BGP Multihoming Techniques

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Presentation Slides

- Available on

  ftp://ftp-eng.cisco.com

  /pfs/seminars/AfNOG2007-BGP-Multihoming.pdf

  And on the AfNOG2007 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

- Feel free to ask questions

BGP Multihoming Techniques

- Why Multihome?
- Definition & Options
- Preparing the Network
- Basic Multihoming
- Service Provider Multihoming
- Using Communities

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
- Using Communities

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

AS Numbers

- An Autonomous System Number is required by BGP
- Obtained from upstream ISP or Regional Registry (RIR)

  AfriNIC, APNIC, ARIN, LACNIC, RIPE NCC

- Necessary when you have links to more than one ISP or to an exchange point
- 16 bit integer, ranging from 1 to 65534

  Zero and 65535 are reserved

  64512 through 65534 are called Private ASNs

Private AS – Application

- **Applications**

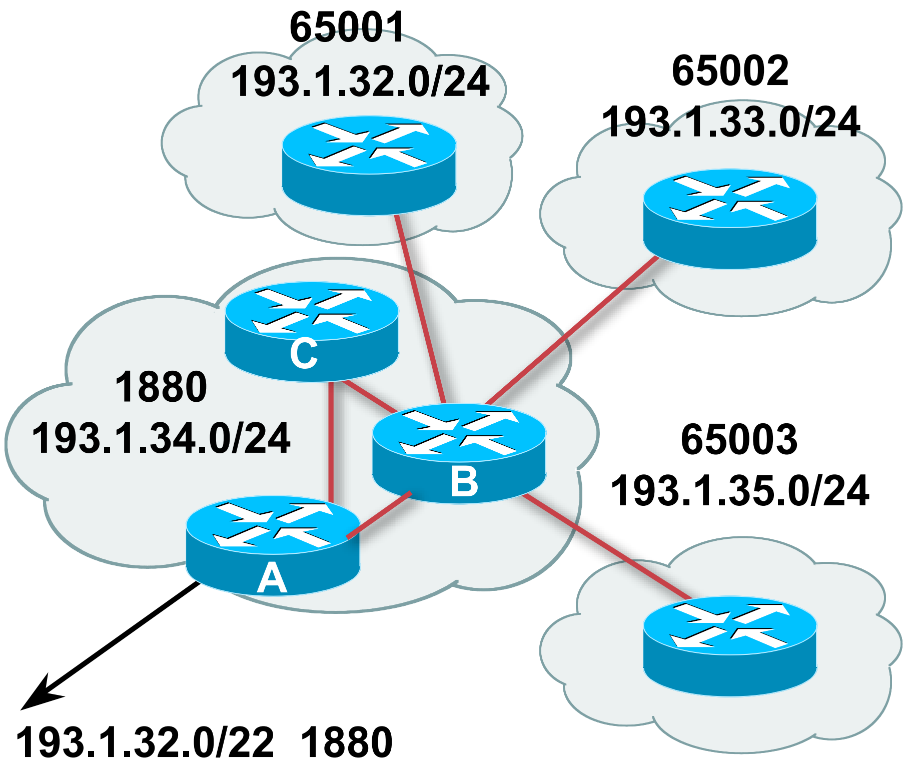
  An ISP with customers multihomed on their backbone (RFC2270)

  -or-

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

  -or-

  Within a BGP Confederation



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 RIR minimum allocation is /21**

  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 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

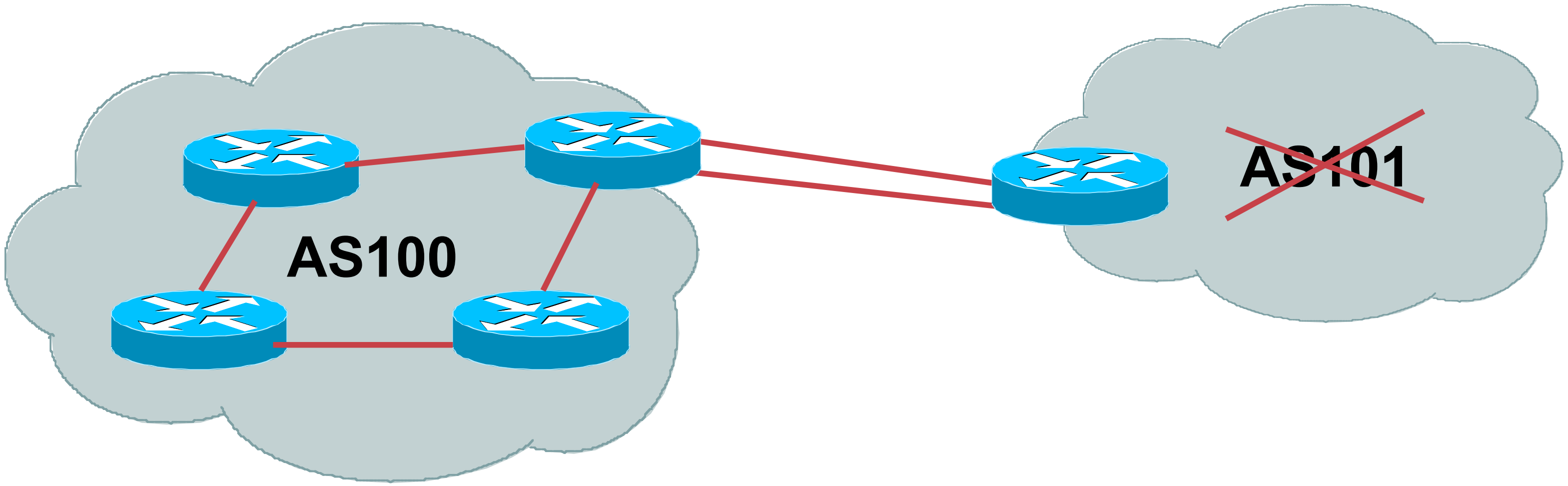
  Consider using the Project Cymru bogon BGP feed

  http://www.cymru.com/BGP/bogon-rs.html

Multihoming Scenarios

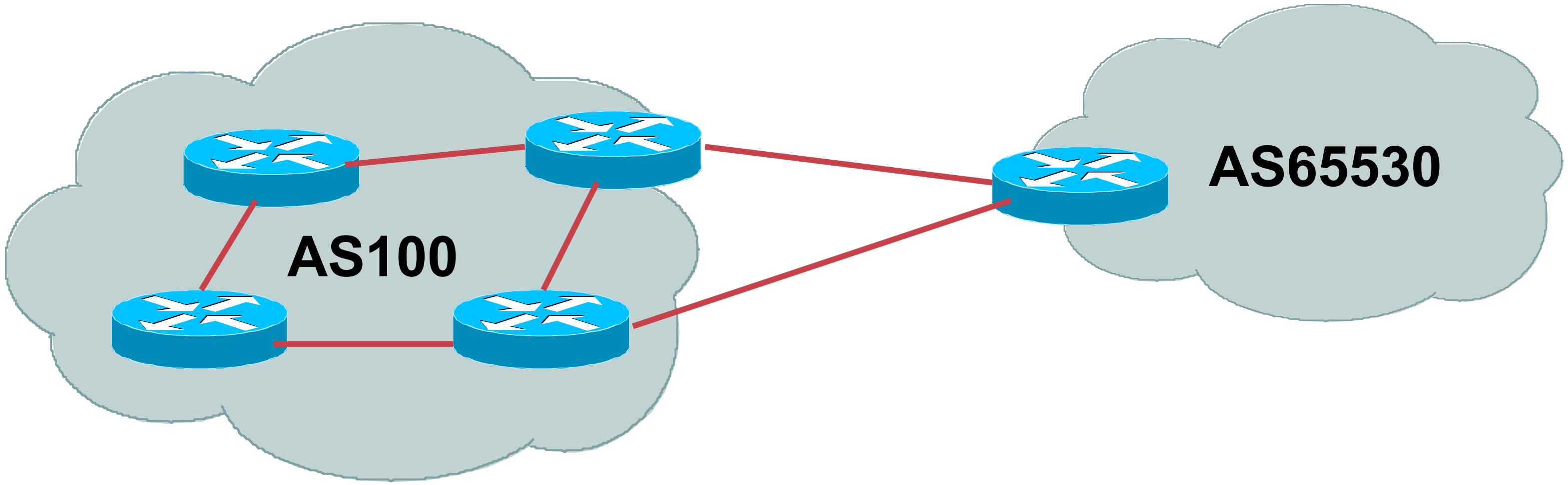
- **Stub network**
- **Multi-homed stub network**
- **Multi-homed network**
- **Load-balancing**

Stub Network



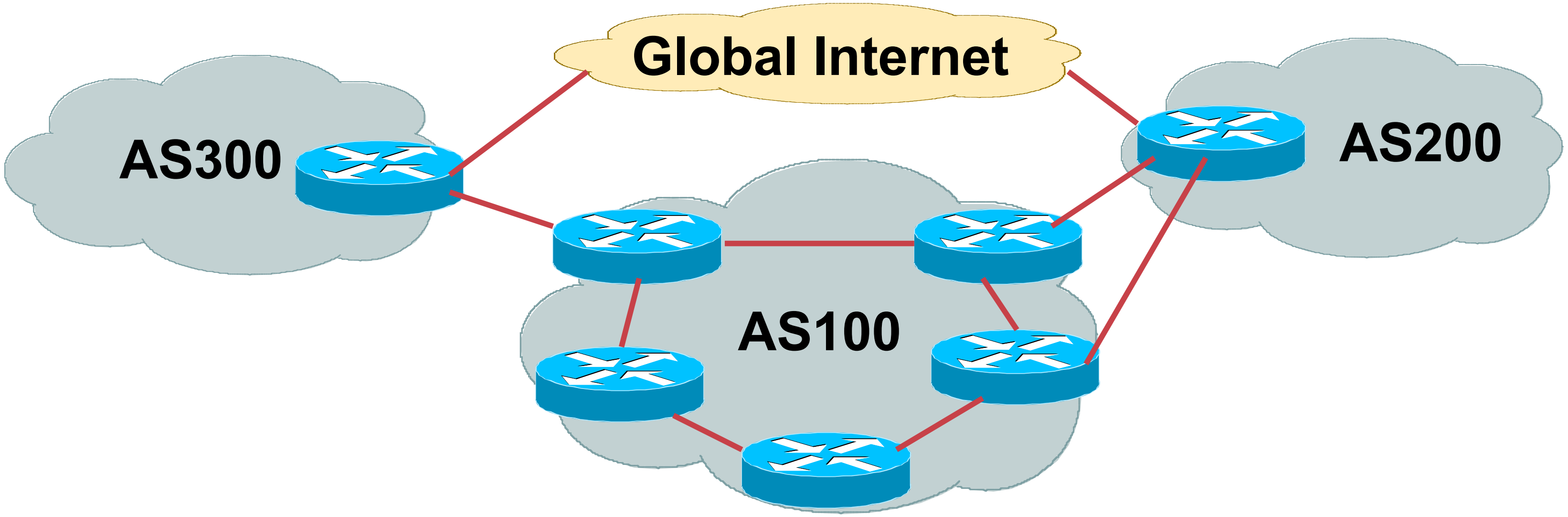
- No need for BGP
- Point static default to upstream ISP
- Router will load share on the two parallel circuits
- Upstream ISP advertises stub network
- Policy confined within upstream ISP's policy

