Enterprise Computing Topics and Their Integration into an Established Information Technology Academic Program

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ABSTRACT

The information technology program at RIT, considered to be the first program of its kind in the United States in 1992, has gone through numerous review cycles and subsequent revisions since then. Originally a "classic" IT program with its five pillars of IT knowledge (programming, database, web technologies, networking, and human computer interaction) it provided a very successful program of instruction that covered all the knowledge areas in a broad but not exceptionally deep fashion, as evidenced by a 90+ percent graduate hiring rate almost every year from then to the present. In those early times, the Internet was barely used, the web was completely new, and networking consisted of basic LAN technologies in small buildings or offices where the majority of traffic was file and printer sharing plus email. The well established programming and database areas were the foundation of that program. Of course there was no mention of anything "enterprise", most certainly not in the context in which we find the industry today. A large scale system might have been described as the airline reservation system (SABRE) or the infrastructure at the banks. All those systems were practically invisible to the general public.

As time went on, the faculty modified the program curriculum to keep in step with evolving technologies as the computing paradigm shifted from the sharing of information within an office setting to the worldwide sharing of everything seen today. The Internet provided the necessary infrastructure that enabled LAN, MAN, and WAN connectivity across the globe and enabled businesses to allow many employees to work remotely and collaborate from out-of-office locations. Many industries configured their command and control infrastructures to be available on the Internet and today homeowners can control their house's infrastructure from their portable cellular telephone.

The technologies that enabled that worldwide ever-present communication, along with the datacenter infrastructure needed to store vast quantities of collected information and serve applications to an ever more data-hungry populace have completely changed the way in which the current computing paradigm is defined. Today, the term "enterprise" has different meanings within different contexts but all definitions of that term agree upon one detail—it means very large scale thinking and deployment.

About seven years ago, this author participated in a workshop hosted by IBM, ostensibly the premier and largest manufacturer of enterprise servers, i.e. the mainframe, in a forum to convince the faculty that large scale thinking was absolutely necessary in our programs. It was about the same that the faculty realized the academic program was becoming somewhat stale and not embracing much of anything beyond the LAN in terms of system size and complexity. That workshop drove home in no uncertain

way that American higher education needed to take a look at their programs and incorporate large scale enterprise thinking into their curricula. From that time to the present our programs have been extensively modified to embrace and include these topics across the curricula

This paper will detail the history of RIT's IT program from beginning to the present time, industry evolution and program focus changes in attempts to remain current, and the inclusion of numerous enterprise topics into the curriculum. Today, these programs span the LAN to the enterprise and everything in between.

1. INTRODUCTION

In the early days of computing academic program development, based upon the existing and well-known computer science and database pillars of computing education, networking from both the hardware and software perspectives was included into the programs as an additional pillar. The hardware component was composed of computer platform hardware and data transporting hardware. Prior to the late 1970's—early 1980's the hardware platform topic discussed at the undergraduate level was primarily large mainframe systems and some smaller minicomputer implementations. Those platforms ran very similar operating systems and were excessively complicated and would have been confusing to unusable by laymen. One needed to be a computer programmer just to navigate those systems. User interfacing was hardly an afterthought and system administration (both later pillars in what as to become IT education) was reserved for the white-coated geniuses in their almost priesthood roles in the datacenters of that time. Data transporting equipment consisted of hard-wired interconnects between computers within buildings or telephone modem usage over the public switched telephone network (PSTN). As such, data speeds were extremely slow although, in those days, it was magical to transfer data at 300 baud over a phone line. All that previous work was shielded from the public, rightly or wrongly. All this was, however, the spark that prepared the computing paradigm for what came next.

There were a few experimental serious hobbyist computers available in the late 1970's but these were not "personal computers" as we define them today. Some, like the Altair 8800 was strictly a hardware geek's toy, not usable for much of anything, and the Atari 2600 that was a gaming computer, not usable for applications commonly used today. The real revolution in computing came with the introduction of the Apple II and the IBM PC. The pioneers that gave these platforms to the world changed the focus of computing education in the late 1980's. Most layman computer users were serious hobbyists fairly knowledgeable of those operating systems and hardware and using the 300 baud telephone modem technology allowed them to communicate with other computers over the PSTN using bulletin board systems, mainly a file sharing paradigm. Computing degree programs were still concentrating upon programming, database, and primitive networking. Later in the 1980's the graphical user interface (GUI) again caused another revolution in computing, namely real systems with useful and usable applications used by non-hobbyist/geek people. Even though "killer apps" appeared that changed the way in which people worked in the office, most notably the spreadsheet and the word processor applications, people and their computers were not interconnected. That, of course, changed in 1992 when the precursor DARPA network became the open and very public Internet, and the operating systems of that period included network support through a network operating system (NOS) within the main OS. The whole world eventually became connected due to that innovation. Again, another revolution but this one was different and the world would never be the same. Virtually everyone in medium to advanced cultures is connected today with their portable devices including very young children, and third-world computing technology penetration is on the horizon today. Computing became ubiquitous and as common as a toaster.

Those three technical revolutions changed the computing landscape in unimaginable ways although the way in which the whole paradigm operates from a technical viewpoint has not. In fact, other than more computing horsepower (CPU cycles with massive amounts of memory), and speedier networks, not all that much has changed in fundamental computing since 1992 (with the exception of virtualization that is simply another software application). The basic applications (not the mini-apps that users get from an app store) have been fairly constant, a personal computer still functions in much the same way hardware-wise; basically computing is just becoming physically smaller with modern portable devices and connection speeds vastly faster and available everywhere from the user's perspective. In 1992, the RIT computer science department split into two units, one remaining as the traditional CS department and the other a new IT department with its faculty focusing upon all five pillars of the computing body of knowledge. An unfortunate outcome of this massive technological innovation was that those systems that started it all, namely mainframe architecture, became forgotten and completely buried by the hype and excitement of real *personal* computing. In hindsight the public could have been expected to forget the past as the vast majority of them would never have interacted with those large scale systems anyway. The tragedy, in this author's humble opinion, was that computing educators did the same thing by ignoring the past, assuming it had withered away, and concentrated only upon then current view of computing (PCs), and IBM did very little, if anything, to promote the mainframe paradigm to the masses. That was certainly the case at RIT by its IT and CS faculty.

