Automation of MitM Attack on Wi-Fi Networks

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https://mvondracek.github.io/wifimitm/

Abstract. Widely used network technologies and principles of wireless security suffer weaknesses that can be exploited to perform the Man-in-the-Middle attack, allowing to eavesdrop or to spoof the network communication. The work focuses on possibilities of automation of the attack with a utilization of available specialized tools. The outcome of the research is the *wifimitm* package and the *wifimitmcli CLI* tool, both implemented in Python. The package provides functionality for automated *MitM* attack and can be used by other software. The *wifimitmcli* tool is capable of performing a successful fully automated attack without any intervention from an investigator.
This research is intended to be used for automated penetration testing and to ease forensic investigation. Finally, a popularization of the fact that such severe attacks can be successfully automated should be used to raise the public awareness about the information security.

Key words: Man-in-the-Middle attack, accessing secured wireless networks, password cracking, dictionary personalization, tampering network topology, impersonation, phishing

1 Introduction

This paper aims at research concerning a security of wireless networks. It delivers a study of widely used network technologies and principles of wireless security. Analyzed technologies and security algorithms suffer weaknesses that can be exploited to perform the Man-in-the-Middle attack. A successful realization of this attack allows not only eavesdropping on all the victim's network traffic but also spoofing the communication [1], [16, pp. 101–120], [21, pp. 4–7].

The victim, in this case, is a suspect conducting his activity on a targeted network. The attacker is a law-enforcement agency investigator with appropriate legal authorization to intercept the communication and further more to perform a direct attack on the network. In some cases, the suspect might be aware of the possibility that his communication might be intercepted or can and do harden his network. For example, he uses any of overlay networking technologies, e.g., *VPN* implemented by *L2TP*, *IPsec* [9, pp. 09–10], *PPTP* in the traditional way to connect securely to some other entity, or anonymization network like Tor, I2P, etc., to create an encrypted tunnel configured on his gateway, for all external

communication. This concept is easy to implement and does not require any additional configuration on endpoint devices. The interception outside of suspect's *LAN* would not yield necessary evidence in comparison with the interception inside. On the one hand, this scheme is considered not secure [5, pp. 425-431], on the other, it is used by large vendors like Cisco[2] or Microsoft[19] for branch office deployment. In these cases, even when an investigator is legally permitted to carry out an attack, this kind of approach to get evidence is scarcely used, because it requires expert domain knowledge to be planned and exercise without any trace noticeable by the suspect. Thus, this process of evidence collection is very expensive and human resource demanding.

The aim of this research is to design, implement and test a tool able to automate the whole process of accessing a secured *WLAN* and to perform data interception. Further more, this tool will be able to tamper with the communication to provide more evidence by getting in the middle of the communication to access otherwise encrypted data in not encrypted form. This way, using the automated tool would not require any expert knowledge from the investigator. For the chosen implementation of the *MitM* attack (Figure 1), It is necessary for an investigator to obtain access to the *WLAN* used by the suspect. Therefore, this research focuses on exploitable weaknesses of particular security algorithms. Upon successful connection to the network, the investigator needs to adjust a network topology. For this purpose, weaknesses of several network technologies can be exploited. From the point when the investigator is connected to the network, and the topology is successfully modified, the investigator can start to intercept or to change all the suspect's network traffic.

Specialized tools focused on exploiting individual weaknesses in security algorithms currently used in *WLAN*s are already available. There are also specialized tools focused on individual steps of the *MitM* attack. Tools that were researched and selected for incorporation are outlined in section 2.

Based on the acquired knowledge, referenced studies and practical experience from manual experiments, authors were able to create an attack strategy. The plan is composed of an appropriate set of available tools. The strategy is then able to select and manage individual steps which are the most suitable for a successful *MitM* attack on given *WLAN*. This strategy further includes ways of impersonation and phishing for cases, when the network is properly secured, and the weakest part of the security is the legitimate user.

