BGP Operations and Security

Best Common Practices (RFC7454 + more)

Next-Hop-Self

- When connecting to another provider or at an Internet Exchange use next-hop-self
  - so that the next hop to the routes they announce is reachable from your AS

Protecting BGP sessions

- MD5 authentication (RFC2385)
  - To protect the BGP TCP session between peers
    - generates a keyed hash (16-byte) - using the TCP segment and the password

```
router bgp 17821
 neighbor 30.30.30.1 password <key-value>
```

    - But susceptible to collision attacks

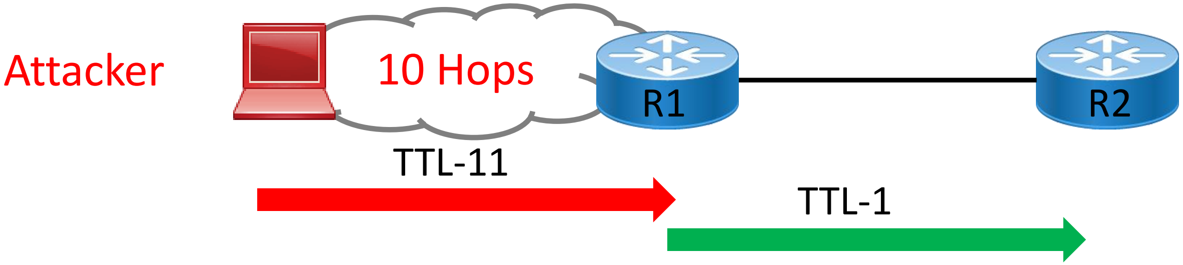
- TCP Authentication Option (RFC5925)
  - Obsoletes RFC2385, but *no known implementations*… please correct ??
    - Key chains (allows moving from one key to another for the same connection), and
    - Support for stronger hash functions

Protecting BGP sessions

- Some organisations dislike MD5, so be flexible
- Do you have any plans to change the key?

Protecting BGP sessions

- GTSM – BGP TTL Security (RFC5082)
  - eBGP has a default TTL of 1
    - Which requires eBGP peers to be directly connected
    - To use any interface other than the directly connected, we generally use `ebgp-mulithop`
  - A remote attacker could send spoofed packets with adjusted TTL values to make it seem like its directly connected

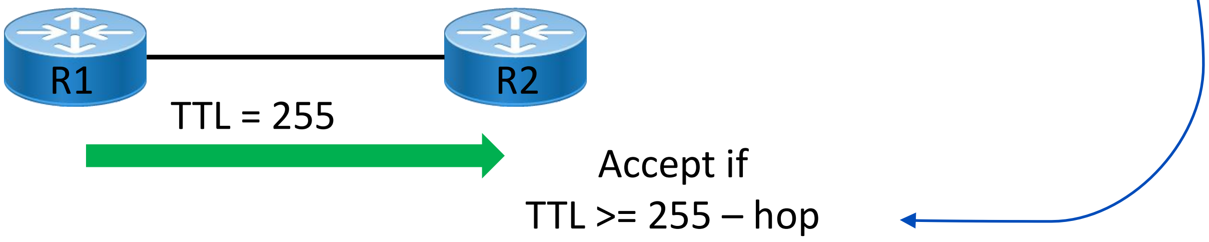


- This way, R2 could be DoSed (will accept the initial TCP SYN) or TCP resets

Protecting BGP sessions

- With GTSM, the TTL between directly connected eBGP peers set to the maximum – 255
  - Only incoming packets with a TTL value equal to or greater than the locally configured value is accepted,
  - Else packet is silently discarded and no ICMP messages generated

```
router bgp 17821
 neighbor <peer-v4/v6 addr> ttl-security hops <1-254>
```

