Assignment 1

- Pick sun.com and one other site. Using whois and ARIN, get as much information as possible about the IP addressing, the DNS and the site (location, owner, etc.)
- Problems (p83): 3.5,c and 3.6
- Due next class March 6

Assignment 1, 3.5c

Plaintext
8

$\longrightarrow$ $8^{17} = 2251799813685248/77 = 8^{17} \bmod 77 =$ Ciphertext
57

p = 7
q = 11
e = 17
n = 77
Φ(n) = 60

KU = {e,n} = {17,77}

8^{17} mod77
$= [(8^8 \bmod 77) \times (8^8 \bmod 77) \times (8^1 \bmod 77)]$
$= (71 \times 71 \times 8) \bmod 77$
= 57

Cipertext
57

$\longrightarrow$ $57^{53} = 57^{53} \bmod 77 =$ Plaintext
8

KR = {d,n} = {53,77}

de = 1 mod 60 and d< 60
53*17 = 15*60+1

Assignment 1, 3.6

Plaintext
M=5 → $= M^5 \bmod 35 =$ Ciphertext
10

KU = {e,n} = {5,35}

- This is done with brute force, starting with 1^5, then 2^5, etc. or, since n=35 we can easily determine the factors p=7 q=5 and then $\phi(n)=6x4=24$, therefore d=5 since 5x5=1x24+1
- Remember that the security of RSA depends wholly on the problem of factoring large numbers

Network Security

Electronic Mail Security

Electronic Mail Security

Agenda:

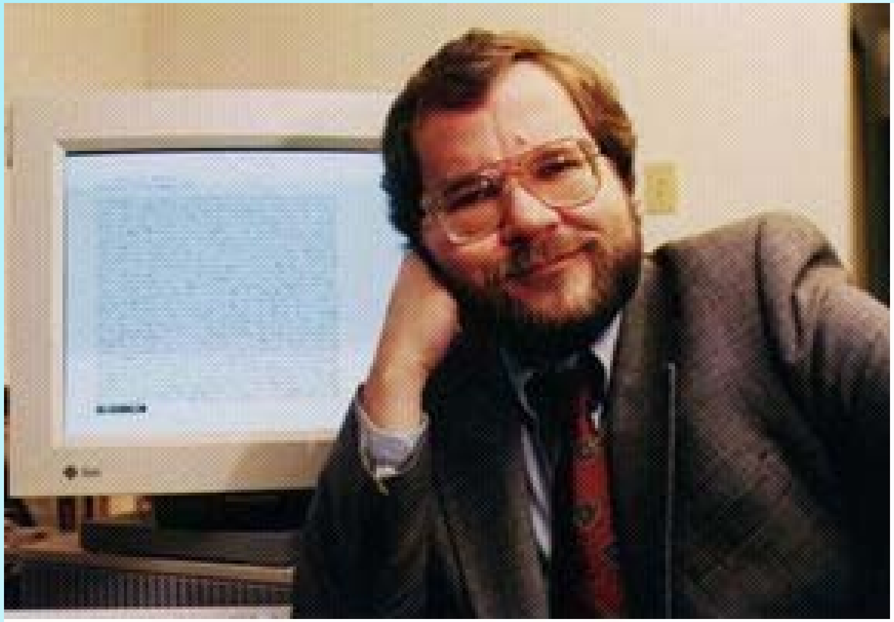
- **Introduction to PGP**
- **5 PGP Services**
- **Key Management**
- **Use of Trust**
- **Demo Of PGP In Use**

Pretty Good Privacy

- 1991 – Creation of a single person, Phil Zimmermann
- Provides confidentiality and authentication services for electronic mail and file storage applications

Phil Zimmermann

- Target of three year criminal investigation
- Gave software away to friend who put it on the Internet in 1991
- Intended to give individuals "the right to be let alone”
- US export restrictions violated – same class as munitions and nuclear weapons
- Government dropped the case in 1996



“PGP has spread like a prairie fire, fanned by countless people who fervently want their privacy restored in the information age”

- Phil Zimmermann, testifying before the US Senate, 1996

Pretty Good Privacy

- Selected best available cryptographic algorithms
- Integrated these algorithms into a general purpose application
- Source code and doc freely available on the net
- Agreement with company (Viacrypt) for low cost commercial version

Notation

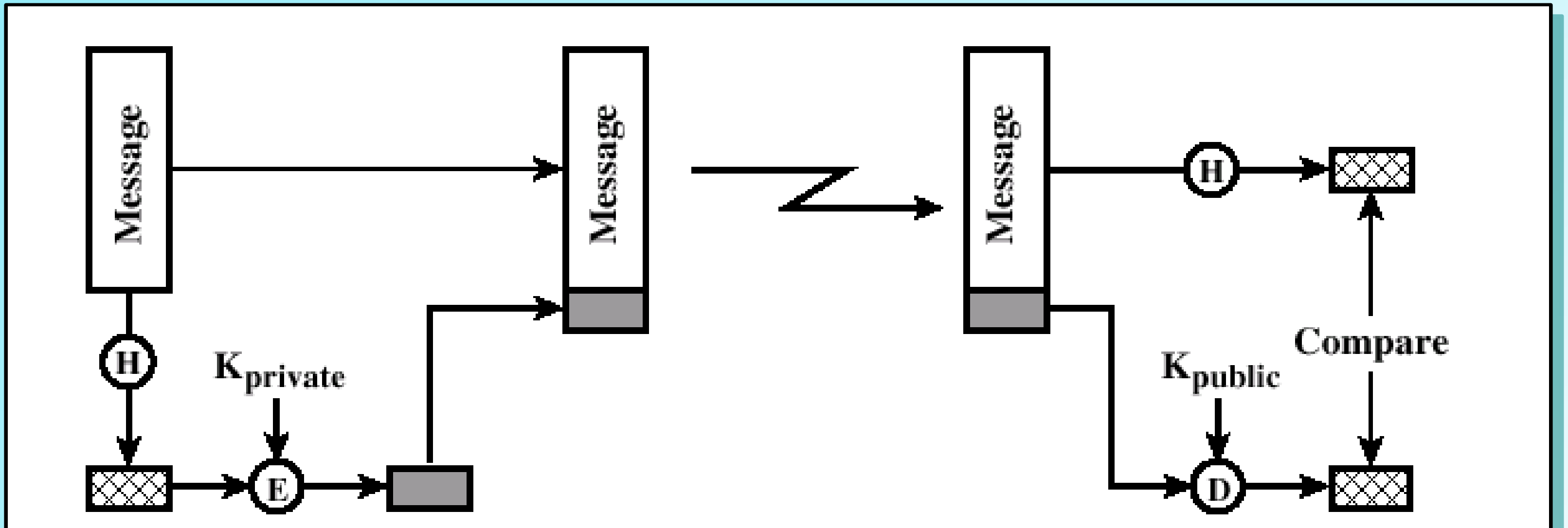
K_S = session key used in conventional encryption
KR_a = private key of user A, used in public key encryption
KU_a = public key of user A, used in public key encryption
EP = public-key encryption
DP = public-key decryption
EC = conventional encryption
DC = conventional decryption
H = hash function
|| = concatenation
Z = compression using ZIP algorithm
R64 = conversion to radix 64 ASCII format

Summary of 5 PGP Services

authentication → | confidentiality →

Function	Algorithms Used	Description
Digital signature	DSS/SHA or RSA/SHA	A hash code of a message is created using SHA-1. This message digest is encrypted using DSS or RSA with the sender's private key, and included with the message.
Message encryption	CAST or IDEA or Three-key Triple DES with Diffie-Hellman or RSA	A message is encrypted using CAST-128 or IDEA or 3DES with a one-time session key generated by the sender. The session key is encrypted using Diffie-Hellman or RSA with the recipient's public key, and included with the message.
Compression	ZIP	A message may be compressed, for storage or transmission, using ZIP.
Email compatibility	Radix 64 conversion	To provide transparency for email applications, an encrypted message may be converted to an ASCII string using radix 64 conversion.
Segmentation	—	To accommodate maximum message size limitations, PGP performs segmentation and reassembly.

