Coursework Focus: Inter-operation of Servers, Workstations, and Network Devices

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Abstract

The paper details both the coursework and hardware used in a new two-semester sequence of data communication courses under development in the Electronics and Computer Technology (ECT) Program at Bowling Green State University (BGSU). (1) The traditional approach of teaching data communications from a well known topics as signal standards, message syntax, time-based and frequency-based transmission techniques, must now share the undergraduate's attention with newer topics. (2) These topics include administration of servers, workstations and network devices. For the educator, the problem posed by these new topics is the unwanted presence of a potentially large amount of vendor specific and proprietary information within the body of work. The curriculum under development at BGSU attempts to (1) minimize transient, or unnecessary, vendor-specific details, while presenting a strong core of new communication fundamentals that enable students to understand and exercise the (2) information technology basic to server, workstation, and network device operation and interaction.

Introduction

Traditional electrical engineering curricula includes a systems and signals course followed by a sequence of communication courses that include such topics as analog signal modulation, baseband digital signal transmission, signal filtering, channel capacity, and message coding. The depths of communication topics are dependent on how, or whether, a communication specialty is offered within the electrical engineering program.

At Bowling Green, our electronics and computer technology program has followed a similar template, while additionally covering topics such as physical interface standards (e.g. RS-232, RS-422). Since our program has a three-semester co-operative education component, emphasis on application over theory has proven beneficial to our students. With the rise of networking applications, and the “network appliance” in both corporate, manufacturing and consumer environments, our students need additional communication systems preparation. This is particularly critical for ECT graduates that seek a career in an Information Technology field. In this employment sector they will compete for jobs with recent graduates from other institutions that may already hold an IT industry related certification. These certifications can be either closely tied to the curriculum, as in the case of many two-year degree granting institutions, or it can exist outside a traditional academic program. Occasionally, Universities and Colleges offer non-core coursework that is tied closely to certification or certification preparation[1]. This is yet another certification route. An example of this relationship is Rensselaer Polytechnic Institute. Rensselaer's Computer Science department hosts a Cisco Networking Academy site that offers elective (non-credit bearing) courses that prepare students for Cisco's Certified Network Associate (CCNA), Certified Network Professional (CCNP), and Certified Internetwork Expert (CCIE) certifications (http://www.rpi.edu/dept/catalog/sos/sos-cs.html). The University of Akron offers Cisco certification as part of an undergraduate minor in its Computer Science department, or as an associate-degree major in its Computer Information Systems program (http://www.commtech.uakron.edu/?/bustech/cis.html). Another example is St. Bonaventure University that offers Microsoft certifications (http://web.sbu.edu/msitacademy/index.html) through their Computer Science department. Like Rensselaer's approach, St. Bonaventure's Microsoft IT Academy courses are non-credit bearing.

It is our intent to give our co-op students and graduating students significant knowledge in information network technologies through a two-semester course sequence. The coursework includes data communication and the information technology fundamentals basic to server, workstation, and network device operation and interaction. The successful student will be able to place fundamental concepts into the context of the local area network (LAN) and wide area network (WAN) operation. It is acknowledged that the curriculum does not contain detailed vendor specific information as, for example, is found in Cisco's Networking Academy, and therefore our students will lack the skill set obtained by such instruction. It is further acknowledged that our program will not be as well positioned as programs that have created an entire specialty in communications engineering[2] (http://www.carleton.ca/cu/ed4life/brochures/commeng.html). However, the knowledge ECT students obtain from the new curriculum will better position them for employment in IT environments than did our previous curriculum. In addition, the knowledge base will incorporate items broader than any available single industry certification (e.g. Cisco, Novell, Microsoft, Sun Microsystems).

Resources

The hardware resources for the two-semester data communication course sequence includes routers, network hubs/switches, servers and workstations. Pricing on new routers from manufacturers require a minimum investment of approximately $1,250 per router (with educational discount). Assuming routers are exercised in pairs, back-to-back, a router bundle would cost $2,500. A switch (new, minimum $1,000) is necessary to concentrate computer workstation traffic. Additional items, ranging from frame-relay units, to CSU/DSUs, can be added on an as-needed basis.

