Cryptography (CS-501)

Security at the Application Layer: PGP and S/MIME

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Objectives

- To explain the general structure of an e-mail application program
- To discuss how PGP can provide security services for e-mail
- To discuss how S/MIME can provide security services for e-mail
- To define trust mechanism in both PGP and S/MIME
- To show the structure of messages exchanged in PGP and S/MIME

16-1 E-MAIL

Let us first discuss the electronic mail (e-mail) system in general.

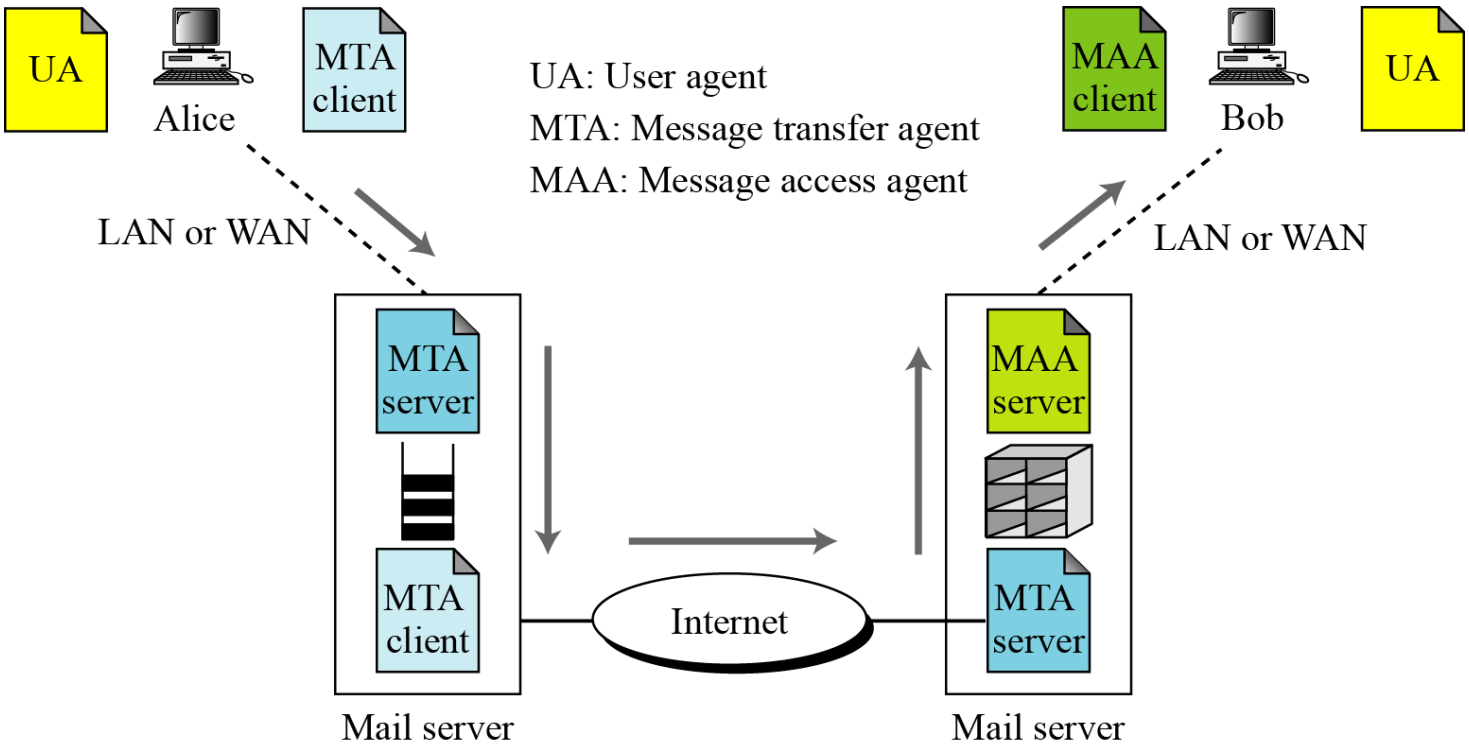
Topics discussed in this section:

16.1.1 E-mail Architecture

16.1.2 E-mail Security

16.1.1 E-mail Architecture

Figure 16.1 *E-mail architecture*



16.1.2 E-mail Security

Cryptographic Algorithms

Note

In e-mail security, the sender of the message needs to include the name or identifiers of the algorithms used in the message.

Certificates

It is obvious that some public-key algorithms must be used for e-mail security.

Cryptographic Secrets

Note

In e-mail security, the encryption/decryption is done using a symmetric-key algorithm, but the secret key to decrypt the message is encrypted with the public key of the receiver and is sent with the message.

16-2 PGP

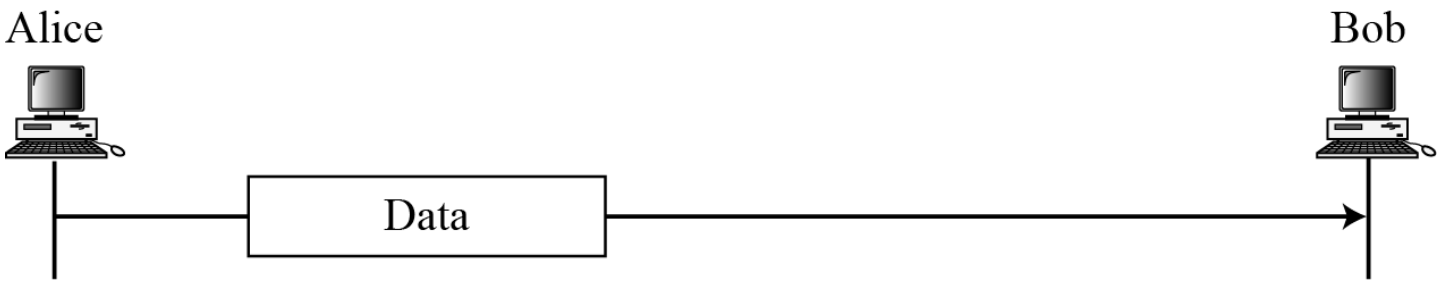
Pretty Good Privacy (PGP) can be used to create a secure e-mail message or to store a file securely for future retrieval.

Topics discussed in this section:

