CS 465
Computer Security

Cryptography Introduction

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Fall 2018

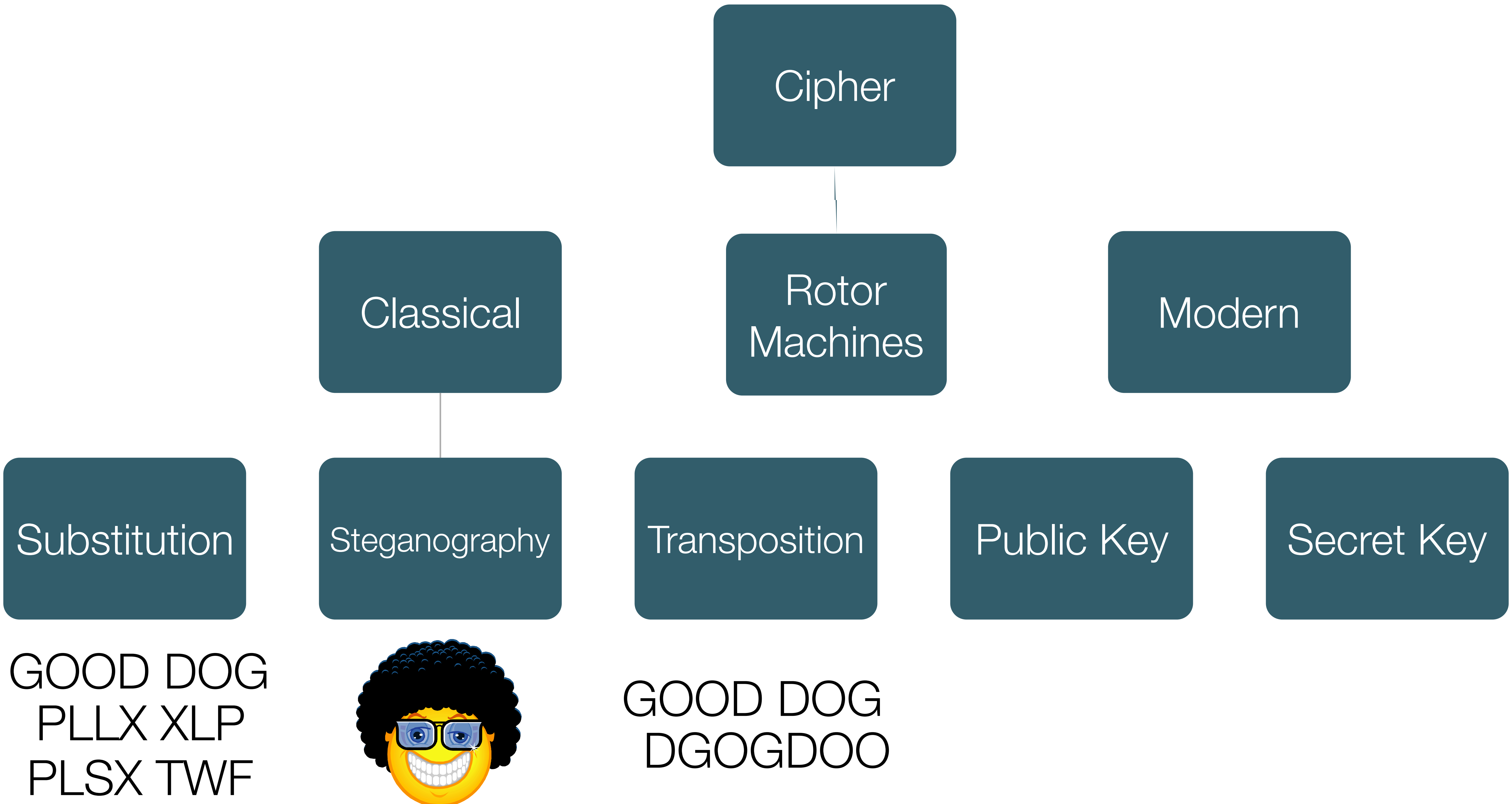
Cryptography

- Literal definition means “hidden writing”
- Until modern times, cryptography was synonymous with encryption, but the field has expanded
- This lecture reviews a high-level description of four cryptographic primitives we will learn about this semester
    - Symmetric Encryption (AES)
    - Public-Key Cryptography (RSA)
    - Secure One-Way Hash (SHA-256)
    - Message Authentication Code (MAC)

What is Encryption?

