

Hálózatok építése és üzemeltetése

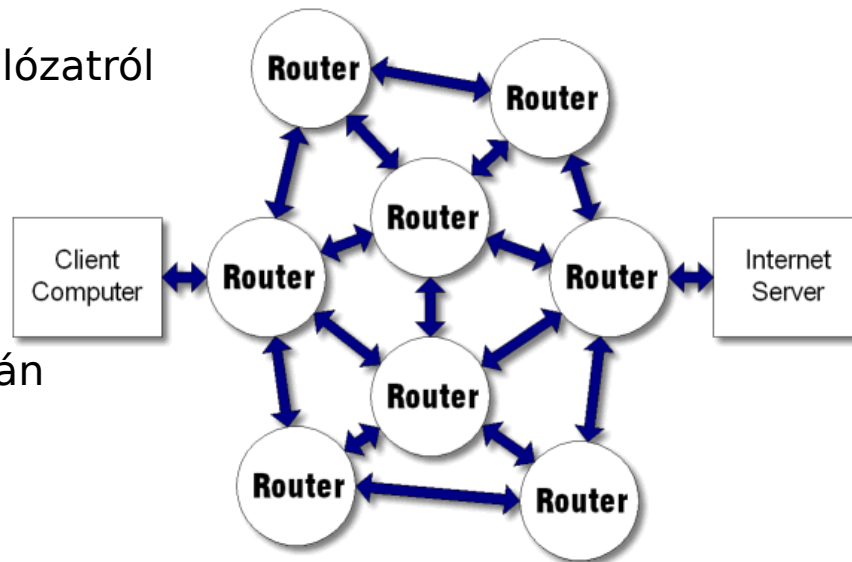
OSPF gyakorlat

Ismétlés

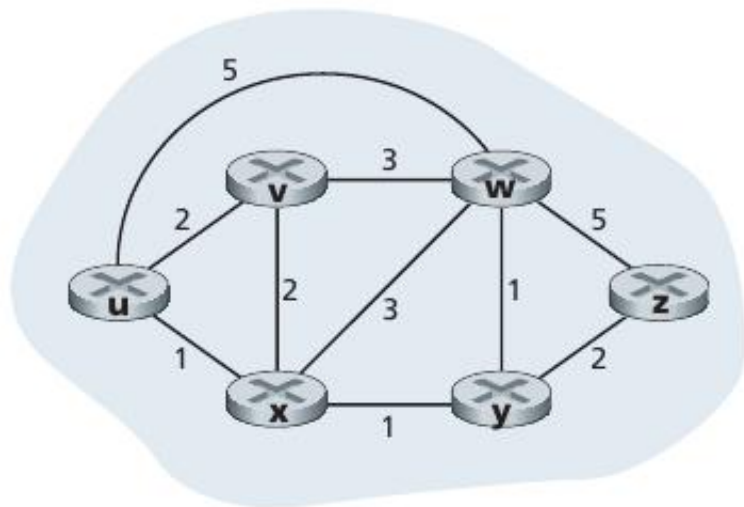
Routing protokollok

▶ 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, sáv szélesség 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 nézetten 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-eket 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:



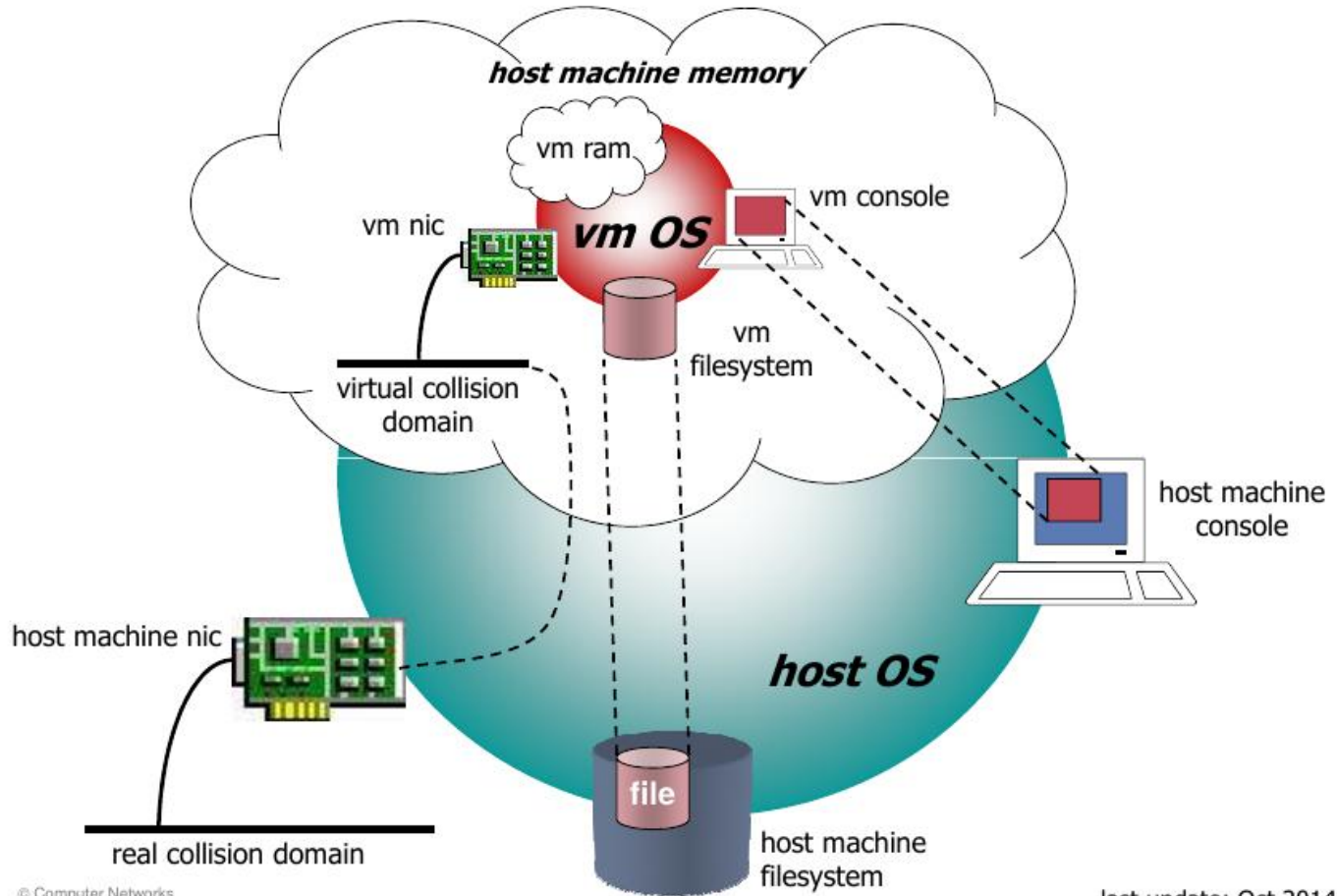
Kathará

a container-based framework
to deploy virtual networks featuring NFV, SDN
and traditional routing protocols

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

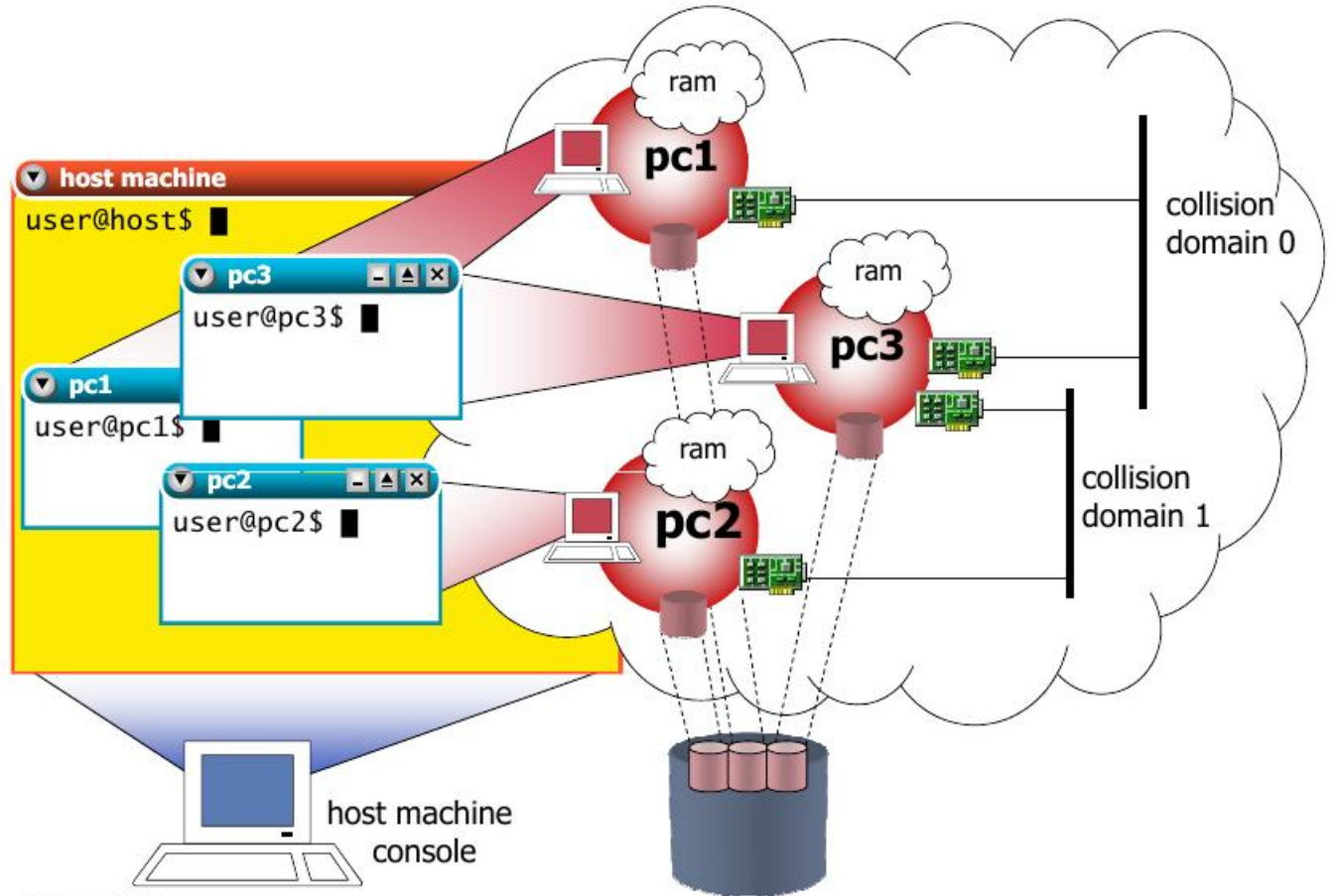
Netkit



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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

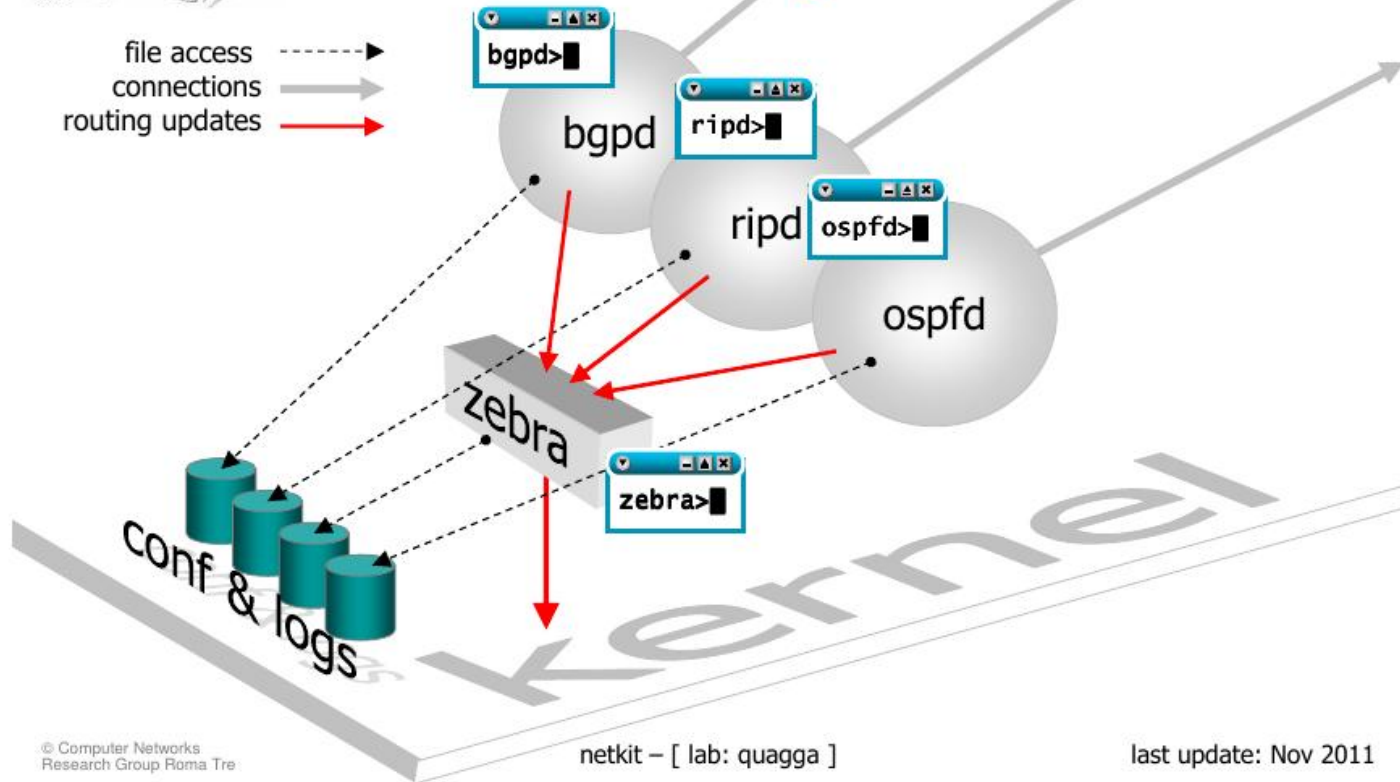
- ▶ Routing Szoftver csomag
 - ▶ GPL
 - ▶ FreeBSD, Linux, Solaris, NetBSD
 - ▶ GNU Zebra volt előbb
 - ▶ Quagga egy fork volt
 - ▶ “The Quagga tree aims to build a more involved community around Quagga than the current centralised model of GNU Zebra.”
 - ▶ az élővilágban a quagga halt ki
 - ▶ a routing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



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netkit - [lab: quagga]

