

Multihoming: Introduction

ISP Workshops



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Acknowledgements

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

Philip Smith

BGP Videos

- NSRC has made a video recording of this presentation, as part of a library of BGP videos for the whole community to use:
 - <https://learn.nsrc.org/bgp#multi-homing>

The screenshot shows the NSRC (Network Startup Resource Center) website. The navigation bar includes links for Home, About, BGP for All (highlighted), perfSONAR, ScienceDMZ, FedIdM, and Contact Us, along with a search bar. The main content area is divided into three columns:

- BGP for All:** A text-based introduction to BGP, explaining it as the primary routing protocol for the Internet and autonomous systems. It also mentions that understanding routing options can lead to efficiencies for institutions and research/education networks.
- Introduction to Routing:** A list of video topics including Internet Routing, Routing Protocols, Introduction to IS-IS (UPDATED), IS-IS Levels, IS-IS Adjacencies, Best Configuration Practices for IS-IS on Cisco IOS, IS-IS Authentication, Default Routes and IPv6, Introduction to OSPF, OSPF Areas, OSPF Adjacencies, Best Configuration Practices for OSPF on Cisco IOS, OSPF Authentication, Default Routes and IPv6, Comparing OSPF and IS-IS, Choosing between OSPF and IS-IS, Migrating from OSPF to IS-IS, Migration Plan, and Finalizing Migration.
- Introduction to BGP:** A list of video topics including Introduction to Border Gateway Protocol, Transit and Peering, Autonomous Systems (UPDATED), How BGP works, Supporting Multiple Protocols, IBGP versus EBGP, Setting up EBGP, and Setting up IBGP.

On the right side, there is a video player for "BGP for All" with a play button and a "Watch on YouTube" button. Below the video player, there are sections for "BGP Case Studies" (listing Peering Priorities, Transit Provider Peering at an IXP, Customer Multihomed between two IXPs, Traffic Engineering for an ISP connected to two IXes, Traffic Engineering for an ISP with two interfaces on one IX LAN, and Traffic Engineering and CDNs) and "Communities" (listing RFC 1998 Traffic Engineering, Simplifying Traffic Engineering, How to Apply Communities to Originated Routes, and How to Use Communities for Service Identification).

Agenda

- Why Multihome?
- The Multihoming Toolset
- How to Multihome – Options
- Basic Principles of Multihoming
- IP Addressing & Multihoming

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?

- Changing upstream provider
- With one upstream, migration means:
 - Disconnecting existing connection
 - Moving the link to the new upstream
 - Reconnecting the link
 - Reannouncing address space
 - Break in service for end users (hours, days,...?)
- With two upstreams, migration means:
 - Bring up link with new provider (including BGP and address announcements)
 - Disconnect link with original upstream
 - No break in service for end users

Why Multihome?

- Not really a reason, but oft quoted...
- Leverage:
 - Playing one upstream provider off against the other for:
 - Service Quality
 - Service Offerings
 - Availability

Why Multihome?

□ Summary:

- Multihoming is easy to demand as requirement of any operation
- But what does it really mean:
 - In real life?
 - For the network?
 - For the Internet?
- And how do we do it?

Multihoming Definition

- More than one link external to the local network
 - Two or more links to the same AS
 - Two or more links to different ASes
- Usually **two** external facing routers
 - One router gives link and provider redundancy only

Multihoming

- The scenarios described here apply equally well to:
 - End-sites being customers of network operators *and*
 - Network operators being customers of other network operators

- Implementation details may be different, for example:
 - End site → ISP Configuration on End-Site
 - ISP1 → ISP2 Network Operators share config

Multihoming: Number Resources

- BGP handles the relationship between Autonomous Systems
 - Each autonomous system is represented by an Autonomous System Number (ASN)
 - Each multihoming organisation requires their own unique ASN
- Address space (IPv4/IPv6) for each autonomous system comes from either:
 - Their upstream *or*
 - A Regional Internet Registry

Autonomous System Number

Range:	
0-4294967295	(32-bit range – RFC6793)
	(0-65535 was original 16-bit range)
Usage:	
0 and 65535	(IANA 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)
65552-131071	(IANA Reserved)
131072-458751	(public Internet)
458752-4199999999	(IANA Reserved/Unallocated)
4200000000-4294967294	(private use only – RFC6996)
4294967295	(IANA Reserved – RFC7300)

- 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
- The entire 16-bit ASN pool has been assigned to the RIRs
 - Around 39700 16-bit ASNs are visible on the Internet
 - (this number is dropping slightly as 32-bit ASN numbers increase)
- Each RIR has also received a block of 32-bit ASNs
 - Out of 42600 assignments, around 35100 are visible on the Internet (September 2023)
- See www.iana.org/assignments/as-numbers

