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W. Hardaker  
Parsons, Inc.  
W. Kumari  
Google  
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Security Considerations for [RFC5011](#) Publishers  
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## Abstract

This document describes the math behind the minimum time-length that a DNS zone publisher must wait before using a new DNSKEY to sign records when supporting the [RFC5011](#) rollover strategies.

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[1.](#) Introduction

[RFC5011](#) [[RFC5011](#)] defines a mechanism by which DNSSEC validators can extend their list of trust anchors when they've seen a new key published in a zone. However, [RFC5011](#) [intentionally] provides no guidance to the publishers of DNSKEYs about how long they must wait before switching to the newly published key for signing records. Because of this lack of guidance, zone publishers may derive incorrect assumptions about safe usage of the [RFC5011](#) DNSKEY advertising and rolling process. This document describes the minimum security requirements from a publishers point of view and is intended to compliment the guidance offered in [RFC5011](#) (which is written to provide timing guidance solely to the Validating Resolvers point of view).

To verify this lack of understanding is wide-spread, the authors reached out to 5 DNSSEC experts to ask them how long they thought they must wait before using a new KSK that was being rolled according to the 5011 process. All 5 experts answered with an insecure value, and thus we have determined that this lack of operational guidance is causing security concerns today. We hope that this document will rectify this understanding and provide better guidance to zone publishers that wish to make use of the [RFC5011](#) rollover process.

One important note about ICANN's upcoming 2017 KSK rollover plan for the root zone: the timing values chosen for rolling the KSK in the root zone appear completely safe, and are not in any way affected by the timing concerns introduced by this draft

### [1.1.](#) Requirements notation

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 [[RFC2119](#)].

## [2.](#) Background

The [RFC5011](#) process describes a process by which a Validating Resolver may accept a newly published KSK as a trust anchor for validating future DNSSEC signed records. This document augments that information with additional constraints, as required from the DNSKEY publication point of view. Note that it does not define any other operational guidance or recommendations about the [RFC5011](#) process from a publication point of view and restricts itself to solely the security and operational ramifications of switching to a new key too soon. Failure of a DNSKEY publisher to follow the minimum recommendations associated with this draft will result in potential denial-of-service attack opportunities against validating resolvers.

## [3.](#) Terminology

**Trust Anchor Publisher** The entity responsible for publishing a DNSKEY that can be used as a trust anchor.

## [4.](#) Timing associated with [RFC5011](#) processing

[RFC5011](#)'s process of safely publishing a new key and then making use of that key falls into a number of high-level steps:

1. Publish a new DNSKEY in the zone but continue to sign with the old one.
2. Wait a period of time.
3. Begin using the new DNSKEY to sign the appropriate resource

records.

4. Optionally mark the older DNSKEY as revoked and publish the revoked key.

This document discusses step 2 of the above process. Some interpretations of [RFC5011](#) have erroneously determined that the wait time is equal to [RFC5011](#)'s "hold down time".

This document describes an attack based on this (common) erroneous belief, which results in a denial of service attack against the zone if that value is used.

## [5.](#) Denial of Service Attack Considerations

If an attacker is able to provide a [RFC5011](#) validating engine with past responses, such as when it is in-path or able to otherwise perform any number of cache poisoning attacks, the attacker may be able to leave the [RFC5011](#)-compliant validator without an appropriate DNSKEY trust anchor. This scenario will remain until an administrator manually fixes the situation.

The following timeline illustrates this situation.

### [5.1.](#) Enumerated Attack Example

The following example settings are used in the example scenario within this section:

TTL (all records) 1 day

DNSKEY RRSIG Signature Validity 10 days

Zone resigned every 1 day

Given these settings, the following sequence of events depicts how a Trust Anchor Publisher that waits for only the [RFC5011](#) hold time timer length of 30 days subjects its users to a potential Denial of Service attack. The timing schedule listed below is based on a new trust anchor (a Key Signing Key (KSK)) being published at time T+0. All numbers in this sequence refer to days before and after such an event. Thus, T-1 is the day before the introduction of the new key,

and T+15 is the 15th day after the key was introduced into the fictitious zone being discussed.

