OSPF Single area setup
OSPF działający w pojedynczym obszarze

- Podczas zajęć zostanie utworzona sieć składająca się z pięciu maszyn wirtualnych przeznaczonych do pracy jako routery OSPF
- Przed uruchomieniem maszyny zostaną wyposażone w podstawową konfigurację
- Zostaną także nadane koszty OSPF poszczególnych interfejsów
- W ramach zajęć proszę:
  - Przeprowadzić analizę działania protokołu OSPF w pojedynczym obszarze (ang. *area*)
  - Wprowadzić zmiany kosztów interfejsów i zaobserwować wynik działania
  - Zapoznać się z funkcją **rutera wyróżnionego** oraz sposobem wyboru rutera wyróżnionego (ang. *designated router*)
  - Zapoznać się ze znaczeniem komunikatów router LSA, network LSA
  - Zapoznać się ze sposobem tworzenia baz wiedzy w protokole OSPF
  - Zapoznać ze znaczeniem sąsiadów (ang. *neighbor*) w protokole OSPF
- **Celem zajęć jest poznanie działania protokołu OSPF w sieci z jednym obszarem OSPF (ang*. single area* OSPF).**

netkit lab(s)

ospf

Version	1.3
Author(s)	Giuseppe Di Battista, Massimo Rimondini
E-mail	contact@netkit.org
Web	http://www.netkit.org/
Description	A set of labs showing the operation of the ospf routing protocol in different scenarios

Modified for the purpose of the IP Networks lab

copyright notice

about ospf

- open shortest path first
- an interior gateway protocol (like rip, is-is)

	specification	authentication confidentiality
version 2	rfc 2328	rfc 5709
version 3 (with ipv6 support)	rfc 5340	rfc 4552

ospf: overview

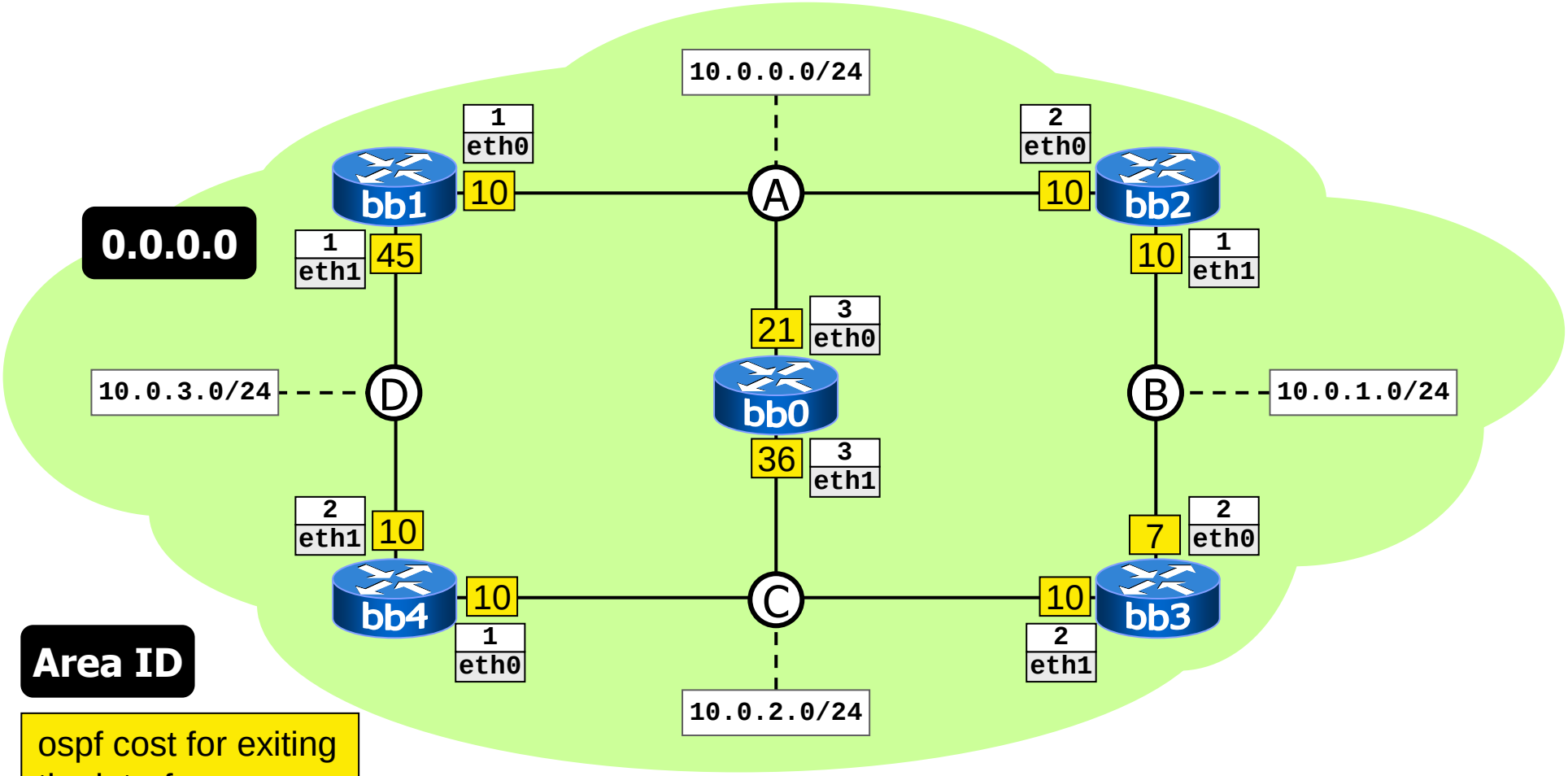
- each router floods its local state (usable interfaces, reachable neighbors) through the network, using link state advertisements (lsa)
- based on this information, each router builds and maintains a link state database (lsdb) describing the whole network topology
  - identical for (almost) all routers
  - 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

- note: designed to operate on broadcast networks, but has modes to operate on non-broadcast ones

