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Simulation Modelling of Cloud Mini and Mega Data Centers Using Cloud Analyst

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Abstract— Cloud Computing has now become a base technology for various other technologies including Internet of Things, Big Data Technologies and many other technologies, the responsibility of Cloud become critical in case of real time applications where the cloud services are required in real time. Delay in the response from Cloud may lead to serious consequences even loss of lives where the processes data from cloud must reach within predefined time interval. The performance of Cloud has experienced delays with the current infrastructure due to multiple issues in Traditional Cloud Network Model. The Paper suggests a proposed architecture Cloud Mini Data Centers simulated using Cloud Analyst to minimize the delays of Cloud Service delivery. The paper also simulate traditional cloud Network model using Cloud Analyst and provides a comparative study of both models.

Keywords: Cloud Computing, Traffic Engineering, Data Center, Latency and Cloud Analyst

I. INTRODUCTION

The Internet is increasingly a platform for online services such as Web search, social networks, multiplayer games, and video streaming distributed across multiple locations for better reliability and performance. The success of cloud computing leads to huge investment in massive data centers by various Cloud service providers [61][62]. The significant investment in capital outlay by these companies represents an on-going trend of moving applications, e.g., desktops or resource-constrained devices like smart phones, into the cloud [14]. With the increase in the number of data centers and end-user devices, the challenges to handling the flood of traffic optimally have also emerged. Various types of services are hosted in Cloud Data Centres. One of the important features of these services is on demand and scalable services. The data center performance not only depends on the infrastructure provided by data centers but also on the accessibility and delivery of services well in time with the least latency [12]. Thus poor traffic management and delivery service can lead to huge business loss [63][64]. The paper suggests an optimal model to deliver cloud traffic through Mini Data Centers which are in the geographical region of the End Users.

II. THE PROBLEM DEFINITION

A. Growing Cloud Traffic

The year-wise Cloud Data Center traffic growth from 2015-to 2021 can be seen in the

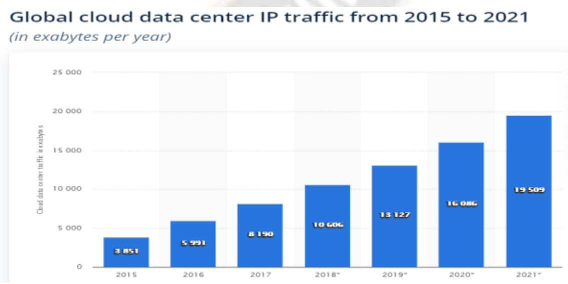

Figure 1 Global Cloud Traffic Source :Statistica.com

B. Challenges With Global-Scale Data Centers

Despite advancements in technologies, the performance of mega Data Centers is not up to the mark. The Mega Data centers have the advantage of hyper scaling. Still Mega Data Center carries a number of flaws like the latency in Delivery

Complex Maintenance, Complicated Cabling, and high amount of energy consumption. According to a census performed by National Resource Defence Council (NRDC), the energy consumed by mega data Centers will be 140 Billion KWh by 2020. Along with these issues, Mega Data Center suffers from a major problem of not keeping data under local Geographical boundaries which; leads to security and regulatory constraints [40].

C. Latency - Increased Response Time

Latency is the time taken by a packet to travel from source to destination. Latency is one of the most important parameters when optimizing cloud traffic [19]. To optimize traffic minimizing latency is very important. Latency explains the amount of delay in getting a reply to a request made [34].To improve the performance of the network reducing latency is one of the most important parameters [22]. The movement of data from one network location to another determines the quantity of latency. Latency can be measured in one way or two (Round Trip Time) [5]. The main components that contribute to latency are transmission medium, propagation, routers, and storage [6]. There are several factors responsible for contribution to latency like Transmission medium, Network Devices, Storage Devices, Global Large Scale Date Centers, Geographical distance between End User and Data Center, Big Data, Packet Fragmentation, Elephant Flows[9][20].

To provide Cloud Services low cost, high reliability and minimum delay are the key requirements. [7] There is a lot of research focused on the first and second demand but the third demand i.e. Low Delay which is becoming increasingly essential is still unexplored [11]. Delay in responses leads to losing customer trust in the cloud and finally causing loss of customers [34]. Real-time applications like self-driving need minimum delay[13]. Delayed responses in such applications could lead to dangerous errors [10]. For example delays in calculations and replies to weather conditions of a geographical area can even cause loss of lives [32]. A delay in the delivery of cloud packets is due to latency [20]. The main hindrances in reducing latency are virtualization, congestion in the network, packet loss, server outages, etc[16]. A centralized server at a far geographical location carries thousands of processors in a big server farm. In the era of cloud computing, a client has to go through a complex network at different locations through different servers [15][58]. Hence calculating latency is very difficult in the cloud computing scenario. At that time the latency is quite predictable. But with the cloud the scenario is not so simple, calculating latency is quite complex [2]. Another complication in calculating delays is identifying the location of the actual infrastructure of the cloud, as many cloud vendors do not disclose the cloud data center location where a customer's services are provided [3][50].

