Università degli Studi Roma Tre
Dipartimento di Informatica e Automazione
Computer Networks Research Group

netkit lab(s)

spanning-tree

Version	2.0
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Description	experiences with the spanning tree protocol

bridge identifier

- the bridge-id is composed by catenating:
  - the priority
    - local to the bridge
    - adminstratively set
    - default: 80-00
  - the bridge mac
    - mac of the "first" port of the bridge
    - usually the lowest mac
- example: 80-00-23-ef-…

the two types of Bridge PDUs

- configuration bpdu
  - contains all the information needed by the spanning tree algorithm, including:
    - root bridge identifier (current root of the spanning tree)
    - root path cost (cost of the path to the root bridge)
    - bridge identifier (identifier of the sender of the bpdu)
    - port identifier (port through which the bpdu is sent)
  - example:

root-bridge-id	**80-00-23-ef-…**
root-path-cost	**100**
bridge-id	**80-00-2d-12-…**
port-id	**6**

- topology change bpdu
  - solely contains the data that is needed to identify the packet as a topology change bpdu

the four operations of the spanning tree algorithm

1. root bridge election
   - a single bridge is chosen to be the root of the spanning tree
2. identification of the root port on each bridge
   - each bridge that is not the root bridge selects one of its ports as the nearest to the root bridge
3. determination of designated bridges
   - for each lan a bridge is chosen as the one which connects the lan to the spanning tree
   - the port of the designated bridge that connects the lan to the spanning tree is called designated port
4. blocking of redundant ports
   - non root ports and non designated ports are placed in blocking state

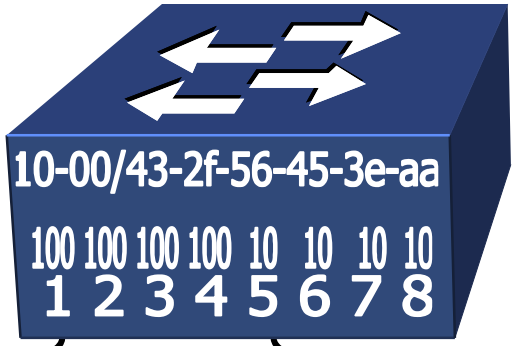
1) root bridge election

- each bridge produces a configuration bpdu in which its own bridge-id is used as root-identifier
- when a bridge receives a configuration bpdu with a lower bridge-id
  - it stops producing configuration bpdus
  - it forwards the new configuration bpdu through all ports
- the root bridge is the one that carries on producing configuration bpdus with its own bridge-id in the root-identifier field

configuration bpdu forwarding

- when a configuration bpdu is produced by a bridge its root-path-cost field is set to zero
- when a configuration bpdu is forwarded by a bridge that is not the root bridge, its fields are updated as follows:
  - the root-path-cost is incremented of the cost of the port of the bridge that received the configuration bpdu
  - the bridge-identifier is set to the bridge-id of the current bridge
  - the port-identifier is set to the port number through which the configuration bpdu is sent

root-bridge-id	**00-00-23-ef-…**
root-path-cost	**100**
bridge-id	**10-00-2d-12-…**
port-id	**6**



root-bridge-id	**00-00-23-ef-…**
root-path-cost	**200**
bridge-id	**10-00-43-2f-…**
port-id	**5**

2) root port identification

- each bridge that is not the root bridge identifies the port through which the root bridge is best reachable
- the root port is chosen to be the one that receives configuration bpdus with
  1. lowest root-path-cost (after adding the port cost)
  2. lowest bridge-identifier
  3. lowest port-identifier
  4. lowest own port-identifier

3) determination of designated bridges

- for each lan a bridge port is chosen to be the designated port based on the configuration bpdus which are forwarded by that port
- the bridge which has the designated port is called designated bridge)
- the designated port is chosen to be the one that sends configuration bpdus with:
  1. lowest root-path-cost
  2. lowest bridge-identifier
  3. lowest port-identifier

4) blocking

- all the ports that are not root ports or designated ports are placed in blocking state
- all the root ports and designated ports are placed in forwarding state

port states

- during the calculation of the spanning tree, the state of a port can be:

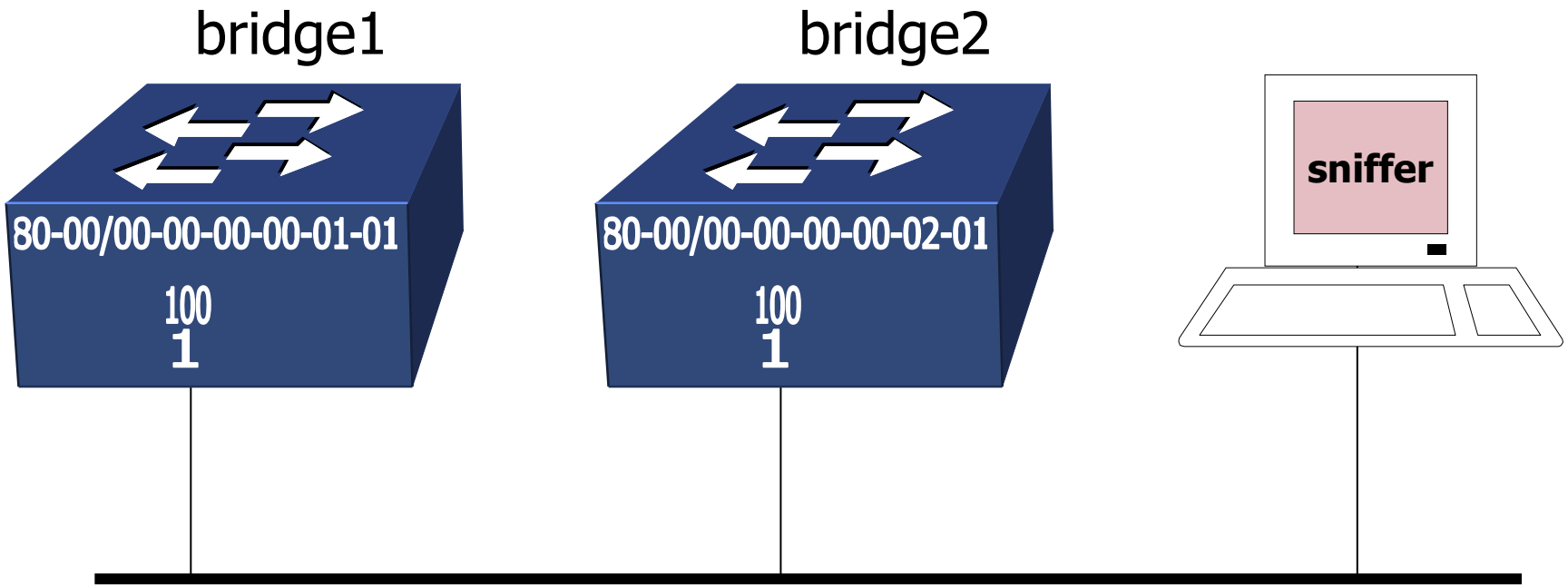
	receives frames	forwards frames	updates database	receives bpdus	transmits bpdus
blocking	✗	✗	✗	✓	✗
listening	✗	✗	✗	✓	✓
learning	✗	✗	✓	✓	✓
forwarding	✓	✓	✓	✓	✓
disabled	✗	✗	✗	✗	✗

timers

- hello time [2]
  - time interval between generation of bpdu by any bridge
- max age [20]
  - amount of time a bridge will wait to receive a bpdu
  - once this timer expires, a topology change notification bpdu will be transmitted
- forward delay [15]
  - amount of time the bridge will remain in the listening and learning port state

[x] = default value set to *x* seconds

lab1: root bridge election



lab1: root bridge election

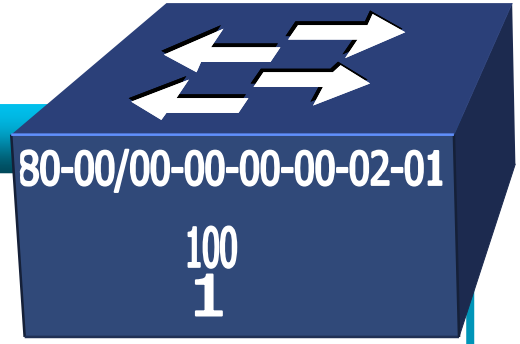
host machine

```
user@localhost:~$ cd netkit-lab_stp-root-election
user@localhost:~/netkit-lab_stp-root-election$ lstart
```

