Distributed Systems

Authentication Protocols

Authentication

- Establish and verify identity
  - allow access to resources

Authentication

Three factors:

- something you have *key, card*
  - can be stolen
- something you know *passwords*
  - can be guessed, shared, stolen
- something you are *biometrics*
  - costly, can be copied (sometimes)

Authentication

factors may be combined

- ATM machine: 2-factor authentication
  - ATM card *something you have*
  - PIN *something you know*

Reusable passwords

- Keep a database of username:password mappings
- Prompt for a user name & password
- Look up the corresponding password in a database (file) to authenticate

```
if (supplied_password == retrieved_password)
    user is authenticated
```

- This is also known as the Password Authentication Protocol (PAP)

Reusable passwords

One problem: what if the password file isn't sufficiently protected and an intruder gets hold of it, he gets all the passwords!

Enhancement:

Store a hash of the password in a file

- given a file, you don't get the passwords
- have to resort to a dictionary or brute-force attack

Reusable passwords

Passwords can be stolen by observing a user's session over the network:

- snoop on telnet, ftp, rlogin, rsh sessions
- Trojan horse
- social engineering
- brute-force or dictionary attacks

One-time password

Different password used each time

- generate a list of passwords

or:

- use an authentication card

Skey authentication

- One-time password scheme
- Produces a limited number of authentication sessions
- relies on one-way functions

Skey authentication

Authenticate Alice for 100 logins

- pick random number, R
- using a one-way function, f(x):

$$
\begin{aligned}
x_1 &= f(R)\\
x_2 &= f(x_1) = f(f(R))\\
x_3 &= f(x_2) = f(f(f(R)))\\
&\dots \qquad \dots\\
x_{100} &= f(x_{99}) = f(\dots f(f(f(R)))\dots)
\end{aligned}
$$

give this list to Alice

- then compute:

$$x_{101} = f(x_{100}) = f(\dots f(f(f(R)))\dots)$$

Skey authentication

Authenticate Alice for 100 logins

store x_{101} in a password file or database record associated with Alice

alice: x_{101}

Skey authentication

Alice presents the *last* number on her list:

Alice to host: { “alice”, x_{100} }

Host computes $f(x_{100})$ and compares it with the value in the database

```
if  ($x_{100}$ provided by alice) = passwd(“alice”)
    replace $x_{101}$ in db with $x_{100}$ provided by alice
    return success
else
    fail
```

next time: Alice presents x_{99}

if someone sees x_{100} there is no way to generate x_{99}.

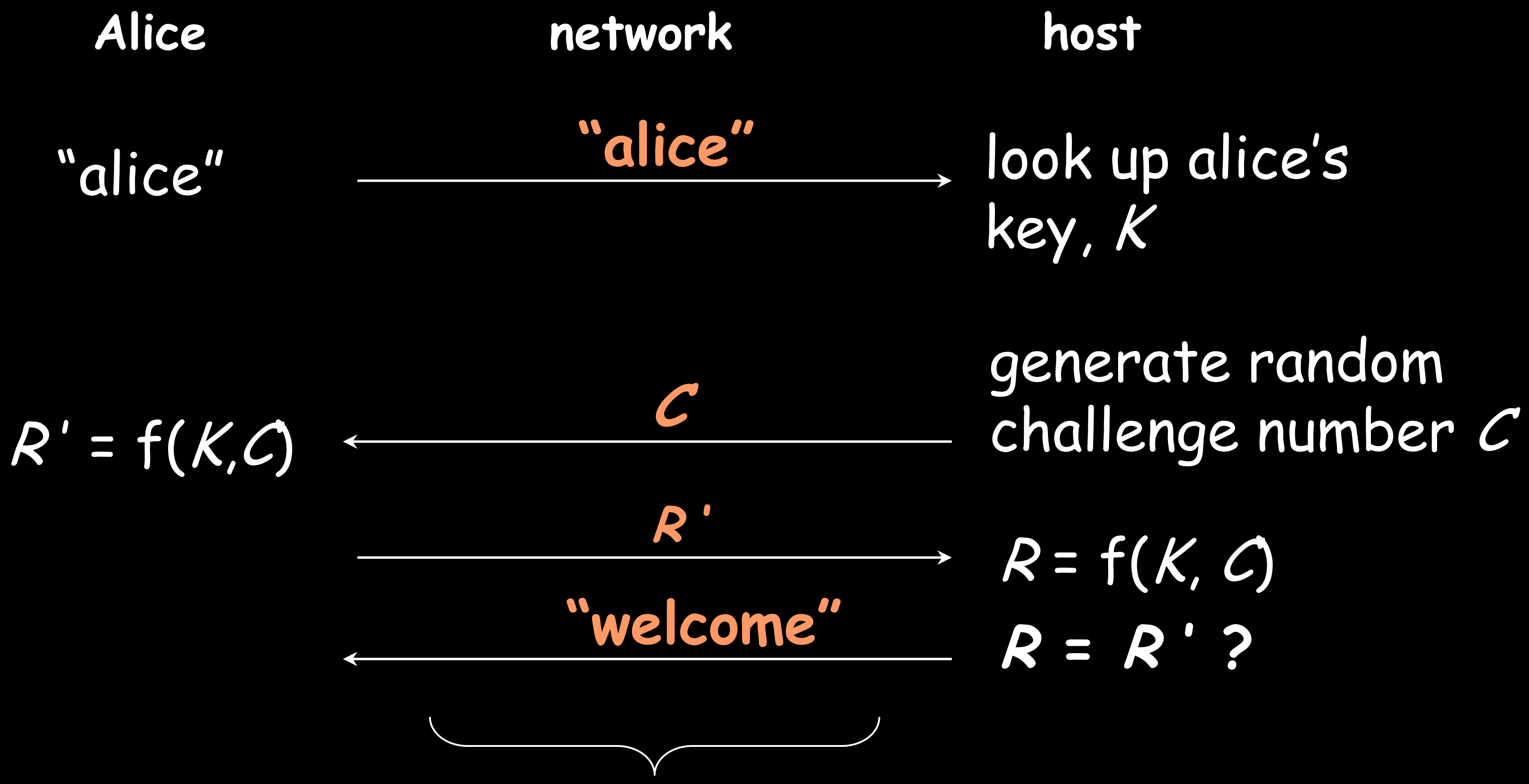
Two-factor authentication with an authenticator card

Challenge/response authentication

- user provided with a challenge number from host
- enter challenge number to challenge/response unit
- enter PIN
- get response: f(PIN, challenge)
- transcribe response back to host

