Cyber Defense

HIGH1-CE9074

Session 3

Introduction to Personal Security

Use a Virtual Private Network (VPN) on public Wi-Fi

Would you fly on a commercial flight if you could afford a private jet? Probably not. A VPN is like your private jet. If you use a VPN, even http traffic will flow encrypted from your machine. Also, your VPN provider's servers will connect to the destination on your behalf and your machine's identity will be kept secret. If you are using a public network (like at an airport or coffee shop), use VPNs like Tunnelbear from tunnelbear.com or your school provided VPN or some other VPN before using entering any sensitive data (like a password or an account number) while you are on a public Wi-Fi.

Why is public Wi-Fi so dangerous? Well, a hacker can create a fake Wi-Fi network that would look and feel very much like a legitimate Wi-Fi. If you use it, the hacker can record your keystrokes, and get your usernames, passwords and other personal information on various sites.

If the hacker also sends fake software updates to your machine and you install it, the hacker will gain full control over your computer without your knowledge.

To make matters worse, all the tools to do all this are readily available on the internet.

Watch Kevin Mitnick hacking using fake Wi-Fi:

https://www.youtube.com/watch?v=bCaARKQ3-cg

If you absolutely have to use public Wifi without VPN, don't log into any site and don't ever update any software while on it.

Emails - SMTP and POP/IMAP

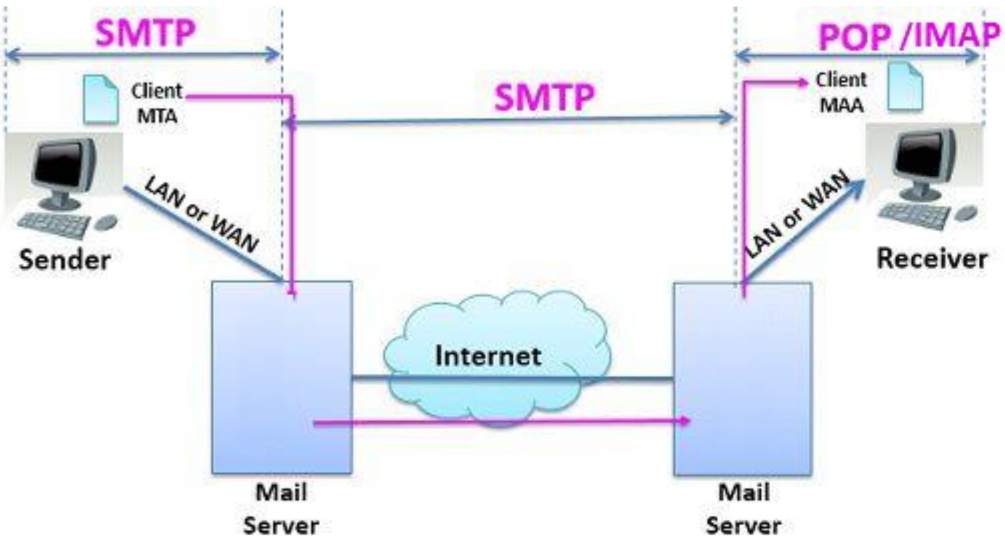
SMTP - Simple Mail Transfer Protocol

POP - Post Office Protocol.

IMAP - Internet Message Access Protocol

When you hit the send button on your email software, your e-mail software (client) connects to your SMTP server using TCP/IP on port 25. Your SMTP server then would become a client and create another TCP/IP connection with the recipient's SMTP server on port 25 to deliver the e-mail. SMTP protocol pretty much stops there, and it does not actually deliver the mail to the recipient.

The recipient of your email would have to use an e-mail software (client) to connect to his/her server using either the POP (port 110) or IMAP (port 143) protocol to retrieve emails.



The message is sent and received in plain-text which is subject to wiretapping.

Watch Kevin Mitnick wiretapping an unsecured email connection:

https://www.youtube.com/watch?v=KcJWXpABpVo

Secured Emails

The good news is today's email software uses secured SMTP connections to send, and secure POP/IMAP connections to retrieve messages. If your SMTP connections are secure connections, then the port changes to 465. If your email software securely retrieves messages using POP3 then the port is 995, for IMAP secured connections the port it 993.

One problem even with a secured connection is that your message may not stay encrypted after it reaches the server, therefore, the server can still read your messages, and the government may also be able to read your messages.

