BGP Multihoming Techniques

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Presentation Slides

- Available on

    ftp://ftp-eng.cisco.com

    /pfs/seminars/APRICOT2009-Multihoming.pdf

    And on the APRICOT2009 website

- Feel free to ask questions any time

Preliminaries

- Presentation has many configuration examples

    Uses Cisco IOS CLI

- Aimed at Service Providers

    Techniques can be used by many enterprises too

BGP Multihoming Techniques

- **Why Multihome?**

- Definition & Options

- Preparing the Network

- Basic Multihoming

- Service Provider Multihoming

Why Multihome?

It's all about redundancy, diversity & reliability

Why Multihome?

- Redundancy

  One connection to internet means the network is dependent on:

  Local router (configuration, software, hardware)

  WAN media (physical failure, carrier failure)

  Upstream Service Provider (configuration, software, hardware)

Why Multihome?

- Reliability

  Business critical applications demand continuous availability

  Lack of redundancy implies lack of reliability implies loss of revenue

Why Multihome?

- Supplier Diversity

    Many businesses demand supplier diversity as a matter of course

    Internet connection from two or more suppliers

    With two or more diverse WAN paths

    With two or more exit points

    With two or more international connections

    Two of everything

Why Multihome?

- Not really a reason, but oft quoted…

- Leverage:

    Playing one ISP off against the other for:

    Service Quality

    Service Offerings

    Availability

Why Multihome?

- Summary:

    Multihoming is easy to demand as requirement for any service provider or end-site network

    But what does it really mean:

    In real life?

    For the network?

    For the Internet?

    And how do we do it?

BGP Multihoming Techniques

- Why Multihome?

- **Definition & Options**

- Preparing the Network

- Basic Multihoming

- Service Provider Multihoming

Multihoming: Definitions & Options

What does it mean, what do we need, and how do we do it?

Multihoming Definition

- More than one link external to the local network

    two or more links to the same ISP

    two or more links to different ISPs

- Usually **two** external facing routers

    one router gives link and provider redundancy only

Autonomous System Number (ASN)

- Two ranges

0-65535	(original 16-bit range)
65536-4294967295	(32-bit range - RFC4893)

- Usage:

0 and 65535	(reserved)
1-64495	(public Internet)
64496-64511	(documentation - RFC5398)
64512-65534	(private use only)
23456	(represent 32-bit range in 16-bit world)
65536-65551	(documentation - RFC5398)
65552-4294967295	(public Internet)

- 32-bit range representation specified in RFC5396

  Defines "asplain" (traditional format) as standard notation

Autonomous System Number (ASN)

- ASNs are distributed by the Regional Internet Registries

  They are also available from upstream ISPs who are members of one of the RIRs

- Current 16-bit ASN allocations up to 49151 have been made to the RIRs

  Around 30600 are visible on the Internet

- The RIRs also have received 1024 32-bit ASNs each

  18 are visible on the Internet (early adopters)

- See **www.iana.org/assignments/as-numbers**

Private-AS – Application

- Applications

  An ISP with customers multihomed on their backbone (RFC2270)

  -or-

  A corporate network with several regions but connections to the Internet only in the core

  -or-

  Within a BGP Confederation

65001
193.0.32.0/24

65002
193.0.33.0/24

1880
193.0.34.0/24

65003
193.0.35.0/24

C

B

A

193.0.32.0/22 1880
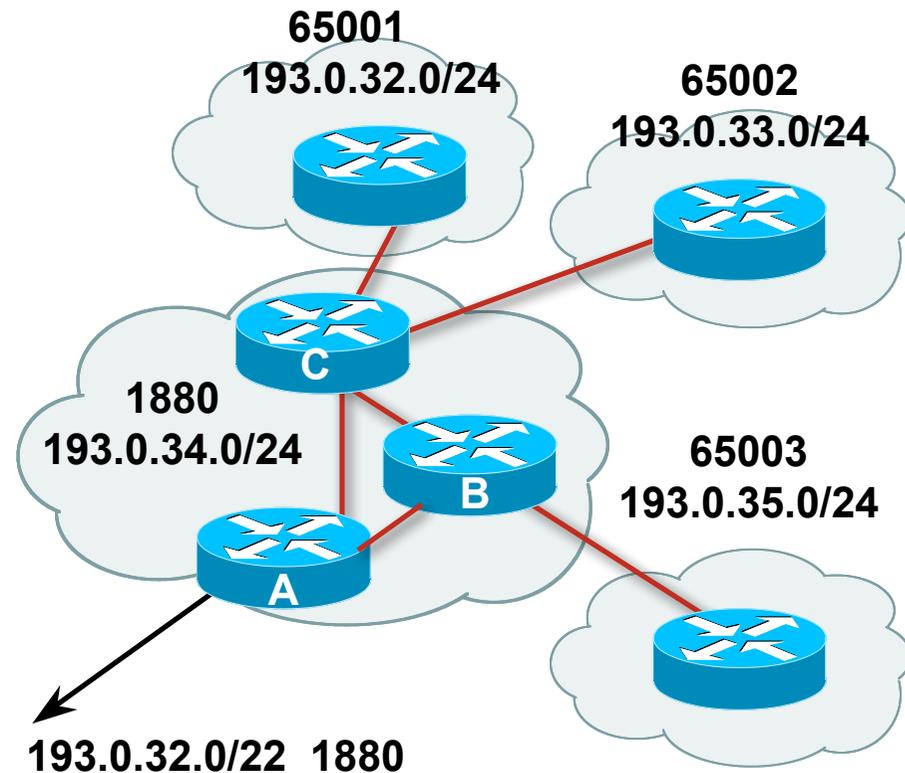
Private-AS – Removal

- Private ASNs MUST be removed from all prefixes announced to the public Internet

    Include configuration to remove private ASNs in the eBGP template

- As with RFC1918 address space, private ASNs are intended for internal use

    They should not be leaked to the public Internet

- Cisco IOS

    ```
    neighbor x.x.x.x remove-private-AS
    ```

Configuring Policy

- Three BASIC Principles for IOS configuration examples throughout presentation:

  prefix-lists to filter prefixes

  filter-lists to filter ASNs

  route-maps to apply policy

- Route-maps can be used for filtering, but this is more "advanced" configuration

Policy Tools

- Local preference

    outbound traffic flows

- Metric (MED)

    inbound traffic flows (local scope)

- AS-PATH prepend

    inbound traffic flows (Internet scope)

- Communities

    specific inter-provider peering

Originating Prefixes: Assumptions

- **MUST** announce assigned address block to Internet

- MAY also announce subprefixes – reachability is not guaranteed

- Current minimum allocation is from /20 to /22 depending on the RIR

  - Several ISPs filter RIR blocks on this boundary

  - Several ISPs filter the rest of address space according to the IANA assignments

  - This activity is called "Net Police" by some

Originating Prefixes

- The RIRs publish their minimum allocation sizes per /8 address block

AfriNIC:	www.afrinic.net/docs/policies/afpol-v4200407-000.htm
APNIC:	www.apnic.net/db/min-alloc.html
ARIN:	www.arin.net/reference/ip_blocks.html
LACNIC:	lacnic.net/en/registro/index.html
RIPE NCC:	www.ripe.net/ripe/docs/smallest-alloc-sizes.html

  Note that AfriNIC only publishes its current minimum allocation size, not the allocation size for its address blocks

- IANA publishes the address space it has assigned to end-sites and allocated to the RIRs:

  www.iana.org/assignments/ipv4-address-space

- Several ISPs use this published information to filter prefixes on:

  What should be routed (from IANA)

  The minimum allocation size from the RIRs

"Net Police" prefix list issues

- Meant to "punish" ISPs who pollute the routing table with specifics rather than announcing aggregates

- Impacts legitimate multihoming especially at the Internet's edge

- Impacts regions where domestic backbone is unavailable or costs $$$ compared with international bandwidth

- Hard to maintain – requires updating when RIRs start allocating from new address blocks

- Don't do it unless consequences understood and you are prepared to keep the list current

    Consider using the Team Cymru or other reputable bogon BGP feed:

    http://www.team-cymru.org/Services/Bogons/routeserver.html

Multihoming Scenarios

- Stub network

- Multi-homed stub network

- Multi-homed network

- Configuration Options

Stub Network

AS100

AS101
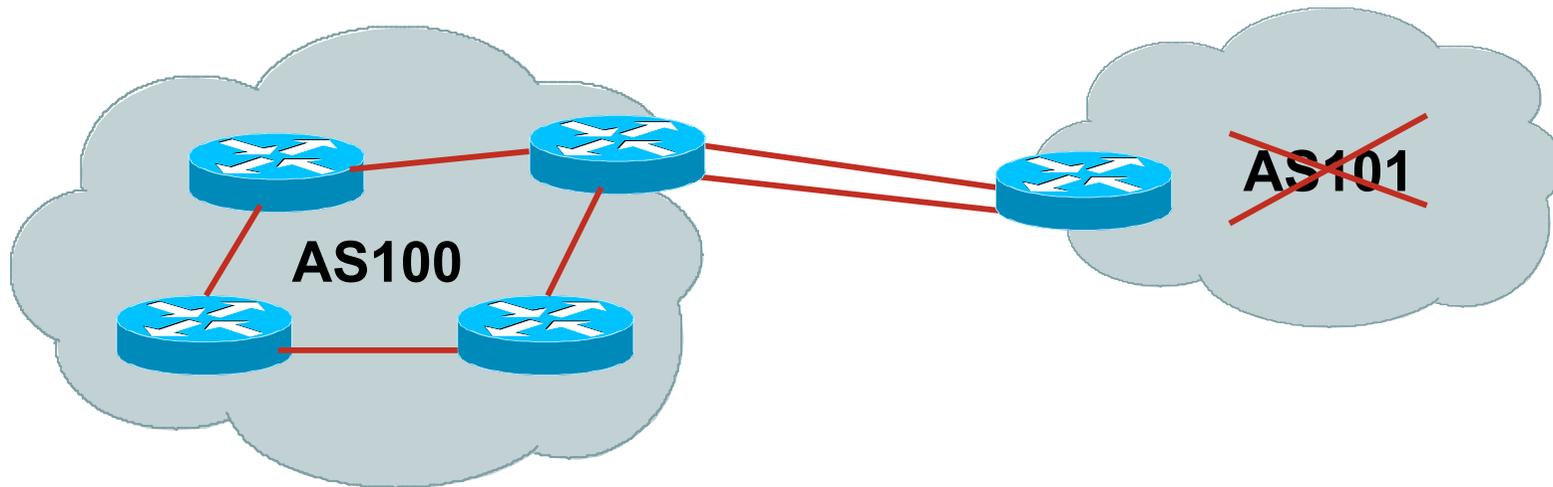
- No need for BGP

- Point static default to upstream ISP

- Upstream ISP advertises stub network

- Policy confined within upstream ISP's policy

Multi-homed Stub Network
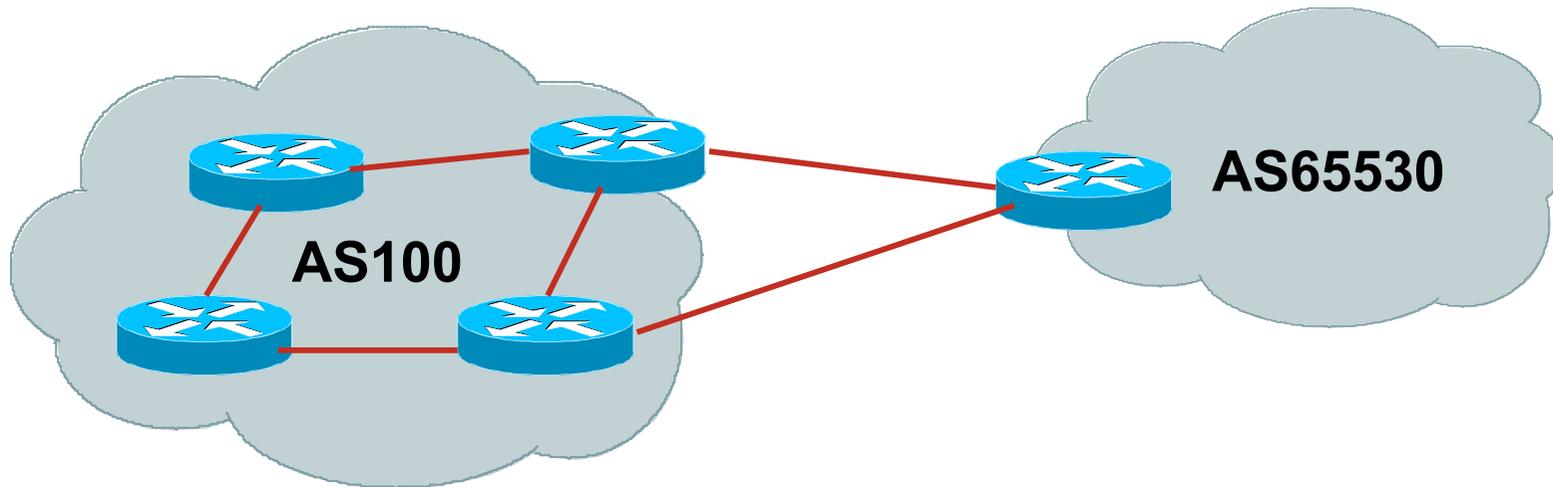
- Use BGP (not IGP or static) to loadshare
- Use private AS (ASN > 64511)
- Upstream ISP advertises stub network
- Policy confined within upstream ISP's policy

