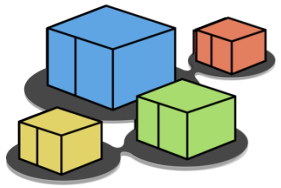

Kathará

kathara lab(s)

ospf with FRRouting

Version	2.0
Author(s)	L. Ariemma, T. Caiazzi, G. Di Battista, M. Rimondini, M. Patrignani
E-mail	contact@kathara.org
Web	http://www.kathara.org/
Description	A set of labs showing the operation of the ospf routing protocol in different scenarios – kathara version of an existing netkit lab

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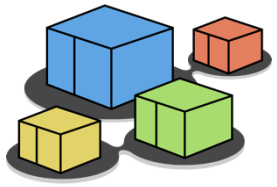

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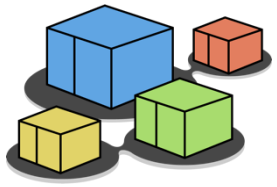

about ospf

- open shortest path first
- an interior gateway protocol

	Specification	authentication Confidentiality
version 2	rfc 2328	rfc 5709
version 3 (with ipv6 support)	rfc 5340	rfc 4552

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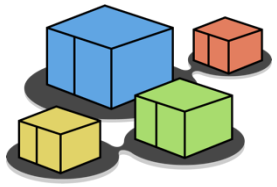

ospf: overview

- each router floods its local state (usable interfaces, reachable neighbors) through the network, using link state advertisements (lsa)
- based on this information, each router builds and maintains a link state database (lsdb) describing the whole network topology
  - identical for (almost) all routers
  - each entry is a router's local state
- each router uses the lsdb to compute a shortest path tree rooted at itself
  - interfaces may be assigned costs

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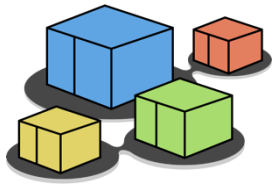

a simple ospf lab

single-area

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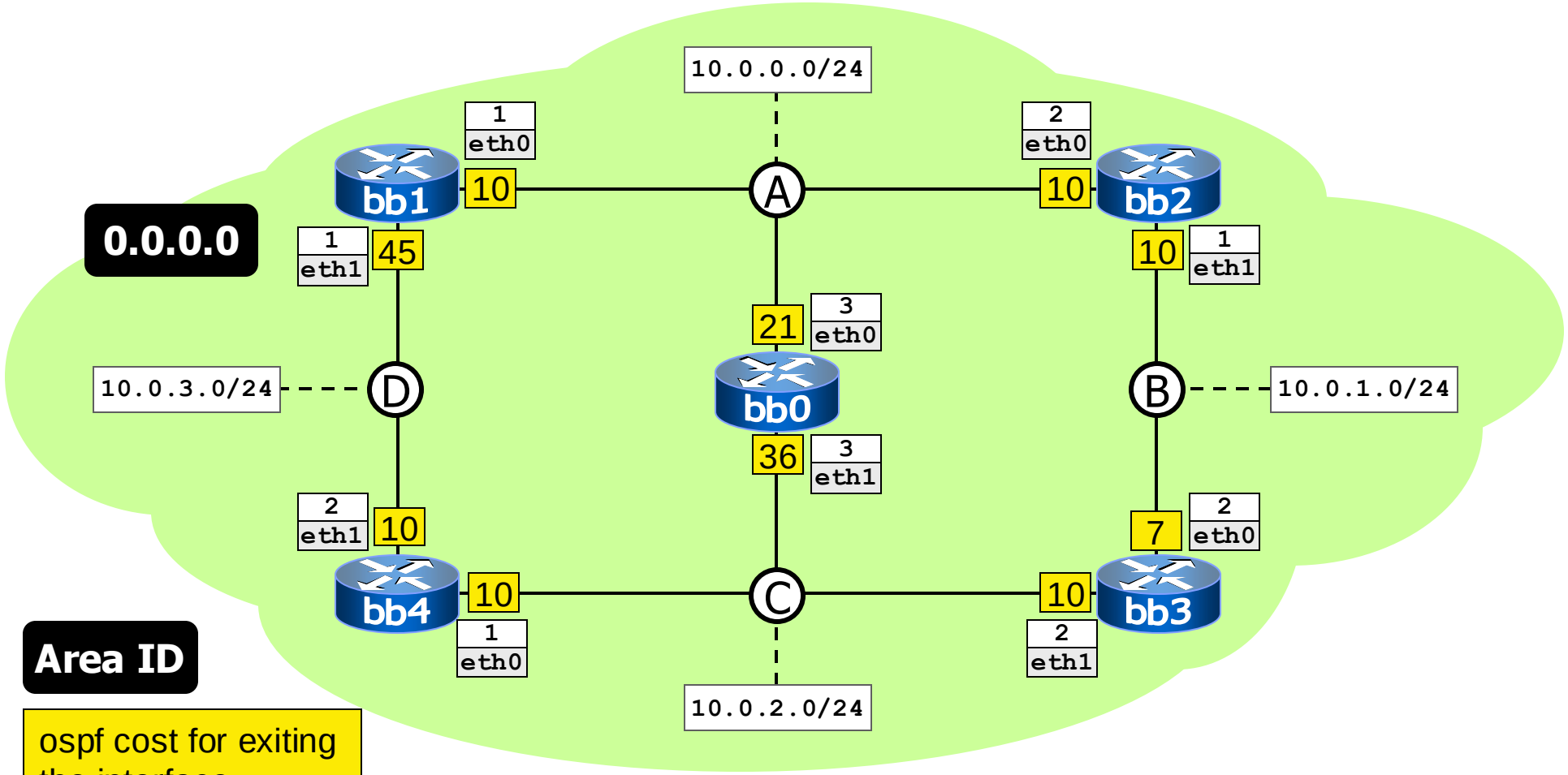
lab topology



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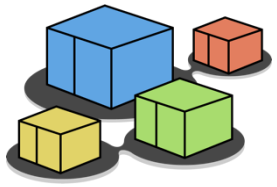

lab description

- single (backbone) area (0.0.0.0)
- each interface is assigned an ospf cost
  - default: 10
  - we have tweaked the costs to force paths taken by traffic
- to set interface costs:

```
interface eth1
ospf cost 45
```

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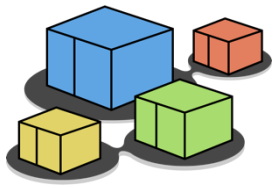
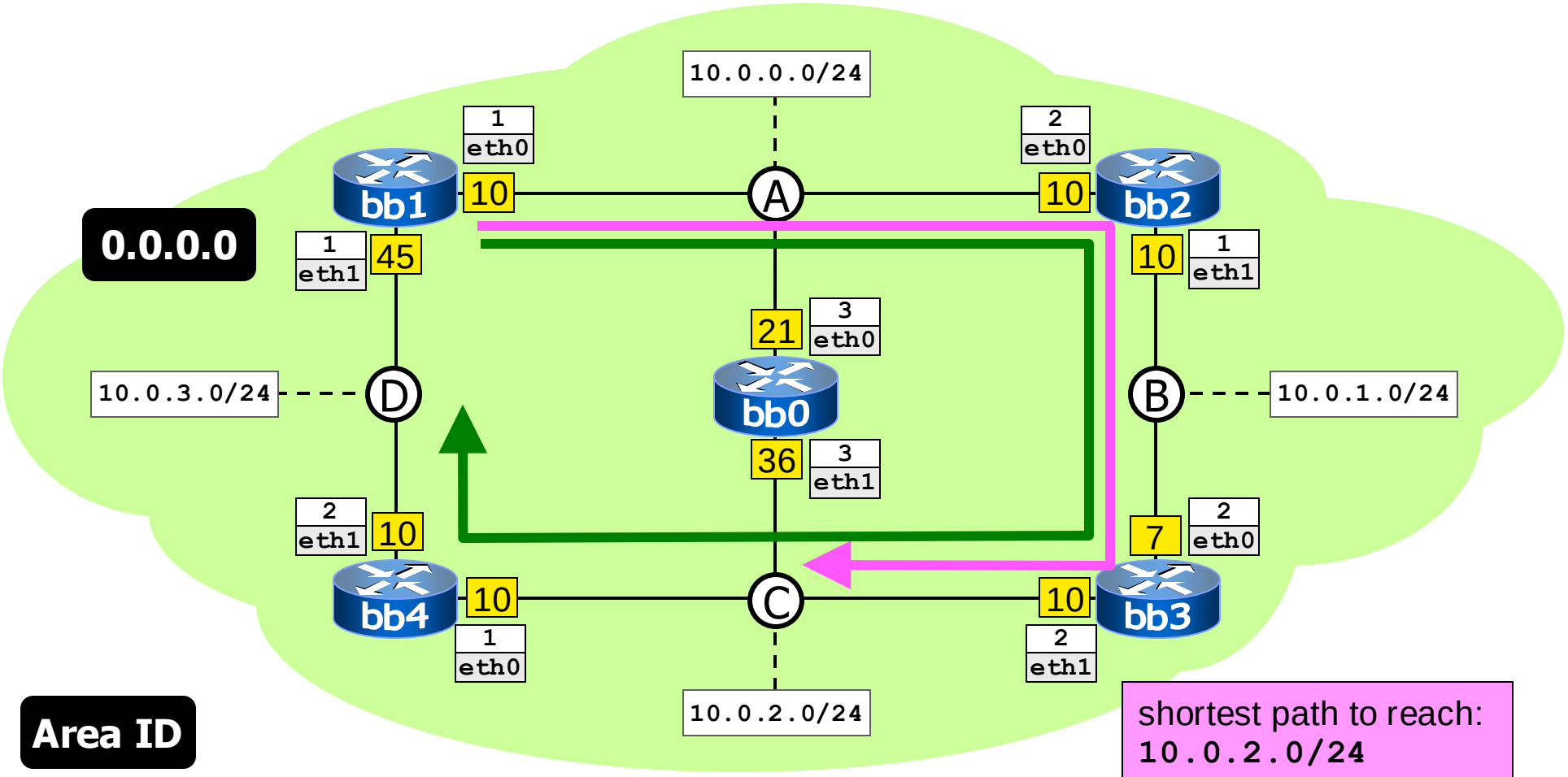


(some) shortest paths



Area ID

ospf cost for exiting the interface

shortest path to reach: `10.0.2.0/24`

shortest path to reach: `10.0.3.0/24`

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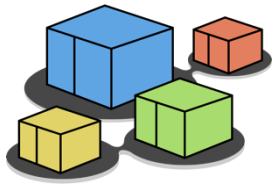

experiments

- perform traceroutes from/to different interfaces
- perform a traceroute from bb1 to 10.0.2.1
  - what path is the traceroute expected to take?
  - what path are ICMP replies expected to take?
- perform a traceroute from bb1 to 10.0.3.2
  - what path is the traceroute expected to take?
  - observe the interplay between ospf routes and directly connected networks (i.e., perform a show ip route in frr)
- try to alter the costs and observe the effect of the changes

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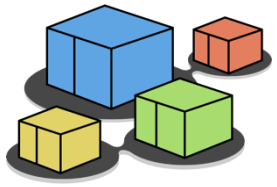

experiments

- access the ospfd cli (or the vtysh cli) on the various routers and issue the following commands:
  - `show ip ospf route`
  - `show ip ospf interface`
  - `show ip ospf neighbor`
  - `show ip ospf database`
- check that the lsdb is exactly the same for all routers

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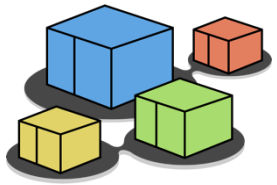

designated routers
(router interfaces designated for each network)

- for each network, one of the interfaces attached to that network is elected as designated (dr)
- priority-based election, using hello packets
  - the router (interface) sending hello packets with highest piority wins the election
  - break ties on highest router id
    - by default, a router id is the address of one of its interfaces
  - priority $\in$ [0,255]
    - default priority: 1
    - priority=0 $\Rightarrow$ never become a dr
- a backup dr (i.e., the one with second highest priority) is also elected, to quickly recover from dr failures

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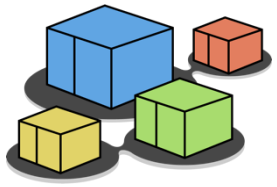

designated routers
(router interfaces designated for each network)

- a change of the dr is a change in ospf's topology model (new lsas are sent)
- for this reason, the dr is changed infrequently
  - if a router with high priority wakes up and finds that a dr already exists, it accepts that dr

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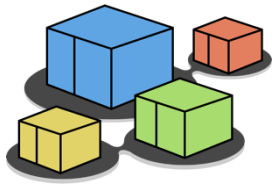

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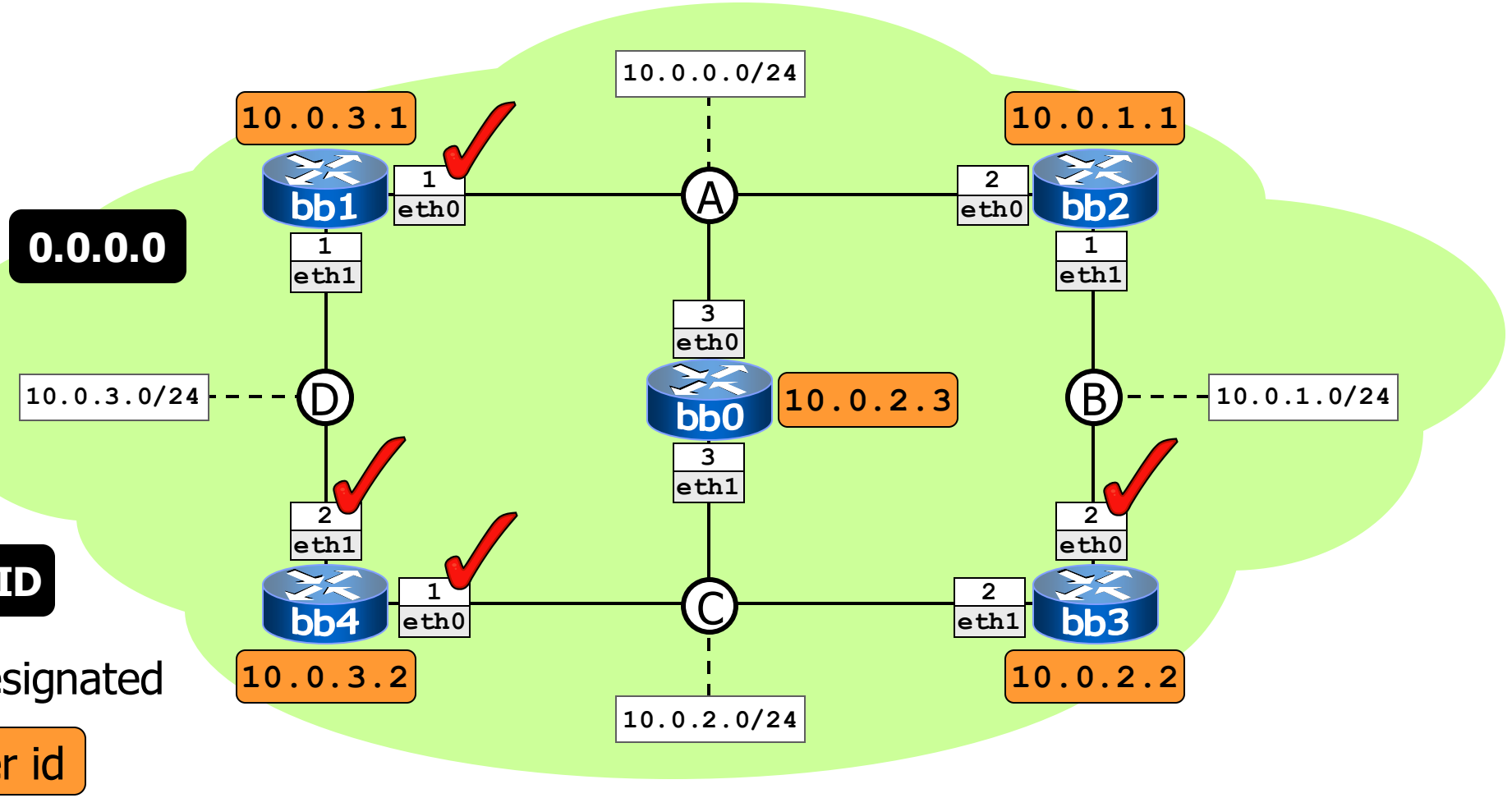
(router interfaces designated for each network)



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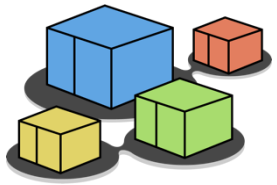
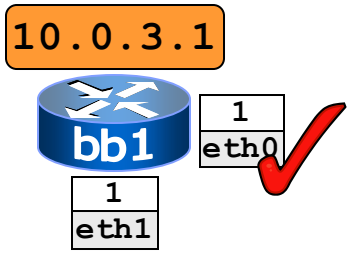


designated routers
(router interfaces designated for each network)

router id

✓ designated



bb1

```
bb1# show ip ospf interface
eth0 is up
  ifindex 20, MTU 1500 bytes, BW 10000 Mbit <UP,BROADCAST,RUNNING,MULTICAST>
  Internet Address 10.0.0.1/24, Broadcast 10.0.0.255, Area 0.0.0.0
  MTU mismatch detection: enabled
  Router ID 10.0.3.1, Network Type BROADCAST, Cost: 10
  Transmit Delay is 1 sec, State DR, Priority 1
  Designated Router (ID) 10.0.3.1 Interface Address 10.0.0.1/24
  Backup Designated Router (ID) 10.0.2.3, Interface Address 10.0.0.3
  Saved Network-LSA sequence number 0x80000002
  Multicast group memberships: OSPFAllRouters OSPFDesignatedRouters
  Timer intervals configured, Hello 10s, Dead 40s, Wait 40s, Retransmit 5
    Hello due in 4.193s
  Neighbor Count is 2, Adjacent neighbor count is 2
eth1 is up
  ifindex 22, MTU 1500 bytes, BW 10000 Mbit <UP,BROADCAST,RUNNING,MULTICAST>
  ...
```

