

Hálózatok építése és üzemeltetése

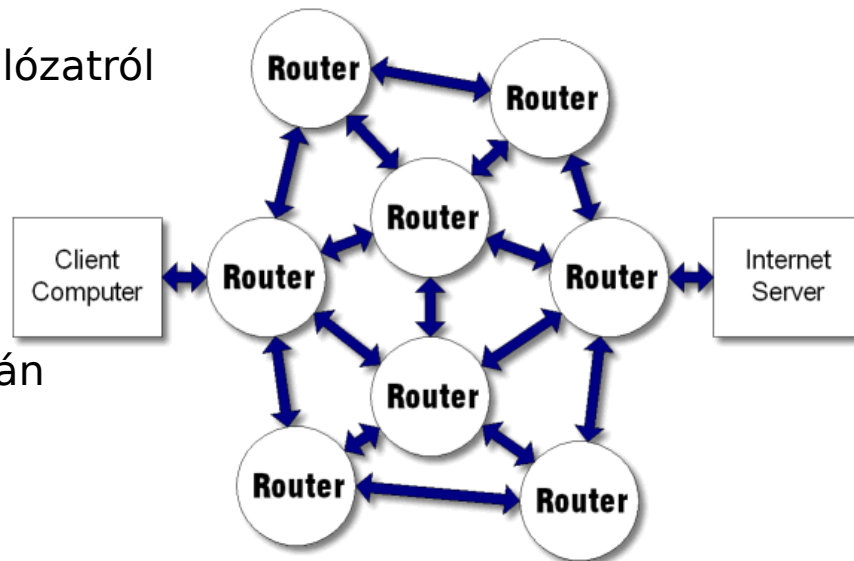
OSPF gyakorlat

Ismétlés

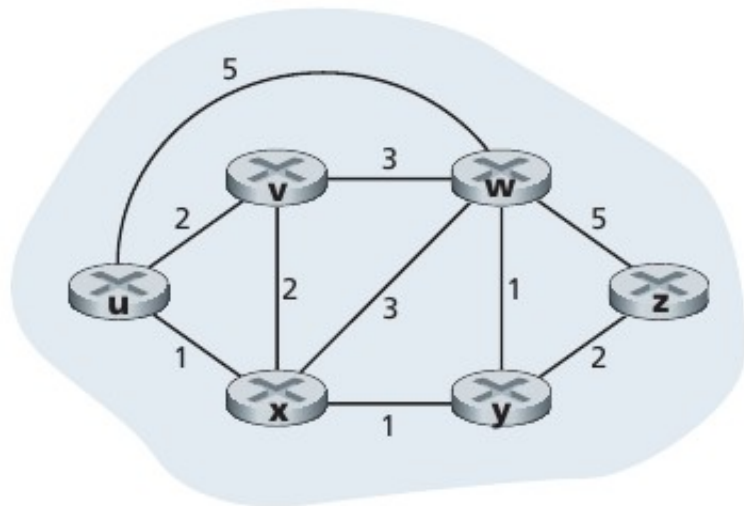
Routing protokollok

► Feladatuk

- optimális útvonal (next hop) kiszámítása bármely csomópontok között
 - aktuális állapot információ gyűjtés a hálózatról
 - útvonalak kalkulálása
- forwarding táblák
 - konfigurálása
 - dinamikus karbantartása, frissítése
 - bejövő routing protokoll üzenetek alapján
- routing információk
 - feldolgozása
 - terjesztése



Routing protokollok



- ▶ **Hálózat: absztrakt gráf**
 - ▶ csomópontok: routerek
 - ▶ élek: linkek
 - ▶ élköltség: valamilyen metrika (pl. késleltetés, sávszélesség kifejezése)
- ▶ **cél:**
 - ▶ (valamilyen értelemben) optimális, legkisebb költségű útvonal meghatározása két csomópont között
 - ▶ pl. legrövidebb út
- ▶ **Ismerős algoritmusok:**
 - ▶ Dijkstra algoritmus
 - ▶ Bellman-Ford algoritmus

Csoportosításuk

- ▶ **Globális vs. Elosztott**
 - ▶ globális: minden router ismeri a teljes topológiát
 - ▶ elosztott: minden router csak a szomszédjait és a tőlük kapott üzeneteket ismeri
- ▶ **Intra-domain vs. Inter-domain**
 - ▶ intra: Interior Gateway Protocol (IGP)
 - ▶ közös adminisztratív domain
 - ▶ rugalmatlan szabályok
 - ▶ egyes esetekben nem jól skálázódik
 - ▶ inter: Exterior Gateway Protocol (EGP)
 - ▶ külön adminisztratív domaineik, AS-ek (Autonomous System) között
 - ▶ jól skálázódik (internet)
- ▶ **Link state vs. Distance Vector (ld. később)**

Csoportosításuk

- ▶ Interior Gateway Protocol (IGP) példák
 - ▶ OSPF (OpenShortest Path First)
 - ▶ IS-IS (Intermediate System to Intermediate System)
 - ▶ RIP (Routing Information Protocol)
 - ▶ EIGRP (Enhanced Interior Gateway Routing Protocol)
- ▶ Exterior Gateway Protocol (EGP)
 - ▶ BGP (Border Gateway Protocol)
 - ▶ Id. MSC (Internet architektúra és szolgáltatások főspecializáció)

Link State alapú routing

- ▶ Működési elv
 - ▶ globális nézeten dolgozik
 - ▶ LSP: Link State Packet (id, costs, seq.no, ttl)
 - ▶ egy router
 - ▶ mindenkinek küld LSP-t (broadcast)
 - ▶ a közvetlenül kapcsolódó linkjeiről
 - ▶ periodikusan újra generálja (seq.no++)
 - ▶ legfrissebb beérkezett LSP-ket tárolja
 - ▶ mindenki ugyanazt a topológiát látja
 - ▶ azon számolja az útvonalakat
 - ▶ útvonalszámítás: Dijkstra algoritmus

Például: OSPF

- ▶ Open Shortest Path First (v2)
- ▶ nyílt, IETF szabvány
 - ▶ v2: RFC 2328
 - ▶ IP felett
- ▶ együttműködés különböző gyártók termékei között!
- ▶ korlátozott erőforrás igény
- ▶ viszonylag gyors, automatikus konvergencia topológia változásokra
- ▶ támogatja
 - ▶ különböző útvonal költségek számítását
 - ▶ hierarchikus, többszintű topológiát
 - ▶ alkalmazás típusára alapozott forgalomirányítást
 - ▶ autentikációt minden üzenetre

Hálózatemulációs környezet

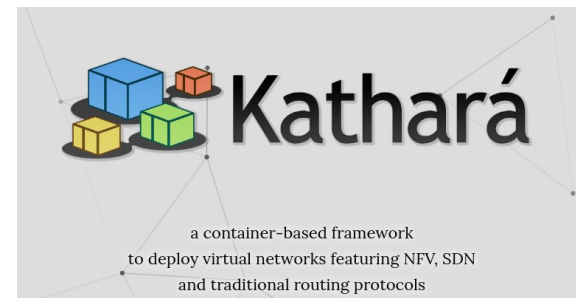
Netkit, Quagga

Netkit

The poor man's system for experimenting
computer networking

Version	2.3
Author(s)	G. Di Battista, M. Patrignani, M. Pizzonia, M. Rimondini
E-mail	contact@netkit.org
Web	http://www.netkit.org/
Description	an introduction to the architecture, setup, and usage of Netkit

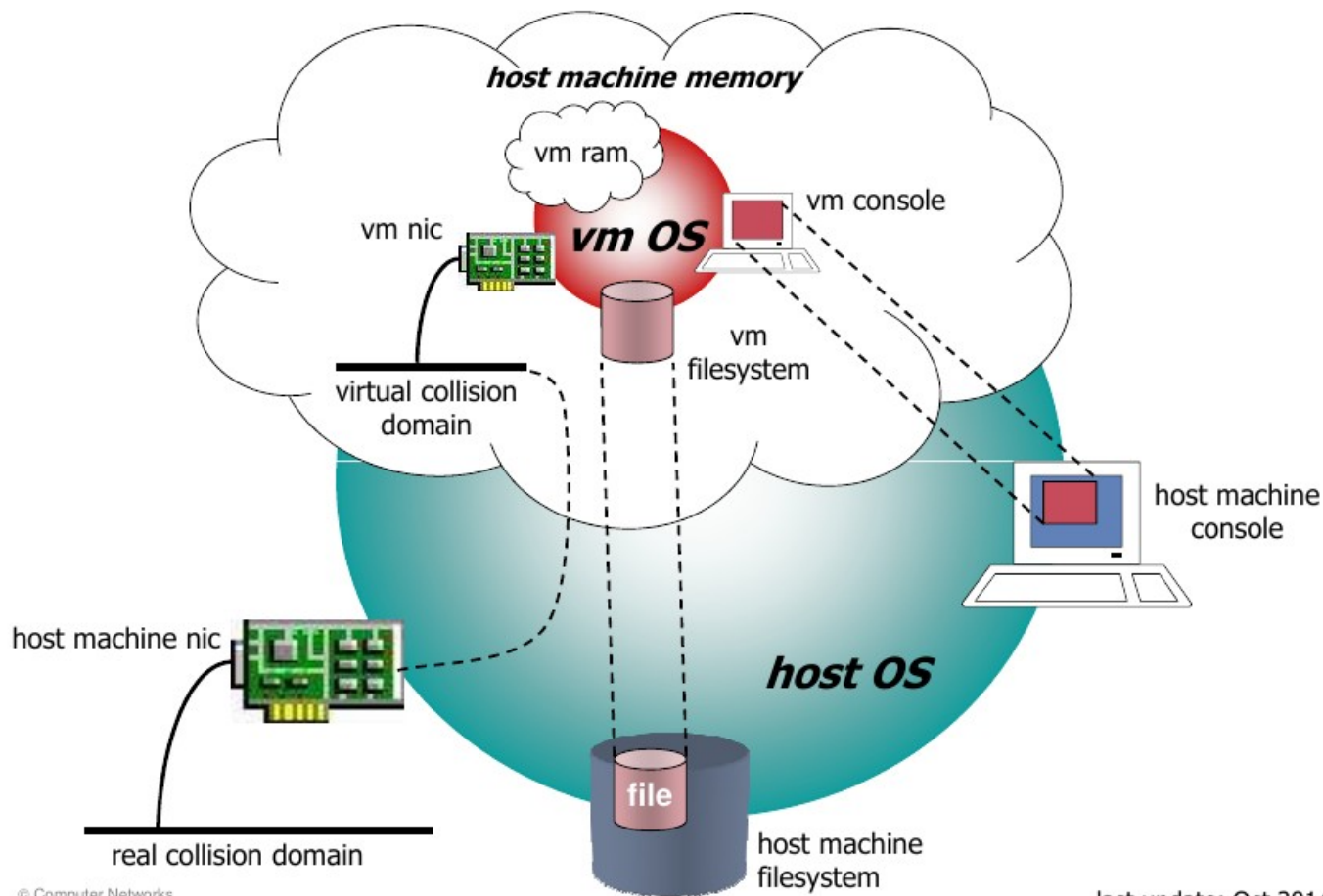
Újabb platformjuk:



netkit: a system for emulating computer networks

- based on uml (user-mode linux)
 - <http://user-mode-linux.sourceforge.net/>
- each emulated network device is a virtual linux box
 - a virtual linux box is one that is based on the uml kernel
- note: the linux os is shipped with software supporting most of the network protocols
 - hence, any linux machine can be configured to act as a bridge/switch or as a router

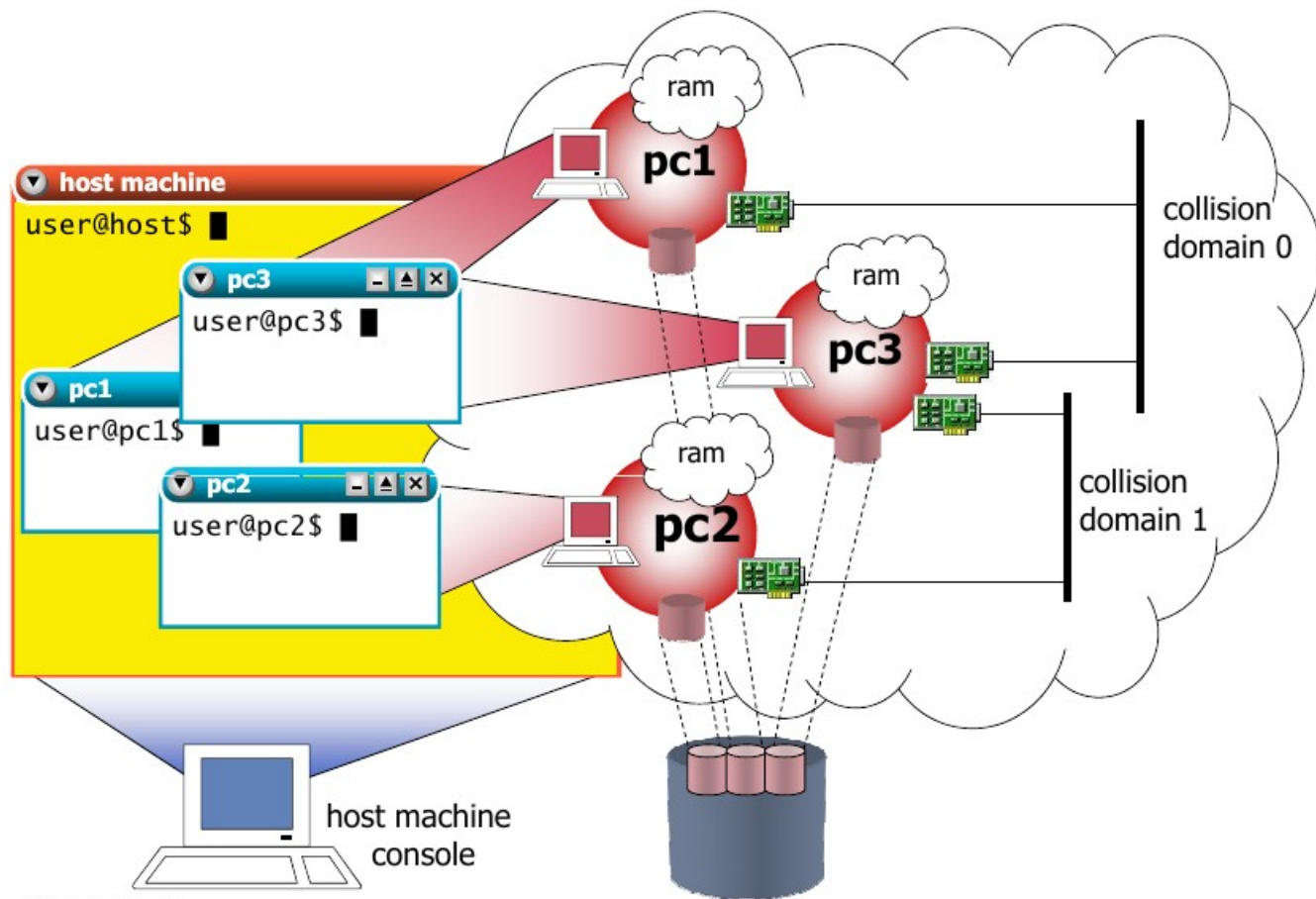
Netkit



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Netkit



netkit vcommands

- allow to startup virtual machines with arbitrary configurations (memory, network interfaces, etc.)
 - **vstart**: starts a new virtual machine
 - **vlist**: lists currently running virtual machines
 - **vconfig**: attaches network interfaces to running vms
 - **vhalt**: gracefully halts a virtual machine
 - **vcrash**: causes a virtual machine to crash
 - **vclean**: “panic command” to clean up all netkit processes (including vms) and configuration settings on the host machine

netkit lcommands

- ease setting up complex labs consisting of several virtual machines
 - **lstart**: starts a netkit lab
 - **lhalt**: gracefully halts all vms of a lab
 - **lcrash**: causes all the vms of a lab to crash
 - **lclean**: removes temporary files from a lab directory
 - **linfo**: provides information about a lab without starting it
 - **ltest**: allows to run tests to check that the lab is working properly

