

ALTO Working Group
Internet-Draft
Intended status: Standards Track
Expires: April 24, 2014

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October 21, 2013

ALTO Extensions for Traffic Engineering (TE) performance metrics in JSON
format
[draft-wu-alto-json-te-02](#)

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. However the base protocol defines only a single cost metric, i.e., the generic "routingcost" metric (Sec. 14.2 of ALTO base specification [[ALTO](#)]). In practice, applications may request network information on other cost (including performance) metrics.

In this document, we define five new base metrics which are delay, jitter, pktloss (packet loss), bandwidth and hopcount. These base metrics are further extended with these nine new metrics linkdelay, linkjitter, linkloss, maxbw (Maximum Bandwidth), maxreservbw (Maximum Reserved Bandwidth), unreservbw (Unreserved Bandwidth), residuebw (Residual Bandwidth), availbw (Available Bandwidth), and utilbw (Utilized Bandwidth). Also a new parameter anomalousstate is added. These fourteen cost metrics are derived from OSPF-TE and ISIS-TE and can be either used as constraint attribute associated with 'routingcost' cost metric attribute or used as returned Cost metrics in the response, or both and hence provide a relatively comprehensive set of cost metrics for ALTO.

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October 2013

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1. Introduction

The ALTO protocol [[ALTO](#)] uses a REST-ful design , and encodes its requests and responses using JSON [[RFC4627](#)] . In ALTO architecture [[ALTO](#)], the ALTO server allows alto information to be gathered from multiple systems(e.g., routing protocol). [[OSPF-TE](#)], [[ISIS-TE](#)], [[BGP-LS](#)] and [[BGP-PM](#)]describes extensions to routing protocol, that can be used to distribute network performance information (such as link delay, delay variation, packet loss, residual bandwidth, and available bandwidth). The mechanism defined in [[OSPF-TE](#)], [[ISIS-TE](#)], [[BGP-LS](#)], and [[BGP-PM](#)]can be used by an ALTO Server to retrieve the necessary performance information supplementing the prefix and network topology data gathered from other sources (such as Path Computation Element (PCE)) in the underlying network.

Cost metric is a basic concept in ALTO. It is used in both the Cost Map Service and the Endpoint Cost Service. However the base protocol defines only a single cost metric, i.e., the generic "routingcost" metric (Sec. 14.2 of [[ALTO](#)]). In practice, applications may request network information on other cost (such as performance) metrics. In this document, we define five new base metrics which are delay, jitter, pktloss (packet loss), bandwidth and hopcount. These base metrics are further extended with these nine new metrics linkdelay, linkjitter, linkloss, maxbw (Maximum Bandwidth), maxreservbw (Maximum Reserved Bandwidth), unreservbw (Unreserved Bandwidth), residuebw (Residual Bandwidth), availbw (Available Bandwidth), and utilbw (Utilized Bandwidth). Also a new parameter anomalousstate is added. These fourteen cost metrics are derived from [[OSPF-TE](#)] and [[ISIS-TE](#)] and can be either used as constraint attribute associated with

'routingcost' cost metric attribute or used as returned Cost metrics in the response, or both and hence provide a relatively comprehensive set of cost metrics for ALTO.

The introduction of a set of cost metrics allows us to extend the flexibility of ALTO services. In particular, both the Cost Map Service and the Endpoint Cost Service allow filtering. However, these two services as defined in the base protocol are limited in that the output information metric and the filtering (constraint) metric must be the same. However, applications may request a filtered "routingcost" Cost Map only for locations where the delay is below a threshold. This is not feasible in the ALTO base protocol. We discuss the overhead of implementing the aforementioned use case using the current base protocol, and propose a simple but effective extension to the "constraint" syntax to ALTO.

[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](#)].

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[3.](#) Cost Metric Extensions: Cost Metrics

[3.1.](#) Cost Metric: delay

Cost Metric name: delay

Metric Description: To specify the average delay over a configurable interval for each source/destination pair between two endpoints (network locations) in the network. It could be either end to end delay or the delay associated with the link (linkdelay). The unit is microseconds.

Cost 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.

Purpose: This is intended to be a new cost metric. 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.

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

Measurement timing: Gather and update at the configurable interval if it is link attribute. See [[OSPF-TE](#)] for configurable interval. The configurable interval for end to end delay could be same as link.

Measurement points with Potential Measurement Domain:
The measurement point could be at any endpoint between source and destination in the network.

