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# Mobile learning architecture using fog computing and adaptive data streaming

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**ABSTRACT**

With the huge development in mobile and network fields, sensor technologies and fog computing help the students for more effective learning, flexible and in and effective manner from anywhere. Using the mobile device for learn encourage the transition to mobile computing (cloud and fog computing) which is led to the ability to design customized system that help student to learn via context aware learning which can be done by set the user preference and use proper methods to show only related manner subject. The presented study works on developing a system of e-learning which has been on the basis of fog computing concepts with deep learning approaches utilized for classification to the data content for accomplishing the context aware learning and use the adaptation of video quality using special equation and the data encrypted and decrypted using 3DES algorithm to ensure the security side of the operation.



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## 1. INTRODUCTION

There has been a continuous development in mobile technologies as well as pervasive Internet connectivity which is allowing users in accessing information anytime and anywhere, such feature might be applied for instrumentation regarding various applications such as education. The use of mobile devices such as laptops, tablets, and smart-phones, are making the process of learning more effective, simple and personal. Mobile learning is the term provided for such learning type [1]. The mobile learning might be utilized along with the e-learning and ubiquitous learning, also it might be specified as a sub-set regarding electronic-learning which involves using mobile devices for allowing the process of learning anytime and anywhere. At the same time, the ubiquitous learning isn't essentially using the mobile devices. Based on a study conducted by Klopfer et al. [2], there have been some properties related to mobile devices which making them suitable for educational intents – individuality, context sensitivity, social interactivity, portability, and connectivity.

Some of the features included in mobile learning are as follows – personalized information, learning throughout space-time, on-the-fly learning [3]. A study conducted by Wang [4] investigated the significance of context sensitivity as well as indicating that the main unique feature that the mobile learning environments must involve. Furthermore, the context-aware mobile learning might be helping the learner for effectively using the provided information. There have been some problems faced when implementing mobile learning, the materials of learning might involve presentations, images, and videos. In addition, supported file types,

storage capacity, screen size, resolution, Internet access, and processing time are major issues which must be dealt with. The approaches of content adaptation must be applied for the purpose of addressing such diversity issue [5]. Many studies are working on such concept of electronic-learning on the basis of fog or cloud technologies in the following way.

A study conducted by [6] designed computer-aided education platform on the basis of cloud computing technologies and mobile communication. With regard to clients, they are developing smart-phone software on the basis of open-source JavaME UI framework (kuix) in addition to Jaber that is specified for being one of the open source instant message protocols. For the purpose of helping the teachers in conveniently using the system, the study developed a website on the basis of Google App Engine, also with the use of communication platform, a student has the ability of communicating with the teacher at any possible time, thus the teacher will know the teaching's situation and the knowledge level of the student, also the teachers will have the ability for answering questions or sending messages to students freely via such communication platform. Practically, through such technical means, it is narrowing the gaps between teachers and students and producing adequate results. A study conducted by [7] suggested electronic-learning system which is based on cloud computing at Education 4.0. The major goal is producing a system which might be applied as a concept to develop e-learning system based on cloud computing which is answering the requirements of Education 4.0. Thus, this study is reviewing the works related to e-learning systems which are based on clouds.

A study conducted by [8] suggesting using LoRaWAN fog computing-based system to provide connectivity to the nodes of IoT used in the campus of University of a Coruña (UDC), Spain. For the purpose of validating the suggested system, smart campus was realistically re-created via in-house created 3-D Ray-launching radio-planning simulator which has the ability to consider minor details, like vegetation, buildings, vehicles, traffic-lights, individuals, and urban furniture. The designed tool might be providing suitable radio propagation estimation in the smart campus system with regard to energy efficiency, capacity, and coverage of the network. The results which are acquired with planning simulator might be put to comparison with empirical measurements for assessing the system's accuracy and operating conditions. The work is presenting experiments showing the adequate results acquired through planning simulator in most significant developed scenario, that have been corroborating with empirical measurements. After that, there will be explanation on the way that the tool might be utilized for designing LoRa WAN infrastructure with regard to 3 smart campus outdoor applications.

