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Cloudlets In Mobile Cloud Computing

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***Abstract*— With recent years, technological advancements in mobile devices such as smart phones, tablets have gained more and more capabilities but they still lack in executing complex rich media and data analysis applications. Due to high network latencies offloading data to the cloud is not always a solution so the cloud has to be moved closer to the mobile user in the form of Cloudlets. Cloudlet is a small cloud located near the mobile user, which makes feasible for the mobile devices to interact with clouds and removes the problem of high latency and low bandwidth. In past few years, advancement in mobile applications and their integration with Cloud computing services hasintroduced a new concept known as Mobile CloudComputing.Mobile Cloud Computing (MCC) is the combination of cloud computing, mobile computing and wireless networks. We have given a brief description about the architecture, implementationand applications of Cloudlet. Also specified how cloudlet provides a solution for overcoming network latency issue.**

***Index Terms*— Cloud computing, Mobile cloud computing, Cloudlet, Mobile computing, Mobile device, Cloudlet Architecture.**

I. INTRODUCTION

Mobile communication systems have shown an explosive growth in past couple of years. As per the recent statistical Studies for 2016 the number of smart phone users is forecast to reach 2.08 Billion. The number of mobile phone users in the world is expected to pass 5 Billion mark by 2019.[1]
Such growth of mobile systems demands very efficient ways of communications for all kinds of applications. The most common applications of mobile systems are interactive in nature. File editing, video streaming, chatting are all interactive enterprise applications. As the capabilities of mobile devices advance (in terms of CPU power, network connectivity and sensors), people increasingly use them for other tasks such as emailing, GPS routing, Internet banking, gaming etc. Although many advances in technology, mobile devices will always be resource poor, as restrictions on weight, size, battery life, and heat dissipation impose limitations on computational resources and make mobile devices more resource constrained than their non-mobile counterparts [2].

These applications are often resource hungry and consume valuable mobile resources, such as battery and storage, much to a user's dissatisfaction. To overcome these issues, researchers have integrated mobile applications with services on the Cloud.

A. Cloudlet

A cloudlet is a mobility-enhanced small-scale cloud datacenter that is located at the edge of the Internet. The main motive of the cloudlet is supporting resource-intensive and interactive mobile applications with lower latency. It is a new architectural element that extends today's cloud computing infrastructure. A cloudlet can be viewed as a "data center in a box" whose goal is to "bring the cloud closer". It represents the middle tier of a 3-tier hierarchy: mobile device --- cloudlet --- cloud. A cloudlet can be viewed as a data center in a box whose goal is to bring the cloud closer. The cloudlet term was first coined by M. Satyanarayanan, Victor Bahl, Ramón Cáceres, and Nigel Davies, [3] and a prototype implementation is developed by Carnegie Mellon University as a research project. [4].

B. Cloudlet Attributes

A cloudlet has four key attributes:

- Only soft state: It is does not have any hard state, but may contain cached state from the cloud. It may also buffer data originating from a mobile device (such as video or photographs) enroute to safety in the cloud.[5]

- Powerful, well-connected and safe: It possesses sufficient compute power (i.e., CPU, RAM, etc.) to offload resource-intensive computations from one or more mobile devices. It has excellent connectivity to the cloud (typically a wired Internet connection) and is not limited by finite battery life (i.e., it is plugged into a power outlet).[5]

- Close at hand: It is logically proximate to the associated mobile devices. "Logical proximity" is defined as low end-to-end latency and high bandwidth (e.g., one-hop Wi-Fi).[5]

- Builds on standard cloud technology: It encapsulates offload code from mobile devices in virtual machines (VMs), and thus resembles classic cloud infrastructure[5]

C. Cloudletvs Cloud

There is significant overlap in the requirements for cloud and cloudlet. At both levels, there is the need for: (a) strong isolation between untrusted user-level computations; (b) mechanisms for authentication, access control, and metering; (c) dynamic resource allocation for user-level

computations; and, (d) the ability to support a very wide range of user-level computations, with minimal restrictions on their process structure, programming languages or operating systems. Meanwhile, there are a few but important differentiators between cloud and cloudlet. [6]

The below table shows the differentiation:-

Table 1. Comparison of Cloudlet and Cloud [7]

Parameter	Cloudlet	Cloud
State	Only soft state	Hard and soft state
Management	Self-managed; little to no professional attention	Professionally administered by 24/7 operator
Environment	"Datacenter in a box" at business premises	Machine room with power conditioning and cooling
Ownership	Decentralized ownership by local business	Centralized ownership by Amazon, Yahoo, etc.
Network	LAN latency/ bandwidth	Internet latency/ Bandwidth
Sharing	Few users at a time	Hundreds to thousands of users at a time

II. ARCHITECTURE OF CLOUDLET

The Cloudlet architecture is broken into three subsystems:
1) Mobile devices
2) Cloudlet
3) Cloud.

