Software Quality

Lesson 1:

Basics

Learning Outcome

On completion of this module, students will be able to:

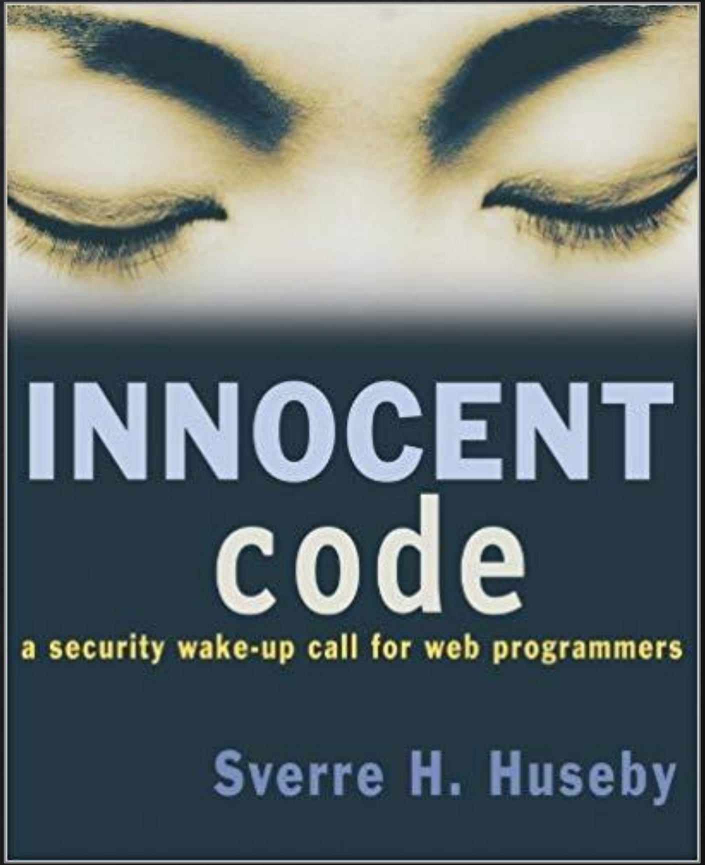
1) Understand web application security and its importance.
2) Understand common mistakes of coders and vulnerabilities of web applications.
3) Explain how could developers' mistakes be exploited to the benefit of the attackers and how to prevent these attacks.
4) Build secure web applications using secure coding practices.

Text Book

- Innocent Code: A Security Wake-Up Call for Web Programmers.

  Wiley; 1 edition (January 30, 2004)

  By Sverre H. Huseby

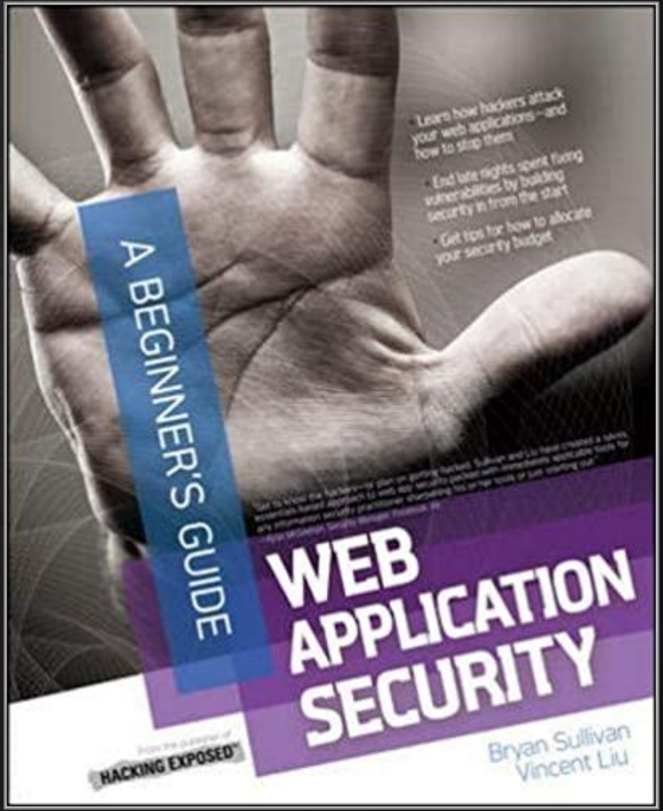


Extra reading

- Web Application Security, A Beginner's Guide.

  McGraw-Hill Education; 1 edition.

  by Bryan Sullivan, Vincent Liu

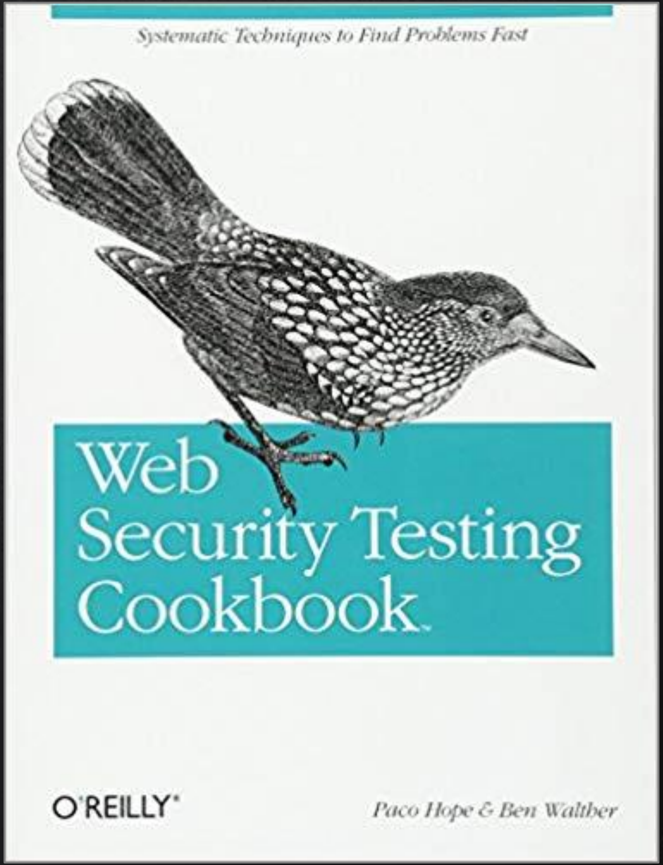

A BEGINNER'S GUIDE
WEB APPLICATION SECURITY
Bryan Sullivan
Vincent Liu
HACKING EXPOSED
Learn how hackers attack your web applications—and how to stop them
End late nights spent fixing vulnerabilities by building security in from the start
Get tips for how to allocate your security budget

Extra reading

- Web Security Testing Cookbook: Systematic Techniques to Find Problems Fast.

