Service Provider Multihoming

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

Service Provider Multihoming

- Previous examples dealt with loadsharing inbound traffic
  - Of primary concern at Internet edge
  - What about outbound traffic?
- Transit ISPs strive to balance traffic flows in both directions
  - Balance link utilisation
  - Try and keep most traffic flows symmetric
  - Some edge ISPs try and do this too
- The original "Traffic Engineering"

Service Provider Multihoming

- Balancing outbound traffic requires inbound routing information
  - Common solution is “full routing table”
  - Rarely necessary
    - Why use the “routing mallet” to try solve loadsharing problems?
  - “Keep It Simple” is often easier (and $$$ cheaper) than carrying N-copies of the full routing table

Service Provider Multihoming MYTHS!!

Common MYTHS

1. You need the full routing table to multihome
   - People who sell router memory would like you to believe this
   - Only true if you are a transit provider
   - Full routing table can be a significant hindrance to multihoming
2. You need a BIG router to multihome
   - Router size is related to data rates, not running BGP
   - In reality, to multihome, your router needs to:
     - Have two interfaces,
     - Be able to talk BGP to at least two peers,
     - Be able to handle BGP attributes,
     - Handle at least one prefix
3. BGP is complex
   - In the wrong hands, yes it can be! Keep it Simple!

Service Provider Multihoming: Some Strategies

- Take the prefixes you need to aid traffic engineering
  - Look at NetFlow data for popular sites
- Prefixes originated by your immediate neighbours and their neighbours will do more to aid load balancing than prefixes from ASNs many hops away
  - Concentrate on local destinations
- Use default routing as much as possible
  - Or use the full routing table with care

Service Provider Multihoming

- Examples
  - One upstream, one local peer
  - One upstream, local exchange point
  - Two upstreams, one local peer
  - Three upstreams, unequal link bandwidths
- Require BGP and a public ASN
- Examples assume that the local network has their own /19 address block

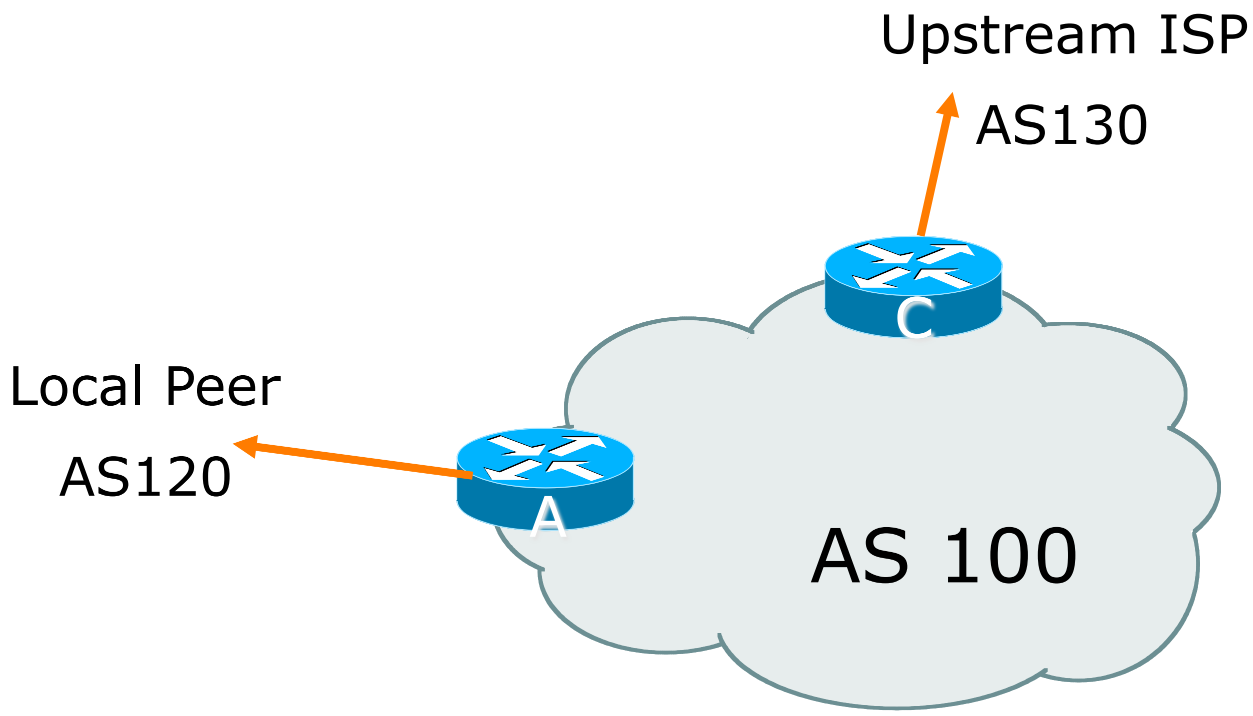
Service Provider Multihoming

One upstream, one local peer

One Upstream, One Local Peer

- Very common situation in many regions of the Internet
- Connect to upstream transit provider to see the "Internet"
- Connect to the local competition so that local traffic stays local
  - Saves spending valuable $ on upstream transit costs for local traffic

One Upstream, One Local Peer



One Upstream, One Local Peer

- Announce /19 aggregate on each link
- Accept default route only from upstream
  - Either 0.0.0.0/0 or a network which can be used as default
- Accept all routes the local peer originates

One Upstream, One Local Peer

- Router A Configuration

Prefix filters inbound

```
router bgp 100
 address-family ipv4
  network 100.64.0.0 mask 255.255.224.0
  neighbor 100.66.10.2 remote-as 120
  neighbor 100.66.10.2 prefix-list my-block out
  neighbor 100.66.10.2 prefix-list AS120-peer in
  neighbor 100.66.10.2 activate
!
ip prefix-list AS120-peer permit 122.5.16.0/19
ip prefix-list AS120-peer permit 121.240.0.0/20
!
ip prefix-list my-block permit 100.64.0.0/19
!
ip route 100.64.0.0 255.255.224.0 null0 250
```

One Upstream, One Local Peer

- Router A – Alternative Configuration

```
router bgp 100
 address-family ipv4
  network 100.64.0.0 mask 255.255.224.0
  neighbor 100.66.10.2 remote-as 120
  neighbor 100.66.10.2 prefix-list my-block out
  neighbor 100.66.10.2 filter-list 10 in
  neighbor 100.66.10.2 activate
!
ip as-path access-list 10 permit ^(120_)+$
!
ip prefix-list my-block permit 100.64.0.0/19
!
ip route 100.64.0.0 255.255.224.0 null0
```

AS Path filters – more “trusting”