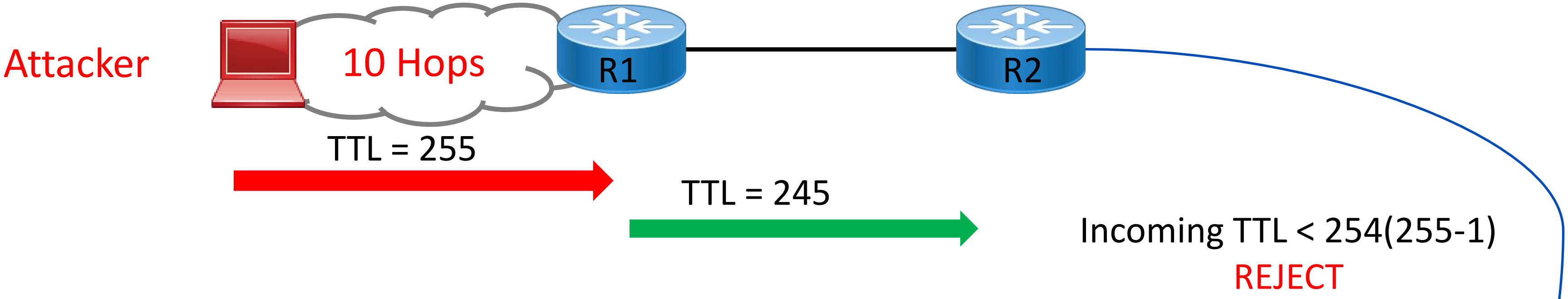


- Needs to be same on both peers!

Protecting BGP sessions

- GTSM – BGP TTL Security (RFC5082)
  - Ex: If R2’s config was

```
router bgp 17821
 neighbor X.X.X.1 ttl-security hops 1
```



```
R2#sh ip bgp neighbors X.X.X.1 | i hop | TTL
  External BGP neighbor may be up to 1 hop away.
Connection is ECN Disabled, Mininum incoming TTL 254, Outgoing TTL 255
```

Prefix Filters - Outbound

- To Customers speaking BGP
  - Probably only a *default route*, or
  - WHOLE Internet feed except default and bogons (special use addresses – rfc6890, rfc1918, unassigned blocks)

- To Peers (other ISPs with whom you peer)
  - Send *your prefixes* + *your downstream customer*, or
  - what you agreed to send

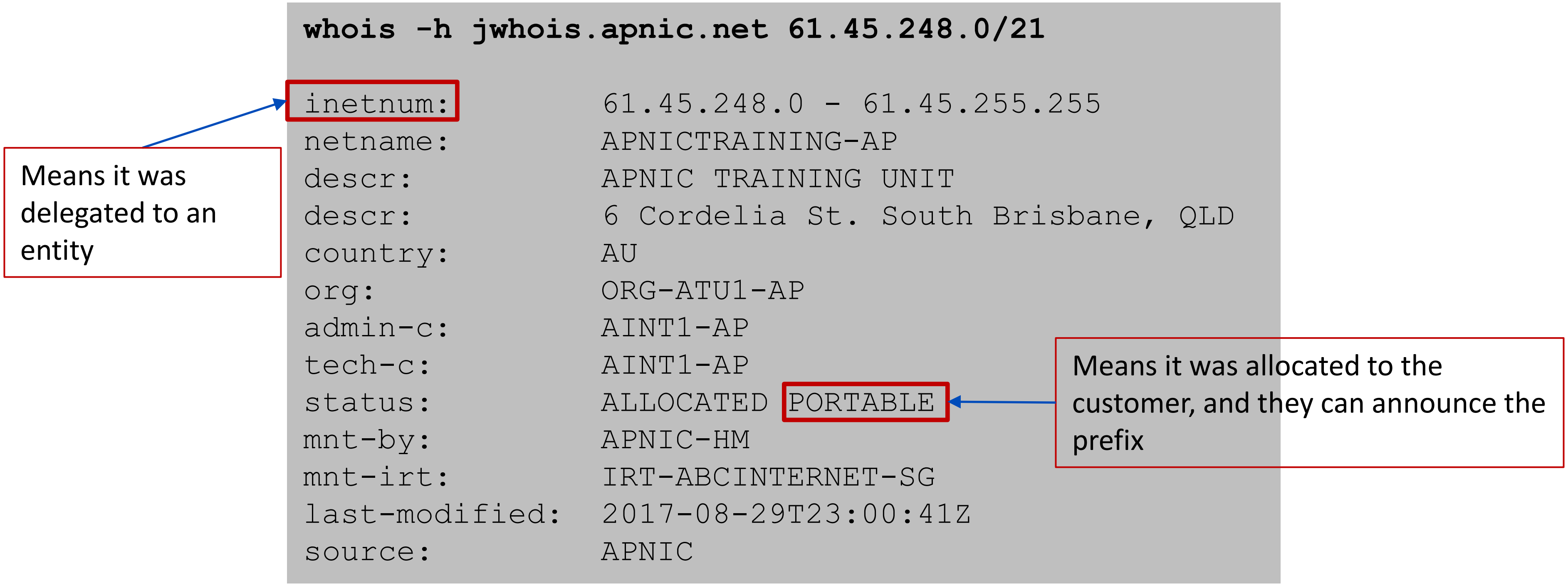
- To Upstream/Transit provider
  - Send *your prefixes* + *your downstream customers*