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Vizsgálati környezet kialakítása

- ▶ **QBF12: BME Cloud (Smallville), template: HaEpUz 2022 ...**
- ▶ ~~IB213 labor: default HaEpUz (Mininet+Netkit) boot image~~
- ▶ ~~Saját gép:~~
 - ▶ ~~Kiadott HaEpUz VM (Jupyter Notebook)~~
 - ▶ ~~de most nem a notebookot használjuk~~
 - ▶ ~~Indítás (importálás): Virtualbox vagy VMware player~~
- ▶ A rendszer egy Ubuntu 64-bit Linux + desktop environment, tartalma:
 - ▶ Mininet hálózatemuláció
 - ▶ Netkit hálózatemuláció
- ▶ OSPF lab indítása:
 - ▶ `$ cd ~/netkit/labs/netkit-lab_ospf-singlearea`
 - ▶ `$ Istart`

BME Cloud (Smallville)

HaEpUz 2022 - Ubuntu 20.04 + xfce4 v15 cloud-

46814.vm.smallville.cloud.bme.hu ☆



RUNNING

Connection details

Protocol SSH
Host vm.smallville.cloud.bme.hu:13202
Host (IPv6) cloud-40082.vm.smallville.cloud.bme.hu:22
Username cloud
Password

[Generate new password!](#)

Command

[Connect \(download client\)](#)

Home Resources Console Access **Network** Activity

Interfaces

[add interface](#)

VM-NET [remove](#)

IPv4 address: 10.9.1.210
IPv6 address: 2001:738:2001:2209:9:1:210:0
DNS name: cloud-40082.vm.smallville.cloud.bme.hu
Groups: -

Port access

Port	Protocol	Action
vm.smallville.cloud.bme.hu:13202	22/tcp	x
vm.smallville.cloud.bme.hu:8852	3389/tcp	x

add rdp

3389

/ tcp [Add](#)

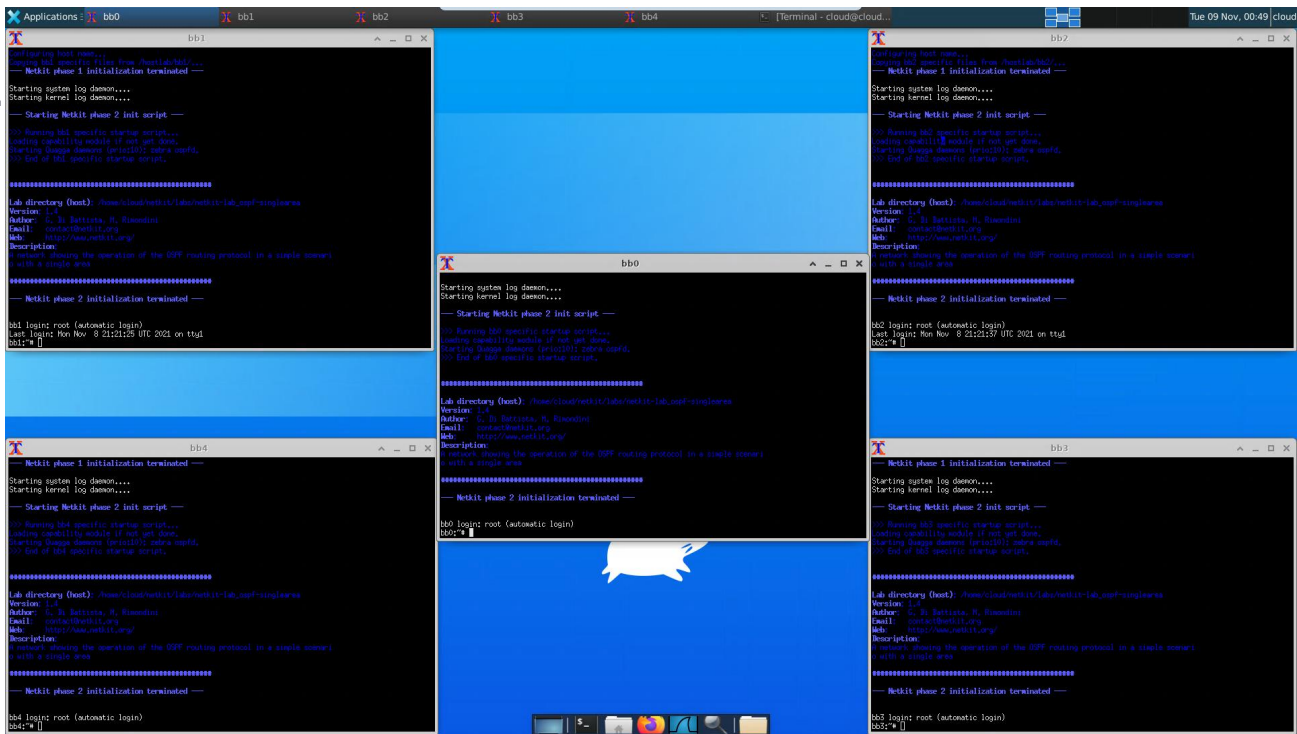
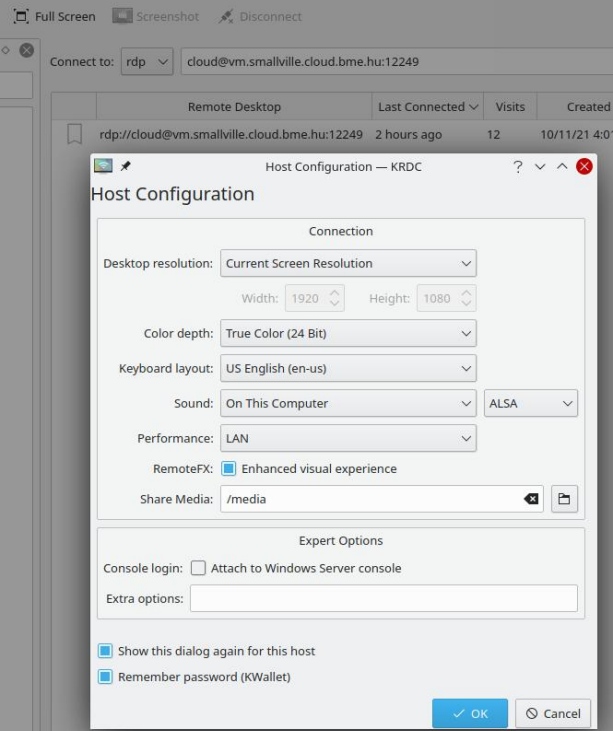
haepuz-1 (unmanaged) [remove](#)

Belépés: rdp

(xfce4 desktop)

rdp kliens

- pl.: krdc, remmina, MS...

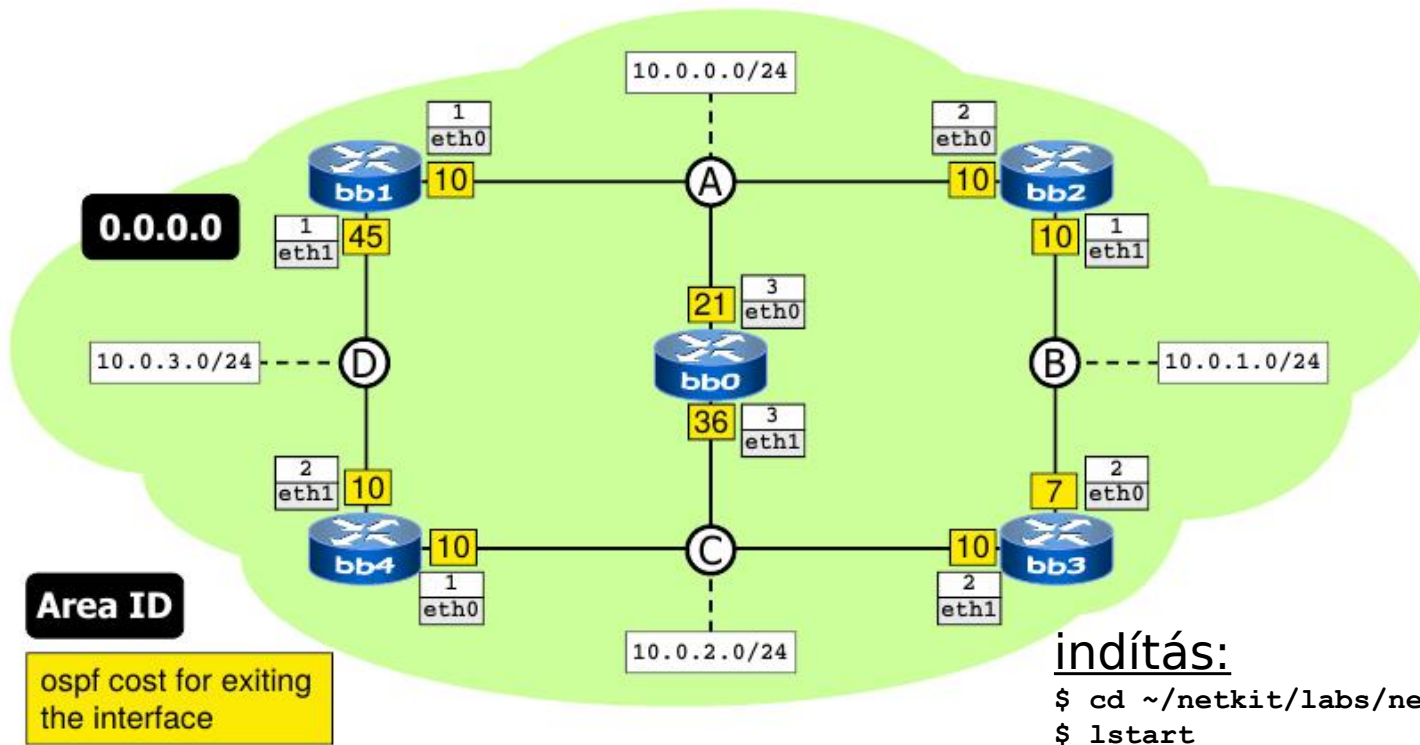


OSPF lab# 1

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!

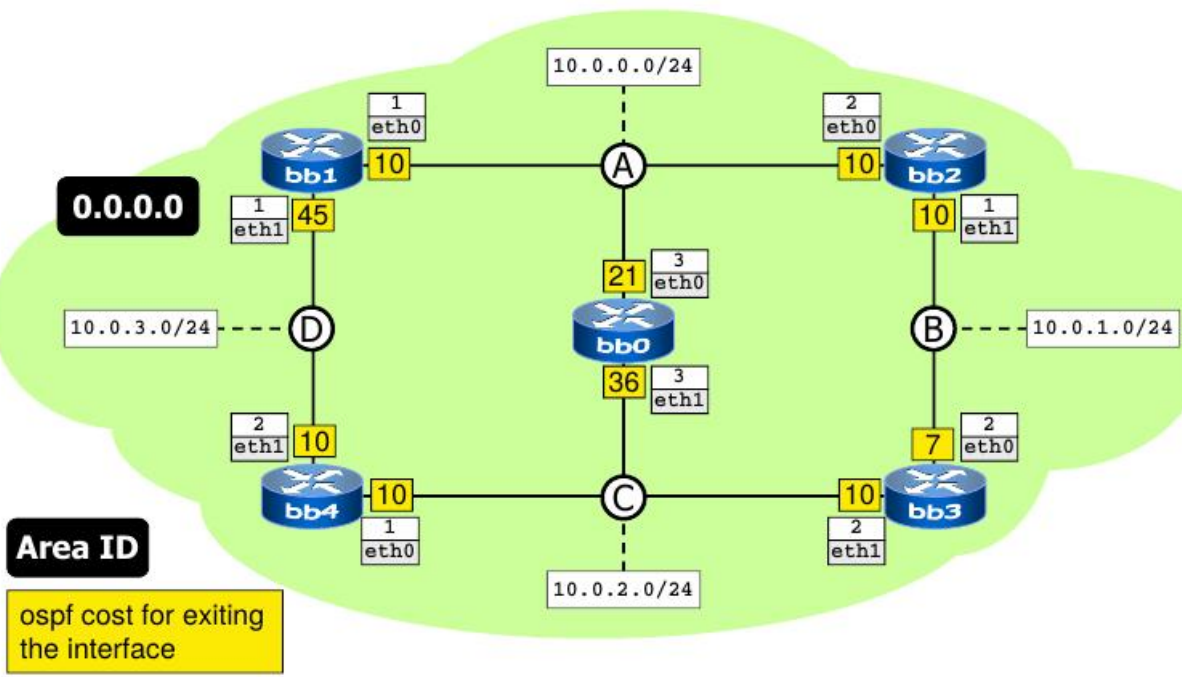
indítás:

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

netkit - [labs: ospf]

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OSPF lab#1 topológia



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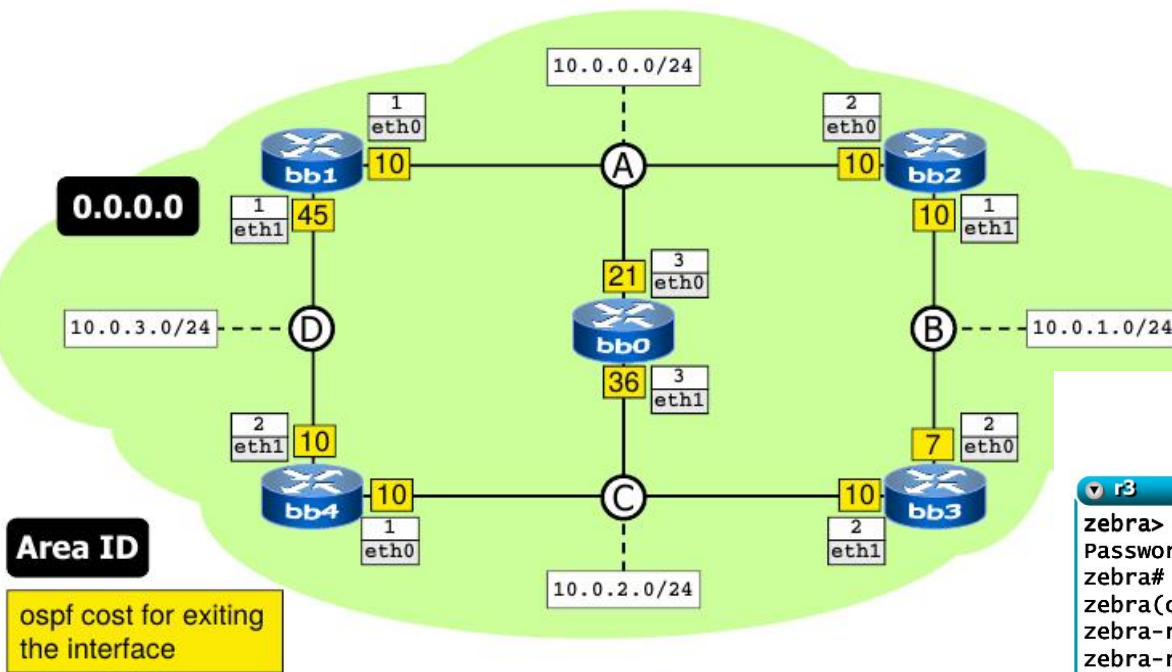
netkit - [labs: ospf]

