International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075 (Online), Volume-9 Issue-1, November 2019

Integration of 6LOWPAN and Cloud Data Centers: The Role of Link Capacity between Sensor Networks and Cloud Data Centers

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Abstract: Internet of Things (IoT) and Internet of Mobile Things (IoMT) acquired widespread popularity by its ease of deployment and support for innovative applications. The sensed and aggregated data from IoT and IoMT are transferred to Cloud through Internet for analysis, interpretation and decision making. In order to generate timely response and sending back the decisions to the end users or Administrators, it is important to select appropriate cloud data centers which would process and produce responses in a shorter time. Beside several factors that determine the performance of the integrated 6LOWPAN and Cloud Data Centers, we analyze the available bandwidth between various user bases (IoT and IoMT networks) and the cloud data centers. Amidst of various services offered in cloud, problems such as congestion, delay and poor response time arises when the number of user request increases. Load balancing/sharing algorithms are the popularly used techniques to improve the performance of the cloud system. Load refers to the number of user requests (Data) from different types of networks such as IoT and IoMT which are IPv6 compliant. In this paper we investigate the impact of homogeneous and heterogeneous bandwidth between different regions in load balancing algorithms for mapping user requests (Data) to various virtual machines in Cloud. We investigate the influence of bandwidth across different regions in determining the response time for the corresponding data collected from data harvesting networks. We simulated the cloud environment with various bandwidth values between user base and data centers and presented the average response time for individual user bases. We used Cloud- Analyst an open source tool to simulate the proposed work. The obtained results can be used as a reference to map the mass data generated by various networks to appropriate data centers to produce the response in an optimal time.

Index Terms: IoT, IoMT, Data Centers, Virtual Machines, Load Balancing, Cloud Computing

I. INTRODUCTION

6LOWPAN provides integrity of sensor devices which senses and transfers data to the 6LBR (6LOWPAN Border Router)[16][17][18][19[20]. The large volume of data gathered over time are processed and interpreted to produce various results and decision by the remote cloud data centers. The transmissions of data across various communication links play a vital role in producing the response in a shorter time. As the popularity of Cloud paradigm increases, the number of users and the tasks executed in the cloud also increases. The servers are overloaded and the response time increases linearly along with the increased user requests. Availability of servers with higher computing capacity reduces the response time of application. Due to the heterogeneity nature of cloud, the capacity of servers varies largely among them in terms of CPU clock cycles, memory, cache and bandwidth. Load balancing algorithms allocates tasks/jobs to servers based on the policy implemented. If an algorithm considers only the count of available servers then it allocates the task to servers based on a round robin fashion. At the other end, if the algorithm considers the capacity of individual servers, then it allocates the task to servers variably. The existence of heterogeneous servers plays a crucial role in determining the performance of the system. Several load balancing algorithms exists in the literature to assign task to servers based on various policies. Round Robin, Weighted Round Robin, Number of Connections Based, Random, Greedy and Hybrid algorithms [15] are the well-known algorithms that exist in the literature for load balancing. In this paper we investigate the outcome of some of the well-known algorithms when applied to virtual machines in data centers with different configurations in terms of CPU Cycles, Memory, Cache and bandwidth. The services provided by the cloud are generally classified as Iaas (Infrastructure as a Service), SaaS (Software as a Service) and PaaS (Platform as a service) [15]. The infrastructure refers to the provision of storage, memory and processing power. The load balancing algorithm receives the request from the user and assigns it to the servers based on the balancing policy. For example the round robin algorithm allocates tasks to the server in a round robin basis. It doesn't consider the processing capacity of the server and other facilities such as memory, storage and available cache. This may lead to occurrence of congestion with a particular server eventually increasing the response time for the task. In order to avoid over assignment to a particular server whose capacity is far below the average of others, the balancing algorithm should consider the individual capacity of the server and assign tasks. To facilitate the readers, we have analyzed the effect of heterogeneous systems in the data centers with various load balancing algorithm and present the performance metrics such as response time in order to gain an insight on the effects. The rest of the paper is organized below. Section II presents the literature review on the existing methodologies and survey performed by various researchers in the literature.

