

Blended Learning Resources in Constrained Bandwidth Environment: Considerations for Network and Multimedia Optimization

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Abstract

The potential of multimedia teaching and learning approach at higher education is well recognized by researchers, as it is a powerful tool to increase the perceived level of user satisfaction, leading to enhance the blended learning process. However, the learning process can be improved significantly by delivering the content using visual media (video, audio, and graphics). On the other hand, such multimedia contents require larger bandwidth for transmission over the Internet, which is limited in developing environments where demand always exceeds the resource. This paper constructs a framework comprising of network optimization and multimedia optimization, as two main components, aimed to improve the multimedia performance in the context of constrained bandwidth environment.

Keywords: *Multimedia, Blended Learning, Optimization, Constrained Bandwidth Environment.*

1. Introduction

The advances in Information Technology (IT) have brought about a fundamental change in content delivery mode at Higher Education (HE). During this technology move, blended learning, a new frontier emerged as an attractive model at university level, as neither virtual nor physical resources could provide the best teaching and learning experience. Blended learning has witnessed an exponential growth from the perspectives of both theoretical and practical implementations, in many parts of the world over the past few decades [6]. Clients (students) today expect more innovative, sophisticated, cost effective, innovative, anytime, anywhere, on demand

accessible engaging learning material in a user friendly environment.

Researchers perceive visual media (video, audio and graphics) as a potential tool for providing an engaging environment as it has the capacity to become a motivating factor for the learners that would in return enhance the learning process as a whole, facilitating the supportive on line learning that is a part of blended learning [4], [5].

However, visual media applications demands for high bandwidth for transmission over the Internet which is the vehicle for multimedia. But research indicates that bandwidth is still very low in many parts of Asia, Africa and Latin America [7]. The heterogeneous network conditions caused by low bandwidth, adversely affect the efficient delivery of multimedia content to the users.

Though there is literature on the area of blended learning, for example, [8], [9], [10], [11], a fewer studies focus on adoption of multimedia learning in blended learning environment in developing countries. The influencing student learning motivation determinants are also seldom considered in previous research. Therefore, transmission of multimedia over the Internet in Constrained Bandwidth Environment (CBE) still remains a challenge. CBE is a peculiar state associated with the context of most Least Developed Countries (LDCs). The prerequisite to successful e- adoption at HE requires optimization of the learning resources that includes network and multimedia content, the basic components of e-learning [2], [3].

Moreover, network and application are symbiotic and are highly correlated [1]. This paper aims to fill the research gap and constructs a framework that clusters those two factors into its two main components to investigate the determinants influencing perceived level of user satisfaction, in the context of constrained low bandwidth environment. The critical literature review and scanning was also carried out prior to the designing of the framework.

2. Basic Concepts

2.1 Blended Learning

In literature, numerous definition of the term blended learning can be found. Different authors perceive blended in different ways. However, from the perspective of higher education, blended learning is the approach that combines the strength of conventional classroom learning with e-learning to optimize the learning process [8]. The definition of e-learning used in this research is the combination of multimedia and network learning [34].

2.2 Constrained Bandwidth Environment (CBE)

Constrained Bandwidth Environment refers to an environment where the Internet bandwidth capacity is insufficient as compared to the demand, coupled with other bottlenecks such as high cost, misuse and mismanagement of available bandwidth, viruses, spam and worms leading to network congestion.

3. CBE Multimedia Content

This section used 4-phased Multi Level Systematic Approach (MLSA) [35] to guide the systematic analysis procedure of identifying visual media (video, audio, and graphics) content compatible with the challenges of constrained bandwidth environment.

At phase I, the study found a huge database (fileinfo.com) [36] for video, audio and graphic formats. The phase I survey results led to phase II where the most commonly used visual media was selected. The findings of second phase inquiry suggested that there are 9 very commonly used video formats namely, Audio Video Interleave (.avi), Moving Pictures Expert Group-4 (MPEG-4) (.mp4), Moving Pictures Expert Group 1,2 (.mpg), Shock Wave Format (.swf), Window Media Video (.wmv), Advanced System Format (.asf), Apple QuickTime Movie (.mov), Real Video (.rv), and Real Media (.rm).

