

1. SMTP cannot transmit executable files or other binary objects. A number of schemes are in use for converting binary files into a text form that can be used by SMTP mail systems, including the popular UNIX UUencode/UUdecode scheme. However, none of these is a standard or even a *de facto* standard.
2. SMTP cannot transmit text data that includes national language characters, because these are represented by 8-bit codes with values of 128 decimal or higher, and SMTP is limited to 7-bit ASCII.
3. SMTP servers may reject mail message over a certain size.
4. SMTP gateways that translate between ASCII and the character code EBCDIC do not use a consistent set of mappings, resulting in translation problems.
5. SMTP gateways to X.400 electronic mail networks cannot handle nontextual data included in X.400 messages.
6. Some SMTP implementations do not adhere completely to the SMTP standards defined in RFC 821. Common problems include:
 - Deletion, addition, or reordering of carriage return and linefeed
 - Truncating or wrapping lines longer than 76 characters
 - Removal of trailing white space (tab and space characters)
 - Padding of lines in a message to the same length
 - Conversion of tab characters into multiple space characters

MIME is intended to resolve these problems in a manner that is compatible with existing RFC 5322 implementations.

OVERVIEW The MIME specification includes the following elements.

1. Five new message header fields are defined, which may be included in an RFC 5322 header. These fields provide information about the body of the message.
2. A number of content formats are defined, thus standardizing representations that support multimedia electronic mail.
3. Transfer encodings are defined that enable the conversion of any content format into a form that is protected from alteration by the mail system.

In this subsection, we introduce the five message header fields. The next two subsections deal with content formats and transfer encodings.

The five header fields defined in MIME are as follows:

- **MIME-Version:** Must have the parameter value 1.0. This field indicates that the message conforms to RFCs 2045 and 2046.
- **Content-Type:** Describes the data contained in the body with sufficient detail that the receiving user agent can pick an appropriate agent or mechanism to represent the data to the user or otherwise deal with the data in an appropriate manner.

- **Content-Transfer-Encoding:** Indicates the type of transformation that has been used to represent the body of the message in a way that is acceptable for mail transport.
- **Content-ID:** Used to identify MIME entities uniquely in multiple contexts.
- **Content-Description:** A text description of the object with the body; this is useful when the object is not readable (e.g., audio data).

Any or all of these fields may appear in a normal RFC 5322 header. A compliant implementation must support the MIME-Version, Content-Type, and Content-Transfer-Encoding fields; the Content-ID and Content-Description fields are optional and may be ignored by the recipient implementation.

MIME CONTENT TYPES The bulk of the MIME specification is concerned with the definition of a variety of content types. This reflects the need to provide standardized ways of dealing with a wide variety of information representations in a multimedia environment.

Table 8.1 lists the content types specified in RFC 2046. There are seven different major types of content and a total of 15 subtypes. In general, a content type declares the general type of data, and the subtype specifies a particular format for that type of data.

Table 8.1 MIME Content Types

Type	Subtype	Description
Text	Plain	Unformatted text; may be ASCII or ISO 8859.
	Enriched	Provides greater format flexibility.
Multipart	Mixed	The different parts are independent but are to be transmitted together. They should be presented to the receiver in the order that they appear in the mail message.
	Parallel	Differs from Mixed only in that no order is defined for delivering the parts to the receiver.
	Alternative	The different parts are alternative versions of the same information. They are ordered in increasing faithfulness to the original, and the recipient's mail system should display the "best" version to the user.
	Digest	Similar to Mixed, but the default type/subtype of each part is message/rfc822.
Message	rfc822	The body is itself an encapsulated message that conforms to RFC 822.
	Partial	Used to allow fragmentation of large mail items, in a way that is transparent to the recipient.
	External-body	Contains a pointer to an object that exists elsewhere.
Image	jpeg	The image is in JPEG format, JFIF encoding.
	gif	The image is in GIF format.
Video	mpeg	MPEG format.
Audio	Basic	Single-channel 8-bit ISDN μ -law encoding at a sample rate of 8 kHz.
Application	PostScript	Adobe Postscript format.
	octet-stream	General binary data consisting of 8-bit bytes.

