UNIVERSITY OF OSLO
Department of informatics

A Network and System Administration Master's Degree Curriculum and Resource Plan for Pakistan

Athar Kaleem

Network and System Administration

Oslo and Akershus University
College of Applied Sciences

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Acknowledgments

- I would like to express my special thanks to everyone who matters in my life in showing me this day when I am capable of writing a Master degree thesis from one of the well reputed universities in the world i-e University of Oslo.

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Abstract

This thesis describes a program of study for a master's degree in network and system administration in Pakistan. It describes the course sequence and the individual courses that will be taught. It also discusses the facilities and computing resources required. It proposes a lab environment based on the Raspberry Pi device and Xen-based virtualization for student work, using the MLN tool for management. Some usability tests for the suggested lab environment were performed and indicated that it would be suitable.

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Chapter 1

Introduction and problem statement

Formal studies of computer networks and system administration are urgently needed today because the infrastructure of computing resources is growing rapidly, resulting in increasing complexity of management. For this reason, many developed countries have already initiated programs of study where many talented students graduate every year to provide the technical workers need in that country. There is a great need for such modern programs of study in Pakistan as well, but there are not currently any available. This thesis focuses on initiating such a program of study in Pakistan.

1.1 INTRODUCTION AND MOTIVATION

Computer networks and systems offering different services are getting more and more congested as the infrastructure expands over the time within organizations. There is a need felt amongst the developed countries to regularize a scheme of study that will satisfy the challenges in the future related to Network and System Administration. Therefore a systematic approach has been adopted to fulfill this need by educational institutes in many countries, including the USA, Norway, Australia and the Netherlands. There is a need to develop such educational programs in Pakistan as well.

1.1.1 EDUCATIONAL EXPERIENCE AND INTERESTS

I will begin with a summary of my own educational background. I completed my undergraduate studies in computer science in Pakistan. These gave me a good sense of the general level of computer education in Pakistan. I discovered I have a natural aptitude for networks and system administration during my undergraduate studies. My interest in networks leaded me to write an undergraduate diploma thesis about the OSPF routing protocol.

I studied at a private institute named Corvit Systems, situated in Lahore, Pakistan. Corvit Systems is known as one of the best institutes in Pakistan regarding network and system administration studies. It charges very high tuition fees. I learned many skills there and had a feeling that I knew enough to work as professional.

Eventually, I travelled to Norway. There, I availed myself of the opportunity to study at Oslo University/Oslo and Akershus University College of Applied Sciences (OAUC) in the network and system administration master's degree program. I quickly found that the level of technical instruction was much higher in Norway than I had seen in Pakistan. The program at OAUC is also much more systematic and comprehensive than the existing programs in Pakistan. In fact, unfortunately, there is no institution in Pakistan where one can learn technical skills in such a comprehensive way as I learned being a student at OAUC.

In Pakistan, there are different private institutes offering some certification programs regarding Network and System Administration but the density of the courses taught and the lab environment given to students does not meet the systematic approach to cover this program of study. This master thesis will focus developing such a systematic approach to introduce the said scheme of study in Pakistan and will provide as complete a plan for implementing it as possible. All the required tools, technologies, configuration, management of resources and course structure will be discussed in detail.

Teaching is another natural aptitude that I inherited from my father and grandfather. I started teaching during undergraduate studies in one of the schools under the ownership of my father. After undergraduate studies, I taught in the Government College in Abbottabad, Pakistan. I also had an opportunity to work as a student assistant for the first year master's degree students in system security course at OAUC. I hope to use this ability in a network and system administration course in Pakistan.

1.1.2 TECHNICAL EDUCATION IN PAKISTAN

Educational institutes in Pakistan fail to produce good quality professionals in the field of network and system administration. The main problem for institutes in Pakistan is a lack of technical people who can manage such programs of studies. There are already well reputed universities and colleges exist in Pakistan where international students from neighboring countries also come for their higher education. There is lot of development seen in the field of IT and many

educational institute offers high quality of education in the field of computer science.

However, there is no formal education in Network and System Administration for local or international students. Although there are highly educated people from well reputed institutes in the world in many fields, there are very few specifically in network and system administration because such schemes of study are too young in the world. Currently students from different educational institutes complete their programs with quite minimum level of skills and professionalism. Thus, Pakistan lacks people who can manage and implement study programs to produce good quality network and system administrators.

If we observe the relevant job market, we will come to know that many companies acquire IT professional services from foreign companies, costing huge amounts of money, because Pakistan lacks technical people. There is need for an educational team aware of and interested in network and system administration. They need proper training, education, skills and vision to initiate master level studies in network and system administration.

1.1.3 GOING ABROAD IS NOT ALWAYS POSSIBLE

Because there is little scholarship support or other financial aid for students from the government in Pakistan, it is not possible for everyone to travel abroad to existing programs in network and system administration. While financial problems are the main reason why many students cannot study abroad in existing programs, there are number of other obstacles as well. There are strict admission processes abroad in well reputed universities in admitting students; thus, many students also fail to gain a seat in a degree program. Obtaining a visa for nationals of developing countries is also quite challenging, and everyone doesn't succeed.

Some students manage to get a visa, and they travel for studies as self-financed students with the intention of managing their expenses with part time jobs. This can result in frustration if part time work is not available. Working can also be an obstruction to succeeding at their studies if one cannot give the necessary time to studies as it deserves. Thus, many international students face significant problems in studying abroad.

Considerations like these have motivated me to create a network and system administration program in Pakistan to serve local students, as well as ones from nearby countries, and to prepare them to be the high quality computer professionals that industry needs.

1.2 PROBLEM STATEMENT

How can a program of study for Network and System Administration be created and implemented in Pakistan? This thesis will consider these questions:

- What is course structure for the said studies?
- How can a lab environment be set up given the technical capabilities and challenges of Pakistan? What tools and technologies are appropriate? What software and hardware can be used? Are low cost hardware solutions adequate to this task?
- What are the other requirements for such a program, including facilities and cost?

I have had a good experience while studying in the master's degree program in Network and System Administration at University of Oslo/OAUC. Using this experience, I will focus on importance of such studies in Pakistan, which is geographically situated in the heart of many developing countries in south Asia, the Middle East and central Asia.

I will examine the Raspberry Pi as a potential component of the program. It is a relatively new, low cost hardware solution which may greatly reduce the startup cost required for such a program of study.

Chapter 2

Background

This chapter discusses several topics which are important background information for this thesis.

- It is important to understand the technical infrastructure of the private and government sectors in Pakistan, as well as available human resources to manage that infrastructure.
- There are different countries offering Network and System Administration degree courses in various parts of the world. Those existing post-graduate programs in Network and System Administration are important to bring into focus while suggesting a similar type of studies in Pakistan. The admission requirements, courses, degree requirements and study duration are important aspects to consider for this thesis.
- Virtualization will be an important technique for network and system administration. Thus, it is important to have a glance over virtualization and education in Pakistan. What are the techniques, technologies and tools to manage virtualization for study purposes? This thesis will focus on a software tool known as MLN. There are other ways to create virtual machines but this tool makes it quite easy and fast to create virtual machines and manage them.
- The Raspberry Pi is a new small credit card size computer developed in the UK by the Raspberry Pi Foundation. It runs the Arch Linux and Debian Linux operating system distributions. It is designed to be capable of performing different tasks for education purpose with minimum cost.

2.1 NEED FOR NSA PROFESSIONALS IN PAKISTAN

In Pakistan's major cities, there is good job market for Network and System Administration professionals. There is such a shortage of properly trained people that private companies often have to hire people without proper skills and then train them according to their needs. In another common scenario, companies

purchase services from international companies as the quality of services within the country offered are quite a bit below the high standards around the world.

For example, a well-known media company, the Jang group, contracted for IT services from the international company ZEN Network Technologies, Ltd. (9 Devonshire Square, London EC2M 4YF United Kingdom). When one of its servers is probed on port 80, it shows that the company does not have its own infrastructure to meet its service requirements. Below is traffic information captured using tcpdump when port 80 is contacted with multiple requests using a Perl script.

```
1       06:44:40.123346 IP 192.168.1.2.34045 > 194-28-157-30.zen
        protection.com.http:Flags [.], ack 105997, win 9659, length 0
2       06:44:40.128644 IP 194-28-157-30.zenprotection.com.http >
        192.168.1.2.34045:Flags [.], seq 105997:107449, ack 117, win
        46, length 1452
3       06:44:40.128753 IP 192.168.1.2.34045 > 194-28-157-30.zen
        protection.com.http:Flags [.], ack 107449, win 10024, length 0
4       06:44:40.133827 IP 194-28-157-30.zenprotection.com.http >
        192.168.1.2.34045:Flags [.], seq 107449:108901, ack 117, win
        46, length 1452
5       06:44:40.133950 IP 192.168.1.2.34045 > 194-28-157-30.zen
        protection.com.http:Flags [.], ack 108901, win 10389, length 0
```

There are other multinational companies seeking significant numbers of skilled professionals throughout the year. Even educational institutes lack highly skilled professionals who can manage their own network infrastructures.

2.2 TECHNICAL EDUCATION IN PAKISTAN

Technical education, by its nature, has to be significant to other sectors of society in order to educate and train the technical human resources needed for socio-economic development. Nowadays, society is rapidly changing, and it is essential for technical education to strength its linkage with the changing requirements of the work place.

Being a part of educational system and a citizen of Pakistan, I have undertaken computer studies in a well reputed institute whose program is quite similar to many other institutes. I also visited and surveyed three different educational institutes in the well-developed city of Abbottabad: Government Post Graduate College (Mandian, Abbottabad), COMSATs Institute of Information Technology (Abbottabad) and Hazara University (Abbottabad). In all of these institutions, there are few computing resources allocated for the students. There are systems which handle student's accounts and credentials, but

there are very few or no computers which give opportunities to students to use them so that they can learn by performing lab tasks so that they can get a feel for real scenarios.

Most of the schools, colleges and universities in Pakistan have not yet transferred from the traditional use of paper to digital world of computing. There are a few trained technical people, but their number is negligible compared to the needs of the expanding technical infrastructure of Pakistan. Most technical people are hired by private or foreign companies as they are not employed within country's public sector because of incompetence in government. Therefore it is felt the need of proper human and educational resources so that Pakistan can build its technical infrastructure in its true essence.

The main reason for this shortage is that advanced education in network and system administration are unavailable in the country's educational institutes. There is no research and development program for such studies. Students interested in network and system administration studies cannot receive instruction as there are not skilled people who can arrange proper infrastructure for them. For example, COMSATs Institute of Information Technology, which resembles other institutes in the country, lacks the proper infrastructure for master's degree level studies. Students are given negligible resources compared to what they need.

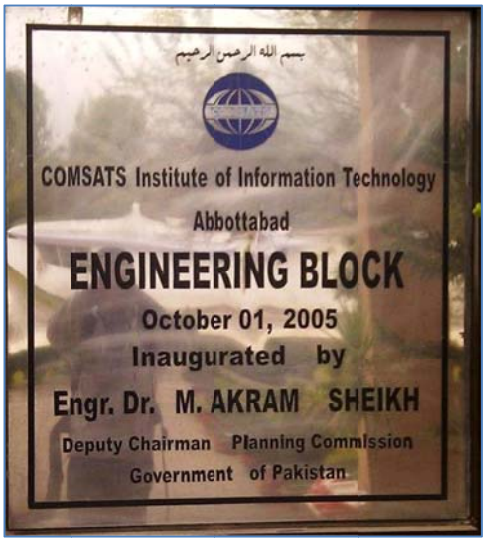

Figure 2.1. COMSATS Institute of Information Technology (Abbottabad)

Figure 2.2 shows the R&D (Research and Development) Lab, which is the only place where master's degree students have opportunity to do research and development in the field of IT. The lab is comprised of fewer than 10 P4-based computers running Windows XP installed. The only allowed connection is on port 80.

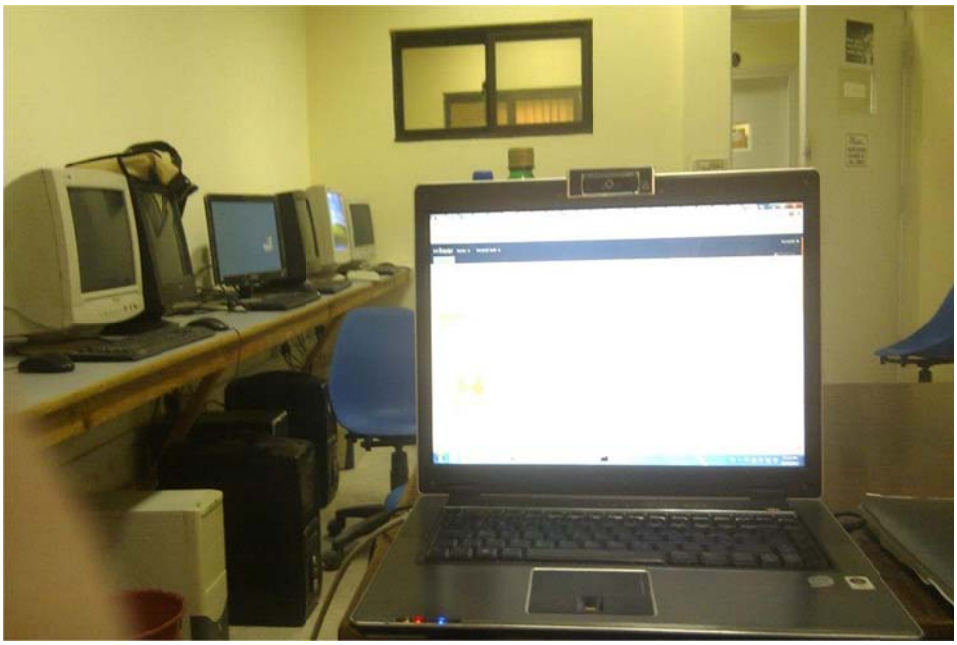

Figure 2.2. R&D Lab at COMSATS Institute of Information Technology (Abbottabad)

There are many IT and computer studies institutes in the country, but none of them offer post-graduate study in Network and System Administration. There is one college found, Pakistan Navy Engineering College, which offers some network and system administration diploma courses, but these are very limited and only at introductory level. They also do not use any open source tools and technologies. Figure 2.3 shows the course contents offered at this institute in Pakistan.

