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# Experimental Framework for Mobile Cloud Computing System

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**Abstract**

Mobile cloud computing is an emerging and fast-growing computing paradigm that has gained great interest from both industry and academia. Consequently, many researchers are actively involved in cloud computing research projects. One major challenge facing mobile cloud computing researchers is the lack of a comprehensive experimental framework to use in their experiments and to evaluate their proposed work. This paper introduces a modeling and simulation environment for mobile cloud computing. The experimental framework can be used to evaluate a wide spectrum of mobile cloud components such as processing elements, storage, networking, applications, etc. The framework is built on top of the CloudExp framework which provides the major building blocks needed for any cloud system. Moreover, mobile cloud experimental framework can exploit CloudExp capabilities to simulate big data generation and processing scenarios. An experimental scenario is also introduced in this paper to demonstrate the capabilities of the proposed framework.


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*Keywords:* Mobile Cloud Computing; Modeling and Simulation; Interactive Simulator; Performance Evaluation

## 1. Introduction

A simulation framework (or simulator) is a very important part of any field that helps researchers to evaluate their proposed work[1]. Simulation frameworks are used in different applications in science, engineering, or other fields for diverse purposes. Computer-based simulation can be used to model theoretical and actual activities or objects of a certain system on a running computer in order to study the functionality of the system. The behavior of any

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proposed system can be predicted by using different simulator variables. The simulation outputs help users to model and study the nature of the proposed systems in many applications, like Mobile Cloud Computing (MCC).

Nowadays, smartphones and tablet PCs are more widespread and users are relying more on them compared to conventional personal computers. This has led to an unprecedented growth in the mobile devices market ushering us into what is known as the era of mobile computing [3]. However, mobile devices suffer from many limitations related to their limited resources. Limitations include: connectivity issues, limited bandwidth, security vulnerabilities, applications compatibility, and a restricted power source since they are mostly powered by batteries. An emerging concept of MCC is showing a great momentum nowadays within mobile service providers and users. It is based on the integration of cloud computing providers and the mobile service system. This integration is achieved by the possibility of offloading mobile data and intensive computation requirements to cloud computing infrastructures[4]. This enables the mobile device to migrate the intensive computation tasks to cloud infrastructures and preserve its limited resources. In addition, mobile devices would no longer require large storage capacity on the device as the user data could be stored in a cloud storage system. The user can easily retrieve his/her data whenever needed. MCC research is expanding quickly and many researchers are engaged in MCC research topics such as data offloading, mobile-cloud subscription, and security. These researchers would appreciate having a unified experimental framework through which they can evaluate the performance of their proposed solution in a low cost realistic manner. To the best of our knowledge, there are no simulation frameworks that consider MCC so far with all its related technologies.

With a predicted market value of US$9.5 billion by 2014 and more than 1 trillion cloud-ready devices in the next four years, MCC is considered as one of today's hottest new technology markets[5]. MCC integrates different major technologies such as smart phones, tablets, services, big data and cloud computing in one platform provided to the end users. Many issues related to the rapidly growing MCC are still challenging such as networking, cloud services, security, quality and availability of services, user data management and many others. In response to these challenges, researchers in both academia and industry are working hard to propose efficient solutions.

The rest of the paper is organized as follows: Section 2 provides an overview of current frameworks that covers mobile computing and mobile cloud computing in the field of cloud computing simulation and modeling. CloudSim, which is the base for CloudExp, is introduced in sub-Section 2.1. The proposed Mobile Cloud Computing experimental framework is fully detailed in Section 3. A use case scenario for the framework is presented in Section 4 where different simulation results are presented. Finally, Section 5 concludes the paper.

## 2. Overview of Current Frameworks

Authors in[6] proposed CloudSim (also called Network-CloudSim) to simulate and study the behavior of parallel and distributed applications in cloud computing environments[6]. It offers the basic entities and classes to simulate a network through the connection of Switches (Aggregate Switch, Edge-Switch and Root Switch), Network Datacenter Broker and Network Datacenter. Still, CloudSim does not support the common network topologies and big data collection in cloud computing as in proposed work of BCube[7], VL2[8] and Portland[9]. Therefore, the network topology coupled with large scale data collections are integrated into our proposed MCC framework. In addition, MCC supports a GUI to easily drag and drop cloudlets and entities, define their properties, mobility, packet size and rate, and establish the connections between the components in the design area, which results in a customized network topology.

