Advanced multimedia solution for interactive teaching via whiteboards over IP networks

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Abstract— **This paper demonstrates a design of interactive multimedia solution, which is usable for streaming lectures with interaction between lector and student. Based on related work and the analysis, selected existing streaming technologies in cooperation with interactive whiteboard are transforming into a multifunctional solution with educational abilities. The overall concept allows capturing of video from camera source and image from interactive whiteboard with layer of drown notes from whiteboard surface. Captured content is streamed in two different streams with bitrate adaptation depending on the multimedia source and is delivered via media server to flash players located in web portal. Live streams are synchronized in time and at the same time are recorded to archive. Concept of web portal includes also voting ability and ability to react in real time from receiver side in form of text questions. Results of voting and real time question queue are dynamically showing to lector, which brings possibility to answer questions directly in live streamed video or possibility to adapt further course of lecture based on real time feedback from students. Proposed design was implemented in form of web portal as experimental realization, which has been tested in classroom. Most of the innovations today can be marked as result of synergy, delivering existing technologies to customers as a new product.**

Index Terms— **Interactive whiteboard, Live streaming, Voting system, E-learning**

I. INTRODUCTION

THE topic of interactive multimedia in education sector is quite extensive and interest for comprehensive solutions for e-learning is always growing. Way of using these technologies in the academic environment depends on the needs and capabilities of teaching members, on learning objectives and content but also on the nature of the educational institution. E-learning in conjunction with interactive multimedia is also becoming essential tools of self-education. In general, computer technology greatly assists in the learning process for learners with disabilities, or for learners with special educational needs. Allows better visibility or customization of text documents, playing text as sound, but

also facilitate access to learning materials for people who cannot attend lecture [1]. In conjunction with the concept of modern technologies in education are increasingly talking about the using of interactive whiteboard. Imaging technique facilitates the teacher's work in form of expanding the possibilities for displaying visual materials, which enhance the diversity of learning. Technology of interactive whiteboard allows dynamically controlling of presented text or graphical information and it brings the interactive elements through the original materials. Usability of whiteboards is currently limited to teach students located in classroom, but the image from the whiteboard's surface could become perfect source for video streaming via network to remote students.

In present it is popular to use streaming technologies such as IPTV for remote access to videos containing learning materials. It allows students to view learning objects or realistic examples, to see sequences in motion, and to listen to narration [2]. Usage of IPTV is polyfunctional, but it has the largest representation in the replacement of analogue television broadcasting. Other usage includes the possibility of distant education, which is unlike video conferencing, technologically simpler option of providing one video stream to large number of recipients, but at the expense of losing interactivity from side of recipients. This fact creates a new dimension in looking at education, where barriers of distance are broken down and there is opportunity to participate in full training process through the network connection anywhere in the world. IPTV adapted to educational purposes appears to be a means, which may in the future as one of the primary sources of education [3,4].

Despite the progress that these technologies have brought, the student is usually situated in the role of passive receiver of teaching materials without the possibility to active intervention. It is therefore necessary to bring more interaction to multimedia elements, display elements and streaming technologies, what transform passive students into the active members of learning process with possibility of remote interaction. Also there is necessary to create environment for interactive distance learning with considering the costs and knowledge of teachers operating the interactive system.

II. THE EXISTING SOLUTIONS OVERVIEW

The Technical University of Kosice has an adequate amount of interactive whiteboards, so there is place to integrate this element into learning process and to provide appropriate

trainings to teachers. In present these interactive whiteboards are used by teachers to present materials for lectures, but whiteboard surface screens are not streamed over the network, so the interaction in lecture is limited for students sitting directly in the class. Some lectures are captured by camera and streamed live or recorded to archive, but there is a lack of picture quality of presented materials and also there is no possibility to interact from remote student side. For those reasons it is necessary to interconnect mentioned learning elements and develop interactive multimedia solution which will satisfy most of requirements in modern educational institution.

Expected functionality of proposed solution can be divided into the following points:

-To deliver live stream of lector speech and image from the camera to students via network.

-To deliver live stream of presented materials with drawn notes on interactive table to students via network.

-Ability to change primary and secondary source of received stream on client side.

-Provide archive of historical lectures with both streams synchronized and possibility to comment lecture or ask question to lector offline.

-Provide high definition resolution for all streaming services.

-Allow to ask questions from students to lector directly during live broadcast via web interface.

-Allow students voting and provide dynamically results of voting from student to lector via web interface.

