Performance Improvement of Wireless Mobile Communication through Offloading

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CERTIFICATION

This thesis paper titled "**Performance Improvement of Wireless Mobile Communication through Offloading**", submitted by the group as mentioned below has been accepted as satisfactory in partial fulfillment of the requirements for the degree of B.Sc. in Electrical, Electronics and Communication Engineering on December,2014

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DECLARATION

This is to certify that the work presented in this thesis paper is the outcome of extensive study and research carried out by the following students under the supervision of Dr. M. Shamim Kaiser, Asst. Professor, Department of Institute of Information Technology, Jahangirnagar University, Savar, Dhaka.

It is also declared that neither this thesis paper nor any part thereof has been submitted elsewhere for any degree, diploma or other qualifications.

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ABSTRACT

Mobile phone is now a device which is used for different types of processing. Cellular communications have made anytime anywhere communication with anyone. But the main constrain is the processing power and Energy required to drive it. Cloud computing has come as a blessing for the mobile computing as it possess a vast resource, high storage capacity, high processing power and high speed. Mobile Cloud computing computation has been offloaded to the cloud, cloud process on data and generates information and processed information is fed back to the mobile device. Thus, offloading means rendering data to the cloud (Internet) where computation would take place. It is expected that processing time in cloud is less than that of mobile. Probability of offloading depends on some parameters i.e. line bandwidth, line length, processing speed of mobile, processing speed of cloud, storage and energy capacity of mobile etc. User can experience different path while offloading. A large path would cost more time to offload. In addition, amount of data to be computed is not always same. When data computation is small, it is more economical and convenient to process them in mobile. Algorithm proposed here for offloading probability (OP) is based on an exponential function. OP increases exponentially with the increase of “computation data” and “allotted bandwidth”. There are maximum limits of “computation data” and “allotted bandwidth” after which OP is 1. This report will show a successive way to decide whether someone should offload or not.

SYMBOLS

W	Data to be computed
ds	Sending data from mobile to cloud
dr	Receiving data from cloud to mobile
S_m	Processing speed of mobile
S_c	Processing speed in cloud
T_{mobile}	Total processing time in mobile
T_s	Sending queue delay
T_c	Processing delay in cloud
T_p	Path delay
T_r	Receiving queue delay
$T_{offload}$	Time taken to offload
T_{total}	Total processing time
P_m	Required power by mobile system for data processing
P_s	Required power to send data from mobile to cloud
P_c	Required power for computing data in cloud

P_r	Required power for receiving data from cloud to mobile
E_{mobile}	Required energy for mobile to process the data
$E_{offload}$	Required energy for offloading data from mobile to cloud
E_{total}	Total energy consumption
B	Bandwidth
c	Velocity of light

ABBREVIATIONS

OP	Offloading Probability
IT	Information Technology
CC	Cloud Computing
MCC	Mobile Cloud Computing
NIST	National Institute of Standards and Technology
API	Application Program Interface
SaaS	Software-as-a-Service
PaaS	Platform-as-a-Service
IaaS	Infrastructure-as-a-Service
CE	Cost Effective
PC	Personal Computer
MC	Mobile Computing
MNO	Mobile Network Operator

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CHAPTER 1

INTRODUCTION

1.1 Overview

Cloud computing, in a whole, refers the sharing of Application, Platform and Infrastructure. Here remote servers are connected to make a broad network to share software, hardware and storage. Users from anywhere having the access to this network can use this resource any time. This facilitates every user with the issues such as cost effectiveness (CE), mobility, high computation power etc. In cloud base computation end users have different devises. But everybody can have the same services as data processing and storage are arranged in a central way. End users offload data to the cloud where data is analyzed according to the user requirement to send data back to end users. As the amount of computation data increases, the probability of using cloud computation increases. This probability also depends on band width of communication line, end user processing speed and cloud processing speed.

1.2 Problem statement

With the pace of technological growth, data computation has become a big concern. Large amount of computation demands complex hardware availability, large storage, reliable software and huge power consumption which make it costly. Problems that we face in traditional computation system are below.

- People, now a days, use smartphone or tablet to get many services like news, weather, entertainment, social networking, games, travel, mail, image processing, voice synthesizing, data analysis etc. And it is not possible to facilitate everyone with the hardware, software and storage to get these services by their own in such a small devices (mobile, tablets etc.) as it is wouldn't be cost effective (CE).

- Traditional computer setup requires users to be in the same place as the data storage. But our demand is to get any service from anywhere regardless the position of the resources. For example- everyday morning we check our mail, or brows social network in Desktop. As the time passes we can't keep ourselves stuck in our home. We have to go to our work places. Or in a vacation we may go to a place far more than our country. So it would be convenient to keep our data or get computation facility from a source we don't have to carry.
- In addition to it, different users uses different devices like mobile, laptop, tablet, desktop, smart TV, Google devices etc. They could be manufactured by different companies or run by different operating system. So, every device may not have the capability to run the same software for a particular service as software is made for only one operating system.

Problems addressed above triggered the necessity of cloud computing. Cloud computing is a process where third parties take the responsibility to compute data. They are called resource provider [1]. People from different places using different devices take the advantage from resource provider. A resource provider should provide below advantages-

- It should reduce the power consumption
- It should provide storage, software, processing power, processing hardware
- It should facilitate mobility of service
- It should provide a wide network

Examples of some resource providers are social networking sites, file sharing sites, Google map, YouTube, Google translator, online news portals, online gaming sites, online businesses sites, online shopping sites etc.

1.3 Assumptions and Limitations

- A scenario is assumed where an end user is accessing to the cloud to offload data.

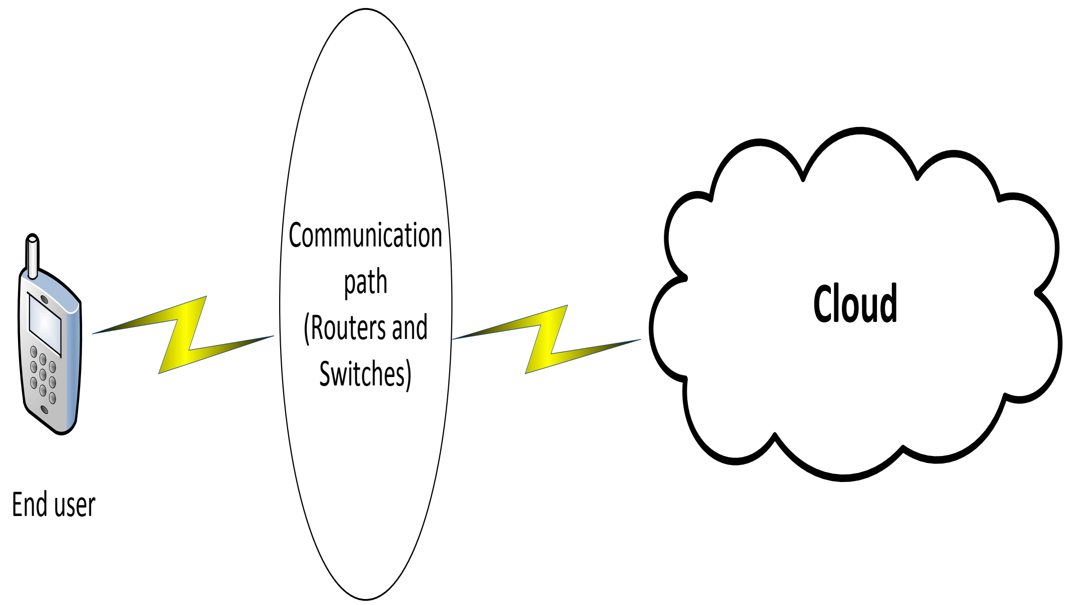

Figure 1: Scenario of cloud computing

- End user has less processing speed than cloud. Every end user uses different devices having distinct capacity to compute. So this survey may not hold true for everyone.
- This survey won't be applicable for real time communication.

- It is presumed that all the computation would be in same server. But computation may take in several servers. Number of server may dynamically change according to user demand.
- Processing time of data here is derived here considering one end user. Multiple users accessing simultaneously to the same server can make this time different.

1.4 Objectives

The main objective of this report is to reduce the processing time of data computation and saving energy.

Other objectives are:

- To review cloud computing and mobile cloud computing
- To propose an algorithm for the graphical representation of offloading probability with data computation and bandwidth
- Performance evaluation of a considered scenario

1.5 Outline of the Report

This report contains five chapters. First chapter would give us a review of this paper i.e. our objective, problem that we face in traditional computation, limitations etc. Second chapter would illustrate about cloud computation, its purpose, taxonomy, distinction with mobile cloud computing and offloading. A scenario is considered in third chapter to analysis line delay, offloading probability, comparison of power consumption and a way to optimize the problem. Chapter four is where numerical results are derived regarding total time, computation time in cloud, offloading and onloading time etc.

CHAPTER 2

LITERATURE REVIEW

2.1 Cloud

Cloud computing or Cloud technology is a buzz word that possess a long history. Due to the rapid deployment of Information Technology (IT) in almost all sectors, IT services demand a lot of computations. Besides it may not be always possible to establish physical connection to every end users.. Thus a cloud, which actually refers a broad network, is created by which every end user is virtually connected with each other.

The main purpose of cloud is to share resources and empower mobile computation. For instance, consider a community of people went for visiting to an Eco-park. Every person has a mobile phone in their hand by which they are taking pictures of their interesting moment. They can now make a virtual cloud to share their moments where everybody can access. This can make their day more interesting and careful.

2.2 Cloud Computing

2.2.1 Definition:

Cloud computing has brought a new era in computing technologies. It offers a lot of opportunities to the users by implementing the utility computing vision.

Barkley RAD defines Cloud Computing as:

"Cloud Computing refers to both the applications delivered as services over the Internet and the hardware and systems software in the datacenters that provide those services. The services themselves have long been referred to as Software as a Service (SaaS). The datacenter hardware and software is what we will call a Cloud.

When a Cloud is made available in a pay-as-you-go manner to the general public, we call it a Public Cloud; the service being sold is Utility Computing. We use the term Private Cloud to refer to internal datacenters of a business or other organization, not made available to the general public. Thus, Cloud Computing is the sum of SaaS and Utility Computing, but does not include Private Clouds. People can be users or providers of SaaS, or users or providers of Utility Computing." (Armbrust et al., 2009, p6)[2].

According to the US National institute of standards and technology (NIST):

"Cloud computing is a model for enabling convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications and services) that can be rapidly provisioned and released with minimal management effort or service interaction[3]."

2.2.2 Important features of Cloud Computing:

- Cloud Computing is a new computing paradigm.
- Infrastructure resources (hardware, storage and system software) and applications are provided in X-as-a-Service manner. When these services are offered by an independent provider or to external customers, Cloud Computing is based on pay per-use business models.
- Virtualization and Dynamic scalability are the two main features of cloud computing.
- Utility computing and SaaS are provided in an integrated manner, even though utility computing might be consumed separately.
- Cloud services are consumed either via Web browser or via a defined API.

2.2.3 Cloud Computing Architecture:

US National Institute of Standards and Technology (NIST) is a well-known institution all over the world for their work in the field of Information Technology. NIST defines the Cloud Computing architecture by describing five essential characteristics, three cloud services models and four cloud deployment models (Cloud Security Alliance, 2009, p14)[4].

