Increase the Performance of Mobile Smartphones using Partition and Migration of Mobile Applications to Cloud Computing

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Abstract

With the increasing use of smartphones devices, mobile applications with richer functionalities are becoming ubiquitous but mobile devices are limited by their resources for computing and power consumption. Cloud the place for abundant resources. Clouds provide opportunity to do huge computations quickly and accurately so we can use cloud for mobile computations. Mobile Cloud Computing (MCC) which combines mobile computing and cloud computing, has become one of a major discussion thread in the IT world in the recent few years. We developed an architecture that uses cloud to do computations that consume resources badly on mobiles. It aims at finding the right spots in an application automatically where the execution can be partitioned and migrated to the cloud. Thus, an elastic application can augment the capabilities of a mobile device including computation power, storage, and network bandwidth, with the light of dynamic execution configuration according to device's status including CPU load, memory, and battery level. We demonstrate results of the proposed application model using data collected from one of our elastic application.

Keywords: Cloud computing, GPS, Mobile cloud computing (MCC), Offloading, Partitioning and migration

1 Introduction

Together with an explosive growth of the mobile applications and emerging of cloud computing concept, mobile cloud computing (MCC) has been introduced to be a potential technology for mobile services. MCC integrates the cloud computing into the mobile environment and overcomes obstacles related to the performance (e.g., battery life, storage, and bandwidth), environment, and security (e.g. Confidentiality, reliability and privacy) discussed in mobile computing. Mobile devices (e.g., smartphone, tablet pcs, etc) are increasingly have become the primary computing platform for many users [1, 2, 3]. Mobile users accumulate rich experience of various services from mobile applications (e.g., iPhone apps, Google apps, etc), which run on the devices and/or on remote servers via wireless networks. The rapid progress of mobile computing (MC) becomes a powerful trend in the development of IT technology as well as commerce and industry fields. However, the mobile devices are facing many challenges in their resources (e.g., battery life, storage, and bandwidth) and communications (e.g., mobility and security). The limited resources significantly impede the improvement of service qualities. Various studies have identified longer battery lifetime as the most desired feature of such systems. Cloud computing (CC) has been widely recognized as the next generation's computing infrastructure. CC offers some advantages by allowing users to use infrastructure (e.g., servers, networks, and storages), platforms, and software (e.g., application programs) provided by cloud providers (e.g., Google, Amazon, and Salesforce) at low cost. In addition, CC enables users to elastically utilize resources in an on-demand fashion [4, 5]. As a result, mobile applications can be rapidly provisioned and released with the minimal management efforts or service provider's interactions. With the explosion of mobile applications and the support of CC for a variety of services for mobile users, mobile cloud computing (MCC) is introduced as an integration of cloud computing into the mobile environment.

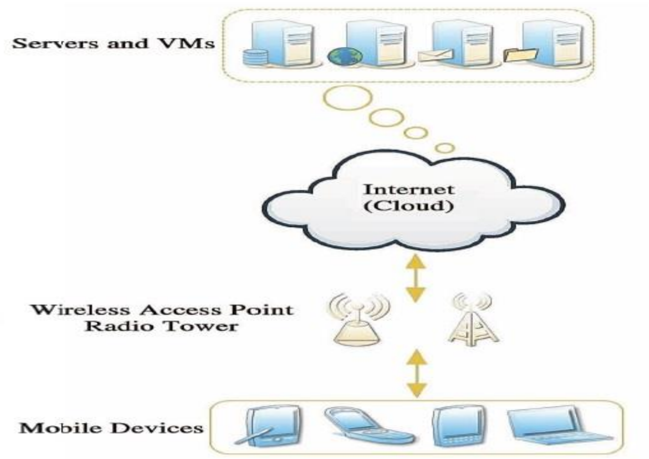


Figure 1: Mobile Cloud Computing (MCC)

Mobile cloud computing (Figure 1) brings new types of services and facilities for mobile users to take full advantages of cloud computing. This paper introduces the basic terminology of cloud computing and mobile cloud computing, its background, key technology, current research status, and its further research perspectives as well.

