CSE 484 / CSE M 584: Computer Security and Privacy

Autumn 2019

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Thanks to Dan Boneh, Dieter Gollmann, Dan Halperin, John Manferdelli, John Mitchell, Franzi Roesner, Vitaly Shmatikov, Bennet Yee, and many others for sample slides and materials ...

Announcements

- My office hours
  - 11/13 (Wed), 11:30am, CSE1 403
  - 11/20 (Wed), 2:30pm, CSE1 403
  - 11/27 (Wed), None
  - 12/4 (Wed), 12:30pm, CSE1 403
- HW 2 available (due 11/15); extra late day if submitted by Saturday 5pm (11/9)
- Final Project checkpoint on Friday (11/8) (group members, brief description)
  - https://courses.cs.washington.edu/courses/cse484/19au/assignments/final_project.html
- No class on Monday (Veterans Day)

Cross-Site Request Forgery (CSRF/XSRF)

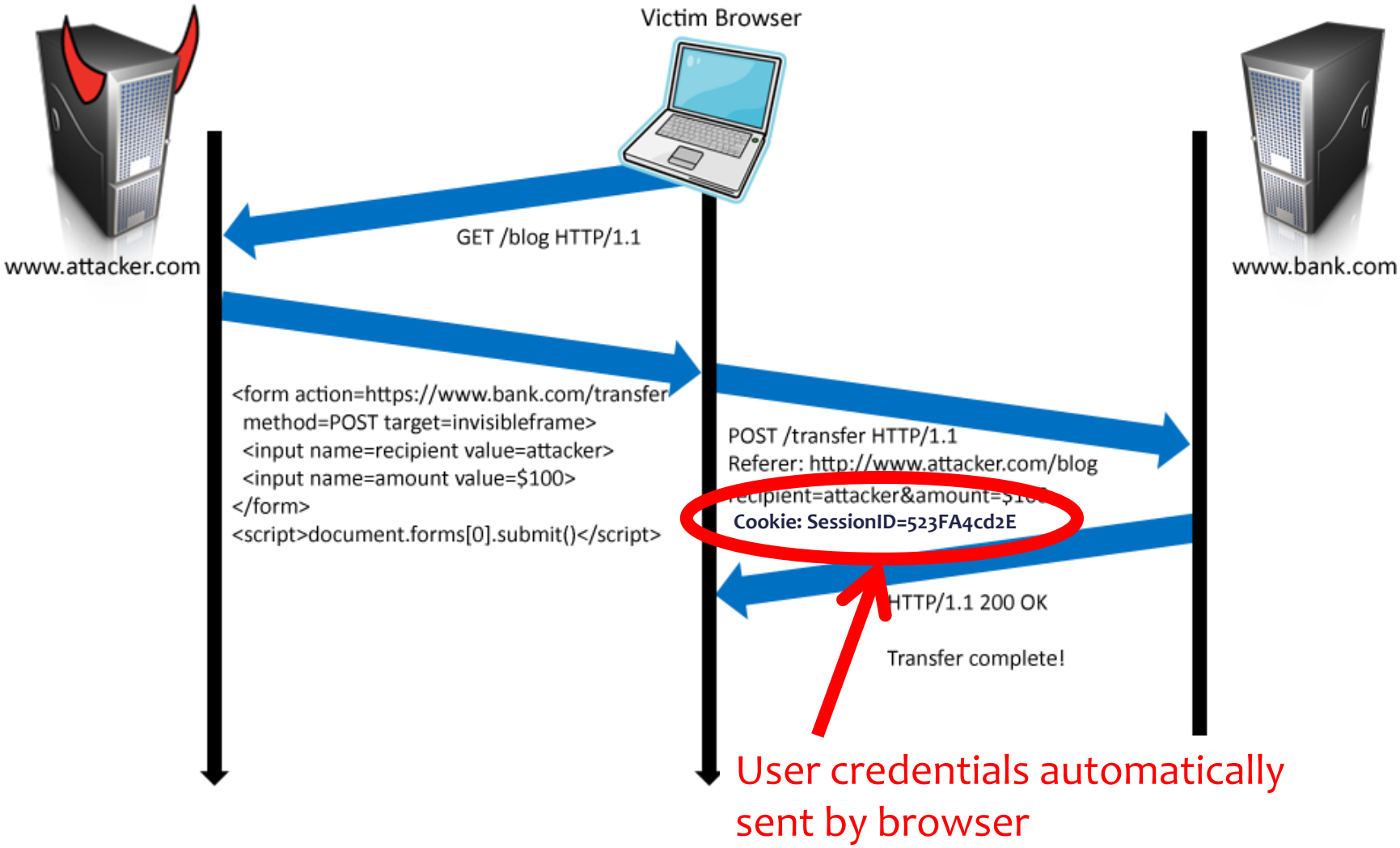
Cross-Site Request Forgery

- Users logs into bank.com, forgets to sign off
  - Session cookie remains in browser state
- User then visits a malicious website containing

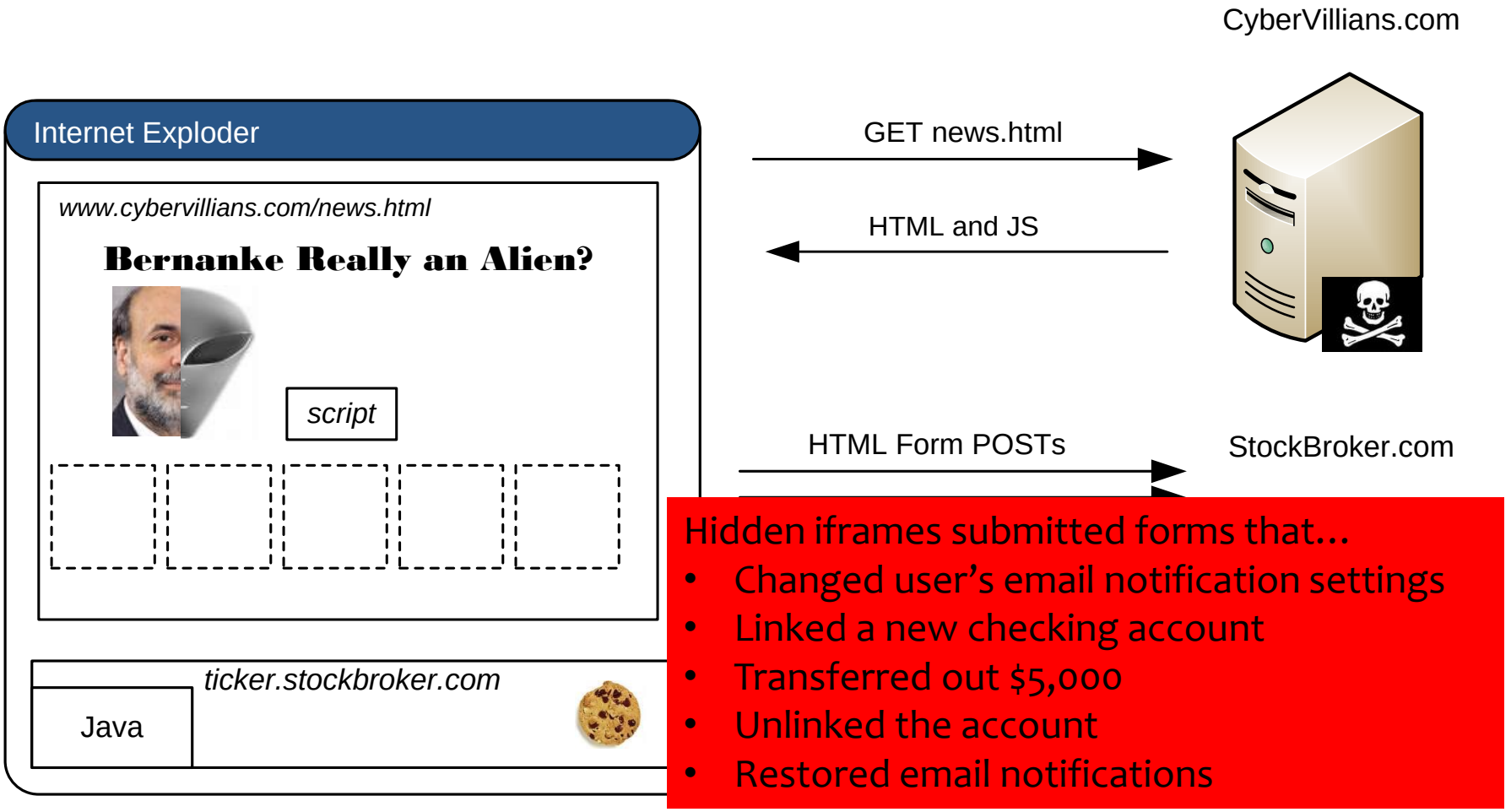
```
<form  name=BillPayForm
 action=http://bank.com/BillPay.php>
 <input  name=recipient  value=badperson> …

 <script> document.BillPayForm.submit(); </script>
```