- the lab is configured to
  - start the two bridges
  - start a virtual machine with a sniffer that listens to the traffic generated for the computation of the spanning tree
    - after 20 packets have been captured, the **`sniffer`** virtual machine is automatically halted
    - a file "**`sniffer.cap`**" is created in the lab directory on the host, for later investigation (e.g., with wireshark, tshark)

lab1: root bridge election

- the elected root bridge can be checked as follows:



bridge2

```
bridge2:~# brctl showstp br0
br0
 bridge id              8000.000000000201
 designated root        8000.000000000101
 root port                 1                    path cost                  100
 max age                  20.00                 bridge max age              20.00
 hello time                2.00                 bridge hello time            2.00
 forward delay            15.00                 bridge forward delay        15.00
 ageing time             300.00
 hello timer               0.00                 tcn timer                    0.00
 topology change timer     0.00                 gc timer                   249.75
 flags                  TOPOLOGY_CHANGE
.....
```

lab1: root bridge election

- a detailed dump of the file **`sniffer.cap`** can be obtained as follows:

host machine

```
user@localhost:~/netkit-lab_stp-root-election$ tshark -V -r sniffer.cap
Frame 1 (60 bytes on wire, 60 bytes captured)
    Arrival Time: May  8, 2007 14:48:25.602819000
    [Time delta from previous packet: 0.000000000 seconds]
    [Time since reference or first frame: 0.000000000 seconds]
    Frame Number: 1
    Packet Length: 60 bytes
    Capture Length: 60 bytes
    [Frame is marked: False]
    [Protocols in frame: eth:llc:stp]
IEEE 802.3 Ethernet
    Destination: Spanning-tree-(for-bridges)_00 (01:80:c2:00:00:00)
.....
```

lab1: root bridge election

- a detailed dump of the file **`sniffer.cap`** can be obtained as follows:

host machine

```
user@localhost:~/netkit-lab_stp-root-election$ tshark -V -r sniffer.cap
Frame 1 (60 bytes on wire, 60 bytes captured)
    Arrival Time: May  8, 2007 14:48:25.602819000
    [Time delta from previous packet: 0.000000000 seconds]
    [Time since reference or first frame: 0.000000000 seconds]
    Frame Number: 1
    Packet Length: 60 bytes
    Capture Length: 60 bytes
    [Frame is marked: False]
    [Protocols in frame: eth:llc:stp]
IEEE 802.3 Ethernet
    Destination: Spanning-tree-(for-bridges)_00 (01:
.....
```

display packet details

dissect saved capture data from file instead of performing a live capture

lab1: root bridge election

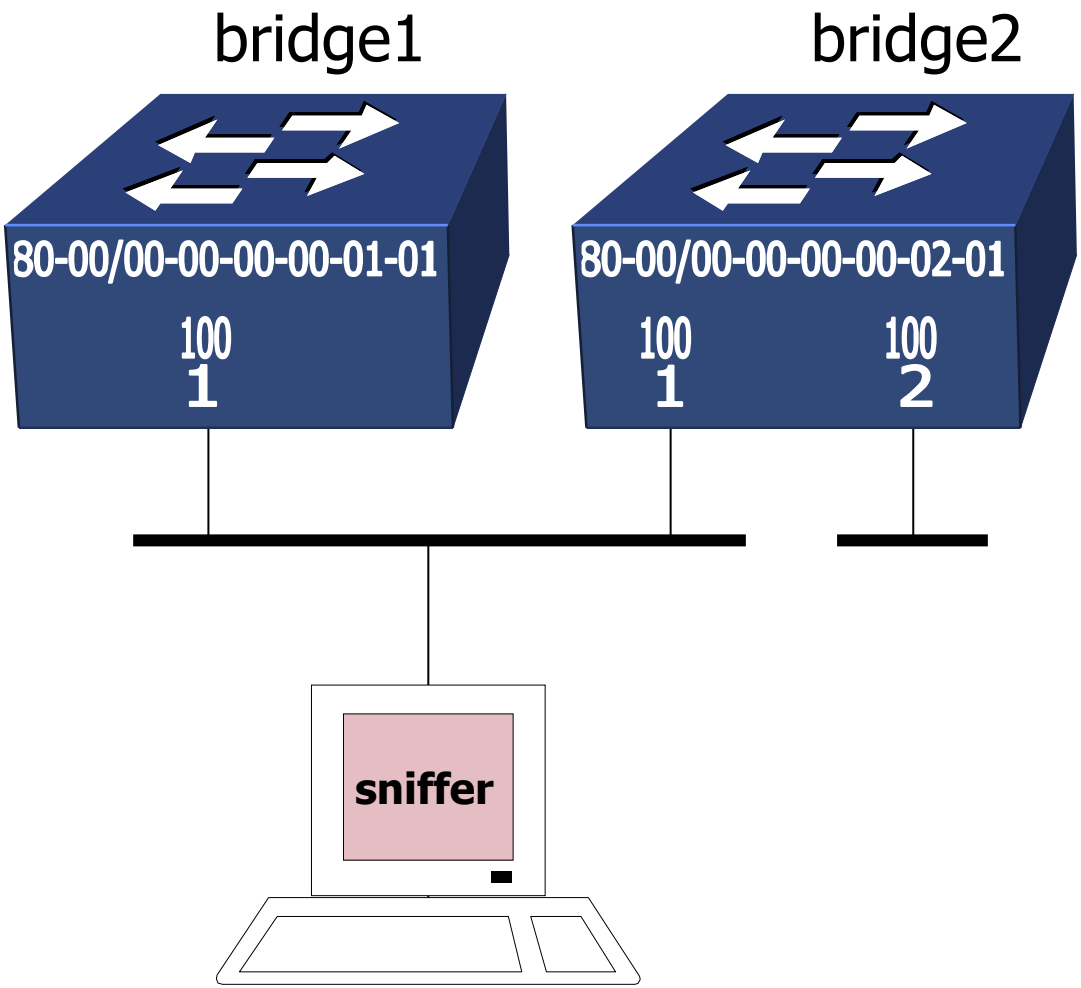
```
⊞ IEEE 802.3 Ethernet
    Destination: Spanning-tree-(for-bridges)_00 (01:80:c2:00:00:00)
    Source: 00:00:00_00:02:01 (00:00:00:00:02:01)
    Length: 38
⊞ Logical-Link Control
    DSAP: Spanning Tree BPDU (0x42)
    SSAP: Spanning Tree BPDU (0x42)
⊞ Spanning Tree Protocol
    Protocol Identifier: Spanning Tree Protocol (0x0000)
    Protocol Version Identifier: Spanning Tree (0)
    BPDU Type: Configuration (0x00)
    BPDU flags: 0x00
        0... .... = Topology Change Acknowledgment: No
        .... ...0 = Topology Change: No
    Root Identifier: 32768 / 00:00:00:00:02:01
    Root Path Cost: 0
    Bridge Identifier: 32768 / 00:00:00:00:02:01
    Port identifier: 0x8001
    Message Age: 0
    Max Age: 20
    Hello Time: 2
    Forward Delay: 15
```

multicast address (all the bridges on the lan)

this is a configuration bpdu

at the beginning the bridge claims to be the root bridge

lab2: topology change



lab2: topology change

host machine

```
user@localhost:~$ cd netkit-lab_stp-topology-change
user@localhost:~/netkit-lab_stp-topology-change$ lstart
```

- in a way similar to lab1, the lab is configured to
  - start the two bridges
  - start a virtual machine with a sniffer
    - the **`sniffer`** virtual machine is **not** automatically halted
    - a file "**`sniffer.cap`**" is created in the lab directory on the host, for later investigation (e.g., with wireshark, tshark)

lab2: topology change

- when a bridge detects a topology change it sends topology change notification bpdus through its root port
- it carries on sending notifications until the designated bridge on the lan attached to the root port acknowledges it
- the designated bridge, in its turn, will send the topology change notification bpdu through its root port, until it is received by the root bridge
- the root bridge starts setting the topology change flag on its configuration bpdus
- all the bridges, upon hearing that a topology change is taking place, will use the forward delay time (usually 15 seconds) instead of the filtering database ageing time (usually 5 minutes) in order to age out the entries of the source address tables

lab2: topology change

- running this command in the lab forces the generation of topology change notification bpdus:

bridge2

```
bridge2:~# brctl addif br0 eth1
```

- the notification is correctly captured by the sniffer after observing at least these lines:

sniffer

```
.....
12:22:24.362414 802.1d tcn
12:22:24.685188 802.1d config TOP_CHANGE TOP_CHANGE_ACK
8000.00:00:00:00:01:01.8001 root 8000.00:00:00:00:01:01 pathcost 0 age 0
max 20 hello 2 fdelay 15
.....
```

lab2: topology change

```
⊞ IEEE 802.3 Ethernet
    Destination: Spanning-tree-(for-bridges)_00 (01:80:c2:00:00:00)
    Source: 00:00:00_00:02:01 (00:00:00:00:02:01)
    Length: 7
⊞ Logical-Link Control
    DSAP: Spanning Tree BPDU (0x42)
    SSAP: Spanning Tree BPDU (0x42)
⊞ Spanning Tree Protocol
    Protocol Identifier: Spanning Tree Protocol (0x0000)
    Protocol Version Identifier: Spanning Tree (0)
    BPDU Type: Topology Change Notification (0x80)
```

bridge2 generates a topology change notification

this is a topology change notification (tcn)