Quagga/Zebra

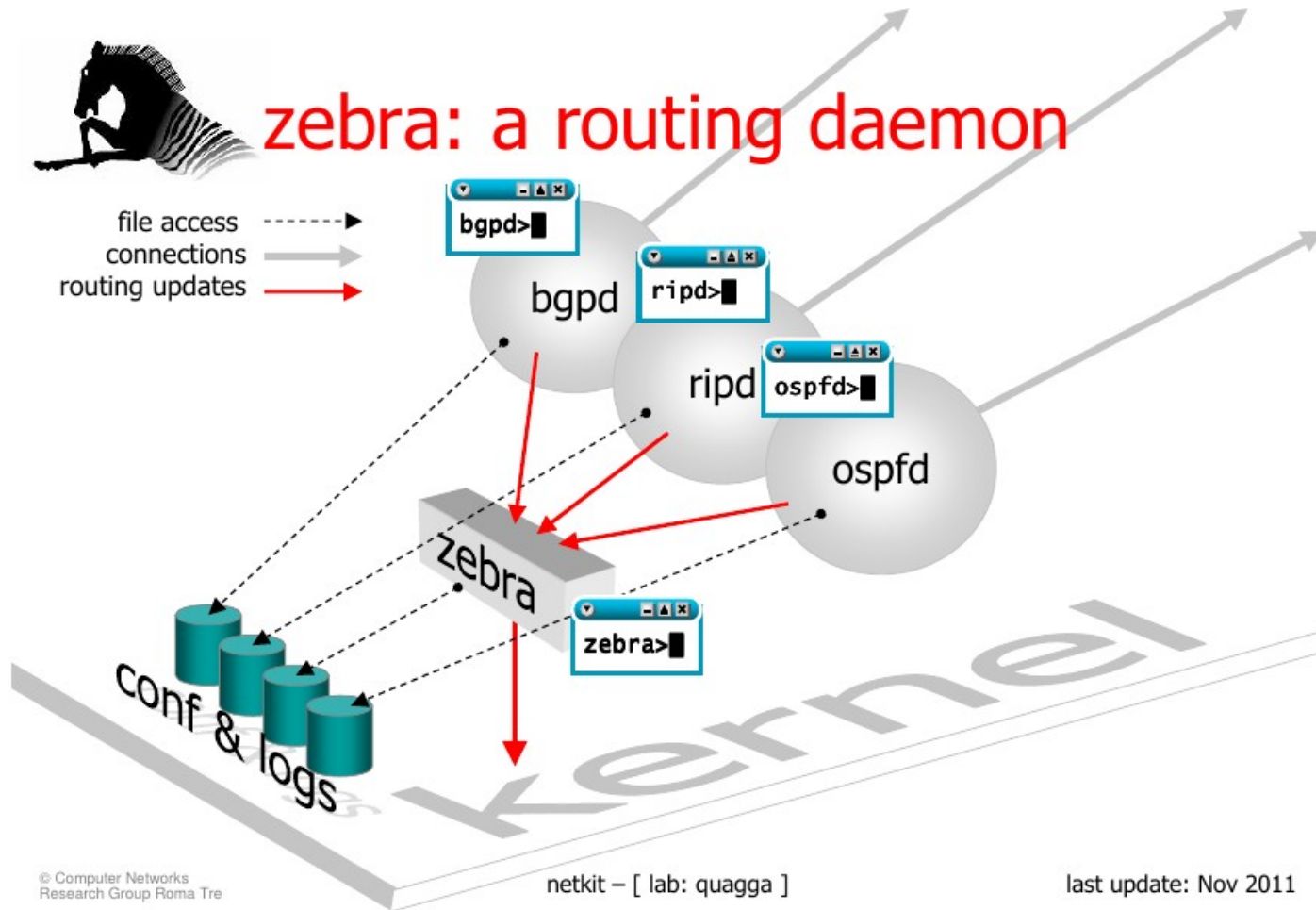
- ▶ Routing Szoftver csomag
 - ▶ GPL
 - ▶ FreeBSD, Linux, Solaris, NetBSD
 - ▶ GNU Zebra volt előbb
 - ▶ Quagga egy fork volt
 - ▶ “The Quagga tree aims to build a more involved community around Quagga than the current centralised model of GNU Zebra.”
 - ▶ az élővilágban a quagga halt ki
 - ▶ a routing világban a zebra

Quagga/Zebra

- ▶ Routing Szoftver csomag
 - ▶ zebra (core daemon)
 - ▶ kernel interface, static routes
 - ▶ zserv szerver (API) -> quagga kliensek felé
 - ▶ quagga démonok
 - ▶ routing protokollok
 - ripd, ripngd, ospfd, ospf6d, bgpd, isisd
 - ▶ mindegyikkel dedikált CLI-n (vty) keresztül kommunikálhatunk
 - hasonló interfész, mint egy HW routernél
 - ▶ speciális quagga tool: vtysh
 - közös front-end minden démonhoz



zebra: a routing daemon



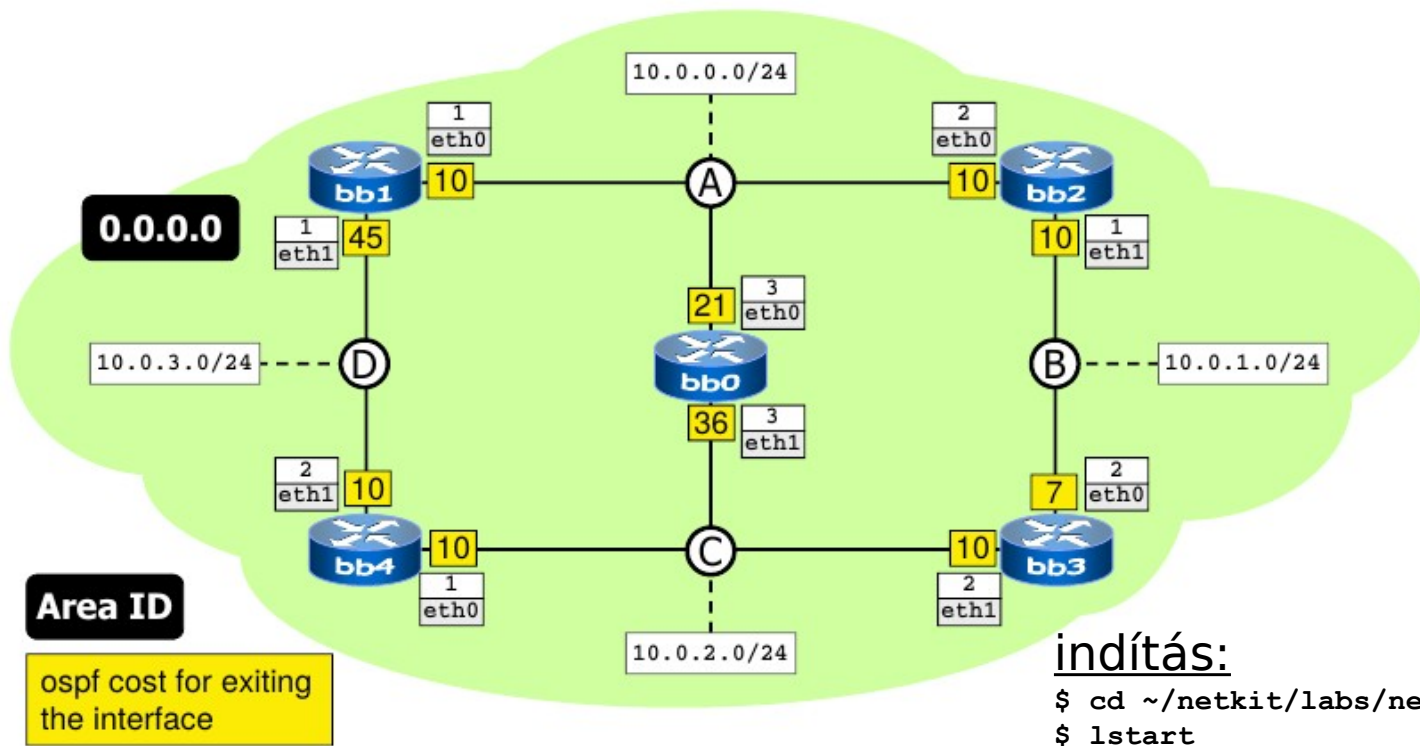
Vizsgálati környezet kialakítása

- ▶ IB213 labor: default HaEpUz (Mininet+Netkit) boot image
- ▶ Saját gép:
 - ▶ Kiadott HaEpUz VM (Jupyter Notebook)
 - ▶ de most nem a notebookot használjuk
 - ▶ Indítás VMware player vagy importálás Virtualbox-ba
- ▶ A rendszer egy Ubuntu 64-bit Linux + desktop environment, tartalma:
 - ▶ Mininet hálózatemuláció
 - ▶ Netkit hálózatemuláció
- ▶ OSPF lab indítása:
 - ▶ `$ cd ~/netkit/labs/netkit-lab_ospf-singlearea`
 - ▶ `$ lstart`

OSPF lab# 1

netkit-lab_ospf-singlearea

OSPF lab#1 topológia



- ▶ single (backbone) area
 - ▶ 0.0.0.0
- ▶ minden interfészhez
 - ▶ ospf cost
 - ▶ default: 10
 - ▶ néha trükkösen van beállítva!

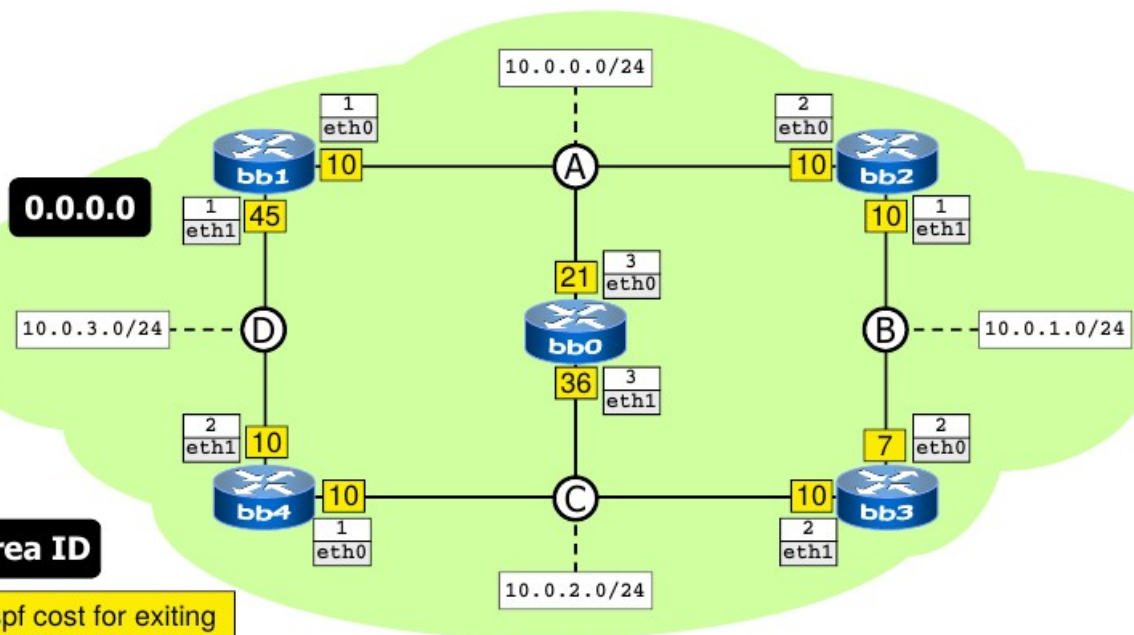
indítás:

```
$ cd ~/netkit/labs/netkit-lab_ospf-singlearea  
$ lstart
```

netkit – [labs: ospf]

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OSPF lab#1 topológia



Area ID

ospf cost for exiting the interface

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Research Group Roma Tre

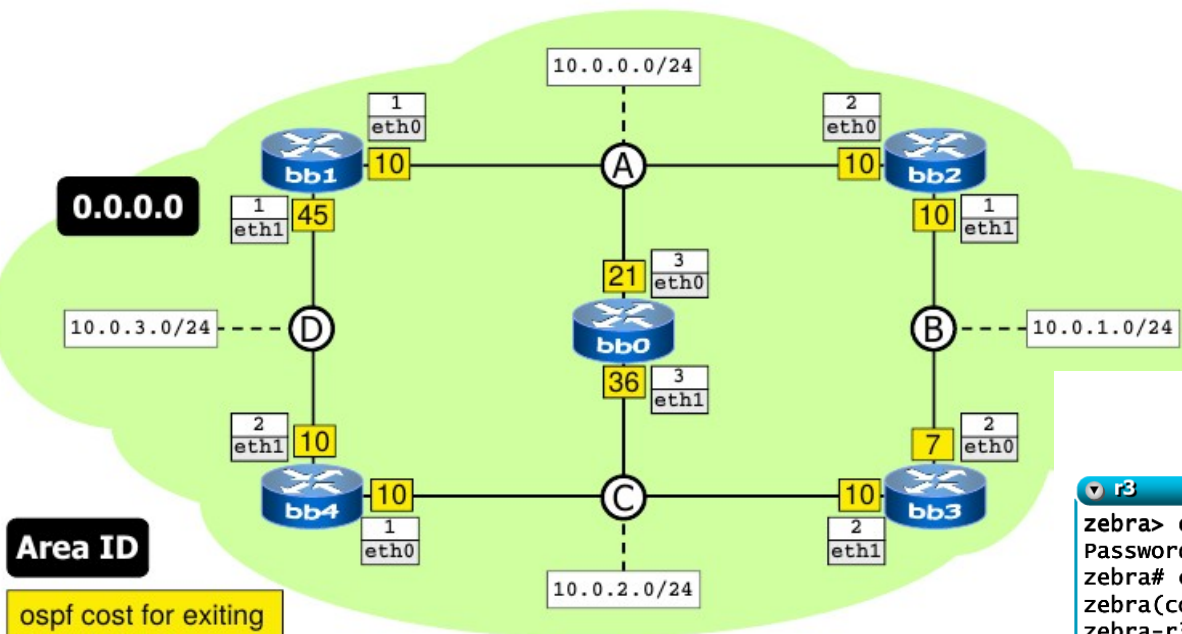
netkit – [labs: ospf]

last update: Nov 20

- ▶ quagga teszt, pl. bb0 routeren
 - ▶ cd /etc/zebra; ls -l
 - ▶ daemon conf fájlok
 - ▶ cat daemons
 - ▶ cat zebra.conf (passwd!)
 - ▶ cat ospfd.conf

```
bb0:/etc/zebra# cat ospfd.conf
!
hostname ospfd
password zebra
enable password zebra
!
! Default cost for exiting an interface is 10
interface eth0
ospf cost 21
interface eth1
ospf cost 36
!
router ospf
! Speak OSPF on all interfaces falling in 10.0.0.0/16
network 10.0.0.0/16 area 0.0.0.0
redistribute connected
!
log file /var/log/zebra/ospfd.log
```

