          BGP Support for Four-Octet Autonomous System (AS) Number Space

Abstract

   The Autonomous System number is encoded as a two-octet entity in the
   base BGP specification.  This document describes extensions to BGP to
   carry the Autonomous System numbers as four-octet entities.  This
   document obsoletes RFC 4893 and updates RFC 4271.

Status of This Memo

   This is an Internet Standards Track document.

   This document is a product of the Internet Engineering Task Force
   (IETF).  It represents the consensus of the IETF community.  It has
   received public review and has been approved for publication by the
   Internet Engineering Steering Group (IESG).  Further information on
   Internet Standards is available in Section 2 of RFC 5741.

   Information about the current status of this document, any errata,
   and how to provide feedback on it may be obtained at
   http://www.rfc-editor.org/info/rfc6793.

1.  Introduction

   In the base BGP specification [RFC4271], the Autonomous System (AS)
   number is encoded as a two-octet entity.  To prepare for the
   anticipated exhaustion of the two-octet AS numbers, this document
   describes extensions to BGP to carry the AS numbers as four-octet
   entities.

   More specifically, this document defines a BGP capability code,
   "support for four-octet AS number capability", to be used by a BGP
   speaker to indicate its support for four-octet AS numbers.  Two
   attributes, AS4_PATH and AS4_AGGREGATOR, are introduced that can be
   used to propagate four-octet-based AS path information across BGP
   speakers that do not support four-octet AS numbers.  This document
   also specifies mechanisms for constructing the AS path information
   from the AS_PATH attribute and the AS4_PATH attribute.

   The extensions specified in this document allow a gradual transition
   from two-octet AS numbers to four-octet AS numbers.

   This document obsoletes RFC 4893 and updates RFC 4271.  It includes
   several clarifications and editorial changes, and it specifies the
   error handling for the new attributes.

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.  Protocol Extensions

   For the purpose of this document, we define a BGP speaker that does
   not support the new four-octet AS number extensions as an OLD BGP
   speaker, and a BGP speaker that supports the new four-octet AS number
   extensions as a NEW BGP speaker.

   BGP carries the AS numbers in the "My Autonomous System" field of the
   OPEN message, in the AS_PATH attribute of the UPDATE message, and in
   the AGGREGATOR attribute of the UPDATE message.  BGP also carries the
   AS numbers in the BGP Communities attribute.

   A NEW BGP speaker uses BGP Capabilities Advertisements [RFC5492] to
   advertise to its neighbors (either internal or external) that it
   supports four-octet AS number extensions, as specified in this
   document.

The capability that is used by a BGP speaker to convey to its BGP
peer the four-octet Autonomous System number capability also carries
the AS number (encoded as a four-octet entity) of the speaker in the
Capability Value field of the capability.  The Capability Length
field of the capability is set to 4.

The AS path information exchanged between NEW BGP speakers is carried
in the existing AS_PATH attribute, except that each AS number in the
attribute is encoded as a four-octet entity (instead of a two-octet
entity).  The same applies to the AGGREGATOR attribute -- the same
attribute is used between NEW BGP speakers, except that the AS number
carried in the attribute is encoded as a four-octet entity.

The AS_PATH attribute and the AGGREGATOR attribute carried between a
NEW BGP speaker and an OLD BGP speaker will continue to contain
two-octet AS numbers.

To preserve the AS path information with four-octet AS numbers across
OLD BGP speakers, this document defines a new BGP path attribute
called AS4_PATH.  This is an optional transitive attribute that
contains the AS path encoded with four-octet AS numbers.  The
AS4_PATH attribute has the same semantics and the same encoding as
the AS_PATH attribute, except that it is "optional transitive", and
it carries four-octet AS numbers.

To prevent the possible propagation of Confederation-related path
segments outside of a Confederation, the path segment types
AS_CONFED_SEQUENCE and AS_CONFED_SET [RFC5065] are declared invalid
for the AS4_PATH attribute and MUST NOT be included in the AS4_PATH
attribute of an UPDATE message.

Similarly, this document defines a new BGP path attribute called
AS4_AGGREGATOR, which is optional transitive.  The AS4_AGGREGATOR
attribute has the same semantics and the same encoding as the
AGGREGATOR attribute, except that it carries a four-octet AS number.

Currently assigned two-octet AS numbers are converted into four-octet
AS numbers by setting the two high-order octets of the four-octet
field to zero.  Such a four-octet AS number is said to be mappable to
a two-octet AS number.

This document reserves a two-octet AS number called "AS_TRANS".
AS_TRANS can be used to represent non-mappable four-octet AS numbers
as two-octet AS numbers in AS path information that is encoded with
two-octet AS numbers.  (In this context, four-octet AS numbers that
are not mapped from two-octet AS numbers are referred to as
"non-mappable".) We denote this special AS number as AS_TRANS for
ease of description in the rest of this specification.  This AS

number is also placed in the "My Autonomous System" field of the OPEN
message originated by a NEW BGP speaker, if and only if the speaker
does not have a (globally unique) two-octet AS number.