-Possibility of starting and stopping broadcast or changing source addresses via web interface.

-Integrate countdown showing value of time left to the end of scheduled lecture.

For satisfy expected requirements, there is need to analyze proper technologies such as interactive whiteboards, streaming technologies, voting systems and web technologies..

A. Interactive Whiteboards

Interactive whiteboard is a large electronic projection area, which is connected to computer. Projector is generally mounted with whiteboard on one stand. Surface of whiteboard reflects the images from computer. Using electronic pen, special stylus or only finger it is possible to easily control computer, or work directly with the board – draw lines, write notes. All movements realized by touching of surface while drawing are captured from whiteboards by sensors and are shown on surface in real time [5,6]. The advantage is the possibility to save notes, texts and images drawn on the surface. Most of the software cooperated with interactive whiteboards includes additional features such as handwriting recognition, rulers, protractors or geographical maps templates [7,8].

Connection of interactive whiteboard with computer is commonly provided by USB, FireWire interface or WIFI. Transforming position on board's surface to position of cursor in computer's operating systems is ensured by system driver.

Capturing the pen's position on surface is usually based on electromagnetic or optic principles. In this solution will be used interactive infrared whiteboard QOMO QWB200-PS with USB connection and infra-red sensors located in the corners of the board, which allows controlling by pen and also by finger.

Unlike conventional projector, in this case are given higher requirements on the projector, which is mounted on whiteboard. The basic difference is minimized projection distance and maintaining a rectangular output image. Short-throw distance is needed to prevent the unwanted shadow from the person controlling the board. The current projector lens shines from top in acute angle, what would be causing a trapezoid shape of output image in conventional projectors. In this solution will be used projector NEC NP610SG.

B. Streaming Technologies

Streaming is a technology, which ensures the transfer of multimedia content over a network. It allows transmission of audio, video or even other multimedia content from sender to recipients. This technology can be used to real-time broadcasting, but also for receiving video on demand (VOD) [3]. Traditional broadcasting operates in a way where videos are broadcasted in real time in accordance with pre-planned schedule or ongoing live events from the cameras. Receiving video on demand allows recipient to choose the video content that will be transmitted at that moment. There are two major approaches how to stream video over the network. First approach uses standard Web server, e.g. Apache Http Server Project, and uses standard hypertext transfer protocol HTTP to deliver video and audio data to the client. The second approach uses separate streaming media server. [9]

Streaming media formats compared with conventional media formats brings many advantages. These benefits include: media content protection against piracy, controlling the flow of content, selection of allowed recipients or easy content management. For this reason, especially due to affordability, these technologies are largely appearing as an appropriate means for providing educational services through the Internet. This all brings a new dimensions and more effective teaching methods then static text and images

Flash Media Live Encoder

This software is built to stream live video in real time and simultaneously convert to Flash. It supports codec H.264 and On2 VP6. The program can simultaneously live broadcast and save the broadcast to file in FLV or equivalent of MP4 - F4V format. [4] This feature is useful for creating video archives in IPTV solution. Encoder has various features influencing quality of streaming beginning from selecting the encoding resolution, ending with the choice of filters to determine the bit rate. The restriction appears to be his platform compatibility, which is defined for Windows and Mac OS, but there is lack of support for control over the command line interface. The program could be controlled through a graphical interface, which eliminates the possibility of automation [10].

In this solution it will be utilized to provide encoding live broadcasts from the cameras and from interactive whiteboard output.

Wowza Media Server

It is fully interactive server for streaming multimedia content with full support for H.264. It is Java server platform, which is also suitable for high deployment with a large number of clients in the network and with continuous operation. Wowza has wide ranging possibilities, not only as a means for streaming stored files. (VOD) or live broadcast, but as a means to secure video conferencing, shared screens or games. There is also the possibility of using modules that provide control of dynamic content such as advertising or playlist. Since Wowza is based on JAVA, there is a possibility to create own modules that can be fully customized. These modules are created using an integrated environment Wowza IDE, which also offers the ability to configure and manage server activity. Concerning security, the server provides it at a high level. It includes protection against unwanted intrusions and even restriction to capture streaming content. These features are provided through an encrypted transfer with RTMP / RTMPS protocol and special security token, which generates a strong protection against applications for recording broadcast content. Usage of server is extensive and it is not depend of type of recipient's device. Broadcast reception is possible via the web interface, custom software applications, mobile devices or set-top box. Wowza is able to stream to all of these devices in parallel and selects the correct protocol and data flow depending on the client [4,11].

