

**VARIATIONAL BAYESIAN HIDDEN MARKOV MODEL FOR THE PREDICTION OF
DISTRIBUTED DENIAL OF SERVICE ATTACKS**

By

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CERTIFICATION

School of Postgraduate Studies, University of Lagos.

This is to certify that the thesis entitled

**VARIATIONAL BAYESIAN HIDDEN MARKOV MODEL FOR THE PREDICTION OF
DISTRIBUTED DENIAL OF SERVICE ATTACK**

Submitted to the School of Postgraduate Studies, University of Lagos for the award of the degree of Doctor of Philosophy (Ph.D.) in Computer Science is a record of original research carried out by:

AFOLORUNSO ADENRELE ABOLANLE

in the Department of Computer Sciences

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DEDICATION

This thesis is, on one hand, dedicated to the evergreen memories of my parents, Alhaji Alli Folorunso Musari (a.k.a. Agbomola) and Mrs. Sarat Anike Adesola Musari (a.k.a. Iye-Sikira), who together laid a good and solid foundation for this achievement; may Almighty Allah grant them Aljanah Fridaous; and on the other to the selfless and awesome angels that we came from the same loin and sucked the same breasts in persons of Mrs. Serifat Adebukunola Alebiosu, Alhaja Sidikat Olasunkanmi Adesanya, Mrs. Taibat Ibiyemi Yusuf, Mrs. Silifat Olayemi Oyelana, Alhaji Muritala Adekoya Alli (a.k.a. Royal Father), Mr. Azeez Obafemi Afolorunso and lastly, but in no way the least, Mrs. Olufunmilola Olaleye Oyesola, who are forever there to support and buy into every of my dreams, no matter how whimsical.

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ABSTRACT

Global interconnectivity of systems has left inter-networked systems vulnerable to various forms of complex attacks. Researchers continue to work on new ways, which includes proactive ones of securing such systems, in order to eradicate or minimise security threats. One of such attempts is network attack prediction systems. Distributed Denial of Service (DDoS) attack is a class of network attack that can span several continents. It floods the computer network with heavy loads of unwanted packets and requests that weigh down the system resources such as memory and processors. Hidden Markov model (HMM) is one of the models that can be used to predict and detect such attacks. Issues associated with the use of HMM are determination of the hidden and observable states and subsequently, the model parameters estimation since the performance of the model depends on the accurate selection of these parameters. Related issue is the need to overcome long training time of the traditional HMM algorithm especially during model construction as well as ensuring that the learning algorithm does not converge to a local maximum. This study presents a novel parsimonious HMM-based model in which the entropy-based values of the network traffic features and the Distributed Denial of Service (DDoS) attack phases form the observable and the hidden states of the model, respectively. Entropy and *K*-Means clustering were deployed respectively to determine the observable and hidden states that characterise the HMM. In order to improve computational efficiency of the algorithm for estimating the parameters of the model, Kullback-Liebler Divergence (KLD) method was employed for reducing and selecting appropriate parameters to achieve a good prediction model. Variational Bayesian Inference (VBI) was employed in optimising the HMM. The performance of the model was evaluated through experiments using DARPA 2000 Intrusion Specific dataset, DARPA 1999 dataset and CAIDA 2007 simulated real time DDoS attack data. The experimental results when compared with an existing work, where Markov Chain was used, show that the model gives faster and higher prediction accuracy for predicting DDoS attack. Specifically, the prediction accuracy, false positive rate and false negative rate show 10%, 11% and 9% improvement, respectively while the computational time was reduced by 42%.

Keywords: DDoS, Network intrusion, Variational Bayesian inference, Hidden Markov model, Kullback-Liebler divergence.

