Teaching Data Communications and Networking to School of Business Undergraduates: A Pedagogical Framework for Juxtaposing Theory and Practice

Michael Gendron and A.T. Jarmoszko
Central Connecticut State University, New Britain, CT USA

gendronm@ccsu.edu jarmoszkoa@ccsu.edu

Abstract

This article proposes a pedagogical framework for teaching an introductory data communications and networking (DCN) course to Management Information Systems (MIS) undergraduate majors within a school of business. Building on the material provided in commonly used DCN undergraduate textbooks, the course introduces students to both theoretical and applied knowledge necessary to solve business and DCN technology problems. Since it is taught in a business school, the course encompasses students' previous business course work, and has a strong business case orientation. All MIS majors at the senior level are required to take it.

Keywords: data communications, networking, network design, IS'97.6, IS2002

Introduction

The importance of Data Communications and Networking (DCN) in undergraduate information systems education has been long recognized by both academics and professionals. This is confirmed -- in particular -- by the content of IS'97 (Davis, Gorgone, Couger, Feinstein, & H.E. Longenecker, 1997) and the draft IS2002 (Gorgone et al., 2002) model curricula for undergraduate degree programs in Information Systems. Today's Information systems normally contain a network component, which may, at times, determine whether a system succeeds or fails. IS'2002.6 states that: "Students who are knowledgeable of and have developed personal information systems will gain an in-depth exposure to information technology hardware and software components and their interaction. A systems view of computer systems will be utilized in identification of computer and telecommunication system components. (Gorgone et al., 2002)" Yet to authors' best knowledge there is no established framework for teaching DCN concepts in an undergraduate IS curriculum. Even such fundamental issues as the methodology for network design are not taught uniformly. Lack of a standardized DCN course framework leads not only to variance in delivered educational content, but also to inconsistent representation of network design documents.

If we look at the advances in systems analysis and design over the past 30 years, we see several methodologies that have emerged (e.g., Chen, 1976; Iivari & Koskela, 1987; McGregor, 1998; Yourdon & Constantine, 1979). Today, it is common to see large systems diagramed using Data Flow Diagrams (DFD), Entity Relationship Diagrams (ERD) or Unified Modeling Language (UML) to name but three of those methods. (Dobing & Parsons, 2000) The established diagramming techniques have symbolic representations for their constituent parts that allow systems analysts to quickly understand the design of a system, even if they did not create the original diagrams. This sort of standardization is needed for network design. While this article does not include a discussion of an actual symbolic language for network design it will introduce a

pedagogical approach to teaching network design principles. Discussion of the symbolic language will occur in a future article.

Below we propose a pedagogical framework for teaching introductory data communications and networking concepts to Management Information Systems (MIS) undergraduate majors within a business school setting. We believe that the innovative nature of the framework lies in the selection of topics to cover and in the novel juxtaposition of DCN theory and practical, case-oriented work. This monograph is based on the experiences of the authors, which spans over 45 years of combined information systems industry and academic experience.

Background

MIS undergraduate DCN textbooks generally present theoretical material well and sometimes supplement it with mini-cases, which often do not provide a unifying linkage between theory and practice. This linkage is required to meet the IS'97 and IS'2002 draft recommendations. While we believe that the recommendations provide foundational precepts on which to base a DCN course, the need to provide the type of hands-on training (installation, configuration and operations experiences) suggested in IS2002.6 is not supported in the literature. For example, IS practitioners feel that network planning skills are the most important topic in a senior-level DCN course, while academics rated it third after awareness of TCP/IP and the ability to use the internet (Johnson, Stallard, & Tanner, 1999). Our framework is designed to provide those planning and design skills. Further, we believe that teaching planning and design skills are appropriate in a business school setting.

The DCN course is included in all known model curricula for information systems education, specifically IS'97 and IS'2002 which our framework is modeled after. DCN course recommendations for these two frameworks can be seen in *Table 1 DCN Course Recommendations from and IS'2002*. We believe our proposed framework substantially covers the recommended curriculum, without the need for hands-on lab experiences.

Furthermore, the approach presented below provides for teaching business school students the following skills:

- the ability to analyze the business needs of an organization and apply the correct networking solutions;
- a high level technical background which allows them to conceptualize a network and specify its components;
- the ability to design and document a large network, convey that design to managers in an understandable way and
- the ability to work network engineers and technicians to ensure the ensure the successful implementation and on going maintenance of a network.