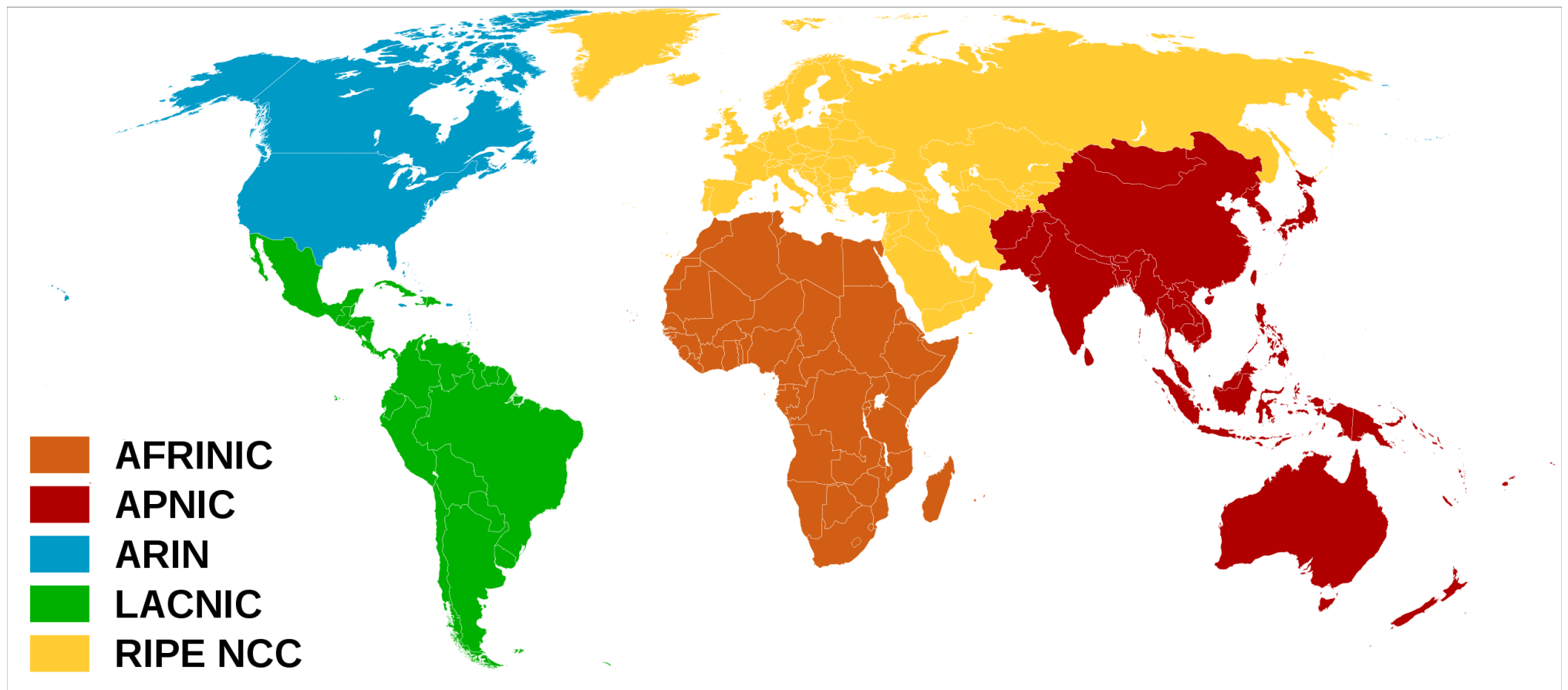
IP Addressing

- IP addresses are also distributed by the Regional Internet Registries
 - They are also available from upstream providers who are members of one of the RIRs
- The entire IPv4 address pool has been almost exhausted
 - The RIRs are operating in “IPv4 runout” mode now
- IPv6 address space is plentiful
 - Network operators receive at least a /32
 - End sites/users receive at least a /48

Where to get Internet Numbering Resources

- Your upstream provider
- Africa
 - AfriNIC – <http://www.afrinic.net>
- Asia and the Pacific
 - APNIC – <http://www.apnic.net>
- North America
 - ARIN – <http://www.arin.net>
- Latin America and the Caribbean
 - LACNIC – <http://www.lacnic.net>
- Europe and Middle East
 - RIPE NCC – <http://www.ripe.net/info/ncc>

