Wireless Intrusion Detection System

Using

FingerPrinting

Manish Sachdev

Department of Computer Science and Engineering
National Institute of Technology Rourkela
Rourkela-769008, Odisha, India
May 2014

Wireless Intrusion Detection System Using FingerPrinting

Thesis submitted in partial fulfillment of the requirements for the degree of

Master of Technology

in

Computer Science and Engineering

(Specialization: Information Security)

by

Manish Sachdev

(Roll No.- 212CS2367)

under the supervision of

Prof. S. K. Jena

Department of Computer Science and Engineering
National Institute of Technology Rourkela
Rourkela, Odisha, 769 008, India

MAY 2014

Department of Computer Science and Engineering
National Institute of Technology Rourkela
Rourkela-769 008, Odisha, India.

Certificate

This is to certify that the work in the thesis entitled ***Wireless Intrusion Detection System using FingerPrinting*** by ***Manish Sachdev*** is a record of an original research work carried out by him under my supervision and guidance in partial fulfillment of the requirements for the award of the degree of Master of Technology with the specialization of Information Security in the department of Computer Science and Engineering, National Institute of Technology Rourkela. Neither this thesis nor any part of it has been submitted for any degree or academic award elsewhere.

Place: NIT Rourkela
Date: May 31, 2014

(Prof. S. K. Jena)
Professor, CSE Department
NIT Rourkela, Odisha

Author's Declaration

I hereby declare that all work contained in this report is my own work unless otherwise acknowledged. Also, all of my work has not been submitted for any academic degree. All sources of quoted information has been acknowledged by means of appropriate reference.

Place: NIT Rourkela
Date: May 31, 2014

(Manish Sachdev)
M.Tech, 212cs2367, CSE Department
NIT Rourkela, Odisha

Acknowledgment

Writing of thesis is a journey through gravel road, but you can make it with the help of the people and resources you get in touch through out your journey. I am thankful to all of these peers who have contributed towards shaping this thesis. First of all, I would like to express my sincere thanks to **Prof. S. K. Jena** for his observations and advice during my thesis work constantly encouraged me to establish the overall direction to the research and to move forward with investigation in depth. He has helped me greatly and been a source of knowledge and my road become straight and easier to go. I am also thankful to **all the professors** at the department for their support. I would also like to special thank to **Asish Dalai Sir**, PhD Scholar at NIT Rourkela, for their help and support to clear my hurdles and understanding. I would like to thank all my friends and lab-mates for their encouragement and understanding. Their help can never be penned with words. One of the most important acknowledgment is for the academic resources that I have got from NIT Rourkela. I would like to thank administrative and technical staff members of the Department who have been kind enough to advise and help in their respective roles. Last, but not the least, **I would like to dedicate this thesis to my Mom and Dad** for their love, patience, and understanding.

Manish Sachdev
Roll No-212CS2367

Abstract

Wireless network is the network which is easy to deploy and very easy to access that network and that network is user friendly. The main reason behind of getting popular is because it provide benefits, like as easy to installation, flexibility, mobility, scalability and reduced cost-of-ownership. But drawback in these wireless networks is that it doesn't provide security as much as required, due to that user faces attacks of various types which are damageable to user informations. One of the serious attack is Identity based attacks which steals the identity of some other user in that network and performed some other attack. The available present security tools to detect such these identity(spoofed MAC) based attacks are quite limited.

In this proposed work a new technique is developed for detecting masquerade(identity) attacks or spoofed MAC attack exploited in 802.11 wireless network. Current methods of device fingerprinting includes only probe request packets fingerprinting, which results in large amount of false positive. In our proposed work fingerprint is created on basis of three frames which are required in three section of connectivity phase and that frames are probe request frame, authentication frame and association frame. Time differences between consecutive frames are take into consideration and on the basis of that fingerprint is created of different device. In this proposed technique cross-correlation method is used to estimate the signals similarity in terms of time lagging to each other. Those signals are captured by different devices. Stored signature of actual device and captured signal of transmitting device is compared using this technique and after that result analysis, identification of device is done.

Keywords: Masquerade Attacks,Device FingerPrinting, Probe-request, authentication request and association request, cross-correlation.

Contents

List of Figures

List of Tables

Chapter 1

Introduction

Chapter 1

Introduction

Wireless LANs(local area network) are hard and difficult and hard to provide stronger security as compared to wired local area network(WLANs), main reason behind these weakness and possibility of attacks is the fact that, these network can be accessed by anyone because wireless signals may goes beyond the physical boundaries. It is not possible to stop the signal to go out of organization or specified boundaries .

Today IEEE 802.11 Wireless LAN(WLAN) [5] got so much popularity which makes it target for attacks and hackers broke the security for unauthorized access. IEEE 802.11 has certain weakness and vulnerabilities in design of MAC protocol which gives more power to hacker to do some big attacks on WLAN. [6]

There are some workstations available which work as a WLAN monitoring systems that observe the nature of network traffic and detect possible and likely attacks in real time. This nature of monitoring system contribute their part in security and robustness of WLAN networks.

There are some already present network-based intrusion detection system [7] [8] which works on IP layer or above and identify an attack that misuse the available weakness of the network and exploit that vulnerability. NIDS(network-based intrusion detection system) [7] [8] identifies the attack irrespective of transfer of packet either through wired network or wireless network. In present, attacks which are hard to detectable by presently available network-based intrusion detection systems are mostly due to weakness of data link-layer protocol vulnerabilities. Some internal properties of IEEE 802.11 WLAN gave a lot of security challenges kind of access of network resources and services after breaching the authorization, promiscuously sniffing of information traveling in that network off the air, identity attacks, denial of service attack, rogue access points, session hijacking attacks and ARP poisoning all are made easier after exploiting the vulnerabilities of data link-layer [9] [10] [11] . In all these attacks DoS(denial of service) or distributed DoS is the kind of attack to perform in which attacker tries to interrupt the availability of WLAN services to the client. These attacks are easy to performed because physical address(MAC address) of NIC(network interface controller) is very easy to make modification in it and that process is called spoofing of MAC address. These spoofing based attacks are specifically dangerous, because these attack hide the identity of actual user and give power to user to perform major attacks.

Today Many organizations by yourself use authentication on application layer, used only into organization campus as IDs and their passwords. Difficulty occur in this approach is that authenticate users credentials are not associated tightly to that client. Here is the case that there is possibility an authenticated user can give his/her ID and password to another user who may be not authenticate to the network and wants access to that network without authenticated ID and password. In the other cases the authenticated user may be cheated into disclosing his/her Id and password through phishing technique [12] [13] [37].

There are some more risk excluding above risks that there is notable important affect of authorized users,who bring unauthorized machines to bring the possibility of harm the network by introducing processes which further introduce malicious activity. [13]

The easily perceived solution is to give authentication assistance to each and every data frame together with control and management frames transmitted from source. Although IEEE 802.11i provide privacy and authentication standard to only data frames not for control and management frames. [6]

1.1 Wireless Networking Basics

The basic technologies of wireless network systems.

1.2 802.11 WLAN

A wireless local area network (WLAN) is a kind of data communication service providing technique in which that network can use either radio frequency technology or infrared technology to make transmission of information and also receiving information over the air. 802.11 standard was implemented and installed as the first Wireless LAN standard and it is based on technology which operates in frequency level of 2.4 GHz and it provides throughput maximum of 1Mbps to 2 Mbps. Today the most used deployment standard is IEEE standard 802.11b and it operates in the frequency range which is same as past 802.11 standards, but it provides speed of maximum of 11 Mbps. [3]

Table 1.1: 802.11 standard family [3]

Protocol	Frequency (GHz)	Typical throughput (Mbps)	Max. data rate (Mbps)	Modulation
802.11	2.4	0.9	2	IR/FHSS/DSSS
802.11a	5	23	54	OFDM
802.11b	2.4	4.3	11	DSSS
802.11g	2.4	19	54	OFDM
802.11n	2.4/5	74	600	OFDM
802.11y	3.7	23	54	OFDM

1.2.1 802.11 Protocol

IEEE 802.11 standard have two separate layers defined in its standard

1. LLC- Logical Link Control layer

2. MAC- Media Access Control layer

covered upto OSI model's Data Link Layer. 802.11 IEEE standard which is used for wireless network defines configurations and specifications for the layer MAC-media access control and for the layer below MAC, PHY-physical layer that is used for communication up to the LLC layer, as figure-1.1 shows that [14].

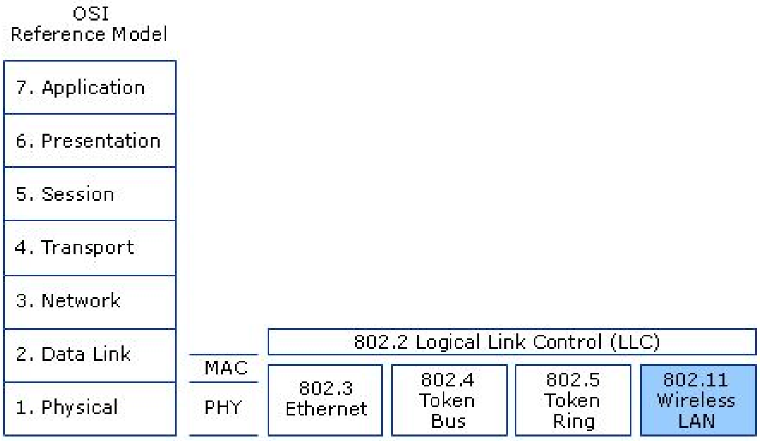


Figure 1.1: 802.11 and OSI Model

1.2.2 WLAN Components

Physical visible architecture of WLAN is somewhat simple and easy to manage. Primary components required in WLAN are Network Interface Cards (NICs) also known as client machine adapters and access points (APs) [3].