On the other hand, Real Audio (.ra), Moving Pictures Experts Group Layer 3 (MP3) (.mp3), Window Media Audio (.wma), and Wave Audio (.wav) emerged as most commonly used audio formats. Whereas Joint Pictures Expert Group (JPEG) (.jpg), Portable Network Graphic (PNG) (.png), Bitmap Image File (.bmp), Graphic Interleave Format (.gif), and Tagged Image File (.tiff) were identified as most commonly used graphic formats.

After completing the phase II research, further investigation of all types of identified visual media was conducted, at phase III. The characteristics used for video formats included: Developer (Publisher), Platform Operability (platforms; Windows, Linux, and Macintosh require to open), Non-proprietary (Non Licensed or Open Source), International standards/ISO (Recognition by International Standard Organization), No packet data dependency and Mix media ability. However, the phase III inquiry of audio and graphics was based upon the following characteristics: Developer, Platform, Non-Proprietary and International Standards. The other two attributes, No packet data dependency and Mix media ability are meant for video formats only.

The phase III investigation was followed by phase IV. Drawing upon the findings of the phase IV survey, the research concluded that MPEG-4 (.mp4), MP3 (.mp3) and JPEG (.jpg) or PNG are, respectively, the video, audio and graphic formats compatible with CBE. We further found that JPEG compression standard is more appropriate as compared to PNG in the context of CBE, required to increase the perceived level of user satisfaction, as it does not make any significant noticeable change in the original image. More importantly, JPEG has its distinct and unique characteristic of providing the “trade off” between quality and size of the graphic file to the user.

4. Related Research Efforts

Among the various models for adoption of blended learning that exist in the literature, the most popular frameworks include: A Framework of Effective Blended Learning in Higher Education Institutions (FEBLH) [8]; 4 Factor Blended Learning Framework (4FBLF) [9]; A Blended Learning Framework (BLF) [10], and A Blended Learning Model (BLM) [11].

An overview of the identified blended learning frameworks suggest that mainly they address issues related to the following components: Institutional (Organizational readiness, administrative & academic affairs etc.); Learners & Lecturers concerns (Audience and their requirement analysis); Pedagogical (Content

analysis, design & learning objectives); Technological Infrastructure (Hardware & software); Learning Content (Teaching, learning or training material); Management & Evaluation (Logistics, learners support service, registering, and assessment); Ethical (Copyright, cultural diversity & equal opportunity); Resources (Human & financial resources); Interface Design (user interface); and Interactivity (Interactivity among various learning modes in blended learning environment).

During the analysis of the survey data, we also noticed that Interface Design and Ethical related issues are addressed only in [10]. Similarly, Interactivity component is discussed in [8], but there is no consideration for Resources component in that framework. To sum up, the identified existing blended learning frameworks, in general, presented the similar components.

Strategies and techniques of introducing technology enhanced learning in LDCs differ significantly than those used in developed countries, due to different cultural and economic conditions [12]. On the other hand, the reviewed literature reveal that many aspects of constrained bandwidth environment are taken for granted that need to be addressed explicitly. Moreover, introduction of an innovation is a complex process which involves its interaction with contextual factors [13]. Thus, it has become increasingly evident that there is a

significant need to fill the knowledge gap, influencing the developing of a new blended learning framework [14] which can be adapted within the given social and infrastructural conditions, with particular emphasis on CBE [8].

5. Proposed Blended Learning Framework

This paper used Khan's framework [10] as basis. Khan's framework addresses a wide range of issues as compared to other identified strategies. The Pedagogical dimension of Khan's framework states that institutions are required to carry out content analysis, but does not provide any details about the type of content compatible with the challenges of constrained bandwidth environment where designing the content is costly. In the same dimension, the framework emphasizes upon the provision of sufficient bandwidth, which is always limited in the context of developing countries that fall under constrained bandwidth environment.

