Enhancing Cloud Computing Environment: Improving Cloud Computing Applications Performance Using Cloudlet-Based Architecture

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Abstract
With the popularity of smart phones and their increasing capabilities, made them very important in the human’s life. However, these mobile devices face some challenges such as battery life, memory, weight and heat dissipation, which cloud limit the computational resources of these devices. Services of cloud computing would offer great solutions to overcome these drawbacks but also, cloud computing services may suffer from long-latency and expensive roaming charges of cellular radio access. Cloudlets would provide some benefits over distance cloud such as faster data transfer, faster processing of application as well as reducing the use of mobile resources. This paper deals with the basic concepts of cloud computing and cloudlets in the IT sector. The impact of the cloudlets on the performance of the cloud computing has been focused in this paper. Moreover, the use of the cloudlets for enhancing the performance and supporting cloud computing environment has been reflected. In another word, this paper describes a cloudlet-based architecture for supporting cloud computing environments. The goal of cloudlets is to reduce network latency and network stress by deploying mobile applications at the network edge; therefore increase the performance of cloud-based applications. We propose cloudlet-based architecture that supports the environments of these applications. This proposed architecture can be used to increase the effectiveness of performance in cloud computing environments. Experimental results are provided, along with an illustrative analysis of text data exchange in the experiment. Results show that the proposed approach is efficient and effectively increase the effectiveness of performance of applications in cloud computing environments.

1. Introduction
The Cloud Computing is a technology by which users can access their data and application from anywhere over the Internet. It integrates different technologies for building a new type of Information Technology (IT) infrastructure. The modern era of the computing has experienced drastic changes in the technological point of view. The Mobile Computing is a technology by which users can send and receive data to wireless devices without the need for physical connections. It uses small size portable computer to run standalone applications through wireless networks or Third-Generation of mobile networks (3G), Fourth-Generation of mobile networks (4G) technology [1].
This paper deals with various aspects of cloud computing and the use of the cloudlets in cloud computing. The advantages of the cloudlets have been mentioned in this paper. In addition, this paper outlines the effect of cloudlets on the cloud computing environment and the benefits of the cloudlets by increasing the performance and security.

### 1.1. Cloud Computing

As commented by Jin [2], Cloud Computing refers with configuring and accessing the data and application online. Cloud Computing is a fundamental principle of reusability of the IT capabilities in the market [3]. This helps in storing data and information over the internet. Cloud Computing has helped in connecting millions of devices with each other in the world. The data and files can be accessed from anywhere in the place with the help of Internet [4]. Those help in providing flexibility to the user’s experience using cloud-computing services [5].

As commented by Fernando [6], the cloud computing has provided many opportunities to the technology in the market. Business organizations are implementing cloud computing in their operation management to analyze the behavior of the operations [7]. Cloud computing has enhanced the efficiency of the servers but not keeping them in the idle state.

### 1.2. Cloudlet

Cloudlets are the mobile enhanced small-scale devices that help in supporting the cloud computing in the market [8]. The main purpose of the cloudlets is to support resources and mobile applications provided to the users in the market [9]. The smart phones and tablets have gained its importance in the modern world. These devices are acting as cloudlets for the users. As mentioned by Carvalho [10], the cloud computing services can be accessed from these smart phones with the help of internet. The power of the Central Processing Unit (CPU) and Random-Access Memory (RAM) are the important factor in supporting cloud-computing services in these cloudlets [11]. Therefore, a cloudlet is a small data center for the users to access their data and information stored in the cloud using the internet.

The goal of the cloudlet is to enhance the response time of the applications running on the mobile devices using the internet [12]. This also helps in increasing the latency of the mobile applications used for the cloud computing services [13]. The cloudlets act as a Virtual Machine (VM) in the mobile device that helps in supporting the cloud services online. The cloud computing has able to provide an efficient and low spectral efficiency to the users in the market [14]. The transformation of the fog computing to mobile edge computing has enhanced the technology of the cloudlets on the market [15]. The cloudlets have helped in advancing the cloud servers in anywhere in the world. These have helped cloud users to access cloud services anywhere and anytime. A cloudlet has helped in controlling, updating, and storing data in the cloud servers.

### 1.3. Advantages of Cloudlet

There are various advantages of the cloudlet discussed as the following:

#### 1.3.1. Accessibility

The cloudlets help in accessing the cloud computing services in the mobile devices. This has helped in the frequent use of the cloud services by the users. The latency of using cloud services has increased in these days [16]. These have also increased the cloud users all over the world by providing cloud services. The cloudlets have reached to every mobile phone of the users enabling the use of the cloud services in the world. Therefore, the accessibility of the cloud services has smoothened in the market [17].

