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Guidance to Avoid Carrying RPKI Validation States in BGP Path Attributes
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Abstract

This document provides guidance to avoid carrying Resource Public Key Infrastructure (RPKI) derived validation states in Border Gateway Protocol (BGP) Path Attributes whose change triggers a BGP UPDATE being sent across external BGP sessions. Annotating routes with BGP Path Attributes carried across external BGP sessions signaling validation states may cause needless flooding of BGP UPDATE messages through the global Internet routing system, for example when Route Origin Authorizations (ROAs) are issued, or are revoked, or when RPKI-To-Router sessions are terminated.

Operators should ensure RPKI-derived validation states are not signaled in BGP Path Attributes whose change triggers a BGP UPDATE being sent across external BGP sessions. Specifically, operators should not associate Prefix Origin Validation state with BGP routes using any form of BGP Communities carried across EBGP session.

This document updates RFC 8097.

Status of This Memo

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1. Introduction

The Resource Public Key Infrastructure (RPKI) [RFC6480] allows for validation of received Border Gateway Protocol (BGP) [RFC4271] routes. By means of a validation process, e.g., BGP Prefix Origin Validation ([RFC6811]), routers attain locally significant validation states.

In the past, some operators and vendors suggested to use BGP Communities ([RFC1997] and [RFC8092]) to annotate received routes with validation states local to a router. Some claim that the practice of signaling validation states could be useful, for example to Internal BGP (IBGP) speakers, in order to avoid each IBGP speaker having to perform their own route origin validation. However, such a practice does not only conflict with core concepts of RPKI, but also threatens the stability of networks.

Annotating a route with a BGP Path Attribute carried across EBGp session (based on validation states) means that BGP UPDATE messages have to be sent to every neighbor when the aforementioned validation states changes. This means that when, for example, Route Origin Authorizations (ROAs) [RFC9582] are issued, or are revoked, or RPKI-To-Router (RTR) [RFC8210] sessions are terminated, new BGP UPDATE messages will have to be sent for all routes that were previously annotated with a BGP Community associated with a different validation state. Furthermore, given that many BGP Communities are carried across EBGp sessions, such a BGP UPDATE might end up propagating through large portions of the Default-Free Zone (DFZ).

Hence, this document provides guidance (Section 5) to avoid carrying RPKI-derived validation states in Border Gateway Protocol (BGP) Path Attributes carried across external BGP sessions. Specifically, operators should not associate BGP Prefix Origin Validation results [RFC6811] with BGP routes using community or community-like attributes, including:

- * BGP Communities [RFC1997],
- * transitive BGP Extended Communities [RFC4360],
- * BGP Large Communities [RFC8092]
- * IPv6 Address Specific BGP Extended Community Attribute [RFC5701]

Furthermore, this document contains data on the measured current impact of BGP Communities used to signal validation states.

Avoiding the use of BGP Communities to signal RPKI-derived validation states prevents BGP UPDATE messages from being flooded into the global Internet routing system.

1.1. Requirements Language

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "NOT RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in BCP 14 [RFC2119] [RFC8174] when, and only when, they appear in all capitals, as shown here.

| Note that the key words are used to stress importance for
| operations; they are not a formal implementation requirement.

2. Scope

This document discusses signaling locally significant RPKI validation states through BGP Path Attributes whose change leads to BGP UPDATES being sent to EBGP neighbors. This includes operator-specific BGP Communities to signal validation states, as well as any current or future standardized well-known BGP Communities denoting validation states. As BGP message churn is associated with internal signaling changes, it is RECOMMENDED that operators also consider the guidance (Section 5) within their network, i.e., between their IBGP speakers.

The guidance in this document applies to all current and future BGP Path Attributes that may be implicitly or explicitly used to signal validation states to EBGP neighbors. Similarly, this guidance also applies to non-ROA validation mechanics based on RPKI; e.g., Autonomous System Provider Authorization (ASPA) [I-D.ietf-sidrops-aspa-profile], BGPsec [RFC8205], and any other future validation mechanic built upon the RPKI.

[RFC8097] introduces an extended community for use in IBGP and selected EBGP scenarios, providing normative guidance on implementations' behavior if and only if support for this feature is explicitly configured. This document does not provide normative guidance regarding implementation behavior, i.e., regarding the support for the extended community for signaling validation state described in [RFC8097]. Instead, guidance in this document is normative regarding operators' use of this feature.

