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HPACK - Header Compression for HTTP/2
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Abstract

This specification defines HPACK, a compression format for efficiently representing HTTP header fields in the context of HTTP/2.

Editorial Note (To be removed by RFC Editor)

Discussion of this draft takes place on the HTTPBIS 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 <<http://tools.ietf.org/wg/httpbis/>>; that specific to HTTP/2 are at <<http://http2.github.io/>>.

The changes in this draft are summarized in [Appendix A.1](#).

Status of This Memo

This Internet-Draft is submitted in full conformance with the provisions of [BCP 78](#) and [BCP 79](#).

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[1.](#) Introduction

This specification defines HPACK, a compression format for efficiently representing HTTP header fields in the context of HTTP/2 [[HTTP2](#)].

[2.](#) HPACK Overview

In HTTP/1.1 (see [[RFC7230](#)]), header fields are encoded without any form of compression. As web pages have grown to include dozens to hundreds of requests, the redundant header fields in these requests now measurably increase latency and unnecessarily consume bandwidth (see [[SPDY-DESC-1](#)] and [[SPDY-DESC-2](#)]).

SPDY [[SPDY](#)] initially addressed this redundancy by compressing header fields using the DEFLATE [[DEFLATE](#)] format, which proved very effective at efficiently representing the redundant header fields. However, that approach exposed a security risk as demonstrated by the CRIME attack (see [[CRIME](#)]).

This document describes HPACK, a new compressor for header fields which eliminates redundant header fields, limits vulnerability to known security attacks, and which has a bounded memory requirement for use in constrained environments.

[2.1.](#) Outline

The HTTP header field encoding defined in this document is based on a header table that maps name-value pairs to index values. The header table is incrementally updated as new values are encoded or decoded.

A list of header fields is treated as an ordered collection of name-value pairs that can include duplicates. Names and values are considered to be opaque sequences of octets. The order of header fields is preserved after being compressed and decompressed.

In the encoded form, a header field is represented either literally or as a reference to a name-value pair in a header table. A list of header fields can therefore be encoded using a mixture of references and literal values.

The encoder is responsible for deciding which header fields to insert as new entries in the header table. The decoder executes the modifications to the header table prescribed by the encoder, reconstructing the list of header fields in the process. This

enables decoders to remain simple and understand a wide variety of encoders.

Examples illustrating the use of these different mechanisms to represent header fields are available in [Appendix D](#).

2.2. Conventions

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in [RFC 2119](#) [[RFC2119](#)].

All numeric values are in network byte order. Values are unsigned unless otherwise indicated. Literal values are provided in decimal or hexadecimal as appropriate. Hexadecimal literals are prefixed with "0x" to distinguish them from decimal literals.

2.3. Terminology

This document uses the following terms:

Header Field: A name-value pair. Both the name and value are treated as opaque sequences of octets.

Header Table: The header table (see [Section 3.3.2](#)) is used to associate stored header fields to index values. This table is dynamic and specific to an encoding or decoding context.

Static Table: The static table (see [Section 3.3.1](#)) is used to associate static header fields to index values. This table is ordered, read-only, always accessible, and may be shared amongst all encoding or decoding contexts.

Header List: A header list is an ordered collection of header fields that are encoded jointly. It can contain duplicate header fields. A complete list of key-value pairs contained in a HTTP request or response is a header list.

Header Field Representation: A header field can be represented in encoded form either as a literal or as an index (see [Section 3.4](#)).

Header Block: An ordered list of header field representations which, when decoded, yields a complete header list.

3. Compression Process Overview

This specification does not describe a specific algorithm for an encoder. Instead, it defines precisely how a decoder is expected to

operate, allowing encoders to produce any encoding that this definition permits.

3.1. Header List Ordering

The compression and decompression process preserve the ordering of header fields inside the header list. An encoder **SHOULD** order header field representations in the header block according to their ordering in the original header list. A decoder **SHOULD** order header fields in the decoded header list according to their ordering in the header block.

In particular, representations for pseudo-header fields (see Section 8.1.2.1 of [\[HTTP2\]](#)) **MUST** appear before representations for regular header fields in a header block. In a decoded header list, pseudo-header fields **MUST** appear before regular header fields.

3.2. Encoding and Decoding Contexts

To decompress header blocks, a decoder only needs to maintain a header table (see [Section 3.3.2](#)) as a decoding context. No other state information is needed.

An encoder that wishes to reference entries in the header table needs to maintain a copy of the header table used by the decoder.

When used for bidirectional communication, such as in HTTP, the encoding and decoding header tables maintained by an endpoint are completely independent. Header fields are encoded without any reference to the local decoding header table; and header fields are decoded without reference to the local encoding header table.

3.3. Indexing Tables

HPACK uses two tables for associating header fields to indexes. The static table (see [Section 3.3.1](#)) is predefined and contains common header fields (most of them with an empty value). The header table (see [Section 3.3.2](#)) is dynamic and can be used by the encoder to index header fields repeated in the encoded header lists.

These two tables are combined into a single address space for defining index values (see [Section 3.3.3](#)).

3.3.1. Static Table

The static table consists of a predefined static list of header fields. Its entries are defined in [Appendix B](#).

3.3.2. Header Table

The header table consists of a list of header fields maintained in first-in, first-out order. The first and newest entry in a header table is always at index 1, and the oldest entry of a header table is at the index corresponding to the number of entries in the header table.

The header table is initially empty.

The header table can contain duplicate entries. Therefore, duplicate entries **MUST NOT** be treated as an error by a decoder.

The encoder decides how to update the header table and as such can control how much memory is used by the header table. To limit the memory requirements of the decoder, the header table size is strictly bounded (see [Section 5.1](#)).

The header table is updated during the processing of a list of header field representations (see [Section 4.2](#)).

3.3.3. Index Address Space

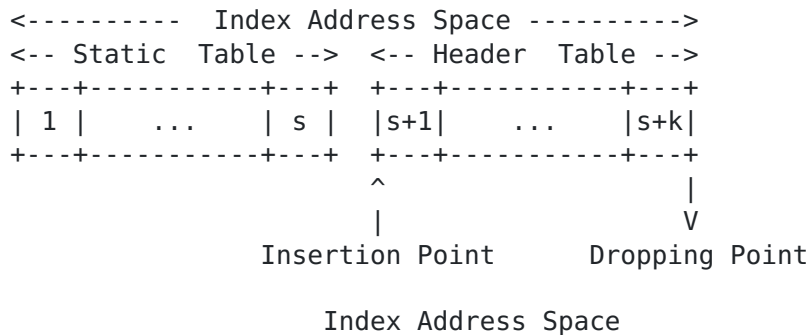
The static table and the header table are combined into a single index address space.

Indices between 1 and the length of the static table (inclusive) refer to elements in the static table (see [Section 3.3.1](#)).

Indices strictly greater than the length of the static table refer to elements in the header table (see [Section 3.3.2](#)). The length of the static table is subtracted to find the index into the header table.

Indices strictly greater than the sum of the lengths of both tables **MUST** be treated as a decoding error.

For a static table size of s and a header table size of k , the following diagram shows the entire valid index address space.



3.4. Header Field Representation

An encoded header field can be represented either as a literal or as an index.

A literal representation defines a header field by specifying its name and value. The header field name can be represented literally or as a reference to an entry in either the static table or the header table. The header field value is represented literally.

Three different literal representations are provided:

- o A literal representation that does not add the header field to the header table (see [Section 7.2.2](#)).
- o A literal representation that does not add the header field to the header table, with the additional stipulation that this header field always use a literal representation, in particular when re-encoded by an intermediary (see [Section 7.2.3](#)).
- o A literal representation that adds the header field as a new entry at the beginning of the header table (see [Section 7.2.1](#)).

An indexed representation defines a header field as a reference to an entry in either the static table or the header table (see [Section 7.1](#)).

4. Header Block Decoding

4.1. Header Block Processing

A decoder processes an encoded header block sequentially to reconstruct the original header list.

Once a header field is decoded and added to the reconstructed header list, it cannot be removed from it. A header field added to the header list can be safely passed to the upper processing layer.

By passing decoded header fields to the upper processing layer, a decoder can be implemented with minimal transitory memory commitment in addition to the header table. The management of memory for handling very large lists of header fields can therefore be deferred to the upper processing layers.

4.2. Header Field Representation Processing

The processing of a header block to obtain a header list is defined in this section. To ensure that the decoding will successfully produce a header list, a decoder **MUST** obey the following rules.

All the header field representations contained in a header block are processed in the order in which they appear, as specified below. Details on the formatting of the various header field representations, and some additional processing instructions are found in [Section 7](#).

An `_indexed representation_` entails the following actions:

- o The header field corresponding to the referenced entry in either the static table or header table is added to the decoded header list.

A `_literal representation_` that is `_not added_` to the header table entails the following action:

- o The header field is added to the decoded header list.

A `_literal representation_` that is `_added_` to the header table entails the following actions:

- o The header field is added to the decoded header list.
- o The header field is inserted at the beginning of the header table.

5. Header Table Management

5.1. Maximum Table Size

To limit the memory requirements on the decoder side, the header table is constrained in size.

The size of the header table is bounded by a maximum size defined by the encoder. The size of the header table **MUST** always be lower than or equal to this maximum size.

By default, the maximum size of the header table is equal to the value of the HTTP/2 setting parameter `SETTINGS_HEADER_TABLE_SIZE` defined by the decoder (see Section 6.5.2 of [HTTP2]). The encoder can change this maximum size (see [Section 7.3](#)), but it MUST stay lower than or equal to the value of `SETTINGS_HEADER_TABLE_SIZE`.

