Solution for Route Leaks Using BGP Communities


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October 26, 2018

Acknowledgements: The authors are grateful to many folks in various IETF WGs for commenting, critiquing, and offering very helpful suggestions (see acknowledgements section in the draft.)
General Principles of the Design

• Why BGP Community: Faster deployment without dependence on vendor implementation changes
• Based on the analysis and knowledge we have so far about RLP/eOTC, independent of encoding (Attribute or Community), at the minimum the RLP info must include:
  ➢ ASN of the RLP-aware AS that most recently asserted that it sent update to a customer or lateral peer; let us call this DO = Down Only indication
  ➢ Leak warning: L = Leak indication
    ➢ L = ASN of the first RLP-aware AS in the path that is forwarding a route in spite of detecting a leak
      ▪ AS in question is avoiding unreachability (absence of alternative route)

Note: RLP = Route Leak Protection; DO alone or DO and L together constitute RLP
Illustration of Down Only (DO) and Leak (L) indications – 1 of 2

Once a route is tainted with $L = X$, it remains tainted with the same ($L = X$) when it propagates. This is “stickiness” of L.

Legend:
- n: AS does not participate in RLP and starts/restarts a leak

Note: RLP = Route Leak Protection; DO alone or DO and L together constitute RLP
Illustration of Down Only (DO) and Leak (L) indications – 2 of 2

Legend:

AS does not participate in RLP and starts a leak

Note: RLP = Route Leak Protection; DO alone or DO and L together constitute RLP
Scenarios:

Scenario 1 ☺

Scenari o 2 ☺

Preferred route: q {4 3 2 1}

Legend:

Green – not violation
Red – violation

AS does not participate in RLP and starts/restarts a leak

Preferred route: q {5 3 2 1}

Seems worse if customer route is selected at AS 6 ☺

Preferred route: q {5 3 2 1}

Shortest path tie; use tie breaker

Leak

Seem s worse if customer route is selected at AS 6 ☺

Preferred route= ?

Shortest path tie; use tie breaker

Leak

Leak

RLP = [DO, L]
Prefixes with Single Path to Tier1

- 1 hop length: 91152
- 2 hops length: 56558
- 3 hops length: 16348
- 4 hops length: 2755
- 5 hops length: 274s
- 6 hops length: 54
- 7 hops length: 5

Measurements by Qrator Labs
RLP-aware AS must perform both Inter- and Intra-AS RLP

Legend:
- AS does not participate in RLP and starts/restarts a leak
- iDO = internal (local) Down Only
- iDO=0 means intra-AS (local) DO does not apply
- iDO=1 means intra-AS (local) DO applies

- R2 (AS4) MUST not send non-customer routes to lateral peer AS6 or transit AS7.

iDO here is similar to iOTC
Detection Rules

• Semantics: Route is a leak = RLP is violated
• A received route violates RLP
  ▪ if L is present in the received route*
  ▪ else (L is absent), the route is received from a customer and DO is present
  ▪ else (L is absent), the route is received from a lateral peer and DO is present that is not the lateral peer’s ASN

* Note: Here by "L is present" we mean that its value is not the default value (all zeros) but is a proper ASN. Effectively "L is absent" if its value is the default value.
* Note: In a correct implementation, L cannot be present without a DO.
Minimum Default Policy

• Whenever there is choice between multiple routes (customer/peer/provider), and each is detected to be in RLP violation, then lower the LocalPref to X (TBD) for each of them. Then apply shortest path criterion*.

* Some network operators may find this inadequate (see the analyzed scenarios)
* But they can locally modify their policy while respecting the basic principle
RFC 8092: BGP Large Communities Attribute

<table>
<thead>
<tr>
<th>Global Administrator (IANA assigned for RLP)</th>
<th>DO = Down Only indication</th>
</tr>
</thead>
<tbody>
<tr>
<td>Local Data Part 1 = DO (ASN value)</td>
<td>L = Leak indication</td>
</tr>
<tr>
<td>Local Data Part 2 = L (ASN value)</td>
<td></td>
</tr>
</tbody>
</table>

When L is not present, then the Local Data Part 2 is set to some default value such as all zeros (TBD).

