Robust Routing Policy Architecture

• Conceptual model of routing policy
• Routing policy terminology
• Routing policy design patterns
  • Maximum Prefix Limits
  • 2 Phase Pruning
  • Classification & Execution
  • Hints
Conceptual model & Terminology

• Attachment points
• Directionality

“One man’s ebgp-out is another man’s ebgp-in.”
– ancient Dutch proverb

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Example

```
routing bgp 15562

neighbor 192.147.168.1 route-map AS2914-in in
neighbor 192.147.168.1 route-map AS2914-out out

route-map AS2914-in deny 10
  match ip address prefix-list bogons-v4
route-map AS2914-in permit 10
  match community graceful-shutdown
  set local-preference 0

```
ebgp-in Filtering – what to accept?

• Phase 1: Pruning: If Bad and Raw Input are sets, then the relative complement of Bad in Raw Input, is the set of elements in Raw Input but not in Bad: Raw Input \ Bad

• Phase 2: Allowlist ∩ Raw Input
Raw Input in context of **ebgp-in**

- **Raw Input** is whatever your EBGP neighbor announces to you
- **Raw Input** can contain anything, in any quantity
- In IETF speak: “**Adj-RIB-In**”
- This is where maximum-prefix limits must be applied!

**Study resource:**
Maximum prefix limits in **ebgp-in**

- These limits are a design feature to ensure the network inherently responds in a way that will cause no or minimal harm to the network or the global Internet.

**Study resource:**
- Fail-safe in engineering: [https://en.wikipedia.org/wiki/Fail-safe](https://en.wikipedia.org/wiki/Fail-safe)
What happens when limits are applied in pre-policy during a full table leak:

Session Teardown

We’re both safe now

invalid

valid

Time

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What happens when limits are applied post-policy

- Full table leak
- Maximum Prefix value
- Invalid paths that made it through the whitelist
- Normal announcements
- Filtered announcements
Pre vs Post policy prefix limits in **ebgp-in**

**Pre policy limits:**

- Protect against memory exhaustion
  - Keep in mind: a pre-policy limit only works if the router remembers the list of rejected routes
- Protect against route leaks

**Post policy limits:**

- Protect against RIB+FIB exhaustion
- To enforce contractual agreements
## Maximum prefix limits in context of `ebgp-in`

<table>
<thead>
<tr>
<th>Vendor</th>
<th>Pre-Policy (the most effective place)</th>
<th>Post-Policy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cisco IOS XR</td>
<td>Not available</td>
<td>“maximum-prefix”</td>
</tr>
<tr>
<td>Cisco IOS XE</td>
<td>Not available</td>
<td>“maximum-prefix”</td>
</tr>
<tr>
<td>Juniper Junos</td>
<td>“prefix-limit”</td>
<td>“accepted-prefix-limit” or “prefix-limit” + “keep none”</td>
</tr>
<tr>
<td>Nokia SR-OS</td>
<td>“prefix-limit”</td>
<td>Not available</td>
</tr>
<tr>
<td>NIC.CZ’s BIRD</td>
<td>“import keep filtered” + “receive limit”</td>
<td>“import limit” or “receive limit”</td>
</tr>
<tr>
<td>OpenBSD’s OpenBGPD</td>
<td>“max-prefix”</td>
<td>Not available</td>
</tr>
</tbody>
</table>
Outbound maximum limits?

This was raised before on nanog@nanog.org – we should work to get outbound maximum prefix limits to use in ebgp-out.

A “self-destruct the session” control action, in case you end up announcing far more than plausible.

