

# kathara lab

bgp: prefix-filtering with frr

<b>Version</b>	2.1
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<b>Description</b>	examples of filtering rules; kathara version of a netkit lab

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# preconditions

- for this lab we assume you have chosen “kathara/frr” as the default image of your Kathará installation
  - execute “kathara settings”
    - select “choose default image”
    - select “kathara/frr”
    - exit from the settings procedure

# applying policies

## 1 announcement filtering

- send/accept an announcement only if some condition is verified
- commands:
  - **prefix-list** used to filter prefixes
  - **filter-list** used to filter as numbers

## 2 announcement tuning

- attach to your announcement some information (attributes) that should be considered by the receiver
- commands:
  - **route-map**
  - **access-list** used to match prefixes or as-paths in a **route-map**

# bgp prefix filtering

# prefix filtering commands

command syntax

```
neighbor <neighbor-ip> prefix-list <p-list-name> in
```

command syntax

```
neighbor <neighbor-ip> prefix-list <p-list-name> out
```

command syntax

```
ip prefix-list <p-list-name> permit <network/mask>
```

command syntax

```
ip prefix-list <p-list-name> deny <network/mask>
```

# prefix filtering: example

—frr configuration file—

```
router bgp 1
! no bgp ebgp-requires-policy (not needed anymore)
neighbor 193.10.11.2 remote-as 2
neighbor 193.10.11.2 description Router 2 of AS2
!
network 195.11.14.0/24
network 195.11.15.0/24
neighbor 193.10.11.2 prefix-list partialIn in
neighbor 193.10.11.2 prefix-list partialOut out
!
ip prefix-list partialOut seq 5 permit 195.11.14.0/24
ip prefix-list partialIn seq 5 deny 200.1.1.0/24
ip prefix-list partialIn seq 10 permit any
```

only 195.11.14.0/24 is announced to neighbor 193.10.11.2

all with the exception of 200.1.1.0/24 is accepted from 193.10.11.2

# about **prefix-lists**



- **prefix-list** entries are ordered according to a sequence number

- explicitly assigned by the user; example:

- `ip prefix-list myPfxList seq 5 permit 10.0.0.0/8`

- implicitly assigned by frr; example:

- `ip prefix-list myPfxList permit 10.0.0.0/8`  
`ip prefix-list myPfxList permit 20.0.0.0/8`

is automatically turned to:

- `ip prefix-list myPfxList seq 5 permit 10.0.0.0/8`  
`ip prefix-list myPfxList seq 10 permit 20.0.0.0/8`



# about **prefix-lists**



- the first matching entry is applied;  
example:

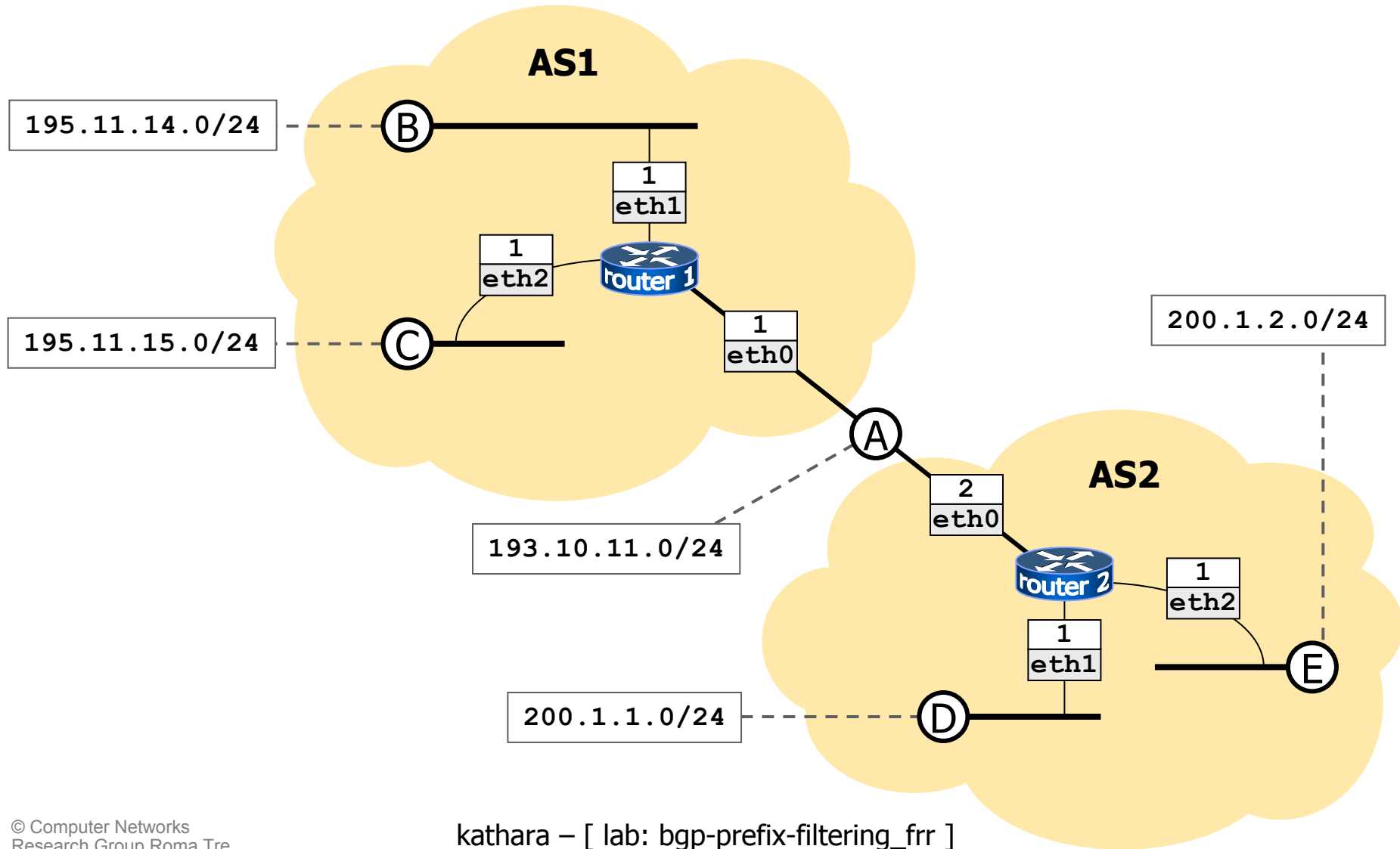
- `ip prefix-list letThru permit 10.0.0.0/8`  
`ip prefix-list letThru deny any`  
accepts 10.0.0.0/8 only
- `ip prefix-list throwAway deny any`  
`ip prefix-list throwAway permit 10.0.0.0/8`  
rejects everything

