Web Security

Computer Security

Peter Reiher

May 24, 2016

Web Security

- Lots of Internet traffic is related to the web

money made from setting information

- Much of it is financial in nature
- Also lots of private information flow around web applications
- An obvious target for attackers

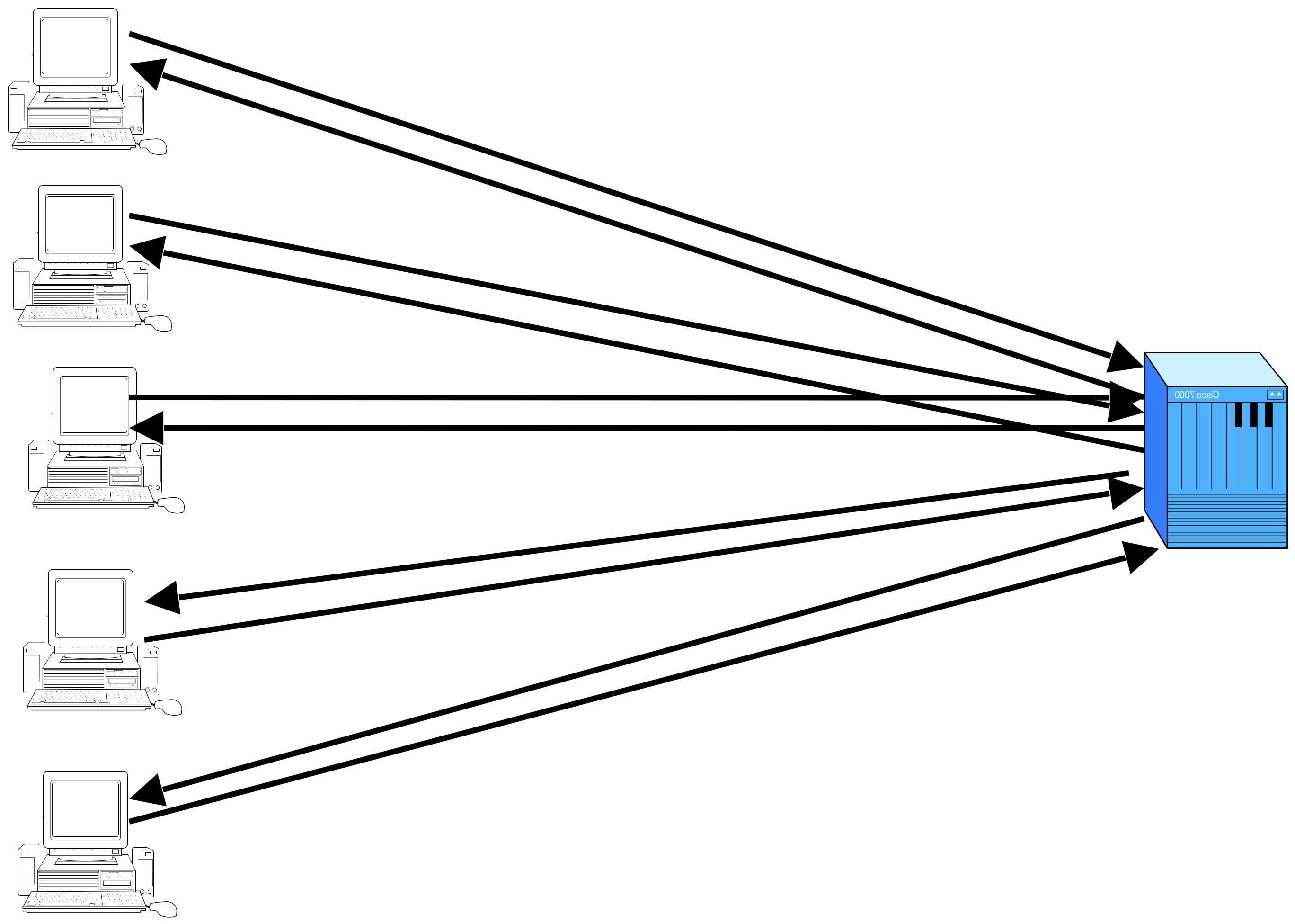
The Web Security Problem

- Many users interact with many servers

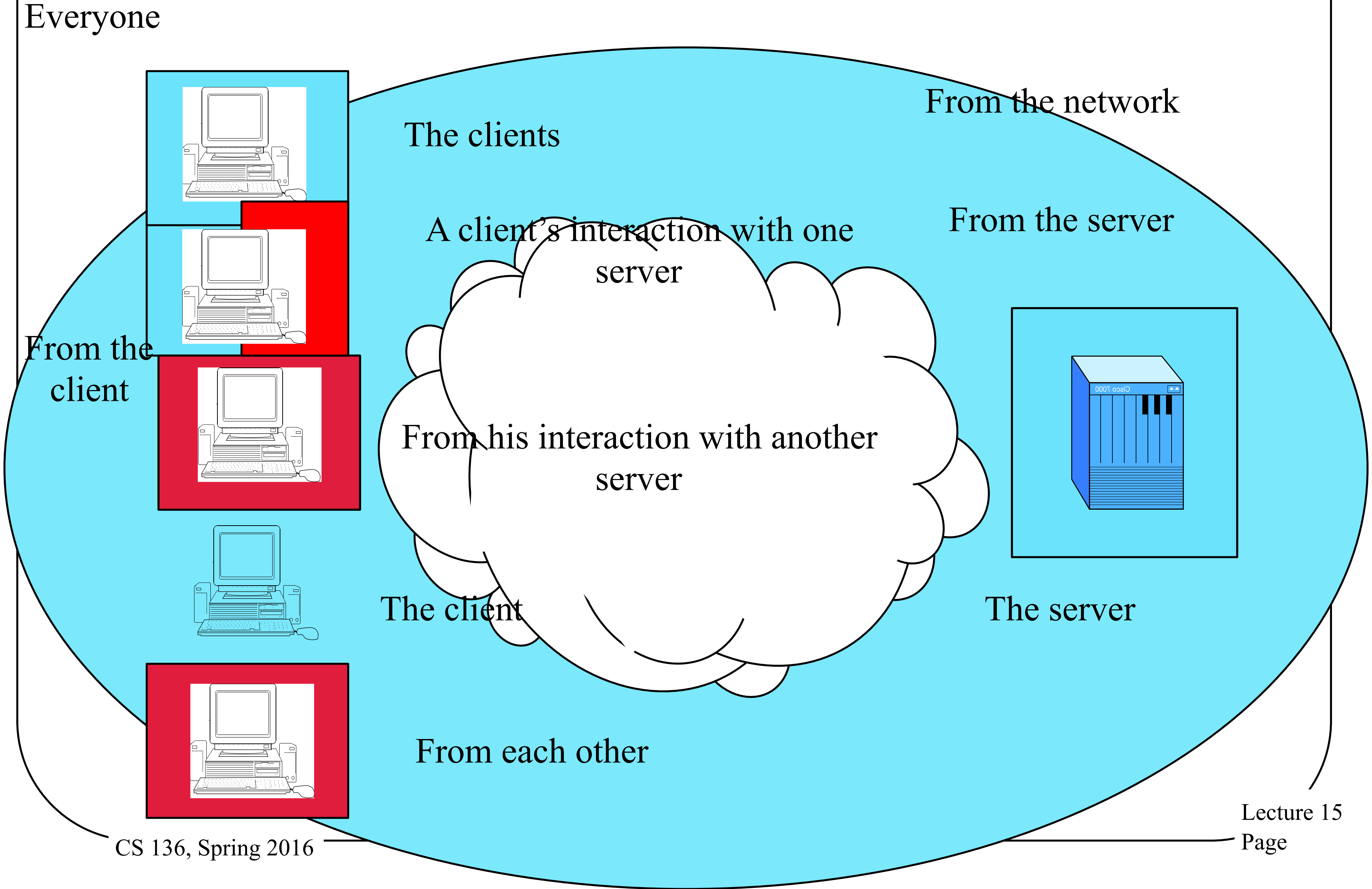
around 1 billion web users

- Most parties have little other relationship
- Increasingly complex things are moved via the web
- No central authority
- Many developers with little security experience
- Many critical elements originally designed with no thought to security
- Sort of a microcosm of the overall security problem

Aspects of the Web Problem



Who Are We Protecting?



What Are We Protecting?

- The client's private data
- The server's private data
- The integrity (sometimes also secrecy) of their transactions
- The client and server's machines
- Possibly server availability
  - For particular clients?