After applying an updated value of the `SETTINGS_HEADER_TABLE_SIZE` parameter that changes the maximum size of the header table used by the encoder, the encoder MUST signal this change via an encoding context update (see [Section 7.3](#)). This encoding context update MUST occur at the beginning of the first header block following the `SETTINGS` frame sent to acknowledge the application of the updated settings (see Section 6.5.3 of [HTTP2]).

Several updates to the value of the `SETTINGS_HEADER_TABLE_SIZE` parameter can occur between the sending of two header blocks. In the case that the value of this parameter is changed more than once, if one of its values is smaller than the new maximum size, the smallest value for the parameter MUST be sent before the new maximum size, using two encoding context updates. This ensures that the decoder is able to perform eviction based on the decoder table size (see [Section 5.2](#)).

This mechanism can be used with a `SETTINGS_HEADER_TABLE_SIZE` parameter value of 0 to completely clear entries from the header table.

The size of the header table is the sum of the size of its entries.

The size of an entry is the sum of its name's length in octets (as defined in [Section 6.2](#)), its value's length in octets (see [Section 6.2](#)), plus 32.

The size of an entry is calculated using the length of the name and value without any Huffman encoding applied.

The additional 32 octets account for the overhead associated with an entry. For example, an entry structure using two 64-bit pointers to reference the name and the value of the entry, and two 64-bit integers for counting the number of references to the name and value would have 32 octets of overhead.

[5.2](#). Entry Eviction when Header Table Size Changes

Whenever the maximum size for the header table is reduced, entries are evicted from the end of the header table until the size of the header table is less than or equal to the maximum size.

5.3. Entry Eviction when Adding New Entries

Whenever a new entry is to be added to the header table, entries are evicted from the end of the header table until the size of the header table is less than or equal to (maximum size - new entry size), or until the table is empty.

If the representation of the added entry references the name of an entry in the header table, the referenced name is cached prior to performing eviction to avoid having the name inadvertently evicted.

If the size of the new entry is less than or equal to the maximum size, that entry is added to the table. It is not an error to attempt to add an entry that is larger than the maximum size; an attempt to add an entry larger than the entire table causes the table to be emptied of all existing entries.

6. Primitive Type Representations

HPACK encoding uses two primitive types: unsigned variable length integers, and strings of octets.

6.1. Integer Representation

Integers are used to represent name indexes, pair indexes or string lengths. To allow for optimized processing, an integer representation always finishes at the end of an octet.

An integer is represented in two parts: a prefix that fills the current octet and an optional list of octets that are used if the integer value does not fit within the prefix. The number of bits of the prefix (called N) is a parameter of the integer representation.

The N-bit prefix allows filling the current octet. If the value is small enough (strictly less than 2^N-1), it is encoded within the N-bit prefix. Otherwise all the bits of the prefix are set to 1 and the value is encoded using an unsigned variable length integer representation (see <http://en.wikipedia.org/wiki/Variable-length_quantity>). N is always between 1 and 8 bits. An integer starting at an octet-boundary will have an 8-bit prefix.

The algorithm to represent an integer I is as follows:

```

if I < 2^N - 1, encode I on N bits
else
    encode (2^N - 1) on N bits
    I = I - (2^N - 1)
    while I >= 128
        encode (I % 128 + 128) on 8 bits
        I = I / 128
    encode I on 8 bits

```

For informational purpose, the algorithm to decode an integer I is as follows:

```

decode I from the next N bits
if I < 2^N - 1, return I
else
    M = 0
    repeat
        B = next octet
        I = I + (B & 127) * 2^M
        M = M + 7
    while B & 128 == 128
    return I

```

Examples illustrating the encoding of integers are available in [Appendix D.1](#).

This integer representation allows for values of indefinite size. It is also possible for an encoder to send a large number of zero values, which can waste octets and could be used to overflow integer values. Excessively large integer encodings - in value or octet length - MUST be treated as a decoding error. Different limits can be set for each of the different uses of integers, based on implementation constraints.

6.2. String Literal Representation

Header field names and header field values can be represented as literal string. A literal string is encoded as a sequence of octets, either by directly encoding the literal string's octets, or by using a Huffman code (see [[HUFFMAN](#)]).

```

  0   1   2   3   4   5   6   7
+---+---+---+---+---+---+---+
| H |   String Length (7+)   |
+---+-----+
| String Data (Length octets) |

```


+-----+

String Literal Representation

A literal string representation contains the following fields:

H: A one bit flag, H, indicating whether or not the octets of the string are Huffman encoded.

String Length: The number of octets used to encode the string literal, encoded as an integer with 7-bit prefix (see [Section 6.1](#)).

String Data: The encoded data of the string literal. If H is '0', then the encoded data is the raw octets of the string literal. If H is '1', then the encoded data is the Huffman encoding of the string literal.

String literals which use Huffman encoding are encoded with the Huffman code defined in [Appendix C](#) (see examples for requests in [Appendix D.4](#) and for responses in [Appendix D.6](#)). The encoded data is the bitwise concatenation of the codes corresponding to each octet of the string literal.

As the Huffman encoded data doesn't always end at an octet boundary, some padding is inserted after it, up to the next octet boundary. To prevent this padding to be misinterpreted as part of the string literal, the most significant bits of the code corresponding to the EOS (end-of-string) symbol are used.

Upon decoding, an incomplete code at the end of the encoded data is to be considered as padding and discarded. A padding strictly longer than 7 bits MUST be treated as a decoding error. A padding not corresponding to the most significant bits of the code for the EOS symbol MUST be treated as a decoding error. A Huffman encoded string literal containing the EOS symbol MUST be treated as a decoding error.

[7.](#) Binary Format

This section describes the detailed format of each of the different header field representations, plus the encoding context update instruction.

[7.1.](#) Indexed Header Field Representation

An indexed header field representation identifies an entry in either the static table or the header table (see [Section 3.3](#)).

An indexed header field representation causes a header field to be added to the decoded header list, as described in [Section 4.2](#).

```

    0   1   2   3   4   5   6   7
+---+---+---+---+---+---+---+---+
| 1 |           Index (7+)          |
+---+---+---+---+---+---+---+

```

Indexed Header Field

An indexed header field starts with the '1' 1-bit pattern, followed by the index of the matching pair, represented as an integer with a 7-bit prefix (see [Section 6.1](#)).

The index value of 0 is not used. It MUST be treated as a decoding error if found in an indexed header field representation.

7.2. Literal Header Field Representation

A literal header field representation contains a literal header field value. Header field names are either provided as a literal or by reference to an existing table entry, either from the static table or the header table (see [Section 3.3](#)).

A literal representation causes a header field to be added to the decoded header list, as described in [Section 4.2](#).

7.2.1. Literal Header Field with Incremental Indexing

A literal header field with incremental indexing representation results in adding a header field to the decoded header list and inserting it as a new entry into the header table.

```

    0   1   2   3   4   5   6   7
+---+---+---+---+---+---+---+---+
| 0 | 1 |           Index (6+)          |
+---+---+---+---+---+---+---+
| H |           Value Length (7+)       |
+---+---+---+---+---+---+---+
| Value String (Length octets)         |
+---+---+---+---+---+---+---+

```

Literal Header Field with Incremental Indexing - Indexed Name

```

    0   1   2   3   4   5   6   7
+---+---+---+---+---+---+---+---+
| 0 | 1 |           0                   |
+---+---+---+---+---+---+---+

```



```

| H |      Name Length (7+)      |
+---+-----+
| Name String (Length octets) |
+---+-----+
| H |      Value Length (7+)     |
+---+-----+
| Value String (Length octets) |
+---+-----+

```

Literal Header Field with Incremental Indexing - New Name

A literal header field with incremental indexing representation starts with the '01' 2-bit pattern.

If the header field name matches the header field name of an entry stored in the static table or the header table, the header field name can be represented using the index of that entry. In this case, the index of the entry is represented as an integer with a 6-bit prefix (see [Section 6.1](#)). This value is always non-zero.

Otherwise, the header field name is represented as a literal string (see [Section 6.2](#)). A value 0 is used in place of the 6-bit index, followed by the header field name.

Either form of header field name representation is followed by the header field value represented as a literal string (see [Section 6.2](#)).

7.2.2. Literal Header Field without Indexing

A literal header field without indexing representation results in adding a header field to the decoded header list without altering the header table.

```

  0   1   2   3   4   5   6   7
+---+---+---+---+---+---+---+
| 0 | 0 | 0 | 0 | Index (4+) |
+---+---+---+---+---+---+
| H |      Value Length (7+)   |
+---+---+---+---+---+---+
| Value String (Length octets) |
+---+---+---+---+---+---+

```

Literal Header Field without Indexing - Indexed Name

```

  0   1   2   3   4   5   6   7
+---+---+---+---+---+---+---+
| 0 | 0 | 0 | 0 |      0      |
+---+---+---+---+---+---+

```



```

| H |      Name Length (7+)      |
+---+-----+
| Name String (Length octets) |
+---+-----+
| H |      Value Length (7+)     |
+---+-----+
| Value String (Length octets) |
+---+-----+

```

Literal Header Field without Indexing - New Name

A literal header field without indexing representation starts with the '0000' 4-bit pattern.

If the header field name matches the header field name of an entry stored in the static table or the header table, the header field name can be represented using the index of that entry. In this case, the index of the entry is represented as an integer with a 4-bit prefix (see [Section 6.1](#)). This value is always non-zero.

