# Energy Efficient Offloading for Mobile Cloud Computing: A Review

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***Abstract:*** Mobile Cloud Computing is an evolving technology that combines the concept of cloud computing into the mobile environment. With the rise of mobile devices the resource demands of applications also grows. However, mobile devices have limited resources like its storage capacity, battery lifetime, bandwidth etc. These limitations can be overcome by offloading of applications, which is the focus of mobile cloud computing (MCC), that is migrating the large or complex computation to servers or cloud and then getting the output directly from these servers. This paper presents an overview of mobile cloud computing, offloading and its benefits, types of offloading that is static and dynamic, and features of mobile cloud computing. Offloading is beneficial as it helps in improving the performance of devices and saves large amount of energy.

***Keywords:*** Mobile cloud computing, Offloading, Static offloading, Dynamic offloading

## I. INTRODUCTION

The term Cloud is concerned with Network or Internet. Cloud is something which is present at remote location. Cloud can provide services over public and private networks. Cloud computing which also known as on-demand computing, is a type of Internet-based computing where the shared resources, data and information are provided to computers and other devices on demand. It is a model for enabling the ubiquitous, on demand access to a shared pool of configurable computing resources.

Mobile cloud computing (MCC) refers to an infrastructure where both the data storage and data processing happens outside of the mobile device. The computing power and data storage are moved away from the mobile devices by the mobile cloud applications into the strong and centralized computing platforms located in clouds, which are then accessed over the wireless connection. The mobile cloud provides the computing resources and infrastructure to support the seamless provision of web services in a lightweight manner. As the usage of mobile devices is increasing day by day. The users now want full access to their data in their smartphones and want each type of new application on phone. However, there are several evolutions but the computational power, energy and storage will always be the constraint. In order to overcome these limitations, offloading is one of the solution which offloads the data from phone to cloud in order to save the energy.

## II. LITERATURE REVIEW

According to Eweoya Ibukun et al. Mobile cloud computing (MCC) is a paradigm of computing which enables an on-demand access to the remote resources on the internet through mobile devices using a utility based payment model [1]. Mobile computing provides effective and efficient access to resources through the mobile devices. MCC provides key technologies such as virtualization, distributed data storage, distributed data management, wireless networks and security etc. in order to

  

deliver its implementation objectives. The issues related to MCC are described as cloud security management, energy awareness, presentation and usability issues, resource constraint and privacy. In order to save energy and improve battery life, offloading of the task is done. Computation offloading is a procedure that takes resource rich computations from a mobile device to the cloud or server to get it processed there and return back the results to the mobile device [2]. The main aim of offloading is to improve performance and save energy. By offloading the execution time of a task is reduced to a great extent. Zhiyuan Li, Cheng Wang considered the handheld computing devices which are connected to a server via a wireless LAN [3]. With wireless connectivity the information and services on the network are accessible to the handheld devices. And it becomes possible to save the energy on these devices by offloading the computation to the server, and develops a program partition scheme which determines whether and how to offload the computation of a given program. The results shows that even under an ordinary, uncontrolled, wireless LAN environment, it results in notable energy-saving.

Xiaohui Gu et al. propose an adaptive offloading system [4] which includes two main parts: a distributed offloading platform and an offloading inference engine. The distributed offloading platform includes application execution monitoring, resource monitoring, application-partitioning and transparent remote procedure call platform support. On the other hand, offloading inference engine contains two decision making problems i.e. adaptive offloading triggering and efficient application partitioning. Shumao Oua et al. presented a runtime offloading middleware for pervasive services [5], and considered a combination of resources rather than only one type of individual resource like memory or CPU , and describes the design issues such as service partitioning, resource awareness, easy to use and implement these issues needs to be considered for designing an offloading system. Dejan Kovachev et al. presented an Adaptive Computation Offloading from Mobile devices into the Cloud [6], and describes that offloading or augmented execution is a technique which is used to overcome from the limitations of mobile devices like computation, memory and battery. The Mobile Augmentation Cloud Services (MACS) middleware is presented which is a service based mobile cloud computing middleware. The main aim of MACS middleware is to allow the execution of elastic mobile applications. The results shows that that the execution time is reduced through offloading, and lot of energy can be saved.

