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Abstract. This paper proposes a novel optimization technique that addresses the most critical issue that impedes the process of technology integration in the universities in developing countries. The problem is addressed by optimizing the network efficiency and multimedia performance that matches with the challenges of constrained low bandwidth environment. The Paper also provides a comprehensive review of the existing blended learning frameworks.

Keywords: Blended Learning, Constrained Low Bandwidth Environment, Optimization.

1 Introduction

Growing demand together with flexible and cost effective higher education with increased accessibility of educational content has redefined the spectrum of university education. In response to the radically changing environment, universities are attempting to adapt new innovative methods of course delivery using increasingly available new learning technologies that exist in the world. Although the first phase of online learning embraced a number of benefits, the lessons learned proved that to facilitate a successful learning process, a single mode of instructional delivery may not provide sufficient choices and social contact [17]. As a result, blended learning, a new educational paradigm emerged as an attractive model in higher education [18].

Whilst blended learning offers a number of benefits, it is not a panacea, there are some obstacles such as; constrained low bandwidth environment which can be a key challenge to its adoption, particularly, in the context of organizations in Least Developed Countries (LDCs) [9], [14]. Although several techniques (e.g., [9], [10], [11], [12], [13]) have been proposed, the issue of implementing an effective and efficient blended learning process in constrained low bandwidth environment has not been adequately addressed. In relation to this research, the process may include optimizing the multimedia performance in an attempt to develop the content relevant to the challenges of developing countries [31] and optimizing the network efficiency. And as such there is a significant need for a new technique [16] that addresses the above issue.

After reviewing and making a comparative study of various existing blended learning strategies, this paper proposes a new optimization technique that focuses on critical factors not currently addressed that are obstacles to the adoption of

technology enhanced learning in constrained low bandwidth environment with particular focus on university settings.

2   Technological Concepts (TC)

2.1   E-learning

E-learning can be instructor led synchronous learning in which instructor and learners both communicate directly with each other by using electronic means, or asynchronous learning where they can communicate with time delay but not in real time. In literature, numerous terms are used to define e-learning [6]. However, the e-learning definition used in this paper is; "a combination of network and multimedia learning".

2.2   Blended Learning

The term blended learning refers to a thoughtful combination of best experiences in traditional face-to-face class room learning and e-learning to enhance the learning process.

2.3   Constrained Low Bandwidth Environment Multimedia (CLBEM)

This study used a Multi Level Systematic Approach (MLSA) for identification of the most suitable multimedia compatible with the context of constrained low bandwidth environment. At level I, we identified a huge database of video formats [19] clustered into 4 groups; commonly used, very commonly used, average, and rare. At level II, we selected most commonly used video formats namely; Audio Video Interleave (.avi), Advanced System Format (.asf), Windows Media Video (.wmv), Apple Quick time Movie (.mov), Moving Pictures Expert Group 4 (.mp4), Moving Pictures Expert Group1, 2 (.mpg), Real Video (.rv), The Shockwave (Flash) Format (.swf), and Real Media (.rm). At level III, we investigated the above selected video formats more critically using different characteristics. The level III investigation was based on the following characteristics; Developer, Platform operatability, Non-Proprietary, International standards, No packet data dependency, and Mix media encoding ability. The deep analysis of level III investigation revealed that only one video format namely, .mp4 has all these characteristics and is compatible with the prevailing constrained low bandwidth environment associated with many developing countries.

## 3   Existing Blended learning Frameworks (Techniques) (EBLF)

This study identified several blended learning implementation strategies such as; 4 Factor Blended Learning Framework (4FBLF) [9], A Framework For Success (FS) [10], A Blended Learning Framework (BLF) [11], The National Youth Development Learning Network (NYDLN) [12], and A Blended Learning Model (BLM) [13]. The reason for selecting these techniques among others is that they are inter-related and pinpoint the essential factors related to three main categories; educational, managerial, and technological required for introducing a successful blended learning intervention in a Higher Education Institution [15].