# prefix-list defaults



- in frr, **prefix-lists** default to **deny**; for example:
  - `ip prefix-list myPrefixList permit 10.0.0.0/8`  
filters out everything but 10.0.0.0/8
  - `ip prefix-list myPrefixList deny 10.0.0.0/8`  
filters out everything
- referencing an undefined **prefix-list** in a **neighbor** statement is equivalent to **denying anything**; for example:
  - `neighbor 10.0.0.1 prefix-list undefinedPrefixList in`  
filters out everything if `undefinedPrefixList` is not defined

# prefix filtering



# prefix filtering

## ■ start the lab

### ▼ host machine

```
user@localhost:~$ cd kathara-lab_bgp-prefix-filtering_frr  
user@localhost:~/kathara-lab_bgp-prefix-filtering_frr$ kathara 1start
```

## ■ check the frr configuration file

### ▼ router1

```
router1:~# less /etc/frr/frr.conf
```

## ■ check the frr log file

### ▼ router1

```
router1:~# less /var/log/frr/frr.log
```

# prefix filtering

## ■ check the routing table

▼ router1

```
root@router1:/# route
```

```
Kernel IP routing table
```

Destination	Gateway	Genmask	Flags	Metric	Ref	Use	Iface
193.10.11.0	0.0.0.0	255.255.255.0	U	0	0	0	eth0
195.11.14.0	0.0.0.0	255.255.255.0	U	0	0	0	eth1
195.11.15.0	0.0.0.0	255.255.255.0	U	0	0	0	eth2
200.1.2.0	193.10.11.2	255.255.255.0	UG	20	0	0	eth0

```
root@router1:/# vtysh
```

```
Hello, this is FRRouting (version 7.5.1).
```

```
Copyright 1996-2005 Kunihiro Ishiguro, et al.
```

```
router1-frr# show ip route
```

```
Codes: K - kernel route, C - connected, S - static, R - RIP,
```

```
O - OSPF, I - IS-IS, B - BGP, E - EIGRP, N - NHRP,
```

```
T - Table, v - VNC, V - VNC-Direct, A - Babel, D - SHARP,
```

```
F - PBR, f - OpenFabric,
```

```
> - selected route, * - FIB route, q - queued, r - rejected, b - backup
```

```
C>* 193.10.11.0/24 is directly connected, eth0, 00:08:56
```

```
C>* 195.11.14.0/24 is directly connected, eth1, 00:08:56
```

```
C>* 195.11.15.0/24 is directly connected, eth2, 00:08:56
```

```
B>* 200.1.2.0/24 [20/0] via 193.10.11.2, eth0, weight 1, 00:08:54
```

```
router1-frr#
```

# prefix filtering

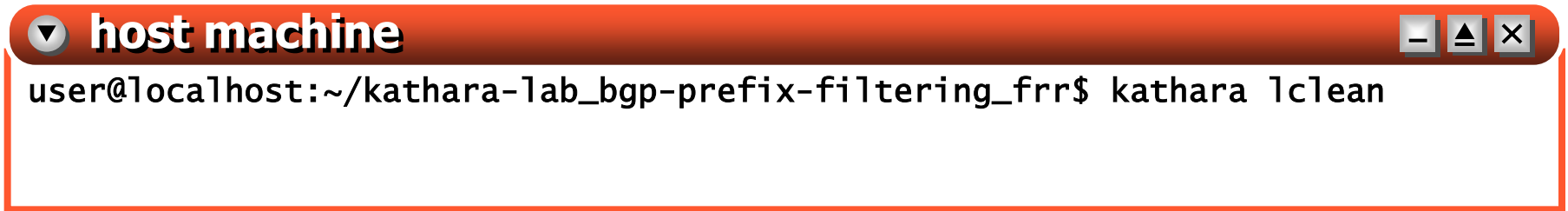
- check the frr cli (command line interface)

▼ router1

```
router1-frr# show ip bgp neighbors
BGP neighbor is 193.10.11.2, remote AS 2, local AS 1, external link
  Description: Router 2 of AS2
  Hostname: router2
    BGP version 4, remote router ID 200.1.2.1,
      local router ID 195.11.15.1
    BGP state = Established, up for 00:11:36
    Last read 00:00:36, Last write 00:00:36
    Hold time is 180, keepalive interval is 60 seconds
    Neighbor capabilities:
      4 Byte AS: advertised and received
      AddPath:
        IPv4 Unicast: RX advertised IPv4 Unicast and received
      Route refresh: advertised and received(old & new)
      Address Family IPv4 Unicast: advertised and received
    ...
    ...
router1-frr# show ip bgp 200.1.1.0
% Network not in table
router1-frr#
```

# prefix filtering

- terminate the lab

A terminal window with a red title bar containing a dropdown arrow, the text 'host machine', and standard window control buttons (minimize, maximize, close). The terminal content shows a shell prompt 'user@localhost:~/kathara-lab\_bgp-prefix-filtering\_frr\$' followed by the command 'kathara 1clean'.

```
user@localhost:~/kathara-lab_bgp-prefix-filtering_frr$ kathara 1clean
```

bgp attributes



# attributes

- a bgp announcement is a “bag” of attributes
- attributes may be
  - “well-known” or optional
    - well-known attributes are understood by any bgp4 speaker
  - mandatory or discretionary
    - mandatory attributes must be present in updates
  - transitive or nontransitive
    - transitive attributes are passed when received
    - nontransitive attributes traverse a single peering

