COM 5335 Network Security
Lecture 5
Introduction to Public-Key Cryptography

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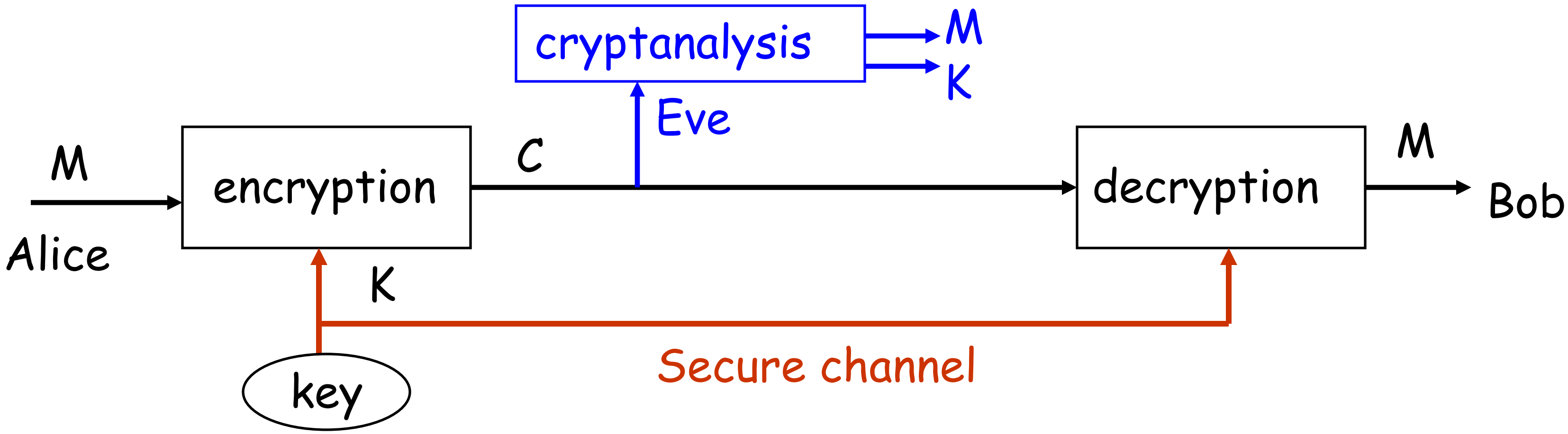
Outline

- Symmetric Cryptographic System
- Key Management
- Centralized Key Management
- Public-Key Encryption
- Public-Key Cryptographic System
- Public-Key vs. Symmetric Key
- Digital Signature

