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Analyzing Fog Computing Technologies for Enhancing M-Learning Networked Environments

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Abstract

The use of a wireless communication network has successfully enriched experiences of learning. In the service of mobile computing, education has now led to the implementation of mobile learning (m-learning). Not only to access educational resources quickly but m-learning also contributes to allowing a wide-ranging collaboration between users as learners. Supported by cloud technology, m-learning nowadays has shown its potential solution in making larger capacity and shorter processes. How-ever, a cloud-based learning architecture would only enhance the power of data storing for the applications. The implementation with the growth of billions of various devices which still needs improvements due to computing performance and content delivery need to put the consideration of fog computing as an opportunity to create an effective and efficient educational service. This paper discusses the current implementation of fog technology including a comparative analysis regarding each type of learning situations in m-learning networked environments by using a comprehensive review and expert evaluation. Findings of this study also examine the benefits and future challenges to give a broader perspective for educational purposes.

Keywords: education, fog computing, mobile, m-learning, network

1 Introduction

A large number of learning resources and educational applications has become a reasonable solution for having an easy way of learning. The use of this huge development of studying process utilizes an integrated data that can be stored in acentralize or distributed storage. Regarding the capability of storing the data, mobile devices can be seen as a significant tool to keep thousands of files. In other words, users can gather more knowledge with simpler access to learn.

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Recently, mobile learning (m-learning) has greatly affected a bigger educational network which is useful for widening opportunity to make everything accessible. As a sub-domain of E-learning [1], m-learning takes part as a situated learning which could connect users spontaneously using GPRS, 4G networks, or Bluetooth technology. As a situated learning in the field of constructive and collaborative way, m-learning is considered to be more informal [2] and stands as an inherent add-on attribute of e-learning [3]. There are many investigations which showed the increasing numbers of m-learning implementation. The phenomenon of this mobile-growth has offered some benefits such as cost-effective [3], better engagement [1], instant delivery of notifications [2], and also easy to accommodate the portable devices in learning processes.

The potency of this developing perspective in learning -could be out of traditional classroom, blended/distance learning- should consider a proper infrastructure, especially to gain a high quality of service. For reaching the goal, the utilization of cloud computing -which provide all the resources in the transparent cloud- can support users in accessing the information and services from any locations [4]. The new wave of Internet evolution through cloud services bring up Mobile Cloud Computing (MCC) environment to be available for educational platforms [5]. Regarding the infrastructure, a cloud server is needed to be allocated to create MCC environment.

However, the allocation of cloud server remained an issue in reaching learners' location. Some researchers has offered that fog would be a potential technology to solve the problem. Actions using fog technologies aimed to create an improvement of computing performance so that resources delivery between learners and the system can be more efficient. The paper is being objected to explore the problems and comprehensively analyze the current progress and future challenges regarding the development of fog in a perspective of enhancing m-learning networked environments.

2 M-Learning Networked Environments

In a networked environment, mobile devices can be connected to fog nodes, which can provide localized computing and storage resources for mobile learning applications. These fog nodes can act as a gateway between the mobile devices and the cloud, providing a more efficient and responsive learning experience.

2.1 Mobile Learning

Since e-learning transformed the education environment into a better experience with ICT-based, m-learning provides learners to utilize their hand-held devices to access and explore information wherever they want. Although the small screen is still a problem, m-learning can emphasize that the mobility would not become a barrier to learn. This concept of situated learning allow a blended alternative for formal education or stands as a supportive improvement to the learners itself. In a wider concept, m-learning is still responsible for changing a perspective of educational environment into a self-learning practice.

As another attribute of e-learning, m-learning is seen to be significant to be implemented because of these following reasons [6]:

- up-to-date information,
- keep up to online discussions,
- high collaboration between learners,
- integration to mobile features, such as media-sharing, contacts, and text/e-mail messages,
- high numbers of smartphone/tablet users,
- online/offline flexibility,
- easy evaluation/monitoring.

