

## SOLUTION FOR MULTIMEDIA TELEVISION SYSTEM AS AN EDUCATIONAL LABORATORY

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The paper provides a functional solution for the implementation of multifunctional and multimedia TV systems from a technical and practical aspect. The multimedia TV system can be used in the educational process and in the TV content production. The paper shows structure of a TV system, functional block diagram of implemented video and audio system with enabled connections of the equipment in the system. In the paper is presented a method for connecting with other television stations, as well as live broadcasting from the field using different protocols. The implemented TV system is designed to produce content of various video formats, so that content can be transmitted and produced up to 4K resolution. The laboratory is designed so that all the signals that are received and sent can be analyzed and measured. The laboratory is implemented at a higher education institution and can be implemented in other educational institutions, as well as in professional television stations and can be used for educational, scientific and professional purpose.

### 1. INTRODUCTION

The television (TV) system represents a group of interconnected and dependent TV devices. The television system makes a television studio with a set of departments which together enable preparation, recording and broadcasting of TV programs [1, 2]. Large television stations, by a rule, have more studios. TV studios are specialized for informative, feature program, TV shows that are recorded or directly broadcasted in the presence of the audience. Depending on the purpose of the TV studio, the equipment is also configured accordingly. One of the roles of the implemented TV studio is to use it as a laboratory for educational purposes but also as a television studio for content production [3 – 5].

This paper presents a functional solution for TV system implemented at the Faculty of Technical Sciences (FTS) in Kosovska Mitrovica within the Erasmus+ CBHE Project: Implementation of the study program Digital Broadcasting and Broadband Technologies (DBBT) [6]. Various TV programs including recording, production, post-production, direct inclusion of viewers and broadcasting TV programs can be realized by installed TV system.

The structure of the implemented TV system on the FTS is shown in Fig. 1. The structure of the television system is designed to be multifunctional and to satisfy all television standards and criteria. The complete television system has been adapted to the rooms of Faculty of technical sciences

and is designed to serve educational purposes, but also to fulfill all production and technical requirements.

The implemented studio consists of the following rooms: Reception room, Studio, Director room, Machine room, Editing room, Graphics and Desk room.

The TV studio is also known as a television production studio that needs to satisfy educational, productional and post productional requirements. It is designed so that there are three scenes. The first scene is designed to be neutral, while the second scene is intended for news and addressing viewers. The green screen is for a virtual studio that provides a real-time combination of people and computer-generated environments and objects, and this is the third scene. There are three video cameras in the studio that are recording in Full HD (High Definition) resolution, with signaling (Tally system) and communication (Intercom system) with director rooms. Lighting in the TV studio uses LED (Light Emitting Diode) panels which is adjustable and can be customized for all scenes. Studio is audibly isolated and complete audio and video content are sent to director room.

Figure 2a shows the appearance of the static scene in the TV studio.

Depending of the television center concept, director room is mostly including: video mixer, audio mixer, video matrix, audio matrix, a video switch, monitor wall for visual image control from various sources, electronic graphics, intercom system for audio communication with staff, sound director room and all other technical studio departments. The layout of the device in director room allows each team member to see the image and signals, to hear the commands and get instructions to be addressed.

Figure 2b shows an example of an implemented video wall in TV director room.

With the video wall, on the monitors, the director room is followed by everything that happens on the scene. Video monitors are professional and high-resolution with true color reproduction and lighting that enable visual image tracking. Computers in director room are equipped with appropriate hardware and all the necessary software for playout, graphics, virtual set, and audio/video control. TV

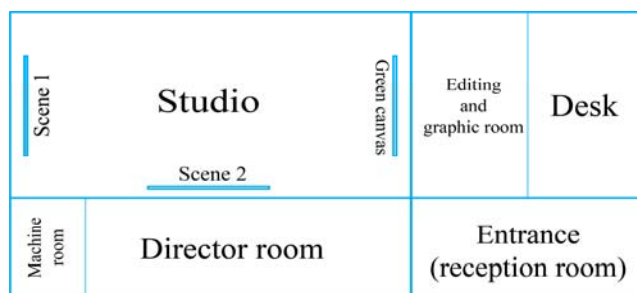


Fig. 1 – Room layout in TV.

