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BGP Unreachability Information SAFI
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Abstract

This document defines a new BGP Subsequent Address Family Identifier (SAFI) called "Unreachability Information" that allows the propagation of prefix unreachability information through BGP without affecting the installation or removal of routes in the Routing Information Base (RIB) or Forwarding Information Base (FIB). This mechanism enables network operators to share information about unreachable prefixes for monitoring, debugging, and coordination purposes while maintaining complete separation from the active routing plane.

Status of This Memo

This Internet-Draft is submitted in full conformance with the provisions of BCP 78 and BCP 79.

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This Internet-Draft will expire on 16 November 2026.

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1. Introduction

BGP-4 [RFC4271] withdrawals are only propagated for prefixes that have been previously announced. This behavior, while preventing certain attack vectors, limits the ability of operators to share information about prefix unreachability for prefixes that were never announced in the first place.

There are several use cases where propagating unreachability information without affecting routing decisions would be valuable:

* Debugging and troubleshooting routing issues across administrative domains
* Sharing information about DDoS targets without null-routing traffic
* Coordinating information about potentially hijacked prefixes
* Monitoring and anomaly detection systems that need visibility into negative routing events
* Providing telemetry about routing system health without affecting production traffic
* Correlating unreachability reports from multiple network vantage points

This document defines a new SAFI that creates a parallel information plane for unreachability data, allowing BGP speakers to share this information while maintaining complete separation from the routing plane.

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.

1.2. Terminology

UI-RIB: Unreachability Information RIB

NLRI: Network Layer Reachability Information

AFI: Address Family Identifier

SAFI: Subsequent Address Family Identifier

TLV: Type-Length-Value

Reporter TLV: A nested TLV structure containing information about one reporting BGP speaker and its associated unreachability details

Aggregation: The process of combining multiple Reporter TLVs from different paths into a single NLRI

Advertising Speaker: The BGP speaker that sends the UPDATE message containing the unreachability information

Reporting Speaker: The BGP speaker that originally generated the unreachability information (identified within a Reporter TLV)

2. Protocol Extensions

2.1. Unreachability Information SAFI

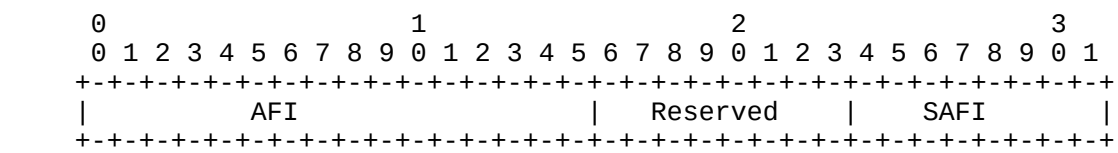
This document defines a new SAFI:

* Value: 81
* Name: Unreachability Information (UNREACH)
* Applicable to AFI: 1 (IPv4) and 2 (IPv6)

2.2. Capability Advertisement

A BGP speaker that wishes to exchange Unreachability Information MUST advertise the corresponding AFI/SAFI capability as defined in [RFC5492].

The Capability Code for Multiprotocol Extensions is 1. The Capability Value field contains:



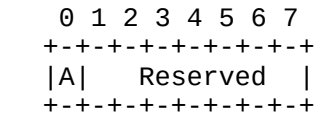
Where:

* AFI = 1 (IPv4) or 2 (IPv6)
* Reserved = 0 (MUST be set to 0 on transmit, ignored on receive)
* SAFI = 81 (Unreachability Information)

Additionally, this document defines a new capability:

* Capability Code: TBD2 (to be assigned by IANA)
* Capability Name: Enhanced Unreachability Information

* Capability Value: 1 octet flags field



Where:

* A bit: If set, speaker supports Aggregation of multiple Reporter TLVs

* Reserved: MUST be zero on transmit, ignored on receive

The A bit indicates support for the aggregation procedures in Section 4.2.1. A speaker that advertises A=1 SHALL combine Reporter TLVs from multiple paths into a single NLRI. A speaker that advertises A=0 MUST NOT perform aggregation and therefore only advertises the Reporter TLVs present on its best path. A peer receiving A=0 MUST NOT send aggregated NLRIs on that session.

2.3. BGP Path Attributes for Carrying Unreachability Information

Unreachability Information NLRI is carried in BGP UPDATE messages using the Multiprotocol Extensions for BGP-4 as defined in [RFC4760]. Specifically:

* MP_REACH_NLRI (Path Attribute Type Code 14): Used to announce unreachability information for one or more prefixes. The presence of a prefix in MP_REACH_NLRI with AFI/SAFI indicating Unreachability Information signifies that the prefix is being reported as unreachable by one or more Reporting Speakers.

* MP_UNREACH_NLRI (Path Attribute Type Code 15): Used to withdraw previously announced unreachability information. The presence of a prefix in MP_UNREACH_NLRI with AFI/SAFI indicating Unreachability Information signifies that the unreachability condition for that prefix has been cleared by all previously Reporting Speakers.

The AFI field in both attributes MUST be set to 1 (IPv4) or 2 (IPv6), and the SAFI field MUST be set to 81 (Unreachability Information).

The NLRI field within MP_REACH_NLRI contains the Unreachability Information NLRI as described in Section 3. The NLRI field within MP_UNREACH_NLRI contains only the prefix (Prefix Length and Prefix) without TLVs.

