On the Development and Teaching of a Broadband Communication-Based Curriculum at Prairie View A&M University

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Abstract

We developed a broadband-based curriculum at Prairie View A&M University (PVAMU). The objective is to meet the demanded need of industry such as Sprint, Texas Instruments, Motorola, and other telecommunication industries by training students in this new area. The intensive exposure of the students to state-of-the-art broadband network testing and design equipment, access technologies, softwares, and techniques prepares the students to be highly productive once they graduate. Therefore, less time is spent in coming up to speed in the work place. This curriculum development is for the training of highly talented students in the area of high-speed (broadband) with emphasis in network design and testing techniques. Three new courses have been developed, two at the undergraduate level (Broadband Communication Systems I and II); and the other at the graduate level (Advanced Broadband Communication Systems). These courses complement the rich curriculum presently offered in the Department of Electrical Engineering at PVAMU. A new high-speed (broadband) access technologies laboratory has also been developed to support both instruction and research. This helps to create an academic instructional and research infrastructure for broadband communication systems-based projects, testing and research.

1. Introduction

Prairie View A & M University (PVAMU) attaches much importance to the training of students like many other universities to meet the needs of future technology trends. As a result of the technology growth shown in the area of broadband communications, PVAMU Electrical Engineering Department has placed much emphasis on trying to develop curriculum and the necessary infrastructure to accommodate this new area of study. This has necessitated the development of new courses, instructional and research laboratory [1], [2].

This paper discusses the development and innovations of a Broadband Communication-based curriculum at PVAMU and the lessons learned that should be very helpful to other educational

institutions. While we have also developed courses at the graduate level, the courses presented in detail in this paper were developed for the undergraduate level education. The objective is to meet the challenging demand by Broadband Communication-Based industries such as Sprint, Lucent, AT&T and other telecommunication industries of training students in the new area of High Speed Communications (Broadband Access Technology and Network). The intensive exposure of the students to state-of-the-art broadband telecommunication testing and design equipment, technologies, softwares and new techniques involved in the trade, prepares the students to be highly productive once they graduate. Therefore, less time is spent in coming up to speed in the work place.

This paper discusses in detail the two new courses (Broadband Communications Systems I & II) that have been developed, at the undergraduate level and then discuss briefly the graduate level course (Advanced Broadband Communication Systems). These courses complement the rich curriculum presently offered in the Department of Electrical Engineering at PVAMU. In this paper, an attempt is made to describe the innovations, the ideas behind the development of these courses and the necessary projects including some of the research topics and lessons learned.

This paper discusses in detail the new State-of-the-Art broadband laboratory that has been developed to support both instruction and research. Figures 1 and 2 show students at work and some of the key equipment in the broadband laboratory. This developed State-of-the-Art broadband laboratory is part of the part of the laboratories that make up the center of excellence for communications systems technology research (CECSTR) laboratories [1], [2]. The new broadband laboratory helps to create an academic instructional and research infrastructure for Broadband Communication-based projects and research. It gives students working in their various research topics and course projects, the much needed hands-on that the students need to succeed in the work place.

In Section 2, we discussed the newly developed courses, goals, course outcomes, topics covered in each course and the selected list of projects. We discussed the lessons learned in Section 3. The conclusion, the acknowledgements and references are discussed in Sections 4, 5 and 6 respectively.

2. The Newly Developed Broadband Communication Systems Courses in the Electrical Engineering Curriculum at PVAMU

PVAMU Electrical Engineering Department identified the need and opportunity for Broadband Communication Systems courses in broadband network design and testing. The intent of the proposed Broadband courses, without question, is to meet the needs of both industry and academia because of the acute shortage of skilled qualified engineers in this growing area of telecommunications. In meeting the industry's need for well trained entry and graduate level Broadband Communication Systems network design and test engineers, this Section discusses the PVAMU Electrical Engineering course curriculum that has been developed in the area of Broadband Communication Systems.

2.1 Detailed Descriptions of the Newly Developed Courses

2.1.1 Course I: ELEG 4313-001 – Broadband Communication Systems I (3-0) Credit 3 semester hours. The text used is [3] and Professor's Notes and Handouts. The other additional course references are [4], [5], [6], and [7].

