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Global Healthcare Village Based on Mobile Cloud Computing

Laleh Boroumand [1], Muhammad Shiraz [1], Abdullah Gani [1], Rashid. H. Khokhar [2]

[1.] Faculty of Computer Science and Information Technology, University of Malaya, Kuala Lumpur, Malaysia
[2.] School of Computing & Mathematics, Charles Sturt University, Australia
Lalehboroumand@siswa.um.edu.my

Abstract: Cloud computing being the use of hardware and software that are delivered as a service over a network has its application in the area of health care. Due to the emergency cases reported in most of the medical centers, prompt for an efficient scheme to make health data available with less response time. To this end, we propose a mobile global healthcare village (MGHV) model that combines the components of three deployment model which include country, continent and global health cloud to help in solving the problem mentioned above. In the creation of continent model, two (2) data centers are created of which one is local and the other is global. The local replay the request of residence within the continent, whereas the global replay the requirements of others. With the methods adopted, there is an assurance of the availability of relevant medical data to patients, specialists, and emergency staffs regardless of locations and time. From our intensive experiment using the simulation approach, it was observed that, broker policy scheme with respect to optimized response time, yields a very good performance in terms of reduction in response time. Though, our results are comparable to others when there is an increase in the number of virtual machines (80-640 virtual machines). The Proportionality in increase of response time is within 9%. The results gotten from our simulation experiments shows that utilizing MGHV leads to the reduction of health care expenditures and helps in solving the problems of unqualified medical staffs faced by both developed and developing countries.
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1. Introduction

Increasing life expectancy and shortage of qualified medical staff in both developed and developing countries are the main reasons that led to the expansion of the cloud-based health care systems. Besides, high health care expenditure can be mentioned as the second reason that causes the concern for the governments to provide health facilities for their citizens. The facts and statistics which were collected from US government and EU projections indicate that in 2015 more than 21% of patients would be in a waiting list for in-patient care about six months in the UK while in Canada is between 12 and 33 weeks [1],[2]. Also in the USA, the huge gap would be seen between the number of required nurses and the ones on the ground. The health care statistics in eleven developing Asian countries in 2014 shows Indonesia, Thailand, India, Vietnam and Malaysia will face shortage of doctors by achieving less than one doctor per 1000 people in 2014 [1].

In addition, through the developing of communication and storage technology, people are expected to access their health records and also wanting to share their medical issue with specialist regardless the time and location. Considering the importance of health care and vital data that should be saved in this system, it should guarantee some requirements such as acceptable accessibility, availability, reliability, and security.

Global healthcare village (GHV) is a concept that used to compress the health world into a village by offering the different type of online health services which making the world like a single village when people can easily access to shared health information and as well use the professional health service. This information includes patient history, hospitals and healthcare organization information such as their location or available facilities and also it involved emergencies service provider and enable them to offer emergency service to the patient at the right time and the right place. Therefore, one of the important concerns about GHV is availability. Because, the existence mentioned health information without the possibility of being available is nonsense. Use of mobile cloud computing architecture is selected by this paper as a proper solution to having available GHV.

For supporting automated e-healthcare, this process is subdivided into two levels by using the improved utility computing technology that. At the first level (Low Healthcare Tier -LHT) the data of the healthcare are gathered via medical staff or wireless sensor network (WSN) while in the second level these data are exposed to the cloud. In addition, in the second level (High Healthcare Tier - HHT) information about the various departments of different hospitals can be shared in the cloud for scientific interaction which can help in achieving a better global health village.

Hereinafter, a brief definition about the LHT layer is presented. Although, LHT is out of scope of this paper but little knowledge about it can be useful for better understanding of the HHT. In LHT, patient information collects by hospital personnel or in the highly automated system, it gathers through using wireless sensors. They are used in two formats which are wearable wireless sensor and environment wireless sensor [3], [4], [5], [6]. Usage of the wearable wireless devices leads to a new concept which is called Wireless Body Area Network (WBAN). WBAN establishes networking between human and devices through integrating bio-sensor and wireless communication. Some of the applications [7], [8], [9] work based on the WBAN, monitor single vital sign while others use various types of bio-sensors [10]. These smart sensors put in the human body or in the wearable devices and communicate with each other via star topology [3],[11]. However, there are some challenges about power consumption, reliability, security, data rate and cost in WBAN [12], [13].

