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Describing TCP with Augmented Packet Header Diagrams

Abstract

This document describes TCP, and a number of its extensions, using Augmented Packet Header Diagrams. This document is an example of the Augmented Packet Header Diagram language: it is not intended as a contribution to any ongoing or future work on maintaining or extending TCP.

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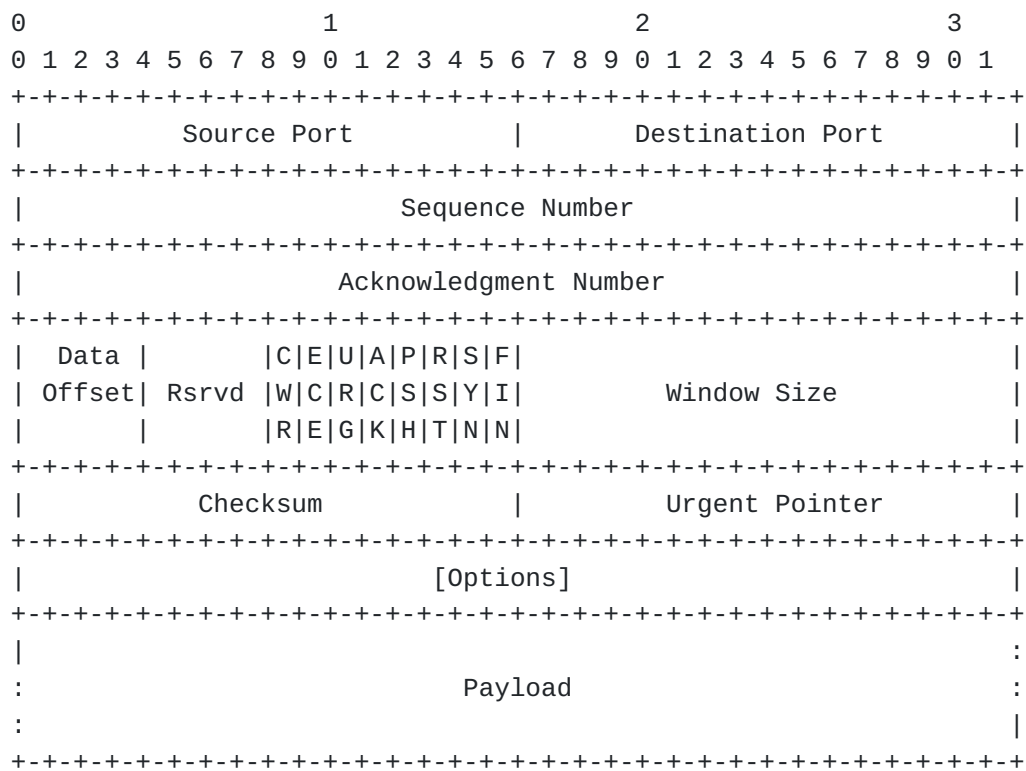
1. Introduction

This document uses Augmented Packet Header Diagrams [[AUGMENTED-DIAGRAMS](#)] to describe TCP [[RFC793](#)], and is intended to further discussion about the design and implementation of the Augmented Packet Header Diagram language and tooling. Given this purpose, this document is not intended as a contribution to any ongoing or future work on maintaining or extending TCP. Further, this document does not necessarily reflect TCP, and its extensions, as presently standardised.

2. TCP Header

This document describes the TCP protocol. The TCP protocol uses TCP Headers.

A TCP Header is formatted as follows:



where:

Source Port: 16 bits. The source port number.

Destination Port: 16 bits. The destination port number.

Sequence Number: 32 bits. The sequence number of the first data octet in this segment (except when the SYN flag is set). If SYN is set the sequence number is the initial sequence number (ISN) and the first data octet is ISN+1.

Acknowledgment Number: 32 bits. If the ACK control bit is set, this field contains the value of the next sequence number the sender of the segment is expecting to receive. Once a connection is established, this is always sent.