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



- **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

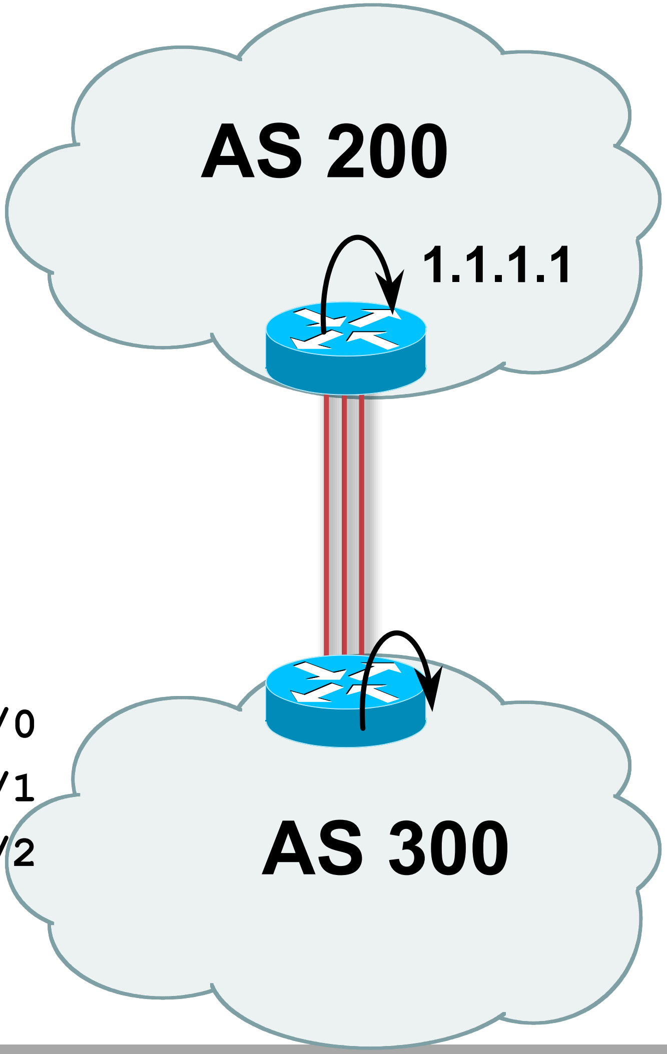
- **Use eBGP multihop**

  eBGP to loopback addresses

  eBGP prefixes learned with loopback address as next hop

- **Cisco IOS**

```
router bgp 300
 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
```



Multiple Sessions to an ISP – Example One

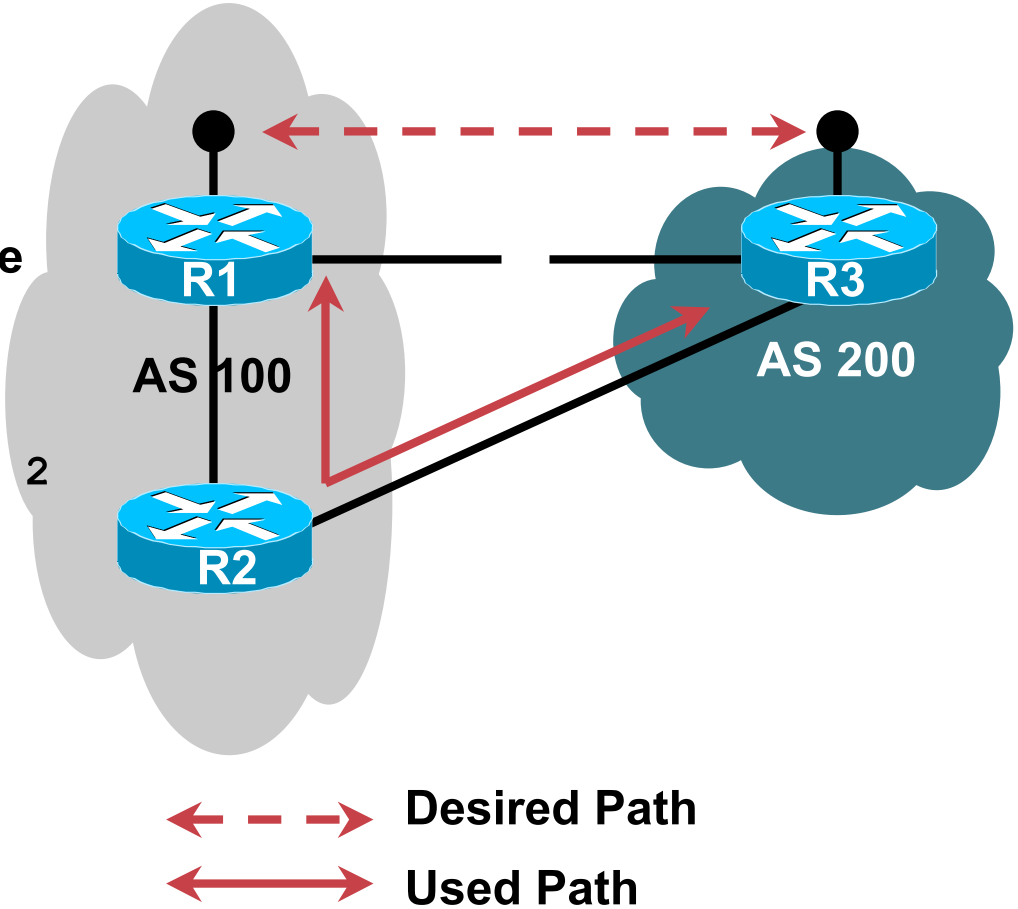
- **One eBGP-multihop gotcha:**

  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



Multiple Sessions to an ISP – Example One

- Try and avoid use of ebgp-multihop unless:

  It's absolutely necessary –or–

  Loadsharing across multiple links

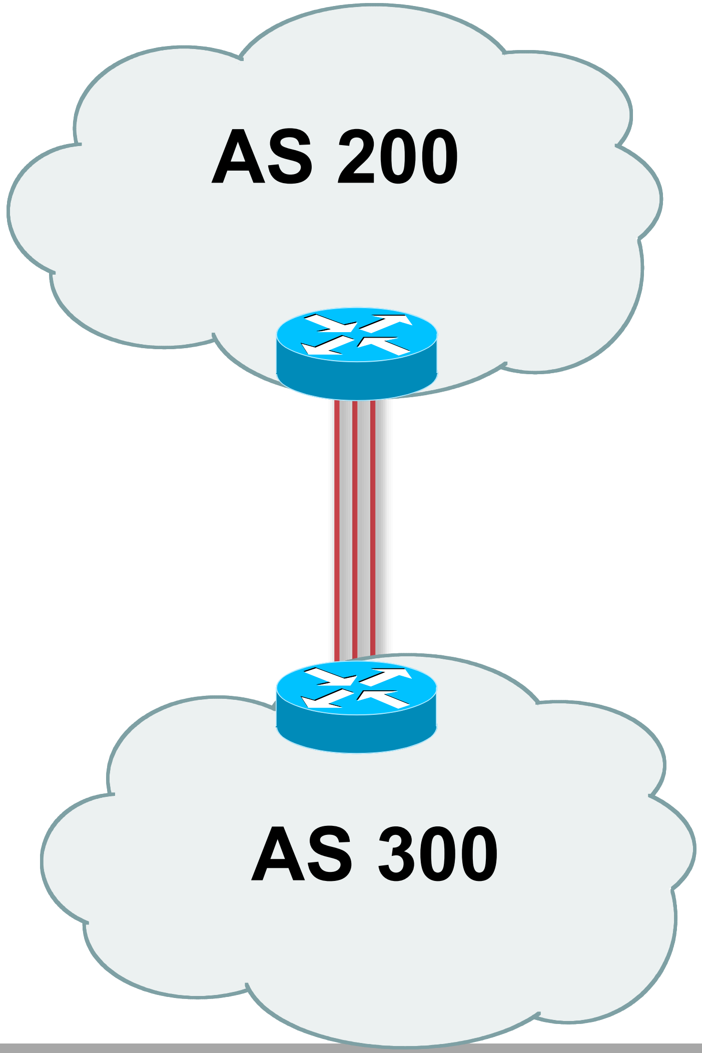
- Many ISPs discourage its use, for example:

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 – Example Two

- **BGP multi-path**
- **Limit to number of parallel paths depending on implementation**
- **For this example, three BGP sessions required**
- **Cisco IOS Configuration**

```
router bgp 300
 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
```



Multiple Sessions to an ISP

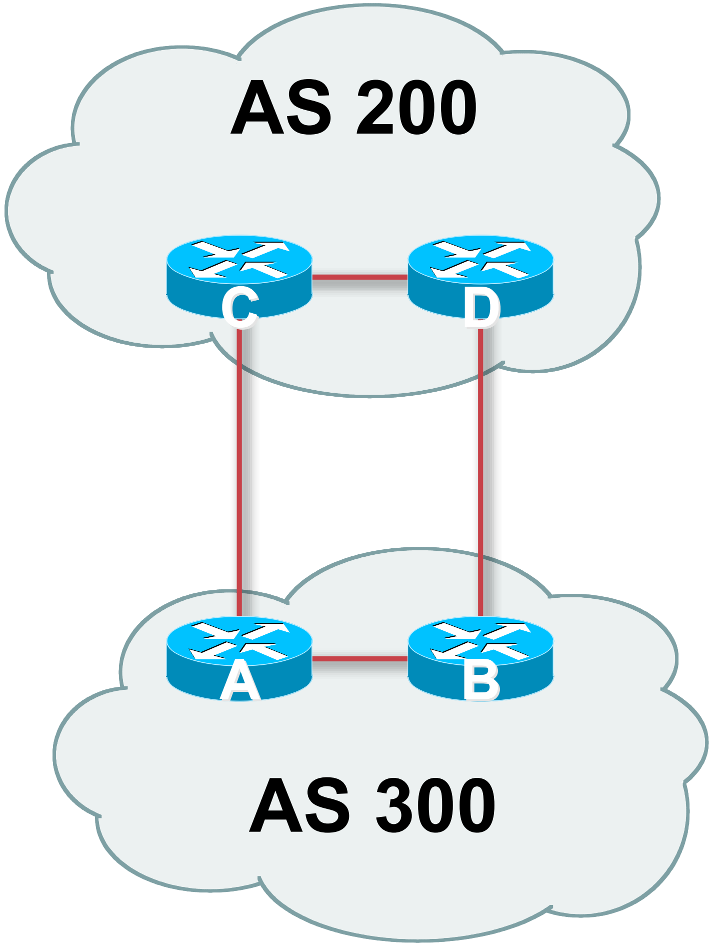
- Simplest scheme is to use defaults
- Learn/advertise prefixes for better control
- Planning and some work required to achieve loadsharing