1). Considering Geographical Distance As The Main Cause Of Latency

We calculated the length of cable between a source and to destination with the following steps [117]

1. Use tracert we get all IP addresses of routers from source to destination.
2. Obtain Autonomous system ID numbers from itoasn.com
3. Find IP addresses Geolocations using https://www.ip2location.com/
4. Find the distance between geolocations using maps.google.com
5. Find the length of cables using https://www.infrapedia.com/app

The geographical location of the data center plays an important role in the latency during communication between the client and server.

III. .PROPOSED MODEL

A. Geographically Distributed Cloud Mini Data Center Architecture

Mega data centres further increases complexity in calculations and retrieving final results. Request received from far geographical locations carries high network overheads [17][18]. Hence we suggest local mini data centers at multiple geographical locations around the world. The idea behind mini data centers is having thousands of data centers geographically distributed worldwide with few servers each (we leave the number and capacity of servers to data centre designers). Each group of servers will keep data that local to that geographical area[29]. The mini data centers are few milliseconds away from client devices [33]. However these data centers must be connected together to each other through backbone networks so that retrieving data for mobile devices at a place other than its home location will be possible and preserving the concept of ubiquitous computing [38]. The geography of proposed network is classified into Local zones, availability zones and Regions [48].

Local Zone: The End users reside inside a single Local Zones. The local zone can be identified as the area under the domain of single Mini Data Center where all cloud services are placed.

Availability Zone: An availability zone may have many Local Zones and hence many Mini Data Centers. The Availability Zone is controlled by SDN Controller which keeps all topology information of that availability zone. The Availability Zone SDN Controller communicates with SDN Controllers at Local Zoned forming a hierarchical structure. The Controllers at

Availability zone communicate with Controllers at Local zone via East –west interface. It is a single failure domain in a region.
Region: The whole geography of the world is divided into various Regions. Regions consist of multiple Availability zones. A Region is defined as an area with round trip time network latency <1 ms.

B. Proposed Packet Traversing Algorithm Through Cloud Mini Data Center Region

Assumptions:
Local Zone – lz1,lz2….lzn
Availability Zone Az1,Az2….Azn
Region R1,R2….Rn
Local Zone Gateway – LZC1, LZC2… LZCn
Availability Zone Gateway – AZC1, AZC2…. AZCn
Regional Gateway RG1, RG2… RGn
Mini Data centre – MDC1,MDC2…MDCn
Mega Data Centre-MgDC1, MgDC2…MgDCn
Below is the Algorithm for packet traversing between end user and Cloud Mini data Centre Domain:

Algorithm Cloud Packet Routing:
Step1: For each packet originated do
A service request originated from the end-user in region R1, Availability zone Az1, and Local zone lz1 is first forwarded to local zone Gateway LZC1 which defines routing rules.
Step 2: The packet is then forwarded to the local mini data center MDC with the least latency from switches of that domain.
Step 3: In case the services of local mini data centers MSC are unavailable, the LZC1Gateway forwards the packet to the Availability zone Gateway say AZC1 which has complete knowledge about the availability zone domain and searches for required service in other MDCn in availability zone and forward it to suitable local zone Gateway say LZC2.
Step 4: If AZC1 fails to find the required services under his availability zone domain it forward requests to Central Region Gateway RC1.
Step 5: The central Gateway has a global view of the region, it tries to find another Availability zone for the required service and, if forward the request to the corresponding availability zone Gateway say AZC2which then forwards it to LCZ and then retrieves the required service from the MDC of that availability zone
Step 6: If the Regional Gateway RC fails to find the service in its region, it forwards the request to the nearby region and follows the steps from step 5 to step 3.

C. Simulation of Traditional Cloud Mega Data Center Network Model Using Cloud Analyst

A testbed was set to model mega cloud data centers in Cloud Analyst. Cloud Analyst is a Cloud Simulator that inherits features of CloudSim to simulate geographically distributed Cloud Data Centers and users under different configuration deployments. Cloud Analyst helps us to model Cloud Data Center Placement in different regions and user bases (group of Users).
As discussed earlier the Mega Cloud Data Center Model Consists of huge data centers with thousands of servers. These data centers are few in numbers and not in proximity of the end users i.e. they may belong to regions other than to which end user of that Data Center belongs. Hence, the in simulation configure Data Center Placement in three regions(R0,R2 and R4), however User bases are kept in three other regions say R1,R3,R5.Various input parameters to simulate the model are as follows:

1) Input Parameters

To Simulate Mega Cloud Data Center Model the following configuration was performed in Cloud Analyst:-
- Throughout the globe, 12 User Bases were Created, 4 User Bases (UB) in 3 regions (R1, R3, R5) each.
- The Data Size Request of each user per Hour is kept 100 bytes.
- The Service Broker Policy is Chosen as “Closest Data Center”.
- Three Data Centers are created one each in Regions 0, Region 2 and Region 4 respectively.
- Each Data Center has Linux Xen Servers with eight physical hardware units each.
- Each Data Centre has 20 Virtual Machines (VM’s), 2048 Memory and 1000 Bandwidth each.
- User grouping factor is set to 40 i.e. number of simultaneous users from a single user base is 40.
- Request Grouping Factor is set to 40 i.e. number of simultaneous requests from a single application server can support 40
- Executable instruction length per request is 100.
- Load balancing policy across VM’s in a single datacenter is chosen to be “Round Robin”.

