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ISIS Extensions in Support of Inter-AS Multiprotocol Label Switching  
(MPLS) and Generalized MPLS (GMPLS) Traffic Engineering

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Abstract

This document describes extensions to the ISIS (ISIS) protocol to support Multiprotocol Label Switching (MPLS) and Generalized MPLS (GMPLS) Traffic Engineering (TE) for multiple Autonomous Systems (ASes). It defines ISIS-TE extensions for the flooding of TE information about inter-AS links which can be used to perform inter-AS TE path computation.

No support for flooding information from within one AS to another AS is proposed or defined in this document.

#### 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 [RFC-2119](#) [[RFC2119](#)].

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## [1. Introduction](#)

[ISIS-TE] defines extensions to the ISIS protocol [[ISIS](#)] to support intra-area Traffic Engineering (TE). The extensions provide a way of



encoding the TE information for TE-enabled links within the network (TE links) and flooding this information within an area. The Extended IS Reachability TLV and Traffic Engineering Router ID TLV, which are defined in [\[ISIS-TE\]](#), are used to carry such TE information. The Extended IS Reachability TLV has several nested sub-TLVs which describe the TE attributes for a TE link.

[\[ISIS-TE-V3\]](#) and [\[GMPLS-TE\]](#) define similar extensions to ISIS [\[ISIS\]](#) in support of IPv6 and GMPLS traffic engineering respectively.

Requirements for establishing Multiprotocol Label Switching (MPLS) TE Label Switched Paths (LSPs) that cross multiple Autonomous Systems (ASes) are described in [\[INTER-AS-TE-REQ\]](#). As described in [\[INTER-AS-TE-REQ\]](#), a method SHOULD provide the ability to compute a path spanning multiple ASes. So a path computation entity that may be the head-end Label Switching Router (LSR), an AS Border Router (ASBR), or a Path Computation Element (PCE [\[PCE\]](#)) needs to know the TE information not only of the links within an AS, but also of the links that connect to other ASes.

In this document, a new TLV, which is referred to as the Inter-AS Reachability TLV, is defined to advertise inter-AS TE information, three new sub-TLVs are defined for inclusion in the Inter-AS Reachability TLV to carry the information about the remote AS number and remote ASBR ID. The sub-TLVs defined in [\[ISIS-TE\]](#), [\[ISIS-TE-V3\]](#) and other documents for inclusion in the Extended IS Reachability TLV for describing the TE properties of a TE link are applicable to be included in the Inter-AS Reachability TLV for describing the TE properties of an inter-AS TE link as well. And two more new sub-TLVs are defined for inclusion in the IS-IS Router Capability TLV to carry the TE Router ID when TE Router ID needs to reach all routers within an entire ISIS routing domain. The extensions are equally applicable to IPv4 and IPv6 as identical extensions to [\[ISIS-TE\]](#) and [\[ISIS-TE-V3\]](#). The detailed definitions and procedures are discussed in the following sections.

This document does not propose or define any mechanisms to advertise any other extra-AS TE information within ISIS. See [Section 2.1](#) for a full list of non-objectives for this work.

## **2. Problem Statement**

As described in [\[INTER-AS-TE-REQ\]](#), in the case of establishing an inter-AS TE LSP traversing multiple ASes, the Path message [\[RFC3209\]](#) may include the following elements in the Explicit Route Object (ERO) in order to describe the path of the LSP:



- a set of AS numbers as loose hops; and/or
- a set of LSRs including ASBRs as loose hops.

Two methods for determining inter-AS paths are currently being discussed. The per-domain method [[PD-PATH](#)] determines the path one domain at a time. The backward recursive method [[BRPC](#)] uses cooperation between PCEs to determine an optimum inter-domain path. The sections that follow examine how inter-AS TE link information could be useful in both cases.

### **[2.1. A Note on Non-Objectives](#)**

It is important to note that this document does not make any change to the confidentiality and scaling assumptions surrounding the use of ASes in the Internet. In particular, this document is conformant to the requirements set out in [[INTER-AS-TE-REQ](#)].