Internet Registry Regions



Source: Wikimedia Commons



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Private AS – Application

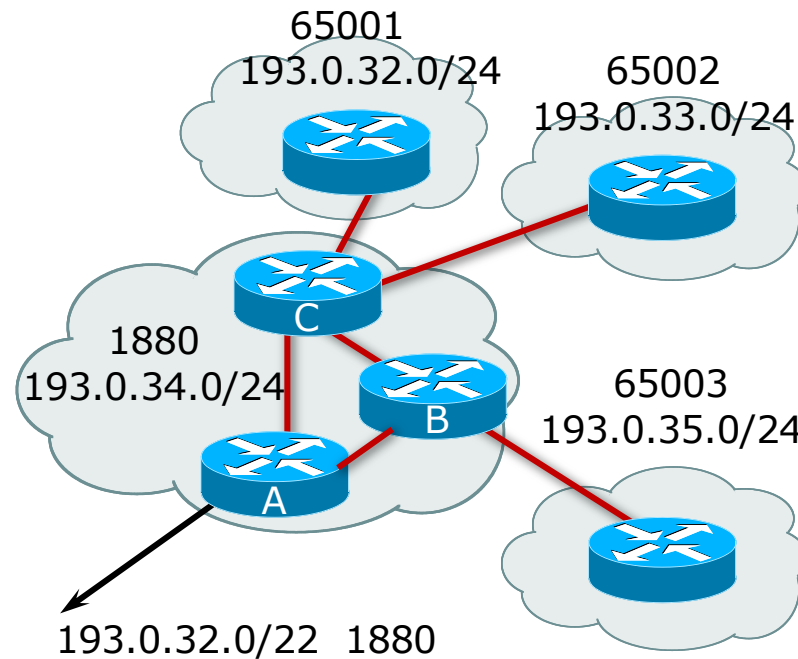
- A network operator with end-sites multihomed on their backbone (RFC2270)

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 must not be leaked to or used on the public Internet
- Cisco IOS

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

More Definitions

□ Transit

- Carrying traffic across a network
- Usually **for a fee**

□ Peering

- Exchanging routing information and traffic
- Usually **for no fee**
- Sometimes called **settlement free peering**

□ Default

- Where to send traffic when there is no explicit match in the routing table

Configuring Policy – Cisco IOS

- Assumptions:
 - Prefix-lists are used throughout
 - Easier/better/faster than access-lists
- Three BASIC Principles
 - **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)
- Subdividing Aggregates
 - Inbound traffic flows (local & 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
- ❑ Minimum allocations:
 - IPv4 is /24
 - IPv6 is /48 (endsite) and /32 (operator)
 - Several Network Operators filter RIR blocks on published minimum allocation boundaries
 - Several Network Operators 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/library/policies/126-afpub-2005-v4-001
 - 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” Network Operators 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 are understood and you are prepared to keep the list current
 - Consider using the Team Cymru or other reputable bogon BGP feed:
 - <https://www.team-cymru.com/bogon-reference-bgp.html>

How to Multihome



Some choices...

Transits

- Transit provider is another autonomous system which is used to provide the local network with access to other networks
 - Might be local or regional only
 - But more usually the whole Internet
- Transit providers need to be chosen wisely:
 - Only one
 - No redundancy
 - Too many
 - More difficult to load balance
 - No economy of scale (costs more per Mbps)
 - Hard to provide service quality
- **Recommendation: at least two, no more than three**

Common Mistakes

- Network Operators sign up with too many transit providers
 - Lots of small circuits (cost more per Mbps than larger ones)
 - Transit rates per Mbps reduce with increasing transit bandwidth purchased
 - Hard to implement reliable traffic engineering that doesn't need daily fine tuning depending on customer activities
- No diversity
 - Chosen transit providers all reached over same satellite or same submarine cable
 - Chosen transit providers have poor onward transit and peering

Peers

- A peer is another autonomous system with which the local network has agreed to exchange locally sourced routes and traffic
- Private peer
 - Private link between two providers for the purpose of interconnecting
- Public peer
 - Internet Exchange Point, where providers meet and freely decide who they will interconnect with
- **Recommendation: peer as much as possible!**

