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The BGP Encapsulation Subsequent Address Family Identifier (SAFI) and the BGP Tunnel Encapsulation Attribute

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Abstract

In certain situations, transporting a packet from one Border Gateway Protocol (BGP) speaker to another (the BGP next hop) requires that the packet be encapsulated by the first BGP speaker and decapsulated by the second. To support these situations, there needs to be some agreement between the two BGP speakers with regard to the "encapsulation information", i.e., the format of the encapsulation header as well as the contents of various fields of the header.

The encapsulation information need not be signaled for all encapsulation types. In cases where signaling is required (such as Layer Two Tunneling Protocol - Version 3 (L2TPv3) or Generic Routing Encapsulation (GRE) with key), this document specifies a method by which BGP speakers can signal encapsulation information to each other. The signaling is done by sending BGP updates using the Encapsulation Subsequent Address Family Identifier (SAFI) and the IPv4 or IPv6 Address Family Identifier (AFI). In cases where no encapsulation information needs to be signaled (such as GRE without

key), this document specifies a BGP extended community that can be attached to BGP UPDATE messages that carry payload prefixes in order to indicate the encapsulation protocol type to be used.

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1. Introduction

Consider the case of a router R1 forwarding an IP packet P. Let D be P's IP destination address. R1 must look up D in its forwarding table. Suppose that the "best match" route for D is route Q, where Q is a BGP-distributed route whose "BGP next hop" is router R2. And suppose further that the routers along the path from R1 to R2 have entries for R2 in their forwarding tables, but do NOT have entries for D in their forwarding tables. For example, the path from R1 to R2 may be part of a "BGP-free core", where there are no BGP-distributed routes at all in the core. Or, as in [MESH], D may be an IPv4 address while the intermediate routers along the path from R1 to R2 may support only IPv6.

In cases such as this, in order for R1 to properly forward packet P, it must encapsulate P and send P "through a tunnel" to R2. For example, R1 may encapsulate P using GRE, L2TPv3, IP in IP, etc., where the destination IP address of the encapsulation header is the address of R2.

In order for R1 to encapsulate P for transport to R2, R1 must know what encapsulation protocol to use for transporting different sorts of packets to R2. R1 must also know how to fill in the various

fields of the encapsulation header. With certain encapsulation types, this knowledge may be acquired by default or through manual configuration. Other encapsulation protocols have fields such as session id, key, or cookie that must be filled in. It would not be desirable to require every BGP speaker to be manually configured with the encapsulation information for every one of its BGP next hops.

In this document, we specify a way in which BGP itself can be used by a given BGP speaker to tell other BGP speakers, "if you need to encapsulate packets to be sent to me, here's the information you need to properly form the encapsulation header". A BGP speaker signals this information to other BGP speakers by using a distinguished SAFI value, the Encapsulation SAFI. The Encapsulation SAFI can be used with the AFI for IPv4 or with the AFI for IPv6. The IPv4 AFI is used when the encapsulated packets are to be sent using IPv4; the IPv6 AFI is used when the encapsulated packets are to be sent using IPv6.

In a given BGP update, the Network Layer Reachability Information (NLRI) of the Encapsulation SAFI consists of the IP address (in the family specified by the AFI) of the originator of that update. The encapsulation information is specified in the BGP "tunnel encapsulation attribute" (specified herein). This attribute specifies the encapsulation protocols that may be used as well as whatever additional information (if any) is needed in order to properly use those protocols. Other attributes, e.g., communities or extended communities, may also be included.

Since the encapsulation information is coded as an attribute, one could ask whether a new SAFI is really required. After all, a BGP speaker could simply attach the tunnel encapsulation attribute to each prefix (like Q in our example) that it advertises. But with that technique, any change in the encapsulation information would cause a very large number of updates. Unless one really wants to specify different encapsulation information for each prefix, it is much better to have a mechanism in which a change in the encapsulation information causes a BGP speaker to advertise only a single update. Conversely, when prefixes get modified, the tunnel encapsulation information need not be exchanged.

