# BGP Policy

BGP Attributes in Detail



## Agenda

- **Introduction**
- **Next hop handling**
- **AS aggregation**
- **Preferences for outgoing traffic**
- **Preferences for incoming traffic**
- **Route origins**
- **Communities**
- **Routing decision details**
- **Routing policies**







## BGP Routing Policy

- **the power of BGP**
  - attributes and route filtering techniques
  - combination of attribute manipulation and filtering can be used for desired routing behavior in the Internet
    - that makes it possible to implement a routing policy
  - implementation of routing policies
- **attributes**
  - more or less simple parameters which can be modified to affect the BGP decision process



## BGP Routing Policy

- **route filtering**
  - can be done on a prefix level
    - filtering NLRI information (IP prefix, length) of BGP routes
    - however, this approach is not really scalable
  - or path level
    - filtering on attributes (e.g. AS number) of BGP routes
    - this is the usual way of expressing policies in the Internet
- **routing policy**
  - is implemented in Input Policy and/or Output Policy Engines of a BGP router

## BGP Routing Policy

- **Policy Engines**
  - can filter (“match”) BGP routes based on the route description (attributes) or NLRI (prefix) of a given BGP route
    - a BGP route will be discarded or passed to other peers in case of a match
  - can manipulate (“set”) attributes of a BGP route or parameter of a BGP router
    - in order to implement a certain policy
    - a BGP route may be changed before it is passed on
- **therefore a detailed understanding of BGP attributes is necessary**



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## Next_Hop Attribute

- **well-known mandatory attribute**
- **next hop definition for IGP**
  - IP address of connected interface of the router that has announced a route
- **next hop definition for BGP is different**
  - for EBGP and IBGP sessions



## Next_Hop Attribute

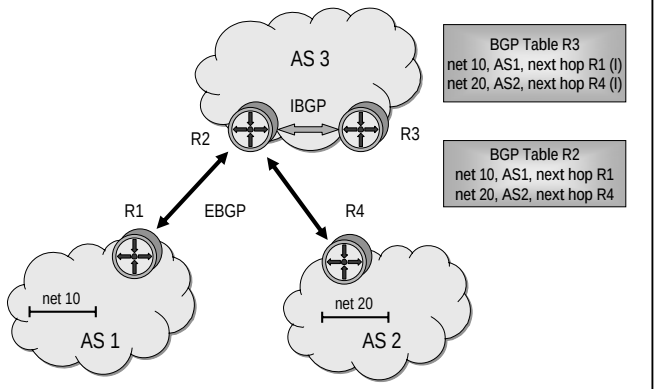
- **for EBGP sessions**
  - next hop is the IP address of neighboring router that announced the route
- **exception of this rule:**
  - two EBGP routers are connected via multi-access media (LAN) but this LAN is used also for connectivity to AS internal routers
    - redirection to the corresponding IGP router
  - special care necessary for NBMA in partially meshed topology
    - Cisco next-hop-self feature

## Next_Hop Attribute

- **for IBGP sessions**
  - 1.) for routes originated inside the AS next hop is the IP address of the neighbor that announced the route
  - 2.) for routes injected into the AS via EBGP next hop learned from EBGP is carried unaltered into IBGP
- **because of this IBGP behavior**
  - recursive IP lookup is necessary if next hop is not directly reachable
  - reachability of next hop must be advertised via some IGP or static routing
    - next hop must be reachable via normal IP routing table

## Next Hop Example 1



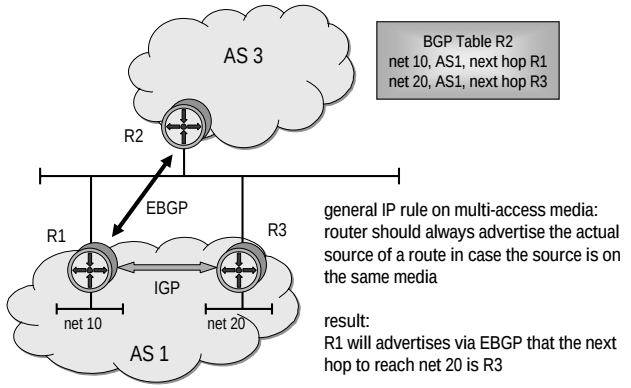

 