In addition to secured connections, you can enable PGP (Pretty Good Privacy) encryption to encrypt the message body so that even the email server or anybody else can't read your messages – they simply deliver. Tools like FlowCrypt will allow you to encrypt your messages using PGP encryption. Of course, your recipient must have the proper key to decrypt the messages.

What is the WWW?

The web consists of billions of browsers (clients) and web servers (servers) connected through wires and wireless networks using TCP/IP Socket connection.

What is HTML?

Hypertext Markup Language (HTML) is a predefined set of tags that we use to construct our web pages. HTML is a presentation tool. We use HTML tags to define attributes like font, color, style of text as well as size, locations of images, generate links to other pages and so on.

A web page is a text file containing data tagged by HTML tags. The browser opens such a file and decorates the content of the file as desired by the HTML tags.

What is HTTP?

HTTP ((Hypertext Transfer Protocol) has nothing to do with HTML other than the fact that these two technology names start with "Hypertext" and are often used together. HTTP is all about transferring text data from point A to point B.

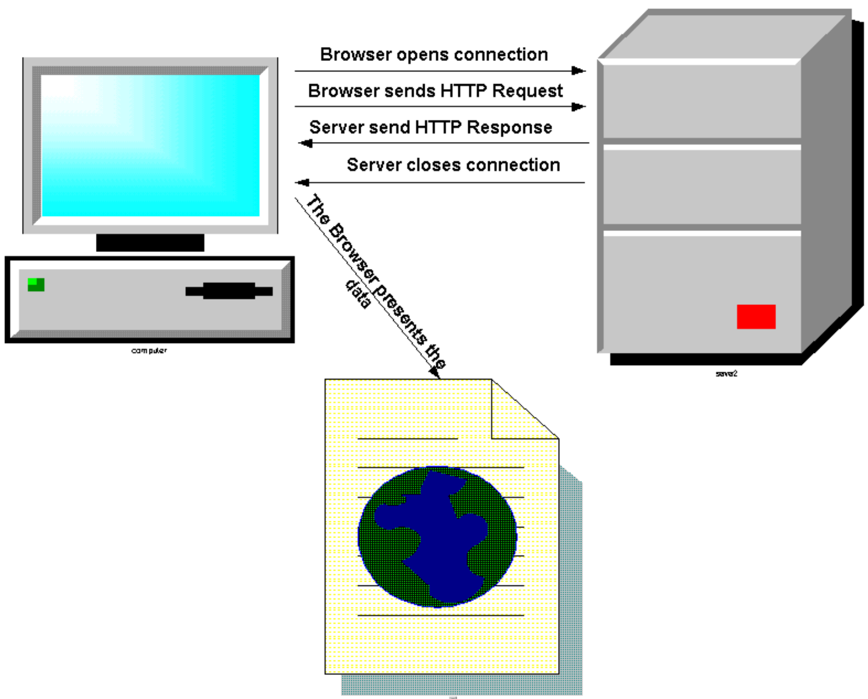
In theory, HTML can be used to mark up some data without ever using HTTP. We do that all the time when we open a web page from our local machine and just view it. On the other hand, we can use HTTP to transfer a word document, excel spreadsheet, pdf, picture, xml files etc.

without ever using an HTML document. However, typically HTTP protocol is used to bring down an HTML document from a server to the browser.

So, what is HTTP? HTTP is the protocol for text exchange on the web. It uses a TCP/IP protocol and socket connection behind the scenes. So, HTTP is really HTTP/TCP/IP. In this paradigm, client application (like a web browser) sends requests to the server (like a web server of an online toy shop) in plain text and receives information (such as a toy catalog) from the server in response in plain text.

An example of a HTTP conversion would be when a user enters the following on his browser: http://csis.pace.edu/~wolf/HTML/htmlnotepad.htm

The following events happen:



1. Browser Opens Connection
2. Browser Sends HTTP Request
3. Server Sends HTTP Response
4. Server Closes the connection

Let's assume, we type the following on our browser:

http://www.example.com/index.html

Browser Opens Connection

The browser opens a TCP/IP Socket connection with the server www.example.com. The browser automatically assumes that the server is listening to the default http port 80. If the server is listening to a different port, you must specify with a colon after the domain name as follows: http://www.example.com:9090/index.html (assuming the server is listening to port number 9090).