lab2: topology change

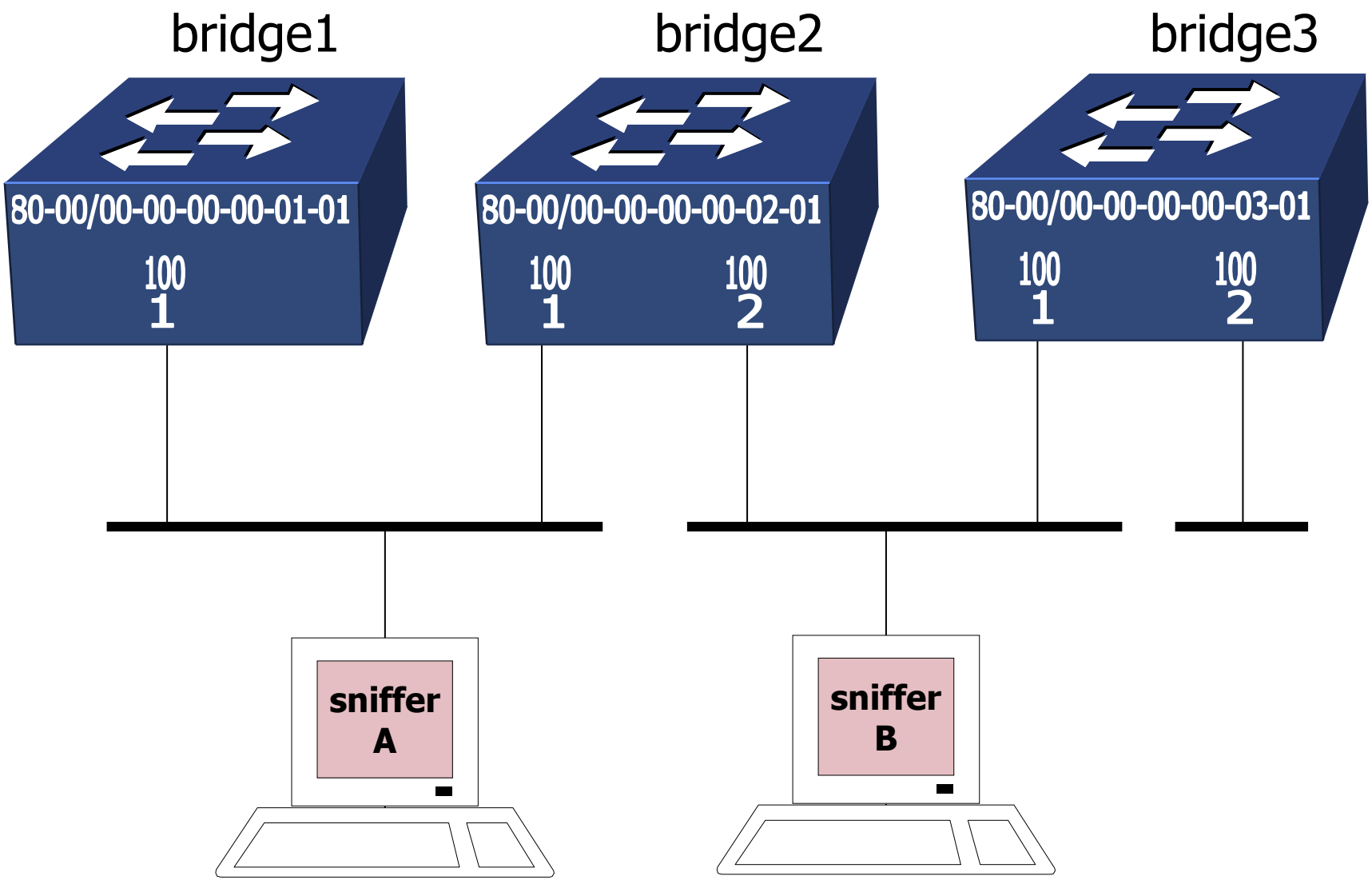
```
⊞ IEEE 802.3 Ethernet
    Destination: Spanning-tree-(for-bridges)_00 (01:80:c2:00:00:00)
    Source: 00:00:00_00:01:01 (00:00:00:00:01:01)
    Length: 38
⊞ Logical-Link Control
    DSAP: Spanning Tree BPDU (0x42)
    SSAP: Spanning Tree BPDU (0x42)
⊞ Spanning Tree Protocol
    Protocol Identifier: Spanning Tree Protocol (0x0000)
    Protocol Version Identifier: Spanning Tree (0)
    BPDU Type: Configuration (0x00)
    BPDU flags: 0x81 (Topology Change Acknowledgment, Topology Change)
        1... .... = Topology Change Acknowledgment: Yes
        .... ...1 = Topology Change: Yes
    Root Identifier: 32768 / 00:00:00:00:01:01
    Root Path Cost: 0
    Bridge Identifier: 32768 / 00:00:00:00:01:01
    Port identifier: 0x8001
    Message Age: 0
    Max Age: 20
    Hello Time: 2
    Forward Delay: 15
```

the root bridge acknowledges the notification

this configuration bpdu carries a topology change notification acknowledgment

the topology change is further propagated

lab3: remote topology change



lab3: remote topology change

host machine

```
user@localhost:~$ cd netkit-lab_stp-remote-change
user@localhost:~/netkit-lab_stp-remote-change$ lstart
```

- the lab is configured to start the whole network and create the following capture files on the host:
  - **`sniffer_A.cap`**
  - **`sniffer_B.cap`**

lab3: remote topology change

- the topology change notification can be triggered by using the following command:

bridge3

```
bridge3:~# brctl addif br0 eth1
```

- the notifications are correctly captured once at least these lines appear in the console of the sniffer virtual machines:

sniffer_A

```
.....
13:01:22.366772 802.1d tcn
13:01:22.367400 802.1d config TOP_CHANGE
TOP_CHANGE_ACK 8000.00:00:00:00:01:01.8001
root 8000.00:00:00:00:01:01 pathcost 0 age
0 max 20 hello 2 fdelay 15
.....
```

sniffer_B

```
.....
13:01:22.365668 802.1d tcn
13:01:22.366464 802.1d config
TOP_CHANGE_ACK 8000.00:00:00:00:02:01.8002
root 8000.00:00:00:00:01:01 pathcost 100
age 1 max 20 hello 2 fdelay 15
.....
```

lab3: remote topology change

```
⊞ IEEE 802.3 Ethernet
    Destination: Spanning-tree-(for-bridges)_00 (01:80:c2:00:00:00)
    Source: 00:00:00_00:03:01 (00:00:00:00:03:01)
    Length: 7
⊞ Logical-Link Control
    DSAP: Spanning Tree BPDU (0x42)
    SSAP: Spanning Tree BPDU (0x42)
⊞ Spanning Tree Protocol
    Protocol Identifier: Spanning Tree Protocol (0x0000)
    Protocol Version Identifier: Spanning Tree (0)
    BPDU Type: Topology Change Notification (0x80)
```

bridge3
port 1

step 1: **bridge3** generates a topology change notification

lab3: remote topology change

```
⊞ IEEE 802.3 Ethernet
    Destination: Spanning-tree-(for-bridges)_00 (01:80:c2:00:00:00)
    Source: 00:00:00_00:02:02 (00:00:00:00:02:02)
    Length: 38
⊞ Logical-Link Control
    DSAP: Spanning Tree BPDU (0x42)
    SSAP: Spanning Tree BPDU (0x42)
⊞ Spanning Tree Protocol
    Protocol Identifier: Spanning Tree Protocol (0x0000)
    Protocol Version Identifier: Spanning Tree (0)
    BPDU Type: Configuration (0x00)
    BPDU flags: 0x80 (Topology Change Acknowledgment)
        1... .... = Topology Change Acknowledgment: Yes
        .... ...0 = Topology Change: No
    Root Identifier: 32768 / 00:00:00:00:01:01
    Root Path Cost: 100
    Bridge Ide
    Port ident
    Message Ag
    Max Age: 2
    Hello Time
    Forward Delay: 15
```

bridge2 port 2

this is just an acknowledgment

step 2: **bridge2** acknowledges (hence, **bridge3** stops sending notifications)

lab3: remote topology change

```
⊞ IEEE 802.3 Ethernet
    Destination: Spanning-tree-(for-bridges)_00 (01:80:c2:00:00:00)
    Source: 00:00:00_00:02:01 (00:00:00:00:02:01)
    Length: 7
⊞ Logical-Link Control
    DSAP: Spanning Tree BPDU (0x42)
    SSAP: Spanning Tree BPDU (0x42)
⊞ Spanning Tree Protocol
     Protocol Identifier: Spanning Tree Protocol (0x0000)
     Protocol Version Identifier: Spanning Tree (0)
     BPDU Type: Topology Change Notification (0x80)
```

bridge2
port 1

step 3: **bridge2** propagates the topology change notification through its root port

lab3: remote topology change

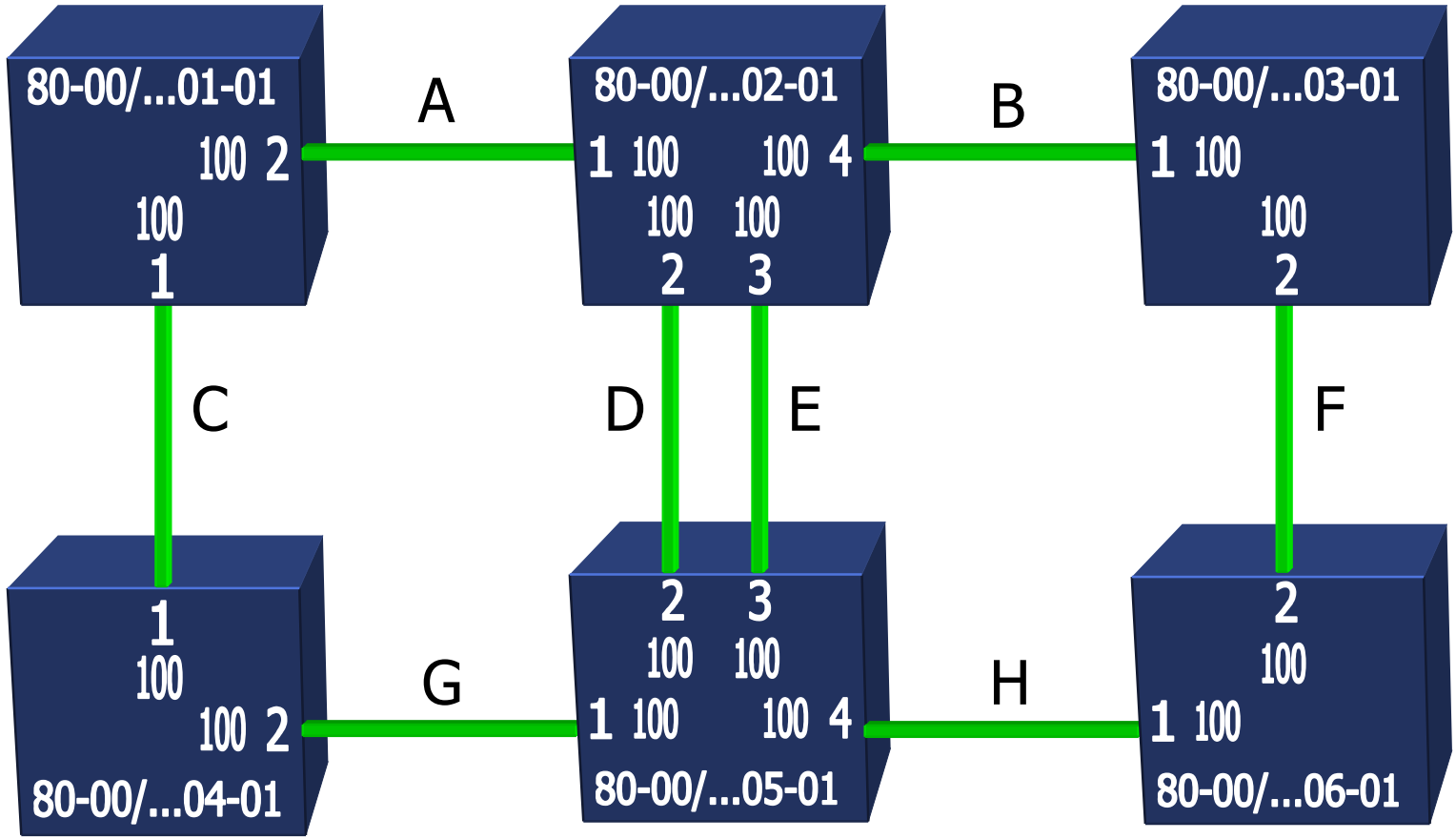
```
⊞ IEEE 802.3 Ethernet
    Destination: Spanning-tree-(for-bridges)_00 (01:80:c2:00:00:00)
    Source: 00:00:00_00:01:01 (00:00:00:00:01:01)
    Length: 38
⊞ Logical-Link Control
    DSAP: Spanning Tree BPDU (0x42)
    SSAP: Spanning Tree BPDU (0x42)
⊞ Spanning Tree Protocol
    Protocol Identifier: Spanning Tree Protocol (0x0000)
    Protocol Version Identifier: Spanning Tree (0)
    BPDU Type: Configuration (0x00)
    BPDU flags: 0x81 (Topology Change Acknowledgment, Topology Change)
        1... .... = Topology Change Acknowledgment: Yes
        .... ...1 = Topology Change: Yes
    Root Identifier: 32768 / 00:00:00:00:01:01
    Root Path Cost: 0
    Bridge
    Port i
    Messag
    Max Ag
    Hello
    Forward Delay: 15
```