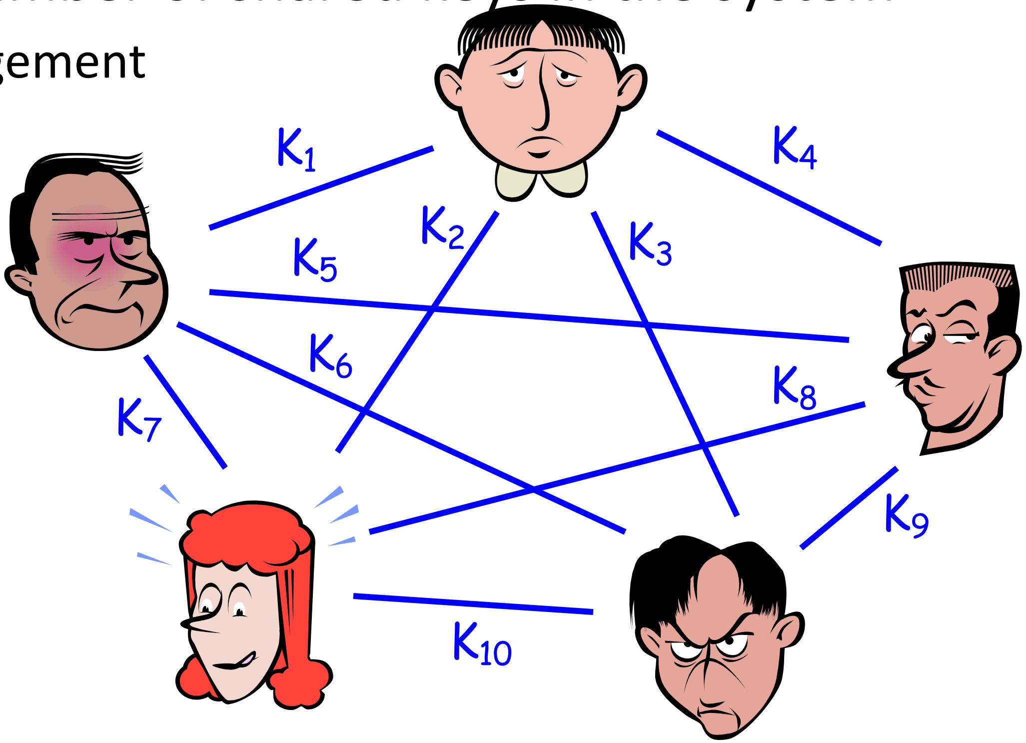
Symmetric (Private-Key) Cryptosystems



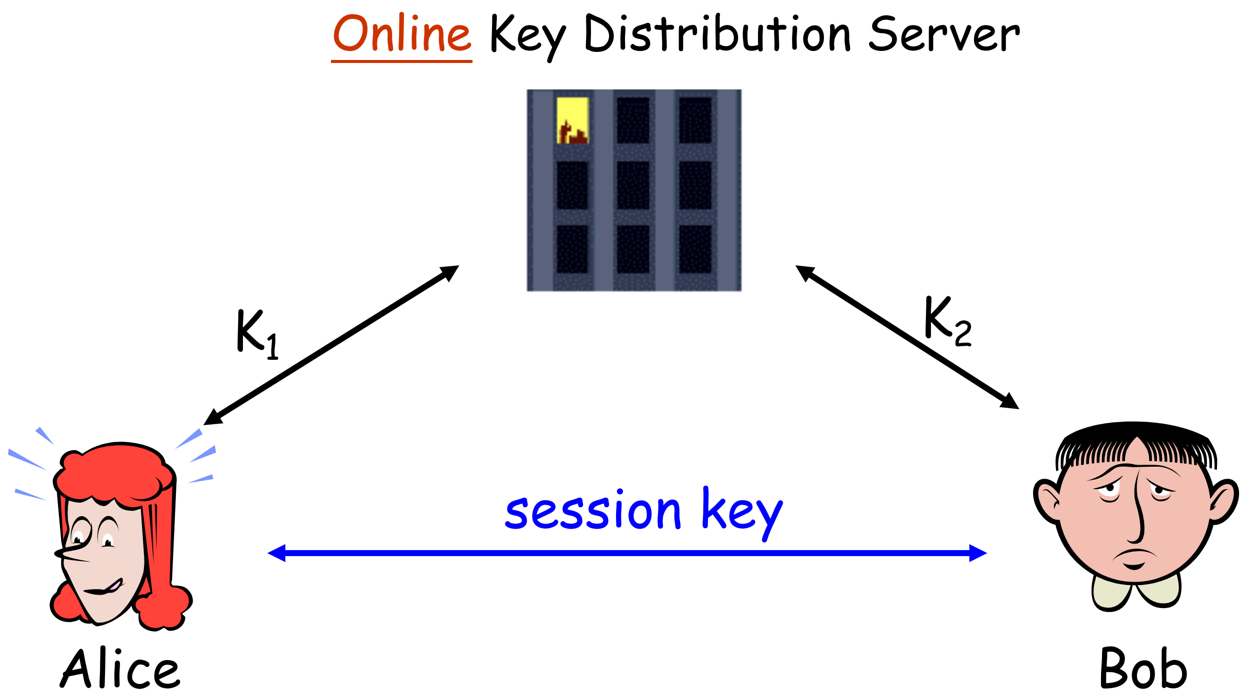
- Alice: sender
- Bob: receiver
- Eve: eavesdropper / Oscar : opponent
- Ciphertext $C = E_K(M)$
- Plaintext $M = E_K^{-1}(C)$
- One of the greatest difficulties: key management
- Algorithms: DES, IDEA, RC2/4/5/6, AES, …

