



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

ISP/ISP Workshops © 2008, Cisco Systems, Inc. www.cisco.com

Multihoming

- The scenarios described here apply equally well to end sites being customers of ISPs and ISPs being customers of other ISPs
- Implementation detail may be different

end site ® ISP	ISP controls config
ISP1 ® ISP2	ISPs share config

ISP/ISP Workshops © 2008, Cisco Systems, Inc. www.cisco.com

AS Numbers

- An Autonomous System Number is required by BGP
- Obtained from upstream ISP or Regional Registry
- Necessary when you have links to more than one ISP or exchange point

ISP/ISP Workshops © 2008, Cisco Systems, Inc. www.cisco.com

Configuring Policy

- 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**

ISP/ISP Workshops © 2008, Cisco Systems, Inc. www.cisco.com

Originating Prefixes

- Basic Assumptions
 - MUST** announce assigned address block to Internet
 - MAY** also announce subprefixes - reachability is not guaranteed
 - RIR minimum allocation is /20 - several ISPs filter RIR blocks on this boundary - "Net Police"

ISP/ISP Workshops © 2008, Cisco Systems, Inc. www.cisco.com

Part of the "Net Police" prefix list

```

!! RIPE
ip prefix-list FILTER permit 62.0.0.0/8 ge 12 le 20
ip prefix-list FILTER permit 193.0.0.0/8 ge 12 le 20
ip prefix-list FILTER permit 194.0.0.0/7 ge 12 le 20
ip prefix-list FILTER permit 212.0.0.0/7 ge 12 le 20
!! APNIC
ip prefix-list FILTER permit 61.0.0.0/8 ge 12 le 20
ip prefix-list FILTER permit 202.0.0.0/7 ge 12 le 20
ip prefix-list FILTER permit 210.0.0.0/7 ge 12 le 20
!! ARIN
ip prefix-list FILTER permit 63.0.0.0/8 le 20
ip prefix-list FILTER permit 64.0.0.0/8 le 20
ip prefix-list FILTER permit 199.0.0.0/8 le 20
ip prefix-list FILTER permit 200.0.0.0/8 le 20
ip prefix-list FILTER permit 204.0.0.0/6 le 20
ip prefix-list FILTER permit 208.0.0.0/7 le 20
ip prefix-list FILTER permit 216.0.0.0/8 le 20
    
```

"Net Police" prefix list issues

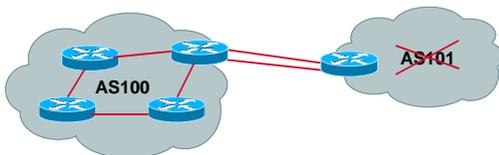
- meant to "punish" ISPs who won't and don't aggregate
- impacts legitimate multihoming
- impacts regions where domestic backbone is unavailable or costs \$\$\$ compared with international bandwidth
- hard to maintain - requires updating when RIRs start allocating from new address blocks
- **don't do it unless consequences understood**

Multihoming Options

Multihoming Scenarios

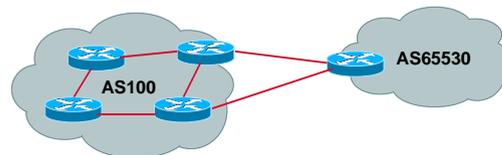
- Stub network
- Multi-homed stub network
- Multi-homed network
- Configuration Options

Stub Network



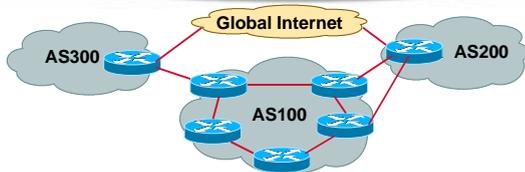
- No need for BGP
- Point static default to upstream ISP
- Upstream ISP advertises stub network
- Policy confined within upstream ISP's policy

Multi-homed Stub Network



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

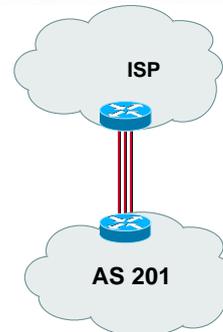
Multi-Homed Network



- 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

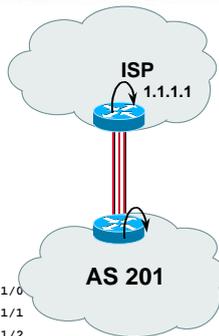
- Several options
 - ebgp multihop
 - bgp multipath
 - cef loadsharing
 - bgp attribute manipulation



Multiple Sessions to an ISP ebgp multihop

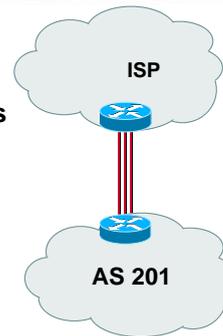
- eBGP to loopback addresses
- eBGP prefixes learned with loopback address as next hop

```
router bgp 201
 neighbor 1.1.1.1 remote-as 200
 neighbor 1.1.1.1 ebgp-multihop 5
 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
```



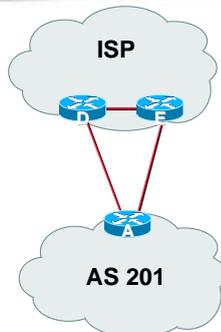
Multiple Sessions to an ISP bgp multi path

- Three BGP sessions required
 - limit of 6 parallel paths
- ```
router bgp 201
 neighbor 1.1.2.1 remote-as 200
 neighbor 1.1.2.5 remote-as 200
 neighbor 1.1.2.9 remote-as 200
 maximum-paths 3
```



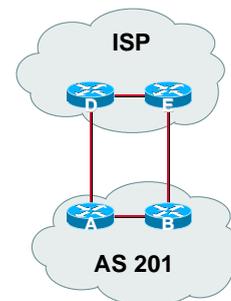
## Multiple Sessions to an ISP

- Use eBGP multi-path to install multiple paths in IP table
  - router bgp 201
  - maximum-path <1-6>
- Load share over the alternate paths
  - per destination loadsharing



## Multiple Sessions to an ISP

- Simplest scheme is to use defaults
- Learn/advertise prefixes for better control



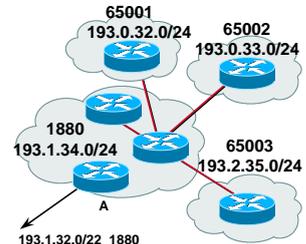
## Multiple Sessions to ISPs

- Planning and some work required to achieve load sharing
  - 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