## Next Hop Example 2




general IP rule on multi-access media: router should always advertise the actual source of a route in case the source is on the same media

result:
R1 will advertises via EBGP that the next hop to reach net 20 is R3

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## AS_Path Attribute

- **describes sequence of AS numbers (list) a route traversed to reach a destination**
  - well-known mandatory attribute
  - originator of a route adds its own AS number when sending the route to its external BGP peers
  - each receiver adds its AS number to the beginning of the list before it passes the route to other external BGP peers
  - passing a route to an internal BGP peer leaves AS_Path intact
- **used to ensure loop-free topology**
- **used to determine best route to a destination**
  - shorter path is always preferred



## AS_Path Aggregation

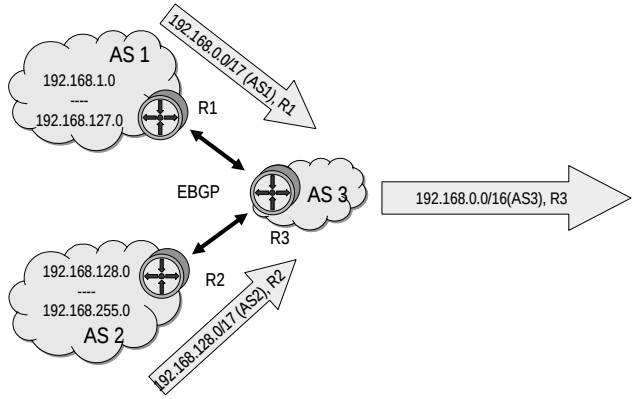
- **aggregation (summarization) of IP addresses**
  - can lead to loss of path information and hence to routing loops or sub-optimal routing
  - information about origination of a route will be lost
- **therefore the following attributes are introduced**
  - Atomic_Aggregate attribute
  - Aggregator attribute
  - AS-Set
- **but be very careful doing aggregation for another party**
  - try do avoid it
    - in most cases it is a design problem but not a principle problem







## Aggregation Example 1

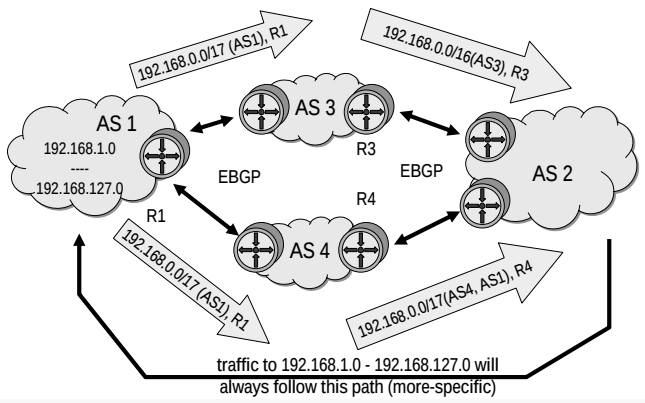





## How specific is a route?

- **more specific = smaller set of destinations**
  - longer prefix
- **less specific = larger set of destinations**
  - shorter prefix
- **general IP routing rule:**
  - when overlapping routes are present in the routing table the more specific route shall take precedence
  - routing rule of longest match prefix
  - also used for BGP

## Aggregation Example 2






## Atomic_Aggregate Attribute

- **if route aggregation done by an BGP router**
  - would cause a loss of information
    - e.g. a certain AS number will not longer be seen in the path
  - then this BGP router must attach the Atomic_Aggregate attribute to this route description
    - well-known discretionary attribute
  - that specifies that some AS´s may be missing from the AS_Path attribute
    - but does not specify which router was the aggregator
      - however can be done optionally by Aggregator attribute
    - also does not specify what AS numbers are missing
- **exception of this rule**
  - aggregate is described by AS-Set parameter