16.2.1 Scenarios

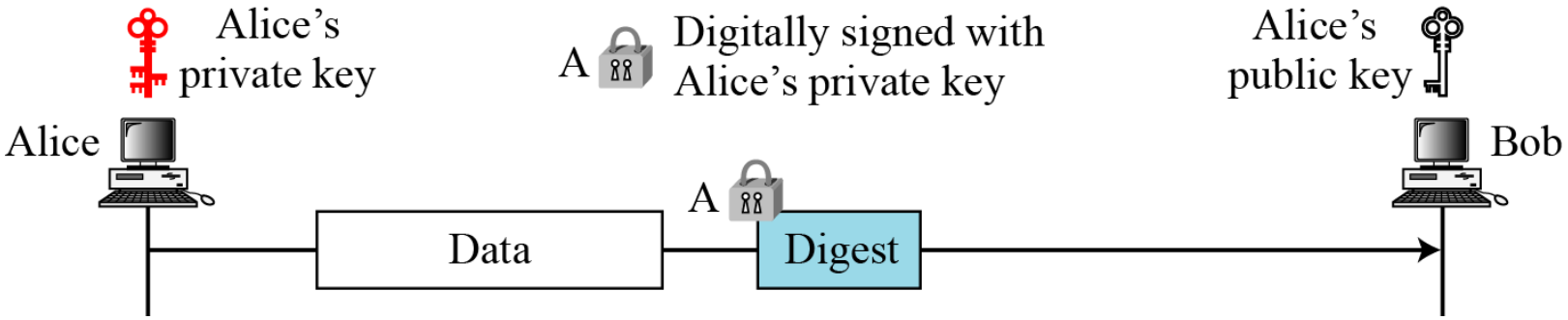
Plaintext

Figure 16.2 *A plaintext message*



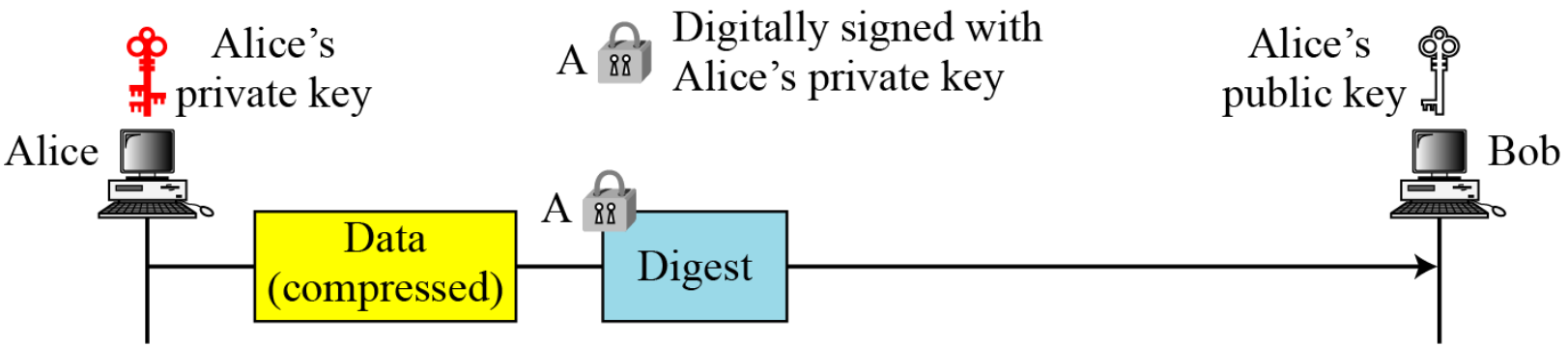
Message Integrity

Figure 16.3 ***An authenticated message***



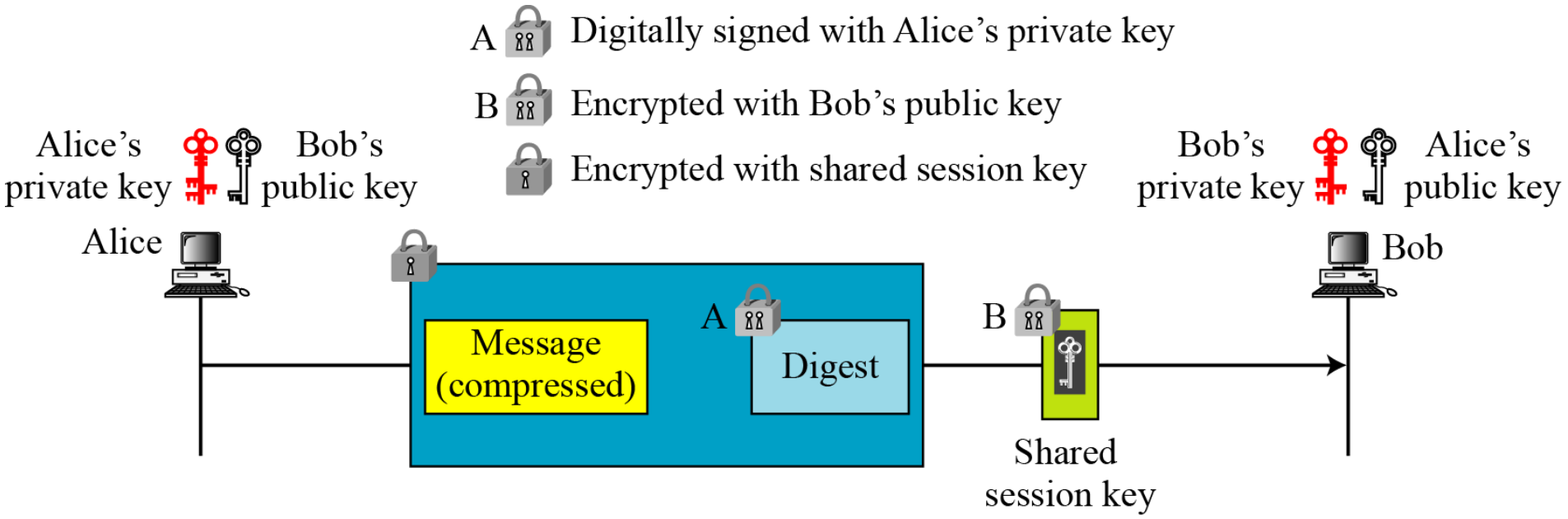
Compression

Figure 16.4 ***A compressed message***



Confidentiality with One-Time Session Key

Figure 16.5 ***A confidential message***



16.2.1 Continued

Code Conversion

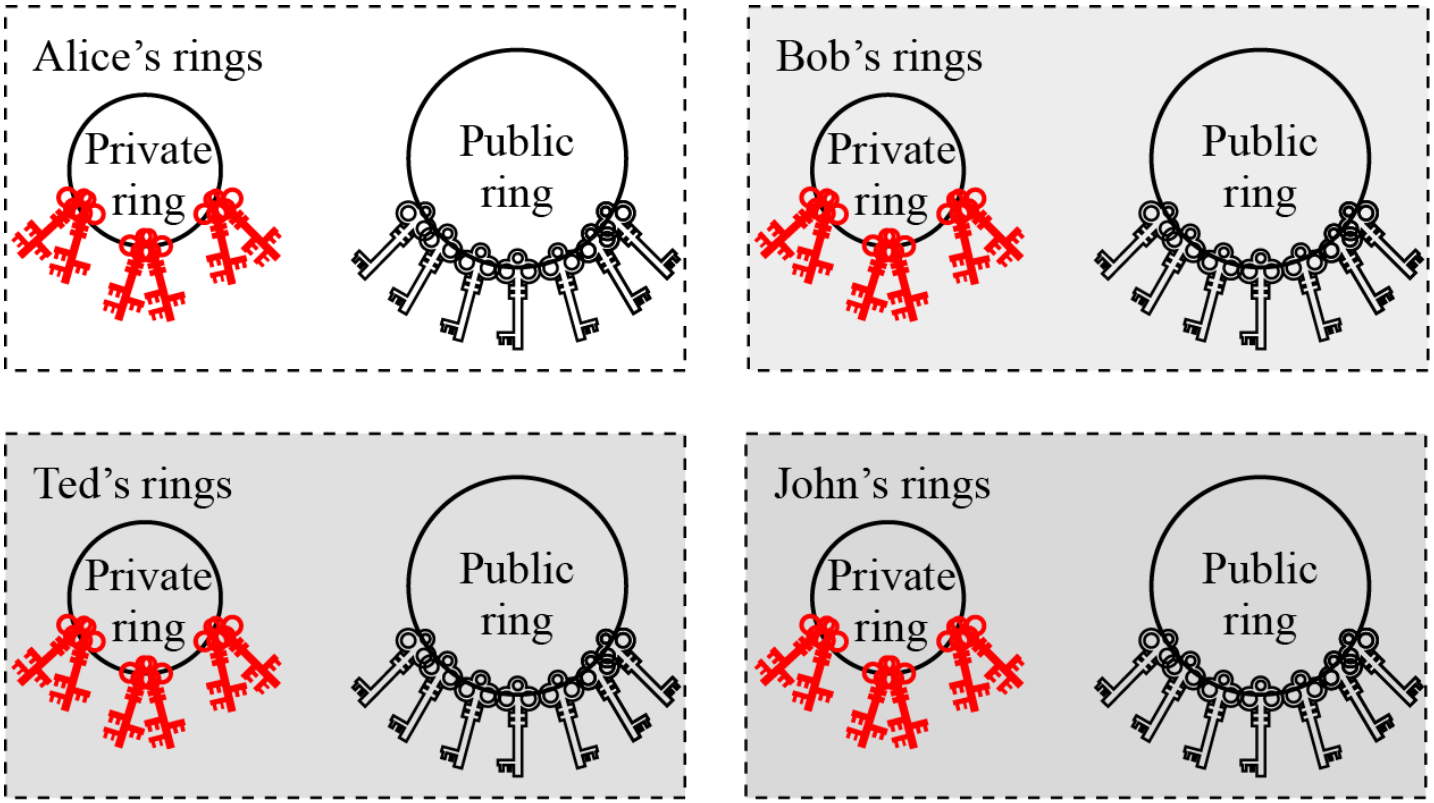
Another service provided by PGP is code conversion. PGP uses Radix-64 conversion.

Segmentation

PGP allows segmentation of the message.

16.2.2 Key Rings

Figure 16.6 *Key rings in PGP*



PGP Algorithms

Table 16.1 *Public-key algorithms*

ID	*Description*
1	RSA (encryption or signing)
2	RSA (for encryption only)
3	RSA (for signing only)
16	ElGamal (encryption only)
17	DSS
18	Reserved for elliptic curve
19	Reserved for ECDSA
20	ElGamal (for encryption or signing)
21	Reserved for Diffie-Hellman
100–110	Private algorithms

16.2.2 Continued

Table 16.2 *Symmetric-key algorithms*

ID	*Description*
0	No Encryption
1	IDEA
2	Triple DES
3	CAST-128
4	Blowfish
5	SAFER-SK128
6	Reserved for DES/SK
7	Reserved for AES-128
8	Reserved for AES-192
9	Reserved for AES-256
100–110	Private algorithms

16.2.2 Continued

Table 16.3 *Hash Algorithms*

ID	*Description*
1	MD5
2	SHA-1
3	RIPE-MD/160
4	Reserved for double-width SHA
5	MD2
6	TIGER/192
7	Reserved for HAVAL
100–110	Private algorithms

16.2.2 Continued

Table 16.4 *Compression methods*

ID	*Description*
0	Uncompressed
1	ZIP
2	ZLIP
100–110	Private methods

16.2.3 PGP Certificates

X.509 Certificates

Protocols that use X.509 certificates depend on the hierarchical structure of the trust.

Note

In X.509, there is a single path from the fully trusted authority to any certificate.

16.2.3 Continued

PGP Certificates

In PGP, there is no need for CAs; anyone in the ring can sign a certificate for anyone else in the ring.

Note

In PGP, there can be multiple paths from fully or partially trusted authorities to any subject.

Trusts and Legitimacy

The entire operation of PGP is based on introducer trust, the certificate trust, and the legitimacy of the public keys.

Figure 16.7 *Format of private key ring table*

User ID	Key ID	Public key	Encrypted private key	Timestamp
⋮	⋮	⋮	⋮	⋮

16.2.3 Continued

Example 16.1

Let us show a private key ring table for Alice. We assume that Alice has only two user IDs, alice@some.com and alice@anet.net. We also assume that Alice has two sets of private/public keys, one for each user ID.

Table 16.5 *Private key ring table for Example 1*

User ID	*Key ID*	*Public Key*	*Encrypted Private Key*	*Timestamp*
alice@anet.net	AB13...45	AB13...45...59	**32452398...23**	031505-16:23
alice@some.com	FA23...12	FA23...12...22	**564A4923...23**	031504-08:11

Figure 16.8 *Format of a public key ring table*

Public ring

User ID	Key ID	Public key	Producer trust	Certificate(s)	Certificate trust(s)	Key Legitimacy	Timestamp
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮

16.2.3 Continued

Example 16.2

A series of steps will show how a public key ring table is formed for Alice.

Table 16.6 *Example 2, starting table*

User ID	*Key ID*	*Public key*	*Prod. trust*	*Certificate*	*Cert. trust*	*Key legit.*	*Time-stamp*
Alice...	AB...	AB.....	F			F	.....

Table 16.7 *Example 2, after Bob is added to the table*

User ID	*Key ID*	*Public key*	*Prod. trust*	*Certificate*	*Cert. trust*	*Key legit.*	*Time-stamp*
Alice...	AB...	AB.....	F			F	.....
Bob...	12...	12.....	F			F	.....

Example 16.2 *Continued*

Table 16.8 *Example 2, after Ted is added to the table*

User ID	*Key ID*	*Public key*	*Prod. trust*	*Certificate*	*Cert. trust*	*Key legit.*	*Time-stamp*
Alice...	AB...	AB.....	F			F	.....
Bob...	12...	12.....	F			F	.....
Ted...	48...	48.....	F	Bob's	F	F	.....

Table 16.9 *Example 2, after Anne is added to the table*

User ID	*Key ID*	*Public key*	*Prod. trust*	*Certificate*	*Cert. trust*	*Key legit.*	*Time-stamp*
Alice...	AB...	AB.....	F			F	.....
Bob...	12...	12.....	F			F	.....
Ted...	48...	48.....	F	Bob's	F	F	.....
Anne...	71...	71.....	P	Bob's	F	F	.....

16.2.3 Continued

Example 16.2 *Continued*

Table 16.10 *Example 2, after John is added to the table*

User ID	*Key ID*	*Public key*	*Prod. Trust*	*Certificate*	*Cert. trust*	*Key legit.*	*Time-stamp*
Alice...	AB...	AB.....	F			F	.....
Bob...	12...	12.....	F			F	.....
Ted...	48...	48.....	F	Bob's	F	F	.....
Anne...	71...	71.....	P	Bob's	F	F	.....
John...	31...	31.....	N	Anne's	P	P	.....

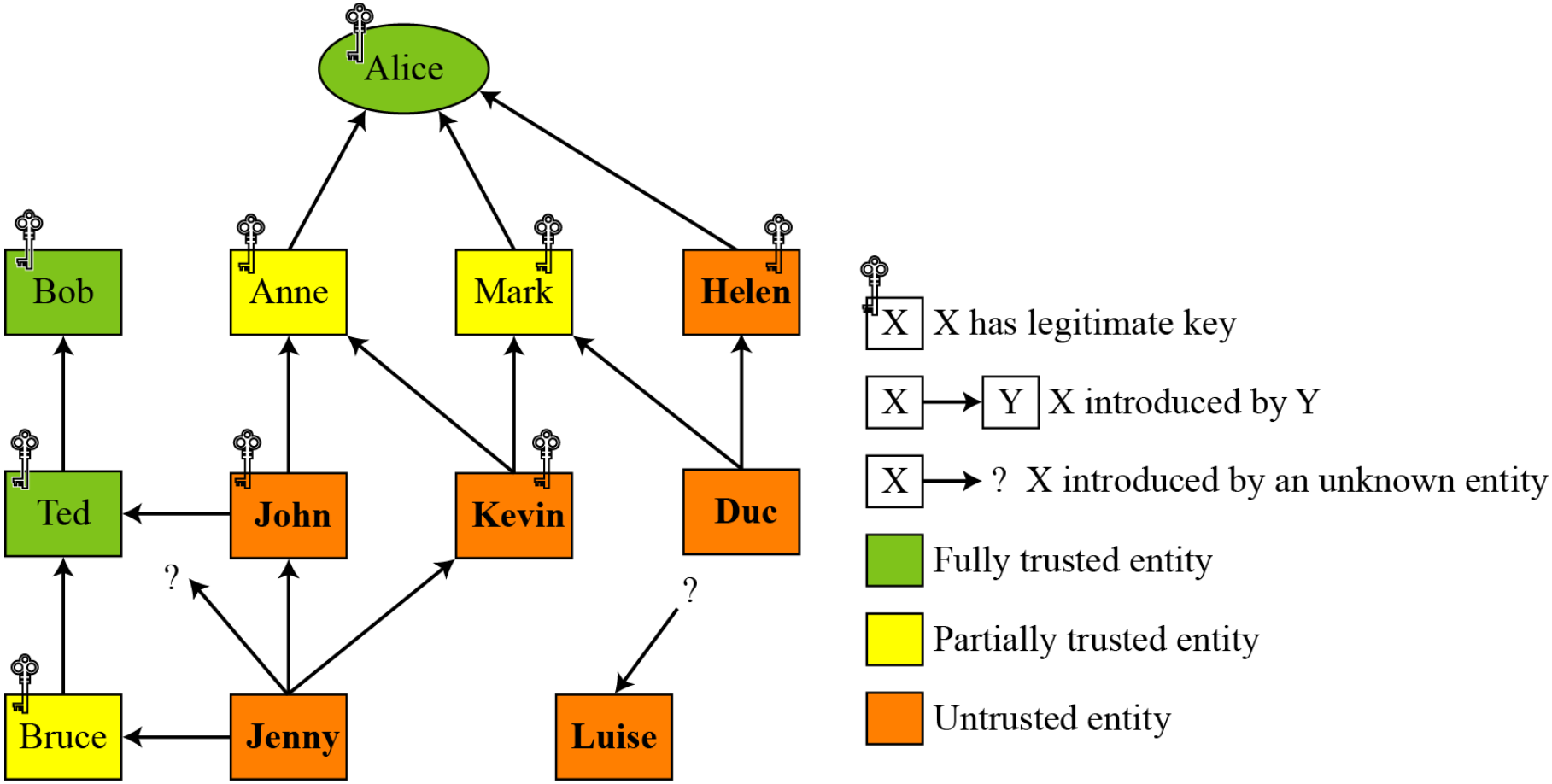
Example 16.2 *Continued*

Table 16.11 *Example 2, after one more certificate received for John*

User ID	*Key ID*	*Public key*	*Prod. trust*	*Certificate*	*Cert. trust*	*Key legit.*	*Time-stamp*
Alice...	AB...	AB.....	F			F	.....
Bob...	12...	12.....	F			F	.....
Ted...	48...	48.....	F	Bob's	F	F	.....
Anne...	71...	71.....	P	Bob's	F	F	.....
John...	31...	31.....	N	Anne's Ted's	P F	F	.....

