Principles of Network Security (cont.)

Kai Shen

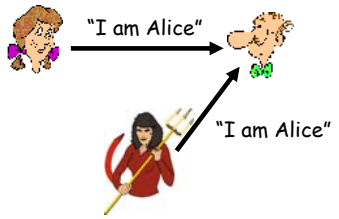
Principles of Network Security

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

Authentication: version 1.0

Authentication: Bob wants Alice to "prove" her identity to him.

Protocol ap1.0: Alice says "I am Alice".

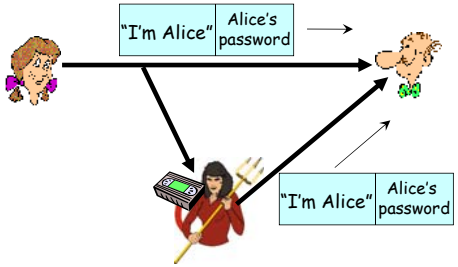


Failure scenario??

Trudy can simply declare herself to be Alice

Authentication: version 2.0

Protocol ap2.0: Alice says "I am Alice" and sends her secret password to "prove" it.



Failure scenario??

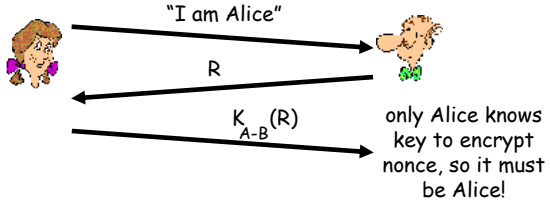
playback attack: Trudy records Alice's packet and later plays it back to Bob

Authentication: version 3.0

Goal: avoid playback attack

Nonce: number (R) used only *once–in-a-lifetime*

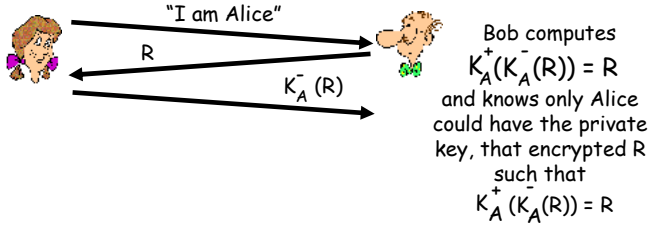
ap3.0: Bob sends Alice a nonce, R. Alice must return R, encrypted with shared secret key



Authentication: version 4.0

ap3.0 requires shared symmetric key. Key distribution can be a problem.

ap4.0: use nonce, public key cryptography.



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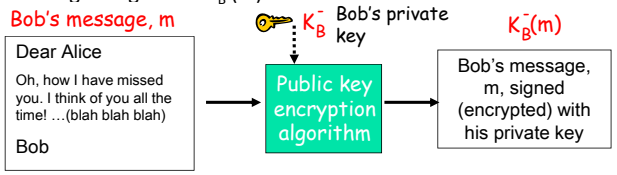
Integrity

- Digital Signatures:
  - cryptographic technique to ensure document integrity.
  - analogous to hand-written signatures.
- Sender (Bob) digitally signs document, establishing he is document owner/creator.
- The recipient (Alice) receives the document and the digital signature.
- The recipient can be sure that the document is
  - verifiable: Bob signed the document.
  - nonforgeable: the document hasn't been changed since Bob signed it.

Digital Signatures

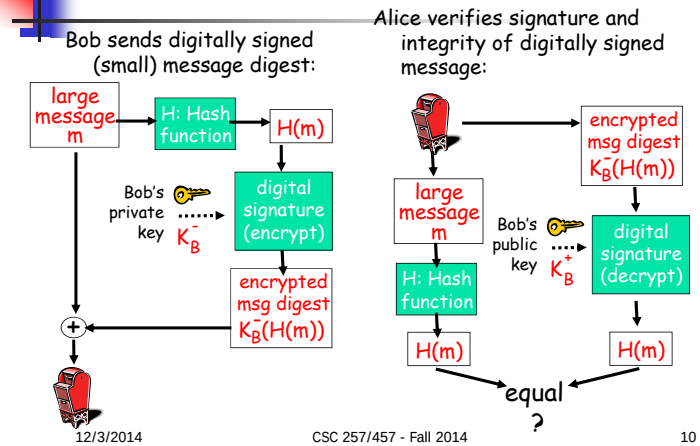
- Bob signs m by encrypting with his private key, creating a digital signature $K_B^-(m)$



- Suppose Alice receives msg m and its digital signature $K_B^-(m)$
- Alice applies Bob's public key K_B^+ to $K_B^-(m)$ then checks whether $K_B^+(K_B^-(m)) = m$.
- If so, whoever signed m must have used Bob's private key.

Problem: computationally expensive to public-key-encrypt long messages.

Signed Message Digest



Message Digests

- Apply a hash function H to m, get a much smaller message digest H(m).
- Public-key-encrypt the message digest to generate the digital signature $K_B^-(H(m))$.

Good/bad hash functions?

- Hint: given a hash function, it is possible for many messages sharing the same digest.

Internet Checksum: Poor Hash Function for Generating Message Digests

Given a message and its Internet checksum, it is easy to find another message with same checksum.

message	ASCII format
I O U 1	49 4F 55 31
0 0 . 9	30 30 2E 39
9 B O B	39 42 D2 42
	B2 C1 D2 AC

message	ASCII format
I O U 9	49 4F 55 39
0 0 . 1	30 30 2E 31
9 B O B	39 42 D2 42
	B2 C1 D2 AC

different messages but identical checksums!

