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ALTO Traffic Engineering Cost Metrics
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Abstract

   Cost Metric is a basic concept in Application-Layer Traffic
   Optimization (ALTO). It is used in both the Cost Map Service and the
   Endpoint Cost Service. Future extensions to ALTO may also use Cost
   Metric.

   Different applications may benefit from different Cost Metrics. For
   example, a Resource Consumer may prefer Resource Providers that have
   low delay to the Resource Consumer. However the base ALTO protocol
   [ALTO] has defined only a single cost metric, i.e., the generic
   "routingcost" metric (Sec. 14.2 of ALTO base specification [ALTO]).

   In this document, we define eleven Cost Metrics, derived from OSPF-TE
   and ISIS-TE, to measure network delay, jitter, packet loss, hop
   count, and bandwidth. The metrics defined in this document provide a
   relatively comprehensive set of Cost Metrics for ALTO focusing on
   traffic engineering (TE). Additional Cost Metrics such as financial
   cost metrics may be defined in other documents.

material or to cite them other than as "work in progress."

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1. Introduction

Cost Metric is a basic concept in Application-Layer Traffic
Optimization (ALTO). It is used in both the Cost Map Service and the
Endpoint Cost Service. In particular, applications may benefit from
knowing network performance measured on several Cost Metrics. For
example, a more delay sensitive application may focus on latency, and
a more bandwidth-sensitive application may focus on available
bandwidth.

In this document, we define eleven Cost Metrics, extending the base
ALTO protocol [ALTO], which has defined only a single Cost Metric,
i.e., the generic "routingcost" metric (Sec. 14.2 of ALTO base
specification [ALTO]).

The Cost Metrics that we define in this document focus on traffic
engineering. Additional metrics may be defined in other documents.
In particular, the Cost Metrics that we define in this document can
be gathered from routing systems; [RFC3630], [RFC3784], [OSPF-TE],
[ISIS-TE], [BGP-LS] and [BGP-PM] define mechanisms that allow an ALTO
Server to retrieve and derive the necessary information to provide
the metrics that we define in this document.

Note that the metrics that the ALTO Server retrieves may be defined
for only links, and hence, the server will need to compose the link
metrics to obtain path metrics used in services such as the Cost Map
Service. In this definition, we define the metrics to be independent
of link or path, considering that future ALTO extensions may define
link-based services, and hence the defined metrics should still be
usable.

One challenge in defining the metrics is that performance metrics
often depend on configuration parameters. For example, the value of
packet loss rate depends on the measurement interval and varies over
time. To handle this issue, ALTO server may collect data on time
periods covering the past, present or only collect data on present
time.

The definitions of a set of Cost Metrics can allow us to extend the
base protocol (e.g., allowing output and constraints use different
Cost Metrics), but such extensions are not in the scope of this
document.

[2](#). Conventions used in this document

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 [RFC2119].

Syntax specifications shown here use the augmented Backus-Naur Form (ABNF) as described in [RFC5234], and are specified as in the base JSON specification [RFC4627].

3. **Metric: Delay**

   Cost Metric name:

      Delay

   Metric Description:

      To specify spatial and temporal aggregated delay between the
      specified source and destination. The spatial aggregation unit is
      specified in the query context (e.g., PID to PID, or endhost to
      endhost); and the temporal unit is specified as the measurement
      interval in the query context. The delay is the time that the
      packet spends to travel from source to destination.

   Metric Unit:

      The unit is microsecond.

   Metric Value Type:

      A single 'JSONNumber' type value containing a non-negative integer
      component that may be followed by an exponent part.

   Cost Mode:

      A Cost Mode is encoded as a US-ASCII string. The string MUST
      either have the value 'numerical' or 'ordinal'.

   Collection Method:

      The delay metric is part of ALTO information provided by ALTO
      server. ALTO server may collect delay metric from routing
      protocol or deploy data source to collect data to compute the
      delay metrics [ALTO-DEPLOYMENT]. The data source can be either
      log server or OAM system or P2P client,etc.

      When the delay metric is collected from routing protocol, it is
      measured over a measurement interval preconfigured by routing
      protocol. As described in Section 5 of [ISIS-TE],the default
      measurement interval is set to 30 seconds.

      ALTO server may also have additional data processing such as

aggregating the results across multiple systems, remove outliers, create additional statistics.

When the data is collected from data source or collected from routing protocol, Either scheduling can be used so that the past and present results for the delay metrics over a period of time are recorded, e.g., measured every hours and aggregated, or only the latest update is recorded.

