ECOR 1055C
Engineering Disciplines I

Introduction to Security and Cryptography

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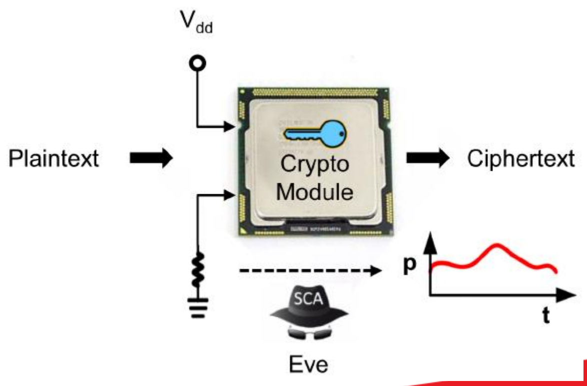
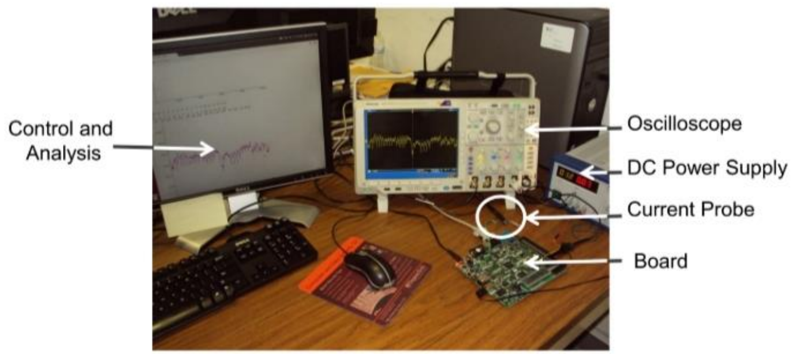
Lecture Outline

- About the instructor
- Introduction to Security and Cryptography
- Key Players in Cryptography
- User’s Perspective
- Developer's Perspective

About the instructor

- Mostafa Taha
  - Systems and Computer Engineering Department
  - Website: https://carleton.ca/mtaha/ , Email: mtaha@sce.carleton.ca
  - Currently teaching SYSC4810B and SYSC4805
- Research Areas:
  - Security of Embedded Systems and the Internet of Things.
  - Implementation of Security and Cryptographic Algorithms.