For the **text type** of body, no special software is required to get the full meaning of the text aside from support of the indicated character set. The primary subtype is *plain text*, which is simply a string of ASCII characters or ISO 8859 characters. The *enriched* subtype allows greater formatting flexibility.

The **multipart type** indicates that the body contains multiple, independent parts. The Content-Type header field includes a parameter (called boundary) that defines the delimiter between body parts. This boundary should not appear in any parts of the message. Each boundary starts on a new line and consists of two hyphens followed by the boundary value. The final boundary, which indicates the end of the last part, also has a suffix of two hyphens. Within each part, there may be an optional ordinary MIME header.

Here is a simple example of a multipart message containing two parts—both consisting of simple text (taken from RFC 2046):

```
From: Nathaniel Borenstein <nsb@bellcore.com>
To: Ned Freed <ned@innosoft.com>
Subject: Sample message
MIME-Version: 1.0
Content-type: multipart/mixed; boundary="simple boundary"

This is the preamble. It is to be ignored, though it is a
handy place for mail composers to include an explanatory
note to non-MIME conformant readers.
-simple boundary

This is implicitly typed plain ASCII text. It does NOT end
with a linebreak.
-simple boundary
Content-type: text/plain; charset=us-ascii

This is explicitly typed plain ASCII text. It DOES end
with a linebreak.
-simple boundary-
This is the epilogue. It is also to be ignored.
```

There are four subtypes of the multipart type, all of which have the same overall syntax. The **multipart/mixed subtype** is used when there are multiple independent body parts that need to be bundled in a particular order. For the **multipart/parallel subtype**, the order of the parts is not significant. If the recipient's system is appropriate, the multiple parts can be presented in parallel. For example, a picture or text part could be accompanied by a voice commentary that is played while the picture or text is displayed.

For the **multipart/alternative subtype**, the various parts are different representations of the same information. The following is an example:

```
From: Nathaniel Borenstein <nsb@bellcore.com>
To: Ned Freed <ned@innosoft.com>
Subject: Formatted text mail
```

```

MIME-Version: 1.0
Content-Type: multipart/alternative;
boundary=boundary42
--boundary42
Content-Type: text/plain; charset=us-ascii
    . . . plain text version of message goes here. . . .
--boundary42
Content-Type: text/enriched
    . . . RFC 1896 text/enriched version of same message
    goes here . . .
--boundary42--

```

In this subtype, the body parts are ordered in terms of increasing preference. For this example, if the recipient system is capable of displaying the message in the text/enriched format, this is done; otherwise, the plain text format is used.

The **multipart/digest subtype** is used when each of the body parts is interpreted as an RFC 5322 message with headers. This subtype enables the construction of a message whose parts are individual messages. For example, the moderator of a group might collect e-mail messages from participants, bundle these messages, and send them out in one encapsulating MIME message.

The **message type** provides a number of important capabilities in MIME. The **message/rfc822 subtype** indicates that the body is an entire message, including header and body. Despite the name of this subtype, the encapsulated message may be not only a simple RFC 5322 message, but also any MIME message.

The **message/partial subtype** enables fragmentation of a large message into a number of parts, which must be reassembled at the destination. For this subtype, three parameters are specified in the Content-Type: Message/Partial field: an *id* common to all fragments of the same message, a *sequence number* unique to each fragment, and the *total* number of fragments.

The **message/external-body subtype** indicates that the actual data to be conveyed in this message are not contained in the body. Instead, the body contains the information needed to access the data. As with the other message types, the message/external-body subtype has an outer header and an encapsulated message with its own header. The only necessary field in the outer header is the Content-Type field, which identifies this as a message/external-body subtype. The inner header is the message header for the encapsulated message. The Content-Type field in the outer header must include an access-type parameter, which indicates the method of access, such as FTP (file transfer protocol).

