BGP Scaling Techniques

ISP Workshops

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Acknowledgements

- This material originated from the Cisco ISP/IXP Workshop Programme developed by Philip Smith & Barry Greene
- Use of these materials is encouraged as long as the source is fully acknowledged and this notice remains in place
- Bug fixes and improvements are welcomed
  - Please email *workshop (at) bgp4all.com*

Philip Smith

BGP Scaling Techniques

- Original BGP specification and implementation was fine for the Internet of the early 1990s
  - But didn’t scale
- Issues as the Internet grew included:
  - Scaling the iBGP mesh beyond a few peers?
  - Implement new policy without causing flaps and route churning?
  - Keep the network stable, scalable, as well as simple?

BGP Scaling Techniques

- Current Best Practice Scaling Techniques
  - Route Refresh
  - Cisco’s Peer-groups
  - Route Reflectors (and Confederations)
- Deprecated Scaling Techniques
  - Soft Reconfiguration
  - Route Flap Damping

Dynamic Reconfiguration

Non-destructive policy changes

Route Refresh

- BGP peer reset required after every policy change
  - Because the router does not store prefixes which are rejected by policy
- Hard BGP peer reset:
  - Tears down BGP peering & consumes CPU
  - Severely disrupts connectivity for all networks
- Soft BGP peer reset (or Route Refresh):
  - BGP peering remains active
  - Impacts only those prefixes affected by policy change

Route Refresh Capability

- Facilitates non-disruptive policy changes
- No configuration is needed
  - Automatically negotiated at peer establishment
- No additional memory is used
- Requires peering routers to support “route refresh capability” – RFC2918
- Tell peer to resend full BGP announcement

```
clear ip bgp x.x.x.x [soft] in
```

- Resend full BGP announcement to peer

```
clear ip bgp x.x.x.x [soft] out
```

Dynamic Reconfiguration

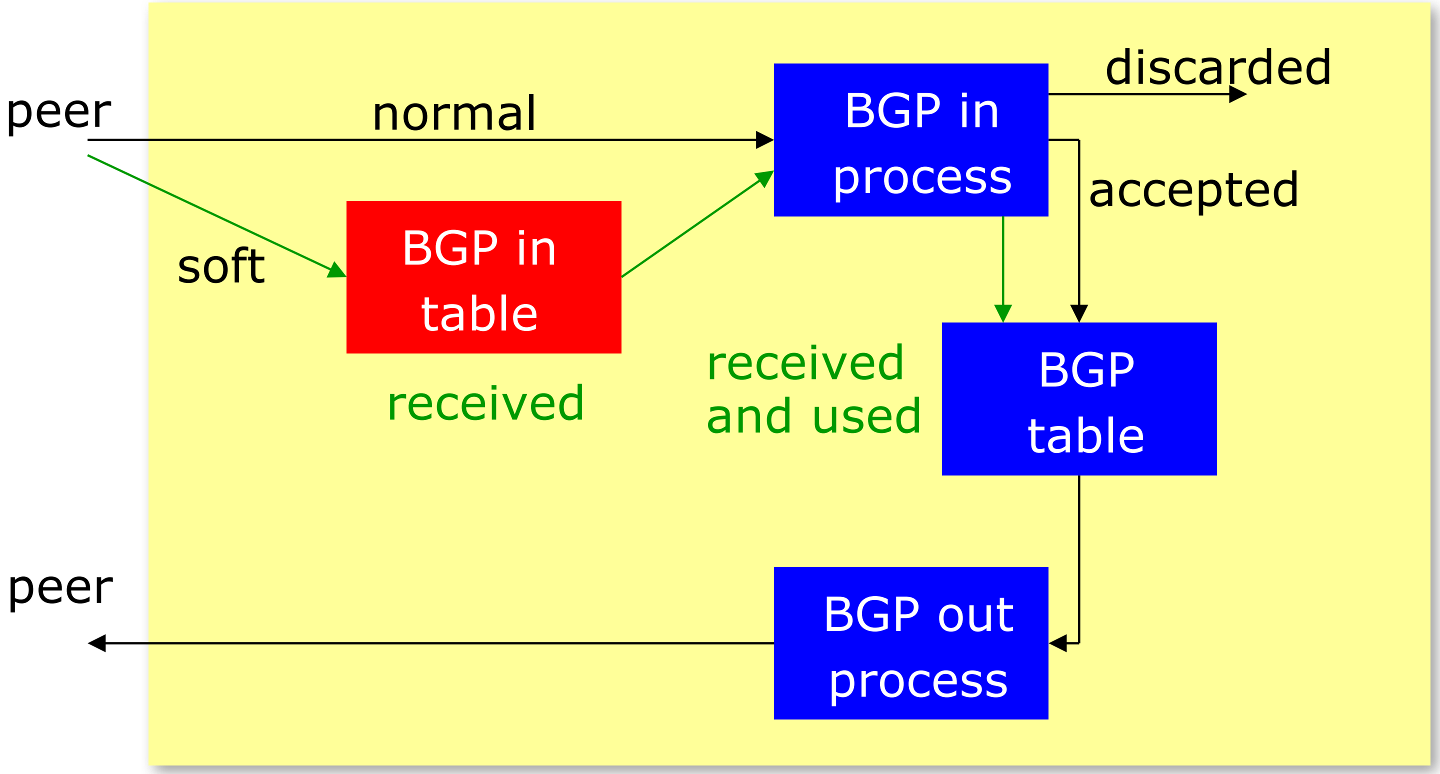
- Use Route Refresh capability
  - Supported on virtually all routers
  - Find out from “show ip bgp neighbor”
  - Non-disruptive, “Good For the Internet”
- Only hard-reset a BGP peering as a last resort

Consider the impact to be equivalent to a router reboot

Cisco's Soft Reconfiguration

- Now deprecated — but:
- Router normally stores prefixes which have been received from peer after policy application
  - Enabling soft-reconfiguration means router also stores prefixes/attributes received prior to any policy application
  - Uses more memory to keep prefixes whose attributes have been changed or have not been accepted
- Only useful now when operator requires to know which prefixes have been sent to a router prior to the application of any inbound policy

Cisco’ s Soft Reconfiguration



Configuring Soft Reconfiguration

```
router bgp 100
 address-family ipv4
  neighbor 1.1.1.1 remote-as 101
  neighbor 1.1.1.1 route-map infilter in
  neighbor 1.1.1.1 soft-reconfiguration inbound
! Outbound does not need to be configured !
```