The proposed framework addresses the above two most critical issues not addressed by Khan's framework, impeding the technology integration process in emerging economies.

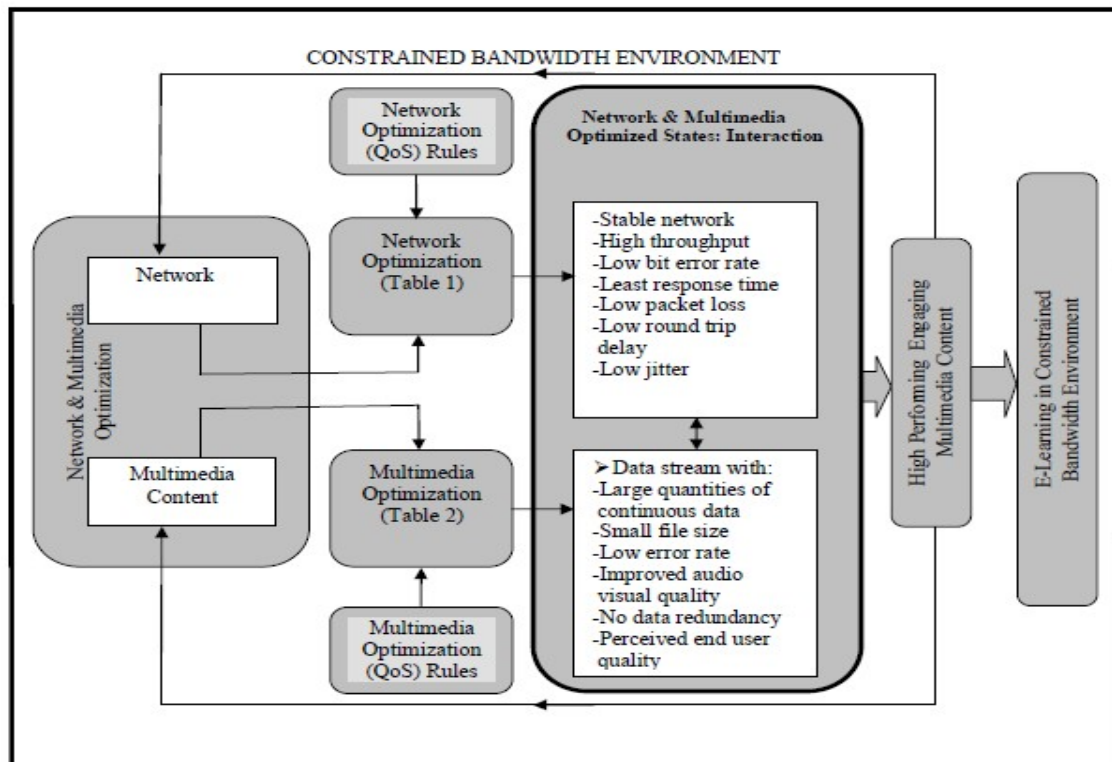


Fig.1 Optimization Based Multimedia Learning Framework for CBE (OBMLFCBE)

Fig.1 presents the design of the proposed framework, comprised of a sequence of processes having their inputs and outputs. Network optimization and Multimedia optimization are two main components of the framework, governed by their respective Quality of Service (QoS) rules, being input to the next process that has High Performing Engaging Multimedia Content as an output, leading to e-learning process in CBE and closes the loop. Network Optimization and Multimedia Optimization together with various related technological concepts are discussed in the sections that follow.

5.1 Network Optimization

Table 1 as mentioned in Fig. 1 outlines the techniques that can be used to optimize the network system in an organization. Filtering the network traffic, aimed to reduce the congestion, can significantly enhance the network efficiency. Network congestion is the state when the demand exceeds the resource which can occur in any link along the path that connects two end hosts. Network congestion is not specific to any region or country, as realized by the researchers long ago [37]. In a state of congestion, the number of packets present in a subnet, are

more than its capacity, thus all packets do not reach at the destination as some are lost. However, if packets are in proportion to the network capacity all packets are delivered to the destination and there is no packet loss.

