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C. Huitema
Private Octopus Inc.
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Evaluation of a Sample of RFCs Produced in 2018

Abstract

This document presents the author's effort to understand the delays involved in publishing an idea in the IETF or through the Independent Stream, from the first individual draft to the publication of the RFC. We analyze a set of randomly chosen RFCs approved in 2018, looking for history and delays. We also use two randomly chosen sets of RFCs published in 2008 and 1998 for comparing delays seen in 2018 to those observed 10 or 20 years ago. The average RFC in the 2018 sample was produced in 3 years and 4 months, of which 2 years and 10 months were spent in the working group, 3 to 4 months for IETF consensus and IESG review, and 3 to 4 months in RFC production. The main variation in RFC production delays comes from the AUTH48 phase.

We also measure the number of citations of the chosen RFC using Semantic Scholar, and compare citation counts with what we know about deployment. We show that citation counts indicate academic interest, but correlate only loosely with deployment or usage of the specifications. Counting web references could complement that.

Status of This Memo

This document is not an Internet Standards Track specification; it is published for informational purposes.

This is a contribution to the RFC Series, independently of any other RFC stream. The RFC Editor has chosen to publish this document at its discretion and makes no statement about its value for implementation or deployment. Documents approved for publication by the RFC Editor are not candidates for any level of Internet Standard; see Section 2 of RFC 7841.

Information about the current status of this document, any errata, and how to provide feedback on it may be obtained at https://www.rfc-editor.org/info/rfc8963.

Copyright Notice

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1. Introduction

As stated on the organization's web site, "The IETF is a large open international community of network designers, operators, vendors, and researchers concerned with the evolution of the Internet architecture and the smooth operation of the Internet." The specifications produced by the IETF are published in the RFC series, along with documents from the IAB, IRTF, and Independent streams (as per RFC 8729). In this memo, the author attempts to understand the delays involved in publishing an idea in the IETF or through the Independent Stream, from the first individual draft to the publication of the RFC. This is an individual effort, and the author's conclusions presented here are personal. There was no attempt to seek IETF consensus.

The IETF keeps records of documents and process actions in the IETF Datatracker [TRKR]. The IETF Datatracker provides information about RFCs and drafts, from which we can infer statistics about the production system. We can measure how long it takes to drive a proposition from initial draft to final publication, and how these delays can be split between working group discussions, IETF reviews, IESG assessment, RFC Editor delays and final reviews by the authors -- or, for Independent Stream RFCs, draft production, reviews by the Independent Submissions Editor, conflict reviews, RFC Editor delays and final reviews. Tracker data is available for all RFCs, not just IETF Stream RFCs.

Just measuring production delays may be misleading. If the IETF or the other streams simply rubber-stamped draft proposals and published them, the delays would be short but the quality and impact might suffer. We hope that most of the RFCs that are published are useful, but we need a way to measure that usefulness. We try to do that by measuring the number of references of the published RFCs in Semantic Scholar [SSCH], and also by asking the authors of each RFC in the sample whether the protocols and technologies defined in the RFCs were implemented and used on the Internet. The citations measured by the Semantic Scholar include citations in other RFCs and in Internet-Drafts. We also measure the number of references on the web, which provides some results but would be hard to automate.

In order to limit the resources required for this study, we selected at random 20 RFCs published in 2018, as explained in Section 2.2. The statistical sampling picked both IETF Stream and Independent Stream documents. For comparison purposes, we also selected at random 20 RFCs published in 1998 and 20 published in 2008. Limiting the sample to 20 out of 209 RFCs published in 2018 allows for in-depth analysis of each RFC, but readers should be reminded that the this is a small sample. The sample is too small to apply general statistical techniques and quantify specific ratios, and discussions of correlation techniques would be inappropriate. Instead, the purpose is to identify trends, spot issues, and document future work.

The information gathered for every RFC in the sample is presented in Section 3. In Section 4, we analyze the production process and the sources of delays, comparing the 2018 sample to the selected samples for 1998 and 2018. In Section 5.1, we present citation counts for the RFCs in the samples, and analyze whether citation counts could be used to evaluate the quality of RFCs.

The measurement of delays could be automated by processing dates and events recorded in the Datatracker. The measurement of published RFCs could be complemented by statistics on abandoned drafts, which would measure the efficiency of the IETF triaging process. More instrumentation would help understanding how large delays happen during working group processes. These potential next steps are developed in Section 6.

2. Methodology

The study reported here started with a simple idea: take a sample of RFCs, and perform an in-depth analysis of the path from the first presentation of the idea to its publication, while also trying to access the success of the resulting specification. This requires defining the key milestones that we want to track, and drawing a random sample using an unbiased process.

2.1. Defining the Important Milestones

The IETF Datatracker records a list of events for each document processed by IETF working groups. This has a high granularity, and also a high variability. Most documents start life as an individual draft, are adopted by a working group, undergo a Working Group Last Call, are submitted to the IESG, undergo an IETF Last Call and an IESG review, get eventually approved by the IESG, and are processed for publication by the RFC Editor, but there are exceptions. Some documents are first submitted to one working group and then moved to another. Some documents are published through the Independent Stream, and are submitted to the Independent Submissions Editor instead of the IESG.

In order to simplify tabulation, we break the period from the submission of the first draft to the publication of the RFC into three big components:

* The working group processing time, from the first draft to the start of the IETF last call;

* The IETF processing time, which lasts from the beginning of the IETF last call to the approval by the IESG, including the reviews by various directorates;

* The RFC production, from approval by the IESG to publication, including the AUTH48 reviews.

For submissions to the Independent Stream, we don’t have a working group. We consider instead the progression of the individual draft until the adoption by the Independent Submissions Editor (ISE) as the equivalent of the "Working Group" period, and the delay from adoption by the ISE until submission to the RFC Editor as the equivalent of the IETF processing time.

We measure the starting point of the process using the date of submission of the first draft listed on that RFC page in the IETF Datatracker. In most cases, this first draft is an individual draft that then resubmitted as a working group draft, or maybe resubmitted with a new name as the draft was searching for a home in an IETF working group, or before deciding for submission on the Independent Stream.

The IETF Datatracker entries for RFCs and drafts do not _always_ list working group events like Working Group Last Call. The only intermediate event that we list between the first draft and the submission to the IESG is the working group adoption, for which we use the date of submission of version 00 of the draft eventually published as RFC. We also use that date (of submission of version 00) for drafts submitted to the Independent Stream.

2.2. Selecting a Random Sample of RFCs

Basic production mechanisms could be evaluated by processing data from the IETF Datatracker, but subjective data requires manual assessment of results, which can be time-consuming. Since our resources are limited, we will only perform this analysis for a small sample of RFCs, selected at random from the list of RFCs approved in 2018. Specifically, we will pick 20 RFC numbers at random between:

* RFC 8307, published in January 2018, and

* RFC 8511, published December 2018.

The list of 20 selected RFCs is: RFC 8411, RFC 8456, RFC 8446, RFC 8355, RFC 8441, RFC 8324, RFC 8377, RFC 8498, RFC 8479, RFC 8453, RFC 8429, RFC 8312, RFC 8492 , RFC 8378, RFC 8361, RFC 8472, RFC 8471, RFC 8466, RFC 8362, and RFC 8468.