The following features are explicitly excluded:

- o There is no attempt to distribute TE information from within one AS to another AS.
- o There is no mechanism proposed to distribute any form of TE reachability information for destinations outside the AS.
- o There is no proposed change to the PCE architecture or usage.
- o TE aggregation is not supported or recommended.
- o There is no exchange of private information between ASes.
- o No ISIS adjacencies are formed on the inter-AS link.

### **[2.2. Per-Domain Path Determination](#)**

In the per-domain method of determining an inter-AS path for an MPLS-TE LSP, when an LSR that is an entry-point to an AS receives a Path message from an upstream AS with an ERO containing a next hop that is an AS number, it needs to find which LSRs (ASBRs) within the local AS are connected to the downstream AS so that it can compute a TE LSP segment across the local AS to one of those LSRs and forward the Path message to it and hence into the next AS. See Figure 1 for an example:



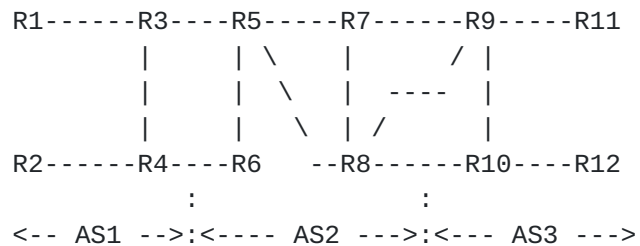


Figure 1: Inter-AS Reference Model

The figure shows three ASes (AS1, AS2, and AS3) and twelve LSRs (R1 through R12). R3 and R4 are ASBRs in AS1. R5, R6, R7, and R8 are ASBRs in AS2. R9 and R10 are ASBRs in AS3.

If an inter-AS TE LSP is planned to be established from R1 to R12, the AS sequence will be: AS1, AS2, AS3.

Suppose that the Path message enters AS2 from R3. The next hop in the ERO shows AS3, and R5 must determine a path segment across AS2 to reach AS3. It has a choice of three exit points from AS2 (R6, R7, and R8) and it needs to know which of these provide TE connectivity to AS3, and whether the TE connectivity (for example, available bandwidth) is adequate for the requested LSP.

Alternatively, if the next hop in the ERO is the entry ASBR for AS3 (say R9), R5 needs to know which of its exit ASBRs has a TE link that connects to R9. Since there may be multiple ASBRs that are connected to R9 (both R7 and R8 in this example), R5 also needs to know the TE properties of the inter-AS TE links so that it can select the correct exit ASBR.

Once the path message reaches the exit ASBR, any choice of inter-AS TE link can be made by the ASBR if not already made by entry ASBR that computed the segment.

More details can be found in the Section 4. of [\[PD-PATH\]](#), which clearly points out why advertising of inter-AS links is desired.

To enable R5 to make the correct choice of exit ASBR the following information is needed:

- o List of all inter-AS TE links for the local AS.
- o TE properties of each inter-AS TE link.





- o AS number of the neighboring AS connected to by each inter-AS TE link.
- o Identity (TE Router ID) of the neighboring ASBR connected to by each inter-AS TE link.

In GMPLS networks further information may also be required to select the correct TE links as defined in [\[GMPLS-TE\]](#).

The example above shows how this information is needed at the entry point ASBRs for each AS (or the PCEs that provide computation services for the ASBRs), but this information is also needed throughout the local AS if path computation function is fully distributed among LSRs in the local AS, for example to support LSPs that have start points (ingress nodes) within the AS.

### **[2.3. Backward Recursive Path Computation](#)**

Another scenario using PCE techniques has the same problem. [\[BRPC\]](#) defines a PCE-based TE LSP computation method (called Backward Recursive Path Computation) to compute optimal inter-domain constrained MPLS-TE or GMPLS LSPs. In this path computation method, a specific set of traversed domains (ASes) are assumed to be selected before computation starts. Each downstream PCE in domain(i) returns to its upstream neighbor PCE in domain(i-1) a multipoint-to-point tree of potential paths. Each tree consists of the set of paths from all Boundary Nodes located in domain(i) to the destination where each path satisfies the set of required constraints for the TE LSP (bandwidth, affinities, etc.).

