Cryptography

CSE 4471: Information Security

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Terminology (1)

- **Cryptography:**
  - Book definition: process/study of making and using codes to secure information transmission
  - It’s really: *the practice/study of rendering information unintelligible to everyone except the intended recipient*
- **Cryptanalysis:** study of obtaining plaintext without knowing key and/or algorithm
- **Cryptology:** study of science of encryption, incl. cryptography
- **Steganography:** process of hiding messages (and the existence thereof) in images, text, etc.
  - See Wayner’s book *Disappearing Cryptography* for more info

Terminology (2)

- **Plaintext:** unencrypted message
- **Ciphertext:** encrypted message
- **Cipher, cryptosystem:** encryption method consisting of algorithm, key, and encryption/decryption procedures
- **Key:** *secret* info used with algorithm to form cipher
- **Kerchhoffs' principle:** a cryptosystem should be secure if everything *but* the key is publicly known
  - Security through obscurity doesn't work!
  - "The enemy knows the system" – Claude Shannon
- **Encrypt:** convert plaintext to ciphertext
- **Decrypt:** convert ciphertext to plaintext

Terminology (3)

- **Keyspace:** # of values that can be used in a key
  - Ranges of possible and actual values may vary
  - This can greatly affect cipher security
- **Entropy:** # of different *actual* values something can have
  - *Not* keyspace, which specifies total # of *possible* values
  - *Example keyspace:* # of 16-char. passwords using upper-, lowercase letters, numbers, punctuation. If someone always uses 4-char. password, entropy much smaller!
  - Security problems have originated in seeds of pseudo-random number generators with low entropy
- **Work factor:** amount of CPU time needed to analyze ciphertext (get plaintext) *without* knowing key or algorithm
- **Pseudo-random number generator (PRNG):** algorithm that creates "random" number sequence whose properties are similar to those of "real" random number sequences

Terminology (4)

- **One-way hash function:** converts message to a value (message digest – MD)
  - One-way: can’t determine message from MD
  - Examples: MD5, SHA-1, etc.
- **Hash collision:** two messages produce same MD
  - Aim: given a message and an MD, you should not be able to find another message that hashes to same MD
- **Nonce:** number only used once, helps prevent replay attacks

Cipher Methods (1)

- Plaintext can be encrypted via bit stream or block cipher methods
- **Bit stream:** each plaintext bit transformed into cipher bit one bit at a time
- **Block cipher:** message divided into blocks (e.g., sets of 8- or 16-bit blocks) and each is transformed into encrypted block of cipher bits using algorithm and key

Cipher Methods (2)