## 2. FOG COMPUTING

This is considered as one of the distributed platforms which might be providing storage, computing, as well as networking services between traditional cloud computing and IoT devices. The data centers that might be residing at the network's edge or as internal nodes related to distributed environments [9]. Also, the fog computing might be specified as the scenario in which some ubiquitous and de-centralized devices have the ability of performing many tasks in wireless and often autonomous approach might be communicating and cooperating via the networks for the purpose of performing the processing tasks and store the date with no third party's intervention [10]. Such tasks might be supporting the essential functions of the network or a few new applications and service run in its virtual environment. Furthermore, the fog computing might be specified as one of the platforms related to distributed computing extending the services provided via cloud datacenters at network's IoT devices [11]. The fog computing might be providing facility such as computing's automating management, in addition to networking and store date between IoT devices and cloud datacenters. The fog computing includes many components related to these applications that might run on the cloud in addition to the edge devices between the cloud and sensor, also it is providing features such as connectivity, communication and network protocols, computational resources, mobility, also interface heterogeneity to the cloud in addition to the data analytics related to distributed network that deal with a lot of necessities of various applications with some requirements such as low latency in addition to dense and wide dense geographical distributions [12].

## 3. DEEP LEARNING

Artificial intelligence (AI), neural networks (NNs), and deep learning are subjects which might be associated to achieve certain aims in some applications. One of the example purposes is classification. The deep learning might be specified as a modern subject. Recently, it has been of high importance in many applications, like NLP and computer vision. In comparison to conventional approaches of machine learning, the deep learning comes with solid learning ability and might effectively utilize the data-sets for feature extraction [13].

The approaches of deep learning using algorithms referred to as NNs, that have been on the basis of information processing approaches related to biological nervous system like brain and such approaches enable

the computer for learning that is represented by each data and what is meant via each of the corresponding models [14]. Recently, the deep neural networks (DNNs) showed significant performance in the tasks of image classification, also it has been specified as a machine learning model of high importance [15]. Since 2006, the deep learning was generally utilized with the advancements in speech recognition. Deep learning's recovery might be due to the next aspects. The development of large-scale annotated training data, including Image Net, for totally showing its extremely large capacity of learning; the rapid developments of high-performance parallel computing systems, including the GPU clusters; major developments in designing the training strategies and network structures [16]. The performance of deep earning in object recognition and image classification presented major advancements due to the major developments related to deep learning.

## 4. CONVOLUTIONAL NEURAL NETWORKS (CNN)

AI, NNs, and deep learning have been subjected which might be associated to achieve some aims in some application. A major approach for establishing modern deep CNNs has been via forming them in 2 NN layers, the first one has been alternating convolutional, while the other one has been max-pooling, they have been followed via a few layers which are dese, also being fully-connected [17]. Any one of the 3D volumes representing layer input as well as being converted into other 3D volume for feeding to the next layer. In the considered example, there are 5 convolutional layers, there are 3 layers of max-pooling type, also there are 3 layers which are fully-connected [17]. Starting from the advancement in the year 2012, the ImageNet competition that has been achieved through AlexNet representing the first entry which utilized deep neural network (DNN), many other DNNs with more complexity were submitted to the challenge for the purpose of achieving good performance [18].

- CNN layers: Through stacking different and multiple layers in CNN, the complex architectures have been developed for classification problems [19].
- Convolution layers: This is the initial layer utilized for abstracting the features from input image [20]. The operation of convolution is extracting various input features. Also, the first convolution layer is extracting low-level features such as corners, lines, and edges. Layers of higher-level are extracting features of higher-level [21].
- Strides layers: With regard to CNN, a stride is representing the number of pixel's shift in input matrix. In the case when the value of stride is one, the at a time, a filter might be moved single pixel. In the case when the value of stride is 2, then at a time, filters have been moved 2 pixels. Also, other stride's values are comparably considered [22].
- Padding layers: In certain cases, the filters are not adequately fit for the specified input image. In such conditions, there are 2 options:
  a) Valid: indicates no padding
  b) Zero-padding: Simply, pad zeros in the picture to get a fit [23].
- Rectified linear unit (ReLU) layers: ReLU is considered as one of the non-linear operations, also it inserts non-linearity in CNN and allowing efficient and rapid training via mapping negative values zero as well as to maintain positive values. Furthermore, there are other non-linearities such as (sigmoid) or (tanh) which might be replacing ReLU. The majority of designers or authors are using ReLU for enhanced performance in it [24].
- Pooling layer: The presented section is contributing to the parameters' number reduction when they are large images. The spatial type pooling, also referred to as down sampling, or sub-sampling, result in dimensionality reduction related to each one of the maps and keeping the significant information. A few of the types related to spatial type pooling have been average pooling, max-pooling, and sum pooling. The max pooling is assuming the biggest element in modified feature map. Suggesting the biggest element might be assuming the average pooling. The sum pooling is produced via summing all elements of feature map [25].
- Fully connected layers (FC): With regard to such type, the matrix of interest has been flattened to a vector form as well as input, such as NN. There are 2 features related to Layer (L-1), each one of them has been (2x2), for instance, has 4 elements. There are 2 features of Layer (L), each one with single element [26]. In such system, the matrix regarding the feature map is going to be turned to vectors (x1, x2, x3 …). Model's creating will be achieved via combination of features with the use of FC layers. Lastly, one activation function, such as "sigmoid" or "soft-max", has been applied for output classified to categories, for instance, boat, house, cat, tree, etc. [27].