- Browser sends cookie, payment request fulfilled!
- Lesson: cookie authentication is not sufficient when side effects can happen

Cookies in Forged Requests



XSRF True Story [Alex Stamos]



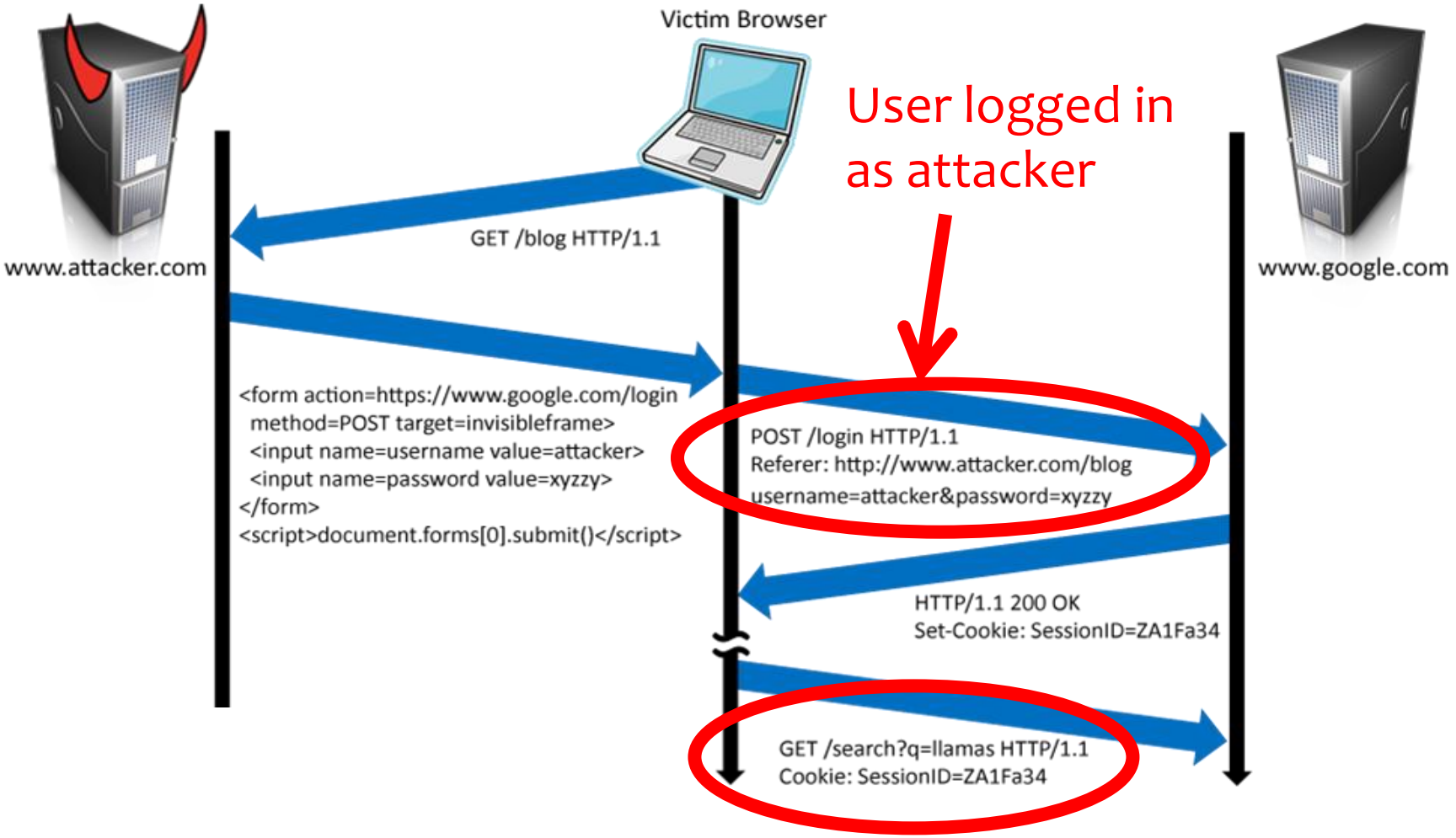
Hidden iframes submitted forms that…

- Changed user's email notification settings
- Linked a new checking account
- Transferred out $5,000
- Unlinked the account
- Restored email notifications

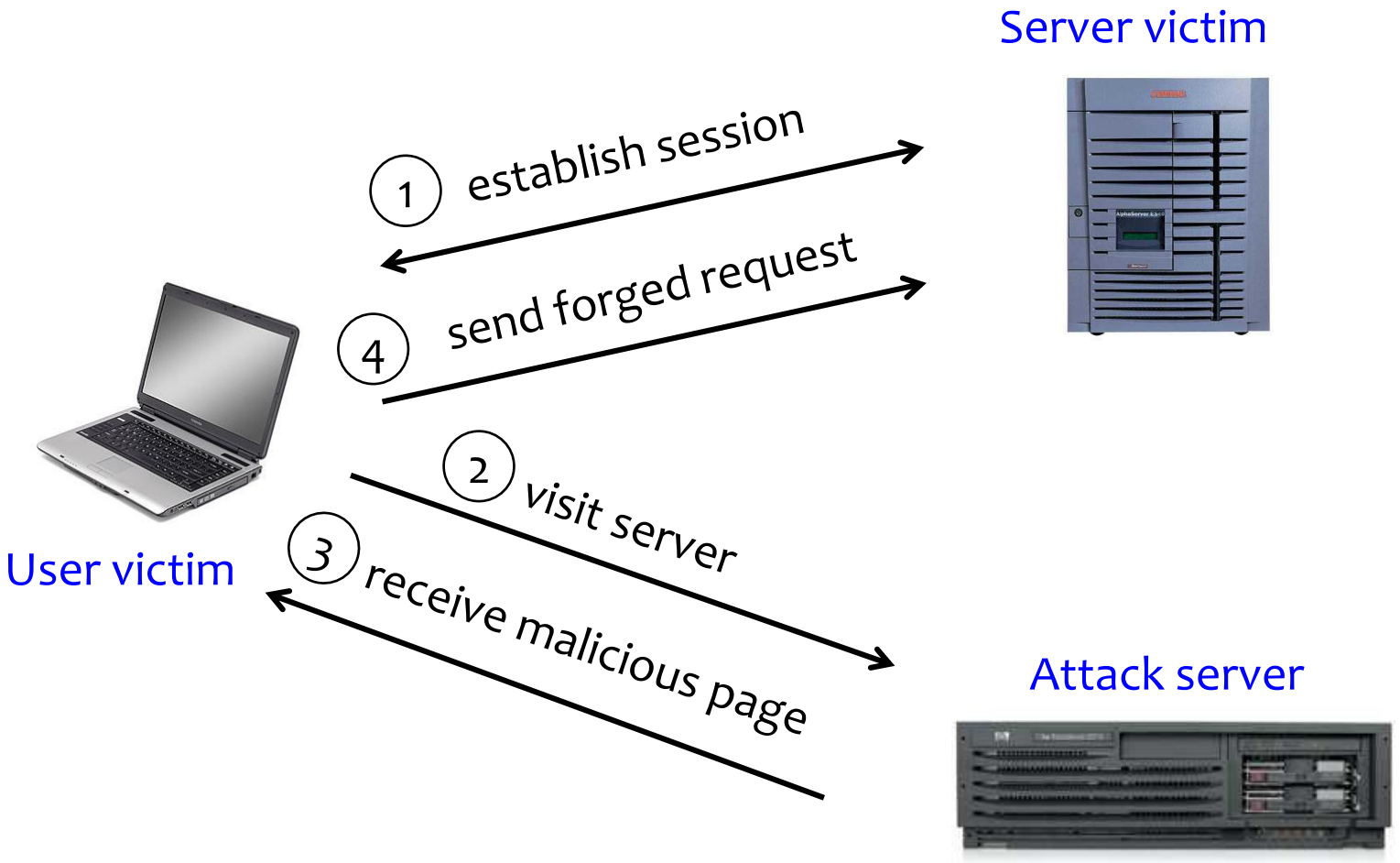
Impact

- Hijack any ongoing session (if no protection)
  - Netflix: change account settings, Gmail: steal contacts, Amazon: one-click purchase
- Reprogram the user's home router
  - Change DNS settings (attacker can see/control all DNS responses)
- Login to the *attacker's* account

Login XSRF: Attacker logs you in as them!



XSRF (aka CSRF): Summary



Q: how long do you stay logged on to Gmail? Financial sites?