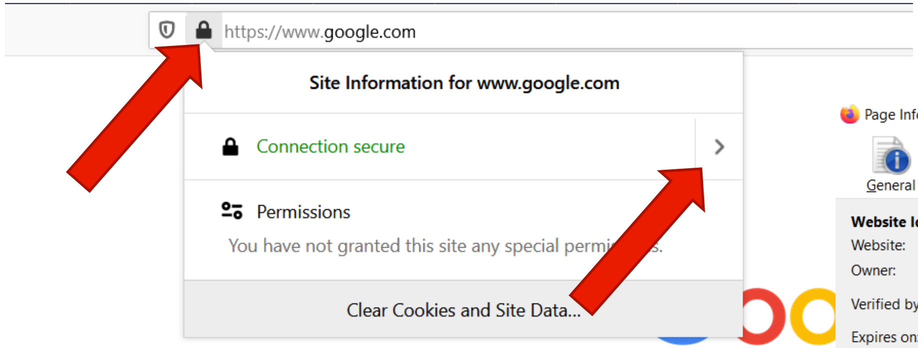
Security and Cryptography

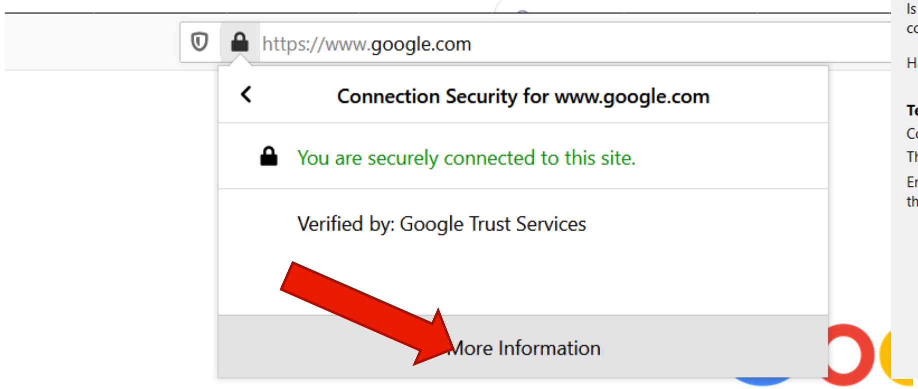
- History of Cryptography

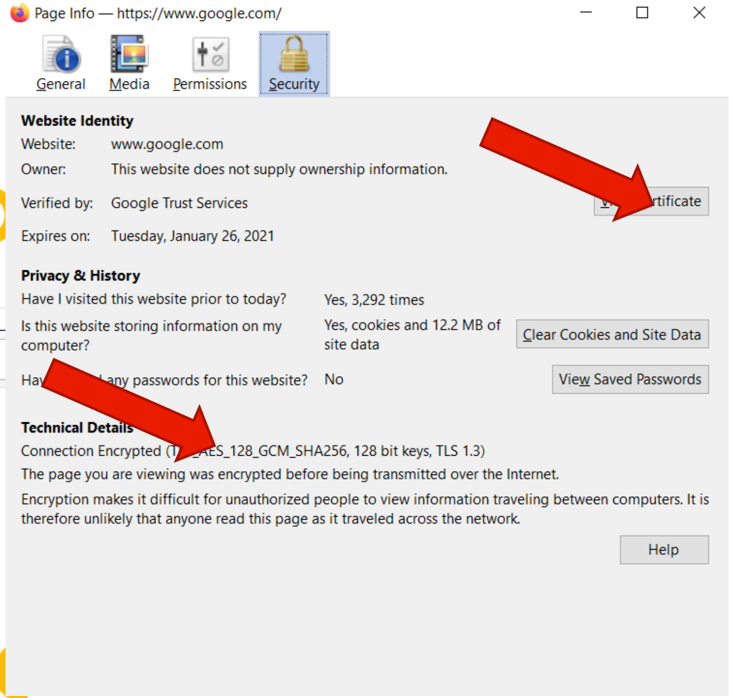
- A fundamental component of our modern life
  - Confidentiality
    - No one is able to decipher your data.
  - Integrity
    - Ensure that the data was not altered.
  - Availability of Data
      - Data is available when needed.
  - Authenticity
    - Message came from the legitimate sender.
  - And many other…