## Aggregator Attribute

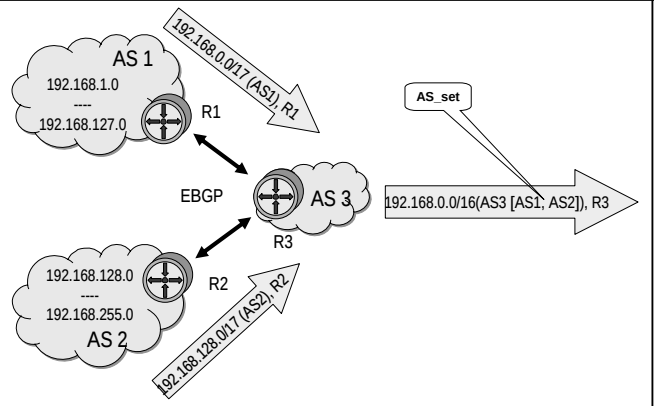
- **specifies the router that has generated an aggregate**
  - AS number
  - Router ID
- **might be added by a BGP peer that performs route aggregation**
  - optional transitive attribute
  - typically useful for troubleshooting



## AS-Set Aggregation

- **as alternative AS-Set could be used**
  - a set includes all the AS´s a route has traversed but in an unordered way (no sequence information)
    - an aggregate of an IP address can be announced while keeping information about the components of the aggregate
      - can be used for avoiding loops
  - done with path segment type of the AS_PATH attribute
  - AS_Path attribute (type 2) consists of
    - path segment type (one octet)
      - 1 = AS_Set (unordered set of AS´s)
      - 2 = AS_Sequence (ordered set of AS´s)
    - path segment length (one octet)
    - path segment value (variable; each AS encoded in two octets)

## AS-Set Example



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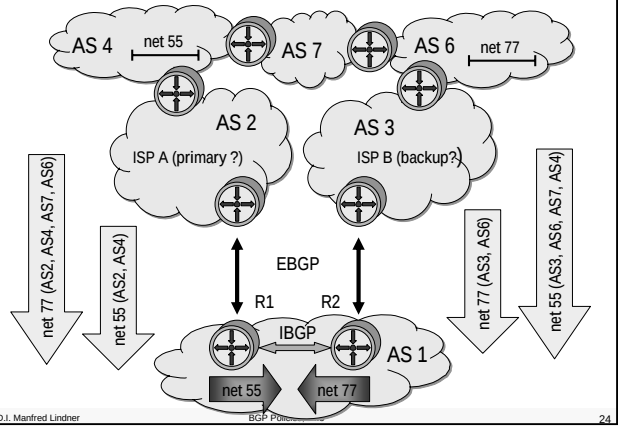
## Local_Preference Attribute

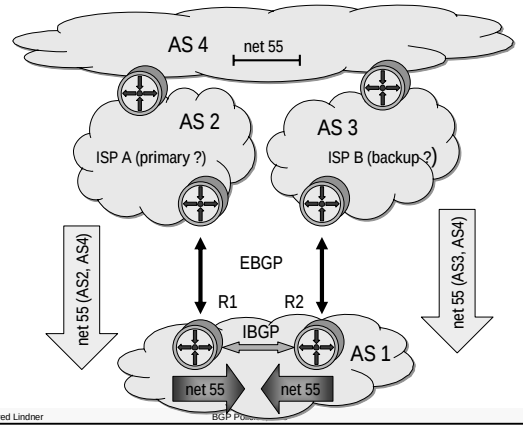
- **well-known discretionary attribute**
- **is used**
  - to set the exit point of an AS to reach a certain destination in case several exit points to that destination exist
- **is exchanged**
  - between IBGP peers only (not passed to EBGP peers)
  - communication between IBGP peers within in AS ensures
    - that all BGP routers will have a common view on how to exit the AS for a given destination
- **a higher local preference value**
  - means more preferred



