

Key Management and Distribution

CSS322: Security and Cryptography

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[css322y13s2l10, Steve/Courses/2013/s2/css322/lectures/key.tex](https://github.com/steve/courses/blob/master/2013/s2/css322/lectures/key.tex), r2965

Contents

Key Distribution and Management

Symmetric Key Distribution using Symmetric Encryption

Symmetric Key Distribution using Asymmetric Encryption

Distribution of Public Keys

X.509 Certificates

Key Management

Challenges

- ▶ How to share a secret key?
- ▶ How to obtain someone else's public key?
- ▶ When to change keys?

Assumptions and Principles

- ▶ Many users wish to communicate securely across network
- ▶ Attacker can intercept any location in network
- ▶ Manual interactions between users are undesirable (e.g. physical exchange of keys)
- ▶ More times a key is used, greater chance for attacker to discover the key

Where Should Encryption Be Performed?

Key Management

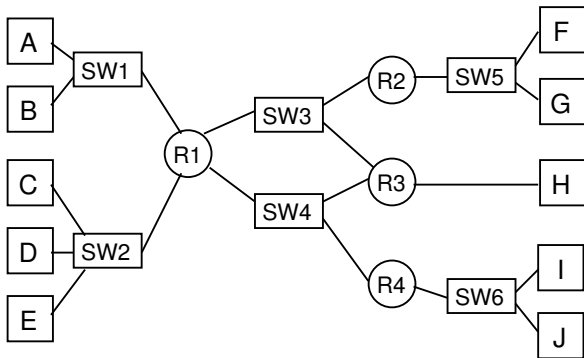
Key Distribution

Symmetric with
Symmetric

Symmetric with
Asymmetric

Public Keys

X.509



- ▶ Number of keys to be exchanged depends on number of entities wishing to communicate
- ▶ Related issue: where to perform encryption
 - ▶ Encrypt separately across each link
 - ▶ Encrypt only at end-points

Link Encryption vs End-to-End Encryption

Link Encryption

- ▶ Encrypt data over individual links in network
- ▶ Each link end-point shares a secret key
- ▶ Decrypt/Encrypt at each device in path
- ▶ Requires all links/devices to support encryption

End-to-End Encryption

- ▶ Encrypt data at network end-points (e.g. hosts or applications)
- ▶ Each pair of hosts/applications share a secret key
- ▶ Does not rely on intermediate network devices

How Many Keys Need To Be Exchanged?

Key Management

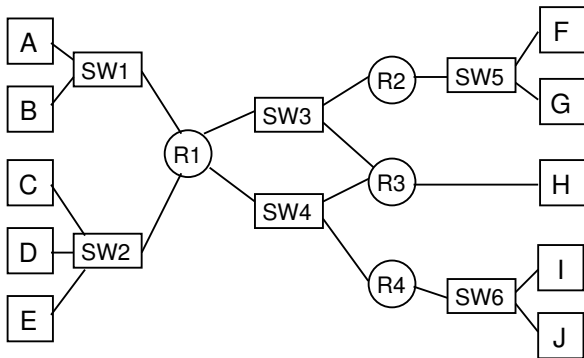
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- ▶ Link-level encryption?
- ▶ End-to-end encryption between hosts?
- ▶ End-to-end encryption between applications?

Exchanging Secret Keys

Option 1: Manual Exchange of All Keys

- ▶ All users exchange secret keys with all other users manually (e.g. face-to-face)
- ▶ Inconvenient

Option 2: Manual Exchange of Master Keys

- ▶ All users exchange **master** key with trusted, central entity (e.g. Key Distribution Centre)
- ▶ **Session** keys automatically exchanged between users via KDC
- ▶ Security and performance bottleneck at KDC

Exchanging Secret Keys

Option 3: Public Key Cryptography to Exchange Secrets

- ▶ Use public-key cryptography to securely and automatically exchange secret keys
- ▶ Example 1: user A encrypts secret with user B's public key; sends to B
- ▶ Example 2: Diffie-Hellman secret key exchange
- ▶ Related issue: How to obtain someone else's public key?