TABLE OF CONTENTS

| | |
|--|-----|
| TITLE | i |
| AUTHOR'S STATEMENT | ii |
| CERTIFICATION | iii |
| DEDICATION | iv |
| ACKNOWLEDGEMENT | v |
| ABSTRACT | ix |
| LIST OF FIGURES | xiv |
| LIST OF TABLES | xv |
| LIST OF ALGORITHMS | xvi |
| | |
| CHAPTER ONE: INTRODUCTION | |
| 1.1 Background to the Study | 1 |
| 1.2 Network Attacks and Network Security | 1 |
| 1.2.1 Network Attacks | 1 |
| 1.2.2 Network Security | 4 |
| 1.3 Intrusion Detection, Prevention and Prediction Systems | 6 |
| 1.3.1 Intrusion Detection Systems (IDS) | 6 |
| 1.3.1.1 Classification of Intrusion Detection Systems | 7 |
| 1.3.2 Intrusion Prevention Systems (IPS) | 10 |
| 1.3.3 Intrusion Forecasting Systems (IFS) and Intrusion Prediction System (IPrS) | 11 |
| 1.3.3.1 Techniques for IFS and IPrS | 12 |
| 1.3.3.1.1 Machine learning | 12 |
| 1.3.4 Nature of Distributed Denial of Service (DDoS) Attack | 14 |

| | | |
|-------|------------------------------------|----|
| 1.4 | Statement of the Problem | 15 |
| 1.5 | Aim and Objectives of the Study | 16 |
| 1.5.1 | Aim of the Study | 16 |
| 1.5.2 | Objectives of the Study | 17 |
| 1.6 | Scope and Limitation of the Study | 17 |
| 1.7 | Significance of the Study | 17 |
| 1.8 | Operational Definition of Terms | 18 |
| 1.9 | List of Abbreviations and Acronyms | 21 |

CHAPTER TWO: LITERATURE REVIEW

| | | |
|-----------|---|----|
| 2.1 | Distributed Denial of Service (DDoS) Attack | 24 |
| 2.2 | Review of Existing Work on Intrusion Prediction Systems | 26 |
| 2.2.1 | Summary of the Review of Existing Works on Intrusion Prediction Systems | 33 |
| 2.3 | Review of Existing Work on DDoS Prediction Systems | 35 |
| 2.3.1 | Summary of the Review of Existing Works on DDoS Prediction Systems | 38 |
| 2.4 | Theories and Concepts Used in the Study | 40 |
| 2.4.1 | Entropy | 41 |
| 2.4.2 | Clustering | 42 |
| 2.4.2.1 | <i>K</i> -Means Clustering | 43 |
| 2.4.3 | Kullback-Liebler Divergence (KLD)/Relative Entropy | 44 |
| 2.4.4 | Hidden Markov Models (HMMs) | 47 |
| 2.4.4.1 | Components of HMM | 47 |
| 2.4.4.2 | HMM-Based Prediction Model | 49 |
| 2.4.4.2.1 | Likelihood Computation - Forward Algorithm | 50 |
| 2.4.4.2.2 | Decoding - The Viterbi Algorithm | 50 |

| | | |
|--|---|----|
| 2.4.4.2.3 | HMM Training: The Baum-Welch Algorithm | 51 |
| 2.4.5 | Variational Bayesian Inference (VBI) | 53 |
| 2.4.5.1 | Choice of Distributions | 55 |
| CHAPTER THREE: RESEARCH METHODOLOGY | | |
| 3.1 | The Model Design | 56 |
| 3.2 | HMM Construction | 58 |
| 3.2.1 | Experimental Datasets Description | 58 |
| 3.2.1.1 | Training Data - DARPA 2000 Intrusion Scenario Specific Datasets | 58 |
| 3.2.1.2 | Test Data I - 1999 DARPA Intrusion Detection Evaluation Dataset | 59 |
| 3.2.1.3 | Test Data II - Center for Applied Internet Data Analysis (CAIDA) 2007 DDoS Attack Dataset | 60 |
| 3.2.2 | Defining the Network States | 61 |
| 3.2.2.1 | Algorithm 1 | 61 |
| 3.2.3 | Determining Model Parameters | 62 |
| 3.2.3.1 | Algorithm 2 | 62 |
| 3.2.4 | HMM Formulation, Training and Testing | 64 |
| 3.2.4.1 | Algorithm 3 | 65 |
| 3.2.4.2 | Algorithm 4 | 66 |
| 3.3 | Reduction of the Observable States Space of the Model | 67 |
| 3.3.1 | Algorithm 5 | 67 |
| 3.4 | VBI-HMM Formulation | 68 |
| 3.4.1 | Algorithm 6 | 68 |
| 3.5 | Evaluation Metrics | 71 |