The Program has obtained equipment donations from a regional ISP and has established a working laboratory LAN/WAN/LAN bridge network using a Cisco 2511 router, two Cisco 2501 routers, four Osicom T1 CSU/DSUs, and switches. Two older Xyplex 3000 routers with 56Kbps CSU/DSUs are also on site. By carefully managing a modest computer budget of $16,000 the program has amassed the software and hardware necessary for two servers and four workstation clients. Network streaming video production hardware and software have been acquired to provide sample real-world application data for transport across the network. An existing set of ten PC-workstations was upgraded to dual network interface (NIC) cards to enable their use in either network laboratory exercises or standard laboratory support applications.

Integration of Network Interests

In preparation for industrial, business, or corporate information technology related employment a student might gravitate to one of a number of various technical specializations, such as network administration or server administration. Certain employers will be satisfied with nothing less than hiring recent graduates that have earned industrial/corporate certifications. However, for a broad number of students such detailed certification could prove a mistake. At graduation, these students may need sufficient "educational experience" latitude to reposition themselves outside a single narrow industry certification. Such latitude is achieved in the two-semester course sequence by the co-mingling of analog, digital, and data communication with networking and operating system (OS) topics.

Co-mingling of fundamental topics with specialty topics already occurs in some courses, for example, certain telecommunication courses. In these courses analog and digital communication techniques, transmission line theory, and etc., are combined with a multitude of telecommunication specific technology topics. Such specific topics can include digital subscriber line (DSL) transmission schemes, optical transmission standards (e.g. SONET), digital subscriber line access multipliers (DSLAMs), and others.

Course Material by Topic

Integration of material for the Electronics and Computer Technology data communication course sequence is preformed both on a tiered basis and conjoined basis. These effects are shown as a two-dimensional structure within Tables 1-4. The descending columns illustrate the tiering of class material, while the adjacent row elements illustrate the conjoining of class material. Classic data communication/communication systems material is the first tier (Table 1: "Foundational Material," columns 1 and 2) of the coursework. Material subsequent to this topic begins with the second tier, "The Physical Interface – Baseband Case." For this second tier, and most remaining tiers, the conjoined information is shown in table columns 3 and 4. Please note, in some cases the mechanics of a table format prevents the inclusion of a more exhaustive list of entries for column four.

The topics in column 1 are arranged (downward) in progression of details. These details concern the communication system, from the nature of the channel and channel interfaces, to system elements, to system topology, architecture and operation, and, to services offered across the system. All topics share the ultimate common objective of data commerce. The presentation of material relevant to this common objective allows students the opportunity to understand the broad issues of data transport systems.

The course design concepts that govern the implementation of table topics must be carefully weighted. A central design constraint is time, since an in-depth discussion of each topic element in the tables would be require lecture durations well beyond the what is considered standard or

Network Topic	Subtopics	Background Topics	Background Subtopics
Foundational Material	**Continuous and Discrete Time Signals**	**None**	
	Frequency Representation		
	Transform Domain, FFT Applications		
	Filters		
	Noise		
	Information Measures		
	Message Entropy		
	Channel Capacity		
The Physical Interface – Baseband Case	**Mechanical Interfaces**	**Digital Baseband Transmission**	**Binary Pulse Amplitude Modulation**
	Media and Transmission Characteristics		**Signal Shape, Intersymbol Interference, Bandwidth**
	Signal Encoding		**Signaling Formats**
	Voltage Levels, Signal Thresholds, and Detection		**Encoding**
	OSI / TCPIP Reference Models		**Detection**
The Physical Interface – Telephony	**Voice Digitization**	**Digital Logic**	**Registers, Buffers, and Buses**
	Data Modulation		**Memory, Nonvolatile, Volatile**
	Digital Subscriber Line Technology at the Local Loop		**Logic Operations and Logic Gates**
		Digital Signal Processing	**Sampling, Quantization, Encoding and Reconstruction of Analog Signals**

