Addressing the Digital Divide through the Implementation of a Wireless School Network

A Mini-Study project presented to the Nelson Mandela Metropolitan University

in partial fulfillment of the requirements for the degree of Masters in Business Information Systems

By

Creswell Du Preez

Supervisor: Johan van Niekerk
ACKNOWLEDGEMENTS

I would like to acknowledge the following people for their contributions to this study project:

1. Johan van Niekerk, my supervisor, for his support and patience during the compilation of this mini dissertation.

2. Chris Nel, Director of ICT Services, NMMU, for funding the pilot project.

3. The Teachers of:
   a. Westville Senior Secondary School
   b. Chapman High School
   c. Triomf Primary School
   d. Cebilihle Primary School

4. Helena Oosthuizen, Education Department, NMMU, for her insights into the current education system in South Africa.
To my wife René and kids Kyle, Danielle and Caleb

Thank you for your patience and love.

“For Laura and Gavin, you are missed.”
God Get’s all the Glory!
# TABLE OF CONTENTS

Abstract .................................................................................................................. 1  
Chapter 1 – Introduction ......................................................................................... 3  
  1.1 Introduction .................................................................................................. 3  
  1.2 ICT as a Possible Education Aid in South Africa ........................................ 4  
  1.3 The Digital Divide ....................................................................................... 6  
  1.4 Problem Statement ...................................................................................... 8  
  1.5 Objectives ................................................................................................... 10  
  1.6 Methodology ............................................................................................... 11  
  1.7 Conclusion .................................................................................................. 15  
  1.8 Chapter Outline .......................................................................................... 16  
Chapter 2 – Education in South African Schools .................................................... 17  
  2.1 Introduction ................................................................................................ 17  
  2.2 Global ICT Trends in Education ................................................................ 18  
  2.3 South African ICT Trends in Education ..................................................... 19  
  2.4 The South African Educational Environment .......................................... 24  
  2.5 Conclusion .................................................................................................. 26  
Chapter 3 – Communications' Technologies ............................................................. 27  
  3.1 Introduction ................................................................................................ 27  
  3.2 Communications' Technologies .................................................................. 27  
    3.2.1 Analogue Modems .............................................................................. 29  
    3.2.2 ISDN ................................................................................................. 32  
    3.2.3 Leased Lines / Dedicated Lines .......................................................... 33  
    3.2.4 DSL .................................................................................................. 34  
    3.2.5 Mobile Telecommunications' Technology ........................................ 38  
    3.2.6 802.11 Based Wireless Networks .................................................... 42  
  3.3 Synopsis of Communications' Technologies .............................................. 46  
  3.4 Conclusion .................................................................................................. 47  
Chapter 4 – Wireless Communications' Technology ............................................... 48  
  4.1 Introduction ................................................................................................ 48  
  4.2 History ......................................................................................................... 49
6.3 Conclusion ........................................................................................................ 84
6.4 Future Research .................................................................................................. 85
Bibliography ............................................................................................................ 86
Table of Figures

Figure 1 – Communications’ Technology Comparison Chart ........................................... 46
Figure 2 - Wireless LAN Throughput by IEEE Standard (Intel Corporation, 2008) 52
Figure 3 - Wireless LAN Standards and Amendments (Intel Corporation, 2008) .. 54
Figure 4 - Relative Distances from the Missionvale Campus of the NMMU ........... 67
Figure 5 - Google Earth Map of Schools’ Locations Relative to the Missionvale Campus........................................................................................................................................... 67
Figure 6 - Pilot Network Cost Breakdown........................................................................ 69
Figure 7 - MikroTik Antenna at Chapman High School in Port Elizabeth, South Africa .......................................................................................................................................................... 71
Figure 8 - MikroTik Antenna at Westville Senior Secondary School in Port Elizabeth, South Africa .......................................................................................................................................................... 72
Figure 9 - Wireless School Network Topology .................................................................. 72
Figure 10 - WSN Hub and Spoke Topology ..................................................................... 74
Abstract

Societal trends have changed more in the last decade than they have in the last century. This is particularly prevalent in the education environment. Concepts such as *Lifelong Learning* (the continued learning/educating of an individual throughout his/her lifetime), *New Competencies* (technology that is now part of almost every skill in the workplace) and *Telecommuting* (more people working from home rather than traditional offices) have become common-place today (Twigg, 1996, pp. 1-2). Education delivery needs to provide for these societal changes in order to ensure competent individuals pass on to the next level of education and ultimately to the work force. With key trends in technology such as *Digitization, Maturation* and *Disintermediation* becoming common in the workplace, education delivery must address the “Digital Divide”. (Twigg, 1996, pp. 2-3).

Historically, schools in South Africa have used traditional teaching methods that have stayed the same for the last century. Educational institutions in South Africa, in particular, the previously disadvantaged schools of the Eastern Cape, face various challenges such as the dwindling ability to collect school fees from parents of scholars and declining financial support from the government. In Chapter Seven of the *Draft White Paper on e-Education*, which was gazetted on 26 August, 2004, the DoE, as part of its implementation strategies, urged the private sector to respond by implementing ICT initiatives nationwide. Phase 1 of the strategy advocated that “Institutions are connected, access the internet and communicate electronically.” (Department of Education, 2004, pp. 37-40).
This dissertation shows that it is feasible to create a communications' network among South African schools. It is believed that such a network can add great value to the education system in South Africa. The potential for this network to address the gap in the Digital Divide is enormous. This dissertation examines various ICT communications' technologies and isolates wireless communications' technology as best suited for this purpose, due to the speeds offered by the technology and the cost structure associated with it. A case study examines a pilot installation of the network and endeavours to prove the concept.
Chapter 1 – Introduction

“We are aware of the fact that South Africa is characterised by enormous contrasts and imbalances ranging from highly developed to under developed areas; from high tech on the one hand to no tech on the other. The challenge facing us is that we close this gap and do it soon” (Communications Minister, Ivy Matsepe-Casaburri) (Mogale, 2005).

1.1 Introduction

Modern commerce and governance are placing increased demands on regional economies and communities, which find them adjusting constantly to the demands of these new orders of commerce and governance. Part of this is the paradox brought about by using information and communication technologies (ICT) to achieve these commercial and governance objectives. On the one hand, ICT offers potential increases in social, economic and cultural capital, but on the other, poses a threat to regional economies and communities as those responsible for ICT implementations favour centralised commerce and services away from them (Marshall & Taylor, 2005, p. 5).

This dissertation focuses on the use of ICT as an education aid which could enable regional communities to become part of this rapidly changing environment. It endeavours to show that wireless technology is a viable and cost-effective mechanism to meet the South African Department of Education’s (DoE) objective of establishing a communications’ network among schools (Department of Education, 2004).
1.2 ICT as a Possible Education Aid in South Africa

Societal trends have changed more in the last decade than they have in the last century. This is particularly prevalent in the education environment. Concepts such as *Lifelong Learning* (the continued learning/educating of an individual throughout his/her lifetime), *New Competencies* (technology that is now part of almost every skill in the workplace) and *Telecommuting* (more people working from home rather than traditional offices) have become common-place today (Twigg, 1996, pp. 1-2).

Education delivery needs to provide for these societal changes in order to ensure competent individuals pass on to the next level of education and ultimately to the work force. With key trends in technology such as *Digitization, Maturation* and *Disintermediation* becoming common in the workplace, education delivery must address the “Digital Divide”, stressed by Matsepe-Casaburri (Twigg, 1996, pp. 2-3).

Historically, schools in South Africa have used traditional teaching methods that have stayed the same for the last century. Educational institutions in South Africa, in particular, the previously disadvantaged schools of the Eastern Cape, face various challenges such as the dwindling ability to collect school fees from parents of scholars and declining financial support from the government.

In Chapter Seven of the *Draft White Paper on e-Education*, which was gazetted on 26 August, 2004, the DoE, as part of its implementation strategies, urged the private sector to respond by implementing ICT initiatives nationwide. Phase 1 of the strategy advocated that “Institutions are connected, access the internet and communicate electronically.” (Department of Education, 2004, pp. 37-40).
The DoE also identifies the following learning outcomes in its National Curriculum Statements – Grades 10-12:

- **“Learning Outcome 1: Hardware and System Software**
  The learner is able to demonstrate an understanding of and competently operate computer-based technologies.

- **Learning Outcome 2: e-Communication**
  The learner is able to apply creative uses of different computer technologies to facilitate electronic communication.

- **Learning Outcome 3: Social and Ethical Issues**
  The learner is able to critically analyse the impact of computer technologies on socio-economic, environmental, political and ethical issues.

- **Learning Outcome 4: Programming and Software Development**
  The learner is able to design, implement, test and deliver efficient and effective solutions to problem situations” (Department of Education, 2003, pp. 12-13).

The DoE has set clear guidelines for ICT in South African schools: the education system needs a communications’ network to facilitate e-communication, whether for administrative purposes or education delivery.

"Unless we get a greater level of access AND adoption of information and communication technology (ICT) for education and development at community level, we will miss the opportunity to turn the "Digital Divide into a digital opportunity for all, particularly for those who risk being left behind and being further marginalised" (Declaration of Principles, WSIS-03/Geneva/Doc/4-E, [Principle 10]) (Marshall & Taylor, 2005).
1.3 The Digital Divide

To a large extent, modern civilisation can be defined by the great inequalities between the wealthy and the poor. “The fight against poverty and inequality is one of the greatest challenges facing mankind in this millennium” (United Nations, 2008). One of these challenges that need to be addressed is commonly known as the “Digital Divide”.

The Digital Divide refers to the gap between those individuals who benefit from digital technology and those who do not (ITU, 2001).

Digital Divide researchers have spent a great deal of time figuring out that the real issue is not so much about access to digital technology, but about the benefits which can be derived from it. The upper-to-middle classes appear to have high quality access to digital technology because the profit motive pushes technologists to work hard at creating "solutions" designed specifically for them. This tends to ignore the poor because the assumption is that designing solutions for them will not be profitable. The result of this is that even where the poor are provided with access to digital technology, it is of low quality. Additionally, the digital technology they do have access to is often of a design that ends up being harmful rather than advantageous. This, in turn, widens the Digital Divide (Digital Divide Organization, 2007).

In his paper “Seven Bridges over the Global Digital Divide”, Foulger (Foulger, 2002) cites seven bridges which can be used to “span the Digital Divide” as:

1. **Social and Legal Constraints**, including censorship and denial of access: Certain countries attempt to strictly control what is made available to users by use of technologies like proxy servers, etc. This has performance and currency of data issues.
It also limits the range and breadth of information being made available to users, provided they have access to the information in the first place.

2. **Economic Priorities**: Some countries are struggling to provide the basic necessities to the population and have no budget to spend on ICT infrastructure.

3. **Basic Infrastructure**, including building and power resources: Many countries lack the necessary infrastructure to generate their own power and can only accommodate computers in the bigger cities. Rural areas generally make use of solar power and fuel cells to provide workable solutions; however, high bandwidth network infrastructure requires the backbone provided by the power infrastructure.

4. **Literacy and Language**: The internet is not only unusable by people who cannot read, but also by those who do not know one of the primary languages of the internet. Literacy, therefore, presents a problem at several levels. Even those individuals, who can read and write, cannot always understand computer manuals written in their own language, let alone in a language they do not understand.

5. **Network Infrastructure and Connectivity**: One of the major benefits of using computers is as communications tools. Networking infrastructure makes this possible. Networks can be used to connect businesses, schools, government departments and service providers together to form one big communications’ network. This infrastructure is expensive and requires specific skills to maintain, which are sometimes not available to certain growing economies.

   It is this section which is the focus of this dissertation: to investigate the feasibility of such a network among schools in the South Africa’s Eastern Cape Province.

6. **Computer Resources**: Computers cost money, not only to purchase, but also to maintain. Most computers have a five-year life-cycle after which they become obsolete and have to be replaced.
Although the cost of high-end computers has come down over the last few years, many users in struggling economies find it difficult to afford one. Many users will also only consider buying a computer only after they have had some sort of training.