## Private-AS - Application

### Applications

- ISP with single-homed customers
- corporate network with several regions and connections to the Internet only in the core



## Private-AS Removal

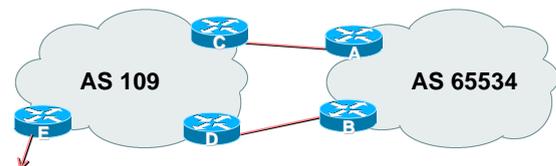
- neighbor x.x.x.x remove-private-AS
- Rules:
  - available for eBGP neighbors only
  - if the update has AS\_PATH made up of private-AS numbers, the private-AS will be dropped
  - if the AS\_PATH includes private and public numbers, private AS number will not be removed...it is a configuration error!
  - if AS\_PATH contains the AS number of the eBGP neighbor, the private-AS numbers will not be removed
  - if used with confederations, it will work as long as the private AS numbers are after the confederation portion of the AS\_PATH



## Two links to the same ISP

- Can use BGP for this to aid loadsharing
  - use a private AS (ASN > 64511)
- upstream ISP proxy aggregates
  - in other words, announces only your address block to the Internet (as would be done if you had one statically routed connection)

## Two links to the same ISP



- AS109 proxy aggregates for AS 65534

## Two links to the same ISP

- Split /19 and announce as two /20s, one on each link  
basic inbound loadsharing
- Example has no practical use, but demonstrates the principles

## Two links to the same ISP

- Router A Configuration

```
router bgp 65534
 network 221.10.0.0 mask 255.255.240.0
 network 221.10.16.0 mask 255.255.240.0
 neighbor 222.222.10.2 remote-as 109
 neighbor 222.222.10.2 prefix-list routerC out
 neighbor 222.222.10.2 prefix-list default in
 !
 ip prefix-list default permit 0.0.0.0/0
 ip prefix-list routerC permit 221.10.0.0/20
 !
 ip route 221.10.0.0 255.255.240.0 null0
 ip route 221.10.16.0 255.255.240.0 null0
```

## Two links to the same ISP

- Router B Configuration

```
router bgp 65534
 network 221.10.0.0 mask 255.255.240.0
 network 221.10.16.0 mask 255.255.240.0
 neighbor 222.222.10.6 remote-as 109
 neighbor 222.222.10.6 prefix-list routerD out
 neighbor 222.222.10.6 prefix-list default in
 !
 ip prefix-list default permit 0.0.0.0/0
 ip prefix-list routerD permit 221.10.16.0/20
 !
 ip route 221.10.0.0 255.255.240.0 null0
 ip route 221.10.16.0 255.255.240.0 null0
```

## Two links to the same ISP

- Router C Configuration

```
router bgp 109
 neighbor 222.222.10.1 remote-as 65534
 neighbor 222.222.10.1 default-originate
 neighbor 222.222.10.1 prefix-list Customer in
 neighbor 222.222.10.1 prefix-list default out
 !
 ip prefix-list Customer permit 221.10.0.0/20
 ip prefix-list default permit 0.0.0.0/0
```

## Two links to the same ISP

- Router D Configuration

```
router bgp 109
 neighbor 222.222.10.5 remote-as 65534
 neighbor 222.222.10.5 default-originate
 neighbor 222.222.10.5 prefix-list Customer in
 neighbor 222.222.10.5 prefix-list default out
 !
 ip prefix-list Customer permit 221.10.16.0/20
 ip prefix-list default permit 0.0.0.0/0
```

## Two links to the same ISP

- Router E is AS109 border router

removes prefixes in the private AS from external announcements

implements the proxy aggregation for the customer prefixes

## Two links to the same ISP

- Router E Configuration

```
router bgp 109
 network 221.10.0.0 mask 255.255.224.0
 neighbor 222.222.10.17 remote-as 110
 neighbor 222.222.10.17 filter-list 1 out
!
 ip route 221.10.0.0 255.255.224.0 null0
!
 ip as-path access-list 1 deny ^65534$
 ip as-path access-list 1 permit ^$
```

- Private AS still visible inside AS109

## Two links to the same ISP

- **Big Problem:**

no backup in case of link failure

- /19 address block not announced

- AS Path filtering “awkward”

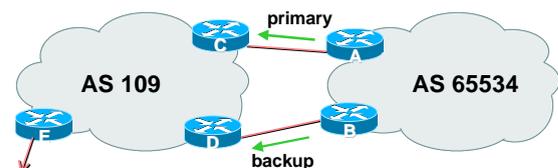
easier to use bgp command

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

## Two links to the same ISP

One link primary, the other link backup only

## Two links to the same ISP



- AS109 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 makes standard announcement
  - backup link increases metric on outbound, and reduces local-pref on inbound
- 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 221.10.0.0 mask 255.255.224.0
 neighbor 222.222.10.2 remote-as 109
 neighbor 222.222.10.2 description RouterC
 neighbor 222.222.10.2 prefix-list aggregate out
 neighbor 222.222.10.2 prefix-list default in
!
 ip prefix-list aggregate permit 221.10.0.0/19
 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 221.10.0.0 mask 255.255.224.0
neighbor 222.222.10.6 remote-as 109
neighbor 222.222.10.6 description RouterD
neighbor 222.222.10.6 prefix-list aggregate out
neighbor 222.222.10.6 route-map routerD-out out
neighbor 222.222.10.6 prefix-list default in
neighbor 222.222.10.6 route-map routerD-in in
!
```

..next slide

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

```
ip prefix-list aggregate permit 221.10.0.0/19
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 109
neighbor 222.222.10.1 remote-as 65534
neighbor 222.222.10.1 default-originate
neighbor 222.222.10.1 prefix-list Customer in
neighbor 222.222.10.1 prefix-list default out
!
ip prefix-list Customer permit 221.10.0.0/19
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 109
neighbor 222.222.10.5 remote-as 65534
neighbor 222.222.10.5 default-originate
neighbor 222.222.10.5 prefix-list Customer in
neighbor 222.222.10.5 prefix-list default out
!
ip prefix-list Customer permit 221.10.0.0/19
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 109
neighbor 222.222.10.17 remote-as 110
neighbor 222.222.10.17 remove-private-AS
neighbor 222.222.10.17 prefix-list Customer out
!
ip prefix-list Customer permit 221.10.0.0/19
```

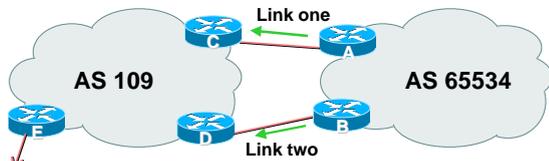
- Router E removes the private AS and customer's subprefixes from external announcements

- Private AS still visible inside AS109

## Two links to the same ISP

With Redundancy and  
Loadsharing

## Two links to the same ISP (with redundancy)



- AS109 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

## Two links to the same ISP

- Router A Configuration