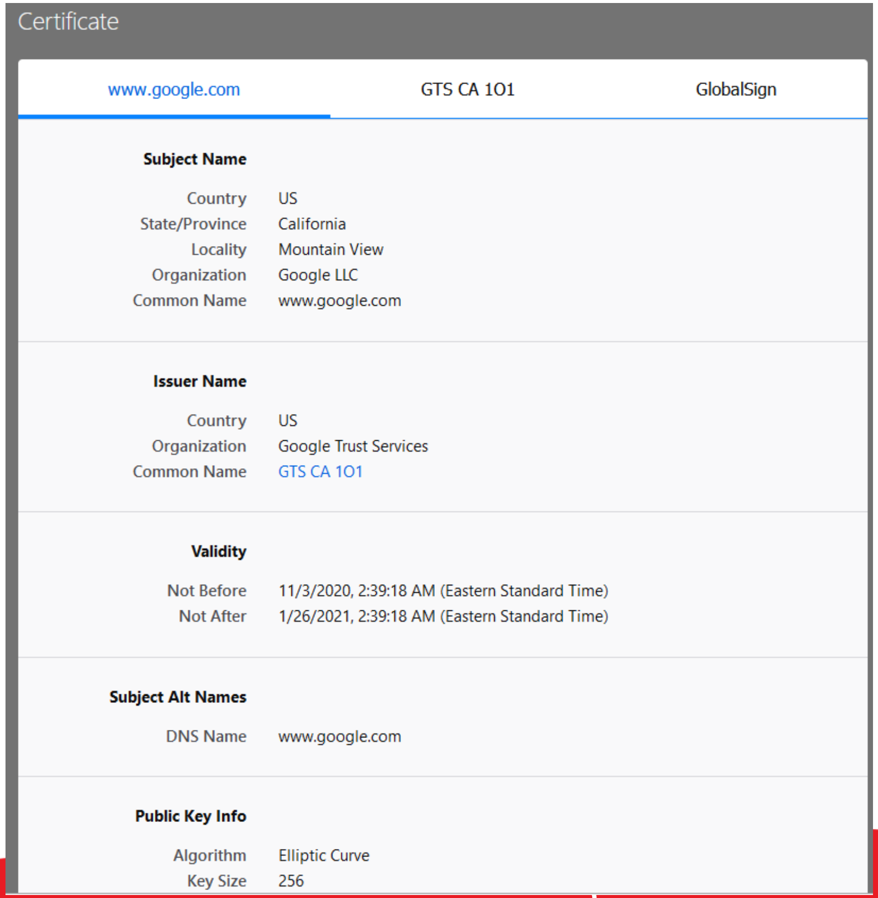
Security and Cryptography

- In Firefox browser



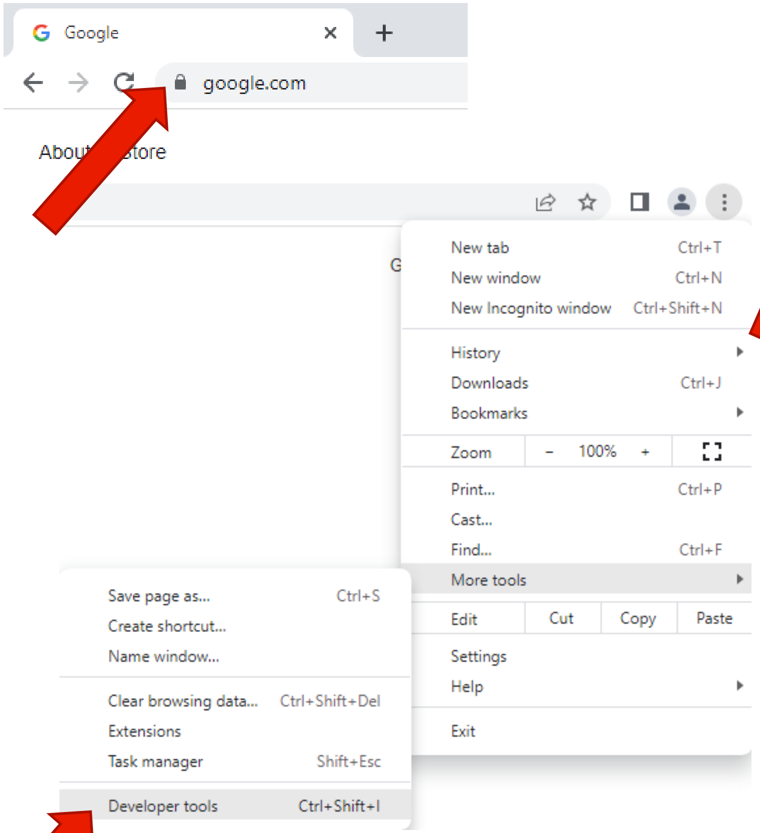


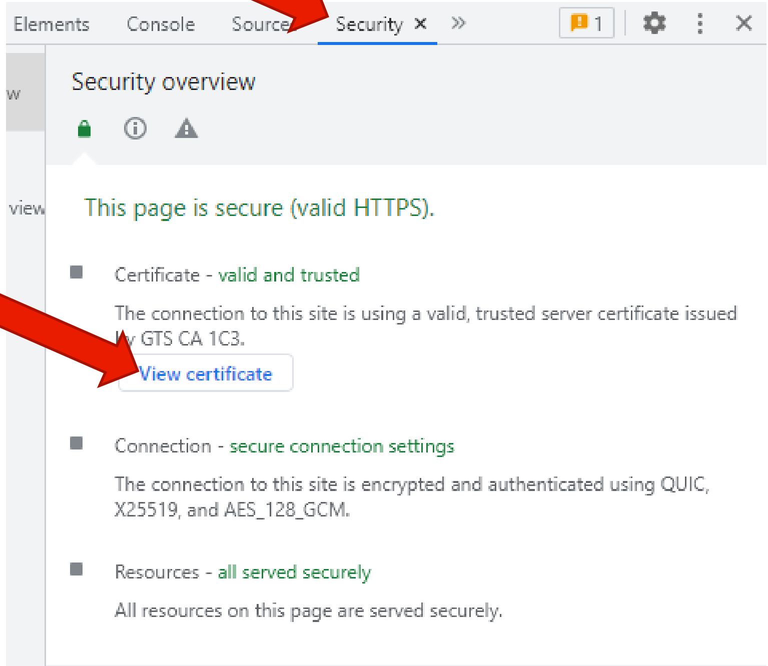


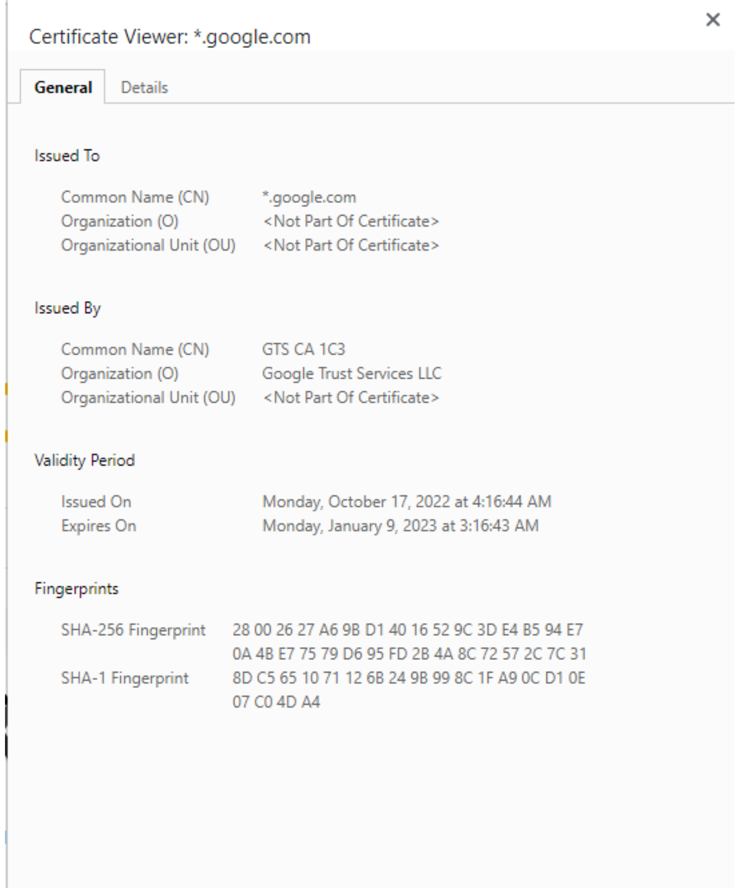


Security and Cryptography

- In Chrome browser

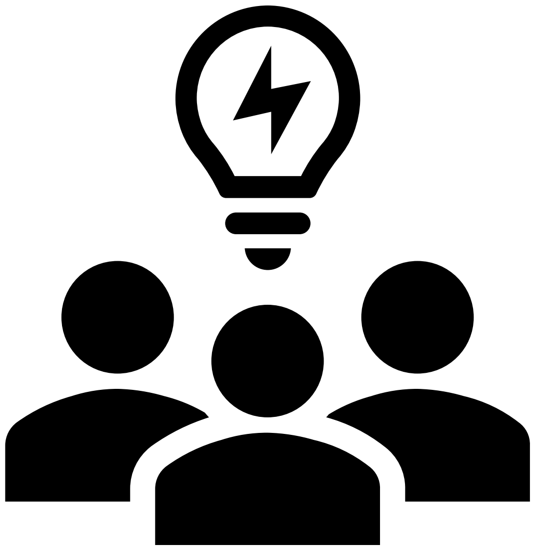






Key Players in Cryptography

- There are three players in this game
  - Mathematicians and Cryptographers
  - Cryptographic Engineers
  - Users