Broader View of CSRF

- Abuse of cross-site data export
  - SOP does not control data export (we've seen this before!)
  - Malicious webpage can initiates requests from the user's browser to an honest server
  - Server thinks requests are part of the established session between the browser and the server (automatically sends cookies)

XSRF Defenses

- Secret validation token


```
<input type=hidden value=23a3af01b>
```

- Referer validation

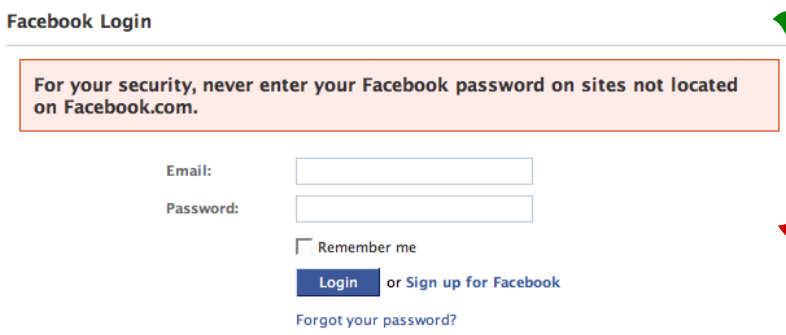

```
Referer:
http://www.facebook.com/home.php
```

Add Secret Token to Forms

```
<input type=hidden value=23a3af01b>
```

- "Synchronizer Token Pattern"
- Include a secret challenge token as a hidden input in forms
  - Token often based on user's session ID
  - Server must verify correctness of token before executing sensitive operations
- Why does this work?
  - **Same-origin policy:** attacker can't read token out of legitimate forms loaded in user's browser, so can't create fake forms with correct token

Referer Validation



```
Referer:
http://www.facebook.com/home.php
```

```
Referer:
http://www.evil.com/attack.html
```

?

```
Referer:
```

- Lenient referer checking – header is optional
- Strict referer checking – header is required

Why Not Always Strict Checking?

- Why might the referer header be suppressed?
  - Stripped by the organization's network filter
  - Stripped by the local machine
  - Stripped by the browser for HTTPS → HTTP transitions
  - User preference in browser
  - Buggy browser
- Web applications can't afford to block these users

- Many web application frameworks include CSRF defenses today

Injection

Injection Attacks

- http://victim.com/copy.php?name=username
- copy.php includes

  system("cp temp.dat $name.dat")
- User calls

  http://victim.com/copy.php?name="a; rm *"
- copy.php executes

  system("cp temp.dat a; rm *.dat");

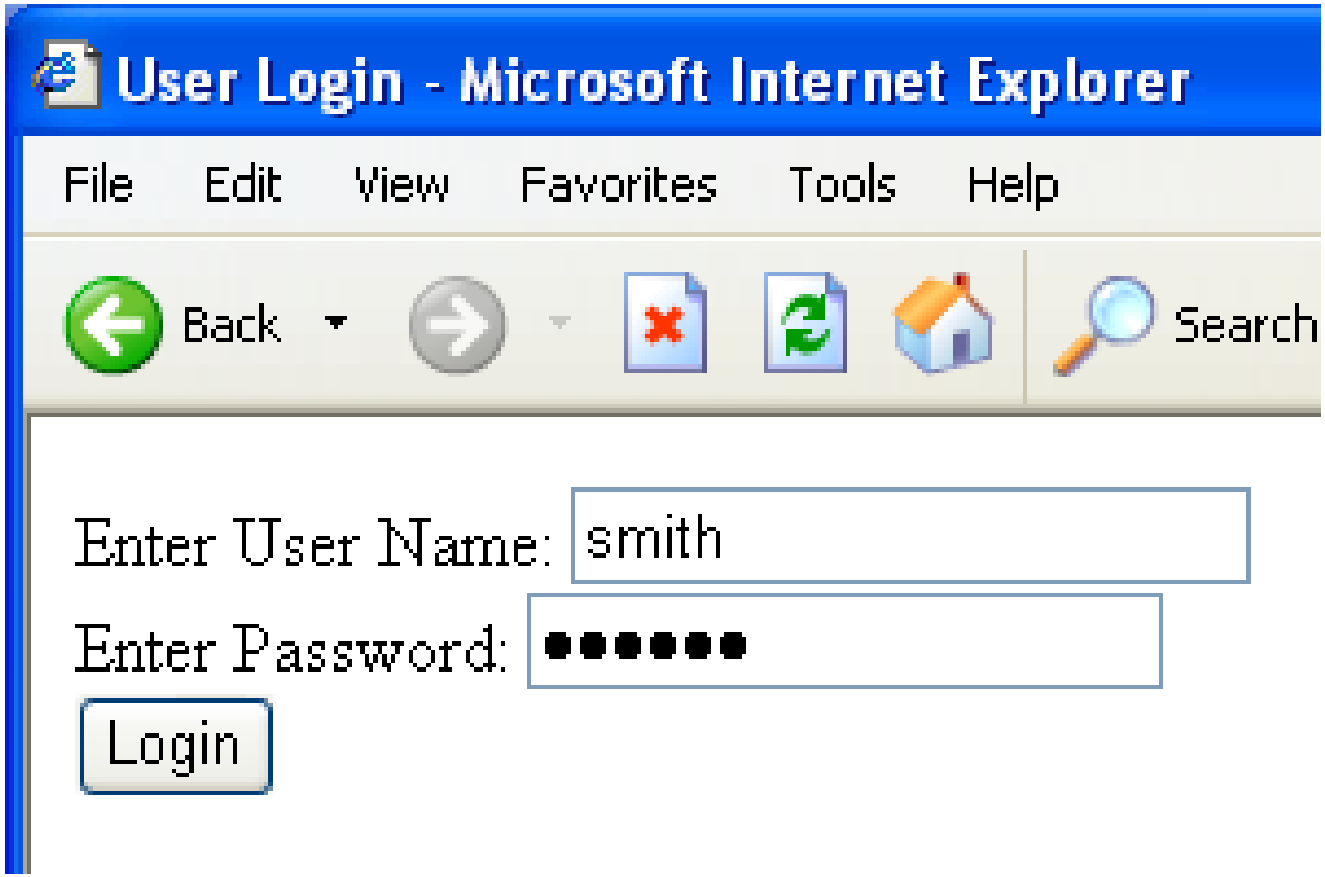
Basic Issues

- User-supplied data is not validated, filtered, or sanitized by application
- User input directly used or concatenated to a string that is used by an interpreter

- Common Injections: SQL, NoSQL, Object Relational Mapping (ORM), LDAP, Object Graph Navigation Library, …