No doubt, making all that a reality required tremendous work upon the engineers, programmers, system administrators, and other innovators across the computing topic spectrum, namely past and future graduates from computing programs (and, of course, some extremely talented non-degreed geniuses of their day like Jobs, Wozniak, Kildall, Gates, Allen, Cerf, and numerous others) but it is the responsibility of current educators to include large scale enterprise thinking and curricular material into the IT computing programs of today. That was not an easy task then and, in fact, was resisted by many traditional computing faculty members from the period between the late 1990's until roughly 2007. It was at that time that IBM came to the sickening conclusion, upon prodding by their large scale system clients, that the old guard of computing, those with the knowledge and experience from the 1960's and '70's were quitting and retiring. Since mainframe topics and the educational focus that might have accompanied them basically disappeared from the horizon, practically no one graduating from higher education possessed the skills necessary to carry on the "legacy" (in quotes as the paradigm lives on very successfully). This technology is far from dead and is present an almost all large scale datacenters worldwide today. As such, IBM began its Academic Initiative program, held conferences and visited select campus nationwide to plead with computing faculty to reintroduce large scale computing topics into program curricula such that, within a college generation or two (four to eight years) an adequate supply of computing graduates with mainframe and large scale experience would be able to supply an ever expanding need in the workforce. Coincidentally, the RIT faculty was beginning to realize a need for moving beyond the small office infrastructure into the much larger enterprise wide-area networking (WAN) space. The hosting of one of IBM's visits to RIT was the impetus needed by this author to begin the move to include mainframe (specifically) topics and other faculty to focus on enterprise systems moving forward.

2. THE FIRST IT PROGRAM

The first (nationally) B.S. degree program in Information Technology, launched in the fall of 1992 at RIT, recognized the need to cover topics in computing that were not simply programming and database related. Industry news during the previous year indicated that networking as we know it today was to become widely available within the following year on PCs. Later in the fall Microsoft released Windows for Workgroups (version 3.11) that provided the necessary software stack in the Windows OS to enable 10BASEx office networking. Shortly thereafter, the concept of the Worldwide Web, web browsing and an interconnected world became reality. RIT's IT program was poised for great success being available at just the right time. The paradigm was completely based upon IBM PCs (and their clones) and Apple Macintosh PCs operating in office environments. Banks and other businesses still used time-sharing systems being interconnected to their mainframes via PSTN connections. Inter-city links, what we now refer to as the WAN, were telephone company (TELCO) owned proprietary networks. There was no

Yahoo, Google or the like that required interconnected datacenters. Effectively there was no enterprise. Therefore the IT program covered computer programming (considered a foundational skill that every computing graduate required), database theory and constructs, the new LAN networking paradigm, the beginning of web based technologies, and finally the rudiments of human-computer interaction (HCI) knowing that a user-driven web experience, the website, would be rich in graphic content an needed to be well-thought about before deployment. Again, there was nothing in the program that related to anything enterprise as there was no enterprise thinking except for those hidden bank-like systems. Certainly, since the beginning of roughly 1983, the mainframe was considered a "dead" and forgotten technology. Everyone was enamored with PCs and the Internet and certainly mainframes had no place participating in that new paradigm.

Given that this early IT degree was of a generalist nature, the major-related curriculum was offered in two course sequences (not including the liberal arts, math, and science courses and the like), core and concentration.

The core consisted of three quarters (one academic year) of introductory programming (the language changed from time to time, starting with Visual basic, then C, C++, and finally Java), introduction to database technologies, introduction to web technologies, a general computing hardware course, two networking courses (introduction to networking and routing & switching), and an introductory course in OS scripting (the bash language). All students in the IT major were required to take this core curriculum.

The concentration areas, consisting of three to five courses each, were designed to give students a choice of deeper-thought topics in their chosen interest areas. The concentrations at that time were web, programming & database, infrastructure-focused networking that covered both the wired and wireless paradigms, and software-focused networking (not to be confused with the recent software-defined networking or SDN), namely systems administration. All the IT pedagogical pillars of knowledge were represented in the concentration choices. Students were also allowed to create their own concentrations by choosing a selection of courses from any/all of those curricular areas. That choice required departmental approval.

This IT degree program continued mostly unchanged, except for altering the curriculum as new advancements within the IT paradigm forced periodic review and subsequent modification of course material, for the remainder of the decade. The faculty of the department had the cumulative experience to teach the core and concentration courses and eventually grew to 50+ members. There was still no serious mention of enterprise topics.

3. THE IT DEPARTMENT SPINS OFF A NETWORKING DEGREE PROGRAM

By the early 2000's tension among the different pillar-focused faculty groups arose and, combined with more and rapid advances in new technology over the previous decade, the networking faculty pushed for an entirely separate networking-focused degree program apart from the larger IT degree program. This program was named Applied Networking and Systems Administration (ANSA). This program, in reality a reconfiguration of the networking portions of the IT program, eliminated all but the introductory database course, and the database, web, and programming concentration areas leaving two tracks for students to choose, as they were then labeled, networking (the infrastructure focus) and sysadmin (the software focus) areas. Students in this new program were clearly networking technology driven and, at that time, preparing themselves for very lucrative career paths as this paradigm was becoming key in the LAN, MAN, and WAN spaces as the world began to embrace planet-scale connectivity. For the first time, the idea of "the enterprise" began appearing in industry and scholarly publications everywhere.

The former IT program kept only the introductory hardware course and the introductory networking hardware course in its core. It no longer had networking or the sysadmin concentration areas, mainly a political consequence of ensuring adequate differentiation between the two programs.

The ANSA program, having thrived for roughly five years, was one of only a very few such programs nationwide, maybe a total of 10 or so. It was decided by the networking faculty at RIT and a few other universities that it was time to elevate the status of the practice of networking skills to a profession. The Accreditation Board of Engineering Technology (ABET) accreditation process was commenced and the ANSA program obtained official accreditation by that body. Having that recognition, as well as RIT's reputation for career-focused education, propelled the ANSA program to new heights for the next few years. The program reached its pinnacle adding roughly 80-100 incoming new freshman each year.

The faculty began discussions in two key areas at that time, security, and the idea of enterprise-scale computing. Security, in all its definitions, or the lack of it, was becoming increasingly a part of daily conversations among computing professionals. The IT department began hiring additional faculty with a security background to cover the knowledge gap among the existing teachers. At first, in its normal *keeping current* responsibility, the faculty added security topics within existing courses across the curriculum. A course called "enterprise provisioning" that had existed under different definitions of "enterprise" was modified to begin to focus on the more modern meaning of the word. It was mainly a focus on large scale Windows and Linux networks and the services need to administer them like DHCP, DNS, LDAP, and so on. It was not the enterprise we talk about today and the networking hardware focus was still the LAN within a corporate building.