When evaluating delays and impact, we will compare the year 2018 to 2008 and 1998, 10 and 20 years ago. To drive this comparison, we pick 20 RFCs at random among those published in 2008, and another 20 among those published in 1998.

The list of the 20 randomly selected RFCs from 2008 is: RFC 5227, RFC 5174, RFC 5172, RFC 5354, RFC 5195, RFC 5236, RFC 5348, RFC 5281, RFC 5186, RFC 5326, RFC 5277, RFC 5373, RFC 5404, RFC 5329, RFC 5283, RFC 5358, RFC 5142, RFC 5271, RFC 5349, and RFC 5301.

The list of the 20 randomly selected RFCs from 1998 is: RFC 2431, RFC 2381, RFC 2387, RFC 2348, RFC 2391, RFC 2267, RFC 2312, RFC 2448, RFC 2374, RFC 2398, RFC 2283, RFC 2382, RFC 2289, RFC 2282, RFC 2404, RFC

2449, RFC 2317, RFC 2394, RFC 2297, and RFC 2323.

2.3. Conventions Used in This Document

The following abbreviations are used in the tables:

BCP	Best Current Practice
Exp	Experimental
Info	Informational
PS	Proposed Standard
DS	Draft Standard [This maturity level was retired by RFC 6410.]

In addition, Status is as defined in RFC 2026, and Stream is as defined in RFC 8729.

3. Analysis of 20 Selected RFCs

We review each of the RFCs listed in Section 2.2 for the year 2018, trying both to answer the known questions and to gather insight for further analyses. In many cases, the analysis of the data is complemented by direct feedback from the RFC authors.

3.1. RFC 8411

"IANA Registration for the Cryptographic Algorithm Object Identifier Range" [RFC8411]:

Status (Length):	Informational (5 pages)
Overview:	4 individual drafts
First draft:	2017-05-08
Last Call start:	2017-10-09
IESG eval. start:	2017-12-28
IESG approved:	2018-02-26 (draft 03)
AUTH48 start:	2018-04-20
AUTH48 complete:	2018-07-17
Published:	2018-08-06
IANA action:	create table

This RFC was published from the individual draft, which was not resubmitted as a working group draft.

The draft underwent minor copy editing before publication.

Some but not all of the long delay in AUTH48 is due to clustering with [RFC8410]. MISSREF state concluded on 2018-05-09 and the document re-entered AUTH48 at once. AUTH48 lasted over two months after that. (For state definitions, see <https://www.rfc-editor.org/about/queue/#state_def>.)

The time after AUTH48 and before publication (3 weeks) partly overlaps with travel for IETF 102 and is partly due to coordinating the cluster.

3.2. RFC 8456

"Benchmarking Methodology for Software-Defined Networking (SDN) Controller Performance" [RFC8456]:

Status (Length):	Informational (64 pages)
Overview:	2 individual drafts; 9 WG drafts
First draft:	2015-03-23
WG adoption:	2015-10-18
Last Call start:	2018-01-19
IESG eval. start:	2018-02-27
IESG approved:	2018-05-25
AUTH48 start:	2018-08-31

AUTH48 complete:	2018-10-16
Published:	2018-10-30

The draft underwent extensive copy editing, covering use of articles, syntax, and word choice. The changes are enough to cause pagination differences. The "diff" tool marks pretty much every page as changed. Some diagrams see change in protocol elements like message names.

According to the author, the experience of producing this document mirrors a typical one in the Benchmarking Methodologies Working Group (BMWG). There were multiple authors in multiple time zones, which slowed down the AUTH48 process somewhat, although the AUTH48 delay of 46 days is only a bit longer than the average draft.

The RFC was part of cluster with [RFC8455].

BMWG publishes Informational RFCs centered around benchmarking, and the methodologies in RFC 8456 have been implemented in benchmarking products.

3.3. RFC 8446

"The Transport Layer Security (TLS) Protocol Version 1.3" [RFC8446], as the title indicates, defines the new version of the TLS protocol. From the IETF Datatracker, we extract the following:

Status (Length):	Proposed Standard (160 pages)
Overview:	29 WG drafts
First draft:	2014-04-17
Last Call start:	2018-02-15
IESG eval. start:	2018-03-02
IESG approved:	2018-03-21 (draft 28)
AUTH48 start:	2018-06-14
AUTH48 complete:	2018-08-10
Published:	2018-08-10

This draft started as a WG effort.

The RFC was a major effort in the IETF. Working group participants developed and tested several implementations. Researchers analyzed the specifications and performed formal verifications. Deployment tests outlined issues that caused extra work when the specification was almost ready. This complexity largely explains the time spent in the working group.

Comparing the final draft to the published version, we find relatively light copy editing. It includes explaining acronyms on first use, clarifying some definitions standardizing punctuation and capitalization, and spelling out some numbers in text. This generally fall in the category of "style", although some of the clarifications go into message definitions. However, that simple analysis does not explain why the AUTH48 phase took almost two months.

This document’s AUTH48 process was part of the "GitHub experiment", which tried to use GitHub pull requests to track the AUTH48 changes and review comments. The RFC Production Center (RPC) staff had to learn using GitHub for that process, and this required more work than the usual RFC. The author and AD thoroughly reviewed each proposed edit, accepting some and rejecting some. The concern there was that any change in a complex specification might affect a protocol that was extensively reviewed in the working group, but of course these reviews added time to the AUTH48 delays.

There are 21 implementations listed in the Wiki of the TLS 1.3

project [TLS13IMP]. It has been deployed on major browsers, and is already used in a large fraction of TLS connections.

3.4. RFC 8355

"Resiliency Use Cases in Source Packet Routing in Networking (SPRING) Networks" [RFC8355] is an Informational RFC. It originated from an informational use-case draft; it was mostly used for the BOF creating the WG, and then to drive initial work and evolutions from the WG.

Status (Length):	Informational (13 pages)
Overview:	2 individual drafts; 13 WG drafts
First draft:	2014-01-31
WG adoption:	2014-05-13
Last Call start:	2017-04-20
IESG eval. start:	2017-05-04 (draft 09)
IESG approved:	2017-12-19 (draft 12)
AUTH48 start:	2018-03-12
AUTH48 complete:	2018-03-27
Published:	2018-03-28

Minor set of copy edits, mostly for style.

No implementation of the RFC itself, but the technology behind it (such as Segment Routing Architecture [RFC8402] and TI-LFA [TI-LFA]) is widely implemented and deployment is ongoing.

According to participants in the discussion, the process of adoption of the source packet routing standards was very contentious. The establishment of consensus at both the working group level and the IETF level was difficult and time-consuming.

3.5. RFC 8441

"Bootstrapping WebSockets with HTTP/2" [RFC8441]

Status (Length):	Proposed Standard (8 pages)
Overview:	3 individual drafts; 8 WG drafts; Updates RFC 6455
First draft:	2017-10-15
WG adoption:	2017-12-19
Last Call start:	2018-05-07 (draft 05)
IESG eval. start:	2018-05-29 (draft 06)
IESG approved:	2018-06-18 (draft 07)
AUTH48 start:	2018-08-13
AUTH48 complete:	2018-09-15
Published:	2018-09-18
IANA action:	table entries

This RFC defines the support of WebSockets in HTTP/2, which is different from the mechanism defined for HTTP/1.1 in [RFC6455]. The process was relatively straightforward, involving the usual type of discussions, some on details and some on important points.