Figure 2 shows main configuration in Cloud Analyst Cloud Mega Data Center Model.

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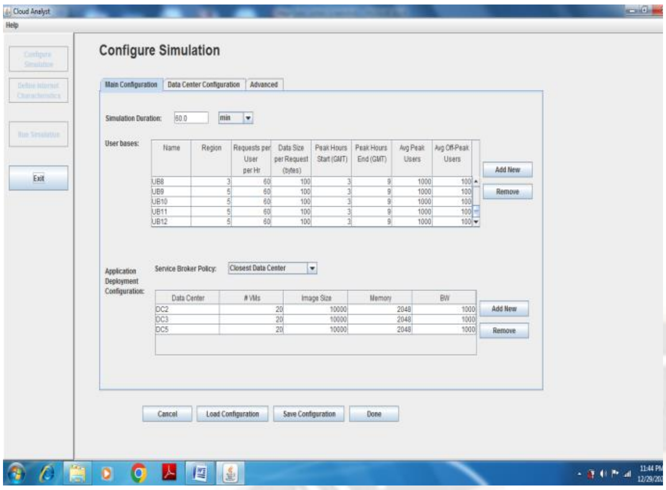

Figure 2 Main Configuration

Figure 3 shows Data Center configuration in Cloud Analyst Cloud Mega Data Center Model.

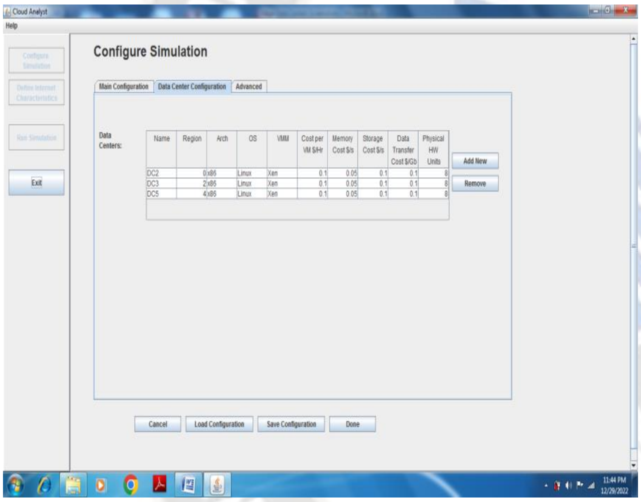

Figure 3 Data Center Configuration

Figure 4 shows Grouping Factor in Cloud Analyst Cloud Mega Data Center Model.

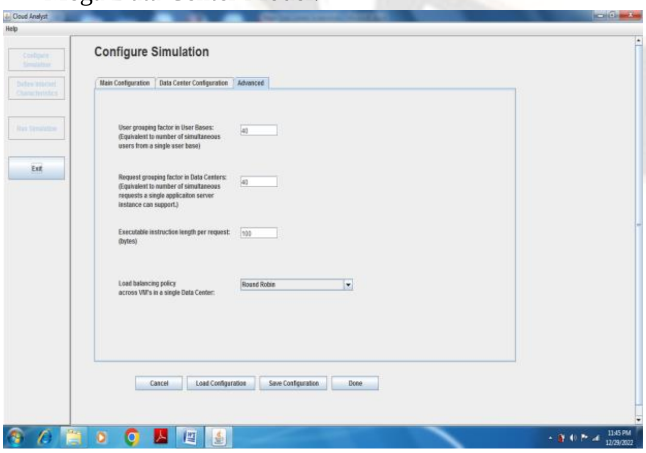

Figure 4 Grouping Factor

After completing the Configuration, execution of the simulated model is performed. The results obtained are then interpreted.

D. Simulation Of Proposed Cloud Mini Data Center Network Model Using Cloud Analyst

Another test bed was set to model Proposed Model – Cloud Mini cloud data centers Model using Cloud Analyst. As discussed earlier the Mini Cloud Data Center Model Consists of small data centers with few low capacity servers (The Number and Capacity of these servers depends on the population of Cloud Users in that region. These data centers are geographically distributed. Each Region Contains Multiple Data centers. Each Region can be divided into multiple availability zones and each availability zones can have multiple local zones. The proposed model suggests one Mini Data Centers in each local zone. The services of the Users in that local zone are satisfied with these Mini Data Centers. Hence in this simulation Twenty four Mini Data Centers are created throughout the world in all six Regions (R0, R1, R2, R3, R4, R5), four in each region. Twenty Four User Bases are created. Various input parameters to simulate the model are as follows:

1. Input Parameters

To Simulate Mini Cloud Data Center Model the following configuration was performed in Cloud Analyst:-