In the HHT, cloud computing process is performed in multilevel structure which includes private health cloud (PrHC), public health cloud (PHC) and Hybrid Health cloud (HHC) for achieving better performance. E-healthcare faces some considerable challenges due to its significant and direct effect on the human life. Accessibility, availability, integrity reliability, security, supporting heterogeneity of devices, and power consumption are the main challenges in the e-healthcare system which is established based on the MCC.

As mentioned before, this paper focuses on the availability issues. Availability includes both data and node availability concepts which are combined together and present total availability as a percentage. The availability concept without concerning to one of the performance or security concept is not valuable. Therefore, this work measure the response time that directly influence to the performance. To achieve this goal, the first step is defining a model and then based on it and its configuration, the availability in terms of the response time could be measured. In fact, in another vision possible to say, one of the drawbacks of GHV system is lacking to have a model that supports transferring health information or result of health computation in the short period of time to both the patient or professional medical staffs across the time and location barrier. To this end, concerning to following factors seem necessary; The quantity of data centers and make a proper decision about the number of VMs that need to run in each datacenter that impact on the response time. Also, concerning about a proper backup system as well as suitable task or query divider policy to delegate tasks to correspondence server, need to address by service broker policies. The propose MGHV model in this paper, efforts to meet the above aforementioned requests.

This paper starts with related work in which both researches which work on health care system based on MCC and the methods which evaluated availability in terms of performance are reviewed. It follows by describing a MGHV model and related details as a main contribution of this paper in Section 3. In Section 4, results which are gained based on simulation experiment are discussed. Finally, Section 5 includes the conclusion of the paper.

2. Related work

2.1 brief reviews of Health care systems based on mobile/cloud computing

Different approaches have been proposed by different researchers to solve the healthcare problem. This approach that exists in mobile healthcare could be classified into two groups which are basically (1) personal health record (PHR), and (2) electronic health record (EHR). Approaches that utilize PHR can help people with self-monitored and self-managed their health. Also, these approaches help to make better decision about choosing a proper health consultant or insurance. While, electronic health records are used in scenarios in which hospitals, specialist and expert medical staffs are involved. They use the EHR information to diagnose the patient illness, monitor the patient's status or share the health information between various hospitals in one or multiple countries. Also, the EHR records are used in the emergency cases. The summary of the conducted studies in this field are written in Table 1.
There are some limitations in the current methods for example in health-ATM method, user should access health-ATM machines for inserting their information or querying related health suggestion. Also, the mentioned methods do not support mobile and global healthcare system.

Table 1. Conducted studied on Health care systems based on mobile/cloud computing

Author	Concluding remarks	Reference
Hsu et al.	The wellness cloud keeps the diet and activities habit of a person, analyze them and suggest the healthy ways via the use of information systems, else providing self-health management.	[14]
Botts et al.	The main idea in this approach is based on automated teller machines (ATMs), and new term HealthATM introduced by the authors. In this approach there are some kiosks used for transferring health information and there is no need to go to clinics and waste time and money.	[15]
Poulymenopoulou et al.	The authors proposed a cloud- based architecture for emergency health care service that consist of four main parts such as work-flow, software, Database and security.	[13]

2.2 brief reviews of the availability of mobile/cloud computing

As mention before, for measuring availability both node and data availability are necessary to concern. Data availability is provided by having redundant instances which store in various machines that happen through replication. Choosing a proper replication method that concern to how many replicas is expected to exist and which part of the data should select as a replica, could affect directly both security and performance which are two concepts that can valuable availability measurement [16], [17] and [18]. In replication model balancing between cloud resource consumption and availability is a concern that could impact on response time that is a main focuses of this paper. On the other hand, node availability and the place of the node in the right place that near to the user influence on the response time that is unpredictable in mobile cloud computing due to its dynamic nature. Node availability computes by fraction of time that the node is under operation. Table 2 shows the studied on mobile cloud computing.