In this specification, a single SAFI is used to carry information for all encapsulation protocols. One could have taken an alternative approach of defining a new SAFI for each encapsulation protocol. However, with the specified approach, encapsulation information can pass transparently and automatically through intermediate BGP speakers (e.g., route reflectors) that do not necessarily understand the encapsulation information. This works because the encapsulation attribute is defined as an optional transitive attribute. New encapsulations can thus be added without the need to reconfigure any

intermediate BGP system. If adding a new encapsulation required using a new SAFI, the information for that encapsulation would not pass through intermediate BGP systems unless those systems were reconfigured to support the new SAFI.

For encapsulation protocols where no encapsulation information needs to be signaled (such as GRE without key), the egress router MAY still want to specify the protocol to use for transporting packets from the ingress router. This document specifies a new BGP extended community that can be attached to UPDATE messages that carry payload prefixes for this purpose.

2. Specification of Requirements

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].

3. Encapsulation NLRI Format

The NLRI, defined below, is carried in BGP UPDATE messages [RFC4271] using BGP multiprotocol extensions [RFC4760] with an AFI of 1 or 2 (IPv4 or IPv6) [IANA-AF] and a SAFI value of 7 (called an Encapsulation SAFI).

The NLRI is encoded in a format defined in Section 5 of [RFC4760] (a 2-tuple of the form <length, value>). The value field is structured as follows:

- Endpoint Address: This field identifies the BGP speaker originating the update. It is typically one of the interface addresses configured at the router. The length of the endpoint address is dependent on the AFI being advertised. If the AFI is set to IPv4 (1), then the endpoint address is a 4-octet IPv4 address, whereas if the AFI is set to IPv6 (2), the endpoint address is a 16-octet IPv6 address.

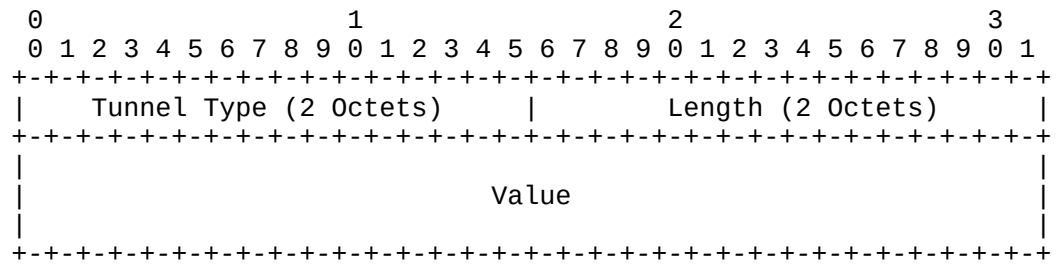
An update message that carries the MP_REACH_NLRI or MP_UNREACH_NLRI attribute with the Encapsulation SAFI MUST also carry the BGP mandatory attributes: ORIGIN, AS_PATH, and LOCAL_PREF (for IBGP neighbors), as defined in [RFC4271]. In addition, such an update message can also contain any of the BGP optional attributes, like the Community or Extended Community attribute, to influence an action on the receiving speaker.

When a BGP speaker advertises the Encapsulation NLRI via BGP, it uses its own address as the BGP nexthop in the MP_REACH_NLRI or MP_UNREACH_NLRI attribute. The nexthop address is set based on the AFI in the attribute. For example, if the AFI is set to IPv4 (1), the nexthop is encoded as a 4-byte IPv4 address. If the AFI is set to IPv6 (2), the nexthop is encoded as a 16-byte IPv6 address of the router. On the receiving router, the BGP nexthop of such an update message is validated by performing a recursive route lookup operation in the routing table.

Bestpath selection of Encapsulation NLRIs is governed by the decision process outlined in Section 9.1 of [RFC4271]. The encapsulation data carried through other attributes in the message are to be used by the receiving router only if the NLRI has a bestpath.