Standard BGP path attributes (AS_PATH, ORIGIN, NEXT_HOP via MP_REACH_NLRI, etc.) apply as defined in [RFC4760] and [RFC4271]. These attributes represent the path taken by the UPDATE message itself, not the paths of individual reporters (which are preserved in Reporter TLVs).

3. NLRI Format

The NLRI is uniquely identified by the combination of Prefix Length and Prefix. Reporter TLVs are NOT part of the NLRI key but provide information about each Reporting Speaker. The presence of an Unreachability Information NLRI for a prefix signifies that one or more speakers report the prefix as unreachable. The withdrawal of such an NLRI indicates that all reporters have cleared their unreachability reports for that prefix.

3.1. Approach to deal with multiple Reporters

When multiple BGP speakers report unreachability for the same prefix, implementers have several options:

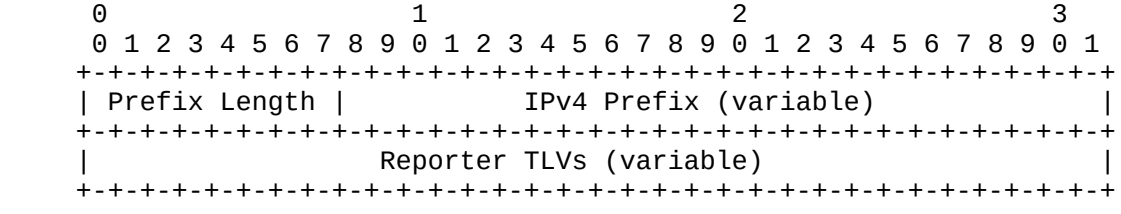
1. Single Reporter: Do nothing and allow the Reporter Identifier of the best path to be used as the only Reporter. This is the simplest approach but loses information from other reporters.

2. Nested TLV Aggregation (Recommended): Implement the nested TLV aggregation approach described in this specification to preserve all reporter perspectives in a single NLRI. This provides the most comprehensive view while maintaining a single BGP path per prefix.

3. BGP ADD-PATH: Use BGP ADD-PATH [RFC7911] to maintain multiple paths, each carrying its own Reporter TLV. This preserves full BGP path attributes per reporter but requires ADD-PATH support.

This specification focuses on the nested TLV aggregation approach as the preferred mechanism, providing detailed procedures and encodings for this method throughout the remainder of this document.

3.2. IPv4 Unreachability NLRI (AFI=1, SAFI=81)

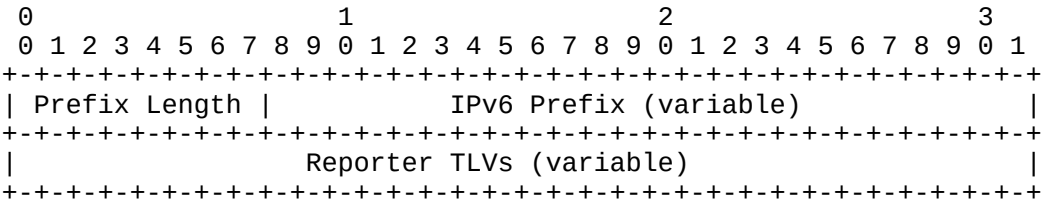


* Prefix Length: 1 octet (0-32 bits)

* IPv4 Prefix: Variable, encoded as in [RFC4271] Section 4.3, and carried in MP_REACH_NLRI per [RFC4760]

* Reporter TLVs: One or more Reporter TLVs (Section 3.4)

3.3. IPv6 Unreachability NLRI (AFI=2, SAFI=81)



* Prefix Length: 1 octet (0-128 bits)

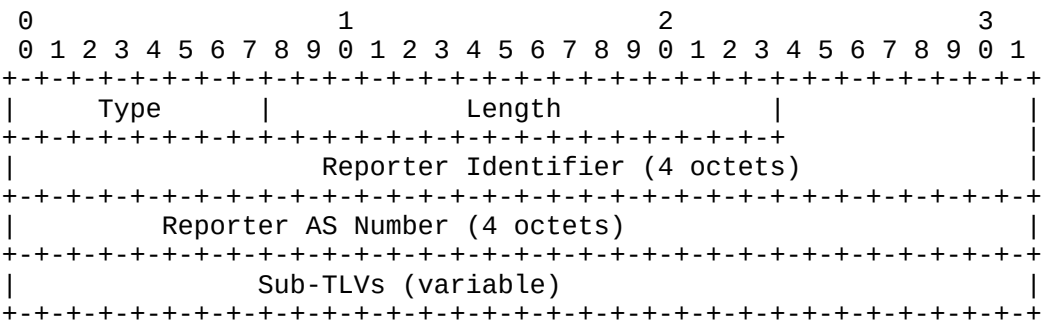
* IPv6 Prefix: Variable, encoded in MP_REACH_NLRI as defined in [RFC4760]

* Reporter TLVs: One or more Reporter TLVs (Section 3.4)

Example IPv6 prefix: 2001:db8::/32.

3.4. Reporter TLV Format

The Reporter TLV is a container that encapsulates information about a single reporting BGP speaker and its associated unreachability details. Multiple Reporter TLVs MAY appear in a single NLRI to represent reports from different speakers.