2.1.2 Course Description: Introduction of various areas of high-speed communication systems. The basic ideas of DSL technology. Telephone subscriber loop environment. Telecommunication's architecture. Loops and Trunks, Broadband Industry Relations. Testing Theory, practices and Scripting. Broadband Industry Related Standards, Study of Broadband Impairments and Possible Solutions. Twisted-Pair channel modeling. Transceiver front-end noise models. Channel capacity testing and analysis techniques of xDSL systems. Issues with xDSL Modulation Techniques - DMT, CAP and 2B1Q. xDSL Deployment Considerations and Market Directions. Students will be expected to research and present various topics of interests in class. Projects are expected from the students at the end of the semester. Other special topics of interest will be covered especially as they relate to xDSL issues. **Prerequisite:** ELEG 3023, and ELEG 3043. Senior standing or permission of Instructor.

2.1.3 Goals: The listed items below are some of the goals we try to achieve in this course. Some of these goals and more advanced related areas of the goals are covered in the other courses.

- Technical Documentation and Presentation – projects, test reports/results require good writing skills and proper documentation methods.
- Desktop tools – PC tools used to conduct analysis and produce test results and include applications such as Microsoft Word, Excel, PowerPoint, Access, and Visio.
- Statistics – testing often requires statistical methods.
- Testing Theory – coursework designed to provide the student with a solid understanding of testing methodology and techniques.
- Testing Practices – coursework designed to provide the student with a working knowledge of how a lab is run and would include topics such as: safety, calibration, test equipment operation, test script execution, testing interoperability issues.
- Test Scripting – coursework designed to introduce test scripting languages through more advanced courses in script language creation. This may require partnership with your IT department.
- Telecommunications Equipment – coursework designed to introduce the various pieces of testing equipment as well as telecommunications equipment to the student. For example this would include the Smartbits, Wireline Simulators, and the DSLAM – (This material should be available from the various vendors).
- Telecommunication's architecture – coursework designed to give the student a working understanding of how various telecommunications technologies are currently deployed – TDM, Voice Packet, and ATM/Frame relay data networks. This would include metropolitan to rural deployment approaches.
- Industry Relations – coursework designed to provide the student with an understanding of the telecommunications industry inter-workings via various forums and regulatory

frameworks to include industry forums such as:

- OBF – establishes the standards on how companies order service form one another
- LERG – coordinates how routing of traffic is to be communicated.
- TAG/IAB – common language forum.
- T1 and its subcommittees – establishes common standards for technical engineering issues.
- DSL forum – establishes common standards and testing for DSL technologies

And regulatory organizations, requirements, and forums such as:

- FCC – Federal regulatory body.
- Telecommunications Act and subsequent reports and orders.
- PUCs – state and local regulatory bodies.
- NRIC – Industry forum established by FCC to address network reliability issues.
- CALEA – most recent law enforcement requirements to the industry.

- Industry Standards – coursework intended to introduce and where appropriate give the student an understanding of the various industry standards such as DSL, ShDSL, H.248, and H.303.
- DSL – coursework designed to give the student the appropriate theoretical and working knowledge of DSL so that testing within the broadband lab is well grounded and meaningful for the student while increasing the probability of achieving quality testing results from the lab.

2.1.4 Course Outcomes for Students: Upon completing this course, the student is expected to:

- To have working knowledge of documenting and presenting projects, test reports/results and good writing skills.
- Be knowledgeable of the necessary Desktop tools, PC tools used to conduct analysis and produce test results and include applications such as Microsoft Word, Excel, PowerPoint, Access, and Visio.
- Understand Statistics because testing often requires statistical methods.
- Understand Testing Theory that should provide the student with a solid understanding of testing methodology and techniques.
- Understand Testing Practices necessary to provide the student with a working knowledge of how a lab is run.
- Have working knowledge of laboratory safety, equipment calibration, test equipment operation, test script execution, and testing interoperability issues.
- Have the ability to understand, write and implement test scripting languages through more advanced courses in script language creation.
- Have working knowledge of the telecommunications equipment used in broadband communication.
- Understand telecommunication's architecture by having a working understanding of how various telecommunications technologies are currently deployed – TDM, Voice Packet, and ATM/Frame relay data networks including metropolitan to rural deployment approaches.
- Be knowledgeable with Industry Relations by providing the student with an understanding

of the telecommunications industry inter-workings via various forums and regulatory frameworks to include industry forums.