There are other private institutes offering similar courses, but they again are without deep knowledge or quality of studies. Many institutes also have vested interests with companies like Microsoft and Cisco. They only offer courses which in reality have nothing to do with becoming highly skilled in the field of network and system administration. Their main focus is to introduce some of the company's proprietary tools and enable the students to pass their certification examinations, by any means available. For example, CCNA, CCNP and MCSE

related-courses are taught at introductory level, and later on students are given dumps of previous exams to pass the exams by mean of cheating [2]. This is why Pakistan has produced the youngest Microsoft certified professional, a 9-year old named girl Arfa Karim [3].

Figure 2.3. Courses offered at one of the institutes in Pakistan

It is quite clear from the above information that Pakistan lacks the skilled people and systematic studies required to excel in the field of IT. Pakistan needs good quality of network and system administration professionals to meet its need in the coming future according to the adopted standards of the developed countries [1].

2.2.1 CURRENT GRADUATE PROGRAMS IN COMPUTER SCIENCE IN PAKISTAN

The Higher Education Commission (HEC) of Pakistan ranks universities by field. The ranking is based on many factors, including the number of students, research productivity and quality, innovation and knowledge transfer, infrastructure, and others [4]. The following were the top 5 computer studies institutes in Pakistan that offered master's degrees in computer science and computer science courses as part of master's degrees in related disciplines.

- COMSAT Institute of Information Technology, Islamabad
    - Master of Science in Computer Science
    - Master of Science in Health Informatics
    - Master of Science in Electrical Engineering
    - Master of Science in Mathematics
- National University of Computer and Emerging Sciences, Islamabad
    - MS Computer Science
    - MS Computer Networks
    - MS Mathematical Sciences
    - MS Electrical Engineering
- Qurtaba University of Science and Information Technology, D I Khan
    - MS Computer Science
    - MS Mathematical Sciences
- Quaid-i-Azam University, Islamabad
    - MPhil Computer Science Program
    - MS Information Science and Technology
    - M.Sc. Computer Science Program
- City University, Peshawar
    - MS Computer Science

Master's degree computer sciences courses taught in the top five universities of Pakistan are listed below organized into general categories.

Programming: programming languages are mainly C, C++, C# and .NET.

- Problem solving and Programming
- Object Oriented Programming
- Comparative Study of Programming Languages
- Theory of Programming
- Theory of Programming Languages
- Design and Analysis of Programming languages

Software engineering: generally taught from an abstract point of view, separate from actual programming.

- Rapid Application Development
- Introduction to Software Engineering
- Software Engineering
- Software Testing Techniques
- Emerging Trends in Software Development
- Software Entrepreneurship
- Software Project Management
- Advanced Software Engineering
- Software Quality Assurance and Testing
- Disciplined Software Processes
- Knowledge Management for Software Engineering
- Software Management & Economics
- Software Architectures
- Software Patterns

Databases and data management: the former is mostly focused on relational databases and SQL.

- Database Design
- Information Retrieval Systems
- Data Mining
- Data Warehousing

Architecture, algorithms and related topics: also typically taught as lecture only, without any practical applications.

- Computer Systems
- Computer Architecture
- Data Structures and Algorithms
- Introduction to Computing Theory
- Operating Systems
- Analysis and Design of Algorithms
- Compiling Techniques
- Advanced Analysis of Algorithms

- Advanced Operating Systems
- Theory of Computation
- Advanced Computer Architecture

Human-Computer interaction: theories of usability, benefits of computing to humans, computing uses in various environments.

- Human Aspects of Computing
- Human Computer Interaction
- Advanced Human-Computer Interaction
- HCI Models and Theories
- Design for Usability

A**rtificial Intelligence and related topics**

- Artificial Intelligence
- Expert Systems
- Neural Networks
- Machine Learning
- Pattern Recognition

Information theory

- Theory of Automata
- Discrete System Simulation
- Information Theory
- Information Systems

Multimedia and web computing

- Computer Graphics
- Multimedia Applications and Design
- Electronic Documents
- Web Technologies
- Web Engineering
- Introduction to Semantic Web
- Multimedia Technology
- World Wide Web and Society
- Semantic Web
- Digital Libraries
- Modeling of Web Information Systems
- Multimedia Retrieval Techniques
- Metadata for Information Resources
- Information Privacy and Access Control
- Multimedia Communications

Information Technology and enterprise computing

- Computer Communications and Networks
- Enterprise Information Infrastructure
- Social Issues in Information Technology
- Computing Case Studies
- Requirements Engineering
- Distributed Systems
- Enterprise Architecture

Miscellaneous courses

- Mobile Computing Systems
- Real Time Systems
- Concurrent Programming
- Research Methods
- Data Compression
- Grid Computing
- Peer-To-Peer Systems
- Ubiquitous Information Interaction

If we go through the courses taught in universities of Pakistan then we will come to know that there are no formal studies in the field of networks and system administration. We also notice that there is very little emphasis on networking and only limited offerings in enterprise computing and infrastructure management.

2.2.2 POTENTIAL STUDENTS FOR NSA GRADUATE STUDY IN PAKISTAN

The number of undergraduate college students in Pakistan in not an easy statistic to access, but it is estimated to be over 1,000,000 including both academic institutions and professional schools [5]. So a mere lack of potential students is not a problem in initiating a network and system administration master program. But what sort of students is suited to these studies?

Network and system administration studies require a good understanding of computer science. A student with a baccalaureate (or equivalent) degree from an accredited institution in computer science, IT, computer engineering or electronics engineering has good potential to succeed with this degree. There will be need of hard work and a good understanding of basics of networks and system administration. Therefore, it is important to evaluate students by use of different means to determine whether he/she can carry on with such studies. Previous educational records give quite good information to evaluate the

student's caliber, and he/she should have a minimum cumulative grade point average of 3.0 or 70%. Students wishing to study NSA program must have a good educational or working record in networking and in systems administration. If a student does not have the necessary background, extra courses will be required to help students to meet the prerequisites.

2.3 EXISTING NSA POST-GRADUATE PROGRAMS

It is always good to analyze the experience of others while initiating a new thing. As mentioned earlier, NSA studies are already taught in numbers of institutes and universities worldwide. Therefore, it is important to know how they recruit new students, what criteria they use in the admission process, how the curriculum is structured and how long it takes to complete the degree program. In this way, one can sort out the overall program structure. This section summarizes the different NSA programs now available.

Previous surveys such as this were performed in 2007 by Burgess and Koymans [6] and by Kacoroski and Tsalolikhin in 2012 [7]. The first work described the programs then in place at the University of Oslo/Oslo University College and the University of Amsterdam. Both of these programs are included in the list in this thesis.

Kacoroksi and Tsalolikhin identified 7 universities offering programs in network and system administration. Of these, 2 were master's degree programs: University of Oslo/Oslo and Akershus University College of Applied Sciences and Florida State University.

At this time, the following universities offer post-graduate programs in network and system administration:

- Florida State University (USA)
- University of Oslo/Oslo and Akershus University College of Applied Sciences (Norway)
- University of Amsterdam (The Netherlands)
- Rochester Institute of Technology (USA)
- Charles Sturt University (Australia)

2.3.1 FLORIDA STATE UNIVERSITY (USA)

Florida State University is located in Talahassee, Florida, USA. It offers an MS degree in Computer Network and System Administration (CSNA) [8]. It focuses

on practical system administration. For example, this degree program requires system administration experience to complete it. The university provides assistance for students in getting an internship.

Admission requirements: Undergraduate degree with GPA 3.0 or better, GRE score of at least 1000 (verbal+quantitative), system administration internship(s)

Prerequisites: Undergraduate courses required (can be completed during the master's degree program in some cases, but not for credit):

- Computer Organization I
- Computer Organization II
- Data Structures, Algorithms and Generic Programming
- Operating Systems and Concurrent Programming

Courses required for MS CNSA Degree Program:

- Computer Architecture
- Network Security, Active and Passive Defenses
- Data and Computer Communications
- Computer and Network Administration
- Advanced Operating Systems
- Concurrent, Parallel, and Distributed Programming
- 6 more courses

Additional requirements: Students have a choice of a thesis (equivalent to 3 courses), a project (equivalent to 2 courses) or a courses-only track. An internship or other experience is also required.

Program length: 12 courses over 2 years

2.3.2 UNIVERSITY OF OSLO/OAUC (NORWAY)

The University of Oslo collaborates with Oslo and Akershus University College of Applied Sciences to teach the Master's in Network and System Administration degree program in Oslo, Norway. Most of the courses are designed and taught by OAUC. I have been a student in the said degree program. This program gives a deep vision of theory, principles and practical issues related to network and system administration. This program focuses on network, system design, analysis, efficiency and security. Most of the course is based on practical skills in UNIX platforms along with the taste of windows and Macintosh platforms. Most of the tasks are practical lab work where students perform in their projects. The degree program consist of such courses which are current trends in the IT industry such

as general system administration, networking, security, information infrastructure and analytical methods to solve problems related to network and system administration.

Admission requirements: Undergraduate degree with at least a C average.

Prerequisites: Degree in Informatics or 80 ECTs in Informatics including Operating Systems, 20 ECTs in programming and 10 ECTs in Mathematics

Courses required for the Master's degree in NSA:

Year	Semester 1	Semester 2
1	Intrusion detection and firewalls Networking technologies and principles Network and system admin. 1	Network and system admin. 2 Research paper Cyberethics Elective
2	Analytic system administration and project methodology Network infrastructure and security lab Elective	Thesis

Program Length: 2 years

2.3.3 UNIVERSITY OF AMSTERDAM (THE NETHERLANDS)

The master's degree program in network and system administration at the University of Amsterdam in Amsterdam, The Netherlands has two separate tracks: networking and forensics [10]. Both are full time studies comprised of one year and part time studies comprised of two years. The academic year has two semesters, each composed of three 4-week blocks.

The program's website states the following objectives for the program:

> To train system and network engineers that are: at an abstract level knowledge of the operation of computer systems and networks in terms of interfaces and protocols; capable of translating that abstract level into concrete systems and network configurations, regardless of the vendor of the underlying systems; capable of obtaining new knowledge about innovations and their potential; able to integrate new technology in an evolutionary manner to an existing situation; able to integrate new technology in an evolutionary manner to an

> existing situation; familiar with the ideas of the Open Source movement and can distinguish between advantages and disadvantages compared to proprietary technology; and able to identify security aspects of systems and networks and if necessary adapt them [10].

Admission requirements/Prerequisites: Undergraduate degree in computer science or a degree in informatics or a related field and passing an assessment on general knowledge (mathematics, reading, writing and presentation) and on basic knowledge of Linux/UNIX, networking and shell scripting.

Courses required for the Master's degree in NSA, Networking track:

Block	**Semester 1**	**Semester 2**
A	Classical Internet Applications Essential Skills	InterNetworking and Routing Large Installation Administration
B	Distributed Internet Applications Security of Systems and Networks	Offensive Technologies Advanced Networking
C	Research Project 1	Networking Research Project 2

Courses required for the Master's degree in NSA, Forensics track:

Block	**Semester 1**	**Semester 2**
A	Classical Internet Applications Essential Skills	Cybercrime and Forensics Large Installation Administration
B	Distributed Internet Applications Security of Systems and Networks	Offensive Technologies Visual Analytics
C	Research Project 1	Forensics Research Project 2

Additional requirements: 2 projects including a report and presentation.

Program Length: 1 year

2.3.4 ROCHESTER INSTITUTE OF TECHNOLOGY (USA)

Rochester Institute of Technology is located in Rochester, NY (USA). This program states that its goal is to "make students capable of availing such technical skill which makes them leaders in a modern IT industry. The main focus of this degree program is to give students technical knowledge and concepts that any business required while implementing solutions to help that business" [11]. This program is available both on-campus and as distance learning.

Admission requirements: Undergraduate degree with at least a 3.0 (B) average.

Prerequisites: C++ computer programming, networking and system administration theory and practice, and statistics.

Courses required for the MS degree in NSA [12]:

Year	Semester 1	Semester 2
1	Research Methods and Proposal Development Enterprise Computing Core course	2 core courses Elective
2	2 core courses Elective	2 Electives Capstone: Thesis or Project

Core courses are:

- Organization behavior and leadership
- Project management
- Secured wireless and wired networks
- Emerging network technologies
- Enterprise security
- Network design and performance

Program Length: 2 years

2.3.5 CHARLES STURT UNIVERSITY (AUSTRALIA)

Charles Sturt University (CSU), in Wagga Wagga, NSW, Australia, offers the Master of Networking and Systems Administration to students who want to have high rank positions in the field of network and system administration [13]. The website states that the program is developed with close consultation with the IT industry so that it can provide a study scheme which allows successful students to have full grasp over of designing, implementation, troubleshooting and managing computer systems and networks. It further states that "CSU's Master of Networking and Systems Administration incorporate preparation for the world's most popular industry certifications from major IT vendors including Cisco and Microsoft." The program has 5 tracks: Microsoft Networking, Cisco, Linux, Microsoft Database Administrator and Oracle.

This program is offered only as distance learning. There is no on-campus option. The academic year is divided into three sessions.

Admissions requirements: Undergraduate degree.