- Then when we change the policy, we issue an exec command

```
clear ip bgp 1.1.1.1 soft [in | out]
```

- Note:
  - When “soft reconfiguration” is enabled, there is no access to the route refresh capability

    ```
    clear ip bgp 1.1.1.1 [in | out]
    ```

  - will also do a soft refresh

Cisco’s Peer Groups

Cisco’s Peer Groups

- Problem – how to scale iBGP
  - Large iBGP mesh slow to build
  - iBGP neighbours receive the same update
  - Router CPU wasted on repeat calculations
- Solution – peer-groups
  - Group peers with the same outbound policy
  - Updates are generated once per group

Cisco's Peer Groups

- Advantages today:
  - Makes configuration easier
  - Makes configuration less prone to error
  - Makes configuration more readable
  - Members can have different inbound policy
  - Can be used for eBGP neighbours too!
- Initial advantages:
  - Lower router CPU load
  - iBGP mesh builds more quickly
  - (Cisco's *update-groups* now provide this)

Configuring a Peer Group

```
router bgp 100
 address-family ipv4
  neighbor ibgp-peer peer-group
  neighbor ibgp-peer remote-as 100
  neighbor ibgp-peer update-source loopback 0
  neighbor ibgp-peer send-community
  neighbor ibgp-peer route-map outfilter out
  neighbor 10.0.0.1 peer-group ibgp-peer
  neighbor 10.0.0.2 peer-group ibgp-peer
  neighbor 10.0.0.2 route-map  infilter in
  neighbor 10.0.0.3 peer-group ibgp-peer
!
```

- Note how 10.0.0.2 has an additional inbound filter over the peer-group

Configuring a Peer Group

```
router bgp 100
 address-family ipv4
  neighbor external-peer peer-group
  neighbor external-peer send-community
  neighbor external-peer route-map set-metric out
  neighbor 160.89.1.2 remote-as 200
  neighbor 160.89.1.2 peer-group external-peer
  neighbor 160.89.1.4 remote-as 300
  neighbor 160.89.1.4 peer-group external-peer
  neighbor 160.89.1.6 remote-as 400
  neighbor 160.89.1.6 peer-group external-peer
  neighbor 160.89.1.6 filter-list infilter in
!
```

- Can be used for eBGP as well

Peer Groups

- Peer-groups are considered obsolete by Cisco:
  - Replaced by update-groups (internal coding – not configurable)
- But are still considered best practice by many network operators
- Cisco introduced peer-templates
  - A much enhanced version of peer-groups, allowing more complex constructs

Cisco’s update-groups (1)

- Update-groups is an internal IOS coding, taking over the performance gains introduce by peer-groups

```
Router1#sh ip bgp 10.0.0.0/26
BGP routing table entry for 10.0.0.0/26, version 2
Paths: (1 available, best #1, table default)
  Advertised to update-groups:
     1
  Refresh Epoch 1
  Local
    0.0.0.0 from 0.0.0.0 (10.0.15.241)
      Origin IGP, metric 0, localpref 100, weight 32768, valid...
```

- The “show” command indicates the prefix is handled by update-group #1

Cisco’s update-groups (2)

- The update group itself lists all the peers which get the same (identical) update:

```
Router1#sh ip bgp update-group 1
BGP version 4 update-group 1, internal, Address Family: IPv4 Unicast
  BGP Update version : 16/0, messages 0
  Topology: global, highest version: 16, tail marker: 16
  Format state: Current working (OK, last not in list)
                Refresh blocked (not in list, last not in list)
  Update messages formatted 11, replicated 13, current 0, refresh 0, limit 1000
  Number of NLRIs in the update sent: max 2, min 0
  Minimum time between advertisement runs is 0 seconds
  Has 13 members:
   10.0.15.242      10.0.15.243      10.0.15.244      10.0.15.245
   10.0.15.246      10.0.15.247      10.0.15.248      10.0.15.249
   10.0.15.250      10.0.15.251      10.0.15.252      10.0.15.253
   10.0.15.254
```

- And this group has 13 members

Peer Groups

- Always configure peer-groups for iBGP
  - Even if there are only a few iBGP peers
  - Easier to scale network in the future
  - Makes configuration easier to read
- Consider using peer-groups for eBGP
  - Especially useful for multiple BGP customers using same AS (RFC2270)
  - Also useful at Exchange Points:
    - Where ISP policy is generally the same to each peer
    - For Route Server where all peers receive the same routing updates

