Copyright is owned by the Author of the thesis. Permission is given for a copy to be downloaded by an individual for the purpose of research and private study only. The thesis may not be reproduced elsewhere without the permission of the Author.
Strategies for Resolving Security and Interference Issues in 802.11 Wireless Computer Networking

A thesis presented in partial fulfilment of the requirements for the degree of

Masters of Engineering
in
Computer Systems Engineering

At Massey University, Palmerston North,
New Zealand.

Gladwin Mendez
2006

Supervisors:
G.A.Punchihewa
Dr Liyanage De Silva
ABSTRACT

This thesis presents the outcomes of the research and development of strategies to improve 802.11 wireless networking security, reduce interference, and investigation into the trends of home users in the city limits of Palmerston North, New Zealand. The main contributions of the research are several types of improvement strategies that reduce interference, add additional layers of security to 802.11, and reports on wireless trends.

The thesis begins with an overview of the current 802.11 security protocols and related issues. The current state of the 802.11 security is presented along with an assessment of efficacy of 802.11. Lastly, the motivations for improving security and reducing interference are explained.

The main improvement presented within the thesis is that of client filtering. The operation of filtering is explained. Using methods from other filtering protocols it's shown that how an additional layer of security can be added to 802.11.

Following this, more improvements are shown that can be used with or without client filtering. The use of smart aerials, wizards and frequency selective materials is discussed and the advantages and disadvantages of each are highlighted, as well as the aspects and issues of implementing the strategies on a home personal computer based platform are presented.

This is followed by a description of the experiments conducted into attenuation and direction sensing. The results of the experiments are presented along with the discussion. Finally, conclusions about the improvements are detailed and the results shown, in addition to research conducted on the trends of 802.11 users to further highlight the need for this research.
Acknowledgements

Firstly, I would like to thank my supervisor and co-supervisors - Amal Punchihewa and Liyanage De Silva.

Secondly I would like to thank Stan Swan from Massey University at Wellington, who has given me his guidance throughout, his insights and comments have been invaluable. Without him this thesis and the research that it concludes would have been impossible.

In addition I would like my family and my friends. Without their support and their vigilance I would not have made it through the year. Thank you for everything.
# ABSTRACT


# ACKNOWLEDGEMENTS


# LIST OF FIGURES


# LIST OF TABLES


# INTRODUCTION

1.1 Background

1.2 Contents of THE Thesis

# ISSUES RELATED TO THE RESEARCH

2.1 Interference
  2.1.1 Microwave Technology
  2.1.2 Bluetooth Technology
  2.1.3 802.11 devices
  2.1.4 Digital cordless phones