## 5. PROPOSED SYSTEM

Using the fog computing strategies and techniques within the e-learning environment is pretty useful but still challengeable filed in general, challenges related to this topic is the security in the first place,

the channel occupancy and the data streaming of the content (audio or video), the presented work is suggesting e-learning system is proposed that try to cover the main issues related to the general concepts used within this field, the data is collected and prepared from different educational and known audio/video sites than it content can be used as an e-learning and according to the preferences of the user the data will be classify to meet that preference and to provide the correlated data only this is done via using the powerful classification technique deep learning (CNN), after that the adaptation of the audio/video quality is done to ensure the quality of service (QOS) according to the available link quality, the result of this is an adaptive quality audio/video and data is ready for transmit and in order to protect the data secret key encryption algorithm used to encrypt the data while the data is streamed from server to client, the client then receive the encrypted data and in his device the data decrypted and the final data formed and viewed to him. Figure 1 showing the general architecture related to the suggested system. The proposed system for e-learning environment using fog computing techniques try to build accurate and usable platform that can hold the main issues related to such system, this system is split up to five main phases each phase have it own algorithms and related internal steps, the phases of the system can be summarized as follow as shown in Figure 1 and Algorithm 1.

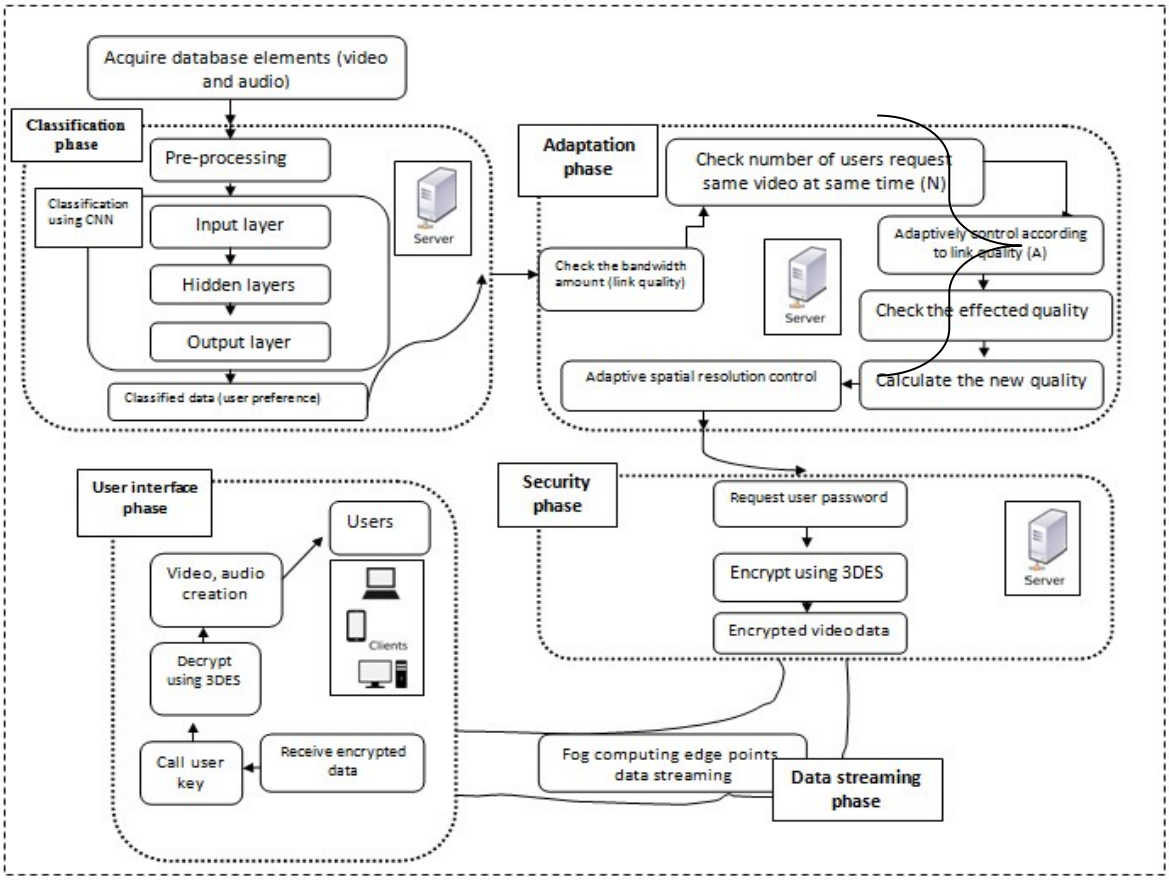


Figure 1. General architecture of the suggested system

1) Classification phase

In this phase the classification method used to check the activity of the classification process is the deep learning convolutional neural network (CNN), this phase includes some internal steps as follow:

- Step1: The first step within this phase where the collected dataset id entered to the system with special specification (each dataset member consist of 3 columns with numeric data which is represent the related information of the video data files, the numeric data used as metric for the data and special indexing of it.
- Step2: The collected data need to pre-process before using it with the training inside the classification algorithm and the classification process itself, the feature numeric numbers related to the columns in step1 is converted to real number to use it as weight within the system.