In this solution it will be utilized as the streaming server for live broadcast or for VOD service in archive.

Web-based video player

Most common web based Flash/HTML5 player with support of RTMP protocol is JWplayer. It brings feature called "dynamic bit rate switching", which set the bit rate of video dynamically according the information from user about bandwidth. This feature decides what bit rate has to be provided to best ensure the continuity and quality of play. Playback can also stop and delay live streaming, then store streaming in temporary memory and then replay from memory for next watching. Player supports various extensions such as publish videos directly on social networks with one control or adding information directly to the video[12]. Another widely used flash/HTML5 web players are Video.JS and FlowPlayer [13,14]. In this solution JWplayer will be utilized to play live broadcast and video on demand in web interface on client side.

Voting systems and testing tools

One of the most time consuming tasks for teacher is verification of real student knowledge and skills. It could be done using voting systems or using testing tools [15,16]. Common voting systems consist of several small hardware voting units and on central unit. Hardware voting units are usually portable and powered by batteries. Central unit can be computer with properly software collecting result from portable units via Bluetooth or WIFI connection [6,17]. Portable voting machines have great functionality, but they are quite expensive to use them for large group of students. For non-anonymous voting it has to pair each device to concrete student to ensure voting relevance. For this reason it is less expensive to integrate voting system in way, where students can vote via web interface after their authentication.

III. SOLUTION DESIGN

Overall solution is based on three ways of access. First role – Lector is using interactive whiteboard to present learning materials of current lecture. He has access to Lector section of portal, where is possibility to see asked questions in real time and dynamically changing voting results. Second role – Students are using personal computers with connection to portal. They have access to Viewer section of portal, where it can be received video streams directly from interactive whiteboard or from video camera capturing lector. There is also possibility to ask questions in form of text in real time or students can vote for one of various numbers of predefined alternatives. Students have also access to Archive section of portal, where it is possible to watch historical lectures. Third role – administrator is responsible for setup new lecture broadcast in time. In administrators section of portal can be configured lecture information, live streaming options, streaming addresses of video sources or recording options for archive lecture.

A. Interconnection between Components

Lector (Fig 1. - con. 1) is standing between interactive whiteboard and laptop. He is using controller or finger to drawing notes (Fig 1. - con. 7) to whiteboard surface or controlling presentation. Layer with drown notes from surface and instruction for change position of visualized objects is send to laptop in cooperation with interactive whiteboard driver (Fig 1. – con. 6). Overlaid image consisting of presentations from laptop and drawings from whiteboard is distributed to beamer (Fig 1. – con. 2). The output is displayed on the interactive whiteboard on one hand (Fig 1. – con. 3), on second hand output is connected to HDMI input located in video streaming computer box. (Fig 1. – con. 4). Lector's person or physical learning objects are captured by video camera. (Fig 1. -con. 5). Output from video camera is also connected to capture card with HDMI input. (Fig 1. – con 5.).

Lector speech is captured by microphone, which is connected to audio mix together with audio output from lector's laptop (Fig 1. – con. 8). Both HDMI input devices containing raw camera source and board image are encoding via two instances of Flash Media Live Encoder (FMLE) (Fig1. Con. 9). Both encoded live streams are delivered as unicast to two applications of one instance of Wowza media server (Fig.1 – con.10), which ensure optimized multicast streaming reachable from web based flash player – JW player (Fig.1 – con.11). These two windows of JWplayer are located into code of web portal in Viewers section. First window is larger – displaying primary streaming source (Fig.1- con.13), second

windows is smaller – displaying secondary streaming source (Fig.1 – con.12), but there is a possibility to swap the streaming source on client side without interruption.

Viewers section of web portal contains also questions board and voting board. Newly asked questions are storing into database (Fig.1 – con.14), from where they are read in real time and sending to queue in Lector section of portal (Fig.1 –

con.16). Voting is configured in Lector section, results of voting is collected to database (Fig.1-con.15) from each voting board in Viewer section and. Voting results are reader from database and they are dynamically shown in voting board window in Lector section (Fig.1 – con. 17).

