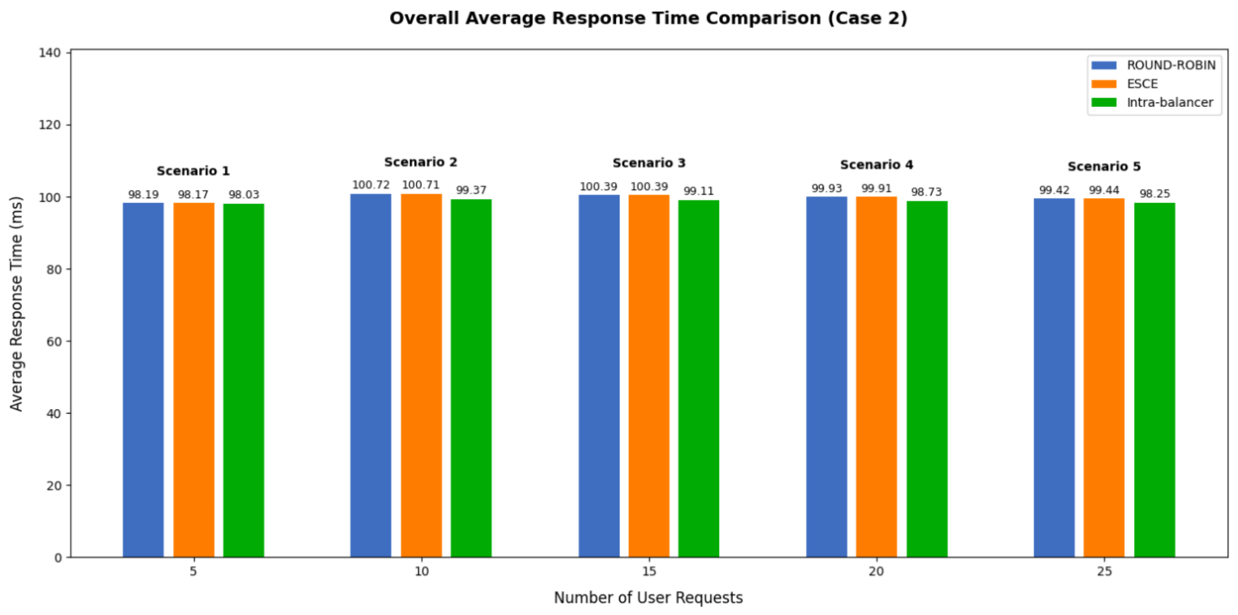
(c)

Fig. 3. Case 1 Comparison of Round-Robin, ESCE, and Intra-balancer in terms of (a) Response Time, (b) Processing Time, and (c) Simulation Result

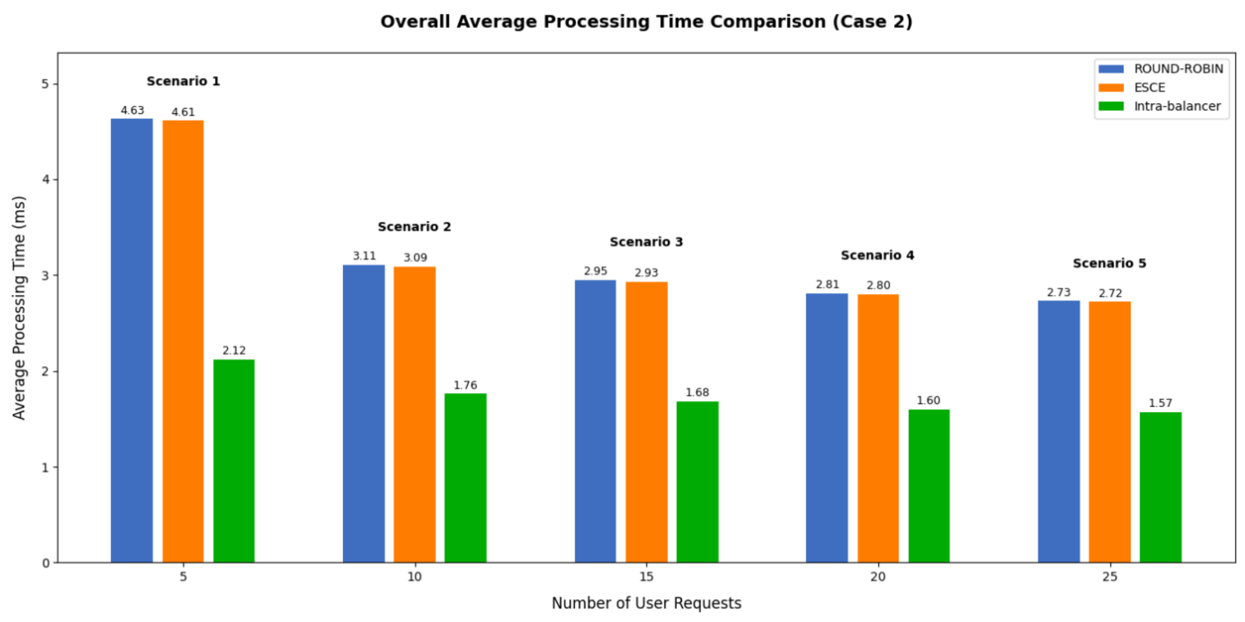
- **Test Case 2:**
  By varying the number of requests per user base while keeping the total number of VMs constant (100 VMs), the intra-balancer consistently maintained response times around **98–99 ms** and processing times near **1.6–2.0 ms**. Table 4 and Fig. 4 denotes this.

