# Foundations of Computer Security

## Lecture 44: Symmetric vs. Asymmetric Encryption

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# Symmetric vs. Asymmetric Systems

Recall that there are two basic types of encryption:

symmetric algorithms: (also called "secret key") use the same key for both encryption and decryption;

asymmetric algorithms: (also called "public key") use different keys for encryption and decryption.

For any encryption approach, there are two major challenges:

Key distribution: how do we convey keys to those who need them to establish secure communication.

Key management: given a large number of keys, how do we preserve their safety and make them available as needed.

# Asymmetric Encryption Primer

In *asymmetric or public key encryption*, different keys are used for encryption and decryption.

Each subject $S$ has a publicly disclosed key $K_S$ ("S's public key") that anyone can use to encrypt, and a privately held key $K_S^{-1}$ ("S's private key"). The relationship is:

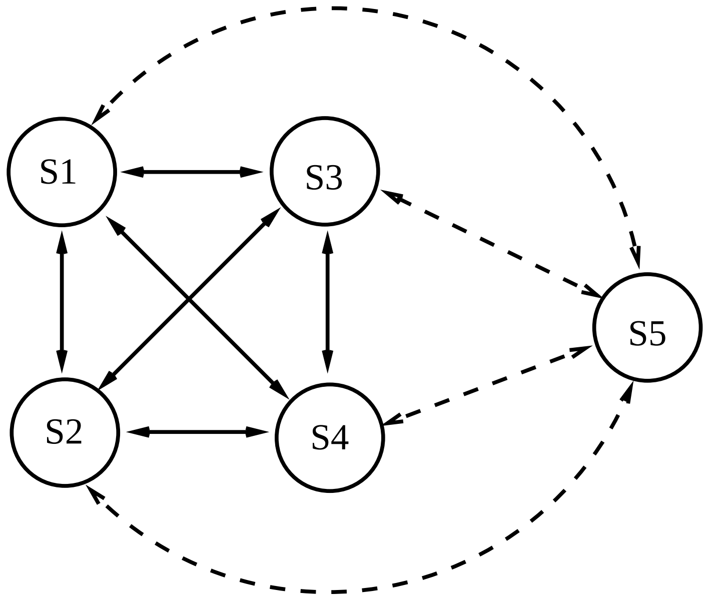
$$M = \{\{M\}_{K_S}\}_{K_S^{-1}}.$$

Anyone wishing to send a message $M$ confidentially to $S$ sends $\{M\}_{K_s}$. Only the holder of $K_S^{-1}$ can decrypt this message.

*Asymmetric encryption largely solves the key distribution problem. Why?*

# How Many Keys: Symmetric Encryption

*Given a symmetric system with n users, how many keys are needed for pairwise secure communication?*



Each time a new user is added to the system, it needs to share a new key with each previous user. Thus, for $n$ users, we have

$$1 + 2 + \ldots + (n-1) = n(n-1)/2 \text{ keys.}$$

This is $O(n^2)$ keys.

# How Many Keys: Asymmetric Encryption

*Given an asymmetric system of $n$ users, how many keys are needed for pairwise secure communication?*

Each time a new user is added to the system, it needs only a public key and a private key.

Thus, for $n$ users, we have $2n$ keys, which is $O(n)$.

Depending on the algorithm, each user may need separate pairs for confidentiality and signing, i.e., $4n$ keys, which is still $O(n)$.

# Characteristics of Keys

Typically, in a symmetric encryption system keys are:

1. randomly generated $k$-bit strings,
2. simple to generate,
3. have no special properties.

In a public key system, keys:

1. have special structure (e.g., are large primes), and
2. are expensive to generate.

Key sizes are not comparable between the two approaches. A 128-bit symmetric key may be equivalent in strength to a 3000-bit public key.

# Lessons

- Using symmetric encryption, security requires that each pair of users share a secret key.
- In an asymmetric system, each user has a public/private key pair.
- Keys in the two approaches have very different characteristics and are not directly comparable.

**Next lecture:** Stream and Block Encryption