

# BGP Scaling Techniques



ISP Training Workshops

# BGP Scaling Techniques

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- 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

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

# Dynamic Reconfiguration



Non-destructive policy changes

# Route Refresh

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- Policy Changes:
  - Hard BGP peer reset required after every policy change because the router does not store prefixes that are rejected by policy
- Hard BGP peer reset:
  - Tears down BGP peering
  - Consumes CPU
  - Severely disrupts connectivity for all networks
- Solution:
  - Route Refresh

# Route Refresh Capability

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- ❑ 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

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- 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

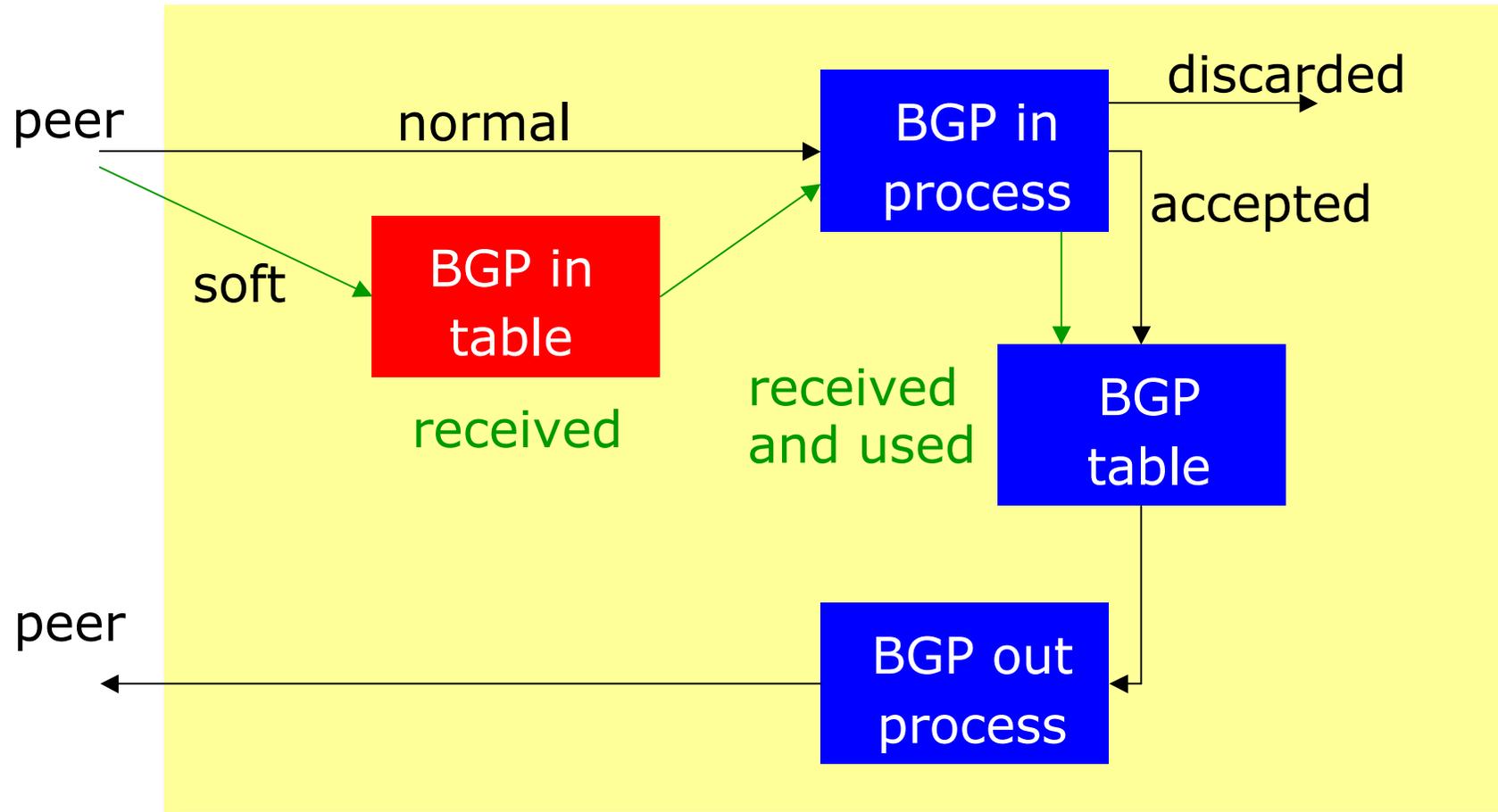
**Consider the impact to be equivalent to a router reboot**

# Cisco's Soft Reconfiguration

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- ❑ **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

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```
router bgp 100
  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

# Peer Groups



# Peer Groups

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- 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

# Peer Groups – Advantages

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- ❑ Makes configuration easier
- ❑ Makes configuration less prone to error
- ❑ Makes configuration more readable
- ❑ Lower router CPU load
- ❑ iBGP mesh builds more quickly
- ❑ Members can have different inbound policy
- ❑ Can be used for eBGP neighbours too!