Access Points

Access Point (AP) is actually equal to a wireless LAN hub . It is a device that allows wireless devices connect to a wired network in a wireless manner also known as Wi-Fi using given standards. The AP normally connects through wired network to router as a standalone device, but it can also be an internal part of the router itself. An Access Point works within a specific provided frequency spectrum and modulation technique that uses the definite 802.11 standard. Main purpose and work of access point is tell the clients which are available of its presence and provide services to that client after authentication and association of that client to the network provided by that Access Point [3].

Network Interface Cards (NICs)

Wireless client adapter which is known as NIC card in workstation in an infrastructure mode or in ad-hoc peer to peer mode [15] connected to Access Point(AP) [3] which provide wireless connectivity to ethernet. PCI- peripheral component interconnect and PCMCIA- Personal Computer Memory Card International Association card is available at the mobile computing devices and also for desktop machines which connects wirelessly to all the network resources available links. NIC card of a station machine scans the available channels of different frequencies provided by wireless access point or another clients for connectivity and association to that AP or that client. There is a software driver which enable the NIC in station machine [3].

MAC Address(Physical Address)

It is also known as physical address of a NIC or a network device. MAC(media access control) address [16] defined for Network Interface Controller hardware of a network device. Each workstation or network device has a MAC address for its NIC card or some other like modems etc. and each and every addresses assigned to these devices are unique and different. These MAC addresses structure is of type XX:XX:XX:XX:XX:XX and values are in hexadecimal format expression, it can contain letters A to F and number 0 to 9. In windows MAC address can be find out by typing **ipconfig /all** in **cmd** and in linux/unix system MAC address can be find out by typing **ifconfig -a** in **terminal**.

Channel Scanning

The main purpose of IEEE 802.11 standard MAC protocol is to scan for available wireless(WLAN) networks. The wireless workstation searches for present wireless networks and after that try to associate with that wireless service resource provider. According to IEEE 802.11 network standards scanning techniques divided into two types. [13]

1. Passive scanning:- This scanning mode include the process in which the NIC of a workstation listens for beacon frames at a time only on one channel

transmitted from Access Points(AP). By using that beacon frames it collects related signal strength of that station and other useful information needed by that Access Point(AP). After using that information,the NIC chooses the Access Point for association to that. [13] [17]

2. Active scanning:- In this mode of scanning Probe request frames are transmitted on every available channels. In responses of probe request frame workstation got Probe response frames from near Access Point(AP) which are eventually processed and analyzed by the workstation NIC. By default scanning technique is Active scanning for most of the NIC card, In this scanning no station have to wait for beacon frames transmitted by access points for connectivity. It provide quick response from an AP. [13] [17]

1.2.3 WLAN Connection Process

IEEE 802.11 standard defined in its standard that each and every stations must have to maintain two variables which are totally dependent on the Authentication, De-Authentication process and other one is Association, DisAssociation, ReAssociation services. Those two variables are

1. Authentication state
2. Association state

Main working of these variables is to find out the order in which some specific services have to be invoked and the other purpose of these variables is to find out when a station starts the service of data delivery. A workstation may be simultaneously authenticated with many available different stations but at a time that workstation be associated with only one other station [5]. All the wireless workstation start in state 1, In this state workstation may use fixed frame types. This frames are used to find out what 802.11 WLAN, an ESS(Extended Service Set) [5], and its Access Points are available and which are required to process the mandatory frame handshake protocols, and to process the authentication service. Only If a workstation is IBSS(Independent Basic Service Set) [5],have permission

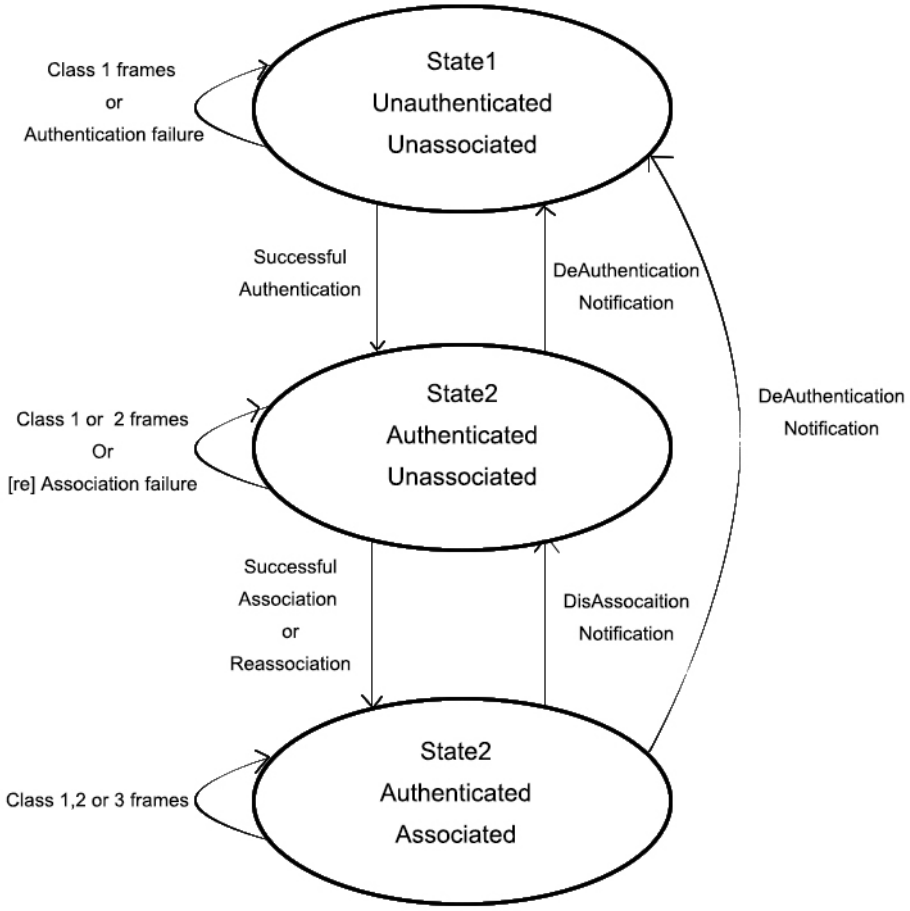


Figure 1.2: Connection Phases

to process data service in state 1 [18]. Probe requests frames announce workstations sustainable transmission data rates and 802.11 other capabilities. Here probe request frame is broadcast from the workstation to BSSID of ff:ff:ff:ff:ff:ff all Access points(AP) and after that all Access Point who receives probe request frames it will respond.

All Access Points who received the probe request frame find out that work station has at least one same sustainable transmission data rates. If they have well matched transmission data rates, a probe response frame is transmitted, which advertising wireless network name in terms of SSID, supported transmission data

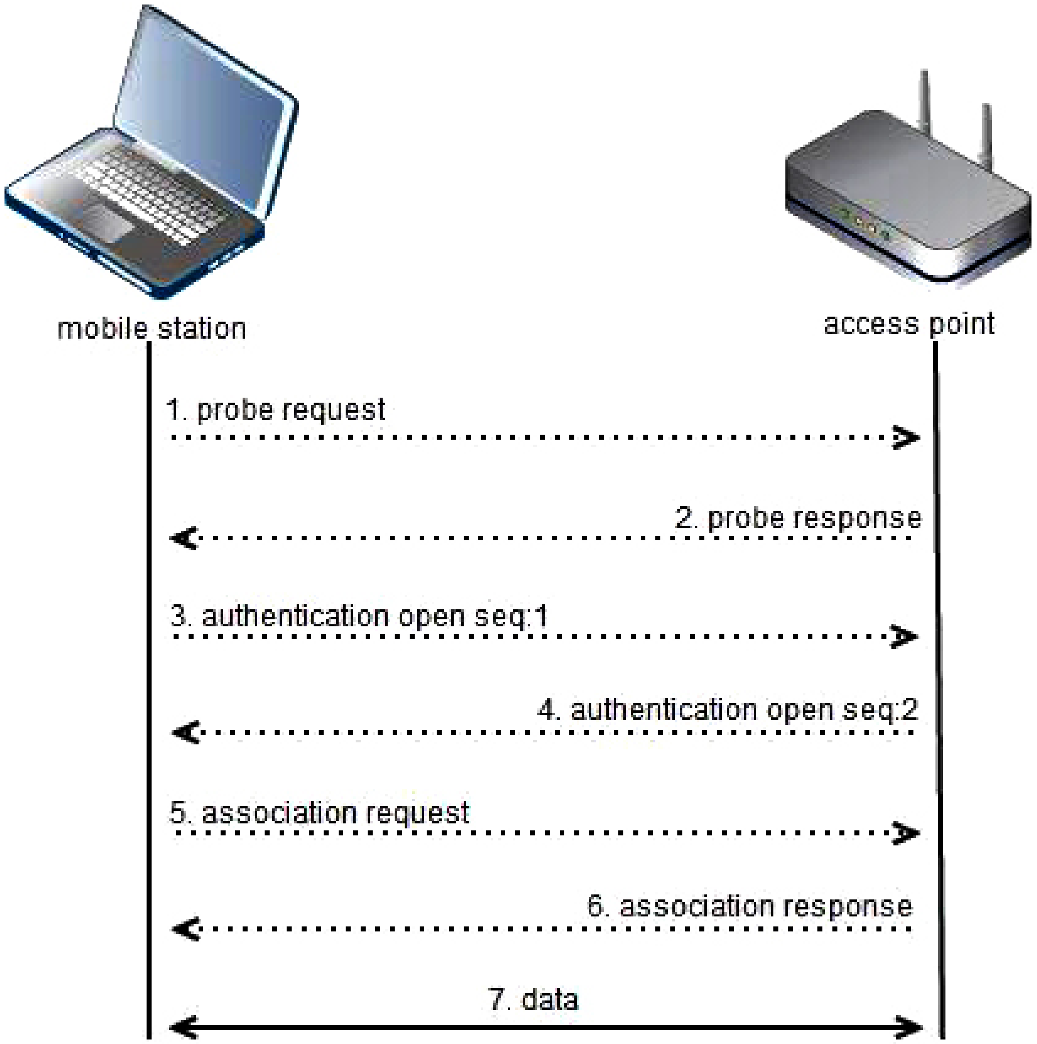


Figure 1.3: Association Process

rates, required encryption if necessary, and other remaining 802.11 capabilities of the Access Point. Workstation receives probe responses from all AP and among all the available network it chooses most compatible network for association. Decision of selecting most Compatibility would be based on encryption type,data rates etc. Once most compatible network is decided workstation will try to authenticate to that APs. Workstation sends a 802.11 authentication frame to an AP from which it wants to associate and setting the authentication process to open and the sequence.At Access Point side it receives the authentication frame transmitted by workstation and responds to tha workstation with authentication frame set to open indicating a sequence [5] [18].

