CS 556 – Computer Security
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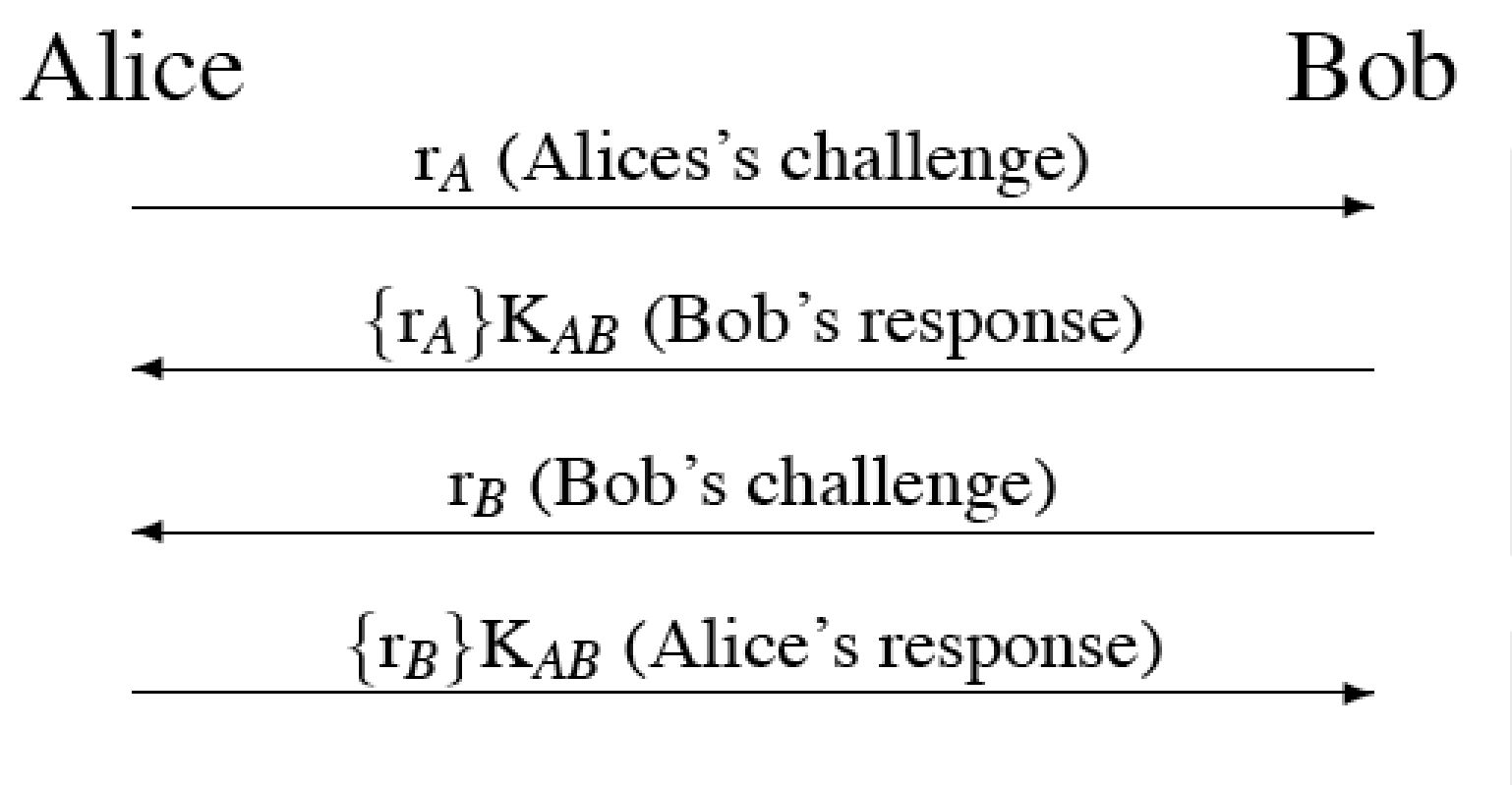
MUTUAL AUTHENTICATION

Mutual Authentication



Mutual Authentication

- Problem – How to share key
  - This is more critical than in the case of secret key based encryption schemes because authentication is a more fundamental issue
- Solution – Mediated Authentication
  - Secret key based – Needham-Schroeder and Kerberos
  - Public key based – X.509

