Chapter 1: Introduction and Problem statement

High-speed telecommunication facilities are becoming the highways of the economy in the new millennium. Communities with efficient access to telecommunication facilities will be able to participate in the fastest growing high-wage sectors of the economy. Telecommunications infrastructure has become the most extensive spatial structure in an urban region with great geographical range. Network sizes may vary between small indoor networks with three or four elements, to massive networks ranging across a whole country or even a continent. Managing vast infrastructure elements like these requires a specialized data management tool (Cai, 2002; French & Jia, 2007).

1.1 Problem statement

As the complexity of computer networks have increased, so has the difficulty to manage and control the networks. The presence of network errors in massive contemporary networks is inevitable. The key to good network management is the quick detection, location and identification of the errors, which in turn improves the reliability of the network. When a large network is managed without an information management system, it becomes difficult to determine and repair the root cause of a network error efficiently, which may lead to financial losses for the network owner (Niu *et al.*, 2010).

The need for an information management system is highlighted by the challenges which arise from managing large networks. Locating a malfunctioning network element in a bulky network without an updated visual representation is near impossible. Retrieving the relevant attribute information for that specific element is another intimidating challenge, as is the task to update the spatial representation and relevant information of the element after it has been repaired or replaced (Niu *et al.*, 2010).

A Geographical Information System (GIS) serves as a singular solution to all the challenges related to computer network management. A GIS combines database management tools with mapping software to collect, share, edit and organize many types of information. In an infrastructure management framework, GIS is a system, which offers an accurate spatial representation (maps), in co-operation with a database which contains non-spatial information about different types of infrastructure. Geographic information systems have powerful data handling and spatial analysis capabilities and are therefore ideal for managing telecommunications infrastructure (ESRI, 2008a; Cai, 2002).

There are a lot of examples of how GIS can be implemented in order to maintain and manage telecommunications networks (Halfawy *et al*., 2002; Meehan, 2007; Turkstra *et al.*, 2003; Barbu & Cumblidge, 2002; Cai, 2002; French & Jia, 2007). These are normally examples of how municipalities provide geographically distant communities with information technology (IT) networks. All of these examples are in a two-dimensional environment (2D) and depicts a telecommunications network on a large outdoor scale (also known as macro scale). When the focus area is indoors, representing the distribution of network elements becomes more complex. This is due to the presence of horizontal as well as vertical cables. For example on a campus, the IT network will consist of features that stretch between geographically distant locations. The network will also connect features which are situated at the same location, but separated by elevation. Such an example is network elements which are situated in the same building, but on separate floors. It will be very difficult to differentiate between identical element types located on different floors, in a 2D environment.

In order to differentiate between features on different levels, the whole network needs to be displayed in a three-dimensional environment (3D). Depicting IT-network components in 3D is very similar to multiple level building layouts. Before the network distribution inside of a building can be accurately illustrated in 3D, it is essential to show the layout of the building in 3D. This is called building interior management (BIM) (Hijazi *et al.,* 2010).

The Potchefstroom campus has 14 computer facilities, each containing a number of personal computers and other network components. The campus also contains hundreds of independent computers used for a wide variety of tasks. Computers used by lecturers, post-graduate students, researchers, administrative workers, maintenance personnel as well as the computer facilities need to be connected via a massive network of telecommunications infrastructure. All additional equipment (for example printers, fax machines and scanners) are also connected to the network through access points. All these computers and machines are constantly sending and receiving data simultaneously and therefore putting the network and programming under immense pressure. The network infrastructure and connectivity have to be managed and maintained frequently (NWU, 2011; Buys, 2010).

Maintaining the infrastructure, which is involved in such a network, goes hand-in-hand with monitoring and preserving the information technological hardware. Currently, the Potchefstroom campus makes use of hard copy CAD maps to locate malfunctioning infrastructure. Most of these maps are out of date and in some cases there is a total lack of data. These maps depicts the building name, location and building layout where the malfunctioning equipment (such as servers and switches) are located, but shows no detail of where it is located inside the building, or it's attributes. Updating the information after alterations to the network have been implemented is a time-consuming process and is often either disregarded or done at a later stage (Buys, 2010).