Table 1: Network Optimization

Network Optimization
- Filter the Network traffic: -block undesirable web applications, spam, viruses and worms -prioritize time sensitive applications over other network traffic -prioritize among user categories -restrict large file download timings - Use gateway websites, proxy and cache servers - Reduce the usage of large bandwidth consumers (e.g., hotmail and yahoo mail) and use campus webmail - Upgrade technological infrastructure and install high performing network systems - Implement bandwidth usage policy, devise bandwidth management committees, train and monitor IT department staff - Form consortium and purchase bandwidth in large quantity

Packet Filter Firewalls and Access Control Lists (ACLs):

In computer network system, information travels from one point to another in form of packets (cluster of bits) that are characterized with attributes such as source address (from where it originates), destination address (where it is destined to arrive), source port, and destination port, among others. Packet filter firewalls are network devices that filter the incoming and outgoing unwanted traffic, aimed to enforce an organization's security policy. A firewall examines the information contained on the header of each arriving packet, and compares it with a set of rules that govern its acceptance or discarding. These rules may be called Quality of Service Rules (QoS), commonly known as Access Control Lists (ACLs) [15], [16], [17]. The rules are applied to the packets in a sequential order from first to last rule before the final action is taken.

Authentication: In general, password based user authentication systems are widely used to restrict the access of unauthorized users to network resources, governed by organization's policy rules [18]. However, users are required to choose strong passwords comprised of a combination of both alphabets and numeric characters.

Prioritizing Network Traffic: By classifying and allocating specific amounts of bandwidth to each category of network traffic, prioritization technique is used to provide absolute guarantee through resource reservation, to enhance the Quality of Service (QoS) for real time multimedia such as video and audio. When applying QoS, time sensitive data is prioritized over other network traffic and processed before all other data streams. Similarly, the technique is used to prioritize among various categories of users, based upon their associated credentials. In constrained bandwidth environment where bandwidth demand exceeds the resource, it is vital to apply QoS [19] and is extremely useful to minimize the packet loss and delay for real time multimedia contents [20].

Time Based ACLs: Time-Based ACLs that are configured on router interfaces in the network are type of ACLs used to restrict the heavy file download timings, to save the bandwidth.

In universities, the students usually download and upload huge files during the busy working hours of the week that consumes a lot of bandwidth which needs to be managed and utilized efficiently for academic purposes. Therefore, the campus network systems need application such as Time Based ACLs to manage the bandwidth to reduce the

upload/download activity, especially during the working hours (08.00 -18.00) throughout the week, and set to be normal again during the weekend. Such ACLs can be configured on a router interface in the network system by using simple command (Cisco IOS Software Release 12.0.1.T), described in Table 2 that presents the general syntax of Time Based ACLs. Time-Based ACLs are implemented by creating the time range on the router, using preferably the Network Time Protocol (NTP).

Table 2: Syntax for Time Based ACLs

R1	Define time-range and assign it a name (configure) # time-range <i>time range- name</i>
R1	Define the period (configure) # [<i>days of the week</i>] to [<i>days of the week</i>]
R1	Apply time range to ACL (configure) # hh : mm to hh : mm
R1	Apply ACL to Interface (configure) # ip access-list: <i>name/number</i> <extended_definition> time-range <i>name_of_time-range</i>

Cache and Proxy. Cache and proxy are local memory techniques. Deployment of proxy caching systems with multiple servers in the organization's network that can serve as intermediary between clients and the central servers on the web, can significantly reduce the network bandwidth consumption, improve the server's performance, and reduce perceived user latency [21], [22], required in the context of developing environments.