Multi-homed Network

Global Internet

AS300

AS200

AS100
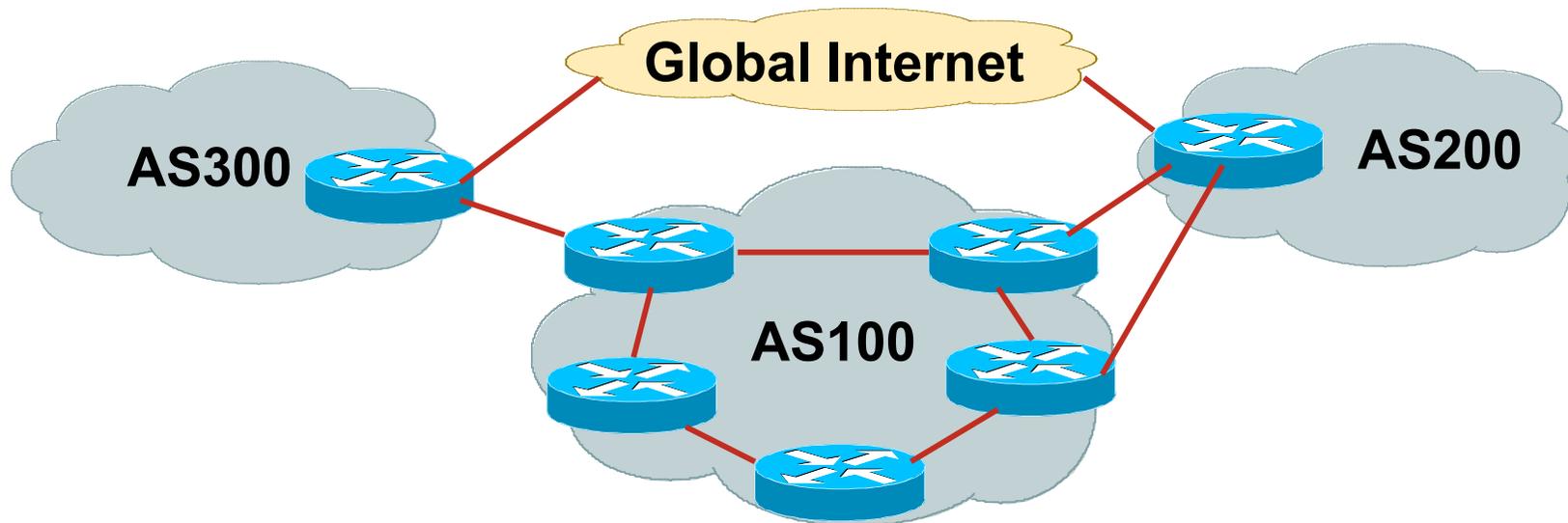
- Many situations possible

  multiple sessions to same ISP

  secondary for backup only

  load-share between primary and secondary

  selectively use different ISPs

Multiple Sessions to an ISP – Example One

- **Use eBGP multihop**

  eBGP to loopback addresses

  eBGP prefixes learned with loopback address as next hop

- **Cisco IOS**

```
router bgp 65534
 neighbor 1.1.1.1 remote-as 200
 neighbor 1.1.1.1 ebgp-multihop 2
 !
 ip route 1.1.1.1 255.255.255.255 serial 1/0
 ip route 1.1.1.1 255.255.255.255 serial 1/1
 ip route 1.1.1.1 255.255.255.255 serial 1/2
```

AS 200

1.1.1.1

AS 65534
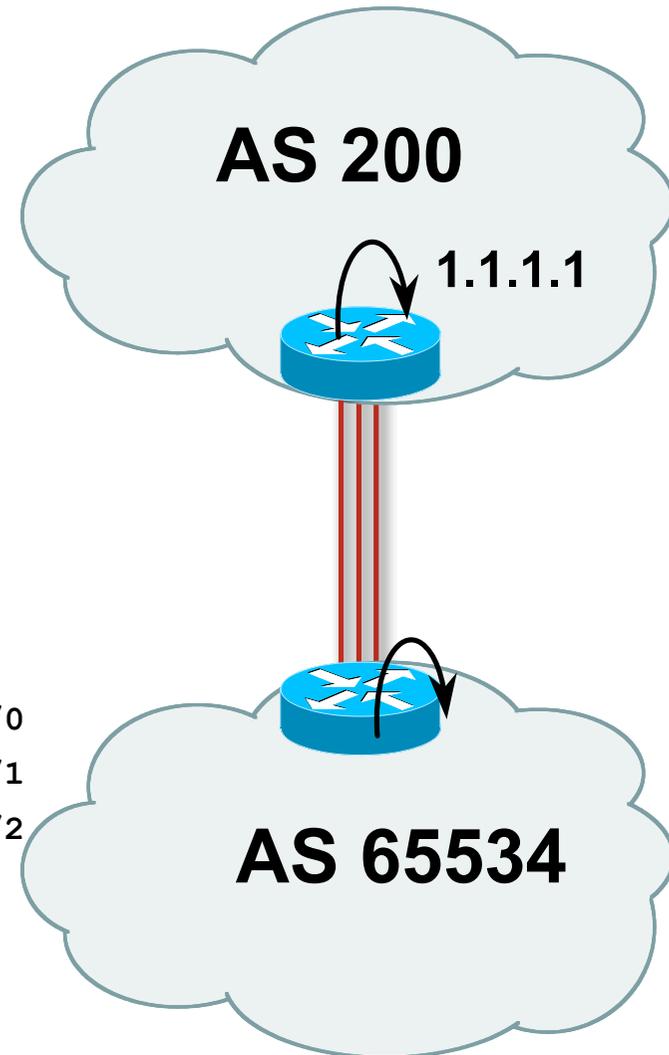
Multiple Sessions to an ISP – Example One

- One eBGP-multihop gotcha:

  R1 and R3 are eBGP peers that are loopback peering

  Configured with:

  `neighbor x.x.x.x ebgp-multihop 2`

  If the R1 to R3 link goes down the session could establish via R2

R1

R3

AS 100

AS 200

R2

← – – → **Desired Path**

←――→ **Used Path**
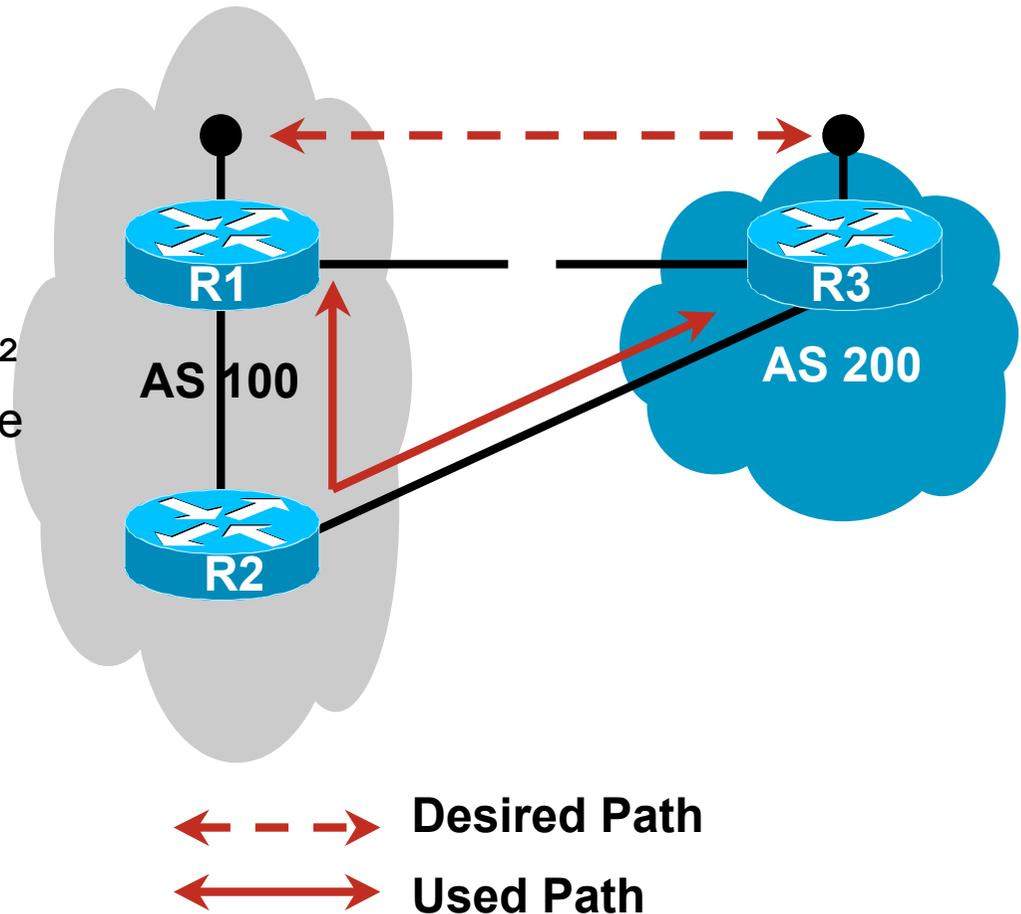
Multiple Sessions to an ISP – Example One

- Try and avoid use of ebgp-multihop unless:

  It's absolutely necessary   –or–

  Loadsharing across multiple links

- Many ISPs discourage its use, for example:

We will run eBGP multihop, but do not support it as a standard offering because customers generally have a hard time managing it due to:
- **routing loops**
- **failure to realise that BGP session stability problems are usually due connectivity problems between their CPE and their BGP speaker**

Multiple Sessions to an ISP
bgp multi path

- Three BGP sessions required

- limit of 6 parallel paths

```
router bgp 201
  neighbor 1.1.2.1 remote-as 200
  neighbor 1.1.2.5 remote-as 200
  neighbor 1.1.2.9 remote-as 200
  maximum-paths 3
```