#### 1.3.2. Security

Cloudlet has increased the security of the data and information stored in the cloud. The mobile device is a secured cloudlet that helps in securing the data and information on the internet [18]. There are various security systems installed in the mobile devices that help in maintaining the security. The cloudlet helps in enhancing the speed of the internet access by the users [19]. The security system of the cloudlet devices is upgraded to modern technology that helps in preventing the cyber attacks over the internet.

#### 1.3.3. Environment

The cloudlet has helped in improving the cloud services in different fields. The Cloud foraging includes the dynamically augmenting of the computing resources in the mobile devices to fix the cloud proximity [20]. The Cloud foraging helps the cloud users to offload expensive processing applications including voice recognition and language translation. The cloudlet has channelized the cloud environment in many applications including the virtual machines in the mobile device. The On-Demand virtual machine is a provisioning tool to assemble the service of the VM during runtime [21]. The cloudlet has provided the benefit of the on-demand service of the cloud to the users by initiating the virtual machine concept in the mobile devices. The users can easily involve in the cloud environment to access their data and files.

### 2. Related Work

Li and Wang [22] introduced the concept of cloudlet properties such as size, lifetime and reachable time and explored the domain of mobile cloudlet in mobile cloud computing through studying cloudlet properties and computing performance. They showed that the number of nodes in the network and how frequently they meet determine the number of resource-rich devices an initiator can connect to for computing service. Moreover, when the task is delay-tolerant, the intermittent connection has little negative effect on optimal performance of a mobile cloudlet.
They also derived upper and lower bounds on the computing capacity and long-term computing speed of a mobile cloudlet. An initiator can use these bounds to decide whether to upload a task to remote clouds or utilize nearby mobile cloudlet. In future, they want to design and implement mobile applications on a mobile cloudlet system to investigate the feasibility and performance of mobile cloudlet computing.

Jindal and Dave [23] proposed a data security protocol for cloudlet-base architecture. They integrated cloudlet with the base station, using the property of perfect forward secrecy. Their protocol did not only protect data from any unauthorized user, but also prevent exposure of data to the cloud owner. The proposed data security protocol comprises of the following components: cloud, cloudlet, data owner who is the mobile device user that uploads the encrypted file on the cloud and finally data sharer who is the mobile device user that wants to access the uploaded data on the cloud by the data owner. Their system model had cloudlets acting as intermediary between the mobile devices and the cloud and each cloudlet serving approximately 100 mobile devices. They had the following assumptions: 1) Cloudlets are trusted. 2) Each cloudlet maintains the cache of frequently accessed files. 3) Data owner maintains authorized sharers list. 4) Cloud servers are assumed to have abundant storage capacity and computation power and are assumed to be always online. 5) Each file has unique ID. 6) A new session key is generated for each file to be uploaded. Their solution, offloaded all the computation intensive tasks on the cloudlet and allowed lightweight wireless devices to securely store and retrieve their data in cloud. Security analysis showed that the proposed protocol safeguards the data stored on the cloud from illegal access.

3. Use Case Specifications: Query About Text Contents

3.1. Brief Description

This use case allows clients to inquire about the text files contents in the available cloud servers. The clients can inquire about words and their occurrences in very long text files. The designed system provides a list of all words and their occurrences that being asked by the clients and compare the elapse times needed for providing answers for all clients’ questions. The purpose of the system is to compare the performance of processes with and without cloudlet while using cloud-based applications in cloud computing environment.

3.2. Actors

Primary Actors- Clients and system administrator.
Flow events:

3.3. First Flow

The following flow presents the communication process between clients and the remote cloud server:
1. First flow starts when the remote cloud server starts at specific machine and specific port and reads a text file and stores each pair (word, occurrences) in hash table by the system administrator.
2. The remote cloud server will receive words requests from clients and reply to the clients with the requested word.
3. The system will display how long the process take to answer all clients’ requests.

3.4. Second Flow

The following flow presents the communication process between clients, a cloudlet, and the remote cloud server:
1. Second flow starts once the remote cloud server starts at specific machine and specific port and reads a text file and stores each pair (word, occurrences) in hash table by the system administrator.
2. The cloudlet server between the remote cloud server and the clients starts at specific machine and specific port by the system administrator. The cloudlet server does not store hash table; it stores the cache only, which is some temporary data that are asked most frequently by clients during their processes.
3. The cloudlet will receive words requests from clients and reply to them with the requested word.
4. If cloudlet does not have the requested words in the cache, it will send to ask the remote cloud server.
5. The remote cloud server replies with the requested words to the cloudlet then to the clients.
6. The system will display how long the process take to answer all clients’ requests.