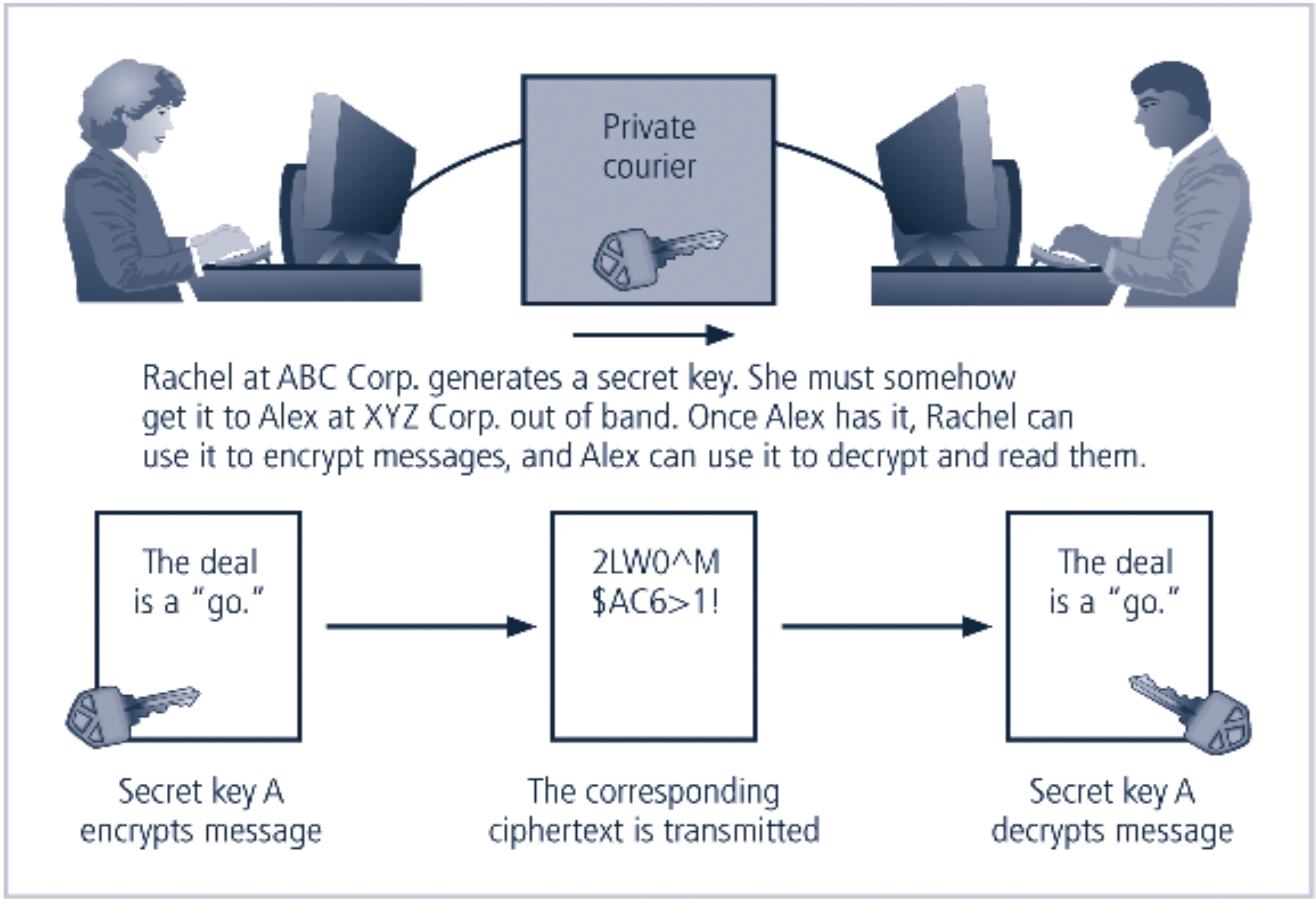
- **Substitution cipher:** substitute one value for another
- **Monoalphabetic substitution:** uses only one alphabet, *e.g.*, ROT13, Radio Orphan Annie decoder
- **Polyalphabetic substitution:** more advanced; uses two or more alphabets, *e.g.*, Vigenère cipher
- **Transposition cipher:** rearranges values within a block to create ciphertext
- **Exclusive OR (XOR):** Boolean algebra function that compares two bits:
  - If they're identical: result = 0
  - Otherwise: result = 1

Bit 1	Bit 2	Bit 1 XOR Bit 2
0	0	0
0	1	1
1	0	1
1	1	0

Cryptographic Algorithms (1)

- Two categories: *symmetric* and *asymmetric*
  - Today's cryptosystems use hybrid combination of both types of algorithms
  - Distinguishing features: #, types of keys used for encryption
- Symmetric: use same "secret key" for message encryption, decryption
  - Computationally efficient
  - Both sender, receiver must have key beforehand
  - If either copy of key is compromised, attacker can decrypt and read messages

Symmetric Encryption Ex. (Fig. 8.3)



Rachel at ABC Corp. generates a secret key. She must somehow get it to Alex at XYZ Corp. out of band. Once Alex has it, Rachel can use it to encrypt messages, and Alex can use it to decrypt and read them.