- Transforming information so that its true meaning is hidden
  - Requires “special knowledge” to retrieve
- Textbook has good examples of early ciphers — be sure to read this, they illustrate some basic concepts
  - Caesar Cipher
  - Vigenere Cipher

Types of Encryption Schemes



Hierarchy & Examples based on:
http://en.wikipedia.org/wiki/Cipher

Perfect Encryption Scheme?

- One-Time Pad (XOR message with key)
- Example*:
  - Message: ONETIMEPAD
  - Key: TBFRGFARFM
  - Ciphertext: IPKLPSFHGQ
  - The key TBFRGFARFM decrypts the message to ONETIMEPAD
  - The key POYYAEAAZX decrypts the message to SALMONEGGS
  - The key BXFGBMTMXM decrypts the message to GREENFLUID

Why is this not practical?

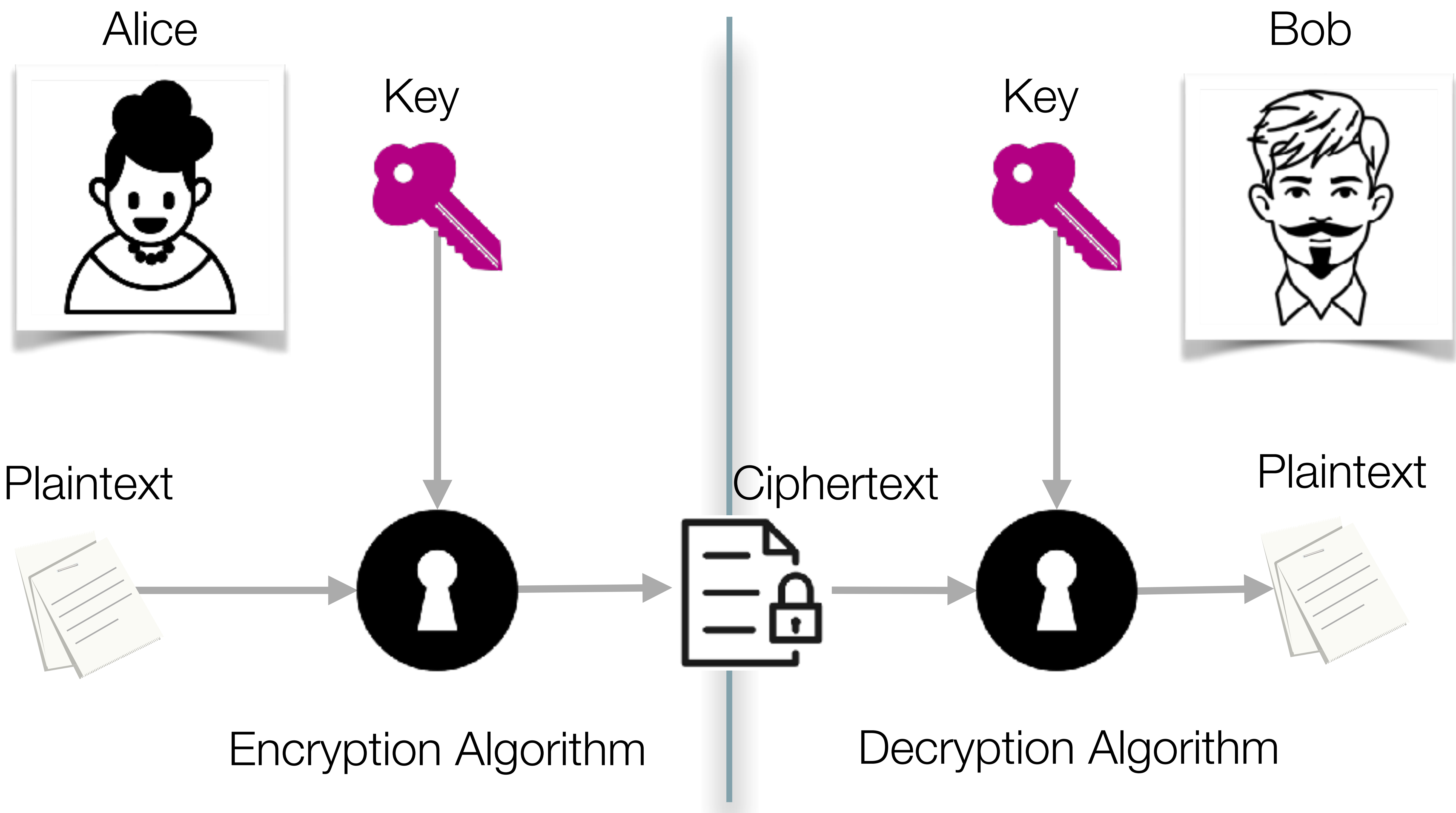
*From Applied Cryptography (Schneier)

