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

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

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

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

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”

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
```

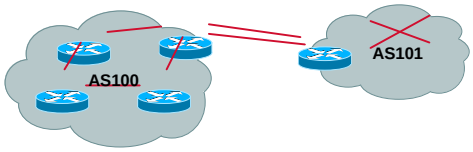

"Net Police" prefix list issues

- 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 Scenarios

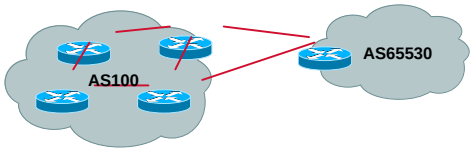
- Stub network
- Multi-homed stub network
- Multi-homed network
- Configuration Options

Stub Network



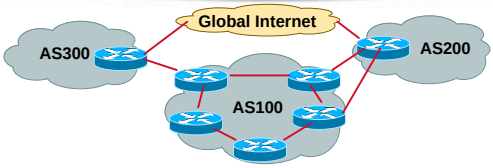
- No need for BGP
- Point static default to upstream ISP
- Upstream ISP advertises stub network
- Policy confined within upstream ISP's policy

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

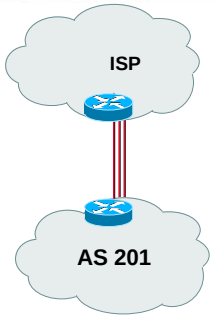
Multi-Homed Network



- Many situations possible
  - multiple sessions to same ISP
  - secondary for backup only
  - load-share between primary and secondary
  - selectively use different ISPs

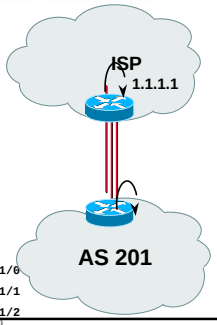
Multiple Sessions to an ISP

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



Multiple Sessions to an ISP ebgp multihop

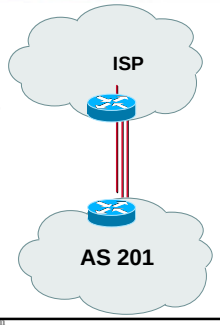
- eBGP to loopback addresses
- eBGP prefixes learned with loopback address as next hop




```
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



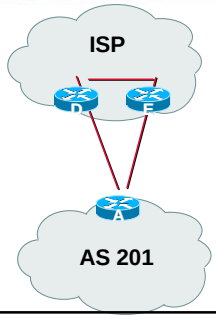

```
router bgp 201
 neighbor 1.1.2.1 remote-as 200
 neighbor 1.1.2.5 remote-as 200
 neighbor 1.1.2.9 remote-as 200
 maximum-paths 3
```


Multiple Sessions to an ISP

- Use eBGP multi-path to install multiple paths in IP table

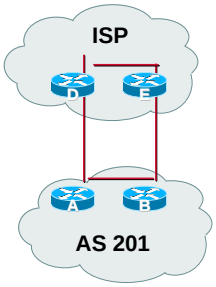
```
router bgp 201
 maximum-path <1-6>
```

- 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

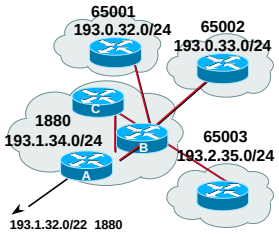


Multiple Sessions to ISPs

- 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 AS 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