One Upstream, One Local Peer

- Router C Configuration

```
router bgp 100
 address-family ipv4
  network 100.64.0.0 mask 255.255.224.0
  neighbor 100.66.10.1 remote-as 130
  neighbor 100.66.10.1 prefix-list default in
  neighbor 100.66.10.1 prefix-list my-block out
  neighbor 100.66.10.1 activate
!
ip prefix-list my-block permit 100.64.0.0/19
ip prefix-list default permit 0.0.0.0/0
!
ip route 100.64.0.0 255.255.224.0 null0
```

One Upstream, One Local Peer

- Two configurations possible for Router A
  - Filter-lists assume peer knows what they are doing
  - Prefix-list higher maintenance, but safer
  - Some ISPs use both
- Local traffic goes to and from local peer, everything else goes to upstream

Aside: Configuration Recommendations

- Private Peers
  - The peering ISPs exchange prefixes they originate
  - Sometimes they exchange prefixes from neighbouring ASNs too
- Be aware that the private peer eBGP router should carry only the prefixes you want the private peer to receive
  - Otherwise they could point a default route to you and unintentionally transit your backbone

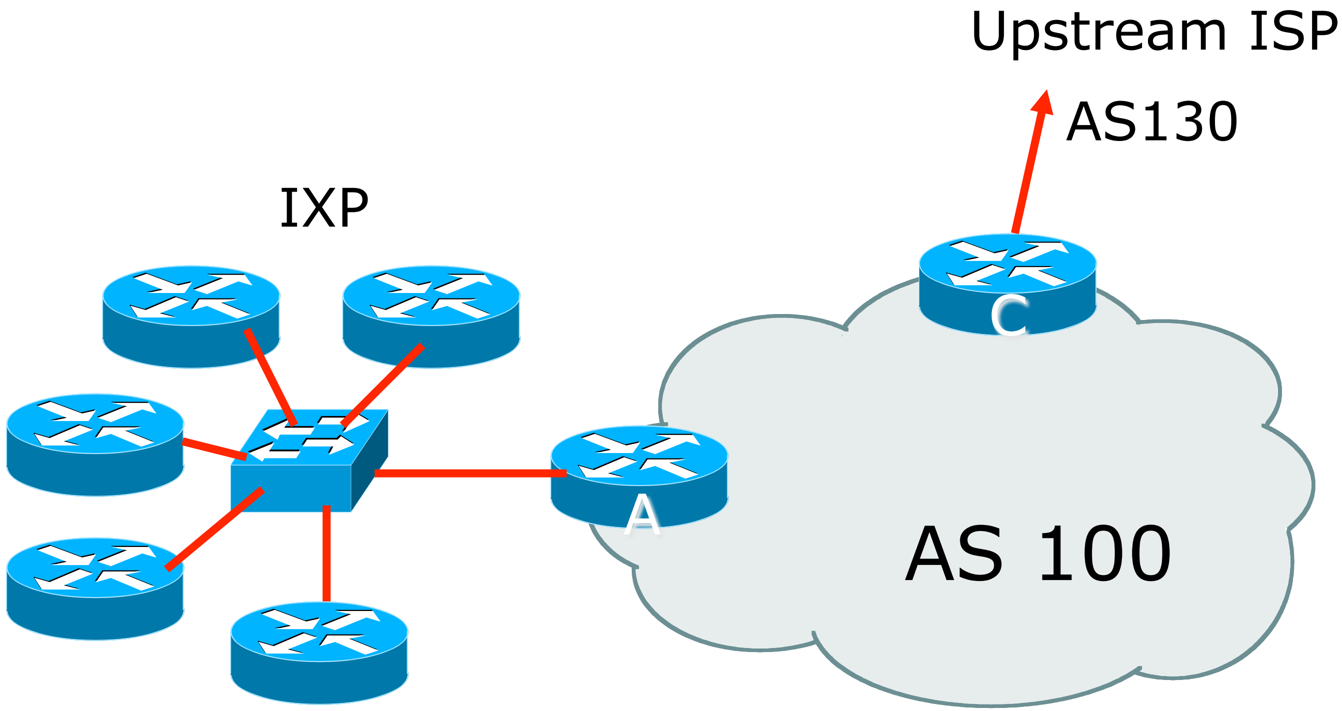
Service Provider Multihoming

One upstream, Local Exchange Point

One Upstream, Local Exchange Point

- Very common situation in many regions of the Internet
- Connect to upstream transit provider to see the "Internet"
- Connect to the local Internet Exchange Point so that local traffic stays local
  - Saves spending valuable $ on upstream transit costs for local traffic
- This example is a scaled up version of the previous one

One Upstream, Local Exchange Point



One Upstream, Local Exchange Point

- Announce /19 aggregate to every neighbouring AS
- Accept default route only from upstream
  - Either 0.0.0.0/0 or a network which can be used as default
- Accept all routes originated by IXP peers

One Upstream, Local Exchange Point

- Router A Configuration

```
interface fastethernet 0/0
 description Exchange Point LAN
 ip address 100.67.10.1 mask 255.255.255.224
!
router bgp 100
 address-family ipv4
  neighbor ixp-peers peer-group
  neighbor ixp-peers prefix-list my-block out
  neighbor ixp-peers remove-private-AS
  neighbor ixp-peers send-community
  neighbor ixp-peers route-map set-local-pref in
!
```

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One Upstream, Local Exchange Point

```
neighbor 100.67.10.2 remote-as 200
neighbor 100.67.10.2 peer-group ixp-peers
neighbor 100.67.10.2 prefix-list peer200 in
neighbor 100.67.10.2 activate
neighbor 100.67.10.3 remote-as 201
neighbor 100.67.10.3 peer-group ixp-peers
neighbor 100.67.10.3 prefix-list peer201 in
neighbor 100.67.10.3 activate
neighbor 100.67.10.4 remote-as 202
neighbor 100.67.10.4 peer-group ixp-peers
neighbor 100.67.10.4 prefix-list peer202 in
neighbor 100.67.10.4 activate
neighbor 100.67.10.5 remote-as 203
neighbor 100.67.10.5 peer-group ixp-peers
neighbor 100.67.10.5 prefix-list peer203 in
neighbor 100.67.10.5 activate
```

...next slide

One Upstream, Local Exchange Point

```
!
ip prefix-list my-block permit 100.64.0.0/19
ip prefix-list peer200 permit 100.65.0.0/19
ip prefix-list peer201 permit 100.66.0.0/19
ip prefix-list peer202 permit 100.67.0.0/19
ip prefix-list peer203 permit 100.68.128.0/19
!
route-map set-local-pref permit 10
 set local-preference 150
!
```