bridge1 port 1

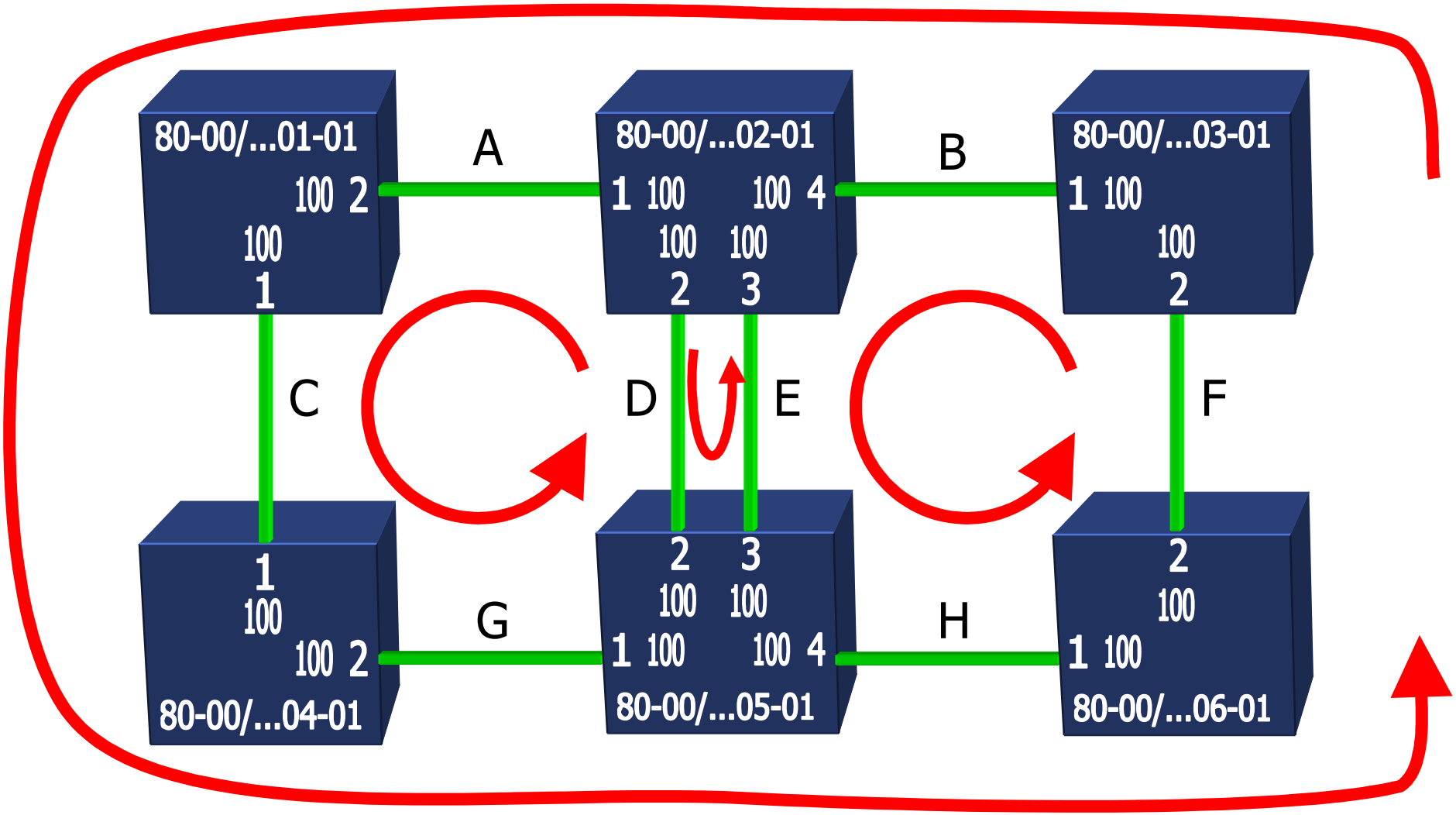
the topology change flag is set

step 4: **bridge1** acknowlegdes (hence, **bridge2** stops sending notifications) and sets the topology change flag

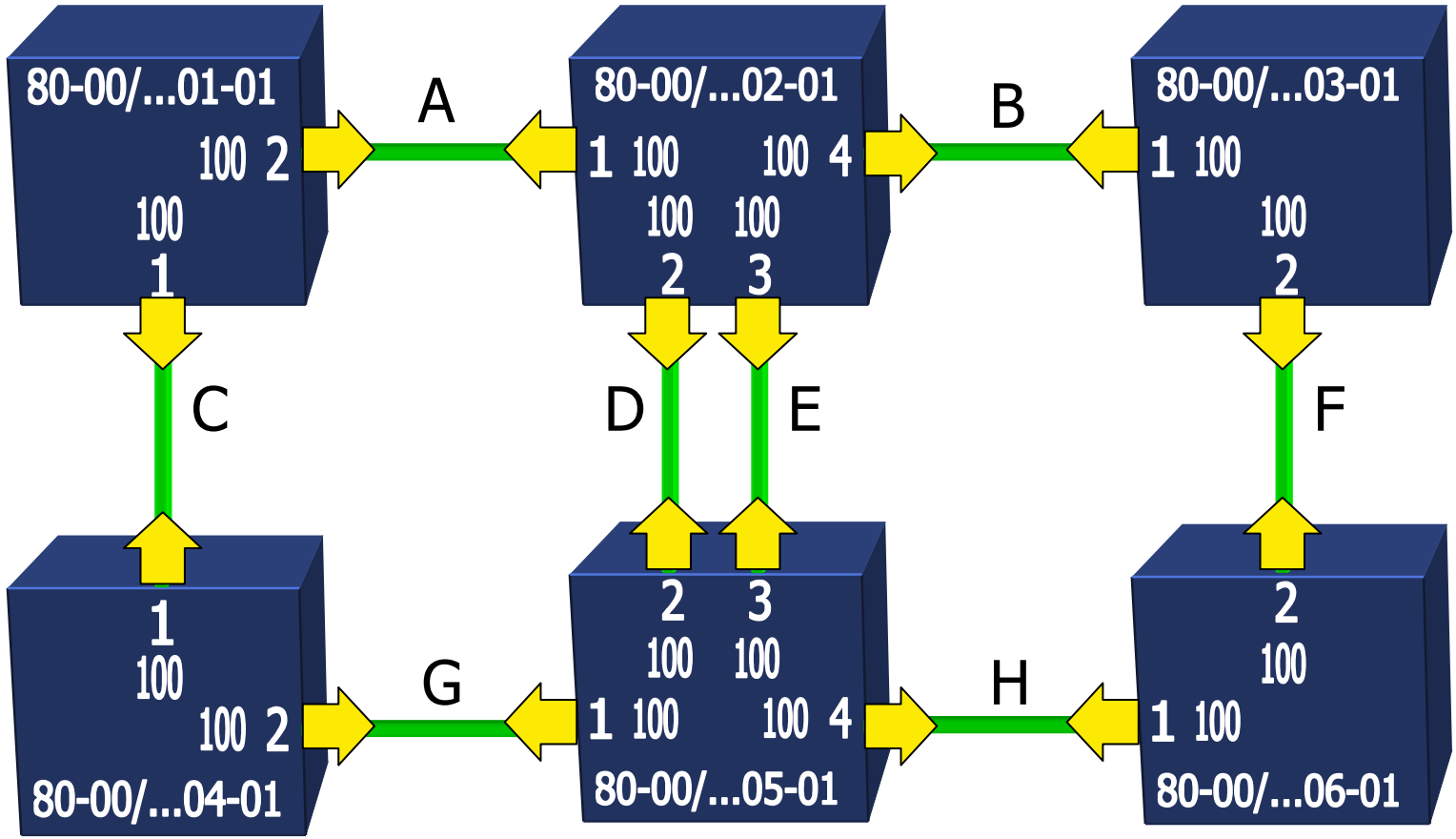
lab4: a more complex scenario



lab4: a more complex scenario



root bridge election



= "I am the root bridge"