Secret Key Based Mediated Authentication

Needham–Schroeder Protocol

- Mediated authentication and key exchange protocol based on trusted third party
  - R M Needham, M D Schroeder, "Using Encryption for Authentication in Large Networks of Computers", CACM, 21(12), Dec 1978, pp993-998
- After authentication communicating parties share a secret key that can be used in future secure exchanges

Needham-Schroeder Protocol

Message 1:	Alice $\rightarrow$ TP	A, B, N_A
Message 2:	TP $\rightarrow$ Alice	$\{N_A, B, K_{AB}, \{K_{AB}, A\}K_{BS}\}K_{AS}$
Message 3:	Alice $\rightarrow$ Bob	$\{K_{AB}, A\}K_{BS}$
Message 4:	Bob $\rightarrow$ Alice	$\{N_B\}K_{AB}$
Message 5:	Alice $\rightarrow$ Bob	$\{N_B - 1\}K_{AB}$

Protocol Analysis

- Problem – suffers from replay attack
  - Message 3 can be subject to replay attack with an old compromised session key by an active attacker
- Solutions
  - Include a timestamp in messages 1 to 3, which requires synchronised clocks
  - Have Alice ask Bob for a random value J_B to be sent to S for return in $\{K_{AB}, A, J_B\}K_{BS}$

Kerberos

Kerberos – Improved Needham-Schroeder

- Designed as part of Project Athena at MIT
- Provides the means of authenticating workstation users (clients) to server and sharing a session key
- Uses the ticket approach
  - Client authenticates itself to an authentication server
  - Authentication Server gives ticket to client
  - Client uses ticket to get authenticated

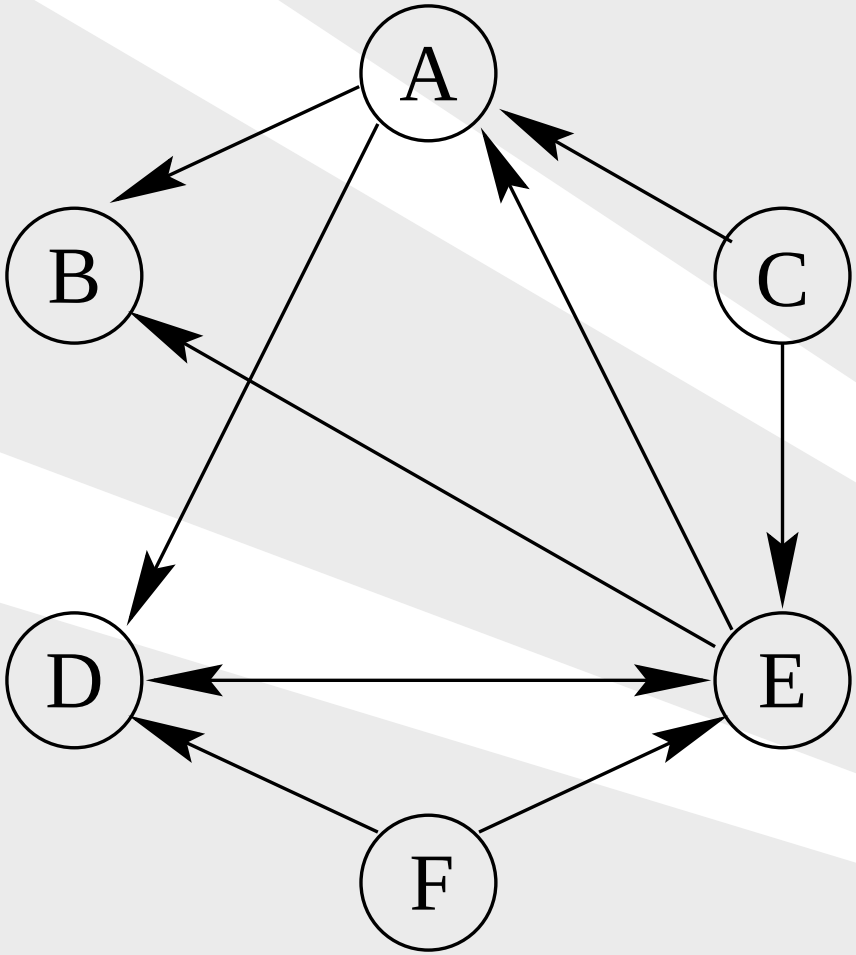
Kerberos (continued)

- Access control may be provided for
  - Each computing resource
  - In either local or remote network (realm)
- Has a Key Distribution Center (KDC) – or Kerberos Server – containing
  - A database of principals (clients and services)
  - Secret encryption keys for these shared with KDC