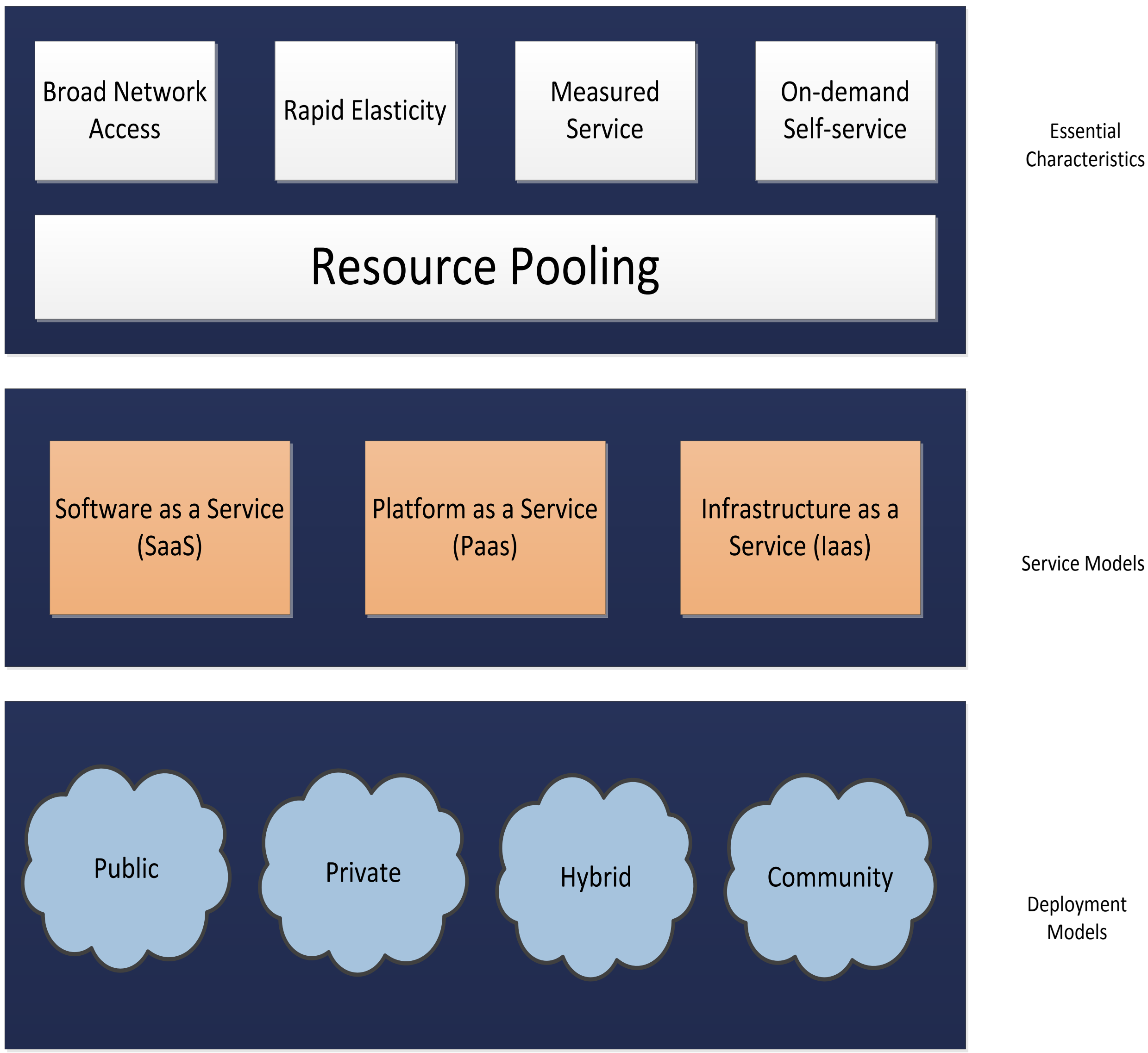

Figure 2: Visual model of Cloud Computing

2.2.4 Essential Characteristics of Cloud Computing:

The five essential characteristics of Cloud Computing are:

On-demand-self-service:

A consumer of cloud computing network must be able to automatically acquire or release the IT resources when the need of these resources increases or decreases without requiring any action from the service providers.

Broad Network Access:

IT resources based on cloud computing should be available in the network and must be able to accessed through normal mechanism.

Resource Pooling:

Physical and Virtual resources are pooled together and based on clients' demand it is dynamically assigned or reassigned.

Rapid Elasticity:

The resources should be unlimited and available in any quantity at any time.

Measured Service:

A cloud computing network has the ability to measure the consumption of resources and to control and optimize the limited areas of resources.

2.2.5 Cloud Service Models:

The "SPI (software, platform, and infrastructure)" are the three cloud service models.

· **Cloud Software as a Service (SaaS)** In this model a consumer can use the applications of the provider which are uploaded in the cloud. It is customizable within limits.

· **Cloud Platform as a Service (PaaS) In** this model an application developer company develops applications and offers the consumers to use these via service providers' platform. Here, creation and modification of applications are possible.

· **Cloud Infrastructure as a Service (IaaS) In** this model computer hardware such as servers, networking technology, storage are delivered to the consumer as a service.

2.2.6 Cloud Deployment Models:

- **Public Cloud:** The cloud infrastructure is open for the public by a particular organization which also hosts the service.

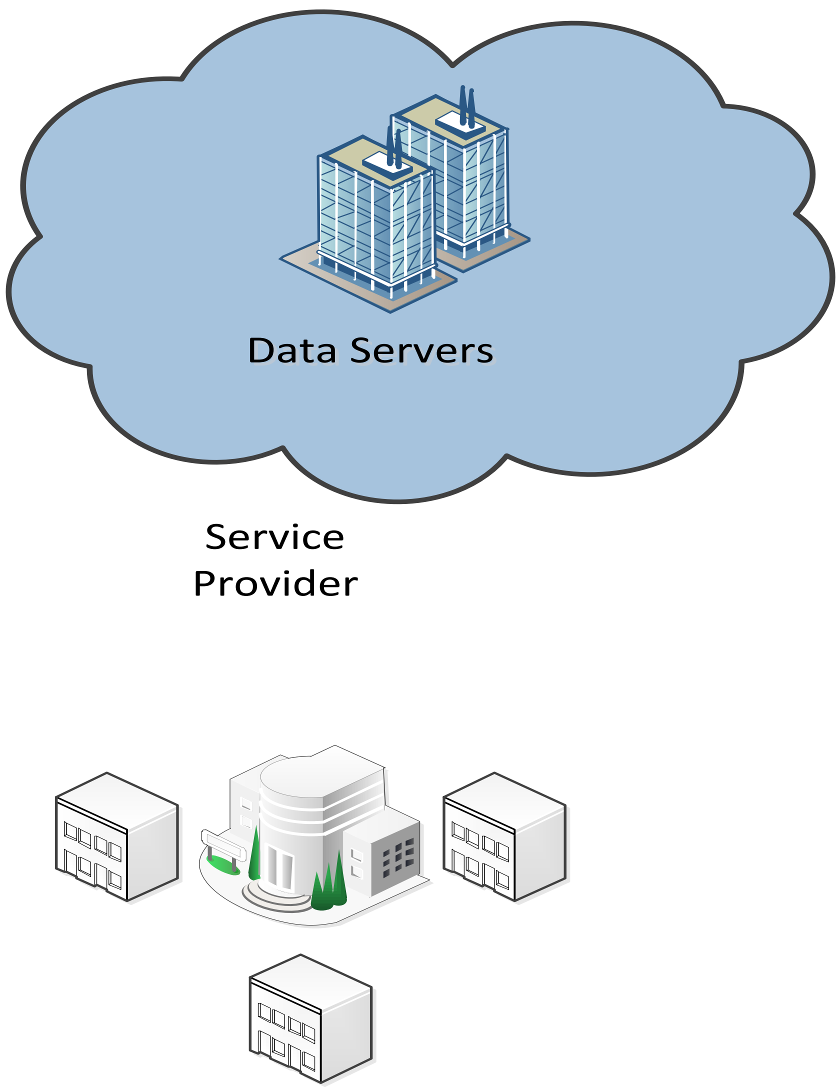

Figure 3: Public Cloud

- **Private Cloud:**

  It is used for single organization only.

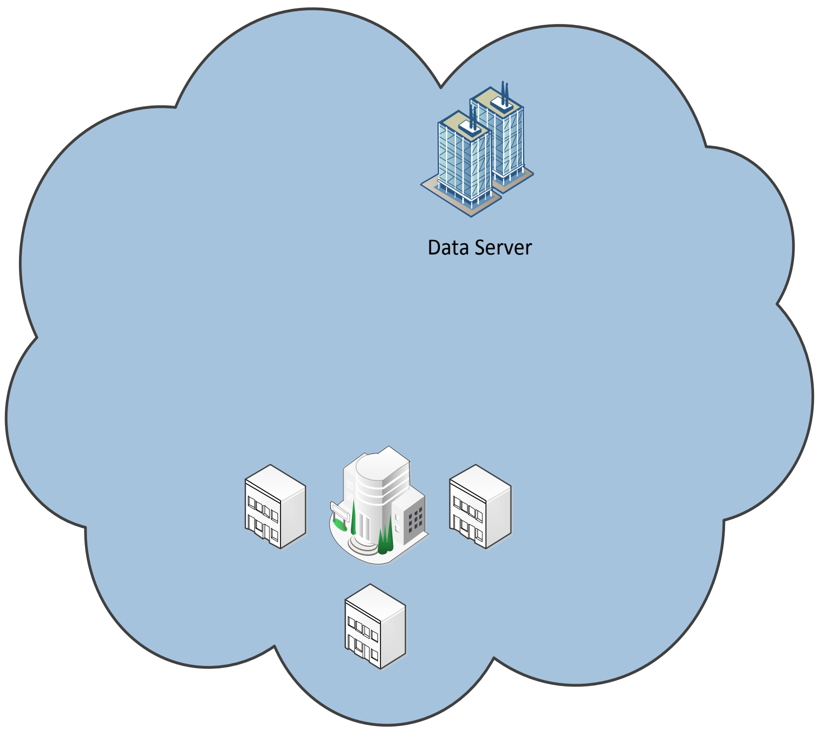

Figure 4: Private Cloud

- **Community Cloud:**

  The cloud infrastructure is shared by several organizations and supports a specific community with shared concerns.

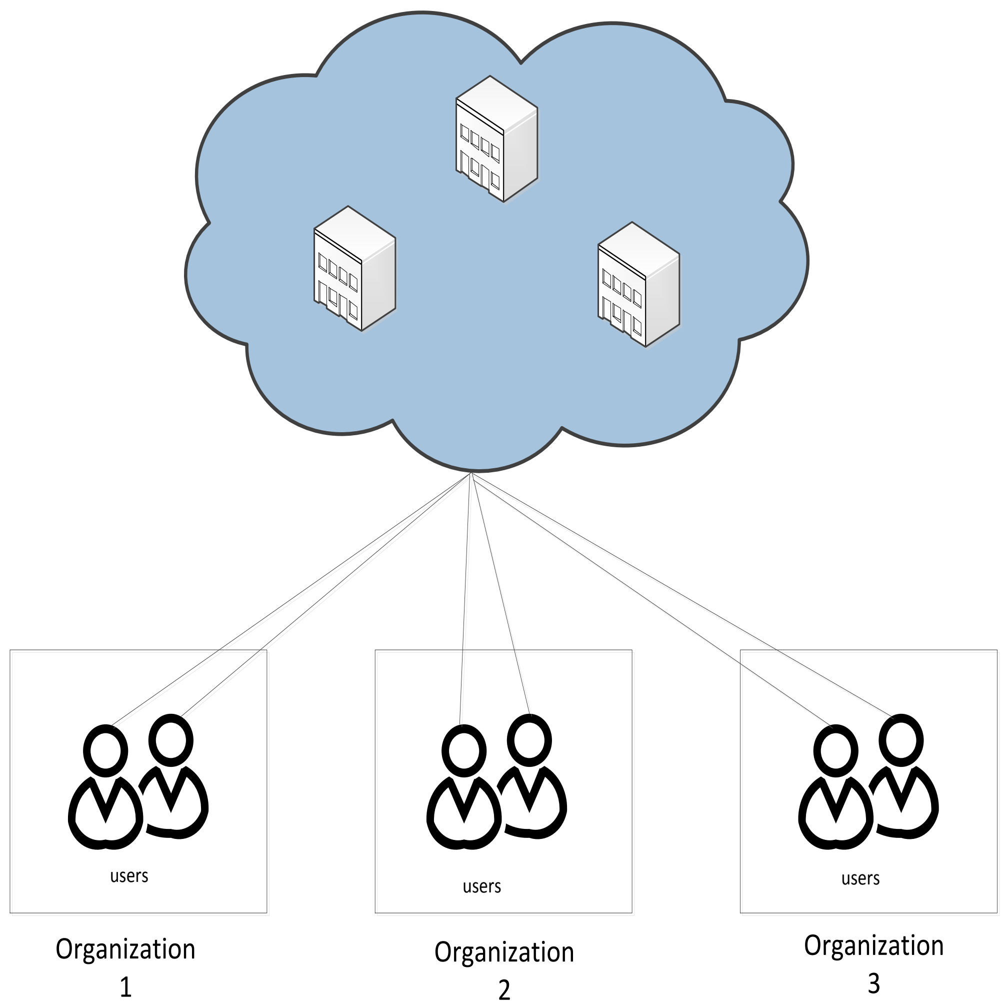

Figure 5: Community Cloud

- **Hybrid Cloud:**

  This model is consisted of two or more clouds (public, private or community). It has unique entitles and offers the benefits of multiple models.