One Upstream, Local Exchange

- Note that Router A does not generate the aggregate for AS100
  - If Router A becomes disconnected from backbone, then the aggregate is no longer announced to the IX
  - BGP failover works as expected
- Note the inbound route-map which sets the local preference higher than the default
  - This is a visual reminder that BGP Best Path for local traffic will be across the IXP
  - (And allows for future case where operator may need to take BGP routes from their upstream(s))

One Upstream, Local Exchange Point

- Router C Configuration

```
router bgp 100
 address-family ipv4
  network 100.64.0.0 mask 255.255.224.0
  neighbor 100.66.10.1 remote-as 130
  neighbor 100.66.10.1 prefix-list default in
  neighbor 100.66.10.1 prefix-list my-block out
  neighbor 100.66.10.1 activate
!
ip prefix-list my-block permit 100.64.0.0/19
ip prefix-list default permit 0.0.0.0/0
!
ip route 100.64.0.0 255.255.224.0 null0
```

One Upstream, Local Exchange Point

- Note Router A configuration
  - Prefix-list higher maintenance, but safer
  - No generation of AS100 aggregate
- IXP traffic goes to and from local IXP, everything else goes to upstream

Aside: IXP Configuration Recommendations

- IXP peers
  - The peering ISPs at the IXP exchange prefixes they originate
  - Sometimes they exchange prefixes from neighbouring ASNs too
- Be aware that the IXP border router should carry only the prefixes you want the IXP peers to receive and the destinations you want them to be able to reach
  - Otherwise they could point a default route to you and unintentionally transit your backbone
- If IXP router is at IX, and distant from your backbone
  - Don’t originate your address block at your IXP router

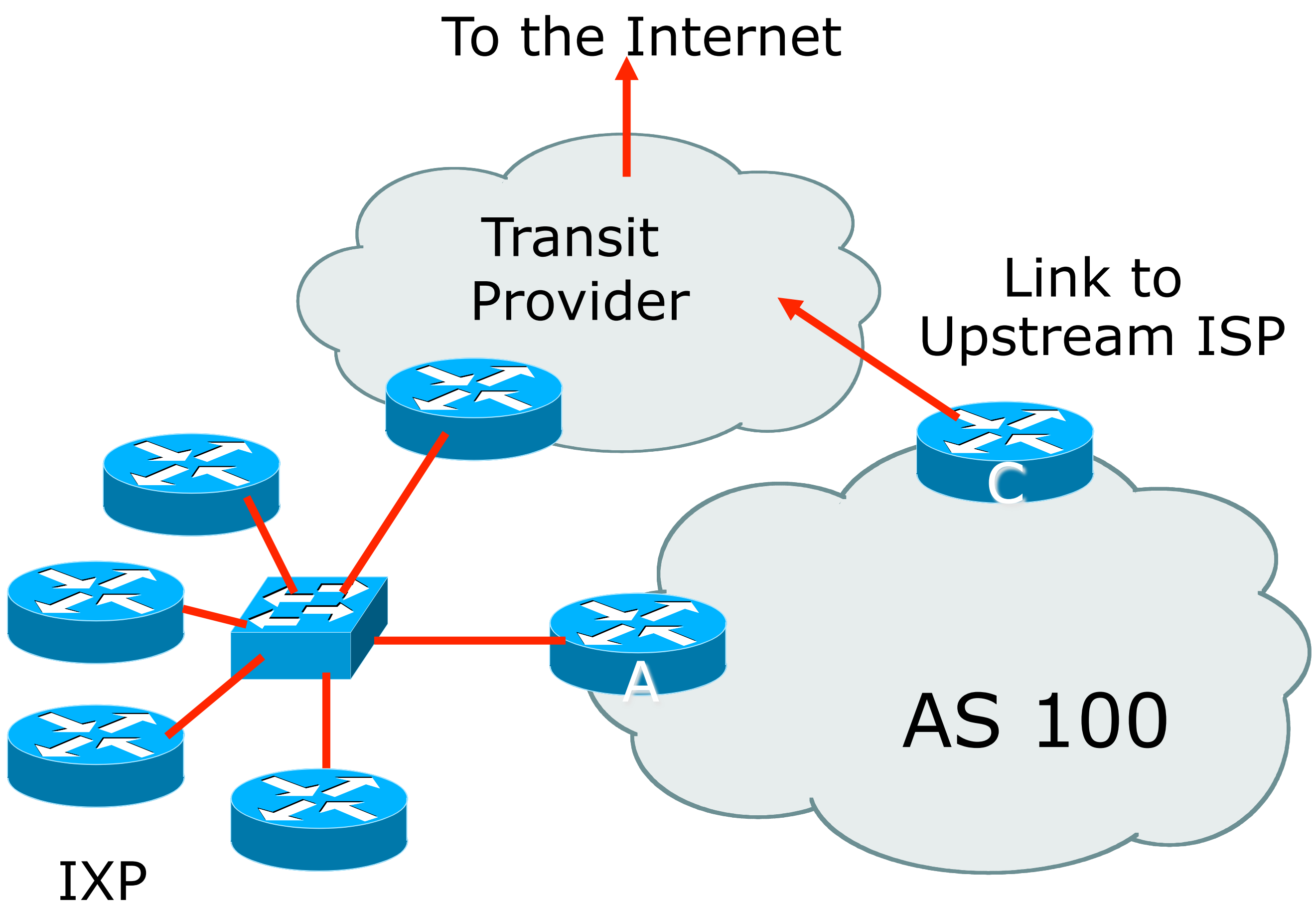
Service Provider Multihoming

Local Exchange Point, with Upstream also being a Peer

Local Exchange Point, with Upstream also being Peer

- Quite a common situation
  - Several local ISPs providing access to the local market
  - One or two licensed international transit providers
  - Licensed transits also peer at the IXP
- How to ensure that:
  - Transit traffic goes on transit link
  - Peering traffic goes on peering link