In the mid to late 2000's another major shift in focus by the networking faculty occurred. The networking faculty group split off from the IT faculty and its department to form a new department, much the same way IT split from CS years earlier, named Networking, Security, and Systems Administration (NSSA) with its foci being those three areas in its title. The split gave the faculty a much greater sense of control over its curricula, and budgeting for larger scale laboratories and equipment improved as well. A graduate degree was established around the same time, focusing on scale, trying to get away from the undergraduate LAN perspective and concentrate on MAN and WAN technologies as well as the infrastructure and security topics related to larger scale systems and their maintenance and deployment. Over the last five years all of the department's curricular laboratory's spaces have been converted from the use of discreet computers are now running in a virtualized environment where the virtualization ratio varies between 5-10:1. This has resulted in less heat and energy consumed, table space required and most importantly it demonstrates to the students that we practice what we preach and they are working with a practical system that implements what they are learning.

The two degree programs flourished for a few more years with no more than basic updating and maintenance.

4. MAINFRAMES AND AN EPIPHANY

In 2007 this author attended a meeting at RIT, hosted by IBM, including a few representatives of IBM's major clients. Their mission was to make the CS, NSSA and IT faculty aware of the very real impending disaster that the retiring generation of people with mainframe experience was about to cause. The mainframe was forgotten, and virtually no university was teaching anything related to the topic. This author came away with a great sense of disbelief that the entire academic computing community had missed 40 years of continuous advancement in enterprise server technology. Whatever the causes were with regard to this massive oversight of technology in our back yard, it was plain that we needed to design courses into our curricula to mitigate that oversight and begin to produce graduates with enough enterprise knowledge to succeed in the world of real enterprise computing. One of this author's goals, in keeping with RIT's long history of career-based education was to expose the students to the varied job titles of mainframe system professionals and the lucrative careers they might enjoy.

The process began shortly after this author and others attended some IBM workshops to get the necessary background knowledge commensurate with what was thought would be enterprise curricular offerings in the networking programs. In some cases, where appropriate, only a few relevant lectures were added to an existing course that related enterprise topics as in a freshman-level core computer hardware course. From the introduction in that first core course that *every* IT and ANSA student must complete, the programs ensure that every graduate has at least working knowledge of the enterprise server space and the job opportunities that may be open to them. In that course, for example, a brief description of mainframe architecture was presented as another platform option to be considered in the hardware space. In other cases, both in the undergraduate and graduate degree programs, entire courses centered on enterprise storage, networking, DevOps, datacenter operations, virtualization, clouds and others were added, some as core and others as elective courses.

Just to keep the history accurate and complete, in 2010 for reasons beyond the scope of this paper, the NSSA department was merged back into the IT department (its name became the Information Sciences and Technologies [IST] department a few years earlier).

5. THE PROGRAMS TODAY

Both the undergraduate and graduate networking programs continue to do well in terms of attracting and graduating qualified students with enterprise scale capabilities. Another reexamination of the degree programs four years ago, due to a massive Institutional schedule realignment of moving to semesters from quarters (was in reality more of a trimester sequence), resulted in the addition of new material and course modification to maintain currency in the curricula and, in an unprecedented focus for the department, raise awareness of enterprise topics moving forward.

The ANSA program still retains the introductory hardware course where enterprise servers are introduced and described, along with the exposure job titles in that space. The computing core consists of the following complete courses (this is not a topic list):

Italicized courses have significant enterprise content.

See appendix 1 for program and course outlines.

Core courses include:

- Computational Problem Solving I & II (programming)
- Computer Systems Concepts (that intro hardware course)
- Intro to Routing & Switching (the LAN course)
- *Wireless Networking*
- *Configuration Management*
- *Sysadmin II*
- Database I
- *Network Services*
- *Virtualization*
- *Network Design & Performance*
- Project Management (undergrad version focused on PM terminology and the PMI PMBOK)

Elective courses include:

- *VoIP & Real Time Data*
- *VoIP & Unified Communications*
- *Mobile Ad-Hoc & Sensor Networks*
- *Storage Architectures*
- *Scalable Computing Architectures*

- *Data Center Operations*
- *System Design and Deployment*
- *Scalable Web Services Architectures*

The M.S. in NSSA underwent massive changes as well and the current representation of that program follows. It always had the focus of increased scale over the undergraduate program, but the change in focus to embrace what is now known as "enterprise computing" was massive.

Core courses:

- Scholarship in IST (a research methods course)
- *Enterprise Computing*
- *Emerging Computing and Network Technologies*
- *Advanced Large Scale Computing*

Elective courses:

- *Advanced Wired Networking Concepts*
- *Advanced Topics in Wireless Networks and Technologies*
- *Network Modeling and Analysis*
- *Design and Deployment of Wireless Networks*
- *Network Management*
- *Enterprise Service Provisioning (a complete rewrite)*
- *Advanced Storage Technologies*
- *Network Design and Performance (grad version)*
- *Enterprise Mobile Computing*
- Information Assurance Fundamentals
- Project Management (grad version focused on large scale systems)

6. CONCLUSION

The IT programs at RIT have evolved over the last 23 years always with the primary goal of currency in the paradigm. The faculty has done a remarkable job given the ever-changing environment in the computing fields. The one area where the faculty, and the faculty of almost every other major college or university, missed an entire technology was the enterprise paradigm, beginning with the mainframe space in the 1960's all the way to its integration into what now has become the field of enterprise scale computing. Worldwide interconnectedness due to the Internet and the ubiquitous nature of computing that mobile devices have spawned has led to the necessity of the large scale systems that support the always increasing appetite for the world's data needs. For sure, moving forward, the focus on the evolution in computing will keep all of us busy updating and maintaining quality higher education programs for the newest generations of computing professionals.