Table 2. Reviews of availability of mobile / cloud computing

Author	Concluding remarks	Reference
Deshmukh et al.	They proposed a model in which servers are divided into master and slave servers. The servers which are in the master level are used for uploading a file and modifying it by users, while the slave ones store chunks of data and won't use by user directly.	[19]
Mar	It discussed about the Secured Virtual Diffused File System (SVDFS) which provide data security, integrity and availability suited for deployment in a public cloud environment through using a file system interface and registry server. For measuring the node availability some basic terms are introduced which are Mean Time of Failure (MTTF), Time to Recover (TTR) and Mean Time between the Failure (MTBF).	[21]
Daniel	The availability of Internet data centers (IDC) is investigated and made it bearable by comparison with performance. IDC has M equivalent machines that respond to user requests and applications which are running in IDC are expected available 99.999 % of the time.	[18]

3. Proposed model of mobile global healthcare village

A high health tire model termed mobile global health village (MGHV) model presents in this section. The MGHV model relates to cloud, unlike other medical information gathering using wireless sensor network (WSN) of a lower health tire.

In MGHV model, all hospitals, clinics and health service providers have their own health data that deploy them on their private health cloud to share information between different departments. Also, if they have any other branches they can share the resources on the cloud between all of them. This information deploy on the private health cloud based on the internal policy of hospitals. Further, this cloud can store the the information about the staffs and available facilities in the hospital. The database which uses by each health provider supposed to be integrated with databases which are in the public health cloud (PHC), otherwise there is no insurance that different organization can use the data of others. Therefore the original health data store in the private health cloud. For supporting data redundancy, if the health provider uses the private clouds it would not cost effective for them. Therefore, public health cloud is introduced. The PHC is divided into country-PHC and continental-PHC while hybrid health cloud (HHC) is considered for the whole world. The country-PHC cloud should record the information of patients, hospitals, clinics and organizations which are working in healthcare field at the country level. This division for PHC is done because different countries have different rules and decision about the health issues that keep some of the information confidential for themselves. Hence, even if the country's governor does not allow deploying all the health information in the continent-PHC at least these information will be stored in the country cloud to share to the internal health service provider. Besides, this information would be separated based on the redundancy algorithms and distributed to the different file server in the encrypted format.

The continental-PHC, is responsible to support all countries-PHC clouds which are located in the same continent. Therefore, MGHV have six continental-PHC clouds that should connect to country-PHC and cooperate with each other to support Global Healthcare Village Cloud (GHVC). Finally, the GHVC proposes for providing global healthcare services regardless the time and location. GHVS as a hybrid health cloud comprises all public health clouds. In fact, in the proposed MGHV a mobile user sends a request to its country-PHC through smart device. The country-PHC is capable of providing health service in all locations in the country based on the information which is replicated from all private clouds. If this user would cross the border into the neighboring countries, there is no concern about the emergency health case in these countries with connecting to continental-PHC. Also, MGHV can guarantee the safe intercontinental journey by implementing GHVC and connecting to the global data center. Therefore, the MGHV model is time and cost effective for both patients and health providers because some of the initial tests will be eliminated and they can use the results that inserted in cloud before. Also, both of them use the health service based on their demand and pay per each service that they use. The major challenge in MGHV is that it should cover a vast healthcare system in the world. The concept of the coverage here is that MGHV should be compatible, integrated and accessible with various health systems. As mentioned before we consider six public health clouds that each of them belongs to each continent and they include two data centers. One of these data centers should offer services to the local users who live on that continent. The other one, as a global datacenter should support outsiders (people out of that continent), and it could be a proper disaster backup for the local one. Therefore, MGHV has 12 data centers which include six global and six local data centers. In addition, the number of VMs has also impacted on the service response time. In MGHV, some VMs provide storage services which are the hosted database services for storing information about the hospital, medical services and patients. Some other VMs consider application servers which supports, different applications that are used by users based on their various mobile devices. In the experimental section using the simulation approach, we compare the result of response time with various numbers of VMs. Despite the benefit of MGHV, such the provision of the global health system that can cover rural area's issues of health and reducing time and cost in the patient's treatment process, this model face some problems which make its implementation more challenging due to limitations of the current MCC model.