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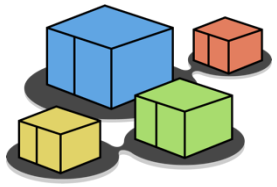

ospf's view of the network

- by exchanging link state update packets, every router learns about the complete network topology, that is:
  - routers
  - subnets
  - adjacencies between routers and networks

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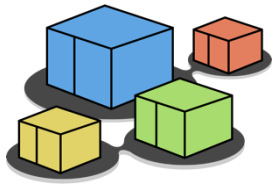
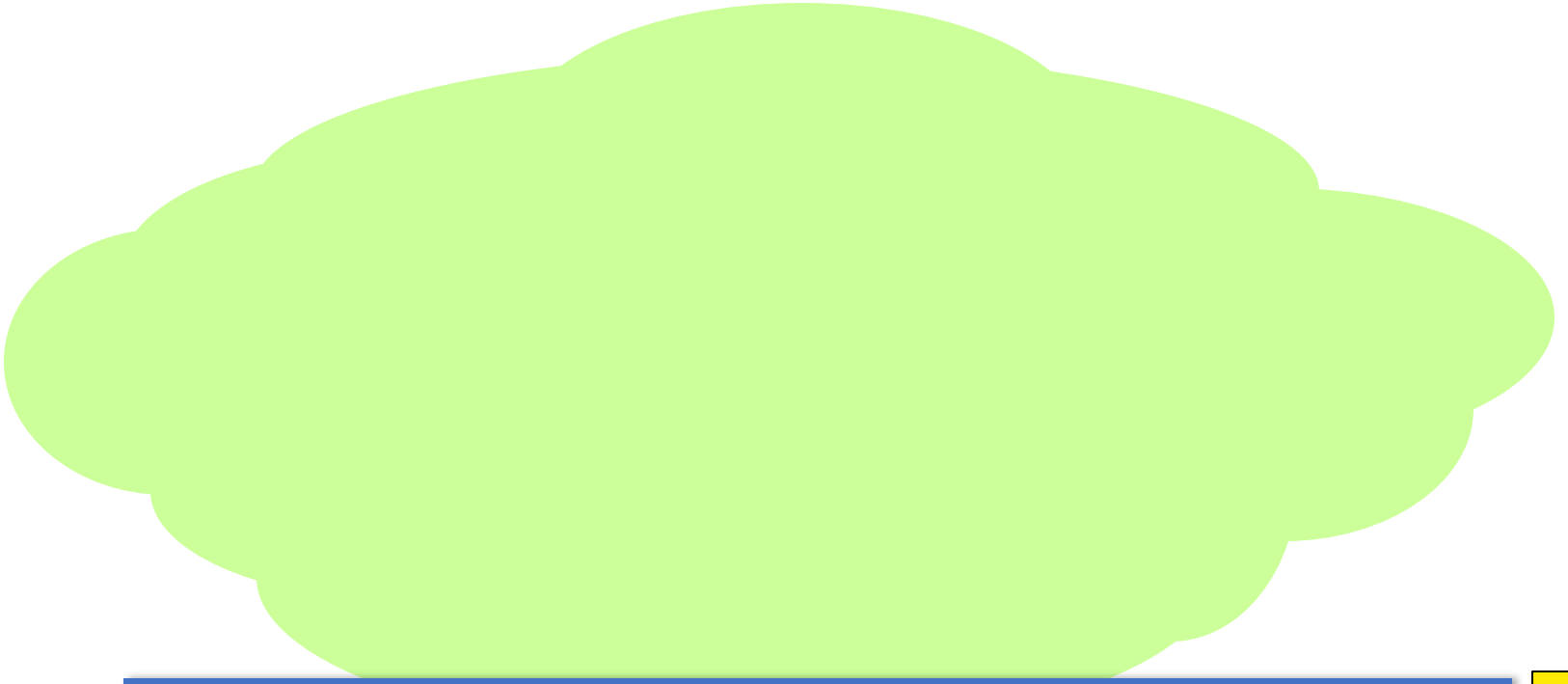


ospf's view of the network



bb0

```
bb0# show ip ospf database
```

for router lsas, the `Link ID` is the router's id

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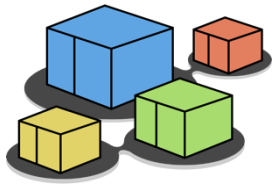
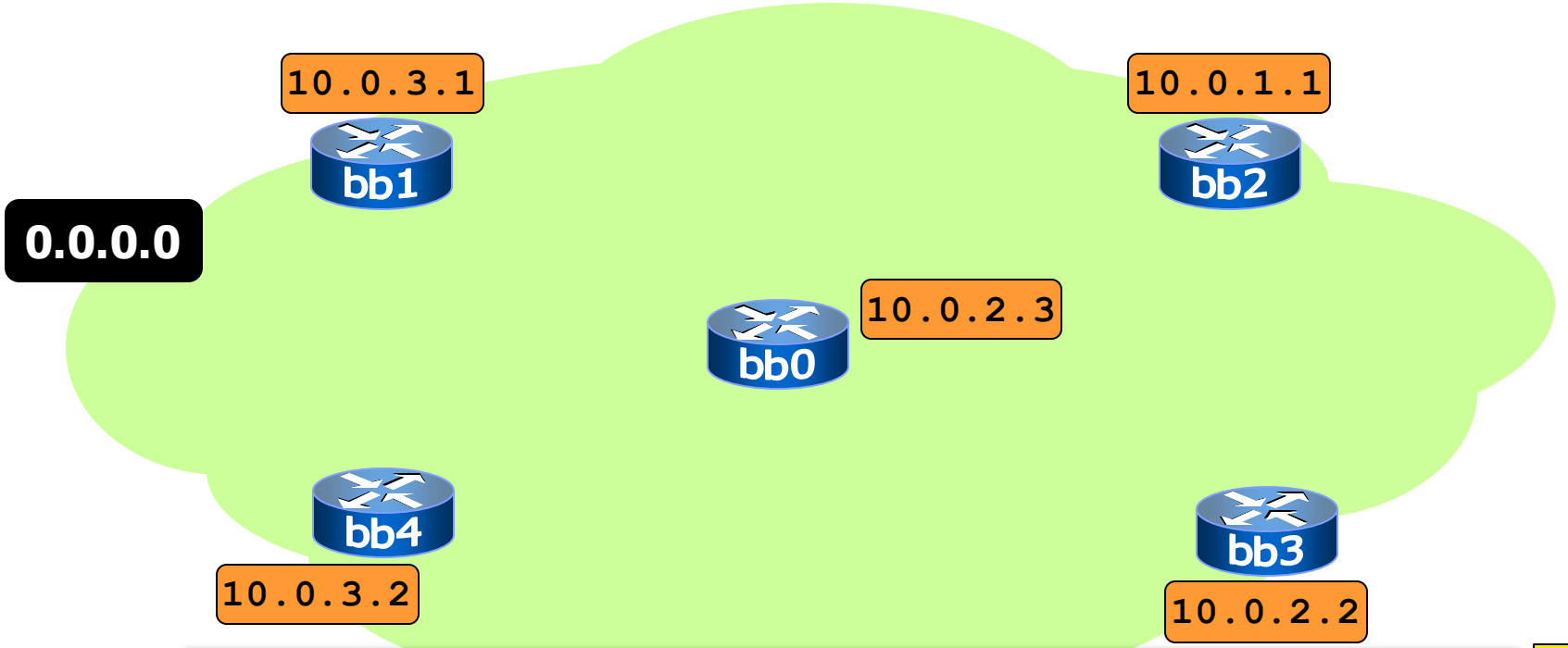


ospf's view of the network



bb0

```
        OSPF Router with ID (10.0.2.3)
                Router Link States (Area 0.0.0.0)
Link ID         ADV Router      Age  Seq#       CkSum  Link
count
10.0.1.1        10.0.1.1        743 0x80000008 0xdfff 2
10.0.2.2        10.0.2.2        743 0x80000008 0xd9ff 2
10.0.2.3        10.0.2.3        742 0x8000000a 0xd9d4 2
10.0.3.1        10.0.3.1        747 0x80000009 0x268e 2
10.0.3.2        10.0.3.2        752 0x80000008 0x4091 2
```

for router lsas, the `Link ID` is the router's id

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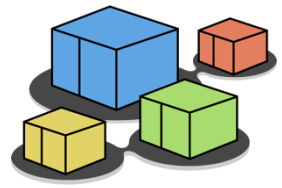
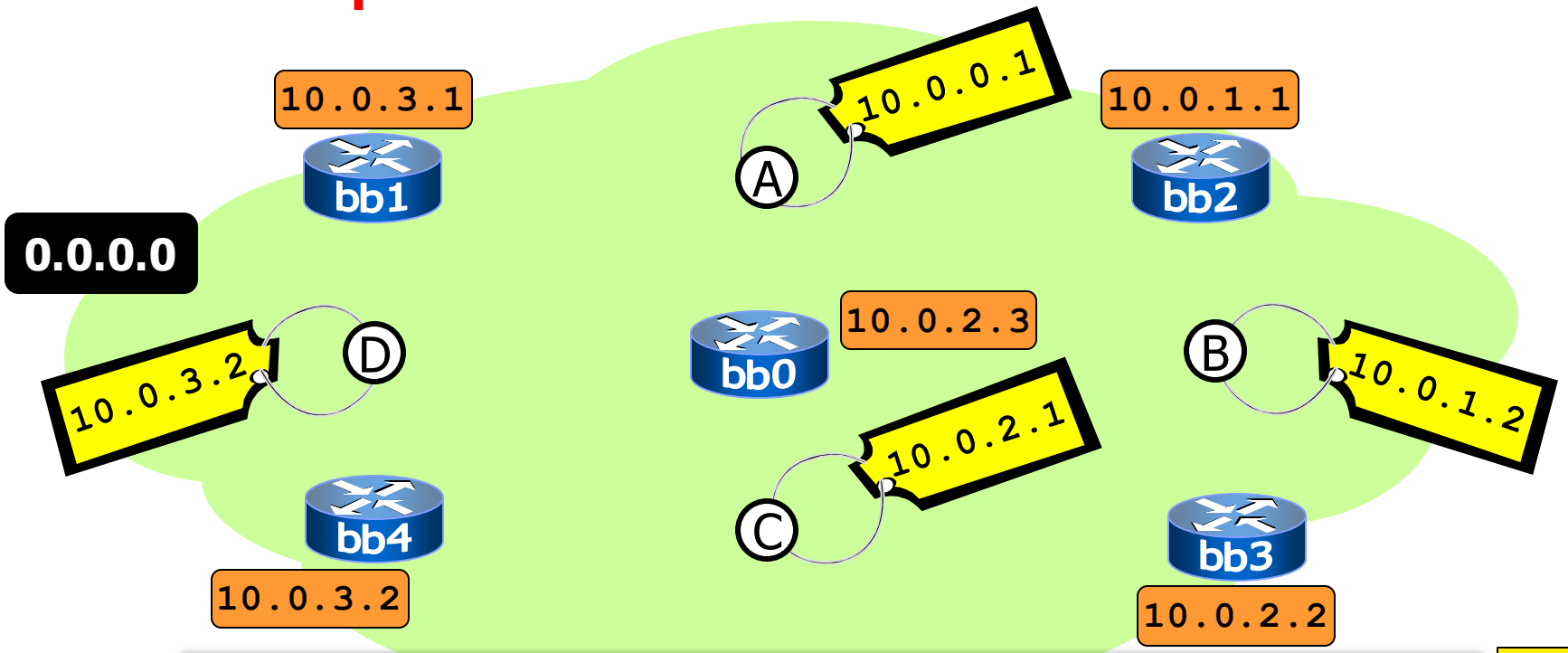


ospf's view of the network



bb0

```
 Net Link States (Area 0.0.0.0)
Link ID         ADV Router      Age  Seq#       CkSum
10.0.0.1        10.0.3.1        749  0x80000002 0x69a9
10.0.1.2        10.0.2.2        743  0x80000001 0x69bb
10.0.2.1        10.0.3.2        752  0x80000002 0x729a
10.0.3.2        10.0.3.2        753  0x80000001 0x6bb3
```

for network lsas, the `Link ID` is the dr's address

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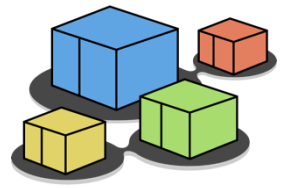
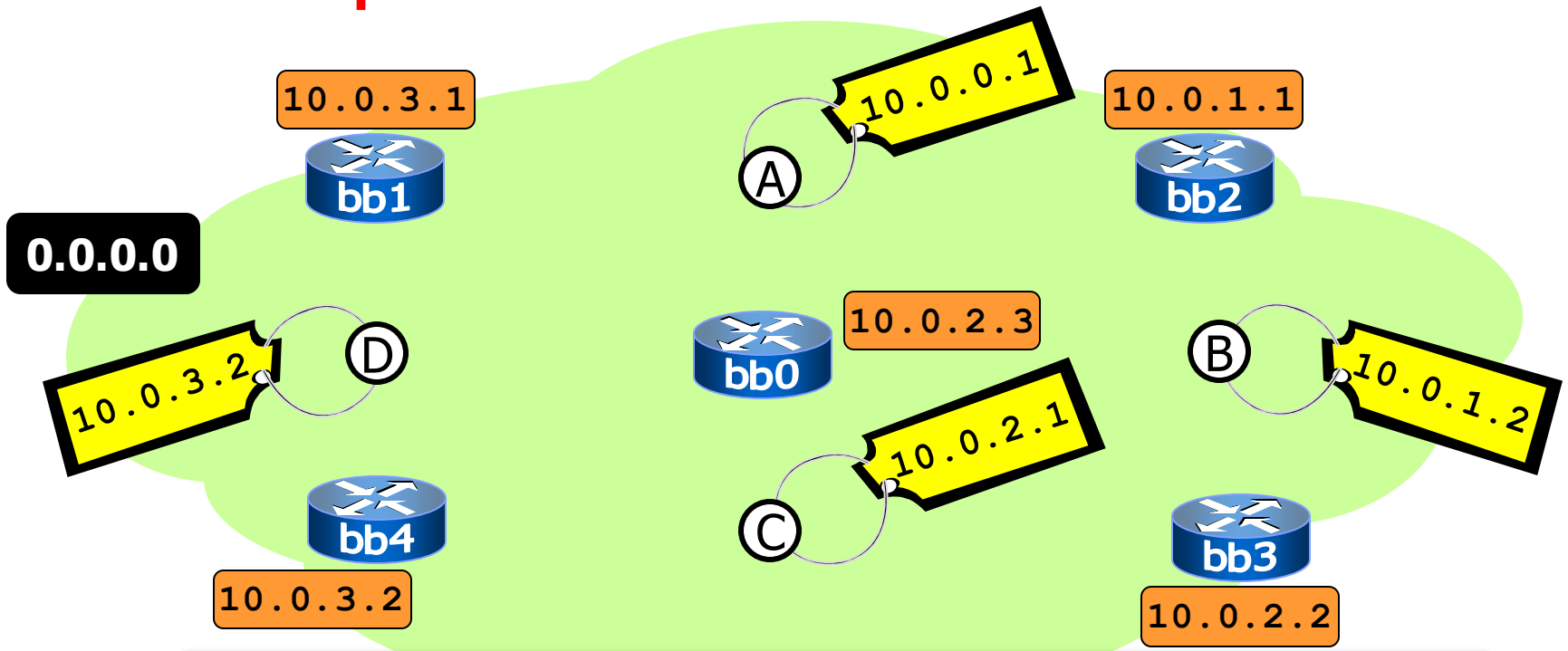


ospf's view of the network



bb0

```
bb0# show ip ospf database router
 Link State ID: 10.0.1.1
   Number of Links: 2
    Link connected to: a Transit Network
     (Link ID) Designated Router address: 10.0.0.1
     (Link Data) Router Interface address: 10.0.0.2
    Link connected to: a Transit Network
     (Link ID) Designated Router address: 10.0.1.2
     (Link Data) Router Interface address: 10.0.1.1
```