Browser Sends HTTP Request

The browser (Client) converts the URL into an HTTP Request and sends it out to the server. An HTTP Request message is composed of:

1) Request Line: describes HTTP Command
2) Header: browser and content information
3) Message Body: contents of message

In this example:

1) Request Line would look like this:

HTTP method	Resource Name	Protocol/Version
GET	index.htm	HTTP/1.1

2) The browser will provide the Header.

3) The Message Body will be empty.

Here is the request line:

GET /index.html HTTP/1.1

Here are the request headers:

Host: www.example.com

Connection: keep-alive

Cache-Control: max-age=0

Upgrade-Insecure-Requests: 1

User-Agent: Mozilla/5.0 (Macintosh; Intel Mac OS X 11_2_1) AppleWebKit/537.36 (KHTML, like Gecko) Chrome/89.0.4389.82 Safari/537.36

Accept:
text/html,application/xhtml+xml,application/xml;q=0.9,image/avif,image/webp,image/apng,*/*;q=0.8,application/signed-exchange;v=b3;q=0.9

Accept-Encoding: gzip, deflate

Accept-Language: en-US,en;q=0.9

If-None-Match: "3147526947+ident+gzip"

If-Modified-Since: Thu, 17 Oct 2019 07:18:26 GMT

Since this is a GET request, the Request Body is missing. The Request Body is present in other types of Requests like POST. GET, POST etc. HTTP commands are called HTTP methods.

Here are some of the HTTP methods appear on the Request Line:

HTTP Methods:

GET: The GET method requests a page/url from the server. The danger with the GET method is that any browser data sent is visible in the browser's url. The GET method was originally designed to get content from the server but now-a-days, it is also used to post data to the server.

POST: The POST method also requests a page/url from the server. It is usually used to save data on the server. The beauty of POST method is that browser data sent to the server is not reality visible. But the data is not secured either.

HEAD: The HEAD method asks for HTTP headers only, it is not interested in the body of the response.

OPTIONS: Typically used to figure out what request headers are expected by the server, what content type is expected and so on.

TRACE: Echo's back the user data, typically used for debugging. Can be a security concern.

PUT: The PUT method can also be used to replace the content on the server. This could be a security concern.

PATCH: Like PUT, PATCH partially replaces the content on the server. This is also a security concern.

DELETE: The DELETE method deletes the page/url. This is obviously a security concern.

CONNECT: The CONNECT method establishes a tunnel to the server. This could be a security problem as well.

GET and POST are the two safe methods that web applications should allow. Among them, POST is preferred whenever possible. HEAD is ok too. Other methods should be disabled on the web server.

Regardless, HTTPS should only be allowed to secure contents.

Server Sends HTTP Response

The Server reads and interprets the request and sends an HTTP Response message back to the browser (Client). An HTTP Response message is composed of:

1) Response Line: Server protocol and status line
2) Header: Response Metadata
3) Message Body: Content of Message

Here is what the response line will look like:

HTTP/1.1 200 OK

Here are the response headers:

Content-Encoding: gzip

Accept-Ranges: bytes

Age: 196537

Cache-Control: max-age=604800

Content-Type: text/html; charset=UTF-8

Date: Fri, 12 Mar 2021 16:09:33 GMT

Etag: "3147526947"

Expires: Fri, 19 Mar 2021 16:09:33 GMT

Last-Modified: Thu, 17 Oct 2019 07:18:26 GMT

Server: ECS (nyb/1D07)

Vary: Accept-Encoding

X-Cache: HIT

Content-Length: 648

This particular site sends the response body in zipped format. However, if you unzip it, here is the response body:

```
<!doctype html>
<html>
<head>
  <title>Example Domain</title>
  <meta charset="utf-8" />
  <meta http-equiv="Content-type" content="text/html; charset=utf-8" />
  <meta name="viewport" content="width=device-width, initial-scale=1" />
  <style type="text/css">
  body {
    background-color: #f0f0f2;
    margin: 0;
    padding: 0;
    font-family: -apple-system, system-ui, BlinkMacSystemFont, "Segoe UI", "Open Sans", "Helvetica Neue", Helvetica, Arial, sans-serif;

  }
  div {
    width: 600px;
    margin: 5em auto;
    padding: 2em;
    background-color: #fdfdff;
    border-radius: 0.5em;
    box-shadow: 2px 3px 7px 2px rgba(0,0,0,0.02);
```

```
    }
    a:link, a:visited {
        color: #38488f;
        text-decoration: none;
    }
    @media (max-width: 700px) {
        div {
            margin: 0 auto;
            width: auto;
        }
    }
    </style>
</head>
<body>
<div>
    <h1>Example Domain</h1>
    <p>This domain is for use in illustrative examples in documents. You may use this
    domain in literature without prior coordination or asking for permission.</p>
    <p><a href="https://www.iana.org/domains/example">More information...</a></p>
</div>
</body>
</html>
```