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studio also receives signals from other sources (satellite, terrestrial, cable television, live inclusion, and exchanges with other televisions).

In the machine room (in the rack) there are devices that emit high heat and noise, so it is equipped with cooling system and soundproofed. There is a video switch, 20×20 matrix, patch box, server, various converters, audio/video distributions and computers.

Figure 2c shows a part of the equipment in the machine room.

In the room that is designed for editing and graphics, there are computers with all the necessary editing and graphics software: Adobe Premiere, After Effects, Photoshop, Illustrator, etc. Computers relate to video director room and desk, so that it is possible to communicate and share content. The indispensable part of designing the television system are desk and editorial staff. Desk boards in the implemented system are editorial and journalistic sections that are responsible for gathering information, planning, organizing, and scheduling realized program.

A virtual studio is a physical space with a green or blue canvas on the wall and floor with oblique edges. Chroma key is a technique used to composite two images or video

streams together based on color hues. It is often used in film industry to replace a scene's background by using a blue or green screen as the initial background and placing the actor in the foreground [7, 8]. The information generated by the tracking sensor technology ensures that the inserted objects remain "bound" to the position in the virtual studio regardless of the camera movements. Precise tracking of camera ensure the perfect assembly of the real and virtual world [9].

Figure 3 shows the principle of implemented chroma key model in TV.

In the proposed solution, the software implementation of the virtual set was achieved using the vMix program. A computer that owns vMix has the appropriate hardware and DeckLink 4K card [10].

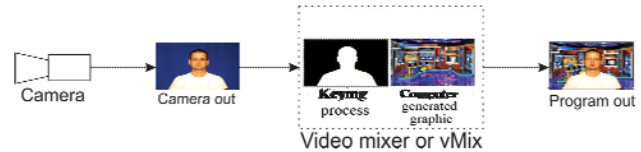


Fig. 3 – Chroma key in TV.

It works with three cameras, and each camera also has its own "virtual" plan, so changing the frame also changes behavior of that virtual scene, which actually tracks (tracking technology) changes on the network, and in this way knows what is happening and simulates the change. The hardware implementation of the virtual set is achieved with a video mixer [8]. This eliminates the need for any post-production work and does not require any physical scenes to be made.

## 2. VIDEO SYSTEM

The laboratory is designed so that the equipment can be used for different purposes: education, learning, researching, production, postproduction, streaming, etc. Figure 4 shows a detailed video scheme of connected devices in the TV system.

The complete video system is set to 1920×1080i resolution. Video cameras, photo cameras, computers, and other accessories are also set to the same resolution, but there is the possibility that the entire system will be set up for 4K resolution. With HD SDI (High-Definition Suction Diesel Injection) outputs from the camera, a signal is outputted to the HD SDI input of connection box, while devices with HDMI (High-Definition Multimedia Interface) interface outputted signal to the HDMI input of connection box (Fig. 4).

All devices (video and audio) from the studio through the connection box are connected to appropriate devices into rack in mechanical room. From the HD SDI connection box, the inputs (1), (2), and (3) of the Patch field, which are used in this case as protection and expansion for the matrix, HDMI video signals from the connection box are further connected to the converters HDMI to HD SDI. The signals are sent from the converter to the input (4) and (5) of Patch field, and from the Patch field all signals are connected to the input of the matrix, respectively.

Input of the matrix (13), (6), (7) and (8) also produces video signals from other sources, in this case output Playout 1 and Playout 2, Graphics and signal from the Ingest output system.

Implemented system also receiving signals from IPTV (Internet Protocol television), cable, terrestrial and satellite TV, through IPTV, DVB-C (Digital Video Broadcasting –



a)



b)



c)

Fig. 2 – a) Scene in a TV studio; b) video director room; c) part of the equipment in the machine room.

