# Lecture 17 – Browser Security

Stephen Checkoway
University of Illinois at Chicago
CS 487 – Fall 2017
Some slides from Bailey's ECE 422
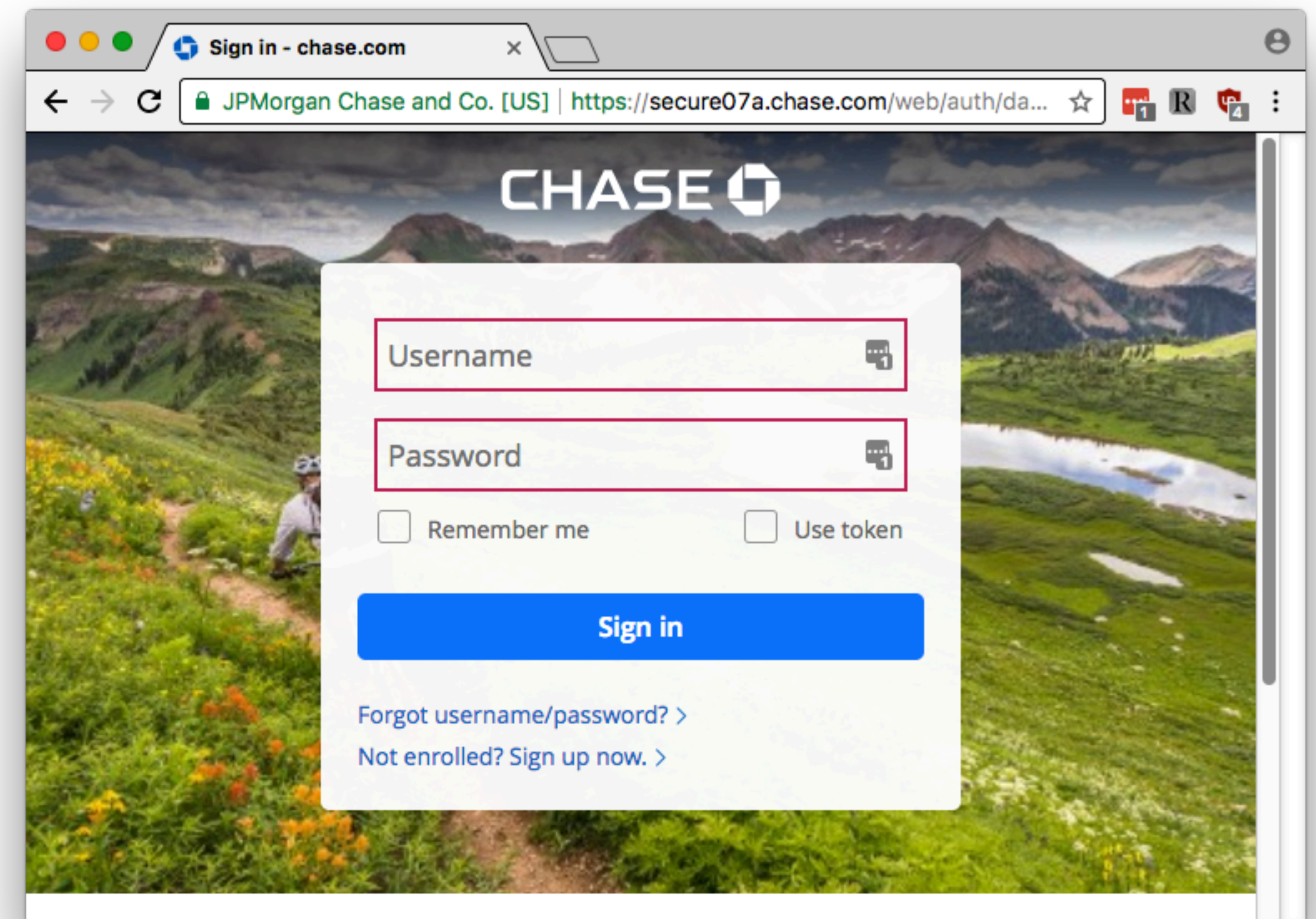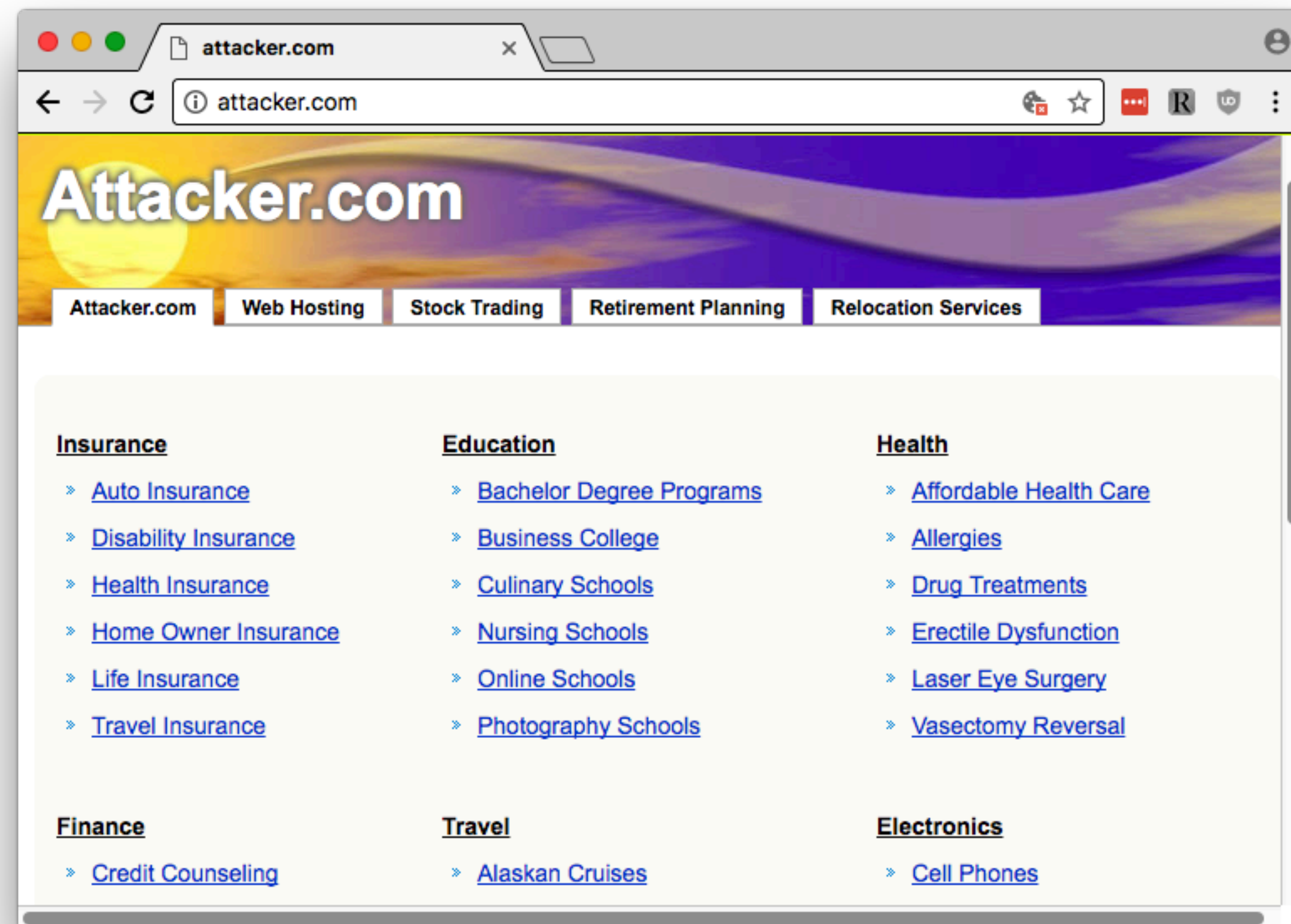
# Documents

- Browser's fundamental role is to display documents comprised of
  - HTML
  - JavaScript
  - Style sheets (CSS)
  - Images
  - Sounds
  - Movies
  - Plugin content
    - Flash
    - SilverLight
    - QuickTime
    - …

# Document Object Model (DOM)

- The browser allows scripts to
  - add/modify/delete/style the DOM elements
  - make changes in response to user actions (e.g., clicks)
  - submit forms
  - browse to a new document altogether

- Scripts in one document can modify another document
  - We say that Page A *scripts* Page B

# Scripting other documents

- Very powerful capability and without constraints would be dangerous

- Consider having attacker.com open while logging into chase.com

- If attacker.com can script chase.com, what could happen?

# Clearly we need separation

- This is Risk #3 from last time

- Same Origin Policy (SOP)
  - Goal: Partition documents into equivalence classes that can script each other (including reading each others' content)
  - Each document is assigned an origin and documents can script other documents in the same origin
  - We construct the origin from the URL

# From URLs to Origins

- General form of a URL
  scheme://user:pass@host:port/path?querystring#fragment

- Most parts are optional giving URLs like
  http://www.uic.edu/chicago
  https://google.com?q=hello+world

- Origins are the triple (scheme, host, port)
  What's the origin for http://www.uic.edu/chicago?


  What's the origin for https://google.com?q=hello+world?

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  What's the origin for http://www.uic.edu/chicago?

  (http, www.uic.edu, 80)

  What's the origin for https://google.com?q=hello+world?

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  http://www.uic.edu/chicago
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- Origins are the triple (scheme, host, port)
  What's the origin for http://www.uic.edu/chicago?

  (http, www.uic.edu, 80)

  What's the origin for https://google.com?q=hello+world?

  (https, google.com, 443)

# Origins

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- Why does the origin include the port?

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  - If not, then http://bank.com can script https://bank.com. An "on-path" attacker could inject <script>…</script> into http://bank.com which affects https://bank.com

- Why does the origin include the port?
  - Think about multiple web servers run by different users on the same machine. Without including the port, https://host.com:8443 could script the entirely unrelated https://host.com

# Not the end of the story

- Documents (and thus scripts) can load elements from other origins including images, scripts, style sheets, and flash objects
  - Loading these elements endorses their content and the included elements are considered to be in the loading document's origin

- Conversely, documents (and thus scripts) can submit forms which sends data from the document to some server
  - Submitting forms declassifies the data sent

- Cross-Origin Resource Sharing (CORS) can enable cross-origin requests

# Web Review | HTTP

gmail.com

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GET / HTTP/1.1
Host: gmail.com