7. **Choice**: Even if computers are given away freely and the internet is available to all, some people will still choose not to use them.

(Foulger, 2002)

Any attempt to comprehensively address the ICT education needs of South African schools will have to consider all the above-mentioned bridges. However, this dissertation focuses exclusively on the fifth one (Network Infrastructure), and examines how a school network in South Africa can aid in bridging the gap in the Digital Divide.

### 1.4 Problem Statement

As part of the transformation process in South Africa, the DoE has various initiatives to make schools more Information-Technology literate. Many of these initiatives require a communications’ network, as discussed by Foulger, in order to be successful. Currently, no such network exists. This lack of a communications’ backbone is especially evident in previously disadvantaged schools which do not have the means to establish this symbiotic communications’ platform which has the potential to reduce operating costs and increase the level of education delivered. These schools, although operating within the DoE’s rules and guidelines, still function independently and could benefit from collaboration in most areas. Very few previously disadvantaged schools have the capacity to pay for operating expenses such as internet bandwidth, etc. These factors add to the increasing gap in the Digital Divide.
This dissertation forms part of a project which aims to address this lack of a communications’ backbone in previously disadvantaged schools and will specifically focus on the following research question: “How can an affordable communications’ backbone, which satisfies the DoE’s curriculum requirements, be established among previously disadvantaged schools?”

This dissertation will endeavour to show that this communications’ backbone has the potential to be beneficial in the following areas:

- **University Multi-disciplinary Research**
  This project has the potential for other disciplines such as Engineering, Marketing and Arts, etc, to benefit from its research findings.

- **Remote Administration and Technical Support**
  Schools which form part of this communications’ network could be administered remotely via VPN (Virtual Private Network) access, allowing software updates and general networking audits by interested parties.

- **Telecommunications and Video Conferencing**
  By implementing VOIP (Voice over IP), telephone costs among these schools could be reduced, if not eliminated. Video conferencing among schools could be realized and this could have a major impact on education delivery.

- **Messaging and Faxing**
  A common email POP/IMAP server could be provided to allow schools to send emails to each other at no cost. Scholars and staff could be given email addresses for communication purposes. Messaging between schools would allow for new and inventive workflow systems. Fax-to-email gateways could be configured to ensure that schools receive faxes sent to their designated email addresses.
• **Knowledge Sharing and Collaboration Services**
  Schools would immediately have access to all the resources that the Nelson Mandela Metropolitan University in Port Elizabeth, South Africa makes available to them. These would include access to the online library systems and guest speakers, etc. By implementing knowledge-sharing and collaborating on software, schools could pool resources and work on projects together. Systems like central content management and online class registers, which allow up-to-date class/school attendance figures, could be put in place. Schools would benefit from initiatives such as video-streaming technologies, which allow a teacher at one school to address a class at another. This network could aid e-learning initiatives among schools, the DoE and other interested parties.

• **Financial Spin-offs for Schools**
  Schools linked to this new network would have the communications’ backbone needed to become proper research stations, and, at a nominal charge to their community users, be able to generate an income from the hiring of these facilities.

1.5 **Objectives**

The overall objective of this research is to design and implement a proof-of-concept wireless network among previously disadvantaged schools in the city of Port Elizabeth. To attain this objective, the following sub-objectives will have to be met:

- Investigate the needs of the South African education delivery system and the DoE’s objectives;
- Investigate communications’ technologies in terms of cost, speed and flexibility;
- Develop a model for the implementation of a communications’ network these schools;
- Implement the proposed model in the form of a pilot as proof of concept.
1.6 Methodology

This dissertation is a mini-study project presented to the Nelson Mandela Metropolitan University in partial fulfillment of the requirements for the degree of Masters in Business Information Systems and as such do not require a dedicated methodology chapter. However, to ensure proper rigor the methodologies adhered to during this study will be briefly outlined.

This dissertation makes use of two primary methodologies: Design Science and Case Studies. In addition to this, literature surveys and argumentation has also been widely used. Case studies represent intensive, detailed description and analysis of a particular project or programme in the context of that project’s environment. This makes them a valuable way to share the experiences of others who have travelled the road before, and are extremely useful for encouraging discussion about best practices and problem-solving strategies. (Freedom Toaster, 2008) Case studies usually follow certain structures: this dissertation adopts the British Educational Communications and Technology Agency (BECTA, 2006, p. 1) guidelines, which follow this general structure:

- Title
- Summary or abstract
- e-Strategy linkage
- Contents
  - Admin functions
  - Organisational information
  - Introduction
  - Barriers and enablers
  - Impact, outcomes and sustainability
  - Transferability and portability
  - Lessons learnt
In addition, it also uses Creswell (Creswell, 2007), which follows the following structure:

- Entry vignette
- Introduction
- Description of the case and its context
- Development of issues
- Detail about the selected issues
- Assertions
- Closing vignette.

The design–science component of this dissertation is based on the guidelines of a design-science project as described by Hevner (Hevner, 2004), who states that two paradigms characterise most of the research in the information-systems discipline: behavioural science and design science. Where the behavioural-science paradigm seeks to develop and verify theories that explain or predict human or organisational behaviour, the design-science paradigm seeks to extend the boundaries of human and organisational capabilities by creating new and innovative artefacts. The design-science paradigm is fundamentally a problem-solving paradigm (Hevner, 2004, pp. 75-76). Hevner identifies the following seven guidelines for design-science in information-systems research:

**Guideline 1: Design as an Artefact**

Hevner states that design-science research must produce a viable artefact in the form of a construct, a model, a method, or an instantiation.
He also states that the artefact must address a specific problem (Hevner, 2004, p. 82). In the case of this dissertation, the model for the Wireless School Network is the artefact.

**Guideline 2: Problem Relevance**

The objective of design-science research is to develop technology-based solutions to important and relevant business problems (Hevner, 2004, p. 84). This dissertation argues the problem relevance in Chapter 2.

**Guideline 3: Design Evaluation**

The utility, quality and efficacy of a design artefact must be rigorously demonstrated via well-executed evaluation methods (Hevner, 2004, p. 85). The model for the wireless school network will be constantly evaluated by the teachers and scholars of the piloted schools. This feedback will be used to tweak and make changes to the network, where necessary. The case-study component of this dissertation also serves as a form of evaluation for the proposed design.

**Guideline 4: Research Contributions**

Effective design-science research must provide clear and verifiable contributions in the areas of the design artefact, design foundations, and/or design methodologies (Hevner, 2004, p. 87). A high-speed wireless network among government schools has never been implemented before. The contribution of this dissertation shows how wireless technology could assist in migrating schools into the 21st century and potentially reduce the gap in the Digital Divide.
**Guideline 5: Research Rigor**
Rigorous methods should be applied in both the construction and evaluation of the design artefact (Hevner, 2004, p. 87). The design of the network in this dissertation follows a methodology which is used in industry when installing wireless networks. The method used was also a form of prototyping.

**Guideline 6: Design as a Search Process**
The search for an effective artefact requires utilizing available means to reach desired ends while satisfying laws in the problem environment (Hevner, 2004, p. 88). Due to the fact that this network was used as a pilot project which worked, shows that a search process for the most suitable technology was conducted (as described in Chapter 3), and that the selected technology was the best fit.

**Guideline 7: Communication of Research**
The research must be presented effectively to technology-oriented as well as management-oriented audiences (Hevner, 2004, p. 90). This dissertation has been communicated to various audiences. The technology-oriented audience was informed of the technical aspects of the wireless pilot project. These individuals have already identified other uses for the technology as well as additional research projects which will stem from this one. Various management-oriented stakeholders have shown keen interest in the project and have expressed interest in formulating a strategy to use this model in other parts of the country. This dissertation itself, and any subsequent publications that will possibly stem from it, also serve to communicate the results.
1.7 Conclusion

This chapter briefly introduced the Digital Divide and how this phenomenon affects Southern African schools. It also highlighted the clear objectives, as set out by the South African DoE, for education delivery and the need for an interconnected education network. The design and implementation of such a network was identified as the primary objective of this project. The rest of this dissertation will firstly examine various alternatives, and will then propose a design, based on wireless technology. This design will then be implemented in a case-study to prove its feasibility.
1.8 Chapter Outline

Chapter 2 – Education in South African Schools focuses on international education trends and compares the current South African education system to them. It endeavours to highlight the South African DoE’s objectives for ICT and focuses on “Learning Outcome 2: e-Communication”, arguing that a communications’ network among schools could benefit education delivery.

Chapter 3 – Communications’ Technologies investigates various communications’ technologies available to the South African public in terms of advantages, disadvantages, cost, speed and flexibility. This chapter highlights wireless technology as a possible communications’ medium for the communications’ network discussed in Chapter 2.

Chapter 4 – Wireless Communications Technology investigates wireless technology in more detail and concentrates on the 802.11a, 802.11b, 802.11g and 802.11n wireless standards. This chapter confirms the finding of Chapter 3 that wireless technology is, indeed, the preferred communications’ medium for the communications’ network discussed in Chapter 2.

Chapter 5 – A Case Study: Implementing a Wireless Network among Four schools and the NMMU examines an installed pilot network among four previously disadvantaged schools and the Missionvale campus of the NMMU, Port Elizabeth, South Africa. This chapter proposes a model for a wireless network as well as the sustainability thereof. It also examines the challenges associated with the use and implementation of the network.

Chapter 6 – Conclusion summarises this dissertation. It revisits the methodology followed and investigates whether all the objectives set out for this dissertation have been met.
Chapter 2 – Education in South African Schools

The aim of this chapter is to further highlight the problem area and provide additional context for the proposed study by examining the South African educational environment, specifically the possible role(s) of ICT technology to reduce the Digital Divide.

2.1 Introduction

“A global revolution is currently taking place in education and training. It is driven by the changing nature of work, the realities of the information age, new global partnerships and an awareness of the need for equal distribution of educational opportunities” (DoE, 2004, pp. 1-10).

Societies are constantly changing; this is particularly prevalent in the education environment. Education is no longer perceived to be a once-off stage in life; rather, it is seen as a process that continues throughout an individual’s lifetime. This concept is called Lifelong Learning. Another concept, called New Competencies, suggests that technology is now part of almost any skill needed in the work place and Telecommuting (more people are working from home rather than traditional offices), have become common-place today (Twigg, 1996, pp. 1-2).

Education delivery needs to provide for these changes in society in order to ensure competent individuals are passed on to the next level of education and, ultimately, to the work force. Technology has become a vital link in most modern areas, with key trends such as Digitization, Maturation and Disintermediation becoming common in the work place.
Education delivery must, therefore, change and address the Digital Divide (as stressed by Communications Minister Ivy Matsepe-Casaburri) to keep up with this dynamic technological climate (Twigg, 1996, pp. 2-3).

This chapter concentrates on the global and local ICT expectations for education delivery and investigates how a communications’ network can play a part in bridging the Digital Divide as well as enhance the education delivery process.

2.2 Global ICT Trends in Education

The modern world is becoming more dependent on technology. Education leaders have no choice but to embrace ICT. ICT should not only be a separate tool to teach, but an integral part of the education-delivery process. “ICT can create new, open learning environments and has become instrumental in shifting the emphasis from a teacher-centred to a learner-centred environment; where teachers move from being the key source of information and transmitter of knowledge to becoming a collaborator and co-learner; and where the role of students changes from one of passively receiving information to being actively involved in their own learning” (UNESCO, 2005).