When process enters into state 2 which shows that workstation decided the access point and authenticated state has to be achieved in these state and after achieving this state process moves toward third state. Completion of this state shows successful authentication. After completion of this state additional frame like association frames or disassociation frames are transmitted to that access point to make associate, re-associate, and disassociate services to the network. Association request frame include chosen compatible required encryption type and remaining other compatible 802.11 capabilities. If the information in the association request frame is same as the capabilities of the AP, Association ID will be created as a result by Access Point for that workstation and after that respond with an association response frame with a message which shows that workstation is now allowed to access network [5] [18].

In this last state 3, all frames are allowed and data delivery service is also allowed. A workstation have to process all the frames it receives in each of the states, it has to process those frames also which are not allowed in that specific state. If a workstation receives frames that are not allowed in state 1 and from other workstation which are not authorized to receiving workstation then it will send a de-authentication frame for deauthentication notification to other workstation. In another case if a workstation receives frames which are not allowed in state 2 from any machine which is authenticated to receiving machine but not associated to that machine will send a dis-association frame for notify disassociation state to that other workstation. All these notifications from workstation will make the situation that other workstation will make a transition to the proper state for proceeding further [5] [18].

1.2.4 802.11 authentication model

Supplicant - Host device/workstation (STA)

Authenticator - Light weight access point(LAP)/access point (AP)

Authentication server - It is an access point or an dedicated server machine on which server application is running

Port - It is a state of logical type which is implemented in software in the AP

The supplicant(Host machine) requests for accessing the services provided in other

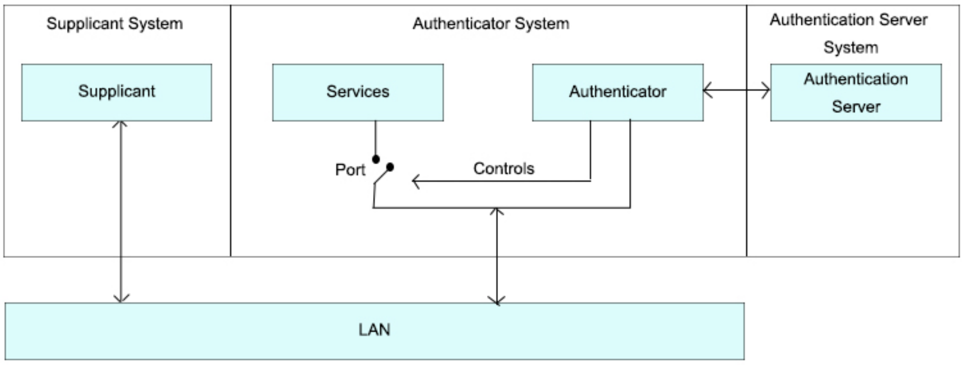


Figure 1.4: 802.11 authentication model [1]

words wants to connect to the network.
The authenticator(access point) controls the services and decide that which host machine can access to that services (controls the state of a port).
The authentication server(access point or any other machine) authorizes the host machine so that it can access to the services.

1. First step include authentication of supplicant(host machine) to the authentication server.

2. If the authentication phase is successful, the authentication server commanded the authenticator to switch the port on so that services can be accessible.

3. The authentication server(AP) tells the supplicant(host machine) that service access is allowed [1].

1.2.5 IEEE 802.11 Rate Adaptation

Standards in IEEE 802.11 implementation provide one of the modulation DSSS (Direct Sequence Spread Spectrum) mainly propose only two data transmission rates: all the transferral and communication are either through speed of 1Mbps or 2Mbps transmission rate. In past, the IEEE specify two high transmission rate expansion:

1. 802.11b whose modulation type is DSSS technology of 2.4GHz band, providing transmission data rates up to 11Mbps.

2. 802.11a, whose modulation type is OFDM(Orthogonal Frequency Division Multiplexing) technology of 5GHz band, providing transmission data transferral rates up to speed of 54 Mbps.

The 802.11g standard that expand the capabilities of 802.11b protocol supports transmission data transferral rates up to speed of 54 Mbps in same band of 2.4 GHz. Wireless Network (802.11 Standard) is highly changeable and inconsistent in nature and there are various reasons for these kind of nature of wireless network. Wireless Network performance will affected mainly due to degradation in quality of with mainly reason are getting interference form other wireless source, fading in strength of signal and attenuation etc.

As the signal becomes weaker, changes of modulation mode and data rate to optimize performance Adaptive Rate Selection (ARS) invoked. In this technique there will be switch between different higher transmission rates [19].

1.3 Address Resolution Protocol

This protocol's main working is to solve out the mapping purpose of logical IP addresses of 32 bit into their corresponding MAC(physical) address of 48 bits. ARP protocol implementation communicates using four messages.

1. ARP Request message:- This message is used to request for resolving given logical IP address to its corresponding associated MAC(physical) address. This ARP-Request frames are broadcasted to every available devices connected to that network.

2. ARP Reply message:- Each workstation which receives this message will process to that request and check it out that if it is allocated that specific IP address and if it contained that requested IP address(logical) then it will inform its MAC address to the requesting workstation.

3. Reverse ARP (RARP) Request message:- A RARP Request is reverse process of ARP request message. In this message it request for IP address(logical) of the device whose given MAC address(physical) transmitted into that request message.

4. Reverse ARP (RARP) Reply message:- It is the response of the RARP request, which containing the MAC address(physical) of corresponding IP address(logical).

Once a workstation receives ARP reply message from other workstation it updates and fill its ARP cache table with the new updated information about association of IP address to MAC address and vice-versa [20].

1.4 MAC Layer Attacks

In Wireless networks it is very easy for attackers who are within range of that network to perform various kind of attacks because it is very easy to sniff that network transmissions. 802.11 standard have many flaws and weakness in its security mechanisms due to some vulnerabilities in its MAC protocol design which give power to attacker to perform various number of possible harmful attacks.There are two ways to perform attack first is passive and other one is active.

Attacks which are due to flaws in MAC Protocol:-

1.4.1 ARP Poisoning Attack

ARP cache poisoning is a activity in which an attacker workstation sends spoofed(fake) (ARP) messages onto a Wireless Local Area Network. Idea behind this activity is to associated IP address of victim(exploited) machine with the MAC address of attacker's machine. So that all the traffic which are meant to be passed to that IP address(victim machine) will now be passed to the attacker machine. ARP spoofing may allow an attacker to track all data frames on a WLAN, modification of the traffic, or instead of modification attacker can stop the traffic too. Mostly this attack is performed for opening door for other attacks, like as session hijacking attacks, man in the middle(MITM) attack and DoS(denial of service) attack [20] [21].

1.4.2 Denial of service (DoS) or Distributed Denial of service (DDoS) attack

Today Denial of service (DoS) or distributed DoS attacks have become a major serious threat to wireless networks. Mainly today it is hard for attackers to overload the victims resources from it's single machine because of cheap hardware,so all the DoS attacks were launched with the help of different distributed machines(attacking hosts). These attacks with this technique is called distributed denial of service (DDoS) attacks. In these attack victim machine get saturated to communication requests or from accessing to resources and due to that it can not respond to authorized legal traffic, or if anyhow it will responds to that it is very slowly as to be seems like not available currently.

To perform this attack attacker may spoof its MAC address with MAC address of victim machine and then send frame like de-authentication or disassociation frame to access point which results victim machine also get disconnects to that wireless network or attacker may spoof its MAC address with the MAC address of Access Point and send disassociation packets to all the machine connected to that Access Point and get all the resources to itself [10] [22].

A SYN flood part of DoS attack happens when a attacker sends a flood of TCP/SYN packets,with a spoofed sender MAC address. All of these packets is like a request for connection,which causing the server to sending back a TCP/SYN-ACK(acknowledge) packet for start and maintain a half-open connection, and after that waiting for a response packet from the sender address but the response never comes because of spoofed sender address . These all half-open connections overload the server capabilities of making connections to other workstations, and due to these half-open connections all legitimate requests goes rejected [22].

1.4.3 Man-In-The-Middle Attack

MITM-man in the middle attack in wireless network is a kind of eavesdropping in which the attacker make connections independently with each of the victims and repeat messages between them, attacker makes them believe that they are communicate to each other directly as in a connection which work as private after handshake,but the true fact is that all the complete communication is watched and controlled by that attacker. In this attack attacker is possibly be able to snatches and checks all messages which are going between that two victims and attacker can also create new messages and inject them into between there communications.A man in middle attack only be possible when attacker succeed in pretend to be second victim for first one and first victim for second one. In the short each hosts be satisfactory to the other host.

In this attack attacker first find out the victim's IP addresses and then perform arpspoof to victim 1 with the IP address of victim 2 and with own MAC address and together with that process perform same process with victim 2 that send spoof arp messages to victim 2 by faking itself as victim 1. Then all the traffic will be pass through that attacker machine and to grab some credentials there are various tools like dsniff [23] [24].

1.5 Security Solutions Basics

1.5.1 802.11 Management frames FingerPrinting

The implementations of 802.11 standards describe broadly various types of frames used by NICs of workstations and access points for communications to each other, and they are also used for controlling and managing the wireless network. Every frame used by wireless network has a control field that describe the IEEE 802.11 frame type, protocol version, and various other useful informations like as power management is active or not, whether WAP/WAP2 is used and so on. In all of these frames there is one information which is always present and that information is MAC addresses of the both destination and source workstation either it may be client machine or access point, for error detection- frame check sequence,frame sequence number etc.