The rest of the paper is organized as follows. Section 2 present cloud computing definitions and basic terminology of mobile cloud computing and its architectures Following that, respectively in the next section the discussion of related work of mobile cloud computing. Following that, Section 4 presents problem definition and system model, and the description of partition cost module and the evaluation. Finally, the conclusion lies in the last section.

2 Overview of Mobile Cloud Computing

In order to help us better understanding of Mobile Cloud Computing, let's start from the two previous techniques: Mobile Computing and Cloud Computing followed by mobile cloud computing.

A. *Mobile Computing*
B. *Cloud Computing*
C. *Mobile Cloud computing*

A. *Mobile Computing*

Mobile computing exactly is described as a form of human-computer interaction by which a computer is expected to be transported during normal usage [6, 7]. Mobile computing is based on a collection of three major concepts: hardware, software and communication. The concepts of hardware can be considered as mobile devices, such as smartphone and laptop, or their mobile components. Software of mobile computing is the numerous mobile applications in the devices, such as the mobile browser, anti-virus software and games. The communication issue includes the infrastructure of mobile networks, protocols and data delivery in their use.it should have the following feature (mobility, Diversity of network conditions, frequent disconnection and consistency, Dis-symmetrical network communication, and Low reliability)

- ***Current status of mobile applications***

Several researchers, [8, 9], have identified the fundamental challenges in mobile computing. Mobile computing environments are characterized by severe resources constraints and frequent changes in operating conditions.

(1) *Offline Applications*: Fat Clients with presentation and business logic processed locally. In offline applications data downloaded from backend. Its advantages(Well Integrated, Optimized Performance, Availability :even without network connectivity).its disadvantages (No Portability, Complex

(2) *Online Applications:* Online Applications: Only presentation layer at the client. All processing done online. Assume constant connectivity with backend. Its advantages: Multiplatform, Direct and Instantaneous Accessibility to better services and its disadvantages: Excessive latency for real time responsiveness, no access to device features, sometimes difficult to maintain sessions for a long time.

B. *Cloud Computing*

[10, 11, 12] Cloud computing refers to the hardware, systems software, and applications delivered as services over the Internet (Figure 2). When a cloud is made available in a payas-you-go manner to the general public, we call it a

Public Cloud. The term Private Cloud is used when the cloud infrastructure is operated solely for a business or an organization. A composition of the two types (private and public) is called a Hybrid Cloud, where a private cloud is able to maintain high service availability by scaling up their system with externally provisioned resources from a public cloud when there are rapid workload fluctuations or hardware failures.

In general, cloud providers fall into three categories:

(1) Infrastructure as a Service (IaaS): offering web-based access to storage and computing power. The consumer does not need to manage or control the underlying cloud infrastructure but has control over the operating systems, storage, and deployed applications.

(2) Platform as a Service (PaaS): giving developers the tools to build and host web applications (e.g., APPRIO [13], software as a service provider, is built using the Force.com [14] platform while the infrastructure is provided by the Amazon Web Service [15]). The users host an environment for their applications. The users control the applications, but do not control the operating system, hardware or network infrastructure, which they are using.

(3) Software as a Service (SaaS): where the consumer uses an application, but does not control the operating system, hardware or network infrastructure. In this situation, the user steers applications over the network. Applications that are accessible from various client devices through a thin client interface such as a web browser.

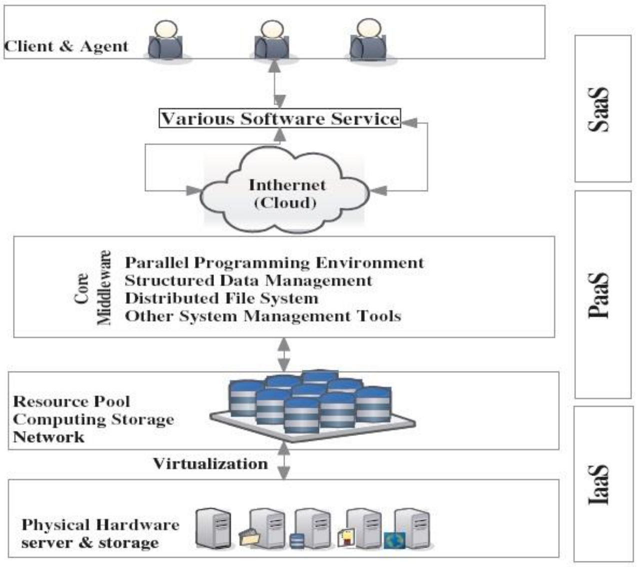


Figure 2: The framework of cloud computing

C. *Mobile Cloud computing*

There are several definitions of mobile cloud computing [16, 17], and different research refers to different concepts of the ‘mobile cloud:

The term mobile cloud computing means to Mobile Cloud computing a combination of cloud computing, wireless infrastructure, portable devices, and location based services have given rise to it. Mobile cloud computing is a model for transparent elastic augmentation of mobile device’s capability.The main objective of mobile cloud computing is to provide a convenient and rapid method for users to access and receive data from the cloud, such convenient and rapid method means accessing cloud computing resources effectively by using mobile devices.

3 Related Works

To give more prospective about the Mobile Cloud Computing, this section discusses the results obtained from other resource.

It was shown in [18] executes video games in the cloud and delivers video stream to resource-poor clients without interrupting the game experience. Many other examples where the cloud can augment mobile devices can be envisioned, e.g. virus scan, mobile file system indexing, augmented reality applications.

In [19] uses VM migration to offload part of their application workload to a resourceful server through either 3G or WiFi. CloneCloud (Figure 3) was tested using Android phones with the clones executing on a Dell desktop running Ubuntu. The system is a flexible application partitioned and execution runtime. It enables unmodified mobile applications to offload part of their execution from mobile devices onto device clones operating in a computational cloud.

It was presented in [20] 'Hyrax' for Android smartphone applications which are distributed both in terms of data and computation based on Hadoop ported to the Android platform. Hyrax (Figure 4) explores the possibility of using a cluster of mobile phones as resource providers and shows the feasibility of such a mobile cloud. As a sample application, they present 'HyraxTube'; which is a simple distributed mobile multimedia search and sharing program. The objective of HyraxTube is to allow users to search through multimedia files in terms of time, quality, and location. There are several of researches about Mobile Cloud Computing can be found in [21, 22, 23, 24]

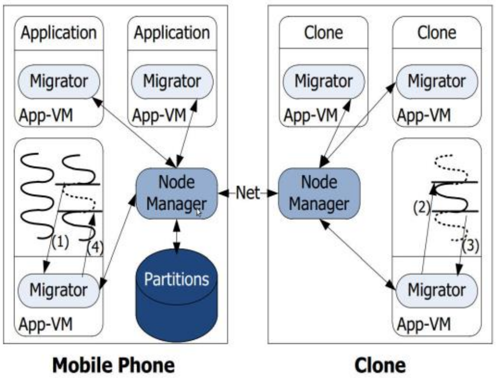


Figure 3: CloneCloud migration overview

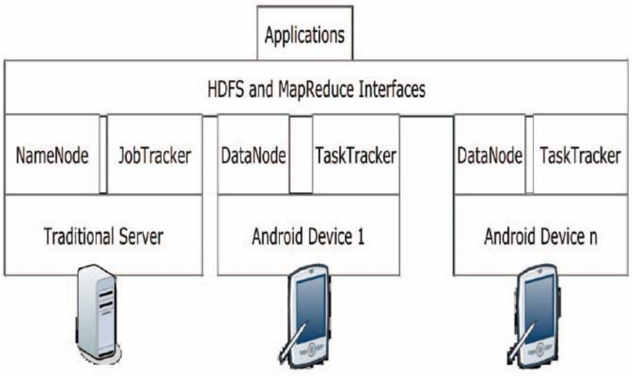


Figure 4: Hyrax infrastructure

4 Problem Definition and System Model

In this section, we present a model for application execution on the cloud-assisted mobile application platform. Application system architecture as shown in Figure 5, first, we define a mobile application profile. Then, we calculate consuming resources for application execution, including resources consumed for computation on mobile execution and a transmission computation to cloud execution. The following Sequence steps for our framework application as shown in Figure 6. We use a mobile smartphone SAMSUNG GALAXY GRAND 1.2 GHz Dual Core CPU, and Android 4 Operating Systems in which performance data is collected and tested. In the experiments, the GPS Test Performance application smartphone calculate some of GPS calculations such as distance between two points or more till 100 points using different algorithms. For our experiment, we calculate the effects of Sending computation to cloud web service and back with results and studying the Offloading computation to save energy on power consumption for smartphone mobile in case of running all processes of application on mobile or by partition and offloading processes to cloud