Physical Security

- Client Workstations
  - None, so cannot be trusted
- Servers
  - Moderately secure rooms with moderately dilligent administration
- Kerberos
  - Highly secure room with extremely diligent system administration

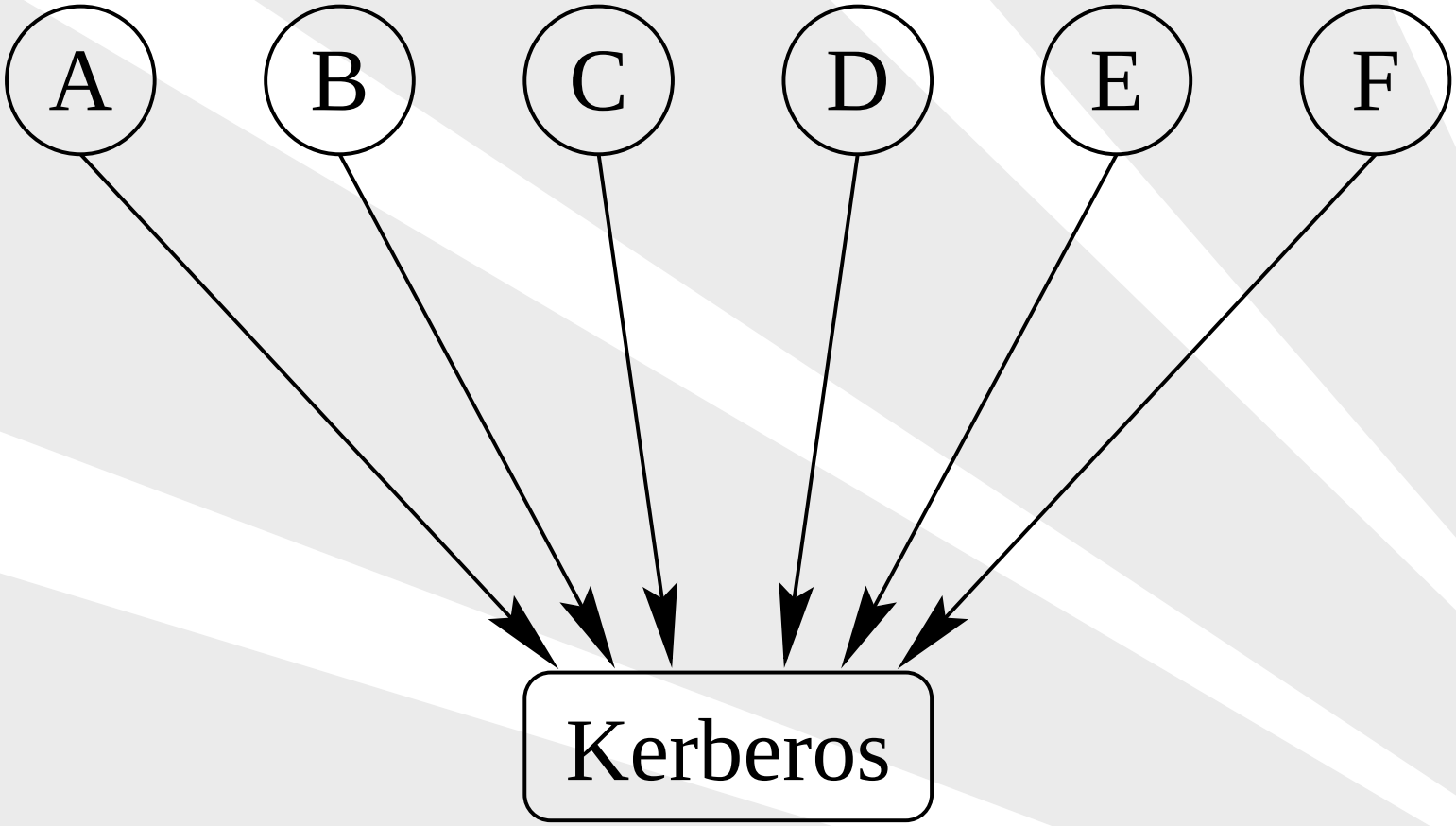
Trust – Bilateral RHOSTS Model



A $\longrightarrow$ B

A trusts B
A will allow users looged on to B to log on to A without a password

Trust – Consolidated Kerberos Model



Trust – Consolidated Kerberos Model

- Breaking into one host provides a cracker no advantage in breaking into other hosts
- Authentication systems can be viewed as trust propagation systems
  - The Rhosts model is a tangled web model
  - The Kerberos model is a centralized star model