a simple ospf lab

single-area

lab topology

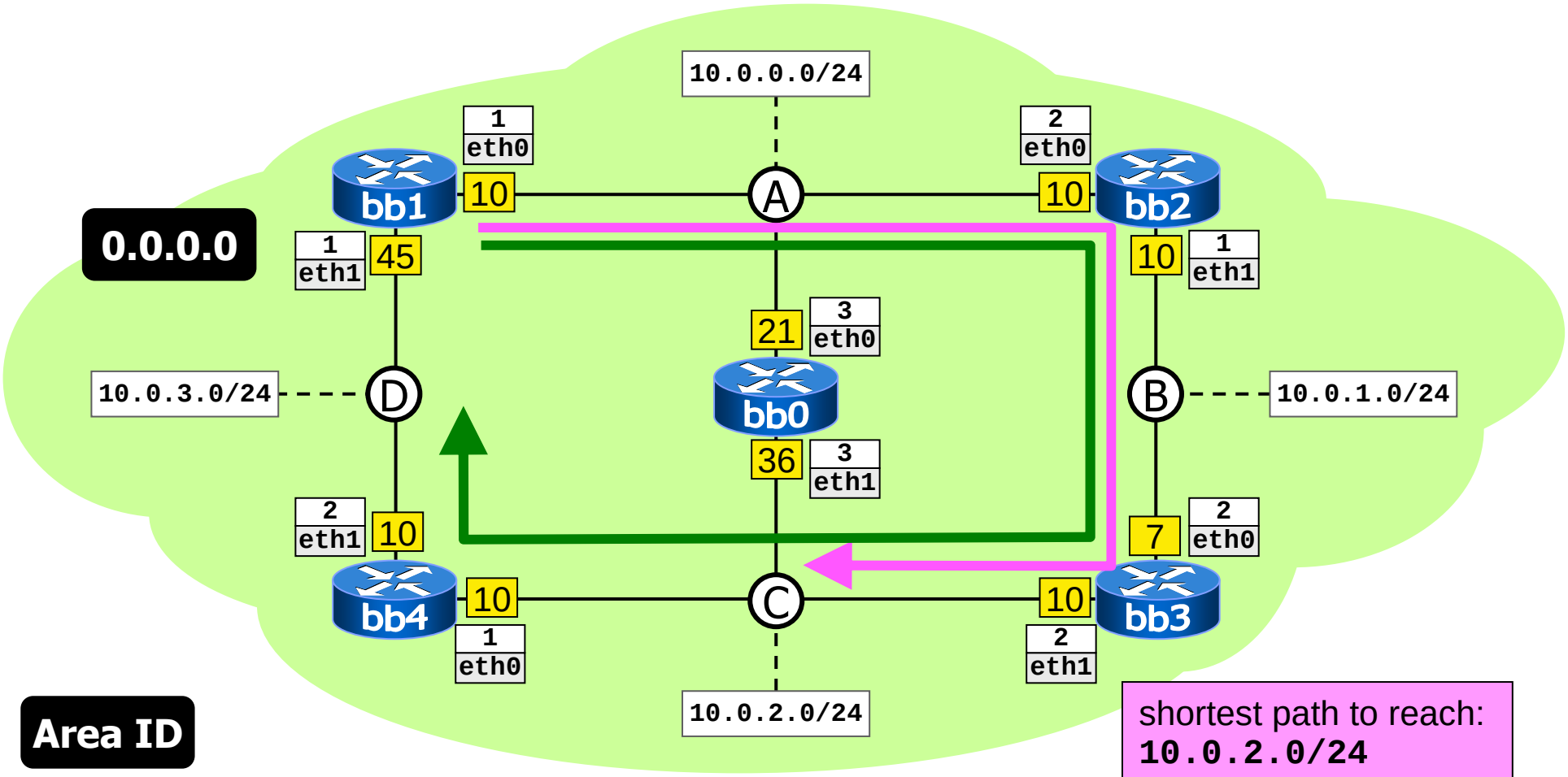


lab description

- 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
```

(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**

experiments

- perform traceroutes from/to different interfaces
- perform a **`traceroute -I (icmp)`** 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 -I`** 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 **`zebra`**, check the administrative distances of different entries)
- try to alter the costs and observe the effect of the changes

experiments

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

designated routers
(router interfaces designated for each network)

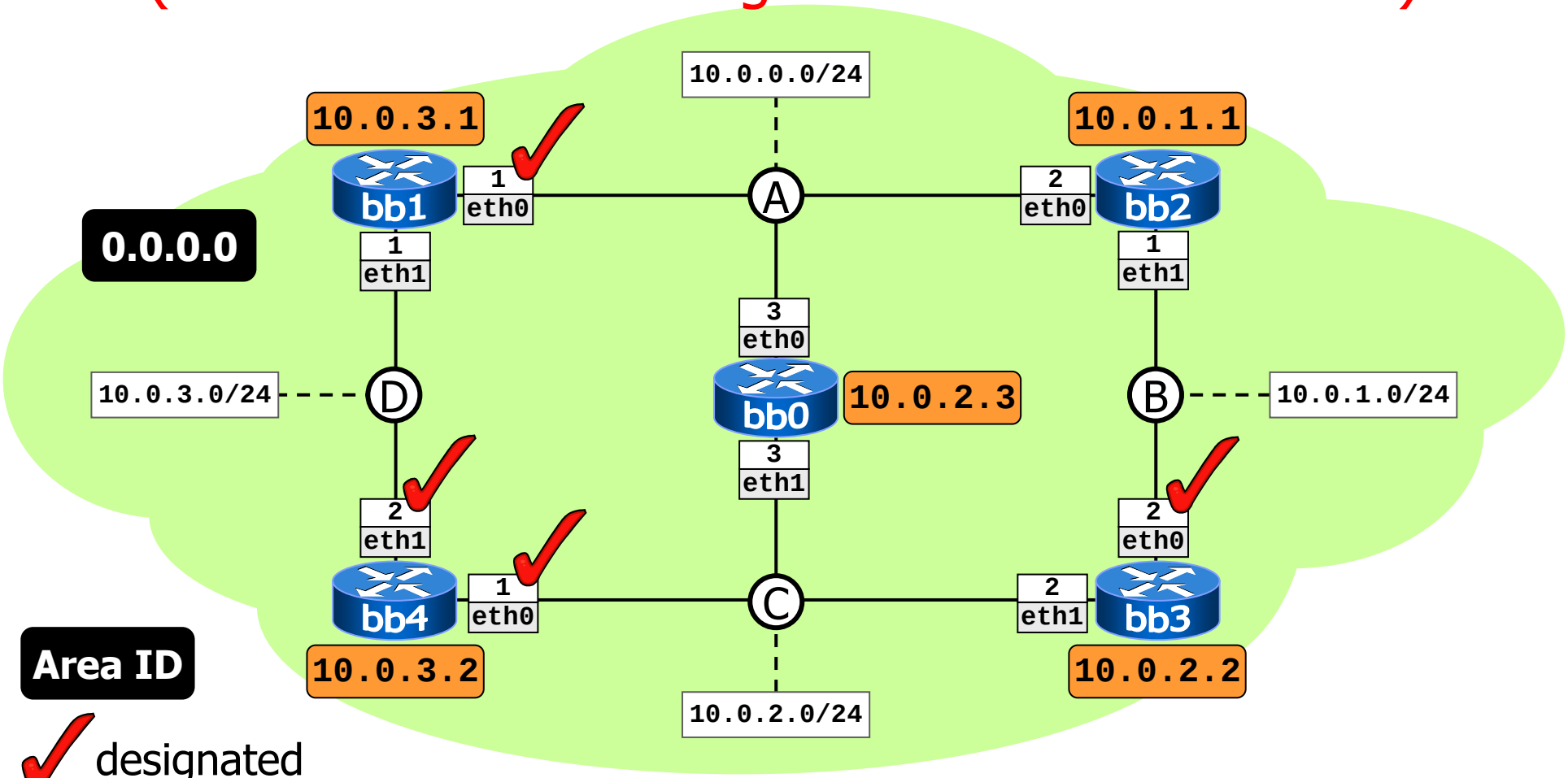
- for each network, one of the interfaces attached to that network is elected as designated (dr)
- priority-based election, using hello packets
  - the router (interface) sending hello packets with **highest priority** wins the election
  - break ties on **highest router id**
    - by default, a router 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

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

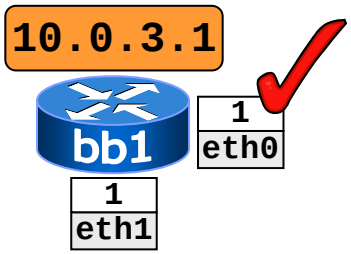
designated routers

(router interfaces designated for each network)



designated routers

(router interfaces designated for each network)



designated

router id

bb1

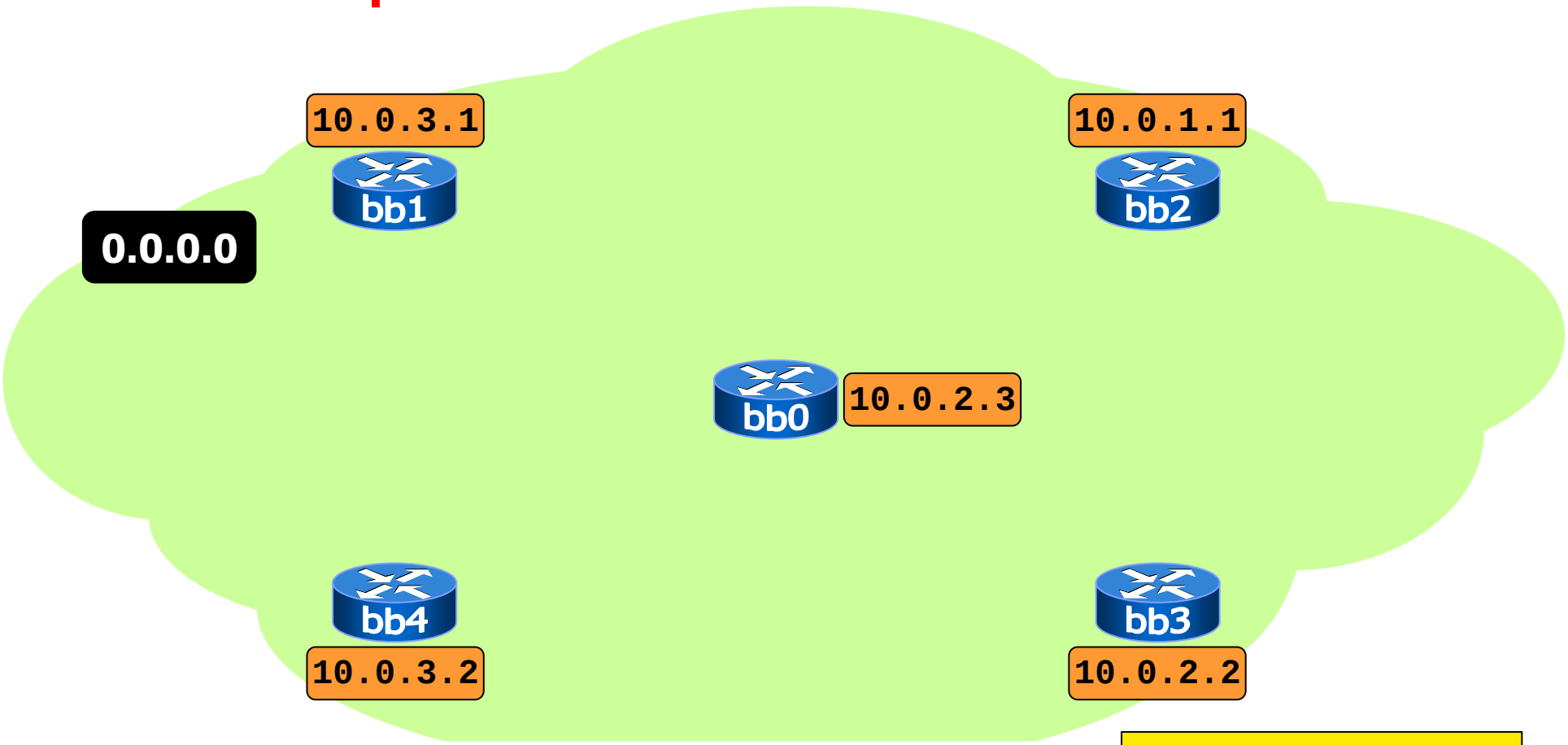
```
bb1# show ip ospf interface
eth0 is up
  ifindex 3, MTU 1500 bytes, BW 0 Kbit <UP,BROADCAST,RUNNING,MULTICAST>
  Internet Address 10.0.0.1/24, Broadcast 10.0.0.255, Area 0.0.0.0
  MTU mismatch detection:enabled
  Router ID 10.0.3.1, Network Type BROADCAST, Cost: 10
  Transmit Delay is 1 sec, State DR, Priority 1
  Designated Router (ID) 10.0.3.1, Interface Address 10.0.0.1
  Backup Designated Router (ID) 10.0.3.2, Interface Address 10.0.0.3
  Multicast group memberships: OSPFAllRouters OSPFDesignatedRouters
  Timer intervals configured, Hello 10s, Dead 40s, Wait 40s, Retransmit 5
    Hello due in 8.784s
  Neighbor Count is 2, Adjacent neighbor count is 2
eth1 is up
  ifindex 4, MTU 1500 bytes, BW 0 Kbit <UP,BROADCAST,RUNNING,MULTICAST>
  Internet Address 10.0.3.1/24, Broadcast 10.0.3.255, Area 0.0.0.0
  MTU mismatch detection:enabled
  Router ID 10.0.3.1, Network Type BROADCAST, Cost: 45
  Transmit Delay is 1 sec, State Backup, Priority 1
  Designated Router (ID) 10.0.3.2, Interface Address 10.0.3.2
  Backup Designated Router (ID) 10.0.3.1, Interface Address 10.0.3.1
  Multicast group memberships: OSPFAllRouters OSPFDesignatedRouters
  Timer intervals configured, Hello 10s, Dead 40s, Wait 40s, Retransmit 5
    Hello due in 3.504s
  Neighbor Count is 1, Adjacent neighbor count is 1
lo is up
  ifindex 1, MTU 16436 bytes, BW 0 Kbit <UP,LOOPBACK,RUNNING>
  OSPF not enabled on this interface
teql0 is down
  ifindex 2, MTU 1500 bytes, BW 0 Kbit <NOARP>
  OSPF not enabled on this interface
bb1#
```

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

ospf's view of the network

ospf's view of the network

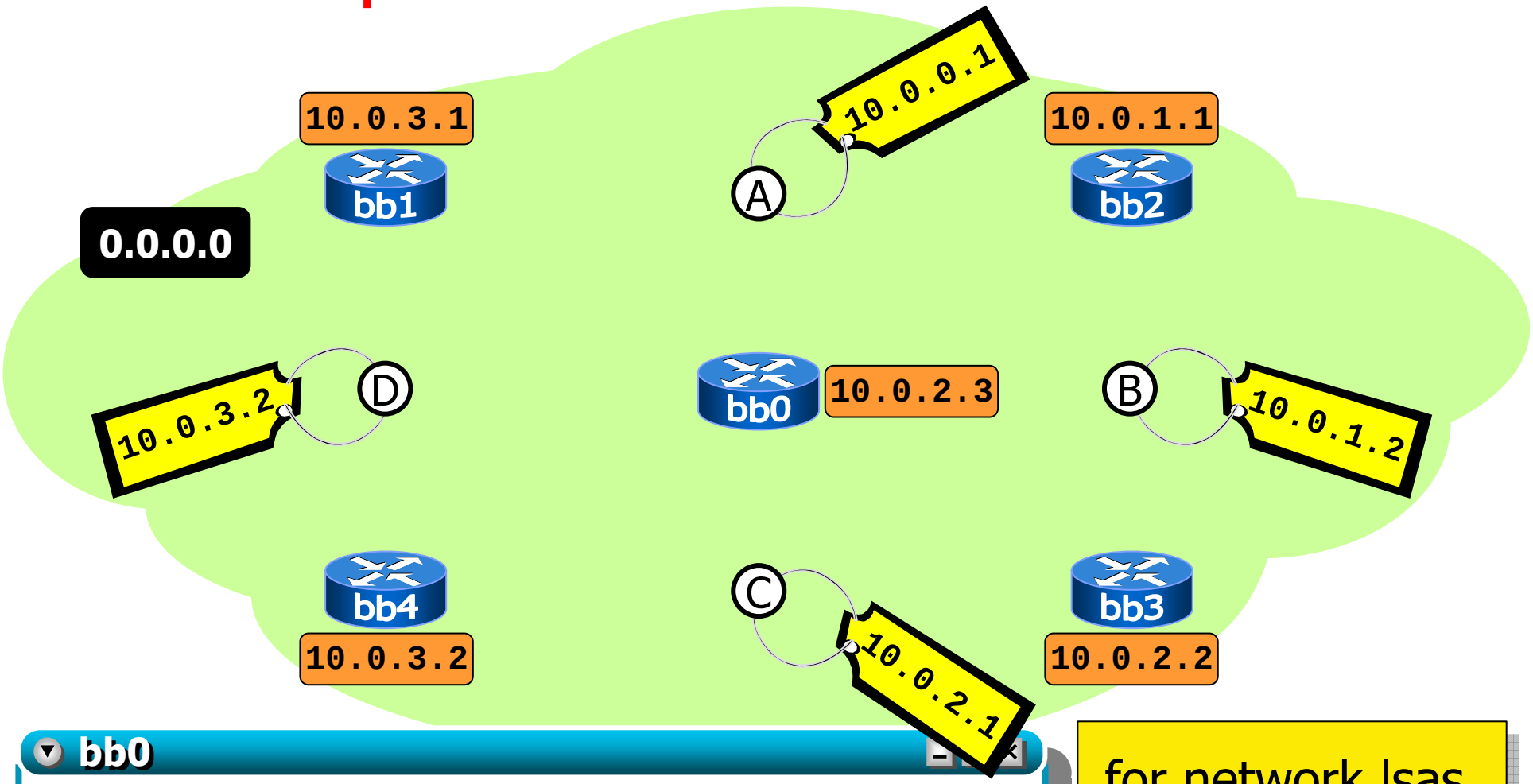


bb0