  O'Reilly Media; 1 edition

  By Paco Hope, Ben Walther

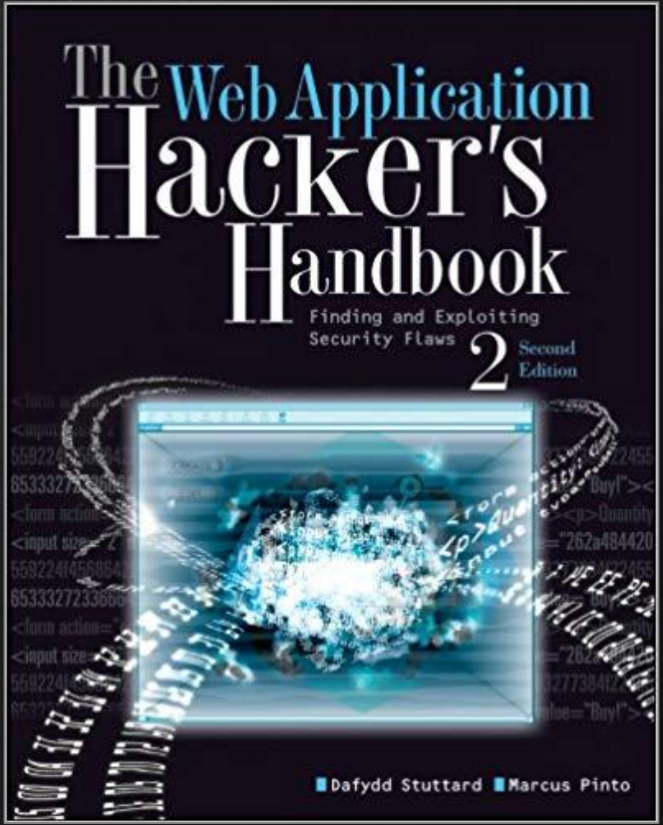


Extra reading

- The Web Application Hacker's Handbook: Finding and Exploiting Security Flaws.

  Wiley; 2 edition (September 27, 2011)

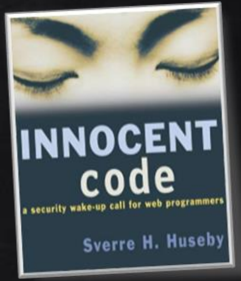
  By Dafydd Stuttard, Marcus Pinto


The Web Application Hacker's Handbook
Finding and Exploiting Security Flaws
2 Second Edition
Dafydd Stuttard Marcus Pinto

Assessment

Final Exam: 100% (Final Grade)

- The exam material covers the contents of the book "Innocent Code", supplemented with variations on it that are addressed in the weekly classes and labs.
- The Exam is MCQ exam, consists of 40 questions.
- The minimum pass mark is 5.5 (27 Correct Answers).



Final Assignment: Pass/Fail (No contribution to the final Grade)

- Description will be published in week 3.
- Deadline of Submission: 8 July 2020

Disclaimer

- You understand that in this class we may cover methods to exploit vulnerabilities in contemporary computer systems and computer networks.
- You further understand that we may learn techniques employed by unethical individuals to circumvent security mechanisms, violate copyright, cause damage, cause financial loss, or break the law in other ways.
- You hereby pledge to use all information obtained in this class in an ethical and responsible manner, properly observing University Policy and the law.

Disclaimer

- You further pledge to abide by course rules, in particular (but not limited to) hacking systems declared off-limits by the instructional staff.

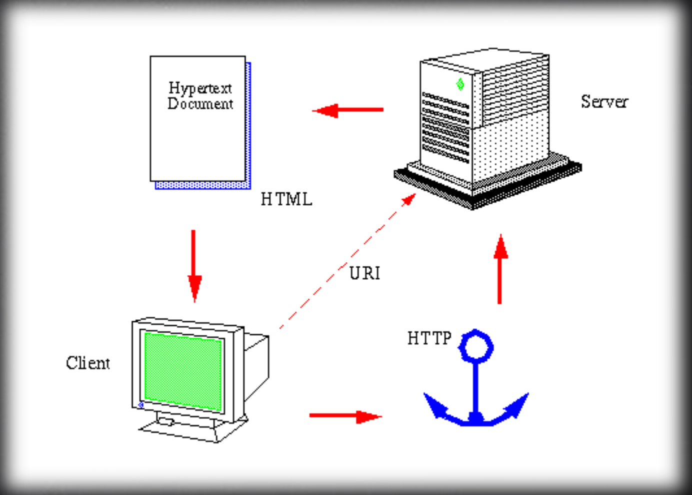
- By using the course materials, you accept that you will only lawfully use it in a test lab – with devices that you own or are allowed to conduct penetration tests on – to enhance your own knowledge.
  We do not endorse use of any information expressed on the course outside of a lab environment.

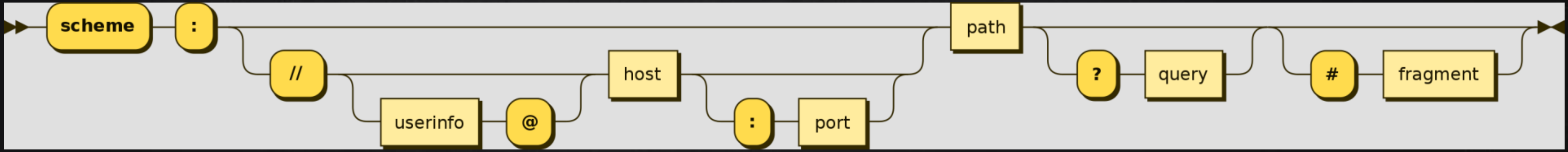
- Any actions and or activities related to the materials contained in this course is solely your responsibility. The misuse of the knowledge and information in this course can result in criminal charges brought against the persons in question.

Introduction

Three specifications are central to the Web:

1. URL (Uniform Resource Locators)
   [URI: Uniform Resource Identifiers]
2. HTML (HyperText Markup Language)
3. HTTP (Hypertext Transfer Protocol)



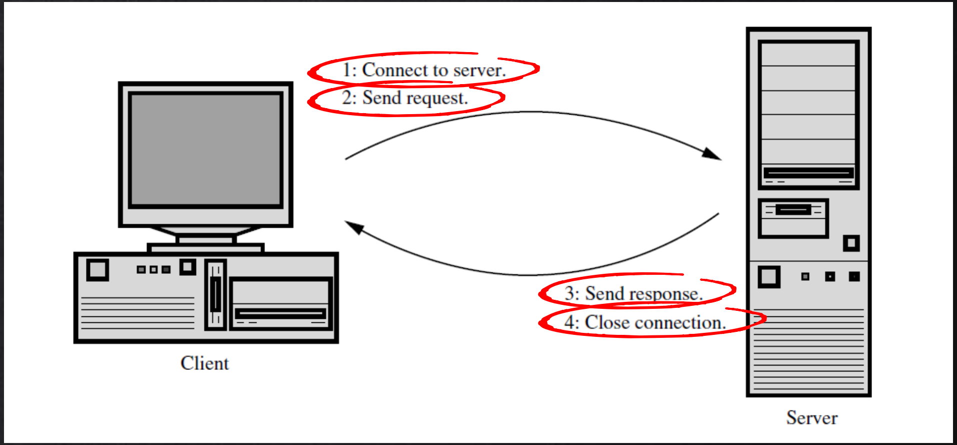


HTTP
(Hypertext Transfer Protocol)

Client-Server Model of WEB

TCP connection is established, the browser sends a HTTP request asking the web server to provide the wanted document.

The web server sends a reply containing the page contents, and closes the connection.



The browser is always the initiating party—the server never "calls back".

This means that HTTP is a client/server protocol.

The client will typically be a web browser, but it need not be. It may be any program capable of sending HTTP requests to a web server.

