CS 5435: Authentication beyond passwords & authorization

Instructor: Tom Ristenpart

https://github.com/tomrist/cs5435-spring2024

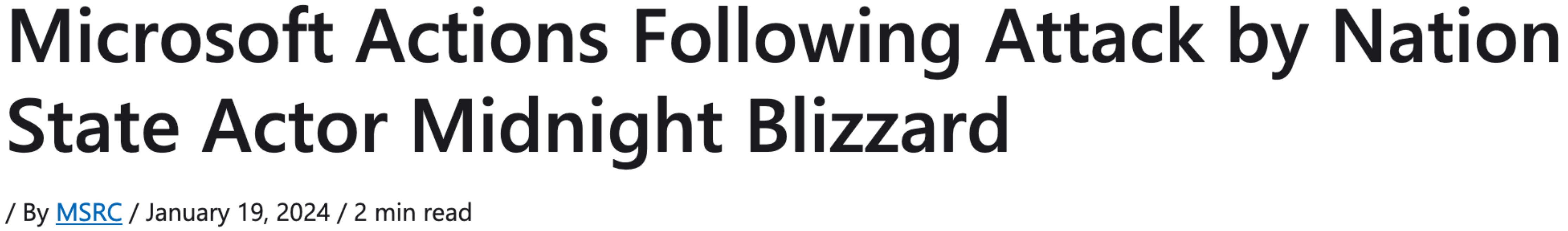
CORNELL TECH

HOME OF THE JACOBS INSTITUTE

Announcements

- TA office hours (In-person): 4pm on Friday
- Stills cheduling Tom’s availability for OH

- First homework will be assigned today (see slack announcements)



Microsoft Actions Following Attack by Nation State Actor Midnight Blizzard

/ By MSRC / January 19, 2024 / 2 min read

- Password spray attack -> compromise accounts
  - Try common passwords across many different accounts
  - Used many compromised residential systems to send requests
    - Only a few requests to each account → evades detection based on many failures
    - Only a slow rate of request from each residential IP → evades detection based on volume

Microsoft Actions Following Attack by Nation State Actor Midnight Blizzard

/ By MSRC / January 19, 2024 / 2 min read

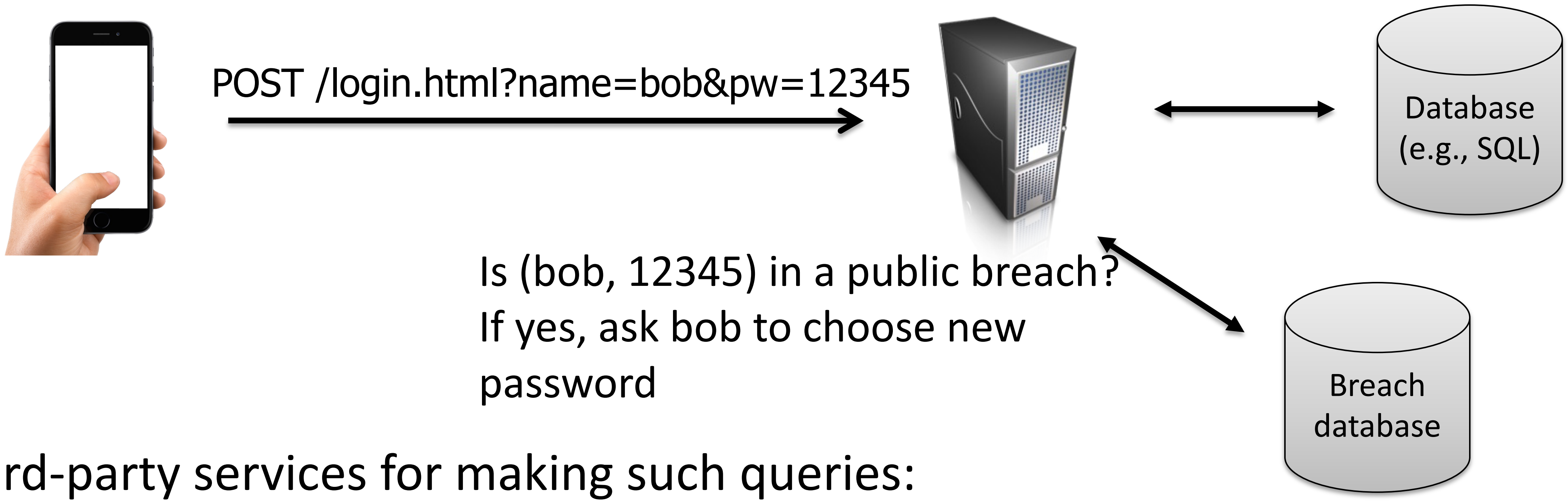
- Password spray attack -> compromise accounts
- Lateral move -> use account to take over OAuth application
  - “legacy test OAuth application that had elevated access to the Microsoft corporate environment.”
  - Create new, malicious OAuth applications
  - Eventually: “the Office 365 Exchange Online *full_access_as_app* role, which allows access to mailboxes.”
- Compromised many executive’s mail, used to monitor what Microsoft new about Midnight Blizzard

Password selection requirements

- [Komanduri et al. ‘11], [Vu et al. ‘07], [Proctor et al. ‘02] and others studied with Amazon Mturk
  - General consensus that it increases resistance at least somewhat
  - Decreases usability (character class requirements very painful)

- Password expiration policies [Zhang et al. ’10]
  - High-level bit: they don’t work
  - Attacker with old password can crack new one very often

Credential stuffing countermeasures


POST /login.html?name=bob&pw=12345
Database (e.g., SQL)
Is (bob, 12345) in a public breach? If yes, ask bob to choose new password
Breach database

Third-party services for making such queries:

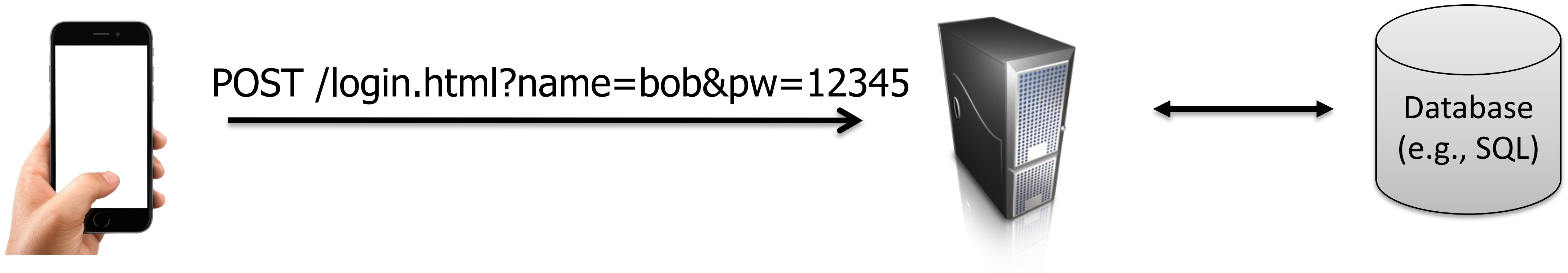
- HaveIBeenPwned
- Google password checker
- CloudFlare Web Application Firewall product
- Apple

Credential tweaking attacks

- Suppose bob changes password to 12345**6**
- Credential stuffing no longer works, but remote guessing attacker could try variants of (leaked) 12345
  - We call this a credential tweaking attack
- Deep learning mechanisms to learn conditional probability distribution
  - p(pw’ | pw)   where pw is leaked password, pw’ is variant
  - Trained from leak data to capture typical password variants
- Experiments showed that 1,316 Cornell accounts vulnerable

[Pal et al. 2019]