In this dialog, we consider two keys being published:

K\_old The older KSK being replaced.

K\_new The new KSK being transitioned into active use, using the [RFC5011](#) process.

In this dialog, the following actors are playing roles in this situation:

Zone Signer The owner of a zone intending to publish a new Key-Signing-Key (KSK) that will become a trust anchor by validators following the [RFC5011](#) process.

[RFC5011](#) Validator A DNSSEC validator that is using the [RFC5011](#) processes to track and update trust anchors.

Attacker An attacker intent on foiling the [RFC5011](#) Validator's ability to successfully adopt the Zone Signer's K\_new key as a new trust anchor.

#### [5.1.1](#). Attack Timing Breakdown

The following series of steps depicts the timeline in which an attack occurs that foils the adoption of a new DNSKEY by a Trust Anchor Publisher that revokes the old key too quickly.

T-1 The last signatures are published by the Zone Signer that signs only K\_old using K\_old. The Attacker queries for, retrieves and caches this keyset and corresponding signatures.

T-0 The Zone Signer adds K\_new to his zone and signs the zone's key set with K\_old. The [RFC5011](#) Validator retrieves the new key set and corresponding signature set and notices the publication of K\_new. The [RFC5011](#) Validator starts the (30-day) hold-down timer for K\_new.

T+5 The [RFC5011](#) Validator queries for the zone's keyset per the Active Refresh schedule, discussed in [Section 2.3 of RFC5011](#).

Instead of receiving the intended published keyset, the Attacker successfully replays the keyset and associated signatures that they recorded at T-1. Because the signature lifetime is 10 days (in this example), the replayed signature and keyset is accepted as valid (being only 6 days old) and the [RFC5011](#) Validator cancels the hold-down timer for K\_new.

T+10 The [RFC5011](#) Validator queries for the zone's keyset and discovers K\_new again, signed by K\_old (the attacker is unable to replay the records cached at T-1, because they have now expired). The [RFC5011](#) Validator starts (anew) the hold-timer for K\_new.

T+15,T+20, and T+25 The [RFC5011](#) Validator continues checking the zone's key set and lets the hold-down timer keep running without resetting it.

T+30 The Zone Signer knows that this is the first time at which some validators might accept K\_new as a new trust anchor, since the hold-down timer of a [RFC5011](#) Validator not under attack that had queried and retrieved K\_new at T+0 would now have reached 30 days. However, the hold-down timer of our attacked [RFC5011](#) Validator is only at 20 days.

T+35 The Zone Signer (mistakenly) believes that all validators following the Active Refresh schedule ([Section 2.3 of RFC5011](#)) should have accepted K\_new as a the new trust anchor (since the

hold down time of 30 days + 1/2 the signature validity period would have passed). However, the hold-down timer of our attacked [RFC5011](#) Validator is only at 25 days; The replay attack at T+5 means its new hold-time timer actually started at T+10, and thus at this time it's real hold-down timer is at T+35 - T+10 = 25 days, which is less than the [RFC5011](#) required 30 days.

T+36 The Zone Signer, believing K\_new is safe to use, switches their active signing KSK to K\_new and publishes a new DNSKEY set signature signed with K\_new. Non-attacked [RFC5011](#) validators, with a hold-down timer of at least 30 days, would have accepted K\_new into their set of trusted keys. But, because our attacked [RFC5011](#) Validator still has a hold-down timer for K\_new at 26 days, it will fail to accept K\_new as a trust anchor and since K\_old is no longer being used, all the KSK records from the zone

signed by K\_new will be treated as invalid. Subsequently, all keys in the key set are now unusable, invalidating all records in the zone of any type and name.

## 6. Minimum [RFC5011](#) Timing Requirements

Given the attack description in [Section 5](#), the correct minimum length of time required for the Zone Signer to wait before using K\_new is:

```
waitTime = addHoldDownTime
           + MIN(3 * (DNSKEY RRSIG Signature Validity) / 2,
                 3 * MAX(original TTL of K_old DNSKEY RRSig) / 2,
                 15 days)
           + 2 * MAX(TTL of all records)
```

The most confusing element of the above equation comes from the "3 \* (DNSKEY RRSIG Signature Validity) / 2" element, but is the most critical to understand and get right.

