A RISK ANALYSIS AND RISK MANAGEMENT METHODOLOGY FOR MITIGATING WIRELESS LOCAL AREA NETWORKS (WLANs) INTRUSION SECURITY RISKS

BY

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by

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ABSTRACT

Every environment is susceptible to risks and Wireless Local Area Networks (WLANs) based on the Institute of Electrical and Electronics Engineers (IEEE) 802.11 standard are no exception. The most apparent risk of WLANs is the ease with which itinerant intruders obtain illicit entry into these networks. These intrusion security risks must therefore be addressed which means that information security risk analysis and risk management need to be considered as integral elements of the organisation’s business plan.

A well-established qualitative risk analysis and risk management methodology, the Operationally Critical Threat, Asset, and Vulnerability Evaluation (OCTAVE) is selected for conducting the WLAN intrusion security risk analysis and risk management process. However, the OCTAVE risk analysis methodology is beset with a number of problems that could hamper a successful WLAN intrusion security risk analysis. The ultimate deliverable of this qualitative risk analysis methodology is the creation of an organisation-wide protection strategy and risk mitigation plan. Achieving this end using the OCTAVE risk analysis methodology requires an inordinate amount of time, ranging from months to years. Since WLANs are persistently under attack, there is a dire need for an expeditious risk analysis methodology. Furthermore, the OCTAVE risk analysis methodology stipulates the identification of assets and corresponding threat scenarios via a brainstorming session, which may be beyond the scope of a person who is not proficient in information security issues.

This research was therefore inspired by the pivotal need for a risk analysis and risk management methodology to address WLAN intrusion attacks and the resulting risks they pose to the confidentiality, integrity and availability of information processed by these networks.

Keywords risk, risk analysis, risk assessment, risk management, OCTAVE, OODA cycle, wireless local area networks (WLANs), wireless intrusion detection system
ACKNOWLEDGEMENTS
The OODA cycle is the perfect embodiment of an effective human behavioural decision-making cycle, which I adopted for this research endeavour. I observed the plethora of fields in information security, I oriented myself by creating a mental image of the various avenues I could unearth, I decided precisely which areas I would explore and I finally took action, resulting in this dissertation.

I moved through various iterations of this cycle and during this nonlinear process, I encountered a number of exceptional people to whom I would like to express my immense gratitude:

- I owe my parents an enormous debt of gratitude for always believing in me and supporting me from the inception of this dissertation. I would never have been able to complete it without their continuous words of encouragement. They are without doubt the greatest assets in my life.
- My sister, Munira, was a major source of inspiration and if it were not for her personal sacrifice, I would never have succeeded.
- The rest of my family, including my brother, sisters and their respective families were instrumental in the accomplishment of this dissertation.
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CORROBORATING MATERIAL

A CD-ROM has been included at the end of this dissertation. The contents of this CD-ROM include a Microsoft Access 2003 database that includes forms and reports for the retrieval and printing of WLAN intrusion security risk analysis and risk management information.
Wireless is a huge whale floating just beneath the surface. All people are seeing is the tail fluke. But one day it’s going to breach, and everyone is going to be surprised at the size of it.

-David Hughes, 1970s Computer Maven
1. INTRODUCTION

1.1 INTRODUCTION
The liberty of being able to gain access to the corporate network without being constrained by a fixed-wired cabling infrastructure has certainly made WLANs an enticing technology. This, in turn, has led to mobile freedom and greater flexibility (McCullough, 2004:8). Large business corporations, government organisations and home users all desire this type of technology but the very nature of WLANs, which is the transmission of signals through the open-air has unleashed an entire spectrum of security concerns (Ciampa, 2001:20) and associated risks ("Best Practices", 2003:1).

The inspiration for this research therefore emanated from the pivotal need for a risk analysis and risk management methodology to address WLAN intrusion attacks and the resulting risks they pose to the confidentiality, integrity and availability of information processed by these networks.

1.2 MOTIVATION FOR THIS STUDY
A number of factors stimulated the research undertaken for this study. The ensuing section discusses these factors.

1.2.1 THE ESCALATING GROWTH OF WLANs
The proliferation and adoption of WLANs in the near future is inevitable as illustrated by the following:

- Anticipated growth of business wireless data users from "6.6 million at the end of 2001, to more than 39 million in 2006" ("Corporate Use", 2002).
- Estimated revenue of U.S. $3 billion from WLAN services offered to an estimated 21 million Americans who will be using this technology in 2007 ("Public Wireless", 2002).
- 50 million wireless devices projected to be installed on LANs by 2006 (Palmer, 2004:359).
Chapter One

- WLAN spending by healthcare providers is expected to grow from $47.8 million in 2002 to $75.8 million in 2007 (Cruz & Klein, 2004:1).

The above statistics and particulars all attest to the fact that WLANs are destined to be a promising technology. It is therefore crucial to address the security issues of these networks. This led to the next motivating factor for this dissertation.

1.2.2 THE SECURITY RISKS POSED BY WLANs

Every environment is susceptible to risks, and WLANs are no exception. According to the CSI/FBI Computer Crime and Security Survey, the only category to indicate an increase in types of attacks or misuse detected in 2005 from 70 respondents is the "abuse of wireless networks" ("Tenth Annual", 2005:14). The broadcasting nature of WLANs, which is the transmission of signals through the open-air rather than in protected cables, has made WLANs more prone to hacker attacks (Miller, 2003:5). This, in turn, has brought about an array of unique security risks not encountered with traditional fixed-wired networks (Lewis & Davis, 2004:10).

This problem is also compounded by the multitude of freely available WLAN hacking tools on the Internet ("Information", 2002:14), as well as the inherent vulnerabilities of WLANs themselves, the most sensationalised being that of the Wired Equivalent Privacy (WEP) protocol, a problem so grave that many companies have decided to abandon wireless networking altogether (Stewart, 2004:367).

WLANs security risks, if not addressed, could ultimately have an adverse effect on the adequate functioning of these networks. This realisation led to the next motivating factor.

1.2.3 ADDRESSING WLANs SECURITY RISKS

The following survey and study results indicate that organisations are not implementing necessary measures to enable them to operate their WLANs in a secure manner:
- According to a survey conducted by Ernst & Young, in which 1 300 organisations in 55 countries were surveyed, half of the respondents claimed that mobile technologies,
including wireless networks are a security concern but not all of these organisations are taking the necessary steps to manage the risks ("Global Information", 2005:13).

- A survey conducted by Deloitte revealed that 33% of the respondents have not taken any measures to protect themselves from "internal wireless communications exposures" ("2005 Global", 2005:13).

- A study conducted by the United States (U.S.) Government Accountability Office (GAO) revealed that federal agencies have to date not completely implemented chief controls such as policies, tools and practices to enable them to operate a WLAN in a secure manner ("Federal Agencies", 2005:1).

There exists an urgent need to implement necessary measures to mitigate WLANs security risks, as these risks can only be mitigated or reduced to an acceptable level rather than being totally eliminated (Park & Dicci, 2003:60). The most apparent security risk of a wireless network is the ease with which an intruder can access the organisation's internal network (Maiwald, 2003:438). It is therefore essential to focus primarily on mitigating WLANs intrusion security risks. This realisation led to the following motivating factor.

1.2.4 MITIGATING WLANs INTRUSION SECURITY RISKS

Deploying appropriate countermeasures can reduce risks to an acceptable level (Ciechanowicz, 1997:223). It is, however, vital to justify the deployment of expensive countermeasures as well as the business incentive for this, through a risk analysis exercise (Fitzgerald, 1995:9; Paul, 2000:122). The prime deliverable of a risk analysis study is the identification of countermeasures for the threats that have been identified (Eloff, Labuschagne & Badenhorst, 1993:598). This indicates that it is necessary to conduct a comprehensive WLAN intrusion security risk analysis exercise, which will facilitate the proposition of suitable countermeasures to reduce WLAN intrusion security risks to a tolerable level.
1.3 PROBLEM STATEMENT AND RESEARCH QUESTIONS

This research recognises the importance of mitigating WLANs intrusion security risks. The problem area can be addressed by considering the following research questions:

1.3.1 WHAT ARE THE POSSIBLE TYPES OF INTRUSION ATTACKS THAT CAN BE LAUNCHED ON WLANs?

One of the most daunting challenges facing the security community is information in the form of intelligence that identifies how the enemy operates (Spitzner, 2003:15). It is therefore necessary to gain an understanding of how WLAN intruders mentally compose themselves for a WLAN invasion attack. Such information will make it possible to construct a taxonomy of the most cited and most probable WLAN intrusion attacks. This is a vital step because security problems must be comprehended and viewed as genuine problems prior to proposing a solution (Fitzgerald, 1995:8).

1.3.2 HOW SHOULD A WLAN INTRUSION SECURITY RISK ANALYSIS EXERCISE BE CONDUCTED?

This research question requires an expository overview of a select risk analysis methodology with a view of customising it specifically for conducting a WLAN intrusion security risk analysis exercise.

1.3.3 WHAT STEPS MUST AN ORGANISATION TAKE TO ENFORCE THE RESULTS OF A WLAN INTRUSION SECURITY RISK ANALYSIS EXERCISE?

A risk analysis terminates at the point where a recommendation is made to senior management to improve the security posture of the organisation. Actually taking heed of the results entails examining the follow-up activities of the WLAN intrusion security risk analysis exercise.

1.4 RESEARCH LIMITATIONS

The delineating factors of this research include:

- This dissertation focuses specifically on WLANs based on the IEEE 802.11 standard. Wireless Personal Area Networks (WPAN), such as Bluetooth based on the IEEE 802.15 standard and Wireless Metropolitan Area Networks (WMAN), WiMax or WirelessMan based on the IEEE 802.16 standard, are beyond the scope of this dissertation.
There are a number of varying WLAN deployment options including but not limited to infrastructure-based, ad hoc and hotspots (Ciampa, 2006:204-205). Since most installations use infrastructure-based WLANs (Housley & Arbaugh, 2003:32; Held, 2003:10), this research is oriented towards a study of infrastructure-based WLANs.

There are two risk analysis approaches, qualitative and quantitative (Peltier, 2001:19; Vennaro, 2005:6). A quantitative approach hinges upon “numeric exposure estimates for risk” (Lichtenstein, 1996:20) such as monetary values, which are often difficult to obtain since the cost of hardware and software continuously fluctuate. Furthermore, it is difficult to quantify the exact damage a WLAN intrusion attack can cause to something abstract such as the reputation of an organisation. As a result only qualitative risk analysis methodologies will be discussed, as this methodology has been proven to be the most frequently used (Nosworthy, 2000:599; Blakley, McDermott & Geer, 2001:102). The assessment of this approach is based on a subjective low/medium/high (Saltmarsh & Browne, 1983:106) basis instead of concrete monetary values.

There are three classes of threats (Peltier, 2004:15; Stoneburner, Goguen & Feringa, 2001:13):
- Natural threats, such as floods, tornadoes and earthquakes.
- Human threats, both inadvertent and malicious.
- Environmental threats, such as pollution and liquid leakage.

People are the greatest security threat to an organisation regardless of their motive (Parker, 2001:61). People have statistically resulted in the greatest loss to information resources (Peltier, 2004:15). The 2005 Global Security Survey conducted by Deloitte revealed that most security breaches stem from human error or poor operational practices ("2005 Global", 2005:14). Therefore, for the purpose of this research, human threats, either inadvertent or malicious, are discussed.

Software tools running on the Microsoft Windows operating system are used, as Windows is the prevailing operating system on most desktops (Howlett, 2005:21).
1.5 TERMINOLOGY USED IN THIS DISSERTATION

For the purpose of this dissertation, the following definitions apply.

INFORMATION SECURITY

*Information Security* encompasses the protection of digital information (Ciampa, 2006:256), as well as the crucial elements such as systems and hardware that use, store and transmit the information (Whitman & Mattord, 2004:4).

WIRELESS CLIENT

The term *wireless client* classifies any wireless device such as laptops, personal digital assistants (PDAs) and mobile phone handsets that are equipped with a wireless network interface card (WNIC) and is capable of receiving and transmitting information via radio waves.

WLAN INTRUDER

The term *WLAN intruder* classifies any individual who invades a WLAN without having the necessary privileges to do so. This individual can be an outsider or someone within the organisation. Thus, the term is broadly used with no regard to the origin or intent of the unauthorised individual.

1.6 STRUCTURE OF THIS DISSERTATION

This dissertation consists of four parts, subdivided into a number of chapters, of which parts II and III correlate to the WLAN intrusion security risk analysis and risk management process. The structure of this dissertation is tabulated below (table 1-1).

<table>
<thead>
<tr>
<th>PART O: BACKGROUND</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHAPTER ONE</td>
</tr>
<tr>
<td>INTRODUCTION</td>
</tr>
</tbody>
</table>

*Chapter one* serves as a background to the research problem for the dissertation, elaborating on aspects such as the motivating factors for the dissertation, the research limitations, an elucidation of the terminology and the structure of the dissertation.

<table>
<thead>
<tr>
<th>PART I: TOWARDS UNDERSTANDING AND IMPROVING THE OCTAVE RISK ANALYSIS AND RISK MANAGEMENT METHODOLOGY FOR MITIGATING WLANs INTRUSION SECURITY RISKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHAPTERS TWO AND THREE</td>
</tr>
</tbody>
</table>
# CHAPTER TWO
AN EXPOSITORY OVERVIEW OF THE OCTAVE RISK ANALYSIS AND RISK MANAGEMENT METHODOLOGY

*Chapter two* provides an overview of the OCTAVE risk analysis and risk management methodology. This chapter provides a critical analysis of these processes emphasising areas that need improvement to conduct a WLAN intrusion security risk analysis and risk management exercise successfully.

# CHAPTER THREE
THE OODA-OCTAVE RISK ANALYSIS AND RISK MANAGEMENT METHODOLOGY FOR MITIGATING WLANs INTRUSION SECURITY RISKS

*Chapter three* examines the OODA cycle as a model to address the weaknesses of the OCTAVE risk analysis methodology. A new risk analysis and risk management methodology, OODA-OCTAVE is synthesised for mitigating WLANs intrusion security risks.

## PARTS II to III
CHAPTERS FOUR TO SEVEN

*Chapters four to seven* correlate to the distinct phases of the OODA-OCTAVE risk analysis and risk management methodology for mitigating WLANs intrusion security risks. It is advisable for the reader at this stage to read chapter three. This will enable the reader to understand the structure of chapters four to six within the proper context of the WLAN intrusion security risk analysis and risk management process.

## PART II: WLAN INTRUSION SECURITY ANALYSIS
CHAPTERS FOUR TO SIX

## CHAPTER FOUR
OBSERVATION: KNOWLEDGE ELICITATION

*Chapter four*, correlating with the observation phase of the OODA cycle entails observing the WLAN operating environment, observing the WLAN intruder and the organisation’s exposure to security risks. This provides an insight into the most important assets that require protection as well as the security vulnerabilities of these important assets. Information gathered from these activities is required for the knowledge elicitation phase necessary for the organisational evaluation.
CHAPTER FIVE
ORIENTATION: TECHNICAL VULNERABILITY ASSESSMENT AND RISK IMPACT

Chapter five, correlating with the orientation phase of the OODA cycle, consists of all the analysis activities of the OCTAVE risk analysis methodology. This includes threat assessment, technological vulnerability assessment and risk impact assessment.

CHAPTER SIX
DECISION: PROTECTION STRATEGY AND RISK MITIGATION PLAN

Chapter six, correlating with the decision phase of the OODA cycle, culminates in the organisation’s decision to create a WLAN organisation-wide protection strategy and WLAN intrusion security risk mitigation plan that has to be presented to senior management for approval.

PART III: WLAN INTRUSION SECURITY RISK MANAGEMENT
CHAPTER SEVEN

ACTION: POST-OCTAVE ACTIVITIES

Chapter seven, corresponding with the action phase of the OODA cycle, comprises the post-OCTAVE activities. This includes implementation of the WLAN organisation-wide protection strategy and WLAN intrusion security risk mitigation plan as well as enacting the remaining risk management activities succeeding this.

PART IV: CONCLUSION
CHAPTER EIGHT

CONCLUSION AND FUTURE RESEARCH

The dissertation terminates with the concluding chapter, chapter eight, which examines whether the research objectives of chapter one have been satisfactorily attained. The extensibility of this research is examined. This chapter terminates with a reflection of possible areas for future research.

Table 1-1: Tabular representation of dissertation layout

The following diagram (figure 1-1) graphically depicts the structure of this dissertation.
PART 0: BACKGROUND
CHAPTER ONE
INTRODUCTION

PART I: CHAPTERS TWO AND THREE
TOWARDS UNDERSTANDING AND IMPROVING THE OCTAVE RISK ANALYSIS AND RISK MANAGEMENT METHODOLOGY FOR MITIGATING WLANs INTRUSION SECURITY RISKS

CHAPTER TWO
AN EXPOSITORY OVERVIEW OF THE OCTAVE ANALYSIS AND RISK MANAGEMENT METHODOLOGY

PART II: CHAPTER FOUR
OBSERVATION: KNOWLEDGE ELICITATION

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PART II: CHAPTER FIVE
ORIENTATION: TECHNICAL VULNERABILITY ASSESSMENT AND RISK IMPACT

PART III
CHAPTER SEVEN
ACTION: POST-OCTAVE ACTIVITIES

PART II: CHAPTER SIX
DECISION: PROTECTION STRATEGY AND RISK MITIGATION PLAN

PART IV: CONCLUSION
CHAPTER EIGHT
CONCLUSION AND FUTURE RESEARCH

Figure 1-1: Graphical depiction of dissertation layout
PART I

TOWARDS UNDERSTANDING AND IMPROVING
THE OCTAVE RISK ANALYSIS AND RISK
MANAGEMENT METHODOLOGY FOR MITIGATING
WLANs INTRUSION SECURITY RISKS

CHAPTER TWO
AN EXPOSITORY OVERVIEW OF THE OCTAVE RISK ANALYSIS AND
RISK MANAGEMENT METHODOLOGY

The average company today is a complex enterprise engulfed by rapid
technological change and fierce global competition. You have to assess
exposure to risk on an ever changing landscape.

-Arthur Levitt
Chairperson of the U.S. Securities Exchange Commission

CHAPTER THREE
THE OODA-OCTAVE RISK ANALYSIS AND RISK MANAGEMENT
METHODOLOGY FOR MITIGATING WLANs INTRUSION SECURITY
RISKS

Machines don't fight wars. Terrain doesn't fight wars. Humans fight wars.
You must get into the mind of humans. That's where the battles are won.

-Col John Boyd
CHAPTER 2

2. AN EXPOSITORY OVERVIEW OF THE OCTAVE RISK ANALYSIS AND RISK MANAGEMENT METHODOLOGY

2.1 INTRODUCTION

WLANs have "associated security risks that must be addressed" (Thomas, 2004:277). Information security risk analysis and risk management, therefore, need to be considered as integral elements in an organisation's business plan. The level of security in any organisation should be proportional to its risks. However, the concept of risk is the least understood concept to pervade the information security domain (Maiwald, 2003:145). This term is often used interchangeably and incorrectly for threats and vulnerabilities, but in reality, a risk "exists when there is a threat and a vulnerability that coincide" (Birch & McEvoy, 1992:50).

Organisations tend to evade considering the fact that security risks can be "controlled or minimised". Important aspects such as risk analysis, risk assessment and risk management, are therefore very seldom topical issues in boardroom agendas (May, 2002:10).

The objective of this chapter is to promote an understanding and improvement of these vital processes in terms of addressing the intrusion security risks of a WLAN operating environment.

2.2 STRUCTURE OF THIS CHAPTER

This chapter commences by defining the term risk and addressing the importance of managing risk. Thereafter the multitude of definitions and objectives regarding information security risk analysis, risk assessment and risk management processes are presented, with the view of standardising the meaning and objective of these processes. It is necessary to have a basic understanding of the processes prior to embarking on a comprehensive WLAN intrusion security risk analysis and risk management exercise.
The OCTAVE (Alberts & Dorofee, 2003) risk analysis and risk management methodology is discussed, as this specific methodology will be used for conducting the WLAN intrusion security risk analysis and risk management exercise. This chapter concludes by critically examining the OCTAVE risk analysis and risk management methodology and highlighting areas that need improvement to conduct a workable WLAN intrusion security risk analysis and risk management exercise successfully.

2.3 DEFINING RISK
The definitions of risk contrast based on different cultures, businesses and environments (Wei, Frinke, Carter & Ritter, 2001:1). Within the information security realm, risk is defined as the probability that a threat agent (cause) will exploit a system vulnerability (weakness) to create a loss to the confidentiality, integrity and availability of an asset (Carroll, 1996:459; "Security Risk", 2005:6).

The following concepts from the definition of risk require further elucidation. A threat can be defined as any person or object that presents danger to an asset (Whitman & Mattord, 2004:43) whereas a vulnerability is a weakness, flaw, hole or anything that may be exploited by a threat that then results in a damaging outcome (Broder, 1984:4; Stephenson, 2004:17). Availability is the requirement that enables authorised users continuous access to information and system resources (Bace, 2000:29). Confidentiality of information is the assurance that "information is accessible only to those who are authorised to view it" (Mash, 2002:11). Integrity is the assurance that a message has not been in any way modified in transmission, either deliberately or by transmission errors (Stanley, 2002:58). An asset is something tangible or intangible and of value to an organisation (Nosworthy, 2000:599; Josang, Bradley & Knapskog, 2004:63).

2.4 THE IMPORTANCE OF MANAGING RISK
Comprehending and managing IT security risk is paramount for protecting organisational resources (Gilliam, 2004:296). Managing risk is so important that a host of government and specific regulations (Deloitte & Touche, 2003:8) are in place to enforce various mechanisms to manage risks. The most prominent of these bodies include:
- The Basel II Capital Accords mandate banks to keep capital reserves explicitly to cover operational risks, including information security risks ("Overview of", 2003).
The Federal Trade Commission (FTC), in response to the requirement stipulated by section 501(b) ("FederalTrade", 2002:36484) of the Financial Modernisation Act of 1999, also known as the Gramm-Leach Bliley Act or GLB Act issued a final safeguards rule that forces financial institutions to be liable for risks in each area of their operations. This is stipulated under paragraph b of Section 314.4 of the final safeguards rule ("FederalTrade", 2002:36489).

The Sarbanes-Oxley Act of 2002 applies to corporations in the U.S. and abroad. The act requires the issuer of securities publicly traded on the U.S. financial markets to create a risk management model for their stakeholders (Raval, 2004:15).

The Health Insurance Portability and Accountability Act (HIPAA) of 1996 establishes a standard for data security in healthcare organisations by outlining a set of technical, physical and administrative security practices to protect electronic patient data (Alberts & Dorofee, 2004:141). This regulation requires each healthcare organisation to conduct a security assessment of the threats that could exploit certain vulnerabilities, thereby gaining access to electronically protected health information (Johnson & Schulte, 2004:48; Geffert, 2004:22).


A prime responsibility of agencies under The Federal Information Security Management Act (FISMA) ("Department of", n.d.) is to perform a risk assessment.

The South African King II report of July 2001 emphasises the importance of risk management (Veijeren, n.d.).

Prior to embarking on the WLAN intrusion security risk analysis and risk management exercise, it is important to have a general understanding of the terms risk analysis, risk assessment and risk management, as well as to comprehend the objectives of these processes. This is discussed in the next section.
2.5 TOWARDS UNDERSTANDING THE DEFINITION AND OBJECTIVE OF INFORMATION SECURITY RISK ANALYSIS, RISK ASSESSMENT AND RISK MANAGEMENT

The subsequent section surveys the literature to elicit the varying definitions and objectives of the terms risk analysis, risk assessment and risk management. Recurring key term(s) and important concepts for the definitions and objectives are italicised and displayed under every definition and objective in order to create a solitary comprehensive definition and objective of the terms risk analysis, risk assessment and risk management. This exercise serves to determine if these concepts are distinct, synonymous or interrelated.

2.5.1 DEFINITION OF RISK ANALYSIS AND RISK ASSESSMENT

Information security risk analysis and assessment has become a large research field since the evolution of network technology (Wei et al., 2001). To obtain a concise definition of the terms risk analysis and risk assessment, it is crucial to analyse the various definitions of these terms as reflected in the literature.

The terms risk analysis and risk assessment are open to a number of definitions including:

- Risk analysis is "the identification and valuation of assets, the identification of threats and their likelihood of occurrence, the assessment of the vulnerability or weakness and the severity thereof" (Moses, 1992:229-230).

- Risk analysis is the "process of identifying the risks to an organisation, assessing the critical functions necessary for an organisation to continue business operations, defining controls that are in place to reduce organisational exposure and evaluating the cost of such controls" (Forcht, 1994:420).

- Risk analysis "should include threat and vulnerability relationships between business units and should be ongoing rather than periodic" (Babiak, Butters & Doll, 2005:183).
"At the heart of risk management is the evaluation of the potential impact of threats on the ability of a company to continue providing products or services to customers. This evaluation phase of the process is risk assessment (Paul, 2000:122). "Risk assessment is a process for tying together information gathered about business assets, their value and their associated vulnerabilities, to produce a measure of the risk to the business from a given project, implementation or design" (Paul, 2000:122). Risk assessments should also provide justification for the deployment of security controls (Paul, 2000:123).

"Risk assessments provide a basis for establishing appropriate policies and selection of cost-effective techniques to implement those policies" ("GAO, Information", 1999:5).

According to the National Institute of Standards and Technology Publication, (Stoneburner et al., 2001:E-2), risk assessment is synonymous with risk analysis and a part of risk management and entails identifying risks to system security, ascertaining the probability of occurrence, the resulting impact and the safeguards that would reduce this impact to an acceptable level.

Information security risk analysis processes "are geared toward imagining and then confirming technical vulnerabilities in information systems so that steps can be taken to mitigate the risks those vulnerabilities create" (Blakley et al., 2002:98).