- **host maintains PIN**
  - computes the same function
  - compares data
- **rely on one-way function**

Challenge-Response authentication



Alice | **network** | **host**

"alice" → **"alice"** → look up alice's key, K

generate random challenge number C

$R' = f(K,C)$ ← $\mathbf{C}$ ←

→ $\mathbf{R'}$ → $R = f(K, C)$

← **"welcome"** ← $\mathbf{R = R'}$ **?**

an eavesdropper does not see K

SecurID card

Username:

paul

Password:

1234032848

PIN + passcode from card

Something you know

Something you have

Passcode changes every 60 seconds

1. Enter PIN
2. Press ◊
3. Card computes password
4. Read off password

Password:

354982

SecurID card

- from RSA, SASL mechanism: RFC 2808
- Compute: AES-hash on:
  - 128-bit token-specific seed
  - 64-bit ISO representation of time of day (Y:M:D:H:M:S)
  - 32-bit serial number of token
  - 32-bits of padding
- Server computes three hashes with different clock values to account for drift.

SecurID

Vulnerable to man-in-the-middle attacks

  - attacker acts as application server
  - user does not have a chance to authenticate server

SKID2/SKID3 authentication

- uses symmetric cryptography
  - shared secret key
- generate a random token
  - ***nonce***
- give it to the other party, which encrypts it
  - returns encrypted result
- verify that the other party knows the secret key

SKID2/SKID3 authentication

Alice chooses a random number (nonce) R_A and sends it to Bob

$\boxed{R_A} \longrightarrow$ Bob

SKID2/SKID3 authentication

$\boxed{R_A} \longrightarrow$ Bob

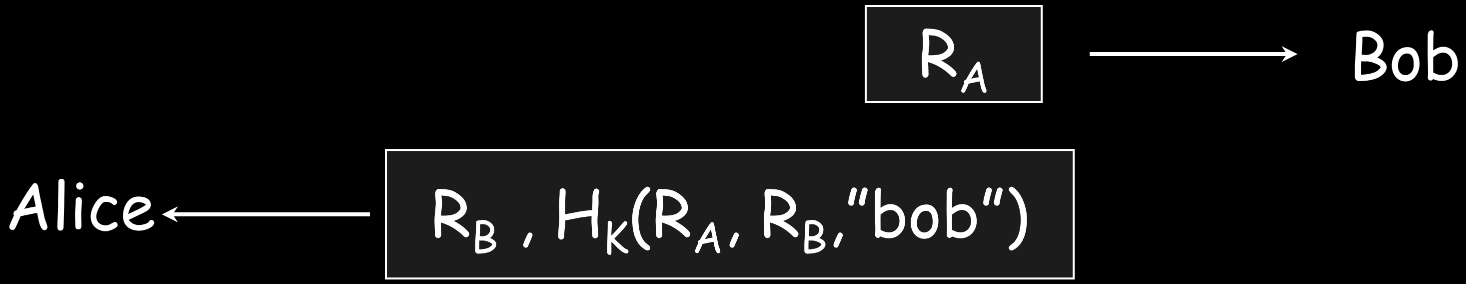
Bob chooses a random number (nonce): R_B.

He computes $H_K(R_A, R_B, \text{"bob"})$ and sends it to Alice with R_B

Alice $\longleftarrow \boxed{R_B\ , \underbrace{H_K(R_A, R_B, \text{"bob"})}}$

Bob shows that he can encrypt Alice's nonce

SKID2/SKID3 authentication



R_A → Bob

Alice ← R_B , $H_K(R_A, R_B, \text{“bob”})$

Alice receives R_B and has R_A.
Computes: $H_K(R_A, R_B, \text{“bob”})$

compares result to verify that Bob was able to encrypt data with key K.

Authentication is complete as far as Alice is concerned (Bob knows the key).

SKID2/SKID3 authentication

R_A ⟶ Bob

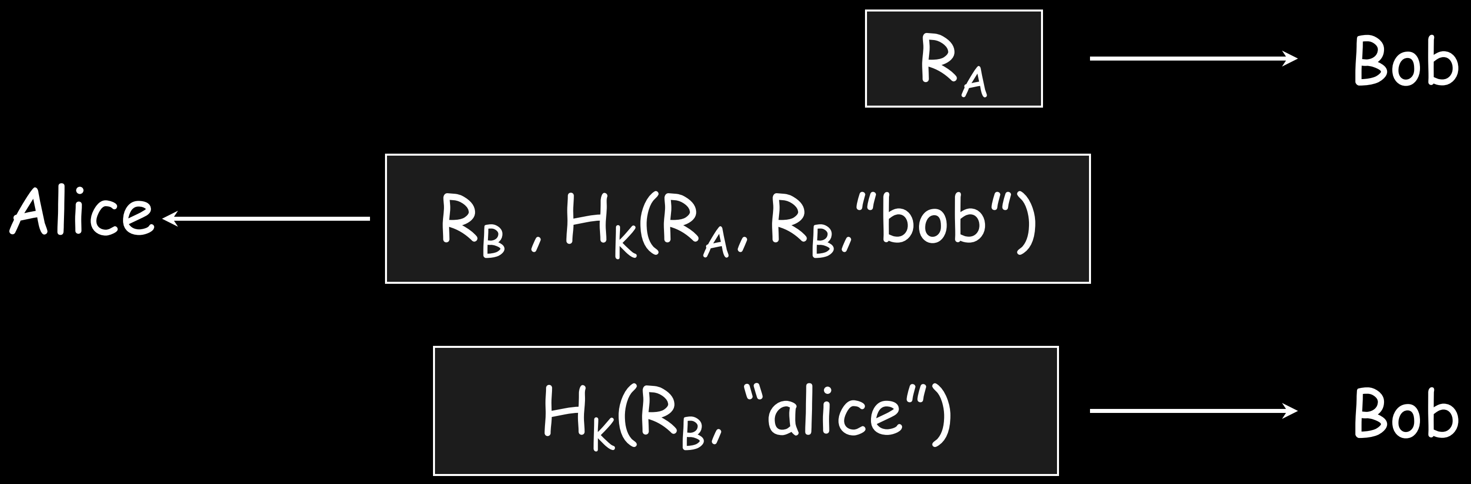
Alice ⟵ R_B , $H_K(R_A, R_B, \text{“bob”})$

Now Alice has to convince Bob (mutual authentication)