4. Tunnel Encapsulation Attribute

The Tunnel Encapsulation attribute is an optional transitive attribute that is composed of a set of Type-Length-Value (TLV) encodings. The type code of the attribute is 23. Each TLV contains information corresponding to a particular tunnel technology. The TLV is structured as follows:



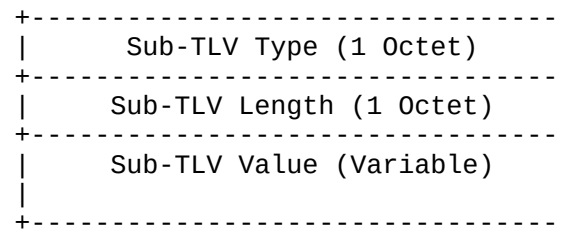
* Tunnel Type (2 octets): identifies the type of tunneling technology being signaled. This document defines the following types:

  - L2TPv3 over IP [RFC3931]: Tunnel Type = 1
  - GRE [RFC2784]: Tunnel Type = 2
  - IP in IP [RFC2003] [RFC4213]: Tunnel Type = 7

  Unknown types are to be ignored and skipped upon receipt.

* Length (2 octets): the total number of octets of the value field.

* Value (variable): comprised of multiple sub-TLVs. Each sub-TLV consists of three fields: a 1-octet type, 1-octet length, and zero or more octets of value. The sub-TLV is structured as follows:



* Sub-TLV Type (1 octet): each sub-TLV type defines a certain property about the tunnel TLV that contains this sub-TLV. The following are the types defined in this document:

  - Encapsulation: sub-TLV type = 1
  - Protocol type: sub-TLV type = 2
  - Color: sub-TLV type = 4

  When the TLV is being processed by a BGP speaker that will be performing encapsulation, any unknown sub-TLVs MUST be ignored and skipped. However, if the TLV is understood, the entire TLV MUST NOT be ignored just because it contains an unknown sub-TLV.

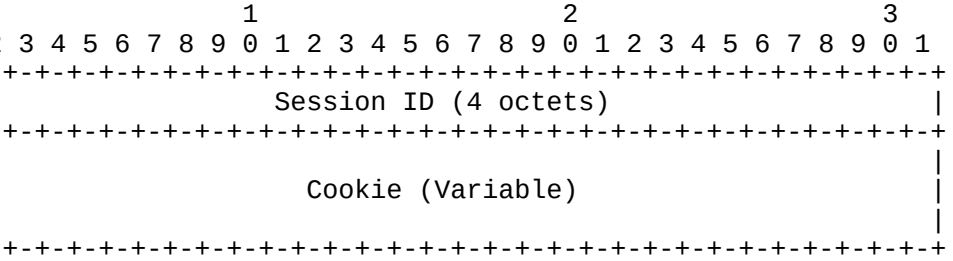
* Sub-TLV Length (1 octet): the total number of octets of the sub-TLV value field.

* Sub-TLV Value (variable): encodings of the value field depend on the sub-TLV type as enumerated above. The following sub-sections define the encoding in detail.

4.1. Encapsulation Sub-TLV

The syntax and semantics of the encapsulation sub-TLV is determined by the tunnel type of the TLV that contains this sub-TLV.

When the tunnel type of the TLV is L2TPv3 over IP, the following is the structure of the value field of the encapsulation sub-TLV:

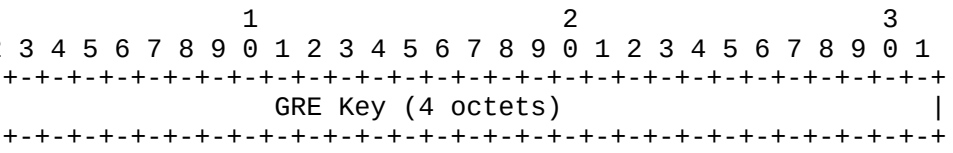


* Session ID: a non-zero 4-octet value locally assigned by the advertising router that serves as a lookup key in the incoming packet's context.

* Cookie: an optional, variable length (encoded in octets -- 0 to 8 octets) value used by L2TPv3 to check the association of a received data message with the session identified by the Session ID. Generation and usage of the cookie value is as specified in [RFC3931].

  The length of the cookie is not encoded explicitly, but can be calculated as (sub-TLV length - 4).

When the tunnel type of the TLV is GRE, the following is the structure of the value field of the encapsulation sub-TLV:



* GRE Key: 4-octet field [RFC2890] that is generated by the advertising router. The actual method by which the key is obtained is beyond the scope of this document. The key is inserted into the GRE encapsulation header of the payload packets sent by ingress routers to the advertising router. It is intended to be used for identifying extra context information about the received payload.