In addition to implementation guidance in [RFC8097], the document also provides non-normative text on possible deployment scenarios where RPKI-derived state might be signaled to EBGP speakers. In that regard, this document updates [RFC8097], adding normative language that these deployment scenarios are NOT RECOMMENDED. Operators MAY

opt to deploy such configurations in restricted environments, e.g., when using multiple ASes in a single administrative domain; Nevertheless, operators are encouraged to take care and precautions to mitigate the risks described in this document when choosing to implement these scenarios.

3. Risks of Signaling Validation State Transitively to EBGp Neighbors

This section outlines the risks of signaling RPKI-derived validation states using transitive BGP Communities. While the current description is specific to BGP communities, the observations hold similar for all attributes that may be added to BGP routes and propagated to EBGp neighbors.

3.1. Triggers for Large-Scale Validation Changes

This section describes examples on how a large amount of RPKI ROA changes may occur in a short time, leading to generation of a large amounts of BGP UPDATE messages.

3.1.1. ROA Issuance

Large-Scale ROA issuance events should be a comparatively rare event for individual networks. However, several cases exist where issuance by individual operators or (malicious) coordinated issuance of ROAs by multiple operators may lead to a high route churn, triggering a continuous flow of BGP UPDATE messages caused by operators using BGP Path Attributes carried across EBGp sessions to signal validation states.

Specifically:

- * When an operator issues new ROAs for their IP address blocks, possibly by issuing one ROA with a non-minimal maxLength (Section 4.3.2.2 of [RFC9582]) covering a large number of prefixes. This may also occur when incorrectly migrating to minimally covering ROAs ([RFC9319]). One example of such a circumstance is when the previous ROA is first revoked (see Section 3.1.2) and the new ROAs are only issued after this revocation has been propagated (due to an operational error or a bug in the issuance pipeline).
- * When multiple Certification Authorities (CAs) coordinate to issue new ROAs at the same time.
- * When a CA has been unavailable or unable to publish for some time, but then publishes all updates at once, or - as unlikely as it is - if a key-rollover encounters issues.

3.1.2. ROA Revocation

Large-Scale ROA revocation should be a comparatively rare event for individual networks. However, several cases exist where revocations by individual operators or (malicious) coordinated revocation of ROAs by multiple operators may lead to a high route churn triggering a continuous flow of BGP Update messages caused by operators to signal validation states using BGP Path Attributes carried across EBGP sessions.

Specifically:

- * When one large operator revokes all ROAs for their IP address blocks at once. This can occur when migrating to minimally covering ROAs [RFC9319], or when revoking one ROA with a long maxLength covering a large number of prefixes.
- * When multiple CAs coordinate to revoke ROAs at the same time.
- * When a CA becomes unavailable or unable to publish for some time, e.g., due to the CA expiring ([CA-Outage1], [CA-Outage2], [CA-Outage3], [CA-Outage4]).

3.1.3. Loss of Cached Validated Payload Information

Similar to the issuance and revocation of ROAs, the validation pipeline of a Relying Party (RP) may encounter issues. Issues may occur on the cache side (Section 3.1.3.1) or on the router side (Section 3.1.3.2) with network connectivity issues having specific impact on either of the two.

While, in general, implementations should not have bugs, operators should not make mistakes, and the network should be reliable, this is usually not the case in practice. Instead, the worst-case of sudden and unexpected, yet unintentional, loss of cached validated payloads is an event that, however unlikely in a specific system, may and will happen. Hence, systems should be resilient in case of unexpected issues, and should not exacerbate issues by inadvertently contributing to BGP UPDATE floods.

Below, examples are provided of events for both categories that may lead to the validation state of routes in one or multiple routers of an operator changing from Valid to NotFound (Section 2 of [RFC6811]). These lists are provided for illustrative purposes and not exhaustive.

3.1.3.1. Potential Issues with a Cache

The following events may impact a cache's ability to provide validated payload information to routers:

- * The RPKI-To-Router (RTR) service may have to temporarily be taken offline by the RP operator for maintenance. While operators should, in general, take care to provision sufficient redundancy, critical vulnerabilities may necessitate the immediate simultaneous shutdown of all RTR instances.
- * A cache may crash due to bugs when ingesting unexpected data from the RPKI, or run into performance issues due to insufficient available memory or limited I/O performance on the host. In the worst case, especially memory issues, can lead to a flapping cache. For example, when the system runs out of memory after a few minutes of transmitting validated payloads to routers.
- * Validation state may lapse due to issues with time synchronization. An example of problems with time synchronization is if the clock of the cache drifts significantly, causing certificates to be considered invalid.
- * The cache may lose its network connectivity in general, or to specific CAs. While, in general, the cache server should be able to temporarily operate from locally stored non-expired data, an operator may have to shutdown the cache in such a case, to prevent dropping prefixes as invalid due to stale data.