Modern, strong encryption ciphers

- AES
- 3DES
- RC4
- RSA

Symmetric Encryption

Symmetric Encryption Model

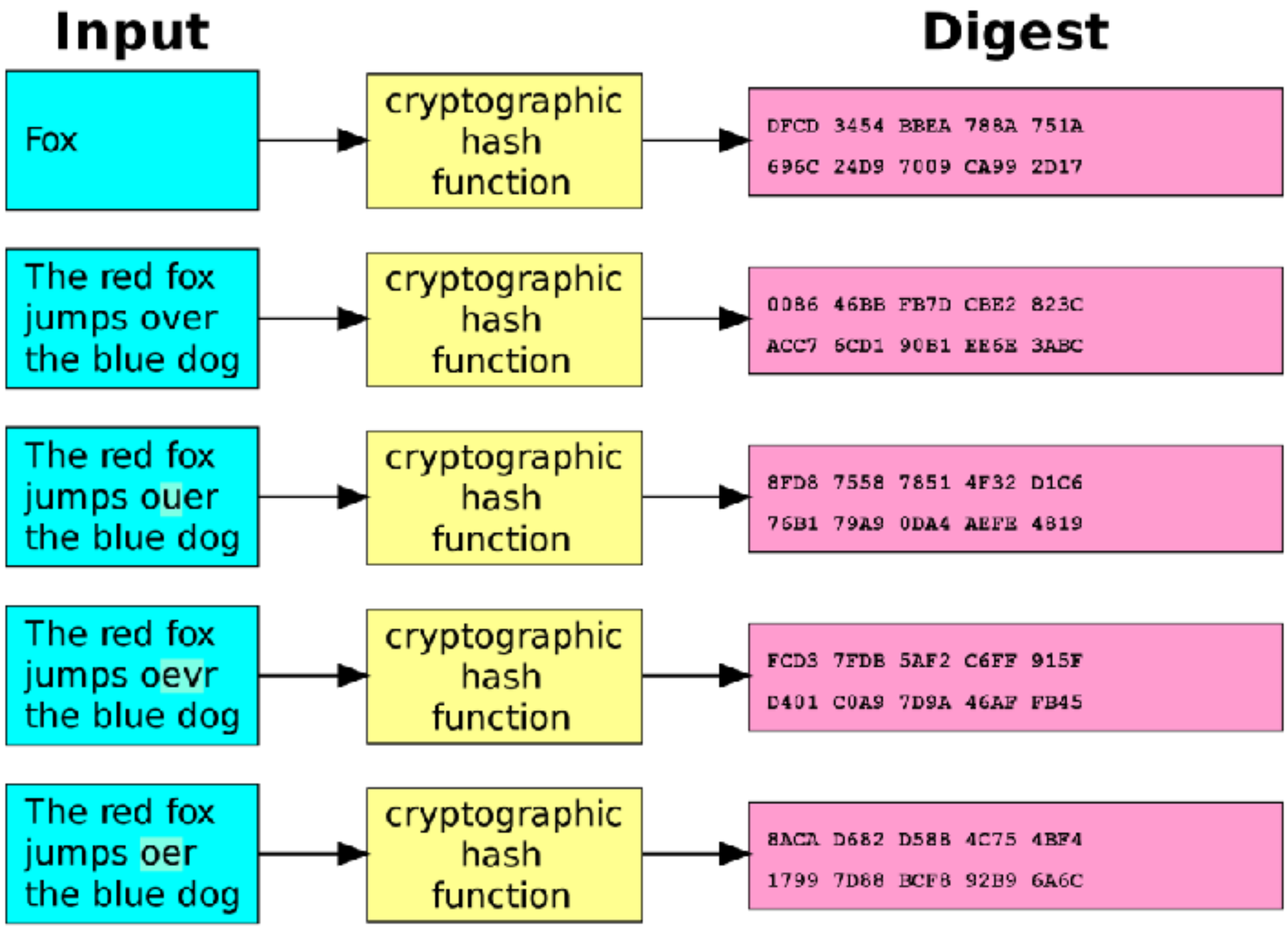


Use Cases

- Web browsing using HTTPS
- Encrypted chat (WhatsApp and Signal)
- Encrypted email (S/MIME and PGP)

Cryptographic Hash Function

Cryptographic Hash Function



Source: http://en.wikipedia.org/wiki/Cryptographic_hash_function

Hashing Use Cases

- Digital signature
- File integrity verification (TripWire)
- Password hashing
- Rootkit detection

MAC

Message Authentication Code (MAC)