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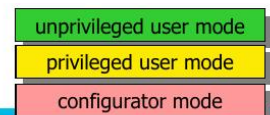
- ▶ quagga teszt, pl. bb0 routeren
 - ▶ cd /etc/zebra; ls -l
 - ▶ daemon conf fájlok
 - ▶ cat daemons
 - ▶ cat zebra.conf (passwd!)
 - ▶ cat ospfd.conf

```
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



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



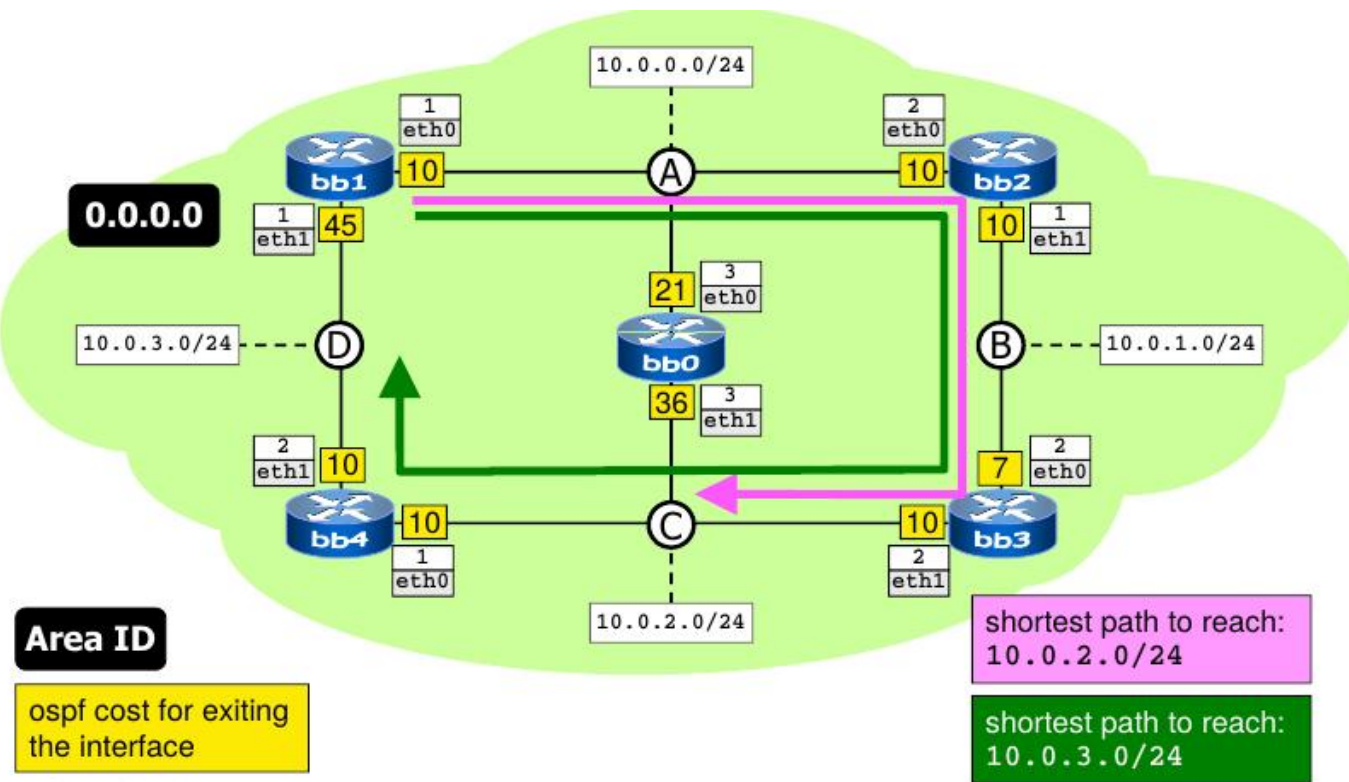
```
r3
zebra> enable
Password: zebra
zebra# configure terminal
zebra(config)# hostname zebra-r3
zebra-r3(config)# password foo
zebra-r3(config)# enable password foo
zebra-r3(config)# quit
zebra-r3# write file
Configuration saved to /etc/zebra/zebra.conf
zebra-r3# disable
zebra-r3> exit
Connection closed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

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netkit - [labs: ospf] last u

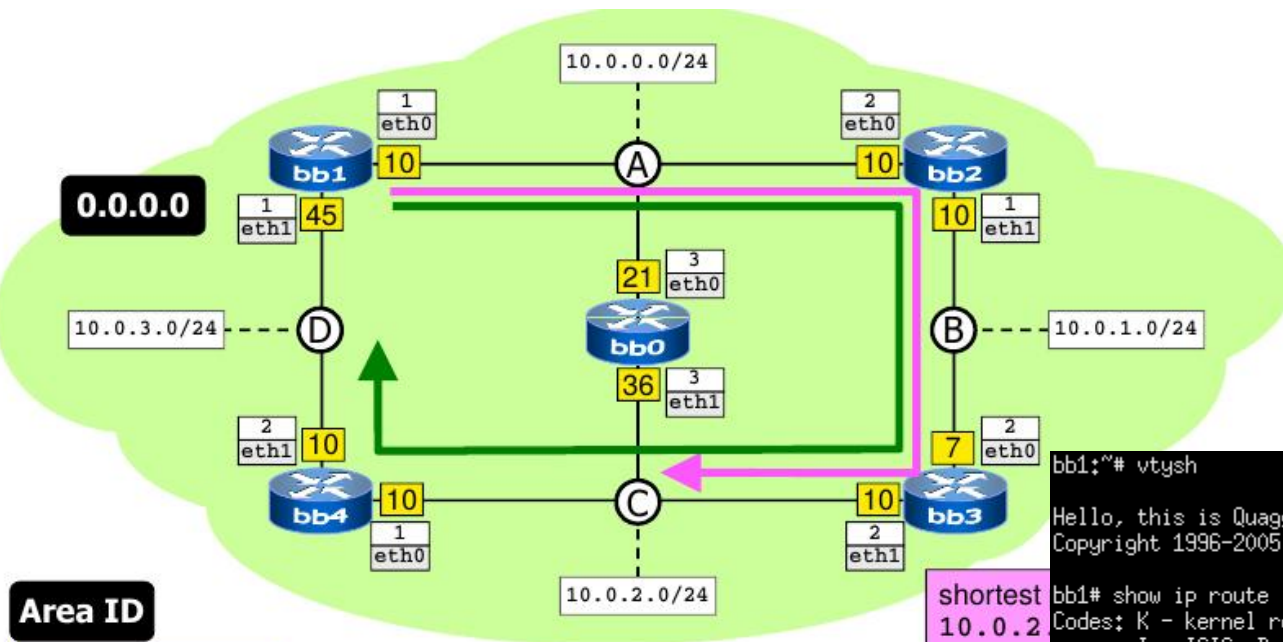


Legrövidebb utak



- ▶ 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

Area ID

ospf cost for exiting the interface

```
bb1:~# vtysh
Hello, this is Quagga (version 0.99.10),
Copyright 1996-2005 Kunihiro Ishiguro, et al.

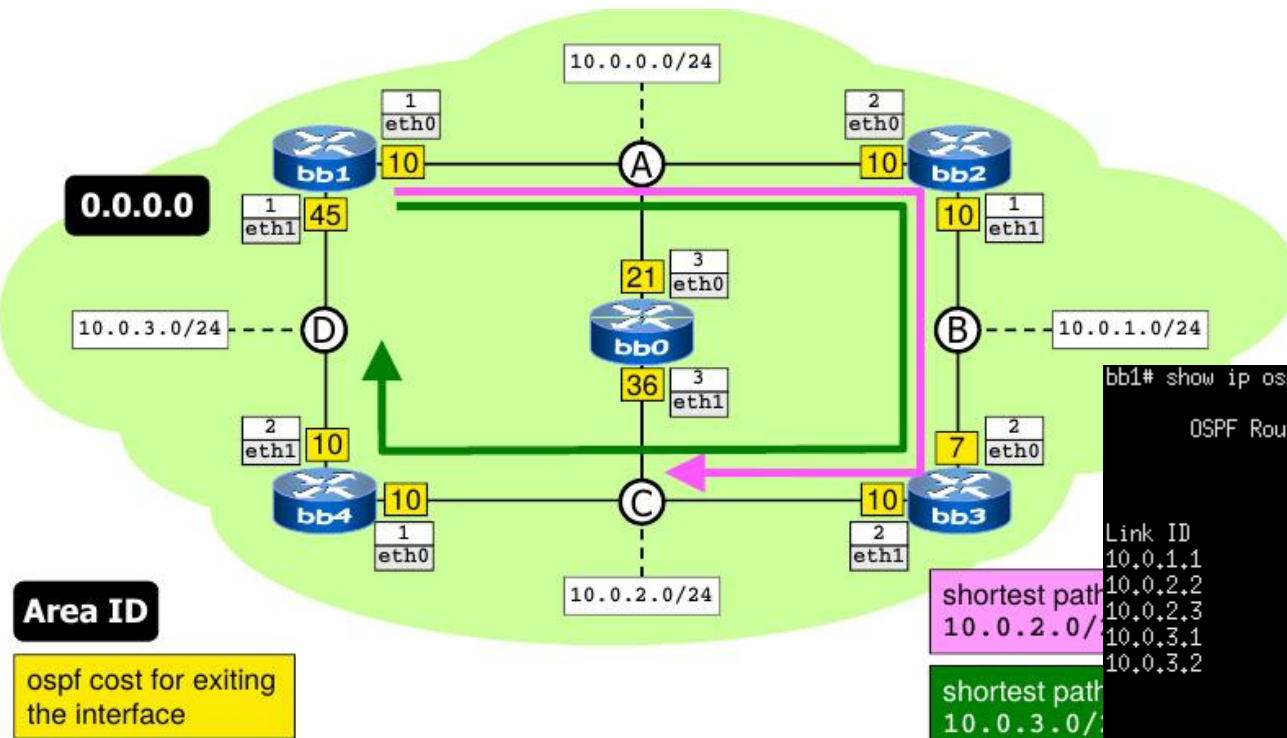
bb1# show ip route
Codes: K - kernel route, C - connected, S - static, R - RIP, O - OSPF,
       I - ISIS, B - BGP, > - selected route, * - FIB route

O 10.0.0.0/24 [110/10] is directly connected, eth0, 00:53:10
C>* 10.0.0.0/24 is directly connected, eth0
O>* 10.0.1.0/24 [110/20] via 10.0.0.2, eth0, 00:53:05
O>* 10.0.2.0/24 [110/30] via 10.0.0.2, eth0, 00:53:05
O 10.0.3.0/24 [110/40] via 10.0.0.2, eth0, 00:53:05
C>* 10.0.3.0/24 is directly connected, eth1
C>* 127.0.0.0/8 is directly connected, lo
bb1#
```