Otherwise, the header field name is represented as a literal string (see [Section 6.2](#)). A value 0 is used in place of the 4-bit index, followed by the header field name.

Either form of header field name representation is followed by the header field value represented as a literal string (see [Section 6.2](#)).

7.2.3. Literal Header Field never Indexed

A literal header field never indexed representation results in adding a header field to the decoded header list without altering the header table. Intermediaries **MUST** use the same representation for encoding this header field.

```

  0   1   2   3   4   5   6   7
+---+---+---+---+---+---+---+
| 0 | 0 | 0 | 1 | Index (4+) |
+---+---+---+---+---+---+
| H |      Value Length (7+)   |
+---+---+---+---+---+---+
| Value String (Length octets) |
+---+---+---+---+---+---+

```

Literal Header Field never Indexed - Indexed Name

```

  0   1   2   3   4   5   6   7
+---+---+---+---+---+---+---+
| 0 | 0 | 0 | 1 |           0           |

```



```

+---+---+-----+
| H |   Name Length (7+)   |
+---+-----+
| Name String (Length octets) |
+---+-----+
| H |   Value Length (7+)   |
+---+-----+
| Value String (Length octets) |
+-----+

```

Literal Header Field never Indexed - New Name

A literal header field never indexed representation starts with the '0001' 4-bit pattern.

When a header field is represented as a literal header field never indexed, it **MUST** always be encoded with this specific literal representation. In particular, when a peer sends a header field that it received represented as a literal header field never indexed, it **MUST** use the same representation to forward this header field.

This representation is intended for protecting header field values that are not to be put at risk by compressing them (see [Section 8.1](#) for more details).

The encoding of the representation is identical to the literal header field without indexing (see [Section 7.2.2](#)).

7.3. Header Table Size Update

A header table size update signals a change to the size of the header table.

```

  0   1   2   3   4   5   6   7
+---+---+---+---+---+---+---+
| 0 | 0 | 1 |   Max size (5+)   |
+---+-----+

```

Maximum Header Table Size Change

A header table size update starts with the '001' 3-bit pattern, followed by the new maximum size, represented as an integer with a 5-bit prefix (see [Section 6.1](#)).

The new maximum size **MUST** be lower than or equal to the last value of the SETTINGS_HEADER_TABLE_SIZE parameter (see Section 6.5.2 of [\[HTTP2\]](#)) received from the decoder and acknowledged by the encoder (see Section 6.5.3 of [\[HTTP2\]](#)).

Reducing the maximum size of the header table can cause entries to be evicted (see [Section 5.2](#)).

8. Security Considerations

This section describes potential areas of security concern with HPACK:

- o Use of compression as a length-based oracle for verifying guesses about secrets that are compressed into a shared compression context.
- o Denial of service resulting from exhausting processing or memory capacity at a decoder.

8.1. Probing Header Table State

HPACK reduces the length of header field encodings by exploiting the redundancy inherent in protocols like HTTP. The ultimate goal of this is to reduce the amount of data that is required to send HTTP requests or responses.

The compression context used to encode header fields can be probed by an attacker that has the following capabilities: to define header fields to be encoded and transmitted; and to observe the length of those fields once they are encoded. This allows an attacker to adaptively modify requests in order to confirm guesses about the header table state. If a guess is compressed into a shorter length, the attacker can observe the encoded length and infer that the guess was correct.

This is possible because while TLS provides confidentiality protection for content, it only provides a limited amount of protection for the length of that content.

Note: Padding schemes only provide limited protection against an attacker with these capabilities, potentially only forcing an increased number of guesses to learn the length associated with a given guess. Padding schemes also work directly against compression by increasing the number of bits that are transmitted.

Attacks like CRIME [[CRIME](#)] demonstrated the existence of these general attacker capabilities. The specific attack exploited the fact that DEFLATE [[DEFLATE](#)] removes redundancy based on prefix matching. This permitted the attacker to confirm guesses a character at a time, reducing an exponential-time attack into a linear-time attack.

8.1.1. Applicability to HPACK and HTTP

HPACK mitigates but does not completely prevent attacks modelled on CRIME [[CRIME](#)] by forcing a guess to match an entire header field value, rather than individual characters. An attacker can only learn whether a guess is correct or not, so is reduced to a brute force guess for the header field values.

The viability of recovering specific header field values therefore depends on the entropy of values. As a result, values with high entropy are unlikely to be recovered successfully. However, values with low entropy remain vulnerable.

Attacks of this nature are possible any time that two mutually distrustful entities control requests or responses that are placed onto a single HTTP/2 connection. If the shared HPACK compressor permits one entity to add entries to the header table, and the other to access those entries, then the state of the table can be learned.

Having requests or responses from mutually distrustful entities occurs when an intermediary either:

- o sends requests from multiple clients on a single connection toward an origin server, or
- o takes responses from multiple origin servers and places them on a shared connection toward a client.

Web browsers also need to assume that requests made on the same connection by different web origins [[ORIGIN](#)] are made by mutually distrustful entities.

8.1.2. Mitigation

Users of HTTP that require confidentiality for header fields can use values with entropy sufficient to make guessing infeasible. However, this is impractical as a general solution because it forces all users of HTTP to take steps to mitigate attacks. It would impose new constraints on how HTTP is used.

Rather than impose constraints on users of HTTP, an implementation of HPACK can instead constrain how compression is applied in order to limit the potential for header table probing.

An ideal solution segregates access to the header table based on the entity that is constructing header fields. Header field values that are added to the table are attributed to an entity, and only the entity that created an particular value can extract that value.

To improve compression performance of this option, certain entries might be tagged as being public. For example, a web browser might make the values of the Accept-Encoding header field available in all requests.

An encoder without good knowledge of the provenance of header fields might instead introduce a penalty for bad guesses, such that attempts to guess a header field value results in all values being removed from consideration in all future requests, effectively preventing further guesses.

Note: Simply removing values from the header table can be ineffectual if the attacker has a reliable way of causing values to be reinstalled. For example, a request to load an image in a web browser typically includes the Cookie header field (a potentially highly valued target for this sort of attack), and web sites can easily force an image to be loaded, thereby refreshing the entry in the header table.

This response might be made inversely proportional to the length of the header field. Marking as inaccessible might occur for shorter values more quickly or with higher probability than for longer values.

Implementations might also choose to protect certain header fields that are known to be highly valued, such as the Authorization or Cookie header fields, by disabling or further limiting compression.

8.1.3. Never Indexed Literals

Refusing to generate an indexed representation for a header field is only effective if compression is avoided on all hops. The never indexed literal (see [Section 7.2.3](#)) can be used to signal to intermediaries that a particular value was intentionally sent as a literal. An intermediary MUST NOT re-encode a value that uses the never indexed literal with a representation that would index it.

8.2. Static Huffman Encoding

There is currently no known threat taking advantage of the use of a fixed Huffman encoding. A study has shown that using a fixed Huffman encoding table created an information leakage, however this same study concluded that an attacker could not take advantage of this information leakage to recover any meaningful amount of information (see [[PETAL](#)]).

8.3. Memory Consumption

An attacker can try to cause an endpoint to exhaust its memory. HPACK is designed to limit both the peak and state amounts of memory allocated by an endpoint.

The amount of memory used by the compressor state is limited by the decoder using the value of the HTTP/2 setting parameter `SETTINGS_HEADER_TABLE_SIZE` (see Section 6.5.2 of [HTTP2]). This limit takes into account both the size of the data stored in the header table, plus a small allowance for overhead.

A decoder can limit the amount of state memory used by setting an appropriate value for the `SETTINGS_HEADER_TABLE_SIZE` parameter. An encoder can limit the amount of state memory it uses by signalling lower header table size than the decoder allows (see [Section 7.3](#)).

The amount of temporary memory consumed by an encoder or decoder can be limited by processing header fields sequentially. An implementation does not need to retain a complete list of header fields. Note however that it might be necessary for an application to retain a complete header list for other reasons; even though HPACK does not force this to occur, application constraints might make this necessary.

[8.4.](#) Implementation Limits

An implementation of HPACK needs to ensure that large values for integers, long encoding for integers, or long string literals do not create security weaknesses.

An implementation has to set a limit for the values it accepts for integers, as well as for the encoded length (see [Section 6.1](#)). In the same way, it has to set a limit to the length it accepts for string literals (see [Section 6.2](#)).

[9.](#) Acknowledgements

This document includes substantial input from the following individuals:

- o Mike Bishop, Jeff Pinner, Julian Reschke, Martin Thomson (substantial editorial contributions).
- o Johnny Graettinger (Huffman code statistics).

[10.](#) References

[10.1.](#) Normative References

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Appendix A. Change Log (to be removed by RFC Editor before publication)

A.1. Since [draft-ietf-httpbis-header-compression-08](#)

- o Removed the reference set.
- o Removed header emission.
- o Explicit handling of several SETTINGS_HEADER_TABLE_SIZE parameter changes.
- o Changed header set to header list, and forced ordering.
- o Updated examples.
- o Exchanged header and static table positions.

A.2. Since [draft-ietf-httpbis-header-compression-07](#)

- o Removed old text on index value of 0.
- o Added clarification for signalling of maximum table size after a SETTINGS_HEADER_TABLE_SIZE update.
- o Rewrote security considerations.
- o Many editorial clarifications or improvements.
- o Added convention section.
- o Reworked document's outline.
- o Updated static table. Entry 16 has now "gzip, deflate" for value.
- o Updated Huffman table, using data set provided by Google.