Archiving of actual lecture is ensured by Wowza Media server in form streaming to two files during live streaming (Fig.1 – con.20). After ending of lecture, information about newly created files are stored into database together with historical voting results or unanswered questions from queue. (Fig.1 – con.21). Archive section of portal contains also two windows with JWplayer, which playing synchronous video on demand from two files but only one playback controller. (Fig.1 – con.22). Administrator section provides possibility to start or stop live streaming (Fig.1 – con.25), possibility to set addresses of streaming sources or possibility to manage archive section. (Fig.1 – con.24) .

B. Live Streaming Bandwidth Based on Type of Multimedia Source

Nowadays, there is a big demand on high quality for media content on the Internet. Standard TV broadcast formats offer a resolution up to 720x576 pixels (SD), which means that the signal is drawn in 576 lines of 720 pixels. Minimum resolution referred to as high definition (HD) is defined as resolution of 1280x720 pixels. Maximum commonly used high resolution live video ends on the value of 1920x1080, which is referred to as "Full HD". However there are higher resolutions for imaging and broadcasting video, which are not yet mass, because there are high costs of equipment [18, 19]. The more pixels can device draw, the more details can be received. Significant impact on the quality of high resolution has the way how the image is recorded and rendered on the screen. Encoding is provided by codec. Codec is compression algorithm, which is used to reduce the file size. Each codec has ability to stream with specific amount bits per second (bit rate), which depends on the level of compression, on the resolution of the video, on the information contained in the transmission or on the number of audio channels. This codec provides encapsulation of video content in video file format container [20].

In this solution it is necessary to define appropriate resolution, codec, file container and bit rate for each streaming source. As a compromise between quality and bandwidth it was chosen the HD (1280x720) resolution for camera source and also for image from interactive whiteboard. In both cases can be used file format container – FLV or F4V and encoding via VP6 [21,22] or H.264 [23] codec. After comparison of mentioned codecs and formats it was decided to choose H.264/AVC (Advanced Video Coding) as default encoding for solution, because of its high compression, hybrid video coding schemes and network friendliness. H.264 can achieve up to 50% improvement in bit-rate efficiency compared to the previous video coding standards. Through the network adaptation layer (NAL), H.264 bit streams can be easily transported over different networks [24,25].

Fig. 1. Interconnection between components of solution.

Even though the quality is not the primary feature of streaming technology, it is the way, how can affect quality. When it comes to multimedia transmission through lines with high bandwidth, then can be used appropriate encoding, which ensures higher quality. When it comes to the transmission through lines with lower bandwidth, then it is possible to use the encoding, which will primarily ensures smooth playback. New streaming technologies had to be designed to provide both quality and transfer time to satisfy Internet end-user. Choosing the appropriate bit rate was subject of testing and surveys from sample of recipients. It was created the small amount of live broadcasts using H.264 video codec with bit rate in range from 500kb/s to 5000kb/s streaming sample video from camera capturing lector or from output from interactive whiteboard displaying presentation with layer of drawn notes. The resolution was in both cases HD (720p). Feedbacks with perception of subjective quality of streamed video was received from recipients and based on results there were created graphs with trend line.

Streaming from camera source capturing lector speech and movements had acceptable quality in 3500kb/s (Fig. 2), but it depends on count of pixel changes in each frame in video. When camera is capturing person with lack of movements, quality of stream can be acceptable in 2500kb/s in HD resolution.

Streaming presentation with drawn notes on interactive table had better results, because in this case the average count of

pixel changes is very small in each frame. The acceptable quality of video starts with 500kb/s (Fig. 3) or 1000kb/s in case of situation, when presented slides are changing very quickly or drawing on whiteboard is frequently used.

C. Design of Web Portal Application

To improve clarity of overall solution is necessary to propose design and functional blocks of major sections of web portal. The important part of design is way, how the streams will be shown and swapped, how the question will be asked and shown to lector, how the votes will be collected and how results will be dynamically evaluated and shown to lector. (Fig. 4, Fig.5)

Integration of JWplayer windows displaying two streams width live broadcast can be ensured by jQuery UI library

Fig. 4. Design of Viewers section of portal.
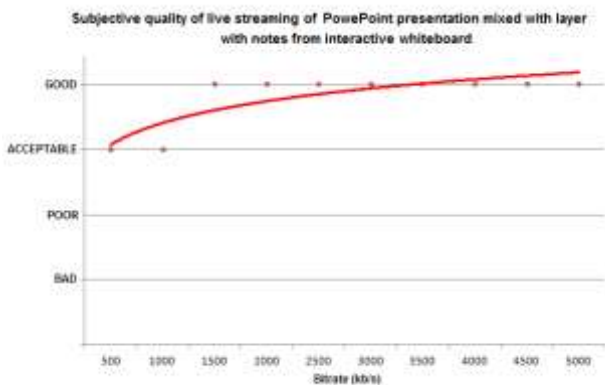

Fig. 2. Subjective quality of camera source.

