Detecting and Combating ARP Spoofing

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ABSTRACT

In light of the 'Sparkle Vulnerability'[1] incident that occurred early in 2016, our team has been particularly interested in preventing Man-In-The-Middle (MITM) attacks. These attacks are easy to perform if one is able to carry out either ARP spoofing or DHCP spoofing. Therefore, our research focuses on techniques to circumvent ARP Spoofing. By doing so, it would reduce the chances of an attacker being able to carry out MITM attacks.

Therefore, we hope to create a program for users to actively detect if they are victims of ARP spoofing, and offer them alternative methods to protect themselves over an unsecure network.

In addition, we hope to extend this project to cover DHCP spoofing in the future.

Categories and Subject Descriptors

C.2.0 [**Computer-Communication Networks**]: General - Data Communications, Security and Protection

; D.4.6 [**Security and Protection**]: Authentication, Verification

General Terms

Network Security, Intrustion Detection System (IDS), Address Resolution Protocol (ARP), spoofing

Keywords

ARP spoofing, ARP Poisoning, network security, attack, MITM, IDS, ARP protection

[1]https://sparkle-project.org/documentation/security/

1. INTRODUCTION

The Address Resolution Protocol (ARP) is an important protocol in computer network communications.
Without this protocol, it would be difficult for computers to communicate with each other, because we would not know the MAC address of the computer we are communicating with. Thus, it would be difficult to establish an IP-to-MAC address mapping.

Since the early days of the computer, the ARP cache has been an easy target for ARP attacks like ARP spoofing. Even until today, it is still relatively easy to carry out an ARP spoof, and it remains rather difficult to defend against it.

Ther is a lack of viable solutions to protect the ARP cache because of the way it is designed. In fact, ARP spoofing is easy to carry out over a wireless network if it is not protected by WPA-Enterprise encryption. Over a Local Area Network (LAN), such attacks require a wiretap if the network uses switches instead of hubs.

Some common attacks that can occur after an ARP Spoof are man-in-the-middle (MITM), Denial-of-Service (DOS), or even session hijacking. In such cases, the security principles of Confidentiality, Integrity and Availability may be violated. We will be illustrating how an ARP Spoof occurs in Section 2.

Some common programs which users can use to carry out such an attack include 'Ettercap' and 'Cain and Abel'. As these programs are open source, almost anyone can easily carry out ARP Spoofing with some basic technical knowledge.

2. BACKGROUND

In order to understand how ARP spoofing occurs, we will need to cover the basics on how computers communicate with each other. In this section, we will be explaining how computers do so, and introduce the basic notions of how an ARP spoof is carried out.

2.1 Models and Abstractions

In computer networking, the communication protocols are categorised and organised into different layers. There are 2 commonly used models - the TCP/IP model and the OSI model.

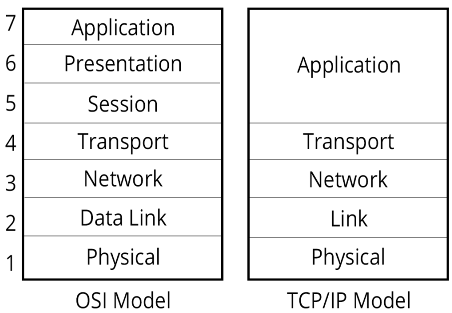
In the TCP/IP Model, there are 5 layers of abstraction:

1. Application Layer
2. Transport Layer
3. Network Layer
4. Link Layer
5. Physical Layer

DHCP is an application layer protocol and ARP is a link layer protocol.

In the OSI Model, there are 7 layers of abstraction:

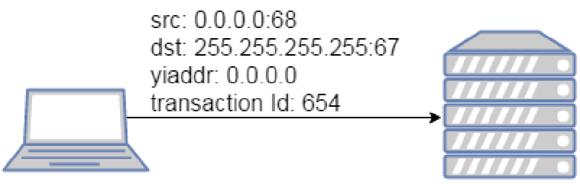
7. Application Layer
6. Presentation Layer
5. Session Layer
4. Transport Layer
3. Network Layer
2. Data Link Layer
1. Physical Layer