    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



BGP Multihoming Techniques

- Why Multihome?
- Definition & Options
- Preparing the Network
- Basic Multihoming
- Service Provider Multihoming
- Using Communities

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

- **Will look at two examples of BGP deployment:**

  Example One: network uses only static routes

  Example Two: network is currently running an IGP

Preparing the Network
Example One

- 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

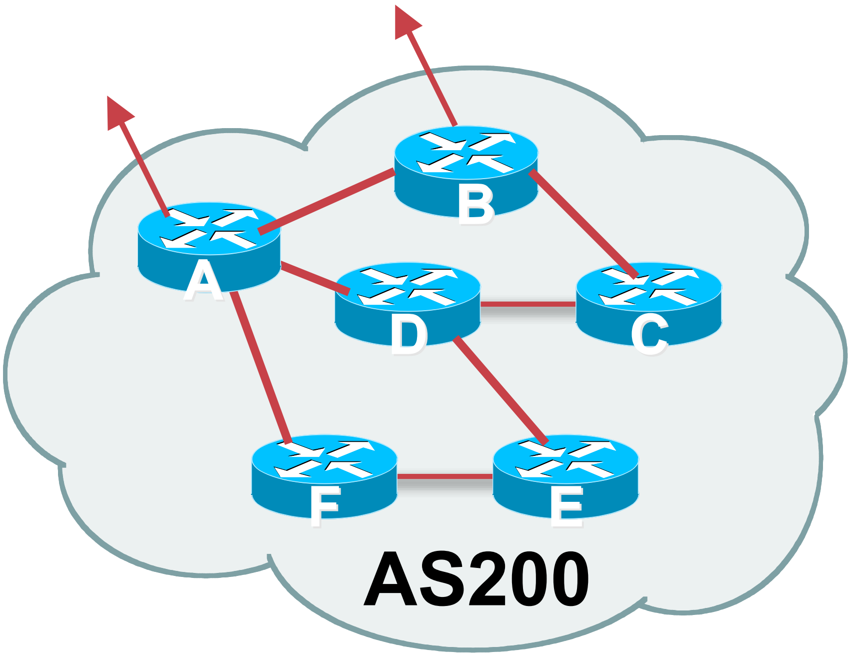
Preparing the Network
iBGP

- **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***



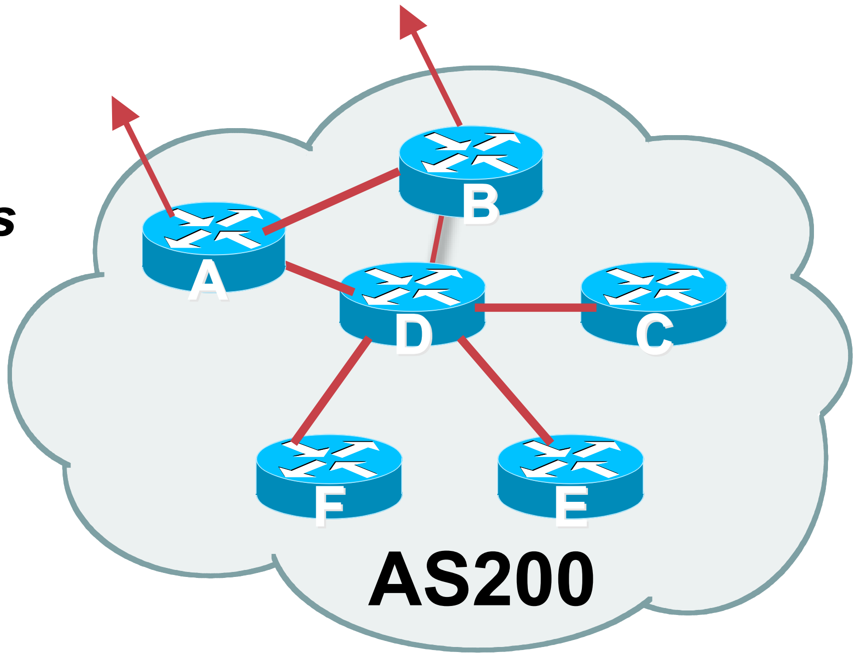
Preparing the Network
iBGP (Transit Path)

- ***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



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
Example Two

- The network is not running any BGP at the moment
  - single statically routed connection to upstream ISP
- The network is running an IGP though
  - All internal routing information is in the IGP
  - By IGP, OSPF or ISIS is assumed

Preparing the Network
IGP

- If not already done, assign loopback interfaces (with /32 addresses) to each router which is running the IGP

    Loopback is used for OSPF and BGP router id anchor

    Used for iBGP and route origination

- Ensure that the loopback /32s are appearing in the IGP

Preparing the Network
iBGP

- Go through the iBGP decision process as in Example One
- Decide full or partial, and the extent of the iBGP reach in the network

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: Reduce BGP distance to be less than the IGP

  (so that iBGP routes take priority)

  Step 4: Carefully remove the "customer" prefixes from the IGP

  Check! Does the network still work?

  Step 5: Restore BGP distance to be greater than IGP

  Step 6: 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 "customer" routes from IGP?

- **Work on one router at a time:**

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

  If so, remove it from the IGP

  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 iBGP you have deployed**

Preparing the Network
Example Two Configuration – Before BGP

```
interface loopback 0
 ip address 121.10.255.1 255.255.255.255
!
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
 passive-interface loopback 0
 redistribute connected subnets       ! Point-to-point links
 redistribute static subnets          ! Customer networks
!
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 if not already there

Preparing the Network
Example Two Configuration – Steps 1 & 2

```
! interface and OSPF configuration unchanged
!
router bgp 100
 redistribute connected subnets route-map point-to-point
 neighbor 121.10.1.2 remote-as 100
 neighbor 121.10.1.2 next-hop-self
 ...
 network 121.10.24.0 mask 255.255.252.0
 network 121.10.28.0 mask 255.255.254.0
 distance bgp 200 200 200
!
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
!
route-map point-to-point permit 5
 match ip address 1
 set community 100:1
!
access-list 1 permit 121.10.0.0 0.0.255.255
```

Add BGP and related configuration in red

Preparing the Network
Example Two Configuration – Steps 3 & 4

```
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
!
router bgp 100
 redistribute connected route-map point-to-point
 neighbor 121.10.1.2 remote-as 100
 neighbor 121.10.1.2 next-hop-self
 ...
 network 121.10.24.0 mask 255.255.252.0
 network 121.10.28.0 mask 255.255.254.0
 distance bgp 20 20 20         ! reduced BGP distance
!
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
!
...etc...
```

OSPF redistribution has been removed, OSPF tidied up

Preparing the Network
Example Two Configuration – Step 5

```
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
!
router bgp 100
 redistribute connected route-map point-to-point
 neighbor 121.10.1.2 remote-as 100
 neighbor 121.10.1.2 next-hop-self
 ...
 network 121.10.24.0 mask 255.255.252.0
 network 121.10.28.0 mask 255.255.254.0
 distance bgp 200 200 200      ! BGP distance restored
!
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
!
...etc...
```

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”
- Using Communities

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

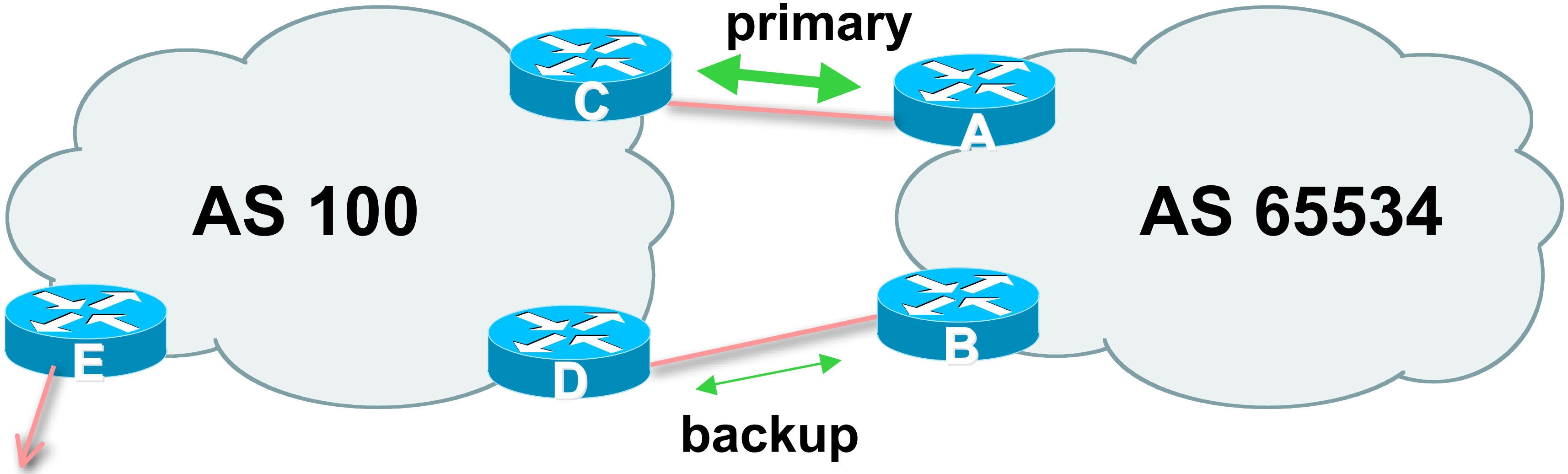
One link primary, the other link backup only

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)



- **Border router E in 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
!
```

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
!
route-map routerD-out permit 10
 match ip address prefix-list aggregate
 set metric 10
route-map routerD-out permit 20
!
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

