# Principles of Network Security

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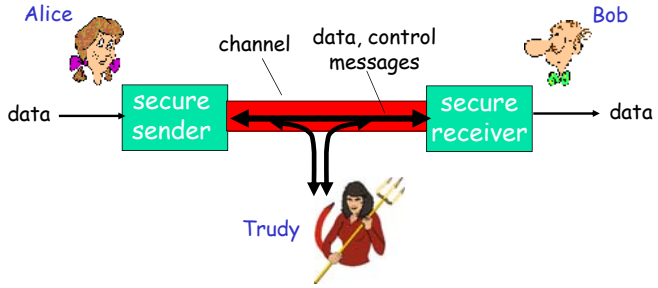
## The Network Security Model

- Bob and Alice want to communicate "securely".
- Trudy (the adversary) has access to the channel.






## Who might Bob and Alice be?

- Web browser/server for electronic transactions (e.g., on-line purchases/banking)
- DNS servers
- Routers exchanging routing table updates
- … well, *real-life* Bobs and Alices!



## What can an adversary do?

- Eavesdrop: understand the content of messages
- Actively changing messages
- Impersonation: fake (spoof) identity
- Denial of service: prevent service from being used by others (e.g., by overloading resources)

## What is Network Security?

Confidentiality: only sender, intended receiver should "understand" message contents.

Authentication: sender, receiver want to confirm identity of each other.

Message Integrity: sender, receiver want to ensure message not altered (in transit, or afterwards).

Access and Availability: services must be accessible and available to (and only to) legitimate users.



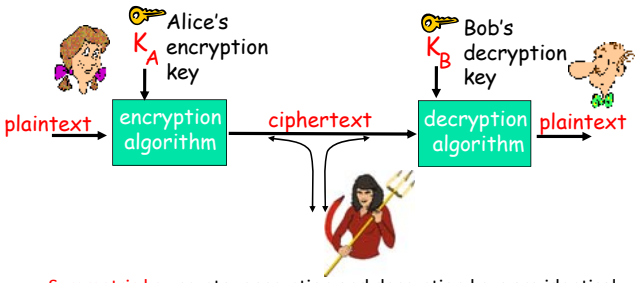
## Principles of Network Security

- Confidentiality: cryptography
- Authentication
- Integrity
- Key distribution and certification



## The Language of Cryptography

First goal of cryptography: confidentiality.




- Symmetric key crypto: encryption and decryption keys are identical. (both are secret)
- Public key crypto: encryption key is public, decryption key is secret.



## Symmetric Key Cryptography: Monoalphabetic Cipher

Monoalphabetic cipher: substitute one letter for another.

```
plaintext:  abcdefghijklmnopqrstuvwxyz
            |                       |
ciphertext: mnbvcxzasdfghjklpoiuytrewq
```

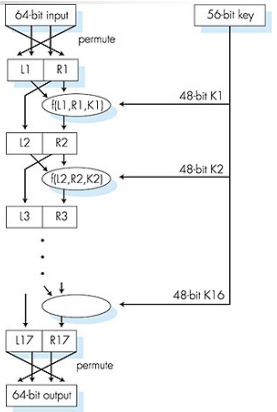
Example: `Plaintext: bob. i love you. alice`
`ciphertext: nkn. s gktc wky. mgsbc`

Q1: How hard to break this simple cipher?
- brute force?
- other?

Q2: How to make it more difficult to break?

## Symmetric Key Cryptography: DES

- DES: Data Encryption Standard
  - US encryption standard [NIST 1993]
  - 56-bit symmetric key, 64-bit plaintext input
  - encryption: initial permutation ⇒ 16 "rounds", each using different 48 bits of key ⇒ final permutation
  - decryption: reverse operation using the same key
- How secure is DES?
  - DES Challenge (1999): 56-bit-key-encrypted phrase decrypted (brute force) in 22 hours 15 minutes
- Making DES more secure:
  - use three keys sequentially (3-DES)
  - use more bits






## AES: Advanced Encryption Standard

- Newer (Nov. 2001) symmetric-key NIST standard, replacing DES
- Processes data in 128 bit blocks
- 128, 192, or 256 bit keys
- Brute force decryption (try each key) taking 1 sec on DES, would take 149 trillion years for 128-bit AES
- Cost
  - 128-bit AES takes a few hundred microseconds to encrypt 4KB data on modern mobile processors
- Block cypher



## Stream Cypher

- Much faster than block cypher like AES
- Fixed-size seed key K expanded (through some kind of shuffled bit shifts) to an infinite key stream C(K)
- For data X, it uses a portion of the key stream (equal length to data X), then xor the data to produce encrypted data
- Same key cannot be used twice, otherwise

  Encrypted(X) = X xor C(K)

  Encrypted(Y) = Y xor C(K)

  ⇨ Encrypted(X) xor Encrypted(Y) = X xor Y

  ⇨ If you know X (or Y), then you know the other

  ⇨ Even if you know neither, you can guess X/Y quite well from X xor Y if X and Y are in a natural language



## Stream Cypher

- How to guarantee the same key is not reused?
  - A shared master key known secretly by the two sides
  - An initialization vector, communicated publicly for each session, augment the master key to create the seed key and key stream for the session
- WEP wireless encryption
  - Employ an initialization vector of 24-bit, but insufficient (doesn't take long to observe sessions with the same initialization vector)

Sources: http://en.wikipedia.org/wiki/Stream_cipher_attack

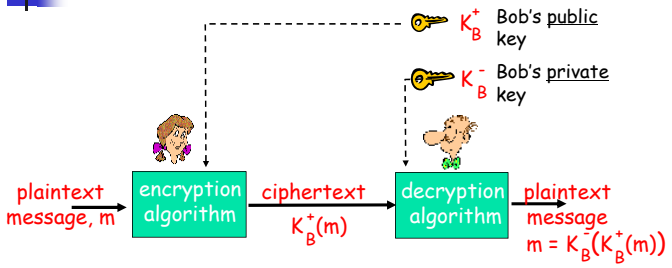
## Public Key Cryptography

Symmetric key cryptography
- requires sender, receiver know shared secret key
- Q: how to agree on key in the first place? (particularly difficult if Trudy is eavesdropping on all communication)

Public key cryptography
- encryption key is different from decryption key
- encryption key is public, known to everyone, also called public key
- decryption key is secret, known only to receiver, also called private key



## Public Key Cryptography




Principle for choosing the public/private key pair:
One should not be able to derive the private key from the public key.



## Public Key Cryptography: RSA (Ron Rivest, Adi Shamir and Len Adleman)

- Choosing keys:
  - Choose two large prime numbers p, q. (e.g., 1024 bits each)
  - Compute n = pq, z = (p-1)(q-1)
  - Choose e (with e<n) that has no common factors with z
  - Choose d such that ed-1 is exactly divisible by z
  - Public key is (n,e). Private key is (n,d)
- To encrypt a message, m (<n): do $c = m^e \bmod n$
- To decrypt a received ciphertext, c: do $m = c^d \bmod n$
- Reason: for any m (relatively prime with n)
  - $m^z \bmod n = 1$; therefore $m^{ed-1} \bmod n = 1$
- Another property: $(m^d \bmod n)^e \bmod n = m$
- RSA is much slower than the symmetric key cryptos (block and certainly stream cyphers)



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