Prerequisites: None

Courses required for the master's degree in NSA, Linux track:

Session	Year 1	Year 2
1	Networking Concepts 1 Linux elective	Core subject Linux elective
2	Networking Concepts 2 Linux elective	Core subject Linux elective
3	Core subject Linux elective	Topics in IT Ethics Linux elective

Core courses are chosen from:

- Wireless Networking Concepts
- Information Systems Strategy
- IT Management Issues
- Network Security
- IT Risk Management
- Network and Security Administration
- Digital Forensics

Linux electives are chosen from:

- Forensic Investigation
- Hacking Countermeasures
- Hardware and Software Essentials
- Linux Fundamentals
- Linux Administration
- Managing Linux Enterprise Servers
- Linux Enterprise Security
- Novell Administration
- Managing Desktop Resources
- IT Service Release, Control and Validation
- IT Service Operational Support and Analysis
- IT Infrastructure Library Foundation
- Project Management Fundamentals
- The Project Lifecycle
- Enterprise Project Management
- Developing Solutions

Program Length: 2 years

2.3.6 SUMMARY AND COMPARISON

The following tables summarize the key facts for these graduate programs in network and system administration. The first table lists the basic information

about each program while the second table indicates the topics covered in the program's core curriculum.

	FSU	**UO/OAUC**	**UA**	**RIT**	**CSU**
Length	2 years	2 years	1 year	2 years	2 years
# Semester courses	12	12	6	12	12
Thesis/project	optional	thesis	4 projects	thesis or project	none
Campus or distance learning	campus	campus	campus	both	distance
Internship	yes	no	no	optional	no

The following table lists the core curriculum dedicated course work by subject area:

Area	**FSU**	**OU/ OAUC**	**UA**	**RIT**	**CSU**
General System Admin	•	•	•		•
Advanced Networking	•	•	•	•	•
Computer Architecture			•		
Scripting/Programming	•	•			
Security	•	•	•	•	•
Web-based Services			•		
Vendor-specific topics					•
Research	•	•	•	•	

2.4 USEFUL TECHNOLOGIES FOR NSA EDUCATION

This section provides a very brief overview of some technologies which will be useful to the proposed master's degree program.

2.4.1 VIRTUALIZATION AND EDUCATION

Virtualization technology is one of the most active topics in the field of computing industry today. Many people associated with IT industry want to take advantage of benefits offered by virtualization technology to create easy and low cost solutions for their organization, whether it is an educational institute, government user, or a private company. In education, virtualization has made it quite easy to allocate resources to students in an efficient way for their research and development studies.

Virtualization consists of using software and hardware to create virtual machines (VMs). Using virtualization, one can make several virtual machines on a single computer which share hardware resources and act like completely independent machines.

The hypervisor, also known as the virtual machine manager, is the tool that allows different operating systems to be installed on a single computer/host for the sake of sharing hardware resources. Each operating system behaves independently because the hypervisor keeps its assigned resources, such as memory, processor, storage and so on, separate from the other VMs. The hypervisor manages the processor and other resources so that VMs do not disrupt each other.

Virtualization gives a number of benefits to any organization [14]. Some of them are listed below:

- Simplifies the data center.
- Can create lab environments for the students.
- Uptime is quite improved.
- Low cost and environment friendly.
- Requires less space.
- Improvement in backup and disaster recovery.
- Facilitate older applications dependent on OS or hardware.
- Make your own cloud.
- Efficient system management.
- Physical Platform independence.

Virtualization has an important role in today's education. Use of virtualization for the sake of education is excellent as it gives number of benefits. Therefore most of the universities, colleges, schools and different organizations in developed countries have already implemented virtualization technology in their infrastructure. Some of the benefits to education are listed below [14]:

- Ensures the same type of environment for all students.
- VMs are accessible from anywhere.
- Access resources from various platforms using different hypervisors.
- Security is well handled.
- Efficient usage and management of tools, installation and management.

Virtualization will play a large part in the master's program described in this thesis.

2.4.2 MLN

MLN (Manage Large Networks) is a program written in Perl to create a comprehensive network of Xen, User Mode Linux or other virtualized systems by using a simple configuration file [15]. It creates virtual machine on demand and automatically and makes configuration and management simple. MLN uses an easy programming language to create different configurations for different purposes. MLN offers commands that allow creation, starting and stopping, and termination of a virtual machine quickly. MLN also provides virtual networks, and those networks can be connected with each other if desired to make a larger network.

2.4.3 RASPBERRY PI HARDWARE

The Raspberry Pi is a small credit card sized, single-board computer developed by computer a United Kingdom (UK) charitable organization called the Raspberry Pi Foundation for computer science education [16]. It is illustrated in Figure 2.4.

The Raspberry Pi computer comes in two versions:

- Model A, costing $25 (USD), has 256MB RAM and one USB port but no network connection.
- Model B, costing $35-$40 (USD), has 512MB RAM, and comes with two USB ports which can be used, for example, for a keyboard and mouse. It has also a network interface card and can be connected to an Ethernet network.

Kits containing cases and external connectors as well as the board itself are also available [17]; some kits also contain electronic components (for example, breadboard and jumper wires) for hardware prototyping. The cost for the latter type of kit is about $120 (USD).

The Raspberry Pi runs a version of the Linux operating system. The Raspberry Pi has been used for many different purposes, some are listed below:

- Simple network storage.
- Media center control.
- Remote control of PCs.
- Low cost Linux computer.

The Raspberry Pi device potentially offers a very low cost way to provide workstations for students in combination with virtualized systems.

Figure 2.4 shows the Raspberry Pi computer. The board is shown at the top. The illustration on the bottom shows it in a case and in use as a workstation as a test system for this thesis.

Figure 2.4. The Raspberry Pi computer

Chapter 3

Curriculum

The proposed Masters of Networking and System Administration degree program gives students such skills that allow them to configure and manage different computer networks in a systematic way. It gives students deep knowledge and technical skills that make them capable of handling complex computer network systems. The curriculum for this master's level program is flexible because of technological updates and fast rate of change in the market. Topics of the curriculum can be delivered through lectures initially and later on must be experienced practically in a lab environment using resources that give students real life example scenarios. Successful graduates can obtain jobs in many fields related to network and system administration. This includes system or network administrator, security analyst, and computer consultant. Detailed descriptions of the curriculum and courses are given in this chapter.

3.1 MISSION STATEMENT

With this program, graduate-level network and system administration education is offered for the first time in Pakistan. The program offers comprehensive, hands-on experience in installing, configuring and administering the large networks and systems used in the world today. This program is much more systematic and comprehensive than existing programs in Pakistan in the field of network and system Administration, whether in the public or the private sector.

A research based studies of NSA make this course so efficient that students can make different new projects, tools, benchmarking etc. and the course can lead to doctorate level studies as well. Beside this a student while doing Master not only properly acquiring knowledge but also getting ready to work in IT industry according to the current trends as a computer architects, system administrators, policy implementers, technical managers, network engineers, IT consultants, security specialists etc. Moreover this scheme of study primarily focuses on developing, adopting and exploring new and easy trends in the field of network and system administration.

Automation is primarily taken in to consideration using which one can automate the comprehensive installations and configurations of systems which is quite exhaustible if done manually. Using same mechanism of automation new tools can be developed to help out system administration tasks. This course offers many options to choose projects and diploma thesis to write needed to avail a degree.

3.2 ADMISSION REQUIREMENTS & PREREQUISITES

This master's program will require a bachelor's degree in Computer Science, Information Technology or an equivalent field for admission. Students must have a GPA of at least 60 on the 0-100 scale common in Pakistan (where passing is 50 or higher), which is equivalent to a US GPA of 2.8 or higher. Applicants with equivalent work experience may also apply.

Students are expected to be proficient in the following skills when they begin the program:

- Browsing and searching for information on the Internet
- Installing and managing a Windows system
- Software installation under Windows
- Windows client networking setup
- Very basic familiarity with Linux and simple commands. Students without Linux experience are required to attend an introductory course during the summer prior to starting the program.

3.3 SEQUENCE OF COURSES

The curriculum will vary from time to time as this is a field of such technology that updates itself frequently throughout the year, adding and expiring different technologies. However the most recent technologies of today are the part of curriculum described here.

The program is designed to be completed in 2 years of full time study, divided into four semesters. The following table lists the courses and activities in each of the four semesters:

Year	Semester 1	Semester 2
1	• Network and system admin. 1 • Intrusion detection and firewalls • Cyberethics	• Network and system admin. 2 • Scripting • Elective
2	• Advanced Networking • Network infrastructure and security lab • Research paper	• Thesis project

The first semester contains the easiest and most introductory courses. Network and system administration 1 provides a broad overview of system administration under Linux. Intrusion detection and firewalls studies a relatively easy topic in some depth. This course will be more challenging for the students, and it will serve as an opportunity for them to evaluate their interest and ability in network and system administration and to decide if the master's program is a good one for them.

The second semester builds on the first. The courses are more difficult and challenging. Topics are covered in more detail. Scripting is taught at this time as it will be needed for Network and system administration 2 in the same semester, as well as the courses in the second year.

The suggested elective course in the second semester should be chosen based on the student's future plans. Those who want to pursue a job after graduation should select something which will broaden their experience and give them more skill. This would include courses database administration, web applications and advanced programming. Students who want to go on to a PhD should select a research-oriented computer science course such as one on advanced computer architectures or advanced algorithms.

The third semester focuses on networking in depth. This is a skill that is needed and sought after in Pakistan, surrounding countries and the Middle East. The Network infrastructure and security lab course will introduce students of benchmarking and analysis techniques for hardware, software and implementation. It will also include information about statistics and experimental design. The research course will teach students to search for published work on topics of interest and importance.

The final thesis project can be a research thesis such as those undertaken at OU/OAUC. However, it can consist of a practical implementation of a tool,

service or solution to a problem, based on the needs and constraints of a local environment. The written thesis will be approximately 50-80 pages in length. Students will give a final presentation on their work.

This program is similar to the one I experienced at UO/OAUC, but some changes are appropriate for the environment and students in Pakistan:

- Some courses have been moved to different semesters compared to UO/OAUC. For example, Cyberethics now appears in the first semester.
- Not all courses are the same number of credits. Network and system administration 1 and the Network infrastructure and security lab are both 15 ECTS.
- The Networking technologies course in the first semester at OAUC has been eliminated. Its content has been moved to Network and system administration 1 and to the new Advanced networking course in semester 3.
- The Analytical system administration course has been eliminated. Some of its content is incorporated into the Network infrastructure and security lab course.
- The Scripting course is a required course in this program.

3.4 COURSE DESCRIPTIONS

Courses along with the contents are proposed in the above section. These are the courses taught in well developed countries of the world with slight differences. These courses give individuals such technical powers that one can have enough vision to handle IT infrastructure at enterprise level. Further detail of the courses and its outcomes are described below.

Notes:

- The "Level" field within each description indicates the level of the course within this master's program.
- Evaluation of students is discussed in detail following the course descriptions.
- All homework assignments described in the following course descriptions are mandatory.

3.4.1 NETWORK AND SYSTEM ADMINISTRATION 1

Basic Information

Name of the course: Network and system administration 1
Level: Elementary

ECTS-equivalent credits: 15
Semester: 1
Evaluation method: Numeric grades 0-100 (50 is passing)

Target Group

This course, along with the follow-on in the second semester, gives the core knowledge for the master's degree in network and system administration curriculum. It is designed for students who have a basic Linux background and understand fundamental commands and concepts.

Learning Outcomes

KNOWLEDGE

- Overview of Linux
- Understanding storage (local and network)
- Understanding file systems, including permissions and quotas
- The boot and shutdown processes and their options
- Networking fundamentals: OSI model, hardware, packets, services
- Periodic processes and system logging
- How resources are shared
- Linux users and groups

SKILLS

- Installing Linux
- Starting up and shutting down the system in different scenarios
- Creating and managing user accounts and groups
- Setting up basic networking on a client system, with either static IP addresses or DHCP. Managing network services.
- Creating and mounting/unmounting local file systems
- Setting file permissions and disk quotas
- Managing network-based storage (SANs and NAS)
- Sharing file system resources with NFS and SAMBA
- Installing and updating software packages
- Using cron to schedule periodic processes
- Examining and interpreting system logs

GENERAL QUALIFICATIONS

- Capable of performing many system administration functions at a beginning/junior level

Organization and working methods
Lectures with demonstrations will be held twice a week. Topics will be divided into small chunks to aid student learning.

Required course work
Students will have weekly homework assignments, related to the lecture topics for that week. For example, when DNS is discusses, the assignment might be to install and configure a DNS server and getting a client system working with that server.

Student will submit a short report for each assignment, including any scripts they have used. Student VMs will also be examined in some cases.

Form of assessment
Assignments 25%
Midterm examination 25%
Final examination 50%

3.4.2 INTRUSION DETECTION AND FIREWALLS

Basic Information
Name of the course: Intrusion detection and firewalls
Level: Elementary
ECTS-equivalent credits: 10
Semester: 1
Evaluation method: Numeric grades 0-100 (50 is passing)

Target Group
This course is designed for first semester students in the network and system administration master's program. It assumes that students are familiar with basic Linux commands and have a general knowledge about the Internet and security threats.

Learning Outcomes
KNOWLEDGE

- Using firewalls for enterprise network security
- Firewall architectures
- Stateful packet filtering
- Network address translation (NAT)
- Approaches to intrusion detection
- Signature, protocol and anomaly-based inspection

- Gathering information and interpreting
- Possible responses to intrusion attempts

SKILLS

- Using the iptables command to configure firewalls and NAT
- Viewing and analyzing network traffic with tcpdump
- Viewing and analyzing network traffic with Wireshark
- Using OSSEC and Snort

GENERAL QUALIFICATIONS

- Ability to configure Linux firewalls for a variety of scenarios
- Ability to select among various IDS/IPS alternatives
- Ability to implement and IDS/IPS system and interpret the resulting data

Organization and working methods
Lectures with demonstrations will be held twice a week.

Required course work
Weekly assignments

Form of assessment
Assignments 25%
Midterm examination 25%
Final examination 50%

3.4.3 CYBERETHICS

Basic Information
Name of the course: Cyberethics
Level: Introductory
ECTS-equivalent credits: 5
Semester: 1
Evaluation method: Numeric grades 0-100 (50 is passing)

Target Group
This course would be appropriate to any student with basic knowledge about computers and computing. It will focus on situations related to network and system administration, but the concepts are applicable to many computing environments.

