# Week 9 Lecture 1

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|---|---|
| Class | BSCCS2003 |
| Created | @November 1, 2021 10:55 AM |
| Materials | |
| Module # | 48 |
| Type | Lecture |
| Week # | 9 |

# Access Control

## What is Access Control?

- Access → Being able to read/write/modify information
- Not all parts of an application is for public access
  - Personal, Financial Company, Grades
- Types of access →
  - read-only
  - read-write (CRUD)
  - modify but not create
  - ...

## Examples

- Linux files →
  - owner, group → access your own files, cannot modify (or even read?) others
  - can be changed by the owner
  - `"root"` or `"admin"` or `"superuser"` has the power to change permissions
- Email →
  - you can read your own email
  - can forward an email to someone else → this is also access!

- E-commerce login →
  - shopping cart etc. visible only to the user
  - financial information (credit card, etc.) must be secure

## Discretionary vs Mandatory

- **Discretionary**
  - you have control over who you share with
  - forwarding emails, changing file access modes etc. possible
- **Mandatory**
  - decisions made by centralized management → users cannot even share information without permission
  - Typically only in military or high security scenarios

## Role based access control

- Access associated with "role" instead of "username"
- Example →
  - Head of the department has access to student records
  - What happens when HoD changes?
- Single user can have multiple roles
  - HoD, Teacher, Cultural advisor, sports club member, ...
- Hierarchies, Groups
  - HoD > Teacher > Student
  - HpD vs sports club member? → No hierarchy here

## Attribute based access control

- Attribute
  - time of the day
  - some attribute of user (citizenship, age, ...)
- Can add extra capability over role-based

## Policies vs Permissions

- Permissions
  - Static rules usually based on simple checks (does the user belong to a group)?
- Policies
  - More complex conditions possible
  - Combine multiple policies
  - Example →
    - Bank employees can view ledger entries
    - Ledger access only after 8AM on working days

## Principle of least privilege

- Entity should have minimal access required to do the job
- Example → Linux file system
  - users can read system libraries but not write
  - some files like `/etc/shadow` are not even readable
  - you can install Python to local files using `"venv"` but not to system path
- Benefits

    - better security → fewer people with access to sensitive files
    - better stability → user cannot accidentally delete important files
    - ease of deployment → can create template filesystems to copy

## Privilege Escalation

- Change user or gain an attribute
    - `"sudo"` or `"su"`
- Usually, combined with explicit logging and extra safety measures
- Recommended
    - do **not** `sudo` unless absolutely necessary
    - never operate as `root` in a Linux/Unix environment unless absolutely necessary

## Context: Web apps

- Admin dashboards, user access, etc.
- Gradebook example:
    - only admin should be able to add/delete/modify
    - users should have read permissions only to their own data

## Enforcing

- Hardware level
    - Security key, hardware token for access, locked doors, etc.
- Operating Systems
    - filesystem access, memory segmentation
- Application level
    - DB server can restrict access to specific databases
- Web application
    - Controllers enforce restrictions
    - Decorators in Python used in frameworks like Flask

# Week 9 Lecture 2

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| Class | BSCCS2003 |
| Created | @November 1, 2021 12:03 PM |
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## Security Mechanisms