We believe these skills to be *sine qua non* of a graduating MIS student.

Table 1 DCN Course Recommendations from IS'97 and IS'2002

Recommendations	IS97.4	IS2002.6
Catalog	Students will gain in-depth experience of telecommunications fundamentals, including voice-video-data for LAN, MANN and WAN including the switched network systems. Data communication and telecommunication models and standards, concepts, and standard organizations will be studied. Installation, configuration, systems integration and management of the technologies will be practiced.	Principles and application of telecommunication and computer systems hardware and software will be presented through lecture, installation, configuration and operations experiences.
Scope	The course provides an in-depth knowledge of telecommunications technologies, hardware and software. Emphasis is upon the analysis and design of networking applications in business. Management of telecommunications networks, cost-benefit analysis and evaluation of connectivity options is also covered. Students learn to evaluate, select and implement different communication options within a business.	This course provides an in-depth knowledge of data communications and networking requirements including networking and telecommunications technologies, hardware, and software. Emphasis is upon the analysis and design of networking applications in organizations. Management of telecommunications networks, cost-benefit analysis, and evaluation of connectivity options are also covered. Students learn to evaluate, select, and implement different communication options within an organization
Topics	Telecommunication devices and standards, media, systems; modems, multiplexers, bridges, routers, gateways and other network hardware and software; network configuration; network applications; coding of data; cost-benefit analysis; distributed versus centralized systems; architectures, topologies and protocols; network performance analysis; privacy, security, reliability; installation of networks; monitoring of networks; management of telecommunications	Telecommunication configurations; network and Web applications; distributed systems; wired and wireless architectures, topologies and protocols; installation, configuration and operation of bridges, routers, switches and gateways; network performance tuning; privacy, security, firewalls, reliability; installation and configuration of LAN and WAN networks; monitoring of networks; management of telecommunications, and communications standards.

Pedagogical Approach

The course is taught at the senior level and it is required for all MIS majors – it is their only required DCN course. MIS students come to the networking class with several prerequisites including an MIS survey course, at least one programming course, and an e-business survey course. Additionally students have a general business core and an undergraduate general education core. This allows us to make certain assumptions about their skills and knowledge.

Our approach to teaching DCN is driven by the standards (IS'97 and IS'2002) and our belief that students should possess both theoretical and practical knowledge at the completion of this course. We accomplish those goals by juxtaposing theory and practice through lecture (theory) and the use of a simulation (practice). The theoretical is fairly straight forward in that it is handled very well in many undergraduate DCN textbooks. Through lectures, in-class activities, and testing we can be fairly sure that the student comprehend the theoretical material. The practice of network design is another matter since we have not found its treatment to be very complete in any undergraduate DCN textbooks, which we have

reviewed and used in class. This has necessitated that we create a simulation and juxtapose it with theory so that one supplements and supports the other.

The Simulation

The DCN course has been taught for many years at our university. During that time the standards and expectations for DCN course content have evolved and it has become necessary to add applied components. We have chosen to use a business case simulation to teach the applied material for several reasons: 1) since we are in a business school the case method is a teaching style which students were familiar with and would be readily understood, 2) it allowed students to gain insight into how many private businesses and the public sector often procure large assets, and 3) using a simulation allowed us to integrate theory and practice while presenting students with a very real-life problem to solve.

The simulation consists of a company, which recently received a large amount of venture capital as startup funding. The company needs a large network and Internet presence, and has developed a Request for Proposal (RFP) which they have sent to a number of potential vendors. The RFP contains instructions indicating that the vendors are to respond with a proposal for network design, cost, and other pertinent information. Between the time the RFP is sent to the vendors and the proposal is due, the company [the customer] plans to hold 2 bidders conferences where vendors could ask specific questions about the company and the RFP. Class time is reserved for the bidders conferences and the course instructor plays the role of the customer. Students are randomly placed into teams, which act as consulting companies or vendors interested in responding to the RFP. In addition to customer-supplier interaction during the bidders conferences, The teams of students are told they could make appointments with the company representatives (e.g. the course instructor) for the purpose of asking additional questions and soliciting needed information. More details about the simulation are presented below.

Course Evaluation

Course evaluation for the network class is summarized in ***Error! Reference source not found.***. Evaluation is done through a large group project, several assignments, and 2 multiple-choice exams. The large group project allows the evaluation of the student's ability to move from a businesses problem to a business solution and for the development of teamwork skills. The assignments are used to reinforce concepts taught in class and allow for the evaluation of student progress through the course material. Some of the assignments are individually graded and others are group graded. Two multiple-choice exams (midterm and final) allow for the evaluation of theoretical concepts.