Proxy server receives requests from users and forwards them to the central server on the web, if the required information is not available in the local cache [22]. Proxy server saves the copies of all the retrieved web pages that can be accessed by users locally, when necessary, instead of retrieving them again from remote server on the web that reduces bandwidth consumption and delay.

On the other hand, cache server is used to save the most popular digital contents locally that are required by the users. The two main purposes of using proxy and cache servers are to speed up users' access to required information leading to increase in perceived level of user satisfaction and reducing the bandwidth requirement.

Network Optimization-System Architecture: Fig.2 presents the system architecture of network optimization. According to Network Optimization System Architecture [23].

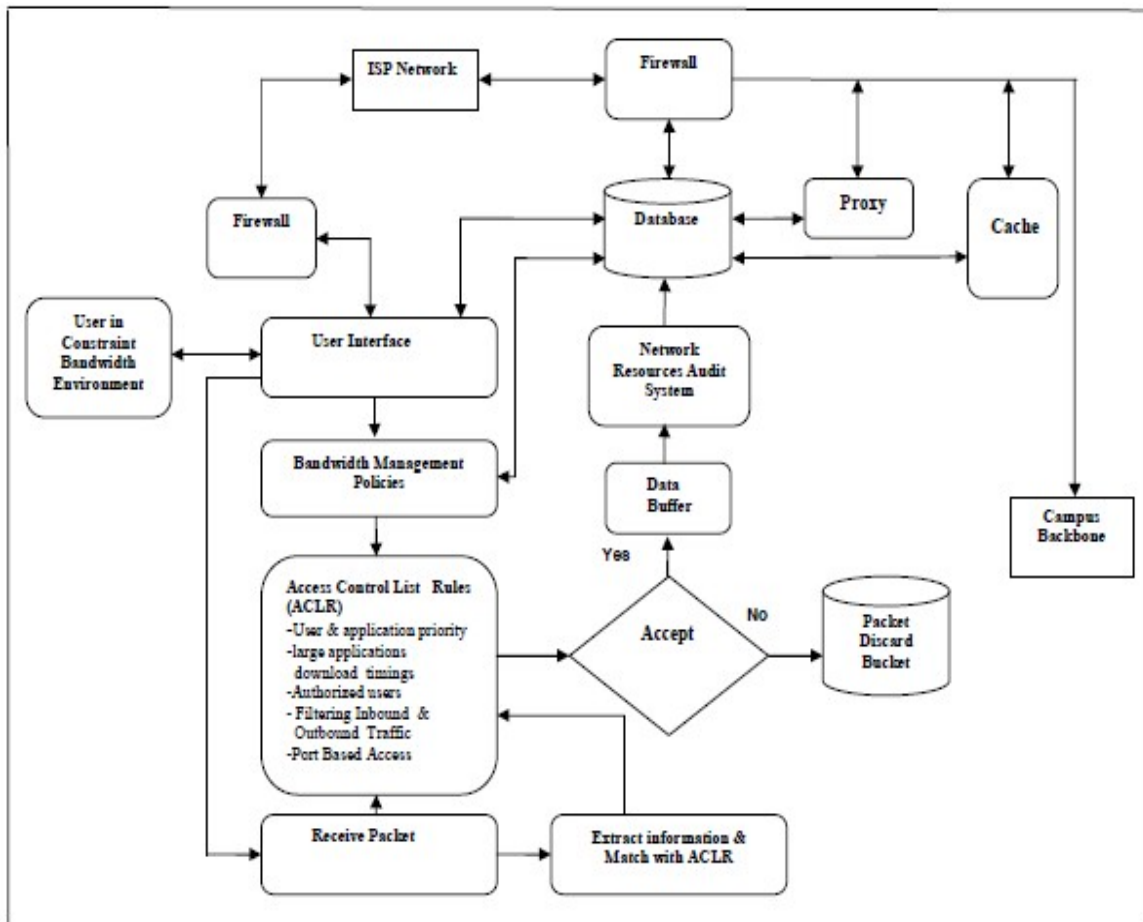


Fig.2 Network optimization-System Architecture

- User submits the request through User Interface(UI)
- Access Control List (ACL) Rules Judgment Unit matches the incoming packet with associated rules stored in Access Control Lists
- If packet does not fall in privileged list, it is sent to packet discard bucket
- If accepted, the Access Control Unit updates the access control lists, and sends information to Data Processing Unit to begin accounting network usage on the subscriber
- Information Retrieval Unit extracts accounting information from the packet and stores it into accounting data buffer
- From accounting data buffer, Data Processing Unit reads information for post-processing, and saves the results into database which is connected with proxy and cache servers
- If the request is not met by proxy and cache servers, it is forwarded to Internet Service Provider (ISP)
 - Finally, the user can find the relevant information in database through UI

5.2 Multimedia Optimization

From the perspective of Internet, the term multimedia refers to the presentation of information using several media such as text, graphics, audio, and video. Implementation of fully interactive multimedia learning systems in constrained bandwidth is still a challenge due to insufficient available bandwidth, signifying the need to redesign the learning content. The compression and streaming techniques [20] shown in Table 3 can enhance the media quality and user experience in resource constrained environments [24].

Table 3: Multimedia Optimization

Multimedia Optimization
• Use multimedia Streaming and Compression techniques -Video: Use .mp4 an audio video format that provides best compression and provides better quality multimedia at lower bit rate -Audio: Use .mp3 audio file that creates 12 times smaller files yet preserves the quality - Graphics: Use Joint Photographic Expert Group (JPEG) or Potable Network Format (PNG) graphic files. JPEG provides trade off between size and visual quality