Reporter TLV Fields:

Type: 1 octet. Value: 1 (Reporter)

Length: 2 octets. Total length of the Reporter Identifier, Reporter AS Number, and Sub-TLVs fields (minimum 8 octets)

Reporter Identifier: 4 octets. BGP Identifier (Router ID) of the Reporting Speaker in network byte order

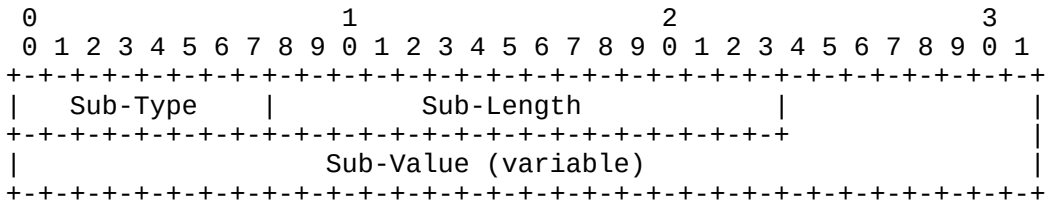
Reporter AS Number: 4 octets. 4-octet AS number of the Reporting Speaker in network byte order. If the AS number is less than 65536, the upper 2 octets are set to 0

Sub-TLVs: Variable length. Contains zero or more Sub-TLVs providing additional details about this reporter's unreachability observation. A Reporter TLV carrying no Sub-TLVs is valid: the presence of the Reporter TLV itself conveys the fact of unreachability, with the Reporter Identifier and Reporter AS Number identifying the speaker that observed it. When the Unreachability Reason Code Sub-TLV (Section 3.5.1) is absent, the reason is treated as Unspecified (code 0).

The combination of Reporter Identifier and Reporter AS Number uniquely identifies the Reporting Speaker. Multiple Reporter TLVs with the same Reporter Identifier and AS Number MUST NOT appear in the same NLRI. If such duplication occurs, only the first occurrence SHOULD be processed.

3.5. Sub-TLV Format

Sub-TLVs appear within Reporter TLVs and provide specific details about the unreachability observation by that reporter.



Defined Sub-TLV Types:

Implementations MUST ignore unknown Sub-TLV types to allow for future extensibility. Multiple Sub-TLVs of the same type SHOULD NOT appear within a single Reporter TLV; if present, only the first occurrence SHOULD be processed.

3.5.1. Unreachability Reason Code Sub-TLV

* Sub-Type: 1
* Sub-Length: 2 octets
* Sub-Value: 2-octet reason code in network byte order

Defined Reason Codes:

* 0: Unspecified
* 1: Policy Blocked
* 2: Security Filtered
* 3: RPKI Invalid
* 4: No Export Policy
* 5: Martian Address
* 6: Bogon Prefix
* 7: Maintenance
* 8: Local Administrative Action
* 9: Local Link Down
* 10-64535: Reserved
* 64536-65535: Reserved for Private Use

Inclusion of the Unreachability Reason Code Sub-TLV is RECOMMENDED. When this Sub-TLV is absent from a Reporter TLV, receivers MUST treat the reason as Unspecified (code 0); this is semantically equivalent to an explicitly encoded Reason Code of 0. A bare Reporter TLV carrying no Sub-TLVs therefore conveys the fact of unreachability with reason Unspecified.

3.5.2. Timestamp Sub-TLV

* Sub-Type: 2
* Sub-Length: 8 octets

* Sub-Value: Unix timestamp (seconds since epoch) in network byte order, indicates when the unreachability event occurred or was detected by this reporter

3.6. Encoding Examples

3.6.1. Single Reporter

Example: 192.0.2.0/24 unreachable, reported by AS 65001, Router ID 198.51.100.1, Reason: RPKI Invalid

Prefix Length: 24 (0x18)
Prefix: 192.0.2.0 (0xC0000200)

Reporter TLV:
  Type: 1
  Length: 24 (0x0018)
  Reporter Identifier: 198.51.100.1 (0xC6336401)
  Reporter AS: 65001 (0x0000FDE9)

  Sub-TLV (Reason):
    Sub-Type: 1
    Sub-Length: 2 (0x0002)
    Sub-Value: 3 (0x0003) [RPKI Invalid]

  Sub-TLV (Timestamp):
    Sub-Type: 2
    Sub-Length: 8 (0x0008)
    Sub-Value: 1733789400 (0x00000000675786D8)

Hexadecimal encoding:
18 C0 00 02 01 00 18 C6 33 64 01 00 00 FD E9 01
00 02 00 03 02 00 08 00 00 00 00 67 57 86 D8

3.6.2. Multiple Reporters

Example: 192.0.2.0/24 unreachable, reported by two speakers

```
   Prefix Length: 24
   Prefix: 192.0.2.0

   Reporter TLV #1:
     Type: 1
     Length: 24
     Reporter Identifier: 198.51.100.1
     Reporter AS: 65001
     Sub-TLV (Reason): 3 (RPKI Invalid)
     Sub-TLV (Timestamp): 1733789400

   Reporter TLV #2:
     Type: 1
     Length: 24
     Reporter Identifier: 198.51.100.2
     Reporter AS: 65002
     Sub-TLV (Reason): 1 (Policy Blocked)
     Sub-TLV (Timestamp): 1733789410

   Total NLRI length: 4 + 27 + 27 = 58 octets
```

4. Operation

4.1. Generating Unreachability Information

A BGP speaker MAY generate an Unreachability Information NLRI when local processing determines, for any reason, that a prefix is to be reported as unreachable. The triggering condition is conveyed by the Reason Code Sub-TLV (Section 3.5.1). This document does not mandate the set of local conditions that cause generation; that set is implementation- and deployment-specific, constrained only by the Reason Codes defined in this document or subsequently registered.