# attribute list

- prefix
  - the section of ip space announced
- as-path
  - the sequence of traversed ases
- origin
  - igp (route is interior to the originating as)
  - egp (route learned via the egp protocol)
  - incomplete (route learned in some other way)
- next-hop
  - to be inserted in the routing table
- metric (multi-exit-discriminator)
  - asking another as to prefer lower values of it
- local-pref
  - prefer higher values
- atomic aggregate
- aggregator
- weight
  - cisco proprietary

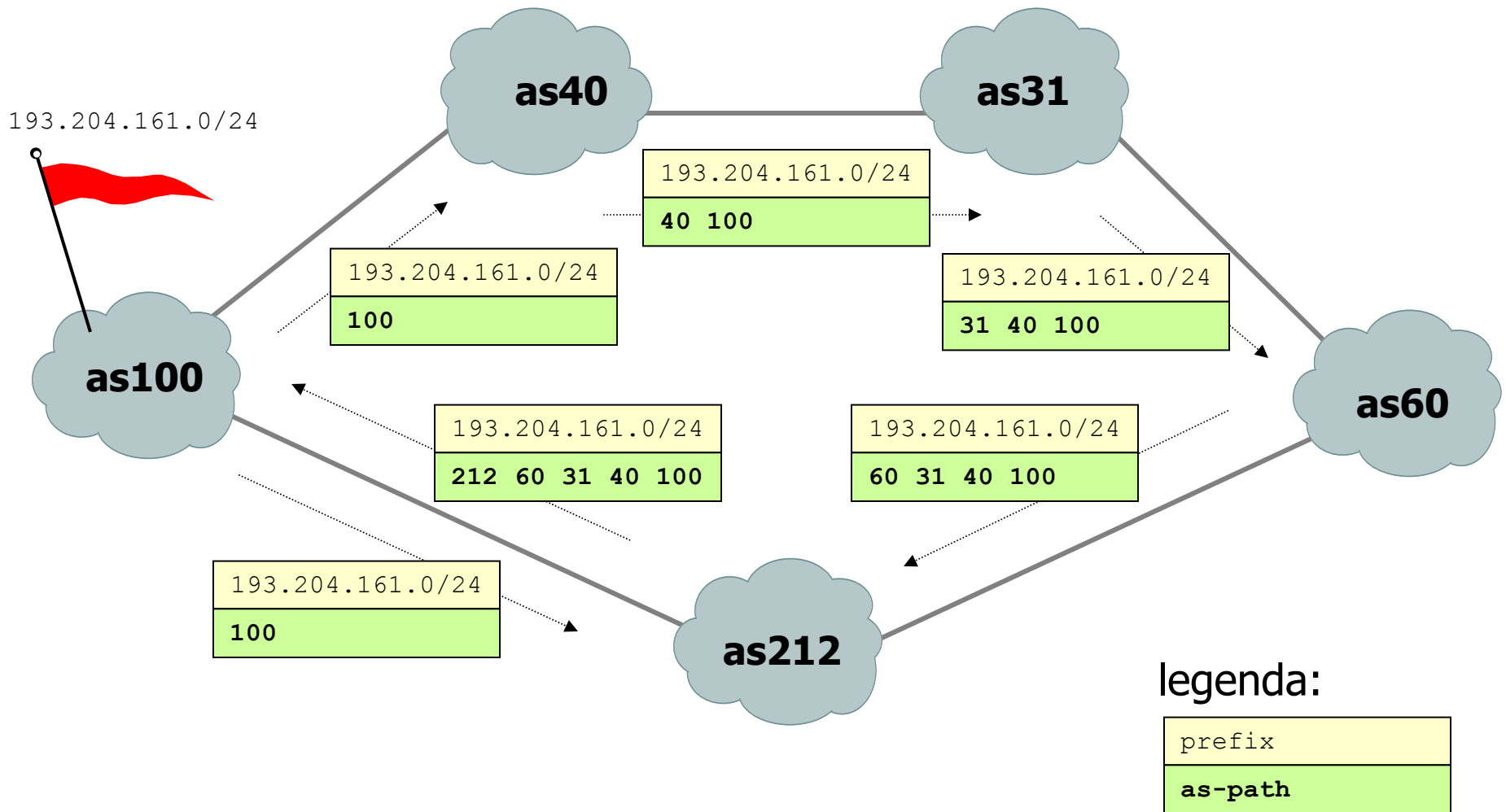
# well-known attributes

- mandatory well-known
  - as-path: the sequence of traversed ASes
  - next-hop: to be inserted in the routing table; in i-bgp stays unchanged
  - origin
- discretionary well-known
  - local preference: asking i-bgp peers to prefer higher values of it
  - atomic aggregate

# optional attributes

- non transitive optional
  - multi-exit discriminator: asking other ASes to prefer lower values of it
- transitive optional
  - aggregator
  - community