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Symmetric Key Distribution using Symmetric Encryption

- ▶ Objective: two entities share same secret key
- ▶ Principle: change keys frequently
- ▶ How to exchange a secret key?
 1. Decentralised Key Distribution: manual distribution of master keys between all entities, automatic distribution of session keys
 2. Key Distribution Centre (KDC): manual distribution of master keys with KDC, automatic distribution of session keys

Key Hierarchy and Lifetimes

Key Management

Key Distribution

Symmetric with Symmetric

Symmetric with Asymmetric

Public Keys

X.509

- ▶ **Master** keys used to securely exchange session keys
- ▶ **Session** keys used to securely exchange data
- ▶ Change session keys automatically and regularly
- ▶ Change master keys manually and seldom
- ▶ Session key lifetime:
 - ▶ Shorter lifetime is more secure; but increases overhead of exchanges
 - ▶ Connection-oriented protocols (e.g. TCP): new session key for each connection
 - ▶ Connection-less protocols (e.g. UDP/IP): change after fixed period or certain number of packets sent

Notation

Key Management

Key Distribution

Symmetric with
SymmetricSymmetric with
Asymmetric

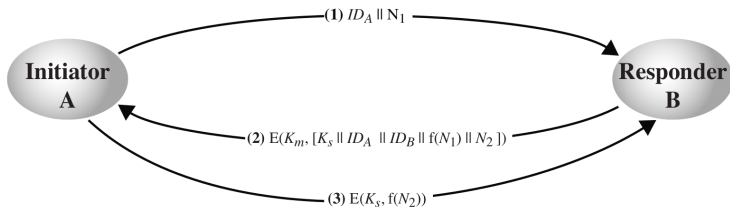
Public Keys

X.509

- ▶ End-systems: A and B , identified by ID_A and ID_B
- ▶ Master key (between A and B): K_m
- ▶ Master keys specific to user: K_a, K_b
- ▶ Session key (between A and B): K_s
- ▶ Nonce values: N_1, N_2
 - ▶ Number used only once
 - ▶ E.g. time-stamp, counter, random value, function $f()$
 - ▶ Must be different for each request
 - ▶ Must be difficult for attacker to guess

Decentralised Key Distribution

- ▶ Each end-system must manually exchange $n - 1$ master keys (K_m) with others
- ▶ Does not rely on trusted-third party



Credit: Figure 14.5 in Stallings, *Cryptography and Network Security*, 5th Ed., Pearson 2011

Using a Key Distribution Centre

- ▶ Key Distribution Centre (KDC) is trusted third party
- ▶ Users manually exchange master keys with KDC
- ▶ Users automatically obtain session key (via KDC) to communicate with other users

Key Distribution with KDC

Key Management

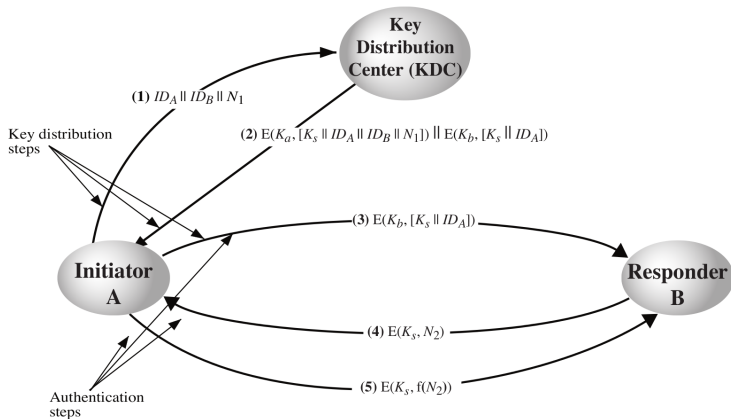
Key Distribution

Symmetric with Symmetric

Symmetric with Asymmetric

Public Keys

X.509



Credit: Figure 14.3 in Stallings, *Cryptography and Network Security*, 5th Ed., Pearson 2011

Hierarchical Key Control

- ▶ Use multiple KDCs in a hierarchy
- ▶ E.g. KDC for each LAN (or building); central KDC to exchange keys between hosts in different LANs
- ▶ Reduces effort in key distribution; limits damage if local KDC is compromised