Prefix filters - Inbound

- Customers speaking BGP
  - only accept prefixes registered to them, or prefixes registered to their customers
  - If assigned out of your block, you already know
- They may claim to have their own prefix allocated to them from a regional registry (Ex- APNIC)
  - You should check that it is theirs to announce
- Encourage them to aggregate their prefix where possible

Prefix Filters - Inbound

- Customers speaking BGP
  - Only accept their prefixes (their customers)
    - Verify that the prefixes were Assigned or Allocated, and
    - Make sure the prefix length does not exceed /24 (IPv4) and /48 (IPv6) – unless negotiated for TE reason



```
whois -h jwhois.apnic.net 61.45.248.0/21

inetnum:        61.45.248.0 - 61.45.255.255
netname:        APNICTRAINING-AP
descr:          APNIC TRAINING UNIT
descr:          6 Cordelia St. South Brisbane, QLD
country:        AU
org:            ORG-ATU1-AP
admin-c:        AINT1-AP
tech-c:         AINT1-AP
status:         ALLOCATED PORTABLE
mnt-by:         APNIC-HM
mnt-irt:        IRT-ABCINTERNET-SG
last-modified:  2017-08-29T23:00:41Z
source:         APNIC
```

Means it was delegated to an entity

Means it was allocated to the customer, and they can announce the prefix

Prefix Filters - Inbound

- Customers speaking BGP
  - Ex: for a customer with the block 61.45.248.0/21 block

```
router bgp 17821
 address-family ipv4
  neighbor X.X.X.1 prefix-list CUST-PREFIX in
!
ip prefix-list CUST-PREFIX permit 61.45.248.0/21 le 24
ip prefix-list CUST-PREFIX deny 0.0.0.0/0 le 32
!
```

Prefix Filters - Inbound

- From Peers: Other ISPs/operators with whom you have agreed to exchange routes
  - Only accept their prefixes and their downstream customers (or what was agreed)
    - Verify they have the authority to route those prefixes (and their customers)
  - Typically prefix length should not exceed /24 (IPv4) and /48 (IPv6)
  - Can use RPSL tools like **bgpq3** - https://github.com/snar/bgpq3

```
bgpq3 -6Al PEERv6-IN AS17660
no ipv6 prefix-list PEERv6-IN
ipv6 prefix-list PEERv6-IN permit 2405:d000::/32
ipv6 prefix-list PEERv6-IN permit 2405:d000:7000::/36
```

Prefix Filters - Inbound

- From Peers
  - Ex: if a peer has `2001:dc0::/32` and `203.119.96.0/20` prefixes

```
router bgp 17821
 address-family ipv4
  neighbor X.X.X.1 prefix-list PEERv4-IN in
 address-family ipv6
  neighbor X:X:X::1 prefix-list PEERv6-IN in
!
ip prefix-list PEERv4-IN permit 203.119.96.0/20 le 24
ip prefix-list PEERv4-IN deny 0.0.0.0/0 le 32
!
ipv6 prefix-list PEERv6-IN permit 2001:dc0::/32 le 48
ipv6 prefix-list PEERv6-IN deny ::/0 le 128
!
```

Prefix Filters - Inbound

- From Upstream (Transit Provider)
  - Could just be a default route

```
router bgp 17821
 address-family ipv4
  neighbor X.X.X.1 prefix-list DEF-IN in
 address-family ipv6
  neighbor X:X:X::1 prefix-list DEFv6-IN in
!
ip prefix-list DEF-IN permit 0.0.0.0/0
!
ipv6 prefix-list DEFv6-IN permit ::/0
```