```
router bgp 65534
 network 221.10.0.0 mask 255.255.224.0
 network 221.10.0.0 mask 255.255.240.0
 neighbor 222.222.10.2 remote-as 109
 neighbor 222.222.10.2 prefix-list routerC out
 neighbor 222.222.10.2 prefix-list default in
!
ip prefix-list default permit 0.0.0.0/0
ip prefix-list routerC permit 221.10.0.0/20
ip prefix-list routerC permit 221.10.0.0/19
!
ip route 221.10.0.0 255.255.240.0 null0
ip route 221.10.0.0 255.255.224.0 null0
```

## Two links to the same ISP

- Router B Configuration

```
router bgp 65534
 network 221.10.0.0 mask 255.255.224.0
 network 221.10.16.0 mask 255.255.240.0
 neighbor 222.222.10.6 remote-as 109
 neighbor 222.222.10.6 prefix-list routerD out
 neighbor 222.222.10.6 prefix-list default in
!
ip prefix-list default permit 0.0.0.0/0
ip prefix-list routerD permit 221.10.16.0/20
ip prefix-list routerD permit 221.10.0.0/19
!
ip route 221.10.0.0 255.255.224.0 null0
ip route 221.10.16.0 255.255.240.0 null0
```

## Loadsharing to the same ISP

- Default route for outbound traffic?

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

e.g. on router A:

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

## Two links to the same ISP

- Router C Configuration

```
router bgp 109
 neighbor 222.222.10.1 remote-as 65534
 neighbor 222.222.10.1 default-originate
 neighbor 222.222.10.1 prefix-list Customer in
 neighbor 222.222.10.1 prefix-list default out
!
ip prefix-list Customer permit 221.10.0.0/19 le 20
ip prefix-list default permit 0.0.0.0/0
```

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

## Two links to the same ISP

- Router D Configuration

```
router bgp 109
neighbor 222.222.10.5 remote-as 65534
neighbor 222.222.10.5 default-originate
neighbor 222.222.10.5 prefix-list Customer in
neighbor 222.222.10.5 prefix-list default out
!
ip prefix-list Customer permit 221.10.0.0/19 le 20
ip prefix-list default permit 0.0.0.0/0
```

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

## Two links to the same ISP

- Router E is AS109 border router
  - removes subprefixes in the private AS from external announcements
  - removes the private AS from external announcement of the customer /19

## Two links to the same ISP (with redundancy)

- Router E Configuration

```
router bgp 109
neighbor 222.222.10.17 remote-as 110
neighbor 222.222.10.17 remove-private-AS
neighbor 222.222.10.17 prefix-list Customer out
!
ip prefix-list Customer permit 221.10.0.0/19
```

- Private AS still visible inside AS109

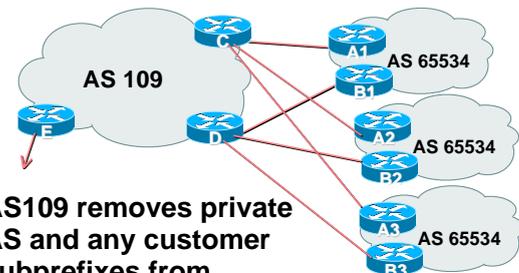
## Loadsharing to the same ISP

- 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)



- AS109 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 *An* and *Bn* configuration same as Router A and B previously

## Two links to the same ISP

- Router A1 Configuration

```
router bgp 65534
 network 221.10.0.0 mask 255.255.224.0
 network 221.10.0.0 mask 255.255.240.0
 neighbor 222.222.10.2 remote-as 109
 neighbor 222.222.10.2 prefix-list routerC out
 neighbor 222.222.10.2 prefix-list default in
!
ip prefix-list default permit 0.0.0.0/0
ip prefix-list routerC permit 221.10.0.0/20
ip prefix-list routerC permit 221.10.0.0/19
!
ip route 221.10.0.0 255.255.240.0 null0
ip route 221.10.0.0 255.255.224.0 null0
```

## Two links to the same ISP

- Router B1 Configuration

```
router bgp 65534
 network 221.10.0.0 mask 255.255.224.0
 network 221.10.16.0 mask 255.255.240.0
 neighbor 222.222.10.6 remote-as 109
 neighbor 222.222.10.6 prefix-list routerD out
 neighbor 222.222.10.6 prefix-list default in
!
ip prefix-list default permit 0.0.0.0/0
ip prefix-list routerD permit 221.10.16.0/20
ip prefix-list routerD permit 221.10.0.0/19
!
ip route 221.10.0.0 255.255.224.0 null0
ip route 221.10.16.0 255.255.240.0 null0
```

## Multiple Dualhomed Customers

- Router C Configuration

```
router bgp 109
 neighbor bgp-customers peer-group
 neighbor bgp-customers remote-as 65534
 neighbor bgp-customers default-originate
 neighbor bgp-customers prefix-list default out
 neighbor 222.222.10.1 peer-group bgp-customers
 neighbor 222.222.10.1 description Customer One
 neighbor 222.222.10.1 prefix-list Customer1 in
 neighbor 222.222.10.9 peer-group bgp-customers
 neighbor 222.222.10.9 description Customer Two
 neighbor 222.222.10.9 prefix-list Customer2 in
```

## Multiple Dualhomed Customers

```
neighbor 222.222.10.17 peer-group bgp-customers
neighbor 222.222.10.17 description Customer Three
neighbor 222.222.10.17 prefix-list Customer3 in
!
ip prefix-list Customer1 permit 221.10.0.0/19 le 20
ip prefix-list Customer2 permit 221.16.64.0/19 le 20
ip prefix-list Customer3 permit 221.14.192.0/19 le 20
ip prefix-list default permit 0.0.0.0/0
```

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

## Multiple Dualhomed Customers

- Router D Configuration