2.1.5 Topics Covered in ELEG 4313-Broadband Communication Systems I

- Introduction to broadband communication concepts and theory (2 classes, 1 week)
- Telecommunication Systems Equipment and signals (2 classes, 1 week)
- Telecommunication's architecture (4 classes, 2 weeks)
- Loops and Trunks (2 classes, 1 week)
- Broadband Industry Relations (3 classes, 1 & 1/2 weeks)
- Testing Theory, practices and Scripting (6 classes, 3 weeks)
- Broadband Industry Related Standards (3 classes, 1 & 1/2 weeks)
- Study of Broadband Impairments and Possible Solutions (3 classes, 1 & 1/2 weeks)
- Selected current case study of communication theory-based application design (2 classes, 1 Week)
- Exams 1 & 3 (2 classes, 1 week)
- Class Project Presentations (4 classes, 2 weeks)

2.2 Course II: ELEG 4323-001 – Broadband Communication Systems II (3-0) Credit 3 semester hours. The text used is [3] and Professor's Notes and Handouts. The other additional course references are [4], [5], [6], and [7].

2.2.1 Course Description: The continuation of the Introduction of various areas of high-speed communication systems. The basic ideas of DSL technology. Telephone subscriber loop environment. Twisted-Pair channel modeling. Transceiver front-end noise models. Channel capacity testing and analysis techniques of xDSL systems. Students will be expected to research and present various topics of interests in class. Projects are expected from the students at the end of the semester. Other special topics of interest will be covered especially as they relate to xDSL issues. **Prerequisite:** ELEG 4313-Broadband Communication Systems I, Senior Standing or permission of Instructor.

2.2.3 Goals: This course continues to develop broadband network communication theory concepts, techniques, and design approaches. Asynchronous Transfer Mode (ATM) is introduced with an overview of the technology, its characteristics, and its architecture. The various ATM cell functions are described and include discussions on the virtual channel identifier and virtual path identifier. The NNI/UNI/PNNI interfaces are discussed, as is access connectivity. Considerable information on the components of ATM Adaptation Layers (AALs), and the various classes of service provided by ATM are presented. We cover the capacity and throughput and how it applies to both public and private ATM backbone networks. Quality of Service (QoS), ATM applications, and advantages and disadvantages of the ATM technology are discussed. We conduct an overview of the technology and the infrastructure and speeds offered by the Synchronous Optical Network (SONET). We discuss the SONET frame, the multiplexing process, and the SONET components of path overhead, line overhead, and section overhead. The discussion continues with the concerns of the Synchronous Payload Envelope (SPE) and the

various SONET pointers. Other topics are end-user topology, and the various equipment elements for SONET, including T-1 multiplexers, digital cross-connect systems, digital switches, regenerators, and optical media. Information on the various SONET standards such as quality of service (QoS), SONET applications, and the advantages and disadvantages of the SONET technology are also discussed.

The various Virtual Private Network (VPN) types, including details about access VPNs, intranet VPNs, and extranet VPNs are discussed. Tunneling, security, and connectivity issues are discussed. Details concerning VPN hardware and software that includes firewalls, gateways, and routers are presented. VPN implementation scenarios are presented, as are VPN standards and applications. Fiber Distributed Data Interface (FDDI) technology and topology which includes a discussion of the various device types utilized in the network. FDDI and the Token Ring are compared, and the FDDI physical specifications, which includes also a presentation on the physical media utilized by FDDI. Other topics covered include FDDI hardware port types and ring connectivity, FDDI architecture, protocol architecture, ring scheduling, and ring operation. The FDDI frame and token format and other FDDI standards are described.

This course discusses POTS and its relationship with the DSL technologies. The components discussed include the Digital Subscriber Line Access Multiplexer (DSLAM) and splitters that are utilized in the network. In-depth presentations follow on Asymmetrical DSL (ADSL), High-bit-rate DSL (HDSL), Symmetrical DSL (SDSL), Very-high-data-rate DSL (VDSL), and Rate Adaptive DSL (RADSL). Information concerning cable television systems and their components are discussed. Also, DSL and cable modem standards, issues, and considerations are discussed. We discuss ISDN, as well as ISDN architecture, connectivity, out-of-bound signaling, and both Basic Rate (BRI) and Primary Rate (PRI) interfaces. An overview of metropolitan area networks and the Switched Multimegabit Data Service (SMDS) connectivity, including in-depth information on the Distributed Queue Dual Bus (DQDB) operation. Sustained Information Rate (SIR) and the various access classes and addressing are discussed. Details concerning the cell structure and the various standards associated with the service are presented.