AS 200

ISP

AS 201
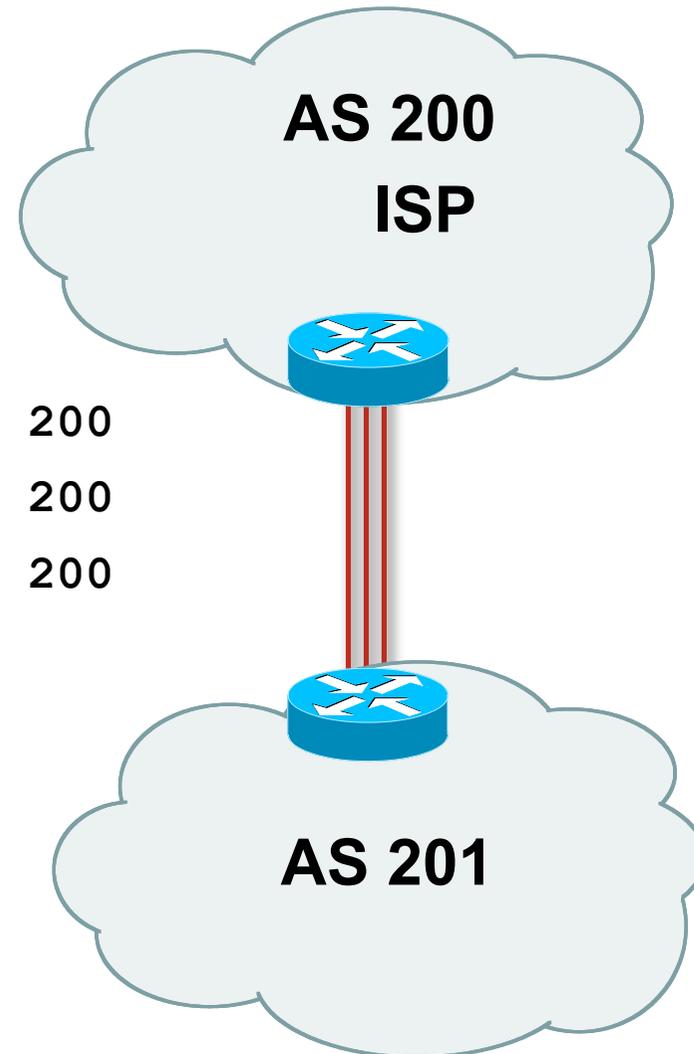
Multiple Sessions to an ISP

- Simplest scheme is to use defaults

- Learn/advertise prefixes for better control

- Planning and some work required to achieve loadsharing

    Point default towards one ISP

    Learn selected prefixes from second ISP

    Modify the number of prefixes learnt to achieve acceptable load sharing

- **No magic solution**
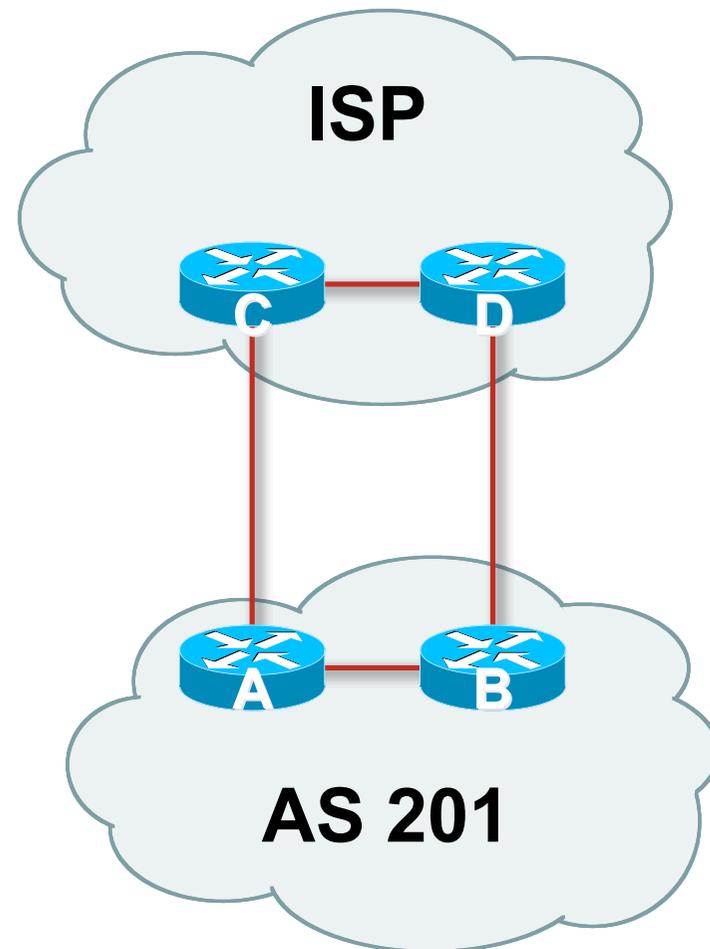
ISP

C   D

A   B

AS 201

BGP Multihoming Techniques

- Why Multihome?

- Definition & Options

- **Preparing the Network**

- Basic Multihoming

- Service Provider Multihoming

- Complex Cases & Caveats

- Using Communities

- Case Study

Preparing the Network

Putting our own house in order first…

Preparing the Network

- We will deploy BGP across the network before we try and multihome

- BGP will be used therefore an ASN is required

- If multihoming to different ISPs, public ASN needed:

  Either go to upstream ISP who is a registry member, or

  Apply to the RIR yourself for a one off assignment, or

  Ask an ISP who is a registry member, or

  Join the RIR and get your own IP address allocation too (this option strongly recommended)!

Preparing the Network

- The network is not running any BGP at the moment

    single statically routed connection to upstream ISP

- The network is not running any IGP at all

    Static default and routes through the network to do "routing"

Preparing the Network
IGP

- Decide on IGP: OSPF or ISIS ☺

- Assign loopback interfaces and /32 addresses to each router which will run the IGP

  - Loopback is used for OSPF and BGP router id anchor

  - Used for iBGP and route origination

- Deploy IGP (e.g. OSPF)

  - IGP can be deployed with NO IMPACT on the existing static routing

    - OSPF distance is 110, static distance is 1

  - Smallest distance wins

Preparing the Network
IGP (cont)

- Be prudent deploying IGP – keep the Link State Database Lean!

    Router loopbacks go in IGP

    WAN point to point links go in IGP

    (In fact, any link where IGP dynamic routing will be run should go into IGP)

    Summarise on area/level boundaries (if possible) – i.e. think about your IGP address plan

Preparing the Network
IGP (cont)

- Routes which don't go into the IGP include:

    Dynamic assignment pools (DSL/Cable/Dial/Wireless)

    Customer point to point link addressing

    (using next-hop-self in iBGP ensures that these do NOT need to be in IGP)

    Static/Hosting LANs

    Customer assigned address space

    Anything else not listed in the previous slide

Preparing the Network
Introduce OSPF

```
interface loopback 0
 ip address 121.10.255.1 255.255.255.255
!
interface Ethernet 0/0
 ip address 121.10.2.1 255.255.255.240
!
interface serial 0/0
 ip address 121.10.0.1 255.255.255.252
!
interface serial 0/1
 ip address 121.10.0.5 255.255.255.252
!
router ospf 100
 network 121.10.255.1 0.0.0.0 area 0
 network 121.10.2.0 0.0.0.15 area 0
 passive-interface default
 no passive-interface Ethernet 0/0
!
ip route 121.10.24.0 255.255.252.0 serial 0/0
ip route 121.10.28.0 255.255.254.0 serial 0/1
```

Add loopback configuration

Customer connections

Preparing the Network
iBGP

- Second step is to configure the local network to use iBGP

- iBGP can run on
  - all routers, or
  - a subset of routers, or
  - just on the upstream edge

- *iBGP must run on all routers which are in the transit path between external connections*

AS200
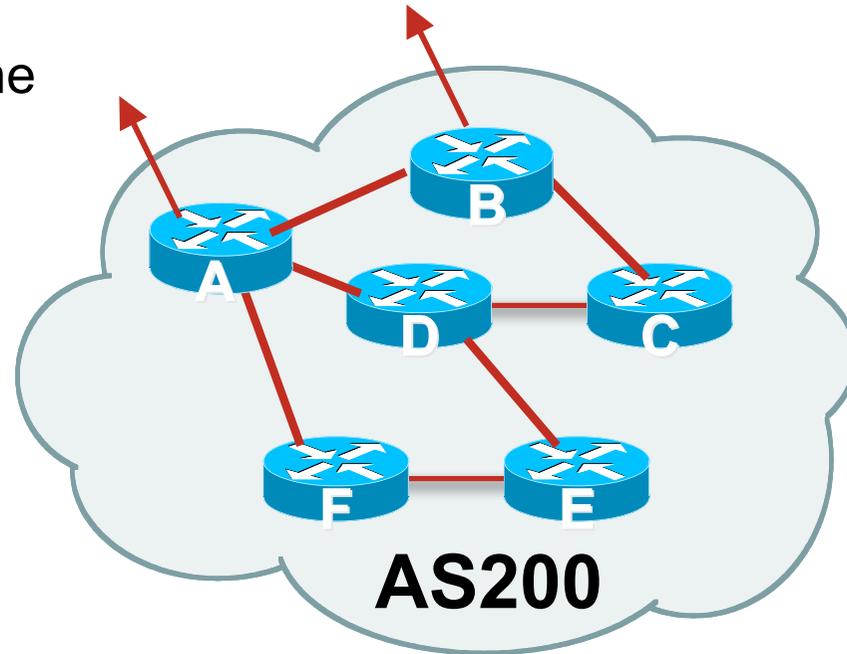
Preparing the Network
iBGP (Transit Path)

- *iBGP must run on all routers which are in the transit path between external connections*

- Routers C, E and F are not in the transit path

  - Static routes or IGP will suffice

- Router D is in the transit path

  - Will need to be in iBGP mesh, otherwise routing loops will result

AS200
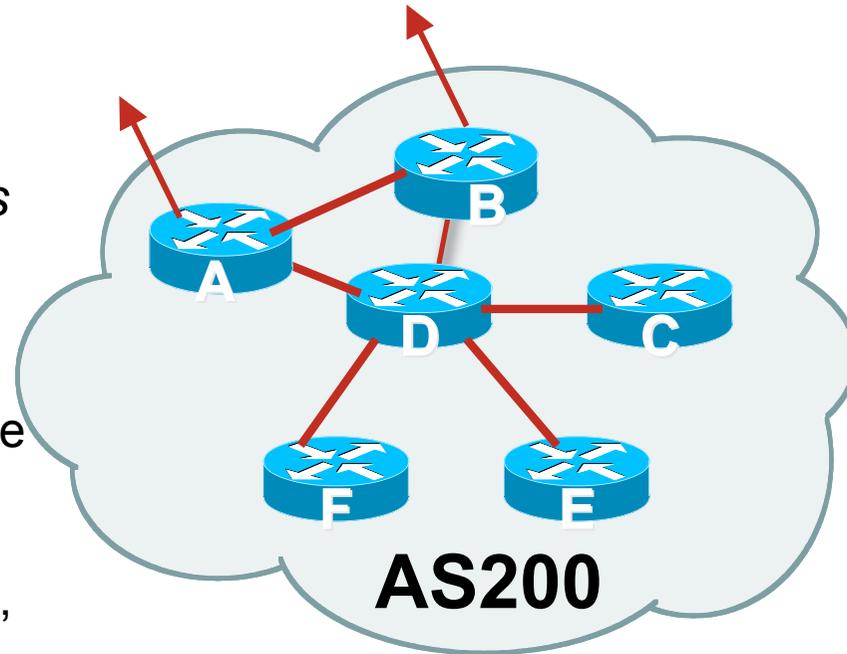
Preparing the Network
Layers

- Typical SP networks have three layers:

    Core – the backbone, usually the transit path

    Distribution – the middle, PoP aggregation layer

    Aggregation – the edge, the devices connecting customers

Preparing the Network
Aggregation Layer

- iBGP is optional

    Many ISPs run iBGP here, either partial routing (more common) or full routing (less common)

    Full routing is not needed unless customers want full table

    Partial routing is cheaper/easier, might usually consist of internal prefixes and, optionally, external prefixes to aid external load balancing

    - Communities and peer-groups make this administratively easy

- Many aggregation devices can't run iBGP

    Static routes from distribution devices for address pools

    IGP for best exit

Preparing the Network
Distribution Layer

- ## Usually runs iBGP

  - Partial or full routing (as with aggregation layer)

- ## But does not have to run iBGP

  - IGP is then used to carry customer prefixes (does not scale)

  - IGP is used to determine nearest exit

- ## Networks which plan to grow large should deploy iBGP from day one

  - Migration at a later date is extra work

  - No extra overhead in deploying iBGP, indeed IGP benefits

Preparing the Network
Core Layer

- Core of network is usually the transit path

- iBGP necessary between core devices

  Full routes or partial routes:

    Transit ISPs carry full routes in core

    Edge ISPs carry partial routes only

- Core layer includes AS border routers

Preparing the Network
iBGP Implementation

- Decide on:

- Best iBGP policy

    Will it be full routes everywhere, or partial, or some mix?

- iBGP scaling technique

    Community policy?

    Route-reflectors?

    Techniques such as peer groups and templates?

Preparing the Network
iBGP Implementation

- **Then deploy iBGP:**

  Step 1: Introduce iBGP mesh on chosen routers

  make sure that iBGP distance is greater than IGP distance (it usually is)

  Step 2: Install "customer" prefixes into iBGP

  Check! Does the network still work?

  Step 3: Carefully remove the static routing for the prefixes now in IGP and iBGP

  Check! Does the network still work?

  Step 4: Deployment of eBGP follows

Preparing the Network
iBGP Implementation

Install "customer" prefixes into iBGP?

- Customer assigned address space

    Network statement/static route combination

    Use unique community to identify customer assignments

- Customer facing point-to-point links

    Redistribute connected through filters which only permit point-to-point link addresses to enter iBGP

    Use a unique community to identify point-to-point link addresses (these are only required for your monitoring system)

- Dynamic assignment pools & local LANs

    Simple network statement will do this

    Use unique community to identify these networks

Preparing the Network
iBGP Implementation

Carefully remove static routes?

- Work on one router at a time:

    Check that static route for a particular destination is also learned either by IGP or by iBGP

    If so, remove it

    If not, establish why and fix the problem

    (Remember to look in the RIB, not the FIB!)

- Then the next router, until the whole PoP is done

- Then the next PoP, and so on until the network is now dependent on the IGP and iBGP you have deployed

Preparing the Network Completion

- Previous steps are NOT flag day steps

  Each can be carried out during different maintenance periods, for example:

  Step One on Week One

  Step Two on Week Two

  Step Three on Week Three

  And so on

  And with proper planning will have NO customer visible impact at all

Preparing the Network
Configuration Summary

- IGP essential networks are in IGP

- Customer networks are now in iBGP

  iBGP deployed over the backbone

  Full or Partial or Upstream Edge only

- BGP distance is greater than any IGP

- Now ready to deploy eBGP

BGP Multihoming Techniques

- Why Multihome?