The final solution was tested during experiments with an available set of equipment. Developed open source software, which could be incorporated into other tools, can perform a fully automated attack and requires zero knowledge. The use case of this software is found in automated penetration testing, forensic investigation, and education.

2 Security Weaknesses in WLAN Technologies

Following network technologies (Sections 2.1, 2.2), which find a significant utilization, unfortunately, suffer from security weaknesses in their protocols. These flaws can be used in the process of the *MitM* attack.

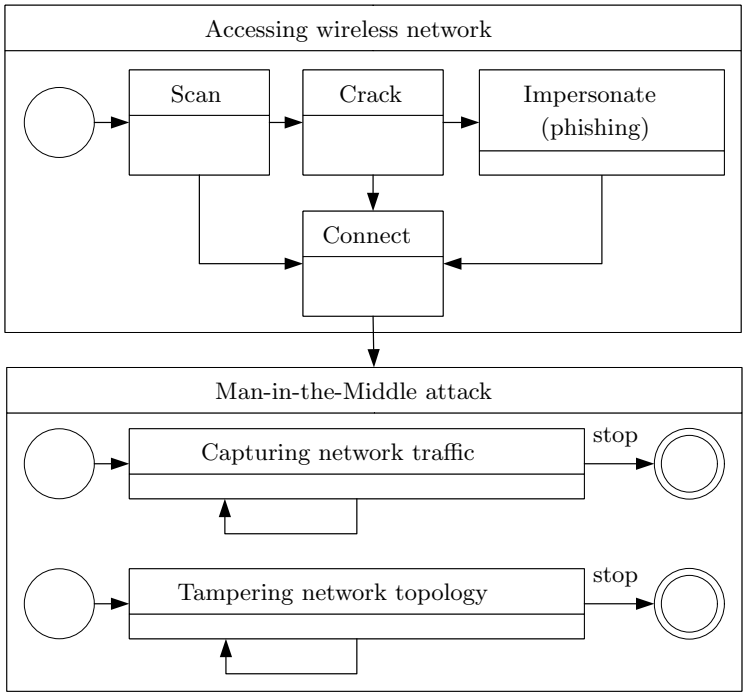

Fig. 1. During the first phase – *Accessing wireless network*, the tool is capable of an attack on *WEP OSA*, *WEP SKA*, *WPA PSK* and *WPA2 PSK* secured *WLAN*s. In a case of the dictionary attack on the device deployed by the UPC company, used dictionaries are personalized by the implicit passwords. In the case of properly secured *WLAN*, impersonation (phishing) can be employed. Using this method, an investigator impersonates the legitimate network to obtain the *WLAN* credentials from the user. For the second phase – *Tampering network topology*, *ARP Spoofing* technique was selected from the researched methods. This method proved itself with reasonable performance during experiments. During this phase, the tool needs to continuously work on keeping the network *stations* (*STA*s) persuaded that the spoofed topology is the correct one. An investigator is now able to capture or modify the traffic. The successful *MitM* attack is established.

2.1 Wireless Security

Wired Equivalent Privacy (*WEP*) is a security algorithm introduced as a part of the IEEE 802.11 standard [6, p. 665], [8, pp. 1167–1169]. At this point, *WEP*

is deprecated and superseded by subsequent algorithms, but is still sometimes used, as can be seen from Table 1 available from *Wifileaks.cz*[1]. *WEP* suffers from weaknesses and, therefore, it has been broken [4]. There are already implemented tools to provide access to wireless networks secured by *WEP* available [18]. Regarding *WEP* secured *WLAN*s, authentication can be either *Open System Authentication* (*OSA*) or *Shared Key Authentication* (*SKA*) [8, pp. 1170–1174]. In the case of *WEP OSA*, any *station* (*STA*) can successfully authenticate to the *Access Point* (*AP*) [17, pp. 4–10]. *WEP SKA* provides authentication and security of transferred communication using a shared key. Confidentiality of transferred data is ensured by encryption using the *RC4* stream cipher. Methods used for cracking access to *WEP* secured networks are based on analysis of transferred data with corresponding *Initialization Vectors* (*IV*s).

