SECURITY BASICS

Internet Protocols

CSC / ECE 573

Fall, 2005

N. C. State University

Announcements

I. *Project progress?*

Today's Lecture

I. Security Basics
II. Encryption Algorithms
III. Digital Signatures and Message Digests
IV. Certificates
V. Authentication Protocols

SOME CRYPTOGRAPHIC PRIMITIVES

Types of Ciphers

- Substitution ciphers
  - substitute one string or character for another
- Transposition cipher
  - scramble sequence of letters
- Ciphers based on sequences of transpositions (permutations) and substitutions of bits are very common

Types of Ciphers (cont'd)

- One-time pad
  - Generate random bit string, same length as plaintext
  - XOR plaintext with random bit string
  - provably secure

```
'N'=78= 0100 1110            'Y'=89= 0101 1001
      ⊕ 1101 1101 OPD              ⊕ 1100 1010 OPD
        1001 0011                    1001 0011
```

can't tell encrypted 'N' from 'Y'

Replay Attacks

- There are lots of situations where message contents should be processed only once
  - attackers will attempt to store and *replay* the message
- *Nonce* = integer value introduced into a message to demonstrate its "freshness"
  - can also be used as a *challenge* (value to be encrypted)

Nonces

- Ways to generate
  - sequence of integer values (sequence number)
  - read the clock at the sending machine (timestamp)
  - combination of both is best
- Used only once, and generated on demand
  - can tell if received previously (i.e., allows detection of replay attacks)
  - also allows bounding the lifetime of authentication information

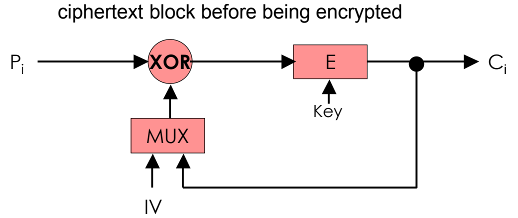
ENCRYPTION ALGORITHMS

Cipher Modes

- All ciphers work on blocks of data (i.e., data is "chunk"ed before processing)
- *Problem*: if a plaintext block appears twice in the input, same output ciphertext will appear twice
  - what's the harm in that?

Cipher Mode Approaches

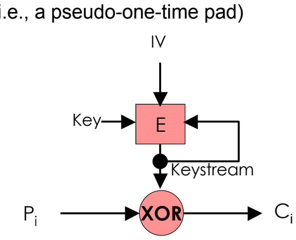
- *Solution 1*: Cipher Block Chaining (CBC)
  - each plaintext block is XOR'ed with previous ciphertext block before being encrypted



initialization vector, used for the first block only

Cipher Mode Approaches (cont'd)

- *Solution 2*: Stream Cipher Mode
  - initialization vector (IV) used to generate a sequence of output blocks
  - these blocks are XORed with plaintext to get ciphertext (i.e., a pseudo-one-time pad)



Symmetric Key Encryption

- Both parties (A and B) must share a single, *secret key*
  - exchange of this secret key must be done over secure (trusted) communications channel
  - a compromised key breaks the scheme
- The encryption and decryption functions can be identical, since the key used is secret

Symmetric Key Encryption (cont'd)

- Most important examples
  - DES – (1977), 56 bit key, not hard to break
  - Triple DES – (1979), 112 bit key, relatively strong
  - AES – (2001), 128 bits or 256 bits, very strong, efficient

Asymmetric (*Public-Key*) Encryption Algorithms

- Keys are generated in pairs
  1. public key K_1 (for encryption or decryption) – easily obtained by anyone
  2. private key K_2 (for decryption or encryption) – only known by one party
  3. $D_{K1}(E_{K2}(P)) = D_{K2}(E_{K1}(P)) = P$
- A "well-known" server stores the public keys, provides them on request

Public-Key Encryption Algorithms (cont'd)

- Must be very difficult to determine the private key from the public key
- Important examples
  - RSA – (1978), 1024 bits, very strong, based on difficulty of factoring
  - El Gamal – (1985), based on discrete logarithms
  - Elliptic curves - 1993

Public-Key Applications

- Application #1
  - anybody can encrypt a message for A, using A's public key
  - only A can decrypt these messages
- Application #2
  - only A can encrypt messages using A's private key
  - anybody can decrypt these messages, using A's public key