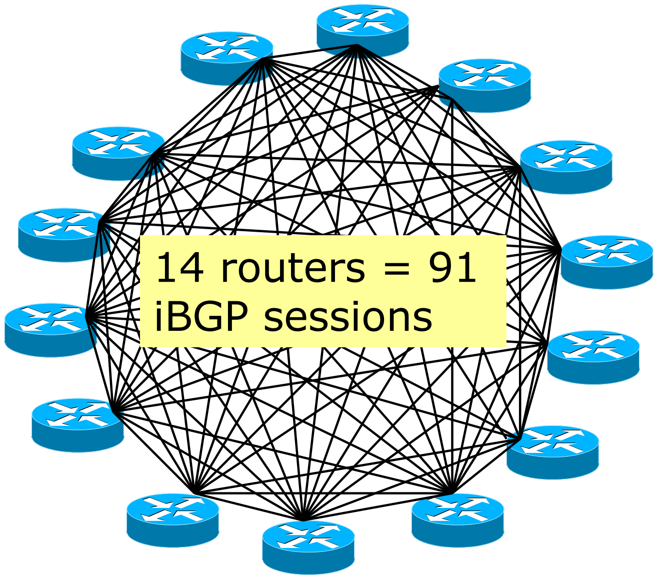
Route Reflectors

Scaling the iBGP mesh

Scaling iBGP mesh

- Avoid ½n(n-1) iBGP mesh

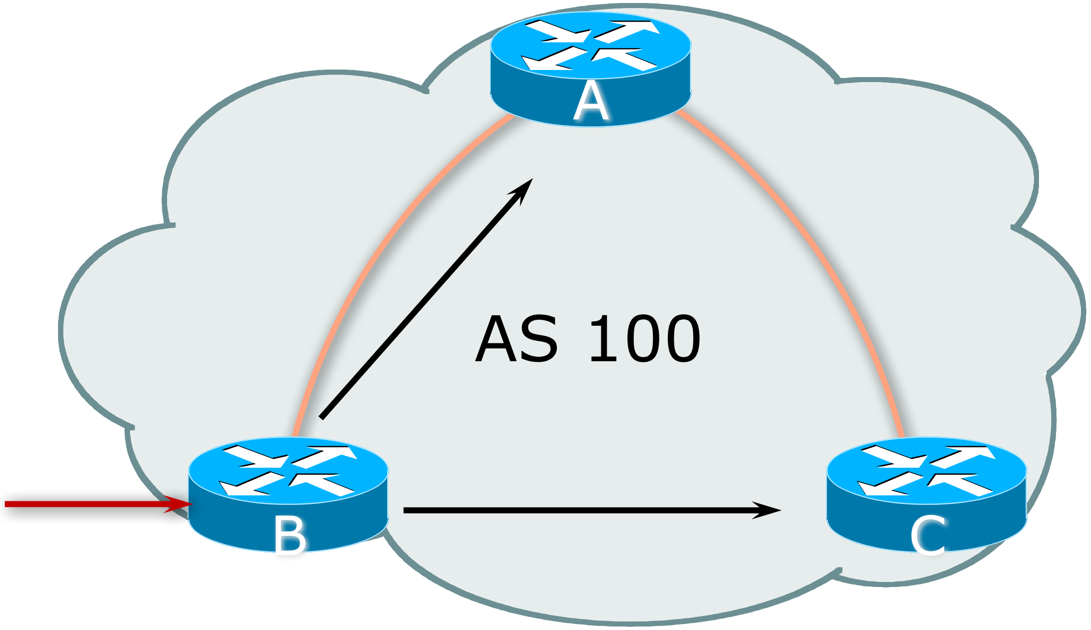
n=1000 ⇒ nearly half a million ibgp sessions!



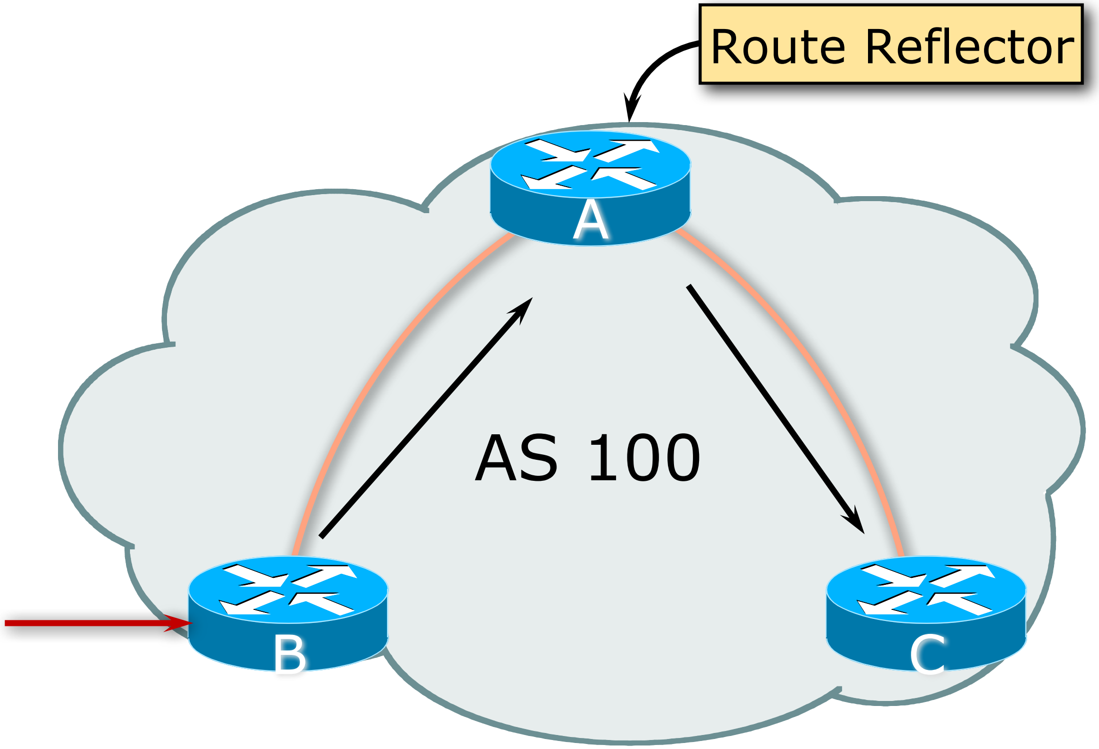
14 routers = 91 iBGP sessions

- Two solutions
  - Route reflector – simpler to deploy and run
  - Confederation – more complex, has corner case advantages

Route Reflector: Principle

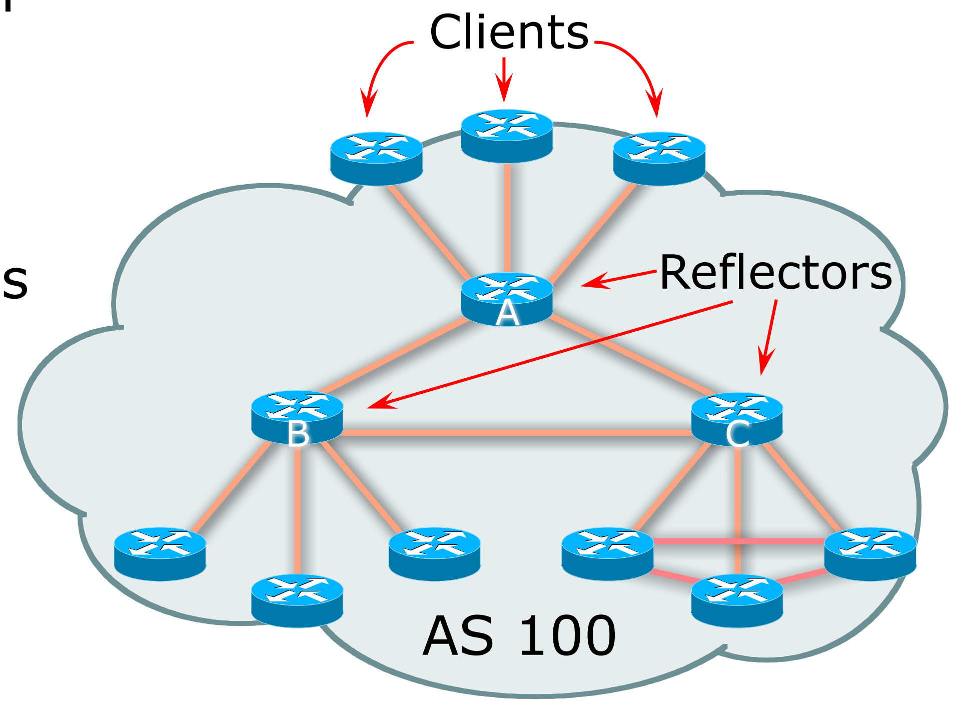


Route Reflector: Principle



Route Reflector

- Reflector receives path from clients and non-clients
- Selects best path
- If best path is from client, reflect to other clients and non-clients
- If best path is from non-client, reflect to clients only
- Non-meshed clients
- Described in RFC4456