- Definition & Options

- Preparing the Network

- **Basic Multihoming**

- "BGP Traffic Engineering"

Basic Multihoming

Learning to walk before we try running

Basic Multihoming

- No frills multihoming

- Will look at two cases:

  Multihoming with the same ISP

  Multihoming to different ISPs

- Will keep the examples easy

  Understanding easy concepts will make the more complex scenarios easier to comprehend

  All assume that the site multihoming has a /19 address block

Basic Multihoming

- This type is most commonplace at the edge of the Internet

    Networks here are usually concerned with inbound traffic flows

    Outbound traffic flows being "nearest exit" is usually sufficient

- Can apply to the leaf ISP as well as Enterprise networks

Basic Multihoming

Multihoming to the Same ISP

Basic Multihoming:
Multihoming to the same ISP

- ## Use BGP for this type of multihoming

  use a private AS (ASN > 64511)

  There is no need or justification for a public ASN

  Making the nets of the end-site visible gives no useful information to the Internet

- ## Upstream ISP proxy aggregates

  in other words, announces only your address block to the Internet from their AS (as would be done if you had one statically routed connection)

Two links to the same ISP

One link primary, the other link backup only

Two links to the same ISP (one as backup only)

- Applies when end-site has bought a large primary WAN link to their upstream a small secondary WAN link as the backup

    For example, primary path might be an E1, backup might be 64kbps

Two links to the same ISP (one as backup only)

primary

C

A

AS 100

AS 65534

E

D

B
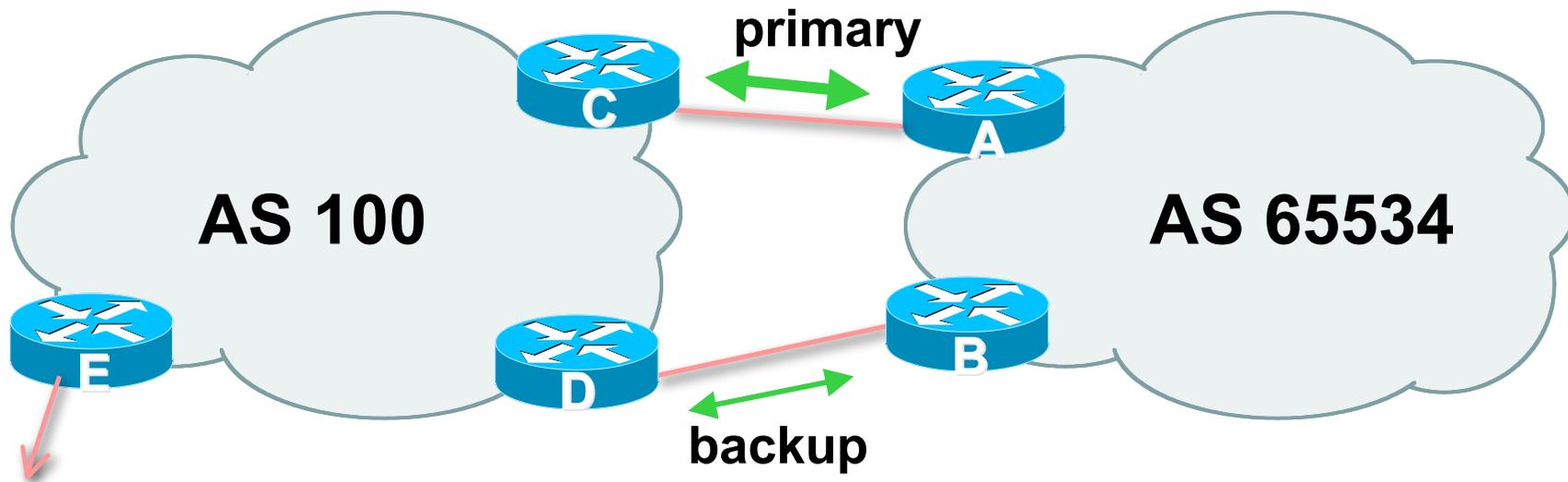
backup

- AS100 removes private AS and any customer subprefixes from Internet announcement

Two links to the same ISP (one as backup only)

- Announce /19 aggregate on each link

    primary link:

        Outbound – announce /19 unaltered

        Inbound – receive default route

    backup link:

        Outbound – announce /19 with increased metric

        Inbound – received default, and reduce local preference

- When one link fails, the announcement of the /19 aggregate via the other link ensures continued connectivity

Two links to the same ISP (one as backup only)

- Router A Configuration

```
router bgp 65534
 network 121.10.0.0 mask 255.255.224.0
 neighbor 122.102.10.2 remote-as 100
 neighbor 122.102.10.2 description RouterC
 neighbor 122.102.10.2 prefix-list aggregate out
 neighbor 122.102.10.2 prefix-list default in
!
ip prefix-list aggregate permit 121.10.0.0/19
ip prefix-list default permit 0.0.0.0/0
!
ip route 121.10.0.0 255.255.224.0 null0
```

Two links to the same ISP (one as backup only)

- Router B Configuration

```
router bgp 65534
  network 121.10.0.0 mask 255.255.224.0
  neighbor 122.102.10.6 remote-as 100
  neighbor 122.102.10.6 description RouterD
  neighbor 122.102.10.6 prefix-list aggregate out
  neighbor 122.102.10.6 route-map routerD-out out
  neighbor 122.102.10.6 prefix-list default in
  neighbor 122.102.10.6 route-map routerD-in in
!
```

..next slide

Two links to the same ISP (one as backup only)

```
ip prefix-list aggregate permit 121.10.0.0/19
ip prefix-list default permit 0.0.0.0/0
!
ip route 121.10.0.0 255.255.224.0 null0
!
route-map routerD-out permit 10
 set metric 10
!
route-map routerD-in permit 10
 set local-preference 90
!
```

Two links to the same ISP (one as backup only)

- Router C Configuration (main link)

```
router bgp 100
  neighbor 122.102.10.1 remote-as 65534
  neighbor 122.102.10.1 default-originate
  neighbor 122.102.10.1 prefix-list Customer in
  neighbor 122.102.10.1 prefix-list default out
!
ip prefix-list Customer permit 121.10.0.0/19
ip prefix-list default permit 0.0.0.0/0
```

Two links to the same ISP (one as backup only)

- Router D Configuration (backup link)

```
router bgp 100
  neighbor 122.102.10.5 remote-as 65534
  neighbor 122.102.10.5 default-originate
  neighbor 122.102.10.5 prefix-list Customer in
  neighbor 122.102.10.5 prefix-list default out
!
ip prefix-list Customer permit 121.10.0.0/19
ip prefix-list default permit 0.0.0.0/0
```

Two links to the same ISP (one as backup only)

- Router E Configuration

```
router bgp 100
  neighbor 122.102.10.17 remote-as 110
  neighbor 122.102.10.17 remove-private-AS
  neighbor 122.102.10.17 prefix-list Customer out
 !
 ip prefix-list Customer permit 121.10.0.0/19
```

- Router E removes the private AS and customer's subprefixes from external announcements

- Private AS still visible inside AS100

Two links to the same ISP

With Loadsharing

Loadsharing to the same ISP

- More common case

- End sites tend not to buy circuits and leave them idle, only used for backup as in previous example

- This example assumes equal capacity circuits

    Unequal capacity circuits requires more refinement – see later

Loadsharing to the same ISP
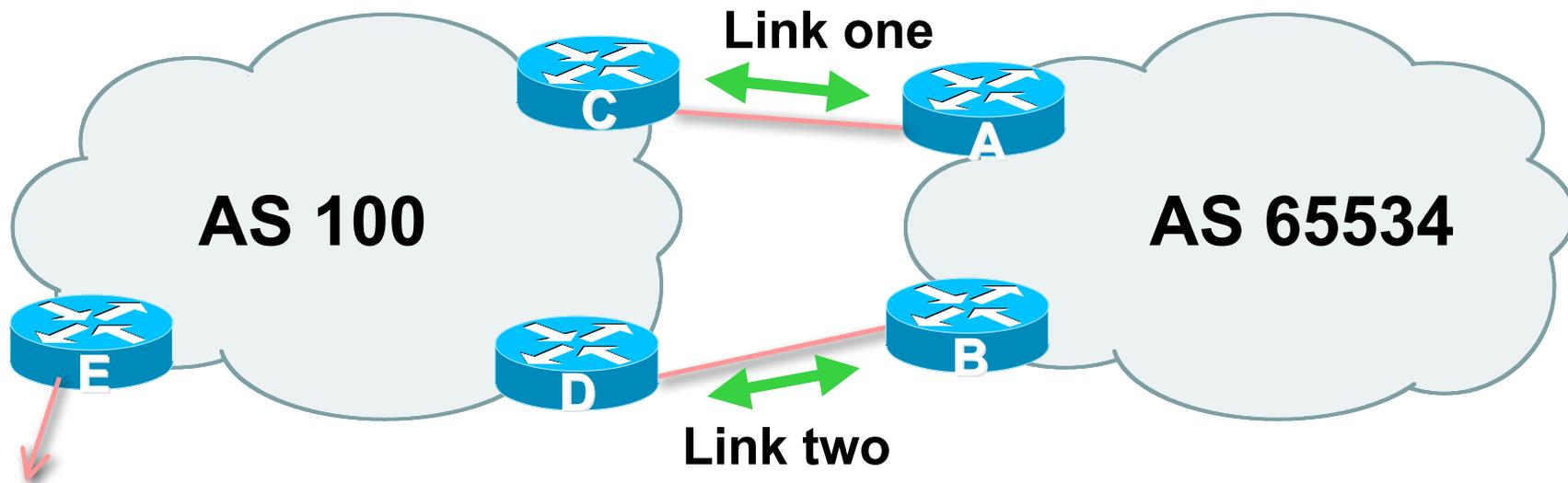
Link one

Link two

AS 100

AS 65534

C

A

E

D

B

- Border router E in AS100 removes private AS and any customer subprefixes from Internet announcement

Loadsharing to the same ISP

- Announce /19 aggregate on each link

- Split /19 and announce as two /20s, one on each link

  basic inbound loadsharing

  assumes equal circuit capacity and even spread of traffic across address block

- Vary the split until "perfect" loadsharing achieved

- Accept the default from upstream

  basic outbound loadsharing by nearest exit

  okay in first approx as most ISP and end-site traffic is inbound

Loadsharing to the same ISP

- Router A Configuration

```
router bgp 65534
 network 121.10.0.0 mask 255.255.224.0
 network 121.10.0.0 mask 255.255.240.0
 neighbor 122.102.10.2 remote-as 100
 neighbor 122.102.10.2 prefix-list routerC out
 neighbor 122.102.10.2 prefix-list default in
!
ip prefix-list default permit 0.0.0.0/0
ip prefix-list routerC permit 121.10.0.0/20
ip prefix-list routerC permit 121.10.0.0/19
!
ip route 121.10.0.0 255.255.240.0 null0
ip route 121.10.0.0 255.255.224.0 null0
```

Loadsharing to the same ISP

- Router C Configuration

```
router bgp 100
  neighbor 122.102.10.1 remote-as 65534
  neighbor 122.102.10.1 default-originate
  neighbor 122.102.10.1 prefix-list Customer in
  neighbor 122.102.10.1 prefix-list default out
!
ip prefix-list Customer permit 121.10.0.0/19 le 20
ip prefix-list default permit 0.0.0.0/0
```

- Router C only allows in /19 and /20 prefixes from customer block

- Router D configuration is identical

Loadsharing to the same ISP

- Router E Configuration

```
router bgp 100
 neighbor 122.102.10.17 remote-as 110
 neighbor 122.102.10.17 remove-private-AS
 neighbor 122.102.10.17 prefix-list Customer out
 !
 ip prefix-list Customer permit 121.10.0.0/19
```

- Private AS still visible inside AS100

Loadsharing to the same ISP

- Default route for outbound traffic?

    Use default-information originate for the IGP and rely on IGP metrics for nearest exit

    e.g. on router A:

    ```
    router ospf 65534
      default-information originate metric 2 metric-type 1
    ```

Loadsharing to the same ISP

- Loadsharing configuration is only on customer router

- Upstream ISP has to

   remove customer subprefixes from external announcements

   remove private AS from external announcements

- Could also use BGP communities

Two links to the same ISP

Multiple Dualhomed Customers

(RFC2270)

Multiple Dualhomed Customers (RFC2270)

- Unusual for an ISP just to have one dualhomed customer

  Valid/valuable service offering for an ISP with multiple PoPs

  Better for ISP than having customer multihome with another provider!