gmail.com

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HTTP/1.1 200 OK

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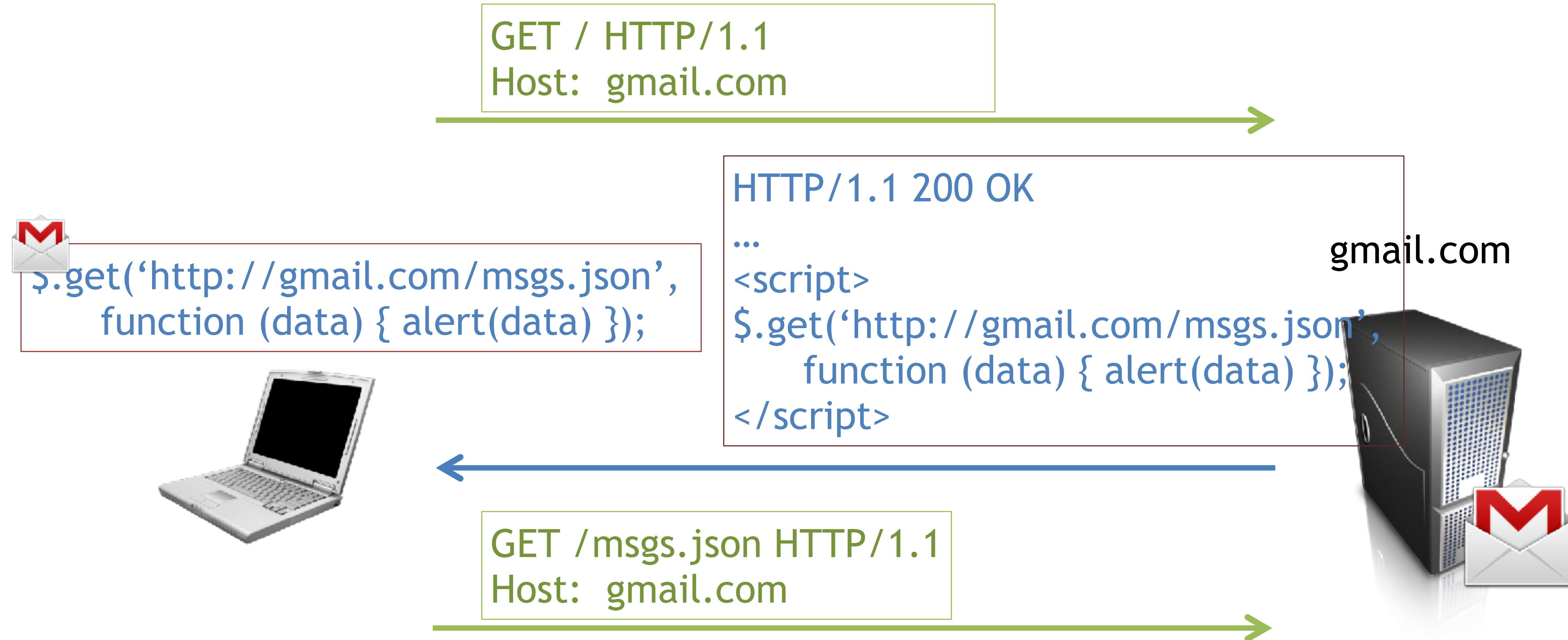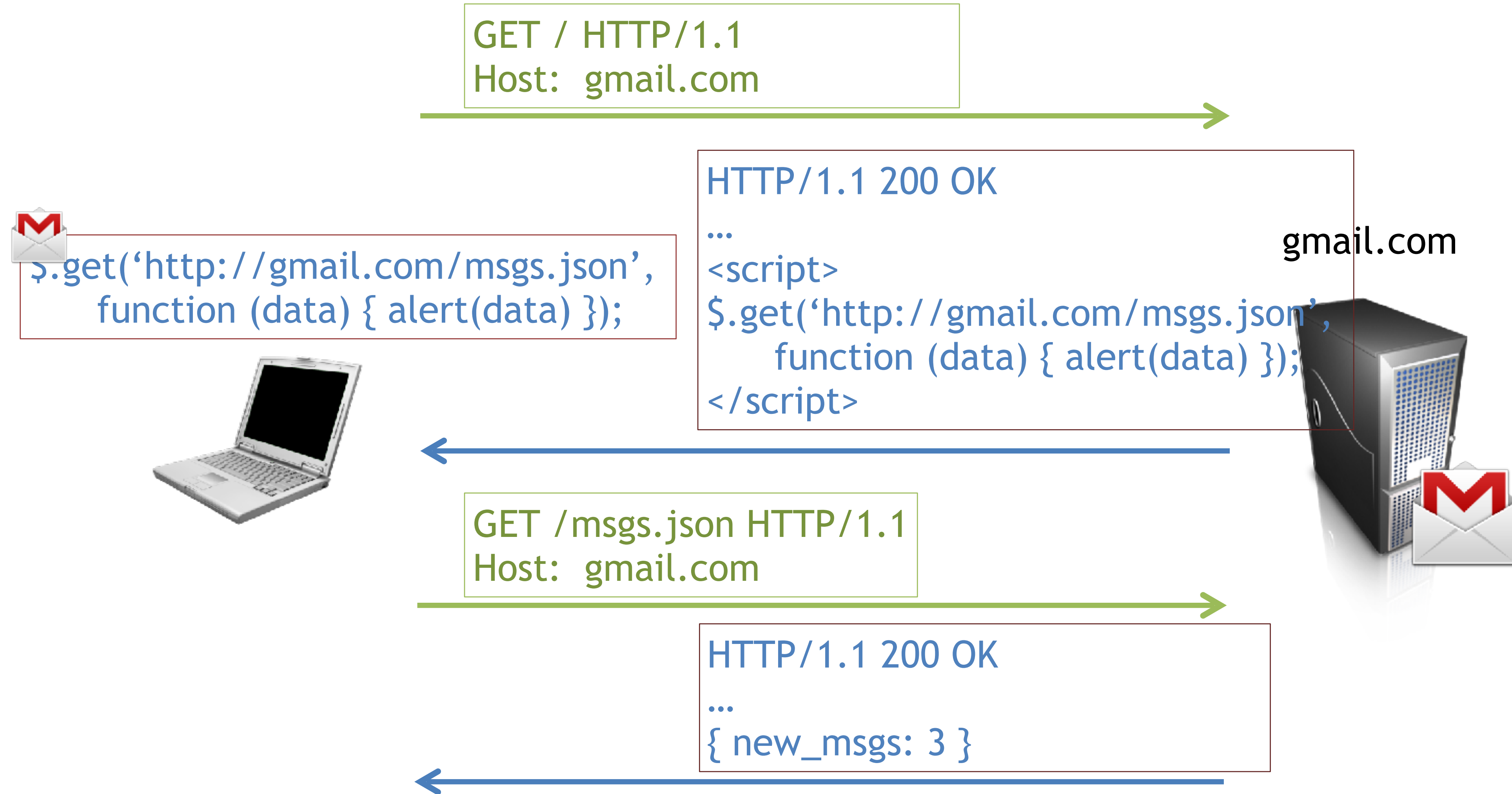$.get('http://gmail.com/msgs.json',
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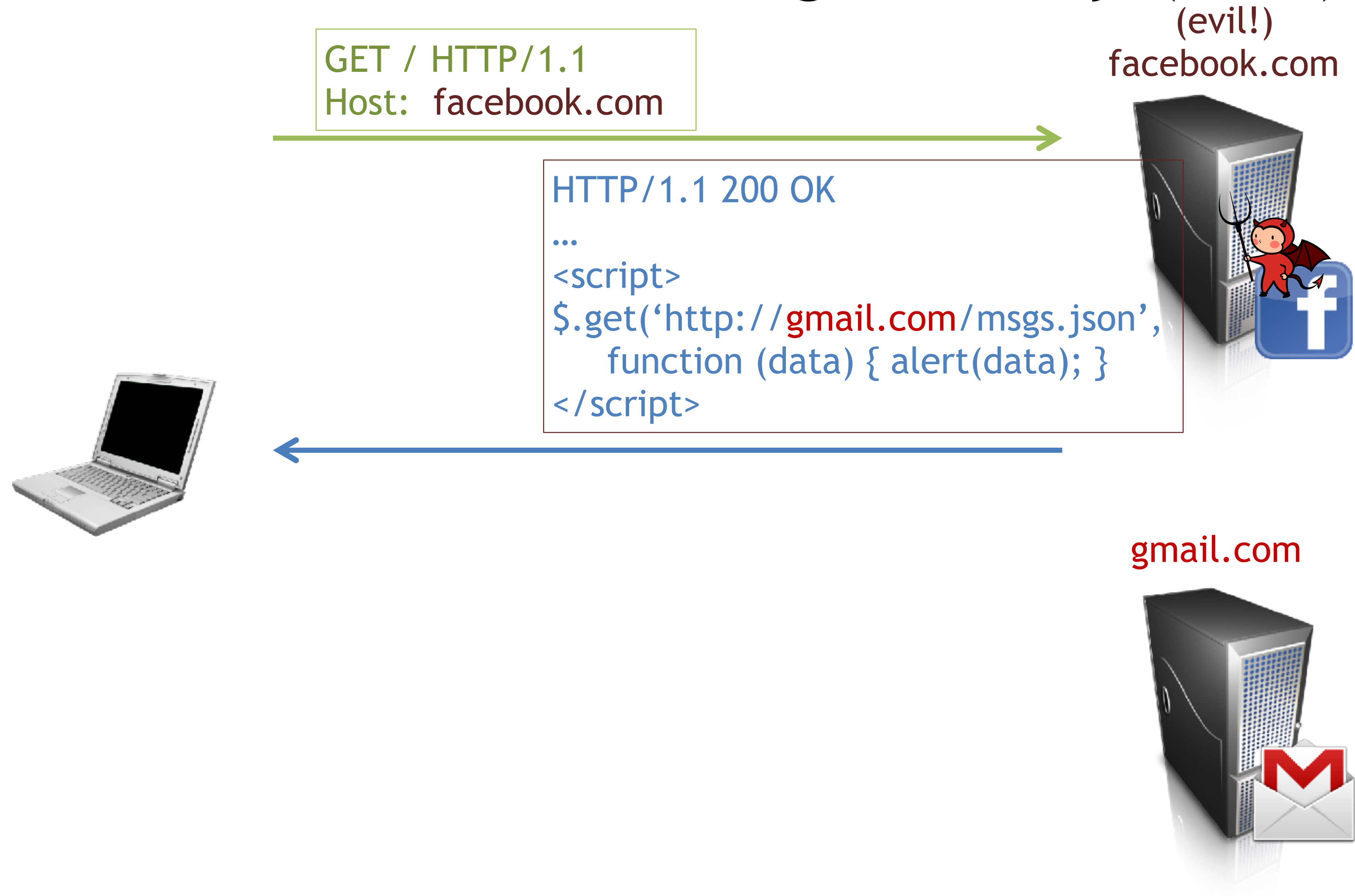