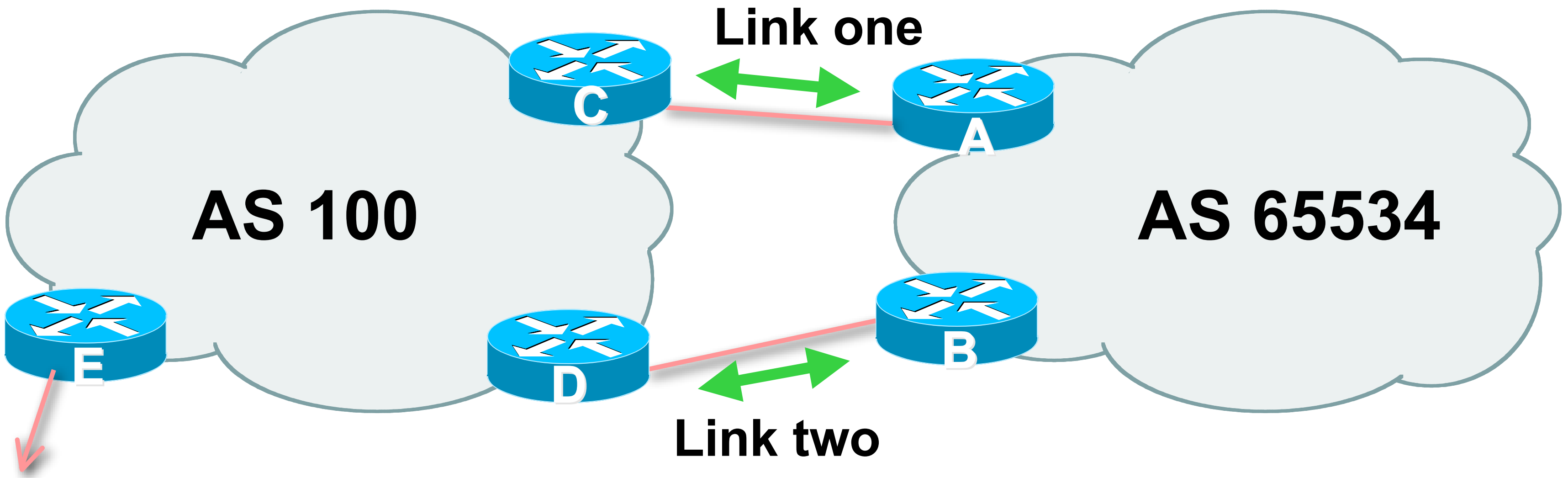
With Loadsharing

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



- 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
```

(Router B configuration is similar but with the other /20)

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

- **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!

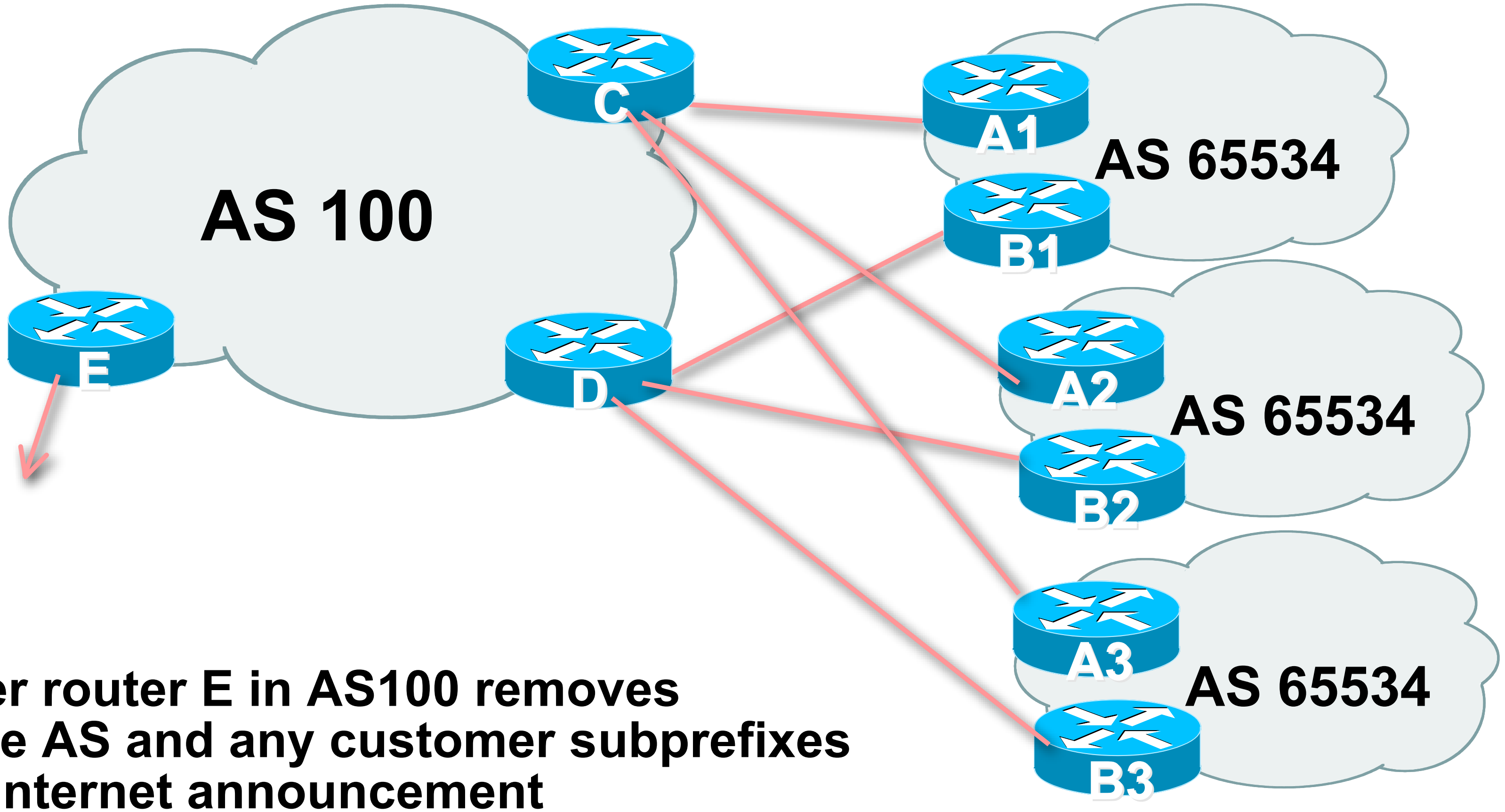
- Look at scaling the configuration

  ⇒ Simplifying the configuration

  Using templates, peer-groups, etc

  Every customer has the same configuration (basically)

Multiple Dualhomed Customers (RFC2270)



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

Multiple Dualhomed Customers

- **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 A*n* and B*n* configuration same as Router A and B previously**

Multiple Dualhomed Customers

- **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
```

Router B1 configuration is similar but for the other /20

Multiple Dualhomed Customers

- **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

```
 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

- 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

- **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?

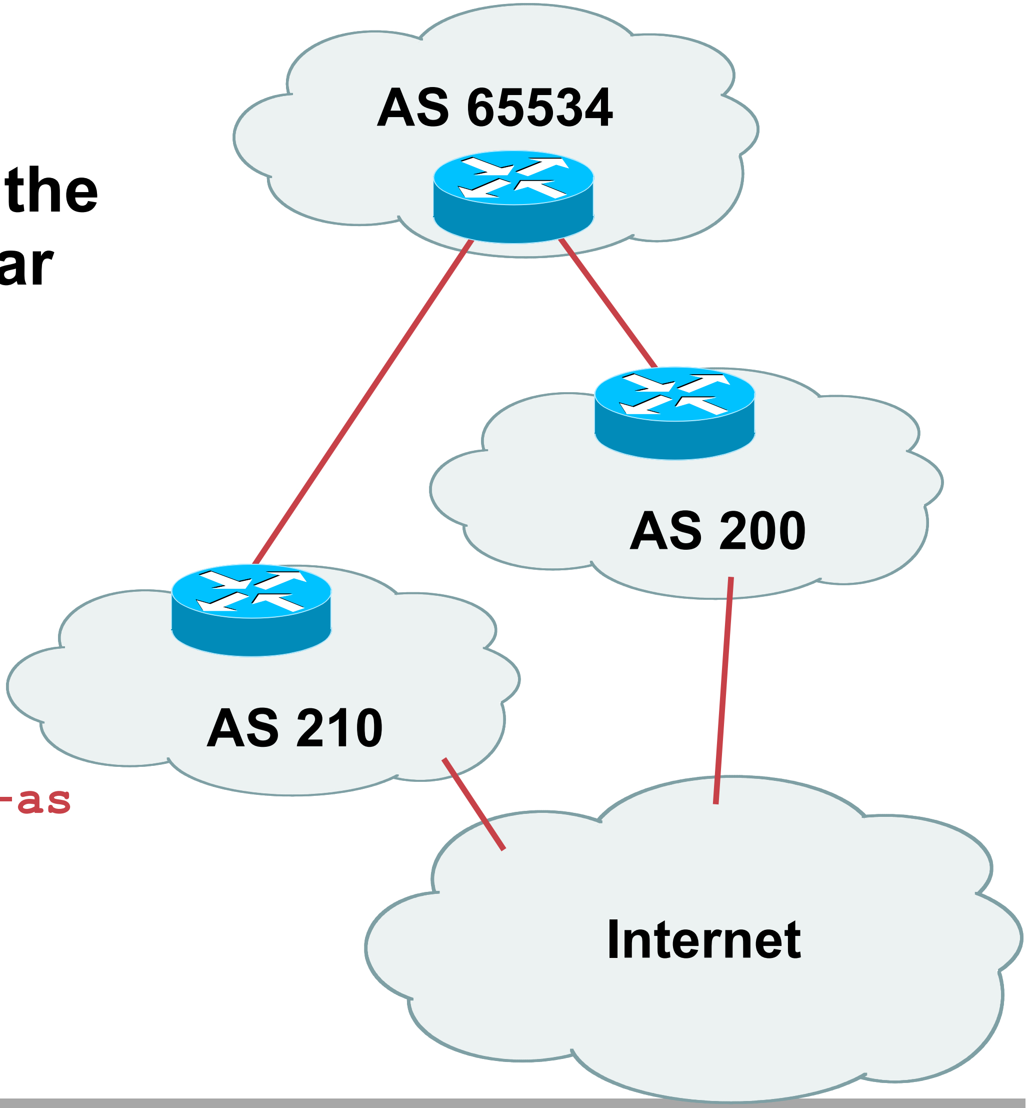
- **Viewing the prefixes originated by AS65534 in the Internet shows they appear to be originated by both AS210 and AS200**

  This is NOT bad

  Nor is it illegal

- **Cisco IOS command is**

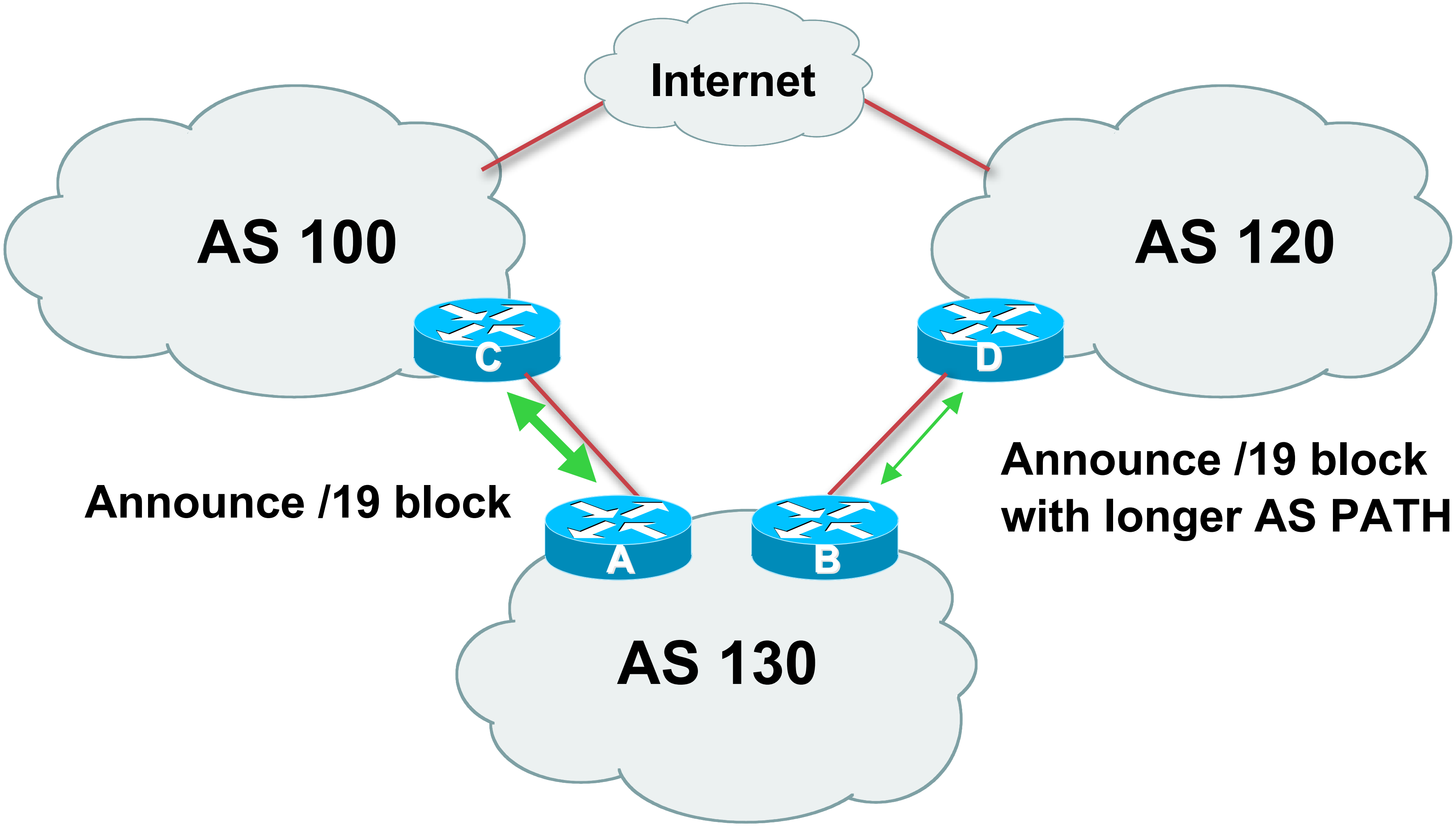
```
show ip bgp inconsistent-as
```



Two links to different ISPs

One link primary, the other link backup only

Two links to different ISPs (one as backup only)



Announce /19 block

Announce /19 block with longer AS PATH

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
```