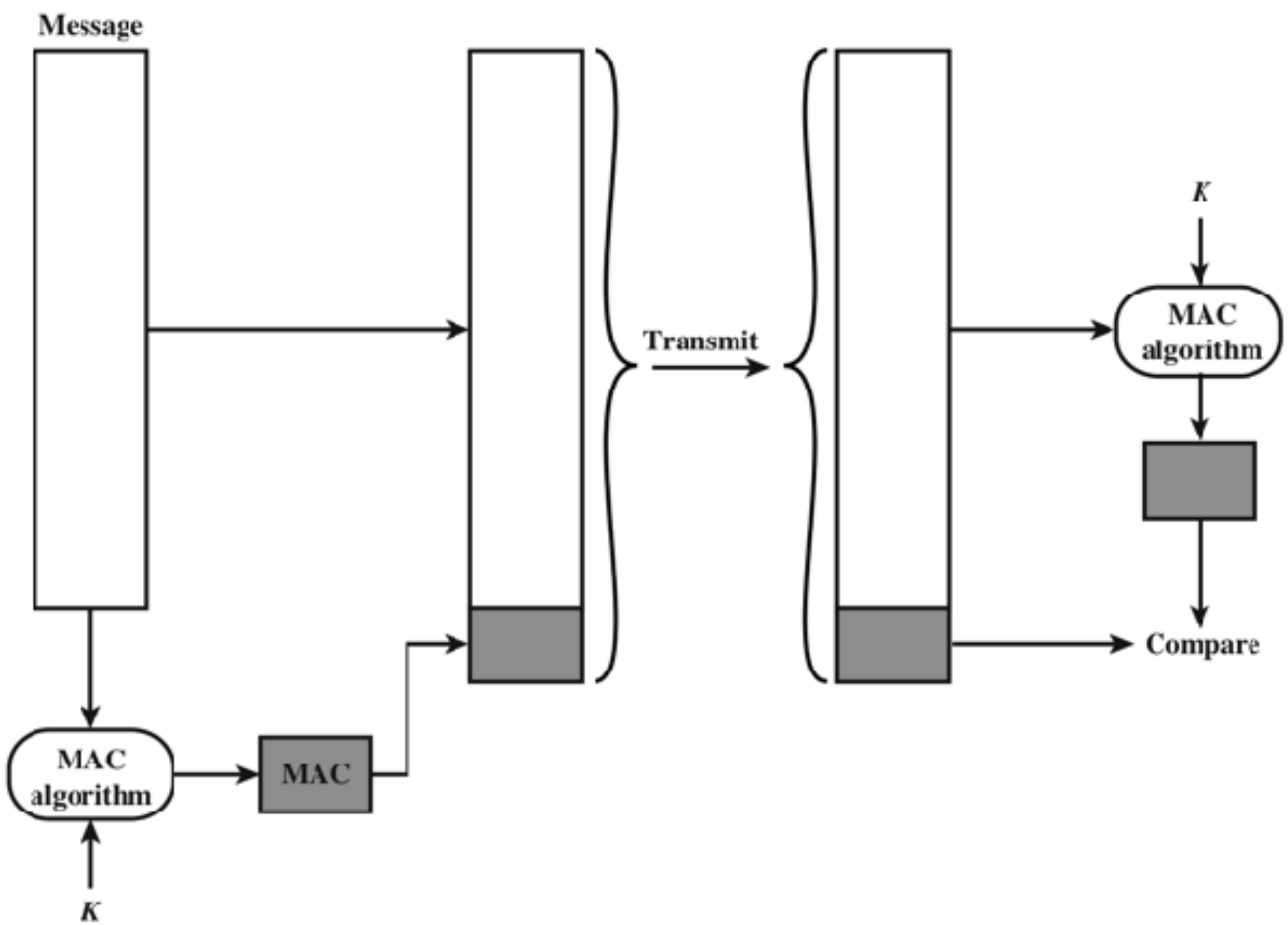


Figure 3.1 Message Authentication Using a Message Authentication Code (MAC)

