

# Multihoming: Introduction

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## ISP Workshops



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# Acknowledgements

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- ❑ 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 displays the NSRC (Network Startup Resource Center) website. The header includes the NSRC logo, navigation links (Home, About, BGP for All, perfSONAR, ScienceDMZ, FedIdM, Contact Us), and a search bar. The main content area is divided into three columns. The left column features a 'BGP for All' section with a description of BGP and a 'Video Topics' list with color-coded buttons for BGP for All, perfSONAR, ScienceDMZ, and FedIdM. The middle column, titled 'Introduction to Routing', lists various topics such as Internet Routing, Routing Protocols, and IS-IS Levels. The right column features a large video player for 'BGP for All' with a play button and a 'Watch on YouTube' link. Below the video player, there are sections for 'BGP Case Studies' and 'Communities'.

**NSRC** Network Startup Resource Center

Home About **BGP for All** perfSONAR ScienceDMZ FedIdM Contact Us Search

### BGP for All

Border Gateway Protocol (BGP) is the primary routing protocol used to transfer data and information on the Internet or autonomous systems. BGP is a Path Vector Protocol which maintains paths to different hosts, networks and gateway routers and determines the routing decision based on rules, filtering, weight and community.

Understanding the myriad options for routing can produce efficiencies for institutions and create opportunities for research and education networks to collaborate.

### Video Topics

- BGP for All
- perfSONAR
- ScienceDMZ
- FedIdM

### Introduction to Routing

- 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
- Finalizing Migration

### Introduction to BGP

- Introduction to Border Gateway Protocol
- Transit and Peering
- Autonomous Systems UPDATED
- How BGP works
- Supporting Multiple Protocols
- IBGP versus EBG
- Setting up EBG
- Setting up IBGP

### BGP Case Studies

- Peering Priorities NEW
- Transit Provider Peering at an IXP NEW
- Customer Multihomed between two IXP members NEW
- Traffic Engineering for an ISP connected to two IXes NEW
- Traffic Engineering for an ISP with two interfaces on one IX LAN NEW
- Traffic Engineering and CDNs NEW

### Communities

- Communities: RFC 1998 Traffic Engineering
- Communities: Simplifying Traffic Engineering
- How to Apply Communities to Originated Routes
- How to Use Communities for Service Identification

# Agenda

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

# Why Multihome?

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## □ 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?

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## □ Reliability

- Business critical applications demand continuous availability
- Lack of redundancy implies lack of reliability implies loss of revenue

# Why Multihome?

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## □ 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?

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- ❑ 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?

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

# Why Multihome?

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## □ 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

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- 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

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- 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

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- ❑ 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

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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)

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- 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 39400 16-bit ASNs are visible on the Internet
    - (this number is dropping slightly as 32-bit ASN announcements increase)
- Each RIR has also received a block of 32-bit ASNs
  - Out of 44500 assignments, around 36500 are visible on the Internet (May 2024)
- See [www.iana.org/assignments/as-numbers](https://www.iana.org/assignments/as-numbers)

# IP Addressing

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- ❑ 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