Some Real Threats

- Buffer overflows and other compromises
  - *Client attacks server*
- Web based social engineering attacks
  - *Client or server attacks client*
- SQL injection
  - *Client attacks server*
- Malicious downloaded code
  - *Server attacks client*

More Threats

- Cross-site scripting
  - *Clients attack each other*
- Threats based on non-transactional nature of communication
  - *Client attacks server*
- Denial of service attacks
  - *Threats on server availability (usually)*

Text
fhs fhiaa

Yet More Threats

- Browser security
  - Protecting interactions from one site from those with another
  - *One server attacks client's interactions with another*
- Data transport issues
  - *The network attacks everyone else*
- Certificates and trust issues
  - *Varied, but mostly server attacks client*

Compromise Threats

- Much the same as for any other network application
- Web server might have buffer overflow
  - Or other remotely usable flaw
- Not different in character from any other application's problem
  - And similar solutions

Solution Approaches

- Patching
- Use good code base
- Minimize code that the server executes
- Maybe restrict server access
  - When that makes sense
- Lots of testing and evaluation
  - Many tools for web server evaluation

Compromising the Browser

- Essentially, the browser is an operating system
  - You can do almost anything through a browser
  - It shares resources among different “processes”
- But it does not have most OS security features
- While having some of the more dangerous OS functionality
  - Like arbitrary extensibility
  - And supporting multiple simultaneous mutually untrusting processes

But My Browser Must Be OK . . .

- After all, I see the little lock icon at the bottom of the page

digital certificate chekco ut pefet d

- Doesn’t that mean I’m safe?
- Alas, no
- What does that icon mean, and what is the security implication?

The Lock Icon

- This icon is displayed by your browser when a digital certificate checks out
- A web site provided a certificate attesting to its identity
- The certificate was properly signed by someone your browser trusts
- That’s all it means

What Are the Implications?

- All you know is that the web site is who it claims to be
  - Which might not be who you think it is
  - Maybe it's `amozon.com`, not `amazon.com`
  - Would you notice the difference?
- Only to the extent that a trusted signer hasn't been careless or compromised
  - Some have been, in the past

Another Browser Security Issue

- What if you’re accessing your bank account in one browser tab
- And a site showing silly videos of cats in another?
- What if one of those videos contains an attack script?
- Can the evil cat script steal your bank account number?

Same Origin Policy

- Meant to foil such attacks
- Built into all modern browsers
  - And also things like Flash
- Basically, pages from a single origin can access each other's stuff
- Pages from a different origin cannot
- Particularly relevant to cookies

Web Cookies

- Essentially, data a web site asks your browser to store
- Sent back to that web site when you ask for another service from it
- Used to set up sessions and maintain state (e.g., authentication status)
- Lots of great information about your interactions with sites in the cookies

every cookie has informatino of the site that created it

Same Origin Policy and Cookies

- Script from one domain cannot get the cookies from another domain
  - Prevents the evil cat video from sending authenticated request to empty your bank account
- Domain defined by DNS domain name, application protocol
  - Sometimes also port

benefits and costs invovled with new tabs in Chrome (TM)

SQL Injection Attacks

- Many web servers have backing databases
  - Much of their information stored in a database
- Web pages are built (in part) based on queries to a database
  - Possibly using some client input . . .

SQL Injection Mechanics

- Server plans to build a SQL query
- Needs some data from client to build it
  - E.g., client's user name
- Server asks client for data
- Client, instead, provides a SQL fragment
- Server inserts it into planned query
  - Leading to a "somewhat different" query

An Example

```
“select * from mysql.user
   where username = ‘ “ . $uid . “ ‘ and
   password=password(‘ “. $pwd “ ‘);”
```

- Intent is that user fills in his ID and password
- What if he fills in something else?

```
'or 1=1; -- '
```

What Happens Then?

- `$uid` has the string substituted, yielding

```
“select * from mysql.user
   where username = ‘ ‘ or 1=1; -- ‘ ‘ and
   password=password(‘ “. $pwd “ ‘);”
```

every following — is a commnet

- This evaluates to true
  – Since 1 does indeed equal 1
  – And `--` comments out rest of line
- If script uses truth of statement to determine valid login, attacker has logged in

Basis of SQL Injection Problem

- **Unvalidated input**
- Server expected plain data
- Got back SQL commands
- Didn’t recognize the difference and went ahead
- Resulting in arbitrary SQL query being sent to its database
  - With its privileges

Some Example Attacks

- 130 million credit card numbers stolen in 2009 with SQL injection attack
- Used to steal 1 million Sony passwords
- Florida's election site compromise by a SQL injection attack (2016)
- Successful SQL injections on Bit9, British Royal Navy, PBS
- Ruby on Rails had built-in SQL injection vulnerability in 2012

Solution Approaches

- Carefully examine all input
- Avoid using SQL in web interfaces
- Parameterized variables

Examining Input for SQL

- SQL is a well defined language
- Generally web input shouldn't be SQL
- So look for it and filter it out
- **Problem**: proliferation of different input codings makes the problem hard
- **Problem**: some SQL control characters are widely used in real data
  - E.g., apostrophe in names