Wi-Fi Protected Access® (*WPA*) was developed by the Wi-Fi Alliance® as a reaction to increasing number of security flaws in *WEP*. The main flaw of *WPA* security algorithm can be identified at the beginning of client device's communication, where an unsecured exchange of confidential information is performed during the four-way handshake. An investigator can obtain this unsecured communication and use it for consecutive cracking of the *Pre-Shared Key* (*PSK*).

Wi-Fi Protected Access® *2* (*WPA2*^{TM}) is a successor of *WPA*, but security flaws of the *WPA PSK* algorithm remain significant also for the *WPA2 PSK*. Information exposed during the handshake can be used for the dictionary attack, which can be further improved by precomputing the *Pairwise Master Keys* (*PMKs*) [12, pp. 37–38], [13, p. 3]. Precomputed lookup tables are already available online[2].

Table 1. Following table summarizes *WLAN* statistics provided by *Wifileaks.cz*. Users of this service voluntarily scan and publish details about *WLAN*s in the Czech Republic. Information in the table show that a significant number of *WLAN*s still use deprecated security algorithms. The statistics consisting of 97 192 922 measurements of 2 548 054 *WLAN*s were published on May 26, 2017.

Security	Count	Ratio
WPA2	1 429 518	56 %
WEP	393 579	15 %
WPA	375 984	15 %
open	67 388	3 %
other	281 585	11 %

A critical security flaw in wireless networks secured by *WPA* or *WPA2* is the functionality called *Wi-Fi Protected Setup*^{TM} (*WPS*). This technology was introduced with an aim to provide a comfortable and secure way of connecting to the network. For a connection to the *WLAN* with *WPS* enabled, it is possible to use an individual *PIN*. However, the process of connecting to the properly

[1] `http://www.wifileaks.cz/statistika/`
[2] `https://www.renderlab.net/projects/WPA-tables/`

secured network by providing *PIN* is very prone to brute-force attacks [7]. Because *WPS* is a usual feature in today's access points and that *WPS* is usually turned on by default, *WPS* can be a very common security flaw even in networks secured by *WPA2* with a strong password. Currently, there are already available automated tools for exploiting *WPS* weaknesses, e.g., *Reaver Open Source*[3].

Table 2. Results of wardriving in Bratislava and Brno focused on UPC vulnerabilities concerning default *WPA2 PSK* passwords [11]. Detailed article about these security flaws is available online [10].

Bratislava (capital of Slovakia) 2016-10-01	Count	Ratio
Total networks	22 172	
UPC networks	3 092	13.95 %
UPC networks, vulnerable	1 327	42.92 % UPC
Brno (city in the Czech Republic) 2016-02-10	**Count**	**Ratio**
Total networks	17 516	
UPC networks	2 868	16.37 %
UPC networks, vulnerable	1 835	63.98 % UPC

Newly purchased access points usually use *WPA2* security by default. Currently, many access points can be found using default passwords not only for wireless network access, but even for *AP*'s web administration. In a case of possible access to the *AP*'s administration, the investigator could focus on changing the network topology by tampering the network configuration. Access to the network management further allows the investigator to lower security levels, disable attack detections, reconfigure *DHCP* together with *DNS* and also clear *AP*'s logs. There are already implemented tools, which exploit relations between *SSID*s and default network passwords, e.g., *upc_keys*[4] by Peter Geissler.[5] These tools could be used in an attack on the network with default *SSID* to improve dictionary attack using possible passwords. High severity of these security flaws is also proven by the fact that a significant amount of *WLAN*s was found using unchanged passwords, as it is shown in Table 2.