- Look at scaling the configuration

  $\Rightarrow$ Simplifying the configuration

  Using templates, peer-groups, etc

  Every customer has the same configuration (basically)

Multiple Dualhomed Customers (RFC2270)
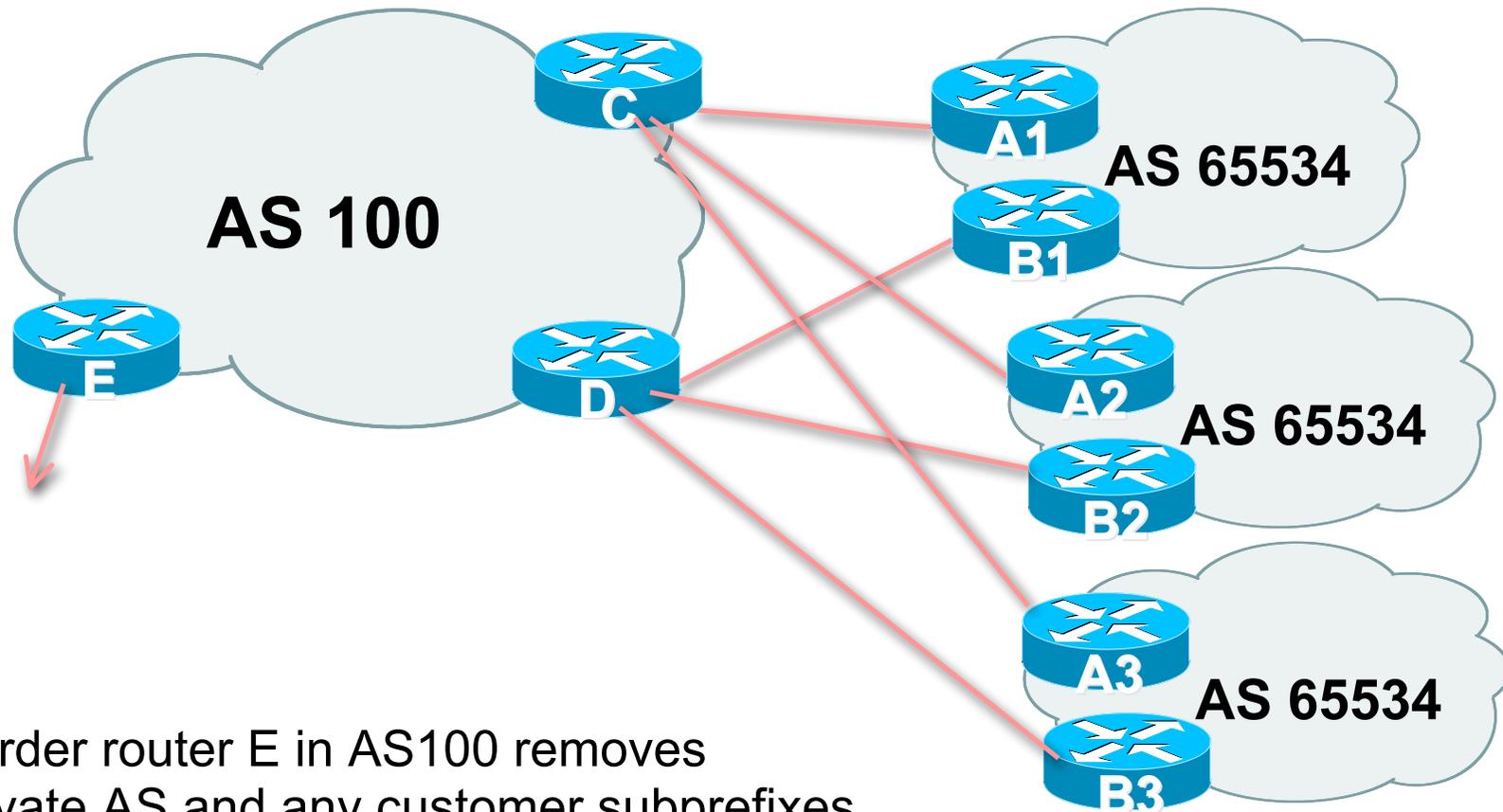
AS 100

C

E

D

A1

B1

AS 65534

A2

B2

AS 65534

A3

B3

AS 65534

- Border router E in AS100 removes private AS and any customer subprefixes from Internet announcement

Multiple Dualhomed Customers (RFC2270)

- Customer announcements as per previous example

- Use the same private AS for each customer

    documented in RFC2270

    address space is not overlapping

    each customer hears default only

- Router An and Bn configuration same as Router A and B previously

Multiple Dualhomed Customers (RFC2270)

- Router A1 Configuration

```
router bgp 65534
 network 121.10.0.0 mask 255.255.224.0
 network 121.10.0.0 mask 255.255.240.0
 neighbor 122.102.10.2 remote-as 100
 neighbor 122.102.10.2 prefix-list routerC out
 neighbor 122.102.10.2 prefix-list default in
!
ip prefix-list default permit 0.0.0.0/0
ip prefix-list routerC permit 121.10.0.0/20
ip prefix-list routerC permit 121.10.0.0/19
!
ip route 121.10.0.0 255.255.240.0 null0
ip route 121.10.0.0 255.255.224.0 null0
```

Multiple Dualhomed Customers (RFC2270)

- Router C Configuration

```
router bgp 100
 neighbor bgp-customers peer-group
 neighbor bgp-customers remote-as 65534
 neighbor bgp-customers default-originate
 neighbor bgp-customers prefix-list default out
 neighbor 122.102.10.1 peer-group bgp-customers
 neighbor 122.102.10.1 description Customer One
 neighbor 122.102.10.1 prefix-list Customer1 in
 neighbor 122.102.10.9 peer-group bgp-customers
 neighbor 122.102.10.9 description Customer Two
 neighbor 122.102.10.9 prefix-list Customer2 in
```

Multiple Dualhomed Customers (RFC2270)

```
 neighbor 122.102.10.17 peer-group bgp-customers
 neighbor 122.102.10.17 description Customer Three
 neighbor 122.102.10.17 prefix-list Customer3 in
!
ip prefix-list Customer1 permit 121.10.0.0/19 le 20
ip prefix-list Customer2 permit 121.16.64.0/19 le 20
ip prefix-list Customer3 permit 121.14.192.0/19 le 20
ip prefix-list default permit 0.0.0.0/0
```

- Router C only allows in /19 and /20 prefixes from customer block

- Router D configuration is almost identical

Multiple Dualhomed Customers (RFC2270)

- Router E Configuration

  assumes customer address space is not part of upstream's address block

  ```
  router bgp 100
   neighbor 122.102.10.17 remote-as 110
   neighbor 122.102.10.17 remove-private-AS
   neighbor 122.102.10.17 prefix-list Customers out
  !
  ip prefix-list Customers permit 121.10.0.0/19
  ip prefix-list Customers permit 121.16.64.0/19
  ip prefix-list Customers permit 121.14.192.0/19
  ```

- Private AS still visible inside AS100

Multiple Dualhomed Customers (RFC2270)

- If customers' prefixes come from ISP's address block

    do **NOT** announce them to the Internet

    announce ISP aggregate only

- Router E configuration:

```
router bgp 100
 neighbor 122.102.10.17 remote-as 110
 neighbor 122.102.10.17 prefix-list my-aggregate out
!
ip prefix-list my-aggregate permit 121.8.0.0/13
```

Basic Multihoming

Multihoming to different ISPs

Two links to different ISPs

- Use a Public AS

    Or use private AS if agreed with the other ISP

    But some people don't like the "inconsistent-AS" which results from use of a private-AS

- Address space comes from

    both upstreams or

    Regional Internet Registry

- Configuration concepts very similar

Inconsistent-AS?

- Viewing the prefixes originated by AS65534 in the Internet shows they appear to be originated by both AS210 and AS200

  This is NOT bad

  Nor is it illegal

- IOS command is

  `show ip bgp inconsistent-as`

AS 65534

AS 200

AS 210

Internet
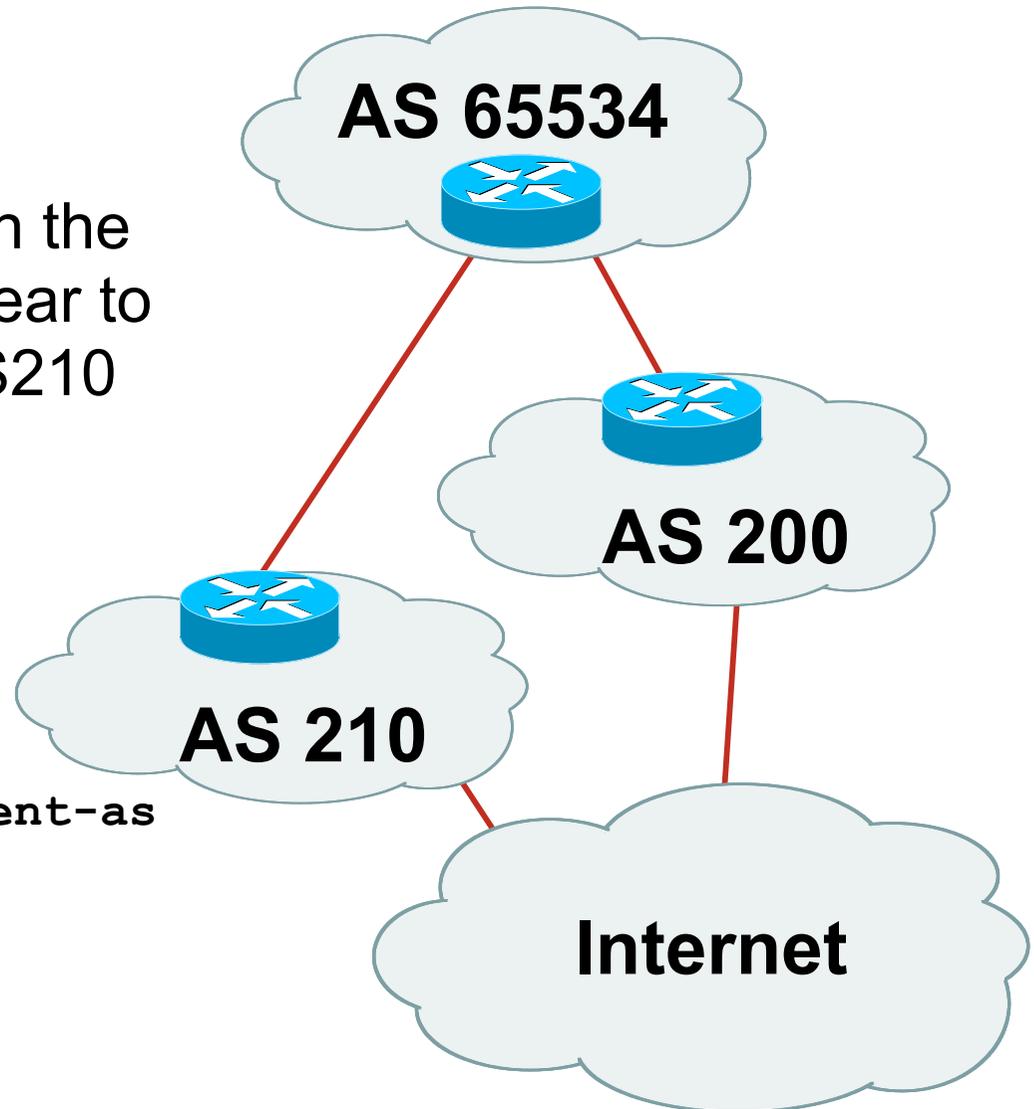
Two links to different ISPs

One link primary, the other link backup only

Two links to different ISPs (one as backup only)
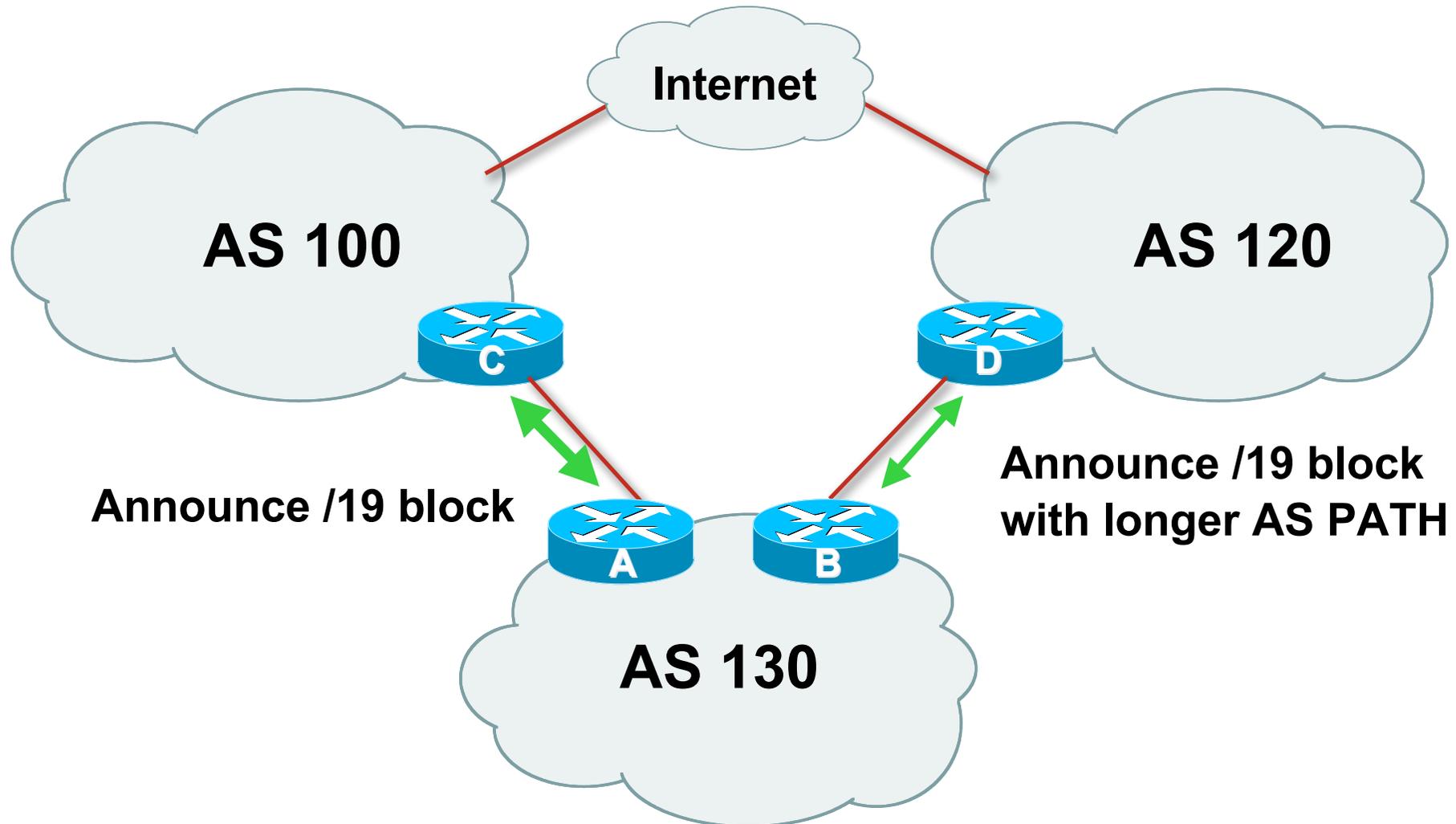
Internet