Recall One Way Hash Function



(b) Using public-key encryption

Digital signature

No key distribution

Less computation since message does not have to be encrypted

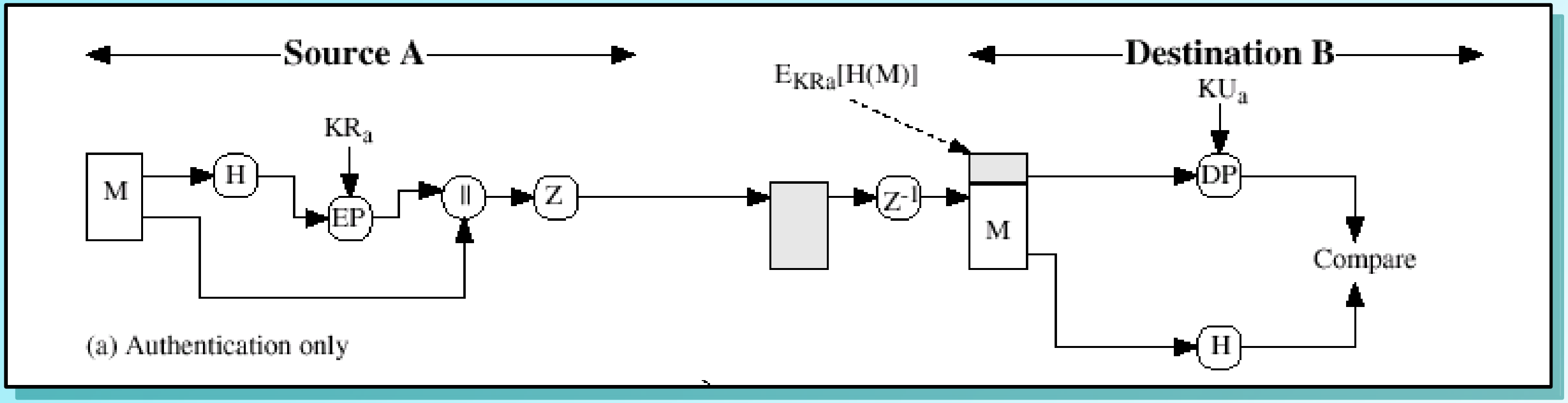
Recall SHA-1 Secure Hash Function

- Developed by NIST in 1995
- Input is processed in 512-bit blocks
- Produces as output a 160-bit message digest
- *Every bit of the hash code is a function of every bit of the input*
- Very secure – so far!

Authentication

1. Sender creates a message
2. Generate a hash code with SHA-1
3. Using sender's private key and RSA, encrypt the hash code and prepend to the message
4. Receiver uses sender's public key to decrypt and recover the hash code
5. Receiver generates a new hash code for the message and compares with the decrypted hash code. If matching, then message is authentic

PGP Cryptographic Functions



(a) Authentication only

Recall Other Public Key Algorithms

- Digital Signature Standard (DSS) – makes use of SHA-1 and presents a new digital signature algorithm (DSA)
- Only used for digital signatures not encryption or key exchange

Authentication

- Other alternatives can be used, e.g., DSS
- Detached signatures are supported
- Good for executables and multi-party signatures (legal contract)

Summary of 5 PGP Services

	Function	Algorithms Used	Description
authentication	Digital signature	DSS/SHA or RSA/SHA	A hash code of a message is created using SHA-1. This message digest is encrypted using DSS or RSA with the sender's private key, and included with the message.
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	Segmentation	—	To accommodate maximum message size limitations, PGP performs segmentation and reassembly.

Recall CAST-128

- 1997, Entrust Technologies
- RFC 2144
- Extensively reviewed
- Variable key length, 40-128 bits
- Used in PGP

Recall Conventional Encryption Algorithms

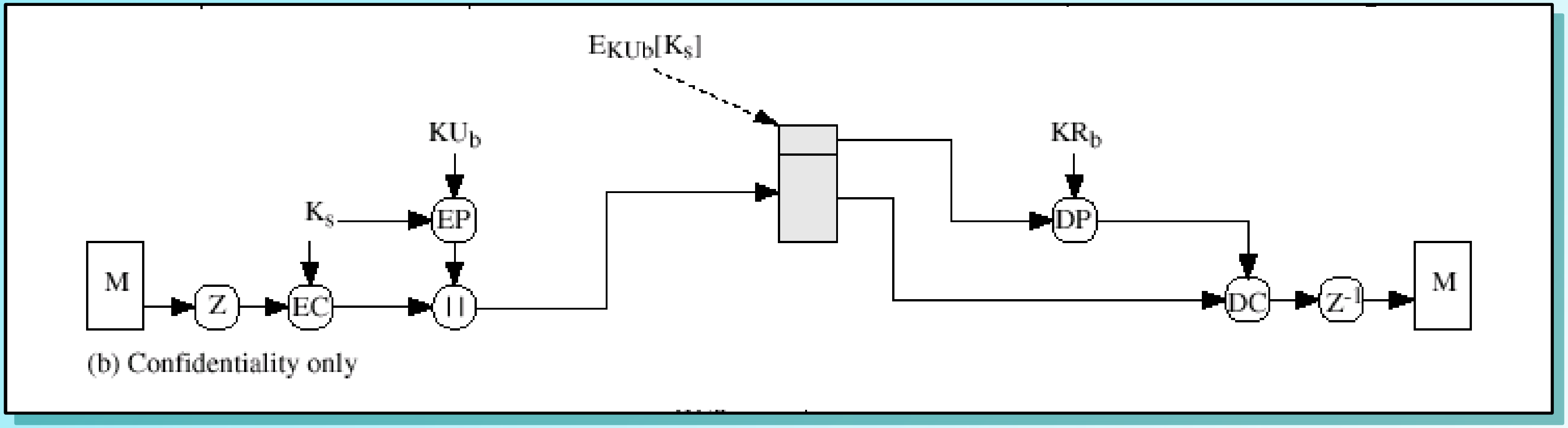
Algorithm	Key Size (bits)	Block Size (bits)	Number of Rounds	Applications
DES	56	64	16	SET, Kerberos
Triple DES	112 or 168	64	48	Financial key management, PGP, S/MIME
AES	128, 192, or 256	128	10, 12, or 14	Intended to replace DES and 3DES
IDEA	128	64	8	PGP
Blowfish	variable to 448	64	16	Various software packages
RC5	variable to 2048	64	variable to 255	Various software packages

We have choices in PGP for confidentiality!