Examples 1:

POST /endpointcost/lookup HTTP/1.1

Host: alto.example.com

Content-Length: 195

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: 231
Content-Type: application/alto-endpointcost+json

```
{
  "meta" : {},
  "data" : {
    "cost-type": {"cost-mode" : "numerical",
                  "cost-metric" : "delay"},
    "map" : {
      "ipv4:192.0.2.2": {
        "ipv4:192.0.2.89" : 10,
        "ipv4:198.51.100.34" : 20,
        "ipv4:203.0.113.45" : 30,
      }
    }
  }
}
```

//Note that these are end to end delay values in microseconds.

Example 2:

POST /endpointcost/lookup HTTP/1.1
Host: alto.example.com
Content-Length: 195
Content-Type: application/alto-endpointcostparams+json
Accept: application/alto-endpointcost+json,application/alto-error+json

```
{
  "cost-type": {"cost-mode" : "numerical",
                "cost-metric" : "routingcost"},
                "constraints" : {"delay ls 15"},
  "endpoints" : {
    "srcs": [ "ipv4:192.0.2.2" ],
    "dsts": [
      "ipv4:192.0.2.89",
      "ipv4:198.51.100.34",
      "ipv4:203.0.113.45"
    ]
  }
}
```


Content-Length: 231

Content-Type: application/alto-endpointcost+json

```
"data": {
  "cost type": {
    "cost-mode": "numerical",
    "cost-metric": "routingcost",
    "constraints" : {"delay ls 15"},
  "map": {
    "ipv4:192.0.2.2": {
      "ipv4:192.0.2.89": 0 ["delay eq 0"],
      "ipv4:198.51.100.34": 15 ["delay eq 3"],
      "ipv4:203.0.113.45": 1 ["delay eq 12"],
    }
  }
}
```

//Note that these are end to end routing cost and delay .

[3.2.](#) Cost Metric: jitter

Cost Metric name: jitter

Metric Description: To specify the average delay variation over a configurable interval for each source/destination pair between two endpoints(network locations)in the network. It could be either end to end jitter or the jitter associated with a link (linkjitter). The unit is microseconds.

Cost 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.

Purpose: 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.

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

Measurement timing: Gather and update at the configurable interval if it is link attribute. See [[OSPF-TE](#)] for configurable interval. The configurable interval for end to end jitter could be same as link.

Measurement points with Potential Measurement Domain:
The measurement point could be at any endpoint between
source and destination in the network.

Examples:

POST /endpointcost/lookup HTTP/1.1

Host: alto.example.com

Content-Length: 195

Content-Type: application/alto-endpointcostparams+json

Accept: application/alto-endpointcost+json,application/alto-error+json

```
{
  "cost-type": {"cost-mode" : "numerical",
    "cost-metric" : "routingcost"},
  "constraints" : {"delay ls 15","jitter ls 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: 231
Content-Type: application/alto-endpointcost+json
"data": {
  "cost type": {
    "cost-mode": "numerical",
    "cost-metric":"routingcost"},
    "constraints": {"delay ls 15","jitter ls 8"},
  "map": {
    "ipv4:192.0.2.2": {
      "ipv4:192.0.2.89": 0 ["delay eq 0", "jitter eq 0"],
      "ipv4:198.51.100.34": 5 ["delay eq 3", "jitter eq 1"],
      "ipv4:203.0.113.45":2 ["delay eq 12", "jitter eq 5"],
    }
  }
}
```

[3.3.](#) Cost Metric: Packet Loss

Cost Metric name: pktloss

Metric Description: To specify a percentage of the total traffic
sent over a configurable interval for each
source/destination pair between two endpoints(network

locations) in the network. It could be either end to end packet loss or the packet loss associated with a link

(linkloss).

Cost Metric Value type:

A single number 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.

Purpose: 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.

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

Measurement timing: Gather and update at the configurable interval if it is link attribute. See [\[OSPF-TE\]](#) for configurable interval. The configurable interval for end to end packet loss could be same as link.

Measurement points with Potential Measurement Domain: The measurement point could be at any endpoint between source and destination in the network.

Examples:

POST /endpointcost/lookup HTTP/1.1

Host: alto.example.com

Content-Length: 195

Content-Type: application/alto-endpointcostparams+json

Accept: application/alto-endpointcost+json,application/alto-error+json

```
{
  "cost-type": {"cost-mode" : "numerical",
    "cost-metric" : "routingcost"},
  "constraints" : {"pktloss le 0.3"},
  "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: 231
Content-Type: application/alto-endpointcost+json
```

```
"data": {
    "cost type": {
        "cost-mode": "numerical",
        "cost-metric": "routingcost",
        "constraints" : {"pktloss le 0.3"},
    "map": {
        "ipv4:192.0.2.2": {
            "ipv4:192.0.2.89": 0 ["pktloss eq 0.0"],
            "ipv4:198.51.100.34": 1 ["pktloss eq 0.0001"],
            "ipv4:203.0.113.45": 0 ["pktloss eq 0.0"],
        }
    }
}
```

[Editor Note: We have to be clear when the new metrics are part of response and when it is not?]

