Cloudlet-based Mobile Cloud Computing for Healthcare Applications

Lo’ai A. Tawalbeh1,2, Waseem Bakheder1
Dept. of Computer Engineering, 3High Performance Computing Centre
1Umm Al-Qura University, Makkah, Saudi Arabia, 4Dept. of Elect. & Computer Eng
2Jordan University of Science & Technology, Jeddah, Saudi Arabia
Irbid, Jordan

Email: latawalbeh@uqu.edu.sa
Email: r.mehmood@gmail.com
Email: h.song@ieee.org
Email: Eng.waseem.b@hotmail.com
Email: tawalbeh@just.edu.jo

Abstract—The smart phones are used in many aspects of our life, shopping on the Internet, and creating and distributing many types of files. But these devices have many limitations including: short battery life time and limited storage and processing. Mobile Cloud Computing technology can help to overcome these limitations. Offloading technique reduces the power consumption and saves the mobile storage by executing the huge tasks at the cloud. The mobile devices are connecting to cloud service providers using 3G or LTE technologies, which introduces some challenges including, limited bandwidth, cost, and latency. In this paper, we propose efficient and secure mobile cloud computing model based on the Cloudlet concept were the mobile devices users can connect directly to cloud resources using cheaper technologies such as Wi-Fi. Once needed, and only if the service is not available in the cloudlet, the user will be connected to the enterprise cloud. The proposed cloudlet-based model can be used in many applications where security and efficiency is required. It can be used for health applications to save and analyze patients medical records. The simulation results of our model show that it is more efficient and reliable than the other mobile could computing models that don’t use the cloudlet.

Keywords—Cloud Computing, Healthcare Applications, Mobile Devices, Cloudlet scheme

I. INTRODUCTION

Mobile devices are used in our daily life to make calls and communicate with others. These mobile devices and specifically the smart phones became a powerful trend in IT industry and e-commerce. However, mobile devices encounter many challenges in their resources, mobility [1], and security [2][3]. These challenges present the issue of executing many powerful programs that could help users in creating a pervasive environment.

Classical Computing focused on computes and performing computation jobs. Nowadays, more recent concepts are related to computing include cloud, networking and communication, IoT, and Big data, all driven by the users’ needs and the required infrastructure to achieve the increasing demand on connectivity and mobility [4]. There are many recent technologies that changed the word. Among these useful technologies is the mobile computing [5] which has many features including portability which allows small devices to work properly while moving from one location to another. The connectivity is among the main features of mobile devices that allows mainly Internet connection which can achieved by different technologies (Wi-Fi, and 4G).

The integration of cloud computing with mobile devices to overcome these devices limitations resulted in new computing trend called Mobile Cloud Computing (MCC) [6]. To propose an efficient MCC model, we should consider some of the challenges facing the real implementation of MCC environment including: the portable devices are restricted by their short battery lifetime, storage and computational power preventing them from performing computation-intensive applications such as image processing and social networking. Another challenge is that portable devices are operated on different wireless networks with different bandwidths and connectivity quality that is affected by the mobility [7]. Mobile Cloud Computing can help solving the limitations of the mobile devices by offloading the tasks that need huge processing to the cloud server resulting in less power consumption [8].

Mobile Cloud Computing is being considered among the biggest trends in next years. In MCC, mobile devices are connecting to cloud service providers using 3G, 4G or LTE technologies. Using such technologies introduces some challenges such as the high cost, limited bandwidth, and connectivity issues as shown in Figure 1. Moreover, protecting the data from attacks over the non-secure wired and wireless channels [9] is a big concern in cloud and mobile cloud computing. Also, the users want to be sure that their data is safe and will be modified by unauthorized entity [10]. There are many symmetric and asymmetric encryption techniques to provide privacy and integrity [11] [12].

Figure 1 Mobile Cloud Computing (MCC).
In this paper, we introduce efficient and secure Mobile Cloud Computing (MCC) model that is based on the Cloudlet concept. In the new model, the mobile devices don’t need to contact the cloud server and instead contact the Cloudlet. This will allow users to connect directly to cloud resources using cheaper technologies such as Wi-Fi.

II. RELATED WORK

There are many efforts done by researchers worldwide on mobile cloud computing. Nowadays, users require many application on their mobile devices, such applications requires data transfer and exchange along with heavy processing. In [13], the author describes how has the Mobile Cloud computing developed from both Cloud computing and mobile computing. He also describes its scope, developments, and current research area challenges. This paper proposed MobiCloud system which was developed at Arizona State University to simplify studying and analyzing MCCs.

On the other hand, rise of networked sensors inspired the researchers to use them to collect different type of data in different useful aspects of life including health, military, crowd management, and in smart cities applications[14]. The big amount of collected data need to be stored effectively, so it will be transferred to the cloud servers for storage and further processing [15].