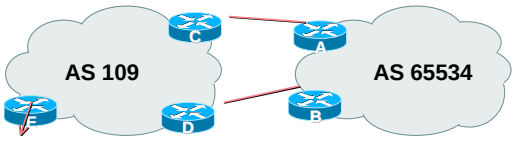
Two links to the same ISP

Basic - No Redundancy

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

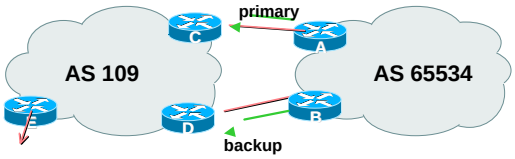
- **Big Problem:**
  - no backup in case of link failure
- /19 address block not announced
- AS Path filtering "awkward"
  - easier to use bgp command

```
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)**

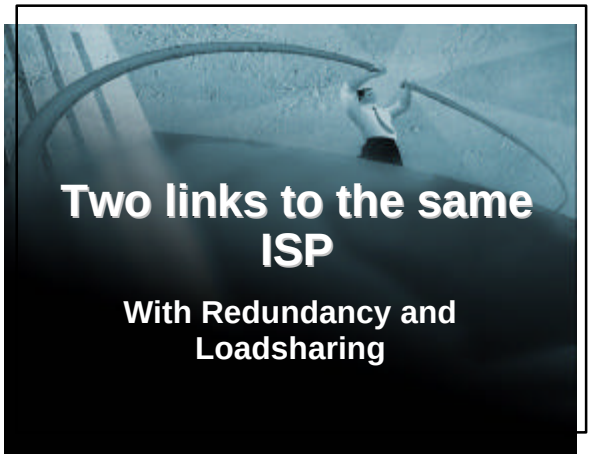
```
router bgp 109
 neighbor 222.222.10.5 remote-as 65534
 neighbor 222.222.10.5 default-originate
 neighbor 222.222.10.5 prefix-list Customer in
 neighbor 222.222.10.5 prefix-list default out
!
ip prefix-list Customer permit 221.10.0.0/19
ip prefix-list default permit 0.0.0.0/0
```


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

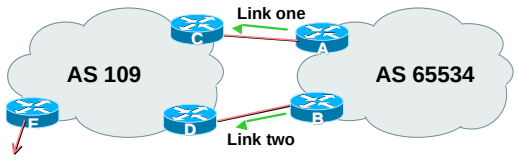
- **Router E Configuration**

```
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)



- 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)

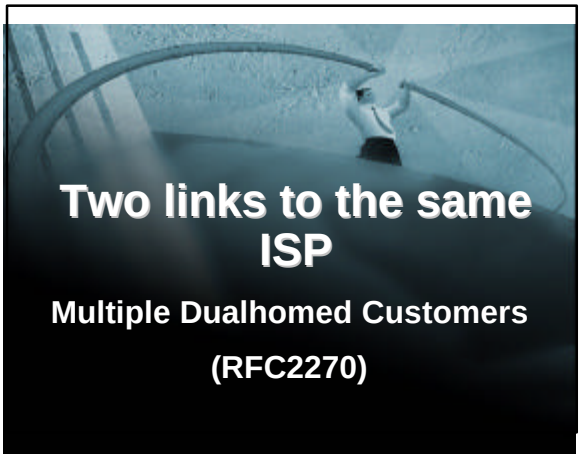
- Router E Configuration

```
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

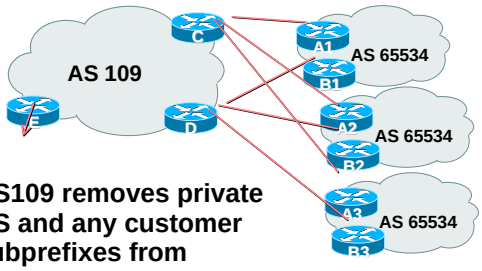


Two links to the same ISP

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 A*n* and B*n* 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

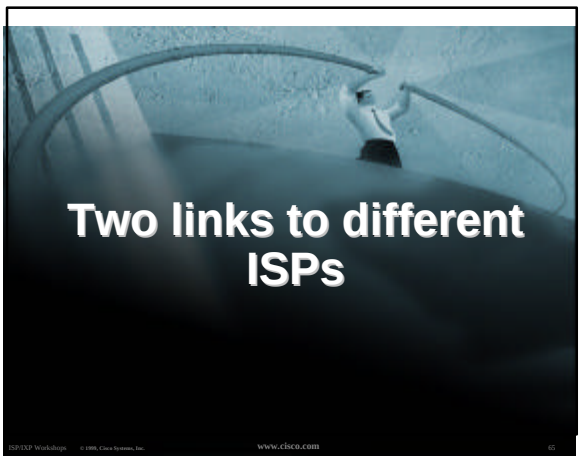
Multiple Dualhomed Customers

- 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

- 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

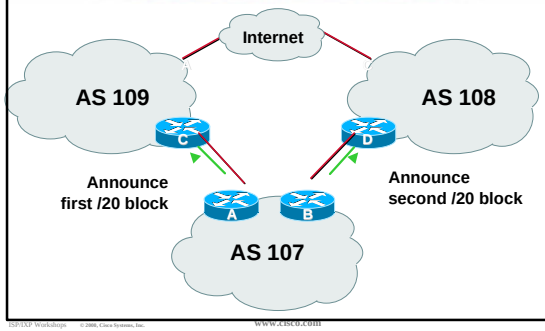
Two links to different ISPs

Basic - No Redundancy

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

Two links to different ISPs



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
```