A GIS system could deliver a more detailed spatial display of the infrastructure. The maintenance tempo on the infrastructure can be improved dramatically by locating malfunctioning hardware quickly and accurately, through a database that contains information about all the hardware. With information easily available, more staff could have access to vital information. The design of a new extension to the network could be best implemented by knowing where the most suitable location is to install new hardware to best interact with the existing network. Geo-referenced information about existing infrastructure could avoid that new projects (for example the construction of a new building) damage the original infrastructure. A well-designed GIS system also offers a dynamic database, which is easily accessible and could be regularly updated (ESRI, 2010a).

The data model will be created by commercial off the shelf GIS software, ArcGIS 10, in order to display the network in 3D. It will represent the campus zones, building outlines, individual floors and rooms, as well as the network elements: switches, network ports and cables. The data model will also depict how the elements are related to one another spatially and non-spatially. Finally the data model will illustrate the connectivity between the features in the IT-network and provide the end-user with a tool to perform network analysis in a 3D environment.

The aim of this study is to determine to what extent GIS software can be implemented in order to manage, analyze and visualize an IT network between buildings as well as inside buildings on a university campus. In order to achieve this aim, the study will present a pilot data model representing the computer network for a part of the Potchefstroom campus of the North West University.

1.2 Objectives

In order to achieve the aim by presenting a working data model for the study area, the study was divided into four objectives:

- Firstly a literature study was done to create an understanding of how telecommunications and especially computer networks are implemented and managed. The literature also describes the concepts of GIS and derives techniques to design and create a GIS for computer networks from existing examples.
- The second objective involves the capturing of necessary data in order to create the data model. This data includes information about the location of utility elements, building layouts, and non-spatial information such as the attributes of persons responsible for the room.
- The design and development of the data model is the third objective. In order to achieve this objective the data model needed to be designed methodically according to the design methods derived from the literature, as well as created physically using the GIS software.
- The final objective is to highlight and describe the capabilities of the data model. This includes the data management and spatial analysis abilities of the data model.

1.3 Study area

The North-West University is one of the leading universities in South Africa. According to the University's website (NWU, 2011), it consists of three campuses namely the Vaal Triangle campus, Mafikeng campus and the Potchefstroom campus. Of the three campuses, the latter has the greatest number of students. The University had a total of approximately 64 906 and 51 433 registered students for 2010 and 2011 respectively. Roughly between

75 - 78% of students registered at the Potchefstroom campus. The Potchefstroom campus is host to 8 faculties, which has 32 individual schools. In addition, the Potchefstroom campus has a large staff component including administrators, lecturers, researchers and maintenance personnel and buildings (Figure 1.1). It is thus essential for the campus to have a large number of connected computer facilities (Eloff, 2010; NWU, 2011).

The pilot project will only be designed and implemented for a predefined part of campus (two buildings). Buildings E4 and E6 (Figure 1.2) are both part of the School of Environmental Sciences and Development, in the Faculty of Natural Sciences. Building E4 is divided into two sections known locally as the Lettie du Plessis building and the De Klerk building. The Lettie du Plessis building houses the Geography and Environmental Management subject group on the campus, while the De Klerk building contains the subject groups Geology and Town- and Regional planning. The Lettie du Plessis building has only a ground floor while the De Klerk building has two floors. Building E6 is locally known as the J.S. van der Merwe building and is home to the subject groups Zoology, Botany and Microbiology. Building E6 has a total of 5 floors (4 floors and a basement floor). Buildings E4 and E6 contain multiple personal computer (PC) laboratories, offices, class rooms and other utility rooms which all utilizes different types of IT infrastructure on a daily basis.