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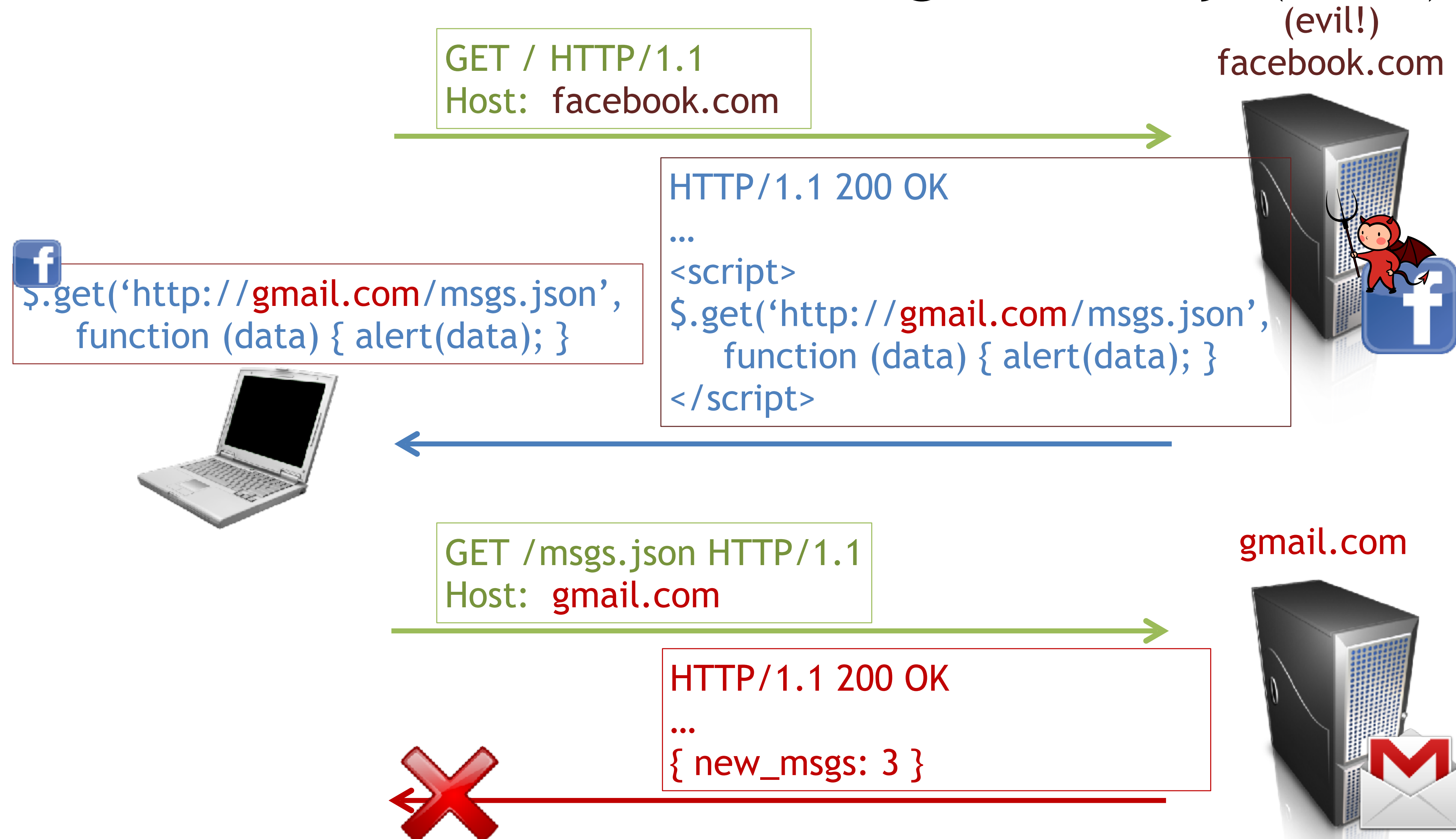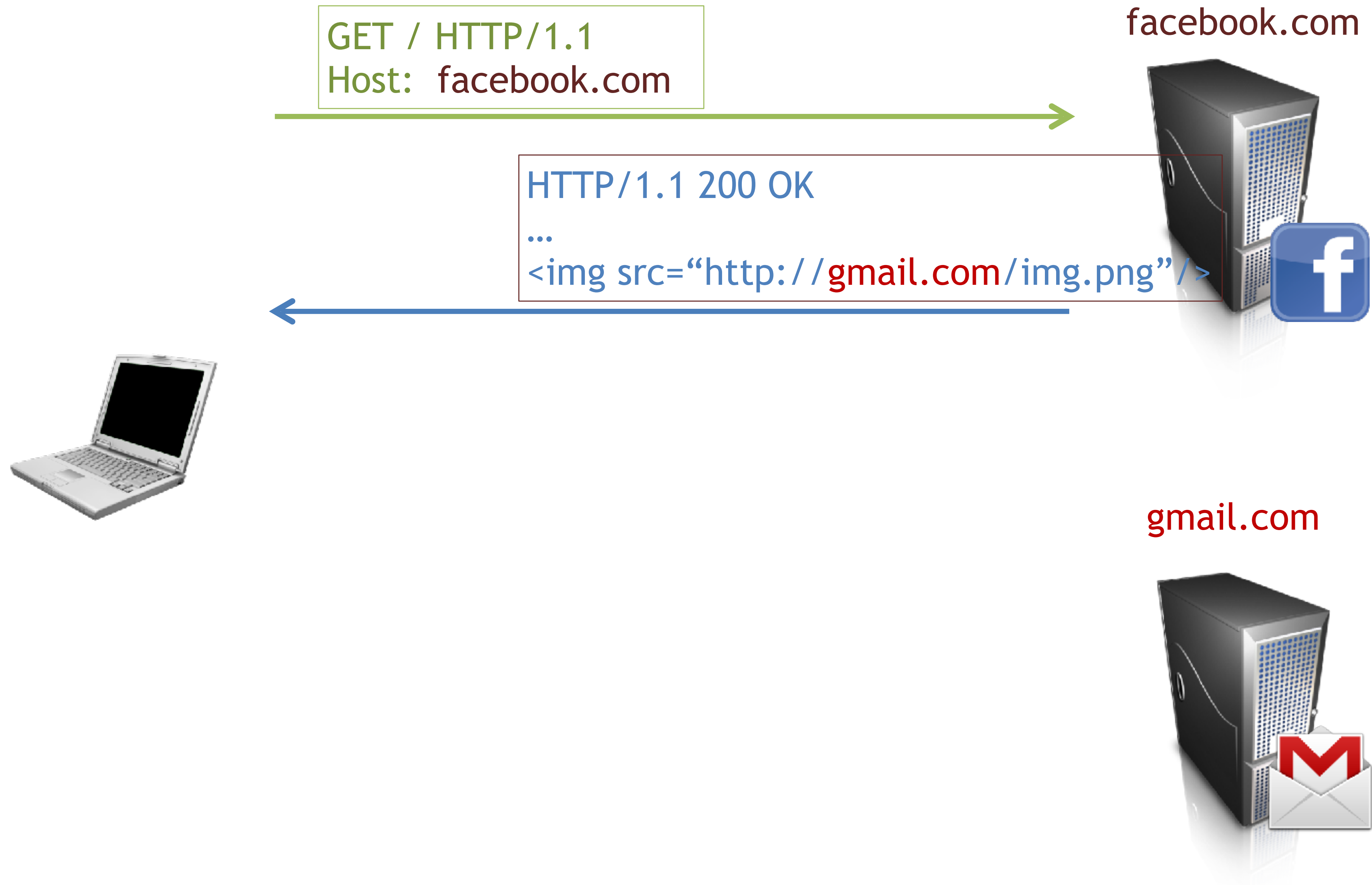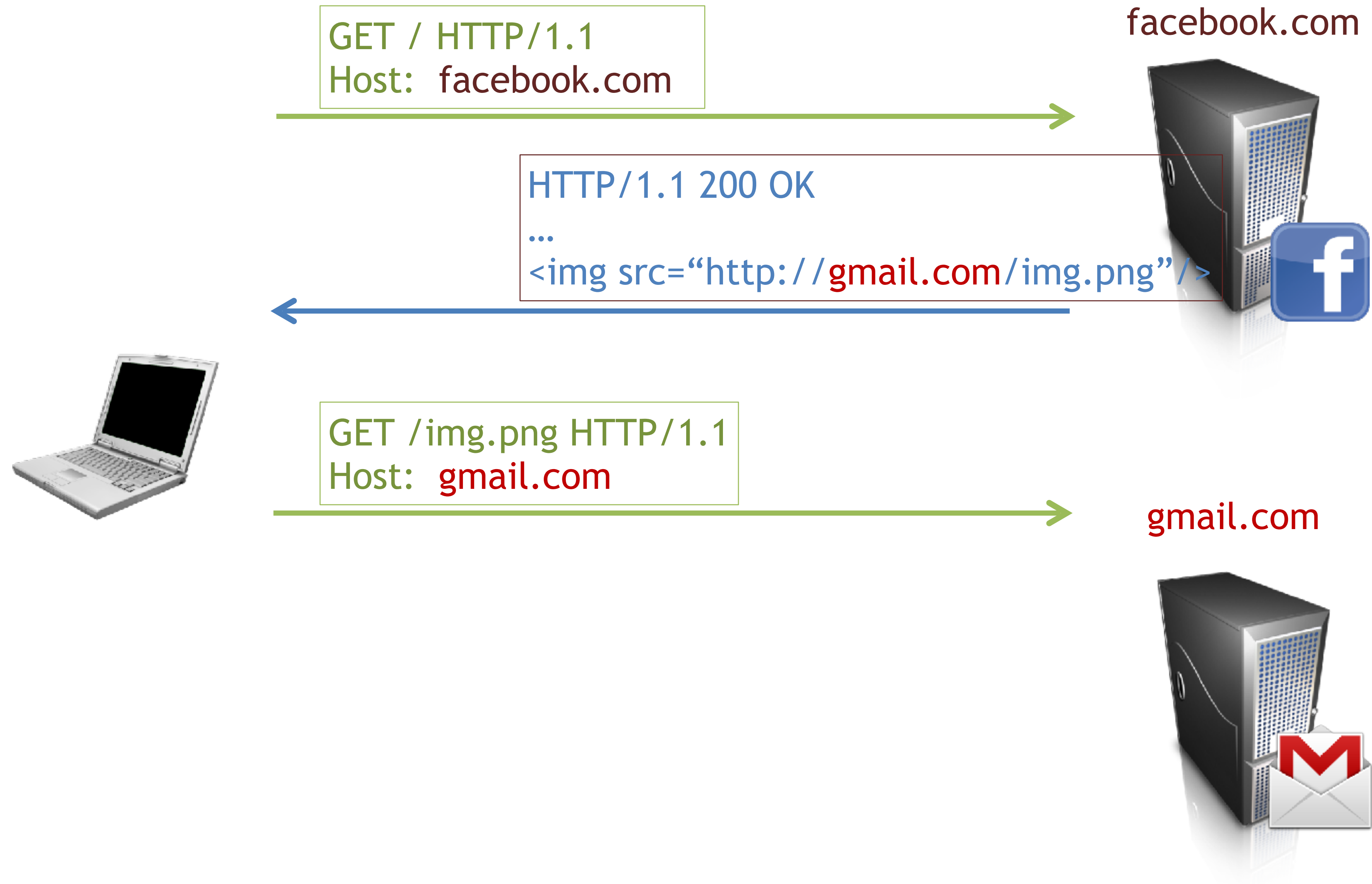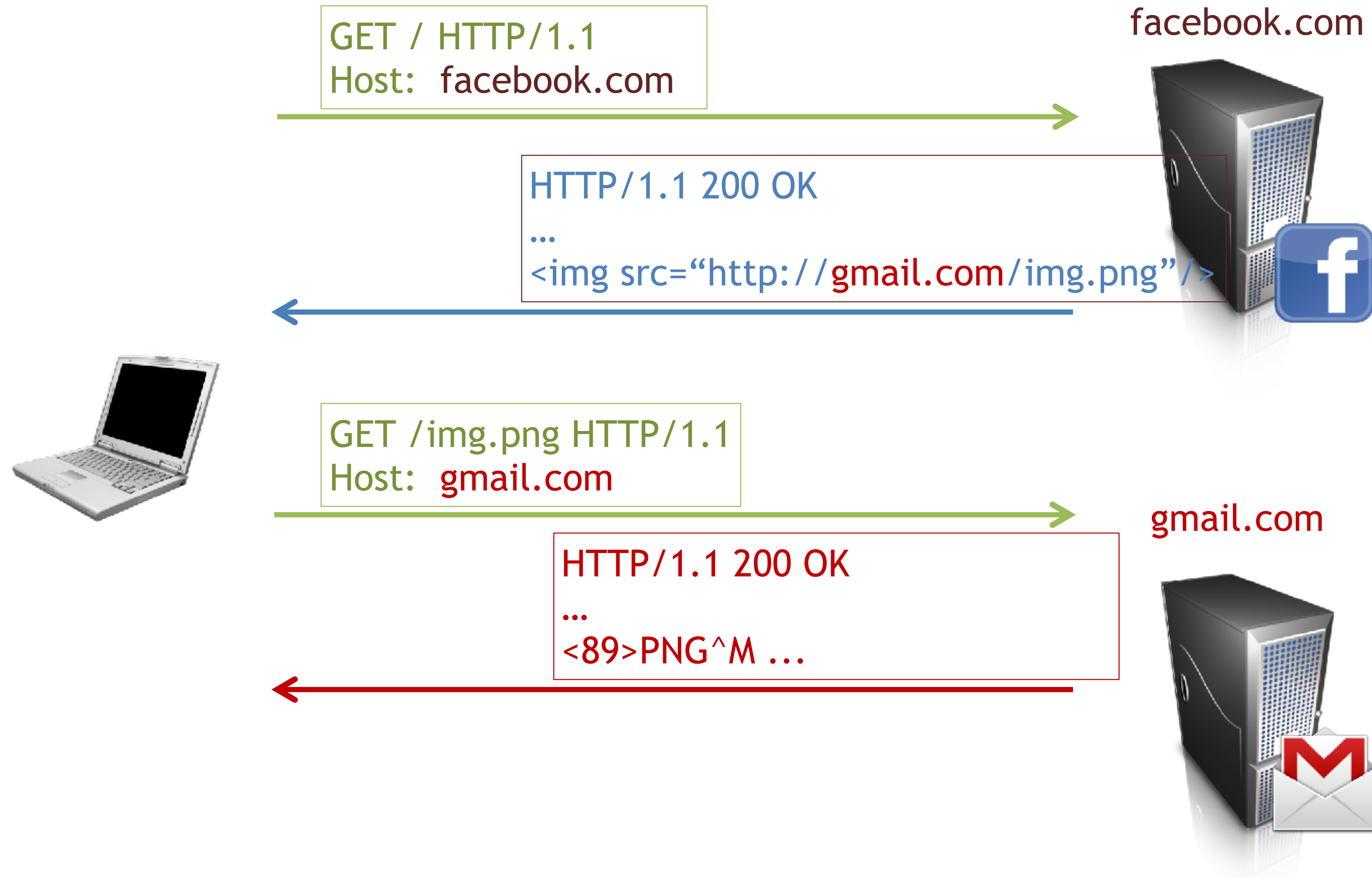
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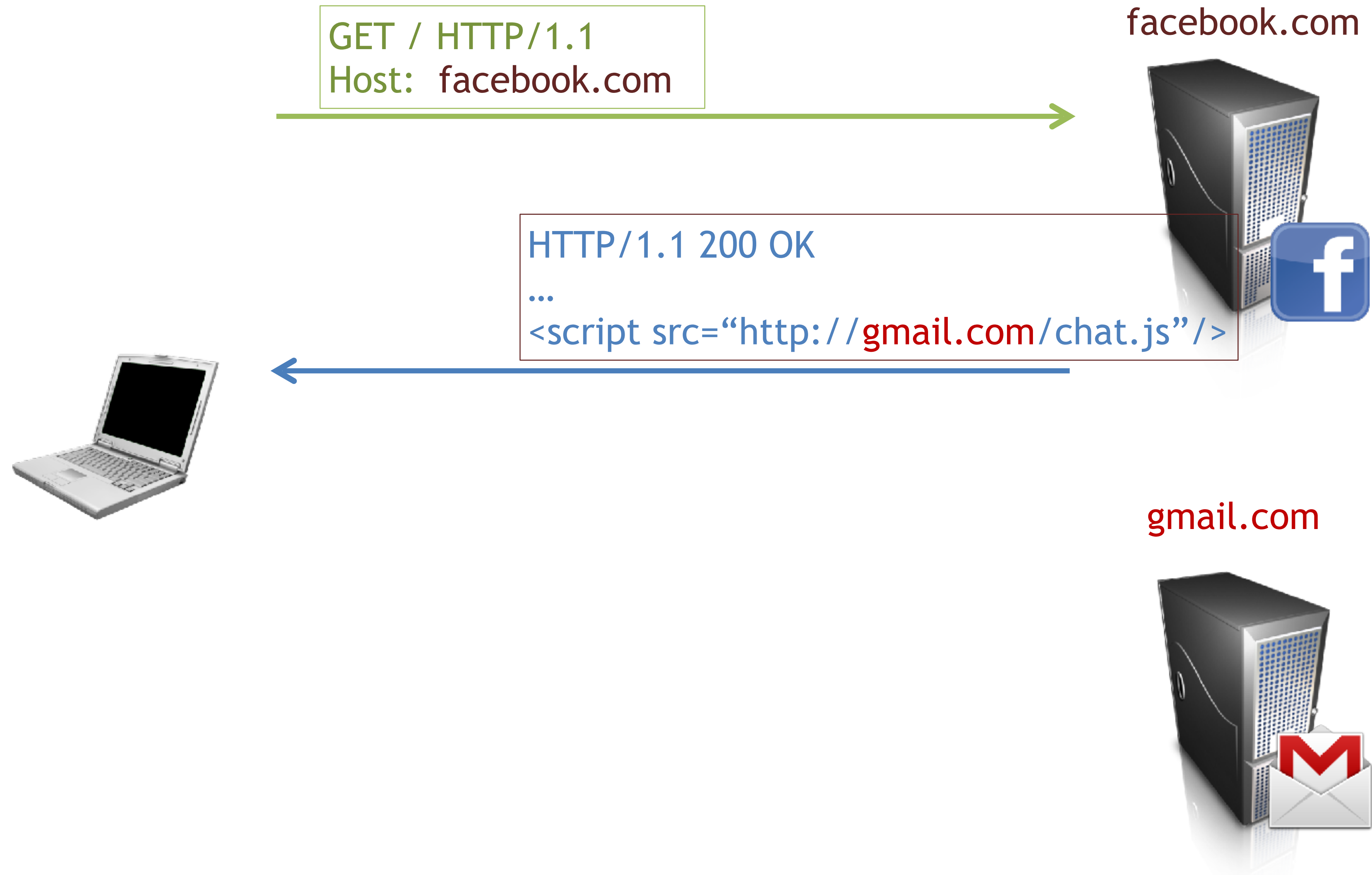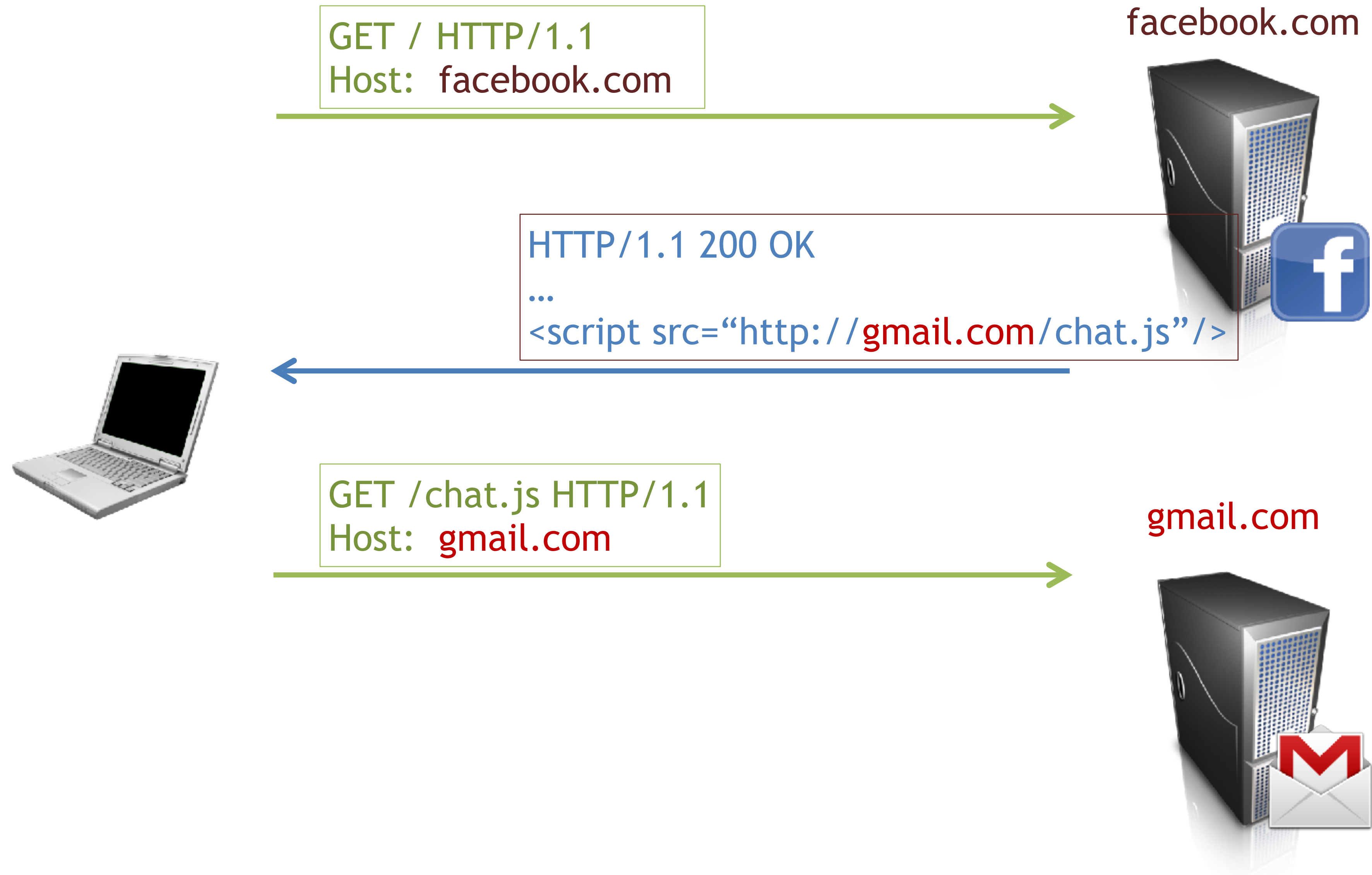facebook.com