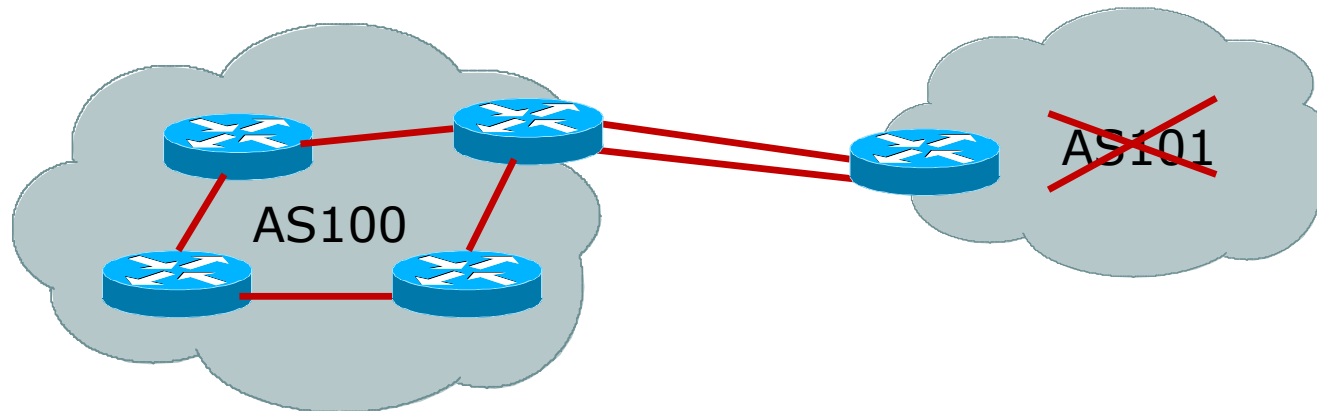
Common Mistakes

- ❑ Mistaking a transit provider's "Exchange" business for a no-cost public peering point
- ❑ Not working hard to get as much peering as possible
 - Physically near a peering point (IXP) but not present at it
 - (Transit sometimes is cheaper than peering!!)
- ❑ Ignoring/avoiding competitors because they are competition
 - Even though potentially valuable peering partner to give customers a better experience

Multihoming Scenarios

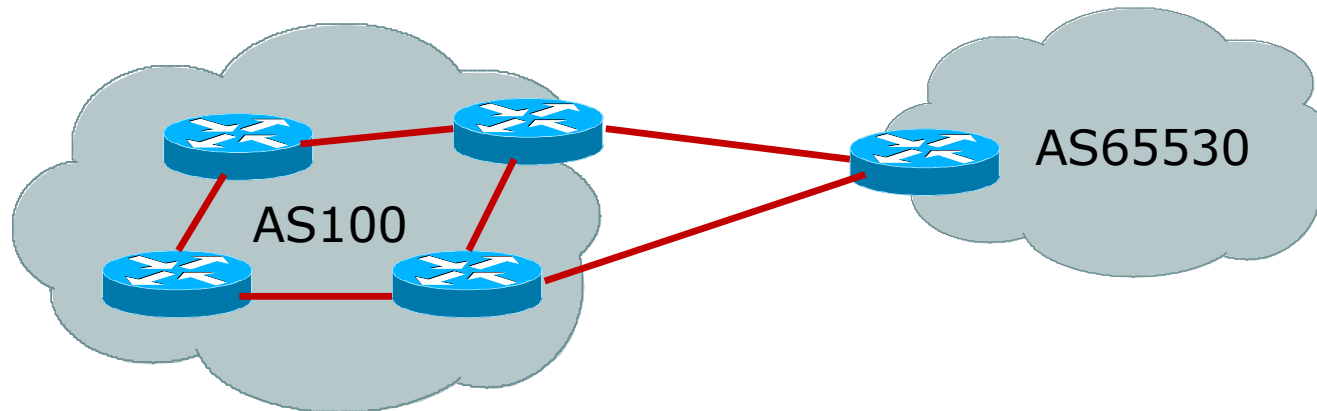
- ❑ Stub network
- ❑ Multi-homed stub network
- ❑ Multi-homed network
- ❑ Multiple Sessions between two ASes

Stub Network



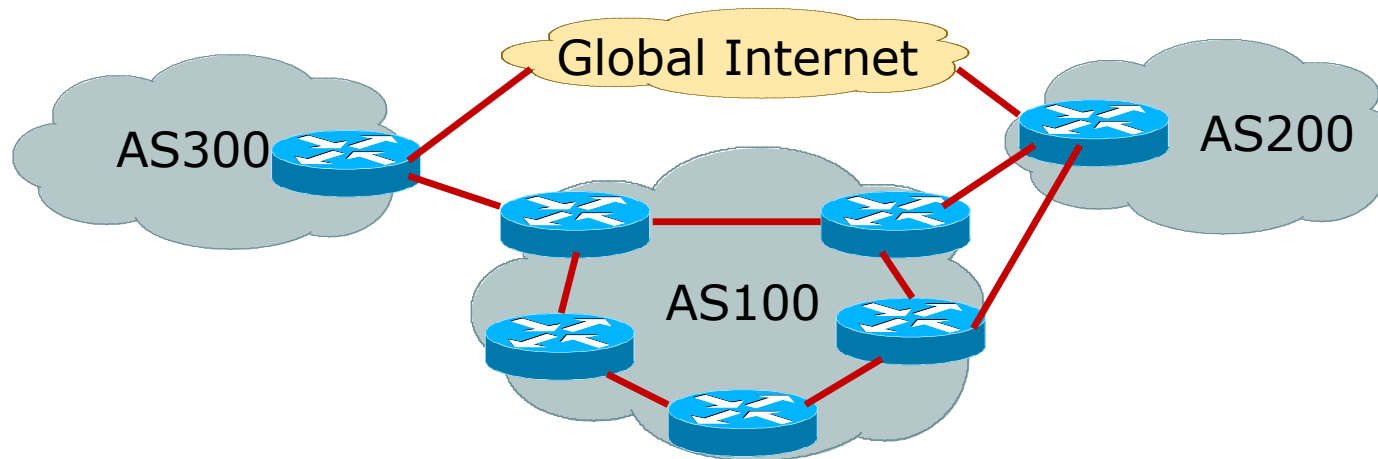
- ❑ No need for BGP
- ❑ Point static default to upstream AS
- ❑ Upstream AS advertises stub network
- ❑ Policy confined within upstream AS's policy