## Scenario without Local Preference 1



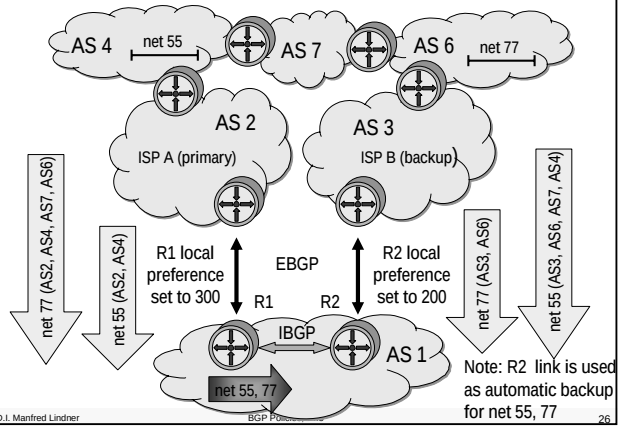
## Scenario without Local Preference 2







## Scenario with Local Preference 1





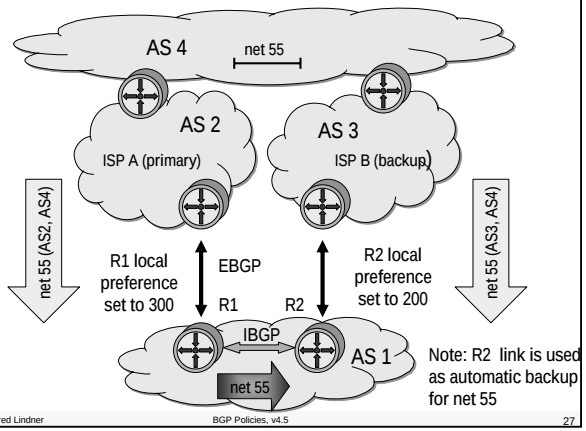








## Scenario with Local Preference 2







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## Multi Exit Discriminator Attribute

- **Multi Exit Discriminator = MED**
- **optional non-transitive attribute**
- **is a hint to external neighbors**
  - about the preferred path into an AS in case of multiple entrance points
  - "external BGP metric"
- **is exchanged between AS´s**
  - but a MED that comes into an AS does not leave the AS
  - MED value used for decision making within the AS
    - however, AS might decide to ignore it



## MED Attribute

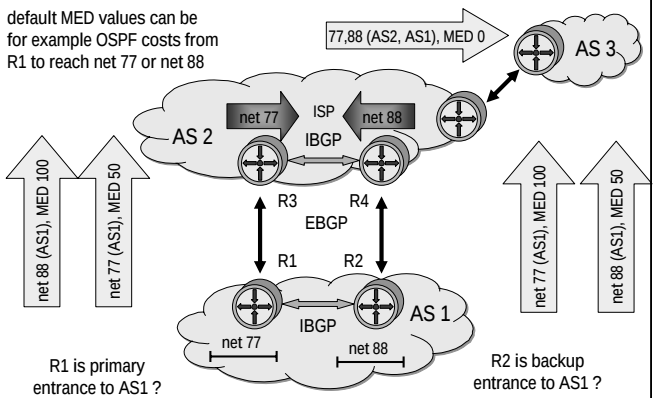
- **MED value**
  - may follow the internal IGP metric of a route
  - the lower the better (closer to given destination)
  - normally compared only for paths from external neighbors that are in the same AS
    - it might be difficult to compare metrics from different neighbors