2.2 Network Technologies Used in WLANs

DHCP is used to provide a network device with a suitable configuration without the need for intervention from the user [3]. *ARP* provides the mapping of *IP* address to the corresponding *MAC* address of the device in local area network based on *IPv4* [14]. *IPv6* utilizes features of *ICMPv6* to map devices in the local

[3] `https://code.google.com/archive/p/reaver-wps/`
[4] `https://haxx.in/upc-wifi/`
[5] UPC company is a major ISP in the Czech Republic, URL: `https://www.upc.cz`

network with Neighbor Discovery. *IPv6* Neighbor Discovery provides similar functionality as *ARP* in *IPv4* networks.

Tampering network topology could be performed at the moment when an investigator is successfully connected to the target wireless network. *DHCP Spoofing* generates fake *DHCP* communication. This attack can also be referred to as *Rogue DHCP*. An investigator can perform this kind of attack to provide devices in the network with malicious configuration, most often a fake default gateway address or *DNS* address. A possible countermeasure, *DHCP Snooping*, is further described in the thesis [20]. A network attack called *ARP* Spoofing focuses on providing the network devices with fake *ARP* messages. Investigator's possibilities are in persuading the suspect that the investigator's *MAC* address is correctly mapped to some specific *IP* address. If the investigator's aim is to be in the *MitM* position, he can persuade the suspect about the mapping of default gateway's *IP* address to the investigator's *MAC* address. Possible defense against *ARP* Spoofing attack is analysis of *ARP* messages transmitted in the network – Dynamic ARP Inspection [20]. The absence of *ARP* in *IPv6* does not guarantee immunity to the attacks based on a very similar principle as *ARP* Spoofing. An investigator can send a specially generated *ICMPv6* neighbor advertisement message to the suspect. The main aim of the investigator is, in this case, the same as in the previous attack. The investigator wants to be in the position suitable for the *MitM* attack. Possible defense is a Neighbor Discovery Inspection, as described in the thesis [20].

2.3 Available Tools for Specific Phases of the MitM Attack on Wireless Networks

From perspective of the intended functionality of the implemented tool, the whole process of *MitM* attack on wireless networks can be divided into three main phases: *Accessing wireless network*, *Tampering network topology* and *Capturing network traffic*, as explained in Figure 1.

To access secured wireless networks, *Aircrack-ng suite*[6] is considered a reliable software solution. Considering the phase *Accessing wireless network* (Figure 1), following tools were utilized. *Airmon-ng* can manage modes of a wireless interface. *Airodump-ng* can be used to scan and detect attacked *AP*. *Aircrack-ng* together with *aireplay-ng*, *airodump-ng* and *upc_keys* can be utilized for cracking *WEP OSA*, *WEP SKA*, *WPA PSK* and *WPA2 PSK*. The tool *wifiphisher*[7] can be used to perform impersonation and phishing. Connection to the wireless network can be established by *netctl*[8]. *MITMf*[9] with its *Spoof* plugin can be used during the *Tampering network topology* phase. *Capturing traffic* can be done by the tool *dumpcap*[10], which is part of the *Wireshark*[11] distribution. Behaviour,

[6] `http://www.aircrack-ng.org/`
[7] `https://github.com/sophron/wifiphisher`
[8] `https://www.archlinux.org/packages/core/any/netctl/`
[9] `https://github.com/byt3bl33d3r/MITMf`
[10] `https://www.wireshark.org/docs/man-pages/dumpcap.html`
[11] `https://www.wireshark.org/`

usage and success rate of individual tools, as well as possibilities of controlling them by the implemented tool, were analyzed. The software selected for individual tasks of the automated *MitM* attack were chosen from the researched variety of available tools based on performed manual experiments, further described in the thesis [20].

3 Attack Automation Using Developed wifimitm Package and wifimitmcli Tool

The implemented tool is currently intended to run on *Arch Linux*[12], but it could be used on other platforms which would satisfy specified dependencies. This distribution was selected because it is very flexible and lightweight. Python 3.5 was selected as a primary implementation language for the automated tool and Bash was chosen for supporting tasks, e.g., installation of dependencies on *Arch Linux* and software wrappers.