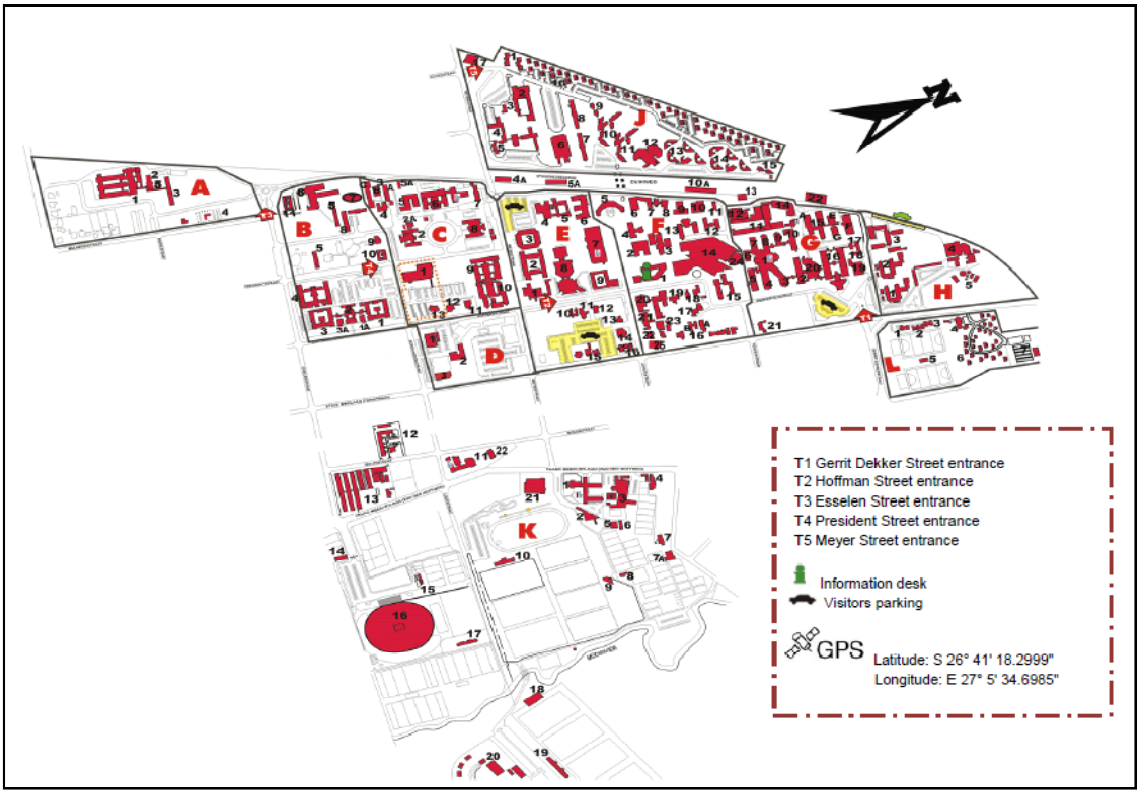

Figure 1.1: Potchefstroom campus plan of the North-West University (NWU, 2011).