Symmetric Key Management

- Each pair of communicating entities needs a shared key
  - Why?
  - For an n-party system, there are n(n-1)/2 distinct keys in the system and each party needs to maintain n-1 distinct keys.
- How to reduce the number of shared keys in the system
  - Centralized key management
  - Public keys



Centralized Key Management



- Only n keys, instead of n(n-1)/2 in the system.
- The server may become the single-point-of-failure and the performance bottleneck.

Asymmetric (Public-Key) Cryptosystems

- First proposed in public by Diffie and Hellman at Stanford University in 1976.
  - known earlier in classified community
- Enable secure message exchange
  - between sender and receiver
    - without ever having to meet in advance to agree on a common secret-key.
- It is **asymmetric** because
  - Those who encrypt messages or verify signatures **may not be able to** decrypt messages or create signatures

Public-Key Cryptography

- Probably most significant advance in the 3000 year history of cryptography
- It uses **two** keys – a public & a private key
- **It is asymmetric:** parties are **not** equal
- It uses clever applications of number theoretic concepts to function
- It complements **rather than** replaces private key cryptography

Public-Key Cryptosystems

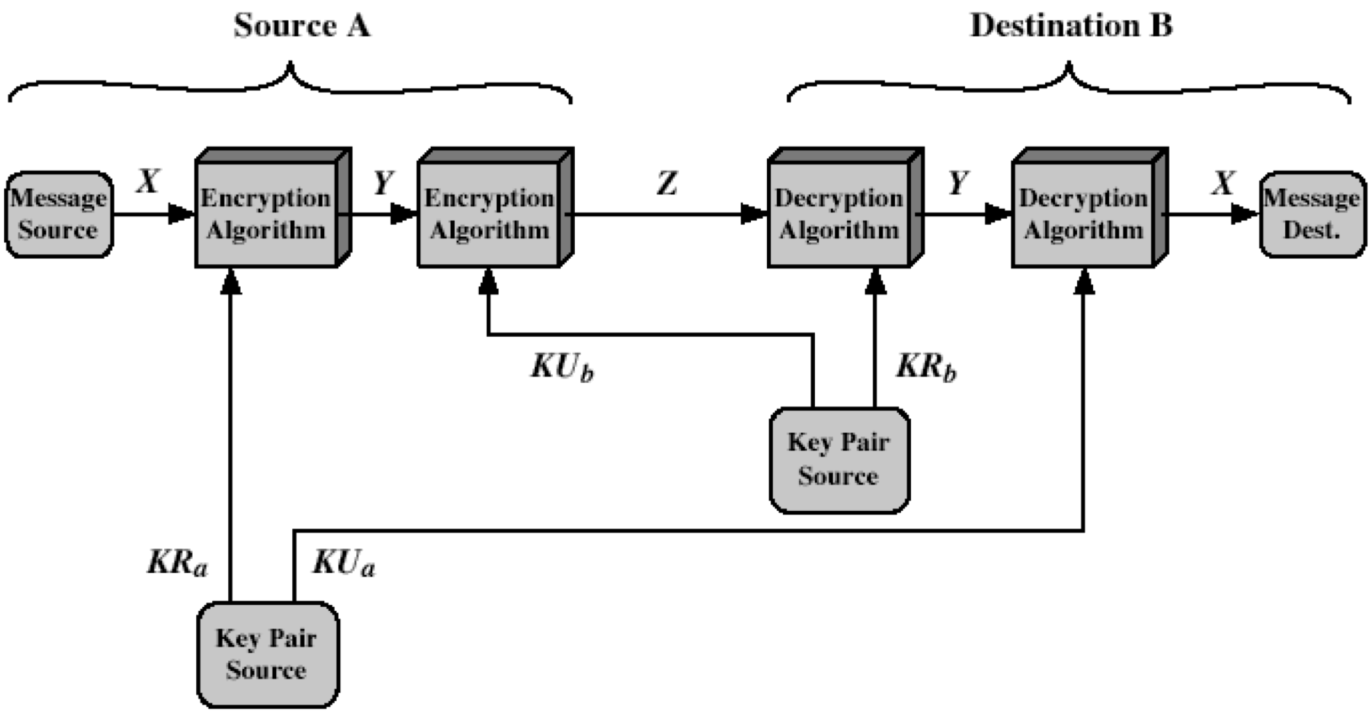
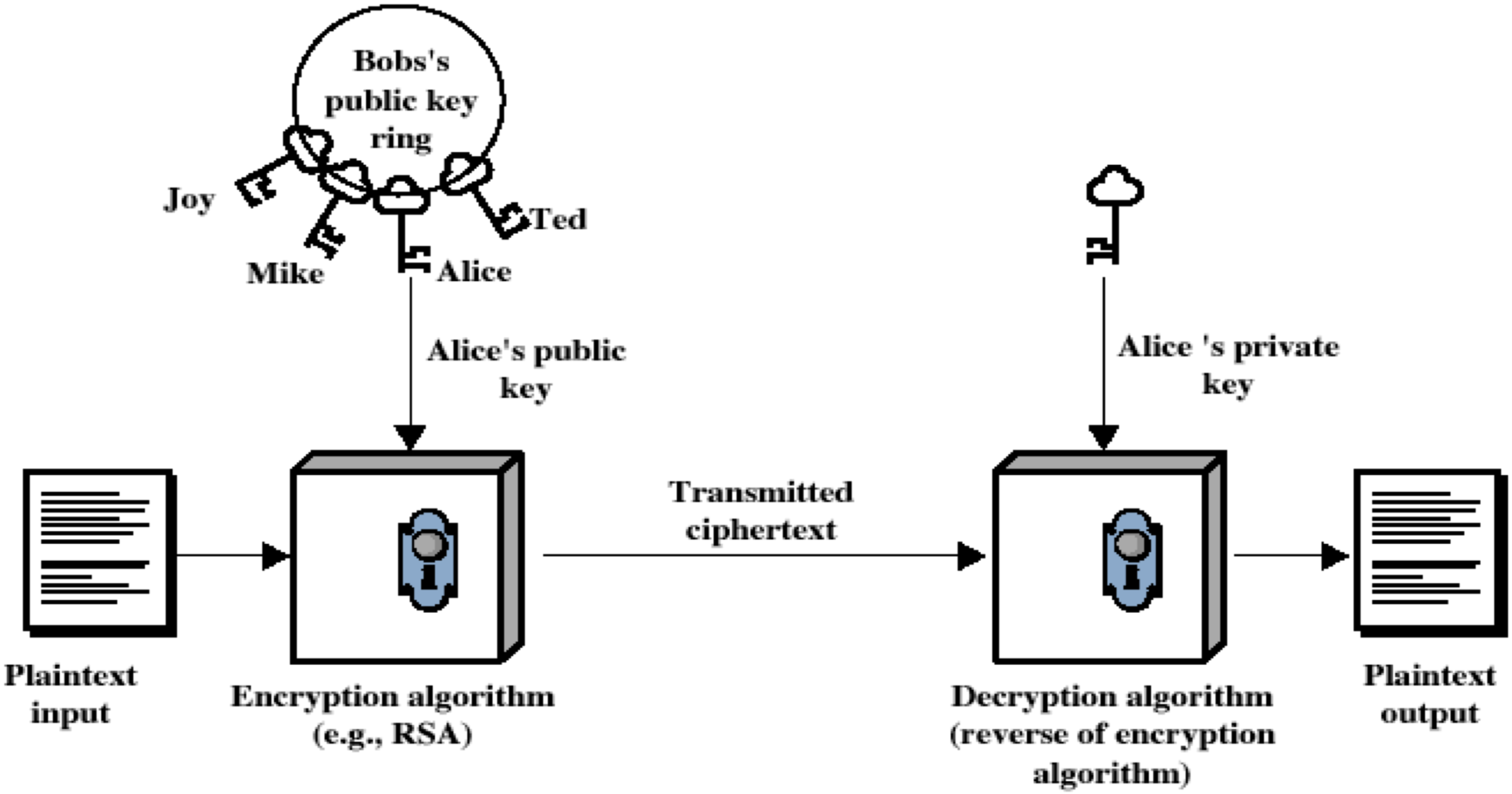