# Configuring a Peer Group

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```
router bgp 100
  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 1.1.1.1 peer-group ibgp-peer
  neighbor 2.2.2.2 peer-group ibgp-peer
  neighbor 2.2.2.2 route-map infilter in
  neighbor 3.3.3.3 peer-group ibgp-peer
```

! note how 2.2.2.2 has different inbound filter from peer-group !

# Configuring a Peer Group

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```
router bgp 100
  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
```

# Peer Groups

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- ❑ Always configure peer-groups for iBGP
  - Even if there are only a few iBGP peers
  - Easier to scale network in the future
- ❑ 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
- ❑ Peer-groups are essentially obsoleted
  - But are still widely considered best practice
  - Replaced by update-groups (internal coding – not configurable)
  - Enhanced by peer-templates (allowing more complex constructs)

# Route Reflectors

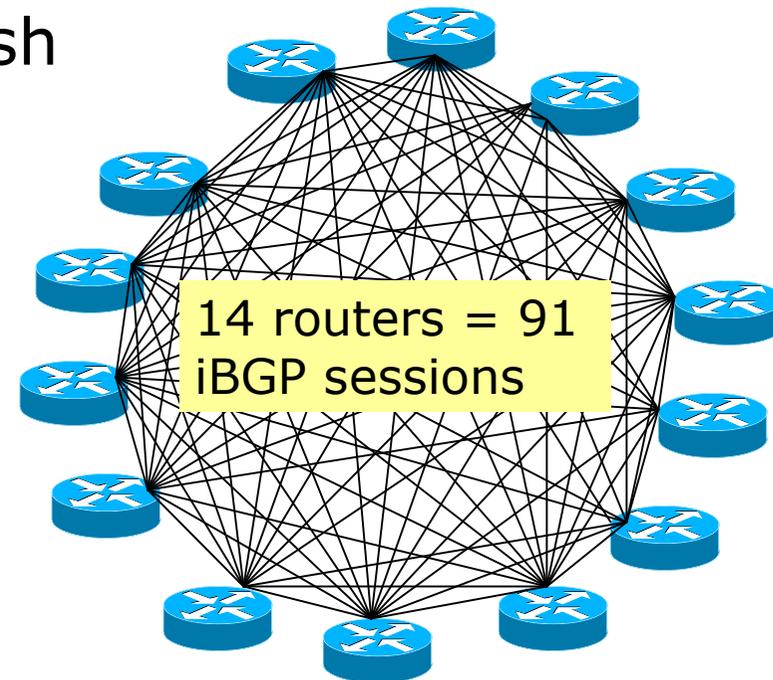


Scaling the iBGP mesh

# Scaling iBGP mesh

- Avoid  $\frac{1}{2}n(n-1)$  iBGP mesh

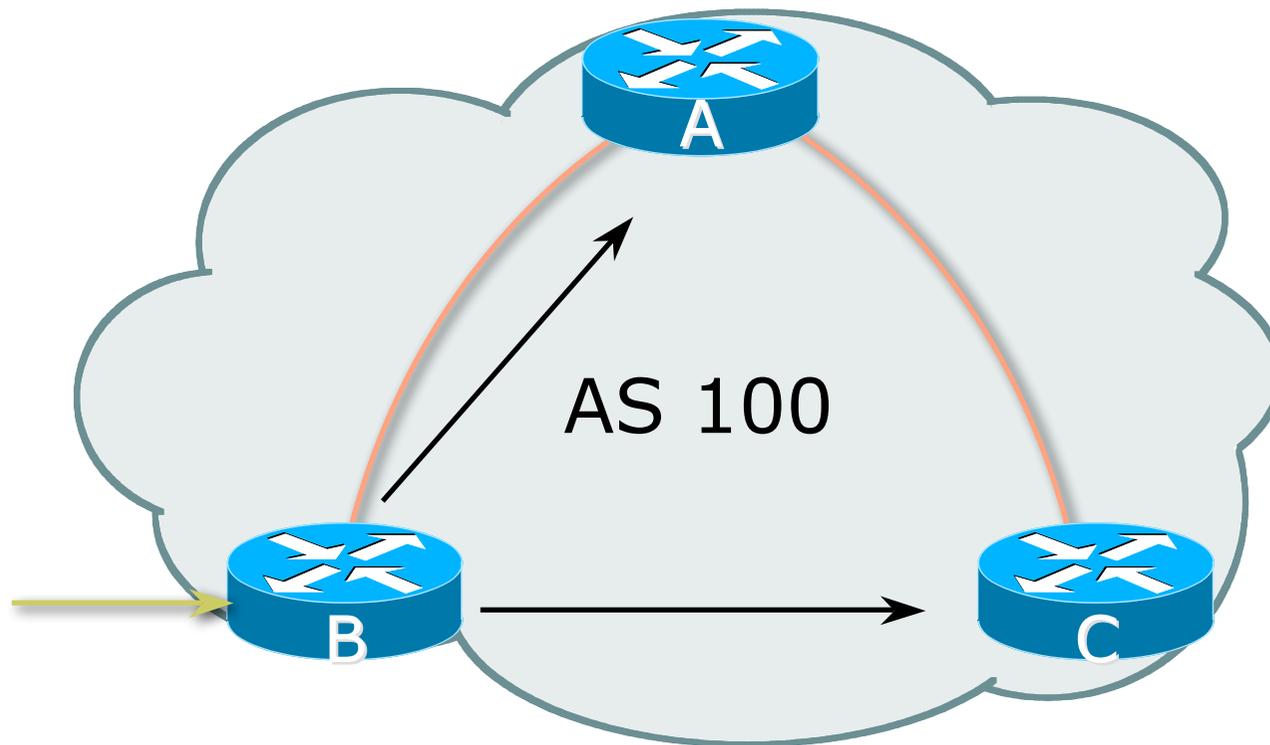
**$n=1000 \Rightarrow$  nearly  
half a million  
ibgp sessions!**