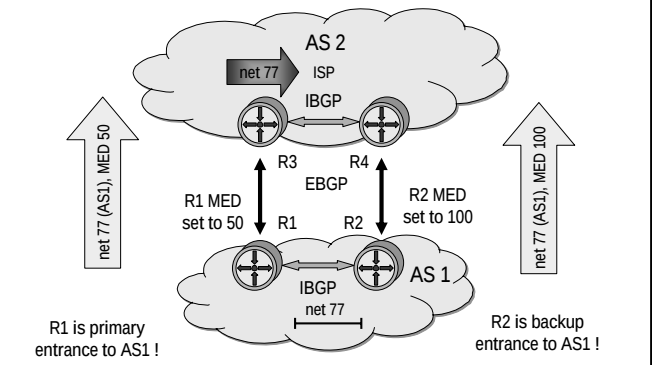


## Scenario MED Default Behavior






## Scenario MED with Manual Set



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## Origin Attribute

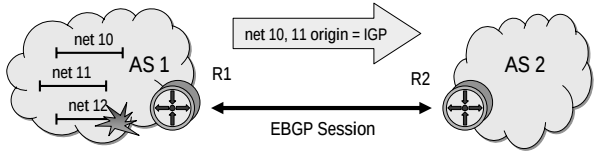
- **specifies how a route was learned by the originator of a network reachability information**
  - well-known mandatory attribute
  - value = 0 means IGP (ex. 1)
    - NLRI is interior to the AS
    - was learned by IGP by originating BGP router
  - value = 1 means EGP-2 (ex. 2)
    - NLRI is external to AS
    - was learned by redistribution of EGP-2 into BGP
  - value = 2 means incomplete
    - NLRI was learned by some other means
      - e.g. static route, manual configuration
      - e.g. statically (example 3) or dynamically (example 4) redistributed







## Origin Example 1



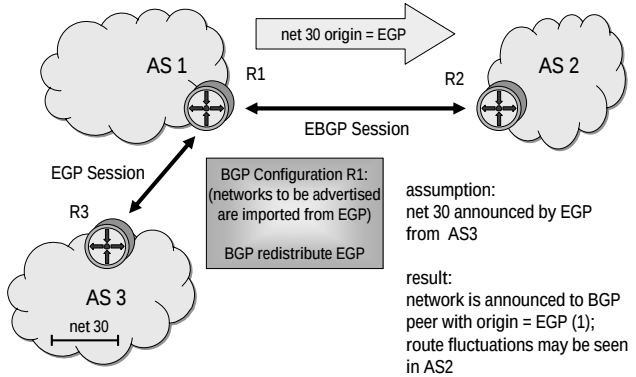

BGP Configuration R1:
(networks to be advertised are manually specified)
network 10
network 11
network 12

assumption:
net 10 and net 11 reachable via IGP within AS1
net 12 not reachable via IGP within AS1
(does not exist in IP routing table of R1)

result:
only networks reachable via IGP are announced to BGP peer with origin = IGP (0);
route fluctuations will be seen in AS2



## Origin Example 2



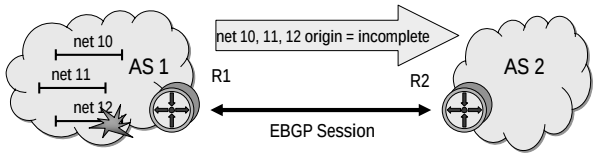

BGP Configuration R1:
(networks to be advertised are imported from EGP)

BGP redistribute EGP

assumption:
net 30 announced by EGP from AS3

result:
network is announced to BGP peer with origin = EGP (1);
route fluctuations may be seen in AS2

## Origin Example 3



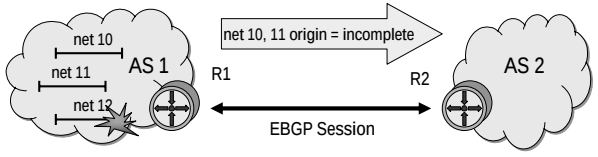

BGP Configuration R1:
(networks to be advertised are manually specified)
network 10
network 11
network 12

assumption:
net 10, net 11 and net 12 are configured as static routes (pointing to null interface) in R1 but net 12 down

result:
all networks are announced to BGP peer with origin = incomplete (2);
route fluctuations will not be seen in AS2



## Origin Example 4




BGP Configuration R1:
(networks to be advertised are imported from IGP)

BGP redistribute IGP

assumption:
net 10 and net 11 reachable via IGP within AS1
net 12 not reachable via IGP within AS1
(does not exist in IP routing table of R1)

result:
only networks reachable via IGP are announced to BGP peer with origin = incomplete (2);
route fluctuations will be seen in AS2









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## Community Attribute 1

- **optional transitive attribute**
- **community is a group of destinations that share a common property**
  - e.g. group of academic or government networks
  - e.g. group of networks which should be handled by a foreign AS in a certain way
  - community is not restricted to one network or one AS
- **community attributes are used**
  - to simplify routing policy based on logical properties rather than IP prefix or AS number (= physical location)
  - to tag routes to ensure consistent filtering or route-selection policy