Multimedia Streaming: Streaming media techniques are applied for transmitting real time video and audio data as a continuous stream to the receiver, once the sender start sending the file, without waiting when full contents are ready in local storage. Playback starts as soon as enough data has been downloaded by the user's computer that can maintain this playback. However, before streaming, multimedia contents must be compressed as these files are heavy. Furthermore, the transmitted data is again decompressed before viewing by the viewer. Real time streaming contains live events such as a lecturer delivering a lecture in the class room. On the other hand, in on demand option, streaming multimedia contents is provided to the client on demand.

Multimedia Compression: By removing the information that is indiscernible by the viewers, compression technique is applied to reduce the enormous amounts of data and the file size to manageable level for efficient transmission of multimedia applications over communication networks. This technique can significantly reduce the bandwidth requirements as required in the context of developing countries. There are two types of compressions; lossy and lossless. In lossless compression exact data is recovered without any loss of information, whereas in lossy compression, original representation cannot be recovered, some data is lost. However, lossy compression provides high compression ratio and is of more practical use. It is used for multimedia contents such as visual media that are not sensitive to losses and contains a lot of redundancies.

Video. Delivery of multimedia contents such as video requires much bandwidth. Therefore, real time transmission of video in low network's bandwidth is a challenge. However, the compression technique that removes the redundant data from the video files until the minimal compression is achieved, under the Quality of Service rule, can significantly reduce the demand for high bandwidth [25].

Section 3 investigation results concluded that MPEG-4 (.mp4), a standard video compression is most appropriate, for utilization in CBE. MPEG-4 has unique attributes that include: efficiently encoding (compressing) mixed media, no packet dependency on previous packet, error resilience [26]. And providing better quality video at low bit rate [27].

Audio. Audio is also a time sensitive application that requires much storage space and greater network bandwidth, whereas the compression technique reduces the storage requirements. MP3 is standard audio compression that is compatible with challenges of CBE, as identified in section 3, capable of providing acceptable sound quality at 64kbps and 128kbps respectively, over single channel and stereo [28]. MP3 is a best sound format with compression ratio 1:12 yet preserving the quality. More importantly, MP3 files can be easily convertible in CBE [29].

Graphics. Graphics can be optimized by reducing size, resolutions and number of colors. The findings of investigation in section 3 suggest that Joint Photographic Expert Groups (JPEG) or PNG type graphic files are compatible with CBE that provide better compression, required in the context of developing countries. However, JPEG algorithm is more appropriate as compared to PNG as it has the distinct attribute of providing users the "trade off" between the file size and quality.