Here are the status codes used by the server on Response Line:

Status Codes:

Code Range	Category
100-199	Information
200-299	Successful (200 OK)
300-399	Redirection
400-499	Client Error (404 File Not found, a command status that we see all the time)
500-599	Server Error

Here are the Multipurpose Internet Mail Extension (MIME) content types used by the server for Header:

MIME Content Types:

text/html

text/plain

text/xml

application/octet-stream

…….

Server Closes the connection

As soon as the response is sent the server closes the connection with the browser. For the next url/page, the browser has to start the connection process from the beginning.

The html page that the server returns may have links to other html pages. When the user clicks on those links the browser sends another brand new request to the server, the server sends another brand new response and browser displays the new page and this request-response game goes on.

Fiddler Tool

There are quite a few free tools out there that allows you to monitor the data you are sending and the data you are receiving over your TCP/IP socket. In other words, these tools allow you to see the raw request and the raw response. Fiddler is one of them. Here is how you get it to work.

Download latest version Fiddler

Install Fiddler

Start Fiddler from your startup menu. You will have a Fiddler console available to you at this point.

Open your browser and type:

http://www.example.com

Fiddler automatically plugs into your browser as a proxy server and will record your requests and responses in the Fiddler console. If it does not, please read Fiddler documentation to find how to manually put the proxy setting in your browser.

The right top section of Fidler is dedicated for the “http request” and the right bottom for the “http response”.

Go to your Fidler and open the “Inspectors” tab of the Top-Right section. Open the “Raw” tab under the “Inspectors” tab and you will see the raw request.

On the Bottom-Right section of Fidler, open the “Raw” tab to see the raw response.

Secured Socket Layer(SSL) and Transport Layer Security (TLS)

SSL is a security protocol for establishing encrypted links between a web server and a browser in online communication. SSL is old technology and companies have moved away from SSL and use TLS instead. There are several versions of TLS out there, but TLS 1.2 is recommended at this point of time and TLS 1.3 is also out. SSL or TLS does not matter, they both require Certificate which we will discuss shortly but before that we need to know a little bit about encryption and decryption techniques.

Symmetric vs Asymmetric Cryptography

Let’s first get our hand around cryptography – a way to encrypt your data to preserve privacy. The symmetric cryptography is something that we are naturally familiar with. You use a secret key and an algorithm to encrypt your data. To decrypt the data, the same key will be needed again. As wonderful as it may be, symmetric cryptography falls apart as soon as a hacker has access to the secret key.

Can we do better? Turns out, we can. We can use asymmetric cryptography. In asymmetric cryptography, the key that you use to encrypt the message is different from the key you use to decrypt the message. How is that possible? Well, the two keys are mathematically related but not identical. For example, to encrypt a message you need a number let’s say 2,035,153 (known as a public key) but to decrypt you need two numbers 1,009 and 2,017 (known as private keys) that are multiplied to get 2,035,153 as the public key. Ok, but can’t I figure out the two private numbers if I have access to the public number? No, it is extremely difficult and time consuming to decode a very long public key into two private keys since they are prime numbers.

In real life public keys are typically thousands of digits (for example: 2048 bits) making it impossible to break down to two private keys in any reasonable amount of time.