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
```

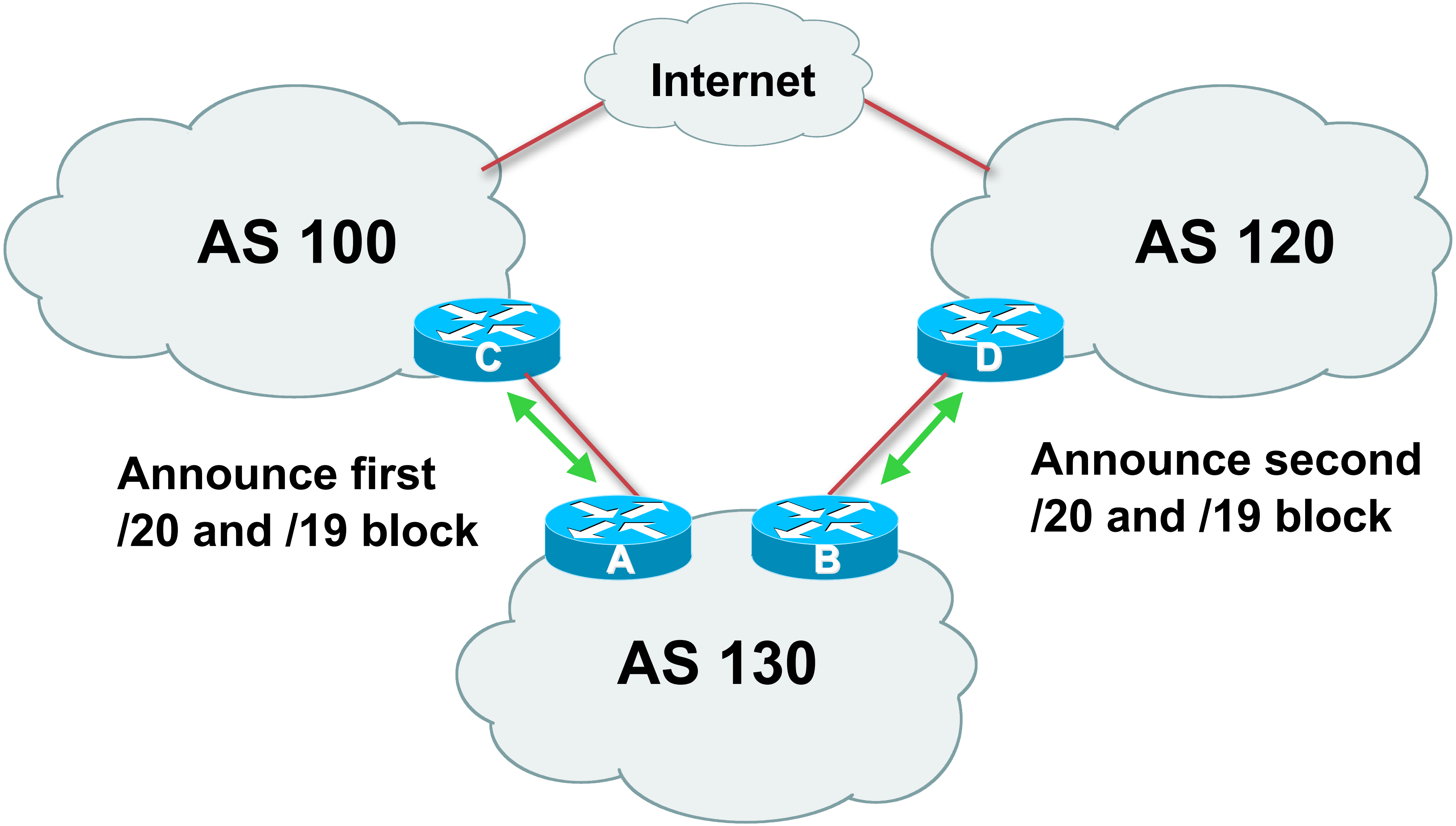
Two links to different ISPs (one as backup only)

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



Announce first /20 and /19 block

Announce second /20 and /19 block

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
```

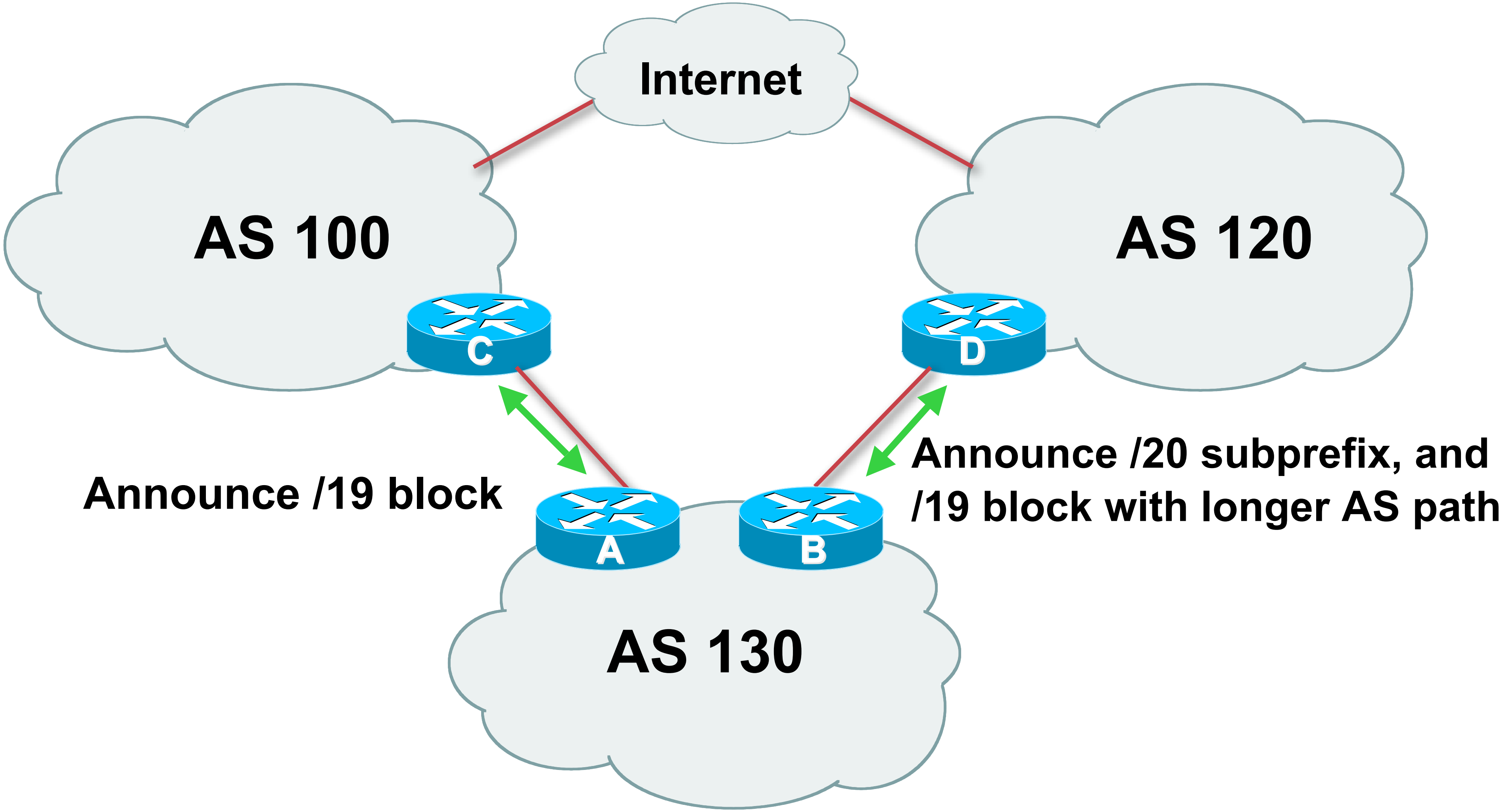
Two links to different ISPs (with loadsharing)