Learning Outcomes

KNOWLEDGE

- Ethics and IT
- Standards and philosophies
- Ethics in Islamic context
- Management ethics
- Organizations and ethics

SKILLS

- Familiarity with important codes of ethics
- Ability to analyze situations with regard to ethical concerns

GENERAL QUALIFICATIONS

- An understanding of ethics and their relation to computing
- Basic familiarity with the major ethical issues facing network and system administrators
- Introduction to the different ethical systems prominent in the world today
- Awareness of ethical standards and issues relevant to working in Pakistan

Organization and working methods

Lectures and discussion once per week. The course will make heavy use of case studies in order to illustrate and apply the concepts.

Required course work

Reading only.

Form of assessment

Final written exam: 100%

3.4.4 SYSTEM AND NETWORK ADMINISTRATION 2

Basic Information

Name of the course: Network and system administration 2
Level: Intermediate
ECTS-equivalent credits: 10
Semester: 2
Evaluation method: Numeric grades 0-100 (50 is passing)

Target Group

This course is designed for second semester master's students in network and system administration. It assumes knowledge equivalent to Network and system administration 1. Students must be fully capable of installing, managing and configuring Linux client systems.

Learning Outcomes

KNOWLEDGE

- Automated system installation
- Configuration management
- The electronic mail system
- Version control systems
- Ticketing systems
- Groupware
- Centralized account management with LDAP
- Virtualization concepts and software

SKILLS

- Configure and implement an automated Linux installation scheme
- Use version control in the context of system administration
- Use a configuration management system to configure and maintain Linux systems
- Create and manage virtual machines
- Install and configure all aspects of electronic mail: SMTP server, client email retrieval via POP/IMAP, detect and prevent UBE (spam), scan mail for viruses, manage mailing lists, administer multiple email domains
- Install and configure centralized authentication for Linux computers using LDAP, including migrating user accounts
- Management of roaming user accounts, including home directories and password changing
- Implement heterogeneous authentication for Linux and Windows systems

GENERAL QUALIFICATIONS

- Capability of managing all aspects of electronic mail using Linux servers
- Ability to set up and manage centralized authentication in a homogeneous Linux environment and a heterogeneous Windows/Linux environment

Organization and working methods

Lectures with demonstrations will be held once a week.

Required course work
3 Projects each lasting 1/3 of the semester:

- Project 1: Automatic installation of a Linux system, including configuration management, version control and an inventory system.
- Project 2: Install an LDAP server including support for centralized user home directories and secure password changes. Configure electronic mail system that routes mail properly, maintains a mail repository from which user mail can be retrieved and handles multiple email domains.
- Project 3: Implement common authentication for Windows and Linux clients using Active Directory. Provide resources to all clients.

All work will be done via one or more VMs. These VMs and the student's report will be used to evaluate the work.

Form of assessment
Each project will be graded and count for 33% of the final grade.

3.4.5 PERL SCRIPTING FOR SYSTEM ADMINISTRATION

Basic Information
Name of the course: Perl scripting for system administration
Level: Intermediate
ECTS-equivalent credits: 10
Semester: 2
Evaluation method: Numeric grades 0-100 (50 is passing)

Target Group
The course is designed for network and system administration students. Students should be familiar with common network and system administration tasks. Previous bash shell scripting is helpful but not required.

Learning Outcomes
KNOWLEDGE

- Perl syntax and constructs
- Important Perl modules
- Amazon EC2 cloud computing and VM management
- Creating plots, web pages and documents using retrieve data

SKILLS

- Write strict-compliant Perl scripts

- Retrieve information from a variety of sources
- Numerically analyze retrieved data
- Create plots with Perl and gnuplot
- Create HTML and LATEX documents with Perl
- Interact with LDAP via Perl
- Use the Amazon EC2 cloud
- Script Amazon EC2 operations using Perl
- Automating common network and system administration tasks via Perl scripts

GENERAL QUALIFICATIONS

- Ability to create Perl scripts to perform network and system administration tasks
- Familiarity with cloud computing in the Amazon EC2 environment

Organization and working methods
The course will meet in one long block each week. Lectures with demonstrations will be held during the first part of the class. The second part will function as a lab session during which students will work on assignments with instructor assistance.

Required course work
An assignment will be given every 2 weeks. One longer project will be assigned during the second half of the course.

Form of assessment
Long project: 50%
Final examination: 50%

3.4.6 ADVANCED NETWORKING

Basic Information
Name of the course: Advanced networking
Level: Advanced
ECTS-equivalent credits: 10
Semester: 3
Evaluation method: Numeric grades 0-100 (50 is passing)

Target Group
This course is designed to teach advanced networking concepts in great depth. Students should have a good understanding and experience of basic networking concepts, services and protocols.

Learning Outcomes
KNOWLEDGE
- Low-level networking and networking devices
- TCP/IP protocols and services
- IPv6 networking
- Routing and routing protocols (including RIP, EIGRP, OSPF, BGP)
- Multicasting
- Quality of service (QoS) and traffic engineering
- IPsec-based security
- Wireless networking

SKILLS
- Configuring routing in a variety of ways
- Migrating from IPv4 to IPv6
- Managing and securing wireless networks
- Designing and implementing traffic flow using QoS

GENERAL QUALIFICATIONS
- Deep understand of networking at all levels
- Ability to select, install and configure appropriate hardware and protocols to implement networking requirements in a variety of environments

Organization and working methods
Lectures with demonstrations will be held twice a week.

Required course work
Weekly assignments.

Form of assessment
Assignments 25%
Midterm examination 25%
Final examination 50%

3.4.7 NETWORK INFRASTRUCTURE AND SECURITY LAB

Basic Information
Name of the course: Network infrastructure and security lab
Level: Advanced
ECTS-equivalent credits: 15
Semester:
Evaluation method: Numeric grades 0-100 (50 is passing)

Target Group
This course is designed for second year students in the master's in network and system administration program. Students should be familiar with a range of network and system administration tasks (as covered in Network and system administration 1 and 2). They must be fluent in Perl scripting (or another scripting language), and be familiar with virtualization.

This course is designed to prepare students for their thesis project work in the fourth semester.

Learning Outcomes
KNOWLEDGE

- The scientific method and experimental design
- Statistical analysis of data, including confidence intervals
- Problems and approaches in network and system administration research and testing
- Data analysis and reporting

SKILLS

- Designing and carrying out experiments
- Using analysis and benchmarking software
- Capturing data
- Analyzing data and making conclusions
- Preparing reports

GENERAL QUALIFICATIONS

- Ability to perform systematic comparison of hardware and software approaches and implementations
- Prepared to plan and complete a master's thesis project

Organization and working methods
Lectures weekly or biweekly.

Required course work
3 experiments of a comparative nature chosen from a list of possibilities or by the student him/herself. Each student will also give a presentation on one of the projects.

Form of assessment
Each project is 33% of the final grade

3.4.8 WRITING THE RESEARCH PAPER

Basic Information
Name of the course: Writing the research paper
Level: Intermediate
ECTS-equivalent credits: 5
Semester: 3
Evaluation method: Numeric grades 0-100 (50 is passing)

Target Group
This course is designed for students in the network and system administration master's program. It covers searching for and understanding published works in network and system administration.

Learning Outcomes
KNOWLEDGE

- Techniques for locating publications in network and system administration
- Focusing search results for the problem at hand
- Reading and interpreting technical publications
- Presenting published research in oral presentations and written reports

SKILLS

- Ability to search for and identify relevant research on network and system administration topics
- Ability to summarize previous research in an area, orally and in writing
- Familiarity with the LATEX publication system

GENERAL QUALIFICATIONS

- Prepared to carry out the background research necessary for the thesis project and to summarize the relevant points in writing

Organization and working methods
The course will be a combination of lectures and student presentations.

Required course work
3 short presentations (5-10 minutes) describing published research, along with a paper of 15-20 pages

Form of assessment
Each oral presentation is worth 20% of the final grade
The research paper is worth 40% of the final grade

3.5 EVALUATION OF STUDENTS

Evaluation of students is important factor in increasing the efficiency of students for their studies. They should be evaluated in such a way that they must perform in the given tasks and also should not be a hassle for them. This can be achieved by dividing the final grades on whole semester including assignments, midterm exams and final exams.

For non-project courses, grades should be divided in the following way:

Assignments = 25% of the final grade
Midterm Exam = 25% of the final grade
Final Exam = 50% of the final grade

For courses having midterm examinations, this exam will be home-based, meaning that students will be given the problem and have a given amount of time to work on it, either at home, in the computing lab or wherever it is convenience. Students will be permitted to consult with one another on this exam, but each student must submit his/her own exam.

Some of the courses which are project based will be evaluated entirely on the quality of the project(s).

3.6 AVAILABILITY OF FACULTY

Managing a master's degree in network and system administration at the institute level requires quite bigger vision of the said field. Moreover, there is a need of proper technical people who can assist students properly in their difficulties during study period. Having some experience with Pakistan's educational system, I know that it might be quite hard to find someone who can facilitate the faculty to conduct such a degree program. However, there are individuals with fewer technical skills who can nevertheless teach different courses of the degree program. An educational institute interested in offering such degree can hire

them and train them according to the demands of the courses. Some of the courses can be found locally in Pakistan for training purpose, and some of them can be arranged in foreign countries. However there will be a need of at least two professionals who have master's degrees in network and system administration from well reputed institutes of the world.

Chapter 4

Computing resources and strategies

This program includes a lot of hands-on work by students. The overall strategy is that students can perform these tasks on virtual machines made through some virtualization technology. If students wish to use their own laptops, this can be achieved by using VirtualBox [18], an open source virtualization product. Otherwise, they will use systems in the computing laboratory. In some cases, they will also use resources in the Amazon EC2 cloud.

4.1 COMPUTING REQUIREMENTS

NSA studies require servers and other dedicated machines for students' projects and assignments in addition to ones in the common computer lab. As an example, we will consider the intrusion detection and prevention systems labs in the Intrusion detection and firewalls course. They require many virtual machines where students can perform their lab work to get hands-on experience in a realistic scenario. In a class of 30 students, each one needs to have 5 virtual machines to carry on with the course work. A student will be given a network of 5 virtual machines according to the topology in Figure 4.1.

As we calculate the required number of VMs for 30 numbers of students then it will cost us 150 VMs required to allocate the students or 75 virtual machines if administration wants students to work in teams of two. Therefore, a server that can support our requirements is needed, as well as another server for backup in case of recovery or fault.

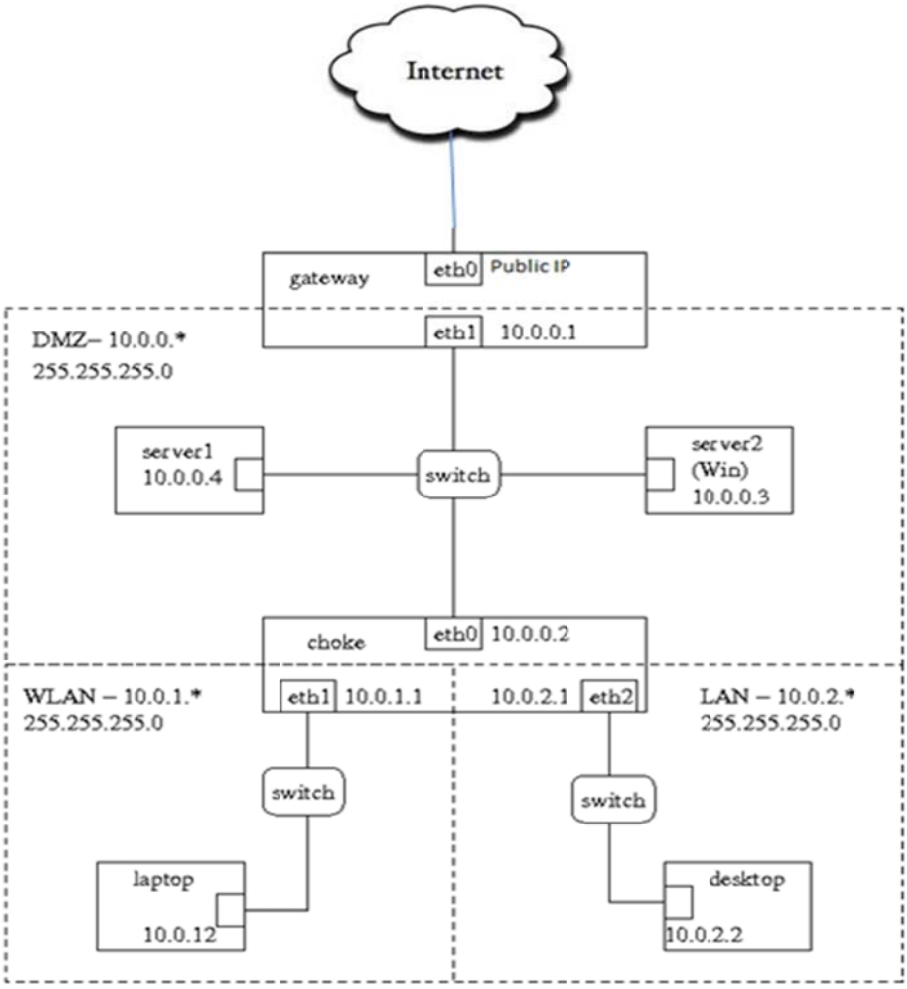

Figure 4.1. Typical student virtual network

There are also server machines required for administrative usage, and workstations needed for students for their course work and projects to be done during studies. There is also a network lab equipped with routers, switches and PCs to do the network-related assignments and projects. The networking infrastructure requires routers, switches, PCs, cabling, and WiFi APs and repeaters. Printers and other peripherals are also required. These requirements are summarized in the following table:

Table 4.1. Summary of Computing Resource Requirements

Resources	Quantity	Specifications
STUDENT LAB		
Servers	2	Processor: 64-bit Intel or AMD, 4 or 8 cores RAM: 320 GB (DDR3) Disk: 4TB, 10K and 15K RPM Serial Attached SCSI (SAS) drives
Raspberry Pi	30	Model B with cases
LCD monitors	30	HDMI support
SAN system 10 TB	1	iSCSI SAN
NETWORK LAB		
Routers	10	Cisco 7200 Series Routers
Switches	10	Cisco Catalyst 3550 Series Switches
WiFi Access Points	As needed	Linksys RE1000
Cabling	As needed	RJ45 STP Cabling
ADMINISTRATIVE SERVERS/BACKUP		
Servers	10	Processor: Intel® Xeon® processor E5-2600 Ram: 8 GB (DDR3) Disk: 1 TB Integrated Serial ATA (SATA)/Serial Attached SCSI (SAS) controller.
SAN Disk 10 TB	1	iSCSI SAN
NETWORK HARDWARE FOR WHOLE FACULTY		
Routers	2	Cisco 7200 Series Routers
Switches	5	Cisco Catalyst 3550 Series Switches
WiFi Access Points	As needed	Linksys RE1000
Cabling	As needed	RJ45 STP Cabling
ADDITIONAL RESOURCES		
Printers	2	Heavy duty Network printers
Printers standalone	5	Faculty support printers
UPS	1/Rack	Server rooms power requirements (up to 5KW)
Generator	1	10 KW output capacity
Internet connectivity	2	Redundant connectivity.

