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VPN over HTTP

Project Report

Author: Daniel Jones (1427970)

BSc Computer Science

supervised by
Dr Ian BATTEN

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School of Computer Science
University of Birmingham

VPN over HTTP

Daniel Jones

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Abstract

Problem: VPN traffic is easy to block, and commonly blocked on free public networks.

Solution: HTTP traffic is rarely blocked, so encoding data into HTTP traffic is one possible way to bypass filtering and blocking on public networks.

Conclusion: It is possible to encode data in such a way that it is difficult to detect that this has been done.

All code that was developed can be found at:

<https://git-teaching.cs.bham.ac.uk/mod-ug-proj-2017/dgj470>

Keywords: VPN, HTTP, Tunnelling, Obfuscation, Steganography

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1 Introduction

The aim of this project is to be able to tunnel data, and by extension operate a VPN over the Hypertext Transfer Protocol (HTTP). There are multiple reasons why this would want to be done, for example:

- To access services that are blocked by the current network
- To hide the fact that blocked services are being accessed
- To maintain privacy regarding services that are being accessed

This project enables connections to be made and transmit data only over the HTTP protocol, and provide all of the benefits highlighted above.

1.1 Paper Overview

1. Introduction

- Summary of the aims the project intends to fulfill
- Short overview of the project

2. Existing Work

- Review of literature surrounding the project

3. Background

- High level overview of concepts and designs essential for the project:
 - HTTP
 - TCP
 - VPN
 - Privacy

4. Specification

- Project specification

5. Design

- High level program architecture and design
- Configurable options
- Design choices

6. Implementation

- Detailed information about how each component functions
- High level overview about data flows

7. Testing

- Testing methodologies
- Testing strategy

8. Project Management

- Explanation of how the project was managed

9. Discussion

- An overview of about what was successful
- A review of what was learned

10. Conclusion

- Compare the project to the aims
- Concludes whether or not the project was successful

2 Existing Work

In this section, I explore some related works, and discuss some literature surrounding Steganography, HTTP, DNS tunneling and detecting tunneled traffic.

There has been a lot of work done on the study of steganography, and using different protocols to hide data. The most work has been done on DNS, as it is often below the radar for firewalls and checking if data is being exfiltrated.

2.1 Image Steganography

Steganography is most commonly used for hiding data in unused or unimportant areas of data[1], and the most common form of data for this is images. This is because all of the colour data in an image is not required for a human to see it, and the human eye is very good at filtering out noise[1].

More advanced approaches to steganography can involve identifying redundant data in images[2] which can be better than changing the least significant bit in an image which can be detected by steganalysis[2].

Steganography that is hidden from computers and is hidden from people are quite different things, and can require quite different approaches. The real challenge is to hide data from both.[2].

2.2 DNS steganography

It is possible to hide data very easily in DNS requests, and this is called DNS Tunneling, and it is often used to get around firewalls and hide which websites are being accessed.[3] This paper highlights the point raised in the previous section, that it is very easy for a human to look at the data and see it's not normal, but non-trivial for a computer. The paper describes how the data is detected, and in doing so describes in depth how the data is encoded and tunneled. DNS tunneling as described in the aforementioned paper has a few advantages and disadvantages. The key advantage is that it can be used in locked down networks, as DNS traffic is often let out, but the main disadvantage is that data transfer is very slow with a lot of overhead.

2.3 HTTP protocol

The HTTP 1.1 Protocol[4] is a protocol that describes how data is sent to and from a client, and it describes many areas where data could be included, HTTP traffic can include: Images, HTML, CSS, Javascript, Binary files, and more.

All of which can be used to hide data.

The headers in HTTP are also a potential vector to hide data, as HTTP Headers are whitespace insensitive, and the order in which the headers are sent do not matter[4].

2.4 Detecting tunneled DNS traffic

There are a variety of ways to detect tunneled traffic, from entropy analysis to performing DNS requests[3]. Another way of performing the lookup is to do character frequency analysis[5]. Frequency analysis looks at the difference in frequency of letters in domain names/english words and in random data. It is similar to but not quite the same as entropy analysis, and it is also more effective[5].

3 Background

This section provides an overview of all of the technologies mentioned in the remainder of the project, along with some more abstract concepts.

3.1 HTTP

HTTP is the most important protocol in this project and as such needs to be covered in detail. HTTP/1.1 is defined in RFC2616[4] and all of the information about HTTP comes from that document unless otherwise specified. HTTP is a Request/Response protocol, which means the client Requests some data from the server, and the server returns it. An example request is as follows:

```
GET / HTTP/1.1
Host: localhost
User-Agent: curl/7.58.0
Accept: */*
```

In this request, there is first the request line, and then a series of headers. The headers are a set of key-value pairs which form a dictionary that tells the server extra information about the client.