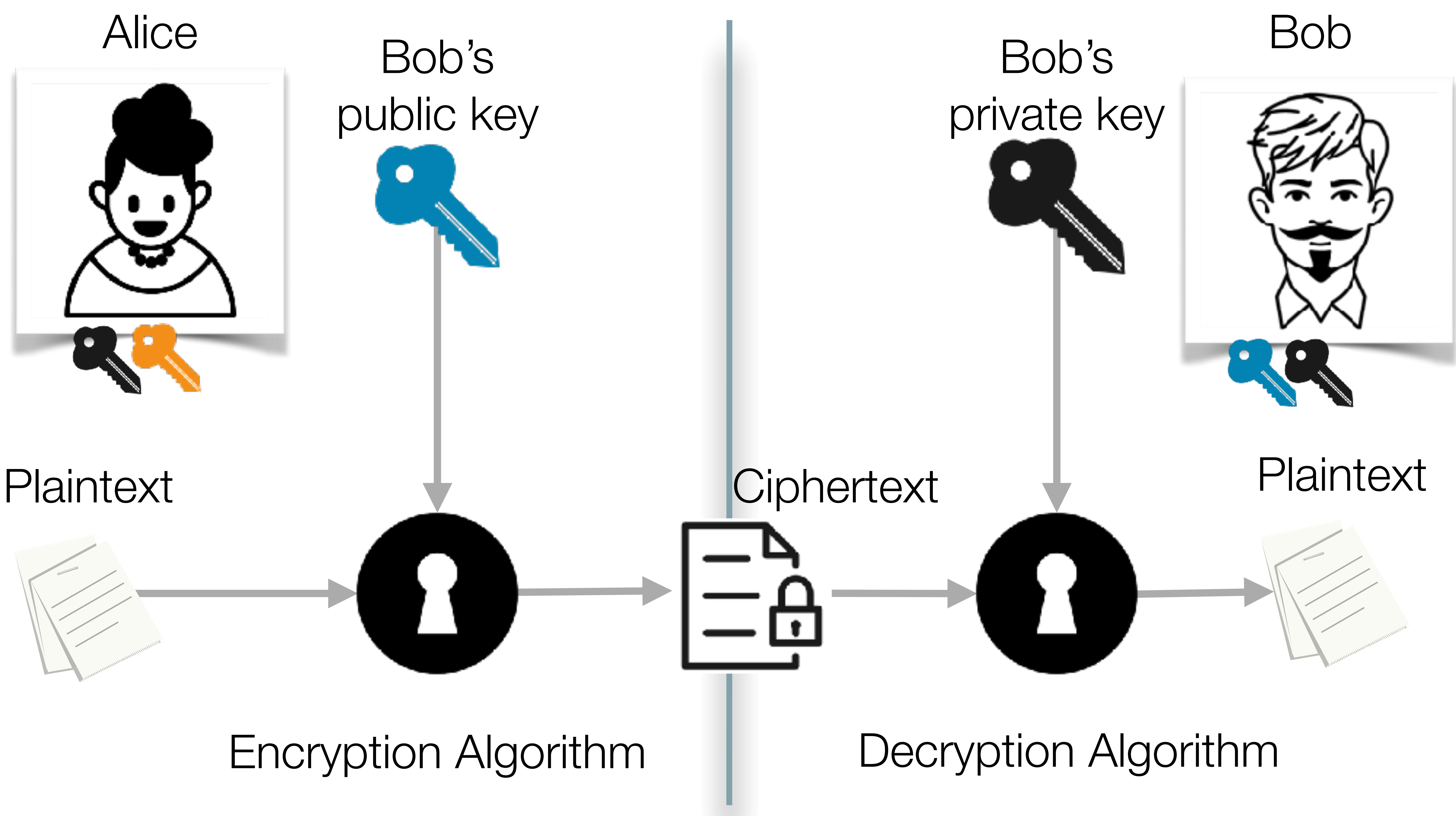
Source: Network Security Essentials (Stallings)

