

# Introduction to BGP

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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

# Border Gateway Protocol

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- ❑ A Routing Protocol used to exchange routing information between different networks
  - Exterior gateway protocol
- ❑ Described in RFC4271
  - RFC4276 gives an implementation report on BGP
  - RFC4277 describes operational experiences using BGP
- ❑ The Autonomous System is the cornerstone of BGP
  - It is used to uniquely identify networks with a common routing policy

# BGP

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- ❑ Path Vector Protocol
- ❑ Incremental Updates
- ❑ Many options for policy enforcement
- ❑ Classless Inter Domain Routing (CIDR)
- ❑ Widely used for Internet backbone
- ❑ Autonomous systems

# Path Vector Protocol

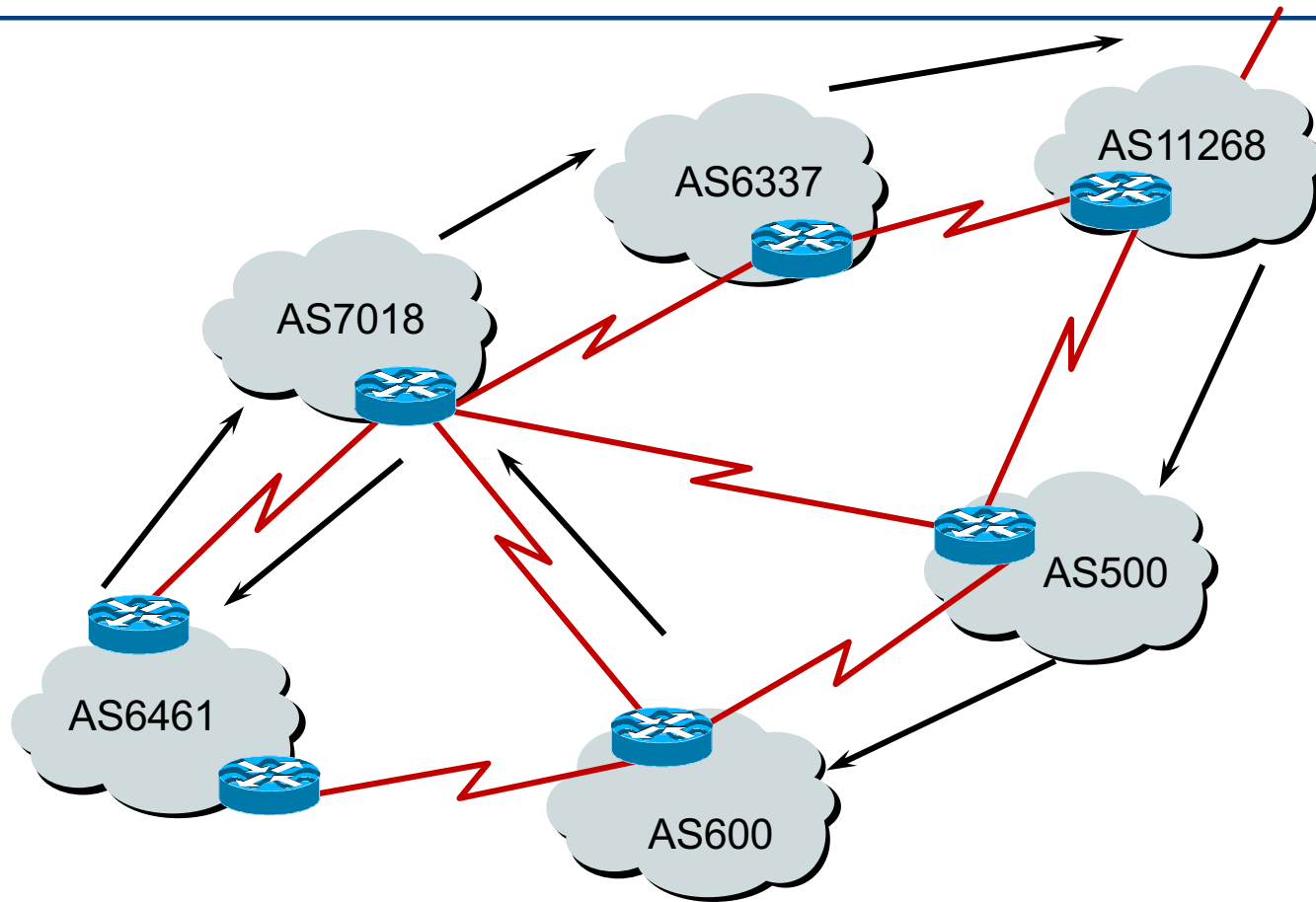
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- BGP is classified as a *path vector* routing protocol (see RFC 1322)
  - A path vector protocol defines a route as a pairing between a destination and the attributes of the path to that destination.

```
12.6.126.0/24  207.126.96.43  1021  0  6461 7018 6337 11268  i
```

AS Path

# Path Vector Protocol



# Definitions

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- **Transit** – carrying traffic across a network
  - (Commercially: for a fee)
- **Peering** – exchanging routing information and traffic
  - (Commercially: between similar sized networks, and for no fee)
- **Default** – where to send traffic when there is no explicit match in the routing table