Comparison of Types of Cryptography

- Public key…
  - more general
  - uses stronger cryptography
  - provides stronger non-repudiation
- Shared key…
  - simpler, cheaper
  - more robust (less centralized)
  - executes faster
- Hybrid approach: use public key for negotiating, distributing secret keys
  - then use symmetric key encryption thereafter

DIGITAL SIGNATURES, MESSAGE DIGESTS, AND CERTIFICATES

Digital Signatures

- A *digital signature* is a piece of information attached by the creator of a message
- Purposes
  1. verify the claimed originator of a message is the real originator
  2. verify the message has not been subsequently altered by someone else
  3. make sure the message cannot be *repudiated* by the originator

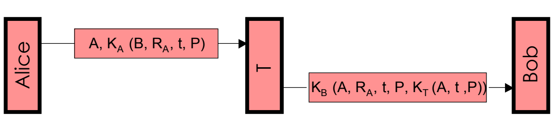
Digital Signatures (cont'd)

- Should be possible for any recipient of the message to verify the signature is valid
- Simplest approach: to each message, append a copy of the message contents, encrypted with the key of the originator
  - encrypted version proves identity of originator, and that message has not been tampered with

Signatures Based on Symmetric Keys

- Uses trusted third party
- Need to include nonce to prevent replay attacks
- Notation
  - A = Alice, B = Bob
  - T = Trusted (3rd party) Server
  - K_A = Encrypt with A's Key
  - R_A = Random # generated by A
  - t = timestamp
  - P = Plaintext

Signatures Based on Symmetric Keys (cont'd)

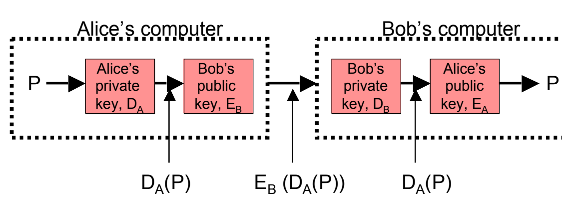


- Assumption: A and T share K_A,

  B and T share K_B, K_T

Signatures Based on Public Keys

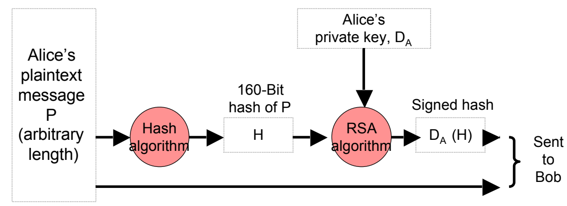
- Eliminates trust in third party, but requires method of distributing public keys



Message Digests

- Drawback of basic signatures = expense of encrypting the entire message
  - improvement: produce a *digest* of the message, encrypt just this digest
  - *digest* = a summary or secure *hash* of a message
  - less overhead (computing and communication)

Message Digest Example



Message Digests

- Desired properties
  1. easy to compute digest from message, but impossible to recover original message from the digest
  2. change of 1 bit of message produces very different digest, and very difficult to find two messages with same digest (*collisions*)

Message Digests (cont'd)

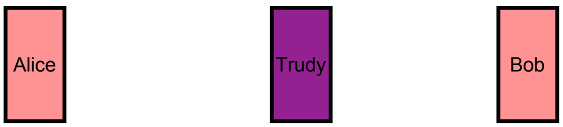
- Algorithms
  - MD5 – (1992), widely used, generates 128-bit digest (RFC 1321), breakable with some effort
  - SHA-1 – (1993), generates 160-bit digest, breakable?
- HMAC (RFC 2104)
  - message authentication code based on a secret key, can be used with any message digest method

CERTIFICATES

Certificates

- A *certificate* is a binding of key to an identity
  - signed by trusted party (e.g., certificate authority)
- Certificates are the means of learning public keys

Why Are Certificates Needed?



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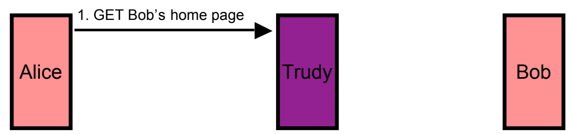

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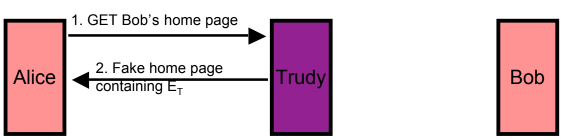

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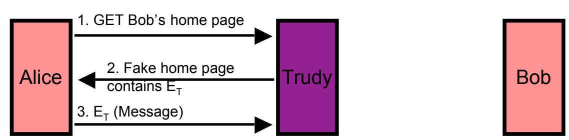