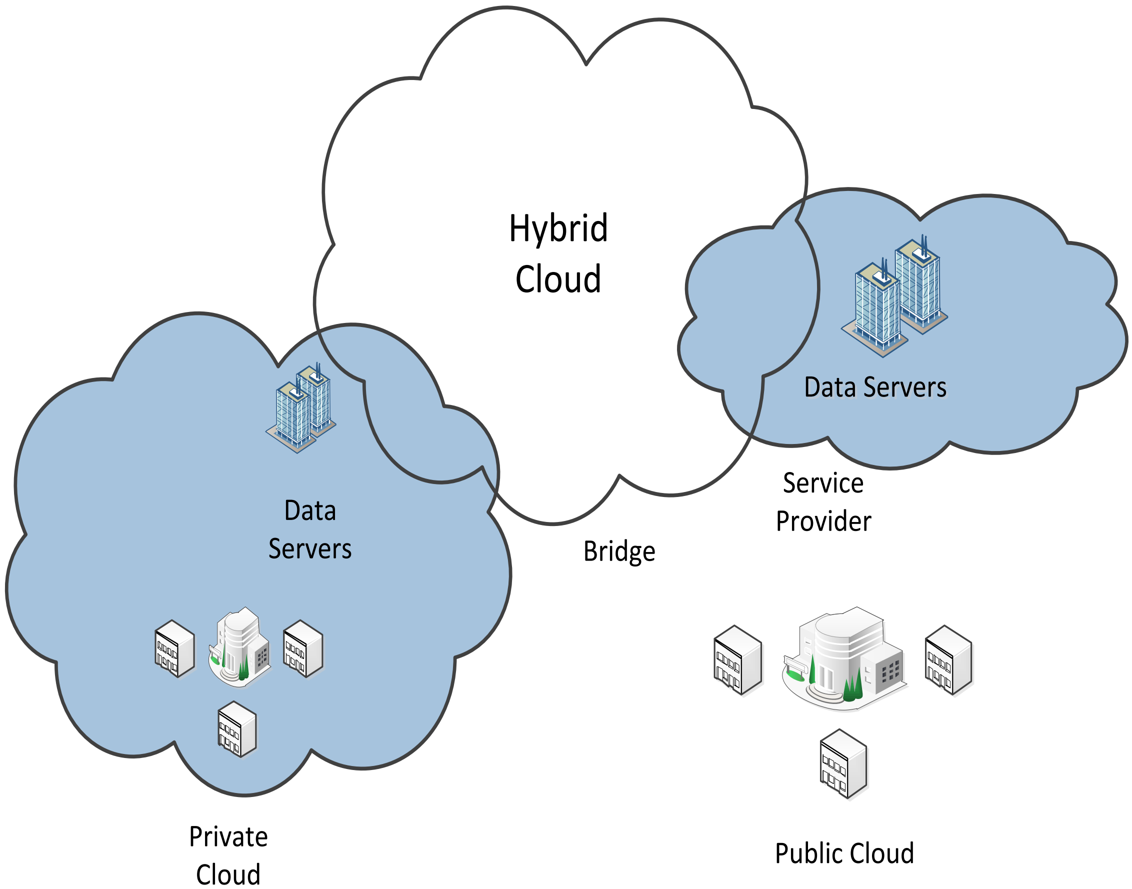

Figure 6: Hybrid Cloud

2.2.7 Benefits of Cloud Computing:

- **Achieve economies of scale**

  It increases the productivity thus decreases cost per unit of any project.

- **Reduce spending on technology infrastructure**

  A user can access his information with minimal spending.

- **Globalize your workforce on the cheap**

  The cloud can be accessed worldwide by internet.

- **Streamline processes**

  Working rate is increased day by day with less manpower.

- **Reduce capital costs**

  For this process there is no need for hardware, so it saves money.

- **Improve accessibility**

  A user can able to access anything, anytime, anywhere.

- **Less personnel training is needed**

  In this process fewer people can do more work on a cloud with a minimum learning on hardware and software.

- **Improve flexibility**

  It improves flexibility at work, makes it easy.

2.3 Mobile Cloud Computing

2.3.1 Concept and Definition:

"Mobile Cloud Computing (MCC) is the combination of cloud computing, mobile computing and wireless networks to bring rich computational resources to mobile users, network operators, as well as cloud computing providers [5]."

Mobile phones are having their positions on the top of people's acceptance. It is more a necessity than a luxury to have a mobile phone now. Now a day, a mobile phone can manage every facility that people generally have through their personal computer (PC). But, as it have the limitations of storage, computation power and power consumption competing with thriving need of large scale application; we have to go for another option.

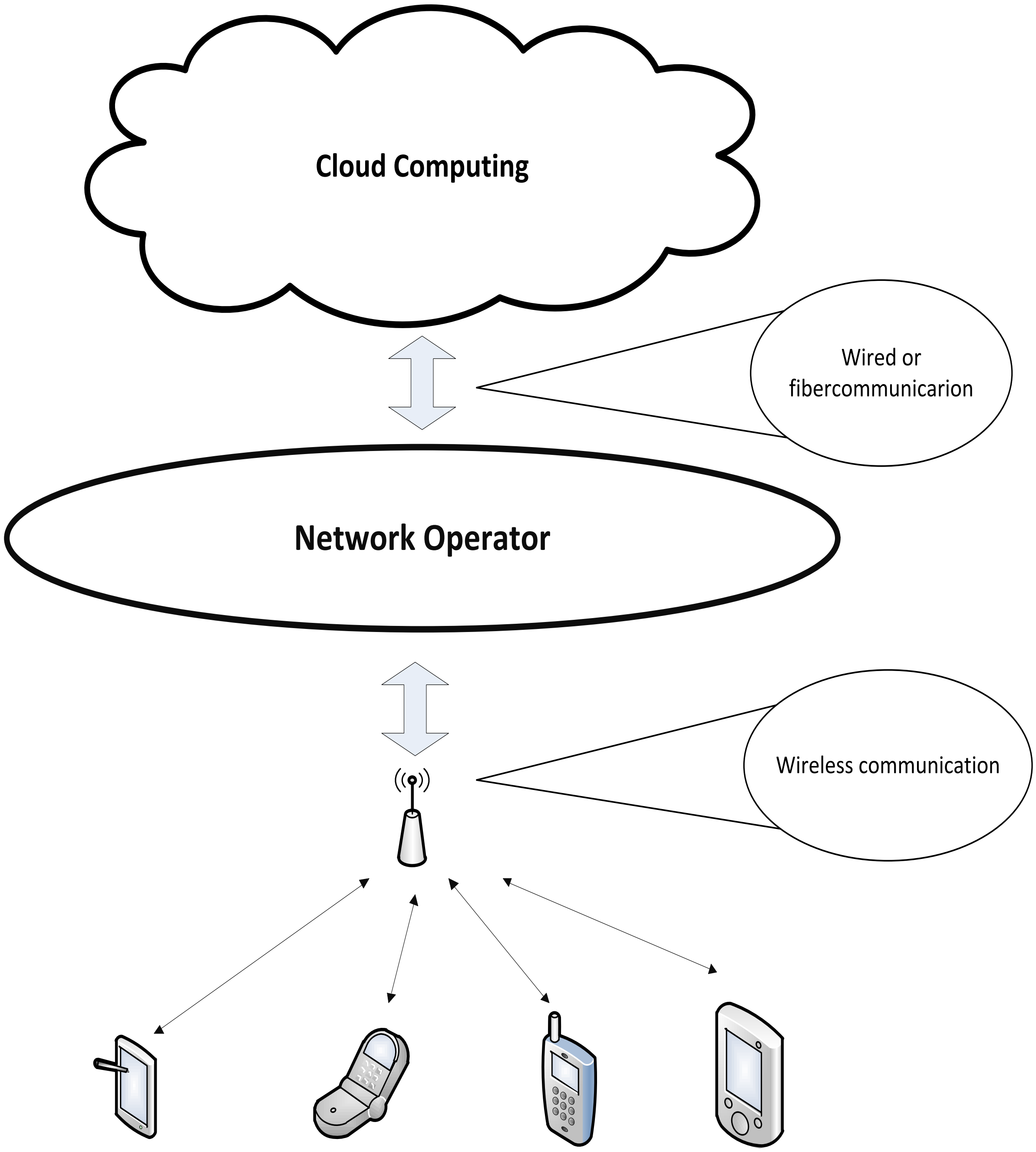

Figure 7: Basic structure of mobile cloud computing

This “another option” is mobile cloud computing (MCC). Mobile cloud computing is the mobile computing (MC) associating with cloud computing (CC). This technology demands a wireless technology, cloud technology and an end device (Smart Phone, Tablet etc.). Modern applications requires high computation power that can be provided by cloud computing. In cloud computation, several servers are connected to build a large network that makes computation easier, less time consuming and less power consuming. A wireless communication device i.e. smart phone, contains all interfacing software like iMesh, Skype, Facebook, Gmail, google+, Yahoo! etc. These interfacing software are used to off-load and no-load data from the mobile devices to cloud. No computation of data processing takes place in the end devices. There are millions of end devices taking this advantage. This, in addition, reduces the cost of the end user. A user needs not to know about the processing software or complex network infrastructure. Having the ability to operate simple interfacing software, s/he can get every computation facility.