```
       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        553  0x80000003 0xe9fa 2
10.0.2.2        10.0.2.2        552  0x80000003 0xe3fa 2
10.0.2.3        10.0.2.3        552  0x80000003 0xe7cd 2
10.0.3.1        10.0.3.1        552  0x80000003 0x3288 2
10.0.3.2        10.0.3.2        548  0x80000004 0x488d 2
```

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

ospf's view of the network

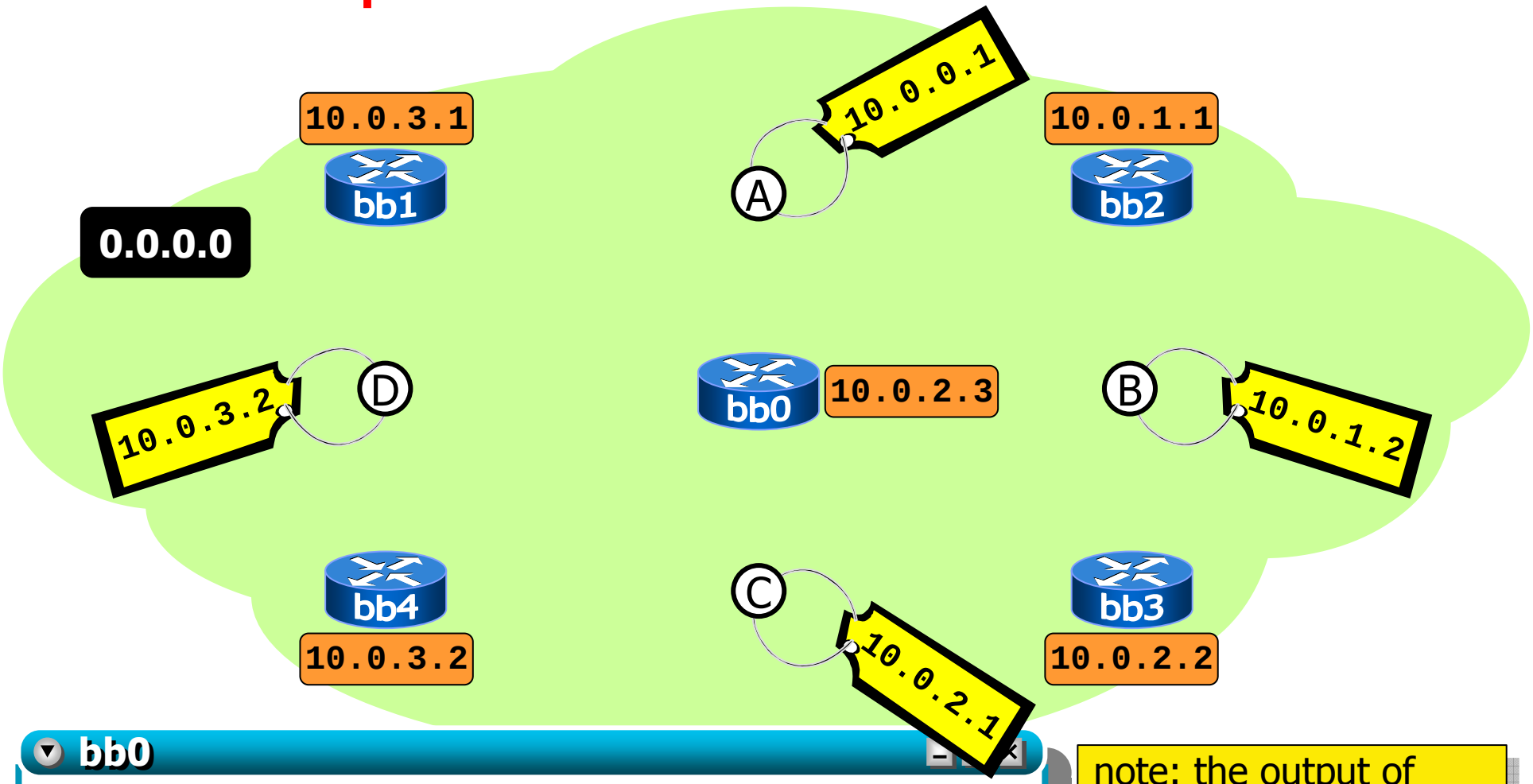


bb0

```
                Net Link States (Area 0.0.0.0)
Link ID         ADV Router      Age  Seq#       CkSum
10.0.0.1        10.0.3.1         557 0x80000001 0x6ba8
10.0.1.2        10.0.2.2         559 0x80000001 0x69bb
10.0.2.1        10.0.3.2         553 0x80000002 0x729a
10.0.3.2        10.0.3.2         553 0x80000001 0x6bb3
```

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

ospf's view of the network

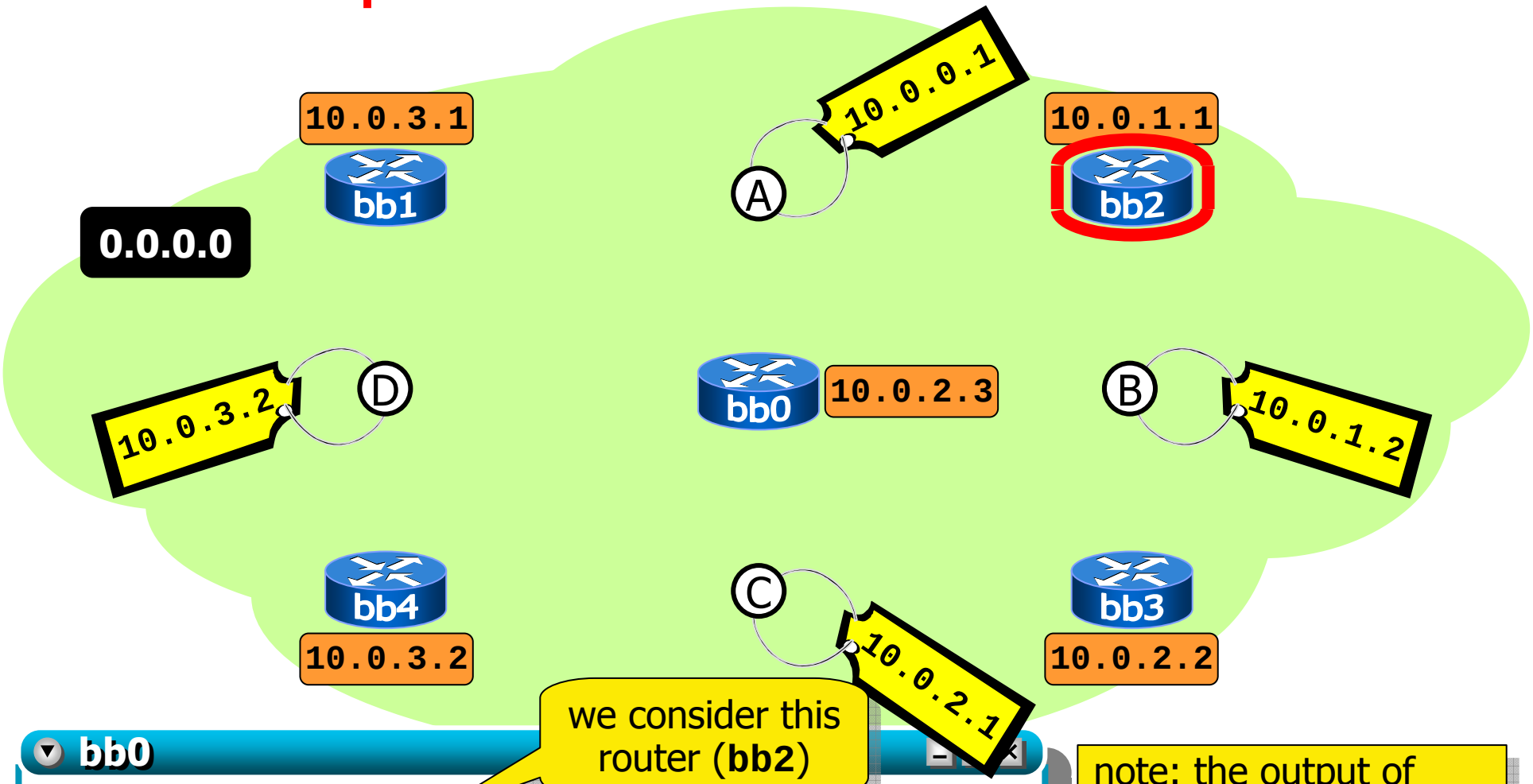


bb0

```
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 database router`** has been summarized

ospf's view of the network



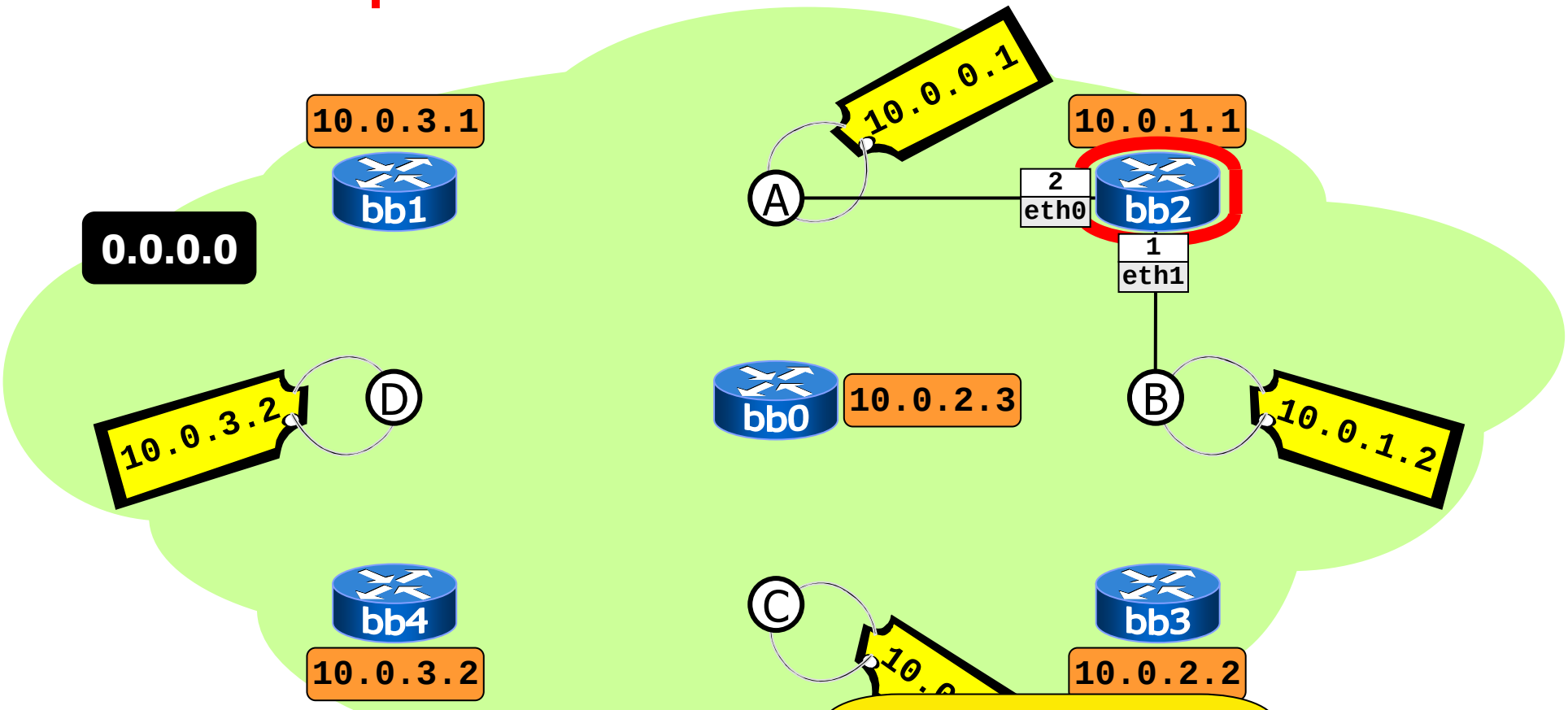
we consider this router (**bb2**)