Throughout the globe, 24 User Bases were Created(UB1-UB12),4 User Bases(UB) in 6 regions(R1,R2,R3,R4,R5,R6). The Data Size Request of each user per Hour is kept 100 bytes. The Service Broker Policy is Chosen as “Closest Data Center”. Twenty Four Data Centers are created Four each in R0, R1, R2, R3, R4, and R5 respectively. Each Data Center has Linux Xen Servers with two physical hardware units each. Each Data Centre has 5 Virtual Machines (VM’s), 512 Memory and 1000 Bandwidth each. User grouping factor is set to 10 i.e. number of simultaneous users from a single user base is 10. Request Grouping Factor is set to 10 i.e. number of simultaneous requests from a single application server can support 10 Executable instruction length per request is 100. To define Internet Characteristics the transmission delay and bandwidth availability between the regions is defined as given in the figure. Load balancing policy across VM’s in a single datacenter is chosen to be “Round Robin”.

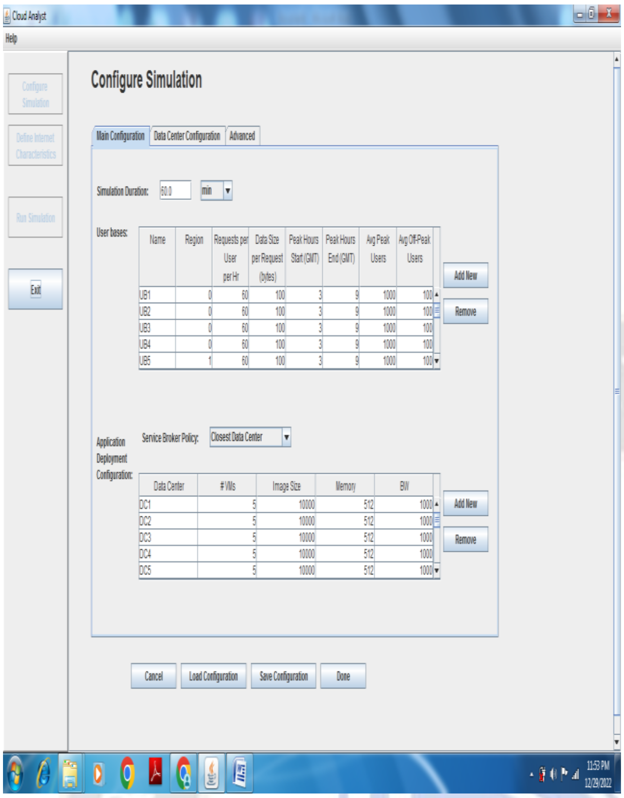

Figure 5 Mini Data Center Main Configuration (4 User bases equally distributed 6 regions,4 Mini Data Centers in each region, with 5 VM's each)

Figure 5 shows Mini Data Center Main Configuration in Mini Data Center Model using Cloud Analyst.

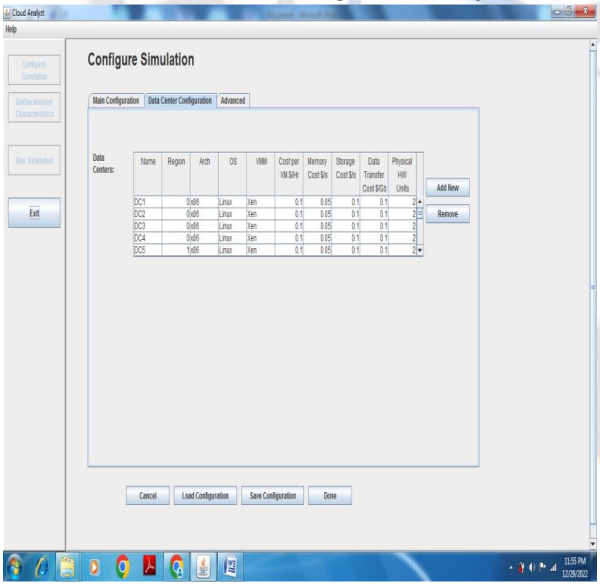

Figure 6 Mini Data Center Data Center Configuration(4 Data Center in each region with 2 Physical Machines)

Figure 6 shows Mini Data Center Configuration in Mini Data Center Model using Cloud Analyst.

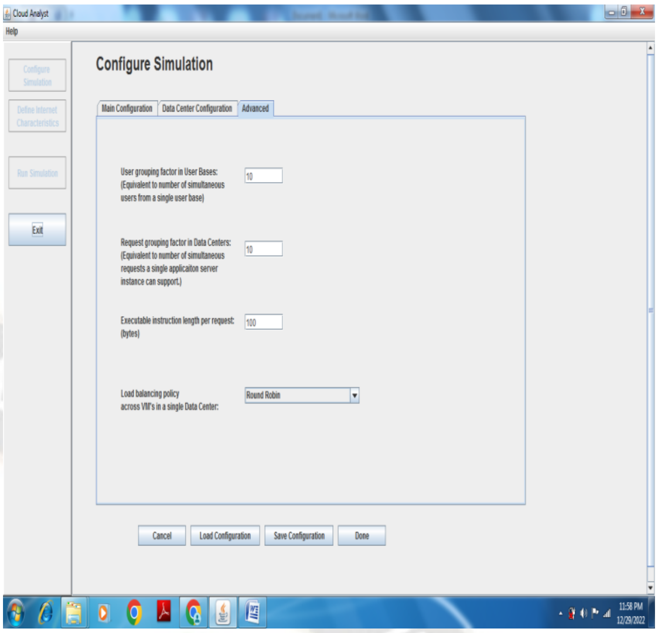

Figure 7 Mini Data Center Advance Configurations (Grouping Factor)

Figure 7 shows Mini Data Center Advanced Configuration in Mini Data Center Model using Cloud Analyst.