Multi-homed Stub Network



- ❑ Use BGP (not IGP or static) to loadshare
- ❑ Use private AS number (see earlier for ranges)
- ❑ Upstream AS advertises stub network
- ❑ Policy confined within upstream AS's policy

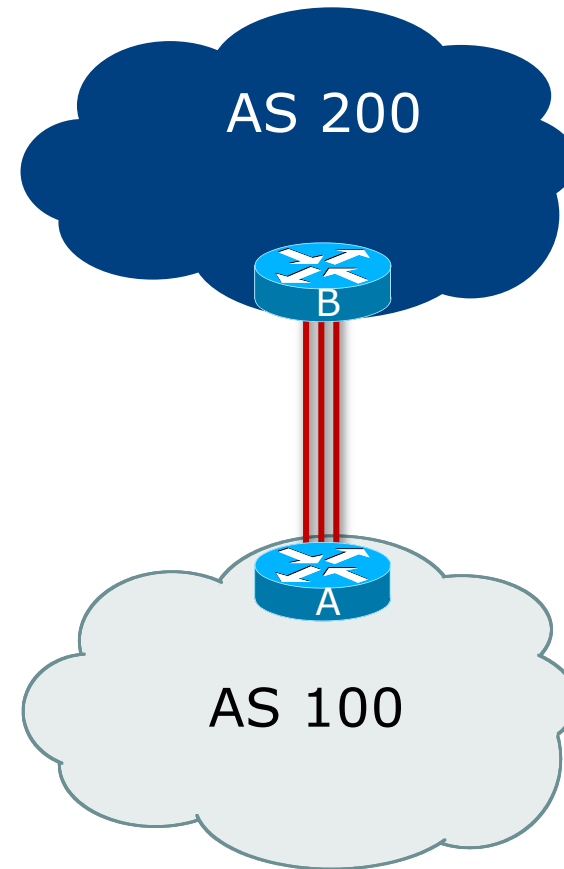
Multi-homed Network



- Several situations possible, including:
 1. Multiple sessions to same AS
 2. Secondary for backup only
 3. Load-share between primary and secondary
 4. Selectively use different ASes

Multiple Sessions between two ASes

- Several options
 - EBGP multihop
 - BGP multipath
 - CEF loadsharing
 - BGP attribute manipulation



Multiple Sessions between two ASes

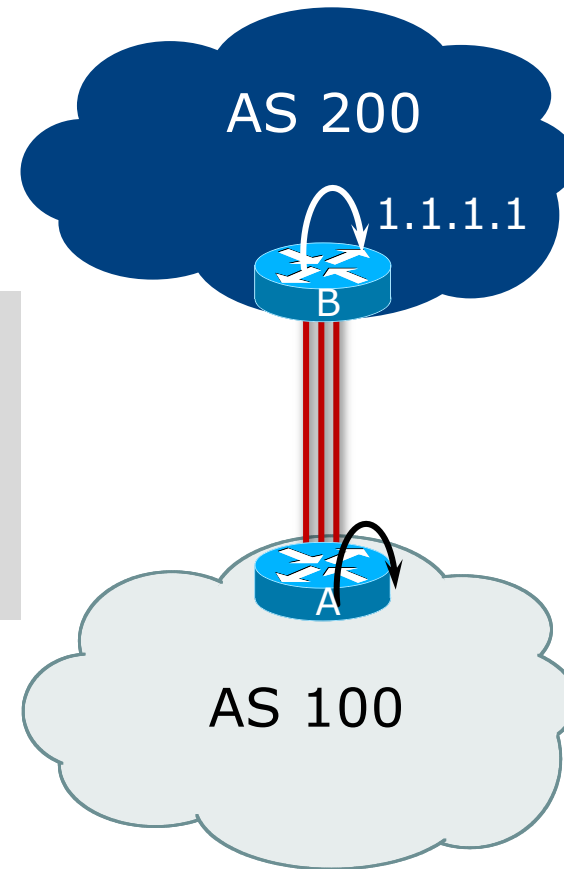
– EBGP multihop

- ❑ Use ebgp-multihop
 - Run EBGP between loopback addresses
 - EBGP prefixes learned with loopback address as next hop