Prefix Filters - Inbound

- From Upstream (Transit Provider)
  - the WHOLE Internet feed

  - Do not accept your own prefixes
  - Do not accept bogons
    - special use addresses – rfc6890, rfc1918, and unassigned blocks
  - Do not accept prefix lengths longer than /24 (IPv4) and /48 (IPv6)

Prefix Filters - Inbound

- From Upstream (Transit Provider) – IPv4

```
router bgp 17821
 address-family ipv4
  neighbor X.X.X.1 prefix-list TRANSITv4-IN in
!
ip prefix-list TRANSITv4-IN deny 0.0.0.0/0              ! Default
ip prefix-list TRANSITv4-IN deny 0.0.0.0/8 le 32        ! Network Zero
ip prefix-list TRANSITv4-IN deny 10.0.0.0/8 le 32       ! RFC1918
ip prefix-list TRANSITv4-IN deny 100.64.0.0/10 le 32    ! RFC6598 shared address
ip prefix-list TRANSITv4-IN deny <your prefix>/X le 32  ! Your address space
ip prefix-list TRANSITv4-IN deny 127.0.0.0/8 le 32      ! Loopback
ip prefix-list TRANSITv4-IN deny 169.254.0.0/16 le 32   ! APIPA
ip prefix-list TRANSITv4-IN deny 172.16.0.0/12 le 32    ! RFC1918
ip prefix-list TRANSITv4-IN deny 192.0.0.0/24 le 32     ! IETF Protocol
ip prefix-list TRANSITv4-IN deny 192.0.2.0/24 le 32     ! TEST1
ip prefix-list TRANSITv4-IN deny 192.168.0.0/16 le 32   ! RFC1918
ip prefix-list TRANSITv4-IN deny 198.18.0.0/15 le 32    ! Benchmarking
ip prefix-list TRANSITv4-IN deny 198.51.100.0/24 le 32  ! TEST2
ip prefix-list TRANSITv4-IN deny 203.0.113.0/24 le 32   ! TEST3
ip prefix-list TRANSITv4-IN deny 224.0.0.0/4 le 32      ! Multicast
ip prefix-list TRANSITv4-IN deny 240.0.0.0/4 le 32      ! Future Use
ip prefix-list TRANSITv4-IN deny 0.0.0.0/0 ge 25        ! Prefixes longer than /24
ip prefix-list TRANSITv4-IN permit 0.0.0.0/0 le 32
```

Prefix Filters - Inbound

- From Upstream (Transit Provider) – IPv6

```
router bgp 17821
 address-family ipv6
  neighbor X:X:X::1 prefix-list TRANSITv6-IN in
!
ipv6 prefix-list TRANSITv6-IN deny 2001::/32 le 128         ! Teredo subnets
ipv6 prefix-list TRANSITv6-IN deny 2001:db8::/32 le 128     ! Documentation
ipv6 prefix-list TRANSITv6-IN deny 2002::/16 le 128         ! 6to4 subnets
ipv6 prefix-list TRANSITv6-IN deny <your::/32> le 128       ! Your prefix
ipv6 prefix-list TRANSITv6-IN deny 3ffe::/16 le 128         ! Old 6bone
ipv6 prefix-list TRANSITv6-IN deny fc00::/7 le 128          ! ULA
ipv6 prefix-list TRANSITv6-IN deny fe00::/9 le 128          ! Reserved IETF
ipv6 prefix-list TRANSITv6-IN deny fe80::/10 le 128         ! Link-local
ipv6 prefix-list TRANSITv6-IN deny fec0::/10 le 128         ! Reserved IETF
ipv6 prefix-list TRANSITv6-IN deny ff00::/8 le 128          ! Multicast
ipv6 prefix-list TRANSITv6-IN permit 2000::/3 le 48         ! Global Unicast
ipv6 prefix-list TRANSITv6-IN deny ::/0 le 128
```

Bogons

- Not all IP (v4 and v6) are allocated by IANA

- Addresses that should not be seen on the Internet are called "Bogons" (also called "Martians")
  - RFC6890+RFC1918s + Reserved space

- IANA publishes list of number resources that have been allocated/assigned to RIRs/end-users
  - https://www.iana.org/assignments/ipv6-unicast-address-assignments/ipv6-unicast-address-assignments.xhtml
  - https://www.iana.org/assignments/ipv4-address-space/ipv4-address-space.xhtml