Confidentiality

1. Sender creates a *message* and *random 128bit number* for *session key*
2. Message encrypted using CAST-128 with the session key
3. Session key encrypted with recipient's public key and prepended to the message
4. Receiver uses it's private key to decrypt and recover the session key
5. Session key is used to decrypt the message

PGP Cryptographic Functions



(b) Confidentiality only

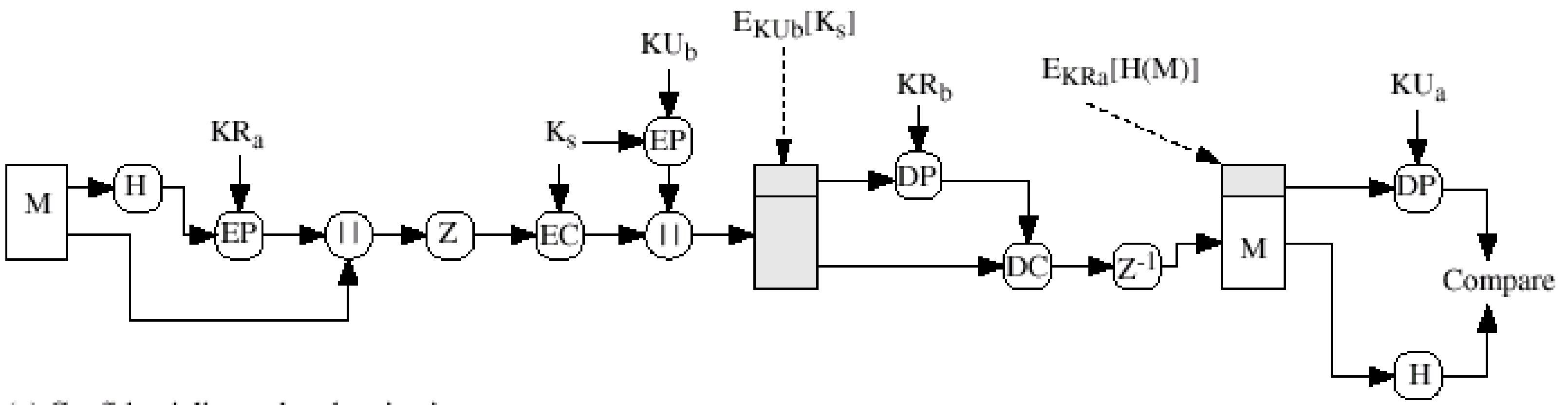
Confidentiality

- Alternatives for conventional encryption: RSA or Diffie-Hellman (ElGamal)
- Conventional algorithms are much faster
- Each message is a one time independent event with its own key
- $768 \leq$ key size ≤ 3072

Confidentiality & Authentication

- Both services can be used for the same message
- First, signature is generated for plaintext and prepended
- Message is encrypted with a session key
- Session key is encrypted with recipient's public key

PGP Cryptographic Functions



(c) Confidentiality and authentication

Summary of 5 PGP Services

authentication → Digital signature
confidentiality → Message encryption

Function	Algorithms Used	Description
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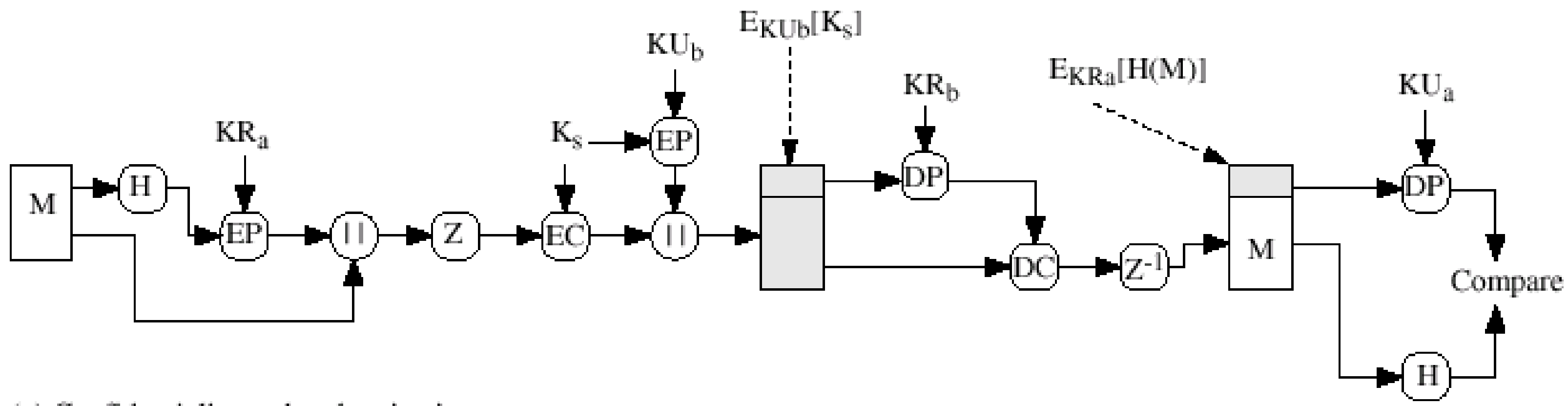
Segmentation	—	To accommodate maximum message size limitations, PGP performs segmentation and reassembly.

Compression – Save Space

- PGP compresses (ZIP) the message after applying the signature but before encryption (default)
- Better to sign an uncompressed message
- PGP's compression algorithm is non-deterministic
- Security is greater if message is encrypted after compression
- Appendix 5A - ZIP