## Community Attribute 2

- **32 bit values (range 0 - 4.294.967.200)**
- **well-known communities**
  - value range 0x00000000 to 0x0000FFFF
  - value range 0xFFFF0000 to 0xFFFFFFFF
  - 0xFFFFFF01 … No_Export
    - a route carrying this community attribute should not be advertised to BGP peers outside of the receiving AS
      - so internal peers of this AS will receive it
  - 0xFFFFFF02 … No_Advertise
    - a route carrying this community attribute should not be advertised to any other BGP peer
      - so even internal peers of the receiving AS will not receive it



## Community Attribute 3

- **private communities**
  - value range 0x00010000 to 0xFFFEFFFF
- **common practice**
  - for using private communities:
  - high order 16 bit: number of AS
    - which is responsible for defining the meaning of the community
  - low order 16 bit: definition of meaning
    - might have only local significance within the defining AS







## Community Example 1

- **several customers, each with a single ISP connection to the Internet**
  - no fault-tolerance if ISP has connectivity problems
  - customers agree on a backup between each other in case their own ISP connection is lost
    - so they setup a private BGP peering
  - but they do not want to take transit traffic for others in normal situations
    - however, the neighboring customer may be seen by some Internet sources closer through the common private link than through the dedicated service provider of the neighbor
    - so in normal situations we would like to ask our ISP not to direct such a traffic toward us
    - but in emergency we should get this traffic for our neighbor



## Community Example 2

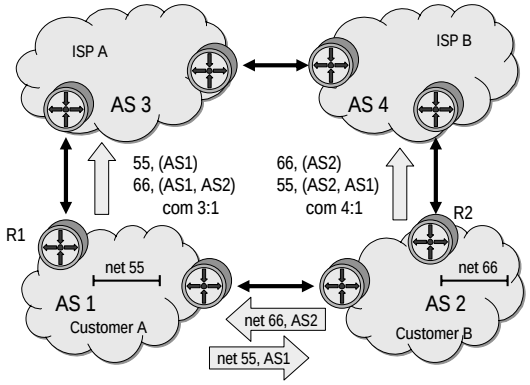
- **ISP´s agree on using local preference to implement this policy**
  - but they do not want to change configurations every time the customers add, change, or remove IP networks
  - so they need a simple stable pattern matching rule that works in general

## Community Example 3

- **ISP´s define special community to identify routes which should be given lower local preference**
  - private community: <AS number of ISP>:1
    - 3:1
    - 4:1
  - if routes with certain condition match this community value, local preference should be reduced from the ISP's default 100 to 50
  - remember: routes with larger local preference are preferred
- **Lets see how this works**