Comparing the final draft and published RFC shows a minor set of copy edits, mostly for style. However, the author recalls a painful process. The RFC includes many charts and graphs that were very difficult to format correctly in the author’s production process that involved conversions from markdown to XML, and then from XML to text. The author had to get substantial help from the RFC Editor.

There are several implementations, including Firefox and Chrome, making RFC 8441 a very successful specification.

3.6. RFC 8324

"DNS Privacy, Authorization, Special Uses, Encoding, Characters, Matching, and Root Structure: Time for Another Look?" [RFC8324]. This is an opinion piece on DNS development, published on the Independent Stream.

```
Status (Length):    Informational (29 pages)
Overview:           5 individual drafts; Independent Stream
First draft:        2017-06-02
ISE review start:   2017-07-10 (draft 03)
IETF conflict review start:  2017-10-29
Approved:           2017-12-18 (draft 04)
AUTH48 start:       2018-01-29 (draft 05)
AUTH48 complete:    2018-02-26
Published:          2018-02-27
```

This RFC took only 9 months from first draft to publication, which is the shortest in the 2018 sample set. In part, this is because the text was privately circulated and reviewed by the ISE’s selected experts before the first draft was published. The nature of the document is another reason for the short delay. It is an opinion piece and does not require the same type of consensus building and reviews as a protocol specification.

Comparing the final draft and the published version shows only minor copy edits, mostly for style. According to the author, this is because he knows how to write in RFC style with the result that his documents often need a minimum of editing. He also makes sure that the document on which the RFC Production Center starts working already has changes discussed and approved during Last Call and IESG review incorporated, rather than expecting the Production Center to operate off of notes about changes to be made.

3.7. RFC 8377

"Transparent Interconnection of Lots of Links (TRILL): Multi-Topology" [RFC8377]

```
Status (Length):    Proposed Standard (20 pages)
Overview:           3 individual drafts; 7 WG drafts; Updates RFCs
                    6325 and 7177
First draft:        2013-09-03
WG adoption:        2015-09-01
Last Call start:    2018-02-19 (draft 05)
IESG eval. start:   2018-03-06 (draft 05)
IESG approved:      2018-03-12 (draft 06)
AUTH48 start:       2018-04-20 (draft 06)
AUTH48 complete:    2018-07-31
Published:          2018-07-31
IANA action:        table entries
```

Minor set of copy edits, mostly for style, also clarity.

3.8. RFC 8498

"A P-Served-User Header Field Parameter for an Originating Call Diversion (CDIV) Session Case in the Session Initiation Protocol (SIP)" [RFC8498].

```
Status (Length):    Informational (15 pages)
Overview:           5 individual drafts; 9 WG drafts
First draft:        2016-03-21
WG adoption:        2017-05-15
Last Call start:    2018-10-12 (draft 05)
IESG eval. start:   2018-11-28 (draft 07)
IESG approved:      2018-12-11 (draft 08)
AUTH48 start:       2019-01-28
```

AUTH48 complete: 2019-02-13
Published: 2019-02-14
IANA action: table rows added.

Copy edits for style, but also clarification of ambiguous sentences.

3.9. RFC 8479

"Storing Validation Parameters in PKCS#8" [RFC8479]

```
Status (Length):    Informational (8 pages)
Overview:           5 individual drafts; Independent Stream
First draft:        2017-08-08
ISE review start:   2018-12-10 (draft 00)
IETF conflict review start:  2018-03-29
Approved:           2018-08-20 (draft 03)
AUTH48 start:       2018-09-20 (draft 04)
AUTH48 complete:    2018-09-25
Published:          2018-09-26
```

The goal of the draft was to document what the gnutls implementation was using for storing provably generated RSA keys. This is a short RFC that was published relatively quickly, although discussion between the author, the Independent Submissions Editor, and the IESG lasted several months. In the initial conflict review, the IESG asked the ISE to not publish this document before IETF working groups had an opportunity to pick up the work. The author met that requirement by a presentation to the SECDISPATCH WG during IETF 102. Since no WG was interested in picking up the work, the document progressed on the Independent Stream.

Very minor set of copy edits, moving some references from normative to informative.

The author is not aware of other implementations than gnutls relying on this RFC.

3.10. RFC 8453

"Framework for Abstraction and Control of TE Networks (ACTN)" [RFC8453]

```
Status (Length):    Informational (42 pages)
Overview:           3 individual drafts; 16 WG drafts
First draft:        2015-06-15
WG adoption:        2016-07-15
Out of WG:          2018-01-26 (draft 11)
Expert review requested:  2018-02-13
Last Call start:    2018-04-16 (draft 13)
IESG eval. start:   2018-05-16 (draft 14)
IESG approved:      2018-06-01 (draft 15)
AUTH48 start:       2018-08-13
AUTH48 complete:    2018-08-20
Published:          2018-08-23
IANA action:        table rows added.
```

Minor copy editing.

3.11. RFC 8429

"Deprecate Triple-DES (3DES) and RC4 in Kerberos" [RFC8429]

```
Status (Length):    BCP (10 pages)
Overview:           6 WG drafts
First draft:        2017-05-01
Last Call start:    2017-07-16 (draft 03)
```

IESG eval. start: 2017-08-18 (draft 04)
IESG approved: 2018-05-25 (draft 05)
AUTH48 start: 2018-07-24
AUTH48 complete: 2018-10-31
Published: 2018-10-31
IANA action: table rows added.

This draft started as a working group effort.

This RFC recommends deprecating two encryption algorithms that are now considered obsolete and possibly broken. The document was sent back to the WG after the first Last Call, edited, and then there was a second Last Call. The delay from first draft to Working Group Last Call was relatively short, but the number may be misleading. The initial draft was a replacement of a similar draft in the KITTEN Working Group, which stagnated for some time before the CURDLE Working Group took up the work. The deprecation of RC4 was somewhat contentious, but the WG had already debated this prior to the production of this draft, and the draft was not delayed by this debate.

Most of the 280 days between IETF LC and IESG approval were because the IESG had to talk about whether this document should obsolete RFC 4757 or move it to Historic status, and no one was really actively pushing that discussion for a while.

The 99 days in AUTH48 are mostly because one of the authors was a sitting AD, and those duties ended up taking precedence over reviewing this document.

Minor copy editing, for style.

The implementation of the draft would be the actual removal of support for 3DES and RC4 in major implementations. This is happening, but very slowly.

3.12. RFC 8312

"CUBIC for Fast Long-Distance Networks" [RFC8312]

Status (Length):   Informational (18 pages)
Overview: 2 individual drafts; 8 WG drafts
First draft: 2014-09-01
WG adoption: 2015-06-08
Last Call start: 2017-09-18 (draft 06)
IESG eval. start: 2017-10-04
IESG approved: 2017-11-14 (draft 07)
AUTH48 start: 2018-01-08
AUTH48 complete: 2018-02-07
Published: 2018-02-07
IANA action: table rows added.

Minor copy editing, for style.