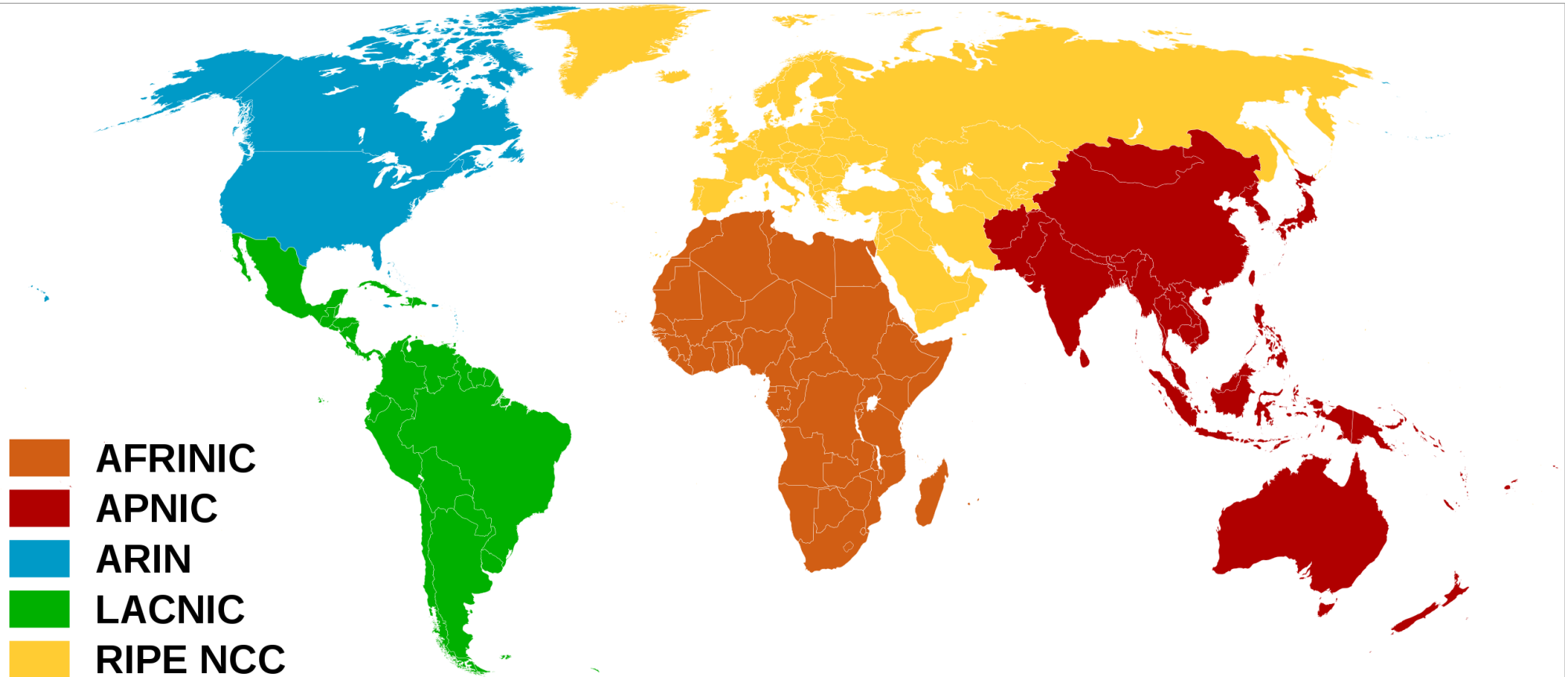


# Where to get Internet Numbering Resources

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- ❑ 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

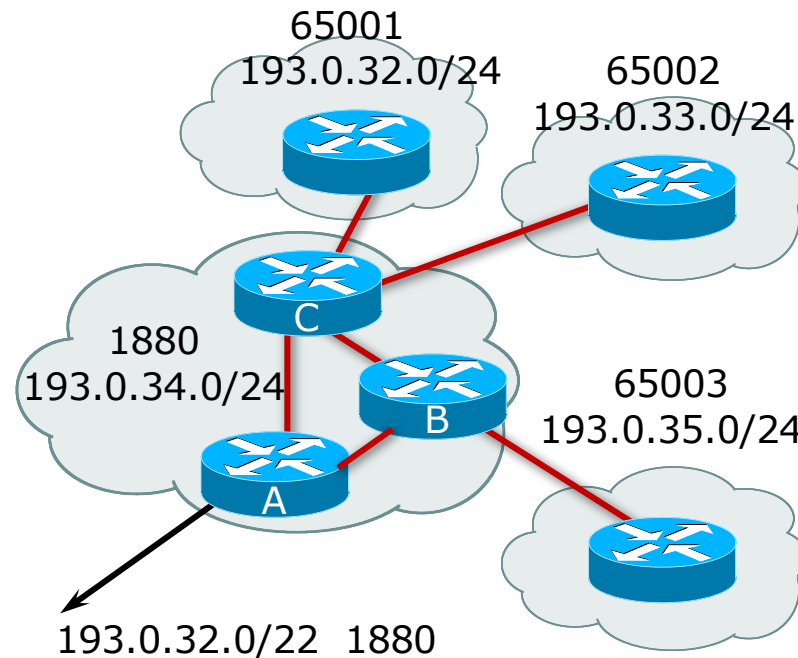
- A network operator with end-sites multihomed on their backbone (RFC2270)

*or*

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

*or*

- Within a BGP Confederation



# Private AS – Removal

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- ❑ 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

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## □ 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

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- ❑ 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

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- ❑ 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