The role of ICT is described in the following manner by the United Nations Educational, Cultural and Scientific Organisation (UNESCO):

  ICT makes natural tools in education because of the simple and fundamental fact that learning is largely based on dealing with information. Listening, talking, reading, writing, reassuring, evaluating, synthesizing and analyzing, solving mathematical problems, memorizing verses and state capitals are all examples of off-computer information processing.
Even more importantly, ICT can be used for other types of information processing, previously marginal in the traditional school, but now becoming more and more essential, such as project planning, or the search for new information outside school textbooks, as well as in the processes of so-called creative writing (drawing, constructing). In many other school activities (such as sport, for example), different kinds of interaction among students can gain from using ICT. The human dimensions of ICT manifest themselves in providing powerful means to open dialogue, fruitful interaction, and synergy between a teacher and student or, rather, between Master and Apprentice, as well as among apprentices themselves – whether in close contact or by long distance.

Historically, information processing and communication have been major school activities. These occurred mainly between the teacher and student with the very modest external support of pencil, paper, and chalkboard. Now, the extensive use of computers, with versatile sensors, peripherals and extensions, allows teachers a whole new degree of sophistication and flexibility (UNESCO, 2005). The role of ICT in education is becoming more crucial in the South African context.

2.3 South African ICT Trends in Education

Historically, schools in South Africa have used traditional teaching methods (pencil, paper and chalkboard), which have stayed the same for the last century. Education institutions in South Africa face various challenges, in particular, the previously disadvantaged schools of the Eastern Cape. These challenges have been set out by the DoE and form part of their expectations for schools and teachers.
In its *National Curriculum Statement Grades 10-12 (General) – Information Technology*, the DoE lists the following principles as its foundation:

- Social transformation;
- Outcomes-based education;
- High knowledge and high skills;
- Integration and applied competence;
- Progression;
- Articulation and portability;
- Human rights, inclusivity, environmental and social justice;
- Valuing indigenous knowledge systems; and

It also states that the Critical Outcomes require learners to be able to:

- identify and solve problems and make decisions using critical and creative thinking;
- work effectively with others as members of a team, group, organisation and community;
- organize and manage themselves and their activities responsibly and effectively;
- collect, analyse, organize and critically evaluate information;
- communicate effectively using visual, symbolic and/or language skills in various modes;
- use science and technology effectively and critically, showing responsibility towards the environment and health of others; and
- demonstrate an understanding of the world as a set of related systems by recognizing that problem-solving contexts do not exist in isolation (Department of Education, 2003, p. 2).
Its Development Outcomes require learners to be able to:

- reflect on and explore a variety of strategies to learn more effectively;
- participate as responsible citizens in the life of local, national and global communications;
- be culturally and aesthetically sensitive across a range of social contexts;
- explore education and career opportunities; and
- develop entrepreneurial opportunities (Department of Education, 2003, p. 2).

In Chapter 2, the DoE defines Information Technology as focusing “on activities that deal with the solution of problems through logical thinking, information management and communications”, and also focuses “on the development of computer applications using current development tools.” Information Technology is seen as a subject that “develops awareness and an understanding of the social, economic and other applications of using computers” (Department of Education, 2003).

The *Curriculum Statement* continues by stating that the understanding of the principles of computing, etc., will be achieved when learners are able to:

- demonstrate an understanding of concepts, principles and knowledge of computers and computer applications in various disciplines;
- demonstrate an understanding of how computers impact on the management of natural resources, cultural values, socio-economic and human-rights development;
- critically analyse the impact of computers on ethical, social, economic and political relations;
- work competently in a dynamic computer-using environment which includes:
  - effective communication,
  - problem-solving approaches,
  - team work,
  - responsible use of technology,
  - precision and accuracy;
- demonstrate proficiency in the use of computers in managing and critically interpreting information;
- demonstrate how the creative uses of different computer technologies facilitate human interaction;
- show proficiency in selecting and customizing appropriate computer applications, hardware and media to provide and communicate innovative solutions across all sectors of society;
- design and program well-tested and user-friendly computer-based solutions to meet specific requirements; and
- prepare for a career path, higher education and lifelong learning, thus enabling learners to become effective members of a computer-using society (Department of Education, 2003, p. 9).

The DoE further identifies the following Learning Outcomes:

- Learning Outcome 1: Hardware and System Software
  The learner is able to demonstrate an understanding of and competently operate computer-based technologies.
- Learning Outcome 2: e-Communication
  The learner is able to apply creative uses of different computer technologies to facilitate electronic communication.
• Learning Outcome 3: Social and Ethical Issues
The learner is able to critically analyse the impact of computer technologies on socio-economic, environmental, political and ethical issues.

• Learning Outcome 4: Programming and Software Development
The learner is able to design, implement, test and deliver efficient and effective solutions to problem situations (Department of Education, 2003, pp. 12-13).

In Chapter Seven of the *Draft White Paper on e-Education*, which was gazetted on 26 August, 2004, the DoE, as part of its implementation strategies, urged the private sector to respond by implementing ICT initiatives nationwide (Department of Education, 2004, p. 37). It goes on to list, as a Phase I approach, that “Institutions are connected, access the internet and communicate electronically” (Department of Education, 2004, p. 40).

Although these expected outcomes are in line with world trends, a major gap exists in the implementation thereof. This dissertation is particularly concerned with “Learning Outcome 2: e-Communication”, as well as responding to the DoE’s gazette request for industry to get involved (Department of Education, 2004, p. 37).

As can be seen from the above extracts from the National Curriculum Statement, there is a major need for schools to communicate with each other. Currently no communications’ network linking schools exists. The educational environment currently does not match the DoE’s intended environment. The next section examines South Africa’s current educational environment.
2.4 The South African Educational Environment

A report released by the DoE earlier this year, highlighted that the school situation has improved considerably over the last 10 years. This report was generated by the National Education Infrastructure Management System (NEIMS). NEIMS is an electronic planning and management tool capturing various information including digital photographs of every school’s condition and the number of teachers and pupils. The report states that “overcrowding has been reduced, electricity installed and the general state of the country’s public schools has improved” (BuaNews, 2007, p. 1). The report, which focused on South Africa’s more than 28 742 public schools, mentioned the following, improvements:

- Overcrowded schools decreased by 51% in 1999 to 24% in 2006;
- Schools with electricity have increased from 11 174 in 1996 to 20 713 in 2006;
- Schools without running water have been reduced from 8 823 in 1996 to 3152 in 2006;
- Schools with no on-site toilets have been reduced from 3 265 in 1996 to 1 532 in 2006 (BuaNews, 2007, p. 1).

However, the department did mention that there was evidence of substantial backlogs remaining in the provision of facilities at schools and that the standards of these facilities were questionable. The department further stated that in some cases, facilities were degraded due to vandalism, neglect and inadequate maintenance, with at least 14% of schools, i.e., approximately 4 060, found to be in a “poor” condition and a further 12%, approximately 3480, in the “very poor” category (BuaNews, 2007).
As mentioned in Chapter 1, Eastern Cape schools are some of the worst in the country. This fact is confirmed by the report which stated that 40% of the province's schools were assessed as being in a poor condition, with the pressing needs being water and sanitation (BuaNews, 2007).

The report also highlighted that one of the major challenges facing schools is that as many as 68% of them do not have any computers. This is particularly relevant for what this dissertation aims to achieve.

NEIMS allows government to quantify and pinpoint those areas and schools needing attention. This data will be helpful in targeting the worst areas and spending resources on alleviating challenges.

ICT infrastructure cannot exist unless the physical infrastructure such as electricity and computers are present in these schools, which means that the DoE’s vision for ICT at schools is hampered by these challenges. But, even if this infrastructure is in place, there are still a few other challenges facing them. These are:

- In most schools, basic computer literacy is lacking. This is true, not only for the pupils, but also for their teachers;
- Most teachers' reference framework lacks basic IT terminology, because it has not been a part of their education;
- In most rural areas, teachers are afraid of trusting their money in an ATM, let alone prescribing a culture of electronic transacting;
- Students are typically more technologically inclined than their teachers;
- In a multi-cultural environment with various official languages, language barriers exist as most of computer terminology is in English.
The ICT issues facing the South African education system should not be seen in isolation (Foulger, 2002). Regardless of these challenges, the DoE’s vision for ICT in schools is clearly stated in the current chapter. The DoE has identified specific objectives and all schools have been mandated to achieve these objectives.

2.5 Conclusion

This chapter investigated the global trends of ICT in education and narrowed in on South African objectives as far as learning outcomes are concerned. It was shown that the DoE is committed to ICT development in schools and has asked industry and various other parties to launch initiatives to achieve just this. It is envisaged that an e-communication network among schools can assist in bridging the Digital Divide by assisting schools described as previously disadvantaged to embrace technology and expose pupils to ICT at an early age, thus satisfying the DoE’s curriculum requirements.

It was shown that the primary focus of this dissertation is in line with “Learning Outcome 2: e-Communication”, of the DoE’s Curriculum Statement (Department of Education, 2003, pp. 12-13), as well as responding to the DoE’s gazette request for industry to get involved (Department of Education, 2004, p. 37).

The remainder of the dissertation will thus attempt to show how an affordable communications’ backbone, that satisfies the DOE’s curriculum requirements, can be established among previously disadvantaged schools.
Chapter 3 – Communications’ Technologies

The aim of this chapter is to investigate various communications’ technologies available to the South African market and then select one of these as a possible candidate for establishing a communications’ network among schools.

3.1 Introduction

Various technologies can assist in addressing the Digital Divide. Communications’ technologies play one of the more fundamental roles as they act as the backbone for other ICT services. Various internet communications’ technologies are available to the South African public. This chapter endeavours to isolate the most favourable one, given the constraints of the South African context, and examines how it can support educational delivery.

3.2 Communications’ Technologies

“The growth and development of information and communication technologies (ICTs) has led to their wide diffusion and application, thus increasing their economic and social impact”. This is according to the Organisation for Economic Co-operation and Development, highlighting the trends in modern technology which have become common place in various aspects of modern living, with specific emphasis on education delivery and much-needed work skills (OECD, 2007).

In today’s high-tech world, humans tend to take technology for granted. People are constantly bombarded with technology in various guises. Very little seems to impress the new, technologically advanced generation of IT users.
In today’s world, the ability for computers to communicate is taken for granted. Using the internet is becoming as common as picking up the telephone and making a call.

Various technologies allow for such communication. This dissertation makes use of the approach described by Mayer (Mayer, 1947) to identify the most suited technology for a communications’ network.

1. **Understanding the problem**
   The introduction of this chapter highlights the usefulness of a communications’ network in aiding education delivery. The problem is to find the best-suited technology to achieve this.

2. **Devising a plan**
   Various communications’ technologies are available to the South African public. This chapter aims to evaluate these based on their **advantages** and **disadvantages** as well as the following criteria:

   1. **Cost**
      South African schools cannot afford high operating overheads and have virtually no funds available for expensive monthly ICT costs that such a communications’ network could potentially impose. The selected technology should be financially sustainable with virtually no monthly overheads.

   2. **Speed**
      This dissertation aims to show that the communications’ network could potentially show benefit in the following areas:
      - University Multi-disciplinary Research;
      - Remote Administration and Technical Support;
      - Telecommunications and Video Conferencing;
      - Messaging and Faxing;
Knowledge Sharing and Collaboration Services;
Financial Spin-off for Schools.
To achieve these goals, the selected technology would have to be fast, preferably with speeds in excess of 5Mbps (Megabits per second) to each school.

3. Flexibility
The selected technology should be easy to install, equipment should be readily available and easily maintained.

3. Reformulating or re-centering
Once the most favourable technology has been identified, it will then be examined separately in Chapter 4.

The most popular modes of electronic communication currently available in South Africa are listed below and will be individually examined and discussed in the following pages:

- Analogue Modems;
- ISDN (Integrated Services Digital Network);
- Leased Lines/Dedicated Lines;
- DSL (Digital Subscriber Lines);
- Mobile Telecommunications Technology;
- 802.11 Based Wireless Networks.

3.2.1 Analogue Modems

- History
The mere idea of a computer, let alone the ability for it to communicate, was thought to be a work of science fiction in the early 1950s. It was during this time that the North American Air Defense needed to transmit data.
It invested a lot of effort into transferring data over existing telephone wires. It was a success, and by the end of the 1950s, it was using modems (modulate/demodulate) to communicate.