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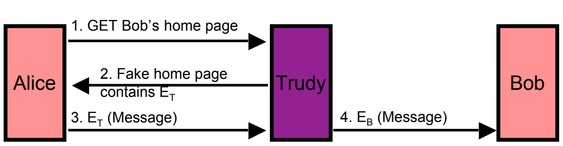
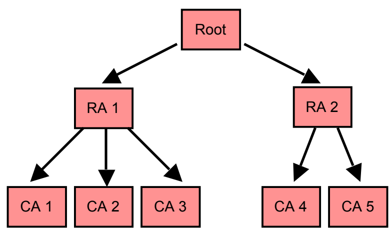


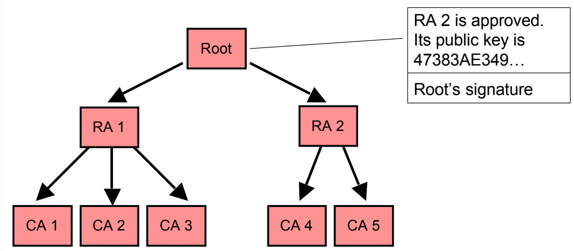
Certificate Hierarchy

- Public key infrastructure (PKI)
  - a hierarchy of certificate authorities
  - each level certifies keys of next level down in the hierarchy
- Basis of trust in certificate hierarchies: root servers
  - many root servers
  - web browsers are preloaded with identity of root servers that can be trusted

Certificate Hierarchy Example



Certificate Hierarchy Example (cont'd)



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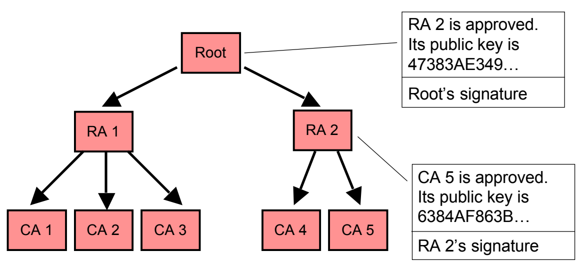


Certificate Revocation

- Keys may change or expire or be compromised
- "Revoking" a certificate is then required
- Example approach: publish *certificate revokation lists (CRLs)*
- Difficult problem, not completely solved

AUTHENTICATION PROTOCOLS

Authentication Protocols

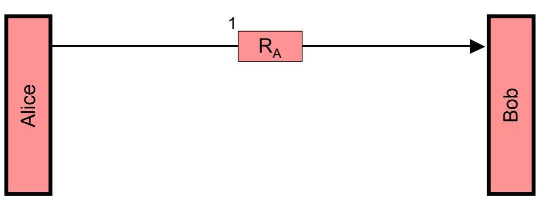
- *Authentication* = verifying identity of someone
- *Authorization* = granting access to resource based on identity

Authentication Based on Shared Secret Key

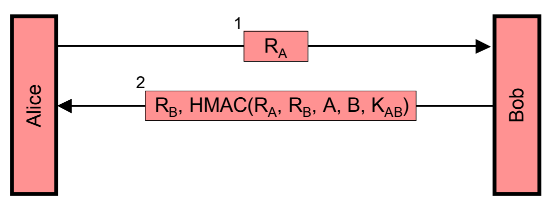
- "Challenge-Response" schemes
  1. send a challenge in encrypted form
  2. wait for expected response, also in encrypted form
- Notation
  - K_{AB} = Shared Key
  - R_A , R_B = random numbers generated by A, B

Authentication Based on Shared Secret Key (cont'd)

Authentication Based on Shared Secret Key (cont'd)



Authentication Based on Shared Secret Key (cont'd)



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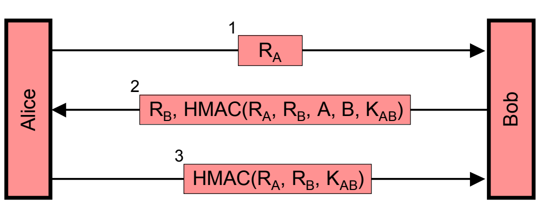
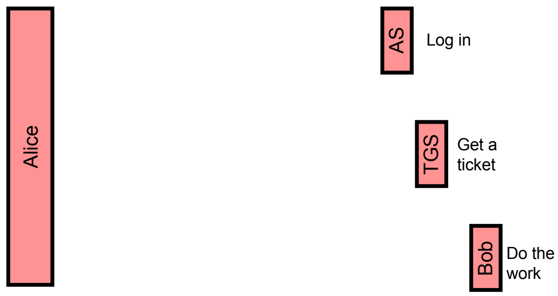