# attributes: prefix & as-path



# attributes: as-path

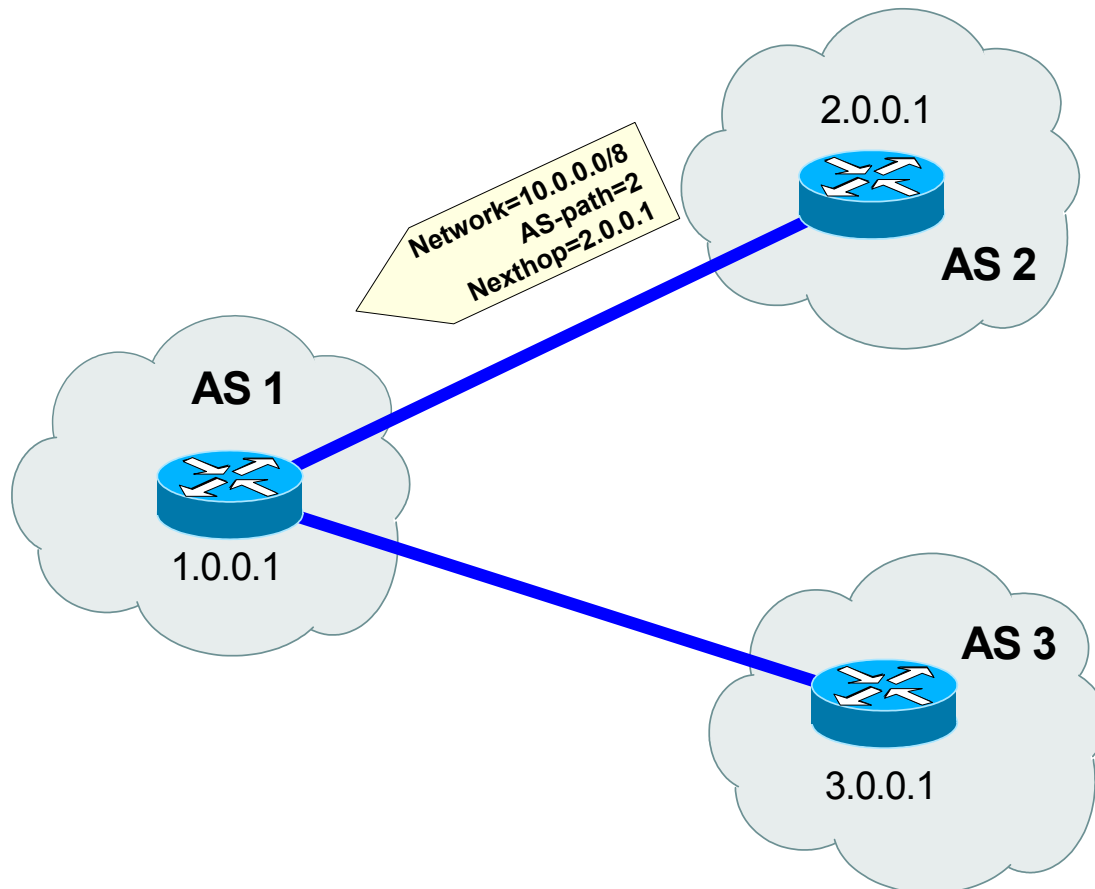
- the as-path is empty when a local route is inserted into the BGP table
- when the announcement goes to a different as (e-BGP) the as number is inserted at the end of the as-path (prepending)
  - a router knows which and how many ases should be traversed to reach the destination
  - loops are avoided
  - policies can be applied
- in i-BGP the as-path does not change

# attributes: nexthop

- where to send packets for a specific ip network
- usually, the nexthop is the router that sends the announcements
  - exceptions:
    - “*shared media*” (ethernet, etc..)
    - i-BGP announcements of networks learned using e-BGP

# attributes: nexthop

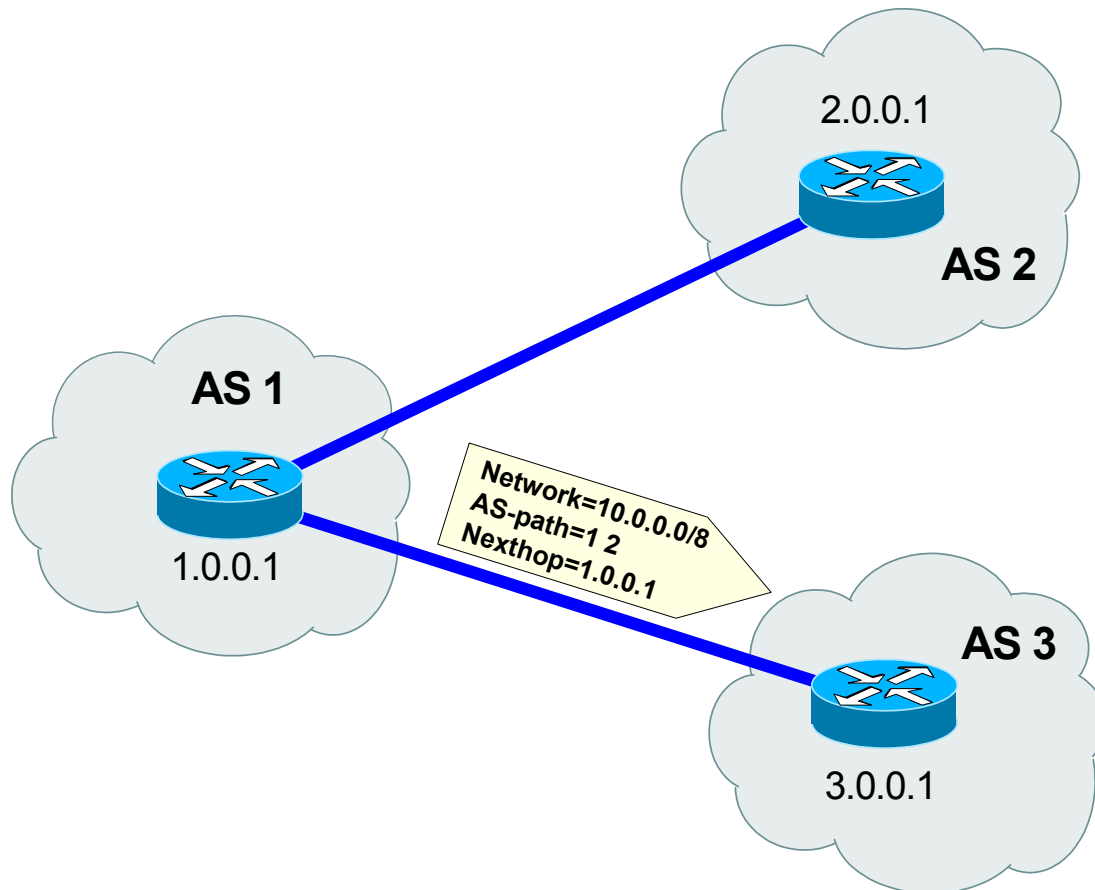
- as 2 router sends an announcement to as 1 specifying 2.0.0.1 as the nexthop