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- ❑ 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

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- The RIRs publish their minimum allocation sizes per /8 address block
  - AfriNIC: [www.afrinic.net/library/policies/126-afpub-2005-v4-001](http://www.afrinic.net/library/policies/126-afpub-2005-v4-001)
  - APNIC: [www.apnic.net/db/min-alloc.html](http://www.apnic.net/db/min-alloc.html)
  - ARIN: [www.arin.net/reference/ip\\_blocks.html](http://www.arin.net/reference/ip_blocks.html)
  - LACNIC: [lacnic.net/en/registro/index.html](http://lacnic.net/en/registro/index.html)
  - RIPE NCC: [www.ripe.net/ripe/docs/smallest-alloc-sizes.html](http://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](http://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

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- ❑ 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

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- ❑ 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

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- ❑ 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

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- ❑ 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

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- ❑ 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

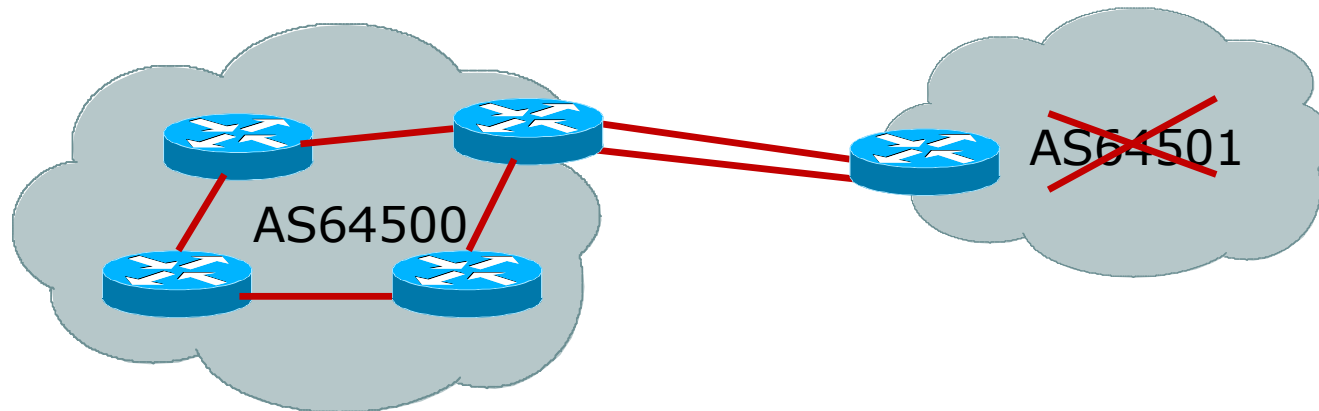
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- ❑ Stub network
- ❑ Multi-homed stub network
- ❑ Multi-homed network
- ❑ Multiple Sessions between two ASes



# Stub Network

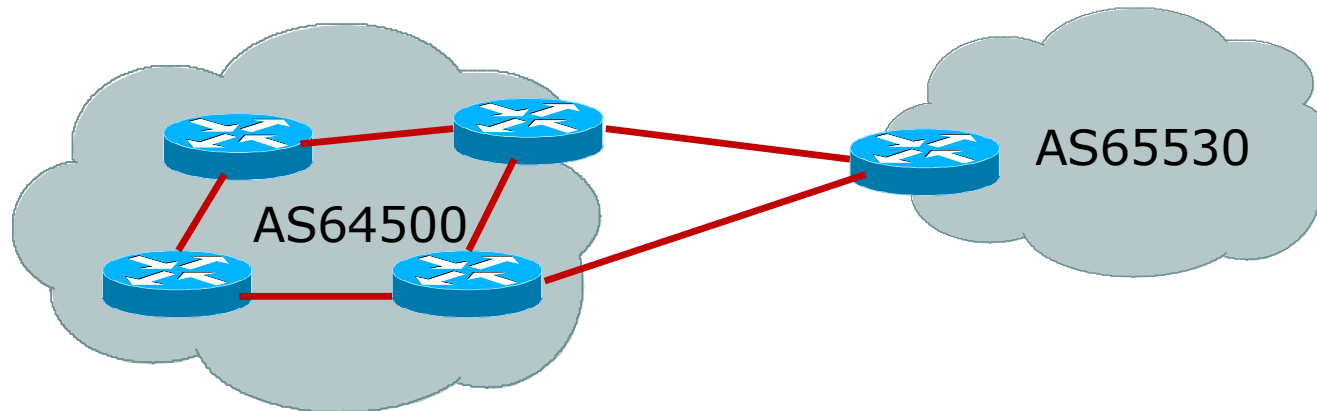
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- ❑ No need for BGP
- ❑ Point static default to upstream AS
- ❑ Upstream AS advertises stub network
- ❑ Policy confined within upstream AS's policy

