Transmission and Switching Systems: Trends of Technology in Education

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***Abstract* – The paper presents the introduction of the most modern telecommunication transmission technologies in education of the course "Transmission and Switching Systems". This course is included in the Master study program "Computer Technology"; thanks to its structure and level, it provides a comprehensive overview of modern telecommunication systems. The education is based on several workplaces in the Laboratory of Data Transmission where students can get familiar with the following topics: signal transmission over optical fiber and other optical components (WDM, DWDM); xDSL (Digital Subscriber Line) transmission technologies; video and voice transmission over IP networks; configuration of CATV systems. The laboratory offers also workplaces for wireless (WiFi) and mobile (GSM, CDMA, UMTS) technologies.**

Index Terms – Laboratory education, Telecommunications, Transmission systems.

INTRODUCTION

The main problem of education in the area of transmission and switching systems is the continuous and very dynamic technology development. The curricula must adapt to the said development, and principles of laboratory education have to follow this trend as well. Modern education in such areas cannot be based only on theoretical knowledge. The cooperation with industry convinces us that it is necessary to join the knowledge from theoretical lessons very closely with practical experience from laboratory exercises in order to improve the competitiveness of our graduates in the job market. The appropriate equipment of measuring workplaces is crucial for application of this principle, in order to avoid the disproportion between the quantity of theoretical issues introduced during the lectures and the number of measurements, implemented configurations and practical tests. For this reason we decided to focus on complex innovation, rebuilding and extension of the measuring workplaces including their technology equipment, so that our students can use the state-of-the-art laboratory facilities corresponding to the current trends, as well as to the technology and safety standards and regulations.

CURRENT STATE

At present time the Department of Telecommunication engineering at the Czech Technical University in Prague, Faculty of Electrical Engineering, performs successive modernization of its laboratories, reflecting the rapid development in the areas of communication technologies. Several laboratory exercises have been newly designed or modernized, which complement the theoretical knowledge obtained by students during specialized lectures. The laboratory exercises are intended mainly for the full-time students of bachelor and subsequent Master programs at the Department, taking the following courses: Means of Data Communications, Principles of Telecommunication Systems, and Transmission and Switching Systems.

LABORATORY EXERCISES

As we are limited by the yearly quota for content innovation, we decided to update the following parts of the course in the current academic year, reflecting the most rapidly developing areas of communication technologies.

1. Data Transmission in CATV (Cable Television) Networks

This exercise makes students familiar with the architecture of the cable television network focusing on data transmission within CATV systems. The considered system (specified by DOCSIS standard) employs two types of transmission channels with different frequency bands – there is a backward channel (upstream direction i.e. from the subscriber / cable modem towards the network) and a forward channel (downstream direction, i.e. from the network towards the subscriber / cable modem). The range of working frequencies is 108—862MHz for the forward channel and 5—45 (or 65) MHz for the backward one. The fixed width of a transmission channel for the downstream direction is 6MHz. The standard also quotes the conditions for use of the specific types of modulations depending on the bit-error-rate (BER) and signal-to-noise ratio (SNR). These theoretical conditions can be expressed by a rather complicated formula for the probability of a bit error (1):

$$P_m = 2\left(1-\frac{1}{\sqrt{M}}\right) erfc\left(\sqrt{\frac{3k\left(\frac{S}{N}-10\log\left(M\,\frac{4-\alpha}{4(1+\alpha)}\right)\right)}{2(M-1)}}\right) * \left[1-\frac{1}{2}\left(1-\frac{1}{\sqrt{M}}\right) erfc\left(\sqrt{\frac{3k\left(\frac{S}{N}-10\log\left(M\,\frac{4-\alpha}{4(1+\alpha)}\right)\right)}{2(M-1)}}\right)\right] \quad (1)$$

where:

M is the number of modulation states,
S/N is the signal-to-noise ratio,
k is the number of bits per symbol,
α is the roll-off-factor
(for 64-QAM, α=0.8; for 256-QAM, α=0.2).