2.3.2 Architecture of Mobile Cloud Computing:

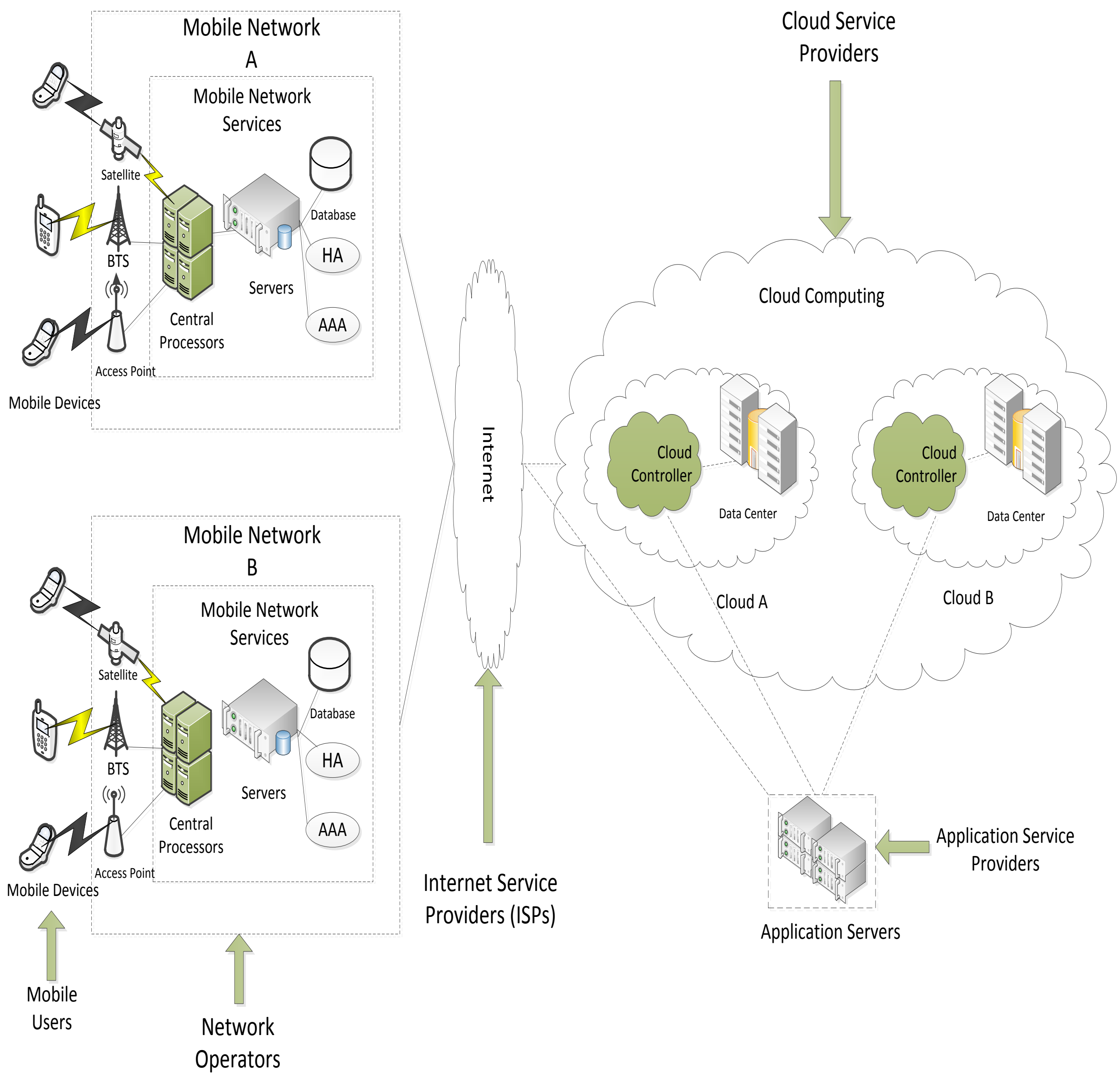

Figure 8: Mobile Cloud Computing Architecture

A general structure of mobile cloud computing is shown in above fig. Mobile devices are wireless devices and not directly connected to the cloud network. A base station (e.g. Satellite, BTS, Access Point etc.) where every mobile devices are connected, works as a connector between mobile devices and mobile network operator (MNO). Base station can make a connection with MNO by either wireless or fiber optic method that depends on the surrounding. MNO authenticates every mobile user's request according to the database to connect them to the cloud network.

2.3.3 Advantages of MCC:

Cloud computing offers us to overcome the problems and limitations of mobile computing.

- **Energy Saving:** It is obvious that large scale computation requires a large amount of power to be consumed. It won't be economical if numerous mobile users consume large amount of power. Cloud computation serves as a basement for all users to compute their data simultaneously. This reduces the per-user power consumption.
- **Increasing Processing Power and Reducing Processing Time:** To increase processing power a vast and complex hardware is required. Cloud computation provides this infrastructure to the user. So mobile user can take this advantage. This would reduce processing time as well.
- **Improving Storage Capacity:** A mobile device possesses a limited storage capacity. MCC enables mobile users to store and analyze a large data on the cloud.
- **Improving Reliability:** Storing data in MCC is more reliable than a mobile device. A mobile device's memory could be fragile or damaged any moment. Besides user could get his device lost. So it is necessary to keep a backup of data into a reliable storage. For example- Google image backup is an

application we will find in every mobile that have Android operating system. It keeps a backup of every image of mobile in the server.

2.3.4 Challenges of MCC:

- In MCC mobile devices have a wireless connection with the base station. Any discontinuity in the wireless communication will stop real time communication.
- Cluster base mobile communication uses different frequencies for different cells. So any movement from one cell to another may cause discontinuity in communication.
- Every day millions of mobile users are accessing into the internet using Facebook, Instagram, Google, Amazon, Yahoo etc. which contain terabytes of information. This information needs to be analyzed instantly. Making software to analyze such a huge data is a big challenge.
- Every mobile user has some data that needs to be preserved and protected. Huge amount of data preservation in hardware is risky.
- Resource providers use multiple servers to run an Application. How many servers we need depends on the user load. One approach can be estimating pick load provision for it. The disadvantage of this approach is that many resources may lie idle for a long time, which is not cost effective.
  Auto-scaling can solve this. This method illustrates that when load increases, more resources/servers are allocated to accommodate the need [6].
- Another challenge of MCC is security. As every user is connected to a service provider there may be questions on aspects such as security and vendor lock-in.

2.3.5 Mobile Cloud Computing Applications:

Figure 9: Applications of Mobile Cloud Computing

- **Mobile Commerce:**

Figure 10: Mobile Commerce

  - Mobile commerce provides business institutions to conduct their business by using mobile devices.
  - Examples: Mobile shopping, Electronic cash payment, mobile advertising etc.

- Only challenge Mobile commerce applications can experience is security.

- **Mobile Learning:**

Figure 11: Learning from a Mobile Device

- Mobile learning is getting popular as it is easy to execute and gives us mobility.
- Traditional Mobile learning faces resource scarcity.
- Cloud based Mobile learning can solve these limitations.

- By Mobile learning learners can access remote learning resources

- **Mobile Healthcare:**

Figure 12: Mobiles as Health Monitor and other medical instrument

- Mobile healthcare minimizes the hustle of traditional medical treatment.
- One can consult with doctors without leaving their home.
- Mobile healthcare offers hospitals and healthcare organizations a variety of on-demand services on clouds
- Examples:
    - Health monitoring services

- Emergency management system
- Health-aware mobile devices (detect pulse-rate, blood pressure, level of alcohol etc)
- Pervasive access of healthcare

- **Mobile Gaming:**

Figure 13: Mobile Gaming

- Mobile game is one of the potential fields of generating revenues for service providers.
- Online gaming is getting popular to the young generations. There are numerous games in the server. People can play according to their taste.

- **Assistive technologies:**

Figure 14: Touchscreen Mobile Phone for Blind

- Pedestrian crossing guide for blind and visually-impaired
- Mobile currency reader for blind and visually impaired
- Lecture transcription for hearing impaired students [7]

- Other applications:

Figure 15: Mobile Device as Remote Home Control

- Sharing photos/videos
- Keyword-based, voice-based, tag-based searching

- Monitoring a house, smart home systems

Figure 16: Monitoring House

2.4 Offloading

2.4.1 Concept and Definition:

The resources of mobile systems are limited, such as battery life, network bandwidth, storage capacity, processor performance etc. These limitations can be mitigated by computation offloading which means sending heavy data to resourceful clouds or servers and receiving the wanted or requested results from the cloud.

As computing technology has advanced day by day, it expands the usage of computers from desktops to a greater range of mobile applications. Such applications are mobile phones, surveillance, environmental sensing, etc. But here, mobile phones are battery powered, less memory, slow processor, etc. Environmental sensors resources are also limited such as slow processor, smaller physical size, less data storage capability. The main limitation of these applications are low bandwidth because they are wireless. So, there is a huge gap between the demand for complex programs and the availability of limited resources.

By computation offloading, these limitations could be overcome. So, Offloading is an aftermath to increase the capabilities of mobile systems by shifting computation to a more resourceful cloud or server. In this process, the computation happens outside of the user computing environment.

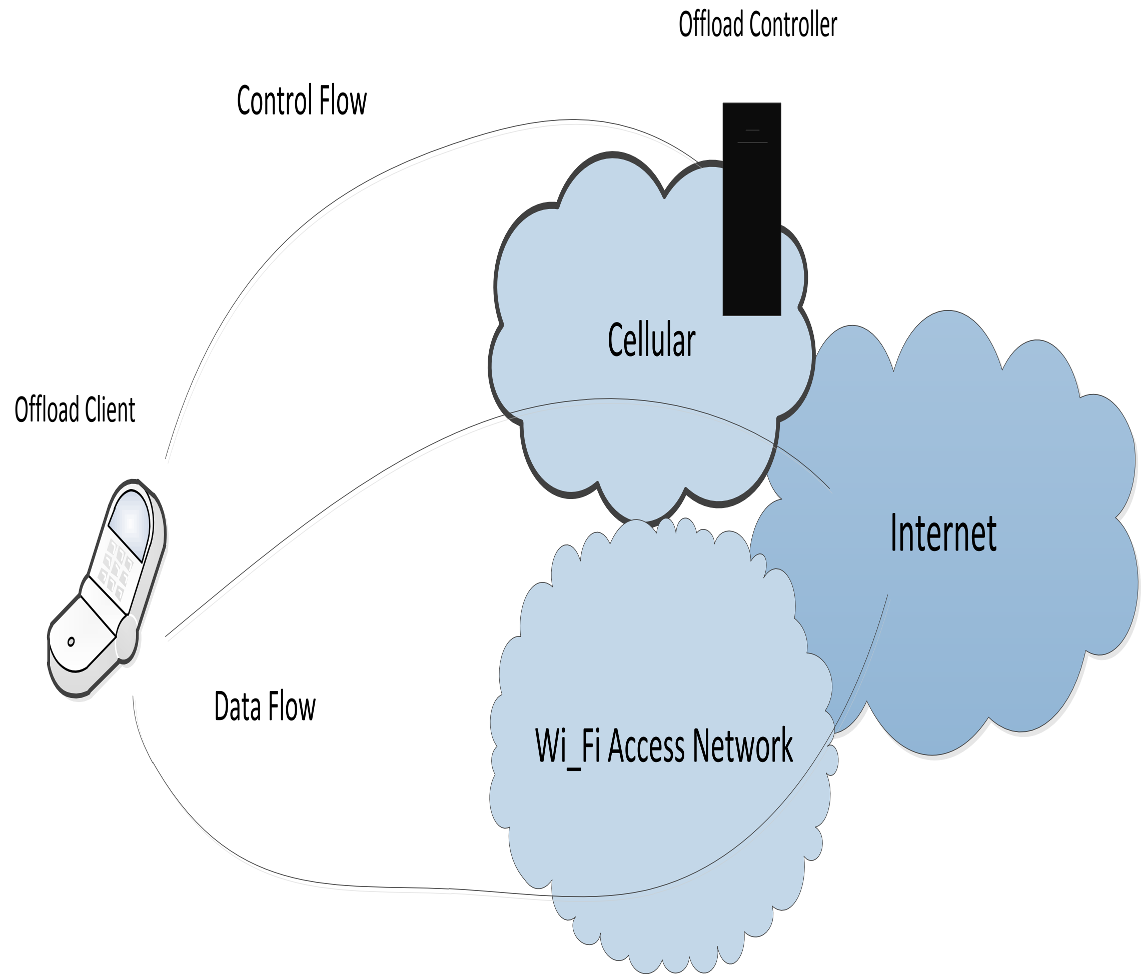

Figure 17: Offloading

2.4.2 Offloading Decisions:

Since offloading shifts computation to a more resourceful server, so a decision should be made of whether and what computation to shift. So, offloading decisions are taken by examining (1) Performance improving and (2) Energy saving.