Risk analysis provides a "proactive methodology to identify vulnerabilities and threats to the corporation's information assets" (Martinez, 2001:268).

Based on the key terms derived above, a comprehensive blended definition for the terms risk analysis and risk assessment is formulated:
Risk analysis is synonymous with risk assessment and forms the basis of risk management. It is a proactive, ongoing activity encompassing the identification and valuation of assets; the identification of real and perceived vulnerabilities associated with a particular asset and their severity; the identification of threats and the likelihood of their occurrence; the examination of threat and vulnerability relationships which result in the manifestation of risks; the impact of this risk manifestation with a view to institutionalising appropriate policies; defining existing controls and proposing viable corrective action so as to reduce the impact to the level which is acceptable for a particular environment.

Having established that risk analysis and risk assessment are interchangeable concepts, from this point forward these terms are used synonymously.

2.5.2 OBJECTIVE OF RISK ANALYSIS

It is now important to determine the objective of risk analysis having created a fitting definition for this process. Once again, the literature is scrutinised to obtain a multitude of objectives with the sole aim of creating a unified objective.

Various objectives of the risk analysis process include:

- The main goal in conducting a risk analysis is to determine the potential losses that could occur from intentional or inadvertent events (Caelli, Longley & Shain, 1989:85).

  potential losses that could occur from intentional or inadvertent events

- The goal of risk assessments should be to comprehend the risks of the particular environment under assessment and to propose a strategy to mitigate these risks to an acceptable level (Vennaro, 2005:2).

  comprehend the risks of the particular environment; mitigate these risks to an acceptable level

- Risk assessment broadly applicable to any type of risk and not strictly confined to information security risk, provide decision makers with information required to comprehend factors that can have negative repercussions for operations and outcomes and make knowledgeable judgements regarding the actions necessary to reduce risk ("GAO, Information", 1999:6).

  any type of risk and not strictly confined to information security risk; reduce risk
The objective of risk analysis should be the preparation of comprehensive information containing motivating factors for defining unacceptable risk and countermeasures to be implemented. This information should be presented to senior management for approval (Badenhorst & Eloff, 1990:342).

Based on the above, a comprehensive blended objective of risk analysis is formulated:

The objective of risk analysis is to identify risks from potential or inadvertent events with a view to reducing the level of risk to an acceptable level. A comprehensive report on the justification for the implementation of countermeasures to reduce the risk to an acceptable level is submitted to senior management for approval. The risks identified are not exclusive to information security and can include any type of risk.

Having established that risk analysis is the foundation of risk management, it is imperative to examine the risk management process. This is focal point of the subsequent section.

2.5.3 DEFINITION OF RISK MANAGEMENT

IT risk management is regarded as being "a perennial top 10 business and technology priority for CIOs" (Hunter & Aron, 2005:2). Risk management is, however, often "shunned or given half-hearted support" because it is simply not "well understood" (Ozier, 1995:221). There is therefore a pivotal need to understand the information security risk management process with a view to standardising the definition and objective of this process.

The term risk management is open to a number of definitions listed below.

"Risk management is the identification of threats and the implementation of measures aimed at reducing the likelihood of those threats occurring and minimising any damage if they do". "Risk analysis and risk control form the basis of risk management where risk control is the application of suitable controls to gain a balance between security, usability and cost" (Nosworthy, 2000:600).
form the basis of risk management where risk control is the application of suitable controls to gain a balance between security, usability and cost

According to the National Institute of Standards and Technology Publication (Stoneburner et al., 2001:E-2), risk management is the process of "identifying, controlling and mitigating information system related risks" and encompasses "risk assessment, cost-benefit analysis and the selection, implementation, test and security evaluation of safeguards." This system review must consider "both effectiveness and efficiency, including impact on the mission and constraints due to policy, regulations and laws."

Risk management entails allocating limited resources to, “mitigate risks, transfer risks or recover from risk events” (Lewis & Davis, 2004:183).

"Risk management should be an ongoing activity that includes phases for assessing risk, implementing controls promoting awareness and monitoring effectiveness" (Paul, 2000:122).

Based on the above, a blended definition of risk management is formulated:

Risk analysis is the underpinning activity of risk management, where risk management is the ongoing process of planning, implementing, promoting awareness and monitoring of viable security measures to mitigate, transfer, eliminate or control the risk to an acceptable level.

2.5.4 OBJECTIVE OF RISK MANAGEMENT

It is important to determine the objective of risk management having created a fitting definition for this process. Once again, it is necessary to study the literature to obtain a multitude of objectives with the sole aim of creating a unified objective.

Various objectives of the risk management process include:

- The aim of risk management is "reduce business exposure by balancing countermeasures investment against risk" (Birch & McEvoy, 1992:45).
reduce business exposure by balancing countermeasures investment against risk

- The purpose of risk management is "to minimise the expected loss" (Suh & Han, 2003:150).

- The goal of risk management is "select risk mitigation, risk transfer and risk recovery measures so as to optimise the performance of an organisation" (Jacobson, 2002:1).

Based on the above, the objective of risk management is formulated:

The objective of risk management is the implementation of appropriate risk mitigation, risk transfer and risk recovery measures to reduce business exposure by balancing countermeasure investment against risk.

The aforementioned sections served to create a solitary comprehensive definition of the terms risk analysis and risk management. The objective of these processes was also determined. Armed with this fundamental information, it is possible to commence a WLAN intrusion security risk analysis exercise having established that risk analysis is the underpinning activity of risk management.

### 2.6 CONDUCTING A WLAN INTRUSION SECURITY RISK ANALYSIS EXERCISE

Since it is so easy to implement a wireless network, all too often no proper risk analysis is done rendering these networks susceptible to a great number of risks (Von Solms & Marais, 2004:634). The most obvious security risk of a wireless network is an intruder's ease of accessing the organisation's internal network (Maiwald, 2003:438). It is therefore crucial to examine the importance of conducting a WLAN intrusion security risk analysis exercise. This is the focal point of discussion of the ensuing section.

#### 2.6.1 THE IMPORTANCE OF CONDUCTING A WLAN INTRUSION SECURITY RISK ANALYSIS EXERCISE

Wireless access significantly increases the risk of a security compromise (Peikari & Fogie, 2003:291), primarily because of the following features of these networks (Yang, Xie &
WLANs have obliterated the need for physical access to wires, making these networks prone to attacks from passive eavesdropping to active interfering. Installing a wireless network has actually been compared "to putting a network point that accesses a company's network on a public sidewalk" (Von Solms & Marais, 2004:633).

It is virtually impossible to control the WLAN range and signal propagation so attacks on a WLAN can occur anywhere, anytime without any sign of the attacker.

WLANs are inherently weak with respect to security, which may result in a security breach.

There is therefore a dire need to perform a WLAN intrusion security risk analysis exercise. If properly conducted, risk analysis can offer organisations a number of benefits (Forcht, 1994:421; Broder, 1984:3; "GAO, Information", 1999:16; Broderick, 2001:15; Kittelberger, 1983:9; Pfleeger & Pfleeger, 2003:527; In et al., 2005:505; Shaffer & Simon, 1994:202), listed below.

- Identification of all assets, vulnerabilities and controls.
- Assurance that the most crucial risks have been identified and appropriately addressed on an ongoing basis.
- Coming to a consensus regarding which risks are the greatest and what measures should be taken to reduce these risks to an acceptable level.
- Justification for the acquisition of and expenditure on deploying security controls.
- Identification and prescription of remedial action in the event of a successful security breach that overrides the security controls designed to protect the information.
- Demonstration of the current security position of the organisation.
- Supporting decision-making for information security policies.
- Providing a heightened degree of interest in security by analysing the strengths and weaknesses of security to all hierarchical organisational levels, ranging from management to operations.
- Providing a means of communicating the risk analysis findings to business unit managers and senior management.
Once organisations understand the pressing need for conducting a WLAN intrusion security risk analysis exercise and the benefits they can accrue from conducting this process, the next step is actually conducting this exercise. Fortunately, formal methodologies for general and specific environments such as Belief-Based Risk Analysis (Josang et al., 2004), CRAMM ("CRAMM Expert", 2003), Cobra ("COBRA - Security", n.d.), CORAS ("CORAS:A Platform", n.d.), EBIOS ("Expression des", 2004), FRAAP (Peltier, 2005), ISRAM (Karabacak & Sogukpinar, 2005), MARION (Coopers, Theron & Du Toit, 1988), LAVA (Smith, 1987), MELISA ("The MARION and", 1990), MEHARI ("Mèthode Harmonisèlle", 2004), OCTAVE (Alberts & Dorofee, 2003), RaMex (Kailay & Jarratt, 1995) and The Buddy System (Jenkins, 1998) that encompass the underpinning principles of risk analysis with well-documented processes can be used.

The following section discusses a well-known qualitative information security risk analysis methodology, Operationally Critical Threat, Asset, and Vulnerability Evaluation (OCTAVE SM1), as this methodology will be used for conducting the WLAN intrusion security risk analysis exercise.

2.6.2 BACKGROUND: A SYNOPSIS OF THE OCTAVE RISK ANALYSIS METHODOLOGY

There are several reasons for selecting the OCTAVE risk analysis methodology:

- OCTAVE addresses both organisational and technological issues pertaining to information security risks (Alberts & Dorofee, 2003:12). Other approaches tend to exclude the business processes, focusing solely on the technical threats and vulnerabilities (Coles & Moulton, 2003:488). This aspect is important because senior managers are now coming to the realisation that there are grave human and organisational risks linked with the use of IT (McKeen & Smith, 2003:61).

- OCTAVE involves people from various hierarchical levels of prime business units, as well as the from the information technology department, in the risk analysis exercise. This is important because, in over 75% of businesses, security strategy is incorrectly ascribed to the IT department (May, 2003:13). Furthermore, risk analysis should

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1 Operationally Critical Threat, Asset and Vulnerability Evaluation and OCTAVE are service marks of Carnegie Mellon University.
cater for the participation of both the manager and staff in the process (Karabacak & Sogukpinar, 2005:149).

- OCTAVE has broad support in U.S. government agencies such as NASA and the DOD and its adoption in the private sector is escalating (Vennaro, 2005:7-8).
- OCTAVE is free and vendor neutral and has been developed by the Software Engineering Institute (SEI), a prestigious centre of technological expertise (Lanz, 2002:21-22).

There are two OCTAVE methods, one for larger, more experienced organisations and OCTAVE-S for smaller, inexperienced organisations (Alberts, Dorofee, Stevens & Woody, 2003:15). For the purpose of this dissertation, only the OCTAVE methodology as applied to large organisations is addressed, as this methodology will ultimately be used to address the intrusion security risks of an enterprise-wide WLAN operating environment.

The SEI (Alberts & Dorofee, 2003:15) developed OCTAVE. OCTAVE is a self-directed risk analysis methodology, which means that different hierarchical members within the organisation conduct the risk analysis and experts are consulted only for very specific and specialised needs. This ultimately results in profound dedication and interest in the risk analysis process, thereby manifesting in greater commitment to the results.

OCTAVE is a systematically structured risk analysis methodology that provides guidance for conducting an analysis of the threats, vulnerabilities, security requirements and levels of risk associated with an organisation’s critical technical and non-technical assets. The result of this analysis is the creation of an organisation-wide protection strategy and a risk mitigation plan to reduce the risks to the assets identified as crucial.

The OCTAVE process comprises three phases (Lanz, 2002:22) emphasising, the organisational, technological and analysis aspects of a security risk analysis. Each phase consists of a predefined number of processes (figure 2-1).

1. Phase 1 (Organisational View): Build asset-based threat profiles.
2. Phase 2 (Technological View): Identify infrastructure vulnerabilities.
2.6.2.1 PHASE 1: ORGANISATIONAL VIEW

In phase 1, the analysis team comprising people who have a great deal of knowledge regarding the organisation as well as its business and technological undertakings hold a series of workshops with senior managers (process 1), operational area managers (process 2) and regular and IT staff (process 3) to extract information regarding (Alberts & Dorofee, 2003:84):

- The most critical technical and/or non-technical assets and the threats to these assets. The participants brainstorm a list of assets.
- The identification of scenarios that threaten the most important assets. The participants brainstorm a list of possible threat scenarios.
- The importance of confidentiality, integrity and availability in protecting these assets.
- The organisation’s current protection strategy if any as well as the weaknesses in the organisation’s policies and practices. The OCTAVE catalog of practices may be used for this purpose. The catalog comprise two types of practices (Alberts & Dorofee, 2003:85):
Strategic Practices, which are well-documented good management practices that, remain stable over a period of time.

Operational Practices which change with advancements in technology.

This phase concludes with process 4 (threat assessment), which is the identification of threats to every critically identified asset, resulting in the creation of a threat profile for that particular asset (Alberts & Dorofee, 2003:112).

2.6.2.2 PHASE 2: TECHNOLOGICAL VIEW

OCTAVE focuses on those portions of the computing infrastructure that are the chief key components of the crucially identified assets (process 5) (Alberts & Dorofee, 2003:137). A vulnerability scan is conducted for the selected components to uncover technological weaknesses (process 6) (Alberts & Dorofee, 2003:158). It may be necessary to outsource this activity to technical experts. The analysis team should, however, evaluate the results to ensure the same high degree of interest and commitment to the risk analysis process.

2.6.2.3 PHASE 3: SECURITY STRATEGY AND PLAN DEVELOPMENT

In the risk analysis process (process 7), the impact of threats on each asset is identified to reflect the subjective high/medium/low impact on each threat resulting in a risk profile for each critically identified asset (Alberts & Dorofee, 2003:171). This is a qualitative determination and deals with the organisation's risk tolerance level. The organisational protection strategy and the risk mitigation plan for the critical assets are drafted (process 8A) (Alberts & Dorofee, 2003:193). The catalog of practices is updated to reflect the new strategic and operational plans for the organisation.

Phase 3 consolidates the information from phases 1 and 2 and creates a vision for long-term organisational protection and a mitigation plan for mid-term vulnerabilities associated with the critical assets. Results are sent to senior management for approval (process 8B) (Alberts & Dorofee, 2003:229).

The following diagram (figure 2-2) depicts the OCTAVE risk analysis activities.
Figure 2-2: OCTAVE risk analysis activities

**Phase 1: Organisational Evaluation**

Process 1-3

- Elicit from different hierarchical levels:
  - Critical assets.
  - Security requirements for critical assets.
  - Threats to critical assets.
  - Current security practices and organisational vulnerabilities.

**Phase 2: Technical Vulnerability Assessment**

(Processes 5-6)

Identify key components that will be examined for technological weaknesses.

**Phase 3: Develop Security Strategy and Plans**

- **Process 7**
  - Identify the impact of threats to critical assets.
  - Create risk evaluation criteria.
  - Evaluate impact of threats on assets.

- **Process 8A**
  - Develop protection strategy, mitigation plans and action list.

- Present results to senior management.
  - (Process 8B)
Since the OCTAVE risk analysis methodology will be used for conducting the WLAN intrusion security risk analysis exercise, it is vitally important to uncover any major flaws that this methodology may have on a general level. The following section assesses the overall strength of the OCTAVE risk analysis methodology.

2.6.2.4 ASSESSING THE STRENGTH OF THE OCTAVE RISK ANALYSIS METHODOLOGY

The General Accounting Office ("GAO, Information", 1999:11-15) framework which outlines the features a concrete risk analysis methodology should possess is used to assess the strength of the OCTAVE risk analysis methodology.

The GAO guide was created for the sole purpose of providing federal managers with guidelines on how to perform an ongoing information security risk assessment by providing examples of four organisations that have institutionalised good risk assessment approaches. The guide discusses the factors that these organisations identified as being critical to the success of their risk assessment exercises. These organisations were selected upon recommendations from government and private sector sources including the National Institute of Standards and Technology (NIST), Office of Management and Budget, private consulting firms, professional associations, a risk assessment software developer and GAO auditors ("GAO, Information", 1999:48).

The OCTAVE risk analysis methodology strength test is in appendix A. This strength test illustrates that OCTAVE is a sound risk analysis methodology and can thus be used for conducting the WLAN intrusion security risk analysis. There is however per se no perfect risk analysis methodology that suits all organisations as every organisation is indeed unique in its characteristics (Lichtenstein, 1996:21). This is particularly true of a WLAN operating environment as WLANs have certain unique characteristics as outlined in section 2.6.1.

The following section outlines the general weaknesses of the OCTAVE risk analysis methodology, which may impinge on a WLAN intrusion security risk analysis exercise.

2.6.2.5 LIMITATIONS OF THE OCTAVE RISK ANALYSIS METHODOLOGY

The drawbacks of the OCTAVE risk analysis methodology include (Lanz, 2002:23; Passori, 2004:2; Vennaro, 2005:8; Broodryk, 2005:1; Timothy, 2005):
Formal training is required in the use of the methodology.

The collaborate approach which requires people from different hierarchical levels to work together may not be possible because people may not work harmoniously with one another.

This methodology enlists a great investment in human resources and time for implementing the process and managing the documentation. Working in a wireless networking environment means subjecting to an array of threats on a continuous basis. Network security is a "dynamic and fluid process" with security risks changing as social conditions change ("Network Security", 2005:1). Any organisation operating a WLAN needs to be extremely agile in preventing intrusion attacks as an attack can cause irrevocable damage. The non-static nature of this environment means that there is a requirement for a risk analysis methodology that is rapid to execute.

An enormous amount of paperwork is involved. Although an automated tool is available (figure 9-1), this tool is expensive and rigid.

This methodology largely relies on the identification of assets and threat scenarios by means of a brainstorming process, something that may be difficult for someone who is not conversant with information security issues.

The eight OCTAVE processes themselves encompass a number of activities. For example, process 7 consists of four activities, including the creation of a narrative impact description, creating the risk evaluation criteria, evaluating the impact of threats on critical assets, and creating a risk profile. All these phases, processes and activities may overwhelm an organisation and give the illusion that conducting a WLAN intrusion security risk analysis process using the OCTAVE risk analysis methodology is a complex and daunting challenge.

Having established that risk analysis is the foundation of risk management, the next step is to determine how a WLAN intrusion security risk management process is conducted. This is the focal point of the next section.

### 2.7 CONDUCTING A WLAN INTRUSION SECURITY RISK MANAGEMENT EXERCISE

Like risk analysis, risk management also has a number of formal methodologies. OCTAVE has a number of post-OCTAVE activities. These are typical risk management activities (Alberts & Dorofee, 2003:10) including:
Planning how to implement the protection strategy and risk mitigation plans.

Implementing the plans.

Monitoring the plans for effectiveness and progress.

Controlling by taking appropriate corrective action for any variations in the execution of the plan.

To ensure that post OCTAVE covers all the risk management activities, the activities of a generic risk management methodology, the Australian/New Zealand standard on risk management ("Standards Australia", 2004) is examined to identify any gaps within the post-OCTAVE activities. The AS/NZS 4360:2004 is "one of the most popular standards in publication" ("Tutorial Notes:", 2004:1) and the only internationally accepted risk management standard ("Standards, methodologies,", 1998-2006).

2.7.1 AUSTRALIAN/NEW ZEALAND STANDARD FOR RISK MANAGEMENT

The Australian/New Zealand Standard for risk management provides the following generic framework for managing risk:

- Establish the context.
- Risk identification.
- Risk analysis.
- Risk evaluation.
- Risk treatment.
- Monitoring and review.
- Communication and consultation.

Precluding the risk analysis activities reveals the following risk management activities:

- Monitoring and review.
- Communication and consultation which is promoting awareness of the plans.

From the above, it can be inferred that post-OCTAVE lacks the following activity:

- Promoting awareness of the plans.

Therefore, a comprehensive risk management methodology using post-OCTAVE activities comprises the following activities:

- Planning how to implement the protection strategy and risk mitigation plans.
The following section critically reviews the OCTAVE risk analysis and risk management methodology.

2.8 CRITICAL EVALUATION OF THE OCTAVE RISK ANALYSIS AND RISK MANAGEMENT METHODOLOGY

The following observations from the expository investigation of the OCTAVE risk analysis and risk management methodology were drawn.

- Despite a few shortcomings that may influence a WLAN intrusion security risk analysis, OCTAVE is an effective risk analysis methodology as indicated by the GAO strength test (appendix A). Therefore, the OCTAVE risk analysis methodology can be used for conducting the WLAN intrusion security risk analysis exercise after ensuring that its shortcomings have been overcome.

- It is established that there are post-OCTAVE activities that are typical risk management activities. These activities were analysed and expanded. Post-OCTAVE can therefore, successfully be used for conducting the WLAN intrusion security risk management exercise.

2.9 CONCLUSION

Conducting an information security risk analysis and risk management process is a crucial undertaking that needs to be performed by any organisation wishing to protect its most critical assets. This chapter has promoted an understanding and serves to standardise the definition and objective of the information security risk analysis, risk assessment and risk management processes. It is important to understand these basic concepts prior to embarking on a comprehensive WLAN intrusion security risk analysis and risk management exercise.

The OCTAVE risk analysis and risk management methodology has been discussed and critically reviewed, as it will be used for conducting the WLAN intrusion security risk
analysis and risk management exercise. It has been established that despite the fact that OCTAVE is a solid risk analysis methodology, it does have a few general shortcomings that may hamper a successful WLAN intrusion security risk analysis. The OCTAVE risk management methodology can be used for conducting the WLAN intrusion security risk management exercise successfully. The next chapter focuses on improving the OCTAVE risk analysis methodology in preparation for conducting a WLAN intrusion security risk analysis exercise.
3. THE OODA-OCTAVE RISK ANALYSIS AND RISK MANAGEMENT METHODOLOGY FOR MITIGATING WLANs INTRUSION SECURITY RISKS

3.1 INTRODUCTION

Every organisation is subject to a succession of risks that could impede its "business operations, growth or profitability" (Moeller, 2004:72). The only environment that is genuinely devoid of risks is one whose future is not marred by uncertainty ("Microsoft Operations", 2004:5). Regrettably, only a minority of organisations actually consider all of the possible risks to which they are exposed to from an information security viewpoint (Howlett, 2005:9). Risks must be managed, which means that they must be identified and analysed and that corresponding mitigation plans must be developed and implemented (Carr, 1997:24-25). These activities are covered by the risk analysis and risk management processes. Neglecting to perform these processes can culminate in "serious financial impacts, commercial embarrassment and fines or sanctions from regulators" (Shaw & Daniels, 2002:14).

The preceding chapter provided a general understanding of these vital processes, stressing the importance of conducting a WLAN intrusion security risk analysis in particular. The OCTAVE risk analysis methodology was found to be flawed in certain respects. The activities of the OCTAVE risk management methodology were analysed and expanded and can be used for conducting the WLAN intrusion security risk management exercise successfully.

The objective of this chapter is therefore to propose a risk analysis and risk management methodology for mitigating WLANs intrusion security risks by overcoming the weaknesses of the OCTAVE risk analysis methodology.
3.2 STRUCTURE OF THIS CHAPTER

This chapter commences with the historical genesis of the Observation-Orientation-Decision-Action (OODA) decision-making cycle. Justification for the selection of this cycle to overcome the weaknesses of the OCTAVE risk analysis methodology is provided.

A new risk analysis and risk management methodology for mitigating WLANs intrusion security risks, OODA-OCTAVE is synthesised, by coalescing the OODA cycle with the OCTAVE risk analysis and risk management methodology. This methodology combines the psychological and temporal aspects of the OODA cycle with the OCTAVE risk analysis methodology to address all the gaps of the OCTAVE risk analysis methodology while remaining true to the OCTAVE risk analysis and risk management methodology.

3.3 THE OODA DECISION-MAKING CYCLE

The OODA decision-making cycle, selected to overcome the deficiencies of the OCTAVE risk analysis methodology, is discussed in the ensuing section.

3.3.1 BACKGROUND: A SYNOPSIS OF THE OODA CYCLE

The OODA cycle (figure 3-1), is a "simple, powerful and insightful model" (Good, 2005:3), immortalised by the late U.S. Air Force Colonel John R. Boyd (1927-1997). The historical development of this cycle stems from the Korean War. Colonel Boyd noted that the performance of the slow U.S. F-86 Sabre fighter aircrafts totally outshone that of the far superior MiG-15 Korean planes. He was perplexed by this situation and attributed the success of the U.S. fighter pilots to the following two factors (Wilson, 2001:14; Chester, 1996:60; Pech & Durden, 2003:169):

1. A larger canopy that provided a more eminent field of vision.
2. A more maneuverable aircraft with "high powered and highly effective hydraulic controls" (Lind, 1985:5) which facilitated faster movement. This meant that the U.S. fighter aircraft had the power to reposition faster from one manoeuvre to another during aerial dog-fights. This rendered the MiG pilots' reaction to the tactical situation ineffective. Such agility manifested in the U.S. pilots' 10 to 1 (Hammond, 2001:36; Brookhiser, 1986:40) kill ratio against the superior MiG-15 Korean planes.
Based on this observation, he developed the OODA cycle, a theoretical model that can be extrapolated to any direct conflict. The basic tenets of the OODA cycle entail that each party to a conflict (Coram, 2002; Polk, 2000):

- Observe oneself, the physical surroundings and the enemy, due to having a greater field of visibility.
- Orient oneself by creating a mental image or snapshot of the situation.
- Decide what to do by considering all the factors present at the time of orientation.
- Act, i.e. implement the decision.

Boyd’s OODA cycle evolved in the following premises (Fadok, 1995:14; Lind, 1985:5):

- Psychological: The sole premise of conflict is to destroy the spirit of the enemy by creating difficult operational and strategic situations.
- Temporal (Speed): The psychological paralysis can be created by moving faster through a number of iterations of the cycle thus inhibiting the adversary's time to decide and act by a greater margin. The idea is to get "inside the mind and decision cycle of the adversary" (Coram, 2002:335).