Trust Model in PGP

Figure 16.9 ***Trust model***



16.2.4 Key Revocation

It may become necessary for an entity to revoke his or her public key from the ring. This may happen if the owner of the key feels that the key is compromised (stolen, for example) or just too old to be safe.

16.2.5 Extracting Information from Rings

Figure 16.10 *Extracting information at the sender site*

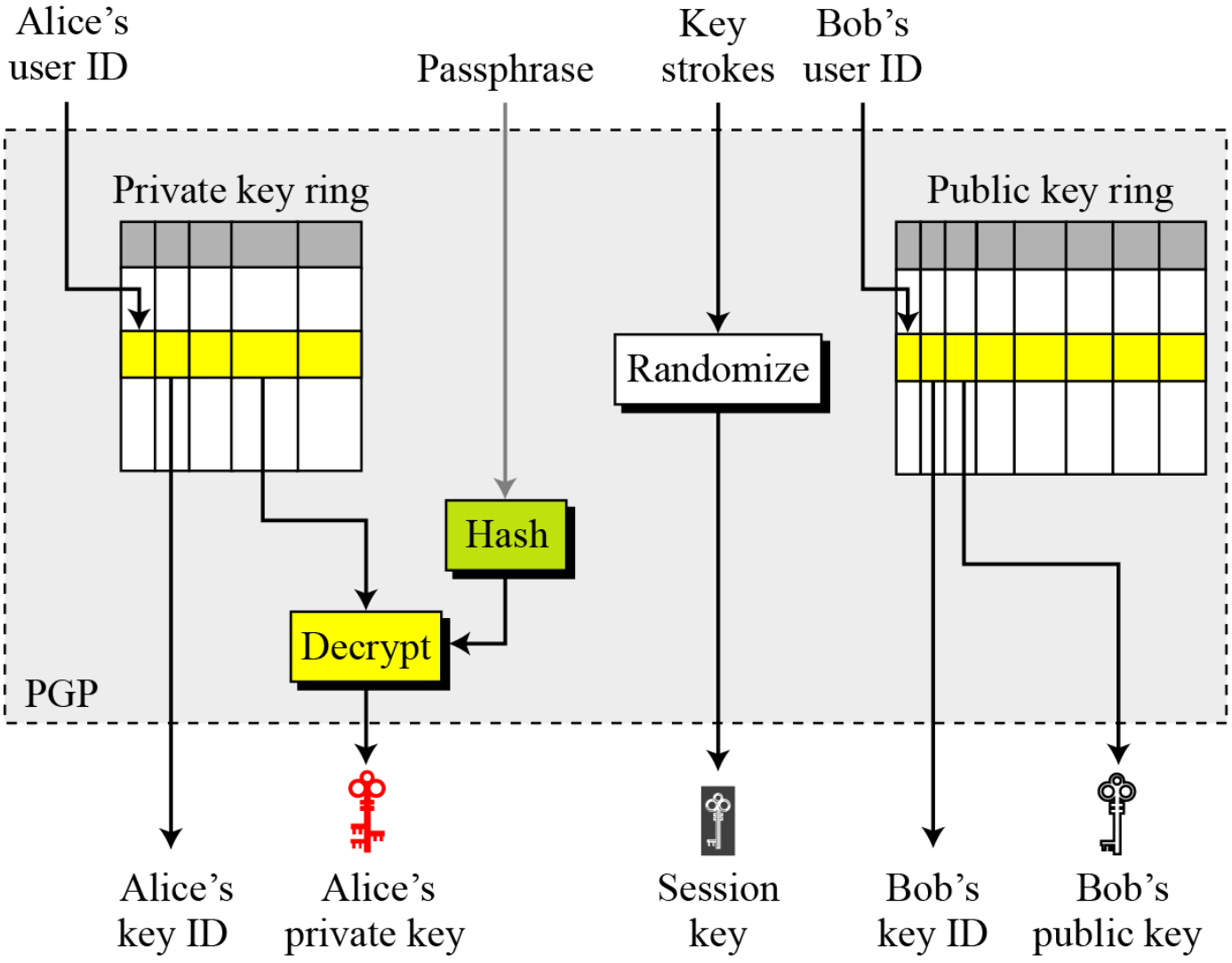
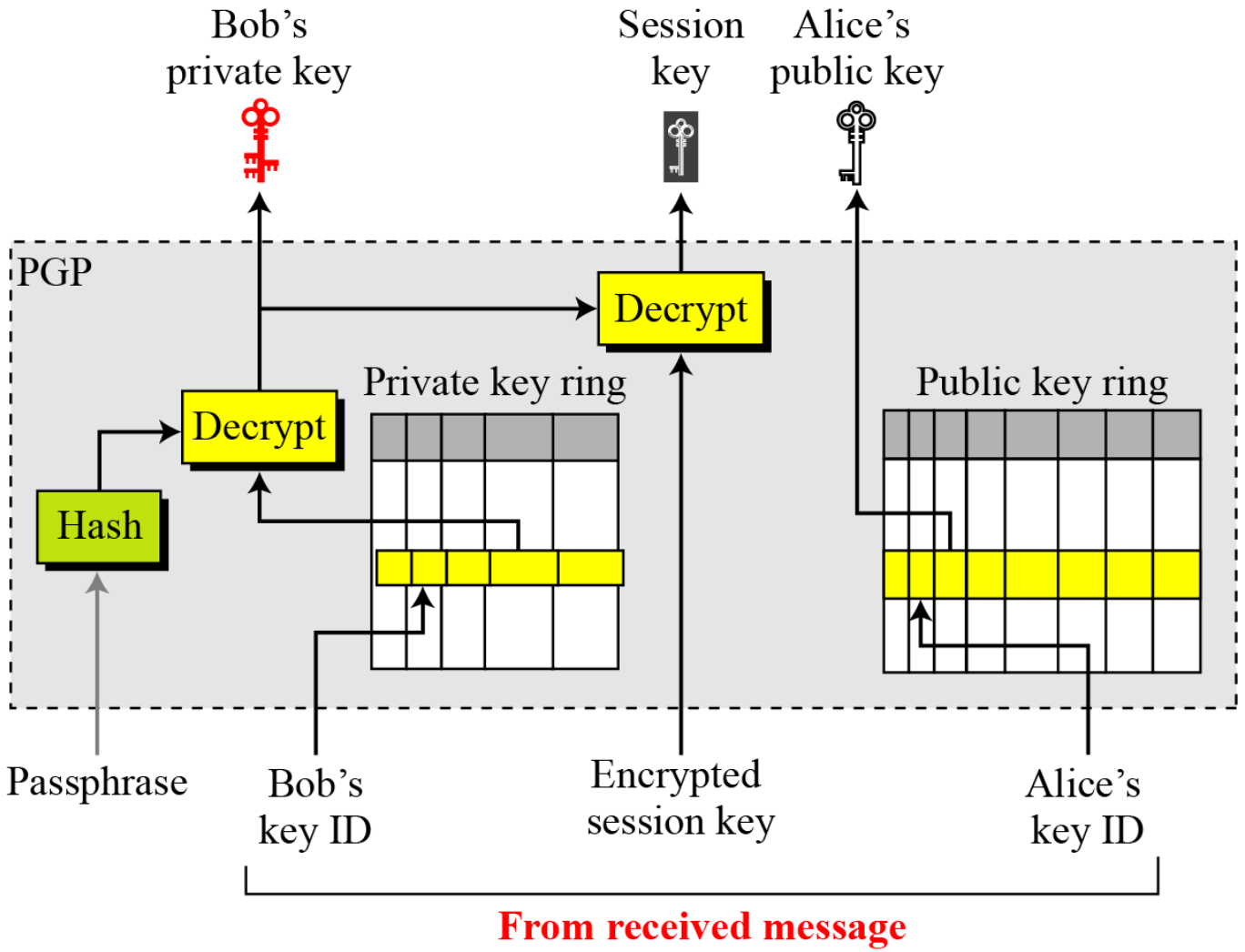
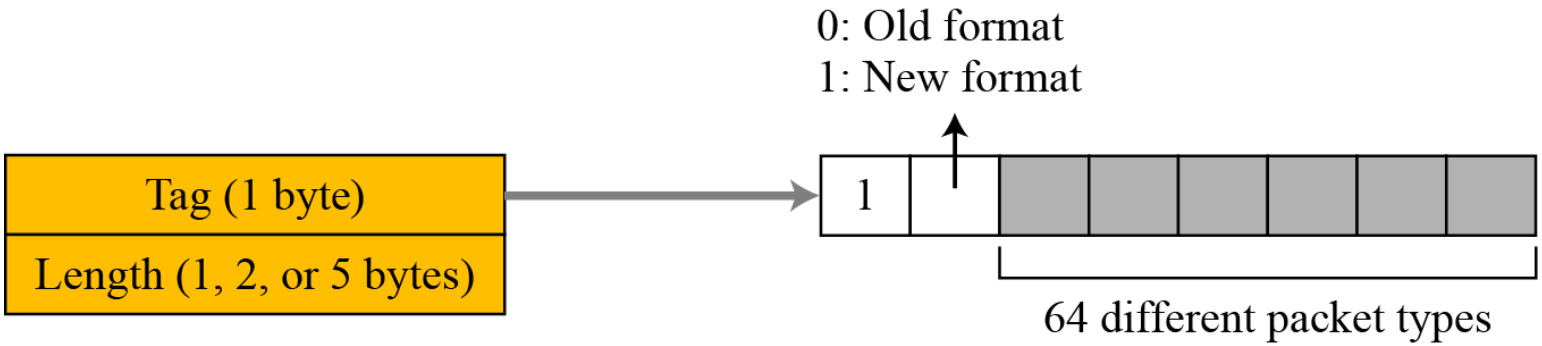


Figure 16.11 *Extracting information at the receiver site*



16.2.6 PGP Packets

Figure 16.12 *Format of packet header*



16.2.6 Continued

Table 16.12 *Some commonly used packet types*

Value	*Packet type*
1	Session key packet encrypted using a public key
2	Signature packet
5	Private-key packet
6	Public-key packet
8	Compressed data packet
9	Data packet encrypted with a secret key
11	Literal data packet
13	User ID packet