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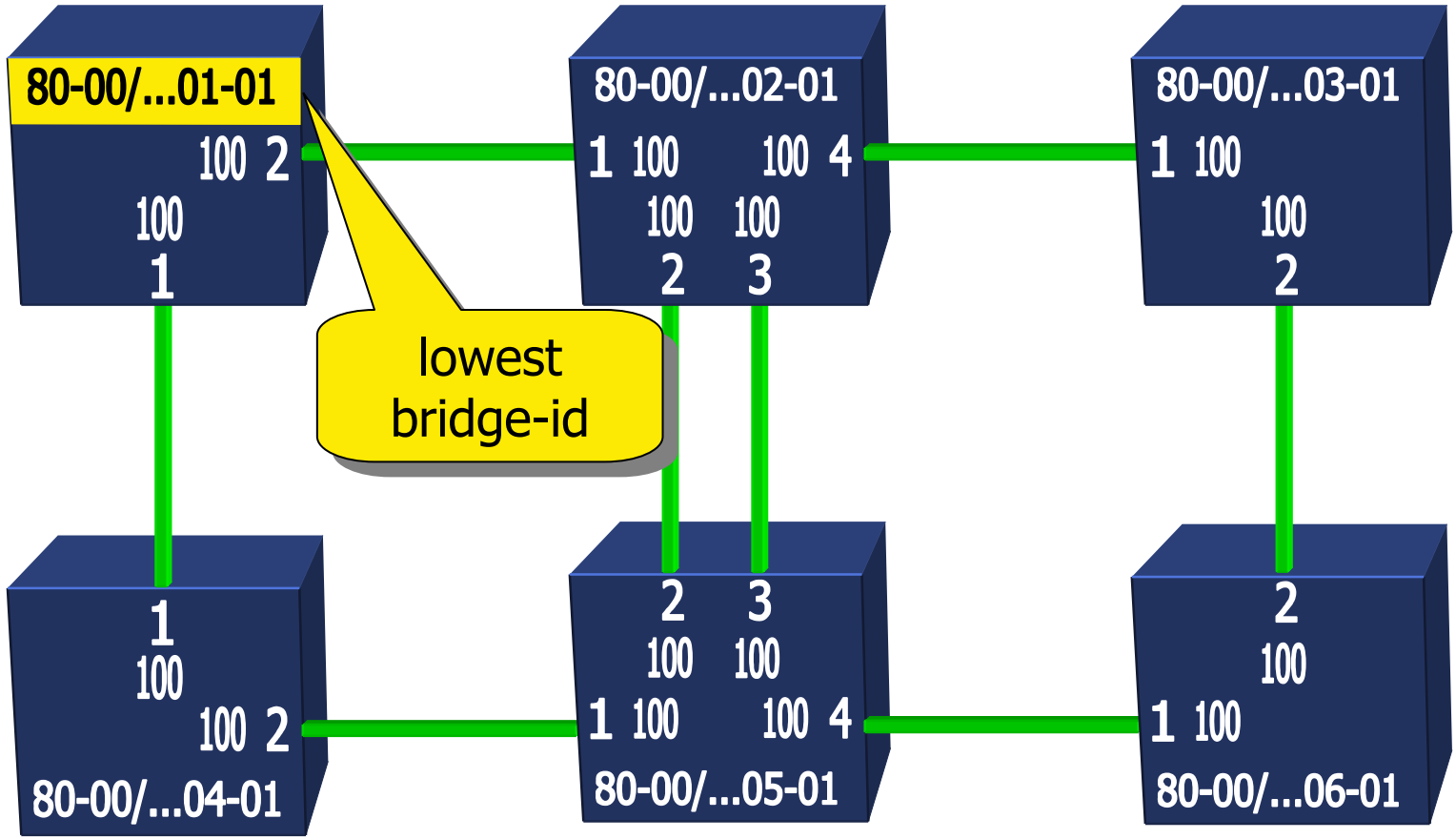
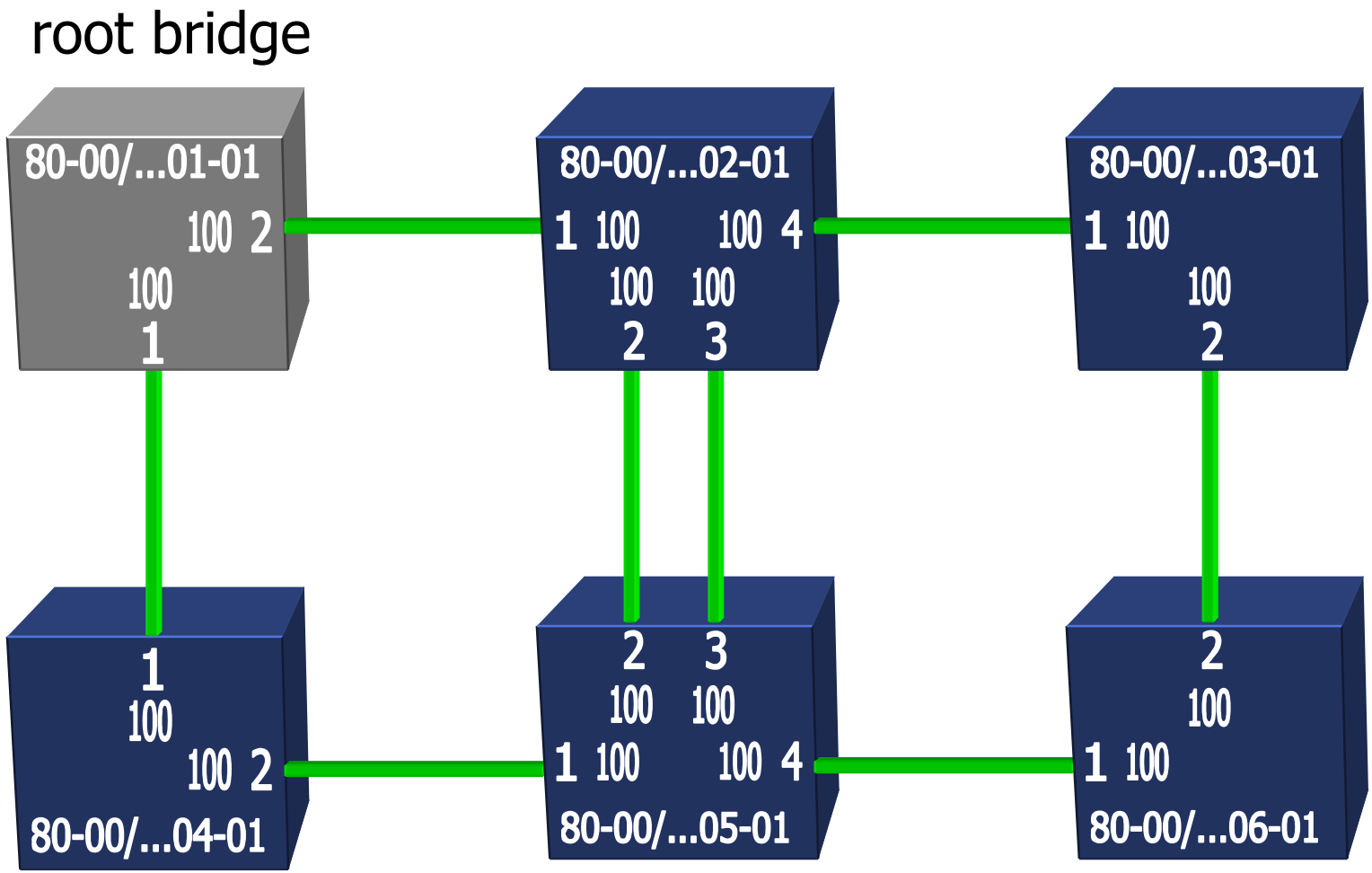
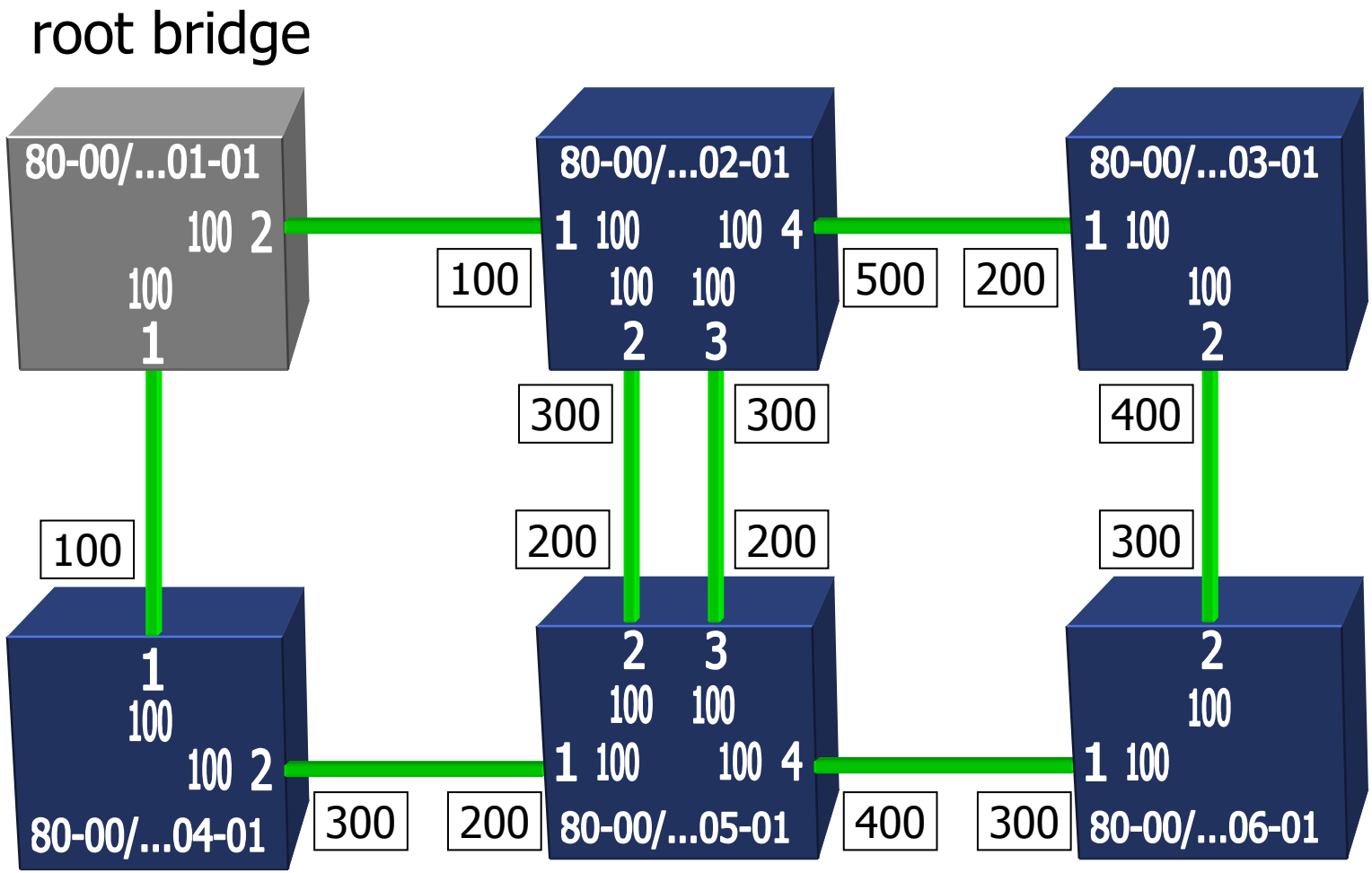
root bridge election



