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R. Fielding, Ed.
Adobe
M. Nottingham, Ed.
Fastly
J. Reschke, Ed.
greenbytes

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Abstract

The Hypertext Transfer Protocol (HTTP) is a stateless application-level protocol for distributed, collaborative, hypertext information systems. This document specifies the HTTP/1.1 message syntax, message parsing, connection management, and related security concerns.

This document obsoletes portions of RFC 7230.

Editorial Note

This note is to be removed before publishing as an RFC.

Discussion of this draft takes place on the HTTP working group mailing list (ietf-http-wg@w3.org), which is archived at <https://lists.w3.org/Archives/Public/ietf-http-wg/>.

Working Group information can be found at <https://httpwg.org/>; source code and issues list for this draft can be found at <https://github.com/httpwg/http-core>.

The changes in this draft are summarized in Appendix D.10.

Status of This Memo

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1. Introduction

The Hypertext Transfer Protocol (HTTP) is a stateless application-level request/response protocol that uses extensible semantics and self-descriptive messages for flexible interaction with network-based hypertext information systems. HTTP is defined by a series of documents that collectively form the HTTP/1.1 specification:

- "HTTP Semantics" [Semantics]

- "HTTP Caching" [Caching]

- "HTTP/1.1 Messaging" (this document)

This document defines HTTP/1.1 message syntax and framing requirements and their associated connection management. Our goal is to define all of the mechanisms necessary for HTTP/1.1 message handling that are independent of message semantics, thereby defining

the complete set of requirements for message parsers and message-forwarding intermediaries.

This document obsoletes the portions of RFC 7230 related to HTTP/1.1 messaging and connection management, with the changes being summarized in Appendix C.2. The other parts of RFC 7230 are obsoleted by "HTTP Semantics" [Semantics].

1.1. Requirements Notation

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "NOT RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in BCP 14 [RFC2119] [RFC8174] when, and only when, they appear in all capitals, as shown here.

Conformance criteria and considerations regarding error handling are defined in Section 3 of [Semantics].

1.2. Syntax Notation

This specification uses the Augmented Backus-Naur Form (ABNF) notation of [RFC5234], extended with the notation for case-sensitivity in strings defined in [RFC7405].

It also uses a list extension, defined in Section 5.5 of [Semantics], that allows for compact definition of comma-separated lists using a '#' operator (similar to how the '*' operator indicates repetition). Appendix A shows the collected grammar with all list operators expanded to standard ABNF notation.

As a convention, ABNF rule names prefixed with "obs-" denote "obsolete" grammar rules that appear for historical reasons.

The following core rules are included by reference, as defined in [RFC5234], Appendix B.1: ALPHA (letters), CR (carriage return), CRLF (CR LF), CTL (controls), DIGIT (decimal 0-9), DQUOTE (double quote), HEXDIG (hexadecimal 0-9/A-F/a-f), HTAB (horizontal tab), LF (line feed), OCTET (any 8-bit sequence of data), SP (space), and VCHAR (any visible [USASCII] character).

The rules below are defined in [Semantics]:

```
  BWS           = <BWS, see [Semantics], Section 1.2.1>
  OWS           = <OWS, see [Semantics], Section 1.2.1>
  RWS           = <RWS, see [Semantics], Section 1.2.1>
  absolute-URI  = <absolute-URI, see [RFC3986], Section 4.3>
  absolute-path = <absolute-path, see [Semantics], Section 2.4>
  authority     = <authority, see [RFC3986], Section 3.2>
  comment       = <comment, see [Semantics], Section 5.4.1.3>
  field-name    = <field-name, see [Semantics], Section 5.3>
  field-value   = <field-value, see [Semantics], Section 5.4>
  obs-text      = <obs-text, see [Semantics], Section 5.4.1.2>
  port          = <port, see [RFC3986], Section 3.2.3>
  query         = <query, see [RFC3986], Section 3.4>
  quoted-string = <quoted-string, see [Semantics], Section 5.4.1.2>
  token         = <token, see [Semantics], Section 5.4.1.1>
  uri-host      = <host, see [RFC3986], Section 3.2.2>
```

2. Message

2.1. Message Format

An HTTP/1.1 message consists of a start-line followed by a CRLF and a sequence of octets in a format similar to the Internet Message Format [RFC5322]: zero or more header field lines (collectively referred to as the "headers" or the "header section"), an empty line indicating the end of the header section, and an optional message body.

```
  HTTP-message   = start-line CRLF
                   *( field-line CRLF )
                   CRLF
                   [ message-body ]
```

A message can be either a request from client to server or a response from server to client. Syntactically, the two types of message differ only in the start-line, which is either a request-line (for requests) or a status-line (for responses), and in the algorithm for determining the length of the message body (Section 6).

```
  start-line     = request-line / status-line
```

In theory, a client could receive requests and a server could receive responses, distinguishing them by their different start-line formats. In practice, servers are implemented to only expect a request (a response is interpreted as an unknown or invalid request method) and clients are implemented to only expect a response.

Although HTTP makes use of some protocol elements similar to the Multipurpose Internet Mail Extensions (MIME) [RFC2045], see Appendix B for the differences between HTTP and MIME messages.

2.2. Message Parsing

The normal procedure for parsing an HTTP message is to read the start-line into a structure, read each header field line into a hash table by field name until the empty line, and then use the parsed data to determine if a message body is expected. If a message body has been indicated, then it is read as a stream until an amount of octets equal to the message body length is read or the connection is closed.

A recipient MUST parse an HTTP message as a sequence of octets in an encoding that is a superset of US-ASCII [USASCII]. Parsing an HTTP message as a stream of Unicode characters, without regard for the specific encoding, creates security vulnerabilities due to the varying ways that string processing libraries handle invalid multibyte character sequences that contain the octet LF (%x0A). String-based parsers can only be safely used within protocol elements after the element has been extracted from the message, such as within a header field line value after message parsing has delineated the individual field lines.

Although the line terminator for the start-line and header fields is the sequence CRLF, a recipient MAY recognize a single LF as a line terminator and ignore any preceding CR.

A sender MUST NOT generate a bare CR (a CR character not immediately followed by LF) within any protocol elements other than the payload body. A recipient of such a bare CR MUST consider that element to be invalid or replace each bare CR with SP before processing the element or forwarding the message.

Older HTTP/1.0 user agent implementations might send an extra CRLF after a POST request as a workaround for some early server applications that failed to read message body content that was not terminated by a line-ending. An HTTP/1.1 user agent MUST NOT preface or follow a request with an extra CRLF. If terminating the request message body with a line-ending is desired, then the user agent MUST count the terminating CRLF octets as part of the message body length.

In the interest of robustness, a server that is expecting to receive and parse a request-line SHOULD ignore at least one empty line (CRLF) received prior to the request-line.

A sender MUST NOT send whitespace between the start-line and the first header field. A recipient that receives whitespace between the start-line and the first header field MUST either reject the message as invalid or consume each whitespace-preceded line without further processing of it (i.e., ignore the entire line, along with any

subsequent lines preceded by whitespace, until a properly formed header field is received or the header section is terminated).

The presence of such whitespace in a request might be an attempt to trick a server into ignoring that field line or processing the line after it as a new request, either of which might result in a security vulnerability if other implementations within the request chain interpret the same message differently. Likewise, the presence of such whitespace in a response might be ignored by some clients or cause others to cease parsing.

When a server listening only for HTTP request messages, or processing what appears from the start-line to be an HTTP request message, receives a sequence of octets that does not match the HTTP-message grammar aside from the robustness exceptions listed above, the server SHOULD respond with a 400 (Bad Request) response.

2.3. HTTP Version

HTTP uses a "<major>.<minor>" numbering scheme to indicate versions of the protocol. This specification defines version "1.1". Section 4.2 of [Semantics] specifies the semantics of HTTP version numbers.

The version of an HTTP/1.x message is indicated by an HTTP-version field in the start-line. HTTP-version is case-sensitive.

```
HTTP-version  = HTTP-name "/" DIGIT "." DIGIT
HTTP-name     = %s"HTTP"
```

When an HTTP/1.1 message is sent to an HTTP/1.0 recipient [RFC1945] or a recipient whose version is unknown, the HTTP/1.1 message is constructed such that it can be interpreted as a valid HTTP/1.0 message if all of the newer features are ignored. This specification places recipient-version requirements on some new features so that a conformant sender will only use compatible features until it has determined, through configuration or the receipt of a message, that the recipient supports HTTP/1.1.

Intermediaries that process HTTP messages (i.e., all intermediaries other than those acting as tunnels) MUST send their own HTTP-version in forwarded messages. In other words, they are not allowed to blindly forward the start-line without ensuring that the protocol version in that message matches a version to which that intermediary is conformant for both the receiving and sending of messages. Forwarding an HTTP message without rewriting the HTTP-version might result in communication errors when downstream recipients use the

message sender's version to determine what features are safe to use for later communication with that sender.

A server MAY send an HTTP/1.0 response to an HTTP/1.1 request if it is known or suspected that the client incorrectly implements the HTTP specification and is incapable of correctly processing later version responses, such as when a client fails to parse the version number correctly or when an intermediary is known to blindly forward the HTTP-version even when it doesn't conform to the given minor version of the protocol. Such protocol downgrades SHOULD NOT be performed unless triggered by specific client attributes, such as when one or more of the request header fields (e.g., User-Agent) uniquely match the values sent by a client known to be in error.

3. Request Line

A request-line begins with a method token, followed by a single space (SP), the request-target, another single space (SP), and ends with the protocol version.

```
request-line   = method SP request-target SP HTTP-version
```

Although the request-line grammar rule requires that each of the component elements be separated by a single SP octet, recipients MAY instead parse on whitespace-delimited word boundaries and, aside from the CRLF terminator, treat any form of whitespace as the SP separator while ignoring preceding or trailing whitespace; such whitespace includes one or more of the following octets: SP, HTAB, VT (%x0B), FF (%x0C), or bare CR. However, lenient parsing can result in request smuggling security vulnerabilities if there are multiple recipients of the message and each has its own unique interpretation of robustness (see Section 11.2).

HTTP does not place a predefined limit on the length of a request-line, as described in Section 3 of [Semantics]. A server that receives a method longer than any that it implements SHOULD respond with a 501 (Not Implemented) status code. A server that receives a request-target longer than any URI it wishes to parse MUST respond with a 414 (URI Too Long) status code (see Section 10.5.15 of [Semantics]).

Various ad hoc limitations on request-line length are found in practice. It is RECOMMENDED that all HTTP senders and recipients support, at a minimum, request-line lengths of 8000 octets.

3.1. Method

The method token indicates the request method to be performed on the target resource. The request method is case-sensitive.

```
method         = token
```

The request methods defined by this specification can be found in Section 8 of [Semantics], along with information regarding the HTTP method registry and considerations for defining new methods.

3.2. Request Target

The request-target identifies the target resource upon which to apply the request. The client derives a request-target from its desired target URI. There are four distinct formats for the request-target, depending on both the method being requested and whether the request is to a proxy.

```
request-target = origin-form
               / absolute-form
               / authority-form
               / asterisk-form
```

No whitespace is allowed in the request-target. Unfortunately, some user agents fail to properly encode or exclude whitespace found in hypertext references, resulting in those disallowed characters being sent as the request-target in a malformed request-line.