Table1. An overview of identified existing blended learning frameworks

Indicators	FS	BLM	BLF	4 FBLF	NYDLN
Institutional (Organizational readiness, administrative & academic affairs etc.)	x	√	√	√	√
Learners & lecturers concerns (Audience analysis; charactristics & needs)	x	√	√	√	√
Pedagogical (Content analysis, design & learning objectives)	x	√	√	√	√
Technological infrastructure (Hardware & software)	√	√	√	√	√
Learning Content (Teaching, learning or training material)	√	√	√	√	√
Management & evaluation (Logistics, learners support service, registering, and assessment)	√	√	√	√	√
Ethical (Copy rights, cultural diversity & equal opportunity)	x	x	√	x	√
Communication (Marketing & change management commmmunication)	√	x	x	x	x
Resources (Human & financial resources)	√	√	√	√	x
Constrained low bandwidth environment	x	x	x	x	x

The issues addressed by these frameworks seem to fall under the titles shown in the first column of the matrix in Table 1. An analysis of the indicators of the reviewed literature suggests that important similarities exist between them; they address the similar issues under different titles and do not address the issue of constrained low bandwidth environment. Hence justifying the need to develop a new blended learning technique which addresses the core issue not addressed by the existing blended learning frameworks effecting the implementation of a new educational paradigm in low economies [16].

4   Proposed Technique for Implementing Blended Learning in Constrained Low Bandwidth Environment
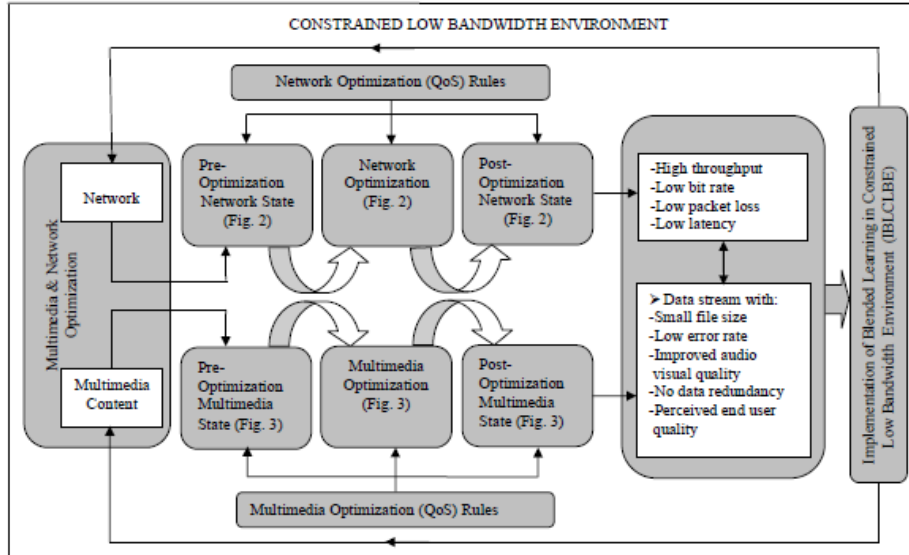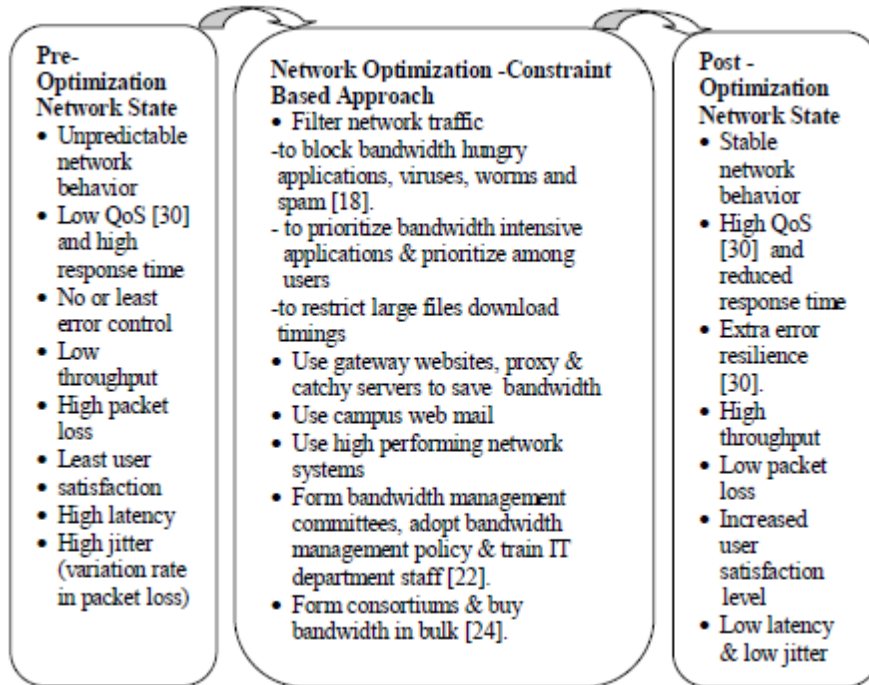