[3.4.](#) Cost Metric: Bandwidth

Cost Metric name: bandwidth

Metric Description: To specify Bandwidth over a configurable interval for each source/destination pair between two endpoints (network locations) in the network. It could be either aggregated bandwidth for end to end path or the bandwidth associated with a link. The units are bytes per second.

Cost 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.

Purpose: 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.

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

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

Examples: (based on Residual Bandwidth (residuebw))

POST /endpointcost/lookup HTTP/1.1
Host: alto.example.com

Content-Length: 195

Content-Type: application/alto-endpointcostparams+json

Accept: application/alto-endpointcost+json,application/alto-error+json

```
{
  "cost-type": {"cost-mode" : "numerical",
    "cost-metric" : "routingcost"},
  "constraints" : {"residuebw gt 1500"},
  "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: 231

Content-Type: application/alto-endpointcost+json

```
"data": {
  "cost type": {
    "cost-mode": "numerical",
    "cost-metric": "routingcost"},
  ...
}
```

```
    "constraints" : {"residuebw gt 1500"},
"map": {
  "ipv4:192.0.2.2": {
    "ipv4:192.0.2.89": 0 ["residuebw eq 0"],
    "ipv4:198.51.100.34": 5 ["residuebw eq 2000"],
    "ipv4:203.0.113.45":2 ["residuebw eq 5000"],
    }
}
```

[3.5.](#) Cost Metric: Hopcount

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 layer (IP perhaps), details TBD for multiple-layer aspect.

Cost Metric Value type:

A single 'JSONNumber' type value containing an integer component that may be prefixed with an optional minus sign.

Purpose: 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.

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

[3.6.](#) Delay Cost Metric Extension: linkdelay

A linkdelay is gathered using [\[OSPF-TE\]](#), [\[ISIS-TE\]](#) or [\[BGP-PM\]](#). It is extended from Delay Cost metric and defined as:

```
Object {  
  LinkName link-name;  
  [JSONBool linkstate;] //TRUE = not steady; FALSE = steady;  
  delay dl;  
}linkdelay;
```

[3.7.](#) Jitter Cost Metric Extension: linkjitter

A linkjitter is gathered using [\[OSPF-TE\]](#), [\[ISIS-TE\]](#) or [\[BGP-PM\]](#). It is extended from Jitter Cost metric and defined as:

```
Object {  
  LinkName link-name;  
  [JSONBool linkstate;] //TRUE = not steady; FALSE = steady;  
  jitter jt;  
}linkjitter;
```

[3.8.](#) Packet Loss Cost Metric Extension: linkloss

A linkloss is gathered using [\[OSPF-TE\]](#), [\[ISIS-TE\]](#) or [\[BGP-PM\]](#). It is extended from Packet loss cost metric and defined as:

```
Object {  
  LinkName link-name;  
  [JSONBool linkstate;] //TRUE = not steady; FALSE = steady;  
  pktloss l;  
}linkloss;
```

[3.9.](#) Bandwidth Cost Metric Extension

[3.9.1.](#) Maximum Bandwidth: maxbw

A maxbw is gathered using [[RFC3630](#)], [[RFC3784](#)] or [[BGP-LS](#)]. It could be either maximum bandwidth for end to end path or the bandwidth associated with a link. It is extended from Bandwidth Cost metric and defined as:

```
Object {  
  BWType      max;  
  [LinkName   link-name;]  
  [JSONBool   linkstate;] //TRUE = not steady; FALSE = steady;  
  Bandwidth bw;  
}maxbw;
```

[3.9.2.](#) Maximum Reserved Bandwidth: maxreservbw

A maxreservbw is gathered using [[RFC3630](#)], [[RFC3784](#)] or [[BGP-LS](#)]. It could be either maximum reserved bandwidth for end to end path or the bandwidth associated with a link. It is extended from Bandwidth Cost metric and defined as:

```
Object {  
  BWType      maxreserved;  
  [LinkName   link-name;]  
  [JSONBool   linkstate;] //TRUE = not steady; FALSE = steady;  
  Bandwidth bw;  
}maxreservbw;
```

[3.9.3.](#) Unreserved Bandwidth: unreservbw

A unreservbw is gathered using [[RFC3630](#)], [[RFC3784](#)] or [[BGP-LS](#)]. It could be either unreserved bandwidth for end to end path or the bandwidth associated with a link. It is extended from Bandwidth Cost metric and defined as:

```
Object {  
  BWType unreserved;  
  [LinkName link-name;]  
  [JSONBool linkstate;] //TRUE = not steady; FALSE = steady;
```



```
Bandwidth bw<1,8>
}unreservbw;
```

//This bandwidth is per priority [TBD].

[3.9.4.](#) Residual Bandwidth: residuebw

A residuebw is gathered using [[OSPF-TE](#)], [[ISIS-TE](#)] or [[BGP-PM](#)]. It could be either residual bandwidth for end to end path or the bandwidth associated with a link. It is extended from Bandwidth Cost metric and defined as:

```
Object {
  BWType Residue;
  [LinkName link-name;]
  [JSONBool linkstate;] //TRUE = not steady; FALSE = steady;
  Bandwidth bw;
}rediduebw;
```

[3.9.5.](#) Available Bandwidth: availbw

A availbw is gathered using [[OSPF-TE](#)], [[ISIS-TE](#)] or [[BGP-PM](#)]. It could be either available bandwidth for end to end path or the bandwidth associated with a link. It is extended from Bandwidth Cost metric and defined as:

```
Object {
  BWType Available;
  [LinkName link-name;]
  [JSONBool linkstate;] //TRUE = not steady; FALSE = steady;
  Bandwidth bw;
}availbw;
```

[3.9.6.](#) Utilized Bandwidth: utilbw

A utilbw is gathered using [[OSPF-TE](#)], [[ISIS-TE](#)] or [[BGP-PM](#)]. It could be either utilized bandwidth for end to end path or the bandwidth associated with a link. It is extended from Bandwidth Cost metric and defined as:

```
Object {  
  BWType Utilized;  
  [LinkName link-name;]  
  [JSONBool linkstate;] //TRUE = not steady; FALSE = steady;  
  Bandwidth bw;  
}utilbw;
```

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[4.](#) Cost Metric Extensions: Parameters

The following sections define Parameters used within cost metrics specified in the [section 3](#).

[4.1.](#) Parameter: anomalousstate

Parameter name: anomalousstate

Purpose: Optimally used in a prefixed cost metric to indicate whether it is steady state of the performance metric.

Description: This state can be used to notify to the ALTO client if the performance metric associated is in a steady state. The ALTO client may use this to perform some action. The anomalousstate is set when the measured value of this parameter exceeds its configured maximum threshold. The anomalousstate is cleared when the measured value falls below its configured threshold. Anomalousstate should be used together with Cost metric we defined in the [section 3](#). Cost Metrics prefixed with 'a:' are reserved for cost metric that does not have steady state network performance. Cost Metrics without prefix 'a:' indicate the cost metric has steady state network performance.

Examples:

```
POST /endpointcost/lookup HTTP/1.1
Host: alto.example.com
Content-Length: 195
Content-Type: application/alto-endpointcostparams+json
Accept: application/alto-endpointcost+json,application/alto-error+json

{
```

```
"cost-type": {"cost-mode" : "numerical",
  "cost-metric" : "routingcost"},
"constraints" : {"delay ls 15"},
"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: 231
Content-Type: application/alto-endpointcost+json