Table 1. Foundation Material Through Physical Interface

Network Topic	Subtopics	Background Topics	Background Subtopics
Data Link Layer	Direct Connection Point-to-Point (e.g. SLIP, PPP)	Buses and Network Topologies	Serial Buses
			Parallel Buses
	Shared Medium, Broadcast Link (e.g. Ethernet)		Star Topology, Ring Topology, Linear Bus Topology
	Switched Multiple Access Link (e.g. TDMA-based protocol)	Data Communications Multiple Access Techniques	Time Division
			Frequency Division
	Linked Layer Services		Code Division
	Address Resolution		
Internet Layer	IP Addresses, IP Address Classes, Format	Data Communications Multiple Access Techniques	Message Structures
			Message Routing
	IP Subnets, Masks		Message Parsing
	Internet Layer Protocol: IP, ICMP		
	Internet Routing		
The small Local Area Network (LAN): Network Architecture of a Cluster of Isolated PCs	Hub Technology		
	Static IP / Dynamic IP, Interface Device Configuration	Operating Systems	Basic Windows-based Network Configuration and Administration Tools
	Route Table: Interface Device, Network, Destination, Gateway, Mask		Basic UNIX/LINUX Network Configuration and Administration Tools
	Diagnostic Tools for Route Operations		
	Domains		
	Local Lookup vs. Domain Name Service		

Table 2. The Data Link Layer Through a Small Local Area Network (LAN)

Network Topic	Subtopics	Background Topics	Background Subtopics
Basic PC-based Network Services	Remote Logins (e.g. Telnet)	Operating Systems	Basic Windows-based Network Configuration and Administration Tools
	File Transfers (e.g. FTP)		
	Session Message Block (SMB) (e.g. File and Printer Shares)		Basic UNIX/LINUX Network Configuration and Administration Tools
Locally Interconnect PC Network Sites	Intranet		
	Ethernet Hub Networks		
	Ethernet Switched Networks		
	Routers		
	Virtual Local Area Networks (VLANs)		
	Highspeed Protocols		
Internet Interconnected PC Network Sites	Internet Access Methods	Data Communication	Digital Modulation Techniques (e.g. QAM)
	Internet Transport Technologies (e.g. Cable) / Internet Backbone (e.g. Asynchronous Transfer Mode (ATM), Synchronous Optical Network (SONET))	Tele-communication Standards and Technologies	Digital Hierarchy
			Fiber-Optics
			Digital Subscriber Line Technologies (e.g. HDSL)
	Internet Security		
Local Computer Services	Browser-based Tools	Browser Languages	Hypertext Markup Language
			Virtual Machine Architecture

Table 3. Basic PC-based Network Services Through Local Computer Services

Network Topic	Subtopics	Background Topics	Background Subtopics
Local Area Networks Services	Peer-to-Peer Services	Operating Systems	Basic Windows-based Network Peer-to-Peer and Server Configuration and Administration Tools
	Server (e.g. Database, Print Services, Remote Terminal Services)		
	Thin Client Services		Basic UNIX/LINUX Peer-to-Peer and Server Configuration and Administration Tools
Browser-based Services on the Internet/Intranet	Web Server	Operating Systems and Third Party Services	Windows
	Streaming Media Services		Linux
			Real Networks
	Client Applications		Macromedia
	E-Commerce		
Ethernet-based Industrial Network Technologies	ModiconTCP	Non-Ethernet-based Industrial Network Devices and Architecture	RS-232, RS-422/RS-485
	EthernetIP (Rockwell Automation)		GPIB
	IDA – Interface for Distributed Automation		Fieldbus Technologies
	ProfiNet (Siemens)		USB, IEEE 1394
Operating System-based Industrial Network Technologies	High Level Application Approach: Foundation Fieldbus	Human Machine Interface	Intellution HMI Adaptions
	Portability Approach: OPC Foundation		Rockwell HMI Adaptions
Industrial Network Applications	Supervisory, Control and Data Acquisition Capabilities	Control Engineering, Industrial Engineering	Current Trends in Industry (e.g. Lean Manufacturing)
	Manufacturing Operation Support		
	Corporate Operation Support		