note: the output of **`show ip ospf database router`** has been summarized

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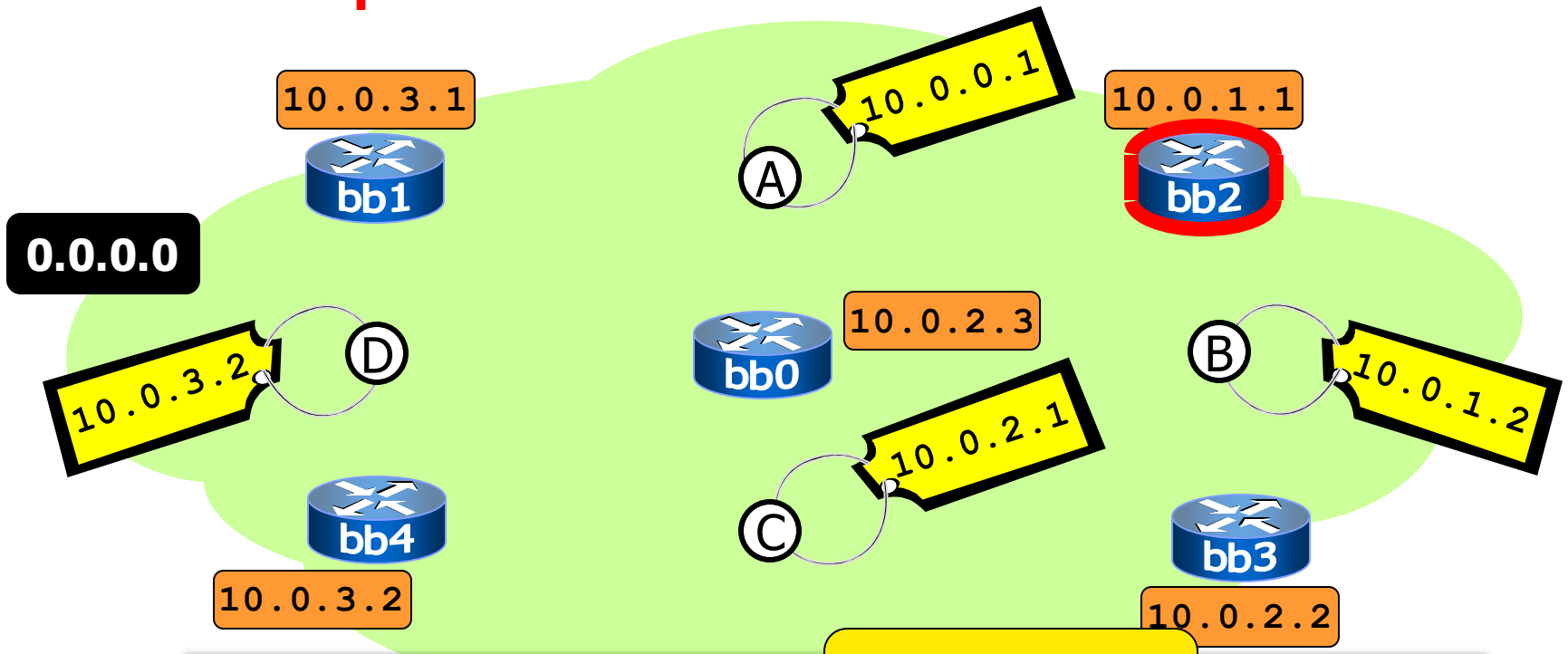
ospf's view of the network




```
bb0# show ip ospf database r
 Link State ID: 10.0.1.1
   Number of Links: 2
    Link connected to: a Transit Network
     (Link ID) Designated Router address: 10.0.0.1
     (Link Data) Router Interface address: 10.0.0.2
    Link connected to: a Transit Network
     (Link ID) Designated Router address: 10.0.1.2
     (Link Data) Router Interface address: 10.0.1.1
```

we consider this router (**bb2**)

note: the output of **`show ip ospf database router`** has been summarized

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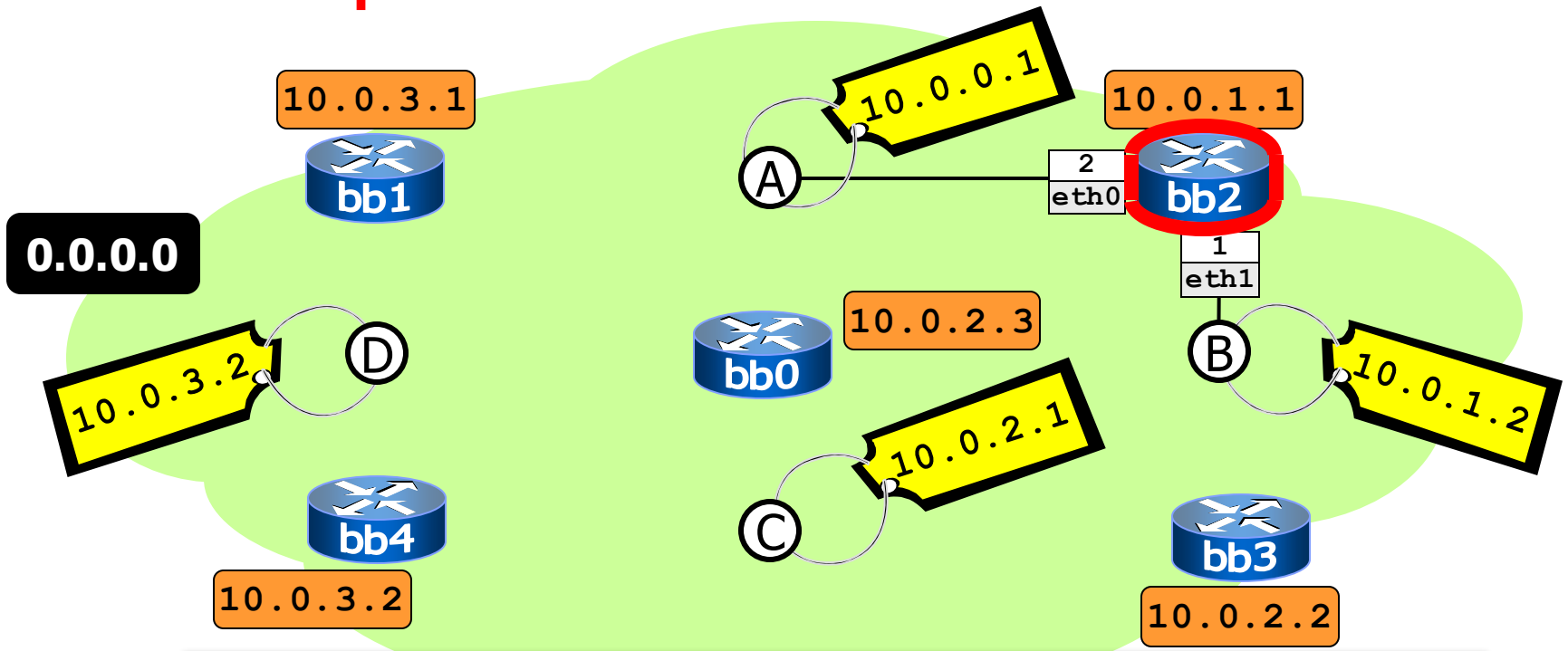
ospf's view of the network



bb0

```
bb0# show ip ospf
 Link State ID: 10
   Number of Links
    Link connected to: a Tra    Network
     (Link ID) Designated Router address: 10.0.0.1
     (Link Data) Router Interface address: 10.0.0.2
    Link connected to: a Transit Network
     (Link ID) Designated Router address: 10.0.1.2
     (Link Data) Router Interface address: 10.0.1.1
```

this router interface...

...is connected to the subnet represented by this dr

output of `ospf` `e router` has been summarized

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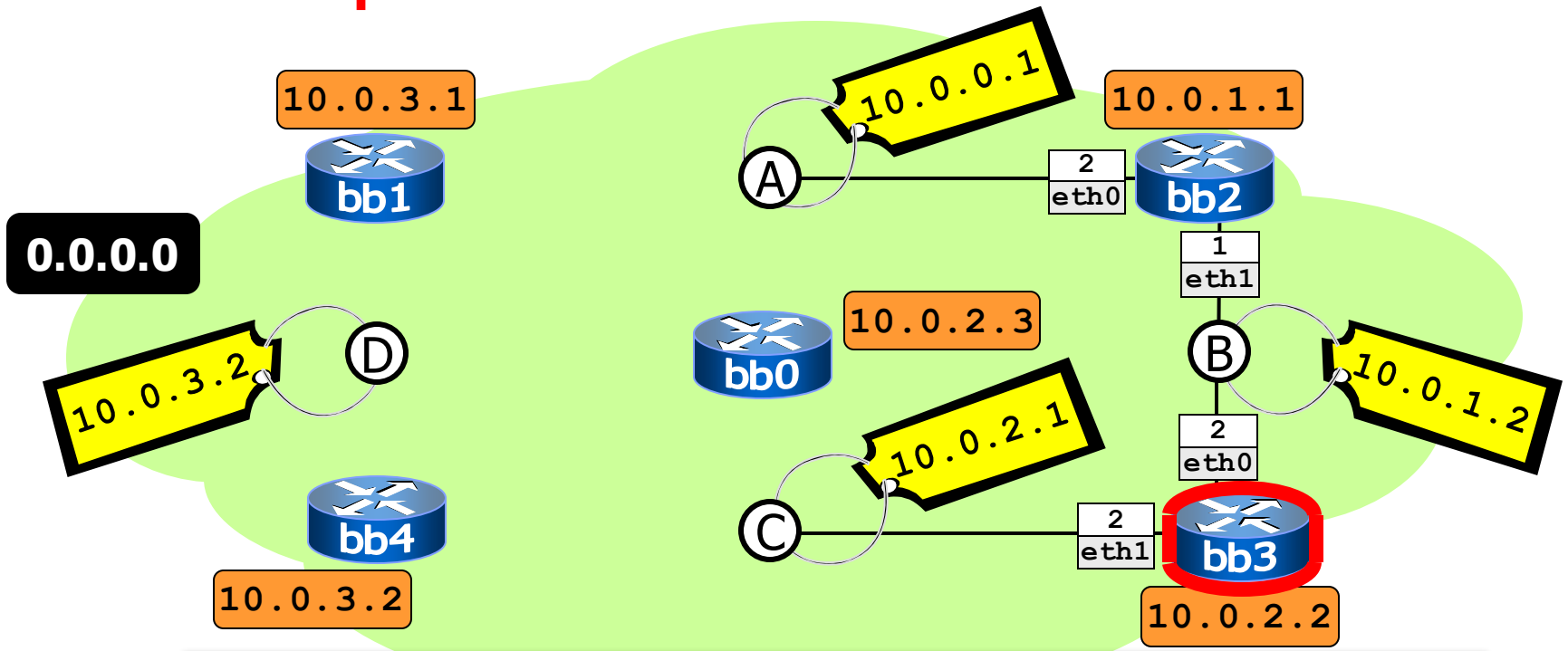
ospf's view of the network



bb0

```
bb0# show ip ospf database router
 Link State ID: 10.0.1.1
   Number of Links: 2
    Link connected to: a Transit Network
     (Link ID) Designated Router address: 10.0.0.1
     (Link Data) Router Interface address: 10.0.0.2
    Link connected to: a Transit Network
     (Link ID) Designated Router address: 10.0.1.2
     (Link Data) Router Interface address: 10.0.1.1
```

note: the output of **`show ip ospf database router`** has been summarized

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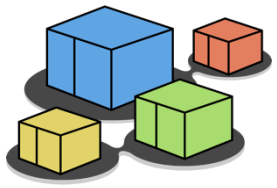
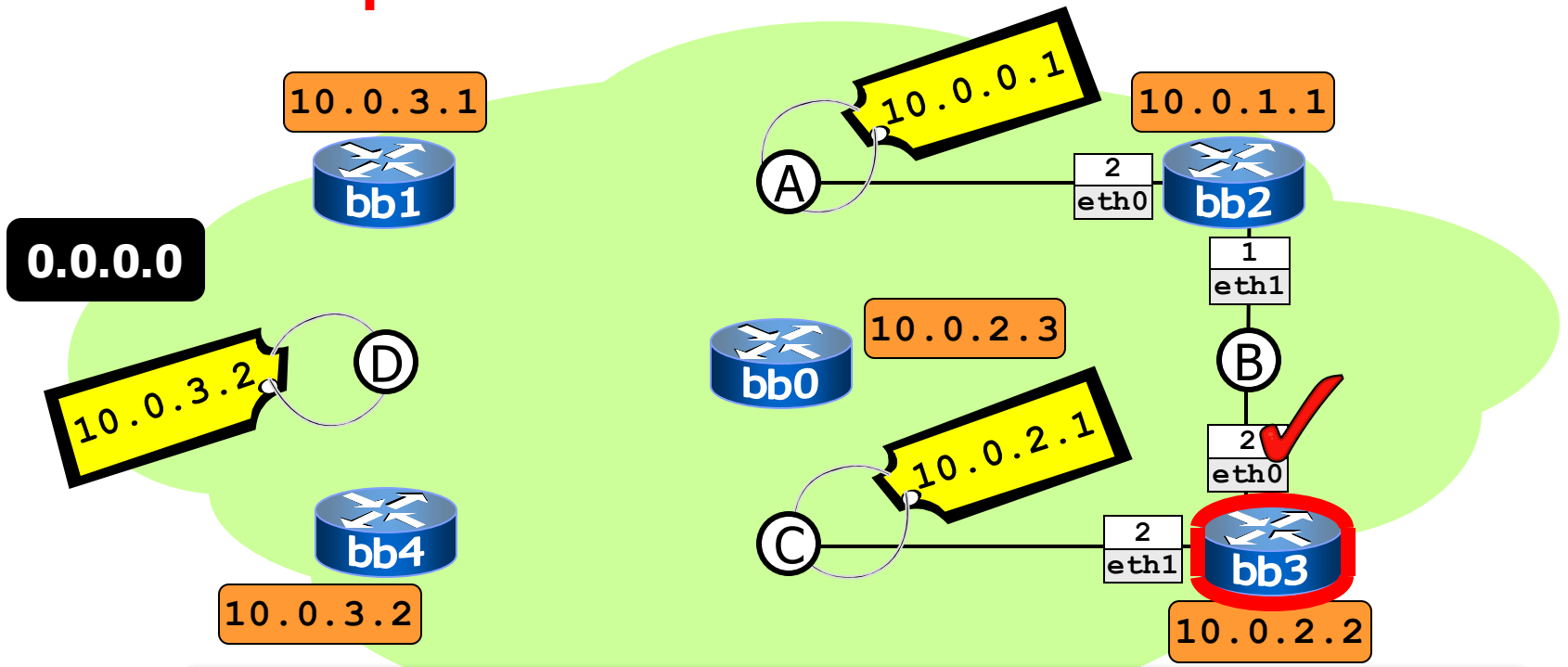


ospf's view of the network



bb0

```
bb0# show ip ospf database router
 Link State ID: 10.0.1.1
   Number of Links: 2
    Link connected to: a Transit Network
     (Link ID) Designated Router address: 10.0.0.1
     (Link Data) Router Interface address: 10.0.0.2
    Link connected to: a Transit Network
     (Link ID) Designated Router address: 10.0.1.2
     (Link Data) Router Interface address: 10.0.1.1
```

note: the output of **`show ip ospf database router`** has been summarized

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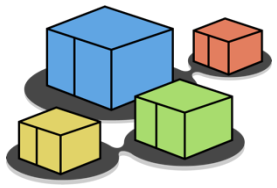
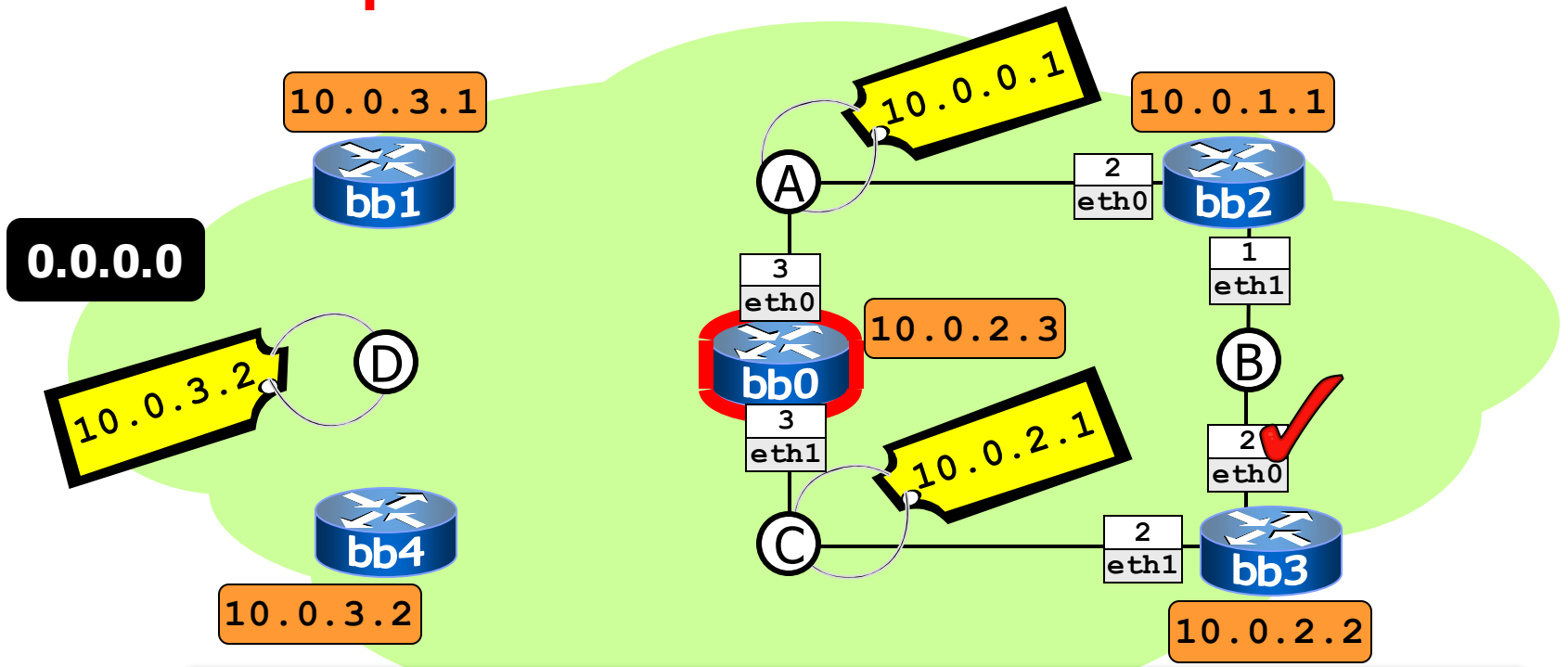