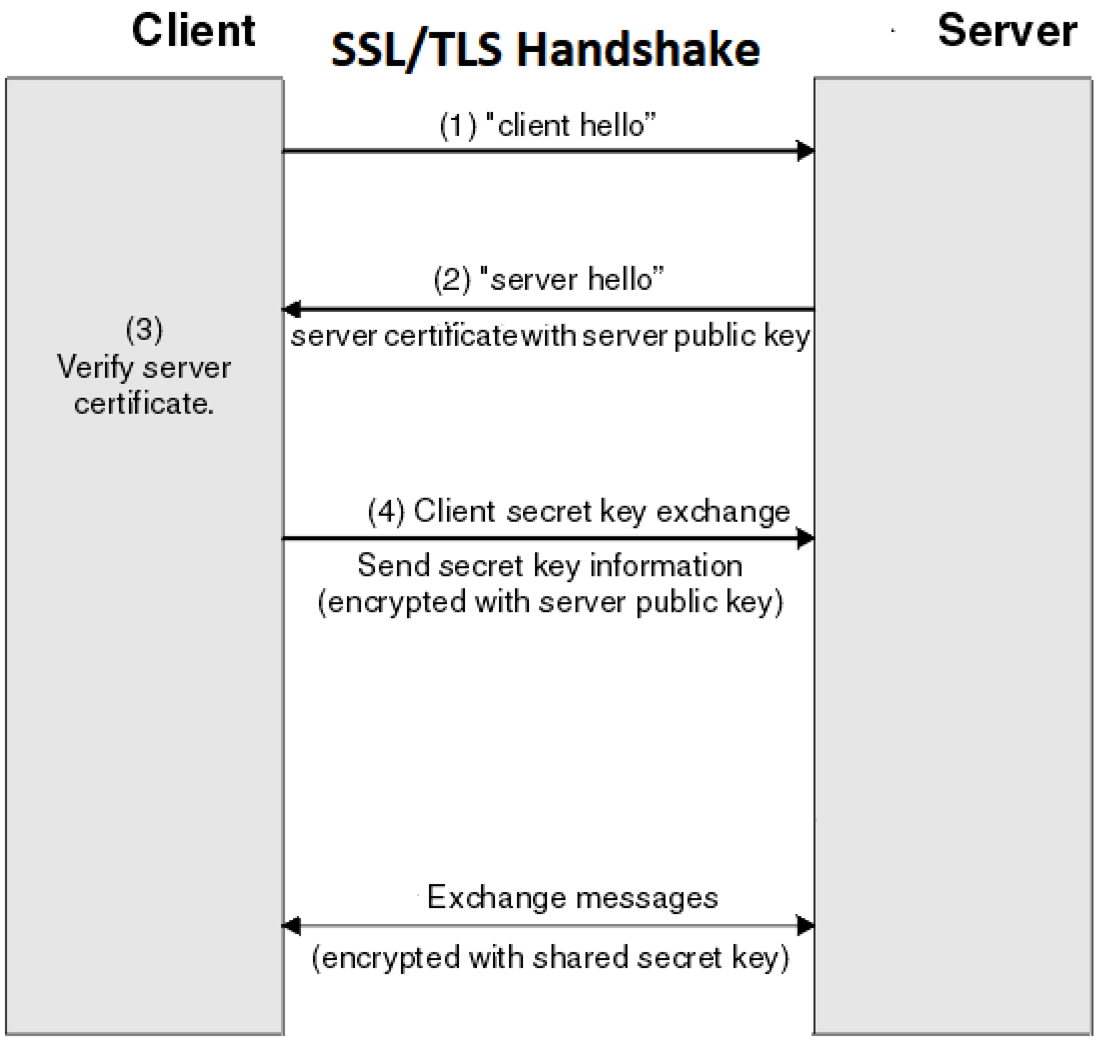
What is Digital Certification?

To rent a car you need to present a valid driver's license. How does the rentaling company know that your driver's license is genuine not a fake one? Well, they don't. So, they validate your driver's license with DMV.

Similarly, let's assume that you visited Google's website for a secured connection and receive a public key. How do you know that there is not a "man in the middle" that gives you it's public key instead and is pretending to be Google? How do you know that you really received a public key from Google? Well, that's where digital certificates come into play. A digital certificate contains a public key but your browser can verify a) The public key belongs to the party you expect it from b) The certificate is issued by a trustworthy certificate issuing authority.

How does SSL/TLS work?

In SSL/TLS both asymmetric and symmetric encryption is used one after another. Sounds crazy? Why? Because communication with long asymmetric keys (let's say 2048 bits) is slow. So, should be avoided as much as possible. On the other hand, a symmetric short key (let's say 256 bits) is very fast. That's why the initial handshake is done using long asymmetric keys and then quickly the communication turns to a symmetric encryption/decryption style. How? Well, let's see.



Your browser sends a hello message to the server. The server returns a hello message with a certificate that contains the long public key. The browser validates that the certificate is genuine and accepts it. It then generates a short random key (called a session key) that will be used for symmetric cryptography going forward for the rest of the session. It then encrypts the key using the server's public key. Browser sends this encrypted session key back to the server. The server decrypts the message using its private key and retrieves the client's random session key from it. Now they both use symmetric cryptography for exchanging messages back and forth using the session key. So, SSL/TLS starts with asymmetric cryptography but ends up in symmetric cryptography. Of course, the symmetric key changes on the next session.