### Types of security checks

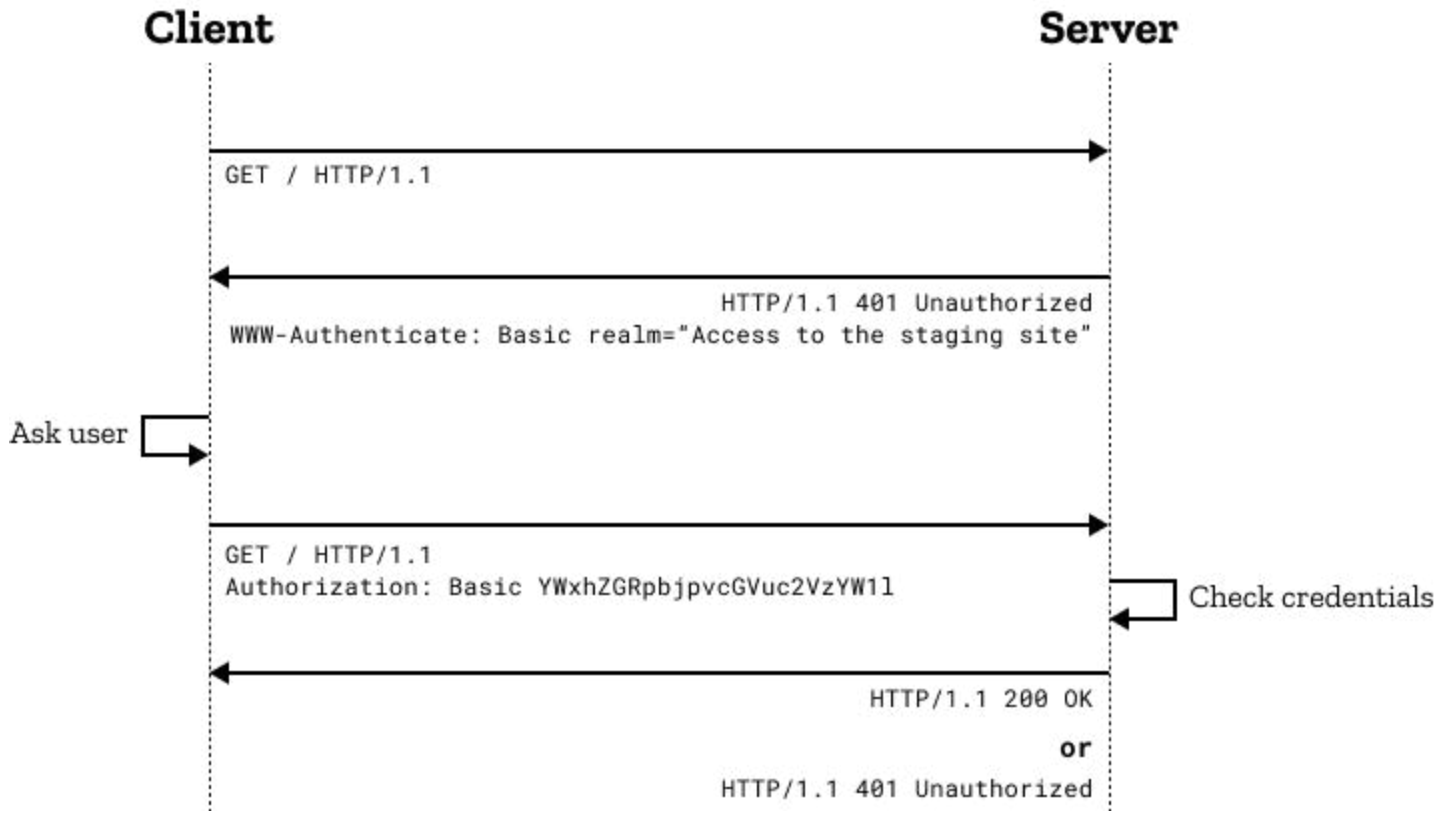
- Obscurity (generally a very bad idea)
  - application listens on non-standard port known only to specific people
- Address →
  - where are you coming from? host based access/deny controls
- Login →
  - username/password provided to each person needing access
- Tokens →
  - access tokens that are difficult/impossible to duplicate
  - can be used for machine-to-machine authentication without passwords

### HTTP authentication

Basic HTTP auth →

- Enforced by the server
- Server returns `"401/Unauthorized"` code to the client
- Contrast with →
  - 404 → not found
  - 403 → forbidden (no option to authenticate)

- Client must respond with access token as an extra "Header" in the next request




*Source: https://developer.mozilla.org/en-US/docs/Web/HTTP/Authentication*

## Problems with HTTP Basic Auth

- Username, Password effectively sent as plain text (base64 encoding)
  - Some minimal security if HTTPS is used (wiretap is difficult)
- Password will be seen in cleartext at the server
  - Should not be needed → better mechanisms possible
- No standard process for `"logout"`

## Digest Authentication

- Message digest → cryptographic function
  - eg. MD5, SHA1, SHA256 etc.
- One-way function
  - $f(A) = B$
  - Easy to compute $B$ given $A$
  - Very difficult (nearly impossible) to compute $A$ given $B$
- Can define such one-way functions on strings
  - String → Binary number

## HTTP Digest Authentication

- Server provides a "nonce" (Number used once) to prevent snooping
- Client must create a secret value including nonce
- Example
  - HA1 = MD5 (username:realm:password)
  - HA2 = MD5 (method:URI)
  - response = MD5 (HA1:nonce:HA2)
- Server and client know all the parameters above, so both will compute the same
- Any third party snooping will see only final response
  - cannot extract original values (username, password, nonce, etc)
  - nonce only used once to prevent replay