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

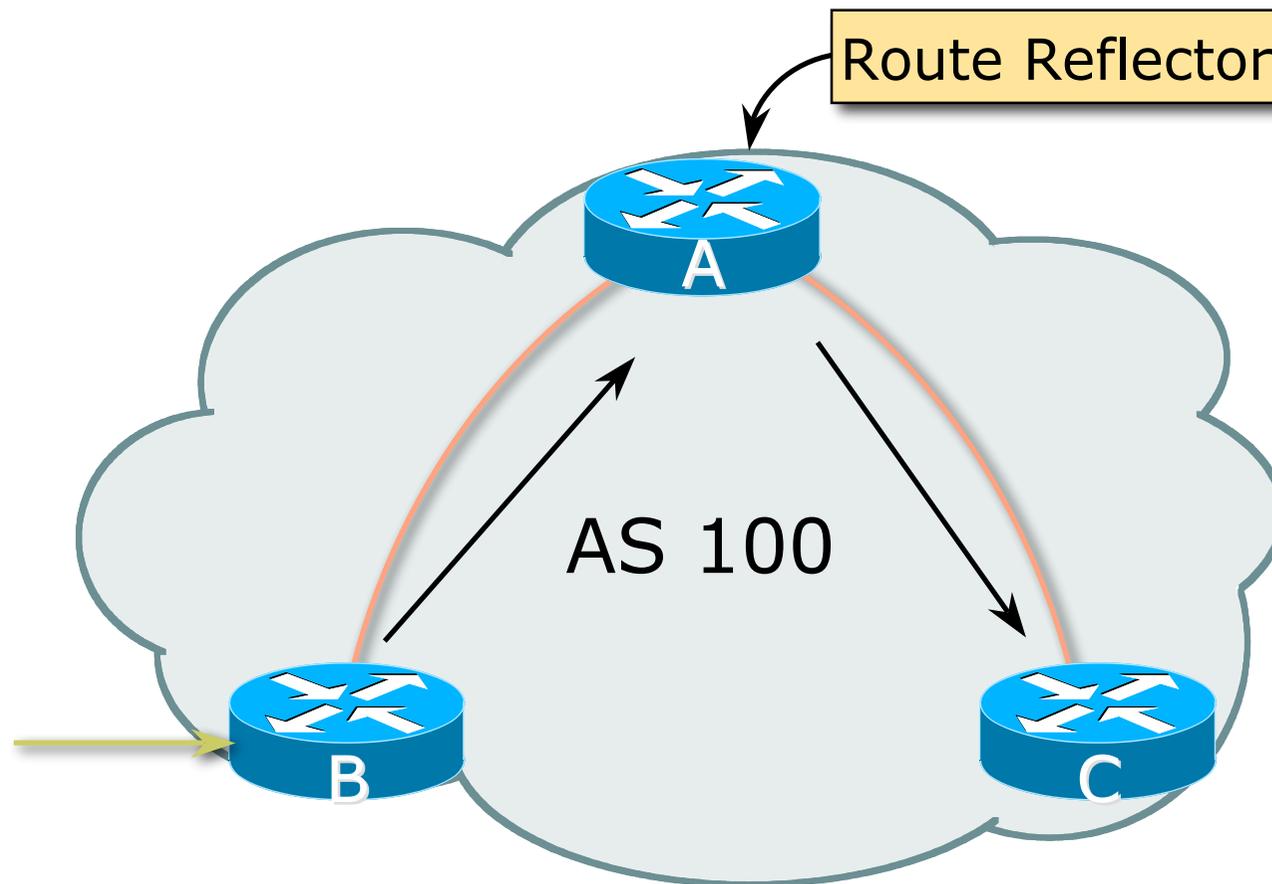
# Route Reflector: Principle

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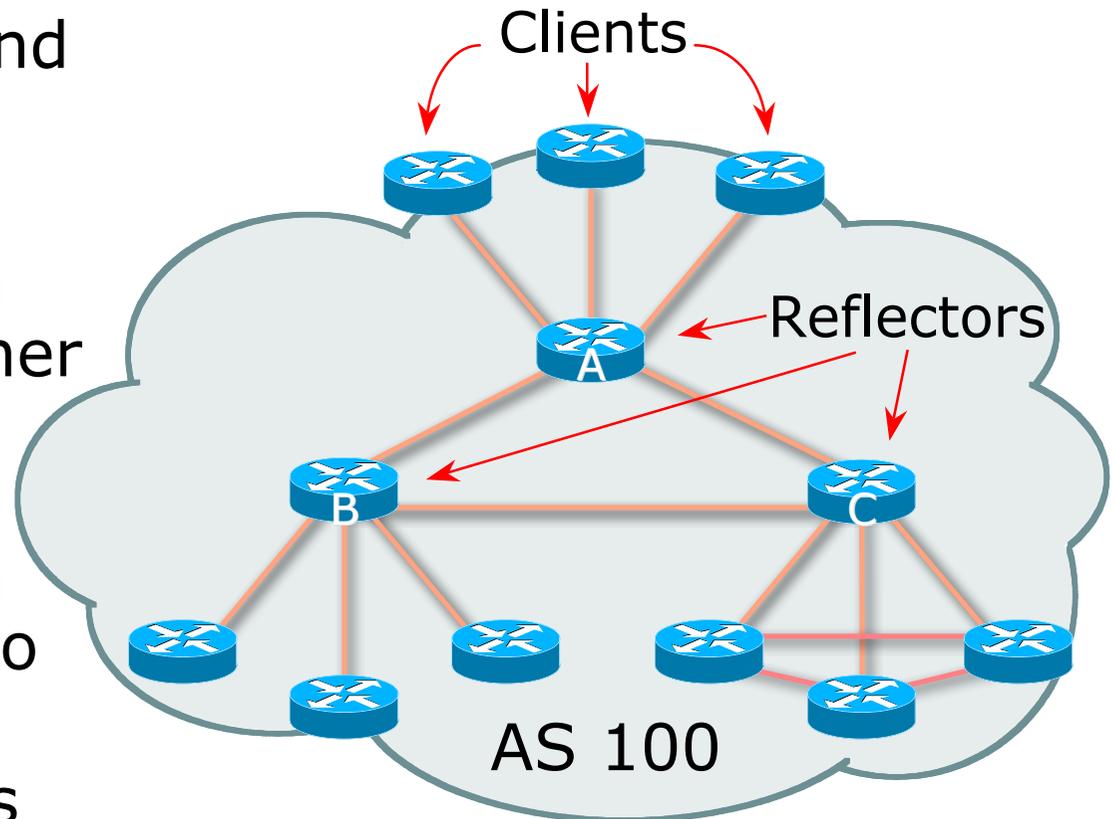
# Route Reflector: Principle