$H_K(R_B, \text{“alice”})$ ⟶ Bob

Alice demonstrates that she can encrypt Bob’s nonce

SKID2/SKID3 authentication

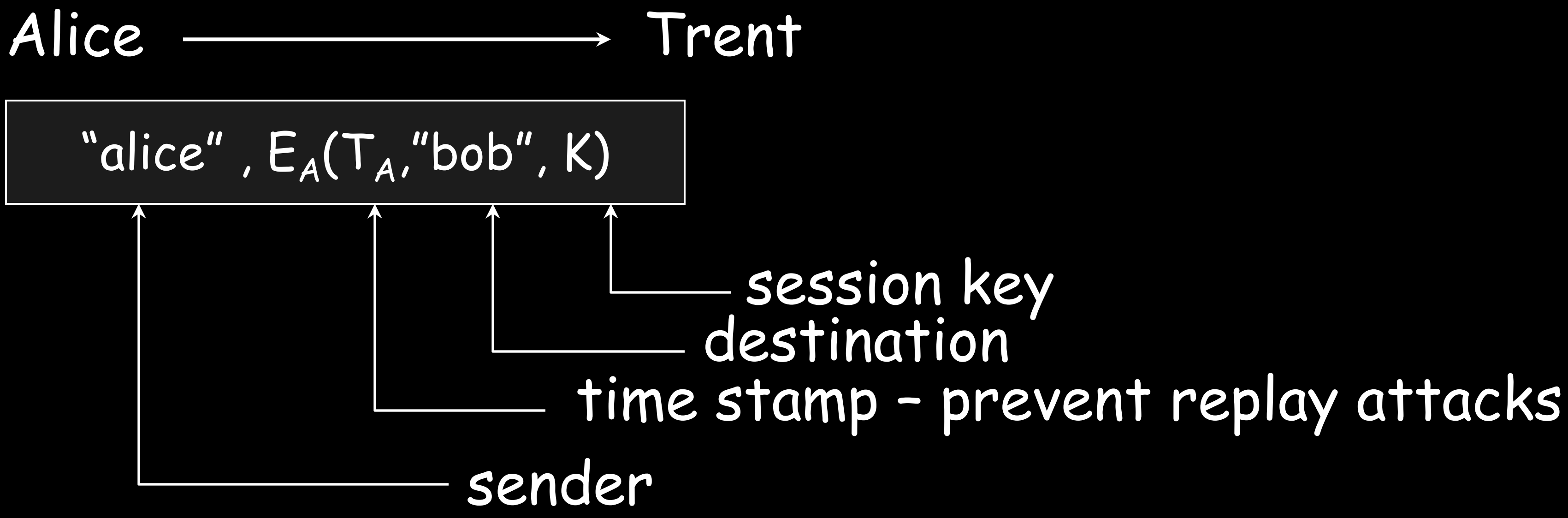


Bob computes $H_K(R_B,$ "alice") and compares Alice's message. If they match, he trusts Alice's identity

Key point: Each party permutes data generated by the other. Challenge the other party with data that will be different each time.

Combined authentication and key exchange

Wide-mouth frog



Alice → Trent

“alice” , $E_A(T_A,$“bob”, $K)$

session key

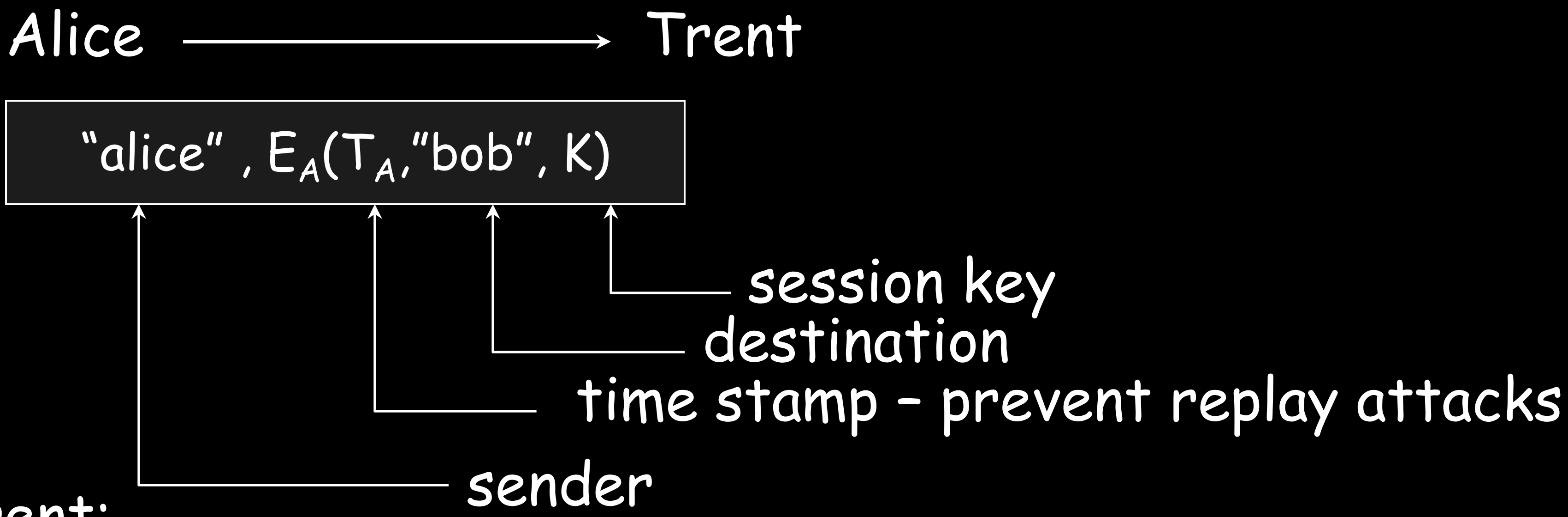
destination

time stamp – prevent replay attacks

sender

- arbitrated protocol – Trent (3rd party) has all the keys
- symmetric encryption for transmitting a **session key**