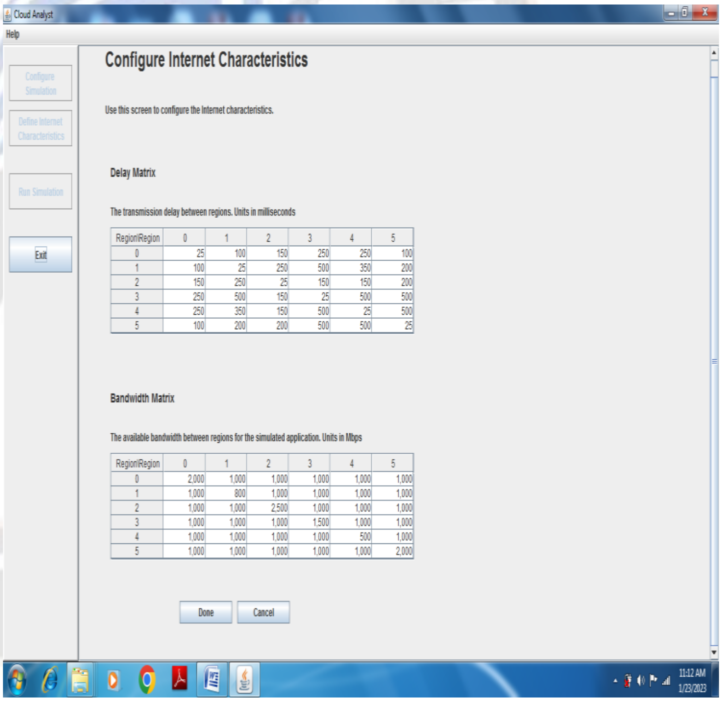

Figure 8 Define Internet Characteristics

Figure 8 shows Mini Data Center Internet Characteristics configuration in Mini Data Center Model using Cloud Analyst. After completing the Configuration, execution of the simulated model is performed. The results obtained are then interpreted. The detailed results and comparison of results are discussed in next section.

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IV. Results of Simulation Modelling through Cloud Analyst

The proposed solution creates two models using Cloud Analyst. The first model is a model that depicts a traditional mega cloud data center model that has large scale data centers around the globe. The second model depicts proposed model called Mini data center model that are distributed throughout the globe and are in proximity to end users. That is end users have mini data centers in their local zone that satisfy the requirements of local users. The results of both models can interpreted with comparison as given below.

A. Simulation Results of Mega Data Center Model using Cloud Analyst

Figure 9 shows a graphical view of Simulation result in Cloud Analyst Cloud Mega Data Center Model.Results of the Simulation Completed at: 29/12/2022 23:46:07.

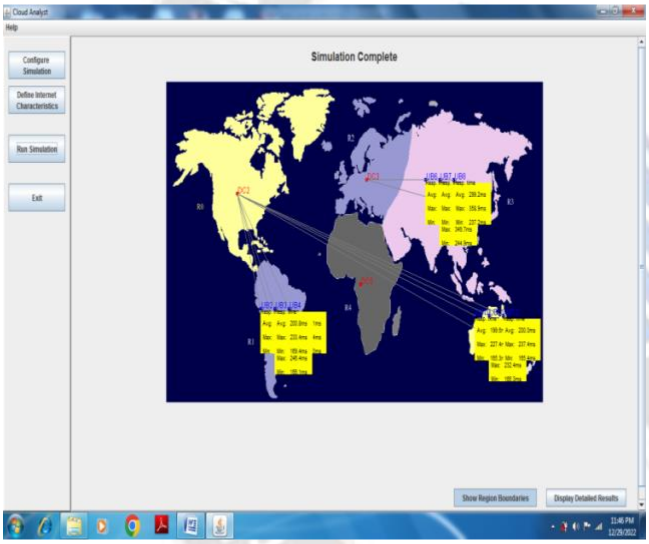

Figure 9 A View of Data Center and User Base connectivity

Table 1 shows Overall Response Time Summary in Mega Data center Model

TABLE 1 OVERALL RESPONSE TIME SUMMARY

	Avg (ms)	**Min (ms)**	**Max (ms)**
Overall response time:	233.99	153.04	370.92
Data Center processing time:	0.43	0.00	0.93

