Feasibility Study for an Education Enhancement Platform using Adaptive Streaming Technologies

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Abstract—Recent researches in education has verified that delivering shorter lectures helps the students to focus on the concepts thoroughly as well as effectively and they are found to be more engaging than the longer ones. While facing the challenges of having short lectures in traditional classroom settings, it is recommended that, delivering video lectures to students in short byte sized chunks is a good way to overcome the issue. This paper conducts a feasibility study of such a system, iLEAP, which is intended to serve as a software platform to deliver video lectures, laboratory experiment videos as well as discussion forum for interactive learning among peer students. Existing technology on bandwidth adaptive streaming will be used to deliver these video lectures to students' devices through a web platform. This technology ensures that the videos are streamed even if the students access the software from constrained network conditions by adapting the video size to the available network in terms of parameters such as frame rate, resolution, colour etc. Evaluation of the technology shows that the system will indeed be able to function satisfactorily under such circumstances while enhancing the overall learning experience of the students.

Keywords—Adaptive-streaming; Education; E-learning; iLEAP; Low-bandwidth Streaming; Priority Streaming.

Abbreviations—integrated Learning Platform (iLEAP); kilobits per second (kbps).

I. Introduction

HAVING students sit in hour (or more) long lectures while explaining complex theoretical concepts is the traditional way of teaching. We cannot expect all the students to understand these concepts by this method of teaching, since it can be really overwhelming for some to assimilate all the information at once. As such, it is highly recommended that, shorter lecture sessions are far more effective in enhancing the students' understanding of the complex theories and their applicability.

A study conducted by Joan Middendorf & Alan Kalish [1] focused on the ebbs and flows of students' focus during a typical class period. The authors determined that students needed a three- to five-minute period of settling down, which would be followed by 10 to 18 minutes of optimal focus. In another study conducted by Guo et al. [Philip J. Guo et al., 13] on the use of video lectures, it has been found that shorter lecture videos are far more engaging than the longer ones. They recommend the lecture videos to be six minutes or less if possible to maximise the students' understanding of the concept. Although these recommendations are not entirely practical to be implemented in face-to-face lectures, it can be realised by having recorded videos of the concepts taught in class and letting the student revisit whenever necessary. This type of lecture delivery also helps in making the learning process more flexible for students.

In order to realise a system which can be used to deliver video lectures to students, through the Internet, it is essential that it is able to function satisfactorily under differing network bandwidths. This is particularly important while considering the fact that, although the basic network infrastructure is present in countries like India and China, high speed internet is still not available in many rural areas in these countries. Moreover, majority of the world population (around 83%) resides in developing world [World Bank Group, 9] and as according to the latest statistics from International Telecommunication Union, 65% of the world's total number of Internet users are from the developing countries, [15]. Thus, having the capability to function in network constrained environments is critical for successful implementation of such a solution.

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Some initiatives were already taken place in the developing world to take advantage of the infrastructure development that followed the proliferation of the Internet based technologies. Desai & Shinde [7] discussed the use of E-learning in India, which makes use of Internet in education and the efforts of the government in letting the rural population climb the ladder of web based education. The paper concludes that although the government has initiated such activities, the universities should adapt their teaching approach to incorporate such technologies while making the education process more flexible. Another similar study by Chen et al. discusses the application of web-based education technology for the basic education in rural areas of China [Minghong Chen et al., 8]. In this regard, these and other related studies indicate the importance of web based teaching platforms and their role in education system in countries all over the world. However, the challenge lies in successfully realising such platforms under low-bandwidth environments, which is common in developing countries.

In this paper, authors present the results of a feasibility study for employing adaptive streaming technologies in realising an integrated learning platform, iLEAP, in which, the students will have an option for flexible viewing of theoretical concepts taught in class through shorter, bite-sized video chunks. The paper discusses specific technologies for reducing the data size as well as for making optimal use of the limited bandwidth conditions. The platform, iLEAP, also plans to have a discussion forum for the students to have active discussions among themselves, overseen by the teaching assistants or the lecturers. Based on the topics raised in the discussion forum, the lecturer may select a few relevant questions and address them in separate videos and upload it on the learning platform. Thus, the iLEAP platform can be very interactive, with the inclusion of the discussion forum, as well as flexible to access, since the students have the flexibility of learning at their own time and space.