2.2 SIGNAL Attenuation
  2.2.1 Theory of attenuation
  2.2.2 Research and experimentation
  2.2.3 Setup
  2.2.4 Results
    2.2.4.1 Polarisation Readings
    2.2.4.2 Interference Readings
    2.2.4.3 Base Readings
      2.2.4.4.1 Brick 1 metre
      2.2.4.4.2 Brick 2.5 meters
      2.2.4.4.3 Brick 5 meters
      2.2.4.4.4 Distance attenuation comparison
    2.2.4.5 Wood
      2.2.4.5.1 Wood 1 metre
      2.2.4.5.2 Wood 2.5 meters
      2.2.4.5.3 Wood 5 meters
      2.2.4.5.4 Distance attenuation comparison
2.2.4.6 Old weatherboard ................................................................. 44
  2.2.4.6.1 Weatherboard 1 metre ................................. 44
  2.2.4.6.2 Weatherboard 2.5 meters ............................... 46
  2.2.4.6.3 Weatherboard 5 meters ..................................... 48
  2.2.4.6.4 Distance attenuation comparison .................. 50
2.2.4.7 Modern weatherboard .................................................... 51
  2.2.4.7.1 Weatherboard at 1 metre .................................. 51
  2.2.4.7.2 Weatherboard at 2.5 meters ............................ 53
  2.2.4.7.2 Weatherboard at 5 meters ............................ 55
  2.2.4.7.4 Distance attenuation comparison .................. 57
2.2.4.8 Findings ......................................................................... 58
2.3 Security Protocols and Issues ............................................. 59
  2.3.1 Wireless Equivalent Privacy ......................................... 60
    2.3.1.1 Issues .................................................................... 61
    2.3.1.2 Improvements .................................................... 63
  2.3.2 Wi-Fi Protected Access ................................................. 64
    2.3.2.1 Issues .................................................................... 64
    2.3.2.2 Improvements .................................................... 65
  2.3.3 Service Set Identifier Broadcast ............................... 66
    2.3.3.1 Common Issues .................................................. 66
  2.3.4 MAC address filtering ................................................. 67
    2.3.4.1 Issues .................................................................... 67
  2.3.5 SecureEasySetup(TM) .................................................. 68
    2.3.5.1 Issues .................................................................... 69
  2.3.6 802.11i ....................................................................... 70
    2.3.6.1 Wi-Fi Protected Access 2 ................................... 70
    2.3.6.2 Robust Security Network ..................................... 70
  2.3.7 Supplemental Methods .................................................... 71
3 TYPES OF ATTACKS ................................................................. 75
  3.1 Passive ............................................................................. 75
  3.2 Active .............................................................................. 76
    3.2.1 RPC Active Attack .................................................. 77
  3.3 Man-in-the-middle ............................................................. 79
4 SECURITY AND INTERFERENCE RESEARCH ......................... 81
4.1 Research of wireless user trends in 2004 ................................................................. 81
  4.1.1 Methods and resources ................................................................................. 81
  4.1.2 Findings of 2004 Research of wireless user trends ...................................... 84
  4.1.3 GIS Imagery ............................................................................................. 89

4.2 Research of wireless user trends in 2005 .............................................................. 95
  4.2.1 Methods and resources ................................................................................. 95
  4.2.2 Findings of 2005 research of wireless user trends ........................................ 98
  4.2.3 GIS Imagery .................................................................................................. 99

5 PROBLEM RESOLUTION ....................................................................................... 133

  5.1 Smart aerials .................................................................................................... 133
    5.1.1 Issues ........................................................................................................ 134

  5.2 Power stepping ................................................................................................. 134
    5.2.1 Issues ........................................................................................................ 135

  5.3 Frequency Selective Surfaces ........................................................................ 135
    5.3.1 Issues ........................................................................................................ 135

  5.4 Time Usage ...................................................................................................... 136
    5.4.1 Issues ........................................................................................................ 136

  5.5 Detection of Attackers .................................................................................... 137
    5.5.1 Issues ........................................................................................................ 137

  5.6 Filtering ............................................................................................................ 137
    5.6.1 Issues ........................................................................................................ 139

  5.6 Setup Wizards .................................................................................................. 139
    5.6.2 Issues ........................................................................................................ 141

  5.7 Solution ............................................................................................................ 141
    5.7.1 Experimentation ...................................................................................... 143

6 CONCLUSIONS ..................................................................................................... 147

7 PUBLICATIONS BY THE AUTHOR .................................................................. 151

8 REFERENCES ....................................................................................................... 152
LIST OF FIGURES