Fig. 1. Constrained Low Bandwidth Environment Optimization Technique for Implementation of Blended Learning

The proposed technique is an extended form of Khan's framework [11], [17]. Fig. 1 shows the pre-optimization states of network and multimedia which act as an input to the optimization process governed by both Network and Multimedia Quality of Service (QoS) Rules, followed by their outputs which turn into inputs for the next process of   interaction between optimized states of the two components of the technique, facilitating the process of implementing an effective and efficient blended learning process in a constrained low bandwidth environment.

4.1 Network Optimization

Fig.2 provides the details of three network states mentioned in the proposed technique, and in subsequent sections, the technical details of network optimization process are discussed briefly with an emphasis on filtering the traffic passing through the network to reduce network congestion caused by; Internet worms, viruses and spam, misuse and mismanagement of bandwidth [18] due to non-existent or ineffective bandwidth management policies [22], [23]. Network congestion is an overloaded network state when resource (bandwidth) demand exceeds the supply resulting into huge consecutive packet loss [7].

Pre-Optimization Network State	Network Optimization -Constraint Based Approach	Post -Optimization Network State
• Unpredictable network behavior • Low QoS [30] and high response time • No or least error control • Low throughput • High packet loss • Least user • satisfaction • High latency • High jitter (variation rate in packet loss)	• Filter network traffic -to block bandwidth hungry applications, viruses, worms and spam [18]. - to prioritize bandwidth intensive applications & prioritize among users -to restrict large files download timings • Use gateway websites, proxy & catchy servers to save bandwidth • Use campus web mail • Use high performing network systems • Form bandwidth management committees, adopt bandwidth management policy & train IT department staff [22]. • Form consortiums & buy bandwidth in bulk [24].	• Stable network behavior • High QoS [30] and reduced response time • Extra error resilience [30]. • High throughput • Low packet loss • Increased user satisfaction level • Low latency & low jitter

Fig, 2. Three Different Network States

Packet Filter Firewalls and Access Control Lists (ACLs). Information over the network system travels in form of discrete packets (cluster of bits) characterized by many attributes. Packet filter firewalls are devices used to enhance the security of the network system that filters the inbound and outbound network traffic based upon the rules that may be called Quality of Service Rules (QoSR), commonly known as Access Control Lists (ACLs) [1], [2].