SQL Injection

Typical Login Prompt

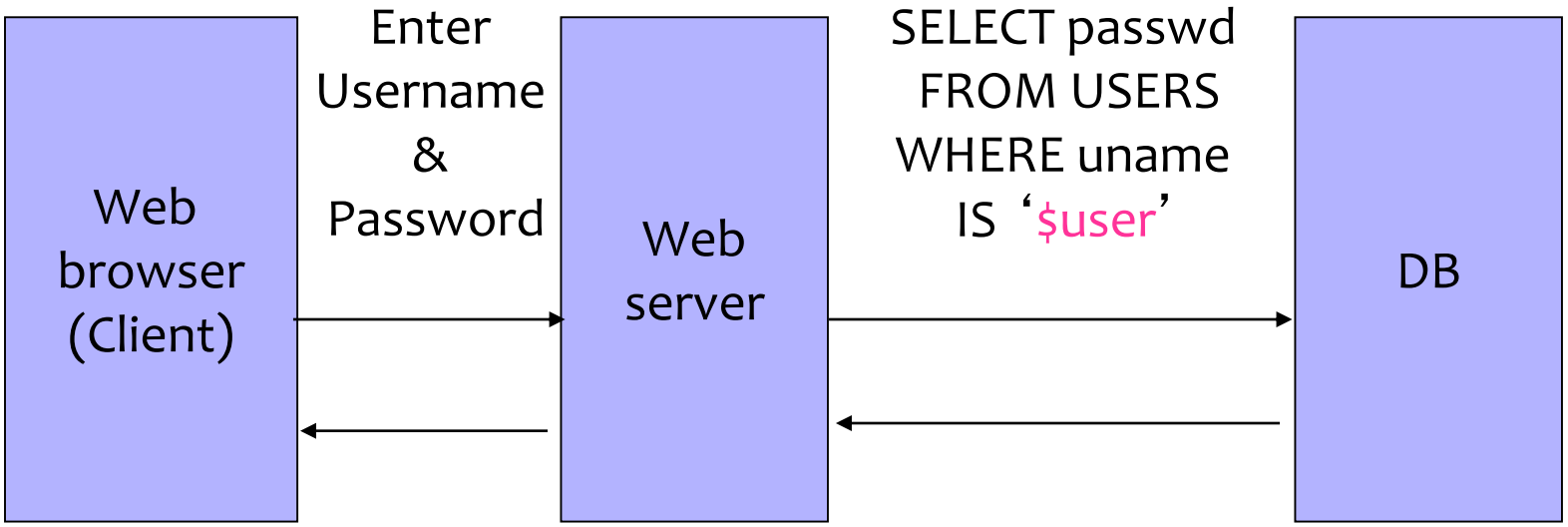


Typical Query Generation Code

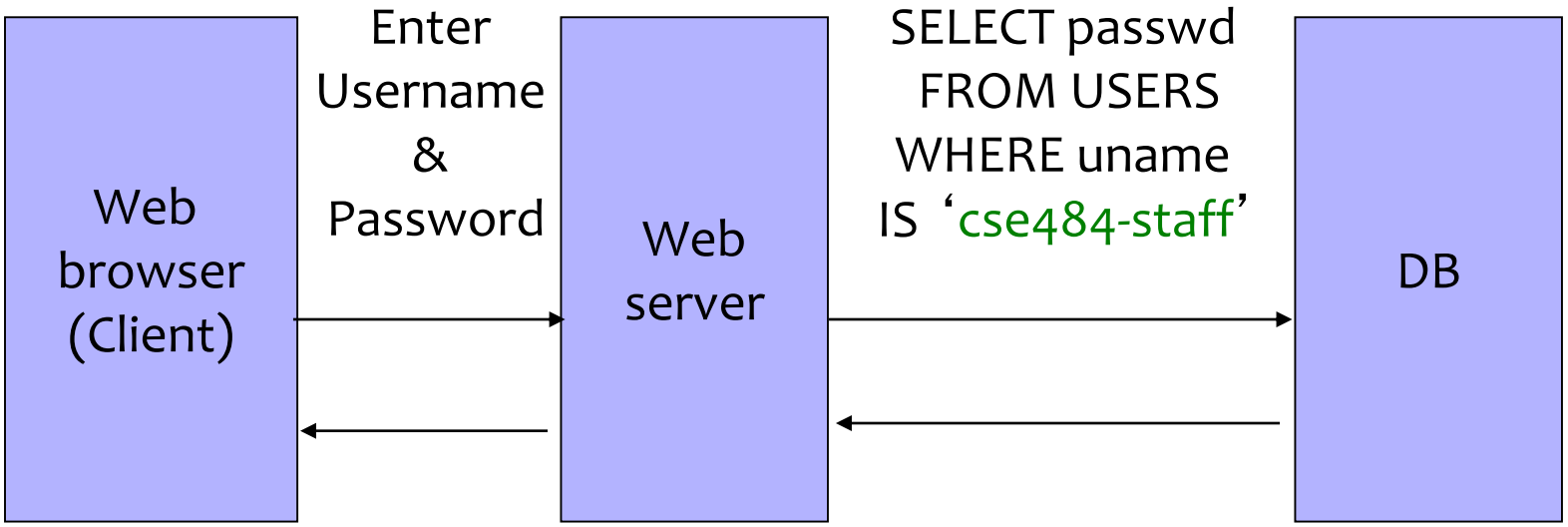
```
$selecteduser = $_GET['user'];
$sql = "SELECT Username, Key FROM Users " .
       "WHERE Username='$selecteduser'";
$rs = $db->executeQuery($sql);
```

What if **'user'** is a malicious string that changes the meaning of the query?