The Reporting Speaker MUST populate the Reporter TLV with its own BGP Identifier and AS Number. The speaker SHOULD include a Reason Code Sub-TLV and SHOULD include a Timestamp Sub-TLV to facilitate temporal correlation.

4.2. NLRI Processing and Aggregation

When a BGP speaker receives an UPDATE message with Unreachability Information SAFI:

1. It MUST NOT install or remove any routes in the Loc-RIB based on this information

2. It MUST maintain a separate Unreachability Information RIB (UI-RIB) for this SAFI

3. It SHOULD apply standard BGP path selection to UI-RIB entries for consistency

4. It MAY propagate the information according to standard BGP rules, local policy, and aggregation procedures defined in Section 4.2.1

5. It MUST NOT mix Unreachability Information NLRI with other SAFIs in the same UPDATE message

4.2.1. Aggregation Procedures

When multiple UPDATE messages arrive advertising unreachability for the same prefix from different neighbors, a BGP speaker supporting aggregation (A bit set in capability) SHOULD combine the Reporter TLVs according to the following procedure:

1. Perform standard BGP path selection on the received updates. The "best path" is determined based on standard BGP decision process, considering only standard BGP attributes (AS_PATH length, LOCAL_PREF, etc.), NOT the content of Reporter TLVs.

2. Extract all Reporter TLVs from the best path.

3. For each non-selected path that would be feasible (not filtered by policy):

   * Extract all Reporter TLVs from that path

   * For each Reporter TLV, check if a Reporter with the same Reporter Identifier and Reporter AS already exists in the aggregated set

   * If not present, add the Reporter TLV to the aggregated set

   * If already present, compare timestamps (if present) and keep the more recent report, or keep the existing entry if timestamps are equal or absent

4. Create a new NLRI containing all unique Reporter TLVs

5. Advertise this aggregated NLRI to appropriate neighbors, with BGP path attributes taken from the best path

A speaker performing aggregation (A=1) MUST place the Reporter TLV corresponding to the best path in the first position of the resulting NLRI. Reporter TLVs drawn from non-selected feasible paths MAY follow in any order. Except for the first position, receivers MUST NOT derive meaning from Reporter TLV ordering; implementations MUST tolerate any ordering of Reporter TLVs past the first.

The interoperability case of an aggregating sender paired with a non-aggregating receiver is resolved by capability negotiation (Section 2.2): a speaker that advertises A=0 will not receive aggregated NLRIs on that session, since its peer MUST NOT send them. The first-position rule above applies regardless, so that any speaker transiting a single aggregated NLRI (for local inspection, BMP export, or display) has a deterministic "first Reporter TLV = best path" invariant to rely on.

The maximum number of Reporter TLVs that can be aggregated in a single NLRI is limited by the maximum BGP UPDATE message size (4096 octets). Implementations SHOULD limit the number of Reporter TLVs to prevent NLRI size from becoming unwieldy. A RECOMMENDED maximum is 50 Reporter TLVs per prefix, which allows for comprehensive multi-vantage-point monitoring while maintaining reasonable message sizes.

If the maximum is reached and a new reporter must be added, implementations SHOULD remove the oldest Reporter TLV (based on Timestamp Sub-TLV if present), unless this is the reporter of the best path. In that case the second oldest reporter should be removed.

4.3. Withdrawal Procedures

Withdrawal of unreachability information operates at two levels:

4.3.1. Individual Reporter Withdrawal

When a BGP speaker determines that a specific reporter no longer considers a prefix unreachable (e.g., receives an UPDATE from that reporter’s AS that doesn’t include the unreachability NLRI, or local policy determines the report is stale), it SHOULD:

1. Remove the corresponding Reporter TLV from the NLRI
2. If other Reporter TLVs remain, re-advertise the NLRI with the remaining Reporter TLVs
3. If no Reporter TLVs remain, withdraw the entire NLRI as described in Section 4.3.2

To facilitate individual reporter withdrawal, implementations MUST track the source of each Reporter TLV (which BGP neighbor or local process it came from).

4.3.2. Complete NLRI Withdrawal

A BGP speaker MUST withdraw an Unreachability Information NLRI (send the prefix in MP_UNREACH_NLRI) when:

* All Reporter TLVs have been removed
* The prefix is explicitly withdrawn by all upstream sources
* Local policy dictates the information should no longer be propagated

The MP_UNREACH_NLRI contains only the prefix (Prefix Length and Prefix) without any TLVs.

4.3.3. Stale Reporter Detection

Implementations SHOULD implement aging mechanisms to remove stale Reporter TLVs:

* If a Timestamp Sub-TLV is present and indicates the report is older than a configurable threshold (RECOMMENDED default: 24 hours), the Reporter TLV MAY be removed
* If the BGP session to the neighbor that provided a Reporter TLV goes down, implementations SHOULD mark associated Reporter TLVs as potentially stale and MAY remove them after a grace period

4.4. Path Selection for Aggregation

The path selection for Unreachability Information SAFI follows standard BGP best path selection (RFC 4271 Section 9.1) with the following clarifications:

* Weight/Local Preference: Apply normally based on local policy.
* AS_PATH Length: Shorter AS_PATH is preferred. This represents the path the UPDATE message took.
* ORIGIN: IGP preferred over EGP over INCOMPLETE.
* MED: Apply if comparing paths from the same neighboring AS.
* BGP Identifier: Use for tie-breaking.