The TCP congestion control algorithm Cubic was first defined in 2005, was implemented in Linux soon after, and was implemented in major OSes after that. After some debates from 2015 to 2015, the TCPM Working Group adopted the draft, with a goal of documenting Cubic in the RFC Series. According to the authors, this was not a high-priority effort, as Cubic was already implemented in multiple OSes and documented in research papers. At some point, only one of the authors was actively working on the draft. This may explain why another two years was spent progressing the draft after adoption by the WG.

The RFC publication may or may not have triggered further implementations. On the other hand, several OSes picked up bug fixes from the draft and the RFC.

3.13. RFC 8492

"Secure Password Ciphersuites for Transport Layer Security (TLS)" [RFC8492]

Status (Length):	Informational (40 pages)
Overview:	10 individual drafts; 8 WG drafts; Independent Stream
First draft:	2012-09-07
Targeted to ISE:	2016-08-05
ISE review start:	2017-05-10 (draft 01)
IETF conflict review start:	2017-09-04
Approved:	2017-10-29 (draft 02)
AUTH48 start:	2018-10-19 (draft 05)
AUTH48 complete:	2019-02-19
Published:	2019-02-21
IANA action:	table rows added.

This RFC has a complex history. The first individual draft was submitted to the TLS Working Group on September 7, 2012. It progressed there, and was adopted by the WG after 3 revisions. There were then 8 revisions in the TLS WG, until the WG decided to not progress it. The draft was parked in 2013 by the WG chairs after failing to get consensus in WG Last Call. The AD finally pulled the plug in 2016, and the draft was then resubmitted to the ISE.

At that point, the author was busy and was treating this RFC with a low priority because, in his words, it would not be a "real RFC". There were problems with the draft that only came up late. In particular, it had to wait for a change in registry policy that only came about with the publication of TLS 1.3, which caused the draft to be published after RFC 8446, and also required adding references to TLS 1.3. The author also got a very late comment while in AUTH48 that caused some rewriting. Finally, there was some IANA issue with the extension registry where a similar extension was added by someone else. The draft was changed to just use it.

Changes in AUTH48 include adding a reference to TLS 1.3, copy editing for style, some added requirements, added paragraphs, and changes in algorithms specification.

3.14. RFC 8378

"Signal-Free Locator/ID Separation Protocol (LISP) Multicast" [RFC8378] is an Experimental RFC, defining how to implement Multicast in the LISP architecture.

Status (Length):	Experimental (21 pages)
Overview:	5 individual drafts; 10 WG drafts
First draft:	2014-02-28
WG adoption:	2015-12-21
Last Call start:	2018-02-13 (draft 07)
IESG eval. start:	2018-02-28 (draft 08)
IESG approved:	2018-03-12 (draft 09)
AUTH48 start:	2018-04-23
AUTH48 complete:	2018-05-02
Published:	2018-05-02

Preparing the RFC took more than 4 years. According to the authors, they were not aggressively pushing it and just let the working group process decide to pace it. They also did implementations during that time.

Minor copy editing, for style.

The RFC was implemented by lispers.net and Cisco, and it was used in doing IPv6 multicast over IPv4 unicast/multicast at the Olympics in PyeungChang. The plan is to work on a Proposed Standard once the experiment concludes.

3.15. RFC 8361

"Transparent Interconnection of Lots of Links (TRILL): Centralized Replication for Active-Active Broadcast, Unknown Unicast, and Multicast (BUM) Traffic" [RFC8361]

Status (Length):	Proposed Standard (17 pages)
Overview:	3 individual drafts; 14 WG drafts
First draft:	2013-11-12
WG adoption:	2014-12-16
Last Call start:	2017-11-28 (draft 10)
IESG eval. start:	2017-12-18 (draft 11)
IESG approved:	2018-01-29 (draft 13)
AUTH48 start:	2018-03-09
AUTH48 complete:	2018-04-09
Published:	2018-04-12

According to the authors, the long delays in producing this RFC were due to a slow uptake of the technology in the industry.

Minor copy editing, for style.

There was at least one partial implementation.

3.16. RFC 8472

"Transport Layer Security (TLS) Extension for Token Binding Protocol Negotiation" [RFC8472]

Status (Length):	Proposed Standard (8 pages)
Overview:	1 individual draft; 15 WG drafts
First draft:	2015-05-29
WG adoption:	2015-09-11
Last Call start:	2017-11-13 (draft 10)
IESG eval. start:	2018-03-19
IESG approved:	2018-07-20 (draft 14)
AUTH48 start:	2018-09-17
AUTH48 complete:	2018-09-25
Published:	2018-10-08

This is a pretty simple document, but it took over 3 years from individual draft to RFC. According to the authors,the biggest setbacks occurred at the start: it took a while to find a home for this draft. It was presented in the TLS WG (because it’s a TLS extension) and UTA WG (because it has to do with applications using TLS). Then the ADs determined that a new WG was needed, so the authors had to work through the WG creation process, including running a BOF.

Minor copy editing, for style, with the addition of a reference to TLS 1.3.

Perhaps partially due to the delays, some of the implementers lost interest in supporting this RFC.

3.17. RFC 8471

"The Token Binding Protocol Version 1.0" [RFC8471]

```
Status (Length):    Proposed Standard (18 pages)
Overview:           1 individual draft; 19 WG drafts
First draft:        2014-10-13
WG adoption:        2015-03-15
Last Call start:    2017-11-13 (draft 16)
IESG eval. start:   2018-03-19
IESG approved:      2018-07-20 (draft 19)
AUTH48 start:       2018-09-17
AUTH48 complete:    2018-09-25
Published:          2018-10-08
```

This document presents a Token Binding Protocol for TLS. We can notice a period of 5 months before adoption of the draft by the WG. That explains in part the overall time of almost 4 years from first draft to publication.

Minor copy editing, for style.

The web references indicate adoption in multiple development projects.

3.18. RFC 8466

"A YANG Data Model for Layer 2 Virtual Private Network (L2VPN) Service Delivery" [RFC8466]

```
Status (Length):    Proposed Standard (158 pages)
Overview:           5 individual drafts; 11 WG drafts
First draft:        2016-09-01
WG adoption:        2017-02-26
Last Call start:    2018-02-21 (draft 07)
IESG eval. start:   2018-03-14 (draft 08)
IESG approved:      2018-06-25 (draft 10)
AUTH48 start:       2018-09-17
AUTH48 complete:    2018-10-09
Published:          2018-10-12
```

Copy editing for style and clarity, with also corrections to the YANG model.

3.19. RFC 8362

"OSPFv3 Link State Advertisement (LSA) Extensibility" [RFC8362] is a major extension to the OSPF protocol. It makes OSPFv3 fully extensible.

```
Status (Length):    Proposed Standard (33 pages)
Overview:           4 individual drafts; 24 WG drafts
First draft:        2013-02-17
WG adoption:        2013-10-15
Last Call start:    2017-12-19 (draft 19)
IESG eval. start:   2018-01-18 (draft 20)
IESG approved:      2018-01-29 (draft 23)
AUTH48 start:       2018-03-19
AUTH48 complete:    2018-03-30
Published:          2018-04-03
```

The specification was first submitted as an individual draft in the IPv6 WG, then moved to the OSPF WG. The long delay of producing this RFC is due to the complexity of the problem, and the need to wait for implementations. It is a very important change to OSPF that makes OSPFv3 fully extensible. Since it was a non-backward compatible change, the developers started out with some very complex migration scenarios but ended up with either legacy or extended OSPFv3 LSAs within an OSPFv3 routing domain. The initial attempts to have a hybrid mode of operation with both legacy and extended LSAs also delayed implementation due to the complexity.