Figure 16.13 *Literal data packet*

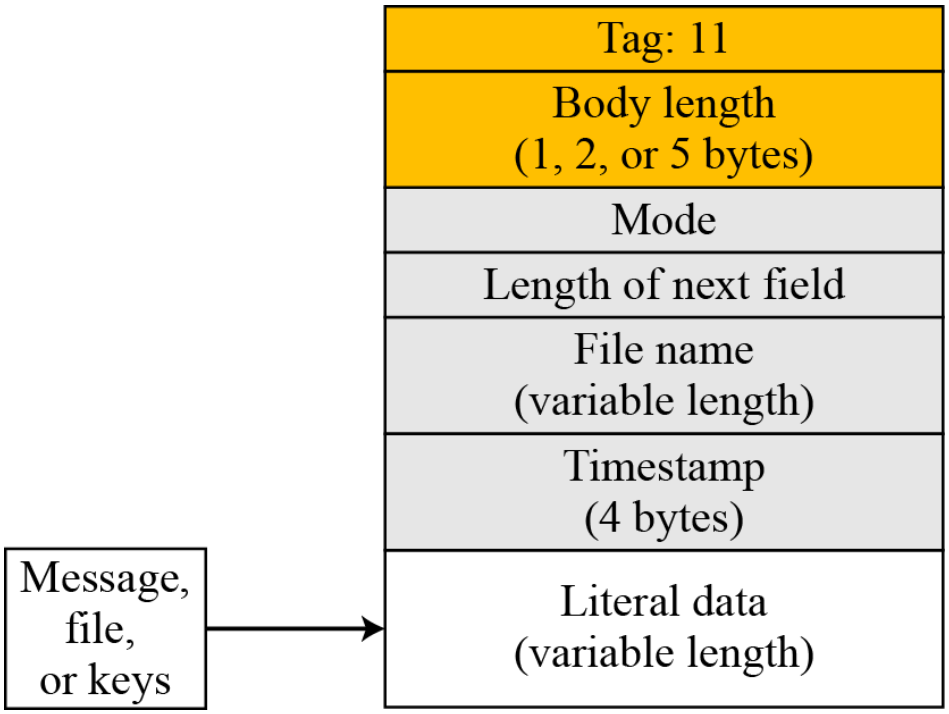


Figure 16.14 *Compressed data packet*

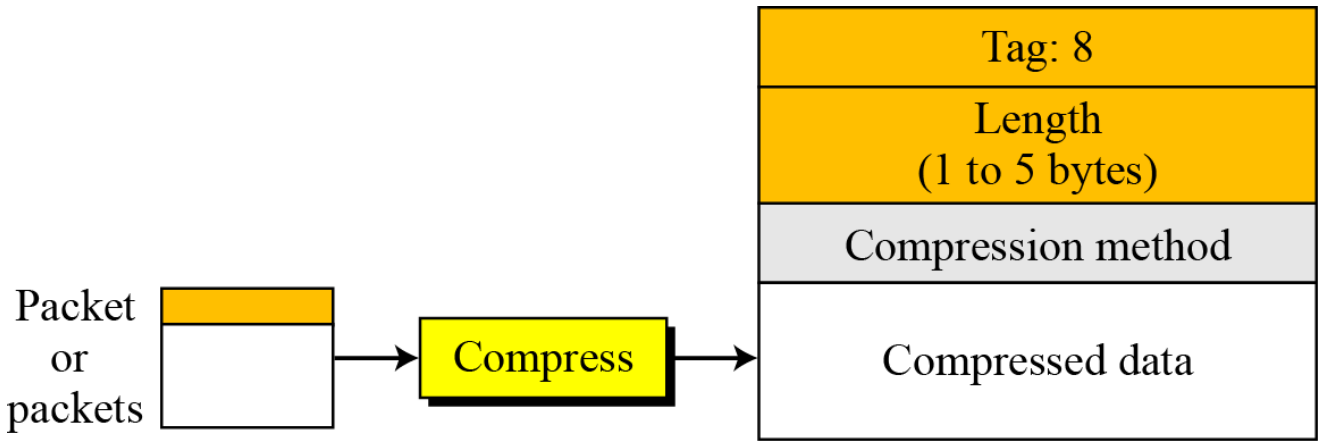


Figure 16.15 *Encrypted data packet*

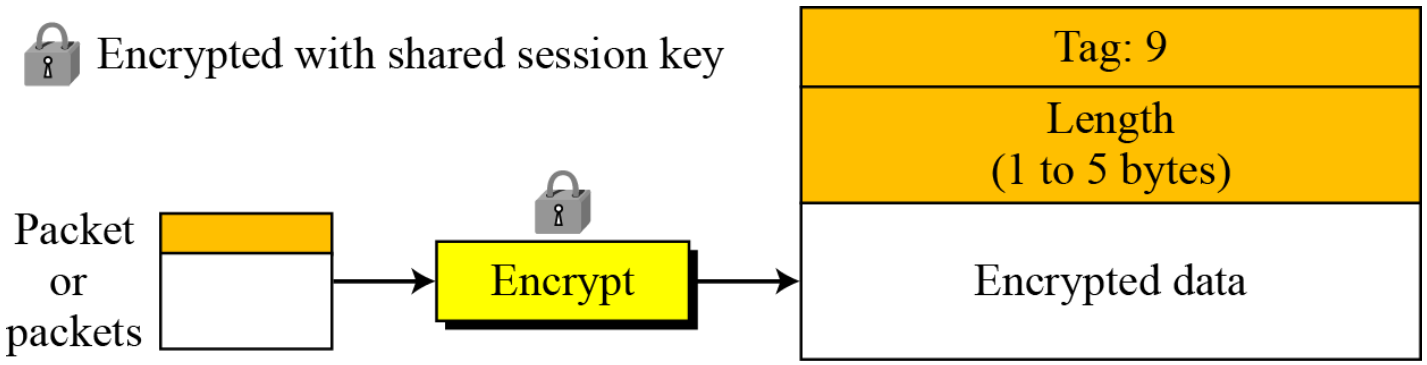
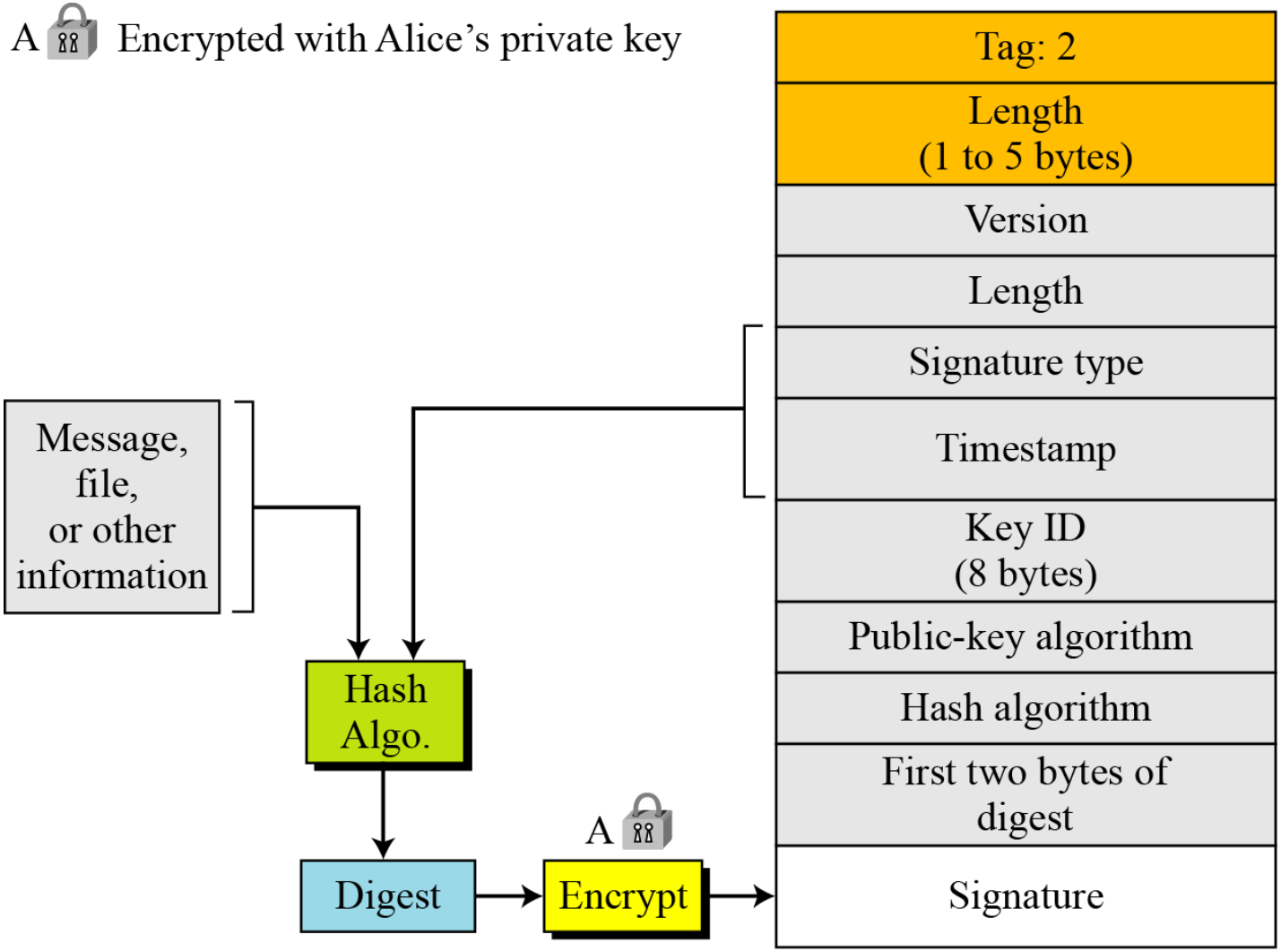


Figure 16.16 *Signature packet*



16.2.6 Continued

Table 16.13 *Some signature values*

Value	*Signature*
0x00	Signature of a binary document (message or file).
0x01	Signature of a text document (message or file).
0x10	Generic certificate of a user ID and public-key packet. The signer does not make any particular assertion about the owner of the key.
0x11	Personal certificate of a user ID and public-key packet. No verification is done on the owner of the key.
0x12	Casual certificate of a User ID and public-key packet. Some casual verification done on the owner of the key.
0x13	Positive certificate of a user ID and public-key packet. Substantial verification done.
0x30	Certificate revocation signature. This removes an earlier certificate (0*x*10 through 0*x*13).