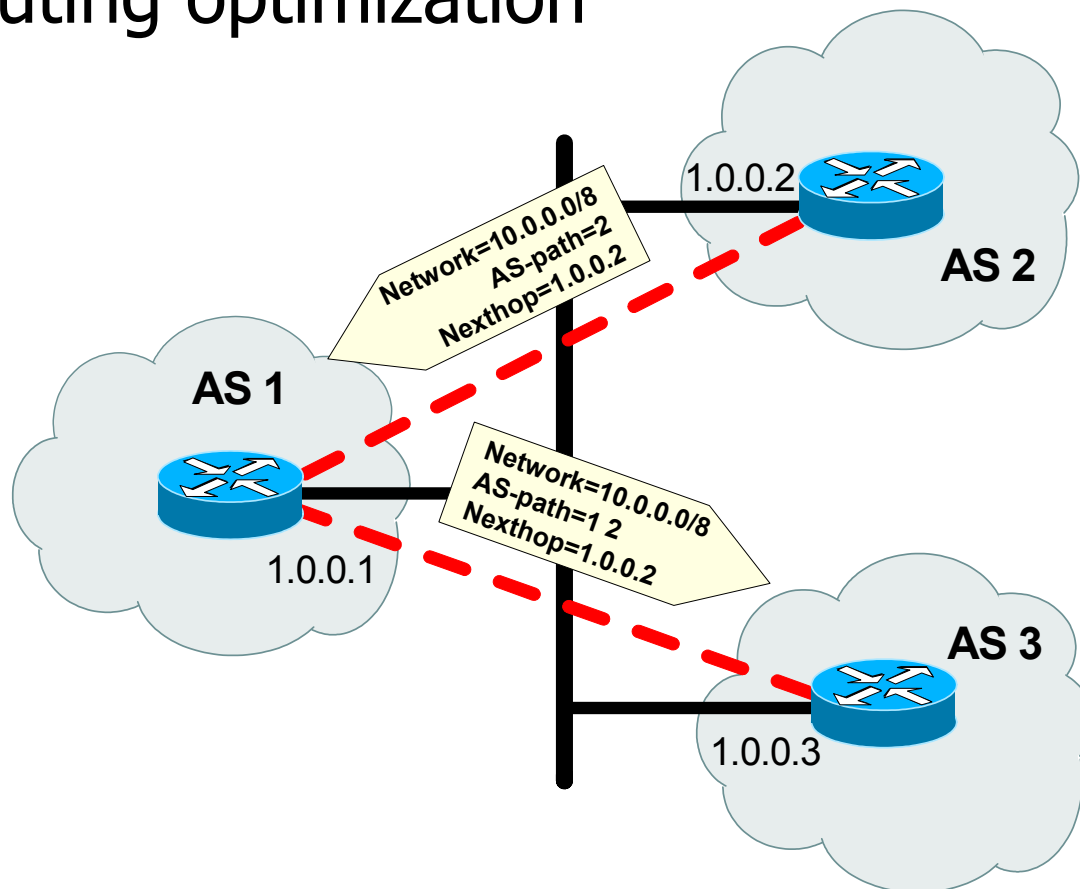
# attributes: nexthop

- as 1 router changes the nexthop



# attributes: nexthop

- shared segment: nexthop stays unchanged
  - routing optimization

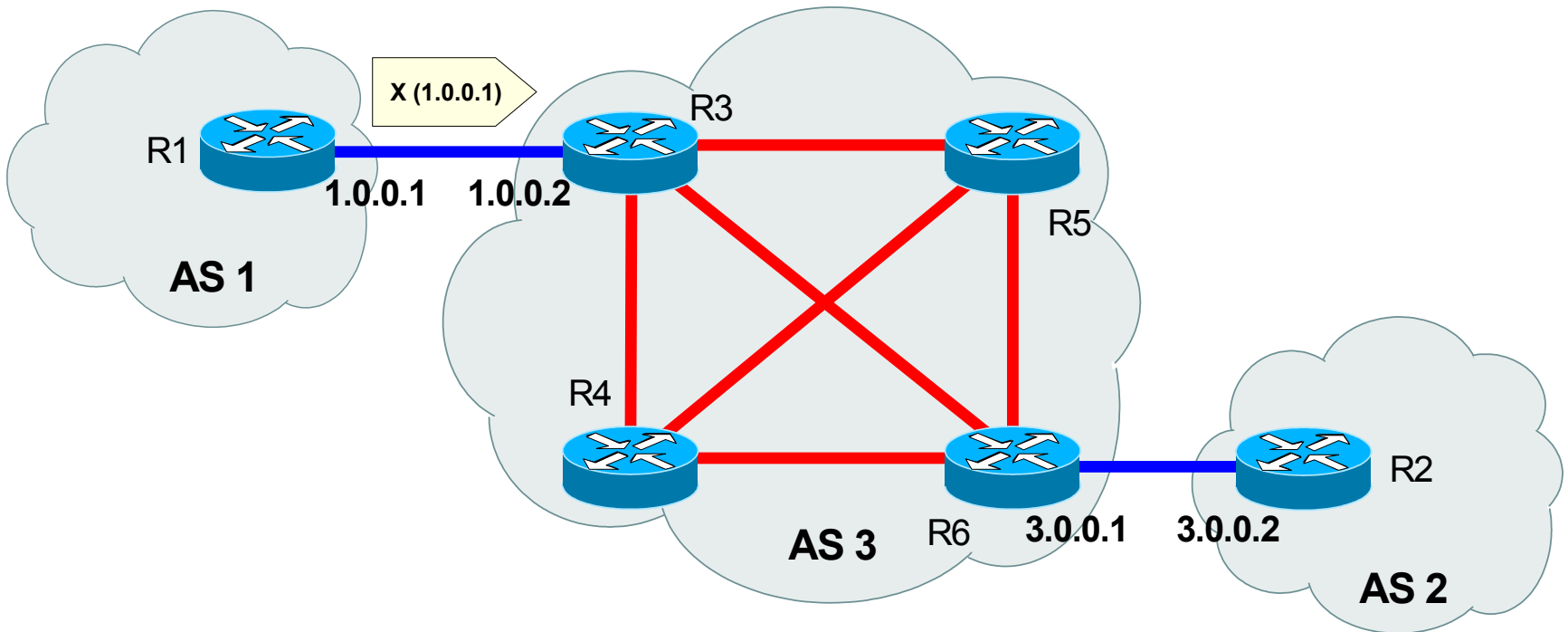


# attributes: nexthop

- if a route learned from e-BGP is propagated using i-BGP, then the nexthop remains the same
  - nexthop equal to the address of the remote peer
- internal routers perform a “recursive lookup” for understanding how to reach the nexthop
  - the routers should know, via igp, how to reach the nexthop