root bridge election



root ports identification



xxx = minimum root-path-cost of bpdus received through the port

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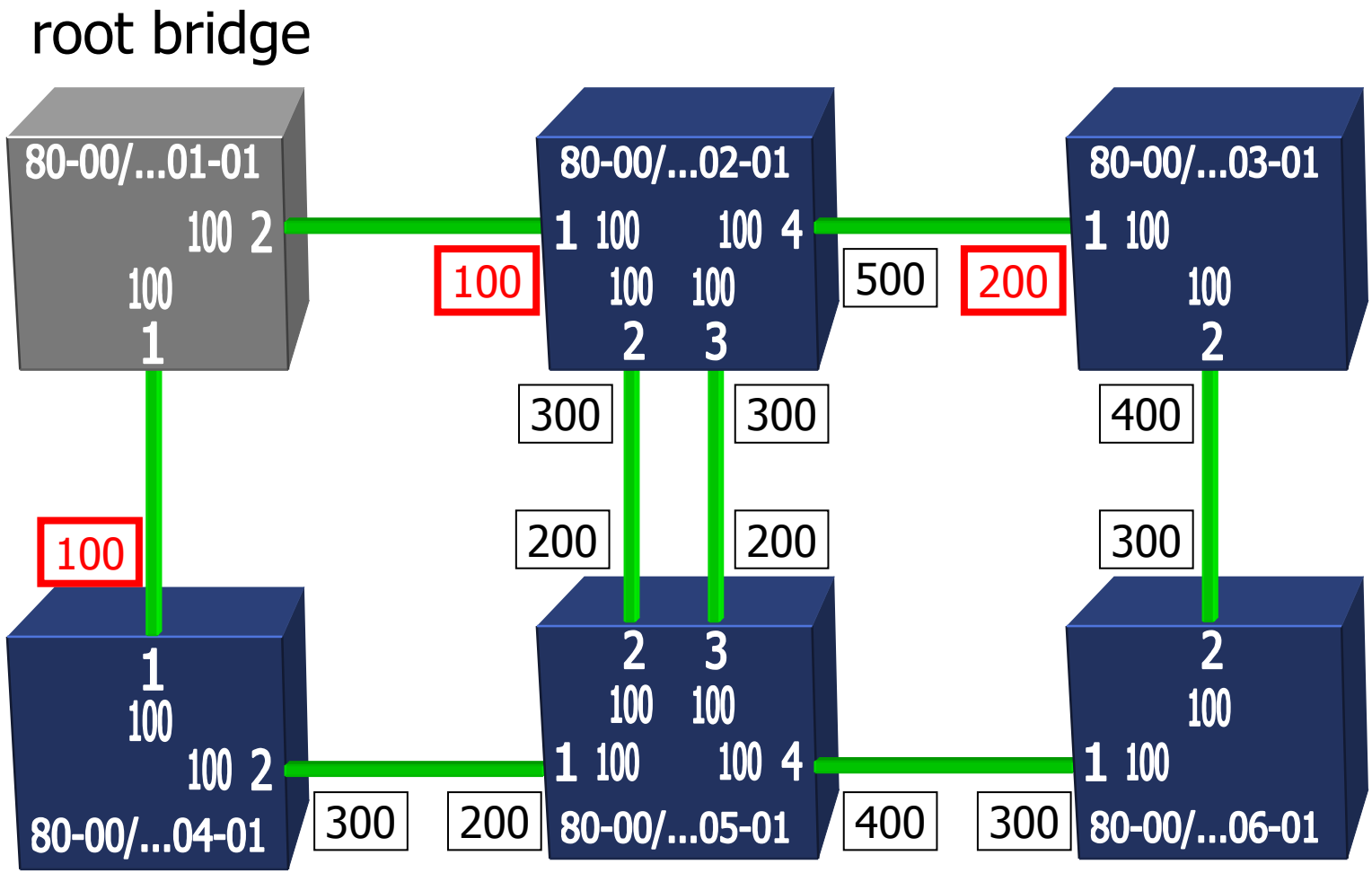
root ports identification



xxx = root port (xxx is the root path cost)

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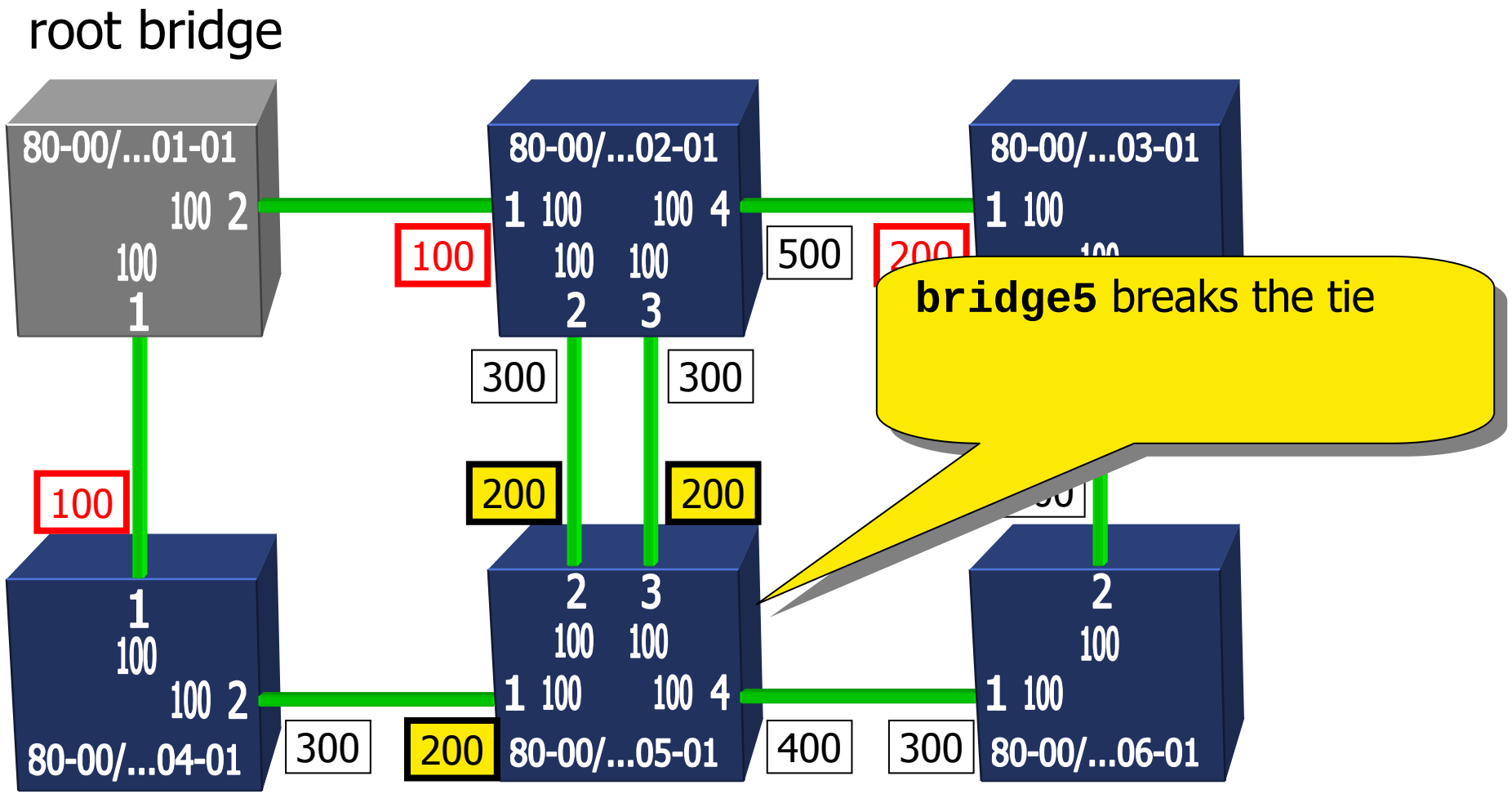
root ports identification



xxx = root port (xxx is the root path cost)