APPENDIX 1

Undergraduate program schedule
Graduate program schedule
Undergraduate course topic outlines
Graduate course topic outlines

Undergraduate Program Schedule

Term: Fall 1		Check course classification (s)			
Course Number & Title	CR	LAS	Maj	New	Prerequisite(s)
ISTE-120 Comp Problem Solving-Info Dom I	4	X			
NSSA-102 Comp System Concepts	3		X		
First Year Writing (WI)	3	X			
MATH-131 Discrete Math (P-7A)	4	X			
Liberal Arts and Sciences (P-1, Ethical)	3	X			
Year One	0				
Term credit total:	17	14	3		
Term: Fall 2		Check course classification (s)			
Course Number & Title	CR	LAS	Maj	New	Prerequisite(s)
NSSA-220 Task Automation w/Interp Lang	3		X		ISTE-121
ISTE-140 Web & Mobile I	3		X		
NSSA-241 Intro to Routing and Switching	3		X		NSSA-102
STAT-145 Introduction to Statistics I	3	X			
Liberal Arts and Sciences (P-2, Artistic)	3	X			
Wellness Activity	0				
Term credit total:	15	6	9		

Term: Spring 1		(Check course classification (s)			
Course Number & Title	CR	LAS	Maj	New	Prerequisite(s)
ISTE-121 Comp Problem Solving-Info Dom II	4	X			ISTE-120
ISTE-190 Found of Modern Info Processing	3	X			
COMM-203 Effective Technical Com	3	X			
MATH-161 Applied Calc (P-7B)	4	X			
Liberal Arts and Sciences (P-3, Global)	3	X			
Wellness Activity	0				
Term credit total:	17	17	0		
Term: Spring 2		(Check course classification (s)			
Course Number & Title	CR	LAS	Maj	New	Prerequisite(s)
NSSA-221 Sys Admin I	3		X		NSSA-220;NSSA-102;NSSA-241
ISTE-230 Intro to Database & Data Mod	3		X		ISTE-120
ISTE-240 Web & Mobile II	3		X		ISTE-120;ISTE-140
Liberal Arts and Sciences Elective (WI)	3	X			
Liberal Arts and Sciences (P-5, Natural Science Inquiry)	4	X			
ISTE-099 Second Year Seminar	0				
Term credit total:	16	7	9		

Coop 1 (After Sophomore year)

Term: Fall 3		Check course classification (s)			
Course Number & Title	CR	LAS	Maj	New	Prerequisite(s)
CIT Concentration Course 1	3		X		
Liberal Arts and Sciences (P-6, Scientific Princ)	4	X			

Term: Spring 3		Check course classification (s)			
Course Number & Title	CR	LAS	Maj	New	Prerequisite(s)
CIT Concentration Course 2	3		X		
CIT Concentration Course 3	3		X		

ISTE-260 Designing the User Exp	3		X		ISTE-140	ISTE-430 Info Requirements Modeling	3		X		ISTE-230
Liberal Arts and Sciences (P-4, Social)	3	X				Liberal Arts and Sciences (I-1)	3	X			
Free Elective 1	3					Free Elective 2	3				
Term credit total:	16	7	6			Term credit total:	15	3	9		
Coop 2 (Before Senior year)											
Term: Fall 4		Check course classification (s)				**Term: Spring 4**		Check course classification (s)			
Course Number & Title	CR	LAS	Maj	New	Prerequisite(s)	**Course Number & Title**	CR	LAS	Maj	New	Prerequisite(s)
ISTE-500 Senior Development Project I	3		X		Completion of 2 Coop	ISTE-501 Senior Development Project II (WI)	3		X		ISTE-500
CIT Concentration Course 4	3		X			CIT Concentration Course 6	3		X		
CIT Concentration Course 5	3		X			Liberal Arts and Sciences (I-3)	3	X			
Liberal Arts and Sciences (I-2)	3	X				Free Elective 4	3				
Free Elective 3	3					Free Elective 5	3				
Term credit total:	15	3	9			Term credit total:	15	3	6		

Program Totals:	**Credits: 126**	**Liberal Arts & Sciences: 60**	**Major: 51**	**Elective & Other: 15**

Cr: credits **LAS:** liberal arts & sciences **Maj:** major requirement **New:** new course

Networking and Communications (*245 Required, pick 2 of following 6)

NSSA 245 Network Services*

NSSA 242 Wireless Networking

NSSA 341 VoIP & Unified Comm I

NSSA 342 VoIP & Unified Comm II

NSSA 441 Advanced Routing and Switching

NSSA 443 Network Design and Performance

NSSA 445 Sensor & Ad-Hoc Networks

Enterprise Administration (*320 and 322 Required, pick one of following 4)

NSSA 320 Configuration Management*

NSSA 322 Systems Administration II*

NSSA 244 Virtualization

NSSA 422 Storage Architectures

NSSA 423 Scalable Computing Architectures

NSSA 425 Data Center Operations

Table 1b: Graduate Program Schedule

Thesis Option

Term: Fall One			
Course Number & Title	Credits	New	Prerequisite(s)
ISTE 605 Scholarship in Information Sciences and Technologies	3		None
NSSA-602 Enterprise Computing	3		None
NSSA 615 Advanced OOP for Networking and Systems Admin	3	X	I year OOP sequence
Term credit total:	-9		

Term: Spring One			
Course Number & Title	Credits	New	Prerequisite(s)
NSSA 620 Emerging Computing and Network Technologies	3		
Elective One	3		
Elective Two	3		
Term credit total:	9		

Term: Fall Two			
Course Number & Title	Credits	New	Prerequisite(s)
Elective Three	3		
NSSA-790 MS Thesis	3		
NSSA 714 Advanced Large Scale Computing	3		
Term credit total:	~~6~~ 9		

Term:			
Course Number & Title	Credits	New	Prerequisite(s)
NSSA-790 MS Thesis	3		
Term credit total:	3		

Program Totals:	**Credits:30**	**For Master's programs, identify the required comprehensive, culminating element(s) (e.g., thesis), including course number if applicable: NSSA-790 MS Thesis**

Project Option

Term: Fall One			
Course Number & Title	Credits	New	Prerequisite(s)
ISTE 605 Scholarship in Information Sciences and Technologies	3		
NSSA-602 Enterprise Computing	3		
NSSA 615 Advanced OOP for Networking and Systems Admin	3	X	I year OOP sequence
Term credit total:	-9		

Term: Spring One			
Course Number & Title	Credits	New	Prerequisite(s)
NSSA 620 Emerging Computing and Network Technologies	3		
Elective One	3		
Elective Two	3		
Term credit total:	9		

Term: Fall Two			
Course Number & Title	Credits	New	Prerequisite(s)
Elective Three	3		
Elective Four	3		
NSSA 714 Advanced Large Scale Computing	3		
Term credit total:	9		

Term:			
Course Number & Title	Credits	New	Prerequisite(s)
NSSA-791 NSSA Project	3		
Term credit total:	3		

Program Totals:	**Credits:30**	**For Master's programs, identify the required comprehensive, culminating element(s) (e.g., thesis), including course number if applicable: NSSA-791 NSSA Project**

UNDERGRADUATE COURSE TOPIC OUTLINES

Wireless Networking

.1	Wireless LAN basics and signals.
.2	Wireless LAN operation (messaging, CSMA/CD, etc)
.3	Wireless LAN design (needs analysis, cost v. benefit, etc)
.4	Wireless LAN layers 1 and 2, and competing standards
.5	Theory underpinnings (electricity, magnetism, RF communications)
.6	Modulation and carriers
.7	Decibels, gain and loss
.8	RF Signal impediments
.9	Signal to noise ratios and channel capacity
.10	Basic antenna theory and types
.11	Radio surveys