Scenario ID	Requests Per Hour	Overall Average Response Time (milliseconds)	Overall Average Processing Time (milliseconds)
Scenario 1	5	98.94	2.12
Scenario 2	10	99.37	1.76
Scenario 3	15	99.11	1.68
Scenario 4	20	98.73	1.60
Scenario 5	25	98.25	1.57

Table 4. Intra-balancer results (Case 2)



(a)



(b)

Fig. 4. Case 2 Comparison of Round-Robin, ESCE, and Intra-balancer in terms of (a) Response Time, and (b) Processing Time

These results affirm that the intra-balancer (our implementation) offers superior performance compared to paper's implementation and traditional load balancing strategies.

6. Comparison and Analysis

1) A detailed analysis comparing the intra-balancer with Round-Robin and ESCE algorithms reveals:

- **Response Time:**

The intra-balancer consistently achieved lower response times. In scenarios with increased VM allocation, it registered a response time of **98.03 ms** compared to higher times observed with Round-Robin and ESCE.

- **Processing Time:**

The processing time using the intra-balancer was minimized to **2.12 ms**, outperforming the competing algorithms that recorded longer processing durations.

- **Efficiency in Resource Utilization:**

By dynamically checking the availability of VMs and efficiently queuing requests, the intra-balancer minimizes idle time and optimizes the use of cloud resources.

Visual comparisons (as seen in the original Figures 3a and 3b) underscore these improvements, confirming the algorithm's effectiveness in handling high-load scenarios.