OSPF lab#1 topológia



netkit - [labs: ospf]

last u

- ▶ quagga teszt, pl. bb0 routeren
 - ▶ telnet localhost zebra
 - ▶ szokásos lehetőségek
 - enable, configure terminal, ?, <tab>, show, list
 - ▶ telnet localhost ospfd
 - ▶ show ip ospf
 - ▶ vtysh (minden démonhoz)

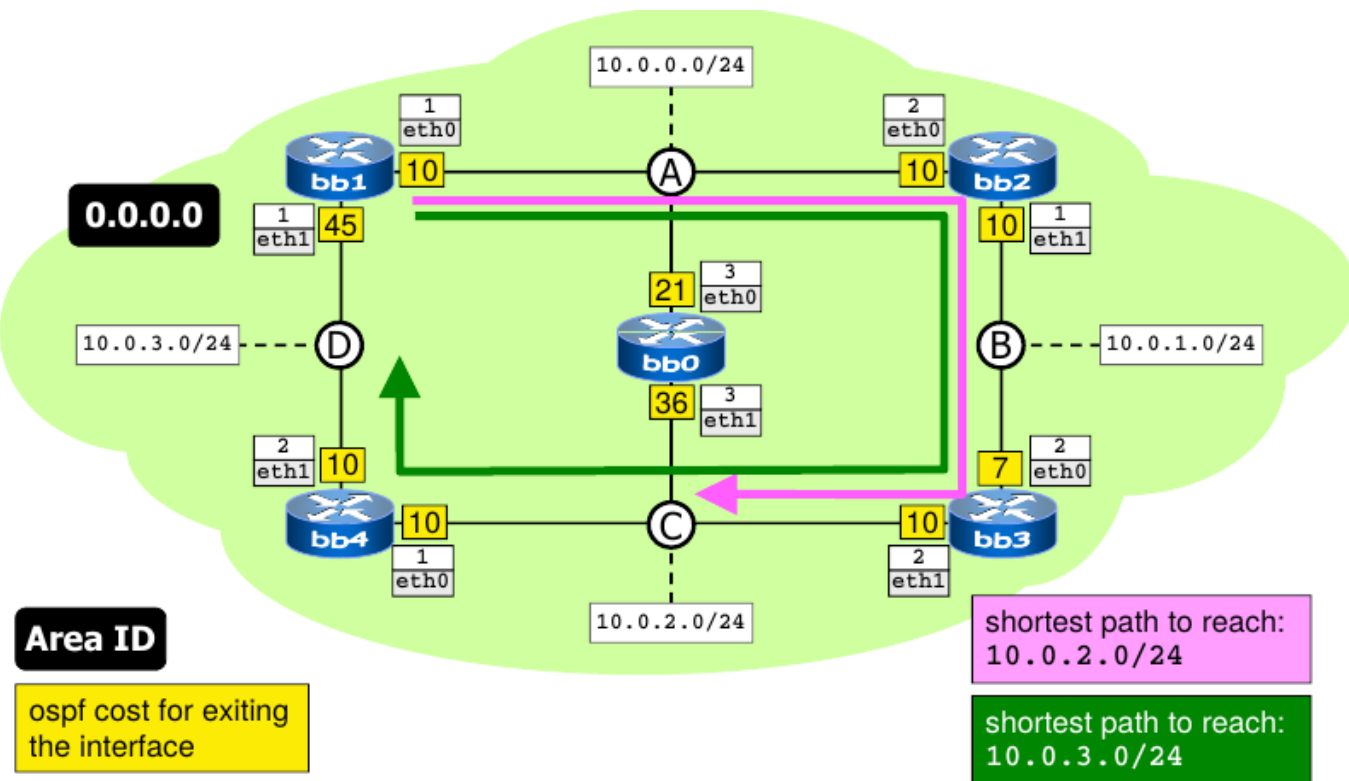
unprivileged user mode
privileged user mode
configurator mode

```
r3
zebra> enable
Password: zebra
zebra# configure terminal
zebra(config)# hostname zebra-r3
zebra-r3(config)# password foo
zebra-r3(config)# enable password foo
zebra-r3(config)# quit
zebra-r3# write file
Configuration saved to /etc/zebra/zebra.conf
zebra-r3# disable
zebra-r3> exit
Connection closed by foreign host.
r3:~#
```

Annotations for the terminal output:

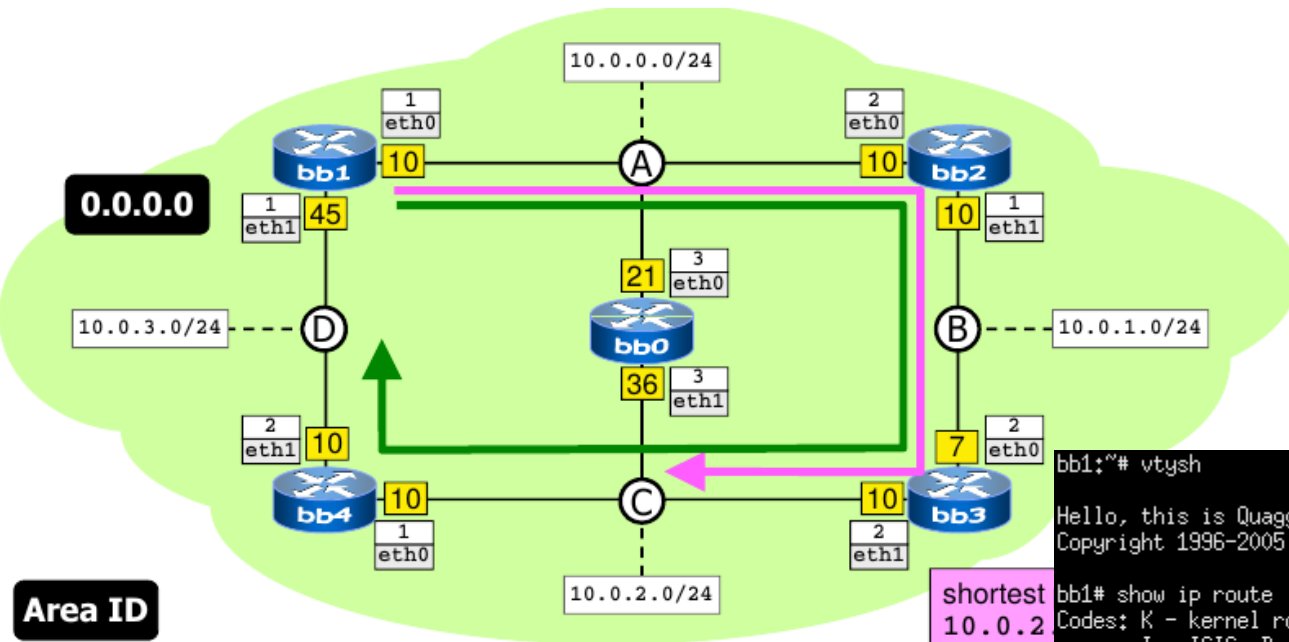
- enter privileged user mode (points to `enable`)
- start editing configuration (points to `configure terminal`)
- edit configuration (points to `hostname zebra-r3`, `password foo`, and `enable password foo`)
- stop editing configuration (points to `quit`)
- write changes to file (points to `write file`)
- exit privileged user mode (points to `disable`)
- exit (points to `exit`)

Legrövidebb utak



- traceroute -l icmp
 - bb1->10.0.2.1
 - melyik útvonal?
 - hogy jönnek vissza az ICMP válaszok?
 - bb1->10.0.3.2
 - melyik útvonal?

Legrövidebb utak



- ▶ routing táblák
 - ▶ értelmezzük minden routeren
 - ▶ vtysh
 - ▶ show ip route
 - ▶ administrative distance: 110 (default OSPF)
 - ▶ ospf metric: 10, 20, ...
 - ▶ connected metric: 1

```
bb1:~# vtysh
```

```
Hello, this is Quagga (version 0.99.10).  
Copyright 1996-2005 Kunihiro Ishiguro, et al.
```

```
bb1# show ip route
```

```
Codes: K - kernel route, C - connected, S - static, R - RIP, O - OSPF,  
I - ISIS, B - BGP, > - selected route, * - FIB route
```

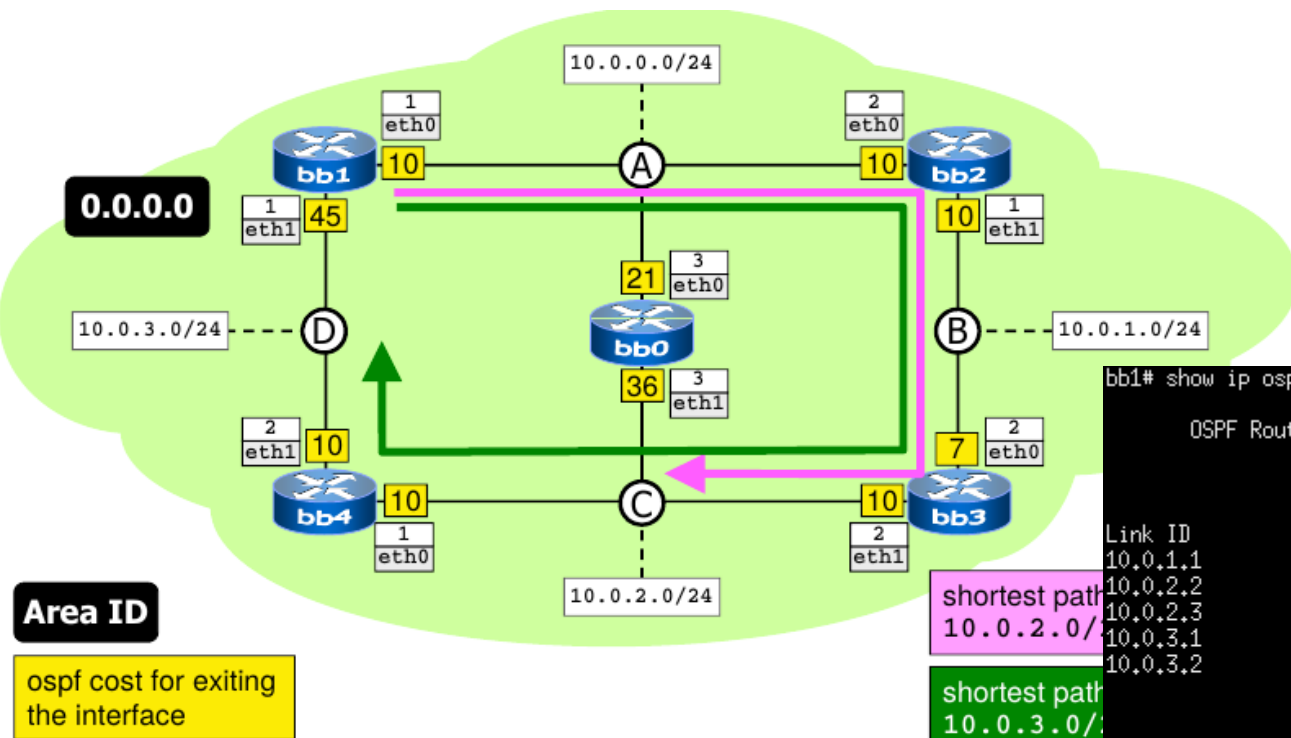
shortest

10.0.2

shortest

10.0.3

Legrövidebb utak



- ▶ ospf vizsgálata
 - ▶ nézzük meg minden routeren
 - ▶ vtysh
 - ▶ show ip ospf database
 - ▶ show ip ospf neighbor
 - ▶ show ip ospf route

```
bb1# show ip ospf database
```

```
OSPF Router with ID (10.0.3.1)
```

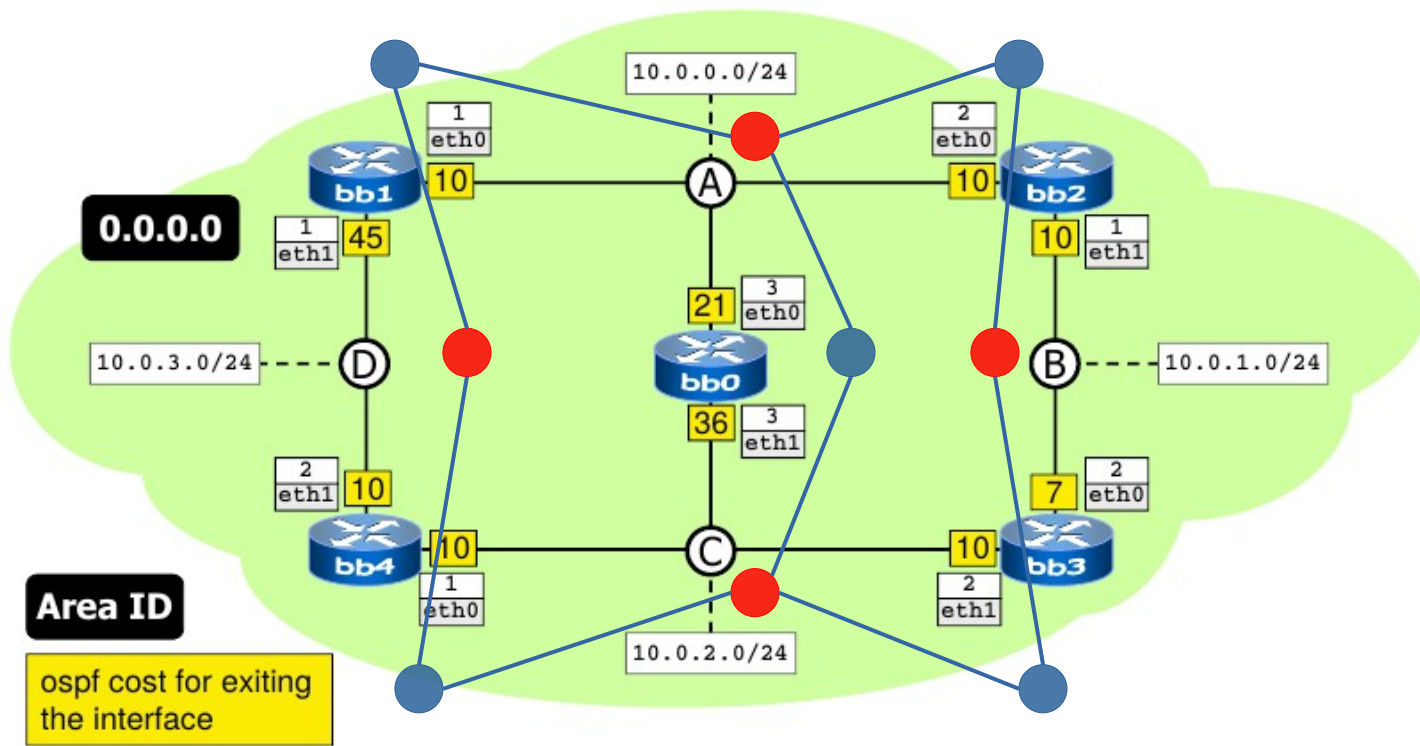
```
Router Link States (Area 0.0.0.0)
```