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)
```

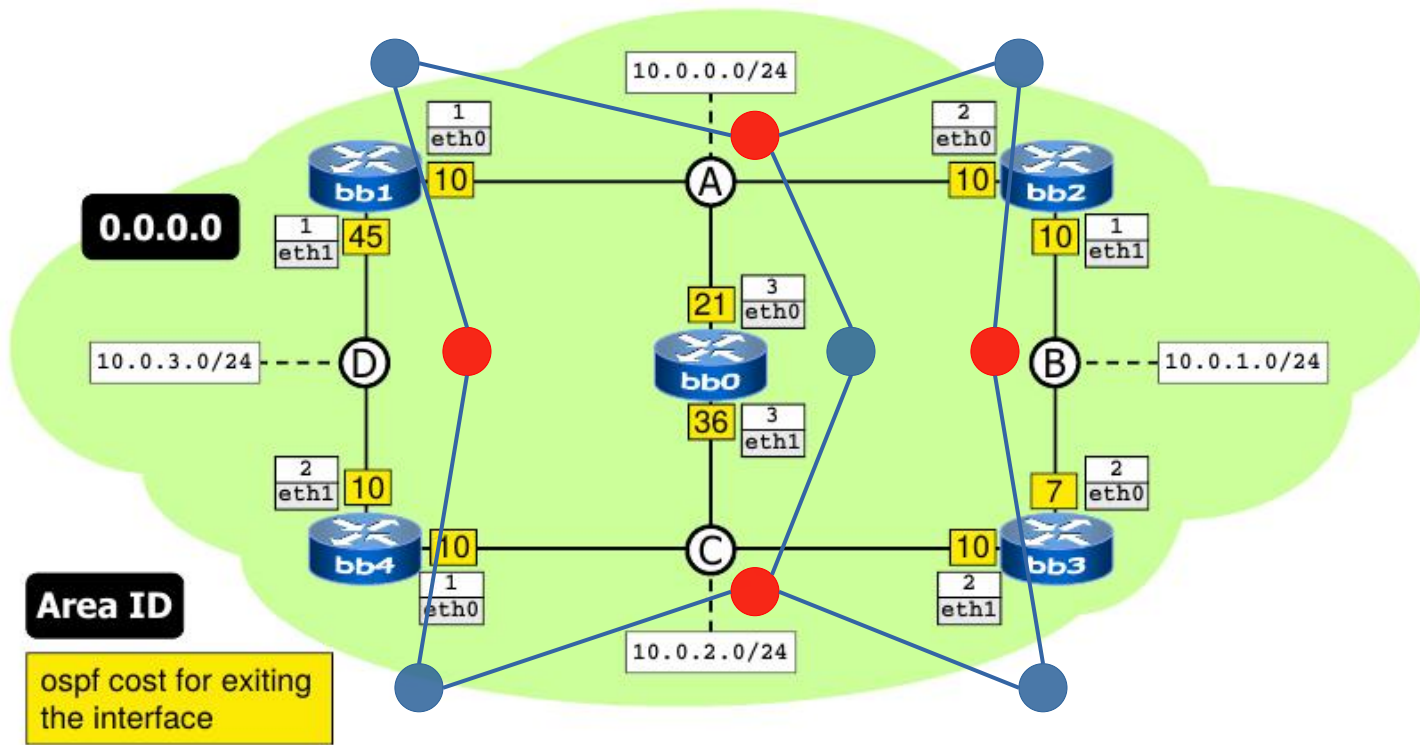
```
Router Link States (Area 0.0.0.0)
```

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

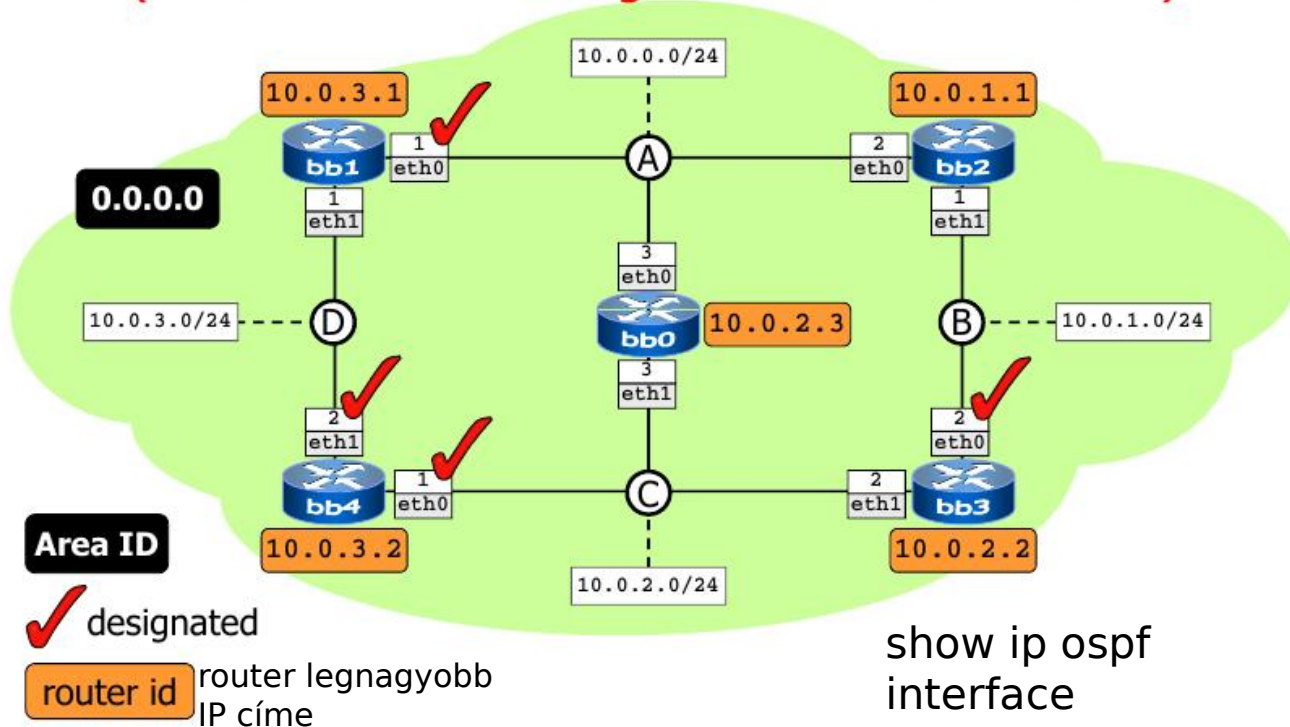
Speciális gráf modell



- ▶ 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)

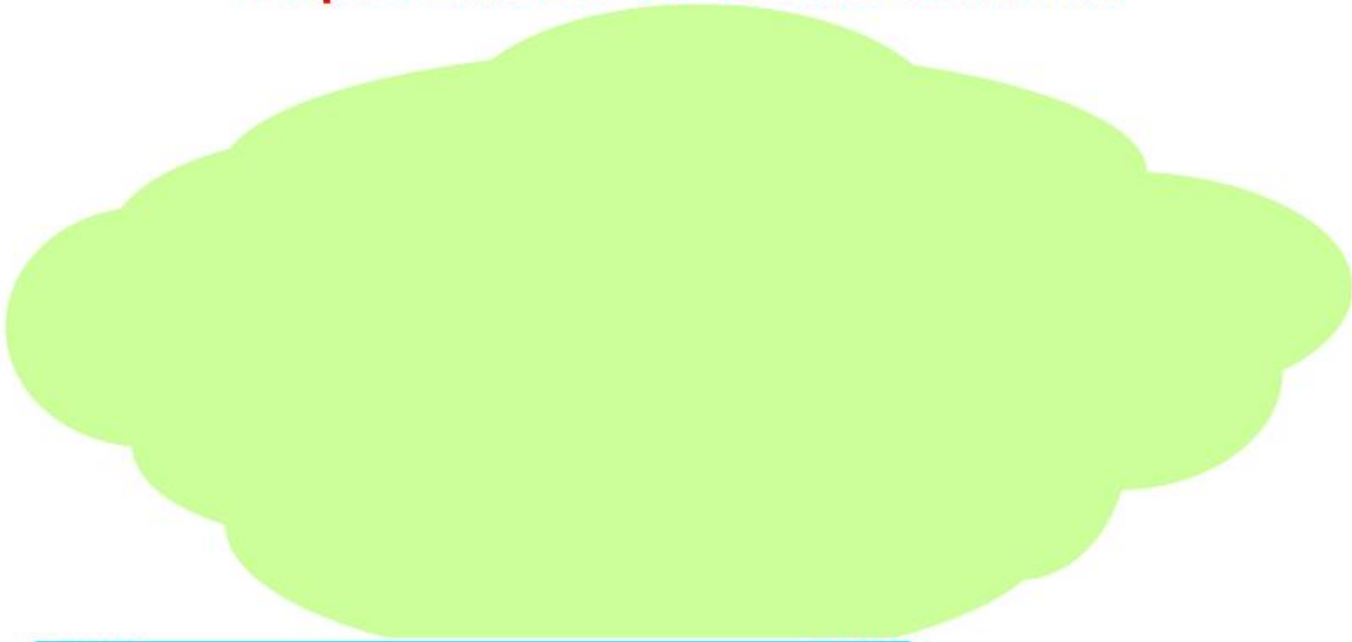


- ▶ Broadcast hálózatoknál
 - ▶ pl. Ethernet
 - ▶ DR és Backup DR: kitüntetett routerek
 - ▶ választás alapján
 - ▶ router id alapján (max.)
 - ▶ (ami interfész id)
 - ▶ többi OSPF router csak velük van full szomszédságban
 - ▶ különben mindenki-mindenkivel kommunikálna
 - ▶ útvonalfrissítés csak DR-től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

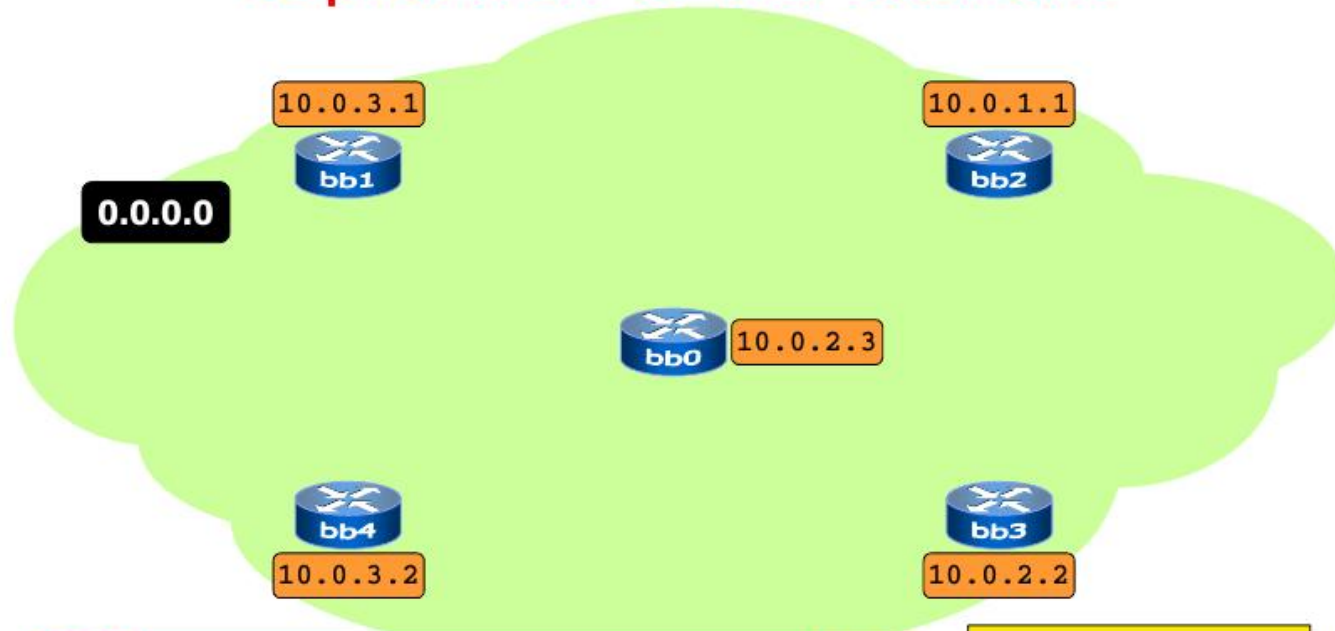
ospf's view of the network



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

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ospf's view of the network



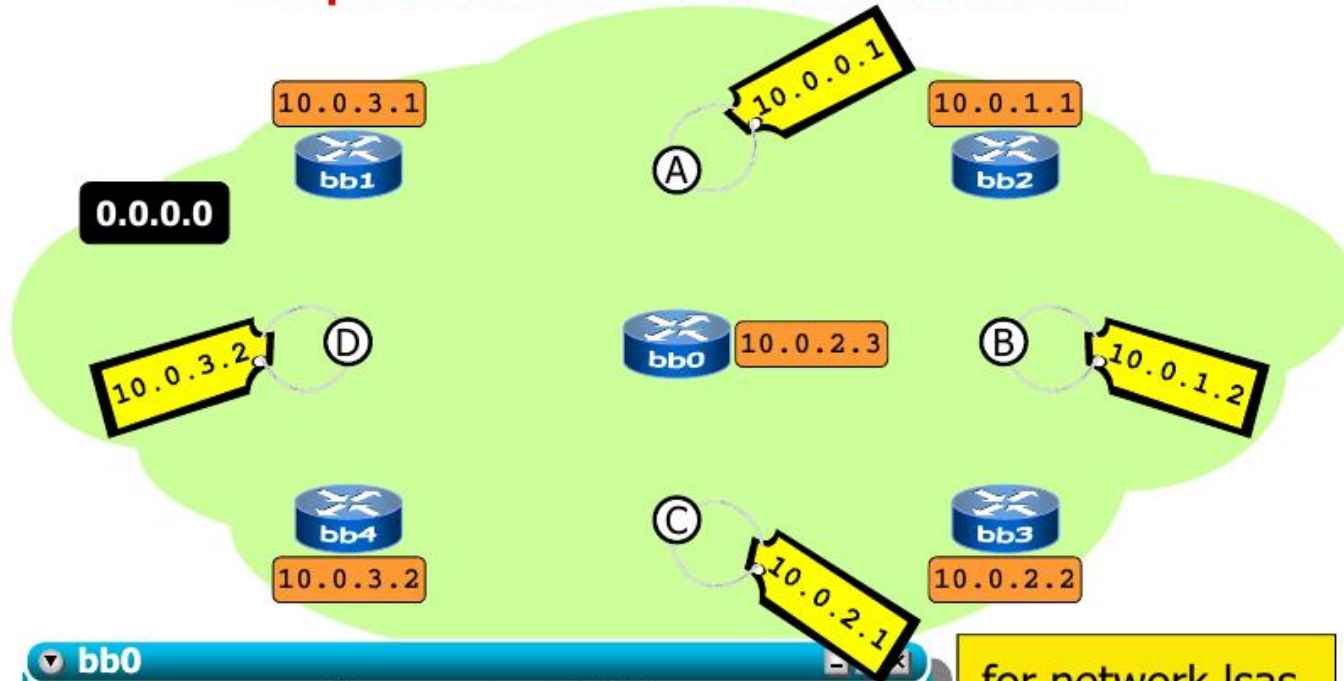
```
bb0
OSPF Router with ID (10.0.2.3)
Router Link States (Area 0.0.0.0)
Link ID      ADV Router   Age  Seq#       CkSum  Link count
10.0.1.1     10.0.1.1    553  0x80000003 0xe9fa 2
10.0.2.2     10.0.2.2    552  0x80000003 0xe3fa 2
10.0.2.3     10.0.2.3    552  0x80000003 0xe7cd 2
10.0.3.1     10.0.3.1    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