Figure 16.17 *Session-key packet*

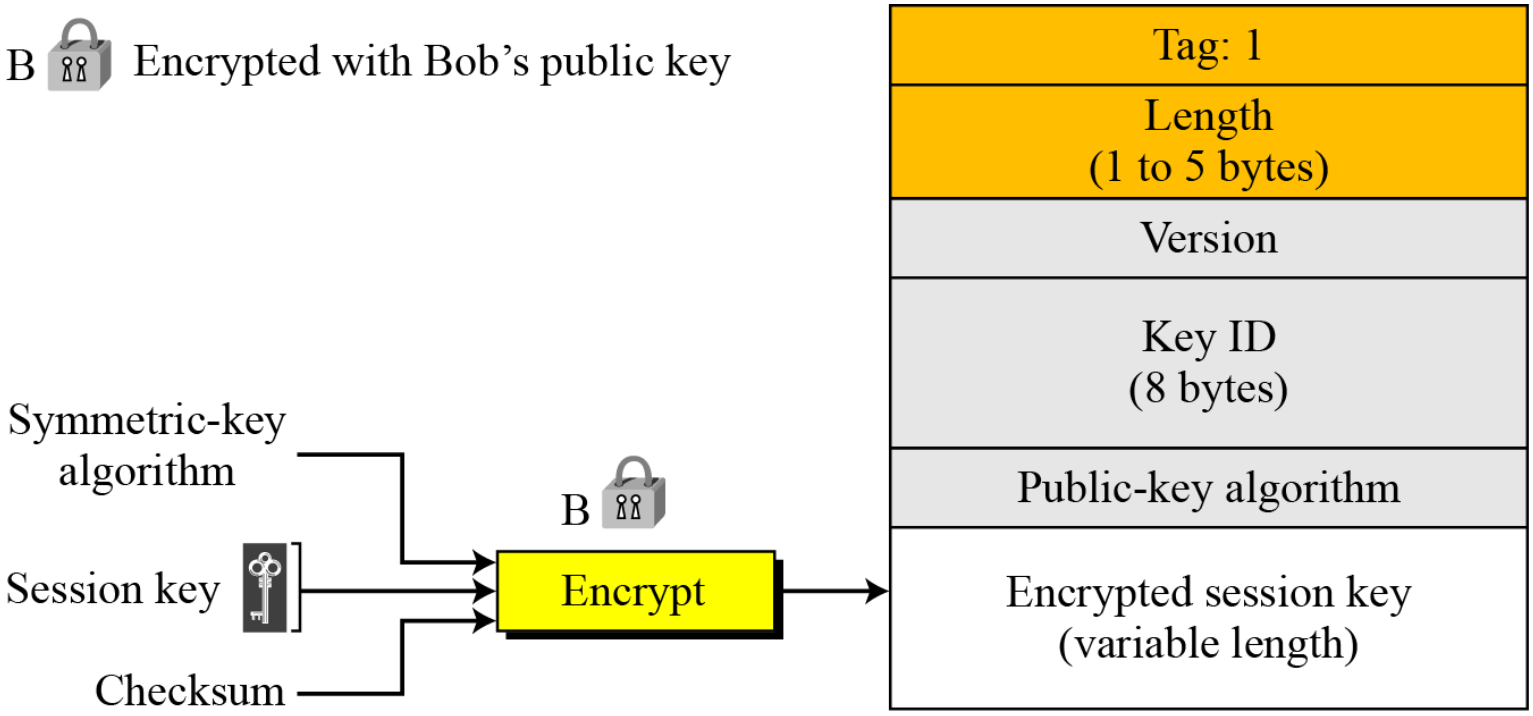


Figure 16.18 *Public-key packet*

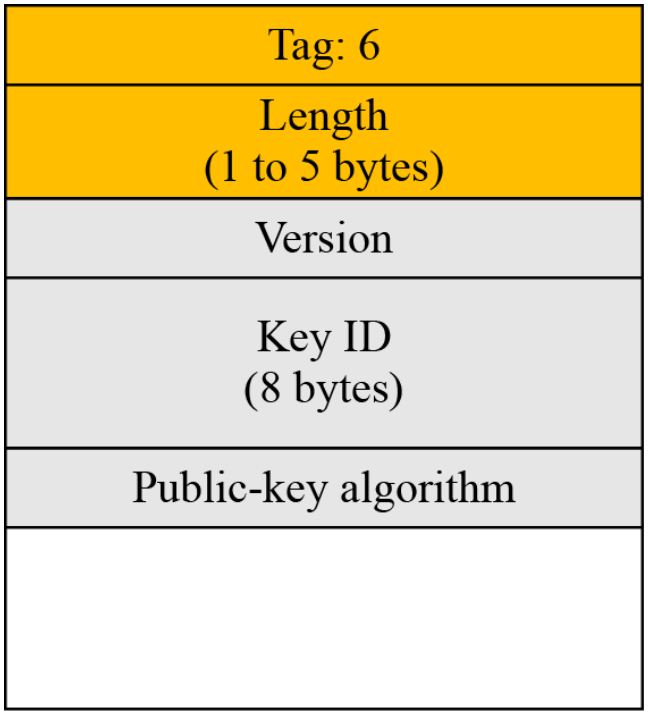
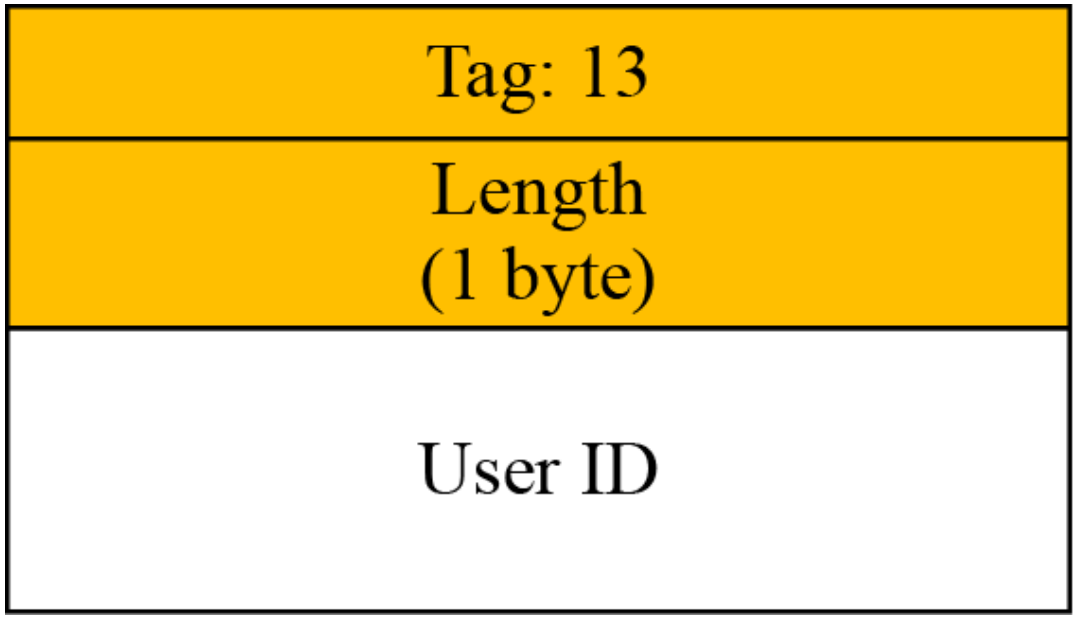