Cable), DVB-T2 (Digital Video Broadcasting – Terrestrial) and DVB-S2 (Digital Video Broadcasting – Satellite) receivers. Video signals obtained from these DVB standards are connected to the Field Meter where the measurement and analysis of the receiving signals, spectrum analysis, level, modulation scheme, etc. can be performed.

One of the five video signals from HDMI 5x1, can be selected on the HDMI switch, which needs to be converted to HD SDI using a converter HD SDI which output is connected to the matrix input (9). A signal from a computer that has a 4K DeckLink [10] card with accompanying software for implementing a virtual set is connected to the (10) the matrix input. The output of the matrix (14) is connected to the ultrascopes, and it is possible to analyze and measure the luminance, chrominance, luminance assembled with a chrominance video signals, the histogram of the video signals, and the analysis and measurement of the audio signals.

Program output from the mixer [11] are connected to the embedder, and it is connected to the input (11) of the matrix, so it can be manipulated and routed to all the signals via the matrix. An input from the signal generator is provided at the input (12) of the matrix, by which it is possible to generate signals with software and perform various signal analyzes and measurements. From the matrix output via the Patch field (06), the embedded HD SDI signal is de-embedded, and the de-embedded HD SDI signal is connected to the video mixer input.

At the output (18) from the matrix via the Patch field, the program output is connected to Encoder H265 which broadcast program to other television systems (IPTV, DVB-T2, DVB-C) and to the switch. By sending a program output to the switch, it

is converted to the transport stream (packets) and distributed to IPTV, the Stream Analyzer and the Decoder H265.

To capture the program output or preview, entire system is connected through a matrix (with (13) HD SDI output) to the HyperDeck with two SSD (Solid State Disk). All incoming signals through the matrix (14) HD SDI output, are analyzed with Ultrascope. Two HDMI outputs from video mixers are connected to two TV monitors as Multiview since this video mixer has 2ME (2 Mix Effects). Program HDMI output is connected to one of the TV monitors, while a six-AUX (Auxiliary) remain for further routing.

### 3. AUDIO SYSTEM

The video and audio signals in the television system are processed separately. The image is processed in a video mixer, while the audio is processed in an audio mixer. Fig. 5 shows a detailed audio scheme of connected devices in the TV system. The audio mixer performs mixing of several input audio signals and there is mixed audio signal on output. In the implemented studio, the audio mixer [12] has 40 audio inputs.

Connection box located in the studio relates to three wired microphones and three wireless microphones with base (called “bugs”). Microphones can be designed as “wire” where microphone signal is transmitted to the audio mixer by copper wire, and “wireless” where microphone signal to audio mixer is transmitted wirelessly, via transmitter and receiver [1]. The transmitter power, which is usually located on the microphone, ranges from 10 mW to 50 mW. The frequency range of wireless microphones is in VHF (Very High Frequency) area (49–108 MHz and 169–216 MHz) and the UHF (Ultra High Frequency) area (450–806 MHz and 900–952 MHz).