Route Reflector Topology

- Divide the backbone into multiple clusters
- At least one route reflector and few clients per cluster
- Route reflectors are fully meshed
- Clients in a cluster could be fully meshed
- Single IGP to carry next hop and local routes

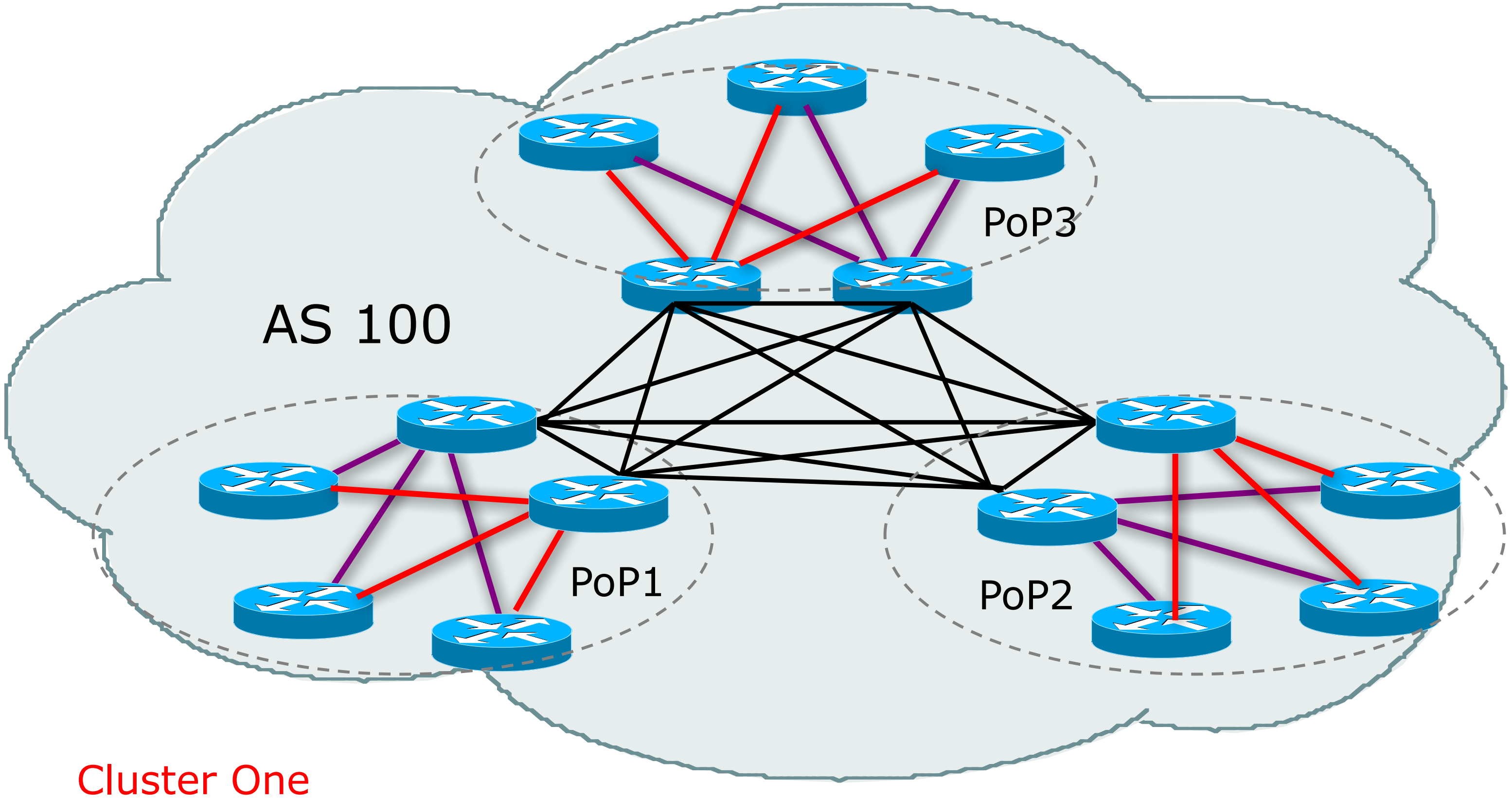
Route Reflectors: Loop Avoidance

- Originator_ID attribute
  - Carries the RID of the originator of the route in the local AS (created by the RR)
- Cluster_list attribute
  - The local cluster-id is added when the update is sent by the RR
  - Cluster-id is router-id by default (usually the address of loopback interface)
  - Do NOT use **`bgp cluster-id x.x.x.x`** unless the two route reflectors are physically/directly connected

Route Reflectors: Redundancy

- Multiple RRs can be configured in the same cluster – not advised!
  - All RRs in the cluster must have the same cluster-id (otherwise it is a different cluster)
- A router may be a client of RRs in different clusters
  - Common today in ISP networks to overlay two clusters – redundancy achieved that way
  - → Each client has two RRs = redundancy

Route Reflectors: Redundancy



Cluster One

Cluster Two

Route Reflector: Benefits

- Solves iBGP mesh problem
- Packet forwarding is not affected
- Normal BGP speakers co-exist
- Multiple reflectors for redundancy
- Easy migration
- Multiple levels of route reflectors