Figure 16.19 *User ID packet*



16.2.7 PGP Messages

Figure 16.20 *Encrypted message*

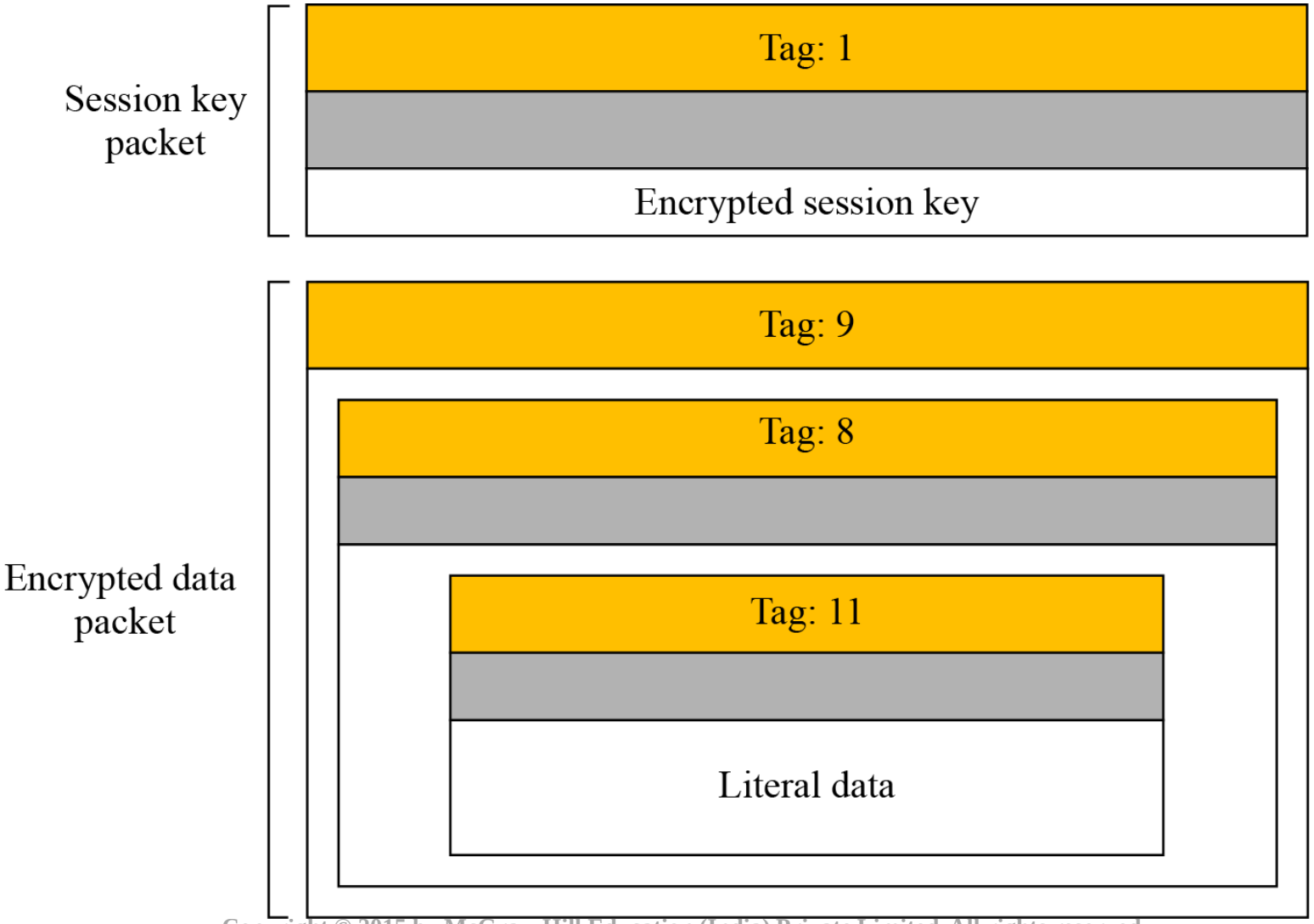


Figure 16.21 *Signed message*

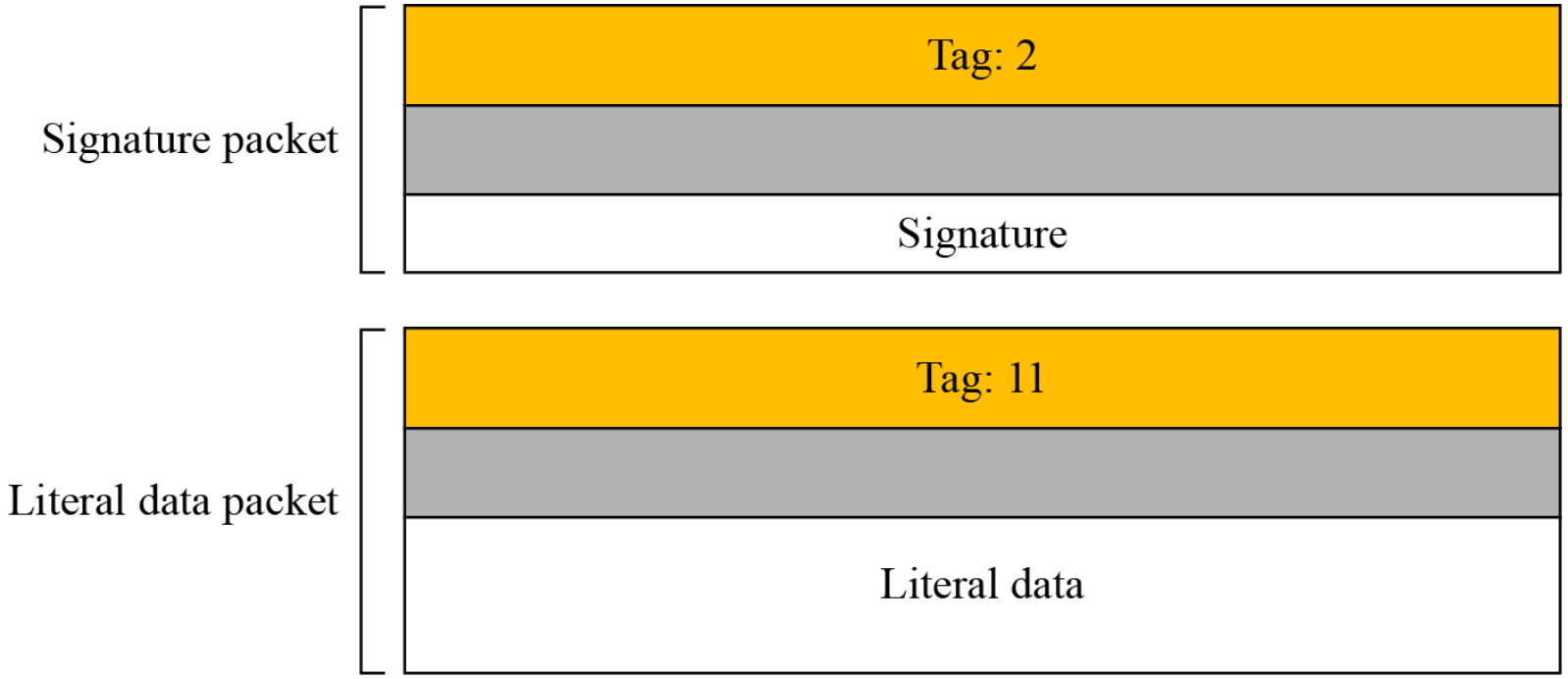
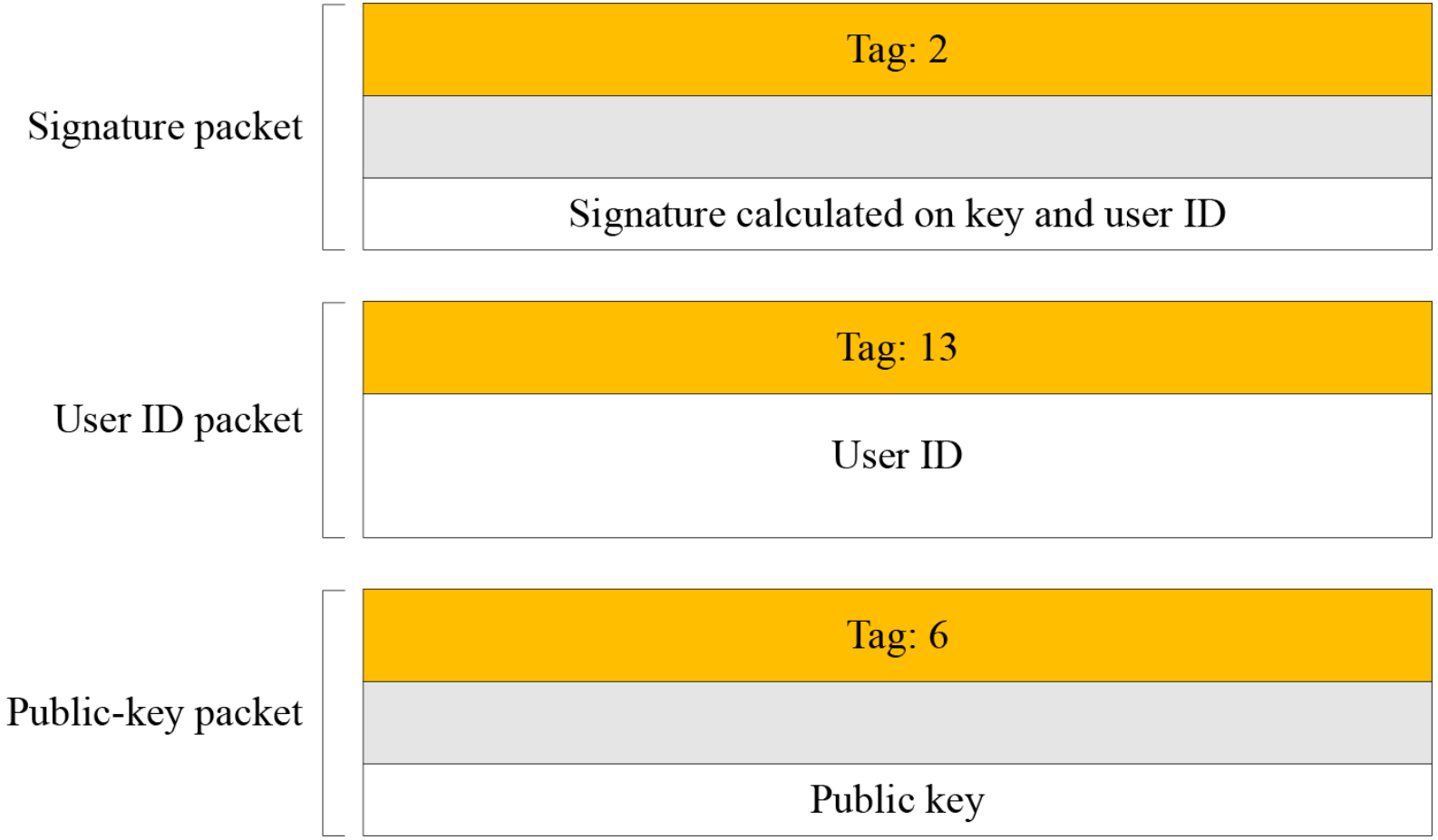


Figure 16.22 *Certificate message*



16-3 S/MIME

Another security service designed for electronic mail is Secure/Multipurpose Internet Mail Extension (S/MIME). The protocol is an enhancement of the Multipurpose Internet Mail Extension (MIME) protocol.

Topics discussed in this section:

16.3.1 Continued

Figure 16.23 ***MIME***

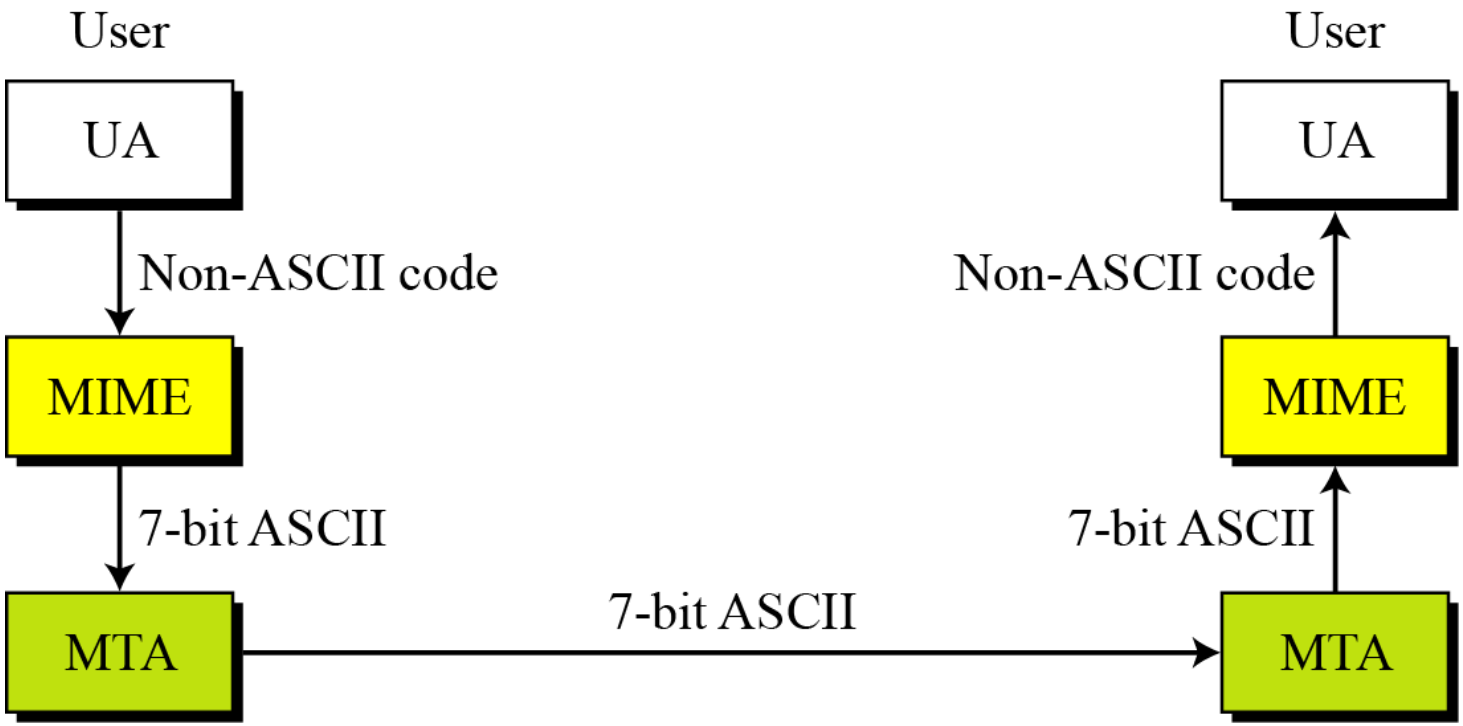
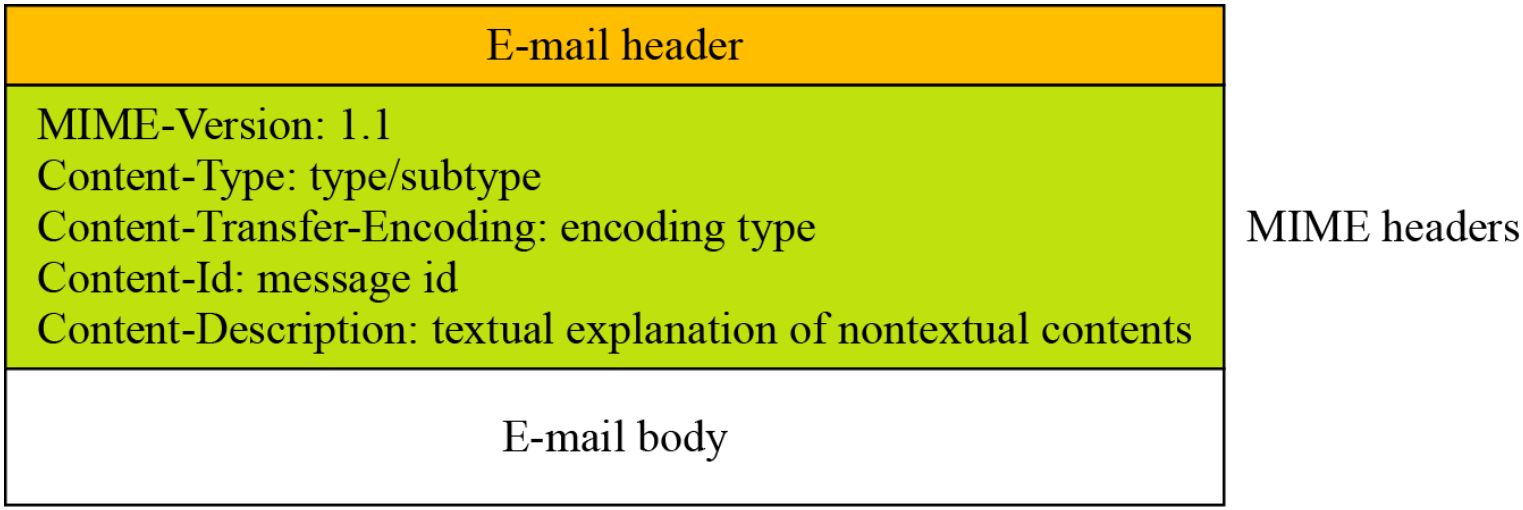


Figure 16.24 ***Teledesic***



16.3.1 Continued

MIME-Version

This header defines the version of MIME used. The current version is 1.1.

MIME-Version: 1.1

Content-Type

The content type and the content subtype are separated by a slash. Depending on the subtype, the header may contain other parameters.