AS 100

AS 120

C

D

Announce /19 block

Announce /19 block with longer AS PATH

A

B

AS 130

Two links to different ISPs (one as backup only)

- Announce /19 aggregate on each link

  primary link makes standard announcement

  backup link lengthens the AS PATH by using AS PATH prepend

- When one link fails, the announcement of the /19 aggregate via the other link ensures continued connectivity

Two links to different ISPs (one as backup only)

- Router A Configuration

```
router bgp 130
 network 121.10.0.0 mask 255.255.224.0
 neighbor 122.102.10.1 remote-as 100
 neighbor 122.102.10.1 prefix-list aggregate out
 neighbor 122.102.10.1 prefix-list default in
!
ip prefix-list aggregate permit 121.10.0.0/19
ip prefix-list default permit 0.0.0.0/0
!
ip route 121.10.0.0 255.255.224.0 null0
```

Two links to different ISPs (one as backup only)

- Router B Configuration

```
router bgp 130
 network 121.10.0.0 mask 255.255.224.0
 neighbor 120.1.5.1 remote-as 120
 neighbor 120.1.5.1 prefix-list aggregate out
 neighbor 120.1.5.1 route-map routerD-out out
 neighbor 120.1.5.1 prefix-list default in
 neighbor 120.1.5.1 route-map routerD-in in
!
ip prefix-list aggregate permit 121.10.0.0/19
ip prefix-list default permit 0.0.0.0/0
!
route-map routerD-out permit 10
 set as-path prepend 130 130 130
!
route-map routerD-in permit 10
 set local-preference 80
```

Two links to different ISPs (one as backup only)

- Not a common situation as most sites tend to prefer using whatever capacity they have

 (Useful when two competing ISPs agree to provide mutual backup to each other)

- But it shows the basic concepts of using local-prefs and AS-path prepends for engineering traffic in the chosen direction

Two links to different ISPs

With Loadsharing

Two links to different ISPs (with loadsharing)

Internet

AS 100

AS 120

C

D

Announce first /20 and /19 block

Announce second /20 and /19 block

A

B

AS 130
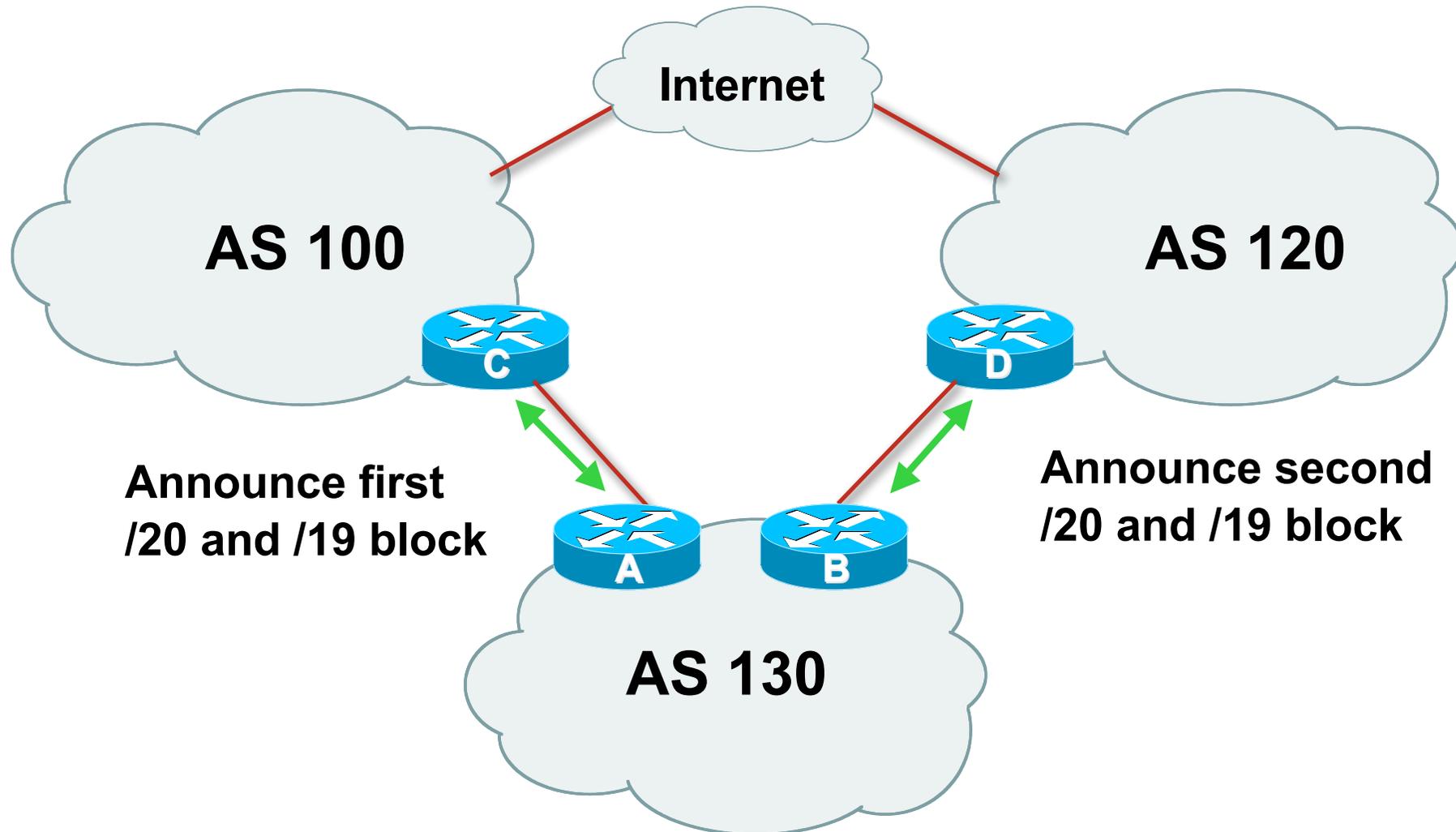
Two links to different ISPs (with loadsharing)

- Announce /19 aggregate on each link

- Split /19 and announce as two /20s, one on each link
   - basic inbound loadsharing

- When one link fails, the announcement of the /19 aggregate via the other ISP ensures continued connectivity

Two links to different ISPs (with loadsharing)

- Router A Configuration

```
router bgp 130
 network 121.10.0.0 mask 255.255.224.0
 network 121.10.0.0 mask 255.255.240.0
 neighbor 122.102.10.1 remote-as 100
 neighbor 122.102.10.1 prefix-list firstblock out
 neighbor 122.102.10.1 prefix-list default in
!
ip prefix-list default permit 0.0.0.0/0
!
ip prefix-list firstblock permit 121.10.0.0/20
ip prefix-list firstblock permit 121.10.0.0/19
```

Two links to different ISPs (with loadsharing)

- Router B Configuration

```
router bgp 130
 network 121.10.0.0 mask 255.255.224.0
 network 121.10.16.0 mask 255.255.240.0
 neighbor 120.1.5.1 remote-as 120
 neighbor 120.1.5.1 prefix-list secondblock out
 neighbor 120.1.5.1 prefix-list default in
!
ip prefix-list default permit 0.0.0.0/0
!
ip prefix-list secondblock permit 121.10.16.0/20
ip prefix-list secondblock permit 121.10.0.0/19
```

Two links to different ISPs (with loadsharing)

- Loadsharing in this case is very basic

- But shows the first steps in designing a load sharing solution

  Start with a simple concept

  And build on it…!

Two links to different ISPs

More Controlled Loadsharing

Loadsharing with different ISPs

Internet

AS 100

AS 120

C

D

Announce /19 block

Announce /20 subprefix, and /19 block with longer AS path

A

B

AS 130
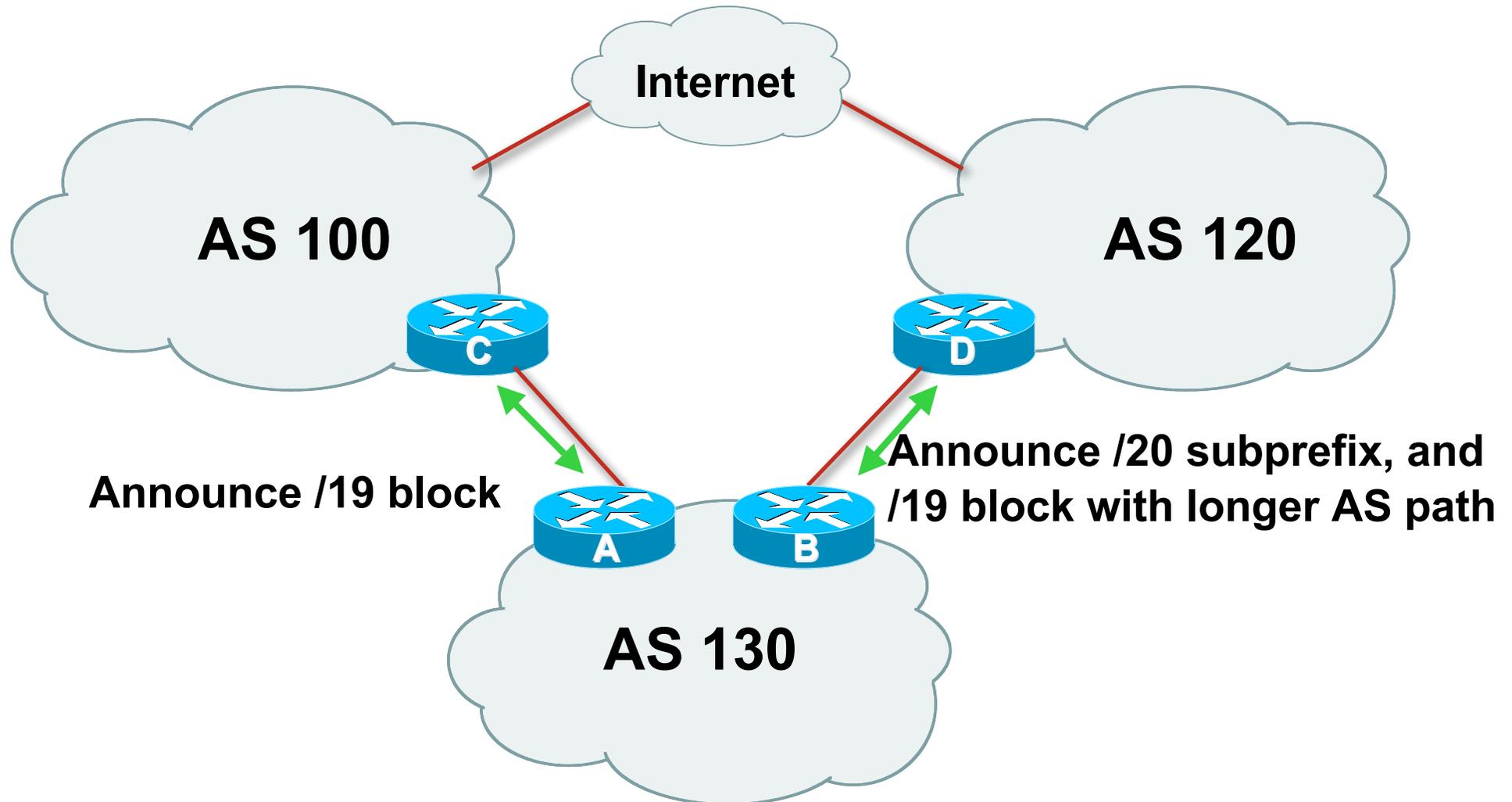
Loadsharing with different ISPs

- Announce /19 aggregate on each link

  On first link, announce /19 as normal

  On second link, announce /19 with longer AS PATH, and announce one /20 subprefix

    controls loadsharing between upstreams and the Internet

- Vary the subprefix size and AS PATH length until "perfect" loadsharing achieved

- Still require redundancy!