Fig. 3. Subjective quality of presentation with drawn notes.
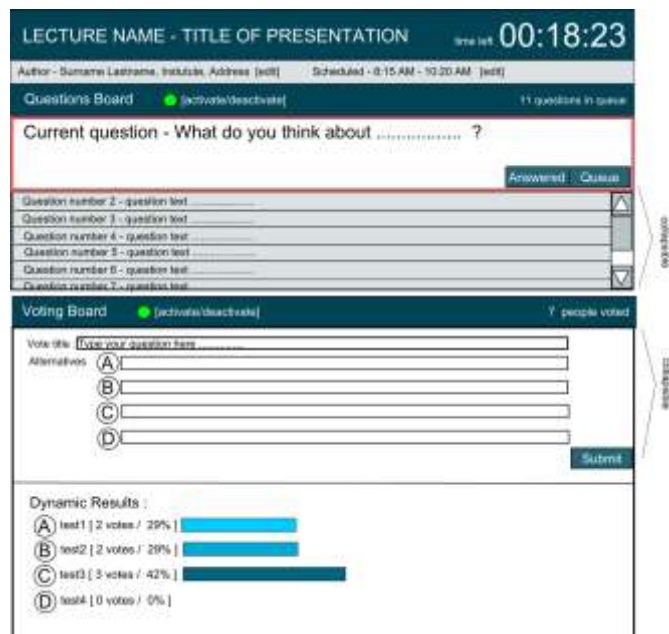

Fig. 5. Design of Lector section of portal.

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[26,27], in which can be defined dynamically changing position or size of JWplayer window controlled by swap button. Playback control of JWplayers should be disabled for ensuring synchronized playback from streaming server, but it can be allowed controllers for volume or switching to full screen. Besides the player windows can be located information about actual lecture such as lecture name, title, lector, scheduled time or another links to learning materials.

Question board in Viewers section can be also implemented by jQuery UI technology in combination with AJAX PHP request to SQL database. Each time unit it sends request to database for respond, if the question function is active from lector side. If it is active, it answered with value of amount of questions in lector's queue. In this time student has possibility to type his question to board, then the question is stored to queue in database. In lector's section in question board it is showing the queue of asked question listed from database at each time unit. The oldest question in the queue is shown first with better visibility.

If lector answers the question directly to the live broadcast, he can push the "Answered" button, then the question will be archived to database and next question takes this place. For better visibility in Lector section of portal, it is better to display question's queue like collapsible panel and display only the oldest question in board.

Voting system in Viewer section can be designed as board showing vote alternatives with possibility to choose one of them. There is also process of sending request to database containing information about activation of voting by lector. Lector in Lector section activates the voting and selects number of alternatives or concrete values. In this time it will be created new vote record with conjunction to current lecture represented by unique ID. If voting is active in the Viewer section the alternatives will be shown and student will have possibility to choose. Each authenticated student has only one vote for one voting. The results of voting are dynamically shown in lector section by sending periodically request to database. The panel for creating new voting and defining alternatives in lector section should be collapsible to ensure better visibility of dynamic results.

In the Lector section of portal it should be displayed the countdown of time left to scheduled ending of lecture. This conception ensures that all information for lector will be on one place on one side display, what interacts with actual lecture and make possibility to dynamically adapt further course of lecture.

IV. EXPERIMENTAL REALIZATION

Solution design was transformed to experimental realization with web interface. Web portal was created using the PHP, HTML, JavaScript language in cooperation with jQuery UI library and jQuery UI theme in CSS.