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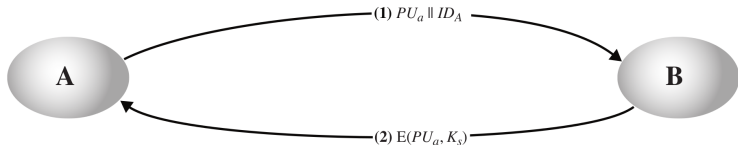
X.509 Certificates

Symmetric Key Distribution using Asymmetric Encryption

- ▶ Asymmetric encryption generally too slow for encrypting large amount of data
- ▶ Common application of asymmetric encryption is exchanging secret keys
- ▶ Three examples:
 1. Simple Secret Key Distribution
 2. Secret Key Distribution with Confidentiality and Authentication
 3. Hybrid Scheme: Public-Key Distribution of KDC Master Keys

Simple Secret Key Distribution

- ▶ Simple: no keys prior to or after communication
- ▶ Provides confidentiality for session key
- ▶ Subject to **man-in-the-middle attack**
- ▶ Only useful if attacker cannot modify/insert messages



Credit: Figure 14.7 in Stallings, *Cryptography and Network Security*, 5th Ed., Pearson 2011

Man-in-the-Middle Attack

Key Management

Key Distribution

Symmetric with
Symmetric

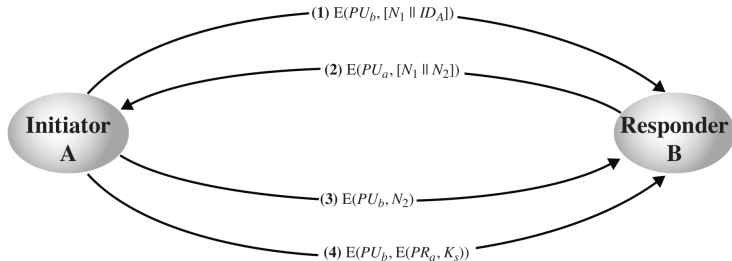
**Symmetric with
Asymmetric**

Public Keys

X.509

Secret Key Distribution with Confidentiality and Authentication

- ▶ Provides both confidentiality and authentication in exchange of secret key



Credit: Figure 14.8 in Stallings, *Cryptography and Network Security*, 5th Ed., Pearson 2011

Hybrid Scheme: Public-Key Distribution of KDC Master Keys

- ▶ Use public-key distribution of secret keys when exchanging master keys between end-systems and KDC
- ▶ Efficient method of delivering master keys (rather than manual delivery)
- ▶ Useful for large networks, widely distributed set of users with single KDC

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Distribution of Public Keys

- ▶ By design, public keys are made public
- ▶ Issue: how to ensure public key of A actually belongs to A (and not someone pretending to be A)
- ▶ Four approaches for distributing public keys
 1. Public announcement
 2. Publicly available directory
 3. Public-key authority
 4. Public-key certificates

Public Announcements

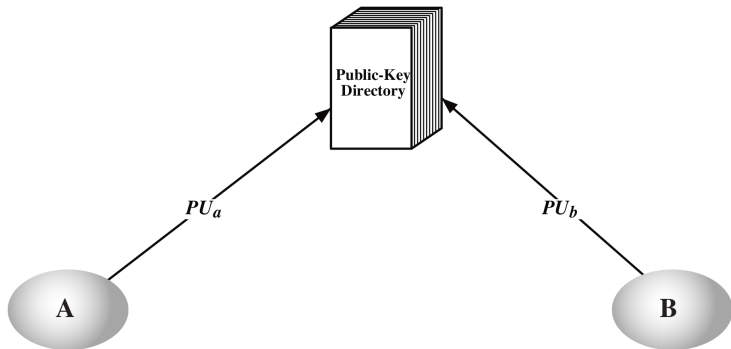
- ▶ Make public key available in open forum: newspaper, email signature, website, conference, . . .
- ▶ Problem: anyone can announce a key pretending to be another user



Credit: Figure 14.9 in Stallings, *Cryptography and Network Security*, 5th Ed., Pearson 2011

Publicly Available Directory

- ▶ All users publish keys in central directory
- ▶ Users must provide identification when publishing key
- ▶ Users can access directory electronically
- ▶ Weakness: directory must be secure