A.3. Since [draft-ietf-httpbis-header-compression-06](#)

- o Updated format to include literal headers that must never be compressed.
- o Updated security considerations.
- o Moved integer encoding examples to the appendix.
- o Updated Huffman table.
- o Updated static header table (adding and removing status values).
- o Updated examples.

A.4. Since [draft-ietf-httpbis-header-compression-05](#)

- o Regenerated examples.
- o Only one Huffman table for requests and responses.
- o Added maximum size for header table, independent of SETTINGS_HEADER_TABLE_SIZE.
- o Added pseudo-code for integer decoding.
- o Improved examples (removing unnecessary removals).

A.5. Since [draft-ietf-httpbis-header-compression-04](#)

- o Updated examples: take into account changes in the spec, and show more features.
- o Use 'octet' everywhere instead of having both 'byte' and 'octet'.
- o Added reference set emptying.
- o Editorial changes and clarifications.
- o Added "host" header to the static table.
- o Ordering for list of values (either NULL- or comma-separated).

A.6. Since [draft-ietf-httpbis-header-compression-03](#)

- o A large number of editorial changes; changed the description of evicting/adding new entries.
- o Removed substitution indexing
- o Changed 'initial headers' to 'static headers', as per issue #258
- o Merged 'request' and 'response' static headers, as per issue #259
- o Changed text to indicate that new headers are added at index 0 and expire from the largest index, as per issue #233

A.7. Since [draft-ietf-httpbis-header-compression-02](#)

- o Corrected error in integer encoding pseudocode.

A.8. Since [draft-ietf-httpbis-header-compression-01](#)

- o Refactored of Header Encoding Section: split definitions and processing rule.
- o Backward incompatible change: Updated reference set management as per issue #214. This changes how the interaction between the reference set and eviction works. This also changes the working of the reference set in some specific cases.
- o Backward incompatible change: modified initial header list, as per issue #188.
- o Added example of 32 octets entry structure (issue #191).
- o Added Header Set Completion section. Reflowed some text. Clarified some writing which was awkward. Added text about duplicate header entry encoding. Clarified some language w.r.t Header Set. Changed x-my-header to mynewheader. Added text in the HeaderEmission section indicating that the application may also be able to free up memory more quickly. Added information in Security Considerations section.

A.9. Since [draft-ietf-httpbis-header-compression-00](#)

Fixed bug/omission in integer representation algorithm.

Changed the document title.

Header matching text rewritten.

Changed the definition of header emission.

Changed the name of the setting which dictates how much memory the compression context should use.

Removed "specific use cases" section

Corrected erroneous statement about what index can be contained in one octet

Added descriptions of opcodes

Removed security claims from introduction.

Appendix B. Static Table Definition

The static table (see [Section 3.3.1](#)) consists of a predefined and unchangeable list of header fields.

The static table was created by listing the most common header fields that are valid for messages exchanged inside a HTTP/2 connection. For header fields with a few frequent values, an entry was added for each of these frequent values. For other header fields, an entry was added with an empty value.

The following table lists the pre-defined header fields that make-up the static table.

Index	Header Name	Header Value
1	:authority	
2	:method	GET
3	:method	POST
4	:path	/
5	:path	/index.html
6	:scheme	http
7	:scheme	https
8	:status	200
9	:status	204
10	:status	206
11	:status	304
12	:status	400
13	:status	404
14	:status	500
15	accept-charset	
16	accept-encoding	gzip, deflate
17	accept-language	

18	accept-ranges		
19	accept		
20	access-control-allow-origin		
21	age		
22	allow		
23	authorization		
24	cache-control		
25	content-disposition		
26	content-encoding		
27	content-language		
28	content-length		
29	content-location		
30	content-range		
31	content-type		
32	cookie		
33	date		
34	etag		
35	expect		
36	expires		
37	from		
38	host		
39	if-match		
40	if-modified-since		
41	if-none-match		
42	if-range		
43	if-unmodified-since		
44	last-modified		
45	link		
46	location		
47	max-forwards		
48	proxy-authenticate		
49	proxy-authorization		
50	range		
51	referer		
52	refresh		
53	retry-after		
54	server		
55	set-cookie		
56	strict-transport-security		
57	transfer-encoding		
58	user-agent		
59	vary		
60	via		
61	www-authenticate		
+-----+-----+-----+			

Table 1: Static Table Entries

Table 1 gives the index of each entry in the static table.

Appendix C. Huffman Code

The following Huffman code is used when encoding string literals with a Huffman coding (see [Section 6.2](#)).

This Huffman code was generated from statistics obtained on a large sample of HTTP headers. It is a canonical Huffman code (see [\[CANONICAL\]](#)) with some tweaking to ensure that no symbol has a unique code length.

Each row in the table defines the code used to represent a symbol:

sym: The symbol to be represented. It is the decimal value of an octet, possibly prepended with its ASCII representation. A specific symbol, "EOS", is used to indicate the end of a string literal.

code as bits: The Huffman code for the symbol represented as a base-2 integer, aligned on the most significant bit (MSB).

code as hex: The Huffman code for the symbol, represented as a hexadecimal integer, aligned on the least significant bit (LSB).

len: The number of bits for the code representing the symbol.

As an example, the code for the symbol 47 (corresponding to the ASCII character "/") consists in the 6 bits "0", "1", "1", "0", "0", "0". This corresponds to the value 0x18 (in hexadecimal) encoded on 6 bits.

sym	code as bits aligned to MSB	code as hex aligned to LSB	len in bits
(0)	11111111 11000	1ff8	[13]
(1)	11111111 11111111 1011000	7fffd8	[23]
(2)	11111111 11111111 11111110 0010	fffffe2	[28]
(3)	11111111 11111111 11111110 0011	fffffe3	[28]
(4)	11111111 11111111 11111110 0100	fffffe4	[28]
(5)	11111111 11111111 11111110 0101	fffffe5	[28]
(6)	11111111 11111111 11111110 0110	fffffe6	[28]
(7)	11111111 11111111 11111110 0111	fffffe7	[28]
(8)	11111111 11111111 11111110 1000	fffffe8	[28]
(9)	11111111 11111111 11101010	ffffea	[24]
(10)	11111111 11111111 11111111 111100	3ffffffc	[30]
(11)	11111111 11111111 11111110 1001	fffffe9	[28]

(12)	11111111 11111111 11111110 1010	fffffea	[28]
(13)	11111111 11111111 11111111 111101	3ffffffd	[30]
(14)	11111111 11111111 11111110 1011	fffffeb	[28]
(15)	11111111 11111111 11111110 1100	fffffec	[28]
(16)	11111111 11111111 11111110 1101	fffffed	[28]
(17)	11111111 11111111 11111110 1110	fffffee	[28]
(18)	11111111 11111111 11111110 1111	fffffef	[28]
(19)	11111111 11111111 11111111 0000	ffffff0	[28]
(20)	11111111 11111111 11111111 0001	ffffff1	[28]
(21)	11111111 11111111 11111111 0010	ffffff2	[28]
(22)	11111111 11111111 11111111 111110	3ffffffe	[30]
(23)	11111111 11111111 11111111 0011	ffffff3	[28]
(24)	11111111 11111111 11111111 0100	ffffff4	[28]
(25)	11111111 11111111 11111111 0101	ffffff5	[28]
(26)	11111111 11111111 11111111 0110	ffffff6	[28]
(27)	11111111 11111111 11111111 0111	ffffff7	[28]
(28)	11111111 11111111 11111111 1000	ffffff8	[28]
(29)	11111111 11111111 11111111 1001	ffffff9	[28]
(30)	11111111 11111111 11111111 1010	ffffffa	[28]
(31)	11111111 11111111 11111111 1011	ffffffb	[28]
' ' (32)	010100	14	[6]
'!' (33)	11111110 00	3f8	[10]
'"' (34)	11111110 01	3f9	[10]
'#' (35)	11111111 1010	ffa	[12]
'\$' (36)	11111111 11001	1ff9	[13]
'%' (37)	010101	15	[6]
'&' (38)	11111000	f8	[8]
' ' (39)	11111111 010	7fa	[11]
'(' (40)	11111110 10	3fa	[10]
')' (41)	11111110 11	3fb	[10]
'*' (42)	11111001	f9	[8]
'+' (43)	11111111 011	7fb	[11]
',' (44)	11111010	fa	[8]
'-' (45)	010110	16	[6]
'.' (46)	010111	17	[6]
'/' (47)	011000	18	[6]
'0' (48)	00000	0	[5]
'1' (49)	00001	1	[5]
'2' (50)	00010	2	[5]
'3' (51)	011001	19	[6]
'4' (52)	011010	1a	[6]
'5' (53)	011011	1b	[6]
'6' (54)	011100	1c	[6]
'7' (55)	011101	1d	[6]
'8' (56)	011110	1e	[6]
'9' (57)	011111	1f	[6]
':' (58)	1011100	5c	[7]
';' (59)	11111011	fb	[8]