- 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



Announce /19 block

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

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
```

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"
- Using Communities

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!!

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

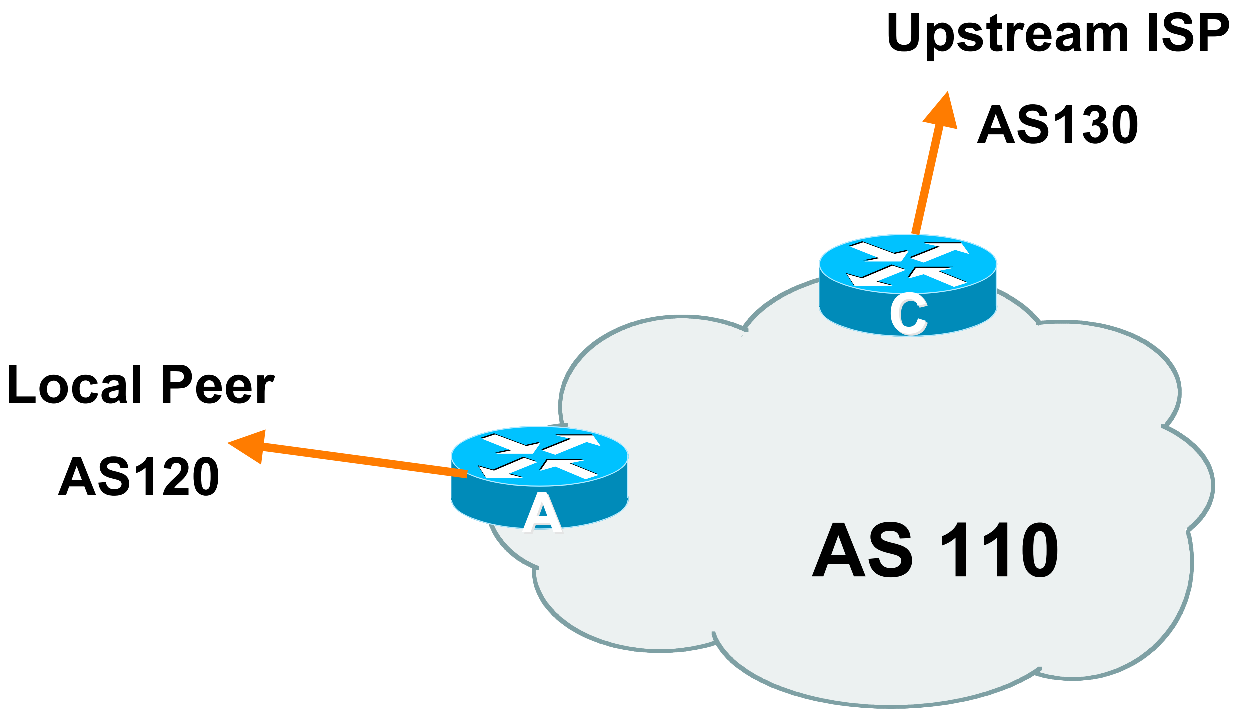
One upstream, one local peer

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 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
```

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 Recommendation

- **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

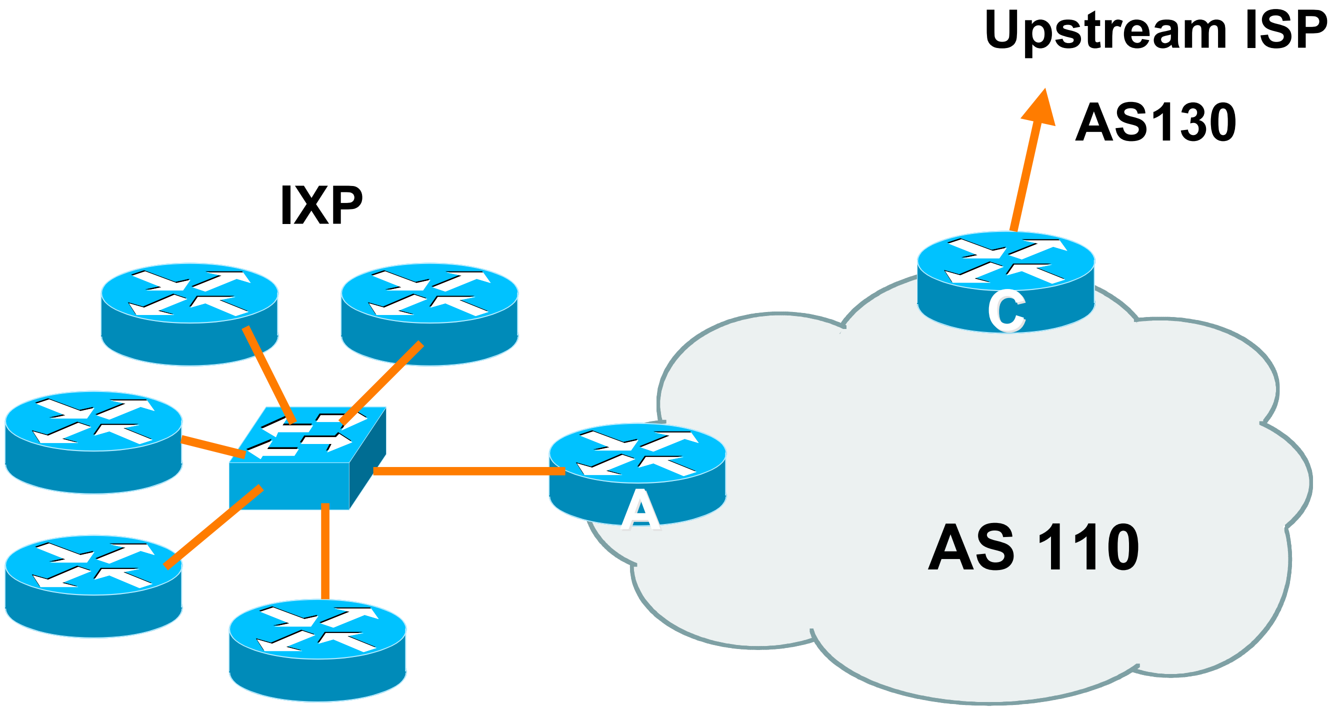
One Upstream, Local Exchange Point

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



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 Recommendation

- 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

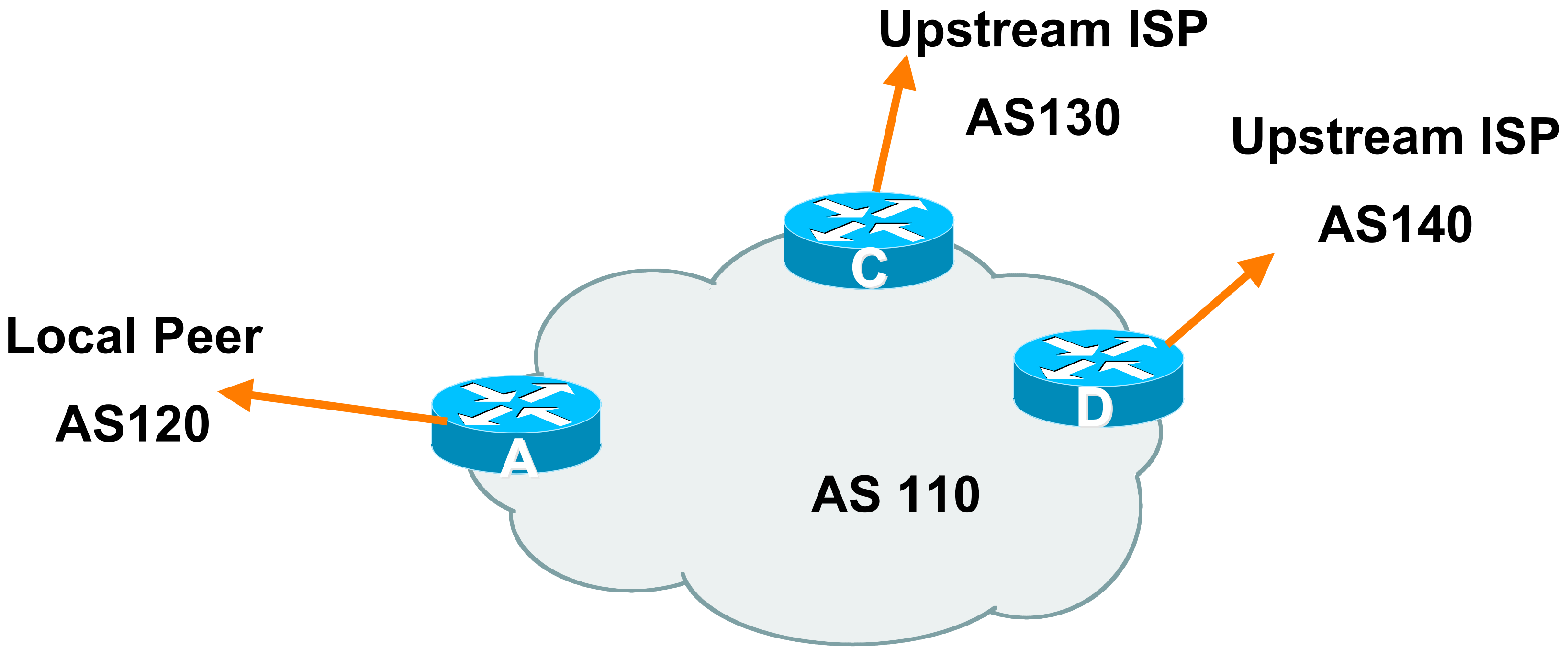
- Connect to both upstream transit providers to see the "Internet"

  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



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 much 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**

```
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
```

