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Resource Efficient Mobile Computing using Cloudlet Infrastructure

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Abstract—**Mobile Cloud Computing (MCC) has been introduced as a viable solution to the inherited limitations of mobile computing. These limitations include battery lifetime, processing power, and storage capacity. By using MCC, the processing and the storage of intensive mobile device jobs will take place in the cloud system and the results will be returned to the mobile device. This will reduce the required power and time for completing such intensive jobs. However, connecting mobile devices with the cloud suffers from the high network latency and the huge transmission power consumption especially when using 3G/LTE connections. In this paper, we introduce a Cloudlet based MCC system aiming to reduce the power consumption and the network delay while using MCC. We merged the MCC concepts with the proposed Cloudlet framework and propose a new framework for the MCC model. Our practical experimental results showed that using the proposed model reduces the power consumption from the mobile device, besides reducing the communication latency when the mobile device requests a job to take place remotely while keeping high quality of service stander.**

Keywords-Mobile Cloud Computing, Cloudlet, Network Performance, Wirless Communication.

I. INTRODUCTION

Mobile devices such as smart phones and tablets became an essential part of many peoples' life all over the world because of their powerful capabilities. Users depend on their mobile devices to make calls, create and edit documents, do image processing, check the social networks (Facebook, twitter, etc.), organize meeting and make video and audio call. On the other hand, the current proliferation of Cloud Computing (CC) paradigm makes a big evolution in Information Technology (IT). The concept of CC relies on network based resource sharing to increase resource availability and reduce the economical and management costs. The cloud is simply a collection of high performance servers with a huge amount of storage resources connected together and accessible through the internet. The cloud resources are provided to the users as a service in pay as you use service model.

In spite of the mobile smart phones benefits and how it makes the life easier, it has many weakness points, such as: limited battery life time, limited processing capabilities, limited storage capacity. These limitations are very important to consider since it is hindering mobile users from doing their daily task in better way. One solution to overcome these limitations is to integrate Cloud Computing technology with mobile devices to produce what is called Mobile Cloud Computing (MCC). In MCC, the processing and storage of intensive jobs are transferred to the resources rich cloud system to take place there. In case of jobs which need high processing and computing capabilities it migrated to the cloud where needed processing done and just the final result returned back to the mobile device. In this technique CC resolves both of the problems limited processing capabilities and limited power of the mobile phones. On the other hand, if there are files, videos, images with a very large size it transferred to the storage inside the cloud and whenever the mobile user needs any of them he just requests it from the cloud; in this technique CC resolves the problem of limited storage capacity of the mobile phones. Recently, MCC becomes one of the most important and hottest research topics because it is emerging the new smart phones with the cloud computing technologies. In this paper, we introduce a practical study of the newly emerged architecture of MCC using a closer cloud capacity to the users using Cloudlet based cloud system.

This paper is organized as the following: in section 2 the description of the cloudlet introduced with details, section 3 contains a literature review for MCC concept. In section 4 we introduce our proposed model architecture. Section 4.1 deals with mobile movement scenarios. In section 4.2 the management of the mobile-cloudlet-cloud connection introduced. The implementation of the proposed model is in section 5, in this section the experimental results show how much the benefits we get from using the new model. Finally we conclude our work in section 6.

II. CLOUD COMPUTING, MOBILE CLOUD COMPUTING AND CLOUDLET

Cloud computing is a new computing paradigm that is continuously evolving and spreading. Empowered by hardware virtualization technology, parallel computing, distributed computing and web services. Cloud computing presents a huge revolution in the Information and Communication Technology [12]. Cloud computing can be defined as “Cloud Computing is a model for enabling convenient, on-demand network access to a shared pool of

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configurable computing resources (e.g., network, servers, storage, applications and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction" [13]. There are several examples for emerging Cloud computing infrastructures/ platforms such as Microsoft Azure [13], Amazon EC2, Google App Engine, and Aneka [14].Furthermore, CC helps companies to improve the IT services, develops applications to achieve unlimited scalability, automaticity on demand services of the IT infrastructure and increases their revenues [14]. Cloud Computing services include: Software as a Service (SaaS), Platform as a Service (PaaS) and Infrastructure as a Service (IaaS). Clients of CC might be users in other Clouds, organizations, enterprises, or might be a single user.