Link ID	ADV Router	Age	Seq#	CkSum	Link count
10.0.1.1	10.0.1.1	473	0x80000007	0xe1fe	2
10.0.2.2	10.0.2.2	474	0x80000007	0xdbfe	2
10.0.2.3	10.0.2.3	473	0x8000000a	0xd9d4	2
10.0.3.1	10.0.3.1	467	0x8000000a	0x248f	2
10.0.3.2	10.0.3.2	469	0x80000009	0x3e92	2

```
Net Link States (Area 0.0.0.0)
```

Link ID	ADV Router	Age	Seq#	CkSum
10.0.0.1	10.0.3.1	467	0x80000006	0x61ad
10.0.1.2	10.0.2.2	474	0x80000004	0x63be
10.0.2.1	10.0.3.2	468	0x80000006	0x6a9e
10.0.3.2	10.0.3.2	468	0x80000005	0x63b7

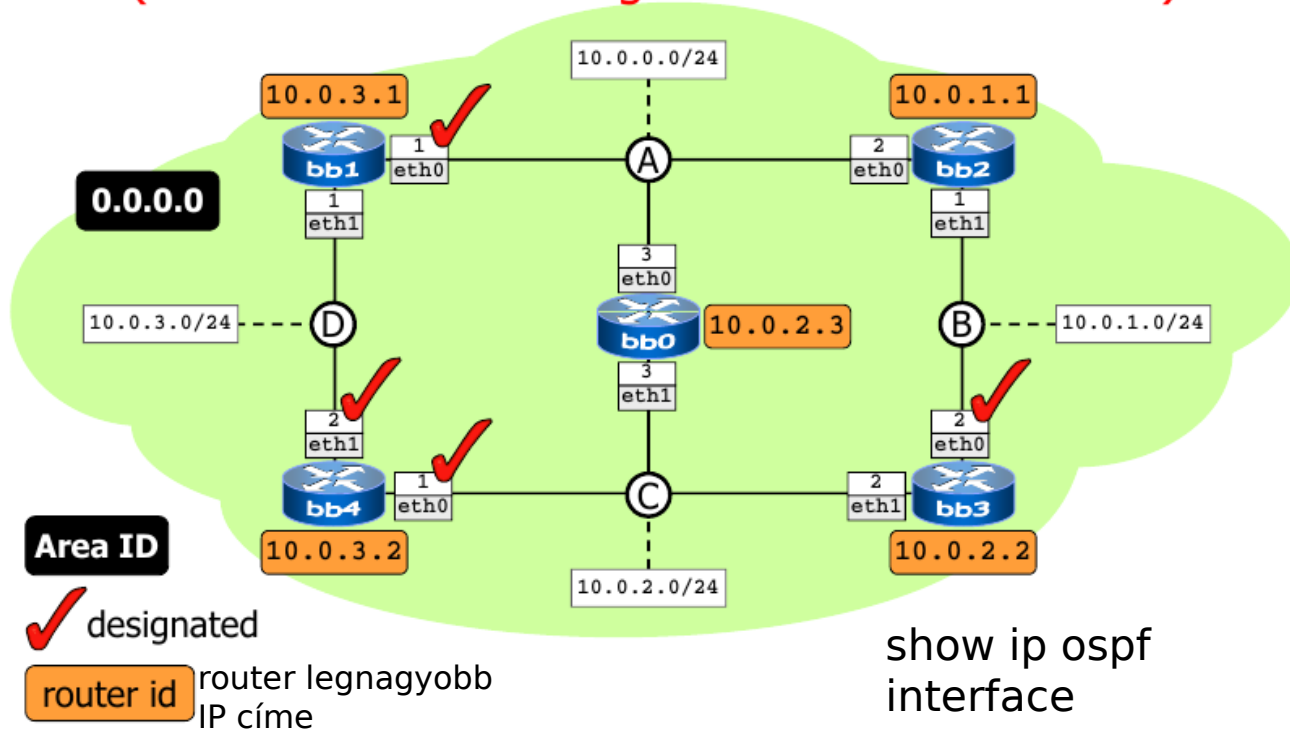
Speciális gráf modell



- ▶ Broadcast hálózatok
 - ▶ nem pont-pont linkek
 - ▶ pl. Ethernet
 - ▶ hálózat is csomópont
- ▶ pont-pont linkeknél
 - ▶ router-router él

Designated Router (DR) és BDR

(router interfaces designated for each network)

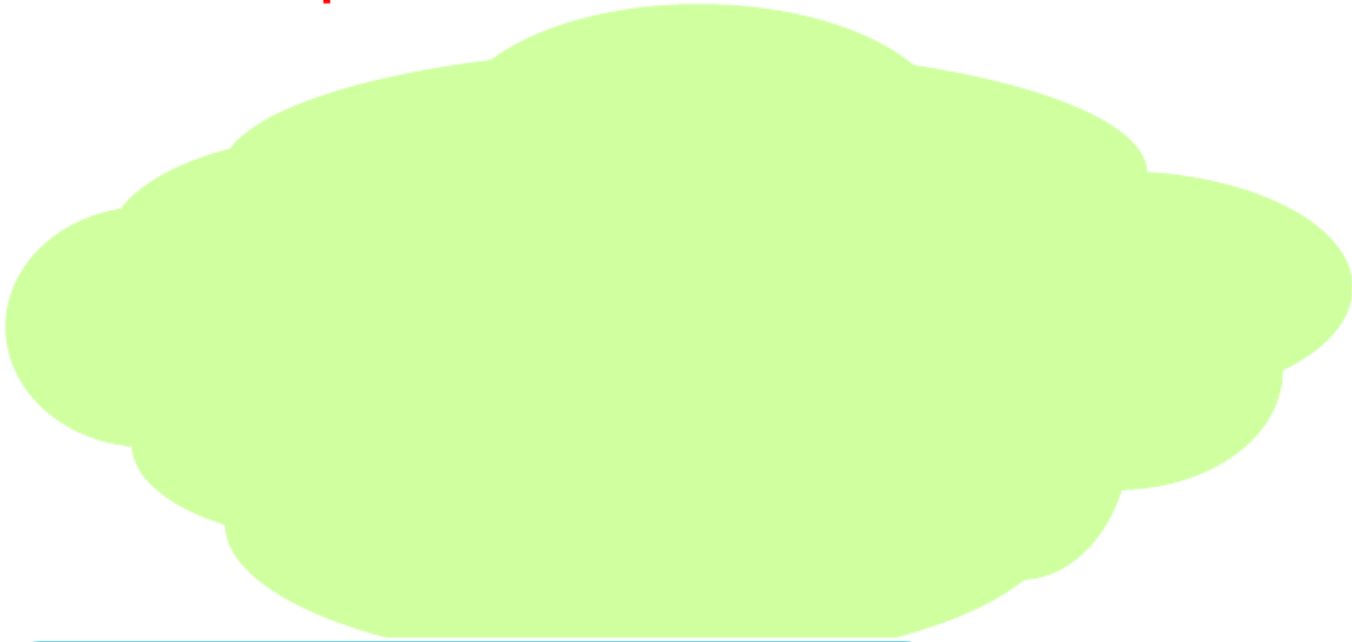


- ▶ Broadcast hálózatoknál
 - ▶ pl. Ethernet
 - ▶ DR és Backup DR: kitüntetett routerek
 - ▶ választás alapján
 - ▶ router id alapján (max.)
 - ▶ (ami interfész id)
 - ▶ többi OSPF router csak velük van full szomszédságban
 - ▶ különben mindenki-mindenkivel kommunikálna
 - ▶ útvonalfrissítés csak DR-től
 - ▶ sok erőforrás spórolható

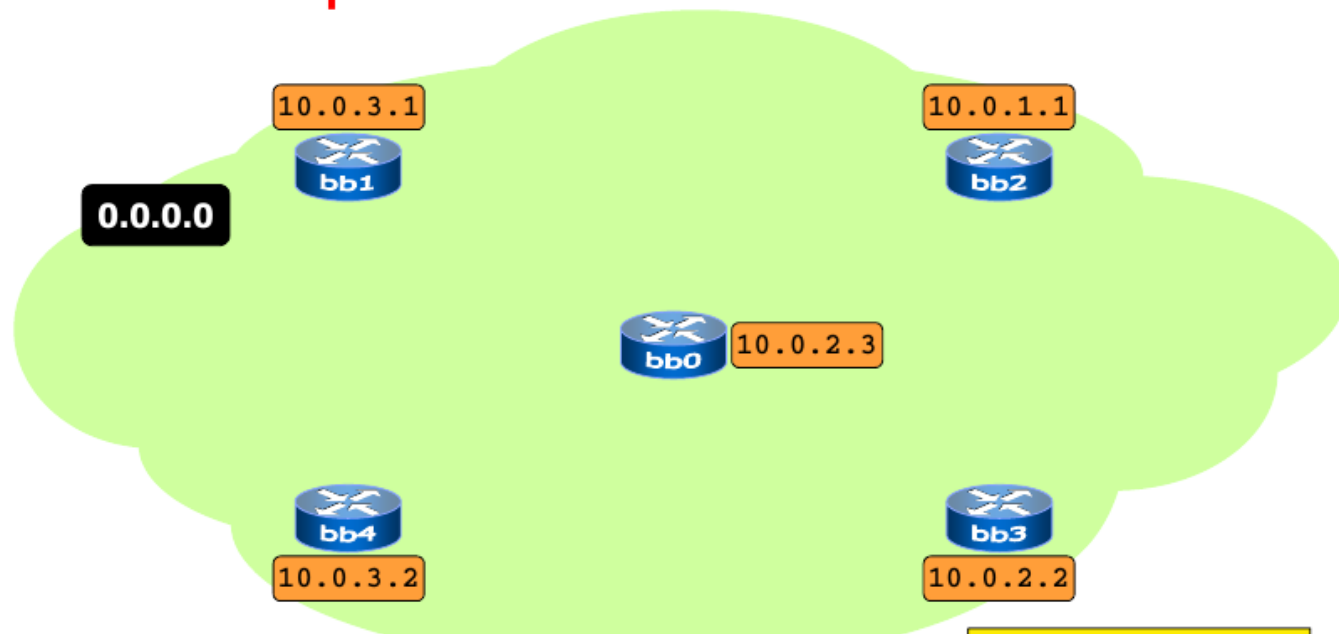
ospf's view of the network

- 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)

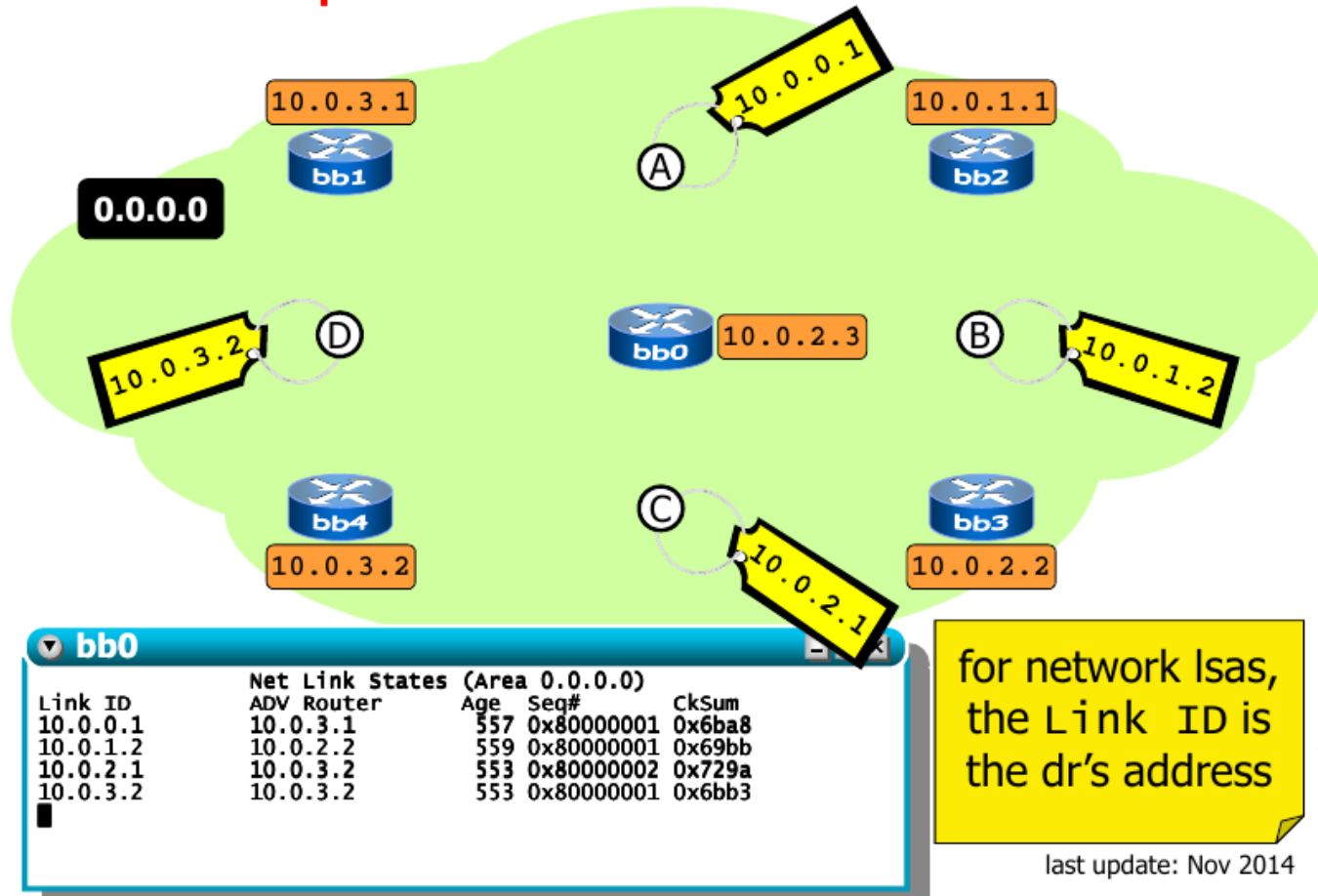
Link ID	ADV Router	Age	Seq#	CkSum	Link count
10.0.1.1	10.0.1.1	553	0x80000003	0xe9fa	2
10.0.2.2	10.0.2.2	552	0x80000003	0xe3fa	2
10.0.2.3	10.0.2.3	552	0x80000003	0xe7cd	2
10.0.3.1	10.0.3.1	552	0x80000003	0x3288	2
10.0.3.2	10.0.3.2	548	0x80000004	0x488d	2