"data": {
  "cost type":{
    "cost-mode": "numerical",
    "cost-metric":"routingcost"
  }
  "constraints": {"delay ls 15"},
  "map": {
    "ipv4:192.0.2.2": {
      "ipv4:192.0.2.89": 0 ["a:delay eq 10"],
    }
  }
}
```

[5.](#) Security Considerations

The properties defined in this document present no security considerations beyond those in [Section 14](#) of the base ALTO specification [[ALTO](#)].

6. 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 3.1
	jitter	[RFCxxxx], Section 3.2
	pktloss	[RFCxxxx], Section 3.3
	linkdelay	[RFCxxxx], Section 3.6
	linkjitter	[RFCxxxx], Section 3.7
	linkloss	[RFCxxxx], Section 3.8
	bandwidth	[RFCxxxx], Section 3.4
	hopcount	[RFCxxxx], Section 3.5
	maxbw	[RFCxxxx], Section 3.9.1
	maxresbw	[RFCxxxx], Section 3.9.2
	unresdbw	[RFCxxxx], Section 3.9.3

		residbw	[RFCxxxx], Section 3.9.4
		availbw	[RFCxxxx], Section 3.9.5
		utilbw	[RFCxxxx], Section 3.9.6
+-----+-----+-----+-----+			

IANA has added the following entries to the "ALTO cost map Parameters" registry, defined in [RFCxxxx] [Section 4.1](#).

+-----+-----+-----+-----+			
Name-			
space	Parameter	Reference	
+-----+-----+-----+-----+			
	anomalousstate	[RFCxxxx], Section 4.1	
+-----+-----+-----+-----+			

[7.](#) References

[7.1.](#) Normative References

- [ALTO] Alimi, R., "ALTO Protocol",
ID [draft-ietf-alto-protocol-16](#), May 2013.
- [BGP-LS] Gredler, H., "North-Bound Distribution of Link-State and
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- [BGP-PM] Wu, Q., "BGP attribute for North-Bound Distribution of

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ID [draft-wu-idr-te-pm-bgp-02](#), October 2013.

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- [RFC5234] Crocker, D., "Augmented BNF for Syntax Specifications: ABNF", [RFC 5234](#), January 2008.

[7.2.](#) Informative References

- [RFC6390] Clark, A. and B. Claise, "Framework for Performance Metric Development", [RFC 6390](#), July 2011.

[Appendix A.](#) Filtering constraint Extensions

[Section 10.2.2.3](#) of "ALTO: Application Layer Traffic Optimization Protocol" [I.D-ietf-alto-protocol] states:
"


```

object {
    CostType    cost-type;
    [JSONString constraints<0..*>;]
    [PIDFilter   pids;]
} ReqFilteredCostMap;

```

```

object {
    PIDName srcs<0..*>;
    PIDName dsts<0..*>;
} PIDFilter;

```

with members:

cost-type The CostType ([Section 9.7](#)) for the returned costs. The cost-metric and cost-mode fields MUST match one of the supported Cost Types indicated in this resource's capabilities ([Section 10.2.2.4](#)). The ALTO Client SHOULD omit the description field, and if present, the ALTO Server MUST ignore the description field.

constraints Defines a list of additional constraints on which elements of the Cost Map are returned. This parameter MUST NOT be specified if this resource's capabilities ([Section 10.2.2.4](#)) indicate that constraint support is not available. A constraint contains two entities separated by whitespace: (1) an operator, 'gt' for greater than, 'lt' for less than, 'ge' for greater than or equal to, 'le' for less than or equal to, or 'eq' for equal to; (2) a target cost value. The cost value is a number that MUST be defined in the same units as the Cost Metric indicated by the cost-metric parameter. ALTO Servers SHOULD use at least IEEE 754 double-precision floating point [IEEE.754.2008] to store the cost value, and SHOULD perform internal computations using double-precision floating-point arithmetic. If multiple 'constraint' parameters are specified, they are interpreted as being related to each other with a logical AND.

In the JSON Object of type ReqFilteredCostMap, the constraint attribute is expressed as:

```

"
[gt | lt | ge | le | eq ] <value>
"

```

In this specification, the constraint attribute is changed to

```
"  
<cost-type2> [gt | lt | ge | le | eq ] <value>  
"
```

Accordingly, the constraints definition is changed to:

```
"  
constraints Defines a list of additional constraints on which  
elements of the Cost Map are returned. This parameter MUST NOT be  
specified if this resource's capabilities ( Section 10.2.2.4)  
indicate that constraint support is not available. A constraint  
contains three entities separated by whitespace: (1)an cost type  
is by default cost-type in the JSON Object of type ReqFilteredCostMap.  
In addition, it could be another cost-type used for the returned cost  
(2) an operator, 'gt' for greater than, 'lt' for less than, 'ge' for  
greater than or equal to, 'le' for less than or equal to, or 'eq' for  
equal to; (3) a target cost value. The cost value is a number that  
MUST be defined in the same units as the Cost Metric indicated by the  
cost-metric parameter. ALTO Servers SHOULD use at least IEEE 754  
double-precision floating point [IEEE.754.2008] to store the cost  
value, and SHOULD perform internal computations using double-  
precision floating-point arithmetic. If multiple 'constraint'  
parameters are specified, they are interpreted as being related to  
each other with a logical AND.  
"
```

Editor-Notes: Filtering constraint extension should move to another document defining multi-metrics filtering in the future.

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JSON for ALTO TE

October 2013

[Appendix B](#). Contributor Addresses

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October 2013

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