The first commercial modem, however, was only available in 1962. AT&T developed it and called it the Bell 103. This first modem allowed full-duplex transmission and was capable of data rates of 300Bps (Bits per second). Shortly after the Bell 103, came the Bell 212, which reached speeds of 1200Bps. This new model employed a method of modulation called phase-shift keying (PSK), which was a better method than the frequency-shift keying (FSK) employed by the Bell 103.

Over the next few years, more and more efforts were focused on increasing the speed of modems. This was not possible, however, unless changes to the existing telephone system were made, as interference of signals caused problems. To compensate for this, equalizers needed to be applied to the lines. The automatic adaptive equalizer was invented in 1965 at Bell Laboratories by Robert Lucky. This invention paved the way for higher modem rates. Modem technology also improved at this time, and by 1980, modems with speeds of up to 14.4Kbps (Kilobits per second) over four-wire leased lines were available.

By 1984, modems were close to transmitting 9.6Kbps over a single-pair circuit on the telephone system. To make this a reality, advances were made in echo cancellation, which keeps the sending modem from picking up its transmitted signal on its own receiver during high-speed transmissions over a single circuit. To counter this, a new, coded, modulation with error-correcting codes was developed. This integral error correction made the signal less susceptible to noise.
Using the same sort of technology, modem speeds were increased to 14.4 Kbps by 1991, 28.8Kbps in 1994, and 33.6Kbps soon afterwards. The latter speed was thought to be the upper limit for phone-line transmissions, but the 56Kbps modem was developed soon after this.

Many other technological advances, similar to the above examples, have been made in the years since then. Today, the use of modems is common in many households. These devices have many advantages and disadvantages.

- **Advantages**
  Analogue modems are easily installable and most modems are vendor packaged, allowing quick configuration.

- **Disadvantages**
  The speeds offered by these modems are no longer adequate for most modern internet applications. Internet is only available on a dialup basis, implying that the user’s telephone line becomes unavailable for voice calls during this time.

- **Cost**
  Analogue modems are cheap; however, the user pays the cost of a local telephone call while connected. These modem speeds are slow; therefore, users can spend hours on the internet, resulting in hefty telephone bills.

- **Speed**
  The fastest modems only manage 56Kbps, which makes this technology somewhat unsuited for the proposed communications’ backbone.
- **Flexibility**
  These modems are only available where physical telephone lines are installed. Some rural schools do not have telephone infrastructure available to them.

3.2.2 ISDN

ISDN is a system of digital phone connections which made its appearance in the last decade or so. ISDN uses 2 x 64Kbps channels resulting in a combined 128Kbps digital connection to the internet and is faster than an analogue modem.

- **History**
  In the 1990s, the very first ISDN standard called the NI-1 (National ISDN 1) was implemented in the US. This standard was poorly received by the industry and the NI-2 (National ISDN 2) standard was adopted by companies such as Motorola and US Robotics, which worked with the Regional Bell Operating Companies (RBOCs) to develop configuration standards for their equipment. These kinds of actions, along with more competitive pricing, inexpensive ISDN connection equipment, and the desire for people to have relatively low-cost, high-bandwidth internet access have made ISDN more popular in recent years (Becker, 2006).

- **Advantages**
  One of the major advantages of ISDN over analogue modems is speed. Because of its digital nature, 64Kbps is guaranteed per channel, resulting in a combined 128Kbps connection to the internet. An added advantage is the ability for users to leave the second channel disconnected allowing incoming and outgoing voice calls or faxing, etc.
• **Disadvantages**
  The disadvantage of ISDN is, once again, that it is a dial-up solution, resulting in a telephone call for the duration of the connection.

• **Cost**
  ISDN-line rental is more expensive than a normal telephone line. Once installed, the service provider cost must be added, and lastly the cost of the telephone calls while connected.

• **Speed**
  As with analogue modems, the speed of this technology also appears to be inadequate for the desired communications’ backbone.

• **Flexibility**
  This technology is also dependent on the reach of the PSTN (public switched telephone network).

3.2.3 **Leased Lines / Dedicated Lines**

Leased lines connect two locations for private voice and/or data telecommunications’ services. A leased line is a reserved circuit between two points. It can span short or long distances. Unlike telephone lines which use the same lines for many different conversations, leased lines maintain a single, open circuit at all times. These lines are usually utilised by businesses as they guarantee bandwidth for network traffic.

• **Advantages**
  Various networking speeds are possible ranging from 64Kbps to 155Mbps (Internet Solutions, 2007), depending on pricing structure.
These speeds are much better than ISDN lines as they are permanently connected between sites. Another major advantage is security: leased lines are reserved for customers’ private network traffic only.

- **Disadvantages**
  These lines are very expensive compared to other technologies. Virtual Private Networking (VPN) across cheaper mediums is becoming more common than the leased-line option.

- **Cost**
  Leased lines are very expensive and in the South African context, one can expect to pay up to R1900.00 per 64Kbps. This exorbitant cost makes this technology too expensive for the desired communications’ network.

- **Speed**
  Speeds of up to 155Mbps are attainable. These speeds are extremely desirable for the communications’ backbone, but come at a price.

- **Flexibility**
  This technology is not very flexible and would require dedicated equipment to maintain the connection (Internet Solutions, 2007).

### 3.2.4 DSL

Today, ADSL technology has become extremely popular. The speeds and prices at which users can connect to the internet make it ideally suited for home and office users alike. Speeds range from 384Kbps to 4Mbps in South Africa.
History

In the late 1980s, Joseph Lechleider, of Bellcore, demonstrated the feasibility of sending broadband signals, establishing his place in history as the originator of broadband technologies. He developed the idea of asymmetry (the A in ADSL), which suggested that a higher rate of data could be sent in one direction. Putting it simply, this was the beginning of the move from analogue to digital (Marples, 2007).

DSL was initially created to deliver video-on-demand (VOD), but this never quite took off. Instead, DSL emerged as something much different to what was originally expected. More and more users of personal computers needed to access the internet faster, both at home and at the office. Taking the pace of business and the amount of networked computers into account, high-speed DSL became the solution. DSL presented opportunities for telecommunications’ companies to meet customer demand for faster internet access.

Different variants of DSL have evolved over the years. These are:

- **HDSL** is the pioneering high-speed format, but is not commercially viable due to its need for two twisted pairs and does not have support for normal telephone services.
- **SDSL** is symmetric DSL. It operates over a single twisted pair with support for standard voice transmission. The problem with this system is that it is limited to relatively short distances.
- **IDSL** stands for ISDN DSL. It is similar to ISDN technology. Its disadvantage is the lack of support for analogue voice and the 128Kbps rate is not much more than a standard V90 modem.
o **VDSL** provides very high bit rate DSL, up to 52Mbps, but requires shorter connection lengths than are generally practical. It has been used in conjunction with an experimental project, FTTC (Fibre to the Curb), but development has slowed down due to commercial viability issues.

o **ADSL** (Asymmetrical Digital Subscriber Line) is the most promising DSL technology, proving suitable for personal broadband requirements and allowing for same channel to still act as a traditional POTS (Plain Old Telephone System) service.

o Rate Adaptive DSL, **RADSL**, is a further advancement which is able to automatically optimise the ADSL data rate to suit the conditions of the line being used (Knagge, 2006).

In the South African context, we are primarily exposed to ADSL, which has grown significantly in popularity; therefore, the rest of this chapter will concentrate on it.

- **Advantages**
  o Unlike ISDN, no special telephone line is required for ADSL as the existing telephone line is used.
  o Relative to other technologies, it is a cost-effective means of obtaining high bandwidth data connection. The improved bandwidth makes various services such as quality streaming of both video and audio possible.
  o ADSL has the added advantage of separating the voice service from the data service, allowing voice calls while connected to the internet.
  o ADSL can easily integrate into WAN technology, allowing backup routes for redundant links.
• **Disadvantages**
  o Customers have to be within a 5 km range from their nearest exchange to qualify for ADSL. Due to this range restriction, this technology is not suited for rural areas, leaving them with very limited access.
  o ADSL-line rentals still cost more than what the average South African household is able to spend on internet access.
  o Asymmetry; Downstream/Upstream ratios may be unacceptably high (three or more). A typical scenario is Telkom’s offering of a 4Mbps downstream line with meagre 384Kbps upstream capability. That is a ratio of 10:1.
  o Reliability and potential downtime issues make DSL risky for mission-critical business systems.

• **Cost**
  Typical costs include a Router of ± R600.00, with ADSL line rentals starting at R245.00 per month for the entry level 384Kbps. Added to this figure would be a data bundle of typically 3GB costing between R200.00 and R300.00 depending on the service provider (Telkom, 2007). These figures are quite pricy for the desired network. The amount of data for the desired network cannot be capped or limited to 3GB as this would become a stumbling block to communications among schools.

• **Speed**
  The current maximum speed offering for ADSL is 4Mbps, which, although fast, still leaves room for improvement.
• **Flexibility**
  ADSL technology is also dependent on the PSTN infrastructure with an additional requirement where the client may not be more than 5 kms from the nearest telephone exchange. This is not desirable for the communications’ network.

3.2.5 **Mobile Telecommunications’ Technology**

• **History**
  Mobile telecommunications’ technology has improved dramatically in the last few years. A wide offering of technologies are currently available. Each one will now be briefly investigated.

• **GPRS (General Packet Radio Service)** is a packet-based wireless communication service that promises data rates from 56 up to 114Kbps and continuous connection to the internet for mobile phone and computer users. The higher data rates allow users to take part in video conferences and interact with multimedia Web sites and similar applications using mobile hand-held devices as well as notebook computers. GPRS is based on Global System for Mobile (GSM) communication and complements existing services such as circuit-switched cellular phone connections and the Short Message Service (SMS) (SearchMobile, 2007).

• **EDGE (Enhanced Data GSM Environment)** is a faster version of the Global System for Mobile (GSM) wireless service designed to deliver data at rates up to 384Kbps and enable the delivery of multimedia and other broadband applications to mobile phone and computer users.
The EDGE standard is built on the existing GSM standard, using the same time-division multiple access (TDMA) frame structure and existing cell arrangements. EDGE became commercially available in 2001. It is regarded as an evolutionary standard on the way to a Universal Mobile Telecommunications System (UMTS) (Baruch, 2007).

- **3G (Third-Generation Wireless Technology and Networks).** 3G is based on an International Telecommunication Union (ITU) initiative for a single, global wireless standard called International Mobile Telecommunications-2000 (IMT-2000). This concept of a single standard evolved into a family of five 3G wireless standards. Of those five, the most widely accepted are CDMA2000, WCDMA (UMTS) and TD-SCDMA (Time Division-Synchronous Code Division Multiple Access). According to the ITU and IMT-2000, a wireless standard must meet the following minimum bit-rate requirements to be considered 3G:

  o 2Mbps in fixed or in-building environments;
  o 384Kbps in pedestrian or urban environments;
  o 144Kbps in wide area mobile environments;
  o Variable data rates in large geographic area systems (satellite).

3G technology benefits the other participants in the wireless value chain. Wireless network operators are able to capitalize on increased voice capacity, greater network efficiency, lower costs per user served, increased ARPU (average revenue per user) and greater service differentiation. 3G technology’s data capabilities open up an enormous world of opportunity for application developers and content providers (3G Today, 2007).
• **3.5G/HSDPA (High-Speed Downlink Packet Access)** is an evolution of WCDMA (Wideband Code Division Multiple Access), optimized for packet-switched data applications. HSDPA provides impressive enhancements over WCDMA on the downlink (also referred to as the forward link) — promising 14.4Mbps peak data rates — resulting in a better end-user experience. Subscribers with the HSDPA service are able to receive emails with large attachments, surf the web or download multimedia or text files faster than ever. For operators, HSDPA offers a three- to five-fold capacity increase over WCDMA, which translates into significantly more data users and lower cost per bit. In December of 2005, the first HSDPA network was launched in the United States. As of July 2007, there are more than 125 commercially available HSDPA networks with an additional 76 planned or in deployment around the world (3G Today, 2007).