Note: this tcp connection model is valid for HTTP/1.x. In HTTP/2 this model was partially changed

Requests and Responses

HTTP is line oriented, just like many other Internet protocols.

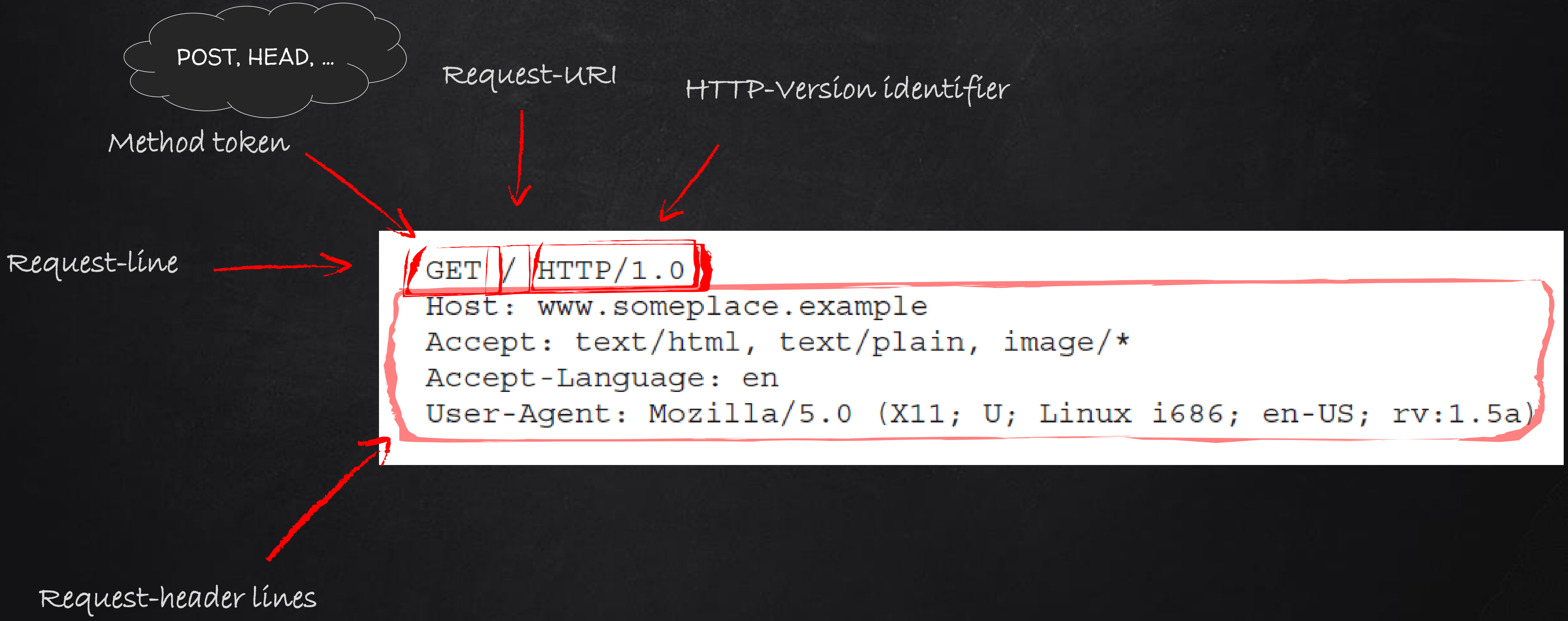
Communication takes place using strings of characters, separated by carriage return (ASCII 13) and line feed (ASCII 10).

Example: http://www.someplace.example

```
GET / HTTP/1.0
Host: www.someplace.example
Accept: text/html, text/plain, image/*
Accept-Language: en
User-Agent: Mozilla/5.0 (X11; U; Linux i686; en-US; rv:1.5a)
```

Request

Get Request



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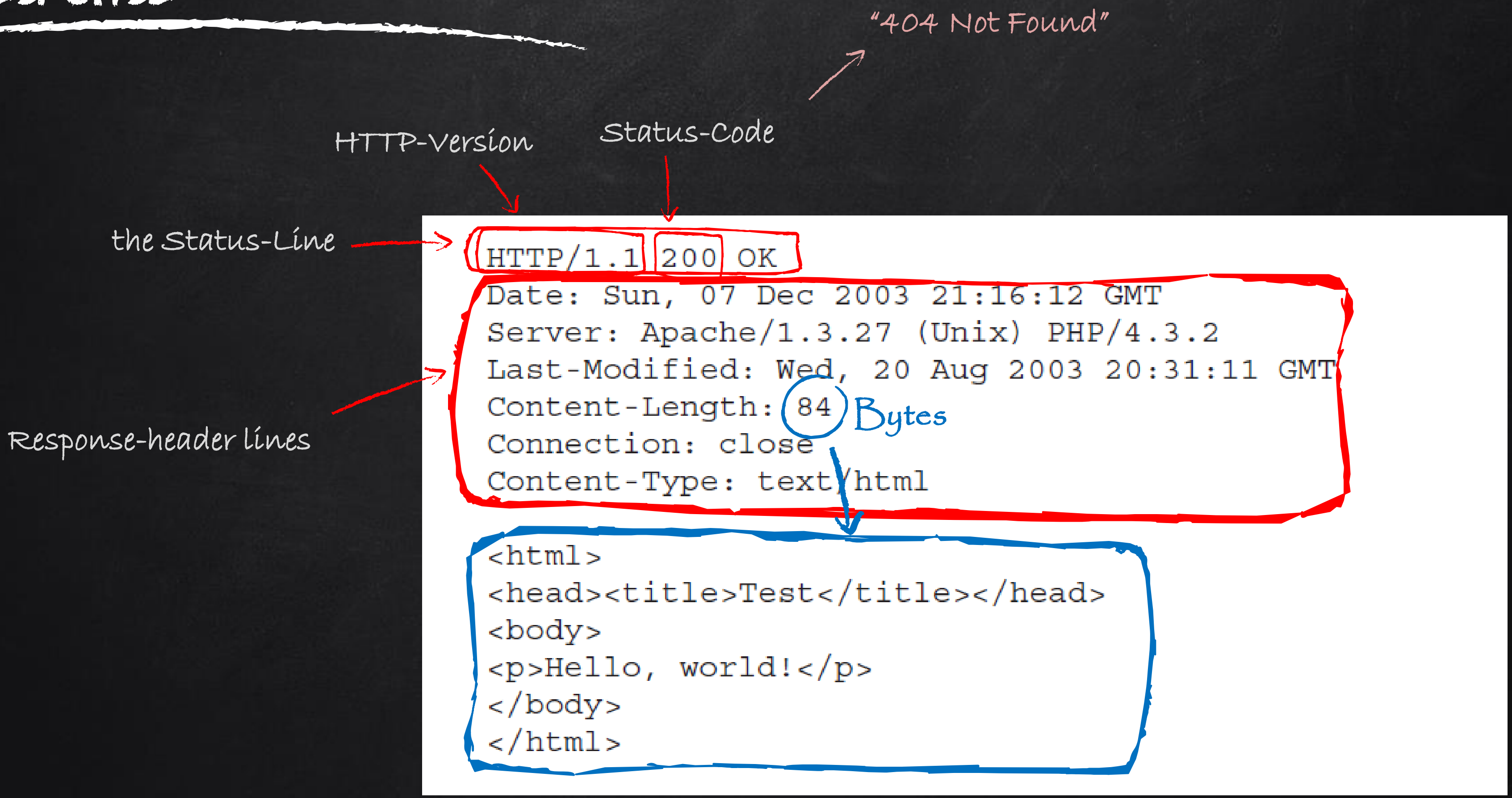
User-Agent: Mozilla/5.0 (X11; U; Linux i686; en-US; rv:1.5a)
```

Response