Viewers can watch or switch videos between windows without interruption. Also they can write and send questions or vote for alternatives in case of those features are enabled (Fig. 6). State of features, new voting or new alternatives are changing dynamically without need to refresh site. The block

on the site can be collapsed and disabled on viewer side on demand on teacher side. Dynamic results of voting and dynamic queue of questions are located in Lector section. The oldest question is on the top of queue and it can be removed by click. New voting can be defined in collapsible block, which will appear after click on related button. Enable or disable voting and question features can be managed by clicking on actual state (Fig. 7). Streaming addresses of RTMP streams and names of stream can be defined in Admin section of portal. Two small windows are showing live previews of both video sources (Fig. 8). There is also possibility to set timer in lecture.
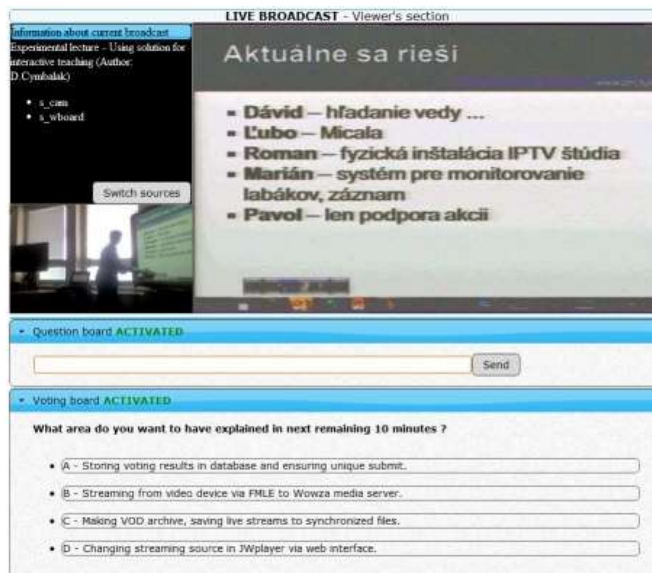

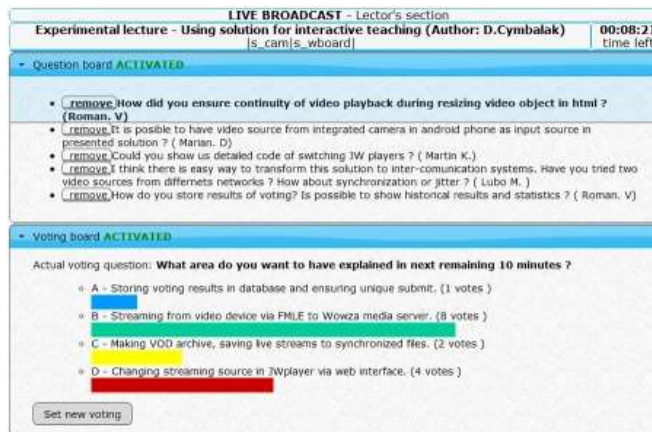Fig. 6. Experimental realization of web portal – Viewer section.

Fig. 7. Lector section of experimental web portal.

Fig. 8. Interface of Admin section of portal.

Overall solution was tested in form of experimental lecture with participants located in the classroom and simultaneously with participants located outside of classroom connected via web portal. Participants consisted of students, but also of some teachers, who could see how to work with this solution and how it influenced the teaching.

In comparison with the traditional form of lecture, several improvements were observed in the teaching process:

- Time was utilized more efficiently due to adaptive reactions of teacher to voting or new questions about presented topic. With this information they can adapt their teaching style appropriately. Based on results teacher can focus on desired topics or eliminate adverse topics.

- Teacher receives a tool to quickly test the gained knowledge of local or remote participants. He could start, stop or change voting or alternatives anytime. Teacher has feedback from participants, which is usable for setting of difficulty, intensity or speed of ongoing lecture.

- Remote participants had possibility to see layer with drawings on whiteboard and also they had possibility to switch video sources without interruption. There is no need to supervise mixing of two streamed video sources (table surface and camera). Both are visible beside from the receiver side and receiver is able to choose which stream will be in bigger window.

- Remote participants had opportunity to immediately respond in form of questions, which are answered by teacher directly to the video. Managing questions and answers became easier, because there is question queue, which ensure right order an equal chance to place question from student's side. There is also a possibility to remove question from queue without answering, if the teacher consider it as not relevant or not important.

- Count of questions had increased, when the questions had been set as anonymous. This feature helps to students, who are shy to ask.