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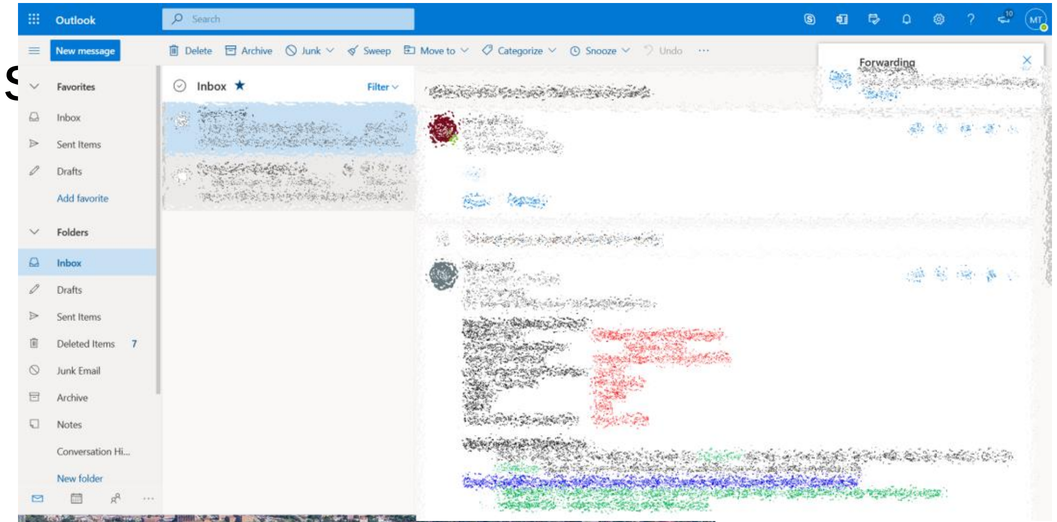
User’s Perspective