```
router bgp 109
 neighbor bgp-customers peer-group
 neighbor bgp-customers remote-as 65534
 neighbor bgp-customers default-originate
 neighbor bgp-customers prefix-list default out
 neighbor 222.222.10.5 peer-group bgp-customers
 neighbor 222.222.10.5 description Customer One
 neighbor 222.222.10.5 prefix-list Customer1 in
 neighbor 222.222.10.13 peer-group bgp-customers
 neighbor 222.222.10.13 description Customer Two
 neighbor 222.222.10.13 prefix-list Customer2 in
```

## Multiple Dualhomed Customers

```
neighbor 222.222.10.21 peer-group bgp-customers
neighbor 222.222.10.21 description Customer Three
neighbor 222.222.10.21 prefix-list Customer3 in
!
ip prefix-list Customer1 permit 221.10.0.0/19 le 20
ip prefix-list Customer2 permit 221.16.64.0/19 le 20
ip prefix-list Customer3 permit 221.14.192.0/19 le 20
ip prefix-list default permit 0.0.0.0/0
```

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

## Multiple Dualhomed Customers

- Router E Configuration is as previously assumes customer address space is not part of upstream's address block

```
router bgp 109
neighbor 222.222.10.17 remote-as 110
neighbor 222.222.10.17 remove-private-AS
neighbor 222.222.10.17 prefix-list Customers out
!
ip prefix-list Customers permit 221.10.0.0/19
ip prefix-list Customers permit 221.16.64.0/19
ip prefix-list Customers permit 221.14.192.0/19
```

- Private AS still visible inside AS109

## 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 109
neighbor 222.222.10.17 remote-as 110
neighbor 222.222.10.17 prefix-list my-aggregate out
!
ip prefix-list my-aggregate permit 221.8.0.0/13
```

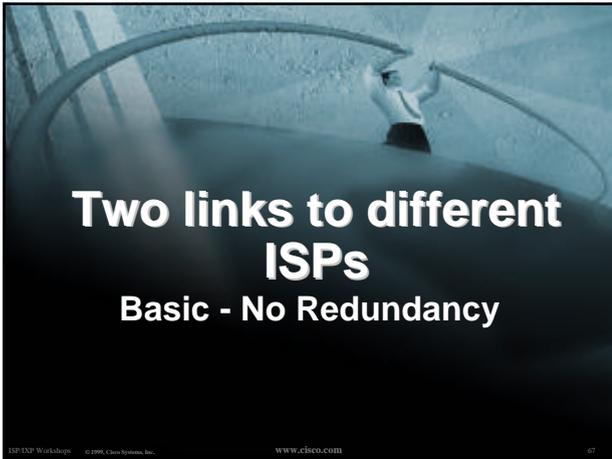
## Multihoming Summary

- Use private AS for multihoming to upstream
- Leak subprefixes to upstream only to aid loadsharing
- Upstream router E configuration is uniform across all scenarios

## Two links to different ISPs

## Two links to different ISPs

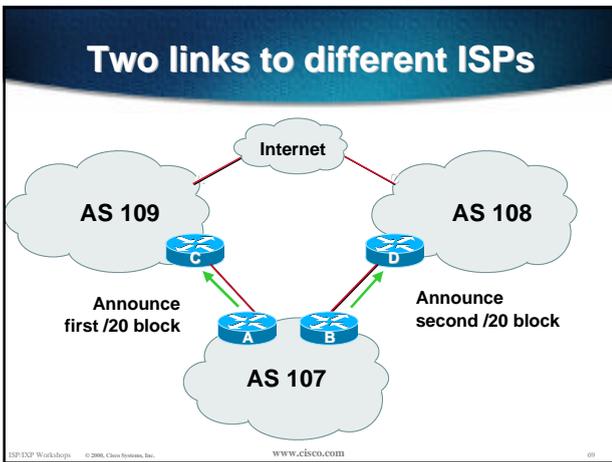
- Use Public ASes  
or use private AS if agreed with the other ISP
- Address space comes from both upstreams (PA space) or Regional Internet Registry (PI space)
- Configuration concepts very similar



## Two links to different ISPs

- Example for PI space
  - ISP network, or large enterprise site
- Split /19 and announce as two /20s, one on each link
  - basic inbound loadsharing

ISP/EXP Workshops © 2008, Cisco Systems, Inc. www.cisco.com 68



## Two links to different ISPs

- Router A Configuration

```

router bgp 107
 network 221.10.0.0 mask 255.255.240.0
 neighbor 222.222.10.1 remote-as 109
 neighbor 222.222.10.1 prefix-list routerC out
 neighbor 222.222.10.1 prefix-list default in
!
ip prefix-list default permit 0.0.0.0/0
ip prefix-list routerC permit 221.10.0.0/20

```

ISP/EXP Workshops © 2008, Cisco Systems, Inc. www.cisco.com 70

## Two links to different ISPs

- Router B Configuration

```

router bgp 107
 network 221.10.16.0 mask 255.255.240.0
 neighbor 220.1.5.1 remote-as 108
 neighbor 220.1.5.1 prefix-list routerD out
 neighbor 220.1.5.1 prefix-list default in
!
ip prefix-list default permit 0.0.0.0/0
ip prefix-list routerD permit 221.10.16.0/20

```

ISP/EXP Workshops © 2008, Cisco Systems, Inc. www.cisco.com 71

## Two links to different ISPs

- Router C Configuration

```

router bgp 109
 neighbor 221.10.1.1 remote-as 107
 neighbor 221.10.1.1 default-originate
 neighbor 221.10.1.1 prefix-list AS107cust in
 neighbor 221.10.1.1 prefix-list default-out out
!

