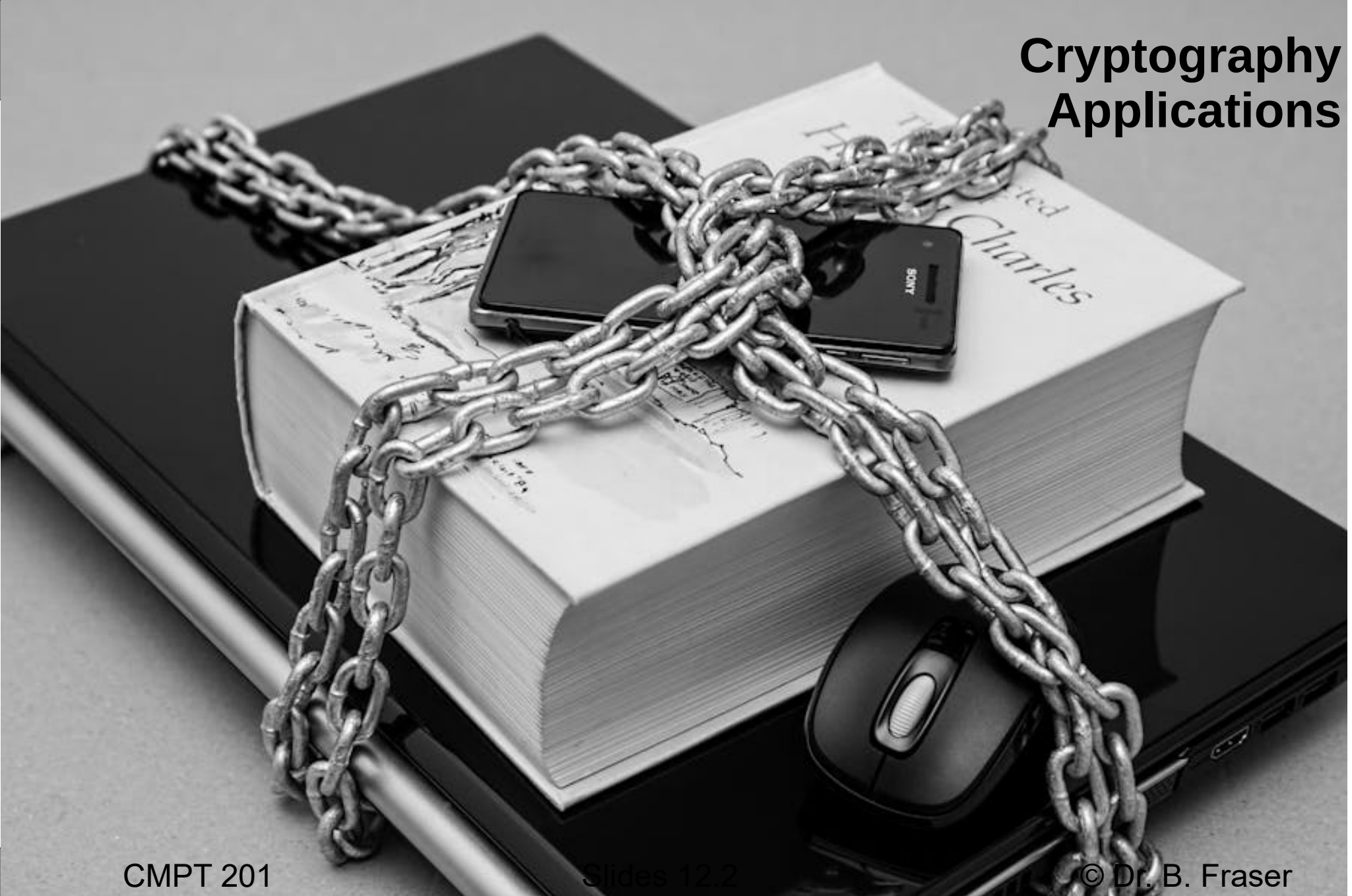


Cryptography Applications



Topics

- How can we safely store passwords?
- How do we verify a document is authentic?
- How can we trust websites?