ospf's view of the network



bb0

```
Link State ID: 10.0.2.3
  Number of Links: 2
   Link connected to: a Transit Network
    (Link ID) Designated Router address: 10.0.0.1
    (Link Data) Router Interface address: 10.0.0.3
   Link connected to: a Transit Network
    (Link ID) Designated Router address: 10.0.2.1
    (Link Data) Router Interface address: 10.0.2.3
```

note: the output of **`show ip ospf database router`** has been summarized

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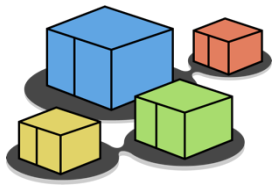
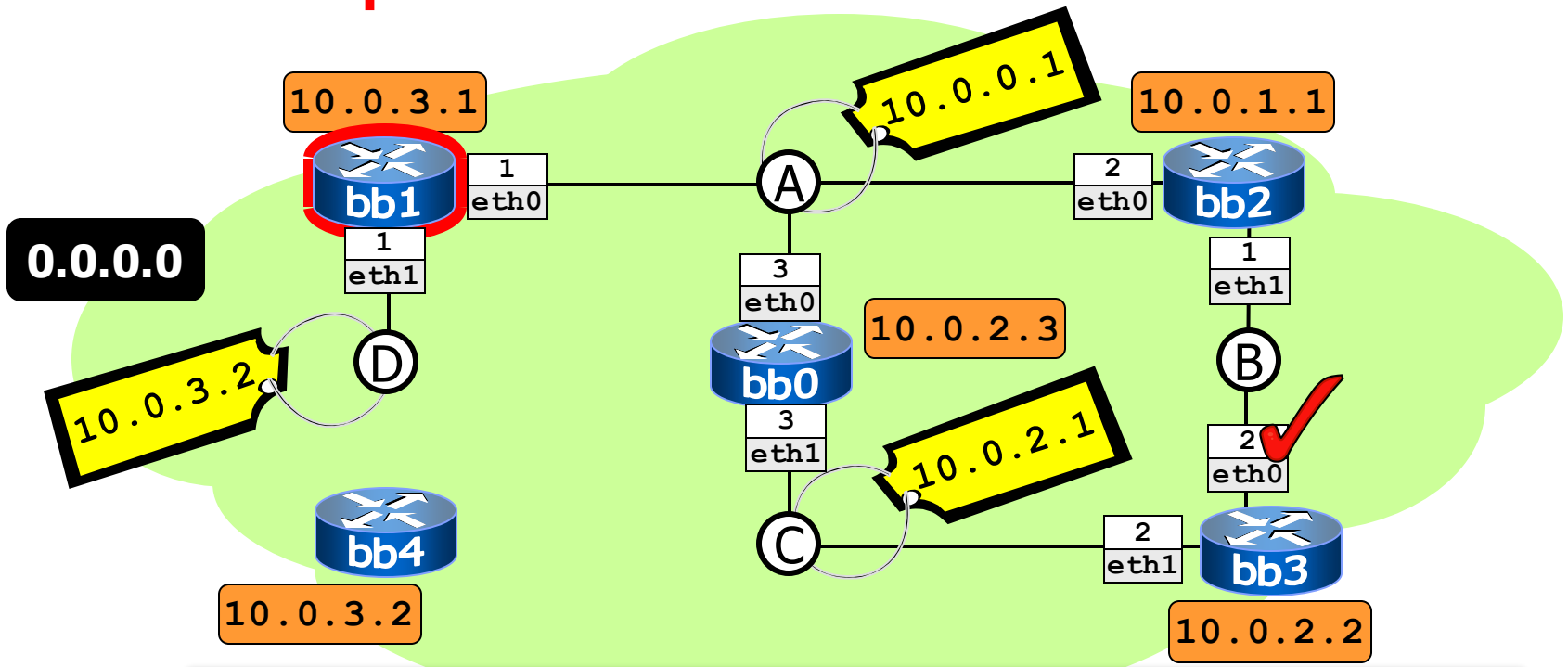


ospf's view of the network



bb0

```
Link State ID: 10.0.3.1
  Number of Links: 2
   Link connected to: a Transit Network
    (Link ID) Designated Router address: 10.0.0.1
    (Link Data) Router Interface address: 10.0.0.1
   Link connected to: a Transit Network
    (Link ID) Designated Router address: 10.0.3.2
    (Link Data) Router Interface address: 10.0.3.1
```

note: the output of **`show ip ospf database router`** has been summarized

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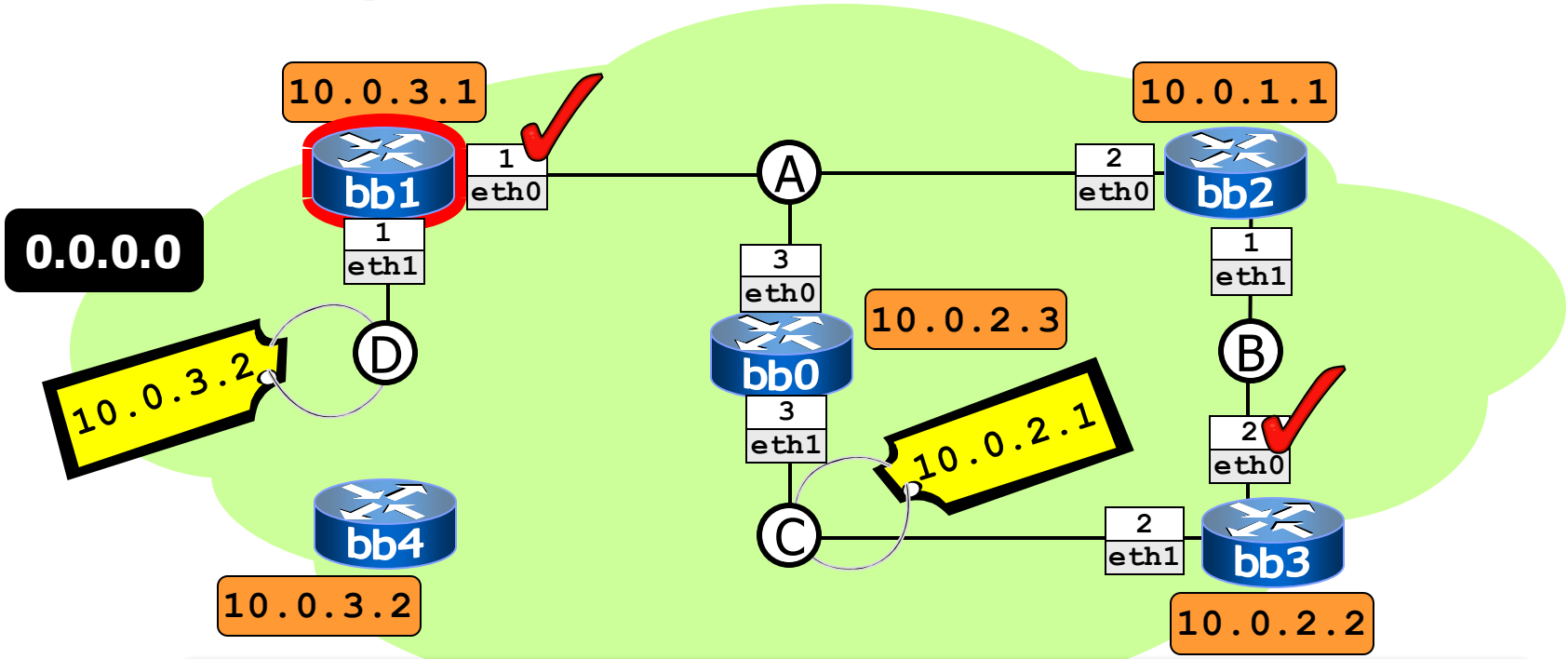
ospf's view of the network



bb0

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Link State ID: 10.0.3.1
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   Link connected to: a Transit Network
    (Link ID) Designated Router address: 10.0.0.1
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   Link connected to: a Transit Network
    (Link ID) Designated Router address: 10.0.3.2
    (Link Data) Router Interface address: 10.0.3.1
```

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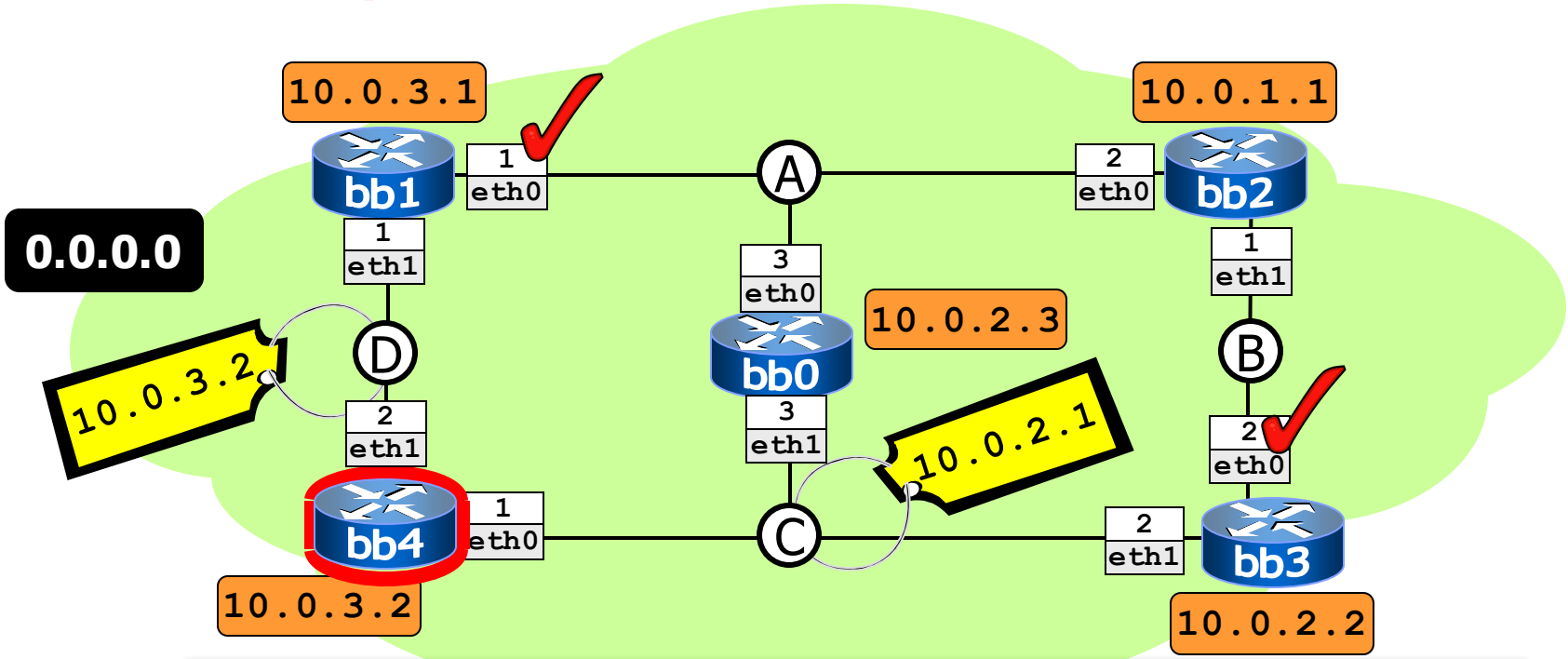
ospf's view of the network



bb0

```
Link State ID: 10.0.3.2
  Number of Links: 2
   Link connected to: a Transit Network
    (Link ID) Designated Router address: 10.0.2.1
    (Link Data) Router Interface address: 10.0.2.1
   Link connected to: a Transit Network
    (Link ID) Designated Router address: 10.0.3.2
    (Link Data) Router Interface address: 10.0.3.2
```

note: the output of **`show ip ospf database router`** has been summarized

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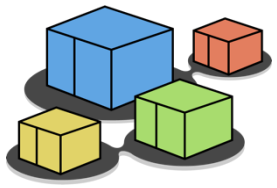

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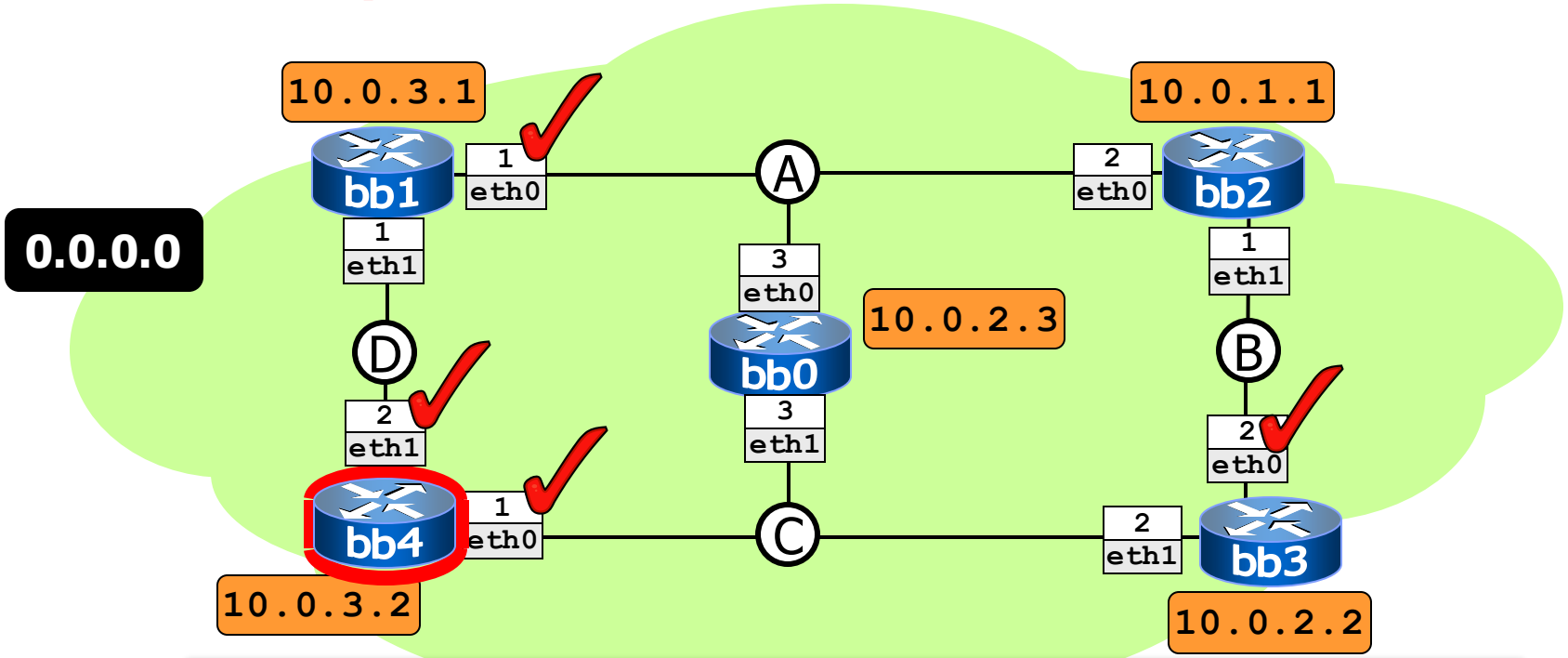

bb0