Revised Manuscript Received on November 30, 2019.
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Section III presents the configuration scenario. Section IV presents the simulation results and interpretations. Section V concludes the paper with future works.

II. LITERATURE SURVEY

The authors in [1] have proposed a dynamic load balancing algorithm named CLB (Cloud Load Balancing). In contrast to the static load balancing algorithms in the literature which considers the servers computing power to assign tasks to server, the proposed approach considers both server computing power and computer loading which avoids the fact that computers will be loaded unevenly. The authors in [2] have made an in-depth study about the existing load balancing algorithm to keep the servers equally loaded and presented a comprehensive analysis on the various load balancing algorithms existing in literature. The authors in [3] have presented various categories of load balancing such as map reduce in Hadoop, nature inspired load balancing, Agent supported load balancing, load balancing in general, application specific and network based. The work considers load balancing as an initiative to ensure quality of service, increased throughput, performance and utilization of resources. The authors in [4] have presented a load balancing algorithm which is based on particle swarm optimization. The work aims at maintaining a balance between energy and performance in order to increase profit. The PSO technique is modified to provide quality of service with reduced energy consumption to allocate migrated VM's on the host. The proposed work is simulated using cloudsim which shows improvement in energy consumption by 14% compared to the existing algorithms. The authors in [5] have presented various quality of service requirements from the users that should be met by providers. In case of failure in meeting the user requirement upon agreement, the provider should compensate the users in terms of penalty. The author in [6] have proposed LBMM (Load Balancing Method for Massive Data) for load balancing while processing massive data in cloud. The authors have also addressed two other schemes named Efficiency of Data Processing and Relatively Free Rate. The proposed LBMM is based on DPE and RFR. The proposed method is compared with consistent hashing method. The results of the experiment shows improved equalization and efficiency in data processing. The authors in [7] proposed artificial bee based algorithm for load balancing in cloud computing. The authors in [8][11][12] proposed algorithms to minimize the response time and access time in cloud based on the QoS parameters of the user. The source code of the simulator used in this paper can be obtained from the online sources as mentioned in [9] [10]. The authors in [13][14] discusses about various simulation environment available for cloud computing and also discusses the execution of load balancing algorithm in it.

III. INTEGRATION OF 6LOWPAN BASED NETWORK WITH CLOUD DATA CENTERS

Data transmission between IoT and IoMT based networks and a cloud data center is shown in the Fig. 1. 6LOWPAN based consists of several instances of DODAG (Destination Oriented Directed Acyclic Graph). There are several static nodes which act as a router to forward the sensed data to the DODAG-ROOT. Mobile nodes are allowed to join the DODAG as leaf node. Each instance of DODAG has a DODAG-ROOT that acts as border router which forwards the data to Internet (Cloud Data Centers).