Table 2. Course Evaluation

EVALUATIVE COMPONENT	USED TO EVALUATE…
Semester Project	ability to move from a business problem to a business network solution.
Assignments	currency with and understanding of course concepts
Midterm	specific technical concepts
Final	specific technical concepts

The course is broken into modules and there are two concurrent threads; the first thread is composed of theoretical material and the second is composed of applied material. The threads are coordinated so the student is concurrently presented with the theory that is necessary to understand the applied material. These are both reinforced by assignments and supplemental materials developed for this course.

Table 3 Course Summary describes the order in which material is presented and assignments are given. One to two weeks is spent on each module; however, it is often necessary to modify the amount of time spent on any one module depending on student mix of technical ability. The theoretical material is pre-

sented using a networking and telecommunications textbook[1], while the applied materials and assignments are based on material developed specifically for this class. A Structured Network Analysis and Design (SNAD) method has been developed which will be discussed in a future article; the material from this methodology is used throughout the course. The supplemental material is summarized in *Table 4 Supplemental Course Material.*

Table 3 Course Summary

Theoretical Thread	**Applied Thread** ***Report Section Discussed***	**Supplemental Material Distributed**	**Assignments** ***Activity***
Course Introduction	Introduce Semester Project (SP)	Request for Proposal (RFP); Floor Plans Detailed Network Design Outline	
Standards	Business Needs *Report Introduction & Requirements*		Submit Questions for Bidder's Conference; On-Line Self-test *First Bidders' Conference*
Physical Layer	Design Concepts *Design and Cost*	RFP Addendum (result of bidder's conference)	Draft of SP introduction and requirements.
Small Single Switch LANS	Diagramming and Nomenclature *Design and Cost*	Diagramming Handout Nomenclature Handout	Single Switch Design Diagram
Larger LANS	Calculating Throughput Diagramming Continued *Design and Cost*	Bandwidth Calculation	MAN Diagrams *Second Bidders' Conference*
Telephony and WANS		RFP Addendum (result of bidder's conference)	Draft SP Network Design
WANs VPNs			Preliminary Hardware List and Costs
Internetworking			

Course Structure

Modules are used to break the course into easy to assimilate topics and make an introduction to this highly technical area much less daunting. A brief description of each course section, summarizing its theoretical and applied material, along with a description of the assignment will now be given.

[1] The theoretical materials is currently being taught using *Business Data Networks and Telecommunications (Panko, 2002) however, this framework and be easily adopted to any undergraduate business school oriented networking text.*

Table 4 Supplemental Course Material

Material Provided	Description
Initial Request for Proposal (RFP)	This is a typical RFP that a consultant may receive for network design and implementation. It provides the basis for the semester project (SP).
Floor Plans	Floor plans (in Microsoft Visio™) for the building described in the RFP
Detailed Network Design Outline	A detailed outline for a network design report. This is the format used to respond to the RFP
Bandwidth Calculation	Two files (Word and Excel) which described how to calculate bandwidth requirements for the RFP.
RFP Addendums	This further describes the building/business/industry, and is the outcome of the bidders conference.
Nomenclature Handout	Worksheets used to teach how to develop a network nomenclature.
Diagramming Handout	Guide to network design and a sample symbolic language to be used for diagramming a network
Small Network Project	Describes a small company, and its needs for a network. Used as the basis for the single switch design project in Section 5.
MAN/LAN project	Describes a large company, and its needs for a network within its main office and between its satellite locations. It is used for the multi-switch design project in section Six.
Slides	PowerPoint slides are available for the theoretical thread in all modules.

Course Introduction (Module 1)

Students come into this course with varying backgrounds. Some have has no networking experience but desire to gain an introduction; others have had substantial experience and want to validate their "in the field." training, while some are only taking this course because it is required within the MIS curriculum. Because of this variability this module attempts to create a baseline of knowledge and to make sure that students have the same understanding of many core concepts.

At the start of the course students are provided information about the semester project, and project teams are formed. The semester project is the culmination of this course and allows students to pull together knowledge gained in prerequisites and in this course. A project titled Ticket Sales, Inc (TSI) is used that incorporates a large virtual private network (VPN), several small site networks, a large site network, Internet connectivity, and a straightforward business plan. The groups are to act as consultants to TSI and provide a network design plan. As outline of the plan can be seen in ***Error! Reference source not found.***The sections of the report are discussed in class as indicated in *Table 3 Course Summary*. Students are given an extensive Request for Proposal (RFP) that they must respond to.