- Step3: The classification step is done using deep learning (CNN), the result of such step is the user preference. The classification and identification step are done using two main methods (using deep learning (CNN) and using machine learning algorithms) which meet the context aware learning where the suggested videos to the user will only related to the classification results which is based on his choices.
- Step4: the related subject connected to the selected subject of the user is shows within the system.

Figure 2 showing the major steps of classification phase.

Algorithm 1. Proposed system

Input: Acquire database elements (video and audio) (server side)
Output: audio/video view (client side)

```
Start
Phase 1 classification phase
step1: data (audio / video) Pre-processing.
Step2: apply the CNN classification algorithm
  • Run input layer.
  • Run hidden layers.
  • Run output layer.
  • Output the classified data.

Phase 2 Adaptation phase
Step3: Check the bandwidth amount (link quality)
Step4: Check number of users request same video at same time (N)
Step5: Adaptively control according to link quality (A)
Step6: Check the effected quality
Step7: Calculate the new quality
Step8: Adaptive spatial resolution control

Phase 3 Security phase
Step9: Request user password
Step10: Encrypt using 3DES
Step11: Encrypted video data

Phase 4: Data streaming phase
Step: data streamed inside channel

Phase 5: User interface phase
Step: Receive encrypted data
Step: Call user key
Step: Decrypt using 3DES
Step: Video, audio creation
Step: show to user

End
```

Phase 1

Phase 2

Phase 3

Phase 5

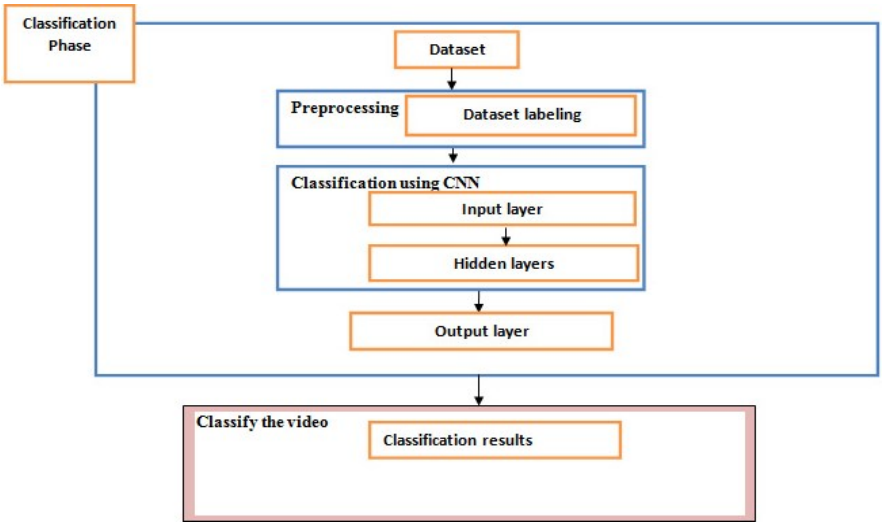


Figure 2. Flowchart of classification using CNN

2) Adaptation phase

In this phase the problem of channel capacity and bandwidth availability solved by adjusting the quality of the audio/video using proper techniques and equations to reduce the resolution of the audio/video in the case when the number of users requests the same video at the same time is huge and the data need to be sent to users at the same time and the channel bandwidth will not be available and the general concept of fog computing was used within the proposed system. Figure 3 and Algorithm 2 summarize the proposed methodology related to mobile video streaming system using adaptive spatial resolution control; this method will be assigned to the server side to the system as shown in Figure 1 where the client side will accept the output resolution video streaming without having any decision to the re-sizing of the resolution.