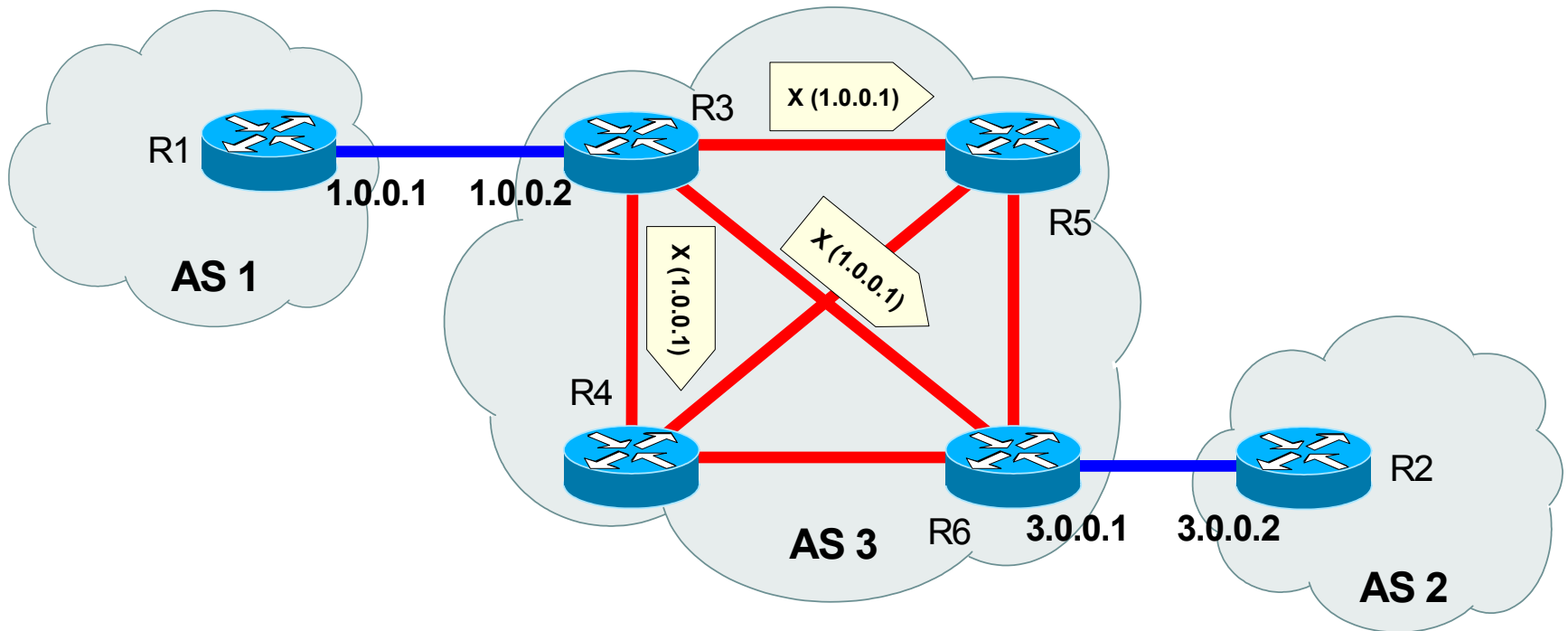
# attributes: nexthop

- R1 announces network X with nexthop 1.0.0.1



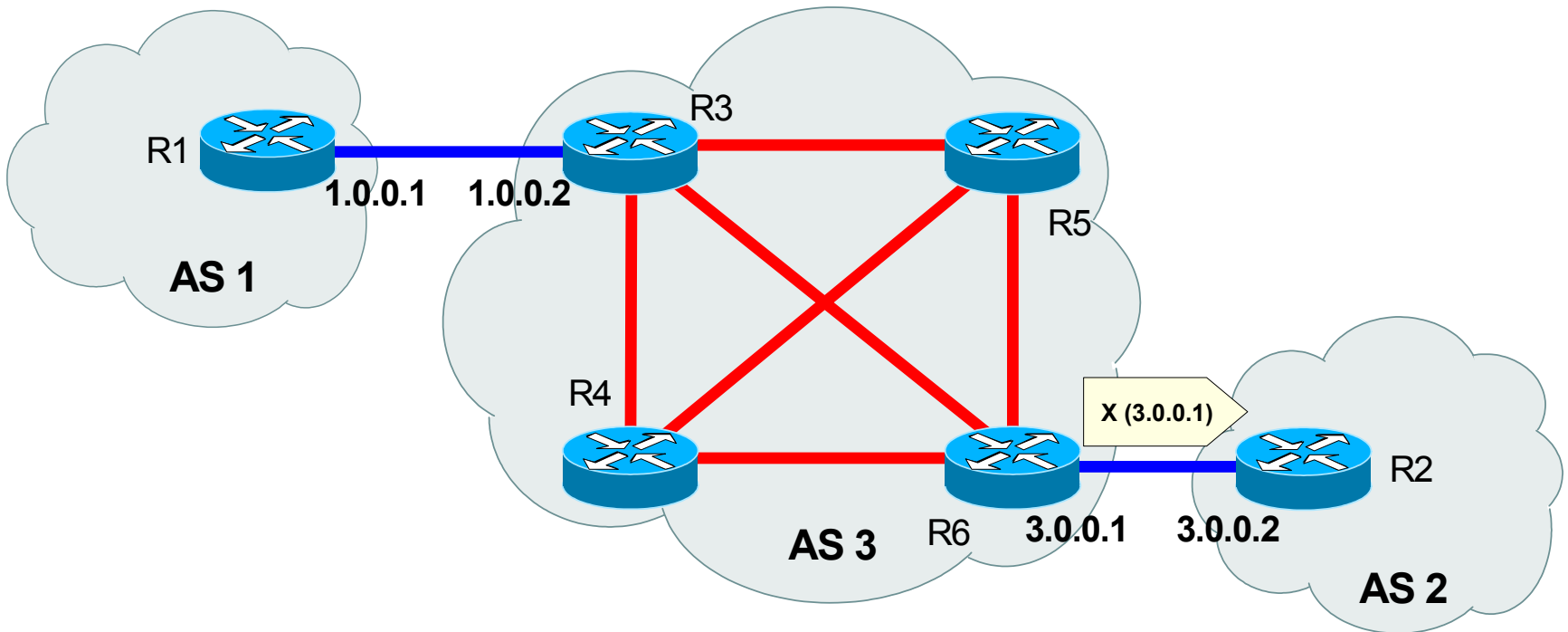
# attributes: nexthop

- the announcement is propagated with i-BGP to R4, R5, and R6
  - the nexthop is unchanged



# attributes: nexthop

- the nexthop changes when the announcement goes to a different as



# attributes: origin

- **igp**
  - declared as internal by the starting AS: "network" command
- **egp**
  - injected into BGP by EGP: backward compatibility
- **incomplete**
  - generated redistributing an igp protocol

# attributes: aggregator

- conveys the IP address of the router or BGP speaker generating the aggregate route
  - useful for debugging purposes



# selection of the “best route” to a prefix

- each router, for each prefix, chooses one of the received announcements as the “best”
- the decision process is fully deterministic
  - no random choice is applied
- only the best routes are (possibly) announced to peers
- selection criteria:
  - more specific and less specific prefixes are considered different prefixes
    - both are injected into the routing table
  - if the next-hop is not reachable (it does not match a line of the routing table of the router) the announcement can not be selected
  - the selection is based both on the values of the attributes and on the constraints imposed by the administrator (e.g. weight)

# bgp decision process (at a router)

for each network prefix, select the route with:

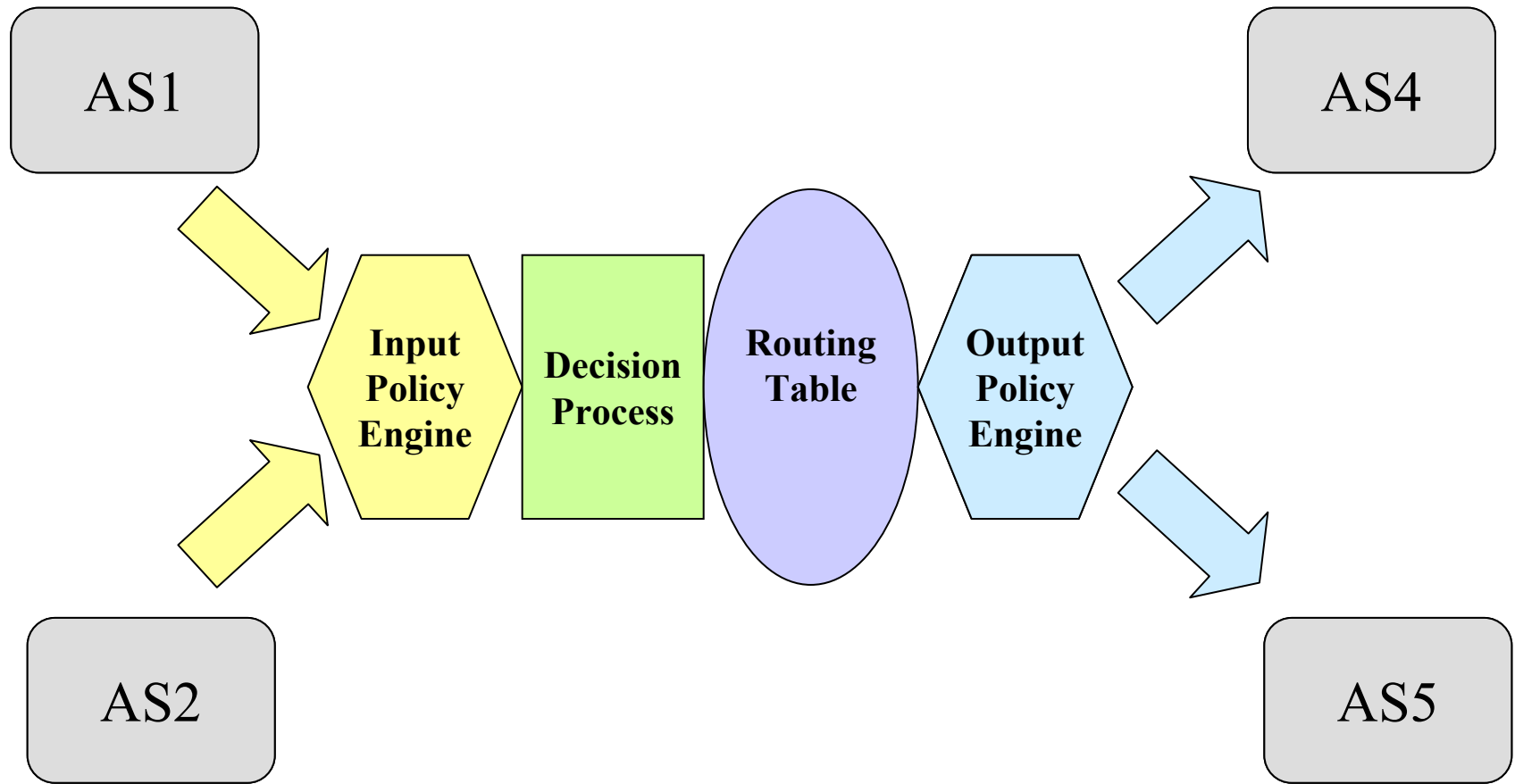
highest  
priority



1. largest weight (cisco proprietary)
2. largest local preference
3. locally originated (by the router itself)
4. shortest as-path length
5. lowest origin (igp<egp<incomplete)
6. lowest multi-exit-discriminator  
(only comparable for the same neighboring as)
7. prefer ebgp over ibgp (hot potato routing)
8. lowest igp metric (to next-hop)
9. lowest router-id (of announcing peer)

lowest  
priority

# BGP decision process and architecture



# as-path filtering

# as-path filtering commands

—command syntax—

```
neighbor <neighbor-ip> filter-list <acl-name> in
```

—command syntax—

```
neighbor <neighbor-ip> filter-list <acl-name> out
```

—command syntax—

```
ip as-path access-list <acl-name> permit <regexp>
```

—command syntax—

```
ip as-path access-list <acl-name> deny <regexp>
```

# as-path filtering commands

- *regexp* may contain the following characters:

.	matches any single character
\	escapes special characters
[ ]	matches a range of characters
^	matches the beginning of a string
\$	matches the end of a string
?	matches zero or one occurrence of a pattern
*	matches zero or more occurrences of a pattern
+	matches one or more occurrences of a pattern
( )	groups characters to form a pattern
	matches one of the patterns on either side
_	a shortcut for [ , { } ]   ^   \$

# as-path filtering example

—frr configuration file—

```
router bgp 100
network 100.1.1.0/24
neighbor 222.2.2.2 remote-as 200
neighbor 222.2.2.2 filter-list myACL in
!
ip as-path access-list myACL permit ^200_300
```

- accept from as 200 only the routes received via as 300

# announcement tuning



# attribute setting commands

—command syntax—

```
neighbor <neighbor-ip> route-map <r-map-name> in
```

—command syntax—

```
neighbor <neighbor-ip> route-map <r-map-name> out
```

—command syntax—

```
route-map <r-map-name> permit <seq-number>  
  match <announce-property>  
  set <attribute-setting>  
  . . .
```

—command syntax—

```
route-map <r-map-name> deny <seq-number>  
  match <announce-property>  
  set <attribute-setting>  
  . . .
```

# about **route-maps**



- **route-maps** may consist of multiple statements
  - statements are processed in the order established by sequence numbers
  - for each received/sent announcement, only one statement is applied
    - the first one without a **match** condition
    - the first one that matches the announcement attributes (prefix, as-path, etc.)
  - announcements that are not matched by any statement, or that are matched by a **deny** statement are simply filtered out
    - **set** commands in a **route-map deny** are useless