2.4.3 Performance Improving:

We can divide a program into two parts: one part that must run on the mobile system and the other part are by offloading the data to cloud.

Let us consider, S_m be the speed of the mobile system and W is the amount of computation. The time to complete the second part on the mobile system is ,

$$\mathrm{Tmobile} = \frac{\mathrm{W}}{\mathrm{Sm}}$$

If the second part is offloaded to a server, the sending data ds takes $\mathrm{Ts} = \frac{\mathrm{ds}}{\mathrm{B}}$ seconds at bandwidth B. Processing delay in cloud, $\mathrm{Tc} = \frac{\mathrm{W}}{\mathrm{Sc}}$ where S_c = processing speed in cloud and T_p is the path delay then, The time to offload and execute the second part is

$$\mathrm{Toffload} = \mathrm{Ts} + \mathrm{Tc} + \mathrm{Tp}$$

.

Offloading improves performance when $\mathrm{Tmobile} > \mathrm{Toffload}$

Or,

$$\frac{\mathrm{W}}{\mathrm{Sm}} > \frac{\mathrm{ds}}{\mathrm{B}} + \frac{\mathrm{W}}{\mathrm{Sc}} + \mathrm{Tp}$$

2.4.4 Energy Saving:

Now-a-days smartphones are used for a vast area of purposes in according with voice communication, web browsing, watching videos from memory card or you tube, playing games, educational purposes, etc. So, battery life is shortening because of the consumption of more power by these applications. In this case, offloading will be a solution because it increases battery life by shifting data computation to cloud or server.

So, if P_m is the power on the mobile system then,

$$\mathrm{Emobile} = \mathrm{Pm} \times \mathrm{Tmobile} = \mathrm{Pm} \times \frac{\mathrm{W}}{\mathrm{Sm}}$$

If P_s is the power required to send data from the mobile system to the cloud. After sending the data if data computation needs power P_c then,

$$\mathrm{Eoffload} = (\mathrm{Ps} \times \mathrm{Ts}) + (\mathrm{Pc} \times \mathrm{Tc})$$

So, Now Offloading saves energy when $\mathrm{Emobile} > \mathrm{Eoffload}$

Or,

$$(\mathrm{Pm} \times \frac{\mathrm{W}}{\mathrm{Sm}}) > \left(\mathrm{Ps} \times \frac{\mathrm{ds}}{\mathrm{B}}\right) + (\mathrm{Pc} \times \frac{\mathrm{W}}{\mathrm{Sc}})$$

So, that’s when we should offload to save time and to save mobile power.

.

CHAPTER 3

SYSTEM MODEL

3.1 Considered Scenario

Let us consider a group of friends enjoying their vacation in Sundarbans. One day they got lost on their way to come to the rest house. One of the friends got an idea to take some photographs of the place where they had lost their path. He thought about to process the images that was captured to locate the place. He had two options to process the image and retrieve their location as well. One of the ways is to upload the photographs to a server or cloud and search where the images belong. This requires an image processing application installed in the cloud. Another way is to run the same application installed in his phone to process the images.

Now we will consider two systems- in one system data will be processed only in mobile and in another system we will send the data to the cloud where data will be processed and the resulting data would be received by the mobile again. Our aim here is to compare these two systems to observe which system consumes less power and takes less time to process data to give a result.

Now for the mobile cloud computing system, the virtual scenario is like below:

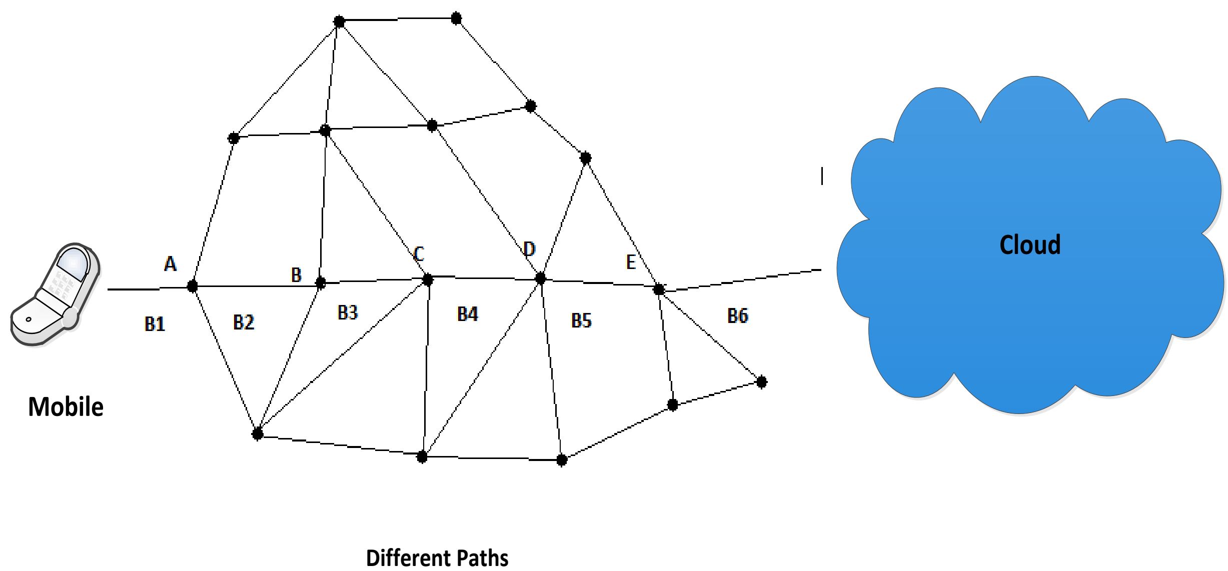

Figure 18: Practical Diagram of MCC Process

Here, data can be sent to the cloud by different paths having different bandwidths and lengths.

Now, a relative comparison of the two systems is described in the next portion in perspective of the power allocation and delay analysis.

3.2 Power Allocation and Delay Analysis

3.2.1 Equations and conditions of offloading for Improving Performance and Saving Energy:

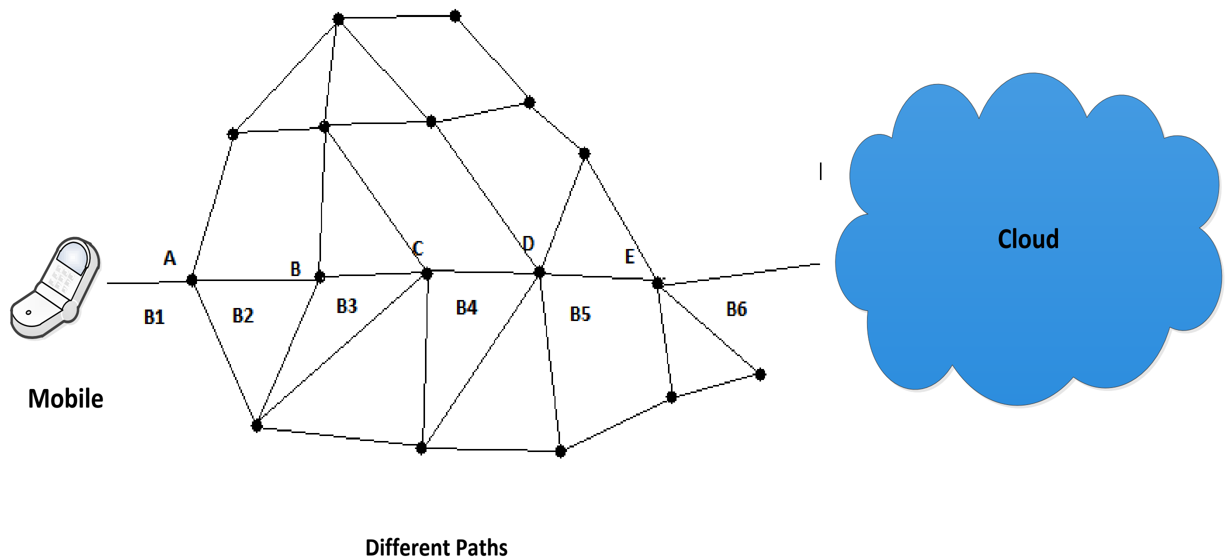

Figure 19: Practical Diagram of MCC Process

There are many switches between our given mobile and cloud, connected to each other. That makes many possible paths to pass data from mobile to cloud.

Let us consider shortest delay link is ABCDE.

Now Bandwidth (BW):

From mobile to A = B_1

From A to B = B_2

From B to C = B_3

From C to D = B_4

From D to E = B_5

From E to Cloud = B_6

Let us consider B_3 is the smallest bandwidth. So the whole path ABCDEwill experience BW B_3.

For Performance Improving:

Considering, total data computation W. So time to execute output on mobile system,

$$\text{Tmobile} = \frac{\text{W}}{\text{Sm}}$$

where, S_m = Speed of mobile system.

To offload data to serve, let us consider the sending data ds and total line speed B_3.

So sending queue delay, $\text{Ts} = \frac{\text{ds}}{\text{B3}}$

And processing delay in cloud, $\text{Tc} = \frac{\text{W}}{\text{Sc}}$

Where, S_c = processing speed in cloud.

So total delay taken if we offload will be,

$$\text{Toffload} = \text{Ts} + \text{Tc} + \text{Tp}$$

Now, if $\text{Tmobile} < \text{Toffload}$ then no offloading is needed.

Otherwise it is convenient to offload while considering only the time.

For Energy Saving:

$$\text{Emobile} = \text{Pm} \times \text{Tmobile} = \text{Pm} \times \frac{\text{W}}{\text{Sm}}$$

$$\text{Eoffload} = (\text{Ps} \times \text{Ts}) + (\text{Pc} \times \text{Tc}) = \left(\text{Ps} \times \frac{\text{ds}}{\text{B3}}\right) + \left(\text{Pc} \times \frac{\text{W}}{\text{Sc}}\right)$$

Now, if $\text{Emobile} < \text{Eoffload}$ then there is no need to offload.

Otherwise it is economical to offload for saving energy and improving performance.

Condition:

To reduce offloading time, it is inevitable to increase the line BW.

3.2.2 Equation of total processing time:

Let us consider the sending data ds and total line speed B_3.

So sending queue delay, $\text{Ts} = \frac{\text{ds}}{\text{B3}}$ and processing delay in cloud, $\text{Tc} = \frac{\text{W}}{\text{Sc}}$ where, S_c = processing speed in cloud.

Let us consider receiving data dr.

So receiving queue delay, $\text{Tr} = \frac{\text{dr}}{\text{B3}}$

So, total processing time will be

$$\text{Ttotal} = \text{Ts} + \text{Tc} + \text{Tr} + 2\text{Tp}$$

3.2.3 Equation of total energy consumption:

Now, if we want to calculate the total energy consumption for total process then,

$$\text{Etotal} = (\text{Ps} \times \text{Ts}) + (\text{Pc} \times \text{Tc}) + (\text{Pr} \times \text{Tr})$$
$$= \left(\text{Ps} \times \frac{\text{ds}}{\text{B3}}\right) + \left(\text{Pc} \times \frac{\text{W}}{\text{Sc}}\right) + \left(\text{Pr} \times \frac{\text{dr}}{\text{B3}}\right)$$

where, P_r is the consumed power when data is received.