Multimedia Optimization - System Architecture: Fig. 3 presents the system architecture of multimedia optimization. Various step involved in streaming [30] include: data acquisition, data compression under Quality of Service (QoS) rules, followed by Data Encryption.

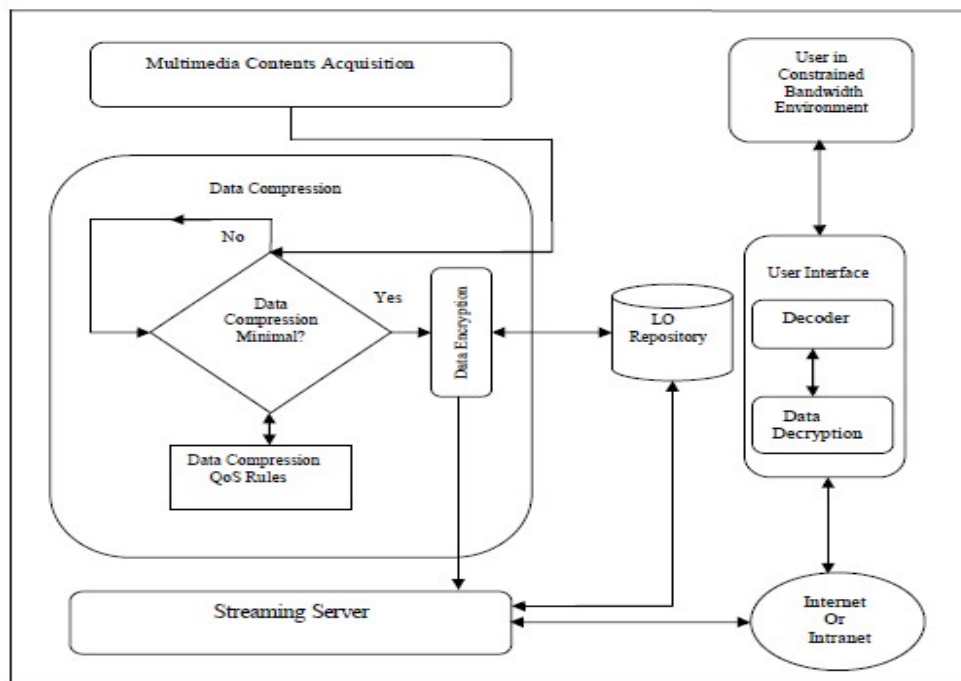


Fig.3 Multimedia Optimization-System Architecture

The encrypted data is transferred to Streaming Server through Learning Object Repository (LOR). On the other side, user in CBE interacts with multimedia contents through User Interface (UI) using Internet or Intranet. However, the data is decrypted and decoded before viewing as described in the figure.

5. Conclusions

The findings from literature review were drawn together to identify core of issues and factors that formed the basis of the designed framework. A framework for implementing blended learning in constrained bandwidth environment consisting of two core components; network optimization and multimedia optimization was then presented and the details for each of the components was provided. Network system architecture and multimedia system architecture were also presented. The framework emphasizes that performance of multimedia (learning) content can be improved when network and multimedia applications are both optimized, to enhance blended learning experience in constrained bandwidth environment, as it would increase the perceived level of user satisfaction.

The proposed framework is based on realistic and idealistic grounds and addresses question of high practical value that leads to instrumental consequences and increased usefulness of knowledge created to help

practitioners and researchers, especially in the context of developing countries. Furthermore, the implementation of the framework will provide remote learners the access to two-way interactive multimedia learning content that have been restricted to on campus students [31].

This research has the potential to make a significant contribution to the existing literature on blended learning, in general, and implementation of blended learning in constrained bandwidth environment, in particular [33], and thereby making major improvements on the landscape of African Higher Education (AHE) system [32].

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