Wide-mouth frog



Alice → Trent

“alice” , $E_A(T_A,$“bob”, $K)$

session key

destination

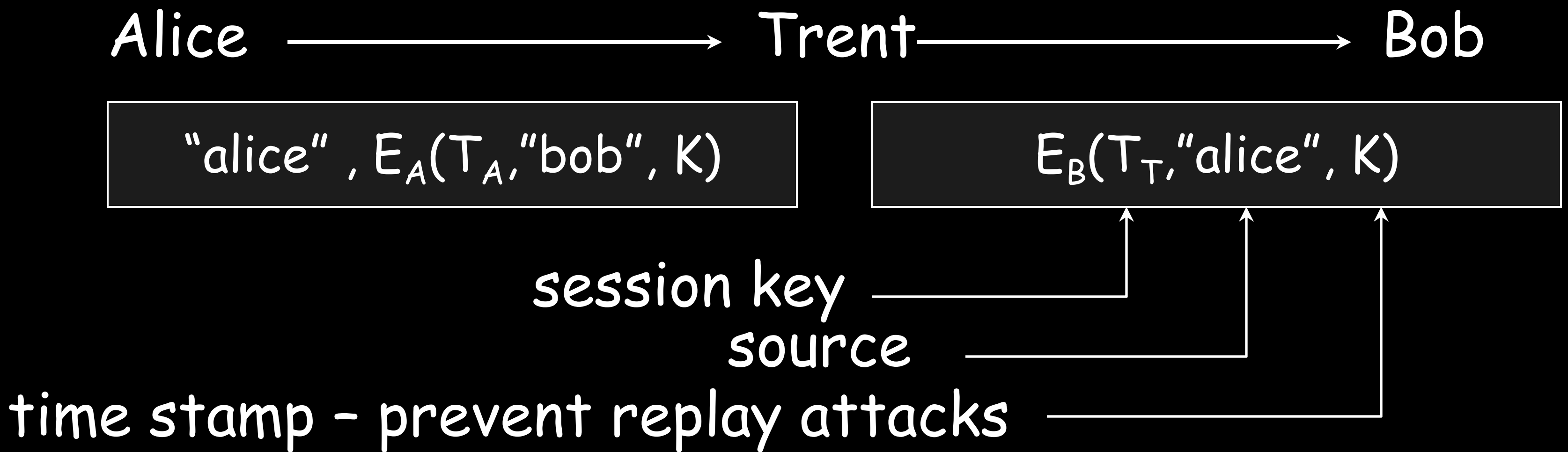
time stamp – prevent replay attacks

sender

Trent:

- looks up key corresponding to sender (“alice”)
- decrypts remainder of message using Alice’s key
- validates timestamp (this is a new message)
- extracts destination (“bob”)
- looks up Bob’s key

Wide-mouth frog



Alice → Trent → Bob

"alice" , $E_A(T_A, \text{"bob"}, K)$

$E_B(T_T, \text{"alice"}, K)$

session key

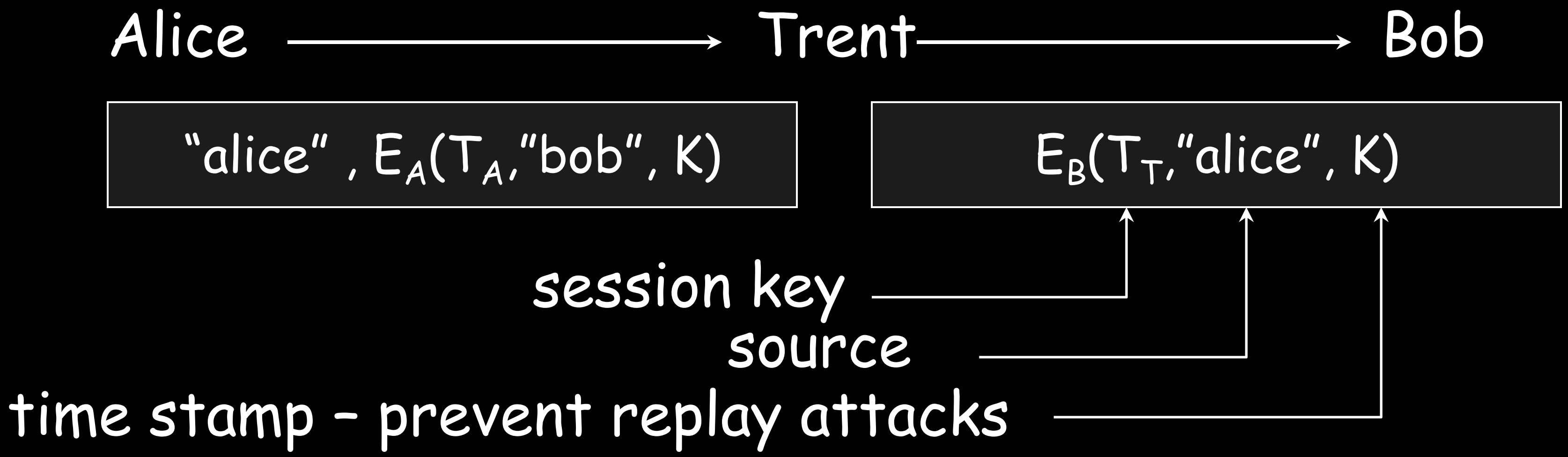
source

time stamp – prevent replay attacks

Trent:

- creates a new message
- new timestamp
- identify source of the session key
- encrypt the message for Bob
- send to Bob

Wide-mouth frog



Alice → Trent → Bob

"alice" , $E_A(T_A, \text{"bob"}, K)$

$E_B(T_T, \text{"alice"}, K)$

session key

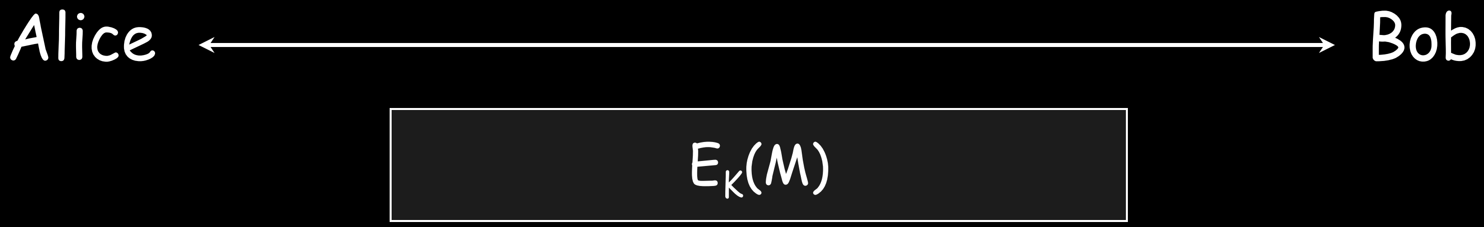
source

time stamp – prevent replay attacks

<u>Bob:</u>

- decrypts message
- validates timestamp
- extracts sender ("alice")
- extracts session key, K