Content-Type: <type / subtype; parameters>

16.3.1 Continued

Table 16.14 *Data types and subtypes in MIME*

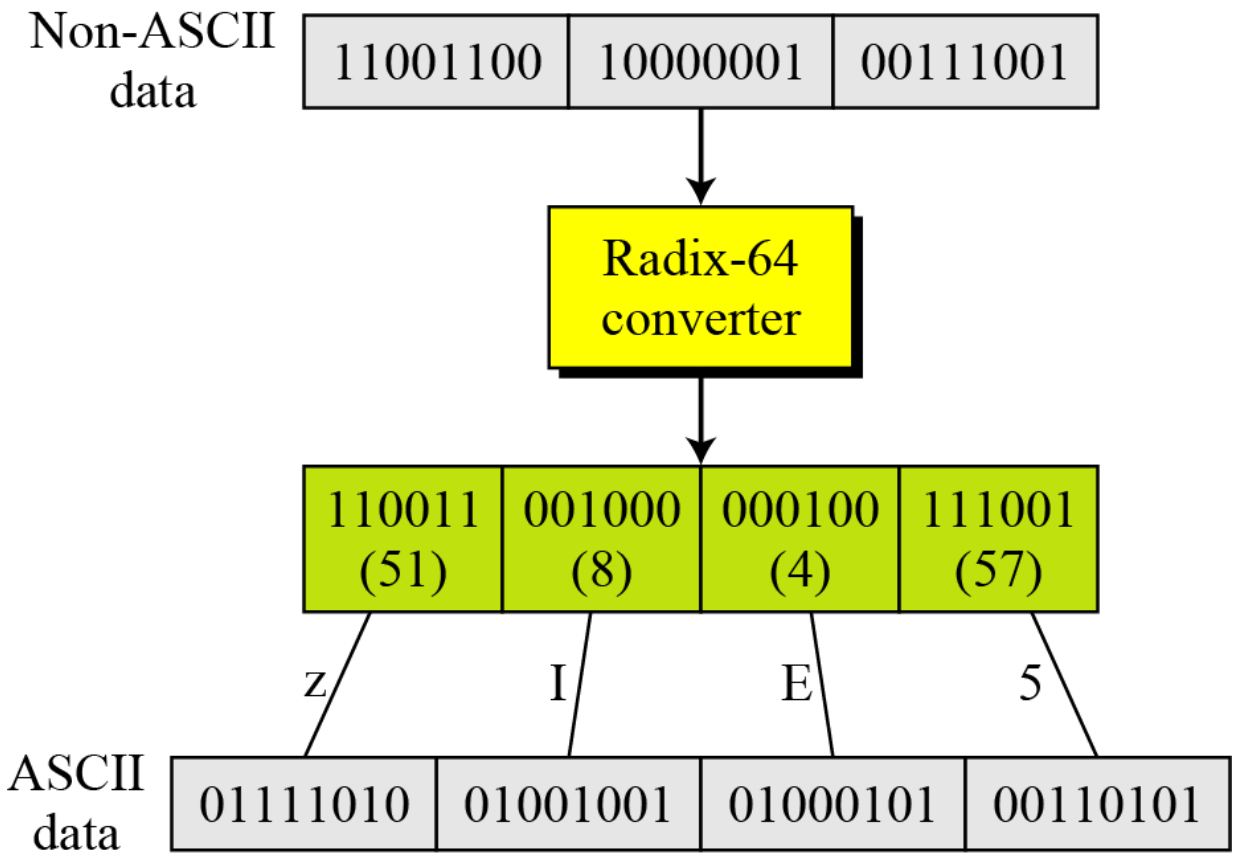
Type	*Subtype*	*Description*
	Plain	Unformatted.
	HTML	HTML format.
Multipart	Mixed	Body contains ordered parts of different data types.
	Parallel	Same as above, but no order.
	Digest	Similar to Mixed, but the default is message/RFC822.
	Alternative	Parts are different versions of the same message.
Message	RFC822	Body is an encapsulated message.
	Partial	Body is a fragment of a bigger message.
	External-Body	Body is a reference to another message.
Image	JPEG	Image is in JPEG format.
	GIF	Image is in GIF format.
Video	MPEG	Video is in MPEG format.
Audio	Basic	Single channel encoding of voice at 8 KHz.
Application	PostScript	Adobe PostScript.
	Octet-stream	General binary data (eight-bit bytes).

16.3.1 Continued

Table 16.15 *Content-transfer-encoding*

Type	*Description*
7bit	NVT ASCII characters and short lines.
8bit	Non-ASCII characters and short lines.
Binary	Non-ASCII characters with unlimited-length lines.
Radix-64	6-bit blocks of data are encoded into 8-bit ASCII characters using Radix-64 conversion.
Quoted-printable	Non-ASCII characters are encoded as an equal sign followed by an ASCII code.

Figure 16.25 *Radix-64 conversion*

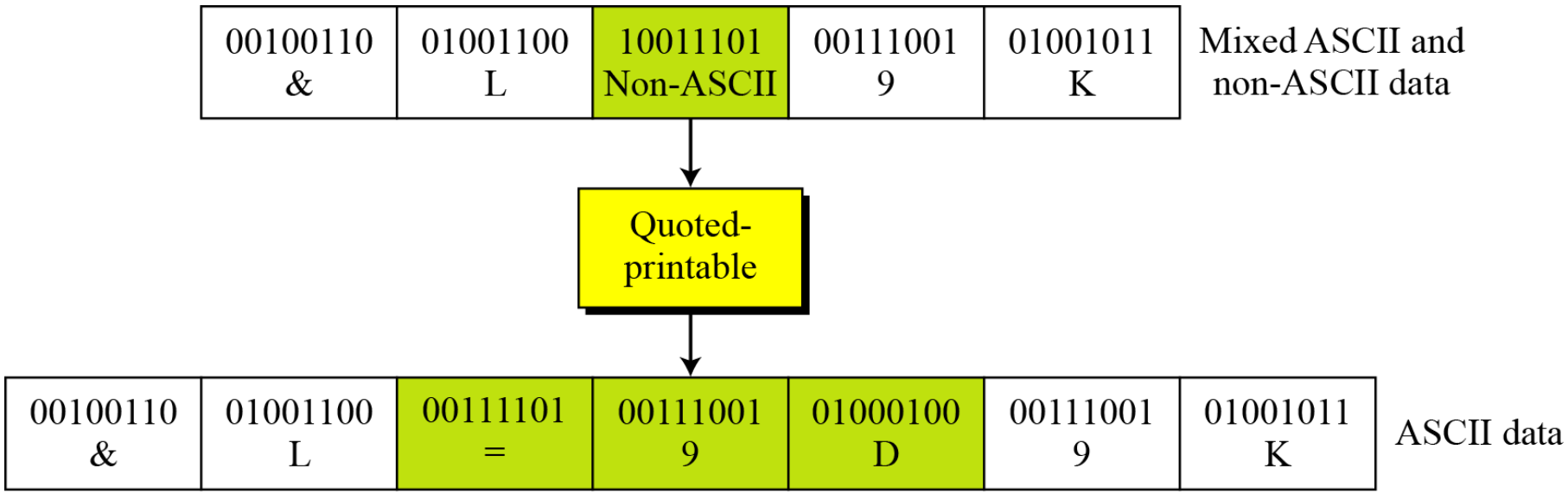


16.3.1 Continued

Table 16.16 *Radix-64 encoding table*

Value	*Code*	*Value*	*Code*	*Value*	*Code*	*Value*	*Code*	*Value*	*Code*	*Value*	*Code*
0	**A**	11	**L**	22	**W**	33	**h**	44	**s**	55	**3**
1	**B**	12	**M**	23	**X**	34	**i**	45	**t**	56	**4**
2	**C**	13	**N**	24	**Y**	35	**j**	46	**u**	57	**5**
3	**D**	14	**O**	25	**Z**	36	**k**	47	**v**	58	**6**
4	**E**	15	**P**	26	**a**	37	**l**	48	**w**	59	**7**
5	**F**	16	**Q**	27	**b**	38	**m**	49	**x**	60	**8**
6	**G**	17	**R**	28	**c**	39	**n**	50	**y**	61	**9**
7	**H**	18	**S**	29	**d**	40	**o**	51	**z**	62	+
8	**I**	19	**T**	30	**e**	41	**p**	52	**0**	63	/
9	**J**	20	**U**	31	**f**	42	**q**	53	**1**		
10	**K**	21	**V**	32	**g**	43	**r**	54	**2**		

Figure 16.26 *Quoted-printable*



16.3.2 S/MIME

S/MIME adds some new content types to include security services to the MIME. All of these new types include the parameter "application/pkcs7-mime," in which "pkcs" defines "Public Key Cryptography Specification."

Cryptographic Message Syntax (CMS)

To define how security services, such as confidentiality or integrity, can be added to MIME content types, S/MIME has defined Cryptographic Message Syntax (CMS). The syntax in each case defines the exact encoding scheme for each content type. For details, the reader is referred to RFC 3369 and 3370.