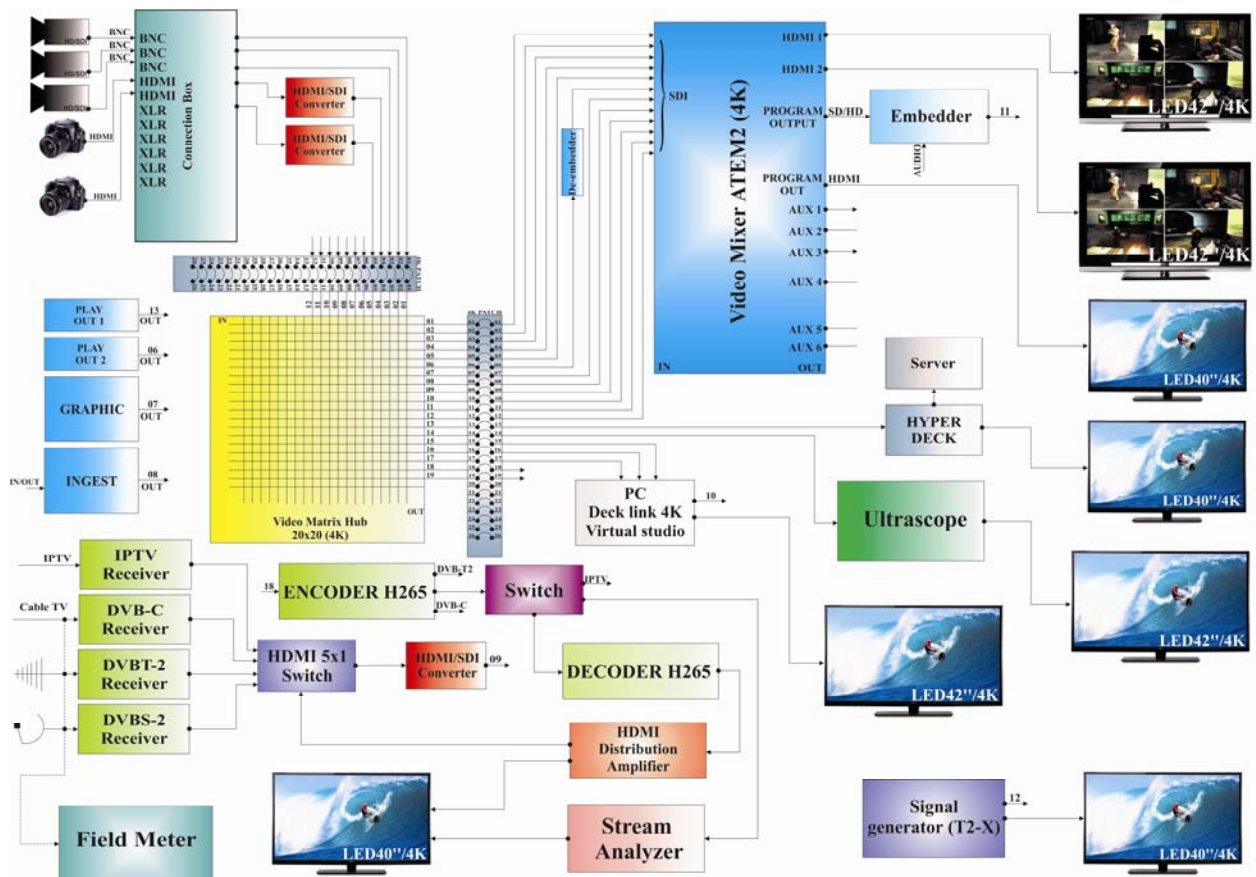


Fig. 4 – A block diagram of the video system.

