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Link-Local Next Hop Capability for BGP  
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Abstract

To support IPv6 [RFC4291] reachability, BGP [RFC4271] relies on the Multiprotocol Extensions as defined in [RFC4760]. [RFC2545] defines the structure of IPv6 next hops. These IPv6 next hops may contain a Global IPv6 address, and optionally can contain an IPv6 Link-Local address when the BGP peer is directly attached and shares a common subnet with the IPv6 Global address.

This document updates [RFC2545] to clarify the encoding of the BGP next hop when the advertising system is directly attached and only an IPv6 Link-Local address is available. A new BGP Capability [RFC5492] is defined to signal support for this updated encoding.

This clarification applies specifically to IPv6 Link-Local addresses and does not pertain to IPv4 Link-Local addresses as defined in [RFC3927].

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## 1. Introduction

To support IPv6 reachability, BGP [RFC4271] relies on the Multiprotocol Extensions as defined in [RFC4760]. [RFC2545] defines the structure of IPv6 next hops. These IPv6 next hops may contain a Global IPv6 address, and optionally can contain an IPv6 Link-Local address when the BGP peer is directly attached and shares a common subnet with the IPv6 Global address.

This document updates [RFC2545] to clarify the encoding of the BGP next hop when the advertising system is directly attached and only an IPv6 Link-Local address is available. A new BGP Capability [RFC5492] is defined to signal support for this updated encoding.

This clarification applies specifically to IPv6 Link-Local addresses and does not pertain to IPv4 Link-Local addresses as defined in [RFC3927].

BGP speakers are now often deployed on point-to-point links in networks where multihop reachability of any kind is not assumed or desired. (All next hops are assumed to be the reachable through a directly connected point-to-point link.) This is common, for instance, in data center fabrics [RFC7938]. In these situations, a Global IPv6 address is not required for the advertisement of reachability information. In fact, providing Global IPv6 addresses in these kinds of networks can be detrimental to Zero Touch Provisioning (ZTP).

Such BGP deployment models require BGP to run on each link, and any simplification of BGP configuration can simplify orchestration and configuration management. This proposal is a step in that direction.

With this new capability, the need for a Global unicast address assigned to the interfaces is eliminated.

Since IPv6 Link-Local addresses are not required to be globally unique, implementations must ensure that they are strictly associated with a specific interface. (See commentary in [RFC4007].)

IPv6 Link-Local addresses are not required to be stable across interface startup or reconfiguration. A change in an interface's Link-Local address invalidates the underlying TCP connection and therefore causes the BGP session to reset; routes are re-advertised through the normal session re-establishment procedures. BGP speakers SHOULD NOT advertise a route whose Next Hop is a Link-Local address that is in the tentative state (Section 5.4 of [RFC4862]); this applies both to a first-party Next Hop (the speaker's own Link-Local address) and to a third-party Next Hop re-advertised from another peer. A Link-Local address in the tentative state is not yet usable for Neighbor Discovery and would therefore yield an unreachable Next Hop at the receiver.

## 2. Link-Local Next Hop Capability

The Link-Local Next Hop capability is a new BGP capability. Its Capability code is 77 and its Capability Length is 0.

A BGP speaker that is willing to use (send and receive) IPv6 Link-Local-only next hops SHOULD advertise the Link-Local Next Hop Capability to its peers only when:

1. It is capable of sending IPv6 Link-Local-only next hops for a route.
2. IPv6 Link-Local neighbors are associated with interfaces as part of their configuration to assist in determining the interface scope of received IPv6 Link-Local-only next hops.

The presence of this capability does not affect the support of Global IPv6 only (16 bytes next hop) and Global IPv6 combined with IPv6 Link-Local (32 bytes next hop), which should continue to be supported as before.

The peers have the flexibility to include both Global and Link-Local BGP IPv6 nexthops, or Link-Local-only IPv6 next hops.

In this document, all procedures described are applicable only when the capability described herein has been successfully advertised by both BGP speakers; i.e., negotiated. When the capability has not been negotiated, the procedures in this document do not apply.

Implementers are encouraged to consult the Appendix for currently known interoperability concerns or incompatibilities when this capability is absent or inconsistently implemented.

### 3. Changes to the Procedure for Encoding IPv6 Next Hops

Section 2 of [RFC2545] notes IPv6 Link-Local addresses are not generally suitable for use in the Next Hop field of the MP\_REACH\_NLRI. In order to support the many uses of IPv6 Link-Local addresses, however, [RFC2545] constructs the Next Hop field in IPv6 route advertisements by setting the length of the field to 32, and including both an IPv6 Global and Link-Local address.

[RFC2545] does not, however, provide an explanation for situations where there is only an IPv6 Link-Local address in the Next Hop field of the MP\_REACH\_NLRI.