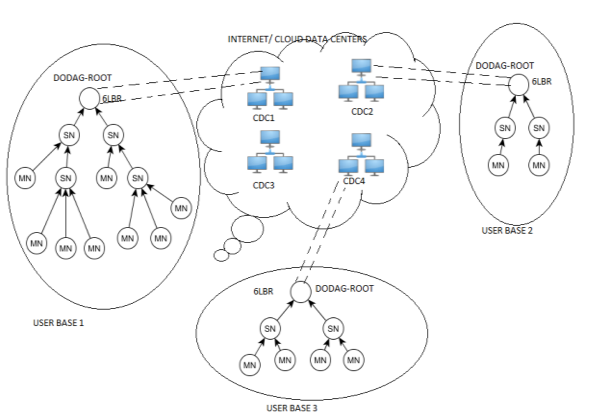


Fig.1: Transmission of Data from IoT to cloud Data Centers

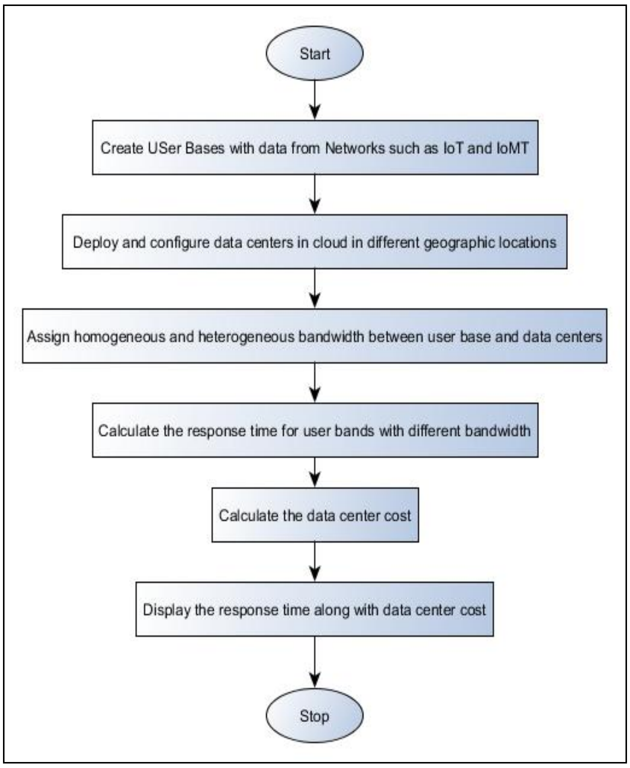


Fig.2: Steps involved in the simulation process

We briefly present the various services provided by Cloud and the relevant tools in the following section. Later we present the steps involved in the analysis process such as user base creation, data center configuration, homogenous and heterogeneous bandwidth allocation in Fig.2

Software as a Service [SaaS]	Multimedia Applications and Web services	Google App and Facebook
Platform as a Service [PaaS]	Software Tools	Microsoft Azure
Infrastructure as a Service [IaaS]	Infrastructure and Hardware (CPU, Memory and Bandwidth)	Amazon EC2, Data centers

Table I: Cloud Computing Stack Architecture [15]

Based upon the services provided by cloud, it can be classified into three major types. Iaas, Paas and Saas which stands for Infrastructure as a Service, Platform as a service and Software as a service. Cloud service providers such as Elastic Cloud compute by amazon, Rackspace are the examples for Iaas. Cloud users and consumers can deploy applications without the need to purchase the needed software, libraries and tools. App Engine from Google and Windows azure are examples for Paas. Google App and Salesforce .com are the examples for software as a service. Users can access the required software through Internet and pay only for what is being used unlike the need to pay for the entire package. [15]

Based upon the computing models followed in cloud, it can be classified into public, private and hybrid. Each of these computing model differs in the way how they are built and being accessed by its users. Public cloud lacks security where it is being thwarted in private cloud. While protecting network and data, private cloud limits the access only to the organization thereby giving the users a feel of accessing a group of servers. [15]

Each system in a network has a job queue which contains the set of jobs that will be executed in that system. The number of jobs in a system's queue is used as measure the load. Several load balancing algorithms are proposed in the literature to balance load among the systems in a network. The main objectives of load balancing algorithms are to increase throughput, resource utilization and minimize response time. Generally load balancing algorithms fall into two category: static and dynamic. The method of load balancing is decided during the compile time itself. Round Robin based load balancing is an example for static load balancing algorithm. [15]

IV. THE IMPACT OF HOMOGENEOUS/ HETEROGENEOUS BANDWIDTH

Table II: Data Center Configuration

Name	Region	Arch	OS	VMM	Cost Per VM $/Hr	Mem. cost $/s	Storage Cost $/s	Data Tran. Cost $/Gb
DC1	3	X86	Linux	Xen	1	0.05	1	1
DC2	2	X86	Linux	Xen	1	0.05	1	1
DC3	0	X86	Linux	Xen	1	0.05	1	1
DC4	1	X86	Linux	Xen	1	0.05	1	1
DC5	4	X86	Linux	Xen	1	0.05	1	1