PGP Cryptographic Functions



(c) Confidentiality and authentication

Summary of 5 PGP Services

authentication → Digital signature
confidentiality → Message encryption

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E-mail Compatibility

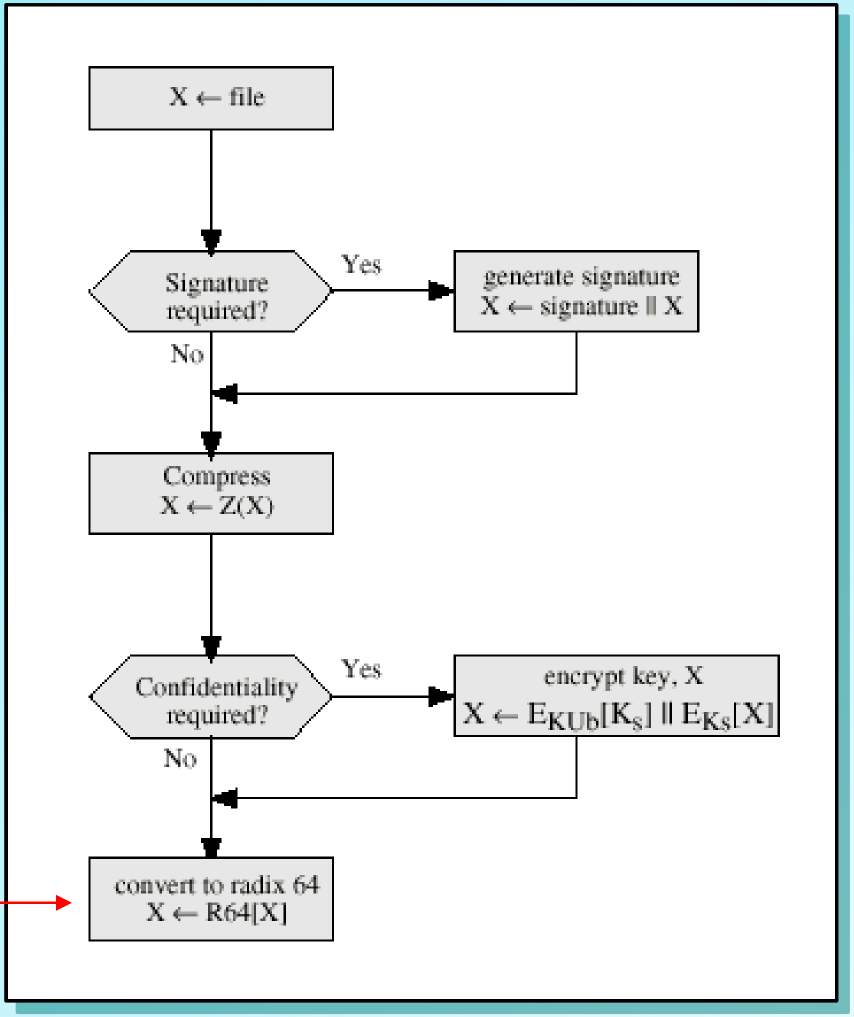
- Part or all of block consists of a stream of arbitrary 8-bit octets
- Many mail systems only allow ASCII text
- PGP converts raw binary stream to a stream of printable ASCII characters
- Radix-64 conversion – 3 binary => 4 ASCII

Stream Of Printable ASCII Chars


```
-----BEGIN PGP PUBLIC KEY BLOCK-----
Version: 2.6.3i
mQBNAi23Dv0AAAECAMm6GNU3nqebKr3HW/fmrEhMlrFkwuZ6KHIYEat92nYfQIUj
lRLgj3TPHTRIMbswyTdaIJA7OvkSgxETLBCExX0ABRG0K0FuZHJlYXMgUmllZ2Vy
IDwxMDAxMTEuMzU0MEBjb21wdXNlcnZlLmNvbT4=
=8t7f
-----END PGP PUBLIC KEY BLOCK-----
```

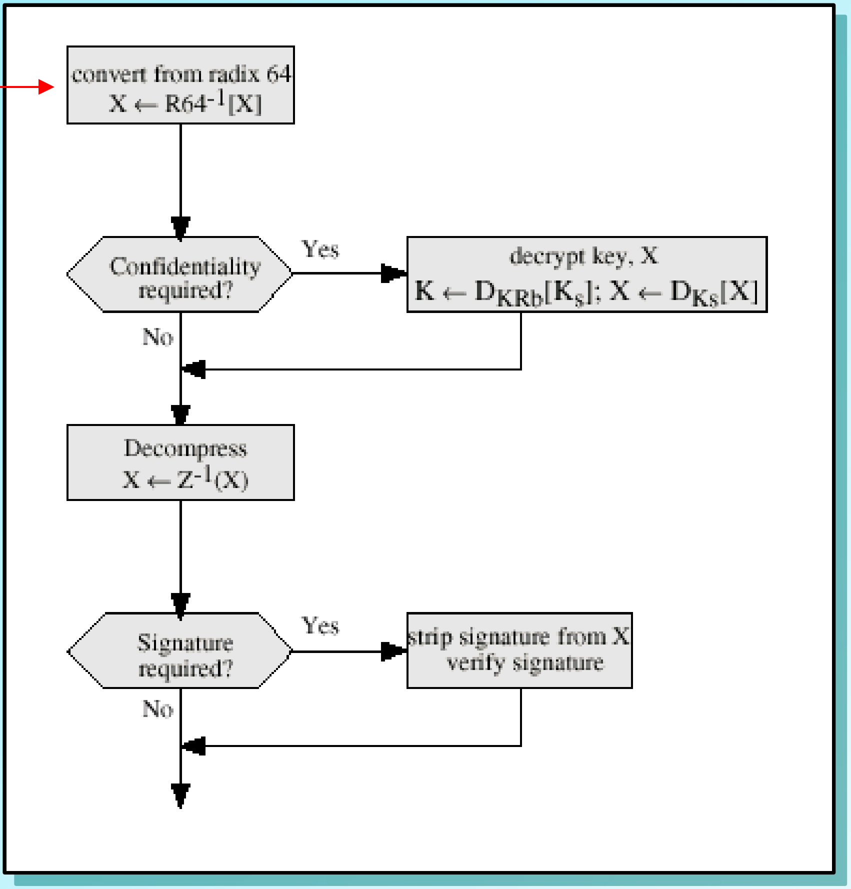
Generic Transmission Diagram

ASCII text



Generic Reception Diagram

ASCII text to binary



Summary of 5 PGP Services

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Segmentation	—	To accommodate maximum message size limitations, PGP performs segmentation and reassembly.

authentication

confidentiality

Segmentation

- Maximum message length restrictions in e-mail
- PGP automatically subdivides a large message into segments small enough to mail separately
- PGP reassembles entire original block at the receiving end

Summary of 5 PGP Services

- Authentication
- Confidentiality
- Compression
- E-Mail Compatibility
- Segmentation

PGP Cryptographic Keys

- **One-time Session** Conventional Keys
- **Public** Keys
- **Private** Keys
- **Passphrase-Based** Conventional

Key Requirements

- A means of generating unpredictable session keys
- Allow users to have multiple public/private key pairs *(need some kind of identity)*
- Each PGP entity must maintain a file of its and its correspondents public/private pairs

Session Key Generation

- Random 128-bit numbers are generated using CAST-128
- Input is a stream of 128-bit randomized numbers based on keystroke input from the user
- Produces a sequence of session keys that is effectively unpredictable