## Client certificates

- Cryptographically secure credentials provided to each client
- Client does not handshake with the server to exchange information, prove knowledge
- Keep cert secure on client end
  - Impossible to reverse and find the key

## Form Input

- Username, Password entered into the form
- Transmitted over link to server
  - link must be kept secure (HTTPS)
- GET requests
  - URL encoded data → very insecure, open to spoofing
- POST requests
  - form multipart data → slightly more secure
  - still needs secure link to avoid data leakage

## Request level security

- One TCP connection
  - One security check may be sufficient
  - other network level issues to consider for TCP security
- Without connection `KeepAlive` →
  - each request needs new TCP connection
  - each request needs new authentication

## Cookies

- Server checks some client credentials, then "sets a cookie"
- Header
  - `Set-Cookie: <cookie-name>=<cookie-value>; Domain=<domain-value>; Secure; HttpOnly`
- Client must send back the cookie with each request
- Server maintains "sessions" for clients
  - Remember cookies
  - Can set timeouts
  - Delete cookie records to "logout"
- Client
  - must send cookies with each request

## API security

- Cookies etc. requires interactive use (browser)
- Basic auth pop-up window

APIs →

- Typically accessed by the machine client or other applications
- Command-line etc. possible
- Use "token" or "API key" for access
  - subject to same restrictions → HTTPS, not part of the URL, etc

# Week 9 Lecture 3

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| Class | BSCCS2003 |
| Created | @November 1, 2021 6:40 PM |
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## Sessions

### Session management

- Client sends multiple requests to server
- Save some "state" information
    - logged in
    - choice of background colour
    - ...
- Server customizes responses based on client session information

Storage →

- Client-side session → completely stored in cookie
- Server-side session → stored on server, looked up from cookie

### Cookies

- Set by server with Set-Cookie header
- Must be returned by the client with each request
- Can be used to store information →
    - theme, background colour, font size → simple no security issues
    - user permissions, username → can also be set in cookie
        - must not be possible to alter

## Example → Flask

```
from flask import session

# Set the session key to some random bytes. Keep this secret!
app.secret_key = b'_5#y2L"F4Q8z\n\xec]/'

@app.route('/')
def index():
  if 'username' in session:
    return f'Logged in as {session["username"]}'
  return 'You are not logged in'
```

```
@app.route('/login', methods=['GET', 'POST'])
def login():
  if request.method == 'POST':
    session['username'] = request.form['username']
    return redirect(url_for('index'))
  return '''
    <form method="post">
      <p><input type="text" name="username"></p>
      <p><input type="submit" value="Login"></p>
    </form>
  '''

@app.route('/logout')
def logout():
  # remove the username from the session if it's there
  session.pop('username', None)
  return redirect(url_for('index'))
```

## Security Issue

- Can user modify a Cookie?
  - Can set any username
- If someone else gets Cookie, can they log in as user?
  - Timeout
  - Source IP
- Cross-site requests
  - Attackers can create page to automatically submit request to another site
  - If user is logged in on other site when they visit the attack page, it will automatically invoke action
  - Verify on the server that the request came from legitimate starting point

## Server side information

- Maintain client information at the server
- Cookie only provides minimal lookup information
- Not easy to alter
- Requires persistent storage at the server
- Multiple backends possible
  - File storage
  - Database
  - Redis, other caching key-value stores

## Enforce authentication

- Some parts of site must be protected
- How?
  - Enforce existence of specific token to access tho those views
- Views
  - determined by the controller

- Protect access to the controller
  - Flask controller → Python function
  - Protect function → add wrapper around it to check auth status
    - Decorator

## Example → `flask_login`

```
from flask_login import login_required, current_user
...

@main.route('/profile')
@login_required
def profile():
  return render_template('profile.html', name=current_user.name)
```

```
from flask_login import login_user, logout_user, login_required
...

@auth.route('/logout')
@login_required
def logout():
  logout_user()
  return redirect(url_for('main.index'))
```

## Transmitted data security

- Assume connection can be "tapped"
- Attacker should not be able to read the data
- HTTP GET URLs not good →
  - logged on firewalls, proxies, etc
- HTTP POST, Cookies etc →
  - if wire can be made safe, then good enough

How to make the wire safe?

