Adapted Cloudlet for Mobile Distance Learning: Design, Prototype and Evaluation

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Abstract. The Open and Distance Learning (ODL) currently operated by some institutions in Nigeria has problems of accessibility from remote locations due to bandwidth and latency issues. To address accessibility problem caused by network delays, cloudlet computing is introduced. With cloudlet technology, distant mobile learners are able to connect to the nearby cloudlet and access the learning content. Instead of relying on a distant cloud with latency issues during access, a nearby cloudlet with rich resources could go a long way to address the resource poverty of a mobile device. This paper presents an architectural design and a prototype implementation of an adapted cloudlet for mobile distance learning. The paper proposes a feature in which the learning content in the cloud or cloudlet platform is adapted to a nearby mobile learner depending on the availability of platform with minimum delays in terms of bandwidth and latency.

Keywords. Adapted cloudlet, elearning, mobile computing, ODL

1. Introduction

The tertiary institutions in Nigeria have not been able to cater for the increasing number of candidates seeking admission into higher institutions towards deriving further education. According to [1], out of the number of candidates that apply for admission every year in the country, only about 5.2% to 15.3% get admitted, meaning that about 84.7% to 94.8% of the candidates seeking admissions every year never get admitted into any of the Nigerian universities. The study appreciate the fact that this low access to higher education in Nigeria could be the result of several factors including low infrastructural facilities [2].

Intelligent voice-based mobile learning [3] and Open and Distant Learning (ODL) [2] introduced to support distant learners have their own limitations. Those learners in the remote villages who attempt to access the ODL portal normally experience network connection delays as a result of bandwidth and latency concern. This situation has made students in such affected locations to always move to the study centers in the nearest city with an improved infrastructure.

Cloud computing is among the evolving technologies currently used for learning. More so, information technology (IT) actors are convinced that this technology is essential for distributed computing and will change the way of

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conceiving and creating of web applications [4]. Cloud Computing is an emerging solution to the resource poverty of mobile devices. A mobile device has the capability to execute a resource-intensive application on a distant high-performance computer server, and support thin client user interactions with the application over the Internet. Unfortunately, the latencies of a distant Wide Area Network (WAN) constitute an obstacle. The cost of WiFi network is lesser than 3G/4G in terms of bandwidth, and the consumption of energy for 3G/4G is more than that of WiFi. This simply implies that cloudlets are evolving while WiFi network is experiencing increasing bandwidth [5].

Using mobile cloud computing means that the mobile device will always depend on the resources available on the cloud to run applications. During access time, there are issues with bandwidth and latency causing delays in processing time as a result of the distant cloud. This has given rise to cloudlet. A cloudlet is a new architectural fusion that arises from the convergence of cloud computing and mobile computing. Cloudlet comprises of three-tier elements involving mobile device, cloudlet and cloud. A cloudlet can be viewed as a 'data center in a box' whose goal is to bring the cloud closer. Easily disrupted critical dependence on a distant cloud is replaced by dependence on a nearby cloudlet and best-effort synchronization with the distant tactical cloud [6].

The convergence of mobile and cloud computing is made possible in a network environment with reliable network resources such as high-bandwidth and end-to-end network. However, the reliability of these resources cannot be guaranteed in an unfriendly environment such as victim of natural disaster or insurgence. When cloud technology is engaged in distance learning, the convenience of open and distant learning irrespective of geographical location is attained. To address this problem and provide succor to the distant learners, adapted method of learning using cloudlet is proposed. It gives mobile users the illusion that they're directly interacting with the cloud. Under failure conditions, the cloudlet masks the absence of the cloud by performing its essential services [7]. Latency issues from the client device to the cloud server can however lower the experienced quality of service (QoS) beyond acceptable levels when using distant cloud servers. Using cloudlets for bringing the cloud closer to the user solves these issues [8]. More so, mobile cloudlet for learning brings technology-based learning to the grass root. The increasingly widening gap between the people who are technologically able and those who are not gives cause for great concern [9].

This paper provides a design, prototype implementation and evaluation approach for an adapted cloudlet in mobile ODL. The mobile learner initiate a connection and an agent processes the request in order to determine the minimum delay in terms of bandwidth and latency. Using a cloudlet also make things easier in meeting the high bandwidth demand of several users simultaneously. The remaining section of the paper contains section 2 with a discussion of related work. The proposed architecture and algorithmic design of ODL for mobile cloudlet are described in section 3. Section 4 and 5 provides the prototype implementation and system evaluation. The last section concludes the paper.