Bogons

- Commonly found as source addresses of DDoS packets

- We should have ingress and egress filters for bogon routes
  - Should not route them nor accept them from peers

- We could manually craft prefix filters based on the bogon list from IANA
  - But bogon list is dynamic
  - New allocations made out of reserved blocks frequently

Bogon Route Server Project

- In comes the Bogon Route Server project by Team Cymru
    - Provides dynamic bogons information using eBGP multihop sessions
  - Traditional bogons (AS65333)
    - martians plus prefixes not allocated by IANA
  - Full-bogons (AS65332)
    - above plus prefixes allocated to RIRs but not yet assigned to ISPs/end-users by RIRs
- For details:
  - http://www.team-cymru.org/bogon-reference-bgp.html

Peering- Bogon Route Servers

- To peer with bogon route servers
  - Write to bogonrs@cymru.com

- You should provide:
  - Your ASN
  - Which bogons you wish to receive
  - Your peering addresses
  - MD5 for BGP?
  - PGP public key (optional)

- It is recommended to have at least 2 (two) peering sessions for redundancy

Maximum Prefix Limit

- It is RECOMMENDED to set the maximum number of prefixes accepted from a peer
  - Prevent memory exhaustion,
  - Prevent impacts of route leaks (where more specifics of big covering prefix gets leaked)

```
router bgp 17821
 address-family ip[v4|v6]
  neighbor <peer-addr|group> maximum-prefix <max-value> [threshold][restart N] [warning-only]
```

- **max-value**: the max prefix limit
- **threshold**: threshold in % of max limit (by default 75%) to generate warning msg
- **restart**: restart BGP connection after N minutes
- **warning-only**: generate a warning msg when limit is exceeded instead of terminating the BGP session

Maximum Prefix Limit

- Setting the max-prefix limit:
  - Allow future growth
    - Ex: If a peer has a /12 block, allowing upto /24s
    - The number of /24s = 4096 ~ max limit
  - IXPs generally publish the max IPv4/v6 prefixes announced by their route servers (RS)
    - Set your max limit accordingly
    - Ex: @HKIX - max prefix limit ~ [(monthly 2-hr avg)/0.7]
  - Examples:

```
neighbor X.X.X.1 maximum-prefix 1000
```

- Drop the peering if more than 1000 prefixes received

```
neighbor X.X.X.1 maximum-prefix 1000 warning-only
```

- Log a warning when it receives more than 1000 prefixes

```
neighbor X.X.X.1 maximum-prefix 1000 90
```

- Logs a warning at 900 prefixes, and drops if more than 1000 received

AS_PATH Filtering

- Do NOT accept/announce prefixes with private ASNs
  - Unless you have customers using private ASNs, or
  - Special arrangements like Cymru Bogon RS

```
router bgp 17821
 address-family ip[v4|v6]
  neighbor <peer-addr|group> remove-private-as [all [replace-as]
```

- Enforce the first ASN in the AS_PATH attribute to be the peer’s ASN
  - except if peering with a RS @IXPs

```
router bgp 17821
 bgp enforce-first-as !by default in IOS
```

AS_PATH Filtering

- Limit the AS-PATH length
  - Unusually long AS-PATHs would cause
    - Memory exhaustion, or
    - Issues like below which caused massive global routing updates (~107K per second) for an hour:
    - https://dyn.com/blog/the-flap-heard-around-the-world/
    - https://dyn.com/blog/longer-is-not-better/

```
bgp-prepend (integer:0-16)
>> bgp-prepend 47868 ~ 47868 mod 256 ~ 252
```

  - Some weird announcements:

```
N*>  45.162.216.0/24  4608 24130 7545 6939 263311 268528 268528 268528 268528 268528 268528
268528 268528 268528 268528 268528 268528 268528 268528 268528 i

N*>  45.162.217.0/24  4608 24130 7545 6939 263311 268528 268528 268528 268528 268528 268528
268528 268528 268528 268528 268528 268528 268528 268528 268528
```

```
0x7F48C876B370  4608 24130 7545 6939 28186 264437 264437 264437 264437 264437 264437 264437
264437 264437 264437 264437 264437 264437 264437 264437 264437 264437 264437 264952 i
```

