Network   Shaofu. Peng
Internet-Draft   Bin. Tan
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                     BGP Metric Credit Based Routing
                   draft-peng-idr-bgp-metric-credit-00

Abstract

   This document defines an optional metric related BGP path attribute
   that can be advertised with BGP intent routes, to provide more clear
   intent information used for the next-hop resolution.

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1. Introduction

   In large-scale networks across multiple domains, BGP can be used to
   advertise intent route and provide end-to-end intent aware path.
   According to corresponding intent information, a BGP intent route
   selects the expected underlay path for the next hop resolution. The
   underlay path may be an MPLS-TE tunnel, an SR policy, an IGP Flex-
   algo route, or a direct link, established segment by segment based on
   the same intent.

   There are many methods to make BGP carry intent information during
   route advertisement.

      [I-D.zhou-idr-inter-domain-lcu] describe a simple method, termed
      as BGP-LU color, combined with [RFC7911], to create multiple BGP-
      LU color path to the same destination, using color as intent
      identifier.

      [I-D.kaliraj-idr-bgp-classful-transport-planes] defines new
      "Classful Transport" SAFI NLRI and "Transport Class" Route Target
      extended community, to advertise intent based routes with related
      Transport Class identifier as intent identifier.

      [I-D.dskc-bess-bgp-car] defines new "BGP CAR" SAFI NLRI that
      contains a Color field as intent identifier to advertise intent
      based routes.

[I-D.lp-lsr-bgp-algorithm] introduces Algorithm Extended Community to advertise BGP algorithm routes, using algorithm as intent identifier.

Once a BGP speaker received an intent route advertised from neighbor, it will check the related intent template in local. The intent template could be a Color template, a Flex-algorithm Definition, or some other modules. The intent template contains a set of constraints, such as the reserved bandwidth to be provided in the path, the boundary minimum and maximum delay, the boundary delay jitter, the boundary packet loss rates, including or excluding specific nodes or links, limiting the calculation of the path in a specific virtual network, and so on. The detailed intent information itself are not recommended to be directly carried in the advertised route.

On the ingress PE node in the network, a BGP intent route to the egress PE will be selected according to the service SLA. The intent template configured on the ingress PE node is generally consistent with the service SLA. However this does not mean that the intent template configured on the intermediate nodes should also be consistent with the service SLA. For example, the SLA of the service is to "provide a path with an upper delay boundary of 100ms from ingress PE to egress PE". In this case, the upper delay of 100ms refers to end-to-end delay constraint, not for each segment. A possible method is to include different delay constraints in the intent template configured on different BGP speakers along the path. However, this static configuration method has shortcomings, because an intent template is not necessarily bound to a specific end-to-end path and may be used for multiple paths.

It can be seen that the information contained in the intent template is not enough to represent the complete intent. This often occurs on cumulable metric attributes.

This document describes extensions to carry the metric credit information in the BGP route advertisement, as a supplement to the intent template, so that the BGP speaker receiving the BGP intent route can establish (or select) the underlay path to the downstream BGP speaker with more accurate intent indication.

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.

2. Extensions for BGP Route Metric

   This section describes some extensions related to metric, so that
   when BGP speaker advertise intent route to upstream neighbors, it
   carries optional metric type, metric, and metric credit information.

2.1. Extensions for Metric Type and Metric

   [RFC7311] defines AIGP Attribute to represent basic IGP default
   metric type and its cumulative value.
   [I-D.ssangli-idr-bgp-generic-metric-aigp] defines extensions to the
   AIGP attribute to carry Generic Metric sub-types, to meet more metric
   types, such as Min Unidirectional delay metric defined in [RFC8570],
   TE Default Metric defined in [RFC5305], Bandwidth Metric defined in
   [I-D.ietf-lsr-flex-algo-bw-con], etc.

   This document reuse the above definitions.

2.2. Extensions for Metric Credit

   A new path attribute type (TBD): METRIC-CREDIT attribute, is
   introduced in this document. It is an optional non-transitive
   attribute, which is used to specify end-to-end total metric credit,
   estimated BGP hop counts, and metric credit piece information.