Password management

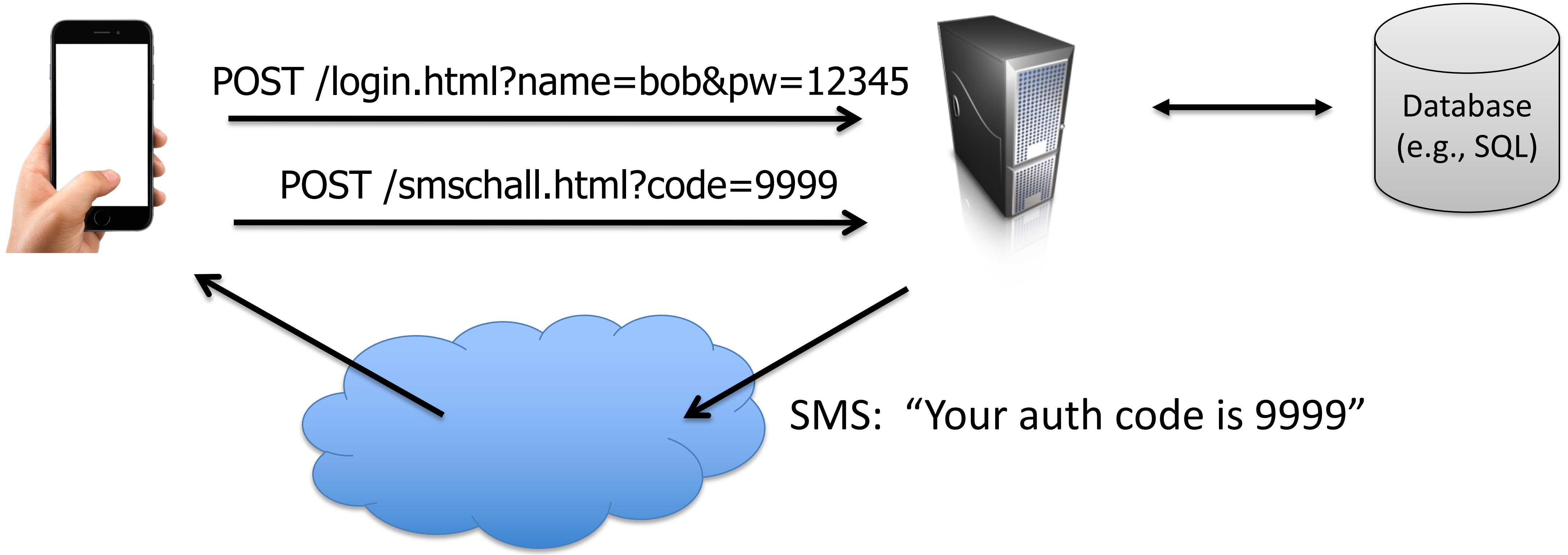


Countermeasure	Purpose
Password hashing	Database leak doesn't immediately reveal user passwords. Slows ***offline guessing attacks***
Strength meters	Nudge / force users to pick stronger passwords to mitigate guessing attacks
Lockout after X failed attempts	Prevent remote guessing attacks (X typically 10, 100, 1000); slows down / prevents ***online guessing attacks***
Compromised credential checks	Check if password is in known breaches

Second factor authentication (2FA)

- Combine passwords with another way to authenticate user
- Second factor usually proof of ownership of:
  - Email address
  - Telephone number (via SMS)
  - Device (via authenticator app)
  - Hardware token (One-time-password token, universal second factor U2F token)

Second factor authentication (2FA)


POST /login.html?name=bob&pw=12345
POST /smschall.html?code=9999
Database
(e.g., SQL)
SMS: "Your auth code is 9999"

Suppose you know someone's password (e.g., due to breach) but their account is protected by SMS-based 2FA. ***What can you do as an attacker?***

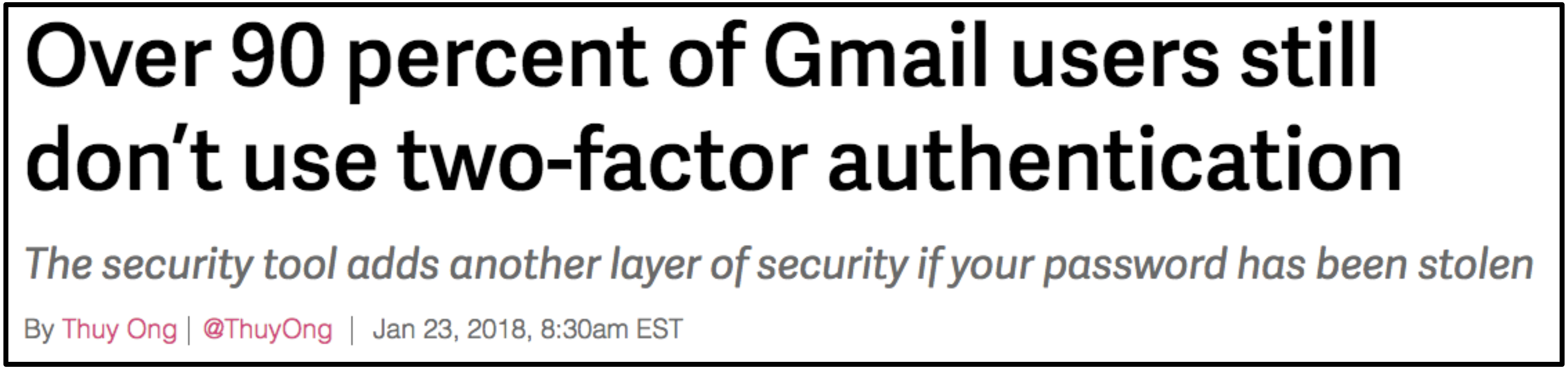
Circumventing SMS-based 2FA

Suppose you know someone's password (e.g., due to breach) but their account is protected by SMS-based 2FA

- Have physical access to device that receives SMS
- Phishing attacks – confuse user into disclosing SMS code to you
- SIM swap – trick phone company into registering victim's phone # to your device
- SMS hijacking: exploit vulnerabilities in cellular network (called SS7)
  https://berlin.ccc.de/~tobias/31c3-ss7-locate-track-manipulate.pdf

[Doerfler et al. 2019]: SMS 2FA circumvented in ~4% of phishing attacks
~26% of targeted attacks

Best practice: use authenticator app and/or hardware token

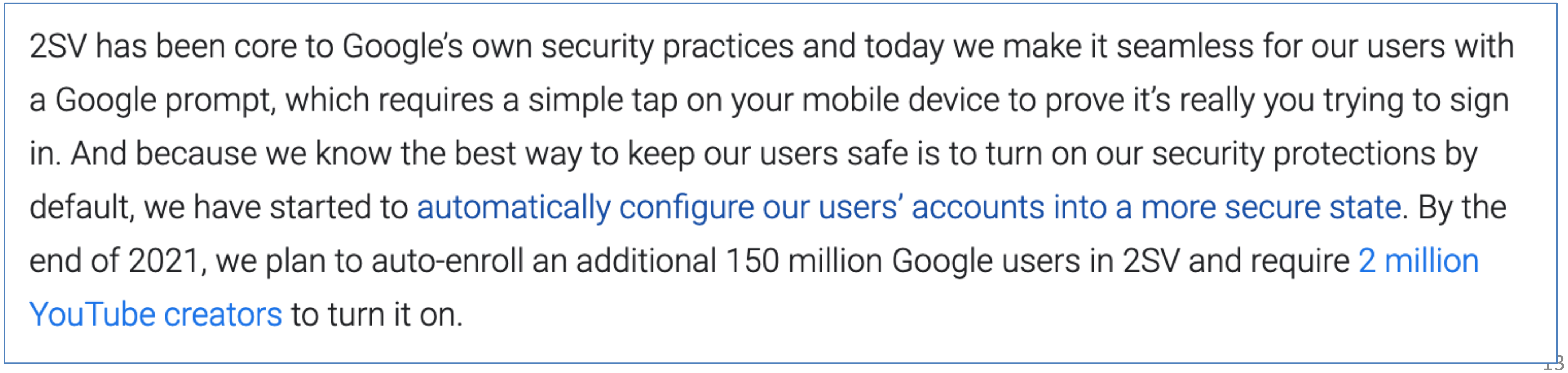


Over 90 percent of Gmail users still don't use two-factor authentication

The security tool adds another layer of security if your password has been stolen

By Thuy Ong | @ThuyOng | Jan 23, 2018, 8:30am EST

Usability remains a key issue preventing adoption



2SV has been core to Google's own security practices and today we make it seamless for our users with a Google prompt, which requires a simple tap on your mobile device to prove it's really you trying to sign in. And because we know the best way to keep our users safe is to turn on our security protections by default, we have started to automatically configure our users' accounts into a more secure state. By the end of 2021, we plan to auto-enroll an additional 150 million Google users in 2SV and require 2 million YouTube creators to turn it on.

Other authentication signals

- Location-based authentication
  - IP-based geolocation
- Device identification
  - Cookies, device fingerprinting
- Behavioral cues
  - Typical actions on platform (even after authenticated)
- Biometrics
  - Fingerprints, etc.

User authentication is huge pain

- Simple typos in passwords cause 3% of Dropbox users to be unable to login in 24 hour period [Chatterjee et al. 2016]

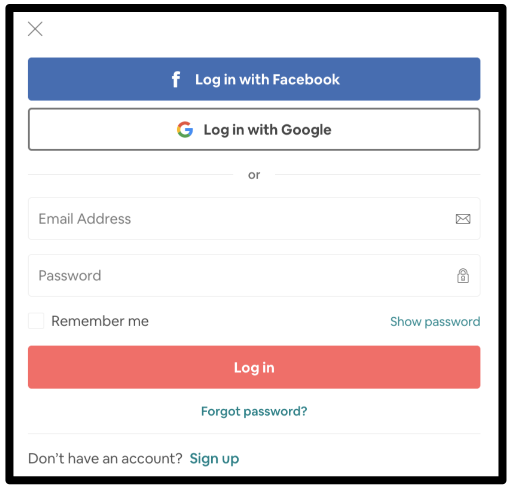
  https://www.cs.cornell.edu/~rahul/papers/pwtypos.pdf

- 52% of users fail login challenges at Google, 3% don't get in within short period of time [Doerfler et al. 2019]

  https://ai.google/research/pubs/pub48119

- How to minimize friction for honest users?

Session handling and login


Log in with Facebook

Log in with Google

or

Email Address

Password

Remember me Show password

Log in

Forgot password?