Storing Passwords

Storing Passwords

- Password verification systems don't store plain text passwords
 - ..
 - Adds security: attacker getting a copy of the password file gives them the hash which cannot be used to log in.
 - To check a password, system checks
 - ..
- Linux stores passwords in /etc/shadow (accessible by root)

```
pwdis_1234:$y$j9T$LirzYIOxIHbbu6Wi/9zCl.$I9AZk5jAaY0uRPQfPnTEu.x5UeMVROrhP.i9gl96DD7:20159:0:99999:7:::  
pwdis_1235:$y$j9T$Rnadt7C63/7Bl1s/3Gx8v0$fvKI5ljHrj2hhnlhb6SkvjPvDQb7Awb3wUKU5YNmKK.:20159:0:99999:7:::  
pwdis_abcd:$y$j9T$/TAalyA61/lpbWM0vB5wA1$jofzhQHkwXjtpqfZ6cXIEwepD1L1V75gNriCM5C3pS7:20159:0:99999:7:::
```

User
name

Salt

Hash

Password
expiry info

Hash alg.
\$y\$=yescript

Rainbow Table Attack

- Rainbow table attack
 - ..
 - Can then quickly search password file of hashes for known passwords.
- Defence: Salt the password.
 - Salt: ..
 - Store salt and hash(user-password || salt)
(|| means concatenation)
 - Verify password:
..
- Attacker cannot reasonably compute hash of all possible passwords along with all possible salts.

Verifying Documents

Secure digest

- Secure digest for summary of document
 - Often used to verify a downloaded file is not corrupted.
 - A secure digest is a summary of a message:
..
 - Typically produced by a cryptographic hash function
e.g., SHA-256.
- Example

```
$ sha256sum ./README.md  
e293cdc4f5c4686772fba8159be9e9636654fed7ce72bfd2e75add8a6833c5ab ./README.md
```

Digital Signature

- Digital signatures combine public key crypto and hashing.
 - Goal: ..
 - The message can be public;
we just want to prove who sent it and that it's unaltered.
- Two parties: signer and verifier.
 - The Signer:
 - Sends a message
 - Wants to prove they sent the message.
 - The Verifier:
 - Receives message
 - Wants to verify the message was sent by the signer and is unaltered.

Signer

- The Signer will:
 - Writes a document: m
 - Computes a message digest: $h(m)$ (e.g., using SHA-256)
 - Not good enough yet: Adversary could write document z , computes $h(z)$ and plant both on the server.
 - ..
(e.g., using RSA public key crypto)
 - This is called signing.
 - Only the signer has the private key, so only the signer can encode with it.
 - Sends the message & the signature:
 $\langle m, \text{enc}(h(m)) \rangle$

Verifier

- The Verifier will:
 - Receives the message and the signature:
 $\langle m, \text{enc}(h(m)) \rangle$
 - Decrypts the signature with..
 $\text{dec}(\text{enc}(h(m))) == h(m)$
 - Computes a message digest: $h(m)$. Let's call it h' .
 - ..
 - If yes, then the message is authentic.
- Since only signer knows their private key,
..
then they must have signed the document.

Trusting Unknown Companies

Digital Certificate

- Digital certificates use digital signatures.
- Scenario
 - Imagine sending password to website (e.g., Instagram).
 - You encrypt your password with Instagram's public key.
 - Only Instagram can decrypt the message, so password is safe.
- Questions
 - ..
 - One way:
Instagram sends you their public key when you first go site.
 - How do you know if the public key really belongs to Instagram?
But a rogue website could disguise as Instagram and send you a wrong key.

Secure Browsing

- HTTP has no encryption.
- HTTPS uses encryption:
 - Instagram sends you its public key in a digital certificate.
 - Digital Certificate:
 - ..
 - Your OS verifies the authenticity of the digital certificate. OS has some built-in..
 - Your browser then uses Instagram's public key to encrypt messages to Instagram.
- Only Instagram can decrypt messages encrypted with their public key.

Digital Cert Operation

- How digital certificates work:
 - A digital certificate is signed by a digital certificate authority
 - E.g., VeriSign, DigiCert
 - OS vendor ships OS with public keys for some trusted digital certificate authorities like DigiCert.
 - This establishes the base level of trust:
 - ..

Digital Certificate Example

- Instagram uses DigiCert:
 - Instagram goes to DigiCert, gives its public key, and requests a digital certificate.
- DigiCert creates a digital certificate:
 - It says "this public key belongs to Instagram"
 - ..