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# iframes

- Complete document inside a document
  <iframe src="https://somewhere.com/page.html"></iframe>

- The contents of each iframe belong to its source origin
  (https, somewhere.com, 443) for the iframe above

- The iframe element itself belongs to its containing document

- iframes obey the SOP

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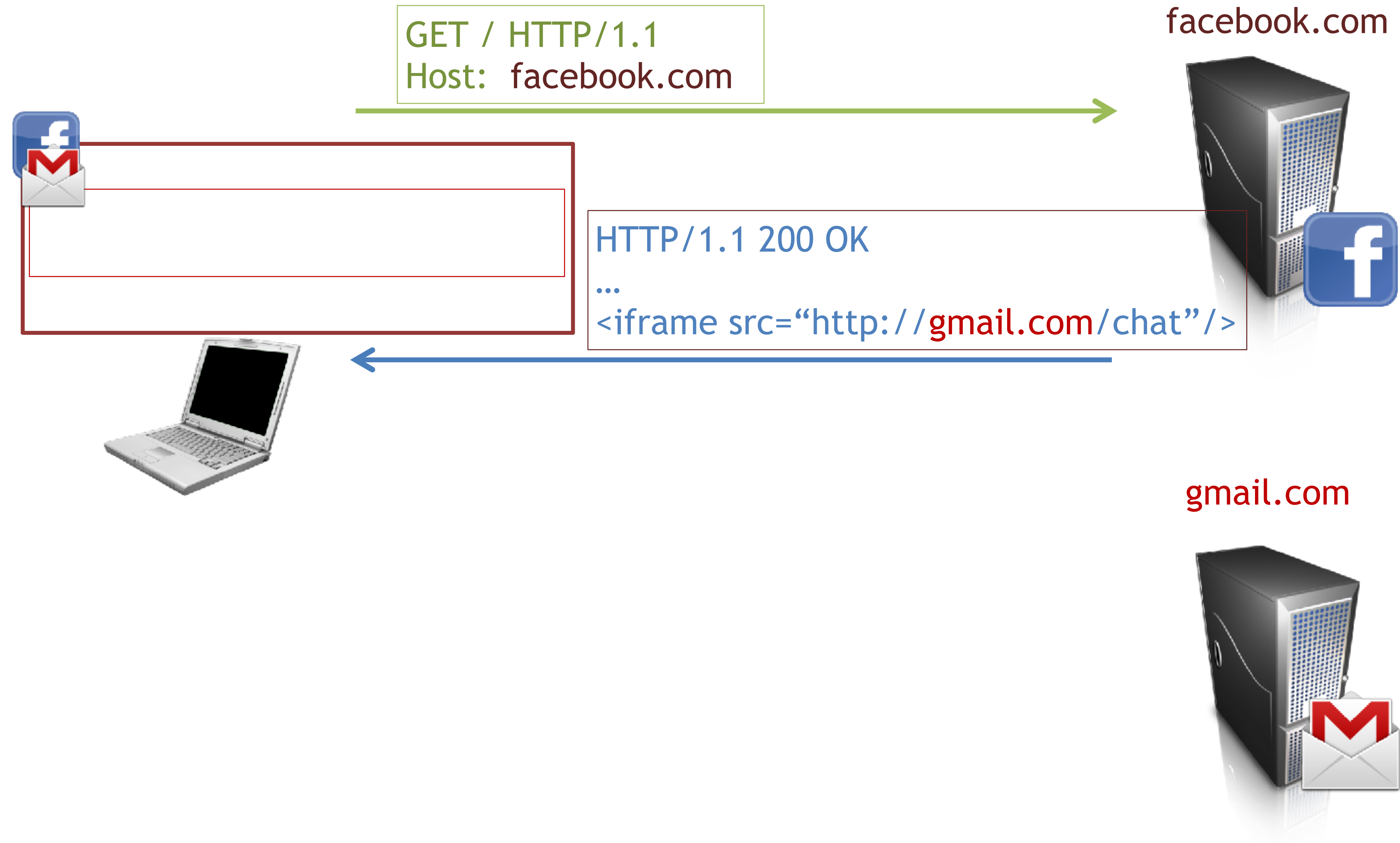
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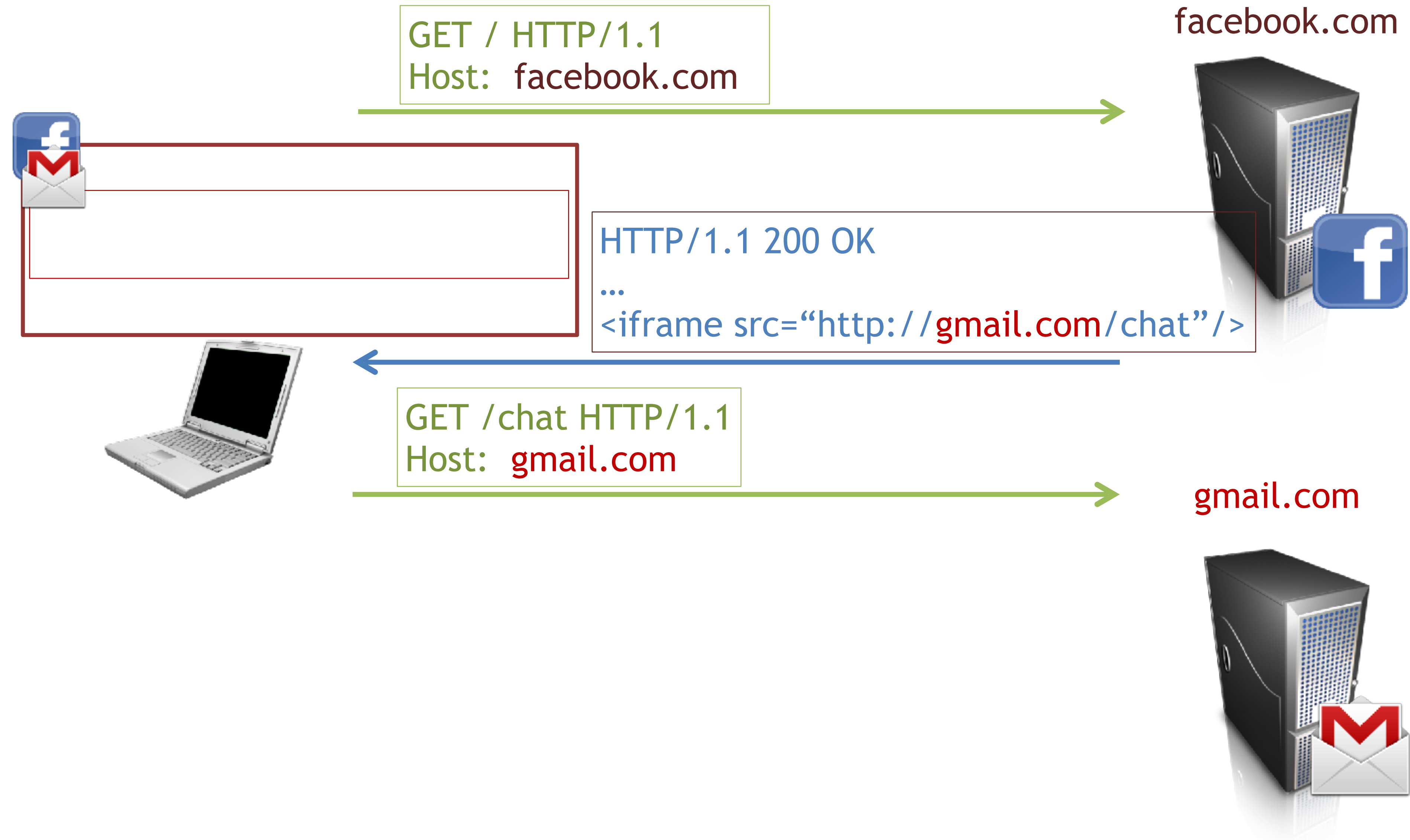
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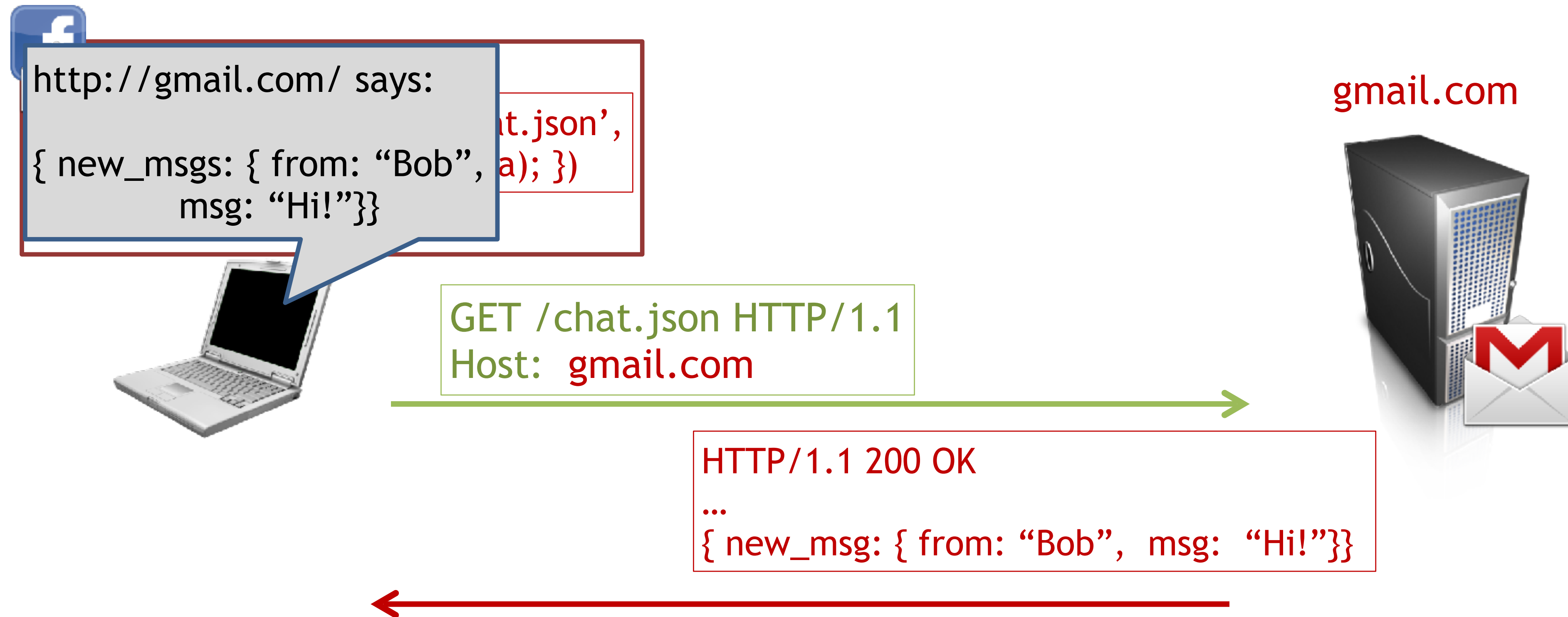
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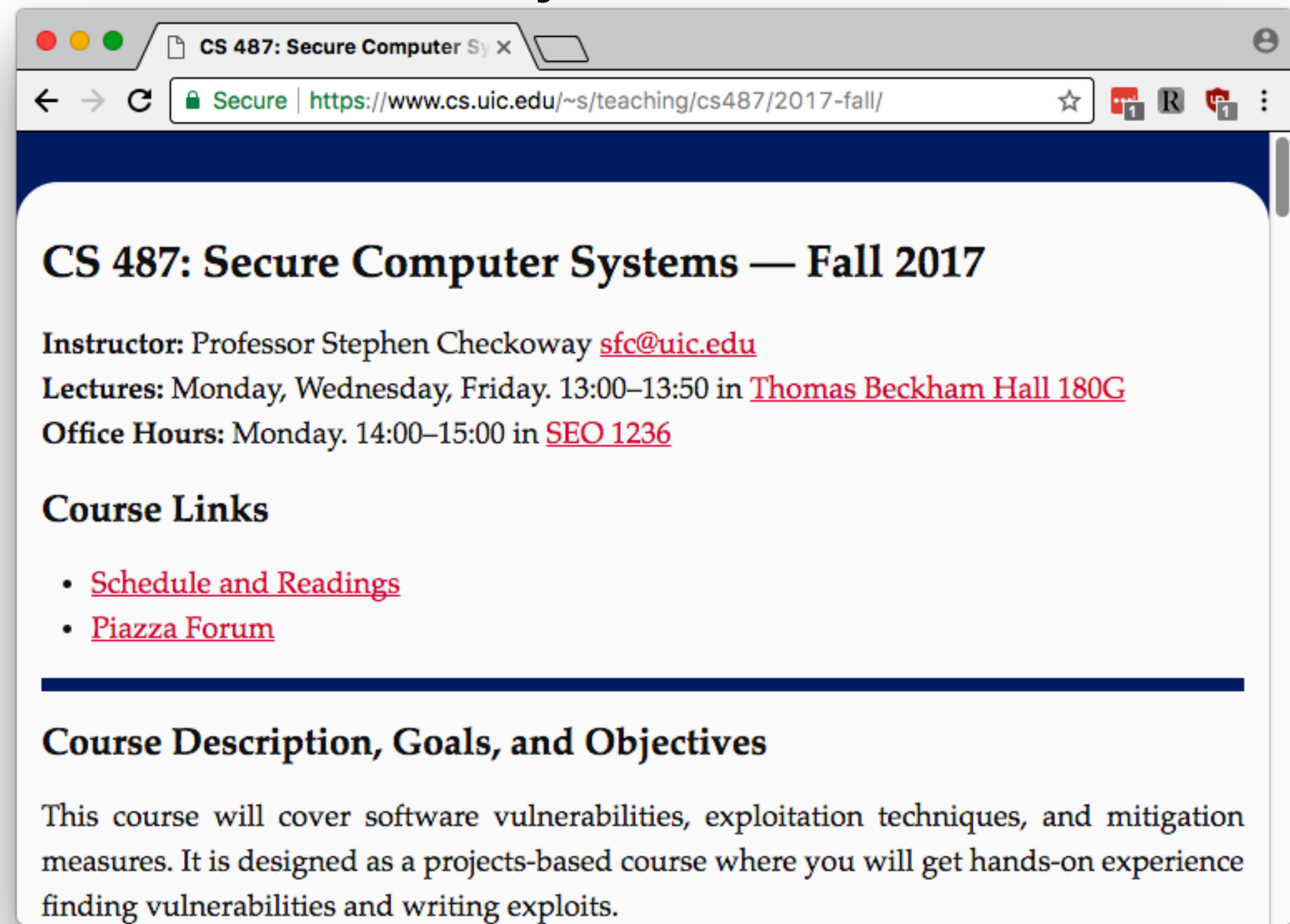# Beware finer-grained origins

- Not all web features respect the SOP

- Example: Cookies can be include a <span style="color:red">path</span>

  - In order to read a cookie with a path, the path of the document's URL must extend the path of the cookie
    Cookie path:          /a/b/c
    Document path:      /a/b          <- Cannot read the cookie
                              /a/b/c/d      <- Can read the cookie

  - This is "finer-grained" than the standard SOP

  - Is this a problem?

# Cookie paths example cont.

- Since documents in the same page can script each other, page /a/b can still read the cookie:
  - Create an iframe with src set to /a/b/c/d (where this the path of some real document that can read the cookie value)
  - Since the iframe is in the same origin, page /a/b can inject a script element into the iframe's document
  - The injected script reads the cookie value and sends it back to the containing page

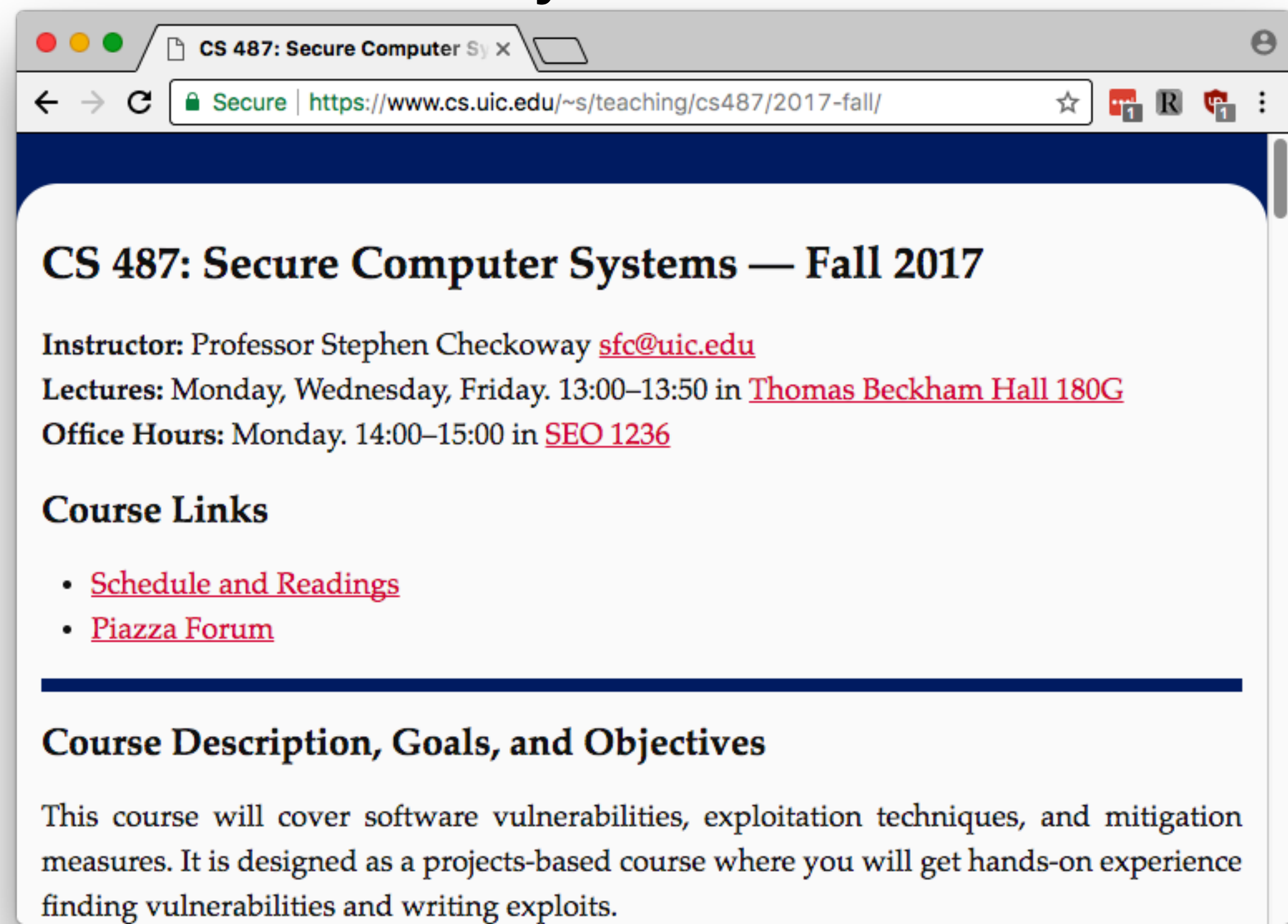- Cookie paths should **not** be used as a security boundary

# Mixed content

- Documents can contain elements loaded over both http and https

- Browsers indicate that this is insecure (by not displaying a lock icon) on the page with mixed content