HMAC Use Cases

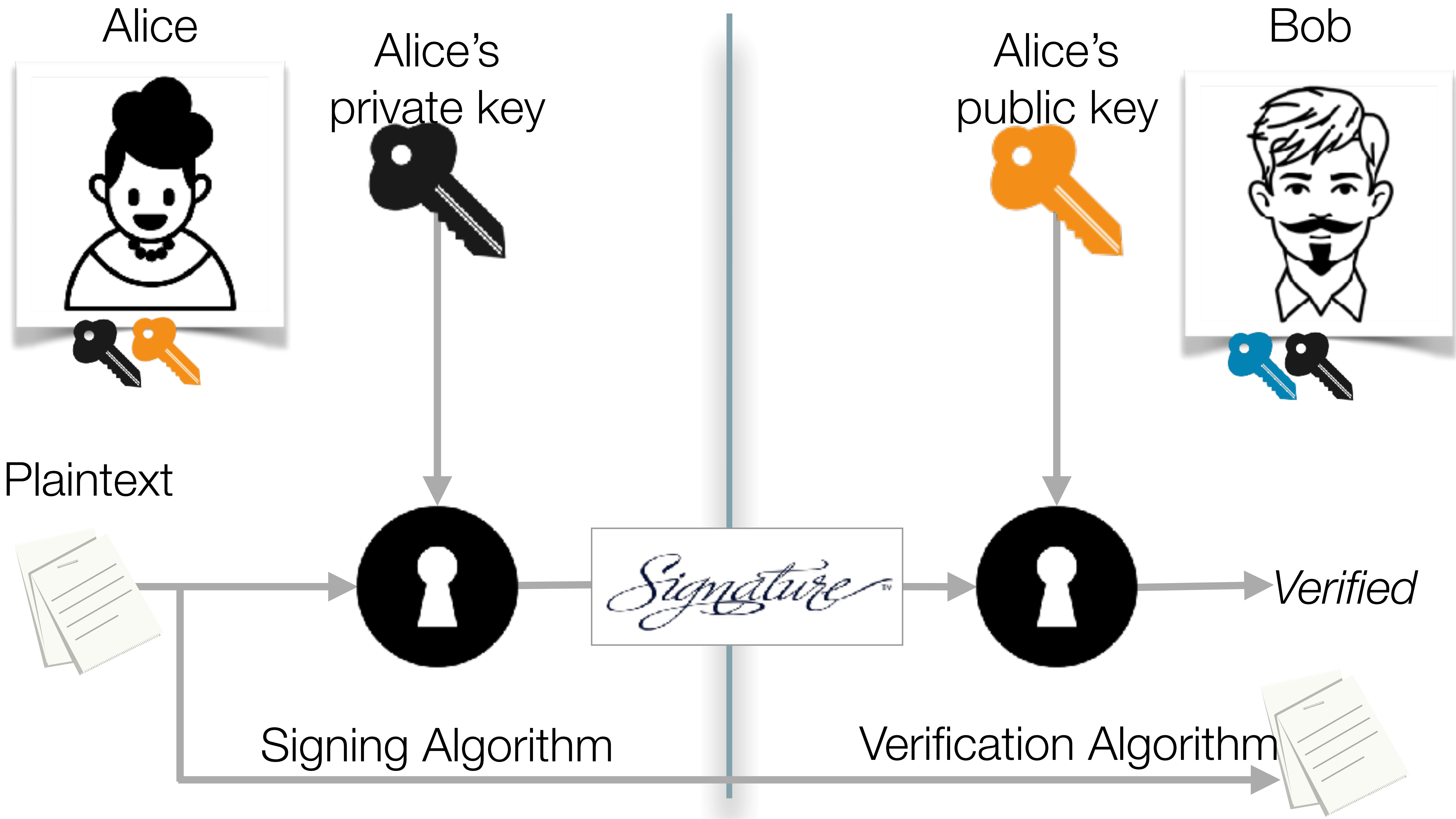
- Web browser message integrity (HTTPS)
- Integrity of messages in authentication protocols
- Cookie integrity
- Web application remote procedure calls