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# 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

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- ❑ 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

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- ❑ 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 (address of loopback)
  - **Do NOT use** `bgp cluster-id x.x.x.x`

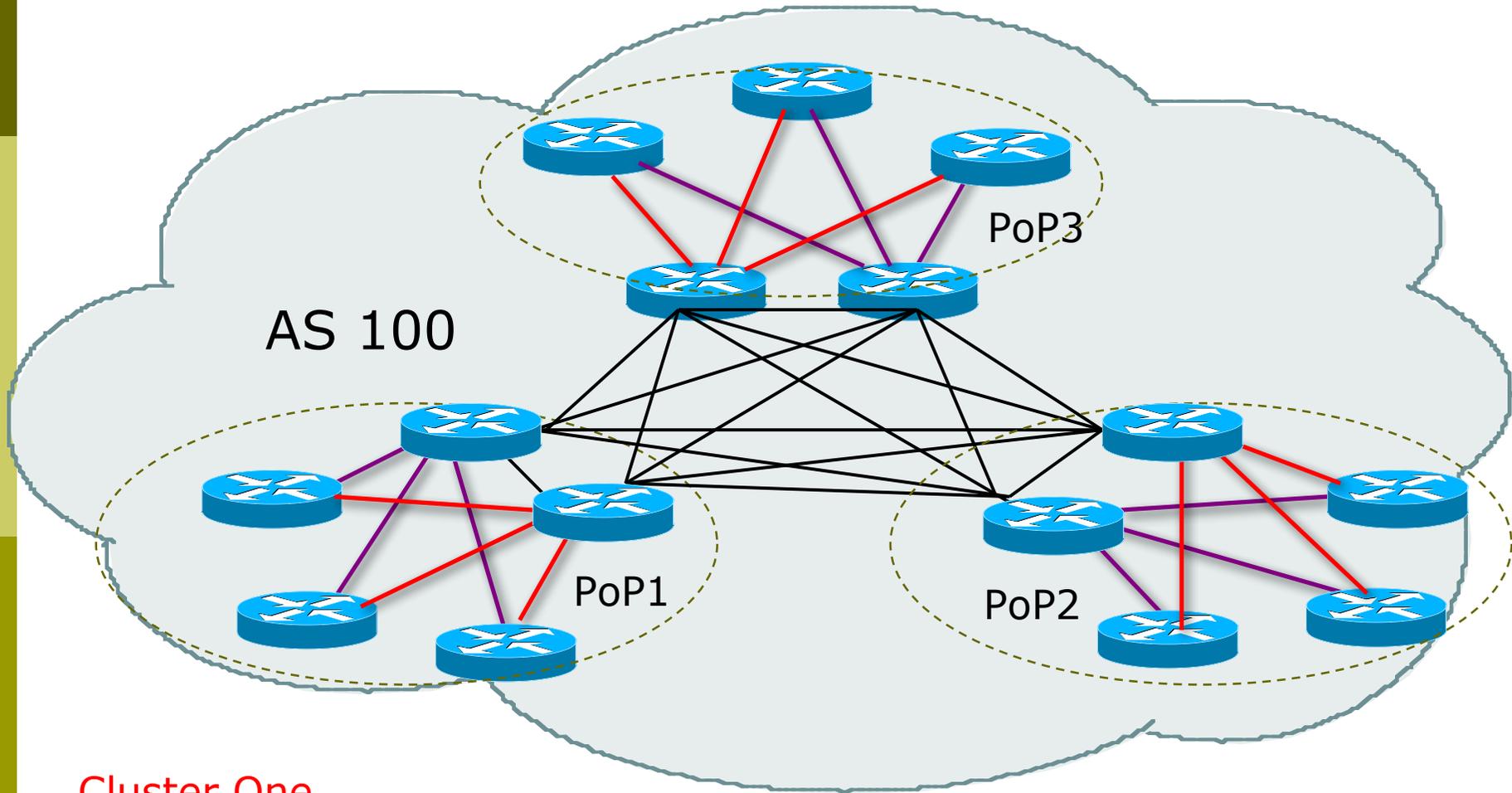
# Route Reflectors: Redundancy

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- 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