- referencing an undefined **route-map** in a **neighbor** statement results in filtering out everything

# all match commands

- match as-path
- match community
- match extcommunity
- **match ip address**
- match ip next-hop
- match ipv6 address
- match metric
- match origin

# all `set` commands

- `set aggregator as`
- `set as-path prepend`
- `set atomic-aggregate`
- `set comm-list`
- `set community`
- `set extcommunity`
- `set ip next-hop`
- `set ipv6 next-hop`
- `set local-preference`
- `set metric`
- `set origin`
- `set originator-id`
- `set weight`

# address match conditions

- **match ip address** can be used in conjunction with **access-lists** or **prefix-lists**

—command syntax—

```
match ip address <acl-name>
```

—command syntax—

```
match ip address prefix-list <prefix-list-name>
```

—command syntax—

```
access-list <acl-name> permit <network/mask>
```

—command syntax—

```
access-list <acl-name> deny <network/mask>
```

# about `access-lists`



- an alternative construction to filter prefixes
- the `as-path access-list` variant allows to filter based on as-paths
- `access-lists` are identified by a name or an integer
  - the integer determines the type of filtering applied
    - 1-99: standard access list (filter from specific IPs)
    - 100-199: extended access list (filter by protocol and/or source/destination IP)

# about access-lists



- no sequence numbers, still the first matching entry applies; example:
  - `access-list permissiveAcl permit any`  
`access-list permissiveAcl deny any`  
allows everything
  - `access-list restrictiveAcl deny any`  
`access-list restrictiveAcl permit any`  
discards everything
- same for **as-path** access-lists; example:
  - `ip as-path access-list noWay deny .*`  
`ip as-path access-list noWay permit ^100_200`  
discards everything

# access-list defaults



- in frr, **access-lists** default to **deny**
- by default, **access-lists** match a prefix as well as all its more specifics; for example:
  - `access-list myList permit 193.100.0.0/16`  
also matches `193.100.5.0/24`, `193.100.192.0/25`, etc.
  - `access-list permissiveList permit 0.0.0.0/0`  
matches everything(!)
- this behavior can be changed by using **exact-match**
- referencing an undefined **access-list** (e.g., in a **filter-list** statement) results in filtering out everything





# attribute setting example

—frr configuration file—

```
router bgp 100
network 100.1.1.0/24
neighbor 222.2.2.2 remote-as 200
neighbor 222.2.2.2 route-map myRouteMap in
!
route-map myRouteMap permit 10
    match ip address myAccessList
    set metric 5
    set local-preference 25
!
route-map myRouteMap permit 20
    set metric 2
!
access-list myAccessList permit 193.204.0.0/16
```