## Community: Route Tagging

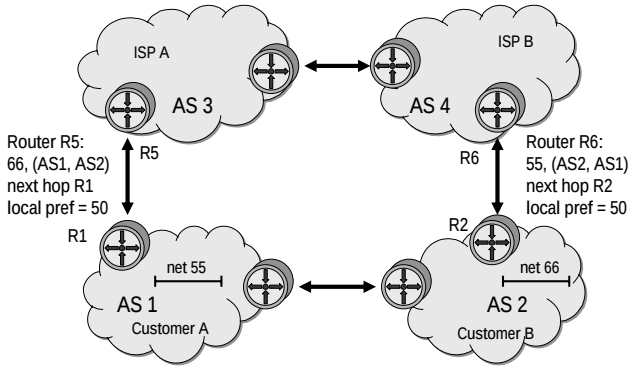






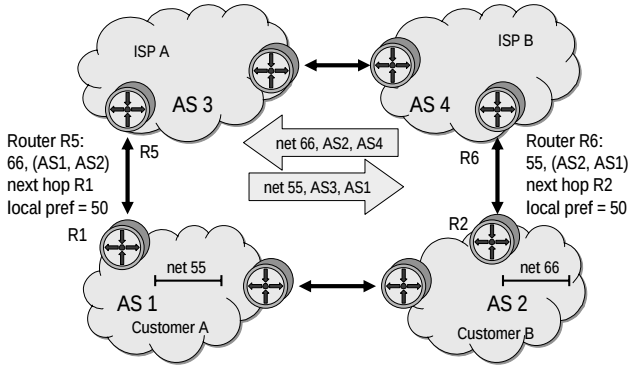



## Community: Set Local Preference

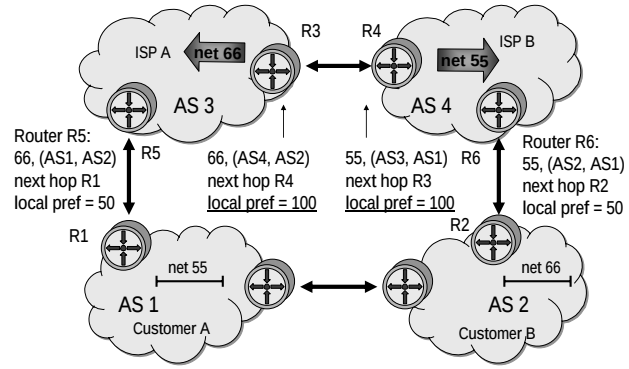





## BGP Updates from ISP Peer

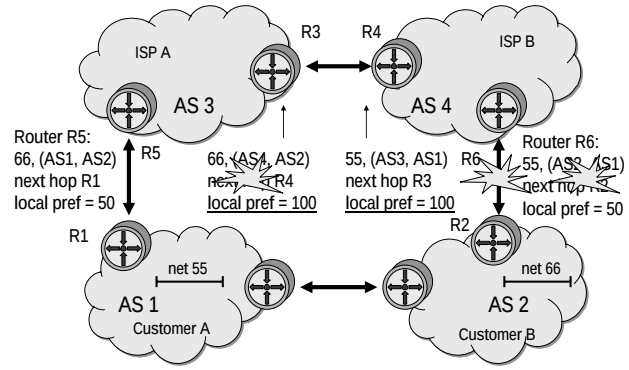


## Community: Route Decision Normal






## Community: Link R2 - R6 down

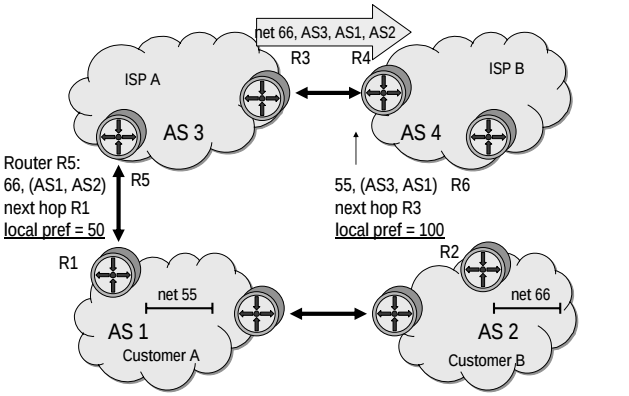









## Community: Route Decision Backup



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## BGP Decision Process 1

- **1./ if next hop is inaccessible, the route is ignored**
  - recursive lookup is done
- **2./ prefer largest weight (Cisco specific, historic)**
  - others might also implement (according to RFC1772)
  - designed for easy translation of public routing policies
    - historically this was the only tool for that
- **3./ prefer the route with the largest local preference**
  - intended to replace weights local to a router, and thus providing a consistent scheme AS-wide



## BGP Decision Process 2

- **4./ if routes have the same local preference prefer the route that was locally originated (by this router)**
- **5./ if routes have the same local preference prefer the route with the shortest path**
  - complies with RFC1772, but not with RFC1771
    - check for implementation specific toggling on and off
- **6./ if AS_Path length is the same, then prefer the route with lowest origin type**
  - IGP < EGP < incomplete







## BGP Decision Process 3

- **7./ if origin type is the same prefer the route with the lowest MED**
  - MED is a distance metrics, so lower is the better
  - consistency from different AS´s might cause problems
    - implementation specific toggle on and off