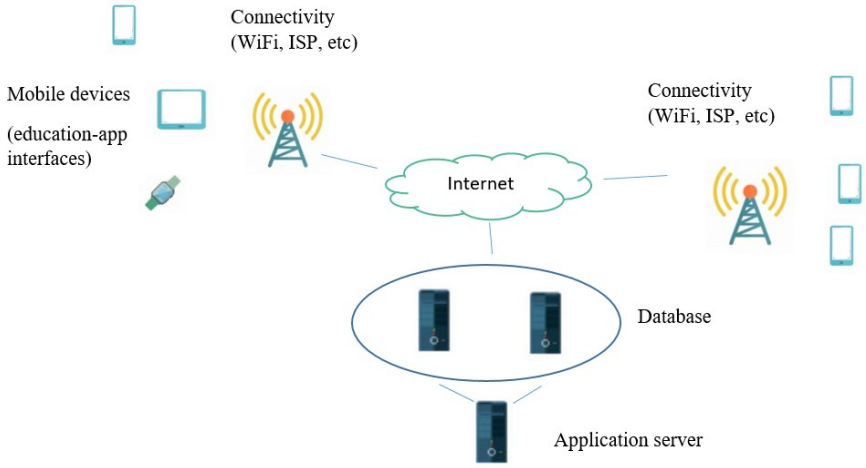


Fig. 1 M-Learning networked environment architecture

Because of those reasons, m-learning within education network would be beneficial to upgrade learning performance for each student. M-learning networked environment can offer a virtual world that could satisfy learners to have an easier access through an architecture given as Figure 1 described.

2.2 Fog Computing

In the era of Internet of Things (IoT), machine-to-machine (M2M) communication has rapidly growing through the use of smart devices including smartphones, tablets, smartwatch, and any other heterogeneous devices. Functions applied in the devices would connect one another supported by a foundation of networks. Fog comes for the view of creating a faster processes near to the device. As an extension of cloud [7], fog localizes nodes to the edge of the network so that the computation could be closer to each connected device [8]. Moreover, there is no exact standard regarding the proposed architecture of fog layers to show each stage of the nodes task.

Fog computing is an emerging computing paradigm that extends the capabilities of cloud computing by bringing computation and data storage closer to the edge of the network, i.e., closer to the devices that are generating and consuming data. Fog computing can provide faster response times and reduce network congestion by processing data closer to the source.

According to [8], overview of layers architecture is based on how the Figure 2 has shown.