```
HTTP/1.1 200 OK
Date: Sun, 07 Dec 2003 21:16:12 GMT
Server: Apache/1.3.27 (Unix) PHP/4.3.2
Last-Modified: Wed, 20 Aug 2003 20:31:11 GMT
Content-Length: 84
Connection: close
Content-Type: text/html

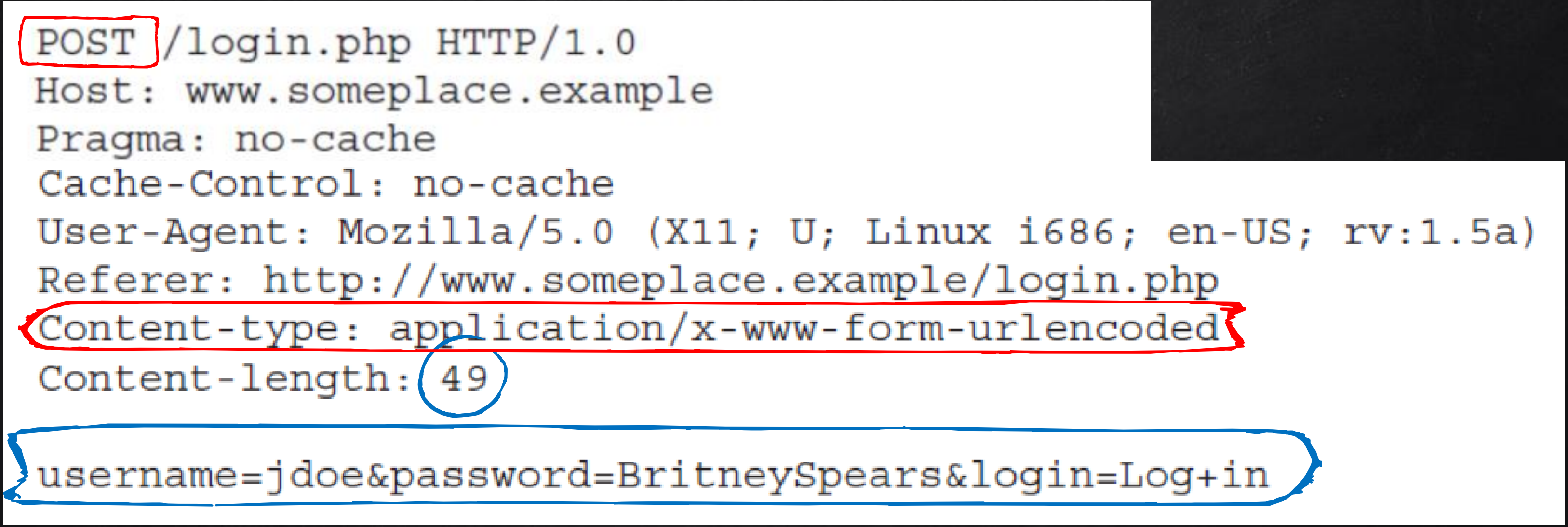
<html>
<head><title>Test</title></head>
<body>
<p>Hello, world!</p>
</body>
</html>
```

Get Request vs. Post Request

POST requests should be used when the action about to be taken has side effects on the server, i.e. when something is permanently changed.

- With GET, a client asks for information.
- With POST, the client contributes information.
- With GET requests, the browser is free to resend the request, for example, when the user presses the "back button" in his browser (not suitable for money transfers in a bank).
- POST requests, on the other hand, cannot be reissued by the browser without first asking the user for permission to do so.
- In a GET request, any parameters are encoded as part of the URL.
- In a POST request, the parameters are "hidden".

Post request example



```
POST /login.php HTTP/1.0
Host: www.someplace.example
Pragma: no-cache
Cache-Control: no-cache
User-Agent: Mozilla/5.0 (X11; U; Linux i686; en-US; rv:1.5a)
Referer: http://www.someplace.example/login.php
Content-type: application/x-www-form-urlencoded
Content-length: 49

username=jdoe&password=BritneySpears&login=Log+in
```

The parameters are encoded as you are used to, but they are hidden in the request rather than being part of the URL.

- URL Encoding refers to the escaping of certain characters by encoding them using a percent sign followed by two hexadecimal digits.

$\text{AT\&T} \longrightarrow \text{AT\%26T}$

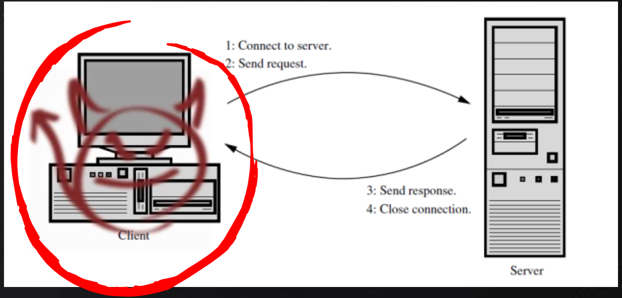
Security Concern

What can be the security concern?

As all requests originate on the client-side, that is, on computers of which the user has full control, nothing stops the attacker from replacing the browser with something completely different.

As HTTP borrows its line oriented nature from the telnet protocol, you may actually use the telnet program to connect to a web server.