The **application type** refers to other kinds of data, typically either uninterpreted binary data or information to be processed by a mail-based application.

MIME TRANSFER ENCODINGS The other major component of the MIME specification, in addition to content type specification, is a definition of transfer encodings for message bodies. The objective is to provide reliable delivery across the largest range of environments.

The MIME standard defines two methods of encoding data. The Content-Transfer-Encoding field can actually take on six values, as listed in Table 8.2. However, three of these values (7-bit, 8-bit, and binary) indicate that no encoding has been done but provide some information about the nature of the data. For SMTP transfer, it is safe to use the 7-bit form. The 8-bit and binary forms may be usable in other mail transport contexts. Another Content-Transfer-Encoding value is x-token, which indicates that some other encoding scheme is used for which a name is to be supplied. This could be a vendor-specific or application-specific scheme. The two actual encoding schemes defined are quoted-printable and base64. Two schemes are defined to provide a choice between a transfer technique that is essentially human readable and one that is safe for all types of data in a way that is reasonably compact.

The **quoted-printable** transfer encoding is useful when the data consists largely of octets that correspond to printable ASCII characters. In essence, it represents nonsafe characters by the hexadecimal representation of their code and introduces reversible (soft) line breaks to limit message lines to 76 characters.

The **base64 transfer encoding**, also known as radix-64 encoding, is a common one for encoding arbitrary binary data in such a way as to be invulnerable to the processing by mail-transport programs. It is also used in PGP and is described in Appendix H.

A MULTIPART EXAMPLE Figure 8.3, taken from RFC 2045, is the outline of a complex multipart message. The message has five parts to be displayed serially: two introductory plain text parts, an embedded multipart message, a richtext part, and a closing encapsulated text message in a non-ASCII character set. The embedded multipart message has two parts to be displayed in parallel: a picture and an audio fragment.

CANONICAL FORM An important concept in MIME and S/MIME is that of canonical form. Canonical form is a format, appropriate to the content type, that is standardized for use between systems. This is in contrast to native form, which is a format that may be peculiar to a particular system. RFC 2049 defines these two forms as follows:

- **Native form:** The body to be transmitted is created in the system's native format. The native character set is used and, where appropriate, local end-of-line conventions are used as well. The body may be any format that corresponds to

Table 8.2 MIME Transfer Encodings

7 bit	The data are all represented by short lines of ASCII characters.
8 bit	The lines are short, but there may be non-ASCII characters (octets with the high-order bit set).
binary	Not only may non-ASCII characters be present but the lines are not necessarily short enough for SMTP transport.
quoted-printable	Encodes the data in such a way that if the data being encoded are mostly ASCII text, the encoded form of the data remains largely recognizable by humans.
base64	Encodes data by mapping 6-bit blocks of input to 8-bit blocks of output, all of which are printable ASCII characters.
x-token	A named nonstandard encoding.

```

MIME-Version: 1.0
From: Nathaniel Borenstein <nsb@bellcore.com>
To: Ned Freed <ned@innosoft.com>
Subject: A multipart example
Content-Type: multipart/mixed;
    boundary=unique-boundary-1
This is the preamble area of a multipart message. Mail readers that
understand multipart format should ignore this preamble. If you are reading
this text, you might want to consider changing to a mail reader that
understands how to properly display multipart messages.

--unique-boundary-1
    . . . Some text appears here . . .
[Note that the preceding blank line means no header fields were given and
this is text, with charset US ASCII. It could have been done with explicit
typing as in the next part.]

--unique-boundary-1
Content-type: text/plain; charset=US-ASCII
This could have been part of the previous part, but illustrates explicit
versus implicit typing of body parts.

--unique-boundary-1
Content-Type: multipart/parallel; boundary=unique-boundary-2

--unique-boundary-2
Content-Type: audio/basic
Content-Transfer-Encoding: base64
    . . . base64-encoded 8000 Hz single-channel mu-law-format audio data goes
here . . . .

--unique-boundary-2
Content-Type: image/jpeg
Content-Transfer-Encoding: base64
    . . . base64-encoded image data goes here . . . .

--unique-boundary-2-
--unique-boundary-1
Content-type: text/enriched

This is richtext. as defined in RFC 1896

    Isn't it cool?

--unique-boundary-1
Content-Type: message/rfc822

From: (mailbox in US-ASCII)
To: (address in US-ASCII)
Subject: (subject in US-ASCII)
Content-Type: Text/plain; charset=ISO-8859-1
Content-Transfer-Encoding: Quoted-printable

    . . . Additional text in ISO-8859-1 goes here . . .

--unique-boundary-1-