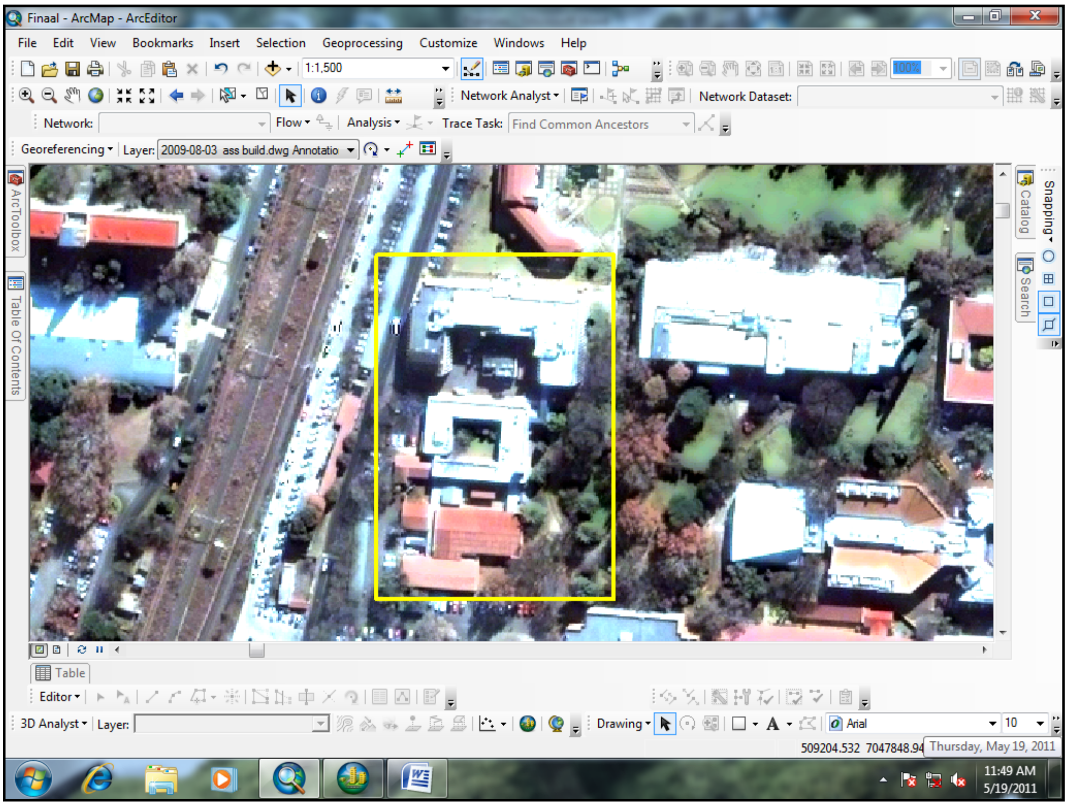

Figure 1.2: Buildings E4 and E6 (QuickBird, 2008)

1.4 Methodology

1.4.1 Literature study

The literature study examines the practical implementation of telecommunication network infrastructure with the main focus on computer networks, specifically on the Potchefstroom campus. The literature study will also compare GIS to alternative data management tools, discuss relevant GIS concepts and design methods before concluding by inspecting several case studies which are similar to this study.

1.4.2 Empirical study

During the empirical study of the project, interviews were done with the employees in charge of monitoring and maintaining the IT-infrastructure of the Potchefstroom campus (Information and Communication Technology department). These interviews helped to create an understanding of how the network is implemented locally, as well as helped to create a sense of the functionality that the data model must include. Interviews were also done with the building infrastructure manager of the study area buildings as well as the University's department of technical services. The aim of these interviews was to gather the spatial and non-spatial data necessary to develop the data model.

The design and development of the data model was done according to chronological design steps of the data model design methods considered in the literature study. This included the conceptual idea of what the data model should represent, the logical organization of the numerous database elements and finally the physical development of the data model. The final product of these steps is a robust generic GIS data model which will be able to solve IT-infrastructure management problems.

The GIS data model was built by utilizing off the shelf Environmental System Research Institute (ESRI) ArcGIS 10 software. ArcGIS 10 offers three data representing environments. ArcCatalog is the data management environment, which offers data organization processes. ArcMap is a two-dimensional (2D) environment which visually displays spatial data according to its position on Earth. ArcMap also provides different analysis techniques that can be applied to the data. The third element of ArcGIS 10 is ArcScene, which is a three-dimensional (3D) data viewing platform. ArcScene visually displays spatial data according to its position on Earth as well as its elevation and allows partial analysis on the data (ESRI, 2011).

Finally the empirical study delivered a description of the tasks which can be performed by utilizing the GIS as well as the abilities to perform analysis on the IT network.

1.5 Chapter layout

The following chapter in the dissertation is Chapter 2: Literature study. Chapter 2 presents a summarized explanation of computer networks infrastructure and its implementation characteristics. The chapter then provides a literature framework of GIS by comparing it to different information management tools and software, describing the basic GIS concepts and illustrating the features and benefits of the geodatabase. Chapter 2 concludes by comparing three geodatabase design methods to one another and examining case studies that provide examples of techniques that are useful to this study.

Chapter 3: Methodology and Design comprises of the conceptual and logical design methods for the geodatabase. This chapter starts by defining the end-product functionalities that was expected of the data model as well as dividing it into thematic layers. Chapter 3 also describes the logical arrangements that were taken into account when the geodatabase was designed. This includes defining the tabular database structure, subtypes, domains, relationship classes, spatial coordinate systems, topological rules and networks. Chapter 3 concludes by proposing a final geodatabase layout.

Chapter 4: Implementation describes the physical design phase of the geodatabase. This entails the actual creation of a geodatabase. The chapter describes the techniques that were use in order to create a functioning data model. Chapter 4 also offers a standard operating procedure to update and maintain the data model. The chapter concludes by providing documentation of the data model, this includes a list of the metadata of the features that participate in the data model as well as a diagram depicting the relationship classes between tables.

The penultimate chapter, Chapter 5: Results and Analysis delivered a list of the capabilities of the data model. It highlights the different functions and how to implement them in order to perform network analysis on the network. Chapter 6: Conclusion summarizes the dissertation and states how the aim of the study was achieved.