Data Offset (DOffset): 4 bits. The number of 32 bit words in the TCP Header. This indicates where the data begins. The TCP header (even one including options) is an integral number of 32 bits long.

Reserved (Rsrvd): 4 bits. A set of control bits reserved for future use. Must be zero in generated segments and must be ignored in received segments, if corresponding future features are unimplemented by the sending or receiving host.

CWR: 1 bit. Congestion Window Reduced

ECE: 1 bit.

ECN-Echo

URG: 1 bit. Urgent Pointer field significant

ACK: 1 bit. Acknowledgment field significant.

PSH: 1 bit. Push Function (see the Send Call description)

RST: 1 bit. Reset the connection

SYN: 1 bit. Synchronize sequence numbers

FIN: 1 bit. No more data from sender.

Window Size: 16 bits. The number of data octets beginning with the one indicated in the acknowledgment field that the sender of this segment is willing to accept.

The window size MUST be treated as an unsigned number, or else large window sizes will appear like negative windows and TCP will not work (MUST-1). It is RECOMMENDED that implementations will reserve 32-bit fields for the send and receive window sizes in the connection record and do all window computations with 32 bits (REC- 1).

Checksum: 16 bits. The checksum field is the 16 bit one's complement of the one's complement sum of all 16 bit words in the header and text. The checksum computation needs to ensure the 16-bit alignment of the data being summed. If a segment contains an odd number of header and text octets, alignment can be achieved by padding the last octet with zeros on its right to form a 16 bit word for checksum purposes. The pad is not transmitted as part of the segment. While computing the checksum, the checksum field itself is replaced with zeros.

Urgent Pointer: 16 bits. This field communicates the current value of the urgent pointer as a positive offset from the sequence number in this segment. The urgent pointer points to the sequence number of the octet following the urgent data. This field is only be interpreted in segments with the URG control bit set.

Options: [TCP Option]; Options#Size == (DOffset-5)*32; present only when DOffset > 5.

Options may occupy space at the end of the TCP header and are a multiple of 8 bits in length. All options are included in the checksum.

Payload. Payload.

3. TCP Options

A TCP Option is one of: a EOL Option, a NOOP Option, a Maximum Segment Size Option, a Window Scale Factor Option, a Timestamp Option, or a SACK Permitted Option.

An EOL Option is formatted as follows:

```
0               1               2               3
0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|           0           |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---
```

where:

Option Kind (Kind): 1 byte; Kind == 0. This option code indicates the end of the option list.

A NOOP Option is formatted as follows:

```
0               1               2               3
0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|           1           |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---
```

where:

Option Kind (Kind): 1 byte; Kind == 1. This option code can be used between options, for example, to align the beginning of a subsequent option on a word boundary.

A Maximum Segment Size Option is formatted as follows:

```
0               1               2               3
0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|           2           |   Length   | Maximum Segment Size (MSS) |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---
```

where:

Option Kind (Kind): 1 byte; Kind == 2.

If this option is present, then it communicates the maximum receive segment size at the TCP endpoint that sends this segment.

Option Length (Length): 1 byte; Length == 4. Option length.

Maximum Segment Size (MSS): 2 bytes. The maximum segment size allowed.

A Window Scale Factor Option is formatted as follows:

```

0                               1                               2                               3
0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|           3           |      Length      |      Window Scale Factor      |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
```

where:

Option Kind (Kind): 1 byte; Kind == 3. If present, this option carries the window scale factor.

Option Length (Length): 1 byte; Length == 3. Option length.

Window Scale Factor: 1 byte. Window scale factor.

A Timestamp Option is formatted as follows:

```

0                               1                               2                               3
0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|           8           |      Length      |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|                                     Timestamp value (TSval)                                     |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|                                     Timestamp echo reply (TSecr)                                     |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
```

where:

Option Kind (Kind): 1 byte; Kind == 8. If present, this option carries a timestamp and an echoed timestamp.