Loadsharing with different ISPs

- Router A Configuration

```
router bgp 130
 network 121.10.0.0 mask 255.255.224.0
 neighbor 122.102.10.1 remote-as 100
 neighbor 122.102.10.1 prefix-list default in
 neighbor 122.102.10.1 prefix-list aggregate out
!
ip prefix-list aggregate permit 121.10.0.0/19
ip prefix-list default permit 0.0.0.0/0
!
ip route 121.10.0.0 255.255.224.0 null0
```

Loadsharing with different ISPs

- Router B Configuration

```
router bgp 130
 network 121.10.0.0 mask 255.255.224.0
 network 121.10.16.0 mask 255.255.240.0
 neighbor 120.1.5.1 remote-as 120
 neighbor 120.1.5.1 prefix-list default in
 neighbor 120.1.5.1 prefix-list subblocks out
 neighbor 120.1.5.1 route-map routerD out
!
route-map routerD permit 10
 match ip address prefix-list aggregate
 set as-path prepend 130 130
route-map routerD permit 20
!
ip prefix-list subblocks permit 121.10.0.0/19 le 20
ip prefix-list aggregate permit 121.10.0.0/19
```

Loadsharing with different ISPs

- This example is more commonplace

- Shows how ISPs and end-sites subdivide address space frugally, as well as use the AS-PATH prepend concept to optimise the load sharing between different ISPs

- Notice that the /19 aggregate block is ALWAYS announced

BGP Multihoming Techniques

- Why Multihome?

- Definition & Options

- Preparing the Network

- Basic Multihoming

- **"BGP Traffic Engineering"**

Service Provider Multihoming

BGP Traffic Engineering

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

Upstream ISP

AS130

C

Local Peer

AS120

A

AS 110
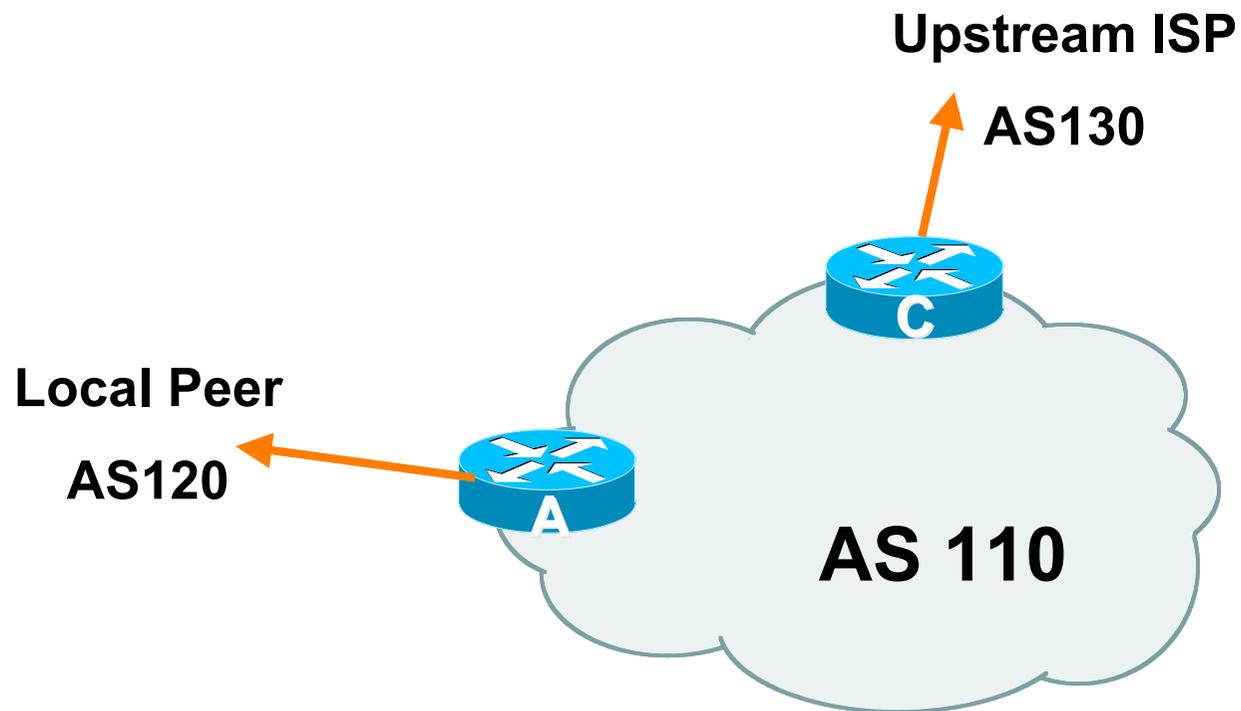
One Upstream, One Local Peer

- 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 from local peer

One Upstream, One Local Peer

- Router A Configuration

```
router bgp 110
 network 121.10.0.0 mask 255.255.224.0
 neighbor 122.102.10.2 remote-as 120
 neighbor 122.102.10.2 prefix-list my-block out
 neighbor 122.102.10.2 prefix-list AS120-peer in
!
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 121.10.0.0/19
!
ip route 121.10.0.0 255.255.224.0 null0 250
```

Prefix filters inbound
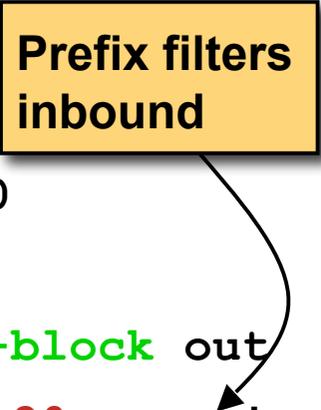
One Upstream, One Local Peer

- Router A – Alternative Configuration

```
router bgp 110
 network 121.10.0.0 mask 255.255.224.0
 neighbor 122.102.10.2 remote-as 120
 neighbor 122.102.10.2 prefix-list my-block out
 neighbor 122.102.10.2 filter-list 10 in
!
ip as-path access-list 10 permit ^(120_)+$
!
ip prefix-list my-block permit 121.10.0.0/19
!
ip route 121.10.0.0 255.255.224.0 null0
```

AS Path filters – more "trusting"

One Upstream, One Local Peer

- Router C Configuration

```
router bgp 110
 network 121.10.0.0 mask 255.255.224.0
 neighbor 122.102.10.1 remote-as 130
 neighbor 122.102.10.1 prefix-list default in
 neighbor 122.102.10.1 prefix-list my-block out
!
ip prefix-list my-block permit 121.10.0.0/19
ip prefix-list default permit 0.0.0.0/0
!
ip route 121.10.0.0 255.255.224.0 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

One Upstream, Local Exchange Point

Upstream ISP

AS130

IXP

C

A

AS 110
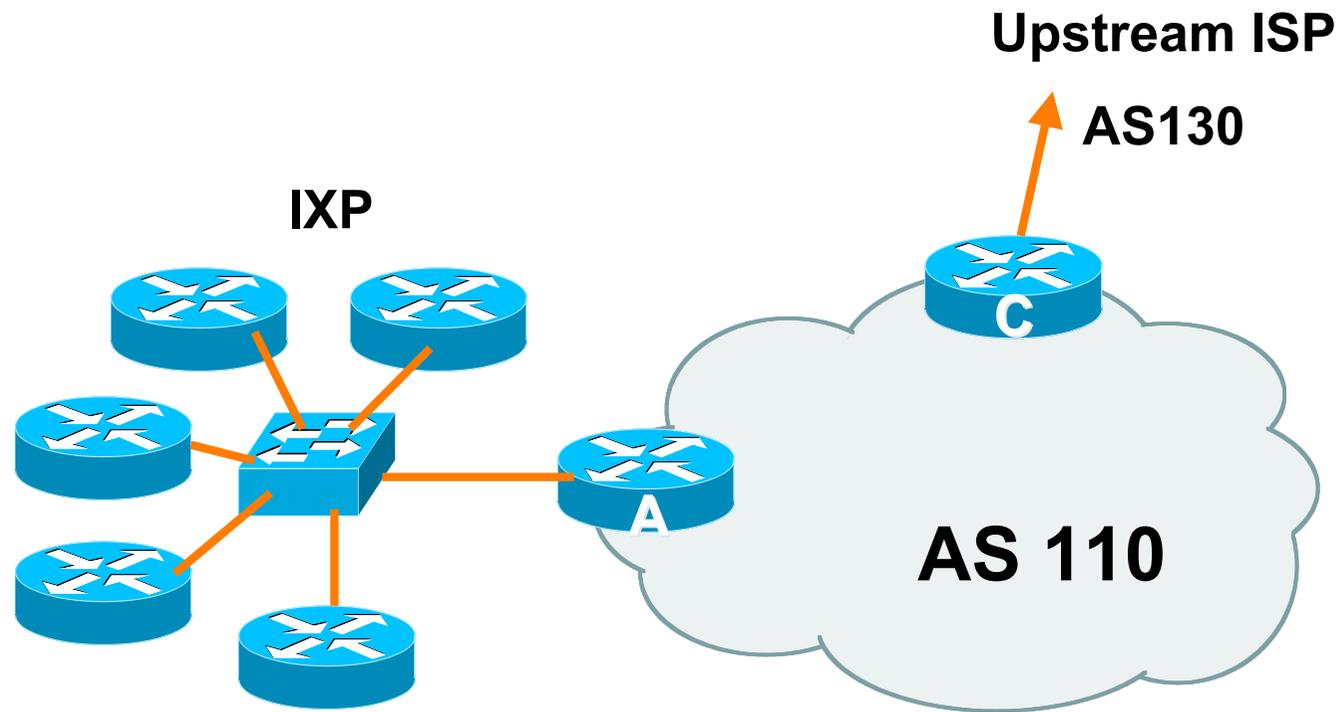
One Upstream, Local Exchange Point

- 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 120.5.10.1 mask 255.255.255.224
 ip verify unicast reverse-path
!
router bgp 110
 neighbor ixp-peers peer-group
 neighbor ixp-peers prefix-list my-block out
 neighbor ixp-peers remove-private-AS
 neighbor ixp-peers route-map set-local-pref in
...next slide
```

One Upstream, Local Exchange Point

```
neighbor 120.5.10.2 remote-as 100
neighbor 120.5.10.2 peer-group ixp-peers
neighbor 120.5.10.2 prefix-list peer100 in
neighbor 120.5.10.3 remote-as 101
neighbor 120.5.10.3 peer-group ixp-peers
neighbor 120.5.10.3 prefix-list peer101 in
neighbor 120.5.10.4 remote-as 102
neighbor 120.5.10.4 peer-group ixp-peers
neighbor 120.5.10.4 prefix-list peer102 in
neighbor 120.5.10.5 remote-as 103
neighbor 120.5.10.5 peer-group ixp-peers
neighbor 120.5.10.5 prefix-list peer103 in
```
..next slide

One Upstream, Local Exchange Point

```
!
ip prefix-list my-block permit 121.10.0.0/19
ip prefix-list peer100 permit 122.0.0.0/19
ip prefix-list peer101 permit 122.30.0.0/19
ip prefix-list peer102 permit 122.12.0.0/19
ip prefix-list peer103 permit 122.18.128.0/19
!
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 AS110

    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 ensures that local traffic crosses the IXP

    (And avoids potential problems with uRPF check)

One Upstream, Local Exchange Point

- Router C Configuration