Credit: Figure 14.10 in Stallings, *Cryptography and Network Security*, 5th Ed., Pearson 2011

Public-Key Authority

Key Management

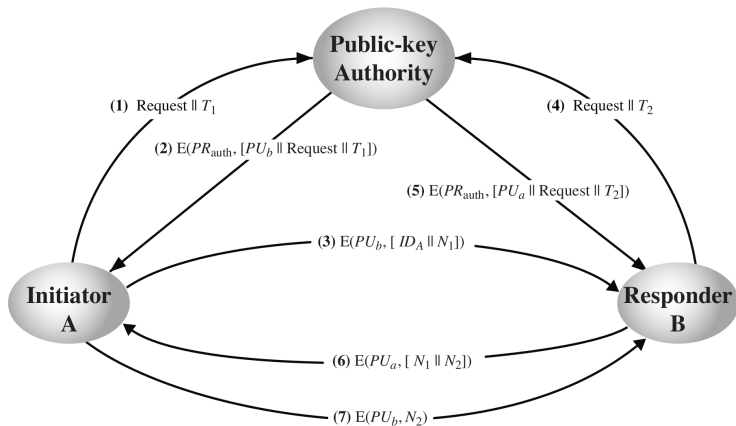
Key Distribution

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- ▶ Specific instance of using publicly available directory
- ▶ Assume each user has already security published public-key at authority; each user knows authorities public key

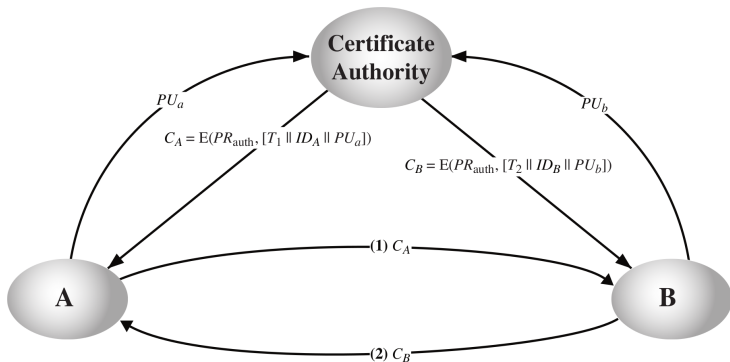


Public-Key Authority

- ▶ First 5 messages are for key exchange; last 2 are authentication of users
- ▶ Although 7 messages, public keys obtained from authority can be cached
- ▶ Problem: authority can be bottleneck
- ▶ Alternative: public-key certificates

Public-Key Certificates

- Assume public keys sent to CA can be authenticated by CA; each user has certificate of CA



Credit: Figure 14.12 in Stallings, *Cryptography and Network Security*, 5th Ed., Pearson 2011

Public Key Certificates

- ▶ A certificate is the ID and public-key of a user signed by CA

$$C_A = E(PR_{auth}, [T || ID_A || PU_a])$$

- ▶ Time-stamp T validates currency of certificate (expiration date)
- ▶ Common format for certificates is X.509 standard (by ITU)
 - ▶ S/MIME (secure email)
 - ▶ IP security (network layer security)
 - ▶ SSL/TLS (transport layer security)
 - ▶ SET (e-commerce)

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X.509

- ▶ Each user has a certificate, although it is created by the Certificate Authority (CA)
- ▶ Certificates are stored in a public directory
- ▶ Certificate format includes:
 - ▶ Version of X.509 certificate
 - ▶ Serial number unique to the issuer (CA)
 - ▶ Signature algorithm
 - ▶ Issuer's name and unique identifier
 - ▶ Period of validity
 - ▶ Subject's name and unique identifier
 - ▶ Subject's public key information: algorithm, parameters, key
 - ▶ Signature
- ▶ Certificates may be revoked before expiry
 - ▶ CA signs a Certificate Revocation List (CRL), which is stored in public directory

Multiple Certificate Authorities

Key Management

Key Distribution

Symmetric with
SymmetricSymmetric with
Asymmetric

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X.509

- ▶ Multiple CA's can be arranged in hierarchy
- ▶ Notation: $Y \ll X \gg$ certificate of X issued by CA Y