The functionality implemented in the *wifimitm* package could be directly incorporated into other software products based on Python language. This way the package would work as a software library. Schema of the *wifimitm* package is in Figure 2.

The *wifimitm* package consists of following modules. The `access` module offers an automated process of cracking selected *WLAN*. It uses modules `wep` and `wpa2`, which implement attacks and cracking based on the used security algorithm. The `wep` module is capable of fake authentication with the *AP*, *ARP replay* attack (to speed up gathering of *IV*s) and cracking the key based on *IV*s. In the case of *WPA2* secured network, the `wpa2` module can perform a dictionary attack, personalize used dictionary and verify a password obtained by phishing. Verification of the password and dictionary attacks are done with a previously captured handshake. The `common` module contains functionality which could be used in various parts of the process for scanning and capturing wireless communication in monitor mode. The `common` module also offers a way to deauthenticate *STA*s from selected *AP*.

If a dictionary attack against a correctly secured network fails, a phishing attack can be managed by the `impersonation`[13] module. The `topology` module can be used to change network topology. It provides functionality for *ARP Spoofing*. The `capture` module focuses on capturing network traffic. It is intended to be used after the tool is successfully connected to the attacked network and network topology was successfully changed into the one suitable for *MitM* attack.

3.1 Attack Data

Various attacks executed against the selected *AP* require some information to be captured first. ARP request replay attack on *WEP* secured networks requires

[12] `https://www.archlinux.org/`

[13] For details concerning individual phishing scenarios, please see *wifiphisher*'s website. `https://github.com/sophron/wifiphisher`

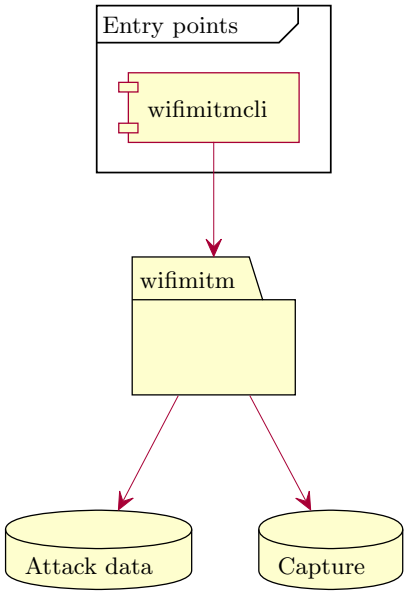

Fig. 2. This figure shows the basic structure of the developed application. The tool *wifimitmcli* uses a functionality offered by the package *wifimitm*. The package is also able to manipulate attack data useful for repeated attacks and capture files with intercepted traffic. Detailed structure of the package is described in section 3.

an ARP request to be obtained in order to start an attacking procedure. Fake authentication in *WEP SKA* secured network needs *PRGA XOR* obtained from a detected authentication. Dictionary attack against *WPA PSK* and *WPA2 PSK* secured networks requires a captured handshake. Finally, for the successful connection to a network, a correct key is required. When the required information is obtained, it can be saved for a later usage to speed up following or repetitive attacks. Data from successful attacks could be even shared between users of the implemented tool.

3.2 Dictionary Personalization

Weaknesses in default network passwords could be exploited to improve dictionary attacks against *WPA PSK* and *WPA2 PSK* security algorithms. The implemented tool incorporates *upc_keys*[14] for generation of possible default passwords if the selected network matches the criteria. The *upc_keys* tool generates passwords, which are transferred to the cracking tool using pipes. With this approach, the implemented tool could be further improved for example to support localized dictionaries.

[14] `https://haxx.in/upc-wifi/`

3.3 Requirements

The implemented automated tool depends on several other tools, which are being controlled. The Python package can be automatically installed by its setup including Python dependencies. Non-Python dependencies can be satisfied by installation scripts and wrappers, which are currently developed for *Arch Linux*.