***In the first step**:* Comparison is conducted using two different types of GPS mode (using mobile GPS), and using mobile network.for each type of GPS, we can get latitude and longitude for each point (it can be calculated by mobile GPS satellite or by mobile network)

***In the second step**:* After selecting GPS mode of operations, we have to choose between manual or automatic calculation to get latitude or longitude for each point

- If automatic calculation is selected, we have to enter number of points and system get points every thirty second;
- If manual calculation is selected, we have to click to get points.

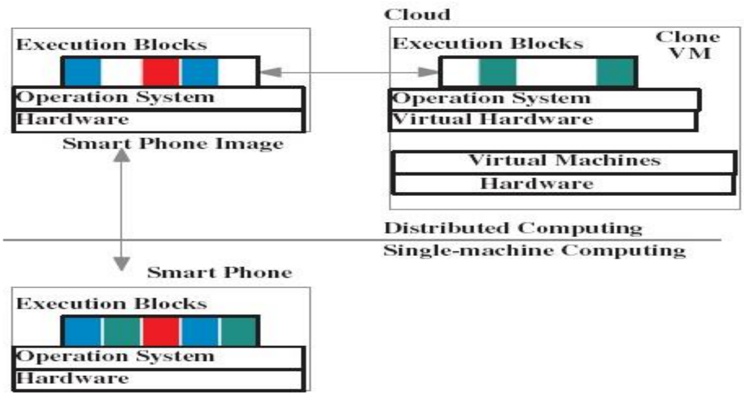


Figure 5: The application system architecture

***In the third step**:* After selecting method to get points either manually or automatic, we have to choose between calculation way on mobile or by partition and offloading to perform part of calculation on mobile and part on cloud server.

A. **In case calculation on mobile**, calculation is conducted in case of getting points manually or automatic Mobile Application will take GPS reading and perform calculations over certain period of time.
   (1) GPS reading to determine latitude and longitude for each point either by GPS for mobile (smart phone, satellite) or from mobile network.
   (2) Then calculate the distance between two point or more using different algorithms.
   (3) The Application will perform all calculations on smart phone device and calculate the results and the consuming resources such as Memory consumed, CPU usage, Time consumed for calculation, battery consumed to perform the processes, time consumed for calculations and for getting points.

B. **In case of partition and offloading calculation on cloud and mobile**, we implement cloud clone application that enables the mobile applications developers to take decision of performing all application processes on an android mobile device or to divide the application processes to execute on mobile & cloud.
   (1) GPS reading to determine latitude and longitude for each point either by GPS for mobile (smart phone, satellite) or from mobile network (this step execute on mobile device).
   (2) Then data (longitude and latitude for each point) is transmitted to cloud server to perform calculation on cloud.
   (3) The distance between two points or more using different algorithms calculations performed on cloud the distance between two points or more using different algorithms.
   (4) The Application will perform distance calculations on cloud server and calculate the results and the consuming resources such as Memory consumed for sending and receiving results, Memory consumed for distance calculations only, Memory consumed for all process from getting points till receive results, CPU usage, Time consumed for calculation, battery consumed to perform the transmitting data, time consumed for calculations and for getting points.

4.1 Mathematical Calculation

Distance using Haversine formula: For our experiment, distance calculations between two point using the ‘haversine’ formula to calculate the great-circle distance between two points – that is, the shortest distance over the earth’s surface. The formula assumes that the earth is a sphere, (we know that it is "ellipse" shaped) – giving an ‘as-the-crow-flies’ distance between the points (ignoring any hills, of course!).