2. Related Work

Several studies have been carried out on the emergence of mobile cloud and cloudlet computing. The impact of cloudlet in interactive mobile cloud applications was analyzed and studied in [5]. To study the impact, a proposal for the design of cloudlet network and service architectures was initiated. The study focuses on several features including file editing, video streaming and collaborative chatting, which are representative enterprise application scenarios. The study in [10] examined the fundamental mobile cloudlet properties that unfold when a mobile cloudlet provides mobile application service. Specifically, they investigated the cloudlet size, cloudlet node's lifetime and reachable time.

The research in [11] introduced the cloudlet approach to design a Multilingual Dictionary, which is a Cloudlet based application specifically developed to be processed on a near cloudlet as well as on a distant cloud. It was used for translating words entered through a mobile device by using a virtual machine (VM) deployment on the cloud/cloudlet and displaying the results on the mobile device. The initial version supported translation between two languages. The focus of the article was to measure the processing time and execution of a multilingual dictionary application running on a mobile device. The application used cloud or cloudlet resources in order to translate the words and display the results back to the mobile device. Execution times of the word translation using cloud or cloudlet was compared.

A usage model in which public displays can be supported with spontaneous use of interactive applications, present an example architecture of the use of cloudlets, and explore how application location impacts users' experience [12]. However, to the best of our knowledge, none of the existing studies on cloudlets provides a design philosophy, implementation and evaluation that involve adaptation of platform depending on availability, bandwidth and latency. In otherwise, the process will be executed either in the cloud or cloudlet depending on the platform with the minimum delay. This is what we regard as adaption of the cloudlet.

3. Proposed Architectural Design

The architecture of a typical cloud-based ODL system is shown Figure 1. It has three levels (Level 1: cloud ODL content, level 2: cloudlets and level 3: associated mobile devices). The mobile device functions as a thin client, with all relevant computation occurring in the nearby cloudlet. Physical proximity of the cloudlet is essential: the end-to-end response time of applications executing in the cloudlet needs to be fast (few milliseconds) and predictable. If no cloudlet is available nearby, the mobile device can gracefully degrade to the use of distant cloud or, in the worst case, solely its own resources. Full functionality and performance can return later, when a nearby cloudlet is discovered.

The proposed system makes use of the architecture in Figure 2. It contains an inclusion of a third level (intelligent layer). The responsibility of the third layer is to intelligently adapt the most suitable platform (cloud or cloudlet) to the process that desire execution. This is advocated to solve the problem of platform availability and delay.

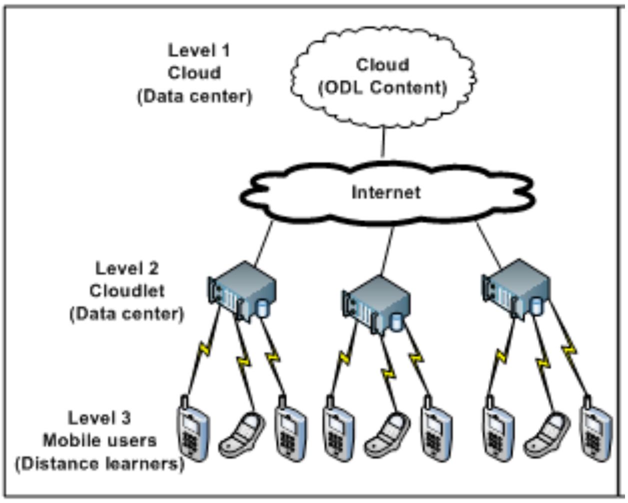

Figure 1. Cloud for Mobile ODL.