```
Link State ID: 10.0.3.2
  Number of Links: 2
   Link connected to: a Transit Network
    (Link ID) Designated Router address: 10.0.2.1
    (Link Data) Router Interface address: 10.0.2.1
   Link connected to: a Transit Network
    (Link ID) Designated Router address: 10.0.3.2
    (Link Data) Router Interface address: 10.0.3.2
```

note: the output of **`show ip ospf database router`** has been summarized

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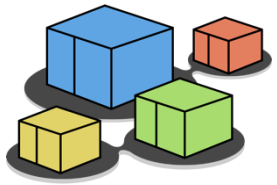

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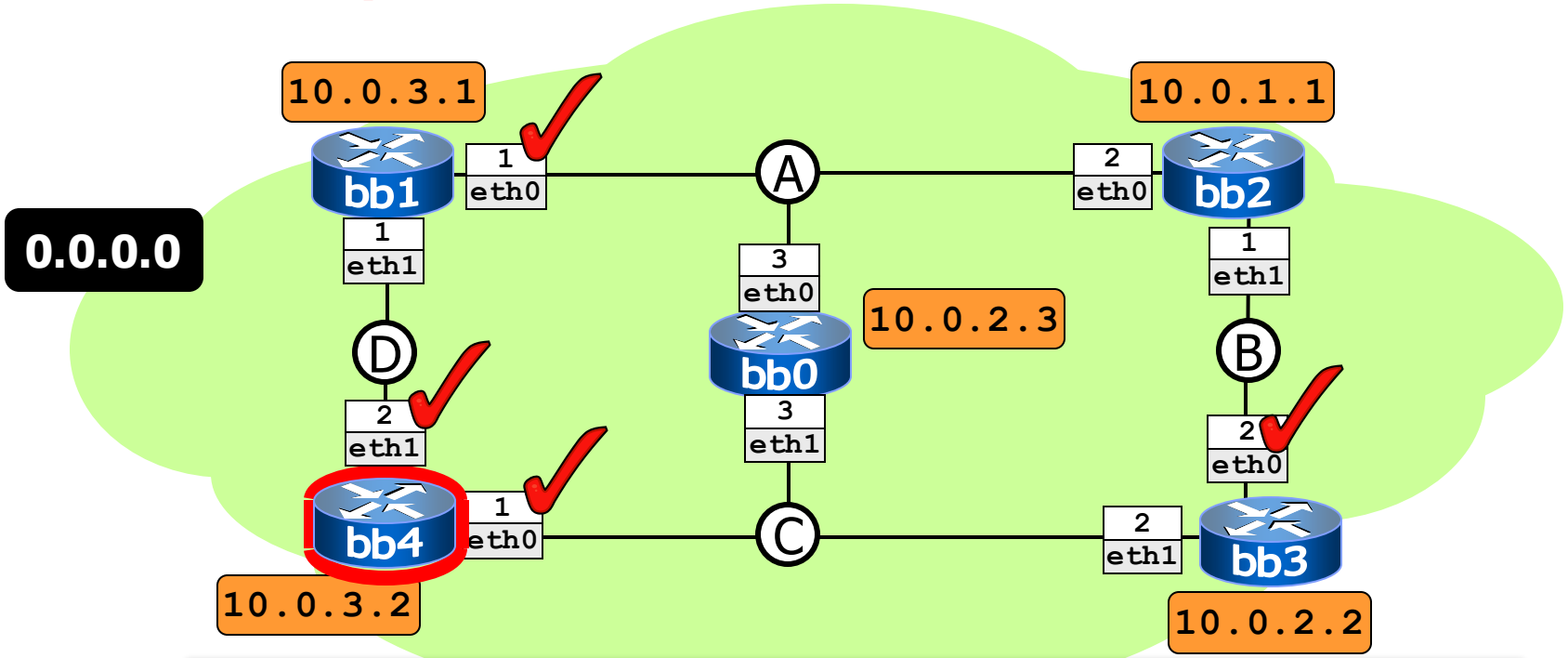

bb0

```
bb0# show ip ospf database network
```

note: the output of **`show ip ospf database network`** has been summarized

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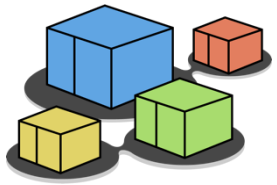

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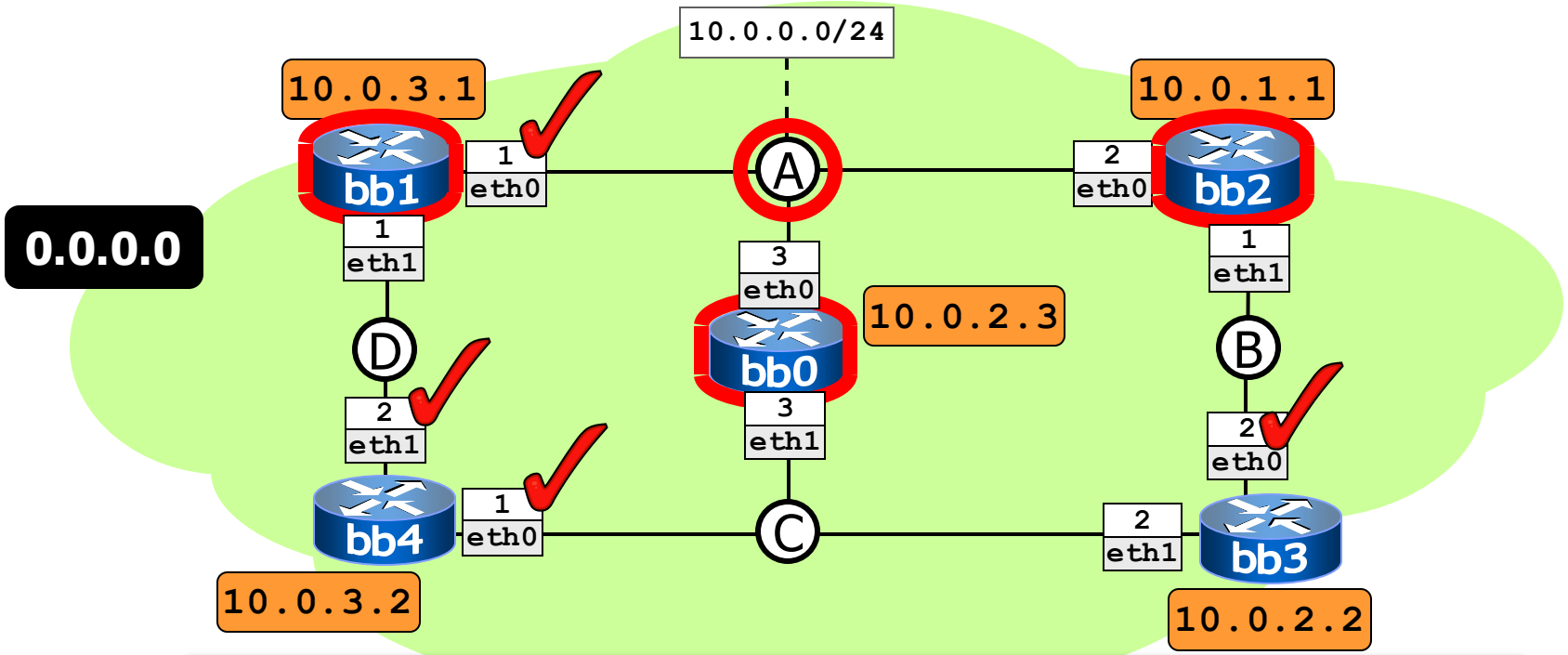

bb0

```
Link State ID: 10.0.0.1 (address of Designated Router)
 Advertising Router: 10.0.3.1
 Network Mask: /24
       Attached Router: 10.0.3.1
       Attached Router: 10.0.1.1
       Attached Router: 10.0.2.3
```

note: the output of **`show ip ospf database network`** has been summarized

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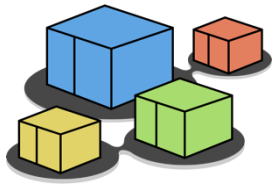

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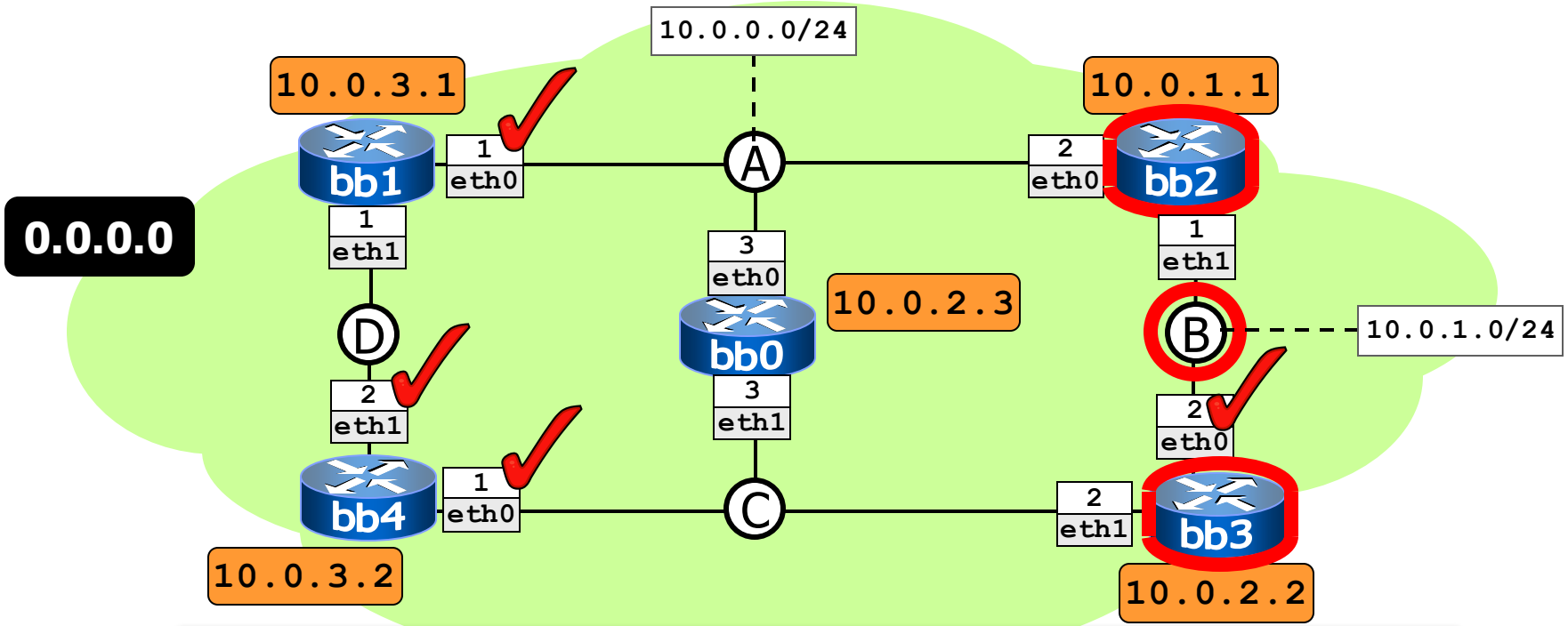

bb0

```
Link State ID: 10.0.1.2 (address of Designated Router)
 Advertising Router: 10.0.2.2
 Network Mask: /24
       Attached Router: 10.0.1.1
       Attached Router: 10.0.2.2
```

note: the output of **`show ip ospf database network`** has been summarized

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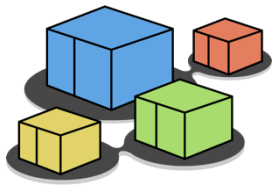
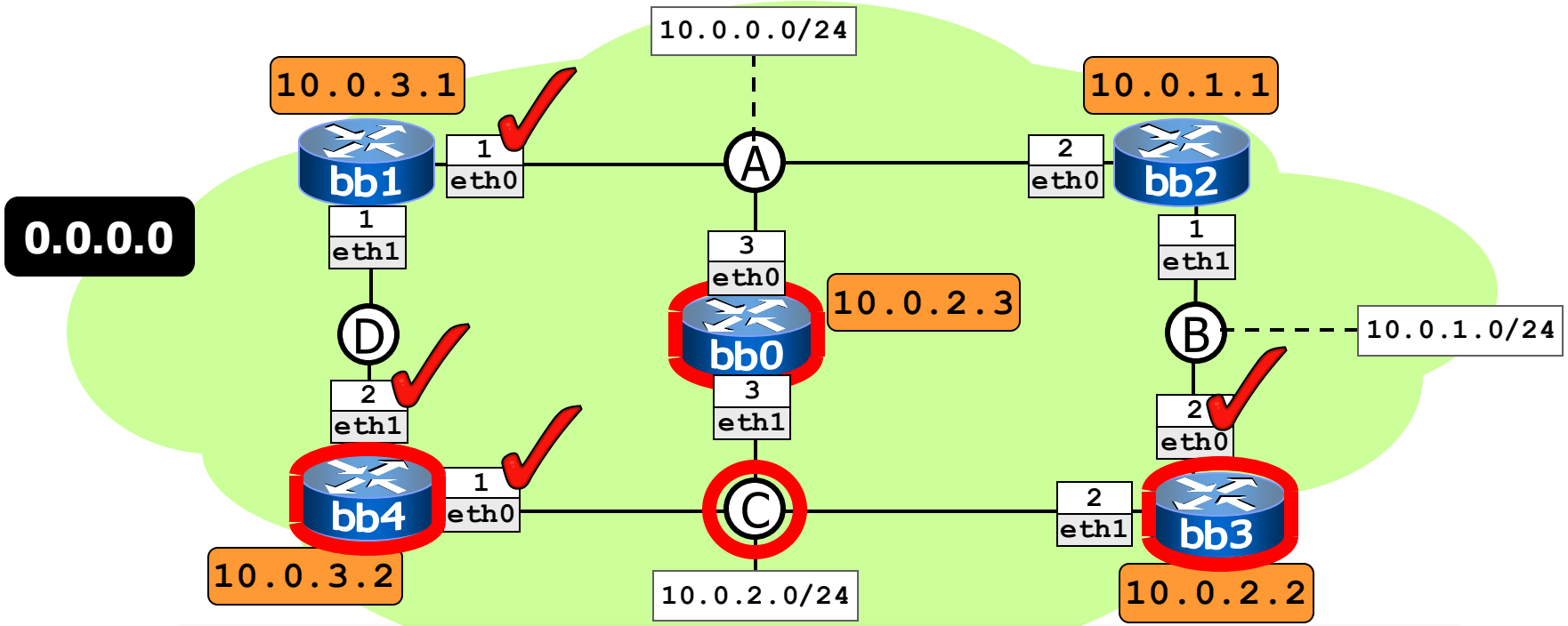


ospf's view of the network



bb0

```
Link State ID: 10.0.2.1 (address of Designated Router)
 Advertising Router: 10.0.3.2
 Network Mask: /24
       Attached Router: 10.0.3.2
       Attached Router: 10.0.2.2
       Attached Router: 10.0.2.3
```

note: the output of **`show ip ospf database network`** has been summarized

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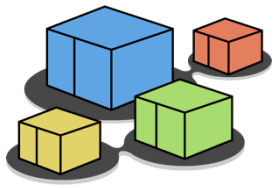
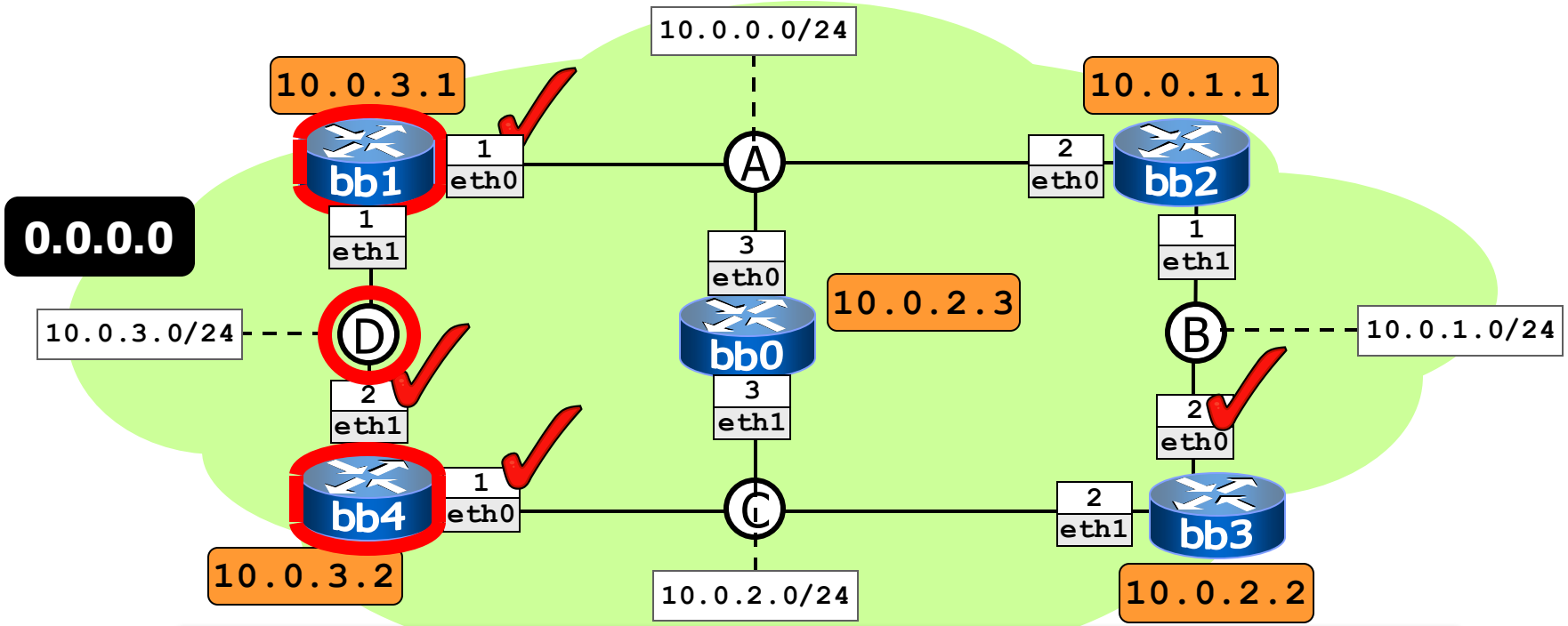


ospf's view of the network



bb0