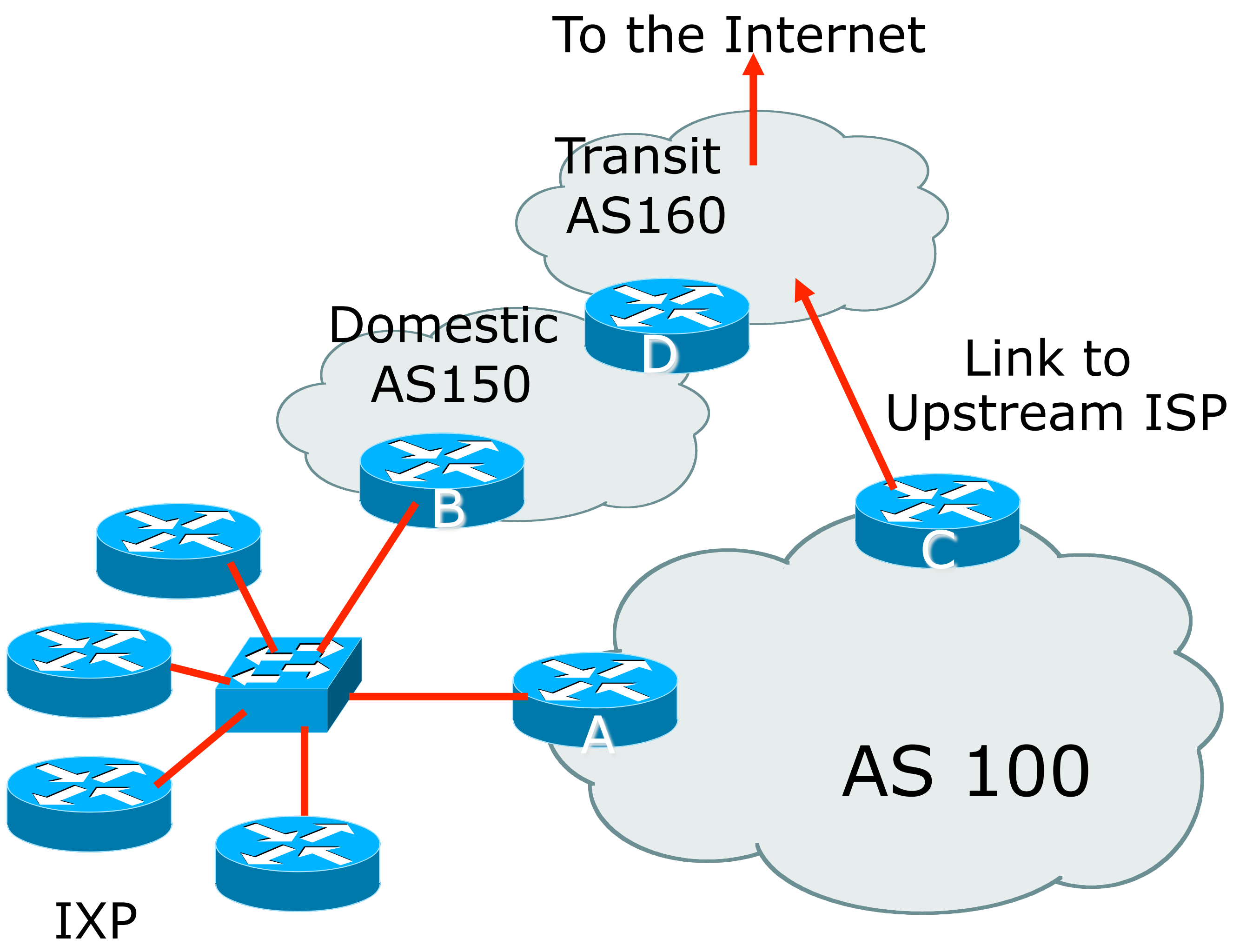
Local Exchange Point, with Upstream also being Peer



Local Exchange Point, with Upstream also being Peer

- Outbound traffic from AS100:
  - Upstream sends full BGP table to AS100
  - Upstream sends domestic routes to IXP peers
  - AS100 uses IXP for domestic traffic
  - AS100 uses Upstream link for international traffic
- Inbound traffic to AS100:
  - AS100 sends address block to IXP peers
  - AS100 sends address block to upstream
  - Best path from upstream to AS100 preferred via the IXP (see previous scenario)
- Problem: how to separate international and domestic inbound traffic?

Solution: AS Separation



Solution: AS Separation

- The transit provider needs to separate their network into domestic (AS150: local routes) and transit (AS160: international routes)
- Transit customers connect to transit AS (AS160)
- Domestic AS (AS150) peers at the IX, passing domestic routes only
- Inbound traffic to AS100 now:
  - AS100 sends address block to IXP peers (including AS150)
  - AS100 sends address block to upstream (AS160)
  - Important: Router D does NOT pass prefixes learned from IX peers to AS160
  - Best path from upstream to AS100 preferred via the transit link

Local Exchange Point, with Upstream also being Peer

- Transit providers who peer with their customers at an IX for local routes need to split their ASNs into two:
  - One AS for domestic business/domestic routes
  - One AS for international transit routes
- Two ASNs are justifiable from the RIRs because the two ASNs have completely different routing policies
  - Domestic AS peers at IXP
  - Transit AS connects transit customers and upstreams

Local Exchange Point, with Upstream also being Peer

- This solution is much easier to implement than other solutions such as complex source address policy routing
- Remember:
  - An Autonomous System is used for representing a distinct routing policy
  - An Autonomous System doesn’t necessarily map onto an organisation
  - A transit business WILL have different routing policy from an access business or a hosting business, and therefore will quite likely have a different ASN