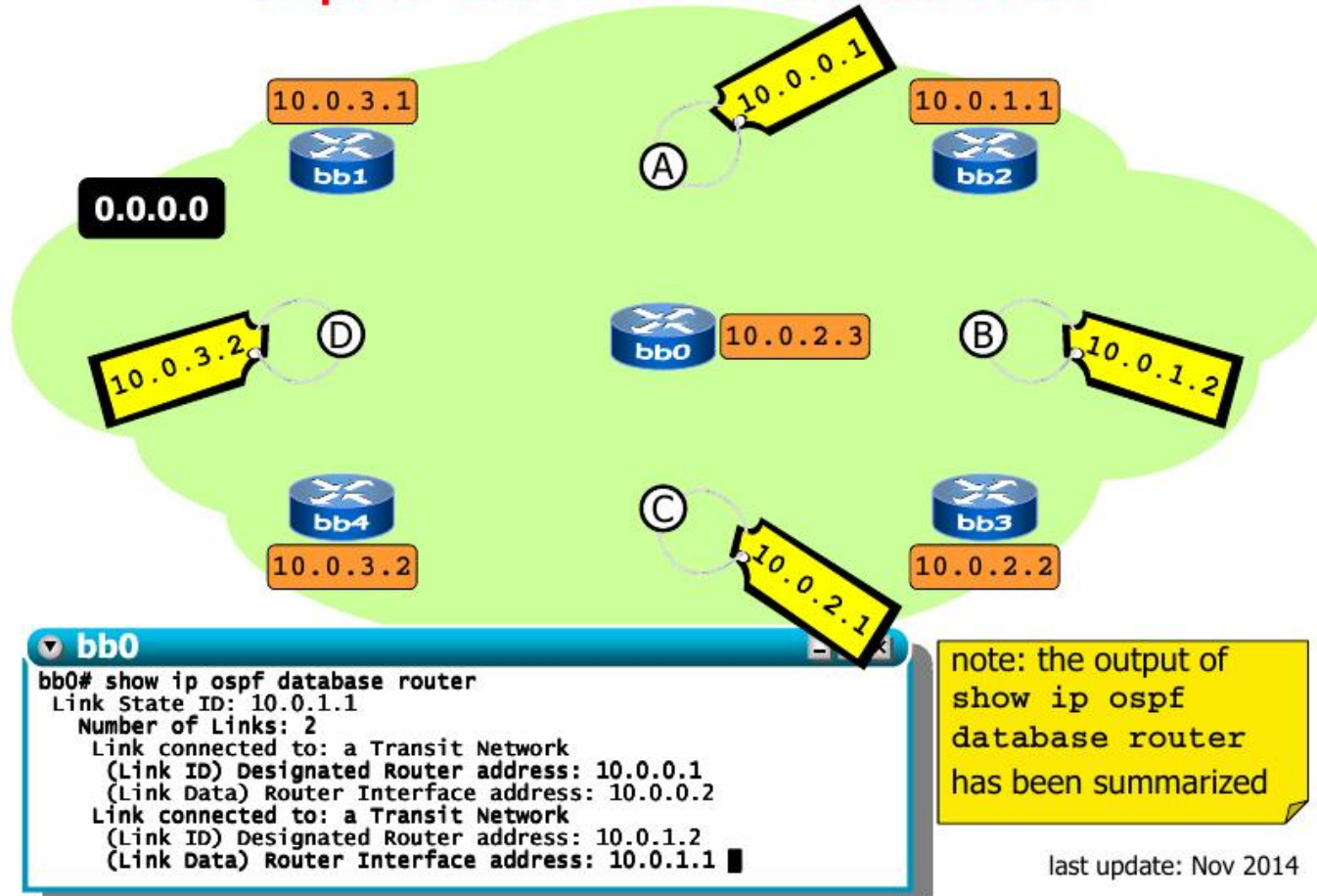
```
bb0
Net Link States (Area 0.0.0.0)
Link ID      ADV Router   Age  Seq#       CkSum
10.0.0.1    10.0.3.1    557  0x80000001 0x6ba8
10.0.1.2    10.0.2.2    559  0x80000001 0x69bb
10.0.2.1    10.0.3.2    553  0x80000002 0x729a
10.0.3.2    10.0.3.2    553  0x80000001 0x6bb3
```

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

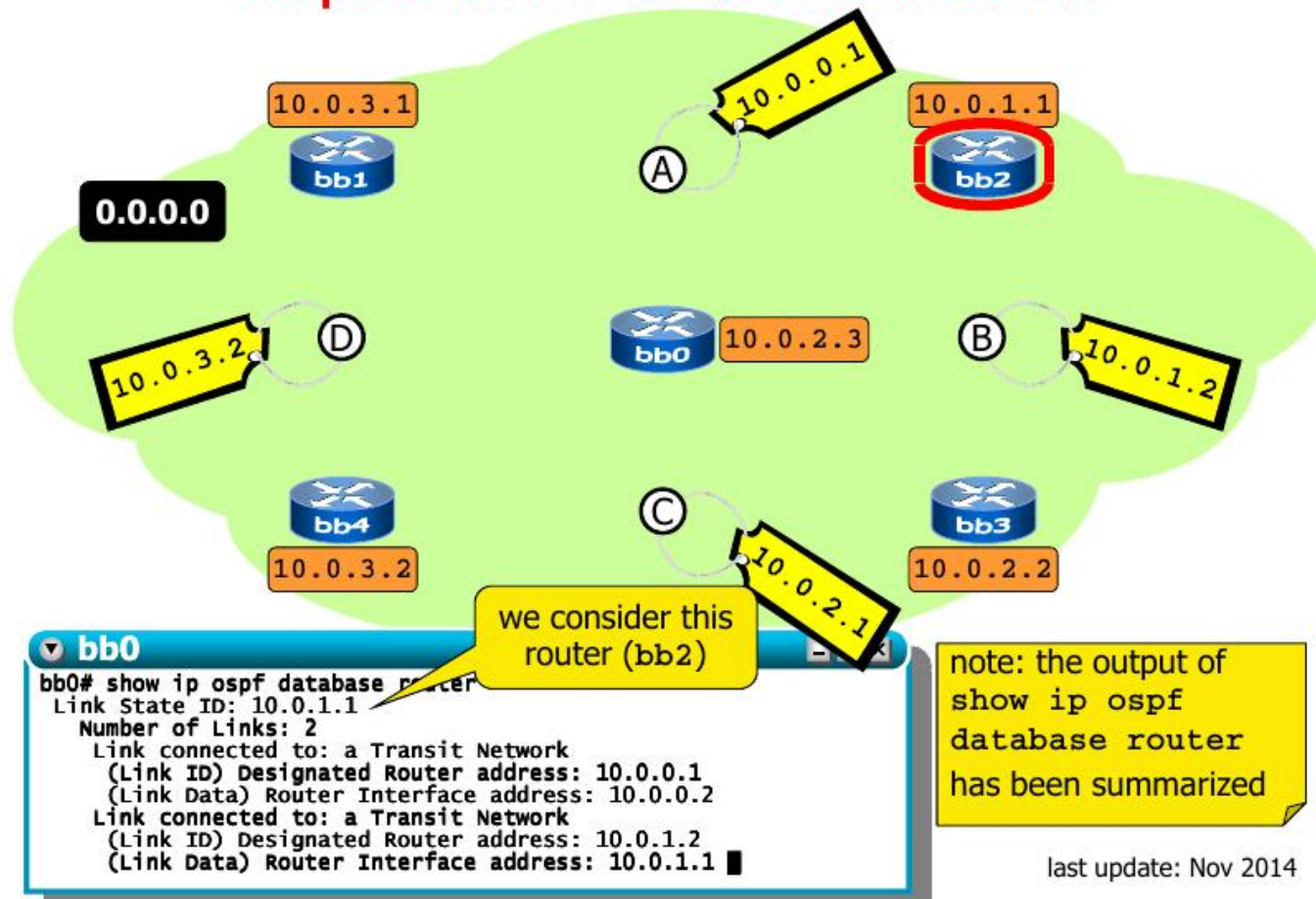
DR IP címe
abban a
hálózatban

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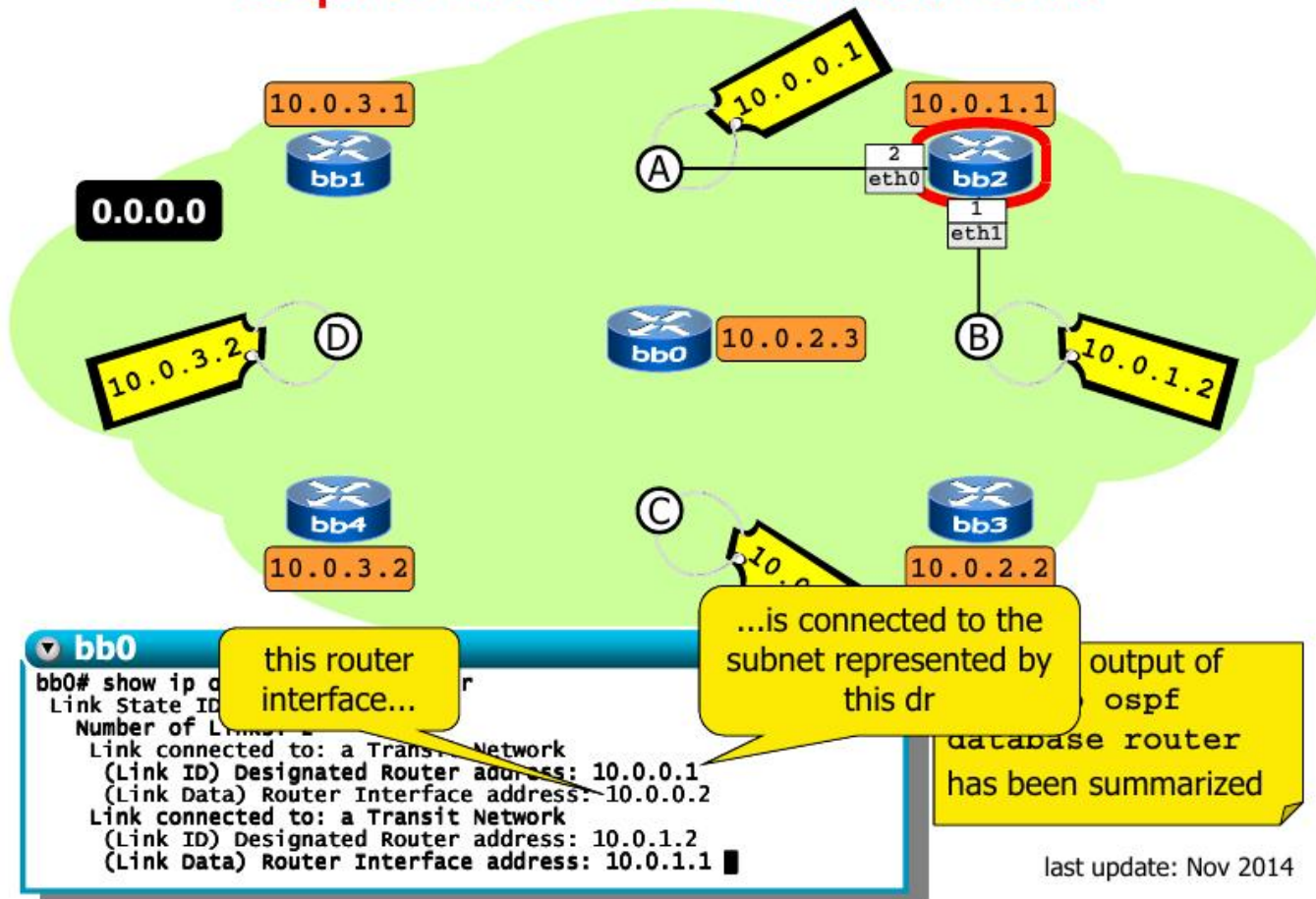
ospf's view of the network