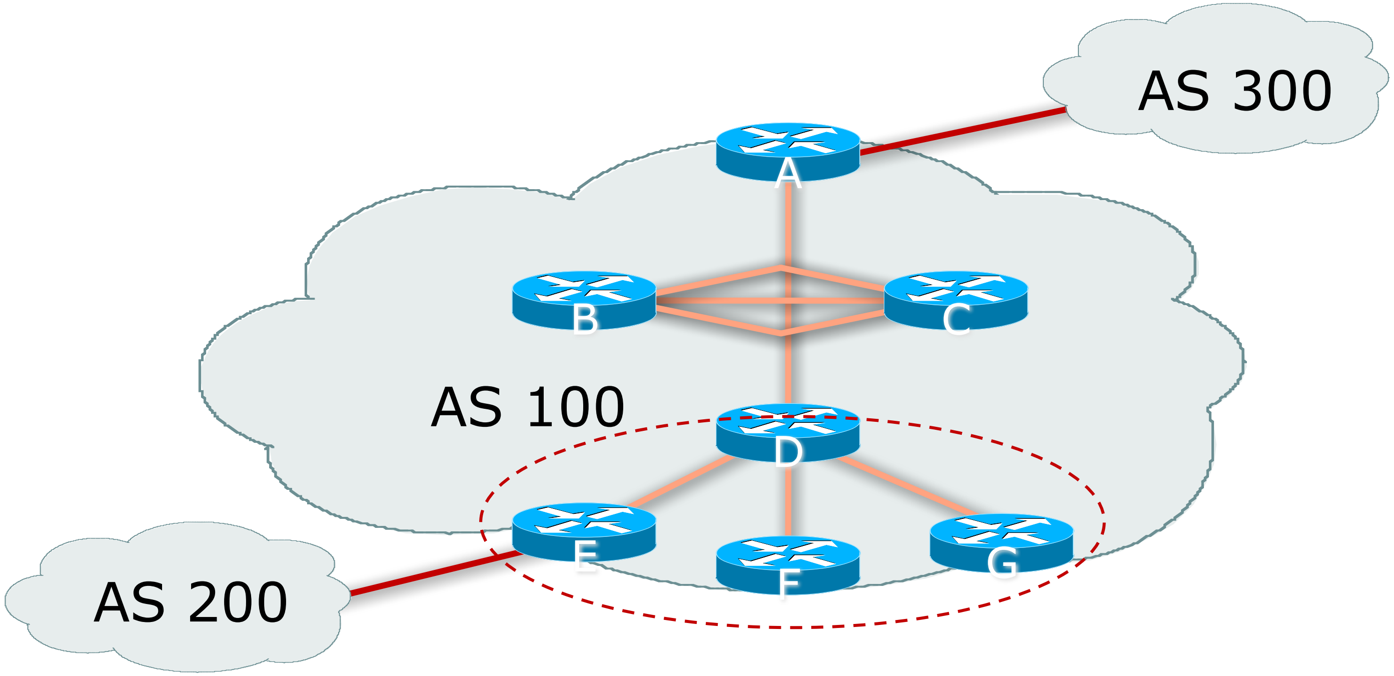
Route Reflector: Deployment

- Where to place the route reflectors?
  - Always follow the physical topology!
  - This will guarantee that the packet forwarding won't be affected
- Typical Service Provider network:
  - PoP has two core routers
  - Core routers are RR for the PoP
  - Two overlaid clusters

Route Reflector: Migration

- Typical ISP network:
  - Core routers have fully meshed iBGP
  - Create further hierarchy if core mesh too big
    - Split backbone into regions
- Configure one cluster pair at a time
  - Eliminate redundant iBGP sessions
  - Place maximum one RR per cluster
  - Easy migration, multiple levels

Route Reflectors: Migration



- Migrate small parts of the network, one part at a time.

Configuring a Peer Group

- Router D configuration:

```
router bgp 100
 address-family ipv4
 ...
  neighbor 1.2.3.4 remote-as 100
  neighbor 1.2.3.4 route-reflector-client
  neighbor 1.2.3.5 remote-as 100
  neighbor 1.2.3.5 route-reflector-client
  neighbor 1.2.3.6 remote-as 100
  neighbor 1.2.3.6 route-reflector-client
 ...
```

BGP Scaling Techniques

- These 3 techniques should be core requirements on all ISP networks
  - Route Refresh (or Soft Reconfiguration)
  - Peer groups
  - Route Reflectors

BGP Confederations

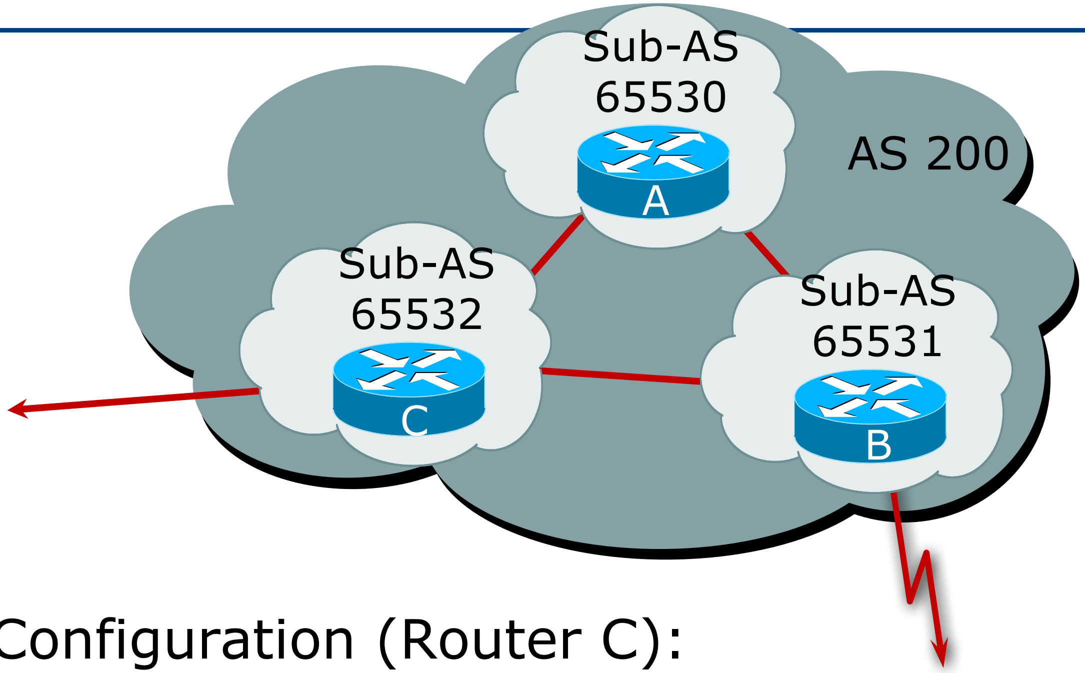
Confederations

- Divide the AS into sub-AS
  - eBGP between sub-AS, but some iBGP information is kept
    - Preserve NEXT_HOP across the sub-AS (IGP carries this information)
    - Preserve LOCAL_PREF and MED
- Usually a single IGP
- Described in RFC5065