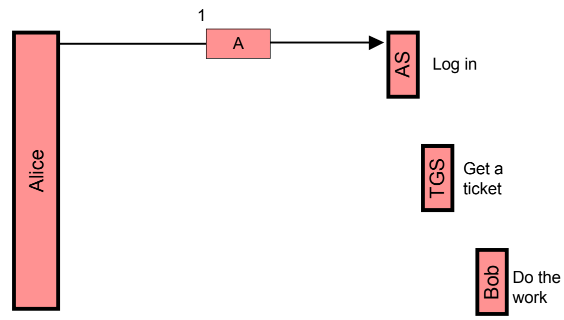
Authentication with Kerberos

- Two servers are needed
  - authentication server (AS) to verify user's identity
  - ticket-granting server (TGS) to issue "proof of identity" certificate
- *Result*: can securely access multiple servers without needing to exchange a password with each one
- Servers then determine what service to provide / allow to user, based on identity
- Password never transmitted across network

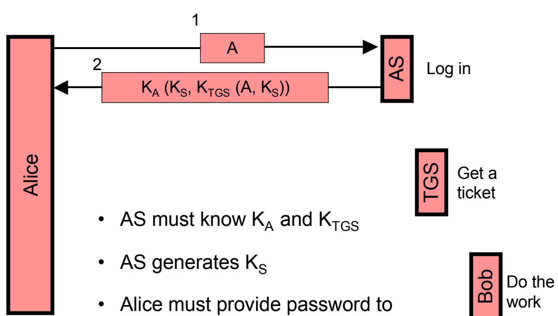
Kerberos Authentication



Kerberos Authentication (cont'd)

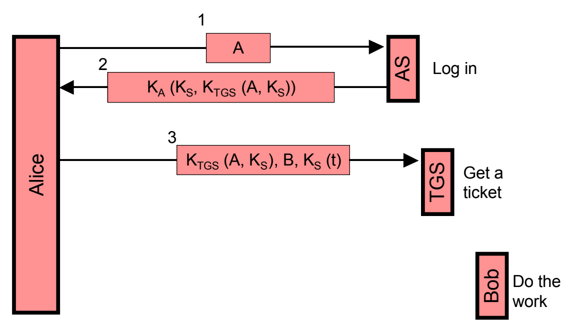


Kerberos Authentication (cont'd)



- AS must know K_A and K_{TGS}
- AS generates K_S
- Alice must provide password to decrypt message 2

Kerberos Authentication (cont'd)



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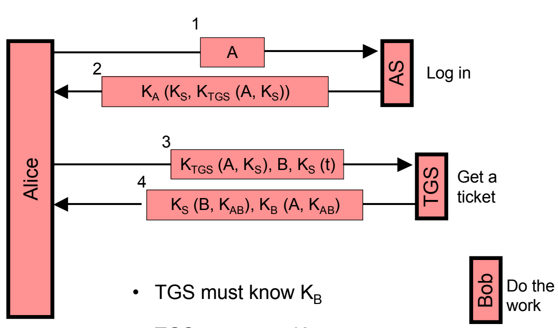
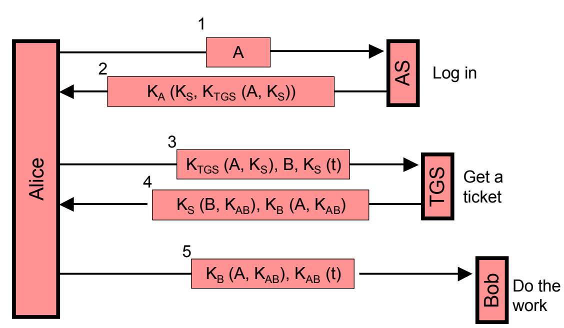
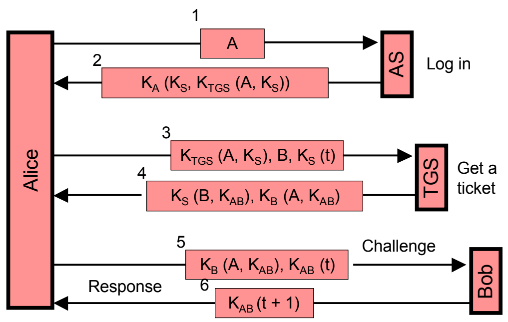