ALTO Sample interval:

The ALTO Server may collect values from the sources measurements done e.g. every second over a period of 30 seconds. The ALTO Server may then aggregate these values over ALTO Sample intevals of at least 30 seconds and provide updates every hour.

Use and Applications:

This is intended to be a constraint attribute value.It could be used as a cost metric constraint attribute used either together with cost metric attribute 'routingcost' or on its own or as a returned cost metric in the response.

Example 1: Delay value on source-destination endpoint pairs
 POST /endpointcost/lookup HTTP/1.1
 Host: alto.example.com
 Content-Length: TBA
 Content-Type: application/alto-endpointcostparams+json
 Accept: application/alto-endpointcost+json,application/alto-error+json

```
{
  "cost-type": {"cost-mode" : "numerical",
                "cost-metric" : "delay"},
  "endpoints" : {
    "srcs": [ "ipv4:192.0.2.2" ],
    "dsts": [
      "ipv4:192.0.2.89",
      "ipv4:198.51.100.34",
      "ipv4:203.0.113.45"
    ]
  }
}

HTTP/1.1 200 OK
Content-Length: TBA
Content-Type: application/alto-endpointcost+json
{
  "meta" :{
    "cost-type": {"cost-mode" : "numerical",
                  "cost-metric" : "delay"
     }
   },
   "endpoint-cost-map" : {
     "ipv4:192.0.2.2": {
       "ipv4:192.0.2.89"    : 10,
       "ipv4:198.51.100.34" : 20,
       "ipv4:203.0.113.45"  : 30,
    }
  }
}
```

4. Metric: Delayjitter

   Cost Metric name:

      Delayjitter

   Metric Description:

      To specify spatial and temporal aggregated jitter (latency
      variation) over the specified source and destination. The spatial
      aggregation unit is specified in the query context (e.g., PID to
      PID, or endhost to endhost); and the temporal unit is specified as
      the measurement interval in the query context.

   Metric Unit:

      The unit is microsecond.

   Metric Value Type:

      A single 'JSONumber' type value containing an integer component
      that may be followed by exponent part.

   Cost Mode:

      A Cost Mode is encoded as a US-ASCII string. The string MUST
      either have the value 'numerical' or 'ordinal'.

   Collection Method:

      The delayjitter metric is part of ALTO information provided by
      ALTO server. ALTO server may collect delayjitter metric from
      routing protocol or deploy data source to collect data to compute
      the delay metrics [ALTO-DEPLOYMENT]. The data source can be
      either log server or OAM system or P2P client, etc.

      When the delayjitter metric is collected from routing protocol, it
      is measured over a measurement interval preconfigured by routing
      protocol. As described in Section 5 of [ISIS-TE], the default
      measurement interval is set to 30 seconds.

      ALTO server may also have additional data processing such as
      aggregating the results across multiple systems, remove outliers,

create additional statistics.

When the data is collected from data source or collected from
routing protocol, either scheduling can be used so that the past
and present results for the delayjitter metrics over a period of
time can be recorded, e.g., measured every hours,or only measure
the latest update.

ALTO Sample interval:

The ALTO Server may collect values from the sources measurements
done e.g. every second over a period of 30 seconds. The ALTO
Server may then aggregate these values over ALTO Sample intevals
of at least 30 seconds and provide updates every hour.

Use and Applications:

This is intended to be a constraint attribute value.It could be
used as a cost metric constraint attribute used either together
with cost metric attribute 'routingcost' or on its own or as a
returned cost metric in the response.

   Example 2: Delayjitter value on source-destination endpoint pairs
   POST /endpointcost/lookup HTTP/1.1
   Host: alto.example.com
   Content-Length: TBA
   Content-Type: application/alto-endpointcostparams+json
   Accept: application/alto-endpointcost+json,application/alto-error+json

   {
     "cost-type": {"cost-mode" : "numerical",
      "cost-metric" : "delayjitter"},
     "endpoints" : {
       "srcs": ["ipv4:192.0.2.2"],
       "dsts": [
         "ipv4:192.0.2.89",
         "ipv4:198.51.100.34",
         "ipv4:203.0.113.45"
       ]
     }
   }
   HTTP/1.1 200 OK
    Content-Length: TBA
    Content-Type: application/alto-endpointcost+json
   {
     "meta": {
              "cost type": {
              "cost-mode": "numerical",
              "cost-metric":"delayjitter"
       }
      },
     "endpoint-cost-map": {
              "ipv4:192.0.2.2": {
              "ipv4:192.0.2.89"   : 0
              "ipv4:198.51.100.34" : 1
              "ipv4:203.0.113.45" : 5
           }
         }
       }

5. Metric: Pktloss

   Cost Metric name:

      pktloss

   Metric Description:

      To specify spatial and temporal aggregated packet loss over the
      specified source and destination. The spatial aggregation unit is
      specified in the query context (e.g., PID to PID, or endhost to
      endhost); and the temporal unit is specified as the measurement
      interval in the query context.