MOCA: A Lightweight Mobile Cloud offloading Architecture is proposed by Arijit Banerjee, Xu Chen [7] which provides offloading resources using an in network cloud platform and defined a design principle to adopt Software defined network (SDN) and cloud technologies into the architecture, without requiring a complete redesigning of the mobile architecture. MOCA integrates with existing mobile network architectures without requiring any more changes, and utilizes SDN techniques in the data plane to redirect the traffic to and from the cloud platform, and then concluded that the approach presents the general evolution of the mobile network architectures using the cloud infrastructure and SDN. Bowen Zhou et al. proposed a Context Sensitive Offloading Scheme for Mobile Cloud Computing Service [8] that provides services by bringing the large number of resources in cloud computing to the vicinity of mobile devices so as to improve the performance of mobile applications and saving the battery of devices. Code offloading is the technique adopted in mobile cloud computing. The results shows that system provides offloading decisions and reduces the cost of energy and execution time by offloading. Yating Wang and Ing-Ray Chen describes the design issue for building MCC applications is code/computation offloading to enhance MCC application performance and conserve mobile device energy [9]. The framework of elastic application processing comprises three parts: application partitioning, code offloading, and remote execution. Application partitioning is a process of identification of units such as threads, methods or classes that can be processed on the cloud. In the Static partitioning, entry and exit points of a remote

  

method call can be statically identified. Application partitioning is essential for code offloading. It requires the application be partitioned at the breakpoints correctly and efficiently.

## III. MOBILE CLOUD COMPUTING

Cloud is the large pool of data which can be accessed from anywhere at any time easily. Cloud computing is the Internet based computing where the shared resources, data and information are provided on demand to computers and other devices. It provides the increased selection of hardware virtualization technologies and service oriented architecture.

### *Cloud Computing Classification*

It can be classified as service model and deployment model. Service model depends on the cloud services being offered and it can be classified as Infrastructure as a Service (IaaS), Platform as a Service (PaaS) and Software as a Service (SaaS). While, deployment model is described upon how a cloud is setup. It can be classified as private, public, hybrid or community.

*Mobile Cloud Computing (MCC)* is the set of techniques that uses cloud resources to empower the mobile applications. Its main goal is to provide better experience and facilities to the mobile users [10] whose devices are limited in terms of storage, battery etc.

There are several existing definitions of Mobile cloud computing and different approaches to mobile cloud.

1. Generally, the term mobile cloud computing refers to run an application like Gmail for mobile on a remote server, where the mobile device acts like a thin client connecting to the remote server [11].

2. The other approach is to consider other mobile devices as resource providers of the cloud and thus making up a mobile peer-to-peer network.

3. The cloudlet concept is also one of the approach to mobile cloud computing, where the mobile device offloads the workload to a local cloudlet which comprises of several multi-core computers with their connection to the remote cloud servers.

### *A. Architecture*

The architecture of mobile cloud computing is shown in the figure 1. Mobile cloud computing is the technology that comprises of mobile computing, cloud computing and internet. The mobile phones connects with a base station by mobile network. The cloud consists of Saas, Paas and Iaas that acts in response to requests by the users. MCC allows the users to access the services without any need to connect with hardware.

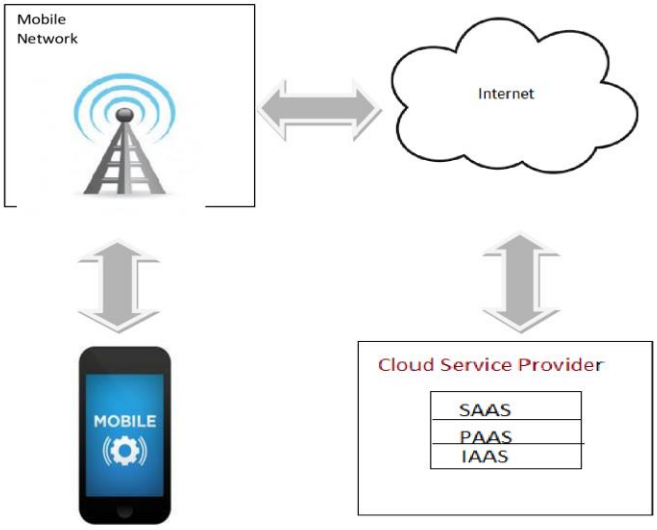


Figure1. Mobile Cloud Computing Architecture

## IV. OFFLOADING

The key feature of Mobile Cloud Offloading is migration of the task from phone or device to cloud or servers for their execution and then retrieving the results from those servers. It is commonly known as Computation offloading. Thus by offloading the task to cloud saves the energy consumption and increases the lifetime of battery. Before offloading, various parameters such as cost such as network cost, time taken to offload and energy consumption are taken into account and if all these parameters results into lower consumption of power then offloading can be done so that it may result out beneficial.

***OFFLOADING BENEFITS:***

An offloading decision is to be make concerning whether and which application to be migrated. Offloading provides several benefits like-

### *A. Improves performance*

Offloading helps in improving the performance of a device. Offloading is an attractive solution for meeting requirements of response time on mobile systems as applications become increasingly complex [12]. Offloading saves a lot of time as the application when offloaded to server executes at a much faster rate as compare to that of device. Thus, Offloading improves performance during the execution, also computation and communication can be performed faster on the server.

### *B. Energy Saving*

Energy is the main constraint for the mobile devices [13]. Now, smartphones are not only used for the calls, they are used for variety of other functions like gaming, surfing etc. As a result more power is consumed and shortens the battery life. Offloading of the computation helps in energy saving by migrating the parts of the application to servers.