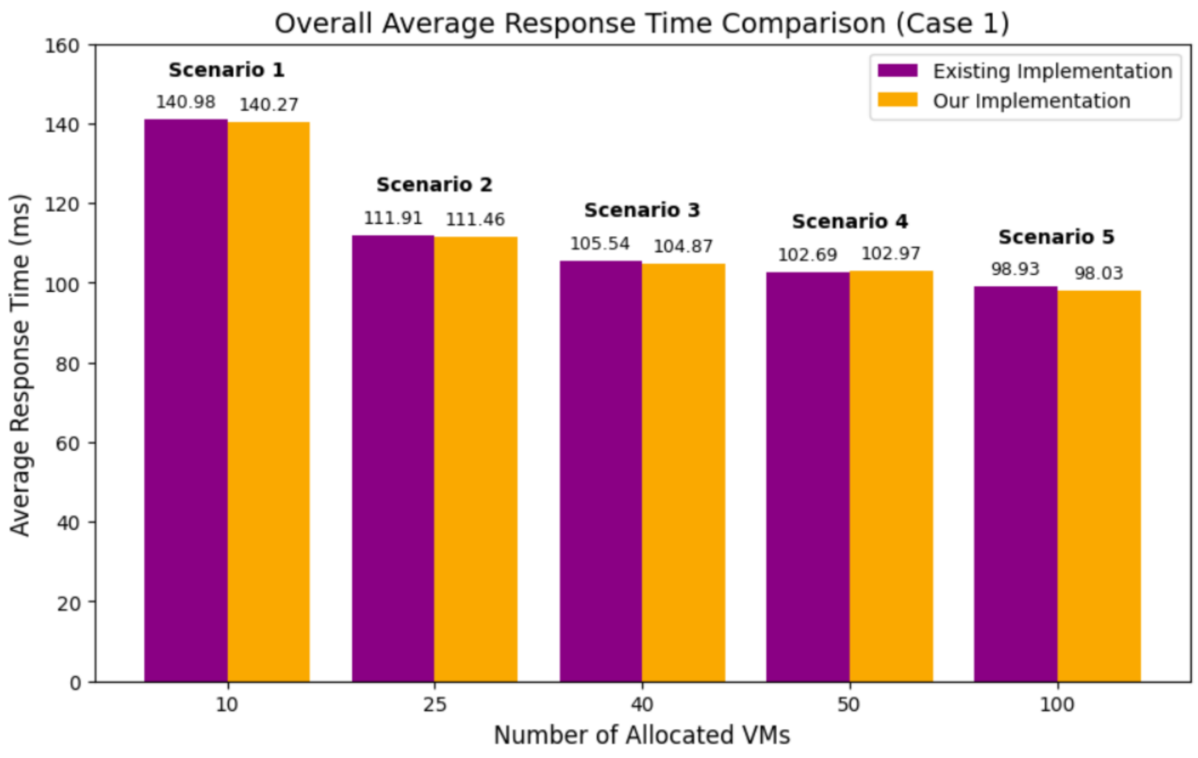
2) A detailed **comparison of existing implementation and our implementation of intra-balancer algorithm** on basis of average response time and average processing time is given below.

- **Test Case 1:**
  Varying the number of available VMs (from 10 to 100) resulted in a commensurate decrease in both response time and processing time. Table 5 and Fig. 5 denote this.

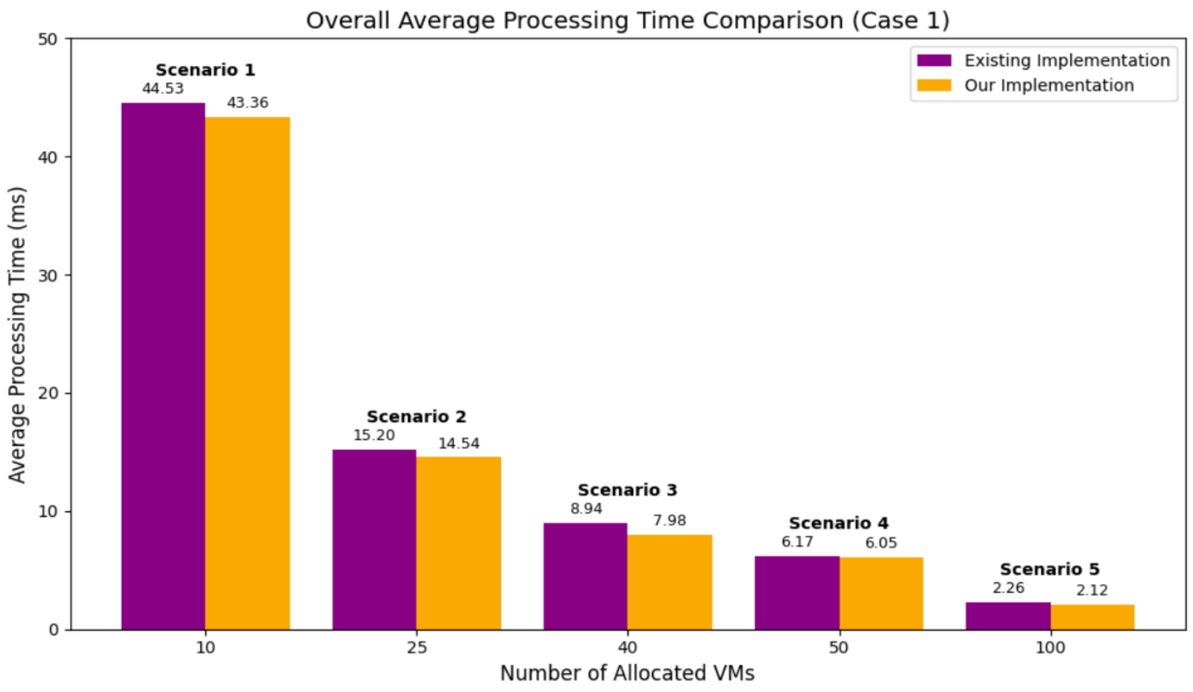
Scenario ID	**Scenario**	**Existing Implementation**		**Our Implementation**	
		Overall Average Response Time (milliseconds)	**Overall Average Processing Time (milliseconds)**	**Overall Average Response Time (milliseconds)**	**Overall Average Processing Time (milliseconds)**
Scenario 1	2 VMs in DC 1,4 VMs in each DC 2 and DC 3	140.98	44.53	140.27	43.36
Scenario 2	5 VMs in DC 1,10 VMs in each DC 2 and DC 3	111.91	15.20	111.46	14.54
Scenario 3	10 VMs in DC 1,15 VMs in each DC 2 and DC 3	105.54	8.94	104.87	7.98