As a first issue, we noted that different countries have different policy and rules in the health area and it will be hard to convince them to use MGHV system. This problem could be solved by providing secured MGHV based on partitioning and encryption algorithms that should investigate in security concept which is out of scope of this research. The other issue is about selecting a proper place for locating data centers in each continent. This type of issue appears because of mobility of users. Also, locations of data centers in lower level (country-level), has an impact on the performance. For country level could choose countries which have more population or more tourists if they have similar policies.

3.1. MGHV's service broker policy

When a mobile user sends a request for utilizing cloud services, one module should be available to navigate this request to the appropriate data center. This module is known as a service broker which are shown in Figure. 1.

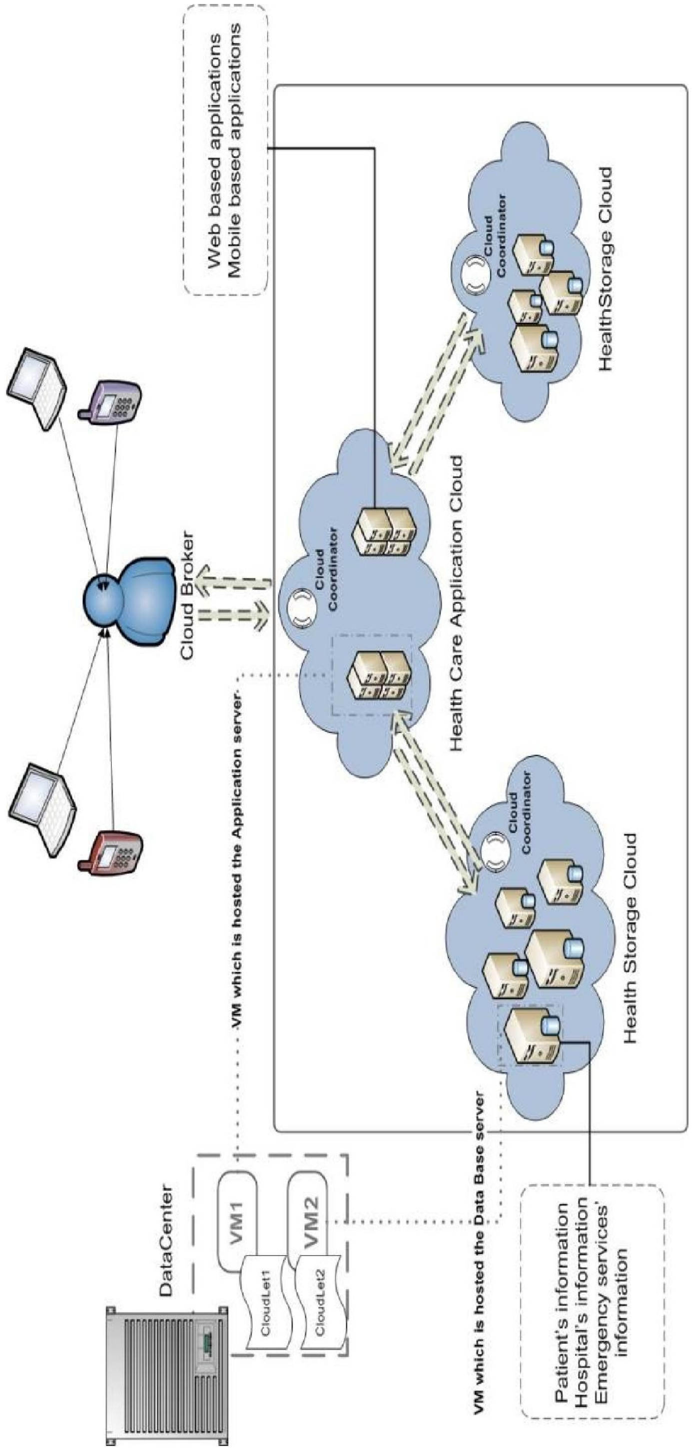

Figure. 1: Logical architecture of MGHV model

This module use service broker policy to indicate which data center is more suitable for responding to the user request. In fact, the service broker receives cloudlet which is generated via user request and check the tag for it (request tag), and then based on its policy, return a datacenter name which is responsible for providing services for the user.