Option Length (Length): 1 byte; Length == 10. Option length.

Timestamp value (TSval): 4 bytes. TSval.

Timestamp echo reply (TSecr): 4 bytes. TSecr.

A SACK Permitted Option is formatted as follows:

```

0                               1                               2                               3
0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|           4           | Length |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
```

where:

Option Kind (Kind): 1 byte; Kind == 4. If present, this option indicates that SACK is permitted.

Option Length (Length): 1 byte; Length == 2. Option length.

4. Comparison with draft-ietf-tcpm-rfc793bis

While the purpose of this document is to give an example use of the Augmented Packet Header Diagrams, and not to contribute to ongoing or future TCP standardisation efforts, it is instructive to draw comparisons with documents that describe the same protocol. In particular, the descriptions of the TCP header ([Section 2](#)) and TCP options ([Section 3](#)) from this document can be compared with Section 3.1 of [[draft-ietf-tcpm-rfc793bis](#)]. We have adopted the same field descriptions to help with this comparison.

Beyond the broad similarities, there are a number of elements where this document describes the protocol differently. For example, the TCP header as defined in [[draft-ietf-tcpm-rfc793bis](#)] contains a variable-length padding field which is not present in the description contained in this document. The Padding field is used to pad the TCP header to a 32-bit boundary, and to ensure that the Payload begins on a 32-bit boundary. The length of the Padding field is the difference between the value of the Data Offset field and the length of the Options field. However, the length of the Options field is itself dependent on the value of the Data Offset field and the particular set of options contained within an instance of the TCP header. The Augmented Packet Header Diagram format cannot express this logic: the lengths of both the Padding and Payload fields would be variable. To overcome this, as shown in [Section 2](#), the description of TCP given in this document relies upon End of List options being syntactically identical to Padding (i.e., being all zeroes). This highlights the limitations of the Augmented Packet Header Diagram format: prose text is much more expressive.

However, the precision required by the Augmented Packet Header Diagram can be beneficial. For example, the description of the Options field in this document sets out an explicit length and presence constraint, where [[draft-ietf-tcpm-rfc793bis](#)] indicates that it is "variable". Similar constraints exist in the description

given in [[draft-ietf-tcpm-rfc793bis](#)], but they are contained with the prose description of the field.

In summary, the most striking comparison to be made is that the description of TCP given in this document is largely similar to that given in [[draft-ietf-tcpm-rfc793bis](#)]. By retaining the overall structure of a packet header diagram and an accompanying list of descriptions for each field, the Augmented Packet Header Diagram format is close to that already in use. This is encouraging: it indicates that the Augmented Packet Header Diagram language can be used to describe realistic protocols, without introducing a format that is unfamiliar or difficult to write.

5. IANA Considerations

This document contains no actions for IANA.

6. Security Considerations

The security implications of the Augmented Packet Header Diagrams format are considered in [[AUGMENTED-DIAGRAMS](#)].

7. Acknowledgements

This work has received funding from the UK Engineering and Physical Sciences Research Council under grant EP/R04144X/1.

8. Informative References

[AUGMENTED-DIAGRAMS]

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[RFC793] Postel, J., "Transmission Control Protocol", RFC 793, September 1981, <<https://www.rfc-editor.org/info/rfc793>>.

[draft-ietf-tcpm-rfc793bis]

Eddy, W., "Transmission Control Protocol (TCP) Specification", Work in Progress, Internet-Draft, draft-ietf-tcpm-rfc793bis-19, 27 October 2020, <<http://www.ietf.org/internet-drafts/draft-ietf-tcpm-rfc793bis-19.txt>>.

Appendix A. Source code repository

The source code for tooling that can be used to parse this document, and generate parser code for the protocol it describes, is available from <https://github.com/glasgow-ipl/ips-protodesc-code>.

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