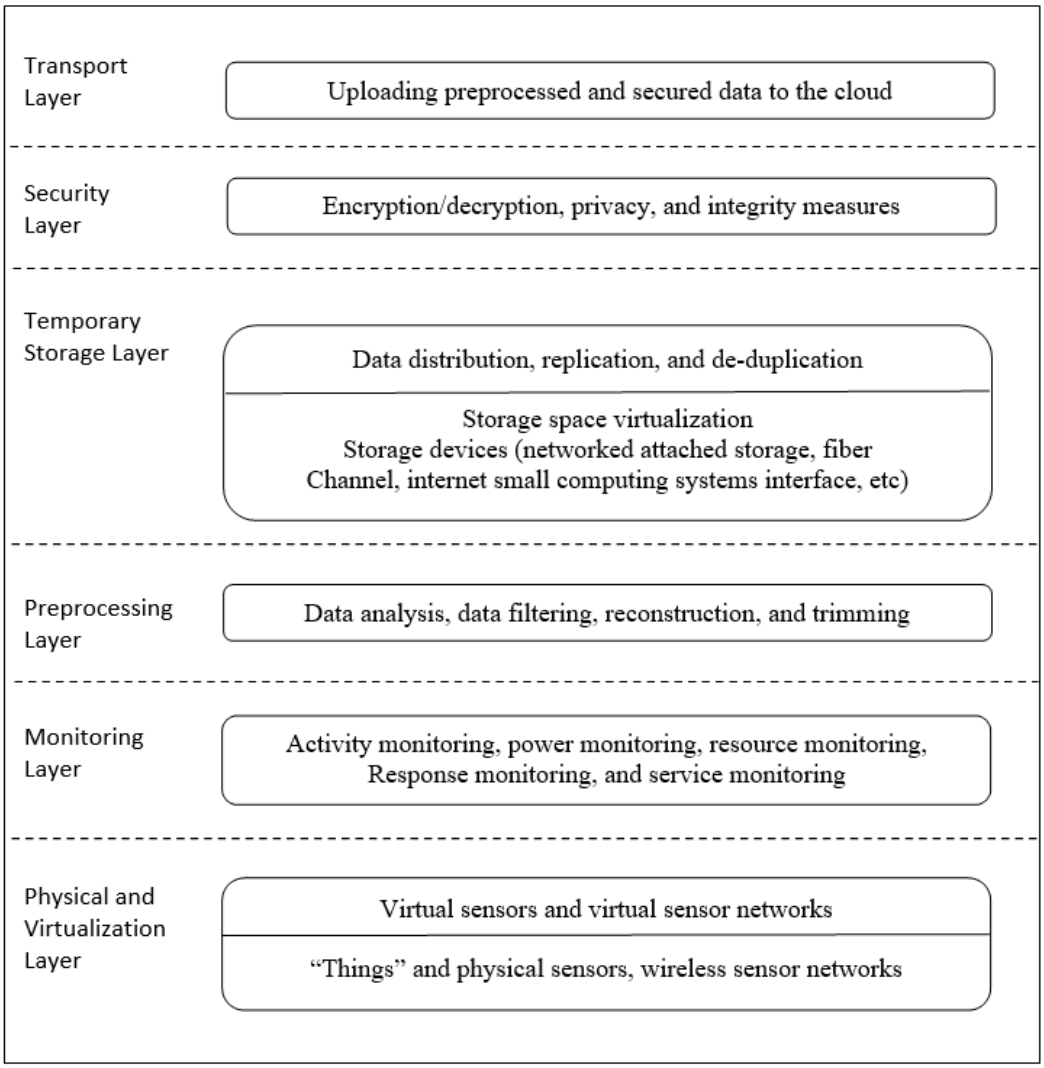


Fig 2. Example of layer architecture of fog [8]

The given layered consists of physical and virtualization layer which could manage node for every single connected object, monitoring layer as the controlling aspect for keeping the task continuity, preprocessing layer that can manage the data, temporary layer which will store a short-time-used of the data, safety and privacy handling within the security layer, and transport layer which will responsible as a readiness of fog to transmit the data to cloud.

Therefore, the cloud technology that allows a longer term of data storing would not be compared as the same level to the fog. Fog technology that uses nodes allow nearby devices to not sending its data directly to the cloud [9]. So, the implementation of going mobile in educational sector might be enhanced due to billions of devices used managing by the cloud service as a database in m-learning networked environments.

3 Method

To begin the study, the described background come up with the following questions:

1) How fog were implemented in m-learning network environments?

2) What are some benefits and challenges of fog m-learning for the future research?

Both are fundamental in taking forward the rationale and become a protocol for the further results. The study started by creating both inclusion and exclusion strategy within the review processes as shown in Table 1.

Table 1: Inclusion and Exclusion Strategy

Criteria	Inclusion	Exclusion
Availability	Full-text	Not full-text
Language	English-written	Non English-written
Year published	2016-2018	Not in the time frame
Relevance	Question-related	Outside the scope
Topic	Computer network, education	Out of the domain field

This review did a comprehensive search based on the planned criteria through several online databases using key-words: fog learning, mobile learning, fog application, fog online learning, and mobile fog learning. To explore the implementation, this study examined the infrastructure of each contents selected. The extracted data is analysed which being investigated based on the perspective of the basis network within m-learning environments.