User Input Becomes Part of Query

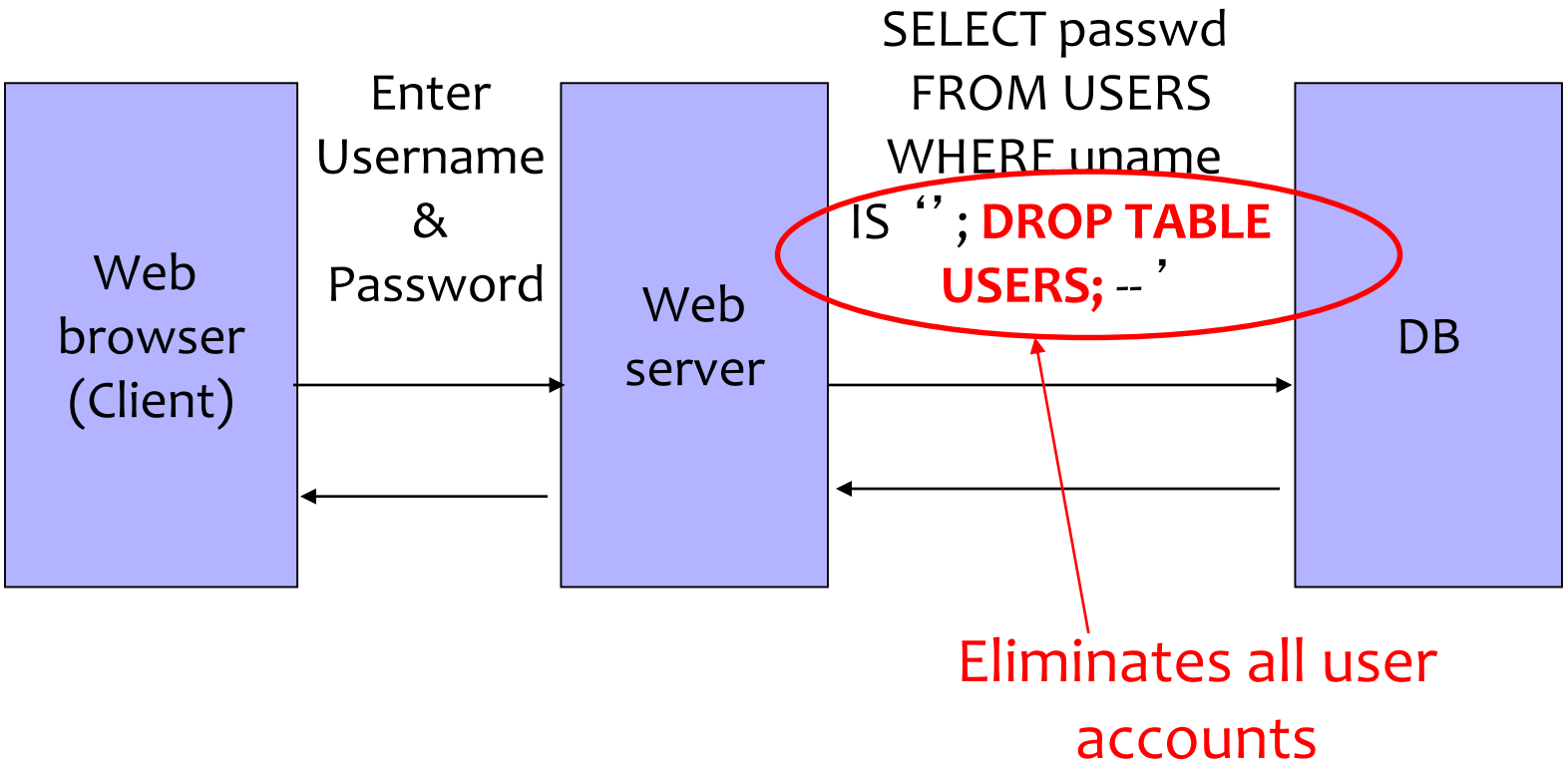


Normal Login

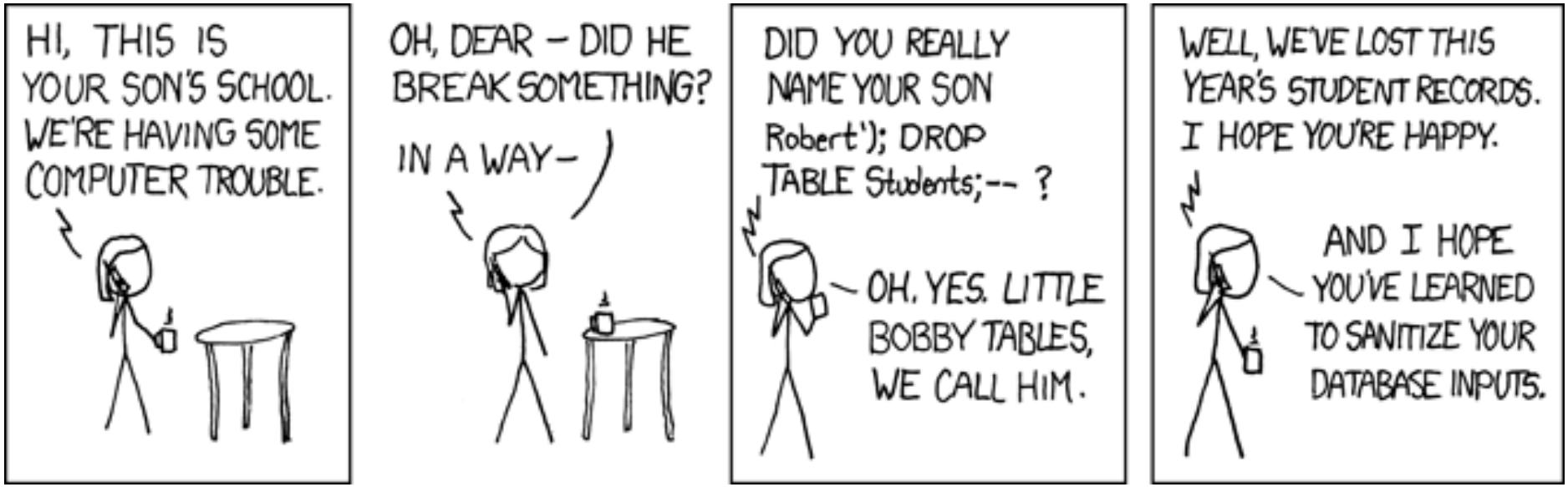


Malicious User Input

SQL Injection Attack

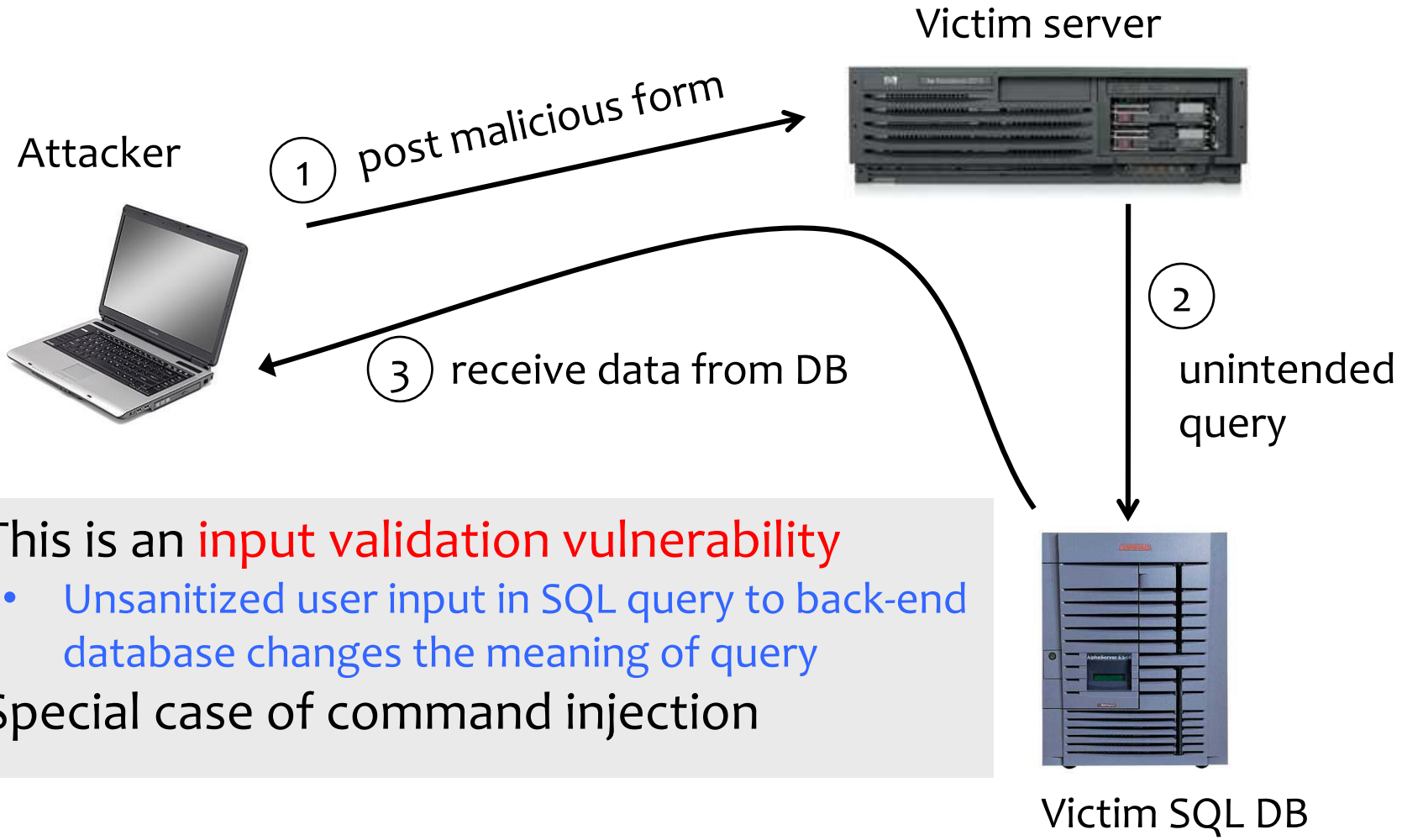


Security Instruction via XKCD



http://xkcd.com/327/

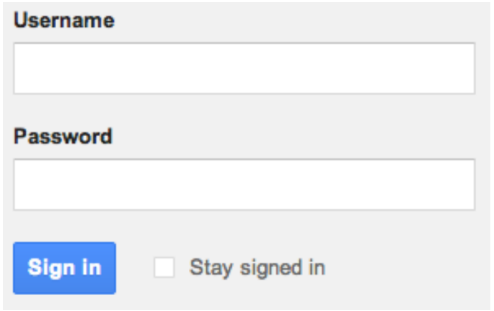
SQL Injection: Basic Idea



- This is an input validation vulnerability
  - Unsanitized user input in SQL query to back-end database changes the meaning of query
- Special case of command injection

Authentication with Backend DB

```
set UserFound = execute(
    "SELECT * FROM UserTable WHERE
    username= ' " & form("user") & " ' AND
    password= ' " & form("pwd") & " ' ");
```



User supplies username and password, this SQL query checks if user/password combination is in the database (note: here we're not thinking about how to actually securely store a password)

```
If not UserFound.EOF
    Authentication correct
  else Fail
```

Only true if the result of SQL query is not empty, i.e., user/pwd is in the database

Using SQL Injection to Log In

- User gives username **' OR 1=1 --**
- Web server executes query

```
set UserFound=execute(
    SELECT * FROM UserTable WHERE
    username= '' OR 1=1 -- … );
```

Always true!

Everything after -- is ignored!

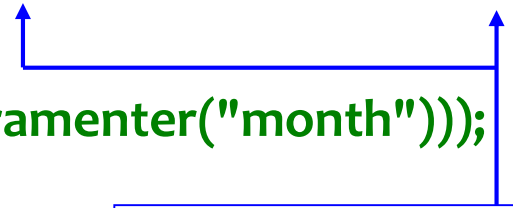
- Now all records match the query, so the result is not empty ⇒ correct "authentication"!

Preventing SQL Injection

- Validate all inputs
  - Filter out any character that has special meaning
    - Apostrophes, semicolons, percent, hyphens, underscores, …
    - Use escape characters to prevent special characters form becoming part of the query code
      - E.g.: escape(O'Connor) = O\'Connor
  - Check the data type (e.g., input must be an integer)

Prepared Statements

```
PreparedStatement ps =
    db.prepareStatement("SELECT pizza, toppings, quantity, order_day "
                + "FROM orders WHERE userid=? AND order_month=?");
ps.setInt(1, session.getCurrentUserId());
ps.setInt(2, Integer.parseInt(request.getParamenter("month")));
ResultSet res = ps.executeQuery();
```