3.1.3.2. Potential Ingestion Issues with a Router

Examples of encountered issues are:

- * An RTR client, especially when implemented as a dedicated daemon, may fail to start, or terminate when receiving unexpected data. Especially when this leads to a flapping client. Flapping may be caused by a bug in the handling of incremental updates leading to a crash. While the initial retrieval is successful, this will lead to flapping between routes being Valid and NotFound.
- * A misconfiguration may impact a router's ability to communicate with the RTR service. For example, an RTR client may lose its credentials or may not receive updated credentials in time when these are changed, or the address of the RTR service changes and is not updated on the router in time.

- * An RTR client may lose network connectivity to the RTR service. Generally, caches should prevent this event causing an immediate impact to the RTR service. However, a RTR client's behavior in case of a flapping network connection with frequent interruptions may lead to unexpected behavior and cache invalidation. Similarly, after cache expiry, routes will change from Valid to NotFound.
- * As an extension of the previous point, multiple operators might be using one central RTR service hosted by an external party, or depend on a similar cache, which becomes unavailable (e.g., due to maintenance or an outage). If local instances are not able to handle loss of this external service without changing validation states, routes will change local validation states from Valid to NotFound. (Loss of external service can be handled by serving from cache, but even this technique fails if the cached information expires.) Naturally, the negative impact in such a case is significantly larger in comparison to each operator runs their own cache.

3.1.4. Outage Scenario Summary

The above non-exhaustive listing suggests that issues in general operations, CA operations, and RPKI cache implementations simply are unavoidable. Hence, operators have to plan and design accordingly.

3.2. Scaling issues

In the case of BGP Prefix Origin Validation ([RFC6811]), for each change in the validation state of a route, an Autonomous System (AS) in which the local routing policy sets a BGP Community based on the validation state, routers would need to send BGP UPDATE messages for more than half of the global Internet routing table if the validation state changes to NotFound. The same, reversed case, would be true for every new ROA created by the address space holders, whereas a new BGP UPDATE would be generated, as the validation state would change to Valid. Similar scaling concerns apply to other RPKI-derived validation mechanisms, as, for example, ASPA verification ([I-D.ietf-sidrops-aspa-verification]).

Furthermore, adding additional attributes to routes increases their size and memory consumption in the Routing Information Base of BGP routers. Given the continuous growth of the global routing table, in general, operators should be conservative regarding the additional information they add to routes.

3.3. Flooding and Cascading of BGP UPDATE Messages

The aforementioned scaling issues are not confined to singular UPDATE events. Instead, changes in validation state may lead to floods and/or cascades of BGP UPDATE messages throughout the Internet.

3.3.1. Flooding of BGP UPDATE Messages

Flooding events are caused by an individual operator losing validation states. If that operator annotates validation states using BGP communities, the AS will send updates for all routes that changed from Valid to NotFound to its customers, as well as updates for routes received from customers to its providers.

Following an RPKI service affecting outage (Section 3.1), given that, at the time of writing, more than half the global Internet routing table [CIDR_Report] nowadays is covered by RPKI ROAs [NIST], such convergence events represent a significant burden. See [How-to-break] for an elaboration on this phenomenon.

3.3.2. Cascading of BGP UPDATE Messages

Some events that are not specific to one operator can also cascade for ASes annotating validation states using BGP communities. These events might include a malicious withdrawal of a ROA, loss of a major CA, or an unexpected downtime of a major centralized RTR service. Given that routers' view of the RPKI with RTR are only loosely consistent, BGP UPDATE messages may cascade - so that one event affecting validation states may actually trigger multiple subsequent BGP UPDATE floods.

Assume, for example, that AS65536 is a customer of AS65537 (both annotating validation states with BGP Communities and using a 300 second RTR cycle), and a centralized RTR service fails. In the example, AS65536 has their routers updated from that cache a second before the service went down, while AS65537 was due for a refresh a second thereafter.

This means that a second after the RTR service went down, AS65537 will trigger a BGP UPDATE flood towards its customers cone. AS65536 will ingest and propagate these BGP UPDATE messages towards its own customer cone as well.

When, roughly 300 seconds later, AS65536 fails to disseminate validated payload information as well, the community set by AS65536 will again change for ROA covered routes, and it will again trigger a BGP UPDATE flood and propagate further on.

Even if either or both of AS65536 and AS65537 use a cache after RTR expiry, the underlying issue would not change, assuming the RTR service downtime spans beyond the cache TTL. Assuming a 30 minute cache TTL, both ASes using a cache would only move the cascading event 30 minutes later. If only one of the two uses a cache, the two flood events get moved further apart. However, the overall issue of two independent floods due to one event remains.