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

router
legnagyobb IP
címe

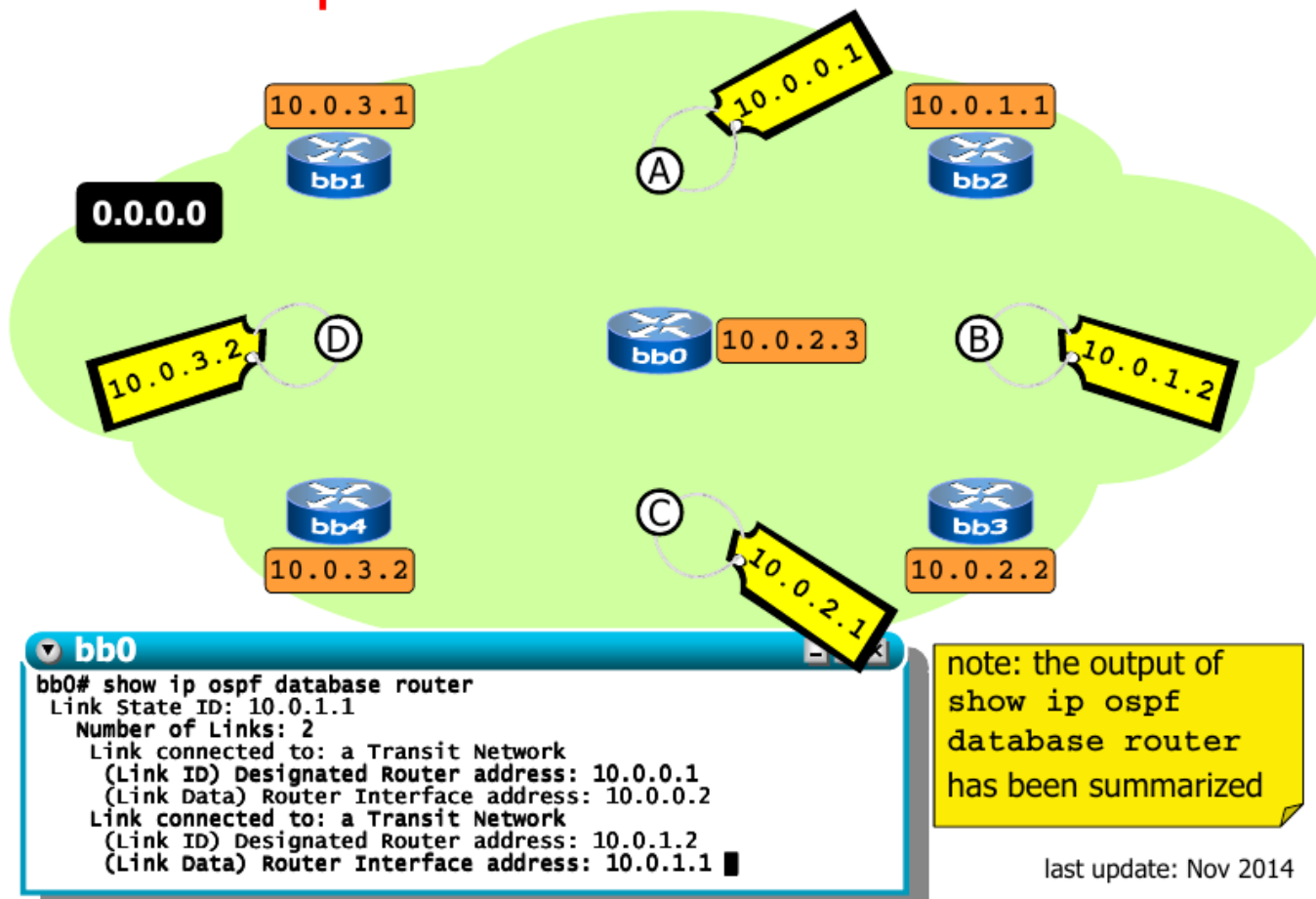
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ospf's view of the network



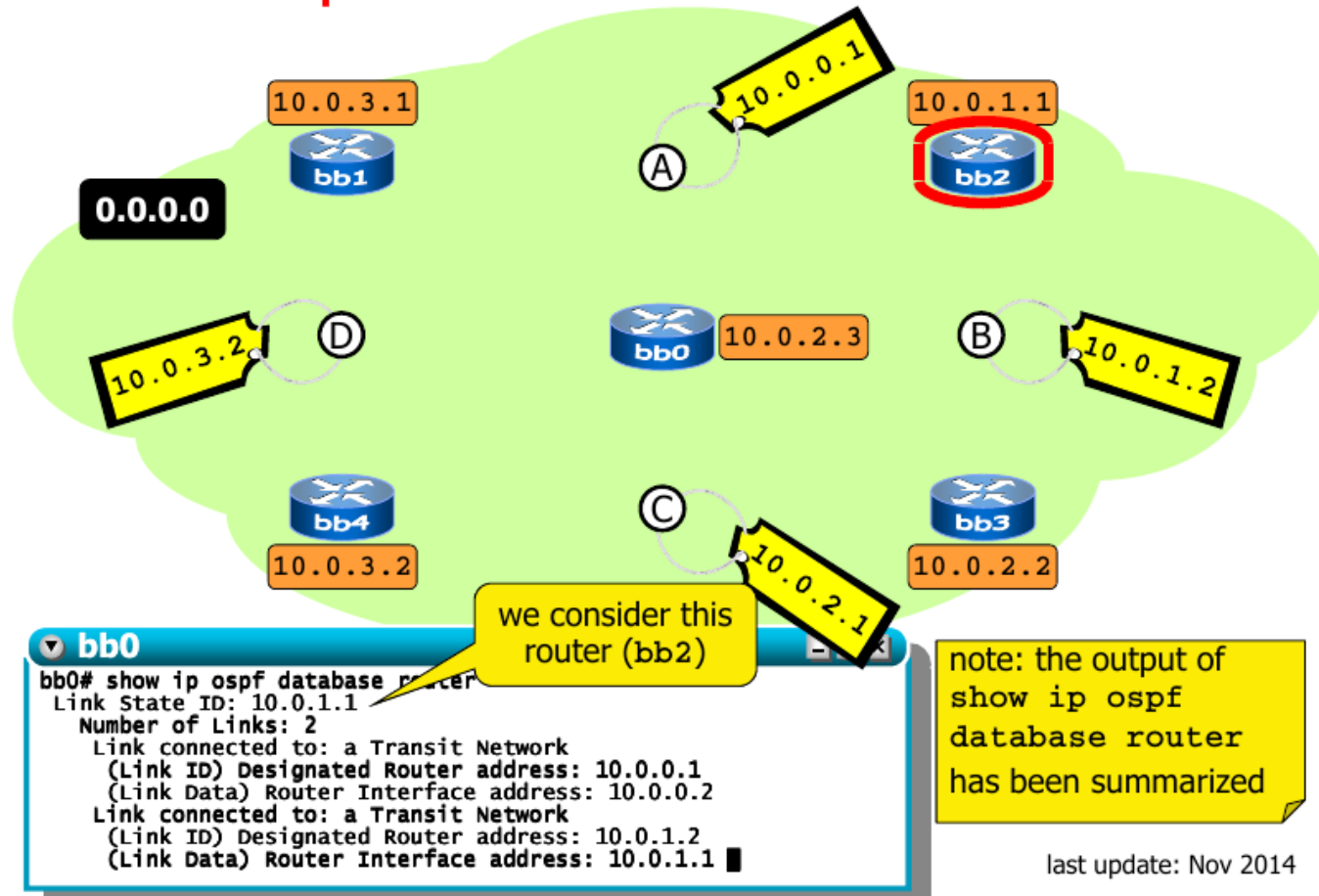
DR IP címe
abban a
hálózatban

ospf's view of the network



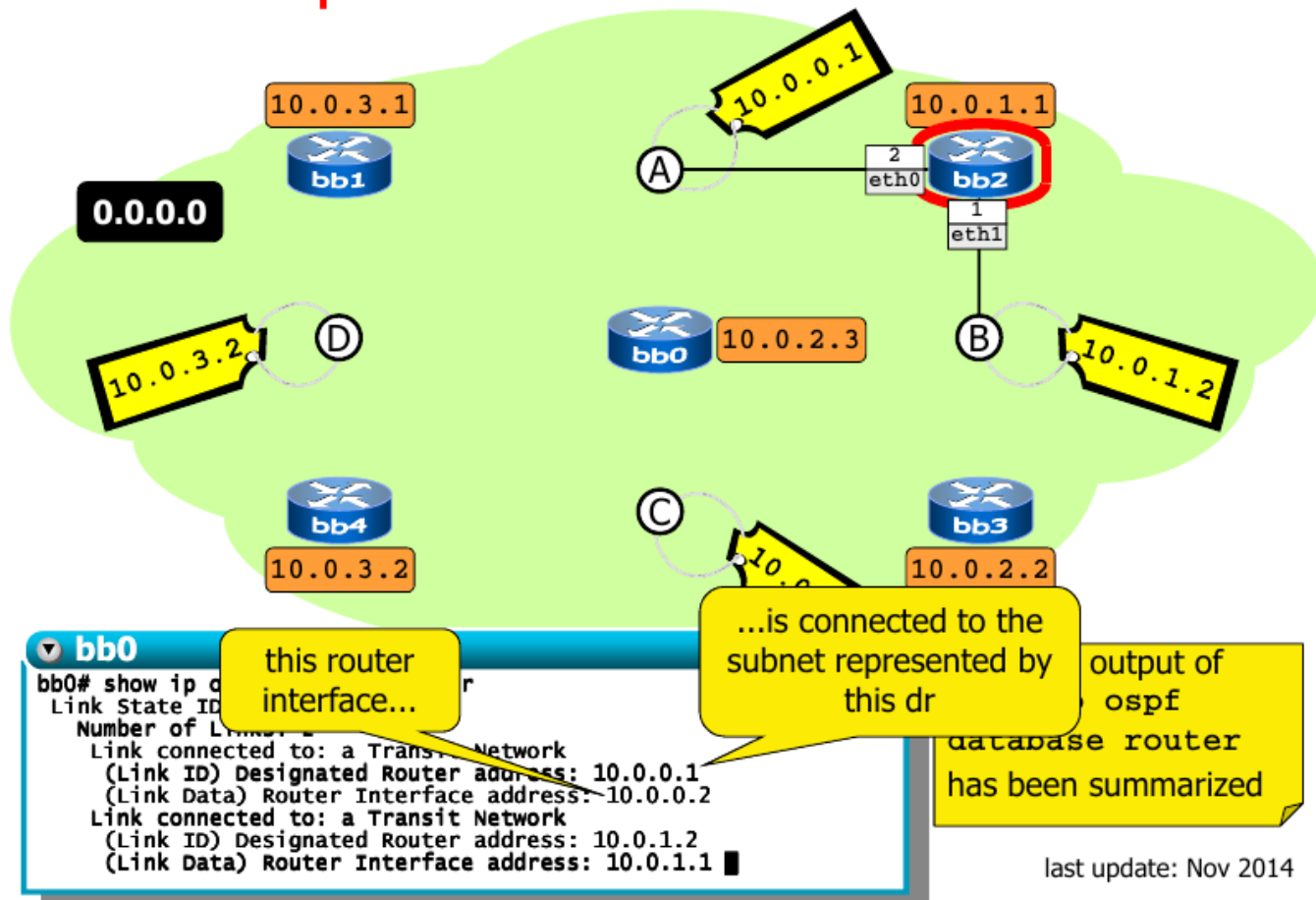
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ospf's view of the network