Haversine Formula:

$$a = \sin^2(\Delta\phi/2) + \cos(\phi_1).\cos(\phi_2).\sin^2(\Delta\lambda/2)$$
$$c = 2.\text{atan2}(\sqrt{a}, \sqrt{(1-a)})$$
$$d = R.c$$

$\Delta\phi$ is latitude difference (lat2– lat1), $\Delta\lambda$ is longitude difference (long2– long1), R is earth’s radius(mean radius = 6,371km).

Distance using Spherical low of Cosines: When Sinnott published the haversine formula, computational precision was limited. Nowadays, most modern computers & languages use IEEE 754 64-bit floating-point numbers, which provide 15 significant figures of precision. With this precision, the simple spherical law of cosines formula gives well-conditioned results down to distances as small as around 1 metre.

Spherical law of cosines formula:

$$d = \text{acos}(\sin(\varphi1).\sin(\varphi2) + \cos(\varphi1).\cos(\varphi2).\cos(\Delta\lambda)).R$$

Distance using Equirectangular approximation: If performance is an issue and accuracy less important, for small distances Pythagoras’ theorem can be used on anequirectangular projection.

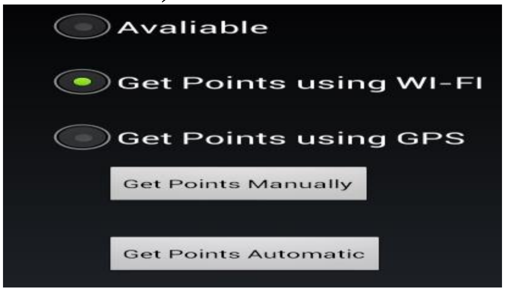
Formula:

$$x = \Delta\lambda.\cos(\varphi)$$
$$y = \Delta\varphi$$
$$d = R.\sqrt{(x^2 + y^2)}$$

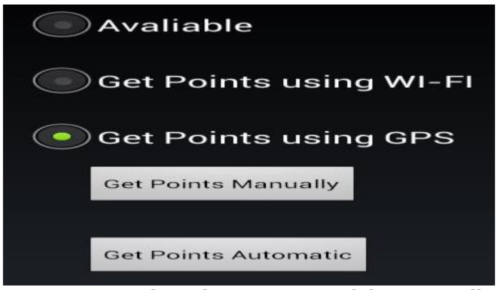
4.2 Experiment (Manual Calculations)

4.2.1 Getting Points using GPS Satellite

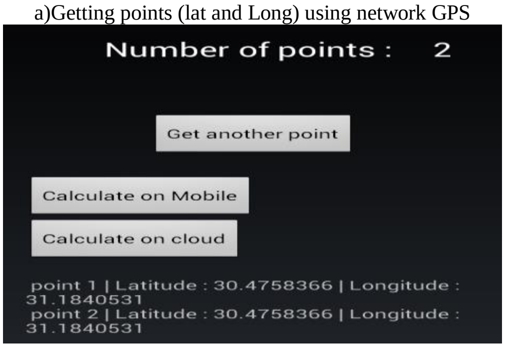
Table 1 shows memory consumed in case of manual calculation in case of getting longitude and latitude for each point manually using GPS satellite for execution application on cloud web services and the for different number of points range from two points till ten points [GPS calculation on mobile smartphone and calculation moved to cloud and return results to mobile).



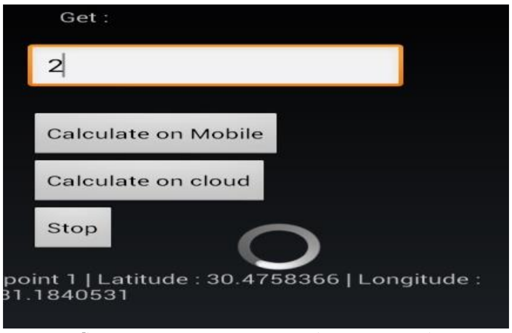
a)Getting points (lat and Long) using network GPS



b) Getting points (lat and Long) using Mobile GPS Satellite



c) Getting points manually



d)Getting Points Automatic(every 30 Sec)

Figure 6: Snapshot of elastic GPS application on Samsung Galaxy Grand

Table 1: Resources consumed for execution application on cloud web services (getting points using gps satellite)