- Bind variables: placeholders guaranteed to be data (not code)
- Query is parsed without data parameters
- Bind variables are typed (int, string, …)

http://java.sun.com/docs/books/tutorial/jdbc/basics/prepared.html

Defenses

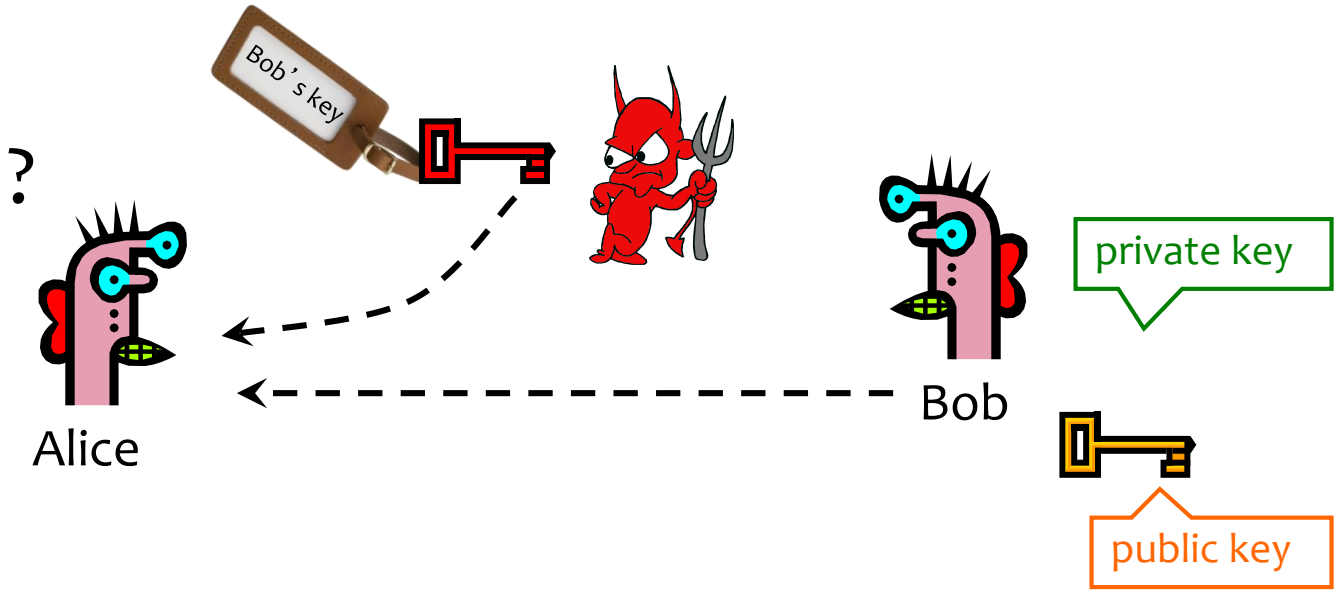
- Use safe APIs, e.g., prepared statements in SQL with parameterized queries
  - Define all the SQL code, then pass in each parameter
  - Separates code from data
- Whitelist-based server-side input validation
- Escape special characters
- Use LIMIT (and other) SQL controls within queries to prevent mass disclosure of records

- Remember Defense in Depth, Least Privilege, etc.

- Remember OWASP https://www.owasp.org/index.php/SQL_Injection_Prevention_Cheat_Sheet
  - (though resources now moved elsewhere, this link is to OWASP given value of OWASP in general)

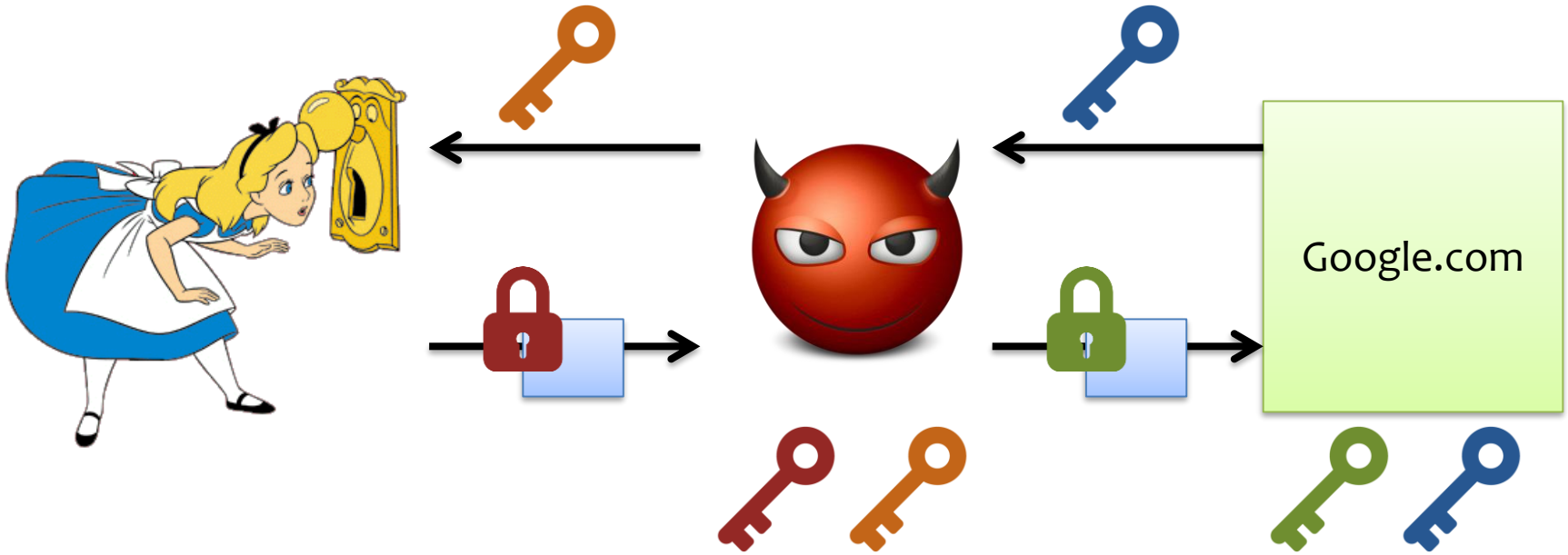
Back to Secure Communications

Authenticity of Public Keys



Problem: How does Alice know that the public key she received is really Bob's public key?

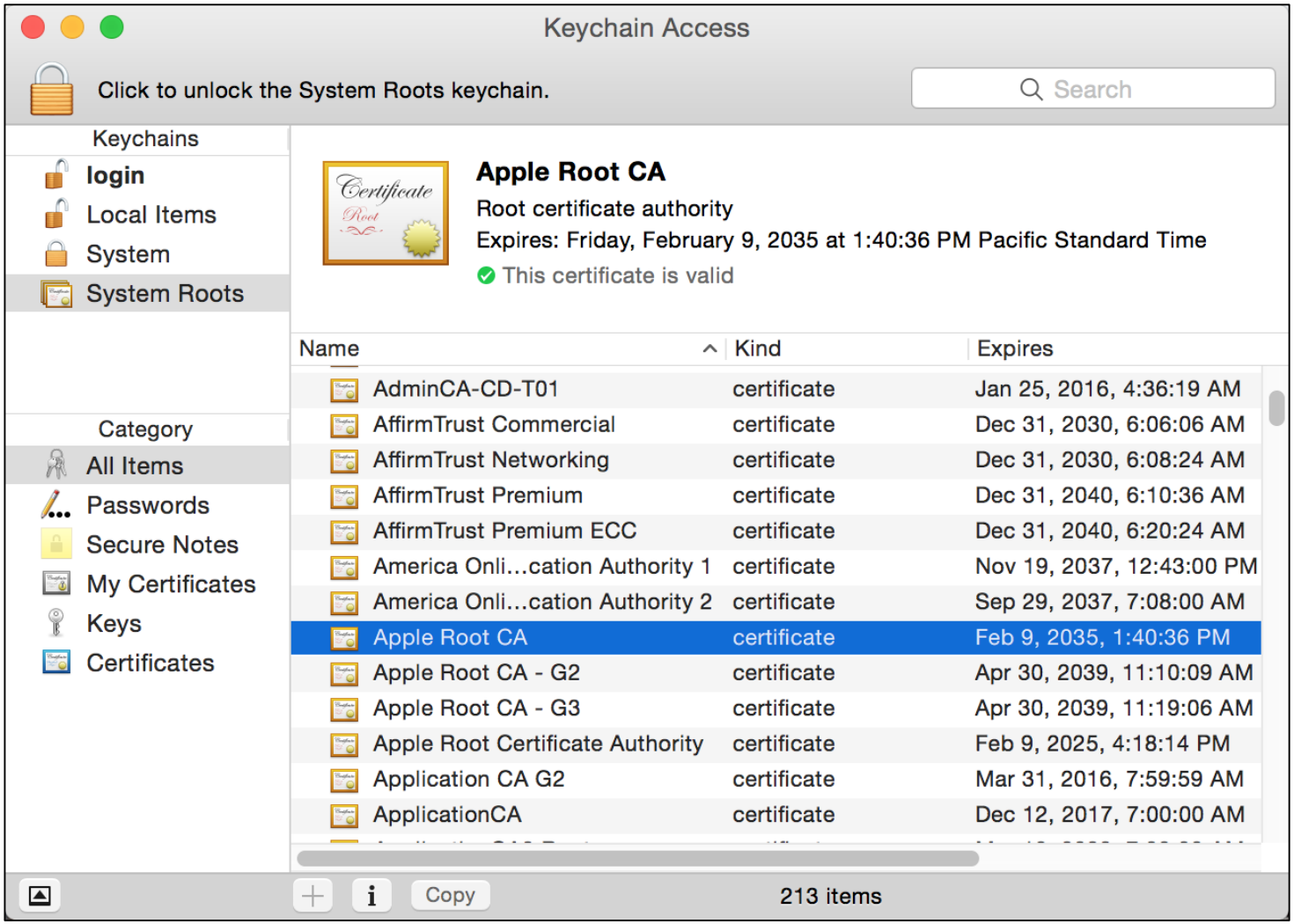
Threat: Man-In-The-Middle (MITM)