## 4.  Operations

### 4.1.  Interaction between NEW BGP Speakers

A BGP speaker that supports four-octet AS numbers SHALL advertise
this to its peers using BGP Capabilities Advertisements.  The AS
number of the BGP speaker MUST be carried in the Capability Value
field of the "support for four-octet AS number capability".

When a NEW BGP speaker processes an OPEN message from another NEW BGP
speaker, it MUST use the AS number encoded in the Capability Value
field of the "support for four-octet AS number capability" in lieu of
the "My Autonomous System" field of the OPEN message.

A BGP speaker that advertises such a capability to a particular peer,
and receives from that peer the advertisement of such a capability,
MUST encode AS numbers as four-octet entities in both the AS_PATH
attribute and the AGGREGATOR attribute in the updates it sends to the
peer and MUST assume that these attributes in the updates received
from the peer encode AS numbers as four-octet entities.

The new attributes, AS4_PATH and AS4_AGGREGATOR, MUST NOT be carried
in an UPDATE message between NEW BGP speakers.  A NEW BGP speaker
that receives the AS4_PATH attribute or the AS4_AGGREGATOR attribute
in an UPDATE message from another NEW BGP speaker MUST discard the
path attribute and continue processing the UPDATE message.

### 4.2.  Interaction between NEW and OLD BGP Speakers

### 4.2.1.  BGP Peering

Note that peering between a NEW BGP speaker and an OLD BGP speaker is
possible only if the NEW BGP speaker has a two-octet AS number.
However, this document does not assume that an Autonomous System with
NEW BGP speakers has to have a globally unique two-octet AS number --
AS_TRANS MUST be used when the NEW BGP speaker does not have a
two-octet AS number (even if multiple Autonomous Systems would
use it).

4.2.2.  Generating Updates

   When communicating with an OLD BGP speaker, a NEW BGP speaker MUST
   send the AS path information in the AS_PATH attribute encoded with
   two-octet AS numbers.  The NEW BGP speaker MUST also send the AS path
   information in the AS4_PATH attribute (encoded with four-octet AS
   numbers), except for the case where all of the AS path information is
   composed of mappable four-octet AS numbers only.  In this case, the
   NEW BGP speaker MUST NOT send the AS4_PATH attribute.

   In the AS_PATH attribute encoded with two-octet AS numbers,
   non-mappable four-octet AS numbers are represented by the well-known
   two-octet AS number, AS_TRANS.  This will preserve the path length
   property of the AS path information and also help in updating the AS
   path information received on a NEW BGP speaker from an OLD BGP
   speaker, as explained in the next section.

   The NEW BGP speaker constructs the AS4_PATH attribute from the AS
   path information.  Whenever the AS path information contains the
   AS_CONFED_SEQUENCE or AS_CONFED_SET path segment, the NEW BGP speaker
   MUST exclude such path segments from the AS4_PATH attribute being
   constructed.

   The AS4_PATH attribute, being optional transitive, will be carried
   across a series of OLD BGP speakers without modification and will
   help preserve the non-mappable four-octet AS numbers in the AS path
   information.

   Similarly, if the NEW BGP speaker has to send the AGGREGATOR
   attribute, and if the aggregating Autonomous System's AS number is a
   non-mappable four-octet AS number, then the speaker MUST use the
   AS4_AGGREGATOR attribute and set the AS number field in the existing
   AGGREGATOR attribute to the reserved AS number, AS_TRANS.  Note that
   if the AS number is mappable, then the AS4_AGGREGATOR attribute MUST
   NOT be sent.

4.2.3.  Processing Received Updates

   When a NEW BGP speaker receives an update from an OLD BGP speaker, it
   MUST be prepared to receive the AS4_PATH attribute along with the
   existing AS_PATH attribute.  If the AS4_PATH attribute is also
   received, both of the attributes will be used to construct the exact
   AS path information, and therefore the information carried by both of
   the attributes will be considered for AS path loop detection.

Note that a route may have traversed a series of Autonomous Systems
with two-octet AS numbers and OLD BGP speakers only.  In that case,
if the route carries the AS4_PATH attribute, this attribute would
have remained unmodified since the route left the last NEW BGP
speaker.  The trailing AS path information (representing Autonomous
Systems with two-octet AS numbers and OLD BGP speakers only) is
contained only in the current AS_PATH attribute (encoded in the
leading part of the AS_PATH attribute).