	Calculations on Cloud			
# of points	GPS memory consumed	connection to cloud memory	Memory consumed for calculation only	Total Memory on Mobile
2	5.050582	1.343775	85.58896	6.394357
3	7.625728	0.7984205	90.784704	8.4241485
4	10.564673	1.27652	102.56821	11.841193
5	13.60835	0.045329	103.8482823	13.653679
6	12.671564	0.431785	106.742794	13.103349
7	20.9655	0.57854	106.8743	21.54404
8	25.56983	0.2678985	101.769765	25.8377285
9	20.87329	0.45698	97.894871	21.33027
10	22.5389	0.53489	108.87314	23.07379

Table 2: Resources consumed in case of partition and offloading to cloud web services (GPS Satellite)

Calculations on mobile Smartphone			
# of points	GPS Memory consumed	Calculation Memory consumed	Total Memory
2	15.027344	31.971785	46.999129
3	14.988281	12.453125	18.10156225
4	12.3945313	12.3125	15.4726563
5	16.328125	8.484375	18.44921875
6	20.3945313	16.3125	24.4726563
7	22.378906	23.34375	28.2148435
8	29.296875	24.3125	35.375
9	26.800781	28.3125	33.878906
10	23.34375	32.484375	31.46484375

Table 2 shows memory consumed for execution all application on mobile smartphones. The memory unit is bytes.

Experimental results are shown in Figures 7, 8, and 9 for different data calculations using manual method for getting longitude and latitude for each point rang from calculating distance between two points till ten points in case of distance range from approximately 100 meter till 16 kilo meter in case of all calculation done on mobile device or application is partitioned and offloading on cloud to perform distance calculation on cloud.
(Figure 7) shows the results of portioned and offloading application and getting latitude and longitude for each point on mobile smart phone and executes distance calculations on cloud. The results include the following matrices:

- Memory consumed on mobile (bytes) for GPS calculation only (getting longitude and latitude for each point).
- Memory consumed on cloud (bytes) for calculating distances between points on cloud.
- Memory consumed for send points longitudes and latitudes to web services or receive results from web services to mobile smart phone.
- Total memory consumed on mobile smartphone for calculations.

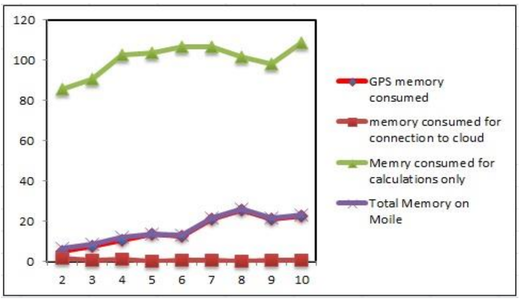


Figure 7: Memory consumed for execution application on cloud (Bytes)

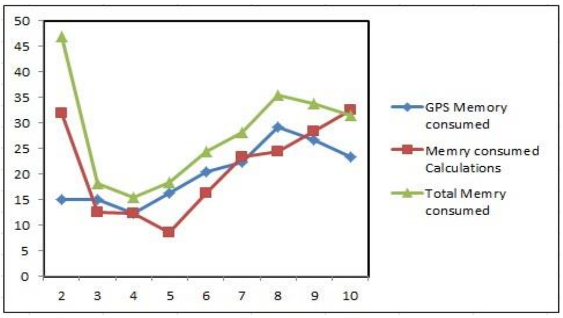


Figure 8: Memory consumed for execution application on mobile (Bytes)

Figure 8 shows the results of execute all application processes on mobile smartphone only. The results include the following matrices:

- Memory consumed in bytes for GPS calculation only (getting longitude and latitude for each point).
- Memory consumed in bytes for calculating distances between points.
- Total Memory consumed to execute application in Mega Hertz.

From the previous two figures: Figures 7 and 8. The performance of execute application on mobile or cloud in terms of memory consumed using different distance and number of points are shown in Figure 9. The total memory consumed on mobile in the case of cloud or in the case of executed all the application on mobile only.

