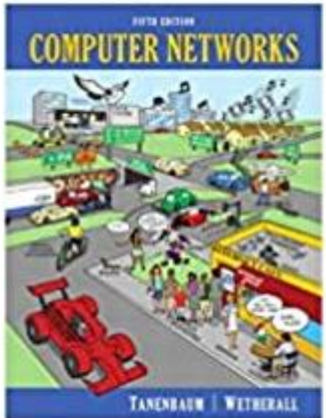
Network Security

Chapter 8

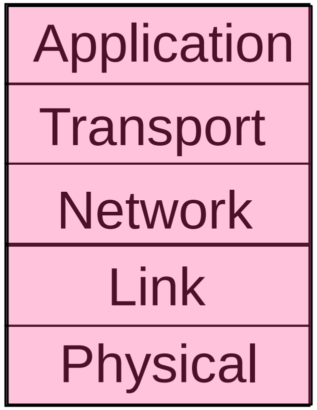
- **Cryptography**
- **Symmetric-Key Algorithms**
- **Public-Key Algorithms**
- **Digital Signatures**
- **Management of Public Keys**

- Communication Security
- Authentication Protocols
- Email Security
- Web Security
- Social Issues



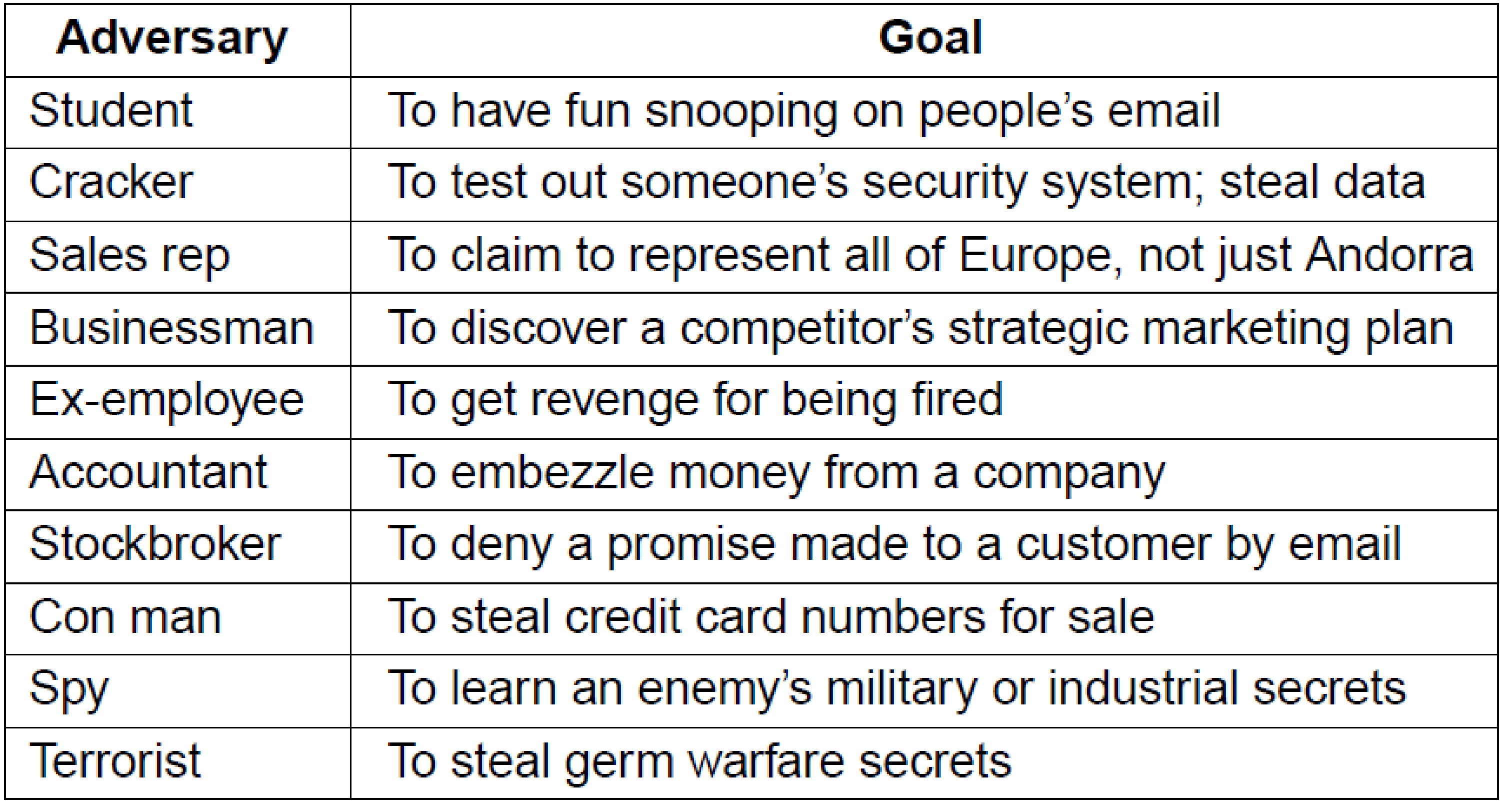
Network Security

Security concerns a variety of threats and defenses across all layers



Network Security

Some different adversaries and security threats



Adversary	Goal
Student	To have fun snooping on people's email
Cracker	To test out someone's security system; steal data
Sales rep	To claim to represent all of Europe, not just Andorra
Businessman	To discover a competitor's strategic marketing plan
Ex-employee	To get revenge for being fired
Accountant	To embezzle money from a company
Stockbroker	To deny a promise made to a customer by email
Con man	To steal credit card numbers for sale
Spy	To learn an enemy's military or industrial secrets
Terrorist	To steal germ warfare secrets

Different threats require different defenses

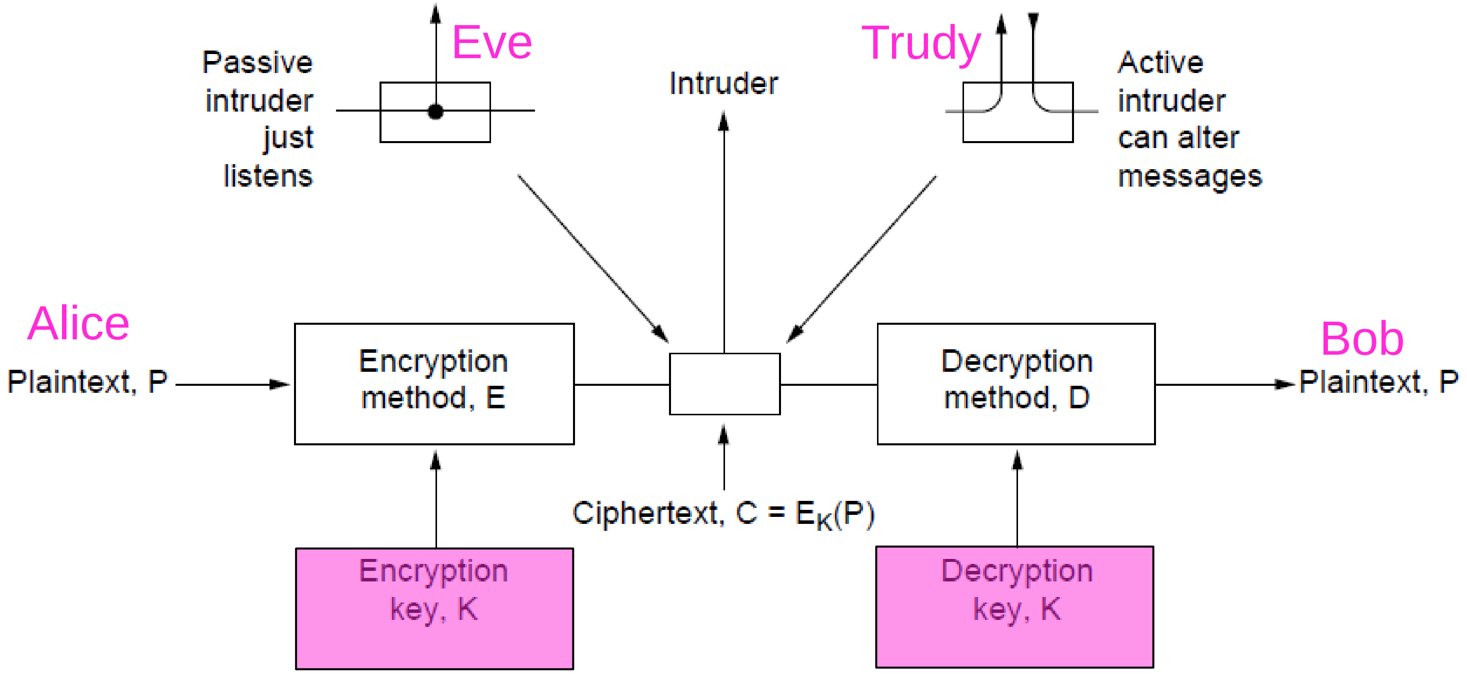
Cryptography

Cryptography is a fundamental building block for security mechanisms.

- Introduction »
- Substitution ciphers »
- Transposition ciphers »
- One-time pads »
- Fundamental cryptographic principles »

Introduction

The encryption model (for a symmetric-key cipher)

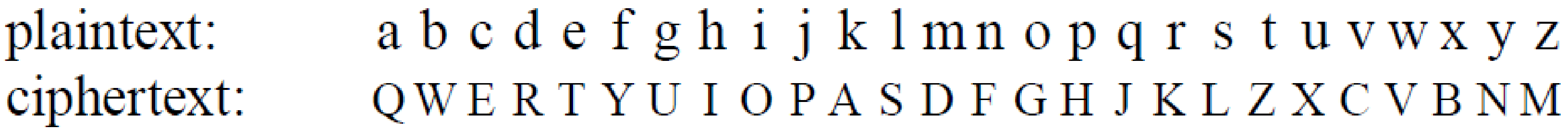


Kerckhoff’s principle:

Algorithms (E, D) must be public; only the keys (K) are secret

Substitution Ciphers

Substitution ciphers replace each group of letters in the message with another group of letters to disguise it



plaintext:	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r	s	t	u	v	w	x	y	z
ciphertext:	Q	W	E	R	T	Y	U	I	O	P	A	S	D	F	G	H	J	K	L	Z	X	C	V	B	N	M

Simple single-letter substitution cipher

Transposition Ciphers

Transposition ciphers reorder letters to disguise them

M	E	G	A	B	U	C	K
7	4	5	1	2	8	3	6
p	l	e	a	s	e	t	r
a	n	s	f	e	r	o	n
e	m	i	l	l	i	o	n
d	o	l	l	a	r	s	t
o	m	y	s	w	i	s	s
b	a	n	k	a	c	c	o
u	n	t	s	i	x	t	w
o	t	w	o	a	b	c	d

← Key gives column order

Plaintext

pleasetransferonemilliondollarsto
myswissbankaccountsixtwotwo

Ciphertext

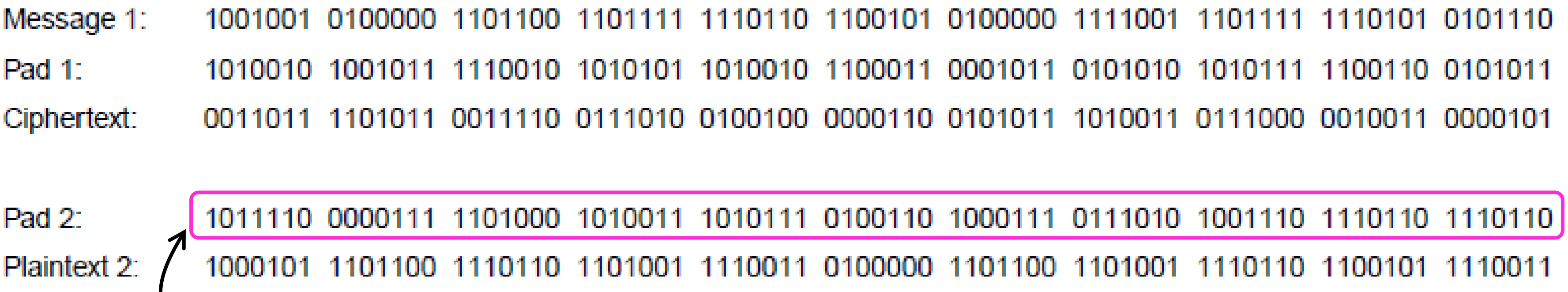
AFLLSKSOSELAWAIATOOSSCTCLNMOMANT
$\underbrace{\text{ESILYNTW}}_{\text{Column 5}}\underbrace{\text{RNNTSOWD}}_{6}\underbrace{\text{PAEDOBUO}}_{7}\underbrace{\text{ERIRICXB}}_{8}$

Simple column transposition cipher

One-Time Pads

Simple scheme for perfect secrecy:

- XOR message with secret pad to encrypt, decrypt
- Pad is as long as the message and can’t be reused!
  - It is a “one-time” pad to guarantee secrecy



Message 1:	1001001	0100000	1101100	1101111	1110110	1100101	0100000	1111001	1101111	1110101	0101110
Pad 1:	1010010	1001011	1110010	1010101	1010010	1100011	0001011	0101010	1010111	1100110	0101011
Ciphertext:	0011011	1101011	0011110	0111010	0100100	0000110	0101011	1010011	0111000	0010011	0000101
Pad 2:	1011110	0000111	1101000	1010011	1010111	0100110	1000111	0111010	1001110	1110110	1110110
Plaintext 2:	1000101	1101100	1110110	1101001	1110011	0100000	1101100	1101001	1110110	1100101	1110011

Different secret pad decrypts to the wrong plaintext

Fundamental Cryptographic Principles

1. Messages must contain some **redundancy**
   - All encrypted messages decrypt to something
   - Redundancy lets receiver recognize a valid message

2. Some method is needed to foil replay attacks
   - Without a way to check if messages are fresh then old messages can be copied and resent
   - For example, add a **timestamp** to messages

Symmetric-Key Algorithms

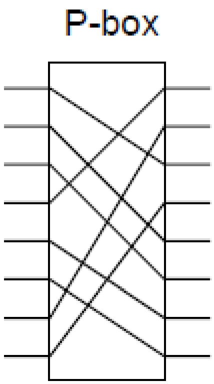
Encryption in which the parties share a secret key

- DES – Data Encryption Standard »
- AES – Advanced Encryption Standard »
- Cipher modes »
- Other ciphers »

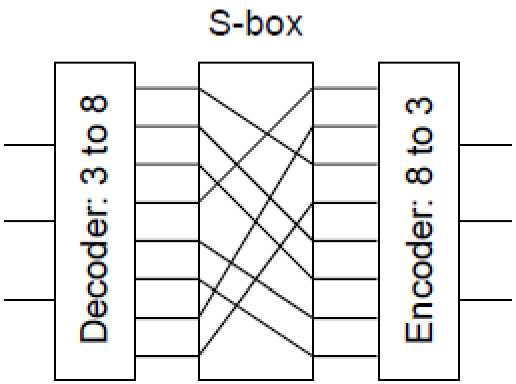
Symmetric-Key Algorithms

Use the same secret key to encrypt and decrypt

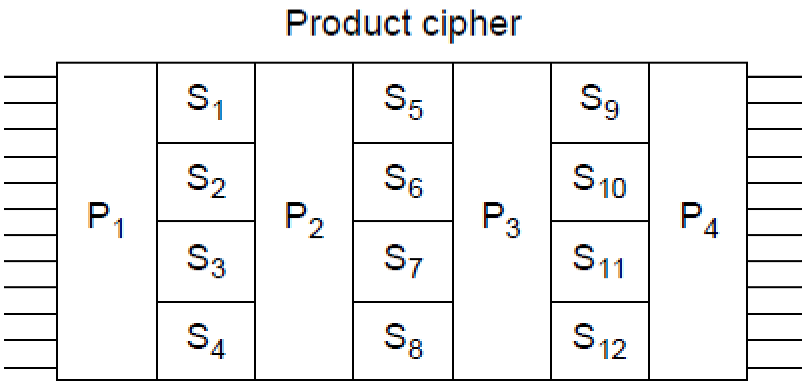
- **Block ciphers** operate a block at a time
- Product cipher combines transpositions/substitutions



Permutation (transposition) box



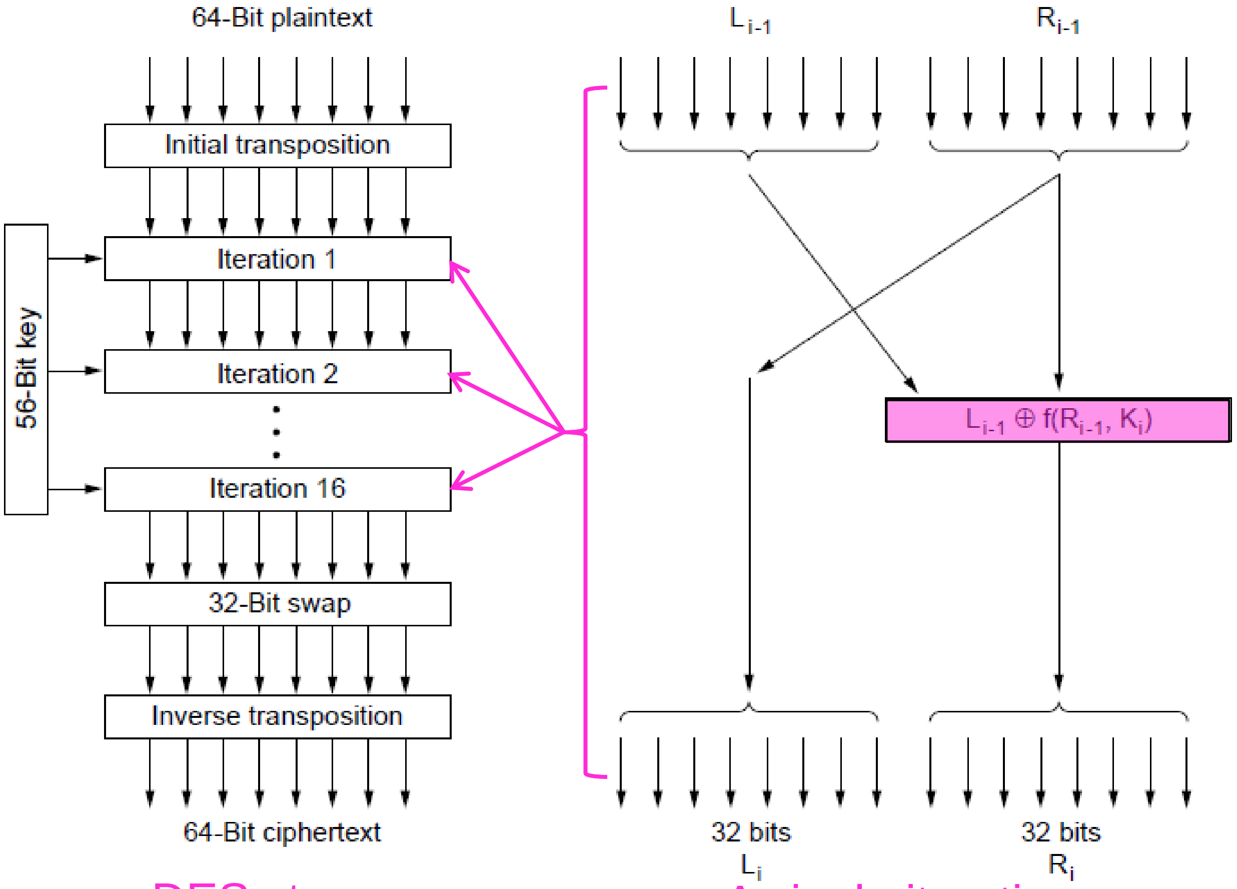
Substitution box



Product with multiple P- and S-boxes

Data Encryption Standard (1)

DES encryption was widely used (but no longer secure)