```
router bgp 110
 network 121.10.0.0 mask 255.255.224.0
 neighbor 122.102.10.1 remote-as 130
 neighbor 122.102.10.1 prefix-list default in
 neighbor 122.102.10.1 prefix-list my-block out
!
ip prefix-list my-block permit 121.10.0.0/19
ip prefix-list default permit 0.0.0.0/0
!
ip route 121.10.0.0 255.255.224.0 null0
```

One Upstream, Local Exchange Point

- Note Router A configuration

  Prefix-list higher maintenance, but safer

  uRPF on the IX facing interface

  No generation of AS110 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

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

Upstream ISP
AS130

Upstream ISP
AS140

Local Peer
AS120

C

D

A

AS 110
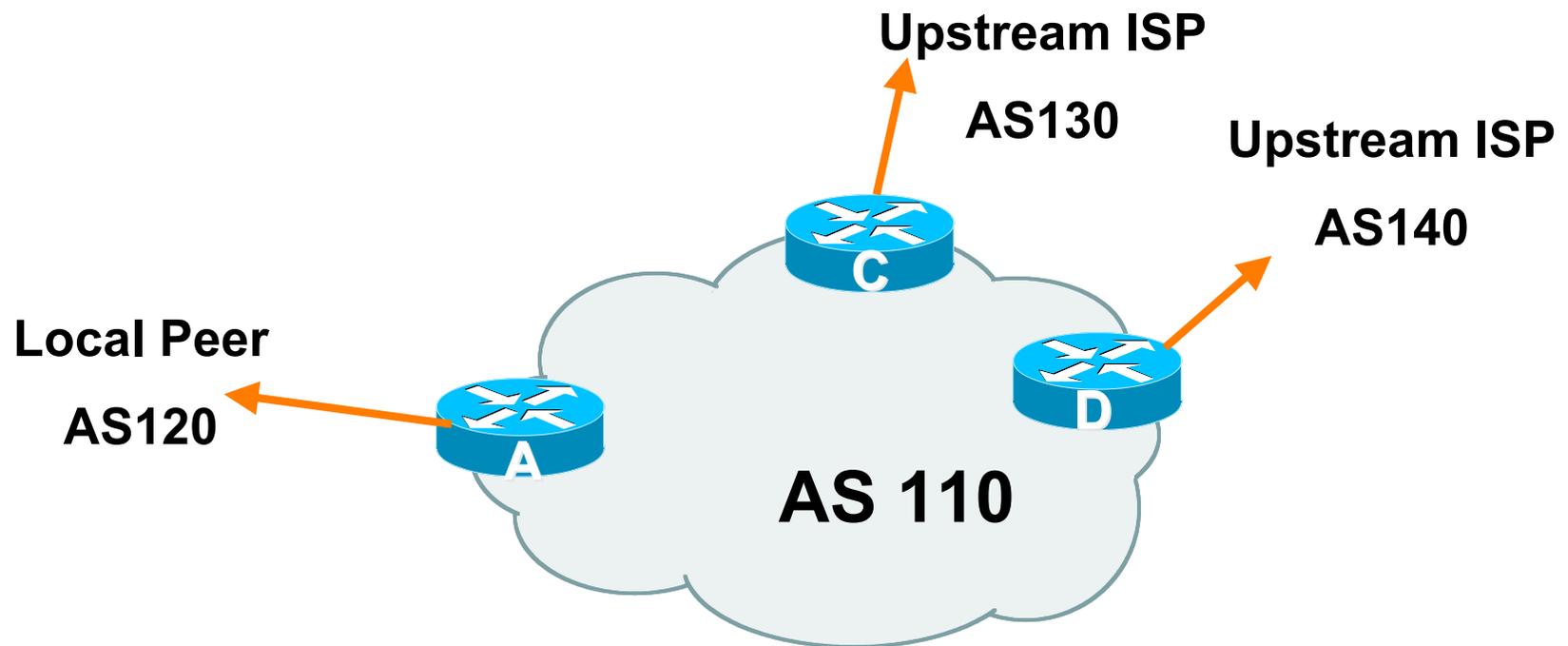
Two Upstreams, One Local Peer

- 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 from 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 110
  network 121.10.0.0 mask 255.255.224.0
  neighbor 122.102.10.1 remote-as 130
  neighbor 122.102.10.1 prefix-list default in
  neighbor 122.102.10.1 prefix-list my-block out
!
ip prefix-list my-block permit 121.10.0.0/19
ip prefix-list default permit 0.0.0.0/0
!
ip route 121.10.0.0 255.255.224.0 null0
```

Two Upstreams, One Local Peer

- Router D Configuration

```
router bgp 110
 network 121.10.0.0 mask 255.255.224.0
 neighbor 122.102.10.5 remote-as 140
 neighbor 122.102.10.5 prefix-list default in
 neighbor 122.102.10.5 prefix-list my-block out
!
ip prefix-list my-block permit 121.10.0.0/19
ip prefix-list default permit 0.0.0.0/0
!
ip route 121.10.0.0 255.255.224.0 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!

Two Upstreams, One Local Peer
Full Routes

- Router C Configuration

<div style="float:right; border:1px solid; background:#f5c842; padding:4px;">
Allow all prefixes in apart from RFC1918 and friends
</div>

```
router bgp 110
  network 121.10.0.0 mask 255.255.224.0
  neighbor 122.102.10.1 remote-as 130
  neighbor 122.102.10.1 prefix-list rfc1918-deny in
  neighbor 122.102.10.1 prefix-list my-block out
  neighbor 122.102.10.1 route-map AS130-loadshare in
!
ip prefix-list my-block permit 121.10.0.0/19
! See www.cymru.com/Documents/bogon-list.html
! ...for "RFC1918 and friends" list
...next slide
```

Two Upstreams, One Local Peer Full Routes

```
ip route 121.10.0.0 255.255.224.0 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 110
  network 121.10.0.0 mask 255.255.224.0
  neighbor 122.102.10.5 remote-as 140
  neighbor 122.102.10.5 prefix-list rfc1918-deny in
  neighbor 122.102.10.5 prefix-list my-block out
!
ip prefix-list my-block permit 121.10.0.0/19
! See www.cymru.com/Documents/bogon-list.html
! ...for "RFC1918 and friends" list
```

Allow all prefixes in apart from RFC1918 and friends
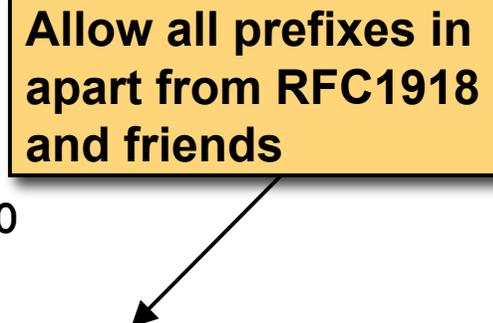
Two Upstreams, One Local Peer Full Routes

- 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

  - 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 110
  network 121.10.0.0 mask 255.255.224.0
  neighbor 122.102.10.1 remote-as 130
  neighbor 122.102.10.1 prefix-list rfc1918-nodef-deny in
  neighbor 122.102.10.1 prefix-list my-block out
  neighbor 122.102.10.1 filter-list 10 in
  neighbor 122.102.10.1 route-map tag-default-low in
!
..next slide
```

Allow all prefixes and default in; deny RFC1918 and friends

AS filter list filters prefixes based on origin ASN

Two Upstreams, One Local Peer Partial Routes

```
ip prefix-list my-block permit 121.10.0.0/19
ip prefix-list default permit 0.0.0.0/0
!
ip route 121.10.0.0 255.255.224.0 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 110
 network 121.10.0.0 mask 255.255.224.0
 neighbor 122.102.10.5 remote-as 140
 neighbor 122.102.10.5 prefix-list default in
 neighbor 122.102.10.5 prefix-list my-block out
!
ip prefix-list my-block permit 121.10.0.0/19
ip prefix-list default permit 0.0.0.0/0
!
ip route 121.10.0.0 255.255.224.0 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 its neighbouring ASes are accepted

  Traffic to those ASes will go over AS130 link

  Traffic to other all other ASes will go over the link to AS140

  What about backup?

Two Upstreams, One Local Peer Partial Routes

- Router C IGP Configuration

```
router ospf 110
default-information originate metric 30
passive-interface Serial 0/0
!
ip route 0.0.0.0 0.0.0.0 serial 0/0 254
```

- Router D IGP Configuration

```
router ospf 110
default-information originate metric 10
passive-interface Serial 0/0
!
ip route 0.0.0.0 0.0.0.0 serial 0/0 254
```

Two Upstreams, One Local Peer Partial Routes

- Partial routes from upstreams

    Use OSPF to determine outbound path

    Router D default has metric 10 – primary outbound path

    Router C default has metric 30 – backup outbound path

    Serial interface goes down, static default is removed from routing table, OSPF default withdrawn

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

    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
    ```

Service Provider Multihoming

Three upstreams, unequal bandwidths

Three upstreams, unequal bandwidths

- Autonomous System has three upstreams

  8Mbps to ISP A

  4Mbps to ISP B

  2Mbps to ISP C

- What is the strategy here?

  One option is full table from each

  3x 270k prefixes $\Rightarrow$ 810k paths

  Other option is partial table and defaults from each

  How??

Diagram

ISP B

AS120

ISP A

AS110

ISP C

AS130

B

A

AS 100
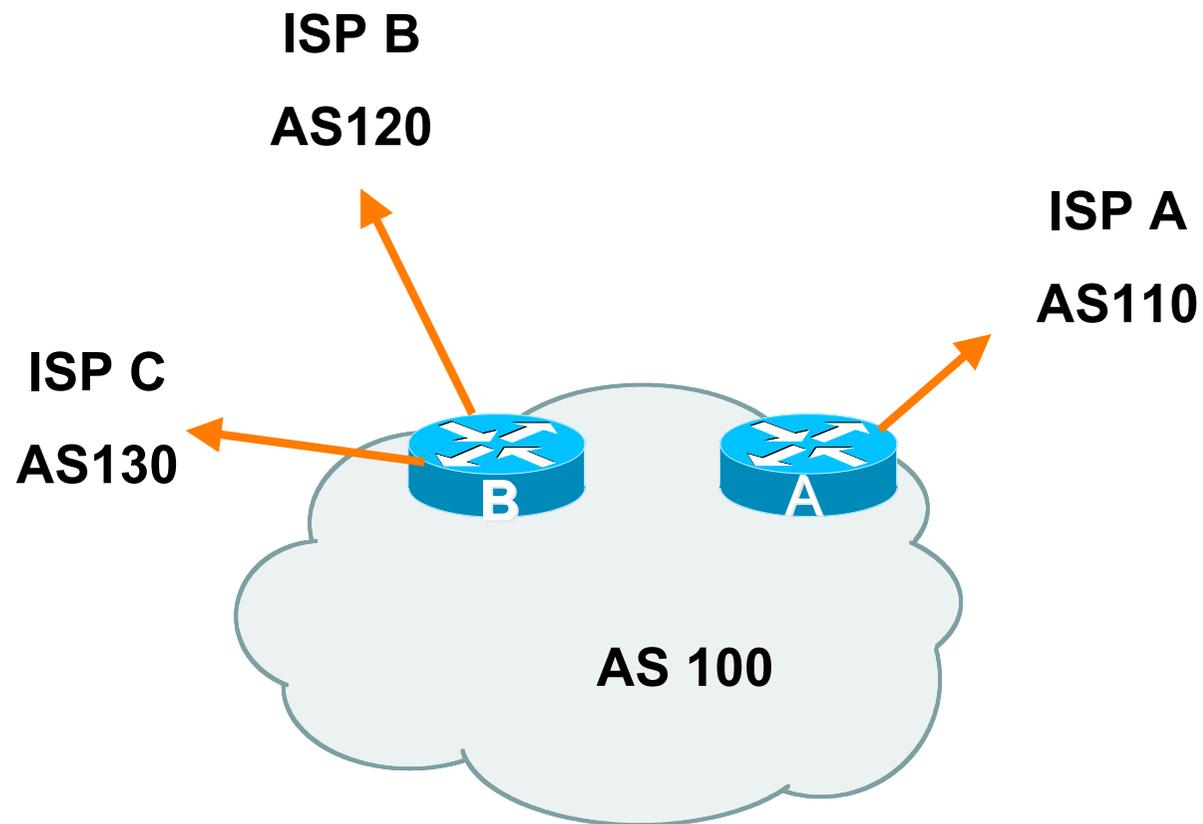
- Router A has 8Mbps circuit to ISP A

- Router B has 4Mbps and 2Mbps circuits 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

    Very rare for any provider to offer anything different

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 ISPs include:

209	Qwest	3549	Global Crossing
701	VerizonBusiness	3356	Level 3
1239	Sprint	3561	Savvis
1668	AOL TDN	7018	AT&T
2914	NTT America		

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   .*
```

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
 network 100.10.0.0 mask 255.255.224.0
 neighbor 122.102.10.1 remote 110
 neighbor 122.102.10.1 prefix-list default in
 neighbor 122.102.10.1 prefix-list aggregate out
!
ip prefix-list default permit 0.0.0.0/0
ip prefix-list aggregate permit 100.10.0.0/19
!
```

Router B: eBGP Configuration Example

```
router bgp 100
 network 100.10.0.0 mask 255.255.224.0
 neighbor 120.103.1.1 remote 120
 neighbor 120.103.1.1 filter-list 1 in
 neighbor 120.103.1.1 prefix-list ISP-B out
 neighbor 120.103.1.1 route-map to-ISP-B out
 neighbor 121.105.2.1 remote 130
 neighbor 121.105.2.1 filter-list 2 in
 neighbor 121.105.2.1 prefix-list ISP-C out
 neighbor 121.105.2.1 route-map to-ISP-C out
!
ip prefix-list aggregate permit 100.10.0.0/19
!
..next slide
```

Router B: eBGP Configuration Example

```
ip prefix-list ISP-B permit 100.10.0.0/19
ip prefix-list ISP-B permit 100.10.0.0/21
!
ip prefix-list ISP-C permit 100.10.0.0/19
ip prefix-list ISP-C permit 100.10.28.0/22
!
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 $\Rightarrow$ default is in RIB $\Rightarrow$ 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

- No need to carry default in iBGP

    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
 network 100.10.0.0 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 100.10.0.2 peer-group ibgp-peers
 neighbor 100.10.0.2 prefix-list ibgp-filter out
 neighbor 100.10.0.3 peer-group ibgp-peers
 neighbor 100.10.0.3 prefix-list ibgp-filter out
!
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 $\Rightarrow$ faster convergence

Summary

Summary

- Multihoming is not hard, really…

  Keep It Simple & Stupid!

- Full routing table is *rarely* required

  A default is often just as good

  If customers want 270k prefixes, charge them money for it

BGP Multihoming Techniques

End of Tutorial