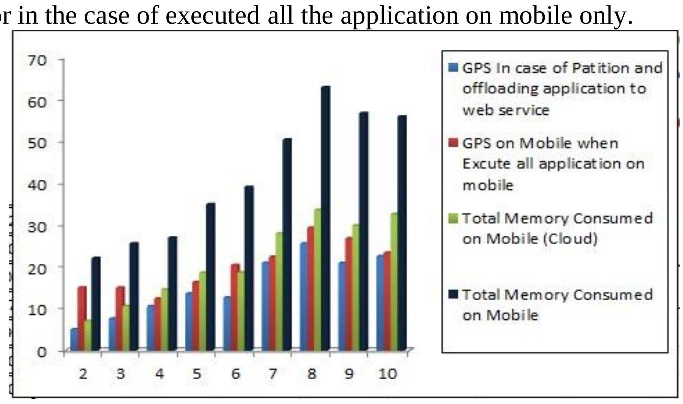


Figure 9: Total memory consumed on mobile for execution application on cloud and on mobile

Results analysis:
According to partition algorithm, most of resources consumed on mobile smartphone will decrease to approximately to half as shown in Figure 9. In case of partition and offloading application most of resources consumed on cloud and minimize the resources consumed in mobile smartphone as shown in Figures 7 and 9.

4.2.2 Getting Points using Network GPS

Table 1 shows memory consumed in case of manual calculation in case of getting longitude and latitude for each point manually using Network GPS and Table 2 shows memory consumed for execution all application on mobile smartphones. The memory unit is bytes.

Experimental results are shown in Figures 10, 11, and 12 for different data calculations using manual method for getting longitude and latitude for each point rang from calculating distance between two points till ten points in case of distance range from approximately 100 meter till 16 kilo meter in case of all calculation done on mobile device or application is partitioned and offloading on cloud to perform distance calculation on cloud.

Table 3: Resources consumed for execution application on cloud web services (Getting points using Network GPS)

Calculations on Cloud				
# of points	GPS memory consumed	connection to cloud memory	Memory consumed for calculation only	Total Memory on Mobile
2	**14.050781**	**1.109375**	**89.058594**	**15.160156**
3	**10.60156**	**0.765625**	**93.7709375**	**11.367185**
4	**1.0546875**	**1.3242188**	**103.6210937**	**2.3789063**
5	**3.609375**	**0.02734375**	**103.0632813**	**3.63671875**
6	**2.8515625**	**0.546875**	**103.4296875**	**3.3984375**
7	**25.8125**	**0.515625**	**80.5**	**26.328125**
8	**15.6645**	**0.23828125**	**91.7345**	**15.90278125**
9	**20.324219**	**0.484375**	**86.8710935**	**20.808594**
10	**9.949219**	**0.51953125**	**98.64975**	**10.46875025**

Table 4: Resources consumed in case of partition and offloading to cloud web services (Network GPS)

Mobile Calculations			
# of points	GPS Memory consumed	Calculation Memory consumed	Total Memory
2	**15.027344**	**10.84375**	**25.871094**
3	**14.988281**	**13.3127304**	**28.3010114**
4	**2.3945313**	**15.56688**	**17.9614113**
5	**6.328125**	**16.9151816**	**23.2433066**
6	**2.3945313**	**21.501**	**23.8955313**
7	**37.378906**	**17.818392**	**55.197298**
8	**9.296875**	**25.515936**	**34.812811**
9	**26.800781**	**21.91938**	**48.720161**
10	**19.34375**	**29.1054**	**48.44915**

Figure 10 shows the results of portioned and offloading application and getting latitude and longitude for each point on mobile smart phone and executes distance calculations on cloud. The results include the following matrices:

- Memory consumed on mobile (bytes) for GPS calculation only (getting longitude and latitude for each point).
- Memory consumed on cloud (bytes) for calculating distances between points on cloud.
- Memory consumed for sending points longitudes and latitudes to web services or receive results from web services to mobile smart phone.
- Total memory consumed on mobile smartphone for calculations.