Contains transpositions & substitutions

DES steps

A single iteration

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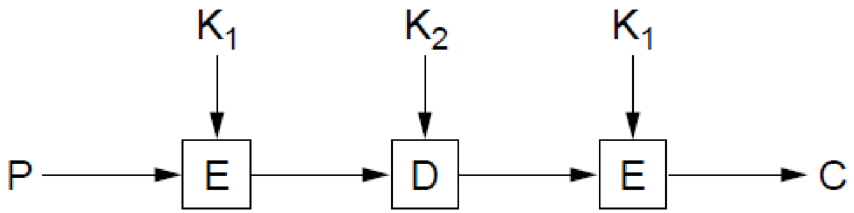
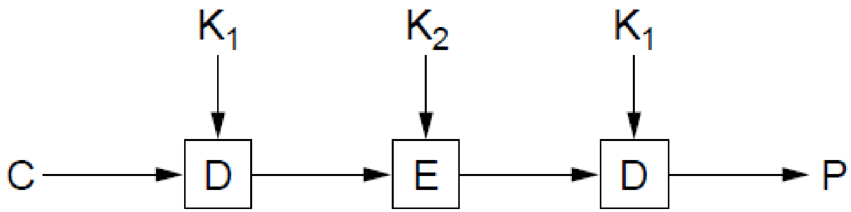
Data Encryption Standard (2)

Triple encryption (3DES) with two 56-bit keys

- Gives an adequate key strength of 112 bits
- Setting $K_1 = K_2$ allows for compatibility with DES



Triple DES encryption



Triple DES decryption

Advanced Encryption Standard (1)

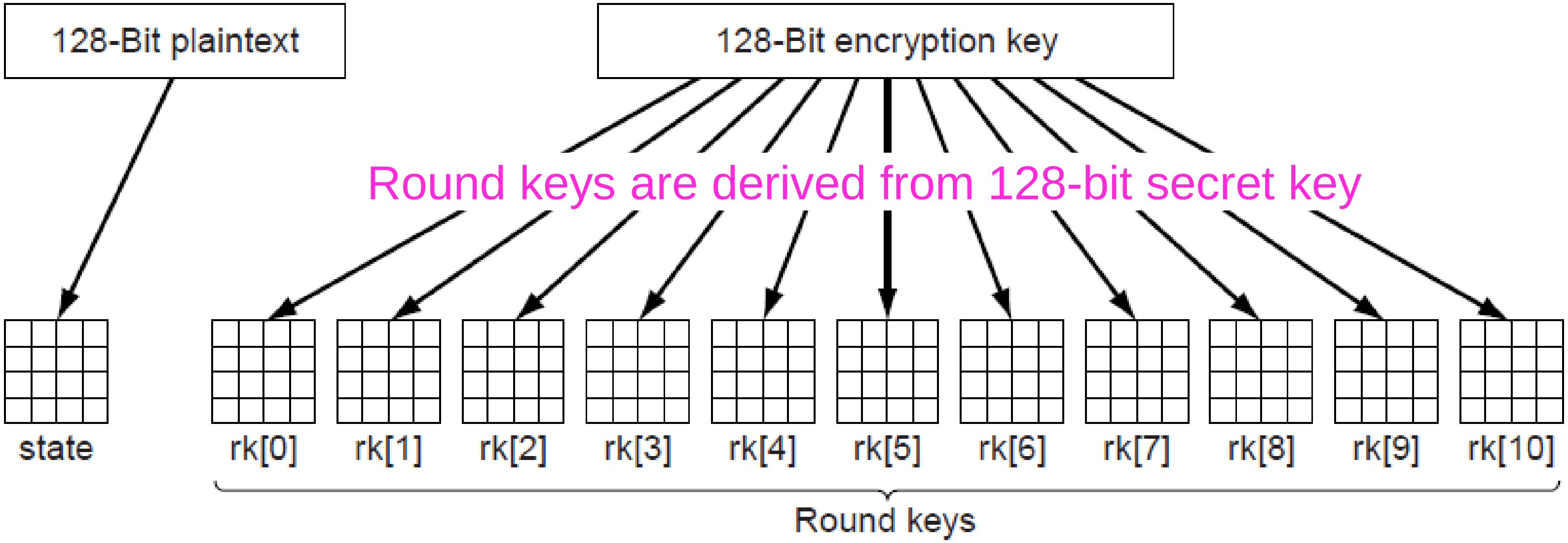
AES is the successor to DES:

- Symmetric block cipher, key lengths up to 256 bits
- Openly designed by public competition (1997-2000)
- Available for use by everyone
- Built as software (e.g., C) or hardware (e.g., x86)
- Winner was Rijndael cipher
- Now a widely used standard

Advanced Encryption Standard (2)

AES uses 10 rounds for 128-bit keys

- Each round uses a key derived from 128-bit key
- Each round has a mix of substitutions and rotations
- All steps are reversible to allow for decryption



Round keys are derived from 128-bit secret key

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Cipher Modes (1)

Several modes of operation may be applied in order to strengthen the effect of the encryption algorithm

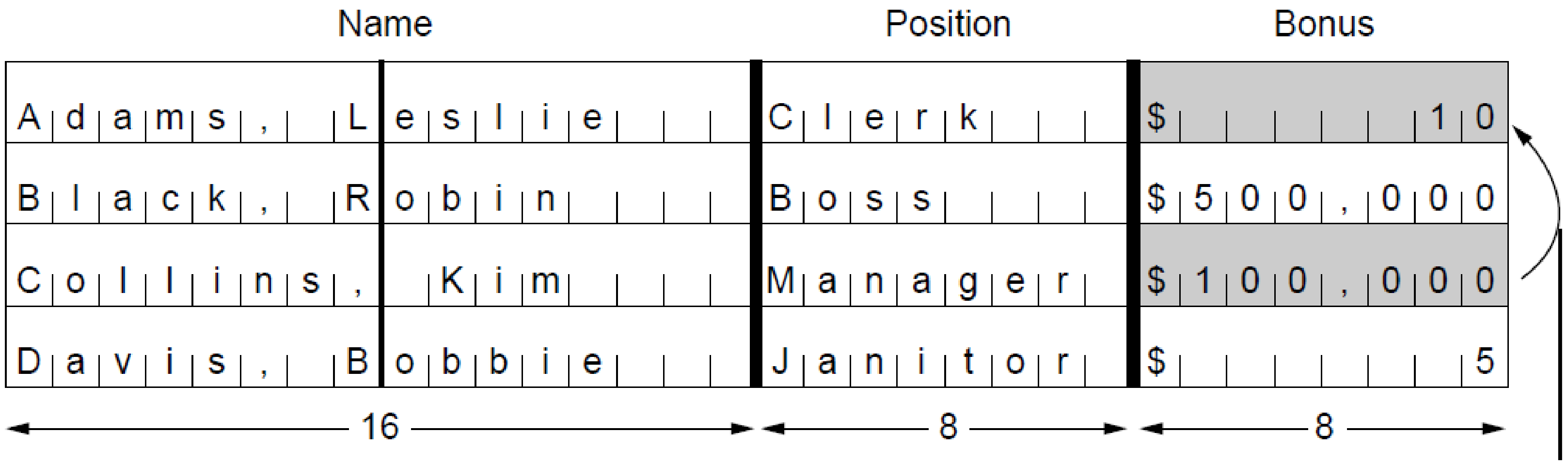
- ECB (Electronic Code Book)
- CBC (Cipher Block Chaining)
- CFB (Cipher FeedBack)
- OFB (Output FeedBack)
- CTR (Counter)

Each mode has its strength and weakness

Cipher Modes (2)

ECB (Electronic Code Book) encrypts each block independently

- It is vulnerable to shifts



Name	Position	Bonus
Adams, Leslie	Clerk	$ 10
Black, Robin	Boss	$500,000
Collins, Kim	Manager	$100,000
Davis, Bobbie	Janitor	$ 5

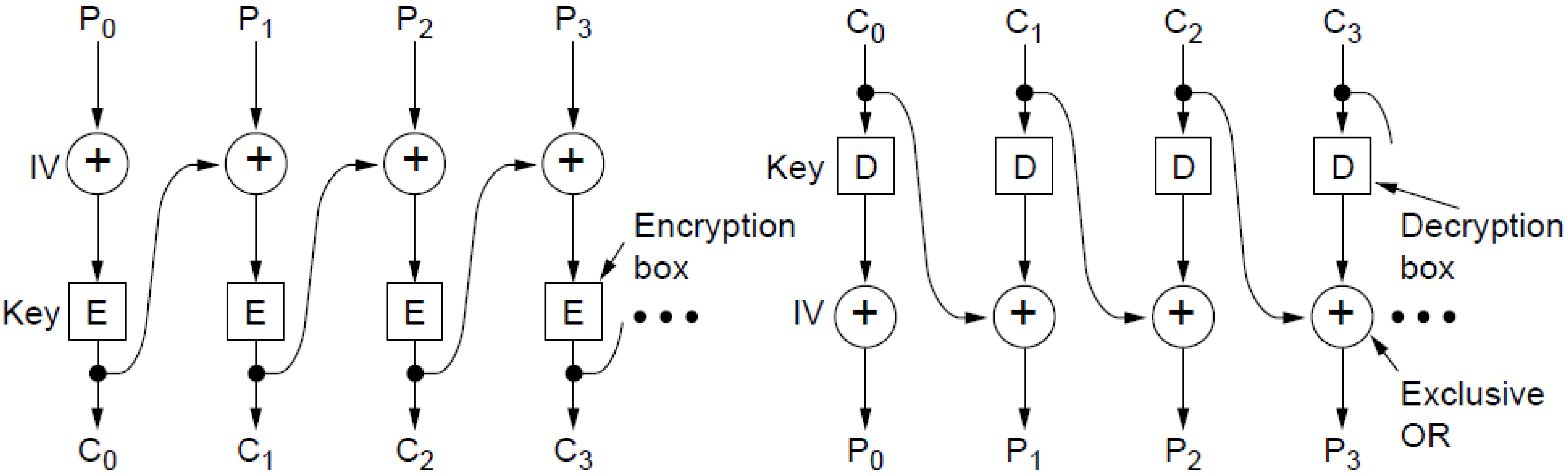
With ECB mode, switching encrypted blocks gives a different but valid message

Leslie gets a large bonus!

Cipher Modes (3)

CBC (Cipher Block Chaining) chains blocks together with XOR to prevent shifts

- Has a random IV for different output



CBC mode encryption

CBC mode decryption

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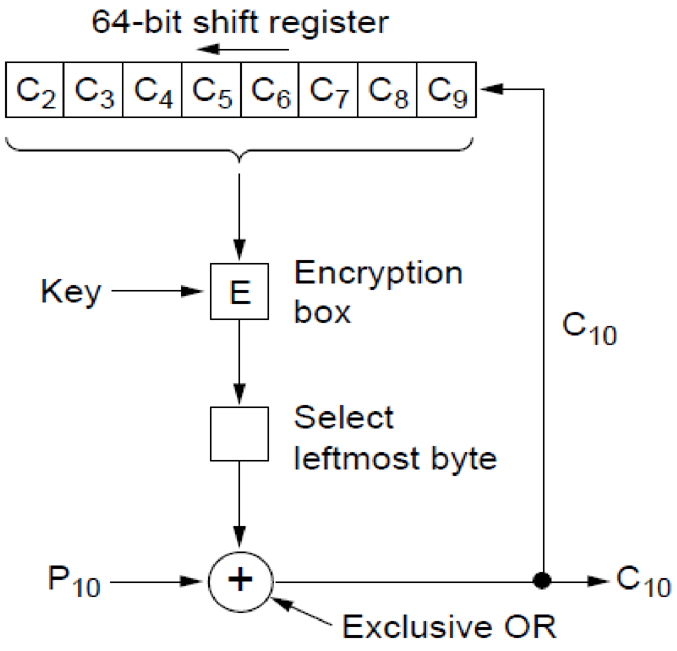
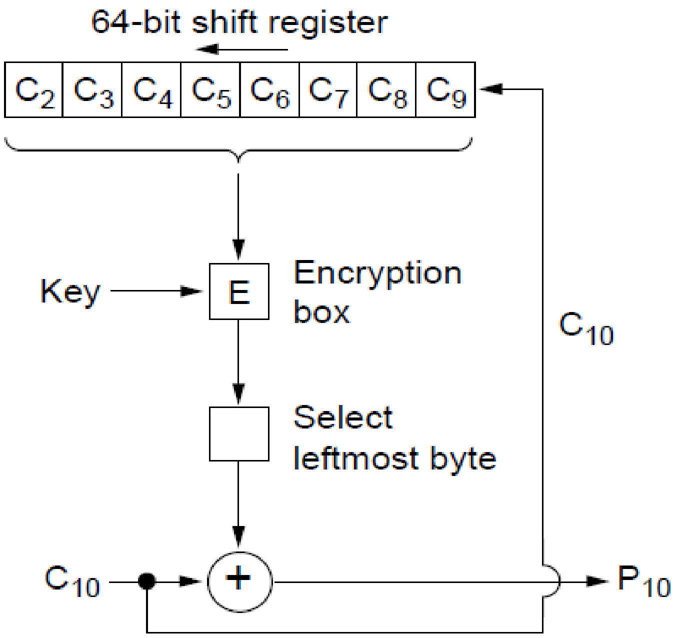
Cipher Modes (4)

CFB (cipher feedback) is similar to CBC mode but can operate a byte (rather than a whole block) at a time



Encryption

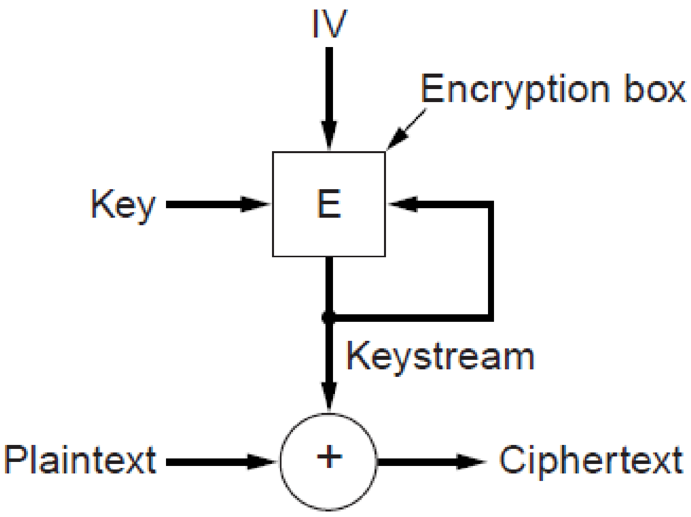


Decryption

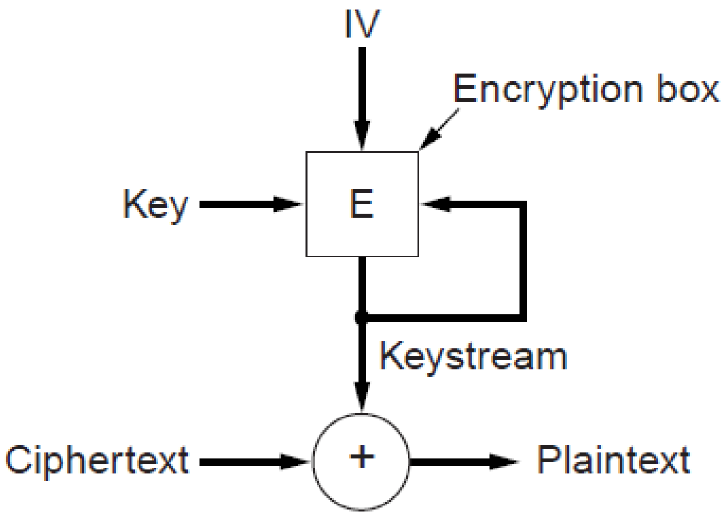
Cipher Modes (5)

OFB (output feedback) uses the key and IV to generate a stream that is a one-time pad

- Can’t reuse (key, IV) pair



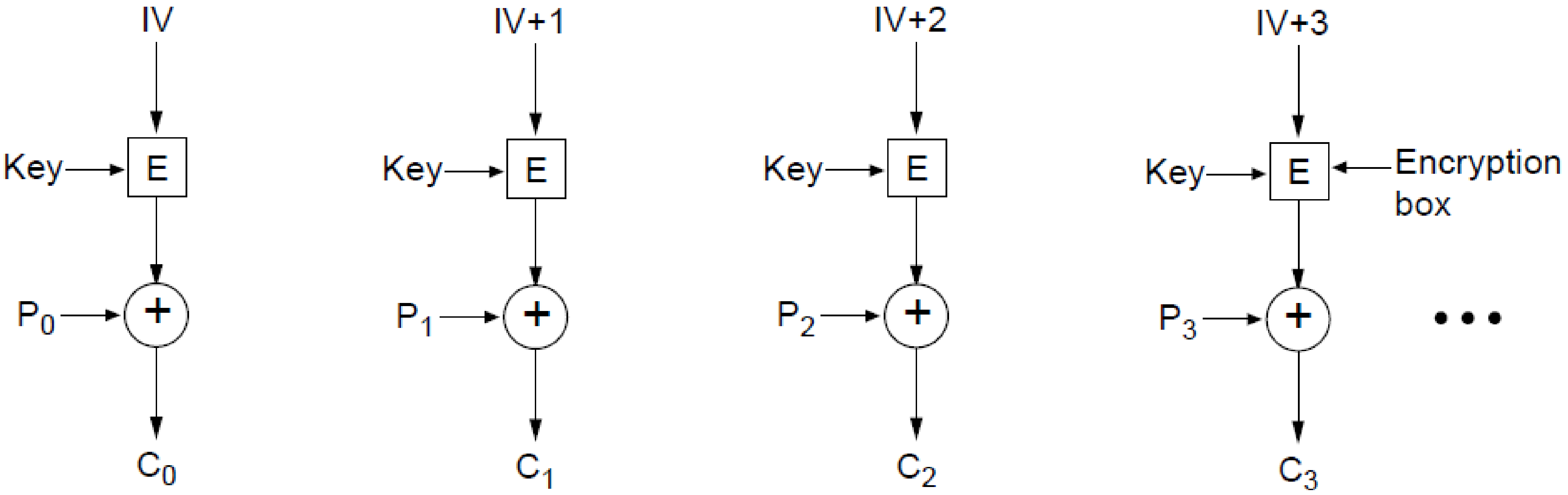
Encryption



Decryption

Cipher Modes (6)

CTR encrypts a counter and XOR it with each message block



Encryption above; repeat the operation to decrypt

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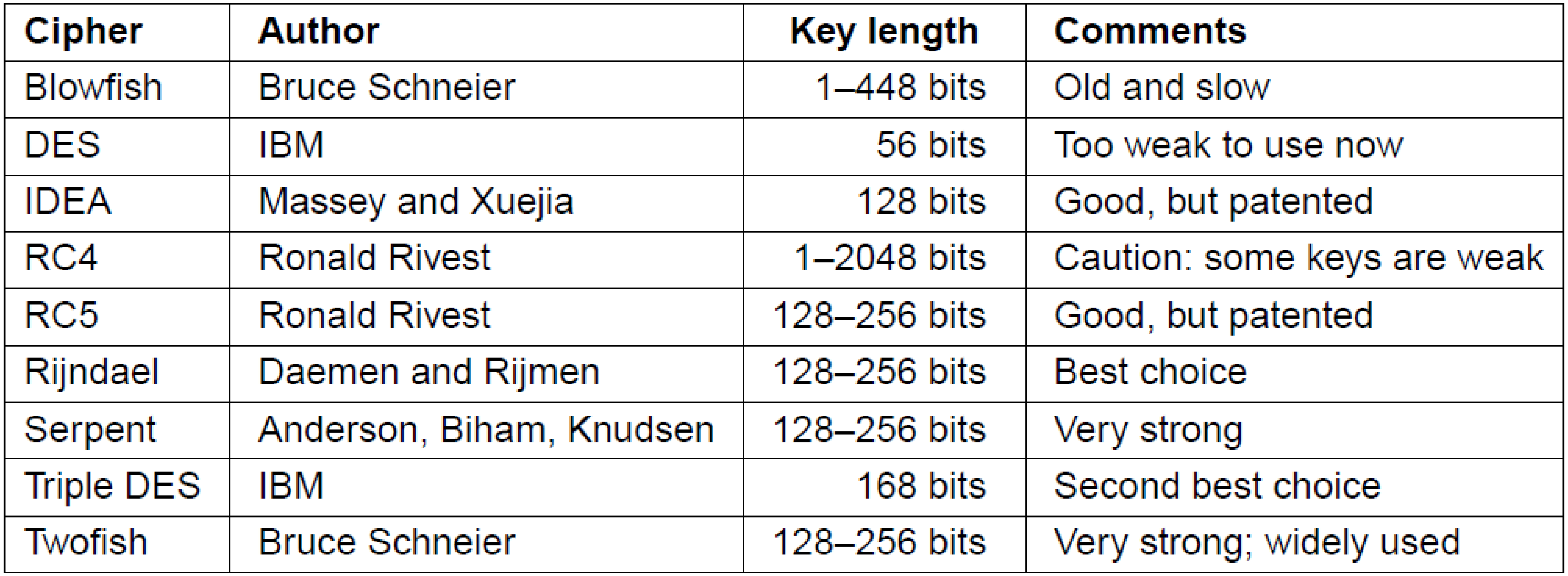
Other Ciphers