II. BACKGROUND

iLEAP is intended to provide a platform for students to make it easier to digest complex concepts in subjects by providing bite-sized chunks of information in recorded video format that they can choose to watch and understand whenever they need, wherever they are, on whatever hardware platform, and as often as the students chooses to watch them.

There have been studies on the effectiveness for such kind of lecture delivery using new technology. A research conducted by Chris Evans [6], evaluated the efficiency of delivering revision lectures through audio-video contents as a revision exercise to students. The results suggested that students find podcasts to be efficient, effective, engaging and easily received learning tools for revision. Other studies by Derek E. Baird & Mercedes Fisher [2], and Palitha Edirisingha & Gilly Salmon [5] also provided similar results in the affirmative for using the technology in delivering lessons.

Based on prior research by educators, it is verified that by delivering shorter lectures helps the students to focus on the concepts thoroughly and they are found to be more engaging than the longer ones. By implementing this project, it is expected to make the students' learning process much more fruitful and flexible as it gives them the flexibility to catch up even if they miss the face-to-face lectures at times.

iLEAP will make use of the adaptive streaming technique for delivering the video content to the students' device. Adaptive streaming technique works in such a way that, if the downlink network that the student is using is found to experience heavy traffic, the content quality (such as frame-rate or resolution) will be adjusted so as to ensure continuous streaming of the video. The algorithm for adaptive streaming has already been developed [Arun & Tan, 10] and the same mechanism can be made use of in this project as well.

The overall system will be developed to be accessible via web browser so that any hardware platform with flash player installed shall have the ability to stream the video content as and when needed. The system would be employing a client-server architecture where the main hardware required would be a central server at the administrator side which will be used to store all the audio-visual contents and to host the discussion forum. The users, i.e. students, will be able to access this from devices which have web browser installed with flash player support. Figure1 shows the rough framework of how the system architecture would look like upon implementation.

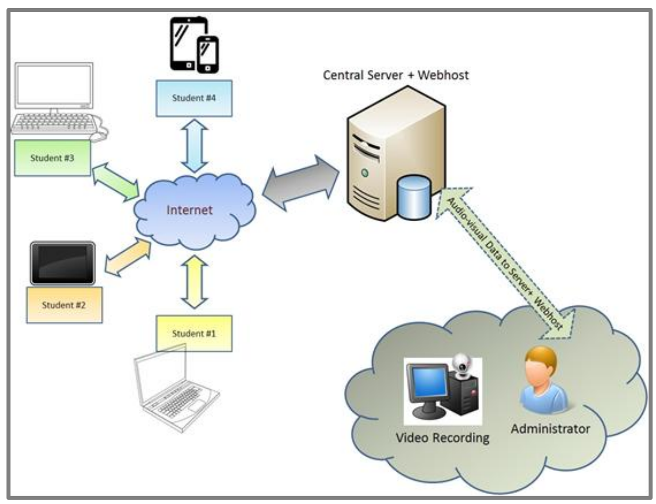

Figure 1: iLEAP System Architecture

III. ADAPTIVE STREAMING TECHNOLOGY

The system will be designed by incorporating the adaptive streaming technique as mentioned above. There are mainly two kinds of adaptation that can take place in this method; either by giving priority to the frame rate or by giving priority to the resolution. This is to ensure that those who are accessing the lecture videos or laboratory experiment videos are able to watch the video without intermittent stoppages

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even when they are accessing the internet from a low bandwidth environment.

3.1. *Frame Rate Priority Streaming*

As the name depicts, frame rate is the priority factor here. A minimum frame rate of R is maintained even when the network bandwidth is as low as 128 kbps. The minimum frame rate is chosen as R=15 for different network speeds. Only 80% of the detected bandwidth will be utilized, leaving a buffer for other data communication to take place.

Resolution will be the dynamic parameter in this streaming class. When the available bandwidth is high, the resolution quality will be adjusted to a high value. When the bandwidth drops, the resolution will be lowered to cater for the video data and thus allowing the streaming to continue. If the bandwidth drops even further, the video will be changed from colour transmission to greyscale which in fact helps the data size to lower further.