## BGP Decision Process 4

- **8./ if routes have the same MED, then prefer the route in the following manner**
  - External (EBGP) better than
  - External Confederations better than
  - Internal (IBGP)
- **9./ if all the preceding scenarios are identical, then prefer the route that has the lowest IGP metric to the BGP next hop**
- **10./ if IGP metric to the BGP next hop is the same, then the BGP router-ID will be the tie breaker**
  - chose route with lowest router ID (IP address)

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## Routing Policy

- **routing policies determine what routing information is exchanged with other AS´s**
- **can be implemented by filtering and manipulating BGP routes**
- **some attributes determine policy by their definition**
  - AS_Path can be used to discard any route that passes a certain AS
  - MED can be used to distinguish between multiple exits of an AS to a neighbor AS
- **NLRI (IP prefix, length) itself may be used for policy**







## Routing Policy Usage Examples

- **to prevent advertisement of private networks to the outside world**
- **to ensure that a certain link to a provider is taken during normal situations in case of multiple links to the outside world (primary versus backup link)**
- **to prevent use of the own AS for transit traffic in case of multiple links**
- **to allow only packets to a certain destination to be routed through the own AS**
- **to achieve symmetry for outgoing and incoming traffic in case of multiple links**
- **to enable load balancing of traffic in case of multiple links**
- **to establish a default routing strategy**



## General Available Routing Policy Options

- inbound/outbound filtering
- identifying routes (“match)
  - match on prefix, MED, Next_Hop, Origin, Community
  - regular expression match on AS_Path
    - pattern of characters represented by a formula
    - e.g. **^10 20$** or **^10**_ *or* _**20$** or **^$** or **.*** or _**10**_ or _**100 1[0-9]**_
- permitting or denying routes
- manipulating attributes (“set”)
  - change Next_Hop
  - change MED
  - change Local_Preference
  - change Origin
  - change / add Community
  - change AS_Path (be careful)

## Regular Expressions 1

- **Period .**
  - matches any single character, including white space
- **Asterisk ***
  - matches 0 or more sequences of the pattern
- **Question Mark ?**
  - matches 0 or 1 occurrences of the pattern
- **Plus Sign +**
  - matches 1 or more occurrences of the pattern
- **Caret ^**
  - matches the beginning of the input string
- **Dollar Sign $**
  - matches the end of the input string



## Regular Expressions 2

- **Brackets [ range ]**
  - designates a range of a single character pattern
- **Underscore _**
  - matches any delimiter(beginning, end, white space)
- **Escape **
  - escapes the next character
- **examples:**

| | |
|---|---|
| ^10 20$ | exact 10 20 |
| ^10_ | 10 .. .. or 10; network behind 10 |
| _20$ | 20 or .. .. 20; networks originated in 20 |
| ^$ | local routes only; originated in local AS |
| .* | matches everything; all paths |
| _10_ | 10 or ..10 or 10.. ; going through 10 |
| _100 1[0-9]_ | .. 100 12 .. or 100 19 or .. 100 10 .. |







## Internet Registry and Routing Registry

- **Internet Registry (IR) handles**
  - official network number assignment
  - AS number assignment
  - domain name registration
  - domain name server registration
- **IR function is delegated to authorized organizations**
  - which are responsible for a special domain of the Internet
  - e.g. InterNIC in the US and RIPE NCC (Europe)
- **Routing Registry (RR) provides**
  - additional services which should help coordination of interconnection of Internet Service Providers (ISP)



## Routing Registry

- **every ISP has its own set of routing policy**
  - the chance for conflicts is very high when interconnecting different ISPs
- **neutral RR´s maintain a databases for their global domains**
  - where ISP´s can register and update their routing policies
- **all databases together form Internetworking Routing Registry (IRR)**
- **RR acts as**
  - repository for routing information and performs consistency checking on the registered information with the other RR´s

## Routing Registry

- **most RR´s are based on RFC 1786 (RIPE 181)**
  - register prefixes with originating AS
  - register AS with policy expression towards all other AS´s
  - register AS contact information
  - policy expression can be translated in AS_Path (path based) or prefix based policy
  - policy expressions allow creation of filters/manipulations
  - AS macros, communities
- **several large RR´s**
  - NSF Routing Arbiter
  - MCI
  - RIPE Routing Registry responsible for Europe

 