```

- Router C only announces default to AS 107
- Router C only accepts AS107's prefix block

ISP/EXP Workshops © 2008, Cisco Systems, Inc. www.cisco.com 72

## Two links to different ISPs

- Router D Configuration

```
router bgp 108
 neighbor 220.1.5.1 remote-as 107
 neighbor 220.1.5.1 default-originate
 neighbor 220.1.5.1 prefix-list AS107cust in
 neighbor 220.1.5.1 prefix-list default-out out
!
```

- Router D only announces default to AS 107
- Router D only accepts AS107's prefix block

## Two links to different ISPs (no redundancy)

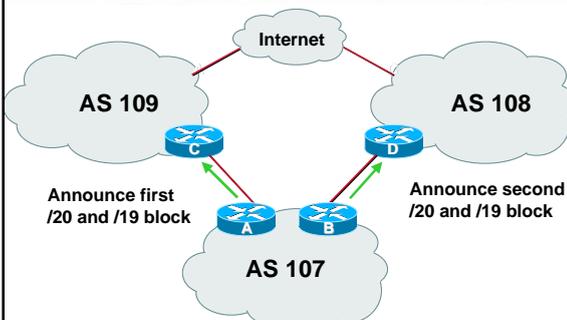
- **Big Problem:**  
no backup in case of link failure
- /19 address block not announced

## Two links to different ISPs With Redundancy

## Two links to different ISPs (with redundancy)

- 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 redundancy)



## Two links to different ISPs (with redundancy)

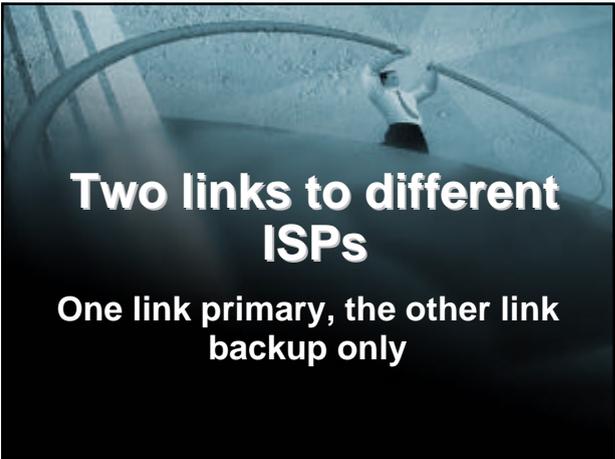
- Router A Configuration

```
router bgp 107
 network 221.10.0.0 mask 255.255.224.0
 network 221.10.0.0 mask 255.255.240.0
 neighbor 222.222.10.1 remote-as 109
 neighbor 222.222.10.1 prefix-list firstblock out
 neighbor 222.222.10.1 prefix-list default in
!
ip prefix-list default permit 0.0.0.0/0
!
ip prefix-list firstblock permit 221.10.0.0/20
ip prefix-list firstblock permit 221.10.0.0/19
```

## Two links to different ISPs (with redundancy)

- Router B Configuration

```
router bgp 107
network 221.10.0.0 mask 255.255.224.0
network 221.10.16.0 mask 255.255.240.0
neighbor 220.1.5.1 remote-as 108
neighbor 220.1.5.1 prefix-list secondblock out
neighbor 220.1.5.1 prefix-list default in
!
ip prefix-list default permit 0.0.0.0/0
!
ip prefix-list secondblock permit 221.10.16.0/20
ip prefix-list secondblock permit 221.10.0.0/19
```



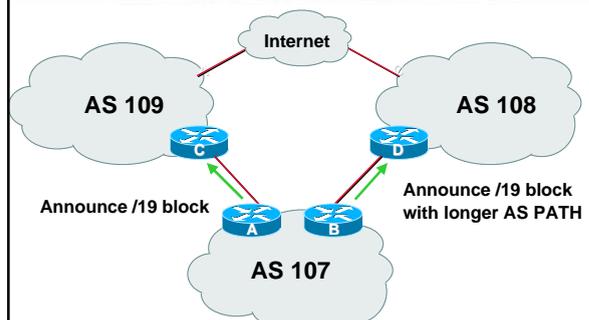
## Two links to different ISPs

One link primary, the other link backup only

## 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)



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

- Router A Configuration

```
router bgp 107
network 221.10.0.0 mask 255.255.224.0
neighbor 222.222.10.1 remote-as 109
neighbor 222.222.10.1 prefix-list aggregate out
neighbor 222.222.10.1 prefix-list default in
!
ip prefix-list aggregate permit 221.10.0.0/19
ip prefix-list default permit 0.0.0.0/0
```

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

- Router B Configuration

```
router bgp 107
network 221.10.0.0 mask 255.255.224.0
neighbor 220.1.5.1 remote-as 108
neighbor 220.1.5.1 prefix-list aggregate out
neighbor 220.1.5.1 route-map routerD-out out
neighbor 220.1.5.1 prefix-list default in
neighbor 220.1.5.1 route-map routerD-in in
!
..next slide
```

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

- Router B Configuration

```
!
ip prefix-list aggregate permit 221.10.0.0/19
ip prefix-list default permit 0.0.0.0/0
!
route-map routerD-out permit 10
 set as-path prepend 107 107
!
route-map routerD-in permit 10
 set local-preference 80
```

## Two links to different ISPs

### More Controlled Loadsharing

## Loadsharing with different ISPs

- Announce /19 aggregate on each link

On first link, announce /19 as normal

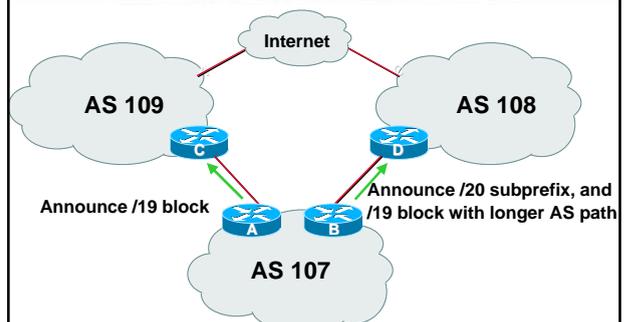
On second link, announce /19 with longer AS PATH, and announce one /20 subprefix

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



## Loadsharing with different ISPs

- Router A Configuration

```
router bgp 107
network 221.10.0.0 mask 255.255.224.0
neighbor 222.222.10.1 remote-as 109
neighbor 222.222.10.1 prefix-list default in
neighbor 222.222.10.1 prefix-list aggregate out
!
ip prefix-list aggregate permit 221.10.0.0/19
```

## Loadsharing with different ISPs

- Router B Configuration

```
router bgp 107
network 221.10.0.0 mask 255.255.224.0
network 221.10.16.0 mask 255.255.240.0
neighbor 220.1.5.1 remote-as 108
neighbor 220.1.5.1 prefix-list default in
neighbor 220.1.5.1 prefix-list subblocks out
neighbor 220.1.5.1 route-map routerD out
!
..next slide..
```