An emerging technology of integrating Mobiles with cloud computing creates a new programming paradigm called Mobile Cloud Computing (MCC). MCC promises to overcome mobile limitations as the processing and storage for intensive jobs transferred to the cloud to take place there and the final results returned back to the mobile device. Mobile cloud computing can be defined as follow "Mobile Cloud Computing (MCC) can be considered as a kind of cloud computing with assistance computing for mobility such as location-awareness, computing capability, and data backup" [15]. As in figure 1, mobile devices in MCC mostly use the 3G/LTE to connect to the cloud and rarely use the Wi-Fi because it is not always available, table 1 compares between these two connection technologies.

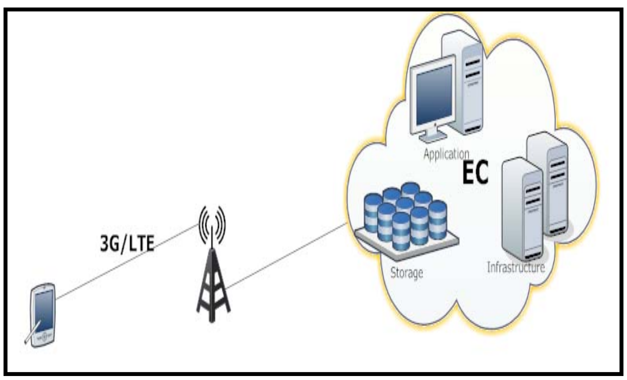

Figure 1. Traditional MCC Architecrure

From table 1 we can notice that using Wi-Fi connection is preferable over the 3G/LTE connections. Cloudlet [3] is a trusted and high capabilities computer or cluster of computers, connected to the internet. Installed along with Wi-Fi APs to allow mobile devices to access it, and in some cases both of the cloudlet and AP are integrated in one entity. In addition, the mobile devices use Wi-Fi to connect to the nearby cloudlet. Through using the low latency, high Bandwidth and one-hop wireless access to the cloudlets mobile device gets a real-time interactive response.

Table 1: LTE and WiFi comparsion

	3G/LTE	WiFi
Power consumption [1][2]	Higher	Lower
Connection Speed[3]	2Mbps	400Mbps
Latency[3]	Higher	Lower

In the cloudlet-based mobile computing figure 2, mobile devices send jobs to the cloudlet to do the required processing and return the final result back, this reduce the transmission delay, also reduces the power consumption of the mobile device .so it makes a great evolution in MCC. In the cloudlet-based mobile computing, mobile devices send jobs to the cloudlet to do the required processing and return the final result back, this reduces the transmission delay, also reduces the power consumption of the mobile device. So it makes a great evolution in MCC. (As shown in figure 2).

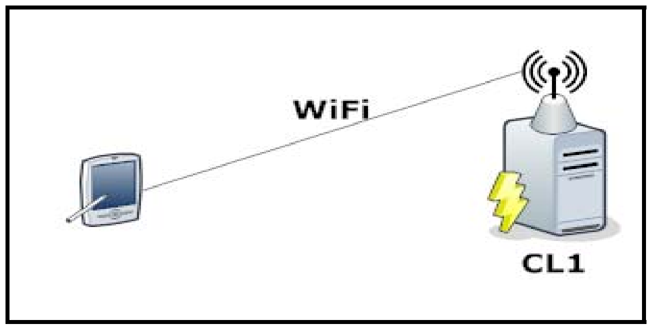

Figure 2: WiFi Connectes Cloudlet and Mobile Device

III. Literature Review

In [4] Author describes how the Mobile Cloud computing developed from both of the Cloud computing and the mobile computing. He also describes its scope, developments and current research area challenges. This paper proposed MobiCloud system developed at Arizona State University to simplify the studying and analyzing of the MCC. Authors of [8] give a survey of MCC's definition, advantages, architecture and applications (Mobile Commerce, Mobile Learning, Mobile Healthcare, and Mobile Gaming). They also describe MCC issues (Low Bandwidth, Availability, Heterogeneity, Computing Offloading, Context-aware mobile cloud services, Security and Enhancing the Efficiency of Data Access) and list the existing solutions. At the end they present the future works in this filed. The impact of using Cloudlet with respect to Cloud mobile computing in interactive applications (file editing, video streaming and collaborative chatting) analyzed in [5].It compared the two models in terms of system throughput and data transfer delay. The paper results showed that in the most of the cases, the use of cloudlet-based model outperformed the cloud-based model.