- In general lecture has become more interesting for participants. Students are enthusiastic to try new technologies, which brings more interest for subject.
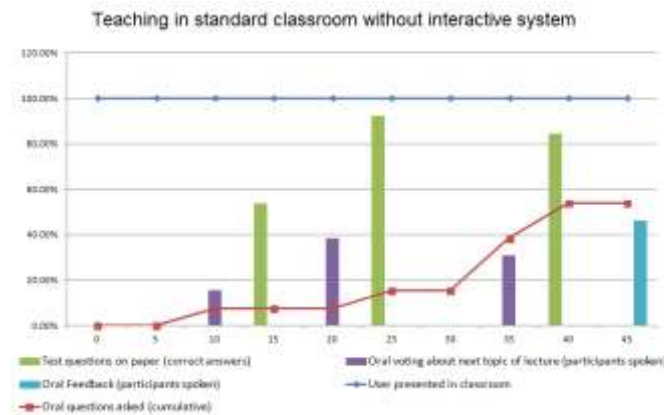

Fig. 9. Percentage of interaction between teacher and students related to duration of lecture in standard classroom.

Fig. 10. Percentage of interaction between teacher and students related to duration of distance lecture via proposed experimental system.

Comparison between standard lecture and same lecture using proposed system could be illustrated on Fig. 9 and Fig. 10. The first case (Fig. 9) is common lecture in the standard classroom with group containing 13 presented participants. The second case (Fig. 10) is lecture for group of another 15 distance participants using presented solution via web interface, in which is streamed scene with teacher and image from whiteboard surface. In both cases have been observer basic parameters of interaction in teaching such as: count of active participants, amount of placed questions, correctness ratio of the testing questions, feedback ratio and attendance ratio on voluntary voting about next progress of lecture. The most significant improvements of tested teaching process with using proposed solution were increasing amount of placed question and increasing of attendance of voluntary voting and feedback. Number of placed question in standard lecture was only 53.85% of present participants on the other hand number of placed question in interactive distance lecture was 113.33% of number of connected participants. Couple of participants were placed the questions twice. Attendance of voluntary voting about next topics of lecture was increased from 28.21% to 97.78%. Students, who react in form of feedback at the end of lecture, were 46.15% of attending participants in standard classroom and 100% of connected participants in interactive distance lecture. Correctness ratio of answering on test questions was almost the same in both cases, but it could be assumed some minor differences in larger sample of participants. Interactive way of learning could influence the attention of the students, which could influence the correctness ratio of answers in the knowledge test. In the other hand this solution of distance teaching could influence a number of connected participants with opened learning streams. This problem could be traceable in form of detecting opened windows at viewers side or detecting the eye location of participant with web camera.

V. CONCLUSION

The concept of described solution brings new perspective of modern education at local university level. Overall solution

has several ways of interactivity between students and teacher. The first is fact, that teacher can use interactive whiteboard, where he can control presentation, drawing notes or using other integrated tools. Lector speech, video from class and also multilayered image from whiteboard is streaming via network to students via web interface. Another possibility of interaction is web section for addressing questions to lector, who answers real time in live broadcast. Voting systems ensures integration of unlimited number of students and voting results are displayed dynamically directly to lector. All of these functionalities are very helpful for learning process not only for distance learning but also for organizing science conferences or corporate trainings.

Fast development in field of interactive multimedia, whiteboards and streaming technology brings various concepts, which integrates whiteboards with IP technologies. This solution is different in way of using cost-effective streaming components with software-based voting and testing system, which eliminates using of additional hardware components. Overall solution could be easily integrated to comprehensive e-learning system or content management system. The web interface could be extended with dynamically refreshing blocks with various kind of functionality, which is interesting benefit in comparison with proprietary systems. The presented system is also usable for another usage, where the two streamed source based on RTMP stream could be sources connected to media server such as video from integrated camera of mobile device, outputs from video-conferencing systems or virtualized webcam from video mixing software with any live processed output combining video, audio, text documents, 3D models, playlist, transparency layers etc.

Future work on this solution will be concentrated on implementing comprehensive web portal, which will have not only described functionality, but also functionality such as creating live broadcast from archived lectures, automate publishing and post processing of archived videos, ability to dynamically upload educational materials during live streaming or possibility to improve voting systems. Interesting functionality would be implementing drawing software module for distant students, which would be able to draw with mouse from browser to surface of whiteboard located in classroom.

It could be mentioned, that interactive multimedia technologies have also many disadvantages. The biggest negative it could be identified are high costs, technical maintenance or experienced operation. But also there is a loss of personal contact between teachers and students. It could have a negative impact on the development of student's communication and expressive skills. The one of the biggest problem is to bring these modern technologies in to the practice. Sometimes it represents a barrier, when teachers must continually educate to keep pace with the times. On the other hand, brings many benefits for learning process, which is becoming more efficient and more interesting.

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