Recipients of an invalid request-line SHOULD respond with either a 400 (Bad Request) error or a 301 (Moved Permanently) redirect with the request-target properly encoded. A recipient SHOULD NOT attempt to autocorrect and then process the request without a redirect, since the invalid request-line might be deliberately crafted to bypass security filters along the request chain.

3.2.1. origin-form

The most common form of request-target is the origin-form.

```
origin-form    = absolute-path [ "?" query ]
```

When making a request directly to an origin server, other than a CONNECT or server-wide OPTIONS request (as detailed below), a client MUST send only the absolute path and query components of the target URI as the request-target. If the target URI's path component is empty, the client MUST send "/" as the path within the origin-form of

request-target. A Host header field is also sent, as defined in Section 6.6 of [Semantics].

For example, a client wishing to retrieve a representation of the resource identified as

```
http://www.example.org/where?q=now
```

directly from the origin server would open (or reuse) a TCP connection to port 80 of the host "www.example.org" and send the lines:

```
GET /where?q=now HTTP/1.1
Host: www.example.org
```

followed by the remainder of the request message.

3.2.2. absolute-form

When making a request to a proxy, other than a CONNECT or server-wide OPTIONS request (as detailed below), a client MUST send the target URI in absolute-form as the request-target.

```
absolute-form  = absolute-URI
```

The proxy is requested to either service that request from a valid cache, if possible, or make the same request on the client's behalf to either the next inbound proxy server or directly to the origin server indicated by the request-target. Requirements on such "forwarding" of messages are defined in Section 6.7 of [Semantics].

An example absolute-form of request-line would be:

```
GET http://www.example.org/pub/WWW/TheProject.html HTTP/1.1
```

A client MUST send a Host header field in an HTTP/1.1 request even if the request-target is in the absolute-form, since this allows the Host information to be forwarded through ancient HTTP/1.0 proxies that might not have implemented Host.

When a proxy receives a request with an absolute-form of request-target, the proxy MUST ignore the received Host header field (if any) and instead replace it with the host information of the request-target. A proxy that forwards such a request MUST generate a new Host field value based on the received request-target rather than forward the received Host field value.

When an origin server receives a request with an absolute-form of request-target, the origin server MUST ignore the received Host header field (if any) and instead use the host information of the request-target. Note that if the request-target does not have an authority component, an empty Host header field will be sent in this case.

To allow for transition to the absolute-form for all requests in some future version of HTTP, a server MUST accept the absolute-form in requests, even though HTTP/1.1 clients will only send them in requests to proxies.

3.2.3. authority-form

The authority-form of request-target is only used for CONNECT requests (Section 8.3.6 of [Semantics]).

```
authority-form = authority
```

When making a CONNECT request to establish a tunnel through one or more proxies, a client MUST send only the target URI's authority component (excluding any userinfo and its "@" delimiter) as the request-target. For example,

```
CONNECT www.example.com:80 HTTP/1.1
```

3.2.4. asterisk-form

The asterisk-form of request-target is only used for a server-wide OPTIONS request (Section 8.3.7 of [Semantics]).

```
asterisk-form  = "*"
```

When a client wishes to request OPTIONS for the server as a whole, as opposed to a specific named resource of that server, the client MUST send only "*" (%x2A) as the request-target. For example,

```
OPTIONS * HTTP/1.1
```

If a proxy receives an OPTIONS request with an absolute-form of request-target in which the URI has an empty path and no query component, then the last proxy on the request chain MUST send a request-target of "*" when it forwards the request to the indicated origin server.

For example, the request

```
OPTIONS http://www.example.org:8001 HTTP/1.1
```

would be forwarded by the final proxy as

```
OPTIONS * HTTP/1.1
Host: www.example.org:8001
```

after connecting to port 8001 of host "www.example.org".

3.3. Reconstructing the Target URI

Since the request-target often contains only part of the user agent's target URI, a server constructs its value to properly service the request (Section 6.1 of [Semantics]).

If the request-target is in absolute-form, the target URI is the same as the request-target. Otherwise, the target URI is constructed as follows:

> If the server's configuration (or outbound gateway) provides a fixed URI scheme, that scheme is used for the target URI. Otherwise, if the request is received over a TLS-secured TCP connection, the target URI's scheme is "https"; if not, the scheme is "http".
>
> If the server's configuration (or outbound gateway) provides a fixed URI authority component, that authority is used for the target URI. If not, then if the request-target is in authority-form, the target URI's authority component is the same as the request-target. If not, then if a Host header field is supplied with a non-empty field-value, the authority component is the same as the Host field-value. Otherwise, the authority component is assigned the default name configured for the server and, if the connection's incoming TCP port number differs from the default port for the target URI's scheme, then a colon (":") and the incoming port number (in decimal form) are appended to the authority component.
>
> If the request-target is in authority-form or asterisk-form, the target URI's combined path and query component is empty. Otherwise, the combined path and query component is the same as the request-target.
>
> The components of the target URI, once determined as above, can be combined into absolute-URI form by concatenating the scheme, "://", authority, and combined path and query component.

Example 1: the following message received over an insecure TCP connection

```
GET /pub/WWW/TheProject.html HTTP/1.1
Host: www.example.org:8080
```

has a target URI of

http://www.example.org:8080/pub/WWW/TheProject.html

Example 2: the following message received over a TLS-secured TCP connection

```
OPTIONS * HTTP/1.1
Host: www.example.org
```

has a target URI of

https://www.example.org

Recipients of an HTTP/1.0 request that lacks a Host header field might need to use heuristics (e.g., examination of the URI path for something unique to a particular host) in order to guess the target URI's authority component.

4. Status Line

The first line of a response message is the status-line, consisting of the protocol version, a space (SP), the status code, another space, and ending with an OPTIONAL textual phrase describing the status code.

```
status-line = HTTP-version SP status-code SP [reason-phrase]
```

Although the status-line grammar rule requires that each of the component elements be separated by a single SP octet, recipients MAY instead parse on whitespace-delimited word boundaries and, aside from the line terminator, treat any form of whitespace as the SP separator while ignoring preceding or trailing whitespace; such whitespace includes one or more of the following octets: SP, HTAB, VT (%x0B), FF (%x0C), or bare CR. However, lenient parsing can result in response splitting security vulnerabilities if there are multiple recipients of the message and each has its own unique interpretation of robustness (see Section 11.1).

The status-code element is a 3-digit integer code describing the result of the server's attempt to understand and satisfy the client's corresponding request. The rest of the response message is to be interpreted in light of the semantics defined for that status code. See Section 10 of [Semantics] for information about the semantics of status codes, including the classes of status code (indicated by the

first digit), the status codes defined by this specification, considerations for the definition of new status codes, and the IANA registry.

```
  status-code    = 3DIGIT
```

The reason-phrase element exists for the sole purpose of providing a textual description associated with the numeric status code, mostly out of deference to earlier Internet application protocols that were more frequently used with interactive text clients.

```
  reason-phrase  = 1*( HTAB / SP / VCHAR / obs-text )
```

A client SHOULD ignore the reason-phrase content because it is not a reliable channel for information (it might be translated for a given locale, overwritten by intermediaries, or discarded when the message is forwarded via other versions of HTTP). A server MUST send the space that separates status-code from the reason-phrase even when the reason-phrase is absent (i.e., the status-line would end with the three octets SP CR LF).

5. Field Syntax

Each field line consists of a case-insensitive field name followed by a colon (":"), optional leading whitespace, the field line value, and optional trailing whitespace.

```
  field-line   = field-name ":" OWS field-value OWS
```

Most HTTP field names and the rules for parsing within field values are defined in Section 5 of [Semantics]. This section covers the generic syntax for header field inclusion within, and extraction from, HTTP/1.1 messages. In addition, the following header fields are defined by this document because they are specific to HTTP/1.1 message processing:

Field Name	Status	Reference
Connection	standard	Section 9.1
MIME-Version	standard	Appendix B.1
TE	standard	Section 7.4
Transfer-Encoding	standard	Section 6.1
Upgrade	standard	Section 9.9

Table 1

Furthermore, the field name "Close" is reserved, since using that name as an HTTP header field might conflict with the "close" connection option of the Connection header field (Section 9.1).

Field Name	Status	Reference	Comments
Close	standard	Section 5	(reserved)

5.1. Field Line Parsing

Messages are parsed using a generic algorithm, independent of the individual field names. The contents within a given field line value are not parsed until a later stage of message interpretation (usually after the message's entire header section has been processed).

No whitespace is allowed between the field name and colon. In the past, differences in the handling of such whitespace have led to security vulnerabilities in request routing and response handling. A server MUST reject any received request message that contains whitespace between a header field name and colon with a response status code of 400 (Bad Request). A proxy MUST remove any such whitespace from a response message before forwarding the message downstream.

A field line value might be preceded and/or followed by optional whitespace (OWS); a single SP preceding the field line value is preferred for consistent readability by humans. The field line value does not include any leading or trailing whitespace: OWS occurring before the first non-whitespace octet of the field line value or after the last non-whitespace octet of the field line value ought to be excluded by parsers when extracting the field line value from a header field line.

5.2. Obsolete Line Folding

Historically, HTTP header field line values could be extended over multiple lines by preceding each extra line with at least one space or horizontal tab (obs-fold). This specification deprecates such line folding except within the message/http media type (Section 10.1).

```
  obs-fold     = OWS CRLF RWS
                 ; obsolete line folding
```

A sender MUST NOT generate a message that includes line folding (i.e., that has any field line value that contains a match to the

obs-fold rule) unless the message is intended for packaging within the message/http media type.

A server that receives an obs-fold in a request message that is not within a message/http container MUST either reject the message by sending a 400 (Bad Request), preferably with a representation explaining that obsolete line folding is unacceptable, or replace each received obs-fold with one or more SP octets prior to interpreting the field value or forwarding the message downstream.

A proxy or gateway that receives an obs-fold in a response message that is not within a message/http container MUST either discard the message and replace it with a 502 (Bad Gateway) response, preferably with a representation explaining that unacceptable line folding was received, or replace each received obs-fold with one or more SP octets prior to interpreting the field value or forwarding the message downstream.

A user agent that receives an obs-fold in a response message that is not within a message/http container MUST replace each received obs-fold with one or more SP octets prior to interpreting the field value.

6. Message Body

The message body (if any) of an HTTP message is used to carry the payload body (Section 7.3.3 of [Semantics]) of that request or response. The message body is identical to the payload body unless a transfer coding has been applied, as described in Section 6.1.

```
message-body = *OCTET
```

The rules for determining when a message body is present in an HTTP/1.1 message differ for requests and responses.

The presence of a message body in a request is signaled by a Content-Length or Transfer-Encoding header field. Request message framing is independent of method semantics, even if the method does not define any use for a message body.

The presence of a message body in a response depends on both the request method to which it is responding and the response status code (Section 4), and corresponds to when a payload body is allowed; see Section 7.3.3 of [Semantics].