1) Response Time by Region

Table 2 shows Response Time by Region in Mega Data center Model

TABLE 2 RESPONSE TIME BY REGION

Userbase	**Avg (ms)**	**Min (ms)**	**Max (ms)**
UB10	199.59	165.32	227.42
UB11	201.11	168.42	237.41
UB12	199.96	165.38	237.42
UB1	200.23	166.12	246.42
UB2	200.21	164.42	244.41
UB3	200.78	169.41	233.42
UB4	201.12	153.04	242.41
UB5	300.57	244.92	349.75
UB6	299.33	250.91	369.25
UB7	304.20	255.41	370.92
UB8	299.23	237.21	358.92
UB9	200.53	166.27	232.41

2) Data Center Request Servicing Times

Table 3 shows Data Center Request Servicing Time in Mega Data center Model

TABLE 3 DATA CENTER REQUEST SERVICING TIME

Data Center	Avg (ms)	Min (ms)	Max (ms)
DC2	0.34	0.02	0.44
DC3	0.59	0.02	0.93
DC5	0	0	0

Cost
Total Virtual Machine Cost ($): 5.90
Total Data Transfer Cost ($): 0.72
Grand Total: ($) 6.62

TABLE 4 COST

Data Center	VM Cost $	Data Transfer Cost $	Total $
DC2	2.00	0.48	2.48
DC3	2.00	0.24	2.24
DC5	1.90	0.00	1.90

Table 4 shows VM Cost, Data Transfer Cost and Total Cost in from Data Centers in Mega Data center Model.

Simulation Results of Mini Data Center Model Using Cloud Analyst

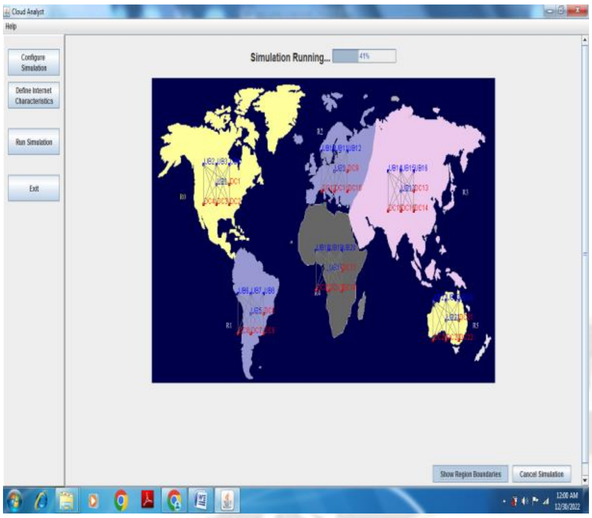

Figure 10 A View of Mini Data Center Connectivity with Local User Bases

Figure 10 shows graphical results of in Mini Data Center Model using Cloud Analyst.

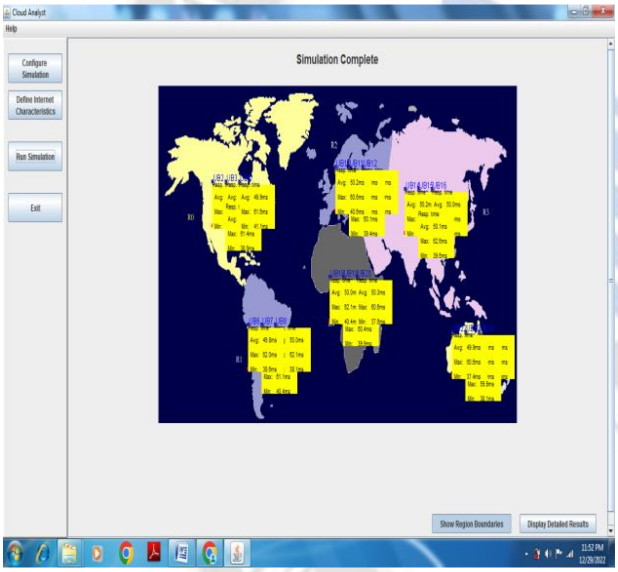

Figure 11 Results of the Simulation Completed at: 29/12/2022 01:04:07

Figure 11 shows results with response time etc in Mini Data Center Model using Cloud Analyst.

3) Overall Response Time Summary

Table 5 shows Overall Response time and Data processing Time in Cloud Mini Data Center Model Simulation using Cloud Analyst.

TABLE 5 :OVERALL RESPONSE TIME AND DATA PROCESSING TIME- CLOUD MINI DATA CENTER

	Avg (ms)	Min (ms)	Max (ms)
Overall response time:	50.07	36.86	63.86
Data Center processing time:	0.48	0.01	0.92

4) Response Time by Region

Table 6 shows Response time by Region in Cloud Mini Data Center Model Simulation using Cloud Analyst.