There are three service broker policies in the cloud including the closest datacenter, optimize response time and dynamic datacenter allocation. In the first one, the user's request transfer to the closest data center based on the user and the data center region, and if more than one data center exists in the region, this policy chooses one of them randomly. Second one allocates datacenter to the user base on the performance of data center and chooses the data center which has a minimum average response time. The third one expands the closest datacenter policy but it cares more about load balancing when more than one data center exists. The impact of existing service broker policies in our model, is represented in Section 4.

The existence service broker policy has a list for storing data centers. But we consider three lists out of them for storing data centers of which one of them store country level datacenter, the second list stores continental data centers, while the final list is responsible for maintaining the global data centers. Also, the existence UserBase configuration in cloud Analyst simulation only store user region while our proposed policy change this configuration and remain both country-cloud number and continent-cloud number beside current-region. The country - cloud number shows the number that indicates the data center which is used by user in country-level access and the continent-level indicates the original continent that the user belongs to. Therefore, when a cloudlet is generated, the current region of the user should check with the country-level of user. If they are same, that means a user is in his/her country and his/her request should be transferred to the country health database, otherwise the current region should compare with the continent-level so as to determine user across the continental border or not. If a user is not on his original continent, the broker policy should select the appropriate global data center. In fact, this service broker works based on the closest datacenter but it's compatible with mobile users and mobile cloud computing. The flowchart in Figure 2 shows the steps of the proposed service policy.