```

Figure 8.3 Example MIME Message Structure

the local model for the representation of some form of information. Examples include a UNIX-style text file, or a Sun raster image, or a VMS indexed file, and audio data in a system-dependent format stored only in memory. In essence, the data are created in the native form that corresponds to the type specified by the media type.

- **Canonical form:** The entire body, including out-of-band information such as record lengths and possibly file attribute information, is converted to a universal canonical form. The specific media type of the body as well as its associated attributes dictates the nature of the canonical form that is used. Conversion to the proper canonical form may involve character set conversion, transformation of audio data, compression, or various other operations specific to the various media types.

8.3 E-MAIL THREATS AND COMPREHENSIVE E-MAIL SECURITY

For both organizations and individuals, e-mail is both pervasive and especially vulnerable to a wide range of security threats. In general terms, e-mail security threats can be classified as follows:

- **Authenticity-related threats:** Could result in unauthorized access to an enterprise's e-mail system.
- **Integrity-related threats:** Could result in unauthorized modification of e-mail content.
- **Confidentiality-related threats:** Could result in unauthorized disclosure of sensitive information.
- **Availability-related threats:** Could prevent end users from being able to send or receive e-mail.

A useful list of specific e-mail threats, together with approaches to mitigation, is provided in SP 800-177 (*Trustworthy E-mail*, September 2015) and is shown in Table 8.3.

SP 800-177 recommends use of a variety of standardized protocols as a means for countering these threats. These include:

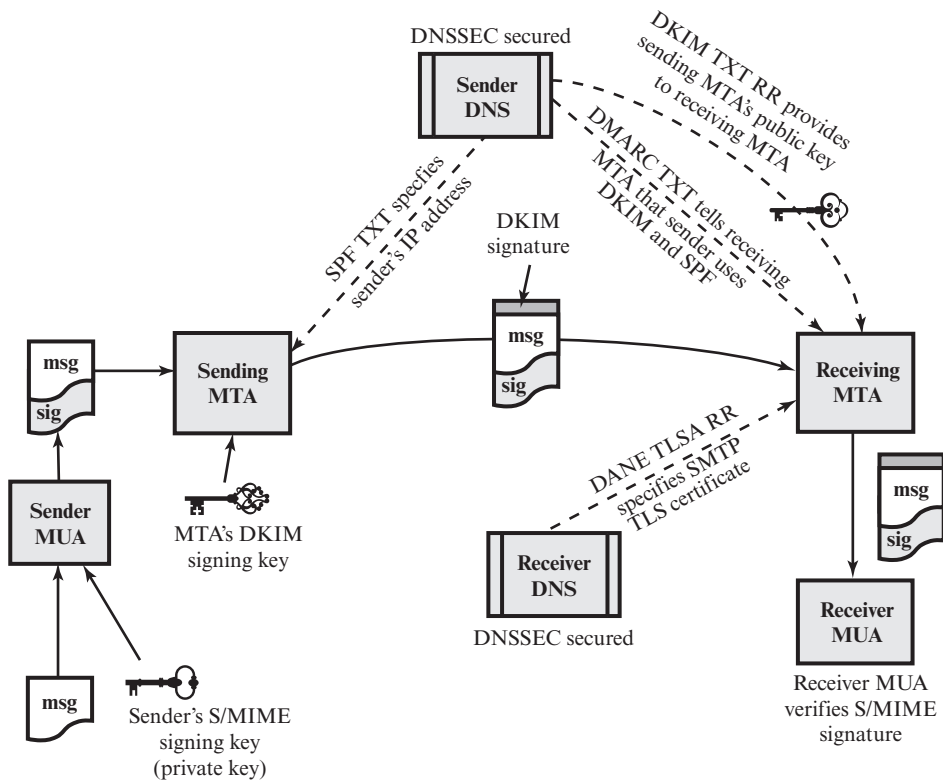
- **STARTTLS:** An SMTP security extension that provides authentication, integrity, non-repudiation (via digital signatures) and confidentiality (via encryption) for the entire SMTP message by running SMTP over TLS.
- **S/MIME:** Provides authentication, integrity, non-repudiation (via digital signatures) and confidentiality (via encryption) of the message body carried in SMTP messages.
- **DNS Security Extensions (DNSSEC):** Provides authentication and integrity protection of DNS data, and is an underlying tool used by various e-mail security protocols.
- **DNS-based Authentication of Named Entities (DANE):** Is designed to overcome problems in the certificate authority (CA) system by providing an alternative channel for authenticating public keys based on DNSSEC, with the

Table 8.3 E-mail Threats and Mitigations

Threat	Impact on Purported Sender	Impact on Receiver	Mitigation
E-mail sent by unauthorized MTA in enterprise (e.g., malware botnet)	Loss of reputation, valid e-mail from enterprise may be blocked as possible spam/phishing attack.	UBE and/or e-mail containing malicious links may be delivered into user inboxes.	Deployment of domain-based authentication techniques. Use of digital signatures over e-mail.
E-mail message sent using spoofed or unregistered sending domain	Loss of reputation, valid e-mail from enterprise may be blocked as possible spam/phishing attack.	UBE and/or e-mail containing malicious links may be delivered into user inboxes.	Deployment of domain-based authentication techniques. Use of digital signatures over e-mail.
E-mail message sent using forged sending address or e-mail address (i.e., phishing, spear phishing)	Loss of reputation, valid e-mail from enterprise may be blocked as possible spam/phishing attack.	UBE and/or e-mail containing malicious links may be delivered. Users may inadvertently divulge sensitive information or PII.	Deployment of domain-based authentication techniques. Use of digital signatures over e-mail.
E-mail modified in transit	Leak of sensitive information or PII.	Leak of sensitive information, altered message may contain malicious information.	Use of TLS to encrypt e-mail transfer between servers. Use of end-to-end e-mail encryption.
Disclosure of sensitive information (e.g., PII) via monitoring and capturing of e-mail traffic	Leak of sensitive information or PII.	Leak of sensitive information, altered message may contain malicious information.	Use of TLS to encrypt e-mail transfer between servers. Use of end-to-end e-mail encryption.
Unsolicited Bulk E-mail (UBE) (i.e., spam)	None, unless purported sender is spoofed.	UBE and/or e-mail containing malicious links may be delivered into user inboxes.	Techniques to address UBE.
DoS/DDoS attack against an enterprises' e-mail servers	Inability to send e-mail.	Inability to receive e-mail.	Multiple mail servers, use of cloud-based e-mail providers.

result that the same trust relationships used to certify IP addresses are used to certify servers operating on those addresses.