ospf's view of the network

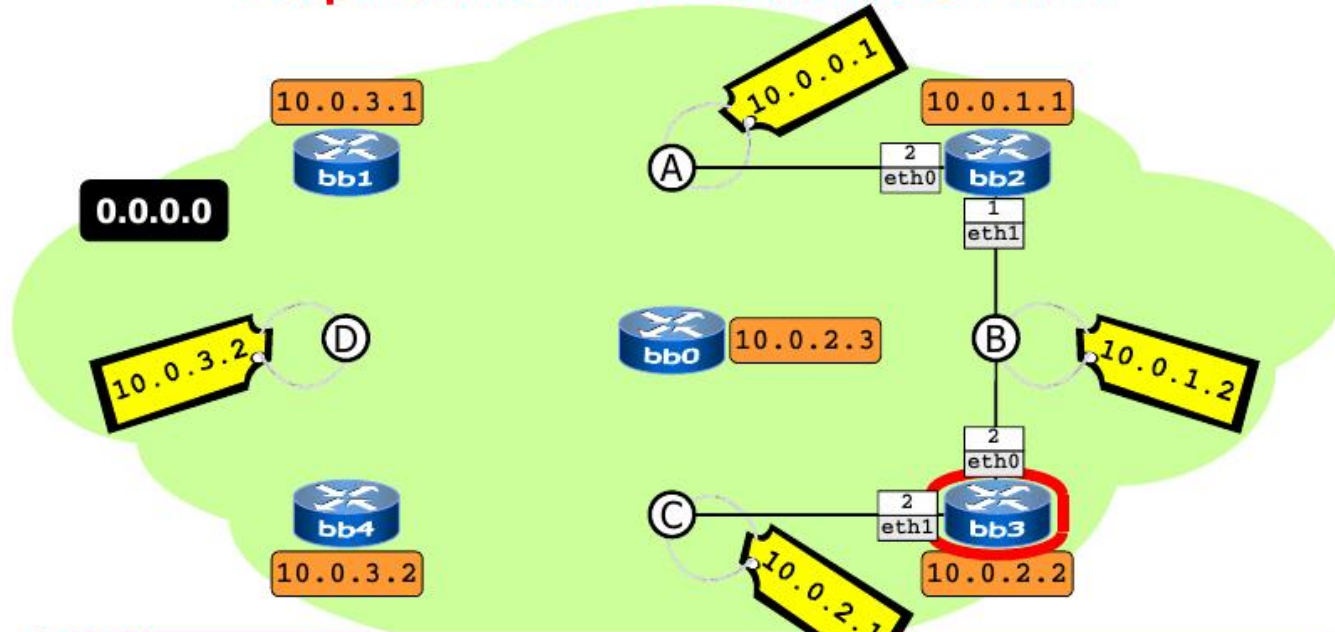


ospf's view of the network



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ospf's view of the network



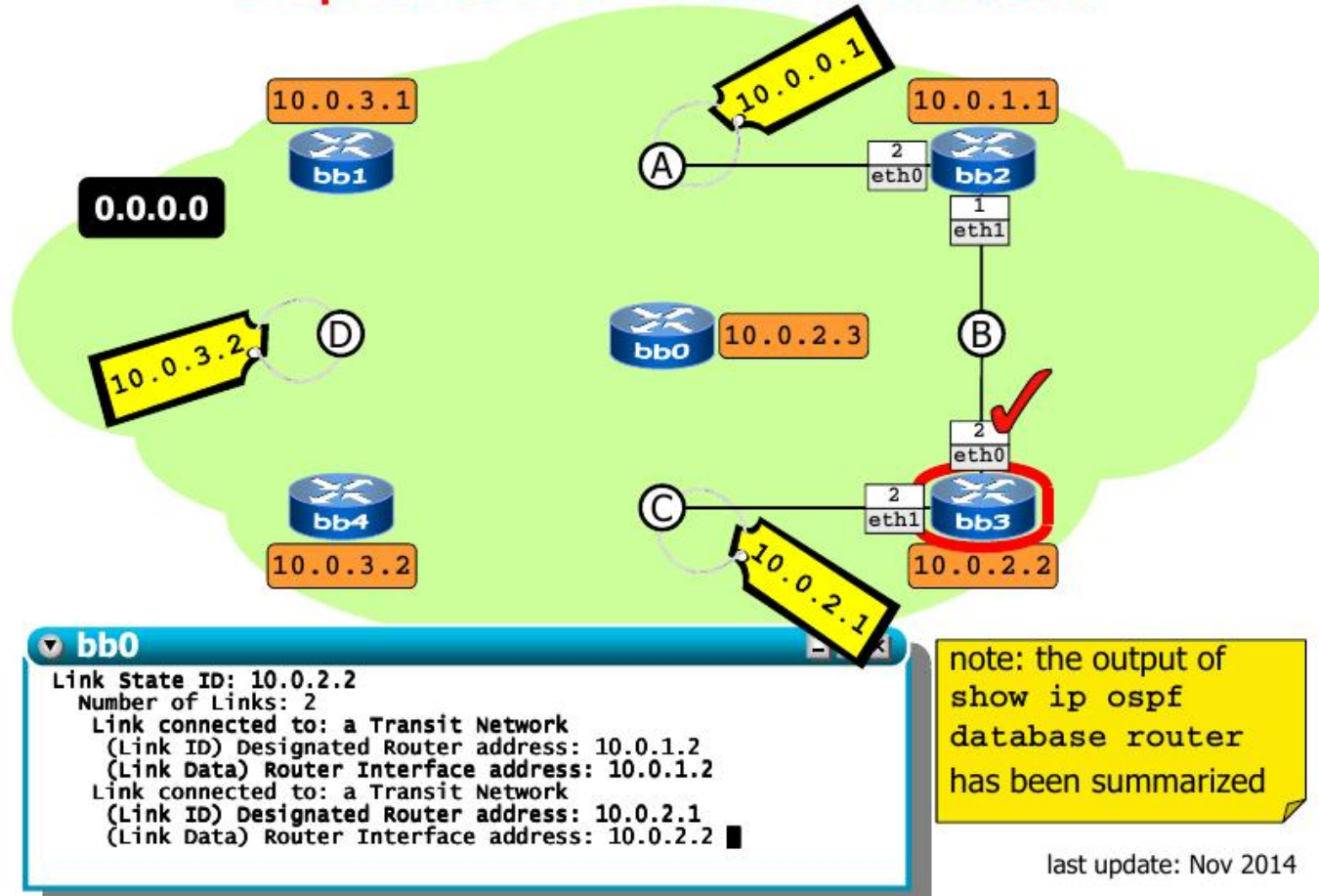
```
bb0
Link State ID: 10.0.2.2
Number of Links: 2
Link connected to: a Transit Network
(Link ID) Designated Router address: 10.0.1.2
(Link Data) Router Interface address: 10.0.1.2
Link connected to: a Transit Network
(Link ID) Designated Router address: 10.0.2.1
(Link Data) Router Interface address: 10.0.2.2
```

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

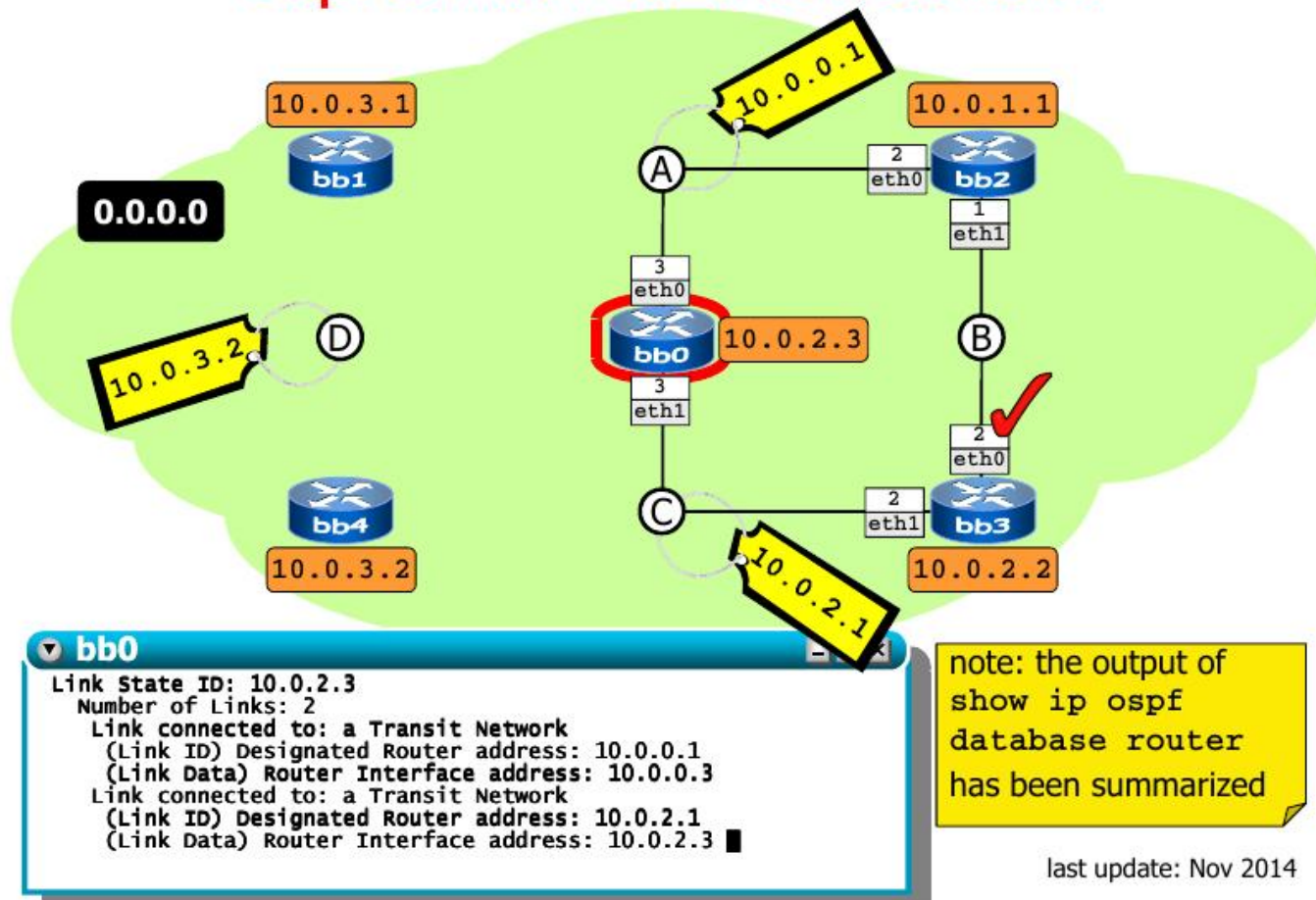
router legnagyobb IP címe

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ospf's view of the network



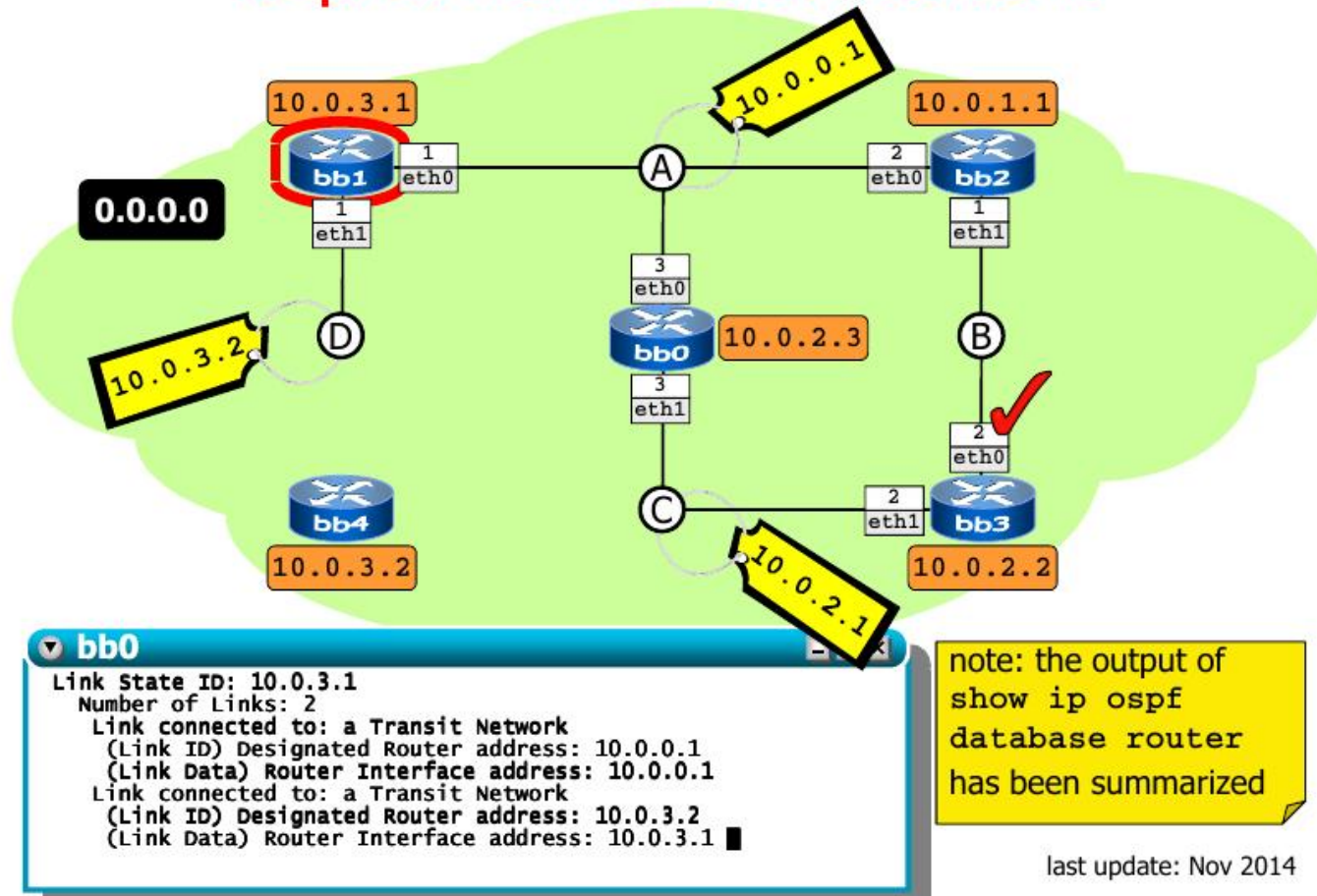
ospf's view of the network



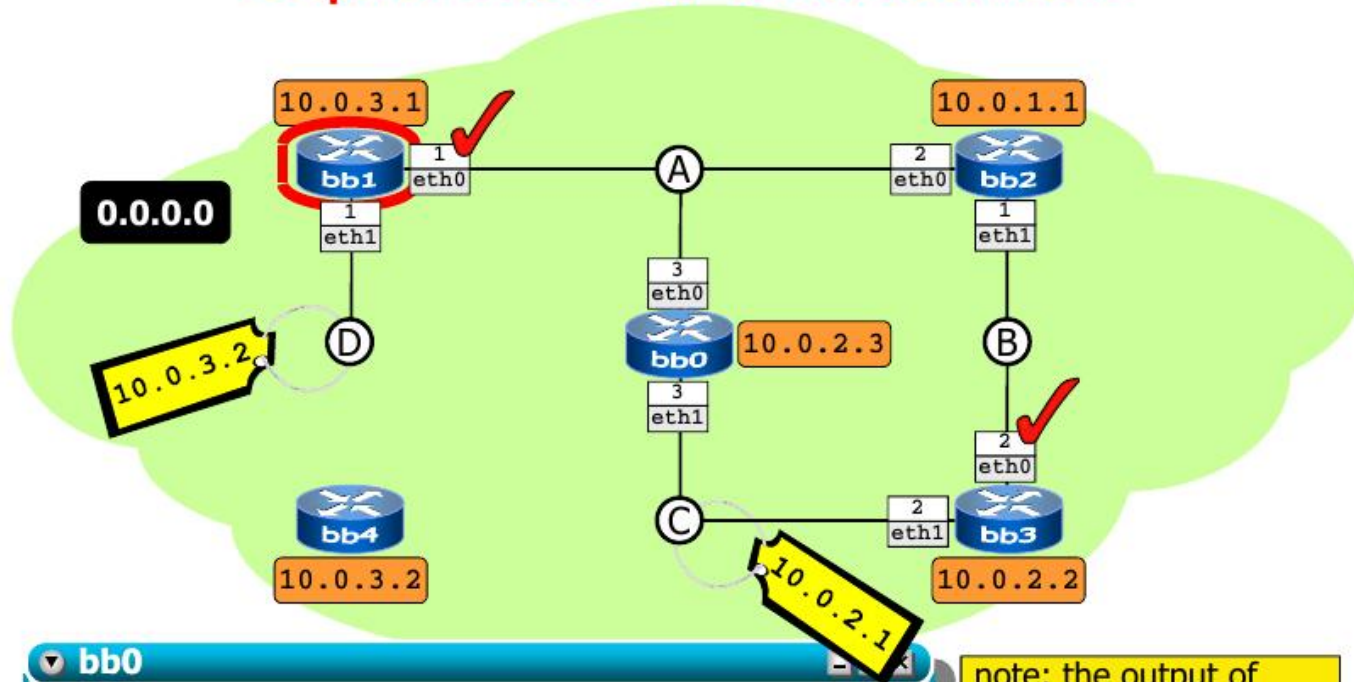
note: the output of show ip ospf database router has been summarized

