2015

Evaluation of TCP Header Fields for Data Overhead Efficiency

Justin k. Yirka
Virginia Commonwealth University

VIRGINIA COMMONWEALTH UNIVERSITY

Evaluation of TCP header fields for data overhead efficiency

Justin Yirka - VCU Department of Computer Science
Mentor: Faye Prichard - VCU Honors College

Introduction

Internet speeds are often the most visible aspect of internet infrastructure. The demand for improved speeds motivates internet service providers and researchers to investigate ways to increase bandwidth, and to utilize existing bandwidth more efficiently.

Physical infrastructure related to bandwidth improvements is constricted by both cost and the pace of hardware development, often especially so in regions most in need of improvement. As such, research is ongoing to improve the efficiency and functionality of software infrastructure.

The transmission control protocol (TCP) is the primary protocol responsible for ensuring the reliable delivery of data on the internet, conveying over 90% of traffic [1]. Like many protocols, TCP requires additional data, overhead, to be transmitted with each packet in order to function.

With this in mind, I evaluated modern implementations of TCP header fields for efficient use of data overhead in order to identify waste and to suggest possible areas for revision and for future research.

TCP Background

TCP is a transport layer protocol. The transport layer is responsible for ensuring reliable, resource-efficient delivery of data through segmentation of data into packets, acknowledgment of receipt, congestion control, and multiplexing of open connections [2][3]. TCP has been updated and modified several times since its introduction in 1981 in order to extend its functionality beyond its original capabilities.

The TCP header, included with every TCP segment, includes fields which identify the connection, manage congestion control mechanisms between two points, and help ensure data integrity.

The TCP header is a minimum of 20 bytes [4]. [1] found that approximately 37% of TCP segments trended toward the ethernet maximum segment size of 1500 bytes, and 44% of packets trended toward the TCP/IP minimum of 40 bytes, with most other packets between those two modes. This means that the TCP overhead ratio generally ranges from about 1% to up to 50% of the segment. Additional overhead from other protocols is also present in each segment, increasing the total overhead ratio.

Acknowledgements

Thank you to Professor Faye Prichard for her mentorship and support, and to the whole VCU Honors College program.

Results

I examined original specifications for TCP mechanisms and then compared them to modern needs and implementations.

Various sources, including updated standards, documentation of current practices, and usage statistics, were used to evaluate the frequency of use as well as the necessity of each header field.

While many possible improvements exist, only those which maintain current functionality and continue to fulfill the purpose of TCP were considered. Some improvements take advantage of TCP options, accepting sporadic increases for a net reduction.

Clearly Inefficient Fields
- URG Flag and Urgent Pointer: No longer used. Only maintained for legacy purposes [5].
- Reserved Bits: No standardized use. Since 1981, only 2 bits (CWR, ECE) standardized. Effectively redundant given easily extendable TCP options.

Improvable Inefficient Fields
- Window: Periodically communicates window for congestion control. Better sent as option.
- ECN Bits (CWR, ECE): Additional congestion control, not well implemented. Work is still needed to evaluate necessity.
- Control Flags: Only used in a small number of packets. More efficient as a TCP option.
- Padding: Limitation due to mismatch between option lengths and data offset specification.

```
 0 1 2 3 4 5 6 7 0 1 2 3 4 5 6 7 0 1 2 3 4 5 6 7 0 1 2 3 4 5 6 7
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|          Source Port          |       Destination Port        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                        Sequence Number                        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                    Acknowledgment Number                      |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|  Data |       |C|E|U|A|P|R|S|F|                               |
| Offset|Reserv.|W|C|R|C|S|S|Y|I|            Window             |
|       |       |R|E|G|K|H|T|N|N|                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|           Checksum            |         Urgent Pointer        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                    Options                    |    Padding    |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                             data                              |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Fig. 1: Annotated TCP Header — Adapted from [4, Fig. 3]

Further Information

Justin Yirka – YirkaJk@vcu.edu
B.S. in Computer Science and in Mathematical Sciences, VCU, Class of 2018

Conclusions

Current inefficiency in the data overhead of TCP should be addressed because many of the header fields are either clearly wasteful or would be more efficient alternatively implemented.

Core design features of TCP, such as the sequencing and acknowledgment numbers, are generally beyond the scope of this discussion, as modification would alter TCP's current functionality. Other features, such as the header checksum, are integral to the purpose of the protocol.

However, most fields are arguably inefficient as they either are not a continuing necessity for TCP's function or they may be more efficiently implemented as TCP options. Further, several fields are no longer widely used and are effectively totally wasteful.

The proposed areas of improvement to TCP could result in a reduction of over 5 bytes per segment.

Admittedly, the savings per individual segment are a small percentage of many packets. However, this savings has the potential to result in a traffic reduction orders of magnitude greater across the general internet.

This savings is especially relevant in the context of TCP acknowledgment packets, often composed of 100% TCP/IP overhead.

This potential suggests a need for further research into the viability of TCP header revision, followed by implementation of proposals. A range of parties have stake in this suggestion, including consumers, content providers, and ISPs.

Finally, I note that results and methods presented are relevant to a range of other ongoing research (e.g., header compression, TCP acknowledgement reduction, overhead modeling).

Works Cited

[1] W. John and S. Tafvelin. Analysis of Internet Backbone Traffic and Header Anomalies Observed. presented at IMC'07 [Online].
[2] *Information technology - Open Systems Interconnection - Basic Reference Model: The Basic Model*, ISO/IEC 7498, 1994. [Online].
[3] Microsoft, Redmond, WA, USA. (2014).*The OSI Model's Seven Layers Defined and Functions Explained*. [Online].
[4] *Transmission Control Protocol*, RFC 793, 1981. [Online].
[5] F. Gont and A. Yourtchenko, "On the Implementation of the TCP Urgent Mechanism," RFC Editor, RFC 6093, 2011. [Online].