What Kerberos Does Not Do

- Makes no sense on an isolated system
- Does not mean that host security can be allowed to slip
- Does not protect against Trojan Horses
- Does not protect against viruses/worms

Kerberos Design Goals

- Impeccability
  - No cleartext passwords on the network
  - No client passwords on servers (server though must store secret server key)
  - Minimum exposure of client key on workstations
- Containment
  - Compromise affects only one client (or server)
  - Limited authentication lifetime (8 hours, 24 hours or more)

Kerberos Design Goals (continued)

- Transparency
  - Password required only at login
  - Minimum modification to existing applications

Kerberos Design Decisions

- Uses timestamps to avoid replays
  - Requires time synchronized within a small window (5 minutes)
- Uses DES-based symmetric key cryptography
- Stateless

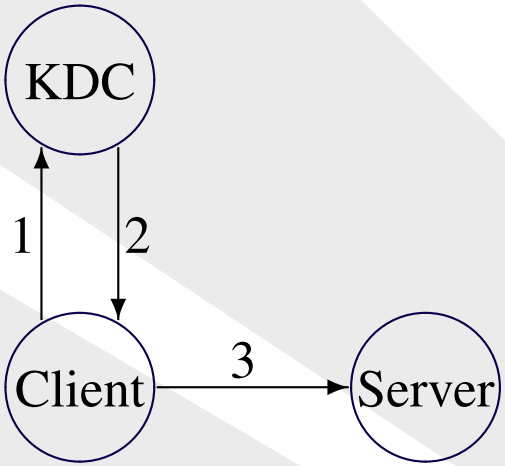
Notation

Symbol used	What it means
c	client principal
s	server principal
KDC	Kerberos server
TGS	Ticket granting server
K_x	private key of x
$K_{c,s}$	session key for c & s
$\{info\}K_x$	string info encrypted in K_x
$T_{c,s}$	ticket for c to use s
A_c	authenticator for c
addr	client's IP address

Notation (continued)

Message in network	Structure of message
$T_{c,s}$ – ticket for c to use s	$\{s,c,addr,timestamp,lifetime,K_{c,s}\}$
A_c – authenticator for c	$\{c,addr,timestamp\}$

Session Key Distribution



1. Client $\rightarrow$ KDC: c, s, n
2. KDC $\rightarrow$ Client: $\{K_{c,s}, n, T_{c,s}\}K_c$
3. Client $\rightarrow$ Server: $A_c, T_{c,s}$

User Authentication

- For user to server authentication, client key is the user's password, converted to a DES Key via a publicly known algorithm

Trust In Workstation

- Untrusted client workstation has K_c
- Workstation is expected to delete it after decrypting message in step 2
- Compromised workstation can compromise one user
- Compromise does not propagate to other users

Authentication Failures

- Ticket decryption by server yields garbage
- Ticket timed out
- Wrong source IP address
- Replay attempt

Kerberos Impersonation

- Active intruder on the network can cause denial of service by impersonation of Kerberos IP address
- Network monitoring at multiple points can help detect such an attack by observing IP impersonation

Kerberos Reliability

- Availability enhanced by keeping slave Kerberos servers with replicas of the Kerberos database
- Slave databases are read only
- Simple propagation of updates from master to slaves ensure consistency

Use of the Session Key

- Kerberos establishes a session key $K_{c,s}$
- Session key can be used by the applications for
  - Client to server authentication (no additional step required in the protocol)
  - Mutual authentication (requires fourth message from server to client $\{f(A_c)\}K_{c,s}$, where f is some publicly known function)
  - Message confidentiality using $K_{c,s}$
  - Message integrity using $K_{c,s}$

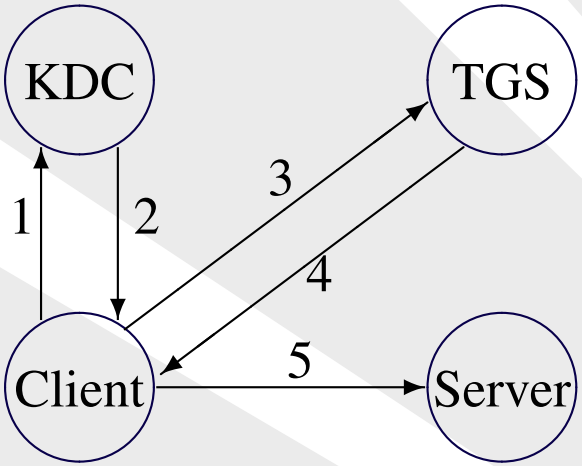
Ticket Granting Service – Why?