   The format of attribute value is shown below.

```
   +------------------------------------------------------+
   | Count of Sources (1 octet)                           |
   +------------------------------------------------------+
   | Flags (1 octet)                                      | <--- 1st Source
   +------------------------------------------------------+
   // Network Address of Source (variable)             //
   +------------------------------------------------------+
   | Total Metric Credit for Source (4 octets)            |
   +------------------------------------------------------+
   | Estimated BGP Hops Count for Source (1 octet)        |
   +------------------------------------------------------+
   // Current Hop Number (1 octet)                      //
   +------------------------------------------------------+
   // Metric Credit Piece [Hops Count] (variable)      //
   +------------------------------------------------------+
   //   ... For other Sources     ...                  // <--- 2nd Source
   +------------------------------------------------------+
```

                  Figure 1: Metric Credit Path Attribute Format

Count of Sources (1 octet): Indicates how many sources (i.e. ingress PE) have corresponding metric credit information.

Flags (1 octet): Currently three flags are defined.

```
   0 1 2 3 4 5 6 7
  +-+-+-+-+-+-+-+-+
  |S|F|P|         |
  +-+-+-+-+-+-+-+-+
```

Figure 2

S-Flag: Source Address Flag. The Network Address of Source field is included when S-Flag is set, and not included when unset.

F-Flag: Address Family Flag. Indicate the address family of the Network Address of Source field. 0 for 32 bits IPv4 address, 1 for 128 bits IPv6 address.

P-Flag: Piece Flag. Indicates whether specific metric credit piece information (Current Hop Number field and Metric Credit Piece [] field) is included.

Network Address of Source (variable octets): Represents the IP address of the source. When S-flag is 0, this field does not exist; When S-flag is 1 and F-flag is 0, this field is a 32-bits IPv4 address; When S-flag is 1 and F-flag is 1, this field is a 128-bits IPv6 address. If this field does not exist, it means that the metric credit information is independent of the specific source. This generally occurs in the scenario that want to control the establishment of intent paths according to the metric credit in coarse granularity. For example, in a small administrative domain, when the egress PE advertise BGP intent routes to multiple ingress PEs, only a single unified metric credit information for all source is carried.

Total Metric Credit for Source (4 octets): Represents the total metric credit from a specific ingress PE (or any source, when the Network Address of Source field does not exist) to egress PE.

Estimated BGP Hops Count for Source (1 octet): Represents the estimated number of BGP hops from a specific ingress PE (or any source, when the Network Address of Source field does not exist) to egress PE. Only those BGP speakers who modified BGP next hop to self when receiving BGP intent route are counted.

Current Hop Number (1 octet): Represents the current index of the array Metric Credit Piece[]. Note that when P-flag is 0, the

"Current Hop Number" and "Metric Credit Piece[]" fields do not exist.
In the BGP intent route advertisement originated from egress PE, the
initial value of Current Hop Number is 0; When the BGP intent route
advertisement received by an upstream BGP speaker and the BGP speaker
modifies the BGP next hop to self, it read the item from the array
Metric Credit Piece[] using Current Hop Number as index, to obtain
the metric credit piece that is available from the current BGP
speaker to the neighbor of the downstream BGP speaker. When the BGP
speaker continue to advertise the route to the upstream BGP speaker
neighbor and modify BGP next hop to self, it increase the Current Hop
Number by 1. Note that when using Current Hop Number as index to
read items from the array Metric Credit Piece[], it must avoid array
out of bounds.

Metric Credit Piece[] (variable octets): Is an array. The number of
items is specified by Estimated BGP Hops Count for Source. Each item
occupies 3 bytes (in microseconds) for each BGP speaker along the
intent path. There are strict restrictions on the use of Metric
Credit Piece[], i.e., BGP intent route must be advertised to a
specific ingress PE hop by hop in strict accordance with the
propagated path expected by egress PE. When an exception occurs,
e.g., a BGP speaker finds that the Current Hop Number value in the
received BGP intent route is greater than or equal to the Estimated
BGP Hops Count for Source value, then it must stop using Metric
Credit Piece[] for BGP next hop resolution.