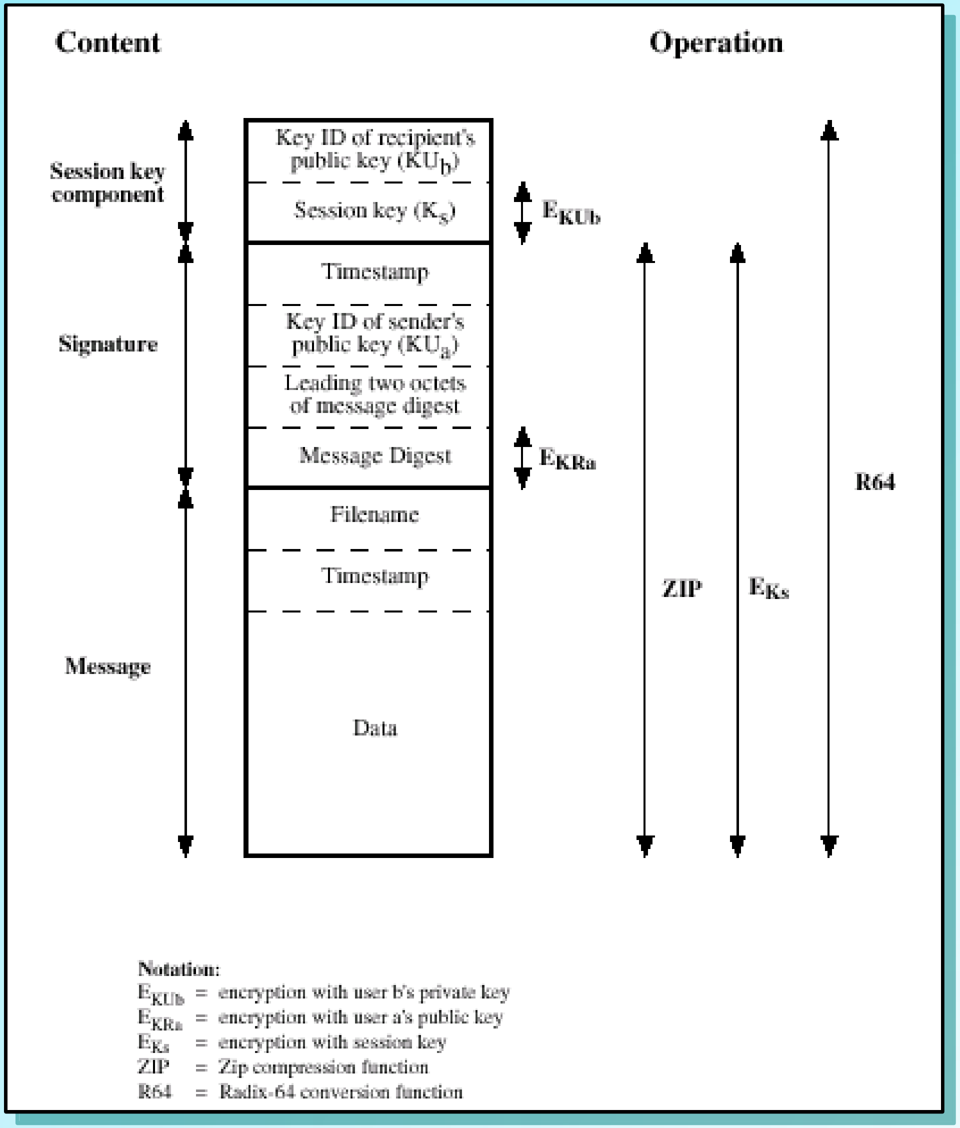
Key Identifiers

- **How does receiver know which public key to us?**
- PGP assigns a key ID to each public key
- It has a high probability of being unique within a user ID – 64-bit

What Does A Transmitted Message Look Like?

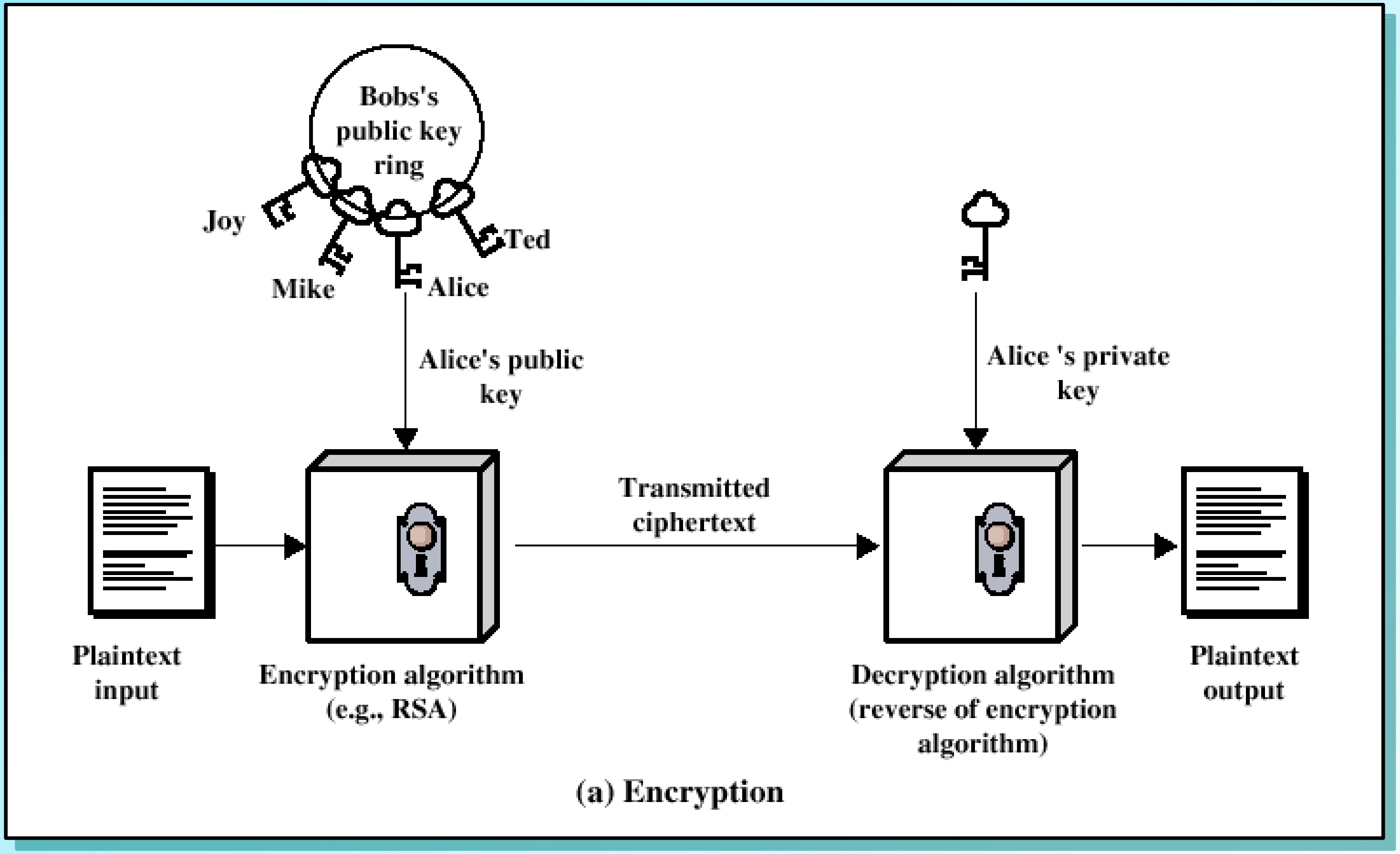
- Message component – actual data plus filename and timestamp
- Signature component – timestamp, message digest, leading two octets of MD (checksum), Key ID of sender’s public key
- Session key component – session key plus ID of recipient’s public key used to encrypt the session key