Avoid SQL in Web Interfaces

- Never build a SQL query based on user input to web interface
- Instead, use predefined queries that users can't influence
- Typically wrapped by query-specific application code
- **Problem**: may complicate development

Use Parameterized Variables

- SQL allows you to set up code so variables are bound parameters
- Parameters of this kind aren't interpreted as SQL
- Pretty much solves the problem, and is probably the best solution

Malicious Downloaded Code

- The web relies heavily on downloaded code
  - Full language and scripting language
  - Mostly scripts
- Instructions downloaded from server to client
  - Run by client on his machine
  - Using his privileges
- Without defense, script could do anything

doesnt matter if it is a s

Types of Downloaded Code

- Java
  - Full programming language
- Scripting languages
  - JavaScript
  - VB Script
  - ECMAScript
  - XSLT

Drive-By Downloads

- Often, user must request that something be downloaded
- But not always
  - Sometimes visiting a page or moving a cursor causes downloads
- These are called *drive-by downloads*
  - Since the user is screwed just by visiting the page

Solution Approaches

- Disable scripts in your browser
- Use secure scripting languages
- Isolation mechanisms
- Virus protection and blacklist approaches
- Parameterized variables

don’t run scripts

Disabling Scripts

- Browsers (or plug-ins) can disable scripts
  - Selectively, based on web site
- The bad script is thus not executed
- **Problem**: Cripples much good web functionality
  - So users re-enable scripting

Use Secure Scripting Languages

- Some scripting languages are less prone to problems than others
- Write your script in those
- **Problem**: secure ones aren't popular
- **Problem**: many bad things can still be done with "secure" languages
- **Problem**: can't force others to write their scripts in these languages

Isolation Mechanisms

- Architecturally arrange for all downloaded scripts to run in clean VM
  - Limiting the harm they can do
- **Problem**: they might be able to escape the VM
- **Problem**: what if a legitimate script needs to do something outside its VM?

Signatures and Blacklists

- Identify known bad scripts
- Develop signatures for them
- Put them on a blacklist and distribute it to others
- Before running downloaded script, automatically check blacklist
- **Problem**: same as for virus protection

Cross-Site Scripting

- XSS cross site scripting
- Many sites allow users to upload information
  - Blogs, photo sharing, Facebook, etc.
  - Which gets permanently stored
  - And displayed
- Attack based on uploading a script
- Other users inadvertently download it
  - And run it . . .

The Effect of XSS

- Arbitrary malicious script executes on user’s machine
- In context of his web browser
  - At best, runs with privileges of the site storing the script
  - Often likely to run at full user privileges

Non-Persistent XSS

- Embed a small script in a link pointing to a legitimate web page
- Following the link causes part of it to be echoed back to the user’s browser
- Where it gets executed as a script
- Never permanently stored at the server

not stored at the server

Persistent XSS

- Upload of data to a web site that stores it permanently Stores the XSS script permenantly
- Generally in a database somewhere
- When other users request the associated web page,
- They get the bad script

Some Examples

- Word Press bug allowed XSS (2016)
- Other XSS vulnerabilities discovered on sites run by Yahoo, Symantec, PayPal, Facebook, LinkedIn, Adobe, Apple App Store, Google Gmail, Fortinet, the Scientology website, thousands of others
- D-Link router flaw exploitable through XSS

Why Is XSS Common?

- Use of scripting languages widespread
  - For legitimate purposes
- Most users leave them enabled in their browsers
- Sites allowing user upload are very popular
- Only a question of getting user to run your script

Typical Effects of XSS Attack

- Most commonly used to steal personal information
  - That is available to legit web site
  - User IDs, passwords, credit card numbers, etc.
- Such information often stored in cookies at client side

Solution Approaches

- Don’t allow uploading of anything
- Don’t allow uploading of scripts
- Provide some form of protection in browser

Disallowing Data Uploading

- Does your web site really need to allow users to upload stuff?
- Even if it does, must you show it to other users?
- If not, just don't take any user input
- **Problem**: Not possible for many important web sites

Don’t Allow Script Uploading

- A no-brainer for most sites
  - Few web sites want users to upload scripts, after all
- So validate user input to detect and remove scripts
- **Problem**: Rich forms of data encoding make it hard to detect all scripts
- Good tools can make it easier

Protect the User's Web Browser

- Similar solutions as for any form of protecting from malicious scripts
- With the same problems:
  - Best solutions cripple functionality
- Firefox Content Security Policy
  - Allows web sites to specify where content can be loaded from