4 Results and Discussions

User mobility presents a significant challenge in mobile learning, as learners may move between different locations and network environments while accessing educational resources. To address this challenge, researchers have proposed various approaches that leverage the capabilities of fog computing to provide localized processing and storage resources for mobile learning applications. These approaches aim to improve the efficiency and responsiveness of mobile learning, while also addressing issues such as network congestion and data privacy.

There are many approaches to achieve an efficient process to handle user mobility issue. The studies worked with the basis of allocating the fog with a proper architecture along with each objective of the work. This study extracted studies regarding current progress of fog in m-learning implementation to answer question (1). By using an evaluation criteria, the data has been through a filtration for each stage as shown in Table 2.

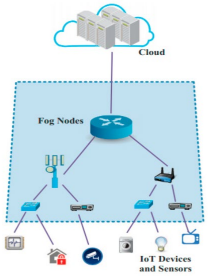
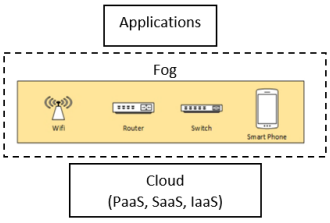
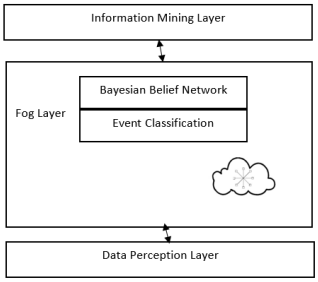
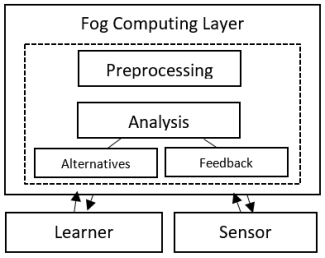
Table 2: Selection Process

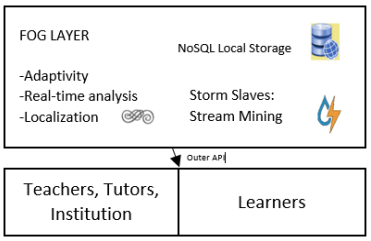
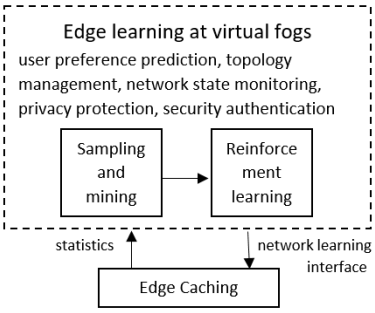
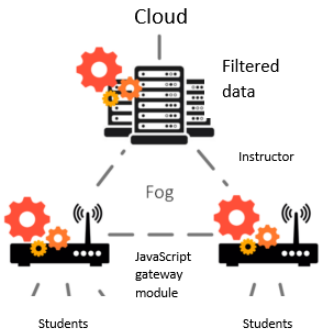
Stages	Discovered
1st	124
2nd	16
3rd	7

To see the progress of fog technology in m-learning, the following selected research has different focus yet still put the consideration about content delivery services to users (Table 3). The data extraction process yielded a wealth of information that was analyzed

to draw meaningful insights. The visualizations and summaries of the data to facilitate a clear understanding of the findings is provided.

Table 3. Data Extraction Results

Objective(s)	Method	Findings & Lesson Learned	Fog Implementation	Reference
To explore a proposed system using fog computing for data streaming service.	Literature-based review and modelling the system architecture which was simulated using COOJA Simulator in Contiki 2.7 OS	The capability of fog server with COAP protocol in controlling the traffic can make a lower response time during request session. The more number of nodes allowed the more number of requests from users		**[10]**
To explore mobile computing system for mobility big data information delivery in initiating smarter societies.	Designed architecture which was implemented into an application scenario with the basis of users' travel journey to learn the current situation from their locations.	As a supporting layer, fog was considered to store the data to get faster access based on users' preferences, location, status, etc. The technology can spread relevant information in any multimedia formats about all types of region including local, national, or international.		**[11]**
To compute the stress index of students so that they can be monitored in health field.	Simulation using a designed system with sensors which can give alert for caregivers using Ubidots IoT development platform.	The fog layer can classify the parameters of physiological aspect through IoT medical devices. By using Bayesian Belief Network (BBN), the result in fog will help to define whether the stress event is normal or abnormal.		**[12]**
To implement an efficient context-aware based mobile learning using fog	Experimental research using the basis of 3-tier (cloud, fog, and edge-tier) architecture which simulated the fog platform by using iFogSim.	Fog would be able to act as server that contains the users' data so that the system can analyze the information of learning patterns, ambient context, and the hardware capabilities. The study showed that fog is superior in compressing latency and network usage of the system.		**[13]**