A discussion of the number of frequency bands and the variety of possible wireless network configuration is presented. These primary categories of wireless networks include local area networks, extended LANs, and mobile computing. An in-dept analysis is directed at wireless LAN, radio, and microwave technologies. These include both satellite and terrestrial transmission systems. Cellular telephony is another topic, which includes information on pagers, mobile telephones, personal digital assistants, and the various networks of the mobile telephone service. An in-depth study of the Personal Communication Service (PCS) is provided. Information concerns both Frequency Division Multiple Access (FDMA) and Code Division Multiple Access (CDMA) transmission techniques. Wireless data technologies, including packet data networks, cellular telephone services, and cellular digital packet data, are important topics, as are wireless standards and associated issues and considerations. Fiber channels are presented and reviews of its underlying technology, emphasizing the medium that is utilized to carry the signals.

Historical perspective of the Internet and the World Wide Web is discussed. A detailed explanation includes the Internet components, access and transport across the network, Internet service providers (ISPs), and Network Service Providers (NSPs). Internet standards and IP

addressing. Intranets and extranets technologies, topologies and applications are discussed. We also discuss Electronic data interchange (EDI) and Computer Telephony Integration (CTI) applications. An overview of network management and the various management activities that include monitoring, reporting, and controlling of the network is discussed. The discussion includes network management architecture and the network management system requirements. This course presents considerable information on CMIP and SNMP protocols, as well as the management information base (MIB) and the abstract syntax notation system. Network management standards, the protocol data units, and network management products and services are discussed. Issues of prevention or trouble shooting and testing broadband networks are discussed including testing theory; practices and Scripting of Broadband Network Systems. There are discussions of coding, in particular trellis-coded modulation. The issue of obtaining the combined performance improvements provided by trellis coding and decision-feedback equalization are addressed, and it is shown how this can be achieved by using transmitter precoding and other new advanced techniques.

2.2.4 Course Outcomes for Students: Upon completing the course, the student is expected to:

- Understand broadband communication theory concepts, techniques, and design approaches.
- Understand the in-depth treatment of the basic principles, design, and achievable performance of Asynchronous Transfer Mode (ATM).
- Understand the technology and the infrastructure and speeds offered by the Synchronous Optical Network (SONET).
- Be knowledgeable with the various Virtual Private Network (VPN) types, including details about access VPNs, intranet VPNs, and extranet VPNs.
- Understand Fiber Distributed Data Interface (FDDI) technology and topology, which includes the various device types utilized in the network.
- Have an understanding of POTS and its relationship with the DSL technologies including the Digital Subscriber Line Access Multiplexer (DSLAM) and splitters that are utilized in the network.
- In-depth understanding of Asymmetrical DSL (ADSL), High-bit-rate DSL (HDSL), Symmetrical DSL (SDSL), Very-high-data-rate DSL (VDSL), and Rate Adaptive DSL (RADSL) including information concerning cable television systems and their components.
- Be knowledgeable of the number of frequency bands and the variety of possible wireless network configuration.
- Be knowledgeable about the Internet components, access and transport across the network, Internet service providers (ISPs), Network Service Providers (NSPs), Internet standards and IP addressing, Intranets and extranets technologies, topologies and applications.
- Know how to model an additive interference such as near- and far-end crosstalk, impulse noise, and background noise.
- Be knowledgeable on how to how to test different broadband-based equipment such as xDSL modems, and broadband systems problem solving techniques, etc.

2.2.5 Topics Covered in ELEG 4323 - Broadband Communication Systems II

- Introduction.
- Asynchronous Transfer Mode
- Synchronous Optical Network
- Virtual Private Network (VPN)
- Digital Subscriber Line
- Integrated Services Digital Network/Broadband ISDN
- Switched Multimegabit Digital Service/Metropolitan Area Network
- Wireless/Personal Communications Service
- Fiber Channel
- Internet/Intranet/Extranet
- Network Management
- Testing, Testing Theory, practices and Scripting of Broadband Network Systems/Problem Solving and Troubleshooting
- Error Correction and Trellis Coding
- Selected current case study of broadband communications
- Exams 1 & 3
- Class Design Project Presentations

2.3. Selected Project List

Project Topics
SONET Ring Sizing Problems and Suggested Solutions
Research, Development and Implementation of Broadband Telephony Experiments Using Feedback Communication System Modules
ADSL and Local Area Networks
Research Paper on POTS Splitters for Broadband Systems
Development and Implementation of DSP-Based Broadband Telephony Experiments Using Feedback Communication System Modules
Study of Wavelet-Based Decomposition and Reconstruction Characteristics for Broadband Systems
Simulating and Observing Local Looping of a Signal on Copper Wire
Investigation of Packet and Circuit Switching Technologies and Their Future Cost Effects
Study of DMT and its Simulation in MATLAB

2.4 Course III: ELEG 5243-001 – Advanced Broadband Communication Systems (3-0) Credit 3 semester hours. The text used is [7] and Professor's Notes and Handouts. The other additional course references are [4], [5], [6], and [7].