   Metric Unit:

      The unit is percentile.

   Metric Value Type:

      A single number value containing an integer component that may be
      followed by a fraction part and/or an exponent part.

   Cost Mode:

      A Cost Mode is encoded as a US-ASCII string. The string MUST
      either have the value 'numerical' or 'ordinal'.

   Collection Method:

      The pktloss metric is part of ALTO information provided by ALTO
      server. ALTO server may collect pktloss metric from routing
      protocol or deploy data source to collect data to compute the
      delay metrics [ALTO-DEPLOYMENT]. The data source can be either
      log server or OAM system or P2P client,etc.

      When the pktloss metric is collected from routing protocol, it is
      measured over a measurement interval preconfigured by routing
      protocol. As described in Section 5 of [ISIS-TE], the default
      measurement interval is set to 30 seconds.

      ALTO server may also have additional data processing such as
      aggregating the results across multiple systems, remove outliers,

create additional statistics.

When the data is collected from data source or collected from
routing protocol, either scheduling can be used so that the past
and present results for this metric over a period of time can be
recorded, e.g.,measured every hours,or only measure the latest
update.

ALTO Sample interval:

The ALTO Server may collect values from the sources measurements
done e.g. every second over a period of 30 seconds. The ALTO
Server may then aggregate these values over ALTO Sample intevals
of at least 30 seconds and provide updates every hour.

Use and Applications:

This is intended to be a constraint attribute value. It could be
used as a cost metric constraint attribute used either together
with cost metric attribute 'routingcost' or on its own or as a
returned cost metric in the response.

Example 3: pktloss value on source-destination endpoint pairs

```
POST /endpointcost/lookup HTTP/1.1
Host: alto.example.com
Content-Length: TBA
Content-Type: application/alto-endpointcostparams+json
Accept: application/alto-endpointcost+json,application/alto-error+json

  {
    "cost-type": {"cost-mode" : "numerical",
     "cost-metric" : "pktloss"},
    "endpoints" : {
      "srcs": [ "ipv4:192.0.2.2" ],
      "dsts": [
        "ipv4:192.0.2.89",
        "ipv4:198.51.100.34",
        "ipv4:203.0.113.45"
      ]
    }
  }
HTTP/1.1 200 OK
Content-Length: TBA
Content-Type: application/alto-endpointcost+json
{
    "meta": {
              "cost type": {
            "cost-mode": "numerical",
            "cost-metric":"pktloss"}
        }
     },
   "endpoint-cost-map": {
          "ipv4:192.0.2.2": {
          "ipv4:192.0.2.89"   : 0,
          "ipv4:198.51.100.34": 1,
          "ipv4:203.0.113.45" : 2,
                            }
              }
 }
```

6. **Metric: Hopcount**

   The metric hopcount is mentioned in [ALTO] as an example. This
   section further clarifies its properties.

   Cost Metric name:

      Hopcount

   Metric Description:

      To specify the number of hops in the path between the source
      endpoint and the destination endpoint.

      Editor Note: Need to specify which level (AS, IP perhaps), details
      TBD for multiple-layer aspect.

   Metric Unit:

      The unit is integer number.

   Metric Value Type:

      A single 'JSONNumber' type value containing an integer component.

   Cost Mode:

      A Cost Mode is encoded as a US-ASCII string. string MUST either
      have the value 'numerical' or 'ordinal'.

   ALTO Sample interval:

      The ALTO Server may collect values from the sources measurements
      done e.g. every second over a period of 30 seconds. The ALTO
      Server may then aggregate these values over ALTO Sample intevals
      of at least 30 seconds and provide updates every hour.

   Use and Applications:

      This is intended to be a constraint attribute value. It could be
      used as a cost metric constraint attribute used either together
      with cost metric attribute 'routingcost' or on its own or as a
      returned cost metric in the response.

7. Metric: Bandwidth

Cost Metric name:

   Bandwidth

Metric Description:

   To specify spatial and temporal aggregated bandwidth over the
   specified source and destination. The spatial aggregation unit is
   specified in the query context (e.g., PID to PID, or endhost to
   endhost); and the temporal unit is specified as the measurement
   interval in the query context.

Metric Unit:

   The units are bytes per second.

Metric Value Type:

   A single 'JSONNumber' type value containing an integer component
   that may be prefixed with an optional minus sign, which may be
   followed by a fraction part and/or an exponent part.