So a PCE needs to select Boundary Nodes (that is, ASBRs) that provide connectivity from the upstream AS. In order that the tree of paths provided by one PCE to its neighbor can be correlated, the identities of the ASBRs for each path need to be referenced, so the PCE must know the identities of the ASBRs in the remote AS reached by any inter-AS TE link, and, in order that it provides only suitable paths in the tree, the PCE must know the TE properties of the inter-AS TE links. See the following figure as an example:

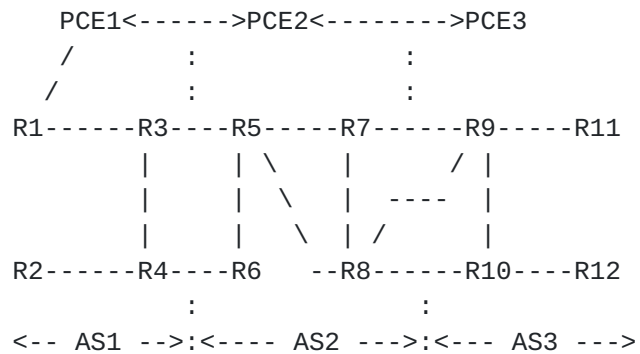


Figure 2: BRPC for Inter-AS Reference Model

The figure shows three ASes (AS1, AS2, and AS3), three PCEs (PCE1, PCE2, and PCE3), and twelve LSRs (R1 through R12). R3 and R4 are ASBRs in AS1. R5, R6, R7, and R8 are ASBRs in AS2. R9 and R10 are ASBRs in AS3. PCE1, PCE2, and PCE3 cooperate to perform inter-AS path computation and are responsible for path segment computation within their own domain(s).

If an inter-AS TE LSP is planned to be established from R1 to R12, the traversed domains are assumed to be selected: AS1->AS2->AS3, and the PCE chain is: PCE1->PCE2->PCE3. First, the path computation request originated from the PCC (R1) is relayed by PCE1 and PCE2 along the PCE chain to PCE3, then PCE3 begins to compute the path segments from the entry boundary nodes that provide connection from AS2 to the destination (R12). But, to provide suitable path segments, PCE3 must determine which entry boundary nodes provide connectivity to its upstream neighbor AS (identified by its AS number), and must know the TE properties of the inter-AS TE links. In the same way, PCE2 also needs to determine the entry boundary nodes according to its upstream neighbor AS and the inter-AS TE link capabilities.

Thus, to support Backward Recursive Path Computation the same information listed in [Section 2.2](#) is required. The AS number of the neighboring AS connected to by each inter-AS TE link is particularly important.

### 3. Extensions to ISIS-TE

Note that this document does not define mechanisms for distribution of TE information from one AS to another, does not distribute any form of TE reachability information for destinations outside the AS, does not change the PCE architecture or usage, does not suggest or recommend any form of TE aggregation, and does not feed private information between ASes. See [Section 2.1](#).



In this document, for the advertisement of inter-AS TE links, a new TLV, which is referred to as the Inter-AS Reachability TLV, is defined and three new sub-TLVs are defined for inclusion in the Inter-AS Reachability TLV to carry the information about the neighboring AS number and the remote ASBR ID of an inter-AS link. The sub-TLVs defined in [[ISIS-TE](#)], [[ISIS-TE-V3](#)] and other documents for inclusion in the Extended IS Reachability TLV are applicable to be included in the Inter-AS Reachability TLV for inter-AS TE links advertisement. And another two new sub-TLVs are defined for inclusion in the IS-IS Router Capability TLV to carry the TE Router ID when the TE Router ID is needed to reach all routers within an entire ISIS routing domain.

While some of the TE information of an inter-AS TE link may be available within the AS from other protocols, in order to avoid any dependency on where such protocols are processed, this mechanism carries all the information needed for the required TE operations.