```
Link State ID: 10.0.3.2 (address of Designated Router)
Advertising Router: 10.0.3.2
Network Mask: /24
      Attached Router: 10.0.3.1
      Attached Router: 10.0.3.2
```

note: the output of **`show ip ospf database network`** has been summarized

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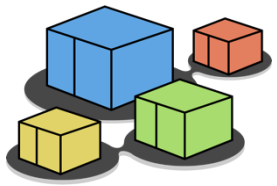

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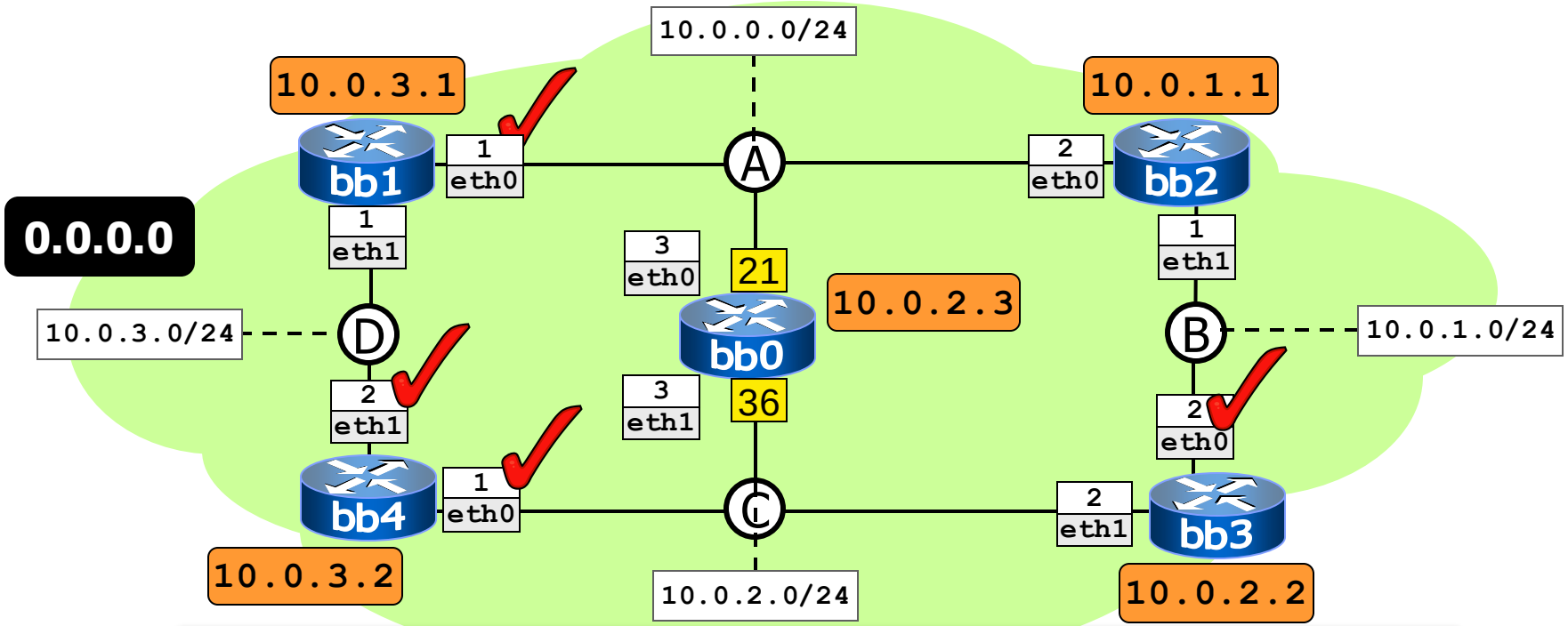

bb0

```
root@bb0:~# vtysh -e "show ip ospf interface" | egrep
"eth|Cost"
eth0 is up
  Router ID 10.0.2.3, Network Type BROADCAST, Cost: 21
eth1 is up
  Router ID 10.0.2.3, Network Type BROADCAST,
```

a shortcut to quickly get the cost

ospf interface costs can be queried on all routers

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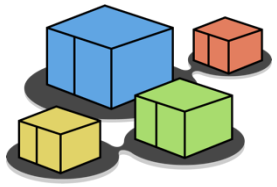

neighborhood

- router neighbors can be shown by using the **`show ip ospf neighbor`** command
- note: lsas are only sent between neighbors in **`Full`** state (i.e., capable of a bidirectional exchange of information); reaching the **`Full`** state requires that:
  - neighbors have been discovered (using hello packets)
  - bidirectional communication is possible
  - a designated router has been elected
- once reached, routers immediately synchronize their lsdbs

bb0

```
bb0# show ip ospf neighbor

    Neighbor ID Pri State           Dead Time Address     Interface         RXmtL RqstL DBsmL
10.0.3.1          1 Full/DR           30.462s 10.0.0.1    eth0:10.0.0.3         0     0     0
10.0.1.1          1 Full/DROther      30.462s 10.0.0.2    eth0:10.0.0.3         0     0     0
10.0.3.2          1 Full/DR           31.587s 10.0.2.1    eth1:10.0.2.3         0     0     0
10.0.2.2          1 Full/DROther      31.586s 10.0.2.2    eth1:10.0.2.3         0     0     0
bb0-frr#
```

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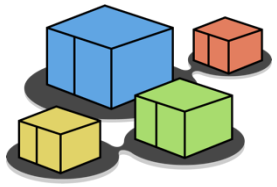

ospf routing table

- To dump the ospf routing table use **`show ip ospf route`**

bb0

```
bb0# show ip ospf route
============ OSPF network routing table ============
N    10.0.0.0/24           [21] area: 0.0.0.0
                           directly attached to eth0
N    10.0.1.0/24           [31] area: 0.0.0.0
                           via 10.0.0.2, eth0
N    10.0.2.0/24           [36] area: 0.0.0.0
                           directly attached to eth1
N    10.0.3.0/24           [46] area: 0.0.0.0
                           via 10.0.2.1, eth1
============ OSPF router routing table =============
============ OSPF external routing table ===========
```

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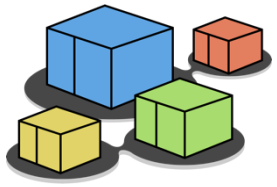

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bb0