The system owner (admin) will setup the best resolution of the video when many numbers of users are within the system requesting the same video for data streaming according to energy consumption and best available picture quality providing the available bit-rate and input video according to number of system users. The new resolution of the chosen video is prepared and down sampled to the calculated resolution and encoded via the encoder. The decoder on the user device (mobile application) when receive the bitrate and the up-samples it will decode the video and display it on screen (after encryption/decryption process is done).

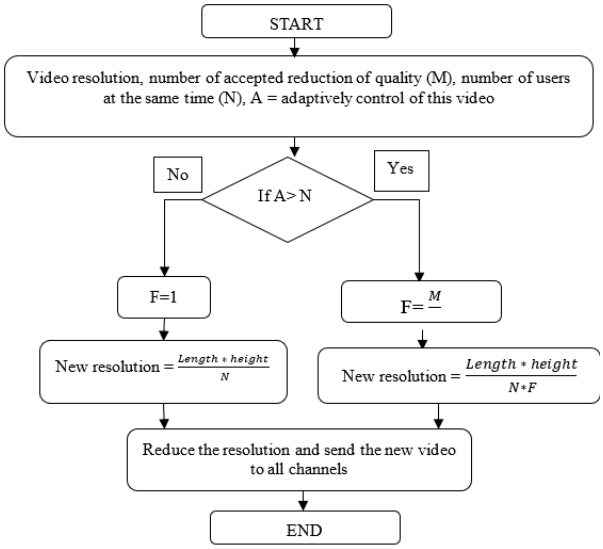


Figure 3. Architecture of proposed adaptive video streaming system

Algorithm 2. Adaptive video streaming

Input: video resolution, number of accepted reduction of quality (M), number of users at the same time (N), A = adaptively control of this video
Output: new output resolution

```
Start
Step1: if N > A the goto step 3
Step2: if N<=A then F=1 AND find new resolution
New resolution = Length * height / N
Goto step 5
Step3: calculate F
F= M/N
Step4: find new resolution
New resolution = Length * height / N*F
Step5: reduce the resolution and send the new video to all channels
End
```

The adaptively is controlled by the server admin or algorithm, since the resolution of the video is cannot reduced to unlimited number of times, where the video content will disappear and cannot be understandable, the system admin (server owner) will indicate the number of times that the max quality of t he video reduced, if the number of user will reflect the requested number then the new video resolution will be founded and send to all users of the system if not then the following equation will be applied,

$$New\ resolution\ = \frac{Length\ *\ height}{N * F}$$

where length and height is the video resolution,
N representing the number of users requested the video streaming at same time and **F** is the factor that adapts the resolution and video quality which is calculated as follow:

$$F = M/N$$

In which M representing the number of users prefer by the system admin (the resolution where the system below it will not be recognizable).
E.g. if $N = 10$ and the preferable number by admin is $M = 3$ the result will be as follow:
$3/10 = 0.3$ which will represent the scale factor of the system
Example 1: video1 resolution is $600 * 600$ and the resolution setup by admin that it can be reduced to 4 times (A = adaptively control according to link quality) and

- 4 users order the video then

$$New\ resolution\ = \frac{Length\ *\ height}{N * F}$$

Since number of users is <=A then F=1

$$\frac{600\ *\ 600}{4 * 1}$$

And the resolution will be distributed on four channels.

- 10 users order the video then

$$New\ resolution\ = \frac{Length * height}{N*F}$$

Since number of users is > A then $F = \frac{M}{N}$ which is

$$\frac{4}{10} = 0.4$$

$$\frac{600\ *\ 600}{10 * 0.4}$$

And the resolution will be distributed on four even if the users are 10 to keep the quality with the accepted levels.