## Loadsharing with different ISPs

```

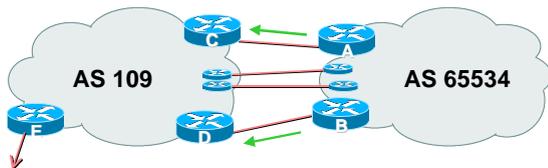
route-map routerD permit 10
 match ip address prefix-list aggregate
 set as-path prepend 107 107
route-map routerD permit 20
!
ip prefix-list subblocks permit 221.10.0.0/19 le 20
ip prefix-list aggregate permit 221.10.0.0/19

```

## Loadsharing Using Communities

### 4 links - Private AS

## Private AS



- AS109 removes private AS and any customer subprefixes from Internet announcement

## Private AS

- Announce /19 aggregate on each link
- Split /19 and announce as four /21s, 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
  - use the no-export community for subprefixes

## Private AS

- Router A Configuration

```

router bgp 65534
 network 221.10.0.0 mask 255.255.224.0
 network 221.10.0.0 mask 255.255.248.0
 neighbor 222.222.10.2 remote-as 109
 neighbor 222.222.10.2 send-community
 neighbor 222.222.10.2 prefix-list subblocks1 out
 neighbor 222.222.10.2 route-map routerC-out out
 neighbor 222.222.10.2 prefix-list default in
!
..next slide

```

## Private AS

```

ip prefix-list subblocks1 permit 221.10.0.0/19
ip prefix-list subblocks1 permit 221.10.0.0/21
!
ip prefix-list firstblock permit 221.10.0.0/21
ip prefix-list default permit 0.0.0.0/0
!
route-map routerC-out permit 10
 match ip address prefix-list firstblock
 set community no-export
route-map routerC-out permit 20

```

## Private AS

- Router B Configuration

```
router bgp 65534
 network 221.10.0.0 mask 255.255.224.0
 network 221.10.24.0 mask 255.255.248.0
 neighbor 222.222.20.2 remote-as 109
 neighbor 222.222.20.2 send-community
 neighbor 222.222.20.2 prefix-list subblocks2 out
 neighbor 222.222.20.2 route-map routerD-out out
 neighbor 222.222.20.2 prefix-list default in
!
```

..next slide

## Private AS

```
ip prefix-list subblocks2 permit 221.10.0.0/19
ip prefix-list subblocks2 permit 221.10.24.0/21
!
ip prefix-list secondblock permit 221.10.24.0/21
ip prefix-list default permit 0.0.0.0/0
!
route-map routerD-out permit 10
 match ip address prefix-list secondblock
 set community no-export
route-map routerD-out permit 20
```

## Private AS

- Router E Configuration

```
router bgp 109
 neighbor 222.222.10.17 remote-as 110
 neighbor 222.222.10.17 remove-private-AS
!
```

- Router E removes the private AS from external announcements
- Router E automatically removes subprefixes with no-export community set
- Private AS still visible inside AS109

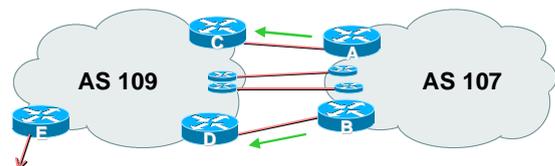
## Private AS

- Router C and D configuration is as previously
- AS109 routers will not advertise prefixes marked with community no-export to other ASes
- AS109 routers still need to filter the private AS
- Only a single /19 prefix is announced to the Internet - no routing table bloat! :-)

## Loadsharing Using Communities

4 links - Public AS

## Public AS



- 4 links between AS107 and AS109

## Public AS

- Announce /19 aggregate on each link
- Split /19 and announce as four /21s, 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

use the no-export community for subprefixes

## Public AS

- Router A Configuration

```
router bgp 107
 network 221.10.0.0 mask 255.255.224.0
 network 221.10.0.0 mask 255.255.248.0
 neighbor 222.222.10.2 remote-as 109
 neighbor 222.222.10.2 send-community
 neighbor 222.222.10.2 prefix-list subblocks1 out
 neighbor 222.222.10.2 route-map routerC-out out
 neighbor 222.222.10.2 prefix-list default in
!
```

..next slide

## Public AS

```
ip prefix-list subblocks1 permit 221.10.0.0/19
ip prefix-list subblocks1 permit 221.10.0.0/21
!
ip prefix-list firstblock permit 221.10.0.0/21
ip prefix-list default permit 0.0.0.0/0
!
route-map routerC-out permit 10
 match ip address prefix-list firstblock
 set community no-export
route-map routerC-out permit 20
```

## Public AS

- Router B Configuration

```
router bgp 107
 network 221.10.0.0 mask 255.255.224.0
 network 221.10.24.0 mask 255.255.248.0
 neighbor 222.222.20.2 remote-as 109
 neighbor 222.222.20.2 send-community
 neighbor 222.222.20.2 prefix-list subblocks2 out
 neighbor 222.222.20.2 route-map routerD-out out
 neighbor 222.222.20.2 prefix-list default in
!
```

..next slide

## Public AS

```
ip prefix-list subblocks2 permit 221.10.0.0/19
ip prefix-list subblocks2 permit 221.10.24.0/21
!
ip prefix-list secondblock permit 221.10.24.0/21
ip prefix-list default permit 0.0.0.0/0
!
route-map routerD-out permit 10
 match ip address prefix-list secondblock
 set community no-export
route-map routerD-out permit 20
```

## Public AS

- Router C Configuration

```
router bgp 109
 neighbor 222.222.10.1 remote-as 107
 neighbor 222.222.10.1 default-originate
 neighbor 222.222.10.1 prefix-list Customer in
 neighbor 222.222.10.1 prefix-list default out
!
```

```
ip prefix-list Customer permit 221.10.0.0/19 le 21
ip prefix-list default permit 0.0.0.0/0
```

## Loadsharing to the same ISP

- Router D Configuration

```
router bgp 109
 neighbor 222.222.10.5 remote-as 107
 neighbor 222.222.10.5 default-originate
 neighbor 222.222.10.5 prefix-list Customer in
 neighbor 222.222.10.5 prefix-list default out
!
ip prefix-list Customer permit 221.10.0.0/19 le 21
ip prefix-list default permit 0.0.0.0/0
```

## Loadsharing to the same ISP

- Router E Configuration

```
router bgp 109
 neighbor 222.222.10.17 remote-as 110
 neighbor 222.222.10.17 filter-list 1 out
!
ip as-path access-list 1 permit ^107$
ip as-path access-list 1 permit ^$
```