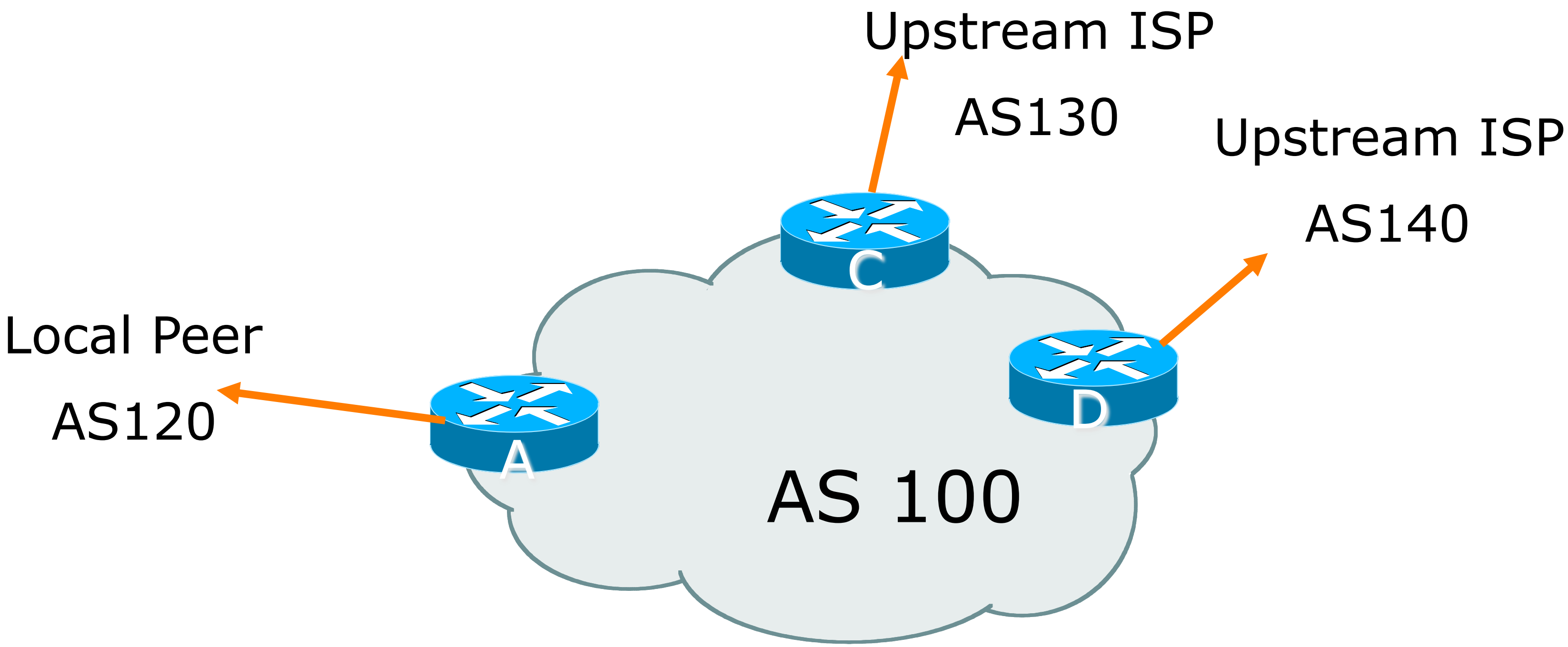
Service Provider Multihoming

Two upstreams, one local peer

Two Upstreams, One Local Peer

- Connect to both upstream transit providers to see the "Internet"
  - Provides external redundancy and diversity – the reason to multihome
- Connect to the local peer so that local traffic stays local
  - Saves spending valuable $ on upstream transit costs for local traffic

Two Upstreams, One Local Peer



Two Upstreams, One Local Peer

- Announce /19 aggregate on each link
- Accept default route only from upstreams
  - Either 0.0.0.0/0 or a network which can be used as default
- Accept all routes originated by local peer
- Note separation of Router C and D
  - Single edge router means no redundancy
- Router A
  - Same routing configuration as in example with one upstream and one local peer

Two Upstreams, One Local Peer

- Router C Configuration

```
router bgp 100
 address-family ipv4
  network 100.64.0.0 mask 255.255.224.0
  neighbor 100.66.10.1 remote-as 130
  neighbor 100.66.10.1 prefix-list default in
  neighbor 100.66.10.1 prefix-list my-block out
  neighbor 100.66.10.1 activate
!
ip prefix-list my-block permit 100.64.0.0/19
ip prefix-list default permit 0.0.0.0/0
!
ip route 100.64.0.0 255.255.224.0 null0
```

Two Upstreams, One Local Peer

- Router D Configuration

```
router bgp 100
 address-family ipv4
  network 100.64.0.0 mask 255.255.224.0
  neighbor 100.66.10.5 remote-as 140
  neighbor 100.66.10.5 prefix-list default in
  neighbor 100.66.10.5 prefix-list my-block out
  neighbor 100.66.10.5 activate
!
ip prefix-list my-block permit 100.64.0.0/19
ip prefix-list default permit 0.0.0.0/0
!
ip route 100.64.0.0 255.255.224.0 null0
```

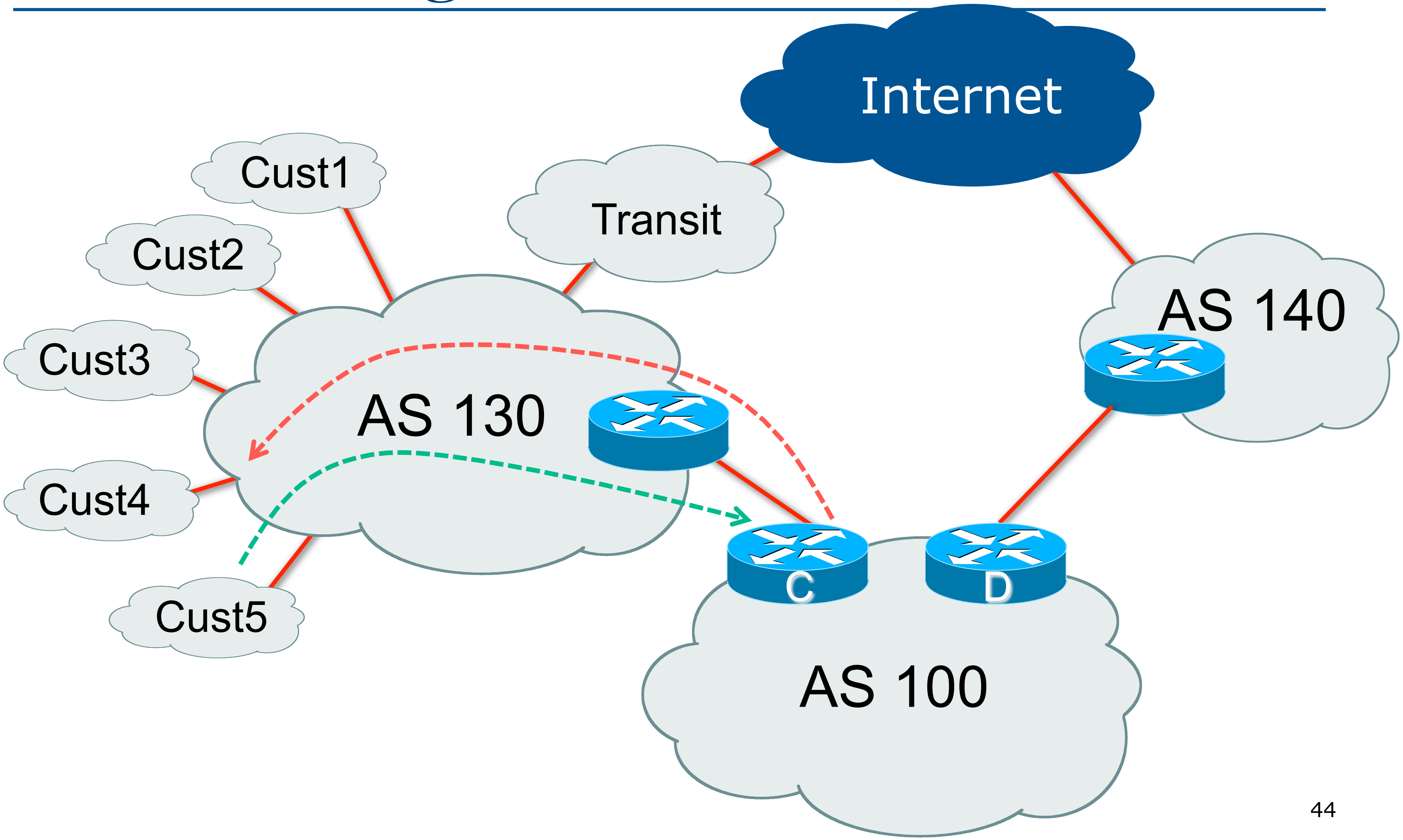
Two Upstreams, One Local Peer

- This is the simple configuration for Router C and D
- Traffic out to the two upstreams will take nearest exit
  - Inexpensive routers required
  - This is not useful in practice especially for international links
  - Loadsharing needs to be better