For leak indication (L) value, it is better to inform which AS detected the leak rather than simply say that a leak was detected.
## Encoding Choice Z: Two Transitive Extended Communities

(Opaque: provides 48 bits for data)

<table>
<thead>
<tr>
<th>1st Community</th>
<th>2nd Community</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1</td>
<td>0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1</td>
</tr>
</tbody>
</table>

| Type high | Sub-type (DO) | \( DO = \text{ASN value} \) | | | \( DO = \text{ASN value (contd.)} \) | unused | | | DO = Down Only indication |
|-----------|--------------|-----------------|----------|-------------------------------|----------|-----------------|-----------------|-----------------|
| ++++++-----|--------------|-----------------|----------|-------------------------------|----------|-----------------|-----------------|-----------------|

| Type high | Sub-type (L) | \( L = \text{ASN value} \) | | | \( L = \text{ASN value (contd.)} \) | unused | | | L = Leak indication |
|-----------|--------------|-----------------|----------|-------------------------------|----------|-----------------|-----------------|-----------------|
| ++++++-----|--------------|-----------------|----------|-------------------------------|----------|-----------------|-----------------|-----------------|

If no leak was detected by RLP-aware ASes up to the current AS, then \( L \) (i.e., the 2\(^{nd}\) Community) is absent in the received update.

**RFC 4360**: BGP Extended Communities Attribute

**RFC 7153**: IANA Registries for BGP Extended Communities

IANA allocated Type high value for RLP

DO = Down Only indication

L = Leak indication
Request WG Inputs

Questions:

• Which type of Community (transitive) is best?
  ▪ Regular Community vs. Large Vs. Extended
• Which has the best chance to propagate farthest?
• How do they compare in terms of deployment speed?
Pseudo Code: Receiver/Sender Actions and Policy

<receiver action for leak detection>
<!– this precedes route selection policy -->
if received route includes L, then save the route in RIB-in as is;
else (L is absent), if route is received from a customer and DO is preset, then add L = local ASN;
else (L is absent), if route is received from a lateral peer and DO is present that is not the lateral peer’s ASN, then add L = local ASN
</receiver action for leak detection>

Comment: “Route does not include L” or “L is absent” if L is either literally absent or has the default (all zeros) value.

$route selection policy$
for each route that includes L, lower the LocalPref to X (TBD);
apply best path selection policy*;
</route selection policy>
* E.g., best path selection based on LocalPref first and then shortest path.

<sender action>
<!-- note: RLP (includes DO and L or just DO) is a *transitive* BGP Community -->
when propagating a route originated by local AS to a customer or lateral peer, add DO = local ASN;
when propagating a route that includes a DO (i.e., was received with a DO) to a customer or lateral peer, replace the DO value with the local ASN;
</sender action>
Thank you.
Comments / questions?
Backup slides
Solution for Route Leaks Using BGP Communities

Background: In Montreal face-to-face meeting of authors, John and Sue advised the team to explore a BGP Community based solution

➢ Motivation: Quicker deployment without dependence on vendor implementation changes

• Detection and mitigation semantics are defined
• Many scenarios are analyzed to examine if the semantics work
• Design choices for encoding using Large Community and Extended Community are presented
• Basic operator policy is described
• Sender and receive actions are specified
• Pseudo code is provided
• The idea is put down some details on paper and invite comments / discussion
Design C: Solution for Route Leaks Using BGP Communities

Background: In the Montreal face-to-face meeting of authors, John and Sue advised the team to explore a BGP Community based solution. They envision the possibility of faster adoption if there are no changes required in commercially shipped BGP code.

• This set of slides are based in part on conversations many of us had in Montreal (face-to-face and emails) and my one-to-one discussions with Alex. Doug and I reviewed the content in the slides several times at NIST.
• Attempt is made to narrow the design down to one set of semantics and one way of encoding using Community
• Many scenarios are analyzed to examine if the semantics work
• Design choices for encoding using Large Community and Extended Community are presented
• Basic policy is described
• Sender and receive actions are specified
• Pseudo code is provided
• The idea is put down some details on paper and invite comments / discussion
General Principles of Design C: Solution Using BGP Communities

• Considering **Community** based encoding of RLP info for **faster adoption**
• Wish to **limit the number of RLP** entries so that they can be accommodated in 1 or 2 Community attributes per update.
  
  Reason: Avoid having a long string of Community attributes per BGP update because the more they are, the lesser the chance that they will all make it through. If some get dropped, then the rest become useless. Also, save memory, simplify processing, and improve robustness.
• Based on the analysis and knowledge we have so far about RLP/eOTC, independent of encoding (Attribute or Community), at the minimum the RLP info must include:
  ⚫ ASN of the RLP-aware AS that **most recently** asserted that it sent update to a customer or lateral peer; let us call this **DO = Down Only indication**
  ⚫ Leak warning: **L = Leak indication**
    ⚫ **L = ASN of the first RLP-aware AS in the path that is forwarding route from customer or lateral peer in spite of detecting a leak**
      ▪ AS in question is avoiding unreachability (absence of alternative route)