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 database router`** has been summarized

ospf's view of the network



bb0

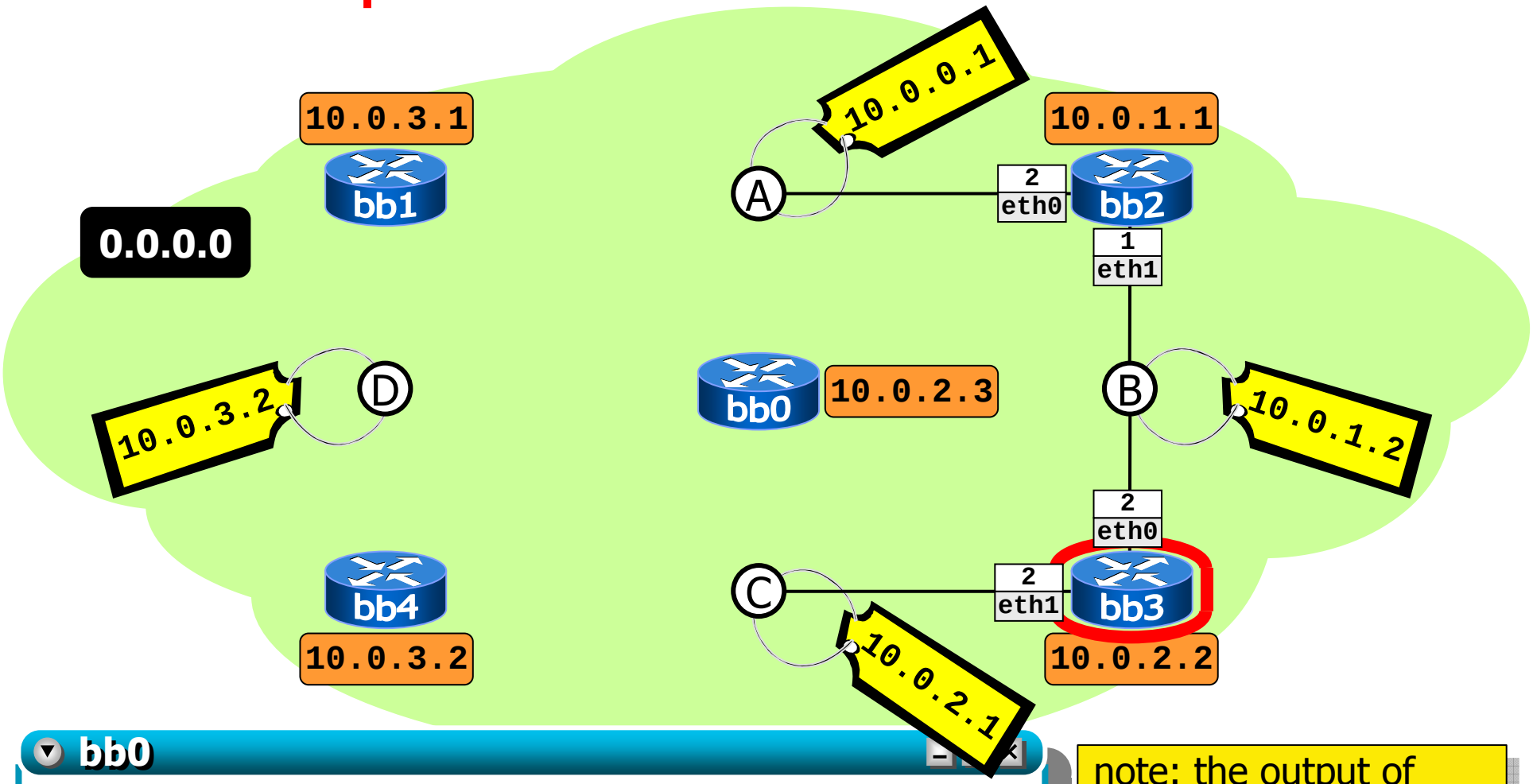
```
bb0# show ip o
 Link State ID
   Number of Links: 2
    Link connected to: a Transit Network
     (Link ID) Designated Router address: 10.0.0.1
     (Link Data) Router Interface address: 10.0.0.2
    Link connected to: a Transit Network
     (Link ID) Designated Router address: 10.0.1.2
     (Link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

this router interface...

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

output of **database** router has been summarized

ospf's view of the network

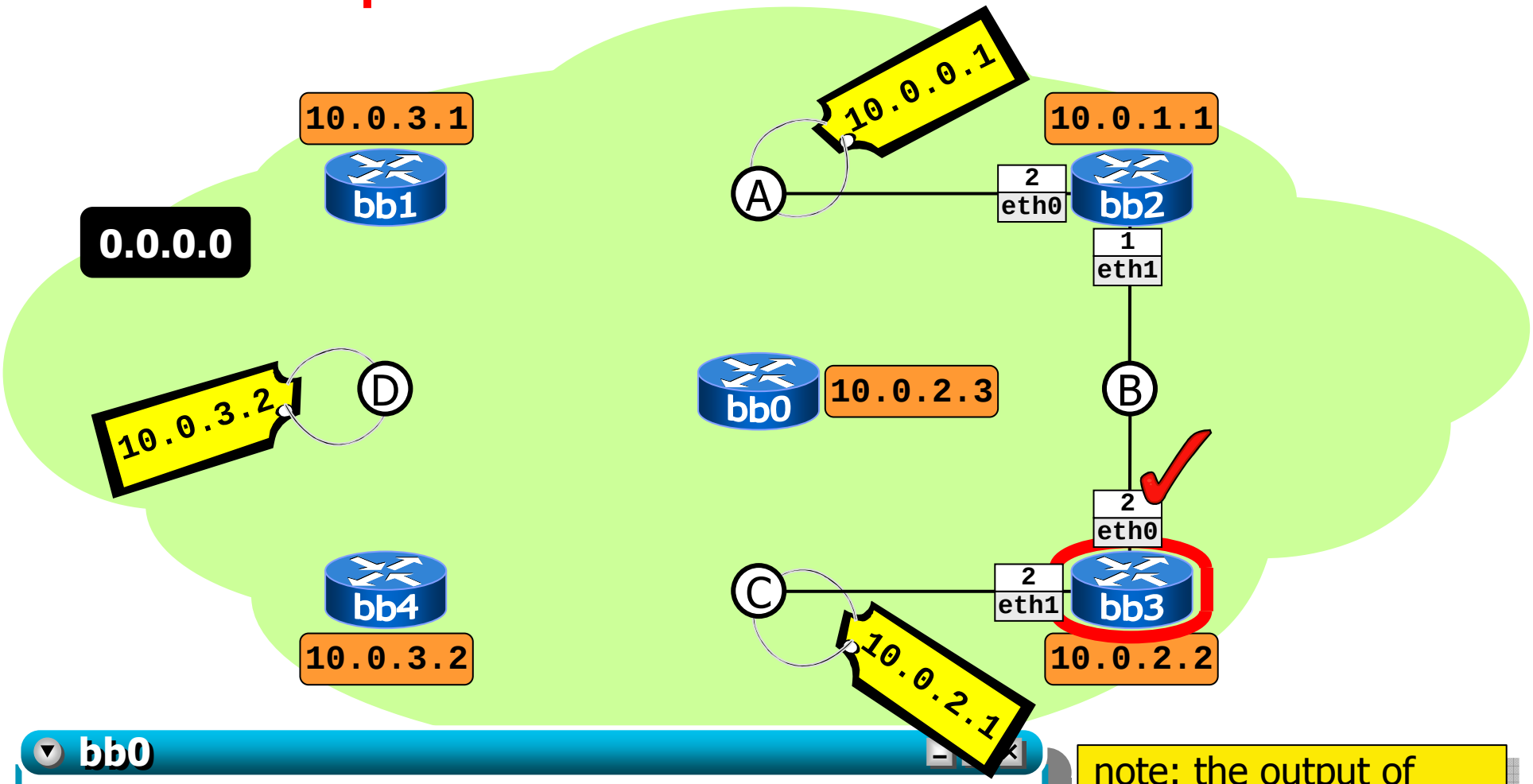


bb0

```
Link State ID: 10.0.2.2
  Number of Links: 2
   Link connected to: a Transit Network
    (Link ID) Designated Router address: 10.0.1.2
    (Link Data) Router Interface address: 10.0.1.2
   Link connected to: a Transit Network
    (Link ID) Designated Router address: 10.0.2.1
    (Link Data) Router Interface address: 10.0.2.2
```

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

ospf's view of the network

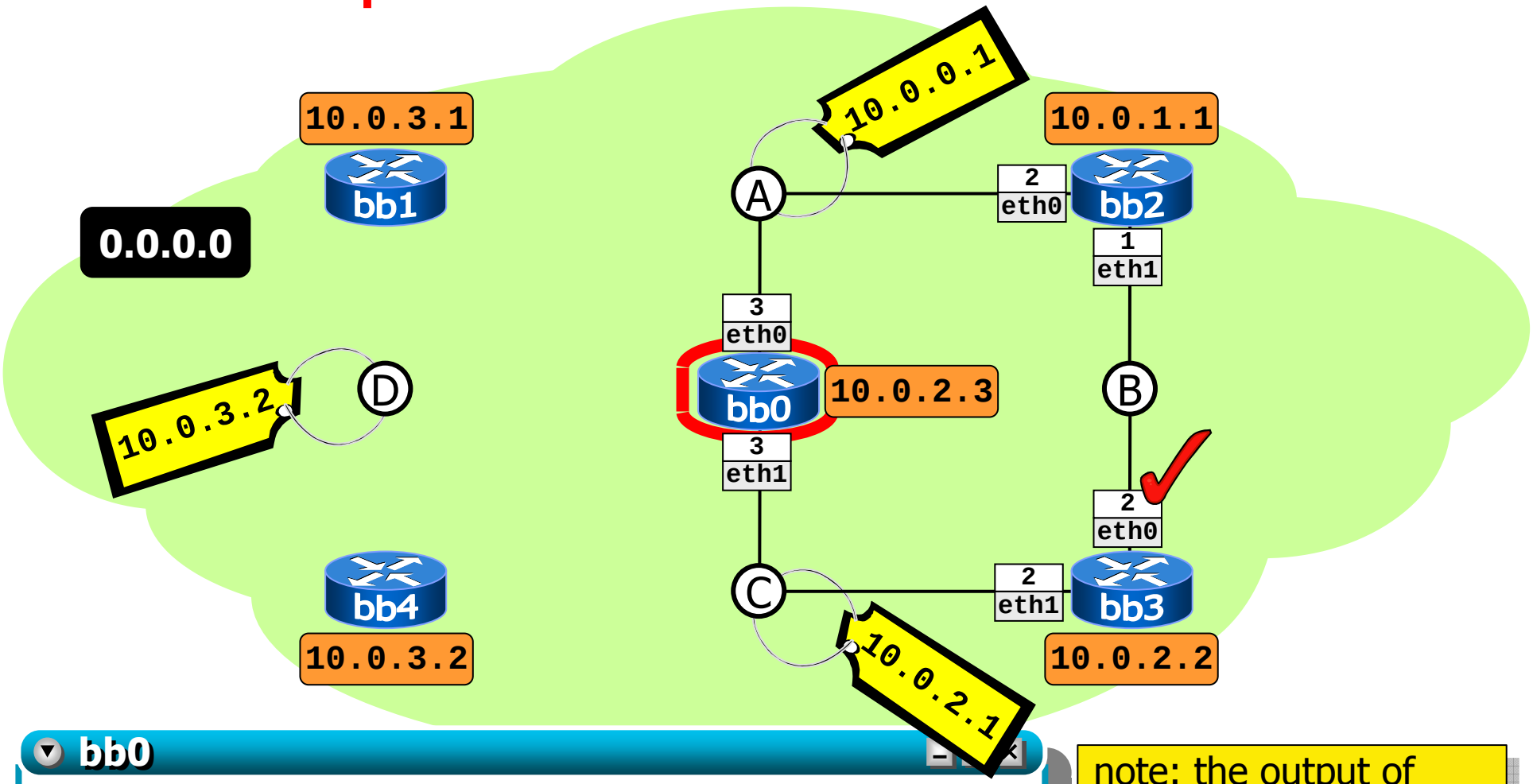


bb0