- ❑ Cisco IOS

```
router bgp 100
  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
```

- ❑ Common error made is to point remote loopback route at IP address rather than specific link

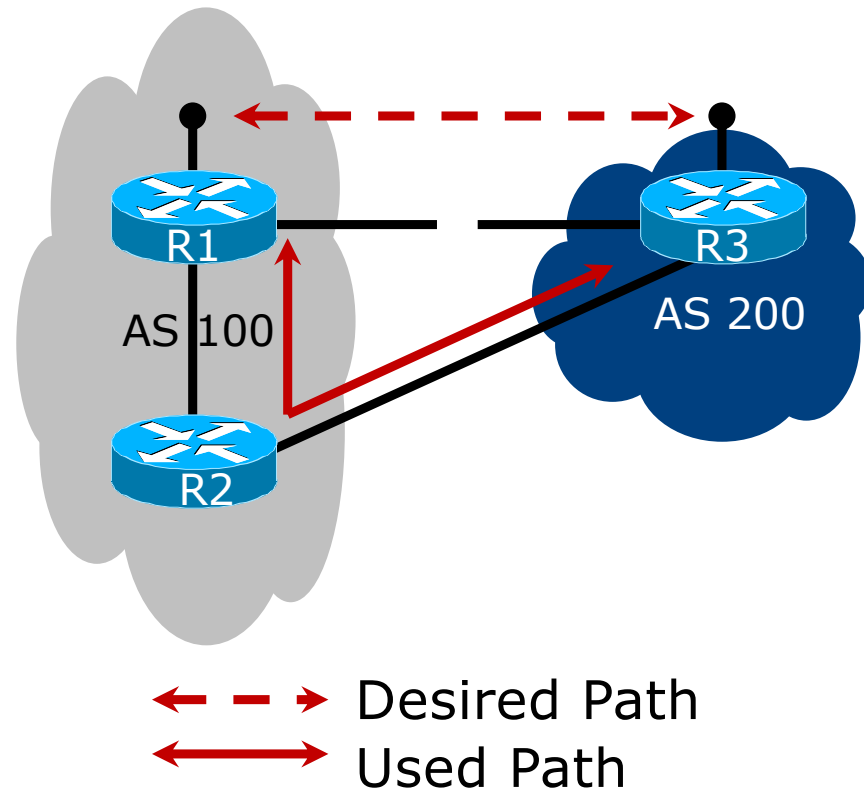


Multiple Sessions between two ASes

– EBGP multihop

- ❑ **One serious ebgp-multihop caveat:**
 - 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
- ❑ Usually happens when routing to remote loopback is dynamic, rather than static pointing at a link



Multiple Sessions between two ASes

– EBGP multihop

- Try and avoid use of ebgp-multihop unless:
 - It's absolutely necessary –or–
 - Loadsharing across multiple links
- Many Network Operators 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:

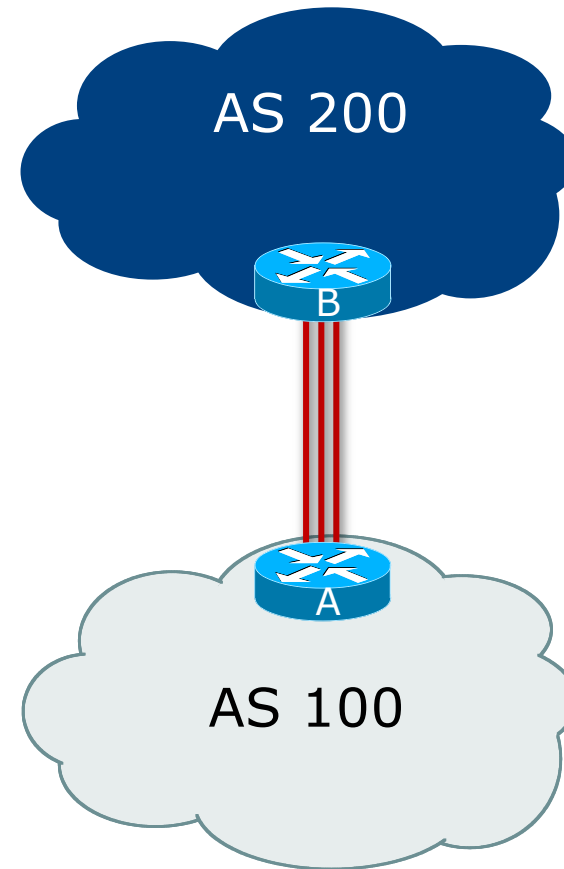
- routing loops
- failure to realise that BGP session stability problems are usually due connectivity problems between their CPE and their BGP speaker