### **[3.1](#). Inter-AS Reachability TLV**

The Inter-AS Reachability TLV has type 141 (which needs to be confirmed by IANA see [Section 6.1](#)), it contains a data structure consisting of:

- 4 octets of Router ID
- 3 octets of default metric
- 1 octet of control information, consisting of:
  - 1 bit of flooding-scope information (S bit)
  - 1 bit of up/down information (D bit)
  - 6 bits reserved
- 1 octet of length of sub-TLVs
- 0-246 octets of sub-TLVs
  - where each sub-TLV consists of a sequence of:
    - 1 octet of sub-type
    - 1 octet of length of the value field of the sub-TLV
    - 0-244 octets of value

Compare to the Extended Reachability TLV which is defined in [[ISIS-TE](#)], the Inter-AS Reachability TLV replaces the "7 octets of System ID and Pseudonode Number" field with a "4 octets of Router ID" field and introduces an extra "control information" field which is consisted of a flooding-scope bit (S bit), a up/down bit (D bit) and 6 reserved bits.

The Router ID field of the Inter-AS Reachability TLV is four octets in length, which contains the Router ID of the router who generates



the Inter-AS Reachability TLV. The Router ID MUST be unique within the ISIS area. If the router generates Inter-AS Reachability TLV with entire ISIS routing domain flooding scope, then the Router ID MUST also be unique within the entire ISIS routing domain. The Router ID could be used to indicate the source of the Inter-AS Reachability TLV.

The flooding procedures for Inter-AS Reachability TLV are identical to the flooding procedures for the GENINFO TLV which are defined in the Section 4 of [\[GENINFO\]](#). These procedures have been previously discussed in [\[ISIS-CAP\]](#). The flooding-scope bit (S bit) SHOULD be set to 0 if the flooding scope is to be limited to within the single IGP area to which the ASBR belongs, or MAY be set to 1 if the information is intended to reach all routers (including area border routers, ASBRs, and PCEs) in the entire ISIS routing domain. The choice between the use of 0 or 1 is an AS-wide policy choice, and configuration control SHOULD be provided in ASBR implementations that supports the advertisement of inter-AS TE links.

The sub-TLVs which are defined in [\[ISIS-TE\]](#), [\[ISIS-TE-V3\]](#) and other documents for describing the TE properties of an TE link are also applicable to be carried in the Inter-AS Reachability TLV to describe the TE properties of an Inter-AS TE link. Apart from these sub-TLVs, three new sub-TLVs are defined for inclusion in the Inter-AS Reachability TLV in this document:

Sub-TLV type	Length	Name
-----	-----	-----
23	4	Remote AS number
24	4	IPv4 Remote ASBR Identifier
25	16	IPv6 Remote ASBR Identifier

The detailed definitions of the three new sub-TLVs are described in [Section 3.3](#).

### **[3.2](#). TE Router ID**

The IPv4 TE Router ID TLV (type 134) and IPv6 TE Router ID TLV (type 140), which are defined in [\[ISIS-TE\]](#) and [\[ISIS-TE-V3\]](#) respectively, only have area flooding-scope, when performing inter-AS TE, the TE Router ID MAY be needed to reach all routers within an entire ISIS routing domain, and it MUST have the same flooding scope as the Inter-AS Reachability TLV does.

[\[ISIS-CAP\]](#) defines a generic advertisement mechanism for ISIS which allows a router to advertise its capabilities within an ISIS area or





The Remote AS number field has 4 octets. When only two octets are used for the AS number, as in current deployments, the left (high-order) two octets MUST be set to zero. The Remote AS Number Sub-TLV MUST be included when a router advertises an inter-AS TE link.



### 3.3.2. IPv4 Remote ASBR ID Sub-TLV

A new sub-TLV, which is referred to as the IPv4 Remote ASBR ID sub-TLV, is defined for inclusion in the Inter-AS Reachability TLV when advertising inter-AS links. The IPv4 Remote ASBR ID sub-TLV specifies the IPv4 identifier of the remote ASBR to which the advertised inter-AS link connects. This could be any stable and routable IPv4 address of the remote ASBR. Use of the TE Router ID as specified in the Traffic Engineering Router ID TLV [[ISIS-TE](#)] is RECOMMENDED.