802.11 management frames are the frames type which are used to enable workstations and access point to create and maintain communications between stations.All IEEE 802.11 management frames have a 24 Bytes standard header. They contain: Frame control,Duration/ID,Destination address(DA),Source address(SA),BSSID,Sequence control,Frame Check Sequence(FCS). The following are common 802.11 management frame subtypes used [25]

- Beacon Frame
- Probe Requets Frame
- Probe-Response Frame
- Authentication Request frame
- Authentication Response
- Association Request frame
- Association Response frame
- Disassociation frame
- Deauthentication frame
- Reassociation Request frame
- Reassociation Response frame
- Information Elements and Fields
- Management Frame Fields
- Management Frame Information Elements

FingerPrinting :- FingerPrinting is the Process of collecting information from the specific workstation to make its profile in order to the identify this workstation in future by comparing its profile to current nature of workstation. This fingerprint should be like the fingerprint in human because human fingerprints are unique and different individually and can't be spoofed. Through this process all the information about workstation, NIC drivers,software and different drivers workstation is using can be find out uniquely as they are observable characteristics.

In this technique a profile is created of workstation through analysis of timing behavior of different 802.11 management frames. Unique timing profile is created because that timing profile is used to find out the actual device by comparing the stored profile to current captured profile [26]. FingerPrinting can be done in two ways

1. **Passive:** It uses a sniffer to capture traffic sent from a system. It analyzes that traffic to find out what the system implementation is. A key point is that passive technique does not send any traffic to the target system but instead just collects the traffic and analyzes it. This technique also refers as noninvasive technique because it does not require co-operation from the system of which fingerprinting is performing [13].

2. **Active:** It discovers related informations about the firmware, the chipset or the driver of an 802.11 standard wireless device by observing and analyzing its responses to a series of crafted, non-standardized malformed 802.11 frames. It is also known as invasive technique because it requires co-operation from the system because this technique depend upon the reply it gets from the system on which fingerprinting is performing [13].

1.5.2 Sequence Numbers

There is a field known as sequence number field present in the 802.11 standard MAC frame header. Each and every frame transmitted from hosts device has a unique sequence number associated with it, host device increments the sequence number every time it transmit a frame. This sequence number field is needed because of re-assembling of fragments at destination hosts device. Re-assemble is needed because of fragments are transmitted in different order so ta reorder all the fragments that sequence number is needed. According to the defined 802.11

standard sequence number field value of each and every frame is assigned by a defined counter variable, value of this counter variable is incremented by one whenever a frame is transmitted and value of sequence number field is always modulo 4096 [6].

According to IEEE 802.11 standards every device which are connected to that network and communicating and during communication each and every management frame and data frame contains the 12-bit sequence number field in its 802.11 MAC header, which is incremented by one every time. Control frames types transmission do not get a sequence number field in their frames [4]. If a workstation is seems as another workstation means one workstation using the identity of another, then this condition(kind an attack) will generate two different chain of values of sequence numbers field which can be detected easily.

There is a wayout by which refined attacker could hide his steps would be have latest values of sequence number of current actual device recently transmitted MAC frame, so that attacker can send its frame by same frame number and by turn that frame into retransmission of that frame by flipping the retransmission bit the 802.11 header and making all this situation as natural retransmission.

In another way attacker would include hijacking the complete sequence by corrupting the actual legal frame by victim machine and instead of that sending out a frame with the next successive sequence number and corrupted frames got drop by the other machine. In this technique there is a weakness that even if sequence number analysis effectively be done there is always a possibilities that refined attacker can easily hide its tracks with respect to the sequence numbers [4].

1.5.3 Signal Strength

This technique may be either passive or active. In this fingerprinting approach, the location of each and every host machine measured by the received signal strength (RSS) of host-transmitted frames and packets with related to n number of installed access points(AP) within that range of that access point. The resultant signal strength(RSSI) in combination of n-tuple represent the signalprint [27] [28] of each host machine at that some location. To handle the situation when there will nonstationary hosts are present, the signalprint(fingerprint) of each wireless host is constantly tracked and updated. That RSS-Received signal strength [27] information, which has been used for Identity Based Attacks detection technique because of its property of location distinction and availability of this feature in the network interface controller (NIC) card in the present off-the-shelf devices. signal strength profiles, which are created as a fingerprint profiles are location specific and that can be used as Identity Based Attacks detection in environments which are static type. In this technique, the receiver machine asks the sender machine (associated with an identity) to report the RSS records and create profiles at the time of their past communication captured. If at some time there is no Identity Based Attacks, the announced RSS(signal strength) variation should be related with the receiver's machine observation. In any case if there is an Identity Based Attacks, the RSS(signal strength) records and profiles observed and analyzed by a exploited node should be a mixture of the RSS produced by the genuine client machine and the attacker machine. Since the attacker machine cannot figure it out that the RSS(signal strength) variations analyzed by the genuine user machine, its reported records and profiles should be less correlated with the victim node's machine, and the attack can be detected [27] [28].

1.6 Intrusion Detection Systems

Intrusion detection System(IDS) [29] [7] [9] can be elaborate as detection system which is of type automated and which is used to alert the available system and security systems by generating an alarm at a location where that attack is taken place. If any attack or intrusions have taken place or something different from natural activity happened IDS come into existence and actions have been taken. An Intrusion Detection system (IDS) is a system used for detection and also as for defensive purpose from network attacks by detecting hostile activities/different from daily activity in a network and then tries to possibly detects and stop such activities that may exploit and compromise the system or network security. IDS attain detection by continuously monitoring and analyzing the network for abnormal activity, some special attacks and activity which are different from daily activity. The prevention part of Intrusion detection and prevention system may involve issuing alerts and generation of alarms as well as taking actions like as direct prevention measures such as blocking a real or suspected host or untrustable connection. In different definition, intrusion detection system is a technique and process which identifying unusual activity and after that make response to that abnormal and malicious activity targeted at computing and networking resources. Apart from these functionality IDS are capable of differentiate between attacks which are generated from inside(insider attacks) the network and external ones generated from outside.

1.7 Summary

Throughout this chapter, what ever is discussed is just to create a basic understanding for this research work. It begins with knowledge basically required like the 802.11 standard, Wireless Network basics, connectivity phases and identity based attacks on 802.11 networks. Basics related to Intrusion Detection Systems and techniques is also discussed. This all basics are very helpful in our proposed technique and also in implementing our technique.

For some more basics information is there are sources available majorly like 802.11 wireless networks MAC layer working and Physical layer working [5] [4]. Intrusion Detection System can be more find out in research paper wired and wireless intrusion detection system :classifications, good characteristics and state of art [8] [7]. Information about identity based attacks on wireless network is on security issues in wireless network [9] [20] [22].

1.8 Thesis Organization

The rest of the thesis is organized as follows.

In **Chapter-2** will provide a overview of the related work and research done till now on detection of identity(spoofed) based attack. Which will lighten you up with a little deep knowledge about spoof attacks and their detection techniques and help you to understand the needs, the drawbacks and various way to detection of spoofed(identity) based attacks.

In **Chapter-3** will take you through our proposed technique of spoofed wireless device detection with management frames with some basic theoretical knowledge about the technology used and the simulation and results of our proposed work.

In **Chapter-4** the overall work with drawbacks is expressed in the section Conclusion and the possible future work is described in the Future Work section.

Chapter 2

Literature Review

Chapter 2

Literature Review

Detecting Identity Based Attacks in Wireless Networks Using Signalprints

In this paper they create a profile called signalprinting type of fingerprint using signal strength reported by access points which are further used for find out what are reliable authorized client stations and other misbehaving unauthorized device. Signalprints are tightly related to current physical location of clients workstation. In this technique any interested packet like as authentication/deauthentication request is transmitted over the wireless network, and then it is captured by access points within that range, that packet include information about signal strength measurements as RSSI levels and passed that information to the centralized server. That information is then stored for future comparison as a signalprint profile, this profile is a tuple created by collecting all measurements reported by all the access points. All signalprint is characterized as a vector in which there will be one entry for each access point captured signal strength measurements. There are different transmitters are installed at different locations which generate different signalprints because signal strength changed either increase or decrease with decreasing or increasing in distance, which helps the monitor system to correctly differentiate clients workstations located at different locations.

One limitation of this technique is that it may not able to differentiate between two devices which are located physically nearby to each other. Masquerading attacks can be detected only if there is difference in signal strength (RSSI) is notable with respect to at least one or more access point.

This technique may also not be capable to detect DoS attacks which are composed of only less packets for example single-packet deauthentication attack which de authenticates the victim machine from that network may go unnoticeable. This attack only be detectable if there are more enough packets involved so that there will be more signalprints for processing and comparison [27].

Identifying Unique Devices through Wireless Fingerprinting

In this paper they propose a wireless device fingerprinting technique in which there will be a profile which is created of different devices using probe request frames timing behaviour.They developed a completely passive technique. Here passive means the process which did not require assistance and help from the fingerprintee machine. Their technique is depend on the probe request frames timing behaviour and its analysis. This process is done by creating the fixed size time interval bins so that all the frames are divided into that timing bins according to their timing information for all the known workstations into that network and that complete information of timing bins is called signature(fingerprint) of machines. Signature is created for each and every machine existed in that network and stored in database for future use.

One of the advantages of this technique is that it doesn't required cooperation from other machine and through this technique they find out uniform minute differences in probe request's timing intervals transmitted from different workstations, even when they used same NIC drivers.

The first limitation in this technique that the two devices which are actually same, sometimes due to traffic in network shows different behaviour and thats the reason its not easy to infer that two devices are same. Sometimes in the other case due to limited samples some different devices also seems like they are the same device because of similar limited samples.

The second limitation is the data and time required to fingerprint each device in that network. As this fingerprinting technique concentrate only on analyzing the inter-burst latencies and due to that it will take around at least an hour , so that profile of signature can be used for finding out which devices are authorized and which are not [26].