Table 4. Local Area Network Services Through Industrial Network Applications

expected practice. One method of introducing additional topics, outside of the lecture format, would be to supplement learning using Web-based resources. Due to the related nature of the material across columns in Tables 1-4, the tables can act as a starting point for design of such an asynchronous learning tool.

Two last remarks in this section about the coursework tables. First, possible laboratory exercises and activities may be inferred from the tables, but they are beyond the scope of this paper. Second, a time scale (e.g. day/date, week etc.) was intentionally omitted from the table. It is left to an individual institution to fit the tables, in part or in whole, to its academic calendar.

Variation of Content

A number of the content elements from Tables 1-4 are well known and have been taught in electrical engineering, computer science, and technical programs, as well as industrial/corporate training programs. An example of one such element is the Open Systems Interconnect (OSI) network reference model. It has been a point of instruction for over twenty years. Telecommunication principles, including voice digitization, multiplexing and framing in T-1 based hierarchical systems, are also well established topics. Other topics, such as local area networks and wide area networks have likewise been developed[3] and delivered at numerous institutions over many years. If these topics already exist in the program curriculum their presence in new courses may be adjusted (reduced, omitted) as necessary. The ECT program intends to retain these mentioned items as content for its data communications courses.

Certain elements from the classic data communication/communication systems topics will not be taught in the coursework. For example, while “Foundational Material” network topic (Table 1) contains concepts from Information Theory, the rigorous mathematical approach (e.g. proofs and lemmas) often associated with that discipline will not be employed. Also, while entropy and minimum codeword length concepts could easily be worked into a modest presentation on data compression techniques, the associated details are left outside this course sequence.

A certain amount of material could be omitted if analog signal related topics are eliminated. However this was not done in our program. It was felt that for the immediate future the data over voice line technology at the local loop (Telco Central Office (CO) to telephone subscriber phone) will remain a common component in delivery of data communication services. Additionally, by keeping this subject in the curriculum, industrial data communication systems that begin with analog sources (process control, data acquisition applications) and terminate in a digital environment will be better understood by the student.

New Elements

The new data communication two-semester sequence includes the topic of integration and concentration of industrial data onto data communication highways[4], principally, Ethernet (802.3) highways. While this area of investigation can include plant floor automation and supervisory control systems, for this coursework the topic is limited to the industrial network system applications and architecture necessary for bringing plant floor data to plant-level or corporate-level business computing services (http://www.ab.com/catalogs/b113/comm/overview.html). Currently a number of industrial network protocols make use of UDP/TCP/IP transport for communicating with devices. A number of these, including EtherNet/IP[5,6] (IP=Industrial Protocol) (Rockwell's port of DeviceNet to Ethernet) and Interface for Distributed Automation[7] (IDA) are open standards. There is a subtle, but critical, message transport distinction between Ethernet and these new open standards. The distinction is that the Ethnernet-TCP/IP practice of explicitly denoting data traffic source and data traffic destination (both IP address and Ethernet hardware address) is not used in these industrial network standards. Rather, these industrial networks employ a “producer/consumer” addressing form by which pre-configured consumers look, by ID number, for messages from particular producers. This a priori knowledge of a static, or routine, communication pattern allows for optimization of communication throughput. An example of such an optimization is the ability of this communication model to distribute producer process data to a large number of consumers (destinations) using a single message transmission. This contrasts with the typical Ethernet-TCP/IP implementation that requires a distinct message transmission to each individual consumer (destination). The communication optimization yielded by these industrial methods is not cost free. The operation of this network architecture on top of a standard Ethernet-TCP/IP network requires addition of appropriate software extensions (e.g. application layer protocols) and-or hardware gateways. However, increased costs are expected to be offset (partially or wholly) as data acquisition and control hardware manufactures adopt the use of lower cost Ethernet interfaces.