Scenario 4	10 VMs in DC 1,20 VMs in each DC 2 and DC 3	102.69	6.17	102.97	6.05
Scenario 5	20 VMs in DC 1,40 VMs in each DC 2 and DC 3	98.93	2.26	98.03	2.12

Table 5. Case 1, Comparison of intra-balancer results b/w existing and our implementation



(a)



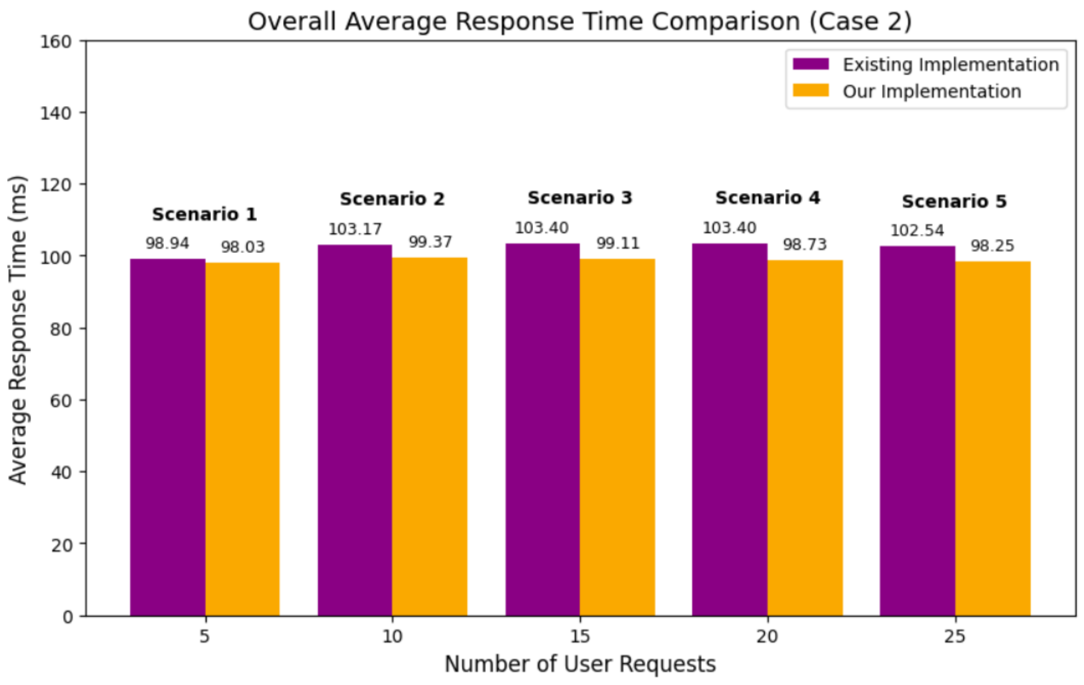
(b)