Two Upstreams, One Local Peer

- Better configuration options:
  - Accept full routing from both upstreams
    - **Expensive & unnecessary!**
  - Accept default from one upstream and some routes from the other upstream
    - **The way to go!**

Loadsharing with different ISPs



Two Upstreams, One Local Peer Full Routes

- Router C Configuration

```
router bgp 100
 address-family ipv4
  network 100.64.0.0 mask 255.255.224.0
  neighbor 100.66.10.1 remote-as 130
  neighbor 100.66.10.1 prefix-list rfc6890-deny in
  neighbor 100.66.10.1 prefix-list my-block out
  neighbor 100.66.10.1 route-map AS130-loadshare in
  neighbor 100.66.10.1 activate
!
ip prefix-list my-block permit 100.64.0.0/19
!
! See http://tools.ietf.org/html/rfc6890

...next slide
```

Allow all prefixes apart from RFC6890 blocks

Two Upstreams, One Local Peer
Full Routes

```
ip route 100.64.0.0 255.255.224.0 null0
!
ip as-path access-list 10 permit ^(130_)+$
ip as-path access-list 10 permit ^(130_)+_[0-9]+$
!
route-map AS130-loadshare permit 10
 match ip as-path 10
 set local-preference 120
!
route-map AS130-loadshare permit 20
 set local-preference 80
!
```

Two Upstreams, One Local Peer Full Routes

- Router D Configuration

```
router bgp 100
 address-family ipv4
  network 100.64.0.0 mask 255.255.224.0
  neighbor 100.66.10.5 remote-as 140
  neighbor 100.66.10.5 prefix-list rfc6890-deny in
  neighbor 100.66.10.5 prefix-list my-block out
  neighbor 100.66.10.5 activate
!
ip prefix-list my-block permit 100.64.0.0/19
!
! See http://tools.ietf.org/html/rfc6890
```

Allow all prefixes apart from RFC6890 blocks

Two Upstreams, One Local Peer
Full Routes

- Router C configuration:
  - Accept full routes from AS130
  - Tag prefixes originated by AS130 and AS130's neighbouring ASes with local preference 120
    - Traffic to those ASes will go over AS130 link
  - Remaining prefixes tagged with local preference of 80
    - Traffic to other all other ASes will go over the link to AS140
- Router D configuration same as Router C without the route-map

Two Upstreams, One Local Peer Full Routes

- Full routes from upstreams
  - Summary of routes received:

ASN	Full Routes		Partial Routes
AS140	650000	@lp 100	
AS130	30000 620000	@lp 120 @lp 80	
Total	1300000		

Two Upstreams, One Local Peer Full Routes

- Full routes from upstreams
  - Expensive – needs lots of memory and CPU
  - Need to play preference games
  - Previous example is only an example – real life will need improved fine-tuning!
  - Previous example doesn't consider inbound traffic – see earlier in presentation for examples

Two Upstreams, One Local Peer Partial Routes: Strategy

- Ask one upstream for a default route
  - Easy to originate default towards a BGP neighbour
- Ask other upstream for a full routing table
  - Then filter this routing table based on neighbouring ASN
  - E.g. want traffic to their neighbours to go over the link to that ASN
  - Most of what upstream sends is thrown away
  - Easier than asking the upstream to set up custom BGP filters for you

Two Upstreams, One Local Peer
Partial Routes

- Router C Configuration

```
router bgp 100
 address-family ipv4
  network 100.64.0.0 mask 255.255.224.0
  neighbor 100.66.10.1 remote-as 130
  neighbor 100.66.10.1 prefix-list rfc6890-deny in
  neighbor 100.66.10.1 prefix-list my-block out
  neighbor 100.66.10.1 filter-list 10 in
  neighbor 100.66.10.1 route-map tag-default-low in
  neighbor 100.66.10.1 activate
!
```

Allow all prefixes apart from RFC6890 blocks

AS filter list filters prefixes based on origin ASN

Two Upstreams, One Local Peer
Partial Routes

```
ip prefix-list my-block permit 100.64.0.0/19
ip prefix-list default permit 0.0.0.0/0
!
ip route 100.64.0.0 255.255.224.0 null0
!
ip as-path access-list 10 permit ^(130_)+$
ip as-path access-list 10 permit ^(130_)+_[0-9]+$
!
route-map tag-default-low permit 10
 match ip address prefix-list default
 set local-preference 80
!
route-map tag-default-low permit 20
!
```

Two Upstreams, One Local Peer Partial Routes

- Router D Configuration

```
router bgp 100
 address-family ipv4
  network 100.64.0.0 mask 255.255.224.0
  neighbor 100.66.10.5 remote-as 140
  neighbor 100.66.10.5 prefix-list default in
  neighbor 100.66.10.5 prefix-list my-block out
  neighbor 100.66.10.5 activate
!
ip prefix-list my-block permit 100.64.0.0/19
ip prefix-list default permit 0.0.0.0/0
!
ip route 100.64.0.0 255.255.224.0 null0
```

Two Upstreams, One Local Peer Partial Routes

- Router C configuration:
  - Accept full routes from AS130
    - (or get them to send less)
  - Filter ASNs so only AS130 and AS130's neighbouring ASes are accepted
  - Allow default, and set it to local preference 80
  - Traffic to those ASes will go over AS130 link
  - Traffic to other all other ASes will go over the link to AS140
  - If AS140 link fails, backup via AS130 – and vice-versa

Two Upstreams, One Local Peer Partial Routes

- Partial routes from upstreams
  - Summary of routes received:

ASN	Full Routes		Partial Routes	
AS140	650000	@lp 100	1	@lp 100
AS130	30000 620000	@lp 120 @lp 80	30000 1	@lp 100 @lp 80
Total	1300000		30002	

Distributing Default route with IGP

- Router C IGP Configuration

```
router ospf 100
default-information originate metric 30
!
```

- Router D IGP Configuration

```
router ospf 100
default-information originate metric 10
!
```

- Primary path is via Router D, with backup via Router C
  - Preferred over carrying default route in iBGP