CHAPTER FOUR: RESULTS AND DISCUSSION

| | | |
|-------|---|----|
| 4.1 | Implementation Platform | 74 |
| 4.2 | Results and Discussion of the Prediction Models | 74 |
| 4.2.1 | HMM Formulation | 74 |
| 4.2.2 | HMM Parameter Space Reduction (KLD-HMM Formulation) | 81 |
| 4.2.3 | VBI-HMM for DDoS Attacks Prediction | 86 |
| 4.3 | Benchmarking of Experimental Results | 88 |
| 4.3.1 | Comparison with <i>APAN</i> (Shin <i>et al.</i> , 2013) | 88 |

CHAPTER FIVE: SUMMARY OF FINDINGS, CONTRIBUTIONS TO KNOWLEDGE CONCLUSION AND POSSIBLE EXTENSIONS

| | | |
|-----|----------------------------|----|
| 5.1 | Summary of Findings | 92 |
| 5.2 | Conclusion | 93 |
| 5.3 | Contributions to Knowledge | 94 |
| 5.4 | Possible Extension | 94 |

| | |
|-------------------|-----------|
| REFERENCES | 96 |
|-------------------|-----------|

| | |
|--|------------|
| APPENDIX A: Experimental Datasets | 106 |
|--|------------|

| | |
|--|------------|
| APPENDIX B: Approval Email To Use CAIDA 2007 DDoS Dataset | 113 |
|--|------------|

| | |
|------------------------------------|------------|
| APPENDIX C: Program Listing | 115 |
|------------------------------------|------------|

LIST OF FIGURES

| Figure | | Page |
|---------------|---|-------------|
| 1 | IDS components | 7 |
| 2 | General architecture of DDoS attack | 26 |
| 3 | Clustering Example | 42 |
| 4 | General Structure of an HMM | 48 |
| 5 | The Flowchart of the Model Architecture | 57 |
| 6 | Hidden Markov Models states for prediction | 79 |
| 7 | Relative entropy distribution of the observable state space | 82 |
| 8 | Convergence Rate of the Loglikelihood of the HMM and KLD-HMM | 83 |
| 9 | Convergence Rate of the Emission Probabilities of the HMM and KLD-HMM | 84 |
| 10 | Convergence Rate of the Transition Probabilities of the HMM and KLD-HMM | 84 |
| 11 | Frequency distribution per state of the two models | 85 |
| 12 | ROC curve of the performance of the HMM and KLD-HMM | 86 |
| 13 | ROC curve of the performance of the HMM, KLD-HMM and VBI-HMM | 87 |
| 14 | ROC curve of the performance of all the models | 88 |
| 15 | Computational time of the Models | 90 |
| 16 | Confusion matrix Comparison of the Models | 90 |
| 17 | Prediction Accuracy of the Models | 91 |

LIST OF TABLES

| Table | | Page |
|--------------|--|-------------|
| 1 | Summary of Existing Works on Intrusion Prediction Systems | 33 |
| 2 | Summary of Existing Works on on DDoS Prediction Systems | 38 |
| 3 | Confusion Matrix | 72 |
| 4 | Sample of Source IP and Destination IP Probabilities | 75 |
| 5 | Occurrence Rate of Packet Type and Packet Length | 76 |
| 6 | Sample Probabilities of Source Port and Destination Port | 77 |
| 7 | Network Features Average for each phase of the DDoS Attack | 78 |
| 8 | Relative Performance Analysis of Various Models | 81 |
| 9 | Confusion Matrices of the Models | 89 |
| 10 | Summary of Findings | 92 |

LIST OF ALGORITHMS

| Algorithm | | Page |
|------------------|---|-------------|
| 1 | Calculating Normalised Entropy | 61 |
| 2 | Clustering Algorithm | 62 |
| 3 | Baum-Welch Algorithm For Training The HMM | 65 |
| 4 | Viterbi Algorithm For Prediction | 66 |
| 5 | Kullback-Liebler Divergence For Reducing Observable State Space | 67 |
| 6 | Variation Bayesian Inference Algorithm | 68 |