Some common symmetric-key cryptographic algorithms



Cipher	Author	Key length	Comments
Blowfish	Bruce Schneier	1–448 bits	Old and slow
DES	IBM	56 bits	Too weak to use now
IDEA	Massey and Xuejia	128 bits	Good, but patented
RC4	Ronald Rivest	1–2048 bits	Caution: some keys are weak
RC5	Ronald Rivest	128–256 bits	Good, but patented
Rijndael	Daemen and Rijmen	128–256 bits	Best choice
Serpent	Anderson, Biham, Knudsen	128–256 bits	Very strong
Triple DES	IBM	168 bits	Second best choice
Twofish	Bruce Schneier	128–256 bits	Very strong; widely used

Can be used in combination, e.g., AES over Twofish

Public-Key Algorithms

Encryption in which each party publishes a public part of their key and keep secret a private part of it

- Diffie-Hellman key exchange »
- RSA (by Rivest, Shamir, Adleman) »

Public-Key Algorithms

Downsides of keys for symmetric-key designs:

- Key must be secret, yet be distributed to both parties
- For N users there are $O(N^2)$ pairwise keys to manage

Public key schemes split the key into public and private parts that are mathematically related:

- Private part is not distributed; easy to keep secret
- Only one public key per user needs to be managed

Security depends on the chosen mathematical property

- Much slower than symmetric-key, e.g., 1000X
- So, use it to set up per-session symmetric keys

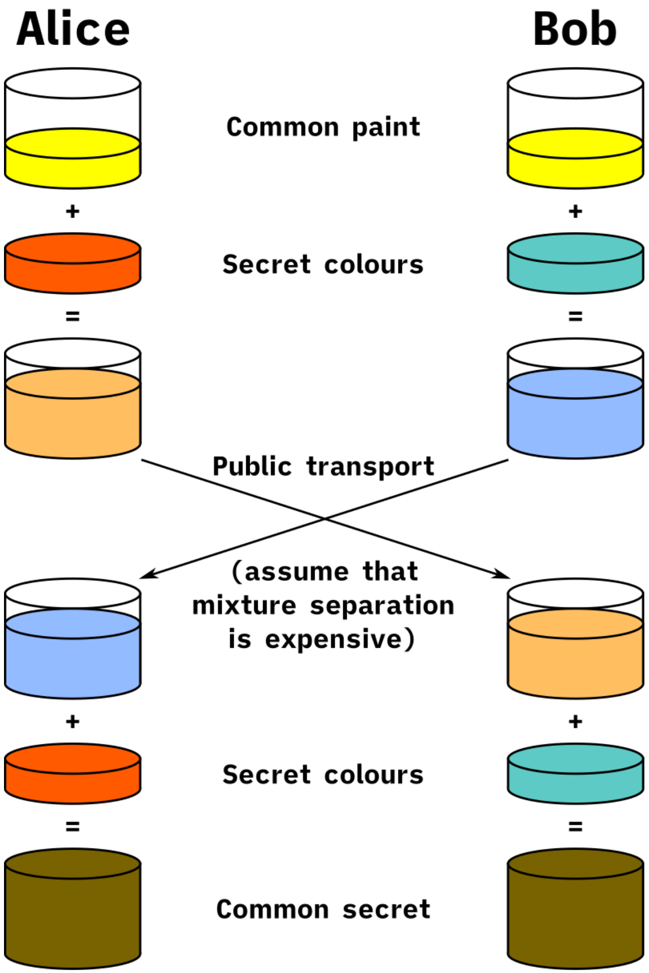
Public Key Cryptography

Diffie, W. and Hellman, M. (1976). **New directions in cryptography**. *IEEE Transactions on Information Theory*, Vol.22, No. 6, pp. 644-654.

2005 Turing award - For inventing and promulgating both asymmetric public-key cryptography, including its application to digital signatures, and a practical cryptographic key-exchange method.

Diffie-Hellman Key Exchange (1)

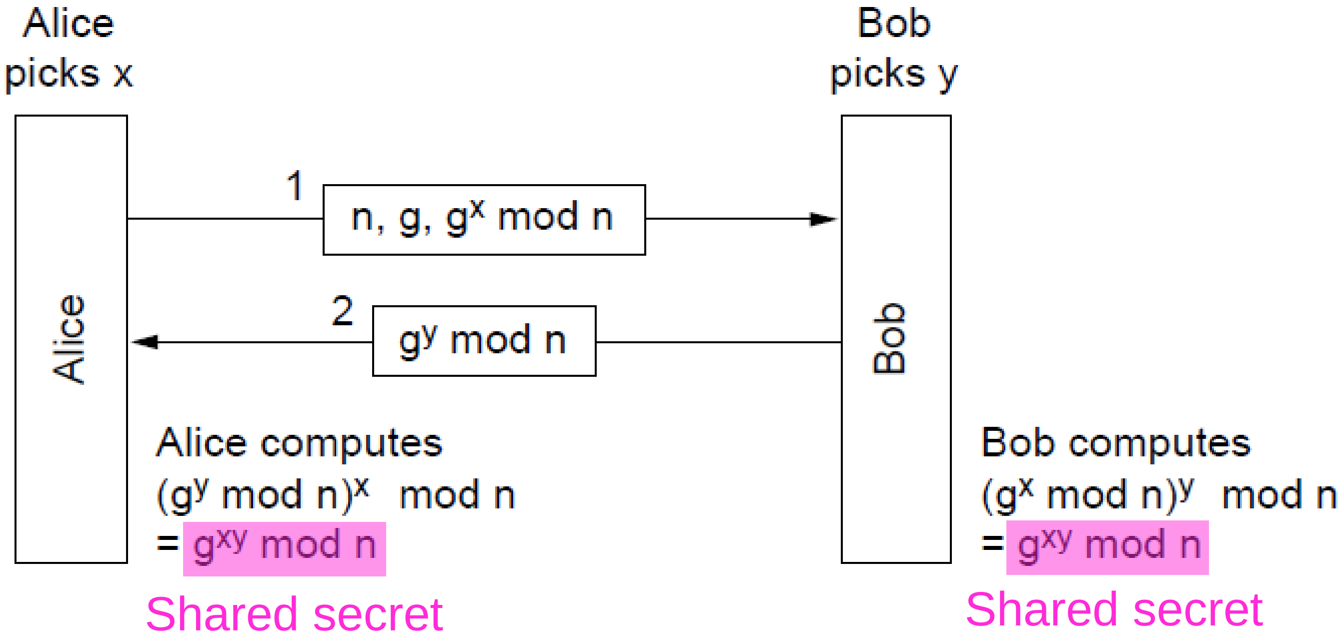
Lets two parties establish a shared secret



Fuente: Wikipedia

Diffie-Hellman Key Exchange (2)

The security of the technique depends crucially on the difficulty of computing logarithms mod n.



Eavesdropper can't compute secret g^{xy} mod n without knowing x or y

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RSA Algorithm

Rivest, R.L., Shamir, A. and Adleman, A. (1978). **A method for obtaining digital signatures and public-key cryptosystems**. *Communications of the ACM*, Vol. 21, No. 2, pp. 120-126.

2002 Turing award - For their ingenious contribution to making public-key cryptography useful in practice.

RSA (1)

RSA is a widely used public-key encryption method whose security is based on the difficulty of factoring large numbers

Key generation:

- Choose two large primes, p and q (typically 1024 bits)
- Compute $n = p \times q$ and $z = (p - 1) \times (q - 1)$.
- Choose d to be relatively prime to z
- Find e such that $e \times d = 1 \bmod z$
- Public key is (e, n), and private key is (d, n)

Encryption (of k bit message, for numbers up to n):

- $\text{Cipher} = \text{Plain}^e \pmod{n}$

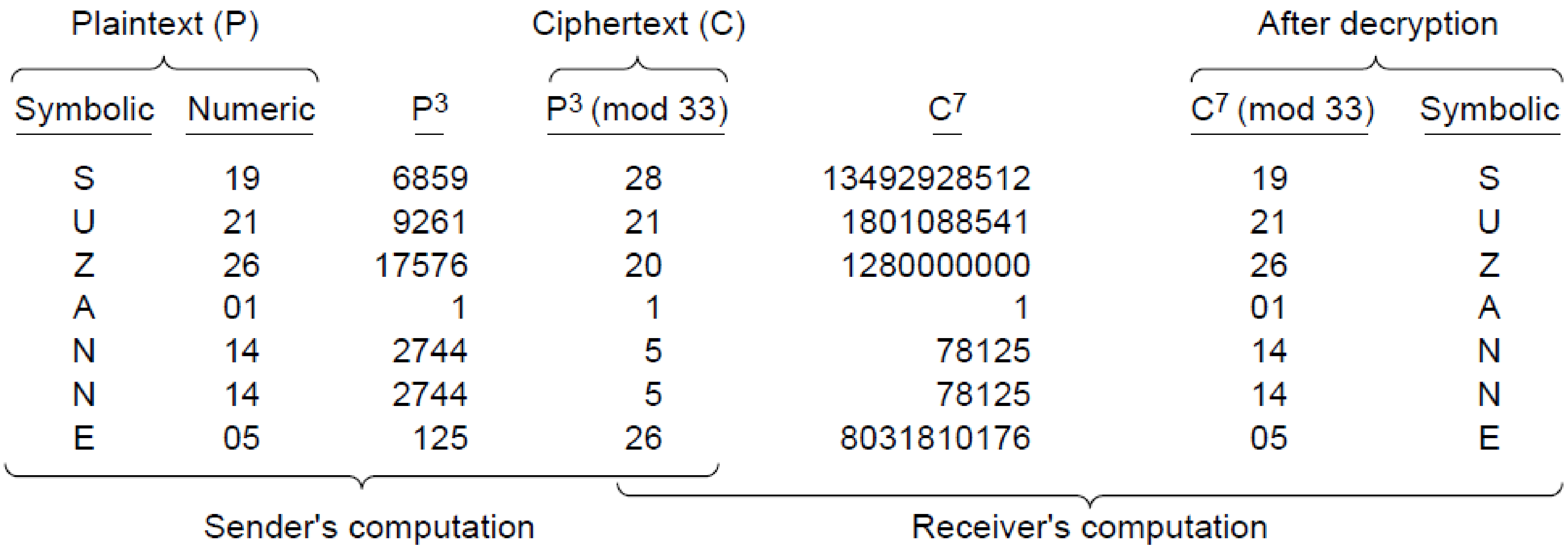
Decryption:

- $\text{Plain} = \text{Cipher}^d \pmod{n}$

RSA (2)

Small-scale example of RSA encryption

- Encrypting 8-bit messages
- For p=3, q=11 → n=33, z=20 → d=7, e=3



Plaintext (P)			Ciphertext (C)		After decryption	
Symbolic	Numeric	P^3	P^3 (mod 33)	C^7	C^7 (mod 33)	Symbolic
S	19	6859	28	13492928512	19	S
U	21	9261	21	1801088541	21	U
Z	26	17576	20	1280000000	26	Z
A	01	1	1	1	01	A
N	14	2744	5	78125	14	N
N	14	2744	5	78125	14	N
E	05	125	26	8031810176	05	E

Sender's computation

Receiver's computation

Encryption: $C = P^3 \bmod 33$

Decryption: $P = C^7 \bmod 33$

RSA (3)

- For p=5, q=7 → n=35, z=24 →
  d=29 (d<n; d,z relatively prime)
  e=5 (ed-1 exactly divisible by z)

encrypt: $\underbrace{\text{bit pattern}}_{00001100} \quad \underbrace{m}_{12} \quad \underbrace{m^e}_{24832} \quad \underbrace{c = m^e \bmod n}_{17}$

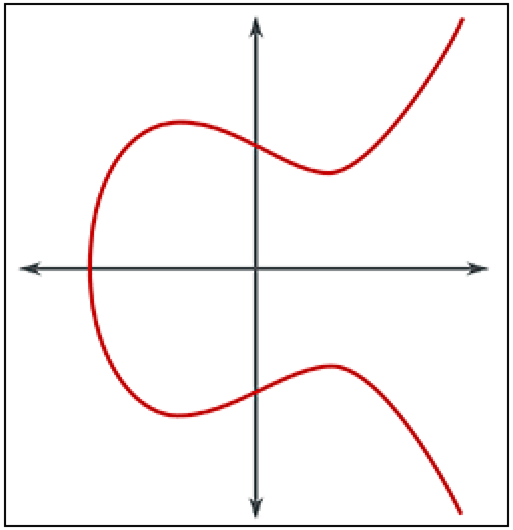
decrypt: $\underbrace{c}_{17} \quad \underbrace{c^d}_{481968572106750915091411825223071697} \quad \underbrace{m = c^d \bmod n}_{12}$

Elliptic Curve Cryptography

Domain parameters: a prime number (n) as a maximum, a curve equation (a and b), and a point on the curve (G).

The private key is a random number (d<n), and the public key (Q) is the public point *dotted* with itself d times.

Computing the private key d from the public key Q is a very good trapdoor function.



$y^2 = x^3 + a\ x + b$

Restricted to whole numbers in [1,n-1]

Digital Signatures

Lets receiver verify the message is authentic

- Symmetric-Key signatures »
- Public-Key signatures »
- Message digests »

Digital Signatures

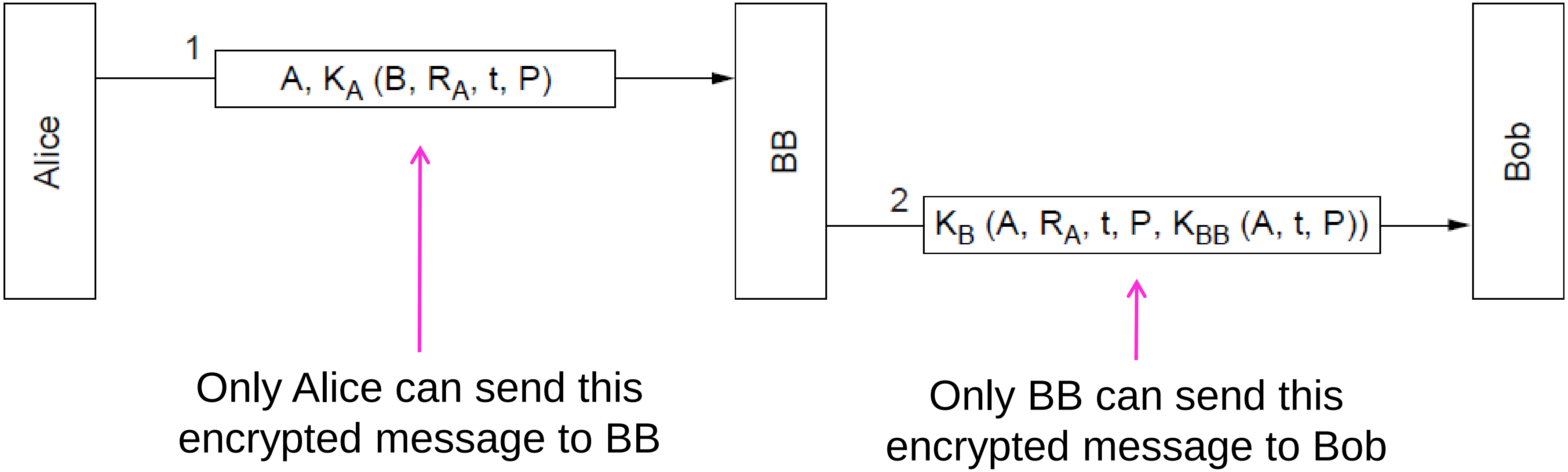
Requirements for a signature:

- Receiver can verify claimed identity of sender.
- Sender cannot later repudiate contents of message.
- Receiver cannot have concocted message himself.

Symmetric-Key Signatures

Alice and Bob each trust and share a key with Big Brother; Big Brother doesn't trust anyone

- A=Alice, B=Bob, P=message, R_A=random, t=time


Alice
1
A, K_A (B, R_A, t, P)
BB
2
K_B (A, R_A, t, P, K_{BB} (A, t, P))
Bob

Only Alice can send this encrypted message to BB

Only BB can send this encrypted message to Bob

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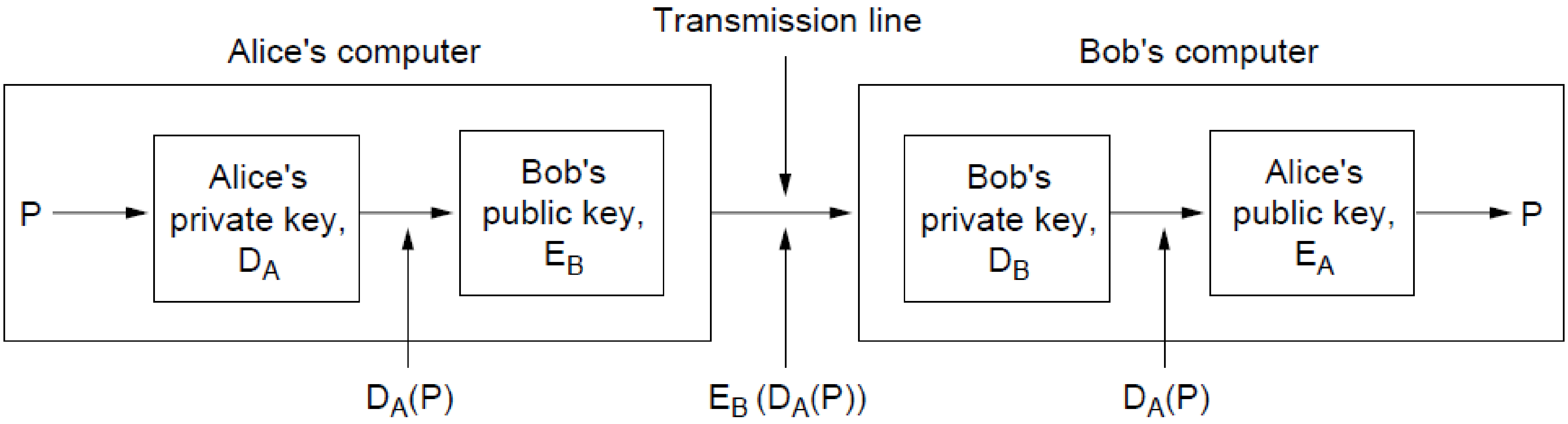
Public-Key Signatures

No Big Brother and assumes encryption and decryption are inverses that can be applied in either order

- But relies on private key kept secret
- RSA & DSS (Digital Signature Standard) widely used



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Message Digests (1)

Message Digest (MD) converts arbitrary-size message (P) into a fixed-size identifier MD(P) with properties:

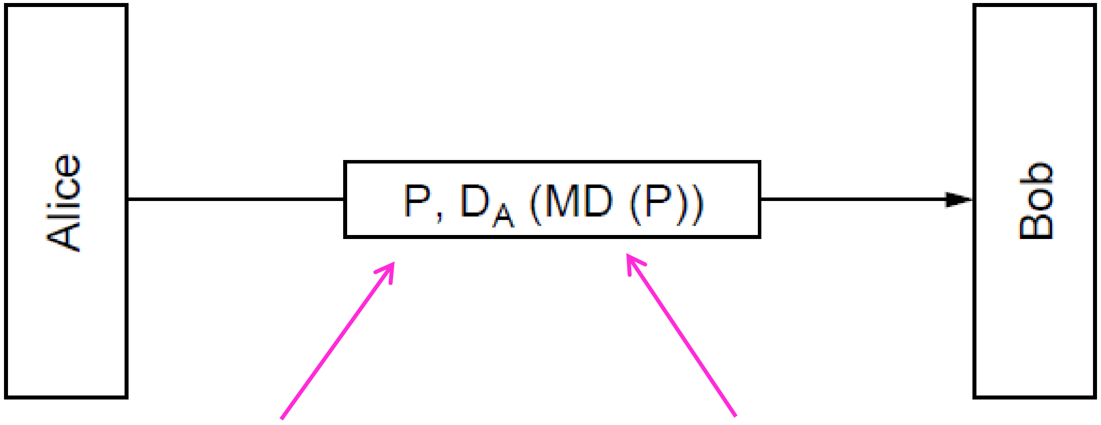
- Given P, easy to compute MD(P).
- Given MD(P), effectively impossible to find P.
- Given P no one can find P′ so that MD(P′) = MD(P).
- Changing 1 bit of P produces very different MD.