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
```


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

Two links to different ISPs

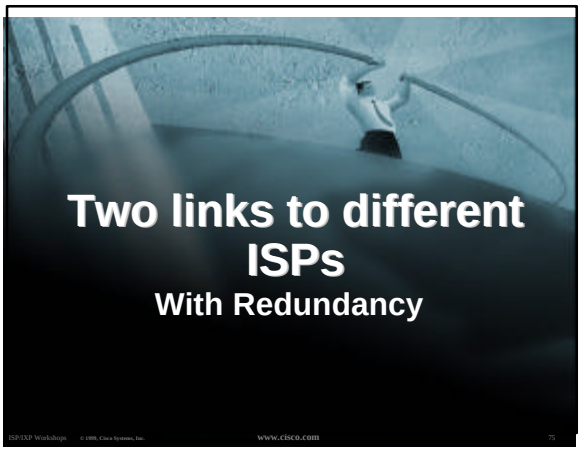
- Router D Configuration

```
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)

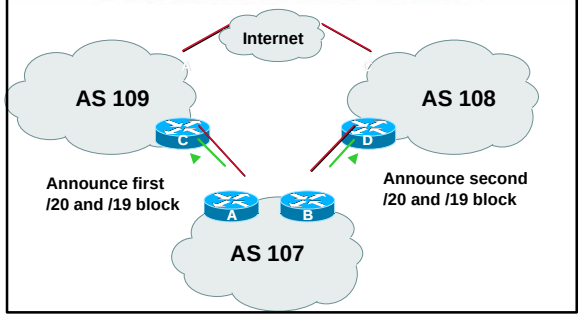
- **Big Problem:**
  - no backup in case of link failure
- /19 address block not announced



Two links to different ISPs (with redundancy)

- 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
```

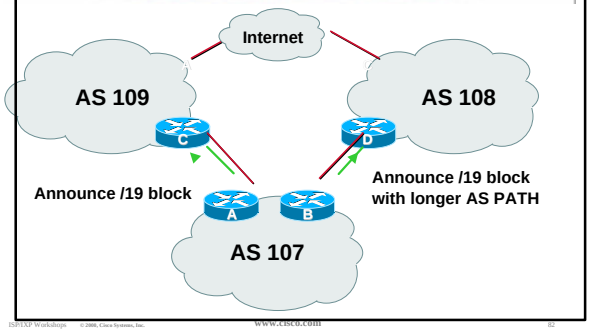

Two links to different ISPs

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)

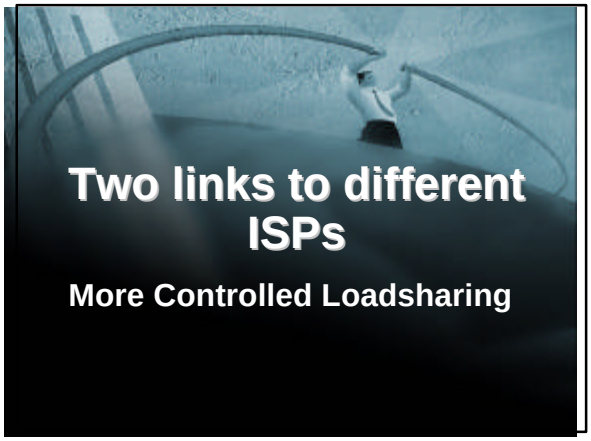
- Router B Configuration

```
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

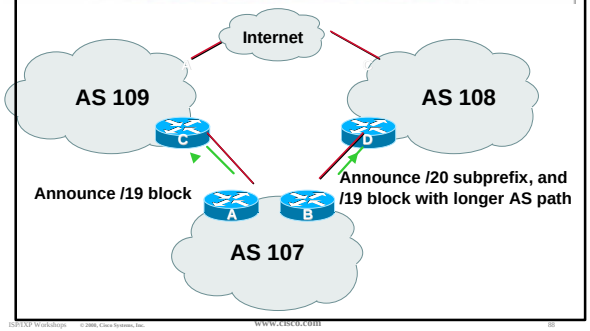
```
!
ip prefix-list aggregate permit 221.10.0.0/19
ip prefix-list default permit 0.0.0.0/0
!
route-map routerD-out permit 10
 set as-path prepend 107 107
!
route-map routerD-in permit 10
 set local-preference 80
```

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..
```

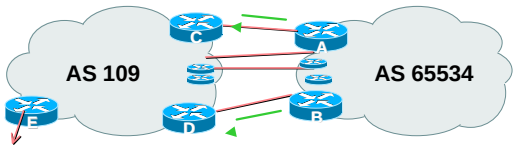
Loadsharing with different ISPs