A modeling and simulation model for MCC is presented in [16]. In [6] the authors have a new architecture called MOCHA for facing recognition applications. The purpose of this architecture is to reduce the response time during facing recognition process. MOCHA integrates Mobile device, cloudlet, and cloud servers. Admission control and resource allocation problems for the running mobile application in the cloudlet discussed in [7]. To solve these problems authors formulate them as a semi-Markov decision process (SMDP). The new model proposed in this paper provides a QoS for different classes of mobile users. In [3] the technical obstacles of using cloudlet in mobile computing have been discussed. A new architecture proposed to deal with these obstacles. This new architecture manages the sessions opened by mobile users inside the cloudlet. The management based on VM instantiation for each mobile user.

The key performance metrics of using VM is to manage jobs execution inside the cloudlets discussed in [10]. These metrics include: overhead of VM life cycle when deploying it in the execution of cloudlet, cloudlet allocation to VM and scheduling of VM. The authors use the CloudSim as a platform environment and they conclude that it's so important to efficiently deploy and manage VMs in CC to reduce the amount of execution time because of the previous performance metrics. [11] Presents a prototype implementation of cloudlet architecture, and shows the advantages of this architecture in the real-time applications. The proposed architecture in this paper is a fine grained cloudlet to manage the running application 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 to the wireless access points. In [9] authors analyze the critical factors that affect the power consumption of mobile clients when using CC, and provide an example in how to save mobile client power. To define the balance between using local mobile computing and remote cloud computing they present their own measurements of the main characteristics of modern mobile devices.

IV. THE PROPOSED ARCHITECTURE

We propose a new MCC cloudlet-based model. The new model is composed of set of distributed and well-connected cloudlets within one location where there is most likely mobiles use cloud services. In addition, all of these cloudlets are connected to the Enterprise remote cloud. Figure 3 shows the basic element of our proposed model. Here the mobile device communicates directly with the cloudlet which connected to the Enterprise cloud.

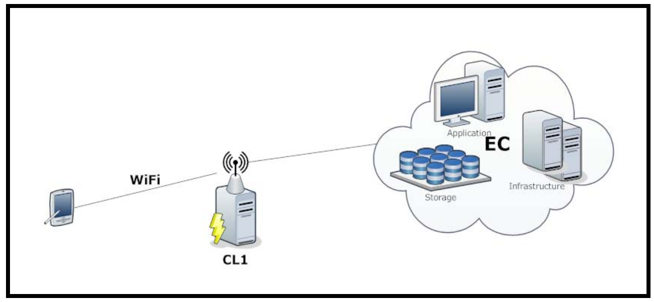

Figure 3: Elements of the Proposed MCC Cloudlet based Model

A. Why we need to connect to the enterprise cloud if we have cloudlet?

1) Heavy non real time jobs might process in the enterprise cloud whiles the real time ones processed by the cloudlet.

2) Accessing a file stored in the Enterprise Cloud (IaaS) .If mobile device has some files in EC and he wants to do some processing on it, he just sends the request for this file, then the file being downloaded from the cloud to the cloudlet and the mobile device can browse or edit it while it in the cloudlet or he can re-download it from the cloudlet and do the jobs locally.

3) Accessing some services that are not available inside the Cloudlet.

B. Mobility Scenarios

Location A: In this situation, the mobile device accesses the EC through CL1 (host CL) and remains in the coverage area of this CL until the requested job completed.

Initial Location is A then moves to location B : In this situation, the mobile device accesses the EC through CL1 but before the completion of the requested job, he changed his location inside the coverage area of CL2 and out of the coverage area of CL1. In this case, the mobile device uses the CL2 to perform new tasks or to complete the previous jobs, so that if there is any data or process remains in the CL1 a request sent to CL1 to send this information to CL2 in order to complete those jobs.