PGP Format

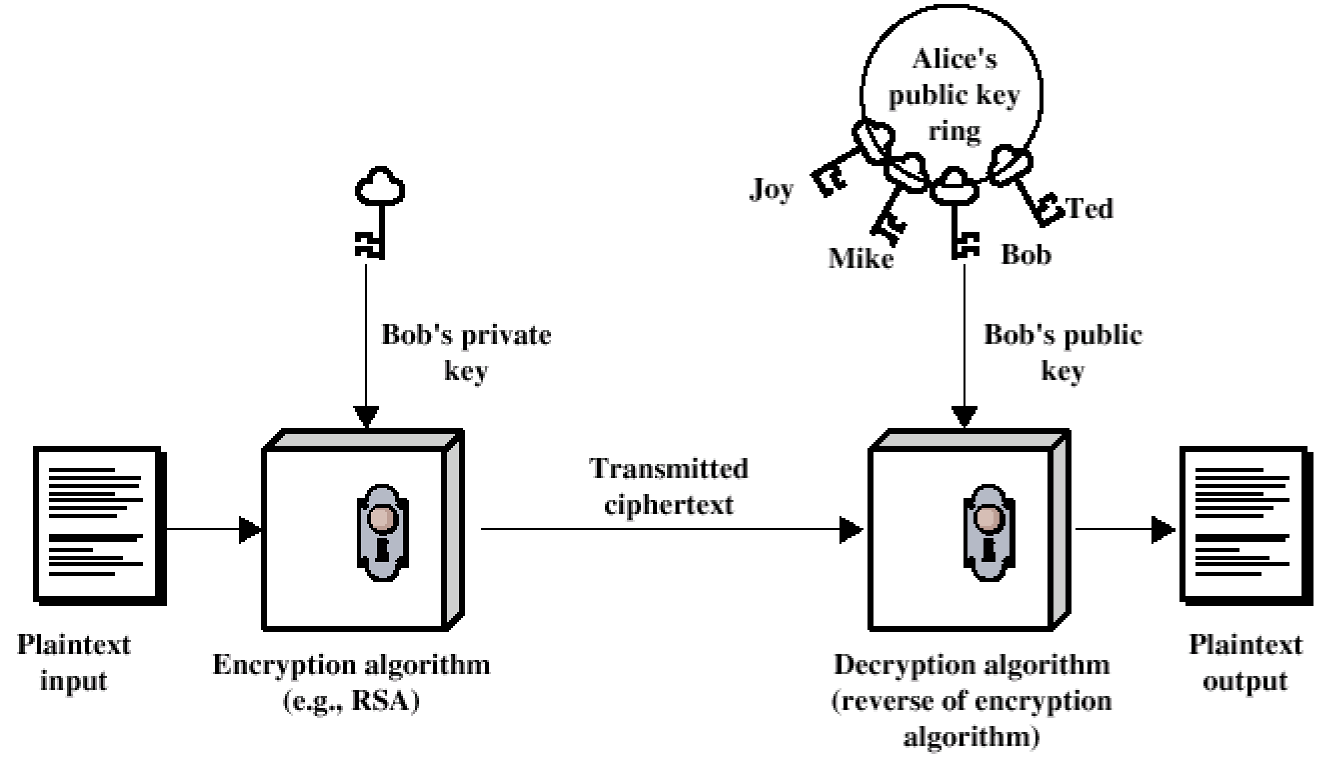


Content
Operation
Session key component
Signature
Message
Key ID of recipient's public key (KUb)
Session key (Ks)
Timestamp
Key ID of sender's public key (KUa)
Leading two octets of message digest
Message Digest
Filename
Timestamp
Data
EKUb
EKRa
ZIP
EKs
R64
Notation:
EKUb = encryption with user b's private key
EKRa = encryption with user a's public key
EKs = encryption with session key
ZIP = Zip compression function
R64 = Radix-64 conversion function

Recall Public Key Encryption



Recall Public Key Authentication



(b) Authentication

Key Rings

- PGP provides a pair of data structures at each node – pub/priv key pairs owned by node & public keys of other users
- Private-Key Ring and Public-Key Ring
- Can view the ring as a table – each row represents one of the pub/priv key pairs

Key Ring Structure

Private Key Ring

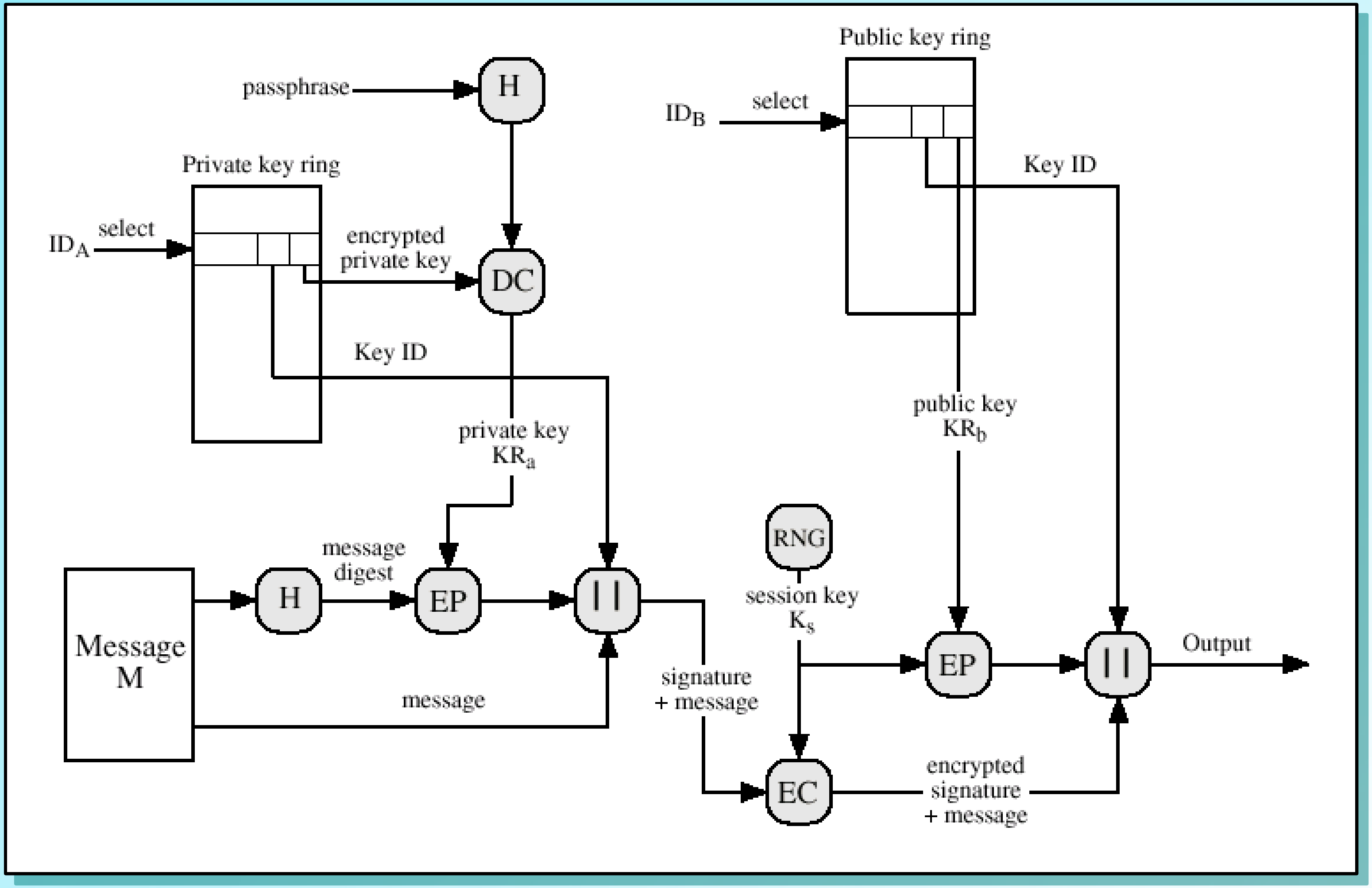
Timestamp	Key ID*	Public Key	Encrypted Private Key	User ID*
• • •	• • •	• • •	• • •	• • •
T_i	$KU_i \bmod 2^{64}$	KU_i	$E_{H(P_i)}[KR_i]$	User i
• • •	• • •	• • •	• • •	• • •