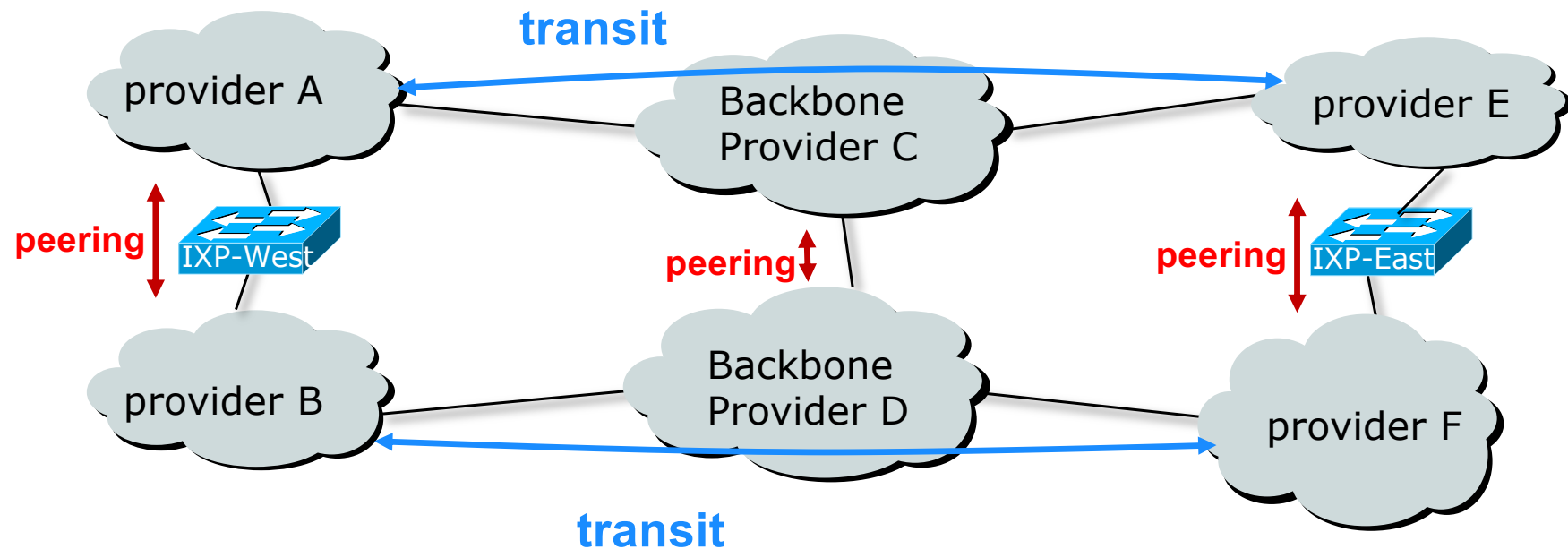
## Default Free Zone

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The default free zone is made up of Internet routers which have routing information about the whole Internet, and therefore do not need to use a default route

NB: is not related to where an ISP is in the hierarchy

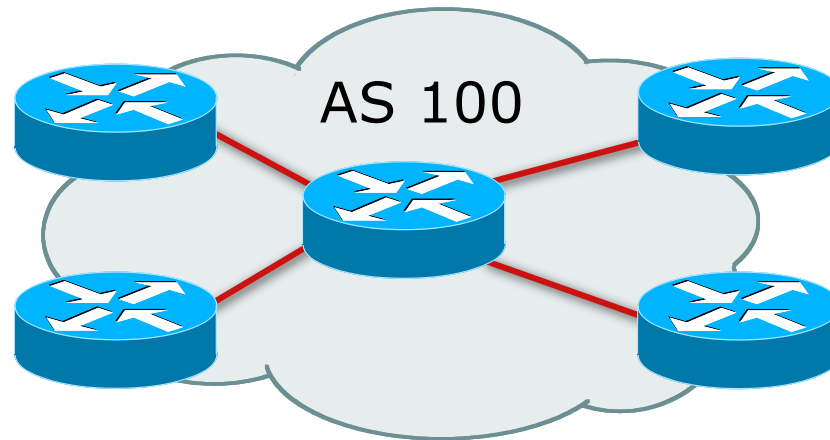
# Peering and Transit example



A and B peer for free, but need transit arrangements with C and D to get packets to/from E and F

# Autonomous System (AS)

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- ❑ Collection of networks with same routing policy
- ❑ Single routing protocol
- ❑ Usually under single ownership, trust and administrative control
- ❑ Identified by a unique 32-bit integer (ASN)

# 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	(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)
65552-4199999999	(public Internet)
4200000000-4294967295	(private use only)

- ❑ 32-bit range representation specified in RFC5396
  - Defines “asplain” (traditional format) as standard notation

# Autonomous System Number

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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 42200 16-bit ASNs are visible on the Internet
- Each RIR has also received a block of 32-bit ASNs
  - Out of 28000 assignments, around 22900 are visible on the Internet (July 2019)
- See [www.iana.org/assignments/as-numbers](http://www.iana.org/assignments/as-numbers)

# Configuring BGP in Cisco IOS

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- This command enables BGP in Cisco IOS:

```
router bgp 100
```

- For ASNs > 65535, the AS number can be entered in either plain or dot notation:

```
router bgp 131076
```