On Physical-Layer Identification of Wireless Devices

In this work, they focus and develop techniques using physical layer properties and thats why this technique is called physical layer identification. In this technique wireless devices are identified characteristics of their analog circuitry which are unique and different from others. In this process physical-layer device identification [30] is done by taking and analyzing properties of analog circuitry of a device during communications between devices and develop a fingerprinting [26] using properties of physical layer. This process identification of device using properties of physical-layer is possible due to imperfections in hardware analog circuitry during manufacturing process. Results of these imperfections and defects introduced in hardware analog circuitry shows in the transmitted signal which makes them correctly measurable. Even if there will be more precise and correct manufacturing and quality control is very good there is possibilities that these manufacturing imperfections could minimized but in practical it is hard to achieve because of high rate productions .

In their process two modules are used for identification of system: enrollment and other one is identification. In enrollment module, signals are captured when devices are communicating from each and every device. These signals are stored as informative manner and called fingerprints of each device stored in database. All devices fingerprint linked with some unique ID representing the corresponding device. In identification module,devices which are communicating in that network are identified using stored reference fingerprints obtained in enrollment module. They use different Physically Unclonable Functions(PUF) [31] [30] for identification of device using physical properties of that device. Devices which contain PUF-enabled RFID processors contain a circuit which represents input challenges to output responses using a function (PUF)and which is discovered by the internal characteristic and variations of that circuit [30].

Passive Data Link Layer 802.11 Wireless Device Driver Fingerprinting

The researcher proposed technique in this paper is completely passive, means no need of getting reply from the victim machine. They choose passive fingerprinting techniques [26] because these techniques have advantages over active techniques interms of transmitting data that passive approaches do not transmit data.Their proposed fingerprinting approach takes advantages of implementations differences to fingerprinting a device because algorithm used for scanning access points is not defined properly and universally in the 802.11 standard. So lack of standard specification of a probing algorithm make wireless device drivers different from each other. Particularly, their approach is focused around statistical analysis of the timing differences(inter-frame) between transmitted probe requests [25]. This timing-based(inter-frame) technique has a many benefits over a content-based technique. There fingerprinting approach moves in two modules: first one is capturing traces and second one is generation of fingerprinting. In first module probe request are capture for fingerprinting of that device. In the second phase probe request behaviour is characterized using that captured data. They chooses binning technique to implement their proposed technique. By using binning approach they characterizes probe requests delta time. Binning approach works by converting an continuous data points(frame timing interval) into discrete size bins. A time bin is an integral time value used for dividing continuous data in discrete. They use equal-width binning means where size of each bin is same. They calculating bin probabilities and bin mean as device signature(fingerprint). These signature are used in future during verification of device. There will be calculating of closeness between stored signature and current collection of device traces.

Drawbacks of their fingerprinting technique is when a new driver version came that version is patched with previous vulnerabilities in driver. Due to that device fingerprint works differently and stored fingerprint work differently [32].

A Passive Approach to Wireless Device Fingerprinting

In this research they provide a wireless device fingerprinting passive approach that utilizes a blackbox-based [33] process. This approach can be used for defensive or offensive purposes and is extensile to any wireless network device. Blackbox testing process is a popular approach which is used to testing the software where the contents used are obscure to the tester. To lead the test, a stimulant is given as input of the software and after that output is analyzed. In this process tester can figure out the result that how the software will respond to the input. In this research blackbox is Access Point instead of software and just same as testers of software are not stick and serious to source code of software, researches in this process not considered the proprietary structure of the Access Point. The packet train is given as input to blackbox which is a access point and after that output which is also packet train is analyzed, although there will be shifting in time of that individual packets in that packet train. That shifting of time is a output of the internal structure of the access point(AP). Because each and every access point(AP) has a structure which distinguish itself from others, and this shifting of time is different for each access point which make it unique for access point. Researchers used wavelet analysis [34] to extract the unique and different patterns which are as a result from internal structure [35].

One limitation of their research work was that the results were for based on very few access point tested. They conduct their experiments using a wireless test set with imitate network traffic as instead of real traffic [35].

Detection of Masqueraded Wireless Access Using 802.11 MAC Layer Fingerprints

This paper acknowledges the situation where the spoofer(attacker) holds up till the authorized client has completed the its session, and afterward of session completion attacker exploits that whitelisted MAC address for the network access [2]. They create a technique focused around analysis statistically of the timing difference between transmitted probe request [25] as interframe timing of probe requests with a specific end goal to recognize a particular wireless driver, and the conclusion is that the dominant part of wireless drivers do have a different fingerprint [26]. There are various differences in implementations of the Null Data frames that can be used for making differences in different NIC drivers. They used seven rules [36] to recognize diverse behaviour with respect to the Null Data frames. The main center of focus in this research is on the attack type MAC spoofing where the exploited machine and attacker don't have to be connected all the while. MAC layer [2] behaviour differs from station to station in various perspectives because of implementations and usage differences of the 802.11 protocol.These differences found out in properties and standards is called fingerprinting properties, and base for making differences are Null Data frame behavior [36].they used various distinctive featrues for making diffeences between various devices. Features are like PS-Poll, Keep Alive, Null before Probe, Null Data Type, Listen Interval, Association Request Duration, Fixed Interval etc.

Advantage of this technique is that this are capable to find out spoofing attacks where the attacker and exploited user is not connected simultaneously. Precomputed stored database of fingerprints is not required [37] .

Sequence Number-Based MAC Address Spoof Detection

In This paper they proposes a technique related to link-layer in which sequence number field of MAC header is used.During communication each host transmit MAC frame with a unique sequence number [2] [4], which the every hosts device increments by one every time it transmits a frame. The main purpose of sequence number is to re-assemble and re-organize fragments of a MAC frame at destination hosts device same as source hosts device. According to their proposed technique monitor system keeps track of each wireless device latest sequence number so that if some attacker try to imitate a hosts device it will need to spoof the MAC source address of that hosts device as well as its related sequence number used during that communication. There are two cases which monitor system covers :-

1. In the first case if captured spoofed frame's sequence number is smaller or equal to current sequence number of that transmitting actual hosts device than that spoofed frame is observed as a retransmitted frame and thus if it is retransmitted frame than that frame's content have to be same as the last frame with the equal sequence number. So in the first case spoofed frame can not do any damage to system because its just a replica to the previous frame same sequence number.

2. In second case if captured spoofed frame's sequence number is larger than the current sequence number of that transmitting actual hosts device, than there is spoofed message whose content is different and may be harmful to the system. This attack cannot be detected soon. This attack can only be exposed if later when actual device transmit its frame with that spoofed frame sequence number and content of its frame is not as same as spoofed message [6].

one weakness figured out in this technique which is most principal that it requires the exploited person machine and attacker machine ought to be in the same network, so that by utilizing ARP request and ARP response to upgrade most latest exploited person sequence number.

2.1 Summary

These are the some of the related I have studied on spoofed device attack identification techniques. Through this literature review all the techniques till now either works on only probe request, signal strength or sequence number field and latest technique is using 802.11 MAC layer implementation properties, which is used to distinguish one device from other. In the case of sequence number detection technique, compulsory and most needed thing is both victim and attacker together will be present in the network only that time attack will be detected. I found the spoofing detection is more tough when both victim and attacker both are not present simultaneously.

Chapter 3

Proposed Technique and Simulation

Introduction

Our Proposed Technique

Implementation

Summary

Chapter 3

Proposed Technique and Simulation

3.1 Introduction

The real motivation behind this proposed work is that today there are several vulnerabilities and weakness in implementations of 802.11 MAC layer standards [5]. Attacks of type MAC spoofing are a remarkable serious threat to 802.11 wireless networks because it is very easy to theft identity of authorized clients in that network and perform other serious attack without showing their actual identity. This proposed algorithm is developed to fingerprint the device using MAC layer properties to find out that spoofing attacks where victim machine and attacker machine not connected together to the network. Fingerprint is created on the basis of different behavior shown by device of which fingerprint is created and each device behavior is unique because there are differences available in implementations of 802.11 protocol. The proposed technique have some part active and some part passive in nature, means it creates fingerprint of the device by using both active and passive technique [37]. Passive technique give positive and strong detection in compare to active technique because this active technique provide stronger detection only if gets reply from the other target system. But active technique is much more faster than passive ones and detects after few frames exchanged.

3.2 Our Proposed Technique

3.2.1 Spoofed Wireless Device Detection using Management Frames Fingerprinting

802.11 standards are diverse in implementations which differ the behavior of each device from other devices [5]. These differences are the main property which make possible for developing fingerprinting using management and control frames of MAC layer and other properties. There is the fact that the approach used in channel scanning for finding out the available nearest access points is not defined in standard manner in 802.11 protocol standards [32] [35]. Due to this fact all manufacturers have implement algorithms and approach in there way which are different from others. By taking all these properties together and creating a profile which is unique for each device and that profile is used for identification of device in future. This whole process is called Wireless Device Driver Fingerprinting and majority of wireless device drivers do have a distinct and unique fingerprint [37]. There is already an available approach [13] [32] which is based on inter-frame timing (timing difference between probe requests) and for fingerprinting statistical analysis is used so that in future that analysis can be used for identifications of that fingerprint device [26] [30] .

Our main approach is based on timing signal behavior which provide diversities in the NIC card [37]. To detect these MAC spoofing attack, our approach mainly focus on timing differences between different frames transmitted by NIC card during communication setup phases [38] [4].

There are various challenges faced during implementation of our proposed device fingerprint approach.

1. In the MAC protocol standards there are various properties and parameters which are associated to MAC frame and combinations of that properties and parameters are distinct for a device. Choosing that parameters is one of the biggest challenge.

2. Upgradation of device firmware can change its possible normal last version of device behavior.

3. Last challenge is like devices from same vendors or different vendors which may have same implementations of MAC protocol standards.