In [16], the authors analyze the critical factors that affect the power consumption of mobile clients when using CC, and provide an example on how to save mobile client power. To strike a balance between using local mobile computing and remote cloud computing, they presented their own measurements of the main characteristics of modern mobile devices.

The key performance metrics of using VM to manage jobs execution inside the cloudlets was discussed in [17]. These metrics includes: the overhead of the VM life cycle when deploying it for execution on the cloudlet, the cloudlet allocation to VM and the scheduling of VM. The authors had used the CloudSim [18] as a platform environment and they had concluded that it is so important to efficiently deploy and manage VMs on CC to reduce the amount of execution time because of the previous performance metrics. The proposed architecture in this paper was a fine grained cloudlet to manage the running applications on the component model, where the cloudlet can be chosen dynamically from any resource rich device inside the LAN and not as traditional concept where the cloudlet is fixed near a wireless access points.

The work in [19] proposed mobile cloud computing model. What makes this model different, is the scalability feature. It can be expanded to have the intended number of cloudlets in the covered area. The real implementation results of this model showed a great efficiency and reasonable power consumption. It is known that the mobile devices are power hungry specially when using them to run excessive applications. Motivated by this fact that optimizing power is very important in mobile cloud system, the researchers in [20] proposed a mathematical model to optimize power consumption in large scale cloudlets MCC.

Another study to find a model that characterize the power consumption in smart phones was conducted in [21]. The authors measured how much each component of the smart phone participates to the total power consumed.

In [22], the authors addressed different issues related to ad-hoc cloud that can be constructed from local devices working together and share resources. They suggested to optimize some of related performance parameters including cost and energy. They used an end-to-end system whereby user applications may be profiled for their resource consumption if augmentation is required, they may negotiate with a local mobile ad-hoc cloud for optimum energy and resource utilization. The approach used for resource negotiation is Genetic Algorithm in order to further enable energy-optimized resource augmentation for mobile ad-hoc clouds.

III. MOBILE CLOUD COMPUTING CLOUDLET MODEL

There are many proposed models for mobile cloud computing. In the basic architecture there is a direct connection between the devices in the network and the mobile devices using different wireless communication technologies including 4G and WiFi as can be seen from Figure 2. The mobile network forwards the users’ service request to the cloud server after validating that he/she is a legitimate user. The cloud provider processes the request and provides the required service.

![Figure 2. Basic Mobile Cloud Computing Model](image)

On the other hand, there are some challenges in mobile cloud computing that are discussed previously and which can be improved through the use of mobile cloud computing model based on Cloudlet scheme. The cloudlet is a computer that is equipped with reasonable specifications and can be accessed by mobile devices within the coverage range. The cloudlets offers the cloud services remotely to the close users with less time and higher throughput [19].

The traditional way in MCC, the mobile devices mostly used the 3G/4G/LTE technology to connect to the cloud and transmit the data. Our proposed cloudlet MCC model is shown in Figure 3. As it can be seen from the figure, the mobile user...
connects to the cloudlets (send task to for processing) which in turn communicates with the master cloudlet when needed all through Wi-Fi technology. The final result will be sent back to the mobile device through Wi-Fi as well which results in reducing the transmission delay, and the power consumption of the mobile device.

The proposed model consists from distributed cloudlets connected to each other through Wi-Fi and to a master Cloudlet as well which is responsible for management and is connected to the main cloud server. If the mobile user is moving away and is not covered by the cloudlet range, then, the mobile user has to connect directly to the enterprise cloud to perform a job using wireless communication technology. But, if the mobile user is still in the /cloudlet or master-cloudlet range, then it can connect directly to those cloudlets using WiFi to carry out the required jobs. The last case happens.

IV. SIMULATION RESULTS

For testing purposes and in order to create an environment that is similar to the real situation, we use the simulation tools to predict the system’s behavior before coming out to real environment. Our proposed model is simulated using the Mobile Cloud Simulator (MCCSIM) tool. This tool offers a generalized and extensible simulation framework that allows seamless modeling of the proposed mobile cloud models. Also, the MCC simulator can be used to evaluate design parameters including power consumption and delay in a dynamic environments easily through graphical user interface which can also be used to modify the simulation configuration parameters. The MCC SIM was used to simulate the proposed cloudlet-based Mobile Cloud Computing model to understand the impact of applying the cloudlet on the power consumption and delay compared to a non-cloudlet MCC. In the simulation environment the cloudlets were distributed evenly so the mobile devices can access it easily. In each experiment, testing time is set for 500s, and the testing area of 800x600 m that contains 2000 mobile users. The mobile users are moving randomly at speed of 2m/s, and sending packets to the cloud with a rate of 0.1Hz using Wi-Fi or 3G, 4G connectivity. The maximum number of user that can connect to each cloudlet is set to 150 users.