```
Link State ID: 10.0.2.2
  Number of Links: 2
   Link connected to: a Transit Network
    (Link ID) Designated Router address: 10.0.1.2
    (Link Data) Router Interface address: 10.0.1.2
   Link connected to: a Transit Network
    (Link ID) Designated Router address: 10.0.2.1
    (Link Data) Router Interface address: 10.0.2.2
```

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

ospf's view of the network

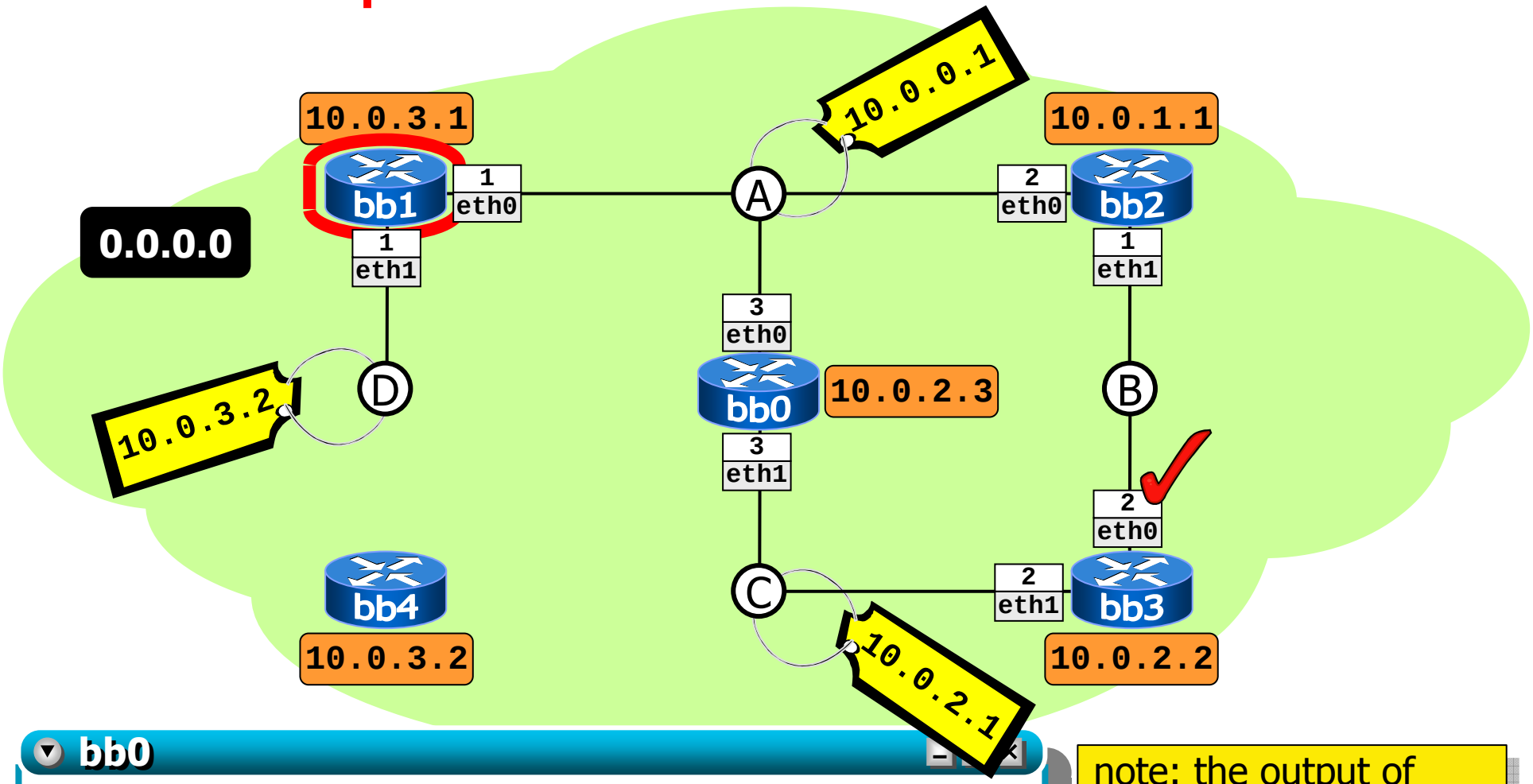


bb0

```
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 database router`** has been summarized

ospf's view of the network

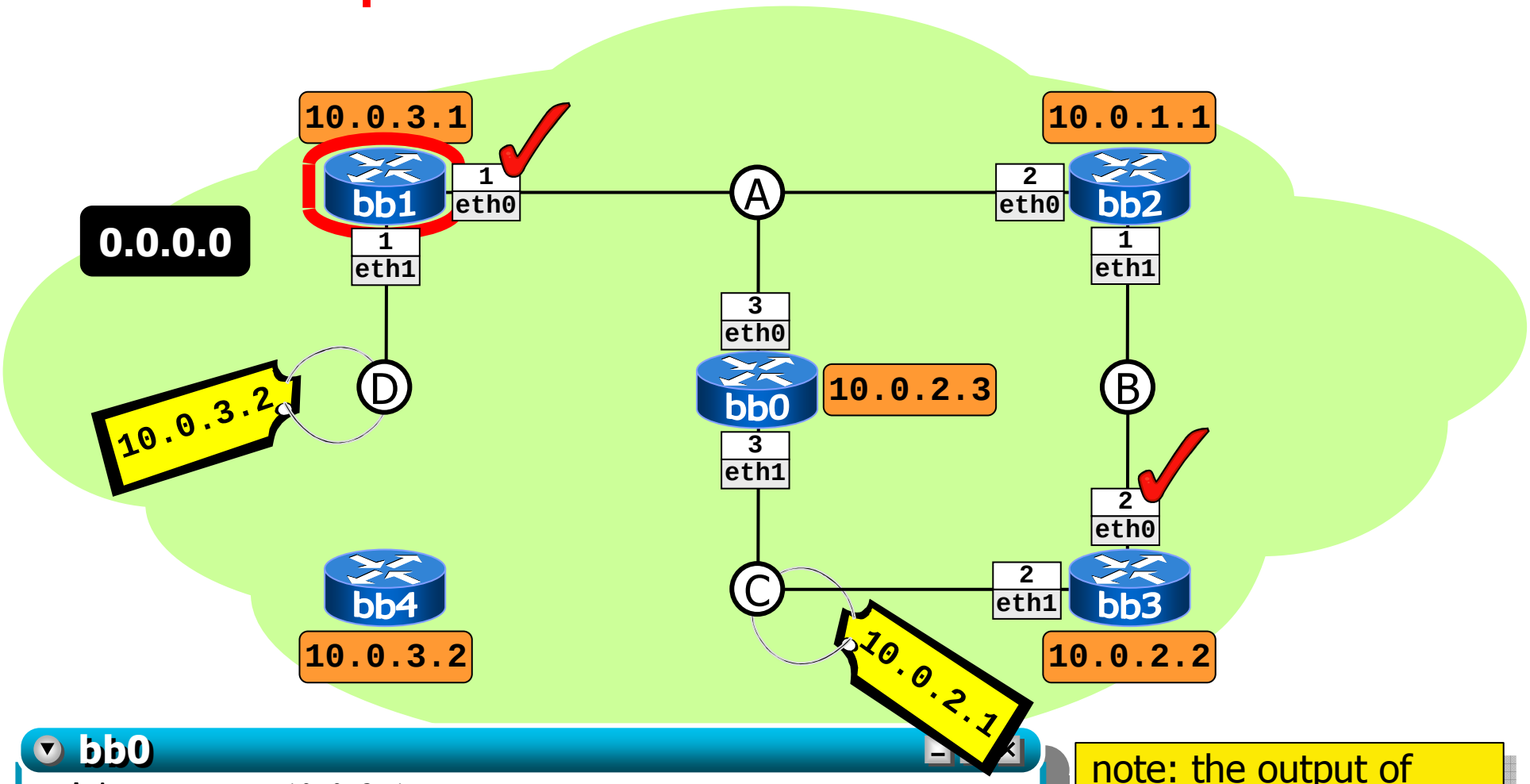


bb0

```
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 database router`** has been summarized

ospf's view of the network

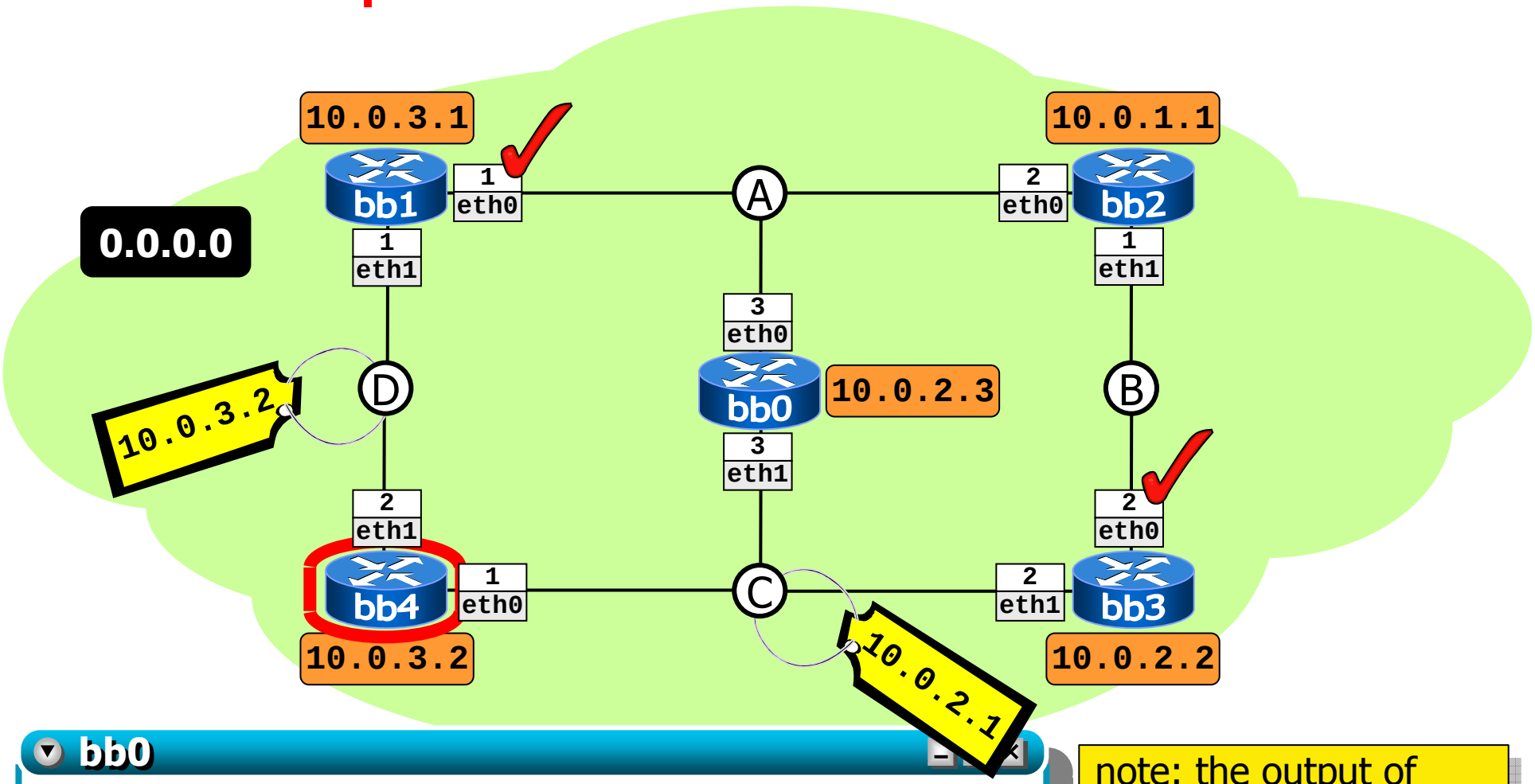


bb0