- Problem: Transparency
  - User should provide password once upon initial login and should not be asked for it on every service request
- Solution: Ticket Granting Service
  - Store session key on workstation in lieu of password

Ticket Granting Service

- Kerberos server authenticates client and provides an initial ticket
- K_c deleted from workstation after this exchange (have to trust the workstation)
- Client submits the initial ticket to a Ticket Granting server to get a ticket for a particular service

Getting a Service Ticket



1. Client $\rightarrow$ KDC: c, tgs, n
2. KDC $\rightarrow$ Client: $\{K_{c,tgs}, n, \{T_{c,tgs}\}K_{tgs}\}K_c$
3. Client $\rightarrow$ TGS: $\{A_c\}K_{c,tgs}, \{T_{c,tgs}\}K_{tgs}, s, n$
4. TGS $\rightarrow$ Client: $\{K_{c,s}, n, \{T_{c,s}\}K_s\}K_{c,tgs}$
5. Client $\rightarrow$ Server: $\{A_c\}K_{c,s}, \{T_{c,s}\}K_s$

Ticket Lifetime

- Lifetime is minimum of
  - Requested lifetime
  - Maximum lifetime for requesting principal
  - Maximum lifetime for requesting service
  - Maximum lifetime of ticket granting ticket
- Maximum lifetime is 21.5 hours

Kerberos Naming

- Users and servers have same name format:
  - `name.instance@realm`
- Mapping of Kerberos authentication names to local system names is left up to the service provider

Kerberos V5 Enhancements

- Naming
  - Kerberos V5 supports V4 names, but also provides for other naming structures such as X.500
- Timestamps
  - V4 timestamps are Unix timestamps (seconds since 1/1/1970). V5 timestamps are in OSI ASN.1 format

Kerberos V5 Enhancements

- Ticket lifetime
  - V4 tickets valid from time of issue to expiry time, and limited to 21.5 hours
  - V5 tickets have start and end timestamps; maximum lifetime can be set by realm
- V5 tickets are renewable, so service can be maintained beyond maximum ticket lifetime

V5 Ticket Renewal

- Tickets can be renewed until minimum of:
  - Requested end time
  - Start time + requesting principal's maximum renewable lifetime
  - Start time + requested server's maximum renewable lifetime
  - Start time + maximum renewable lifetime of realm

Kerberos V5 Preauthentication

- In Kerberos V4 anybody can request a TGT for any user
  - TGT is encrypted with user's secret key (password)
  - Perform an offline attack on TGT by trying to decrypt it with different passwords
- Kerberos V5 introduces preauthentication to make sure only the true user requests TGT
  - Simplest preauthentication involves user encrypting a timestamp with her secret key. If server is able to decrypt message and get timestamp within a window, preauthentication is successful.
  - Other types of preauthentication protocols also possible