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Cluster One

Cluster Two

# Route Reflector: Benefits

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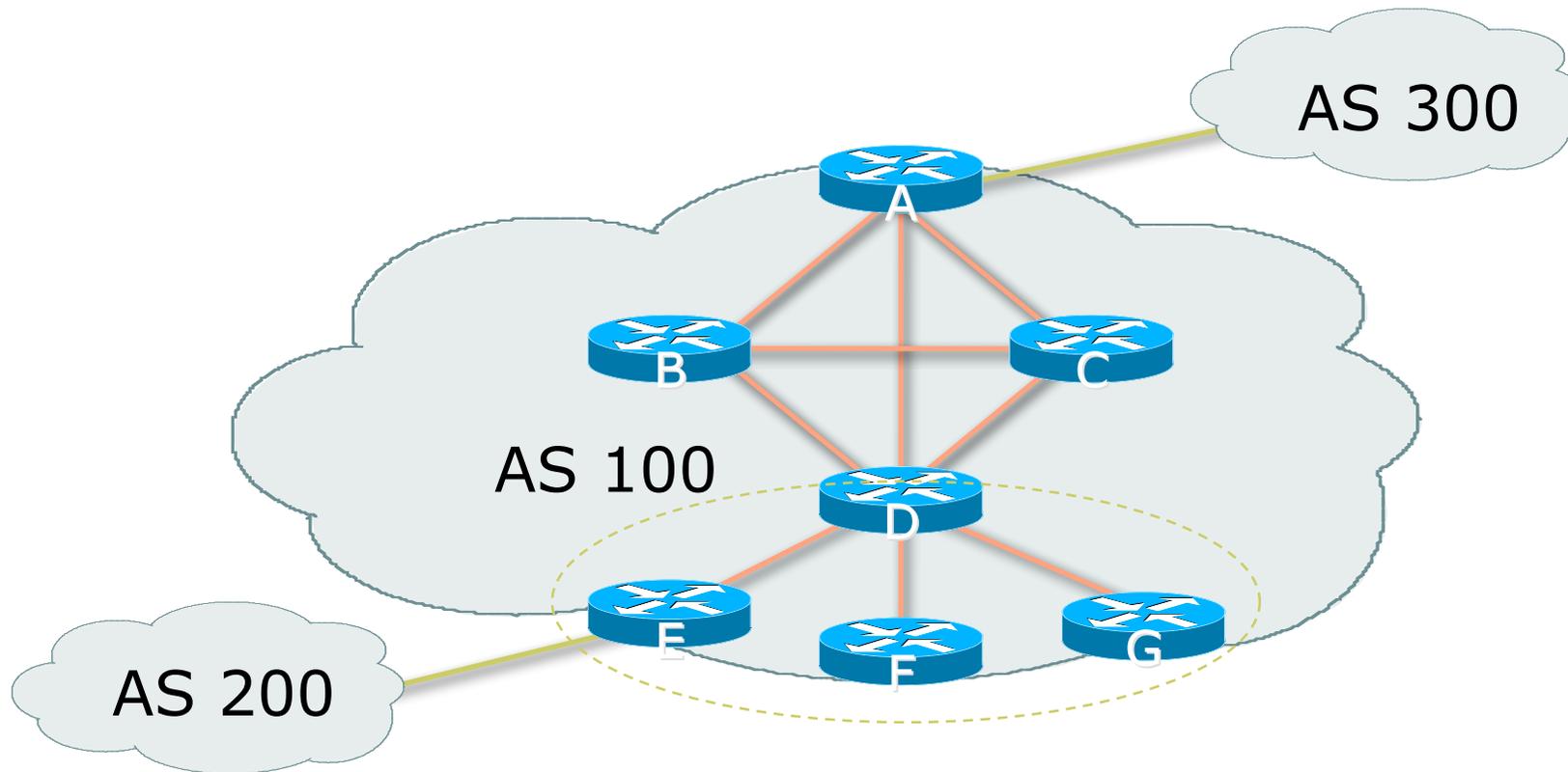
- ❑ Solves iBGP mesh problem
- ❑ Packet forwarding is not affected
- ❑ Normal BGP speakers co-exist
- ❑ Multiple reflectors for redundancy
- ❑ Easy migration
- ❑ Multiple levels of route reflectors

# Route Reflectors: Migration

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- Where to place the route reflectors?
  - Follow the physical topology!
  - This will guarantee that the packet forwarding won't be affected
- Configure one RR at a time
  - Eliminate redundant iBGP sessions
  - Place one RR per cluster