'<' (60)	11111111 1111100	7ffc [15]
'=' (61)	100000	20 [6]
'>' (62)	11111111 1011	ffb [12]
'?' (63)	11111111 00	3fc [10]
'@' (64)	11111111 11010	1ffa [13]
'A' (65)	100001	21 [6]
'B' (66)	1011101	5d [7]
'C' (67)	1011110	5e [7]
'D' (68)	1011111	5f [7]
'E' (69)	1100000	60 [7]
'F' (70)	1100001	61 [7]
'G' (71)	1100010	62 [7]
'H' (72)	1100011	63 [7]
'I' (73)	1100100	64 [7]
'J' (74)	1100101	65 [7]
'K' (75)	1100110	66 [7]
'L' (76)	1100111	67 [7]
'M' (77)	1101000	68 [7]
'N' (78)	1101001	69 [7]
'O' (79)	1101010	6a [7]
'P' (80)	1101011	6b [7]
'Q' (81)	1101100	6c [7]
'R' (82)	1101101	6d [7]
'S' (83)	1101110	6e [7]
'T' (84)	1101111	6f [7]
'U' (85)	1110000	70 [7]
'V' (86)	1110001	71 [7]
'W' (87)	1110010	72 [7]
'X' (88)	11111100	fc [8]
'Y' (89)	1110011	73 [7]
'Z' (90)	11111101	fd [8]
'[' (91)	11111111 11011	1ffb [13]
'\' (92)	11111111 1111110 000	7fff0 [19]
']' (93)	11111111 11100	1ffc [13]
'^' (94)	11111111 111100	3ffc [14]
'_' (95)	100010	22 [6]
'`' (96)	11111111 1111101	7ffd [15]
'a' (97)	00011	3 [5]
'b' (98)	100011	23 [6]
'c' (99)	00100	4 [5]
'd' (100)	100100	24 [6]
'e' (101)	00101	5 [5]
'f' (102)	100101	25 [6]
'g' (103)	100110	26 [6]
'h' (104)	100111	27 [6]
'i' (105)	00110	6 [5]
'j' (106)	1110100	74 [7]
'k' (107)	1110101	75 [7]

'l' (108)	101000	28	[6]
'm' (109)	101001	29	[6]
'n' (110)	101010	2a	[6]
'o' (111)	00111	7	[5]
'p' (112)	101011	2b	[6]
'q' (113)	1110110	76	[7]
'r' (114)	101100	2c	[6]
's' (115)	01000	8	[5]
't' (116)	01001	9	[5]
'u' (117)	101101	2d	[6]
'v' (118)	1110111	77	[7]
'w' (119)	1111000	78	[7]
'x' (120)	1111001	79	[7]
'y' (121)	1111010	7a	[7]
'z' (122)	1111011	7b	[7]
'{' (123)	11111111 1111110	7ffe	[15]
' ' (124)	11111111 100	7fc	[11]
'}' (125)	11111111 111101	3ffd	[14]
'~' (126)	11111111 11101	1ffd	[13]
(127)	11111111 11111111 11111111 1100	ffffffc	[28]
(128)	11111111 11111110 0110	fffe6	[20]
(129)	11111111 11111111 010010	3fffd2	[22]
(130)	11111111 11111110 0111	fffe7	[20]
(131)	11111111 11111110 1000	fffe8	[20]
(132)	11111111 11111111 010011	3fffd3	[22]
(133)	11111111 11111111 010100	3fffd4	[22]
(134)	11111111 11111111 010101	3fffd5	[22]
(135)	11111111 11111111 1011001	7fffd9	[23]
(136)	11111111 11111111 010110	3fffd6	[22]
(137)	11111111 11111111 1011010	7fffd9	[23]
(138)	11111111 11111111 1011011	7fffdb	[23]
(139)	11111111 11111111 1011100	7fffdc	[23]
(140)	11111111 11111111 1011101	7ffdd	[23]
(141)	11111111 11111111 1011110	7ffdde	[23]
(142)	11111111 11111111 11101011	ffffeb	[24]
(143)	11111111 11111111 1011111	7ffddf	[23]
(144)	11111111 11111111 11101100	ffffec	[24]
(145)	11111111 11111111 11101101	ffffed	[24]
(146)	11111111 11111111 010111	3fffd7	[22]
(147)	11111111 11111111 1100000	7fffe0	[23]
(148)	11111111 11111111 11101110	ffffee	[24]
(149)	11111111 11111111 1100001	7fffe1	[23]
(150)	11111111 11111111 1100010	7fffe2	[23]
(151)	11111111 11111111 1100011	7fffe3	[23]
(152)	11111111 11111111 1100100	7fffe4	[23]
(153)	11111111 11111110 11100	1fffdc	[21]
(154)	11111111 11111111 011000	3fffd8	[22]
(155)	11111111 11111111 1100101	7fffe5	[23]

(156)	11111111 11111111 011001	3fffd9	[22]
(157)	11111111 11111111 1100110	7fffe6	[23]
(158)	11111111 11111111 1100111	7fffe7	[23]
(159)	11111111 11111111 11101111	ffffef	[24]
(160)	11111111 11111111 011010	3fffd9	[22]
(161)	11111111 11111110 11101	1fffd9	[21]
(162)	11111111 11111110 1001	fffe9	[20]
(163)	11111111 11111111 011011	3fffdb	[22]
(164)	11111111 11111111 011100	3fffdc	[22]
(165)	11111111 11111111 1101000	7fffe8	[23]
(166)	11111111 11111111 1101001	7fffe9	[23]
(167)	11111111 11111110 11110	1fffd9	[21]
(168)	11111111 11111111 1101010	7fffea	[23]
(169)	11111111 11111111 011101	3fffd9	[22]
(170)	11111111 11111111 011110	3fffd9	[22]
(171)	11111111 11111111 11110000	fffff0	[24]
(172)	11111111 11111110 11111	1fffd9	[21]
(173)	11111111 11111111 011111	3fffd9	[22]
(174)	11111111 11111111 1101011	7fffeb	[23]
(175)	11111111 11111111 1101100	7fffec	[23]
(176)	11111111 11111111 00000	1fffe0	[21]
(177)	11111111 11111111 00001	1fffe1	[21]
(178)	11111111 11111111 100000	3fffe0	[22]
(179)	11111111 11111111 00010	1fffe2	[21]
(180)	11111111 11111111 1101101	7fffed	[23]
(181)	11111111 11111111 100001	3fffe1	[22]
(182)	11111111 11111111 1101110	7fffee	[23]
(183)	11111111 11111111 1101111	7fffef	[23]
(184)	11111111 11111110 1010	fffea	[20]
(185)	11111111 11111111 100010	3fffe2	[22]
(186)	11111111 11111111 100011	3fffe3	[22]
(187)	11111111 11111111 100100	3fffe4	[22]
(188)	11111111 11111111 1110000	7ffff0	[23]
(189)	11111111 11111111 100101	3fffe5	[22]
(190)	11111111 11111111 100110	3fffe6	[22]
(191)	11111111 11111111 1110001	7ffff1	[23]
(192)	11111111 11111111 11111000 00	3ffffe0	[26]
(193)	11111111 11111111 11111000 01	3ffffe1	[26]
(194)	11111111 11111110 1011	fffeb	[20]
(195)	11111111 11111110 001	7fff1	[19]
(196)	11111111 11111111 100111	3fffe7	[22]
(197)	11111111 11111111 1110010	7ffff2	[23]
(198)	11111111 11111111 101000	3fffe8	[22]
(199)	11111111 11111111 11110110 0	1ffffec	[25]
(200)	11111111 11111111 11111000 10	3ffffe2	[26]
(201)	11111111 11111111 11111000 11	3ffffe3	[26]
(202)	11111111 11111111 11111001 00	3ffffe4	[26]
(203)	11111111 11111111 11111011 110	7ffffde	[27]

(204)	11111111 11111111 11111011 111	7ffffdf	[27]
(205)	11111111 11111111 11111001 01	3ffffe5	[26]
(206)	11111111 11111111 11110001	fffff1	[24]
(207)	11111111 11111111 11110110 1	1ffffed	[25]
(208)	11111111 11111110 010	7fff2	[19]
(209)	11111111 11111111 00011	1fffe3	[21]
(210)	11111111 11111111 11111001 10	3ffffe6	[26]
(211)	11111111 11111111 11111100 000	7ffffe0	[27]
(212)	11111111 11111111 11111100 001	7ffffe1	[27]
(213)	11111111 11111111 11111001 11	3ffffe7	[26]
(214)	11111111 11111111 11111100 010	7ffffe2	[27]
(215)	11111111 11111111 11110010	fffff2	[24]
(216)	11111111 11111111 00100	1fffe4	[21]
(217)	11111111 11111111 00101	1fffe5	[21]
(218)	11111111 11111111 11111010 00	3ffffe8	[26]
(219)	11111111 11111111 11111010 01	3ffffe9	[26]
(220)	11111111 11111111 11111111 1101	ffffffd	[28]
(221)	11111111 11111111 11111100 011	7ffffe3	[27]
(222)	11111111 11111111 11111100 100	7ffffe4	[27]
(223)	11111111 11111111 11111100 101	7ffffe5	[27]
(224)	11111111 11111110 1100	fffec	[20]
(225)	11111111 11111111 11110011	fffff3	[24]
(226)	11111111 11111110 1101	fffed	[20]
(227)	11111111 11111111 00110	1fffe6	[21]
(228)	11111111 11111111 101001	3fffe9	[22]
(229)	11111111 11111111 00111	1fffe7	[21]
(230)	11111111 11111111 01000	1fffe8	[21]
(231)	11111111 11111111 1110011	7ffff3	[23]
(232)	11111111 11111111 101010	3fffea	[22]
(233)	11111111 11111111 101011	3fffeb	[22]
(234)	11111111 11111111 11110111 0	1ffffee	[25]
(235)	11111111 11111111 11110111 1	1ffffef	[25]
(236)	11111111 11111111 11110100	fffff4	[24]
(237)	11111111 11111111 11110101	fffff5	[24]
(238)	11111111 11111111 11111010 10	3ffffea	[26]
(239)	11111111 11111111 11110100	7ffff4	[23]
(240)	11111111 11111111 11111010 11	3ffffeb	[26]
(241)	11111111 11111111 11111100 110	7ffffe6	[27]
(242)	11111111 11111111 11111011 00	3ffffec	[26]
(243)	11111111 11111111 11111011 01	3ffffed	[26]
(244)	11111111 11111111 11111100 111	7ffffe7	[27]
(245)	11111111 11111111 11111101 000	7ffffe8	[27]
(246)	11111111 11111111 11111101 001	7ffffe9	[27]
(247)	11111111 11111111 11111101 010	7ffffea	[27]
(248)	11111111 11111111 11111101 011	7ffffeb	[27]
(249)	11111111 11111111 11111111 1110	ffffffe	[28]
(250)	11111111 11111111 11111101 100	7ffffec	[27]
(251)	11111111 11111111 11111101 101	7ffffed	[27]