# Multi-homed Stub Network

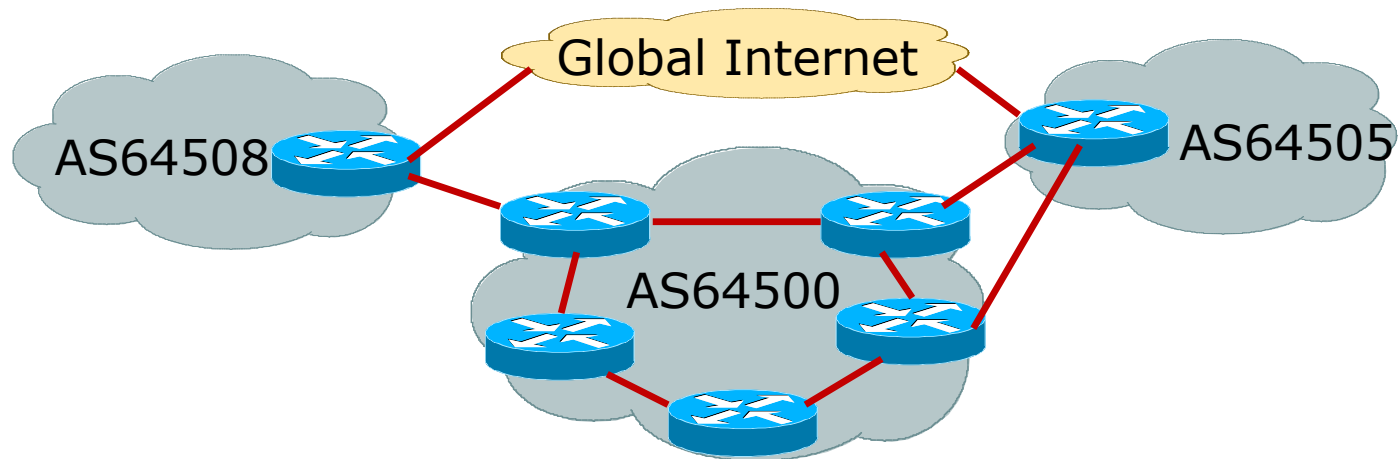
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- ❑ Use BGP (not IGP or static) to loadshare
- ❑ Use private AS number (see earlier for ranges)
- ❑ Upstream AS advertises stub network
- ❑ Policy confined within upstream AS's policy

# Multi-homed Network

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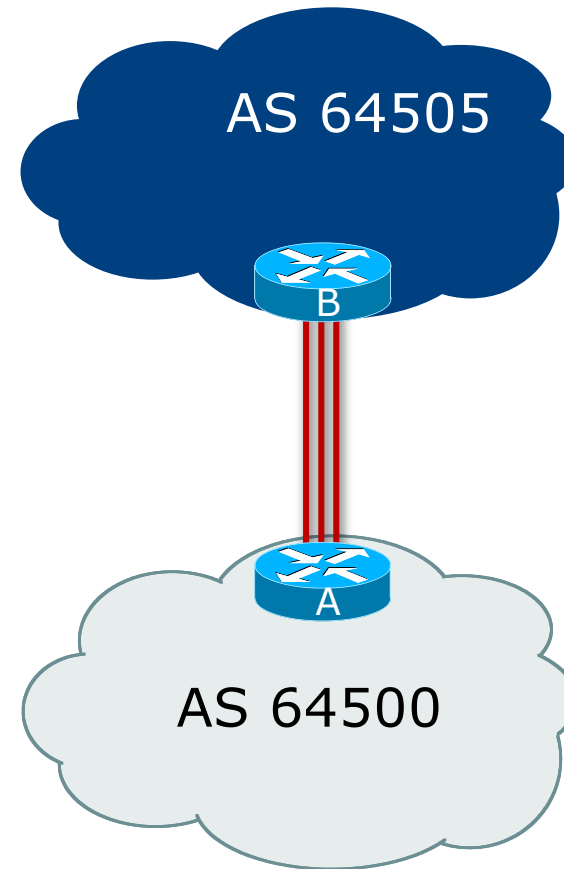