3. Process of Received Metric Credit

When a BGP speaker receives BGP intent route with metric credit
information from neighbors, it obtains the intent identifier from
the route advertisement, looks up the intent template locally to
obtain the detailed intent information, and selects underlay path
according to the intent information.

The metric credit attribute information contained in the route
advertisement can provide a suggested metric credit value for this
BGP speaker to select underlay path destinated to the downstream
neighbor BGP speaker.

3.1. Only Total Metric Credit Provided

If the metric credit attribute only contains the total metric credit
related to the source, but does not contain the explicit metric
credit piece information, then for each source:

   Let metric_residual_value = "Total Metric Credit for Source" -
   "metric of AIGP Attribute"

Let average_metric_credit_value = "Total Metric Credit for Source" / "Estimated BGP Hops Count for Source"

The suggested metric credit for the current segment is the minimum value of metric_residual_value (note: negative values need to be excluded) and average_metric_credit_value for all sources.

3.2. Metric Credit Piece Provided

If the BGP intent route advertisement also contains explicit metric credit piece information, then:

Let explicit_metric_credit_piece_value = Metric Credit Piece[Current Hop Number]

The suggested metric credit for the current segment is the minimum value of metric_residual_value (note: negative values need to be excluded) and explicit_metric_credit_piece_value for all sources.

It is recommended that this option is mainly used in the case that only a single source related metric credit piece information is included in the intent route that is advertised to a single ingress PE. Multiple source related metric credit piece information may bring conflicts and cause inaccurate suggested metric credit.

To include explicit BGP speaker list in the route advertisement and specify metric credit piece for each segment, will be described in the next version.

3.3. Select Underlay Path According to Suggested Metric Credit

The purpose of suggested metric credit is to restrict that the cumulative metric of the resolved underlay path cannot exceed the expected value. However, in some cases, if the BGP speaker finds that there is no underlay path that can meet the suggested value, this constraint can be relaxed appropriately by local policy.

For the BGP intent route installed on the received BGP speaker, the metric value is updated to the metric of AIGP attribute plus the cumulative metric of the underlay path for the corresponding metric type.

4. Examples

4.1. Example of Intent with Average Metric Credit

   As shown in Figure 3, it contains two IGP domains. BGP neighbors are
   established between PE1 and ABR, ABR and PE2, to advertise BGP intent
   routes. Egress PE2 advertise its loopback route, loopback-PE2, to
   ABR through BGP, and carries intent identifier and metric credit
   attribute.

```
       +---------P1---------+    +---------P4---------+
      /         |          \  /         |          \
    PE1--------P2----------ABR-----------P5----------PE2
      \         |          / \          |          /
       +--------P3---------+   +---------P6---------+

    |<---- IGP domain 1 ---->||<---- IGP domain 2 ---->|

       TE-path-11: PE1-P1-ABR   TE-path-12: ABR-P4-PE2
       TE-path-21: PE1-P3-ABR   TE-path-22: ABR-P6-PE2
```
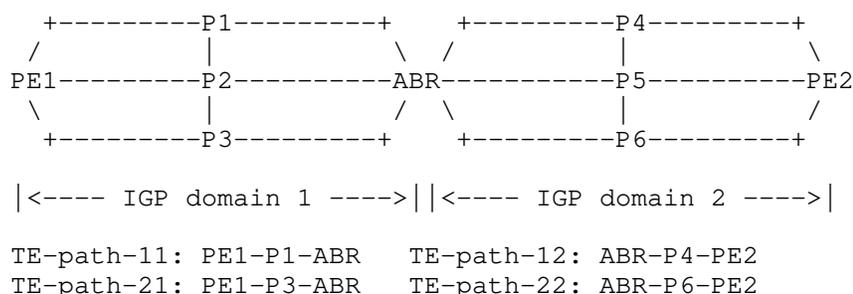
                    Figure 3: Inter-area Intent Routing

   There are two services to communicate between ingress PE1 and egress
   PE2. The intent of the first service is that the end-to-end total
   delay of the transport path used shall not exceed 10ms, for the
   intent of the second service, it is 100ms. Since two intent aware
   paths need to be instantiated between the same source/destination for
   two services, in general, two intent identifiers, intent-1000 and
   intent-2000, need to be configured on the egress PE2.