Distribution of Public Keys

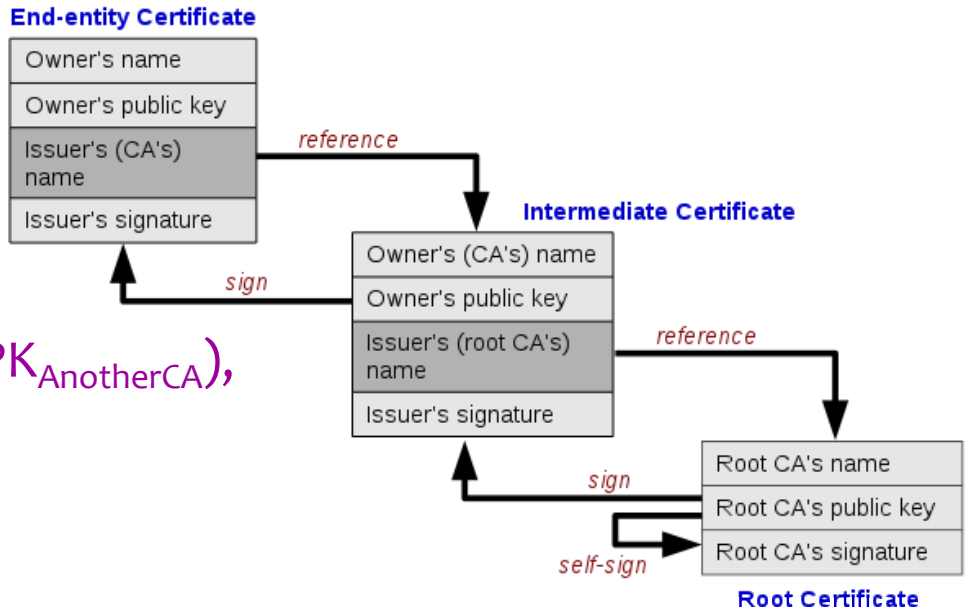
- Public announcement or public directory
  - Risks: forgery and tampering
- Public-key certificate
  - Signed statement specifying the key and identity
    - sig_{CA}("Bob", PK_B)
- Common approach: certificate authority (CA)
  - Single agency responsible for certifying public keys
  - After generating a private/public key pair, user proves his identity and knowledge of the private key to obtain CA's certificate for the public key (offline)
  - Every computer is pre-configured with CA's public key

Trusted(?) Certificate Authorities



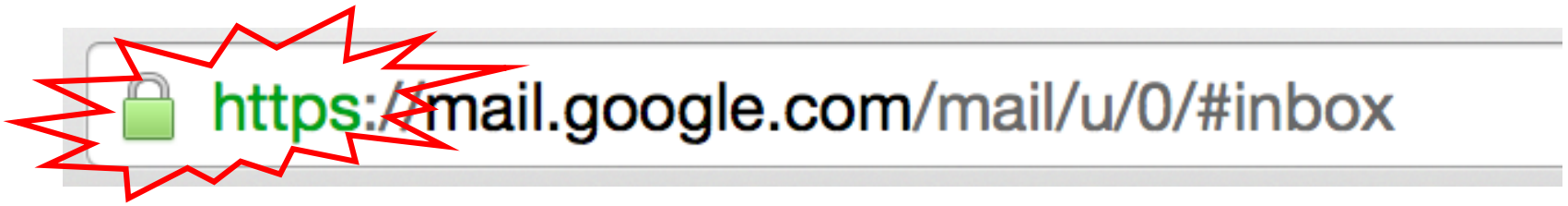
Hierarchical Approach

- Single CA certifying every public key is impractical
- Instead, use a trusted root authority (e.g., Verisign)
  - Everybody must know the root's public key
  - Instead of single cert, use a certificate chain
    - $sig_{Verisign}$("AnotherCA", $PK_{AnotherCA}$), $sig_{AnotherCA}$("Alice", PK_A)



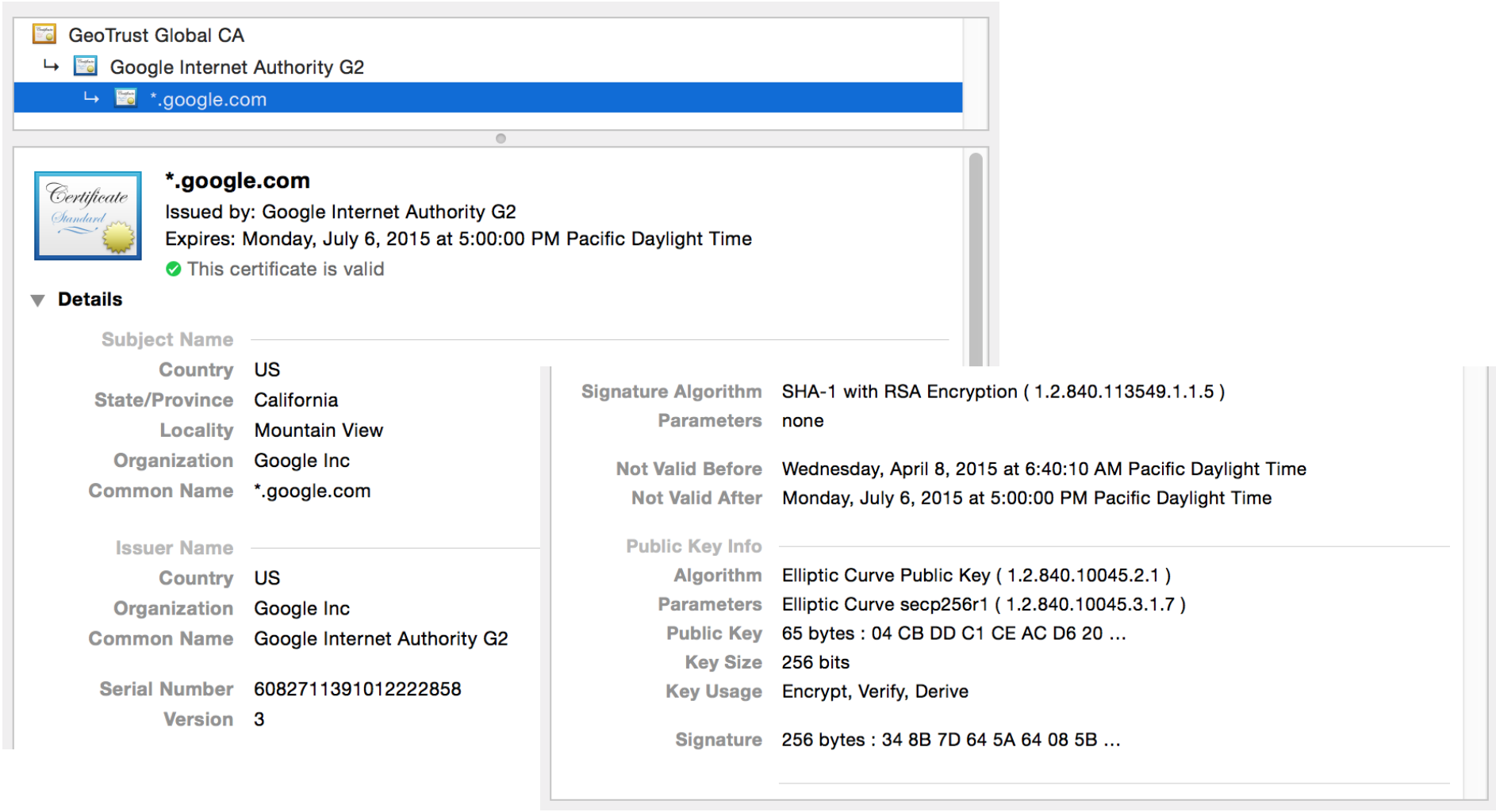
  - What happens if root authority is ever compromised?