Multiple Sessions between two ASes

– bgp multi path

- ❑ Three BGP sessions required
- ❑ Platform limit on number of paths (could be as little as 6)
- ❑ Full BGP feed makes this unwieldy
 - 3 copies of Internet Routing Table goes into the FIB

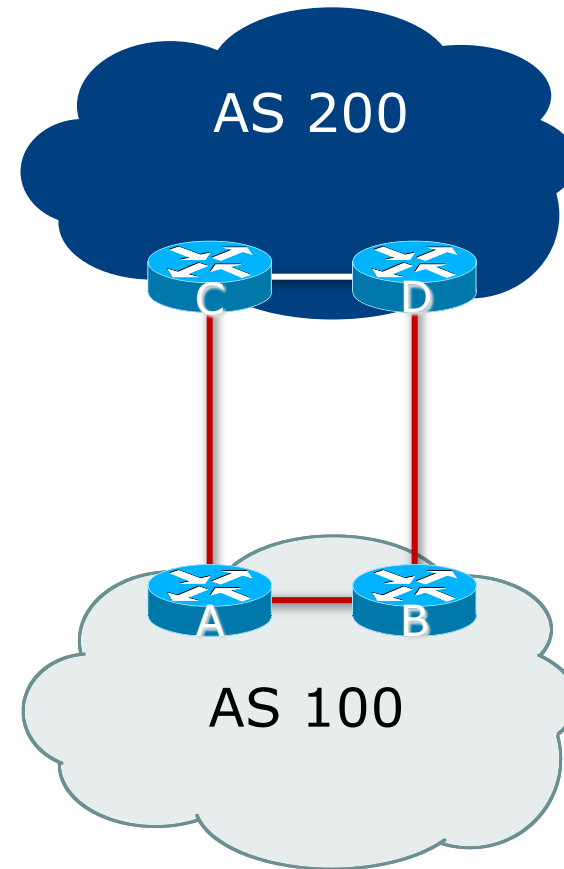
```
router bgp 100
  neighbor 100.64.2.1 remote-as 200
  neighbor 100.64.2.5 remote-as 200
  neighbor 100.64.2.9 remote-as 200
  maximum-paths 3
```



Multiple Sessions between two ASes

– BGP attributes & filters

- ❑ Simplest scheme is to use defaults
- ❑ Learn/advertise prefixes for better control
- ❑ Planning and some work required to achieve loadsharing
 - Accept default on one link
 - Learn selected prefixes from the other link
 - Modify the number of prefixes learnt to achieve acceptable load sharing
- ❑ **No magic solution**



Basic Principles of Multihoming



Let's learn to walk before we try running...

The Basic Principles

- Announcing address space attracts traffic
 - (Unless policy in upstream providers interferes)
- Announcing the AS aggregate out a link will result in traffic for that aggregate coming in that link
- Announcing a subprefix of an aggregate out a link means that all traffic for that subprefix will come in that link, even if the aggregate is announced somewhere else
 - The most specific announcement wins!

The Basic Principles

- To split traffic between two links:
 - Announce the aggregate on both links – ensures redundancy
 - Announce one half of the address space on each link
 - (This is the first step, all things being equal)
- Results in:
 - Traffic for first half of address space comes in first link
 - Traffic for second half of address space comes in second link
 - If either link fails, the fact that the aggregate is announced ensures there is a backup path

The Basic Principles

- The keys to successful multihoming configuration:
 - Keeping traffic engineering prefix announcements independent of customer IBGP
 - Understanding how to announce aggregates
 - Understanding the purpose of announcing subprefixes of aggregates
 - Understanding how to manipulate BGP attributes
 - Too many upstreams/external paths makes multihoming harder (2 or 3 is enough!)

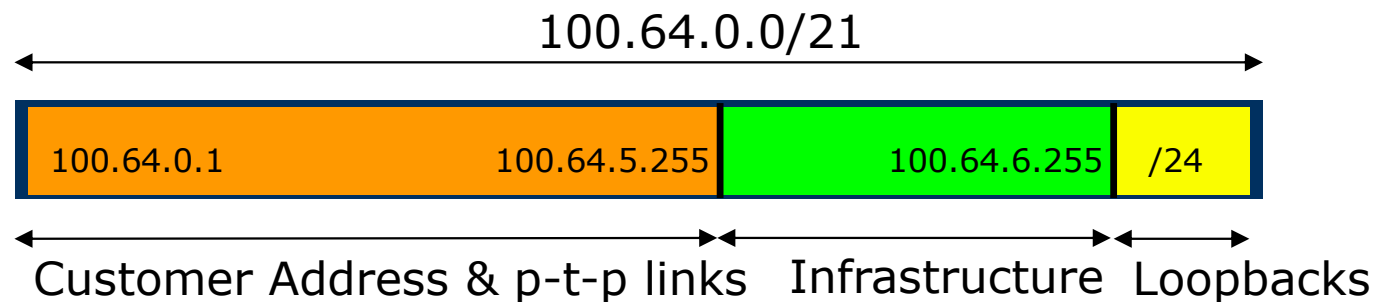
IP Addressing & Multihoming



How Good IP Address Plans assist with
Multihoming

IP Addressing & Multihoming

- IP Address planning is an important part of Multihoming
- Previously have discussed separating:
 - Customer address space
 - Customer p-t-p link address space
 - Infrastructure p-t-p link address space
 - Loopback address space