4. Design

The purpose of this work is to facilitate the process of communications between Clients and Remote Cloud Servers through Cloudlets. The general experiment architecture is shown in figure 1. The cloudlet acts as intermediary between remote cloud servers and clients as illustrated in figure 2.
5. Implementation Details

In order to simulate a real cloud environment and to obtain accurate results, 5 virtual machines were deployed (1 cloud VM server, 1 VM cloudlet and 3 VM clients) over a public network between the USA, the UK and Germany. The remote cloud VM server was installed in N. California in the USA with ip address (54.219.181.202). It had the following characteristics (2.40 GHz Intel (R) Xeon (R) CPU E5-2676 v3, 1 GB RAM and 30 GB disk) and ran Windows Server 2008 and VMware Workstation 9.0. The VM cloudlet was installed in London in the UK with ip address (35.176.133.117). It had the following characteristics (2.40 GHz Intel (R) Xeon (R) CPU E5-2676 v3, 1 GB RAM and 30 GB disk) and ran Windows Server 2008 and VMware Workstation 9.0. The 3 VM clients were installed in Frankfurt in Germany with the following ip addresses: the first client with ip address (54.93.213.110), the second client with ip address (52.59.207.98), and the third client with ip address (52.59.227.48). The three clients had the characteristics of (2.40 GHz Intel (R) Xeon (R) CPU E5-2676 v3, 1 GB RAM and 30 GB disk) and run VMware Workstation 9.0.

Two scenarios of data exchange were compare between clients and their application, the first scenarios is direct connections among clients and their application, and the second is connections between clients and their application through a cloudlet. Thus, the primary objective of this work is to measure the data latency and the efficiency of the performance in two different scenarios in cloud computing environment. The internal structure is like the following: the data will reside in the remote cloud server and will be requested by cloudlet based on clients requests. The clients and servers were implemented using JAVA.

<table>
<thead>
<tr>
<th>PCs No.</th>
<th>CPU</th>
<th>Speed</th>
<th>RAM</th>
<th>disk</th>
</tr>
</thead>
<tbody>
<tr>
<td>PC1</td>
<td>Intel (R) Xeon (R) CPU E5-2676 v3</td>
<td>2.40 GHz</td>
<td>1 GB</td>
<td>30 GB</td>
</tr>
<tr>
<td>PC2</td>
<td>Intel (R) Xeon (R) CPU E5-2676 v3</td>
<td>2.40 GHz</td>
<td>1 GB</td>
<td>30 GB</td>
</tr>
<tr>
<td>PC3</td>
<td>Intel (R) Xeon (R) CPU E5-2676 v3</td>
<td>2.40 GHz</td>
<td>1 GB</td>
<td>30 GB</td>
</tr>
<tr>
<td>PC4</td>
<td>Intel (R) Xeon (R) CPU E5-2676 v3</td>
<td>2.40 GHz</td>
<td>1 GB</td>
<td>30 GB</td>
</tr>
<tr>
<td>PC5</td>
<td>Intel (R) Xeon (R) CPU E5-2676 v3</td>
<td>2.40 GHz</td>
<td>1 GB</td>
<td>30 GB</td>
</tr>
</tbody>
</table>
6. Evaluation

The results were collected from 5 virtual machines, 1 as a remote cloud server, 1 as cloudlet and 3 as clients. Measurements of 3 clients in two scenarios were taken. It can be concluded with that the 3 clients get the requested data in the second scenario -where clients ask cloudlet- more faster than getting it in the first scenario.

<table>
<thead>
<tr>
<th>Items</th>
<th>Time needed to get data with direct connection between clients and remote cloud without cloudlet in between</th>
<th>Time needed to get data with clients connecting remote cloud through cloudlet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Client 1 (ip: 54.93.213.110)</td>
<td>1 362 777 milliseconds</td>
<td>1 031 556 milliseconds - 20%</td>
</tr>
<tr>
<td>Client 2 (ip: 52.59.207.98)</td>
<td>1 305 123 milliseconds</td>
<td>1 008 946 milliseconds - 23%</td>
</tr>
<tr>
<td>Client 3 (ip: 52.59.227.48)</td>
<td>1 290 222 milliseconds</td>
<td>967 666 milliseconds - 25%</td>
</tr>
</tbody>
</table>

From the experiment above, improvements in the performance can be observed when the cloudlet architecture is used. The results show that the improvements in the performance would be in the range between (20% - 25%) while using text files data exchange.

7. Conclusions

It can be concluded that the cloud computing has enchanted the growth of the IT sector in the market. The cloud computing has enhanced the flexibility in accessing the data and information of the clients over the internet. Moreover, the cloudlets used in the cloud services have increased the efficiency of the cloud services. The cloudlets are the small data center used by the clients at their home or work place. The cloudlet has influenced the cloud services in many ways including enriching performance of the cloud servers and supporting cloud environment on the mobile devices. The virtual machine technology in the mobile devices has strengthened the cloudlets.

References