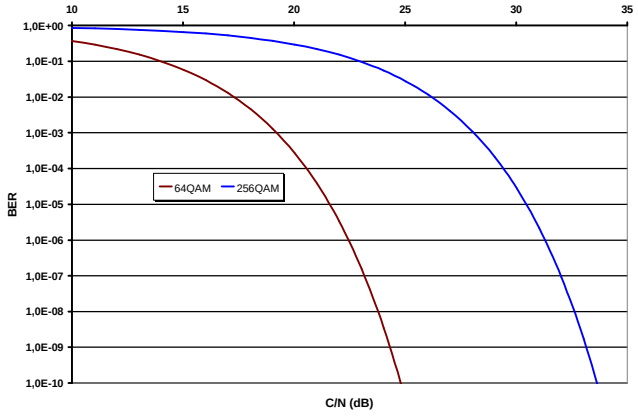

FIGURE 1
BIT ERROR RATIO VS. SIGNAL-TO-NOISE FOR SEVERAL LEVELS OF M-QAM

During the exercise, students verify the assumed conditions by decreasing the signal-to-noise ratio and measuring the bit error rate [1]. The other theoretical knowledge (influence of particular modulation type, width of transmission channel, transmission power etc.) is demonstrated using the proper technology.

2. Signal Transmission over Optical Fiber

For illustration of theoretical principles in the area of optical transmission media we have chosen a complex didactic system containing optical transmitter and receiver along with a set of various accessories (optical modules, optical path, connectors). The system offers comprehensive introduction of an optical transmission facility, allowing measurements of attenuation (fiber, tract, spectrum dependence) and of the parameters of radiation sources (LED and laser ones – transmission and V-A characteristics, stability, modulation properties). As the system is equipped with various types of detectors (PIN, APD) made from different materials (Si, Ge, InGaAs), it is also possible to explore their parameters (sensitivity, frequency response, modulation properties, etc.) [2].

The laboratory exercises emphasizes the following aspects:

- Transmission of optical radiation over a fiber,
- Fundamental physical principles,
- Measurements of fiber parameters,
- Radiation sources and detectors,
- Optical communication system,
- Modern optical elements – parameters and applications,
- Optical wave multiplexes WDM,
- Optical fiber sensors.

Since the system is based on plastic (polymer) fibers and the transmission employs light beams in the visible part of spectrum, it is possible to make such experiments as "critical bending radius" (causing the leakage of optical signal from a single-mode fiber and macro-bend losses). This theoretical condition is described by (2):

$$R = \frac{20\lambda}{\left(n_1 - n_2\right)^{\frac{3}{2}}}\left(2{,}748 - 0{,}996\frac{\lambda}{\lambda_c}\right) \qquad (2)$$

3. Video Transmission over IP Networks

This exercise is of a "demo" nature. Its goal is to make students familiar with the technology and capabilities of devices intended for unidirectional or bi-directional transmission of a video signal over IP (Internet Protocol) networks.