Fig. 5. Case 1 Comparison of existing and our implementation of Intra-balancer in terms of (a) Response Time, and (b) Processing Time

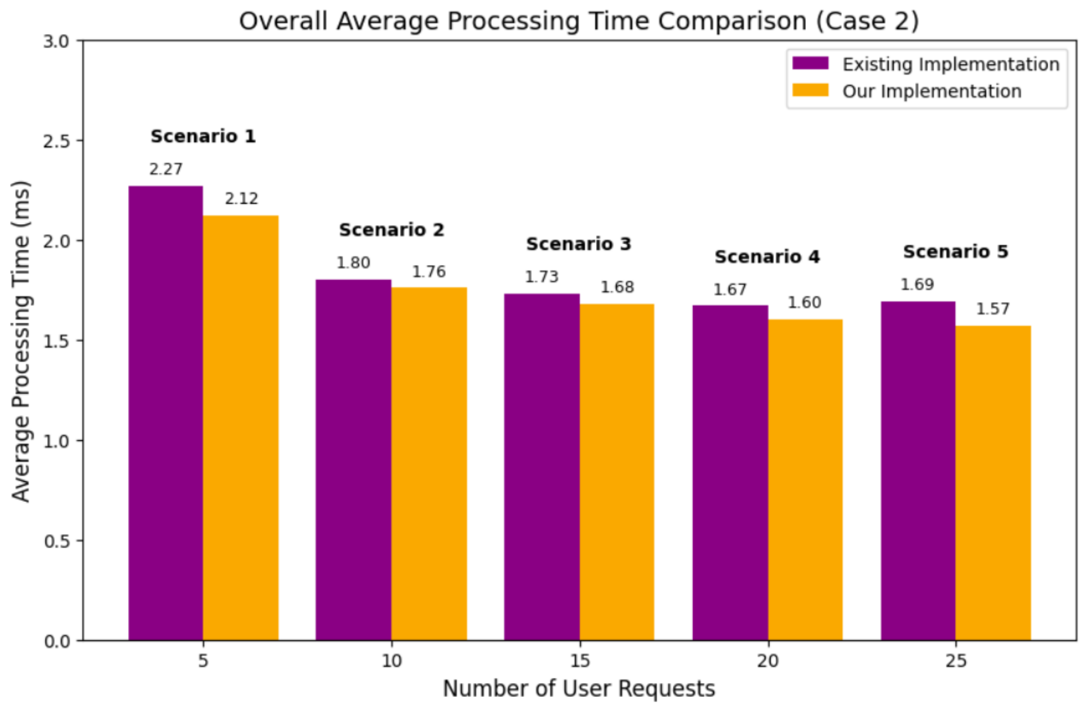
- **Test Case 2:**
  By varying the number of requests per user base while keeping the total number of VMs constant (100 VMs), the intra-balancer consistently maintained response and processing times. Table 6 and Fig. 6 denote this.

Scenario ID	**Requests Per Hour**	**Existing Implementation**		**Our Implementation**	
		Overall Average Response Time (milliseconds)	**Overall Average Processing Time (milliseconds)**	**Overall Average Response Time (milliseconds)**	**Overall Average Processing Time (milliseconds)**
Scenario 1	5	98.94	2.27	98.03	2.12
Scenario 2	10	103.17	1.80	99.37	1.76
Scenario 3	15	103.40	1.73	99.11	1.68
Scenario 4	20	103.40	1.67	98.73	1.60
Scenario 5	25	102.54	1.69	98.25	1.57

Table 6. Case 2, Comparison of intra-balancer results b/w existing and our implementation



(a)



(b)

Fig. 6. Case 2 Comparison of existing and our implementation of Intra-balancer in terms of (a) Response Time and (b) Processing Time

7. Architecture Diagram

Below (Fig. 7) is a simplified architecture diagram of the implemented solution:

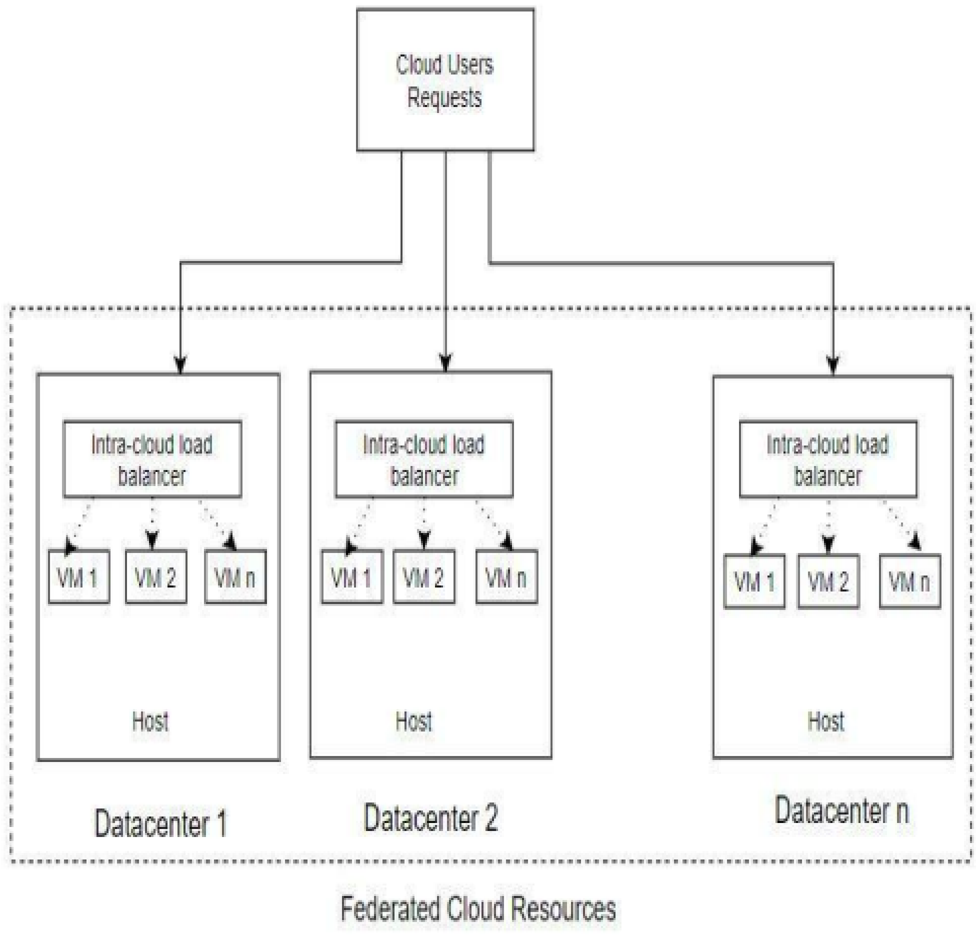


Fig.7. A System Architecture with proposed Intra-cloud load balancer and Federated Cloud Infrastructures

Description:

- **Cloud User Requests** are first routed through a central gateway to the federated cloud.
- Each **Datacenter** hosts its own **Intra-Datacenter Load Balancer** which monitors VM status.
- The load balancer assigns incoming requests to the first available VM from the respective VM pool, ensuring even distribution and reduced processing time.

Below Fig. 8, shows the flowchart (self-explanatory) of the proposed Intra datacenter load balancing algorithm.