- Router E only has to announce AS107 in the same way it announces other ASes

## Public AS

- AS109 routers will not advertise prefixes marked with community no-export to other ASes
- AS109 ISP has no configuration work to do
  - AS107 ISP can control his own loadsharing
- Only a single /19 prefix is announced to the Internet - no routing table bloat! :-)



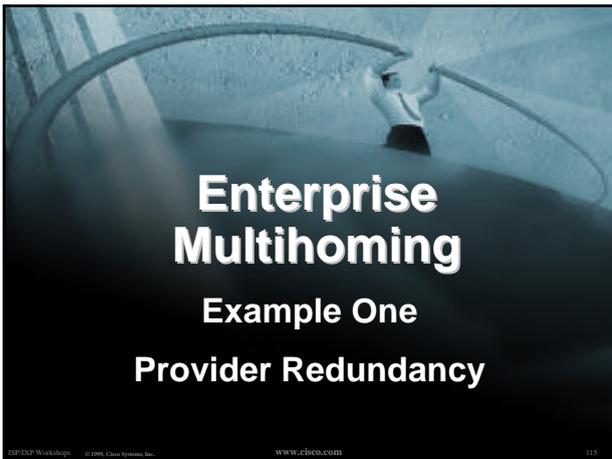
## Enterprise Multihoming

## Enterprise Multihoming

- Common scenario in Internet today
- More and more non-SPs multihoming for:
  - service provider redundancy
  - link redundancy
- Issues on Internet today:
  - Routing Table size accelerating
  - more and more /24 prefixes appearing in Internet Routing Table
  - ASN consumption accelerating

## Small ISP Multihoming

- These examples also apply to ISPs who don't yet have their own address block
- ISPs **should** obtain their own address block
  - Get it from RIR
  - Makes multihoming easier
  - Makes changing upstreams easier
  - Does not cause so much fragmentation in Internet Routing Table



## Enterprise Multihoming

- Common situation is enterprise multihoming
  - address space used by enterprise comes from both upstream ISPs
  - multihoming and loadsharing more difficult
  - want to avoid leaking subprefixes of upstream provider address space when possible
  - require provider redundancy (not just link redundancy)

ISP/EXP Workshops © 2008, Cisco Systems, Inc. www.cisco.com 116

## Enterprise Multihoming

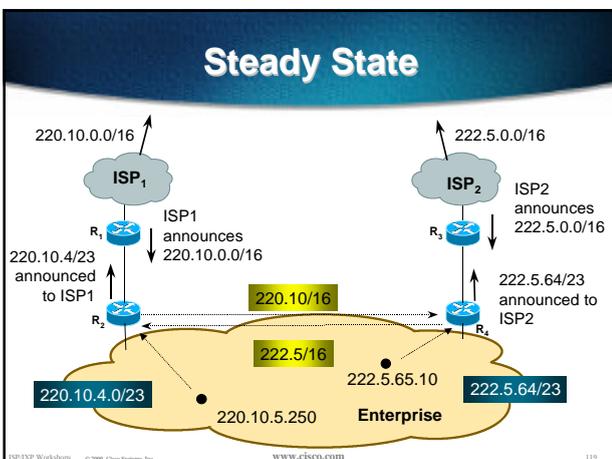
- Address space from upstream should match link bandwidth to upstream, e.g.
  - ISP1 @ Enterprise = 256kbps @ /22
  - ISP2 @ Enterprise = 128kbps @ /23
  - assumes address space is uniformly distributed across network
  - assumes that there is a requirement for 3x /23 in the Enterprise backbone
- Next example assumes equal bandwidth links from Enterprise to ISP1 and ISP2

ISP/EXP Workshops © 2008, Cisco Systems, Inc. www.cisco.com 117

## Enterprise Multihoming Conditional Advertisement

- New conditional advertisement feature in BGP
  - loadsharing under normal conditions
  - subprefixes only announced in failure scenarios
  - requires upstreams to announce **only one** prefix to enterprise border network

ISP/EXP Workshops © 2008, Cisco Systems, Inc. www.cisco.com 118



## Steady State

- ISP1 has 220.10.0.0/16 address block
- ISP2 has 222.5.0.0/16 address block
- Enterprise customer multihomes
  - upstreams don't announce subprefixes
  - can use private AS (ASN>64511)
  - R2 and R4 originate default in their IGP
  - outbound traffic uses nearest exit (IGP metrics)

ISP/EXP Workshops © 2008, Cisco Systems, Inc. www.cisco.com 120

## Steady State

- Router2 configuration:

```
router bgp 65534
network 220.10.4.0 mask 255.255.254.0
network 222.5.64.0 mask 255.255.254.0
neighbor <R1> remote-as 150
neighbor <R1> prefix-list isp1-in in
neighbor <R1> prefix-list isp1-out out
neighbor <R1> advertise-map isp2-sb non-exist-map isp2-bb
neighbor <R4> remote-as 65534
neighbor <R4> update-source loopback 0
!
ip route 220.10.4.0 255.255.254.0 null0 250
..next slide
```

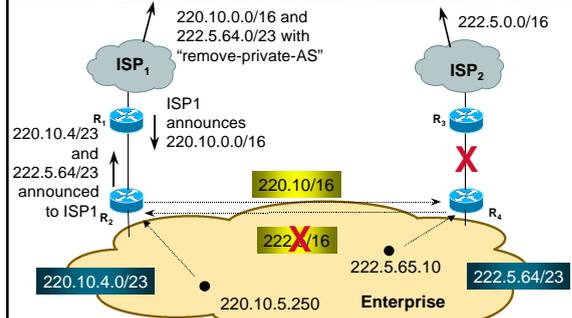
## Steady State

```
ip route 222.5.64.0 255.255.254.0 null0 250
!
ip prefix-list isp1-out permit 220.10.4.0/23
ip prefix-list isp2-out permit 222.5.64.0/23
!
ip prefix-list isp1-in permit 220.10.0.0/16
ip prefix-list isp2-in permit 222.5.0.0/16
!
route-map isp2-sb permit 10
match ip address prefix-list isp2-out
!
route-map isp2-bb permit 10
match ip address prefix-list isp2-in
!
```

## Steady State

- Router2 peers iBGP with Router4  
hears ISP2's /16 prefix
- Router2 peers eBGP with Router1  
hears ISP1's /16 prefix only  
announces 220.10.4.0/23 only