Figure 4.2 illustrates these resources in place.

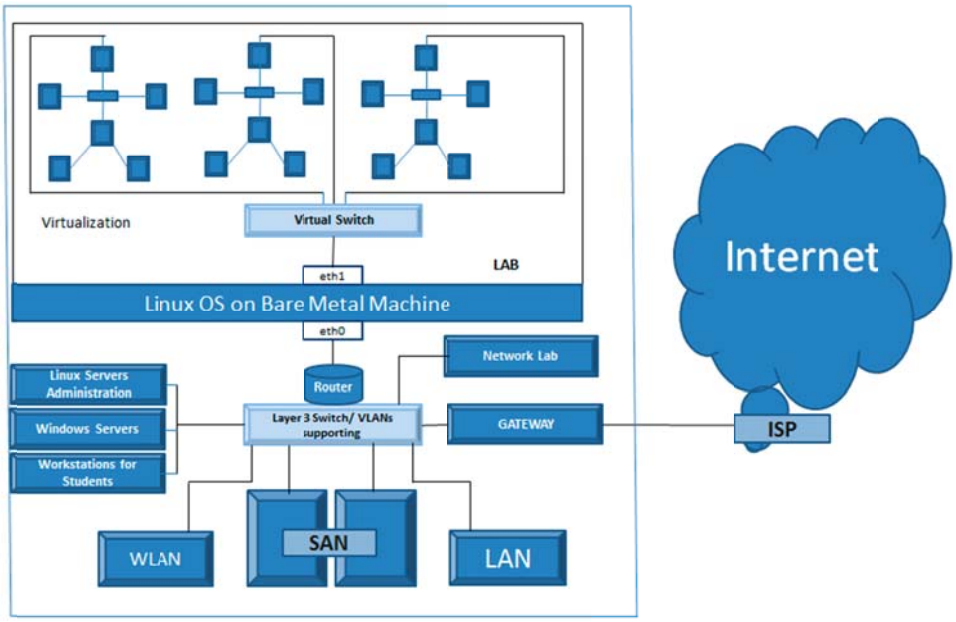

Figure 4.2. Computing resources for the NSA master's program

4.2 USING MLN TO MANAGE STUDENT ENVIRONMENTS

Creating many VMs by hand is both tedious and time consuming. It is necessary to automate this process in some way. The Manage Large Networks (MLN) tool can help with this process.

MLN is a program written in Perl to create a Xen, User Mode Linux (UML) or other virtualized systems by using a simple configuration file. It creates virtual machines on demand and automatically, and makes configuration and management simple. MLN also provides virtual networks, and those networks can be connected with each other if desired to make a larger network.

Using MLN, one can create an environment for virtualization using either UML or Xen. The different characteristics of UML and XEN are compared in Figure 4.3.

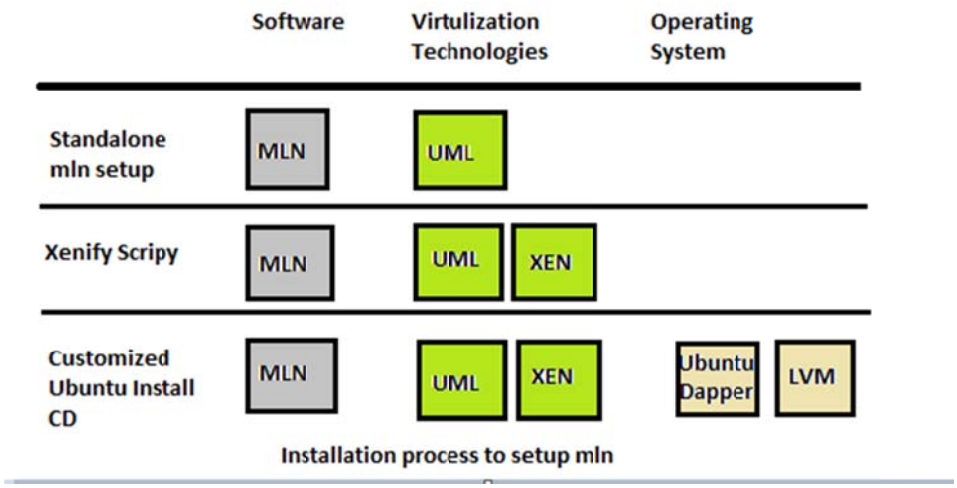

Figure 4.3. Comparing UML and Xen with MLN

The first task is to install MLN itself. A modified ISO of a Ubuntu Dapper distribution installation CD and available online. This allows you to install and prepare MLN environment quickly. However one may find issues related to updating or installing programs later as this is an older version of Ubuntu. One can also manually set up MLN.

MLN requires the following packages be already installed in order to work:

- **Perl**: MLN is written in Perl. MLN also includes plugins to configure virtual machines in many ways ,and those plugins are are written in. Therefore, one needs to install Perl.
- **UML** or **Xen**: The desired virtualization environment must be installed.
- **bridge-utils:** Hosted virtual machines communicate through bridges. Therefore, one need the bridge-utils package, which contains a utility to create and manage bridge devices.
- **screen:** Screen is a program that enables users to emulate multiple console "windows." One can use some keystrokes to create new windows and switch between them. It is a convenient interface to virtual machines, and MLN supports it. It is optional, however.
- **sudo:** sudo is a program that allows a user/process to have root privilege for one command.

Choosing between UML and Xen must also be done. UML is a specialized Linux kernel which runs as binary. It usually does not require root access to run

making it more flexible. But performance-wise, it is slower when compare dwith XEN.

XEN is a virtualization platform which can support VMs running many different operating systems. Performance-wise XEN is more efficient than UML. However, it requires root access and is a bit more complicated

Xen seems to be the best to use in this scenario where our network topology for intrusion detection and prevention systems needs to have different operating systems such as Linux and Windows.

In this thesis, the modified Ubuntu Dapper ISO was used to install the server operating system with Xen and MLN.

4.2.1 CONFIGURING MLN PROJECTS

A project can be created using MLN programming language in which one write correct syntax to create multiple virtual machines along with single or multiple Ethernet switches. Below is a very simple example project file in which the project nsathesis has three virtual machines, named gateway, apache and dns. There is one switch to which all the three virtual machines are connected, named vmbr0.

```
1       global {
2          project nsathesis
3       }
4       switch vmbr0 { }
5
6       host gateway {
7          network eth0 {
8             switch vmbr0
9          }
10      }
11      host apache {
12         network eth0 {
13            switch vmbr0
14         }
15      }
16      host dns {
17         network eth0 {
18            switch vmbr0
19         }
20      }
```

The following example MLN project file shows some of the features available when creating a Xen VM:

```
1     global {
2        project xenvm
3     }
4
5     host example {
6        xen                                  # make Xen VM
7        memory 128M                          # RAM
8        template ubuntu-server.ext3          # OS image
9        size 2GB                             # virt. disk size
10       nameserver 10.0.0.100                # networking
11       network eth0 {
12          address 10.0.0.2
13          netmask 255.255.255.0
14          gateway 10.0.0.1
15       }
16       users {                              # add user & pwd.
17          athar encoded-password
18       }
19    }
```

This file defines the virtual machine's specification and initial configuration like memory allocation, OS image file, switch, host IP address, nameserver, and so on.

MLN offers superclasses and variables to make defining multiple VMs easy. They also help to keep the information regarding VMs consistent. Superclasses and Variables

Here is an example using a variable to define the IP address of the DNS server:

```
1     global {
2        project nsathesis
3        $dns_address = 10.0.0.100
4     }
5     host dns {
6        network eth0 {
7           address $dns_address
8        }
9     }
10    host gateway {
11       name_server $dns_address
12       ...
13    }
```

The following project file shows the use of superclasses to define many hosts easily:

```
1     global {
2        project ids
3        $sanserver = 10.0.0.200
4        $externip = 192.168.24                # external IP prefix
5        $vncpasswd = encoded-password
6     }
7
8     superclass common {                      # settings for all VMs
9        xen
10       iscsi $sanserver                      # virt. disk on SAN
11       users {
12          athar encoded-password
13       }
14       size 4000M
15       memory 1024M
16    }
17
18    superclass sclin {                       # Linux VMs settings
19       superclass common
20       template linux_ids.ext3
21       root_passwd encoded-password
22    }
23
24    superclass scwin {                       # Windows VMs settings
25       superclass common
26       template winXP_ids.ntfs
27       vncpasswd $vncpasswd
28    }
29
30    host win {                               # Windows VM
31       superclass scwin
32       vncdisplay 7000
33       size 6000M
34       network eth0 {
35          switch lan
36          netmask 255.255.255.0
37       }
38       winconfig {
39          users {                           # Add Windows user
40             student $vncpasswd
41          }
42       }
43    }
44
45    host gwhost {                            # 1st Linux VM: gateway
46       superclass sclin
47       size 10000M
48       memory 2048M
49       network eth0 {
```

```
50          address 10.0.0.1
51          switch lan
52       }
53       network eth1 {                        # 2nd network interface
54          address ${externip}.50
55          netmask 255.255.255.0
56          gateway ${externip}.1
57       }
58       nameserver ${externip}.100
59    }
60
61    host linux1 {                            # 2nd Linux VM
62       superclass sclin
63       network eth0 {
64          address 10.0.0.3
65          netmask 255.255.255.0
66          gateway 10.0.0.1
67       }
68    }
69
70    host linux2 {                            # 3rd Linux VM
71       superclass sclin
72       network eth0 {
73          address 10.0.0.4
74          netmask 255.255.255.0
75          gateway 10.0.0.1
76       }
77    }
78
79    switch lan { }                           # Virtual LAN
```

This project also uses variables to simplify configuration.

4.3 RASPBERRY PI USABILITY TESTS

The Raspberry Pi was developed by members of computer laboratory at the Cambridge University in 2000. They had found trouble while educating new students. New students do not have such programming skills as they had a decade before. In 2012, the foundation's work came to realization.

Linux was chosen as the operating system because of low memory overhead, making it possible to run in such a simple device that does not have built-in nonvolatile memory. Linux is also generally free and has great potential as a teaching tool. Distributions often come with a programming language already installed.

In many places in the world, computers are not readily available, as they are in most industrialized countries, and electricity is expensive. Cheap computing for all can allow more people to be involved in computer science all over the world, and also lead to useful innovations.

For this master's program, the Raspberry Pi offers a very low cost way to provide students with workstations. Some tasks can be performed on the Raspberry Pi system itself, and it can also be used to connect to VMs on a server.

The systems in the system administration lab do not have any displays attached. The systems are accessible only over a network. One can access only using command line-based means (SSH and shells) or VNC.

Moreover most of the system administration tasks that student need to perform can be done with the Raspberry Pi efficiently as there is no lot of processing needed to access the remote machines. Therefore, the Raspberry Pi has the strength to replace the expensive machines usually placed in labs as end user machines to perform tasks. Simply students can have the Raspberry Pi in their pockets to connect to network and display.

Command line based access via a Raspberry Pi system will work well. There is some question about graphical performance, however. In order to test if the Raspberry Pi will provide acceptable performance for VNC, several experiments were done which performed a task on the Raspberry Pi and on a PC laptop. The PC laptop has 2 GB of RAM and runs Windows (referred to as "PC").

The following are the different experiment that were conducted:

- Manipulating an image with GIMP. 3 different file sizes were used.
- Adding new users to LDAP using the phpldapadmin web-based tool.
- Working on OTRS to issue tickets to customers.
- Streaming video from the Internet in a browser.

All tests were done via a VNC connection to a VM on the server. These tasks were chosen to be as graphically intensive as possible in order to stress the Raspberry Pi.

4.3.1 IMAGE MANIPULATION TESTS

GIMP is the GNU Image Manipulation Program. It is an open source program to perform different task related to images. The GIMP software is hosted on a virtual machine with 1 GB RAM. Experiments have been completed on the Raspberry Pi and PC according to procedure summarized below. This

procedure is repeated for 3 sizes of image files: small.jpg, medium.jpg and large.jpg. The image characteristics are listed below:

Image file	File size (MB)	Expanded size (MB)	Dimensions (cm)	Dimensions (pixels)	Resolution (dpi)
small.jpg	4	11.4	25x11	3000x1333	300
medium.jpg	11	47.4	50x22	6000x2760	300
large.jpg	17	137.3	82.5x40	9900x4849	300

Test procedure:

Make a VNC connection to the VM installed with GIMP.

Open GIMP before beginning.

Repeat 20 times:

Start timing.

1. Open the test file (File->Open).
2. Choose Image->Transform->Flip horizontally
3. Choose Filter->Distorts->Mosaic. Click OK in the next dialog.
4. Choose Filter->Distorts->Page Curl. Click OK in the next dialog.
5. Choose View->Zoom->200%
6. Choose File->Close.
7. Choose File->Open and select roses.jpg.

Stop timing when roses image appears.

Time is measured in seconds using a stopwatch.

Figure 4.4 shows part of the test procedure in progress.

Figure 4.4. Running gimp over VNC connection to host Ubuntu Server

Figure 4.5 shows the results of the tests for the small image size.