Don't have an account? Sign up

$$\xrightarrow{\text{GET /login.html}}$$

$$\xleftarrow{\phantom{\text{GET /login.html}}}$$

Set-Cookie: AnonSessID=134fds1431

POST /login.html?name=bob&pw=12345

$$\xrightarrow{\phantom{\text{POST}}}$$

Cookie: AnonSessID=134fds1431

Need to check password matches registered version

$$\xleftarrow{\phantom{\text{POST}}}$$

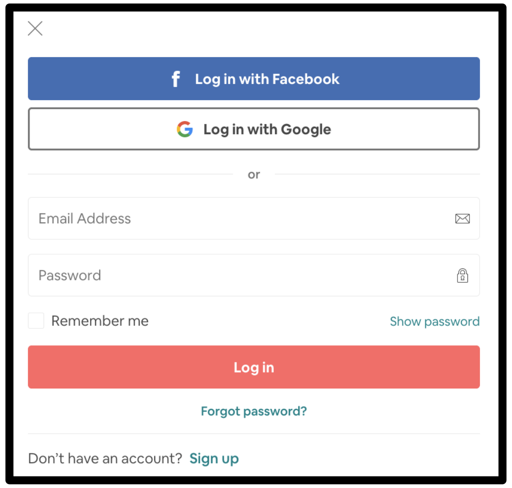
Set-Cookie: SessID=83431Adf

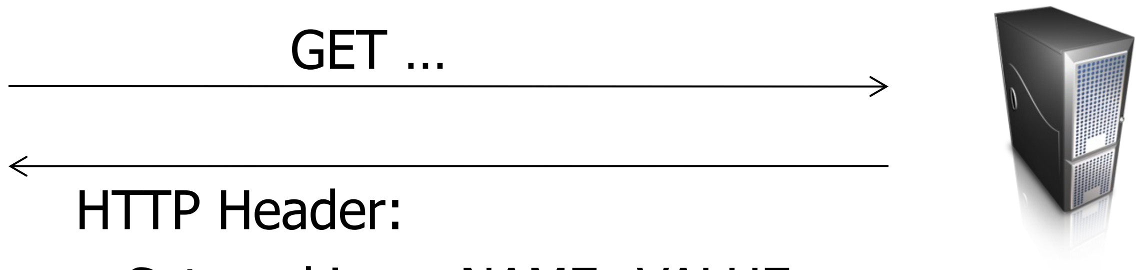
GET /account.html

$$\xrightarrow{\phantom{\text{GET}}}$$

Cookie: SessID=83431Adf

Cookies: Setting/Deleting


Log in with Facebook
Log in with Google
or
Email Address
Password
Remember me
Show password
Log in
Forgot password?
Don't have an account? Sign up



HTTP Header:

Set-cookie: NAME=VALUE ;
domain = (when to send) ;
path = (when to send)
secure = (only send over SSL);
expires = (when expires) ;
HttpOnly

scope

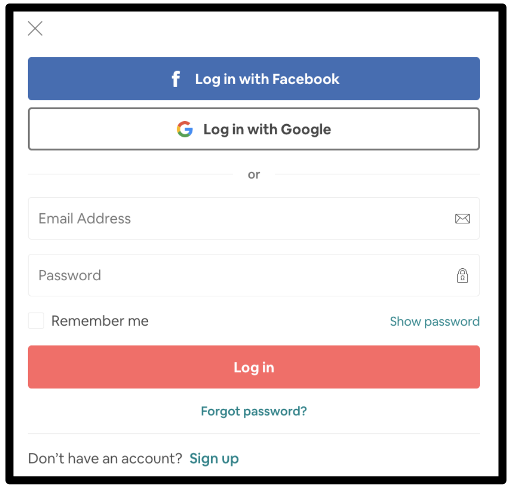
if expires=NULL:
this session only

- Delete cookie by setting “expires” to date in past
- Default scope is domain and path of setting URL
- Client can also set cookies (Javascript)

Cookie scope rules (domain and path)

- Say we are at tech.cornell.edu
  - Any non-top level domain (non-TLD, TLD = top level domain) suffix can be scope:
    - allowed: tech.cornell.edu or cornell.edu
    - disallowed: www.cornell.edu or wisc.edu
- Path can be set to anything
- Default is domain and path of request

Cookies: reading by server


Log in with Facebook

Log in with Google

or

Email Address

Password

Remember me

Show password

Log in

Forgot password?

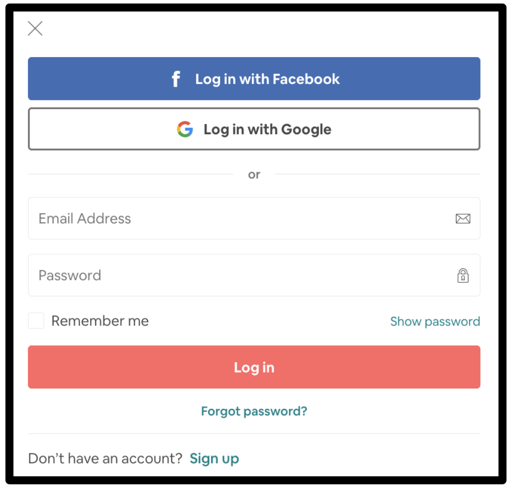
Don't have an account? Sign up

GET /url-domain/url-path

Cookie: name=value

- Browser sends all cookies such that
  - domain scope is suffix of url-domain
  - path is prefix of url-path
  - protocol is HTTPS if cookie marked "secure"

Session handling and login



GET /login.html →

← Set-Cookie: AnonSessID=134fds1431

POST /login.html?name=bob&pw=12345 →

Cookie: AnonSessID=134fds1431

Need to check password matches registered version

←

Set-Cookie: SessID=83431Adf

Cookie acts as ***bearer token***

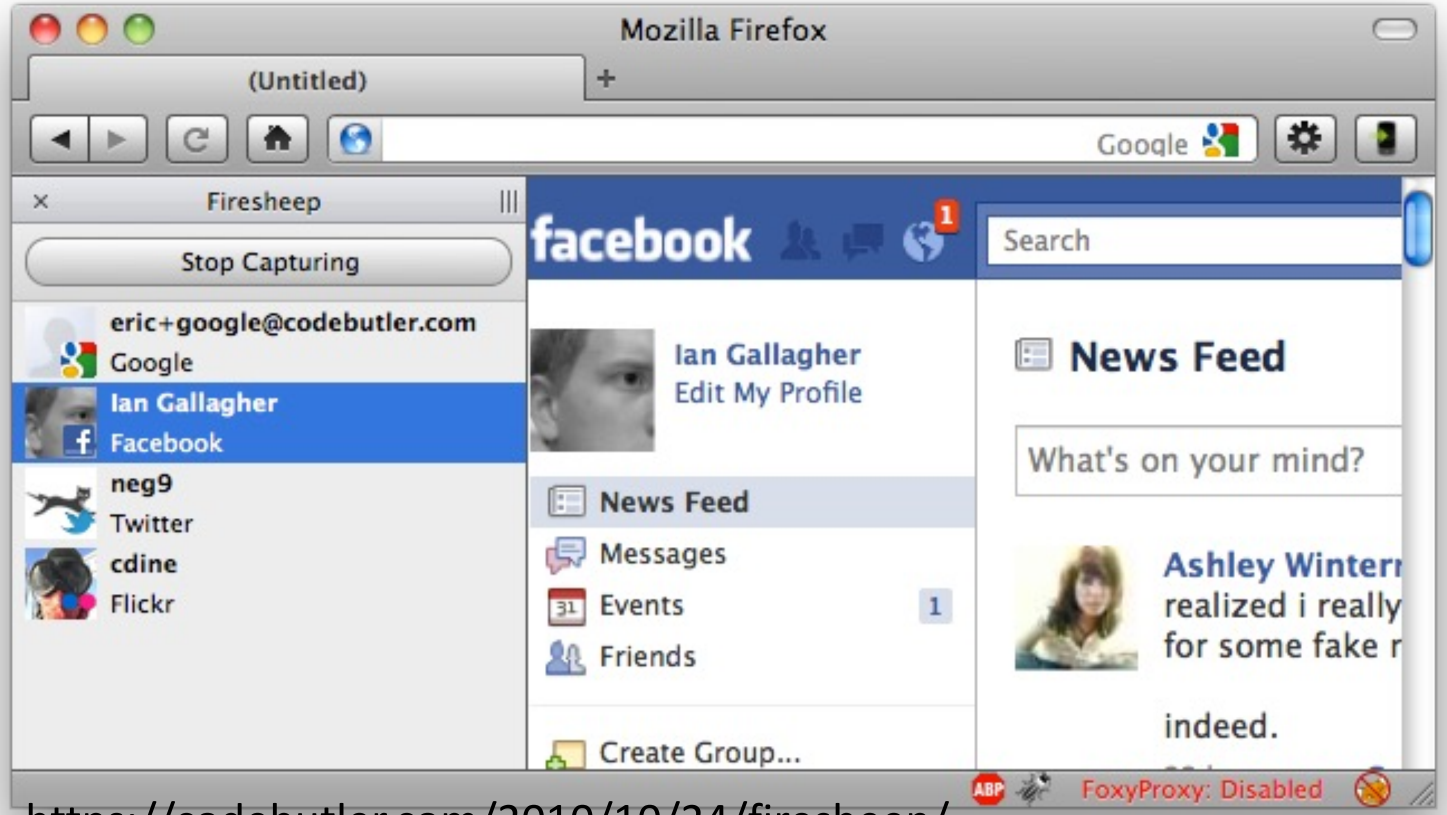
GET /account.html →

Cookie: SessID=83431Adf

Session hijacking

- If attacker can steal cookie, this can be sufficient for masquerading as client
- How could session cookies be stolen?