• **Advantages**

  In addition to providing faster bit rates and greater capacity over previous-generation technologies, these later technologies excel by effectively:

  o Delivering mobile data;
  o Offering greater network capacity;
  o Operating with existing second-generation technologies;
  o Enabling rich data applications such as VOIP, video telephony, mobile multimedia, interactive gaming and more.

  3G wireless services further enable consumers and professionals to experience excellent voice quality as well as a wide array of compelling data services, including:

  o Mobile internet connectivity;
- Mobile email;
- Multimedia services, such as digital photos and movies taken by and shared via wireless handsets;
- Wireless application downloading;
- Video-on-demand and short-format Clipcast™ content;
- Real-time multiplayer gaming;
- Enhanced emergency and location-based services;
- Low-latency push-to-talk and push-to-video message services.

**Disadvantages**
- Although mobile devices capable of using GPRS are relatively cheap, those capable of using the later technologies such as EDGE and 3G are still relatively expensive in South Africa;
- Although various cell phone operators in South Africa have populated most of the metropolitan areas with 3G-capable infrastructure, the coverage of these devices are still lacking in rural areas.

**Cost**
The cost of mobile communications is not really dependent on the type of technology employed, but rather on the traffic generated by the selected technology. Most cellular providers charge per megabyte of data transmitted and received. Data charges typically range from R 1.85 per megabyte (out of bundle pricing), to as low as 19c for those users purchasing a 10GB data package per month (Vodacom, 2007). This pricing, however, makes data communications via the mobile networks very expensive for the average cellular user.
• **Speed**
Although great improvements have been made to mobile telecommunications in the last few years, the speed is still dependent on the cellular signal which fluctuates per location and tower congestion.

• **Flexibility**
Mobile technology is extremely flexible and easy to use. The technology is dependent on the cellular network coverage which could pose networking problems during network congestion.

### 3.2.6 802.11 Based Wireless Networks

Wireless technology has improved significantly over the last few years. This technology, based on the WLAN (Wireless Local Area Network) 802.11 standard, has become extremely popular and extensively used by both home and business users. It provides a simple, yet powerful, communications’ medium for both home and business users.

• **History**
In 1997, the Institute of Electrical and Electronics Engineers (IEEE) created the first WLAN Standard, 802.11, named after the group of engineers that worked on the project. This specification details the framework necessary for a standard method of wireless-networked communications. It uses the 2.4GHz microwave band designated for low-power, unlicensed use by the FCC in the US. in 1985. 802.11 provided for network speeds of one or two megabits, using either of two incompatible encoding schemes: Frequency Hopping Spread Spectrum (FHSS), or Direct Sequence Spread Spectrum (DSSS) (Flickenger, 2003).
• **Advantages**

Wireless technology has some major advantages over their wired counterparts. Some of these advantages are:

  o **Deployment**
    
    Unlike wired networks, wireless networks have a low infrastructure setup cost. The installation is quick and relatively easy.

  o **Mobility**
    
    Public wireless networks have made it easy for individuals to work from outside the boundaries of the work place. Mobile workers can now communicate with their clients and fellow workers from practically anywhere.

  o **Convenience**
    
    The ability for users to surf the internet from coffee shops, airports and even hotel rooms has become common place in today’s society. Venues which do not offer this service have become the exception rather than the norm.

  o **Expandability**
    
    The nature of the equipment allows additional users to access the APs (Access Points) without requiring changes in infrastructure as with wired networks.

  o **Cost**
    
    Wireless equipment is cheap and can be easily installed in both office and outdoor environments.

  o **Productivity**
    
    Wireless technology stretches and overcomes the normal work boundaries allowing employees the freedom to work outside these boundaries. Employees are able to work from virtually anywhere, resulting in increased productivity.
• **Disadvantages**
  
  - **Security**
    Wireless networks use radio frequencies to send and receive data. The mere fact that these are broadcast through the air lends itself to various security issues. In a wired environment, hackers would need to get access to the physical cable first, before they attempt to hack. In a wireless environment, these signals are open for anyone to receive and manipulate.
  
  - **Range**
    In an indoor environment, the range of standard wireless equipment is in the order of tens of meters depending on the amount of walls that these signals will have to penetrate. Although this is adequate for most homes, it may be necessary to add hardware to attenuate signals for office environments.
  
  - **Reliability**
    Like any radio frequency transmission, wireless networks are prone to interference. In a home environment, wireless communications equipment will have to do battle with devices such as cordless telephones, wireless mouses and keyboard sets and a host of other video-streaming type devices also utilizing the same 2.4GHz band. In long distance applications, wireless networks are prone to interference by other wireless networks.
  
  - **Speed**
    Although amazing progress has been made in the speeds of wireless networks, the typical speeds remain between 1 – 300Mbps. Wired networks are now standardizing on 1Gbps equipment. This, plus the fact that wireless media use shared bandwidth, sees the technology lacking in this area.
• **Cost**  
The major benefit of wireless networks is realised when businesses wish to connect disparate sites together. The cost of the equipment is a once-off expense and no expensive monthly line rental fees are necessary. The speeds range anywhere from 5 – 54 Mbps which would have been costly if this was done using the previously evaluated technologies. Wireless APs, capable of linking up to 40 devices, typically cost between R 800.00 and R3,000.00 (this equates to R20 – R75 per device). The speed of these devices range from 54 – 300Mbps and are typically used in a home or office environment. The cost of long-range wireless equipment varies between R1,500.00 – R10,000.00 with speeds varying from 11-300Mbps (Eurobyte, 2007).

• **Speed**  
With speeds up to 300Mbps, this technology appears to be ideal for the desired communications’ network.

• **Flexibility**  
The equipment can be mounted virtually anywhere as long as “line-of-site” is achieved. Equipment can be easily moved or removed should it be required. Equipment is readily available. It appears as if this technology may be flexible enough to satisfy the requirements of the communications’ network.
### 3.3 Synopsis of Communications’ Technologies

<table>
<thead>
<tr>
<th>Technology</th>
<th>Cost</th>
<th>Speed</th>
<th>Flexibility</th>
<th>Applicability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analogue Modems</td>
<td>Initial cost low</td>
<td>Slow - Max 56Kbps</td>
<td>Dependent on PSTN infrastructure</td>
<td>Not suitable</td>
</tr>
<tr>
<td></td>
<td>Monthly cost is dependent on usage</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ISDN</td>
<td>Initial cost low</td>
<td>Slow – Max 128Kbps</td>
<td>Dependent on PSTN infrastructure</td>
<td>Not suitable</td>
</tr>
<tr>
<td></td>
<td>Monthly cost is dependent on usage</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leased Lines / Dedicated Lines</td>
<td>Initial cost high</td>
<td>Fast – Max 155Mbps</td>
<td>Dependent on Telecommunications infrastructure</td>
<td>Not suitable</td>
</tr>
<tr>
<td></td>
<td>Monthly cost extremely high</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DSL</td>
<td>Initial cost average</td>
<td>Fast – Max 52Mbps</td>
<td>Dependent on PSTN infrastructure / Distance from nearest exchange</td>
<td>Not suitable</td>
</tr>
<tr>
<td>Mobile Telecommunications Technology</td>
<td>Initial cost average</td>
<td>Fast – Max 14.4Mbps</td>
<td>Dependent on Cellular Communications Network</td>
<td>Not suitable</td>
</tr>
<tr>
<td></td>
<td>Monthly cost is based on bandwidth usage</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>802.11 Based Wireless Networks</td>
<td>Initial cost average</td>
<td>Fast – Max 300Mps</td>
<td>Dependent on line-of-site and distance between equipment</td>
<td>Best suited for a Wireless School Network</td>
</tr>
<tr>
<td></td>
<td>No monthly costs</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Figure 1 – Communications’ Technology Comparison Chart**

The previous sections examined various communications’ technologies. Although they have come a long way, the following is apparent from Figure 1:

- Analogue modems and ISDN applications are no longer viable, both due to speed and cost;
- Leased Lines/Dedicated lines are too expensive;
• DSL and Mobile Telecommunications Technology, although extremely popular, currently have expensive bandwidth pricing structures;
• The remaining wireless technology appears to be both cost effective and offers the highest bandwidth compared to other technologies examined in this chapter. It appears to be best suited for the desired communications’ network.

3.4 Conclusion

This chapter examined various alternative technologies in order to analyze their suitability for a school network. Amongst the solutions were analogue modems, ISDN, Leased Lines, DSL, Mobile telecommunications technologies and 802.11 based networks. Each technology was examined in terms of advantages, disadvantages, cost, speed and network flexibility. Wireless-based networks appear to be the best suited technology for a school communications’ network; therefore, the next chapter will examine it in more depth.
Chapter 4 – Wireless Communications’ Technology

This chapter examines wireless communications’ technology in more detail as it was selected as the preferred technology for a school communications’ network in the previous chapter.

4.1 Introduction

In the previous chapter, this dissertation evaluated various communications’ technologies for use in the pilot project. Given the constraints, wireless technology was selected as the most applicable for use in this project. This technology holds many advantages including speeds of between 5-300Mbps. The cost of creating this high-speed network between schools would also be relatively cheap compared to other technologies. It is becoming increasingly crucial for businesses and organisations to communicate effectively and efficiently with either themselves, or other businesses. Technology has advanced extremely fast. Developing countries such as South Africa still lack infrastructure, as a result, bandwidth is expensive and could be a limiting factor for the adoption of technologies. The use of wireless technology could help to overcome this lack of physical infrastructure. This chapter aims to clarify the standards surrounding wireless technology as well as its uses and benefits over traditional networks.

Wireless technology has opened a new avenue for previously technology-starved countries to achieve high-speed networks without too much effort and money. These networks have increased in popularity to such an extent that they are fast becoming common in the home, small businesses and even larger organisations in South Africa and the rest of the world.
4.2 History

In 1971, researchers at the University of Hawaii developed the world’s first Wireless Local Area Network (WLAN), named ALOHAnet. The network included seven computers deployed over four islands to communicate with the central computer on the Oahu Island without using phone lines. Wireless hardware was very expensive and initially only used as an alternative for cabled LAN in places where cabling was difficult or impossible. Wireless, in its infancy, was only used for industry-specific applications using proprietary protocols. These were later replaced by standards (History of Wireless Communication, 2007).

In 1997, the Institute of Electrical and Electronics Engineers (IEEE) created the first WLAN Standard, 802.11, named after the group of engineers that worked on the project. This specification details the framework necessary for a standard method of wireless-networked communications. It uses the 2.4GHz microwave band designated for low-power, unlicensed use by the FCC in the US. in 1985. 802.11 provided for network speeds of one or two megabits, using either of two incompatible encoding schemes: Frequency Hopping Spread Spectrum (FHSS), or Direct Sequence Spread Spectrum (DSSS). In September of 1999, the 802 committee extended the specification, and decided to standardize on DSSS. This extension became known as the 802.11b. These extensions made it possible for new equipment to continue to interoperate with older 802.11 DSSS hardware. The technology typically allowed for ranges of approximately 450 meters. The wide acceptance of 802.11b in late 1999 is widely regarded as the start of the popular wireless networking phenomenon. Various standards have since made their appearance as part of the 802.11 family. This chapter will briefly examine the differences between these. Figure 2 provides a table of the most popular standards and each will be briefly examined.
4.2.1 802.11

Approved by the IEEE in 1997, it defines three possible physical layers:
- FHSS at 2.4GHz;
- DSSS at 2.4 GHz; and,
- Infrared.
Data rates of 1 to 2Mbps could be achieved.