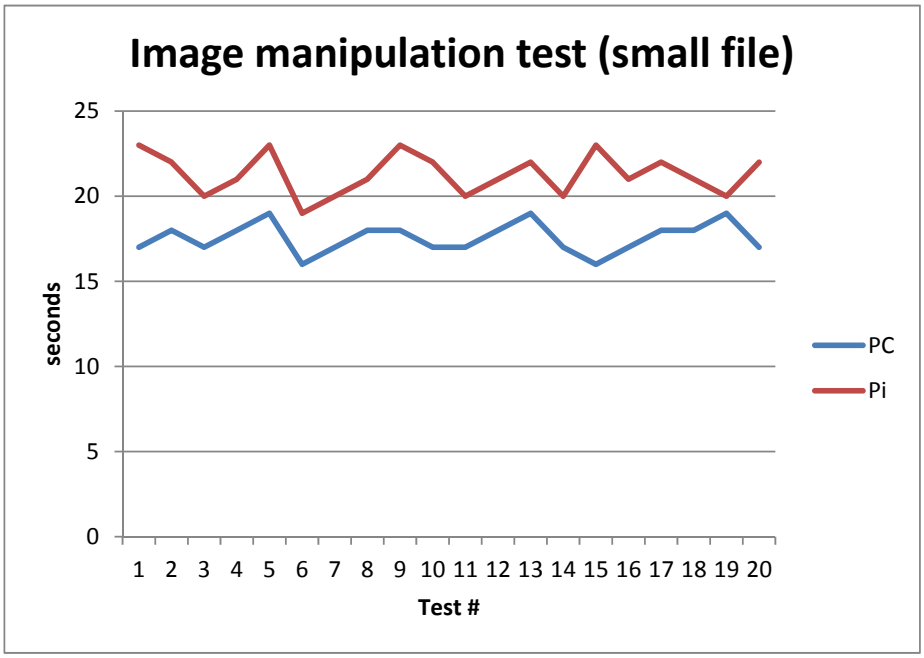

Figure 4.5. Results for image manipulation test (small file size)

It has been observed that there is a slight difference of time between Raspberry Pi and PC to complete the experiment. There were 20 experimetns conducted. Data is collected in terms of seconds, their mean value and standard devitation value is calculated to analyze further. The mean value for the completion of an experiment is 17.55 seconds and 21.3 seconds on PC and Raspberry Raspberry Raspberry Pi, respectively (standard deviation 0.9 and 1.2). PC performed experiments with faster response time, but Raspberry Pi also gave a satisfactory response time.

Figure 4.6 shows the results for the experiments for the medium size picture. is conducted and data is collected in seconds. The Mean and standard deviation is calculated both for PC and Raspberry Pi. PC has a mean value of 43 seconds and Raspberry Pi has a mean value of 48.45 seconds. The standard deviations are 1.2 and 1.8 seconds, respectively.. Again it is noted that PC is comparatively faster than Raspberry Pi but the difference is not so big that someone can rule out using Raspberry Pi for working in graphical environment.

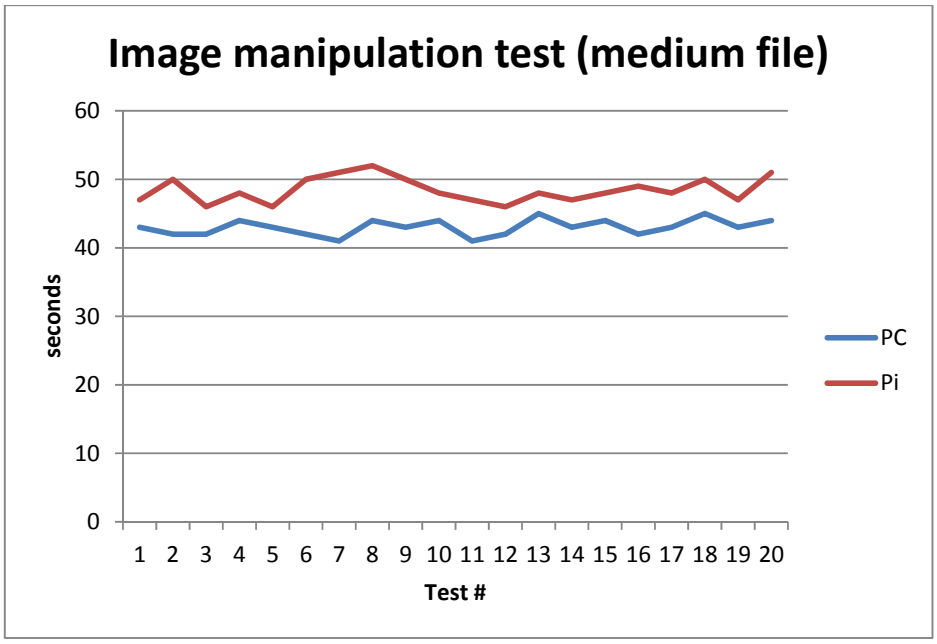

Figure 4.6. Results for image manipulation test (medium file size)

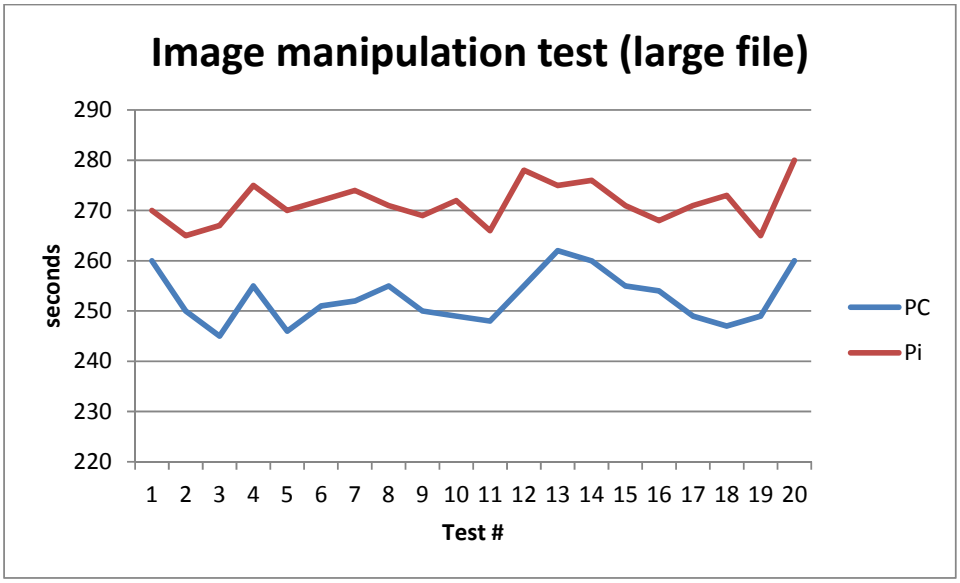

Figure 4.7. Results for image manipulation test (large file size)

Figure 4.7 shows the results for the large size image. The third experiment took quite a bit longer time than the previous experiments to complete. It shows the similar results to the previous two experiments. PC completed its experiments with a mean value of 253.6 seconds, and Raspberry Pi did so with a mean value of 271.4 seconds. Standard deviation values are quite close for both

Raspberry Pi and PC: 4.1 and 5.0 seconds, respectively. Once again, the Raspberry Pi performs almost as well as the PC.

4.3.2 ADDING USERS TO LDAP

LDAP Lightweight Directory Access Protocol is an application protocol for accessing and maintaining distributed directory information services over an IP network. System administrators have to use it frequently throughout their career. It is installed and configured on a machine and can be accessed in a graphical environment using phpldapadmin (illustrated in Figure 4.8). The graphical environment can be accessed through the web using a browser.

This experiment is designed in such a way that LDAP and phpldapadmin are installed and configured a virtual machine with 1GB RAM. Phpldapadmin is accessed via browser on both PC and Raspberry Pi. Users have been added 20 times and the elapsed time is noted for both computers.

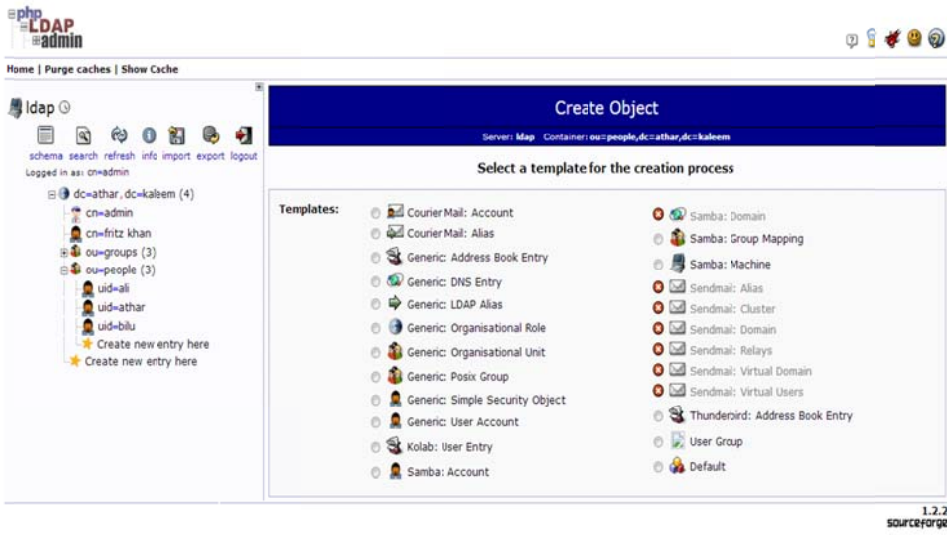

Figure 4.8. The phpLDAPadmin LDAP administration tool

There is negligible difference noted for the elapsed time between PC and Raspberry Pi. Mostly, they have the same response time or a slight difference of one second, which is quite difficult to measure. PC has the 1.7 seconds as its mean value and Raspberry Pi has 2.4 seconds. This is such not a considerable difference that one would prefer using a standalone PC over Raspberry Pi to do similar transactions through a web browser.

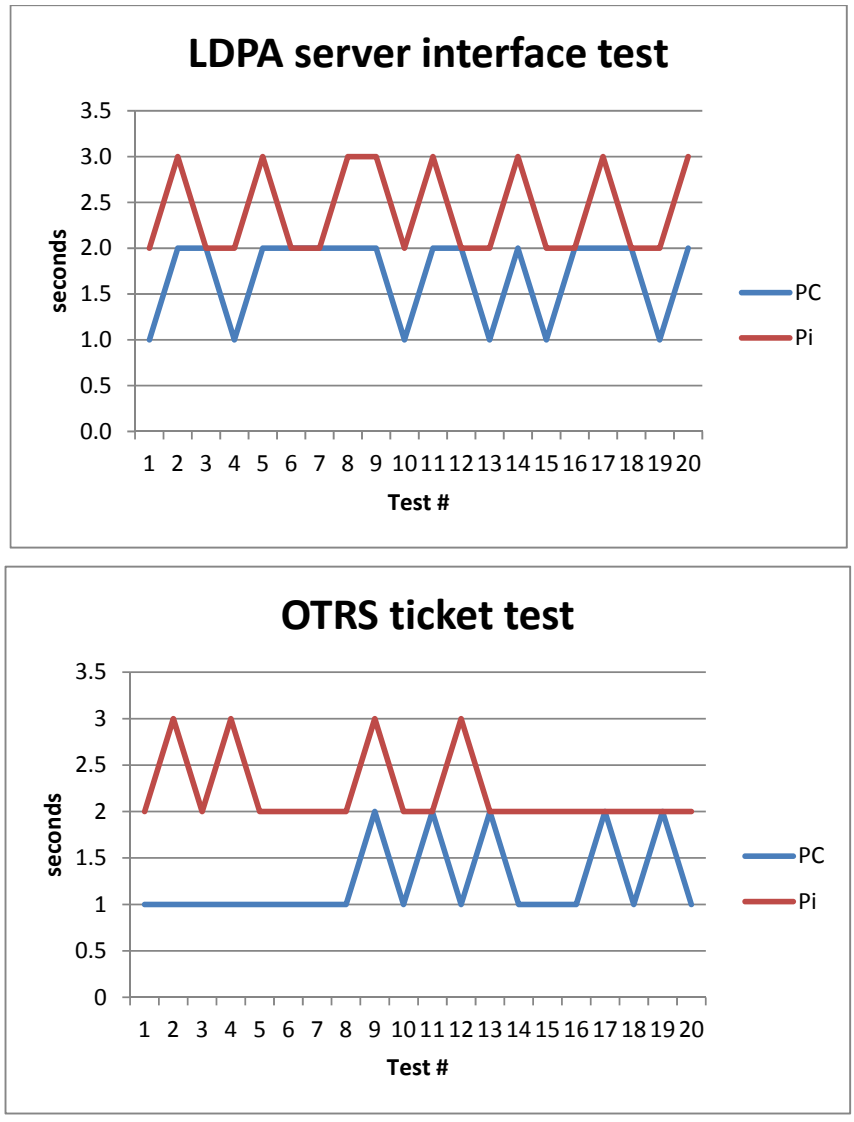

Figure 4.9. Results for LDAP and OTRS web-based administration tests

Also there is negligible difference noted in standard deviation values (about 0.5 seconds for both). The standard deviation values are large compared to the data values, but this is due to the short duration of the test and the difficulty in measuring the elapsed time. Therefore we can say that PC and Raspberry Pi work the same with respect to graphical web interfaces.

4.3.3 USING OTRS TO ISSUE TICKETS

OTRS is the Open Source Ticket Request System used to resolve different queries regarding customers (see Figure 4.10). It has many features which help system administrators and business managers to manage customer telephone calls and e-mails. An experiment is designed and OTRS is installed on one of the virtual machine with 1GB RAM. An SMTP server is also set up to handle emails while issuing tickets.

After installation of OTRS on the VM, a web browser is used to configure OTRS and access the main page. After successful configuration, a ticket is issued to one of the user and the time is noted to complete the process of the ticket issuing query. There were 20 experiments conducted, and the data was collected. These operations were also very rapid and showed the same pattern as the LDAP user add operations. The mean was 1.3 and 2.2 seconds for PC and PI, respectively (standard deviations 0.4 seconds for both).