- Infection of client device
- Monitoring unencrypted network connections



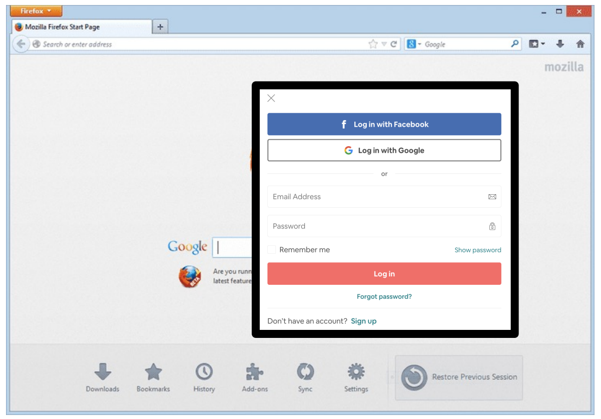
https://codebutler.com/2010/10/24/firesheep/

Authentication vs. authorization

- Authentication securely confirm identity
- Authorization gives (authenticated) party right to access something

Single-sign on (SSO)

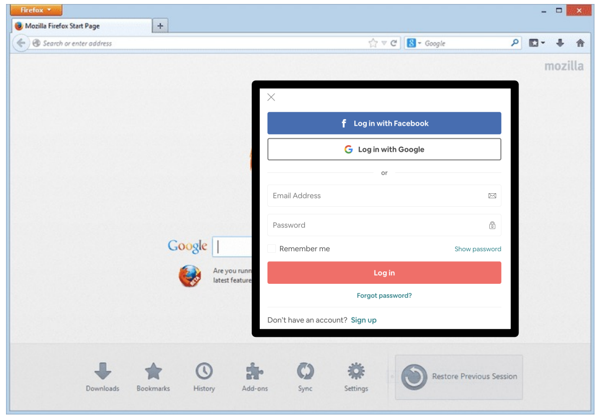
- ***Identity provider (IdP)*** handles authentication
  - (e.g., via username & password)
- Log into ***relying party (RP)*** via attestion by IdP
- Most cases: distinct web servers



Identity provider (IdP)
(e.g.:
identity.cornell.edu)

Relying party (RP)
(e.g.: account.html?user=tom)

How might SSO work?



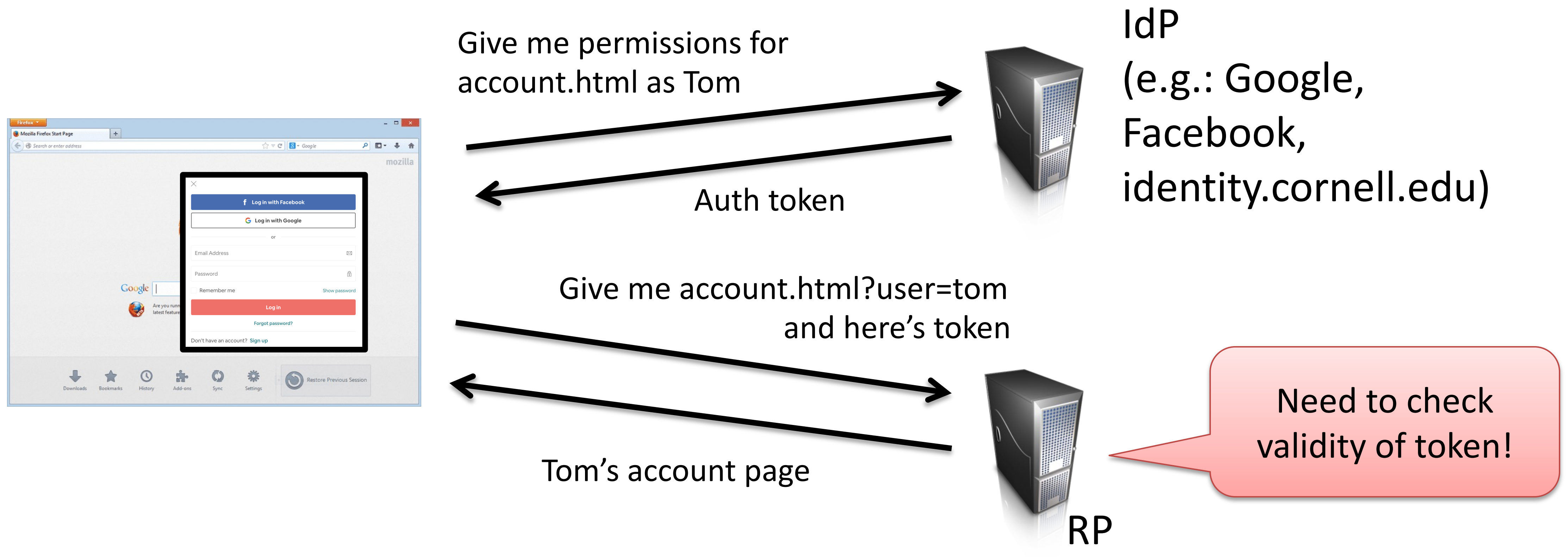
Identity provider (IdP)
(e.g.:
identity.cornell.edu)

Relying party (RP)
(e.g.: account.html?user=tom)

<u>In-class 5-minute exercise:</u>
How would you securely authorize browser to access www.cornell.edu/account.html?user=tom based on authentication to identity.cornell.edu?

Single-sign on (SSO)

- Many standards for solving these problems:
  - SAML, OpenID Connect + OAuth 2.0, …
- Involve combination of logical flows plus some cryptography


Give me permissions for account.html as Tom
Auth token
IdP (e.g.: Google, Facebook, identity.cornell.edu)
Give me account.html?user=tom and here's token
Tom's account page
RP
Need to check validity of token!
Log in with Facebook
Log in with Google
Email Address
Password
Remember me
Show password
Log in
Forgot password?
Don't have an account? Sign up

OAuth 2.0

- Widely used authorization protocol standard
- Used for web apps and mobile apps
- Two of the authorization grant types:

Authorization code
Used for server-side applications to obtain access to resources

Implicit
Often used for client-side applications, such as client-side javascript or mobile app

https://www.digitalocean.com/community/tutorials/an-introduction-to-oauth-2

OAuth 2.0 implicit flows

Request triggers redirect to authorization request

```
https://authserv.com/authorize?
                    response_type=code &
                    client_id=CLIENT_ID &
                    redirect_uri=https://myapp.com/callback &
                    scope=read
```

Tutorial: https://www.digitalocean.com/community/tutorials/an-introduction-to-oauth-2