An example response is as follows:

```
HTTP/1.0 200 OK
Server: SimpleHTTP/0.6 Python/3.6.4
Date: Tue, 20 Mar 2018 14:25:01 GMT
Content-type: text/html
Content-Length: 10088
Last-Modified: Tue, 13 Mar 2018 15:27:09 GMT
```

```
<!doctype html>
<html>
<head>
...
```

In this request the response line is sent, along with some headers which provide important meta-data about the response itself, which is then included when the headers are finished.

3.1.1 HTTP Encoding types

HTTP has a variety of different encoding types and methods. These are specified in the **Transfer-Encoding** and **Content-Encoding**, both of which are used in similar ways to perform compression and other encoding of data.

Transfer encoding allows for chunked encoding[6], which splits the page or portions of data up into multiple sections, and sends the length for each section separately. This is done as then servers can send data as it is generated, rather than having to buffer the entire page.

3.2 TCP

TCP is defined in RFC793[7] and all of the information about TCP comes from there unless otherwise specified. TCP is a connection based protocol that allows for reliable data transfer between a server and a client.

TCP connections are a connection between two sockets, one active and one passive.

A passive socket is listening, and is typically a **server** whereas an active socket is connecting and is typically a **client**.

3.3 Steganography

Steganography is defined as[8]:

the art or practice of concealing a message, image, or file within another message, image, or file

For example this could be encoding data into an image, or into a HTTP stream.

3.4 Obfuscation

Obfuscate is defined as[9]:

to be evasive, unclear, or confusing

Obfuscation is simply the act of being **evasive, unclear, or confusing**.

When applied to computers, this is similar to steganography and the two terms are often used interchangeably, however steganography is the art of concealing and disguising data, whereas obfuscation just makes data difficult to read and understand.

3.5 Encryption

Encryption is the process of converting data to an unrecognizable or ‘encrypted’ form. It is commonly used to protect sensitive information so that only authorized parties can view it[10].

There are many types of encryption, AES and RSA are two major examples.

It’s generally referred to as bad practice to ‘roll your own crypto’[11], which simply means that it is a bad idea to write a cryptographic algorithm yourself, or to try and come up with your own cryptographic scheme.

3.6 Privacy

Privacy on the internet is often overlooked, however, it is vitally important[12]. Almost everything that you do on the internet is tracked by multiple parties: Your internet service provider (ISP), the websites you are visiting, DNS servers, third party servers and many more. These parties could all be gathering information about you to sell.

3.7 Blocking of services

When you connect to Public Wi-Fi, often the provider will limit what content you have access to, often by blocking ‘ports’ or preventing a blacklist of websites.

HTTP is run over port 80, and this is often one of the only ports available. ISP’s have also been known to block certain websites.

3.8 Data Tunnelling

Data Tunnelling is a term for transmitting data in a different form to how it is usually transmitted. A VPN is an example of this, as is an SSH (Secure SHell) tunnel.

3.9 Binary

Binary is how a computer represents data, and it is a series of 1’s and 0’s, each one is called a bit. All characters have a binary representation, and typically characters are made up of 8 bits. Some files and formats don’t have a concept of characters, and instead use a stream, which means that they are dealt with a bit at a time.

3.10 VPN

A VPN or Virtual Private Network which is defined in RFC2764[13], is a piece of software, split into a server and a client, where the server and the client (or clients) form a network which is both virtual and private.

For a network to be private, it needs to be encrypted so no one else can see the data, and for it to be virtual, it only has to exist inside computers, and not physically connected by cables.

In practical terms this means that data is tunnelled from one computer to another, generally by use of `tun` or `tap` devices. IP packets can be read from and written to a `tun` device.

Ethernet frames can be read from and written to a `tap` device.

Which ever device type is used, the packets/frames are transmitted through an existing connection to a remote client or server, which will also read and write from a corresponding device.

A typical example of a VPN is OpenVPN, <https://openvpn.net/>.

4 Specification

4.1 Functional Requirements

1. The system must allow duplex communication with a remote server and local client
2. All communication between the user and the server must be encapsulated within the HTTP Protocol
3. The user must be able to browse websites
4. The user must be able to connect to a remote server, over SSH for example
5. The server and client must expose a TCP port which can be used for multiple applications
6. The server must act as a valid HTTP server serving a valid web page if navigated to
7. The server must act as a mirror to another HTTP server when serving HTTP to both the client and any other clients that may discover it
8. The system should not encrypt data traveling over it, data should be assumed to be already encrypted
9. The client should poll the server for data
10. When the client or server has data to send, the client should increase the frequency of requests
11. The system should be able to serve multiple clients at a time without interference

4.2 Non-functional Requirements

1. The extra data encapsulated within the HTTP protocol must be done in such a way that it looks like typical HTTP traffic and is not easy or obvious to spot.
2. The connection speed must be such that browsing the internet is possible without undue difficulty.
3. If the connection drops, the server and client must work to re-establish the connection

5 Design

6 Implementation

7 Testing

8 Project Management

9 Discussion

10 Conclusion

11 Bibliography

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12 Appendices