(252)	11111111 11111111 11111101 110	7ffffee	[27]
(253)	11111111 11111111 11111101 111	7ffffef	[27]
(254)	11111111 11111111 11111110 000	7fffff0	[27]
(255)	11111111 11111111 11111011 10	3ffffee	[26]
EOS (256)	11111111 11111111 11111111 111111	3fffffff	[30]

[Appendix D](#). Examples

A number of examples are worked through here, covering integer encoding, header field representation, and the encoding of whole lists of header fields, for both requests and responses, and with and without Huffman coding.

[D.1](#). Integer Representation Examples

This section shows the representation of integer values in details (see [Section 6.1](#)).

[D.1.1](#). Example 1: Encoding 10 Using a 5-bit Prefix

The value 10 is to be encoded with a 5-bit prefix.

- o 10 is less than 31 ($2^5 - 1$) and is represented using the 5-bit prefix.

0	1	2	3	4	5	6	7	
+	+	+	+	+	+	+	+	+
	X		X		0		1	
+	+	+	+	+	+	+	+	+

10 stored on 5 bits

[D.1.2](#). Example 2: Encoding 1337 Using a 5-bit Prefix

The value $I=1337$ is to be encoded with a 5-bit prefix.

1337 is greater than 31 ($2^5 - 1$).

The 5-bit prefix is filled with its max value (31).

$I = 1337 - (2^5 - 1) = 1306$.

I (1306) is greater than or equal to 128, the while loop body executes:

$I \% 128 == 26$

$26 + 128 == 154$

154 is encoded in 8 bits as: 10011010

I is set to 10 ($1306 / 128 == 10$)

I is no longer greater than or equal to 128, the while loop terminates.

I, now 10, is encoded on 8 bits as: 00001010.

The process ends.

0	1	2	3	4	5	6	7	
X	X	X	1	1	1	1	1	Prefix = 31, I = 1306
1	0	0	1	1	0	1	0	1306 >= 128, encode(154), I=1306/128
0	0	0	0	1	0	1	0	10 < 128, encode(10), done

D.1.3. Example 3: Encoding 42 Starting at an Octet Boundary

The value 42 is to be encoded starting at an octet-boundary. This implies that a 8-bit prefix is used.

- o 42 is less than 255 ($2^8 - 1$) and is represented using the 8-bit prefix.

0	1	2	3	4	5	6	7	
0	0	1	0	1	0	1	0	42 stored on 8 bits

D.2. Header Field Representation Examples

This section shows several independent representation examples.

D.2.1. Literal Header Field with Indexing

The header field representation uses a literal name and a literal value. The header field is added to the header table.

Header list to encode:

custom-key: custom-header

Hex dump of encoded data:

```
400a 6375 7374 6f6d 2d6b 6579 0d63 7573 | @.custom-key.cus
746f 6d2d 6865 6164 6572                | tom-header
```

Decoding process:

```
40          | == Literal indexed ==
0a          |   Literal name (len = 10)
6375 7374 6f6d 2d6b 6579 | custom-key
0d          |   Literal value (len = 13)
6375 7374 6f6d 2d68 6561 6465 72 | custom-header
                                | -> custom-key: custom-head\
                                |   er
```

Header Table (after decoding):

```
[ 1] (s = 55) custom-key: custom-header
    Table size: 55
```

Decoded header list:

custom-key: custom-header

D.2.2. Literal Header Field without Indexing

The header field representation uses an indexed name and a literal value. The header field is not added to the header table.

Header list to encode:

:path: /sample/path

Hex dump of encoded data:

```
040c 2f73 616d 706c 652f 7061 7468      | ../sample/path
```

Decoding process:

```

04                                | == Literal not indexed ==
                                |   Indexed name (idx = 4)
                                |   :path
0c                                |   Literal value (len = 12)
2f73 616d 706c 652f 7061 7468    | /sample/path
                                | -> :path: /sample/path

```

Header table (after decoding): empty.

Decoded header list:

:path: /sample/path

D.2.3. Literal Header Field never Indexed

The header field representation uses a literal name and a literal value. The header field is not added to the header table, and must use the same representation if re-encoded by an intermediary.

Header list to encode:

password: secret

Hex dump of encoded data:

```

1008 7061 7373 776f 7264 0673 6563 7265 | ..password.secre
74                                         | t

```

Decoding process:

```

10                                | == Literal never indexed ==
08                                |   Literal name (len = 8)
7061 7373 776f 7264              | password
06                                |   Literal value (len = 6)
7365 6372 6574                  | secret
                                | -> password: secret

```

Header table (after decoding): empty.

Decoded header list:

password: secret

D.2.4. Indexed Header Field

The header field representation uses an indexed header field, from the static table.

Header list to encode:

```
:method: GET
```

Hex dump of encoded data:

82 | .

Decoding process:

```
82 | == Indexed - Add ==  
   |   idx = 2  
   |   -> :method: GET
```

Header table (after decoding): empty.

Decoded header list:

```
:method: GET
```

D.3. Request Examples without Huffman Coding

This section shows several consecutive header lists, corresponding to HTTP requests, on the same connection.

D.3.1. First Request

Header list to encode:

```
:method: GET
:scheme: http
:path: /
:authority: www.example.com
```

Hex dump of encoded data:

```
8286 8441 0f77 7777 2e65 7861 6d70 6c65 | ...A.www.example
2e63 6f6d                                | .com
```

Decoding process:

```
82                                | == Indexed - Add ==
                                |   idx = 2
                                | -> :method: GET
86                                | == Indexed - Add ==
                                |   idx = 6
                                | -> :scheme: http
84                                | == Indexed - Add ==
                                |   idx = 4
                                | -> :path: /
41                                | == Literal indexed ==
                                |   Indexed name (idx = 1)
                                |     :authority
0f                                |   Literal value (len = 15)
7777 772e 6578 616d 706c 652e 636f 6d | www.example.com
                                | -> :authority: www.example\
                                |   .com
```

Header Table (after decoding):

```
[ 1] (s = 57) :authority: www.example.com
    Table size: 57
```

Decoded header list:

```
:method: GET
:scheme: http
:path: /
:authority: www.example.com
```

[D.3.2.](#) Second Request

Header list to encode:


```
:method: GET
:scheme: http
:path: /
:authority: www.example.com
cache-control: no-cache
```

Hex dump of encoded data:

```
8286 84be 5808 6e6f 2d63 6163 6865      | ....X.no-cache
```

Decoding process:

```
82      | == Indexed - Add ==
        |   idx = 2
        |   -> :method: GET
86      | == Indexed - Add ==
        |   idx = 6
        |   -> :scheme: http
84      | == Indexed - Add ==
        |   idx = 4
        |   -> :path: /
be      | == Indexed - Add ==
        |   idx = 62
        |   -> :authority: www.example\
        |   .com
58      | == Literal indexed ==
        |   Indexed name (idx = 24)
        |   cache-control
08      |   Literal value (len = 8)
6e6f 2d63 6163 6865 | no-cache
        | -> cache-control: no-cache
```

Header Table (after decoding):

```
[ 1] (s = 53) cache-control: no-cache
[ 2] (s = 57) :authority: www.example.com
      Table size: 110
```

Decoded header list:


```
:method: GET
:scheme: http
:path: /
:authority: www.example.com
cache-control: no-cache
```

D.3.3. Third Request

Header list to encode:

```
:method: GET
:scheme: https
:path: /index.html
:authority: www.example.com
custom-key: custom-value
```

Hex dump of encoded data:

```
8287 85bf 400a 6375 7374 6f6d 2d6b 6579 | ....@.custom-key
0c63 7573 746f 6d2d 7661 6c75 65      | .custom-value
```

Decoding process:

```
82          | == Indexed - Add ==
            |   idx = 2
            | -> :method: GET
87          | == Indexed - Add ==
            |   idx = 7
            | -> :scheme: https
85          | == Indexed - Add ==
            |   idx = 5
            | -> :path: /index.html
bf          | == Indexed - Add ==
            |   idx = 63
            | -> :authority: www.example\
            |   .com
40          | == Literal indexed ==
0a          |   Literal name (len = 10)
6375 7374 6f6d 2d6b 6579 | custom-key
0c          |   Literal value (len = 12)
6375 7374 6f6d 2d76 616c 7565 | custom-value
            | -> custom-key: custom-valu\
            |   e
```


Header Table (after decoding):

```
[ 1] (s = 54) custom-key: custom-value
[ 2] (s = 53) cache-control: no-cache
[ 3] (s = 57) :authority: www.example.com
    Table size: 164
```

Decoded header list:

```
:method: GET
:scheme: https
:path: /index.html
:authority: www.example.com
custom-key: custom-value
```

D.4. Request Examples with Huffman Coding

This section shows the same examples as the previous section, but using Huffman encoding for the literal values.