Figure 9.4 Public-Key Cryptosystem: Secrecy and Authentication

Public-Key Applications

- 3 major categories:
  - **encryption/decryption** (provide secrecy)
  - **digital signatures** (provide authentication)
  - **key exchange** (of session keys)
- Some algorithms are suitable for all uses, others are specific to one

PKC: Just Another Illustration



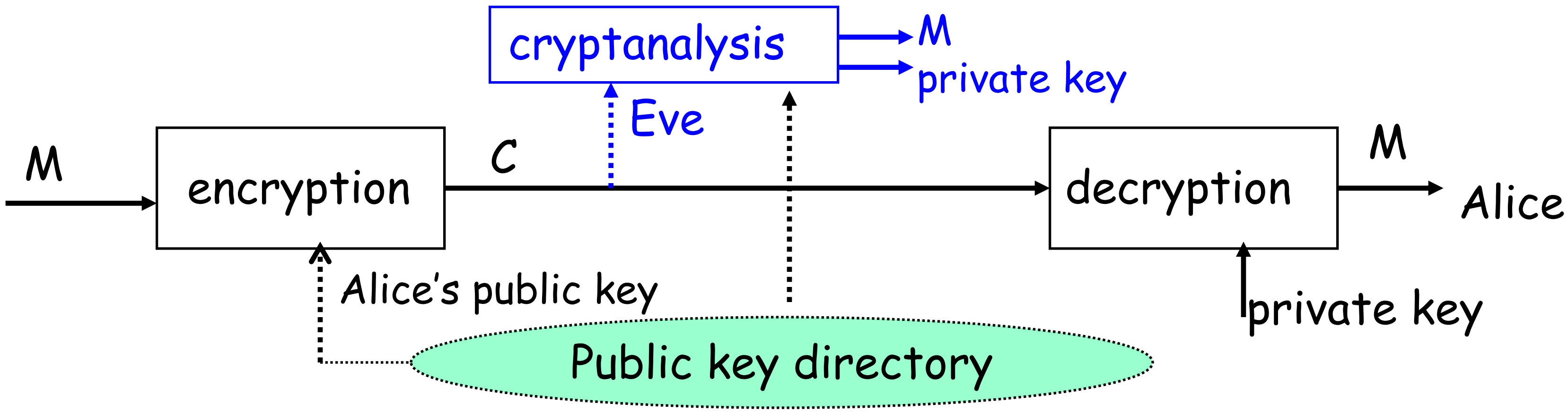
Security of Public Key Schemes

- Security relies on a **large enough** difference in difficulty between **easy** (en/decrypt) and **hard** (cryptanalysis) problems
- Similar to private key schemes, brute force **exhaustive search** attack is always theoretically possible
  - But keys used are too large (>512bits) to break that way
- It requires the use of **very large numbers**
  - **slow** when compared to private key schemes

PKC Computational Characteristics

- Public-Key algorithms rely on two keys with the characteristics:
  - computationally infeasible to find decryption key knowing only algorithm & encryption key
  - computationally easy to en/decrypt messages when the relevant (en/decrypt) key is known
  - either of the two related keys can be used for encryption, with the other used for decryption (in some schemes).

Public-Key Cryptosystem



- $C = E_{PK}(M)$
- $M = D_{SK}(C) = D_{SK}(E_{PK}(M))$
- Public keys are published.
- Each private key is known to the receiver only.
- Difficult for Eve to find out SK from PK.

Why Public-Key Cryptography?

- Initially proposed to address two key issues:
  - **key distribution** – how to have secure communications in general without having to trust a KDC with your key
  - **digital signatures** – how to verify a message comes intact from the claimed sender
- Ripple Effect: Make e-commerce possible.