Message digests (also called cryptographic hashes) can “stand for” messages in protocols, e.g., authentication

• MD5	128-bit hash
• SHA-1	160-bit hash
• SHA-2	256-bit hash

Message Digests (2)

Public-key signature for message authenticity but not confidentiality with a message digest



Alice

$P, D_A (MD (P))$

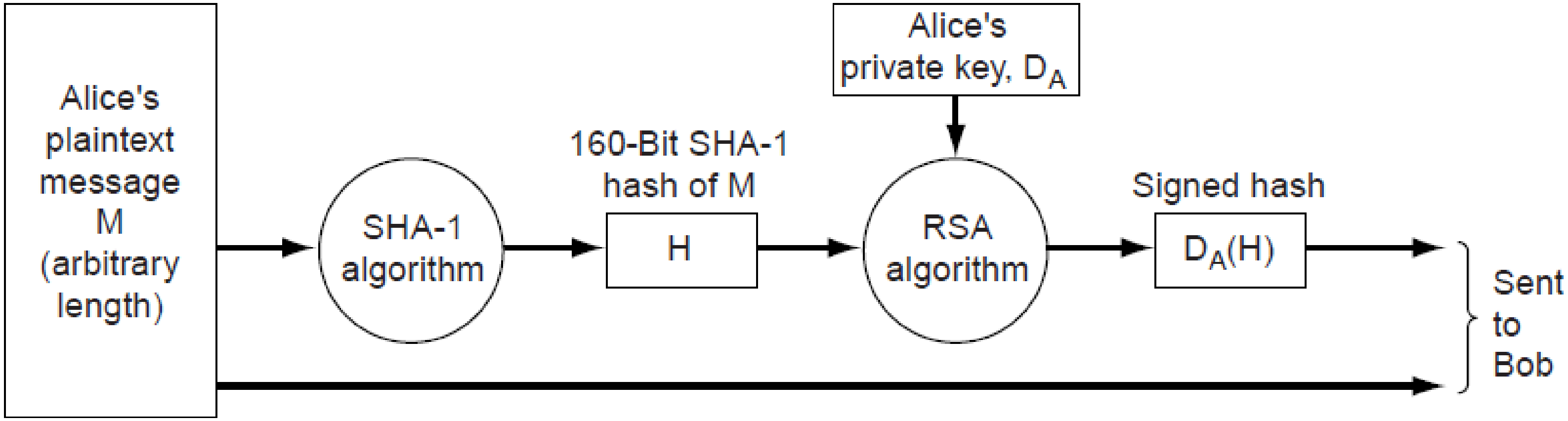
Bob

Message sent
in the clear

Alice signs
message digest

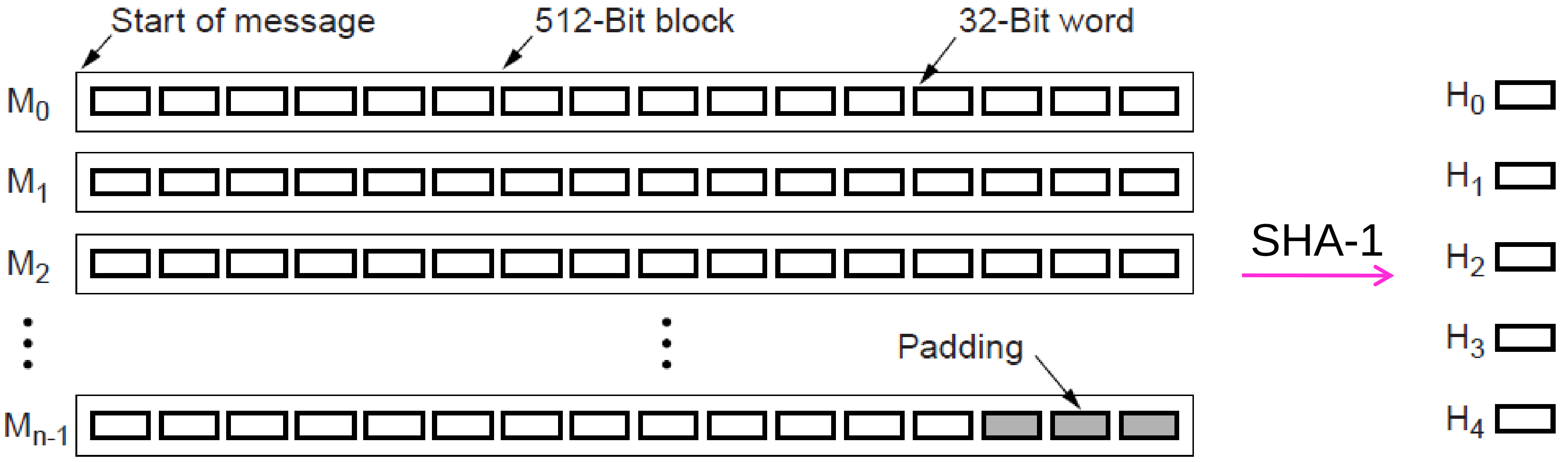
Message Digests (3)

In more detail: example of using SHA-1 message digest and RSA public key for signing nonsecret messages



Message Digests (4)

SHA-1 digests the message 512 bits at a time to build a 160-bit hash as five 32-bit components



Message in 512-bit blocks

Five 32-bit hashes output

https://andersbrownworth.com/blockchain/hash

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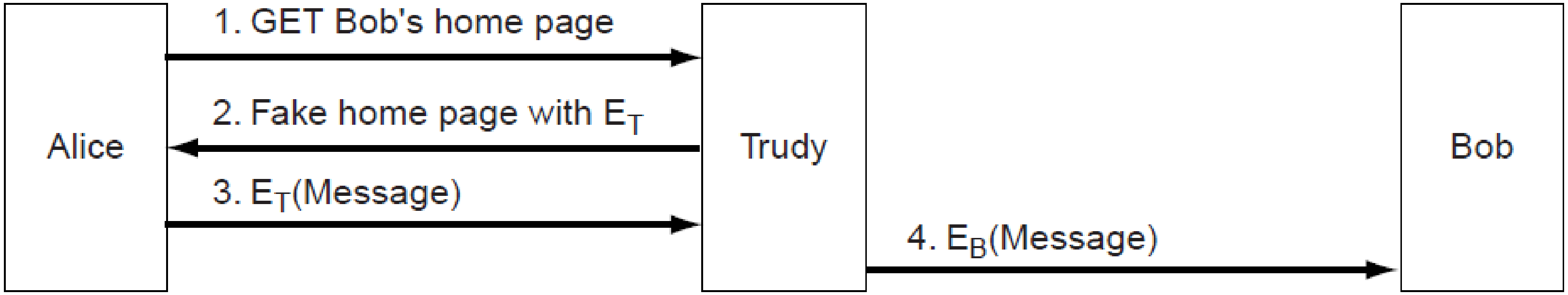
Management of Public Keys

We need a trusted way to distribute public keys

- Certificates »
- X.509, the certificate standard »
- Public Key Infrastructures »

Management of Public Keys

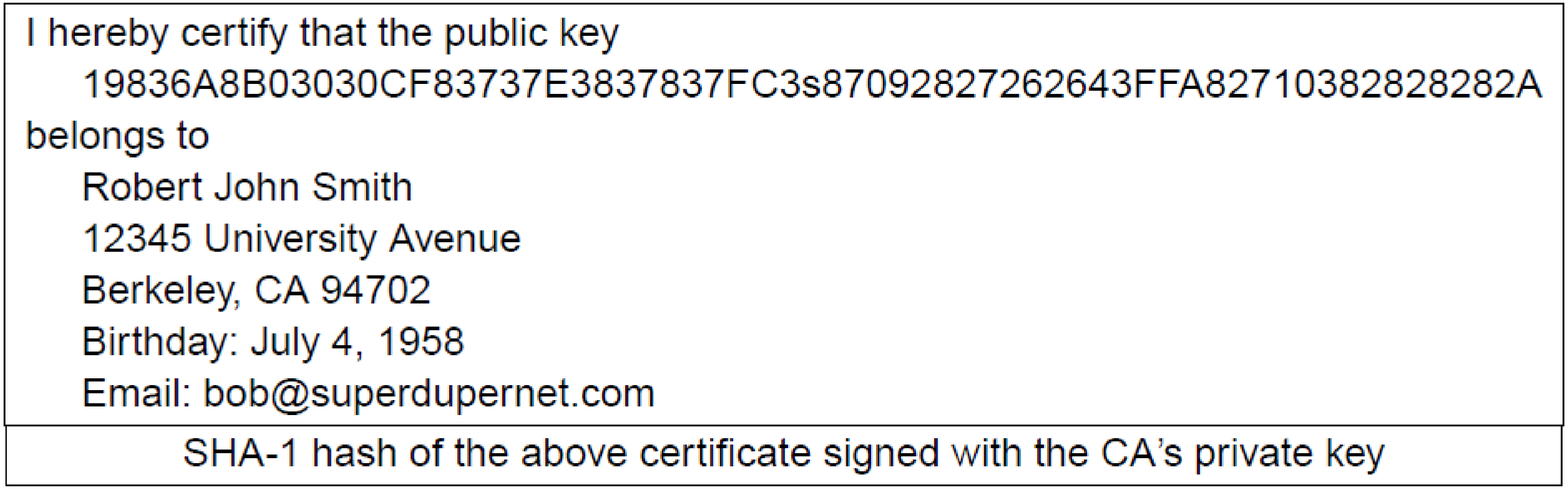
Trudy can subvert encryption if she can fake Bob’s public key; Alice and Bob will not necessarily know



Trudy replaces E_B with E_T and acts as a “man in the middle”

Certificates

CA (Certification Authority) issues signed statements about public keys; users trust CA and it can be offline



I hereby certify that the public key
    19836A8B03030CF83737E3837837FC3s87092827262643FFA82710382828282A
belongs to
    Robert John Smith
    12345 University Avenue
    Berkeley, CA 94702
    Birthday: July 4, 1958
    Email: bob@superdupernet.com

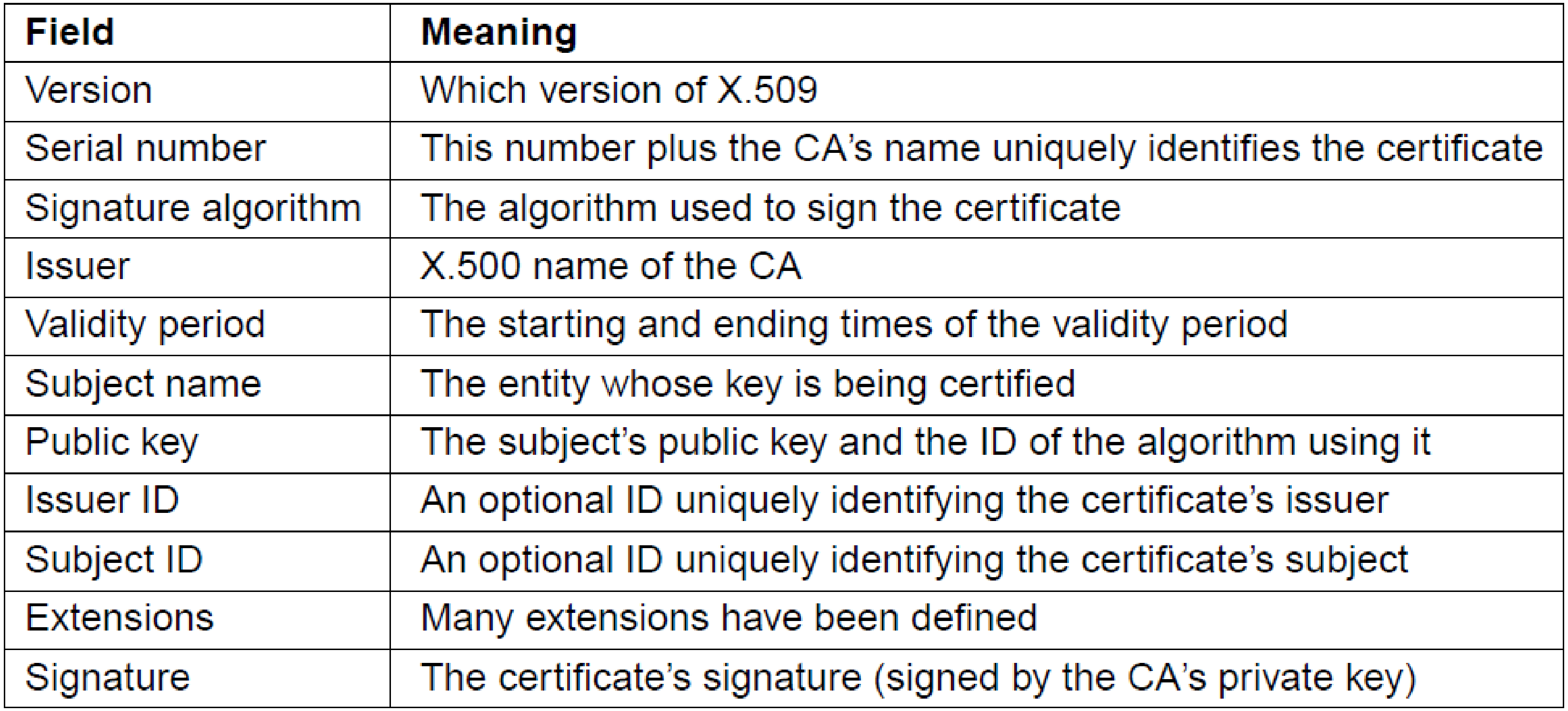
SHA-1 hash of the above certificate signed with the CA’s private key

A possible certificate

X.509

X.509 is the standard for widely used certificates

- Ex: used with TLS for secure Web browsing



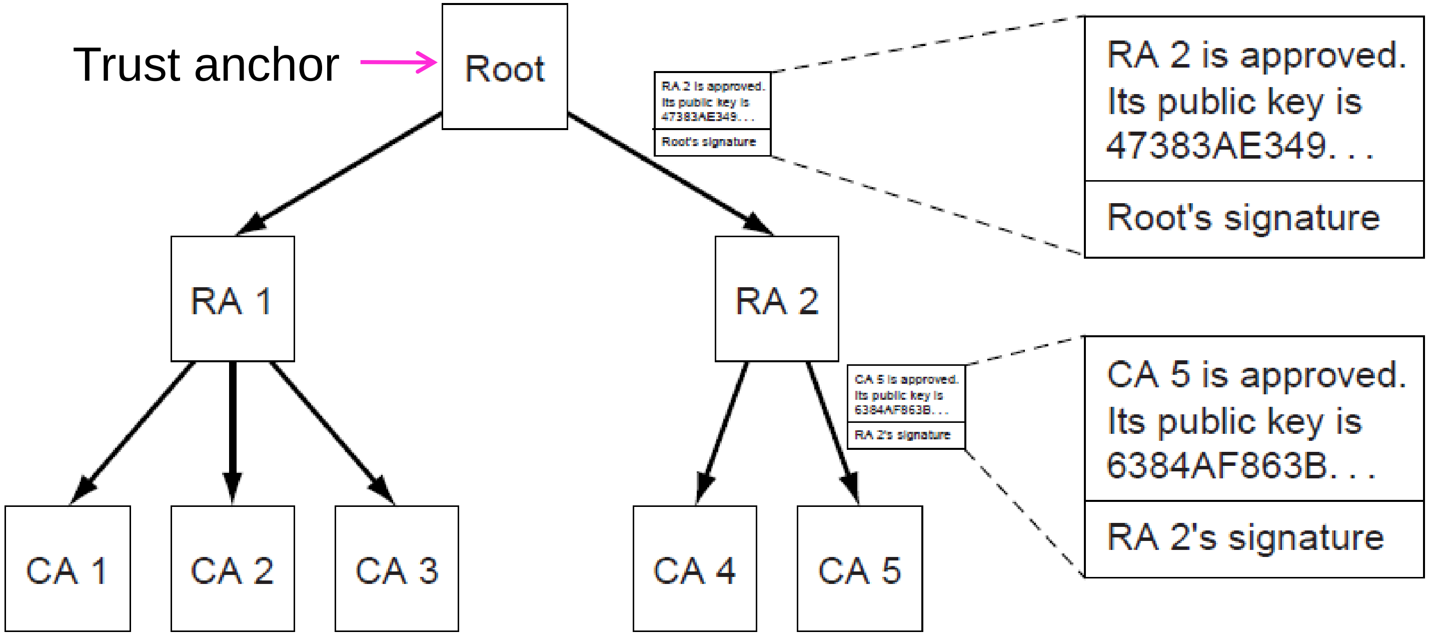
Field	Meaning
Version	Which version of X.509
Serial number	This number plus the CA's name uniquely identifies the certificate
Signature algorithm	The algorithm used to sign the certificate
Issuer	X.500 name of the CA
Validity period	The starting and ending times of the validity period
Subject name	The entity whose key is being certified
Public key	The subject's public key and the ID of the algorithm using it
Issuer ID	An optional ID uniquely identifying the certificate's issuer
Subject ID	An optional ID uniquely identifying the certificate's subject
Extensions	Many extensions have been defined
Signature	The certificate's signature (signed by the CA's private key)

Basic fields in X.509 certificates

Public Key Infrastructures (PKIs)

PKI is a system for managing public keys using CAs

- Scales with hierarchy, may have multiple roots
- Also need CRLs (Certificate Revocation Lists)


Trust anchor
Root
RA 1
RA 2
CA 1
CA 2
CA 3
CA 4
CA 5
RA 2 is approved. Its public key is 47383AE349. . .
Root's signature
RA 2 is approved. Its public key is 47383AE349. . .
Root's signature
CA 5 is approved. Its public key is 6384AF863B. . .
RA 2's signature
CA 5 is approved. Its public key is 6384AF863B. . .
RA 2's signature

Hierarchical PKI

Chain of certificates for CA 5

Java Cryptography Architecture

The JCA contains a "provider" architecture and a set of APIs for digital signatures, message digests (hashes), certificates and certificate validation, encryption (symmetric/asymmetric block/stream ciphers), key generation and management, and secure random number generation

These APIs allow developers to easily integrate security into their application code.

https://docs.oracle.com/javase/8/docs/technotes/guides/security/crypto/CryptoSpec.html