```
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 database router`** has been summarized

ospf's view of the network

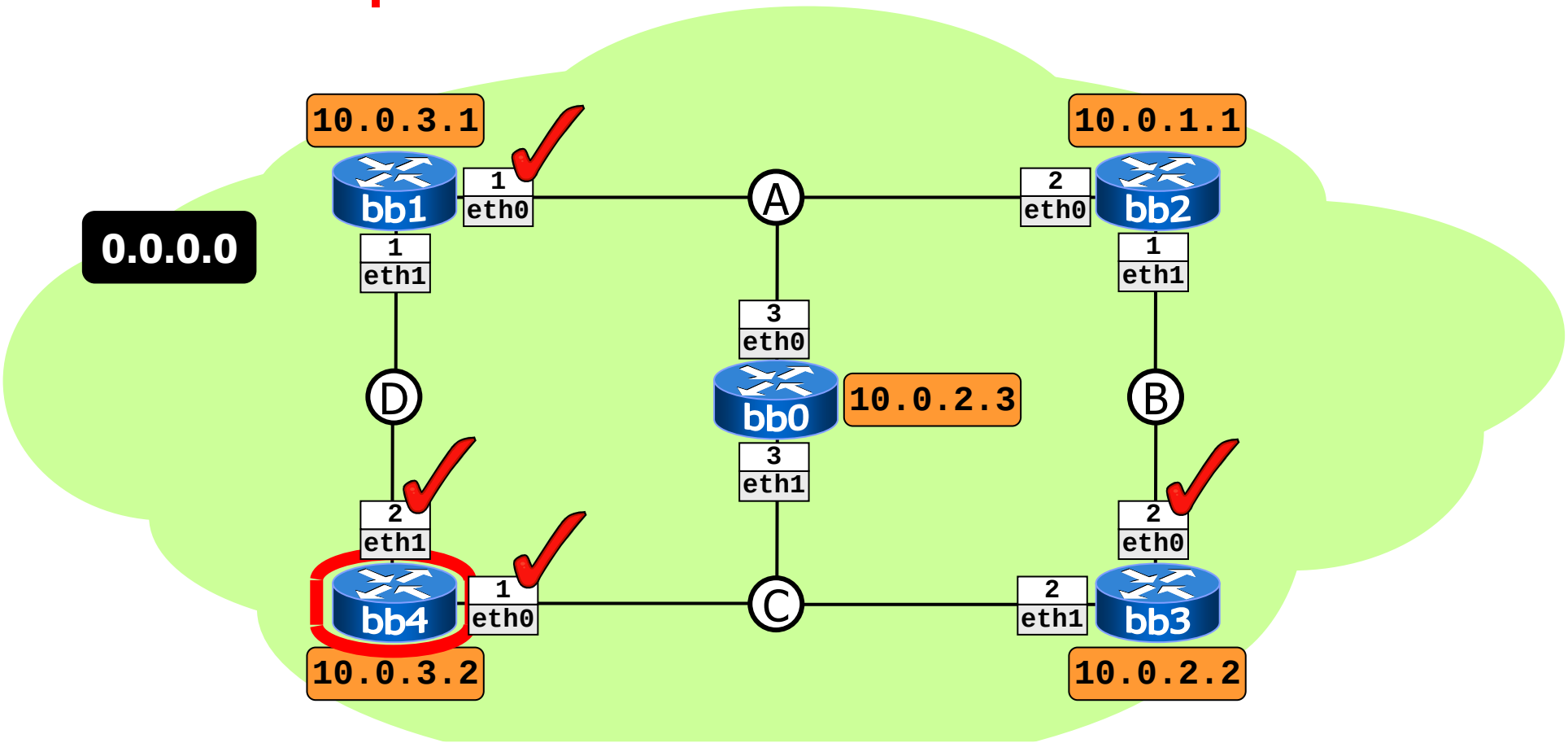


bb0

```
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 database router`** has been summarized

ospf's view of the network

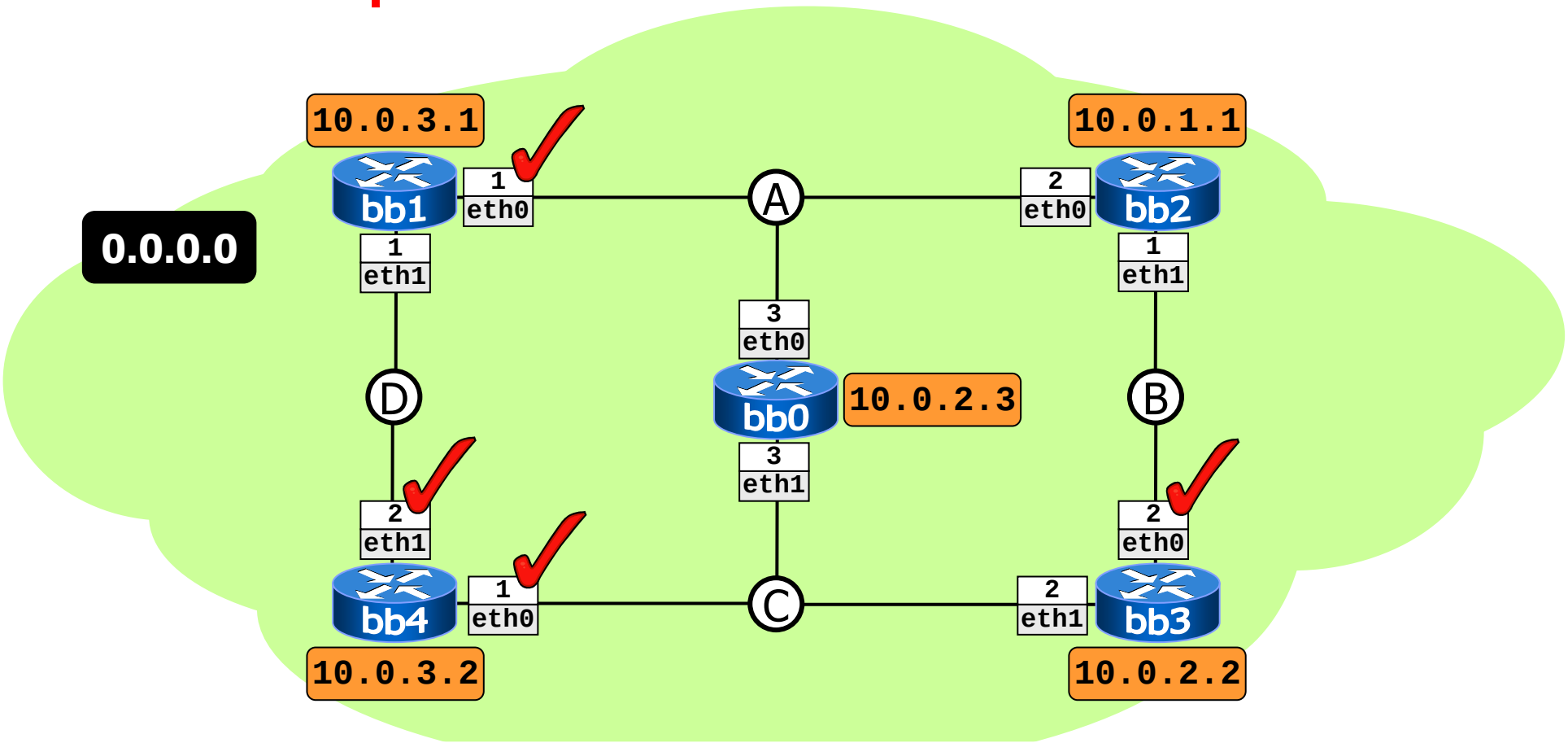


bb0

```
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 database router`** has been summarized