A BGP speaker receiving an MP\_REACH\_NLRI with the Next Hop field length set to 16 classifies the address as follows. If the address is in fe80::/10, the Next Hop is a Link-Local-only Next Hop as defined in this document. Otherwise, the address is treated as a Global IPv6 Next Hop per [RFC2545]. A Link-Local-only Next Hop received without the Link-Local Next Hop Capability having been negotiated is not conformant with [RFC2545]; receivers MAY accept such a Next Hop and apply the procedures of this document, or MAY ignore the route.

If an implementation intends to send a single IPv6 Link-Local forwarding address in the Next Hop field of the MP\_REACH\_NLRI, it MUST set the length of the Next Hop field to 16 and include only the IPv6 Link-Local address in the Next Hop field.

If an implementation intends to send both a IPv6 Global and Link-Local forwarding address in the Next Hop field of the MP\_REACH\_NLRI, it MUST set the length of the Next Hop field to 32 and include both the IPv6 Global and Link-Local addresses in the Next Hop field.

When both an IPv6 Global and a Link-Local address are present in the Next Hop field, the choice of which of these is to be installed for forwarding is implementation-specific.

#### 4. IPv6 Next Hop Procedures for Internal and External Peers

Section 5.1.3 of [RFC4271] defines how the NEXT\_HOP field is used by BGP for internal and external peering. [RFC2545] does not explicitly discuss next hop procedures in a similar fashion, only the conditions for when the Global IPv6 address is on the same subnet as the peer that a Link-Local IPv6 address is also included in the next hop.

This section defines the behaviors for setting IPv6 next hops when the Link-Local Next Hop Capability has been negotiated between two peers. The next hop MAY consist of only a Link-Local IPv6 next hop.

If, after completing these procedures, there are no IPv6 next hop addresses included in the next hop, the BGP route MUST not be advertised to its peer. Instead, treat-as-withdraw (Section 2 of [RFC7606]) is used.

1. When sending a message to an internal peer, if the route is not locally-originated, the BGP speaker SHOULD NOT modify the Global IPv6 next hop, if one is present, unless it has been explicitly configured to announce its own IP address as the next hop.

If the internal peer is more than one IP hop away, the BGP speaker MUST NOT include a Link-Local IPv6 next hop.

If the internal peer is one IP hop away, and the route is not locally-originated, and the route was received from a peer on the same interface as the peer the route is being announced to, the BGP speaker MAY include the received Link-Local IPv6 nexthop for the route. (This is a form of "third-party" next hop.)

When announcing a locally-originated route to an internal peer, or the BGP speaker has been explicitly configured to announce its own IP address as the next hop, the BGP speaker SHOULD use the

Global IPv6 address of the interface of the router through which the announced network is reachable for the speaker as the next hop, if present. If the route is directly connected to the speaker, or if the interface address of the router through which the announced network is reachable for the speaker is the internal peer's address, the next hop MUST include its own Link-Local IPv6 address.

If, after evaluating the above procedures, there are no IPv6 next hops included with the route, the route MUST NOT be announced to the remote BGP speaker. (Treat-as-withdraw.)

These procedures also apply when the BGP speaker is functioning as a route-reflector ([RFC4456]). A Route Reflector (RR) reflecting a route with a link-local-only next hop MUST NOT advertise that route to a client unless the client shares the same link-layer segment as the original advertiser. For all other clients, the RR MUST either rewrite the next hop to its own address (next-hop-self) or consider the route ineligible for advertisement to that specific peer.

Successful negotiation of the Link-Local Next Hop Capability between an RR and a client does not, by itself, guarantee that the client shares the same link-layer segment as the original advertiser of a Link-Local-only route. When an RR has negotiated this capability with a client that is not on the same link as the originator and the RR has not been configured to rewrite the next hop, routes with a Link-Local-only next hop will be suppressed for that client without any in-band diagnostic signal. To aid troubleshooting in such deployments, implementations SHOULD log this suppression, or otherwise expose it through operator notification (e.g., via BMP or YANG telemetry), so that unexpected reachability gaps can be detected.

2. When sending a message to an external peer, X, and the peer is one IP hop away from the speaker:
  - \* If the route being announced was learned from an internal peer or is locally-originated, the BGP speaker can use an interface address of the internal peer router (or the internal router) through which the announced network is reachable for the speaker for the Global IPv6 next hop and shares a common subnet with this address, and/or a Link-Local IPv6 next hop, provided that peer X is directly attached. This is a form of "third party" next hop.