Figure 16.27 *Signed-data content type*

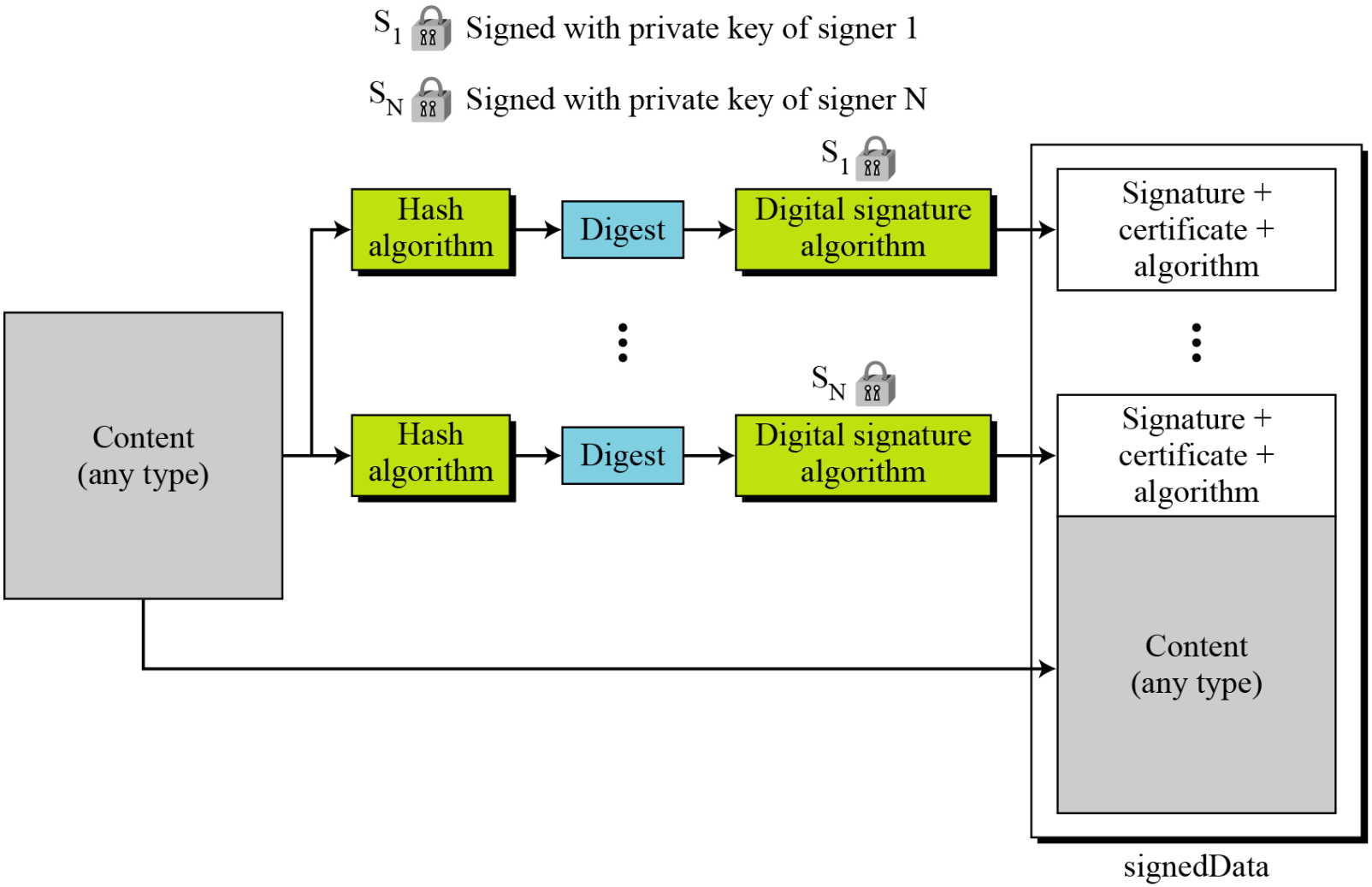


Figure 16.28 *Enveloped-data content type*

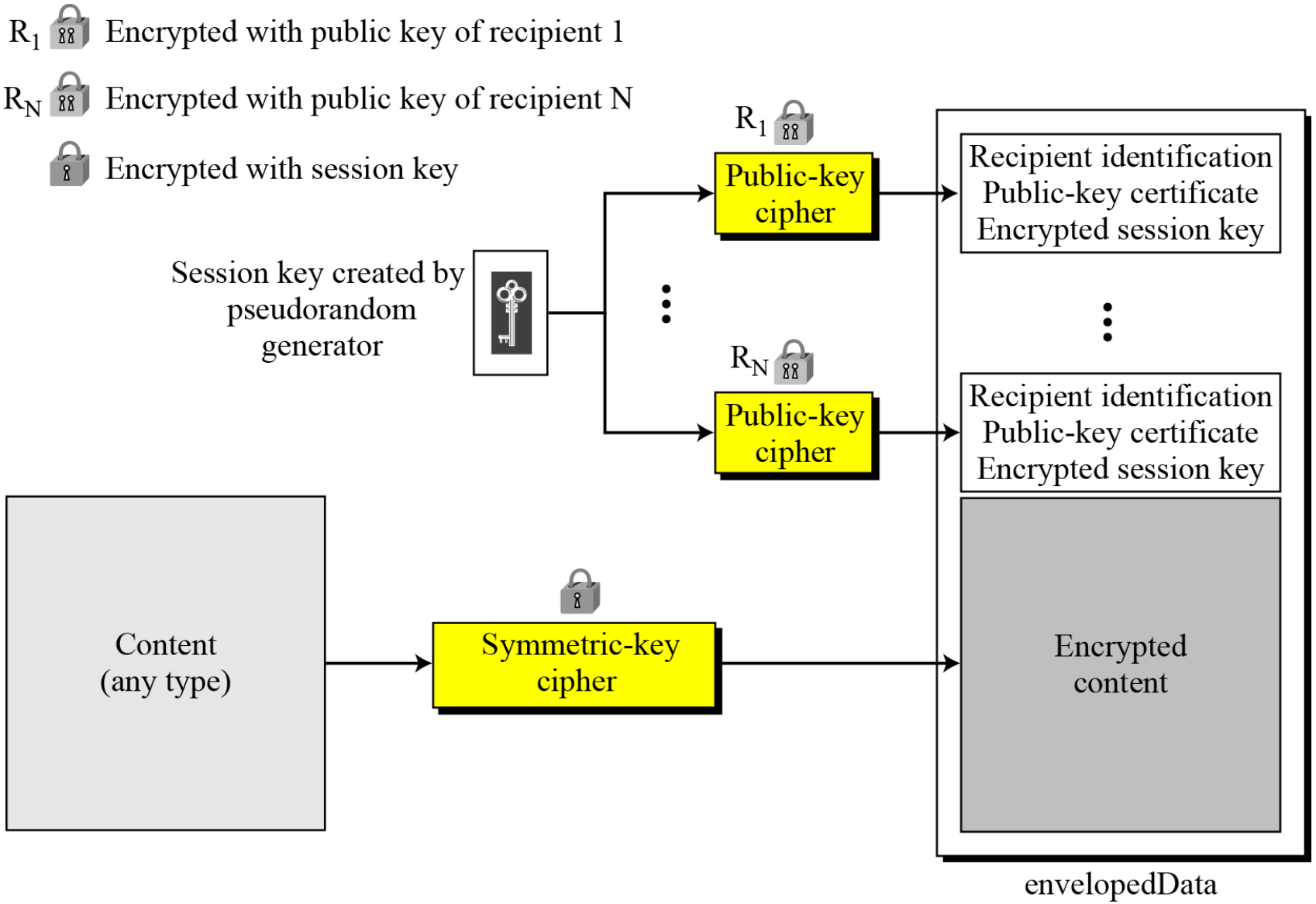


Figure 16.29 *Digest-data content type*

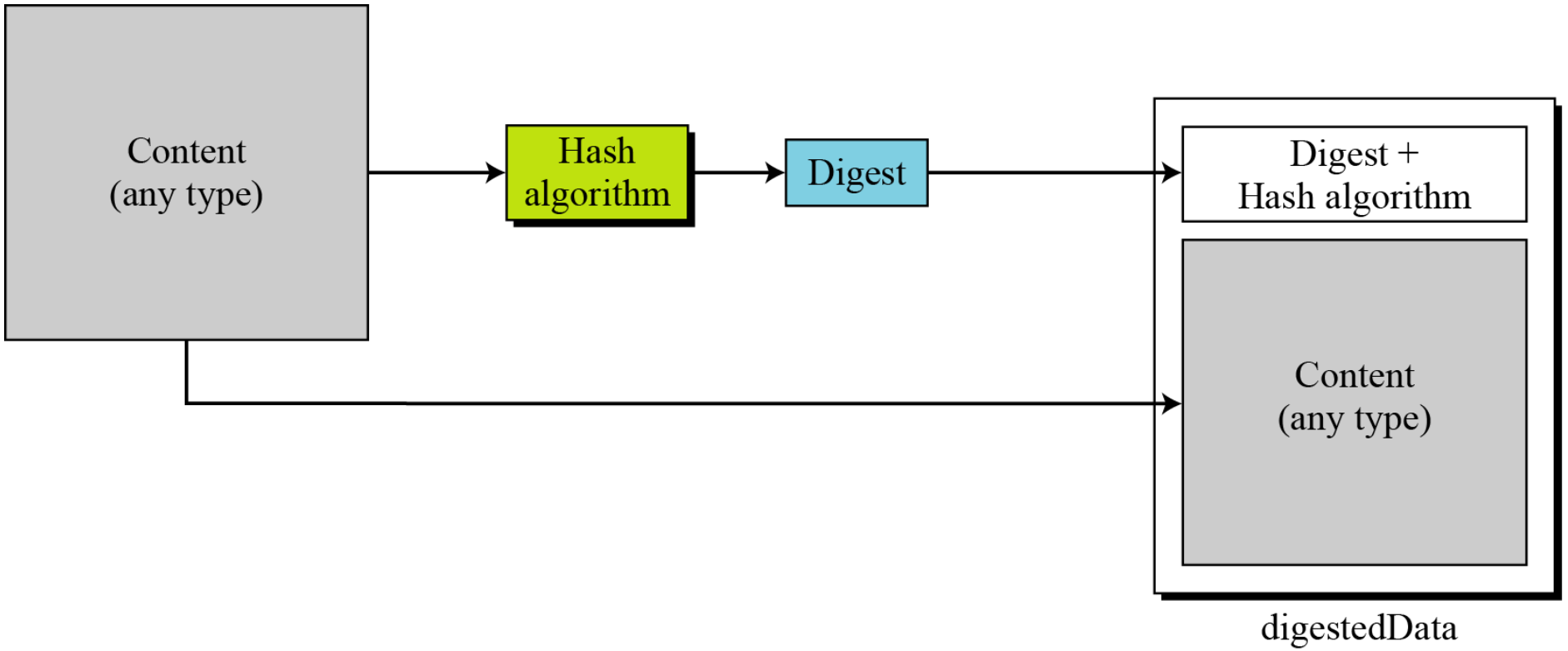
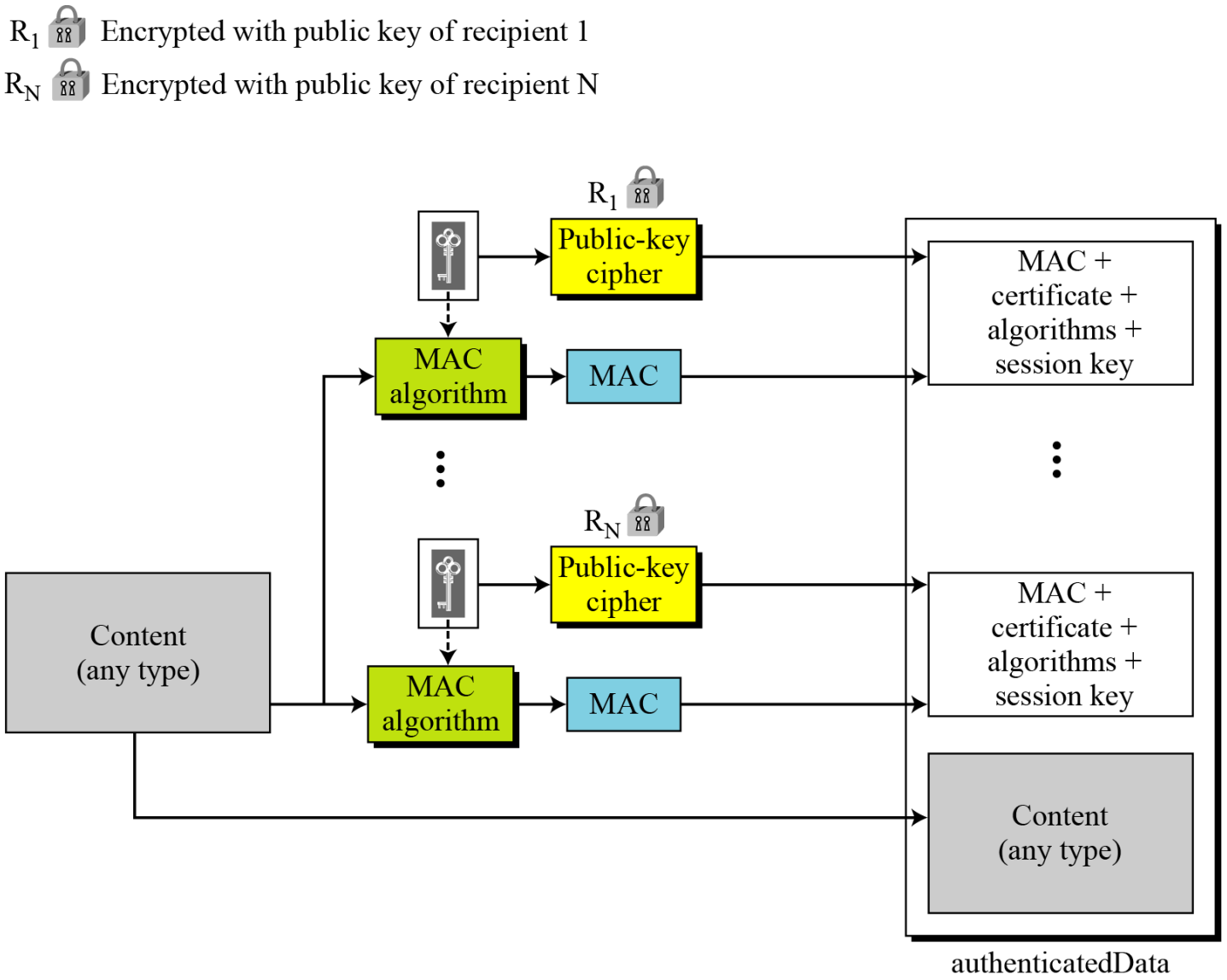


Figure 16.30 *Authenticated-data content type*



Cryptographic Algorithms

S/MIME defines several cryptographic algorithms. The term "must" means an absolute requirement; the term "should" means recommendation.

Table 16.17 *Cryptographic algorithm for S/MIME*

Algorithm	*Sender must support*	*Receiver must support*	*Sender should support*	*Receiver should support*
Content-encryption algorithm	Triple DES	Triple DES		1. AES 2. RC2/40
Session-key encryption algorithm	RSA	RSA	Diffie-Hellman	Diffie-Hellman
Hash algorithm	SHA-1	SHA-1		MD5
Digest-encryption algorithm	DSS	DSS	RSA	RSA
Message-authentication algorithm		HMAC with SHA-1		

16.3.2 Continued

Example 16.3

The following shows an example of an enveloped-data in which a small message is encrypted using triple DES.

```
Content-Type: application/pkcs7-mime; mime-type=enveloped-data
Content-Transfer-Encoding: Radix-64
Content-Description: attachment
name="report.txt";
cb32ut67f4bhijHU21oi87eryb0287hmnklsgFDoY8bc659GhIGfH6543mhjkdsaH23YjBnmN
ybmlkzjhgfdyhGe23Kjk34XiuD678Es16se09jy76jHuytTMDcbnmlkjgfFdiuyu678543m0n3h
G34un12P2454Hoi87e2ryb0H2MjN6KuyrlsgFDoY897fk923jljk1301XiuD6gh78EsUyT23y
```