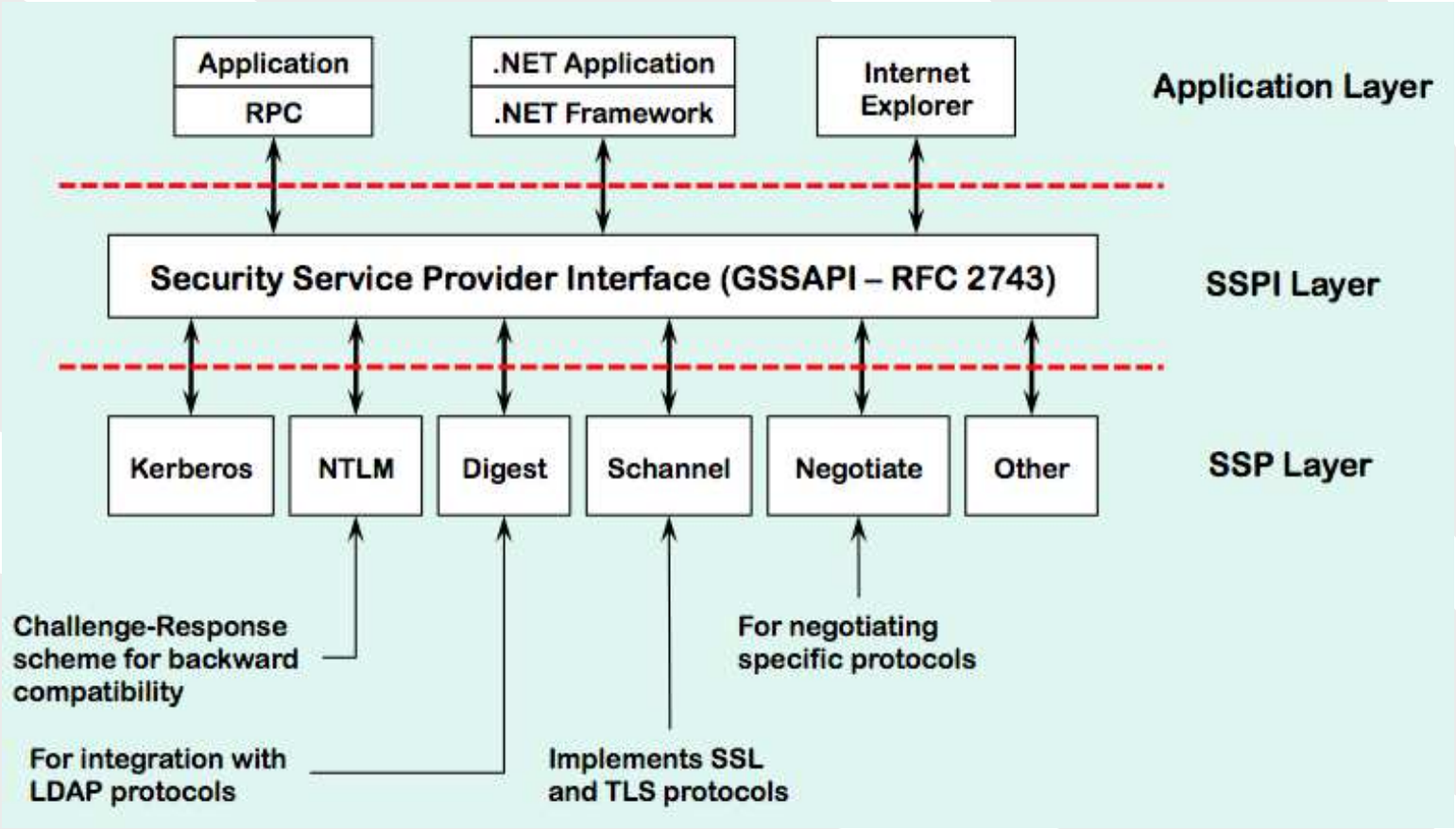
Kerberos in Practice

- Kerberos server needs to be secured and on-line
  - Server compromise is a major source of vulnerability
- Currently two Kerberos versions
  - V4: restricted to single realm
  - V5: allows inter-realm authentication

MS Windows Authentication

- Based on Kerberos V5
  - 128 bit RC4-HMAC
  - 56 bit DES-CBC-CRC
  - 56 bit DES-CBC-MD5
- Has extensions for using public-key certificates