Demo: Go to https://www.nyu.edu

Click on the lock icon, click on certificate and go to the details page.

Who issued the certificate?

When does the certificate expire?

How long is the public key?

What DNS names are supported by the certificate? (subject and subject alternative names)

Now, go to https://www.mscdirect.com

Answer the same questions.

Introduction to Password Protection

Password Weaknesses

If you are not careful, your password can be cracked. More than a billion online usernames and passwords have already been stolen by cybercriminals and most are sold on darknet. But it goes beyond hacked passwords. In 2009, a survey showed that 18% of people use the same password for multiple sites. 44% uses short password (less than 8 characters). 44% users write their password down on a piece of paper or in a digital document. Here are some examples of commonly used passwords taken from the real world: 123456, password, 111111, welcome, ninja, freedom, baseball, superman, America, starwars, batman, spiderman, startrek.

Password Encryption (Hashing)

Even passwords that are not as common as shown above but weak in nature can be cracked. So, how do they steal passwords you may ask. Are they saved in plain text? Probably not. Are they encrypted? They can be but as it turns out encrypting a password is not the most protective measure since all you need to decrypt all the passwords is the key and hackers are good at finding the key. That's why passwords are generally hashed and not encrypted. What's the difference? The difference between hashing and encryption is that encrypted data can be decrypted but hashed value can never be reversed. Once hashed, you can never retrieve the original value from the hash. That sounds strange since we need to validate a password. Don't worry, that is absolutely no problem.

Let's assume you entered your password in an online site for the first time. The password is hashed and saved to the database. Next day you went back to the site and entered your password again. Now, it is time to validate your password. What the site will do is, 1) hash the password you just entered and 2) compare it with the saved hashed value. If they are identical, your password is correct, and you are in.

Let's do a password hashing. Go to:

http://www.fileformat.info/tool/hash.htm

Type in “freedom” for String hash. After all, “freedom” is one of the most popular passwords. Let’s take a strong hash like SHA-256 value:

13b1f7ec5beaefc781e43a3b344371cd49923a8a05edd71844b92f56f6a08d38

Looks cryptic, right? Let’s now see how hackers crack this password.

Rainbow Table

“If the mountain won't come to Muhammad, then Muhammad must go to the mountain."

That’s exactly what happens with hashed passwords.

If a hashed password cannot not be reversed, how does password hacking work? Sure, a hacker can hack your hashed password but what good a is hashed password to the hacker? He/she still can’t figure out the password, right? Wrong. Hackers use a Rainbow Table (some call it a Magic Table) to get around it. A Rainbow Table is a database of hashed passwords. If the hacker can look up your password’s hashed value in this table, the hacker has the password in the next column.

Let’s now go to the following site to find a rainbow table:

http://reverse-hash-lookup.online-domain-tools.com/

Copy/paste the hashed value and change the hash-function to SHA-256 on the dropdown below it.

Click on Reverse and you will see it will reverse the hash showing the following result:

Hash #1: freedom

Brute Force Cracking

Passwords can also be cracked using the brute force mechanism and without a rainbow table. I gave you a password protected zip file that you need to crack the password for. Install “John the Ripper on your machine”. Copy “secret.zip” from “demo3” folder to John’s Run folder.

Run the following command:

zip2john secret.zip >hash.txt

you can open hash.txt now to review the hashed value of my password that I used to encrypt my file.

Now, run,

John hash.txt

In a minute, you should see the password in clear text.

Use the password to open the zip file and read my secret text file inside the zip.

However, I have another zip file with a long password. John the ripper tried for a month to crack it and eventually hung. No cracking was possible.

What do you learn from here? If you are going to protect your zip file or spreadsheet, use a long password so a brute force cracking program will take forever to crack it or the rainbow tables will be needs to be infinitely long.

Better security options

So, how does a company go about protecting its users from rainbow table attack or brute force attack? Well, there are few things that can be done:

Secure the hashed file: The hashed file containing all passwords for all users need to be protected with utmost security.

Force a long password: The longer the password gets, the harder it gets to create a rainbow table since the permutation and combination of different letters and symbols grows exponentially as the length of the password grows, so the brute force method takes longer and longer.