2.4.1 Course Description: Advanced areas of High Speed (Broadband) Communication Systems. Advanced testing and analysis techniques of various high-speed (Broadband) communication systems. Detailed study of the different types of xDSLs, the DSLAM Issues. Packet Switching and Circuit Switching. International Issues and broadband. Advanced detailed issues concerning Broadband Standards and Standard related Issues with more Emphasis on xDSL. Broadband Migration Issues and Special Topics of Interests. Students will be expected to research and present various topics of interests in class. Projects are expected from the students at the end of the semester. Other special topics of interest will be covered especially as they relate to Broadband Communication Systems. **Prerequisite:** ELEG 4323 or equivalent, Graduate Standing or permission of Instructor.

3.0 Impact to the PVAMU and Students

- Educational training of students through student research and hands on experiments that uses Broadband technologies and techniques.
- Attracting more students especially minority students to the field of Broadband Communications Systems by providing support for their training.
- Enhancing the electrical engineering curriculum in the study of Broadband Communication Systems and their application to telecommunication systems and signal processing.
- To provide avenues for collaboration with other research laboratories within the university and industry.
- To expose students to real industrial experience by serving as interns with industry.

4.0 Lessons Learned

With the experiences we have acquired in developing and teaching these courses, we have learned some lessons that we want to share with our colleagues in engineering education in this Section. Some of the questions that come up are as follows: How much state-of-the-art can we teach in an undergraduate education? How much responsibility new employers must shoulder in applying the undergraduate studies to their particular specialty? There should be no reservations to the state-of-the-art we must teach to our students. The constraints as we see them are how much we can fold into a semester and what level of knowledge we should impact on our students to make them productive once they are employed.

We started with just one course, ELEG 4313, the Broadband Communication Systems I. We quickly realized that one semester will not allow us to finish all the materials required. So we made it a two semester course by adding the ELEG 4323, Broadband Communication Systems II. We also involved the industrial sector, that is, our sponsors and those that will end up employing the students for input in the course development. We got their suggestions on those topics that will form the body of knowledge that they expect their entry-level engineers to have both at the undergraduate and graduate levels. These industrial partners also target the students for coop programs and for future hiring. That kind of input from industry helps to solve the problem of the responsibilities of the new employers in applying the undergraduate studies to their particular specialty.

It is absolutely important to give the students hands-on work in the laboratory and also in the form of projects and research work. Figures 1 and 2 show the students working in the broadband lab and some of the state-of-the-art equipment in the laboratory. This reinforces to the students the theories delivered in the lectures by the professor. The class presentations of the projects and research works of the students are also very important. This helps the students to acquire good writing and communication skills needed in the industry. Exposure of the students to the importance of teamwork should be emphasized. Their class projects and research help them to acquire these skills as well.

5.0 Summary and Conclusion

In summary, we have discussed the development of a broadband communication systems-based curriculum at PVAMU. The curriculum is currently meeting its objectives as planned by training students in this new area. The intensive exposure of the students to state-of-the-art broadband network testing and design equipment, technologies, softwares and techniques have helped to prepare the students to be highly productive once they graduate. Therefore, less time is now spent in coming up to speed in the work place. This curriculum development has help the telecommunication industries to increase their hiring of PVAMU students especially, those with this highly demanding skill in the area of broadband access technologies.

6.0 Acknowledgements

The author wishes to thank Sprint, Inc. for supporting this curriculum development effort. Without their vision and that of the able administrators of both Sprint, Inc. and PVAMU, this could not have been possible. Special thanks to the President of PVAMU who made it possible for us to have the necessary space to house the Laboratory that is supporting the courses developed and the research space in this new area of technological challenge. Thanks to the many students who are doing research with the author in this area of broadband access technologies and those students that have taking the courses.

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Figure 1: Students working in the newly developed Broadband Telecommunication Research Laboratory

Figure 2: Some of the State-of-the-Art Equipment in the newly developed Broadband Telecommunication Research Laboratory.

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