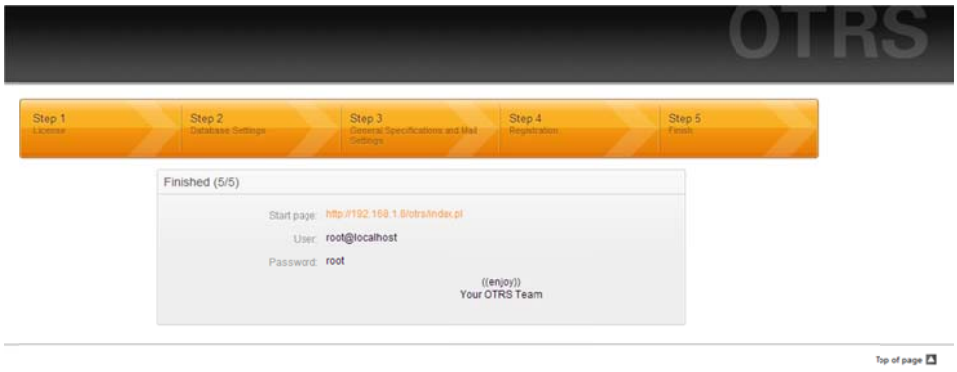

Figure 4.10. OTRS software

Figure 4.11 shows the mean results for all of these tests. The error bars are two times the standard deviation. The results for the web administration interface tests are multiplied by 10 to make it easier to plot all tests together. A logarithmic scale is used for the Y axis for the same reason. The graph shows that there is only a small difference between the Raspberry Pi and the PC.

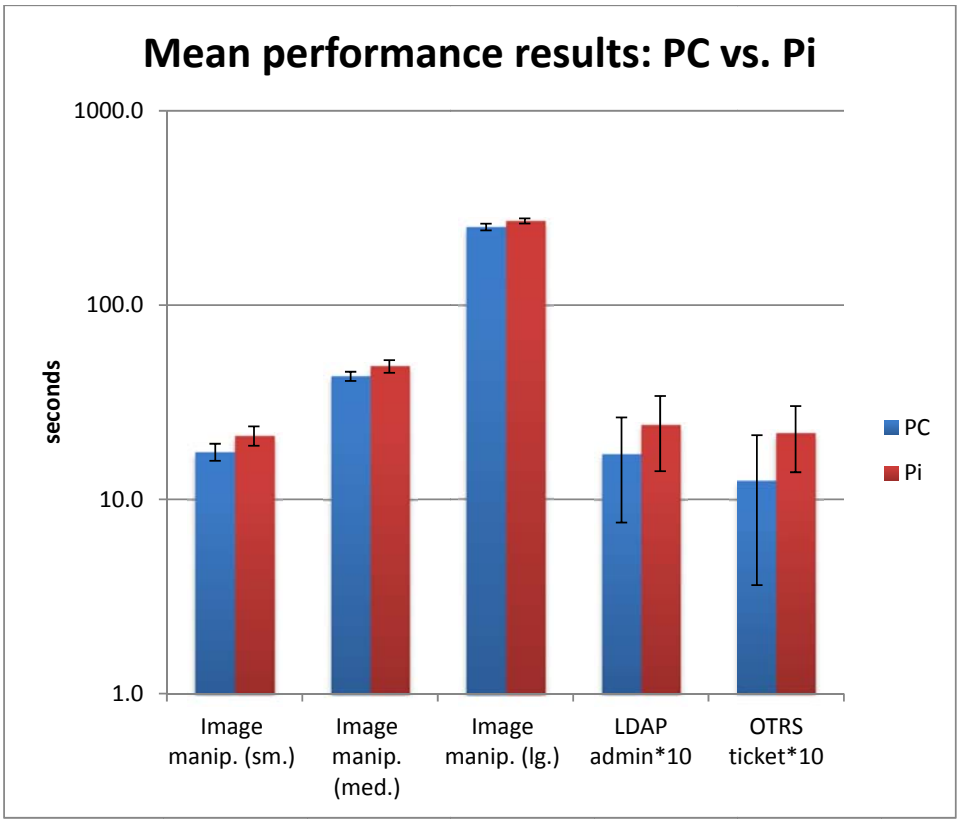

Figure 4.11. Results for all tests

Figure 4.12 plots the performance penalty for the Raspberry Pi for each test, as a percentage of the elapsed time on the PC. Most of the values are quite small. The largest values are for the web interface tests, for which the elapsed time is tiny anyway.

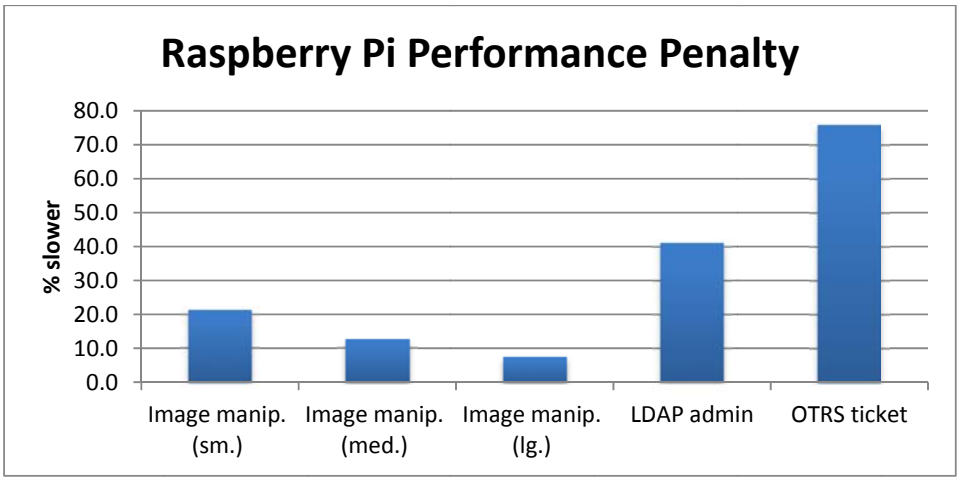

Figure 4.12. Raspberry Pi performance penalties vs. PC

4.3.4 STREAMING VIDEO TEST

In previous experiments, it has been noticed that there is a negligible or only a slight difference between PC and Raspberry Pi. There is a need to find a task where one can see a considerable difference between Raspberry Pi and PC. Therefore, an experiment of streaming video is designed and performed to find out if Raspberry Pi can handle processing like PC does.

A video file is hosted on a virtual machine installed with an OS Ubuntu 12.10 Server. Mplayer is an application which plays the video on Linux based systems. A VNC connections is establish in different time slots from Raspberry Pi and PC to the VM hosting the movie. The movie is played, and it is streamed through VNC connection towards the Raspberry Pi and PC.

This experiment saturated the resources of Raspberry Pi and a clear difference has been seen between the Raspberry Pi and PC. During the experiment, memory and CPU usage are also monitored to find the cause of difference noted in experiments.

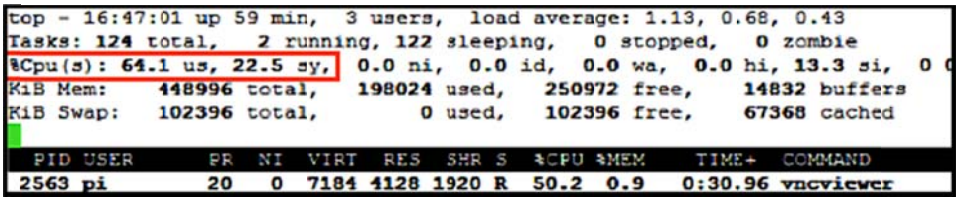

Figure 4.13. Raspberry Pi performance data during streaming video test

As it can be seen clearly in Figure 4.13, the Raspberry Pi can only use 50% of CPU. The rest of CPU usage is consumed keeping by the OS. Other services, such as xdesktop, are also consuming the processing resource. Therefore, clear distortion is noticed when displaying streaming data on the Raspberry Pi.

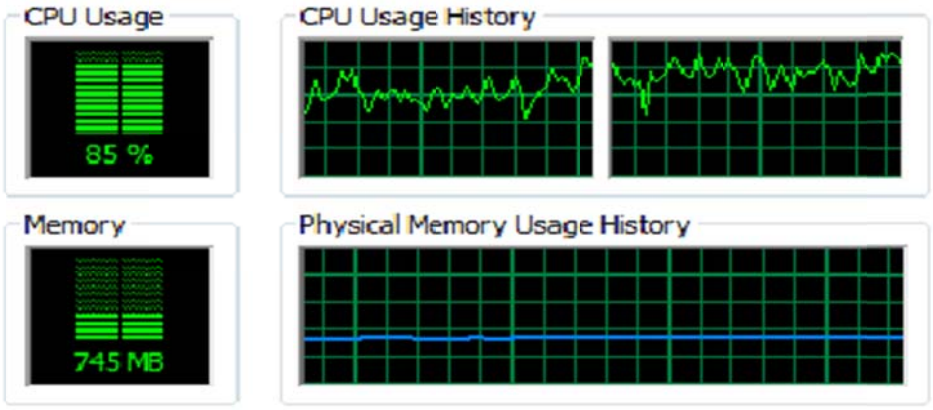

Figure 4.14. PC CPU and memory stats during streaming video test

In contrast, on PC the video plays properly. No distortion or delays were observed throughout the experiment. Figure 4.14 shows that PC has enough processing resource to handle the VNC process efficiently.

Based on these results, one can say that the Raspberry Pi is not efficient for VNC operations requiring significant local processing. This is not surprising considering its specifications.

Chapter 5

Facilities and finances

This chapter discusses the physical building and power requirements for the proposed master's degree program in network and system administration. It also considers connectivity issues.

5.1 CLASSROOM AND LAB SPACE

A network and system administration program is a quite resource demanding program of study. It requires planned facilities so that students can have a perfect study environment during their studies. In general, the building for a faculty of computer sciences can accommodate this program along with other courses being taught already.

However, NSA studies require additional facilities for conducting lab tasks. Most of the course work is practical lab work. Therefore, some extra steps need to be taken to setup such an environment that students can perform their tasks properly. This requires proper lecture and lab rooms.

The study environment for the students will be mostly practical-oriented. Therefore it would be a requirement to have such a lecture room where one can have access to lab computers as well. At least two lecture rooms along with lab computers need to be arranged for initiating this scheme of study. Generally such facility can be arranged easily in an institute where there are already computer sciences studies in progress. The same computer lab can be used as for other courses related to computer sciences.

In addition to this, the networking part of Network and system administration 1 and the Advanced networking course need a completely different environment besides computer lab. These courses require some equipment related to layer 2 and layer 3 of an OSI model, the data link layer and network layer, respectively. Switches are used for LAN to handle data link layer

traffic, while routers are used to handle network layer traffic. Therefore, an extra room is required to make a lab environment where routers and switches will be placed for the lab work in this course.

Many courses, including the Intrusion detection and firewalls course, require some server machines in many virtual machines will be given to students to work on. Those servers can be placed in another separate room or in a room already used for placing servers providing services to students or faculty.

The Network and system administration 2 course's lab work requires separate machines for each student with good specifications. Those machines will be placed in a separate room where students will be given controlled access to work on those machines. Those machines can be remotely accessed once they are configured properly, and most of the tasks will be performed remotely.

Furthermore, it would be good idea to arrange for a quiet study room where students can sit and work on their studies without any interference. There should be also a social room for students where they can share ideas and do combined work when appropriate.

Figure 5.1 provides a diagram depicting the building requirement needed for the students to carry on studies in network and system administration.

The rooms need to be well furnished according to the requirements of that room. Proper sittings, computer desks, racks for server rooms and connectivity are the main furnishing requirements for initiating the network and system administration program.

5.2 POWER

Network and system administration studies are 100% dependent on electric power. There will be equipment like personal computers, servers, routers, switches and multimedia that need power to run on. Currently Pakistan is facing a shortage of 4000-10000 MW of electricity. There is a demand of 17000 MW of electricity currently, whereas the production fluctuates between 7000 MW and 13000 MW depending on how much water is available in dams and the capacities of any alternative energy resources.

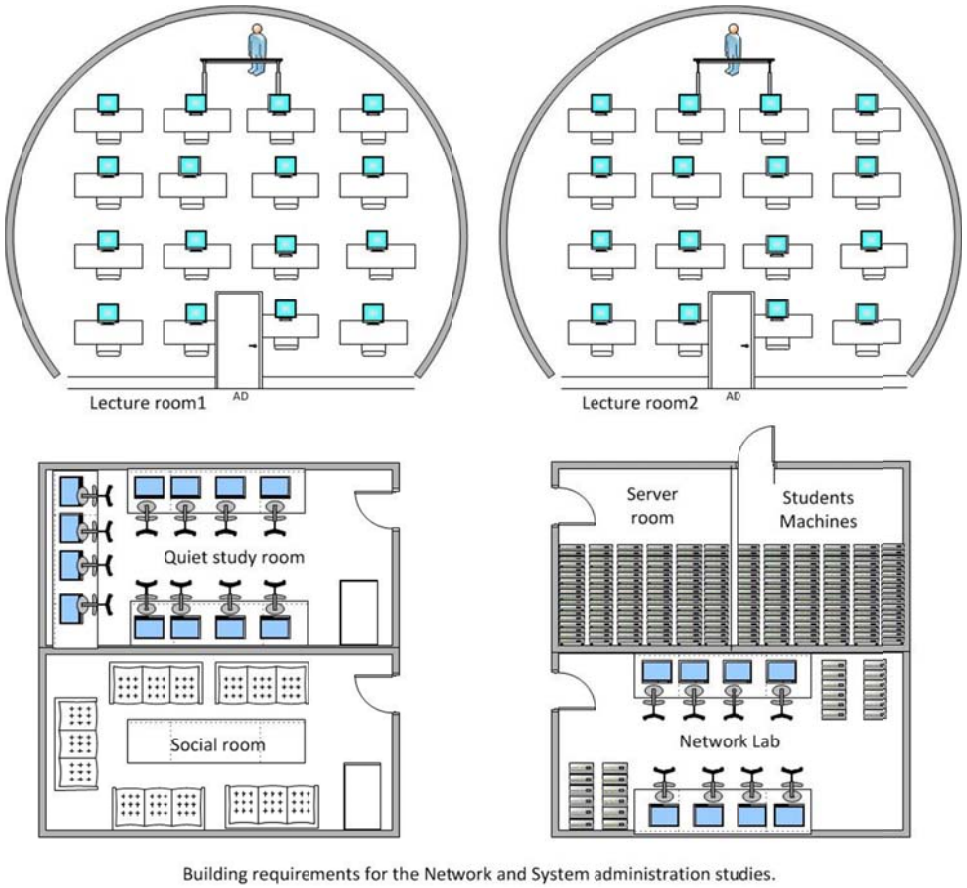

Figure 5.1. Facilities for the NSA program

Figure 5.2. Headline related to power problems in Pakistan

Because of this, the masses are suffering, and even educational institutes are not exempted from power outages. Since Pakistan is a country facing a huge problem regarding its electricity demand, therefore one must focus on planning for the power needed for all the equipment to run all of the time. Therefore, UPC devices are needed to handle the intermittent short power outages, and a generator is necessary for the longer power outages.