Confederations

- Visible to outside world as single AS – "Confederation Identifier"
  - Each sub-AS uses a number from the private space (64512-65534)
- iBGP speakers in sub-AS are fully meshed
  - The total number of neighbors is reduced by limiting the full mesh requirement to only the peers in the sub-AS
  - Can also use Route-Reflector within sub-AS

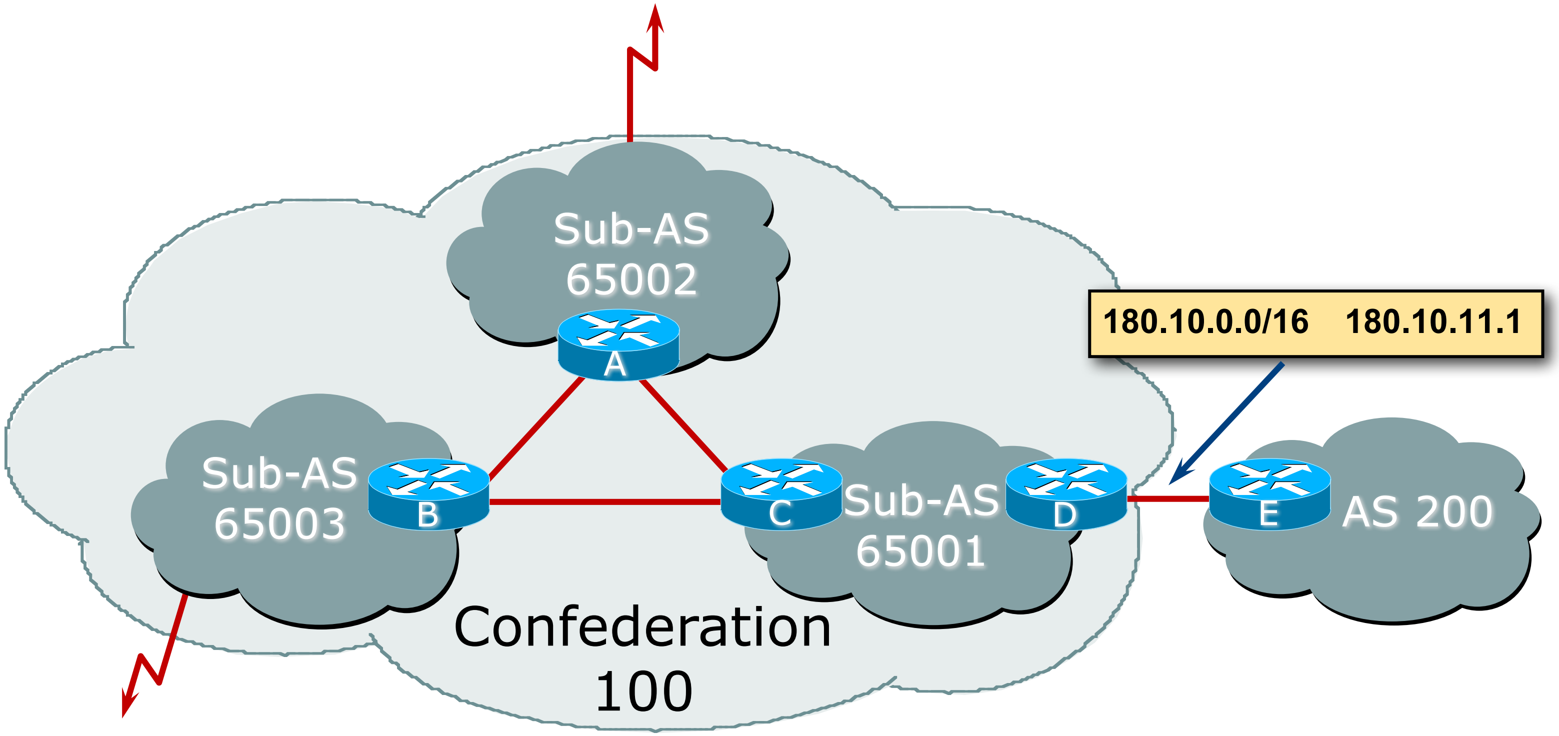
Confederations



- Configuration (Router C):

```
router bgp 65532
 bgp confederation identifier 200
 bgp confederation peers 65530 65531
 neighbor 141.153.12.1 remote-as 65530
 neighbor 141.153.17.2 remote-as 65531
```