SmartSim toolkit introduced for modelling the application processing capabilities in mobile devices. It simulates the system and behaviour modelling of mobile devices with an easily configurable environment[10]. Other authors exploited the well-known CloudSim framework in their experiments. The authors on MuSIC project used an integrated platform of both MATLAB and CloudSim for their simulation and results generation[3]. Using a real-time testbed for simulating MCC related experiments was used in many previous works. The authors in[2,11,12] used a real testbed to evaluate their cloudlet based MCC system. A cloudlet is a new architectural cloud element that arises from the convergence of mobile computing and cloud computing[4]. It represents the middle level of a 3-level hierarchy; entity, cloudlet and cloud. The main issue of such approach is the limited scalability of the experiments and the high costs related to it.

CloudExp presents a new simulation module that handles MCC[13]. The MCC module in CloudExp provides the basic capabilities for users to conduct MCC related experiments. Using CloudExp, the researchers can configure the MCC module to create and simulate MCC-related experiments. Many parameters can be used to configure the MCC related experiments. These parameters are ranging from number of mobile users, connection type, connection bandwidth, data rate, and authentication mechanism.

## 3. Mobile Cloud-Computing Simulator

### *3.1. Overview*

The objective of this section is to describe MCC framework simulator. The MCC software is specialized for entity networking, cloud support and big data processing. It is a flexible tool used to study the cost of data communication between end users and the cloud infrastructure. MCC can be considered as a commercial software provider, which provides comparatively more graphical support or powerful visual interface for the users. The proposed graphical user interface (GUI) can be used to construct the infrastructure of the entities and topology from the lower layer, like physical layer to the upper layer, or like application layer. The object-oriented programming technique proposed in this framework is used to generate the drawing from the real systems to the operation of graphical design. The GUI of the proposed framework is shown in Figure 1. As shown in the figure, the configuration, the deployment of the topology and the simulation output can be accessible visually and very intuitively. The parameters of the simulation configuration can be also adjusted easily and the simulation can be repeated many times using easy configuration in the GUI.