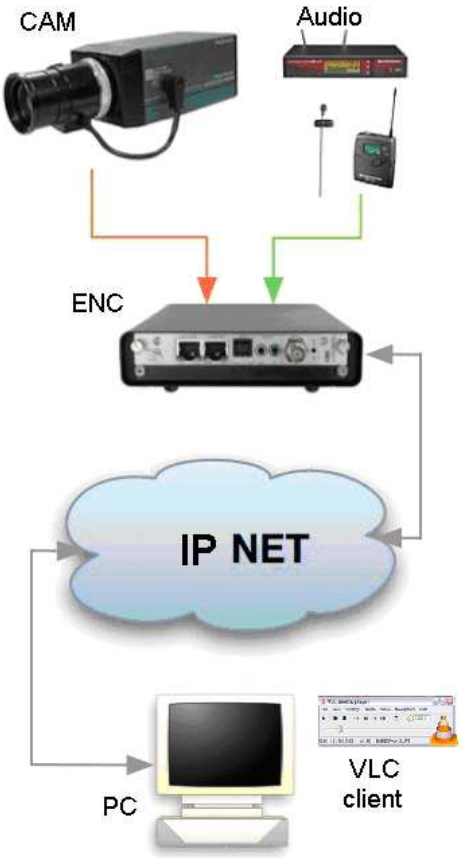

FIGURE 2
HW MPEG-2 ENCODER TERACUE ENC-100

The exercise is divided into two parts. Within the first one, students set up a videoconferencing connection using a pair of VCON HD3000 units, and then experiment with modification of communication parameters – including transmission speed (from 64kbps up to 4Mbps under H.261, H263, H263+, and H263++ standards), image resolution CIF (352 x 288 pixels) and QCIF (176 x 144 pixels), and picture frequency (15 frames per second and 30 frames per second). For the audio signal, codecs may be selected according to the appropriate standards (G.711, G.722, G.723.1, G.728, and

G.729). For each set of parameters, students perform subjective quality evaluation of the audio and video signals transmitted over an IP network.

The second part is focused on a unidirectional distribution of a high-quality video signal. [3]. For this purpose, Teracue ENC-100 hardware MPEG-2 real-time encoder is used, together with a camera, microphone, and a PC with VideoLAN media player.

Student can influence the output data rate in the range between 800kbps and 15Mbps (VBR or CBR) for video stream and 256 or 320 kbps for audio stream, depending on the required quality of picture; the following options are supported:

- 720x576 pixels,
- 384x576 pixels,
- 384x288 pixels.

Again, students perform subjective quality evaluation of the audio and video signals transmitted over an IP network and record the results.

4. Wireless and Mobile Technologies

This exercise introduces the basic principles needed for operation and configuration of wireless (IEEE 802.11 b/g) and mobile (EDGE, UMTS CDMA) networks. In the first part, dealing with wireless, students use access points and PCs with Wi-Fi USB adaptor to set up and configure a small private network. During the configuration process they pay attention to the modulations – DSSS, CCK (802.11b); OFDM, 16-QAM, QPSK, BPSK (802.11g) – and to encryption mechanisms (WEP 64/128-bit, WPA). Asus components are used for this – specifically, WL-167g USB adaptor and WL-500g access point. When the network is set up and configured properly, students can verify its transmission parameters.

Within the second part students measure the transmission capabilities of the technologies offered by Czech mobile operators – especially data transmission using EDGE (Enhanced Data Rates for GSM Evolution), UMTS TDD (Universal Mobile Telecommunications System – Time Division Duplexing) and CDMA 1xEV-DO (Evolution-Data Only). The measurements determine effective data throughput (transmission performance) and so-called ping delay (latency), comparing the results achievable with the different technologies.

5. xDSL Technologies

The laboratory exercises "xDSL Technologies" reflects the trend of subscriber Internet connections in the Czech Republic, where the majority is currently based on ADSL and its versions. Specifically, students are introduced to:

- ADSLoISDN – using frequency band from 138kHz to 1.1MHz, reaching downstream speed up to 8Mbps and upstream up to 1Mbps;
- ADSL2 – for frequency band below 1.1MHz, maximum transmission speed being approximately 9.5Mbps;
- ADSL2+ – for frequency band below 2.208MHz, downstream speed up to 25Mbps, upstream speed up to 1Mbps.

Students set up a data link beginning at ADSL ATU-C (central unit), followed by an artificial cable (1200m), attenuation element and ADSL ATU-R (remote unit) with a PC. Then they verify the theoretical maximum transmission throughput and reachable distance, registering the number of allocated bits for different values of sound-to-noise ratio.

SUMMARY

High-quality modern equipment of laboratories is a fundamental condition for successful increasing of the future graduates' competitiveness in the job market. The objective of the performed innovations is to reflect the continuous dynamic development in the area of ICT. Future steps will be aimed towards IP-based technologies, e.g. IPTV (Internet Protocol Television).

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