Wide-mouth frog



Alice

Bob

$E_K(M)$

Since Bob and Alice have the session key, they can communicate securely using the key

Kerberos

- authentication service developed by MIT
  - project Athena 1983-1988
- trusted third party
- symmetric cryptography
- passwords not sent in clear text
  - assumes only the network can be compromised

Kerberos

Users and services authenticate themselves to each other

To access a service:

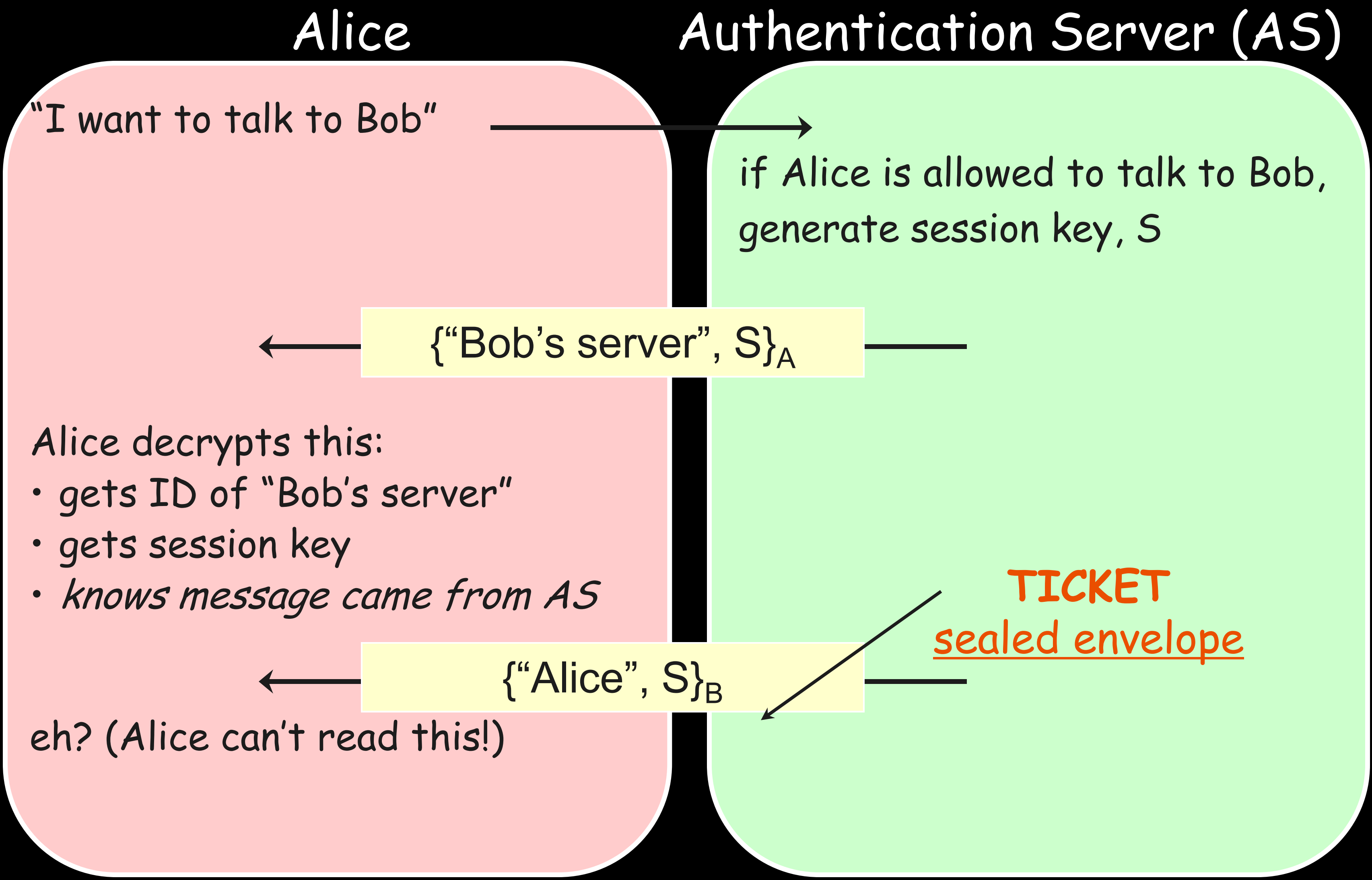
- user presents a ticket issued by the Kerberos authentication server
- service examines the ticket to verify the identity of the user

Kerberos

- user *Alice* wants to communicate with a service *Bob*
- both Alice and Bob have keys

- Step 1:
  - Alice authenticates with Kerberos server
    - Gets session key and ***sealed envelope***
- Step 2:
  - Alice gives Bob a session key (securely)
  - Convinces Bob that she also got the session key from Kerberos

Authenticate, get permission



Alice

Authentication Server (AS)

"I want to talk to Bob"

if Alice is allowed to talk to Bob, generate session key, S

$\{\text{“Bob’s server”}, S\}_A$

Alice decrypts this:

- gets ID of "Bob's server"
- gets session key
- *knows message came from AS*

TICKET

sealed envelope

$\{\text{“Alice”}, S\}_B$

eh? (Alice can't read this!)