6.1. Transfer-Encoding

The Transfer-Encoding header field lists the transfer coding names corresponding to the sequence of transfer codings that have been (or will be) applied to the payload body in order to form the message body. Transfer codings are defined in Section 7.

```
Transfer-Encoding = 1#transfer-coding
```

Transfer-Encoding is analogous to the Content-Transfer-Encoding field of MIME, which was designed to enable safe transport of binary data over a 7-bit transport service ([RFC2045], Section 6). However, safe transport has a different focus for an 8bit-clean transfer protocol. In HTTP's case, Transfer-Encoding is primarily intended to accurately delimit a dynamically generated payload and to distinguish payload encodings that are only applied for transport efficiency or security from those that are characteristics of the selected resource.

A recipient MUST be able to parse the chunked transfer coding (Section 7.1) because it plays a crucial role in framing messages when the payload body size is not known in advance. A sender MUST NOT apply chunked more than once to a message body (i.e., chunking an already chunked message is not allowed). If any transfer coding other than chunked is applied to a request payload body, the sender MUST apply chunked as the final transfer coding to ensure that the message is properly framed. If any transfer coding other than chunked is applied to a response payload body, the sender MUST either apply chunked as the final transfer coding or terminate the message by closing the connection.

For example,

```
Transfer-Encoding: gzip, chunked
```

indicates that the payload body has been compressed using the gzip coding and then chunked using the chunked coding while forming the message body.

Unlike Content-Encoding (Section 7.1.2 of [Semantics]), Transfer-Encoding is a property of the message, not of the representation, and any recipient along the request/response chain MAY decode the received transfer coding(s) or apply additional transfer coding(s) to the message body, assuming that corresponding changes are made to the Transfer-Encoding field value. Additional information about the encoding parameters can be provided by other header fields not defined by this specification.

Transfer-Encoding MAY be sent in a response to a HEAD request or in a 304 (Not Modified) response (Section 10.4.5 of [Semantics]) to a GET request, neither of which includes a message body, to indicate that the origin server would have applied a transfer coding to the message body if the request had been an unconditional GET. This indication is not required, however, because any recipient on the response chain (including the origin server) can remove transfer codings when they are not needed.

A server MUST NOT send a Transfer-Encoding header field in any response with a status code of 1xx (Informational) or 204 (No Content). A server MUST NOT send a Transfer-Encoding header field in any 2xx (Successful) response to a CONNECT request (Section 8.3.6 of [Semantics]).

Transfer-Encoding was added in HTTP/1.1. It is generally assumed that implementations advertising only HTTP/1.0 support will not understand how to process a transfer-encoded payload. A client MUST NOT send a request containing Transfer-Encoding unless it knows the server will handle HTTP/1.1 requests (or later minor revisions); such knowledge might be in the form of specific user configuration or by remembering the version of a prior received response. A server MUST NOT send a response containing Transfer-Encoding unless the corresponding request indicates HTTP/1.1 (or later minor revisions).

A server that receives a request message with a transfer coding it does not understand SHOULD respond with 501 (Not Implemented).

6.2. Content-Length

When a message does not have a Transfer-Encoding header field, a Content-Length header field can provide the anticipated size, as a decimal number of octets, for a potential payload body. For messages that do include a payload body, the Content-Length field value provides the framing information necessary for determining where the body (and message) ends. For messages that do not include a payload body, the Content-Length indicates the size of the selected representation (Section 7.2.4 of [Semantics]).

> Note: HTTP's use of Content-Length for message framing differs significantly from the same field's use in MIME, where it is an optional field used only within the "message/external-body" media-type.

6.3. Message Body Length

The length of a message body is determined by one of the following (in order of precedence):

1. Any response to a HEAD request and any response with a 1xx (Informational), 204 (No Content), or 304 (Not Modified) status code is always terminated by the first empty line after the header fields, regardless of the header fields present in the message, and thus cannot contain a message body.

2. Any 2xx (Successful) response to a CONNECT request implies that the connection will become a tunnel immediately after the empty line that concludes the header fields. A client MUST ignore any Content-Length or Transfer-Encoding header fields received in such a message.

3. If a Transfer-Encoding header field is present and the chunked transfer coding (Section 7.1) is the final encoding, the message body length is determined by reading and decoding the chunked data until the transfer coding indicates the data is complete.

   If a Transfer-Encoding header field is present in a response and the chunked transfer coding is not the final encoding, the message body length is determined by reading the connection until it is closed by the server. If a Transfer-Encoding header field is present in a request and the chunked transfer coding is not the final encoding, the message body length cannot be determined reliably; the server MUST respond with the 400 (Bad Request) status code and then close the connection.

   If a message is received with both a Transfer-Encoding and a Content-Length header field, the Transfer-Encoding overrides the Content-Length. Such a message might indicate an attempt to perform request smuggling (Section 11.2) or response splitting (Section 11.1) and ought to be handled as an error. A sender MUST remove the received Content-Length field prior to forwarding such a message downstream.

4. If a message is received without Transfer-Encoding and with an invalid Content-Length header field, then the message framing is invalid and the recipient MUST treat it as an unrecoverable error, unless the field value can be successfully parsed as a comma-separated list (Section 5.5 of [Semantics]), all values in the list are valid, and all values in the list are the same. If this is a request message, the server MUST respond with a 400 (Bad Request) status code and then close the connection. If this is a response message received by a proxy, the proxy MUST close

the connection to the server, discard the received response, and send a 502 (Bad Gateway) response to the client. If this is a response message received by a user agent, the user agent MUST close the connection to the server and discard the received response.

5. If a valid Content-Length header field is present without Transfer-Encoding, its decimal value defines the expected message body length in octets. If the sender closes the connection or the recipient times out before the indicated number of octets are received, the recipient MUST consider the message to be incomplete and close the connection.

6. If this is a request message and none of the above are true, then the message body length is zero (no message body is present).

7. Otherwise, this is a response message without a declared message body length, so the message body length is determined by the number of octets received prior to the server closing the connection.

Since there is no way to distinguish a successfully completed, close-delimited message from a partially received message interrupted by network failure, a server SHOULD generate encoding or length-delimited messages whenever possible. The close-delimiting feature exists primarily for backwards compatibility with HTTP/1.0.

A server MAY reject a request that contains a message body but not a Content-Length by responding with 411 (Length Required).

Unless a transfer coding other than chunked has been applied, a client that sends a request containing a message body SHOULD use a valid Content-Length header field if the message body length is known in advance, rather than the chunked transfer coding, since some existing services respond to chunked with a 411 (Length Required) status code even though they understand the chunked transfer coding. This is typically because such services are implemented via a gateway that requires a content-length in advance of being called and the server is unable or unwilling to buffer the entire request before processing.

A user agent that sends a request containing a message body MUST send a valid Content-Length header field if it does not know the server will handle HTTP/1.1 (or later) requests; such knowledge can be in the form of specific user configuration or by remembering the version of a prior received response.

If the final response to the last request on a connection has been completely received and there remains additional data to read, a user agent MAY discard the remaining data or attempt to determine if that data belongs as part of the prior response body, which might be the case if the prior message's Content-Length value is incorrect. A client MUST NOT process, cache, or forward such extra data as a separate response, since such behavior would be vulnerable to cache poisoning.

7. Transfer Codings

Transfer coding names are used to indicate an encoding transformation that has been, can be, or might need to be applied to a payload body in order to ensure "safe transport" through the network. This differs from a content coding in that the transfer coding is a property of the message rather than a property of the representation that is being transferred.

```
transfer-coding = token *( OWS ";" OWS transfer-parameter )
```

Parameters are in the form of a name=value pair.

```
transfer-parameter = token BWS "=" BWS ( token / quoted-string )
```

All transfer-coding names are case-insensitive and ought to be registered within the HTTP Transfer Coding registry, as defined in Section 7.3. They are used in the TE (Section 7.4) and Transfer-Encoding (Section 6.1) header fields.

Name	Description	Reference
chunked	Transfer in a series of chunks	Section 7.1
compress	UNIX "compress" data format [Welch]	Section 7.2
deflate	"deflate" compressed data ([RFC1951]) inside the "zlib" data format ([RFC1950])	Section 7.2
gzip	GZIP file format [RFC1952]	Section 7.2
trailers	(reserved)	Section 7.2
x-compress	Deprecated (alias for compress)	Section 7.2
x-gzip	Deprecated (alias for gzip)	Section 7.2

Table 2

Note: the coding name "trailers" is reserved because its use would conflict with the keyword "trailers" in the TE header field (Section 7.4).

7.1. Chunked Transfer Coding

The chunked transfer coding wraps the payload body in order to transfer it as a series of chunks, each with its own size indicator, followed by an OPTIONAL trailer section containing trailer fields. Chunked enables content streams of unknown size to be transferred as a sequence of length-delimited buffers, which enables the sender to retain connection persistence and the recipient to know when it has received the entire message.

```
  chunked-body   = *chunk
                   last-chunk
                   trailer-section
                   CRLF

  chunk          = chunk-size [ chunk-ext ] CRLF
                   chunk-data CRLF
  chunk-size     = 1*HEXDIG
  last-chunk     = 1*("0") [ chunk-ext ] CRLF

  chunk-data     = 1*OCTET ; a sequence of chunk-size octets
```

The chunk-size field is a string of hex digits indicating the size of the chunk-data in octets. The chunked transfer coding is complete when a chunk with a chunk-size of zero is received, possibly followed by a trailer section, and finally terminated by an empty line.

A recipient MUST be able to parse and decode the chunked transfer coding.

Note that HTTP/1.1 does not define any means to limit the size of a chunked response such that an intermediary can be assured of buffering the entire response.

The chunked encoding does not define any parameters. Their presence SHOULD be treated as an error.

7.1.1. Chunk Extensions

The chunked encoding allows each chunk to include zero or more chunk extensions, immediately following the chunk-size, for the sake of supplying per-chunk metadata (such as a signature or hash), mid-message control information, or randomization of message body size.

```
chunk-ext      = *( BWS ";" BWS chunk-ext-name
                    [ BWS "=" BWS chunk-ext-val ] )

chunk-ext-name = token
chunk-ext-val  = token / quoted-string
```

The chunked encoding is specific to each connection and is likely to be removed or recoded by each recipient (including intermediaries) before any higher-level application would have a chance to inspect the extensions. Hence, use of chunk extensions is generally limited to specialized HTTP services such as "long polling" (where client and server can have shared expectations regarding the use of chunk extensions) or for padding within an end-to-end secured connection.

A recipient MUST ignore unrecognized chunk extensions. A server ought to limit the total length of chunk extensions received in a request to an amount reasonable for the services provided, in the same way that it applies length limitations and timeouts for other parts of a message, and generate an appropriate 4xx (Client Error) response if that amount is exceeded.

7.1.2. Chunked Trailer Section

A trailer section allows the sender to include additional fields at the end of a chunked message in order to supply metadata that might be dynamically generated while the message body is sent, such as a

message integrity check, digital signature, or post-processing status. The proper use and limitations of trailer fields are defined in Section 5.6 of [Semantics].

```
trailer-section   = *( field-line CRLF )
```

A recipient that decodes and removes the chunked encoding from a message (e.g., for storage or forwarding to a non-HTTP/1.1 peer) MUST discard any received trailer fields, store/forward them separately from the header fields, or selectively merge into the header section only those trailer fields corresponding to header field definitions that are understood by the recipient to explicitly permit and define how their corresponding trailer field value can be safely merged.