Confederations: Next Hop



180.10.0.0/16 180.10.11.1

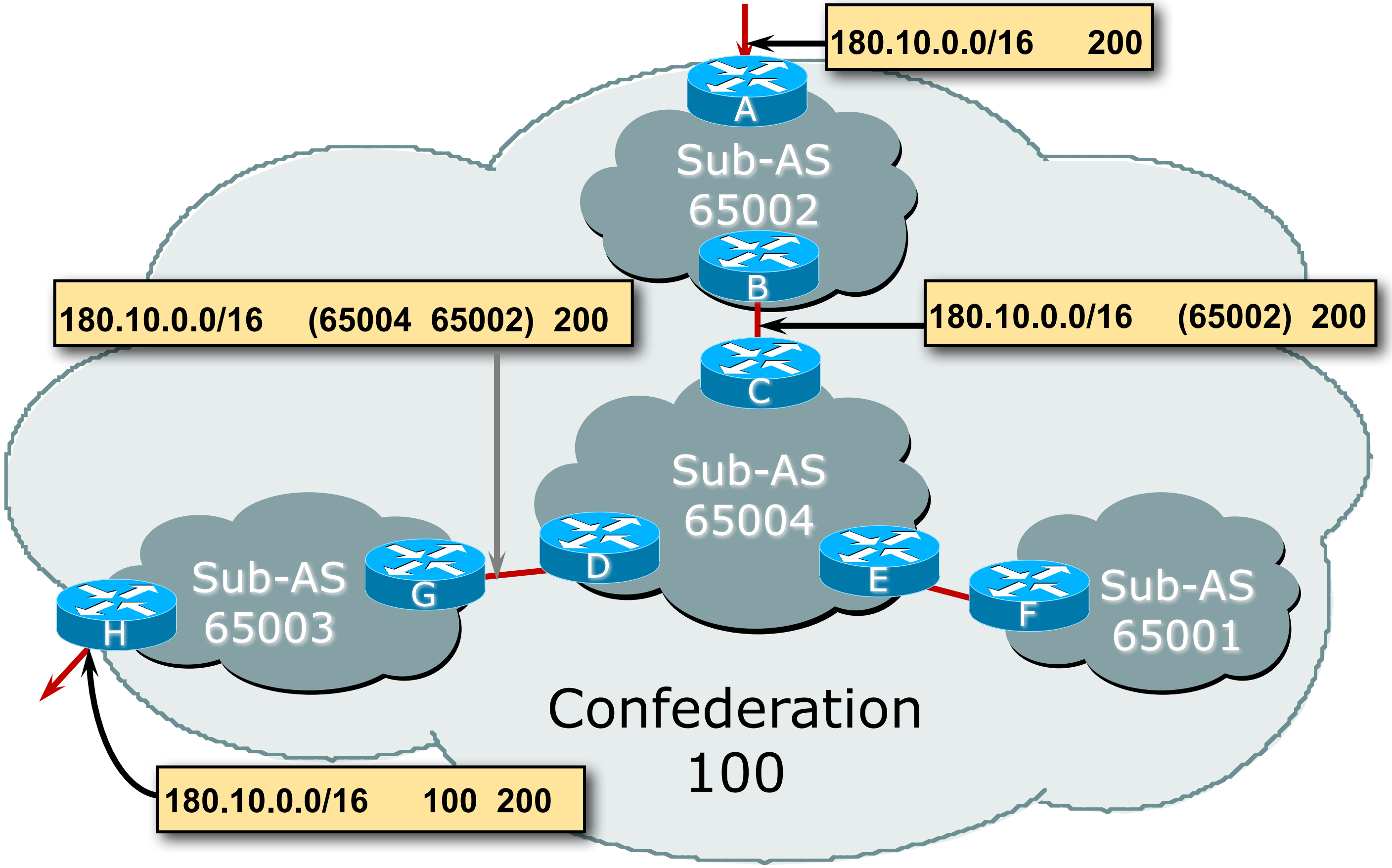
Confederation: Principle

- Local preference and MED influence path selection
- Preserve local preference and MED across sub-AS boundary
- Sub-AS eBGP path administrative distance

Confederations: Loop Avoidance

- Sub-AS traversed are carried as part of AS-path
- AS-sequence and AS path length
- Confederation boundary
- AS-sequence should be skipped during MED comparison

Confederations: AS-Sequence



Route Propagation Decisions

- Same as with “normal” BGP:
  - From peer in same sub-AS → only to external peers
  - From external peers → to all neighbors
- “External peers” refers to
  - Peers outside the confederation
  - Peers in a different sub-AS
    - Preserve LOCAL_PREF, MED and NEXT_HOP

Confederations (cont.)

- Example (cont.):

```
BGP table version is 78, local router ID is 141.153.17.1
Status codes: s suppressed, d damped, h history, * valid, > best, i - internal
Origin codes: i - IGP, e - EGP, ? - incomplete

Network         Next Hop     Metric LocPrf Weight Path
*> 10.0.0.0     141.153.14.3   0     100       0     (65531) 1 i
*> 141.153.0.0 141.153.30.2   0     100       0     (65530) i
*> 144.10.0.0  141.153.12.1   0     100       0     (65530) i
*> 199.10.10.0 141.153.29.2   0     100       0     (65530) 1 i
```

More points about confederations

- Can ease “absorbing” other ISPs into your ISP
  - e.g., if one ISP buys another
  - (can use local-as feature to do a similar thing)
- You can use route-reflectors with confederation sub-AS to reduce the sub-AS iBGP mesh

Confederations: Benefits

- Solves iBGP mesh problem
- Packet forwarding not affected
- Can be used with route reflectors
- Policies could be applied to route traffic between sub-AS’s

Confederations: Caveats

- Minimal number of sub-AS
- Sub-AS hierarchy
- Minimal inter-connectivity between sub-AS’s
- Path diversity
- Difficult migration
  - BGP reconfigured into sub-AS
  - Must be applied across the network

RRs or Confederations ?

	Internet Connectivity	Multi-Level Hierarchy	Policy Control	Scalability	Migration Complexity
Confederations	Anywhere in the network	Yes	Yes	Medium	Medium to High
Route Reflectors	Anywhere in the network	Yes	Yes	Very High	Very Low

New network operators deploy Route Reflectors from Day One

Route Flap Damping

Network Stability for the 1990s

Network Instability for the 21st Century!

Route Flap Damping

- For many years, Route Flap Damping was a strongly recommended practice
- Now it is strongly discouraged as it causes far greater network instability than it cures
- But first, the theory…

Route Flap Damping

- Route flap
  - Going up and down of path or change in attribute
    - BGP WITHDRAW followed by UPDATE = 1 flap
    - eBGP neighbour going down/up is NOT a flap
  - Ripples through the entire Internet
  - Wastes CPU
- Damping aims to reduce scope of route flap propagation