Under certain conditions, it may not be possible to reconstruct all
of the AS path information from the AS_PATH and the AS4_PATH
attributes of a route.  This occurs, for example, when two or more
routes that carry the AS4_PATH attribute are aggregated by an OLD BGP
speaker, and the AS4_PATH attribute of at least one of these routes
carries at least one four-octet AS number (as opposed to a two-octet
AS number that is encoded in 4 octets).  Depending on the
implementation, either the AS4_PATH attribute would be lost during
route aggregation, or both the AS_PATH attribute and the AS4_PATH
attribute would contain valid, partial information that cannot be
combined seamlessly, resulting in incomplete AS path information in
these cases.

A NEW BGP speaker MUST also be prepared to receive the AS4_AGGREGATOR
attribute along with the AGGREGATOR attribute from an OLD BGP
speaker.  When both of the attributes are received, if the AS number
in the AGGREGATOR attribute is not AS_TRANS, then:

   - the AS4_AGGREGATOR attribute and the AS4_PATH attribute SHALL
     be ignored,

   - the AGGREGATOR attribute SHALL be taken as the information
     about the aggregating node, and

   - the AS_PATH attribute SHALL be taken as the AS path
     information.

Otherwise,

   - the AGGREGATOR attribute SHALL be ignored,

   - the AS4_AGGREGATOR attribute SHALL be taken as the information
     about the aggregating node, and

   - the AS path information would need to be constructed, as in all
     other cases.

In order to construct the AS path information, it is necessary to
first calculate the number of AS numbers in the AS_PATH and AS4_PATH
attributes using the method specified in Section 9.1.2.2 of [RFC4271]
and in [RFC5065] for route selection.

If the number of AS numbers in the AS_PATH attribute is less than the
number of AS numbers in the AS4_PATH attribute, then the AS4_PATH
attribute SHALL be ignored, and the AS_PATH attribute SHALL be taken
as the AS path information.

If the number of AS numbers in the AS_PATH attribute is larger than
or equal to the number of AS numbers in the AS4_PATH attribute, then
the AS path information SHALL be constructed by taking as many AS
numbers and path segments as necessary from the leading part of the
AS_PATH attribute, and then prepending them to the AS4_PATH attribute
so that the AS path information has a number of AS numbers identical
to that of the AS_PATH attribute.  Note that a valid
AS_CONFED_SEQUENCE or AS_CONFED_SET path segment SHALL be prepended
if it is either the leading path segment or is adjacent to a path
segment that is prepended.

5.  Handling BGP Communities

As specified in [RFC1997], when the high-order two octets of the
community attribute is neither 0x0000 nor 0xffff, these two octets
encode the AS number.  Quite clearly, this would not work for a NEW
BGP speaker with a non-mappable four-octet AS number.  Such BGP
speakers should use four-octet AS specific extended communities
[RFC5668] instead.

6.  Error Handling

This section provides an update to RFC 4271 [RFC4271] with respect to
the error conditions noted here and their handling.

Given that the two-octet AS numbers dominate during the transition
and are carried in the AS_PATH attribute by an OLD BGP speaker, in
this document the "attribute discard" approach is chosen to handle a
malformed AS4_PATH attribute.

Similarly, as the AS4_AGGREGATOR is just informational, the
"attribute discard" approach is chosen to handle a malformed
AS4_AGGREGATOR attribute.

The AS4_PATH attribute and AS4_AGGREGATOR attribute MUST NOT be
carried in an UPDATE message between NEW BGP speakers.  A NEW BGP
speaker that receives the AS4_PATH attribute or the AS4_AGGREGATOR
attribute in an UPDATE message from another NEW BGP speaker MUST
discard the path attribute and continue processing the UPDATE
message.  This case SHOULD be logged locally for analysis.

In addition, the path segment types AS_CONFED_SEQUENCE and
AS_CONFED_SET [RFC5065] MUST NOT be carried in the AS4_PATH attribute
of an UPDATE message.  A NEW BGP speaker that receives these path
segment types in the AS4_PATH attribute of an UPDATE message from an
OLD BGP speaker MUST discard these path segments, adjust the relevant
attribute fields accordingly, and continue processing the UPDATE
message.  This case SHOULD be logged locally for analysis.

The AS4_PATH attribute in an UPDATE message SHALL be considered
malformed under the following conditions:

   -  the attribute length is not a multiple of two or is too small
      (i.e., less than 6) for the attribute to carry at least one AS
      number, or

   -  the path segment length in the attribute is either zero or is
      inconsistent with the attribute length, or

   -  the path segment type in the attribute is not one of the types
      defined: AS_SEQUENCE, AS_SET, AS_CONFED_SEQUENCE, and
      AS_CONFED_SET.

A NEW BGP speaker that receives a malformed AS4_PATH attribute in an
UPDATE message from an OLD BGP speaker MUST discard the attribute and
continue processing the UPDATE message.  The error SHOULD be logged
locally for analysis.