Public Key Ring

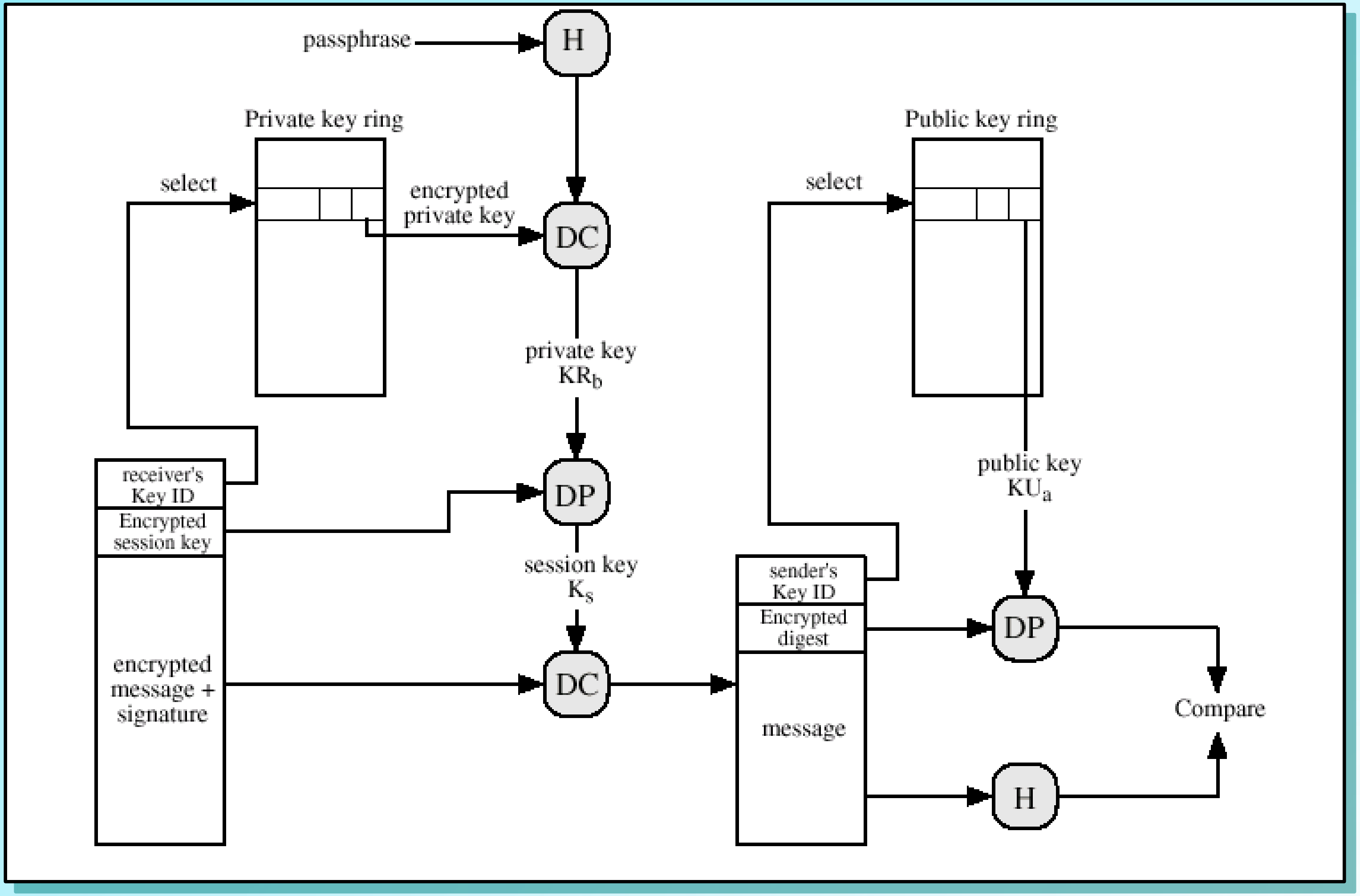
Timestamp	Key ID*	Public Key	Owner Trust	User ID*	Key Legitimacy	Signature(s)	Signature Trust(s)
• • •	• • •	• • •	• • •	• • •	• • •	• • •	• • •
T_i	$KU_i \bmod 2^{64}$	KU_i	$trust\_flag_i$	User i	$trust\_flag_i$		
• • •	• • •	• • •	• • •	• • •	• • •	• • •	• • •

* = field used to index table

PGP Message Generation



PGP Message Reception



Public Key Management

- Physically get the key from *B*
- Verify a key by telephone
- Obtain *B's* public key from a mutually trusted individual *D*
- Obtain *B's* public key from a trusted certifying authority