MITMf has a number of dependencies. Therefore, the installation script also creates a virtual environment dedicated to *MITMf*. After installation, *MITMf* can be easily run encapsulated in its environment. *Wifiphisher* is also installed in its own environment and run using a wrapper. Tool *upc_keys* is compiled during installation. Some changes in *wifiphisher*'s source code were implemented, the installation script therefore applies a software patch. Other software dependencies are installed using a package manager.

Due to the nature of concrete steps of the attack, a special hardware equipment is required. During the scanning and capturing of network traffic without being connected to the network, an attacking device needs a wireless network interface in monitor mode. For sending forged packets, the wireless network interface also needs to be capable of packet injection. To be able to perform a phishing attack, a second wireless interface capable of master (AP) mode has to be available. The user can check whether his hardware is capable of packet injection using the *aireplay-ng* tool. Managing monitor mode of interface is possible with the *airmon-ng* tool.

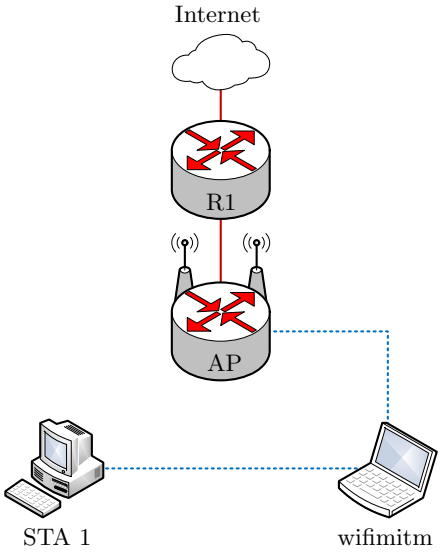

Fig. 3. This figure shows the network topology used for the first performance testing (Section 4) and success rate measurements (Section 5). Results of this performance testing are in Figure 5.

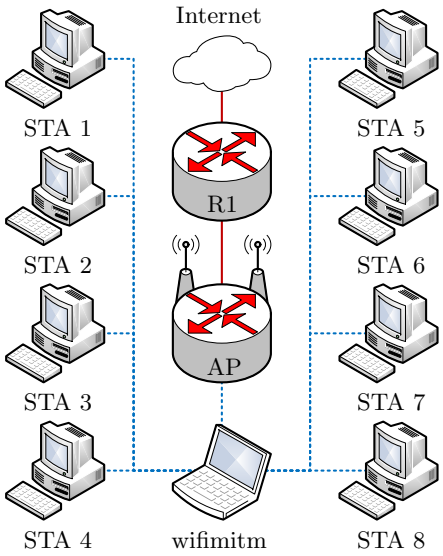

Fig. 4. This figure shows the network topology consisting of 8 *STA*s and 1 *AP* which was used for the second performance testing (Section 4). Results of this performance testing are in Figure 6.

4 Attack's Performance Impact

A scheme of the networks used for the experiments is shown in Figures 3 and 4. The *STAs* were correctly connected to the *AP* and they were successfully communicating with the Internet. The implemented *wifimitmcli* tool was then started and automatically attacked the network.

The performance impact of the *wifimitm* was compared using setups based on SOHO[15] environment. Both experiments were also evaluated based on the fact, whether the attack being performed was revealed or whether the users had any suspicion about the malicious transformation of their *WLAN*. Results of the testing are presented in Figures 5 and 6.