It is these aspects of psychology and tempo that are lacking in the OCTAVE risk analysis methodology. The next section examines how the OODA cycle addresses some of the gaps of the OCTAVE risk analysis methodology.
3.4 ADDRESSING THE WEAKNESSES OF THE OCTAVE RISK ANALYSIS METHODOLOGY

The OCTAVE risk analysis methodology suffers from several limitations (section 2.6.2.5); including an astonishingly long time to conduct the process and the requirement for the identification of assets and corresponding threat scenarios via a brainstorming process. The OODA cycle address both of these limitations. The predominant theme of the OODA cycle is that in order to annihilate the adversary, it is necessary to ("What is Killing", 2004:3):

- Disrupt the adversary's OODA cycle, thereby rendering the adversary's actions ineffective. This effectively means understanding the mindset of the WLAN intruder. Understanding how these itinerant intruders mentally compose themselves for a WLAN intrusion attack unravels typical threat scenarios that an intruder can exploit. This is in accord with information security strategy and tactics, which largely resemble those used in warfare (Whitman & Mattord, 2004:287) by drawing on the philosophy of Sun Tzu who states, "If you know your enemy and know yourself, you need not fear the result of a hundred battles..." (Tzu, 1988). The Honeynet Project echoes the same sentiment by stating that one first has to know one's attacker before one can defend oneself (The Honeynet Project, 2002:1). It is precisely this kind of intelligence regarding the enemy and how it attacks, together with its corresponding motives and tactics, that is lacking in network security (The Honeynet Project, 2002). Consequently, it is essential to study the cognitive processes of the enemy in order to develop an intuitive understanding of the most important assets that need the most protection, as well as of scenarios that threaten these assets. It is not possible to do this by a brainstorming process. Therefore, obtaining an understanding of the information flow of its adversary enables an organisation to examine systems proactively, correcting vulnerabilities before they are exploited, by making informed choices regarding protection strategies.

- Traverse more quickly through one's own loop to disorient the enemy. A fundamental understanding of the WLAN intruder's invasion techniques makes it possible for the organisation to rapidly determine the impact of these attacks. A high risk impact signals the proposition of an enterprise-wide protection strategy and risk mitigation plan to subdue the adversary prior to the manifestation of any attack.
The OODA cycle also ensures that the OCTAVE risk management process is recognised as a vital follow-up activity of the risk analysis process in the following manner:

- The OODA cycle has a clearly delineated element, action, which advocates executing the decision and this element is an integral part of the cycle. This conforms to typical risk management activities.

To overcome the drawbacks of the OCTAVE risk analysis methodology and include the OCTAVE risk management methodology as a vital follow-up activity, the OODA elements are assimilated with the OCTAVE risk analysis and risk management activities, resulting in the synthesis of a new risk analysis and risk management methodology, OODA-OCTAVE.

The intricacies of the OODA cycle with the intertwining of the four phases (figure 3-2) as espoused by Colonel Boyd (Boyd, 1995) manifest in a multitude of loops. Each loop is examined and fused with the phases and processes of the OCTAVE risk analysis and risk management methodology in order to enhance these processes. The next section discusses this newly developed risk analysis and risk management methodology for mitigating WLANs intrusion security risks.
Figure 3-2: Reproduction of Colonel John R. Boyd's sketch of the OODA cycle as espoused in his summation, "A Discourse on Winning and Losing" on 28 June 1995
### 3.5 THE OODA-OCTAVE RISK ANALYSIS AND RISK MANAGEMENT METHODOLOGY FOR MITIGATING WLANs INTRUSION SECURITY RISKS

A new risk analysis and risk management methodology, OODA-OCTAVE is synthesised (figure 3-3). It combines the temporal and psychological aspects of the OODA cycle with the OCTAVE risk analysis methodology in order to address some of the gaps in the latter.

![Figure 3-3: High-level diagram depicting the OODA-OCTAVE risk analysis and risk management methodology for mitigating WLANs intrusion security risks](image)

#### 3.5.1 WLAN INTRUSION SECURITY RISK ANALYSIS

The OCTAVE risk analysis activities are combined with the OOD elements as follows.

#### 3.5.1.1 OBSERVATION – KNOWLEDGE ELICITATION

In the observation phase (figure 3-2), the current environment, the subject and the adversary are observed. Information is received from outside the environment as well as in terms of feedback from previous OODA cycles (Owen, Burstein & Mitchell, 2004:19). In this phase, the data of situational analysis is collected (Schechtman, 1996:35). When this information is applied to a WLAN operating environment, the organisation can observe the WLAN operating environment, the WLAN intruder and its own exposure to security
attacks and obtain data regarding the security posture of its WLAN operating environment and its susceptibility to invasion attacks.

From this, it is possible to deduce which assets are important and require the most protection and to uncover the vulnerabilities of these assets. Such information forms the input required for phase 1 (processes 1-3) of the OCTAVE risk analysis process. Information gathered from these activities is required for the knowledge elicitation phase necessary for the organisational evaluation. This input solves two other problems of the OCTAVE risk analysis methodology:

✓ The challenges of collaboration among members from different hierarchical levels in the organisation. Phase 1, processes 1-3 normally require a host of workshops and structured interviews with members of different hierarchies in the organisation to elicit their views on what they construe as being the most important assets and the corresponding threats to these assets. The need for time-consuming workshops and structured interviews is eliminated. This shortens the OCTAVE risk analysis process and reduces the paperwork.

✓ It also solves the problem of identifying assets and corresponding threat scenarios from participants via a brainstorming process. Important assets can be identified from observing the WLAN operating environment and the threat scenarios can be identified from studying the WLAN intruder's decision-making cycles.

3.5.1.2 ORIENTATION: TECHNICAL VULNERABILITY ASSESSMENT AND RISK IMPACT
Orientation, which is how one analyses/synthesises a situation and creates mental images based subjectively on one's experience, culture, heritage and long-term memories stored in one's subconscious directly guides decision but is in itself also shaped by observation, action and new feedback (Hammonds, 2002:98) (figure 3-2). New information from the observation phase is fused into the "existing mental framework" and the process of destruction and creation begins (Schechtman, 1996:35).

☐ Destruction (analysis) entails decomposing a problem into sub-problems that are comprehended easily.

☐ Analysing and interpreting information facilitates the creation (synthesis) of new knowledge, expands on existing knowledge and permits knowledge to be reused (Owen et al., 2004:25).
The orient phase terminates at a point where the subject achieves a "coherent state of situational knowledge" (McCauley-Bell & Freeman, 1996:1581). Situation awareness is to "build awareness of complex, evolving situations in a timely and accurate manner" (Bladon, Hall & Andy Wright, 2002:886). More succinctly, orientation centres on organising the information so as to make an initial assessment (Blodgett, Gendreau, Guertin, Potvin & Seguin, 2003:146). This entails grouping all the analysis activities of the OCTAVE risk analysis methodology and equates with phase 1 (process 4) (threat assessment), phase 2 (processes 5 and 6) (technological vulnerability assessment) and phase 3 (process 7) (risk impact assessment). Logically grouping these phases and processes facilitates a better understanding of the OCTAVE risk analysis methodology. These activities encompass analysing and consolidating information and conclude in a state where the organisation has knowledge of its unique WLAN intrusion security risks (situation awareness).

3.5.1.3 DECISION: PROTECTION STRATEGY AND RISK MITIGATION PLAN
In the decision phase (figure 3-2), situational knowledge gleaned from the orientation phase facilitates a hypothesis to be developed, charting a course of action. This means carefully weighing the repercussions of a situation and proposing an action plan proposed (McCauley-Bell & Freeman, 1996:1581). This equates to phase 3 (process 8A) of the OCTAVE risk analysis process, where an organisational protection strategy and risk mitigation plan is proposed. It is possible to re-enter the observation phase from the decision phase prior to embarking on a course of action. This may be a necessary activity to reaffirm previous activities or to consolidate new observations.

3.5.2 WLAN INTRUSION SECURITY RISK MANAGEMENT
The OCTAVE risk management activities are coalesced with the action element of the OODA cycle as follows:

3.5.2.1 ACTION: POST-OCTAVE ACTIVITIES
In the action phase (figure 3-2), the decision is executed by implementing the action. Action should be executed swiftly, unpredictably and disproportionately in order to confuse the intruder (Spitaletta, 2003:41). This correlates to the post-OCTAVE activities where the actual implementation of the organisation-wide protection strategy and proposed countermeasure is done. A countermeasure is "a technical or non-technical
security method used to counteract a threat to a system” (Kailay & Jarratt, 1995:450). At the same time, any new interaction with the environment is fed into the observation phase to commence the cycle anew. The loop from action back into observation equates to the continuous monitoring aspect of risk management.

The implicit guidance and control from orientation to both observation and action illustrate that once a situation has been correctly analysed, it is possible to go directly from observing the situation to taking action without having to go through the intermediate orientation and decision phases. This means that if the same observations are made, it is possible to go directly from the knowledge elicitation phase directly to the risk management phase, circumventing the orient phase. This means the same protection strategy and risk mitigation plan can be enforced.

✓ This facilitates shortening of the OCTAVE risk analysis and risk management process.

The limiting factors of the OCTAVE risk analysis methodology include amongst others a great deal of investment in human time, resources and formal training. To overcome this problem the researcher has developed a database for storing all of the WLAN intrusion security risk analysis and risk management information (figures 3-4 to 3-5). Appendix E contains details regarding the logical design of the database.

The database serves to encapsulate both the OCTAVE risk analysis and risk management processes consolidated with the OODA cycle by permitting the organisation to cycle faster through the risk analysis process and include the OCTAVE risk management process as a vital component follow-up activity to the risk analysis process.

✓ This database precludes the need to invest in human resources, paper resources and formal training, thus shortening the cycle.

✓ The OCTAVE phases, processes and activities are succinctly laid out. There is no explicit mention of any phase number or process number such as phase 1, process 3, thereby providing an uncomplicated view of the OCTAVE risk analysis process.
The OODA-OCTAVE Risk Analysis and Risk Management Methodology for Mitigating WLANs Intrusion Security Risks

Figure 3-4: Database for storing WLAN intrusion security risk analysis information

Figure 3-5: Database for storing WLAN intrusion security risk management information

Figure 3-6 is a detailed diagram depicting the OODA-OCTAVE risk analysis and risk management methodology for mitigating WLANs intrusion security risks.
Figure 3-6: The OODA-OCTAVE risk analysis and risk management methodology for mitigating WLANs intrusion security risks.
3.6 CONCLUSION

This chapter centred on the proposition of the OODA-OCTAVE risk analysis and risk management methodology for mitigating WLANs intrusion security risks. This methodology serves to solve the problems regarding the OCTAVE risk analysis methodology and ensure that risk management is included as a vital follow-up component to risk analysis. The next chapter commences the WLAN intrusion security risk analysis exercise with the first phase, observation: knowledge elicitation.
PART II

WLAN INTRUSION SECURITY RISK ANALYSIS

CHAPTER FOUR
OBSERVATION: KNOWLEDGE ELICITATION

Wireless LANs are a breeding ground for new attacks because the technology is young and organic growth creates the potential for a huge payoff for hackers.

- Pete Lindstrom, Hurwitz Group
September 2002

CHAPTER FIVE
ORIENTATION: TECHNICAL VULNERABILITY ASSESSMENT AND RISK IMPACT

It will not do for the army to act without knowing the opponent's condition, and to know the opponent's condition is impossible without espionage

-Du Mu

CHAPTER SIX
DECISION: PROTECTION STRATEGY AND RISK MITIGATION PLAN

Wireless IDS is needed not only for people that have deployed WLANs, but also for enterprises that have not deployed one. And the reason why is that attacks from a WLAN into a wired network are a very real threat

- Brian Mansfield
4. OBSERVATION: KNOWLEDGE ELICITATION

4.1 INTRODUCTION

WLANs can be used primarily as an extension to supplement fixed-wired networks (Panko, 2005:218; Fung, 2005:184) or may function as independent networks ("Federal Agencies", 2005:6). This underlines the importance of having a basic understanding of these networks, particularly the security issues as security is "perhaps the biggest shortcoming of the 802.11 standard" (Khan & Khwaja, 2003:69).

The mobile environment has generated novel vulnerabilities that do not exist in fixed-wired networks (Zhang, Lee & Huang, 2003:545), vulnerabilities, which if exploited by malicious intruders could manifest in risks. It is therefore crucial to understand and mitigate these risks before they have dire consequences. A security assessment can aid in managing the security risks within an organisation (Baccam, 2004:2). This chapter commences with the conduction of a WLAN intrusion security risk assessment.

The objective of this chapter is to uncover all the operational issues prevalent in a WLAN operating environment that may lead to an invasion attack.

4.2 STRUCTURE OF THIS CHAPTER

This chapter commences with the conduction of the WLAN intrusion security risk analysis process. The preparatory activities as well as the activities required for the knowledge elicitation phase required for the organisational evaluation are covered.

The observation phase of the OODA cycle encompasses three aspects as outlined in the previous chapter. These three aspects include observing the environment, observing the enemy and observing oneself. This chapter, is therefore, structured according to these three aspects.
The first aspect, observing the environment entails studying the WLAN operating environment. This chapter commences with a synopsis of WLANs, elaborating on aspects such as the benefits and drawbacks of deploying this technology in contrast to fixed-wired networks, the components and architecture of WLANs as well as the most common standards in WLAN technology. The next phase, observing the enemy consists of an in-depth study of the OODA cycle of WLAN intruders to obtain an understanding of their information flow. The final aspect is observing oneself, which is an expository overview from the organisation's side to determine how secure its WLAN operating environment really is.

The following diagram (figure 4-1) depicts the role of this chapter within the overall context of the dissertation.
PART I
TOWARDS UNDERSTANDING AND IMPROVING THE OCTAVE RISK ANALYSIS AND RISK MANAGEMENT METHODOLOGY FOR MITIGATING WLANs INTRUSION SECURITY RISKS

CHAPTER TWO: AN EXPOSITORY OVERVIEW OF THE OCTAVE RISK ANALYSIS AND RISK MANAGEMENT METHODOLOGY

CHAPTER THREE: THE OODA-OCTAVE RISK ANALYSIS AND RISK MANAGEMENT METHODOLOGY FOR MITIGATING WLANs INTRUSION SECURITY RISKS

PART II
ORIENTATION:
TECHNICAL VULNERABILITY ASSESSMENT AND RISK IMPACT

PART II
CHAPTER SIX
DECISION: PROTECTION STRATEGY AND RISK MITIGATION PLAN

PART II
CHAPTER FIVE

PART III
CHAPTER SEVEN
ACTION: POST-OCTAVE ACTIVITIES

WLAN INTRUSION SECURITY RISK MANAGEMENT

PART IV: CONCLUSION
CHAPTER EIGHT: CONCLUSION AND FUTURE RESEARCH

Figure 4-1: The role of chapter four within the overall context of the dissertation
4.3 TERMINOLOGY USED IN THIS CHAPTER

For the purpose of this chapter, the following definitions apply.

**BANDWIDTH**

*Bandwidth* is the amount of data that can typically be transferred over a communications medium and is measured in bits per second (bps), where kilobits per second (kbps) is 1 000 bps, megabits per second (Mbps) is a million bps and gigabits per second (Gbps) is 1 billion bps (Gallo & Hancock, 2002:55).

**HERTZ (HZ)**

*Hertz* is the chief unit of measurement for radio frequencies (Palmer, 2004:360) and is "the number of cycles being carried per second" (Hallberg, 2003:14). *Megahertz (MHz)* is "the measurement of cycles in millions of cycles per second" and *gigahertz (GHz)*, "billions of cycles per second" (Stair & Reynolds, 2006:94).

**IP ADDRESS**

An *IP address* is a 32-bit dotted decimal address, where each byte can be represented in dotted decimal notation as four numbers ranging from 0 to 255 separated by periods (Ciampa, 2006:179; McCullough, 2004:35).

**OSI MODEL**

The *OSI model* is a theoretical model used to standardise communications across networks and outline the interoperability between their components (White, 2004:16).

Commencing the WLAN intrusion security risk analysis process entails executing the following preparatory activities.

4.4 PREPARATION FOR THE WLAN INTRUSION SECURITY RISK ANALYSIS EXERCISE

A designated leader is ascribed the task of conducting the risk analysis process. The researcher assumes this role. Scribes are responsible for documenting the risk analysis information. The database is used to record the WLAN intrusion security risk analysis information.

The researcher investigated a typical WLAN operating environment at the University of South Africa (UNISA). The preparatory activities for the WLAN intrusion security risk
exercise include obtaining senior management sponsorship and delineating the scope of the evaluation. The researcher obtained the necessary permission from the network administrator at UNISA and limited the scope of the evaluation to analyse the infrastructure-based WLAN. This information is stored in the database (figure 4-2). It is also necessary to assemble an analysis team. A small analysis team comprising the IT manager and two WLAN users was assembled. The analysis team was informed of the true meaning and objective of risk analysis and risk management (sections 2.5.1 to 2.5.4) and introduced to the OCTAVE risk analysis and risk management methodology using the database and figure 2.2.

Figure 4-2: WLAN intrusion security risk analysis preparatory activities

The next section covers the activities of the knowledge elicitation phase.

4.5 OBSERVING THE ENVIRONMENT - BACKGROUND: A SYNOPSIS OF WLANS

An IEEE 802.11 WLAN is a group of wireless clients located in a limited geographical area that use radio frequency (RF) technology to receive and transmit at rates of up to 2 Mbps in the air (Housley & Arbaugh, 2003:32; Dean, 2003:437; White, 2004:99). Radio frequencies are "high frequency alternating current (AC) signals passed along copper wire or conductor until an antenna radiates them into the air" (Lewis & Davis, 2004:53).

WLANs provide a number of advantages and disadvantages over traditional fixed-wired networks. The following section briefly surveys the benefits and drawbacks of deploying WLANs in relation to their wired counterparts.

4.5.1 BENEFITS OF DEPLOYING WLANs

Some of the most compelling benefits of deploying WLANs include (Park & Dicoi, 2003:60; Karygiannis & Owens, 2002:12; Park, Ganz & Ganz, 1998:237; Carter, 2005: 27):
Flexibility: It is possible to install WLANs more easily, cost-effectively and much more rapidly than traditional fixed-wired networks.

Mobility: WLAN users can access network files and the Internet any time without being confined to a wiring infrastructure.

Easy expansion: It is easy to add wireless clients to a WLAN by equipping them with a wireless network adapter card. Adding computers to fixed networks entails drilling holes and running cables.

4.5.2 DRAWBACKS OF DEPLOYING WLANs

The drawbacks of deploying WLANs include (Dean, 2006:311; McCullough, 2004:8; Palmer, 2004:363):

- Wired networks transmit much more data per second than wireless networks. The reason for this is that 802.11 uses the CSMA/CA (Carrier Sense Multiple Access with Collision Avoidance) to access the shared medium. This means that a wireless client after sensing that the medium is idle, sends a small frame called a request to send (RTS) stipulating the time it requires the medium. A frame is a unit of data sent over a network carried at the Data Link layer (layer 2) of the OSI model (Palmer & Sinclair, 2003:7). The receiving wireless client acknowledges the request by sending a small packet called clear to send (CTS). A packet is a unit of data sent over a network carried at the Network layer (layer 3) of the OSI model (Palmer & Sinclair, 2003:7). The sending wireless client sends the data frames for which the receiving wireless client issues an acknowledgement packet (ACK) to the transmitting wireless client to indicate that it has successfully received the packet. This use of ACK packets creates additional overhead, which culminates in wireless networks achieving between one-third and one-half of their theoretical maximum throughput. Throughput is the "actual amount of data that can be transferred" (Tomsho, Tittel & Johnson, 2004:412).

- Wired networks are prone to interference but to a lesser degree than wireless networks. Wired networks are not impeded by obstacles and interference such as hills and stormy weather (Palmer, 2004:363), as are wireless networks. Furthermore, the performance degradation of wired networks over the same distance is less than that of wireless networks.
WLANs operate in the 2.4 GHz, Industrial, Scientific and Medical (ISM) frequency spectrum using either frequency-hopping spread spectrum (FHSS) or direct-sequence spread spectrum (DSSS) (Khan & Khwaja, 2003:59) where the local RF regulatory body does not require the end-user to purchase a license to use the airwaves.

*Spread spectrum* entails using a greater bandwidth than that which is actually required in order to support a given data rate (Stallings, 2004:33). In *FHSS*, the signal jumps from one frequency to another within a band in a synchronisation pattern known to the channel’s receiver and transmitter (Maxim & Pollino, 2002:172; Dean, 2003:420; Stallings, 2001:21). In *DSSS*, a signal’s bits are spread into a sequence of multiple bits and allotted over different frequencies at once. Each bit is coded in such a way that the receiver upon receiving the bits can reassemble the original signal (Dean, 2003:420).

Over the years, the IEEE has developed a host of standards for the computer and electronics industry (Miller, 2003:9). 802.11, the first standard for WLANs was published on 26th June 1997 (Barnes et al., 2002:133).

Over the years, the IEEE has expanded the 802.11 standards to include the following variants:

4.5.3 IEEE STANDARDS
The most popular 802.11 extensions regarded as "de facto standards" ("Wireless LAN", 2005:2) include 802.11b, 802.11a and 802.11g (Khan & Khwaja, 2003:58; Dean, 2003:440). These three standards are discussed below.

4.5.3.1 802.11b
The most widely deployed standard, 802.11b, approved in September 1999 (Maxim & Pollino, 2002:175), also known as wireless fidelity or WiFi, specifies a data rate of up to 11 Mbps using DSSS in the 2.4 GHz ISM frequency band. For 802.11b, a total of 14 channels are defined by the IEEE standard in the ISM band with each channel occupying 22 MHz. (Dean, 2003:440; Park & Dicoi, 2003:61; Flickenger, 2003:4).
4.5.3.2 802.11a

802.11a, presented in 2002 (White, 2004:222) establishes a new unlicensed frequency band for wireless networking and increases throughput for networks to 54 Mbps (Kapp, 2002:84) using frequencies in the 5 GHz (Stallings, 2004:34) Unlicensed National Information Infrastructure (UNII) band (Park & Dicoi, 2003:61). The UNII is reserved for devices that provide a short range as well as high-speed wireless digital communication (Ciampa, 2006:52). 802.11a uses orthogonal frequency division multiplexing (OFDM), in which 52 carriers are used in transmitting data from a single source to obtain a 54 Mbps channel bit rate (Varshney, 2003:102).

4.5.3.3 802.11g

The 802.11g specification, approved by the IEEE in May 2003 (Tanzella, 2003:3) has a data transmission rate of up to 54 Mbps in the 2.4 GHz band and is backward compatible with 802.11b (Carter, 2005:37).

When the 802.11b standard was established in 1999 (Dean, 2006:314), the IEEE added new Physical and Data Link layers to the OSI model (Figure 4-3) without any variation to the other layers of the OSI model.

![Addition of Physical and Data Link layers to the OSI model](image)

The Physical layer dictates the transmission mode of data. The Physical medium has three layer specifications (Tanzella, 2003:2, Stallings, 2001:21):

- Direct-sequence spread spectrum (DSSS) operating in the 2.4 GHz ISM band.
- Frequency hopping spread spectrum (FHSS) operating in the 2.4 GHz ISM band.
- Infrared, a relatively unused technique in networking (Kapp, 2002:82).
The Data Link layer comprises the Media Access Control (MAC) layer and the Logical Link Control (LLC) layer (Tanzella, 2003:2):

- The MAC layer describes how computers receive and transmit data and maintain communication with other wireless clients after being authenticated successfully (McCullough, 2004:31).
- The 802.11 standard does not specify any changes to the LLC layer. This layer provides error and flow control as well as an interface to higher layers in the OSI model (Stallings, 2004:32). All modifications are confined solely to the MAC sublayer of the Data Link layer (Ciampa, 2001:92).

The MAC protocol permits only one client to transmit at a given point in time and that data transmitted is in blocks or MAC frames (figure 4-4).

![Figure 4-4: Format of an IEEE 802.11 frame](image)

It is important to understand 802.11 frames as they contain useful information that permits monitoring (Yang, Xie & Sun, 2004:1951). This information can provide insight to determine whether an intrusion attack has taken place. Frames are divided into three groups (Dean, 2006:313; Forouzan, 2003:339):

1. Management frames are those involved in communication between wireless clients and access points (APs). Wireless clients and APs are the basic components of WLANs. The following section provides a discussion of these components.
2. Control frames are those related to medium access and data delivery.
3. Data frames are those that carry the data sent between stations.
4.5.4 ARCHITECTURE OF WLANs

The basic components of a WLAN constitute:

- A wireless client equipped with a wireless network interface card (WNIC). The WNIC functions at the Physical and Data Link layers of the OSI model. Every WNIC has a MAC address, a 48-bit number set (Palmer, 2004:263) that provides identification at layer 2 of the OSI model (Carter & Shumway, 2001:113). The first 24 bits is a 24-bit organisationally unique identifier (OUI) that indicates the manufacturer of the WNIC which if known can reveal the name of the manufacturer from a searchable database ("IEEE OUI and", n.d.) The other 24 bits denote a 24-bit unique card identifier. The WNIC possesses an antenna making it possible to send and receive wireless signals.

- An access point (AP) that effectively functions as a bridge between the wired and wireless networks. An AP consists of an antenna, a radio transmitter/receiver on one end and MAC bridge to the wired infrastructure at the other end through which it is able to communicate with all devices connected to the wired network such as printers and servers. If the AP is able to connect the WLAN to any other type of network or to the Internet, it must also act as a router (Khan & Khwaja, 2003:48). A router allows "multiple users to share a single broadband Internet connection and directs traffic by routing data between clients" (McCullough, 2004:11).

The wireless client and the AP communicate via radio waves. A radio wave occurs when an electric current passes through a wire emanating a magnetic field in the space around the wire (Ciampa, 2001:34). Every AP also has a number called a basic station system ID (BSSID) assigned to it. The BSSID is essentially the MAC address of the AP (Howlett, 2005:318).