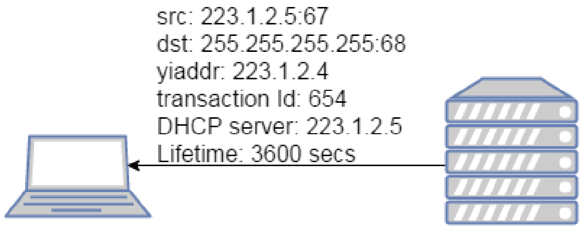
2.2 Computer Communications

In a typical modern computer, all IP addresses are resolved dynamically through the use of the Dynamic Host Configuration Protocol (DHCP). This is carried out in the following steps:

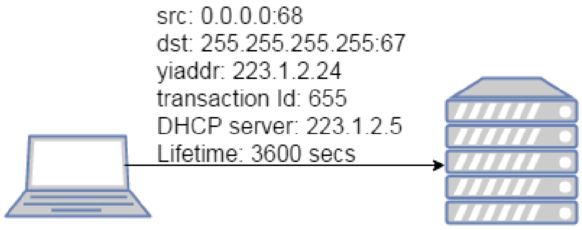
1. DHCP Discover:
The new host broadcasts a DHCP discover message, where 255.255.255.255 is a typical broadcast address.



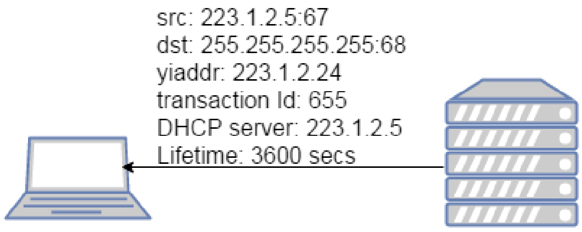
2. DHCP Offer:
The DHCP server responds with a DHCP offer.



3. DHCP Request:
The host selects from the offers and sends a DHCP request.

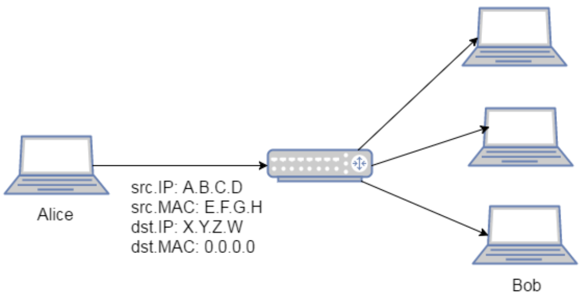


4. DHCP ACK:
The DHCP Server confirms the requested parameters.

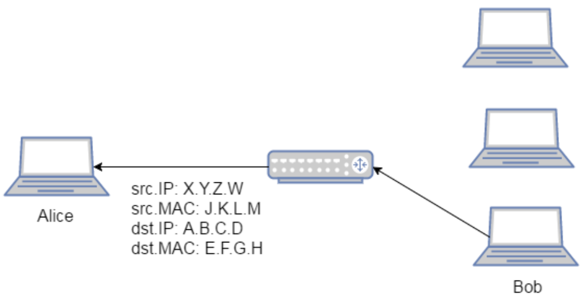


After that, assuming everyone has already had their IPs assigned to them via DHCP, suppose the the user Alice wishes to send some information to Bob. The following steps are then carried out:

1. ARP Request: Alice's computer sends out an ARP request to find out which MAC address has Bob's IP.



2. When Bob's computer receives the request, he sends back an ARP response packet.



3. Alice gets the response and stores the corresponding IP-to-MAC entry into the ARP cache.

2.3 Poisoning the ARP Cache

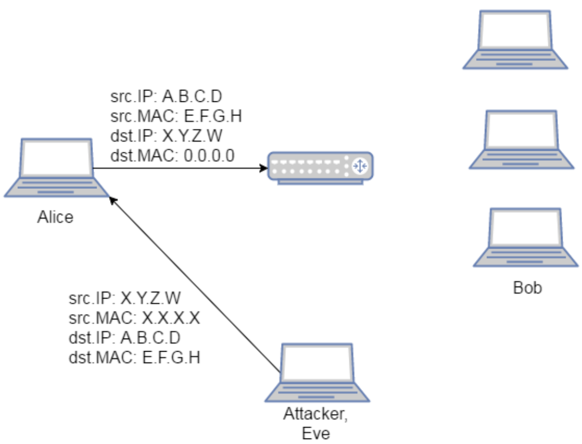
For ARP spoofing to work, the attacker typically has to be in the same network as his victim[3]. Sniffing is carried out to first determine the victim's IP address on the network. This can be done using a network sniffer such as Wireshark.