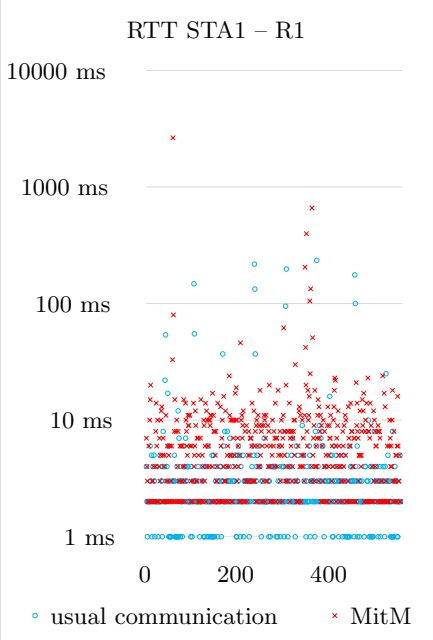

Fig. 5. The first *WLAN* for performance testing was the same as for the success rate measurements described in Section 5. Figure shows comparison of the measured *RTT* between *STA1* and *R1* during usual communication and during successful *MitM* attack. The results show the performance impact is not critical. Discussion with the users of the attacked network proved this attack unrecognizable.

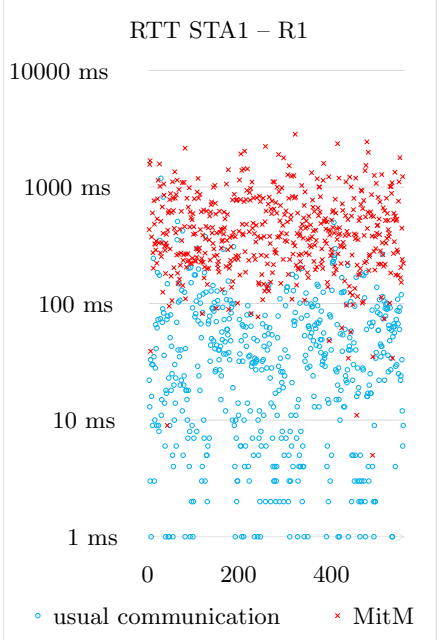

Fig. 6. The second performance testing consisted of 8 *STA*s and 1 *AP* connected to the Internet – streaming videos, downloading large files, etc. The figure compares the *RTT* between *STA1* and *R1* similarly. The performance impact is more severe than in Figure 5. Despite the performance impact, the users had no suspicion that they were under *MitM* attack. Instead, they blamed the amount of devices for network congestion.

[15] small office/home office

5 Experiments Concerning Various Network Configurations and Devices

The test was considered successful if the *wifimitmcli* was able to capture network traffic according to the concept of *MitM*. For the test to be correct, no intervention (help) from the investigator was allowed during the attack performed by *wifimitmcli*. Results of the success rate measurements are shown in Tables 3, 4.

Table 3. This table presents results of the success rate measurements. A successful attack is marked using a *checkmark* symbol (✓) and unsuccessful attack is marked using a *times* symbol (×). In the case when the attack was not fully successful, the question mark (?) is used. Such partially successful test (? symbol) can for example happen in situation where the suspect is sending only a portion of his traffic through the investigator. Some of the used *STA*s lack *WEP SKA* settings (☐ symbol). Testing *WPA PSK* and *WPA2 PSK* networks were configured with password "`12345678`" and *WEP* secured networks used password "`A_b#1`".

		Lenovo G580, Windows 10	Lenovo G505s, Windows 8.1	Dell Latitude E6500, Ubuntu 17.04	HTC Desire 500, Android 4.1.2	Apple iPhone 4, iOS 7.1.2
Linksys WRT610N	*open*	✓	✓	✓	✓	✓
	WEP OSA	✓	✓	✓	✓	✓
	WEP SKA	☐	☐	✓	✓	✓
	WPA PSK	✓	✓	✓	✓	✓
	WPA2 PSK	✓	✓	✓	✓	✓
Linksys WRT54G	*open*	✓	✓	✓	✓	✓
	WEP OSA	✓	✓	✓	✓	✓
	WEP SKA	☐	☐	✓	✓	✓
	WPA PSK	✓	✓	✓	✓	✓
	WPA2 PSK	✓	✓	✓	✓	✓
Linksys WRP400	*open*	✓	✓	✓	✓	✓
	WEP OSA	✓	✓	✓	✓	✓
	WEP SKA	☐	☐	✓	✓	✓
	WPA PSK	✓	✓	✓	✓	✓
	WPA2 PSK	✓	✓	✓	✓	✓
TP-LINK TL-WR841N	*open*	?	×	✓	✓	✓
	WEP OSA	?	×	✓	✓	×
	WEP SKA	☐	☐	✓	✓	×
	WPA PSK	?	×	✓	✓	×
	WPA2 PSK	?	×	✓	✓	×
D-Link DVA-G3671B	*open*	✓	✓	✓	✓	✓
	WEP OSA	✓	✓	✓	✓	✓
	WEP SKA	☐	☐	✓	✓	✓
	WPA PSK	✓	✓	✓	✓	✓
	WPA2 PSK	✓	✓	✓	✓	✓