To explain a proposed framework that integrates fog to virtual learning architecture in the basis of big data streams	Experimental research with case study which applied a preliminary implementation using Xiaomi AMAZFIT smartband and Android smartphone with a capability of big data stream mining from SAMOA.	The basic implementation of fog e-learning architecture contributes in reducing the number of dropouts students. By involving two comparison groups of students in eCampus University, the proposed framework has successfully utilized the fog technology to better performances.		**[14]**
To explore edge learning in 5G networks in constructing the cognitive contentcentric networking (C-CCN) by using the fog-enabled edge learning (FEL) framework	Simulated the 5G system using the proposed framework within five communities in two typical use cases, such as FEL-based personalized CCN acceleration and FELenhanced CCN mobility control which was evaluated for each case to see the fog performances	FEL can reduce content transmission delay which showed from the simulation. The decreasing hop count between content providers and requesters made less average latency because of the local fogs. The content statistics can make content to be personalized adaptively for each requester by using fog nodes.		**[15]**
To design active learning lab activity using IoT application integrated by fog computing	Experimental design using three scenarios; IoT+edge, IoT+Cloud, and Fog scenario with a proper setup of classroom (BYOB approach), materials, and software to fulfil a set of the course's objectives.	The representation of instructor's device can act as a fog node to select the significant data by a specific constraint to make more meaningful result. The heterogeneous user interfaces can also be integrated in fog scenario.		**[16]**

4.1 Current Progress

The study of [13] has successfully brought up the issue of context aware to mobile learning. By using an experimental research, the basis of 3-tier made adaptive context possible. Not only for compressing latency, fog was also be managed to improve the network usage of the system.

According to [14], fog stands as a significant technology due to the streams of big data within networks which can be managed by an efficient mining techniques. The research structured fog layer that can directly absorb data from sensors and smart devices which the participated students applied. The data could be managed to get a preliminary processing in fog to control adaptivity, real-time analysis, and localization of users.

For a broader purpose, Arfat et al., 2017 [11] has worked in creating smarter societies for a travel journey. The fog was considered to store the data to get faster access, including multimedia formats. Meanwhile, in the lines of data streaming, the fog server takes a control to the traffic so the implementation is developed due to the more requests from users [10].

Besides big data, fog can also made the network edge to behaving such of learning process [15]. The edge caching would transmit the data to virtual fogs so that mobile activity can utilize the network in creating user preferences and monitoring. Considering to the association with m-learning, the students act as user in the simulated 5G system.

Moreover, a study of [16] put the perspective of user role to the fog which was implemented in lab activity. Instructor's device could be acted as a local fog to select meaning data. Besides, this implementation give an insight in which the fog scenario can be compared to cloud scenario.

Different with the previous problem, mobile environment can also be adopted to students' health. By concerning the physiological aspect, the fog can enable event monitoring due to the classification needed for the report result [12].

4.2 Benefits and Challenges

The following summary provides an overview of the benefits and challenges associated with fog computing based on the extracted result, as described by Table 4.