Send key

Alice

Alice encrypts a timestamp with session key

$\{\text{"Alice"}, S\}_B, T_S$

sealed envelope

Bob

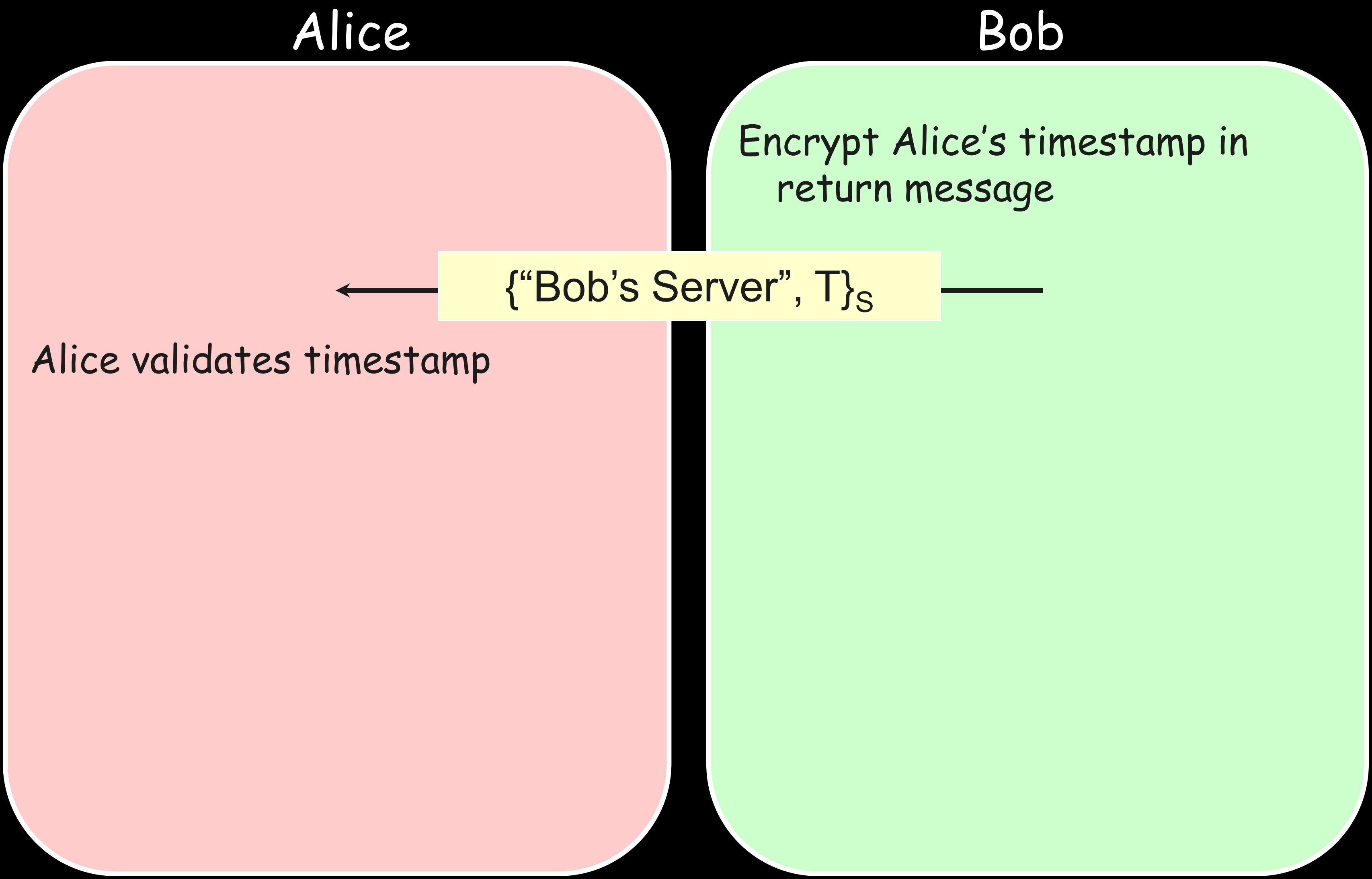
Bob decrypts envelope:

- envelope was created by Kerberos on request from Alice
- gets session key

Decrypts time stamp

- validates time window
- Prevent replay attacks

Authenticate recipient



Alice

Bob

Encrypt Alice’s timestamp in return message

$\{\text{“Bob’s Server”}, T\}_S$

Alice validates timestamp

Kerberos key usage

- Every time a user wants to access a service
  - User's password (key) must be used each time (in decoding message from Kerberos)
- Possible solution:
  - Cache the password (key)
  - Not a good idea
- Another solution:
  - Split Kerberos server into Authentication Server + Ticket Granting Server

Ticket Granting Service (TGS)

TGS + AS = KDC (Kerberos Key Distribution Center)

- Before accessing any service, user requests a ticket to contact the TGS
- Anytime a user wants a service
  - Request a ticket from TGS
  - Reply is encrypted with session key from AS for use with TGS
- TGS works like a temporary ID

Using Kerberos

```
$ kinit
Password:  enter password
```

ask AS for permission (session key) to access TGS

Alice gets:

$\{\text{“TGS”}, S\}_{A}$

$\{\text{“Alice”}, S\}_{TGS}$

Compute key (A) from password to decrypt session key S and get TGS ID.

You now have a ticket to access the Ticket Granting Service

Using Kerberos

```
$ rlogin somehost
```

rlogin uses TGS Ticket to request a ticket for the *rlogin* service on *somehost*

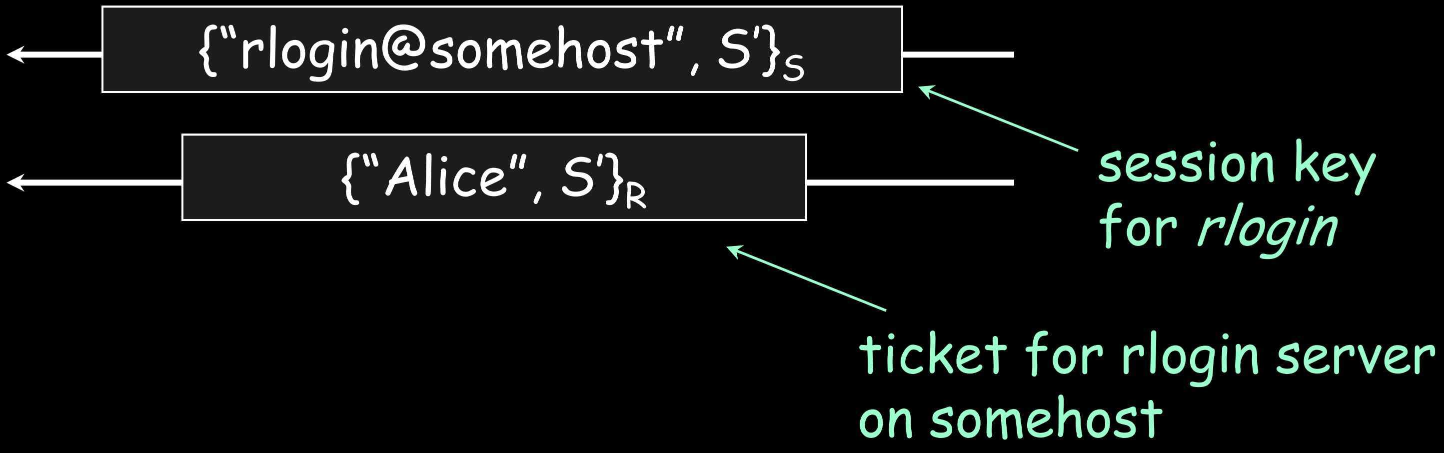
Alice sends session key, S, to TGS

rlogin

$\{\text{“Alice”}, S\}_{TGS}, T_S$

TGS

Alice receives session key for rlogin service & ticket to pass to rlogin service



$\{\text{“rlogin@somehost”}, S'\}_S$

$\{\text{“Alice”}, S'\}_R$

session key for *rlogin*

ticket for rlogin server on somehost

Public key authentication

Like SKID, demonstrate we can encrypt or decrypt a nonce:

- Alice wants to authenticate herself to Bob:
- Bob: generates nonce, *S*
  - presents it to Alice
- Alice: encrypts *S* with her private key (sign it) and send to Bob

Public key authentication

Bob:

look up “alice” in a database of public keys

- decrypt the message from Alice using Alice’s public key
- If the result is *S*, then it was Alice!