Note: RLP = Route Leak Protection; DO alone or DO and L together constitute RLP
Limitations:
In the following circumstances, a leaked route may not be detected:
• A leak between two or more consecutive ASes that are not participating
• AS dropping a transitive BGP Community used for RLP
• Implementation errors (ideally there should be none)

Design assumptions:
• In the absence of an alternative route, an AS may forward a route that is detected to be a leak.
AS4 cannot tell if it is a customer or peer route from AS3
Hence, it is mandatory for iOTC/RLP-aware AS (AS3 here) to implement both inter-AS and intra-AS solutions. Then, AS3 will simply never forward any p2p or P2C routes (received at R1) to AS4.
Choices regarding Leak (L) indication

- DO must reflect the most recent AS in the path that sets DO – this is understood to be better based on previous analysis.

<table>
<thead>
<tr>
<th></th>
<th>Down Only (DO)</th>
<th>Leak (L)</th>
<th>Choice</th>
</tr>
</thead>
<tbody>
<tr>
<td>Choice 1</td>
<td>ASN value updated to show the most recent AS in the path that sets DO.</td>
<td>ASN of the first AS that set L (sticky)</td>
<td>✓</td>
</tr>
<tr>
<td>Choice 2</td>
<td>- same as above -</td>
<td>Replaceable</td>
<td>Benefit?</td>
</tr>
</tbody>
</table>

With Choice 1, there is the benefit that L provides information about how far back in the path the initial leak occurred. Thus, L complements DO. Also, Choice 1 has less processing cost.
Minimum Default Policy:

• Whenever there is choice between a customer route and a provider route, and both are detected to be in RLP violation, then lower the LocalPref to X (TBD) for each of them. Then shortest path criterion would typically make the customer route preferred*.

* This mitigates persistent oscillation possibility

○ Caveat 1: This has an unfortunate downside that in some cases this may result in choosing route from provider over customer even when the provider route is a detour of the customer route. This may be due to prepends by the customer (customer P0 in Scenario 8, slide 15). (Note: Applying the Route Leak Theorem can help avoid this. But we let go of that for simplicity of implementation.)

○ Caveat 2: Also, in some cases this would cause customer route to be preferred over the provider route even when evidently the customer route has two valley-free violations while the provider route has only one such violation. Both routes have L (leak indication) in them. See Scenario 3, slide 11.

○ We can possibly live with these caveats although we can avoid them if the Route Leak Detection Theorem (Slide 32) is put to use.
Generalized Minimum Default Policy

• Whenever there is choice between multiple routes (customer/peer/provider), and each is detected to be in RLP violation, then lower the LocalPref to X (TBD) for each of them. Then apply shortest path criterion*.

* Some network operators may find this inadequate (see the analyzed scenarios)
* But they can locally modify their policy while respecting the basic principle
Scenario analyses:
Does this scheme with RLP = [DO, L] along with the policy work?
More Scenarios:

Green – not violation
Red – violation

Scenario 4 😊

Legend:

n
AS does not participate in RLP and starts/restarts a leak

Preferred route: q {4 3 2 1}
Shortest path

Preferred route: q {4 3 2 1}
Shortest path

RLP = [DO, L]
More Scenarios:

**Green** – not violation
**Red** – violation

Legend:
- AS does not participate in RLP and starts/restarts a leak

Scenario 6 🎯

Seems worse if customer route is selected at AS 8 🎯
Preferred route = ?
Shortest path tie; use tie breaker

RLP = [DO, L]
Leak not detectable if consecutive ASes not participating

**Legend:**
- **Green** – not violation
- **Red** – violation

AS does not participate in RLP and starts/restarts a leak

Scenario 7 😊

AS4 selects the bad path. It cannot detect that the route from AS 3 is a leak.
Alexander’s scenario

Scenario 8 😊

Route 1: \( q \{P_0 X S\} \)

Route 2: \( q \{P_3 P_1 X S\} \)

- \( P_1 \)
- \( P_0 \)
- \( P_2 \)
- \( P_3 \)
- \( P_4 \)

Decision Policy (Algorithm):
- Route 1 clearly violated \([S]\).
- \([P_3]\) in Route 2 is expected (good).
- But LD = \([P_0]\) is in both routes.
- Hence, the provider route is not clean either.
- Given both routes are in violation of the RLP, P2 prefers the shorter customer route.
(There is a stable convergence.)
Encoding RLP in BGP Communities

Relevant RFCs:

**RFC 4360**: BGP Extended Communities Attribute
**RFC 7153**: IANA Registries for BGP Extended Communities
**RFC 8092**: BGP Large Communities Attribute
Three choices:

Choice X: One Transitive Large Community: Global Administrator, DO (ASN value), L (ASN value)