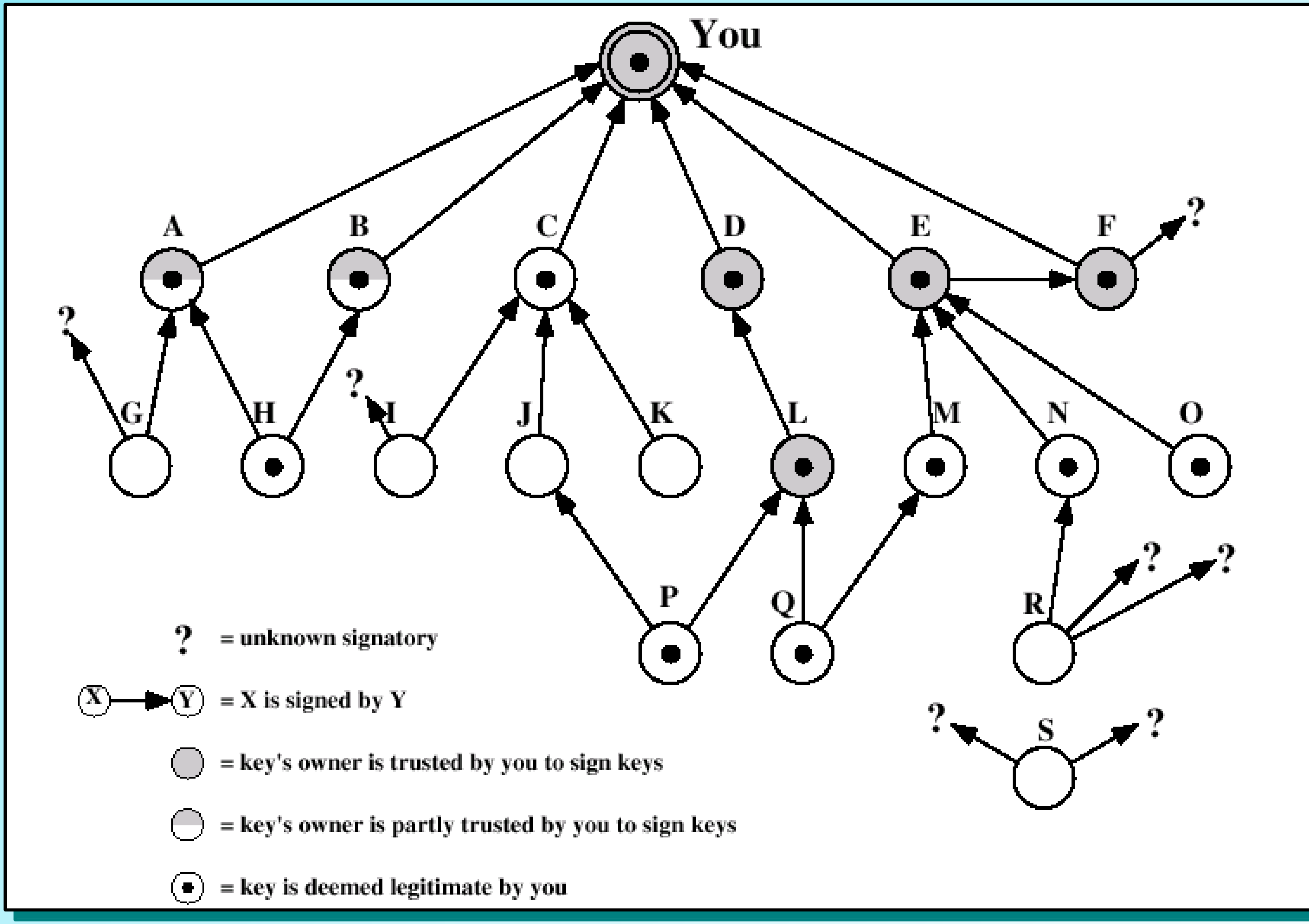
Use of Trust

- Associated with each public key is a key legitimacy field – extent that PGP will trust that this is a valid public key
- Signature trust field – degree PGP user trusts the signer to certify public keys
- Owner trust field – degree to which this public key is trusted to sign other public-key certificates
- Contained in a structure referred to as a trust flag byte

Trust Flag Byte Contents

(a) Trust Assigned to Public-Key Owner (appears after key packet; user-defined)	(b) Trust Assigned to Public Key/User ID Pair (appears after User ID packet; computed by PGP)	(c) Trust Assigned to Signature (appears after signature packet; cached copy of OWNERTRUST for this signator)
OWNERTRUST Field —undefined trust —unknown user —usually not trusted to sign other keys —usually trusted to sign other keys —always trusted to sign other keys —this key is present in secret key ring (ultimate trust) BUCKSTOP bit —set if this key appears in secret key ring	KEYLEGIT Field —unknown or undefined trust —key ownership not trusted —marginal trust in key ownership —complete trust in key ownership WARNONLY bit —set if user wants only to be warned when key that is not fully validated is used for encryption	SIGTRUST Field —undefined trust —unknown user —usually not trusted to sign other keys —usually trusted to sign other keys —always trusted to sign other keys —this key is present in secret key ring (ultimate trust) CONTIG bit —set if signature leads up a contiguous trusted certification path back to the ultimately trusted keyring owner

PGP Trust Model Example



Revoking Public Keys

- A user may wish to revoke his public key
- Reasons: compromise suspected or used too long or lost private key
- Owner issues a key revocation certificate, signed by the owner

Important URLs

- http://en.wikipedia.org/wiki/Pretty_Good_Privacy
  Good review of PGP, its history and current status
- http://www.pgp.com/
  New home for PGP – This is the commercial version
- http://www.openpgp.org/
  This is the site for OpenPGP

Important URLs

- http://www.npr.org/templates/story/story.php?storyId=5227744 Story at NPR about how very few people use encryption
- http://www.clairewolfe.com/wolfesblog/00001945.html NPR story about how very few people use encryption, and then gives a tutorial on installing and using GNU Privacy Guard and Enigmail with the Thunderbird email program

Download PGP

- http://www.pgpi.org/download/gnupg/
  Windows version is: GnuPG 1.2.2
- http://enigmail.mozdev.org/download.html
  Enigmail download

Pathetic Demo Attempt

Generating Keys

- Type: gpg –gen-key
- You should end up with something like this:

```
gpg: C:/Documents and Settings/vcosta/Application Data/gnupg\trustdb.gpg: trustd
b created
gpg: key 254870BB marked as ultimately trusted
public and secret key created and signed.

gpg: checking the trustdb
gpg: 3 marginal(s) needed, 1 complete(s) needed, PGP trust model
gpg: depth: 0  valid:   1  signed:   0  trust: 0-, 0q, 0n, 0m, 0f, 1u
gpg: next trustdb check due at 2006-05-18
pub   1024D/254870BB 2006-03-19 [expires: 2006-05-18]
      Key fingerprint = 6C4F 1C6E DF6C 5D93 FC82  3886 FC47 EB04 2548 70BB
uid                  Vincent J. Costa (PapaCosta) <vcosta@optonline.net>
sub   2048g/A98D696E 2006-03-19 [expires: 2006-05-18]

$
```

Homework

- Read Chapter Five, Section 1, PGP
- S/MIME will be covered later
- Obtain PGP software and install it
- Try sending me an email (vcosta@optonline.net) and your public key

Reminder: Term Paper

- Due Monday, May 1
- Should be about 6-8 pages (9 or 10 font, single space)
- Suggested template: http://www.acm.org/sigs/pubs/proceed/
- This should be an opportunity to explore a selected area
- Send me your topic by March 20th

Reminder: Term Paper

Possible topics:

- Elliptic Curve Cryptography
- Cyber Forensics
- Digital Rights Management
- Security In Software Development
- Virtualization & Security
- Legal, Ethical Issues Around Security & Privacy
- Wireless/Mobile Security
- Phishing/Identity Theft
- Distributed DoS Attacks
- Electronic Cash
- Anti-Virus Software
- Any Topic Discussed In Class
- Programming Project Can Be Substituted If You Want