3.2.4 Equation of time required for offloading considering both queue delay and path delay:

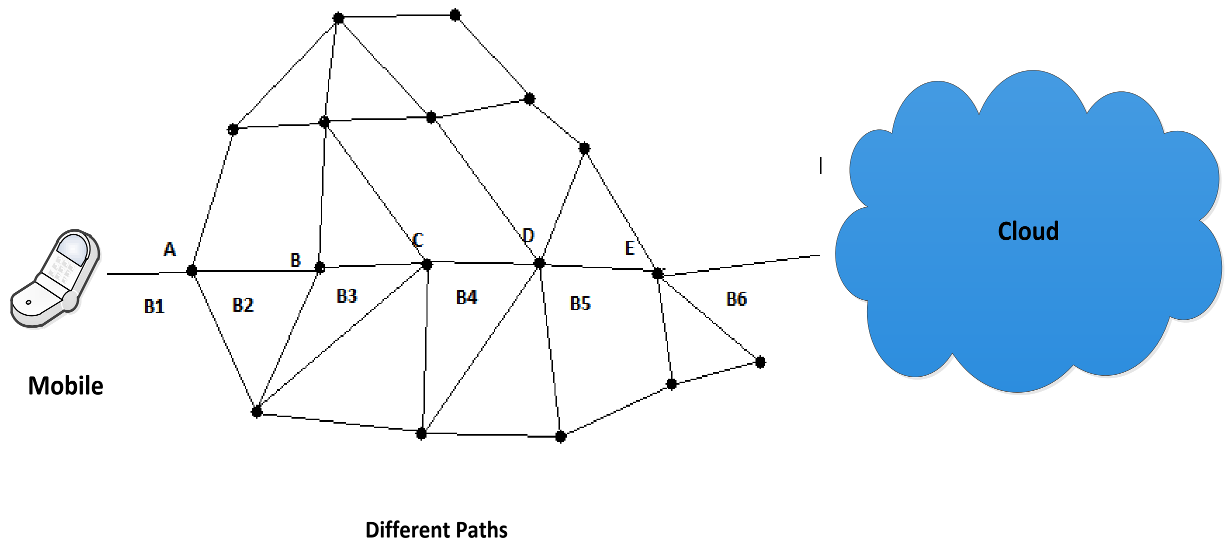

Figure 20: Practical Diagram of MCC Process

Here, shortest delay link is ABCDE.

Considering, total data computation = W.

Time to execute output on mobile system,

$$\text{Tmobile} = \frac{\text{W}}{\text{Sm}}$$

Now, if distance of the paths that data will follow is D_1, D_2, D_3, D_4, D_5, D_6 and velocity of data is c; [c = velocity of light]

Then, Total propagation delay,

$$Tp = \frac{D1 + D2 + D3 + D4 + D5 + D6}{c} = \frac{D}{c}$$

So, Total offloading time will be,

$$Toffload = \text{queue delay} + \text{path delay} = (Ts + Tc) + Tp = \left(\frac{ds}{B3} + \frac{W}{Sc}\right) + \frac{D}{c}$$

So, if $Tmobile > Toffload$ then it's better to offload the data.

3.3 Optimization Problem

Here,

$$\text{queue delay} = \frac{ds}{B} + \frac{W}{Sc}$$

Case 1:

$$\text{queue delay}_{max} = \frac{ds}{B} + \frac{W}{Sc}$$

If the server is fast, then queue delay would be maximum if data exchange (ds) is heavy.

Case 2:

$$\text{queue delay}_{min} = \frac{ds}{B} + \frac{W}{Sc}$$

If the server is fast, then queue delay would be minimum if data exchange (ds) is light.

Now, Offloading improves performance when

$$\frac{W}{Sm} > \frac{ds}{B} + \frac{W}{Sc} + Tp$$

Queue delay is much bigger than path delay, so, it can be written,

$$\frac{W}{Sm} > \frac{ds}{B} + \frac{W}{Sc}$$

Or,

$$W \times \left(\frac{1}{Sm} - \frac{1}{Sc}\right) > \frac{ds}{B}$$

If the server is fast then,

Case 1:

Offloading can improve performance when data computation (W) is heavy with light data exchange (ds). So,

$$W_{max} \times \left(\frac{1}{Sm} - \frac{1}{Sc}\right) > \frac{ds_{\min}}{B}$$

Case 2:

Offloading cannot improve performance in case of light data computation (W) with heavy data exchange (ds). In this case,

$$W_{\min} \times \left(\frac{1}{Sm} - \frac{1}{Sc}\right) < \frac{ds_{\max}}{B}$$

CHAPTER 4

NUMERICAL RESULTS

4.1 Finding out the shortest delay link to decide whether we'll offload or not and total processing time for each path

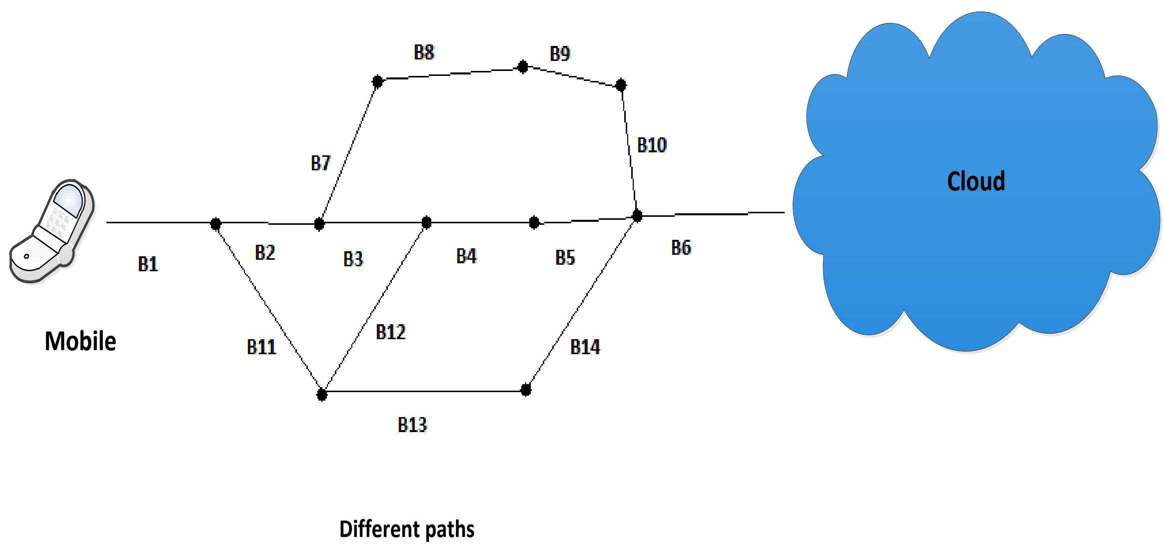

Figure 21: Bandwidths of different paths in the MCC Process

Let,

Total Data Computation, W = 50 MB

Speed of the mobile system, S_m = 50 MB/s

Sending data, ds = 20 MB

Processing speed in cloud, S_c = 200 MB/s

Receiving data, dr = 5 MB

So,

$B_1 = B_5 = B_{10} = B_{14} = 500$ MHz

$B_2 = B_4 = B_9 = B_{13} = 400$ MHz

$B_3 = B_6 = B_8 = B_{11} = B_{12} = 450$ MHz and

$D_1 = D_6 = D_{11} = 10$ km

$D_2 = D_{10} = D_{12} = D_{14} = 8$ km

$D_3 = D_5 = D_{13} = 15$ km

$D_4 = D_8 = D_9 = 12$ km

The paths are,

1. $D_1D_2D_3D_4D_5D_6$
2. $D_1D_{11}D_{13}D_{14}D_6$
3. $D_1D_{11}D_{12}D_4D_5D_6$
4. $D_1D_2D_7D_8D_9D_{10}D_6$

Here, Smallest Bandwidth is 400 MHz.

Calculation of processing time in mobile:

$$\text{Tmobile} = \frac{\text{ds}}{\text{Sm}} = \frac{50}{50} = 1 \text{ sec}$$

Calculation of offloading time:

Here,

$$\text{Toffload} = \text{queue delay} + \text{path delay} = (\text{Ts} + \text{Tc}) + \text{Tp} = \left(\frac{\text{ds}}{\text{B3}} + \frac{\text{W}}{\text{Sc}}\right) + \frac{\text{D}}{\text{c}}$$

For 1st path,

$$\text{Toffload} = \left(\frac{20}{400} + \frac{50}{200}\right) + \frac{\{(10 + 8 + 15 + 12 + 15 + 10) \times 1000\}}{3 \times 10^8}$$
$$= 0.300233333 \text{ sec}$$

For 2nd path,

$$\text{Toffload} = \left(\frac{20}{400} + \frac{50}{200}\right) + \frac{\{(10 + 10 + 15 + 8 + 10) \times 1000\}}{3 \times 10^8}$$
$$= 0.300176666 \text{ sec}$$

For 3rd path,

$$\text{Toffload} = \left(\frac{20}{400} + \frac{50}{200}\right) + \frac{\{(10 + 10 + 8 + 12 + 15 + 10) \times 1000\}}{3 \times 10^8}$$
$$= 0.300216666 \text{ sec}$$

For 4th path,

$$\text{Toffload} = \left(\frac{20}{400} + \frac{50}{200}\right) + \frac{\{(10 + 8 + 10 + 12 + 12 + 8 + 10) \times 1000\}}{3 \times 10^{8}}$$

$$= 0.300233333 \text{ sec}$$

So, second path is the shortest delay link.

Calculation of total processing time:

Here,

$$\text{Ttotal} = \text{queue delay} + \text{path delay} = (\text{Ts} + \text{Tc} + \text{Tr}) + \text{Tp}$$

$$= \left(\frac{\text{ds}}{\text{B3}} + \frac{\text{W}}{\text{Sc}} + \frac{\text{dr}}{\text{B3}}\right) + 2 \times \frac{\text{D}}{\text{c}}$$

For 1st path,

$$\text{Ttotal} = \left(\frac{20}{400} + \frac{50}{200} + \frac{5}{400}\right) + \frac{\{2 \times (10 + 8 + 15 + 12 + 15 + 10) \times 1000\}}{3 \times 10^{8}}$$

$$= 0.3129666667 \text{ sec}$$

For 2nd path,

$$\text{Ttotal} = \left(\frac{20}{400} + \frac{50}{200} + \frac{5}{400}\right) + \frac{\{2 \times (10 + 10 + 15 + 8 + 10) \times 1000\}}{3 \times 10^{8}}$$

$$= 0.3128533333 \text{ sec}$$

For 3rd path,

$$\text{Ttotal} = \left(\frac{20}{400} + \frac{50}{200} + \frac{5}{400}\right) + \frac{\{2 \times (10 + 10 + 8 + 12 + 15 + 10) \times 1000\}}{3 \times 10^8}$$

$$= 0.3129333333 \text{ sec}$$

For 4th path,

$$\text{Ttotal} = \left(\frac{20}{400} + \frac{50}{200} + \frac{5}{400}\right) + \frac{\{2 \times (10 + 8 + 10 + 12 + 12 + 8 + 10) \times 1000\}}{3 \times 10^8}$$

$$= 0.3129666667 \text{ sec}$$

So, here second path is the shortest delay link.

Decision:

From these calculations, it has been seen that total processing time in mobile is 1 sec and in case of offloading, the total processing time for second path is only 0.3128533333sec.So, Computation offloading procedure should be used.

4.2 Graphical Representation of dependency of different parameters of Offloading Equation on each other

4.2.1 Plot of processing time in mobile vs. processing speed in mobile:

It shows a plot of time taken by mobile(Y) to compute with the change of processing speed of the mobile(X).