```
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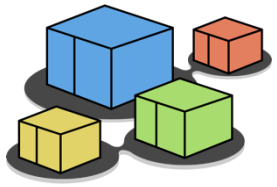
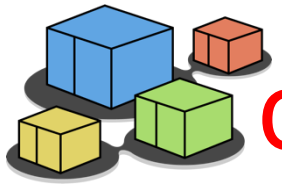
N    10.0.0.0/24             [21] area: 0.0.0.0
                             directly attached to eth0
N    10.0.1.0/24             [31] area: 0.0.0.0
                             via 10.0.0.2, eth0
N    10.0.2.0/24             [36] area: 0.0.0.0
                             directly attached to eth1
N    10.0.3.0/24             [46] area: 0.0.0.0
                             via 10.0.2.1, eth1
============ OSPF router routing table =============
============ OSPF external routing table ===========
```

route cost



experiments

- issue the **`show ip ospf database`** and **`show ip ospf neighbor`** commands on different routers
- capture and look at exchanged ospf packets using **`tcpdump`**



ospf is fast at detecting topology changes

- case #1: link fault
  - bring down a single network interface using **`ip link`**
    - the change is immediately propagated by the router inside lsa packets
    - routing tables are immediately updated (**`show ip ospf route`**)

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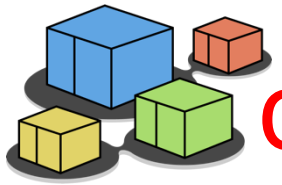

ospf is fast at detecting topology changes

- case #1: link fault
  - bring down a single network interface using **`ip link`**
    - the change is immediately propagated by the router inside lsa packets
    - routing tables are immediately updated (**`show ip ospf route`**)
    - the lsdb is handled a little differently...

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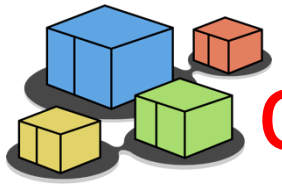

ospf is fast at detecting topology changes

- case #1: link fault
  - bring down a single network interface using **`ip link`**
    - if this brings down a dr, the information is immediately flushed from the lsdb(s)...
      - ...and eventually reannounced when a dr is re-elected
    - otherwise, ospf waits expiry of the `RouterDeadInterval` timer (default: 40s) before removing the adjacency from the lsdb (**`show ip ospf database network`**)
      - note: networks that are connected to one router only, called stub networks, are only visible using **`show ip ospf database router`**

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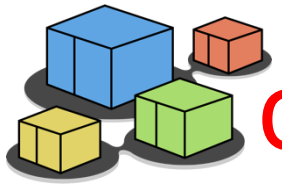

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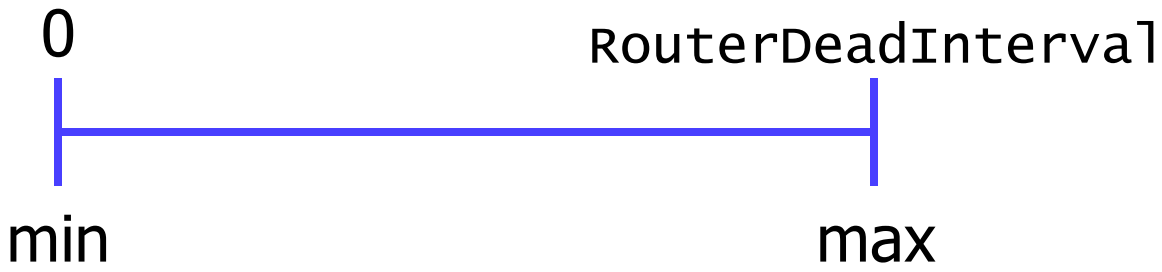
- case #1: link fault
  - bring down a single network interface using **`ip link`**

overall reaction time (estimated)



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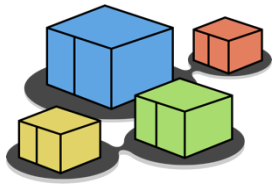

ospf is (often) fast at detecting topology changes

- case #2: router fault
  - bring down a router (by crashing it or by shutting down all its interfaces simultaneously)
  - the router has no chance to propagate lsas
    - the change *cannot* be immediately propagated
    - neighboring routers can only realize it (and update routing tables) after expiry of the `RouterDeadInterval` timer

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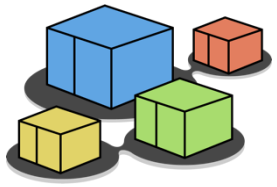

ospf is (often) fast at detecting topology changes

- case #2: router fault
  - bring down a router (by crashing it or by shutting down all its interfaces simultaneously)
  - after the change has been propagated...
    - ...lsdb information about networks for which the failed router was not dr is immediately flushed from other routers' lsdbs
      - the dr takes care of sending appropriate lsas
    - ...lsdb information about networks for which the failed router was dr (including those where a dr will be re-elected) and about routers is more "tough"
      - ospf waits for the lsa to expire (expiration happens when the age of the lsa reaches the `MaxAge` value of 1 hour) before taking any actions

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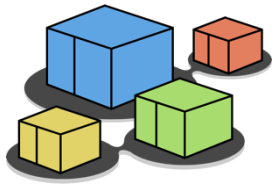

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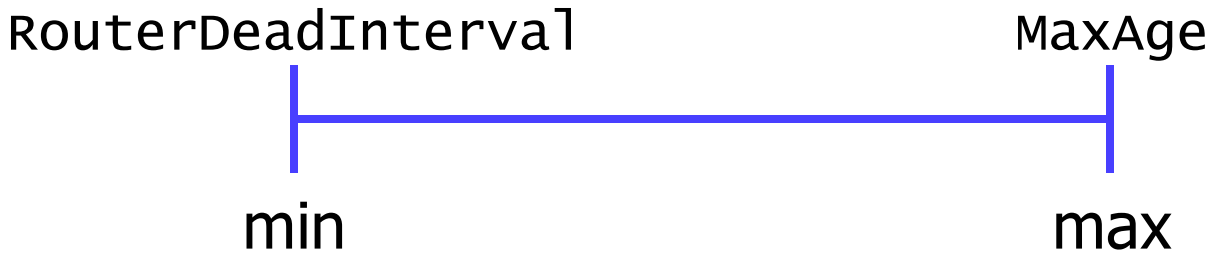
  - bring down a router (by crashing it or by shutting down all its interfaces simultaneously)

overall reaction time (estimated)



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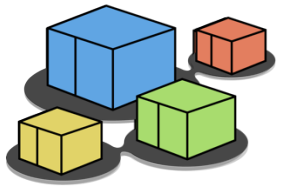

Kathará

lab: ospf-multiarea

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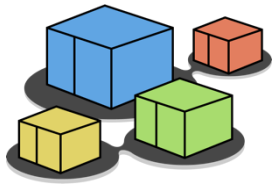

ospf areas

- an abstraction that simplifies administration and improves scalability
  - the topology of an area is invisible from the outside
  - routers internal to a given area don’t see the detailed external topology
- each area runs a separate instance of the link state routing algorithm
  - all routers in an area construct the same lsdb
  - each router keeps a distinct lsdb for each area it belongs to

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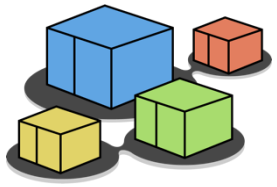

ospf areas

- identified by a 32-bit number,
  often in dotted decimal notation (1.2.3.4)
  - different interfaces of the same router can be assigned to different areas
  - each
    - router interface...
    - network...
    - router adjacency...

    ...is associated with a single area

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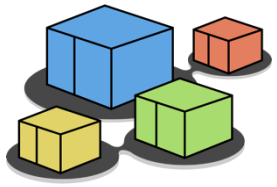

area types

- backbone (0.0.0.0)
  - must be (virtually) connected
  - all other areas are connected to it
  - contains all the area border routers
- stub
  - does not receive advertisements of external routes
  - internal nodes are offered a default route
  - cannot contain autonomous system boundary routers
  - the backbone can’t be a stub area
- transit
  - used to pass traffic from one adjacent area to another, via virtual links

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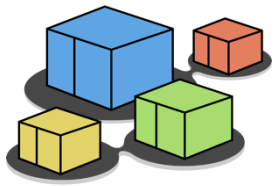

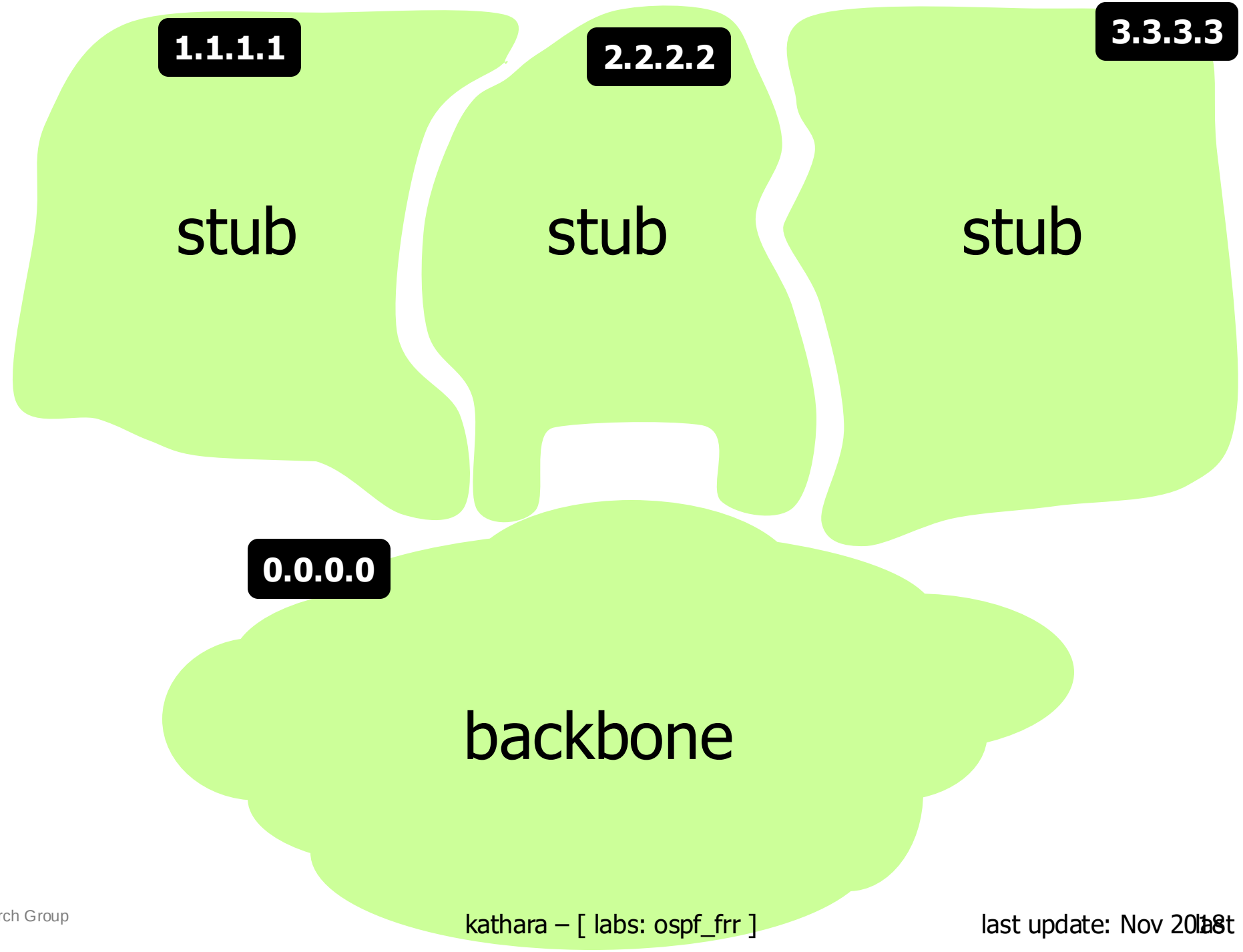

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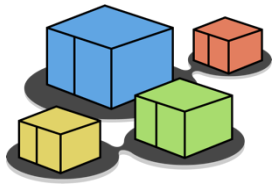

router types

- internal router
  - all interfaces belong to the same area
- area border router (abr)
  - connects one or more areas to the backbone
  - keeps multiple lsdbs, one for each area
- backbone router
  - has at least one interface connected to the backbone
  - an abr is always a backbone router
- autonomous system boundary router (asbr)
  - imports and floods routing information from other routing protocols (typically, bgp)
- note: a router can be of more than one type

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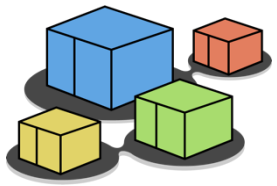

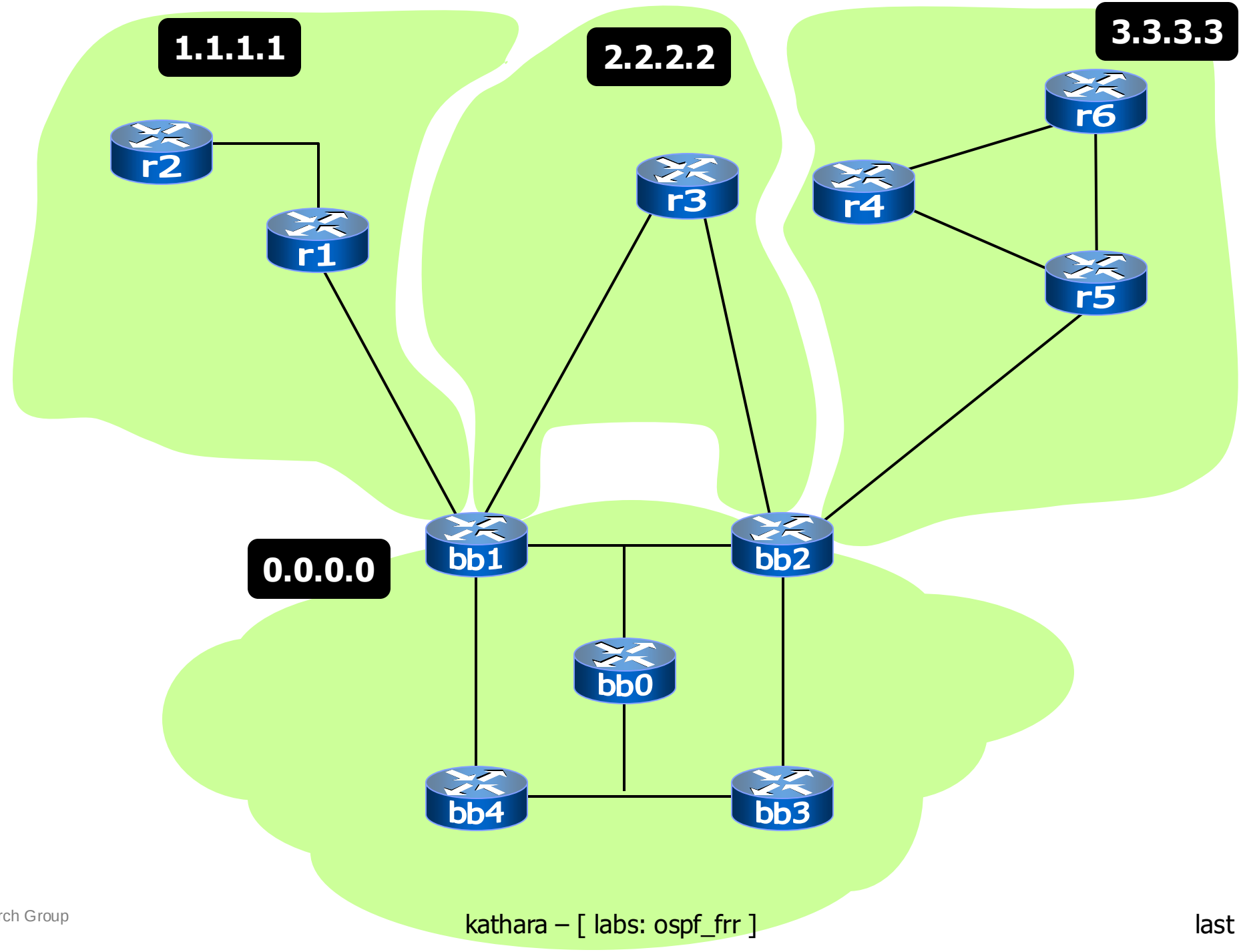

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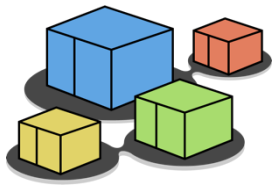

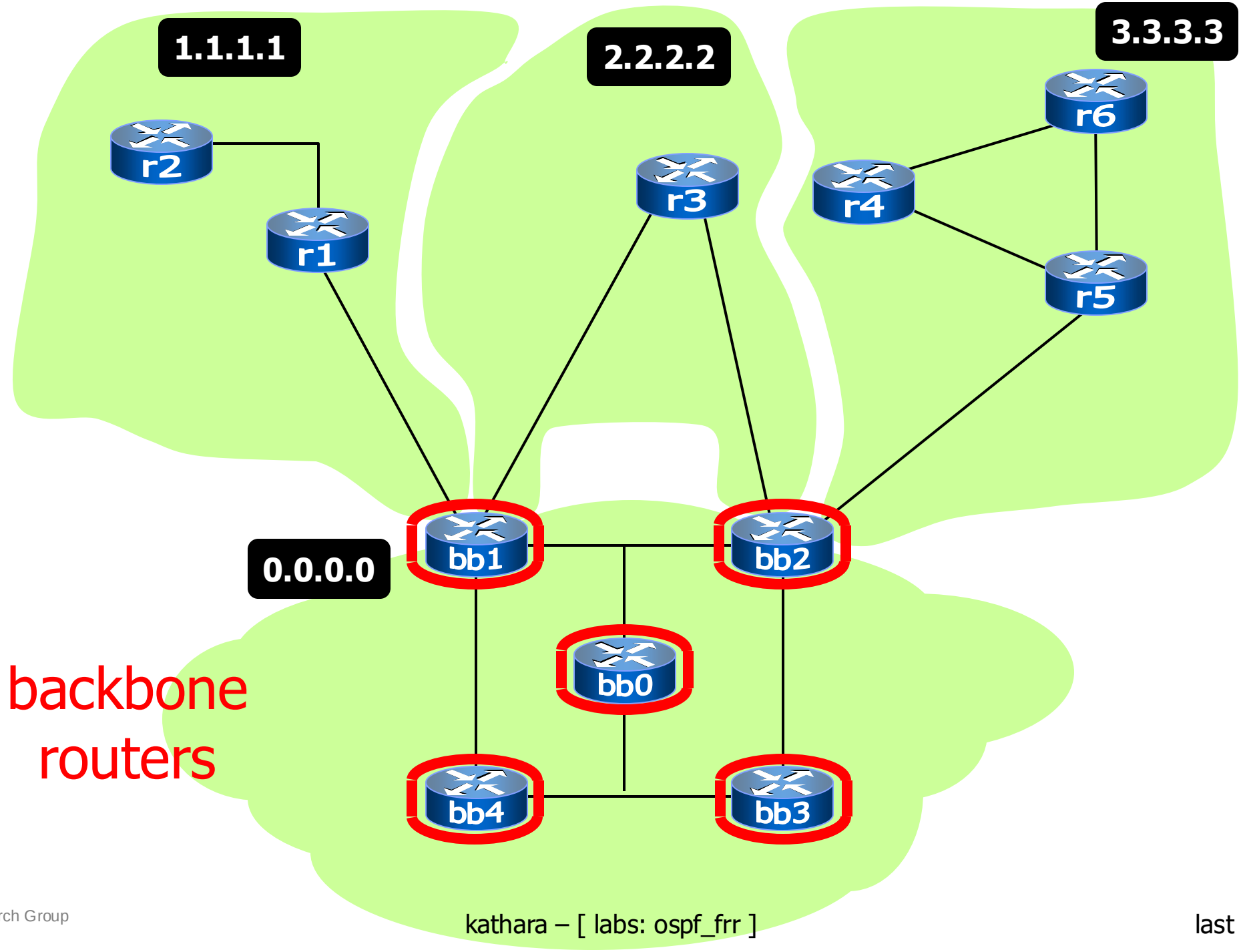

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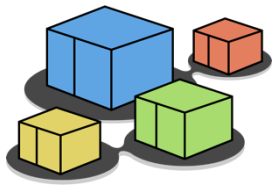

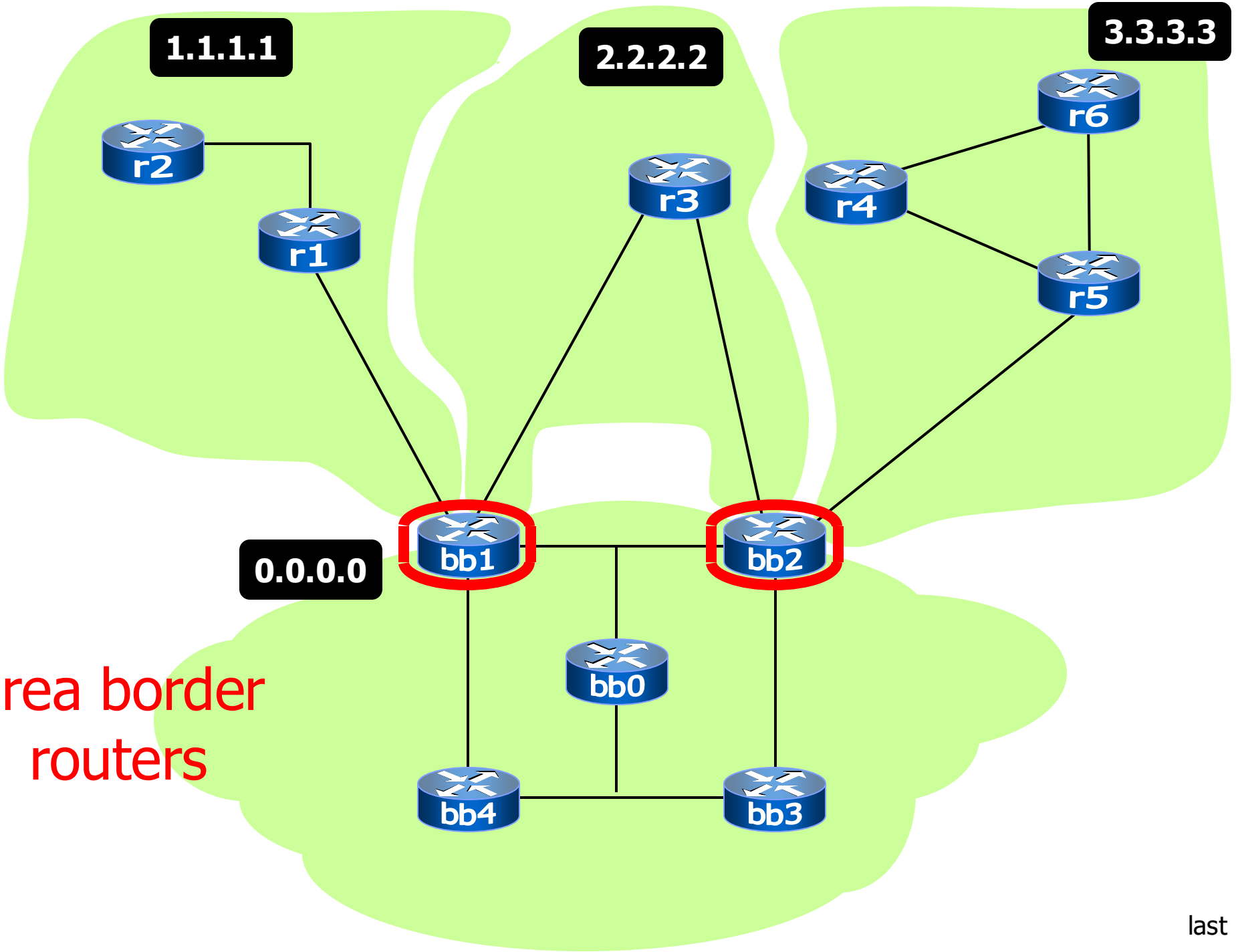

area border routers

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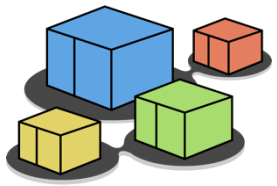

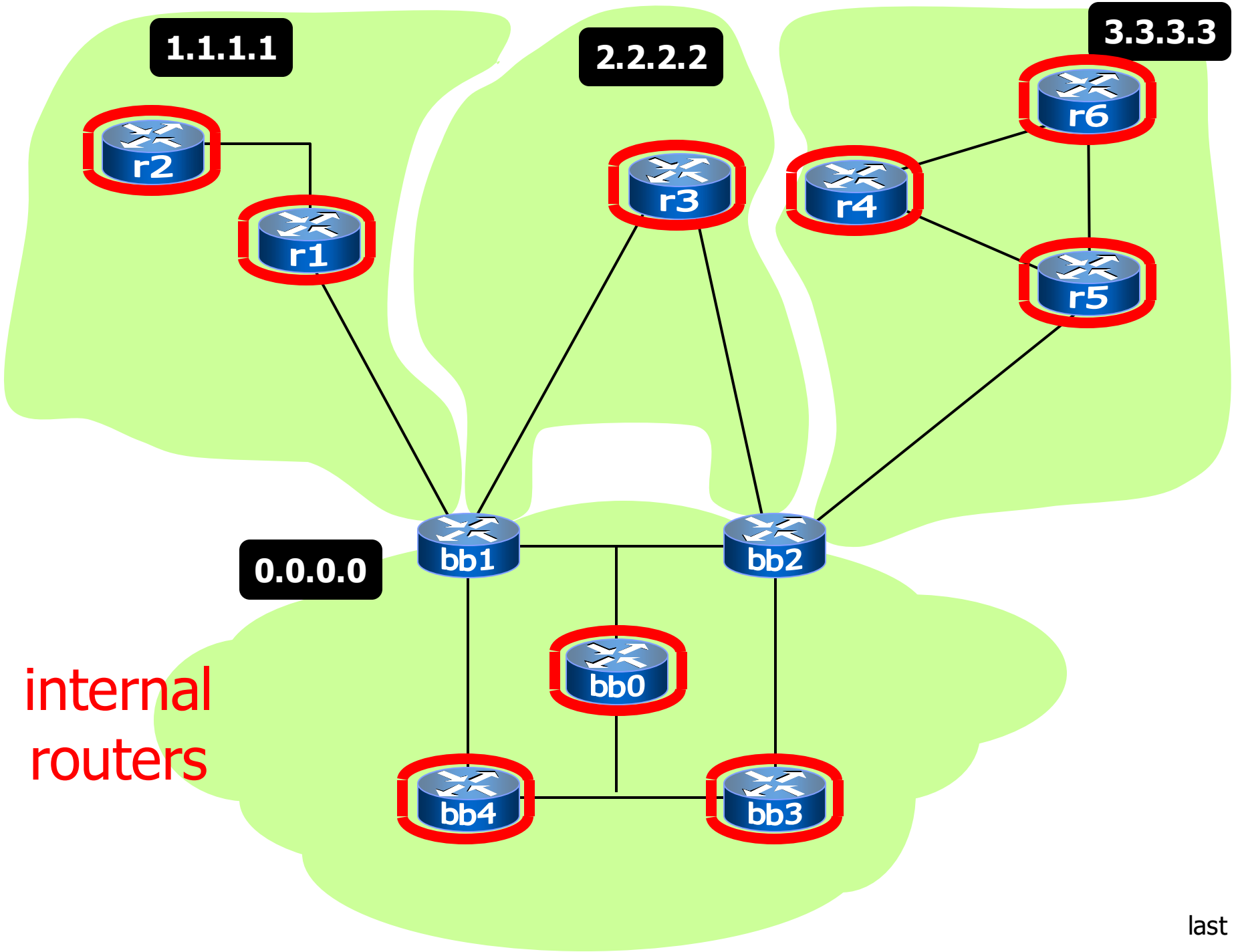

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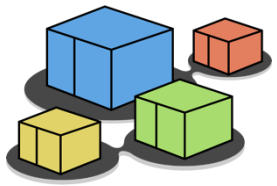

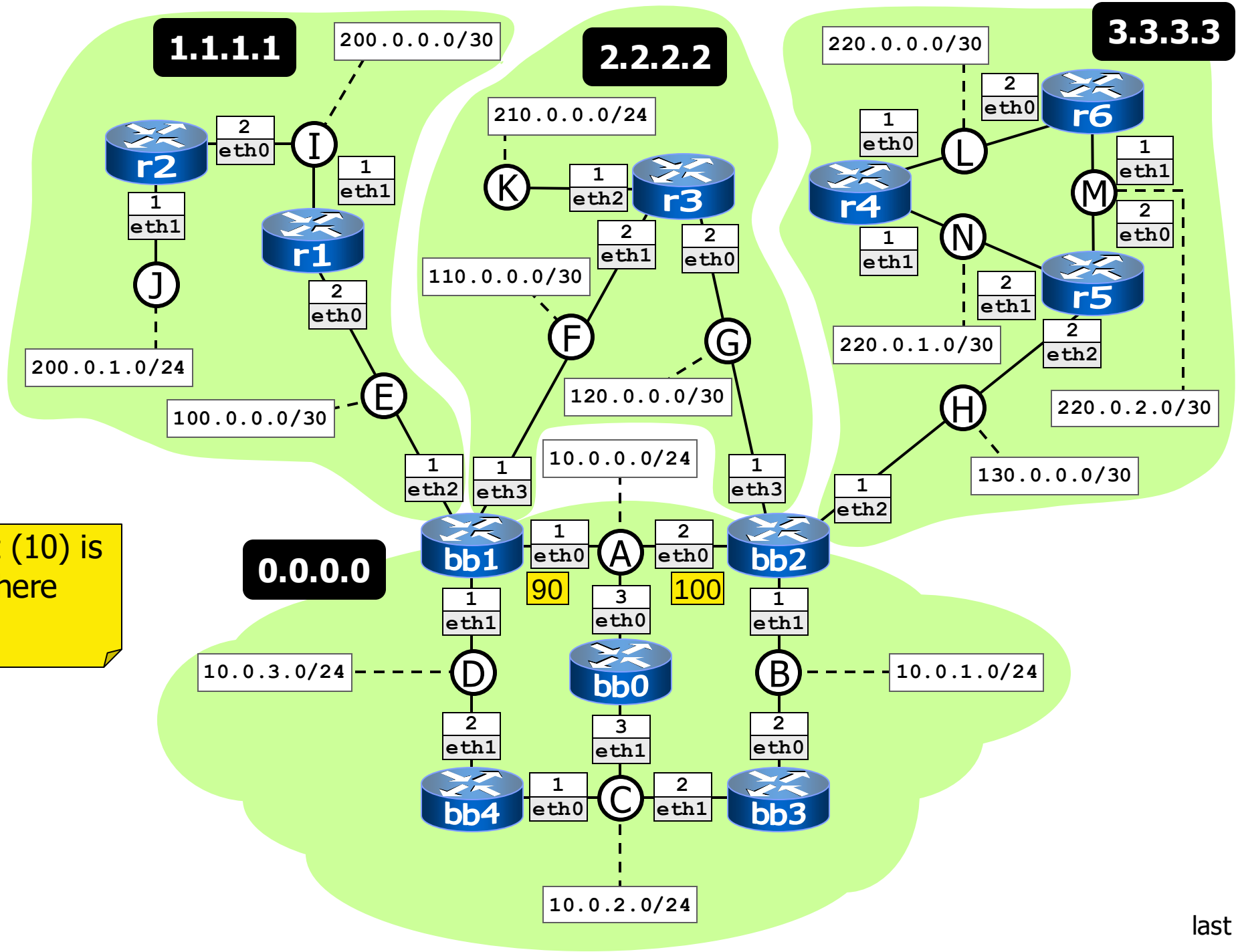

default cost (10) is assumed where unspecified

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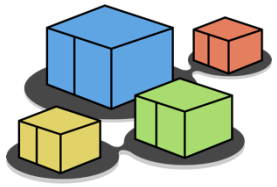
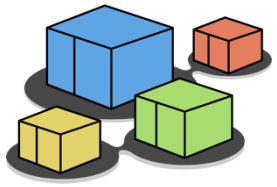


area configuration

- area information is found in two places
  - when enabling ospf on router interfaces
    `network 200.0.0.0/16 area 1.1.1.1`
  - when specifying the area type (not required for the backbone)
    `area 1.1.1.1 stub`



ospf path types

- there are 4 path types
  1. intra-area
  2. inter-area
  3. external type 1
  4. external type 2
- types can coexist in the same network
- each type is preferred over the following ones

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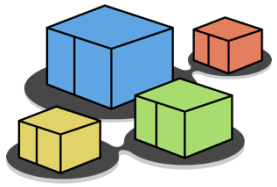
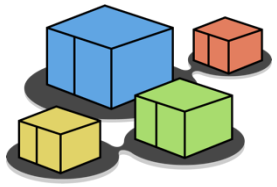


ospf path types

- intra-area paths
  - calculated using the shortest-path tree



ospf path types

- inter-area paths
  - abrs inject summary information inside each area, to make it aware of available destinations in other areas
    - such information includes the cost of the shortest path from the abr to the destination
    - if multiple subnets are summarized into a single network, the route cost will be the maximum cost to any of the component subnets
  - an inter-area path is always composed of:
    - an intra-area path from the source to the abr
    - a backbone path between the source and destination areas
    - an intra-area path to the destination

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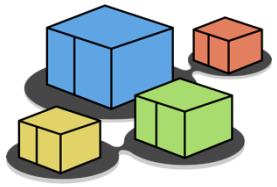

ospf path types

- external paths are learned from other routing protocols (e.g., bgp)
- type 1: the cost is expressed in terms of
  - the external (bgp) route cost* +
  - the ospf cost to the asbr

  example with bgp cost=495, ospf cost=10:

```
N E1 50.0.0.0/16        [505] tag: 0
                        via 10.0.1.2, eth1
```

* cost used when redistributing the protocol (bgp) into ospf; default for bgp=20; configurable by using `redistribute bgp metric` *`value`*

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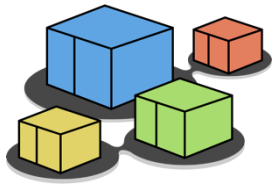

ospf path types

- external paths are learned from other routing protocols (e.g., bgp)
- type 1: the cost is expressed in terms of
  - the external (bgp) route cost* +
  - the ospf cost to the asbr
- type 2: the cost is expressed in terms of
  - the external (bgp) route cost* only (distance to the asbr is only used to break ties)

example with bgp cost=495, ospf cost=10:

```
N E2 50.0.0.0/16      [10/495] tag: 0
                      via 10.0.1.2, eth1
```

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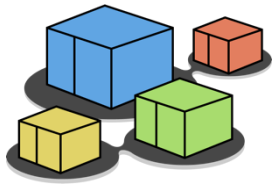

ospf path types

- external paths are learned from other routing protocols (e.g., bgp)
- type 1: the cost is expressed in terms of
  - the external (bgp) route cost* +
  - the ospf cost to the asbr
- type 2: the cost is expressed in terms of
  - the external (bgp) route cost* only (distance to the asbr is only used to break ties)
- metric type is user-configurable

```
redistribute bgp metric-type 2 metric 495
```

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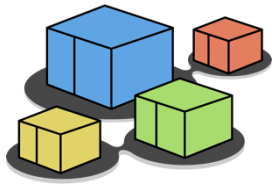


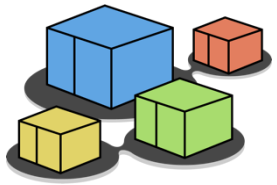
experiments

- check that routers know detailed topology information only about their own area

r2

```
r2# show ip ospf neighbor

Neighbor ID     Pri State           Up Time    Dead Time Address  Interface      RXmtL RqstL DBsmL
200.0.0.1         1 Full/Backup     1m17s      32.279s 200.0.0.1  eth0:200.0.0.2     0     0     0
```



experiments

- check that routers know detailed topology information only about their own area

r2

```
r2# show ip ospf database router
 OSPF Router with ID (200.0.1.1)
                Router Link States (Area 1.1.1.1 [Stub])
  ...
  Link State ID: 110.0.0.1
  ...
   Number of Links: 1
    Link connected to: a Transit Network
     (Link ID) Designated Router address: 100.0.0.2
     (Link Data) Router Interface address: 100.0.0.1
    ...
  Link State ID: 200.0.0.1
  ...
   Number of Links: 2
    Link connected to: a Transit Network
     (Link ID) Designated Router address: 100.0.0.2
     (Link Data) Router Interface address: 100.0.0.2
     ...
    Link connected to: a Transit Network
     (Link ID) Designated Router address: 200.0.0.2
     (Link Data) Router Interface address: 200.0.0.1
     ...
```

note: the output has been summarized

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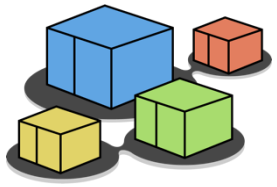

experiments

- check that routers know detailed topology information only about their own area

r2

```
r2# show ip ospf database network
       OSPF Router with ID (200.0.1.1)
                Net Link States (Area 1.1.1.1 [Stub])
  LS age: 759
  Options: 0x0  : *|-|-|-|-|-|-|-
  LS Flags: 0x6
  LS Type: network-LSA
  Link State ID: 100.0.0.2 (address of Designated Router)
  Advertising Router: 200.0.0.1
  LS Seq Number: 80000001
  Checksum: 0x09ec
  Length: 32
  Network Mask: /30
        Attached Router: 110.0.0.1
        Attached Router: 200.0.0.1
  LS age: 763
  Options: 0x0  : *|-|-|-|-|-|-|-
  LS Flags: 0x3
  LS Type: network-LSA
  Link State ID: 200.0.0.2 (address of Designated Router)
  Advertising Router: 200.0.1.1
  LS Seq Number: 80000001
  ...
```

note: the output has been summarized

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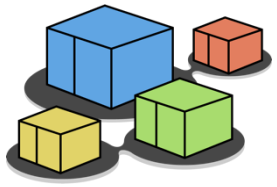

experiments

- check what routers know about the outside of the area, using the **`show ip ospf database summary`** command
  - in particular, check the **`Metric`** values, that show how far away the destination is from the advertising abr
- check that routers in stub areas are offered a default route, whereas routers in the backbone are not
  - also check what **`Metric`** is assigned to the default route

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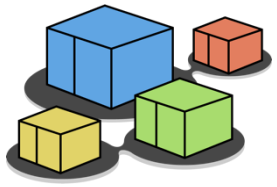

experiments

- experiment ospf's recovery capabilities
  - when multiple equal cost routes are available, ospf keeps all of them
  - check it by verifying what **`r3`** knows about the default route

r3

```
r3# show ip ospf route
============ OSPF network routing table ============
N IA 0.0.0.0/0              [11] area: 2.2.2.2
                            via 110.0.0.1, eth1
                            via 120.0.0.1, eth0

...
```

inter-area path

equal cost routes

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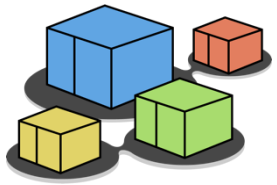

experiments

- experiment ospf's recovery capabilities
  - when multiple equal cost routes are available, ospf keeps all of them
  - check it by verifying what **`r3`** knows about the default route
  - zebra performs the actual selection

r3

```
r3# 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, F - PBR, f - OpenFabric, > - selected route,
       * - FIB route, q - queued, r - rejected, b - backup t - trapped, o - offload
failure

O>* 0.0.0.0/0 [110/11] via 110.0.0.1, eth1, weight 1, 00:18:15
  *                    via 120.0.0.1, eth0, weight 1, 00:18:15
```

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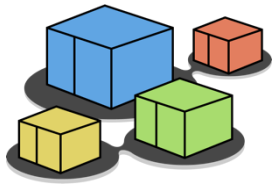

experiments

- experiment ospf's recovery capabilities
  - when multiple equal cost routes are available, ospf keeps all of them
  - check it by verifying what **`r3`** knows about the default route
  - zebra performs the actual selection
    - now bring **`bb1`**'s **`eth3`** down using **`ifconfig`**, wait a few seconds and check how the routing is changed
    - bring **`bb1`**'s **`eth3`** back up and check again how the routing is changed

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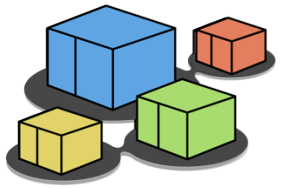

Kathará

lab: ospf-complex

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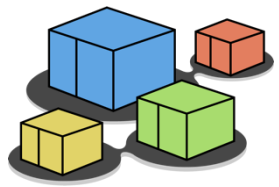

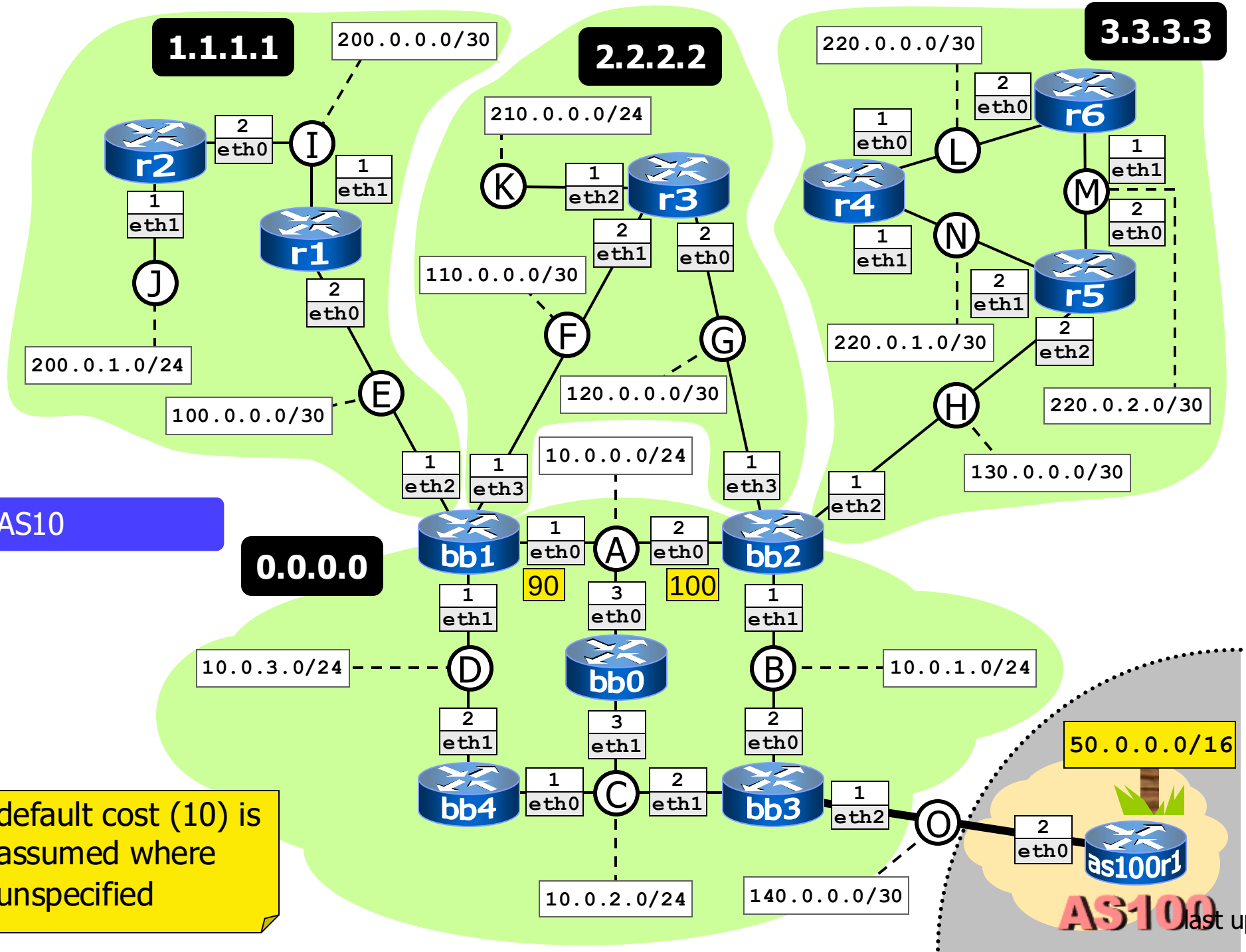

default cost (10) is assumed where unspecified

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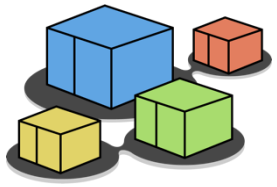

lab description

- same as multiarea + some information is injected via bgp from an external as
  - also, abrs are configured to just inject the default route
    `area 1.1.1.1 stub no-summary`
- perform the same experiments as for the multiarea lab
  - in addition, check asbr information using
    - **`show ip ospf database asbr-summary`**
  - also check that such information is not propagated inside stub areas

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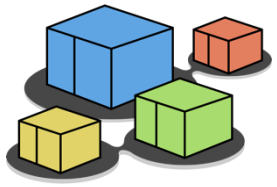
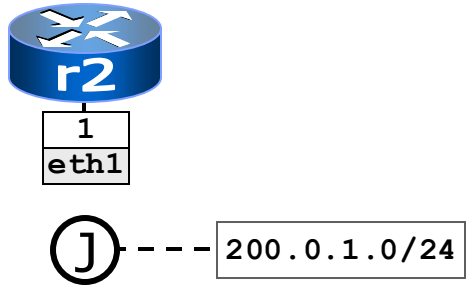


a quick note about stub networks

- "stub" = not used for transit
- three possible situations:



ospf is enabled also on the stub network's interface	then	the stub network is advertised in the entire ospf domain	but → interface uselessly sends hello packets
ospf is not enabled on the stub network's interface	then	the stub network is advertised	but → the stub network is advertised as an AS-external route (hence, only through the backbone)
ospf is enabled on the stub network's interface, which is configured as `passive-interface` ✓	then	the stub network is advertised in the entire ospf domain	but → N/A

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