  Note that the key is optional. Unless a key value is being advertised, the GRE encapsulation sub-TLV MUST NOT be present.

4.2. Protocol Type Sub-TLV

The protocol type sub-TLV MAY be encoded to indicate the type of the payload packets that will be encapsulated with the tunnel parameters that are being signaled in the TLV. The value field of the sub-TLV contains a 2-octet protocol type that is one of the types defined in [IANA-AF] as ETHER TYPEs.

For example, if we want to use three L2TPv3 sessions, one carrying IPv4 packets, one carrying IPv6 packets, and one carrying MPLS packets, the egress router will include three TLVs of L2TPv3 encapsulation type, each specifying a different Session ID and a different payload type. The protocol type sub-TLV for these will be IPv4 (protocol type = 0x0800), IPv6 (protocol type = 0x86dd), and MPLS (protocol type = 0x8847), respectively. This informs the ingress routers of the appropriate encapsulation information to use

with each of the given protocol types. Insertion of the specified Session ID at the ingress routers allows the egress to process the incoming packets correctly, according to their protocol type.

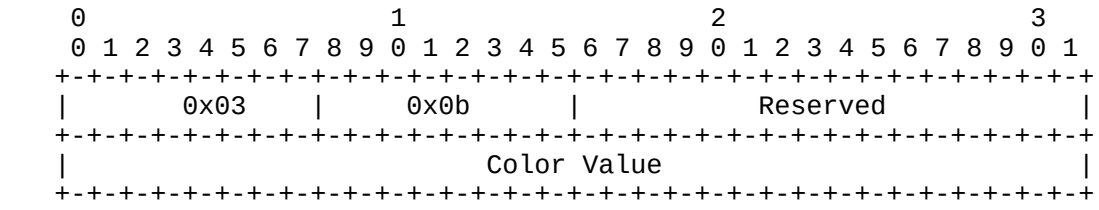
Inclusion of this sub-TLV depends on the tunnel type. It MUST be encoded for L2TPv3 tunnel type. On the other hand, the protocol type sub-TLV is not required for IP in IP or GRE tunnels.

4.3. Color Sub-TLV

The color sub-TLV MAY be encoded as a way to color the corresponding tunnel TLV. The value field of the sub-TLV contains an extended community that is defined as follows:

4.3.1. Color Extended Community

The Color Extended Community is an opaque extended community [RFC4360] with the following encoding:



The value of the high-order octet of the extended type field is 0x03, which indicates it is transitive. The value of the low-order octet of the extended type field for this community is 0x0b. The color value is user defined and configured locally on the routers. The same Color Extended Community can then be attached to the UPDATE messages that contain payload prefixes. This way, the BGP speaker can express the fact that it expects the packets corresponding to these payload prefixes to be received with a particular tunnel encapsulation header.

4.4. Tunnel Type Selection

A BGP speaker may include multiple tunnel TLVs in the tunnel attribute. The receiving speaker MAY have local policies defined to choose different tunnel types for different sets/types of payload prefixes received from the same BGP speaker. For instance, if a BGP speaker includes both L2TPv3 and GRE tunnel types in the tunnel attribute and it also advertises IPv4 and IPv6 prefixes, the ingress router may have local policy defined to choose L2TPv3 for IPv4 prefixes (provided the protocol type received in the tunnel attribute matches) and GRE for IPv6 prefixes.

Additionally, the Encapsulation SAFI UPDATE message can contain a color sub-TLV for some or all of the tunnel TLVs. The BGP speaker SHOULD then attach a Color Extended Community to payload prefixes to select the appropriate tunnel types.

In a multi-vendor deployment that has routers supporting different tunneling technologies, including color sub-TLV to the Encapsulation SAFI UPDATE message can serve as a classification mechanism (for example, set A of routers for GRE and set B of routers for L2TPv3). The ingress router can then choose the encapsulation data appropriately while sending packets to an egress router.