Cost Mode:

   A Cost Mode is encoded as a US-ASCII string. string MUST either
   have the value 'numerical' or 'ordinal'.

ALTO Sample interval:

   The ALTO Server may collect values from the sources measurements
   done e.g. every second over a period of 30 seconds. The ALTO
   Server may then aggregate these values over ALTO Sample intevals
   of at least 30 seconds and provide updates every hour.

Use and Applications:

   This is just a definition of a class of cost metric 'bandwidth'.
   The use of this cost metric is always in conjunction with what it
   represents, which could be Max Bandwidth (maxbw), Residual
   Bandwidth (residuebw) etc.

This is intended to be a constraint attribute value It could be
used as a cost metric constraint attribute used together with cost
metric attribute 'routingcost' or on its own or as a returned cost
metric in the response.

8. **Metric: Maximum Bandwidth**

Cost Metric name:

   Maximum Bandwidth

Metric Description:

   To specify spatial and temporal maximum bandwidth over the
   specified source and destination. The spatial aggregation unit is
   specified in the query context (e.g., PID to PID, or endhost to
   endhost); and the temporal unit is specified as the measurement
   interval in the context interval.

Metric Unit:

   The units are bytes per second.

Metric Value Type:

   A single 'JSONNumber' type value containing an integer component
   that may be followed by an exponent part.

Cost Mode:

   A Cost Mode is encoded as a US-ASCII string. The string MUST
   either have the value 'numerical' or 'ordinal'.

Collection Method:

   The Maximum Bandwidth metric is gathered using [RFC3630],
   [RFC3784] or [BGP-LS]. It is extended from Bandwidth cost metric
   and is part of ALTO information provided by ALTO server. ALTO
   server may collect Maximum Bandwidth metric from routing protocol
   or deploy data source to collect data to compute the delay metrics
   [ALTO-DEPLOYMENT]. The data source can be either log server or
   OAM system or P2P client,etc.

   When the Maximum Bandwidth metric is collected from routing
   protocol, it is measured over a measurement interval preconfigured
   by routing protocol. As described in Section 5 of [ISIS-TE], the
   default measurement interval is set to 30 seconds.

ALTO server may also have additional data processing such as
aggregating the results across multiple systems, remove outliers,
create additional statistics.

When the data is collected from data source or collected from
routing protocol, either scheduling can be used so that the past
and present results for this metric over a period of time can be
recorded, e.g.,measured every hours,or only measure the latest
update.

ALTO Sample interval:

The ALTO Server may collect values from the sources measurements
done e.g. every second over a period of 30 seconds. The ALTO
Server may then aggregate these values over ALTO Sample intevals
of at least 30 seconds and provide updates every hour.

Use and Applications:

This is intended to be a constraint attribute value. It could be
used as a cost metric constraint attribute used either together
with cost metric attribute 'routingcost' or on its own or as a
returned cost metric in the response.

Example 4: maxbw value on source-destination endpoint pairs

```
POST/ endpointcost/lookup HTTP/1.1
Host: alto.example.com
Content-Length: TBA
Content-Type: application/alto-endpointcostparams+json
Accept: application/alto-endpointcost+json,application/alto-error+json

{
   "cost-type": { "cost-mode":  "numerical",
   "cost-metric":  "maxbw"},
   "endpoints":  {
      "srcs": [ "ipv4 : 192.0.2.2" ],
      "dsts": [
        "ipv4:192.0.2.89",
        "ipv4:198.51.100.34",
        "ipv4:203.0.113.45"
      ]
   }
 }

HTTP/1.1 200 OK
Content-Length: TBA
Content-Type: application/alto-endpointcost+json
{
    "meta": {
          "cost-type": {
          "cost-mode": "numerical",
          "cost-metric": "maxbw"
          }
    },
 "endpoint-cost-map": {
          "ipv4:192.0.2.2": {
          "ipv4:192.0.2.89":     0,
          "ipv4:198.51.100.34" : 2000,
          "ipv4:203.0.113.45":  5000,
                      }
        }
 }
```

9. Metric: Maximum Reserved Bandwdith

   Cost Metric name:

      Maximum Reserved Bandwidth

   Metric Description:

      To specify spatial and temporal maximum reserved bandwidth over
      the specified source and destination. The spatial aggregation
      unit is specified in the query context (e.g., PID to PID, or
      endhost to endhost); and the temporal unit is specified as the
      measurement interval in the query context.

   Metric Unit:

      The units are bytes per second.

   Metric Value Type:

      A single 'JSONNumber' type value containing an integer component
      that may be followed by an exponent part.