OAuth 2.0 implicit flows

Request triggers redirect to authorization request

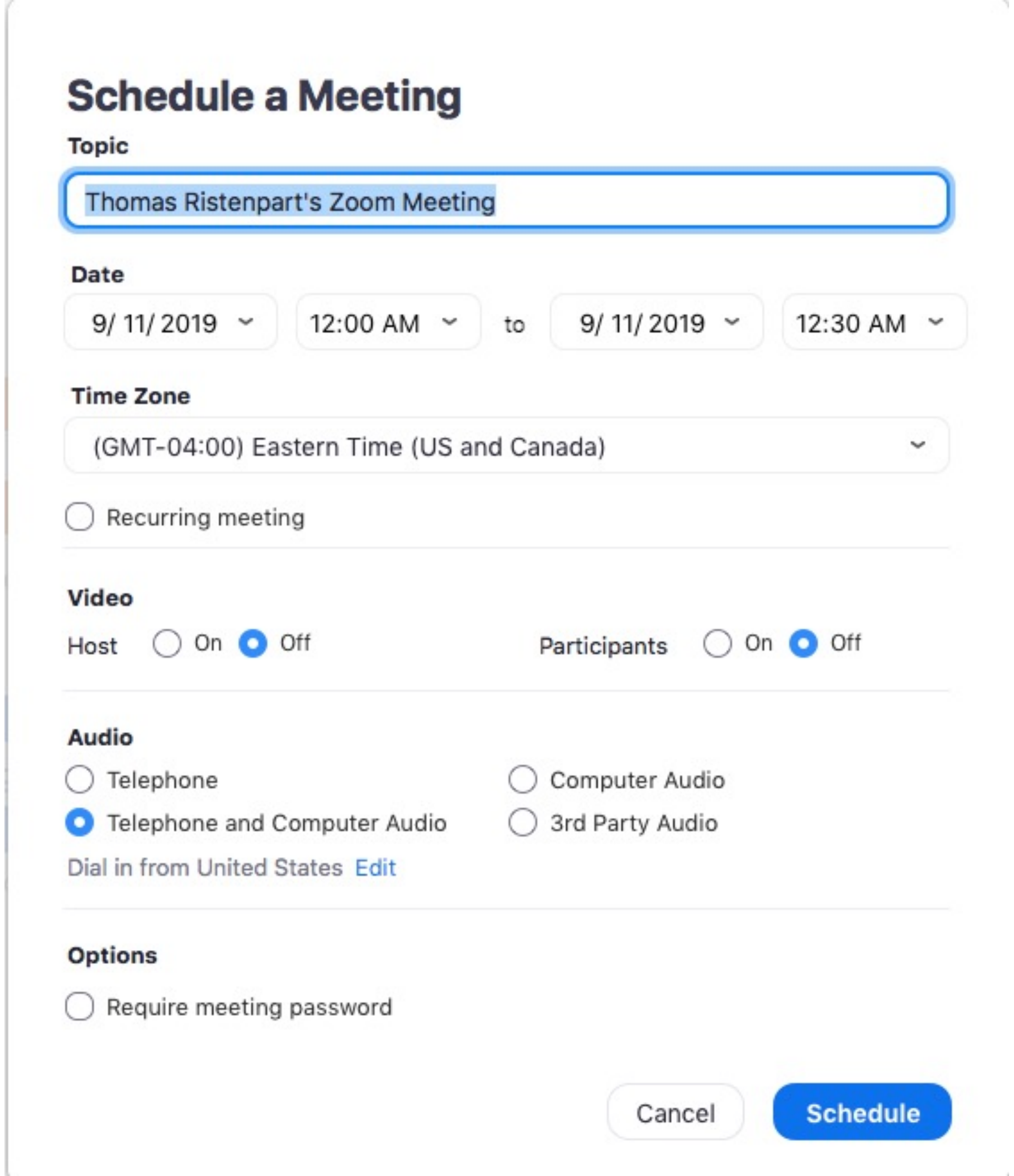
https://authserv.com/authorize?
response_type=code &
client_id=CLIENT_ID &
redirect_uri=https://myapp.com/callback &
scope=read

Redirects browser via redirect URI, with an auth token

https://myapp.com/callback?token=ACCESS_TOKEN

Now client-side can use this token to access resource

Tutorial: https://www.digitalocean.com/community/tutorials/an-introduction-to-oauth-2



Schedule a Meeting

Topic

Thomas Ristenpart's Zoom Meeting

Date

9/ 11/ 2019 12:00 AM to 9/ 11/ 2019 12:30 AM

Time Zone

(GMT-04:00) Eastern Time (US and Canada)

☐ Recurring meeting

Video

Host On [✓ Off] Participants On [✓ Off]