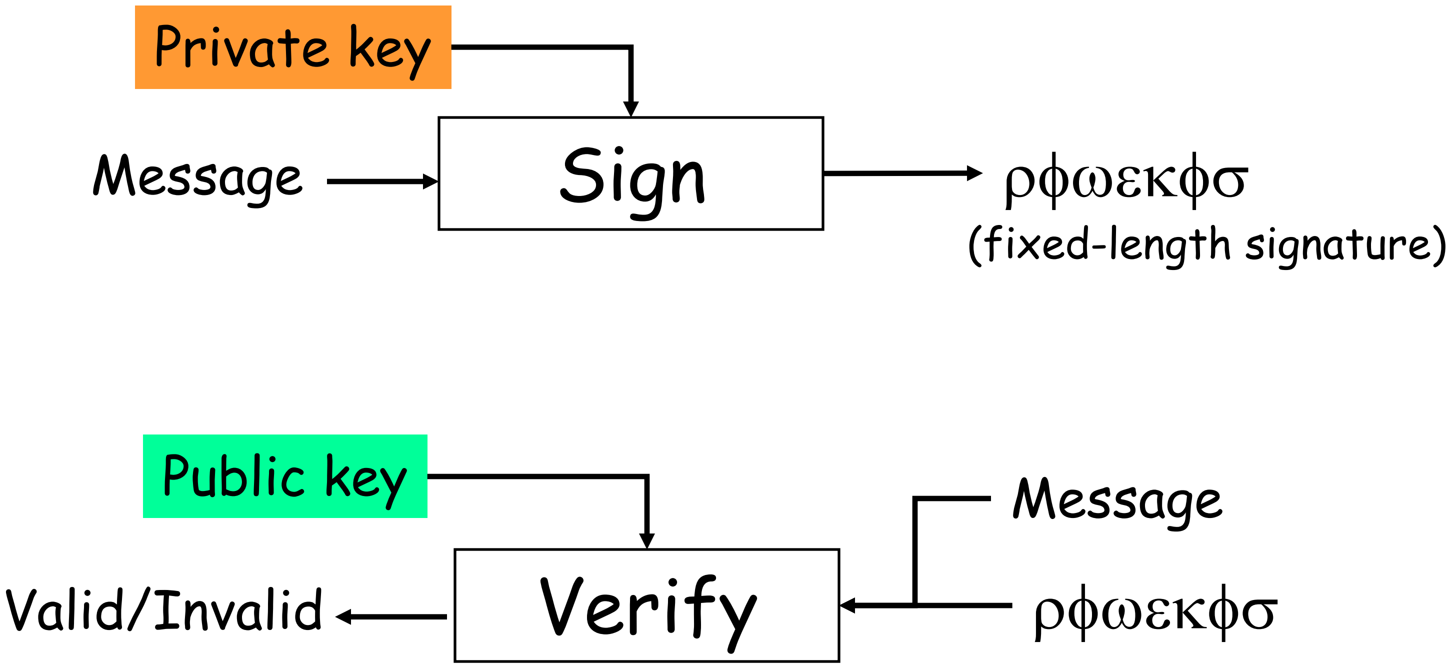
Private-Key vs. Public-Key

Private-Key	Public-Key
Two parties MUST trust each other	Two parties DO NOT need to trust each other
Both share same key (or one key is computable from the other)	Two separate keys: a public and a private key
Typically faster	Typically slower
Examples: DES, IDEA, RC5, AES, …	Examples: RSA, ElGamal Encryption, ECC…

Digital Signature

- Is there a functional equivalence to a handwritten signature?
  - Easy for legitimate user to sign
  - But hard for anyone else to forge
  - Easy for anyone to verify
  - Dependent on message & signer (key)
- Public key!
  - Sign: “invert” function using private key
  - Verify: compute function using public key

Digital Signatures



- Only the signer (who has a private key) can generate a valid signature
- Everyone (since the corresponding public key is published) can verify if a signature with respect to a message is valid