Challenges

Instructional challenges are numerous in the networking field. One such problem is the minimization of irrelevant or minimally relevant vendor specific network material. This material can be of the form of software, firmware or hardware details that are likely to be of a transitory interest. This is made particularly complex in the case of Microsoft software, whose client and server OSes change on a frequent basis (18 months or less). For example, in their PC-based OS, Windows '95, Microsoft did not endorse TCP/IP and their networking architecture did not support routing, while subsequent OSes did support TCP/IP and routing. Thus network administration, network topology and network capabilities became significantly different (more capable, more complex) following the OS version change. Microsoft networking software changes have not been limited to acceptance of TCP/IP and routing.

Microsoft has provided several versions of a popular remote client hosting service on its server operating systems. Within the NT 4.0 Server OS offering the service was provided in the special software edition named “Terminal Server Edition.” This was the first Microsoft product that allowed for operation of server hosted applications from a remote client machine. The server hosted every software application, including the client’s Windows desktop graphical user interface session. In Microsoft's next server OS offering, Windows 2000 Server, Terminal Server Edition software was embedded into the basic OS package, and was renamed Terminal Services. The newest server from Microsoft, .NET Server, also contains terminal services capabilities. In each rendition of the service, the functionality of terminal services was (is) subject to changes, each change magnitude ranging from cosmetic to substantive. One example of such a change is the OS modification that allows Microsoft’s Internet Explorer to initiate remote client sessions with the terminal services host. The challenge in course instruction is to avoid distracting minutia created from these different Microsoft server OS offerings while concentrating on important OS network concepts and services.

In the hardware world, network devices such as routers have technology teaching issues similar to software. CISCO is now using its 2600 series routers as the core for its sequence of basic network administration certification classes (CCNA, CCNP). This router series supplanted the venerable 2500 series router line. Unlike the previous series, the 2600 series features swappable interface modules. It also supports Virtual Lan (VLANs) routing. Its most obvious outward difference from the 2500 series interface is its compatibility with remote CISCO graphical management and configuration tools. Significant changes are not limited to those between two different model series however, severe operational differences can also occur between same model number devices. Such is the case of the 2500 series routers. Same series routers can have different Internetwork Operating System (IOS) versions and different memory specifications. Ultimately, for precise operational equivalence the 2500 series routers must have identical hardware and firmware.

While it is proper for laboratory instructions to go into sufficient details to operate with a given Server OS or router configuration tool (such as CISCO's 2500 series router Command Language Interface), lecture material must concentrate on the principles and concepts that arch over these tools. It is a particularly difficult task, considering the speed at which new offerings and updates are being released.

Coursework Reviews

To insure the long term success of the two-semester data communication course sequence it will be necessary for the ECT program to perform future coursework reviews. These reviews will rely on four evaluation components. These components are: (1) an existing non-university member ECT advisory board, (2) the existing ECT faculty member program committee, (3) undergraduate students, and (4) employers whose businesses are cooperative employment sites (coop sites) for ECT major students. During the performance of the reviews measures will be developed and computed with regard to three primary outcomes: (1) student learning, (2) student placement, and (3) student recruitment. Adjustments to the curriculum will be made based on the outcome of the reviews.

Summary

To better prepare students in its undergraduate Electronics and Computer Technology program for careers in industry, business, and commerce[8] a new two-semester course sequence in data communications has been initiated. Its primary feature is the systematic development of network communication channel, device, and service topics within the context of the Ethernet based Intranet and Internet. This reflects a convergence between services and technologies now occurring in the data communication industry[9]. The coursework allows for introduction of both fundamental data communication material and crucial network/services topics. Possible variations in course content are discussed, and important new material based on industrial network protocols are delineated. Finally, the challenges of laboratory and lecture instruction are acknowledged, with a number of specific challenges cited.

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