D.4.1. First Request

Header list to encode:

```
:method: GET
:scheme: http
:path: /
:authority: www.example.com
```

Hex dump of encoded data:

```
8286 8441 8cf1 e3c2 e5f2 3a6b a0ab 90f4 | ...A.....:k....
ff                                     | .
```

Decoding process:

82	== Indexed - Add ==
	idx = 2
	-> :method: GET
86	== Indexed - Add ==
	idx = 6
	-> :scheme: http
84	== Indexed - Add ==
	idx = 4
	-> :path: /
41	== Literal indexed ==
	Indexed name (idx = 1)
	:authority
8c	Literal value (len = 12)
	Huffman encoded:
f1e3 c2e5 f23a 6ba0 ab90 f4ff:k.....
	Decoded:
	www.example.com
	-> :authority: www.example\
	.com

Header Table (after decoding):

```
[ 1] (s = 57) :authority: www.example.com
    Table size: 57
```

Decoded header list:

```
:method: GET
:scheme: http
:path: /
:authority: www.example.com
```

D.4.2. Second Request

Header list to encode:

```
:method: GET
:scheme: http
:path: /
:authority: www.example.com
cache-control: no-cache
```

Hex dump of encoded data:


```
8286 84be 5886 a8eb 1064 9cbf      | ....X....d..
```

Decoding process:

```
82      | == Indexed - Add ==
        |   idx = 2
        |   -> :method: GET
86      | == Indexed - Add ==
        |   idx = 6
        |   -> :scheme: http
84      | == Indexed - Add ==
        |   idx = 4
        |   -> :path: /
be      | == Indexed - Add ==
        |   idx = 62
        |   -> :authority: www.example\
        |   .com
58      | == Literal indexed ==
        |   Indexed name (idx = 24)
        |   cache-control
86      |   Literal value (len = 6)
        |   Huffman encoded:
a8eb 1064 9cbf |   ...d..
        |   Decoded:
        |   no-cache
        |   -> cache-control: no-cache
```

Header Table (after decoding):

```
[ 1] (s = 53) cache-control: no-cache
[ 2] (s = 57) :authority: www.example.com
      Table size: 110
```

Decoded header list:

```
:method: GET
:scheme: http
:path: /
:authority: www.example.com
cache-control: no-cache
```

[D.4.3.](#) Third Request

Header list to encode:

```
:method: GET
:scheme: https
:path: /index.html
:authority: www.example.com
custom-key: custom-value
```

Hex dump of encoded data:

```
8287 85bf 4088 25a8 49e9 5ba9 7d7f 8925 | ....@.%.I.[.]..%
a849 e95b b8e8 b4bf | .I.[....
```

Decoding process:

```
82 | == Indexed - Add ==
   |   idx = 2
   |   -> :method: GET
87 | == Indexed - Add ==
   |   idx = 7
   |   -> :scheme: https
85 | == Indexed - Add ==
   |   idx = 5
   |   -> :path: /index.html
bf | == Indexed - Add ==
   |   idx = 63
   |   -> :authority: www.example\
   |   .com
40 | == Literal indexed ==
88 |   Literal name (len = 8)
   |   Huffman encoded:
25a8 49e9 5ba9 7d7f | %.I.[.].
   |   Decoded:
   |   custom-key
89 |   Literal value (len = 9)
   |   Huffman encoded:
25a8 49e9 5bb8 e8b4 bf | %.I.[....
   |   Decoded:
   |   custom-value
   |   -> custom-key: custom-valu\
   |   e
```

Header Table (after decoding):


```
[ 1] (s = 54) custom-key: custom-value
[ 2] (s = 53) cache-control: no-cache
[ 3] (s = 57) :authority: www.example.com
    Table size: 164
```

Decoded header list:

```
:method: GET
:scheme: https
:path: /index.html
:authority: www.example.com
custom-key: custom-value
```

D.5. Response Examples without Huffman Coding

This section shows several consecutive header lists, corresponding to HTTP responses, on the same connection. The HTTP/2 setting parameter SETTINGS_HEADER_TABLE_SIZE is set to the value of 256 octets, causing some evictions to occur.

D.5.1. First Response

Header list to encode:

```
:status: 302
cache-control: private
date: Mon, 21 Oct 2013 20:13:21 GMT
location: https://www.example.com
```

Hex dump of encoded data:

```
4803 3330 3258 0770 7269 7661 7465 611d | H.302X.privatea.
4d6f 6e2c 2032 3120 4f63 7420 3230 3133 | Mon, 21 Oct 2013
2032 303a 3133 3a32 3120 474d 546e 1768 | 20:13:21 GMTn.h
7474 7073 3a2f 2f77 7777 2e65 7861 6d70 | ttps://www.examp
6c65 2e63 6f6d | le.com
```

Decoding process:

```

48      | == Literal indexed ==
      |   Indexed name (idx = 8)
      |   :status
03      |   Literal value (len = 3)
3330 32 |   302
      |   -> :status: 302
58      | == Literal indexed ==
      |   Indexed name (idx = 24)
      |   cache-control
07      |   Literal value (len = 7)
7072 6976 6174 65 |   private
      |   -> cache-control: private
61      | == Literal indexed ==
      |   Indexed name (idx = 33)
      |   date
1d      |   Literal value (len = 29)
4d6f 6e2c 2032 3120 4f63 7420 3230 3133 |   Mon, 21 Oct 2013
2032 303a 3133 3a32 3120 474d 54         |   20:13:21 GMT
      |   -> date: Mon, 21 Oct 2013 \
      |   20:13:21 GMT
6e      | == Literal indexed ==
      |   Indexed name (idx = 46)
      |   location
17      |   Literal value (len = 23)
6874 7470 733a 2f2f 7777 772e 6578 616d |   https://www.exam
706c 652e 636f 6d                       |   ple.com
      |   -> location: https://www.e\
      |   xample.com

```

Header Table (after decoding):

```

[ 1] (s = 63) location: https://www.example.com
[ 2] (s = 65) date: Mon, 21 Oct 2013 20:13:21 GMT
[ 3] (s = 52) cache-control: private
[ 4] (s = 42) :status: 302
      Table size: 222

```

Decoded header list:

```

:status: 302
cache-control: private
date: Mon, 21 Oct 2013 20:13:21 GMT
location: https://www.example.com

```


D.5.2. Second Response

The (":status", "302") header field is evicted from the header table to free space to allow adding the (":status", "307") header field.

Header list to encode:

```
:status: 307
cache-control: private
date: Mon, 21 Oct 2013 20:13:21 GMT
location: https://www.example.com
```

Hex dump of encoded data:

```
4803 3330 37c1 c0bf          | H.307...
```

Decoding process:

```
48          | == Literal indexed ==
            |   Indexed name (idx = 8)
            |   :status
03          |   Literal value (len = 3)
3330 37    | 307
            | - evict: :status: 302
            | -> :status: 307
c1          | == Indexed - Add ==
            |   idx = 65
            | -> cache-control: private
c0          | == Indexed - Add ==
            |   idx = 64
            | -> date: Mon, 21 Oct 2013 \
            |   20:13:21 GMT
bf          | == Indexed - Add ==
            |   idx = 63
            | -> location: https://www.e\
            |   xample.com
```

Header Table (after decoding):

```
[ 1] (s = 42) :status: 307
[ 2] (s = 63) location: https://www.example.com
[ 3] (s = 65) date: Mon, 21 Oct 2013 20:13:21 GMT
[ 4] (s = 52) cache-control: private
      Table size: 222
```


Decoded header list:

```
:status: 307
cache-control: private
date: Mon, 21 Oct 2013 20:13:21 GMT
location: https://www.example.com
```

D.5.3. Third Response

Several header fields are evicted from the header table during the processing of this header list.