```
telnet www.someplace.example 80
```



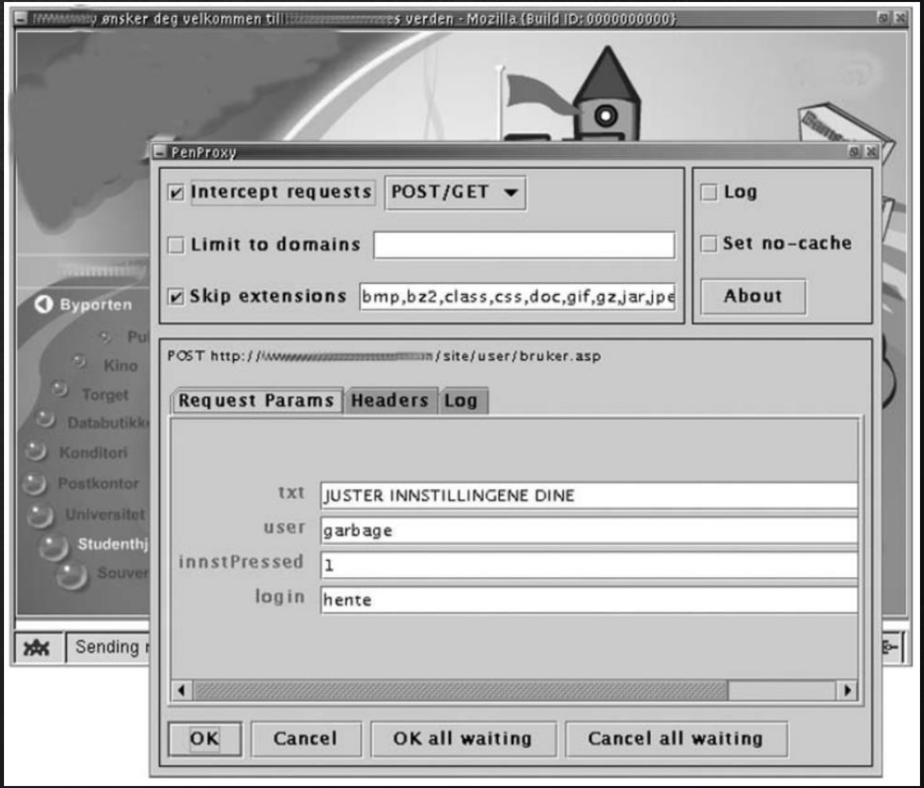
⚠ Everybody can write a program to connect a socket and do the actual protocol conversation for him/her.

Proxy

There are freely available programs that will aid them in manipulating all data that get sent to the server.

Some of these programs are proxies that sit between your browser and any web server, and that pop up nice dialogs whenever your browser sends anything.

The proxies let you change headers and data before they are passed to the server.


PenProxy

[✓] Intercept requests POST/GET
[ ] Limit to domains
[✓] Skip extensions bmp,bz2,class,css,doc,gif,gz,jar,jpe
[ ] Log
[ ] Set no-cache

POST http://[illegible]/site/user/bruker.asp

txt	JUSTER INNSTILLINGENE DINE
user	garbage
innstPressed	1
login	hente

The Referer header

A Referer header is sent by most browsers on most requests.

- The header contains the URL of the document from which the request originated.

Example: http://www.site.example/index.html

```
<img src="http://www.images.example/img/cindy.jpg"/>
<a href="http://www.news.example/index.html">News</a>
```

The HTML snippet includes an image from www.images.example and links to a page on www.news.example.

WHAT IS THE SECURITY CONCERN WITH REFERER HEADER?

When the browser views the HTML, it will immediately connect to `www.images.example` to obtain the image.

- When requesting the image, the browser sends a Referer header like this:

```
Referer: http://www.site.example/index.html
```

The URL points to the page from which the image was referred.

Any Java Applets, ActiveX, scripts and plug-ins included in the page would give the same Referer header.

And not only included objects: if the user clicks the link given above, `www.news.example` will receive the same Referer header.

Risks?

Let's see it online: https://www.hogeschoolrotterdam.nl/

1. It leaks information to remote sites.
   Any part of the URL, including parameters, will be visible to the third-party web server and any proxies that handle the request.

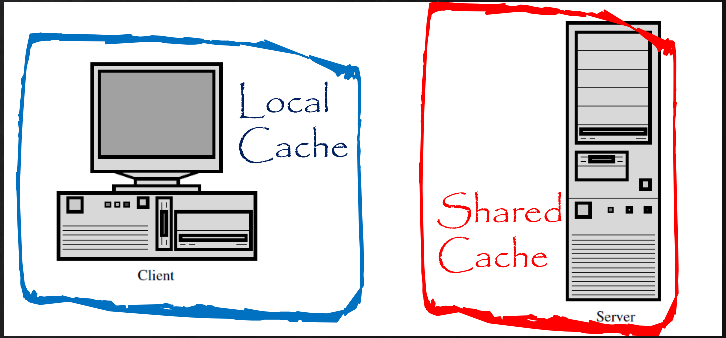
2. The Referer header originates on the client.
   Some web sites check this header to make sure the request originated from a page generated by them (e.g. to prevent attackers from saving web pages, modifying forms, and posting them off their own computer).
   - This security mechanism will fail, as the attacker will be able to modify the Referer header to look like it came from the original site.

Caching

Caching refers to temporarily storing documents close to the final destination, in order to reduce download times.

Two types of web caches:

- Local cache: is managed by the browser itself. When the browser requests a document from a remote server, it often stores a copy on the disk or in memory.
- Shared (proxy) cache: is typically a server in the local area network. If one user reads an on-line newspaper, and another user reads the same paper shortly after, the proxy cache may serve a local copy of the document to the second user.



Security Concern

Some documents should not be cached. For example:

- Visitors a stock information web site most likely want up to date stock information, not yesterday's news.
- People might be able to use the back button to see other people's web pages in a shared browser, such as in Banks, Internet cafés.

Such sites need a way to tell browsers and proxies that documents should not be cached, or that they may only be cached for a limited time.

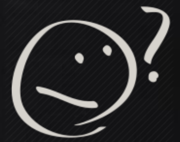
As with most other control information on the web, cache control is handled by HTTP headers.

Different versions of HTTP specify different mechanisms for cache control.

Cookies

HTTP is a stateless protocol (no ties connecting different requests from the same client).

- We would like to have state between requests. What state for example?

  Google search engine once used cookies to allow users (even non-registered ones) to decide how many search results per page they wanted to see.

- Cookies are introduced as an extension to HTTP to give us just the state.

  With cookies, the web server asks the client to remember a small piece of information.

  This information is passed back by the client on each subsequent request to the same server.

Cookies

HTTP headers are used for both setting and returning cookies.

When server wants the client to remember a cookie, it passes a Set-Cookie header in the reply:

```
Set-Cookie: Customer="79"; Version="1"; Path="/"; Max-Age=1800
```

Name of cookie and its value

To which parts of the document hierarchy on this server that cookie should be returned

How many seconds to remember it

Cookies are returned using the Cookie header:

```
Cookie: $Version="1"; Customer="79"; $Path="/"
```

Cookies

Drawbacks:

- Firstly, cookies may be limited in size, so space consuming states cannot be safely represented using cookies.
- Secondly, cookies are handled on the client-side, so we have to keep making sure that a misbehaving user doesn't change the state to his own liking.

Both limitations would be solved if we could keep the state information on the server side.

Sessions

Sessions (Session Objects)

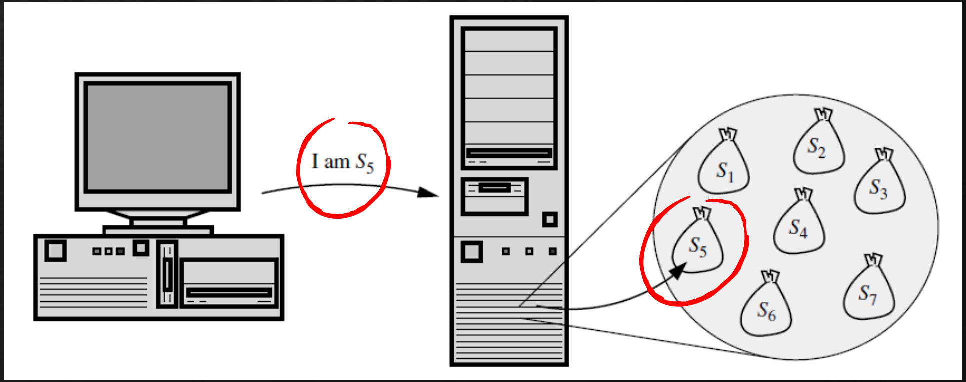
Sessions are server-side collections of variables that make up the state.

How to associate a set of data on the server to the correct client?

Answer: Session ID

- The common approach is to have the client pass a session ID on each request.

The session ID uniquely identifies one session object on the server, the session object "owned" by the client making the request.



Security problem with sessions?

Session hijacking

Many web sites use a session-based log-in, in which a session is initiated once the user has given a valid user name and password.

If somebody gets access to the session ID of a logged in user?

[redacted]

The attacker would not need to know the password of the victim, as the session ID works as a "short-time password" or a proof of successful authentication after a user has logged in.

Session hijacking

How would the attacker gain access to the session ID?

- Guess it,
- Calculate it,
- Brute-force it,
- Find it by trial and error
- Cross-site Scripting
- Use referer header
- Packet sniffing
- …

Countermeasure

The security of sessions lay in the secrecy of the session ID.

The number one goal to prevent session hijacking is to keep the session ID unavailable to third parties.

As an extra precaution, many web sites implement secondary measures to limit the risk of session hijacking, even if a session ID becomes available to attackers.

- However, none of these secondary mechanisms offer full protection against hijacking.

The secrecy of the session ID is the only mechanism that gives real protection.

Secondary Measures

1. Tie the session ID to the IP address of the client.

   It will not protect against attackers who hide behind the same web proxy as the victim, as all requests from the same proxy will come from the same IP address.

2. Tie the session ID to certain HTTP headers passed by the client, such as the User-Agent header.

   This approach isn't bulletproof either: an attacker could mimic the headers sent by several popular browsers. One of the combinations would probably let him through.