```
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

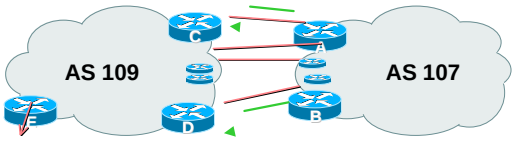
```
router bgp 109
 neighbor 222.222.10.17 remote-as 110
 neigbhor 222.222.10.17 remove-private-AS
!
```

- 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! :-)

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

- 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

Example One

Provider Redundancy

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)

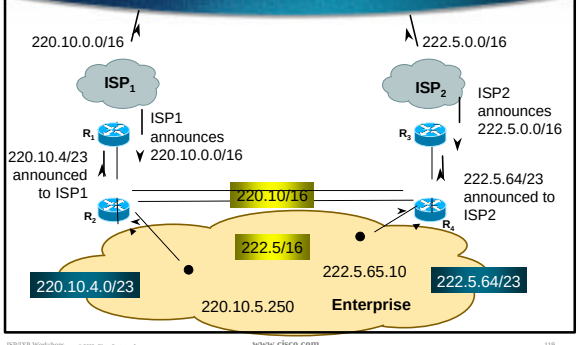
Enterprise Multihoming

- 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

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

Steady State



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)

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
```

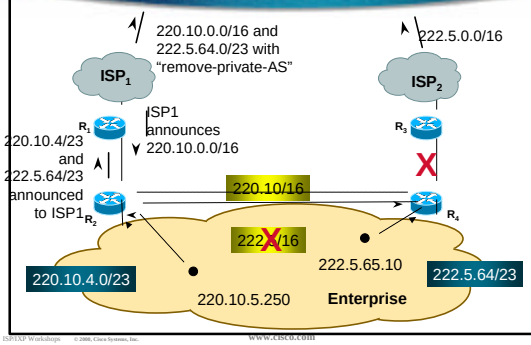

Steady State

```
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

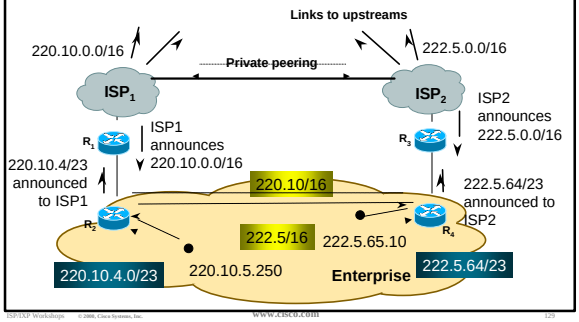
Example Two

Link Redundancy

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

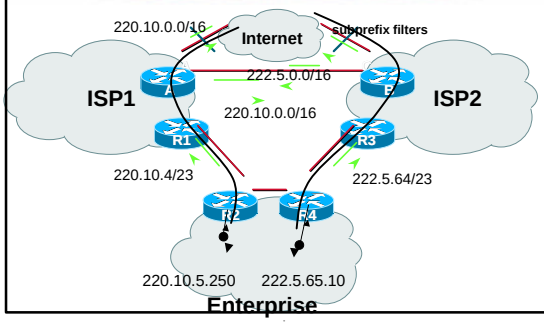
Steady State



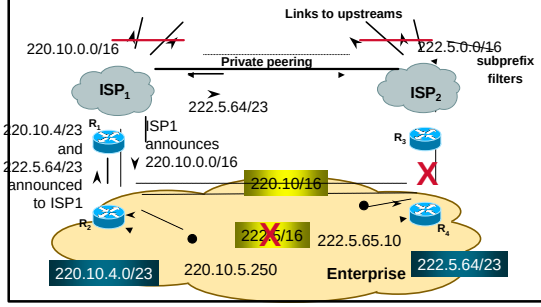
Steady State

- 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

Traffic Flow Steady State



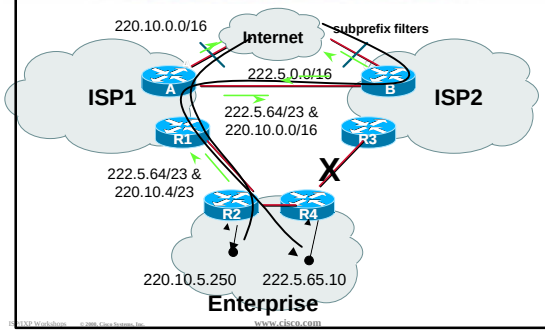
Link Failure



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

Cisco Systems

Empowering the Internet Generation℠