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ospf's view of the network



ospf's view of the network

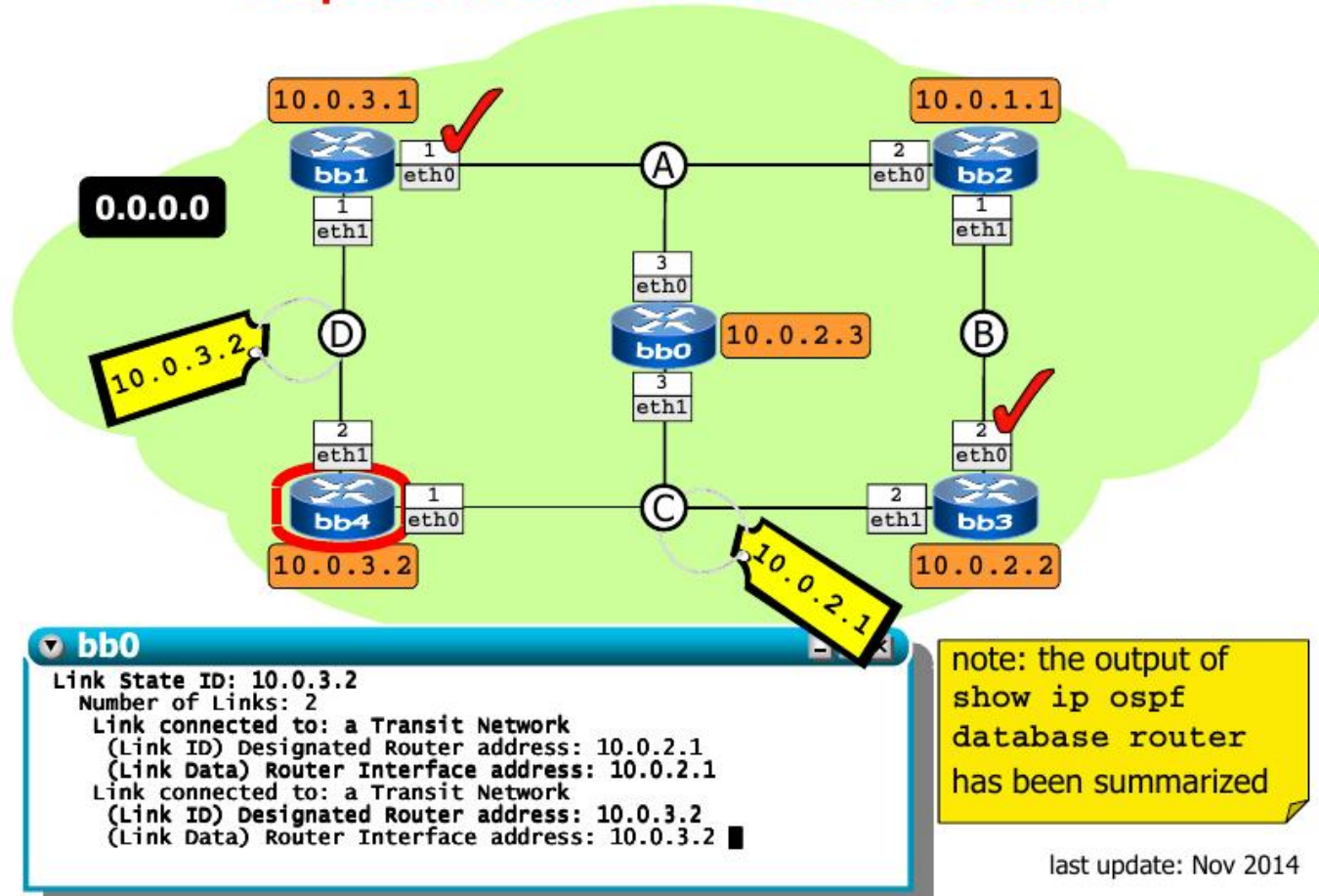


```
bb0
Link State ID: 10.0.3.1
Number of Links: 2
Link connected to: a Transit Network
(Link ID) Designated Router address: 10.0.0.1
(Link Data) Router Interface address: 10.0.0.1
Link connected to: a Transit Network
(Link ID) Designated Router address: 10.0.3.2
(Link Data) Router Interface address: 10.0.3.1
```

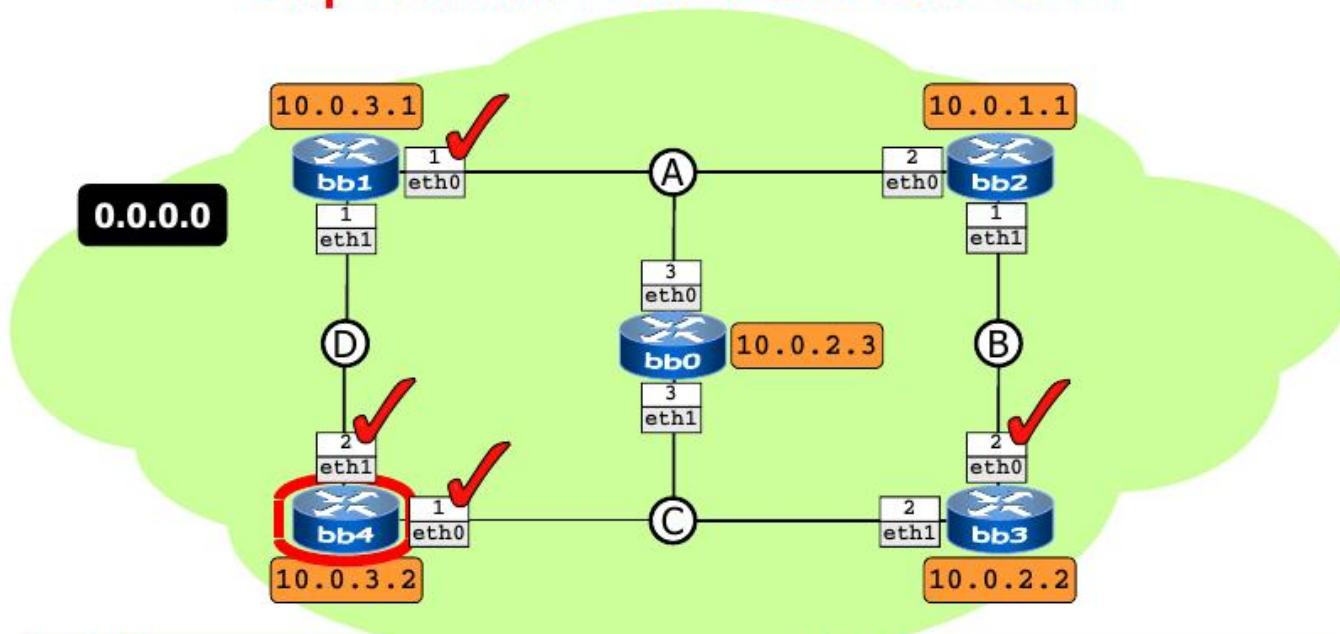
note: the output of show ip ospf database router has been summarized

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ospf's view of the network



ospf's view of the network

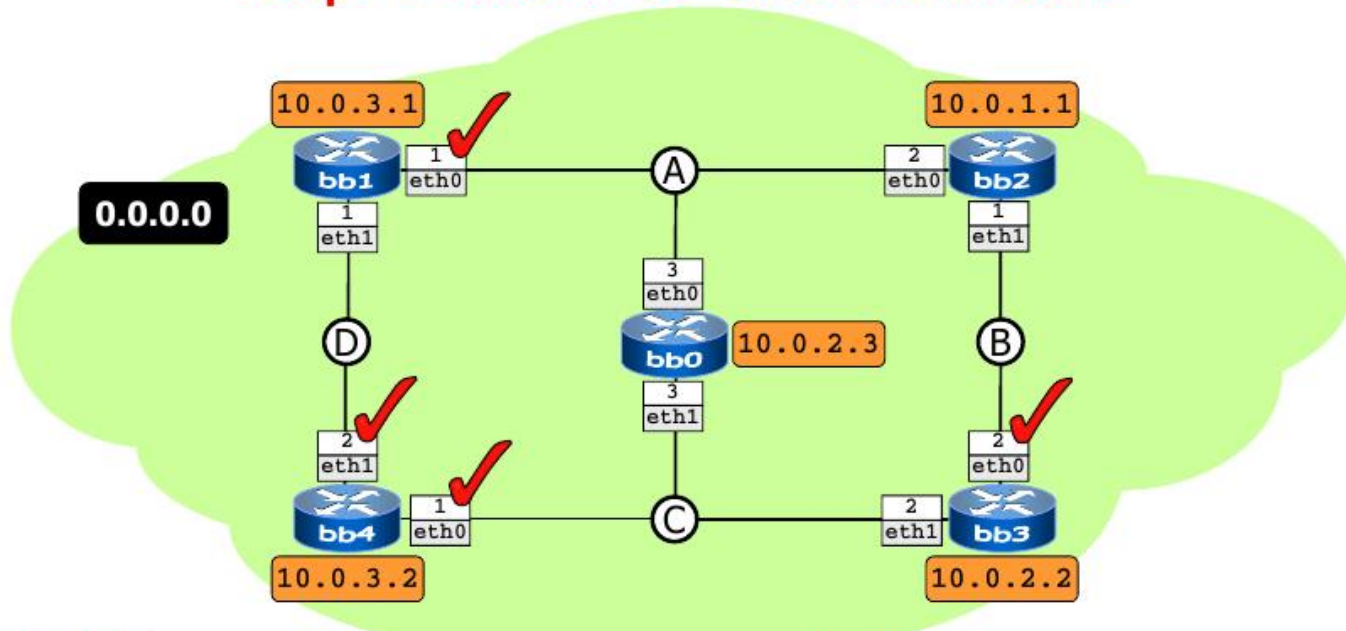


```
bb0
Link State ID: 10.0.3.2
Number of Links: 2
Link connected to: a Transit Network
(Link ID) Designated Router address: 10.0.2.1
(Link Data) Router Interface address: 10.0.2.1
Link connected to: a Transit Network
(Link ID) Designated Router address: 10.0.3.2
(Link Data) Router Interface address: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

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

last update: Nov 2014

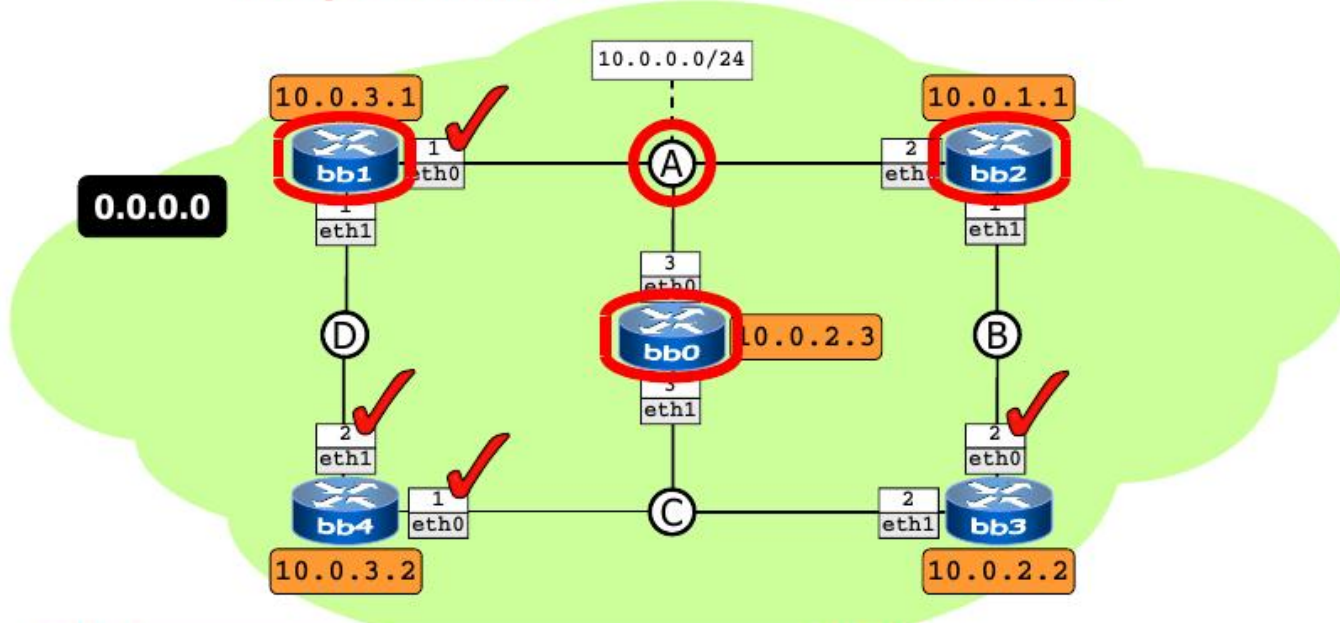
ospf's view of the network



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

last update: Nov 2014

ospf's view of the network

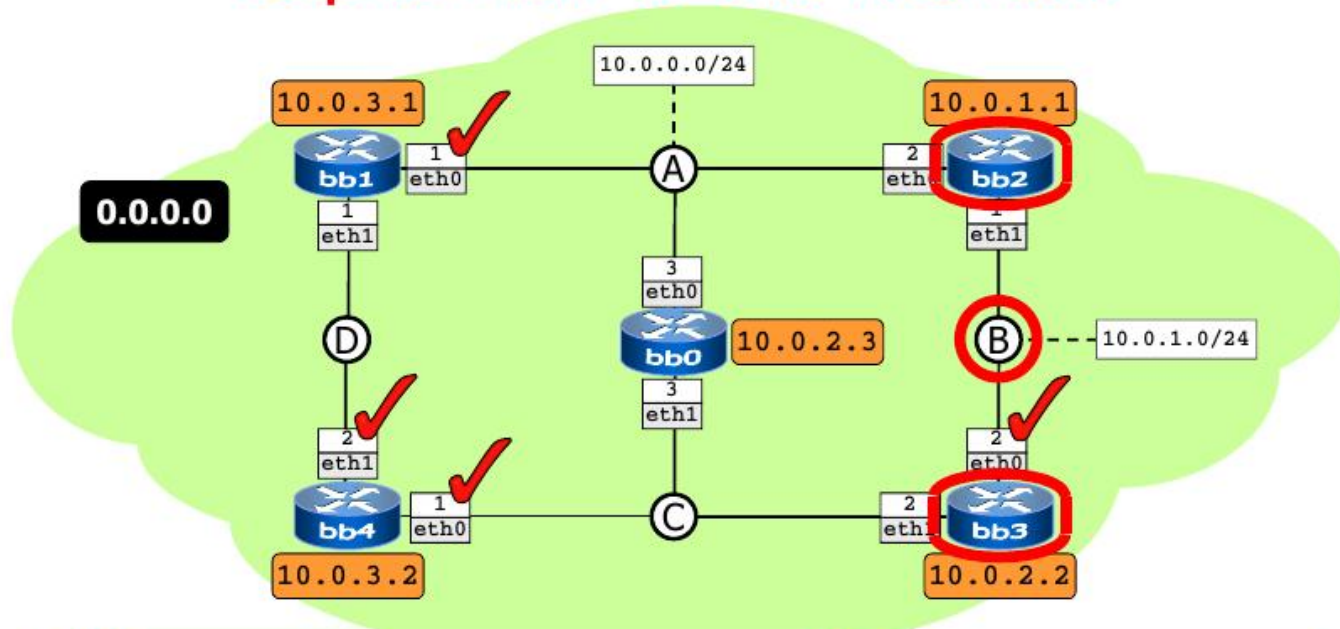