Two Upstreams, One Local Peer Partial Routes

- Partial routes from upstreams
  - Not expensive – only carry the routes necessary for loadsharing
  - Need to filter on AS paths
  - Previous example is only an example – real life will need improved fine-tuning!
  - Previous example doesn't consider inbound traffic – see earlier in presentation for examples

Aside: Configuration Recommendation

- When distributing internal default by iBGP or OSPF/ISIS
  - Make sure that routers connecting to private peers or to IXPs do **NOT** carry the default route
  - Otherwise they could point a default route to you and unintentionally transit your backbone
  - Simple fix for Private Peer/IXP routers:

```
ip route 0.0.0.0 0.0.0.0 null0
ipv6 route ::/0 null0
```

Service Provider Multihoming

Three upstreams, unequal bandwidths

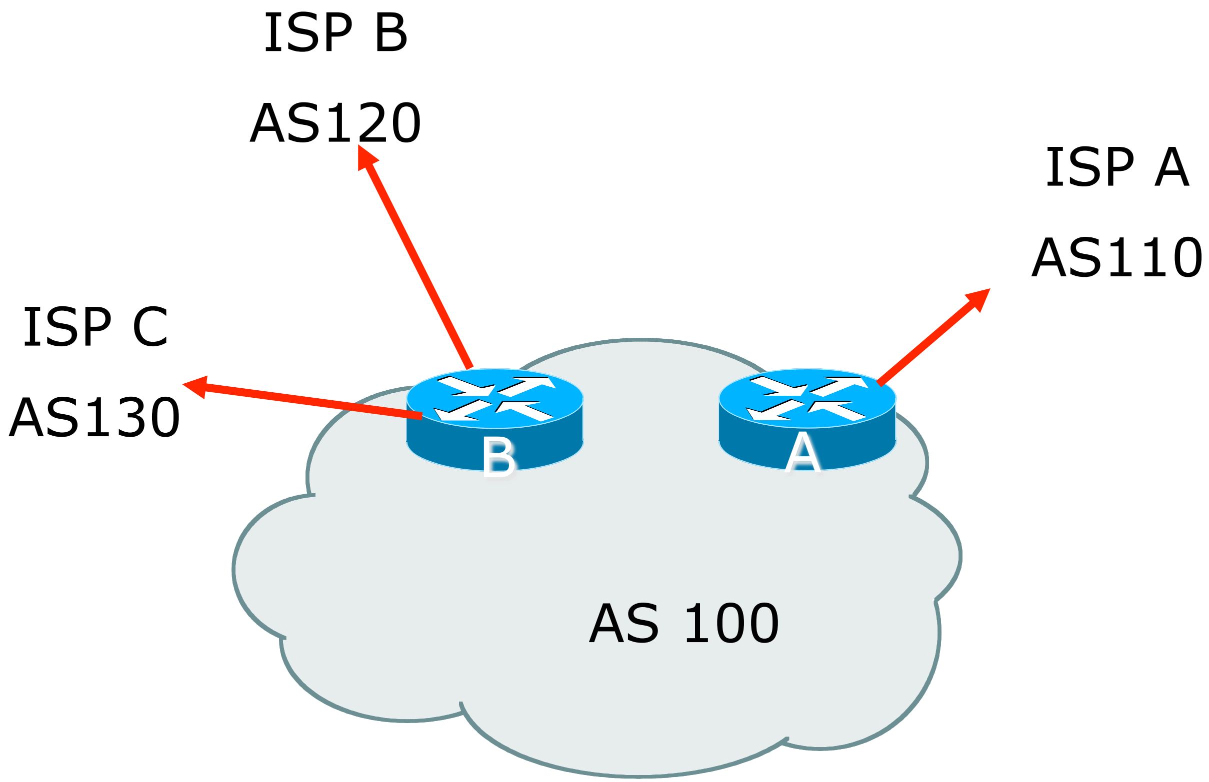
Three upstreams, unequal bandwidths

- This example based on real life complex 3-upstream configuration
- Autonomous System has three upstreams
  - 2.5Gbps to ISP A
  - 1Gbps to ISP B
  - 622Mbps to ISP C
- What is the strategy here?
  - One option is full table from each
    - 3x 650k prefixes ⇒ 1950k paths
  - Other option is partial table and defaults from each
    - How??

Strategy

- Two external routers (gives router redundancy)
  - Do NOT need three routers for this
- Connect biggest bandwidth to one router
  - Most of inbound and outbound traffic will go here
- Connect the other two links to the second router
  - Provides maximum backup capacity if primary link fails
- Use the biggest link as default
  - Most of the inbound and outbound traffic will go here
- Do the traffic engineering on the two smaller links
  - Focus on regional traffic needs

Diagram



- Router A has 2.5Gbps link to ISP A
- Router B has 1Gbps and 622Mbps links to ISPs B&C

Outbound load-balancing strategy

- Available BGP feeds from Transit providers:
  - Full table
  - Customer prefixes and default
  - Default Route
- These are the common options on Internet today
  - Very rare for any provider to offer anything different
  - Very rare for any provider to customise BGP feed for a customer

Outbound load-balancing strategy

- Accept only a default route from the provider with the **largest** connectivity, ISP A
  - Because most of the traffic is going to use this link
- If ISP A won't provide a default:
  - Still run BGP with them, but discard all prefixes
  - Point static default route to the upstream link
  - Distribute the default in the IGP
- Request the full table from ISP B & C
  - Most of this will be thrown away
  - ("Default plus customers" is not enough)

Outbound load-balancing strategy

- How to decide what to keep and what to discard from ISPs B & C?
  - Most traffic will use ISP A link — so we need to find a good/useful subset
- Discard prefixes transiting the global transit ISPs
  - Global transit ISPs generally appear in most non-local or regional AS-PATHs
- Discard prefixes with ISP A's ASN in the path
  - Makes more sense for traffic to those destinations to go via the link to ISP A

Outbound load-balancing strategy

- Global Transit (Tier-1) ISPs at the time of this exercise included:

209	CenturyLink	(Qwest)
701	VerizonBusiness	(UUNET)
1229	TeliaSonera	(Telia)
1239	Softbank	(Sprint)
1668	AOL TDN	
2914	NTT America	(NTT/Verio)
3549	Level 3	(GlobalCrossing)
3356	Level 3	
3561	CenturyLink	(Savvis, ex C&W)
7018	AT&T	