Among the two types of streaming classes presented below, either can be utilised for different purposes. For example, delivery of laboratory experiment videos will need good quality to view the experiment set-up clearly, and thus demand a minimum resolution for delivering the videos. In this case, the system can be operated in resolution priority streaming class. Similarly, the delivery of regular lecture videos does not need to be of the highest quality in terms of resolution and thus can be run in frame rate priority class.

3.2. *Resolution Priority Streaming*

Similar to the first case, as the name suggests, the priority here is resolution of the video. In this case, the resolution quality is fixed to be maintained at all the time. Even when the available bandwidth drops to lower levels, the system will continue streaming by dynamically adjusting the frame rate. Again, only 80% of the detected bandwidth will be utilized, leaving a buffer for other data communication to take place. If the bandwidth drops even further, similar to the earlier case, colour video will be converted to greyscale before streaming and thus achieving a low data rate video.

Figure2 shows the flow-chart explaining the mechanism of the priority based streaming in network limited conditions. The algorithm works in such a way that, at first, it measures the sending data rate at the server and receiving data rate at the receiver. The receiver then sends back the information back to the server and a comparison between these two values decides whether to increase the video quality or to reduce it. For e.g., if the priority is set for frame rate and the sending rate is much more than the receiving rate, this implies that the network is congested and most of the sent data is not able to reach the destination. As a result, the resolution will be reduced. If the priority is for resolution, the frame rate will be reduced as a result. However if the sending rate and the receiving rate is almost equal (that is, if the receiving rate is within 95% of the sending rate), the algorithm will increase the video quality parameter so as to maximize the available bandwidth usage. The value 95% is chosen based on empirical results after noticing that in most conditions, the network is bound to lose around 5% of the transmitted data due to existing traffic conditions. The increment and decrement of the video parameters happens in an additive increment- multiplicative decrement fashion in order to sustain the session continuity. This whole algorithm can be repeated in every minute or so, so that the user doesn't experience too many variations in video quality while the network is also optimally utilized.

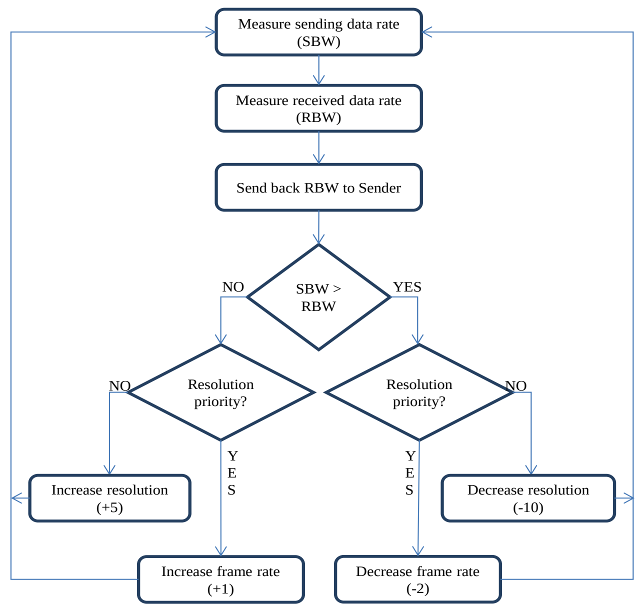

Figure 2: Priority-based Streaming Algorithm

IV. EVALUATION

This section evaluates the performance of the streaming classes under differing bandwidth conditions. It also shows the details of the data savings that greyscale transformation brings for enabling the video transmission in low bandwidth situations.

4.1. *Analysis of Streaming Priority Class*

All the above implementations are tested out in different available network bandwidth conditions. NetLimiter [14], software capable of controlling the upstream and downstream bandwidth, was used to limit the bandwidth to the desired level in each scenario. As mentioned earlier, a specific case of minimum frame rate R=15 is considered for this analysis. Table 1 shows the performance of the frame rate priority case in each network speed. The program is modified to detect the dropped frame from the jitter buffer and tests are run for each network case until a total of at least 1000 packets were being received. The Table shows that the system is able to keep the minimum frame rate to an average value of more than 13, lower than 15, probably due to the network traffic during the time of the experiment.