- Or

```
router bgp 2.4
```

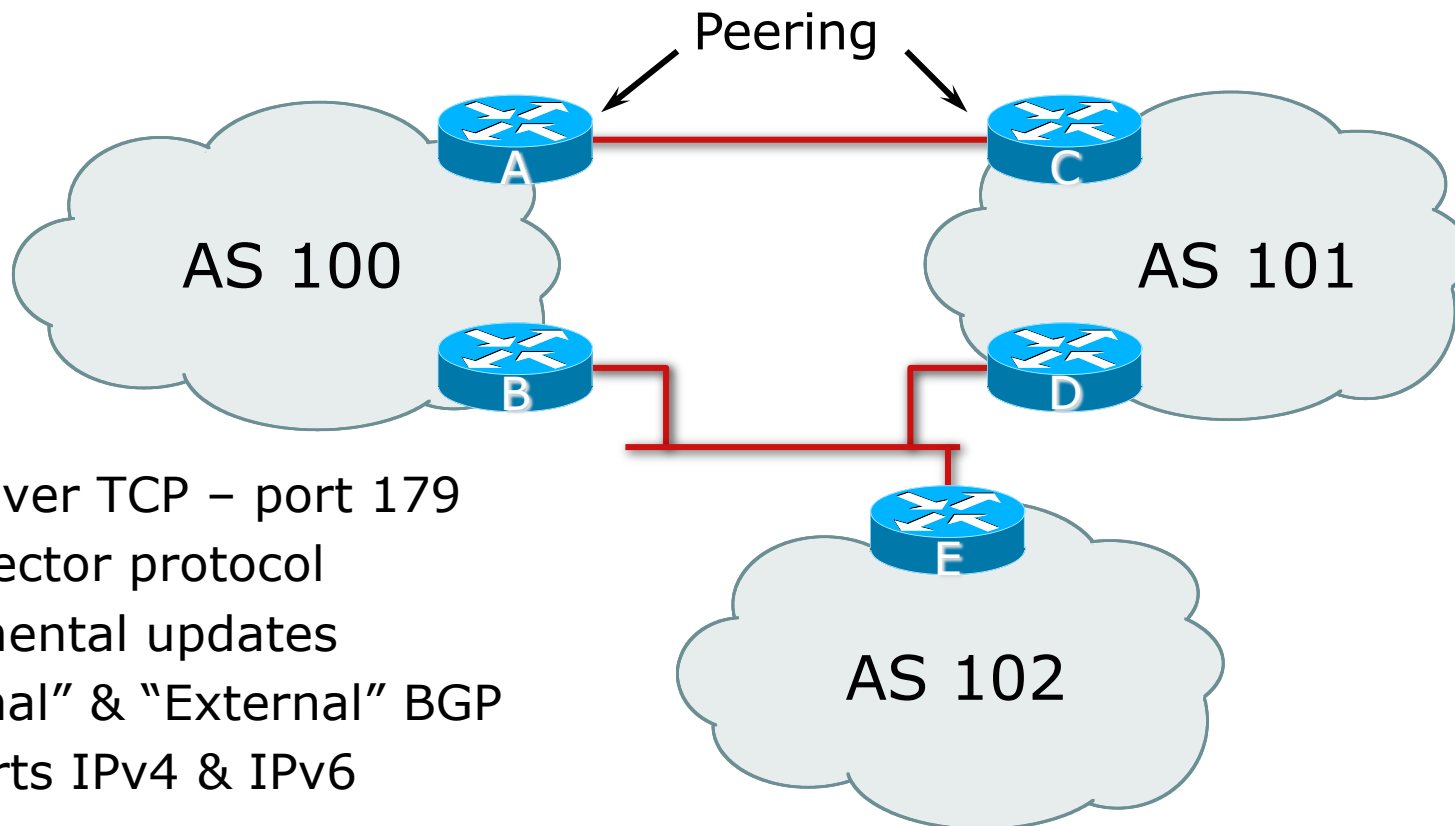
- IOS will display ASNs in plain notation by default

- Dot notation is optional:

```
router bgp 2.4  
bgp asnotation dot
```

# BGP Basics

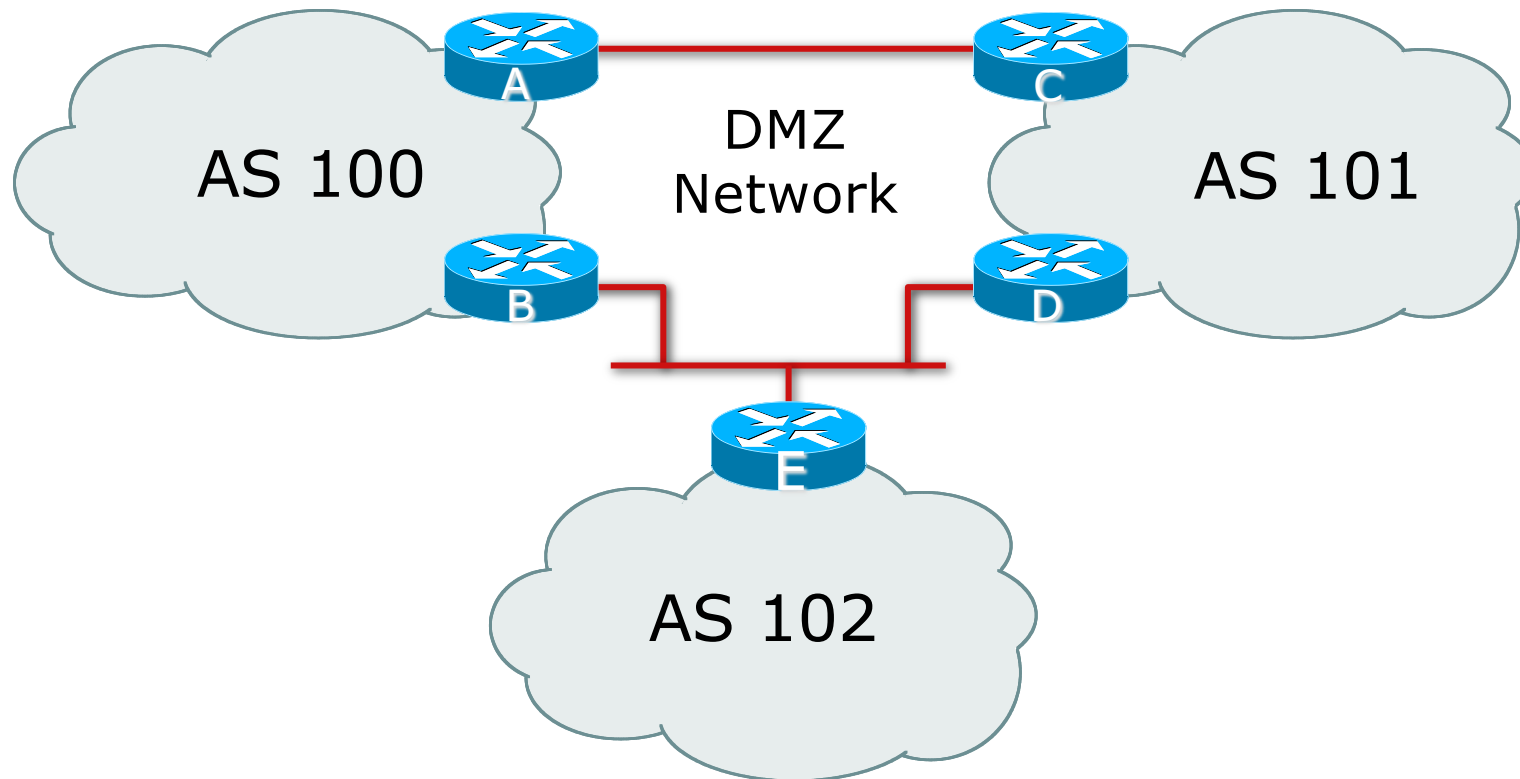
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- ❑ Runs over TCP – port 179
- ❑ Path vector protocol
- ❑ Incremental updates
- ❑ "Internal" & "External" BGP
- ❑ Supports IPv4 & IPv6