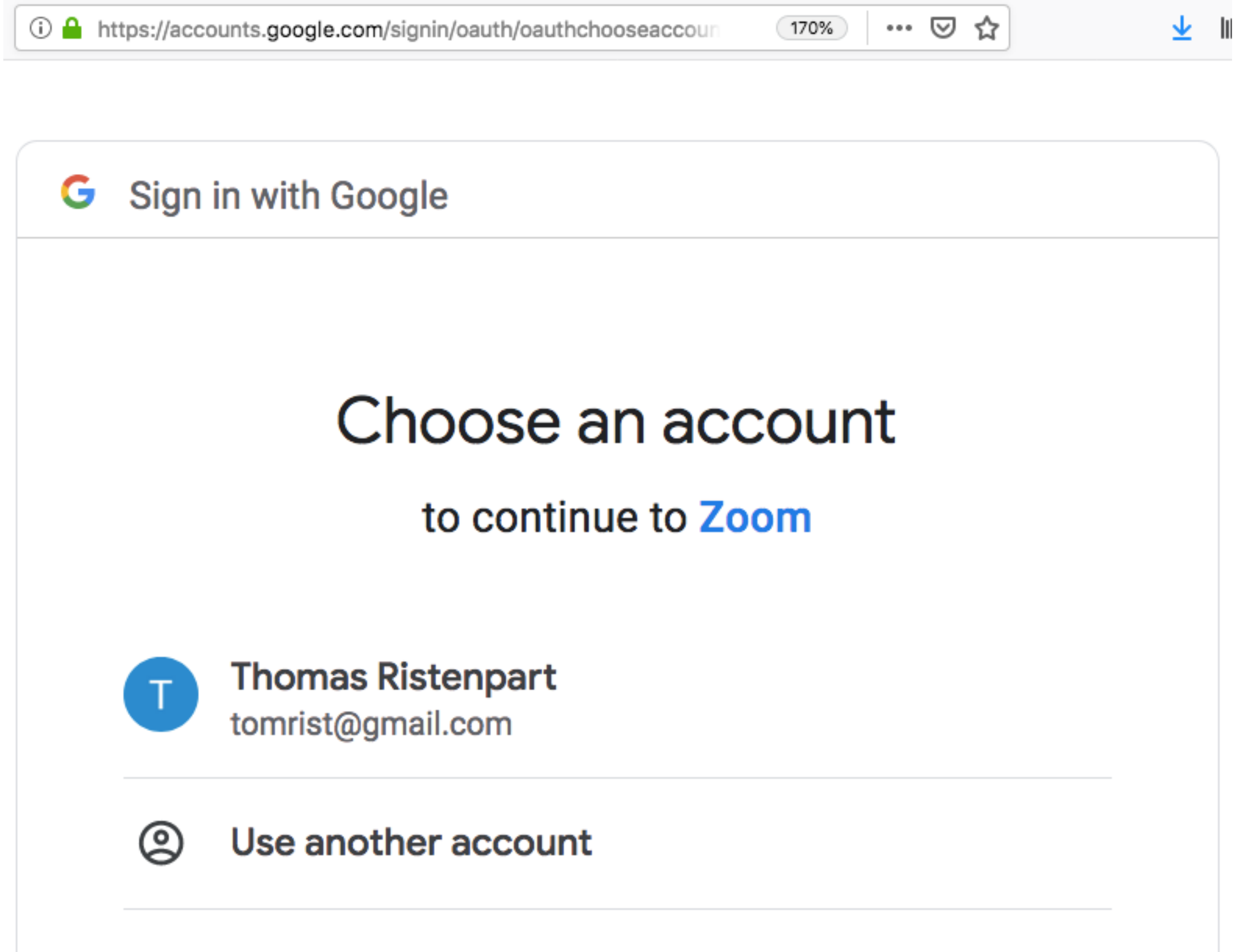
Audio

Telephone Computer Audio [✓ Telephone and Computer Audio] 3rd Party Audio

Dial in from United States Edit

Options

☐ Require meeting password



https://accounts.google.com/signin/oauth/oauthchooseaccou

170%

Sign in with Google

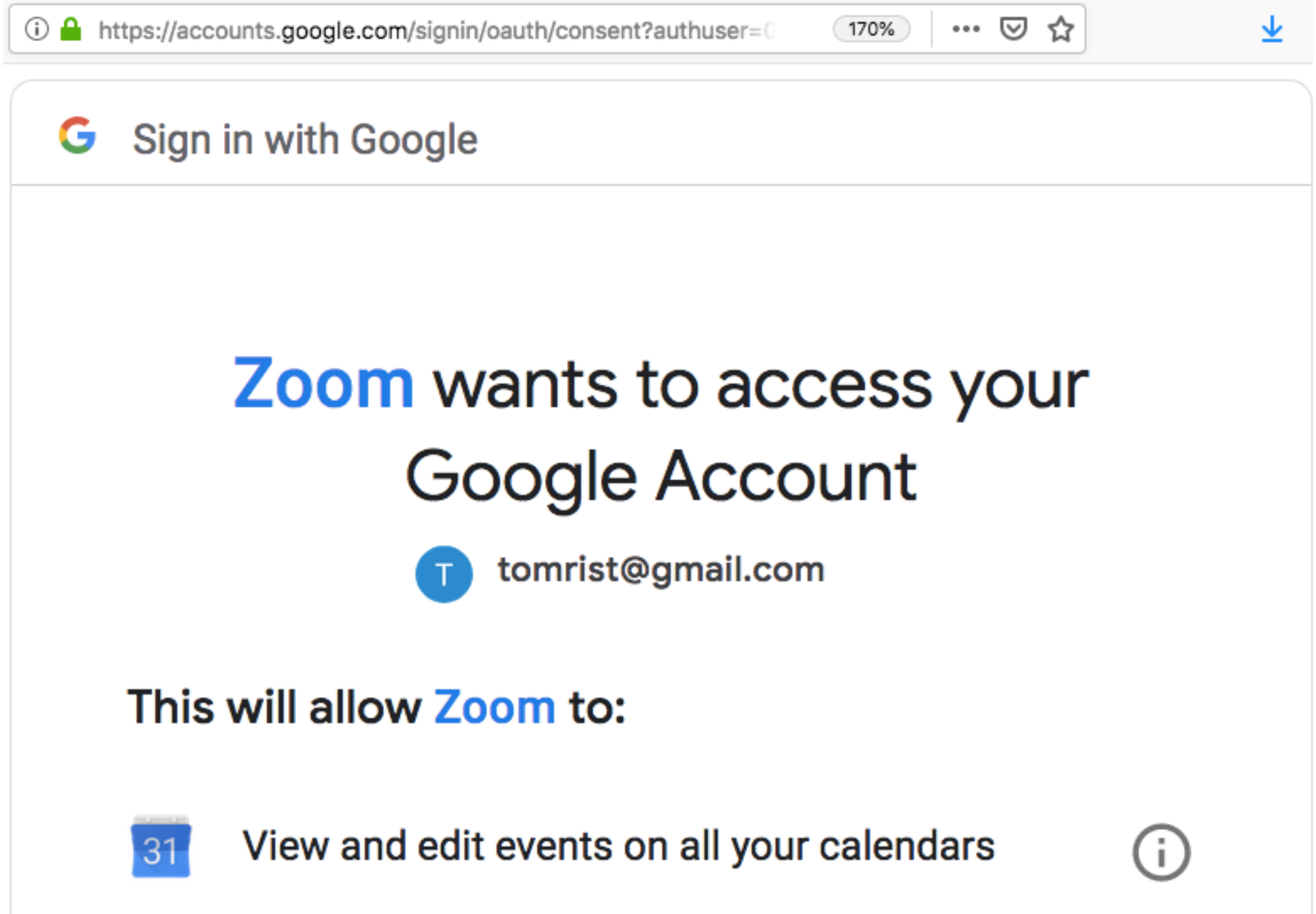
Choose an account

to continue to Zoom

Thomas Ristenpart

tomrist@gmail.com

Use another account


https://accounts.google.com/signin/oauth/consent?authuser=(

Sign in with Google

Zoom wants to access your Google Account

tomrist@gmail.com

This will allow Zoom to:

View and edit events on all your calendars

What can go wrong?

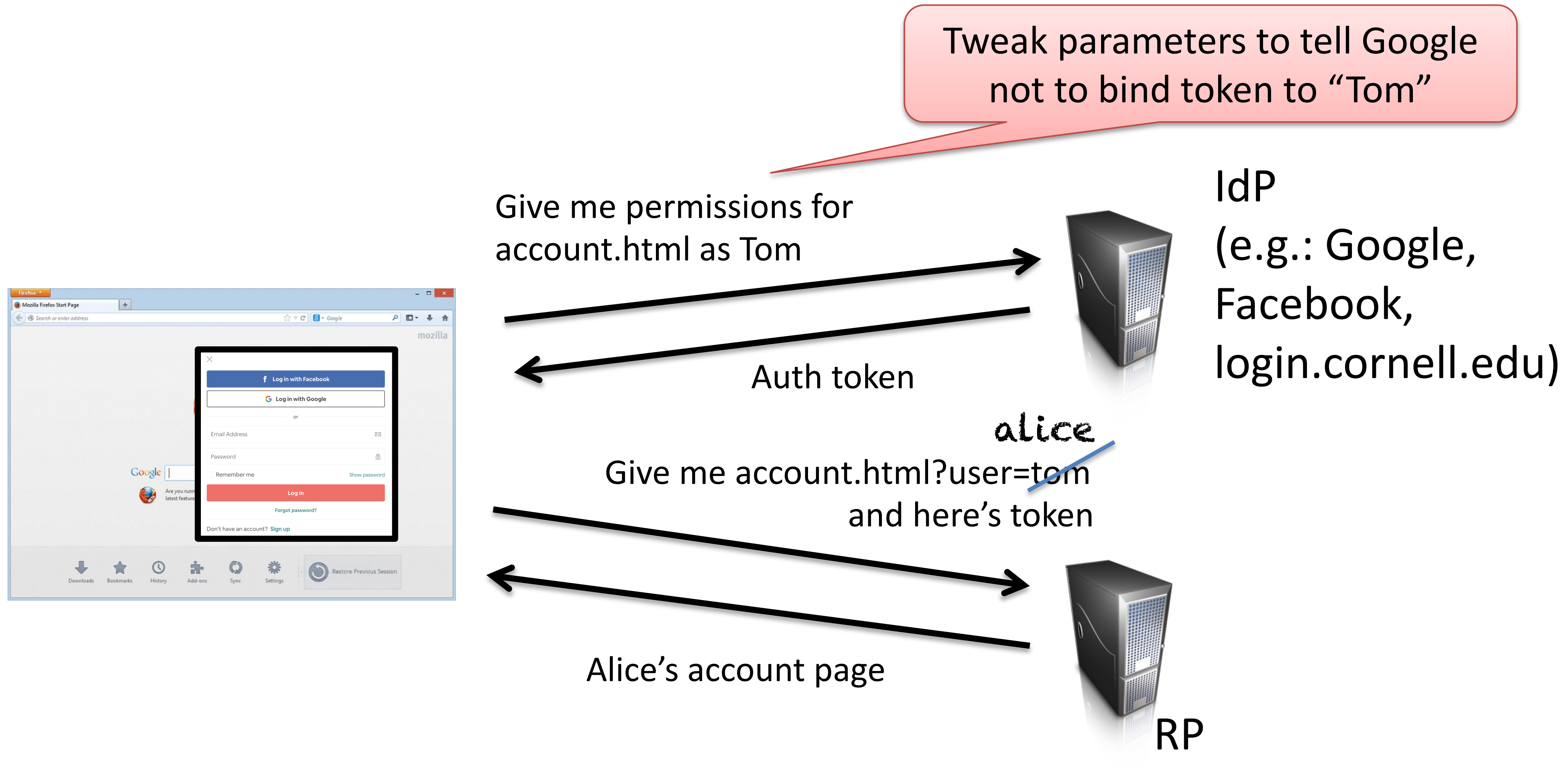
- [Wang, Chen, Wang 2012] built tool to explore OAuth security
- Found ***lots*** of vulnerabilities:

> *The web SSO systems we found to be vulnerable include those of Facebook, Google ID, PayPal Access, Freelancer, JanRain, Sears and FarmVille. All the discovered flaws allow unauthorized parties to log into victim user's accounts on the RP, as shown by the videos in [33]*

- Eg: Google's SSO could be told not to bind auth token to user's identity, and the relying party could be tricked into giving access to arbitrary victim account

https://www.microsoft.com/en-us/research/wp-content/uploads/2012/05/websso-final.pdf

Vulnerability diagrammatically


Tweak parameters to tell Google not to bind token to "Tom"
Give me permissions for account.html as Tom
Auth token
IdP (e.g.: Google, Facebook, login.cornell.edu)
alice
Give me account.html?user=~~tom~~ and here's token
Alice's account page
RP
Log in with Facebook
Log in with Google
Email Address
Password
Remember me
Show password
Log in
Forgot password?
Don't have an account? Sign up

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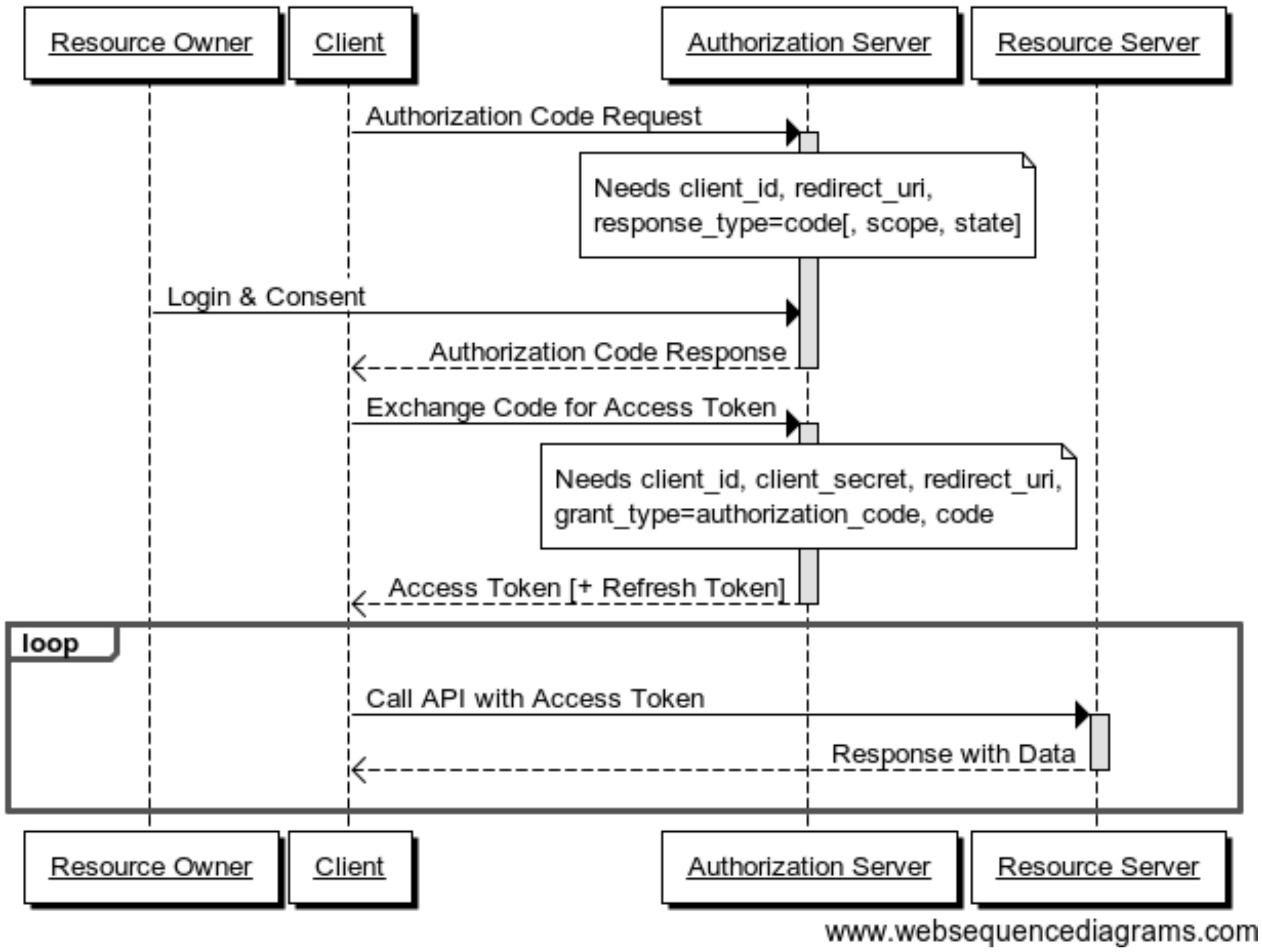
- These fixed, but logical bugs in authentication & authorization rampant in web apps
  – CSRF, XSS bugs (stay tuned) often target authorization logic