   Cost Mode:

      A Cost Mode is encoded as a US-ASCII string. The string MUST
      either have the value 'numerical' or 'ordinal'.

   Collection Method:

      The Maximum Reserved Bandwdith is gathered using [RFC3630],
      [RFC3784] or [BGP-LS]. It is extended from Bandwidth Cost metric
      defined as part of ALTO information provided by ALTO server. ALTO
      server may collect Maximum Reserved Bandwdith metric from routing
      protocol or deploy data source to collect data to compute the
      delay metrics [ALTO-DEPLOYMENT]. The data source can be either
      log server or OAM system or P2P client,etc.

      When the Maximum Reserved Bandwdith metric is collected from
      routing protocol, it is measured over a measurement interval
      preconfigured by routing protocol. As described in Section 5 of
      [ISIS-TE], the default measurement interval is set to 30 seconds.

ALTO server may also have additional data processing such as
aggregating the results across multiple systems, remove outliers,
create additional statistics.

When the data is collected from data source or collected from
routing protocol, either scheduling can be used so that the past
and present results for this metric over a period of time can be
recorded, e.g.,measured every hours,or only measure the latest
update.

ALTO Sample interval:

The ALTO Server may collect values from the sources measurements
done e.g. every second over a period of 30 seconds. The ALTO
Server may then aggregate these values over ALTO Sample intevals
of at least 30 seconds and provide updates every hour.

Use and Applications:

This is intended to be a constraint attribute value. It could be
used as a cost metric constraint attribute used either together
with cost metric attribute 'routingcost' or on its own or as a
returned cost metric in the response.

Example 5: maxresbw value on source-destination endpoint pairs

```
POST/ endpointcost/lookup HTTP/1.1
Host: alto.example.com
Content-Length: TBA
Content-Type: application/alto-endpointcostparams+json
Accept: application/alto-endpointcost+json,application/alto-error+json

  {
    "cost-type" { "cost-mode":  "numerical",
    "cost-metric":  "maxresbw"},
    "endpoints":  {
      "srcs": [ "ipv4 : 192.0.2.2" ],
      "dsts": [
        "ipv4:192.0.2.89",
        "ipv4:198.51.100.34",
        "ipv4:203.0.113.45"
      ]
    }
  }
HTTP/1.1 200 OK
Content-Length: TBA
Content-Type: application/alto-endpointcost+json
{
    "meta": {
          "cost-type": {
          "cost-mode": "numerical",
          "cost-metric": "maxresbw"
          }
    },
  " endpoint-cost-map": {
          "ipv4:192.0.2.2" {
          "ipv4:192.0.2.89" :     0,
          "ipv4:198.51.100.34": 2000,
          "ipv4:203.0.113.45":  5000,
                         }
           }
  }
```

10. Metric: Unavailable Reserved Bandwidth

   Cost Metric name:

      Unavailable Reserved Bandwidth

   Metric Description:

      To specify spatial and temporal unavailable reserved bandwidth
      over the specified source and destination. The spatial
      aggregation unit is specified in the query context (e.g., PID to
      PID, or endhost to endhost); and the temporal unit is specified as
      the measurement interval in the query context.

   Metric Unit:

      The units are bytes per second.

   Metric Value Type:

      A single 'JSONArray' type with each value containing an integer
      component that may be followed by an exponent part.

   Cost Mode:

      A Cost Mode is encoded as a US-ASCII string. The string MUST
      either have the value 'numerical' or 'ordinal'.

   Collection Method:

      The Unavailable Reserved Bandwidth metric is gathered using
      [RFC3630], [RFC3784] or [BGP-LS]. It is extended from Bandwidth
      Cost metric and defined as part of ALTO information provided by
      ALTO server. ALTO server may collect Unavailable Reserved
      Bandwidth metric from routing protocol or deploy data source to
      collect data to compute the delay metrics [ALTO-DEPLOYMENT]. The
      data source can be either log server or OAM system or P2P
      client,etc.

      When the Unavailable Reserved Bandwidth metric is collected from
      routing protocol, it is measured over a measurement interval
      preconfigured by routing protocol. As described in Section 5 of
      [ISIS-TE],the default measurement interval is set to 30 seconds.

ALTO server may also have additional data processing such as
aggregating the results across multiple systems, remove outliers,
create additional statistics.

When the data is collected from data source or collected from
routing protocol, either scheduling can be used so that the past
and present results for this metric over a period of time can be
recorded, e.g.,measured every hours,or only measure the latest
update.

ALTO Sample interval:

The ALTO Server may collect values from the sources measurements
done e.g. every second over a period of 30 seconds. The ALTO
Server may then aggregate these values over ALTO Sample intevals
of at least 30 seconds and provide updates every hour.