Windows SSPI Architecture



Certificate-Based Mutual Authentication Protocols

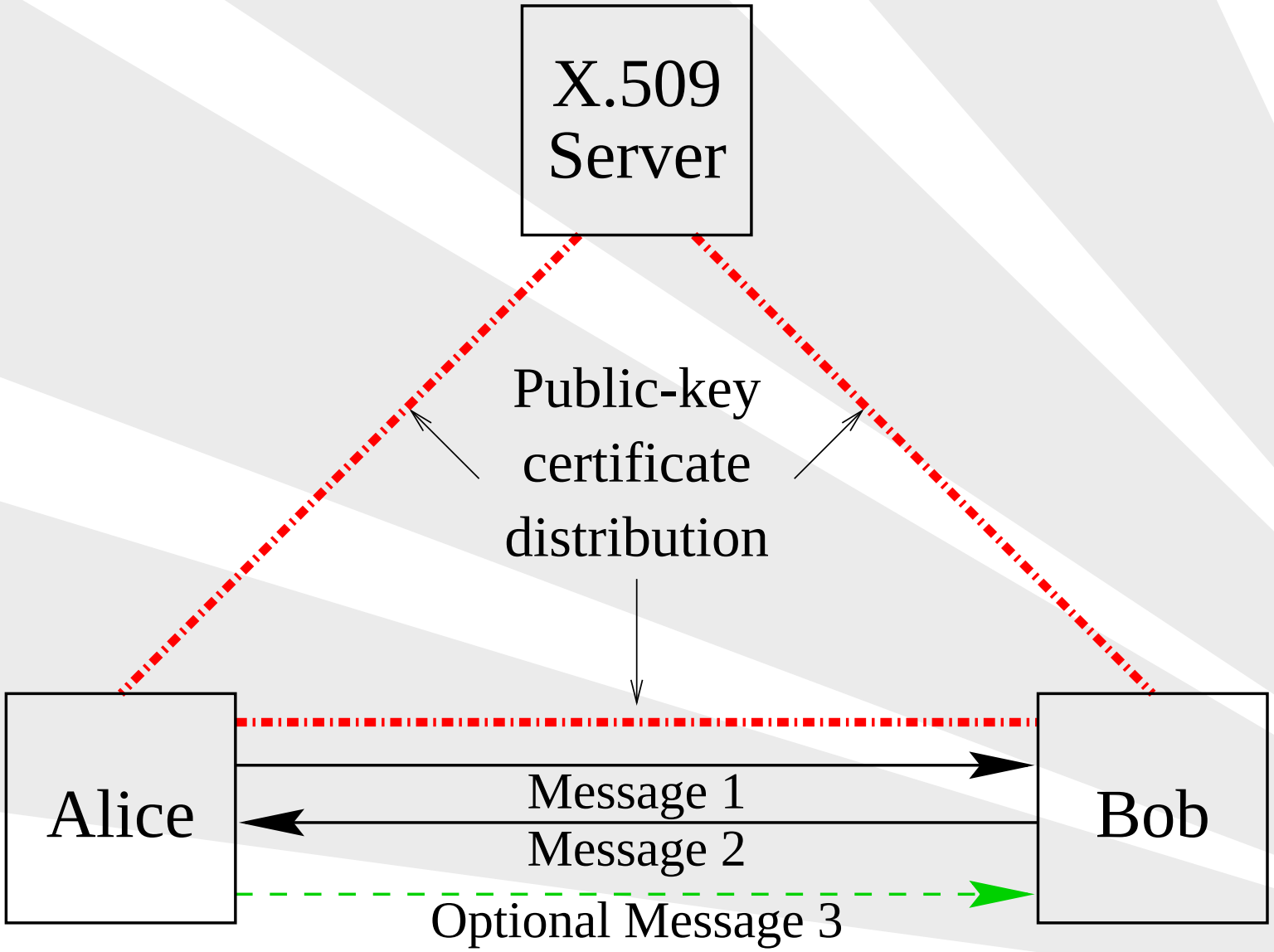
X.509 – Directory Authentication Service

- Part of CCITT X.500 directory services
- Defines framework for authentication services
- Directory may store public-key certificates
- Uses public-key cryptography and digital signatures
- Algorithms not standardised but RSA is recommended
- Does not require physically secured on-line servers – Advantage over Kerberos

Symbols Used

- $E_x\{\}$: indicates encryption of a sequence of data values under the public key of party x
- $S_x\{\}$: indicates a sequence of data values together with a signature over those values, using the private key of party x
- ts_{xy}: a current time-stamp generated by party x to assist party y in detecting replayed messages (may contain both generation and expiry date/time for the message conveying it)
- nrv_{xy}: a non-repeating value sent by party x to assist party y in detecting replayed messages
- key_{xy} a secret key generated by x to be used in protecting subsequent communications between x and y

X.509 Authentication Exchange



X.509 Authentication Exchange

Message 1:

$$A,\ S_A\{ts_{AB},\ nrv_{AB},\ B,\ E_B\{key_{AB}\}\}$$

- The field $E_B\{key_{AB}\}$ is optional
- B verifies A's signature, checks that the identifier B in the message is correct, checks that the time-stamp is current and (optionally if an effective non-repeating value procedure is in use) checks the non-repeating value as protection against replay

X.509 Authentication Exchange

Message 2:

$$S_B\{ts_{BA},\ nrv_{BA},\ A,\ nrv_{AB},\ E_A\{key_{BA}\}\}$$

- The field $E_A\{key_{BA}\}$ is optional
- A performs the correspondinng set of actions