3. Have variable session IDs, a scheme in which the session ID is changed for every request.

   Unfortunately, this wouldn't give full protection either. An attacker that got access to a session ID could quickly present it to the web site before the victim do a new request.

   The attacker would thus completely take over the session, blocking the victim from further access.

The number one measure against session hijacking is to make sure session IDs won't be leaked to third parties in the first place.

Without a valid session ID, session hijacking is very hard.

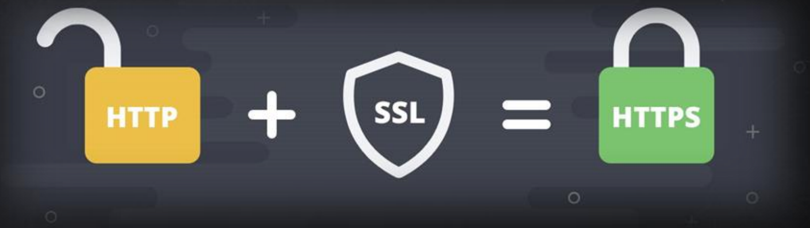
HTTPS

HTTPs: Encrypted Communication

To make a web server secure, encryption plays an important role.

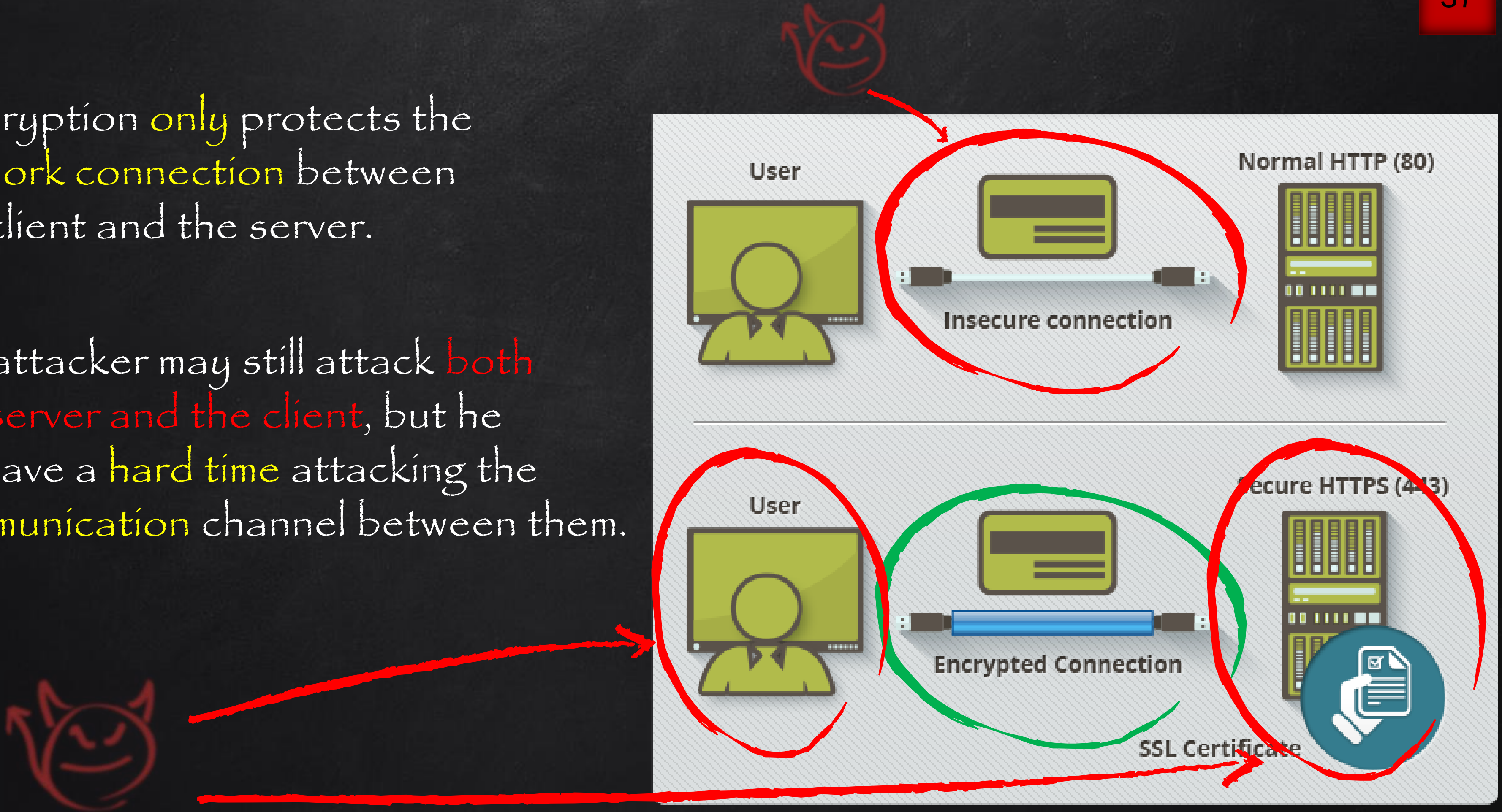
In a web setting, encryption usually means HTTPS.

- HTTPS may be described as HTTP communicated over an encrypted channel.
- The encrypted channel can be provided by the following protocols:
  - Secure Socket Layer (SSL)
  - Transport Layer Security (TLS)



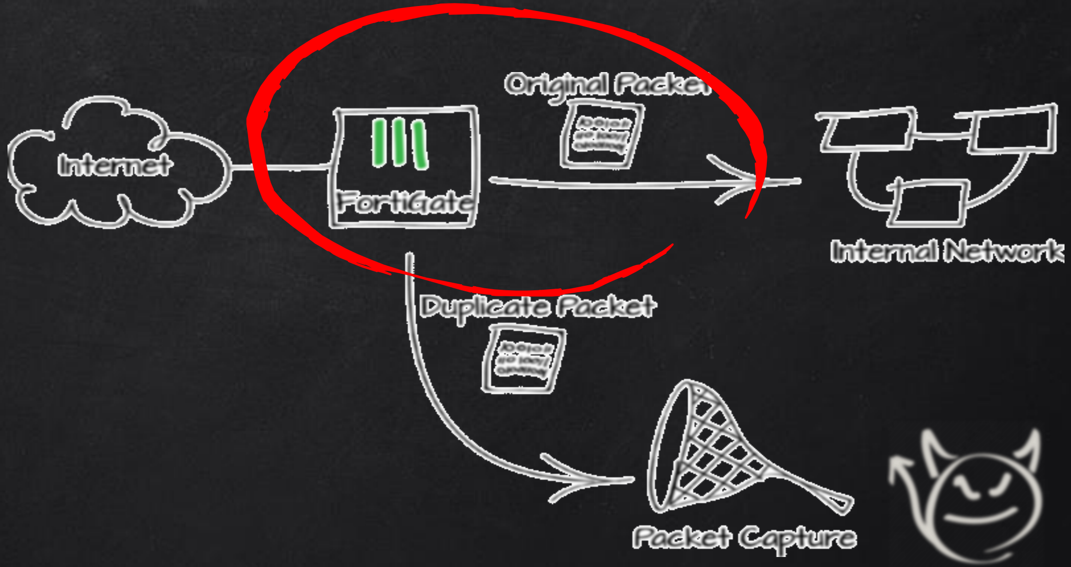
Encryption only protects the network connection between the client and the server.

An attacker may still attack both the server and the client, but he will have a hard time attacking the communication channel between them.



Packet Sniffing

Packet sniffing attacks the network transport rather than the application or the client.

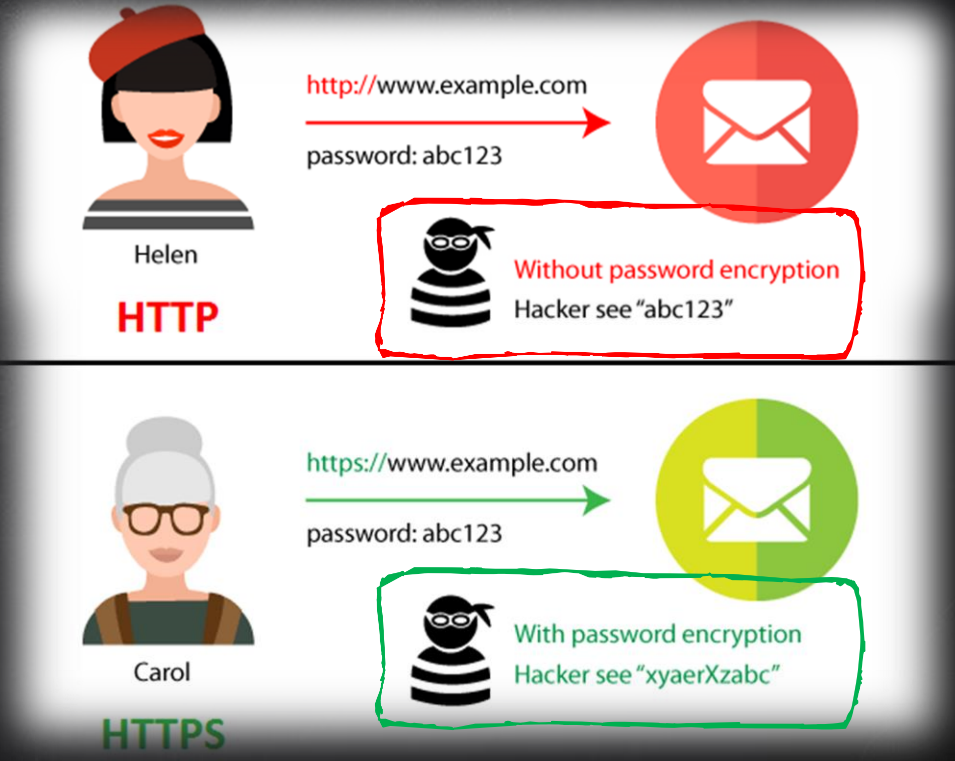


The correct approach to protect against sniffing is to encrypt all communication.

Defeat Packet Sniffing using HTTPS

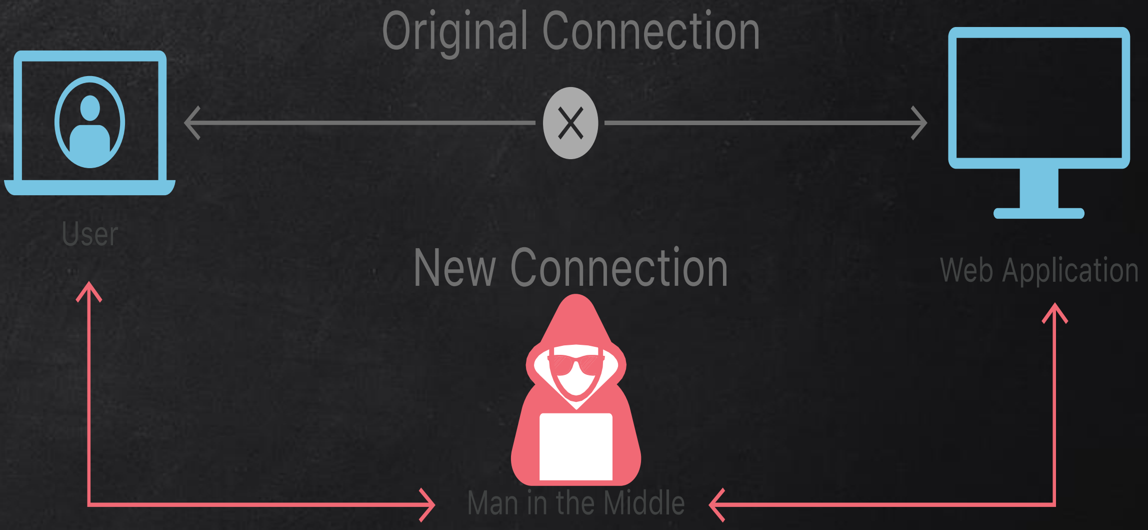
HTTPS makes it impossible for someone to listen to traffic in order to extract secrets.

People may still sniff packets, but the packets contain seemingly random data.



Man in the Middle (MITM)

In MITM, the attacker fools the victim's computer into connecting to him rather than the real server (e.g. a bank).



The attacker then connects to the target server on behalf of the victim, and effectively sits between the communicating parties, passing messages back and forth.

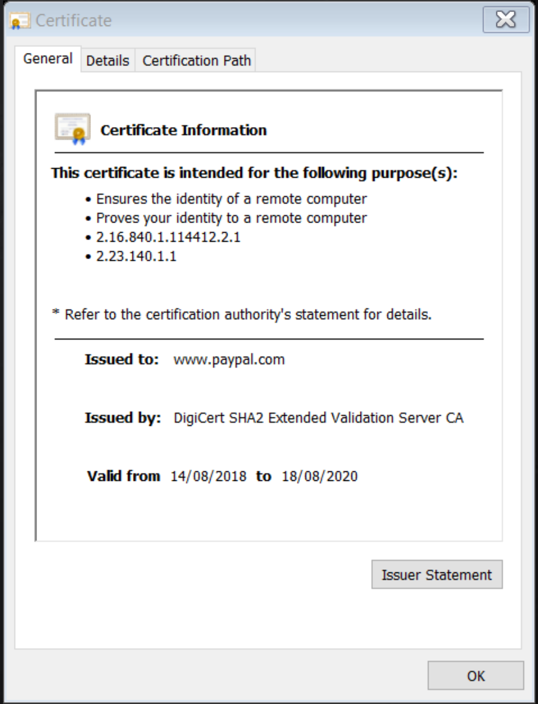
- He may thus both listen to and modify the communication.

When HTTPS is used, the clients will always verify the server's certificate.

Due to the way certificates are generated, the man in the middle will not be able to create a fake, but valid certificate for the web site.

Note that HTTPS in real life doesn't always solve the problems completely:

- Ignorant user
- Fake website with similar domain name
- Certification authorities' mistakes
- Bugs in browsers
- ….



Certificate Information