4.2.2 802.11a

802.11a and 802.11b were both ratified on September 16, 1999. 802.11a operates in the 5GHz UNII band and is capable of speeds up to 54Mbps. It uses an encoding technique called Orthogonal Frequency Division Multiplexing (OFDM). 802.11a promised higher speeds and less interference than devices utilizing the 2.4GHz range. It only came to market much later than 802.11b, and suffers from range problems: at the same power and gain, signals at 5GHz appear to travel only half the distance of their 2.4GHz counterparts. This is problematic for WAN designers and implementers. Because this, 802.11b received widespread adoption before 802.11a, since this technology offered no upgrade path for existing users as these two types are incompatible. Compared to 802.11b equipment, 802.11a equipment is not nearly as ubiquitous or inexpensive. Nevertheless, the technology has become extremely popular in a MAN (Metropolitan Area Network) environment, as more and more people fill the 2.4GHz range, leading to congested wireless channels (IEEE, 2007).
4.2.3 802.11b

802.11b, although extremely popular up until a few months ago, is now outdated. Initially this was very well received by the industry and was included in most network-enabled devices such as laptops, cell phones, and other mobile devices. It offers speeds of up to 11Mbps. It operates using DSSS at 2.4GHz and will automatically select best data rate (1, 2, 5.5, or 11Mbps) depending on the available signal strength. As mentioned earlier, its greatest advantage is its ubiquity. Most mobile devices now ship with both 802.11b and 802.11g embedded (IEEE, 2007).

4.2.4 802.11g

In 2003, the 802.11b standard received a long-awaited boost in speed through a new amendment to the 802.11 standard, ratified by the IEEE. The new standard, 802.11g, raises the data rate of 802.11b type networks to 54Mbps. This new amendment allows 802.11g devices to fall back onto 802.11b networks, allowing devices to coexist on the same network. 802.11g networks have made it easier for both business and home users to expand existing networks and to utilize the higher data rates for multimedia applications, etc. Most modern devices allow for SuperG mode, further increasing the data rate of 802.11g networks to 108Mbps (IEEE, 2007).

4.2.5 802.11n

802.11n is a proposed amendment to the 802.11 standard to improve system performance. Although the N standard is still in "draft" stage, according to the IEEE, many hardware vendors already sell "pre-N" or "Draft-N" hardware, based on the most recent draft.
These vendors anticipate the final version will not be significantly different from the draft and in a bid to get the early mover advantage, are pushing ahead with the technology (Thornycroft, 2008, pp. 19-20). The 802.11n standard is expected to be significantly faster than previous standards such as 802.11b and 802.11g, previously discussed, with many experts proclaiming that this wireless technology will finally allow consumers to move beyond traditional 10/100 wired LANs. This standard is anticipated to be ratified in 2009 (IEEE, 2007).

The preceding section examined various wireless-networking standards. Figure 2 shows a synopsis of these.

<table>
<thead>
<tr>
<th>IEEE WLAN Standard</th>
<th>Over-the-Air (OTA) Estimates</th>
<th>Media Access Control Layer, Service Access Point (MAC SAP) Estimates</th>
</tr>
</thead>
<tbody>
<tr>
<td>802.11b</td>
<td>11 Mbps</td>
<td>5 Mbps</td>
</tr>
<tr>
<td>802.11g</td>
<td>54 Mbps</td>
<td>25 Mbps (when .11b is not present)</td>
</tr>
<tr>
<td>802.11a</td>
<td>54 Mbps</td>
<td>25 Mbps</td>
</tr>
<tr>
<td>802.11n</td>
<td>Up to 600 Mbps</td>
<td>Up to 400 Mbps</td>
</tr>
</tbody>
</table>

*Figure 2 - Wireless LAN Throughput by IEEE Standard (Intel Corporation, 2008)*

Although this technology is now established, newer standards are very quickly evolving. Figure 3 shows various other wireless standards currently available.
## Wireless LAN standards and amendments

<table>
<thead>
<tr>
<th>Standard</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>802.11</td>
<td>The original WLAN Standard. Supports 1Mbps to 2Mbps.</td>
</tr>
<tr>
<td>802.11a</td>
<td>High speed WLAN standard for 5GHz band. Supports 54Mbps.</td>
</tr>
<tr>
<td>802.11b</td>
<td>WLAN standard for 2.4GHz band. Supports 11Mbps.</td>
</tr>
<tr>
<td>802.11d</td>
<td>International roaming — automatically configures devices to meet local RF regulations.</td>
</tr>
<tr>
<td>802.11e</td>
<td>Addresses quality of service requirements for all IEEE WLAN radio interfaces.</td>
</tr>
<tr>
<td>802.11f</td>
<td>Defines inter-access point communications to facilitate multiple vendor-distributed WLAN networks.</td>
</tr>
<tr>
<td>802.11g</td>
<td>Establishes an additional modulation technique for 2.4GHz band. Supports speeds up to 54Mbps.</td>
</tr>
<tr>
<td>802.11h</td>
<td>Defines the spectrum management of the 5GHz band.</td>
</tr>
<tr>
<td>802.11k</td>
<td>Defines and exposes radio and network information to facilitate radio resource management of a mobile Wireless LAN.</td>
</tr>
<tr>
<td>802.11n</td>
<td>Provides higher throughput improvements. Intended to provide speeds up to 500 Mbps.</td>
</tr>
<tr>
<td>802.11s</td>
<td>Defines how wireless devices can interconnect to create an ad-hoc (mesh) network.</td>
</tr>
<tr>
<td>802.11r</td>
<td>Provides fast (&lt;50 millisecond), secure and QoS-enabled inter-access point roaming protocol for clients.</td>
</tr>
<tr>
<td>802.11u</td>
<td>Adds features to improve interworking with external (non-802) networks where the user is not pre-authorized for access.</td>
</tr>
<tr>
<td>802.11v</td>
<td>Enhances client manageability, infrastructure assisted roaming management, and filtering services.</td>
</tr>
<tr>
<td><strong>802.11z</strong></td>
<td>Creates tunnel direct link setup between clients to improve peer-peer video throughput.</td>
</tr>
<tr>
<td>-------------</td>
<td>----------------------------------------------------------------------------------</td>
</tr>
<tr>
<td><strong>802.11aa</strong></td>
<td>Robust video transport streaming.</td>
</tr>
</tbody>
</table>

Figure 3 - Wireless LAN Standards and Amendments (Intel Corporation, 2008)

### 4.3 Advantages of Wireless Technology

Wireless technology has various advantages over its wired counterparts. These advantages were briefly discussed in the Chapter 3. A more detailed discussion follows.

- **Deployment**
  Unlike wired networks, wireless networks have a low infrastructure setup cost. The installation is quick and relatively easy. Additional access points, laptops, and other wireless capable devices can easily be associated to existing infrastructure. Service providers and installers can pre-configure devices before shipping to their clients. Although the installation of wireless equipment requires a little configuration time, most home users can begin using it within minutes.

- **Mobility**
  Public wireless networks have made it easy for individuals to work from outside the boundaries of the work place. Mobile workers can now communicate with their clients and fellow workers from practically anywhere.
In an office environment, users are no longer restricted to certain areas such as wired offices, etc, for internet and LAN connectivity; instead, facilities such as boardrooms, conference facilities and previously un-wired offices, can now cater for intranet and internet access to employees and visitors alike.

- **Convenience**
  The ability for users to surf the internet from coffee shops, airports and even hotel rooms has become common place in today’s society. Venues which do not offer this service have become the exception rather than the norm. As discussed before, offices and homes can become wireless “hotspots” without costly cabling.

- **Expandability**
  The nature of the equipment allows additional users to access the APs (Access Points) without requiring changes in infrastructure as with wired networks. Most APs are capable of associating up to 40 nodes. By simply adding another AP, one could effectively double the amount of nodes at a fraction of the cost of wired infrastructure.

- **Cost**
  Wireless equipment is cheap and can be easily installed in both office and outdoor environments. The initial purchase of an AP may cost more than installing two wired network points, but this cost is quickly absorbed as more nodes are added to the network. As most laptops and mobile devices are now 802.11b/g compliant, there would be no extra cost incurred by adding these devices to the network.
• **Productivity**
  Wireless technology stretches and overcomes the normal work boundaries allowing employees the freedom to work outside these boundaries. Critical emails can be sent from virtually anywhere. Documents can be typed and sent to meetings, and this “virtual office”, allows employees to video-conference from anywhere in the world.

• **Simplicity**
  Whether used in the home, small business or large corporate environments, wireless equipment can be deployed without timely and costly wired installation costs. Organisations can add additional buildings to their network by simply deploying directional or omni-directional antennae to each.

• **Flexibility**
  Wireless networks are more flexible than their wired counterparts as they can be easily added to an existing network and be removed from same, should they no longer be required. This makes setting up temporary networks, typically deployed for conferences, seminars, etc., relatively simple.

• **Speed**
  The most common wireless networks, 802.11b started out at 11Mbps and other standards have quickly advanced to 248Mbps which compares favourably to their wired counterparts. Figure 1 showed the data rate comparison between these different standards.

• **Reach**
  Wireless communications can use two modes of operation in conjunction with each other.
It allows long-distance wireless links to provide access to the remote locations. From here, omni-directional APs can provide local access. Long-distance wireless links can reach considerable distances. The later IEEE 802.11 standards would be well suited for these applications.

4.4 Disadvantages of Wireless Technology

As with most technologies, wireless technology has some disadvantages as well. This section examines these disadvantages.

- **Security**
  Wireless networks use radio frequencies to send and receive data. The mere fact that these are broadcast through the air lends itself to various security issues. In a wired environment, hackers would need to get access to the physical cable first, before they attempt to hack. In a wireless environment, these signals are open for anyone to receive and manipulate. Security will be dealt with as a separate issue at a later stage.

- **Range**
  In an indoor environment, the range of standard wireless equipment is in the order of tens of meters depending on the amount of walls that these signals will have to penetrate. Although this is adequate for most homes, it may be necessary to add hardware for office environments.

- **Reliability**
  Such as any radio frequency transmission, wireless networks are prone to interference.
In a home environment, wireless communications equipment will have to do battle with devices such as cordless telephones, wireless mouse and keyboard sets and a host of other video streaming type devices also utilizing the same 2.4GHz band. In long distance applications, wireless networks are prone to interference by other wireless networks.

- **Speed**
  Although amazing progress has been made in the speeds of wireless networks, the typical speeds remain between 1 – 248Mbps, whereas their wired counterparts offer speeds of 1Gbps. This, plus the fact that wireless media is shared amongst the nodes leaves the technology lacking. (However, this may soon be a thing of the past, as Gigabit Wireless may soon be available using the 60GHz band (Gingichashvili, 2007).

### 4.5 Security

In an article by Brad C. Johnson (Johnson, 2002), he attributes the current state of wireless insecurity to the following:

- The default configurations of the wireless “servers” (APs) are insecure. They are set to “open” to make them easy to deploy and use out the box.
- The physical transport is invisible and, therefore, it is difficult to understand and control its boundaries.
- There are interoperability issues between Access Points. That is, because the security and configuration features vary by vendor, if you have more than one type of Access Point (even if it’s different types of access points from the same vendor) you are going to have to understand (in detail) what the compatibility issues are among them.
• Many wireless setups are installed by end-users and not by IT or security professionals.
• The standard data encryption protocol (WEP) that is used on almost every Access Point in the market has been proven to be insecure (Johnson, 2002).

Unlike the boundaries of wired networks, which are physically controlled, wireless network users and administrators have no way of knowing how far the network goes. Wireless network boundaries are constantly in a state of flux due to various reasons. Some of these include:

• Barriers, such as people, walls, equipment, etc., can influence the signals;
• Interference from other devices can reduce the distance;
• Type of antennae used can have an effect on the distance.