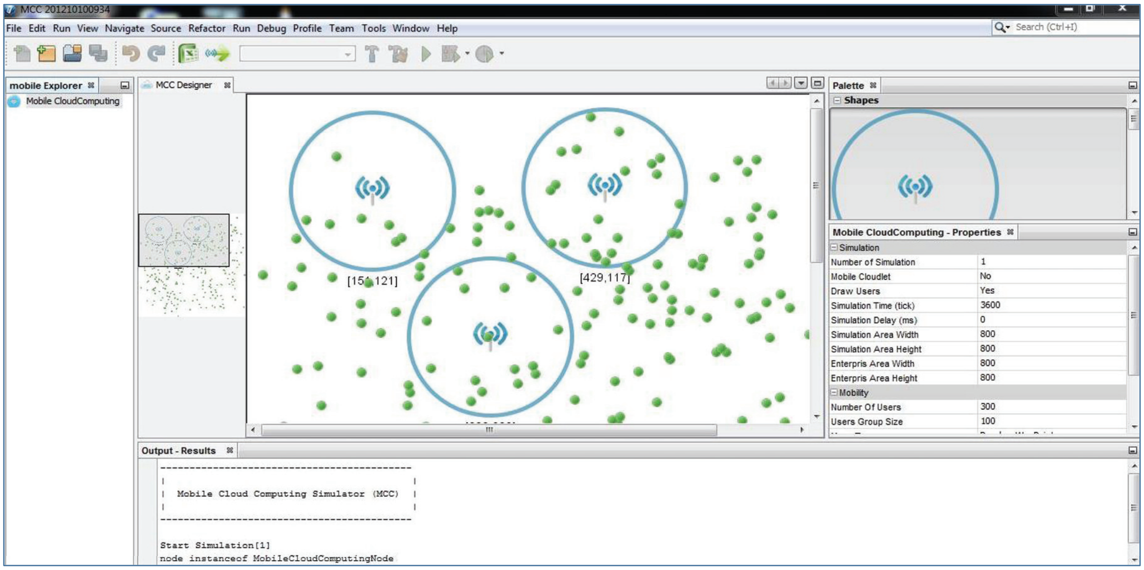


Figure 1: GUI of the proposed MCC framework

The structure of MCC is based on a process of data stream management system, which means that the data flow from the end entity to the enterprise cloud in a regular rate[12]. As many other simulators, MCC also provides software design tools for users to describe the packet size, format and rate. Hierarchical construction is used to organize the data flow in the networks and by deploying cloudlets in the designed area as shown in Figure 1[4]. Cloudlet system represents a full cloud system capabilities but in a small scale[4]. It may vary from a workstation like system to a more complex set of physical servers. Cloudlet uses a virtualization middleware that translates its hardware components to a set of virtual components enclosed in Virtual Machines (VMs). Each VM is assigned a part of the available hardware resources. The hardware resources range from one CPU to a set of CPUs that support multi-core technology. Cloudlet system is also equipped with sufficient memory capacity per physical server. More memory capacity will help the cloudlet system to support more VMs efficiently. It also contains a moderate size of storage capacity that may reach Terabyte scale. To support the main functionalities of the system, the cloudlet must support a set of transceivers (i.e. antennas) that is capable of receiving and sending the data packet from and to the entities. The GUI interface, shown in Figure 1, and the software design tools are also valuable to support the users to construct the system that they want to design.

### *3.2. Main Features*

Basically, MCC has three main components: modeling or design, simulation or execution, and study or analysis. In the design component, MCC produces built-in graphical settings for entities and cloudlets deployment to create all possible kinds of data flow between the end entity and cloud. The graphical environment includes the monitored area, number of entities and mobile entities, number of cloudlets and placements, cloudlet mobility, packet rate and size, number of VMs, maximum connected entities, etc. The simulation components uses many features, like simulation time, number of simulations, draw entities, etc. In the study or analysis component, the experiment outcomes and dataset which can be used for analysis purposes are presented in a very simple way. MCC provides friendly user diagrams, statistics, charts and the animation of the entities and proposed cloudlets, which is created by MCC for users' convenience, as we will explain in Section 4. Two primary main performance metrics are generated by MCC, namely, end to end packet delay and power cost, and many other secondary metrics.

The proposed mobile cloud computing experimental framework uses CloudExp as the base design platform and introduces many new enhancements and extensions on top of it. These enhancements and extensions include:

- The integration of dynamic workload generator to simulate large scale data generation from the mobile devices.
- Including different mobility scenarios for the mobile devices.
- The integration of a MapReduce framework available in CloudExp to handle parallel data processing paradigms and Big Data problems.
- Introducing the emerging concept of cloudlet based MCC experiments.
- Provide an easier configurable framework for faster experiments design and results generation.

### *3.3. Data Communication*

WiFi is a popular technology that allows an electronic device to exchange data or connect to the internet wirelessly using radio waves. While cellular network is a radio network distributed over areas, each served by at least one fixed-location transceiver. A cellular network enables large number of mobile phones to communicate with each other and with fixed transceivers of Internet. The trade between using these two technologies is the following. With WiFi, a BAN user will be able to transmit the data packet to the cloud using smart phone with low power and low delay compared with cellular technology, but with transmission range does not exceed 100m[14]. Such WiFi capability is crucial to overcome the power constraint in mobile environment while successfully transmitting data to the cloud system.

In our implementation, the WiFi technology will be available in the cloudlet area. It was shown that, via WiFi, the transmission power of data packet will cost 30 mw with delay of 0.045 ms[14]. On the other hand, a longer transmission range cellular network connection (e.g. 3G and LTE) is capable of transmitting the data packet to the cloud from any location that is covered by cellular network, which is usually a wider geographic area compared with the WiFi. It was shown that, via cellular connection, the transmission power of data packet will cost 300 mw with delay of 0.45 ms[14]. While the cellular connection is very costly in terms of power, transmission delay and connection cost (the WiFi is mostly free of charge), it's very important to support mobile users in case of the absence of the cloudlet in the range and to support the scalability of the system under large number of users.

## 4. Results and Discussions

In order to study the experiment settings of MCC on the performance results, the following sample experiments were conducted. The goal of these experiments is to study the flexibility of the proposed MCC framework by looking into the impact of cloudlet deployments on the performance results of power and delay. Each experiment lasted for 3600s or one hour in area of 800x800m. In each experiment, 500 human subjects are moving in the area of the simulator and each user sends a packet to the cloud with a rate of 0.1Hz using WiFi or cellular technology, which depends on the available technology, as we discussed in Section 3. The users are assigned to move with a random way point mobility model with a speed of 2m/s and a random pause time of 1s to 10s. The proposed mobility scenario here represents a real life application of moving students, solders or firefighters in a closed area. Figure 2 shows the designed area with different number of cloudlet. In each experiment, the number of cloudlets is changed from zero to 10. Zero number of cloudlet means, there is no cloudlet in the area and each user needs to use cellular technology to transmit the data packet to the cloud, as we discussed in Section 3. The maximum number of users in each cloudlet is assumed to be 100 users.