7.1.3. Decoding Chunked

A process for decoding the chunked transfer coding can be represented in pseudo-code as:

```
length := 0
read chunk-size, chunk-ext (if any), and CRLF
while (chunk-size > 0) {
   read chunk-data and CRLF
   append chunk-data to decoded-body
   length := length + chunk-size
   read chunk-size, chunk-ext (if any), and CRLF
}
read trailer field
while (trailer field is not empty) {
   if (trailer fields are stored/forwarded separately) {
       append trailer field to existing trailer fields
   }
   else if (trailer field is understood and defined as mergeable) {
       merge trailer field with existing header fields
   }
   else {
       discard trailer field
   }
   read trailer field
}
Content-Length := length
Remove "chunked" from Transfer-Encoding
Remove Trailer from existing header fields
```

7.2. Transfer Codings for Compression

The following transfer coding names for compression are defined by the same algorithm as their corresponding content coding:

compress (and x-compress)
See Section 7.1.2.1 of [Semantics].

deflate
See Section 7.1.2.2 of [Semantics].

gzip (and x-gzip)
See Section 7.1.2.3 of [Semantics].

The compression codings do not define any parameters. Their presence SHOULD be treated as an error.

7.3. Transfer Coding Registry

The "HTTP Transfer Coding Registry" defines the namespace for transfer coding names. It is maintained at <https://www.iana.org/assignments/http-parameters>.

Registrations MUST include the following fields:

- Name
- Description
- Pointer to specification text

Names of transfer codings MUST NOT overlap with names of content codings (Section 7.1.2 of [Semantics]) unless the encoding transformation is identical, as is the case for the compression codings defined in Section 7.2.

The TE header field (Section 7.4) uses a pseudo parameter named "q" as rank value when multiple transfer codings are acceptable. Future registrations of transfer codings SHOULD NOT define parameters called "q" (case-insensitively) in order to avoid ambiguities.

Values to be added to this namespace require IETF Review (see Section 4.8 of [RFC8126]), and MUST conform to the purpose of transfer coding defined in this specification.

Use of program names for the identification of encoding formats is not desirable and is discouraged for future encodings.

7.4. TE

The "TE" header field in a request indicates what transfer codings, besides chunked, the client is willing to accept in response, and whether or not the client is willing to accept trailer fields in a chunked transfer coding.

The TE field-value consists of a list of transfer coding names, each allowing for optional parameters (as described in Section 7), and/or the keyword "trailers". A client MUST NOT send the chunked transfer coding name in TE; chunked is always acceptable for HTTP/1.1 recipients.

```
TE        = #t-codings
t-codings = "trailers" / ( transfer-coding [ t-ranking ] )
t-ranking = OWS ";" OWS "q=" rank
rank      = ( "0" [ "." 0*3DIGIT ] )
          / ( "1" [ "." 0*3("0") ] )
```

Three examples of TE use are below.

```
TE: deflate
TE:
TE: trailers, deflate;q=0.5
```

When multiple transfer codings are acceptable, the client MAY rank the codings by preference using a case-insensitive "q" parameter (similar to the qvalues used in content negotiation fields, Section 7.4.4 of [Semantics]). The rank value is a real number in the range 0 through 1, where 0.001 is the least preferred and 1 is the most preferred; a value of 0 means "not acceptable".

If the TE field value is empty or if no TE field is present, the only acceptable transfer coding is chunked. A message with no transfer coding is always acceptable.

The keyword "trailers" indicates that the sender will not discard trailer fields, as described in Section 5.6 of [Semantics].

Since the TE header field only applies to the immediate connection, a sender of TE MUST also send a "TE" connection option within the Connection header field (Section 9.1) in order to prevent the TE field from being forwarded by intermediaries that do not support its semantics.

8. Handling Incomplete Messages

A server that receives an incomplete request message, usually due to a canceled request or a triggered timeout exception, MAY send an error response prior to closing the connection.

A client that receives an incomplete response message, which can occur when a connection is closed prematurely or when decoding a supposedly chunked transfer coding fails, MUST record the message as incomplete. Cache requirements for incomplete responses are defined in Section 3 of [Caching].

If a response terminates in the middle of the header section (before the empty line is received) and the status code might rely on header fields to convey the full meaning of the response, then the client cannot assume that meaning has been conveyed; the client might need to repeat the request in order to determine what action to take next.

A message body that uses the chunked transfer coding is incomplete if the zero-sized chunk that terminates the encoding has not been received. A message that uses a valid Content-Length is incomplete if the size of the message body received (in octets) is less than the value given by Content-Length. A response that has neither chunked transfer coding nor Content-Length is terminated by closure of the connection and, thus, is considered complete regardless of the number of message body octets received, provided that the header section was received intact.

9. Connection Management

HTTP messaging is independent of the underlying transport- or session-layer connection protocol(s). HTTP only presumes a reliable transport with in-order delivery of requests and the corresponding in-order delivery of responses. The mapping of HTTP request and response structures onto the data units of an underlying transport protocol is outside the scope of this specification.

As described in Section 6.3 of [Semantics], the specific connection protocols to be used for an HTTP interaction are determined by client configuration and the target URI. For example, the "http" URI scheme (Section 2.5.1 of [Semantics]) indicates a default connection of TCP over IP, with a default TCP port of 80, but the client might be configured to use a proxy via some other connection, port, or protocol.

HTTP implementations are expected to engage in connection management, which includes maintaining the state of current connections, establishing a new connection or reusing an existing connection,

processing messages received on a connection, detecting connection failures, and closing each connection. Most clients maintain multiple connections in parallel, including more than one connection per server endpoint. Most servers are designed to maintain thousands of concurrent connections, while controlling request queues to enable fair use and detect denial-of-service attacks.

9.1. Connection

The "Connection" header field allows the sender to list desired control options for the current connection.

When a field aside from Connection is used to supply control information for or about the current connection, the sender MUST list the corresponding field name within the Connection header field.

Intermediaries MUST parse a received Connection header field before a message is forwarded and, for each connection-option in this field, remove any header or trailer field(s) from the message with the same name as the connection-option, and then remove the Connection header field itself (or replace it with the intermediary's own connection options for the forwarded message).

Hence, the Connection header field provides a declarative way of distinguishing fields that are only intended for the immediate recipient ("hop-by-hop") from those fields that are intended for all recipients on the chain ("end-to-end"), enabling the message to be self-descriptive and allowing future connection-specific extensions to be deployed without fear that they will be blindly forwarded by older intermediaries.

Furthermore, intermediaries SHOULD remove or replace field(s) whose semantics are known to require removal before forwarding, whether or not they appear as a Connection option, after applying those fields' semantics. This includes but is not limited to:

- Proxy-Connection (Appendix C.1.2)
- Keep-Alive (Section 19.7.1 of [RFC2068])
- TE (Section 7.4)
- Trailer (Section 5.6.3 of [Semantics])
- Transfer-Encoding (Section 6.1)
- Upgrade (Section 9.9)

The Connection header field's value has the following grammar:

```
Connection        = 1#connection-option
connection-option = token
```

Connection options are case-insensitive.

A sender MUST NOT send a connection option corresponding to a field that is intended for all recipients of the payload. For example, Cache-Control is never appropriate as a connection option (Section 5.2 of [Caching]).

The connection options do not always correspond to a field present in the message, since a connection-specific field might not be needed if there are no parameters associated with a connection option. In contrast, a connection-specific field that is received without a corresponding connection option usually indicates that the field has been improperly forwarded by an intermediary and ought to be ignored by the recipient.

When defining new connection options, specification authors ought to document it as reserved field name and register that definition in the Hypertext Transfer Protocol (HTTP) Field Name Registry (Section 5.3.2 of [Semantics]), to avoid collisions.

The "close" connection option is defined for a sender to signal that this connection will be closed after completion of the response. For example,

```
Connection: close
```

in either the request or the response header fields indicates that the sender is going to close the connection after the current request/response is complete (Section 9.7).

A client that does not support persistent connections MUST send the "close" connection option in every request message.

A server that does not support persistent connections MUST send the "close" connection option in every response message that does not have a 1xx (Informational) status code.

9.2. Establishment

It is beyond the scope of this specification to describe how connections are established via various transport- or session-layer protocols. Each connection applies to only one transport link.

9.3. Associating a Response to a Request

HTTP/1.1 does not include a request identifier for associating a given request message with its corresponding one or more response messages. Hence, it relies on the order of response arrival to correspond exactly to the order in which requests are made on the same connection. More than one response message per request only occurs when one or more informational responses (1xx, see Section 10.2 of [Semantics]) precede a final response to the same request.

A client that has more than one outstanding request on a connection MUST maintain a list of outstanding requests in the order sent and MUST associate each received response message on that connection to the highest ordered request that has not yet received a final (non-1xx) response.

If an HTTP/1.1 client receives data on a connection that doesn't have any outstanding requests, it MUST NOT consider them to be a response to a not-yet-issued request; it SHOULD close the connection, since message delimitation is now ambiguous, unless the data consists only of one or more CRLF (which can be discarded, as per Section 2.2).

9.4. Persistence

HTTP/1.1 defaults to the use of "persistent connections", allowing multiple requests and responses to be carried over a single connection. The "close" connection option is used to signal that a connection will not persist after the current request/response. HTTP implementations SHOULD support persistent connections.

A recipient determines whether a connection is persistent or not based on the most recently received message's protocol version and Connection header field (if any):

- If the "close" connection option is present, the connection will not persist after the current response; else,
- If the received protocol is HTTP/1.1 (or later), the connection will persist after the current response; else,
- If the received protocol is HTTP/1.0, the "keep-alive" connection option is present, either the recipient is not a proxy or the message is a response, and the recipient wishes to honor the HTTP/1.0 "keep-alive" mechanism, the connection will persist after the current response; otherwise,
- The connection will close after the current response.

A client MAY send additional requests on a persistent connection until it sends or receives a "close" connection option or receives an HTTP/1.0 response without a "keep-alive" connection option.

In order to remain persistent, all messages on a connection need to have a self-defined message length (i.e., one not defined by closure of the connection), as described in Section 6. A server MUST read the entire request message body or close the connection after sending its response, since otherwise the remaining data on a persistent connection would be misinterpreted as the next request. Likewise, a client MUST read the entire response message body if it intends to reuse the same connection for a subsequent request.

A proxy server MUST NOT maintain a persistent connection with an HTTP/1.0 client (see Section 19.7.1 of [RFC2068] for information and discussion of the problems with the Keep-Alive header field implemented by many HTTP/1.0 clients).

See Appendix C.1.2 for more information on backwards compatibility with HTTP/1.0 clients.

9.4.1. Retrying Requests

Connections can be closed at any time, with or without intention. Implementations ought to anticipate the need to recover from asynchronous close events. The conditions under which a client can automatically retry a sequence of outstanding requests are defined in Section 8.2.2 of [Semantics].