Public Key Encryption

Public Key Encryption Model



Public Key Digital Signature Model



Examples of Public Key Cryptography

- Diffie-Hellman
- RSA
- Elliptic Curve Cryptography (ECC)
- Identity-based Encryption (IBE)

Symmetric Encryption

Requirements

- Strong algorithm (cipher)

  Attacker is unable to decrypt ciphertext or discover the key even if attacker has samples of ciphertext/plaintext created using the secret key

- Fast

- Assumption: Sender and receiver must securely obtain and store the secret key

Kerckhoffs' Principle

- The security of the symmetric encryption depends on the secrecy of the key, not the secrecy of the algorithm

Dr. Auguste Kerckhoffs (1835-1903)
Dutch linguist and cryptographer

Types of Ciphers

- Block cipher (3DES, AES)
  - Plaintext is broken up into fixed-size blocks
  - Typical block size: 64, 128 bits
- Stream cipher (RC4)
  - Process plaintext continuously
  - Usually one byte at a time

What can go wrong?

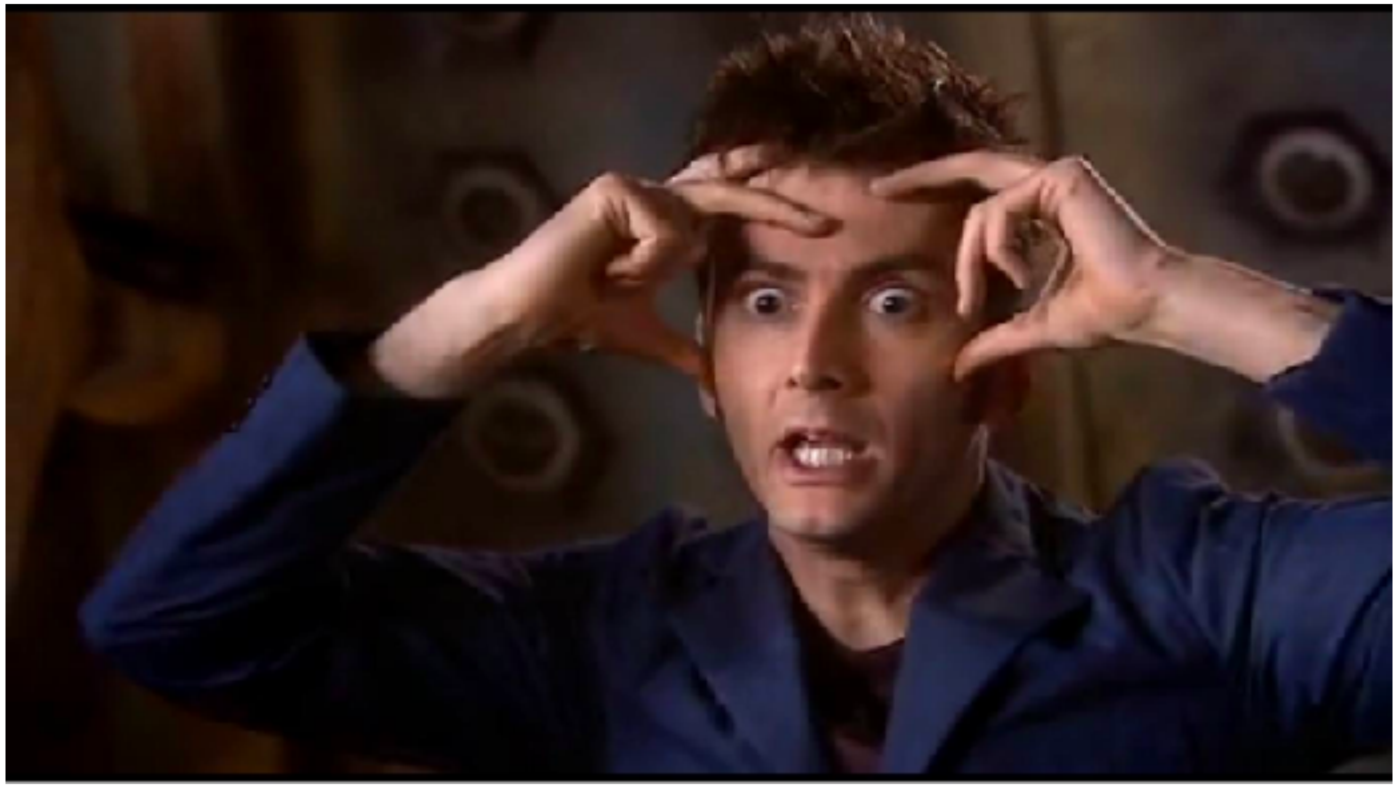
- Algorithm
  - Relying on the secrecy of the algorithm
    - Example: Substitution ciphers
  - Using an algorithm incorrectly
    - Example: WEP used RC4 incorrectly

What can go wrong?

- Key
  - Too big
    - Slow
    - Storage
  - Too small
    - Vulnerable to brute force attack – try all possible keys