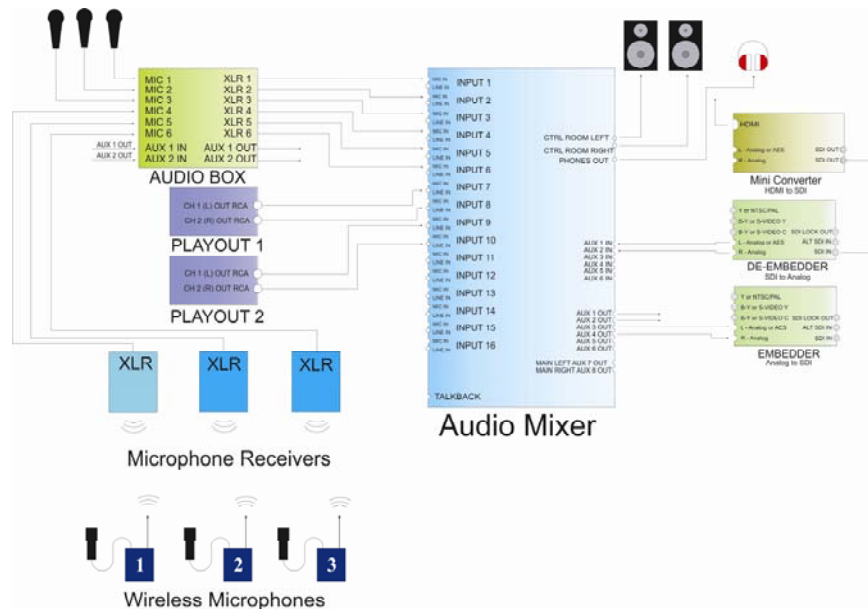


Fig. 5 – A block diagram of the audio system.

Signals are transmitted by radio waves, modulated AM (Amplitude Modulation), FM (Frequency Modulation) or some kind of digital modulation [1, 13].

Audio signals from the connection box are connected to audio mixer on its (1) – (6) microphone inputs. There are also two AUX outputs from the connection box, one of them is audio program output and audio program preview, but, if necessary, it can be routed and changed depending on the situation. The (7), (8) line inputs in the audio mixer are connected to the Payout, split on the left and right channels. There are two Payout systems in the implemented laboratory, audio signals are split on the left and right output and connected in the (9), (10) line input in the audio mixer. Signals from (3), (4) AUX outputs are connected the embedder which combine the audio program output with video program output as shown in the scheme of the video system (Fig. 4).

#### 4. INTERACTIVE CONNECTIONS WITH OTHER TV SYSTEMS

Laboratory distributing signals from an encoder to a cable (DVB-C) and a terrestrial network (DVB-T2), and it is possible to distribute the signal using Internet Protocol (IP), thus forming a television system based on internet protocol (IPTV). Although, the IP protocol is used to transmit video signals over all types of networks, the implemented studio provides the opportunity to connect with other television systems in the form of signal exchanges. This exchange is enabled by the Set Top Box (STB) on the receiving side which decodes incoming stimulated signal packets [13–14].

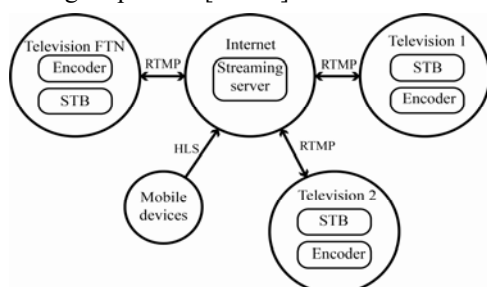


Fig. 6 – The method for connection with other TV systems.

Two basic ways of delivering video signals over an IP network are downloading content and streaming content. Downloading content is a process that takes over the whole content from the server, which content is stored on the local server. Signal transmission using IP protocol allows interactivity, so it is possible to provide the following options: VOD (Video on demand), Search for content, Program schema, Content scheduling, Chat, etc.

Figure 6 shows the method of implementing a TV system connection with other TV systems or devices.

With the streaming content, it is not necessary to download the entire content, but it is sent in real time and then immediately deleted. The protocols most used for streaming are HLS (HTTP Live Streaming), RTP (Real-Time Transport Protocol), RTSP (Real Time Streaming Protocol), RTMP (Real-Time Messaging Protocol) and RTMPE (Real-Time Messaging Protocol Encrypted). Connecting to other television systems or laboratories is achieved through the streaming server where Wowza Streaming Engine is installed [15]. Wowza media system is a software solution for streaming live content and VOD content. With the Flash Media Live Encoder that supports Wowza, content is encoded (H.264 – video and AAC – audio) using the RTMP protocol. On the receiving side, the streamed content can be downloaded via the STB that supports the specified protocols or via the PC with the editing card. Communication and exchange with other television systems, communication with devices (Mobile phones, tablets, cameras with encoder) that can be anywhere on the ground has been enabled in this system [16]. The solution for this is the Wowza media server and their software solution in the form of an application using the HLS/RTMP protocol.