A. SIMULATION CONFIGURATION

In this experimental set up we created data centers as shown in the Table II. Five different data centers are configured with various operating systems, virtual machine monitor , processor architecture, cost incurred for memory access, storage and data transfer cost. The data centers are located in different regions across the globe. All virtual machines follow X86 architecture. Linux is the operating system running on every virtual machine. Xen virtual machine monitors supervises the virtual machines. The cost to access memory, storage and data transfer are set as shown in the table. The number of user bases created is 7. The user grouping factor is set to 1000. The number of request grouping factor is set to 100. Round robin algorithm is used as load balancing algorithm across virtual machines. Closest data center is selected as service broker policy. The bandwidth matrix is set as shown in Table III and Table IV. The bandwidth is varied in each simulation. We used three different bandwidth values such as 2000 Mbps, 500 Mbps and 100 Mbps. The bandwidth between different regions is set to any one of the above values in homogeneous bandwidth configuration. In heterogeneous bandwidth configuration, the value differs between each region. It varies between 500 Mbps to 1250 Mbps as shown in Table IV.

Region / Region	0	1	2	3	4	5
0	2000	2000	2000	2000	2000	2000
1	2000	2000	2000	2000	2000	2000
2	2000	2000	2000	2000	2000	2000
3	2000	2000	2000	2000	2000	2000
4	2000	2000	2000	2000	2000	2000
5	2000	2000	2000	2000	2000	2000

Table III: Homogeneous Bandwidth Configuration between Regions (2000 Mbps for all regions)

Region / Region	0	1	2	3	4	5
0	2000	250	500	750	1000	1250
1	250	2000	500	750	1000	1250
2	500	500	2000	750	1000	1250
3	750	750	750	2000	1000	1250
4	1000	1000	1000	1000	2000	500
5	1250	1250	1250	1250	500	2000

Table IV: Heterogeneous Bandwidth Configuration between Regions (Varying from 500 Mbps to 2000Mbps)

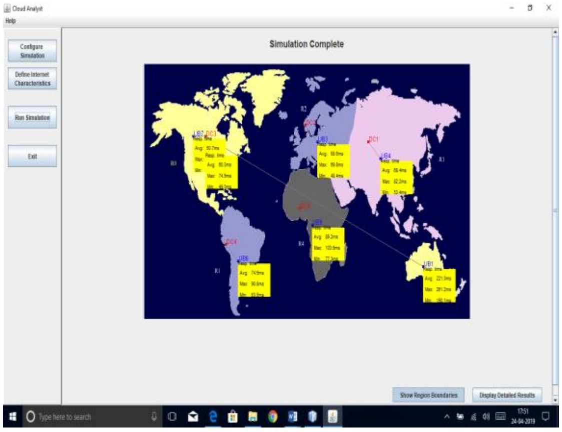
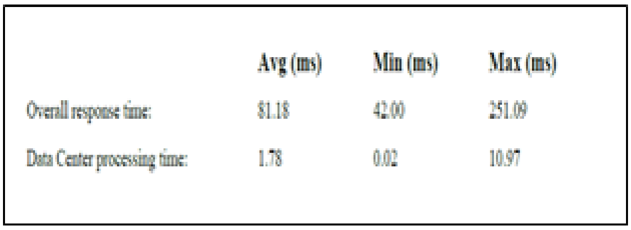


Fig.3: Placement of Data Centers and User Base in Cloud Analyst Simulation Tool

Six different regions across the globe are selected to place data centers and generate user request. The users are grouped using a factor 1000 and user requests are grouped using a factor 100. The closest data center service broker policy selects the nearest data center to the user from where the request has been generated. Assigning the request to the virtual machines is done through round robin scheduling algorithm.