- \* Otherwise, if the route being announced was learned from an external peer, the speaker can use a Global IPv6 address of any adjacent router (known from the received next hop) that the speaker itself uses for local route calculation in the next hop, provided that peer X shares a common subnet with this Global IPv6 address. Similarly, the speaker can use the received Link-Local IPv6 address, provided that peer X is directly attached. This is a second form of "third party" next hop attribute.
  - \* Otherwise, if the external peer to which the route is being advertised shares a common subnet with one of the interfaces of the announcing BGP speaker, the speaker MAY use the Global IPv6 address associated with such an interface in the next hop. If the external peer is one IP hop away, the announcing BGP speaker SHOULD include a Link-Local IPv6 next hop. These are known as "first party" next hops.
  - \* By default (if none of the above conditions apply), the BGP speaker SHOULD use the IP address of the interface that the speaker uses to establish the BGP connection to peer X in the next hop attribute. The Global IPv6 address, if one is present, SHOULD be included. If the BGP speaker is one IP hop away, the Link-Local IPv6 address SHOULD be included, and MAY be the only next hop address in the next hop. If no next hops are included, the route MUST NOT be announced (treat-as-withdraw).
3. When sending a message to an external peer X, and the peer is multiple IP hops away from the speaker (aka "multihop EBGP"):
- \* Link-Local IPv6 next hops MUST NOT be included. If a BGP speaker receives a route with a link-local-only next hop, the route SHOULD be considered unusable for forwarding, consistent with the next-hop resolvability requirements described in [RFC4271].
  - \* The speaker MAY be configured to propagate a Global IPv6 next hop. In this case, when advertising a route that the speaker learned from one of its peers, the Global IPv6 next hop of the advertised route is exactly the same as the next hop attribute of the learned route.
  - \* By default, the BGP speaker SHOULD use the Global IPv6 address of the interface that the speaker uses in the next hop to establish the BGP connection to peer X.

- \* If a Global IPv6 next hop is not included, the route MUST NOT be advertised to the external peer (treat-as-withdraw).

## 5. Interaction with RFC 8950

Section 3 of [RFC8950] requires the Next Hop field to be 32 octets: a Global-or-unspecified IPv6 address followed by a Link-Local IPv6 address, whenever IPv4 NLRI is carried with an IPv6 Next Hop.

When both the Link-Local Next Hop Capability defined in this document and the Extended Next Hop Encoding capability ([RFC8950]) have been negotiated between two peers, a 16-octet Link-Local-only Next Hop is permitted for IPv4 NLRI carried with an IPv6 Next Hop, provided the receiving peer is directly attached. When this combination has not been negotiated, a sender MUST follow the rules in Section 3 of [RFC8950] and encode the Next Hop as 32 octets. A receiver that observes a 16-octet Link-Local-only Next Hop for IPv4 NLRI in the absence of the negotiated combination MAY accept the Next Hop and apply the procedures of this document, or MAY ignore the route.

## 6. Error handling

These procedures apply only when the Link-Local Next Hop Capability has been negotiated for a BGP session.

A BGP speaker receiving an MP\_REACH\_NLRI with the length of the Next Hop Field set to 32, where the update contains anything other than a Global IPv6 followed by a Link-Local IPv6 address, SHOULD do the following.

A 32-byte Next Hop field carrying two IPv6 Link-Local addresses is not produced by a conforming implementation of [RFC2545] or of this document; however, this form of next hop has been observed in deployment (see, for example, the Bird implementation report in Appendix B). Receivers SHOULD use the second Link-Local IPv6 address for forwarding, because the second slot is the position that carries the Link-Local address in the conforming Global-then-Link-Local layout defined by [RFC2545], and thus is the value the sender most likely intended as the Link-Local next hop.

When the first IPv6 address is 0::0/0 and the second IPv6 address is an IPv6 Link-Local address, the second address is used for forwarding.

If the Next Hop field is malformed, the implementation MUST handle the malformed UPDATE message using the approach of "treat-as-withdraw", as described in section 7.3 of [RFC7606].



If the Next Hop field is properly formed, but the IPv6 Link-Local next hop is not reachable (as determined by an examination of the IPv6 neighbor table), the route SHOULD be considered unusable for forwarding purposes, in accordance with the next hop resolvability conditions described in [RFC4271]. The implementation MAY withdraw the route from its routing table, but this is not considered a protocol error.

## 7. Operational Considerations

In Zero-Touch Provisioning (ZTP) and BGP Unnumbered environments, the reachability of the next hop is dynamic. To ensure operational visibility and scaling, implementations SHOULD support the following.

**\*Protocol Interoperability:** Implementations SHOULD support BGP Add-Path [RFC7911] and Extended Next-Hop Encoding [RFC8950] to ensure full path utilization in IPv4-over-IPv6 underlays.

**\*Monitoring and Telemetry:** Implementations SHOULD provide specific telemetry via the BGP Monitoring Protocol (BMP) [RFC7854] or a BGP YANG model (e.g., [I-D.ietf-idr-bgp-model]) to expose the state of link-local capability negotiation.