Authentication. User Authentication System (UAS) can be introduced by issuing log in passwords to authorized users to restrict the access to network resources from unauthorized users under the policy rules [3].
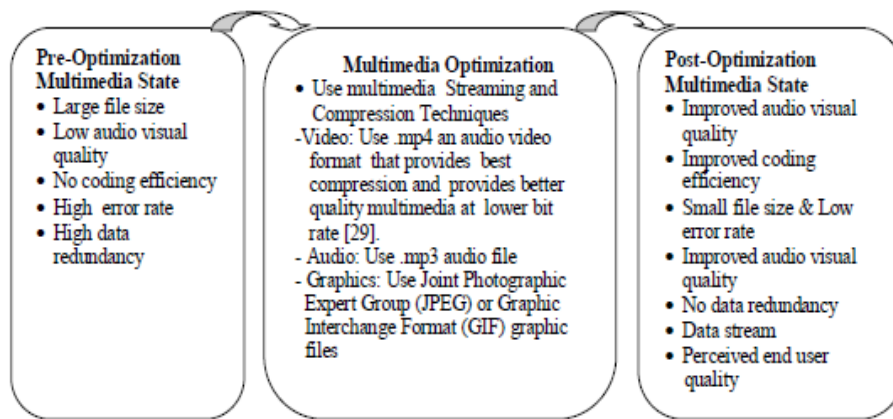
Prioritizing network traffic. Prioritization technique is used to enhance the Quality of Service (QoS) for real time applications such as VoIP and video by processing it before all other data streams. Similarly, the technique is used to prioritize among various categories of users based upon their associated privileges [3], [4].

Time Based ACLs (TBA). Time-Based ACLs are configured on router interfaces in the network to restrict the heavy file download timings to save the bandwidth.

Cache and Proxy. Cache and proxy are local memory devices that can considerably save bandwidth in low bandwidth environments [5]. The cache stores the digital contents most frequently required by the students. While proxy servers save the recently or more visited Web Pages. When using cache and proxy method, all user requests pass through cache and proxy servers.

4.2   Multimedia Optimization (MO)

Fig. 3 describes the details of three different multimedia states stated in the proposed new technique. In education, multimedia refers to present information using variety of media which includes; text, graphics, audio, and video [28]. The transmission of multimedia applications such as; video and audio over the network in the context of a constrained low bandwidth environment is still a challenge. However, the course performance can be enhanced by using multimedia streaming and compression techniques [20] explained in the following sections.

Pre-Optimization Multimedia State
- Large file size
- Low audio visual quality
- No coding efficiency
- High error rate
- High data redundancy

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 [29].
- Audio: Use .mp3 audio file
- Graphics: Use Joint Photographic Expert Group (JPEG) or Graphic Interchange Format (GIF) graphic files

Post-Optimization Multimedia State
- Improved audio visual quality
- Improved coding efficiency
- Small file size & Low error rate
- Improved audio visual quality
- No data redundancy
- Data stream
- Perceived end user quality

Fig. 3. Three Different Multimedia States

Multimedia Streaming. Streaming techniques are applied for delivering audio and video files efficiently that start playing one after another in the form of a stream on the client's computer when full contents are not downloaded completely. However, before streaming, multimedia contents must be compressed as these files are very large and data is again decoded (decompressed) before viewing by the user.

Multimedia Compression. Multimedia compression refers to reducing of the multimedia file size that can significantly reduce the bandwidth requirements.

Video. For digital videos, compression is achieved by removing the redundant data from the video files until the minimal compression level is achieved under Quality of Service rule. MPEG-4 (.mp4) [25] as identified in section 2.3 is to be used as the standard compression format that can efficiently encode (compress) mixed media and is "error resilient to enable robust transmission of compressed data" [24]. And has an inbuilt technique where many macro blocks are grouped together such that there is no packet data dependency on the previous packet [26], [27]. In addition to that MPEG-4 also provides better quality media at low bit rate [29].

Audio. Audio files should be saved as Mono Audio Files (MAF) because they are smaller as compared to Stereo Audio Files (SAF). For compression MPEG-3(.mp3) format should be used.

Graphics. Optimize the performance of graphics by reducing size, resolutions and number of colors. Joint Photographic Expert Groups (JPEG) and Graphic Interchange Format (GIF) type graphic files provide better compression.

5   Conclusion

This paper has proposed a novel technique showing how to implement a successful blended learning intervention in low bandwidth economies by underpinning the most critical issues not addressed by other techniques. Currently, most organizations in LDC's have not strategically implemented online learning or blended learning in their programme offerings, although there is need [8], and therefore this research besides the scientific, has its highly pragmatic justification. The implementation of the proposed technique will lead African Universities to increase access to their own demand-driven programs in a "sustainable and cost-effective manner" and to convert millions of human resources from liability to become pivotal in their country's economic development [21].

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