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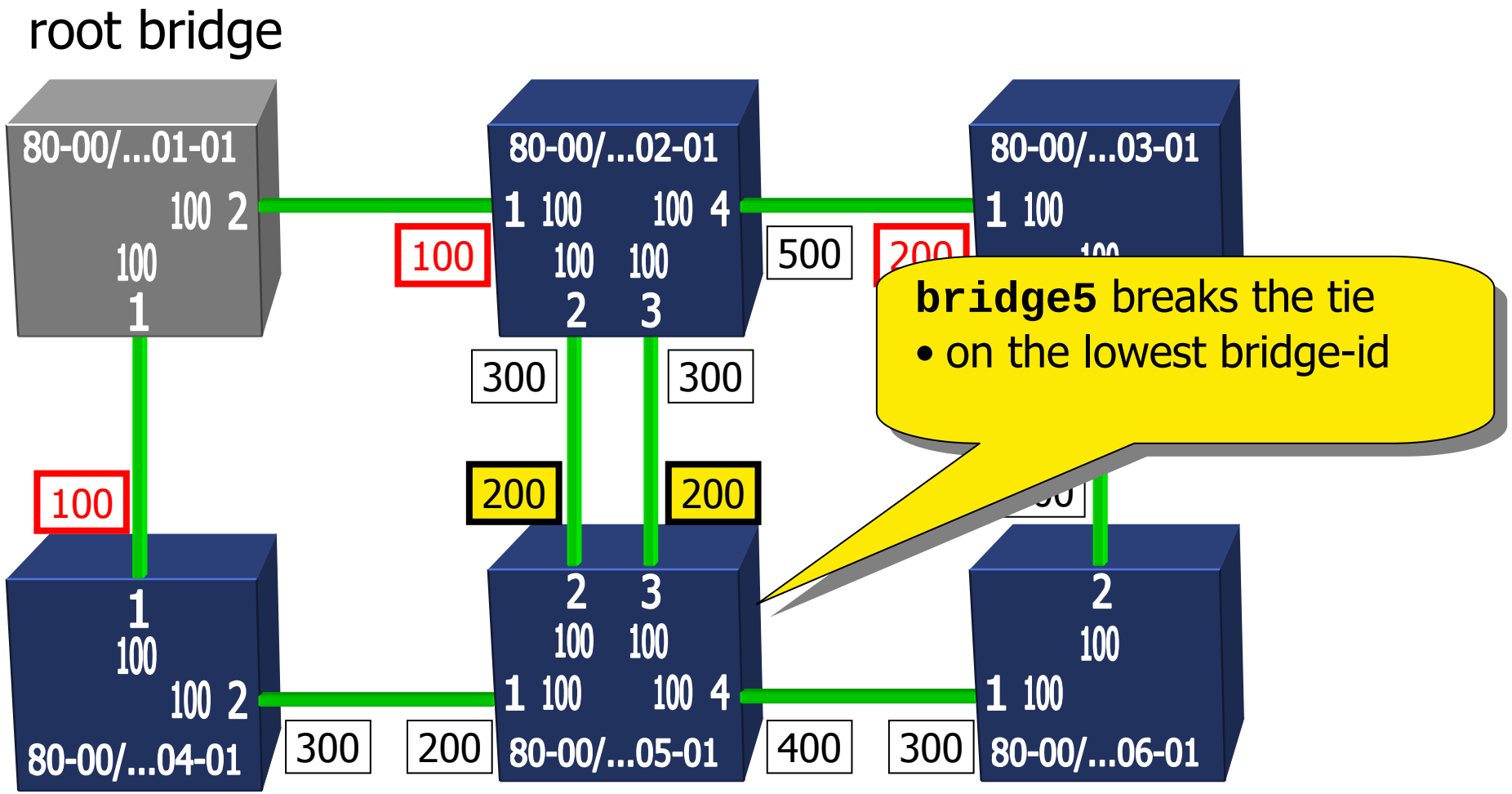
root ports identification



xxx = root port (xxx is the root path cost)

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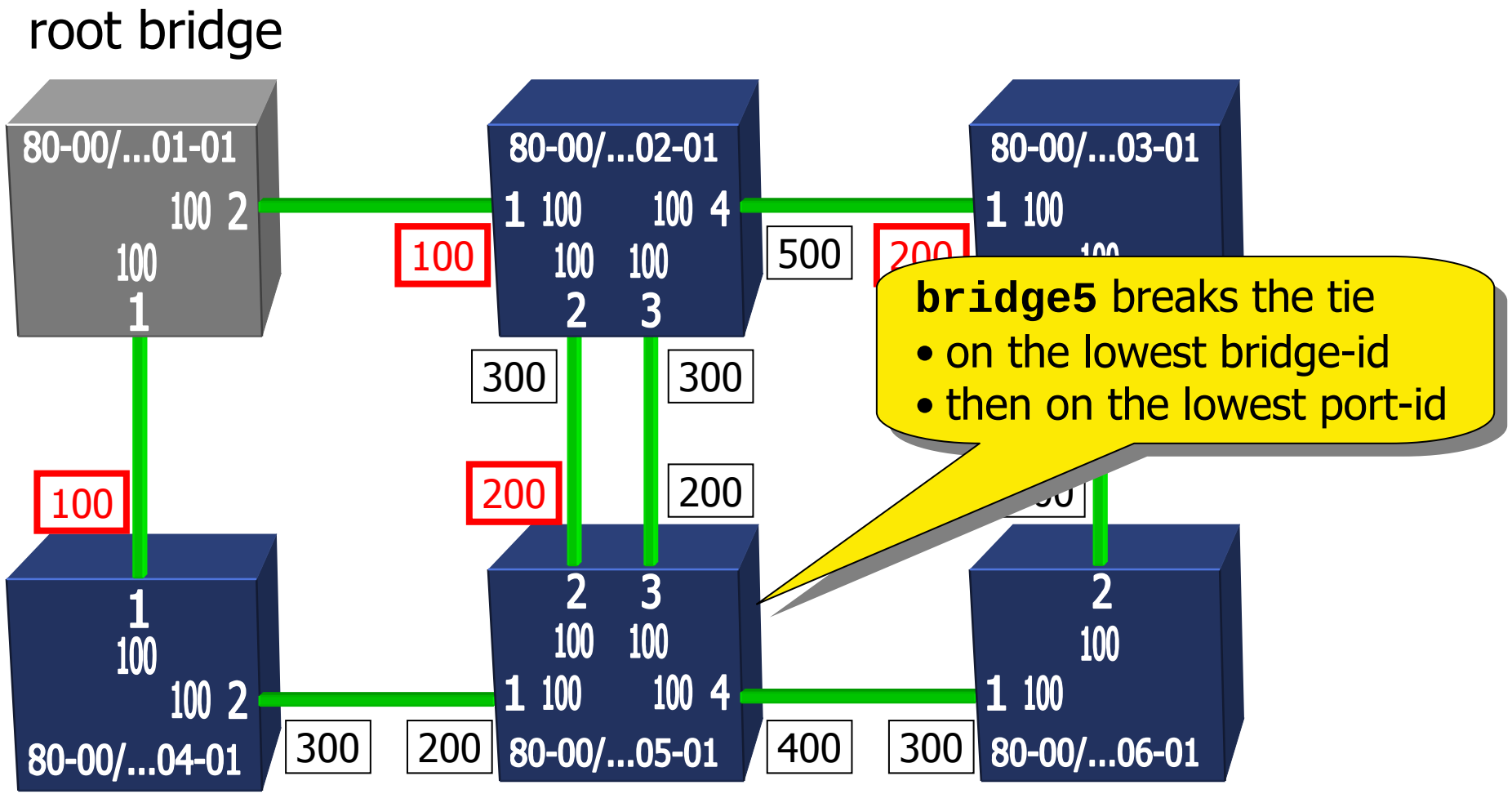
root ports identification



xxx = root port (xxx is the root path cost)