- **Sender Policy Framework (SPF):** Uses the Domain Name System (DNS) to allow domain owners to create records that associate the domain name with a specific IP address range of authorized message senders. It is a simple matter for receivers to check the SPF TXT record in the DNS to confirm that the purported sender of a message is permitted to use that source address and reject mail that does not come from an authorized IP address.
- **DomainKeys Identified Mail (DKIM):** Enables an MTA to sign selected headers and the body of a message. This validates the source domain of the mail and provides message body integrity.
- **Domain-based Message Authentication, Reporting, and Conformance (DMARC):** Lets senders know the proportionate effectiveness of their SPF and DKIM policies, and signals to receivers what action should be taken in various individual and bulk attack scenarios.



DANE = DNS-based Authentication of Named Entities
 DKIM = DomainKeys Identified Mail
 DMARC = Domain-based Message Authentication, Reporting, and Conformance
 DNSSEC = Domain Name System Security Extensions
 SPF = Sender Policy Framework
 S/MIME = Secure Multi-Purpose Internet Mail Extensions
 TLSA RR = Transport Layer Security Authentication Resource Record

Figure 8.4 The Interrelationship of DNSSEC, SPF, DKIM, DMARC, DANE, and S/MIME for Assuring Message Authenticity and Integrity

Figure 8.4 shows how these components interact to provide message authenticity and integrity. Not shown, for simplicity, is that S/MIME also provides message confidentiality by encrypting messages.

8.4 S/MIME

Secure/Multipurpose Internet Mail Extension (S/MIME) is a security enhancement to the MIME Internet e-mail format standard based on technology from RSA Data Security. S/MIME is a complex capability that is defined in a number of documents. The most important documents relevant to S/MIME include the following:

- **RFC 5750, S/MIME Version 3.2 Certificate Handling:** Specifies conventions for X.509 certificate usage by (S/MIME) v3.2.

- **RFC 5751, S/MIME) Version 3.2 Message Specification:** The principal defining document for S/MIME message creation and processing.
- **RFC 4134, Examples of S/MIME Messages:** Gives examples of message bodies formatted using S/MIME.
- **RFC 2634, Enhanced Security Services for S/MIME:** Describes four optional security service extensions for S/MIME.
- **RFC 5652, Cryptographic Message Syntax (CMS):** Describes the Cryptographic Message Syntax (CMS). This syntax is used to digitally sign, digest, authenticate, or encrypt arbitrary message content.
- **RFC 3370, CMS Algorithms:** Describes the conventions for using several cryptographic algorithms with the CMS.
- **RFC 5752, Multiple Signatures in CMS:** Describes the use of multiple, parallel signatures for a message.
- **RFC 1847, Security Multiparts for MIME—Multipart/Signed and Multipart/Encrypted:** Defines a framework within which security services may be applied to MIME body parts. The use of a digital signature is relevant to S/MIME, as explained subsequently.

Operational Description

S/MIME provides for four message-related services: authentication, confidentiality, compression, and e-mail compatibility (Table 8.4). This subsection provides an overview. We then look in more detail at this capability by examining message formats and message preparation.

AUTHENTICATION Authentication is provided by means of a digital signature, using the general scheme discussed in Chapter 3 and illustrated in Figure 3.15. Most commonly RSA with SHA-256 is used. The sequence is as follows:

1. The sender creates a message.
2. SHA-256 is used to generate a 256-bit message digest of the message.

Table 8.4 Summary of S/MIME Services

Function	Typical Algorithm	Typical Action
Digital signature	RSA/SHA-256	A hash code of a message is created using SHA-256. This message digest is encrypted using SHA-256 with the sender's private key and included with the message.
Message encryption	AES-128 with CBC	A message is encrypted using AES-128 with CBC with a one-time session key generated by the sender. The session key is encrypted using RSA with the recipient's public key and included with the message.
Compression	unspecified	A message may be compressed for storage or transmission.
E-mail compatibility	Radix-64 conversion	To provide transparency for e-mail applications, an encrypted message may be converted to an ASCII string using radix-64 conversion.