Cross-Site Request Forgery

- CSRF fool server into thinking trusted user made a request
- Works the other way around
- An authenticated and trusted user attacks a web server
  - Usually someone posing as that user
- Generally to fool server that the trusted user made a request

CSRF in Action

- Attacker puts link to (say) a bank on his web page
- Unsuspecting user clicks on the link
- His authentication cookie goes with the HTTP request
  - Since it's for the proper domain
- Bank authenticates him and transfers his funds to the attacker

Issues for CSRF Attacks

- Not always possible or easy
- Attacks sites that don’t check referrer header
  - Indicating that request came from another web page
- Attacked site must allow use of web page to allow something useful (e.g., bank withdrawal)
- Must not require secrets from user
- Victim must click link on attacker’s web site
- And attacker doesn’t see responses

CSRF In the Wild

- CSRF possibility in Verizon Mobile App API
- eBay CSRF problem in Magneto e-commerce system
- A CSRF-based pharming toolkit that attacked wireless routers discovered
- CSRF problem in Arris cable modems

Exploiting Statelessness

- HTTP is designed to be stateless
- But many useful web interactions are stateful
- Various tricks used to achieve statefulness
  - Usually requiring programmers to provide the state
  - Often trying to minimize work for the server

A Simple Example

- Web sites are set up as graphs of links
- You start at some predefined point
  - A top level page, e.g.
- And you traverse links to get to other pages
- But HTTP doesn’t “keep track” of where you’ve been
  - Each request is simply the name of a link

Why Is That a Problem?

- What if there are unlinked pages on the server?
- Should a user be able to reach those merely by naming them?
- Is that what the site designers intended?

A Concrete Example

- The ApplyYourself system
- Used by colleges to handle student applications
- For example, by Harvard Business School in 2005
- Once all admissions decisions made, results available to students

What Went Wrong?

- Pages representing results were created as decisions were made
- Stored on the web server
  - But not linked to anything, since results not yet released
- Some appliers figured out how to craft URLs to access their pages
  - Finding out early if they were admitted

The Core Problem

- No protocol memory of what came before
- So no protocol way to determine that response matches request
- Could be built into the application that handles requests
- But frequently isn’t
  - Or is wrong

Solution Approaches

- Get better programmers
  - Or better programming tools
- Back end system that maintains and compares state
- Front end program that observes requests and responses
  - Producing state as a result
- Cookie-based
  - Store state in cookies (preferably encrypted)

Data Transport Issues

- The web is inherently a network application
- Thus, all issues of network security are relevant
- And all typical network security solutions are applicable
- Where do we see problems?

(Non-) Use of Data Encryption

- Much web traffic is not encrypted
  - Or signed
- As a result, it can be sniffed
- Allowing eavesdropping, MITM attacks, alteration of data in transit, etc.
- Why isn't it encrypted?

Why Web Sites Don't Use Encryption

- Primarily for cost reasons
- Crypto costs cycles
- For high-volume sites, not encrypting messages lets them buy fewer servers
- They are making a cost/benefit analysis decision
- And maybe it's right?

Problems With Not Using Encryption

- Sensitive data can pass in the clear
  – Passwords, credit card numbers, SSNs, etc.
- Attackers can get information from messages to allow injection attacks
- Attackers can readily profile traffic
  – Especially on non-secured wireless networks

Using Encryption on the Web

- Some web sites support use of HTTPS
  - Which permits encryption of data
  - Based on TLS/SSL
- Performs authentication and two-way encryption of traffic
  - Authentication is certificate-based
- HSTS (HTTP Strict Transport Security) <u>requires</u> browsers to use HTTPS

Increased Use of Web Encryption

- These and other problems have led more major web sites to encrypt traffic
- E.g., Google announced in 2014 it would encrypt all search requests
- Facebook, Twitter adopted HSTS in 2014
  - Overall, only 5% of web sites have adopted it as of 2016, though
- Arguably, <u>all</u> web interactions should be encrypted

Sometimes Encryption Isn’t Enough

- Especially powerful “attackers” can subvert this process
  - Man-in-the-middle attacks by ISPs
  - NSA compromised key management
  - NSA also spied on supposedly private links
- Usually impossible for typical criminal
- Hard or impossible for a user to know if this is going on

good news: not a lot of people can do this to you
bad news: the people who can do this to you, you won’t know who they are

Conclusion

- Web security problems not inherently different than general software security
- But generality, power, ubiquity of the web make them especially important
- Like many other security problems, constrained by legacy issues