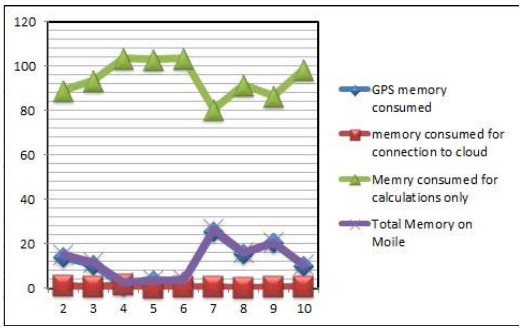


Figure 10: Memory consumed for execution application on cloud (Bytes)

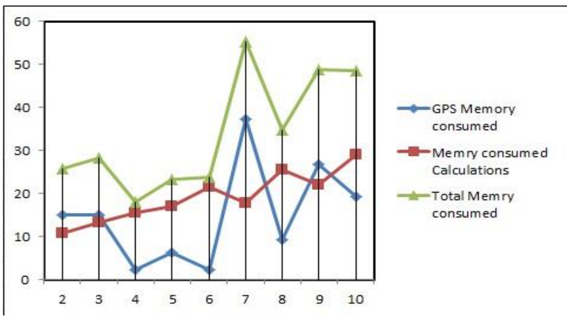


Figure 11: Memory consumed for execution application on Mobile (Bytes)

Figure 11 shows the results of execute all application processes on mobile smartphone only. The results include the following matrices:

- Memory consumed in bytes for GPS calculation only (getting longitude and latitude for each point).
- Memory consumed in bytes for calculating distances between points.
- Total Memory consumed to execute application in Mega Hertz.

From the previous two figures: Figures 10 and 11. The performance of execute application on mobile or cloud in terms of memory consumed using different distance and number of points are shown in Figure 12. The total memory consumed on mobile in the case of cloud or in the case of executed all the application on mobile only.

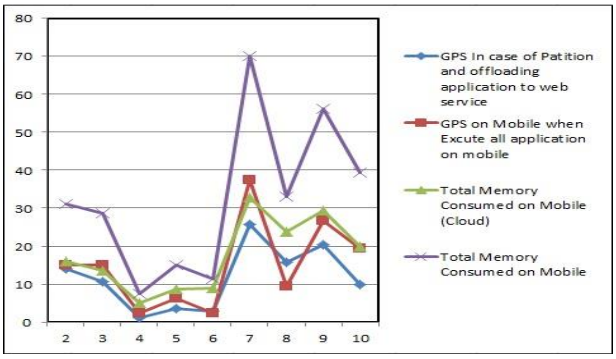


Figure 12: Total Memory consumed on mobile for execution application on cloud and on mobile

Results analysis:
According to partition algorithm, most of resources consumed on mobile smartphone will decrease to approximately half as shown in Figure 11. In case of partition and offloading application, most of resources consumed on cloud and minimized the resources consumed in mobile smartphone as shown in Figures 10 and 12.

5 Conclusion and Future Work

In this paper, we proposed the elastic partition algorithm and partition cost module. Sending computation to another machine is a good idea. Thus, cloud computing can save energy for mobile users through computation offloading. Virtualization, a fundamental feature in cloud computing, lets applications from different customers run on different virtual machines, thereby providing separation and protection. The advantages of Mobile Cloud Computing: Cloud computing can be a promising solution for mobile computing due to many reasons (e.g., mobility, communication, and portability so that cloud can be used to overcome obstacles in mobile computing, thereby pointing out advantages of MCC. Mobile cloud computing can extending battery lifetime (Battery is one of the main concerns for mobile devices). And can reduce power consumption for mobile devices. these solutions require changes in the structure of mobile devices, and mobile application .Computation offloading technique is proposed with the objective to migrate the large computations and complex processing from resource-limited devices (i.e., mobile devices) to resourceful machines (i.e., servers in clouds). This avoids taking a long application execution time on mobile devices which results in large amount of power consumption. The results demonstrate that the remote application execution can save energy significantly
In mobile cloud computing, application offloading is implemented as a software level solution for augmenting computing capabilities of smart mobile devices. In this paper, we present a survey of the energy-efficient technologies in mobile cloud computing, provide the definitions and architectural designs of MCC. We summarize related works in energy-efficient wireless transmission.

We believe that there are still great opportunities for researchers to make ground-breaking contributions in this field, thus bringing significant impacts to the development in the industry. We hope our work will provide a better understanding of design challenges surrounding energy-efficient MCC.

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