Hash function property: given digest x for message m, computationally infeasible to find another message m' that shares the same digest. Pre-image resistance. Collision resistance.

Good Hash Functions for Generating Message Digests

- MD5
  - computes 128-bit message digest in 4-step process.
  - appears difficult to construct message m whose MD5 hash is equal to x.
- SHA-1
  - [NIST, FIPS PUB 180-1]
  - 160-bit message digest
- SHA-2
  - More bits: SHA256, SHA512

http://en.wikipedia.org/wiki/Cryptographic_hash_function

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Key Distribution and Certification

Symmetric key distribution problem:

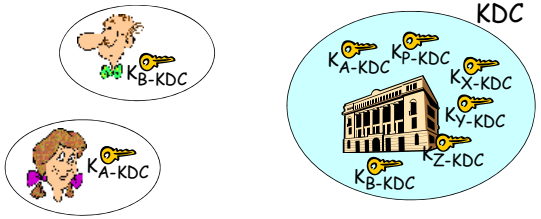
- How do Alice and Bob establish shared secret key over network without Trudy's knowledge?

Public key distribution problem:

- When Alice obtains Bob's public key (from web site, e-mail, diskette), how does she know it is Bob's public key, not Trudy's?

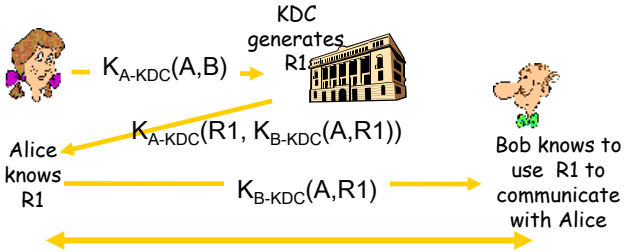
Secret Key Distribution: Key Distribution Center (KDC)

- KDC: server shares different secret key with *each* registered user (many users).
- Alice, Bob know own symmetric keys, $K_{A\text{-}KDC}$ $K_{B\text{-}KDC}$, for communicating with KDC.



Key Distribution using KDC

Q: How does KDC allow Bob, Alice to determine shared symmetric secret key to communicate with each other?



Alice and Bob communicate: using R1 as session key for shared symmetric encryption

Security Vulnerability with Public Key Distribution

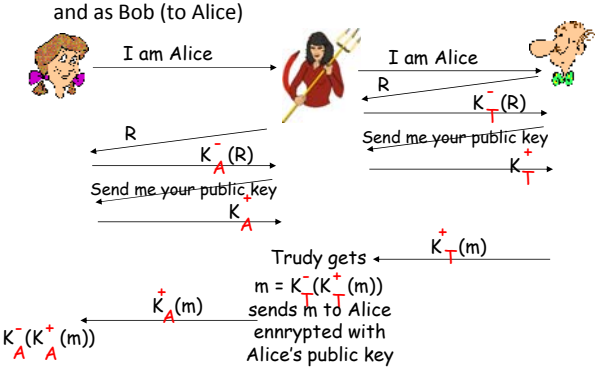
A case example for public key-based authentication.

Bob computes $K_A^+(K_A^-(R)) = R$ and knows only Alice could have the private key, that encrypted R such that $K_A^+(K_A^-(R)) = R$

What if Bob doesn't know Alice's public key ahead of time?

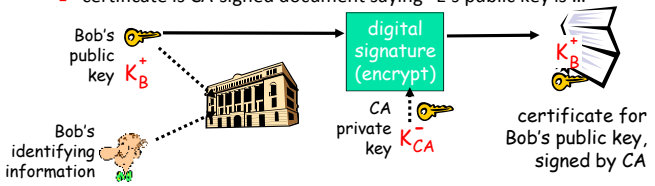
Security vulnerability when public keys are not well known

Man (woman) in the middle attack: Trudy poses as Alice (to Bob) and as Bob (to Alice)



Public Key Distribution: Certification Authorities

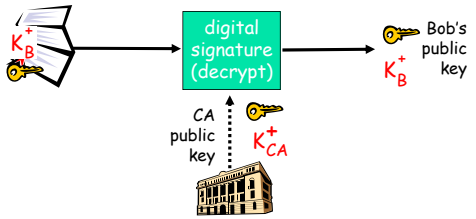
- Certification authority (CA): trustable by everyone; everyone knows its public key.
- E (person, router) registers its public key with CA.
  - E provides "proof of identity" to CA.
  - CA creates certificate binding E to its public key.
  - certificate is CA-signed document saying "E's public key is …"



Certification Authorities (cont.)

When Alice wants to verify Bob's public key:

- gets Bob's certificate (Bob or elsewhere).
- apply CA's public key to Bob's certificate, verify Bob's public key.



Key Certification Methods

- Public key certificate signed by a certification authority
- Peer certification:
  - If A knows B personally, they can verify each other's public keys using offline means and sign them;
- Certificate chain leading to a certificate authority
  - CA signs A's public key certificate
  - A signs B's public key certificate
  - B signs C's public key certificate
  - If you trust all signers (CA, A, B in this case), then you can trust the certificate.

Summary: Principles of Network Security

Cryptography:

- symmetric keys: protocols? weakness?
- public keys: protocol? weakness?

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)

Key Distribution and Certification:

- problem and solution for symmetric / public keys

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