The AP functions as the base station for the WLAN and "the set of wireless devices with which a single AP communicates defines a basic service set (BSS)" (Shay, 2004:450). Two types of BSS identifiers exist, the infrastructure BSS and the independent BSS (IBSS) (Sharma, 2004:115).

4.5.4.1 INDEPENDENT BSS (IBSS)

An IBSS (figure 4-5) also called an ad hoc network or peer-to-peer network (Flickenger, 2003:18) is a network created spontaneously to cater for some immediate need. There is
no AP present and each wireless client simply communicates with other clients. This opens a completely new avenue of security issues that is beyond the scope of this study.

Figure 4-5: Independent BSS

4.5.4.2 INFRASTRUCTURE BSS

An infrastructure BSS comprises at least one AP, which is the central hub for the WLAN (figure 4-6).

Figure 4-6: Infrastructure BSS
The scope of the WLAN intrusion security risk analysis exercise is an infrastructure BSS at the University of South Africa (UNISA). This WLAN environment is a small environment with one Cisco Aironet Series 1200 AP and 10 wireless clients all equipped with Cisco Aironet 802.11a/b/g WNICs.

The collection of all basic service sets is called an extended service set (ESS), where several APs can serve a large number of WLAN clients over a greater area (figure 4-7), resulting in larger networks. Wireless clients can roam between these APs without losing connectivity to the WLAN. The ESS has an alphanumeric value (ESSID) programmed into the router to denote which subnet it is part of. A distribution service set (DSS) facilitates communication between wireless clients and APs on different BSSs.

In order for wireless clients to communicate with an AP, the wireless client establishes a relationship called association with the AP (Peikari & Fogie, 2003:137). Two types of scanning accomplish the association process (Held, 2003:46). Various types of management frames are exchanged (Edney & Arbaugh, 2004:55):
APs transmit beacon frames containing a unique identifier called a service set identifier (SSID), a 32 byte or less than 32 bytes network name (Berghel & Uecker, 2004:15) for the BSS which wireless clients use in order to authenticate with the WLAN, a process termed passive scanning (Carter, 2005:312). The wireless client determines which AP has the clearest and strongest signal. The wireless client sends an authenticate message to this AP. The AP responds with an authenticate response. The client then sends an associate request management frame including its capabilities and supported rates to which the AP responds with an associate response management frame containing a 2-byte status code if the association was successful (Yang et al., 2004:1951) as well as the station ID number for the particular client (Ciampa, 2001:109). The station can now begin transmitting and receiving information on the WLAN.

In order for a wireless client to find new APs, the wireless client transmits probe frames to discover APs, a process termed active scanning (Dean, 2006:312) to which APs issue a probe response. Wireless clients can therefore obtain information about APs in the area.

Upon successful association with an AP as illustrated in figure 4.8 of the sample UNISA WLAN operating environment, the AP can then share this information with other APs, facilitating the task of a client re-associating with another AP.

![Wireless Network Connection 3 (Loftus)](Image)

*Figure 4-8: Successfully associating with an AP in the sample UNISA WLAN operating environment*

Studying the WLAN operating environment aids in identifying critical assets. This is required for the first activity of the knowledge elicitation phase; covered in appendix C Information required for the remaining activities of the knowledge elicitation phase is obtained by studying the OODA cycle of the WLAN intruder. This is covered in the following section.
4.6 OBSERVING THE INTRUDER: OODA CYCLE OF THE WLAN INTRUDER

Metaphorically, "security is like a game of chess" (Wagner & Soto, 2000:255) in the sense that one must foresee all sorts of moves that the WLAN intruder may make and consequently enforce the necessary security measures to avert these attacks. The following section focuses on the OODA cycle of the WLAN intruder. The essence of this is to gain an understanding of how WLAN intruders operate in order to defend a network against intrusion attacks.

4.6.1 OBSERVATION

In order to launch an intrusion attack on WLANs, the WLAN intruder first has to observe the external environment by discovering the presence of APs. This activity, commonly referred to as war driving, takes place when an attacker "accesses a company network from outside the physical perimeter of the company facility" (Stewart, 2004:367).

War driving or WLAN discovery, is accomplished by using active and/or passive scanners. Appendix B contains examples of WLAN discovery using active and passive scanners for selected areas in South Africa.

Another mode of discovering APs is by war chalking. War chalking entails drawing certain symbols to indicate the presence of APs. These symbols include open node indicating that an AP is broadcasting its SSID, closed node meaning that the SSID is not being broadcast by an AP and WEP node indicating that communications are being encrypted through the use of WEP keys (Quinion, 2002).

Having discovered the presence of WLANs, the next step is to uncover the security holes of these networks in order to launch an invasion attack. This activity is covered in the orientation phase of the OODA cycle of the WLAN intruder.

4.6.2 ORIENTATION

Orientation is the interaction of mental images, views or impressions. It is shaped by "genetic heritage, cultural traditions, views, previous experiences and unfolding circumstances" (Hammond, 2001:164).
Equating this to the OODA cycle of the WLAN intruder, the orientation phase is shaped by the inherent vulnerabilities of WLANs, peoples' experiences using WLANs that have been highlighted in the media, books, Internet, journal articles and by vulnerabilities that are discovered and exploited on a continuous basis. This next section explores the orientation phase of the WLAN intruder.

4.6.2.1 Cultural Traditions

Literally, the word *cultural* refers to "a way of life" ("Cambridge Dictionaries", n.d.) and *traditions* to a principle or mode of acting adopted by a group of people ("Cambridge Dictionaries", n.d.). Applying this to WLANs security equates to the customs adopted in achieving security on these networks. Encryption and authentication within the APs and the WLAN cards are the fundamental tenets of security on WLANs ("Wireless LAN Policies", 2003:2; "WIRELESS LANs: Risks", 2003:1; Williams, 2001:91).

Wired Equivalent Privacy (WEP), a link-layer security protocol (Flickenger, 2003:221) has prevailed since the inception of the 802.11 standard in 1999 (Carter, 2005:190). WEP is the current security method for WLANs and provides authentication and encryption at the MAC layer of the OSI model (Tanzella, 2003:4). Encryption entails transforming code into an unreadable format by combining the code and a key to "produce random-looking numbers" (Edney & Arbaugh, 2004:19) and then restoring it to its original form at the destination (McCullough, 2004:167). WEP is based on the Ron's Code4 (RC4) stream cipher (Adelstein et al., 2004:482), a symmetric cipher which means that the same key is used for both encryption and decryption (Khan & Khwaja, 2003:124). A *stream cipher* "is a mathematical algorithm that expands a short key into an infinite pseudorandom key stream" (Held, 2001:51).

Below is an overview of how WEP accomplishes authentication and encryption on WLANs.

- **Authentication** is the process of verifying that a "user has permission to access the network" (Ciampa, 2001:110). Two modes of authentication are defined by WEP (Khan & Khwaja, 2003:128):
  - Open Systems Authentication-In this mode, any wireless client can associate with an AP and gain access to the network (Regan, 2003:8).
  - Shared Key Authentication-In this mode, both the wireless clients and the AP must have preconfigured matching WEP keys. The wireless client sends an
authentication request to the AP. The AP generates a challenge and sends this challenge to the wireless client. The wireless client uses its cryptographic key that is shared with the AP. WEP encrypts the challenge and if this challenge is successfully decrypted by the AP, the client will be able to authenticate with the AP.

**Encryption**

The WEP encryption (figure 4-9) process consists of the following steps (Arora, 2003):

- The sender generates a 24-bit initialisation vector (IV) which is concatenated with a secret key to produce a unique key for every packet.
- The key stream sequence is generated by plugging the unique key into the RC4 PRNG, a pseudo-random number generator (Lewis & Davis, 2004:194).
- WEP appends a 32-bit cyclic redundancy check (CRC) to the end of the plaintext. The CRC is used as an integrity check value (ICV) to detect any changes in the plaintext message.
- An exclusive OR (XOR) between the plaintext plus the CRC combination and the key stream yields the ciphertext. The IV, which is pre-pended to the ciphertext is transmitted in clear text. *Exclusive or (XOR)*, is a Boolean operator that contrasts two numbers to ascertain whether they are the same or not. If the numbers are the same, a "0" is returned; else, a value of "1" is returned (Sutton, 2002:6).
4.6.2.2 PREVIOUS EXPERIENCE

Previous experience when mapped to a WLAN environment refers to citing known security issues regarding these networks.

4.6.2.2.1 WEP

The development of WEP has been primarily to address the security issues with WLANs. Ironically, the introduction of WEP has brought about its own set of security problems. (Fluhrer, Mantin & Shamir, 2001; Borisov, Goldberg & Wagner, 2001; Arbaugh, Shankar & Wan, 2001; Stubblefield, Ioannidis & Rubin, 2002; Walker, 2000).

There are several reasons for the weaknesses of WEP (Peikari & Fogie, 2003; McCullough, 2004; Campbell, 2003; Regan, 2003; Lewis & Davis, 2004; Ciampa, 2006):

- WEP keys are statically assigned which means they are not likely to be changed. This makes it virtually impractical to protect the key. Furthermore, the APs and the wireless clients use the same key. This means that if WLAN intruders gain possession of this key, they can easily authenticate to the WLAN since wireless clients are authenticated and not specific users.
Authentication between the wireless client and the AP is a one-way authentication. The AP authenticates the wireless client, without being authenticated itself.

The aim of the IV is to protect information and ideally should not appear twice, otherwise a collision will occur (Carter & Shumway, 2002:135), but its short length (3 bytes) (Berghel & Uecker, 2004:16) means that it can only take $2^{24}$ (16,777,216), about 17 million values (Edney & Arbaugh, 2004:75), before it starts repeating. If a WLAN intruder captures a substantial number of packets the intruder will eventually find two packets of ciphertext that have been created using the same IV and the intruder can derive the plain text in a table attack. Increasing the key length will only exponentially increase the time it takes to crack the key and will do nothing to double the protection.

The IV sent in plaintext means that the WLAN intruder could easily view the first 24 bits of each key sent.

If two messages are encrypted using the same IV and the same key, then XORing the two ciphertexts will cause the keystream to cancel out and the result will be the XOR of the two plaintexts (Borisov et al., 2001:4).

CRC computes a checksum that is included with every packet. The receiver decrypts the frame and re-computes the CRC, which is contrasted with the one computed with the original message. If the two CRC's are not equal, this denotes an error. Since CRC is a linear checksum (Sutton, 2002:9), it allows for controlled modification of the ciphertext. It is, therefore possible to flip bits and pass the CRC check successfully.

Many tools are available to facilitate the task of WEP Cracking, the most popular being Airsnort ("AirSnort Homepage", n.d.) and WEPCrack ("WEPCrack - An", n.d.). Both these tools run under the Linux operating system and passively observe WLAN traffic. When a substantial amount of data has been collected, repetitions can be observed and the encryption subsequently broken.

4.6.2.3 GENETIC HERITAGE

Literally, the term genetic means, "antecedents of something" ("Merriam-Webster", n.d.) and heritage means "something transmitted by or acquired from a predecessor" ("Merriam-Webster", n.d.). This part of the OODA cycle when mapped to a WLAN environment, is the default (inherited) configurations of these networks. 802.11 networks do not offer any security by default (Carter & Shumway, 2001:107) and are devoid of the most rudimentary security measures of "encryption, personalised Service Set Identifiers". 
(SSIDs) and MAC address filtering” ("Enterprise Approaches", 2003) which are discussed below.

4.6.2.3.1 **WEP**

WEP has two default configurations (Cam-Winget, Housley, Wagner & Walker, 2003:36):

- Users are not obliged to use WEP and are oblivious of the encryption features of WEP. In fact, only a quarter of corporate WLANs use WEP for encryption (Miller, 2003:24). Support for 40-bit encryption is only mandatory for WiFi certification by the Wireless Ethernet Compliance Alliance (WECA). WECA is an organisation that ensures interoperability of WLAN products (Khan & Khwaja, 2003:123-124). Despite the fact that, WEP is severely flawed, it can prevent novice intruders (Carter, 2005:191) and postpone intrusion attacks (Bhagyavati, Summers & DeJoie, 2004:84).

- In the shared-key authentication mode, WEP keys used to authenticate wireless clients are by default shared between the AP and all of the wireless clients in a software-accessible storage. If a WLAN intruder manages to gain access to a wireless device, the intruder has total access to the WEP key and can authenticate to the AP. WEP does not have a key management protocol, therefore it would be a monumental task to create new WEP keys and distribute these keys to all the wireless clients.

4.6.2.3.2 **Service Set Identifier (SSID)**

WLAN SSIDs are typically announced in the broadcast beacon frames sent by APs. It is meant for client stations to easily identify available WLANs and the APs providing the service. Every AP has a default SSID allocated by the manufacturer, e.g. tsunami for Cisco equipment and Linksys for Linksys equipment. Many organisations neglect to change the default name of the AP and instead retain the default SSIDs. It is possible to obtain these SSIDs from the default wireless configurations web site ("Default Wireless", n.d.). Furthermore, the SSID is set to broadcast mode by default, which easily allows WLAN intruders to associate with an AP. War-drivers equipped with tools such as Netstumbler sometimes scan for the SSIDs broadcast by APs to discover potential targets. WLAN intruders can set the SSID on their client to attempt to join that WLAN.

Most wireless routers permit authentication if the wireless client simply has a blank entry for the SSID (Miller, 2003:199) from which the client can obtain an IP address from a Dynamic Host Configuration Protocol (DHCP) server and from there free access to the
WLAN. DHCP automates the assignment of IP address to wireless clients as they connect to the wireless LAN (McCullough, 2004:38).

4.6.2.3 Mac address filtering
MAC address filtering means wireless clients are restricted from authenticating and associating with an AP based on their MAC addresses. The MAC address of a WNIC provides access control. Access control is "a process that limits those than can use a system resource" (Housley & Arbaugh, 2003:33). MAC addresses, are however, broadcast in plain text by WEP during packet transfers (Park & Dicoi, 2003:63). This means that a WLAN intruder can capture a valid MAC address by eavesdropping using a sniffer such as Ethereal and then program his/her card to have the identical MAC address using a utility such as SMAC ("SMAC Official", n.d.) (figure 4-10) and successfully gain free rein entry to the WLAN as a legitimate user. A packet sniffer (network analyser) (protocol analyser) is "a program that captures or intercepts data from information packets as they travel over the network" (Khan & Khwaja, 2003:96).

In addition to the above, most network administrators neglect to change the following default settings:
4.6.2.3.4 AP passwords

It is possible to manage the AP through a web interface by typing in the IP address in the address field of the browser. This brings about a password-protected administrative interface. The default password for this interface as allotted by the manufacturer is always the same. It is a trivial task to determine the manufacturer by means of a sniffer program. Therefore the intruder can link the manufacturer to the default IP address and default password by searching for this vendor-specific information on the Internet and from there manipulate the AP settings successfully (Pandya & Frazin, n.d:1069).

4.6.2.3.5 Simple network management protocol (SNMP) parameters

Monitoring, controlling and managing network devices that use TCP/IP is accomplished by using SNMP (Lewis & Davis, 2004: 317). SNMP has three community strings. SNMPv1 and SNMPv2 agents use the commonly known community string "public", have assigned read and write privileges. If a WLAN intruder gains access to an AP that uses SNMP to monitor APs and wireless clients, the intruder can comfortably write information to the AP since the intruder has free read and write privileges (Karygiannis & Owens, 2002:3-27).

4.6.2.3.6 DHCP setup on wireless routers

Every computer connected to the Internet or a routed network must have a designated IP address, assigned by DHCP. If DHCP is not disabled, it distributes IP addresses to any wireless client that requests one and this includes unauthorised users as well.

4.6.2.3.7 Default subnet

Disabling DHCP means nothing if the default subnet is not changed too since most devices use the default subnet of 192.168.0.0 with a corresponding subnet mask of 255.255.255.0 (Pandya & Frazin, n.d:1070).

4.6.2.4 NEW INFORMATION

New information when mapped to a WLAN operating environment refers to the new standards and protocols developed, primarily to overcome the weaknesses in the WEP protocol. WLAN intruders must be abreast of this information so that they can discover which avenues of attack they can still exploit and what new security features can halt their attacks. The new standards include:
4.6.2.4.1 802.1x: Port-based network access control

802.1x describes a method of port authentication whereby the client (supplicant) sends Extensible Authentication Protocol (EAP) packets to an AP (authenticator) which in turn verifies the clients credentials from a central data source such as a RADIUS (Remote Dial-In user service) server. Port-based authentication essentially means that a switch (a switch is a device that routes a frame to the intended destination by recognising the destination address (Forouzan, 2003:136)) permits authorised users to connect to a network through a port (Ciampa, 2006:308). A port is an application-specific address on a particular receiving machine to which packets are directed (Hallberg, 2003:96). If the client’s credentials match, the RADIUS server sends a WEP key to the client. The client and AP use this WEP session key to encrypt the data traffic. The word client is broadly used as opposed to wireless client because this mode of authentication applies to wired networks as well.

There are several implementations of EAP including Transport Layer Security (EAP-TLS), EAP-MD5, Lightweight EAP (LEAP), Protected EAP (PEAP) and Tunneled Transport Layer Security (EAP-TTLS) (Bhagyavati et al., 2004:85; Regan, 2003:8; Ciampa, 2006:310).

The mode of authentication used on the sample WLAN operating environment is EAP-FAST (Flexible Authentication via Secure Tunneling) (figure 4-11). The typical set-up of the EAP-FAST at the sample UNISA WLAN operating environment is as follows:

- EAP-FAST uses a symmetric key algorithm to achieve a tunnel authentication process that relies on manual Protected Access Credential (PAC) provisioning that is managed via an Authentication, Authorisation and Accounting server (AAA) such as Cisco's Secure Access Control Server (ACS).
- EAP-FAST authentication takes place between the wireless clients and the ACS server.
- The wireless clients and the AP are configured with WEP encryption.
- An external user database together with EAP-FAST provides user authentication.
802.1x provides enhanced security by virtue of mutual authentication as well as by dynamic per user and per session encryption keys ("Give your network", 1995-2005:4).

A significant disadvantage of 802.1x is that it requires more back-end equipment and a dedicated RADIUS server with 802.1x capabilities (Maxim & Pollino, 2002:196). 802.1x is itself not the panacea for curing the problems with WEP, as it is prone to man-in-the-middle attacks as well as session hijacking attacks (Arbaugh & Mishra, 2002:7). The man-in-the-middle attack occurs primarily because 802.1x uses only one-way authentication. Once a client authenticates and a switch port opens, further communications between the supplicant and the switch are not authenticated. An intruder can thus capture the legitimate wireless client's MAC and IP addresses by sniffing and successfully authenticate with the RADIUS server. Upon successful authentication, it will be possible to take over the session of the legitimate client.

802.1x addresses authentication but not encryption and must therefore work as a component of both WiFi Protected Access (WPA) and 802.11i in order to address encryption (Williamson, 2004:10). The following section discusses this.

4.6.2.4.2 802.11 and WPA

802.11i overcomes most of WEP's inadequacies but because a large installed base of legacy systems will continue for some time (Adelstein et al., 2004:482) before 802.11i is fully
embraced, WLAN intruders can still exploit the vulnerabilities of WEP. For new systems, 802.11i and WPA are collective names for a host of security protocols.

The following table (table 4-1) outlines the marked differences between these two standards:

<table>
<thead>
<tr>
<th><strong>WPA</strong></th>
<th><strong>802.11i</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>WPA is a standard proposed by the WiFi Alliance in November 2002 (Fung, 2005:198) as an intermediary standard before the ratification of 802.11i..</td>
<td>802.11i, also known as robust network security (RNS) ratified in June 2004 (Williams, 2004) is a standard proposed by the IEEE to replace WEP.</td>
</tr>
<tr>
<td>WPA uses the Temporal Key Integrity Protocol (TKIP) with the RC4 stream encryption algorithm. TKIP provides for better encryption by (Arora, 2003):</td>
<td>802.11i uses the Counter Mode with Cipher Block Chaining Message Authentication Code Protocol (CCMP) with the Advanced Encryption Standard (AES) cipher for encryption. AES offers the following enhancements over WEP (Park &amp; Dicoi, 2003:64):</td>
</tr>
<tr>
<td>Preventing the use of static keys by generating a new encryption key for each 802.11 packet (Neoh, 2003:9).</td>
<td>Key sizes of 128, 192 or 256 bits.</td>
</tr>
<tr>
<td>Larger IV values (Edney &amp; Arbaugh, 2004:235) that are hashed which means that they are encrypted rendering them difficult to sniff (Peikari &amp; Fogie, 2003:278). Hashe are a special use of one-way function that provides authentication and verification by virtue of encryption (Howlett, 2005:285).</td>
<td>Eliminating the reuse of the 24-bit IV.</td>
</tr>
<tr>
<td>A Message Integrity Check (MIC) that prevents an intruder from modifying and resenting packets (Peikari &amp; Fogie, 2003:278). This is a bid to overcome the problems with the CRC function of WEP.</td>
<td>AES also suffers from the following drawbacks (Park &amp; Dicoi, 2003:65; Wong, 2003:8):</td>
</tr>
<tr>
<td></td>
<td>An organisation has to replace all its APs in order to be compatible with this standard.</td>
</tr>
<tr>
<td></td>
<td>Large key sizes mean that greater processing power is required by wireless clients for encryption and decryption.</td>
</tr>
<tr>
<td></td>
<td>AES also requires greater power consumption which is not provided by current WNICs.</td>
</tr>
</tbody>
</table>
TKIP however, also relies on a pre-shared key and is therefore, also susceptible to *man-in-the-middle* attacks (Godber & Dasgupta, 2003). Both TKIP and WEP will eventually be replaced with the Advanced Encryption Standard (AES), which uses the more robust Rijnadael algorithm (Cannon, 2006:143).

WiFi Protected Access 2 (WPA2) ratified in September 2004 (Ciampa, 2006:299) is the newer generation of WPA security. WPA2 is based on the IEEE 802.11i standard. WPA2 uses AES for encryption and IEEE 802.1x for authentication. WPA2 allows both AES and TKIP clients to co-exist on the same WLAN.

Table 4-1: Differences between 802.11i and WPA

<table>
<thead>
<tr>
<th>WPA</th>
<th>802.11i</th>
</tr>
</thead>
<tbody>
<tr>
<td>Better key management.</td>
<td>AES is however one of the most concrete encryption schemes and to date has not been subjected to any attacks (&quot;Give your network&quot;, 1995-2005:9).</td>
</tr>
</tbody>
</table>

### 4.6.2.4.3 Social environment of WLAN intruders

WLAN intruders typically obtain new information on intrusion techniques from dedicated WLAN hacking sites on the Internet ("Scanning and", 2004) as well as by socially interacting with other users on user groups on the Internet. Furthermore, there are certain hacking conventions such as DEFCON ("Welcome to DEF", 1992), Hackers on Planet Earth (HOPE) ("2600 The Hacker", 1995) and ToorCon ("ToorCon 7", n.d.) to discuss hacking techniques and tools. All this information equips WLAN intruders with a wealth of information and an arsenal of tools to launch potentially devastating intrusion attacks.

The orientation phase terminates at the point where WLAN intruders have an awareness of the security holes they can exploit in WLANs. The next step entails creating a hypothesis of
WLAN intrusion attacks. This is covered in the decision phase of the OODA cycle of the WLAN intruder discussed below.

4.7 DECISION

After discovering the presence of WLANs and creating a mental image of the security weaknesses of these networks, WLAN intruders can contrive on the various types of intrusion attacks to launch where an intrusion is defined as "violations of security policy, usually characterised as attempts to affect the confidentiality, integrity or availability of a computer or network" (Bace, 2002:37-2). These attacks could be simple innocuous attacks or potentially devastating ones.

Some of the types of intrusion attacks include (Sundaram, 1996:5; Karygiannis & Owens, 2002:20; Buzzard, 1999:323):

4.7.1 DENIAL-OF-SERVICE (DOS) ATTACKS

A DOS attack is specifically aimed at preventing legitimate users from using the WLAN. A common form of DOS attack is jamming which entails removing a wireless client off the air by superseding the AP's signal with a stronger signal (Lewis & Davis, 2004:157). Jamming can occur in the following instances:

- By a malicious user who consciously emanates a signal from another wireless device in order to saturate the bandwidth thereby denying legitimate users the opportunity of using the WLAN.
- By inadvertent users who download large files, once again saturating the bandwidth.
- By electronic devices such as cordless phones (figure 4-12), baby monitors, elevator motors, photocopying machines, theft protection devices and microwave ovens (Maxim & Pollino, 2002:51; Ciampa, 2001:19) that use the same frequency range as 802.11b and 802.11g (Carter, 2005:29).
Battery exhaustion is also a means of a denial-of-service attack (Stanley, 2002:12) where software placed in the wireless client can interfere with the power management function. This exhausts the battery more rapidly, forcing the wireless client off the network.

If the default AP settings are not changed and the WLAN intruder has free rein to manipulate the administrative console of the AP, the intruder can launch a DOS attack by changing certain settings on the AP, thereby denying legitimate wireless users access to the resources on the WLAN.

Another common type of DOS attack occurs with the 802.11 protocol, where a flood of 802.11 associate frames from an offending WLAN intruder renders it difficult for other legitimate wireless clients to associate with the AP because the WLAN intruder occupies the slots of other wireless clients. The WLAN intruder can also send a fleet of disassociate commands, forcing all wireless clients to disconnect from the WLAN.
4.7.2 MASQUERADE ATTACKS

A rogue AP deemed among the "greatest security threats in corporate America" (Chartoff & Boyland, 2004:41) can be successfully deployed in a WLAN environment by having the same SSID as the legitimate AP. If open authentication is used, a client can authenticate with the rogue AP if the rogue AP emanates a stronger signal than the legitimate AP (figure 4-13). Software tools such as FakeAP ("Projects - FakeAP", 2001-2002), render it possible to create virtual APs with a strong signal and MAC address to pose as legitimate APs.