This certificate is intended for the following purpose(s):

- Ensures the identity of a remote computer
- Proves your identity to a remote computer
- 2.16.840.1.114412.2.1
- 2.23.140.1.1

* Refer to the certification authority's statement for details.

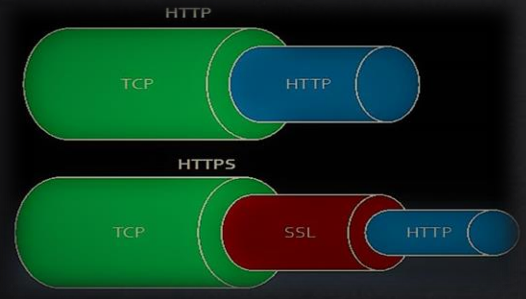
Issued to: www.paypal.com

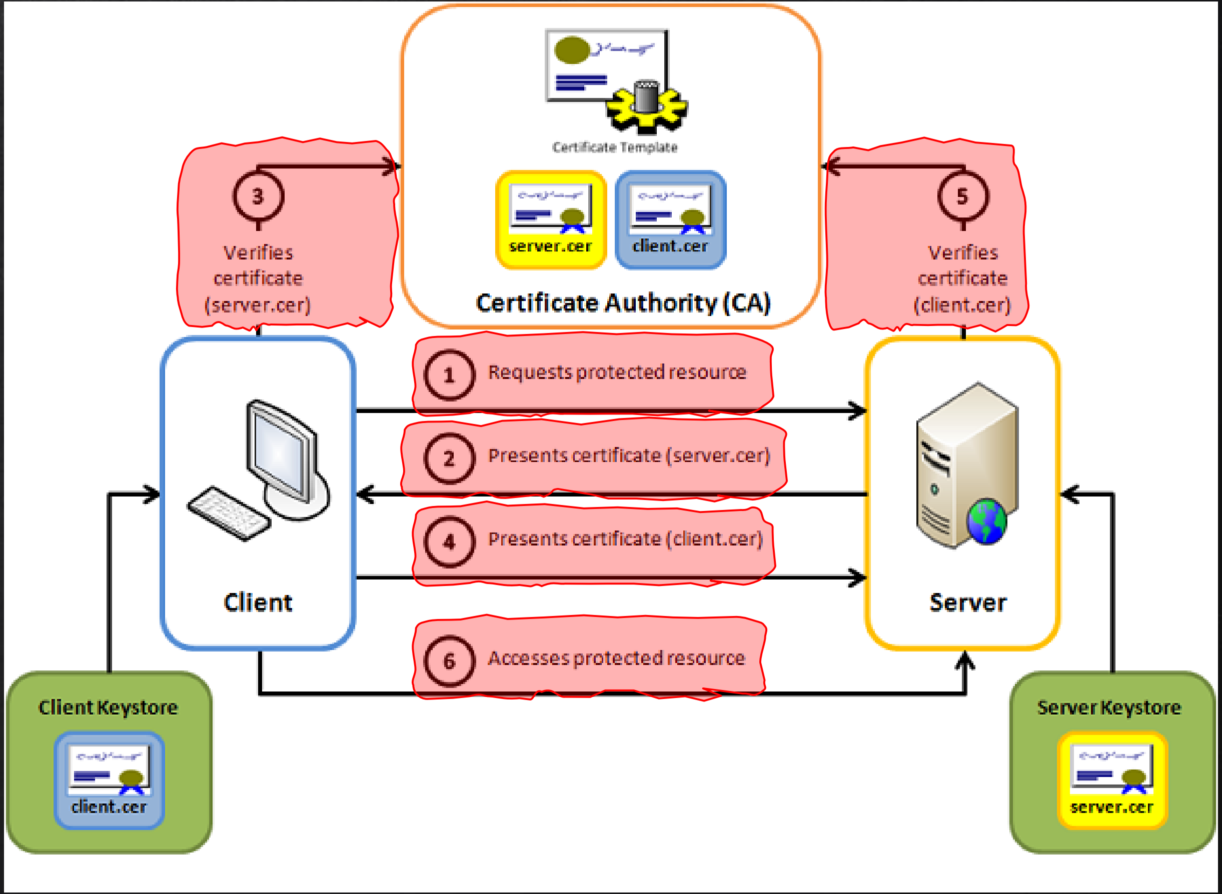
Issued by: DigiCert SHA2 Extended Validation Server CA

Valid from 14/08/2018 **to** 18/08/2020

Certificate based Mutual Authentication

When HTTPS is used, the clients will always verify the server's certificate.




Certificate Template
server.cer
client.cer
Certificate Authority (CA)
3 Verifies certificate (server.cer)
5 Verifies certificate (client.cer)
1 Requests protected resource
2 Presents certificate (server.cer)
4 Presents certificate (client.cer)
6 Accesses protected resource
Client
Server
Client Keystore
client.cer
Server Keystore
server.cer

Defeat MITM using HTTPS

HTTPS provides good protection of the communication channel, unless:

- The user neglects the warnings from the browser.
- The browser allows the user to neglect its warnings.
- The user falls for cheap domain name or protocol tricks played by an attacker.
- The CA may be tricked into giving out false certificates.
- The browser vendor trusts a CA that the user wouldn't trust.
- The browser (or server) has a buggy SSL/TLS implementation.
- The user's computer is controlled by an attacker.

HTTPS is not a magic bullet, however it is a good widely available mechanism for securing web traffic.

Summary

Summary

- HTTP is a simple, text-oriented protocol.
- Clients connect to servers and send requests, each of which draws a response from the server.
- Headers are used to control the communication, and to pass cookies.
- All request headers and data are controlled by the client.
- An attacker may thus easily pass headers and data after his own liking.

Summary

- Sessions are server-side containers for state information.
- Attackers may be able to hijack the sessions of other users by getting hold of their session ID.
- Several measures are available to make session hijacking hard, but the real solution is to keep the session ID a secret.
- HTTPS protects data that pass between the client and the server.
- Unfortunately, real world implementations of HTTPS are not bulletproof. Many weak links play a part in the game, and some of those links may easily break.

Your tasks for this week

Reading:

- "Innocent Code: A Security Wake-Up Call for Web Programmers" (Chapter 1).

Practical:

- HW 01: Installation of Postman