# Route Reflectors: Migration



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

# Configuring a Route Reflector

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## □ Router D configuration:

```
router bgp 100
...
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

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

# BGP Confederations



# Confederations

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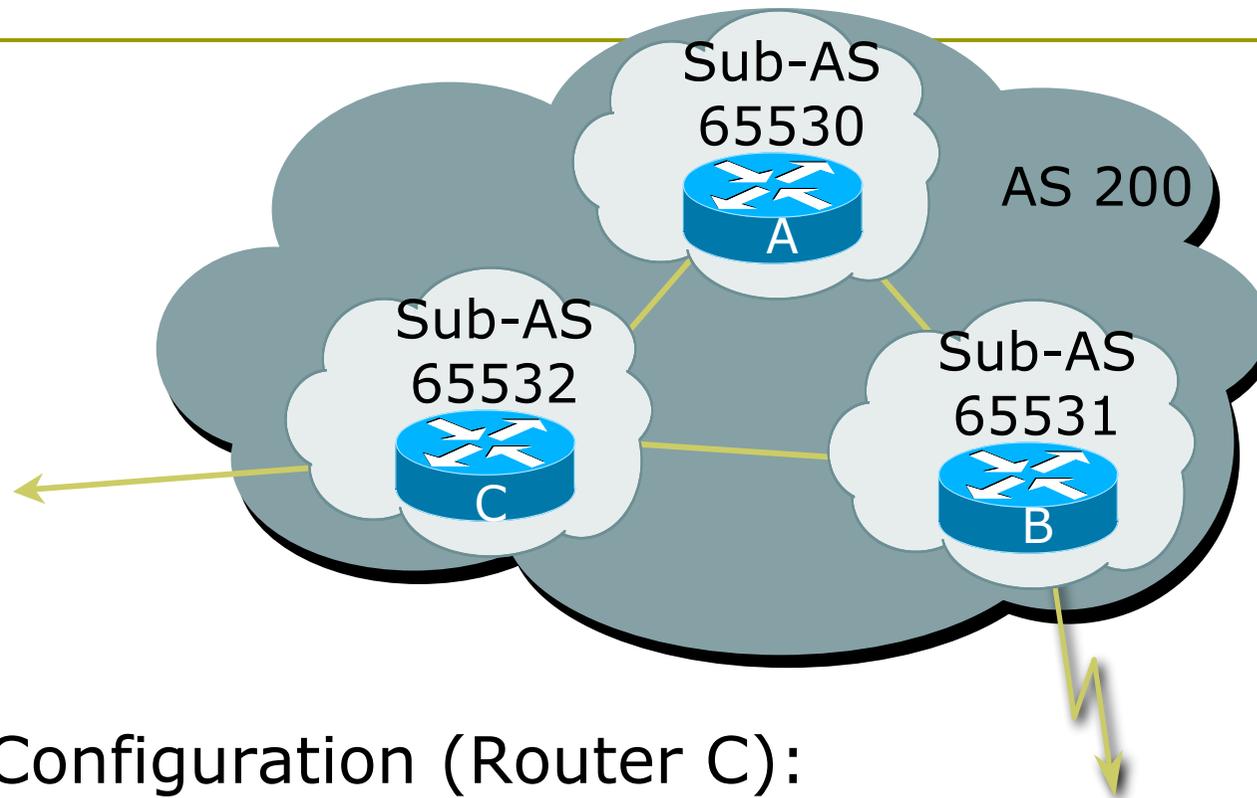
- Divide the AS into sub-AS
  - eBGP between sub-AS, but some iBGP information is kept
    - Preserve NEXT\_HOP across the sub-AS (IGP carries this information)
    - Preserve LOCAL\_PREF and MED
- Usually a single IGP
- Described in RFC5065

# Confederations

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- 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

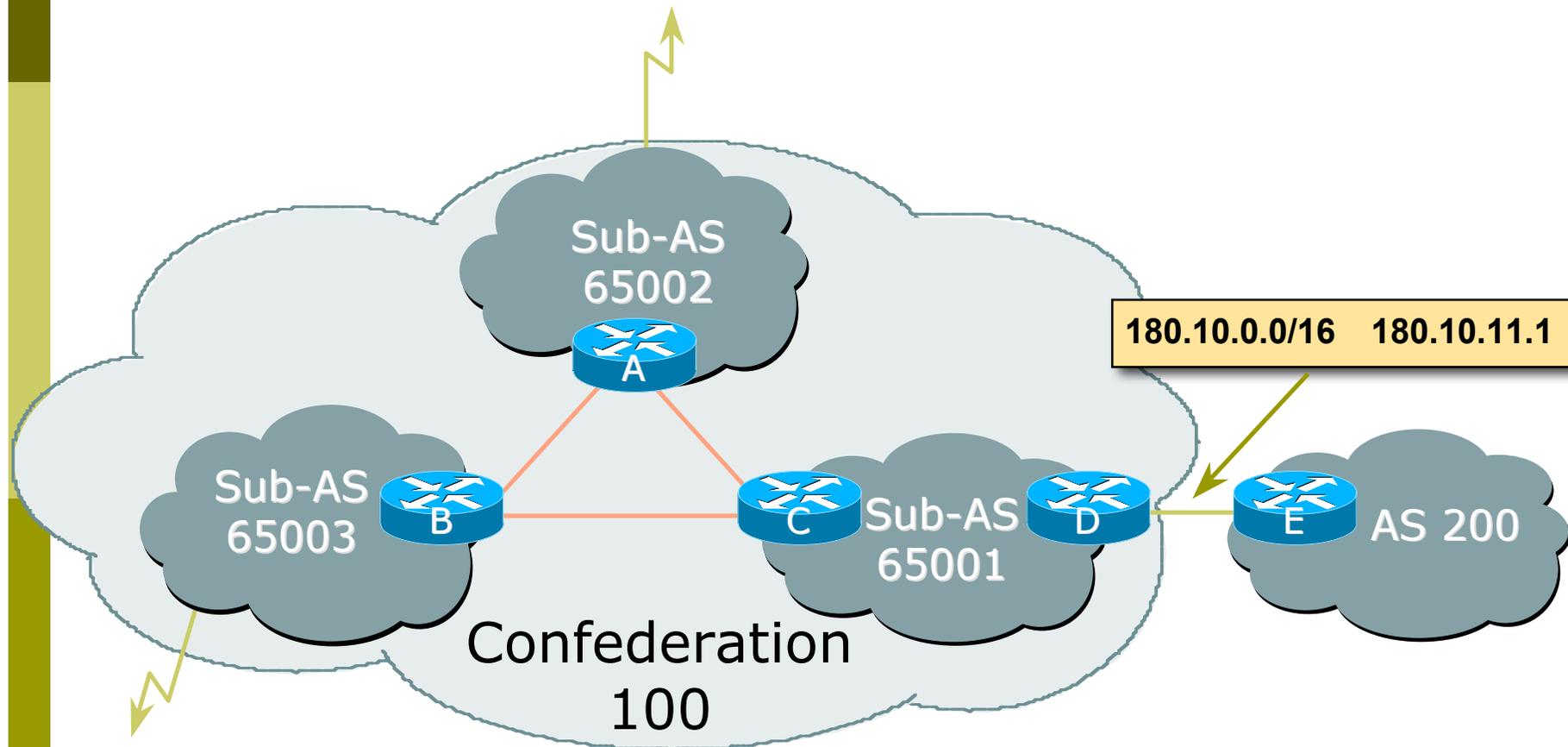
# Confederations



## □ 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



# Confederation: Principle

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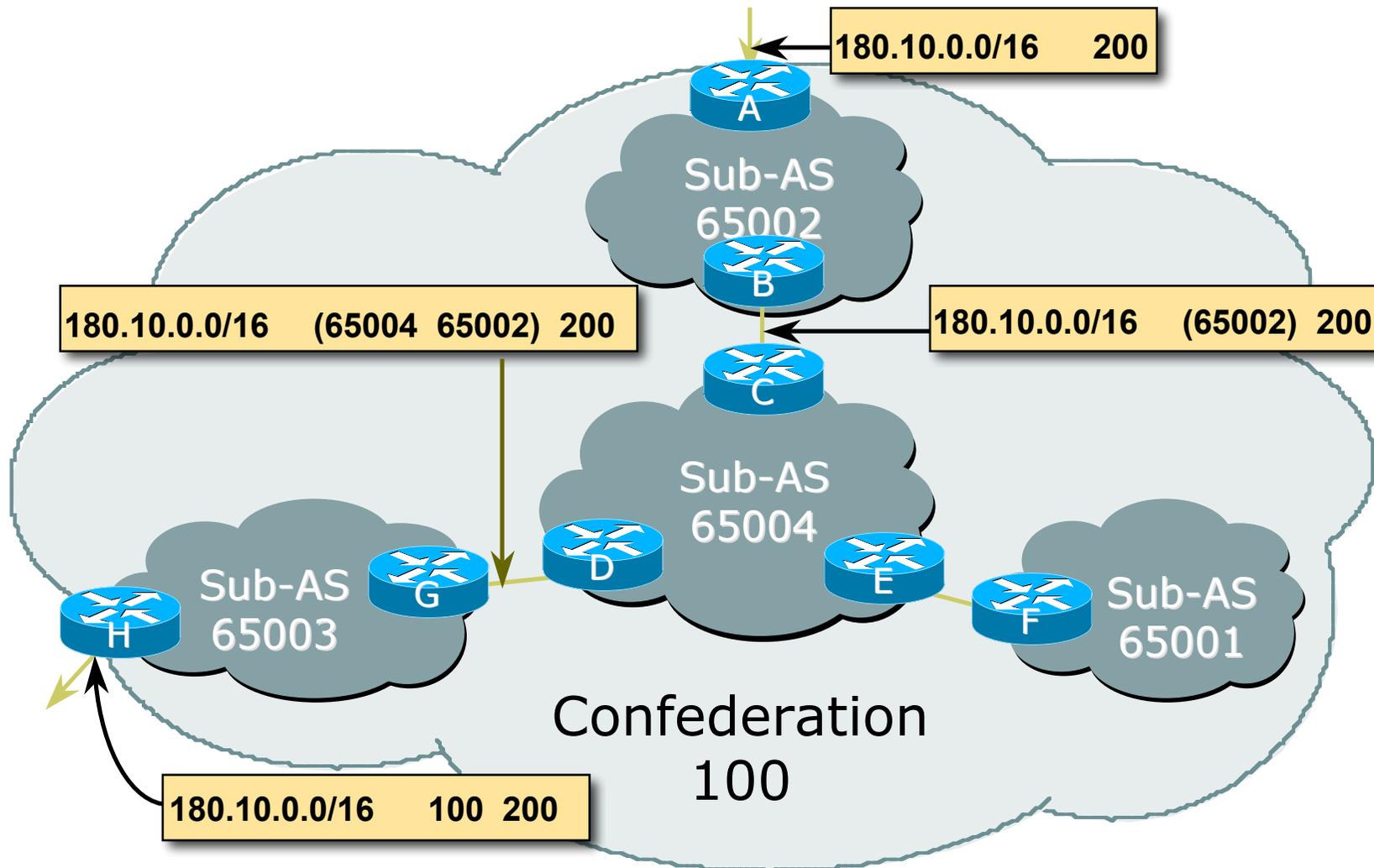
- ❑ Local preference and MED influence path selection
- ❑ Preserve local preference and MED across sub-AS boundary
- ❑ Sub-AS eBGP path administrative distance

# Confederations: Loop Avoidance

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- ❑ 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

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- 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.)