#### 5. TESTING THE TV STUDIO CONNECTION WITH ANOTHER TV SYSTEM

The structure of the television system is designed to be multifunctional and to satisfy all television standards but also to be used as educational laboratory. Also, system can be used as tool for distance learning and be adopted to implement research models in education for analysis like conducted in [17, 18].

On the server located in the engine room, was installed Wowza Streaming Engine where is configured the applications which will allow the connection with other television studios and a mobile device from the field. A new application is made for each stream: there is application for the stream from this studio in Kosovska Mitrovica to studio in School of Electrical and Computer Engineering of Applied Studies in Belgrade, the application for mobile live broadcast from the field and application from for studio in Belgrade to studio in Kosovska Mitrovica. It must be opened two ports in the network: 1935 and 8088. Using the Wirecast [19] software, which is installed on the computer in the studio and serves as an encoder, the server parameters are configured: public IP address, port, and the name of the previously created application in Wowza, resolution, bitrate, etc. Thus, formed stream can be received using STB devices or VLC player. Figure 7a shows a stream sent from a studio in Kosovska Mitrovica, and Fig. 7b shows the stream sent (received) from studio in Belgrade.



a)



b)



c)

Fig. 7 – Streaming signal from: a) studio in Kosovska Mitrovica; b) studio in Belgrade; c) live streaming from mobile phone.

Live broadcasting from field using the mobile phone was realized using the GoCoder application [20]. The application is configured with same parameters as server with the only difference in name. Fig. 7c shows live broadcasting from the field using a mobile phone and 4G network. In this way a connection with another TV studio and live broadcast from the field is realized by using RTMP and HLS protocols. Received signal from mobile phone in

studio is configured on STB device by entering parameters of the stream (public IP address, port and application name, and it looks like: `rtmp://147.91.144.107:1935/ftn/mLive` or if stream uses HLS protocol:

`http://147.91.144.107:1935/ftn/mLive/playlist.m3u8`).

Figure 8 shows an overview of active connections and used protocols.

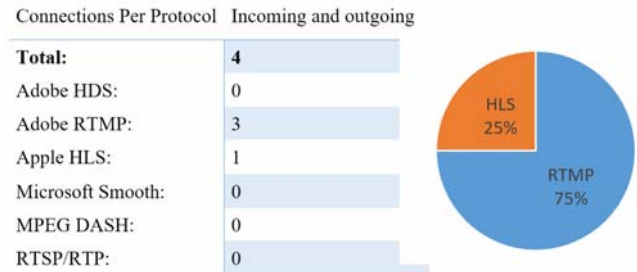


Fig. 8 – Monitoring of active connections and protocols.

From Fig. 8 the total number of established connections is four, where connections using the RTMP protocol are between the studios, while HLS represents the connection with the team on the field. Depending on the situation, other protocols can be used. Since connection with the team on the field and the exchange of signals with other television studios are through internet connection, stability, and quality, both objective and participative, depends on the speed of internet bandwidth. To adapt the video to all users, on the server where Wowza Streaming Engine was installed, stream transcoding was made using different resolutions and different bitrate that significantly affect the quality. Three categories of video resolution were analyzed for stream. Table 1 gives the encoder parameters for the applied SD (Standard Definition) resolution, HD (High Definition) resolution and FullHD (Full High Definition) resolution.

Table 1

Encoder parameters for streaming

	SD	HD	Full HD
<b>Resolution</b>	720×576	1280×720	1920×1080
<b>Number of Frame Per Second (FPS)</b>	25	25	25
<b>Average bitrate [kb/s]</b>	1025	2252	4500
<b>Audio bitrate [kb/s]</b>	128	128	128
<b>Sample rate frequency [Hz]</b>	44100	44100	44100

Figure 9 shows the number of received packets in one second for observed interval of 60 seconds, as well as the number of lost packets when streaming SD, HD and FullHD resolution, respectively. Graphs were obtained using the Wireshark software package [21] used to analyze the IP packets. The above graph (line) refers to the number of received packages by the server to the user, while the lower graph (line) represents the number of lost packets.