- Mobile device: - Mobile devices, such as Smartphone's, tablets perform tasks like capturing image, face recognition, File editing and video streaming etc. These processes are send as request in raw form to the cloudlet for processing. After preprocessing the request is sent to the cloud to perform real time processing over a large database located in the cloud.
- Cloudlet: - The cloudlet is a special-purpose inexpensive compute box with the capability of massively parallel processing. A cloudlet is used as an intermediary between the mobile devices and the cloud servers and determines how to partition the requests, in terms of tasks, among itself and multiple cloud servers.
- Cloud: -A client program which is running on the cloudlet sends a request to the servers on cloud where the actual program runs on virtual instances in parallel and the results are sent back to the mobile device or cloudlet.

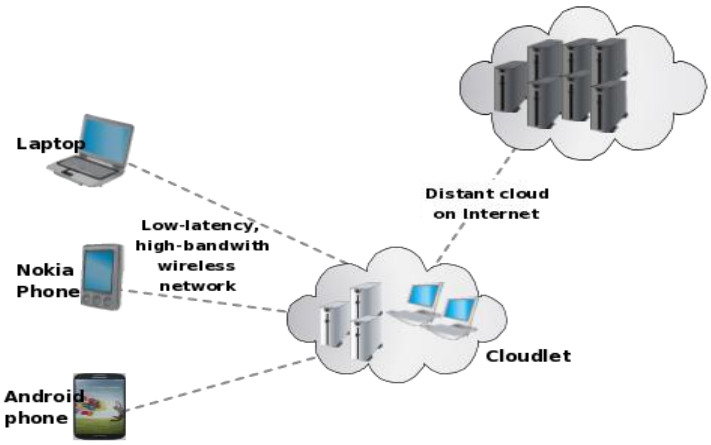

Fig. (1). Cloudlet Architecture [Adapted from http://creately.com/diagram/example/hqtttrms/Cloudlet%20Architecture] [8]

III. IMPLEMENTATION OF CLOUDLET

For the implementation of cloudlet we require two levels of hierarchies comprising client and server. Upper layer of cloudlet have cloud which comprises of various servers and provides computational and information resources. The lower layer of cloudlet comprises of large no of clients which access the information and computational resources from the cloud.

A cloudlet is used as an intermediary between the mobile devices and the cloud servers to promote and facilitate local computation and this creates three layer implementation.

In other words we can say a cloudlet is acting as an intermediate and resource-rich computer or mobile device which is well connected with Internet and easily available to nearby devices. The cloud server supports cloudlet to sort out tasks which cannot be handled by cloudlet.

Mobile user uses the technology of virtual machine to rapidly send request for processing the tasks on a nearby cloudlet and hence uses services over WLAN. Network latency is a main obstacle in cloud computing and to deal with this problem cloudlets are implemented.

Challenges in implementation of Cloudlets:-

While implementing the concept of cloudlet on cloud computing environment, system faces following challenges:

- Physical proximity in cloudlets is essential.
- Faster response time.
- It should deliver predictable result.
- Self-management.
- Constraints related to power should be avoided.
- Thereshould be some security set up mechanism.

IV. APPLICATION OF CLOUDLETS

Cloudlets aim to support mobile applications that are both resource-intensive and interactive. Following are some of the applications of cloudlets: - [6]

- Augmented reality applications: -Augmented

reality (AR) is a live direct or indirect view of a physical, real-world environment whose elements are supplemented by computer-generated sensory input such as sound, video, graphics or GPS data.

- Cloud games: -Cloud gaming, sometimes called gaming on demand, is a type of online gaming. Currently there are two main types of cloud gaming: cloud gaming based on video streaming and cloud gaming based on file streaming. Cloud gaming aims to provide end users frictionless and direct play-ability of games across various devices.
- Google Glass: -Google Glass is an optical head-mounted display, that is designed in the shape of a pair of eyeglasses.Google Glass displayed information in a smartphone-like hands-free format.