You encounter this every day…

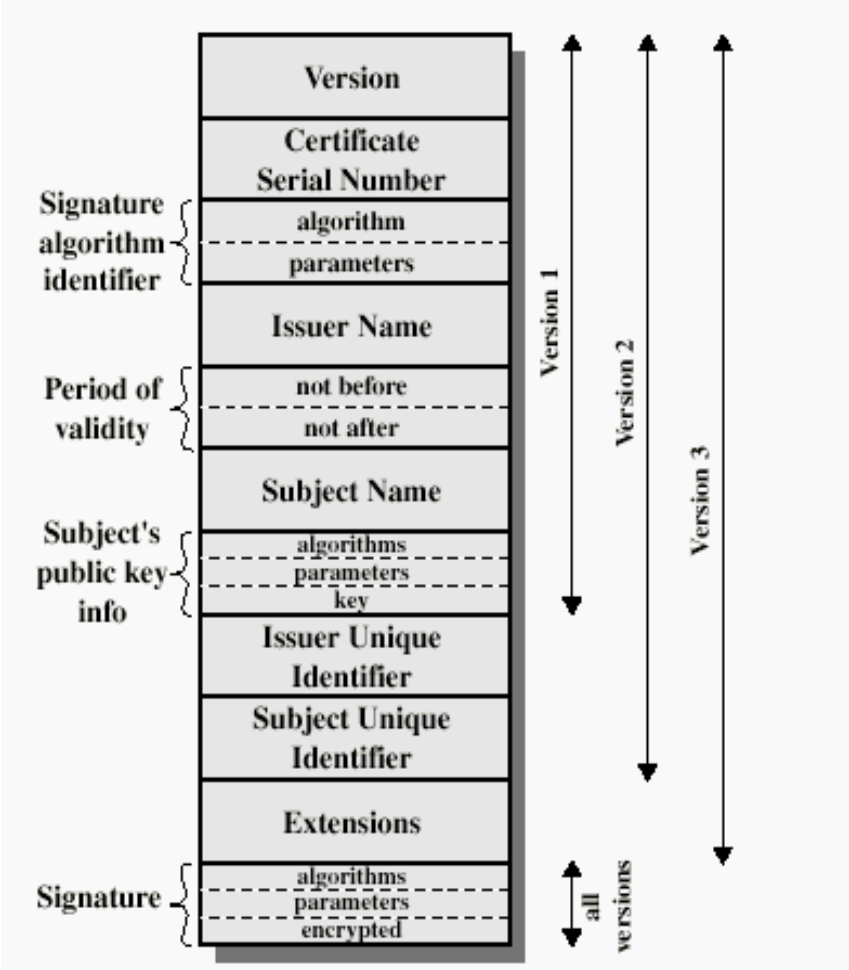


SSL/TLS: Encryption & authentication for connections

Example of a Certificate



X.509 Certificate

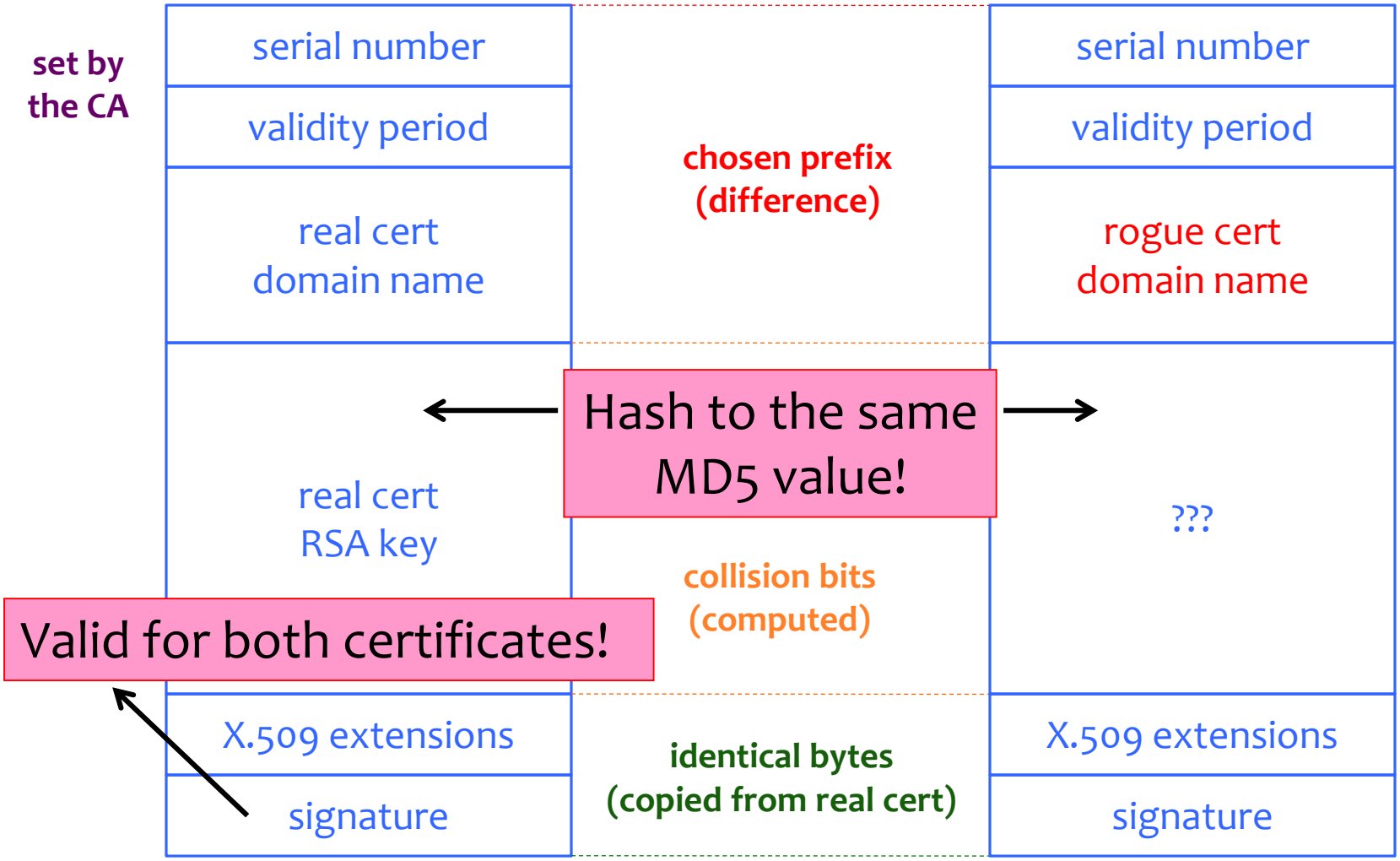


Many Challenges…

- Hash collisions
- Weak security at CAs
  - Allows attackers to issue rogue certificates
- Users don't notice when attacks happen
  - We'll talk more about this later in the course
- Etc…

[Sotirov et al. "Rogue Certificates"]

Colliding Certificates



Attacking CAs

DigiNotar Hacked by Black.Spook and Iranian Hackers Posted by Mikko @ 09:05 GMT | Comments

DigiNotar is a Dutch Certificate Authority. They sell SSL certificates.

Somehow, somebody managed to get a rogue SSL certificate from them on **July 10th, 2011**. This certificate was issued for domain name **.google.com**.

What can you do with such a certificate? Well, you can impersonate Google — assuming you can first reroute Internet traffic for google.com to you. This is something that can be done by a government or by a rogue ISP. Such a reroute would only affect users within that country or under that ISP.

Security of DigiNotar servers:

- All core certificate servers controlled by a single admin password (Prod@dm1n)
- Software on public-facing servers out of date, unpatched
- No anti-virus (could have detected attack)

Consequences

- Attacker needs to first divert users to an attacker-controlled site instead of the real Google, Yahoo, Skype, but then…
  - For example, use DNS to poison the mapping of mail.yahoo.com to an IP address
- … "authenticate" as the real site
- … decrypt all data sent by users
  - Email, phone conversations, Web browsing

Certificate Revocation

- Revocation is very important
- Many valid reasons to revoke a certificate
  - Private key corresponding to the certified public key has been compromised
  - User stopped paying his certification fee to this CA and CA no longer wishes to certify him
  - CA's private key has been compromised!
- Expiration is a form of revocation, too
  - Many deployed systems don't bother with revocation
  - Re-issuance of certificates is a big revenue source for certificate authorities

Certificate Revocation Mechanisms

- Certificate revocation list (CRL)
  - CA periodically issues a signed list of revoked certificates
    - Credit card companies used to issue thick books of canceled credit card numbers
  - Can issue a "delta CRL" containing only updates
- Online revocation service
  - When a certificate is presented, recipient goes to a special online service to verify whether it is still valid
    - Like a merchant dialing up the credit card processor

Attempt to Fix CA Problems:

Certificate Transparency

- **Problem:** browsers will think nothing is wrong with a rogue certificate until revoked
- **Goal:** make it impossible for a CA to issue a bad certificate for a domain *without the owner of that domain knowing*
  - (Then what?)
- **Approach:** auditable certificate logs

www.certificate-transparency.org

Attempt to Fix CA Problems:

Certificate Pinning

- Trust on first access: tells browser how to act on subsequent connections
- HPKP – HTTP Public Key Pinning
  - Use these keys!
  - HTTP response header field "`Public-Key-Pins`"
- HSTS – HTTP Strict Transport Security
  - Only access server via HTTPS
  - HTTP response header field "`Strict-Transport-Security`"