Copy editing for style and clarity.

This specification either was or will be implemented by all the router vendors.

3.20. RFC 8468

"IPv4, IPv6, and IPv4-IPv6 Coexistence: Updates for the IP Performance Metrics (IPPM) Framework" [RFC8468].

Status (Length):	Informational (15 pages)
Overview:	3 individual drafts; 7 WG drafts
First draft:	2015-08-06
WG adoption:	2016-07-04
Last Call start:	2018-04-11 (draft 04)
IESG eval. start:	2018-05-24 (draft 05)
IESG approved:	2018-07-10 (draft 06)
AUTH48 start:	2018-09-13
AUTH48 complete:	2018-11-05
Published:	2018-11-14

RFC 8468 was somehow special in that there was not a technical reason or interest that triggered it, but rather a formal requirement. While writing RFC 7312, the IP Performance Metrics (IPPM) Working Group realized that RFC 2330, the IP Performance Metrics Framework supported IPv4 only and explicitly excluded support for IPv6. Nevertheless, people used the metrics that were defined on top of RFC 2330 (and, therefore, IPv4 only) for IPv6, too. Although the IPPM WG agreed that the work was needed, the interest of IPPM attendees in progressing (and reading/reviewing) the IPv6 draft was limited. Resolving the IPv6 technical part was straightforward, but subsequently some people asked for a broader scope (topics like header compression, 6LoWPAN, etc.), and it took some time to figure out and later on convince people that these topics are out of scope. The group also had to resolve contentious topics, for example, how to measure the processing of IPv6 extension headers, which is sometimes nonstandard.

The time in AUTH48 state for this document was longer than average. According to the authors, the main reasons include:

* Workload and travel caused by busy work periods of all coauthors

* Time zone difference between coauthors and editor (at least US, Europe, and India, not considering travel)

* RFC Production Center proposed and committed some unacceptable modifications that needed to be reverted

* Lengthy discussions on a new document title (required high effort and took a long time, in particular reaching consensus between coauthors and editor was time-consuming and involved the AD)

* RFC Production Center correctly identified some nits (obsoleted personal websites of coauthors) and coauthors attempting to fix them.

The differences between the final draft and the published RFC show copy editing for style and clarity, but do not account for the back and forth between authors and editors mentioned by the authors.

4. Analysis of Process and Delays

We examine the 20 RFCs in the sample, measuring various characteristics such as delay and citation counts, in an attempt to identify patterns in the IETF processes.

4.1. Delays from First Draft to RFC

We look at the distribution of delays between the submission of the first draft and the publication of the RFC, using the three milestones defined in Section 2.1: processing time in the working group, IETF processing time, and RFC production time. The following table shows the number of days in each phase for the 20 RFCs in the sample:

RFC	Status	Pages	Overall	WG	IETF	Edit
8411	Info	5	455	154	140	161
8456	Info	64	1317	1033	126	158
8446	PS	160	1576	1400	34	142
8355	Info	13	1517	1175	243	99
8441	PS	8	327	204	31	92
8324	Info (ISE)	29	270	38	161	71
8377	PS	8	1792	1630	21	141
8498	Info	15	1059	935	59	65
8479	Info (ISE)	8	414	233	144	37
8453	Info	42	1165	1036	46	83
8429	BCP	10	548	76	313	159
8312	Info	18	1214	1113	16	85
8492	Info (ISE)	40	2358	1706	172	480
8378	Exp	21	1524	1446	27	51
8361	PS	17	1612	1477	62	73
8472	PS	8	1228	899	249	80
8471	PS	18	1228	899	249	80
8466	PS	158	771	538	124	109
8362	PS	33	1871	1766	41	64
8468	Info	15	1196	979	90	127
average		35	1172	948	117	118
average (not ISE)		36	1200	999	110	104

Table 1

The average delay from first draft to publication is about 3 years and 3 months, but this varies widely. Excluding the RFCs from the Independent Stream, the average delay from start to finish is 3 years and 4 months, of which on average 2 years and 9 months are spent getting consensus in the working group, and 3 to 4 months each for IETF consensus and for RFC production.

The longest delay is found for [RFC8492], 6.5 years from start to finish. This is however a very special case -- a draft that was prepared for the TLS Working Group and failed to reach consensus. After that, it was resubmitted to the ISE, and incurred atypical production delays.

On average, we see that 80% of the delay is incurred in WG processing, 10% in IETF review, and 10% for edition and publication.

For IETF Stream RFCs, it appears that the delays for Informational documents are slightly shorter than those for protocol specifications, maybe six months shorter on average. However, there are lots of differences between individual documents. The delays range from less than a year to more than 5 years for protocol specifications, and from a year and 3 months to a bit more than 4 years for Informational documents.

We can compare the delays in the 2018 samples to those observed 10 years ago and 20 years before:

RFC (2008)	Status	Pages	Delay
5326	Exp	54	1584
5348	PS	58	823
5281	Info	51	1308
5354	Exp	23	2315
5227	PS	21	2434
5329	PS	12	1980
5277	PS	35	912
5236	Info (ISE)	26	1947
5358	BCP	7	884
5271	Info	22	1066
5195	PS	10	974
5283	PS	12	1096
5186	Info	6	2253
5142	PS	13	1005
5373	PS	24	1249
5404	PS	27	214
5172	PS	7	305
5349	Info	10	1096
5301	PS	6	396
5174	Info	8	427

Table 2

RFC (1998)	Status	Pages	Delay
2289	PS	25	396
2267	Info	10	unknown
2317	BCP	10	485
2404	PS	7	488
2374	PS	12	289
2449	PS	19	273
2283	PS	9	153
2394	Info	6	365
2348	DS	5	699
2382	Info	30	396
2297	Info (ISE)	109	28
2381	PS	43	699
2312	Info	20	365
2387	PS	10	122
2398	Info	15	396
2391	PS	10	122
2431	PS	10	457
2282	Info	14	215
2323	Info (ISE)	5	unknown
2448	Info (ISE)	7	92

Table 3

We can compare the median delay, and the delays observed by the fastest and slowest quartiles in the three years:

Year	Fastest 25%	Median	Slowest 25%
2018	715	1221	1537
2008	869	1081	1675
1998	169	365	442

Table 4

The IETF takes three to four times more to produce an RFC in 2018 than it did in 1998, but about the same time as it did in 2008. We can get a rough estimate of how this translates in terms of "level of attention" per RFC by comparing the number of participants in the IETF meetings of 2018, 2008, and 1998 [IETFCOUNT] to the number of RFCs published these years [RFCYEAR].