- ❑ Several situations possible, including:
  1. Multiple sessions to same AS
  2. Secondary for backup only
  3. Load-share between primary and secondary
  4. Selectively use different ASes

# Multiple Sessions between two ASes

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- ❑ Several options
  - EBGP multihop
  - BGP multipath
    - ❑ Multiple paths in the FIB
  - BGP attribute manipulation



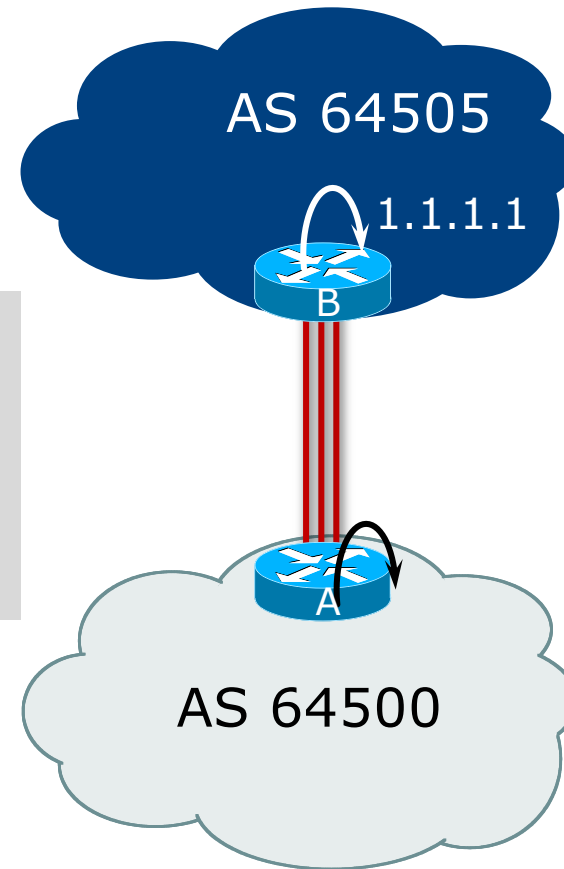
# Multiple Sessions between two ASes

## – EBGP multihop

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

```
router bgp 64500
  neighbor 1.1.1.1 remote-as 64505
  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

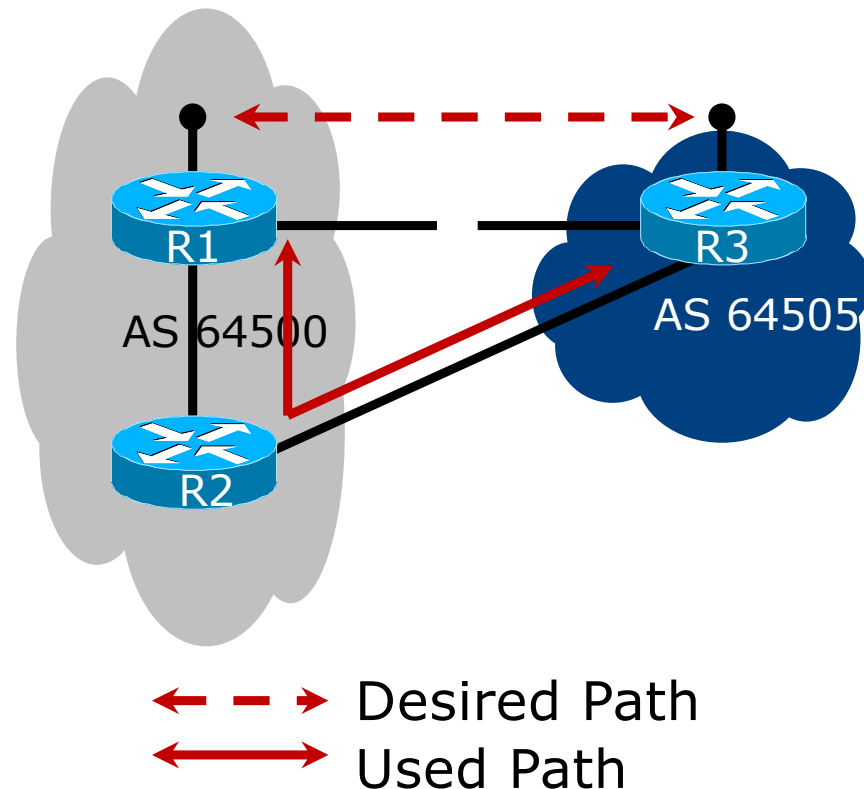


# Multiple Sessions between two ASes

## – 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

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- 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:

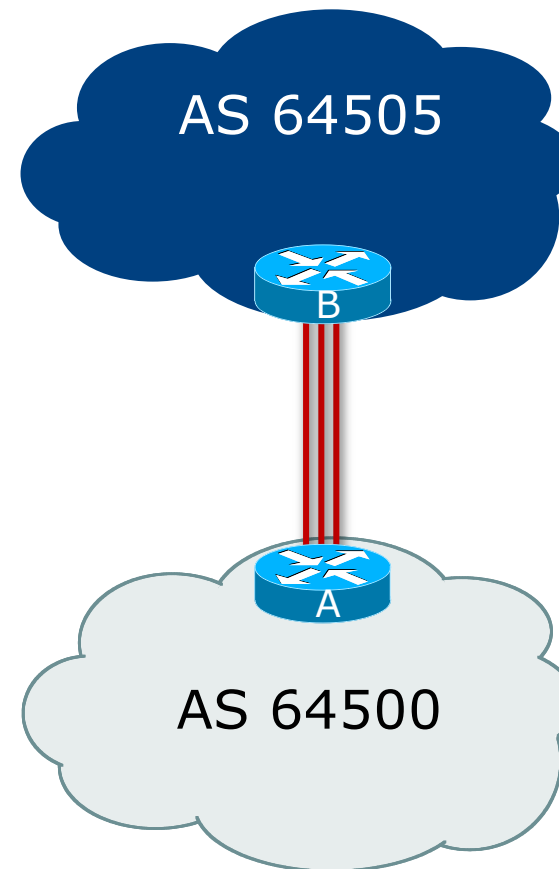
- routing loops
- failure to realise that BGP session stability problems are usually due connectivity problems between their CPE and their BGP speaker

# 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 64500
  neighbor 100.64.2.1 remote-as 64505
  neighbor 100.64.2.5 remote-as 64505
  neighbor 100.64.2.9 remote-as 64505
  maximum-paths 3
```



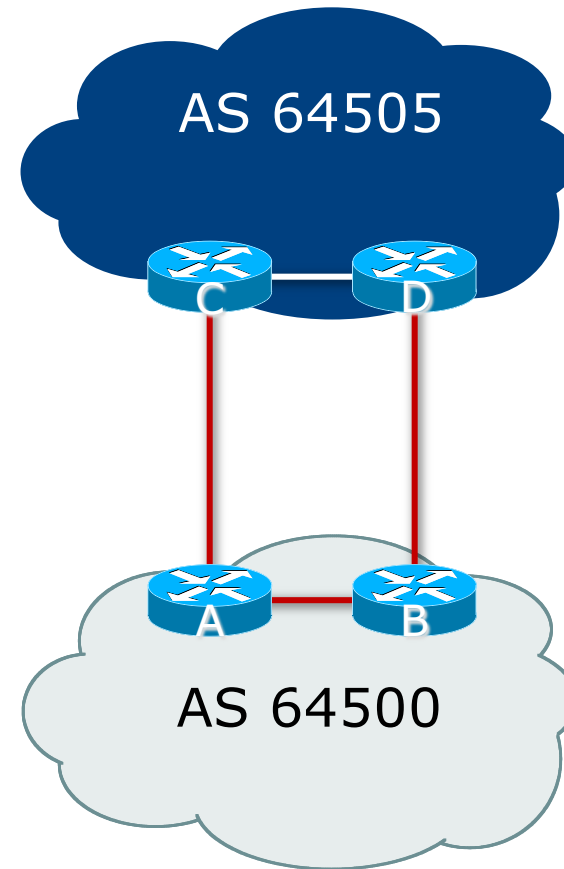


# Multiple Sessions between two ASes

## – BGP attributes & filters

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- ❑ 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

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- ❑ 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

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- ❑ 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

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- 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!)