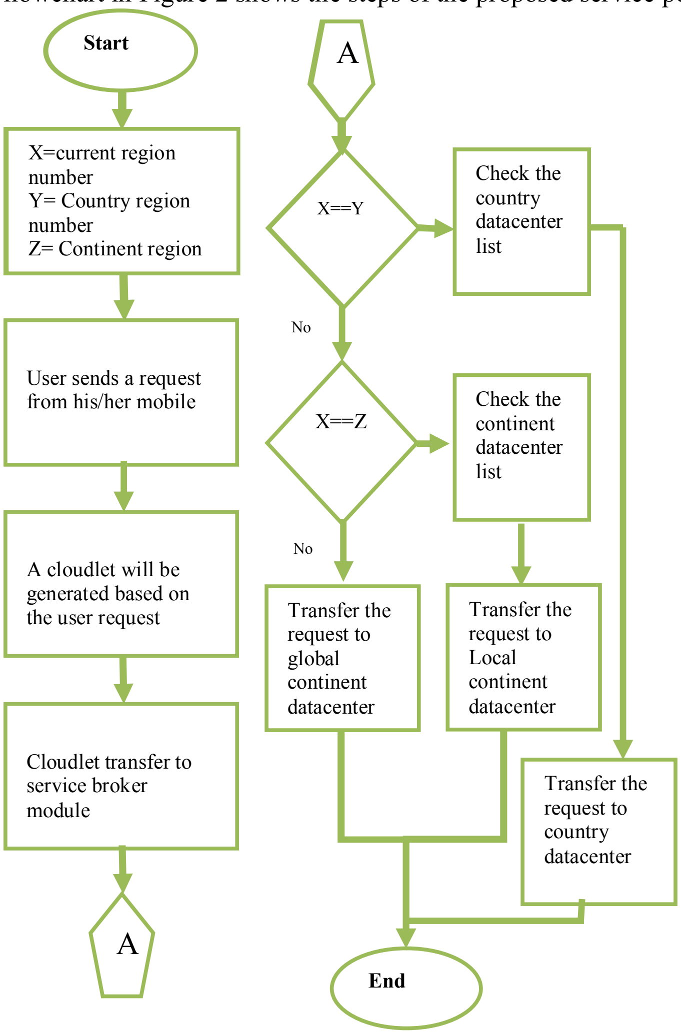

Figure. 2: flow diagram of the proposed service broker policy

Algorithm 1: pseudo code of proposed MGHV service broker policy.

```
//For Continent level
//Initialization

Mobile-users = number of mobile users;
Location =array (   // it contains continents);
// keep the original continent of user
User-Original-Region=array ();
//keep the current continent of user
User-Current-Region=array ();
Move=array (); //keep track of user movement
//mobile users who are using MGHV are distributed in the world.
 The original region is allocated to them randomly.
 for (i=0; i< Mobile-user; i++){
// original region keep a continent name randomly
Original-Region = location [array-rand(location)];
Push Original-Region to the User-Original-Region array;
}
Users change their location;
for (i=0; i< Mobile-user; i++){
// original region keep a continent name randomly
Current-Region = location [array-rand(location)];
Push Current-Region to the User-Original-Region array;
}
//Service Broker Module
Reset the pointer of User-Current-Region;
Reset the User-Original-Region;
for (i=0; i< Mobile-user; i++){
   If (user-Current-region[i] == user-Original-region[i]){
         User did not cross the border of continent;
      Push False to the Move array;
}
  Else {
     User did cross the border of continent;
     Push True to the Move array;
} }
Service broker receives users' cloudlet;
Check the Move ();
If
"the Move content is True for the specific user the request will be send to the Global
DataCenter";
Else
"the request will be send to the Local DataCenter";
```

Figure. 3: pseudo code of proposed MGHV service broker policy

Following pseudo code (Figure. 3) presents the MGHV service broker policy in the continent level. In the initialization step the number of mobile users is determined. Also, there are two arrays. We define another array which is known as move array for tracking user's movement.

After initialization, mobile users are distributed in the world through using loops and random selection from location array which includes six continents. These random continents will be stored in the original region array for each user. Second loop does the same thing to store the current location of the users in the current region array. In the service broker modules we use move array to keep the movement status of each user. In this part user original continent will be compared with the current region. If they are same that means the user is still in his/her continent and therefore, a false value is pushed into the move array.

False value means user did not cross the border while true value indicates that the user is in the new continent. Therefore, after receiving user's cloudlet, service broker module decides only based on the content of the move array. If the value in the move array for user who generates the request is false, his/her request transfers to the local data center otherwise, it is transferred to the global data center.

4. Experimental and simulation results

Name	Region	Arch	OS	VMM	Cost per VM	Memory cost $/s	Storage cost $/s	Data Transfer cose $/Gb	Physical hard-ware units
DC1 DC2	0	X86	Linux	Xen	0.1	0.05	0.1	0.1	20
DC3 DC4	1	X86	Linux	Xen	0.1	0.05	0.1	0.1	20
DC5 DC6	2	X86	Linux	Xen	0.1	0.05	0.1	0.1	20
DC7 DC8	3	X86	Linux	Xen	0.1	0.05	0.1	0.1	20
DC9 DC10	4	X86	Linux	Xen	0.1	0.05	0.1	0.1	20
DC11 DC12	5	X86	Linux	Xen	0.1	0.05	0.1	0.1	20

In this section the MGHV model is simulated with CloudAnalyst simulator which is built in CloudSim and extends the model of Internet application behavior. The CloudAnalyst provides a graphical interface that helps to configure different entities easily. Simulating the MGHV model in the

CloudAnalyst consists three main steps. First of all, it needs to define the data centers and their location. The CloudAnalyst has six regions that are numbered from 0 to 5 and they indicate six continents which are North America, South America, Europe, Asia, Africa, Oceania. The following table (Table 3) shows the configuration of data centers for MGHV. All of the Datacenters use 64 bits Linux as their operating system. The virtual machine monitor is Xen and we consider 1 Tbps bandwidth. Also, we consider 20 quad core servers for each data center, and each core consists 8 VMs, and therefore, each data center host 640 VMs. Hereinafter, we investigate the average response time of the MGHV model based on the CloudAnalyst simulation results in which the number of VMs and the service broker policy were varied.