AS_PATH Filtering

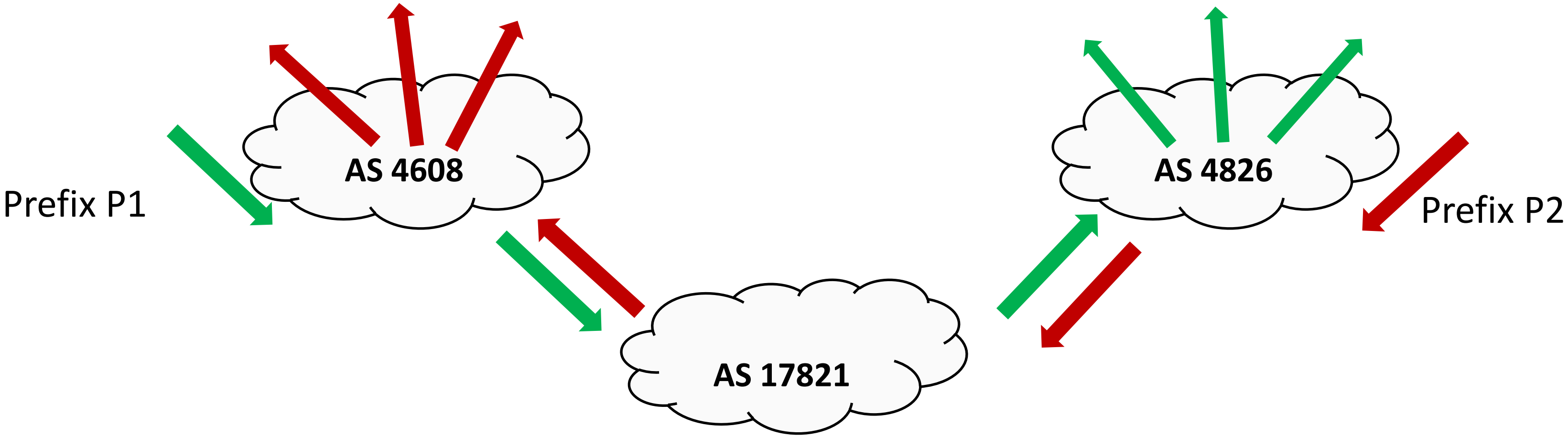
- Limit the AS-PATH length
  - The internet would be around 5-10 ASes deep on average
  - Longest AS-PATHs could be ~ 30 ASNs
  - Consider limiting the AS-PATH length for prefixes you accept

```
router bgp 17821
 bgp maxas-limit <1-254>
```

RFC 8212 – BGP default reject

- On many platforms, BGP is implicitly permissive!
  - AS-to-AS leaks common during maintenance

```
router bgp 17821
 !
 neighbor X.X.X.1 remote-as 4608
 neighbor X.X.X.1 description eBGP with Upstream-1
 !
 neighbor A.A.A.1 remote-as 4826
 neighbor A.A.A.1 description eBGP with Upstream-2
```



RFC 8212 – BGP default reject

- **RFC8212**- eBGP route propagation without policies
  - Neither accept nor announce routes from/to eBGP peers without explicit policy (import/export) configurations
    - implicit deny-all associated with eBGP sessions!
  - Changes to RFC4271:
    - Decision Process: *Routes contained in an Adj-RIB-In associated with an EBGP peer SHALL NOT be considered eligible in the Decision Process if no explicit Import Policy has been applied*.
    - Route Dissemination: *Routes SHALL NOT be added to an Adj-RIB-Out associated with an EBGP peer if no explicit Export Policy has been applied.*

RFC 8212 – BGP default reject

- But very few known implementations:
  - IOS-XR (all versions)
  - BIRD (2.0.1 and higher)
  - OpenBGPD (6.4 and higher)
  - Nokia SR OS (19.5.R1 and above)
    - https://github.com/bgp/RFC8212

- For those OSes that don't support RFC8212 yet
  - Shut the BGP session with the peer (group) during configuration
  - Define and apply explicit export and import policies to the eBGP peer(s)
  - Then no shut the BGP session
  - Talk to your vendors and force them to support RFC8212!

