Computation-intensive offloading to cloud: concepts and challenges

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Abstract: Running heavy applications on intelligent mobile devices is increasing enormously. Applications of different domains such as scientific, business, social media, multimedia, games, and many more run excessively by mobile users. The users need reliable services and efficient execution of their intended applications in the mobile environment. Mobile Cloud Computing (MCC) fulfills the need of mobile clients for executing high-performance computing applications. Computational offloading is a trusted paradigm for running heavy applications. This study aims to discuss the concept of computation offloading where the heavy part(s) of an executing application offloads to the cloud for increasing computational resources. In MCC architecture cloud is a crucial component provides a resourceful infrastructure to resource constraint mobile devices. Intelligent computational offloading minimizes challenges related to all the components in the functional process; transforms mobile devices into a resource-rich environment. The cooperation among the components achieves an efficient high-performance computation for running heavy applications in the mobile cloud environment.

Keywords: Mobile devices, high performance computing, offloading, cloud computing, mobile cloud architecture.

I. INTRODUCTION

Since, computing technology has been influencing human in their professional and personal affairs. The technology inventions attract its users to adopt in every affair. It has significantly changed our approach for trade, education, and research. The unique feature of integration with other technologies stands alone computing technology. It evolves, embeds, and integrates with other technologies. The use and application of computing technology reached in every hand. The scale of its architectural development, functional behavior, ease of access, and performance efficiency has attracted people of every walk of life [1]. Moreover, the integration with mobile computing, cloud computing, and the intelligent system has drastically changed the user's consumption scale. Mobile Cloud Computing (MCC) describes as an infrastructure that facilitates high-performance computing and data storage in the cloud environment for performance efficiency. For Mobile Cloud Applications (MCA), the process of execution carries out in the cloud. The intelligent computational services are offered by the service providers on subscription for mobile users. [1]

The subscribed users consume MCC resources for computational power, dynamic memory allocation, storage, and energy efficiency. MCC architecture converts mobile devices into resource-rich devices with high-performance efficiency. [2]

In MCC architecture, mobile devices don't require having an extremely powerful configuration system. Because the computational competence required for executing a performance application is executed in the cloud. During the execution, the mobile device acts as an interface between the client and cloud resources. This is achieved by a reliable computing paradigm that offloads computational-intensive part of executing the application to the cloud, called computational offloading. An MCC architecture is heavily depends on offloading. This study aims to explore the offloading concepts and potential challenges in MCC architecture.

Figure 1: An abstract view of mobile access in cloud environment

The rest of this paper is structured as section two discusses the concept of cloud services and MCC service architecture. Section three provides offloading process in the mobile cloud environment and section four focuses on the analysis of major challenges. Finally, we conclude and write about future research direction.

II. CLOUD SERVICES

Cloud computing is an umbrella term used to refer to web-based development and services over the internet, group of interconnected computers with different sizes and configuration; provides services to the clients with a single interface. [3] Cloud services offered on subscription and its architecture can be broadly categorized into the following:

Software as a Service (SaaS): It is a model in which software is offered as a service to the user. It is hosted on service and users access the software by using a web browser.

Platform as a Service (PaaS): It offers a computing platform as a service. They are able to install the applications on a platform. The platform offers secondary functions such as web servers, database, and load balancing, etc.

Infrastructure as a Service (IaaS): The cloud offers platform virtualization to the customer. The user is offered a virtual machine with some storage instead of buying resources they just hire it.

MCC Architecture

Mobile cloud computing (MCC) at its simplest form refers to an infrastructure where both the data storage and the data processing happen outside of the mobile device [4].

MCC architecture is primarily based on cloud computing infrastructure and the integration of both cloud and mobile technology. Mobile cloud applications move the computing power and data storage away from mobile devices and into the cloud, bringing applications and mobile computing to not just smartphone users but a much broader range of mobile subscribers [1]. The execution of high-performance computing applications offloads to the cloud for performance efficiency.