Allow all prefixes in apart from RFC1918 and friends

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 BGP 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-deny in
 neighbor 122.102.10.1 prefix-list my-block out
 neighbor 122.102.10.1 filter-list 10 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
!
ip as-path access-list 10 permit ^(130_)+$
ip as-path access-list 10 permit ^(130_)+_[0-9]+$
```

Allow all prefixes in; deny RFC1918 and friends

AS filter list filters prefixes based on origin ASN

Two Upstreams, One Local Peer
Partial Routes

- **Router D BGP 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?

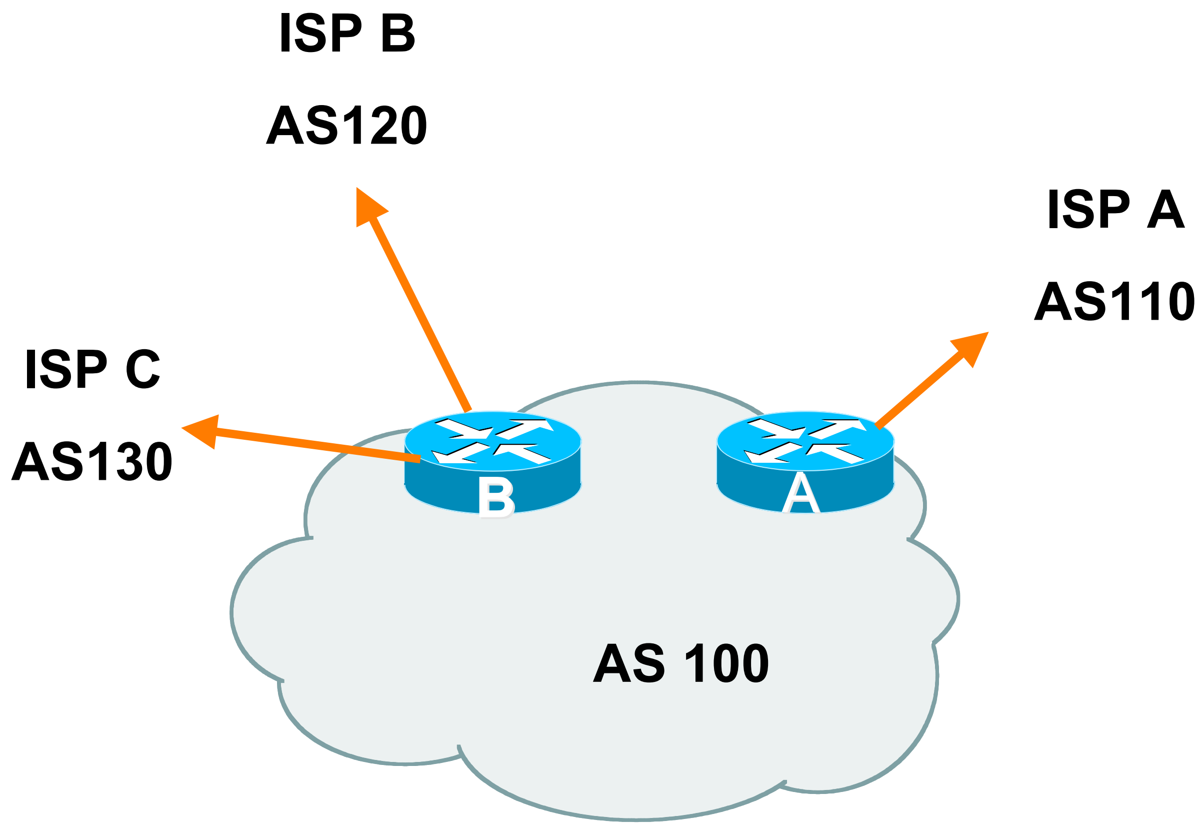
  One option is full table from each

  ⇒ 3x 200k prefixes ⇒ 600k paths

  Other option is partial table and defaults from each

  How??

Diagram



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:**

1239	Sprint	3561	Savvis
3549	Global Crossing	3356	Level 3
7018	AT&T	701	UUNET
2914	Verio	209	Qwest

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 ⇒ 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
- 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 ⇒ faster convergence

BGP Multihoming Techniques

- Why Multihome?
- Definition & Options
- Preparing the Network
- Basic Multihoming
- “BGP Traffic Engineering”
- Using Communities

Communities

How they are used in practice

Using Communities: RFC1998

- Informational RFC
- Describes how to implement loadsharing and backup on multiple inter-AS links

  BGP communities used to determine local preference in upstream’s network

- Gives control to the customer
- Simplifies upstream’s configuration

  simplifies network operation!

RFC1998

- Community values defined to have particular meanings:

ASx:100	set local pref 100	preferred route
ASx:90	set local pref 90	backup route if dualhomed on ASx
ASx:80	set local pref 80	main link is to another ISP with same AS path length
ASx:70	set local pref 70	main link is to another ISP

RFC1998

- **Sample Customer Router Configuration**

```
router bgp 130
 neighbor x.x.x.x remote-as 100
 neighbor x.x.x.x description Backup ISP
 neighbor x.x.x.x route-map config-community out
 neighbor x.x.x.x send-community
!
ip as-path access-list 20 permit ^$
ip as-path access-list 20 deny .*
!
route-map config-community permit 10
 match as-path 20
 set community 100:90
```

RFC1998

- **Sample ISP Router Configuration**

```
! Homed to another ISP
ip community-list 70 permit 100:70
! Homed to another ISP with equal ASPATH length
ip community-list 80 permit 100:80
! Customer backup routes
ip community-list 90 permit 100:90
!
route-map set-customer-local-pref permit 10
 match community 70
 set local-preference 70
!
```

..next slide

RFC1998

```
route-map set-customer-local-pref permit 20
 match community 80
 set local-preference 80
!
route-map set-customer-local-pref permit 30
 match community 90
 set local-preference 90
!
route-map set-customer-local-pref permit 40
 set local-preference 100
```

RFC1998

- Supporting RFC1998

    Many ISPs do, more should

    Check AS object in the Internet Routing Registry

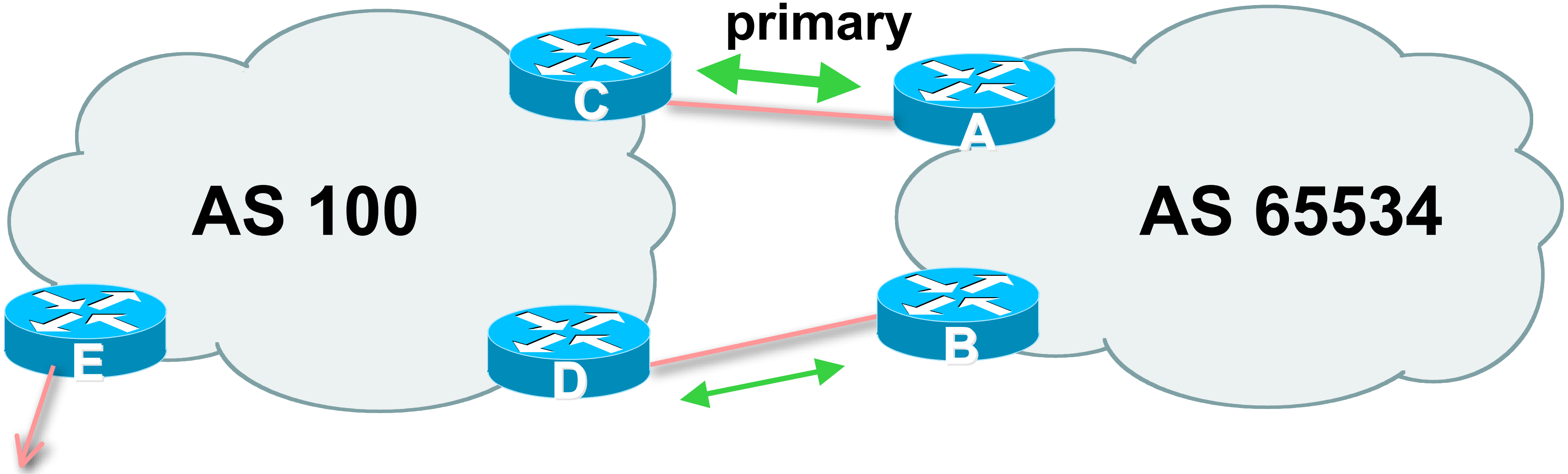
    If you do, insert comment in AS object in the IRR

    Or make a note on your website

Two links to the same ISP

One link primary, the other link backup only

Two links to the same ISP



- AS100 proxy aggregates for AS 65534

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

- Announce /19 aggregate on each link

  primary link makes standard announcement

  backup link sends community

- 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
!
```

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 send-community
 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
!
route-map routerD-out permit 10
 match ip address prefix-list aggregate
 set community 100:90
route-map routerD-out permit 20
!
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 route-map bgp-cust-in 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
!
..next slide
```

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