ISP B peering Inbound AS-PATH filter

```
ip as-path access-list 1 deny _209_
ip as-path access-list 1 deny _701_
ip as-path access-list 1 deny _1239_
ip as-path access-list 1 deny _3356_
ip as-path access-list 1 deny _3549_
ip as-path access-list 1 deny _3561_
ip as-path access-list 1 deny _2914_
ip as-path access-list 1 deny _7018_
!
ip as-path access-list 1 deny _ISPA_
ip as-path access-list 1 deny _ISPC_
!
ip as-path access-list 1 permit _ISPB$
ip as-path access-list 1 permit _ISPB_[0-9]+$
ip as-path access-list 1 permit _ISPB_[0-9]+_[0-9]+$
ip as-path access-list 1 permit _ISPB_[0-9]+_[0-9]+_[0-9]+$
ip as-path access-list 1 deny   .*
```

Don't need ISPA and ISPC prefixes via ISPB

Outbound load-balancing strategy: ISP B peering configuration

- Part 1: Dropping Global Transit ISP prefixes
  - This can be fine-tuned if traffic volume is not sufficient
  - (More prefixes in = more traffic out)
- Part 2: Dropping prefixes transiting ISP A & C network
- Part 3: Permitting prefixes from ISP B, their BGP neighbours, and their neighbours, and their neighbours
  - More AS_PATH permit clauses, the more prefixes allowed in, the more egress traffic
  - Too many prefixes in will mean more outbound traffic than the link to ISP B can handle

Outbound load-balancing strategy

- Similar AS-PATH filter can be built for the ISP C BGP peering
- If the same prefixes are heard from both ISP B and C, then establish proximity of their origin ASN to ISP B or C
  - e.g. ISP B might be in Japan, with the neighbouring ASN in Europe, yet ISP C might be in Europe
  - Transit to the ASN via ISP C makes more sense in this case

Inbound load-balancing strategy

- The largest outbound link should announce just the aggregate
- The other links should announce:
  a) The aggregate with AS-PATH prepend
  b) Subprefixes of the aggregate, chosen according to traffic volumes to those subprefixes, and according to the services on those subprefixes
- Example:
  - Link to ISP B could be used just for Broadband/Dial customers — so number all such customers out of one contiguous subprefix
  - Link to ISP C could be used just for commercial leased line customers — so number all such customers out of one contiguous subprefix

Router A: eBGP Configuration Example

```
router bgp 100
 address-family ipv4
  network 100.64.0.0 mask 255.255.224.0
  neighbor 100.66.10.1 remote 110
  neighbor 100.66.10.1 prefix-list default in
  neighbor 100.66.10.1 prefix-list aggregate out
  neighbor 100.66.10.1 activate
!
ip prefix-list default permit 0.0.0.0/0
ip prefix-list aggregate permit 100.64.0.0/19
!
```

Router B: eBGP Configuration Example

```
router bgp 100
 address-family ipv4
  network 100.64.0.0 mask 255.255.224.0
  neighbor 100.66.1.1 remote 120
  neighbor 100.66.1.1 filter-list 1 in
  neighbor 100.66.1.1 prefix-list ISP-B out
  neighbor 100.66.1.1 route-map to-ISP-B out
  neighbor 100.66.1.1 activate
  neighbor 100.67.2.1 remote 130
  neighbor 100.67.2.1 filter-list 2 in
  neighbor 100.67.2.1 prefix-list ISP-C out
  neighbor 100.67.2.1 route-map to-ISP-C out
  neighbor 100.67.2.1 activate
!
ip prefix-list aggregate permit 100.64.0.0/19
!
```

…next slide

Router B: eBGP Configuration Example

```
ip prefix-list ISP-B permit 100.64.0.0/19
ip prefix-list ISP-B permit 100.64.0.0/21
!
ip prefix-list ISP-C permit 100.64.0.0/19
ip prefix-list ISP-C permit 100.64.28.0/22
!
route-map to-ISP-B permit 10
 match ip address prefix-list aggregate
 set as-path prepend 100
!
route-map to-ISP-B permit 20
!
route-map to-ISP-C permit 10
 match ip address prefix-list aggregate
 set as-path prepend 100 100
!
route-map to-ISP-C permit 20
```

/21 to ISP B "dial customers"

/22 to ISP C "biz customers"

e.g. Single prepend on ISP B link

e.g. Dual prepend on ISP C link

What about outbound backup?

- We have:
  - Default route from ISP A by eBGP
  - Mostly discarded full table from ISPs B&C
- Strategy:
  - Originate default route by OSPF on Router A (with metric 10) — link to ISP A
  - Originate default route by OSPF on Router B (with metric 30) — links to ISPs B & C
  - Plus on Router B:
    - Static default route to ISP B with distance 240
    - Static default route to ISP C with distance 245
  - When link goes down, static route is withdrawn

Outbound backup: steady state

- Steady state (all links up and active):
  - Default route is to Router A — OSPF metric 10
  - (Because default learned by eBGP ⇒ default is in RIB ⇒ OSPF will originate default)
  - Backup default is to Router B — OSPF metric 20
  - eBGP prefixes learned from upstreams distributed by iBGP throughout backbone
  - (Default can be filtered in iBGP to avoid “RIB failure error”)

Outbound backup: failure examples

- Link to ISP A down, to ISPs B&C up:
  - Default route is to Router B — OSPF metric 20
  - (eBGP default gone from RIB, so OSPF on Router A withdraws the default)
- Above is true if link to B or C is down as well
- Link to ISPs B & C down, link to ISP A is up:
  - Default route is to Router A — OSPF metric 10
  - (static defaults on Router B removed from RIB, so OSPF on Router B withdraws the default)

Other considerations

- Default route should not be propagated to devices terminating non-transit peers and customers
- Rarely any need to carry default in iBGP
  - Best to filter out default in iBGP mesh peerings
- Still carry other eBGP prefixes across iBGP mesh
  - Otherwise routers will follow default route rules resulting in suboptimal traffic flow
  - Not a big issue because not carrying full table

Router A: iBGP Configuration Example

```
router bgp 100
 address-family ipv4
  network 100.64.0.0 mask 255.255.224.0
  neighbor ibgp-peers peer-group
  neighbor ibgp-peers remote-as 100
  neighbor ibgp-peers prefix-list ibgp-filter out
  neighbor 100.64.0.2 peer-group ibgp-peers
  neighbor 100.64.0.2 activate
  neighbor 100.64.0.3 peer-group ibgp-peers
  neighbor 100.64.0.3 activate
!
ip prefix-list ibgp-filter deny 0.0.0.0/0
ip prefix-list ibgp-filter permit 0.0.0.0/0 le 32
!
```

Three upstreams, unequal bandwidths: Summary

- Example based on many deployed working multihoming/loadbalancing topologies
- Many variations possible — this one is:
  - Easy to tune
  - Light on border router resources
  - Light on backbone router infrastructure
  - Sparse BGP table ⇒ faster convergence

Service Provider Multihoming

ISP Workshops