There are 3 common ways to poison the ARP cache. The first is to send a broadcast request, the second is to send multiple responses, and the third is an unsolicited response. In this paper, we will only cover the second method[5].

If an attacker, Eve, wishes to carry out ARP spoofing, this is typically what happens:

1. Alice's computer sends out an ARP request to find out what is Bob's MAC address.

2. Before Bob's computer can reply, the attacker, Eve, sends a spam of packets to Alice's computer, claiming to be Bob. The ARP cache then becomes poisoned.



In this case, there is a race condition between Eve and Bob to send a response to Alice. If Eve succeeds in responding to Alice before Bob can do so, Alice's ARP cache becomes successfully poisoned.

3. CURRENT SOLUTIONS AND MITIGATIONS

There are currently many solutions in the market to combat ARP Spoofing. However, many of these solutions are described to have major issues. From [4], [1] and [2], these are the summaries and drawbacks of current implementations in the market:

1. Use of Cryptographic Techniques
Examples: S-ARP
This method suggests that the ARP protocol be redesigned with cryptographic measures in place. However, implementing such cryptographic measures severely degrades the runtime performance of the ARP protocol.

2. Passive Detection
Examples: Agnitum Outpost Firewall
Such methods only detect ARP spoofing but are unable to do anything to correct it. In addition, this method assumes that initial setting of ARP entries are correct, as the initial database is used for comparing with an incoming ARP packet to check if it has been spoofed.

3. Kernel-based patches
Examples: Anticap, Antidote
A patch is given to fix the OS Kernel. However, this may cause compatibility issues.

4. Making ARP entries static
In this method, ARP entries are configured to be static. In this case, DHCP will not be used to resolve local IP addresses for a computer. However, it will not be very user-friendly for standard office workers to configure, and will be very difficult for network administrators to manage IP-to-MAC mappings in a huge company.

4. GOALS

In taking up this project, we hoped to achieve the following goals:

1. Provide users with a means to actively combat ARP spoofing
2. Make any network more secure.
3. Provide a GUI for users to see what is happening in their network in real-time.

5. PROOF OF CONCEPT

5.1 Implementation System

Operating System:
OSX El Capitan, Arch-Linux [Manjaro 15.12 Capella]

Software Used and Programming Language:
Python 2.7 with the following libraries: scipy, scapy, matplotlib, tkinter, numpy
Ettercap
Wireshark

5.2 Assumptions

1. Attacker's computer has a normal network stack.

2. Victim computer has at least one TCP port open.

3. All devices have a TCP/IP network stack up and running.

4. Attacker only modifies his data in the Ethernet layer. If he modifies his data in the Network layer as well, then we would not be able to determine who the attacker is, although

we can detect that it is an ARP spoof based on the volume of packets sent.

5.3 Overall Architecture

put a summary of the software system here.

5.4 The Attacker

In our solution, we used Ettercap to stimulate an ARP Spoofing attack.

5.5 The Defender Module

(ming xuan's code)

5.6 The Spoof Detection Engine (IDS)

(wenqi's code)

5.7 The GUI

to insert a picture once GUI is completed

6. OUR SOLUTION VERSUS CURRENT SOLUTIONS

In contrast to current available solutions, we tried to adopt an active method of detecting ARP spoofing.

7. LIMITATIONS AND FUTURE WORK

Our project has several flaws which we were unable to resolve within a reasonable timeframe:

1. Our solution will not work on a network that employs WPA-Enterprise level of encryption. This is because the structure of WPA-Enterprise is such that each user can only see his incoming or outgoing network connections.

2. Our solution assumes that the user does not have any form of defence installed on his computer. (eg. no firewall that can prevent ARP spoofing, a network that does not use any enterprise level encryption, etc.)

3. The attacks have only been tested to work for various users across the wireless network which uses no encryption, WEP, WPA, and WPA2. While it might work on a network that uses a hub, it might require a wiretap for a switched network.