# Demarcation Zone (DMZ)

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- DMZ is the link or network shared between ASes

# BGP General Operation

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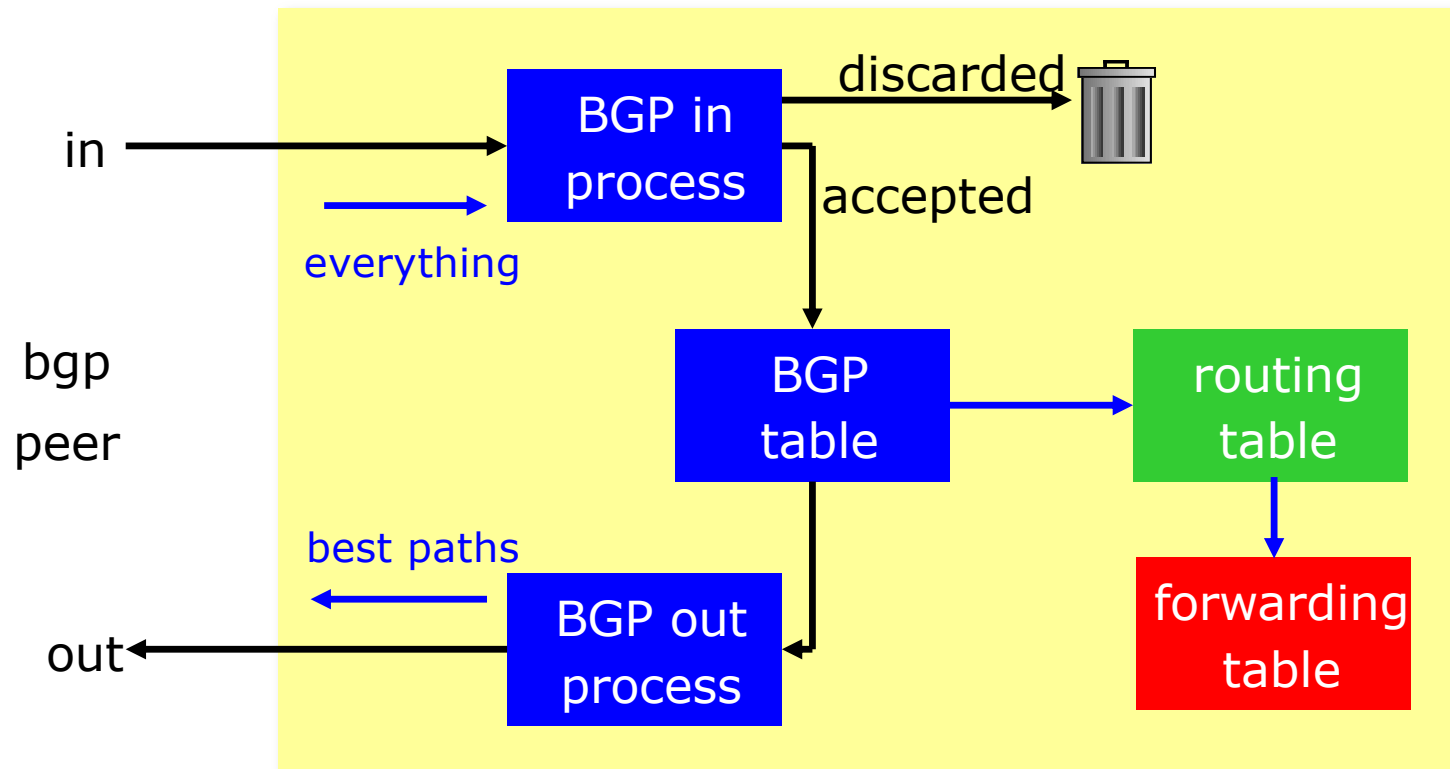
- ❑ Learns multiple paths via internal and external BGP speakers
- ❑ Picks the best path and installs it in the routing table (RIB)
- ❑ Best path is sent to external BGP neighbours
- ❑ Policies are applied by influencing the best path selection