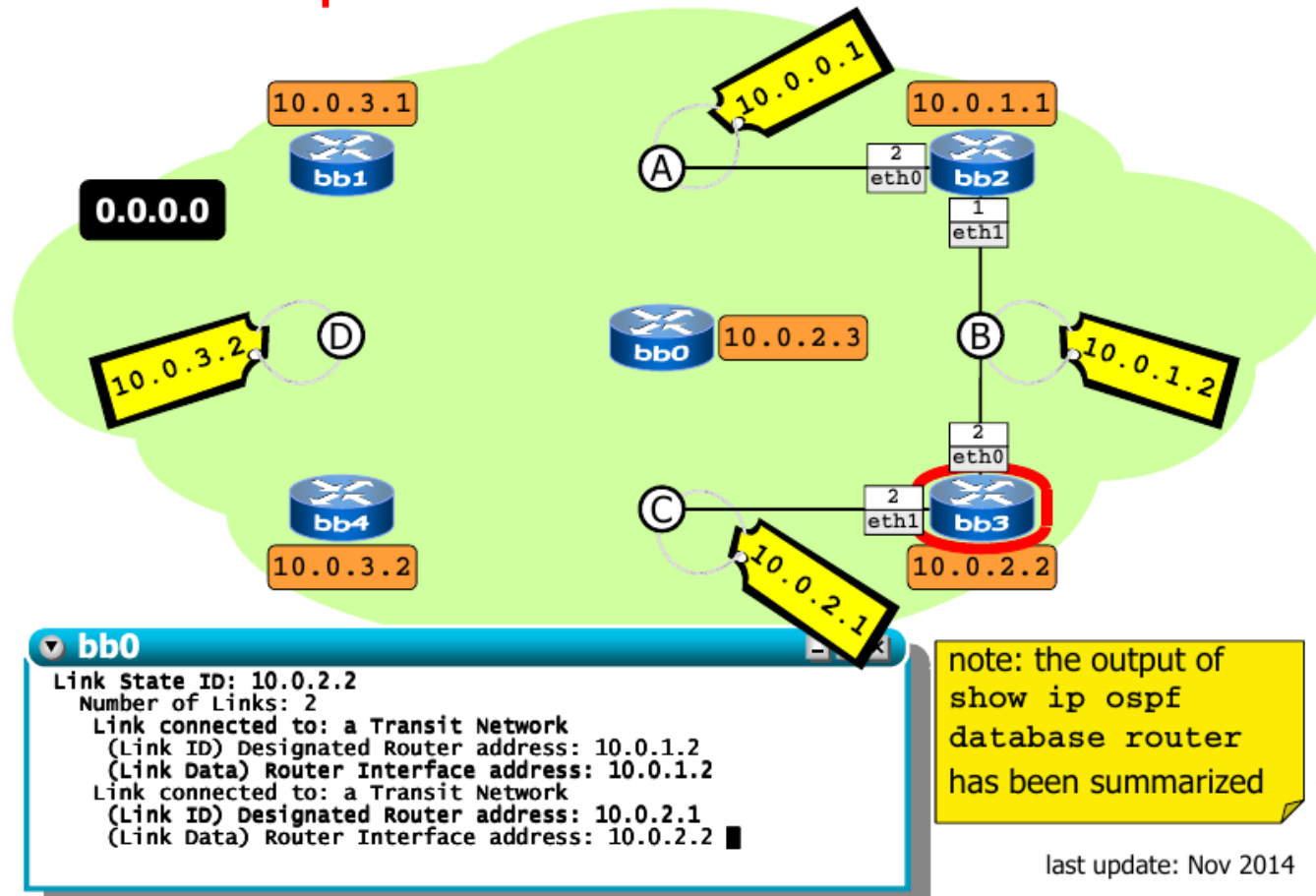


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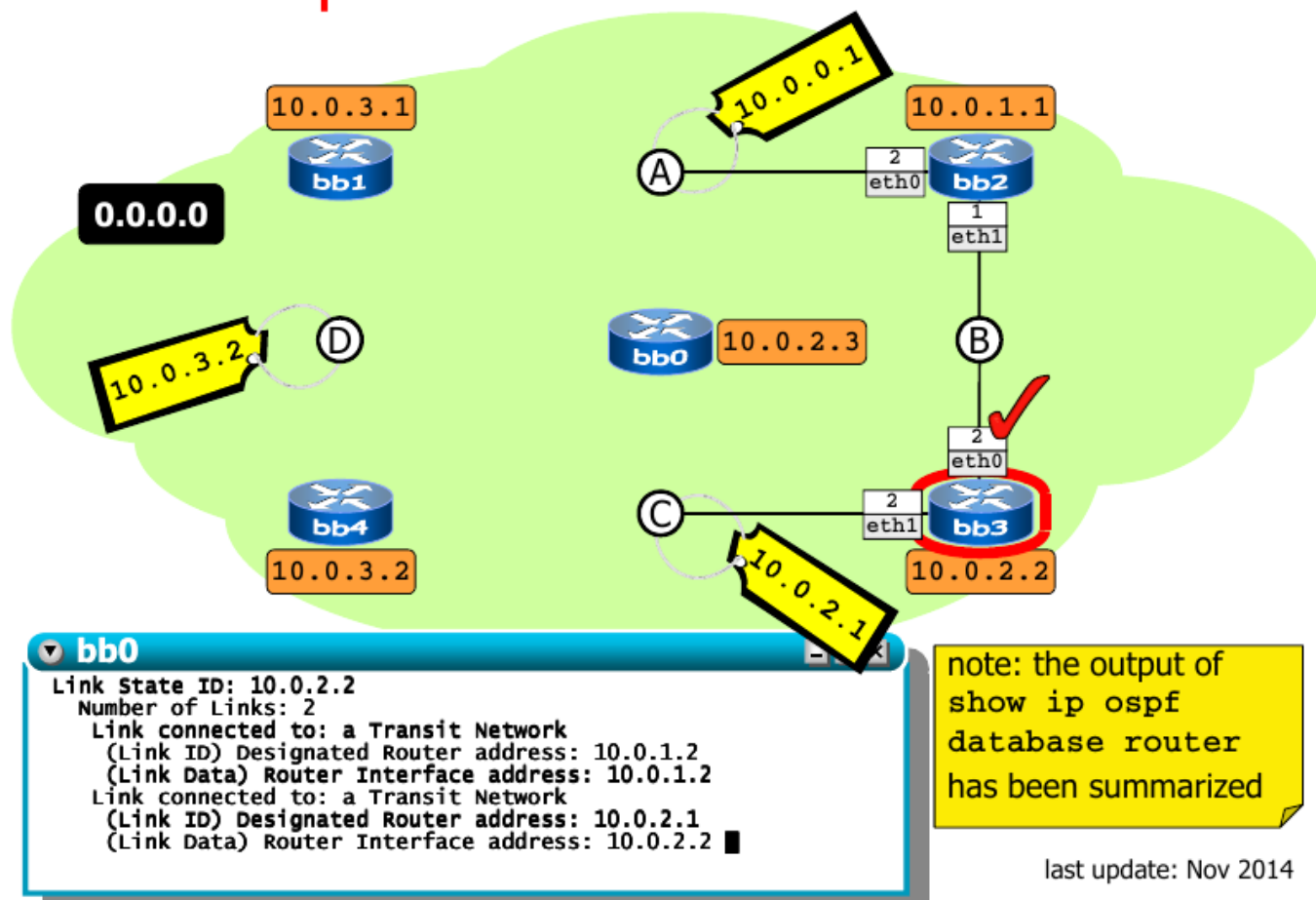
ospf's view of the network