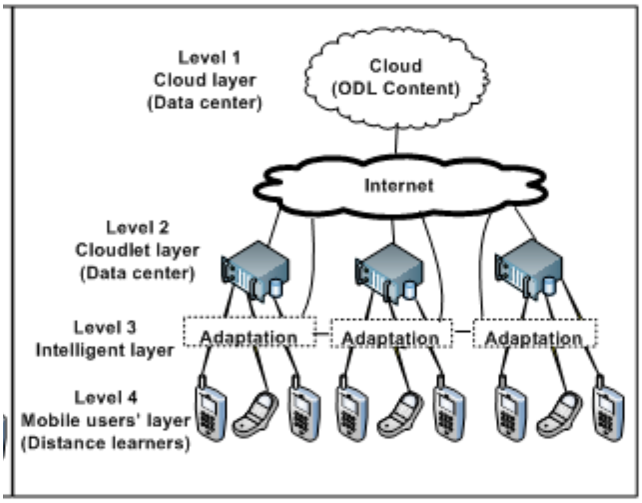

Figure 2. Adapted Cloudlet for Mobile ODL

In Figure 2, the mobile learner initiates a process execution. The minimum delay for route cloudlet and cloud are computed. Thereafter, the execution of the process is assigned to one of the platforms depending on which of them has the minimum delay. The process of adaptation involves the usage of the platform that guarantees speed and quality of service (QoS) to the user.

```
Input the learning request of mobile client;
output minimum Delay D;
compute delay D(C) ; \\ C = Cloud
\\ L = cloudlet, i = 1st cloudlet , etc.
compute delay D(Li) for i=1 to N;
DO WHILE (i < N)
  if (D(C)>D(Li) then
    min=D(Li);
   execute process on cloudlet Li;
 else
   min=D(C);
   execute process on cloud C;
 endif
ENDDO
```

Figure 3. Algorithm of Adapted Cloudlet for Mobile ODL

The algorithm of adapted cloudlet for mobile ODL is shown in Figure 3. The mobile client sends a request for process execution as input, while the minimum delay D is delivered after computation. The delay is computed for the cloud and all cloudlets. If the delay of the cloud is the minimum then D(C) is taken as the minimum. If the delay of cloudlet is the minimum, then D(Li) is taken as the minimum. The justification for the proposed system is based on the fact that the network connection to a distant cloud is vulnerable to wireless jamming or other modes of Denial of Service (DoS). The DoS threat can never be completely eliminated since most communication is done using wireless connection [7].

4. Prototype Implementation

A prototype implementation of mobile ODL was carried out to simulate the workings of the adapted cloudlet concept. The tools used engaged for the web interface include: HTML as the front end, PHP for the server side programming, Apache as the middleware and MySQL as the database. Opera mobile emulator was used to display the mobile content. Figure 4 contains the web home page of the distance learning for cloudlet, while Figure 5 and 6 shows the mobile version of the cloudlet platform with the list of courses available for upload and download.

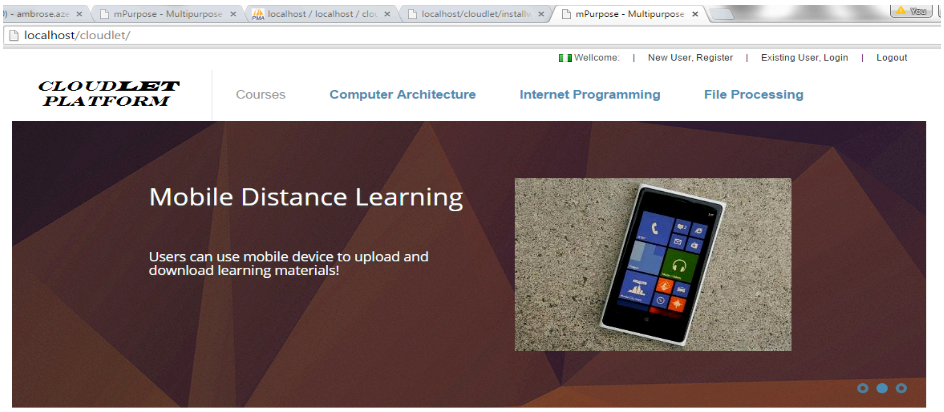

Figure 4. The distance learning web home page

Figure 5. Mobile Cloud Platform

Figure 6. Mobile Cloudlet Platform

5. Systems Evaluation

The adapted cloudlet prototype implementation was evaluated to determine its viability and usability. The technique used for the system evaluation is Cognitive walkthrough strategy [13]. Cognitive Walkthrough Strategy combines one or a group of evaluators who inspect a user interface by going through a set of tasks and evaluate its ease of use and understandability. Questionnaire was used as survey instrument with five sections namely: background information, user experience with mobile ODL, task completion success, task completion speed, ease of use and interface navigation with the system. A total of 61 questionnaires were administered to post graduate and undergraduate students but only 52 responses were received, analyzed and reported. The questions were designed using five point Likert-scale where 1= strongly disagree, 2=disagree, 3=undecided, 4=agree and 5=strongly agree. First, we briefly explained the task sequences and process to get result. A questionnaire was given to the users. Figure 7 shows the usability evaluation.