- Other documents in the same origin are not similarly marked as insecure
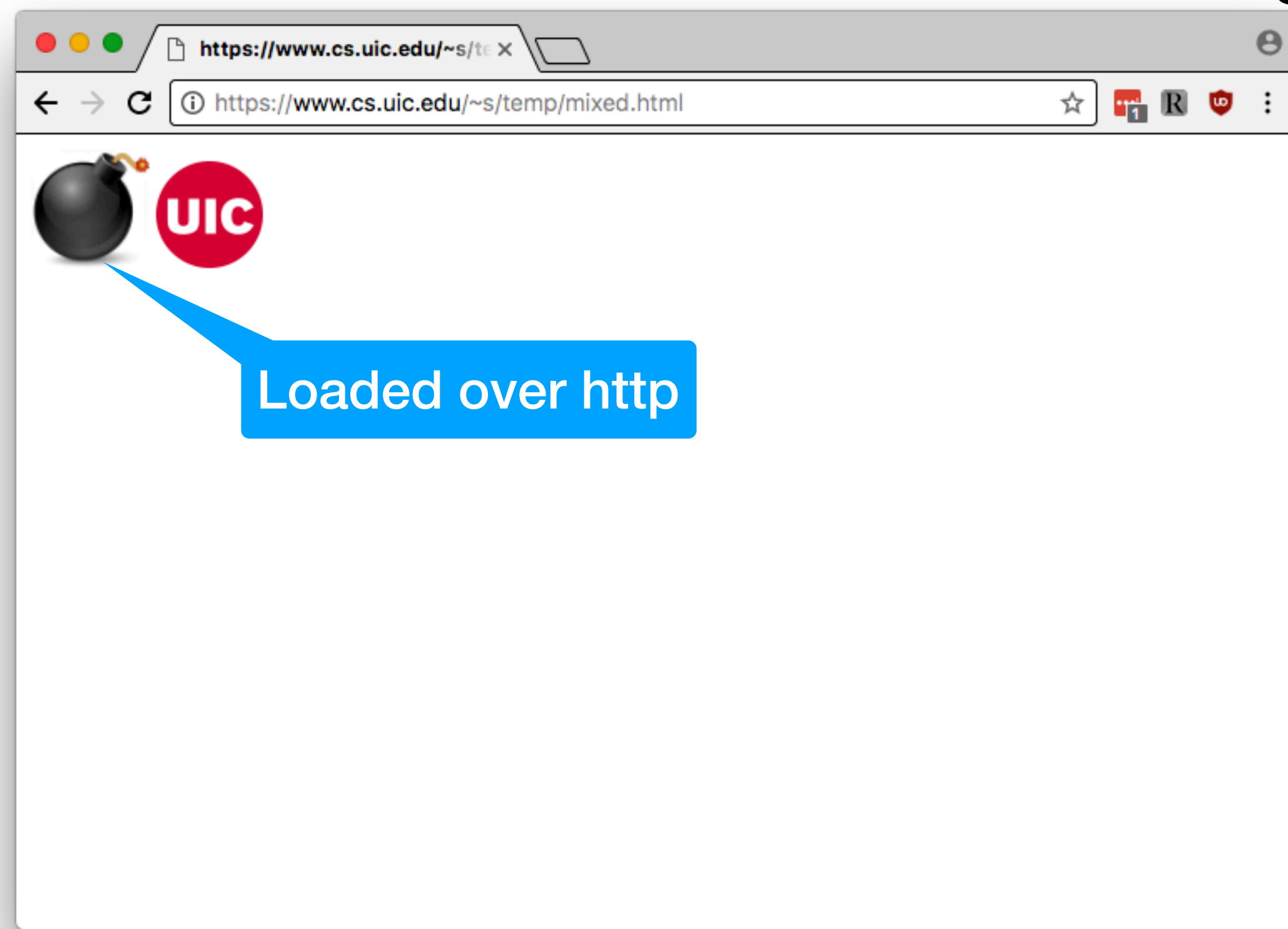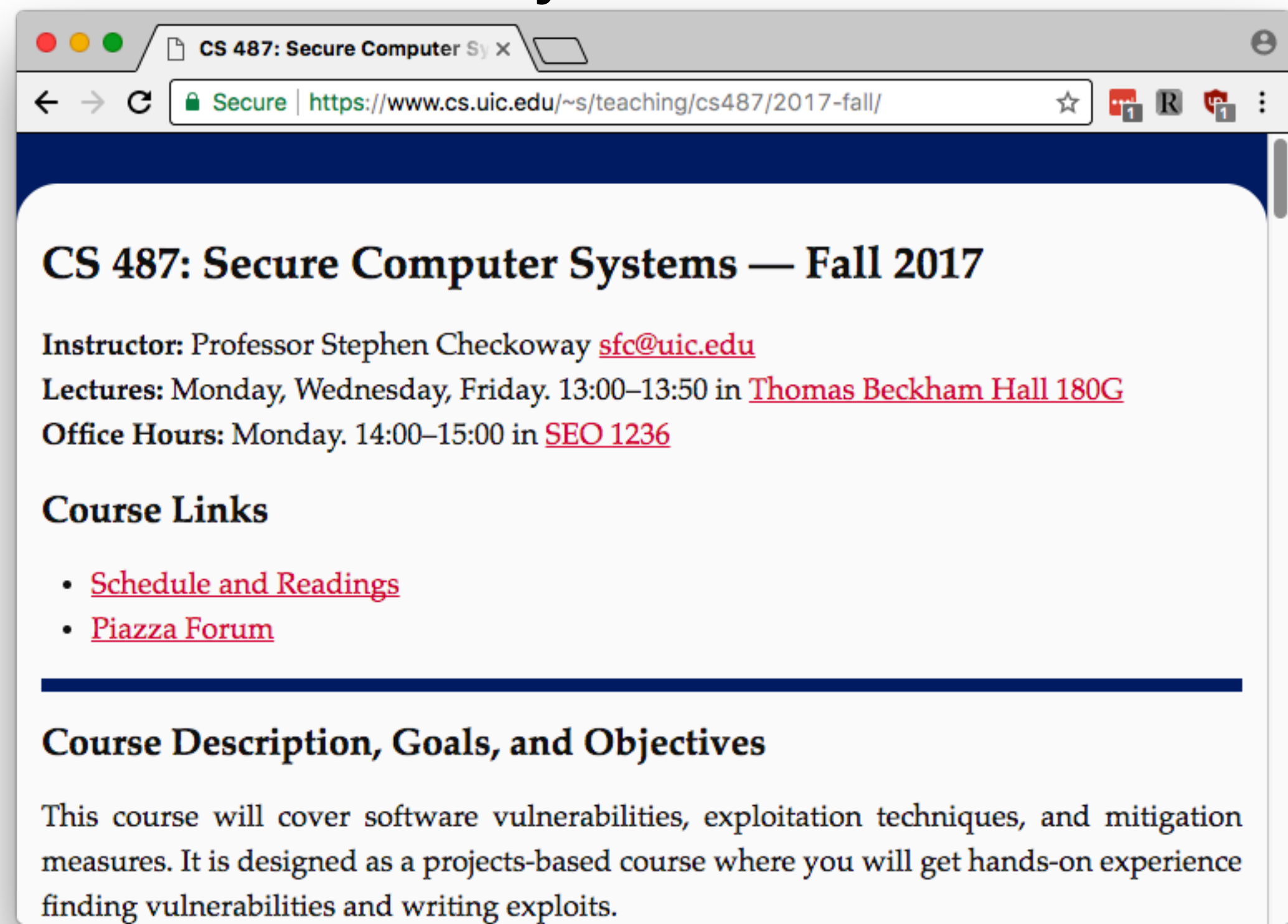
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Loaded over http



## CS 487: Secure Computer Systems — Fall 2017

**Instructor:** Professor Stephen Checkoway sfc@uic.edu
**Lectures:** Monday, Wednesday, Friday. 13:00–13:50 in Thomas Beckham Hall 180G
**Office Hours:** Monday. 14:00–15:00 in SEO 1236

### Course Links

- Schedule and Readings
- Piazza Forum

### Course Description, Goals, and Objectives

This course will cover software vulnerabilities, exploitation techniques, and mitigation measures. It is designed as a projects-based course where you will get hands-on experience finding vulnerabilities and writing exploits.
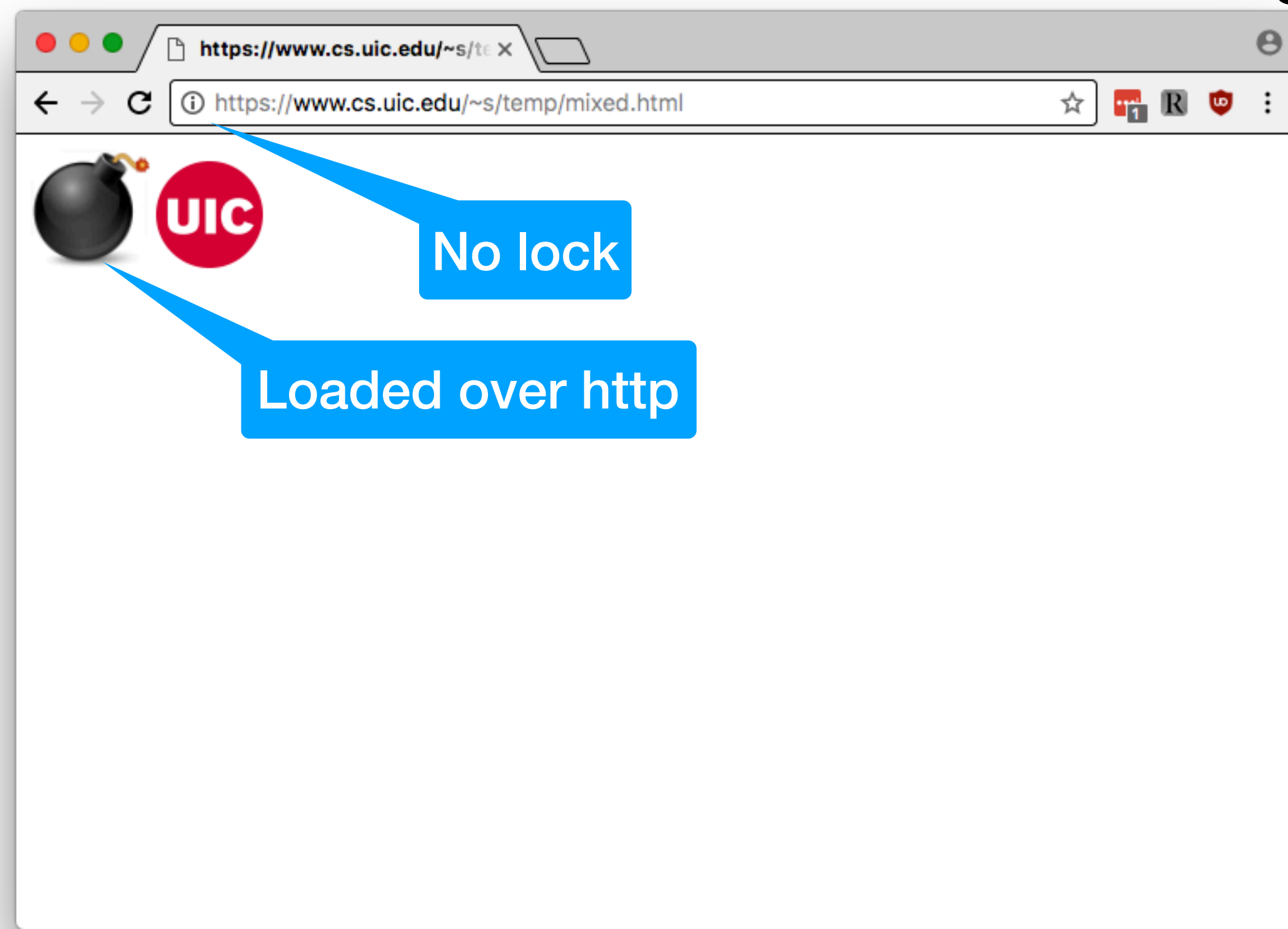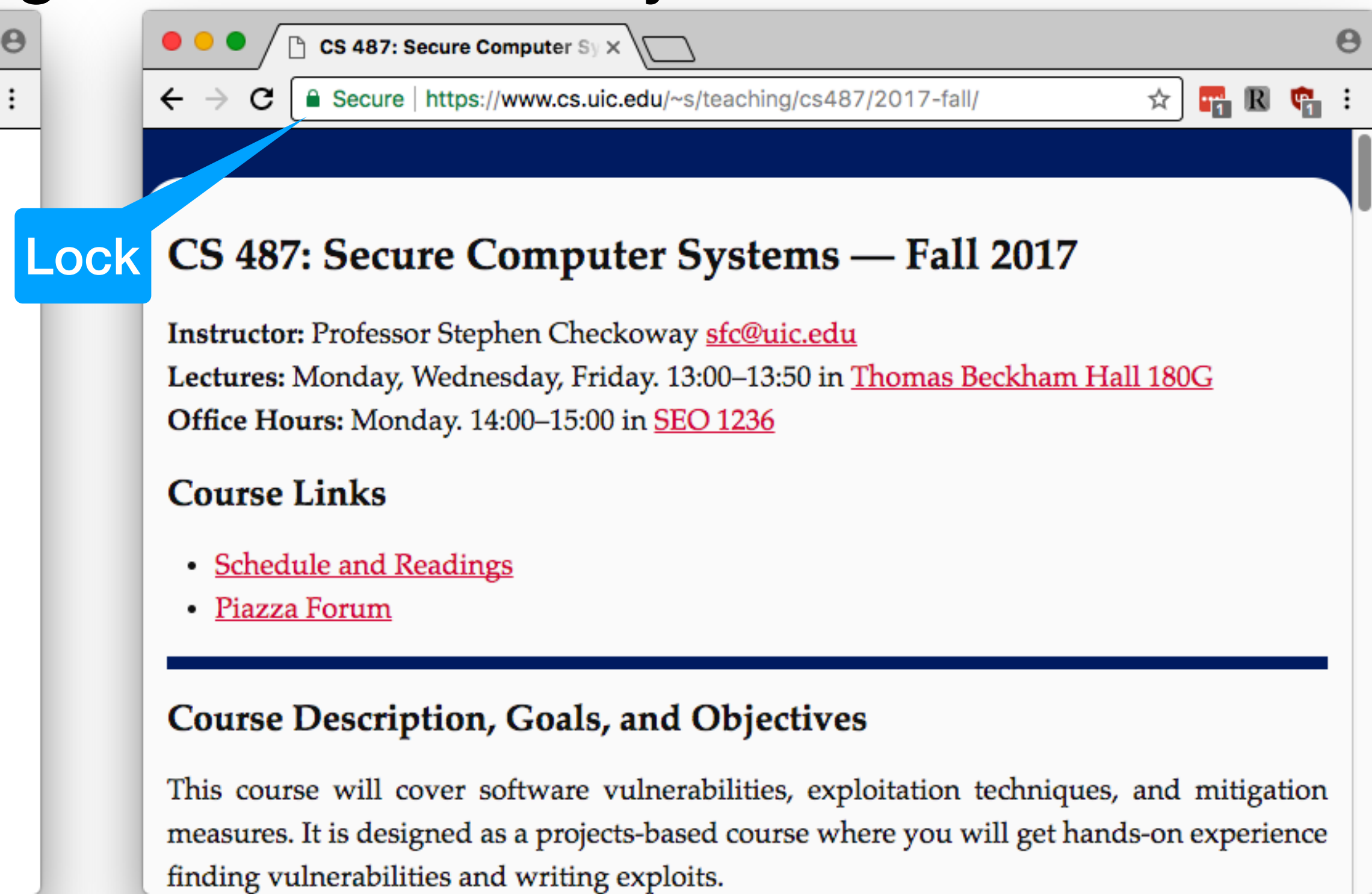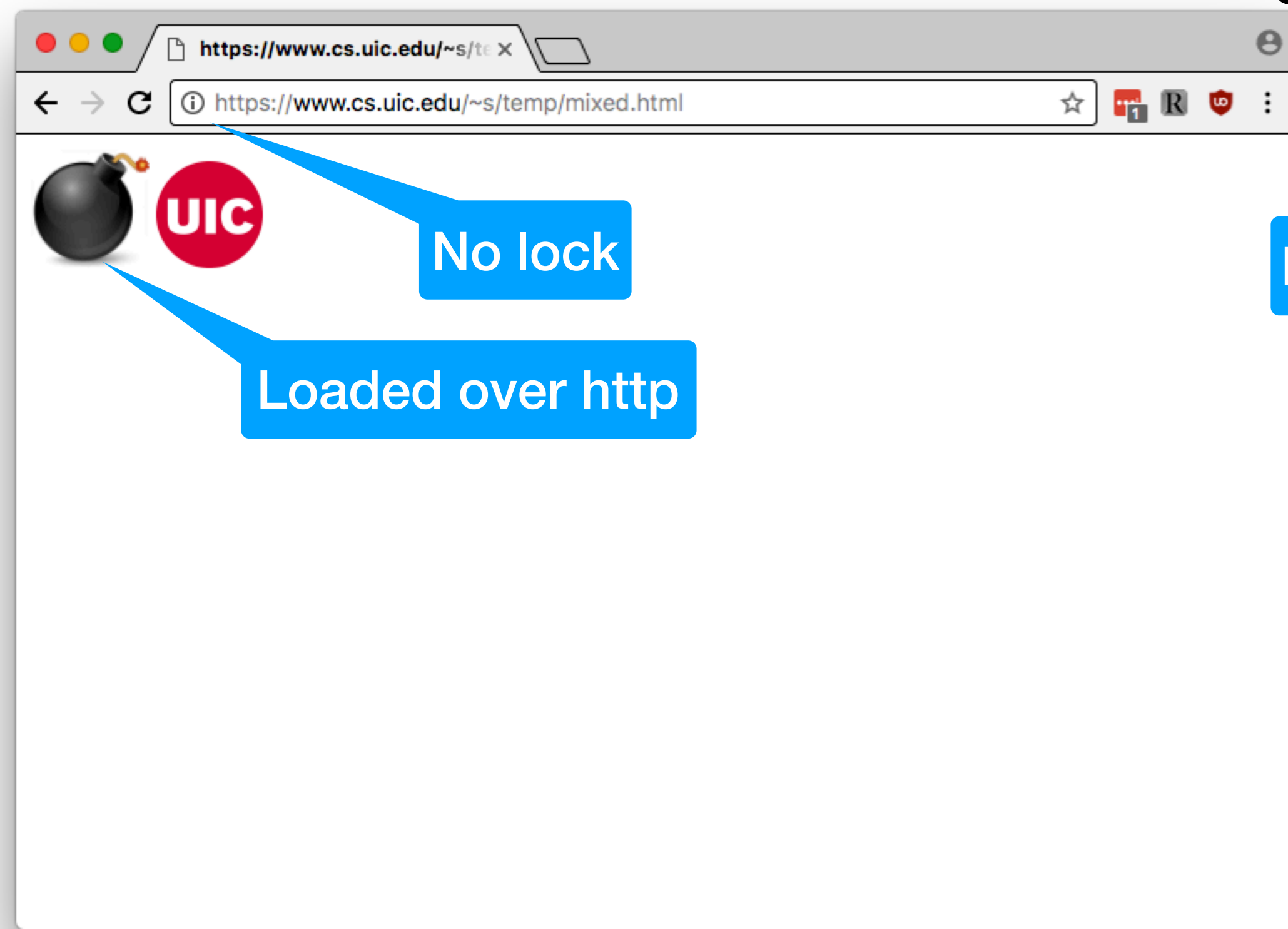
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No lock

Loaded over http



CS 487: Secure Computer Sy ×

Secure | https://www.cs.uic.edu/~s/teaching/cs487/2017-fall/

## CS 487: Secure Computer Systems — Fall 2017

**Instructor:** Professor Stephen Checkoway sfc@uic.edu
**Lectures:** Monday, Wednesday, Friday. 13:00–13:50 in Thomas Beckham Hall 180G
**Office Hours:** Monday. 14:00–15:00 in SEO 1236

### Course Links

- Schedule and Readings
- Piazza Forum

### Course Description, Goals, and Objectives

This course will cover software vulnerabilities, exploitation techniques, and mitigation measures. It is designed as a projects-based course where you will get hands-on experience finding vulnerabilities and writing exploits.