Table 4;Physical hardware details of DC

ID	Memory	Storage	Available BW	Number of processor	Processor speed	VM policy
1	204800	100000000	1000000	4	1000	Time-Shared

The details of one physical hardware presents in Table 4 and each DC has 20 physical hardwares. The second step belongs to application deployment configuration in which service broker policy, number of VMs, memory, Image size and bandwidth will be initialized. Finally, Userbase is expected to configure that presents the number of concurrent users who get access to the data centers in both peak and off-peak hours.
Also, data size that can transfer in the network per each request and number of request per each user will be determined at this level.

Figure 4 shows a comparison of the average response time for 12 data centers for closest datacenter and optimize response time policies through the variation of the number of VMs. As mentioned earlier, if servers utilize their capacity completely, then they will have 32 VMs, and therefore, the total number of VMs in each datacenter would be 640.

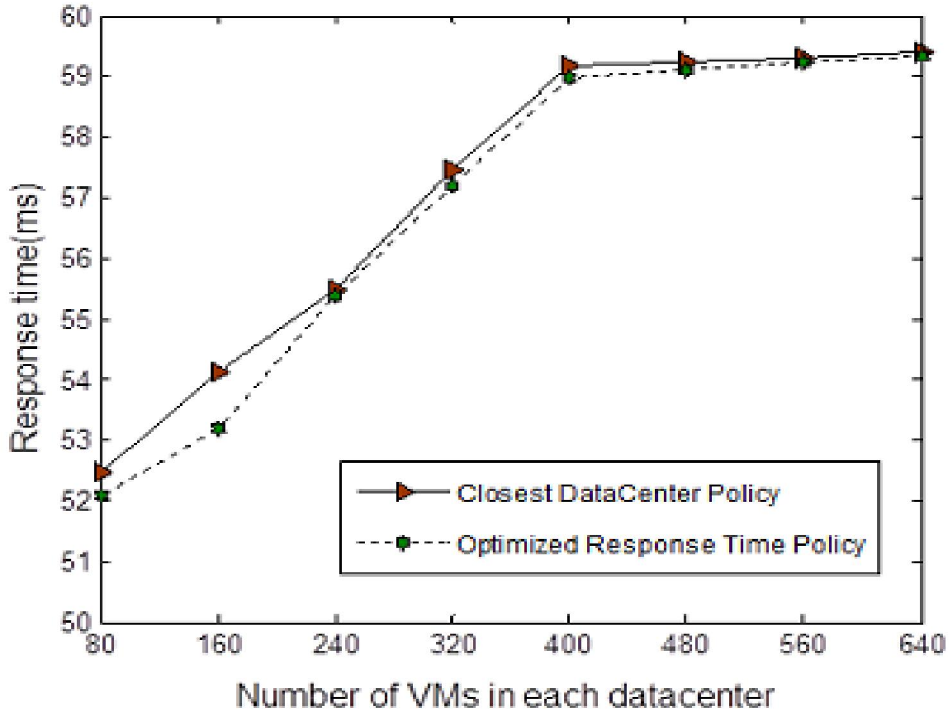

Fig0ure. 4: Average response time for MGHV model during 60 minutes via using closest datacenter policy and Optimize response time policy

In that case, the average response time for the closest datacenter and optimize response time policy is 59.39 and 59.33 milliseconds respectively. Optimize policy response to the user's request faster than closest policy due to its consideration on the performance of data centers. Figure 5 above shows both policies when the amount of VMs increase, and the response time for user request also have an upward trend. In fact, the response time change between 52.48ms and 59.33ms by using closest datacenter policy while it is between 51.7ms and 59.33ms in the other policy.

Figure 5 reveals the average response time for optimum response time policy and dynamic with load balancing policy. It is clear that in this case also, the average response time increase with a growing number of VMs, but still the optimal response time policy need less amount of time for answering user's requests. The average response time based on the number of simultaneous users on a single user base is illustrated in Figure 5. It can be clearly seen that the average response time varies from 50ms to 150ms while the number of users increase from 10 to 100,000. It can be also observed that the average response time for 400VMs and 640VMs, is almost same. The average response time increase drastically from 60ms to 150ms for 10 to 1000 users. It is clearly shown also that for more than 1000 users, it is approximately constant and about 60ms and 150ms for 80VMs and 400, 640VMs, respectively.