Only BIRD supports this today. We’ll need to standardize this in IETF.
Rejecting Bad – defense in depth in **ebgp-in**

- Bogon or Private ASNs
- Bogon or Private Prefixes
- Leaks (example: NTT seeing Comcast via Level3)
- IXP more-specifics
- RPKI Invalid announcements
- Your own space and more-specifics

**Study resource:**
NLNOG BGP Filter Guide
[http://bgpfilterguide.nlnog.net/](http://bgpfilterguide.nlnog.net/)
Creating a whitelist for **ebgp-in**

**Study resource:**
ARIN-WHOIS:
https://www.youtube.com/watch?v=L2Zo9AqQqww

Overview of IRR and RPKI Sources:
https://ripe76.ripe.net/archives/video/22/
Now what...?
“When in doubt, always use BGP communities.”
- traditional Belgian saying
What is a BGP community?

“A community is a group of destinations which share some common property.”

- RFC 1997

Study resource:
How to use BGP communities?

- **Classification** on the **ebgp-in** attachment point
  - “set community XXX additive”
- **Execution** on the **ibgp-in** and **ebgp-out** attachment point
  - “match community YYY”

### Common Classifiers
- “learned from transit customer”
- “route via peering partner”
- “learned from upstream provider”
- “route learned in Europe”
- “route learned in Denver, CO”

### Common Execution Outcomes
- Announce to this EBGP neighbor
- Do not announce
- Prepend AS_PATH once

Study resource:
Day in the life of a BGP announcement

1. AS 15562 announces 192.147.168.0/24 to AS 2914

2. The routing policy at the **ebgp-in** attachment point in 2914 doesn’t reject the announcement: it was not a bogon, and part of the whitelist

3. Still inside **ebgp-in**, AS 2914’s policy classifies the route as “from customer” and “learned in Europe” using BGP communities

4. Still inside **ebgp-in**, features such as LOCAL_PREF modification, blackholing are executed

5. The route announcement propagates to other 2914 routers

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6. Announcement passes through **ibgp-in**, this is an attachment point that offers opportunity for advanced features such as selective blackholing, traffic engineering for anycasters, etc.

7. Announcement enters **ebgp-out**, at this attachment point the classifiers decide whether the route will be announced, and final features are applied such as prepends
### Example Classifier / Execution matrix

<table>
<thead>
<tr>
<th>Classifier (attached in ebgp-in)</th>
<th>ebgp-out to customer</th>
<th>ebgp-out to peer</th>
<th>ebgp-out to upstream</th>
</tr>
</thead>
<tbody>
<tr>
<td>Learned from customer</td>
<td>accept</td>
<td>accept</td>
<td>accept</td>
</tr>
<tr>
<td>Learned from peer</td>
<td>accept</td>
<td>reject</td>
<td>reject</td>
</tr>
<tr>
<td>Learned from upstream</td>
<td>accept</td>
<td>reject</td>
<td>reject</td>
</tr>
<tr>
<td>NO CLASSIFIER</td>
<td>reject</td>
<td>reject</td>
<td>reject</td>
</tr>
</tbody>
</table>

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Without a classifier, reject at ebgp-out?!

• "Reject routes without communities in ebgp-out" coincidentally is an incredible safety device, consider:
  • What if you connect a BGP speaker to your network and don’t configure policies?
  • What if you accidentally remove the routing policy at the ebgp-in attachment point on a session with one of your upstreams?
• If the route does not contain BGP communities that provide explicit guidance on what to do – the route should not be propagated
• The worst way of configuring ebgp-out policies is doing only a match on a prefix-list and calling it a day.
• Bonus: as your network grows, using BGP communities is the least amount of work!
Without a classifier, reject at **ebgp-out**?!

- "*Reject routes without communities in *ebgp-out"* is an incredible safety device.

- We call this "Robust Termination of the routing policy"

- By applying the *Fail Closed* principle we prioritize security. The network "outage" that results from a failure to correctly set BGP communities on the route is just a delay in the provisioning process. This is far less costly than leaking.
Avoid regular expressions where possible.

- Trying to be clever can result in public embarrassment
- your coworkers will thank you if `grep` just works

Curse or policy? `^\( 6\( 451\[2–9]\|4\[6–9]\.)\.|5\.)\(_\( 6\( 451\[2–9]\|4\[6–9]\.)\.|5\.)\)*\)\._\.*\)`

“Always code as if the guy who ends up maintaining your routing policy will be a violent psychopath who knows where you live. Write routing policy for readability.”