# Mixed content

- Documents can contain elements loaded over both http and https

- Browsers indicate that this is insecure (by not displaying a lock icon) on the page with mixed content

- Other documents in the same origin are not similarly marked as insecure

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- Yes, script injected from the element loaded over http could script other pages in the same origin…

- …except modern browsers explicitly do not run scripts loaded via http in an https page, so not really any more

# Cross-origin attacks

# Setup

- Web attacker
  - Controls one or more domains (e.g., attacker.com, evil.com)
  - Can cause the victim to browse to a page serving JavaScript at one of these domains

- Victim is logged in to bank.com (or any other interesting site)

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- Can the attacker's script use XMLHttpRequest("https://bank.com/transfer?from=victim&to=attacker")?

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- Can the attacker's script use XMLHttpRequest("https://bank.com/transfer?from=victim&to=attacker")?
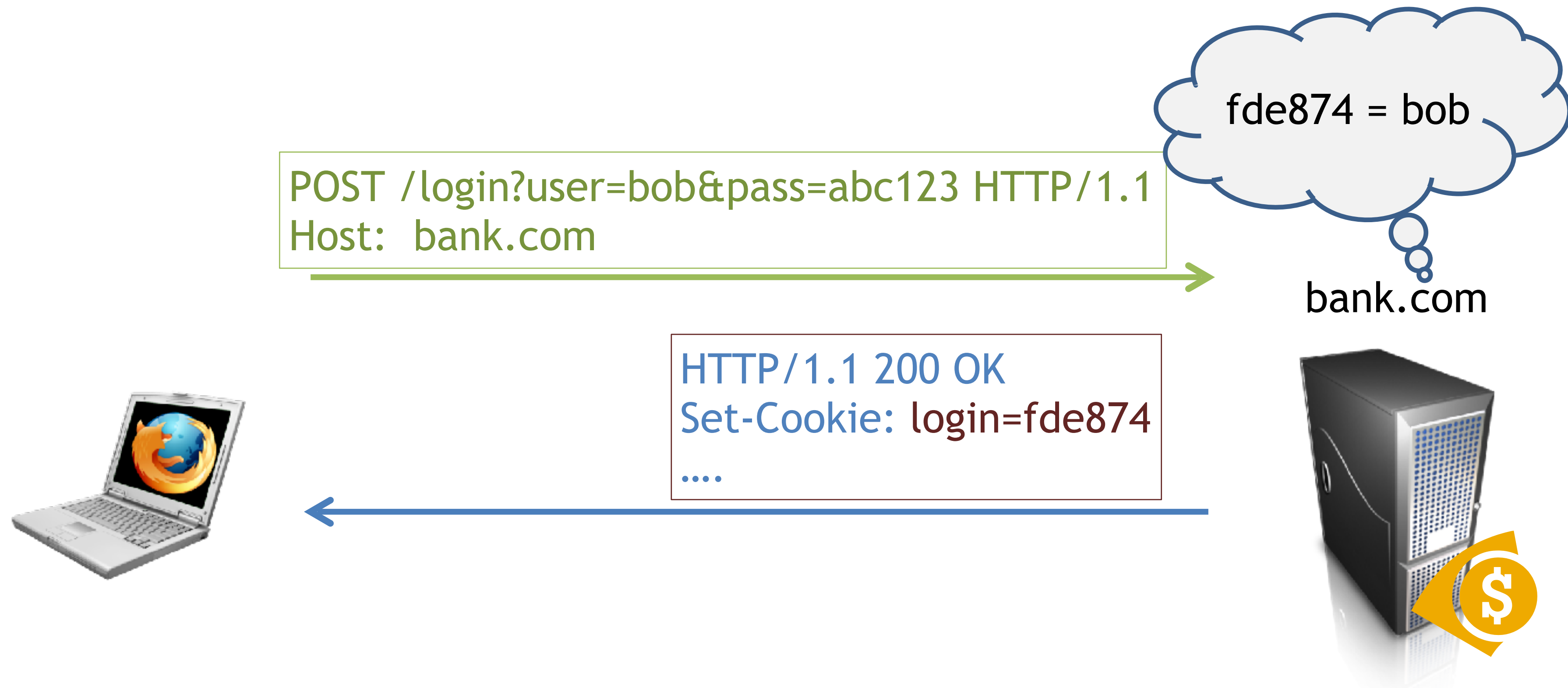  - Yes! Same origin policy doesn't prevent this. The script just cannot read the response

# Cross-site request forgery (CSRF)

- The attacker's site instructs the victim's browser to make a request to an honest site (e.g., using XMLHttpRequest or even just an enticing link)

- An XMLHttpRequest allows both GET and POST

- The browser sends all relevant cookies, including any sessions cookies identifying the logged in victim

- From the server's perspective, it looks exactly like a normal request from the victim's browser
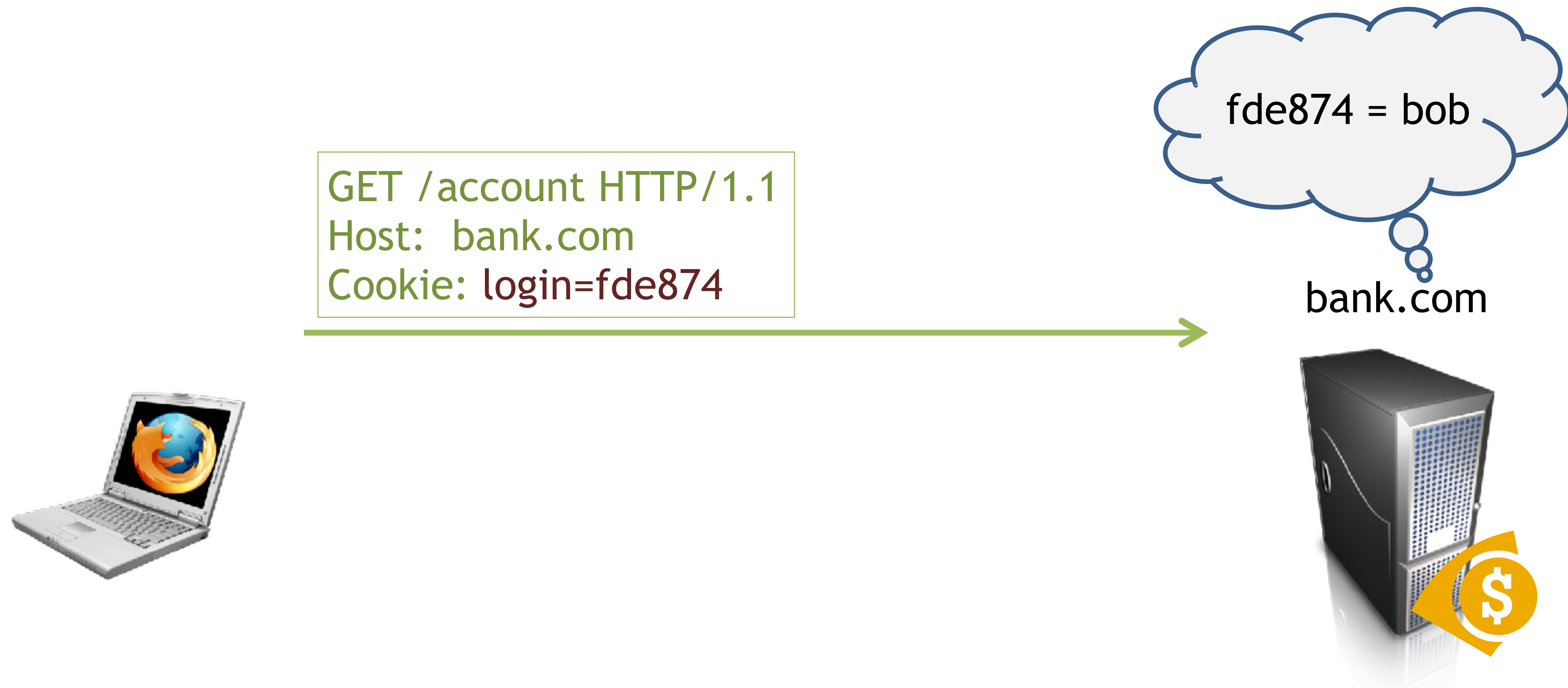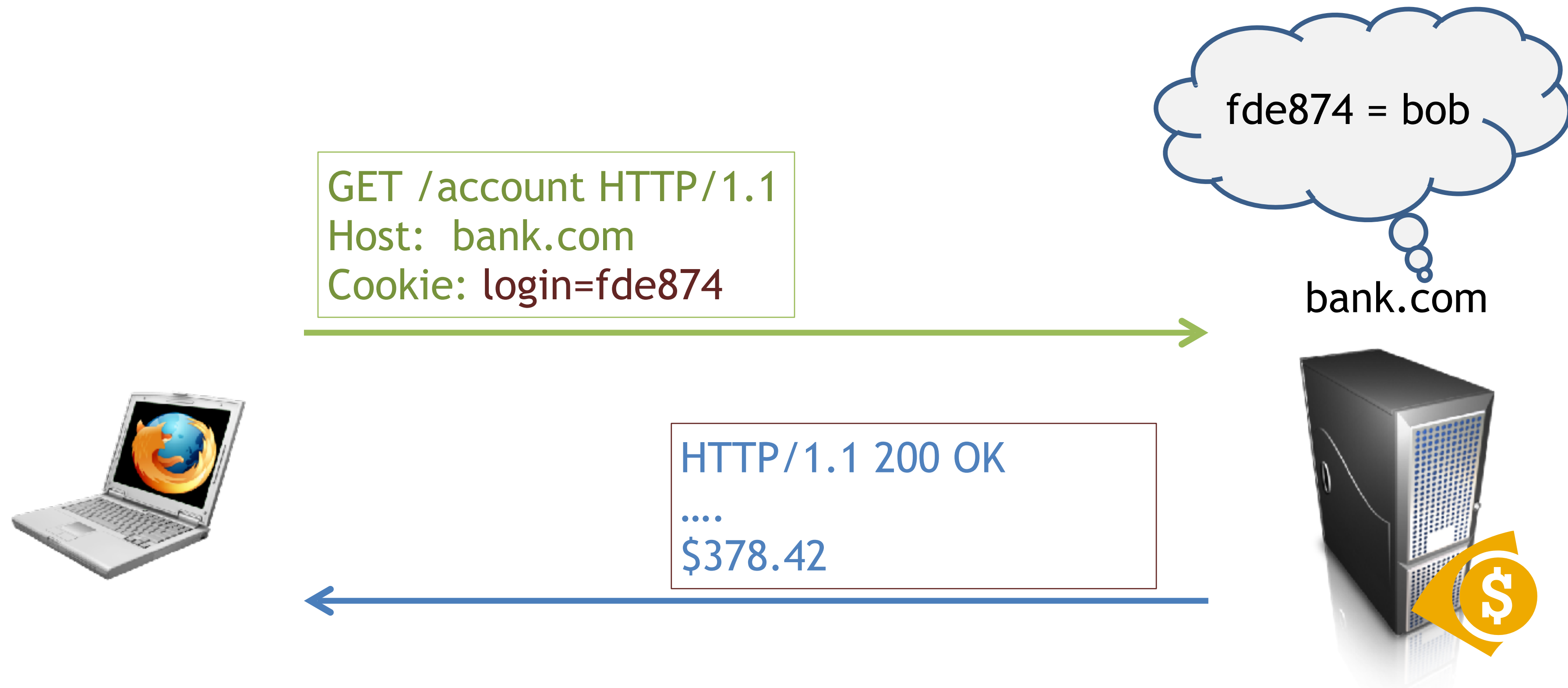
# Cross-site Request Forgery (CSRF)

POST /login?user=bob&pass=abc123 HTTP/1.1
Host:  bank.com

bank.com

HTTP/1.1 200 OK
Set-Cookie: login=fde874
....

# Cross-site Request Forgery (CSRF)

POST /login?user=bob&pass=abc123 HTTP/1.1
Host:   bank.com

fde874 = bob

bank.com

HTTP/1.1 200 OK
Set-Cookie: login=fde874
....