   The intent-1000 template may have the following configuration:

      metric-type: Unidirectional Link Delay (ms)

      total-metric-credit: 10 (ms)

      metric-credit enabled

   The intent-2000 template may have the following configuration:

      metric-type: Unidirectional Link Delay (ms)

      total-metric-credit: 100 (ms)

      metric-credit enabled

   The above intent template are also configured in other BGP speakers
   (i.e., ABR and PE1). However, it should be noted that since the

intent template contains the metric credit enabled command, these BGP speakers, for the matched intent routes that are not originated from themselvs, will not select the underlay path to the downstream BGP speaker neighbor only according to the total metric contained in the intent template. Instead, they should obtain the suggested metric credit from the received BGP intent route, and then select the appropriate underlay path that meets the suggested metric credit.

The total metric credit included in the intent template is mainly used for egress PE2 to generate metric credit information that is encoded in the originated intent route. Other BGP speakers (non initiator) cannot directly use it to select underlay paths.

PE2 advertises two BGP intent routes, <prefix = loopback-PE2, intent-id = 1000> and <prefix = loopback-PE2, intent-id = 2000>, which are advertised to ABR respectively. The BGP next hop in the advertised route is set to PE2.

The metric related information encoded in <prefix = loopback-PE2, intent-id = 1000> is:

   metric-type: Unidirectional Link Delay

   metric: assume an initial value of 0

   metric-credit information:

      Count of Sources: 1

      S-Flag = 1, F-Flag = 0, P-Flag = 0

      Network Address of Source: loopback-PE1

      Total Metric Credit for Source: 10

      Estimated BGP Hops Count for Source: 2

Similarly, the metric related information encoded in <prefix = loopback-PE2, intent-id = 2000> is:

   metric-type: Unidirectional Link Delay

   metric: assume an initial value of 0

   metric-credit information:

      Count of Sources: 1

        S-Flag = 1, F-Flag = 0, P-Flag = 0

        Network Address of Source: loopback-PE1

        Total Metric Credit for Source: 100

        Estimated BGP Hops Count for Source: 2

   After receiving the first route advetisement, ABR knows that the
   suggested metric credit from itself to the downstream BGP speaker
   neighbor PE2 is 5ms, i.e., the average metric credit 5, the residual
   metric credit 10, taking the minimum one, then select an ultra-low
   delay path not exceeding 5ms to progress PE2, assuming TE path-12 in
   Figure 3.

   After receiving the second route advetisement, ABR knows that the
   suggested metric credit from itself to the downstream BGP speaker
   neighbor PE2 is 50ms, i.e., the average metric credit 50, the
   residual metric credit 100, taking the minimum one, then select a low
   delay path not exceeding 50ms to progress PE2, assuming TE path-22 in
   Figure 3.

   ABR continues to advertise the above two BGP intent routes to the
   upstream BGP speaker neighbor PE1, where the metric is accumulated by
   the selected underlay path, the BGP next hop is modified to ABR, and
   the metric credit information is unchanged.

   After receiving the first route advetisement, PE1 knows that the
   suggested metric credit from itself to the downstream BGP speaker
   neighbor ABR is 5ms, i.e., the average metric credit 5, the residual
   metric credit 6, taking the minimum one, then select an ultra-low
   delay path to ABR, assuming TE path-11 in Figure 3.

   After receiving the second route advetisement, PE1 knows that the
   suggested metric credit from itself to the downstream BGP speaker
   neighbor ABR is 50ms, i.e., the average metric credit 50, the
   residual metric credit 60, taking the minimum one, then select a low
   delay path to ABR, assuming TE path-12 in Figure 3.

4.2. Example of Intent with Metric Credit Piece

   Based on the first example, assume that two IGP domains are managed
   by a single provider, which is familiar with the performance of the
   network, and the propagated path of BGP intent route is clear, then,
   intent template may include explicit metric credit piece information.

   Thus the intent routes originated from PE2 will contain more
   information related with metric credit piece.