In this mode, an AP can pose as a legitimate AP and force clients to associate with it thereby capturing the necessary credentials from the client. The WLAN intruder can then use the authentication requests of the legitimate user in an attempt to associate with a legitimate AP in order to gain access to the wired network. This is a classic case of the man-in-the-middle attack where the rogue AP acts as an AP to the wireless client and a user to the legitimate AP.

The WLAN intruder, now posing as a rogue AP, can also create a DOS attack by sending a constant stream of disassociate commands forcing the clients to detach themselves from the WLAN. The attacker can then use this opportunity to use the victim's MAC address to...
hijack the user's session because in essence the user is not actually disconnected from the network.

Rogue APs, can also be installed by well-meaning employees who wish to extend the range of the WLAN but do not have the necessary permission to do so. This opens up security windows that WLAN intruders can exploit (Chartoff & Boyland, 2004:88).

4.7.3 PENETRATION OF THE SECURITY CONTROL SYSTEM
Penetration of the security control system can occur by using a port scanner such as Superscan, SNScan, Look@Lan (Lewis & Davis, 2004:167) which an intruder can use to determine if a specific service is running on the victims computer (McCullough, 2004:79). One of the most popular port scanners is Network Mapper (NMap) and the prime advantages of this port scanner include (Howlett, 2005:96-97):
- NMap has a conglomerate of variations regarding how one can scan the network.
- NMap is easy to use.

The following figure (figure 4-14) depicts the output of a typical scan that was done on the sample UNISA WLAN operating environment using Nmap, Version 3.93. From this output it is possible to see the tcp ports that are open on the victim computer with an IP address of 163.200.217.19.

![Figure 4-14: NMap scanning at the sample UNISA WLAN operating environment](image-url)
4.7.4 LEAKAGE

APs can broadcast signals ranging from about 150 feet to approximately 1 500 feet depending on their configuration ("Federal Agencies", 2005:10). Therefore, APs can broadcast signals outside the physical boundaries of a building. As a result of this, an AP that is in close proximity of another WLAN can emanate a powerful signal that filtrates into the air space of a neighbouring WLAN, causing the wireless clients of the neighbouring WLAN to associate with this AP and reveal sensitive information ("Wireless LAN - What", 2003:2).

4.7.5 MONITORING COMMUNICATIONS (EAVESDROPPING)

The open-air nature of wireless communication means information transmitted or received over a wireless network is prone to interception and eavesdropping. A WLAN intruder can capture messages between the AP and the wireless client by intercepting the radio transmission between the AP and the wireless client by using a wireless packet sniffer such as Ethereal. It is then possible to gather information such as "user logon credentials, networking information, e-mail or potentially anything else that traverses the segment" (Carter & Shumway, 2001:17).

The following diagram (figure 4-15) illustrates the output of an Ethereal scan conducted on the sample UNISA WLAN operating environment. Ethereal was used as it is one of the most popular and powerful sniffers available (Flickenger, 2003:94; Peikari & Fogie, 2003:167).

From this scan, it is possible to see how easy it can be to analyse the HTTP protocol and view the contents of the packet in plain ASCII.
4.7.6 MALICIOUS USE

This can occur when a WLAN intruder physically steals a legitimate WNIC that has a MAC address pre-programmed as allowed on the AP and then uses this card to authenticate with the AP. A WLAN intruder can also maliciously use someone else’s wireless Internet access. A reported incident of this has occurred, where David M. Kauchak was fined $250 and a years court supervision for illegally surfing the Web from his laptop (Green, 2006).

In a similar incident, the first of its kind in U.K., Gregory Straszkiewicz, was fined 500 pounds and 12 months conditional discharge for hijacking a wireless broadband connection (Ilett, 2005).

4.7.7 REPLAY ATTACKS

Cyclic Redundancy Checks do not provide any means of ensuring the integrity of a data stream that a WLAN intruder has intentionally corrupted. If a WLAN intruder has knowledge of a certain data stream, it is possible to change the contents and successfully complete the transaction with a legitimate checksum. The receiver would have no knowledge of this because the checksum would match.
4.7.8 SOCIAL ENGINEERING

Social engineering is a "non-technical means" (McMahon, 2003:301) used by WLAN intruders to lure unsuspecting WLAN users to disclose their usernames and passwords in order to gain illicit entry into the network. Getting WLAN users to disclose this information can be a trivial task as most users are naïve and trusting. Kevin Mitnick, a famous reformed hacker illustrates how easy it is to exploit human trust with a study conducted in the U.K. This study revealed that seven out of 10 office workers readily disclosed their usernames and passwords in return for an Easter egg when approached at London's Waterloo station (Glazier, 2006).

4.7.9 BRUTE FORCE ATTACKS

As expounded previously, when a wireless client wishes to authenticate itself with an AP, it commonly sends a probe request packet out on all the channels (section 4.4.4). The AP receives this packet and sends a probe response packet back to the wireless client. The probe response packet contains vital information including the SSID, which the wireless client uses to ascertain with which AP it will associate. A brute force probe occurs when a wireless client has been sending probes of the AP with different SSIDs in them, in an attempt to guess the SSID of the AP.

A brute force attack can also occur when a persistent WLAN intruder uses all possible combinations of letters and numbers to guess the username/password of a legitimate user and then use this information to gain illicit entry to the WLAN.

Having created a hypothesis of the multitude of possible attacks, the next stage is to activate the WLAN intrusion attack plan. This action phase of the OODA cycle of the WLAN intruder discusses this.

4.8 ACTION

Having decided on the possible types of WLAN intrusion attacks, the final stage is to carry out these attacks in practice.

After observing the OODA cycle of the WLAN intruder, an organisation must observe itself to uncover any major security holes in its WLAN environment, which intruders can use as windows of opportunity to launch intrusion attacks.
4.9 OBSERVING ONESELF

To sense oneself, it is necessary for an organisation to determine whether its APs are freely open and accessible to WLAN intruders. This is a relatively simple task, accomplished by visiting the Wireless Geographic Logging Engine (Wigle) website. By entering the MAC address of the AP, obtainable by issuing an ipconfig/all command on a Windows XP operating system (figure 4-16), an organisation can ascertain whether its APs have been discovered. An organisation can also use NetStumbler to check that its WLANs are not freely open and accessible to anyone.

![Figure 4-16: Obtaining the MAC address of a WNIC](image)

Having completed all three aspects of the observation phase, the risk analysis team can now begin enacting the remaining activities of the knowledge elicitation phase. Appendix C covers these activities.

4.10 CONCLUSION

This chapter concludes at a point of situational analysis, where the University is enriched with knowledge regarding the real and perceived type of intrusion attacks that could be launched on its WLAN operating environment. This was determined by studying how WLAN intruders mentally compose themselves to enter WLANs illicitly. Studying the WLAN operating environment rendered it possible to pinpoint the most important assets that require the greatest protection.

This chapter covered the WLAN intrusion security organisational view. The next chapter focuses on the continuation of the WLAN intrusion security risk analysis exercise by covering the analysis activities required for the orientation phase.
5. ORIENTATION: TECHNICAL VULNERABILITY ASSESSMENT AND RISK IMPACT

5.1 INTRODUCTION

A risk analysis immediately conjures up the notion of a technological evaluation (Alberts & Dorofee, 2003:137). Security, however, is a "business or organisational problem", yet many organisations adopt only a "technology-centric" approach (Caralli & Wilson, 2004:8). Conducting a WLAN intrusion security risk analysis exercise encompasses both an organisational evaluation and a technological evaluation. Having completed the organisational evaluation, this chapter focuses on the technological evaluation.

The objective of this chapter is to illustrate how each critically identified asset is threatened, the technological weaknesses present in the WLAN infrastructure and how threats can affect the University's missions and aims.

5.2 STRUCTURE OF THIS CHAPTER

"When evaluating risks to organisational processes, analysts generally begin by performing an assessment to provide a snapshot of current risks" (Alberts & Dorofee, 2004:142). This is accord with the orientation phase of the OODA cycle. The orientation phase advocates creating a mental image or snapshot of the situation.

The orientation phase advocates commencing an initial assessment. This equates to the threat assessment, technological vulnerability assessment and risk impact assessment of the WLAN intrusion security risk analysis process to cover all the analysis activities. The analysis information is stored in the database.

The following diagram (figure 5-1) depicts the role of this chapter within the overall context of the dissertation.
Figure 5-1: The role of chapter five within the overall context of the dissertation
5.3 THREAT ASSESSMENT
Conducting a threat assessment comprises the following activity (Alberts & Dorofee, 2003:48):

5.3.1 IDENTIFYING THREATS TO CRITICAL ASSETS
This step entails creating a threat profile for the critically identified asset (infrastructure BSS), by mapping the outcomes of the various areas of concern. The outcomes include disclosure, modification, loss/destruction and interruption (appendix C, figures 11-2 to 11-10). A threat profile, defines the range of threats than can affect an asset using the following properties (Alberts & Dorofee, 2003:112):

- Asset—something of value to the University.
- Actor—who or what may violate the security requirements (confidentiality, integrity, availability) of an asset.
- Motive (optional)—defines whether the actor’s intentions are deliberate or accidental.
- Access (optional)—how the asset is accessed by the actor (network access, physical access).
- Outcome—the immediate outcome (disclosure, modification, destruction, loss, interruption) of violating the security requirements of an asset.

Threat profiles contain categories grouped according to source. The main threat category is:

- Human actors using wireless network access-These are wireless network-based threats to the critical assets.

Figure 5-2 illustrates the asset-based threat profile for human actors using wireless network access. Since the origin or intent of the unauthorised individual are of no consequence (section 1.4), these properties are not considered. The ☑ next to the outcome indicates that particular outcome manifestation.
Figure 5-2: Asset-based threat profile for human actors using wireless network access

5.4 TECHNOLOGICAL VULNERABILITY ASSESSMENT

The technological vulnerability assessment addresses the technological aspects of information security highlighting the technological vulnerabilities in relation to the assets, security requirements and threats of phase 1 (Alberts & Dorofee, 2003:37). The first step of this phase is the selection of infrastructure components which are examined for technological weaknesses and comprises the following two activities (Alberts & Dorofee, 2003:48):

5.4.1 IDENTIFY KEY CLASSES OF COMPONENTS

In order to identify key classes of components, it is necessary to have a network topology diagram. The network topology diagram (figure 5-3), is that of the UNISA WLAN operating environment as this environment has been sampled for the WLAN intrusion security risk analysis exercise.
Figure 5-3: Topology diagram of the sample UNISA WLAN operating environment

**EXTERNAL USER DATABASE (LDAP)**
Used for user authentication with EAP-FAST

**CISCO SECURE ACCESS CONTROL SERVER (ACS SERVER)**

**ENTERPRISE NETWORK**

**CISCO AIRONET 1200 SERIES ACCESS POINT**
SSID: LoftuS
MAC: 00:14:69:3B:BF:60-G

**EAP-FAST AUTHENTICATION BETWEEN THE WIRELESS CLIENTS AND THE ACS SERVER**

**WIRELESS CLIENTS WITH IP ADDRESSES IN THE RANGE OF 163.20.217.16 – 163.200.217.31**
For system assets, the system of interest is the asset itself (Alberts & Dorofee, 200:144). Therefore, the system of interest is the infrastructure-based network itself. Identifying key classes of components related to the system of interest entails examining the types of components that are part of the system of interest. By examining the topology diagram, the following important components are identified (figure 5-4).

**Figure 5-4:** Identifying key classes of components

5.4.2 IDENTIFY INFRASTRUCTURE COMPONENTS TO EXAMINE

This entails pinpointing very specific components which are examined for technological vulnerabilities. Therefore drilling down the key classes of components reveals the wireless clients and the APs as the two most important infrastructure components. These are the two most important constituents of the WLAN operating environment (figures 5-5 and 5-6). A vulnerability analysis approach and the specific tools for conducting the vulnerability analysis exercise are selected.
Figure 5-5: Identifying wireless clients as an infrastructure component

Figure 5-6: Identifying APs as an infrastructure component
The next step is to identify technological weaknesses with respect to the infrastructure components identified (wireless clients and APs) and comprises the following two activities (Alberts & Dorofee, 2003:49):

5.4.3 RUN VULNERABILITY EVALUATION TOOLS ON SELECTED INFRASTRUCTURE COMPONENTS

A vulnerability assessment is "a systematic, point-in-time examination of an organisation's technology base, policies and procedures" (Alberts & Dorofee, 2003:6).

AirMagnet ("Enterprise Wireless", n.d.), is used to conduct a point-in-time analysis of the sample UNISA WLAN operating environment. The aim of this vulnerability exercise is to pinpoint vulnerabilities related to the most important infrastructure components (wireless clients and APs) identified.

To ensure that the vulnerabilities are all current ones, these vulnerabilities can be checked, against the Wireless Vulnerabilities and Exploits Catalogue (WVE), a catalogue for wireless vulnerabilities and exploits ("Wireless Vulnerabilities", n.d.). However, this catalogue is not yet very comprehensive and currently lists only 50 results for WLANs exploits and vulnerabilities.

Figure 5-7 illustrates the APs that detected.

![Figure 5-7: APs that were detected on the sample UNISA WLAN operating environment.](image)

LoftuS circled in the diagram indicates the SSID of the AP with a MAC address of 00:12:79:3E:DD:2D. Figure 5-8 illustrates one of the vulnerabilities relating to the wireless
client detected on the sample UNISA WLAN operating environment as well as an explanation of this particular vulnerability.

**Figure 5-8: Vulnerability detected on the sample UNISA WLAN operating environment**

5.4.4 REVIEW TECHNOLOGICAL VULNERABILITIES AND SUMMARISE THE RESULTS

The vulnerability assessment generated the following report.

- Detailed information of policy violations (Security IDS/IPS and Performance Intrusion) (figure 5-9).
All Alarm Detail

Time Period: 13:30:28 Tuesday, October 11, 2005

Description: This report contains detailed information of policy violations (Security IDS/IPS and Performance Intrusion) that AirMagnet has detected in the 802.11 wireless network. An insecure network can usually be fixed by reconfiguring some of the network equipment, by using additional software or hardware and always being in the forefront of implementing the latest security standards to provide good security for sensitive data such as employee salary data or company financial information. A closely monitored and well tuned WLAN system can achieve a higher throughput than a poorly managed one. AirMagnet ensures WLAN performance and efficiency by monitoring the WLAN and alerting the wireless administrator on early warning signs for trouble. This includes reporting the devices which are vulnerable to violations/are violating and actions that can be performed to nullify such violations. With the comprehensive suite of security monitoring technologies, AirMagnet alerts the user on more than 120 different threat conditions.

Total Alarms: 7

Alarm: Device unprotected by TKIP
Category: Security
Severity: Warning
MAC: 00:14:69:3B:BF:60
AP: CVV-WiAP1-FI05-

Alarm: Exposed Wireless Station detected
Category: Security
Severity: Warning
MAC: 00:0C:F1:09:B7:D3

Alarm: Exposed Wireless Station detected
Category: Security
Severity: Warning
MAC: 00:0C:F1:4F:6A:5A

Alarm: Channel with high noise level
Category: Performance
Severity: Warning
MAC: 4

Figure 5-9: Report on policy violations
The vulnerability scan reveals the following technological vulnerabilities detected on the wireless client, one of the most important infrastructure components identified:

- One of the wireless clients is not using TKIP for encryption. TKIP is a necessary mode of encryption protection. WLAN traffic encrypted with TKIP and MIC combats packet forgery and replay attacks. Additionally, TKIP overcomes the weakness of the static WEP key and key reuse problem.
- An exposed wireless client. Figure 5-8 explains this vulnerability.

5.5 RISK IMPACT ASSESSMENT

The objective of the risk impact assessment is to identify and analyse the risks to the mission-critical asset (infrastructure BSS) and comprises the following activities (Alberts & Dorofee, 2003:50):

5.5.1 CREATE NARRATIVE IMPACT DESCRIPTION

A narrative statement that describes how a threat affects the University for the threat outcomes (disclosure, modification, loss/destruction and interruption) is given (figures 5-10 to 5-14).

![Figure 5-10: Impact description for the outcome disclosure](image)

![Figure 5-11: Impact description for the outcome modification](image)

![Figure 5-12: Impact description for the outcome modification](image)
5.5.2 CREATE RISK EVALUATION CRITERIA

An overall set of impact evaluation criteria are defined for the threats to the University’s critical asset (infrastructure BSS) (figure 5-15). Definitions for three levels of qualitative evaluation, high, medium and low are defined for multiple aspects. The impact areas are all high impact areas meaning that it is absolutely crucial that the transitory information, student information, financial information, human resources information and the information products of the University be protected and preserved at all times. Any compromise thereof, will severely diminish the status of the University. There is no medium or low impact.
5.5.3 EVALUATE THE IMPACT OF THREATS TO CRITICAL ASSETS

Each risk is reviewed and a corresponding impact measure assigned (figures 5-16 to 5-20).
5.5.4 CREATE RISK PROFILE
Impact measures affixed to the asset-based threat profile trees result in the creation of an asset-based risk profile (figure 5-21).
CONCLUSION

All the analysis activities provide the University with a sense of knowledge regarding its unique WLAN intrusion security risks (situation awareness). The concluding process, decision: protection strategy and risk mitigation plan enables the organisation to address these risks in practice and develop a WLAN enterprise-wide protection strategy and WLAN intrusion security risk mitigation plan for the University. This is the focus of the subsequent chapter.
CHAPTER 6

6. DECISION: PROTECTION STRATEGY AND RISK MITIGATION PLAN

6.1 INTRODUCTION

The open nature of WLANs makes them a perfect target for itinerant hackers to execute intrusion attacks. The lack of protection rendered by recognised security countermeasures (Zhang et al., 2003:545) further aggravates this problem. However, if properly designed, certain countermeasures can detect an intrusion attack.

The desirable outcome of this exercise is the development of a WLAN enterprise-wide protection strategy and the recommendation of an appropriate risk mitigation plan capable of reducing WLANs intrusion security risks to an acceptable level.

6.2 STRUCTURE OF THIS CHAPTER

This chapter centres on the culmination of the WLAN intrusion security risk analysis process on the basis by which the organisation decides on what security measures to enforce. This therefore conforms to the decision: protection strategy and risk mitigation plan of the WLAN intrusion security risk analysis process.

The following diagram (figure 6-1) depicts the role of this chapter within the overall context of the dissertation.
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Figure 6-1: The role of chapter six within the overall context of the dissertation
6.3 WLAN ENTERPRISE-WIDE PROTECTION STRATEGY AND RISK MITIGATION PLAN

The risk impact criteria all connote a high degree impact (figure 5-21), signalling the importance of developing a WLAN enterprise-wide protection strategy and WLAN intrusion security risk mitigation plan. Risk mitigation planning involves the actions and activities performed prior to a risk, either to prevent a risk from occurring altogether or to reduce the impact or consequences of its occurrence to an acceptable level ("Microsoft Operations", 2004:31).

6.3.1 CREATION OF A WLAN ENTERPRISE-WIDE PROTECTION STRATEGY

This activity entails the development of a long-term WLAN protection strategy for enterprise-wide improvement for the University. This strategy is structured against the backdrop of the catalogue of practices. The WLAN enterprise-wide protection strategy appears in appendix D.

6.3.2 CREATION OF A WLAN RISK MITIGATION PLAN

The focus of this activity is a more tactical view to reduce intrusion security risks to the University's most crucial asset (infrastructure BSS) by means of action plans or countermeasures (Alberts & Dorofee, 2003:208).

One particular countermeasure, a wireless intrusion detection system (wireless IDS), is particularly apt at shielding a network against intruders (Kachirski & Guha, 2002:153) and should be included as a fundamental security countermeasure in the organisation's WLAN computing infrastructure. The following in-depth section provides a justification for the deployment and consolidation of a wireless IDS in the University's WLAN computing infrastructure.

6.4 JUSTIFICATION OF A WIRELESS IDS FOR MITIGATING WLANS INTRUSION SECURITY RISKS

The rapid adoption of WLANs has dramatically changed the entire outlook of network security rendering these networks more vulnerable to "malicious attacks" (Yang et al., 2004:1949). There is an immediate need for a mechanism to protect WLANs from intrusion attacks. The most widespread and common vulnerabilities of WLANs were explored and it was demonstrated that the exploitation of these vulnerabilities can
manifest in real risks that can affect the confidentiality, integrity and availability of
information. It can, therefore be argued that a wireless IDS should form a salient
component as a "second wall of defense" (Zhang et al., 2003:546; Yang, Hu & Chen,
2004:150) or an additional layer of protection (Adelstein et al., 2004:482) in the WLAN
computing infrastructure.

It should be emphasised that a wireless IDS is only "part of the security puzzle" (Potter,
2004:5) and should not function in solitude as the only mode of protection (McHugh,
Christie & Allen, 2000:42). At present, innumerable security technologies such as
"firewalls, encryption technology, authentication devices, vulnerability checking tools"
(Goan, 1999:46), are capable of counteracting various security breaches. Security measures
such as encryption technology and authentication devices which usually form the first layer
of defense (Zhang et al., 2003:546) in WLAN security have already been discussed in the
observation: knowledge elicitation phase (chapter 4).

Additional security countermeasures may include a virtual private network (VPN) and a
firewall. A VPN uses encryption to create a tunnel, a secure means of communication
across an untrusted network such as the Internet between the user's device and the
destination (McCullough, 2004:65; Park & Dicoi, 2003:64). A firewall is any device used
to impede or selectively allow network traffic (Carter & Shumway, 2002:53). Ideally, a
firewall should be placed near the AP between the fixed-wired network and the wireless
network (Miller, 2003:224).

The following section provides an overview of wireless intrusion detection systems
stemming from the historical emanation of these systems.

6.4.1 BACKGROUND: A SYNOPSIS OF INTRUSION DETECTION SYSTEMS (IDSs)
IDSs can be classified as the tools and methods that monitor computer systems and
network traffic to identify and report possible hostile attacks originating from outside the
organisation and also for system misuse or attacks originating from within the

The genesis of intrusion detection dates from 1980 commencing with James Anderson’s
for the U.S. Air Force. In 1985, Stanford Research Institute (SRI) was funded by the U.S. Navy to build the initial type of Intrusion Detection Expert System (IDES). Dr. Dorothy Denning assisted in leading this team and a year later published a paper entitled, An Intrusion Detection Model (Denning, 1986) for the 1986 IEEE Symposium on Security and Privacy. This paper is regarded as being the seminal work on intrusion detection.

Conceptually a wireless IDS is similar to wired IDS (Yang et al., 2004:1949) but marked differences between wireless and wired-line networks, particularly the "structural and behavioural differences" (Kachirski & Guha, 2002:154) render current IDS designs unsuitable for wireless networks. Wired intrusion detection systems operate at layer 3 (IP layer) and above of the OSI model ("Wireless LANs:Defending", 2004:2) whereas WLANs generally refer to the Physical and Data Link layers of the OSI model. A wireless IDS must therefore function at the Data Link layer or even possibly the Physical layer if optimal security is required (Lim & Schmoyer, 2003:68).

The following section provides an overview of the functions that a wireless IDS must possess.

6.4.2 FUNCTIONS OF A WIRELESS IDS SYSTEM

The functionality that a wired-line IDS must possess can well be extended to a wireless IDS. Therefore, a wireless IDS must be capable of (Yang et al., 2004:1949, Bacea, 2002:11):

- Monitoring and analysing both user and system activities.
- Recognising patterns of known attack.
- Identifying abnormal network activity.
- Detecting policy violations.
- Providing an audit trail to ascertain how far the intruder got and the origin of the attack.
- Assessing the integrity of crucial system and data files.
- Auditing system configurations and vulnerabilities.

The next section provides an overview of the operational design of a wireless IDS.
6.5 OPERATIONAL DESIGN OF A WIRELESS IDS

To study the operational design of a wireless IDS, it is necessary to exploit the literature in order to uncover what has generally been included in this area as well as study a few notable wireless IDSs. The aim of this exercise is to propose the inclusion of a wireless IDS in the University's WLAN computing infrastructure by demonstrating the effectiveness of this system. At present a large number of commercial and open-source wireless IDSs are available, including AirDefense ("Enterprise Wireless Intrusion", 2001-2005), AirMagnet ("Enterprise Wireless", n.d.), Network Chemistry ("Network Chemistry-The", 2005), AirTight Networks ("AirTight Networks," 2005), Highwall Technologies ("Highwall Technologies", 2005), Red-M ("Red-M-Home", 2005), Snort-Wireless (Lockhart, 2003-2005) and WIDZ ("Loud-Fat-Blokes-World-Of-Weird", n.d.).

Of these systems, two notable commercial wireless intrusion detection system (IDSs)/intrusion prevention systems (IPSs), AirDefense Enterprise and AirMagnet Enterprise were considered as these systems have been labelled the "industry veterans" (Bulk, 2005:2) and an "interesting pair of competitors" (Turvey, 2005:2). These systems are wireless IDSs/IPSs meaning they are able to detect and prevent intrusion attacks. The detection part of the wireless IDS/IPS is reactive in nature, in a sense that corrective action can only take place after a breach of security. The prevention part entails a "programmatic approach to vulnerability assessment to identify any potential weaknesses in the security deployment before they can be exploited ("AirMagnet Enterprise", 2005:ii).