FIGURE 8-3 **Example of Symmetric Encryption**

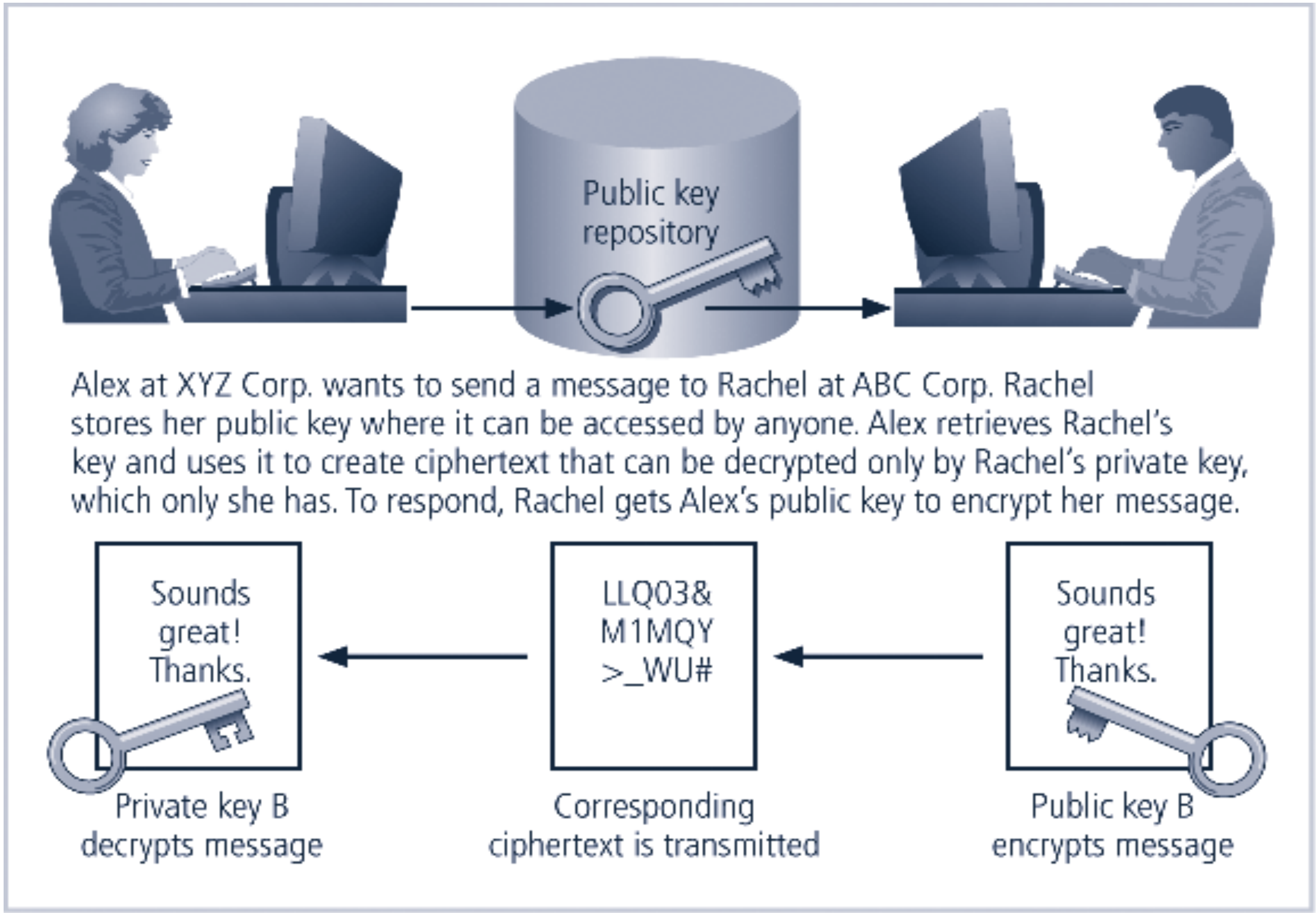
Cryptographic Algorithms (2)

- Data Encryption Standard (DES): one of most popular symmetric encryption cryptosystems
  - 64-bit block size; 56-bit key
  - Adopted by NIST in 1976 as federal standard for encrypting non-classified information
- Triple DES (3DES): created to provide security far beyond DES
- Advanced Encryption Standard (AES): developed to replace both DES and 3DES

Cryptographic Algorithms (3)

- Asymmetric (public key) encryption
  - Uses two different but related keys; either key can encrypt or decrypt message
  - If Key A encrypts message, only Key B can decrypt
  - Highest value: one key is private, the other is public

Asymmetric Encryption Ex. (Fig. 8.4)



Alex at XYZ Corp. wants to send a message to Rachel at ABC Corp. Rachel stores her public key where it can be accessed by anyone. Alex retrieves Rachel's key and uses it to create ciphertext that can be decrypted only by Rachel's private key, which only she has. To respond, Rachel gets Alex's public key to encrypt her message.

FIGURE 8-4 Example of Asymmetric Encryption

Cryptography Tools

- Public Key Infrastructure (PKI): combination of software, encryption methodologies, protocols, contracts, and third-party services enabling secure communications among users
- PKI systems use public-key encryption
  - Include digital certificates, cert. authorities (CAs)

Digital Signatures

- Encrypted messages whose authenticity can be mathematically proven
- Created to address need for info. verification in electronic communications (e.g., e-commerce, online healthcare portals, etc.)
- Digital signatures use asymmetric crypto.

Digital Certificates

- Electronic document containing key value and identifying information about entity that controls key

- Digital signature attached to certificate's container file to certify file is from entity it claims to be from

Protocols for Secure Communications

- Transport Layer Security (TLS): Public-key crypto. protocol for secure HTTP communications
  - Secure Socket Layer (SSL): older protocol that achieves similar purpose
- Email encryption: S-MIME, PGP, GPG
  - Secure Multipurpose Mail Extensions (S-MIME): Adds encryption, authentication to existing mail extensions
  - Pretty Good Privacy (PGP): Free software that encrypts email
  - GNU Privacy Guard (GPG): Similar free tool used on *nix-like systems

Summary

- Cryptography provides sophisticated approach to security
  - Many security-related tools use embedded encryption technologies
  - Encryption converts a message into a form that unintended recipients cannot read
- Many tools are available, both symmetric and asymmetric