Additional topics

Communication Security

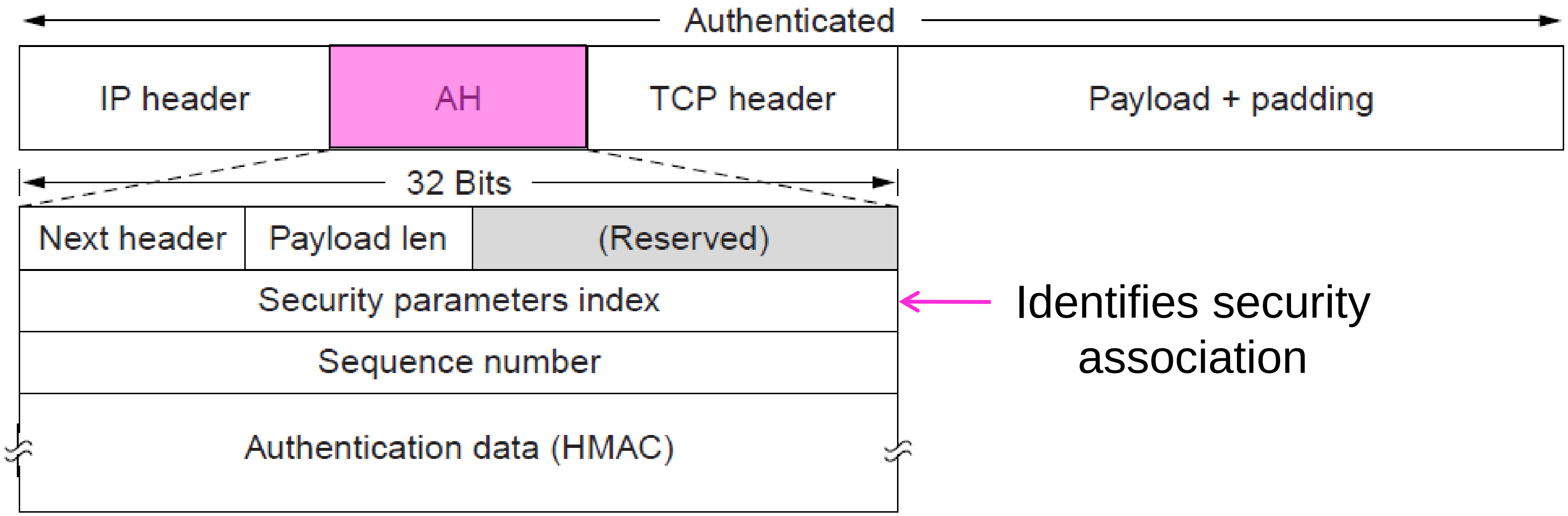
Applications of security to network protocols

- IPsec (IP security) »
- Firewalls »
- Virtual private networks »
- Wireless security »

IPsec (1)

IPsec adds confidentiality and authentication to IP

- Secret keys are set up for packets between endpoints called security associations
- Adds AH header; inserted after IP in transport mode



Authenticated

IP header	AH	TCP header	Payload + padding

32 Bits

Next header	Payload len	(Reserved)
Security parameters index		
Sequence number		
Authentication data (HMAC)		

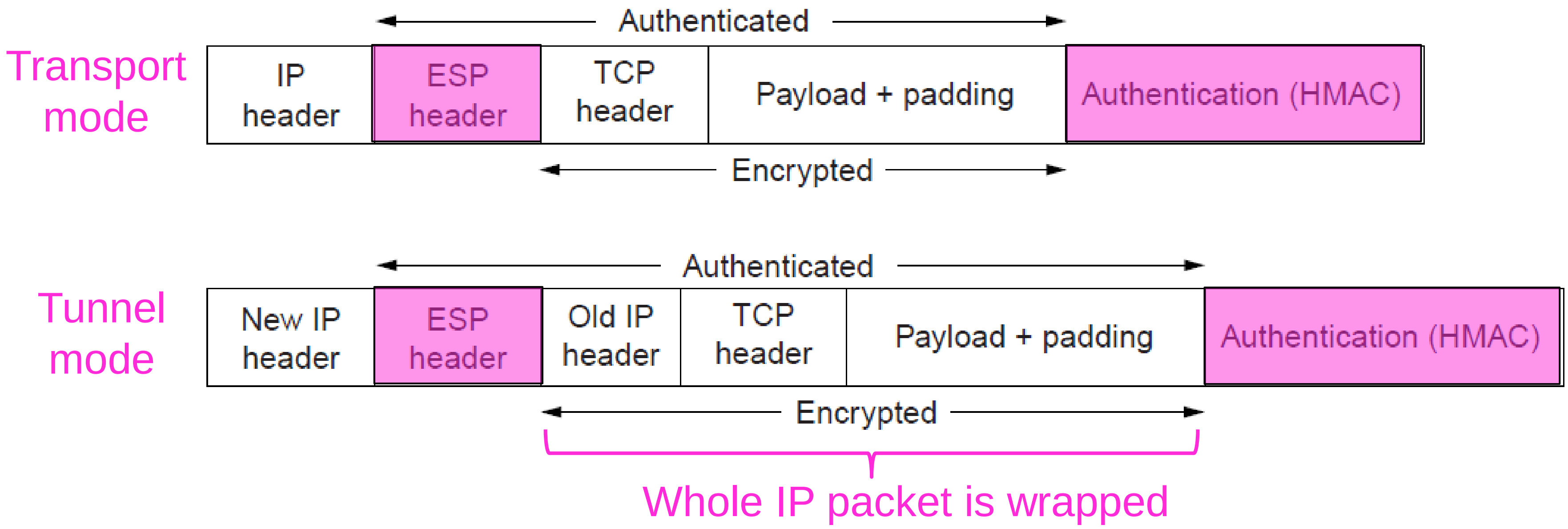
Identifies security association

AH (Authentication Header) provides integrity and anti-replay

IPsec (2)

ESP (Encapsulating Security Payload) provides secrecy and integrity; expands on AH

- Adds ESP header and trailer; inserted after IP header in transport or before in tunnel mode



Transport mode

Authenticated

IP header	ESP header	TCP header	Payload + padding	Authentication (HMAC)

Encrypted

Tunnel mode

Authenticated

New IP header	ESP header	Old IP header	TCP header	Payload + padding	Authentication (HMAC)

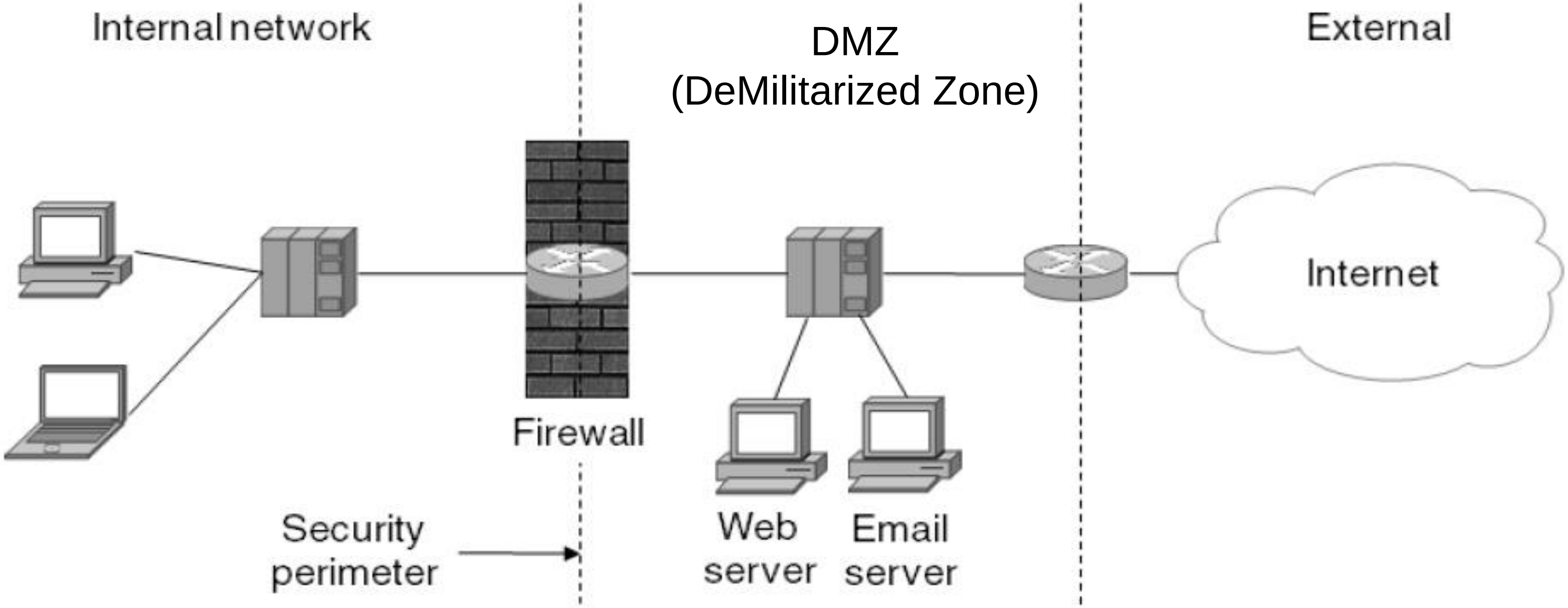
Encrypted

Whole IP packet is wrapped

Firewalls

A firewall protect an internal network by filtering packets

- Can have stateful rules about what packets to pass
  - E.g., no incoming packets to port 80 (Web) or 25 (SMTP)
- DMZ helps to separate internal from external traffic
  - E.g., run Web and Email servers there



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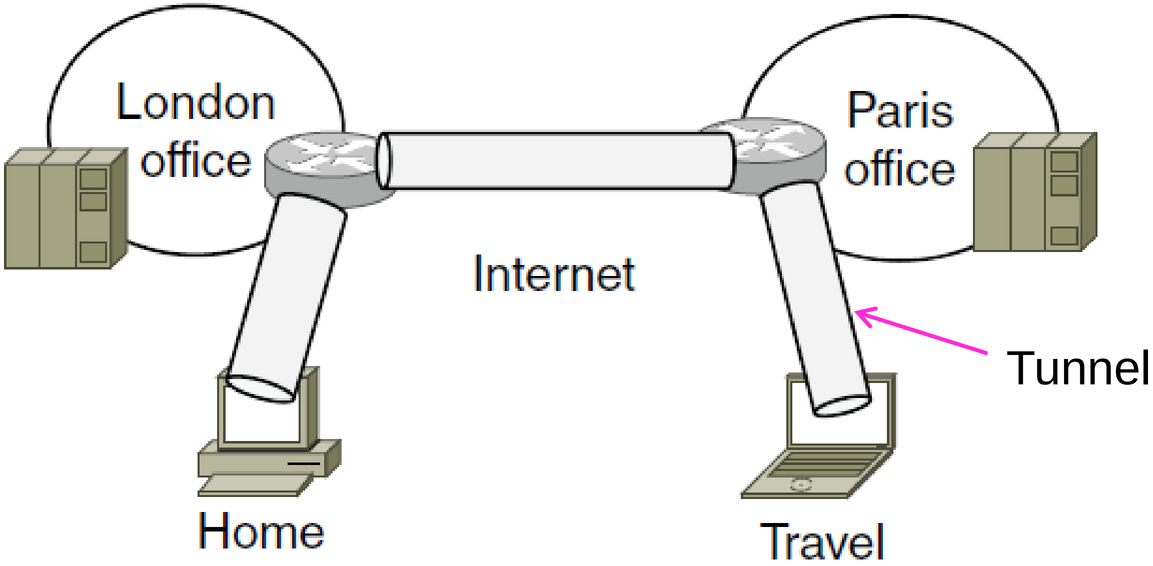
Virtual Private Networks (1)

VPNs (Virtual Private Networks) join disconnected islands of a logical network into a single virtual network

- Islands are joined by tunnels over the Internet

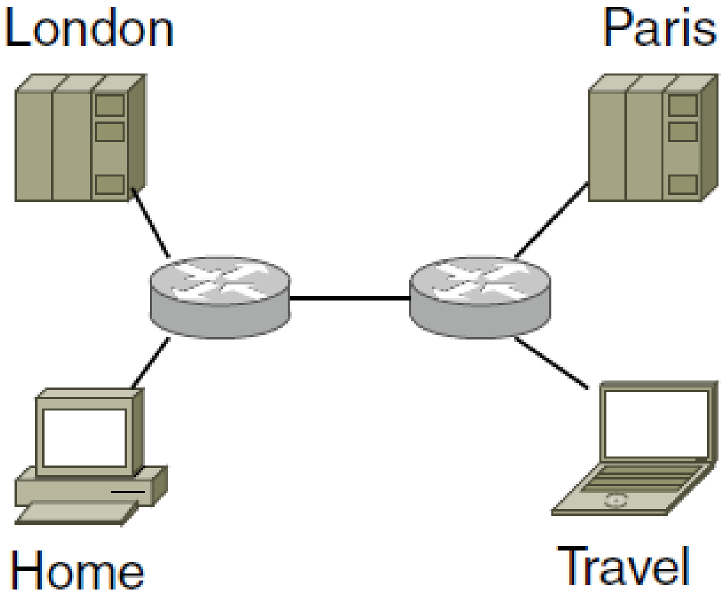


VPN joining London, Paris, Home, and Travel

Virtual Private Networks (2)

VPN traffic travels over the Internet but VPN hosts are separated from the Internet

- Need a gateway to send traffic in/out of VPN



Topology as seen from inside the VPN

Wireless Security (1)

Wireless signals are broadcast to all nearby receivers

- Important to use encryption to secure the network
- This is an issue for 802.11, Bluetooth, 3G, …

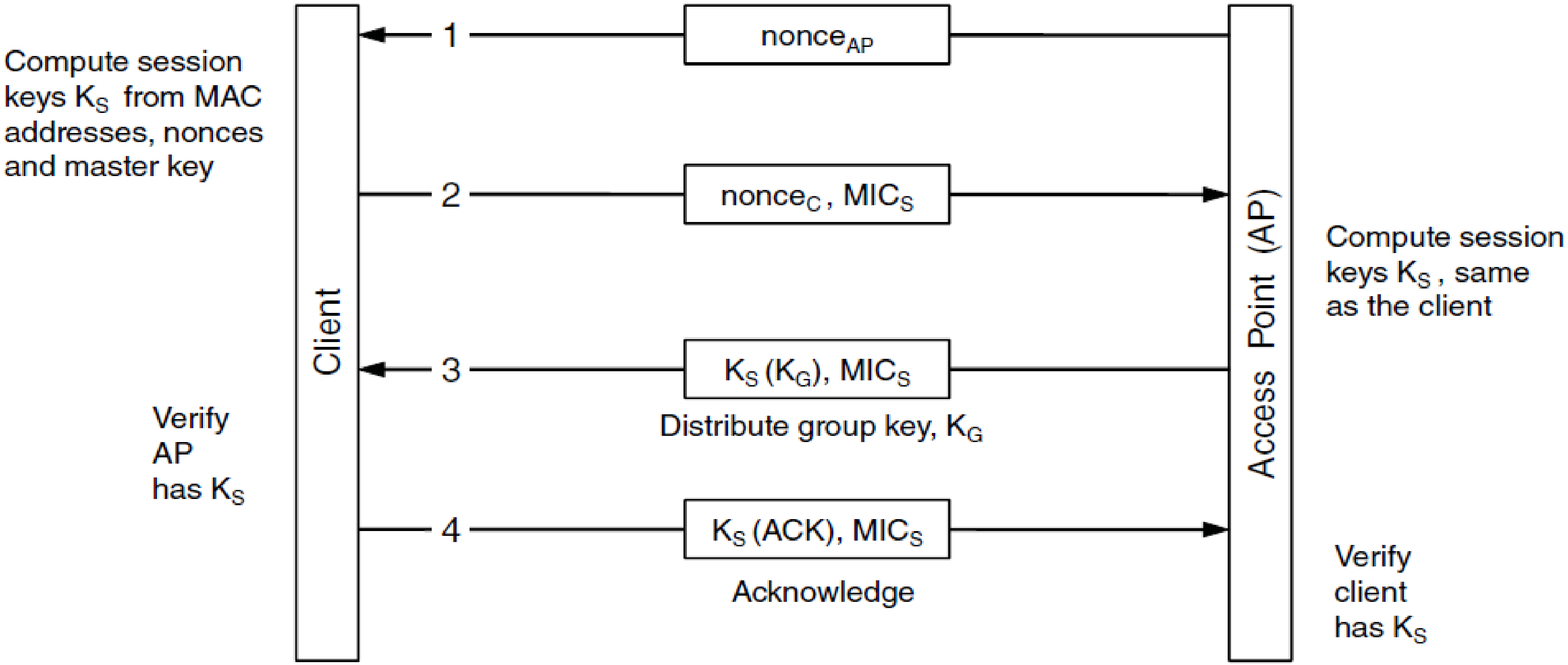
Common design:

1. Clients have a password set up for access
2. Clients authenticate to infrastructure and set up a session key
3. Session key is then used to encrypt packets

Wireless Security (2)

802.11i session key setup handshake (step 2)

- Client and AP share a master key (password)
- MIC (Message Integrity Check) is like a signature
- $K_X(M)$ means a message M encrypted with key K_X



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Authentication Protocols

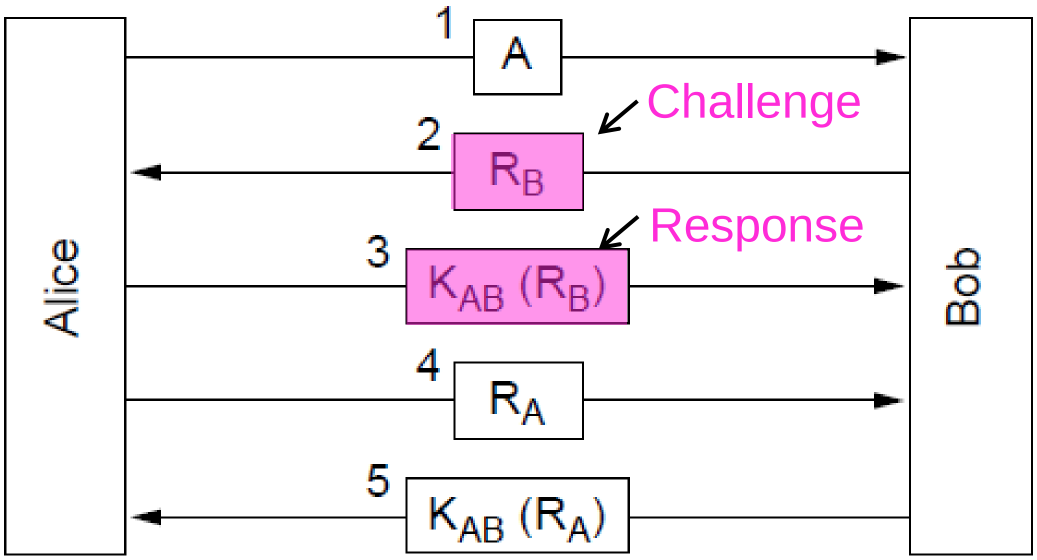
Authentication verifies the identity of a remote party

- Shared Secret Key »
- Diffie-Hellman Key Exchange »
- Key Distribution Center »
- Kerberos »
- Public-Key Cryptography »

Shared Secret Key (1)

Authenticating with a challenge-response (first attempt)

- Alice (A) and Bob (B) share a key K_{AB}
- R_X is random, K_X (M) is M encrypted with key K_X



Challenge

Response

Bob knows it's Alice

Alice knows it's Bob

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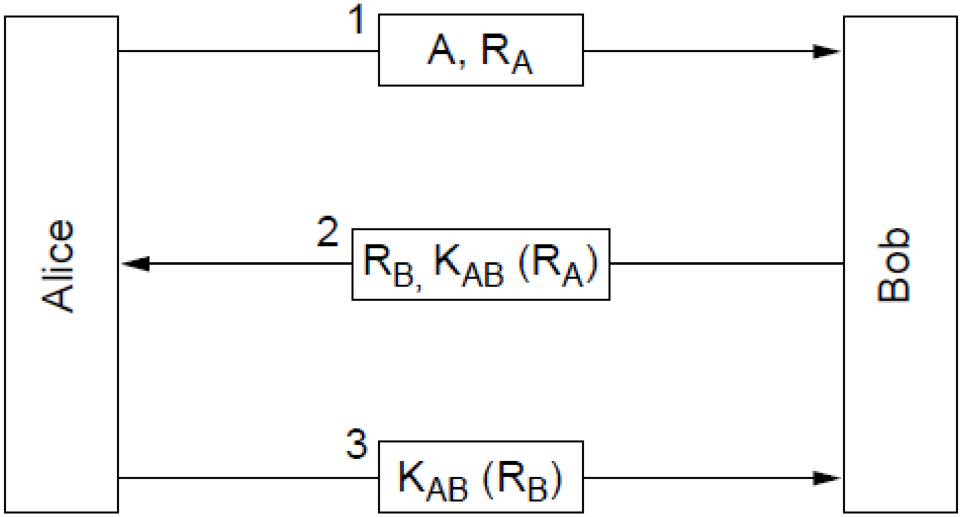
Shared Secret Key (2)