Configuration Management

6.1 System administration: an overview.

6.2 Perl Scripts for Navigating and Manipulating File Systems

- 6.2.1 File system attributes
- 6.2.2 File system walking
- 6.2.3 Testing file and directory attributes
- 6.2.4 Checking system integrity

6.3 Perl Support for User Administration

- 6.3.1 Account creation and administration
- 6.3.2 Scripts to aid in user administration
- 6.3.3 User monitoring

6.4 Accessing Name and Directory Services in Perl

- 6.4.1 Resolving names via DNS
- 6.4.2 Host files vs. DNS vs. NIS vs. WINS
- 6.4.3 LDAP access
- 6.4.4 Active Directory access

6.5 Creating and Analyzing Log Files in Perl

- 6.5.1 Text log files
- 6.5.2 Binary log files
- 6.5.3 Log file analysis

6.6 Perl Scripts for System and Network Monitoring

- 6.6.1 Noticing changes and suspicious activity
- 6.6.2 SNMP via Perl
- 6.6.3 Preventing suspicious activity

Sysadmin II

6.1.TCP/IP v4 and v6

6.2.IP Transport Layer Protocols

6.3.Service deployment strategies

6.4.Directory Services
6.5.Security and Authentication Services
6.6.Platform Interoperability Services
6.7.Mail Services
6.8.Web Server and Support Services
6.9.Configuration Services
6.10. UC Service gateways and alternative service platforms
6.11. Writing conventions specific to networking and systems administration

Network Services

- 6.1. IPv4 and IPv6
  - 1.1.1. Major changes – structure, operation, addressing
- 6.2. Transport Layer Protocols
  - 6.2.1. Overview of the TCP/IP Protocol Suite
  - 6.2.2. Specifics of UDP and TCP (v4)
  - 6.2.3. UDP and TCP operation (v6)
- 6.3. Dynamic Configuration (DHCP)
  - 6.3.1. Evolution of RARP, BootP and DHCP
  - 6.3.2. Configuration/installation of BootP/DHCP service
  - 6.3.3. Neighbor discovery and other essential ICMP services in IPv6
  - 6.3.4. DHCP v6
  - 6.3.5. IPv6 address allocation strategies
- 6.4. DNS
  - 6.4.1. History
  - 6.4.2. Servers
  - 6.4.3. Record types
  - 6.4.4. Configuration files
  - 6.4.5. Primary versus Secondary servers
  - 6.4.6. Subdomains
  - 6.4.7. Load Balancing
  - 6.4.8. DNS Security
  - 6.4.9. DNS for IPv6
- 6.5. SSH
  - 6.5.1. Overview of remote access
  - 6.5.2. Overview of SSH
  - 6.5.3. SSH configuration/installation implementation and administration
  - 6.5.4. Secure SSH
- 6.6. Kerberos
  - 6.6.1. Authentication
  - 6.6.2. Overview of Kerberos
  - 6.6.3. Kerberos configuration/installation and administration
  - 6.6.4. Trusts
- 6.7. Directory Services
  - 6.7.1. Authorization
  - 6.7.2. History
  - 6.7.3. LDAP
  - 6.7.4. Active Directory
  - 6.7.5. Directory Services Security

6.7.6. Impact of IPv6
6.8. Monitoring (IPv4 and IPv6)
6.8.1. Monitoring for Operations
6.8.2. Monitoring for Auditing
6.8.3. Monitoring protocols
6.8.4. Implementation, data, and costs

Virtualization

6.1) Traditional virtualized topologies: VLANs, trunks, VRF
6.2) Desktop virtualization: VMWare WKS, KVM, Virtualbox
6.3) Server virtualization and hypervisors: ESXi, Hyper-V, XEN
6.4) Storage: SSD, SCSI, network storage
6.5) Software Defined Networking
6.6) Cloud structures

Network Design & Performance

6.1 Introduction to OPNET
6.1.1 OPNET Startup and Tutorial Materials
6.1.2 OPNET Labs
6.2 Identifying Your Customer's Needs and Goals
6.2.1 Analyzing Business Goals and Constraints
6.2.2 Analyzing Technical Goals and Tradeoffs
6.2.3 Characterizing the Existing Internetwork
6.2.4 Characterizing Network Traffic
6.3 Project Management and Presentation Skills.
6.3.1 Managing Resources, Time, Money and Scope
6.3.2 Essential Presentation Skills
6.4 Logical Network Design
6.4.1 Designing a Network Topology
6.4.2 Designing Models for Addressing and Naming
6.4.3 Selecting Switching and Routing Protocols
6.4.4 Developing Network Security Strategies
6.4.5 Developing Network Management Strategies
6.5 Physical Network Design
6.5.1 Selecting Technologies and Devices for Campus Networks
6.5.2 Selecting Technologies and Devices for Enterprise Networks
6.6 Testing, Optimizing, and Documenting Your Network Design
6.6.1 Testing Your Network Design
6.6.2 Optimizing Your Network Design
6.6.3 Documenting Your Network Design

VoIP & Real Time Data

6.1 Basic traditional telephony system
6.11 PSTN, circuit switching
6.12 Plain Old Telephone System (POTS)
6.13 Cellular
6.14 Private Branch Exchange (PBX)
6.15 Signaling System 7 (SS7)

6.16 Signaling

6.2 Telecommunications wiring
  6.2.1 Local loop
  6.2.2 Punch-downs
  6.2.3 Basic wiring
  6.2.4 Electrical specifications and signals

6.3 Remote access technologies
  6.3.1 Dial up
  6.3.2 Cable
  6.3.3 Digital subscriber line (DSL)

6.4 Next generation telephony systems
  6.4.1 Mixing traffic types
  6.4.2 Quality
  6.4.3 Security
  6.4.4 Power
  6.4.5 E911
  6.4.6 Types of calls
  6.4.7 Gateways
  6.4.8 Applications and soft-phones
  6.4.9 Codecs
    6.4.9.1 G.711, G.723, G.726, G..728, G.729

6.5 Protocols
  6.5.1 Session Initiation Protocol (SIP)
  6.5.2 H.323
  6.5.3 Others: H.225, H.245, H.248, etc.

6.6 Current systems
  6.6.1 Skype
  6.6.2 Vonage
  6.6.3 MSN Messenger
  6.6.4 Call managers
  6.6.5 Contemporary IP based solutions such as Cisco and Avaya