Use and Applications:

This is intended to be a constraint attribute values. The values
correspond to the bandwidth that can be reserved with a setup
priority of 0 through 7. It could be used as a cost metric
constraint attribute used Either together with cost metric
attribute 'routingcost' or on its own or as a returned cost metric
in the response.

Example 6: unresbw value on source-destination endpoint pairs
In this example, the Collection method specifies that the
'unresbw' values are defined as the 'unavailable bandwidth' specified
in section 2.5.8 of RFC3630: 8 unavailable bandwidth value are
reported in the same OSPF message using the same TLV. Each value
is corresponding to the bandwidth that can be reserved with a setup
priority of 0 through 7.

```
POST/ endpointcost/lookup HTTP/1.1
Host: alto.example.com
Content-Length: TBA
Content-Type: application/alto-endpointcostparams+json
Accept: application/alto-endpointcost+json,application/alto-error+json

  {
   "cost-type" { "cost-mode":  "numerical",
   "cost-metric":  "unresbw[1,8]" },
   "endpoints":  {
      "srcs": [ "ipv4:192.0.2.2" ],
      "dsts": [
        "ipv4:192.0.2.89",
        "ipv4:198.51.100.34",
        "ipv4:203.0.113.45"
      ]
    }
  }

HTTP/1.1 200 OK
Content-Length: TBA
Content-Type: application/alto-endpointcost+json
{
    "meta": {
          "cost-type": {
          "cost-mode": "numerical",
          "cost-metric": "unresbw[1,8]"
        }
  },
 "endpoint-cost-map" {
          "ipv4:192.0.2.2" {
          "ipv4:192.0.2.89" :   [0,0,0,0,0,0,0,0],
          "ipv4:198.51.100.34": [0,0,0,0,0,0,0,2000],
          "ipv4:203.0.113.45":  [0,0,0,0,0,0,0,5000],
                         }
       }
 }
```

11. Metric: Residue Bandwidth

   Cost Metric name:

      Residue Bandwidth

   Metric Description:

      To specify spatial and temporal residual bandwidth over the
      specified source and destination. The spatial aggregation unit is
      specified in the query context (e.g., PID to PID, or endhost to
      endhost); and the temporal unit is specified as the measurement
      interval in the query context.

   Metric Unit:

      The units are bytes per second.

   Metric Value Type:

      A single 'JSONArray' type with each value containing an integer
      component that may be followed by an exponent part.

   Cost Mode:

      A Cost Mode is encoded as a US-ASCII string. The string MUST
      either have the value 'numerical' or 'ordinal'.

   Collection Method:

      The Residue Bandwidth metric is gathered using [OSPF-TE],
      [ISIS-TE] or [BGP-PM]. It is extended from Bandwidth Cost metric
      and is part of ALTO information provided by ALTO server. ALTO
      server may collect Residue Bandwidth metric from routing protocol
      or deploy data source to collect data to compute the delay metrics
      [ALTO-DEPLOYMENT]. The data source can be either log server or
      OAM system or P2P client,etc.

      When the Residue Bandwidth metric is collected from routing
      protocol, it is measured over a measurement interval preconfigured
      by routing protocol. As described in Section 5 of [ISIS-TE],the
      default measurement interval is set to 30 seconds.

ALTO server may also have additional data processing such as
aggregating the results across multiple systems, remove outliers,
create additional statistics.

When the data is collected from data source or collected from
routing protocol, either scheduling can be used so that the past
and present results for this metric over a period of time can be
recorded, e.g.,measured every hours,or only measure the latest
update.

ALTO Sample interval:

The ALTO Server may collect values from the sources measurements
done e.g. every second over a period of 30 seconds. The ALTO
Server may then aggregate these values over ALTO Sample intevals
of at least 30 seconds and provide updates every hour.

Use and Applications:

This is intended to be a constraint attribute values. The values
correspond to the bandwidth that can be reserved with a setup
priority of 0 through 7. It could be used as a cost metric
constraint attribute used Either together with cost metric
attribute 'routingcost' or on its own or as a returned cost metric
in the response.