The IPv4 Remote ASBR ID sub-TLV is TLV type 24 (which needs to be confirmed by IANA see [Section 6.2](#)), and is four octets in length. The format of the IPv4 Remote ASBR ID sub-TLV is as follows:

```

      0                   1                   2                   3
      0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|                               Type                               |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|                               Remote ASBR ID                     |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+

```

The IPv4 Remote ASBR ID sub-TLV MUST be included if the neighboring ASBR has an IPv4 address. If the neighboring ASBR does not have an IPv4 address (not even an IPv4 TE Router ID), the IPv6 Remote ASBR ID sub-TLV MUST be included instead. An IPv4 Remote ASBR ID sub-TLV and IPv6 Remote ASBR ID sub-TLV MAY both be present in an Extended IS Reachability TLV.

### 3.3.3. IPv6 Remote ASBR ID Sub-TLV

A new sub-TLV, which is referred to as the IPv6 Remote ASBR ID sub-TLV, is defined for inclusion in the Inter-AS Reachability TLV when advertising inter-AS links. The IPv6 Remote ASBR ID sub-TLV specifies the IPv6 identifier of the remote ASBR to which the advertised inter-AS link connects. This could be any stable and routable IPv6 address of the remote ASBR. Use of the TE Router ID as specified in the IPv6 Traffic Engineering Router ID TLV [[ISIS-TE-V3](#)] is RECOMMENDED.

The IPv6 Remote ASBR ID sub-TLV is TLV type 25 (which needs to be confirmed by IANA see [Section 6.2](#)), and is sixteen octets in length. The format of the IPv6 Remote ASBR ID sub-TLV is as follows:



When the TE Router ID is needed to reach all routers within an entire ISIS routing domain, the IS-IS Router Capability TLV MUST be included in its LSP. And if an ASBR supports Traffic Engineering for IPv4, the IPv4 TE Router ID sub-TLV MUST be included if the ASBR has an IPv4 TE Router ID. If the ASBR does not have an IPv4 TE Router ID, the IPv6 TE Router sub-TLV MUST be included instead. An IPv4 TE Router ID sub-TLV and IPv6 TE Router ID sub-TLV MAY both be present in an IS-IS Router Capability TLV.



The information advertised comes from the ASBR's knowledge of the TE capabilities of the link, the ASBR's knowledge of the current status





and usage of the link, and configuration at the ASBR of the remote AS number and remote ASBR TE Router ID.

Legacy routers receiving an advertisement for an inter-AS TE link are able to ignore it because they do not know the new TLV and sub-TLVs that are defined in [Section 3](#) in this document. They will continue to flood the LSP, but will not attempt to use the information received.

In the current operation of ISIS TE the LSRs at each end of a TE link emit LSAs describing the link. The databases in the LSRs then have two entries (one locally generated, the other from the peer) that describe the different 'directions' of the link. This enables CSPF to do a two-way check on the link when performing path computation and eliminate it from consideration unless both directions of the link satisfy the required constraints.

In the case we are considering here (i.e., of a TE link to another AS) there is, by definition, no IGP peering and hence no bi-directional TE link information. In order for the CSPF route computation entity to include the link as a candidate path, we have to find a way to get LSAs describing its (bidirectional) TE properties into the TE database.

This is achieved by the ASBR advertising, internally to its AS, information about both directions of the TE link to the next AS. The ASBR will normally generate a LSA describing its own side of a link; here we have it 'proxy' for the ASBR at the edge of the other AS and generate an additional LSA that describes that devices 'view' of the link.

Only some essential TE information for the link needs to be advertised; i.e., the Interface Address, the Remote AS number and the Remote ASBR ID of an inter-AS TE link.

Routers or PCEs that are capable of processing advertisements of inter-AS TE links SHOULD NOT use such links to compute paths that exit an AS to a remote ASBR and then immediately re-enter the AS through another TE link. Such paths would constitute extremely rare occurrences and SHOULD NOT be allowed except as the result of specific policy configurations at the router or PCE computing the path.



#### **4.1. Origin of Proxied TE Information**

[Section 4](#) describes how to an ASBR advertises TE link information as a proxy for its neighbor ASBR, but does not describe where this information comes from.

Although the source of this information is outside the scope of this document, it is possible that it will be a configuration requirement at the ASBR, as are other, local, properties of the TE link. Further, where BGP is used to exchange IP routing information between the ASBRs, a certain amount of additional local configuration about the link and the remote ASBR is likely to be available.