The content of Reporter TLVs (number of reporters, reason codes, etc.) MUST NOT influence path selection. Path selection determines which UPDATE's BGP attributes are used for propagation, while aggregation combines Reporter TLVs from multiple paths.

4.5. Interaction with Route Reflection

Route Reflectors process Unreachability Information SAFI like any other AFI/SAFI combination:

* Apply standard route reflection rules
* ORIGINATOR_ID and CLUSTER_LIST attributes apply normally to the UPDATE message, not to individual reporters
* Route Reflectors SHOULD support aggregation to combine reports from multiple clients
* When reflecting to clients, include all aggregated Reporter TLVs

The distinction between the ORIGINATOR_ID BGP attribute and the Reporter Identifier field in Reporter TLVs is important:

* ORIGINATOR_ID identifies the originator of the BGP UPDATE message for loop prevention
* Reporter Identifier identifies the speaker that observed and reported the unreachability condition
* These MAY be different in aggregated scenarios

4.6. Communities and Attributes

Standard BGP communities and attributes apply to the UPDATE message:

* NO_EXPORT, NO_ADVERTISE, and NO_EXPORT_SUBCONFED work as defined
* Large Communities [RFC8092] MAY be used for policy control of aggregation behavior
* AS_PATH is constructed normally for the UPDATE message path
* ORIGIN SHOULD be set to INCOMPLETE for locally generated information, reflecting that the information does not originate from routing protocol state

4.7. Interaction with Graceful Restart

BGP Graceful Restart (GR) as defined in [RFC4724] applies to the Unreachability Information SAFI. This section describes how UI-RIB is handled during restart scenarios.

4.7.1. Graceful Restart Capability

A BGP speaker that supports Graceful Restart for Unreachability Information SAFI MUST include the AFI/SAFI pair (AFI=1 or 2, SAFI=81) in the Graceful Restart Capability advertisement as defined in RFC 4724.

The "Forwarding State" (F) bit for this SAFI:

* Since Unreachability Information does not affect the forwarding plane (Loc-RIB or FIB), there is no forwarding state to preserve.

* The F bit SHOULD be set to 0 in the Graceful Restart Capability for this AFI/SAFI combination.

* Receiving Speakers MUST NOT interpret the F bit for this SAFI as indicating preservation of forwarding state. The F bit, if set, has no defined meaning for this SAFI and MUST be ignored.

* Implementations MAY use the F bit in future extensions to signal UI-RIB preservation capabilities, but such usage is outside the scope of this document.

4.7.2. Restarting Speaker Behavior

When a BGP speaker restarts and has negotiated GR for the Unreachability Information SAFI:

1. The speaker SHOULD set the F bit to 0 in the Graceful Restart Capability for this AFI/SAFI pair, as there is no forwarding state associated with this SAFI.

2. If the speaker preserved its UI-RIB across the restart, it SHOULD re-advertise all retained UI-RIB entries to its peers as soon as possible after restart, but MAY do so gradually to avoid overwhelming the network.

3. If the speaker did NOT preserve its UI-RIB across the restart, it SHOULD rebuild the UI-RIB from local information sources before re-advertising entries.

4. The speaker MUST send an End-of-RIB (EoR) marker for this SAFI after completing the re-advertisement of UI-RIB entries. The EoR marker is an UPDATE message with no NLRI and the MP_UNREACH_NLRI attribute containing the AFI/SAFI pair but no withdrawn routes.

4.7.3. Receiving Speaker Behavior

When a BGP speaker detects that a peer has restarted with GR capability for Unreachability Information SAFI:

1. The speaker MUST mark all UI-RIB entries learned from the restarting peer as stale. Stale marking occurs regardless of the F bit value, since the F bit has no defined semantics for this SAFI.

2. Stale entries MUST NOT be immediately withdrawn. They MUST be retained for the duration of the Restart Time advertised in the peer's GR Capability, or until the End-of-RIB marker is received, whichever comes first.

3. During the Restart Time period:

   * Stale entries MAY be used for monitoring and correlation purposes

   * Implementations MAY mark stale entries distinctly in display and APIs

   * Stale entries SHOULD NOT be propagated to other peers unless explicitly configured to do so

4. Upon receiving the End-of-RIB marker from the restarting peer:

   * All stale entries that were not refreshed MUST be removed from the UI-RIB

   * Reporter TLVs from the restarted peer that were part of aggregated NLRIs MUST be removed if not refreshed

   * If removal of Reporter TLVs leaves other Reporter TLVs for the same prefix, the NLRI SHOULD be re-advertised with the remaining Reporter TLVs

5. If the Restart Time expires before receiving the End-of-RIB marker, all stale entries MUST be removed immediately.

4.7.4. Route Reflector Considerations

Route Reflectors implementing Graceful Restart for this SAFI:

* MUST properly handle stale marking of UI-RIB entries from restarting clients
* SHOULD NOT reflect stale entries to other clients unless configured with a specific policy to do so
* MUST correctly manage ORIGINATOR_ID and CLUSTER_LIST for entries that transition through stale and refresh phases
* SHOULD send End-of-RIB markers to clients after the RR itself completes restart processing