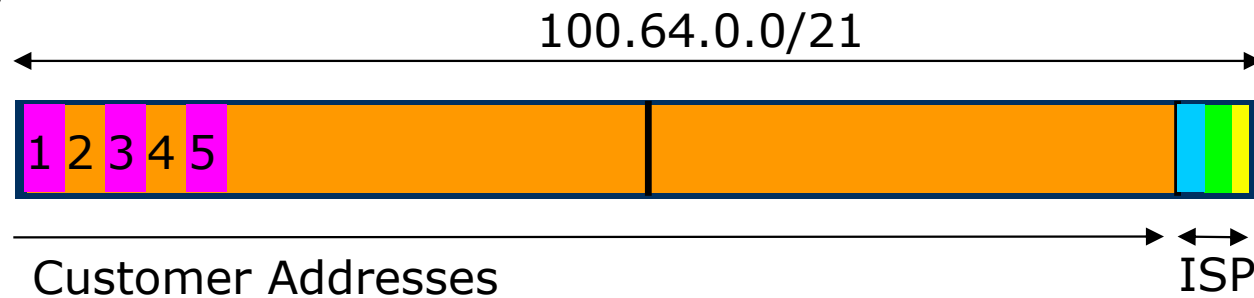


IP Addressing & Multihoming

- Router loopbacks and backbone point-to-point links make up a small part of total address space
 - And they don't attract traffic, unlike customer address space
- Links from the Network Operator's Aggregation edge to customer router needs one /30
 - Small requirements compared with total address space
 - Some operators use IP unnumbered
- Planning customer assignments is a very important part of multihoming
 - Traffic engineering involves subdividing aggregate into pieces until load balancing works

Unplanned IP addressing

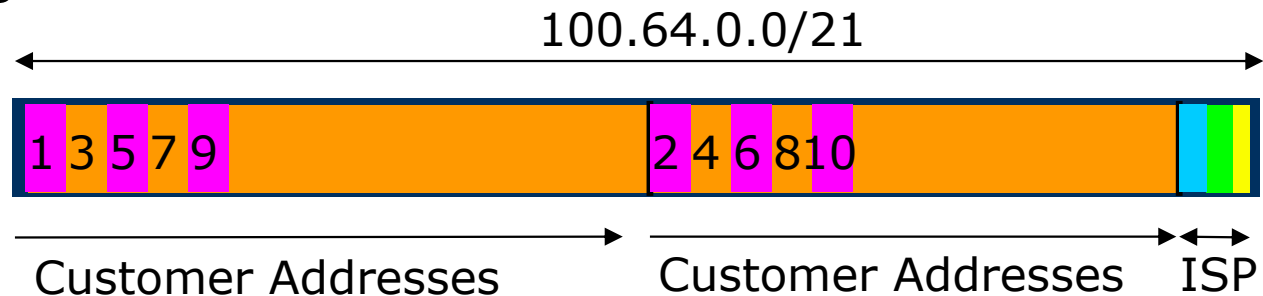
- Network Operator fills up customer IP addressing from one end of the range:



- Customers generate traffic
 - Dividing the range into two pieces will result in one /22 with all the customers, and one /22 with just the Network Operator infrastructure the addresses
 - No loadbalancing as all traffic will come in the first /22
 - Means further subdivision of the first /22 = harder work

Planned IP addressing

- If Network Operator fills up customer addressing from both ends of the range:



- Scheme then is:
 - First customer from first /22, second customer from second /22, third from first /22, etc
- This works also for residential versus commercial customers:
 - Residential from first /22
 - Commercial from second /22

Planned IP Addressing

- ❑ This works fine for multihoming between two upstream links (same or different providers)
- ❑ Can also subdivide address space to suit more than two upstreams
 - Follow a similar scheme for populating each portion of the address space
- ❑ Don't forget to always announce an aggregate out of each link

Summary

- Presentation has covered:
 - Why Multihome?
 - The Multihoming Toolset
 - How to Multihome – Options
 - Basic Principles of Multihoming
 - IP Addressing & Multihoming

Multihoming: Introduction



ISP Workshops