Add salt to password: We will discuss salt next but it essentially a) adds length to the password b) provides randomness to the generated hash. Together it makes Rainbow table generation an impossible task.

Ask for two factor authentication: Like the idea of salt, two factor authentication can be used to further enhance the authentication security. In two factor authentication you need a password and a code. After you enter the correct password, you are challenged with the code. The code is usually texted to your phone or emailed to you. The idea is you have the correct password and access to another device of yours to log in.

Salting Password

Rainbow tables only work because the same password is hashed to the exactly same value. If two users have the same password, they'll have the same hashes. What if we could stop this? What if we add a random (and long) string to each password before hashing and save this string called “salt” with the user id and hashed value?

Let’s take our example of an easy password “freedom”. Let’s add a randomly generated salt to the password “Ut45hjs1dds”. Together we get “freedomUt45hjs1dds”. SHA-256 hash value of this password is: ab3ea23056f8f3c71c8e43b68d88d4cea83aab75df38a0ff79280799a804ae05

If you try to look up this in any rainbow table, you will not find the reverse value because it is a hash of a very long string. More importantly, let’s assume that another user uses the same password “freedom”. This time, the randomly generated salt would be different. Let’s say it is “H78yrt2allau”. Together we get “freedomH78yrt2allau”. SHA-256 hash value of this password is: db4658237125ec28b78071e1384b9e3d7c982e431ef44e4666814c143262df1e. This hash value is significantly different from the previous hash although the password is the same. Anybody who tries to create a rainbow table now must create a table that has all possible passwords as well as all possible salts. Together, the task becomes impossible since the possibilities are infinite.

So, saving the salt and hashed password increases the complexity of the password.

Long Password

Almost all sites force you to use special characters and at least 8 characters for a password but a longer password is much harder to crack than a short cryptic password. For example, “!2Hjrdwu” may take minutes to crack but “IlovedozencrispycreamDonuts” will take months. Is that harder to remember than the cryptic one? Obviously not, yet much stronger. If a salt is added to this password, the probability of cracking this password reaches zero.

Use Different Passwords for Different Sites

The first problem is that many sites do not use salted password. The second problem is sites are often hacked and hacked user id and hashed password is sold is black market like Darknet. If you use the same password for multiple sites and one of the sites is hacked, your password is now exposed for many other sites. Therefore, it is a very wise idea that your password be different for different sites.

Use Password Manager

Using different passwords for different sites and using long passwords make sense but managing all these passwords could easily become a nightmare. The best option is to use an online vault also known as a "password manager" like Lastpass.com or onepassword.com and save all your passwords there.

Now, is saving all your passwords in one site safe? Isn't that equivalent of putting all your eggs in one basket? Yes, you are right. However, the alternative is even more dangerous. What are you going to do? Write down all passwords in a file? On a piece of paper?

There is some good news about password managers. Password managers like LastPass and Sticky Password use zero-knowledge security protocols that encrypt users' master passwords with an encryption key that is stored only on users' devices (so that the companies have 'zero knowledge' of users' passwords). This encryption includes thousands of rounds of authentication hashing, where an algorithm converts a string of text into a longer string, making it more difficult for hackers to crack the hashed text.

Demo: Lastpass

Use Two Factor Authentication for Password Manager

Fortunately, there is a way to secure your password manager even more. Use two-factor-authentication for the password manager. This way, even if someone cracks your password for the password manager (which is hard to do), he/she still needs access to your phone or email to get into your account.

Demo: Lastpass demo

Watch Kevin Mitnick cracking password:

https://www.youtube.com/watch?v=K-96JmC2AkE

Homework 3

1. Like HTTP, there is a protocol to transfer files from one computer to another. It is called FTP. FTP is just as insecured as HTTP and should be avoided at all costs. What should you use instead? (hint: there are at least 3 options, FTPS, SFTP and AS2. Look them up and try to describe them).
2. What is the difference between hashing and encryption?
3. Who is DigiNotar? What was the issue with DigiNotar? How did the browsers deal with the issue?
4. A company decided to salt passwords the following way:

   Take the user input and hash it.

   Concatenate the hashed value with the password as salt.

   And then hash it again and save the ultimate hashed value.

Although they are salting each password with a different salt, and they never have to save the salt value, it is still not the best way to do it.

What is the problem with salting this way?

(Hint: How many rainbow tables will be needed to crack all the passwords of all users if the salting mechanism is known to the user and he/she gains access to the hashed passwords).