The AS4_AGGREGATOR attribute in an UPDATE message SHALL be considered
malformed if the attribute length is not 8.

A NEW BGP speaker that receives a malformed AS4_AGGREGATOR attribute
in an UPDATE message from an OLD BGP speaker MUST discard the
attribute and continue processing the UPDATE message.  The error
SHOULD be logged locally for analysis.

7.  Transition

   When an Autonomous System is using a two-octet AS number, then the
   BGP speakers within that Autonomous System MAY be upgraded to support
   the four-octet AS number extensions on a piecemeal basis.  There is
   no requirement for a coordinated upgrade of the four-octet AS number
   capability in this case.  However, if an Autonomous System wishes to
   use a four-octet AS number as its own AS number, then this document
   assumes that an Autonomous System can use a four-octet AS number only
   after all the BGP speakers within that Autonomous System have been
   upgraded to support four-octet AS numbers.

   A non-mappable four-octet AS number cannot be used as a "Member AS
   Number" of a BGP Confederation until all the BGP speakers within the
   Confederation have transitioned to support four-octet AS numbers.

   In an environment where an Autonomous System that has OLD BGP
   speakers peers with two or more Autonomous Systems that have NEW BGP
   speakers and use AS_TRANS (rather than having a globally unique
   mappable AS number), the use of the MULTI_EXIT_DISC attribute
   [RFC4271] by the Autonomous System with the OLD BGP speakers may
   result in a situation where the MULTI_EXIT_DISC attribute will
   influence route selection among the routes that were received from
   different neighboring Autonomous Systems.

   Under certain conditions, it may not be possible to reconstruct all
   of the AS path information from the AS_PATH and the AS4_PATH
   attributes of a route.  This occurs when two or more routes that
   carry the AS4_PATH attribute are aggregated by an OLD BGP speaker,
   and the AS4_PATH attribute of at least one of these routes carries at
   least one four-octet AS number (as opposed to a two-octet AS number
   that is encoded in 4 octets).  When such aggregation results in
   creating a route that is less specific than any of the component
   routes (routes whose Network Layer Reachability Information (NLRI)
   covers the NLRI of all the component routes), loss of the AS path
   information does not create the risk of a routing loop.  In all other
   cases, loss of the AS path information does create the risk of a
   routing loop.

8.  Manageability Considerations

   If the BGP4-MIB [RFC4273] is supported, there are no additional
   manageability concerns that arise from the use of four-octet AS
   numbers, since the InetAutonomousSystemNumber textual convention
   [RFC4001] is defined as Unsigned32.

   When IP Flow Information Export (IPFIX) [RFC5101] is supported, there
   are no additional manageability concerns that arise from the use of
   four-octet AS numbers.  The bgpSourceAsNumber and
   bgpDestinationAsNumber information elements [IANA-IPFIX] can continue
   to be used, with a new template record, specifying the new length of
   4 bytes.

9.  IANA Considerations

   This document expands the pool for AS numbers from 0-65535 to
   0-4294967295.  The AS numbers are managed by the IANA "Autonomous
   System Numbers" registry.  Other than expanding the AS number pool,
   this document does not propose any modifications to the existing
   policies and procedures pertaining to the allocation of AS numbers.

   This document uses a BGP capability code to indicate that a BGP
   speaker supports four-octet AS numbers.  Capability Code 65 has been
   assigned by IANA per [RFC5492].

   In addition, this document introduces two BGP optional transitive
   attributes, and their type codes have been assigned by IANA.  The
   first one is the AS4_PATH attribute, value 17, which preserves the AS
   path information with four-octet AS numbers across old BGP speakers.
   The second one is the AS4_AGGREGATOR attribute, value 18, which is
   similar in use to the current AGGREGATOR attribute, but it carries a
   four-octet AS number.

   Finally, IANA has replaced a reference to RFC 4893 with a reference
   to this document for a reserved two-octet AS number -- AS_TRANS
   (23456).  Also, IANA has replaced a reference to RFC 4893 with a
   reference to this document for the "32-bit Autonomous System Numbers"
   registry.

10.  Security Considerations

   This extension to BGP does not change the underlying security issues
   inherent in the existing BGP, except for the following:

   The inconsistency between the AS_PATH attribute and the AS4_PATH
   attribute can create loss of the AS path information, and potential
   routing loops in certain cases, as discussed in this document.  This
   could be exploited by an attacker.

   It is a misconfiguration to assign a non-mappable four-octet AS
   number as the "Member AS Number" in a BGP Confederation before all
   the BGP speakers within the Confederation have transitioned to
   support four-octet AS numbers.  Such a misconfiguration would weaken
   AS path loop detection within a Confederation.

11.  Acknowledgments

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