The metric related information encoded in <prefix = loopback-PE2, intent-id = 1000> is:

   metric-type: Unidirectional Link Delay

   metric: assume an initial value of 0

   metric-credit information:

      Count of Sources: 1

      S-Flag = 1, F-Flag = 0, P-Flag = 1

      Network Address of Source: loopback-PE1

      Total Metric Credit for Source: 10

      Estimated BGP Hops Count for Source: 2

      Current Hop Number: 0

      Metric Credit Piece [2]: [0] = 4, [1] = 6

Similarly, the metric related information encoded in <prefix = loopback-PE2, intent-id = 2000> is:

   metric-type: Unidirectional Link Delay

   metric: assume an initial value of 0

   metric-credit information:

      Count of Sources: 1

      S-Flag = 1, F-Flag = 0, P-Flag = 1

      Network Address of Source: loopback-PE1

      Total Metric Credit for Source: 100

      Estimated BGP Hops Count for Source: 2

      Current Hop Number: 0

      Metric Credit Piece [2]: [0] = 40, [1] = 60

After receiving the first route advetisement, ABR knows that the suggested metric credit from itself to the downstream BGP speaker

neighbor ABR is 4ms, i.e., the explicit metric credit piece 4, the
residual metric credit 10, taking the minimum one, then select an
ultra-low delay path to PE2, assuming TE path-12 in Figure 3.

After receiving the second route advetisement, ABR knows that the
suggested metric credit from itself to the downstream BGP speaker
neighbor ABR is 40ms, i.e., the explicit metric credit piece 40, the
residual metric credit 100, taking the minimum one, then select a low
delay path to PE2, assuming TE path-22 in Figure 3.

ABR continues to advertise the above two BGP intent routes to the
upstream BGP speaker neighbor PE1, where the metric is accumulated by
the selected underlay path, the BGP next hop is modified to ABR, and
the Current Hop Number is incremented by 1.

After receiving the first route advetisement, PE1 knows that the
suggested metric credit from itself to the downstream BGP speaker
neighbor ABR is 6ms, i.e., the explicit metric credit piece 6, the
residual metric credit 6, taking the minimum one, then select an
ultra-low delay path to ABR, assuming TE path-11 in Figure 3.

After receiving the second route advetisement, PE1 knows that the
suggested metric credit from itself to the downstream BGP speaker
neighbor ABR is 60ms, i.e., the explicit metric credit piece 60, the
residual metric credit 60, taking the minimum one, then select a low
delay path to ABR, assuming TE path-12 in Figure 3.

4.3. Example of Intent Shared by Multiple Path

As shown in Figure 4, it contains three AS. BGP neighbors are
established between PE1 and ASBR1, ASBR1 and ASBR2, ASBR1 and ASBR3,
ASBR2 and PE2, ASBR3 and PE3, to advertise BGP intent routes carrying
intent identifier and metric credit attribute.

```
     +---------P1---------+           +--------P4---------+
    /         |          \           /        |          \
 PE1---------P2----------ASBR1---ASBR2--------P5----------PE2
    \         |         / \        \          |          /
     +--------P3--------+   \       +-------P6---------+
                            \
                             \
                              \      +---------P7---------+
                               \    /         |          \
                                +--ASBR3-------P8----------PE3
                                    \         |          /
                                     +--------P9--------+
```
TE-path-11:PE1-P1-ASBR1 TE-path-12:ASBR1-ASBR2 TE-path-13: ASBR2-P4-PE2
TE-path-21:PE1-P3-ASBR1 TE-path-22:ASBR1-ASBR3 TE-path-23: ASBR3-P7-PE3
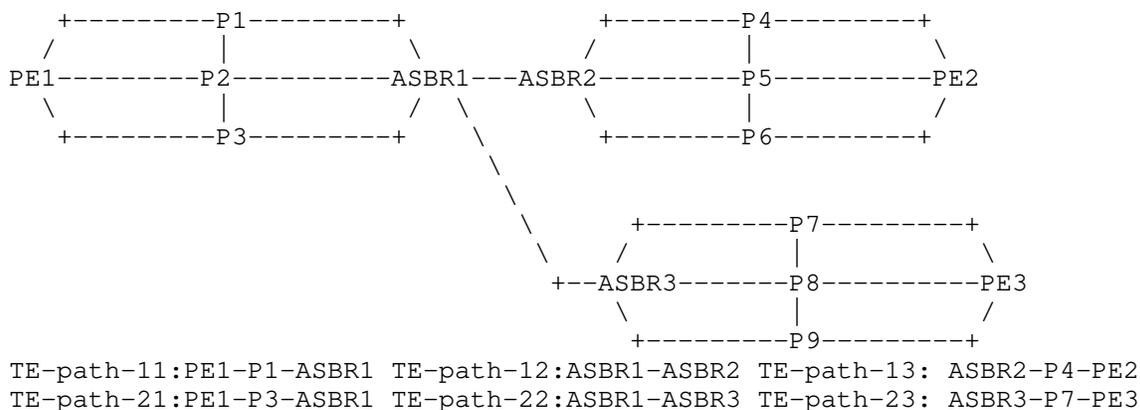
                     Figure 4: Inter-AS Intent Routing