6.7 Systems Integration
6.8 Migration strategies
6.9 Technologies required, hardware/software
6.10 Testing
6.11 Capacity planning
6.12 Basic Quality of Service
6.13 Basic security
6.14 Packet loss and delay/jitter
6.15 Systems knowledge required

VoIP & Unified Communications

6.1 History and Migration of Emerging Network Applications
  6.1.1 Introduction
  6.1.2 Concepts and Terminology

6.1.3 Drivers for Network convergence

6.2 Characteristics of the Internet

6.2.1 Architecture of the Internet

6.2.2 Internet Service Providers and the telephone network

6.2.3 Attributes of the Internet

6.2.4 Circuit vs. packet networks

6.2.5 Real time vs. non real time

6.3 Multimedia Communications

6.3.1 Operation and analysis

6.3.2 Voice and video standards

6.3.3 Voice and video coding

6.3.4 Multimedia communication protocols

6.3.5 Streaming applications

6.4 Emerging Network Applications

6.4.1 Internet protocol suite

6.4.2 Computer networks and Internet applications

6.4.3 Voice over IP and video conferencing

6.4.4 Differentiated Services

6.5 Issues with Internet Applications

6.5.1 Traffic models, performance criteria

6.5.2 Performance considerations and traffic engineering

6.5.3 Quality of Service (QoS)

6.5.4 Network management

6.5.5 Security

6.5.6 Designing, social issue

6.6 Deployments of Emerging Network Applications

6.6.1 Integration of VoIP and the public switch telephone network (PSTN)

6.6.2 Internet access networks

6.6.3 Last mile communication

6.6.4 Wired vs. wireless infrastructures

6.7 Unified Communications

6.8 Case studies

Mobile Ad-Hoc & Sensor Networks

6.1. Introduction of ad-hoc/sensor networks

6.1.1. Key definitions of ad-hoc/sensor networks

6.1.2. Advantages of ad-hoc/sensor networks

6.1.3. Unique constraints and challenges

6.1.4. Driving Applications

6.2. Wireless Communications/Radio Characteristics

6.3. Ad-Hoc wireless networks

6.4. Media Access Control (MAC) Protocols

6.4.1. Issues in designing MAC protocols

6.4.2. Classifications of MAC protocols

6.4.3. MAC protocols

6.5. Routing Protocols

6.5.1. Issues in designing routing protocols

6.5.2. Classification of routing protocols

6.5.3. Routing protocols

6.6. Networking Sensors

6.6.1. Unique features

6.6.2. Deployment of ad-hoc/sensor network

6.6.3. Sensor tasking and control

6.6.4. Transport layer and security protocols

6.7. Network Simulation Platforms and Tools

6.7.1. Modeling sensor networks

6.7.2. Modeling ad hoc networks

6.8. Applications of Ad-Hoc/Sensor Network and Future Directions.

6.8.1. Ultra wide band radio communication
6.8.2. Wireless fidelity systems

Storage Architectures

6.1 Storage Overview
- 6. 1.1 Enterprise storage requirements
- 6. 1.2 Shared storage
- 6. 1.3 Block transport
- 6. 1.4 File transport
- 6. 1.5 Direct attached storage (DAS)
- 6. 1.6 Network attached storage (NAS)
- 6. 1.7 Storage area networks (SAN)

6.2 I/O Techniques
- 6. 2.1 SCSI
- 6. 2.2 Fibre Channel SAN
- 6. 2.3 IP Storage
- 6. 2.4 Infiniband
- 6. 2.5 FCoE (Fibre Channel over Ethernet)

6.3 Redundant arrays of inexpensive disks (RAID)
- 6. 3.1 RAID-0 (striping)
- 6. 3.2 RAID-1 (mirroring)
- 6. 3.3 RAID-0+1 (mirrored stripes)
- 6. 3.4 RAID-10 (striped mirrors)
- 6. 3.5 Parity based RAID (3,4,and 5)

6.4 File systems and network attached storage
6.5 Storage virtualization
6.6 SAN implementation
- 6. 6.1 SAN components
- 6. 6.2 SAN topologies

6.7 Using SANs for high availability storage
- 6. 7.1 Level 1: path level redundancy
- 6. 7.2 Level 2: switch level redundancy
- 6. 7.3 Level 3: fabric level redundancy

6.8 IP based storage communications
- 6. 8.1 iSCSI
- 6. 8.2 Fibre channel over IP (FCIP)
- 6. 8.3 Internet fibre channel protocol (iFCP)

6.9 Application of storage networks
- 6. 9.1 Network back-up
- 6. 9.2 Archiving
- 6. 9.3 Business continuity

6.10 Management of storage networks
6.11 Removable media management
6.12 The Storage Networking Industry Association (SNIA) shared storage model

Scalable Computing Architectures

- 6.1 Enterprise environment overview
  - 6.1.1 Enterprise vs. SOHO environments
  - 6.1.2 Distributed vs. centralized computing models
  - 6.1.3 Cluster computing
  - 6.1.4 Server farms
  - 6.1.5 Mainframe systems
- 6.2 Enterprise system considerations
  - 6.2.1 Information systems in large organizations
  - 6.2.2 Data analysis and database design
  - 6.2.3 Multimedia design and support
  - 6.2.4 Data mining
  - 6.2.5 Middleware
  - 6.2.6 End user support
  - 6.2.7 Security
  - 6.2.8 Operating systems in the enterprise
  - 6.2.9 Programming languages in the enterprise
  - 6.2.10 Batch vs, real-time processing
  - 6.2.11 Job entry
  - 6.2.12 Data storage
  - 6.2.13 Backups
  - 6.2.14 Disaster recovery
- 6.3 Enterprise networking
  - 6.3.1 Multi-user support
  - 6.3.2 Remote user access
  - 6.3.3 End-to-end systems design
  - 6.3.4 Clustering
  - 6.3.5 Backend technologies
  - 6.3.6 System availability
  - 6.3.7 System design
- 6.4 Enterprise system administration
  - 6.4.1 System operation
  - 6.4.2 System programming
  - 6.4.3 Status monitoring applications
  - 6.4.4 System analysis
  - 6.4.5 Career options

Data Center Operations

- 6.1 Introduction to data centers,
- 6.2 The role of data centers in organizational computing strategies,
- 6.3 Physical facility design,
  - 6.3.1 Data center requirements,
  - 6.3.2 Alternative models,
  - 6.3.3 Green computing and facility design,
- 6.4 Application and data characteristics,
  - 6.4.1 Floating point operations,
  - 6.4.2 Transaction processing,
  - 6.4.3 Input/output requirements,
  - 6.4.4 Fault tolerance,