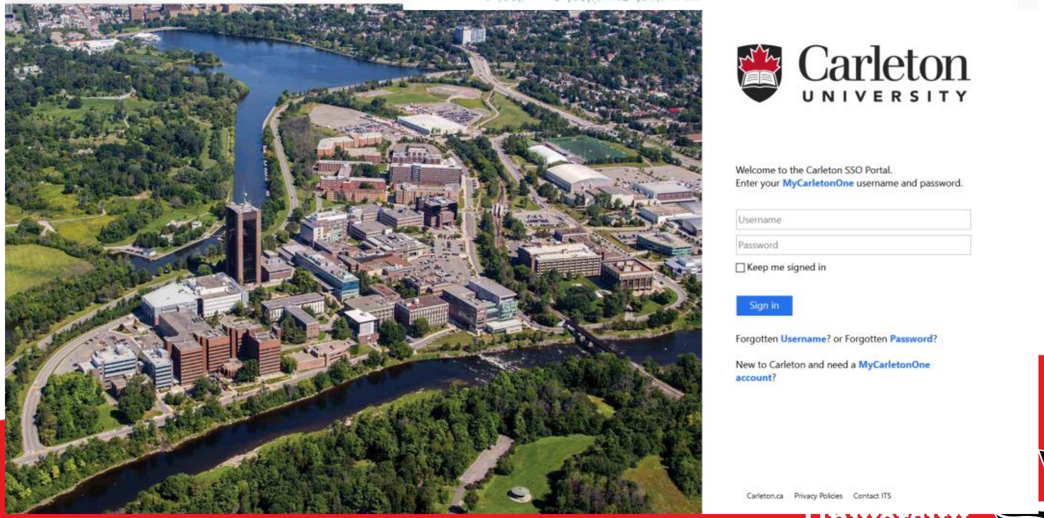
User’s Perspective

- Some helpful hints:
    1. Always initiate your own secure channels

User’s Perspective

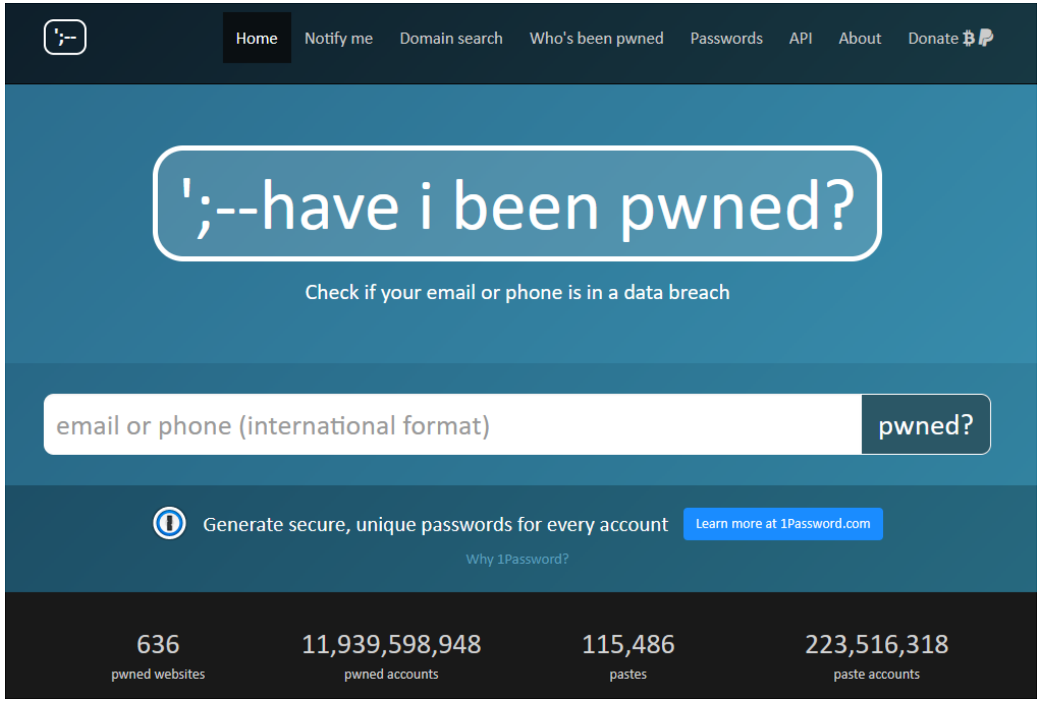
- Some helpful hints:
  1. Always initiate your own secure channels
  2. Protect your email