TABLE 6: RESPONSE TIME BY REGION

Userbase	Avg (ms)	Min (ms)	Max (ms)
UB10	50.16	40.61	60.61
UB11	50.22	39.36	62.85
UB12	50.09	39.36	59.85
UB13	50.07	39.61	62.61
UB14	50.23	38.37	60.36
UB15	50.18	40.86	62.61
UB16	50.06	38.52	60.61
UB17	50.25	39.89	61.37
UB18	49.96	39.46	62.14
UB19	50.27	40.62	60.13
UB1	50.13	38.86	61.36
UB20	50.33	37.62	61.98
UB21	49.97	38.11	61.11
UB22	49.91	37.36	60.61
UB23	50.03	36.86	59.86
UB24	50.12	39.61	60.36
UB2	50.13	39.61	61.61
UB3	49.72	36.86	63.86
UB4	49.94	41.11	61.61
UB5	50.06	40.37	60.86
UB6	49.74	38.62	62.03
UB7	50.10	37.63	63.36
UB8	49.99	38.11	62.12
UB9	50.05	40.36	60.11

5) Data Center Request Servicing Times

Table 7 shows Data Center Request Servicing Time in Cloud Mini Data Center Model Simulation using Cloud Analyst.

TABLE 7: DATA CENTER REQUEST SERVICING TIME

Data Center	Avg (ms)	Min (ms)	Max (ms)
DC10	0.47	0.02	0.86
DC11	0.47	0.02	0.86
DC12	0.48	0.01	0.86
DC13	0.49	0.02	0.88
DC14	0.50	0.02	0.87
DC15	0.47	0.03	0.88
DC16	0.46	0.02	0.86
DC17	0.47	0.03	0.89
DC18	0.50	0.03	0.91
DC19	0.49	0.03	0.89
DC1	0.49	0.01	0.87
DC20	0.48	0.03	0.92
DC21	0.47	0.01	0.87
DC22	0.47	0.01	0.86
DC23	0.47	0.01	0.87
DC24	0.47	0.02	0.86
DC2	0.48	0.01	0.86
DC3	0.47	0.01	0.86
DC4	0.49	0.01	0.86
DC5	0.48	0.02	0.89
DC6	0.48	0.03	0.90

DC7	0.47	0.03	0.90
DC8	0.49	0.02	0.90
DC9	0.47	0.01	0.86

Cost

Total Virtual Machine Cost ($):
12.00
Total Data Transfer Cost ($):
1.54
Grand Total: ($)
13.54

TABLE 8 VM COST AND DATA TRANSFER COST

Data Center	VM Cost $	Data Transfer Cost $	Total $
DC11	0.50	0.07	0.57
DC22	0.50	0.06	0.56
DC10	0.50	0.06	0.56
DC21	0.50	0.07	0.57
DC20	0.50	0.06	0.56
DC2	0.50	0.06	0.56
DC1	0.50	0.06	0.56
DC4	0.50	0.06	0.56
DC3	0.50	0.07	0.57
DC6	0.50	0.07	0.57
DC5	0.50	0.06	0.56
DC8	0.50	0.07	0.57
DC19	0.50	0.06	0.56
DC7	0.50	0.06	0.56
DC18	0.50	0.06	0.56
DC17	0.50	0.06	0.56
DC9	0.50	0.07	0.57
DC16	0.50	0.06	0.56
DC15	0.50	0.06	0.56
DC14	0.50	0.07	0.57
DC13	0.50	0.07	0.57
DC24	0.50	0.06	0.56
DC12	0.50	0.06	0.56
DC23	0.50	0.06	0.56

Table 8 shows VM Cost and Data Transfer Cost in Cloud Mini Data Center Model using Cloud Analyst

V. COMPARISON OF RESULTS OBTAINED THROUGH CLOUD ANALYST SIMULATIONS OF MEGA CLOUD NETWORK MODEL AND MINI CLOUD NETWORK MODEL

The comparison of results of the traditional cloud network model –Mega Data Center and Proposed Data Center Network model –Mini Data Center Model is as follows:

The average overall response time of Mega Data Center is 233.99 while in Mini Data Center it is 50.07.This shows significant reduction in average overall response time in Mini Data Center. Table 9 shows the overall response time in Mega Data Center and Mega Data Center.

TABLE 9: OVERALL RESPONSE TIME IN MEGA DC AND MINI DC

	(Mega Data Center	Mini Data Center
Overall response time(ms):	233.99	50.07

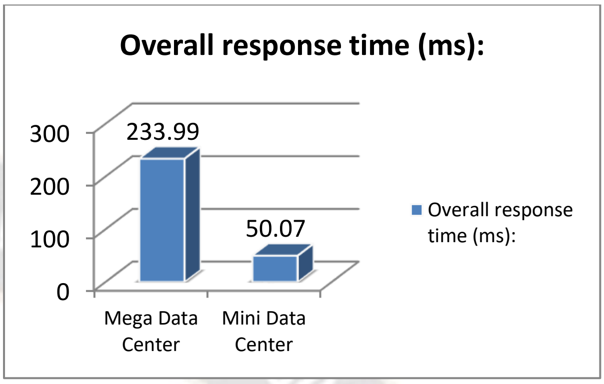

Figure 12: Overall Response time in Mega DC and Mini DC

Figure 12 shows the graphical representation of overall response time in Mega Data Center and Mega Data Center. Table 10 shows Average Response time for various User Bases in Mega Data Center and Mini Data Center.