Apple Siri and Google Now which perform compute-intensive speech recognition in the cloud are further examples in this emerging space.

- Apple Siri: - Siri is a computer program that works as an intelligent personal assistant and knowledge navigator, part of Apple Inc.'s iOS, watchOS, and tvOS operating systems. The feature uses a natural language user interface to answer questions, make recommendations, and perform actions by delegating requests to a set of Web services.
- Google Now: -Google Now is an intelligent personal assistant developed by Google. Google Now is available within the Google Search mobile application for Android and iOS, as well as the Google Chrome web browser on personal computers. Google Now uses a natural language user interface to answer questions, make recommendations, and perform actions by delegating requests to a set of web services.

Akamai Technologies, Inc. is a content delivery network (CDN) and cloud services provider headquartered in Cambridge, Massachusetts, in the United States. Listed below are the various applications provided by Akamai Technologies: - [8]

- Edge Redirector:
  Easily manage and offload high volumes of URL redirects to the Akamai Edge
- Visitor Prioritization:
  User-friendly waiting room application for business continuity during peak traffic
- Image Converter;
  Dynamically manipulate images in the cloud for responsive web design
- Request Control:
  Provide fast and easy access control for your web applications
- Forward Rewrite:
  Rewrite clean or semantic URLs at the Edge of the Akamai Intelligent Platform
- API Prioritization :
  Prioritize visitor traffic segments to your API driven native mobile app or single-page application
- Audience Segmentation :
  Perform a traffic split with cookies for A/B testing with session stickiness
- Phased Release :
  Facilitate a fast rollout of code changes to production with real users and the ability to failback
- Input Validation:
  Protect your site from behavioral or brute force attacks through misuse of web forms

V. SOLUTION FOR OVERCOMING NETWORK LATENCY PROBLEM

Clouds are typically far from the mobile user, and the High WAN latency makes it insufficient for real-time Applications. To cope with this high latency, Satyanarayanan introduced the concept of cloudlets: Trusted, resource rich computers in the near vicinity of the Mobile user (e.g. near or colocated with the wireless access point). Mobile users can then rapidly instantiate custom virtual machines (VMs) on the cloudlet running the required software in a thin client fashion. [2]

Cloudlets are decentralized and widely dispersedInternet infrastructure whose compute cycles andstorage resources can be leveraged by nearby mobile computers. A cloudlet may be a cluster of multicorecomputers, with gigabit internal connectivity and a highbandwidth wireless LAN. A cloudlet can also be a verypowerful multi-core server with Internet connectivitydepending on the application scenario. Cloudlets have so far been proposed to assist mobile users, directly connected to them in terms of storage and processing. In addition to assisting mobile devices associated with them in storage and processing, cloudlets can also be used to cache and transfer content to mobile nodes using affordable wireless technologies such as WiFi and WiFi repeaters and/or Flashlinq. Flashlinq can give a wireless range of upto at least 500 meters. Cloudlet also simplifies the challenge of meeting bandwidth demand of multiple users, such as HD video and high-resolution images. [2]

VI. CONCLUSION

The basic limitation of all mobile devices is shortage of resources, the concept of Mobile Cloud Computing overcomes this issue. In Mobile Cloud Computing we integrate cloud computing with the mobile computing. But this integration results in a new obstacle of handling network and this is a serious problem. To overcome this issue the concept of Cloudlet was introduced.

From the above study we can say that using cloudlet Mobile users seamlessly utilize nearby computers to obtain the resource benefits of cloud computing without incurring WAN delays and jitter. So we need to more focus more on

the concept of cloudlet as a middleware for Mobile Cloud Computing.

Their ability to provide low latency, high bandwidth access to energy-unlimited high-end computing within one wireless hop of mobile devices is transformative. Many valuable applications can be created using cloudlets.

If we summarize the study we can conclude with some benefits of Cloudlets as listed below:-

- Latency reduction: - Cloudlets helps in reducing networklatency.
- Battery saving: - Battery saving can be done by offloading data on a cloud using cloudlet.
- Bandwidth saving: - Bandwidth can be reduced by compression.
- App streaming: - Cloudlets help in app streaming by reduce the app gap, it also reduces device cost.
- Reliable connectivity: -Cloudlet provides reliable connectivity with the cloud.

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