Example 7: residuebw value on source-destination endpoint pairs

```
POST/ endpointcost/lookup HTTP/1.1
Host: alto.example.com
Content-Length: TBA
Content-Type: application/alto-endpointcostparams+json
Accept: application/alto-endpointcost+json,application/alto-error+json

  {
   "cost-type": { "cost-mode":  "numerical",
   "cost-metric":  "residubw"},
   "endpoints":  {
     "srcs": [ "ipv4 : 192.0.2.2" ],
     "dsts": [
       "ipv4:192.0.2.89",
       "ipv4:198.51.100.34",
       "ipv4:203.0.113.45"
     ]
   }
}

HTTP/1.1 200 OK
Content-Length: TBA
Content-Type: application/alto-endpointcost+json
{
   "meta": {
         "cost-type" {
         "cost-mode": "numerical",
         "cost-metric": "residubw"
      }
    },
  "endpoint-cost-map" {
         "ipv4:192.0.2.2" {
         "ipv4:192.0.2.89" :     0,
         "ipv4:198.51.100.34": 2000,
         "ipv4:203.0.113.45":  5000,
                     }
         }
  }
```

12. Metric: Available Bandwidth

   Cost Metric name:

      Available Bandwidth

   Metric Description:

      To specify spatial and temporal availaible bandwidth over the
      specified source and destination. The spatial aggregation unit is
      specified in the query context (e.g., PID to PID, or endhost to
      endhost); and the temporal unit is specified as the measurement
      interval in the query context.

   Metric Unit:

      The units are bytes per second.

   Metric Value Type:

      A single 'JSONArray' type with each value containing an integer
      component that may be followed by an exponent part.

   Cost Mode:

      A Cost Mode is encoded as a US-ASCII string. The string MUST
      either have the value 'numerical' or 'ordinal'.

   Collection Method:

      The Available Bandwidth metric is gathered using [OSPF-TE],
      [ISIS-TE] or [BGP- PM]. It is extended from Bandwidth Cost metric
      and is part of ALTO information provided by ALTO server. ALTO
      server may collect Available Bandwidth metric from routing
      protocol or deploy data source to collect data to compute the
      delay metrics [ALTO-DEPLOYMENT]. The data source can be either
      log server or OAM system or P2P client,etc.

      When the Available Bandwidth metric is collected from routing
      protocol, it is measured over a measurement interval preconfigured
      by routing protocol. As described in Section 5 of [ISIS-TE],the
      default measurement interval is set to 30 seconds.

ALTO server may also have additional data processing such as
aggregating the results across multiple systems, remove outliers,
create additional statistics.

When the data is collected from data source or collected from
routing protocol, either scheduling can be used so that the past
and present results for this metric over a period of time can be
recorded, e.g.,measured every hours,or only measure the latest
update.

ALTO Sample interval:

The ALTO Server may collect values from the sources measurements
done e.g. every second over a period of 30 seconds. The ALTO
Server may then aggregate these values over ALTO Sample intevals
of at least 30 seconds and provide updates every hour.

Use and Applications:

This is intended to be a constraint attribute values. The values
correspond to the bandwidth that can be reserved with a setup
priority of 0 through 7. It could be used as a cost metric
constraint attribute used Either together with cost metric
attribute 'routingcost' or on its own or as a returned cost metric
in the response.

  Example 8: availbw value on source-destination endpoint pairs

  POST /endpointcost/lookup HTTP/1.1
  Host: alto.example.com
  Content-Length: TBA
  Content-Type: application/alto-endpointcostparams+json
  Accept: application/alto-endpointcost+json,application/alto-error+json

    {
     "cost-type": { "cost-mode": "numerical",
     "cost-metric": "availbw"},
      "endpoints":   {
        "srcs": ["ipv4 : 192.0.2.2"],
        "dsts": [
          "ipv4:192.0.2.89",
          "ipv4:198.51.100.34",
          "ipv4:203.0.113.45"
        ]
     }
       }

  HTTP/1.1 200 OK
  Content-Length: TBA
  Content-Type: application/alto-endpointcost+json
  {
     "meta": {
           "cost-type": {
           "cost-mode": "numerical",
           "cost-metric": "availbw"
          }
     },
  "endpoint-cost-map": {
           "ipv4:192.0.2.2" {
           "ipv4:192.0.2.89" :   0,
           "ipv4:198.51.100.34": 2000,
           "ipv4:203.0.113.45": 5000,
                      }
        }
  }

13. Metric: Utilized Bandwidth

   Cost Metric name:

      Utilized Bandwidth

   Metric Description:

      To specify spatial and temporal utilized bandwidth over the
      specified source and destination. The spatial aggregation unit is
      specified in the query context (e.g., PID to PID, or endhost to
      endhost); and the temporal unit is specified as the measurement
      interval in the query context.

   Metric Unit:

      The units are bytes per second.

   Metric Value Type:

      A single 'JSONArray' type with each value containing an integer
      component that may be followed by an exponent part.

   Cost Mode:

      A Cost Mode is encoded as a US-ASCII string. The string MUST
      either have the value 'numerical' or 'ordinal'.