During the semester, the two bidders' conferences are the main vehicle for customer-supplier interaction about the RFP. As work on the project progresses, students are required to turn in drafts of the various sections of their final deliverable.

In addition to the RFP, the following materials are also distributed: initial RFP, Floor Plans, and Detailed Network Design Plan Outline.

Standards Model (Module Two)

Most network hardware today is based on the TCP-IP/OSI hybrid model (Panko, 2002). This model is introduced and discussed extensively. If students can understand this model and the functions of its 5-layers they will be better able to understand the functioning of network switching and routing equipment. Because this material is complex, and usually foreign even to students with networking experience, it will take longer to cover than other modules, therefore extra time is allotted.

Two Page Executive Summary of Networking Recommendation

1) Introduction
   a) Purpose of the report;
   b) Description of the company
   c) Description of industry and how the company fits into the industry
2) Requirements
   a) Industry Requirements
   b) Company Requirements
   c) Personnel Impacted by the network and their requirements by department.
3) Design
   a) Nomenclature
   b) Diagrams
      i) Enterprise Level Design Diagram
      ii) Core Diagrams
      iii) Workgroup Diagram(s)
   c) Justification Narratives
   d) Cabling List
4) Cost
   a) For all equipment and services give cost.
5) Equipment Literature
   a) For all equipment selected its technical literature must be included. This is usually available on the web. This ensures that the instructor has the information to grade the project.

Figure 1 - Semester Project Report Outline

An assignment composed of an online quiz is given. Students are allowed to take the quiz as often as they wish. Since the material is complex, students' comprehension is enhanced via, the combination of moving slowly through the material, having online resources (slides, supplemental reading material, tutorials, etc.), and an online quiz that can be retaken numerous times.

A class session is used for a bidders conference and students are told to submit RFP questions in advance of the event. TSI management, represented by the course instructor, responds to these questions interactively and following. As a result of the bidders conference, a supplement to the RFP is distributed based on the questions asked. The goal of the first bidders' conference is for students to learn about the business needs of TSI, which constitutes the first two sections of the network design report (**Error! Reference source not found.**).

Business needs are divided into the needs of the industry, and the company management. The RFP gives some information about TSI, but the students are expected to research the ticket sales industry as well. The idea is that you cannot design a network until you understand the need of the industry, and the needs of the individual company management. The banking industry is used as example: the industry has a need for security and is highly regulated, while an individual bank may have a specific set of needs that have to do with a document management solution they wish to use. In other words, during the first bidders' conference, students are not expected to ask technical questions about network design, but rather to focus on the business aspects.

Physical Layer (Module Three)

Students are introduced to analog and digital signaling, media types, different types of transmission (copper, fiber optic, radio signaling, etc) and various physical layer topologies. The concept of a structured cabling plan is introduced since it will be thoroughly discussed din the next module.

Based on the bidders' conference in the last module, an addendum to the RFP is distributed. It answers the questions asked by students. A discussion of the design and cost section of the semester report is begun. Students use their own research, the original RFP, and the RPF addendum in the assignment for this module – they must submit a draft of the introduction (without the executive summary of the design) and requirements sections of the semester project report.

Small, Single Switch LAN (Module Four)

This module presents Ethernet switching and relates it to the TCP-IP/OSI hybrid model. Encapsulation is presented. The small single switched LAN is discussed as are switching tables and techniques, as well as switch pricing. Design and diagramming concepts are introduced.

Students are given handouts which discuss symbolic techniques to represent network components (diagramming), and structured cabling plan development (nomenclature). Both diagramming and nomenclature are presented in class, and are to be used this modules assignment, for the upcoming assignments and the semester project. Students must submit a diagram and nomenclature for a single switch LAN.

Larger LANs (Module Five)

The goal of this module is to take the concepts learned thus far and extend them to a multi-switch environment. Ethernet, wireless, ATM and legacy LANS are presented. Wide area networking is also introduced. Techniques are presented for calculating bandwidth requirements. The discussion of the semester project continues with the design and cost sections.

The assignment is to design a metropolitan area network. They are to use the design and nomenclature techniques presented earlier and must calculate the bandwidth requirements for Internet connectivity to this network.