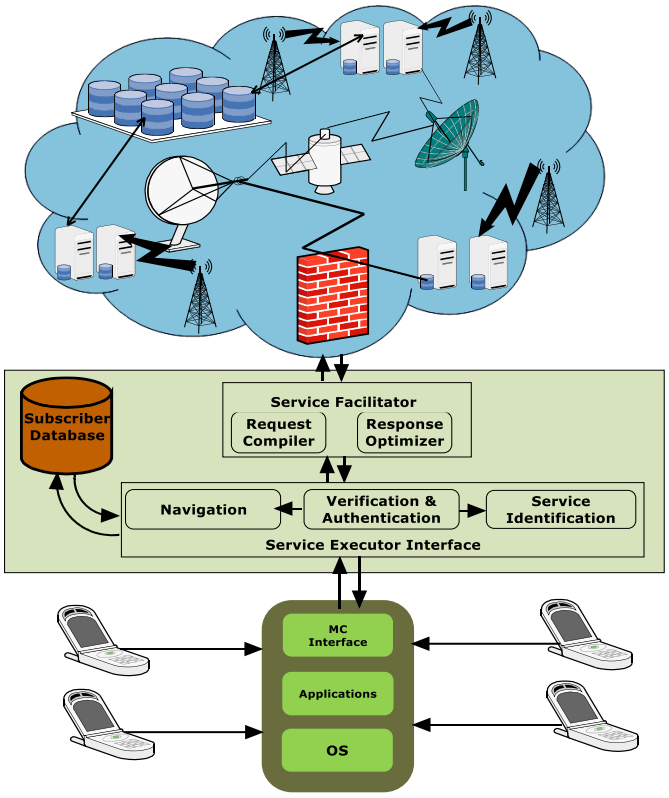

Figure 2: MCC service architecture for executing mobile cloud application

III. Offloading Concept in MCC

Offloading is a widely used concept in computing and communication technology. It offloads computational tasks to extremely powerful infrastructure. Offloading in MCC architecture inherits the offloading characteristics and it integrates with devices intelligence. The integration of intelligent mobile devices with cloud computing provides a resource-rich environment for mobile clients. Moreover, the offloading technique facilitates an efficient execution environment for mobile clients. [5] Cloud-based computation offloading helps the mobile devices to expand their cloud computing services on mobile applications by presenting virtually unlimited and dynamic resources of computations shown in figure 3. Therefore the small screen device helps to minimize the battery consumptions and implement applications which are not able to perform due to constraints resources. Recently mobile cloud applications such as, M-Healthcare, M-Learning, Social Networks, and Gaming involve robust communications which consume the device resources very heavily. Here, computation offloading strongly supports the execution and utilization of cloud resources.

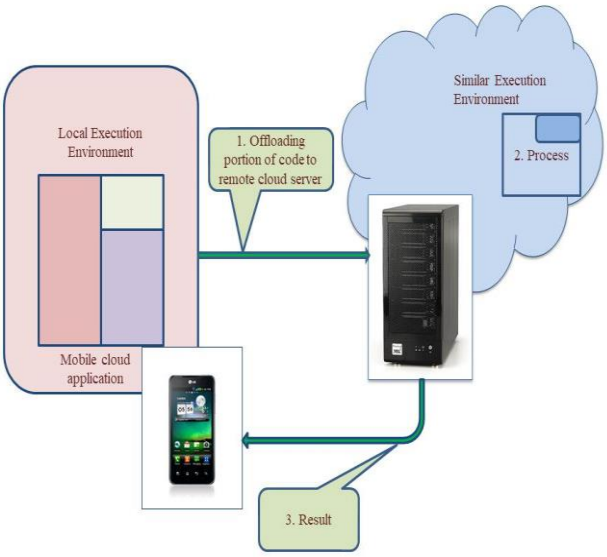

Figure 3: Offloading Process in MCC

Generally the cloud-based computation offloading processes as follows:

• First, the applications need to be divided into segments, offloading-centric.

• Second, the offloading decision takes on particular fulfillment of the application running which consumes most of the local resources energy. The offloading decision to the cloud on the parts of the running program is crucial; computation performs in the cloud to the local enactment of the mobile device upon receiving a transfer request. An offloading system requires a collateral enforcement environment as a mobile client. [6] The computing process creates a virtual machine (VM) for the mobile device requested for computation in the cloud.