### C. *Reduced Time and Cost*

With offloading a lot of time can be saved which depends on resources like less memory will be used which in turn helps in cost reduction

## V. OFFLOADING DECISION

The offloading decision can be taken statically or dynamically.

### A. *Static/Partial Offloading*

In static offloading application is partitioned during its development. This approach uses the performance prediction models to evaluate the performance of the system, then the application is partitioned into client and server tasks. As it uses prediction model, parameters such as data size and execution timing which acts as the deciding factor for offloading should be known beforehand. However, it is difficult to know the exact execution time before the actual execution takes place and the inaccurate data can result into inefficient offloading result.

A static approach as suggested in [3] that divides the program into server and client tasks. The information about the computation time and data to be shared is profiled and then cost graph is constructed based on the information and then partitioning into the subtasks is done in order to offload it to the server or cloud. The application produces the cost graphs demonstrating energy usage and data transmission.

A static framework is suggested in [14] which is COSMOS and provides computation offloading as a service for mobile devices. It receives demands for computation offloading from mobile users and then allocates them to a shared set of compute resources and then these resources can be acquired dynamically from a commercial cloud service provider. The framework provides benefits of computation offloading with minimum compute resource leasing cost. The applications like face detection and voice recognition can run seamlessly using COSMOS.

The advantages of static offloading includes its simpler process and the low overhead during the execution. On the other hand its disadvantage is it is valid only if the parameters are known already [15].

### B. *Dynamic/Complete Offloading*

Dynamic network environment refers to the changing connection status and bandwidth that affects the process of offloading. The term dynamic offloading means that the modules may be transferred for execution onto the cloud when the application is running, that is when the program is partitioned at run time and can adjust to varied run-time conditions, such as network latency or bandwidth [16], it is referred as dynamic offloading. The dynamic offloading strategies initially statically analysis the code and parameters in order to perform dynamic/online profiling during execution. Based on the information that is obtained from dynamic profiling, the application is partitioned into client and server tasks and the execution then continues with the updated configuration.

The application partitioning is performed by analysing the code [17]. The framework described is dynamic in nature. The various benefits to run a specific application as a remote task are evaluated. Its main purpose is low power. So, the tasks that are safe if made to execute remotely are identified. And, the two versions of same task are created in order to execute them locally and remotely. This

benefit of this technique is realized by implementing in the SUIF2 compiler, the result shows huge speed up in the face recognition code on mobile applications. Thus, performance is improved.

An approach is demonstrated which provides a dynamic offloading technique, and takes into account the behavior of application execution. The whole history of the execution pattern is profiled which is then later used for taking the optimal computation offloading decision. The computation offloading decision is made for each resource that is static (offloads most used classes), dynamic (moves only invoked classes), no action, or profile for later use. The offloading technique is useful for applications with large running times. The application executes faster using this technique.

Its benefit is that decision is based on the actual conditions and taken at the execution time. Also, it is adaptable to different run-time conditions, such as fluctuating network bandwidths. While its disadvantage is its higher overhead as the program needs to monitor the run-time conditions.

## VI. FEATURES OF MOBILE CLOUD COMPUTING

Following are the features of Mobile cloud computing -

Reliability: The user can have access to data and various services using any mobile device at anytime and anywhere as long as user is connected to the Internet.

Scalability**:** The cloud services can scale up with less effort and modification to infrastructure to meet the dynamic demands of the users. Thus new users and applications can be added without any constraint.

Improved Storage Capacity**:** Storage is always a major constraint for the mobile devices. MCC enables users to store and retrieve large amount of data on the cloud using wireless networks. It helps in increasing the processing power as the processing is done on the cloud i.e. outside the mobile devices which in turn saves energy and storage space.

Easy Integration: Mobile cloud computing provides the benefit of integrating services from different service Providers in demand to the user requests with less effort.

Multiple Platforms: Users have the advantage of using the online services from any platform as the Mobile cloud computing supports multiple platforms.

Reduced Cost: Time consumption is less which in turn reduces cost. Thus Mobile Cloud Computing provides the benefit of cost reduction.

More battery life: Battery lifetime is always a problem when users executes complex and heavy applications. MCC provides advantage of executing applications on the cloud thus saving the power of mobile devices and results in long battery lifetime.

Various other features include security, agility and reduced maintenance.

## VII. CONCLUSION

Offloading is an important aspect of mobile cloud computing. It is a promising approach to overcome limitations of mobile devices and enhances the user experience. This paper provides a review of offloading and its decision making techniques, i.e. static and dynamic. Static offloading is

based on prediction model and takes more time while dynamic offloading is based on real time. Thus it can be concluded that offloading is important for the resource constrained devices, as it provides better user experience by reducing the execution time of applications and improves the performance by saving time and energy.

**Conflict of interest:** The authors declare that they have no conflict of interest.

**Ethical statement:** The authors declare that they have followed ethical responsibilities.

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