3) Security phase

A problem associated to using fog computing technology has been the security issues, within this work a private key method used to encrypt the data transmitted from server-side to client-side inside the fog computing map which is 3DES. This algorithm will be in both server-side (for encryption) and client-side (for decryption) and the key for this operation is the user password. The developing a system of e-learning which has been on the basis of fog computing concepts with deep learning approaches utilized for classification to the data content for accomplishing the context aware learning and use the adaptation of video quality using special equation and the data encrypted and decrypted using 3DES algorithm to ensure the security side of the operation.

4) Data streaming phase

The data of the video streamed as bits using the channel of the video streaming which based on fog computing this allow the client on the server side to view the video without the need to download it. The data Streaming is continuously generated by different sources. And it processed incrementally using Stream Processing techniques without needs to access to all data. In addition, it is usually used in the context of big data in which it is generated by many different sources at high speed.

5) User interface phase

The data received on the client side (mobile phone) with programmed application using android studio that will decrypt the data encrypted in the server side using the user password and show the video on the user device. System outcome many dataset elements were used to tests the activity of the proposed framework, the user preferences set up six times each time the user requests special lecture and the number of

users requested the same lecture is changed 3 times, within the tested framework with data set elements, the network admin set that these resolutions can be reduce quality 4 times maximum according to link quality at the moment of requesting the video and 2 scenarios assumed where:

a) One user request the videos

$$New\ resolution\ = \frac{Length\ *\ height}{N * F}$$

N= number of users =1, F=1 since the number of user is <= the number assigned by the system according to the link quality.

$$\frac{484\ *\ 360}{1 * 1}$$

Same quality will stream to the requested user.

b) 10 users order the video then

$$New\ resolution\ = \frac{Length\ *\ height}{N * F}$$

Since number of users is > A then $F = \frac{M}{N}$ which is

$$\frac{4}{10} = 0.4$$

$$\frac{484\ *\ 360}{10 * 0.4}$$

And the resolution will be distributed on four even if the users are 10 to keep the quality with the accepted levels. Table 1 show the experiments results of the videos after applying the quality reduction. In order to check the effectively related to the suggested system it has been compared to some of the suggested system within the same field as shown in Table 2.

Table 1. Experiments results of the videos after applying the quality reduction

| No. | Lecture name | Resolution | | Resolution/2 | | Resolution/4 | |
|---|---|---|---|---|---|---|---|
| | | (Width | High) | (Width | High) | (Width | High) |
| 1. | C++ programing Language | 484 | 360 | 242 | 180 | 121 | 90 |
| 2. | Introduction to Data Mining | 1280 | 720 | 640 | 360 | 320 | 180 |
| 3. | Hub, Switch, & Router What's the difference | 1440 | 1080 | 720 | 450 | 360 | 270 |
| 4. | Network Security | 1920 | 1080 | 960 | 540 | 480 | 270 |
| 5. | Self-Organizing Maps | 640 | 480 | 320 | 240 | 160 | 120 |
| 6. | Computer Science Vs. Computer Engineering | 854 | 480 | 427 | 240 | 213 | 120 |

Table 2. Brief of analysis of different features provided put compared to other models

| Features | [6] | [7] | [8] | Proposed system |
|---|---|---|---|---|
| Detects and takes into account the real-world contexts (real educational videos) | No | No | Yes | Yes |
| Situates learners in more than one learning scenario | Yes | Yes | Yes | Yes |
| Adapting learning content for individual learners | Yes | No | No | Yes |
| Adapting learning interface for individual learners | No | No | No | Yes |
| Provides learning guidance or support across contexts | No | No | Yes | Yes |
| Considering online learning status of learners | No | Yes | No | Yes |
| Learning from previous implementations and thus changing the content | No | No | No | Yes |

## 6. CONCLUSION:

The use of mobile devices such as laptops, tablets, and smart-phones, are making the process of learning more effective, simple and personal. Mobile learning is the term provided for such learning type. The mobile learning might be utilized along with the e-learning and ubiquitous learning, also it might be specified as a sub-set regarding electronic-learning which involves using mobile devices for allowing the process of learning anytime and anywhere. In this paper a proposed architecture of fog-based e-learning framework using many techniques related to the main manner of the system deep learning for classifying the data to comply with user preferences and quality adaptation to change video resolution while send it via data streaming and the sent data were encrypted using 3DES. The benefits of the frame work are to meet the user (student needs) and using fog computing which

faster than other techniques. The presented study works on developing a system of e-learning which has been on the basis of fog computing concepts with deep learning approaches utilized for classification to the data content for accomplishing the context aware learning and use the adaptation of video quality using special equation and the data encrypted and decrypted using 3DES algorithm to ensure the security side of the operation.

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