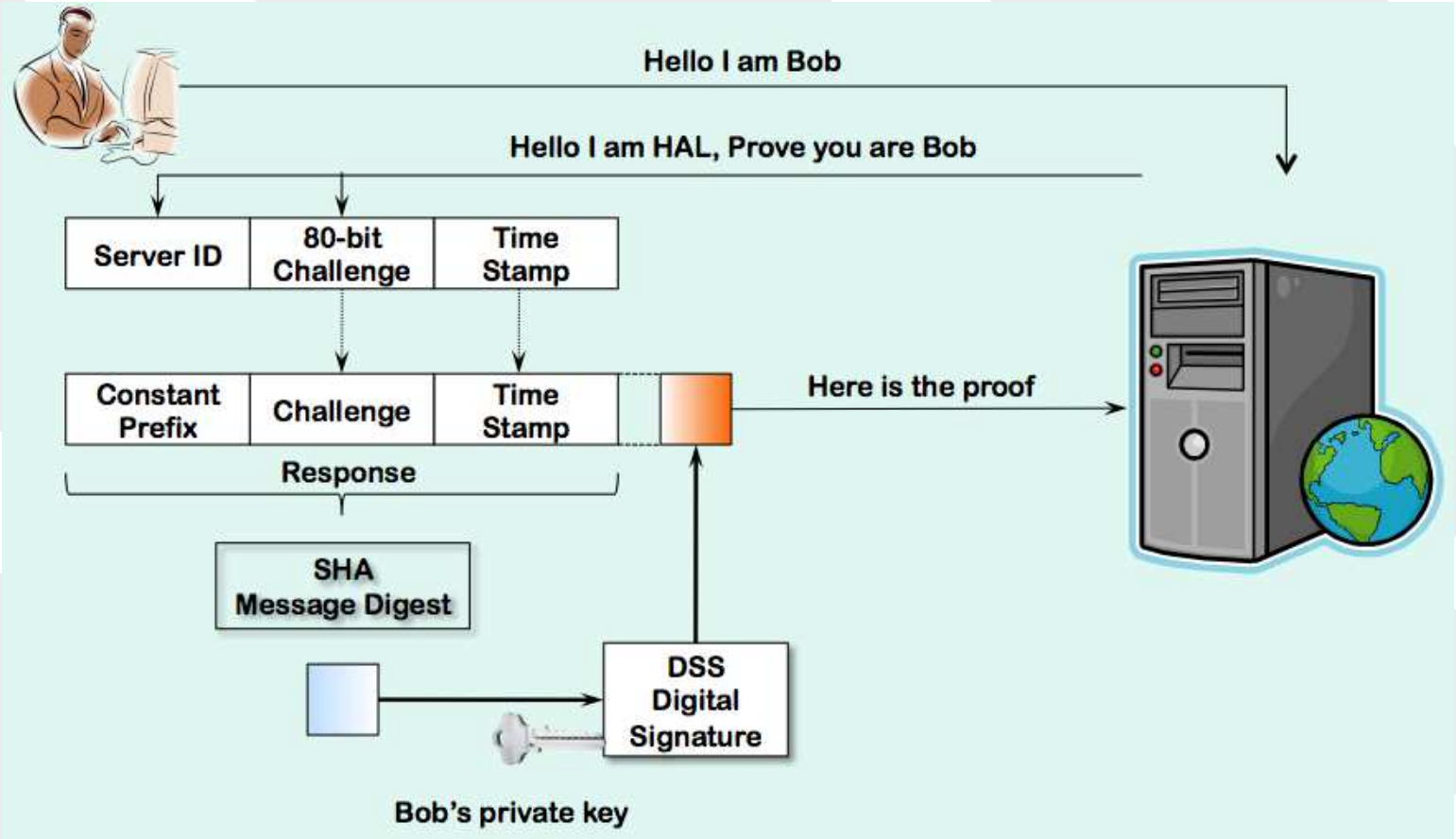
Optional Message 3: The first two messages are identical except that the time-stamps are not conveyed. The third message is

$$S_A\{B,\ nrv_{BA}\}$$

LOCKOut Fortezza Authentication Protocol

- Fortezza is a PCMCIA card developed by the NSA to provide general purpose cryptographic capabilities
  - Has built in implementation for SHA and DSS among other features
  - Tamper evident
- Computes hash functions and digital signatures for authentication

LOCKOut Fortezza Authentication



Authenticated Diffie-Hellman

- Three way authentication exchange that combines public-key based mutual authentication with a Diffie-Hellman key derivation exchange
- Has an advantage over Kerberos and X.509 in that compromise of a signature key will not compromise the secrecy of the session key derived previously in conjunction with the authentication

Authenticated Diffie-Hellman