   In this example, the same type of service needs to communicate
   between PE1 and PE2, PE1 and pE3. The intent of this type of service
   is the specific value related to the end-to-end total delay and
   distance of the transport path used.

   PE2 and pE3 will respectively config the intent templates with the
   same intent identifier, e.g., intent-1000.

   The intent-1000 template configured on PE2 have the following
   configuration:

      metric-type: Unidirectional Link Delay (ms)

      total-metric-credit: 200 (ms)

      metric-credit enabled

   The intent-1000 template also configured on PE3 have the following
   configuration:

      metric-type: Unidirectional Link Delay (ms)

      total-metric-credit: 300 (ms)

      metric-credit enabled

   PE2 advertises BGP intent route, <prefix = loopback-PE2, intent-id =
   1000>, which is advertised to ASBR2. The metric related information
   encoded is:

      metric-type: Unidirectional Link Delay

metric: assume an initial value of 0

metric-credit information:

Count of Sources: 1

S-Flag = 1, F-Flag = 0, P-Flag = 0

Network Address of Source: loopback-PE1

Total Metric Credit for Source: 200

Estimated BGP Hops Count for Source: 3

Similarly, PE3 advertises BGP intent route, <prefix = loopback-PE3, intent-id = 1000>, which is advertised to ASBR3. The metric related information encoded is:

metric-type: Unidirectional Link Delay

metric: assume an initial value of 0

metric-credit information:

Count of Sources: 1

S-Flag = 1, F-Flag = 0, P-Flag = 0

Network Address of Source: loopback-PE1

Total Metric Credit for Source: 300

Estimated BGP Hops Count for Source: 3

Then, ASBR2 and ASBR3 will use the suggested metric credit 66 and 100, taking minimum value from residual metric credit and average metric credit, to select the transport path for <prefix = loopback-PE2, intent-id = 1000> and <prefix = loopback-PE3, intent-id = 1000> respectively, assuming TE path-13 with cumulated metric 60 and TE path-23 with cumulated metric 100 in Figure 4.

Similarly, ASBR1 will also use suggested metric credit 66 and 100, to select the transport path for <prefix = loopback-PE2, intent-id = 1000> and <prefix = loopback-PE3, intent-id = 1000> respectively, assuming TE path-12 with cumulated metric 10 and TE path-22 with cumulated metric 10 in Figure 4.

Similarly, PE1 will also use suggested metric credit 66 and 100, to
select the transport path for <prefix = loopback-PE2, intent-id =
1000> and <prefix = loopback-PE3, intent-id = 1000> respectively,
assuming TE path-11 with cumulated metric 60 and TE path-21 with
cumulated metric 100 in Figure 4.

5. IANA Considerations

    This document request the METRIC_CREDIT entry to the "BGP Path
    Attributes" registry:

```
+=======+========================+================+
| Value | Code                   |   Reference    |
+=======+========================+================+
| TBD   | METRIC_CREDIT          | This Document  |
+-------+------------------------+----------------+
```

6. Security Considerations

    TBD

7. Acknowledgements

    TBD

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Authors' Addresses

Shaofu Peng
ZTE Corporation
China

Email: peng.shaofu@zte.com.cn

Bin Tan
ZTE Corporation
China

Email: tan.bin@zte.com.cn