Figure 2.1: Location of centre burst frequency in relation to 802.11 channels .................. 15
Figure 2.2: Effect of microwave interference on an 802.11 signal ................................ 15
Figure 2.3: Frequency usage of 802.11 and Bluetooth .................................................. 16
Figure 2.4: Dimensions of rudimentary cage ................................................................. 20
Figure 2.5: Experimental layout ..................................................................................... 21
Figure 2.6: Free Space Loss over distance for 2.4 GHz signals ........................................ 21
Figure 2.7: Anritsu Portable Spectrum Analyser used ..................................................... 22
Figure 2.8: Frequency allocation of 2.4 GHz channels .................................................... 23
Figure 2.9: Experimental setup ....................................................................................... 24
Figure 2.10: Initial measurement taken looking for anomalous readings ....................... 25
Figure 2.11: Base reading ............................................................................................... 25
Figure 2.12: Vertical Polarization Readings ................................................................... 26
Figure 2.13: 5m vertical polarization interference ........................................................... 27
Figure 2.14: 5m interference with weatherboard ............................................................. 28
Figure 2.15: Averaged and smoothed graphs of signal measurements at 1, 2.5 and 5 meters .... 29
Figure 2.16: Measurements taken for brick at 1 metre .................................................. 30
Figure 2.17: Averaged and smoothed signal through Brick at 1 metre ........................... 31
Figure 2.18: Calculated attenuation/signal drop through brick at 1 metre ................. 31
Figure 2.19: Measurements taken for brick at 2.5 meters ............................................. 32
Figure 2.20: Averaged and smoothed signal through Brick at 2.5 meters ................... 32
Figure 2.21: Calculated attenuation/signal drop through brick at 2.5 meters ............ 33
Figure 2.22: Measurements taken for brick at 5 meters .............................................. 34
Figure 2.23: Averaged and smoothed signal through Brick at 5 meters ..................... 35
Figure 2.24: Calculated attenuation/signal drop through brick at 5 meters ............... 35
Figure 2.25: Measured signal at different distances ..................................................... 36
Figure 2.26: Measurements taken for wood at 1 metre ................................................ 37
Figure 2.27: Averaged and smoothed signal through Wood at 1 metre ...................... 38
Figure 2.28: Calculated attenuation/signal drop through Wood at 1 metre ........... 38
Figure 2.29: Measurements taken for wood at 2.5 meters ......................................... 39
Figure 2.30: Averaged and smoothed signal through Wood at 2.5 meters ................ 40
Figure 2.31: Calculated attenuation/signal drop through Wood at 2.5 meters ........... 40
Figure 2.32: Measurements taken for wood at 5 meters ............................................. 41
Figure 2.33: Averaged and smoothed signal through Wood at 5 meters ................... 42
Figure 2.34: Calculated attenuation/signal drop through wood at 5 meters .............. 42
Figure 2.35: Measured signal at different distances ..................................................... 43
Figure 2.36: Measurements taken for weatherboard at 1 metre ............................ 44
Figure 4.44: Distribution of channel 11 Co-channel interference ............................................. 129
Figure 4.45: Channel 11 wireless density .............................................................................. 130
Figure 4.46: Channel 11 conflict potentials ......................................................................... 131
Figure 5.1: Power stepping option in a modified Linksys WRT54g ...................................... 135
Figure 5.2: Time usage access restrictions .......................................................................... 136
Figure 5.3: SNR measurements taken in a home environment over 40 mins ...................... 138
Figure 5.4: Authentication process ....................................................................................... 138
Figure 5.5: Illustrating the scenario in practice ...................................................................... 139
Figure 5.6: An example of a possible signal adjusting wizard ............................................. 140
Figure 5.7: Factors involved in calculation SOM .................................................................... 140
Figure 5.8: Illustrating the scenario in practice ..................................................................... 142
Figure 5.9: Authentication process for directional and signal filtering .................................. 142
Figure 5.10: Physical dimension of the pentenna ................................................................. 143
Figure 5.11: Setup in parking lot ......................................................................................... 144
Figure 5.12: View from above pentenna .............................................................................. 144
Figure 5.13: Measurement setup .......................................................................................... 145
Figure 5.14: The near radiation pattern of the pentenna enclosure ..................................... 145
Figure 5.15: The far radiation pattern of the pentenna enclosure ......................................... 146
Figure 5.16: Measurement of directional and SNR information .......................................... 147
Figure 6.1: Wireless security and interference strategies ...................................................... 149
LIST OF TABLES