9.4.2. Pipelining

A client that supports persistent connections MAY "pipeline" its requests (i.e., send multiple requests without waiting for each response). A server MAY process a sequence of pipelined requests in parallel if they all have safe methods (Section 8.2.1 of [Semantics]), but it MUST send the corresponding responses in the same order that the requests were received.

A client that pipelines requests SHOULD retry unanswered requests if the connection closes before it receives all of the corresponding responses. When retrying pipelined requests after a failed connection (a connection not explicitly closed by the server in its last complete response), a client MUST NOT pipeline immediately after connection establishment, since the first remaining request in the prior pipeline might have caused an error response that can be lost again if multiple requests are sent on a prematurely closed connection (see the TCP reset problem described in Section 9.7).

Idempotent methods (Section 8.2.2 of [Semantics]) are significant to pipelining because they can be automatically retried after a connection failure. A user agent SHOULD NOT pipeline requests after a non-idempotent method, until the final response status code for that method has been received, unless the user agent has a means to detect and recover from partial failure conditions involving the pipelined sequence.

An intermediary that receives pipelined requests MAY pipeline those requests when forwarding them inbound, since it can rely on the outbound user agent(s) to determine what requests can be safely pipelined. If the inbound connection fails before receiving a response, the pipelining intermediary MAY attempt to retry a sequence of requests that have yet to receive a response if the requests all have idempotent methods; otherwise, the pipelining intermediary SHOULD forward any received responses and then close the corresponding outbound connection(s) so that the outbound user agent(s) can recover accordingly.

9.5. Concurrency

A client ought to limit the number of simultaneous open connections that it maintains to a given server.

Previous revisions of HTTP gave a specific number of connections as a ceiling, but this was found to be impractical for many applications. As a result, this specification does not mandate a particular maximum number of connections but, instead, encourages clients to be conservative when opening multiple connections.

Multiple connections are typically used to avoid the "head-of-line blocking" problem, wherein a request that takes significant server-side processing and/or has a large payload blocks subsequent requests on the same connection. However, each connection consumes server resources. Furthermore, using multiple connections can cause undesirable side effects in congested networks.

Note that a server might reject traffic that it deems abusive or characteristic of a denial-of-service attack, such as an excessive number of open connections from a single client.

9.6. Failures and Timeouts

Servers will usually have some timeout value beyond which they will no longer maintain an inactive connection. Proxy servers might make this a higher value since it is likely that the client will be making more connections through the same proxy server. The use of

persistent connections places no requirements on the length (or existence) of this timeout for either the client or the server.

A client or server that wishes to time out SHOULD issue a graceful close on the connection. Implementations SHOULD constantly monitor open connections for a received closure signal and respond to it as appropriate, since prompt closure of both sides of a connection enables allocated system resources to be reclaimed.

A client, server, or proxy MAY close the transport connection at any time. For example, a client might have started to send a new request at the same time that the server has decided to close the "idle" connection. From the server's point of view, the connection is being closed while it was idle, but from the client's point of view, a request is in progress.

A server SHOULD sustain persistent connections, when possible, and allow the underlying transport's flow-control mechanisms to resolve temporary overloads, rather than terminate connections with the expectation that clients will retry. The latter technique can exacerbate network congestion.

A client sending a message body SHOULD monitor the network connection for an error response while it is transmitting the request. If the client sees a response that indicates the server does not wish to receive the message body and is closing the connection, the client SHOULD immediately cease transmitting the body and close its side of the connection.

9.7. Tear-down

The Connection header field (Section 9.1) provides a "close" connection option that a sender SHOULD send when it wishes to close the connection after the current request/response pair.

A client that sends a "close" connection option MUST NOT send further requests on that connection (after the one containing "close") and MUST close the connection after reading the final response message corresponding to this request.

A server that receives a "close" connection option MUST initiate a close of the connection (see below) after it sends the final response to the request that contained "close". The server SHOULD send a "close" connection option in its final response on that connection. The server MUST NOT process any further requests received on that connection.

A server that sends a "close" connection option MUST initiate a close of the connection (see below) after it sends the response containing "close". The server MUST NOT process any further requests received on that connection.

A client that receives a "close" connection option MUST cease sending requests on that connection and close the connection after reading the response message containing the "close"; if additional pipelined requests had been sent on the connection, the client SHOULD NOT assume that they will be processed by the server.

If a server performs an immediate close of a TCP connection, there is a significant risk that the client will not be able to read the last HTTP response. If the server receives additional data from the client on a fully closed connection, such as another request that was sent by the client before receiving the server's response, the server's TCP stack will send a reset packet to the client; unfortunately, the reset packet might erase the client's unacknowledged input buffers before they can be read and interpreted by the client's HTTP parser.

To avoid the TCP reset problem, servers typically close a connection in stages. First, the server performs a half-close by closing only the write side of the read/write connection. The server then continues to read from the connection until it receives a corresponding close by the client, or until the server is reasonably certain that its own TCP stack has received the client's acknowledgement of the packet(s) containing the server's last response. Finally, the server fully closes the connection.

It is unknown whether the reset problem is exclusive to TCP or might also be found in other transport connection protocols.

9.8. TLS Connection Closure

TLS provides a facility for secure connection closure. When a valid closure alert is received, an implementation can be assured that no further data will be received on that connection. TLS implementations MUST initiate an exchange of closure alerts before closing a connection. A TLS implementation MAY, after sending a closure alert, close the connection without waiting for the peer to send its closure alert, generating an "incomplete close". Note that an implementation which does this MAY choose to reuse the session. This SHOULD only be done when the application knows (typically through detecting HTTP message boundaries) that it has received all the message data that it cares about.

As specified in [RFC8446], any implementation which receives a connection close without first receiving a valid closure alert (a "premature close") MUST NOT reuse that session. Note that a premature close does not call into question the security of the data already received, but simply indicates that subsequent data might have been truncated. Because TLS is oblivious to HTTP request/response boundaries, it is necessary to examine the HTTP data itself (specifically the Content-Length header) to determine whether the truncation occurred inside a message or between messages.

When encountering a premature close, a client SHOULD treat as completed all requests for which it has received as much data as specified in the Content-Length header.

A client detecting an incomplete close SHOULD recover gracefully. It MAY resume a TLS session closed in this fashion.

Clients MUST send a closure alert before closing the connection. Clients which are unprepared to receive any more data MAY choose not to wait for the server's closure alert and simply close the connection, thus generating an incomplete close on the server side.

Servers SHOULD be prepared to receive an incomplete close from the client, since the client can often determine when the end of server data is. Servers SHOULD be willing to resume TLS sessions closed in this fashion.

Servers MUST attempt to initiate an exchange of closure alerts with the client before closing the connection. Servers MAY close the connection after sending the closure alert, thus generating an incomplete close on the client side.

9.9. Upgrade

The "Upgrade" header field is intended to provide a simple mechanism for transitioning from HTTP/1.1 to some other protocol on the same connection.

A client MAY send a list of protocol names in the Upgrade header field of a request to invite the server to switch to one or more of the named protocols, in order of descending preference, before sending the final response. A server MAY ignore a received Upgrade header field if it wishes to continue using the current protocol on that connection. Upgrade cannot be used to insist on a protocol change.

```
  Upgrade          = 1#protocol

  protocol         = protocol-name ["/" protocol-version]
  protocol-name    = token
  protocol-version = token
```

Although protocol names are registered with a preferred case, recipients SHOULD use case-insensitive comparison when matching each protocol-name to supported protocols.

A server that sends a 101 (Switching Protocols) response MUST send an Upgrade header field to indicate the new protocol(s) to which the connection is being switched; if multiple protocol layers are being switched, the sender MUST list the protocols in layer-ascending order. A server MUST NOT switch to a protocol that was not indicated by the client in the corresponding request's Upgrade header field. A server MAY choose to ignore the order of preference indicated by the client and select the new protocol(s) based on other factors, such as the nature of the request or the current load on the server.

A server that sends a 426 (Upgrade Required) response MUST send an Upgrade header field to indicate the acceptable protocols, in order of descending preference.

A server MAY send an Upgrade header field in any other response to advertise that it implements support for upgrading to the listed protocols, in order of descending preference, when appropriate for a future request.

The following is a hypothetical example sent by a client:

```
  GET /hello HTTP/1.1
  Host: www.example.com
  Connection: upgrade
  Upgrade: websocket, IRC/6.9, RTA/x11
```

The capabilities and nature of the application-level communication after the protocol change is entirely dependent upon the new protocol(s) chosen. However, immediately after sending the 101 (Switching Protocols) response, the server is expected to continue responding to the original request as if it had received its equivalent within the new protocol (i.e., the server still has an outstanding request to satisfy after the protocol has been changed, and is expected to do so without requiring the request to be repeated).

For example, if the Upgrade header field is received in a GET request and the server decides to switch protocols, it first responds with a 101 (Switching Protocols) message in HTTP/1.1 and then immediately follows that with the new protocol's equivalent of a response to a GET on the target resource. This allows a connection to be upgraded to protocols with the same semantics as HTTP without the latency cost of an additional round trip. A server MUST NOT switch protocols unless the received message semantics can be honored by the new protocol; an OPTIONS request can be honored by any protocol.

The following is an example response to the above hypothetical request:

```
HTTP/1.1 101 Switching Protocols
Connection: upgrade
Upgrade: websocket

[... data stream switches to websocket with an appropriate response
(as defined by new protocol) to the "GET /hello" request ...]
```

When Upgrade is sent, the sender MUST also send a Connection header field (Section 9.1) that contains an "upgrade" connection option, in order to prevent Upgrade from being accidentally forwarded by intermediaries that might not implement the listed protocols. A server MUST ignore an Upgrade header field that is received in an HTTP/1.0 request.

A client cannot begin using an upgraded protocol on the connection until it has completely sent the request message (i.e., the client can't change the protocol it is sending in the middle of a message). If a server receives both an Upgrade and an Expect header field with the "100-continue" expectation (Section 9.1.1 of [Semantics]), the server MUST send a 100 (Continue) response before sending a 101 (Switching Protocols) response.

The Upgrade header field only applies to switching protocols on top of the existing connection; it cannot be used to switch the underlying connection (transport) protocol, nor to switch the existing communication to a different connection. For those purposes, it is more appropriate to use a 3xx (Redirection) response (Section 10.4 of [Semantics]).

9.9.1. Upgrade Protocol Names

This specification only defines the protocol name "HTTP" for use by the family of Hypertext Transfer Protocols, as defined by the HTTP version rules of Section 4.2 of [Semantics] and future updates to

this specification. Additional protocol names ought to be registered using the registration procedure defined in Section 9.9.2.

Name	Description	Expected Version Tokens	Reference
HTTP	Hypertext Transfer Protocol	any DIGIT.DIGIT (e.g, "2.0")	Section 4.2 of [Semantics]

9.9.2. Upgrade Token Registry

The "Hypertext Transfer Protocol (HTTP) Upgrade Token Registry" defines the namespace for protocol-name tokens used to identify protocols in the Upgrade header field. The registry is maintained at <https://www.iana.org/assignments/http-upgrade-tokens>.