A shortened two-way authentication (second attempt)

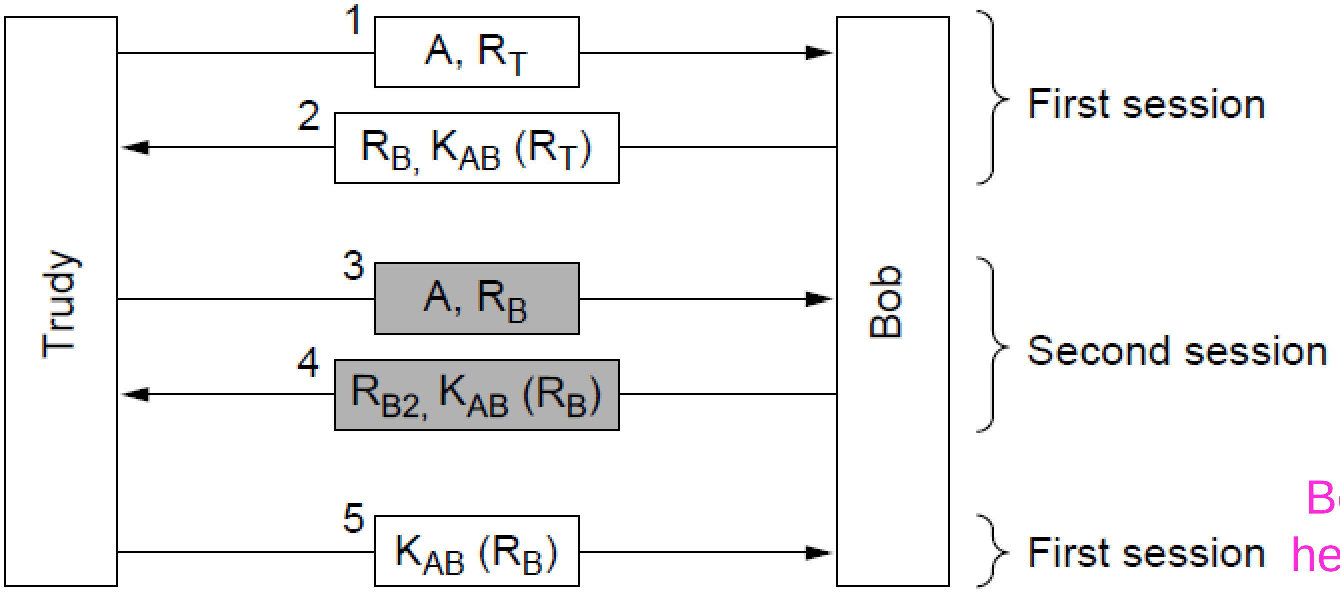
- But it is vulnerable to reflection attack



Shared Secret Key (3)

Trudy impersonates Alice to Bob with reflection attack

- Second session gets Bob to give Trudy the response



Bob thinks he is talking to Alice now

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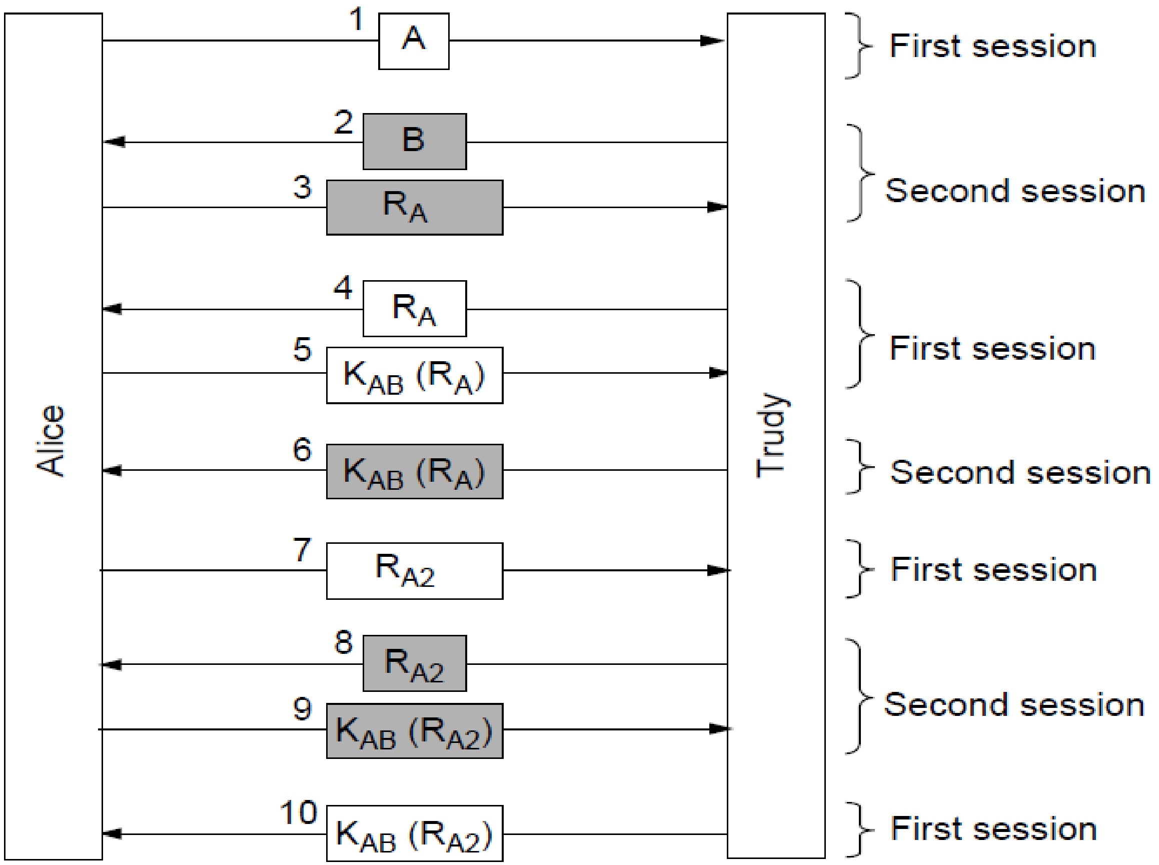
Shared Secret Key (4)

First attempt is also vulnerable to reflection attack!

- Trudy impersonates Bob to Alice after Alice initiates



Alice thinks she is talking to Bob

Alice thinks she is talking to Bob again

Shared Secret Key (5)

Moral: *Designing a correct authentication protocol is harder than it looks; errors are often subtle.*

General design rules for authentication:

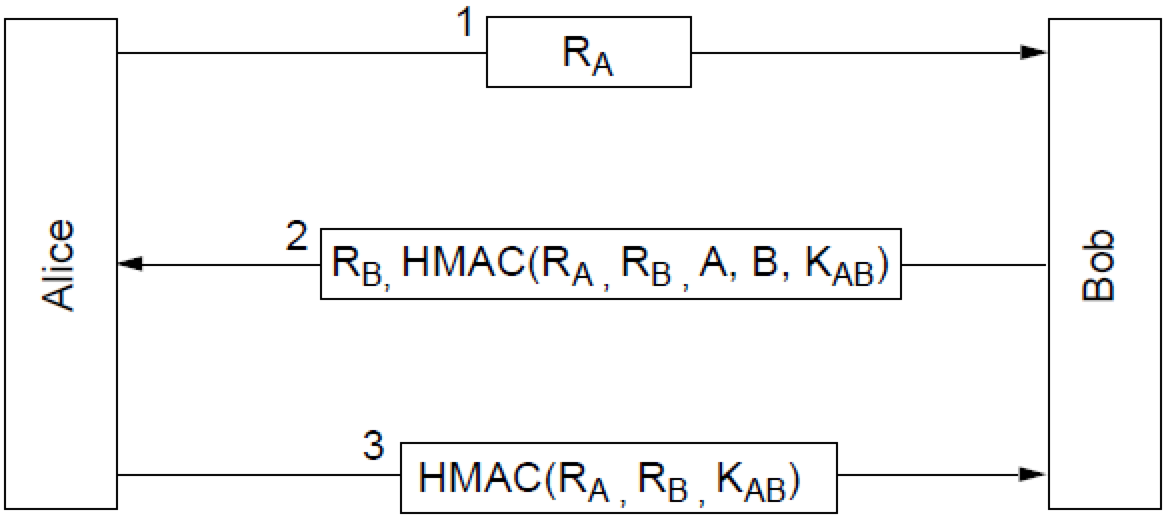
1. Have initiator prove who she is before responder
2. Initiator, responder use different keys
3. Draw challenges from different sets
4. Make protocol resistant to attacks involving second parallel session

Shared Secret Key (6)

An authentication protocol that is not vulnerable

- HMAC (Hashed Message Authentication Code) is an authenticator, like a signature

Alice knows
it's Bob

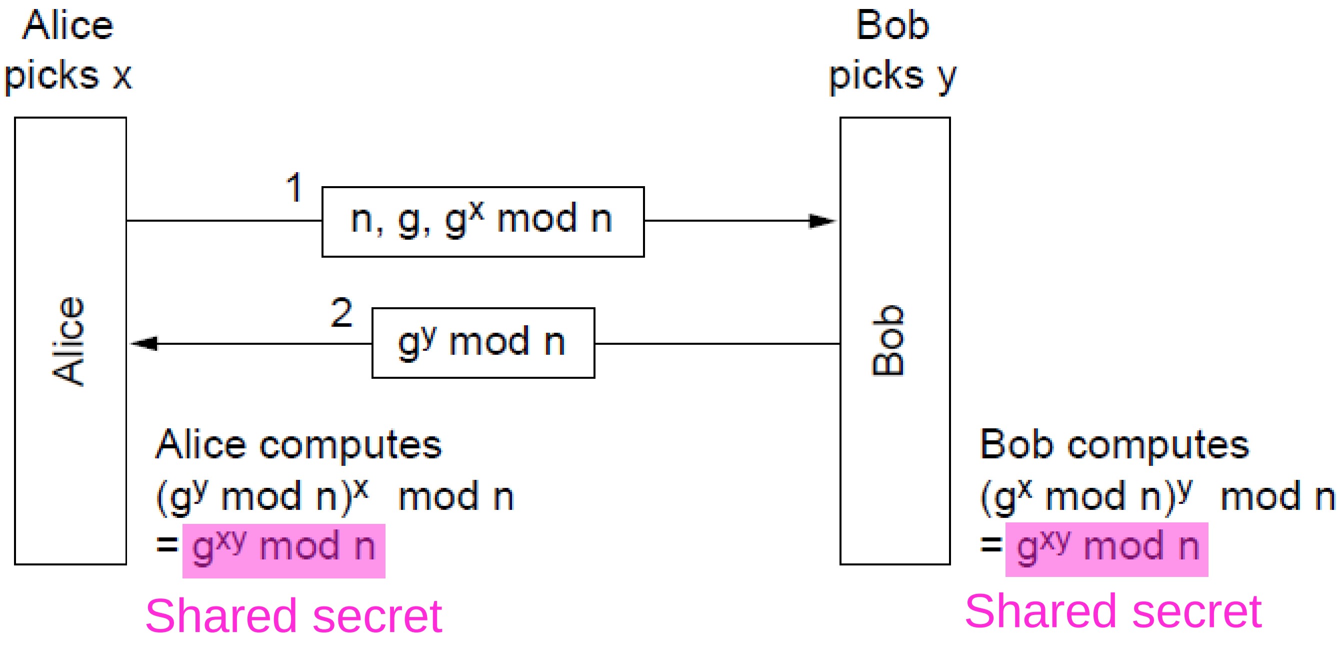

1
R_A
Alice
2
R_B, HMAC(R_A , R_B , A, B, K_{AB})
Bob
3
HMAC(R_A , R_B , K_{AB})

Bob knows
it's Alice

Diffie-Hellman Key Exchange (1)

Lets two parties establish a shared secret

- Eavesdropper can't compute secret g^{xy} mod n without knowing x or y



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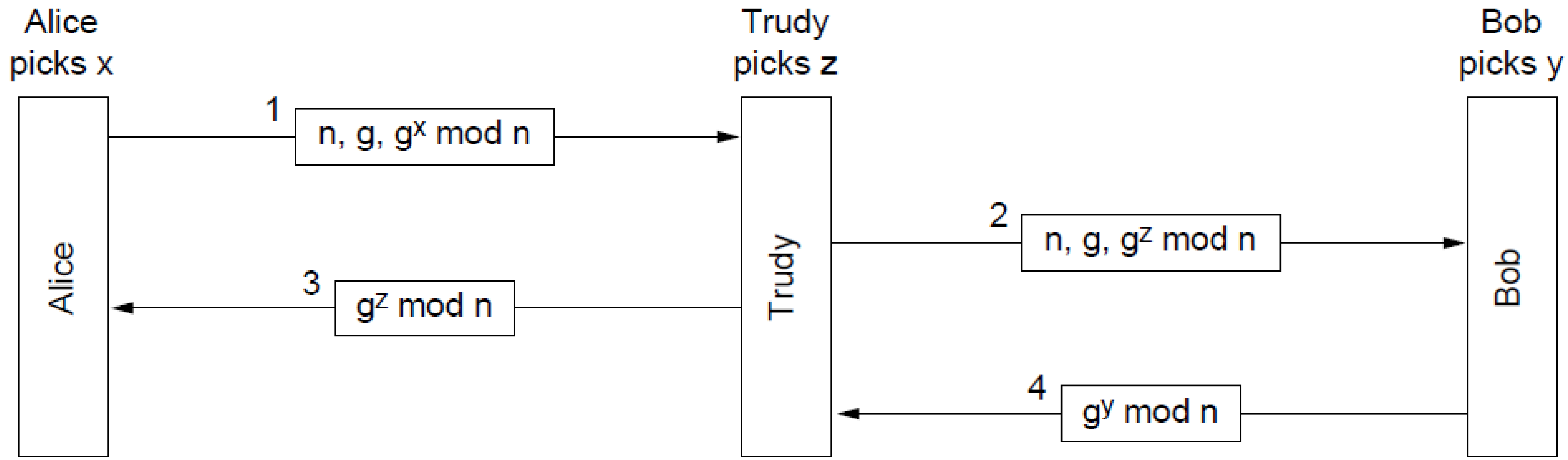
Diffie-Hellman Key Exchange (2)

But it is vulnerable to a man-in-the-middle attack

- Need to confirm identities, not just share a secret



g^{xz} mod n

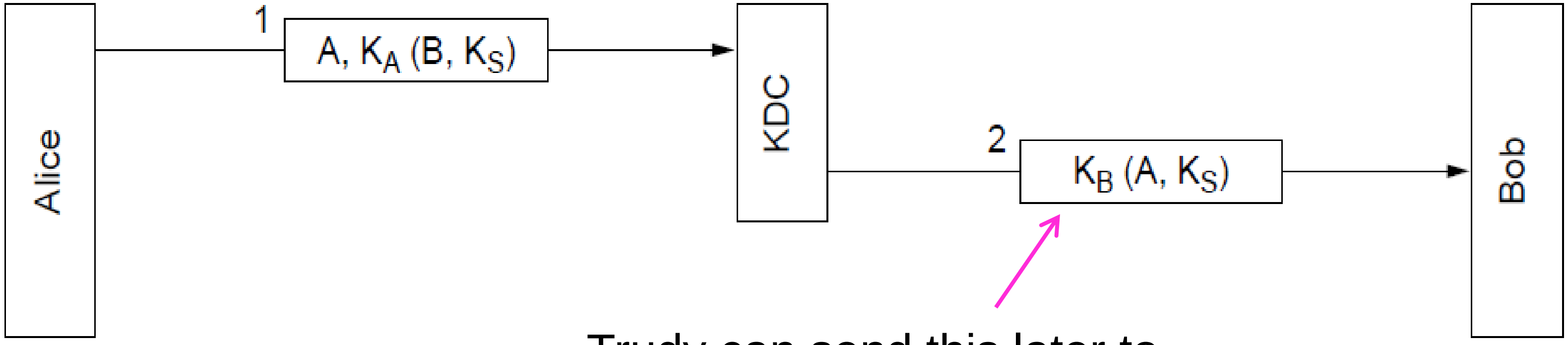
g^{xz} mod n
g^{zy} mod n

g^{zy} mod n

KDC – Key Distribution Center (1)

Trusted KDC removes need for many shared secrets

- Alice and Bob share a secret only with KDC (K_A, K_B)
- End up with K_S, a shared secret session key
- First attempt below is vulnerable to replay attack in which Trudy captures and later replays messages



Alice has session key K_S

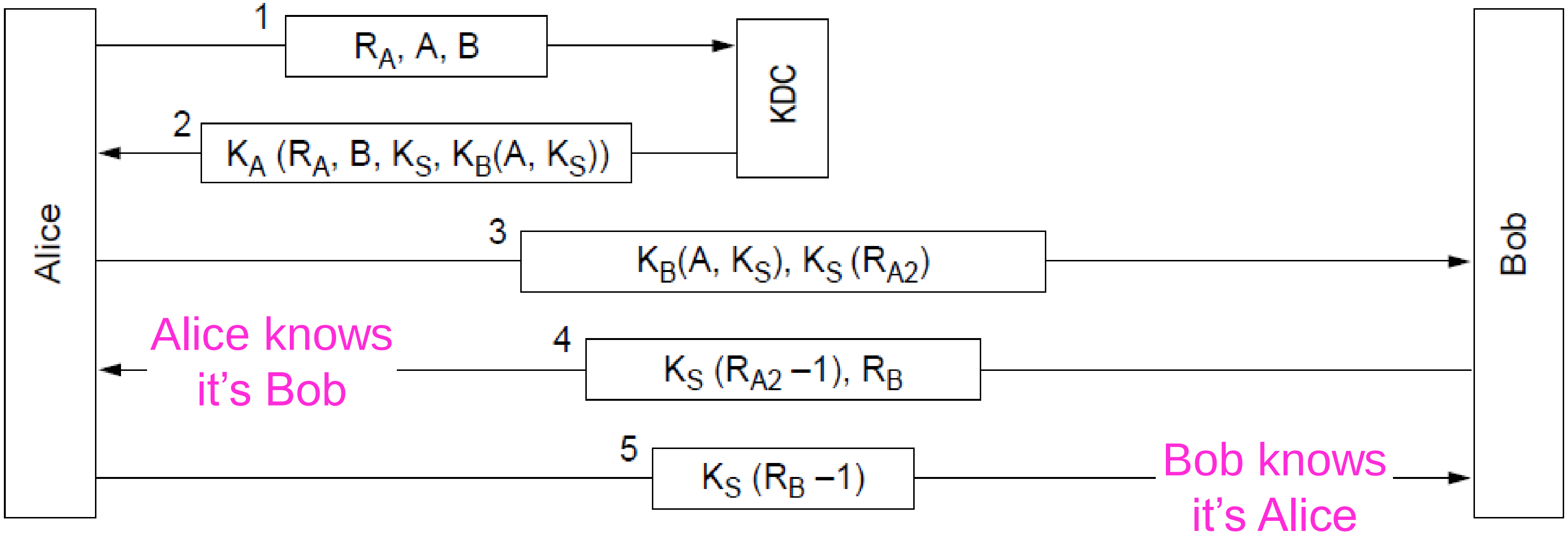
Trudy can send this later to impersonate Alice to Bob

Bob has session key K_S

Key Distribution Center (2)

The Needham-Schroeder authentication protocol

- Not vulnerable to replays; doesn't use timestamps


Alice
KDC
Bob
1 R_A, A, B
2 K_A (R_A, B, K_S, K_B(A, K_S))
3 K_B(A, K_S), K_S (R_{A2})
4 K_S (R_{A2} –1), R_B
5 K_S (R_B –1)
Alice knows it's Bob
Bob knows it's Alice