# Constructing the Forwarding Table

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- BGP “in” process
  - Receives path information from peers
  - Results of BGP path selection placed in the BGP table
  - “best path” flagged
- BGP “out” process
  - Announces “best path” information to peers
- Best path stored in Routing Table (RIB) if:
  - Prefix and prefix length are unique (after best path selection)
  - and*
  - Lowest “protocol distance”
- Best paths in the RIB are installed in forwarding table (FIB)

# Constructing the Forwarding Table



# Supporting Multiple Protocols

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## □ RFC4760

- Defines Multi-protocol Extensions for BGP4
- Enables BGP to carry routing information of protocols other than IPv4
  - e.g. MPLS, IPv6, Multicast etc
- Exchange of multiprotocol NLRI must be negotiated at session startup

## □ RFC2545

- Use of BGP Multiprotocol Extensions for IPv6 Inter-Domain Routing
- Address family for IPv6

# Supporting Multiple Protocols

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## ❑ Independent operation

- One RIB per protocol
  - ❑ IPv6 routes in BGP's IPv6 RIB
  - ❑ IPv4 routes in BGP's IPv4 RIB
- Each protocol can have its own policies

## ❑ NEXTHOP

- Address of the next router must be of the same address family as that of the local router

# Supporting Multiple Protocols

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- ❑ Cisco IOS assumes that all BGP neighbours will exchange IPv4 unicast prefixes

- We need to remove this assumption

```
router bgp 100
  no bgp default ipv4-unicast
```

- ❑ For operational simplicity, the desire is for:
  - IPv4 neighbours to exchange IPv4 unicast prefixes
  - IPv6 neighbours to exchange IPv6 unicast prefixes
- ❑ Failure to do this results in:
  - IPv6 neighbours appearing to be set up to exchange IPv4 unicast prefixes
  - Cluttered configuration
  - Confusing troubleshooting and diagnosis

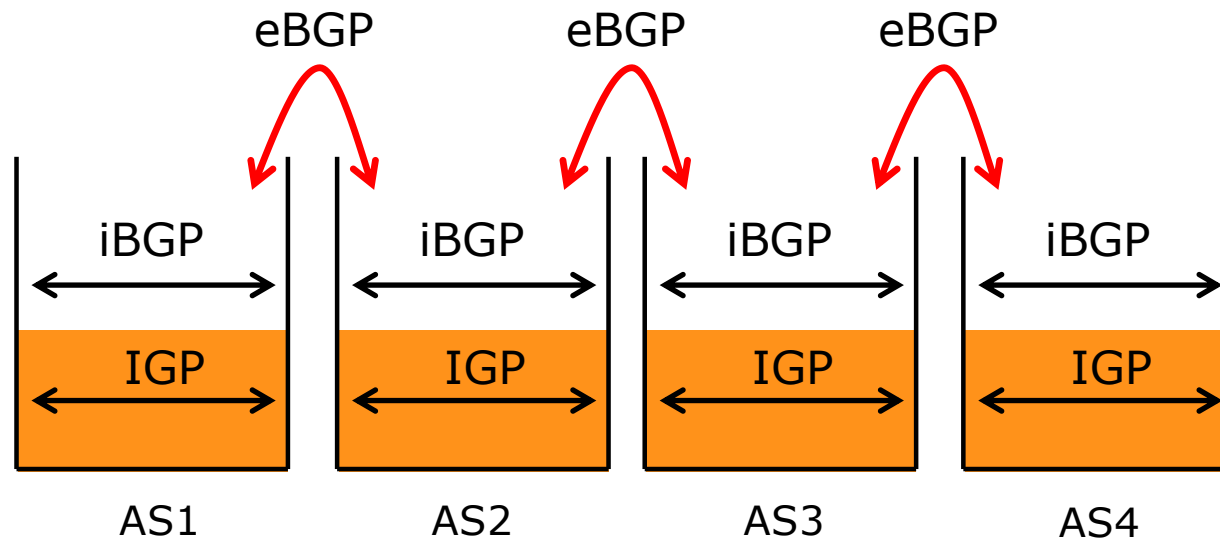
# eBGP & iBGP

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- BGP is used
  - Internally (iBGP)
  - Externally (eBGP)
- iBGP used to carry
  - Some/all Internet prefixes across ISP backbone
  - ISP's customer prefixes
- eBGP used to
  - Exchange prefixes with other ASes
  - Implement routing policy

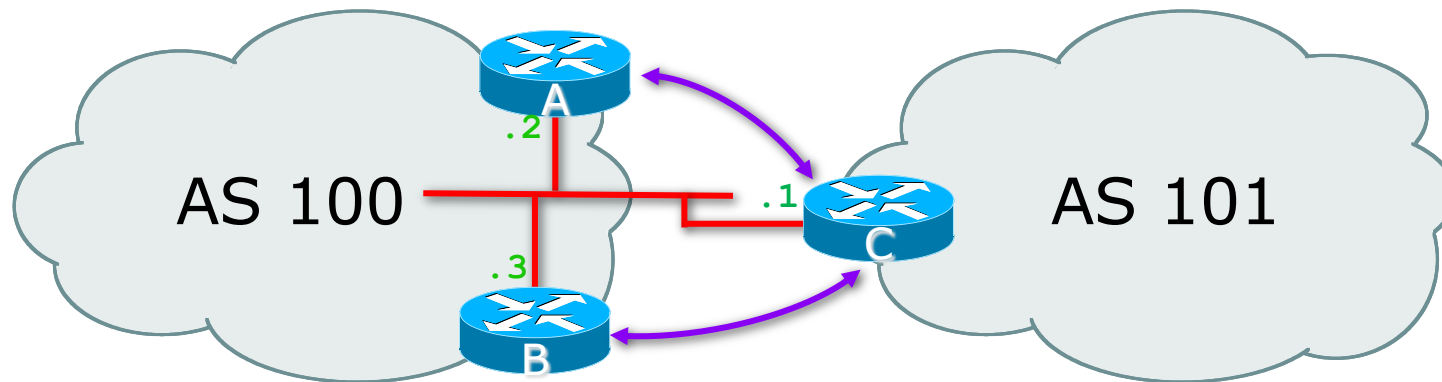
# BGP/IGP model used in ISP networks

## □ Model representation



# External BGP Peering (eBGP)

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- ❑ Between BGP speakers in different AS
- ❑ Should be directly connected
- ❑ **Never** run an IGP between eBGP peers