Data computation= 50 Mb

Equation: Y= $\frac{50}{X}$

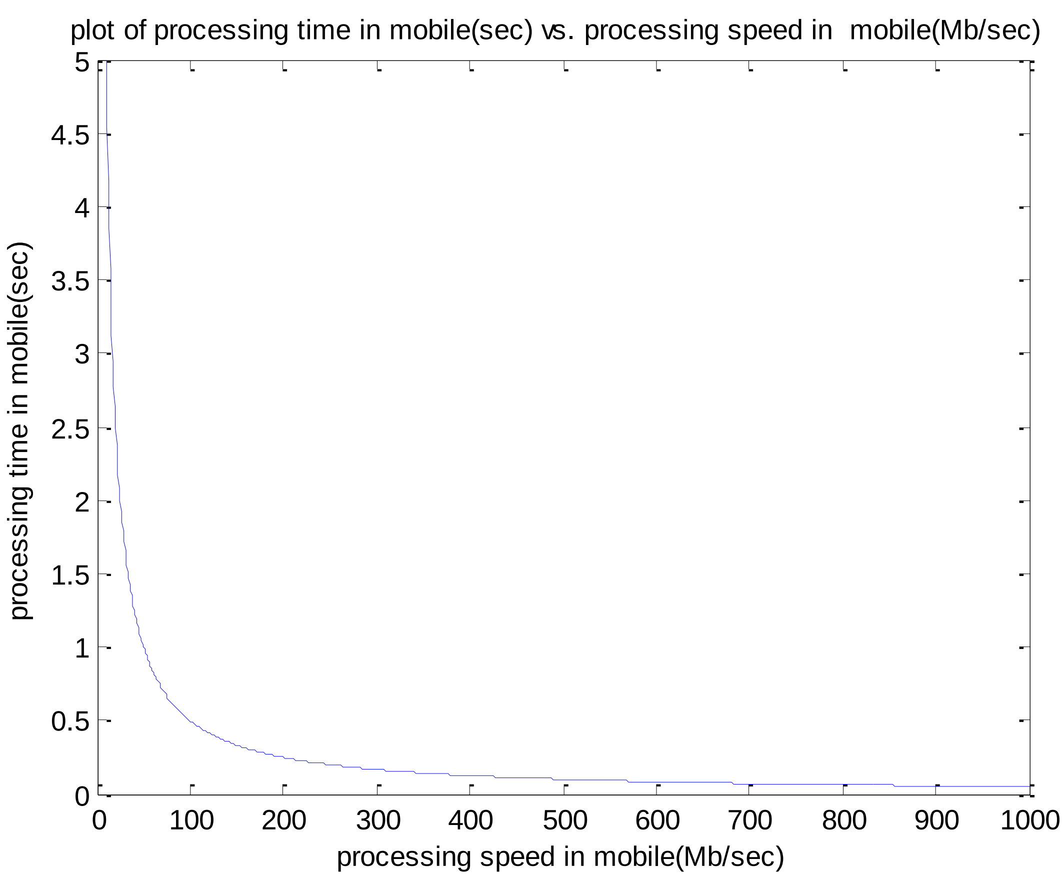

Figure 22: Plot of processing time in mobile vs. processing speed in mobile

Here, processing time in mobile is decreasing with the increase of processing speed in mobile.

For total time:

$$\text{Ttotal} = \frac{\text{ds}}{\text{B}} + \frac{\text{W}}{\text{Sc}} + \frac{\text{dr}}{\text{B}} + 2 \times \frac{\text{D}}{\text{c}}$$

Where,

ds= Sending data

dr= Receiving data

W= Data computation

Sc= Processing Speed in cloud

B= Line bandwidth

D= Line distance

c= speed of light

4.2.2 Plot of total processing time vs. processing speed in cloud:

Here,

ds=20 Mb

B= 400 MHz

W=50 Mb

D=53Km

S_c = 200 MB/s

dr= 2 Mb

then,

$$T_{total} = 0.30535 sec$$

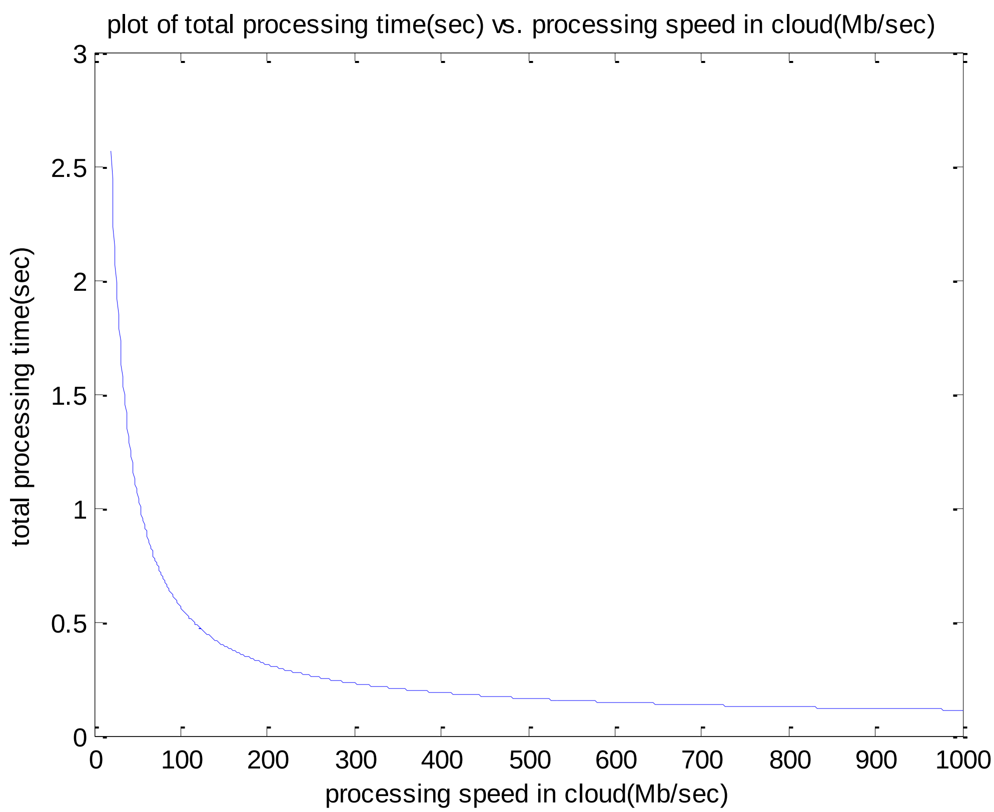

Figure 23: Plot of total processing time vs. processing speed in cloud

Here, total processing time is decreasing with the increase of processing speed in cloud.

4.2.3 Plot of total processing time vs. bandwidth:

Here,

ds=20 Mb

B= 400 MHz

W=50 Mb

D=53Km

S_c = 200 MB/s

dr= 2 Mb

then,

$T_{total} = 0.30535 sec$

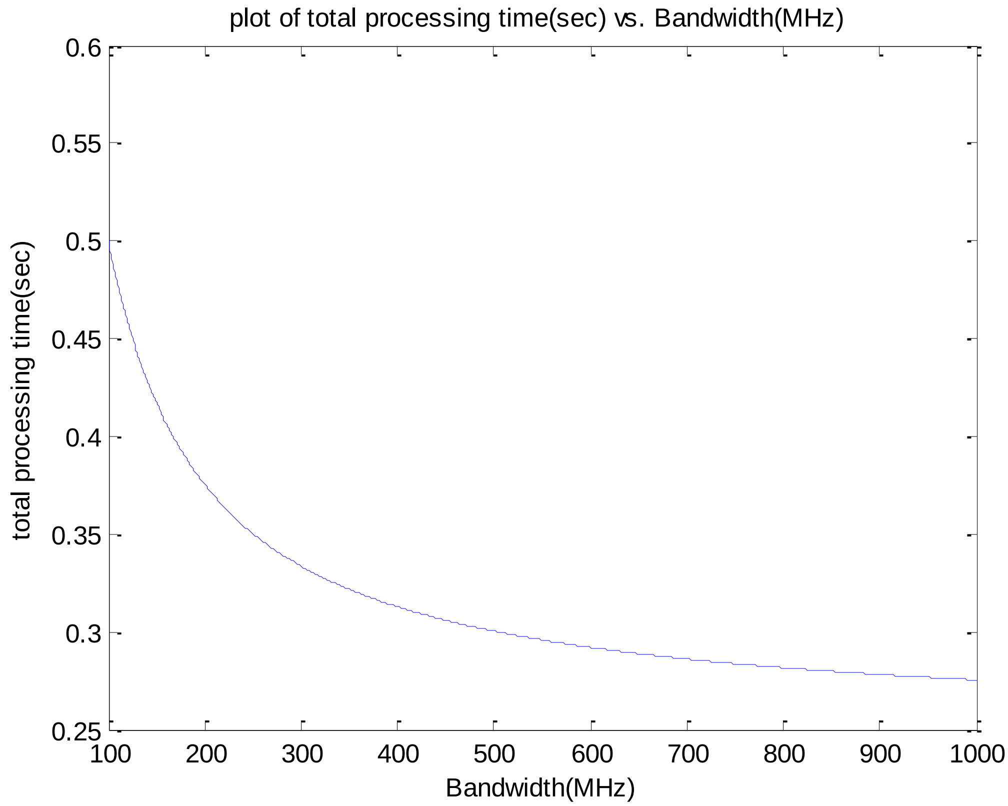

Figure 24: Plot of total processing time vs. bandwidth

Here, total processing time is decreasing with the increase of bandwidth.

4.2.4 Plot of cloud processing speed vs. bandwidth:

With the change of Line Bandwidth (MHz) what should be the least processing speed in cloud (Sc), this figure shows it. Equation for this:

$$\mathrm{Sc} = \frac{\mathrm{W}}{\mathrm{Ttotal} - \frac{\mathrm{ds}}{\mathrm{B}} - \frac{\mathrm{dr}}{\mathrm{B}} - \mathrm{Path\ delay}}$$

Here,

$T_{total} = 0.30535\mathrm{sec}$

B= 400 MHz

ds=20 Mb

D=53Km

W=50 Mb

dr= 2 Mb

then,

S_c = 200 MB/s

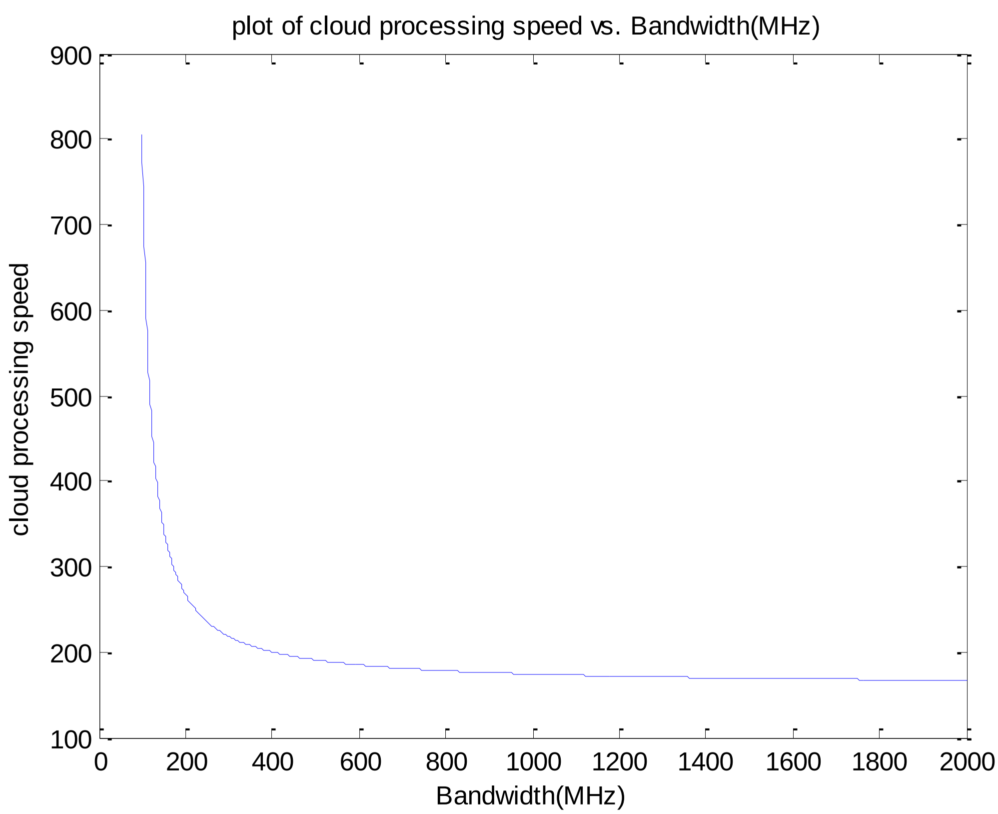

Figure 25: Plot of cloud processing speed vs. bandwidth

Here, cloud processing speed is decreasing with the increase of bandwidth.