4.7.5. Implementation Recommendations

* Restart Time for this SAFI SHOULD be configurable independently from other AFI/SAFI combinations, with a RECOMMENDED default of 120 seconds.
* Implementations SHOULD provide configuration options to:
  - Enable/disable preservation of UI-RIB across restarts
  - Control whether stale entries are propagated during GR
  - Set the Restart Time for this SAFI
  - Configure actions when End-of-RIB is not received in time
* Implementations SHOULD log GR events for this SAFI to aid in debugging, including:
  - Detection of peer restart
  - Stale marking of entries
  - Receipt of End-of-RIB marker
  - Removal of stale entries

4.8. Preventing State Explosion

To prevent unbounded growth of the UI-RIB:

1. Implementations SHOULD limit the number of Reporter TLVs per prefix (RECOMMENDED maximum: 50)

2. Implementations SHOULD implement rate limiting for accepting new unreachability information

3. Default maximum UI-RIB size SHOULD be configurable with a reasonable default (e.g., 100,000 prefixes)

4. Implementations SHOULD implement memory limits for total Reporter TLV storage

5. Error Handling

Error handling for the Unreachability Information SAFI follows [RFC7606] and [RFC4760] Section 7. Per-class actions are specified in Section 5.1 through Section 5.4.

The primary action for session-level errors is "session reset". A receiver that supports "AFI/SAFI disable" per [RFC7606] Section 7 MAY apply it in place of "session reset", confining the impact to the Unreachability Information SAFI rather than the entire BGP session.

Checks in Section 5.1 are performed before those in Section 5.2; on first error the corresponding action MUST be taken and further NLRI parsing MUST cease. All error conditions MUST be logged.

5.1. NLRI Structural Errors

A receiver MUST apply "session reset" per [RFC7606] Section 4, or "AFI/SAFI disable" per [RFC7606] Section 7 if supported, on any of the following:

* NLRI length below the minimum for this SAFI: 1 octet (Prefix Length) plus the octets of the Prefix for the negotiated AFI, plus at least 11 octets for one Reporter TLV in MP_REACH_NLRI; 1 octet plus the Prefix octets in MP_UNREACH_NLRI.

* NLRI length inconsistent with the enclosing MP_REACH_NLRI or MP_UNREACH_NLRI attribute length.

* Prefix Length outside the range permitted for the negotiated AFI (0-32 for AFI=1, 0-128 for AFI=2): the Prefix field boundary cannot be determined, and any subsequent Reporter TLVs cannot be parsed.

5.2. Non-Key Field Errors

A receiver MUST apply "treat-as-withdraw" per [RFC7606] Section 2 on any of the following:

* An MP_REACH_NLRI containing no Reporter TLVs after the Prefix (Section 3 requires one or more).

* An MP_UNREACH_NLRI containing any octets after the Prefix (Section 4.3 prohibits TLVs in withdrawals).

5.3. Reporter TLV Errors

Consistent with the principle in [RFC9552] Section 5.1, unknown or malformed Reporter TLVs MUST NOT cause the enclosing NLRI to be considered malformed.

* Unrecognized Reporter TLV Type: the TLV MUST be ignored; parsing resumes at the next TLV boundary computed from the Length field.

* Malformed Reporter TLV (Length inconsistent with the remaining NLRI data, or less than the 8-octet minimum required to carry the Reporter Identifier and Reporter AS Number): the TLV MUST be discarded. If one or more well-formed Reporter TLVs remain, they MUST be processed; otherwise "treat-as-withdraw" MUST be applied to the NLRI.

* Duplicate Reporter TLVs (identical Reporter Identifier and Reporter AS Number within a single NLRI): only the first occurrence is processed, per Section 3.4.

* Reporter TLV count exceeding the implementation limit (Section 4.8): excess TLVs MUST be discarded.

5.4. Sub-TLV Errors

Unrecognized Sub-TLV Types within a Reporter TLV MUST be silently ignored per Section 3.5. A Sub-TLV whose Sub-Length is inconsistent with the available data within the enclosing Reporter TLV MUST be discarded; processing of the enclosing Reporter TLV and any remaining Sub-TLVs continues. Duplicate Sub-TLVs of the same Sub-Type within a single Reporter TLV are handled per Section 3.5: only the first occurrence is processed.

6. Deployment Considerations

6.1. Incremental Deployment

The Unreachability Information SAFI can be deployed incrementally:

* Speakers that don't support it simply don't negotiate the capability
* Mixed environments work correctly with normal BGP capability negotiation
* Can be enabled on specific sessions for testing
* Aggregation support (A bit in capability) is OPTIONAL; speakers without it can still propagate single-reporter NLRIs
* Speakers MAY use BGP dynamic capabilities to enable or disable this SAFI without resetting the BGP session

6.2. Use Cases

Example deployment scenarios:

Inter-AS Debugging: Enable between cooperating ASes for troubleshooting. Aggregation provides comprehensive view of why different ASes find a prefix unreachable.

Route Collectors: Deploy on route collector sessions for enhanced telemetry. Collectors can aggregate reports from multiple feeders to provide consolidated unreachability view.

DDoS Coordination: Share attack target information without null-routing. Multiple reports from different locations confirm attack patterns.

Security Monitoring: Track suspicious unreachability patterns. Correlation of reports from multiple vantage points aids in distinguishing localized issues from widespread problems.

RPKI Validation Monitoring: Track RPKI validation failures across different ASes. Aggregation shows consensus or disagreement on RPKI status.