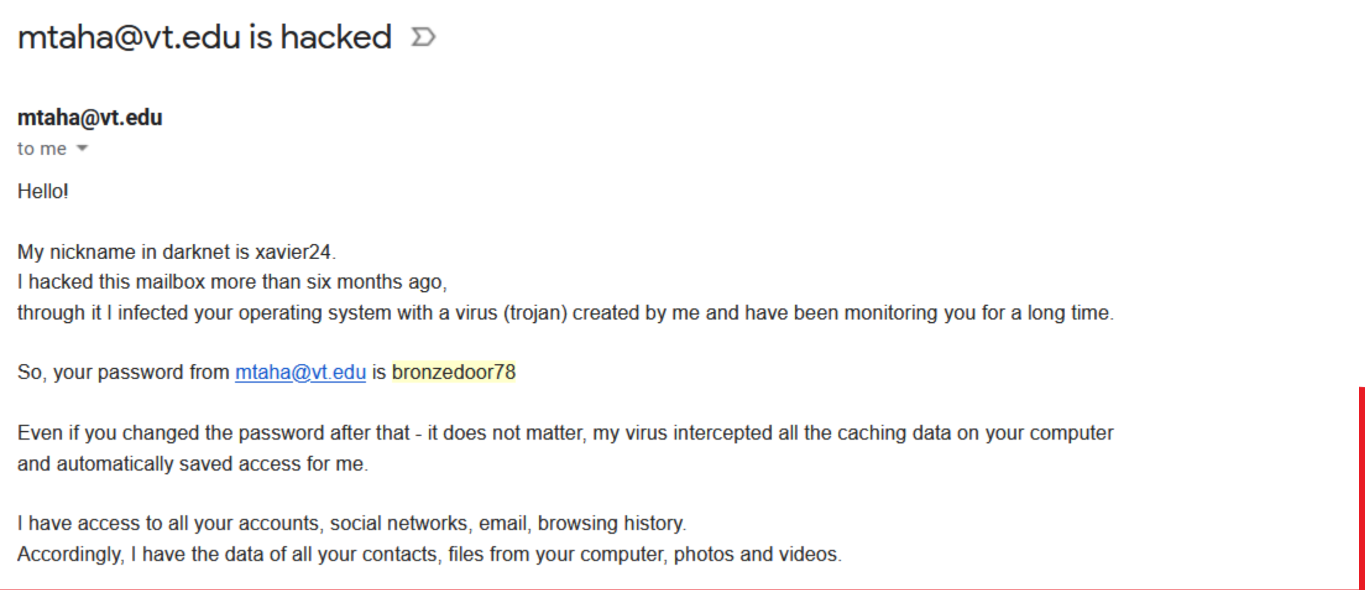




User's Perspective

- Some helpful hints:
  1. Always initiate your own secure channels
  2. Protect your email
  3. Understand Data Breaches
     - Check: https://haveibeenpwned.com/





User’s Perspective

- Some helpful hints:
  1. Always initiate your own secure channels
  2. Protect your email
  3. Understand Data Breach
     - Check: https://haveibeenpwned.com/
  4. Use unique passwords with a password manager
     1. Using “forgot your password” feature
     2. Using your email as a password manager
     3. Using offline password manager
     4. Using online password manager

Developer's Perspective

Developer's Perspective

- Coding for Security and Cryptographic Applications
  - Cryptographic Requirement:

  - Design a password verification code that accepts 8-bytes of user input and compares it against an 8-byte stored value.
  - Theoretical security:
    - The stored secure key is one of $256^8 = 2^{64} =$ $18{,}446{,}744{,}073{,}709{,}551{,}616 = 18.4 \times 10$^18 = 18 exa
    - If a computer can check 1 million tries each second, it would need around 584,542 years to finish testing all the cases.
    - This seems to be a pretty good security.

Developer's Perspective

- Coding for Security and Cryptographic Applications
  - Implementation
  - Can you spot any problem?
  - Hint: assume the adversary can measure the response time.

Algorithm 4 Password verification.

Input: $\widetilde{P} = (\widetilde{P}[0], \ldots, \widetilde{P}[7])$ (and $P = (P[0], \ldots, P[7])$)
Output: '`true`' or '`false`'

1: **for** $j = 0$ to 7 **do**
2:     **if** $(\widetilde{P}[j] \neq P[j])$ **then return** '`false`'
3: **end for**
4: **return** '`true`'

Marc Joye, "Basics of Side-Channel Analysis"

Developer's Perspective

- Coding for Security and Cryptographic Applications
  - Execution-Time Attack

  - $\tilde{P}[0]$ is wrong:
    return ‘false’ very quickly
  - $\tilde{P}[0]$ is correct and $\tilde{P}[1]$ is wrong
    return ‘false’ after some time.
  - $\tilde{P}[0]$ and $\tilde{P}[1]$ are correct, but $\tilde{P}[2]$ is wrong
    return ‘false’ after more time.

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Developer's Perspective

- Coding for Security and Cryptographic Applications
  - For 0 ≤ n ≤ 255, test $\tilde{P}(n) = (n, 0,0,0,0,0,0,0)$ and measures the corresponding running time, $\tau[n]$.
  - Find the maximum running time.

$$\tau[n_0] := \max_{0 \le n \le 255} \tau[n]$$

    Assign $P[0]$ to $\tilde{P}(n0)$.
  - Repeat for the second byte:
    For 0 ≤ n ≤ 255, test $\tilde{P}(n) = (P[0], n, 0,0,0,0,0,0)$
  - And so on.
  - Assume using the same machine as previous (1 million test / sec). 255 trials can be tested in 1 msec. The entire password could be found in 8 msec!!!!!

Algorithm 4 Password verification.

Input: $\tilde{P} = (\tilde{P}[0], \ldots, \tilde{P}[7])$ (and $P = (P[0], \ldots, P[7])$)
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Developer's Perspective

- Coding for Security and Cryptographic Applications
  - Part of computing an RSA Digital Signature
    First proposed in 1977, still in use today.

d_j is the secret value.

If $d_j = 0$, do only ($R_0 \leftarrow R_0{}^2$)

If $d_j = 1$, do, do both
($R_0 \leftarrow R_0{}^2$) and ($R_0 \leftarrow R_0 \times R1$)

Algorithm 5 Computation of an RSA signature.