Open-source wireless IDS systems such as Snort-Wireless were also investigated as Snort is one of the most widely deployed IDS available today (Potter, 2004:5). Snort-Wireless is currently capable of detecting rogue APs, ad hoc networks, DOS attacks, MAC spoofing and Netstumblers (Lockhart, 2003-2005). The reason why Snort-Wireless was considered is that it is a viable solution since it is an open-source wireless IDS. However, the researcher concluded that this tool would not be suitable for the University WLAN operating environment because the operational and deployment requirements of Snort would require a great deal of investment in time and expert human resources. If these systems are not succinctly pre-configured to look exactly for what they should, they will fail to function optimally.
AirMagnet Enterprise and AirDefense Enterprise have a very similar architectural design, hence they have been labelled as being an "interesting pair of competitors". The operational design of the wireless IDS/IPS, is examined by virtue of studying AirMagnet Enterprise 6.0, since it was the overall category winner for the Best Wireless Security ("SC Magazine", 2006). However, features of AirDefense that are lacking or better than those in AirMagnet are discussed. The aim of this exercise is to illustrate the effectiveness of a wireless IDS to senior management.

The operational design of a wireless IDS/IPS using AirMagnet Enterprise 6.0 is examined within the framework of the OODA cycle since the design of this system is dynamic, constantly requiring refinements and updating for a non-static environment.

6.5.1 OBSERVATION

A wireless IDS observes functions by using information sources such as IDS sensors. There are two types of sensors, network-based sensors and host-based sensors (Endorf et al., 2004:19, Kachirski & Guha, 2002:154).

- Network-based sensors can monitor traffic as it flows through a network to other hosts on the network (Koziol, 2003:2). In the AirMagnet Enterprise System, the AirMagnet SmartEdge sensors, which are network-based sensors capture and analyse wireless packets. These SmartEdge sensors can typically be AirMagnet handheld devices or laptop devices. The AirMagnet console governs the user interface to the SmartEdge sensors by providing an insightful interface. The following diagram (figure 6-2), illustrates a SmartEdge sensor observing the sample UNISA WLAN operating environment.

The consensus is to deploy sensors (network-based sensors) wherever an AP is located (Carter & Shumway, 2002:72, Poblete, 2005). This has a number of advantages (Yang et al., 2004:1950):

- By covering the APs with a blanket of sensors, attacks and misuse can be detected.
- It is possible to ascertain the location of the intruder physically.

For the AirMagnet Enterprise System, the general rule is to deploy one sensor for every 6 APs ("Enterprise Quick", 2005). AirMagnet can support approximately 1 500 sensors with a single server ("Enterprise-hardened", 2005). Since the University already has a Cisco
Aironet 1200 AP (section 4.4.4.2), this AP can be used as a sensor to provide information to the enterprise server (Turvey, 2005:3). This can significantly reduce costs, precluding the need to invest in a dedicated sensor.
Figure 6-2: SmartEdge sensor monitoring the sample UNISA WLAN operating environment
Host-based sensors operate on a single protected host and inspect audit or log data for any activity deemed intrusive (McHugh et al., 2000:45). AirDefense Personal, is a host-based sensor designed for complete wireless end-point security (WEPS) that may work as stand-alone host-based sensor or in concert with the AirDefense Enterprise 7.0 server to prevent wireless security vulnerabilities from affecting wireless clients. The AirDefense Personal agent constantly monitors the activity and configuration of the wireless client to prevent policy violations or malicious attacks such as redirection attacks, man-in-the-middle attacks, deauthentication attacks and secures the network from probing laptop problems ("Wireless Protection", 2002-2005:4). Figure 6-3 illustrates AirDefense personal running on a wireless client in the sample UNISA WLAN operating environment. It is also possible to enforce a wireless policy by using AirDefense Personal (figure 6-4).

Users are warned of the attack and AirDefense Personal takes the necessary action to halt the attack before it is successful.

In the stand-alone mode users can enforce individual policies. AirDefense Personal agents can also report to the Enterprise 7.0 server for centralised management of security events and the enforcement of new or updated agent policies (figure 6-5) ("AirDefense Enterprise 6.0", 2005).
Figure 6-3: AirDefense personal on the sample UNISA WLAN operating environment

Figure 6-4: Using AirDefense personal to enforce a policy
Figure 6-5: Managing multiple AirDefense personal agents using the personal manager
6.5.2 ORIENTATION

Analysis of the wireless packets takes place in the orientation phase. Intrusion detection techniques are broadly classified as misuse detection and anomaly detection (Zhang et al., 2003:546):

- Anomaly detection techniques have been applied to the problem of detecting intrusion since the research field of intrusion detection was first formalised with the publication of Anderson’s seminal report in 1980 (Anderson, 1980). Anomaly detection builds profiles of normal user and system behaviour and any activity that deviates drastically from this accepted normal usage profile is labelled intrusive (Campbell, 2003:337). Anomaly detection modules can be constructed by enabling a logging system and studying the log files to note deviations in certain behaviour (Sharma, 2004:118). AirMagnet enterprise can study these patterns and generate an alarm upon detection of a specific abnormality (“AirMagnet Enterprise 6.0”, 2005:84).

- Signature detection, also referred to as rules-based detection, pattern matching and misuse detection uses pattern matching to detect known attack patterns (Endorf et al., 2004:16). Signature detection entails recording unique activity patterns into a signature. The user’s activity is compared with this signature. Pending a match, an alert indicates that an intrusion has taken place.

The SmartEdge sensors capture 802.11 packets using the 802.11b, 802.11g or 802.11a band (“AirMagnet Enterprise 6.0 User”, 2005:66) and can perform a total local analysis of the packets without having to send them through to the centralised server. The sensor is able to identify more than 120 classes of threats and a large number of specific attack tools (“Enterprise-hardened”, 2005) in real time. At the crux of this solution is the industry’s most advanced analysis engine, called AirWISE. AirWISE automatically analyses any wireless network to identify security and performance threats proactively. AirMagnet’s AirWISE engine (zero-day analysis) provides alerts on devices that are repeatedly committing security and performance violations.

The SmartEdge sensors are capable of conducting a continuous vulnerability assessment of the network (figures 5-7 to 5-9). The continuous scanning means that it is not necessary to enlist the assistance of a large number of personnel to survey the area frequently (Lindstrom, 2003:3) which may very well be a large geographically dispersed area in the case of an enterprise WLAN (Henning, 2003:56). Owing to the open nature of wireless
networks, new vulnerabilities can come into being as soon as the vulnerability analysis has been done rendering this labour and capital exercise (Chartoff & Boyland, 2004:41) an exercise in futility ("Wireless LANs:Risks", 2003:9).

The following section provides an overview on how AirMagnet's intelligent SmartEdge sensors are able to detect some of the possible type of intrusion attacks identified in the observation: knowledge elicitation phase (figures 6-6 to 6-9) ("AirMagnet Handheld", n.d.).

6.5.2.1 **AIRMAGNET SMARTEDGE SENSORS DETECTION OF WLAN INTRUSION ATTACKS AND POLICY VIOLATION**

![Figure 6-6: Unauthorised AP detected](image)

"Figure 6-6: Unauthorised AP detected"
Figure 6-7: DOS (flood association request) attack detected

Figure 6-8: MAC address masquerading detected
Figure 6-9 illustrates how SmartEdge sensors are capable of detecting a policy violation; unconfigured AP. AirMagnet SmartEdge sensors scan the WLAN for unconfigured APs by matching factory default settings against an internal database of well-known default configurations such as default configurations for the SSID ("AirMagnet Enterprise 6.0", 2005:15).

![Unconfigured AP detected](image)

It is possible to customise the SmartEdge sensors policy management to detect a range of intrusion attacks, configuration vulnerabilities and user authentication and encryption configurations (figure 6-10).
The SmartEdge sensors are capable of detecting configuration vulnerabilities such as ad-hoc stations, APs broadcasting their SSIDs, an AP with a configuration that has changed and APs using default configuration. A comprehensive explanation of these vulnerabilities is provided. Figure 6-11 illustrates some of the configuration vulnerabilities detected by the researcher when doing a sample scan of an area in Centurion, South Africa on 10th October 2005 together with an explanation of one of these vulnerabilities (figure 6-12).
Figure 6-11: Configuration vulnerabilities detected

AP broadcasting SSID

AP GemTek:63:43:B5 (SSID: Zenex) is currently broadcasting its SSID (Zenex) in clear text. For security reasons, it is generally recommended that the SSID broadcast be turned off in the AP configuration. For Cisco Aironet AP, this configuration is called "Broadcast SSID in beacon." Even though turning off SSID broadcast does not secure your WLAN by any definition, it does prevent your AP from being discovered by war-driving tools such as NetStumbler. Turning off SSID broadcast also blocks out casual WLAN hackers who do not have sophisticated tools and knowledge. Please note that AirMagnet can discover un-broadcasted SSID and APs.

Figure 6-12: Explanation of one of the configuration vulnerabilities
It is possible to create new policy profiles without using any of AirMagnet's pre-configured policy profiles ("AirMagnet Enterprise 6.0 User", 2005:215). Thus it will be possible to create a new policy or edit an existing policy to take into account the operational policies outlined in appendix D (section 12.2).

The AirMagnet SmartEdge sensors can detect an intruding device using the AirMagnet find tool located on the laptop analyser (figure 6-13).

![Figure 6-13: AirMagnet find tool locating an intruding device](image)

All events, such as traffic statistics, identified APs and wireless clients, performance and security anomalies are periodically passed from the AirMagnet SmartEdge sensors to a centralised enterprise server ("AirMagnet SmartEdge", 2005:5). Communications between all AirMagnet components use SSL/TLS, ensuring all traffic is secure and VPN/firewall friendly ("Enterprise Quick", 2005). If the LAN or WAN link between the sensor and the centralised enterprise server goes down, AirMagnet is able to retrieve all the alarms and events that occurred during this missed period (Bulk, 2005:5). The centralised enterprise server integrates with other systems and does correlation, reporting, notification and alerting of all the WLAN events from the different sensors.

In the AirDefense Wireless IDS/IPS, the centralised server correlates events and statistics from all the sensors and agents. The centralised server runs a multi-dimensional engine
(figure 6-14) that amalgamates several detection technologies. The server is responsible for centrally managing and monitoring the policies.

![AirDefense multidimensional correlation engine](image)

**Figure 6-14: AirDefense multidimensional correlation engine**

The following section provides an overview of how the centralised enterprise server is able to detect and prevent some of the possible types of intrusion attacks and policy violations identified in the observation: knowledge elicitation phase. The SmartEdge sensors are also capable of detecting some of these attacks.

### 6.5.2.2 Airmagnet Centralised Enterprise Detection of WLAN Intrusion Attacks and Policy Violations

The centralised enterprise server, governed by the AirMagnet Enterprise Console provides detailed information on the security and performance events that have occurred in the last 24 hours, plus full custom reporting for any time period (figure 6-15) ("Enterprise Quick", 2005:8). The AirMagnet Enterprise Console allows users to view network activities by location or sensor throughout the network. When more detailed information is required, the Enterprise Console can directly connect to any individual sensor for real-time analysis and remote troubleshooting, using the AirMagnet Remote Analyser. The remote analyser can be launched by double-clicking a particular sensor.
Figure 6-15: AirMagnet Enterprise Console
AirDefense Enterprise 7.0 includes multiple dashboards based on administrative roles such as the Manager Dashboard (figure 6-16) ("AirDefense Enterprise", 2005) that presents valuable information about the operation of the network.
The centralised enterprise server provides a separate Rogue/IDS page (figure 6-17) ("Enterprise Quick", 2005:11) that allows for simple start/stop of wired/wireless blocking and provides all the historical blocking information.

Figure 6-17: Rogue IDS screen
Upon detecting a rogue device, it is possible to use the triangulation feature to pinpoint the location of the rogue device (figure 6-18) ("Enterprise Quick", 2005:13).

Figure 6-18: Rogue triangulation
Both the AirMagnet centralised enterprise server and the SmartEdge sensors detect MAC address spoofing by studying the IEEE-authorised OUI and 802.11 frame sequence number signature ("AirMagnet Enterprise 6.0", 2005:83). The 2-byte sequence control field of an 802.11 frame (figure 4-4), collates fragments of 802.11 frames. The initial 4 bits denote a fragment number and the remaining 12 bits a sequence number progressively incremented by one if the frame is not fragmented which is always 0 for AirMagnet (Wright, 2005:14). WLAN intruders cannot alter this sequence number. As a result, it is possible to identify a spoofed MAC frame by scrutinising the pattern of successive sequence numbers for any deviation thereof (Wright, 2003:6). Furthermore, a specific manufacturer should allocate MAC addresses. Therefore, by monitoring the first 3 bytes exclusive to that specific manufacturer, it will be possible to determine spoofed MAC addresses (Wright, 2003:4).

Both the AirMagnet centralised enterprise server and the SmartEdge sensors monitors the wireless client authentication process and identifies DOS attack signatures against the AP. An incomplete authentication and association process activates the AirMagnet Enterprise attack detection and statistical signature matching process. The DOS detection module uses statistical methods on the signal strengths and noise levels in which a time differential between beacons is the focus of statistical analysis (Lackey, Roths & Goddard, 2003:9). AirMagnet detects MAC address masquerading pending a successful client association to detect this form of DOS attack.

Like the SmartEdge sensors, the AirMagnet centralised enterprise server is also able to check for policy violations. Therefore, the AirMagnet centralised enterprise server can detect a violation of some of the policies documented in appendix D. The AirMagnet centralised enterprise is able to validate an organisation's WLAN security deployment by monitoring on the authentication transactions and traffic encryption methods against the specified security deployment policy, which AirMagnet Enterprise learns from the AirMagnet policy configuration. AirMagnet Enterprise alerts the administrator on any AP operating without any layer 2 data encryption mechanisms such as WEP, TKIP or AES ("AirMagnet Enterprise 6.0", 2005:128). The AirMagnet centralised enterprise server is capable of detecting configuration vulnerabilities such as ad-hoc stations, APs broadcasting their SSIDs, an AP with a
configuration that has changed and APs using default configuration ("AirMagnet Enterprise", 2005:7-14).
The AirMagnet Spectrum analyser included in AirMagnet Enterprise 7.0 caters for the identification of RF jamming devices in real time by using spectral fingerprinting techniques (figure 6-19) ("AirMagnet Spectrum", 2006:2). Figure 6-19 illustrates the identification of a microwave jamming device.
Both the AirMagnet centralised enterprise server and the SmartEdge sensors generate a *device probing for AP* alarm when WLAN intruders probe the WLAN using WLAN discovery or war driving tools such as NetStumbler ("AirMagnet Enterprise", 2005:62).

Both the AirMagnet centralised enterprise server and the SmartEdge sensors generate an alert on weak key implementations and recommends a device firmware upgrade ("AirMagnet Enterprise", 2005:89). *Firmware* is programming that is inserted into programmable read-only memory (programmable ROM), to become a permanent part of a computing device ("Define firmware": 2000-2006).

AirDefense Enterprise 7.0 provides administrators with the ability to review and rewind detailed records of wireless activity to assist in a forensic investigation (figure 6-20) ("AirDefense Enterprise", 2005). This is possible by virtue of a special console, the AirDefense IntelliCenter, incorporated into the AirDefense server. Using this console makes it is possible to ("AirDefense Enterprise", 2005) ("Enterprise Class", 2002-2005:3):

- Rewind and review all device, network, connectivity, traffic and location information for any period with granularity (device, AP, location, group, enterprise).
- Have forensic records that ensure compliance with regulations can be audited.
- Store, analyse and mine data efficiently over extended periods.
Figure 6-20: AirDefense forensic engine
6.5.3 DECISION
Having decided that an intrusion has indeed taken place, necessary notification must take place. AirMagnets notification methods include ("Enterprise-hardened", 2005) SNMP versions 1, 2 and 3, sysLog, eventLog, e-mail, Page over Internet, instant messaging and short messenger service (SMS).

6.5.4 ACTION
AirMagnet Enterprise takes action in the following manner ("AirMagnet Enterprise 6.0 User", 2005:4):

- The AirMagnet Enterprise wired trace and block rogue device feature (figure 6-17) tracks down the wired-side IP address of the rogue AP and manually blocks it. The results will include the switch IP address and the port to which the rogue AP is connected. AirMagnet Enterprise also provides the feature of wired auto-trace and auto-blocking, in which the rogue AP is traced and automatically blocked on detection.

- The wireless trace and block rogue feature (figure 6-17) allows the SmartEdge Sensor to associate with the rogue AP and discovers the IP address used by or through the rogue AP to connect to the enterprise wired network. The sensor can suspend wireless communication from the rogue AP. AirMagnet Enterprise also provides the feature of wireless auto-trace and auto-blocking, in which the rogue AP is traced and automatically blocked as soon as it is detected. Figure 6-21 illustrates the wired port lookup and suppression feature of AirDefense 7.0.

Figure 6-21: Wired port lookup feature of AirDefense Enterprise 7.0
In this regard, AirMagnet Enterprise and AirDefense Enterprise are not only intrusion detection systems but also intrusion prevention systems because they prevent unauthorised access to the WLAN.

The link from the action phase again to observation phase entails conducting maintenance activities on the wireless IDS/IPS. This includes updating new signatures, installing IDS upgrades and re-evaluating the placement of IDS sensors. Figure 6-18 depicts the architectural design of a wireless IDS/IPS using the AirMagnet Enterprise 6.0 system.

The degree to which WLAN intrusion security risks are capable of been mitigated can be determined by studying the operational features of the wireless IDS/IPS. It is necessary to revisit the nine areas of concern (figures 11-2 to 11-10) to determine the extent to which these intrusion security risks are capable of been mitigated by preventing a risk from occurring altogether or to reduce the impact or consequences of its occurrence to an acceptable level by taking corrective action.

- First area of concern: The first area of concern is rogue APs (figure 11-2). The AirMagnet Enterprise Block Rogue feature (figure 6-17, section 6.5.4) is an immediate solution to prevent a rogue AP from further risking WLAN security.
- Second area of concern: War-driving and wireless client probing for association with an AP with any SSID using NetStumbler can be reduced to an acceptable level by configuring APs not to broadcast their APs. The enterprise-wide protection strategy (appendix D, table 12-15) documents this information. Furthermore, the 24x7 network-monitoring feature of the AirMagnet policy management can detect APs that broadcast their SSIDs (figures 6-11 to 6-12). AirMagnet also generates the device probing for an AP alarm.
- Third area of concern: WLAN traffic encrypted with TKIP and MIC defeats packet forgery and replay attacks. AirMagnet can issue an alarm if the AP is unprotected by TKIP (figure 5-9). The WLAN enterprise-wide protection strategy (appendix D) also stipulates the use of TKIP to provide message integrity verification (table 12-11).
- Fourth area of concern: Table 12-14 of the WLAN enterprise-wide protection strategy advocates that users should not divulge any sensitive information.
- Fifth area of concern: AirMagnet Enterprise detects continuous RF noise over a certain threshold for a potential RF jamming attack (figure 6-19). A reported RF
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A jamming attack can be further investigated by tracking down the noise source using the AirMagnet find tool (figure 6-10) on the laptop and handheld analysers. As far as DOS association floods are concerned, AirMagnet can detect this type of DOS attack (figure 6-7). The WLAN security officer can log on to the AP to check the current association table status or use the active Tools (Diagnostics, DHCP, Ping) (figure 6-10) to test the wireless service provided by this AP. These tools are available via the remote analyser on the Enterprise system (figure 6-15) as well as on the laptop and handheld analysers.

☑ Sixth area of concern: In order to mitigate the security risk of MAC address spoofing, (figure 6-8), it is essential to ensure that all APs deploy a strong form of authentication. EAP-FAST, which is currently the mode of encryption (figure 11-14), alleviates the problem of MAC addresses been broadcast in plain text by WEP.

☑ Seventh area of concern: In EAP-FAST, a tunnel is created between the client and the server using a PAC (Protected Access Credential) to authenticate each other. After the tunnel establishment process, the client is authenticated using the user-name and password credentials. Thus even though, the client has stolen the WNIC, the client will not be able to gain access to the WLAN because of the need of knowing the user-name and password credentials.

☑ Eighth area of concern: 802.11i with AES and WPA with TKIP can overcome the IV problems. The WLAN enterprise-wide protection strategy (appendix D, table 12-11) documents the use of these two modes of encryption.

☑ Ninth area of concern: Retaining the default settings of APs, SSIDs, SNMP and DHCP can cause AirMagnet to signal an alarm regarding this (figure 6-9). Care should be taken to ensure these default settings are disabled. The WLAN enterprise-wide protection strategy (appendix D, table 12-15) advocates the disabling of these default settings.

☑ The current organisational vulnerability of the University (figure 11-15), indicates that wireless clients do not have personal firewalls installed. This prevents a port scanner from communicating with open ports. Installing a stand-alone wireless personal intrusion detection system such as AirDefense personal makes it possible to detect eavesdropping attacks. The AirDefense Personal agent can also prevent policy violations or malicious attacks such as redirection attacks, man-in-the-middle attacks, deauthentication attacks and secure the network from probing laptop
problems. The WLAN enterprise-wide protection strategy (appendix D, table 12-15) advocates the deployment of personal firewalls on the wireless clients.
Figure 6-22: Operational design of a wireless IDS/IPS using AirMagnet

1. **Orient**
   - Deeming that an intrusive activity has indeed taken place.

2. **Observe**
   - The sensors observe all wireless packets in flight.
   - SmartEdge Sensors can monitor over 120 security and performance vulnerabilities.

3. **Act**
   - Taking necessary action against the WLAN intruder.

4. **Maintenance Activities**
   - The centralised enterprise server stores and correlates all network events, configures sensors, and manages custom notifications to people or other systems.
   - The Enterprise Management Console, the user interface to the enterprise server can connect directly to any sensor.

SSL/TLS

Deeming that an intrusive activity has indeed taken place.

Taking necessary action against the WLAN intruder.

The sensors observe all wireless packets in flight.

SmartEdge Sensors can monitor over 120 security and performance vulnerabilities.

The centralised enterprise server stores and correlates all network events, configures sensors, and manages custom notifications to people or other systems.

The Enterprise Management Console, the user interface to the enterprise server can connect directly to any sensor.
The above theoretical description of a wireless IDS/IPS has been designed to detect and mitigate WLAN intrusion attacks to an acceptable level, but no matter how much forethought goes into the planning of such a system, "developing systems that are absolutely secure is extremely difficult, if not generally impossible" (Denning, 1986:118).

6.6 WLAN INTRUSION SECURITY RISK ANALYSIS CONCLUDING ACTIVITIES

The following activities are the concluding activities of the WLAN intrusion security risk analysis process (Alberts & Dorofee, 2003:51):

6.6.1 PREPARATION TO MEET WITH SENIOR MANAGEMENT
Senior management should receive the WLAN intrusion security risk analysis results.

6.6.2 PRESENTATION OF RISK INFORMATION
Senior management should receive the following risk information:
Information regarding the most important assets, the security requirements for these assets as well as the areas of concern. The database can generate these reports. As far as the technological vulnerability assessment is concerned, a live demonstration using a tool such as the AirMagnet handheld analyser should be performed. It would also be advisable to discuss the impact of a WLAN intrusion attack verbally with senior management using the information from the risk impact assessment instead of presenting them with reports. This serves to heighten the severity of a WLAN intrusion attack.

6.6.3 REVIEW AND REFINEMENT OF WLAN ENTERPRISE-WIDE PROTECTION STRATEGY AND WLAN INTRUSION SECURITY MITIGATION PLAN
Senior management should receive the WLAN enterprise-wide protection strategy and WLAN intrusion security risk mitigation plan for review and modification. The WLAN intrusion security risk mitigation plan should be a condensed plan outlining the features of a wireless IDS/IPS as senior management may not read a voluminous report. These reports can be generated from the database.
6.6.4 CREATION OF SUBSEQUENT STEPS
This milestone marks the termination of the WLAN intrusion security risk analysis process. The ensuing chapter addresses the follow-up activities of the WLAN intrusion security risk analysis process.

It is at this stage fitting to review the objective of risk analysis as outlined in chapter two, section 2.5.4 to see whether this objective has been realised. The objective of risk analysis is to identify risks from potential or inadvertent events (these real and perceived threat scenarios were identified by virtue of studying the OODA cycle of the WLAN intruder) with a view to reducing the level of risk to an acceptable level (the risk profile indicated a high risk impact degree meaning that the risks should be mitigated. A WLAN enterprise-wide protection strategy and WLAN intrusion security risk mitigation plan was proposed to reduce the risks to an acceptable level). A report on the justification for the implementation of countermeasures to reduce the risk to an acceptable level should be submitted to senior management for approval (a report on the proposition of a wireless IDS is presented to senior management.

6.7 CONCLUSION
This chapter concludes the WLAN intrusion security risk analysis process. However, the entire exercise could be an exercise in futility if there is no follow-up and implementation of the results that were proposed. The next chapter therefore addresses the post-OCTAVE activities.
PART

WLAN INTRUSION
SECURITY RISK
MANAGEMENT

CHAPTER SEVEN

ACTION: POST-OCTAVE ACTIVITIES

Words are nothing but words; Power lies in deeds. Be a person of action.
- Mali Oriot Mamudu Konyate
7. ACTION: POST-OCTAVE ACTIVITIES

7.1 INTRODUCTION

Subject to senior management approval, the next step is implementing the results of the WLAN intrusion security risk analysis process. This entails conducting typical risk management activities. Risk management is a crucial activity because it succeeds risk analysis and aids in reducing the exposure of risk.

The objective of this chapter is the enforcement of the WLAN enterprise-wide protection strategy and implementation of the WLAN intrusion security risk mitigation plan.

7.2 STRUCTURE OF THIS CHAPTER

This chapter focuses on conducting the WLAN intrusion security risk management process whereby the organisation actually implements the results of the WLAN intrusion security risk analysis exercise. This entails carrying out the post-OCTAVE activities.

The following diagram (figure 7-1) depicts the role of this chapter within the overall context of the dissertation.
Figure 7-1: The role of chapter seven within the overall context of the dissertation
The post-OCTAVE activities include:

7.3 PLANNING HOW TO IMPLEMENT THE WLAN ENTERPRISE-WIDE PROTECTION STRATEGY AND WLAN INTRUSION SECURITY RISK MITIGATION PLAN

Implementation of a wireless IDS/IPS entails contacting the relevant vendors. Carefully designed countermeasures such as wireless IDSs/IPSs can detect and mitigate WLAN intrusion security risks but a great deal of forethought has to go into the deployment issues of such a countermeasure. In the initial stages, an organisation should develop a detailed, well-designed deployment plan.