6.3. Operational Recommendations

* Enable aggregation on route collectors and monitoring systems to maximize visibility

* Configure reasonable Reporter TLV limits based on expected number of reporters

* Use Timestamp Sub-TLVs to facilitate debugging of temporal aspects of unreachability

* Monitor UI-RIB size and Reporter TLV counts for capacity planning

7. Security Considerations

The Unreachability Information SAFI introduces new security considerations:

1. Information Leakage: Unreachability information might reveal network topology or operational issues. Reporter TLVs explicitly identify reporting ASes and routers. Operators SHOULD carefully consider peering policies for this SAFI.

2. State Exhaustion: Malicious peers could attempt to exhaust memory by advertising large numbers of unreachable prefixes or including excessive Reporter TLVs. Implementations SHOULD enforce limits as described in Section 4.8.

3. False Information: Peers could advertise false unreachability information or spoof Reporter TLVs. This SAFI SHOULD only be enabled with trusted peers. Consider validating Reporter Identifiers and AS Numbers against known valid values.

4. Prefix Hijacking: The SAFI could be used to claim prefixes are unreachable when they’re not. Since this doesn’t affect routing, the impact is limited to monitoring systems.

5. Reporter Impersonation: A malicious speaker could include Reporter TLVs claiming to represent other ASes. Implementations SHOULD validate that Reporter AS Numbers in TLVs are consistent with the AS_PATH of UPDATEs that introduced them.

6. Aggregation Amplification: A malicious speaker could send many UPDATEs with different Reporter TLVs for the same prefix, causing downstream aggregating speakers to accumulate and propagate large numbers of Reporter TLVs. Rate limiting and Reporter TLV limits mitigate this.

Operators SHOULD:

* Use BGP TCP-AO [RFC5925] or MD5 for session protection

* Implement prefix filtering for unreachability information

* Monitor UI-RIB size and Reporter TLV counts

* Enable this SAFI only with explicitly trusted peers

* Validate Reporter AS Numbers against expected values

* Configure appropriate Reporter TLV limits per prefix

* Implement rate limiting on incoming unreachability UPDATEs

8. IANA Considerations

8.1. SAFI Assignment

IANA has assigned a SAFI value from the "Subsequent Address Family Identifiers (SAFI) Parameters" registry within the "Border Gateway Protocol (BGP) Parameters" registry group, applicable to AFI 1 (IPv4) and AFI 2 (IPv6):

* Value: 81

* Description: Unreachability Information

* Reference: This document

8.2. BGP Capability Code

IANA is requested to assign a new BGP Capability Code from the "Capability Codes" registry within the "Border Gateway Protocol (BGP) Parameters" registry group:

* Value: TBD2

* Description: Enhanced Unreachability Information

* Reference: This document

8.3. BGP Unreachability Information Reporter TLV Types

IANA is requested to create a new registry called "BGP Unreachability Information Reporter TLV Types" under the "Border Gateway Protocol (BGP) Parameters" registry page.

Registration Procedure: Standards Action

Initial registrations:

Value	Description	Reference
0	Reserved	This document
1	Reporter TLV	This document
2-254	Unassigned	
255	Reserved	This document

8.4. BGP Unreachability Information Sub-TLV Types

IANA is requested to create a new registry called "BGP Unreachability Information Sub-TLV Types" under the "Border Gateway Protocol (BGP) Parameters" registry page.

Registration Procedure: RFC Required

Initial registrations:

Value	Description	Reference
0	Reserved	This document
1	Unreachability Reason Code	This document
2	Timestamp	This document
3-254	Unassigned	
255	Reserved	This document

8.5. BGP Unreachability Reason Codes

IANA is requested to create a new registry called "BGP Unreachability Reason Codes" under the "Border Gateway Protocol (BGP) Parameters" registry page.

Registration Procedure: RFC Required for values 0-64535, Reserved for Private Use for values 64536-65535

Initial registrations:

Value	Description	Reference
0	Unspecified	This document
1	Policy Blocked	This document
2	Security Filtered	This document
3	RPKI Invalid	This document
4	No Export Policy	This document
5	Martian Address	This document
6	Bogon Prefix	This document
7	Maintenance	This document
8	Local Administrative Action	This document
9	Local Link Down	This document
10-64535	Unassigned	
64536-65535	Reserved for Private Use	This document

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Appendix A. Implementation Considerations

Implementers should consider the following aspects when implementing the Unreachability Information SAFI with nested Reporter TLVs:

1. UI-RIB should store both the NLRI and associated Reporter TLVs with tracking of which neighbor provided each Reporter TLV

2. Show commands should clearly display all reporters for a given prefix, including Reporter ID, AS, Reason, and Timestamp

3. MIB/YANG models need structures to represent multiple reporters per prefix

4. BMP [RFC7854] should be extended to convey Reporter TLV information in monitoring messages

5. Efficient data structures for Reporter TLV storage and lookup are important for performance

6. Consider implementing a local database to track reporter history for forensic analysis

Appendix B. Detailed Examples

B.1. Complete UPDATE Message Example

An UPDATE message advertising that 192.0.2.0/24 is unreachable, reported by AS 65001 (Router 198.51.100.1) due to RPKI validation failure:

```
BGP UPDATE Message:
  Withdrawn Routes Length: 0
  Total Path Attribute Length: (calculated)

  Path Attributes:
    MP_REACH_NLRI (Type 14, Flags 0x90):
      AFI: 1 (IPv4)
      SAFI: 81 (Unreachability Information)
      Next Hop Length: 0
      Reserved: 0
      NLRI:
        Prefix Length: 24
        Prefix: 192.0.2.0
        Reporter TLV:
          Type: 1
          Length: 24
          Reporter ID: 198.51.100.1
          Reporter AS: 65001
          Sub-TLV (Reason):
            Sub-Type: 1
            Sub-Length: 2
            Reason: 3 (RPKI Invalid)
          Sub-TLV (Timestamp):
            Sub-Type: 2
            Sub-Length: 8
            Value: 1733789400

    AS_PATH (Type 2):
      Segment Type: AS_SEQUENCE
      Segment Length: 1
      AS: 65001

    ORIGIN (Type 1):
      Value: INCOMPLETE (2)
```