Table 4. Benefits and Challenges of Fog Computing

Benefit	Challenge	Reference
Increase the competence of context learning	security and privacy maintenance degree	[13]
Reduce time		[14]
Decrease the content transmission delay	high cost to place the learning tasks for distributed data	[15]
Achieve bandwidth savings, contextual location awareness, and low latency	advance to develop	[16]
Low response time	Not available	[10]
Faster access	Not available	[11]
Helpful in event classification from heterogeneous datasets.	Not available	[12]

The table provides a summary of benefits and challenges of using fog computing in mobile learning, based on six research studies. Fog computing can increase context

learning competence, reduce processing time, achieve bandwidth savings, reduce content transmission delay, improve response time, and help classify events from heterogeneous datasets.

However, fog computing also poses challenges such as security and privacy risks, high maintenance degree, complexity in network engineering, and high cost of deploying and maintaining fog nodes. These challenges require careful consideration and design to ensure the effective and efficient implementation of fog-based localization solutions, as a previous study has stated that localisation plays a crucial role in identifying the location of nodes, events, or data sources [17].

The implementation of fog has a good performance in enhancing cloud. This advantage showed that the realization of network improvement can make an opportunity to educational experience as well. Some previous studies brought up some issue regarding big data [14], [10], [11] -which still become hot topics and relevant to recent problems [18].

In addition, the closer location of edge to the user device is also driven by a fog computing paradigm. By this reason, nodes in fog layer stands as a key for how the fog can be in the middle of users' devices and cloud. Regarding this capability of fog nodes, some exploration occur in the lines of solving the generic problem of cloud can't solve [19]. Interestingly, the power of fog in making selection, contextualization, adaptation, and filtration is showed to be promising for human interaction. Many researchers try to achieve a better system by using some approaches according to the cases [20, 21]. However, the process of fog development seemed to be in early stage so there still some problems due to the high-cost and any other advanced difficulties.

The use of fog has been implemented in many possible aspects such as context awareness, latency, cost, time, privacy, and etcetera. In educational field, m-learning can make such of wider access for learners. For example, the environment changes can make difference to how the people communicate (Figure 3 and 4).

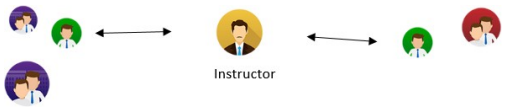


Fig. 3 instructor-led

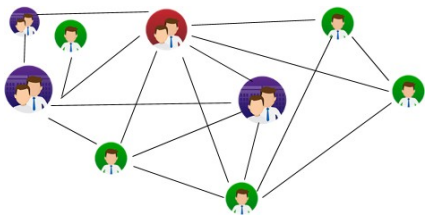


Fig. 4 learners-led

According to the problem analysis of each previous study, the general highlights of considering fog technology in m-learning implementation can be seen based on its control, time, and number and cohorts. It obviously concerns especially to the synchronous-type of time and many-type of number of cohorts. By the constructive event to the educational network (See Figure 4), the fog should be analysed to make such of efficiency.

In a mobile learning scenario, a student could be using a mobile device to access an educational application. The application could be hosted on a fog node, which would provide localized processing and storage resources. The fog node could also communicate with other fog nodes or the cloud to access additional resources, such as data or computing power. In summary, mobile learning in a networked environment in

fog computing offers the potential to provide learners with a flexible and efficient learning experience by leveraging the resources of fog nodes that are closer to the edge of the network. However, to expand any benefits, the improvement of fog computing can be expanded for any environment. The potency and capability to improve executive systems can also be seen nowadays to get more into some data retrievals [22], to achieve portability that need more speed and accuracy for users.

6 Conclusion

From the results, the implementation of fog can be enhanced time to time. This enhancement brought up from the tendency of fog to make an efficiency over the cloud. In m-learning network environments, the current progress showed to be in a premature scope. This might be happen by the fact of under prioritization. However, the fog in m-learning network environments is considered to be potential field to explore because of the recent mobility issue which needs some solution. Moreover, the impact of fog can also be seen from the previous study. It showed that fog computing has capability in giving benefits such as reduce time, context awareness, event classification, and many others. For further research, the challenge is described so that the fog in m-learning networked environments can make improvements.

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