Because IPv6 Link-Local addresses (fe80::/10) are not globally unique, a BMP collector cannot, in general, distinguish two peers that share the same Link-Local address on different interfaces of the monitored router using only the information in the BMP per-peer header. In deployments that use Link-Local addresses for BGP peering, operators SHOULD rely on additional identifying information -- such as the BGP Router ID carried in the per-peer header together with interface index or interface name -- to disambiguate peers. [I-D.lin-grow-bmp-peer-interface] defines a Peer-Interface TLV for BMP that carries this information alongside the per-peer header; that work and this document are complementary in BMP deployments that include Link-Local-only BGP sessions.

**\*Graceful Restart Interaction:** If a Restarting Speaker ([RFC4724]) re-establishes the BGP session with a Link-Local address that differs from the one in effect before the restart, peers retaining its routes as stale during the Restart Time will hold next hops that reference the previous Link-Local address. Unlike Global IPv6 Next Hops, where the routing system may provide alternative reachability, Link-Local Next Hops are resolved purely via Neighbor Discovery on the bound interface and have no routing fallback; forwarding to such stale next hops is silently lost until the Restart Time expires or new advertisements propagate. Operators deploying this capability together with Graceful Restart SHOULD ensure that Link-Local addresses remain stable across restart, and implementations SHOULD treat a change in the local Link-Local address as a session reset rather than as a graceful restart event.

## 8. Acknowledgements

The authors would like to thank Vipin Kumar, Dinesh Dutt, Donald Sharp, Jeff Haas, Mukul Srivastava and Brian Carpenter for their contributions to this draft.

This document builds on prior work exploring the use of IPv6 Link-Local addresses as BGP next hops. Notably, [I-D.kumar-idr-link-local-nexthop] and [I-D.kato-bgp-ipv6-link-local] identified operational limitations and proposed mechanisms to enable Link-Local next hop propagation in BGP. These drafts laid the groundwork for defining a standardized capability-based approach, as presented in this document, to ensure interoperable signaling and safe deployment of Link-Local next hops across BGP sessions.

## 9. IANA Considerations

IANA has assigned capability number 77 for the Link-Local Next Hop Capability described in this document. This registration is in the BGP Capability Codes registry.

+=====+	
Value	Description
+=====+	
77	Link-Local Next Hop Capability
+-----+	

Table 1: Link-Local Next Hop Capability

## 10. Security Considerations

The mechanism described in this draft can be used as a component of zero-touch provisioning (ZTP) for building BGP peering across point-to-point links. This method, then, can be used by an attacker to form a peering session with a BGP speaker, ultimately advertising incorrect routing information into a routing domain in order to misdirect traffic or cause a denial of service. By using IPv6 Link-Local addresses, the attacker would be able to forgo the use of a valid IPv6 address within the domain, making such an attack easier.

Operators SHOULD carefully consider security when deploying Link-Local addresses for BGP peering. Operators SHOULD filter traffic on links where BGP peering is not intended to occur to prevent speakers from accepting BGP session requests, as well as other mechanisms described in [RFC7454].

Operators MAY also use some form of cryptographic validation on links within the network to prevent unauthorized devices from forming BGP peering sessions. Authentication, such as the TCP authentication [RFC5925], may provide some relief if it is present and correctly configured. However, the distribution and management of keys in an environment where global addresses on BGP speakers are not present may be challenging.

Operators also MAY instruct a BGP peer which has received an UPDATE with an unreachable NEXT\_HOP to disable the peering session over which the invalid NEXT\_HOP was received pending manual intervention.

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#### Appendix A. Motivations for a Capability

Link-Local-only next hops have been inconsistently supported in prior BGP implementations. This capability can permit two conforming implementations to interoperate without additional configuration.

#### Appendix B. Inconsistency Reports

According to [RFC7942], "This will allow reviewers and working groups to assign due consideration to documents that have the benefit of running code, which may serve as evidence of valuable experimentation and feedback that have made the implemented protocols more mature".

FRRouting (<https://github.com/frrouting/frr/commit/606fdbb1fab98bac305dca3d19eb38b140b7c3e6>) IPv6 next-hop handling when GUA/LL is set to ::/LL.

Bird (<https://gitlab.nic.cz/labs/bird/-/commit/17de3a023f7bde293892b41bfafe5740c8553fc8>) handling LL/LL case.

#### Appendix C. Implementation Report

According to [RFC7942], "This will allow reviewers and working groups to assign due consideration to documents that have the benefit of running code, which may serve as evidence of valuable experimentation and feedback that have made the implemented protocols more mature".

FRRouting (<https://github.com/FRRouting/frr/pull/17871>) implementation.

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