Table 2.1: Illustrating the different 802.11 standards .............................................................. 17
Table 2.2: Attenuation through different materials................................................................. 19
Table 2.3: Country 802.11b/g Channel use ........................................................................ 23
Table 2.4: Comparing Theoretical and Measured Actual Attenuation ........................................ 29
Table 2.5: Comparison of Attenuation values ....................................................................... 58
Table 2.6: Illustrating negligible performance drop using WEP ........................................... 62
Table 4.1: Channel distribution of WLAN's in Palmerston North ........................................... 102
Table 4.2: WLAN's detected per district ............................................................................... 108
Table 4.3: Commercial units, residential and income values per district ......................... 110
Table 4.4: Education effect on WLAN numbers .................................................................... 114
Table 4.5: Encryption usage according to district ................................................................. 118
Table 5.1: Additional authentication fields added to increase security ............................... 138
Table 5.2: Additional authentication fields added to increase security ............................... 141
1 INTRODUCTION

The introduction to this thesis covers both the literature survey, and the background information, beginning with the general background and scope of the research. Then the remaining introduction is divided into three separate and distinct chapters following the overall introduction that provide a more detailed look at the facts of wireless networks.

The first of these covers current security protocols and interference sources that affect 802.11 wireless networks or Wireless Local Area Networks (WLAN), descriptions and their flaws and issues. Secondly, 802.11 security and interference issues are analysed to find where and why it needs attention, and thirdly a summary of the types of wireless attacks that can be used against 802.11 networks.

1.1 BACKGROUND

The initial intention for this research was nurtured in the last year of my undergraduate course. Having just successfully having completed a 4th year project on extending wireless computer networks, the security issues that were found during the research sparked my interest.

The most interesting part of the research was the fact that due to the ease of use and plummeting price of wireless hardware there was now a large take up of wireless by home users. The biggest issue that was found was the small percentage of people who had enabled some sort of security measures on their network.

There are millions of wireless networks have been created across the globe, and the number are increasing drastically everyday. While originally wireless was only obtainable for companies who could afford the hardware, wireless is now standard with most home consumer laptops. They exist to improve free up users from wires and truly mobilise users and make setup of home networks easier, cheaper and less obtrusive.

However, while it is easy to setup a wireless network, the setup and wizards to setup wireless security easily are still lacking. In addition the ramifications of not setting up any security are not properly stated by hardware manufacturers. Most home security protocols are vulnerable and can be cracked given the time. The uptake of wireless devices is also causing issues with co-channel interference. This research was initially started to come up with several strategies that could be used in wireless communications to improve security and reduce interference. Once the strategies were formulated, it was hoped that improvements could be found that would improve the situation and provide a better and more secure service to the users of WLANs. All the
improvements are part of an ongoing push for better quality service, better security and greater efficiency.

1.2 CONTENTS OF THE THESIS

Firstly, an overview of the current state of 802.11 home wireless security protocols and sources of interference, as well as descriptions of the various issues associated with each type. This will encompass the 802.11a, 802.11b and 802.11g standards.

After this, the types of attacks are discussed and then the need for reducing interference and improving security is outlined. This includes research done on wireless interference and security trends within the city limits of Palmerston North. Wireless usage trends according to districts, income, education and commercial numbers. The security results are compared with worldwide values to ascertain whether the city follows international trends.

Then the improvements targeted in this research are introduced as mechanisms to significantly reduce ability of attackers from infiltrating a network, and thus improve security and reducing interference. Three chapters are dedicated to filtering, with the first detailing the two types of aggregation and their respective operation, as well as how filtering will improve security and reduce interference. This is followed by a chapter dealing with another development to deal with security and interference. The third chapter outlines additional steps and education of end users.

The design and details of testing environment for the assessment of the proof of concept is described. This is followed discussion of the results of the experiments.

The conclusions are made against the objectives of the research presented by the thesis, and about the outcome.