3.2.2 Basics Behind Proposed Technique

This section will give basic knowledge on the 802.11 MAC protocol standard, 802.11 MAC frames [5] used in network. These frames are used for fingerprinting the device.

Functionality of MAC Layer

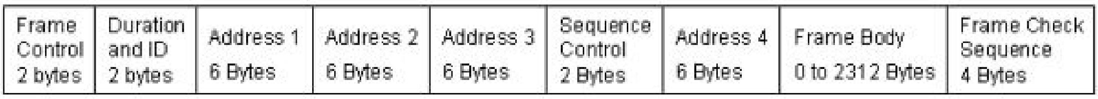
1. Providing data delivery in reliable way

2. Good Control access to the shared wireless medium.

3. Data delivers in protective way [5].

MAC Layer Packet Structure

The basic MAC(Medium Access Control) [5] layer packet format [2] which is passed to PHY(Physical) layer from the MAC layer is shown in figure. Some of the fields of this basic frame format is not contained by all the packets. But in data packets all of these fields are present. Four addresses field are present in frame format and all of these needed because sometimes users are connected to different access points and due to that MAC address of access point is also required. So addresses of both the access points and addresses of both the clients are present in these four address fields [39].



Frame Control 2 bytes	Duration and ID 2 bytes	Address 1 6 Bytes	Address 2 6 Bytes	Address 3 6 Bytes	Sequence Control 2 Bytes	Address 4 6 Bytes	Frame Body 0 to 2312 Bytes	Frame Check Sequence 4 Bytes

Figure 3.1: MAC Layer Packet Structure [2]

Management Frames The main purpose and use of management frames are to create and maintain the wireless network between the station machine and access point. The usage of management frames is not just important for creating link between devices but also they are useful in maintaining the network link in for confirming that the station machine are still present there, but with considering this there are other network link also present with some good related parameters to get a best connectivity. These frames have many different subtypes [40].

Table 3.1: 802.11 Management Frames [4]

Type Description	Subtype value	Subtype Description
Management	0000	Association request
Management	0001	Association response
Management	0010	Reassociation request
Management	0011	Reassociation response
Management	0100	Probe request
Management	0101	Probe response
Management	0110	Timing Advertisement
Management	0111	Reserved
Management	1000	Beacon
Management	1001	ATIM
Management	1010	Disassociation
Management	1011	Authentication
Management	1100	Deauthentication
Management	1101	Action
Management	1110	Action No Ack
Management	1111	Reserved

Control Frames The main purpose of these control frames are in the supporting in data frames delivery. These frames purpose is to avoid collision between frames due to hidden station problem connectivity. The other purpose is to acknowledge frames during transmission of frames are correctly. Sequence control field which is available in default MAC frame format is not present in control frames [40].

Table 3.2: 802.11 Control Frames [4]

Type Description	Subtype value	Subtype Description
Control	00000110	Reserved
Control	0111	Control Wrapper
Control	1000	Block Ack Request (BlockAckReq)
Control	1001	Block Ack (BlockAck)
Control	1010	PS-Poll
Control	1011	RTS
Control	1100	CTS
Control	1101	ACK
Control	1110	CF-End
Control	1111	CF-End + CF-Ack

Null Data Frames Behavior These frames are important and special type of used frames in 802.11 wireless network. They are special data frames in which frame body field is empty in MAC frame format and these are the only frame which are not defined universally in the 802.11 standards [5]. But in actual NIC implementation these frames are used in variety of features used by NIC card like scanning of channel, association keep alive, PS-Power save management etc. There are seven rules defined in “Null Data Frame: A Double-Edged Sword in IEEE 802.11 WLANs” [36] which is used for identification of different behavior shown by these frames [37].

3.2.3 Proposed Technique

In our proposed approach available features of 802.11 standard implementation [5] which make distinguishable each device from other device are used, and this complete collection of this information is called fingerprinting properties.

The whole proposed approach is divided into three types of information first is based on Probe request details, second is authentication request details, and third one is association request details.

The whole process working is divided into 3 phases

1. Packet capture and Information extraction
2. Creation of Fingerprint signature
3. Measurement of Similarity

First Phase

In this phase probe requests frames, authentication request frames,and association request frames and other management frames are captured and from those frames information are extracted like inter arrival time,delta time between frames,power constraint,supported rates etc. These information are features of NIC card which makes it distinguishable from others device NIC card [4].

Table 3.3: Management frames usable fields

Property	Values
Arrival time	Arrival time of Frame
Epoch time	time relative to epoch
Time delta from previous frame	Time difference between two consecutive frame
Time from first frame	Relative time from first frame
Timestamp	Time synchronization
Type/Subtype	different type and subtype of management frames
Sequence number	Sequence number field mod 4096 in each frame

Second Phase

After the process of frames capturing and extraction of information from selected three frames- probe request, authentication request, and association request transmitted by network device of which want to make fingerprint as a signature of that device. Second phase is generation of fingerprint. In this phase selected main information are used which distinguish the device from others. So for generating fingerprint Autocorrelation function is used. In this phase all the three related frames informations are passed to autocorrelation function [44] [45] and generated result is used as a fingerprint of that device and stored in the database. That stored fingerprint later used for identification.

Third phase

In the third phase measurement is done and find out the most similar signature from the database to find out the actual device.

3.3 Implementation

3.3.1 Experimental Setup

In this section all necessary setup are discussed. All software,specific NIC configurations, hardware for capturing and processing informations which is required in this approach. Some of the NIC properties and configurations makes process harder for collecting all the required informations. All the collected informations should be in such a manner which should be processable.

3.3.2 Required Equipment

In this experiment all the main machines and hardware used are :-

1. DAP-1155 Wireless N150 Access Point -Access Point
2. HP laptop(Pavilion dv6-3053tx) with kali linux operating system and atheros model ar9285 802.11 b/g/n wifi adapter - monitor system
3. HP laptop(Pavilion G6-2309TU) with windows 8 operating system and atheros model ar9485 802.11 b/g/n wifi adapter - host machine
4. Dell Laptop (Inspiron 15 3521) with ubuntu operating system and DW1520 Wireless-N WLAN Half-Mini Card - host machine

3.3.3 Required Software

1. Wireshark (version 1.8.14):- This software is a open source network analyzer and packet sniffer. This tool can put the NIC(Network interfcae controller) into promiscuous mode(only supportable) so that it can see all flowing traffic in that network on that selected interface. Output file produced by this tool is in pcap format. Tshark is the terminal based mode of wireshark and this

terminal mode is used to convert pcap file into csv(comma seperated value) file which is used for processing [41].

2. Airmon-ng (version 1.1):- Airmon-ng is the part of Aircrack-ng network software suite which include analysis tool,packet sniffer, wireless security (WEP/WPA/WPA2) cracker. Airmon-ng is a script which is used for putting NIC into monitor mode on selected interfaces and for again putting that NIC into normal managed mode [42].

3. Matlab (version R2012a):- This software provide environment interactive in nature and used for computation of numerical data, data visualization, high level programming. It provide functionality of graph plotting derived from data and functions, manipulations in matrix, different algorithms implementations [43].

3.3.4 Complete Detailed Process

First Phase :- Capturing Packets

This process is done by first put the NIC card of monitor system into monitor mode using airmon-ng [42] tool. After that wireshark [41] start capturing packets on that monitor interface. If the packet capturing in an environment where various other network are also present than after capturing the packet filtering is done according to device of which fingerprinting is created. That pcap file is converted into csv file using tshark terminal mode of wireshark. Commands which are used on kali linux terminal for changing managed mode to monitor mode is given below

1. ifconfig - used to find out the interface used by wireless card

2. iwconfig - find out the card working mode

3. ifconfig wlan0 down - down interface wlan0

4. airmon-ng start wlan0 - create an interface whose working is in monitor mode. That interface is a sub-interface of wlan0

5. ifconfig wlan0 up - up interface wlan0

After capturing packets of type probe request,authentication request and association request and other management frames(Informative elements) in pcap file. Filtering is perfomed and useful information is collected using tshark and that is used to convert that pcap file into csv(comma separated values) file.

1. tshark -r capturedfile.cap -T fields -e frame.number - e frame.time -e frame.time_relative -e frame.time_epoch -e netmon_802_11.timestamp -e wlan.sa -e wlan.seq >capturedfile.csv

Second Phase:- FingerPrint Generation Process

Timing intervals of Probe request,Authentication request, Authentication request for any specific device have periodical and nearly same assumable each time traffic is captured. Past experiments shown that probe requests intervals are different for every NIC [13] [32]. In this phase information collected about probe request, authentication request and association request for fingerprinting the device has been presented as signal s(t) in terms of timing, where s is event discrete in nature that happens in time t. Analysis and fingerprint is generated based on timing property of all these three packets and together with this process a profile is created of device using informative element shown in table-3.3 [37] [4].

First of all mean and variance is calculated for timing differences for each of probe request and relative time from last frame for authentication request frame and association request frame. After that autocorrelation function is used. This function is used for finding periodic patterns in the signal etc. Dataset of n data values $\{D_1,D_2 \ldots D_n\}$ of which mean μ and variance σ^2 is known then autocorrelation function [44] [45] is defined as

$$\hat{A}(k) = \frac{1}{n * \sigma^2} \sum_{t=1}^{n-k} (D_t - \mu)(D_{t+k} - \mu) \tag{3.1}$$

where k < n

After calculating the autocorrelation of signal to itself discrete fourier transform(DFT) [46] is applied to that for generating the signal.

$$Y_l(f) = \sum_{n=0}^{l-1} A_l[n] e^{-2\pi kn/N}, k\epsilon\mathbb{Z} \tag{3.2}$$

autocorrelation function is also used to find out the similarity between observations as a function of the time lag between them. If correlated function applied to signal to itself then that function is called autocorrelation function.