7.4 IMPLEMENTING THE PLANS

This entails circulating the enterprise-wide protection strategy document to all personnel within the University. The corporate manual on the University intranet should contain a copy of this policy. As far as implementing the wireless IDS/IPS is concerned, the AirMagnet Surveyor should be used to determine the strategic location of APs. It will be possible to determine where to place the network-based sensors after determining where the APS should be located as the consensus is to deploy sensors (network-based sensors) wherever an AP is located. AirMagnet Surveyor permits the conduction of site surveys by providing a range of scientific tools to assist with the positioning of APs. AirMagnet Surveyor allows one to see the RF coverage, signal interference and packet statistics as well as simulate corrective action before actual implementation.

AirMagnet Survey PRO is a separate version of the Survey software released with the new version of AirMagnet Enterprise 7.0. The Survey PRO caters for ("AirMagnet Survey", 2002-2006; "AirMagnet Survey", 2006:2):

- Integration with AirMagnet spectrum analyser-using both Survey PRO and Spectrum Analyser facilitates viewing both WiFi and spectrum analysis data. This provides an overview of how the RF spectrum relates to WiFi performance.
- AirWISE for site surveys-AirWISE allows users to enter a variety of design requirements for the wireless LANs and document all areas that fail to meet their standards.
- Capacity planning-ensures that there are enough access points to meet the number of users for that particular area and satisfy their network performance needs.
Multi-floor survey-simultaneously displays results of up to four floors of a structure allowing a user to map an AP’s signal and view how it reaches and affects floors above and below the AP. This can prevent signal leakage. This can therefore mitigate the second area of concern (figure 11-3).

7.5 PROMOTING AWARENESS OF THE PLANS
User awareness is paramount for the successful implementation of the WLAN security policy. Users are sometimes oblivious to the security policies, procedures and standards of an organisation (Von Solms & Von Solms, 2004:375). At present, less than half of all organisations keep users abreast of the impact of information security issues and users receive no training on how to respond to a security breach ("Global Information", 2005:13). A survey conducted by Deloitte reveals that only 22% of the respondents have issued guidelines for safe use of WiFi and only 57% have established security policies regarding organisational wireless usage ("2005 Global", 2005:30). A study conducted by the U.S. GAO, revealed that 18 out of 24 federal agencies have not established any training programmes with regard to wireless security policies ("Federal Agencies", 2005:18).

7.6 MONITORING THE PLANS FOR EFFECTIVENESS AND PROGRESS
A dedicated network administrator should continuously monitor the wireless IDS/IPS system to see if intrusion attempts are averted and if users are complying with the wireless policy. It is necessary to take reactive measures when an intrusion is detected.

7.7 CONTROLLING BY TAKING APPROPRIATE CORRECTIVE ACTION FOR ANY VARIATIONS IN THE EXECUTION OF THE PLAN
To date, AirMagnet has been capable of detecting more than 130 threats ("Mobile Solution", 2005). However, WLAN intruders always find new and innovative ways of intruding WLANs. AirMagnet can detect these "day-zero" attacks which are vulnerabilities exploited on the very day they are discovered. Enterprise 6.0 includes day-zero alarms, which look specifically for out of the ordinary clustering or trends to identify new variations on existing attacks or novel tools that combine and repeat attacks ("AirMagnet Completes", 2005). Another form of control can be to take action against personnel contravening the WLAN policy rules.
The database contains a section (figure 7-2) for the post-OCTAVE activities, which can be used by the network administrator subject to senior management approval of the WLAN enterprise-wide protection strategy and WLAN intrusion security risk mitigation plan.

![WLAN Intrusion Security Risk Management](image)

**Figure 7-2: Post-OCTAVE activities**

This terminates the WLAN intrusion security risk management process. It is therefore fitting to review the objective of risk management as outlined in chapter two, section 2.5.4 to ascertain whether this objective has been realised.

The objective of risk management is the implementation of appropriate risk mitigation (implementing the WLAN enterprise-wide protection strategy and WLAN intrusion security risk mitigation plan subject to senior management approval), risk transfer and risk recovery measures to reduce business exposure by balancing countermeasure investment against risk (the benefits of deploying a wireless IDS as a risk mitigation countermeasure can transcend the costs incurred of deploying this system).

### 7.8 CONCLUSION

This chapter terminates the OODA-OCTAVE risk analysis and risk management methodology for mitigating WLANs intrusion security risks. The next chapter concludes with final remarks about this methodology.
PART IV

CONCLUSION

CHAPTER EIGHT

CONCLUSION AND FUTURE RESEARCH

The policy of being too cautious is the greatest risk of all.

- Jawaharlal Nehru
8. CONCLUSION AND FUTURE RESEARCH

8.1 INTRODUCTION
This principle aim of this research was to develop a risk analysis and risk management methodology for mitigating WLANs intrusion security risks.

In this chapter, the researcher evaluates the degree to which this aim has been accomplished. This dissertation terminates with a section reflecting possible avenues for further research.

8.2 ASSESSING THE DEGREE TO WHICH RESEARCH QUESTIONS HAVE BEEN ADDRESSED
The research questions posed in chapter one will be re-examined to determine the extent to which they have been addressed in this dissertation.

8.2.1 WHAT ARE THE POSSIBLE TYPES OF INTRUSION ATTACKS THAT CAN BE LAUNCHED ON WLANs?
This question was answered by studying the OODA cycle of WLAN intruders. This presented insight to the real and perceived security issues of WLANs. A literature study revealed DOS attacks, masquerade attacks, penetration of the security control system, leakage, eavesdropping, malicious use, replay attacks, social engineering and brute force attacks as some of the possible WLAN invasion attacks (chapter four). The default settings of WEP, SSID, MAC address filtering, AP passwords, SNMP and DHCP settings also provide opportunities for attack.

8.2.2 HOW SHOULD A WLAN INTRUSION SECURITY RISK ANALYSIS EXERCISE BE CONDUCTED?
The OCTAVE risk analysis methodology was selected for conducting the WLAN intrusion security risk analysis exercise. This methodology was put through the GAO strength test
(appendix A) and the outcome of this test revealed that the OCTAVE risk analysis methodology is a sound risk analysis methodology. However, the OCTAVE risk analysis methodology was found to be flawed in a few respects as outlined in chapter two, section 2.7.2.1. These flaws, which could have an impact on a WLAN intrusion security risk analysis exercise, include an extremely long time to conduct the process and relying on a brainstorming process for asset and threat scenario identification.

To overcome these weaknesses, it was proposed that the OCTAVE risk analysis methodology be improved by fusing it with the observe, orient and decision elements from the OODA cycle. The OODA cycle can overcome the weaknesses of the OCTAVE risk analysis methodology because it advocates moving rapidly though the cycle thereby arriving at a decision in a shorter time. It also entails getting into the mind of the adversary. This unravels typical threat scenarios which can not be done by a brainstorming process. Unravelling typical threat scenarios eliminates the need to go through the structured interviews (phase1, processes 1-3), which in turn facilitates shortening of the OCTAVE risk analysis process. A database was created for the storage, retrieval and printing of WLANs intrusion security risk analysis and risk management information. This database precluded the need for formal training and investment in paper and human resources, thereby shortening the OCTAVE risk analysis process.

The OODA cycle can also ensure that the OCTAVE risk management process is recognised as a vital follow-up activity of the risk analysis process. This is because the OODA cycle has a clearly delineated element, action, which advocates executing the decision. This element is an integral part of the cycle. Therefore, the OODA cycle was assimilated with the OCTAVE risk analysis and risk management processes. Consequently, it evolved into the OODA-OCTAVE risk analysis and risk management methodology for mitigating WLANs intrusion security risks (chapter three).

The WLAN intrusion security risk analysis exercise was conducted in a sample educational environment. By conducting a WLAN intrusion security risk analysis exercise, it was possible to determine the most important assets, the current protection practices and organisational vulnerabilities and the real and perceived threat scenarios in the WLAN operating environment (appendix C). Nine areas of concern (appendix C, figures 11-2 to 11-
10) were identified. A vulnerability scan uncovered technological vulnerabilities and the threat impact on the University's mission and objective was examined (chapter five).

The risk impact criteria connoted a high degree of impact (figure 5-21). It therefore became necessary to create a WLAN enterprise-wide protection strategy (appendix D) and to justify the deployment of a wireless IDS/IPS as one of several security countermeasures capable of mitigating WLANs intrusion security risks (chapter six).

The WLAN enterprise-wide protection strategy (appendix D) documents a host of strategic and operational practices to be adopted by the University.

To justify the deployment of a wireless IDS/IPS, the operational and deployment issues of a wireless IDS/IPS were investigated. A wireless IDS/IPS can only possess a certain degree of functionality before a new WLAN security attack emerges, in which case the impact of the threat has to be determined and the functionality of the wireless IDS/IPS has to be updated. It is because of the cyclic nature of WLAN attacks that the operational design of the wireless IDS/IPS was constructed using the OODA cycle (chapter six). Two selected wireless IDSs/IPSs, AirMagnet Enterprise 6.0 and AirDefense Enterprise 7.0 were studied.

It was illustrated that by enforcing a WLAN enterprise-wide protection strategy and deploying a wireless IDS/IPS (chapter 6), WLANs intrusion security risks can be reduced to an acceptable level either by taking action after an intrusion has taken place to prevent its reoccurrence (intrusion detection) or to prevent an intrusion from taking place altogether (intrusion prevention).

AirMagnet and AirDefense are intrusion detection systems rather than intrusion prevention systems because they are able to report that an intrusion attack has taken place and then offer advice on how to remedy the situation. The only real intrusion prevention feature of these systems is its ability to auto trace and auto block rogue APs.

As far as the deployment issues are considered, AirMagnet Surveyor was reviewed (chapter seven) as it can determine the strategic location of APs. It will be possible to determine where to place the network-based sensors after determining where the APS should be
located as the consensus is to deploy sensors (network-based sensors) wherever an AP is located.

8.2.3 WHAT STEPS MUST AN ORGANISATION TAKE TO ENFORCE THE RESULTS OF A WLAN INTRUSION SECURITY RISK ANALYSIS EXERCISE?

Post-OCTAVE activities were critically evaluated and expanded (chapter two). These activities conforming to the action phase of the OODA cycle were included as a vital component in the OODA-OCTAVE risk analysis and risk management methodology for mitigating WLANs intrusion security risks. The database also has a separate form for storing WLANs intrusion security risk management information.

The post-OCTAVE activities focused on the actual institutionalisation of the WLAN enterprise-wide protection strategy and WLAN intrusion security risk mitigation plan and the continuous monitoring thereof (chapter seven). It was deduced that promoting user awareness is an activity that requires attention.

8.3 EXTENSIBILITY OF RESEARCH

This research specifically focused on addressing the intrusion security risks of a WLAN operating environment as this technology has been statistically proved to be a promising future technology (chapter one). However, because of the relentless pace at which technology evolves, no technology can be stagnant and there will always be future developments and enhancements.

One particular technology, WiMax (world interoperability for microwave access) based on the IEEE 802.16a standard, is destined to have more than 7 million subscribers by 2009 and is expected to grow more rapidly than WiFi with Intel anticipating WiMax functionality on half of the world's notebooks by 2008 (Carter, 2005:21-22). Other projected standards include the 802.16e standard and Mobile Broadband Wireless Access (MBWA), based on the IEEE 802.20 standard (Cannon, 2006:180). Since these are also wireless networks, they also require an expeditious risk analysis methodology. The OODA-OCTAVE risk analysis and risk management methodology can in future be used to address the intrusion security risks of these wireless networking environments.
8.4 FUTURE RESEARCH
The following issues require further research:

- To study the OODA cycle of the WLAN intruder, a great deal of reference to existing literature was made. This served to expose the current vulnerabilities of these networks. A more adept approach would be to use a *honeypot*. A honeypot, or a network of honeypots, termed a *honeynet* can be used to "research hacking methods and techniques" (Carter & Shumway, 2002:73). By using such a decoy tool, it will be possible to observe the behaviour of WLAN intruders and to ascertain the different types of attacks that can occur. A honeypot will not affect the operational systems therefore posing no risk to the network (Endorf et al., 2004:358).

- The database has several limitations that require enhancement. These include enhancing the database to cater for the probability that not all of the outcomes may materialise. Furthermore, the database should be converted into an executable file that can be used on any system, precluding the need to have the Microsoft Access 2003 application installed on that particular system.

- Constructing a comprehensive WLAN policy can be an exercise in futility if no one takes heed of this policy. It is therefore necessary to create a WLAN user awareness model. In addition, it is important to enlist the participation of senior management for the enforcement of the WLAN policy and deployment of the WLAN risk mitigation plan.

8.5 CONCLUSION
In conclusion, it is befitting to include a piece of the eulogy that was published in *Inside the Pentagon* written by General Charles Krulak who was at that stage the Commandant of the U.S. Marine Corps (Hammond, 2001:3) after Colonel John Boyd’s demise in 1997.

11 Mar 97

To the Editor:

"I was deeply saddened to learn of the passing of Colonel John Boyd, USAF (Ret). How does one begin to pay homage to a warrior like John Boyd? He was a towering intellect who made unsurpassed contributions to the American art of war. Indeed, he was one of the central architects in the reform of military thought which swept the services, and in particular the Marine Corps, in the 1980s. From John Boyd we learned about competitive decision making on the battlefield-
compressing time, using time as an ally. Thousands of officers in all our services knew John Boyd by his work on what was to be known as the *Boyd Cycle or the OODA Loop.* ................."

Colonel Boyd’s contribution to military strategy, in particular his development of the OODA cycle was acknowledged even in his eulogy. Colonel Boyd advocated that attacking the mind of the adversary prior to a battle is the quintessence of intelligent fighting. This philosophy was extended to the risk analysis process. The development of the OODA-OCTAVE risk analysis and risk management methodology can allow organisations to proactively defend their WLAN operating environments and reap the benefits of this promising technology.
9. **APPENDIX A: ASSESSING THE STRENGTH OF THE OCTAVE RISK ANALYSIS METHODOLOGY**

The GAO guideline is used to assess the strength of the OCTAVE risk analysis methodology. A ☑ denotes that OCTAVE has satisfied the particular criterion.

<table>
<thead>
<tr>
<th>(GAO:1999)</th>
<th>Obtain senior management support and involvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>☑</td>
<td>OCTAVE stipulates senior management sponsorship to the point that senior managers actually have to participate in the process (phase 1, process 1). This is a crucial step in order to leverage interest and commitment from the rest of the team as information security will not be sufficiently addressed without the support and initiative of executive management (Von Solms &amp; Von Solms, 2004:372). Furthermore, the success of any risk analysis exercise is subject to the role of top management in decision-making and selection undertaking (Broder, 1984:3; Badenhorst &amp; Eloff, 1990:342).</td>
</tr>
</tbody>
</table>

| | Designate focal points: This entails assembling a group of individuals to guide and govern the risk analysis process. |
| | The focal point of the OCTAVE method is the analysis team, a group of people from various hierarchical levels of the organisation who have a substantial amount of knowledge regarding the organisation, its business and technological processes to lead and manage the OCTAVE risk analysis process. |

<table>
<thead>
<tr>
<th>Define procedures</th>
<th>OCTAVE uses a three-phase approach to examine the organisational and technological issues of the organisation (Whitman &amp; Mattord, 2004: 345). Each phase consists of a number of processes.</th>
</tr>
</thead>
<tbody>
<tr>
<td>☑</td>
<td>Phase 1: Build asset-based threat profiles</td>
</tr>
<tr>
<td></td>
<td>Identify senior management knowledge.</td>
</tr>
<tr>
<td></td>
<td>Identify operational area management knowledge.</td>
</tr>
<tr>
<td></td>
<td>Identify staff knowledge.</td>
</tr>
<tr>
<td></td>
<td>Create threat profiles.</td>
</tr>
</tbody>
</table>
### Phase 2: Identify infrastructure vulnerabilities
- Identify key components.
- Evaluate selected components.

### Phase 3: Develop security strategy and plans
- Conduct risk analysis.
- Develop protection strategy.

<table>
<thead>
<tr>
<th>Criterion</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Involve business and technical experts</strong></td>
<td>This criterion is satisfied because the analysis team incorporates participants from both business units and the IT sector.</td>
</tr>
<tr>
<td><strong>Hold business units responsible</strong></td>
<td>Since the analysis team comprises people from the business sector, it is safe to assume that these people are conversant with the business processes and could therefore be held accountable for this aspect.</td>
</tr>
<tr>
<td><strong>Limit scope of individual assessments</strong></td>
<td>In phase 1, senior management pinpoints the operational areas to be included in the scale of the evaluation.</td>
</tr>
<tr>
<td><strong>Document and maintain results</strong></td>
<td>The results can be stored in a database for future reference and modification.</td>
</tr>
<tr>
<td><strong>Identify threats and the likelihood of those threats materialising</strong></td>
<td>In OCTAVE, participants examine threats to the top five assets that they have identified. OCTAVE has four predefined sources of threat (Alberts &amp; Dorofee, 2003:94).</td>
</tr>
</tbody>
</table>

**THREAT SOURCES**

**Deliberate Actions by People**
- People inside the organisation.
- People outside the organisation.

**Accidental Actions by People**
Identify and rank critical assets and operations

Asset identification is the very first activity of the knowledge elicitation workshop (phase 1, processes 1-3). The participants outline a general list of the assets used by the organisation. They then filter out the most important assets and provide a rationale for the selection of these particular assets.
### Estimate potential damage

It is possible to estimate the potential damage by virtue of frequency and subjective probability in phase 3, process 8 (Alberts & Dorofee, 2003:184).

### Identify cost-effective mitigating controls

Based on the compilation of results from the risk impact assessment, the analysis team constructs a set of protection strategies, mitigation plans and a list of near-term item actions for the organisation under review (phase 3, process 8A).

### Document assessment findings

**Outputs of OCTAVE include:**
- Asset-based threat profile.
- Organisation-wide protection strategy.
- Asset risk mitigation plan.
- Action list.
- Asset-based risk profile.
- Final report.

### Questionnaires

In OCTAVE, there are a number of methods for eliciting the information requirements of users. Interviews are conducted with various members of the organisation from different hierarchical levels. Information is collected with the aid of questionnaires and surveys to be analysed by the analysis team. The following table is an example of a questionnaire to determine the assets that are most important to the OCTAVE participants (Alberts & Dorofee, 2003:365-367).

| Process 1 – Identify Senior Management Knowledge |
| Process 2 – Identify Operational Area Knowledge |
| Process 3 – Identify General Staff Knowledge |
| Process 3 – Identify IT Staff Knowledge |

1. What are the important assets?
<table>
<thead>
<tr>
<th>Consider:</th>
</tr>
</thead>
<tbody>
<tr>
<td>- information</td>
</tr>
<tr>
<td>- systems</td>
</tr>
<tr>
<td>- software</td>
</tr>
<tr>
<td>- hardware</td>
</tr>
<tr>
<td>- people</td>
</tr>
</tbody>
</table>

2. Are there any other assets that the department/service is required to protect (e.g., by law or regulation)?

3. What related assets are important to the department/service?

Consider:

- information
- systems
- software
- hardware
- people

4. Of the assets that have been identified for the department/service, which are the most important? What is the rationale for selecting these assets as important?

Software to facilitate documentation and analysis

OCTAVE is a manual risk analysis approach and does not leverage the use of automated tools. This does not mean that a software tool cannot be created for the OCTAVE risk analysis methodology. The Advanced Technology Institute ("OCTAVE Automated", n.d) has created such a tool. (figure 9-1).
Figure 9-1: OCTAVE Automated Tool

<table>
<thead>
<tr>
<th>Phase 1</th>
<th>Process 1</th>
<th>Process 2</th>
<th>Process 3, Staff</th>
<th>Process 3, IT Staff</th>
<th>Process 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phase 2</td>
<td>Process 5</td>
<td>Process 6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phase 3</td>
<td>Process 7</td>
<td>Process 8A</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 9-1: Assessing the strength of the OCTAVE risk analysis methodology
10. APPENDIX B: ACTIVE AND PASSIVE WLAN DISCOVERY FOR SELECTED AREAS IN SOUTH AFRICA

10.1 ACTIVE WLAN DISCOVERY IN V & A WATERFRONT (CAPE TOWN) USING NETSTUMBLER

Active WLAN discovery is a relatively easy task accomplished by using:

- A portable computer.
- A wireless NIC.
- Software such as NetStumbler 0.4.0 ("NetStumbler", n.d.) (figure 10-1).
- An optional external antenna to receive signals from greater distances and a global positioning system (GPS) to record the precise location where each AP is situated.

NetStumbler, authored by Marinus Milner, a freeware Windows utility that allows the detection of WLANs using 802.11b, 802.11a and 802.11g is probably the most extensively used wireless site survey tool (Cannon, 2006:115). NetStumbler operates by sending a probe-request signal from the wireless client to which APs within the signal range respond by broadcasting their beacon frames approximately every 10 milliseconds (Peikari & Fogie, 2003:29), provided they are configured to broadcast their SSIDs. NetStumbler works in concert with a GPS to map precise locations of identified WLANs and the resulting maps and data are posted on websites such as the Wigle website ("WiGLE-Wireless", n.d.).
The following diagram (figure 10-2) illustrates a subsection of a scan that was conducted at the V & A Waterfront area and surrounding areas, Cape Town by the researcher on 28th September 2005 at 10:30 using NetStumbler, an HP Compaq nx9010 notebook and a Cisco Aironet 350 series WNIC. NetStumbler provides detailed information about APs including the MAC address of the AP, the SSID, which is the WLAN’s name, the radio channel in use, the vendor name, whether or not encryption has been enabled and the RF signal strength which is basically the signal-to-noise ratio.

![Table and Diagram](image)

Figure 10-2: Active WLAN discovery at the V & A Waterfront, Cape Town using NetStumbler

The following diagram (figure 10-3) illustrates the signal-to-noise ratio of a particular AP depicting how strong the signal in this particular area is. WLAN intruders can use this information and look for where the signal increases and decreases to locate the base on the wireless network.
The filters facilitate distilling precise information about a particular AP. For illustrative purposes, the author has singled out all APs that do not have encryption enabled (figure 10-4).
Appendix B

Figure 10-4: APs that do not have encryption enabled

Statistical Analysis: The researcher located the presence of 124 APs in a span of approximately 30 minutes. Of these 124 APs, 30 did not have WEP enabled (figure 10-5).

Figure 10-5: Statistical analysis of War driving at V & A Waterfront, Cape Town
Thus it can be inferred from the above statistical analysis that WLAN security is indeed a very critical problem.

10.2 ACTIVE WLAN DISCOVERY IN MIDRAND USING NETSTUMBLER

The following subsection of a NetStumbler log (figure 10-6) illustrates a typical WLAN discovery exercise conducted by Stephan Blanchard in the Midrand area, South Africa on 13th August 2005.

![Figure 10-6: Active WLAN discovery in Midrand, South Africa using NetStumbler](image)

The following diagram (figure 10-7) illustrates the number of APs that have retained their default SSIDs.
It can again be deduced, that WLAN security is indeed cause for concern.

NetStumbler can also provide information on what type of WLAN network exists, i.e. infrastructure-based or peer-to-peer. The following diagram (figure 10-8) depicts how NetStumbler detected an ad hoc network created by the researcher.

10.3 PASSIVE WLAN DISCOVERY IN EASTERN PRETORIA USING KISMET

NetStumbler is an active scanner, sending out probe requests and waiting for probe responses. This means that it will not detect networks that disable SSID broadcasting. This activity can be accomplished by using a passive scanner such as Kismet ("Kismet", n.d.), which runs on Linux or AirMagnet ("Enterprise Wireless", n.d.) which runs on Windows. Passive scanners can detect cloaked SSIDs and other devices probing APs without participating rendering it difficult to detect this type of intrusive activity (Sharma, 2004:116). It can identify clients that have associated to an AP (either by MAC addresses -
which are not encrypted, even with WEP-enabled WLANs) or IP addresses, and determine the manufacturer/model ID of the devices. The downside to passive scanners is that if an AP sends out beacon signals occasionally, the passive scanner will not pick up these APs (Howlett, 2005:328).

The following example provided by Nic Roets illustrates how APs are graphically mapped. Roets performed this WLAN scanning between 17th November 2004, scanning very small part of Eastern Pretoria. The following hardware was used:
- Notebook with 802.11b (BenQ JB 5000U).
- Entry level GPS (Garmin Etrex). The Garmin Etrex is the size of a large cellphone and is battery-powered. It locks on to the signals of the GPS satellites (about 1 minute). Thereafter it performs certain calculations and displays the location on its black and white screen. It is accurate to about 4 metres when there are no obstructions. The GPS will then report the location to Kismet via the non-USB serial port.