# Configuring External BGP

## □ Router A in AS100

```
interface FastEthernet 5/0
ip address 102.102.10.2 255.255.255.240
!
router bgp 100
address-family ipv4
network 100.100.8.0 mask 255.255.252.0
neighbor 102.102.10.1 remote-as 101
neighbor 102.102.10.1 prefix-list RouterC-in in
neighbor 102.102.10.1 prefix-list RouterC-out out
neighbor 102.102.10.1 activate
!
```

ip address on  
ethernet interface

Local ASN

Select IPv4 or IPv6

Remote ASN

Inbound and  
outbound filters

ip address of Router C  
ethernet interface

# Configuring External BGP

## □ Router C in AS101

```
interface FastEthernet 1/1/0
ip address 102.102.10.1 255.255.255.240
!
router bgp 101
address-family ipv4
network 100.100.64.0 mask 255.255.248.0
neighbor 102.102.10.2 remote-as 100
neighbor 102.102.10.2 prefix-list RouterA-in in
neighbor 102.102.10.2 prefix-list RouterA-out out
neighbor 102.102.10.2 activate
!
```

ip address on  
ethernet interface

Local ASN

Select IPv4 or IPv6

Remote ASN

Inbound and  
outbound filters

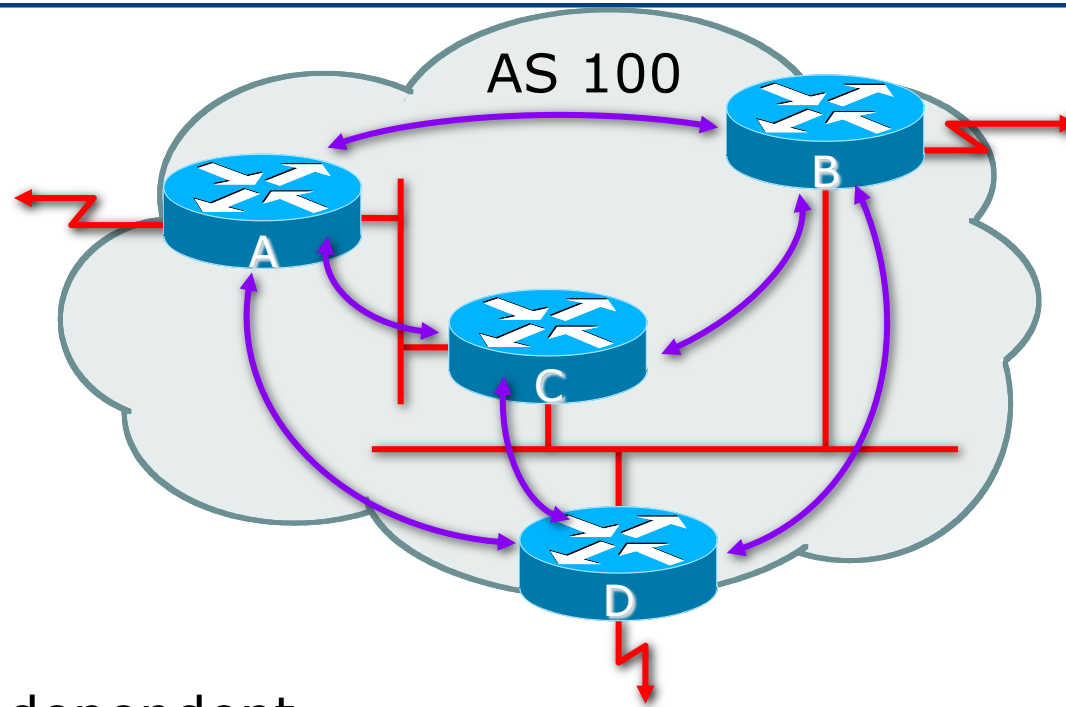
ip address of Router A  
ethernet interface