# Cross-site Request Forgery (CSRF)



GET /account HTTP/1.1
Host: bank.com
Cookie: login=fde874

fde874 = bob

bank.com

# Cross-site Request Forgery (CSRF)

fde874 = bob

bank.com

GET /account HTTP/1.1
Host:  bank.com
Cookie: login=fde874

HTTP/1.1 200 OK
....
$378.42

# Cross-site Request Forgery (CSRF)

Click me!!!
http://bank.com/transfer?to=badguy&amt=100

fde874 = bob

bank.com

# Cross-site Request Forgery (CSRF)

Click me!!!
http://bank.com/transfer?to=badguy&amt=100
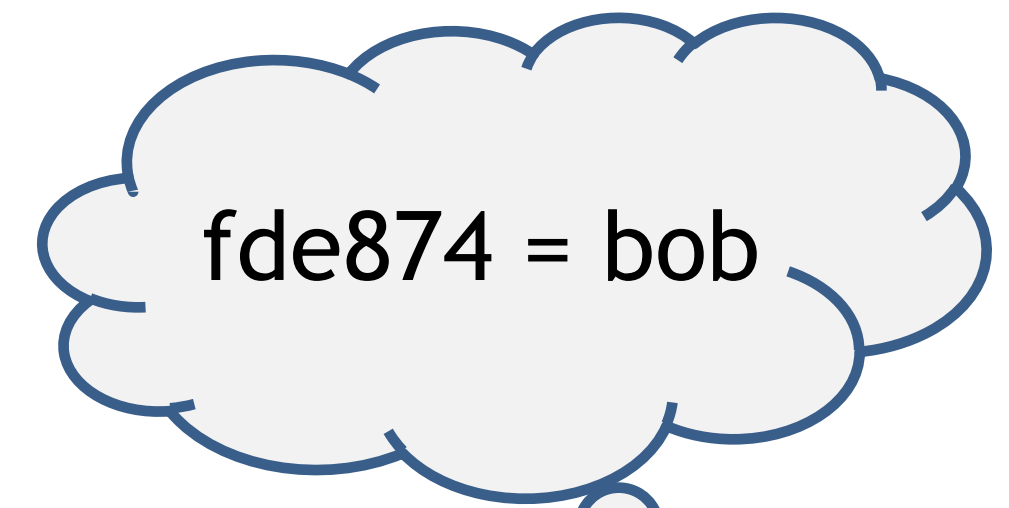
fde874 = bob

bank.com

GET /transfer?to=badguy&amt=100 HTTP/1.1
Host: bank.com
Cookie: login=fde874

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Click me!!!
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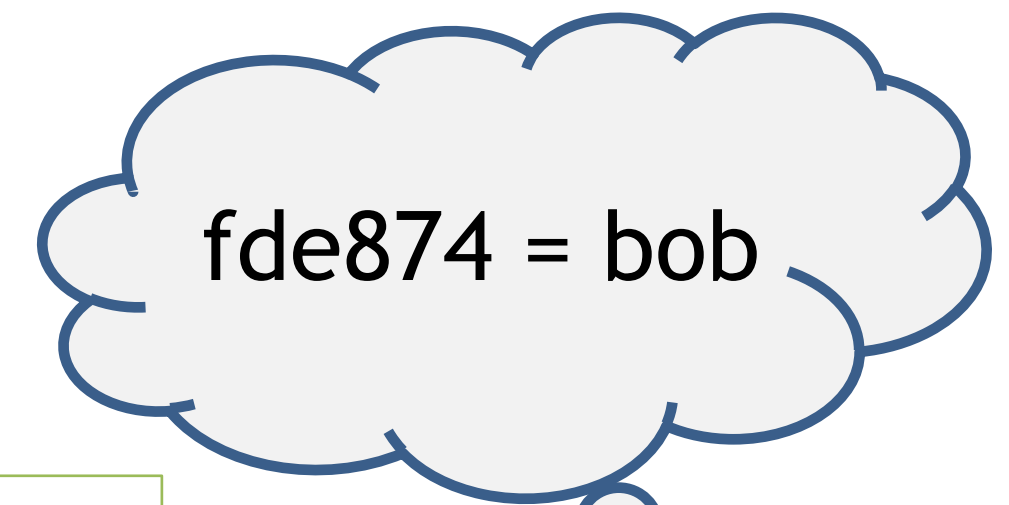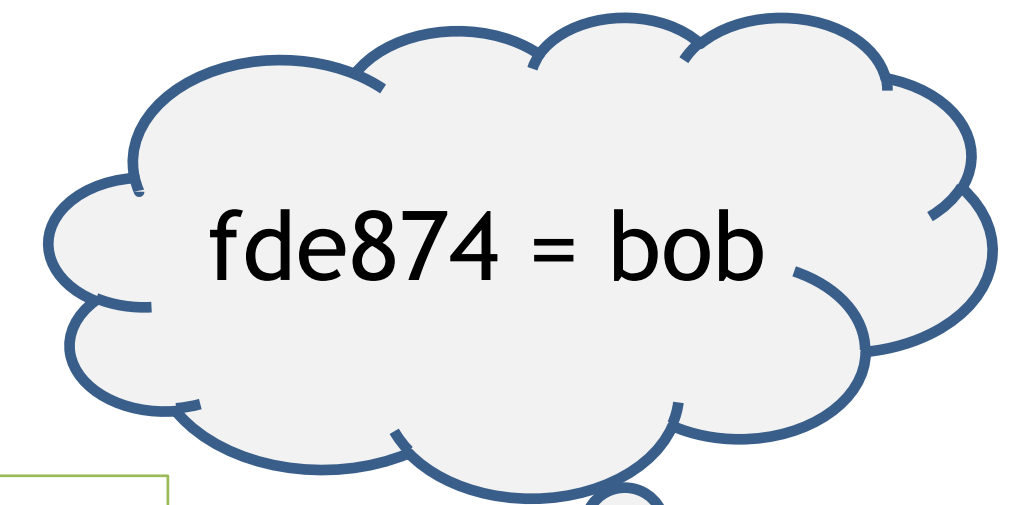
bank.com

GET /transfer?to=badguy&amt=100 HTTP/1.1
Host: bank.com
Cookie: login=fde874

HTTP/1.1 200 OK
….
Transfer complete: -$100.00

# Why not make requests directly?

- **Use the browser's state:** The browser sends cookies, client certificates, basic auth credentials in the request

- **Set the browser's state:** The browser parses and acts on responses, even if the JavaScript cannot read the responses

- **Leverage the browser's network connectivity:** The browser can connect to servers the malicious site cannot reach (e.g., those behind a firewall)
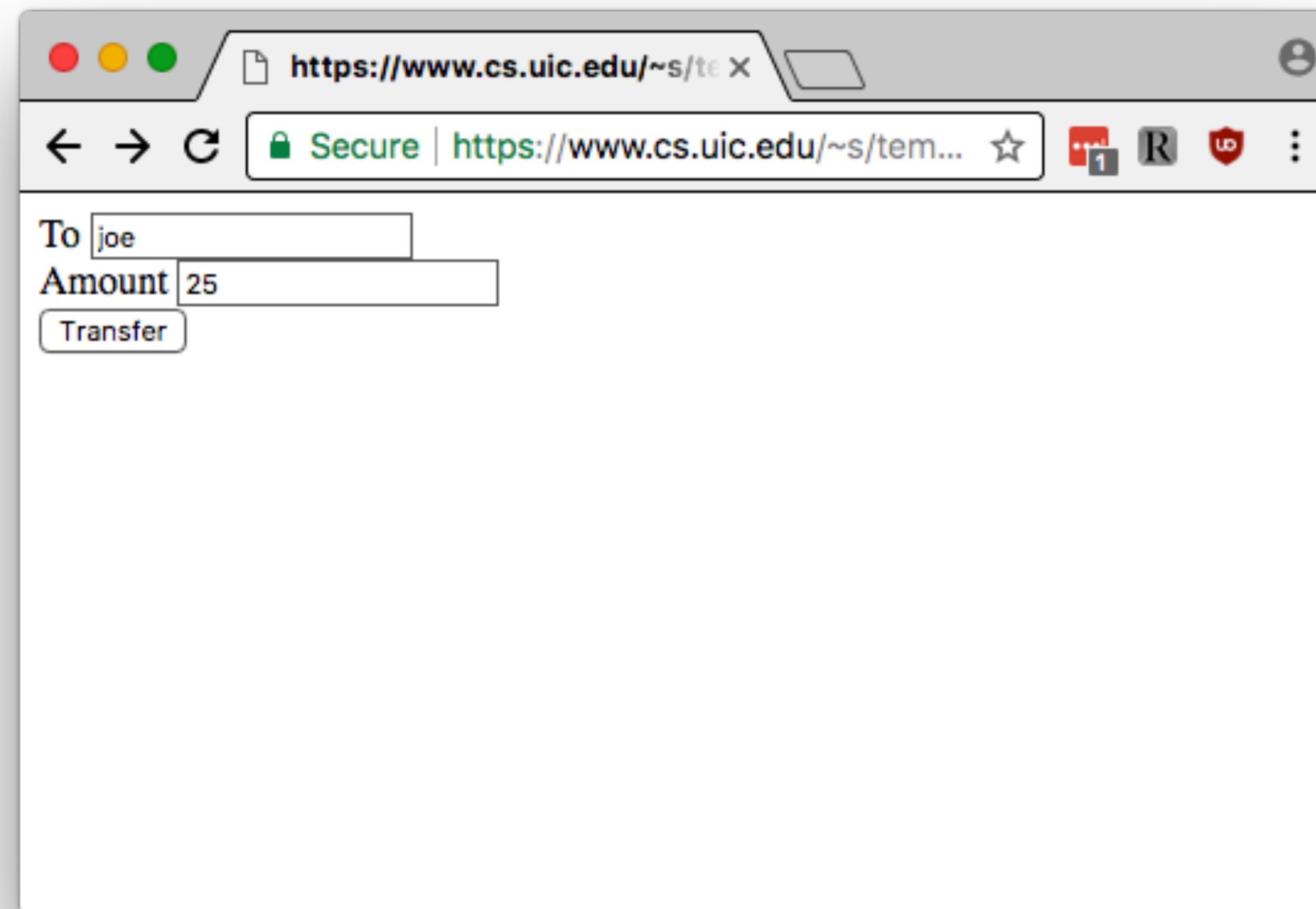
# CSRF Defenses

- Need to "authenticate" each user action originates from the legitimate site

- Only needed for actions that change state (E.g., POST but not GET)
  - Why isn't it needed for GET?

- Possibilities
  - Secret token
  - HTTP Referer header (yes, Referer not Referrer, it was misspelled)
  - Custom HTTP header
  - Origin header

# Secret token

- Hidden form field with the token value

- The token should be unpredictable to attackers

- Random numbers work, but then need to be stored server side

- Using crypto, we can do better (HMAC)

- The token should be sent along with every POST and checked by the server

- This is a hassle for dynamically-generated content since it needs to include the tokens

- What prevents malicious script from fetching the page (e.g., with XMLHttpRequest), reading the token, and then sending a response with the token?

# Example CSRF token

```
<form action="/transfer" method="post">
  <input type="hidden" name="token" value="8d64">
  To <input type="text" name="to"><br>
  Amount <input type="text" name="amount"><br>
  <input type="submit" value="Transfer">
</form>
```

# CSRF Defenses

HTTP/1.1 200 OK
Set-Cookie: login=fde874

<form action="/transfer" method="post">
  <input type="hidden" name="token" value="8d64">
…

fde874 = bob

bank.com

This is not actually how POST data is encoded and sent, but the principle is the same

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HTTP/1.1 200 OK
Set-Cookie: login=fde874

<form action="/transfer" method="post">
  <input type="hidden" name="token" value="8d64">
...

fde874 = bob

bank.com

POST /transfer?to=joe&amt=25&token=8d64 HTTP/1.1
Host:  bank.com
Cookie: login=fde874

This is not actually how POST data is encoded and sent, but the principle is the same

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HTTP/1.1 200 OK
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POST /transfer?to=joe&amt=25&token=8d64 HTTP/1.1
Host:  bank.com
Cookie: login=fde874

HTTP/1.1 200 OK
....
Transfer complete: -$25.00
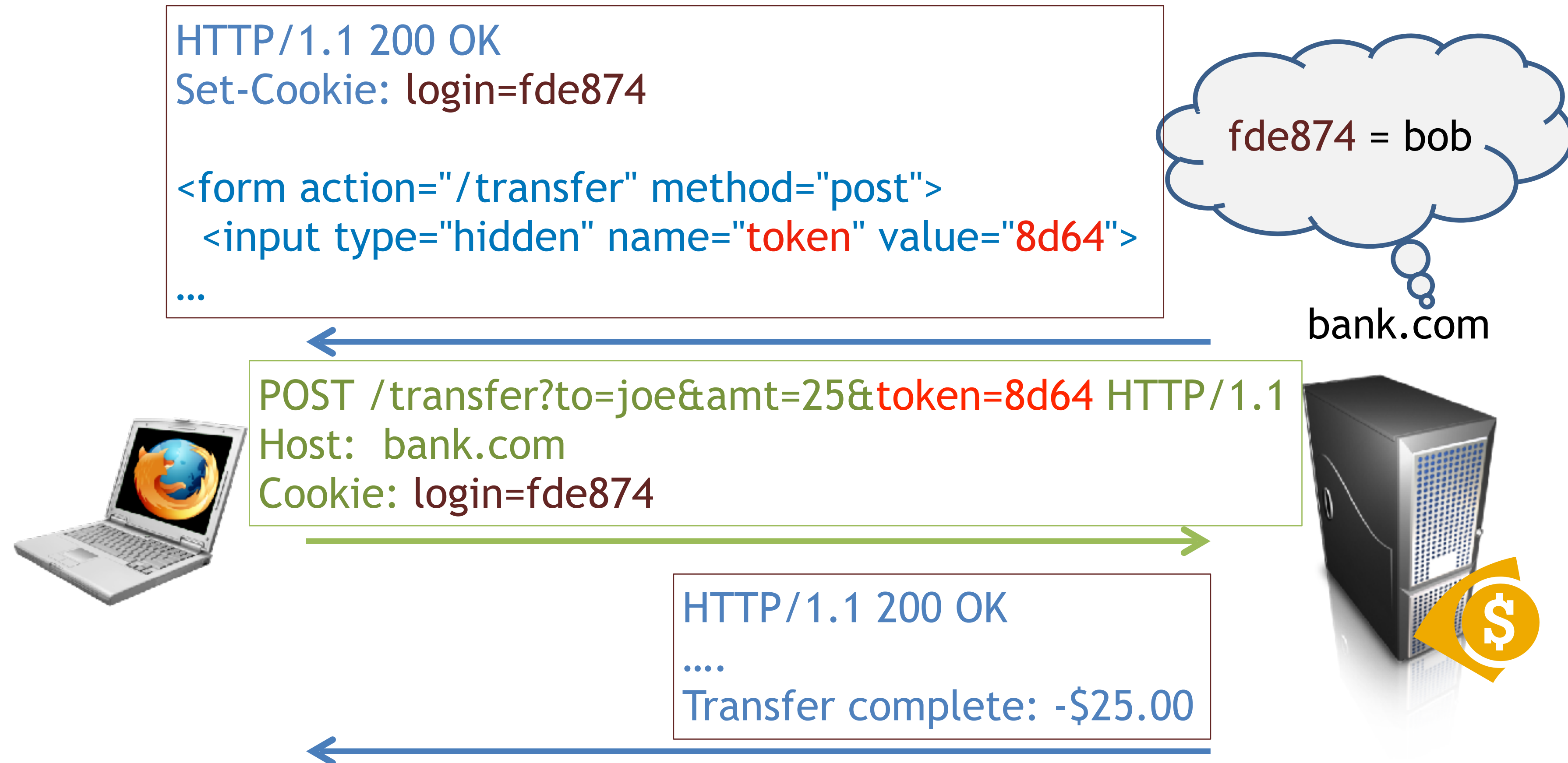
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# Referer header

- Sent by the browser and contains the URL of the page containing the link that was clicked or form that was submitted

- Easy to handle server side, just check that the request comes with the correct Referer header

- However, it is frequently stripped by the browser or middle boxes (for privacy reasons)

- It's stripped less often over HTTPS since middle boxes can't modify content

# Custom HTTP header

- XMLHttpRequest supports adding custom headers but browsers disallow them on cross-origin requests

- Server can check that the custom header is present

# Origin header

- The evolution of the Referer header but only contains the scheme, host, and port, not the full URL

- As with the Referer and custom headers, the server checks the Origin is correct

- Supported by all major browsers

- Unlike custom headers, it's part of the standard

# Cross-site scripting (XSS)

- XSS is a method for attackers to embed content (often JavaScript) in another page

- Two basic types
  - Reflected XSS
  - Stored XSS

# Reflected XSS

- Web attacker causes the victim to click a link to a legitimate page where the link contains some script

- The server includes the script verbatim in the legitimate page which is sent back to the browser