Each registered protocol name is associated with contact information and an optional set of specifications that details how the connection will be processed after it has been upgraded.

Registrations happen on a "First Come First Served" basis (see Section 4.4 of [RFC8126]) and are subject to the following rules:

1. A protocol-name token, once registered, stays registered forever.

2. A protocol-name token is case-insensitive and registered with the preferred case to be generated by senders.

3. The registration MUST name a responsible party for the registration.

4. The registration MUST name a point of contact.

5. The registration MAY name a set of specifications associated with that token. Such specifications need not be publicly available.

6. The registration SHOULD name a set of expected "protocol-version" tokens associated with that token at the time of registration.

7. The responsible party MAY change the registration at any time. The IANA will keep a record of all such changes, and make them available upon request.

8. The IESG MAY reassign responsibility for a protocol token. This will normally only be used in the case when a responsible party cannot be contacted.

10. Enclosing Messages as Data

10.1. Media Type message/http

The message/http media type can be used to enclose a single HTTP request or response message, provided that it obeys the MIME restrictions for all "message" types regarding line length and encodings.

Type name: message

Subtype name: http

Required parameters: N/A

Optional parameters: version, msgtype

version: The HTTP-version number of the enclosed message (e.g., "1.1"). If not present, the version can be determined from the first line of the body.

msgtype: The message type -- "request" or "response". If not present, the type can be determined from the first line of the body.

Encoding considerations: only "7bit", "8bit", or "binary" are permitted

Security considerations: see Section 11

Interoperability considerations: N/A

Published specification: This specification (see Section 10.1).

Applications that use this media type: N/A

Fragment identifier considerations: N/A

Additional information:

Magic number(s): N/A

Deprecated alias names for this type: N/A

File extension(s): N/A

Macintosh file type code(s): N/A

Person and email address to contact for further information:
See Authors' Addresses section.

Intended usage: COMMON

Restrictions on usage: N/A

Author: See Authors' Addresses section.

Change controller: IESG

10.2. Media Type application/http

The application/http media type can be used to enclose a pipeline of one or more HTTP request or response messages (not intermixed).

Type name: application

Subtype name: http

Required parameters: N/A

Optional parameters: version, msgtype

version: The HTTP-version number of the enclosed messages (e.g., "1.1"). If not present, the version can be determined from the first line of the body.

msgtype: The message type -- "request" or "response". If not present, the type can be determined from the first line of the body.

Encoding considerations: HTTP messages enclosed by this type are in "binary" format; use of an appropriate Content-Transfer-Encoding is required when transmitted via email.

Security considerations: see Section 11

Interoperability considerations: N/A

Published specification: This specification (see Section 10.2).

Applications that use this media type: N/A

Fragment identifier considerations: N/A

Additional information:

Deprecated alias names for this type: N/A

Magic number(s): N/A

File extension(s): N/A

Macintosh file type code(s): N/A

Person and email address to contact for further information:
See Authors' Addresses section.

Intended usage: COMMON

Restrictions on usage: N/A

Author: See Authors' Addresses section.

Change controller: IESG

11. Security Considerations

This section is meant to inform developers, information providers, and users of known security considerations relevant to HTTP message syntax, parsing, and routing. Security considerations about HTTP semantics and payloads are addressed in [Semantics].

11.1. Response Splitting

Response splitting (a.k.a, CRLF injection) is a common technique, used in various attacks on Web usage, that exploits the line-based nature of HTTP message framing and the ordered association of requests to responses on persistent connections [Klein]. This technique can be particularly damaging when the requests pass through a shared cache.

Response splitting exploits a vulnerability in servers (usually within an application server) where an attacker can send encoded data within some parameter of the request that is later decoded and echoed within any of the response header fields of the response. If the decoded data is crafted to look like the response has ended and a subsequent response has begun, the response has been split and the content within the apparent second response is controlled by the attacker. The attacker can then make any other request on the same persistent connection and trick the recipients (including

intermediaries) into believing that the second half of the split is an authoritative answer to the second request.

For example, a parameter within the request-target might be read by an application server and reused within a redirect, resulting in the same parameter being echoed in the Location header field of the response. If the parameter is decoded by the application and not properly encoded when placed in the response field, the attacker can send encoded CRLF octets and other content that will make the application's single response look like two or more responses.

A common defense against response splitting is to filter requests for data that looks like encoded CR and LF (e.g., "%0D" and "%0A"). However, that assumes the application server is only performing URI decoding, rather than more obscure data transformations like charset transcoding, XML entity translation, base64 decoding, sprintf reformatting, etc. A more effective mitigation is to prevent anything other than the server's core protocol libraries from sending a CR or LF within the header section, which means restricting the output of header fields to APIs that filter for bad octets and not allowing application servers to write directly to the protocol stream.

11.2. Request Smuggling

Request smuggling ([Linhart]) is a technique that exploits differences in protocol parsing among various recipients to hide additional requests (which might otherwise be blocked or disabled by policy) within an apparently harmless request. Like response splitting, request smuggling can lead to a variety of attacks on HTTP usage.

This specification has introduced new requirements on request parsing, particularly with regard to message framing in Section 6.3, to reduce the effectiveness of request smuggling.

11.3. Message Integrity

HTTP does not define a specific mechanism for ensuring message integrity, instead relying on the error-detection ability of underlying transport protocols and the use of length or chunk-delimited framing to detect completeness. Additional integrity mechanisms, such as hash functions or digital signatures applied to the content, can be selectively added to messages via extensible metadata fields. Historically, the lack of a single integrity mechanism has been justified by the informal nature of most HTTP communication. However, the prevalence of HTTP as an information

access mechanism has resulted in its increasing use within environments where verification of message integrity is crucial.

User agents are encouraged to implement configurable means for detecting and reporting failures of message integrity such that those means can be enabled within environments for which integrity is necessary. For example, a browser being used to view medical history or drug interaction information needs to indicate to the user when such information is detected by the protocol to be incomplete, expired, or corrupted during transfer. Such mechanisms might be selectively enabled via user agent extensions or the presence of message integrity metadata in a response. At a minimum, user agents ought to provide some indication that allows a user to distinguish between a complete and incomplete response message (Section 8) when such verification is desired.

11.4. Message Confidentiality

HTTP relies on underlying transport protocols to provide message confidentiality when that is desired. HTTP has been specifically designed to be independent of the transport protocol, such that it can be used over many different forms of encrypted connection, with the selection of such transports being identified by the choice of URI scheme or within user agent configuration.

The "https" scheme can be used to identify resources that require a confidential connection, as described in Section 2.5.2 of [Semantics].

12. IANA Considerations

The change controller for the following registrations is: "IETF (iesg@ietf.org) - Internet Engineering Task Force".

12.1. Field Name Registration

Please update the "Hypertext Transfer Protocol (HTTP) Field Name Registry" at <https://www.iana.org/assignments/http-fields> with the field names listed in the two tables of Section 5.

12.2. Media Type Registration

Please update the "Media Types" registry at <https://www.iana.org/assignments/media-types> with the registration information in Section 10.1 and Section 10.2 for the media types "message/http" and "application/http", respectively.

12.3. Transfer Coding Registration

Please update the "HTTP Transfer Coding Registry" at <https://www.iana.org/assignments/http-parameters/> with the registration procedure of Section 7.3 and the content coding names summarized in the table of Section 7.

12.4. Upgrade Token Registration

Please update the "Hypertext Transfer Protocol (HTTP) Upgrade Token Registry" at <https://www.iana.org/assignments/http-upgrade-tokens> with the registration procedure of Section 9.9.2 and the upgrade token names summarized in the table of Section 9.9.1.

12.5. ALPN Protocol ID Registration

Please update the "TLS Application-Layer Protocol Negotiation (ALPN) Protocol IDs" registry at <https://www.iana.org/assignments/tls-extensiontype-values/tls-extensiontype-values.xhtml> with the registration below:

Protocol	Identification Sequence	Reference
HTTP/1.1	0x68 0x74 0x74 0x70 0x2f 0x31 0x2e 0x31 ("http/1.1")	(this specification)

13. References

13.1. Normative References

[Caching] Fielding, R., Ed., Nottingham, M., Ed., and J. Reschke, Ed., "HTTP Caching", draft-ietf-httpbis-cache-09 (work in progress), July 2020.

[RFC1950] Deutsch, L. and J-L. Gailly, "ZLIB Compressed Data Format Specification version 3.3", RFC 1950, DOI 10.17487/RFC1950, May 1996, <https://www.rfc-editor.org/info/rfc1950>.

[RFC1951] Deutsch, P., "DEFLATE Compressed Data Format Specification version 1.3", RFC 1951, DOI 10.17487/RFC1951, May 1996, <https://www.rfc-editor.org/info/rfc1951>.

[RFC1952] Deutsch, P., Gailly, J-L., Adler, M., Deutsch, L., and G. Randers-Pehrson, "GZIP file format specification version 4.3", RFC 1952, DOI 10.17487/RFC1952, May 1996, <https://www.rfc-editor.org/info/rfc1952>.

[RFC2119] Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels", BCP 14, RFC 2119, DOI 10.17487/RFC2119, March 1997, <https://www.rfc-editor.org/info/rfc2119>.

[RFC3986] Berners-Lee, T., Fielding, R., and L. Masinter, "Uniform Resource Identifier (URI): Generic Syntax", STD 66, RFC 3986, DOI 10.17487/RFC3986, January 2005, <https://www.rfc-editor.org/info/rfc3986>.

[RFC5234] Crocker, D., Ed. and P. Overell, "Augmented BNF for Syntax Specifications: ABNF", STD 68, RFC 5234, DOI 10.17487/RFC5234, January 2008, <https://www.rfc-editor.org/info/rfc5234>.

[RFC7405] Kyzivat, P., "Case-Sensitive String Support in ABNF", RFC 7405, DOI 10.17487/RFC7405, December 2014, <https://www.rfc-editor.org/info/rfc7405>.

[RFC8174] Leiba, B., "Ambiguity of Uppercase vs Lowercase in RFC 2119 Key Words", BCP 14, RFC 8174, DOI 10.17487/RFC8174, May 2017, <https://www.rfc-editor.org/info/rfc8174>.

[RFC8446] Rescorla, E., "The Transport Layer Security (TLS) Protocol Version 1.3", RFC 8446, DOI 10.17487/RFC8446, August 2018, <https://www.rfc-editor.org/info/rfc8446>.

[Semantics] Fielding, R., Ed., Nottingham, M., Ed., and J. Reschke, Ed., "HTTP Semantics", draft-ietf-httpbis-semantics-09 (work in progress), July 2020.

[USASCII] American National Standards Institute, "Coded Character Set -- 7-bit American Standard Code for Information Interchange", ANSI X3.4, 1986.

[Welch] Welch, T., "A Technique for High-Performance Data Compression", IEEE Computer 17(6), June 1984.

13.2. Informative References

[Err4667] RFC Errata, Erratum ID 4667, RFC 7230, <https://www.rfc-editor.org/errata/eid4667>.