ospf's view of the network

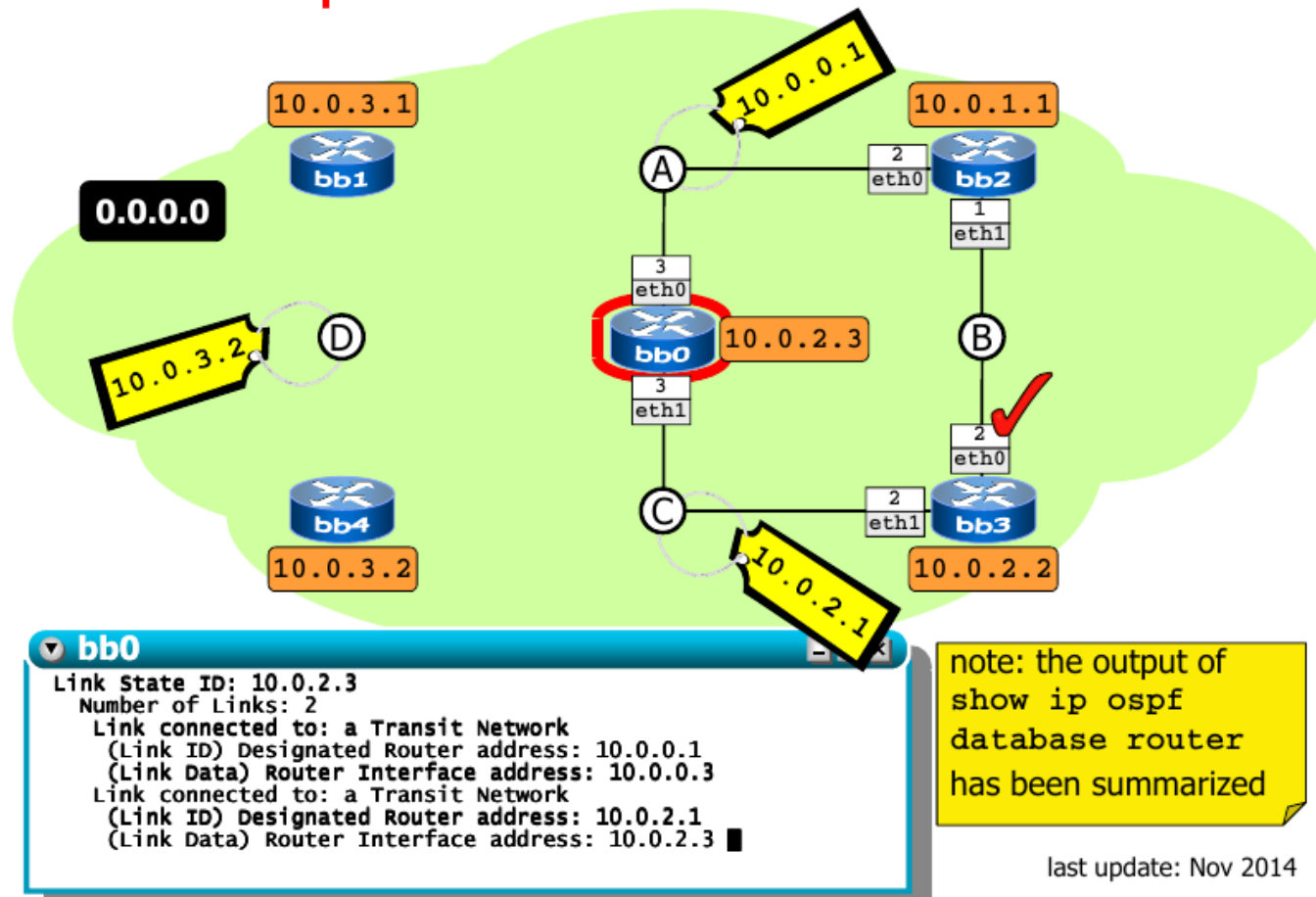


ospf's view of the network



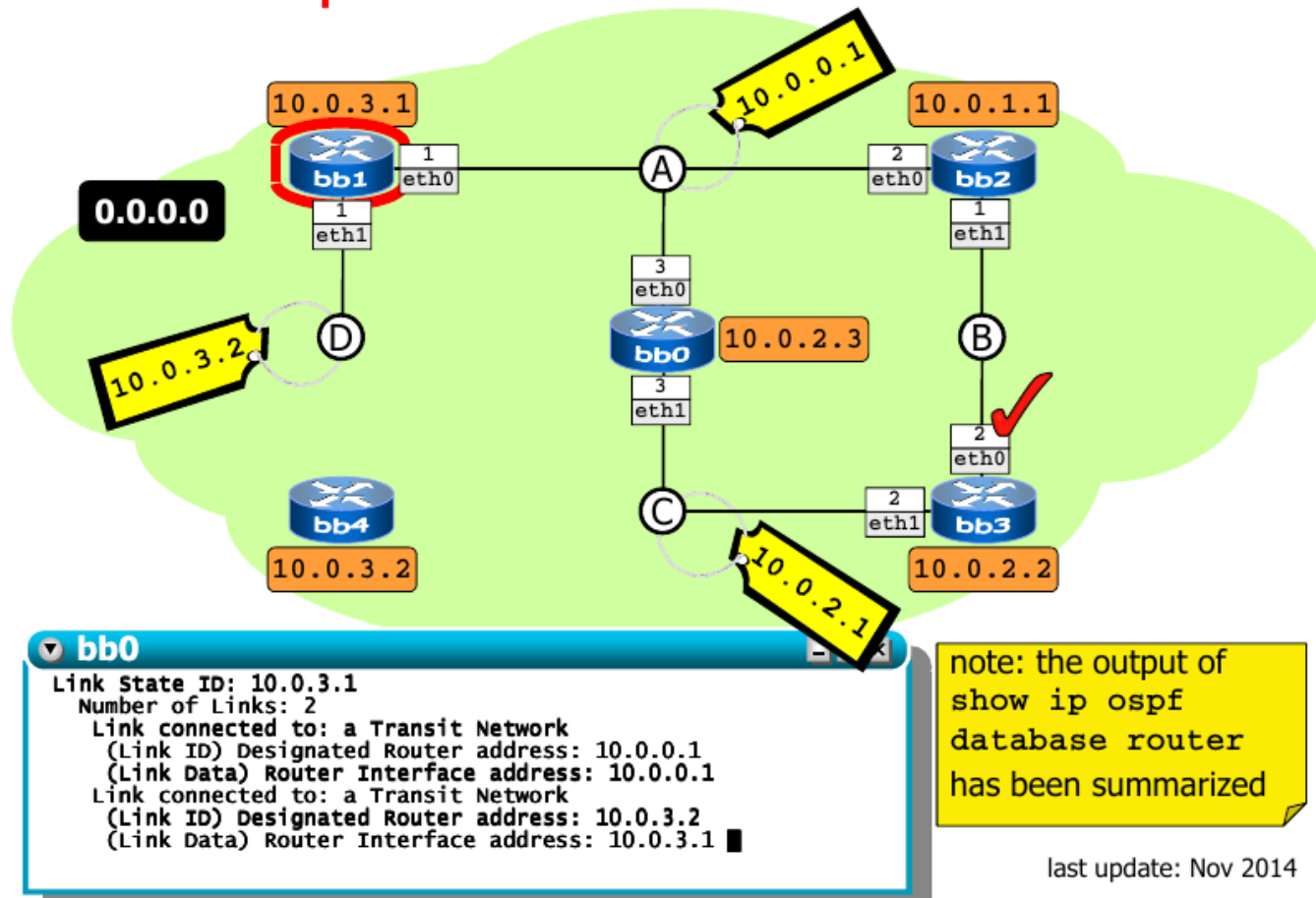
last update: Nov 2014

ospf's view of the network



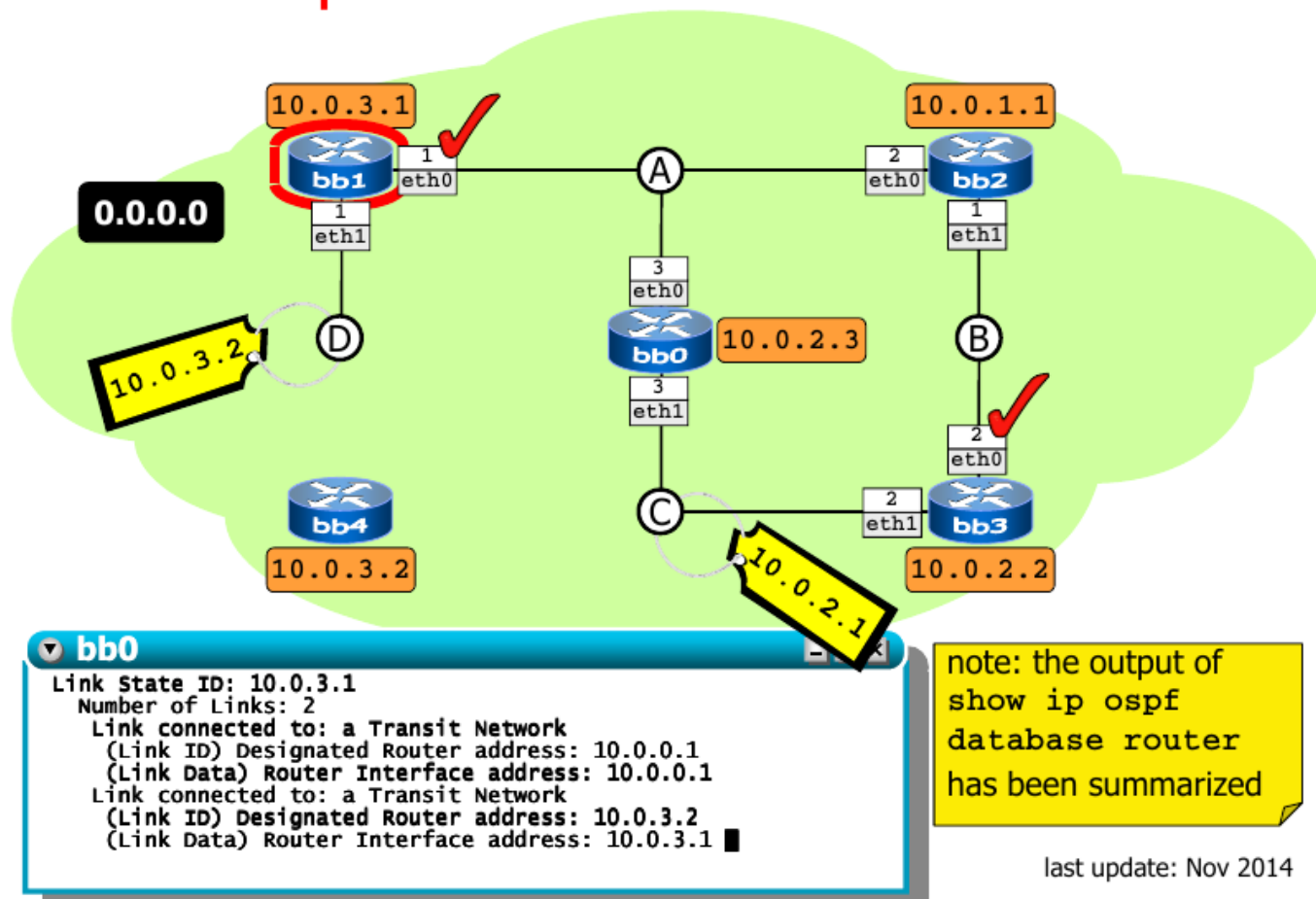
last update: Nov 2014

ospf's view of the network

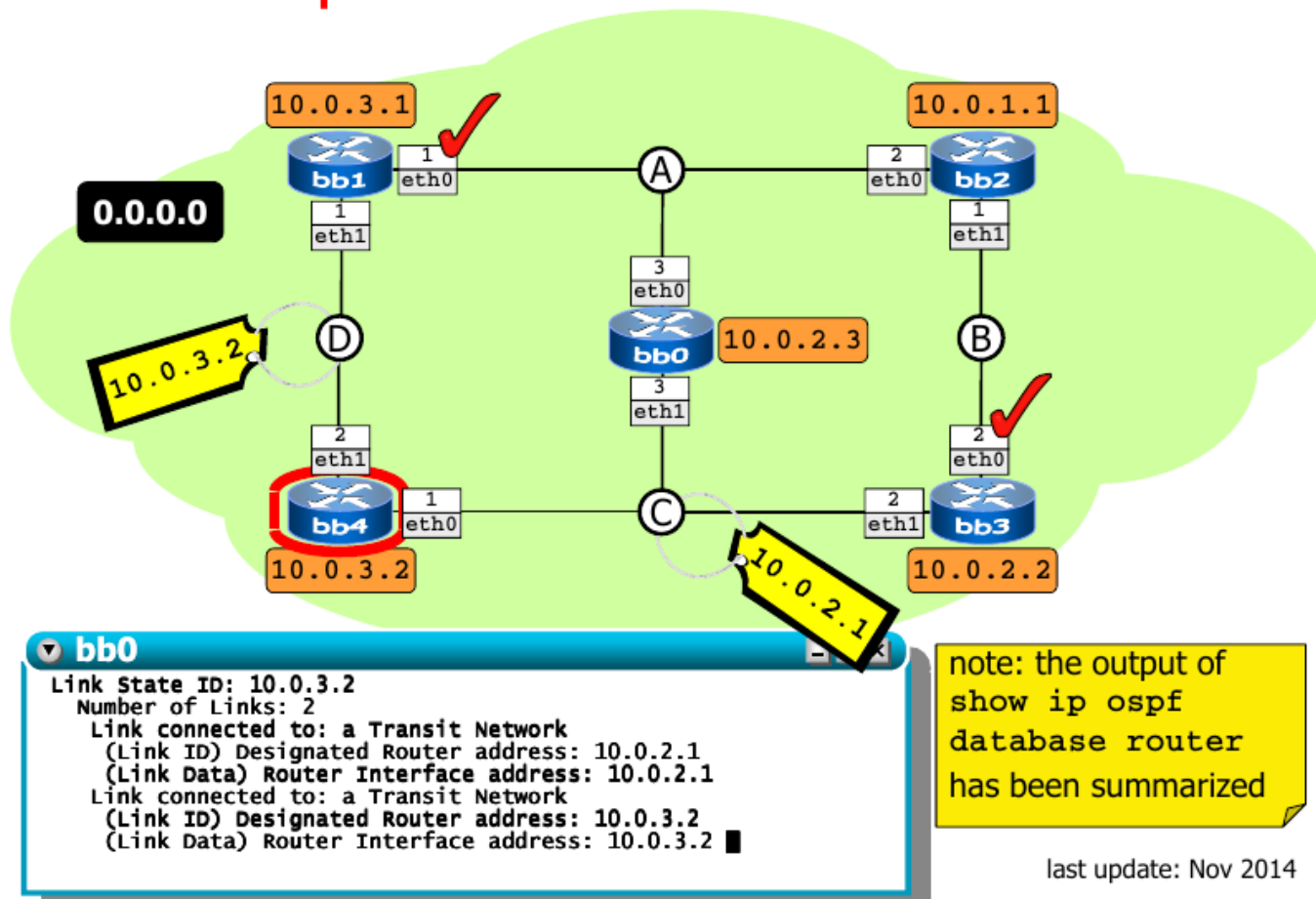


last update: Nov 2014

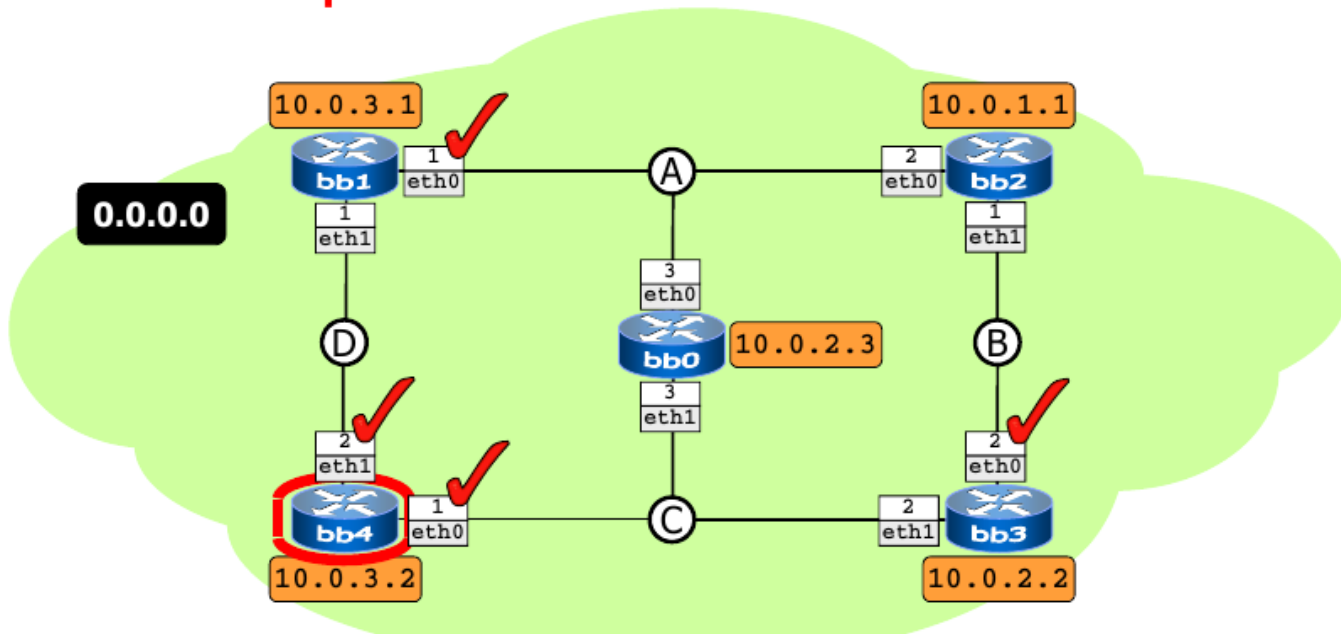
ospf's view of the network



ospf's view of the network



ospf's view of the network



```

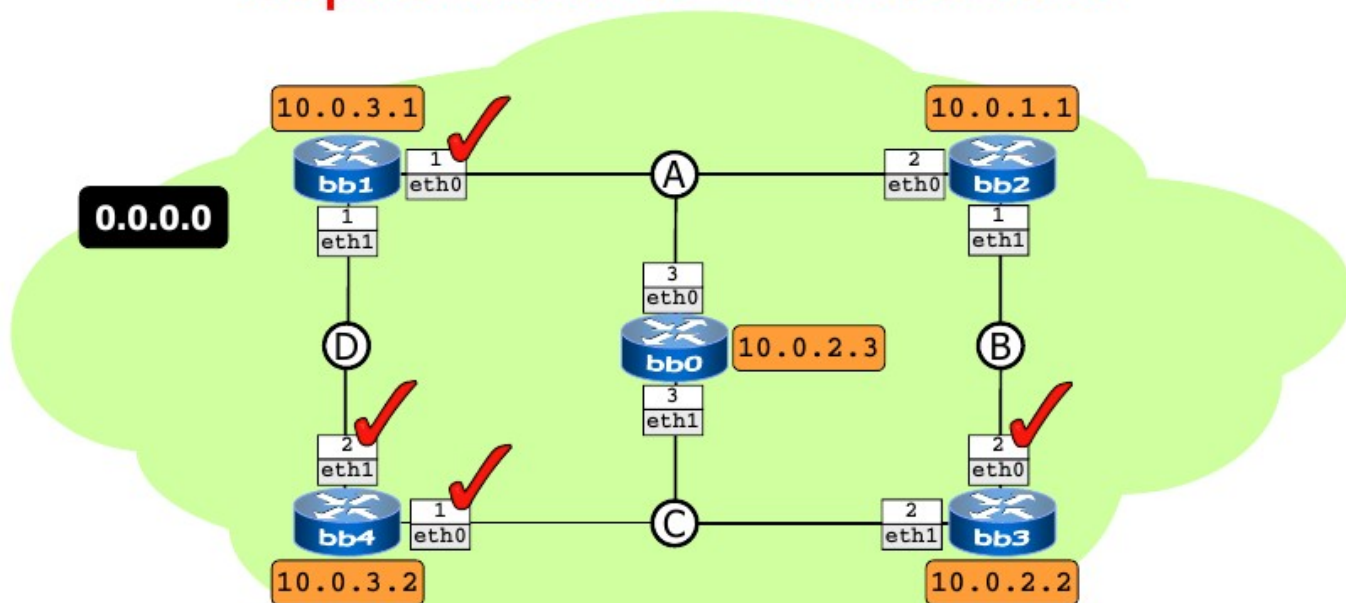
bb0
Link State ID: 10.0.3.2
Number of Links: 2
  Link connected to: a Transit Network
    (Link ID) Designated Router address: 10.0.2.1
    (Link Data) Router Interface address: 10.0.2.1
  Link connected to: a Transit Network
    (Link ID) Designated Router address: 10.0.3.2
    (Link Data) Router Interface address: 10.0.3.2

```

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

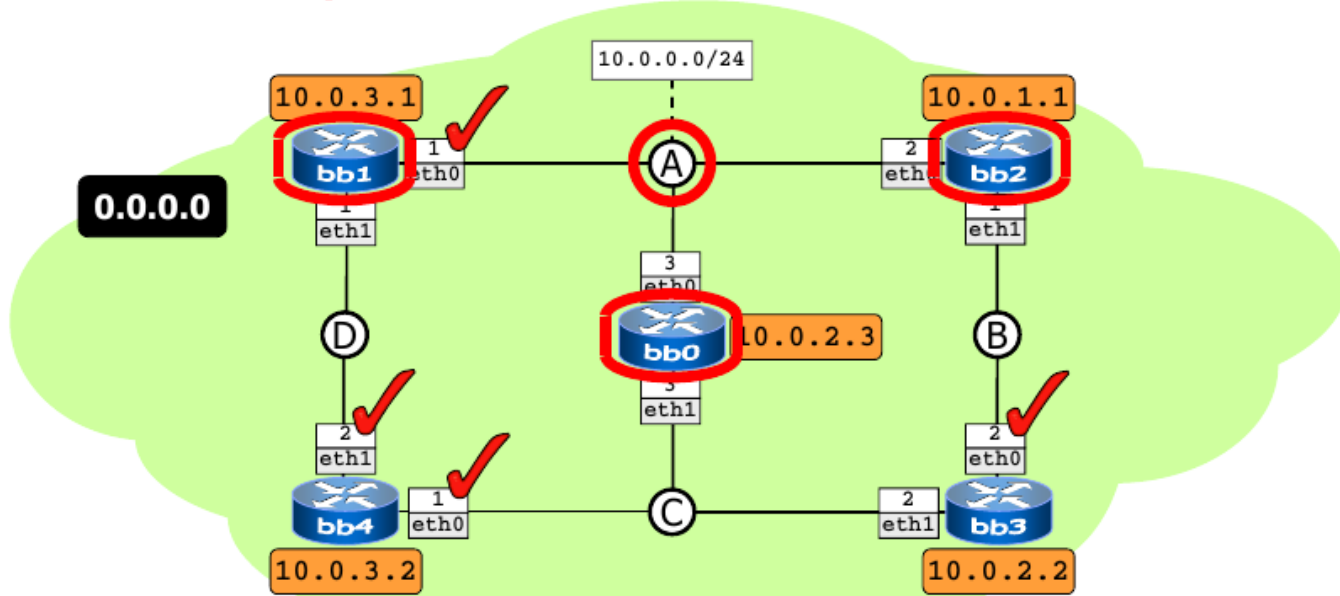
last update: Nov 2014

ospf's view of the network



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

ospf's view of the network

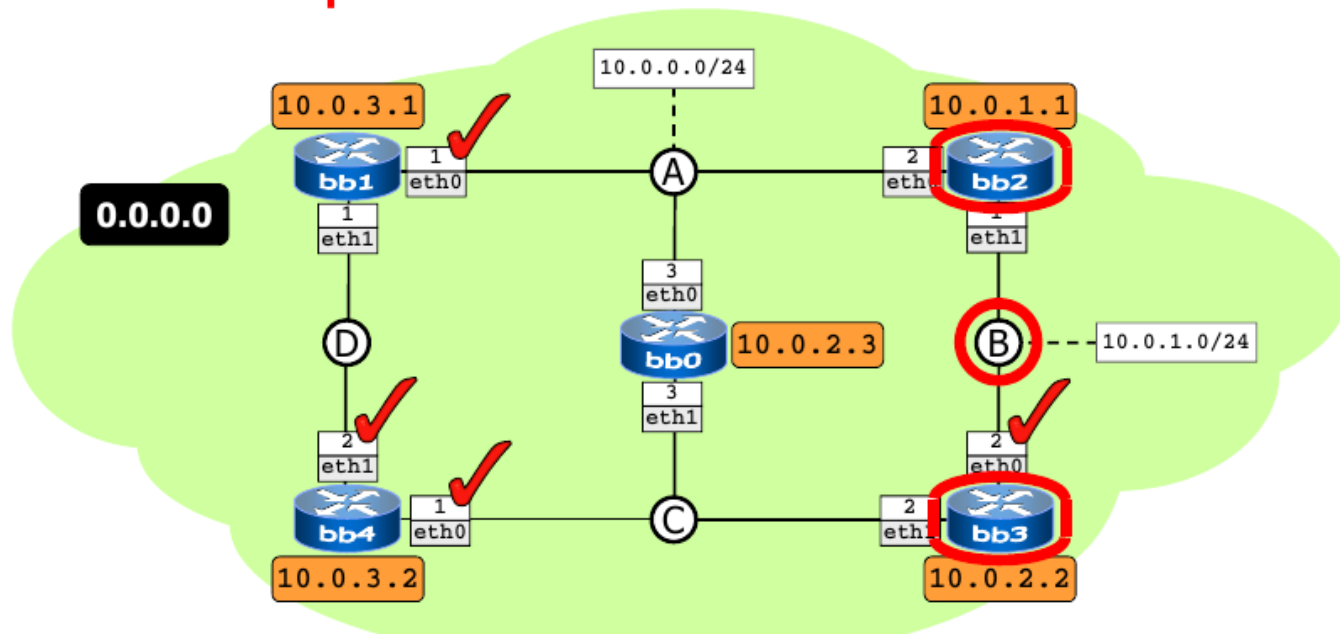


```
bb0
Link State ID: 10.0.0.1 (address of Designated Router)
Advertising Router: 10.0.3.1
Network Mask: /24
  Attached Router: 10.0.3.1
  Attached Router: 10.0.1.1
  Attached Router: 10.0.2.3
```