Third Phase- FingerPrint Comparison

In this phase device identification is performed with the help of cross correlation. Cross correlation technique is used to analysis and find out the similarity between between two signals, one is the stored database signal(fingerprint) and another one is captured during the time of identification of device. This functions find out the correlations between signals in terms of similarity or tell about the offset between two signal. Result obtained after applied the cross correlation provide a offset value, which tells that device is actual device or device with faked MAC address.The cross-correlation [47] function onto the frequency domain obtained from fourier transform [46] is called the cross spectrum or cross energy density spectrum. Cross correlation for frequency domain can be calculated as

$$\Phi = FT[Y^*(f)Z(f)] \tag{3.3}$$

$$corr = ifft(conjugate(fft(Y(f))) * fft(Z(f))) \tag{3.4}$$

where fft=fast fourier transform
ifft= inverse fast fourier transform
Y(f)=Stored signal
Z(f)=captured signal during identification

we have applied all these three phases used for identification of device. All these three phases experimented on 4 machines and one monitor machine. From those 2 machines one have atheros ar9485 NIC card and other one have dw1520 wireless Wlan half-mini NIC card. By using properties of MAC layer and after analysis of those properties and decision is made that either device is actual one or not the actual device as it is behaving and registered as some one else.

3.3.5 Results

In this section results will be shown of our proposed technique of different machine and discussed about them.

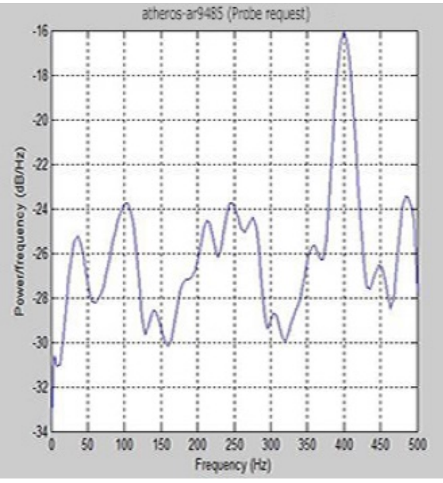


Figure 3.2: Probe request timing estimation for atheros ar 9485 NIC card

Figure-3.2 and Figure-3.3 is the result of probe request frames transmitted by atheros ar-9485 card (hp machine) and DW1520 Wireless-N WLAN Half-Mini card (Dell machine). This is generated by processing timing details of each frames transmitted by both of the machine and then resul is converted that time signal into frequency signal which tells the power trasnmitted by that signal on corresponding device. This signal is generated by after applying autocorrelation function [44] [45] to that signal itself.

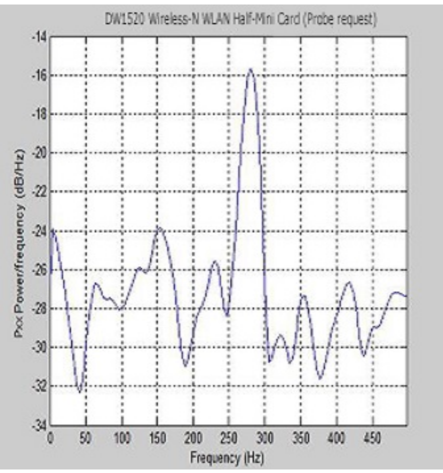


Figure 3.3: Probe request timing estimation for DW1520 Half-Mini card NIC card

Figure-3.4 and Figure-3.5 is the result of Authentication request frames transmitted by atheros ar-9485 card (hp machine) and DW1520 Wireless-N WLAN Half-Mini card (Dell machine). This frame is transmitted by probe response from the access point and according to this information, relative time difference between them is used as a processing element.

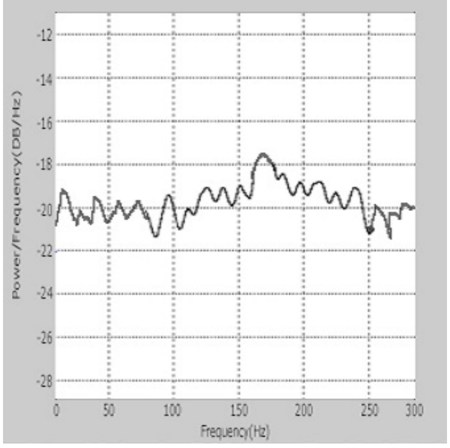


Figure 3.4: Authentication Request relative time estimation after each probe response for atheros ar-9485

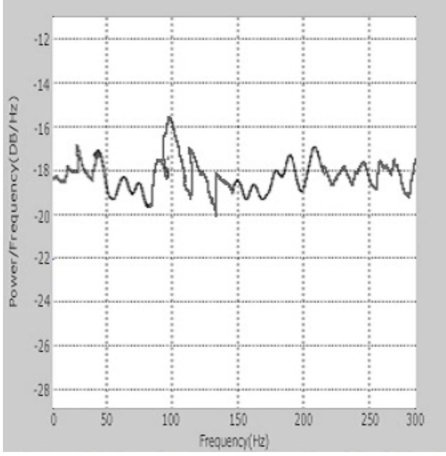


Figure 3.5: Authentication Request relative time estimation after each probe response for DW1520 Half-Mini card

Figure-3.6 and Figure-3.7 is the result of Association request frames transmitted by atheros ar-9485 card (hp machine) and DW1520 Wireless-N WLAN Half-Mini card (Dell machine). This frame is transmitted by authentication response from the access point and according to this information, relative time difference between them is used as a processing element.

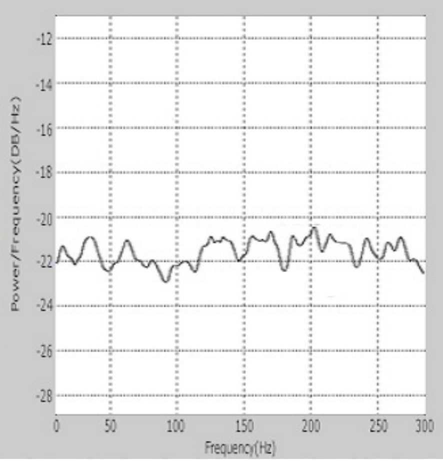


Figure 3.6: Association Request relative time estimation after each authentication response for atheros ar-9485

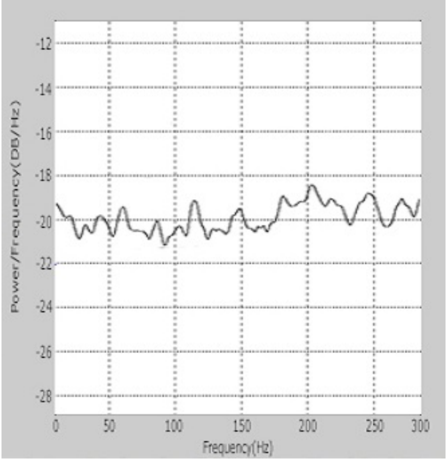


Figure 3.7: Association Request relative time estimation after each authentication response for DW1520 Half-Mini card

Figure-3.8 is the result of differences between probe request pattern transmitted by atheros ar-9485 card (hp machine) and DW1520 Wireless-N WLAN Half-Mini card (Dell machine). Cross correlation measures of similarity of two signals as a function of a time-lag applied to one of them. This graph tells that lag by around 7 seconds and correlation value is 0.65 which is more than 0.4 confirms that there is difference between them.

Figure-3.9 is the result of differences between authentication request pattern transmitted by atheros ar-9485 card (hp machine) and DW1520 Wireless-N WLAN Half-Mini card (Dell machine) in response of probe response from access point. This graph tells that lag by around 3 seconds and correlation value is 0.45 which is more than 0.4 confirms that there is difference between them.

Figure-3.10 is the result of differences between association request pattern transmitted by atheros ar-9485 card (hp machine) and DW1520 Wireless-N WLAN Half-Mini card (Dell machine) in response of successful authentication response from access point. This graph tells that lag by around 7 seconds and correlation value is 0.41 which is more than 0.4 confirms that there is difference between them.

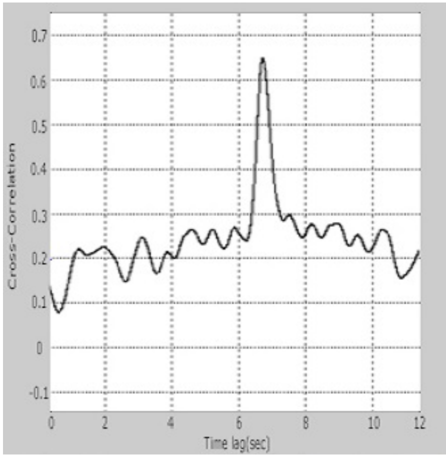


Figure 3.8: Cross correlation estimation for probe request between atheros NIC and DW1520 Half-Mini card

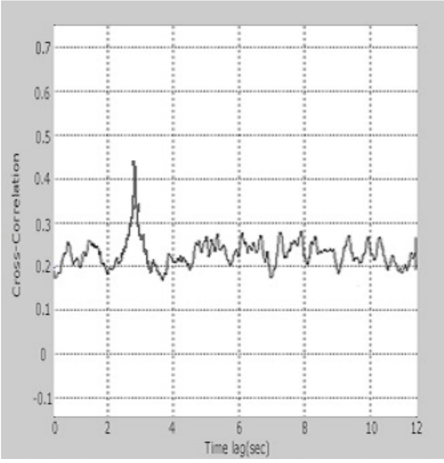


Figure 3.9: Cross correlation estimation for Authentication request signal between atheros NIC and DW1520 Half-Mini card

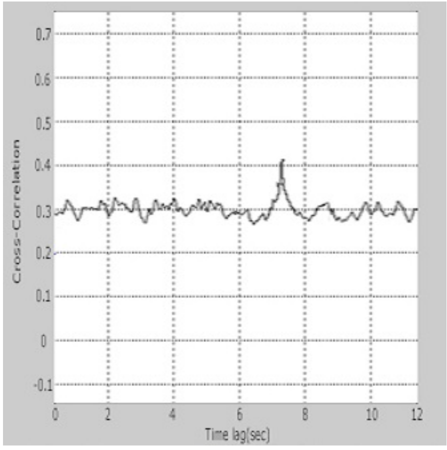


Figure 3.10: Cross correlation estimation for Association request signal between atheros NIC and DW1520 Half-Mini card

3.4 Summary

This chapter covers all my proposed work, implementations and obtained results. In the results which tells about the differences between devices which have taken for experiments.