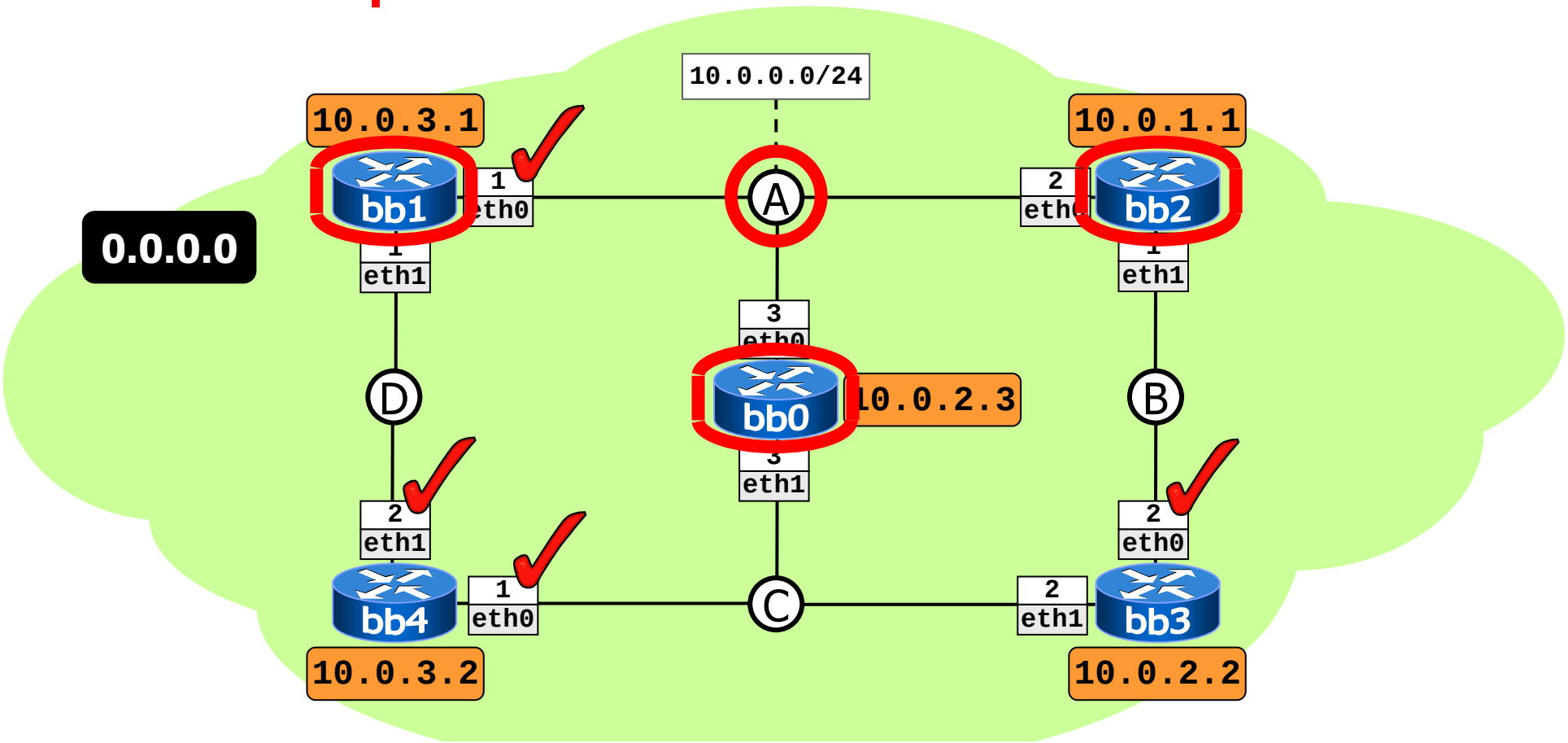
ospf's view of the network



bb0

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

ospf's view of the network

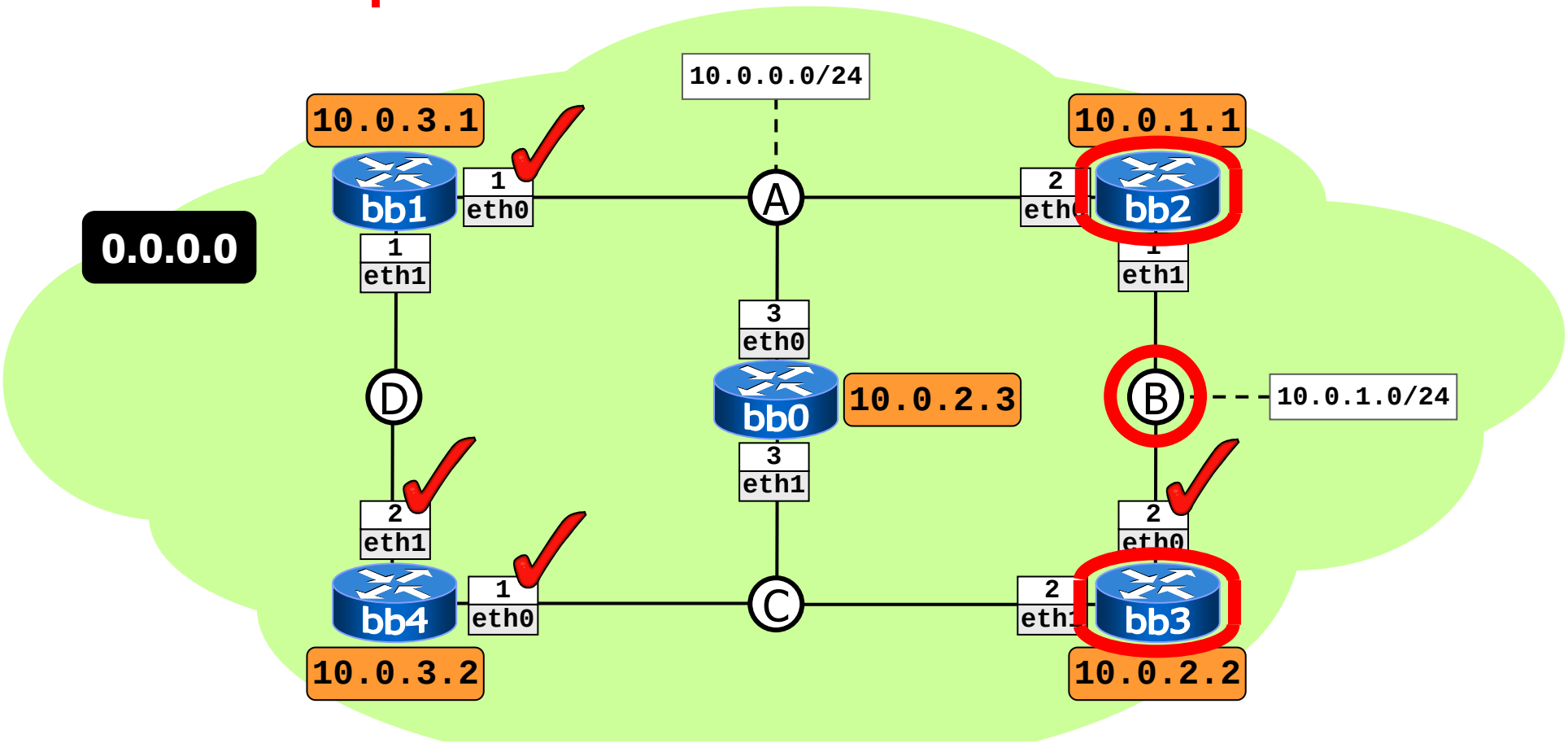


bb0

```
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 database network`** has been summarized

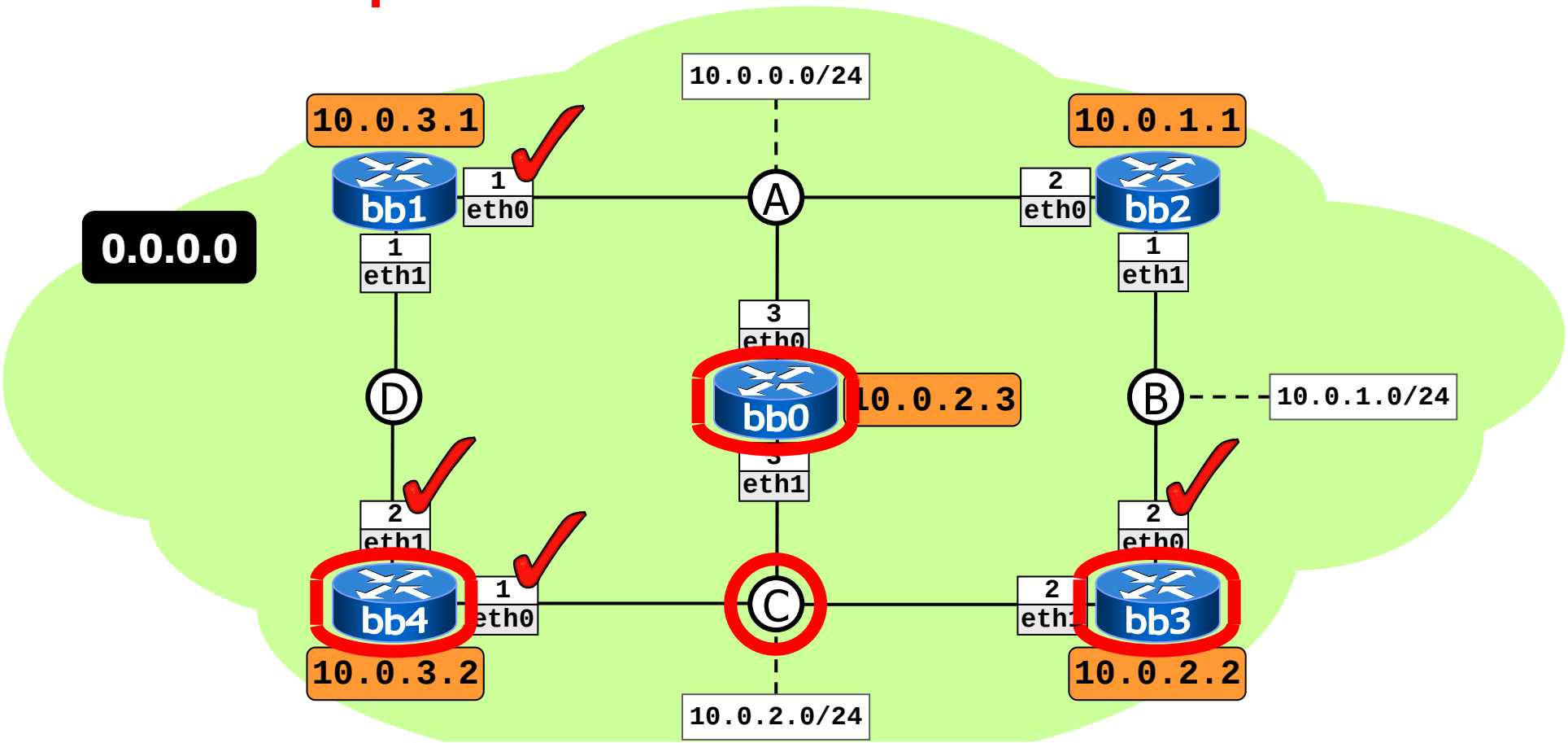
ospf's view of the network




```
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 database network`** has been summarized