Year	Number of RFCs	Spring P.	Summer P.	Fall P.	Average P.	Attendees/ RFC
2018	208	1235	1078	879	1064	5.1
2008	290	1128	1181	962	1090	3.8
1998	234	1775	2106	1705	1862	8.0

Table 5

The last column in the table provides the ratio of average number of participants to the number of RFCs published. If the IETF were a centralized organization, and if all participants and documents were equivalent, this ratio would be the number of participants dedicated to produce an RFC on a given year. This is of course a completely abstract figure because none of the hypotheses above are true, but it still gives a vague indication of the "level of attention" applied to documents. We see that this ratio has increased from 2008 to 2018, as the number of participants was about the same for these two years but the number of published RFCs decreased. However, this ratio was much higher in 1998. The IETF had many more participants, and there were probably many more eyes available to review any given draft. If we applied the ratios of 1998, the IETF would be producing 119 documents in 2018 instead of 208.

4.2. Working Group Processing Time

The largest part of the delays is spent in the working groups, before the draft is submitted to the IESG for IETF review. As mentioned in Section 2.1, the only intermediate milestone that we can extract from the IETF Datatracker is the date at which the document was adopted by the working group, or targeted for independent submission. The breakdown of the delays for the documents in our sample is:

RFC	Status	WG	Until adoption	After adoption
8411	Info	154	0	154
8456	Info	1033	209	824
8446	PS	1400	0	1400
8355	Info	1175	102	1073
8441	PS	204	65	139
8324	Info (ISE)	38	0	38
8377	PS	1630	728	902
8498	Info	935	420	515
8479	Info (ISE)	233	0	233
8453	Info	1036	396	640
8429	BCP	76	0	76

8312	Info	1113	280	833
8492	Info (ISE)	1706	1428	278
8378	Exp	1446	661	785
8361	PS	1477	399	1078
8472	PS	899	105	794
8471	PS	1127	153	794
8466	PS	538	178	360
8362	PS	1766	240	1526
8468	Info	979	333	646
Average		948	285	663

Table 6

The time before working group adoption averages to a bit more than 9 months, compared to 1 year and almost 10 months for processing time after adoption. We see that RFC 8492 stands out, with long delays spent attempting publication through a working group before submission to the Independent Submissions Editor. If we remove RFC 8492 from the list, the average time until adoption drops to just over 7 months, and becomes just 25% of the total processing time in the WG.

There are a few documents that started immediately as working group efforts, or were immediately targeted for publication in the Independent Stream. Those documents tend to see short processing times, with the exception of RFC 8446 on which the TLS Working Group spent a long time working.

4.3. Preparation and Publication Delays

The preparation and publication delays include three components:

* the delay from submission to the RFC Editor to beginning of AUTH48, during which the document is prepared (referred to as "RFC edit" below);

* the AUTH48 delay, during which authors review and eventually approve the changes proposed by the editors (referred to as "AUTH48" below);

* the publication delay, from final agreement by authors and editors to actual publication (referred to as "RFC Pub" below).

The breakdown of the publication delays for each RFC is shown in the following table.

RFC	Status	Pages	RFC edit	AUTH48	RFC Pub	Edit (total)
8411	Info	5	53	88	20	161
8456	Info	64	98	46	14	158
8446	PS	160	85	57	0	142

8355	Info	13	83	15	1	99
8441	PS	8	56	33	3	92
8324	Info (ISE)	29	42	28	1	71
8377	PS	8	39	102	0	141
8498	Info	15	48	16	1	65
8479	Info (ISE)	8	31	5	1	37
8453	Info	42	73	7	3	83
8429	BCP	10	60	99	0	159
8312	Info	18	55	28	2	85
8492	Info (ISE)	40	355	123	2	480
8378	Exp	21	42	9	0	51
8361	PS	17	39	31	3	73
8472	PS	8	59	8	13	80
8471	PS	18	59	8	13	80
8466	PS	158	84	22	3	109
8362	PS	33	49	11	4	64
8468	Info	15	65	53	9	127
Average			74	39	5	118
Average (without 8492)			59	35	5	99

Table 7

On average, the total delay appears to be about four months, but the average is skewed by the extreme values encountered for [RFC8492]. If we exclude that RFC from the computations, the average delay drops to a just a bit more than 3 months: about 2 months for the preparation, a bit more than one month for the AUTH48 phase, and 5 days for the publishing.

Of course, these delays vary from RFC to RFC. To try explain the causes of the delay, we compute the correlation factor between the observed delays and several plausible explanation factors:

* the number of pages in the document,

* the amount of copy editing, as discussed in Section 4.4,

* whether or not IANA actions were required,

* the number of authors,

* the number of draft revisions,

* the working group delay.

We find the following values:

Correlation	RFC edit	AUTH48	Edit(total)
Number of pages	0.50	-0.04	0.21
Copy-Edit	0.42	0.24	0.45
IANA	-0.14	-0.21	0.12
Number of authors	0.39	-0.07	0.18
Number of drafts	0.18	-0.33	-0.19
WG delay	0.03	-0.16	-0.15

Table 8

We see some plausible explanations for the production delay. It will be somewhat longer for longer documents or for documents that require a lot of copy editing (see Section 4.4). Somewhat surprisingly, it also tends to increase with the number of authors. It does not appear significantly correlated with the presence or absence of IANA action.

The analysis of RFC 8324 in Section 3.6 explains its short editing delays by the experience of the author. This makes sense: if a document needs less editing, the editing delays would be shorter. This is partially confirmed by the relation between the amount of copy editing and the publication delay.

We see fewer plausible explanations for the AUTH48 delays. These delays vary much more than the preparation delay, with a standard deviation of 20 days for AUTH48 versus 10 days for the preparation delay. In theory, AUTH48 is just a final verification: the authors receive the document prepared by the RFC production center, and just have to give their approval, or maybe request a last minute correction. The name indicates that this is expected to last just two days, but in average it lasts more than a month.

We often hypothesize that the number of authors influences the AUTH48 delay, or that authors who have spent a long time working on the document in the working group somehow get demotivated and spend even longer to answer questions during AUTH48. This may happen sometimes, but our statistics don’t show that - if anything, the numerical results point in the opposite direction.

After asking the authors of the RFCs in the sample why the AUTH48 phase took a long time, we got three explanations:

1. Some RFCs have multiple authors in multiple time zones. This slows down the coordination required for approving changes.

2. Some authors found some of the proposed changes unnecessary or undesirable, and asked that they be reversed. This required long exchanges between authors and editors.

3. Some authors were not giving high priority to AUTH48 responses.

As mentioned above, we were not able to verify these hypotheses by looking at the data. The author’s experience with this document suggests another potential delay for the Independent Stream RFC: processing delay by the Independent Submissions Editor, discussed in Section 4.5.

4.4. Copy Editing

We can assess the amount of copy editing applied to each published RFC by comparing the text of the draft approved for publication and the text of the RFC. We do expect differences in the "boilerplate" and in the IANA section, but we will also see differences due to copy editing. Assessing the amount of copy editing is subjective, and we do it using a scale of 1 to 4:

1: Minor editing

2: Editing for style, such as capitalization, hyphens, "that" versus "which", and expanding all acronyms at least once.

3: Editing for clarity in addition to style, such as rewriting ambiguous sentences and clarifying use of internal references. For YANG models, that may include model corrections suggested by the verifier.

4: Extensive editing.

The following table shows that about half of the RFCs required editing for style, and the other half at least some editing for clarity.