6.5 Network infrastructures,
6.6 Power distribution,
6.7 Heating, ventilation and air conditioning (HVAC),
6.8 Storage technologies,
    6.8.1 Storage area networks (SAN),
    6.8.2 Network attached storage (NAS),
    6.8.3 Direct attached storage (DAS),
6.9 Large scale computing architectures,
    6.9.1 Reliability, availability, and serviceability,
    6.9.2 High-availability computing,
    6.9.3 Clustering technologies
    6.9.4 Load balancing,
    6.9.5 Fault tolerance,
    6.9.6 Device naming practices and resolution techniques
6.10 Disaster recovery,
    6.10.1 Replication requirements,
    6.10.2 Rules and regulations,
6.11 Emerging datacenter technologies

System Design and Deployment

6.1 Data Gathering Methodologies
    6.1.1 Determining what information is needed
    6.1.2 Interviews
    6.1.3 Group techniques
    6.1.4 Observation techniques
    6.1.5 Participant Observations
    6.1.6 Surveys
    6.1.7 Tools for collecting performance and other technical data
6.2 Data Analysis
    6.2.1 Qualitative analysis
    6.2.2 Quantitative analysis
6.3 Solution Design
    6.3.1 Principles of solution design
6.4 Organization Structure and Culture
    6.4.1 Understanding the corporate culture
    6.4.2 How is culture communicated
    6.4.3 Selecting the best project management structure
6.5 Defining the Project
    6.5.1 Understanding the project life cycle
    6.5.2 Project scope
    6.5.3 Defining project priorities
6.6 Project Timing
    6.6.1 Methods for estimating times
    6.6.2 Constructing a time line
    6.6.3 Developing a project schedule
    6.6.4 Resource scheduling
    6.6.5 Controlling changes to the schedule
6.7 Project Cost Management
    6.7.1 Methods for estimating costs
    6.7.2 Developing a budget
    6.7.3 Tracking and managing costs
6.8 Project Communications and Leadership
    6.8.1 Developing a communications plan
    6.8.2 Information distribution

- 6.8.3 Presentation Design
- 6.8.4 Running effective meetings
- 6.8.5 Team development models
- 6.8.6 Conflict resolution

- 6.9 Risk Management
  - 6.9.1 Risk identification
  - 6.9.2 Risk assessment
  - 6.9.3 Risk response development
  - 6.9.4 Contingency planning
  - 6.9.5 Change control management
  - 6.9.6 Maintaining quality
- 6.10 Procurement management
  - 6.10.1 Procurement planning
  - 6.10.2 Solicitation planning
  - 6.10.3 Solicitation
  - 6.10.4 Source selection
  - 6.10.5 Contract administration
- 6.11 Executing the project
  - 6.11.1 Selecting the project leader
  - 6.11.2 Selecting the core team
  - 6.11.3 Deployment
- 6.12 Project Audit and Closure
  - 6.12.1 Project audits
  - 6.12.2 Project closure

Scalable Web Services Architectures

- 6.1. Workload characterization
- 6.2. Application elasticity
- 6.3. Service oriented architectures
- 6.4. SQL Database architectures
- 6.5. NoSql database architectures
- 6.6. High availability
- 6.7. Service level agreements
- 6.8. Load balancing
- 6.9. Multi-tiered architectures
- 6.10. Horizontal scaling
- 6.11. Vertical scaling
- 6.12. Disaster recovery
- 6.13. Risk management
- 6.14. Multi-availability zone architectures
- 6.15. Multi-cloud service provider architectures
- 6.16. Version control
- 6.17. Release management

GRADUATE COURSE TOPIC OUTLINES

Enterprise Computing

1. Enterprise environment overview

1.1. Distributed vs. centralized computing models

1.2. Public and private clouds
1.3. Cluster/grid computing
1.4. Server farms
1.5. Mainframe systems

2. Ethical Issues in an Enterprise Computing Environment
2.1. Ethics in the Context of Computing and the Information Age
2.2. Ethical Considerations for Systems Administrators
2.3. Ethical Considerations in Security
2.4. Ethical Considerations for Network Administrators
2.5. Ethics, Privacy and the Law

3. Enterprise system considerations
3.1. Information systems in large organizations
3.2. Capacity planning
3.3. Data analysis and database requirements
3.4. Multimedia requirements
3.5. Data mining
3.6. Middleware
3.7. End user support
3.8. Operating systems in the enterprise
3.9. Programming languages in the enterprise

4. Enterprise networking
4.1. Multi-user support
4.2. Remote user access
4.3. End-to-end systems design
4.4. Backend technologies
4.5. System availability

5. Enterprise storage architectures
5.1. Requirements of large scale storage
5.2. Federated data issues
5.3. SAN, NAS, technologies
5.4. Backend technologies
5.5. Storage system design

6. Enterprise security
6.1. Security planning
6.2. Documentation
6.3. Disaster recovery
6.4. Business continuity
6.5. Storage security
6.6. Network security
6.7. Policies

7. Enterprise system administration
7.1. System operation
7.2. System programming
7.3. Status monitoring applications
7.4. System analysis

Emerging Computing and Network Technologies

6.9 Limitations of current technologies
6.10 High Performance Transport Protocols
6.11 Multiplexing Methodologies
6.12 Optical Networking Technologies
6.13 Cluster, Cloud, and Grid Computing
6.14 Virtualization
6.15 Storage-Area-Networks Protocols
6.16 Mass Storage
6.17 Emerging Wireless Technologies
6.18 IPv6
6.19 Mobile IP
6.20 Encrypted Tunnel Technologies

6.21 Voice and Data Convergence
6.22 QoS
6.23 Ad Hoc Networks
6.24 Network Processors and applications
6.25 Active Networks
6.26 Green Networks
6.27 Emerging Technology Deployment Issues

Advanced Large Scale Computing

3. Enterprise-scale system considerations
4. Enterprise-scale business considerations
5. Data center, NOC, Switching center operations
6. Advanced large-scale networking
7. Advanced large-scale storage architectures
8. Enterprise and cloud security
9. Advanced large-scale system administration
10. Disaster recovery/business continuity
11. Enterprise migration planning

Advanced Wired Networking Concepts

8. Wired Networking Concepts
- **8.1.** Physical Layer – Approaches and Challenges
- **8.2.** MAC layer Solutions
- **8.3.** Routing layer and protocols
- **8.4.** Transport layer
- **8.5.** Multicasting
- **8.6.** Integration with wireless networks
- **8.7.** Security challenges
- **8.8.** QoS
- **8.9.** Traffic measurement