Traffic Filters

- **BCP38** (RFC2827)
  - Since 1998!
  - https://tools.ietf.org/html/bcp38

- Only allow traffic with valid source addresses to
  - Leave your network
    - Only packets with source address from your own address space
  - To enter/transit your network
    - Only source addresses from downstream customer address space

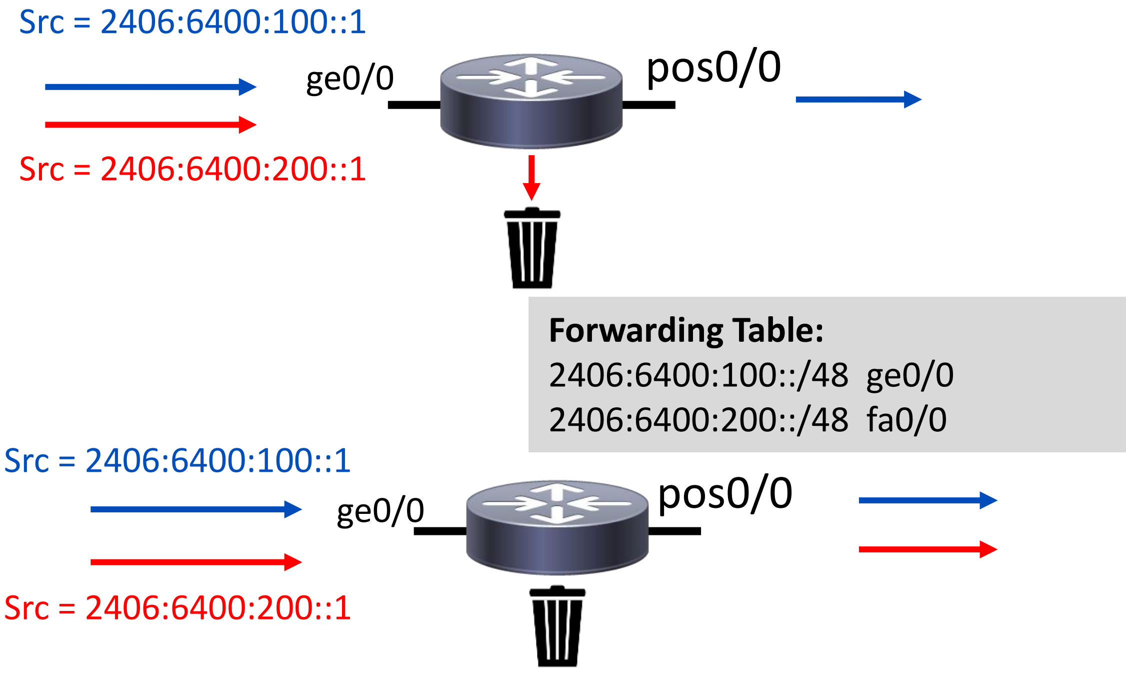
uRPF – Unicast Reverse Path

- Unicast Reverse Path Forwarding (uRPF)
  - Router verifies if the source address of incoming packets is in the Forwarding table and also checks the incoming interface
    - Drop if not!
  - ***Recommended on customer facing interfaces***

```
(config-if)#ipv6 verify unicast source reachable-via {rx | any}
```

uRPF – Unicast Reverse Path

- Modes of Operation (IOS):
  - Strict: verifies both source address and incoming interface with entries in the forwarding table
  - Loose: verifies existence of route to source address



Src = 2406:6400:100::1

ge0/0

pos0/0

Src = 2406:6400:200::1

Forwarding Table:
2406:6400:100::/48 ge0/0
2406:6400:200::/48 fa0/0

Src = 2406:6400:100::1

ge0/0

pos0/0

Src = 2406:6400:200::1

Image source: "Cisco ISP Essentials", Barry Greene & Philip Smith 2002

MANRS

- Mutually Agreed Norms of Routing Security
  - An ISOC led initiative to implement industry best practices to ensure security of routing system
  - https://www.manrs.org/
    - Inbound/outbound filtering – prefix/as-path
    - Source address validation – BCP38
    - Coordination – correct & up to date contacts
    - Validation – ROAs/IRR objects

Acknowledgement:

- Philip Smith
- Cisco Systems

Questions