RFC	Status	Copy Edit
8411	Info	2
8456	Info	4
8446	PS	3
8355	Info	2
8441	PS	2
8324	Info (ISE)	2
8377	PS	3
8498	Info	3
8479	Info (ISE)	1
8453	Info	2
8429	BCP	2
8312	Info	2
8492	Info (ISE)	3
8378	Exp	2
8361	PS	2
8472	PS	2
8471	PS	2

8466	PS	3
8362	PS	3
8468	Info	3

Table 9

This method of assessment does not take into account the number of changes proposed by the editors and eventually rejected by the authors, since these changes are not present in either the final draft or the published RFC. It might be possible to get an evaluation of these "phantom changes" from the RFC Production Center.

4.5. Independent Stream

Out of 20 randomly selected RFCs, 3 were published through the Independent Stream. One is an independent opinion, another a description of a non-IETF protocol format, and the third was [RFC8492], which is a special case. Apart from this special case, the publication delays were significantly shorter for the Independent Stream than for the IETF Stream.

The authors of these 3 RFCs are regular IETF contributors. This observation motivated a secondary analysis of all the RFCs published in the Independent Stream in 2018. There are 14 such RFCs: 8507, 8494, 8493, 8492, 8483, 8479, 8433, 8409, 8374, 8369, 8367, 8351, 8328, and 8324. (RFCs 8367 and 8369 were published on 1 April 2018.) The majority of the documents were published by regular IETF participants, but two of them were not. One describes "The BagIt File Packaging Format (V1.0)" [RFC8493], and the other the "Yeti DNS Testbed" [RFC8483]. They document a data format and a system developed outside the IETF and illustrate the outreach function of the Independent Stream. In both cases, the authors include one experienced IETF participant, who presumably helped outsiders navigate the publication process.

The present document experienced some publication delays due to the Independent Submissions Editor. The ISE is a bottleneck and is a volunteer resource. Although the ISE as a lone person operating as a volunteer is still roughly adequate resource for the job, the delivery will necessarily be best effort with delays caused by spikes in ISE load, work commitments, and other life events. These delays may not be fundamentally critical to RFC delivery, but they are capable of introducing a significant percentage delay into what might otherwise be a smooth process.

5. Citation Counts

In this exploration, we want to examine whether citation counts provide a meaningful assessment of the popularity of RFCs. We obtain the citation counts through the Semantic Scholar API, using queries of the form: <https://api.semanticscholar.org/v1/paper/10.17487/rfc8446?include_unknown_references=true>

In these queries, the RFC is uniquely identified by its DOI reference, which is composed of the RFC Series prefix 10.17487 and the RFC identifier. The queries return a series of properties, including a list of citations for the RFC. Based on that list of citations, we compute three numbers:

* The total number of citations

* The number of citations in the year of publication and the year after that

* For the RFC published in 1998 or 2008 that we use for comparison, the number of citations in the years 2018 and 2019.

All the numbers were retrieved on October 6, 2019.

5.1. Citation Numbers

As measured on October 6, 2019, the citation counts for the RFC in our sample set were:

RFC (2018)	Status	Total	2018-2019
8411	Info	1	0
8456	Info	1	1
8446	PS	418	204
8355	Info	3	3
8441	PS	1	1
8324	Info (ISE)	0	0
8377	PS	0	0
8498	Info	0	0
8479	Info (ISE)	0	0
8453	Info	3	3
8429	BCP	0	0
8312	Info	25	16
8492	Info (ISE)	4	4
8378	Exp	1	1
8361	PS	0	0
8472	PS	1	1
8471	PS	1	1
8466	PS	0	0
8362	PS	1	1
8468	Info	1	1

Table 10

The results indicate that [RFC8446] is by far the most cited of the 20 RFC in our sample. This is not surprising, since TLS is a key Internet Protocol. The TLS 1.3 protocol was also the subject of extensive studies by researchers, and thus was mentioned in a number of published papers. Surprisingly, the Semantic Scholar mentions a number of citations that predate the publication date. These are probably citations of the various draft versions of the protocol.

The next most cited RFC in the sample is [RFC8312] which describes the Cubic congestion control algorithm for TCP. That protocol was also the target of a large number of academic publications. The other RFCs in the sample only have a small number of citations.

There is probably a small bias when measuring citations at a fixed date. An RFC published in January 2018 would have more time to accrue citations than one published in December. That may be true to some extent, as the second most cited RFC in the set was published in January. However, the effect has to be limited. The most cited RFC was published in August, and the second most cited was published in 2019. (That RFC got an RFC number in 2018, but publication was slowed by long AUTH48 delays.)

5.2. Comparison to 1998 and 2008

In order to get a baseline, we can look at the number of references for the RFCs published in 2008 and 1998. However, we need to take time into account. Documents published a long time ago are expected to have accrued more references. We try to address this by looking at three counts for each document: the overall number of references over the document's lifetime, the number of references obtained in the year following publication, and the number of references observed since 2018:

RFC (2008)	Status	Total	2008-2009	2018-2019
5326	Exp	138	14	15
5348	PS	14	3	0
5281	Info	69	15	7
5354	Exp	17	13	0
5227	PS	19	1	2
5329	PS	24	6	1
5277	PS	32	3	2
5236	Info (ISE)	25	5	4
5358	BCP	21	2	0
5271	Info	7	2	0
5195	PS	7	4	2
5283	PS	8	1	0
5186	Info	14	4	2
5142	PS	8	4	0
5373	PS	5	2	0
5404	PS	1	1	0
5172	PS	2	0	0
5349	Info	8	0	2
5301	PS	5	1	0
5174	Info	0	0	0

Table 11

RFC (1998)	Status	Total	1998-1999	2018-2019
2289	PS	2	0	1
2267	Info	982	5	61
2317	BCP	9	1	2
2404	PS	137	6	1
2374	PS	42	4	0
2449	PS	7	2	0
2283	PS	17	3	2
2394	Info	13	2	1
2348	DS	5	0	0
2382	Info	17	12	0
2297	Info (ISE)	36	11	0
2381	PS	39	12	0
2312	Info	14	3	0
2387	PS	4	1	0
2398	Info	17	0	1
2391	PS	31	3	0
2431	PS	3	0	0
2282	Info	8	0	0
2323	Info (ISE)	1	0	0
2448	Info (ISE)	0	0	0

Table 12

We can compare the median number of citations and the numbers of citations for the least and most popular quartiles in the three years:

References	Lower 25%	Median	Higher 25%
RFC (2018)	0	1	3
RFC (2008)	6.5	11	21.75
RFC (2008), until 2009	1	2.5	4.5
RFC (2008), 2018 and after	0	0	2
RFC (1998)	4.75	13.5	32.25

RFC (1998), until 1999	0	2	4.25
RFC (1998), 2018 and after	0	0	1

Table 13

The total numbers show new documents with fewer citations than the older ones. This can be explained to some degree by the passage of time. If we restrict the analysis to the number of citations accrued in the year of publishing and the year after that, we still see about the same distribution for the three samples.

We also see that the number of references to RFCs fades over time. Only the most popular of the RFC produced in 1998 are still cited in 2019.

5.3. Citations versus Deployments

The following table shows side by side the number of citations as measured in Section 5.1 and the estimation of deployment as indicated in Section 3.