Chapter 4

Conclusion and Future Scope

Chapter 4

Conclusion And Future Scope

4.1 Conclusion

In proposed research it is experimented and identification is done with stored fingerprint and captured fingerprint during identification of device. This technique is able to identify and find out which device is without spoofed MAC address and actual device and which one is spoofed one in the condition where the both victim(exploited)device and attacker device need not to be simultaneously connected . Here this experiment is performed with various machines and it is resulted that our proposed technique is mostly identify the device correctly. Our technique provide stronger and correctly identification of device because it uses three phase identification, first is on basis of probe request, second is on basis of authentication phase and third is on basis of association phase.

4.2 Future Scope

After more than one decade of research on spoof detection and prevention by all the researchers through out the world, none of the proposed technique is able to stop MAC spoofing attacks(Identity based attacks) when NIC card of both the attacker and victim have same developer. Both NIC card at mostly times produce same properties, so to differentiate between them is a typical task. Also today there is a concept called Hardware Abstraction Layer is used in some NIC card which allows program developers to write software independently for any device, which provide high performance. This proposed work is also not able to correctly identify the device when developer of that NIC card is same. So in the future work main work to develop technique which is used to identify devices of same developer means devices which have same properties and also identify device which have HAL(Hardware abstraction layer) concept used in development of that device.

Bibliography

[1] J. NETWORKS, "802.1x: Port-based authentication standard for network access control (nac)," tech. rep., JUNIPER NETOWRKS, 2010.

[2] "Mac frame formats - ieee." http://grouper.ieee.org/groups/802/15/pub/2001/Jul01/01292r1P802-15_TG3-Proposed-Changes-to-Frame-Formats.pdf.

[3] T. Karygiannis and L. Owens, "Wireless network security," *NIST special publication*, vol. 800, p. 48, 2002.

[4] "802.11-2012 ieee std wireless lan medium access control (mac) and physical layer (phy) specifications," 2012.

[5] M. Ergen, "Ieee 802.11 tutorial," *University of California Berkeley*, vol. 70, 2002.

[6] F. Guo and T.-c. Chiueh, "Sequence number-based mac address spoof detection," in *Recent Advances in Intrusion Detection*, pp. 309–329, Springer, 2006.

[7] T. S. Sobh, "Wired and wireless intrusion detection system: Classifications, good characteristics and state-of-the-art," *Computer Standards & Interfaces*, vol. 28, no. 6, pp. 670–694, 2006.

[8] "Introduction to intrusion detection isca publications prepared by rebeka bace." http://www.icsa.net/html/communities/ids/White%20paper/Intrusion1.pdf.

[9] S. Boora, Y. Kumar, and B. Kochar, “A survey on security issues in mobile ad-hoc networks,” *IJCSMS International Journal of Computer Science and Management Studies*, 2011.

[10] K. Bicakci and B. Tavli, “Denial-of-service attacks and countermeasures in ieee 802.11 wireless networks,” *Computer Standards & Interfaces*, vol. 31, no. 5, pp. 931–941, 2009.

[11] “Wireless lan: Security issues and solutions.” `http://www.sans.org/reading-room/whitepapers/wireless/wireless-lan-security-issues-solutions-1009`.

[12] “Phishing.” `http://en.wikipedia.org/wiki/Phishing`.

[13] C. L. Corbett, R. A. Beyah, and J. A. Copeland, “Using active scanning to identify wireless nics,” in *Information Assurance Workshop, 2006 IEEE*, pp. 239–246, IEEE, 2006.

[14] “802.11 and osi model.” `http://technet.microsoft.com/en-us/library/cc757419(v=ws.10).aspx`.

[15] “Wireless lan.” `http://en.wikipedia.org/wiki/Wireless_LAN`.

[16] “Mac address.” `http://nms.ncc.metu.edu.tr/yurt/Read_Me_Oku_Beni/MAC-address-EN.pdf`.

[17] V. Gupta, R. A. Beyah, and C. L. Corbett, “A characterization of wireless nic active scanning algorithms.,” in *WCNC*, pp. 2385–2390, 2007.

[18] “802.11 association process explained.” `https://kb.meraki.com/knowledge_base/80211-association-process-explained`.

[19] S. Biaz and S. Wu, “Rate adaptation algorithms for ieee 802.11 networks: A survey and comparison,” in *Computers and Communications, 2008. ISCC 2008. IEEE Symposium on*, pp. 130–136, IEEE, 2008.

[20] N. Behboodian and S. A. Razak, “Arp poisoning attack detection and protection in wlan via client web browser,” *International Conference on Emerging Trends in Computer and Image Processing (ICETCIP’2011)*, 2011.

[21] “Arp spoofing.” `http://en.wikipedia.org/wiki/ARP_spoofing`.

[22] Q. Gu and P. Liu, “Denial of service attacks,” *Handbook of Computer Networks: Distributed Networks, Network Planning, Control, Management, and New Trends and Applications, Volume 3*, pp. 454–468, 2007.

[23] “Man-in-the-middle attack.” `http://en.wikipedia.org/wiki/Man-in-the-middle_attack`.

[24] “Man in the middle - hacking illustrated.” `http://www.slideshare.net/infosecinstitute/man-in-the-middle-hacking-illustrated-4908785`.

[25] “Understanding 802.11 frame types.” `http://www.wi-fiplanet.com/tutorials/article.php/1447501`.

[26] L. C. C. Desmond, C. C. Yuan, T. C. Pheng, and R. S. Lee, “Identifying unique devices through wireless fingerprinting,” in *Proceedings of the first ACM conference on Wireless network security*, pp. 46–55, ACM, 2008.

[27] D. B. Faria and D. R. Cheriton, “Detecting identity-based attacks in wireless networks using signalprints,” in *Proceedings of the 5th ACM workshop on Wireless security*, pp. 43–52, ACM, 2006.

[28] Y. Sheng, K. Tan, G. Chen, D. Kotz, and A. Campbell, “Detecting 802.11 mac layer spoofing using received signal strength,” in *INFOCOM 2008. The 27th Conference on Computer Communications. IEEE*, IEEE, 2008.

[29] W. Li and A. Joshi, “Security issues in mobile ad hoc networks-a survey,” *Department of Computer Science and Electrical Engineering, University of Maryland, Baltimore County*, pp. 1–23, 2008.

[30] B. Danev, D. Zanetti, and S. Capkun, "On physical-layer identification of wireless devices," *ACM Computing Surveys (CSUR)*, vol. 45, no. 1, p. 6, 2012.

[31] S. Devadas, E. Suh, S. Paral, R. Sowell, T. Ziola, and V. Khandelwal, "Design and implementation of puf-based" unclonable" rfid ics for anti-counterfeiting and security applications," in *RFID, 2008 IEEE International Conference on*, pp. 58–64, IEEE, 2008.

[32] J. Franklin, D. McCoy, P. Tabriz, V. Neagoe, J. V. Randwyk, and D. Sicker, "Passive data link layer 802.11 wireless device driver fingerprinting," in *Proc. 15th USENIX Security Symposium*, pp. 167–178, 2006.

[33] B. Beizer, *Black-box testing: techniques for functional testing of software and systems.* John Wiley & Sons, Inc., 1995.

[34] J. C. Goswami and A. K. Chan, *Fundamentals of wavelets: theory, algorithms, and applications*, vol. 233. John Wiley & Sons, 2011.

[35] K. Gao, C. Corbett, and R. Beyah, "A passive approach to wireless device fingerprinting," in *Dependable Systems and Networks (DSN), 2010 IEEE/IFIP International Conference on*, pp. 383–392, IEEE, 2010.

[36] W. Gu, Z. Yang, C. Que, D. Xuan, and W. Jia, "On security vulnerabilities of null data frames in ieee 802.11 based wlans," in *Distributed Computing Systems, 2008. ICDCS'08. The 28th International Conference on*, pp. 28–35, IEEE, 2008.

[37] C. Idland, T. Jelle, and S. F. Mjølsnes, "Detection of masqueraded wireless access using 802.11 mac layer fingerprints," in *Digital Forensics and Cyber Crime*, pp. 283–301, Springer, 2013.

[38] K. Gopinath, P. Bhagwat, and K. Gopinath, "An empirical analysis of heterogeneity in ieee 802.11 mac protocol implementations and its implications," in *Proceedings of the 1st international workshop on Wireless network testbeds, experimental evaluation & characterization*, pp. 80–87, ACM, 2006.

[39] B. E. Henty, "A brief tutorial on the phy and mac layers of the ieee 802.11 b standard," *White paper, Intersil*, 2001.

[40] E. Holgernes, "Detecting identity thefts in open 802.11 e enabled wireless networks," 2010.

[41] E. W. Ulf Lamping, Richard Sharpe, "Wireshark user's guide." `http://www.wireshark.org/docs/wsug_html_chunked/`.

[42] "airmon-ng [aircrack-ng]." `www.aircrack-ng.org/doku.php?id=airmon-ng`, 2010.

[43] "Matlab." `http://www.mathworks.in/help/matlab/getting-started-with-matlab.html`, 2014.

[44] Proakis and Manolakis, "Signal processing - continuous and discrete." `http://ocw.mit.edu/courses/mechanical-engineering/2-161-signal-processing-continuous-and-discrete-fall-2008/lecture-notes/lecture_22.pdf`, 2008.

[45] "Autocorrelation." `http://en.wikipedia.org/wiki/Autocorrelation`, 2014.

[46] "Discrete fourier transform." `http://en.wikipedia.org/wiki/Discrete_Fourier_transform`, 2014.

[47] "Cross correlation." `http://en.wikipedia.org/wiki/Cross-correlation`, 2014.