We note further that it is possible, and may be operationally advantageous, to obtain some of the required configuration information from BGP. Whether and how to utilize these possibilities is an implementation matter.

#### **5. Security Considerations**

The protocol extensions defined in this document are relatively minor and can be secured within the AS in which they are used by the existing ISIS security mechanisms.

There is no exchange of information between ASes, and no change to the ISIS security relationship between the ASes. In particular, since no ISIS adjacency is formed on the inter-AS links, there is no requirement for ISIS security between the ASes.

Some of the information included in these new advertisements (e.g., the remote AS number and the remote ASBR ID) is obtained manually from a neighboring administration as part of commercial relationship. The source and content of this information should be carefully checked before it is entered as configuration information at the ASBR responsible for advertising the inter-AS TE links.

It is worth noting that in the scenario we are considering a Border Gateway Protocol (BGP) peering may exist between the two ASBRs and this could be used to detect inconsistencies in configuration (e.g., the administration that originally supplied the information may be lying, or some manual mis-configurations or mistakes are made by the operators). For example, if a different remote AS number is received in a BGP OPEN [[BGP](#)] from that locally configured into ISIS-TE, as we describe here, then local policy SHOULD be applied to determine whether to alert the operator to a potential mis-configuration or to suppress the ISIS advertisement of the inter-AS TE link. Note,



further, that if BGP is used to exchange TE information as described in [Section 4.1](#), the inter-AS BGP session SHOULD be secured using mechanisms as described in [[BGP](#)] to provide authentication and integrity checks.

## 6. IANA Considerations

IANA is requested to make the following allocations from registries under its control.

### 6.1. Inter-AS Reachability TLV

This document defines the following new ISIS TLV type, described in [Section 3.4](#), that needs to be registered in the ISIS TLV code-point registry:

Type	Description	IIH	LSP	SNP
----	-----	---	---	---
141	Inter-AS reachability information	n	y	n

### 6.2. Sub-TLVs for the Inter-AS Reachability TLV

This document defines the following new sub-TLV types, described in Sections [3.3.1](#), [3.3.2](#) and [3.3.3](#), of top-level TLV 141 (see [section 6.1](#) above) that need to be registered in the ISIS sub-TLV registry for TLV 141, note that these three new sub-TLVs SHOULD NOT appear in TLV 22 (or TLV 222) and MUST be ignored in TLV 22 (or TLV 222):

Type	Description	Length
----	-----	-----
23	Remote AS number	4
24	IPv4 Remote ASBR Identifier	4
25	IPv6 Remote ASBR Identifier	16

As described above in [Section 3.1](#), the sub-TLVs which are defined in [[ISIS-TE](#)], [[ISIS-TE-V3](#)] and other documents for describing the TE properties of an TE link are applicable to describe an inter-AS TE link and MAY be included in the Inter-AS Reachability TLV when advertising inter-AS TE links. And it's possible that some sub-TLVs may be defined for inclusion in both TLV 22 and TLV 141 in the future. It's better if these sub-TLVs have the same registry value no matter where they are included in TLV 22 or TLV 141. The same condition will occur when these sub-TLVs need to be included in TLV 222. So, in order to simplify the registration and reduce the



potential code point conflict, this document suggests that TLV 22, TLV 141 and TLV 222 share the same sub-TLV registry. The proposal is that change the current Registry Name from "Sub-TLVs for TLV 22" to "Sub-TLVs for TLV 22, 141 and 222" and add three columns ("May be present on TLV 22", "May be present on TLV 141" and "May be present on TLV 222") to the registry for indicating whether a specific sub-TLV may be present on the TLV.

### **6.3. Sub-TLVs for the IS-IS Router Capability TLV**

This document defines the following new sub-TLV types, described in Sections [3.3.4](#) and [3.3.5](#), of top-level TLV 242 (which is defined in [[ISIS-CAP](#)]) that need to be registered in the ISIS sub-TLV registry for TLV 242:

Type	Description	Length
----	-----	-----
11	IPv4 TE Router ID	4
12	IPv6 TE Router ID	16

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