   Collection Method:

      The Utilized Bandwidth metric is gathered using [OSPF-TE],
      [ISIS-TE] or [BGP-PM]. It is extended from bandwidth cost metric
      and is part of ALTO information provided by ALTO server. ALTO
      server may collect Utilized Bandwidth metric from routing protocol
      or deploy data source to collect data to compute the delay metrics
      [ALTO-DEPLOYMENT]. The data source can be either log server or
      OAM system or P2P client,etc.

      When The Utilized Bandwidth metric is collected from routing
      protocol, it is measured over a measurement interval preconfigured
      by routing protocol. As described in Section 5 of [ISIS-TE],the
      default measurement interval is set to 30 seconds.

ALTO server may also have additional data processing such as
aggregating the results across multiple systems, remove outliers,
create additional statistics.

When the data is collected from data source or collected from
routing protocol, either scheduling can be used so that the past
and present results for this metric over a period of time can be
recorded, e.g.,measured every hours,or only measure the latest
update.

ALTO Sample interval:

The ALTO Server may collect values from the sources measurements
done e.g. every second over a period of 30 seconds. The ALTO
Server may then aggregate these values over ALTO Sample intevals
of at least 30 seconds and provide updates every hour.

Use and Applications:

This is intended to be a constraint attribute values. The values
correspond to the bandwidth that can be reserved with a setup
priority of 0 through 7. It could be used as a cost metric
constraint attribute used Either together with cost metric
attribute 'routingcost' or on its own or as a returned cost metric
in the response.

Example 9: utilbw value on source-destination endpoint pairs

```
POST /endpointcost/lookup HTTP/1.1
Host: alto.example.com
Content-Length: TBA
Content-Type: application/alto-endpointcostparams+json
Accept: application/alto-endpointcost+json,application/alto-error+json

 {
  "cost-type": {"cost-mode" : "numerical",
   "cost-metric" :   "utilbw"},
   "endpoints":   {
        "srcs" : [ "ipv4 : 192.0.2.2" ],
        "dsts" : [
          "ipv4:192.0.2.89",
          "ipv4:198.51.100.34",
          "ipv4:203.0.113.45"
       ]
     }
 }

HTTP/1.1 200 OK
Content-Length: TBA
Content-Type: application/alto-endpointcost+json
 {
  "meta": {
          "cost type": {
          "cost-mode": "numerical",
          "cost-metric": "utilbw"
         }
   },
  "endpoint-cost-map": {
            "ipv4:192.0.2.2" {
            "ipv4:192.0.2.89" :    0,
            "ipv4:198.51.100.34" : 2000,
            "ipv4:203.0.113.45" :  5000,
                        }
          }
  }
```

14. Security Considerations

   The properties defined in this document present no security
   considerations beyond those in Section 15 of the base ALTO
   specification [ALTO].

   However concerns addressed in Sections "15.1 Authenticity and
   Integrity of ALTO Information", "15.2 Potential Undesirable Guidance
   from Authenticated ALTO Information" and "15.3 Confidentiality of
   ALTO Information" remain of utmost importance. Indeed, TE
   performance is a highly sensitive ISP information and sharing TE
   metric values in numerical mode requires full mutual confidence
   between the entities managing the ALTO Server and Client. Numerical
   TE performance information will most likely be distributed by ALTO
   Servers to Clients under strict and formal mutual trust agreements.
   One the other hand, ALTO Clients must be cognizant on the risks
   attached to such information that they would have acquired outside
   formal conditions of mutual trust.

15. IANA Considerations

   IANA has added the following entries to the ALTO cost map Properties
   registry, defined in Section 3 of [RFCXXX].

```
     +-----------+--------------+-----------------------+
     | Namespace | Property     | Reference             |
     +-----------+--------------+-----------------------+
     |           | delay        | [RFCxxxx], Section 3  |
     |           | jitter       | [RFCxxxx], Section 4  |
     |           | pktloss      | [RFCxxxx], Section 5  |
     |           | hopcount     | [RFCxxxx], Section 6  |
     |           | bandwidth    | [RFCxxxx], Section 7  |
     |           |  maxbw       |[RFCxxxx],  Section 8  |
     |           |  maxresbw    |[RFCxxxx], Section 9   |
     |           |  unresdbw    |[RFCxxxx], Section 10  |
     |           |  residbw     |[RFCxxxx], Section 11  |
     |           |  availbw     |[RFCxxxx], Section 12  |
     |           |  utilbw      |[RFCxxxx], Section 13  |
     +-----------+--------------+-----------------------+
```

16. References

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16.2. Informative References

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