The analysis from the preliminary questions shows 56% for 'do you own/use a mobile phone', are you having challenges with accessing learning content on the web? (63%), do you think use of adapted cloudlet will minimize the bandwidth issues experienced on ODL? (69%), will you need more computing skills/training/time to be able to use the system? (62%). The survey question attributes shows Task completion success (3.97), Task Completion Speed (3.94), Ease of Use (4.10) and Interface Navigation (4.01). The resultant average gave 4.01. Several usability studies suggest that system with "Very Bad Usability" would have 1 as mean rating, "2 as Bad Usability", 3 as Average Usability, "4 as Good Usability" and "5 as Excellent Usability". It was proposed in [14] that "Good Usability" should have a mean rating of 4 on a 1-5 scale and 5.6 on a 1-7 scale. It can therefore be concluded that the prototype system presented in this paper has "Good Usability" based on the average total rating of 4.01.

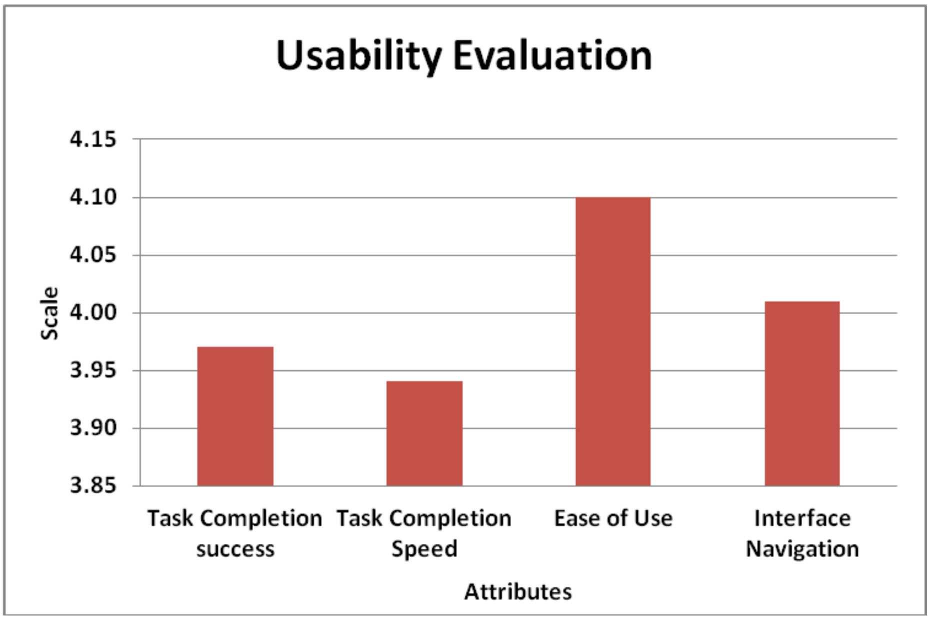

Figure 7. Analysis of Usability Attributes

6. Conclusion

This paper has presented a mobile ODL for adapted cloudlet to assist the mobile distant learners to be connected online and real-time irrespective of network delay that may arise as a result of bandwidth and latency challenges. Distant students are not able to effectively participate in the learning processes, as a result of incessant disconnections from the cloud. To solve this problem, cloudlet was introduced to allow users connect to nearby resource-rich and high latency cloudlet. However, a disconnection may still arise that may make the mobile client to do its own execution irrespective of resource restriction. A prototype implementation and system evaluation was carried out to determine the validity of the proposed cloudlet concept.

With the proposed concept, the mobile cloudlet is able to support distance application resources on the move using WIFI, which is cheaper than 3G/4G networks. A mobile learner could have the illusion that he or she is interacting with the cloud, when in true sense is interacting with a cloudlet.

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