[Klein] Klein, A., "Divide and Conquer - HTTP Response Splitting, Web Cache Poisoning Attacks, and Related Topics", March 2004, <http://packetstormsecurity.com/papers/general/whitepaper_httpresponse.pdf>.

[Linhart] Linhart, C., Klein, A., Heled, R., and S. Orrin, "HTTP Request Smuggling", June 2005, <http://www.watchfire.com/news/whitepapers.aspx>.

[RFC1945] Berners-Lee, T., Fielding, R., and H. Nielsen, "Hypertext Transfer Protocol -- HTTP/1.0", RFC 1945, DOI 10.17487/RFC1945, May 1996, <https://www.rfc-editor.org/info/rfc1945>.

[RFC2045] Freed, N. and N. Borenstein, "Multipurpose Internet Mail Extensions (MIME) Part One: Format of Internet Message Bodies", RFC 2045, DOI 10.17487/RFC2045, November 1996, <https://www.rfc-editor.org/info/rfc2045>.

[RFC2046] Freed, N. and N. Borenstein, "Multipurpose Internet Mail Extensions (MIME) Part Two: Media Types", RFC 2046, DOI 10.17487/RFC2046, November 1996, <https://www.rfc-editor.org/info/rfc2046>.

[RFC2049] Freed, N. and N. Borenstein, "Multipurpose Internet Mail Extensions (MIME) Part Five: Conformance Criteria and Examples", RFC 2049, DOI 10.17487/RFC2049, November 1996, <https://www.rfc-editor.org/info/rfc2049>.

[RFC2068] Fielding, R., Gettys, J., Mogul, J., Nielsen, H., and T. Berners-Lee, "Hypertext Transfer Protocol -- HTTP/1.1", RFC 2068, DOI 10.17487/RFC2068, January 1997, <https://www.rfc-editor.org/info/rfc2068>.

[RFC2557] Palme, F., Hopmann, A., Shelness, N., and E. Stefferud, "MIME Encapsulation of Aggregate Documents, such as HTML (MHTML)", RFC 2557, DOI 10.17487/RFC2557, March 1999, <https://www.rfc-editor.org/info/rfc2557>.

[RFC5322] Resnick, P., "Internet Message Format", RFC 5322, DOI 10.17487/RFC5322, October 2008, <https://www.rfc-editor.org/info/rfc5322>.

[RFC7230] Fielding, R., Ed. and J. Reschke, Ed., "Hypertext Transfer Protocol (HTTP/1.1): Message Syntax and Routing", RFC 7230, DOI 10.17487/RFC7230, June 2014, <https://www.rfc-editor.org/info/rfc7230>.

[RFC7231] Fielding, R., Ed. and J. Reschke, Ed., "Hypertext Transfer Protocol (HTTP/1.1): Semantics and Content", RFC 7231, DOI 10.17487/RFC7231, June 2014, <https://www.rfc-editor.org/info/rfc7231>.

[RFC8126] Cotton, M., Leiba, B., and T. Narten, "Guidelines for Writing an IANA Considerations Section in RFCs", BCP 26, RFC 8126, DOI 10.17487/RFC8126, June 2017, <https://www.rfc-editor.org/info/rfc8126>.

Appendix A. Collected ABNF

In the collected ABNF below, list rules are expanded as per Section 5.5.1 of [Semantics].

```
BWS = <BWS, see [Semantics], Section 1.2.1>

Connection = connection-option *( OWS "," OWS connection-option )

HTTP-message = start-line CRLF *( field-line CRLF ) CRLF [
 message-body ]
HTTP-name = %x48.54.54.50 ; HTTP
HTTP-version = HTTP-name "/" DIGIT "." DIGIT

OWS = <OWS, see [Semantics], Section 1.2.1>

RWS = <RWS, see [Semantics], Section 1.2.1>

TE = [ t-codings *( OWS "," OWS t-codings ) ]
Transfer-Encoding = transfer-coding *( OWS "," OWS transfer-coding )

Upgrade = protocol *( OWS "," OWS protocol )

absolute-URI = <absolute-URI, see [RFC3986], Section 4.3>
absolute-form = absolute-URI
absolute-path = <absolute-path, see [Semantics], Section 2.4>
asterisk-form = "*"
authority = <authority, see [RFC3986], Section 3.2>
authority-form = authority

chunk = chunk-size [ chunk-ext ] CRLF chunk-data CRLF
chunk-data = 1*OCTET
chunk-ext = *( BWS ";" BWS chunk-ext-name [ BWS "=" BWS chunk-ext-val
 ] )
chunk-ext-name = token
chunk-ext-val = token / quoted-string
chunk-size = 1*HEXDIG
chunked-body = *chunk last-chunk trailer-section CRLF
comment = <comment, see [Semantics], Section 5.4.1.3>
connection-option = token

field-line = field-name ":" OWS field-value OWS
field-name = <field-name, see [Semantics], Section 5.3>
field-value = <field-value, see [Semantics], Section 5.4>

last-chunk = 1*"0" [ chunk-ext ] CRLF

message-body = *OCTET
```

```
method = token

obs-fold = OWS CRLF RWS
obs-text = <obs-text, see [Semantics], Section 5.4.1.2>
origin-form = absolute-path [ "?" query ]

port = <port, see [RFC3986], Section 3.2.3>
protocol = protocol-name [ "/" protocol-version ]
protocol-name = token
protocol-version = token

query = <query, see [RFC3986], Section 3.4>
quoted-string = <quoted-string, see [Semantics], Section 5.4.1.2>

rank = ( "0" [ "." *3DIGIT ] ) / ( "1" [ "." *3"0" ] )
reason-phrase = 1*( HTAB / SP / VCHAR / obs-text )
request-line = method SP request-target SP HTTP-version
request-target = origin-form / absolute-form / authority-form /
 asterisk-form

start-line = request-line / status-line
status-code = 3DIGIT
status-line = HTTP-version SP status-code SP [ reason-phrase ]

t-codings = "trailers" / ( transfer-coding [ t-ranking ] )
t-ranking = OWS ";" OWS "q=" rank
token = <token, see [Semantics], Section 5.4.1.1>
trailer-section = *( field-line CRLF )
transfer-coding = token *( OWS ";" OWS transfer-parameter )
transfer-parameter = token BWS "=" BWS ( token / quoted-string )

uri-host = <host, see [RFC3986], Section 3.2.2>
```

Appendix B. Differences between HTTP and MIME

HTTP/1.1 uses many of the constructs defined for the Internet Message Format [RFC5322] and the Multipurpose Internet Mail Extensions (MIME) [RFC2045] to allow a message body to be transmitted in an open variety of representations and with extensible fields. However, RFC 2045 is focused only on email; applications of HTTP have many characteristics that differ from email; hence, HTTP has features that differ from MIME. These differences were carefully chosen to optimize performance over binary connections, to allow greater freedom in the use of new media types, to make date comparisons easier, and to acknowledge the practice of some early HTTP servers and clients.

This appendix describes specific areas where HTTP differs from MIME. Proxies and gateways to and from strict MIME environments need to be aware of these differences and provide the appropriate conversions where necessary.

B.1. MIME-Version

HTTP is not a MIME-compliant protocol. However, messages can include a single MIME-Version header field to indicate what version of the MIME protocol was used to construct the message. Use of the MIME-Version header field indicates that the message is in full conformance with the MIME protocol (as defined in [RFC2045]). Senders are responsible for ensuring full conformance (where possible) when exporting HTTP messages to strict MIME environments.

B.2. Conversion to Canonical Form

MIME requires that an Internet mail body part be converted to canonical form prior to being transferred, as described in Section 4 of [RFC2049]. Section 7.1.1.2 of [Semantics] describes the forms allowed for subtypes of the "text" media type when transmitted over HTTP. [RFC2046] requires that content with a type of "text" represent line breaks as CRLF and forbids the use of CR or LF outside of line break sequences. HTTP allows CRLF, bare CR, and bare LF to indicate a line break within text content.

A proxy or gateway from HTTP to a strict MIME environment ought to translate all line breaks within text media types to the RFC 2049 canonical form of CRLF. Note, however, this might be complicated by the presence of a Content-Encoding and by the fact that HTTP allows the use of some charsets that do not use octets 13 and 10 to represent CR and LF, respectively.

Conversion will break any cryptographic checksums applied to the original content unless the original content is already in canonical form. Therefore, the canonical form is recommended for any content that uses such checksums in HTTP.

B.3. Conversion of Date Formats

HTTP/1.1 uses a restricted set of date formats (Section 5.4.1.5 of [Semantics]) to simplify the process of date comparison. Proxies and gateways from other protocols ought to ensure that any Date header field present in a message conforms to one of the HTTP/1.1 formats and rewrite the date if necessary.

B.4. Conversion of Content-Encoding

MIME does not include any concept equivalent to HTTP/1.1's Content-Encoding header field. Since this acts as a modifier on the media type, proxies and gateways from HTTP to MIME-compliant protocols ought to either change the value of the Content-Type header field or decode the representation before forwarding the message. (Some experimental applications of Content-Type for Internet mail have used a media-type parameter of ";conversions=<content-coding>" to perform a function equivalent to Content-Encoding. However, this parameter is not part of the MIME standards).

B.5. Conversion of Content-Transfer-Encoding

HTTP does not use the Content-Transfer-Encoding field of MIME. Proxies and gateways from MIME-compliant protocols to HTTP need to remove any Content-Transfer-Encoding prior to delivering the response message to an HTTP client.

Proxies and gateways from HTTP to MIME-compliant protocols are responsible for ensuring that the message is in the correct format and encoding for safe transport on that protocol, where "safe transport" is defined by the limitations of the protocol being used. Such a proxy or gateway ought to transform and label the data with an appropriate Content-Transfer-Encoding if doing so will improve the likelihood of safe transport over the destination protocol.

B.6. MHTML and Line Length Limitations

HTTP implementations that share code with MHTML [RFC2557] implementations need to be aware of MIME line length limitations. Since HTTP does not have this limitation, HTTP does not fold long lines. MHTML messages being transported by HTTP follow all conventions of MHTML, including line length limitations and folding, canonicalization, etc., since HTTP transfers message-bodies as payload and, aside from the "multipart/byteranges" type (Section 7.3.5 of [Semantics]), does not interpret the content or any MIME header lines that might be contained therein.

Appendix C. HTTP Version History

HTTP has been in use since 1990. The first version, later referred to as HTTP/0.9, was a simple protocol for hypertext data transfer across the Internet, using only a single request method (GET) and no metadata. HTTP/1.0, as defined by [RFC1945], added a range of request methods and MIME-like messaging, allowing for metadata to be transferred and modifiers placed on the request/response semantics. However, HTTP/1.0 did not sufficiently take into consideration the

effects of hierarchical proxies, caching, the need for persistent connections, or name-based virtual hosts. The proliferation of incompletely implemented applications calling themselves "HTTP/1.0" further necessitated a protocol version change in order for two communicating applications to determine each other's true capabilities.

HTTP/1.1 remains compatible with HTTP/1.0 by including more stringent requirements that enable reliable implementations, adding only those features that can either be safely ignored by an HTTP/1.0 recipient or only be sent when communicating with a party advertising conformance with HTTP/1.1.