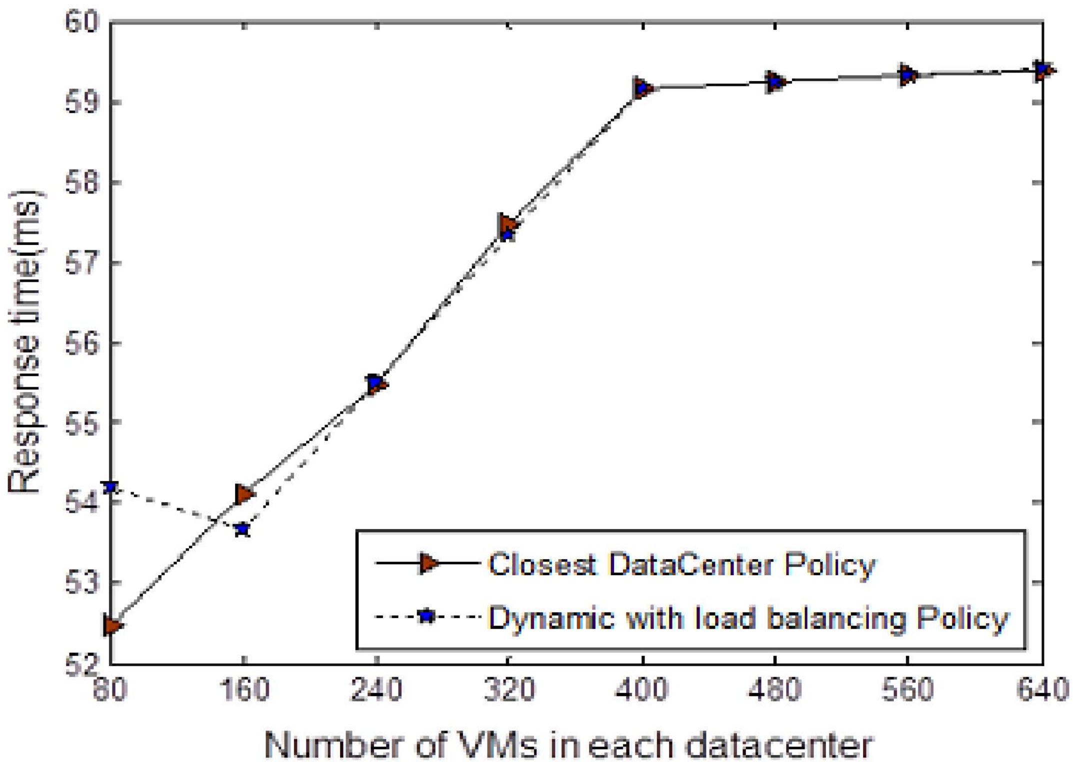

Figure. 05: Average response time for MGHV model during 60 mins via using closest datacenter policy and dynamic policy

5. Conclusion

This paper introduces a mobile global health village (MGHV) which is a new model for globalizing the health care system based on the mobile cloud computing (MCC). For having minimum response time and better accessibility, we consider three Sub-levels health cloud and propose mobile based service broker policy. The results of simulations show that for MGHV model, optimize response time service broker has the lowest response time with a value of 50.33 ms for 640 VMs in comparison with the closest datacenter and dynamic policy. Also, we choose a push-pull merges replication for updating databases. More research is needed for bridging the gap in the mobile cloud computing such as mobile database server and service broker policy which are compatible with MCC. Service broker policy in the mobile cloud computing should consider the load balancing and also it should be able to select the correct datacenter in a hybrid cloud for responding to the mobile user's request.

Corresponding Author:
Laleh Boroumand Jazi
Department of Computer Science
University of Malaya, Malaysia
E-mail: Laleh.b127@gmail.com

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