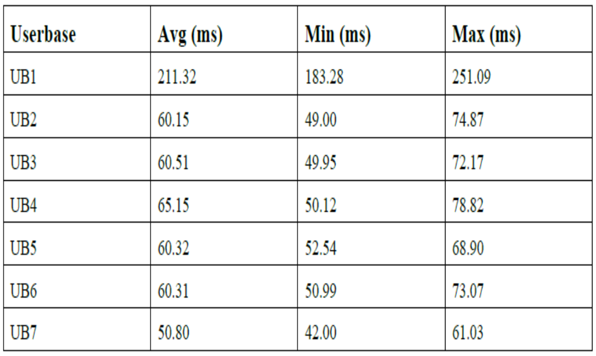
B. RESULTS AND DISCUSSION

The bandwidth for communication between different regions plays a crucial role in determining the response time of the users from various locations. The response time from a nearest data center increases significantly, if there is no enough support for larger bandwidth. We simulated with different bandwidth configurations such as homogeneous and heterogeneous between various regions. In homogeneous configuration, the values set are 2000 Mbps, 500 Mbps and 100 Mbps. We used a single value for all regions in each simulation. In heterogeneous configuration, the bandwidth between different regions are varied from 250 Mbps to 2000 Mbps. The response time in each case varies proportionate to the available bandwidth between regions. In cases where the user base and data centers are available in the same region, the response time remains low. The cost of virtual machine and data transfer cost remains same for all cases.



	Avg (ms)	Min (ms)	Max (ms)
Overall response time:	81.18	42.00	251.09
Data Center processing time:	1.78	0.02	10.97

Table V: Over all Response time (Bandwidth @2000 Mbps)



Userbase	Avg (ms)	Min (ms)	Max (ms)
UB1	211.32	183.28	251.09
UB2	60.15	49.00	74.87
UB3	60.51	49.95	72.17
UB4	65.15	50.12	78.82
UB5	60.32	52.54	68.90
UB6	60.31	50.99	73.07
UB7	50.80	42.00	61.03

Table VI: Average Response Time per User base (Bandwidth @ 2000 Mbps)

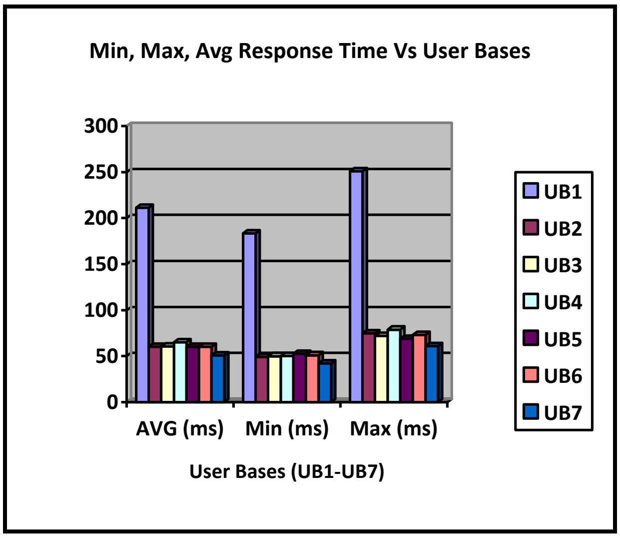
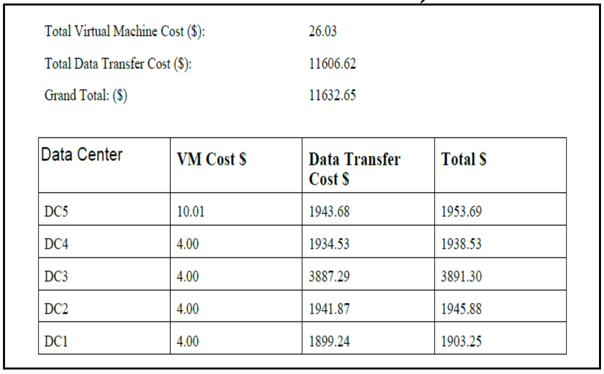


Fig.4: Min, Max, Average Response Time in (ms) per User base (Bandwidth @ 2000 Mbps)

Table VII: Virtual Machine and Data Transfer cost (For all Bandwidth Values)



Total Virtual Machine Cost ($): 26.03
Total Data Transfer Cost ($): 11606.62
Grand Total: ($) 11632.65