HTTP/1.1 has been designed to make supporting previous versions easy. A general-purpose HTTP/1.1 server ought to be able to understand any valid request in the format of HTTP/1.0, responding appropriately with an HTTP/1.1 message that only uses features understood (or safely ignored) by HTTP/1.0 clients. Likewise, an HTTP/1.1 client can be expected to understand any valid HTTP/1.0 response.

Since HTTP/0.9 did not support header fields in a request, there is no mechanism for it to support name-based virtual hosts (selection of resource by inspection of the Host header field). Any server that implements name-based virtual hosts ought to disable support for HTTP/0.9. Most requests that appear to be HTTP/0.9 are, in fact, badly constructed HTTP/1.x requests caused by a client failing to properly encode the request-target.

C.1. Changes from HTTP/1.0

This section summarizes major differences between versions HTTP/1.0 and HTTP/1.1.

C.1.1. Multihomed Web Servers

The requirements that clients and servers support the Host header field (Section 6.6 of [Semantics]), report an error if it is missing from an HTTP/1.1 request, and accept absolute URIs (Section 3.2) are among the most important changes defined by HTTP/1.1.

Older HTTP/1.0 clients assumed a one-to-one relationship of IP addresses and servers; there was no other established mechanism for distinguishing the intended server of a request than the IP address to which that request was directed. The Host header field was introduced during the development of HTTP/1.1 and, though it was quickly implemented by most HTTP/1.0 browsers, additional requirements were placed on all HTTP/1.1 requests in order to ensure complete adoption. At the time of this writing, most HTTP-based

services are dependent upon the Host header field for targeting requests.

C.1.2. Keep-Alive Connections

In HTTP/1.0, each connection is established by the client prior to the request and closed by the server after sending the response. However, some implementations implement the explicitly negotiated ("Keep-Alive") version of persistent connections described in Section 19.7.1 of [RFC2068].

Some clients and servers might wish to be compatible with these previous approaches to persistent connections, by explicitly negotiating for them with a "Connection: keep-alive" request header field. However, some experimental implementations of HTTP/1.0 persistent connections are faulty; for example, if an HTTP/1.0 proxy server doesn't understand Connection, it will erroneously forward that header field to the next inbound server, which would result in a hung connection.

One attempted solution was the introduction of a Proxy-Connection header field, targeted specifically at proxies. In practice, this was also unworkable, because proxies are often deployed in multiple layers, bringing about the same problem discussed above.

As a result, clients are encouraged not to send the Proxy-Connection header field in any requests.

Clients are also encouraged to consider the use of Connection: keep-alive in requests carefully; while they can enable persistent connections with HTTP/1.0 servers, clients using them will need to monitor the connection for "hung" requests (which indicate that the client ought stop sending the header field), and this mechanism ought not be used by clients at all when a proxy is being used.

C.1.3. Introduction of Transfer-Encoding

HTTP/1.1 introduces the Transfer-Encoding header field (Section 6.1). Transfer codings need to be decoded prior to forwarding an HTTP message over a MIME-compliant protocol.

C.2. Changes from RFC 7230

Most of the sections introducing HTTP's design goals, history, architecture, conformance criteria, protocol versioning, URIs, message routing, and header fields have been moved to [Semantics]. This document has been reduced to just the messaging syntax and connection management requirements specific to HTTP/1.1.

Prohibited generation of bare CRs outside of payload body. (Section 2.2)

In the ABNF for chunked extensions, re-introduced (bad) whitespace around ";" and "=". Whitespace was removed in [RFC7230], but that change was found to break existing implementations (see [Err4667]). (Section 7.1.1)

Trailer field semantics now transcend the specifics of chunked encoding. The decoding algorithm for chunked (Section 7.1.3) has been updated to encourage storage/forwarding of trailer fields separately from the header section, to only allow merging into the header section if the recipient knows the corresponding field definition permits and defines how to merge, and otherwise to discard the trailer fields instead of merging. The trailer part is now called the trailer section to be more consistent with the header section and more distinct from a body part. (Section 7.1.2)

Disallowed transfer coding parameters called "q" in order to avoid conflicts with the use of ranks in the TE header field. (Section 7.3)

Appendix D. Change Log

This section is to be removed before publishing as an RFC.

D.1. Between RFC7230 and draft 00

The changes were purely editorial:

- Change boilerplate and abstract to indicate the "draft" status, and update references to ancestor specifications.
- Adjust historical notes.
- Update links to sibling specifications.
- Replace sections listing changes from RFC 2616 by new empty sections referring to RFC 723x.
- Remove acknowledgements specific to RFC 723x.
- Move "Acknowledgements" to the very end and make them unnumbered.

D.2. Since draft-ietf-httpbis-messaging-00

The changes in this draft are editorial, with respect to HTTP as a whole, to move all core HTTP semantics into [Semantics]:

- Moved introduction, architecture, conformance, and ABNF extensions from RFC 7230 (Messaging) to semantics [Semantics].
- Moved discussion of MIME differences from RFC 7231 (Semantics) to Appendix B since they mostly cover transforming 1.1 messages.
- Moved all extensibility tips, registration procedures, and registry tables from the IANA considerations to normative sections, reducing the IANA considerations to just instructions that will be removed prior to publication as an RFC.

D.3. Since draft-ietf-httpbis-messaging-01

- Cite RFC 8126 instead of RFC 5226 (<https://github.com/httpwg/http-core/issues/75>)
- Resolved erratum 4779, no change needed here (<https://github.com/httpwg/http-core/issues/87>, <https://www.rfc-editor.org/errata/eid4779>)
- In Section 7, fixed prose claiming transfer parameters allow bare names (<https://github.com/httpwg/http-core/issues/88>, <https://www.rfc-editor.org/errata/eid4839>)
- Resolved erratum 4225, no change needed here (<https://github.com/httpwg/http-core/issues/90>, <https://www.rfc-editor.org/errata/eid4225>)
- Replace "response code" with "response status code" (<https://github.com/httpwg/http-core/issues/94>, <https://www.rfc-editor.org/errata/eid4050>)
- In Section 9.4, clarify statement about HTTP/1.0 keep-alive (<https://github.com/httpwg/http-core/issues/96>, <https://www.rfc-editor.org/errata/eid4205>)
- In Section 7.1.1, re-introduce (bad) whitespace around ";" and "=" (<https://github.com/httpwg/http-core/issues/101>, <https://www.rfc-editor.org/errata/eid4667>, <https://www.rfc-editor.org/errata/eid4825>)

- In Section 7.3, state that transfer codings should not use parameters named "q" (<https://github.com/httpwg/http-core/issues/15>, <https://www.rfc-editor.org/errata/eid4683>)

- In Section 7, mark coding name "trailers" as reserved in the IANA registry (<https://github.com/httpwg/http-core/issues/108>)

D.4. Since draft-ietf-httpbis-messaging-02

- In Section 4, explain why the reason phrase should be ignored by clients (<https://github.com/httpwg/http-core/issues/60>).

- Add Section 9.3 to explain how request/response correlation is performed (<https://github.com/httpwg/http-core/issues/145>)

D.5. Since draft-ietf-httpbis-messaging-03

- In Section 9.3, caution against treating data on a connection as part of a not-yet-issued request (<https://github.com/httpwg/http-core/issues/26>)

- In Section 7, remove the predefined codings from the ABNF and make it generic instead (<https://github.com/httpwg/http-core/issues/66>)

- Use RFC 7405 ABNF notation for case-sensitive string constants (<https://github.com/httpwg/http-core/issues/133>)

D.6. Since draft-ietf-httpbis-messaging-04

- In Section 9.9, clarify that protocol-name is to be matched case-insensitively (<https://github.com/httpwg/http-core/issues/8>)

- In Section 5.2, add leading optional whitespace to obs-fold ABNF (<https://github.com/httpwg/http-core/issues/19>, <https://www.rfc-editor.org/errata/eid4189>)

- In Section 4, add clarifications about empty reason phrases (<https://github.com/httpwg/http-core/issues/197>)

- Move discussion of retries from Section 9.4.1 into [Semantics] (<https://github.com/httpwg/http-core/issues/230>)

D.7. Since draft-ietf-httpbis-messaging-05

- In Section 7.1.2, the trailer part has been renamed the trailer section (for consistency with the header section) and trailers are no longer merged as header fields by default, but rather can be

discarded, kept separate from header fields, or merged with header fields only if understood and defined as being mergeable (<https://github.com/httpwg/http-core/issues/16>)

- In Section 2.1 and related Sections, move the trailing CRLF from the line grammars into the message format (<https://github.com/httpwg/http-core/issues/62>)
- Moved Section 2.3 down (<https://github.com/httpwg/http-core/issues/68>)
- In Section 9.9, use 'websocket' instead of 'HTTP/2.0' in examples (<https://github.com/httpwg/http-core/issues/112>)
- Move version non-specific text from Section 6 into semantics as "payload body" (<https://github.com/httpwg/http-core/issues/159>)
- In Section 9.8, add text from RFC 2818 (<https://github.com/httpwg/http-core/issues/236>)

D.8. Since draft-ietf-httpbis-messaging-06

- In Section 12.5, update the APLN protocol id for HTTP/1.1 (<https://github.com/httpwg/http-core/issues/49>)
- In Section 5, align with updates to field terminology in semantics (<https://github.com/httpwg/http-core/issues/111>)
- In Section 9.1, clarify that new connection options indeed need to be registered (<https://github.com/httpwg/http-core/issues/285>)
- In Section 1.1, reference RFC 8174 as well (<https://github.com/httpwg/http-core/issues/303>)

D.9. Since draft-ietf-httpbis-messaging-07

- Move TE: trailers into [Semantics] (<https://github.com/httpwg/http-core/issues/18>)
- In Section 6.3, adjust requirements for handling multiple content-length values (<https://github.com/httpwg/http-core/issues/59>)
- Throughout, replace "effective request URI" with "target URI" (<https://github.com/httpwg/http-core/issues/259>)
- In Section 6.1, don't claim Transfer-Encoding is supported by HTTP/2 or later (<https://github.com/httpwg/http-core/issues/297>)

D.10. Since draft-ietf-httpbis-messaging-08

- In Section 2.2, disallow bare CRs (<https://github.com/httpwg/http-core/issues/31>)
- Appendix A now uses the sender variant of the "#" list expansion (<https://github.com/httpwg/http-core/issues/192>)
- In Section 5, adjust IANA "Close" entry for new registry format (<https://github.com/httpwg/http-core/issues/273>)

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Acknowledgments

See Appendix "Acknowledgments" of [Semantics].

Authors' Addresses

Roy T. Fielding (editor)
Adobe
345 Park Ave
San Jose, CA 95110
United States of America

EMail: fielding@gbiv.com
URI: https://roy.gbiv.com/

Mark Nottingham (editor)
Fastly

EMail: mnot@mnot.net
URI: https://www.mnot.net/

Julian F. Reschke (editor)
greenbytes GmbH
Hafenweg 16
Muenster 48155
Germany

EMail: julian.reschke@greenbytes.de
URI: https://greenbytes.de/tech/webdav/