These factors make managing the security of wireless networks extremely difficult. Johnson continues by saying that there are inherent problems in the products currently available. He mentions the following:

• Authentication: The default authentication mode for most APs is “open” which allows any client to connect or associate with it;
• Authorization: The authorization control on most APs is MAC (Medium Access Control)-level address filtering (i.e., these allow or disallow the forwarding of packets). Unfortunately you can change the MAC address of most clients to be anything you want it to be;
• Access Point Configuration: All major AP products are set up to be in their most insecure configuration out of the box;
• Encryption: The Standard WEP (Wired Equivalent Protection) protocol has been proven to be insecure in several fundamental ways. It requires only a modicum of CPU capability and network traffic to determine the supposedly "secret" WEP encryption keys;

• Client WEP Key Storage: Leading vendors either store the WEP keys directly on the client wireless card or on the local disk in a way that is obvious and easy for anybody to copy and use;

• As previously mentioned, wireless boundaries are difficult to determine.

Matthew Gast (Gast, 2002) re-iterates seven security problems with wireless equipment as:

a. Easy Access – Wireless networks are easy to find.
b. “Rogue” Access Points – Users can get hold of an AP and install it on the corporate network, leaving huge security holes.
c. Unauthorised Use of Service – Users may leave the default insecure settings of the access points in place, thus leaving their computers open for hackers to abuse.
d. Service and Performance Constraints – Wireless LANs have significantly lower bit rates than the wired counterparts.
e. MAC Spoofing and Session Hijacking – 802.11 networks do not authenticate frames. Every frame has a source address, but there is no guarantee that the source AP put it in the air in the first place is genuine. Attackers can use this vulnerability to re-direct traffic at will.
f. Traffic Analysis and Eavesdropping – 802.11 provides little or no protection against attacks that passively observe traffic.
g. Higher-Level Attacks – Once an attacker gains access to a wireless network, other systems could be compromised (Gast, 2002).
Various industry initiatives are underway to address these fundamental flaws in the technology and include the IEEE Security subgroup (Enhanced Security Network and a replacement for WEP) and the IETF’s Extensible Authentication Protocol (EAP). Although various security concerns are prevalent around wireless networking, using the technology in the educational context may or may not pose a big threat, depending on the initiatives making use of the network. Individuals and organisations wanting to make use of the network to communicate sensitive data should investigate ways of securing data, which will inevitably be available in the very near future.

4.6 Wireless Applications

Wireless technology; however, appears to be ideal for organisations which span municipal roads, even municipal boundaries. An organisation with multiple sites can link these together with a wireless backbone and share information, databases, and various other knowledge management-type applications. The data rate offerings of this technology also make it well suited for multimedia streaming and VOIP (Voice over IP)-type applications.

The usage scope of wireless technology is immense, and applications in the following fields are very possible:

- Education (schools, universities);
- Transportation (railways, marine, commuter services, airports);
- Local and national government;
- Medical institutions, including clinics and hospitals;
- Connecting central offices to remote branch offices;
- Internet service providers;
• Emergency services, including emergency or temporary communication services;
• Suburban businesses and business parks;
• Real-estate management companies with multi-dwelling buildings.

4.7 Conclusion

This chapter examined wireless technology with specific reference to the following standards: 802.11a, 802.11b, 802.11g, and 802.11n. Based on this, the following main advantages and disadvantages of the technology were highlighted:

- **Advantages:** Easy to deploy; Excellent mobility; Convenient; Expandable; Cost efficient; Increased user productivity; Simplicity; Flexibility; Speed; and Reach.

- **Disadvantages:** Security; Range; Reliability; and Speed.

Although there are still security concerns surrounding the technology, the uses and pure applications of the technology are vast. The possibility of connecting schools via this technology is becoming a reality. The data rates attainable could be significant enough to support collaboration, video-conferencing, VOIP, and many more applications. As shown in the previous chapter, the cost of any other technology would not be economically viable for such an endeavour.

Chapter 5 presents a case study of a Wireless School Network pilot project which was established between the NMMU and four schools in the Nelson Mandela Metropolitan Municipality in Port Elizabeth, South Africa.
Chapter 5 - A Case Study:
Implementing a Wireless Network between Four Schools and the NMMU

This chapter presents the proposed design of the communications' infrastructure in the form of a case study. Case-study research was chosen because this form of design, despite adhering to industry best practices still requires a certain amount of trial and error. This is an ongoing project.

5.1 Abstract

Chapter 2 investigated the world’s vision for education delivery with specific emphasis on ICT in schools. It also re-iterated the Department of Education's expectations for ICT delivery in schools and summarised the expected outcomes. Numerous initiatives are currently on the way to gather information from schools which can be used for capacity planning, budget allocation, etc. These initiatives are hampered by the lack of a communications' network between schools. In previous chapters, it became apparent that wireless technology could be used for such a network due to various advantages over its counterparts. This wireless school network has the potential to revolutionize this challenged education environment.

This chapter reports on a case study for a pilot wireless network installed among four schools in the northern suburbs of Port Elizabeth, South Africa. The case study adheres to the guidelines of the British Educational Communications and Technology Agency (BECTA) (BECTA, 2006), as well as those prescribed by Creswell (Creswell, 2007). Chapter 1, Section 1.6 contains these guidelines.
5.2 E-Strategy Linkage

In Chapter Seven of the *Draft White Paper on e-Education*, which was gazetted on 26 August, 2004, the DoE, as part of its implementation strategies, urged the private sector to respond in implementing ICT initiatives nationwide (Department of Education, 2004, p. 37). It went on to list, as a Phase I approach, that “Institutions are connected, access the internet and communicate electronically” (Department of Education, 2004, p. 40).

Although these expected outcomes are in line with world trends, a major gap exist in the implementation thereof. This dissertation and, in particular, this pilot project, is concerned with “Learning Outcome 2: e-Communication”, as well as responding to the DoE’s gazetted request for industry to get involved (Department of Education, 2004, p. 37).

This case study aims to address this communications’ network dearth and proposes wireless technology as a possible solution. It describes the pilot network established between four schools and the NMMU (Missionvale campus) in Port Elizabeth, South Africa.
5.3 Administration Functions

5.3.1 Theme

This case study maps various themes to the major ones listed below:

- Learning and teaching;
- Curriculum;
- Continual Professional Development (CPD);
- Resources;
- Assessment;
- Communities of Practice (CoP).

5.3.2 Executive Summary

The case study examines a pilot network established between the Missionvale campus, NMMU and the four Port Elizabeth schools:

1. Triomf Primary School – Salsoneville;
2. Westville Senior Secondary School – Sanctor;
3. Chapman High School – Gelvandale;
4. Cebilihle Primary School – Missionvale.

MikroTik Wireless equipment (MikroTik, 2008) was used for the network. The overall cost of the project was approximately R38, 000.00 and networking speeds among these schools averaged 9Mbps.
5.4 Organizational Information

5.4.1 Implementing Engineer

Name: Creswell Du Preez
Job Title: Systems Engineer: Integration
Organisation: ICT Services – Nelson Mandela Metropolitan University
Address: University Way, Summerstrand, Port Elizabeth, 6000
Email: creswell@nmmu.ac.za
Contact Phone: +27 41 5043346
Maturity of project: New (Less than 2 years)

5.4.2 Affected Organisations

- Department of Education
- Nelson Mandela Metropolitan University
- Nelson Mandela Metropolitan University – Missionvale Campus
- Nelson Mandela Metropolitan University – ICT Services

5.4.3 Schools

Situated in the previously disadvantaged areas of Port Elizabeth, these four schools have been vandalised; however, have placed emphasis on maintaining good ICT infrastructure. Specific teachers have been earmarked to teach, administer and maintain the networks. Some of these schools have been chosen to run other projects concurrently; these are Cisco academies, Shuttleworth programmes and other projects. Figure 4 shows the relative distances from the four schools to the Missionvale campus with the furthest school being 5km and the nearest one less than one km away. Figure 5 shows the relative distances from Missionvale campus using a Google Earth map.
Introduction

The ICT Services department of the Nelson Mandela Metropolitan University prides itself in an established and well-managed networking infrastructure.
The NMMU lists, as one of its values, “Engagement - We engage with our stakeholders and communities with special emphasis on the Nelson Mandela Metropole and the Southern Cape” (Nelson Mandela Metropolitan University, 2008). This pilot project endeavours to achieve this value by providing a communications’ network between schools and the university. The Missionvale campus, situated in the previously disadvantaged area of Missionvale, Port Elizabeth, is one of the NMMU’s campuses. It is geographically well situated for the role of wireless “high-site” and has clear line-of-sight to most schools in the northern and surrounding areas. The selected four schools connect to each other via this high site, thus forming a wide area school network. It is envisaged that the NMMU ICT Services will act as the facilitator for e-communication among these schools as well as provide basic infrastructure to host the communications’ infrastructure in the future.

The benefits of the pilot project have already been described in detail in Section 1.4 of Chapter 1. To reiterate briefly, these include:

- University Multi-disciplinary Research;
- Remote Administration and Technical Support;
- Telecommunications and Video Conferencing;
- Messaging and Faxing;
- Knowledge Sharing and Collaboration Services; and,
  Financial Spin-off for Schools.

The project was kindly funded by the ICT Services department of the NMMU at a total cost of R38, 000.00. Figure 6 on page 69 contains a cost breakdown.
The four schools needed to satisfy certain criteria in order to be selected as the pilot phase had limited funding. The criteria are discussed below.

- **Line-of-Sight to Missionvale Campus**
  Wireless technology is a line-of-sight technology, i.e., the quality of signal and potential bandwidth between towers are dependent on whether these two towers have any buildings, trees, etc., in their path. It was, therefore, important that the schools were within range and clearly visible from the high-site at the Missionvale campus.

- **Supporting Hardware**
  The schools needed to have a laboratory environment with at least 20 computers to show benefit from this pilot. These computers had to be in daily use and not “white elephants, as was the case with certain schools. Hardware needed to be well maintained and in working order.

- **Security at the Schools**
  The wireless antennae needed to be installed in a secured area at the schools and insured by them. The school staff also needed to accept responsibility for the hardware.

---

**Figure 6 - Pilot Network Cost Breakdown**

<table>
<thead>
<tr>
<th>Technology</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Missionvale High-Site</td>
<td>R 15,000.00</td>
</tr>
<tr>
<td>3 x 120° Antennae</td>
<td></td>
</tr>
<tr>
<td>4 x 90° Antennae at each school</td>
<td>R 20,000.00</td>
</tr>
<tr>
<td>Professional fees (Mikrotik Certified Engineer) +</td>
<td>R  3,000.00</td>
</tr>
<tr>
<td>Sundries (Cables + Attaching Poles)</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>R 38,000.00</strong></td>
</tr>
</tbody>
</table>
• **More than One Initiative**
  Schools were targeted which were in the process of participating in more than one initiative, i.e., part of this project as well as part of university projects, Cisco projects, etc.

• **Staff**
  Staff at the school needed to accept responsibility for the wireless network and demonstrate a willingness to participate in the project.

The chosen schools were selected because of the following hardware configurations:

- Westville has a laboratory of 30 Windows-based machines with a file server.
- Chapman has a laboratory of 40 Windows-based machines, a lab of Ubuntu Linux machines donated by the Shuttleworth Foundation and two file servers.
- Triomf has a laboratory of 20 machines and a file server.
- Cebilihle has 20 machines and a file server.

The next section describes the actual network which was implemented and examines the technical implications of the installed hardware.
5.6 The Pilot Network

As previously discussed, it was imperative to ensure that more than just one project was running to maximise effect. Unlike other initiatives, it was also important to ensure that all the requirements described in Chapter 3, Section 3.2 were met. These were cost, speed and flexibility. Speed had to be at least 5Mbps, so that video streaming, VOIP and collaboration systems would be viable.

The equipment of choice for this network was MikroTik (MikroTik, 2008) wireless antennae, using the 5GHz band and 802.11a technology. The result was 9Mbps to each school. The high site at the Missionvale campus is equipped with 3 x 54Mbps 120° antennae allowing it to cover 360° and a total bandwidth of 192Mbps, enough to cater for 19 – 25 schools. Figures 7 and 8 show the MikroTik antennae at Chapman High and Westville Senior Secondary schools.