Big Numbers

- Cryptography uses REALLY big numbers
  - 1 in 2^{61} odds of winning the lotto and being hit by lightning on the same day
  - 2^{92} atoms in the average human body
  - 2^{128} possible keys in a 128-bit key
  - 2^{170} atoms in the planet
  - 2^{190} atoms in the sun
  - 2^{233} atoms in the galaxy
  - 2^{256} possible keys in a 256-bit key



Thermodynamic Limitations*

- Physics: To set or clear a bit requires no less than kT
  - k is the Boltzman constant ($1.38*10^{-16}$ erg/ºK), T is the absolute temperature of the system
- Assuming T = 3.2ºK (ambient temperature of universe)
  - $kT = 4.4*10^{-16}$ ergs
- Annual energy output of the sun $1.21*10^{41}$ ergs
  - Enough to cycle through a 187-bit counter
- Build a Dyson sphere around the sun and collect all energy for 32 years
  - Enough energy to cycle through a 192-bit counter.

*From Applied Cryptography (Schneier)

A supernova produces in the neighborhood of 10^{51} ergs

Enough to cycle through a 219-bit counter

Assignment

- Review this slide deck regularly to learn the high level abstractions for these primitives. I'll expect you to describe them to me on an exam without any notes.
  - You don't really know something until you can teach it to someone else
- Study the AES NIST spec and watch the YouTube demo