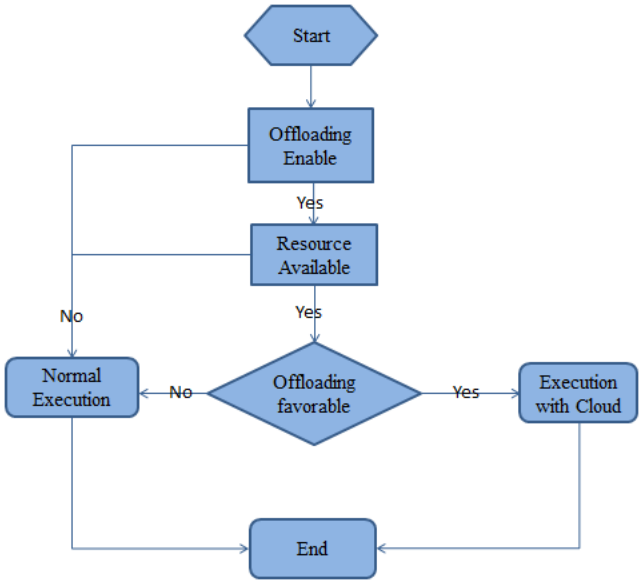

Figure 4: Offloading decision process

• Finally, the offloaded portion of the running application program returns to the device and integrates back to the original process. Therefor a cloud-based computation offloading improves performance and saves the device resources, more specifically, extends the battery life of the mobile device.

Usually, the computation offloading saves the device resources without degrading the normal response time of the mobile applications running in the mobile device. Many, research studies have been evolving for computation

offloading to the cloud and proved that it is one of the best solutions for improving computation performance and significantly saves the local device resources. [7] Further, the deficiency of computation offloading is determined by its capability to address (*what*, *when*, *where*, *how*) the following four fundamental questions: [8]

What to offload: Before offloading decision, the application needs to be partitioned using both static and dynamic annotations following partitioning, a mechanism at the actual run time and the offloading decision chooses what part of code should be offloaded.

When to offload: Different variables such as available transmission capacity, data size, and energy to execute the code influence the offloading decision. These variables consume local resources of the device; an offloading decision based on the variables improves the performance of the executing application. The code for offloading the computation part of the application has to be executed locally whereas the computation-intensive part of the application executes in the cloud away from the mobile client. Moreover, this minimizes the transmission execution time of the application offloading to the cloud and avoids network conjunction.

Where to offload: This identifies the target location in the cloud to offload the computation-intensive code has to be offloaded.

How to offload: It introduces a code of offloading program which describes how the devices have to schedule code offloading operations.

IV. Computation Offloading Challenges in Mobile Cloud Environment

As shown in **figure 5**, MCC is the result of the integration of mobile communication devices, communication network, and cloud environment. The MCC architecture inherits the functionality of these technology and diverse in nature. MCC architecture is complex if any of the cooperative technology or component(s) are failed to function effectively in the offloading process, the effectiveness of MCC architecture deteriorated. Further, each cooperating technology contains several sub-technologies which are required to function effectively during the computational offloading. [9]

The new development to the cooperating technology will help in improving MCC performance for example; the fifth generation mobile network which is expected to be operational by 2020 is prepared to support various types of emerging applications with a strong quality of service. [10] It is also going to provide strong support for different co-existing radio access technologies to carry out high data traffic. [11]

Computation offloading for high-performance computing (HPC) applications such as healthcare, image processing, business and many more are based on user preferences and will be more effective. [12]

There are certain limitations with the existing MCC architecture; it is difficult to find a quality link between varied wireless networks, to obtain multiple cloud services, [13] and failed to prioritized user preferences of mobile clients.