The [RFC5011](#) "Active Refresh" requirements state that:

A resolver that has been configured for an automatic update of keys from a particular trust point MUST query that trust point (e.g., do a lookup for the DNSKEY RRSig and related RRSig records) no less often than the lesser of 15 days, half the original TTL for the DNSKEY RRSig, or half the RRSig expiration interval and no more often than once per hour.

The important timing constraint that must be considered is the last point at which a validating resolver may have received a replayed the original DNSKEY set (K\_old) without the new key. It's the next query of the [RFC5011](#) validator that the assured K\_new will be seen. For the following paragraph, we use the more common case where (DNSKEY RRSig Signature Validity) is greater than (original TTL for the DNSKEY RRSig), although the equation above takes both cases into account.

Thus, the worst case scenario of this attack is when the attacker can replay K\_old at just before (DNSKEY RRSIG Signature Validity). If a [RFC5011](#) validator picks up K\_old at this point, it will not have a hold down timer started at all. It's not until the next "Active Refresh" time that they'll pick up K\_new with assurance, and thus start their hold down timer. Thus, this is not at (DNSKEY RRSIG Signature Validity) time past publication, but rather  $3 * (\text{DNSKEY RRSIG Signature Validity}) / 2$ .

The extra  $2 * \text{MAX}(\text{TTL of all records})$  is the standard added safety margin when dealing with DNSSEC due to caching that can take place. Because the 5011 steps require direct validation using the signature validity, the authors aren't yet convinced it is needed in this particular case.

For the parameters listed in [Section 5.1](#), our example:

```
waitTime = 30
           + 3 * (10) / 2
           + 2 * (1)      (days)

waitTime = 47              (days)
```

This hold-down time of 47 days is 12 days longer than the frequently perceived 35 days in T+35 above.

## [7.](#) IANA Considerations

This document contains no IANA considerations.

## [8.](#) Operational Considerations

A companion document to [RFC5011](#) was expected to be published that describes the best operational practice considerations from the perspective of a zone publisher and Trust Anchor Publisher. However, this companion document was never written. The authors of this document hope that it will at some point in the future, as [RFC5011](#) timing can be tricky as we have shown. This document is intended



ramifications (specifically a denial of service attack against an [RFC5011](#) Validator). This document does not attempt to document any other missing operational guidance for zone publishers.

## 9. Security Considerations

This document, is solely about the security considerations with respect to the Trust Anchor Publisher of [RFC5011](#) trust anchors / keys. Thus the entire document is a discussion of Security Considerations

## 10. Acknowledgements

The authors would like to especially thank to Michael StJohns for his help and advice. We would also like to thank Bob Harold, Shane Kerr, Matthijs Mekking, Duane Wessels, and everyone else who assisted with this document.

## 11. Normative References

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- [RFC5011] StJohns, M., "Automated Updates of DNS Security (DNSSEC) Trust Anchors", STD 74, [RFC 5011](#), DOI 10.17487/RFC5011, September 2007, <<http://www.rfc-editor.org/info/rfc5011>>.

## Appendix A. Changes / Author Notes.

From -00 to -02:

Additional background and clarifications in abstract.

Better separation in attack description between attacked and non-attacked resolvers.

Some language cleanup.

Clarified that this is maths ( and math is hard, let's go shopping!)

Changed to " <?rfc include='reference....'?> " style references.

From -02 to -03:

Minor changes from Bob Harold

Clarified why 3/2 signature validity is needed

Changed min wait time math to include TTL value as well

#### Authors' Addresses

Wes Hardaker  
Parsons, Inc.  
P.O. Box 382  
Davis, CA 95617  
US

Email: [ietf@hardakers.net](mailto:ietf@hardakers.net)

Warren Kumari  
Google  
1600 Amphitheatre Parkway  
Mountain View, CA 94043  
US

Email: [warren@kumari.net](mailto:warren@kumari.net)