From given figures can be seen that the number of received packets increases with the higher resolution, or the increase in bitrate, because it is necessary to transfer a larger amount of information. Also, the number of lost packets increases, but if the receiver (user) has the required bitrate (which is greater or equal to the bitrate that stream being sent), this number of lost packets will not impair the quality of signal reception.

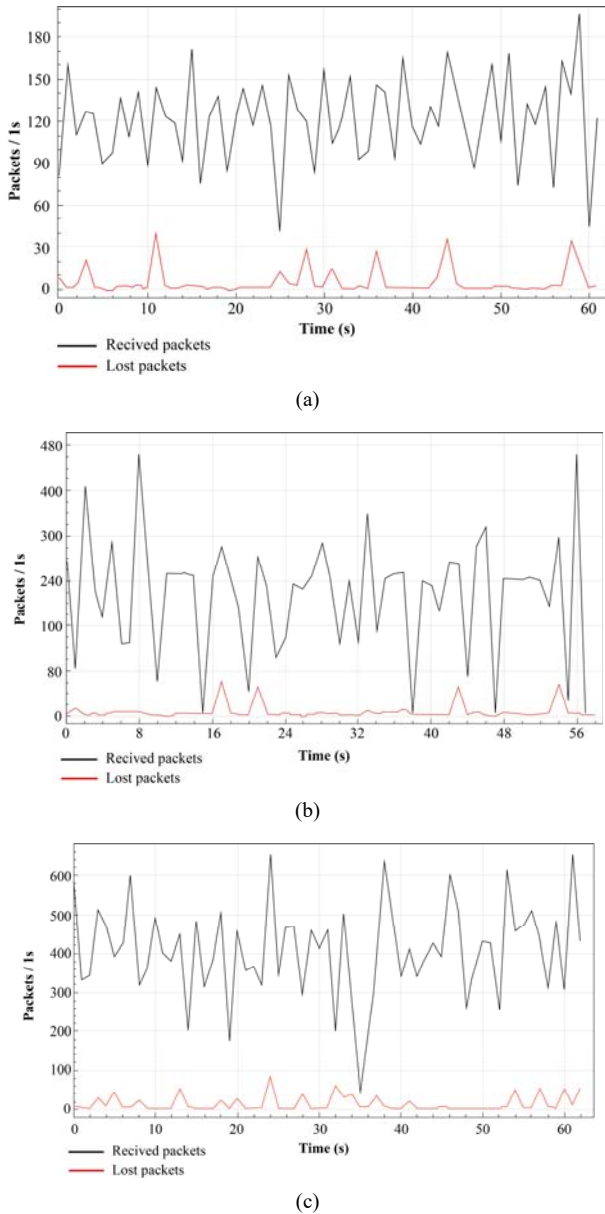


Fig. 9 – Number of received and lost packets for the observed interval of 60 s for: (a) SD resolution; (b) HD resolution; (c) FullHD resolution.

## 6. CONCLUSIONS

The development of digital technologies enables realization of TV systems with a wide range of possibilities for different purposes. In this case, using the optimal devices and the way of their networking, a multifunctional multimedia TV system can be used as an educational laboratory and television system. Proposed laboratory enables production and realization of television programs, also enables education, learning, researching, and measuring in the field of television technology and multimedia system, production and postproduction (recording of TV content, graphic processing, editing, visual effects, live broadcasting and more). With this system, students can get acquainted with the principles of implementation of TV programs, as well as with the work of multimedia systems from the engineering aspect. Also, can get acquainted with designing TV systems, broadcasting signals, used protocols for streaming. In this

way, they acquire practical and immediately applicable knowledge. The implemented system has the possibility of interactive communication over IP with other TV systems or individuals via mobile devices. The mentioned laboratory can also be used as a system for the distribution of TV program in real time.

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