## Link Failure



## Link Failure

- Peering between Router 4 and Router3 (ISP2) goes down  
222.5.0.0/16 prefix withdrawn
- Conditional advertisement process activated  
Router2 starts to announce 222.5.64.0/23 to Router1
- Connectivity for Enterprise maintained

## Enterprise Multihoming

- Conditional advertisement useful when address space comes from both upstreams  
no subprefixes leaked to Internet unless in failure situation
- Alternative backup mechanism would be to leak /23 prefixes with longer AS path  
routing table bloat, reachability issues

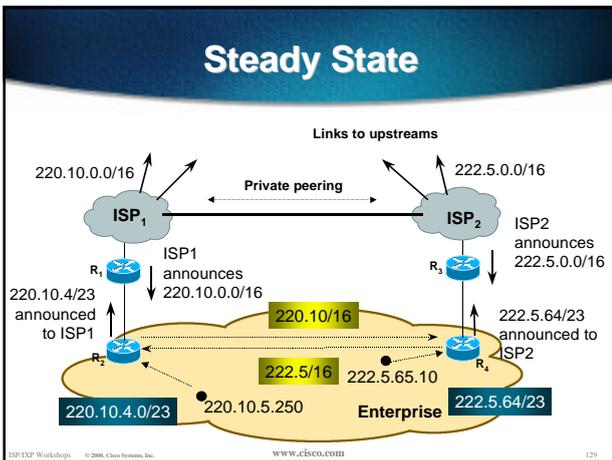
# Enterprise Multihoming

## Example Two

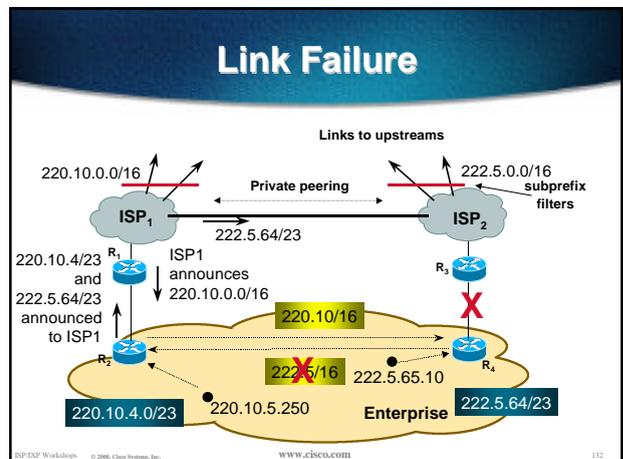
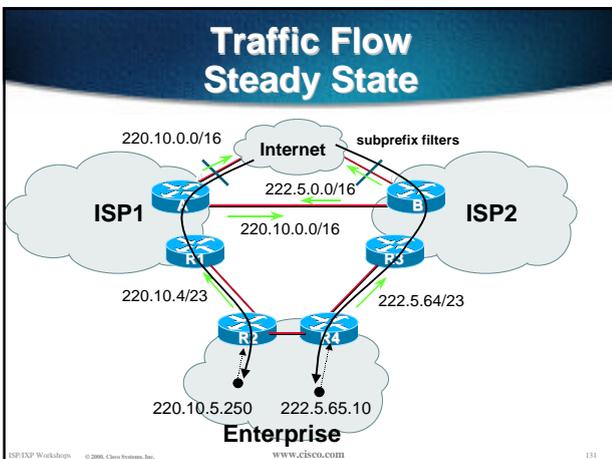
### Link Redundancy

ISP/EXP Workshops © 2008, Cisco Systems, Inc. www.cisco.com 127

- ## Enterprise Multihoming
- Situation similar to previous example
    - address space used by enterprise comes from **both** upstream ISPs
    - use conditional advertisement
    - want to avoid leaking subprefixes of upstream provider address space into the Internet
- ISP/EXP Workshops © 2008, Cisco Systems, Inc. www.cisco.com 128



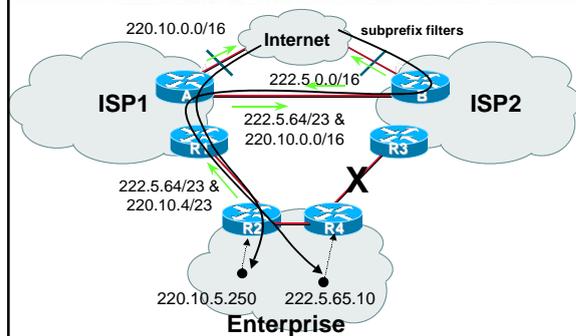
- ### Steady State
- ISP1 and ISP2 have private peering
    - exchange each other's prefixes
    - enterprise customer is looking for link redundancy only
    - no subprefixes leaked to Internet
  - Configuration of R2 as in previous example
- ISP/EXP Workshops © 2008, Cisco Systems, Inc. www.cisco.com 130



## Link Failure

- R3 @ R4 link goes down
  - conditional advertisement effective
  - 222.5.64/23 announced by R2 to R1
  - 222.5.64/23 announced by ISP1 to ISP2
- Filters!
  - ISP1 and ISP2 filter subprefixes from their blocks outbound to Internet
  - backup yet no subprefixes leaked to Internet

## Link Failure



## Configuration

- RouterA ISP1 border router configuration:
 

```
router bgp 150
network 220.10.0.0 mask 255.255.0.0
neighbor <routerB> remote-as 108
neighbor <routerB> prefix-list isp2-in in
neighbor <routerB> prefix-list isp2-out out
neighbor <upstream> remote-as 110
neighbor <upstream> prefix-list rfc1918-dsua in
neighbor <upstream> prefix-list myblock out
!
ip route 220.10.0.0 255.255.0.0 null0
..next slide
```

## Configuration

```
ip prefix-list isp2-out permit 220.10.0.0/16
ip prefix-list isp2-out permit 222.5.64.0/23
!
ip prefix-list isp2-in permit 222.5.0.0/16
ip prefix-list isp2-in permit 220.10.4.0/23
!
ip prefix-list myblock permit 220.10.0.0/16
!
```

- The “myblock” prefix list ensures that no subprefixes are leaked to the Internet routing table

## Recommendations

- Address space for Enterprise network should be obtained from **both** upstreams according to link bandwidths
- Address space should be distributed according to utilisation
  - loadsharing is about address assignment policies, monitoring bandwidth utilisation, as well as BGP attribute manipulation
- Use a private AS - no need for a public AS
  - needs agreement between two upstreams