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

last update: Nov 2014

ospf's view of the network



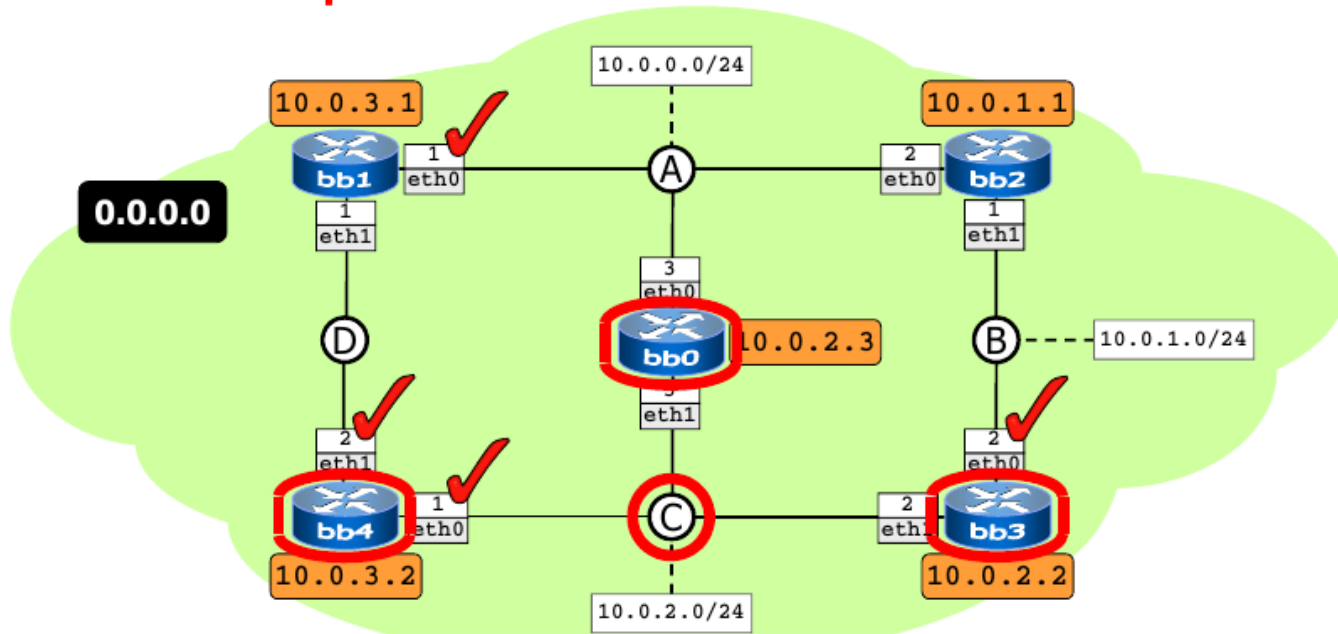
bb0

```
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 ospf
database network
has been summarized

last update: Nov 2014

ospf's view of the network



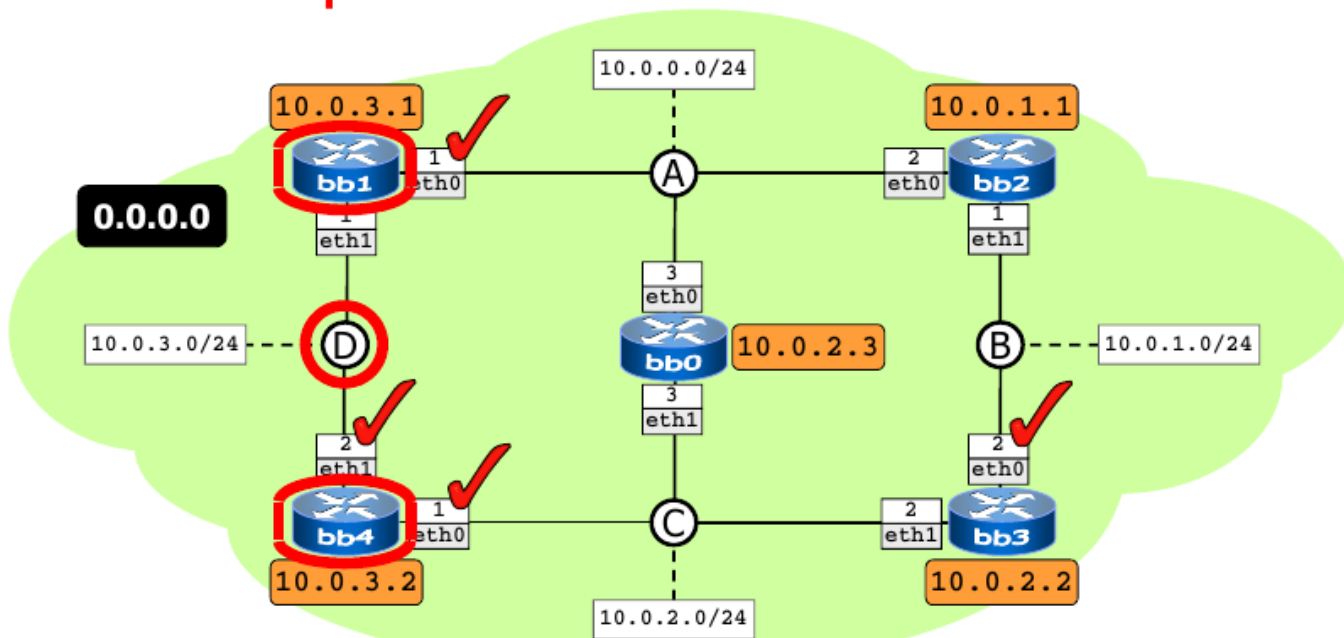
▼ **bb0**

```
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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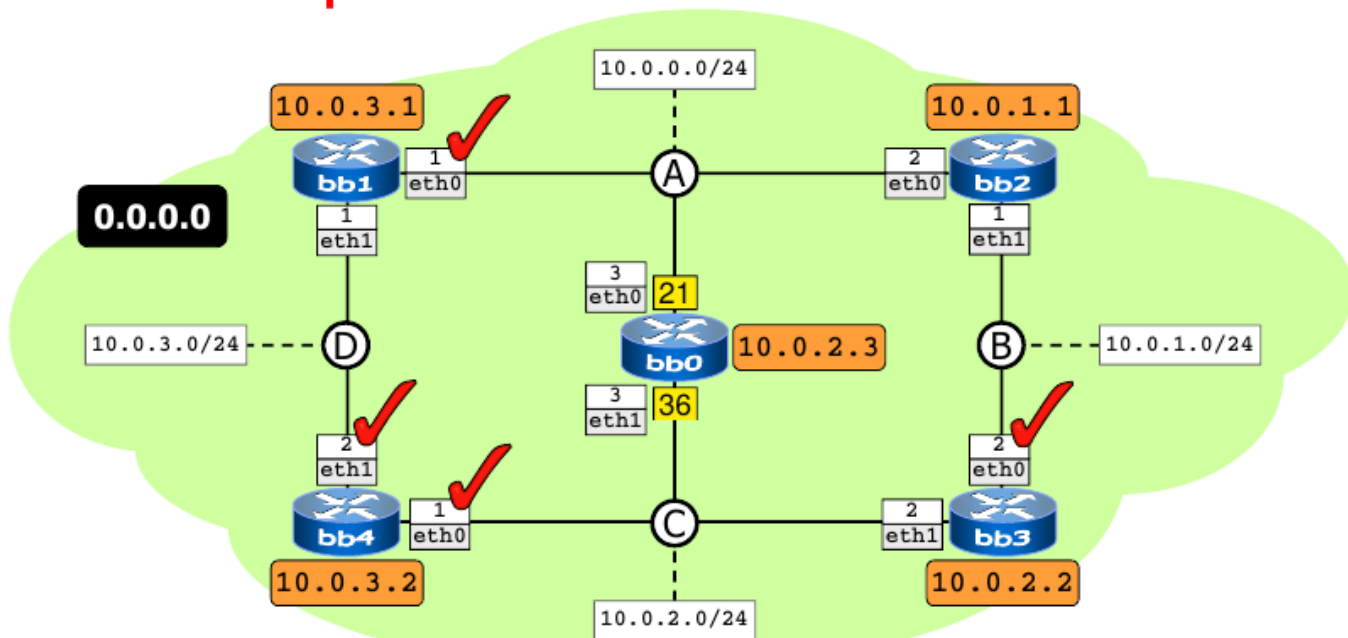
ospf's view of the network



```
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

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
```

ospf interface costs can be queried on all routers

a shortcut to quickly get the cost

last update: Nov 2014

Dinamikus működés

- ▶ OSPF üzenetek (Hello, majd LSA-k)
- ▶ Mi történik, ha lemegy egy link?
- ▶ Mi történik, ha lemegy egy DR link?
- ▶ Mi történik, ha lemegy egy router?

Dinamikus működés

- ▶ OSPF Hello üzenetek, később LSA-k
 - ▶ tcpdump -ne ip proto ospf
 - ▶ (esetleg -vv a részletes nézethez)
 - ▶ vizsgáljuk meg részletesebben
 - ▶ (később is érdemes pl. az egyik routeren futtatni)

Dinamikus működés

- ▶ Mi történik, ha lemegy egy link?
 - ▶ ifconfig vagy ip parancs használható
 - ▶ pl. BB3 eth1 interfész down (majd up)
 - ▶ hogy változnak az útvonalak?
 - ▶ pl. BB1-ről → 10.0.2.1 felé
 - traceroute -I icmp 10.0.2.1
 - ▶ routing táblák vizsgálata
 - show ip ospf route

Dinamikus működés

- ▶ Mi történik, ha lemegy egy link?
 - ▶ ifconfig vagy ip parancs használható
 - ▶ pl. BB3 eth1 interfész down (majd up)
 - ▶ hogy változnak az útvonalak?
 - ▶ pl. BB1-ről → 10.0.2.1 felé
 - traceroute -I icmp 10.0.2.1
 - ▶ routing táblák vizsgálata
 - show ip ospf route

```
bb1:~# traceroute 10.0.2.1
traceroute to 10.0.2.1 (10.0.2.1), 64 hops max, 40 byte packets
 1  10.0.0.3 (10.0.0.3)  9 ms  1 ms  1 ms
 2  10.0.2.1 (10.0.2.1)  13 ms  2 ms  0 ms
```

```
bb1# sho ip route
Codes: K - kernel route, C - connected, S - static, R - RIP, O - OSPF,
       I - ISIS, B - BGP, > - selected route, * - FIB route

O   10.0.0.0/24 [110/10] is directly connected, eth0, 00:20:30
C>* 10.0.0.0/24 is directly connected, eth0
O>* 10.0.1.0/24 [110/20] via 10.0.0.2, eth0, 00:19:37
O>* 10.0.2.0/24 [110/46] via 10.0.0.3, eth0, 00:01:17
O   10.0.3.0/24 [110/45] is directly connected, eth1, 00:01:17
C>* 10.0.3.0/24 is directly connected, eth1
C>* 127.0.0.0/8 is directly connected, lo
```

Dinamikus működés

- ▶ Mi történik, ha DR link megy le?
 - ▶ pl. BB3 eth0 down majd up
 - ▶ BB2-n ellenőrizzük az OSPF interfészeket és database-t
 - show ip ospf interface
 - show ip ospf database
 - ▶ BB3 eléri a 10.0.1.0 hálózatot?
 - ▶ BB3-n húzzuk vissza az eth0 interfészt
 - ▶ BB2-n újra vizsgáljuk az interfészeket/database-t
 - show ip ospf interface
 - show ip ospf database
 - show ip ospf database network

Dinamikus működés

- ▶ Mi történik, ha DR link megy le
 - ▶ pl. BB3 eth0 down majd up
 - ▶ BB2-n ellenőrizzük az OSPF interfészt
 - show ip ospf interface
 - show ip ospf database
 - ▶ BB3 eléri a 10.0.1.0 hálózatot? igen, 2 úton is, 40-es költségű lesz az aktív
 - ▶ BB3-n húzzuk vissza az eth0 interfészt
 - ▶ BB2-n újra vizsgáljuk az interfészeket/database-t

```
bb2# show ip ospf database
```

```
OSPF Router with ID (10.0.1.1)
```

```
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	87	0x80000009	0xc718	2
10.0.2.2	10.0.2.2	83	0x8000000f	0xc112	2
10.0.2.3	10.0.2.3	200	0x8000000a	0xd9d4	2
10.0.3.1	10.0.3.1	1673	0x80000006	0x2c8b	2
10.0.3.2	10.0.3.2	201	0x80000005	0x468e	2

```
Net Link States (Area 0.0.0.0)
```

Link ID	ADV Router	Age	Seq#	CkSum
10.0.0.1	10.0.3.1	1693	0x80000002	0x69a9
10.0.1.1	10.0.1.1	87	0x80000001	0x80a7
10.0.2.1	10.0.3.2	201	0x80000004	0x6e9c
10.0.3.2	10.0.3.2	1680	0x80000001	0x6bb3

```
eth1 is up
ifindex 4, MTU 1500 bytes, BW 0 Kbit <UP,BROADCAST,RUNNING,MULTICAST>
Internet Address 10.0.1.1/24, Broadcast 10.0.1.255, Area 0.0.0.0
MTU mismatch detection:enabled
Router ID 10.0.1.1, Network Type BROADCAST, Cost: 10
Transmit Delay is 1 sec, State DR, Priority 1
Designated Router (ID) 10.0.1.1, Interface Address 10.0.1.1
No backup designated router on this network
Multicast group memberships: OSPFAllRouters OSPFDesignatedRouters
Timer intervals configured, Hello 10s, Dead 40s, Wait 40s, Retransmit 5
Hello due in 5.124s
Neighbor Count is 0, Adjacent neighbor count is 0
```

```
eth1 is up
ifindex 4, MTU 1500 bytes, BW 0 Kbit <UP,BROADCAST,RUNNING,MULTICAST>
Internet Address 10.0.1.1/24, Broadcast 10.0.1.255, Area 0.0.0.0
MTU mismatch detection:enabled
Router ID 10.0.1.1, Network Type BROADCAST, Cost: 10
Transmit Delay is 1 sec, State DR, Priority 1
Designated Router (ID) 10.0.1.1, Interface Address 10.0.1.1
Backup Designated Router (ID) 10.0.2.2, Interface Address 10.0.1.2
Multicast group memberships: OSPFAllRouters OSPFDesignatedRouters
Timer intervals configured, Hello 10s, Dead 40s, Wait 40s, Retransmit 5
Hello due in 1.600s
Neighbor Count is 1, Adjacent neighbor count is 1
```

Dinamikus működés

- ▶ Mi történik, ha lemegy egy router?
 - ▶ pl. minden interfészét down állapotba kapcsoljuk
 - ▶ házi feladat