Telephony and WANS (Module Six)

This module reinforces the idea that most wide area networking is based on telephone carriers as well as the integration of voice and data carriers. Public switched telephone networking is discussed and how it affects our ability to create wide and local area networks.

A second bidders' conference is held and another RFP addendum is distributed. Students must submit a draft network design for the TSI project. This is reviewed and quickly returned so comments can be incorporated into the final report.

WANs and VPNs (Module Seven)

Wide area networking is continued, and the ability to build a private network versus using carrier leased lines and the Internet is presented. VPNs are also discussed. The assignment for this module is the submission of a preliminary hardware and cost list.

Internetworking (Module Eight)

Routers tie together networks. In this module routing is introduced, along with forwarding table creation, TCP/IP standards used in routing, and TCP handshaking. Additionally, layer 3 and layer 3 Ethernet switches are discussed. All of this material is held to the end since it is not necessarily needed for the semester project. There are no additional handouts or assignments.

Conclusion

It is not difficult to teach the "how" of network design, but teaching the "why" is a challenge. Our experience using the two-thread framework presented in this paper is that student can much better under-

stand the "why" of network design, and learn the "how" at a very high level. We feel this is an appropriate mix of skills for business school undergraduates. Anecdotally, we have seen the following: 1) several student report that they have gone on to obtain further network credentials (e.g., Cisco CCNA and Microsoft MCSE) as a result of this DCN course, and 2) a group of students formed a successful consulting company after graduation and report that the skills learned in this class largely affected their choice of networking as a career path. These types of positive outcomes were not reported by students who took this class under the former method of presenting the material.

A framework for introducing business school MIS majors to networking and telecommunications has been introduced in this article. Approximately 150 students have been taught using the framework in its current form. It has been very successful and students report that they found it useful for their continued career growth due to its focus on DCN design methodologies.

References

Chen, P. P.-S. (1976). The entity relationship model. *ACM Transactions on Database Systems, 1*(1), 9-36.

Davis, G. B., Gorgone, J. T., Couger, J. D., Feinstein, D. L., & H.E. Longenecker, J. (1997). IS'97 Model Curriculum and Guidelines for Undergraduate Degree Programs in Information Systems. *Data Base, 28*(1), Bi-B94.

Dobing, B., & Parsons, J. (2000). Understanding the Role of Use Cases in UML: A Review and Research Agenda. *Journal of Database Management, Oct-Dec*.

Gorgone, J. T., Davis, G. B., Valacich, J. S., Heikki, T., Feinstein, D. L., & Longenecker, H. E. (2002). *IS'2002 Model Curriculum Guidelines for Undergraduate Degree Programs in Information Systems*, [Web]. ACM, AIS, AITP. Available: http://www.is2000.org/ [2002, Dec 12].

Iivari, J., & Koskela, E. (1987). The PIOCO model for information systems design. *MIS Quarterly, 11*(3), 401-419.

Johnson, L. E., Stallard, J. J., & Tanner, T. R. (1999). An empirical analysis of the content of the data communications course: Academics' and practitioners' perspectives. *Information Technology, Learning, and Performance Journal, 17*(2), 1-14.

McGregor, J. (1998). Testing models: the requirements model. *The Journal of Object-Oriented Programming, 11*(3), 20-31.

Panko, R. (2002). *Business data networks and telecommunications* (Fourth ed.). Upper Saddle River: Prentice Hall.

Yourdon, E., & Constantine, L. L. (1979). *Structured design*. United States of America: Prentice-Hall, Inc.

Biographies

Michael Gendron is currently Associate Professor in the Department of Management Information Systems, School of Business, Central Connecticut State University. His research and teaching interests include Networking and Data Communications, Data and Information Quality, Internet Governance and Healthcare Informatics. Prior to joining CCSU faculty, Dr. Gendron has held positions such as Chief Information Officer, Technology Coordinator, Networking and Telecommunications Consultant. He has over 27 years of industry and academic experience.

Andrzej Tomasz Jarmoszko is an also Associate Professor in the Department of Management Information Systems, School of Business, Central Connecticut State University. His primary teaching areas are systems analysis and design and data communications and networking. Prior to joining CCSU faculty, Dr. Jarmoszko was Manager for Strategic Planning at a major mobile communications company in Central Europe. His research interests include Information Systems curriculum, aligning knowledge management with the strategy process, and strategic management in the communications industry.