- TGS must know K_B
- TGS generates K_{AB}

Kerberos Authentication (cont'd)



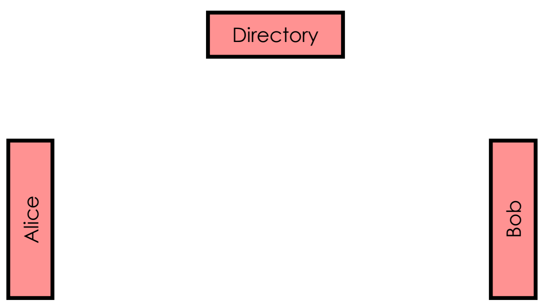
Kerberos Authentication (cont'd)



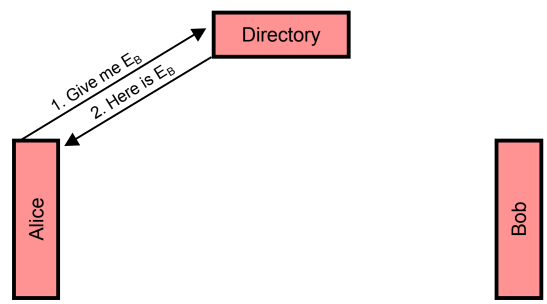
Public-Key Authentication

- Much easier
- Note: communication with directory must be authenticated

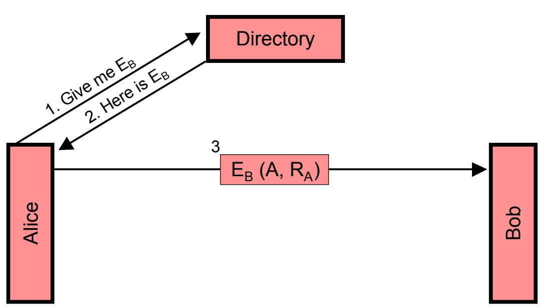
Public-Key Authentication (cont'd)



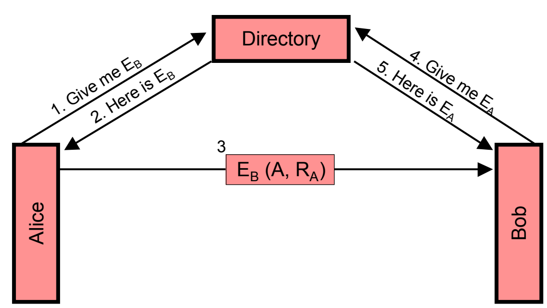
Public-Key Authentication (cont'd)



Public-Key Authentication (cont'd)



Public-Key Authentication (cont'd)



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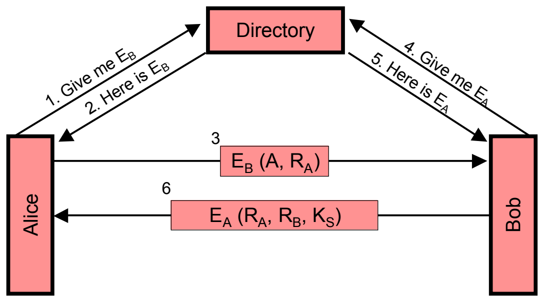

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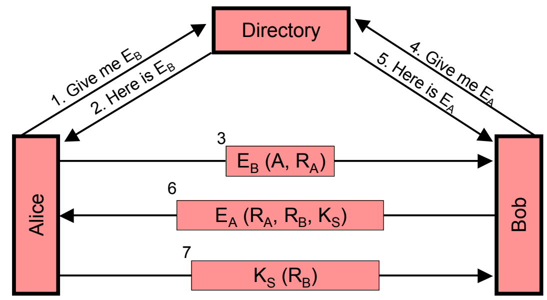

Summary

- Security is a high priority
  - protecting Internet protocols
  - using Internet protocols to provide secure communication
- There are two types of encryption
  1. symmetric key is more widely used and cheaper
  2. public key is more powerful
- Signatures are a means of verifying the origin and validity of messages

Summary (cont'd)

- Digests are hashes provide secure, low-cost signatures
- Certificates are a way to delegate trust
- Authentication protocols are surprisingly complex
  - most widely used = Kerberos

Next Lecture

- Tunneling, VPNs, and NAT