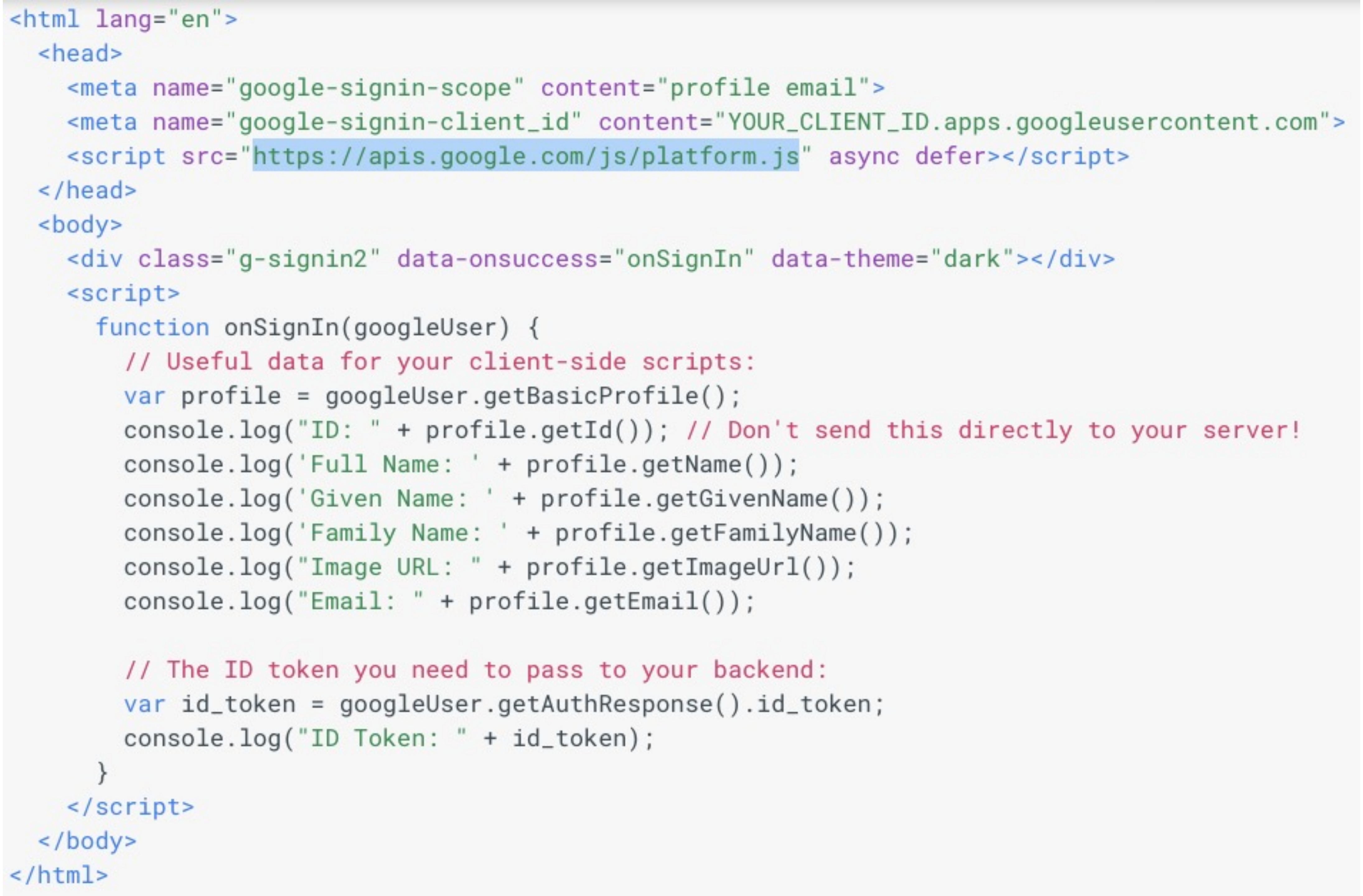
https://www.microsoft.com/en-us/research/wp-content/uploads/2012/05/websso-final.pdf

Next time

- Abuse of (authenticated/authorized) accounts
  - Commercial abuse
- Then we’ll move on to interpersonal abuse

Authorization Code Grant Flow

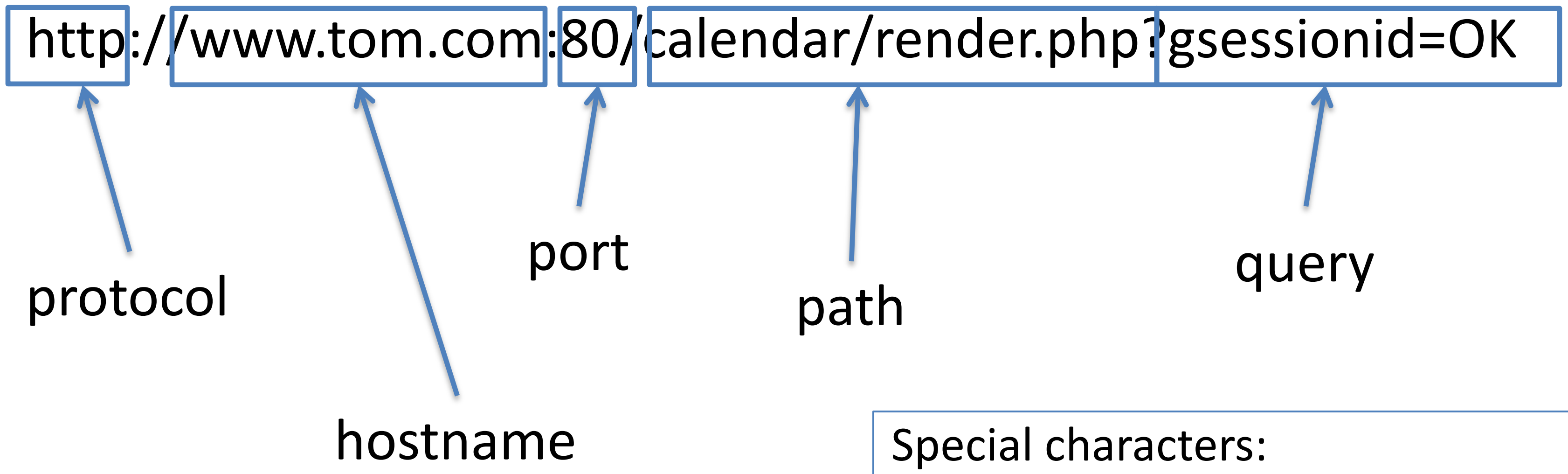

Resource Owner
Client
Authorization Server
Resource Server
Authorization Code Request
Needs client_id, redirect_uri, response_type=code[, scope, state]
Login & Consent
Authorization Code Response
Exchange Code for Access Token
Needs client_id, client_secret, redirect_uri, grant_type=authorization_code, code
Access Token [+ Refresh Token]
loop
Call API with Access Token
Response with Data
Resource Owner
Client
Authorization Server
Resource Server
www.websequencediagrams.com



```html
<html lang="en">
  <head>
    <meta name="google-signin-scope" content="profile email">
    <meta name="google-signin-client_id" content="YOUR_CLIENT_ID.apps.googleusercontent.com">
    <script src="https://apis.google.com/js/platform.js" async defer></script>
  </head>
  <body>
    <div class="g-signin2" data-onsuccess="onSignIn" data-theme="dark"></div>
    <script>
      function onSignIn(googleUser) {
        // Useful data for your client-side scripts:
        var profile = googleUser.getBasicProfile();
        console.log("ID: " + profile.getId()); // Don't send this directly to your server!
        console.log('Full Name: ' + profile.getName());
        console.log('Given Name: ' + profile.getGivenName());
        console.log('Family Name: ' + profile.getFamilyName());
        console.log("Image URL: " + profile.getImageUrl());
        console.log("Email: " + profile.getEmail());

        // The ID token you need to pass to your backend:
        var id_token = googleUser.getAuthResponse().id_token;
        console.log("ID Token: " + id_token);
      }
    </script>
  </body>
</html>
```