5.3 CONNECTIVITY

Network and system administration studies are all about connectivity and services. From the first day, students need to connect to their virtual machines, from within the campus or from outside the campus remotely. Therefore, it will be a requirement to build an internet infrastructure for this program that students can start work on their study tasks without any problems in connectivity. For this reason, redundant connections to the Internet are vital.

5.4 INVESTMENT AND FINANCE CONSIDERATIONS

The objective of providing a master's degree program that brings innovation and research at educational institutions in the country is strongly linked with the investment made into the education sector. In this way, an institute can compete and progress along with other well reputed institutes in the world. Network and system administration studies are quite investment-demanding as there are many resources needed to allocate to students. Students will progress through different courses, and all of those courses need appropriate resources so that students can perform their lab work properly and avail themselves of the opportunity for hands-on experience in their respective studies.

Generally to start with such degree program one should consider a sizeable investment for the required facilities:

- Building and furnishings
- Computing equipment: workstations, servers, networking, multimedia
- Power Backup
- Faculty Expense
- Maintenance and upgrades
- Professional memberships

There are different sets of rooms needed to initiate such degree program. It's the most important step to include it to the plan. There is need of lecture rooms,

faculty offices, system administration lab, networking lab and quiet room. Altogether there is need of 15 rooms required according to the type and purpose of room.

5.4.1 EQUIPMENT

Network and system administration studies are all about computer equipment. This includes many things like PCs, servers, networking equipment, multimedia equipment, power backup and so on. The estimated cost of the important equipment required to initiate NSA studies is given in the following table:

Resource	Quantity	Estimate (PKR)
Servers: coursework	2	1,200,000
Servers: administrative/backup	10	1,000,000
SAN 10 TB	2	2,000,000
Routers	12	1,100,000
Switches	15	1,000,000
Cabling	As needed	100,000
WiFi Access Points	As needed	500,000
Raspberry Pi with cases	30	260,000
PCs for NSA2 students	30	3,000,000
LCD Monitors	30	300,000
LCD TVs	4	140,000
Printers (network)	2	210,000
Printers standalone	5	100,000
UPS 1/Rack	5	300,000
Generator	1	225,000
Internet connectivity ISP	2	40,000
Other supplies	As needed	100,000
Approximate total cost		**11,575,000 PKR ~685,000 NOK**

5.4.2 FACULTY

NSA studies need experienced and well trained professionals in the field of Network and System Administration as its faculty members. One can start this degree program with at least three professionals who are significantly skilled in UNIX/Linux based systems, services and security. Moreover they also should have hands on experience in advance networking course. There will be a need for student assistants who can assist students when needed. Recruitment of staff also requires a good budget according to current trends in the country. Furthermore, all the expenses to keep faculty running also needed to be considered.

5.4.3 MAINTENANCE AND UPGRADES

NSA studies require equipment maintenance and upgrading on an ongoing basis. Replacement and upgrading of hardware equipment will be required as more and more advanced technologies become available. Electrical equipment may stop working and its maintenance and eventual replacement should be focused on when considering the overall cost that this degree program requires.

Updates also occur on the software side. The program will need to update their software which require licensing. For example, Snort is an important intrusion prevention system which requires the latest snort rules to work efficiently and make one's network system secure. Snort is an open source tool, but snort rules may need licensing. Also, in some cases proprietary solutions will need to be purchased and licensed. All these things are part of overall costs when planning to initiate degree program in network and system administration.

Sometimes, software updates will also require the latest hardware equipment. For example, PROXMOX is an important tool for virtualization which only supports 64 bit architecture processors. One would have to switch from 32-bit to 64-bit processing to use such a tool.

5.4.4 PROFESSIONAL MEMBERSHIPS

Studies in any discipline cannot be highly fruitful if teaching material and technologies adopted are not up to date. There are many different organizations throughout the world which conduct conferences and produce publications. One can get benefit from such organizations. They often require membership to have access to those conferences and the publications. The following are the two organizations which are quite active in the field of computing and system administration for UNIX-based operating systems:

- The USENIX Association came into being in 1973. Its focus is study and development of UNIX-based computing. It has earned a good name and held in high regard among the computer professionals, researchers, developers and organizations who work on computer operating systems. It publishes many journals and paper which are quite significant for the industry and that institutes need in order to keep up with the latest work.

- LISA is a Special Interest Group of the USENIX Association. It holds conferences and training for professionals. These introduce the latest tools, techniques, information and services relevant to system administrators or organizations.

Chapter 6

Conclusion and future work

This thesis has been carried out substantial analysis and practical work to explore the possibility of initiating a master's level program in network and system administration in Pakistan. After a glance over my experience, I managed to write such a document which can help out Pakistan's needs in producing quality network and system administrators. Recent technical education regarding NSA has been evaluated and examined to find where there is a need of improvement. After finding the current programs offered in educational institutes, it was noticed that no NSA studies at master's level is available in any educational institute in Pakistan. Existing NSA programs have been also evaluated worldwide to find out the mechanism to initiate similar type of studies in Pakistan. The curriculum structure along with course descriptions is proposed in the thesis work.

6.1 ANALYSIS AND FUTURE WORK

The technologies needed to set up the required lab environments have been discussed. Computing resources and strategies along with their practical demonstrations is presented in this thesis. Several experiments were performed to find out the usability of a small credit card size computer named Raspberry Pi. Tests to check VNC connection, interacting with web applications and streaming video were carried out. It is found it is quite efficient in performing different tasks related to network and system administration. Those experiments compared a standalone PC to the Raspberry Pi, and the difference between them was negligible. Therefore, the Raspberry Pi has shown its capability to assist NSA students in performing their normal tasks in a graphical environment.

Unfortunately, only a single Raspberry Pi device was available for this research/ There are number of other experiments that can test more the scalability of the Raspberry Pi in a realistic lab environment that should be performed before a final decision is made.

A lab design was present virtualization with the help of Xen and MLN. Installation and configuration has been taken place. It was felt that installation and configuration was quite exhausting some times as no online updates regarding documentations and support is available for MLN. Also, MLN does not completely support KVM, another virtualization solution for Linux is becoming more popular and common than Xen. Therefore, future work should involve MLN support for KVM.

Facilities and initial cost requirement were also considered. The cost estimates will also need to be updated whenever a program is actually started.

Master studies in Network and System Administration has been evaluated to initiate in Pakistan. This includes huge workout in managing all the things. It will be crucial to note the number of students recruited in the beginning of studies for the first time. There is possibility of frustration during this early time if there are too many students at the same time when one needs to manage and troubleshoot different labs and environments. Therefore it would be good to start with limited number of students, and later on, after gaining a firm grip over the management, one can increase the number of students.

This project is written with the consent to fulfill my rights over my country, therefore it is intended to conduct seminars in different educational institutes and governing bodies responsible for higher education in Pakistan. This has been started while working on this thesis. Two seminars have been conducted in the Government Post Graduate College Mandian Abbottabad and at Hazara University Pakistan (see Figure 6.1). There was great enthusiasm from students and faculty over bringing such studies of network and system administration into Pakistan. I am quite confident I can bring it into life.

Figure 6.1 The author conducting a seminar at Hazara Univeristy

References

[1] "Problems and prospects of technical education in Pakistan," Dr. IFTIKHAR HUSSAIN SHAH, University of Arid Agriculture, Murree Road, Rawalpindi / Institute of Education and Research.

[2] There are many websites devoted to questions and answers from previous exams. Some are free and some charge a fee. See for example www.pass4sure.com/certification/ccna-dumps.html and www.examcollection.com.

[3] news.cnet.com/9-year-old-earns-accolade-as-Microsoft-pro/2100-1012_3-5793614.html?type=pt&part=inv&tag=feed&subj=news.

[4] Higher Education Commission, Pakistan, www.hec.gov.pk/INSIDEHEC/DIVISIONS/QALI/OTHERS/RANKINGOFUNIVERSITIES/Pages/CategoryWise.aspx.

[5] See education.stateuniversity.com/pages/1146/Pakistan-HIGHER-EDUCATION.html.

[6] Mark Burgess and Karst Koymans, "Master Education Programmes in Network and System Administration," *Proceedings of the 21st Large Installation System Administration Conference (LISA '07), Dallas, TX* (Berkeley, CA: USENIX Association, 2007) 215-29.

[7] C.S. Kacoroski and A. Tsalolikhin, "Degree Programs in System Administration," poster presented at: LISA 2012: 26th Large Installation System Administration Conference (San Diego, CA), 12 Dec 2012.

[8] www.cs.fsu.edu/current/grad/cnsa_ms.php.

[9] www.UiOA.no/english/studies/programmes/nsa-master.

[10] studiegids.uva.nl/web/uva/2011_2012/en/p/171_133015.html.

[11] www.rit.edu/emcs/ptgrad/_program_detail.php?id=53.

[12] www.ist.rit.edu//assets/pdf/MS_NSA_Handbook.pdf.

[13] www.csu.edu.au/courses/postgraduate/networking_systems/course-overview#.UUXPPRfI0tB.

[14] See www.theresearchpedia.com/research-articles/benefits-of-virtualization-for-education-industry; www.techrepublic.com/whitepapers/virtualization-in-education/332889; www.infoworld.com/d/virtualization/top-10-

benefits-server-virtualization-177828?page=0,2; software.intel.com/en-us/articles/the-advantages-of-using-virtualization-technology-in-the-enterprise.

[15] mln.sourceforge.net.

[16] www.raspberrypi.org/about.

[17] An example is Maker Shed, www.makershed.com/Raspberry_Pi_Starter_Kit_Includes_Raspberry_Pi_p/msrpik.htm. The Raspberry Pi device used in this thesis was obtained from this vendor.

[18] www.virtualbox.org

Appendix A

MLN example

```
# mln register_template -m "NSA template" /tmp/nsa_lin.ext3
Copying nsa_lin.ext3
No need to extract.
# mln list_templates
All available templates:
Name:               Real name:                Size (Bytes)
ubuntu-server.ext3  ubuntu-server-V0.1.ext3   158334976
nsa_lin.ext3        nsa_lin.ext3              314574848
ubuntu-desktop.ext3 ubuntu-desktop-V0.1.ext3  1469054976
Debian-4.0.ext3     Debian-4.0-V1.0.ext3      314574848
# cd ../files/root
# cat nsa.mln
global {
  project nsa
}
superclass common {
      template nsa_lin.ext3
      nameserver 10.0.0.100
}
host gw {
     superclass common
     memory 1024
     network eth0 {
        address 10.0.0.1
        netmask 255.255.255.0
       }
}
host client {
     superclass common
     memory 750M
     template Debian-4.0-V1.0.ext3
     network eth0 {
        address 10.0.0.2
        netmask 255.255.255.0
        }
}
```

```
switch lan { }
# mln build -r -f nsa.mln
Service hosts:
-> Switch lan
Bridge: lan.nsa
Xen enabled
++ printing Superclasses ++
--> Superclass common
common: template = nsa_lin.ext3
++ printing Hosts ++
--> Host client (XEN)
client: nameserver = '10.0.0.100'
client: superclass = 'common'
client: memory = '750M'
client: template = Debian-4.0-V1.0.ext3
printing network
client: Network interfaces
Interface eth0
 address: 10.0.0.2
  netmask: 255.255.255.0
--> Host gw (XEN)
gw: nameserver = '10.0.0.100'
gw: superclass = 'common'
gw: memory = '1024M'
printing network
gw: Network interfaces
Interface eth0
 address: 10.0.0.1
  netmask: 255.255.255.0
+---> BUILDING nsa
Saving Config file : /opt/mln/projects/root/nsa/nsa.mln
---> Building switch lan
---> Building XEN host client
Template size: 314574848
New size: 262144000
WARNING: Template is larger then new filesystem!
Adjusting size to fit template.
Filesystem size: 300M
Building filesystem: copying, growing, fsck, resize, done
---> Building XEN host gw
Template size: 471859200
New size: 262144000
WARNING: Template is larger then new filesystem!
Adjusting size to fit template.
Filesystem size: 450M
Building filesystem: copying, growing, fsck, resize, done
+---> STARTING VM FOR FILESYSTEM CONFIGURATION (1 of 1)
Service hosts:
---> Configuring XEN host client
```

```
Adding interface eth0
Importing modules from: /tmp/mln/modules/2.6.16-xen
---> Configuring XEN host gw
Adding interface eth0
Importing modules from: /tmp/mln/modules/2.6.16-xen
+---> SHUTTING DOWN VIRTUAL MACHINE
+---> PROJECT nsa FINISHED
# mln status example1
nsa host client down
nsa host gw down
nsa switch lan down
# mln start -p nsa
Setting up lan
Starting client.nsa in screen
Starting gw.nsa in screen
```