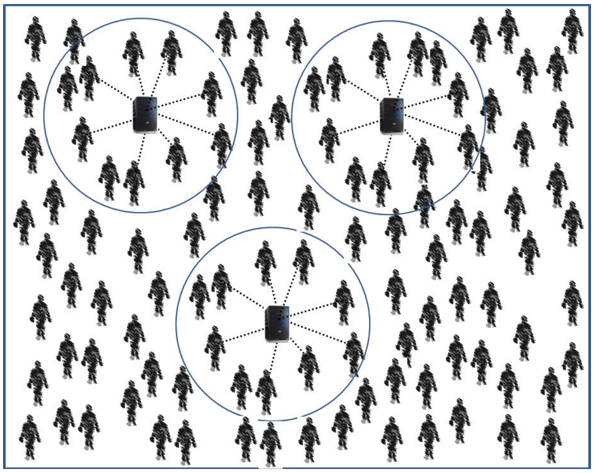

Figure 2: MCC designed area with different number of cloudlets

Figure 3 shows the performance results of the transmission power and delay for different number of cloudlets in the designed area which were shown in Figure 2. In Figure 3, each transmission power and delay point in y-axis corresponds to the average of 10 different experiments, where each point in the figure shows the average power and delay per user and per packet. The following observation can be made from Figure 3. First, the zero number of cloudlets scenario shows the worst performance in terms of power and delay, where the packet transmission power was 300mw and packet delay was 0.45ms per user and per packet. The reason is that each subject has to send the data packet to the enterprise cloud directly using cellular connection, which is very costly in terms of power and delay, as we discussed in Section 3. Then, the trends of the power and delay results go down by increasing the number of cloudlets in the designed area. The final conclusion that we can made from figures 2 and 3 is the cost of data collections from all users can be reduced by increasing the number of cloudlets for given number of users in the designed area.

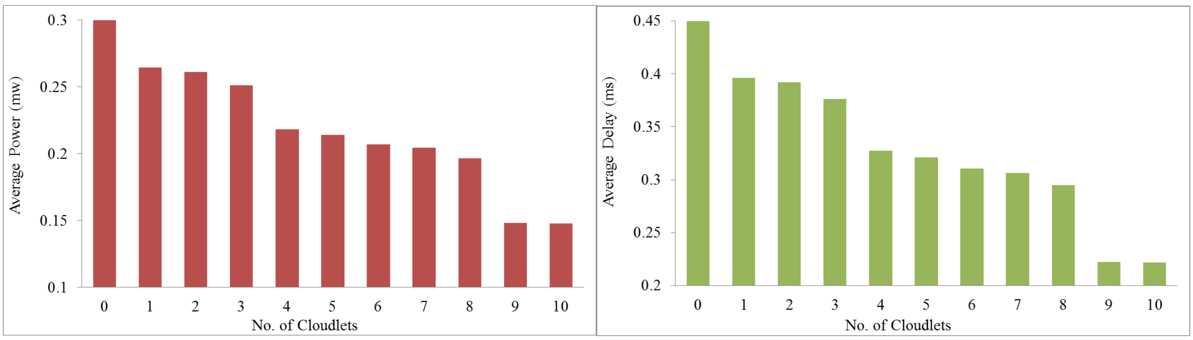


Figure 3: Average power and delay verses the number of cloudlets

## 5. Conclusions

This paper has presented an experimental framework for the emerging mobile cloud computing system, a comprehensive, easy-to-use, and efficient mobile cloud computing modeling and simulation toolkit. The proposed framework fills in a large gap in mobile cloud computing research caused by the lack of having a comprehensive and easy-to use framework, in addition to the limited availability and the high costs of conducting experiments in real cloud computing environments. The experimental framework provides a rich, yet simple, GUI to build cloud infrastructure and present results and charts to the research to enable configuration analysis and evaluation. This allows users to customize all aspects in a mobile cloud infrastructure from the host processing nodes to the network topology. Moreover, the modularity in the proposed design allows users to integrate new components or extend existing ones easily and effectively. Users can modify the different components and their parameters, run simulations, and analyze results.

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