- The browser interprets it as script coming from the legitimate origin

# Cross-Site Scripting (XSS)

```php
<?php

echo "Hello, " . $_GET["user"] . "!";
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GET /?user=Bob HTTP/1.1

HTTP/1.1 200 OK
...
Hello, Bob!

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http://vuln.com/
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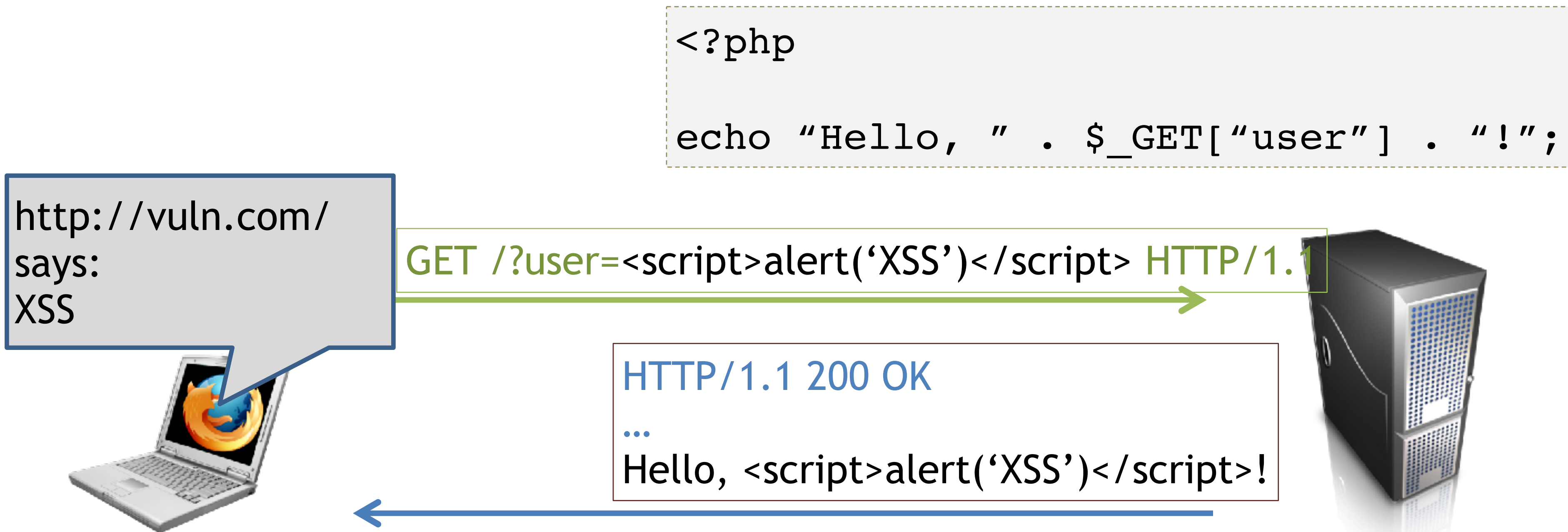
Click me!!!
http://vuln.com/?user=<script>alert('XSS')</script>

# Cross-Site Scripting (XSS) Attack

(evil!)
facebook.com

GET / HTTP/1.1
Host:  facebook.com

HTTP/1.1 200 OK

…
<iframe src="http://gmail.com/?user=<script>
    $.get('http://gmail.com/msgs.json',
        function (data) { alert(data); })
</script>"></iframe>

gmail.com

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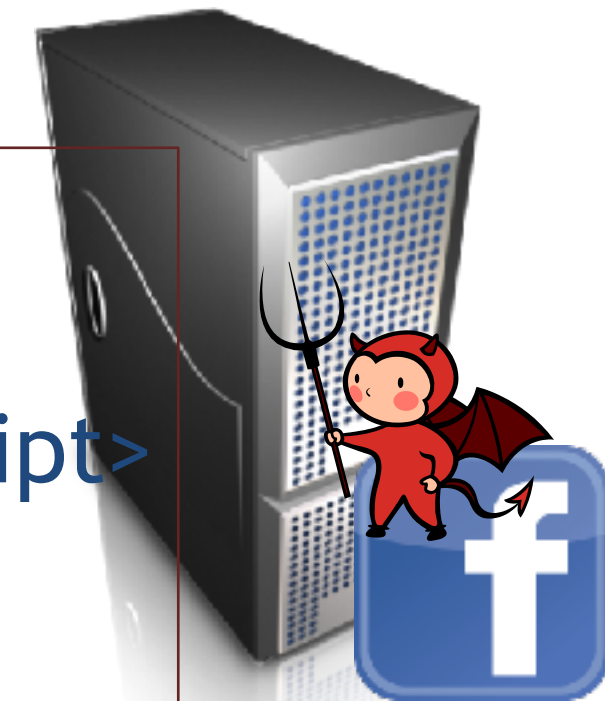
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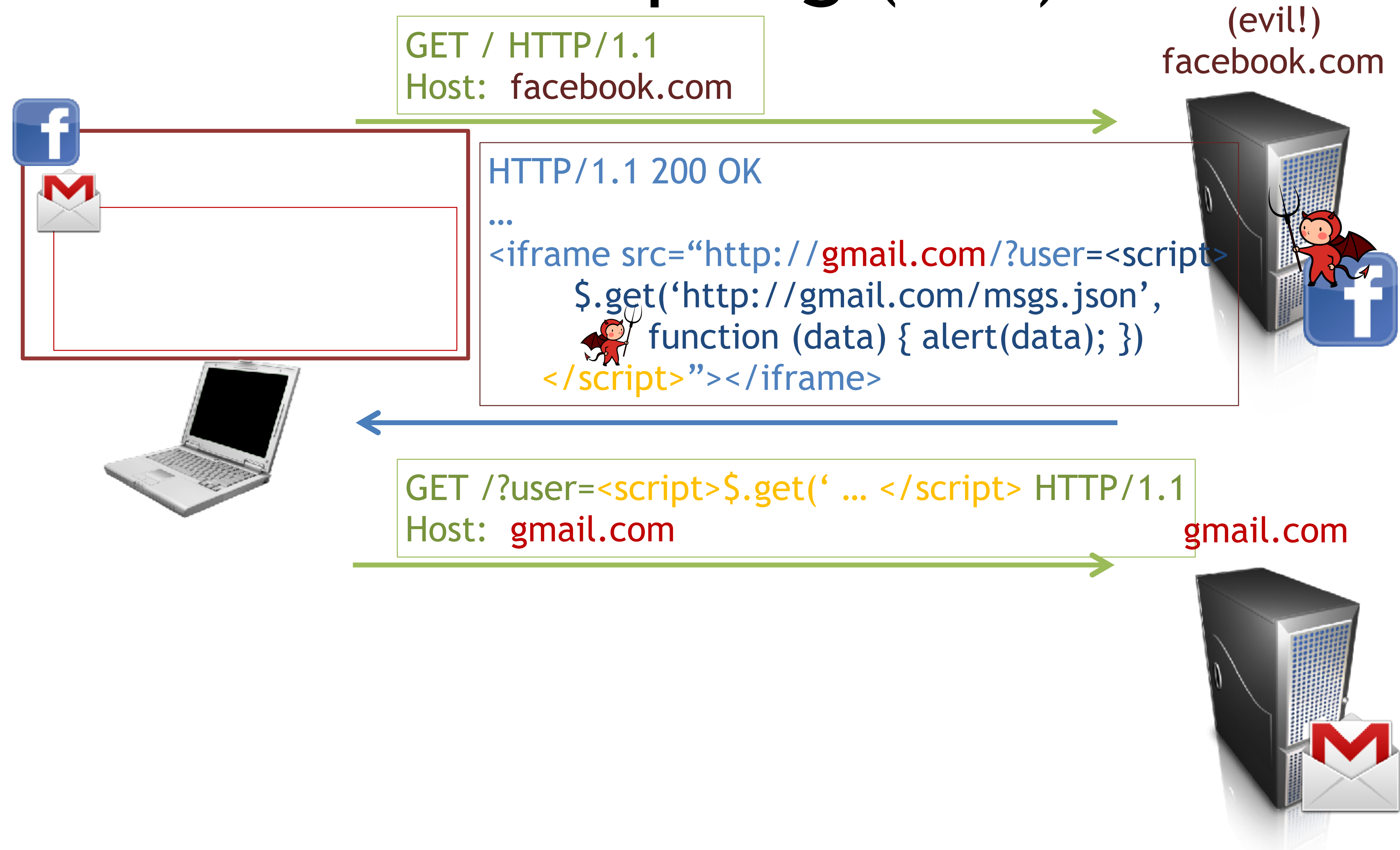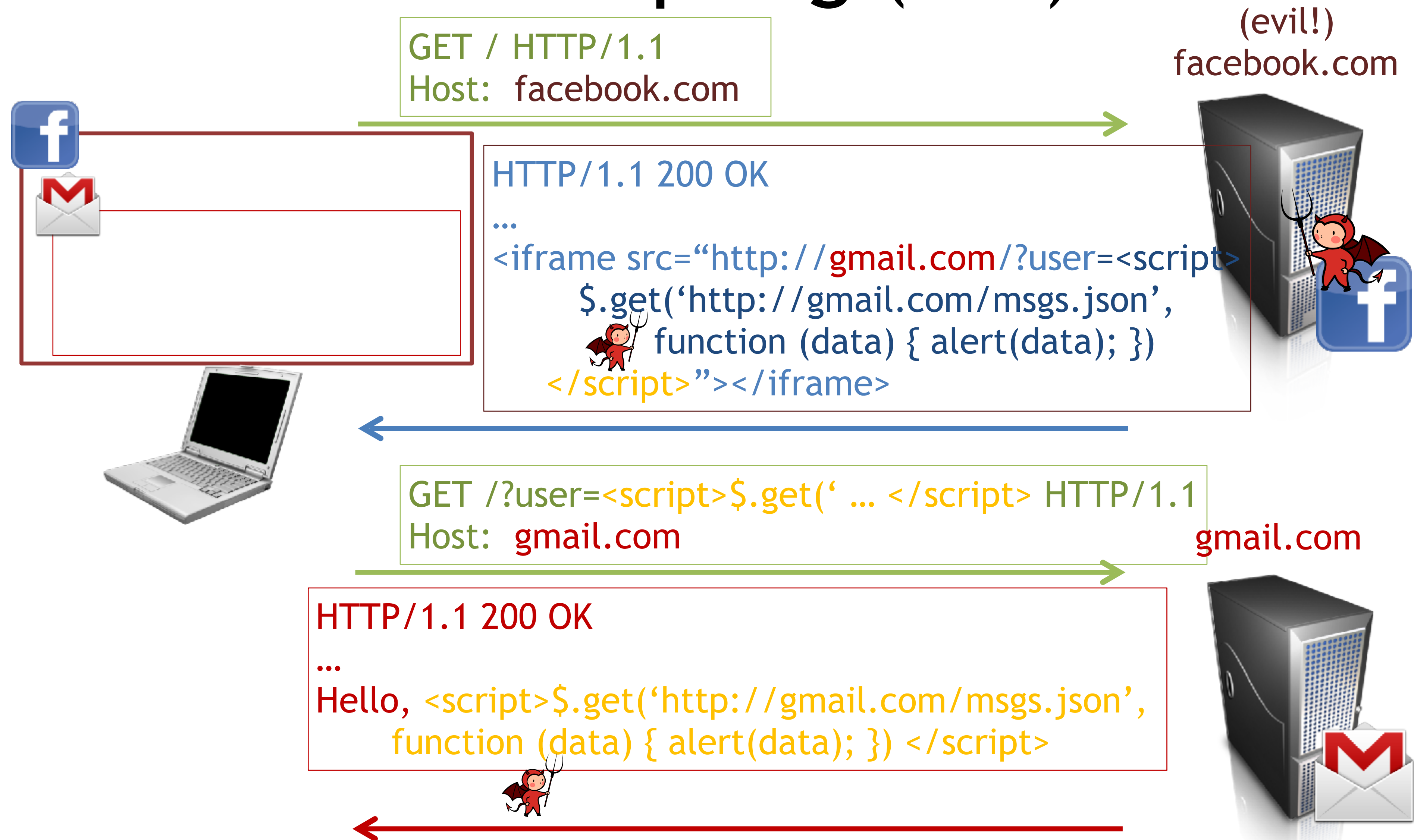</script>"></iframe>

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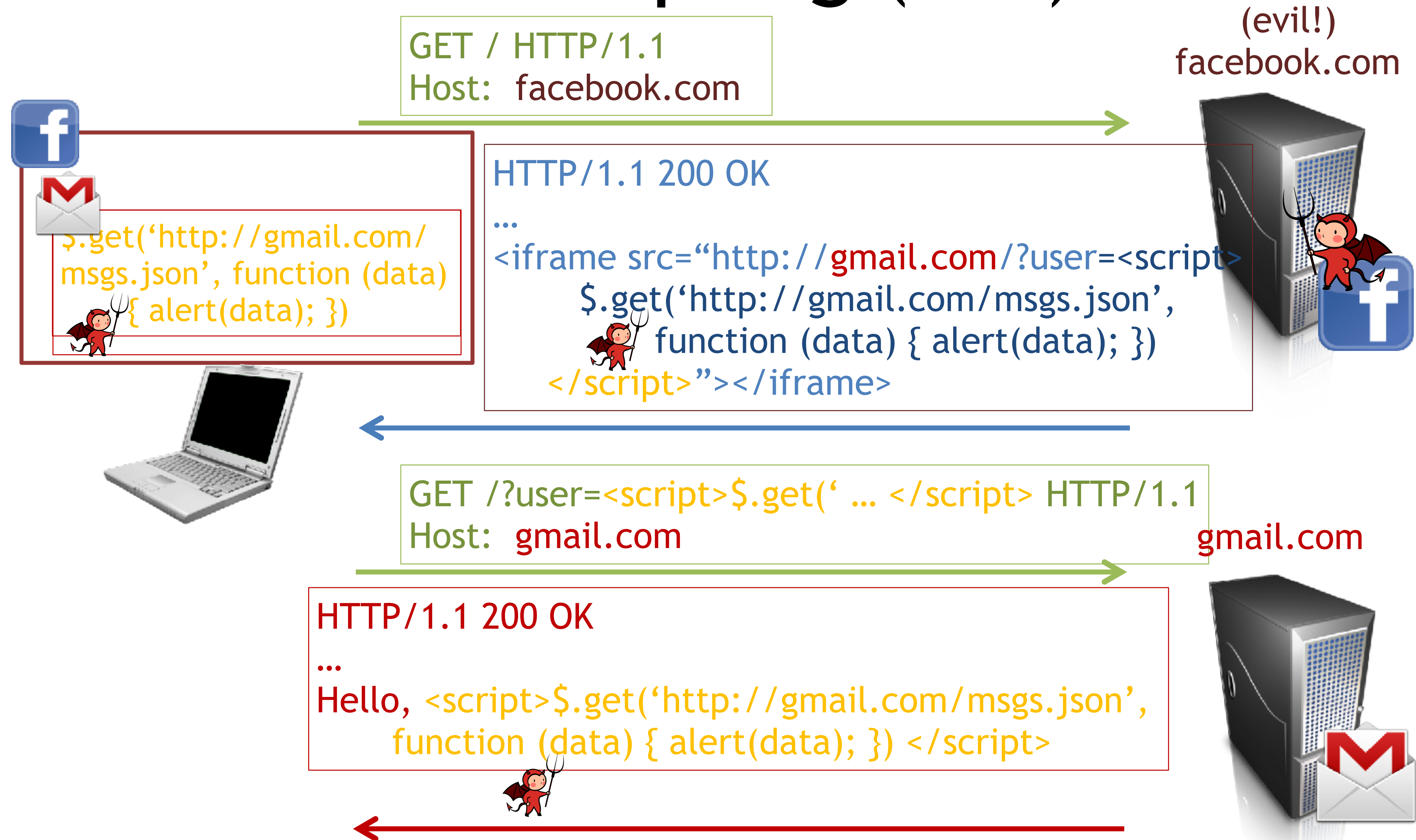
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```
$.get('http://gmail.com/
msgs.json', function (data)
{ alert(data); })
```

```
GET /msgs.json HTTP/1.1
Host:  gmail.com
```

gmail.com

```
HTTP/1.1 200 OK
...
{ new_msgs: 3 }
```

# Cross-Site Scripting (XSS) Attack

# XSS capabilities

- Execute arbitrary scripts in the context (i.e., Origin) of the vulnerable server

- Manipulate the DOM of the vulnerable page

- Submit/read forms (including any CSRF tokens)

- Read cookies

- Install event handlers

- In essence, anything that JavaScript can do!

# Stored XSS

- Some web sites serve user-generated content but fail to properly sanitize the user's input

- The attacker POSTs some HTML with JavaScript on the page (e.g., a post on a forum)

- When victims visit the page, the attacker's script is served and the browser (not realizing it came from the attacker) executes it as normal

- The script can do anything JavaScript can do!

# Example: Samy worm

- Myspace allowed users to insert HTML in their profiles, but disallowed \<script\>

- Some browsers support JavaScript inside CSS
  \<div style="background:url('javascript: eval(...)')"\>

- Myspace disallowed the word javascript but Internet Explorer (at the time anyway) allowed
  java
  script
  which bypassed their filter

- Other filters were bypassed by using eval()

# Example: Samy worm

- Samy Kamkar discovered this and put some script in his profile

- When his page was viewed by a victim, the victim's browser would run the script which would modify the victim's profile to include "but most of all, samy is my hero" as well as the script itself

- Within 20 hours, over one million people's profiles were infected

- Myspace had to go offline to fix the problem

- Kamkar pleaded guilty to a felony and got 3 years probation, a fine, and restricted computer use (now he makes cool YouTube videos!)