# Week 9 Lecture 4

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| Class | BSCCS2003 |
| Created | @November 2, 2021 12:03 PM |
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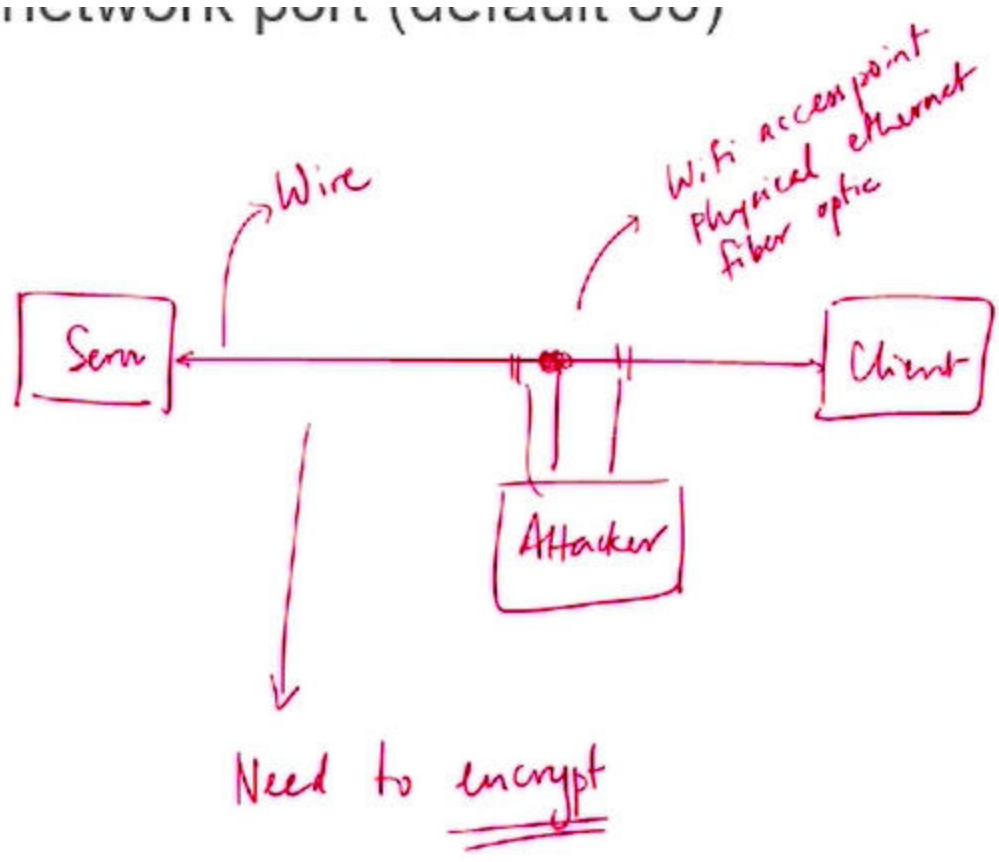
# HTTPS

## Normal HTTP process

- Open connection to server on a fixed network port (default 80)
- Transmit HTTP request
- Receive HTTP response

Safety of transmitted data?

- Can be tapped
- Can be altered

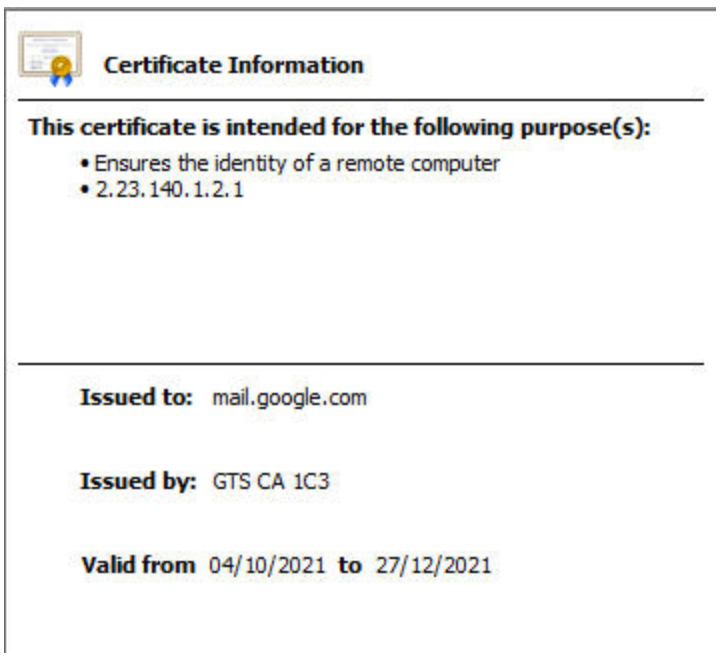



## Secure sockets

- Set up an "encrypted" channel between the client and the server
- How?
  - Need a shared secret → eg. long binary string → this is the "key"
  - XOR all the input data with key to generate new binary data
  - Attacker without the key cannot derive the actual data
- How to set up the shared secret?
  - Must assume anything on the wire can be tapped
  - What about pre-existing key?
  - Secure side channel → send a token by a post, SMS