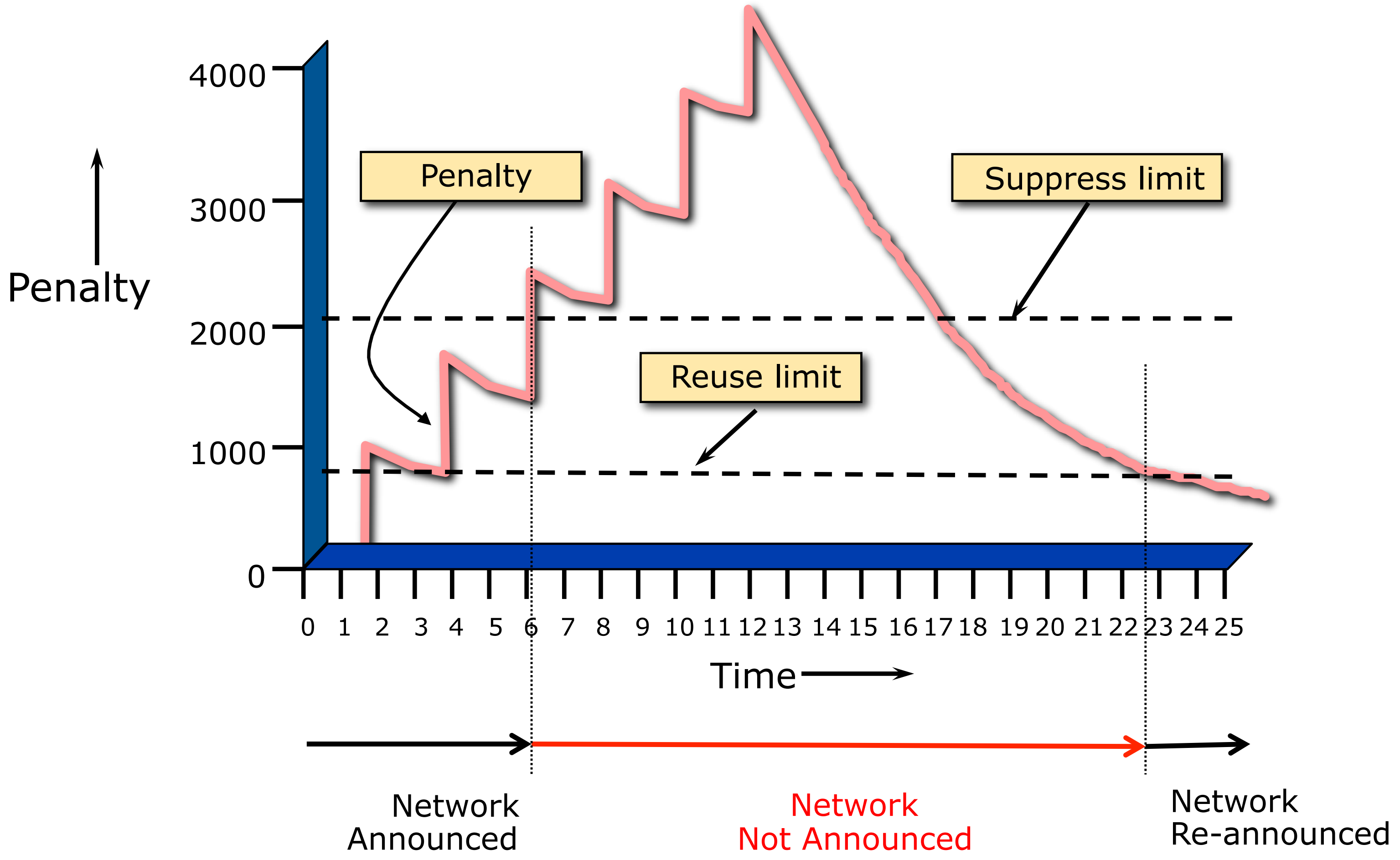
Route Flap Damping (continued)

- Requirements
  - Fast convergence for normal route changes
  - History predicts future behaviour
  - Suppress oscillating routes
  - Advertise stable routes
- Implementation described in RFC 2439

Operation

- Add penalty (1000) for each flap
  - Change in attribute gets penalty of 500
- Exponentially decay penalty
  - Half life determines decay rate
- Penalty above suppress-limit
  - Do not advertise route to BGP peers
- Penalty decayed below reuse-limit
  - Re-advertise route to BGP peers
  - Penalty reset to zero when it is half of reuse-limit

Operation


Penalty
4000
3000
2000
1000
0
Penalty
Suppress limit
Reuse limit
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
Time
Network
Announced
Network
Not Announced
Network
Re-announced

Operation

- Only applied to inbound announcements from eBGP peers
- Alternate paths still usable
- Controlled by:
  - Half-life (default 15 minutes)
  - reuse-limit (default 750)
  - suppress-limit (default 2000)
  - maximum suppress time (default 60 minutes)

Configuration

- Fixed damping

```
router bgp 100
 bgp dampening [<half-life> <reuse-value> <suppress-penalty> <max suppress time>]
```

- Selective and variable damping

```
bgp dampening [route-map <name>]
route-map <name> permit 10
 match ip address prefix-list FLAP-LIST
 set dampening [<half-life> <reuse-value> <suppress-penalty> <max suppress time>]
ip prefix-list FLAP-LIST permit 192.0.2.0/24 le 32
```

Operation

- Care required when setting parameters
- Penalty must be less than reuse-limit at the maximum suppress time
- Maximum suppress time and half life must allow penalty to be larger than suppress limit

Configuration

- Examples – ✗
  - bgp dampening 15 500 2500 30
    - reuse-limit of 500 means maximum possible penalty is 2000 – no prefixes suppressed as penalty cannot exceed suppress-limit
- Examples – ✓
  - bgp dampening 15 750 3000 45
    - reuse-limit of 750 means maximum possible penalty is 6000 – suppress limit is easily reached

Maths!

- Maximum value of penalty is

$$\text{max-penalty} = \text{reuse-limit} \times 2^{\left(\frac{\text{max-suppress-time}}{\text{half-life}}\right)}$$

- Always make sure that suppress-limit is LESS than max-penalty otherwise there will be no route damping

Route Flap Damping History

- First implementations on the Internet by 1995
- Vendor defaults too severe
  - RIPE Routing Working Group recommendations in ripe-178, ripe-210, and ripe-229
  - http://www.ripe.net/ripe/docs
  - But many ISPs simply switched on the vendors' default values without thinking

Serious Problems:

- "Route Flap Damping Exacerbates Internet Routing Convergence‟
  - Zhuoqing Morley Mao, Ramesh Govindan, George Varghese & Randy H. Katz, August 2002
- “What is the sound of one route flapping?”
  - Tim Griffin, June 2002
- Various work on routing convergence by Craig Labovitz and Abha Ahuja a few years ago
- “Happy Packets”
  - Closely related work by Randy Bush et al

Problem 1:

- One path flaps:
  - BGP speakers pick next best path, announce to all peers, flap counter incremented
  - Those peers see change in best path, flap counter incremented
  - After a few hops, peers see multiple changes simply caused by a single flap → prefix is suppressed

Problem 2:

- Different BGP implementations have different transit time for prefixes
  - Some hold onto prefix for some time before advertising
  - Others advertise immediately
- Race to the finish line causes appearance of flapping, caused by a simple announcement or path change → prefix is suppressed

Solution:

- Misconfigured Route Flap Damping will seriously impact access to:
  - Your network *and*
  - The Internet
- More background contained in RIPE Routing Working Group document:
  - www.ripe.net/ripe/docs/ripe-378
- Recommendations now in:
  - www.rfc-editor.org/rfc/rfc7196.txt and www.ripe.net/ripe/docs/ripe-580

BGP Scaling Techniques

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