For offload:

$$\text{Toffload} = \frac{\text{ds}}{\text{B}} + \frac{\text{W}}{\text{Sc}} + \frac{\text{D}}{\text{c}}$$

4.2.5 Plot of offloading time vs. processing speed in cloud:

Here,

ds=20 Mb

B= 400 MHz

W=50 Mb

D=53Km

S_c = 200 MB/s

Then, $T_{\text{offload}} = 0.30018\text{sec}$

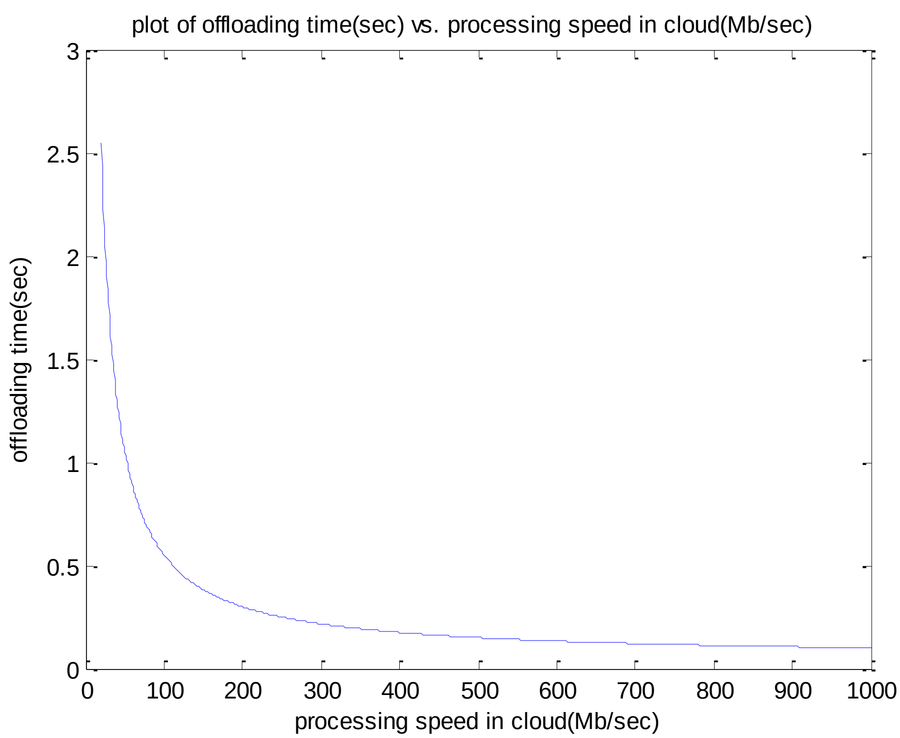

Figure 26: Plot of offloading time vs. processing speed in cloud

Here, offloading time is decreasing with the increase of processing speed in cloud.

4.2.6 Plot of offloading time vs. bandwidth:

Here,

Ds = 20 Mb

B = 400 MHz

W = 50 Mb

D = 53Km

S_c = 200 MB/s

Then, $T_{offload} = 0.30018sec$

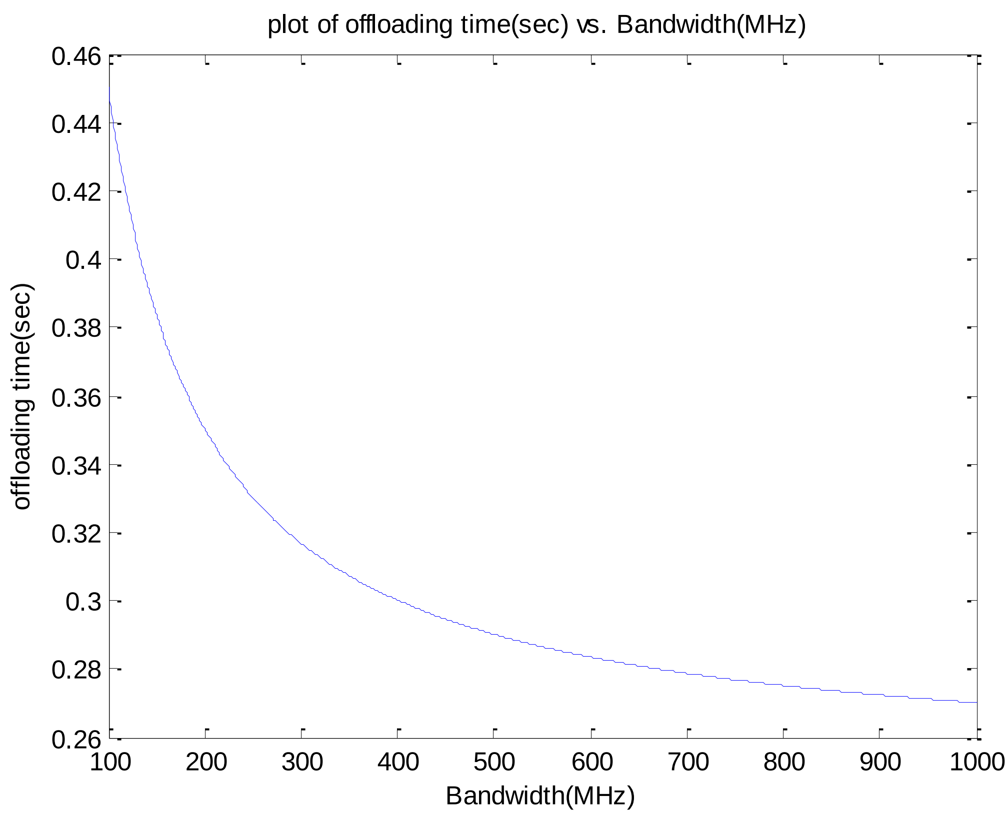

Figure 27: Plot of offloading time vs. bandwidth

Here, offloading time is decreasing with the increase of bandwidth.

4.3 Probability of offloading

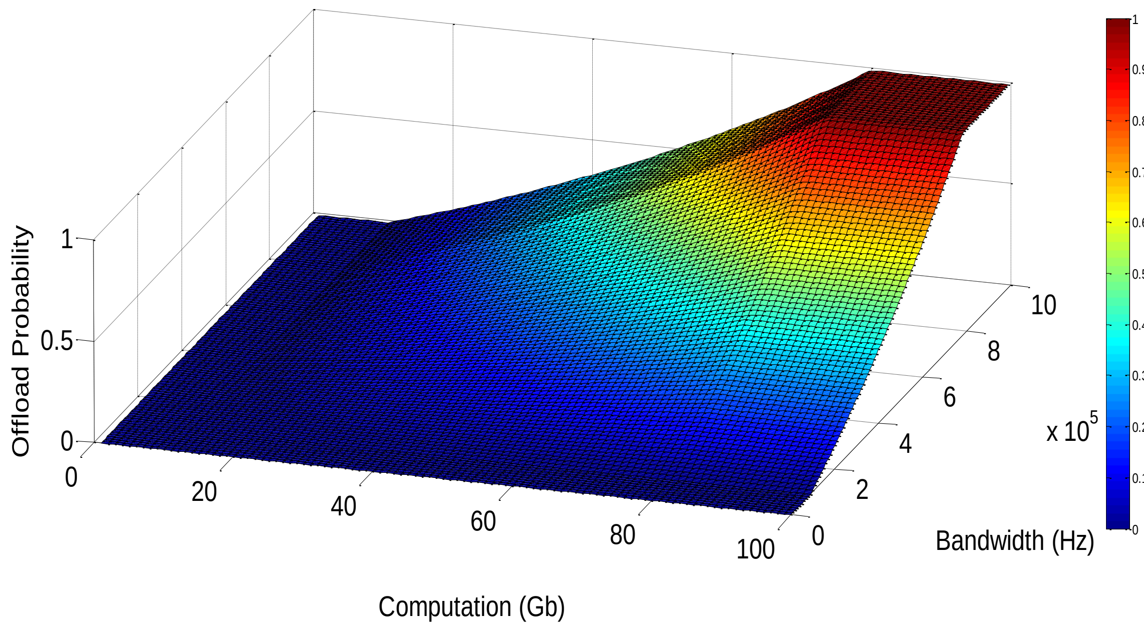

Figure 28: Graphical representation of offloading probability with respect to Data Computation and Bandwidth

Offloading probability depends on two parameters- “Data computation” and “Offered bandwidth”. Here maximum data computation is 100 GB and maximum Bandwidth 10^6 Hz. For this scenario we have chosen not to offload until 10% of maximum data to be computed or 10% of maximum BW to be offered. Probability follows the equation: $y = e^{x-.1} - 1$

Where, y= probability to offload.

x= normalized computation or bandwidth.

The 3D graph shows every probability as the product of two probabilities (Probability due to computation and probability due to computation).

CHAPTER 5

CONCLUSION AND FUTURE WORK

5.1 Conclusion

Mobile cloud computing is one of mobile technologies that combines the advantages of both mobile computing and cloud computing, thereby providing optimal services for mobile users. This technology allows for much more efficient computing by centralizing data storage, processing and bandwidth. Since mobile systems have limited resources, hereby data offloading in cloud may alleviate these limitations. In this thesis paper, conditions for data offloading are introduced and an algorithm for the graphical representation of offloading probability with data computation and bandwidth is proposed. The dependency of different parameters of the delay equation is showed in graphically. So, at last it can be said that Data offloading is an intelligent way for processing data because of the vast resources of cloud systems.

5.2 Future Work

- Complexity analysis of Algorithm is not done in this report and it can be done in future.
- Offloading problem can be solved by using bio-inspired algorithm.

References:

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[4] Cloud Security Alliance. (2009). Security Guidance for Critical Areas of Focus in Cloud Computing.

[5] Wikipedia.org/wiki/mobile_cloud_computing

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[7] http://onlinelibrary.wiley.com/doi/10.1002/wcm.1203/full

Appendix:

Algorithm:

```
clc;

clear all;

close all;

x=1:100;%data to be computed%

y=1:10000:1000000;%bandwidth%

X=x/100;%normalized%

Y=y/1000000;%normalized%

for i=1:length(x)

  if x(i)>(.1*100)%considering to offload when at least 30% of maximum data to be
computed%

      z=exp(X(i)-.1)-1;

      if z>=1

          p1(i)=1;

      else p1(i)=z;

      end

  else p1(i)=0;

  end
```

```
end

% plot(p1);

for j=1:length(y)

   if y(j)>(.1*1000000)%considering to offload when at least 20% of maximum bandwidth is available%

       z=exp(Y(j)-.1)-1;

       if z>=1

          p2(j)=1;

       else p2(j)=z;

       end

   else p2(j)=0;

   end

end

% plot(p2)

for i=1:length(p1)

   for j=1:length(p2)

       p(i,j)=p1(i)*p2(j);

   end

end

surf(x,y,p)
```