ospf's view of the network

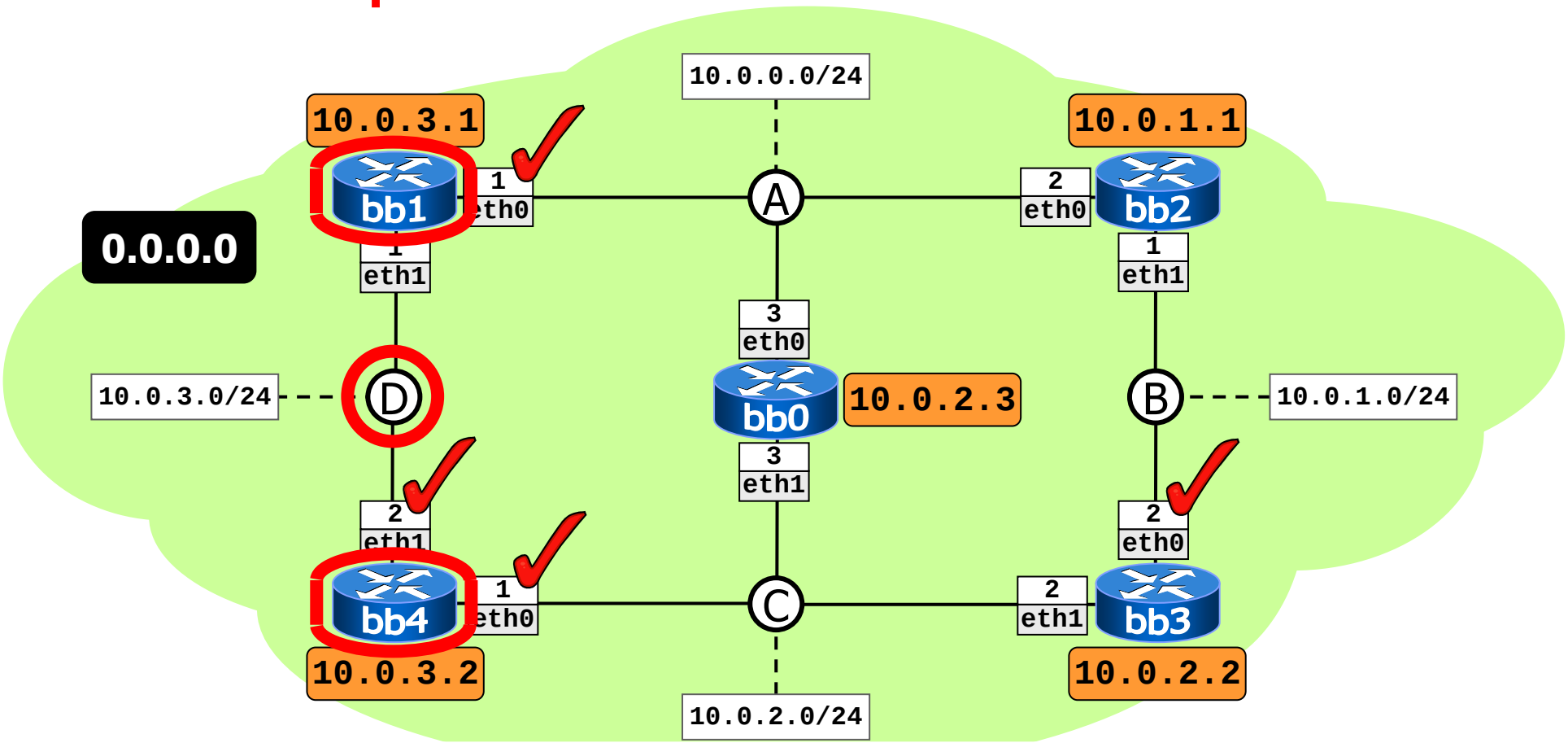


bb0

```
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 database network`** has been summarized

ospf's view of the network

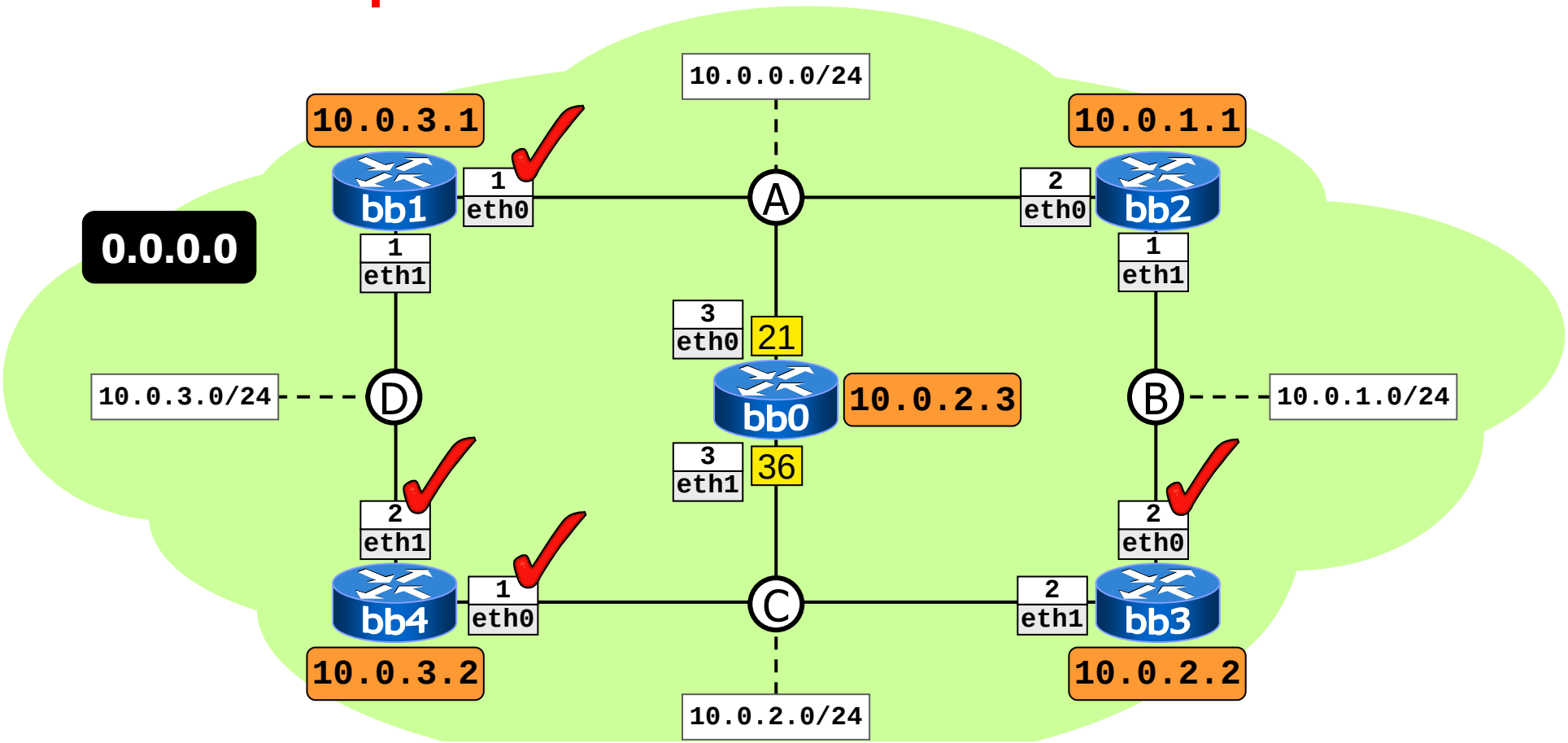


bb0

```
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 database network`** has been summarized

ospf's view of the network



bb0

```
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, Cost: 36
```

a shortcut to quickly get the cost

ospf interface costs can be queried on all routers

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

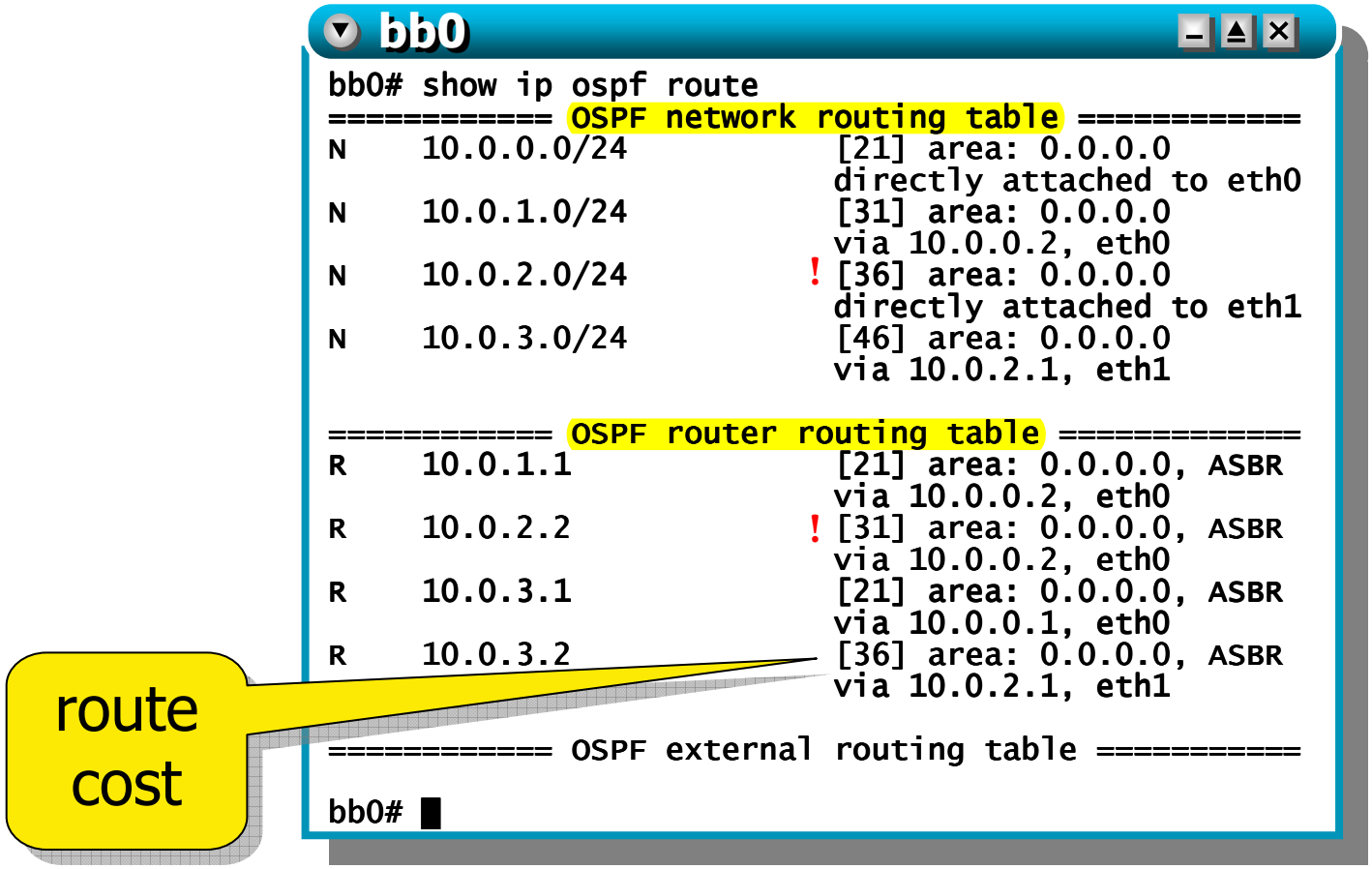
bb0

```
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#
```

ospf routing table

- the ospf routing table can be dumped by using **`show ip ospf route`**



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`**

changing the interface **cost**

- Issue the **`ping -R`** and **`traceroute`** commands from **`bb1`** to **`10.0.2.1`**
  - Analyze the result
- Change the cost of **`eth0`** of **`bb3`** from 7 to 700
  - Issue the **`ping -R`** and **`traceroute`** commands from **`bb1`** to **`10.0.2.1`**
  - Explain the difference with the previous result
  - Sniff traceroute packets at **`bb4 (eth0)`** using **`tcpdump`**
- Change the cost of eth1 of bb3 from 10 to 300
  - Issue the command **`ping -R`** and **`traceroute`** from **`bb1`** to **`10.0.2.1`**
  - Analyze the result

Reporting

- Please deliver the following items to the UPEL system using your account
  1. A photocopy or a screenshot showing the output of the following commands executed on router bb1
     - **`show ip ospf interface`**
     - **`show ip ospf database`**
     - **`show ip ospf neighbor`**

Lab Scenario Personalization

- Modify the default scenario in the following way
  - Change the IP address of the `eth1` interface of `bb1` to `10.0.3.<LAB-ID>`, where LAB-ID is your personal ID assigned by the lab instructor
- Observe the changes
  - Has the router-id of bb1 changed?
    - If the answer is „no” – what could be done to change the router-id of bb1?
  - Are there any changes in the results of the following commands in comparison to previous settings?
    - **`show ip ospf interface eth1`**
    - **`show ip ospf database`**
    - **`show ip ospf neighbor`**

Reporting

- Please deliver the following items to the UPEL system using your account
  1. A photocopy or a screenshot showing the output of the following commands executed on router bb1
     - **`show ip ospf interface eth1`**
     - **`show ip ospf database`**
     - **`show ip ospf neighbor`**

ospf is fast at detecting topology changes

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

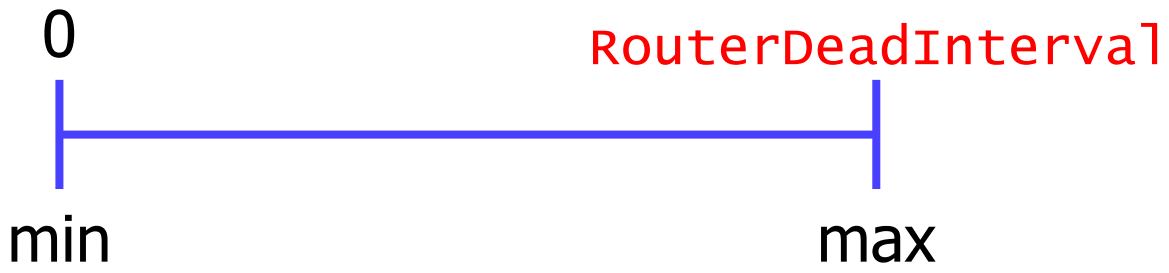
ospf is fast at detecting topology changes

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

ospf is fast at detecting topology changes

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

overall reaction time (estimated)



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

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

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)

overall reaction time (estimated)