## Types of security

- Channel (wire) security
  - Ensure that no one can tap the channel → most basic need for other auth mechanisms, etc.
- Server authentication
  - How do we know we are actually connection to mail.google.com and not some other server?
  - DNS hijacking is possible → redirect to another server
  - Server certificates
  - Common root of trust needed → someone who "vouches for" mail.google.com
- Client certificate
  - Rare but useful → server can require client certificate
  - Used especially in corporate intranets etc




## Chain of Trust

- Chain of trust
  - mail.google.com issued certificate by
  - GTS CA1C3 issued certificate by
  - GTS Root R1
- GTS Root R1 certificate stored in Operating System or Browser
  - Do you trust your OS? Do you trust your browser?
    - interesting question, ngl
- From there on a secure (crypto) chain

## Potential problems

- Old browsers
  - Not updated with new chains of trust
- Stolen certificates at root of trust
  - Certificate revocation, invalidation possible
  - Need to ensure OS, browser can update their trust stores
- DNS hijacking
  - Give false IPs for server as well as entries along chain of trust
  - But certification in OS will fail against eventual root of trust

## Impact of HTTPS

- Security against wiretapping
- Better in public WiFi networks

Negative →

- Affects caching of resources (proxies cannot see content)
- Performance impact due to run-time encryption

# Week 9 Lecture 5

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| Class | BSCCS2003 |
| Created | @November 2, 2021 1:10 PM |
| Materials | |
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# Logging

## What is logging?

- Record all accesses to app
- Why?
  - Record bugs
  - Number of visits, usage patterns
  - Most popular links
  - Site optimization
  - Security checks
- How?
  - Built into the app → output to a log file
  - Direct output to analysis pipeline

## Server logging

- Built in to Apache, Nginx, ...
- Just accesses and URL accessed
- Can indicate possible security attacks →
  - Large number of requests in short duration
  - Requests with "malformed" URLs

- Repeated requests to unusual endpoints

## Application level logging

- Python logging framework
  - Output to a file, other "stream" handlers
- Details of application access
  - Which controllers
  - What data models
  - Possible security issues
- All server errors

```
! base ~/g/m/gradebook flask run
 * Serving Flask app 'application:app' (lazy loading)
 * Environment: development
 * Debug mode: on
 * Running on http://127.0.0.1:5000/ (Press CTRL+C to quit)
 * Restarting with stat
 * Debugger is active!
 * Debugger PIN: 674-210-362
127.0.0.1 - - [06/Sep/2021 21:04:21] "GET / HTTP/1.1" 200 -
127.0.0.1 - - [06/Sep/2021 21:04:21] "GET /static/css/style.css HTTP/1.1" 304 -
127.0.0.1 - - [06/Sep/2021 21:04:21] "GET /favicon.ico HTTP/1.1" 404 -
127.0.0.1 - - [06/Sep/2021 21:04:27] "GET /user/ HTTP/1.1" 200 -
127.0.0.1 - - [06/Sep/2021 21:04:27] "GET /static/css/style.css HTTP/1.1" 304 -
127.0.0.1 - - [06/Sep/2021 21:04:34] "GET /user/1 HTTP/1.1" 200 -
127.0.0.1 - - [06/Sep/2021 21:04:34] "GET /static/css/style.css HTTP/1.1" 304 -
```

## Log rotation

- High volume logs → mostly written, less analysis
- Cannot store indefinitely
  - Delete old entries
- Rotation →
  - Keep last N files
  - Delete oldest file
  - Rename log.i to log.i+1
  - Fixed space used on server

## Logs on custom app engines

- Google App Engine
  - custom logs
  - custom reports
- Automatic security analysis

## Time series analysis

- Logs are usually associated with timestamps
- Time series analysis →
  - How many events per unit time
  - Time of specific incident(s)
  - Detect patterns (periodic spikes, sudden increase in load)
- Time-series databases
  - RRDTool, InfluxDB, Prometheus, ...

    - Analysis and visualization engines

## Summary

Security is the key to successful applications

- Requires good understanding of principles
    - Crypto
    - SQL, OS Vulnerabilities, ...
- Good frameworks to be preferred
- Analyze, Identify, Fix