B.2. Aggregation Example

```
Router R1 receives two UPDATEs for 192.0.2.0/24:

UPDATE 1 (from Neighbor N1, AS 65100):
  AS_PATH: 65100
  Reporter TLV:
    Reporter ID: 198.51.100.1, AS: 65001
    Reason: RPKI Invalid (3)
    Timestamp: 1733789400

UPDATE 2 (from Neighbor N2, AS 65200):
  AS_PATH: 65200
  Reporter TLV:
    Reporter ID: 198.51.100.2, AS: 65002
    Reason: Policy Blocked (1)
    Timestamp: 1733789410

R1 Path Selection:
  - Compare AS_PATH length: both length 1
  - Compare by BGP ID: UPDATE 1 wins

R1 Aggregation:
  - Extract Reporter TLV from UPDATE 1 (best path)
  - Extract Reporter TLV from UPDATE 2 (add to aggregated set)
  - Result: NLRI with 2 Reporter TLVs

R1 Advertisement to downstream:
  AS_PATH: 65100 (from best path)
  NLRI for 192.0.2.0/24:
    Reporter TLV #1:
      Reporter ID: 198.51.100.1, AS: 65001
      Reason: 3, Timestamp: 1733789400
    Reporter TLV #2:
      Reporter ID: 198.51.100.2, AS: 65002
      Reason: 1, Timestamp: 1733789410
```

B.3. Withdrawal Example

Scenario: Reporter 198.51.100.1 (AS 65001) clears its unreachability report, but Reporter 198.51.100.2 (AS 65002) maintains its report.

```
   Initial State on Router R1:
     UI-RIB Entry for 192.0.2.0/24:
       Reporter TLV #1: 198.51.100.1/AS65001 (from Neighbor N1)
       Reporter TLV #2: 198.51.100.2/AS65002 (from Neighbor N2)

   Event: N1 sends MP_UNREACH_NLRI for 192.0.2.0/24

   R1 Processing:
     1. Identify that withdrawal came from N1
     2. Find Reporter TLVs associated with N1
     3. Remove Reporter TLV for 198.51.100.1/AS65001
     4. Check remaining Reporter TLVs
     5. Reporter TLV #2 still present
     6. Re-advertise NLRI with remaining Reporter TLV

   R1 Advertisement to downstream:
     MP_REACH_NLRI for 192.0.2.0/24:
       Reporter TLV #2:
         Reporter ID: 198.51.100.2, AS: 65002
         Reason: 1, Timestamp: 1733789410

   Later Event: N2 also sends MP_UNREACH_NLRI for 192.0.2.0/24

   R1 Processing:
     1. Remove Reporter TLV for 198.51.100.2/AS65002
     2. No Reporter TLVs remain
     3. Send MP_UNREACH_NLRI for 192.0.2.0/24

   R1 Advertisement to downstream:
     MP_UNREACH_NLRI:
       AFI: 1, SAFI: 81
       Withdrawn Route: 192.0.2.0/24
```

Appendix C. Comparison with ADD-PATH Approach

This nested TLV approach differs from using BGP ADD-PATH [RFC7911] in several fundamental ways:

C.1. Architectural Differences

ADD-PATH Approach: Maintains multiple complete BGP paths for the same prefix, each with full set of BGP attributes (AS_PATH, communities, etc.). Each reporter’s information travels as a separate BGP UPDATE path.

Nested TLV Approach: Aggregates multiple reporter perspectives into a single BGP path. Only one set of BGP attributes (representing the advertising path), but multiple Reporter TLVs within the NLRI.

C.2. Advantages of Nested TLV Approach

* No ADD-PATH capability negotiation required - works with all BGP implementations
* More compact representation - single UPDATE can carry reports from many speakers
* Explicit aggregation model designed for consolidating multiple perspectives
* Lower BGP state - one path entry instead of multiple
* Easier correlation - all reports for a prefix in one NLRI

C.3. Disadvantages of Nested TLV Approach

* More complex specification and implementation
* BGP attribute ambiguity - AS_PATH represents the path of the UPDATE message, not the original paths reporters observed
* Withdrawal complexity - requires tracking which neighbor provided each Reporter TLV
* NLRI size can grow large with many reporters
* Non-standard pattern in BGP protocol design
* Path selection doesn’t consider reporter content
* New capability bit and processing logic required

C.4. When to Use Each Approach

Use ADD-PATH when:

* Full BGP path information per reporter is important
* Independent lifecycle management is critical
* ADD-PATH is already widely deployed in the network
* Standard BGP mechanisms are preferred

Use Nested TLV when:

* ADD-PATH support is limited or unavailable
* Compact aggregation is desired

* Monitoring systems want single consolidated view

* Lower BGP state is important

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