```
bb0
Link State ID: 10.0.0.1 (address of Designated Router)
Advertising Router: 10.0.3.1
Network Mask: /24
Attached Router: 10.0.3.1
Attached Router: 10.0.1.1
Attached Router: 10.0.2.3
```

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

last update: Nov 2014

ospf's view of the network

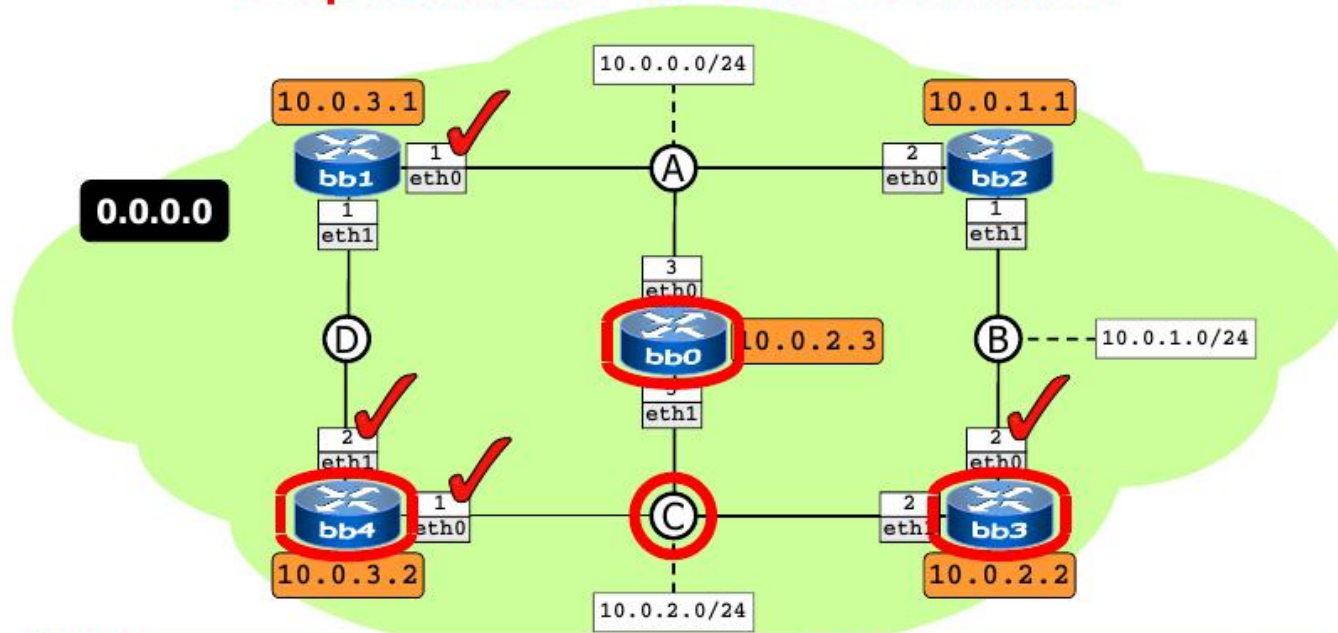


```
bb0
Link State ID: 10.0.1.2 (address of Designated Router)
Advertising Router: 10.0.2.2
Network Mask: /24
  Attached Router: 10.0.1.1
  Attached Router: 10.0.2.2
```

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

last update: Nov 2014

ospf's view of the network

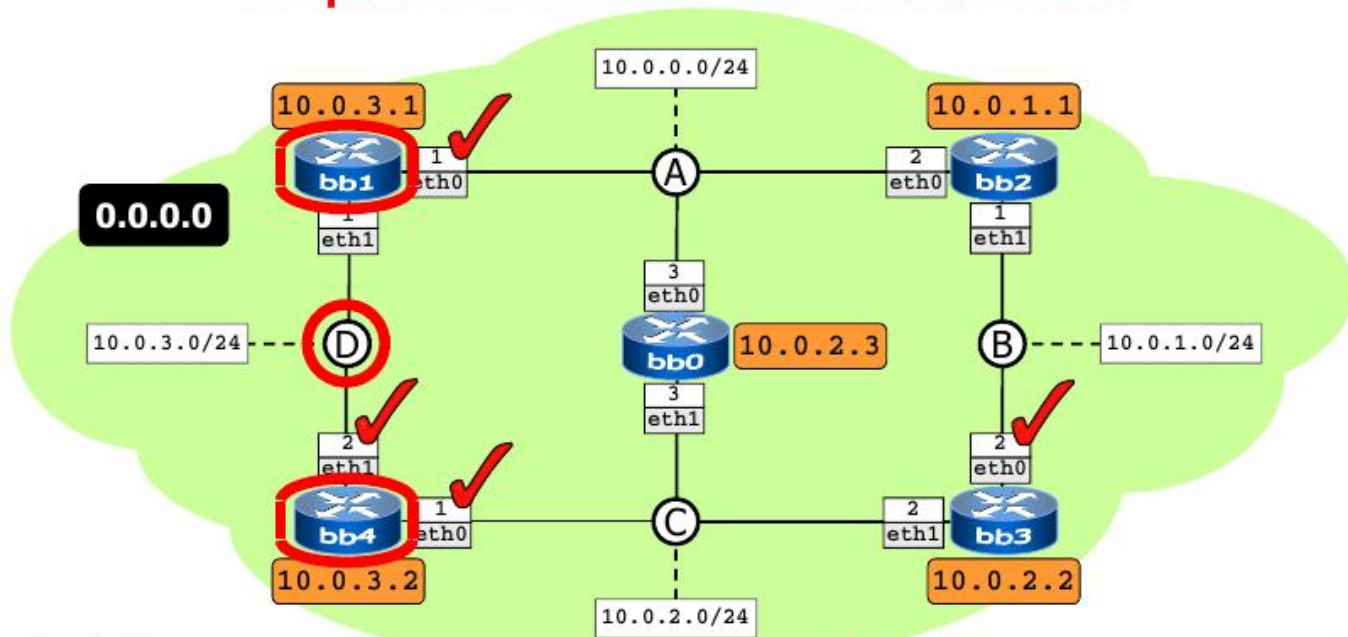


```
bb0
Link State ID: 10.0.2.1 (address of Designated Router)
Advertising Router: 10.0.3.2
Network Mask: /24
  Attached Router: 10.0.3.2
  Attached Router: 10.0.2.2
  Attached Router: 10.0.2.3
```

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

last update: Nov 2014

ospf's view of the network

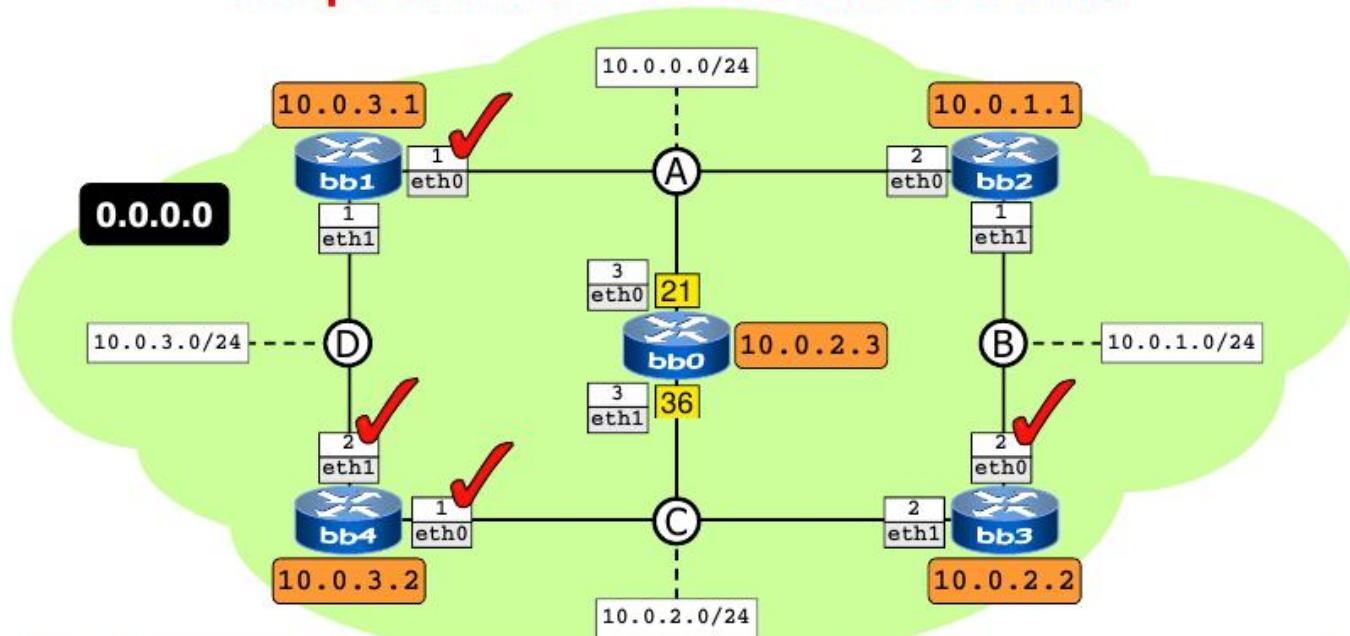


```
bb0
Link State ID: 10.0.3.2 (address of Designated Router)
Advertising Router: 10.0.3.2
Network Mask: /24
  Attached Router: 10.0.3.1
  Attached Router: 10.0.3.2
```

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

last update: Nov 2014

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

last update: Nov 2014

Dinamikus működés

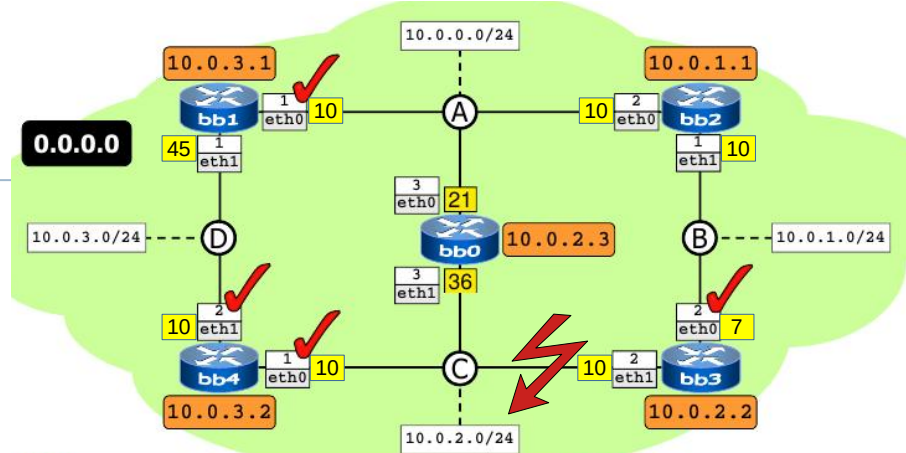
- ▶ OSPF üzenetek (Hello, majd LSA-k)
- ▶ Mi történik, ha lemegy egy link?
- ▶ Mi történik, ha lemegy egy DR link?
- ▶ Mi történik, ha lemegy egy router?

1. feladat: Router kommunikáció

- ▶ 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)

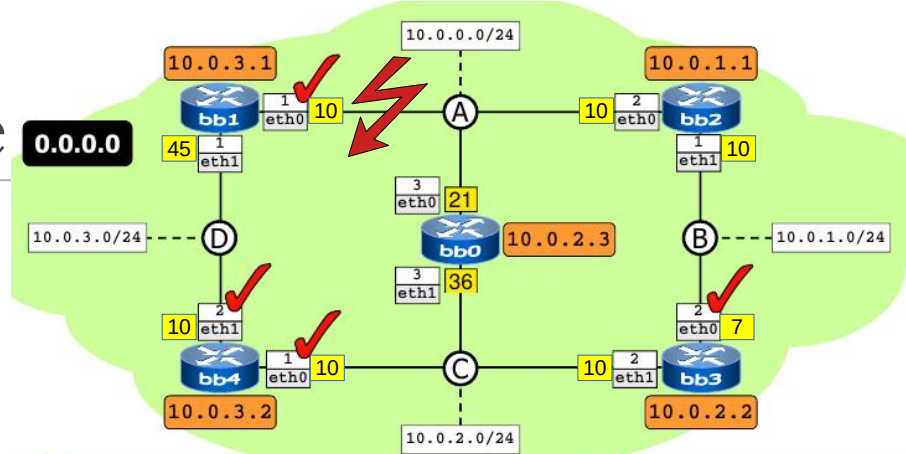
2. feladat: link kiesése

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



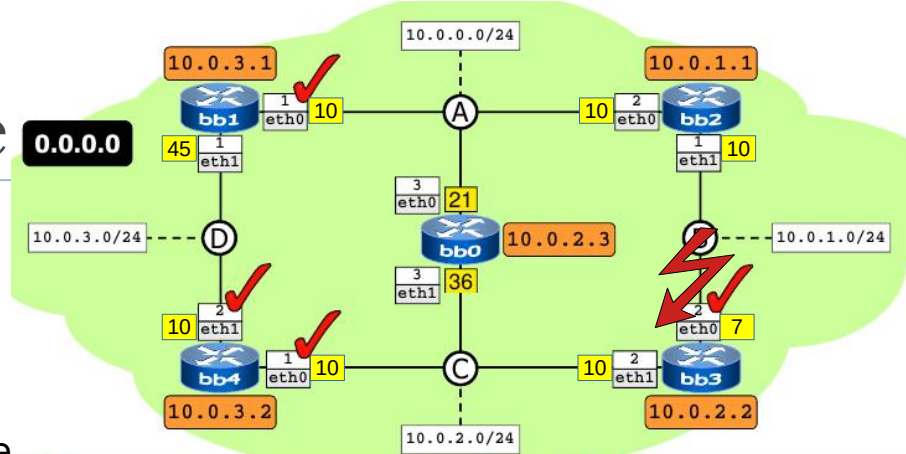
3a. feladat: DR link kiesése

- ▶ Mi történik, ha DR link megy le?
 - ▶ pl. BB1 eth0 down
 - ▶ BB4-en router kommunikáció figyelése
 - tcpdump -ne ip proto ospf
 - ▶ BB2-n ospfd logok figyelése
 - tail -f /var/log/quagga/ospfd.log
 - ▶ BB0-n OSPF database ellenőrzése
 - show ip ospf database
 - ▶ BB1-en útvonalak ellenőrzése
 - BB1 eléri a 10.0.0.0 hálózatot?
 - mi történt?
 - ▶ BB1-en húzzuk vissza az eth0 interfészt
 - ▶ mindent vizsgáljunk újra



3b. feladat: DR link kiesése

- ▶ Mi történik, ha DR link megy le?
 - ▶ pl. BB3 eth0 down
 - ▶ BB2-n ospfd logok figyelése
 - tcpdump -ne ip proto ospf
 - ▶ BB0-n OSPF interfészek és database figyelése
 - show ip ospf interface
 - show ip ospf database
 - ▶ BB3 eléri a 10.0.1.0 hálózatot?
 - ▶ mi történt a 10.0.1.0 hálózathoz tartozó “Net Link”-kel?
 - ▶ BB3-n húzzuk vissza az eth0 interfészt
 - ▶ mindent vizsgáljunk újra



4. feladat: router kiesése

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