```
  ip prefix-list Customer permit 121.10.0.0/19
  ip prefix-list default permit 0.0.0.0/0
  !
  ip community-list 90 permit 100:90
  !
<snip>
  route-map bgp-cust-in permit 30
   match community 90
   set local-preference 90
  route-map bgp-cust-in permit 40
   set local-preference 100
```

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

- This is a simple example
- It looks more complicated than the same example presented earlier which used local preference and MEDs
- But the advantage is that this scales better

  With larger configurations, more customers, more options, it becomes easier to handle each and every requirement

Service Provider use of Communities

Some working examples

Background

- RFC1998 is okay for “simple” multihomed customers

  assumes that upstreams are interconnected

- ISPs have created many other communities to handle more complex situations

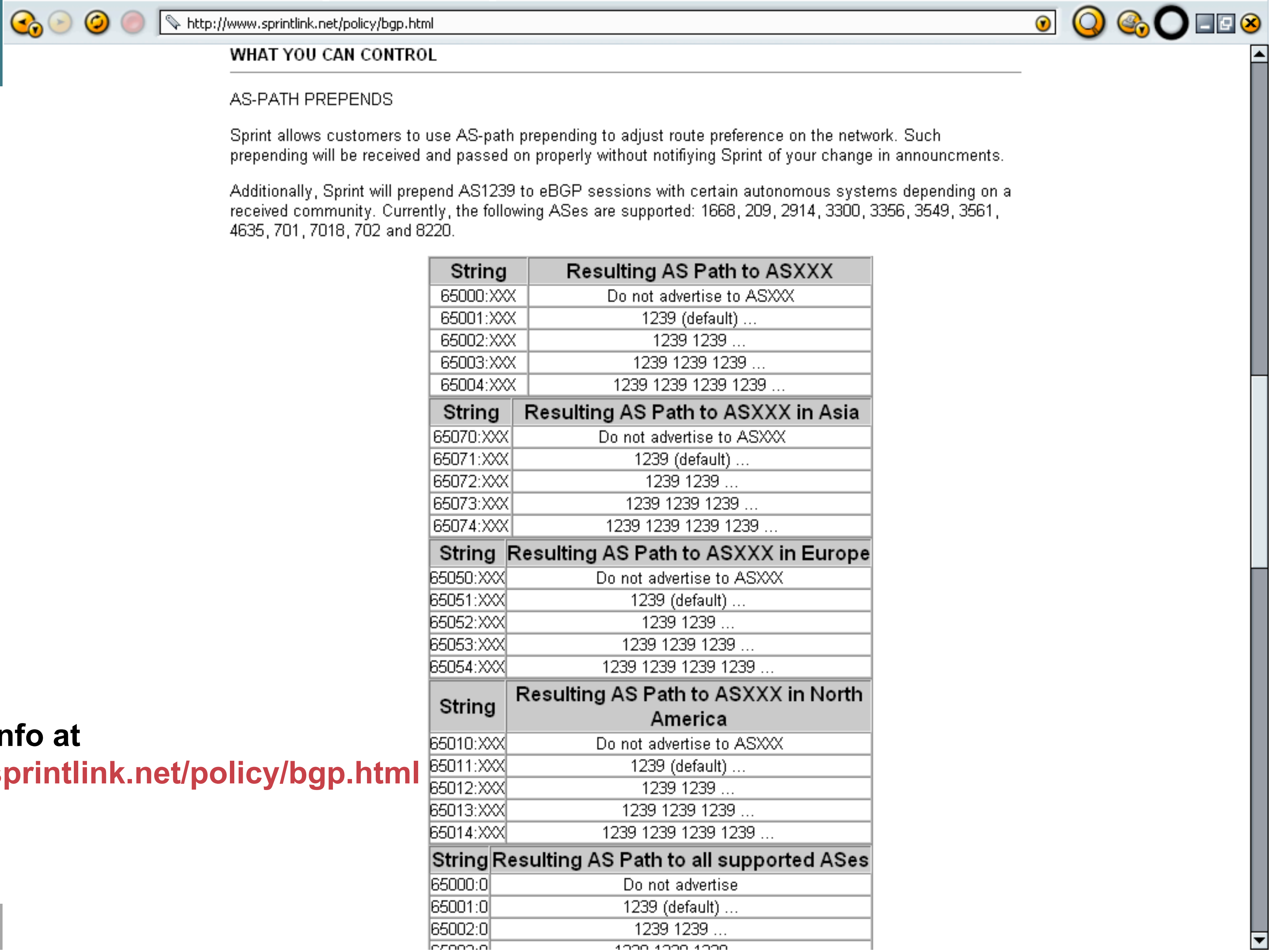
  Simplify ISP BGP configuration

  Give customer more policy control

ISP BGP Communities

- There are no recommended ISP BGP communities apart from
  - RFC1998
  - The four standard communities
    - www.iana.org/assignments/bgp-well-known-communities
- Efforts have been made to document from time to time
  - totem.info.ucl.ac.be/publications/papers-elec-versions/draft-quoitin-bgp-comm-survey-00.pdf
  - But so far… nothing more… ☹
  - Collection of ISP communities at www.onesc.net/communities
- ISP policy is usually published
  - On the ISP's website
  - Referenced in the AS Object in the IRR

Some ISP Examples: Sprintlink



http://www.sprintlink.net/policy/bgp.html

WHAT YOU CAN CONTROL

AS-PATH PREPENDS

Sprint allows customers to use AS-path prepending to adjust route preference on the network. Such prepending will be received and passed on properly without notifiying Sprint of your change in announcments.

Additionally, Sprint will prepend AS1239 to eBGP sessions with certain autonomous systems depending on a received community. Currently, the following ASes are supported: 1668, 209, 2914, 3300, 3356, 3549, 3561, 4635, 701, 7018, 702 and 8220.

String	Resulting AS Path to ASXXX
65000:XXX	Do not advertise to ASXXX
65001:XXX	1239 (default) ...
65002:XXX	1239 1239 ...
65003:XXX	1239 1239 1239 ...
65004:XXX	1239 1239 1239 1239 ...

String	Resulting AS Path to ASXXX in Asia
65070:XXX	Do not advertise to ASXXX
65071:XXX	1239 (default) ...
65072:XXX	1239 1239 ...
65073:XXX	1239 1239 1239 ...
65074:XXX	1239 1239 1239 1239 ...

String	Resulting AS Path to ASXXX in Europe
65050:XXX	Do not advertise to ASXXX
65051:XXX	1239 (default) ...
65052:XXX	1239 1239 ...
65053:XXX	1239 1239 1239 ...
65054:XXX	1239 1239 1239 1239 ...

String	Resulting AS Path to ASXXX in North America
65010:XXX	Do not advertise to ASXXX
65011:XXX	1239 (default) ...
65012:XXX	1239 1239 ...
65013:XXX	1239 1239 1239 ...
65014:XXX	1239 1239 1239 1239 ...

String	Resulting AS Path to all supported ASes
65000:0	Do not advertise
65001:0	1239 (default) ...
65002:0	1239 1239 ...
65003:0	1239 1239 1239

More info at
www.sprintlink.net/policy/bgp.html

Some ISP Examples
AAPT

```
aut-num:      AS2764
as-name:      ASN-CONNECT-NET
descr:        AAPT Limited
admin-c:      CNO2-AP
tech-c:       CNO2-AP
remarks:      Community support definitions
remarks:
remarks:      Community  Definition
remarks:      ------------------------------------------------
remarks:      2764:2 Don't announce outside local POP
remarks:      2764:4 Lower local preference by 15
remarks:      2764:5 Lower local preference by 5
remarks:      2764:6 Announce to customers and all peers
                           (incl int'l peers), but not transit
remarks:      2764:7 Announce to customers only
remarks:      2764:14 Announce to AANX
notify:       routing@connect.com.au
mnt-by:       CONNECT-AU
changed:      nobody@connect.com.au 20050225
source:       CCAIR
```

More at http://info.connect.com.au/docs/routing/general/multi-faq.shtml#q13

Some ISP Examples
MCI Europe

```
aut-num: AS702
descr:   MCI EMEA - Commercial IP service provider in Europe
remarks: MCI uses the following communities with its customers:
         702:80     Set Local Pref 80 within AS702
         702:120    Set Local Pref 120 within AS702
         702:20     Announce only to MCI AS'es and MCI customers
         702:30     Keep within Europe, don't announce to other MCI AS's
         702:1      Prepend AS702 once at edges of MCI to Peers
         702:2      Prepend AS702 twice at edges of MCI to Peers
         702:3      Prepend AS702 thrice at edges of MCI to Peers
         Advanced communities for customers
         702:7020   Do not announce to AS702 peers with a scope of
                    National but advertise to Global Peers, European
                    Peers and MCI customers.
         702:7001   Prepend AS702 once at edges of MCI to AS702
                    peers with a scope of National.
<snip>
         Additional details of the MCI communities are located at:
         http://global.mci.com/uk/customer/bgp/
mnt-by:  WCOM-EMEA-RICE-MNT
changed: rice@lists.mci.com 20041006
source:  RIPE
```

And several more!

Some ISP Examples
BT Ignite

```
aut-num:      AS5400
descr:        BT Ignite European Backbone
remarks:
remarks:      Community to                         Community to
remarks:      Not announce      To peer:           AS prepend 5400
remarks:
remarks:      5400:1000 All peers & Transits       5400:2000
remarks:
remarks:      5400:1500 All Transits               5400:2500
remarks:      5400:1501 Sprint Transit (AS1239)    5400:2501
remarks:      5400:1502 SAVVIS Transit (AS3561)    5400:2502
remarks:      5400:1503 Level 3 Transit (AS3356)   5400:2503
remarks:      5400:1504 AT&T Transit (AS7018)      5400:2504
remarks:      5400:1505 UUnet Transit (AS701)      5400:2505
remarks:
remarks:      5400:1001 Nexica (AS24592)           5400:2001
remarks:      5400:1002 Fujitsu (AS3324)           5400:2002
remarks:      5400:1003 Unisource (AS3300)         5400:2003
<snip>
notify:       notify@eu.bt.net
mnt-by:       CIP-MNT
source:       RIPE
```

And many many more!

Some ISP Examples
Carrier1

```
aut-num:    AS8918
descr:      Carrier1 Autonomous System
<snip>
remarks:    Community  Definition
remarks:    *
remarks:    8918:2000  Do not announce to C1 customers
remarks:    8918:2010  Do not announce to C1 peers, peers+ and transit
remarks:    8918:2015  Do not announce to C1 transit providers
remarks:    *
remarks:    8918:2020  Do not announce to Teleglobe (AS 6453)
remarks:    8918:2035  Do not announce to UUNet     (AS 702)
remarks:    8918:2040  Do not announce to Cogent    (AS 174)
remarks:    8918:2050  Do not announce to T-Systems (AS 3320)
remarks:    8918:2060  Do not announce to Sprint    (AS 1239)
remarks:    *
remarks:    8918:2070  Do not announce to AMS-IX peers
remarks:    8918:2080  Do not announce to NL-IX peers
remarks:    8918:2090  Do not announce to Packet Exchange Peers
<snip>
notify:     inoc@carrier1.net
mnt-by:     CARRIER1-MNT
source:     RIPE
```

And many many more!

Some ISP Examples
Level 3

```
aut-num:      AS3356
descr:        Level 3 Communications
<snip>
remarks:      ---------------------------------------------------------
remarks:      customer traffic engineering communities - Suppression
remarks:      ---------------------------------------------------------
remarks:      64960:XXX - announce to AS XXX if 65000:0
remarks:      65000:0   - announce to customers but not to peers
remarks:      65000:XXX - do not announce at peerings to AS XXX
remarks:      ---------------------------------------------------------
remarks:      customer traffic engineering communities - Prepending
remarks:      ---------------------------------------------------------
remarks:      65001:0   - prepend once  to all peers
remarks:      65001:XXX - prepend once  at peerings to AS XXX
remarks:      65002:0   - prepend twice to all peers
remarks:      65002:XXX - prepend twice at peerings to AS XXX
remarks:      65003:0   - prepend 3x to all peers
remarks:      65003:XXX - prepend 3x     at peerings to AS XXX
remarks:      65004:0   - prepend 4x to all peers
remarks:      65004:XXX - prepend 4x     at peerings to AS XXX
<snip>
mnt-by:       LEVEL3-MNT
source:       RIPE
```

And many many more!

Creating your own community policy

- **Consider creating communities to give policy control to customers**

  Reduces technical support burden

  Reduces the amount of router reconfiguration, and the chance of mistakes

  Use the previous examples as a guideline

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 200k prefixes, charge them money for it

BGP Multihoming Techniques

End of Tutorial