9. The Expanding Realm of Wired Technologies & Networks
- **9.1.** Peer to peer networks
- **9.2.** Future internet architecture
- **9.3.** Real-time Multimedia Applications
- **9.4.** Smart grid
- **9.5.** IPv4 and IPv6 integration and transition

10. Standards

Advanced Topics in Wireless Networks and Technologies

11. Wireless networks and challenges
- **11.1.** Physical Layer –topics will cover OFDM, WCDMA and UWB among others
- **11.2.** MAC Layer – Random access versus scheduled access, influence of multiple antennas and antenna arrays on MAC layer
- **11.3.** Routing Layer and upcoming protocols
- **11.4.** Transport Layer – Challenges of TCP in wireless
- **11.5.** Applications layer – challenges of multimedia support for users on the move
- **11.6.** Addressing the challenges through cross layered techniques
- **11.7.** Addressing the challenges through integration across layers.
- **11.8.** Network coding and channel coding

12. Case studies based on upcoming wireless technologies & networks
- **12.1.** Cellular, 4G, LTE
- **12.2.** WiFi, WiMAX
- **12.3.** Wireless Mesh networks
- **12.4.** Sensor networks
- **12.5.** MANETs
- **12.6.** Mobile Networks
- **12.7.** Personal Area Networks

13. Related Standards and their current status

Network Modeling and Analysis

14. Basic Mathematical Background
15. Modeling Complex Networks
16. Communities in complex networks and applications
17. Centrality of complex networks and its applications
18. Robustness of scale-free networks
19. Epidemic dynamics in complex networks
20. Techniques for Modeling
21. Network Modeling and Simulation
22. Network Modeling and SimulationTools

Design and Deployment of Wireless Networks

7. 802.11n
    1. Operation
    2. Protocol structure
    3. Architecture
8. Wireless ISP
9. Cellular
    1. 3G/4G
    2. CDMA
    3. GSM
10. Wireless Local Loop
11. Wimax
    1. Operation
    2. Protocol structure
    3. Architecture
12. Mobile IP
    1. Usage
    2. Need
13. Wireless Routing

Network Management

23. Introduction to Network Management Concepts
    - **23.1.** Strategic importance of communication networks and its management
    - **23.2.** Importance of Network Management
    - **23.3.** Complexity of Network Management
    - **23.4.** Critical Success factors for Network Management
    - **23.5.** Network Management Processes and Procedures – configuration management, accounting management, security management, performance management and fault management
    - **23.6.** Two aspects of Management – monitoring and control
    - **23.7.** Static and dynamic information
    - **23.8.** Manager / Agent Model
    - **23.9.** Polling and Event Reporting
24. Network Management Architectures
    - **24.1.** OSI NM model
    - **24.2.** IEEE NM Model
    - **24.3.** Internet NM Model – SNMP, CMIP
    - **24.4.** Categorization of NM models based on architecture
    - **24.5.** Web based management
25. Fundamentals of SNMP
    - **25.1.** Simple Network Management Protocol
    - **25.2.** Structure of Management Information
    - **25.3.** Management Information Base – static and dynamic
    - **25.4.** Management sub trees

- **25.5.** Management Objects
- **25.6.** Working of SNMP
- **25.7.** Community
- **25.8.** Access Policy

26. SNMP versions
- **26.1.** SNMP version 1
- **26.2.** SNMP version II
- **26.3.** SNMP version III

27. Configuration Management
28. Performance Management
29. Fault Management
30. Accounting Management
31. Remote Monitoring

Enterprise Service Provisioning (a complete rewrite)

32. Service provisioning architectures
- **32.1.** Traditional model
- **32.2.** Virtual services
- **32.3.** Cluster deployment
- **32.4.** Experimental options

33. The traditional model
- **33.1.** Traditional service deployment technologies
- **33.2.** Process model
- **33.3.** Architecture issues
- **33.4.** Programming concepts
- **33.5.** Finance and economics
- **33.6.** Deployment issues

34. Virtual services
- **34.1.** Virtualization technologies
- **34.2.** Process model
- **34.3.** Architecture issues
- **34.4.** Programming concepts
- **34.5.** Finance and economics
- **34.6.** Deployment issues

35. Cluster deployment
- **35.1.** Cluster technologies
- **35.2.** Process model
- **35.3.** Architecture issues
- **35.4.** Programming concepts
- **35.5.** Finance and economics
- **35.6.** Deployment issues

36. Recent advances and current research

Advanced Storage Technologies

1. Components, structure and protocols of storage systems
2. Disk arrays, mirroring and RAID
3. File system structures and organization
4. Distributed file systems and NAS
5. Storage networking (including SAN)
6. Data protection and disaster recovery
7. Longevity and morbidity
8. Storage security

9. Performance
10. Interoperability
11. Storage Virtualization

Network Design and Performance (grad version)

12. Identifying business goals and constraints
    1. Scope of project
    2. Impact of applications
    3. Company politics
    4. Budgetary constraints
13. Analyzing technical goals and constraints
    1. Scalability
    2. Availability
    3. Performance
    4. Manageability
    5. Usability
    6. Affordability
14. Network Component review
    - 14.1. Structured Cabling Standards
    - 14.2. Media types
    - 14.3. Wireless Networking and Internetworking Devices
15. Analyzing the existing network
    1. Infrastructure
    2. Health of existing network
16. Analyzing existing network traffic
    1. Traffic flow
    2. Traffic load
    3. Traffic behavior
    4. Quality of Service issues
17. Designing a network topology
    1. Flat design
    2. Mesh Design
    3. Hierarchical design
    4. Redundancy
    5. Campus design
    6. Enterprise design
18. Designing addressing scheme
    1. Hierarchical addressing
    2. Route summarization
19. Selecting appropriate network devices and protocols
    1. Bridging and switching methods
    2. Routing protocols
20. Developing network security strategies
    1. Security design
    2. Security mechanisms
21. Designing campus networks
    1. Cabling
    2. Devices
22. Designing enterprise networks
    1. Remote access
    2. WAN technologies
23. Testing, optimizing, and documenting networks
    1. Prototype design
    2. Tools for testing

Enterprise Mobile Computing

37. What is Enterprise Mobile Computing?

38. Enterprise Mobile Computing Architecture
39. Mobile Computing Through Telephony
40. Emerging Technologies (Bluetooth, WiMax, Mobile IP, IPv6)
41. General Packet Radio Service (GPRS)
42. OS for wireless device.
43. Wireless Devices with Windows CE
44. Mobility in Wireless LANs
45. Mobile Ad Hoc Networks
46. Sensor Networks.
47. Security Issues in Mobile Computing