We considered three connection scenarios in the simulation of our new model. The first scenario, when the mobile device is connected to the enterprise cloud (EC) through 3G. In the second scenario, the mobile device is connected to the EC through one master-Cloudlet. The final scenario, the mobile device is connected to the EC through Cloudlets which connected to master-cloudlet.

V. USAGE OF THE PROPOSED MOBILE CLOUD MODEL FOR E-HEALTH SYSTEM

An important domain where cloud computing and cloudlet technologies are critically needed is the healthcare sector. The proposed mobile cloud model based on the cloudlet scheme can be used to analyze the data and patients records and extract recommendations. In this section, we review some work relevant to cloud-based healthcare systems.
Healthcare applications demand increasingly large amounts of computational and communication resources. Moreover, these applications require access to large amounts of data within and outside the boundaries of the organization. The access patterns are typically dynamic and this dynamic nature of data and computational interaction (e.g., service orchestration, service access) is to grow; it is being only limited by the granularity of interaction that the current applications and systems are able to provide and sustain [23]. The next generation healthcare infrastructure therefore will have to support a diverse range of applications and their ability to communicate with each other within and across the organizational boundaries [24].

No wonder that cloud computing is revolutionizing most industrial and public sectors. The work in [25] provided a practical contractual framework paper for risk management and mitigation for outsourcing healthcare data to a cloud environment. Risk management is particularly important in healthcare with cloud computing because of the sensitivity of healthcare data and apparent risk of cloud computing as it provides resources as a service. There are increasing penalties for healthcare organizations associated with heightened enforcement of data privacy and security laws. There is limited oversight of cloud providers as the privacy laws in a digital world have failed to keep abreast of the exponential growth in ICT. Therefore a high measure of confidence is required in making any decisions to adopt cloud computing in healthcare and other organizations. The healthcare transport capacity sharing model presented in [26] illustrates how sharing transport load and capacity in a smart city can improve efficiencies in meeting demand for city services. Such a system requires ubiquitous data and process sharing across multiple scales, and, therefore, represents a class of healthcare systems that could benefit from cloudlet based mobile computing.

A quantitative modeling study to demonstrate the potential of computational grids (remotely accessible shared pool of resources) for its use in healthcare organizations to deploy diverse medical applications is presented in [27]. Although this study is focused on grid computing but is applicable for cloud computing. Multiple organizational and application scenarios for grid deployment in the healthcare area are considered including four different classes of healthcare applications and 3 different types of healthcare organizations. The computational requirements of key healthcare applications are identified and, for each scenario, the system performance is analyzed using the results. Various performance measures of interest such as blocking probability and throughput could be computed from the provided results. The paper provides an interesting insight into computational requirements of healthcare applications and provides a platform to explore communication requirements of healthcare applications. These requirements are important because the traffics on future networks connecting healthcare systems are likely to be dominated by the analytics applications requiring high granularity large number of communications requiring near zero network latencies. These individual communications though may not be heavy in terms of data, however will create significant traffic due to the large number of communications. The computing and communication requirements from this study can be used and applied to our master-cloudlet scheme to understand cloud performance for healthcare applications. A whitepaper [28] by Hitachi Data Systems examines the different aspects of cloud adoption and how healthcare providers can move forward with a cloud-based solution. The drivers including delivery of cost-effective healthcare, government incentives, clinical innovation, and big data growth are discussed. The challenges of cloud computing in healthcare including privacy, security, and workflow challenges are explored. The clinical and business benefits of cloud adoption for healthcare are described, along with cloud economics and healthcare cloud solution checklist. A number of other related works discussed cloud computing in healthcare including Cloud Computing for Healthcare Organizations: Cloud Computing: Building a New Foundation for Healthcare [29] by IBM, Impact of Cloud Computing on Healthcare [30] by Cloud Standards Customers Council, and Your Cloud in Healthcare [31] by VMware.

VI. CONCLUSION

Mobile cloud computing (MCC) is a very important technology that has many useful applications in our world nowadays. There are many different MCC architectures proposed in the past few years. In this paper, we propose an efficient model for mobile cloud computing that utilizes the cloudlet concept. The model is implemented in a way such that the mobile user requests the service from the cloud through the nearest Cloudlet via wireless technologies (mainly Wi-Fi). This way, the users will obtain the requested services from the cloud faster and in less time compared to the case when there is not cloudlet and direct connection should be made between the mobile users and the cloud. Moreover, the energy drain is one of the important limitations for mobile devices. The cloudlet scheme allows faster service requests and responses to/from the cloud, and so results in less power dissipation.

The proposed model has many useful applications in our daily life such as in education, crowd management, banking and business sector, and E-health systems. As case study, we applied the cloudlet model in E-Health system were it can be used to collect patients data, store it, and analyze it in order to help the caregivers take the correct decisions at right times. The simulation results obtained by MCCSIM show that our model out performs classical non-cloudlet mobile cloud computing models.

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