Header list to encode:

```
:status: 200
cache-control: private
date: Mon, 21 Oct 2013 20:13:22 GMT
location: https://www.example.com
content-encoding: gzip
set-cookie: foo=ASDJKHQKBZX0QWE0PIUAXQWE0IU; max-age=3600; version=1
```

Hex dump of encoded data:

88c1	611d	4d6f	6e2c	2032	3120	4f63	7420		..a.Mon, 21 Oct
3230	3133	2032	303a	3133	3a32	3220	474d		2013 20:13:22 GM
54c0	5a04	677a	6970	7738	666f	6f3d	4153		T.Z.gzipw8foo=AS
444a	4b48	514b	425a	584f	5157	454f	5049		DJKHQKBZX0QWE0PI
5541	5851	5745	4f49	553b	206d	6178	2d61		UAXQWE0IU; max-a
6765	3d33	3630	303b	2076	6572	7369	6f6e		ge=3600; version
3d31									=1

Decoding process:

88	== Indexed - Add ==
	idx = 8
	-> :status: 200
c1	== Indexed - Add ==
	idx = 65
	-> cache-control: private
61	== Literal indexed ==
	Indexed name (idx = 33)
	date
1d	Literal value (len = 29)
4d6f 6e2c 2032 3120 4f63 7420 3230 3133	Mon, 21 Oct 2013
2032 303a 3133 3a32 3220 474d 54	20:13:22 GMT
	- evict: cache-control: pr\
	ivate
	-> date: Mon, 21 Oct 2013 \
	20:13:22 GMT
c0	== Indexed - Add ==
	idx = 64
	-> location: https://www.e\
	xample.com
5a	== Literal indexed ==
	Indexed name (idx = 26)
	content-encoding
04	Literal value (len = 4)
677a 6970	gzip
	- evict: date: Mon, 21 Oct\
	2013 20:13:21 GMT
	-> content-encoding: gzip
77	== Literal indexed ==
	Indexed name (idx = 55)
	set-cookie
38	Literal value (len = 56)
666f 6f3d 4153 444a 4b48 514b 425a 584f	foo=ASDJKHQKBZXO
5157 454f 5049 5541 5851 5745 4f49 553b	QWE0PIUAXQWE0IU;
206d 6178 2d61 6765 3d33 3630 303b 2076	max-age=3600; v
6572 7369 6f6e 3d31	ersion=1
	- evict: location: https:/\
	/www.example.com
	- evict: :status: 307
	-> set-cookie: foo=ASDJKHQ\
	KBZXOQWE0PIUAXQWE0IU; ma\
	x-age=3600; version=1

Header Table (after decoding):


```
[ 1] (s = 98) set-cookie: foo=ASDJKHQKBZX0QWE0PIUAXQWE0IU; max-age\
      =3600; version=1
[ 2] (s = 52) content-encoding: gzip
[ 3] (s = 65) date: Mon, 21 Oct 2013 20:13:22 GMT
      Table size: 215
```

Decoded header list:

```
:status: 200
cache-control: private
date: Mon, 21 Oct 2013 20:13:22 GMT
location: https://www.example.com
content-encoding: gzip
set-cookie: foo=ASDJKHQKBZX0QWE0PIUAXQWE0IU; max-age=3600; version=1
```

D.6. Response Examples with Huffman Coding

This section shows the same examples as the previous section, but using Huffman encoding for the literal values. The HTTP/2 setting parameter `SETTINGS_HEADER_TABLE_SIZE` is set to the value of 256 octets, causing some evictions to occur. The eviction mechanism uses the length of the decoded literal values, so the same evictions occurs as in the previous section.

D.6.1. First Response

Header list to encode:

```
:status: 302
cache-control: private
date: Mon, 21 Oct 2013 20:13:21 GMT
location: https://www.example.com
```

Hex dump of encoded data:

```
4882 6402 5885 aec3 771a 4b61 96d0 7abe | H.d.X...w.Ka..z.
9410 54d4 44a8 2005 9504 0b81 66e0 82a6 | ..T.D. ....f...
2d1b ff6e 919d 29ad 1718 63c7 8f0b 97c8 | -..n..)....c.....
e9ae 82ae 43d3                          | ....C.
```

Decoding process:

```

48      | == Literal indexed ==
      |   Indexed name (idx = 8)
      |   :status
82      |   Literal value (len = 2)
      |   Huffman encoded:
6402    | d.
      |   Decoded:
      |   302
      |   -> :status: 302
58      | == Literal indexed ==
      |   Indexed name (idx = 24)
      |   cache-control
85      |   Literal value (len = 5)
      |   Huffman encoded:
aec3 771a 4b | ..w.K
      |   Decoded:
      | private
      | -> cache-control: private
61      | == Literal indexed ==
      |   Indexed name (idx = 33)
      |   date
96      |   Literal value (len = 22)
      |   Huffman encoded:
d07a be94 1054 d444 a820 0595 040b 8166 | .z...T.D. ....f
e082 a62d 1bff | ...-...
      |   Decoded:
      | Mon, 21 Oct 2013 20:13:21 \
      | GMT
      | -> date: Mon, 21 Oct 2013 \
      | 20:13:21 GMT
6e      | == Literal indexed ==
      |   Indexed name (idx = 46)
      |   location
91      |   Literal value (len = 17)
      |   Huffman encoded:
9d29 ad17 1863 c78f 0b97 c8e9 ae82 ae43 | .)....C.....C
d3      | .
      |   Decoded:
      | https://www.example.com
      | -> location: https://www.e\
      | xample.com

```

Header Table (after decoding):


```
[ 1] (s = 63) location: https://www.example.com
[ 2] (s = 65) date: Mon, 21 Oct 2013 20:13:21 GMT
[ 3] (s = 52) cache-control: private
[ 4] (s = 42) :status: 302
    Table size: 222
```

Decoded header list:

```
:status: 302
cache-control: private
date: Mon, 21 Oct 2013 20:13:21 GMT
location: https://www.example.com
```

D.6.2. Second Response

The (":status", "302") header field is evicted from the header table to free space to allow adding the (":status", "307") header field.

Header list to encode:

```
:status: 307
cache-control: private
date: Mon, 21 Oct 2013 20:13:21 GMT
location: https://www.example.com
```

Hex dump of encoded data:

```
4883 640e ffc1 c0bf          | H.d.....
```

Decoding process:

```

48      | == Literal indexed ==
      |   Indexed name (idx = 8)
      |   :status
83      |   Literal value (len = 3)
      |   Huffman encoded:
640e ff | d..
      |   Decoded:
      |   307
      |   - evict: :status: 302
      |   -> :status: 307
c1      | == Indexed - Add ==
      |   idx = 65
      |   -> cache-control: private
c0      | == Indexed - Add ==
      |   idx = 64
      |   -> date: Mon, 21 Oct 2013 \
      |   20:13:21 GMT
bf      | == Indexed - Add ==
      |   idx = 63
      |   -> location: https://www.e\
      |   xample.com

```

Header Table (after decoding):

```

[ 1] (s = 42) :status: 307
[ 2] (s = 63) location: https://www.example.com
[ 3] (s = 65) date: Mon, 21 Oct 2013 20:13:21 GMT
[ 4] (s = 52) cache-control: private
    Table size: 222

```

Decoded header list:

```

:status: 307
cache-control: private
date: Mon, 21 Oct 2013 20:13:21 GMT
location: https://www.example.com

```

D.6.3. Third Response

Several header fields are evicted from the header table during the processing of this header list.

Header list to encode:


```
:status: 200
cache-control: private
date: Mon, 21 Oct 2013 20:13:22 GMT
location: https://www.example.com
content-encoding: gzip
set-cookie: foo=ASDJKHQKBZX0QWE0PIUAXQWE0IU; max-age=3600; version=1
```

Hex dump of encoded data:

```
88c1 6196 d07a be94 1054 d444 a820 0595 | ..a..z...T.D. ..
040b 8166 e084 a62d 1bff c05a 839b d9ab | ...f...-...Z....
77ad 94e7 821d d7f2 e6c7 b335 dfdf cd5b | w.....5...[
3960 d5af 2708 7f36 72c1 ab27 0fb5 291f | 9`..'..6r..'..).
9587 3160 65c0 03ed 4ee5 b106 3d50 07   | ..1`e...N...=P.
```

Decoding process:

```
88          | == Indexed - Add ==
            |   idx = 8
            |   -> :status: 200
c1          | == Indexed - Add ==
            |   idx = 65
            |   -> cache-control: private
61          | == Literal indexed ==
            |   Indexed name (idx = 33)
            |   date
96          |   Literal value (len = 22)
            |   Huffman encoded:
d07a be94 1054 d444 a820 0595 040b 8166 | .z...T.D. ....f
e084 a62d 1bff          | ...-...
            |   Decoded:
            |   Mon, 21 Oct 2013 20:13:22 \
            |   GMT
            |   - evict: cache-control: pr\
            |   ivate
            |   -> date: Mon, 21 Oct 2013 \
            |   20:13:22 GMT
c0          | == Indexed - Add ==
            |   idx = 64
            |   -> location: https://www.e\
            |   xample.com
5a          | == Literal indexed ==
            |   Indexed name (idx = 26)
            |   content-encoding
83          |   Literal value (len = 3)
            |   Huffman encoded:
```


9bd9 ab	...
	Decoded:
	gzip
	- evict: date: Mon, 21 Oct\
	2013 20:13:21 GMT
77	-> content-encoding: gzip
	== Literal indexed ==
	Indexed name (idx = 55)
	set-cookie
ad	Literal value (len = 45)
	Huffman encoded:
94e7 821d d7f2 e6c7 b335 dfdf cd5b 39605...[9`
d5af 2708 7f36 72c1 ab27 0fb5 291f 9587	..'..6r..'...)
3160 65c0 03ed 4ee5 b106 3d50 07	1`e...N...=P.
	Decoded:
	foo=ASDJKHQKBZXOQWEOPIUAXQ\
	WE0IU; max-age=3600; versi\
	on=1
	- evict: location: https:/\
	/www.example.com
	- evict: :status: 307
	-> set-cookie: foo=ASDJKHQ\
	KBZXOQWEOPIUAXQWE0IU; ma\
	x-age=3600; version=1

Header Table (after decoding):

```
[ 1] (s = 98) set-cookie: foo=ASDJKHQKBZXOQWEOPIUAXQWE0IU; max-age\
    =3600; version=1
[ 2] (s = 52) content-encoding: gzip
[ 3] (s = 65) date: Mon, 21 Oct 2013 20:13:22 GMT
    Table size: 215
```

Decoded header list:

```
:status: 200
cache-control: private
date: Mon, 21 Oct 2013 20:13:22 GMT
location: https://www.example.com
content-encoding: gzip
set-cookie: foo=ASDJKHQKBZXOQWEOPIUAXQWE0IU; max-age=3600; version=1
```

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