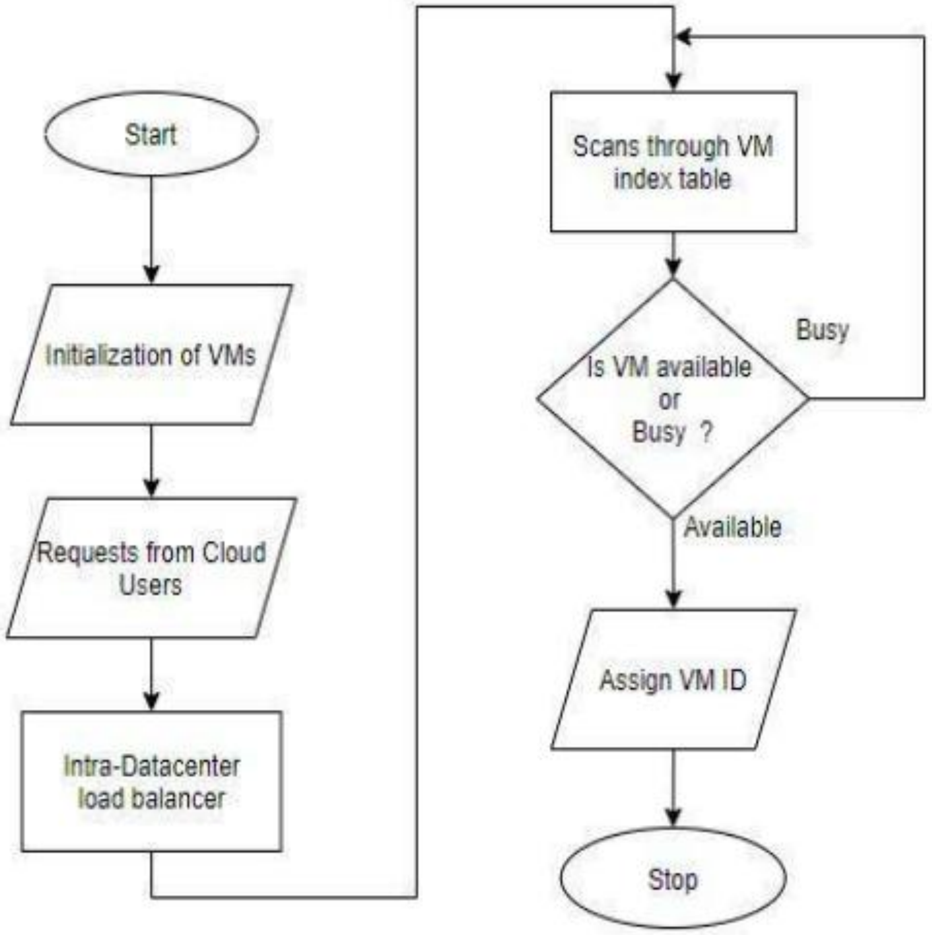

Start
Initialization of VMs
Requests from Cloud Users
Intra-Datacenter load balancer
Scans through VM index table
Is VM available or Busy ?
Busy
Available
Assign VM ID
Stop

Fig. 8. The Flowchart of the Proposed Intra-datacenter Load Balancing Algorithm

8. Future Scope

Future enhancements to the solution could include:

- **Integration of AI/ML:**
  Implementing machine learning algorithms (Re-enforcement algorithm) to predict virtual machine (VM) workload and optimize request distribution dynamically.
- **Enhanced Security:**
  Incorporating additional security protocols and fault-tolerance mechanisms to safeguard against potential failures or malicious attacks.

- **Advanced Simulation Models:**
  Utilizing more sophisticated simulation tools or real-time monitoring systems to further refine the load balancing strategy.

9. Conclusion

The proposed intra-datacenter load balancing algorithm successfully adapts the throttled algorithm to the federated cloud environment, addressing the critical challenge of uneven request distribution. The simulation results clearly indicate enhanced performance in terms of both response and processing times. This work not only improves load distribution within individual datacenters but also contributes to maintaining a higher QoS in cloud computing infrastructures. Future adaptations could further optimize performance by integrating advanced optimization techniques.

10. References

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3. D. A. Shafiq, N. Z. Jhanjhi, and A. Abdullah, "Load balancing techniques in cloud computing environment: A review," J. King Saud Univ. - Comput. Inf. Sci., no. xxxx, 2021, doi: 10.1016/j.jksuci.2021.02.007.

4. B. Panchal and S. Parida, "Review Paper on Throttled Load Balancing Algorithm in Cloud Computing Environment," Int. J. Sci. Res. Sci. Eng. Technol., vol. 2, no. 4, pp. 2395–1990, 2018.

5. https://cloudsim-setup.blogspot.com/2013/01/running-and-using-cloud-analyst.html

❖ Github Link

https://github.com/Ankit-IITJ/VCC_Project.git

❖ Video Link

https://drive.google.com/file/d/1Sro92xGHAAzv_wSbRLc_Lp7Mm5mdKeSS/view?usp=sharing