Data Center	VM Cost $	Data Transfer Cost $	Total $
DC5	10.01	1943.68	1953.69
DC4	4.00	1934.53	1938.53
DC3	4.00	3887.29	3891.30
DC2	4.00	1941.87	1945.88
DC1	4.00	1899.24	1903.25

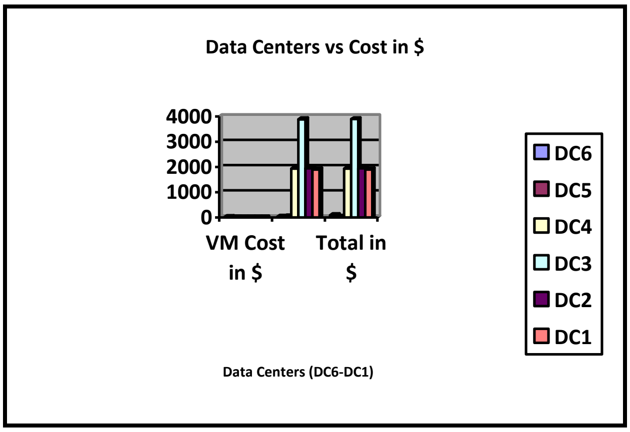
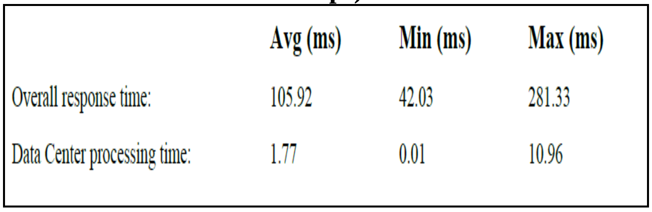


Fig.5: Virtual Machine and Data Transfer cost (For all Bandwidth Values

Table VIII: Over all Response time (Bandwidth @500 Mbps)



	Avg (ms)	Min (ms)	Max (ms)
Overall response time:	105.92	42.03	281.33
Data Center processing time:	1.77	0.01	10.96

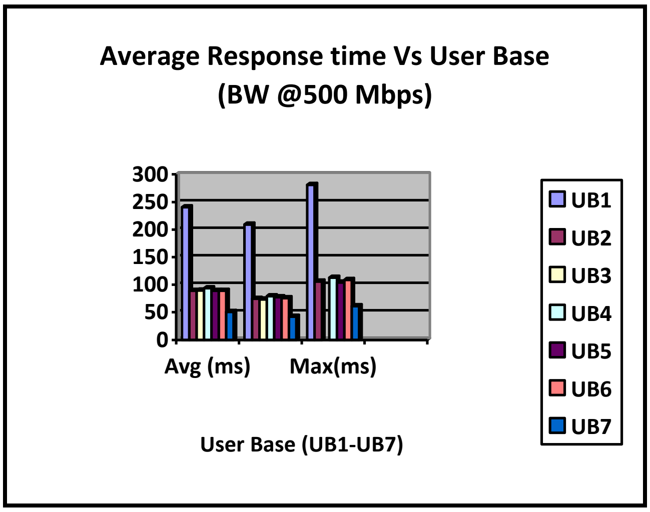


Fig.6: Min, Max, Average Response Time in (ms) per User base (Bandwidth @ 500 Mbps)

Table IX: Over all Response time (Bandwidth @100 Mbps)

	Avg (ms)	Min (ms)	Max (ms)
Overall response time:	237.84	42.18	498.44
Data Center processing time:	1.79	0.01	10.90

Table X: Average Response Time per User base (Bandwidth @ 100 Mbps)

Userbase	Avg (ms)	Min (ms)	Max (ms)
UB1	396.16	333.61	498.44
UB2	243.01	194.21	299.51
UB3	243.67	183.99	312.61
UB4	244.51	186.48	347.95
UB5	243.36	188.90	335.44
UB6	243.03	188.67	297.85
UB7	50.99	42.18	61.23