Certificate Viewer: *.instagram.com

General

Details

Issued To

Common Name (CN)	*.instagram.com
Organization (O)	Meta Platforms, Inc.
Organizational Unit (OU)	<Not Part Of Certificate>

Issued By

Common Name (CN)	DigiCert SHA2 High Assurance Server CA
Organization (O)	DigiCert Inc
Organizational Unit (OU)	www.digicert.com

Validity Period

Issued On	Wednesday, March 19, 2025 at 5:00:00 PM
Expires On	Thursday, April 10, 2025 at 4:59:59 PM

SHA-256 Fingerprints

Certificate	80106977e80587ecc06a316459f7dcad3dac37534018e96327756d796d3ba7f8
Public Key	51743cfead6538ec5a157fdb65541de4462cf3ebe6a181ad67f6212d6035576

Digital Certificate Example (cont)

- Instagram Digital Certificate
 - When browser connects to Instagram, Instagram sends the digital certificate.
 - Browser uses its trusted public key for DigiCert to verify the digital certificate from Instagram.
 - If your OS is not compromised, this whole process is secure based on the first level of trust.
 - If the OS is compromised, there is no 1st level of trust and this whole process is not secure.
- Encryption Use
 - ..
(public key is slow and generates lots of data)
 - Rest of communication..
(faster, smaller)

Chain of Trust

- Digital certificates rely on the chain of trust
 - To trust the public key sent by Instagram, we need to trust DigiCert's signature.
 - To trust DigiCert's signature, we need to trust DigiCert's public key.
 - In order to trust DigiCert's public key (shipped with OS), we need to trust that our OS is not compromised.
- Chain of trust relies on the root of trust being trustworthy.
 - Our root of trust is the OS.

Activity: SSH

- [Opt] Spin up new container: `docker run -it ghcr.io/sfu-cmpt-201/base`
- Generate public/private key with ed25519 & passphrase
`$ ssh-keygen -t ed25519 -C "your email address"`
 - Look at files in `~/.ssh`
- SSH SFU
 - `ssh <yourID>@csil-cpu01.csil.sfu.ca -p24`
Asks user name & password; use VPN if off campus.
- SSH Keys
 - SSH SFU; manually add pub key to end of `~/.ssh/authorized_keys`
 - Log-out, log-in (asks passphrase)
- SSH Agent: Avoids passphrase; Stores key in memory.
`eval ssh-agent`
`ssh-add`
`kill $SSH_AGENT_PID`

Hash Collisions

Birthday Match = Hash Collision

- Birthday Match
 - In a class of 30 people, probability of two students having the same birthday is..
https://en.wikipedia.org/wiki/Birthday_attack
- Hash Collisions
 - Given enough messages,
..
 - i.e., can we show that a hash function
..
- (Recall) Strong collision resistance:
It should be difficult to find two messages x and x' where $h(x) == h(x')$.
 - i.e., given a hash function, it should be difficult to find two values that produce the same hash.

Birthday Attack

- Attacker use a contract the customer is expected to sign (say agreement to buy company for \$100,000).
- Attacker then:
 - ..
(adding a space, adding commas, adding typos, ...)
 - Creates malicious altered copies (sale price \$100,000,000)
 - Goal: ..
 - Customer given benign copy to sign using their private key and hash of document.
 - Attacker then..
 - Since the contracts have same hash, attacker can claim customer signed malicious contract using their private key!

Demo: Hash Collision

- Demo: Collision in Crypto Hash Functions
 - MD5 was a widely used crypto hash function but was found to be insecure by 2005.
 - No longer in use.
- Get images & Compare Hashes

```
$ wget https://s3-eu-west-1.amazonaws.com/md5collisions/ship.jpg
$ wget https://s3-eu-west-1.amazonaws.com/md5collisions/plane.jpg
$ openssl dgst -md5 ship.jpg
$ openssl dgst -md5 plane.jpg
```

 - Algorithm exists to manipulate a pair of images into having the same MD5 hash.
- SHA255 is not yet known to be insecure.

```
$ openssl dgst -sha256 ship.jpg
$ openssl dgst -sha256 plane.jpg
```

ABCD: Birthday

- A birthday attack is successful when attackers find:
 - a) Two images that look the same but have different binary data.
 - b) Two students in CMPT 201 who have the same birthday.
 - c) A second document which matches the hash of a single given document.
 - d) Hash collision of a benign and malicious document.

Summary

- Passwords
 - Store salted and hashed passwords to avoid rainbow tables.
- Digest
 - A hash of a document.
- Digital Signatures
 - Sign a hash with a private key.
- Digital Certificates
 - Sign document to show who really owns a public/private key.
 - Chain of trust for distributing certificates.
 - Root of trust built into OS.
- Hash Collisions
 - Duplicate hash (digital signature) is a security issue.
 - Birthday attack to find duplicates.