Uniform resource locators (URLs)

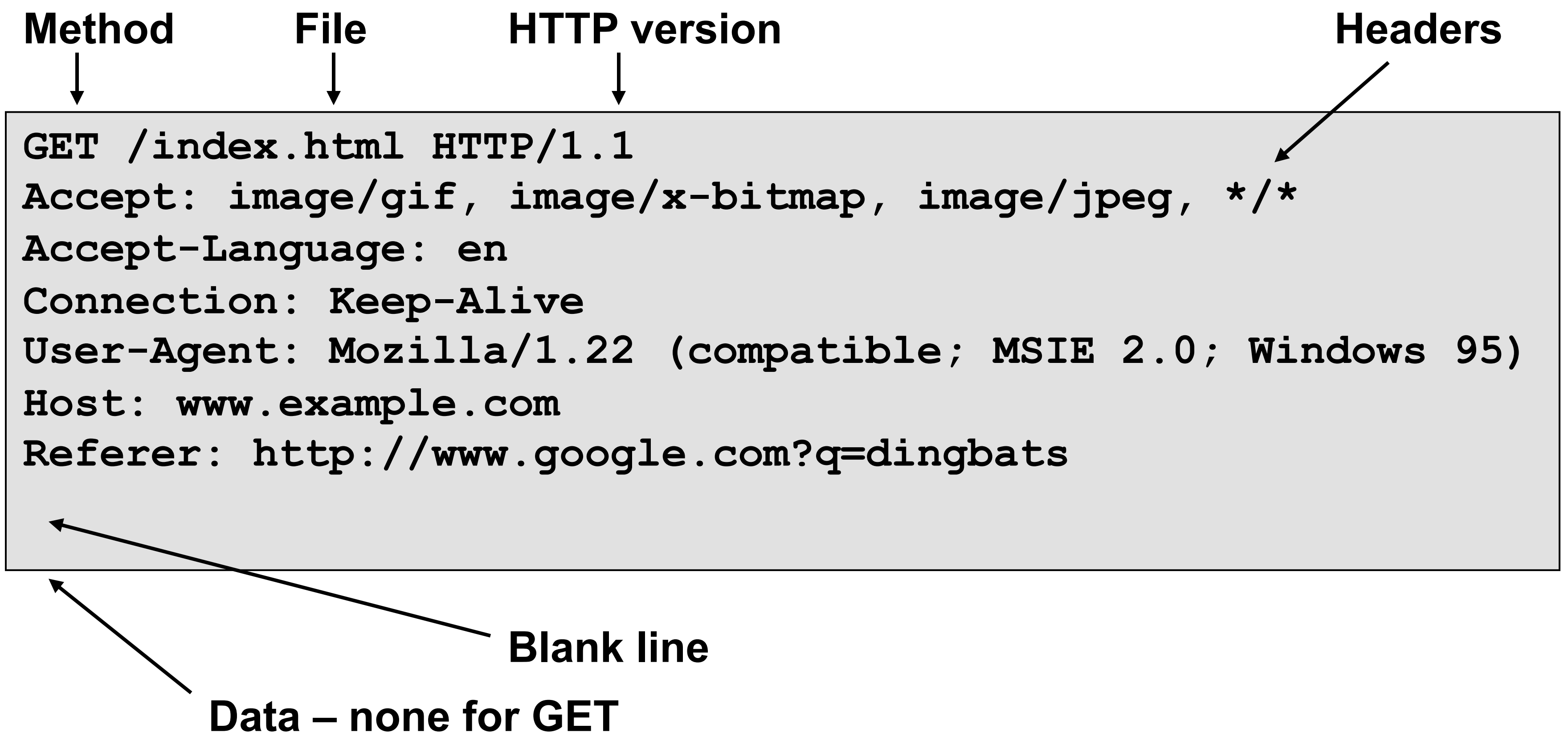


URL's only allow ASCII-US characters.
Encode other characters:

%0A = newline
%20 = space

Special characters:
+ = space
? = separates URL from parameters
% = special characters
/ = divides directories, subdirectories
# = bookmark
& = separator between parameters

HTTP Request

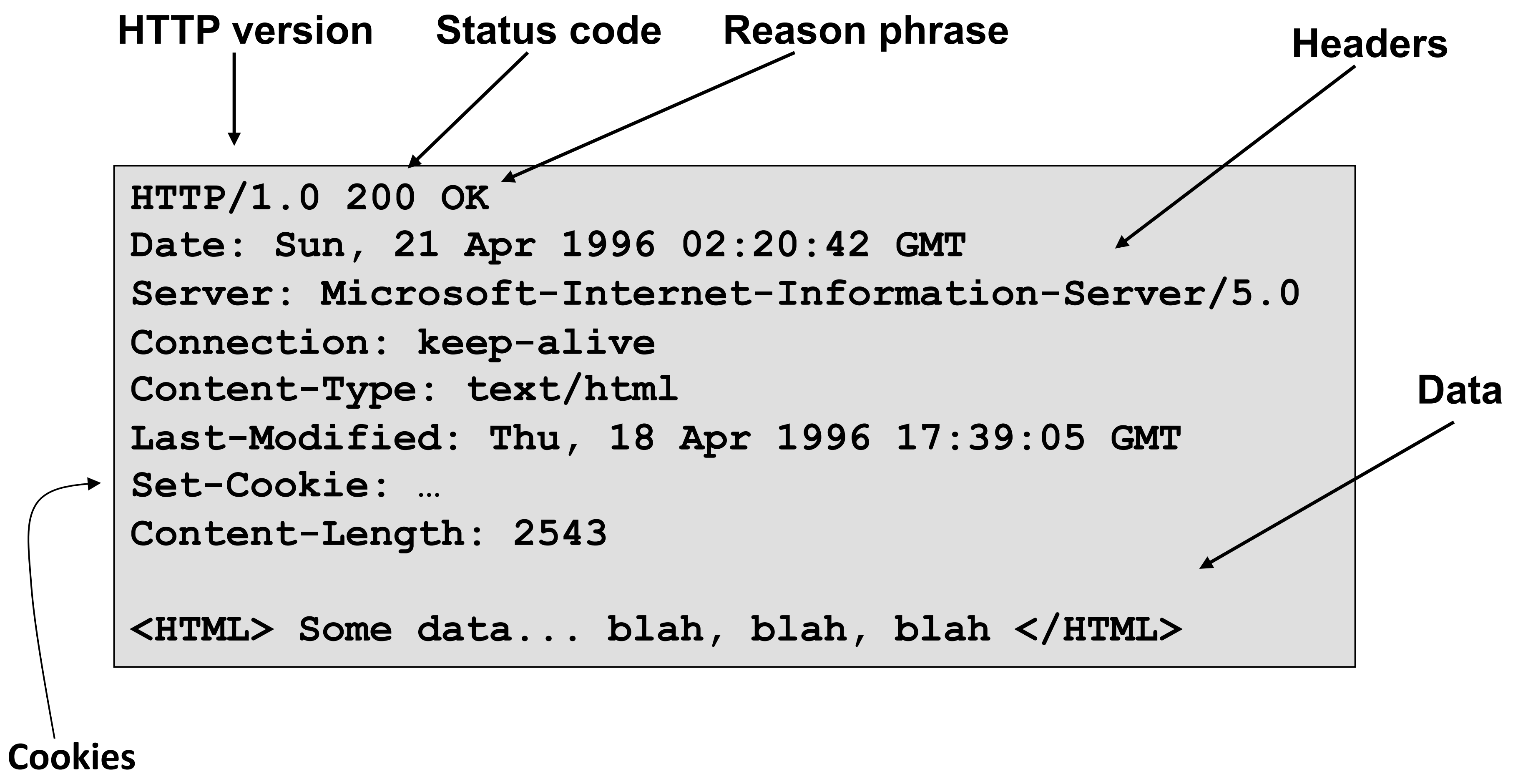


```
GET /index.html HTTP/1.1
Accept: image/gif, image/x-bitmap, image/jpeg, */*
Accept-Language: en
Connection: Keep-Alive
User-Agent: Mozilla/1.22 (compatible; MSIE 2.0; Windows 95)
Host: www.example.com
Referer: http://www.google.com?q=dingbats

```

GET : no side effect POST : possible side effect

HTTP Response



```
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
Set-Cookie: …
Content-Length: 2543

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