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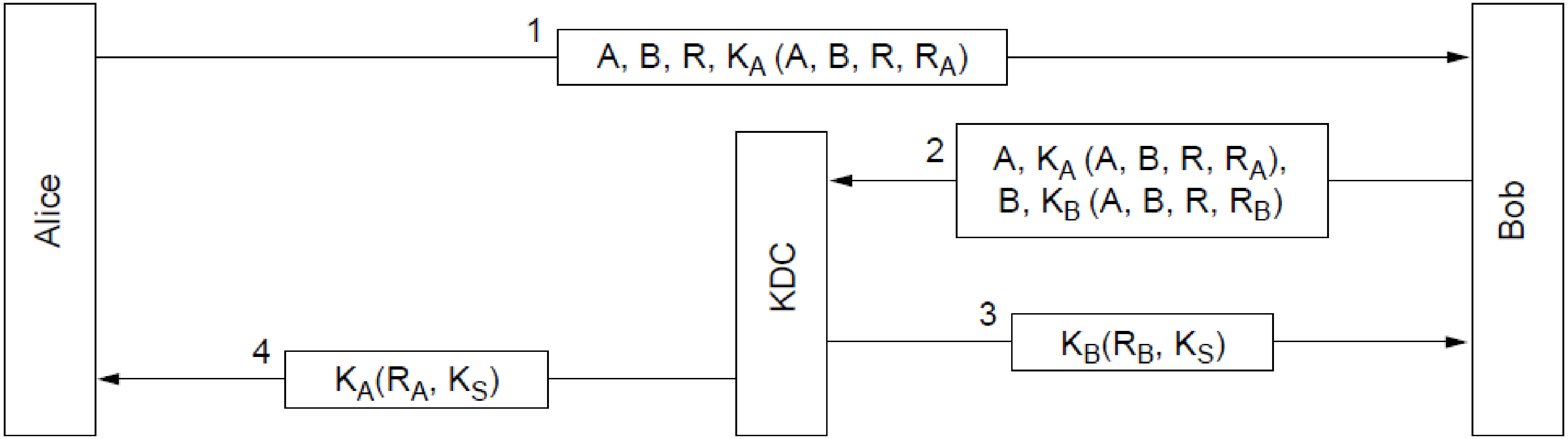
Key Distribution Center (3)

The Otway-Rees authentication protocol (simplified)

- Slightly stronger than previous; Trudy can't replay even if she obtains previous secret K_S



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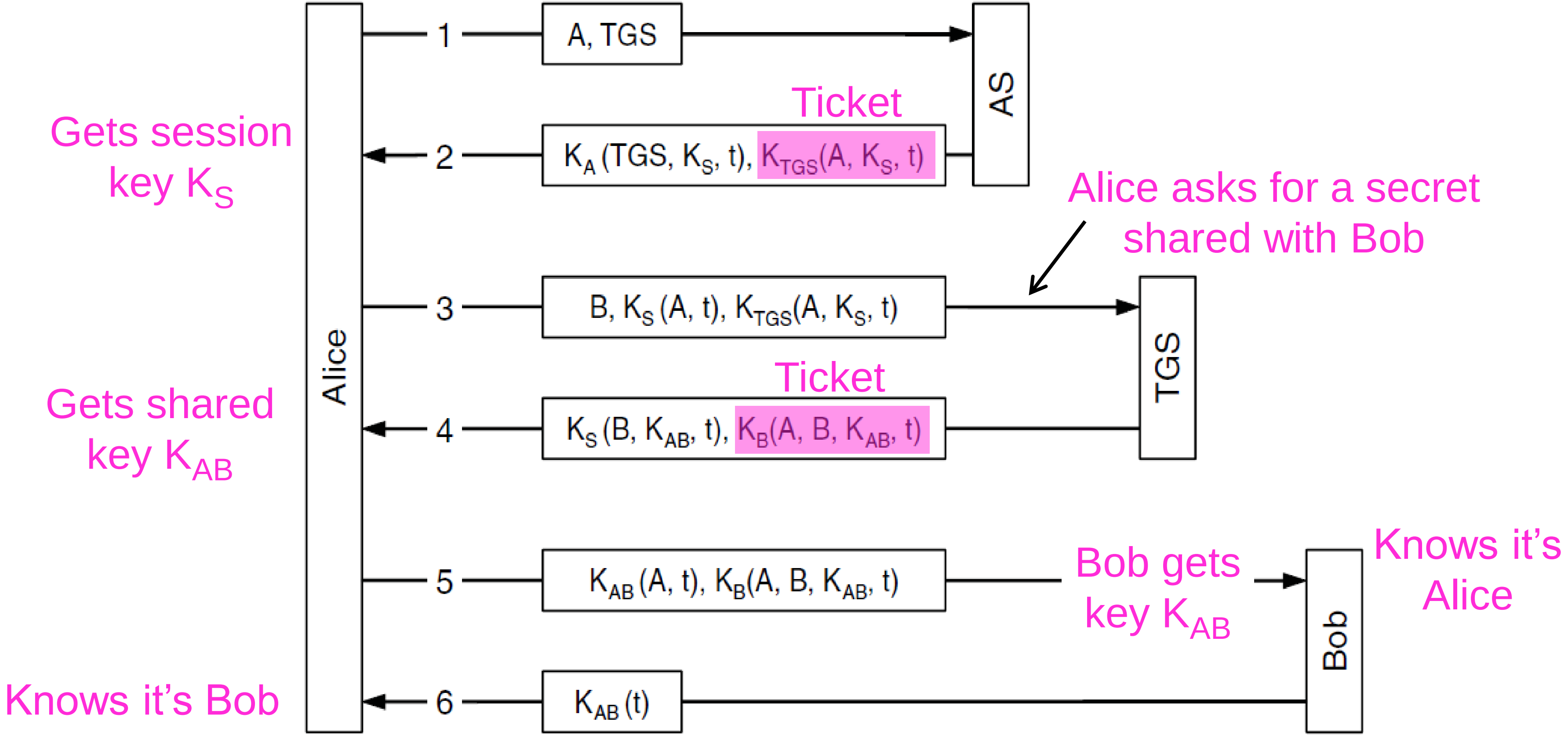
Kerberos

Kerberos V5 is a widely used protocol (e.g., Windows)

- Authentication includes TGS (Ticket Granting Server)



Gets session key K_S

Gets shared key K_{AB}

Knows it's Bob

Alice
AS
TGS
Bob
1
A, TGS
2
Ticket
K_A(TGS, K_S, t), K_{TGS}(A, K_S, t)
3
B, K_S(A, t), K_{TGS}(A, K_S, t)
4
Ticket
K_S(B, K_{AB}, t), K_B(A, B, K_{AB}, t)
5
K_{AB}(A, t), K_B(A, B, K_{AB}, t)
6
K_{AB}(t)

Alice asks for a secret shared with Bob

Bob gets key K_{AB}

Knows it's Alice

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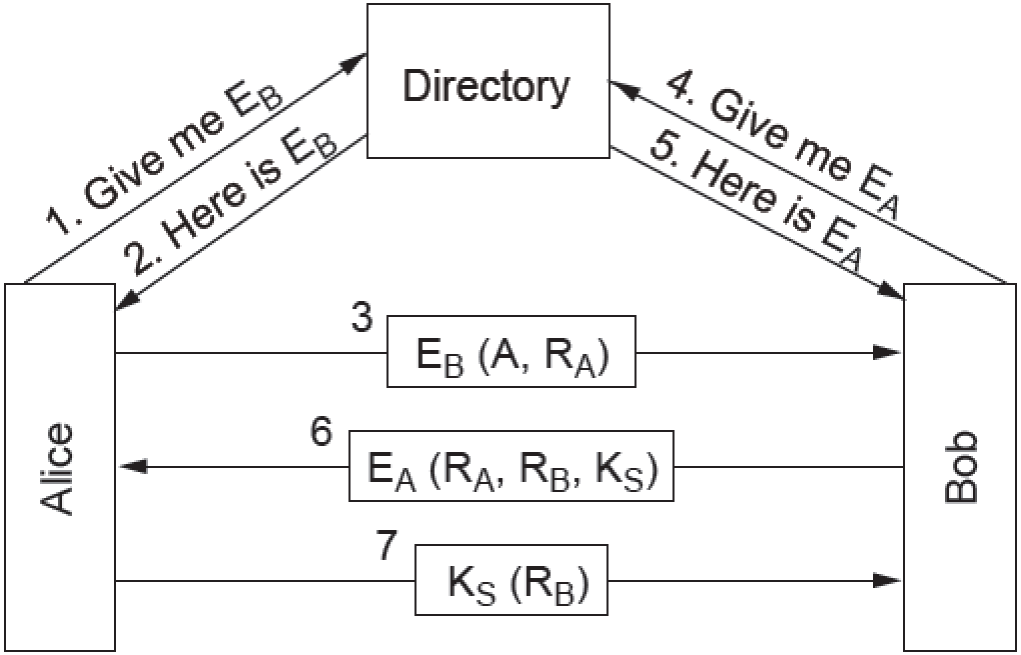
Public-Key Cryptography

Mutual authentication using public-key cryptography

- Alice and Bob get each other's public keys (E_A, E_B) from a trusted directory; shared K_S is the result



Email Security

Use of security for authenticated, confidential email

- PGP—Pretty Good Privacy »

PGP—Pretty Good Privacy (1)

PGP uses public- and symmetric-key cryptography for email secrecy and signatures; it also manages keys

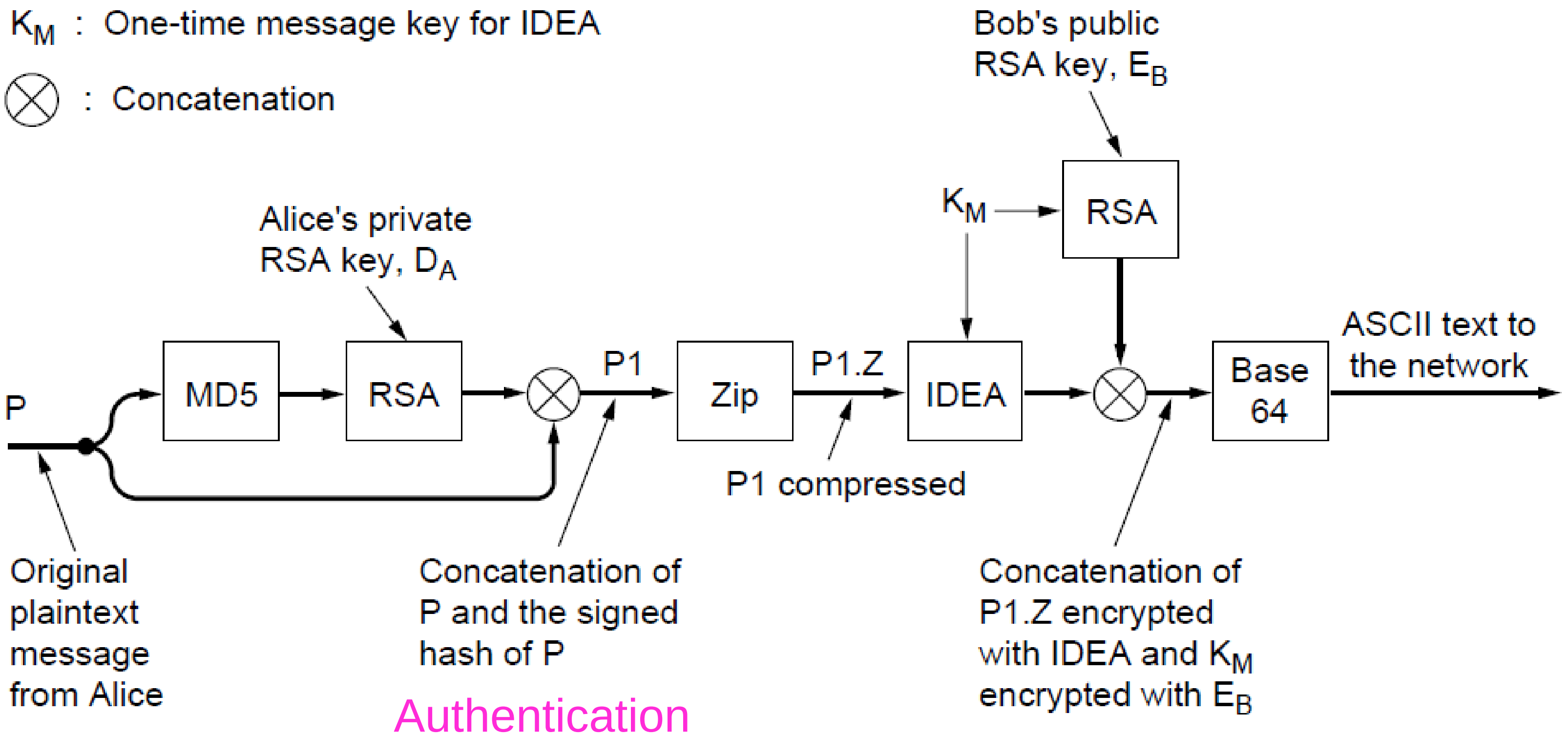
Levels of public-key strengths:

- Casual (384 bits):
  - Can be broken easily today.
- Commercial (512 bits): b
  - Breakable by three-letter organizations.
- Military (1024 bits):
  - Not breakable by anyone on earth.
- Alien (2048 bits):
  - Unbreakable by anyone on other planets

PGP—Pretty Good Privacy (2)

Signing and encrypting a message from Alice to Bob

- For speed, message symmetric-key IDEA encrypted with K_M; K_M is RSA public-key encrypted with K_B


K_M : One-time message key for IDEA
⊗ : Concatenation
Bob's public RSA key, E_B
Alice's private RSA key, D_A
K_M
RSA
P
MD5
RSA
P1
Zip
P1.Z
IDEA
Base 64
ASCII text to the network
P1 compressed
Original plaintext message from Alice
Concatenation of P and the signed hash of P
Concatenation of P1.Z encrypted with IDEA and K_M encrypted with E_B

Authentication

Confidentiality

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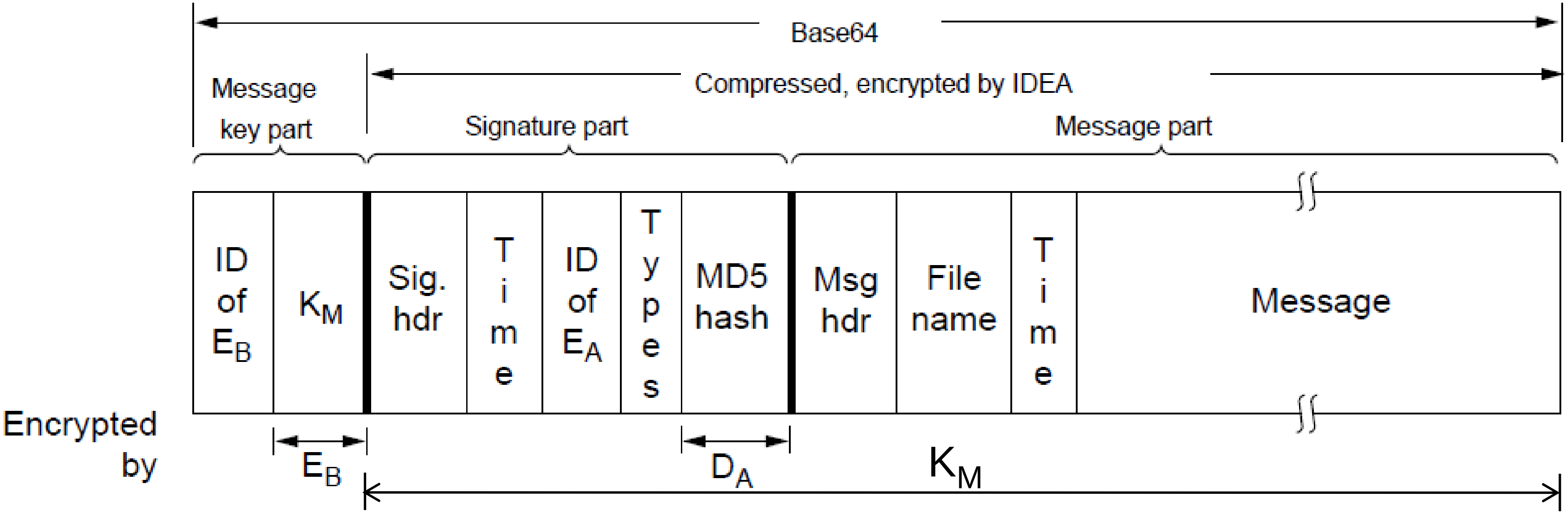
PGP—Pretty Good Privacy (3)

Three parts of a PGP message and their encryption:



PGP also manages public keys for a user:

- Private key ring has user’s public/private keys
- Public key ring has correspondent’s public keys

Web Security

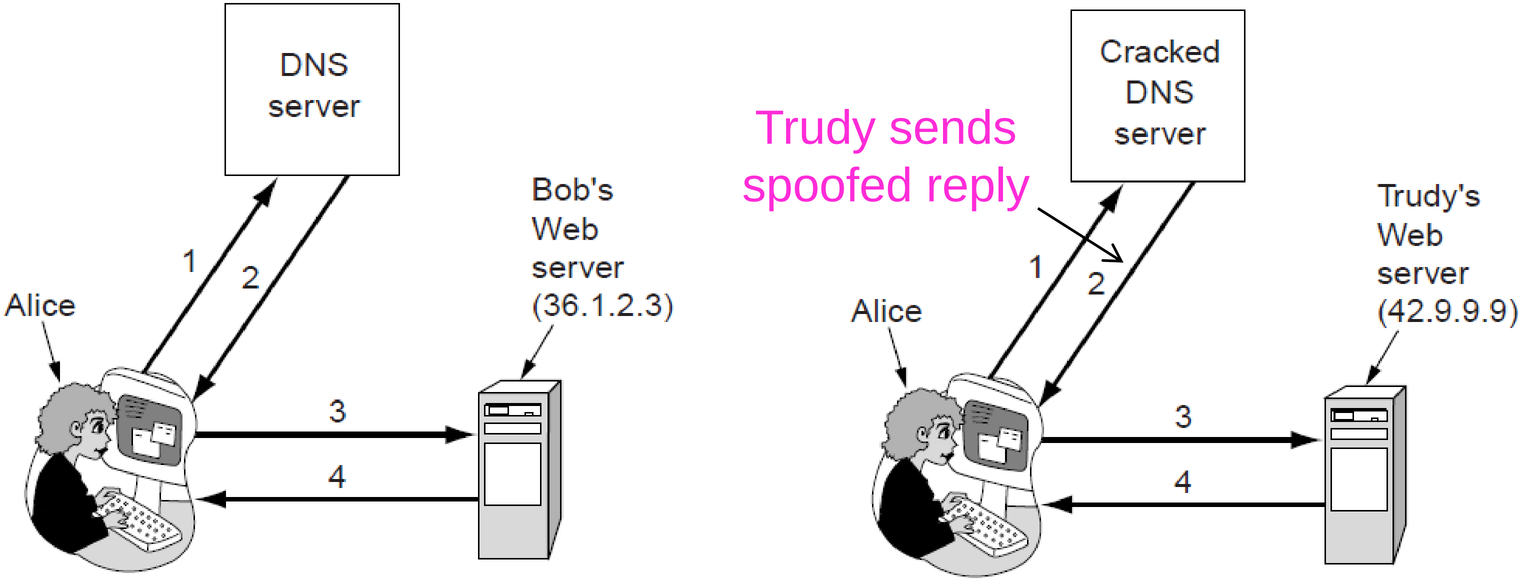
Applications of security to the Web

- Secure naming »
- SSL—Secure Sockets Layer »
- TLS – Transport Layer Security

Many other issues with downloaded code

Secure Naming (1)

DNS names are included as part of URLs – so spoofing DNS resolution causes Alice contact Trudy not Bob