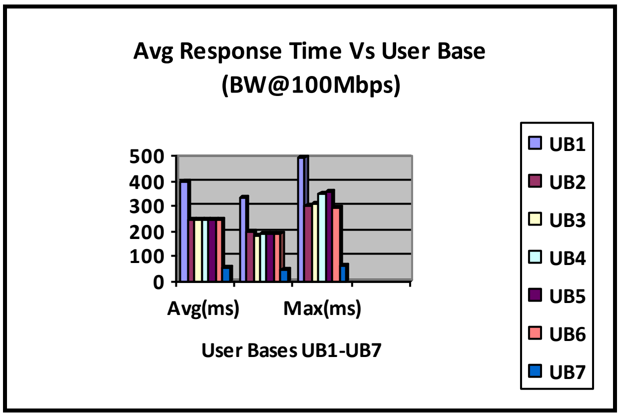


Fig.7: Average Response Time per User base (Bandwidth @ 100 Mbps)

Table XI: Over all Response time (Heterogeneous Bandwidth)

	Avg (ms)	Min (ms)	Max (ms)
Overall response time:	82.00	42.00	257.14
Data Center processing time:	1.78	0.02	10.97

Table XII: Average Response Time per User base (Heterogeneous Bandwidth)

Userbase	Avg (ms)	Min (ms)	Max (ms)
UB1	217.06	186.27	257.14
UB2	60.08	49.00	74.87
UB3	60.56	49.95	72.17
UB4	65.22	50.12	78.82
UB5	60.39	52.54	68.90
UB6	60.24	50.99	73.07
UB7	50.79	42.00	61.03

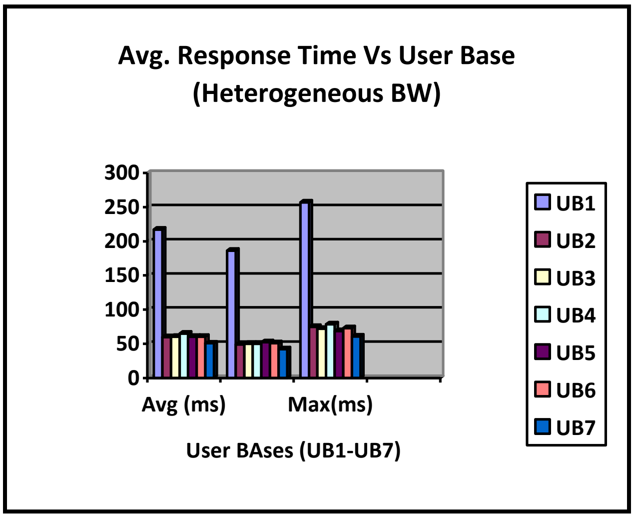


Fig.8: Average Response Time per User base (Heterogeneous Bandwidth)

The impact of homogeneous bandwidth and heterogeneous bandwidth over response time obtained through simulation are given in Table V to Table XII. The graphical interpretations are provided in Fig.4 to Fig.8. In each case the average response time of user bases varies proportionate to the available bandwidth. It is exceptional for some of the user bases such as UB7 where the request is served by the data center which is available closer to it. The virtual machine cost and data transfer cost remains almost same for all cases since response time is not influenced by these factors.

V. CONCLUSION

Large volume of environmental data sensed and gathered by networks such as IoT and IoMT are transferred to Cloud Data Centers through Internet for analysis and interpretation. The response time is determined by the processing capability of cloud data centers and communication capacity between user base (IoT and IoMT) and cloud data centers. Heterogeneity is an important attribute that affects the performance of the network in many ways. Cloud inherits heterogeneity in terms of devices, operating systems, platforms, communication media, link capacity etc. It is important to identify the effects of heterogeneous components in cloud to gain an insight on the performance offered by cloud system. In this paper we have analyzed the impact of homogeneous and heterogeneous communication bandwidth available between various regions where cloud data centers are deployed and the user base. We have investigated the impact of all bandwidth level using a simulation tool called Cloud-Analyst. We provided the results that well demonstrate the influence of communication bandwidth which determines the response time of the cloud data centers. The results provided in this paper would help the researchers and industrialist to design efficient system to improve the response time of cloud for the data collected from networks like IoT and IoMT that often populates data from different geographical location.

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