Choice Y: Two Transitive Large Communities:
  1\textsuperscript{st} one: Global Administrator, 16-bit Type (value assigned for DO), DO (ASN value)
  2\textsuperscript{nd} one: Global Administrator, 16-bit Type (value assigned for L), L (ASN value)

(Choice Y is similar to what John suggested)

Choice Z: Two Transitive Extended Communities (Opaque):
  1\textsuperscript{st} one: 0x03, 8-bit Sub-Type (value assigned for DO), DO (ASN value)
  2\textsuperscript{nd} one: 0x03, 8-bit Sub-Type (value assigned for L), L (ASN value)

DO = Down Only indication
L = Leak indication
Encoding Choice X: Single Transitive Large Community

<table>
<thead>
<tr>
<th>0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1</th>
<th>0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1</th>
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<tbody>
<tr>
<td>+-------------------------------------------</td>
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</tr>
<tr>
<td>+-------------------------------------------</td>
<td>---------------------------------------------</td>
</tr>
<tr>
<td></td>
<td>Local Data Part 2 = L (ASN value)</td>
</tr>
<tr>
<td>+-------------------------------------------</td>
<td>---------------------------------------------</td>
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</tbody>
</table>

When L is not present, then the Local Data Part 2 is set to some default value such as all zeros (TBD).

For leak indication (L) value, it is better to inform which AS detected the leak rather than simply say that a leak was detected.

RFC 8092: BGP Large Communities Attribute

DO = Down Only indication
L = Leak indication
Encoding Choice Y: Two Transitive Large Communities

(Choice Y is similar to what John suggested)

1st Community

<table>
<thead>
<tr>
<th>0 1 2 3</th>
<th>0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st Community</td>
<td>Global Administrator (IANA assigned for RLP)</td>
</tr>
<tr>
<td></td>
<td>Type code = IANA allocated value for DO</td>
</tr>
<tr>
<td></td>
<td>Local Data Part 2 = DO (ASN value)</td>
</tr>
</tbody>
</table>

2nd Community

<table>
<thead>
<tr>
<th>0 1 2 3</th>
<th>0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>2nd Community</td>
<td>Global Administrator (IANA assigned for RLP)</td>
</tr>
<tr>
<td></td>
<td>Type code = IANA allocated value for L</td>
</tr>
<tr>
<td></td>
<td>Local Data Part 2 = L (ASN value)</td>
</tr>
</tbody>
</table>

Global Admin. AS number is shared across RLP and other similar applications.

DO = Down Only indication

L = Leak indication

If no leak was detected by RLP-aware ASes up to the current AS, then L (i.e., the 2nd Community) is absent in the received update.
Encoding Choice Z: Two Transitive Extended Communities

(Opaque: provides 48 bits for data)

0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-
| Type high | Sub-type (DO) | DO = ASN value |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-
| DO = ASN value (contd.) | unused |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-

If no leak was detected by RLP-aware ASes up to the current AS, then L (i.e., the 2nd Community) is absent in the received update.
Choosing Between Encoding Choices X, Y, and Z

• In Choice X, both DO and X are accommodated in only one Community attribute. Hence, it is more economical than Choices Y and Z in terms of memory and possibly processing.
• Also, may be there is better chance that the single RLP Community attribute in Choice X survives farther (i.e., over greater number of hops) in the update propagation (as compared to two Community attributes in Choices Y and Z).
• Choices Y and Z have more bits to play with in case they’re necessary for richer semantics (though the need for that is not evident at this point).
Pseudo Code – operator preferences (if any)

<receiver action for leak detection>
<!– this precedes route selection policy -->
if received route includes L, then save the route in RIB-in as is;
else (L is absent), if route is received from a customer and DO is preset, then add L = local ASN;
else (L is absent), if route is received from a lateral peer and DO is present that is not the lateral peer’s ASN, then add L = local ASN
</receiver action for leak detection>

Comment: “Route does not include L” or “L is absent” if L is either literally absent or has the default (all zeros) value.

<route selection policy>
[insert code according to operator preferences here]*
</route selection policy>

* E.g., Examples: (1) Operator may prefer route from transit provider over customer if both have L present; (2) Operator may prefer route from customer over transit provider if both have L present, and the latter is a detour of the former (i.e., the customer AS is common to both paths).

<sender action>
<!– note: RLP (includes DO and L or just DO) is a *transitive* BGP Community -->
when propagating a route originated by local AS to a customer or lateral peer, add DO = local ASN;
when propagating a route that includes a DO (i.e., was received with a DO) to a customer or lateral peer, replace the DO value with the local ASN;
</sender action>