TABLE 10 :AVERAGE RESPONSE TIME FOR VARIOUS USERBASES

User Base	Avg (ms) Response Time Mega Data Center	Avg (ms) Response Time -Mini Data Center
UB1	200.23	50.13
UB2	200.21	50.13
UB3	200.78	49.72
UB4	201.12	49.94
UB5	300.57	50.06
UB6	299.33	49.74
UB7	304.2	50.1
UB8	299.23	49.99
UB9	200.53	50.05
UB10	199.59	50.16
UB11	201.11	50.22
UB12	199.96	50.09

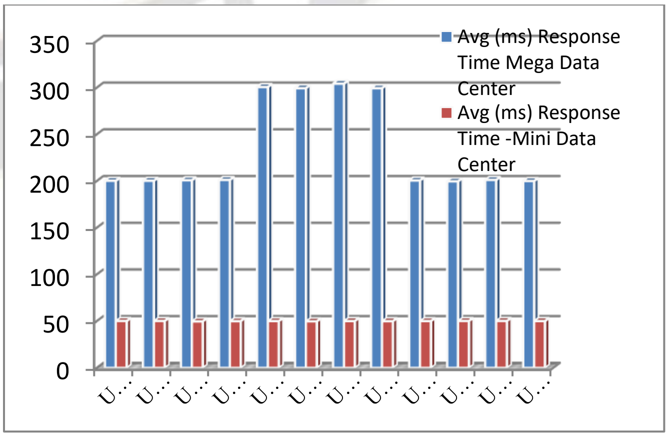

Figure 13 :Average Response time for various UserBases

Figure 13 shows graphical representation of Average Response time for various UserBases in Mega Data Center and Mini Data Center.

We can see significant reduction in average response time by Region in Mini Data Center Network Model.

The average cost of VM in mega data center is $2.0(Approx), Cost of Data transfer is $0.48 in three data centers of Mega Datacenter Model while in mini Data Centers VM cost is $ 0.50 and Cost of Data Transfer is $0.07(Approx) in all 24 Data Centers which shows significant reduction in cost in Mini Data Center.

Table 4.11 shows the total Cost for each mega Data Center and Mini Data Center.

TABLE 11 :TOTAL COST FOR MEGA DC AND MINI DC

	For each Mega Data Center	For each Mini Data Center
Total $(VM Cost+ Data Transfer Cost	2.48	0.57

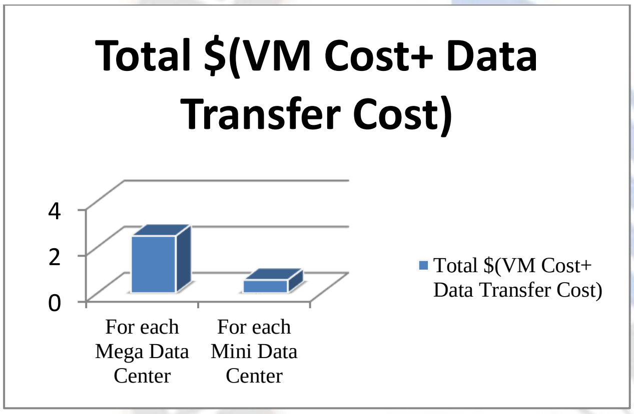

Figure 14 shows graphical representation of the total Cost for each mega Data Center and Mini Data Center.

The advantages of the Proposed Cloud Mini Data Centers Model are as follows:

1. Minimized latency as the number of hops of Cloud traffic is much less than that in the Mega Datacenter Model.
2. Optimized Routing as the packet does need not to travel long distances and the visibility of the destination is clear to local network devices and an optimal route can be chosen.
3. Optimal use of Bandwidth-as packets rarely passes through long haul Backbone networks. Cloud services are available with local Mini Data Centers.
4. Reduced Cost- Since, Bandwidth Utilization is minimized the cost of services is significantly reduced.
5. Solve Legacy issues in Geographical Boundaries.

In this research simulation modeling is performed using Cloud Analyst. Through Cloud Analyst two models were created, the first model created is the traditional Mega Data Center model that depicts one mega data center in a few regions that are geographically far from end users, and the second model represents a proposed Multiple Mini data center in proximity to end users. The results obtained through both simulations show that the proposed model outperforms the traditional Cloud Model in terms of latency and Cost.

From the analysis based Cloud Analyst of this Implementation on both Mega Cloud only and Mega Cloud with Mini Data Centers that the Cloud with Mini Data Center is performing better as compare to traditional Mega Cloud.

CONCLUSION

We find that the mail cause of latency for delivery of cloud traffic is the geographical distance between the end user and the cloud data center. The paper suggests solution to Cloud Traffic issues by suggesting Mini Cloud Data Centers distributed throughout the geography. The paper models the two architecture i.e Traditional Cloud Network Model and Proposed Mini Data Center Cloud Network through simulation. The simulation model for Traditional Cloud Network and the proposed Mini Data Center Cloud Network Model are designed using Cloud Analyst. The results of simulation show that the proposed Network Architecture Simulation of Mini Data Centers outperforms the traditional Cloud Network performance in terms of latency and Cost and solves many problems related to routing and Bandwidth.

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