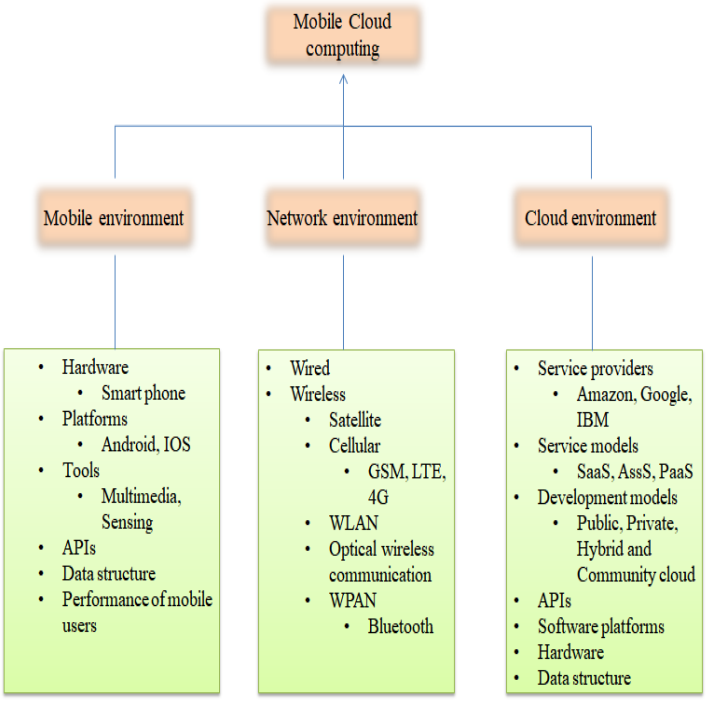

Figure 5: The diversity tree in mobile cloud environment

A. Performance Criteria

Clients the MCC environment, required to consume authentic services at different levels of the service architecture. Additionally, the clients heavily depend on intensive computation, service on demand, low latency, quick response time, and low-cost service consumption for the execution of their applications. [14]

B. Cloud Service Recommendation

The satisfaction of mobile cloud clients has compelled the researchers to discover new solutions to bring cloud services and resources closer to them [14]. The recommended solutions are not replacing but enhancing the cloud computing service model; this is an essential requirement of MCC clients to overcome the limitations for executing efficiently their computation-intensive applications.

C. Mobility

It is the most needed aspect in MCC environment. The cloud architecture strongly supports mobility and overcomes the limitations of executing mobile applications using different cloud platforms shown in **figure 6**. The cloud service architecture enhances the mobility for the clients in MCC. The integration of both improves computation offloading. Here, the computation tasks of executing applications sent to different locations depending on the requirements. Locations such as cloud data center, cloudlet, mobile cloudlet or any location in MCC architecture. [14] The results of the intensive computation are received by the device irrespective of its location. The effective coordination among these technologies attains sufficient mobility in the process of computation offloading.

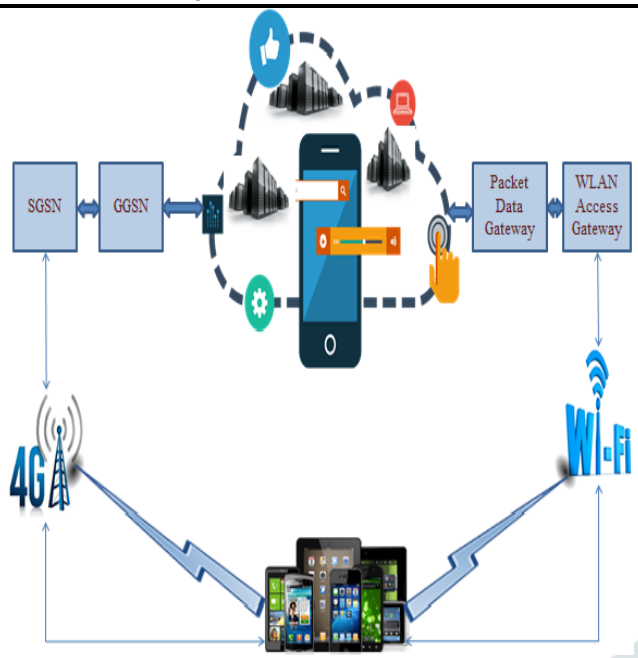

Figure 6: Cloud access platform in mobile environment

V. Conclusion and Future Work

In this paper, we presented MCC concept, computation intelligence, and specific challenges encountered in computational offloading. The study determines that MCC architecture is heavily depends on offloading when executing high-performance computing applications. It identifies the intelligence of computational offloading that explains partial offloading. Partial offloading that describes how few segments of executing code of an application offload to the cloud. The partial offloading process heavily depends on MCC components such as device configuration, bandwidth, latency time, service providers, and cloud infrastructure. The efficient contribution of these components increases efficiency otherwise it degrades the efficiency and leads to different challenges. The challenges such as unnecessary consumption of MCC resources like bandwidth, execution time, delay in quick response time, longer data transfer rate and high energy cost. Performance efficiency achieves by overcoming these challenges. The computational offloading will be effective only if all the cooperating components in MCC architecture perform seamlessly. In future, the work can be taken up in many aspects like, we propose service architecture for mobile communication in cloud environment and elaborate major applications such as computation offloading for battery energy efficiency. It virtually reduces computational cost and mobility issue by implementing the derived formula on specific condition.

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