- Adaption of John F. Wood’s motto, 1991
Write separate policies and prefix-lists for IPv4 and IPv6

• What is the meaning of an IPv4 prefix-list match on an IPv6 route? Undefined?
• Don’t run IPv4 over IPv6 or vice versa on EBGP: each AFI their own session

Some things simply don’t mix very well... 😊
How many policies to generate?

- One separate policy per ASN per `ebgp-in` attachment point
  - You need per-ASN unique prefix-list filters
- Policies for `ebgp-out` often can be shared across customers
- Peering/Upstreams may share an `ebgp-out`, if you can do conditional matching inside the policy for per-peer specific outbound traffic engineering (otherwise generate `ebgp-out` per-peer)
- `ibgp-out` is often the same across the whole network
- `ibgp-in` is often generated per-device (for selective blackholing & friends)
Overview: so, how many policies are we talking?

<table>
<thead>
<tr>
<th>Attachment point</th>
<th>When / where to create</th>
<th>Count</th>
<th>Order of magnitude in NTT</th>
</tr>
</thead>
<tbody>
<tr>
<td>ebgp-in</td>
<td>Per EBGP neighbor, per device, per AFI</td>
<td>( N ) EBGP neighbors * 2</td>
<td>Tens of thousands</td>
</tr>
<tr>
<td>ebgp-out</td>
<td>Per group (customers, peers, etc), per AFI</td>
<td>( N ) groups * 2</td>
<td>High hundreds</td>
</tr>
<tr>
<td>ibgp-in</td>
<td>Per device, per AFI</td>
<td>( N ) devices * 2</td>
<td>Low hundreds</td>
</tr>
<tr>
<td>ibgp-out</td>
<td>Network wide, one per AFI</td>
<td>2</td>
<td>1*</td>
</tr>
</tbody>
</table>

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Avoid “\textbf{set community X}” to delete communities

- Some BGP implementations \textbf{delete all} communities and add X
- Some BGP implementations \textbf{delete some} communities and add X
- Some BGP implementations add X, and \textbf{don’t delete anything}
- Instead: use “\textbf{delete community Y}, “\textbf{set community X additive}”
  - Be precise and concise, delete as little as possible.

NTT went from tens of thousands of instances of “\textbf{set community}” to just a few hundred after implementing support for \texttt{GRACEFUL\_SHUTDOWN}.

\textbf{Study resource:}
Well-known Communities behavior: \url{https://tools.ietf.org/html/draft-ymbk-grow-wkc-behavior}
What to communities to delete?

• Network administrators SHOULD scrub inbound communities with their number in the high-order bits, and allow only those communities that customers/peers can use as a signaling mechanism.

• Networks administrators SHOULD NOT remove other communities applied on received routes.

• This may be the one place where regular expressions are acceptable.

Study resources:
What to communities to send?

• Send at least your geolocation BGP communities to EBGP
• Just like we ask people to be considerate in what they delete, we now ask to be conservative on how many communities you send to others.
• Rule of thumb: don’t send more than 4 BGP communities per route
• Publicly document what your communities mean, on your own website
RFC 8212 – Default Deny on EBGP

What happens when no routing policy is defined at the EBGP attachment points? There now is a RFC that defines what should happen: safety first, don’t exchange routes!

- Cisco IOS XR, BIRD 2.0.2, and OpenBGPD 6.4 support RFC 8212 natively 🎉
- On Arista this can be enabled under “router bgp ...”:
  - bgp missing-policy direction in action deny
  - bgp missing-policy direction out action deny
- On Juniper Junos this can be done with a SLAX script (no native support yet): [https://github.com/packetsource/rfc8212-junos](https://github.com/packetsource/rfc8212-junos)
- On Nokia support is coming in 2019-2020.
- Ask your vendors!
Questions, Comments – job@ntt.net