![Figure 7 - MikroTik Antenna at Chapman High School in Port Elizabeth, South Africa](image-url)
Figure 8 - MikroTik Antenna at Westville Senior Secondary School in Port Elizabeth, South Africa

Figure 9 is a graphical representation of the Wireless School Network (WSN).

Wireless School Network (WSN) Topology

Figure 9 - Wireless School Network Topology
Each school is linked to the Missionvale high-site and then routed into a secure VLAN (Virtual Local Area Network) at the NMMU. Schools can access resources at other schools by routing via the virtual network at Missionvale campus. The MikroTik hardware has built-in firewall capabilities, making the network secure for the school. DHCP (Dynamic Host Configuration Protocol) services, which are used to provide every host with a valid IP (Internet Protocol) address, can be centralised at the NMMU, but are currently restricted to the school itself. The WSN is then routed into the school lab by means of a centralised switch, or directly into the server hardware.

During the pilot, speeds of in excess of 9Mbps were recorded during a file copy operation between the file servers at Westville Senior Secondary School and Chapman High School. The installation of the antennae took a single day for all four schools, with the antennae at the high site taking another day.

The NMMU has agreed, in principle, to host a common file server at the Missionvale campus, which provides the following services:

- Mail and Instant Messaging Services;
- Collaboration and Document Management Services; and,
- VOIP Services.

During the pilot phase, the high-site the Missionvale campus was used, but a high-site could be a school, or even a government building. This will ensure that schools in the area will always have a one to connect to. (See Figure 10.)
The schools or high-sites would not necessarily have to be connected to Missionvale campus, but could rather follow a hub and spoke topology, as depicted in Figure 10. Redundancy would obviously have to be built into those high-sites where other high-sites depended on them. One would also not want more than one high-site hanging off another, as this could reduce the effect of the network.

One of the major benefits of creating a WSN is that sponsors could pool resources like internet links and create an internet pipe for the network. A proxy server could be set up at the University to manage the bandwidth and to prioritise certain government sites. This will allow all participating schools to benefit from the resources currently only allocated to specific schools.
5.7 Barriers and Enablers

Various barriers and enablers of the WSN are discussed in the sections below.

5.7.1 Barriers

Certain barriers need to be overcome to ensure the success of the WSN. These are:

- **Money**
  Money is one of the major barriers as the cost of the equipment requires an initial capital outlay. The DoE generally has other priorities to consider like sanitation, electricity, and schooling infrastructure, making little or no funds available for other initiatives like this WSN. The success of this project will, therefore, require third-party and industry involvement.

- **Technology**
  Wireless technology is a line-of-sight technology, which requires the connecting towers to see each other. It is prone to interference and one could experience a drop in bandwidth in heavily developed metropolitan areas. Good research should be conducted before its implementation.

- **Distance between Schools**
  Many schools in the rural areas of the Eastern Cape have great distances between them and may require specialised wireless equipment to connect them. This will increase the cost of the technology implementation.
• **Seven “Bridges” as Described by Foulger** (Foulger, 2002)
  Foulger’s seven bridges (Chapter 1, section 1.3) are all barriers to the WSN. Six relevant barriers are:
  1. Social and Legal Constraints;
  2. Economic Priorities;
  3. Basic Infrastructure;
  4. Literacy and Language;
  5. Computer Resources;

• **Crime**
  Theft and vandalism are problems in South Africa and special effort should be made by the school staff and broader community to ensure the safety of the equipment.

5.7.2 **Enablers**

Various enablers can help with the quick deployment of the WSN. These are:

• **Technology**
  The benefits of wireless technology were discussed extensively in Chapter 3. It is apparent that this technology is best suited for the wireless school network pilot. The technology’s speed, range and flexibility, coupled with easy installation and low maintenance, make it ideal for the application. It acts as enabler to realise the objectives set by the DoE for an “e-communication” network.
**Money**

The costing structure for wireless technology favours a capital rather than operating expenditure model. The cost of the equipment is a once-off cost, rather than a monthly one. This makes it easier to get funding for particular schools where organisations have an interest in them. The price of wireless equipment has been reduced considerably over the last few years and the cost of equipment could have dropped by as much as 30%, making the price to get a school connected even cheaper. It is hoped that this pilot project will serve as catalyst for more schools to be added to this network.

**Government Support**

The establishment of a school communications’ network has government support, as explained in Chapter 2. This certainly makes it easier to approach organisations for funding as it is a mandated initiative.

### 5.8 Impact, Outcomes and Sustainability

It is envisioned that the enabled schools can start addressing the Digital Divide immediately. The project has had an impact on a limited number of both learners and teachers. The use of this network cannot be an individual effort: it must get industry and the DoE buy in. The network will have to be maintained by the schools themselves.

What is apparent from this pilot is that “Learning Outcome 2: e-Communication”, can be done, and has been done. It is now up to the DoE and industry to grow this network. However, buy-in from teachers and the educational community must be achieved before the efficient use of the network can be demonstrated.
This pilot asserts that each impacted school should start a WSN committee, made up of both students and teachers, with occasional input from interested industry partners. This committee will ensure the smooth running of the network and will be responsible for launching new initiatives and making sure that the network is kept relatively safe. It will be tasked with duties such as:

- ensuring the network security of the school;
- ensuring an up-to-date Web presence;
- ensuring that the school network remains virus free, etc.

5.9 Transferability and Portability

The WSN can be easily deployed to other schools if they meet the following criteria:

- Distance – the schools must be in line-of-sight from a high-point;
- Funding needs must be met;
- School infrastructure must support the network;
- School staffing must be willing to accept responsibility for the equipment and be willing to be trained.

The network can be grown by installing more high points, creating a hub and spoke network. As some schools are already connected to the network, it is essential to get buy in from government and businesses.
5.10 Lessons Learnt

- The previously disadvantaged schools in the Eastern Cape have a significant lack of technological literacy. In selecting the schools, it was difficult to convince certain teachers of the benefits of the network, and some schools took up to two months to give the go-ahead.

- The highest points of certain schools, where the antennae were to be erected, was a considerable distance from the labs, leaving the installation team with creative ways of connecting the network cable to the labs.

- Line-of-sight, which impacted the network speed, was difficult to achieve from some schools.

- Concern was raised over the security of the antennae at the schools; however, during a vendor dispute at the university, the antennae at the Missionvale campus were stolen. The schools are, thus, not the only vulnerable points and more attention should be given to security at the university itself. New equipment is being procured at this time.

- It was difficult to find sponsorships for the equipment.

- The cost of equipment can be greatly reduced by approaching the hardware vendors and ordering in bulk.

- Care must be taken to extend the current network, rather than creating new standalone networks.
5.11 Conclusion

This chapter provided a proof of concept for a school communications’ network in the form of a case study. This case study asserts that this form of wireless school network is feasible and that good results were attained during the pilot project. The speed of the network met the requirements of a decent communications network, as well as being flexible enough to cater for government initiatives like the National Education Infrastructure Management System (NEIMS). The network fully addresses “Learning Outcome 2: e-Communication”, as well to the DoE’s request for industry to get involved (Department of Education, 2004, p. 37).
Chapter 6 – Conclusion

This dissertation focused on the following research question: “How can an affordable communications’ backbone that satisfies the DoE’s curriculum requirements be established among previously disadvantaged schools?” This chapter examines whether this research question has been addressed.

6.1 Introduction

This dissertation tried to address the gap in the Digital Divide by proposing a communications’ network among schools, which could be used by both government and various interested parties. It examined international education trends and then compared the current South African education environment to them. The dissertation then focused on addressing “Learning Outcome 2: e-Communication”, as identified by the South African DoE in its National Curriculum Statements – Grades 10-12 (Department of Education, 2003, pp. 12-13). It focused on the use of ICT as education aid and endeavoured to show that a schools communications’ network could enable regional school communities to become part of the rapidly changing information technology environment. It endeavoured to prove that wireless technology is a viable and cost effective mechanism to meet the DoE’s objective of establishing a communications’ network between schools (Department of Education, 2004).

6.2 Discussion

This dissertation endeavoured to address the specific problem of establishing a communications’ network among schools, as pointed out by Foulger (Foulger, 2002).
A pilot network now exists among four previously disadvantaged schools in the poorest province of South Africa, the Eastern Cape. This symbiotic communications' platform could potentially empower these previously disadvantaged schools to reduce operating costs and increase the level of education delivered, while simultaneously reducing the digital gap. Digital Divide.

This dissertation endeavored to meet the following objectives as set out in the introductory chapter:

- **Design and implement a proof-of-concept wireless network among previously disadvantaged schools in Port Elizabeth, South Africa.**
  This objective was met by the implementation of the Wireless School Network between four disadvantaged schools and the Missionvale campus of the NMMU in Port Elizabeth, South Africa as described in the case study in Chapter 5.

- **Investigate the needs of the South African educational systems and DoE’s objectives.**
  This objective was met by the evaluation of international education trends as well as the current South African DoE’s objectives in Chapter 2.

- **Investigate communications’ technologies in terms of cost, speed and flexibility.**
  This objective was met via a design-science process. Due to the fact that this network was used as a pilot project which worked, shows that a Search Process for the best-suited technology was conducted. This was described in Chapter 3 and the selected technology was described in Chapter 4.
- **Design a model for the implementation of a communications’ network among these schools.**
  
  This objective was met via a design-science process. In this process, the Wireless School Network, as described in Chapter 5, was the **Artifact** that has been delivered. The **Relevance of this problem** was argued in Chapter 2, which showed it to be a significant goal of the DoE. **Research Rigor** was demonstrated by the design of the network. This network followed a methodology which is used in industry when installing wireless networks. The method used was also a form of prototyping. (See Figures 9 and 10.)

- **Implement the proposed model in the form of the pilot as proof of concept**
  
  This objective was met via a design-science process. A high-speed wireless network among government schools has never been done before. The **Research Contribution** of this dissertation showed how wireless technology could assist in migrating schools into the 21st century and potentially reduce the gap in the Digital Divide. Chapter 5 suggested a model for a communications’ network as well as detailed the implementation thereof.

- **Monitor sustainability of the project by the schools.**
  
  This objective was met via a design-science process. The monitoring of the Wireless School Network will be an ongoing event for the next few years. It is advisable that future researchers re-visit the network to determine whether it has made an impact and whether it is still maintainable in the South African education climate. This process forms part of **Design Evaluation.**
The case-study component of this dissertation also serves as a form of evaluation for the proposed design.

This dissertation has been communicated to various audiences, thus satisfying **Communication of Research**, as outlined by design science. The technology-oriented audience was informed of the technical aspects of the wireless pilot project. These individuals have already identified other uses for the technology as well as additional research projects which will stem from this one. Various management-oriented stakeholders have shown keen interest in the project and have expressed an interest in formulating a strategy to use this model in other parts of the country. This dissertation itself, and any subsequent publications that will possibly stem from it, also serves to communicate the results.

### 6.3 Conclusion

This dissertation showed that it is feasible to create a communications’ network among South African schools. It is believed that such a network can add great value to the education system in South Africa. The potential for this network to address the gap in the Digital Divide is enormous. It examined various ICT communications’ technologies and found that wireless communications’ technology is best suited for such a network, due to the speeds offered by the technology and the cost structure associated with it. A case study examined a pilot installation of the network and proved the concept. The future growth of the network is now completely dependent on additional funding from the South African Department of Education and industry stakeholders. The success of the network will, ultimately, be determined by the effective use thereof.
6.4 Future Research

The network lends itself to opportunities for future research where issues like security, effectiveness, new initiatives, sustainability and various other areas need to be researched.

It is hoped that this network could become a major aid to the education system in South Africa and that it will play a part in reducing the gap in the Digital Divide.
Bibliography