However, 13 fps is a well acceptable number in a general video transfer application. As per previous studies conducted on the effect of lower frame rates on human perception, it is pointed out that a frame rate of 10-15 is sufficient for almost all the different tasks to be performed unless the requirement

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is for sophisticated tasks; such as speech reading based on video frames. The study also pointed out that the frame rate reduction from 25 to 15 is often perceptually similar in appearance to the viewers [Jessie YC Chen & Jennifer E. Thropp, 4]. According to study conducted by Paul and Meyer, a frame rate between 10 and 15 for a video playback are sufficient for the human sight to create the sensation of visual continuity [Read & Meyer, 2].

Table 1: Analysis of Frame Rate Priority Class

Network Speed, (kbps)	Total Received Packets, P_t	Total Dropped Packets, P_d	P_d / P_t Ratio, F_d	Average Frame Rate, $F_r = (1 - F_d) \times 15$
128	1000	165	0.165	12.52
256	1000	76	0.076	13.86
384	1000	105	0.105	13.43
512	1000	93	0.093	13.60
768	1000	111	0.111	13.34
1024	1000	118	0.118	13.23

There is no quantitative method to determine the quality factor or resolution of the incoming image at the receiver end other than visual inspection. The only possible method is to determine the frame rate at which they are supposed to transmit and draw conclusions from there. Using the measurement method as in Table 1, the performance analysis of resolution priority class is shown in Table 2, where the resolution parameters of the motion jpeg file (Compression Quality, Scaling Factor) is kept at (23, 0.5). Results show that the measured frame rate very close to the expected value. Again, the slight difference is probably due to high jitter during the experiment session.

Table 2: Analysis of Resolution Priority Class

Network Speed (kbps)	Frame Rate at Sender	Measured Frame Rate at Receiver
128	6 (with greyscale)	4.8
256	6	4.98
384	8	6.7
512	10	8.4
768	15	12.6
1024	20	15.8

4.2. Analysis of Greyscale Transformation of Video

In order to assess the performance enhancements that greyscale conversion can achieve, trials runs were conducted with differing values of compression quality and scaling factor. The frame rate priority streaming scenario with a fixed frame rate of 15 was considered for this test. The usable bandwidth on the user was increased to 2Mbps to avoid any network bottleneck. First measurement was taken when no greyscale is used for all six cases. In the next run, the greyscale conversion was activated. Results in Table 3 show that the average reduction in the data rate with greyscale conversion is 43%. This is significant improvement which will be useful in the realization of iLEAP.

Table 3: Effect of Greyscale Image Transmission on Data Rate

(Q,F)	Total Data Rate without Greyscale (kbps)	Total Data Rate with Greyscale Activated(kbps)
35,0.5	575	325
20,0.5	450	260
10,0.5	330	195
35,0.25	240	130
20,0.25	200	110

V. CONCLUSION

Feasibility study for implementing adaptive streaming in an education enhancement software, iLEAP, was presented in this paper. In-house technology for reducing the data size in video stream were introduced, such as frame rate and resolution priority streaming as well as greyscale conversion of content videos. This system is aimed to assist the students to better understand the theoretical concepts taught in class by delivering them as shorter, bite-sized video chunks. The adaptation technique to be implemented in the system was evaluated in differing network conditions for performance analysis. The results show that the system is indeed able to stream the video from one end to the other while employing the mentioned technique and is expected to be critical in the development of iLEAP.

The technology used in this feasibility study can be used in other applications as well, where streaming in low-bandwidth network condition is required. One example is in telemedicine, which is a very useful method of making medical consultations available to the rural population through the use of audio-visual communication technologies [Sajeesh Kumar & Ellen R Cohn, 12]. The adaptive-streaming methods mentioned in this paper becomes especially important while considering the fact that these telemedicine networks are believed to be very useful in developing countries, where the majority of the population resides in rural areas and are in real need of such systems to access specialised medical care [Mantas & Hasman, 2013]. This type of adaptive-streaming mechanism can also be used in other purposes such as monitoring of traffic or other similar environments as well. Considering its wide range of applications, this technology can be further explored and further refined to be effectively implemented in real-world situations.

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