Initial location is B then moves to location C: In this situation, the mobile device accesses the EC through CL2 but before the completion of the requested job, he changed his location out of the coverage area of host CL. Unfortunately, there is no available CL at location C. In this case, the mobile device has to use the costly 3G/LTE connection to access the EC. Using this connection, mobile device can perform new tasks or complete the previous job, so that if there is any data or process remains in the CL2 he sends a request to CL2 to send these information to EC in order to complete those jobs.

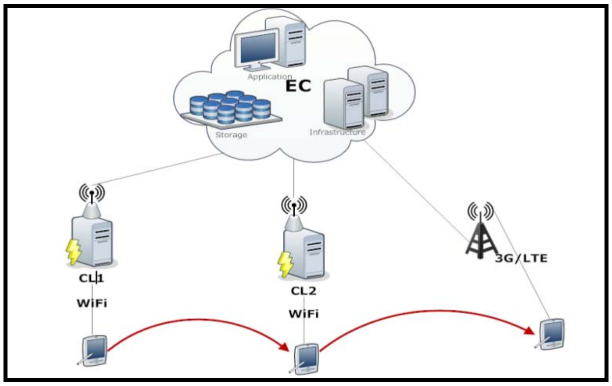

Figure 4: Mobility Scenarios

C. Management

In the movement scenarios discussed above, there were situations where the mobile device leaves the coverage area of the host CL to the coverage area of a new one before completion all of the started jobs. In order to complete the jobs that were running in the host CL, the new CL must be provided with full information about the host CL besides what are the services or files that mobile devices used them inside it. There are two approaches to manage this information, discussed next.

i) Centralized approach

In this approach, the EC is responsible for managing and tracking mobile device movement in the system. This management done by storing the tracking information about the mobile device. This information includes (Table 2)

Table 2: Mobile device status

Parameter	Value
Current status	Connected or disconnected
Connection type	Direct or Cloudlet
Current services	Names of currently used services
Current files	Names of currently used files
Recent Cloudlets	IDs of the recently used cloudlets
Incomplete Jobs	IDs of incomplete jobs along with the host cloudlet

ii) De-centralized approach

In this approach, the mobile device itself is responsible for managing its movement in the system. The mobile devices store a movement history along with the service currently running and the hosting CL to provide this information to new CL as needed. (as shown in Table 3).

Table 3: Cloudlet and Job information

Parameter	Value
Recent Cloudlets	IDs of the recently used cloudlets
Incomplete Jobs	IDs of incomplete jobs along with the responsible cloudlet

Using one of the above two approaches depends on the simplicity and easiness of management required on the mobile side. Because in the first approach the mobile device is not aware about the management process, and everything done by the EC.

V. Experimantal Results and Evaluation

As an initial step in the implementation of the new model, we have built a single Cloudlet and made a performance comparison with respect to 3G connection:

A. Experimental Setup:

Our testbed is consisted of the following components:

1. *Cloudlet server*: Lenovo ThinkPad Laptop (Core i5, 4 GB memory, windows 7).
2. *Access point:* BandLuxe PR30 series router, connected to the internet through 3G connection.
3. Mobile Device: Samsung Galaxy Note N7000 (Note I).

B. Experimental Results:

To test the implementation model we upload a file of size **226 KB** to both the Cloudlet and to the enterprise Cloud. In the implementation we are interested in the amount of power consumed during the uploading process, the amount of time needs to complete the job, and the throughput of the whole process. Table four shows Cloudlet and Enterprise cloud results comparison

Table 4: Cloudlet and Enterprise cloud results comparison

	Connection Type	Power (mW)	Delay (s)	Throughput (KB/s)
Cloudlet	Wi-Fi	455	226	1001.63
Enterprise Cloud	3G	923	2223	101.83

From this implementation we can see how much the use of Wi-Fi is preferable over the use of 3G, since it consumes power less than one half of the power consumes while using the 3G connection. Also it gives us about 10-times of throughput with respect to 3G connection throughput.

VI. CONCLUSION

In this paper, we introduced the Cloudlet novel concept and based on it, we proposed a new architecture for MCC model. The new model takes into account the mobility and the movement nature of the mobile devices and how to deal with this issue. Also it suggests two approaches to manage the mobile application running in the cloud/cloudlet. Experimental results showed that the new model achieved the goals in reducing the power consumption of the mobile device, besides reducing the communication latency when the mobile device requests a job to take place remotely.

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