- Bob is convinced.

For mutual authentication, Alice has to present Bob with a nonce that Bob will encrypt with his private key and return

Public key authentication

- Public key authentication relies on binding identity to a public key
- One option:

  get keys from a trusted source
- Problem: requires always going to the source
  - cannot pass keys around

- Another option: ***sign the public key***
  - **digital certificate**

X.509 Certificates

ISO introduced a set of authentication protocols: X.509

Structure for public key certificates:

- version
- serial #
- algorithm, params
- issuer
- validity time
- distinguished name
- public key (alg, params, key)
- signature of CA

Trusted Certification Authority issues a signed certificate

X.509 certificates

When you get a certificate

- Verify signature
  - hash contents of certificate data
  - Decrypt CA's signature with CA's public key

Obtain CA's public key (certificate) from trusted source

- Certification authorities are organized in a hierarchy
- A CA certificate may be signed by a CA above it
  - certificate chaining

Certificates prevent someone from using a phony public key to masquerade as another person

Example: Root Certificates in IE

As of January 2007
http://support.microsoft.com/kb/931125

Agencia Catalana de Certificacio
ANCERT
AOL
Arge Daten
AS Sertifitseerimiskeskuse
Asociacion Nacional del Notariado Mexicano
A-Trust
Austria Telekom-Control Commission
Autoridad Certificadora Raiz de la Secretaria de Economia
Autoridad de Certificacion Firmaprofesional
Autoridade Certificadora Raiz Brasileira
Belgacom E-Trust
CAMERFIRMA

Example: Root Certificates in IE

As of January 2007
http://support.microsoft.com/kb/931125

CC Signet
Certicámara S.A.
Certipost s.a./n.v.
Certisign
CertPlus
Colegio de Registradores
Comodo Group
ComSign
Correo
Cybertrust
Deutsche Telekom
DigiCert
DigiNotar B.V.
Dirección General de la Policía – Ministerio del Interior – España.
DST

Example: Root Certificates in IE

As of January 2007
http://support.microsoft.com/kb/931125

Echoworx
Entrust
eSign
EUnet International
First Data Digital Certificates
FNMT
Gatekeeper Root CA
GeoTrust
GlobalSign
GoDaddy
Government of France
Government of Japan Ministry of Internal Affairs and Communications
Government of Tunisia National Digital Certification Agency
Hongkong Post
IPS SERVIDORES

Example: Root Certificates in IE

As of January 2007
http://support.microsoft.com/kb/931125

IZENPE
KMD
Korea Information Security Agency
Microsec Ltd.
NetLock
Network Solutions
Post.Trust
PTT Post
Quovadis
RSA
Saunalahden Serveri
SECOM Trust.net
SecureNet
SecureSign
SecureTrust Corporation

Example: Root Certificates in IE

As of January 2007
http://support.microsoft.com/kb/931125

Serasa

SIA

Sonera

Spanish Property & Commerce Registry

Swisscom Solutions AG

SwissSign AG

S-TRUST

TC TrustCenter

TDC

Thawte

Trustis Limited

TurkTrust

TW Government Root Certification Authority

U.S. Government Federal PKI

Example: Root Certificates in IE

As of January 2007
http://support.microsoft.com/kb/931125

- Unizeto Certum
- UserTRUST
- ValiCert
- VeriSign
- Visa
- Wells Fargo
- WISeKey
- XRamp

Transport Layer Security (TLS)
aka Secure Socket Layer (SSL)

- Sits on top of TCP/IP
- Goal: provide an encrypted and possibly authenticated communication channel
  - Provides authentication via RSA and X.509 certificates
  - Encryption of communication session via a symmetric cipher
- Enables TCP services to engage in secure, authenticated transfers
  - http, telnet, ntp, ftp, smtp, …

Secure Sockets Layer (SSL)

client

server

hello(version, protocol)

hello(version, protocol)

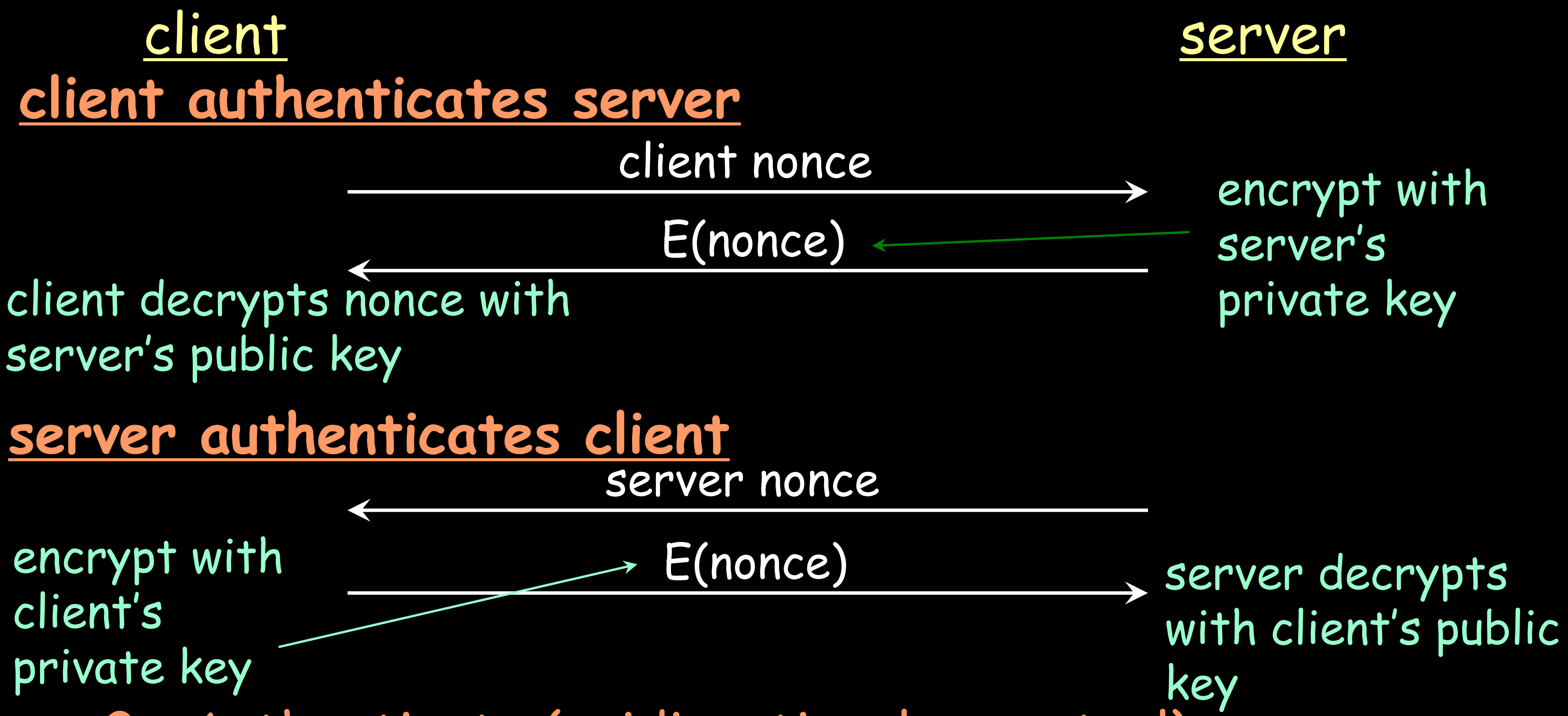
certificate (or public key)