The following software was used:
- The Gentoo-linux operating system.
- Kismet WLAN discovery which runs on Linux. Kismet creates a number of files, including Kismet.csv, a comma delimited file which can be exported into Excel (figure 10-9).
- Gpsbabel software to graphically map the location of APs and other wireless devices (including clients and active scanners) from Kismet to GoogleEarth (figure 10-10).
Appendix B

Figure 10-9: Passive WLAN Discovery in Eastern Pretoria using Kismet

<table>
<thead>
<tr>
<th>Network Type</th>
<th>ESSID</th>
<th>BSSID</th>
<th>Info</th>
<th>Channel</th>
<th>Cloaked WEP</th>
<th>Decrypt</th>
</tr>
</thead>
<tbody>
<tr>
<td>infrastructure</td>
<td>Fort Knox</td>
<td>00:07:46:76:DA:19</td>
<td>3</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>infrastructure</td>
<td>G604T_WIRELESS</td>
<td>00:0F:3D:9A:21:8B</td>
<td>6</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>infrastructure</td>
<td>Greenfields Hatfield</td>
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<td>3</td>
<td>No</td>
<td>No</td>
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</tr>
<tr>
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<td>Greenfields Hatfield</td>
<td>00:11:0A:12:B5:C6</td>
<td>0</td>
<td>No</td>
<td>No</td>
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</tr>
<tr>
<td>probe</td>
<td>home</td>
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<td>No</td>
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<tr>
<td>ad-hoc</td>
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<td>02:02:06:08:61:50</td>
<td>6</td>
<td>No</td>
<td>No</td>
<td>No</td>
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<tr>
<td>infrastructure</td>
<td>IFS-Africa</td>
<td>00:ED:9B:5B:5B:5C</td>
<td>2</td>
<td>No</td>
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<td>No</td>
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<tr>
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<tr>
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<td>Jacques</td>
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<tr>
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<td>LEGDE</td>
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<tr>
<td>infrastructure</td>
<td>linksys</td>
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<tr>
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<td>No</td>
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<tr>
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<td>linksys</td>
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<td>2</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

Figure 10-10: Graphical depiction of APs in Eastern Pretoria
10.4 ACTIVE AND PASSIVE WLAN DISCOVERY IN SUNNYSIDE, PRETORIA USING AIRMAGNET

To illustrate the differences between active and passive WLAN discovery, the researcher sampled a small area in Sunnyside, Pretoria on 10th October 2005 using a HP Compaq nx9010 notebook and a Cisco Aironet 350 series WNIC. Figure 10-11 illustrates active WLAN discovery using NetStumbler and figure 10-12 illustrates passive WLAN discovery using AirMagnet done at precisely the same time.

Figures 10-11 and 10-12 make it unmistakeably clear that passive WLAN discovery reveals much more information that active WLAN discovery and actually detects APs that have cloaked SSIDs. Both NetStumbler and AirMagnet detected the AP with SSID ShowUs since
this AP is configured to broadcast its SSID. AirMagnet, however detected several other APs that were not detected by NetStumbler.
11. APPENDIX C: WLAN INTRUSION SECURITY
ORGANISATIONAL KNOWLEDGE

11.1 KNOWLEDGE ELICITATION
This activity requires that staff from different hierarchical levels of the organisation contributes their perspectives on what they regard as being the most important assets, what is currently being done to protect these assets and what organisational vulnerabilities exist. The information stated above is obtained via structured interviews and workshops. Since one of the premises of the OODA cycle entails moving through the OODA cycle faster than the intruder, this laborious and time-consuming can be eliminated, since all this information can be retrieved from studying the WLAN operating environment and the OODA cycle of the WLAN intruder as well as the organisations own susceptibility to WLANs intrusion security risks.

The information required for the WLAN intrusion security organisational knowledge elicitation process is stored in the database. The following activities are undertaken during this phase (Alberts & Dorofee, 2003:47):

11.1.1 IDENTIFY THE MOST IMPORTANT ASSETS
Having a basic understanding of WLANs is particularly important to an organisation since this highlights what assets are important and worth defending.

Assets broadly fall into the following categories (Alberts & Dorofee, 2003:88):
- Information–documented (paper or electronic) information or intellectual assets used to meet the mission of the organisation.
- Systems–information systems that process and store information. Systems are a combination of information, software, and hardware assets. Any host, client, server, or network can be considered a system.
- Software–software applications such as operating systems, database applications, networking software, office applications and custom applications.
- Hardware–information technology physical devices.
- People–the people in the organisation, including their skills, training, knowledge and experience.
By studying the WLAN operating environment the following important system asset has been identified (figure 11-1):

![Figure 11-1: Identify the most important assets](image)

### 11.1.2 IDENTIFY AREAS OF CONCERN

Scenarios that threaten the most important assets based on typical sources and outcomes of threats are constructed.

The sources include (Alberts & Dorofee, 2003:95):

- Deliberate actions by people–This group includes people inside and outside the organisation who might take deliberate action against the assets.
- Accidental actions by people–This group includes people inside and outside the organisation who inadvertently harm the assets.

The threat outcomes fall into the following categories (Alberts & Dorofee, 2003:95):

- Disclosure or viewing of sensitive information.
- Modification of important or sensitive information.
- Destruction or loss of important information, hardware or software.
- Interruption of access to important information, software, applications or services.

The following nine areas of concern have been identified (figures 11-2 to 11-10).
Figure 11-2: First area of concern

Figure 11-3: Second area of concern
Cyclic Redundancy Checks do not provide any means of ensuring the integrity of a data stream that has been corrupted by a WLAN intruder. If a WLAN intruder has knowledge of a certain data stream, it is possible to change the contents and successfully complete the transaction with a legitimate checksum. The receiver would have no knowledge of this because the checksum would match.

Figure 11-4: Third area of concern

Luring unsuspecting WLAN users to disclose their usernames and passwords in order to gain illicit entry into the network can compromise the confidentiality and integrity of information because the user will have access to the legitimate users information and can modify this information at will.

Figure 11-5: Fourth area of concern
Figure 11-6: Fifth area of concern

Figure 11-7: Sixth area of concern
Appendix C

Figure 11-8: Seventh area of concern

Figure 11-9: Eight area of concern
Figure 11-10: Ninth area of concern

Although 802.1x is also subject to man-in-the-middle attacks and session hijacking attacks, (section 4.5.2.4), this is not a major concern for the University as the University has the EAP-FAST encryption scheme which is quite a robust encryption scheme. EAP-FAST helps prevent man-in-the-middle attacks, dictionary attacks, packet and authentication forgery attacks ("AirMagnet Enterprise", 2005, 141). A man-in-the-middle attack is therefore not a major cause for concern. TKIP is also prone to man-in-the-middle attacks (Table 4-1) but not a major cause for concern as EAP-FAST prevents this type of attack.

11.1.3 IDENTIFY SECURITY REQUIREMENTS FOR THE MOST IMPORTANT ASSETS
The security requirement for the crucially identified asset (infrastructure BSS) (figure 11-11 to 11-13) is documented. The security requirements outline the qualities of an asset that are important to safeguard. The security requirements include (Alberts & Dorofee, 203:98):

- Confidentiality–Safeguarding information from people who are not authorised to view this information.
- Integrity–Ensuring the authenticity, accuracy and completeness of an asset.
- Availability–Denoting when or how often an asset must be present or ready for use.
All of the security requirements are equally important. No requirement is selected as being the most important. The nine areas of concern (figures 11-2 to 11-10) have illustrated how these requirements can be compromised.

Figure 11-11: Security requirement in respect of integrity

Figure 11-12: Security requirement in respect of confidentiality
11.1.4 CAPTURE KNOWLEDGE OF CURRENT SECURITY PRACTICES AND ORGANISATIONAL VULNERABILITIES

The following figure (figures 11-14 to 11-15) outlines the current security practices and organisational vulnerabilities of the University. Organisational vulnerabilities connote weaknesses in the organisational policy or practice that could manifest in unauthorised action (Alberts & Dorofee, 2003:105).
Figure 11-14: Current protection strategy

Figure 11-15: Current organisational vulnerabilities
12. APPENDIX D: WLAN ENTERPRISE-WIDE PROTECTION STRATEGY

Sections 12.1 and 12.2 cover the development of a WLAN enterprise-wide protection strategy for the University. The catalog of practices calibrated for a WLAN educational operating environment consists of two sections reflecting the strategic and operational best practices for the University. This catalog is constructed from references that were used in the original compilation of the Catalog of Practices (Alberts & Dorofee, 2003:443-445):

- British Standards (British Standards Institution, February).
- NIST Principles and Practices (Swanson & Guttman, 1996).

To update the catalog for a WLAN operating environment, the following references were consulted:

- Wireless Policy Development (Part 1-2) (Farshchi\textsuperscript{a}, 2003; Farshchi\textsuperscript{b}, 2003).
12.1 STRATEGIC PRACTICES

<table>
<thead>
<tr>
<th>WLAN SECURITY AWARENESS AND TRAINING</th>
</tr>
</thead>
<tbody>
<tr>
<td>All WLAN users fully comprehend their respective security roles and responsibilities.</td>
</tr>
<tr>
<td>There is adequate in-house expertise for all supported services, mechanisms and technologies (e.g., logging, monitoring, or encryption) including their secure operation.</td>
</tr>
<tr>
<td>Ensure that WLAN users on the network are fully trained in computer security awareness and the risks associated with wireless technology. Periodic reminders must be provided to all WLAN users.</td>
</tr>
<tr>
<td>WLAN technology users’ understanding of security information is documented and conformance is periodically verified.</td>
</tr>
</tbody>
</table>

Table 12-1: WLAN security awareness and training

<table>
<thead>
<tr>
<th>WLAN SECURITY STRATEGY</th>
</tr>
</thead>
<tbody>
<tr>
<td>The University’s strategies routinely incorporate WLANs security considerations.</td>
</tr>
<tr>
<td>WLANs security strategies and policies take into consideration the University’s mission, strategies and goals.</td>
</tr>
<tr>
<td>WLANs security strategies, goals and objectives are documented and are routinely reviewed, updated and communicated to all members of the University.</td>
</tr>
</tbody>
</table>

Table 12-2: WLAN security strategy

<table>
<thead>
<tr>
<th>WLAN SECURITY MANAGEMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Management allocates sufficient funds and resources to WLANs information security activities.</td>
</tr>
<tr>
<td>Security roles and responsibilities are defined for all wireless users within the university.</td>
</tr>
<tr>
<td>Develop an agency security policy that addresses the use of wireless technology, including 802.11.</td>
</tr>
<tr>
<td>The University's hiring and termination practices for personnel take WLANs information security issues into account.</td>
</tr>
<tr>
<td>The required levels of information security regarding WLANs and how they are applied to individuals and groups are documented and enacted.</td>
</tr>
<tr>
<td>The University manages WLANs information security risks, including:</td>
</tr>
<tr>
<td>▪ Assessing risks to information security to comprehend the value of the assets that require protection.</td>
</tr>
</tbody>
</table>
WLAN SECURITY MANAGEMENT

- Taking steps to mitigate information security risks.
- Maintaining an acceptable level of risk.
- Using information security risk assessments to help select cost-effective security/control measures, balancing implementation costs against potential losses.

Management receives and acts upon routine reports summarising the results of:

- Review of system logs.
- Review of audit trails.
- Technology vulnerability assessments.
- Security incidents and the responses to them.
- Risk assessments.
- Physical security reviews.
- Security improvement plans and recommendations.

Ensure that wireless networks are not used until they comply with the agency’s security policy.

Table 12-3: WLAN security management

WLAN SECURITY POLICIES AND REGULATIONS

The University has a comprehensive set of documented, current security policies that are periodically reviewed and updated. These policies address key security topic areas, including:

- WLANs security strategy and management.
- WLANs security risk management.
- System and network management.
- System administration tools.
- Monitoring and auditing.
- Authentication and authorisation.
- Vulnerability management.
- Encryption.
- Security architecture and design.
- Incident management.
- Staff security practices.
- Applicable laws and regulations.
<table>
<thead>
<tr>
<th><strong>WLAN SECURITY POLICIES AND REGULATIONS</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Awareness and training.</td>
</tr>
<tr>
<td>Collaborative information security.</td>
</tr>
<tr>
<td>Contingency planning and disaster recovery.</td>
</tr>
</tbody>
</table>

There is a documented process for management of security policies, including:

- Creation.
- Administration (including periodic reviews and updates).
- Communication.

The University has a documented process for evaluating and ensuring compliance with information security policies for WLANs, applicable laws and regulations and insurance requirements.

The University uniformly enforces its security policies.

Testing and revision of security policies and procedures are restricted to authorised personnel.

---

<table>
<thead>
<tr>
<th><strong>COLLABORATIVE SECURITY MANAGEMENT</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>The University has policies and procedures for protecting information when working with external institutions.</td>
</tr>
<tr>
<td>The University has verified that outsourced security services, mechanisms and technologies meet its security needs and requirements.</td>
</tr>
<tr>
<td>The University documents, monitors and enforces protection strategies for information belonging to external universities that is accessed from its own infrastructure components or is used by its own personnel.</td>
</tr>
<tr>
<td>The University provides and verifies awareness and training on applicable external universities' security policies and procedures for personnel who are involved with those external institutions.</td>
</tr>
<tr>
<td>There are documented procedures for external personnel whose services have been terminated specifying appropriate security measures for ending their access. These procedures are communicated and coordinated with the external university.</td>
</tr>
</tbody>
</table>

---

Table 12-4: WLAN security policies and regulations

Table 12-5: Collaborative security management
An analysis of operations, applications, and data criticality has been performed.

The University has documented:

- Business continuity or emergency operation plans.
- Disaster recovery plan(s).
- Contingency plan(s) for responding to emergencies.

The contingency, disaster recovery and business continuity plans consider physical and electronic access requirements and controls.

The contingency, disaster recovery and business continuity plans are periodically reviewed, tested and revised.

All personnel needed to participate are:

- Aware of the contingency, disaster recovery and business continuity plans.
- Understand and are able to carry out their responsibilities.

Table 12-6: Contingency planning/disaster recovery
12.2 OPERATIONAL PRACTICES

<table>
<thead>
<tr>
<th>INFORMATION TECHNOLOGY SECURITY SYSTEM AND WLAN MANAGEMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>There are documented security plans(s) for safeguarding the system and WLANs.</td>
</tr>
<tr>
<td>Security plan(s) are periodically reviewed, tested and updated.</td>
</tr>
<tr>
<td>Sensitive information is protected by secure storage such as:</td>
</tr>
<tr>
<td>- Defined chains of custody.</td>
</tr>
<tr>
<td>- Removable storage media.</td>
</tr>
<tr>
<td>- Discard process for sensitive information or its storage media.</td>
</tr>
<tr>
<td>The integrity of installed software is regularly verified.</td>
</tr>
<tr>
<td>All systems are up to date with respect to revisions, patches and recommendations in security advisories.</td>
</tr>
<tr>
<td>There is a documented data backup plan that:</td>
</tr>
<tr>
<td>- Is routinely updated.</td>
</tr>
<tr>
<td>- Is periodically tested.</td>
</tr>
<tr>
<td>- Calls for regularly scheduled backups of both software and data.</td>
</tr>
<tr>
<td>- Requires periodic testing and verification of the ability to restore from backups.</td>
</tr>
<tr>
<td>All WLAN users understand and are able to carry out their responsibilities under the backup plans.</td>
</tr>
<tr>
<td>Changes to IT hardware and software are planned, controlled and documented.</td>
</tr>
<tr>
<td>IT staff members follow procedures when issuing, changing and terminating users’ passwords, accounts and privileges:</td>
</tr>
<tr>
<td>- Unique user identification is required for all information system users, including third-party users.</td>
</tr>
<tr>
<td>- Default accounts and default passwords have been removed from systems.</td>
</tr>
<tr>
<td>Only necessary services are running on systems; all unnecessary services have been removed.</td>
</tr>
</tbody>
</table>

*Table 12-7: Information technology security system and WLAN management*
## WLAN SECURITY SYSTEM ADMINISTRATION AND TOOLS

New security tools, procedures and mechanisms regarding WLANs are routinely reviewed for applicability in meeting the University’s security strategies.

Tools and mechanisms for secure system and WLAN administration are used, routinely reviewed and updated or replaced. Examples include:

- Data integrity checkers.
- Cryptographic tools.
- Vulnerability scanners.
- Password quality-checking tools.
- Virus scanners.
- Process management tools.
- Intrusion detection systems.
- Secure remote administrations.
- Network service tools.
- Traffic analysers.
- Incident response tools.
- Forensic tools for data analysis.

*Table 12-8: WLAN security system administration and tools*

## WLAN SECURITY MONITORING AND AUDITING

System and network monitoring and auditing tools are routinely used by the University.

- Activity is monitored by the IT staff.
- System and network activity is logged/recorded.
- Logs are reviewed on a regular basis.
- Unusual activity is dealt with according to the appropriate policy or procedure.
- Tools are periodically reviewed and updated.

Firewall and other security components are periodically audited for compliance with policy.

*Table 12-9: WLAN security monitoring and auditing*
### WLAN AUTHENTICATION AND AUTHORISATION

Appropriate access controls and user authentication (e.g., file permissions, network configuration) consistent with policy are used to restrict user access to:

- Information.
- Systems utilities.
- Program source code.
- Sensitive systems.
- Specific applications and services.
- WLAN connections within the University.
- WLAN connections from outside the University.

Access control methods/mechanisms restrict access to resources according to the access rights determined by policies and procedures.

Access control methods/mechanisms are periodically reviewed and verified.

Methods or mechanisms are provided to ensure that sensitive information has not been accessed, altered or destroyed in an unauthorised manner.

Authentication mechanisms are used to protect the availability, integrity and confidentiality of sensitive information.

User authentication such as biometrics, smart cards, two-factor authentication and Public Key Infrastructure (PKI) is deployed. Biometrics can prove a user’s identity before the user connects to the WLAN. PKI can ensure the integrity of the wireless transmission and ascertain who sent the message.

User authentication mechanisms for the management interfaces of the AP is enabled.

Auditing technology to analyse the records produced by RADIUS for suspicious activity is deployed.

Other forms of authentication for the wireless network such as 802.1x for port-based authentication and key distribution via an external authentication server such as RADIUS and Kerberos are considered. Kerberos is used to identify the identity of network users.

Enable utilisation of key-mapping keys (802.1x) rather than default keys so that sessions use distinct WEP keys.

| Table 12-10: WLAN authentication and authorisation |
### WLAN SECURITY: ENCRYPTION

Appropriate security controls are used to protect sensitive information while in storage and during transmission, including:

- Data encryption during transmission.
- Data encryption when writing to disk.
- Use of public key infrastructure.
- Virtual private network technology.
- Encryption for all Internet-based transmission.

Encrypted protocols are used when remotely managing systems, routers and firewalls.

Encryption controls and protocols are routinely reviewed, verified and revised.

All security features of the WLAN product, including the cryptographic authentication and WEP privacy features are enabled. Use WEP for minimal protection when using legacy devices.

Ensure that the encryption key sizes are at least 128-bits or as large as possible.

Ensure that the encryption being used is sufficient given the sensitivity of the data on the network and the processor speeds of the computers.

AP management traffic security is enhanced by using SNMPv3 or equivalent cryptographically protected protocol.

An 802.11 security product that offers other security features such as enhanced cryptographic protection or user authorisation features is deployed.

Use TKIP to prevent key-scheduling attacks.

Use WPA with TKIP as a secure means for encrypting the WLAN. TKIP can provide message integrity verification.

Use 802.11i with AES for the most robust form of protection if it is available on the AP.

| Table 12-11: WLAN security: Encryption |

### WLAN SECURITY ARCHITECTURE AND DESIGN

System architecture and design for new and revised systems include consideration of:

- Security strategies, policies and procedures.
- History of security compromises.
- Results of security risk assessments.

The University has up-to-date diagrams that show the WLAN architecture and network topology.

| Table 12-12: WLAN security architecture and design |
**WLAN SECURITY INCIDENT MANAGEMENT**

Documented procedures exist for identifying, reporting and responding to suspected security incidents and violations, including:

- WLANs-based incidents.
- Social engineering incidents.

Incident management procedures are periodically tested, verified and updated.

There are documented policies and procedures for working with law-enforcement agencies.

*Table 12-13: WLAN security: Incident management*

**STAFF SECURITY**

**GENERAL STAFF PRACTICES**

All WLAN users follow good security practice, such as:

- Securing information for which they are responsible.
- Not divulging sensitive information to others (resistance to social engineering).
- Having adequate ability to use information technology hardware and software.
- Using good password practices.
- Understanding and following security policies and regulations.
- Recognising and reporting incidents.

All staff at all levels of responsibility implement their assigned roles and responsibility for information security.

There are documented procedures for authorising and overseeing all personnel (including individuals from third-party universities) who work with sensitive information or who work in locations where the information resides. This includes:

- Employees
- Contractors, partners, collaborators and personnel from third-party universities.
- Systems maintenance personnel.
- Facilities maintenance personnel.

*Table 12-14: General staff practices*
## TECHNICAL AND OPERATIONAL RECOMMENDATIONS

<table>
<thead>
<tr>
<th>Recommendation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Empirically test AP range boundaries to determine the precise extent of the wireless coverage.</td>
</tr>
<tr>
<td>Make sure that APs are turned off when they are not used (e.g. after hours and on weekends).</td>
</tr>
<tr>
<td>Make sure that the reset function on APs is used only when needed and is only invoked by an authorised group of people.</td>
</tr>
<tr>
<td>Restore the APs to the latest security settings when the reset functions are used.</td>
</tr>
<tr>
<td>Place APs in secured areas to prevent unauthorised physical access and user manipulation. Mount APs out of reach and out of plain view. Bolt them down securely in locked steel enclosures.</td>
</tr>
<tr>
<td>Ensure that AP channels are at least five channels removed from any other nearby wireless networks to prevent interference.</td>
</tr>
<tr>
<td>When disposing of access points that will no longer be used by the agency, clear access point configuration to prevent disclosure of network configuration, keys, passwords, etc.</td>
</tr>
<tr>
<td>Disable all insecure and nonessential management protocols on the APs.</td>
</tr>
<tr>
<td>Change the default SSID in the APs.</td>
</tr>
<tr>
<td>Disable the broadcast SSID feature, so that the client SSID must match that of the AP.</td>
</tr>
<tr>
<td>Validate that the SSID character string does not reflect the agency’s name (division, department, street, etc.) or products.</td>
</tr>
<tr>
<td>Ensure that all APs have strong administrative passwords and that the passwords are changed regularly.</td>
</tr>
<tr>
<td>If the access point supports logging, turn it on and review the logs on a regular basis. This can be used to determine tracking of user activities and misuse detection.</td>
</tr>
<tr>
<td>Take a complete inventory of all APs and 802.11 wireless devices.</td>
</tr>
<tr>
<td>Locate APs on the interior of buildings instead of near exterior walls and windows as appropriate.</td>
</tr>
<tr>
<td>Ensure that the client NIC and AP support firmware upgrade so that security patches may be deployed as they become available (prior to purchase).</td>
</tr>
<tr>
<td>Configure SNMP settings on APs for least privilege (i.e., read only). Disable SNMP if it is not used. SNMPv1 and SNMPv2 are not recommended.</td>
</tr>
<tr>
<td>Use a local serial port interface for AP configuration to minimise the exposure of</td>
</tr>
</tbody>
</table>
### TECHNICAL AND OPERATIONAL RECOMMENDATIONS

<table>
<thead>
<tr>
<th>Sensitive management information.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Understand and make sure that all default parameters are changed.</td>
</tr>
<tr>
<td>Make sure that default shared keys are periodically replaced by more secure unique keys.</td>
</tr>
<tr>
<td>Install a properly configured firewall between the wired infrastructure and the wireless network (AP or hub to APs).</td>
</tr>
<tr>
<td>Install antivirus software for all wireless clients. Ensure that the antivirus software is regularly updated with new virus definitions.</td>
</tr>
<tr>
<td>Install personal firewall software for all wireless clients.</td>
</tr>
<tr>
<td>Disable file sharing for wireless clients (especially in suspect environments).</td>
</tr>
<tr>
<td>Deploy MAC access control lists.</td>
</tr>
<tr>
<td>Consider installation of Layer 2 switches in lieu of hubs for AP connectivity.</td>
</tr>
<tr>
<td>Deploy IPsec-based Virtual Private Network (VPN) technology for wireless communications.</td>
</tr>
<tr>
<td>Fully test and deploy software patches and upgrades regularly.</td>
</tr>
<tr>
<td>Ensure that external boundary protection is in place around the perimeter of the building or buildings of the agency.</td>
</tr>
<tr>
<td>Ensure that the “ad hoc mode” for 802.11 has been disabled.</td>
</tr>
<tr>
<td>Use static IP addressing on the network.</td>
</tr>
<tr>
<td>Disable DHCP.</td>
</tr>
<tr>
<td>Ensure that management traffic destined for APs is on a dedicated wired subnet.</td>
</tr>
<tr>
<td>Use SNMPv3 and/or SSL/TLS for Web-based management of APs.</td>
</tr>
<tr>
<td>Ensure that the client NIC and AP support firmware upgrade so that security patches may be deployed as they become available (prior to purchase).</td>
</tr>
<tr>
<td>Ensure that external boundary protection is in place around the perimeter of the building or buildings of the agency.</td>
</tr>
<tr>
<td>Deploy intrusion detection agents on the wireless part of the network to detect suspicious behaviour or unauthorised access and activity.</td>
</tr>
<tr>
<td>Fully comprehend the magnitude of deploying any security feature or product prior to deployment.</td>
</tr>
<tr>
<td>Designate an individual to track the progress of 802.11 security products and standards (IETF, IEEE, etc.) and the threats and vulnerabilities with the technology.</td>
</tr>
</tbody>
</table>
WAIT UNTIL FUTURE RELEASES OF 802.11 WLAN TECHNOLOGIES INCORPORATE FIXES TO THE SECURITY FEATURES OR PROVIDE ENHANCED SECURITY FEATURES.

Table 12-15: Technical and operational recommendations
13. APPENDIX E: DEVELOPMENT OF THE OODA-OCTAVE RISK ANALYSIS AND RISK MANAGEMENT DATABASE

The aim of this appendix is to illustrate the logical development of the OODA-OCTAVE risk analysis and risk management database. The database was developed in Microsoft Access 2003 as shown in figure 13.1.

![Entity-Relationship diagram](image)

*Figure 13-1: The Entity-Relationship diagram as shown in Microsoft Access 2003*

The accompanying CD contains the OODA-OCTAVE database. The interested reader can view the contents of this CD for the design of the tables, queries, forms and reports.
14. REFERENCES


References


References


References