# Internal BGP (iBGP)

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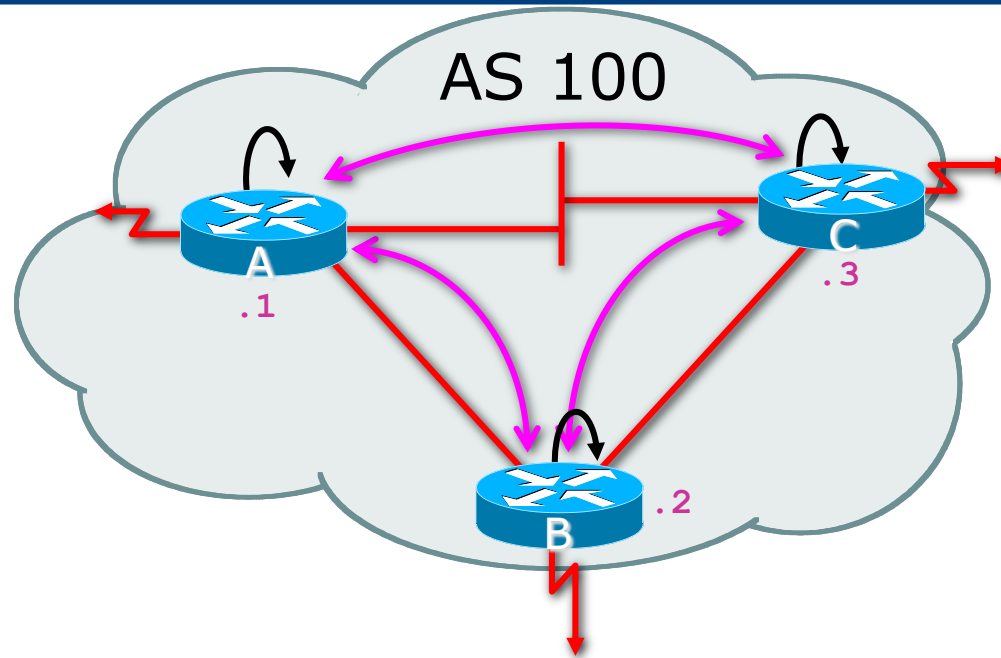
- ❑ BGP peer within the same AS
- ❑ Not required to be directly connected
  - IGP takes care of inter-BGP speaker connectivity
- ❑ iBGP speakers must be fully meshed:
  - They originate connected networks
  - They pass on prefixes learned from outside the ASN
  - They do not pass on prefixes learned from other iBGP speakers

# Internal BGP Peering (iBGP)



- ❑ Topology independent
- ❑ Each iBGP speaker must peer with every other iBGP speaker in the AS as per ↔

# Peering between Loopback Interfaces



- ❑ Peer with loop-back interface
  - Loop-back interface does not go down – ever!
- ❑ Do not want iBGP session to depend on state of a single interface or the physical topology

# Configuring Internal BGP

## □ Router A in AS100

```
interface loopback 0
 ip address 105.3.7.1 255.255.255.255
!
router bgp 100
 address-family ipv4
  network 100.100.1.0 mask 255.255.255.0
  neighbor 105.3.7.2 remote-as 100
  neighbor 105.3.7.2 update-source loopback0
  neighbor 105.3.7.2 activate
  neighbor 105.3.7.3 remote-as 100
  neighbor 105.3.7.3 update-source loopback0
  neighbor 105.3.7.3 activate
!
```

ip address on  
loopback interface

Local ASN

Local ASN

ip address of Router B  
loopback interface

# Configuring Internal BGP

## □ Router B in AS100

```
interface loopback 0
 ip address 105.3.7.2 255.255.255.255
!
router bgp 100
 address-family ipv4
  network 100.100.1.0 mask 255.255.255.0
  neighbor 105.3.7.1 remote-as 100
  neighbor 105.3.7.1 update-source loopback0
  neighbor 105.3.7.1 activate
  neighbor 105.3.7.3 remote-as 100
  neighbor 105.3.7.3 update-source loopback0
  neighbor 105.3.7.3 activate
!
```

ip address on  
loopback interface

Local ASN

Local ASN

ip address of Router A  
loopback interface

# Inserting prefixes into BGP

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- Two ways to insert prefixes into BGP
  - `redistribute static`
  - `network` command

# Inserting prefixes into BGP – redistribute static

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## ❑ Configuration Example:

```
router bgp 100
  address-family ipv4
    redistribute static
ip route 102.10.32.0 255.255.254.0 serial0
```

- ❑ Static route must exist before redistribute command will work
- ❑ Forces origin to be “incomplete”
- ❑ Care required!

# Inserting prefixes into BGP – redistribute static

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## ❑ Care required with redistribute!

- `redistribute routing-protocol` means everything in the named *routing-protocol* will be transferred into the current routing protocol
- Will not scale if uncontrolled
- Best avoided if at all possible
- `redistribute` normally used with route-maps and under tight administrative control

# Inserting prefixes into BGP – network command

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## ❑ Configuration Example

```
router bgp 100
  address-family ipv4
    network 102.10.32.0 mask 255.255.254.0
  ip route 102.10.32.0 255.255.254.0 serial0
```

- ❑ A matching route must exist in the routing table before the network is announced
- ❑ Forces origin to be “IGP”

# Configuring Aggregation

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- Three ways to configure route aggregation
  - `redistribute static`
  - `aggregate-address`
  - `network` command

# Configuring Aggregation – Redistributing Static

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## ❑ Configuration Example:

```
router bgp 100
  address-family ipv4
    redistribute static
  ip route 102.10.0.0 255.255.0.0 null0
```

## ❑ Static route to “null0” is called a pull up route

- Packets only sent here if there is no more specific match in the routing table
- Care required – see previously!

# Configuring Aggregation – Network Command

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## ❑ Configuration Example

```
router bgp 100
  address-family ipv4
    network 102.10.0.0 mask 255.255.0.0
  ip route 102.10.0.0 255.255.0.0 null0
```

- ❑ A matching route must exist in the routing table before the network is announced
- ❑ Easiest and best way of generating an aggregate

# Configuring Aggregation – aggregate-address command

---

## ❑ Configuration Example:

```
router bgp 100
  address-family ipv4
    network 102.10.32.0 mask 255.255.252.0
    aggregate-address 102.10.0.0 255.255.0.0 [summary-only]
  !
ip route 102.10.32.0 255.255.252.0 null 0
```

- ❑ Requires more specific prefix in BGP table before aggregate is announced
- ❑ **summary-only** keyword
  - Optional keyword which ensures that only the summary is announced (the more specific routes are suppressed)