hello done

certificate (or none)

1. Establish protocol, version, cipher suite, compression mechanism, exchange certificates (or send public key)

Secure Sockets Layer (SSL)



client

server

client authenticates server

client nonce

encrypt with server's private key

E(nonce)

client decrypts nonce with server's public key

server authenticates client

server nonce

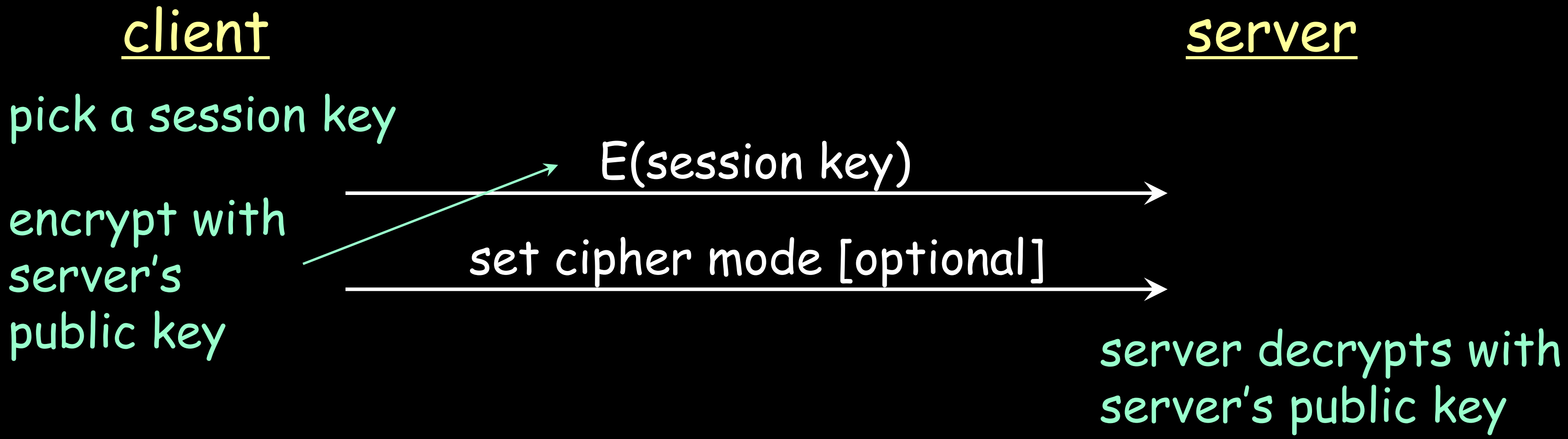
encrypt with client's private key

E(nonce)

server decrypts with client's public key

2. Authenticate (unidirectional or mutual) [optional]

Secure Sockets Layer (SSL)



client

server

pick a session key

encrypt with
server's
public key

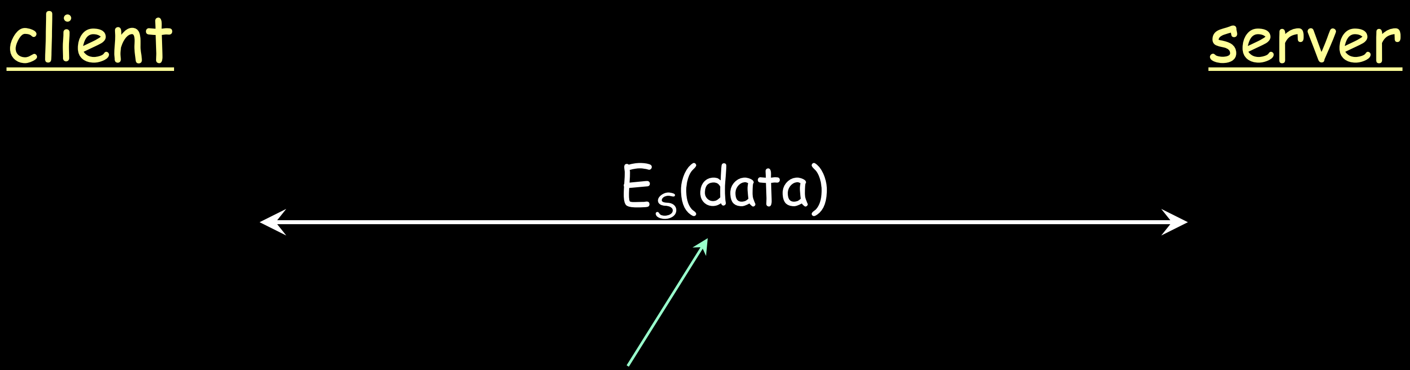
E(session key)

set cipher mode [optional]

server decrypts with
server's public key

3. Establish session key
(for symmetric cryptography)

Secure Sockets Layer (SSL)



client

server

E_S(data)

encrypt and decrypt with session key
and symmetric algorithm (e.g. RC4)

4. Exchange data (symmetric encryption)

The end.