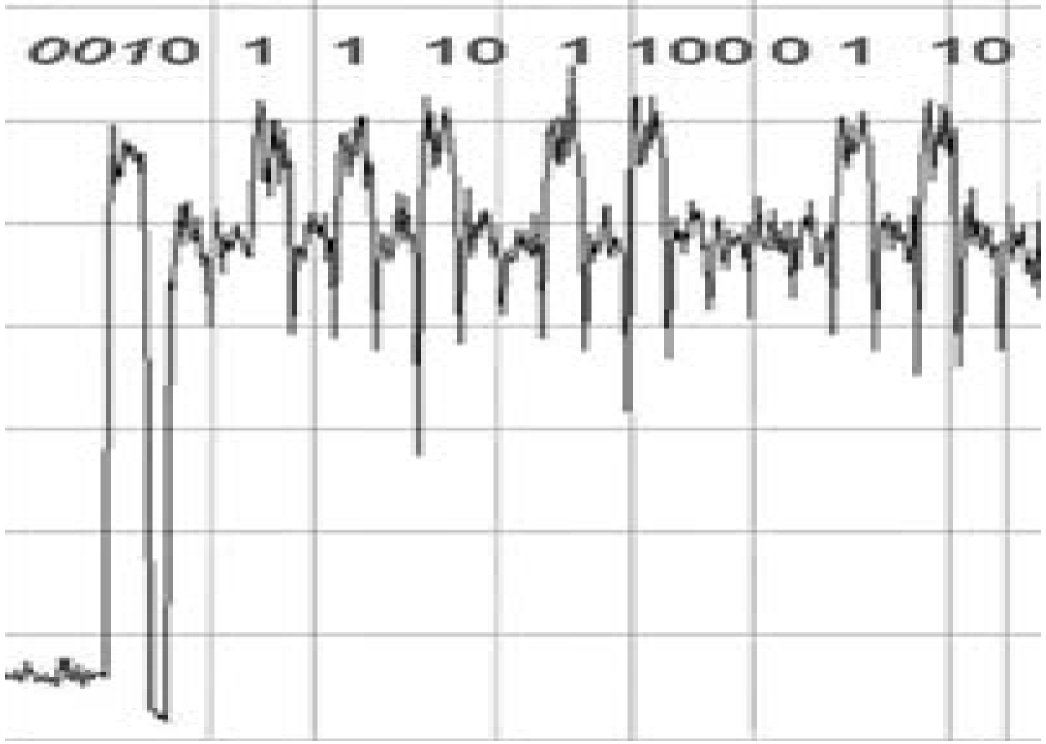
Input: $m, N, d = (d_{k-1}, \ldots, d_0)_2$, and $\mu : \{0,1\}^* \to \mathbb{Z}/N\mathbb{Z}$
Output: $S = \mu(m)^d \pmod N$

```
R_0 ← 1; R_1 ← μ(m)
for j = k − 1 downto 0 do
    R_0 ← R_0^2 (mod N)
    if (d_j = 1) then R_0 ← R_0 · R_1 (mod N)
end for
return R_0
```

Marc Joye, “Basics of Side-Channel Analysis”

Developer's Perspective

- Coding for Security and Cryptographic Applications
  - Power-Consumption Attack



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Output: $S = \mu(m)^d \pmod{N}$

1: $R_0 \leftarrow 1; R_1 \leftarrow \mu(m)$
2: **for** $j = k-1$ downto 0 **do**
3: $\quad R_0 \leftarrow {R_0}^2 \pmod{N}$
4: $\quad$ **if** $(d_j = 1)$ **then** $R_0 \leftarrow R_0 \cdot R_1 \pmod{N}$
5: **end for**
6: **return** R_0

Marc Joye, "Basics of Side-Channel Analysis"

Introduction to Security and Cryptography

- Lecture Summary:
  - Do your part as a user
    - Initiate your own secure channels
    - Protect your email
    - Understand Data Breaches
    - Use unique passwords

  - As a developer
    - Be cautious about coding/modeling for security/cryptography applications.
    - Efficiency may be your worst enemies.

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