# Summary

## BGP neighbour status (IPv4)

```
Router6>show ip bgp summary
```

```
BGP router identifier 10.0.15.246, local AS number 10
```

```
BGP table version is 16, main routing table version 16
```

```
7 network entries using 819 bytes of memory
```

```
14 path entries using 728 bytes of memory
```

```
2/1 BGP path/bestpath attribute entries using 248 bytes of memory
```

```
0 BGP route-map cache entries using 0 bytes of memory
```

```
0 BGP filter-list cache entries using 0 bytes of memory
```

```
BGP using 1795 total bytes of memory
```

```
BGP activity 7/0 prefixes, 14/0 paths, scan interval 60 secs
```

Neighbor	V	AS	MsgRcvd	MsgSent	TblVer	InQ	OutQ	Up/Down	State/PfxRcd
10.0.15.241	4	10	9	8	16	0	0	00:04:47	2
10.0.15.242	4	10	6	5	16	0	0	00:01:43	2
10.0.15.243	4	10	9	8	16	0	0	00:04:49	2
...									

BGP Version

Updates sent  
and received

Updates waiting

# Summary

## BGP neighbour status (IPv6)

```
Router1>sh bgp ipv6 unicast summary
BGP router identifier 10.10.15.224, local AS number 10
BGP table version is 28, main routing table version 28
18 network entries using 2880 bytes of memory
38 path entries using 3040 bytes of memory
9/6 BGP path/bestpath attribute entries using 1152 bytes of memory
4 BGP AS-PATH entries using 96 bytes of memory
0 BGP route-map cache entries using 0 bytes of memory
0 BGP filter-list cache entries using 0 bytes of memory
BGP using 7168 total bytes of memory
BGP activity 37/1 prefixes, 95/19 paths, scan interval 60 secs
```

Neighbor	V	AS	MsgRcvd	MsgSent	TblVer	InQ	OutQ	Up/Down	State/PfxRcd
2001:DB8::2	4	10	185	182	28	0	0	02:36:11	16
2001:DB8::3	4	10	180	181	28	0	0	02:36:08	11
2001:DB8:0:4::1	4	40	153	152	28	0	0	02:05:39	9



Neighbour Information



BGP Messages Activity

# Summary

## BGP Table (IPv4)

```
Router6>sh ip bgp
BGP table version is 18, local router ID is 10.0.15.246
Status codes: s suppressed, d damped, h history, * valid, > best, i - internal,
               r RIB-failure, S Stale, m multipath, b backup-path, f RT-Filter,
               x best-external, a additional-path, c RIB-compressed,
Origin codes: i - IGP, e - EGP, ? - incomplete
RPKI validation codes: V valid, I invalid, N Not found
```

Network	Next Hop	Metric	LocPrf	Weight	Path
*>i 10.0.0.0/26	10.0.15.241	0	100	0	i
*>i 10.0.0.64/26	10.0.15.242	0	100	0	i
*>i 10.0.0.128/26	10.0.15.243	0	100	0	i
*>i 10.0.0.192/26	10.0.15.244	0	100	0	i
*>i 10.0.1.0/26	10.0.15.245	0	100	0	i
*> 10.0.1.64/26	0.0.0.0	0		32768	i
*>i 10.0.1.128/26	10.0.15.247	0	100	0	i
*>i 10.0.1.192/26	10.0.15.248	0	100	0	i
*>i 10.0.2.0/26	10.0.15.249	0	100	0	i
*>i 10.0.2.64/26	10.0.15.250	0	100	0	i
*>i 10.0.2.128/26	10.0.15.251	0	100	0	i
*>i 10.0.2.192/26	10.0.15.252	0	100	0	i
*>i 10.0.3.0/26	10.0.15.253	0	100	0	i
*>i 10.0.3.64/26	10.0.15.254	0	100	0	i

# Summary

## BGP Table (IPv6)

```
Router6>sh bgp ipv6 unicast
BGP table version is 18, local router ID is 10.0.15.246
Status codes: s suppressed, d damped, h history, * valid, > best, i - internal,
               r RIB-failure, S Stale, m multipath, b backup-path, f RT-Filter,
               x best-external, a additional-path, c RIB-compressed,
Origin codes: i - IGP, e - EGP, ? - incomplete
RPKI validation codes: V valid, I invalid, N Not found
```

Network	Next Hop	Metric	LocPrf	Weight	Path
*>i 2001:DB8:1::/48	2001:DB8::1	0	100	0	i
*>i 2001:DB8:2::/48	2001:DB8::2	0	100	0	i
*>i 2001:DB8:3::/48	2001:DB8::3	0	100	0	i
*>i 2001:DB8:4::/48	2001:DB8::4	0	100	0	i
*>i 2001:DB8:5::/48	2001:DB8::5	0	100	0	i
*> 2001:DB8:6::/48	::	0		32768	i
*>i 2001:DB8:7::/48	2001:DB8::7	0	100	0	i
*>i 2001:DB8:8::/48	2001:DB8::8	0	100	0	i
*>i 2001:DB8:9::/48	2001:DB8::9	0	100	0	i
*>i 2001:DB8:A::/48	2001:DB8::A	0	100	0	i
*>i 2001:DB8:B::/48	2001:DB8::B	0	100	0	i
*>i 2001:DB8:C::/48	2001:DB8::C	0	100	0	i
*>i 2001:DB8:D::/48	2001:DB8::D	0	100	0	i
*>i 2001:DB8:E::/48	2001:DB8::E	0	100	0	i

# Summary

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- ❑ BGP – path vector protocol
- ❑ Multi-protocol (IPv4 & IPv6)
- ❑ iBGP versus eBGP
- ❑ Stable iBGP – peer with loopbacks
- ❑ Announcing prefixes & aggregates

# Introduction to BGP



ISP Workshops