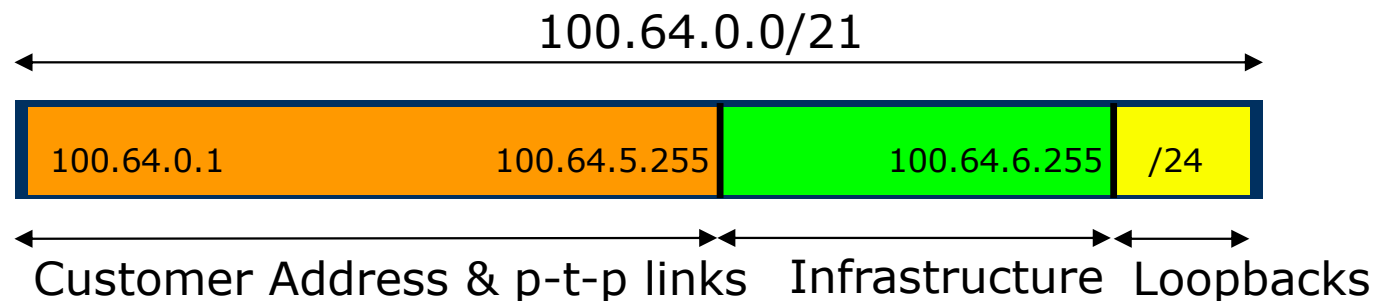
# IP Addressing & Multihoming



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

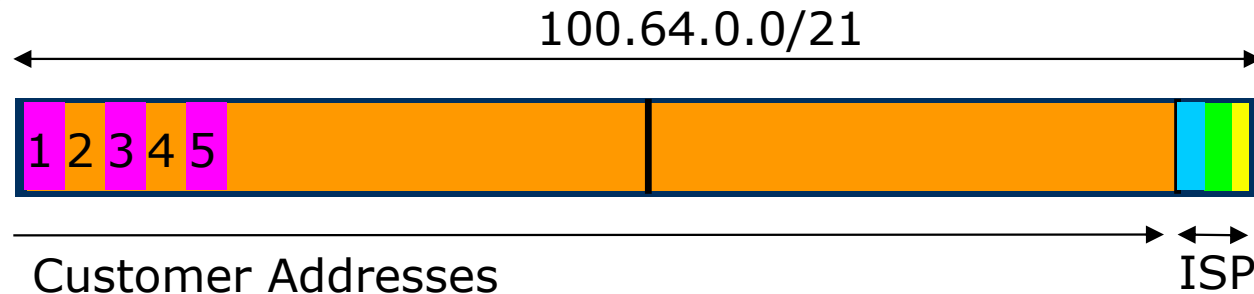
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- ❑ Router loopbacks and backbone point-to-point links make up a small part of total address space
  - And they don't attract traffic, unlike customer address space
- ❑ Links from the Network Operator's Aggregation edge to customer router needs one /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

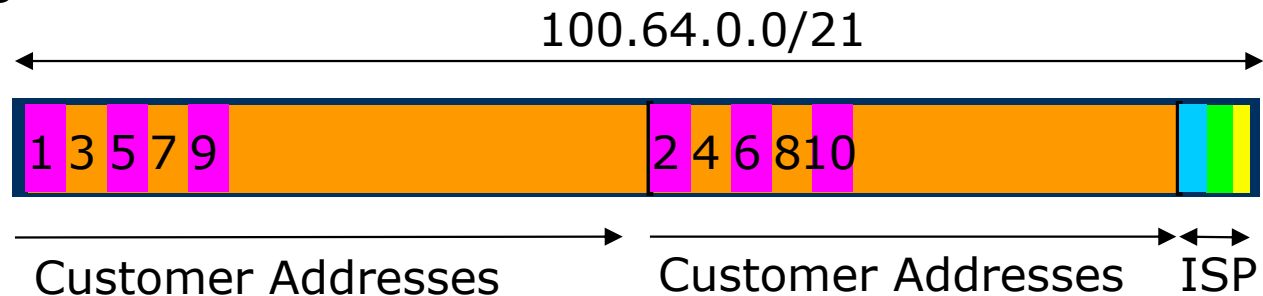
- Network Operator fills up customer IP addressing from one end of the range:



- 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

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- ❑ 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

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

# Multihoming: Introduction



ISP Workshops