Trudy sends spoofed reply

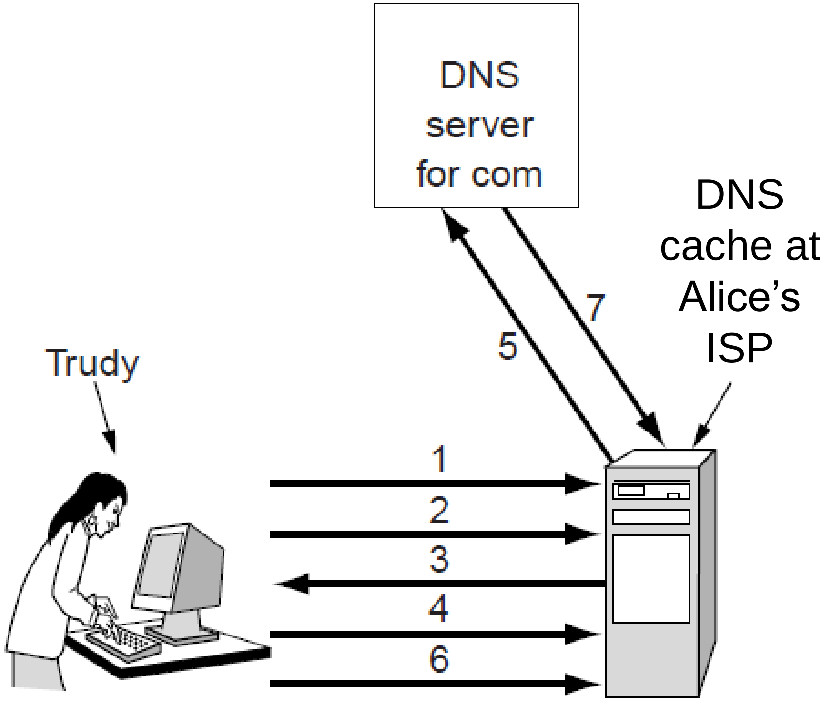
1. Give me Bob's IP address
2. 36.1.2.3 (Bob's IP address)
3. GET index.html
4. Bob's home page

1. Give me Bob's IP address
2. 42.9.9.9 (Trudy's IP address)
3. GET index.html
4. Trudy's fake of Bob's home page

Secure Naming (2)

How Trudy spoofs the DNS for *bob.com* in more detail

- To counter, DNS servers randomize seq. numbers

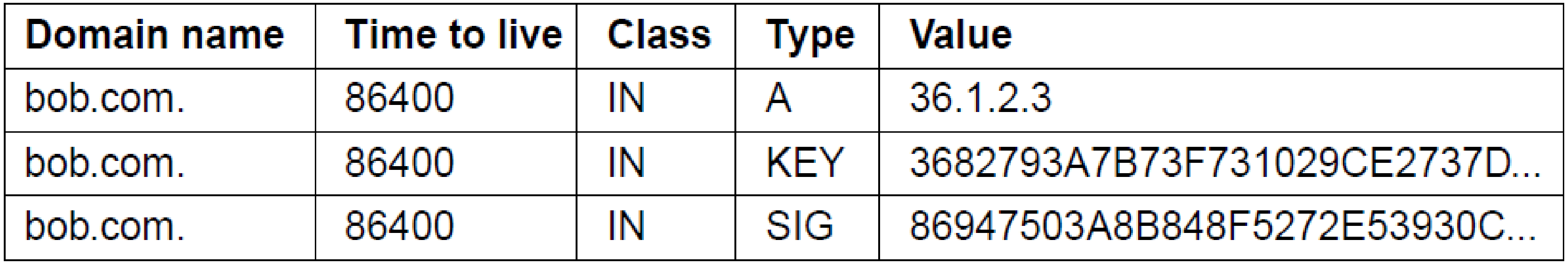


1. Look up foobar.trudy-the-intruder.com
   (to force it into the ISP's cache)
2. Look up www.trudy-the-intruder.com
   (to get the ISP's next sequence number)
3. Request for www.trudy-the-intruder.com
   (Carrying the ISP's next sequence number, n)
4. Quick like a bunny, look up bob.com
   (to force the ISP to query the com server in step 5)
5. Legitimate query for bob.com with seq = n+1
6. Trudy's forged answer: Bob is 42.9.9.9, seq = n+1
7. Real answer (rejected, too late)

Secure Naming (3)

DNSsec (DNS security) adds strong authenticity to DNS

- Responses are signed with public keys
- Public keys are included; client starts with top-level
- Also optional anti-spoofing to tie request/response
- Now being deployed in the Internet



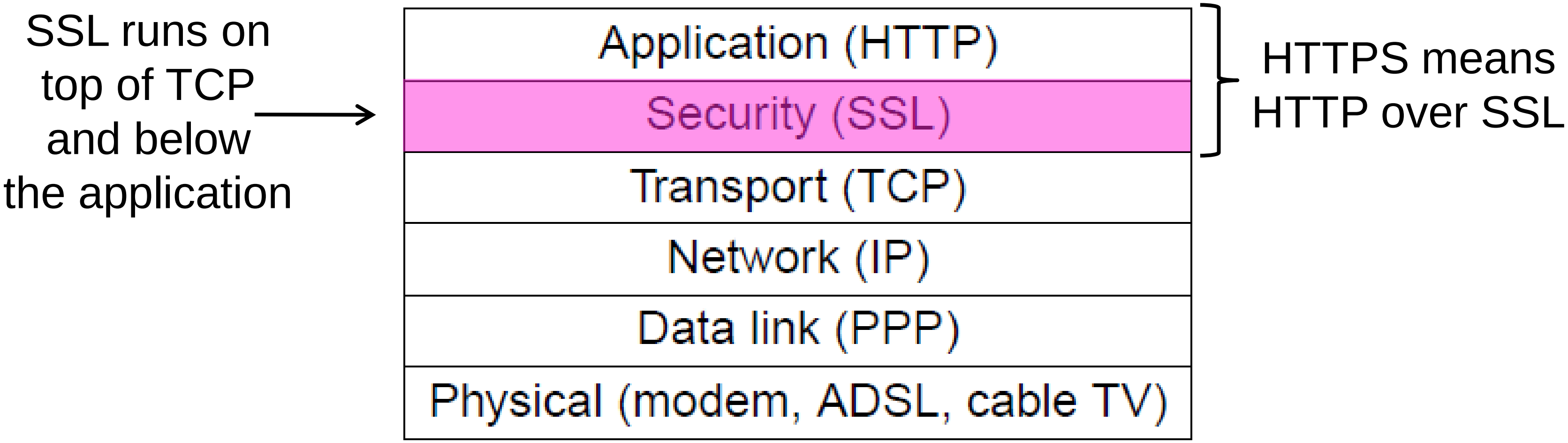
Domain name	Time to live	Class	Type	Value
bob.com.	86400	IN	A	36.1.2.3
bob.com.	86400	IN	KEY	3682793A7B73F731029CE2737D...
bob.com.	86400	IN	SIG	86947503A8B848F5272E53930C...

Resource Record set for *bob.com*.
Has Bob’s public key (KEY), and is signed by .com server (SIG)

SSL—Secure Sockets Layer (1)

SSL provides an authenticated, secret connection between two sockets; uses public keys with X.509

- TLS (Transport Layer Security) is the IETF version



SSL runs on top of TCP and below the application

Application (HTTP)

Security (SSL)

Transport (TCP)

Network (IP)

Data link (PPP)

Physical (modem, ADSL, cable TV)

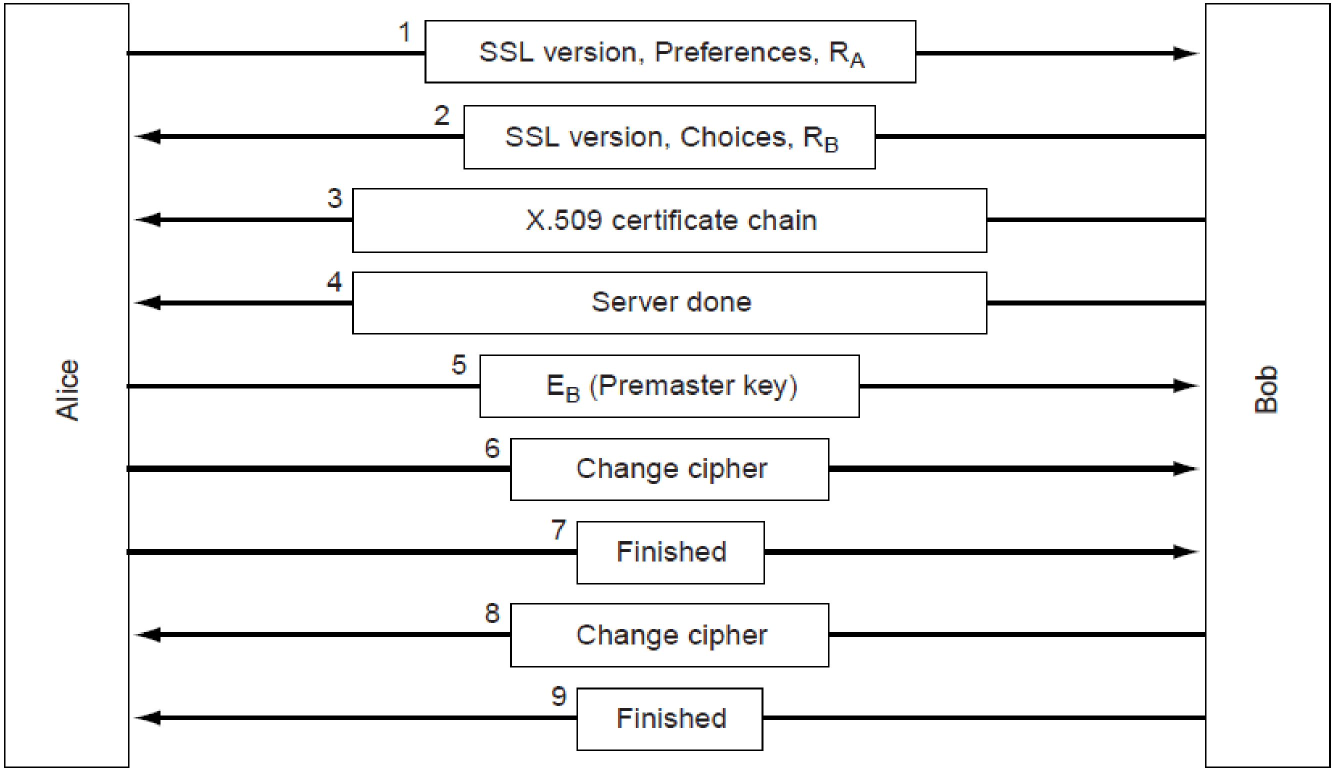
HTTPS means HTTP over SSL

SSL in the protocol stack

SSL—Secure Sockets Layer (2)

Phases in SSL V3 connection establishment (simplified)

- Only the client (Alice) authenticates the server (Bob)
- Session key computed on both sides (E_B, R_A, R_B)



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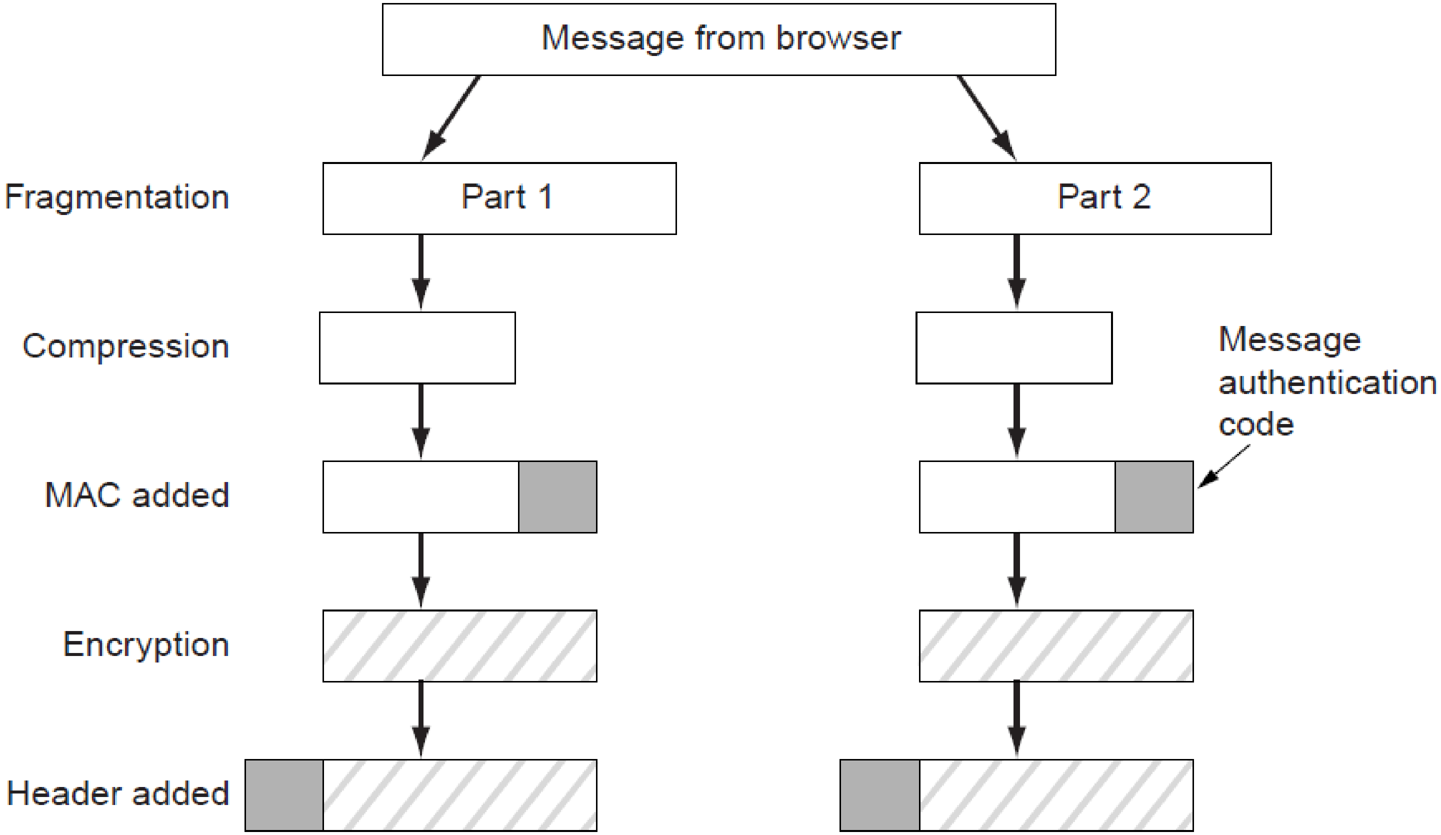
SSL—Secure Sockets Layer (3)

Data transmission using SSL. Authentication and encryption for a connection use the session key.



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Social Issues

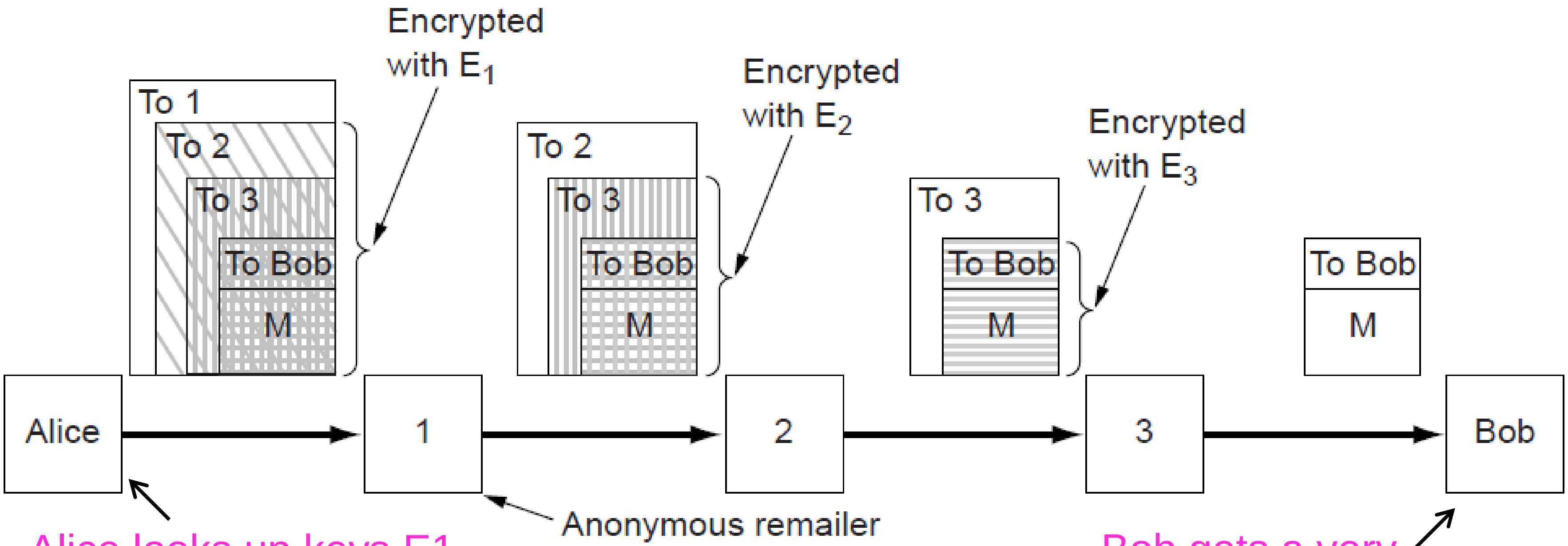
Networks give rise to many social issues

- Privacy »
- Freedom of speech »

Privacy

Anonymous remailers hide the identity of the sender

- Unlike PGP, which only hides message contents
- A chain can be used for stronger anonymity



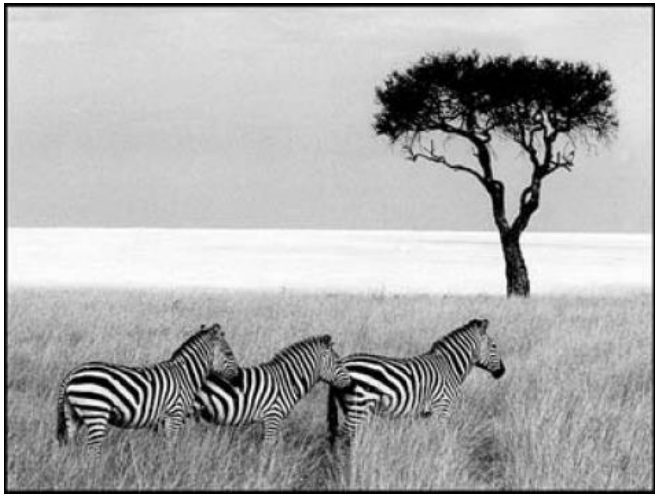
Alice looks up keys E1, E2, E3 separately

Bob gets a very anonymous mail

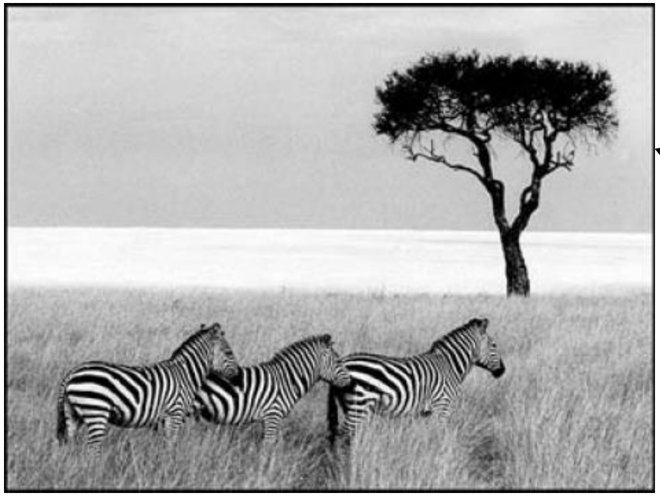
Freedom of Speech

Steganography hides messages on unrelated content

- Can help avoid censorship or protect ownership



“Three zebras and a tree”



Text hidden in low-order bits

“Three zebras and a tree,” with five plays by Shakespeare”

End

Chapter 8