We hope to improve our solution for a more varied set of systems in the future. Furthermore, if we are able to tell who our attacker is, we hope to implement a more aggressive method to counter their ARP attacks, such as spoofing them back.

In addition, this project could be extended to prevent DHCP Spoofing from the local to remote network, by implementing DHCP Snooping.

8. CONCLUSION

Through this project, we have learnt that ARP Spoofing is not easy to defend against. Even though there are solutions on the market that have been out for a while, unless one is using a network encrypted by WPA-Enterprise, it is otherwise easy to fall prey to such attacks.

Furthermore, as active detection of ARP spoofing is not widely implemented yet, our solution may not be entirely foolproof. Thus, we will need to put in more work to make the solution more viable for a wider variety of situations.

(to modify conclusion and include more stuff)

9. ACKNOWLEDGEMENTS

First and foremost, we would like to thank Prof. Hugh Anderson for his guidance and patience with us throughout the semester. Our initial project was to investigate the hacking of Hello Barbie. However, we eventually decided to change the topic for various reasons, and he very kindly allowed us to do so. This is despite the topic being changed quite late in the semester, and on top of it, was self-proposed.

Our thanks also goes out to him for loaning us the Hello Barbie even though we eventually dropped the project.

In addition, our appreciation also goes out to our friends who have loaned us various items for our project, such as a DLink Dir-825 router which runs on DD-RWT, so that we could work on the project in school.

10. REFERENCES

[1] N. Behboodian and S. A. Razak. Arp poisoning attack detection and protection in wlan via client web browser. pages 20–24, December 2011.

[2] G. Kaur and J. Malhotra. A review of latest techniques to secure wireless networks against arp poisoning attacks. *International Journal of the Future Generation Communication and Networking*, 8(2):225–232, 2015.

[3] A. Ornaghi and M. Valleri. Man in the middle attacks. 2003.

[4] V. Ramachandran and S. Nandi. Detecting arp spoofing: An active technique. pages 1–13.

[5] R. Wagner. Address resolution protocol spoofing and man-in-the-middle attacks. August 2001.

Table 1: Frequency of Special Characters

Non-English or Math	Frequency	Comments
Ø	1 in 1,000	For Swedish names
π	1 in 5	Common in math
\$	4 in 5	Used in business
Ψ_1^2	1 in 40,000	Unexplained usage

10.1 Tables

Because tables cannot be split across pages, the best placement for them is typically the top of the page nearest their initial cite. To ensure this proper "floating" placement of tables, use the environment **table** to enclose the table's contents and the table caption. The contents of the table itself must go in the **tabular** environment, to be aligned properly in rows and columns, with the desired horizontal and vertical rules. Again, detailed instructions on **tabular** material is found in the *LaTeX User's Guide*.

Immediately following this sentence is the point at which Table 1 is included in the input file; compare the placement of the table here with the table in the printed dvi output of this document.

To set a wider table, which takes up the whole width of the page's live area, use the environment **table*** to enclose the table's contents and the table caption. As with a single-column table, this wide table will "float" to a location deemed more desirable. Immediately following this sentence is the point at which Table 2 is included in the input file; again, it is instructive to compare the placement of the table here with the table in the printed dvi output of this document.

Table 2: Some Typical Commands

Command	A Number	Comments
`\alignauthor`	100	Author alignment
`\numberofauthors`	200	Author enumeration
`\table`	300	For tables
`\table*`	400	For wider tables

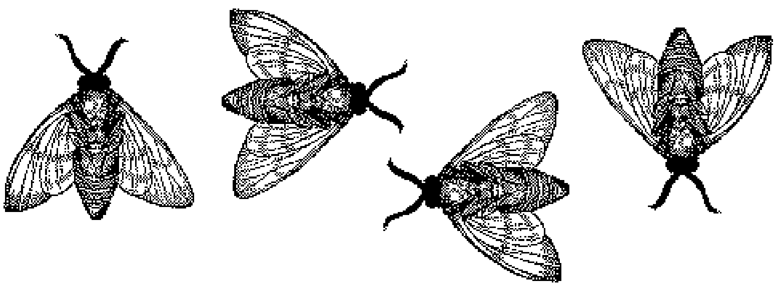


Figure 1: A sample black and white graphic (.eps format) that needs to span two columns of text.