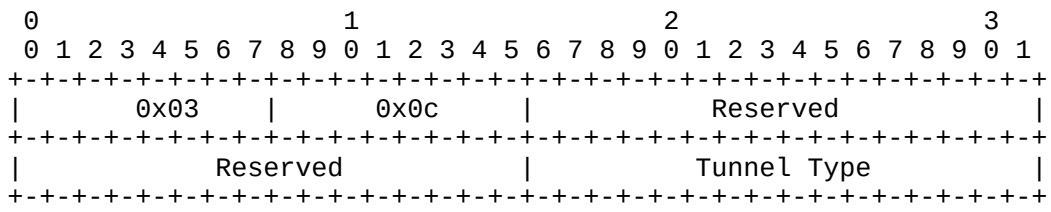
If a BGP speaker originates an update for prefix P with color C and with itself as the next hop, then it MUST also originate an Encapsulation SAFI update that contains the color C.

Suppose that a BGP speaker receives an update for prefix P with color C, that the BGP decision procedure has selected the route in that update as the best route to P, and that the next hop is node N, but that an Encapsulation SAFI update originating from node N containing color C has not been received. In this case, no route to P will be installed in the forwarding table unless and until the corresponding Encapsulation SAFI update is received, or the BGP decision process selects a different route.

Suppose that a BGP speaker receives an "uncolored" update for prefix P, with next hop N, and that the BGP speaker has also received an Encapsulation SAFI originated by N, specifying one or more encapsulations that may or may not be colored. In this case, the choice of encapsulation is a matter of local policy. The only "default policy" necessary is to choose one of the encapsulations supported by the speaker.

4.5. BGP Encapsulation Extended Community

Here, we define a BGP opaque extended community that can be attached to BGP UPDATE messages to indicate the encapsulation protocol to be used for sending packets from an ingress router to an egress router. Considering our example from the Section 1, R2 MAY include this extended community, specifying a particular tunnel type to be used in the UPDATE message that carries route Q to R1. This is useful if there is no explicit encapsulation information to be signaled using the Encapsulation SAFI for a tunneling protocol (such as GRE without key).



The value of the high-order octet of the extended type field is 0x03, which indicates it's transitive. The value of the low-order octet of the extended type field is 0x0c.

The last two octets of the value field encode a tunnel type as defined in this document.

For interoperability, a speaker supporting Encapsulation SAFI MUST implement the Encapsulation Extended Community.

5. Capability Advertisement

A BGP speaker that wishes to exchange tunnel endpoint information must use the Multiprotocol Extensions Capability Code as defined in [RFC4760], to advertise the corresponding (AFI, SAFI) pair.

6. Error Handling

When a BGP speaker encounters an error while parsing the tunnel encapsulation attribute, the speaker MUST treat the UPDATE as a withdrawal of existing routes to the included Encapsulation SAFI NLRIs, or discard the UPDATE if no such routes exist. A log entry should be raised for local analysis.

7. Security Considerations

Security considerations applicable to softwires can be found in the mesh framework [MESH]. In general, security issues of the tunnel protocols signaled through Encapsulation SAFI are inherited.

If a third party is able to modify any of the information that is used to form encapsulation headers, to choose a tunnel type, or to choose a particular tunnel for a particular payload type, user data packets may end up getting misrouted, misdelivered, and/or dropped.

8. IANA Considerations

IANA assigned value 7 from the "Subsequent Address Family" Registry, in the "Standards Action" range, to "Encapsulation SAFI", with this document as the reference.

IANA assigned value 23 from the "BGP Path Attributes" Registry, to "Tunnel Encapsulation Attribute", with this document as the reference.

IANA assigned two new values from the "BGP Opaque Extended Community" type Registry. Both are from the transitive range. The first new value is called "Color Extended Community" (0x030b), and the second is called "Encapsulation Extended Community"(0x030c). This document is the reference for both assignments.

IANA set up a registry for "BGP Tunnel Encapsulation Attribute Tunnel Types". This is a registry of two-octet values (0-65535), to be assigned on a first-come, first-served basis. The initial assignments are as follows:

Tunnel Name	Type
L2TPv3 over IP	1
GRE	2
IP in IP	7

IANA set up a registry for "BGP Tunnel Encapsulation Attribute Sub-TLVs". This is a registry of 1-octet values (0-255), to be assigned on a "standards action/early allocation" basis. This document is the reference. The initial assignments are:

Sub-TLV name	Type
Encapsulation	1
Protocol Type	2
Color	4

9. Acknowledgements

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