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## □ 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

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- ❑ 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

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- ❑ 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

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- 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

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	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

**Most new service provider networks now deploy Route Reflectors from Day One**

# Route Flap Damping



Network Stability for the 1990s

Network Instability for the 21st  
Century!

# Route Flap Damping

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- ❑ 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

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- 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)

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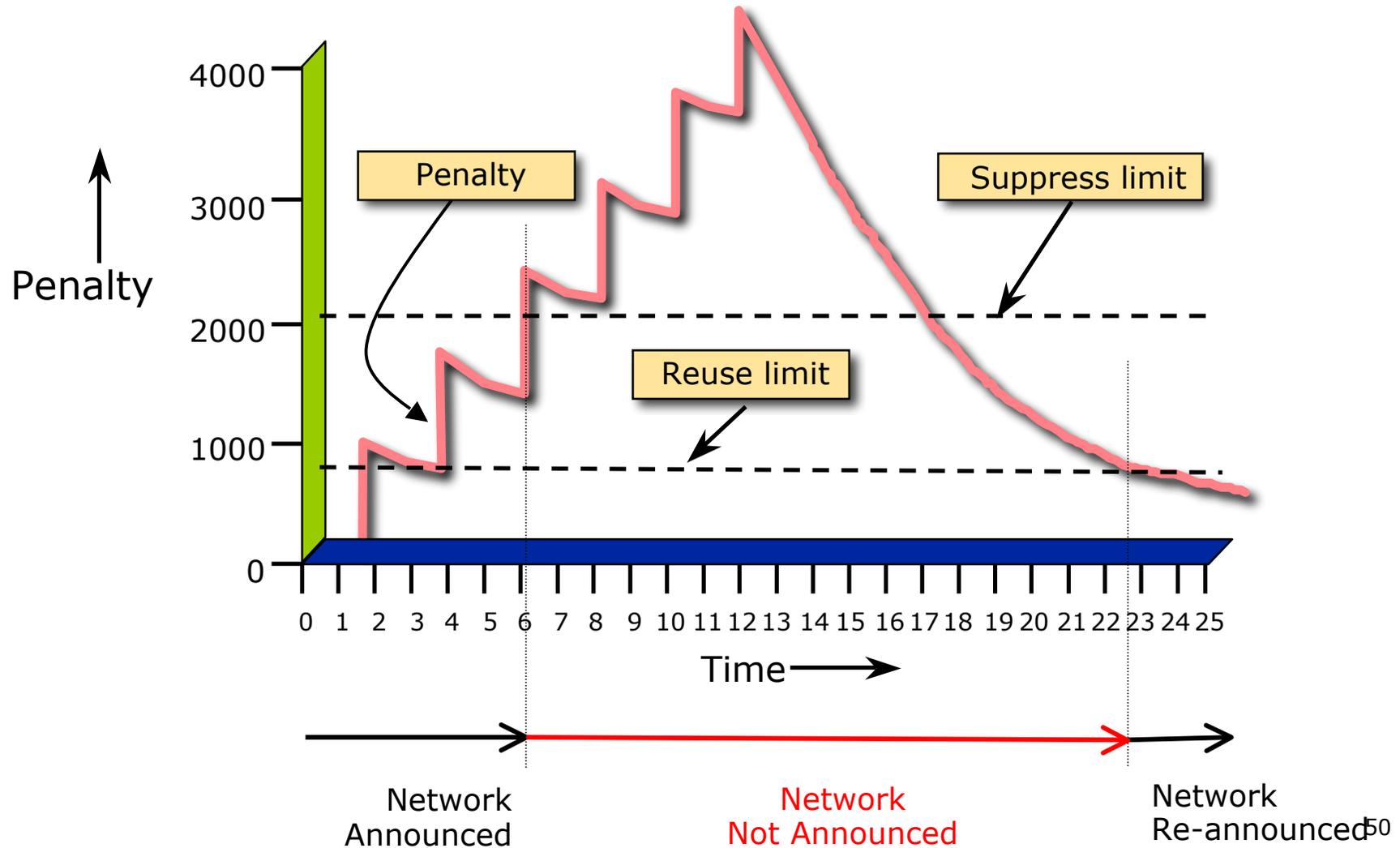
- Requirements
  - Fast convergence for normal route changes
  - History predicts future behaviour
  - Suppress oscillating routes
  - Advertise stable routes
- Implementation described in RFC 2439

# Operation

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- 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



# Operation

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- ❑ 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> <maximum 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> <maximum 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

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## □ 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!

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- 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

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- 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:

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- "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:

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## □ 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:

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- 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:

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- ❑ Do NOT use Route Flap Damping whatever you do!
- ❑ RFD will unnecessarily impair access to:
  - Your network and
  - The Internet
- ❑ More information contained in RIPE Routing Working Group recommendations:
  - [www.ripe.net/ripe/docs/ripe-378.\[pdf,html,txt\]](http://www.ripe.net/ripe/docs/ripe-378.[pdf,html,txt])
- ❑ Work is underway to try and find ways of making RFD usable:
  - <http://datatracker.ietf.org/doc/draft-ymbk-rfd-usable/>

# BGP Scaling Techniques



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