3.4. Observed data

In February 2024, a data-gathering initiative [Side-Effect] reported that between 8% and 10% of BGP UPDATE messages seen on the Routing Information Service (RIS), contained publicly-known communities from large ISPs signaling either NotFound or Valid BGP Origin Validation results. The study also demonstrated that the creation or removal of a ROA object triggered a chain of updates in a period of circa 1 hour following the change.

Such a high percentage of unnecessary BGP UPDATE messages constitutes a considerable level of noise, impacting the capacity of the global routing system while generating load on router CPUs and occupying more RAM than necessary. Containing this information within the administrative boundaries of a single AS helps reduce the burden on the rest of the global routing platform, reducing workload and noise.

Please note that this data stems from a point-in-time measurement and may be subject to change in the future.

3.5. Lacking Benefit of Signaling Validation State

RTR has been developed to communicate validated payload information to routers. BGP Path Attributes are not signed, and provide no assurance against third parties adding them. While BGP Communities might be filtered at a network edge, this does not fix the problem of BGP Paths being added in IBGP or EBGP. In contrast, using the RTR provides direct information that can be used to secure BGP Path Attributes.

Given that BGP Path Attributes carried across external BGP sessions are not signed, they provide even less information to other parties except introspection into internal validation mechanics of an AS. Crucially, such attributes provide no actionable information for external BGP neighbors. If an AS validates and enforces based on RPKI (e.g., BGP Prefix Origin Validation), then Invalid routes would never be imported and, hence, never be sent to neighbors. Hence, the argument that exposing validation states through, for example, BGP Communities enables customers to filter Invalid routes is moot, as the only routes a customer should see are NotFound and Valid.

4. Advantages of Dissociating Validation States and BGP Path Attributes

As outlined in Section 3, signaling validation states through BGP Path Attributes carried across EBGP sessions represents risks for the stability of the global routing ecosystem. Not signaling validation states, hence, has tangible benefits, specifically:

- * Reduction of memory consumption on customer/peer facing PE routers (less BGP communities == less memory pressure).
- * No effect on the age of a BGP route when a ROA or ASPA is issued or revoked.
- * Avoids having to resend, e.g., more than 850,000 BGP routes towards BGP neighbors (for the own customer cone towards peers and providers, for the full table towards customers) if the RPKI cache crashes and RTR sessions are terminated, or if flaps in validation are caused by other events. This corresponds to point-in-time IPv4/IPv6 combined data as of mid-2026, based on the current global Internet routing table size of around 1,300,000 prefixes, of which roughly 65% is covered by ROAs.

5. Guidance

Operators MUST NOT signal RPKI-derived validation states using BGP Path Attributes carried across EBGP sessions.

The document acknowledges that specific operational requirements, such as a BGP implementation used by an operator still being dependent on annotating RPKI-derived validation states using BGP Path Attributes, may necessitate the use of BGP path attributes to signal validation states between iBGP speakers within the same AS. If this is the case, the dependent operator MUST ensure that these attributes are removed before announcing Network Layer Reachability Information (NLRI) to EBGP neighbors. Depending on the supported functionality of the BGP implementations in use in a given AS, removal of the aforementioned attributes may not be consistently possible across the AS, leading to the conditions this document is intended to discuss.

6. Operational Considerations

BGP Routers participating in the global Internet routing system may not be equipped to handle BGP message churn in all directions at global scale, especially if routing churn cascades, persists, or repeats periodically. Following the guidance in Section 5 allows operators to enhance the stability of local routing tables and the global Internet routing system, in particular.

7. Security Considerations

BGP is not guaranteed to converge, and the view on the global RPKI within an individual administrative domain is only loosely consistent. External validation states annotated in a received NLRI may either depend on a different view on the RPKI than the one in the local administrative domain, or the NLRI may be several hours old itself. Hence, any purported validation states contained in a received route announcement would only have significance in the sender's own local scope.

Additionally, the use of BGP Path Attributes carried across EBGP sessions to signal RPKI-derived validation states may enable attackers to cause notable route churn. This can be accomplished by an attacker issuing and withdrawing signed objects (e.g., ROAs for their prefixes), or by the attacker continuously altering such attributes used to signal RPKI-derived validation states for NLRI they re-advertise. The latter is possible as NLRI contain no information allowing an ingesting party to validate the authenticity and integrity of the aforementioned attributes.

8. IANA Considerations

This document does not make any request to IANA.

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