Table 4. The following table shows the results of public experiments. Visitors of the Brno University of Technology, Faculty of Information Technology were invited to let their devices be attacked. Testing network utilized *Linksys WRP400* device as an AP. Symbols used in the table are the same as in Table 3.

Model	OS	Attack
HTC Desire 500	Android 4.1.2	✓
HTC Desire 820	Android 6.0.1	✓
Apple iPhone 6	iOS 10.3.1	✓
Apple iPhone 5s	iOS 10.2.1	✓
Apple iPhone 5	iOS 10.3.1	✓
Apple iPhone 5c	iOS 9.2.1	✓
Apple iPhone 4	iOS 7.1.2	✓

Results of experiments (Table 3, 4 and the thesis [20, pp. 42–43]) show, that open networks can be very easily attacked. *WEP OSA* and *WEP SKA* secured networks can be successfully attacked even if they use a random password. *WPA PSK* and *WPA2 PSK* secured networks suffer from weak passwords (dictionary attack), default passwords and mistakes of users (impersonation and phishing). As Figures 5, 6 and Tables 3, 4 show, *MitM* attack using the *wifimitm* is successfully feasible in the target environments.

6 Conclusions

The goal of this research was to implement a tool that would be able to automate all the necessary steps to perform the *MitM* attack on *WLAN*s. The authors searched for and analyzed a range of software and methods focused on penetration testing, communication sniffing and spoofing, password cracking and hacking in general. To be able to design, implement and test the tool capable of such attack, knowledge of different widespread security approaches was essential. The authors further focused on possibilities of the *MitM* attack even in the case that given *WLAN* is secured correctly. Therefore, methods and tools for impersonation and phishing were researched and analyzed.

The authors' work and research resulted in a development of the *wifimitm* package implemented in the Python language. This package serves as a software library which provides functionality for automated *MitM* attack on *WLAN*s. The developed package is, therefore, beneficial for others because it can be easily incorporated into other tools. The product of this research is also a tool which incorporates the functionality of the *wifimitm* package. This tool named *wifimitmcli* manages the individual steps of automated *MitM* attack and serves as a *CLI*. The implemented software comes with a range of additions for a convenient usage, e.g., requirements installation scripts for *Arch Linux*, requirements check, a Python package setup with *wifimitmcli* installation and of course a manual page.

The *wifimitmcli* tool, and therefore *wifimitm* as well, was tested during experiments with an available set of equipment. As the results show, the implemented software product is able to perform an automated *MitM* attack on *WLAN*s successfully.

This research and its products could find a good utilization in combination with other security researches carried out at the Brno University of Technology, Faculty of Information Technology. It can serve in an investigation done by forensic researchers [15]. A software capable of automated *MitM* attack on *WLAN*s can also be used to improve the security of networks by automatically detecting their vulnerabilities. This way, *wifimitmcli* can be considered an automated penetration testing tool.

In the future iterations of the development, the product could focus on exploiting the weaknesses of widely used *WPS*. Concerning the current state of the product, it does not focus on enterprise *WLAN*s, which suffer their weaknesses as well.

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