RFC (2018)	Status	Citations	Deployment
8411	Info	1	medium
8456	Info	1	medium
8446	PS	418	high
8355	Info	3	medium
8441	PS	1	high
8324	Info (ISE)	0	N/A
8377	PS	0	unknown
8498	Info	0	unknown
8479	Info (ISE)	0	one
8453	Info	3	unknown
8429	BCP	0	some
8312	Info	25	high
8492	Info (ISE)	4	one
8378	Exp	1	some
8361	PS	0	one
8472	PS	1	medium
8471	PS	1	medium
8466	PS	0	unknown
8362	PS	1	medium
8468	Info	1	some

Table 14

From looking at these results, it is fairly obvious that citation counts cannot be used as proxies for the "value" of an RFC. In our sample, the two RFCs that have high citation counts were both widely deployed, and can certainly be described as successful, but we also see many RFCs that saw significant deployment without garnering a high level of citations.

Citation counts are driven by academic interest, but are only loosely correlated with actual deployment. We saw that [RFC8446] was widely cited in part because the standardization process involved many researchers, and that the high citation count of [RFC8312] is largely due to the academic interest in evaluating congestion control protocols. If we look at previous years, the most cited RFC in the 2008 sample is [RFC5326], an experimental RFC defining security extensions to an experimental delay tolerant transport protocol. This protocol does not carry a significant proportion of Internet traffic, but has been the object of a fair number of academic studies.

The citation process tends to privilege the first expression of a concept. We see that with the most cited RFC in the 1998 set is [RFC2267], an informational RFC defining Network Ingress Filtering that was obsoleted in May 2000 by [RFC2827]. It is still cited frequently in 2018 and 2019, regardless of its formal status in the RFC Series. We see the same effect at work with [RFC8441], which garners very few citations although it updates [RFC6455] that has a large number of citations. The same goes for [RFC8468], which is sparsely cited while the [RFC2330] is widely cited. Just counting citations will not indicate whether developers still use an old specification or have adopted the revised RFC.

5.4. Citations versus Web References

Web references might be another indicator of the popularity of an RFC. In order to evaluate these references, we list here the number of results returned by searches on Google and Bing, looking for the search term "RFCnnnn" (e.g., "RFC8411"), and copying the number of results returned by the search engines. The table below presents the results of these searches, performed on April 4, 2020.

RFC (2018)	Status	Citations	Google	Bing
8411	Info	1	301	94
8456	Info	1	266	8456
8446	PS	418	25900	47800
8355	Info	3	521	114
8441	PS	1	2430	59500
8324	Info (ISE)	0	393	138
8377	PS	0	264	10900
8498	Info	0	335	10100
8479	Info (ISE)	0	564	11000
8453	Info	3	817	11400

8429	BCP	0	391	41600
8312	Info	25	1620	2820
8492	Info (ISE)	4	323	9400
8378	Exp	1	418	11600
8361	PS	0	499	92
8472	PS	1	496	169
8471	PS	1	1510	11600
8466	PS	0	766	173
8362	PS	1	67	147
8468	Info	1	453	127

Table 15

The result counts from Bing are sometimes surprising. Why would RFC 8441 gather 59,500 web references? Looking at the results in detail, we find a mix of data. Some of them are logs of development projects implementing Web Sockets, which is exactly what we are looking for, but others appear spurious. For example, a shop selling rugby jerseys is listed because its phone number ends with "8441". Other pages were listed because street numbers or product numbers matched the RFC number. The same type of collision may explain the large reference counts on Bing for RFCs 8377, 8498, 8479, 8453, 8429, 8378, and 8471. The result counts on Bing do not appear to provide a good metric.

On Google, all RFCs garner at least a 250 references, largely because the whole RFC catalog is replicated on a large number of web servers. Deviations from that baseline are largely correlated with the number of citations in the Semantic Scholar, with a couple of exception: RFC 8441 and RFC 8471 garner more references than the low citation counts would predict. Looking at the results, we find many references in development databases explaining how these protocols are implemented in various code bases and open source projects. This means that counting Google results would give some indication about an RFC’s popularity, complementing the citation counts.

There are some practical problems in using the counts of Google results. Google searches are personalized, the results depend on the source of the queries, and the counts may vary as well. The search results depend on the search algorithm, and there is no guarantee that counts will not change when the algorithm changes. On the other hand, the results do indicate that some of the RFCs in our sample are being used by developers or in deployments.

6. Observations and Next Steps

The author’s goal was to get a personal understanding of the "chain of production" of the RFCs, and in particular to look at the various causes of delays in the process. As shown in Section 4, the average RFC was produced in 3 years and 4 months, which is similar to what was found in the 2008 sample, but more than three times larger than the delays for the 1998 sample.

The working group process appears to be the main source of delays. Efforts to diminish delays should probably focus there, instead of on the IETF and IESG reviews or the RFC production. For the RFC production phase, most of the variability originates in the AUTH48 process, which is influenced by a variety of factors such as number of authors or level of engagement of these authors.

Most of the delay is spent in the working group, but the IETF Datatracker does not hold much information about what happens inside the working groups. For example, events like Working Group Last Calls were not recorded in the history of the selected drafts available in the Datatracker. Such information would have been interesting. Of course, requiring that information would create an administrative burden, so there is clearly a trade-off between requiring more work from working group chairs and providing better data for process analysis. (It appears that this information can be available in the Datatracker for more recent drafts, if the WG chairs use the Datatracker properly.)

The Independent Stream operates as expected. The majority of the authors of the Independent Stream RFCs appear to be in IETF insiders, but there is significant amount of engagement by outside parties.

The analysis of citations in Section 5.1 shows that citation numbers are a very poor indication of the "value" of an RFC. Citation numbers measure the engagement of academic researchers with specific topics, but have little correlation with the level of adoption and deployment of a specific RFC. The result counts of Google searches do capture references outside academia, such as logs of development projects. This might be informative, but it is not clear that the counts would not change over time due to algorithm changes or personalization.

This document analyses a small sample of RFCs "in depth". This allowed gathering of detailed feedback on the process and the deployments. On the other hand, much of the data on delays is available from the IETF Datatracker. It may be worth considering adding an automated reporting of delay metrics in the IETF Datatracker.

This document only considers the RFCs that were published in a given year. This approach can be criticized as introducing a form of "survivor bias". There are many drafts proposed to the IETF, and only a fraction of them end up being published as RFCs. On one hand, this is expected, because part of the process is to triage between ideas that can gather consensus and those that don’t. On the other hand, we don’t know whether that triage is too drastic and has discouraged progress on good ideas.

One way to evaluate the triage process would be to look at publication attempts that were abandoned -- for example, drafts that expired without progressing or being replaced. The sampling methodology could also be used for that purpose. Pick maybe 20 drafts at random, among those abandoned in a target year, and investigate why they were abandoned. Was it because better solutions emerged in the working group? Or maybe because the authors discovered a flaw in their proposal? Or was it because some factional struggle blocked a good idea? Was the idea pursued in a different venue? Hopefully, someone will try this kind of investigation.

7. Security Considerations

This document does not specify any protocol.

We might want to analyze whether security issues were discovered after publication of specific standards.

8. IANA Considerations

This document has no IANA actions.

Preliminary analysis does not indicate that IANA is causing any particular delay in the RFC publication process.

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Author's Address

Christian Huitema
Private Octopus Inc.
427 Golfcourse Rd
Friday Harbor, WA 98250
United States of America

Email: huitema@huitema.net