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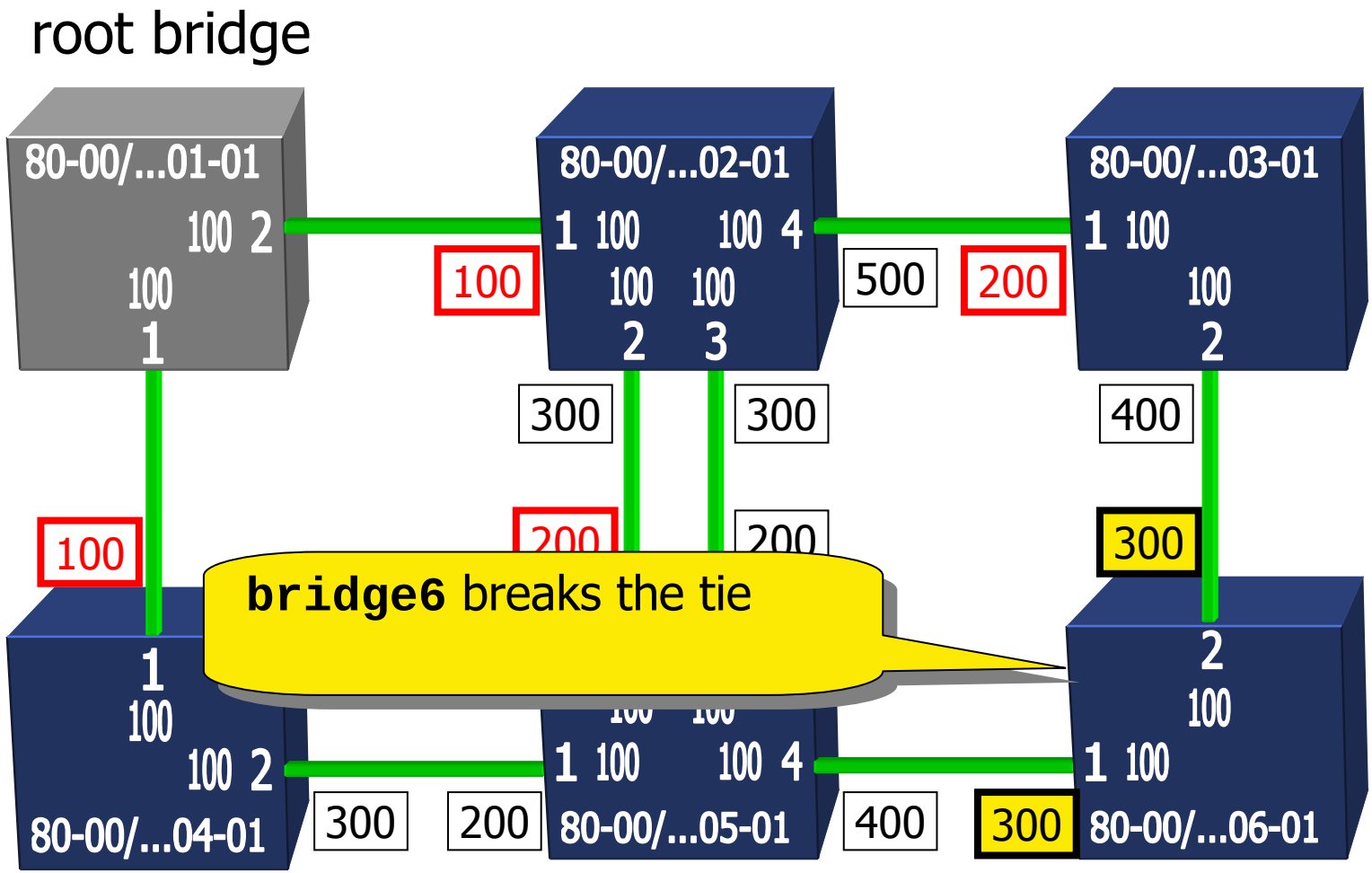
root ports identification



xxx = root port (xxx is the root path cost)

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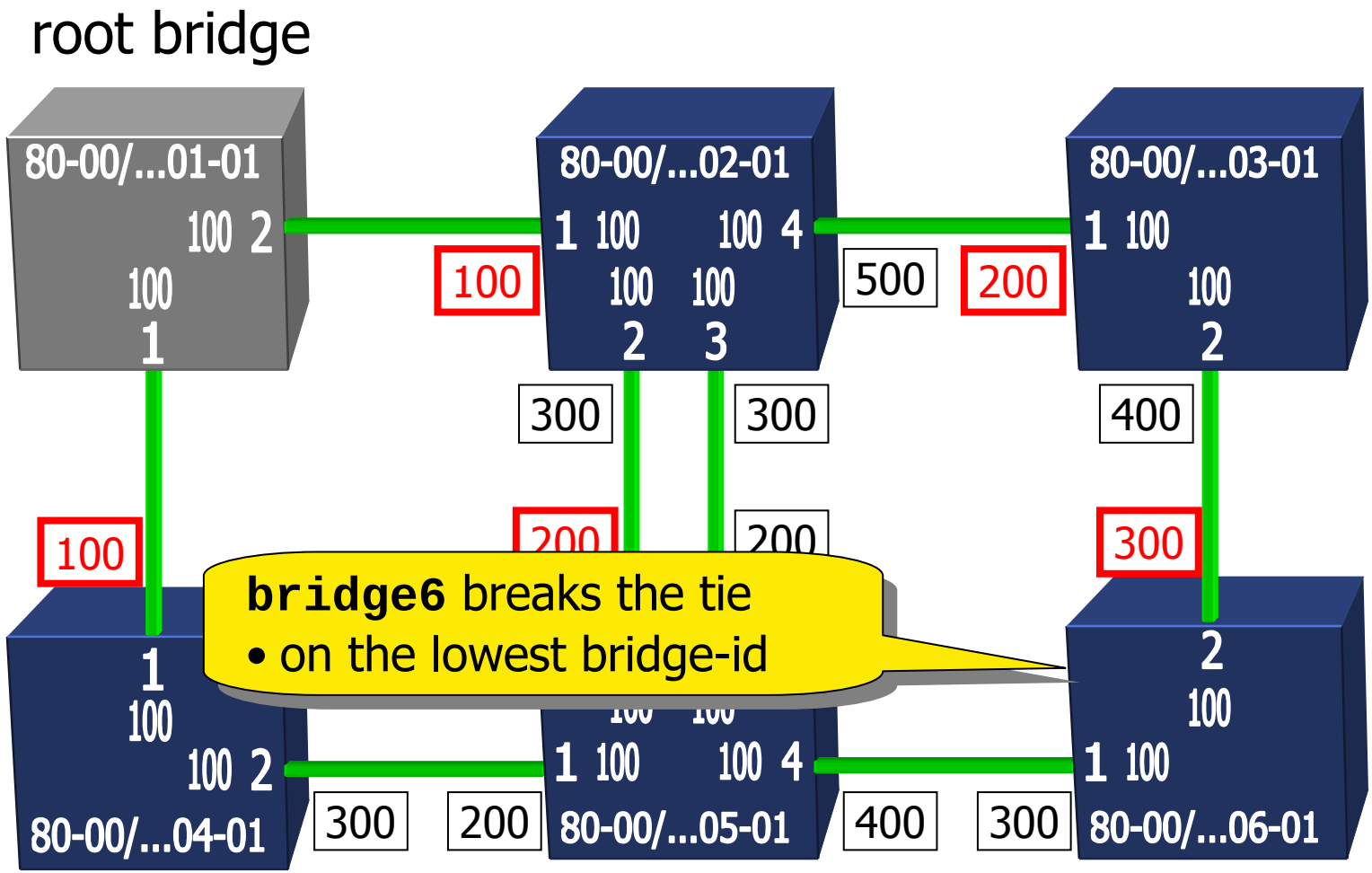
root ports identification



xxx = root port (xxx is the root path cost)

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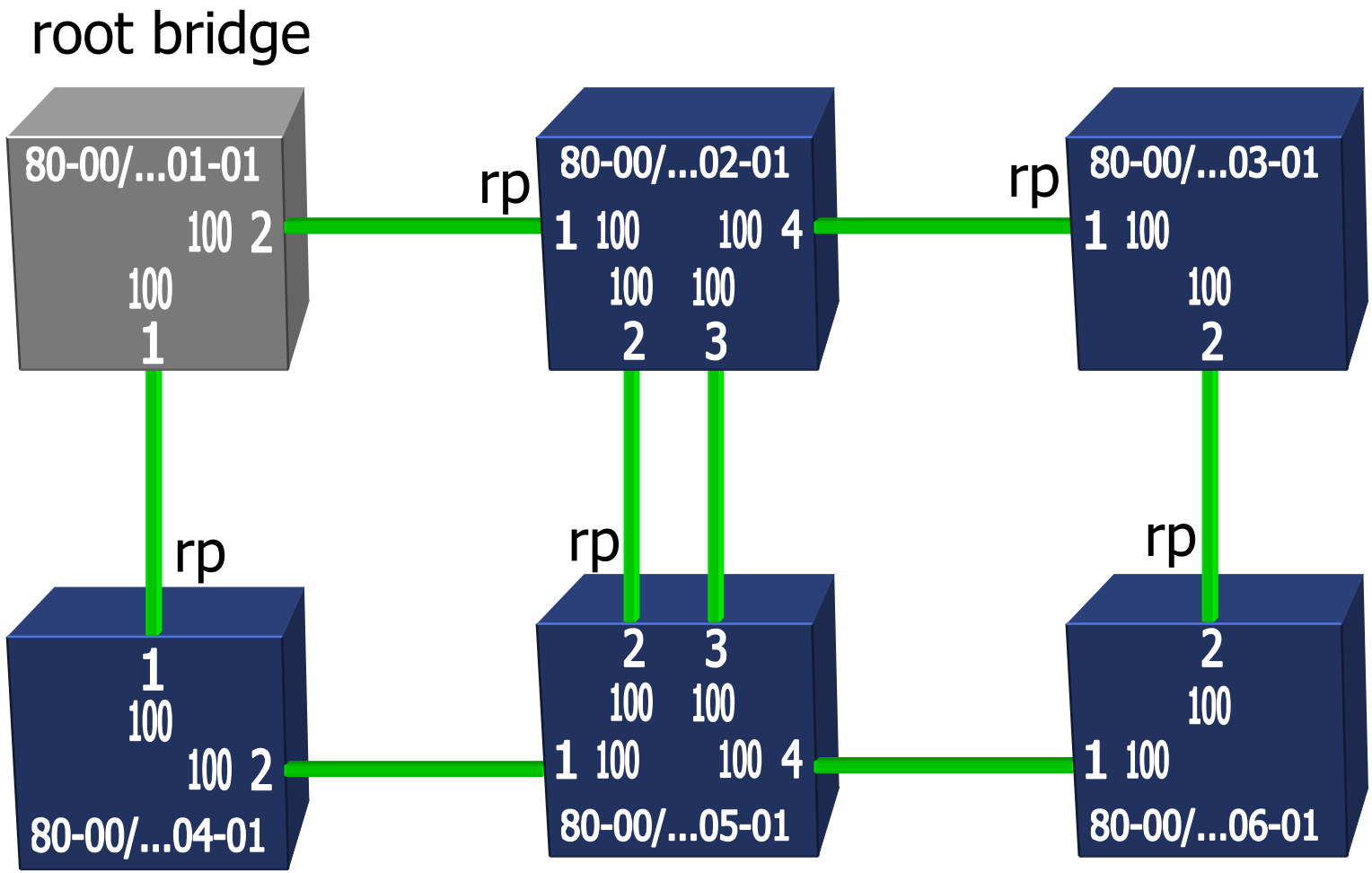
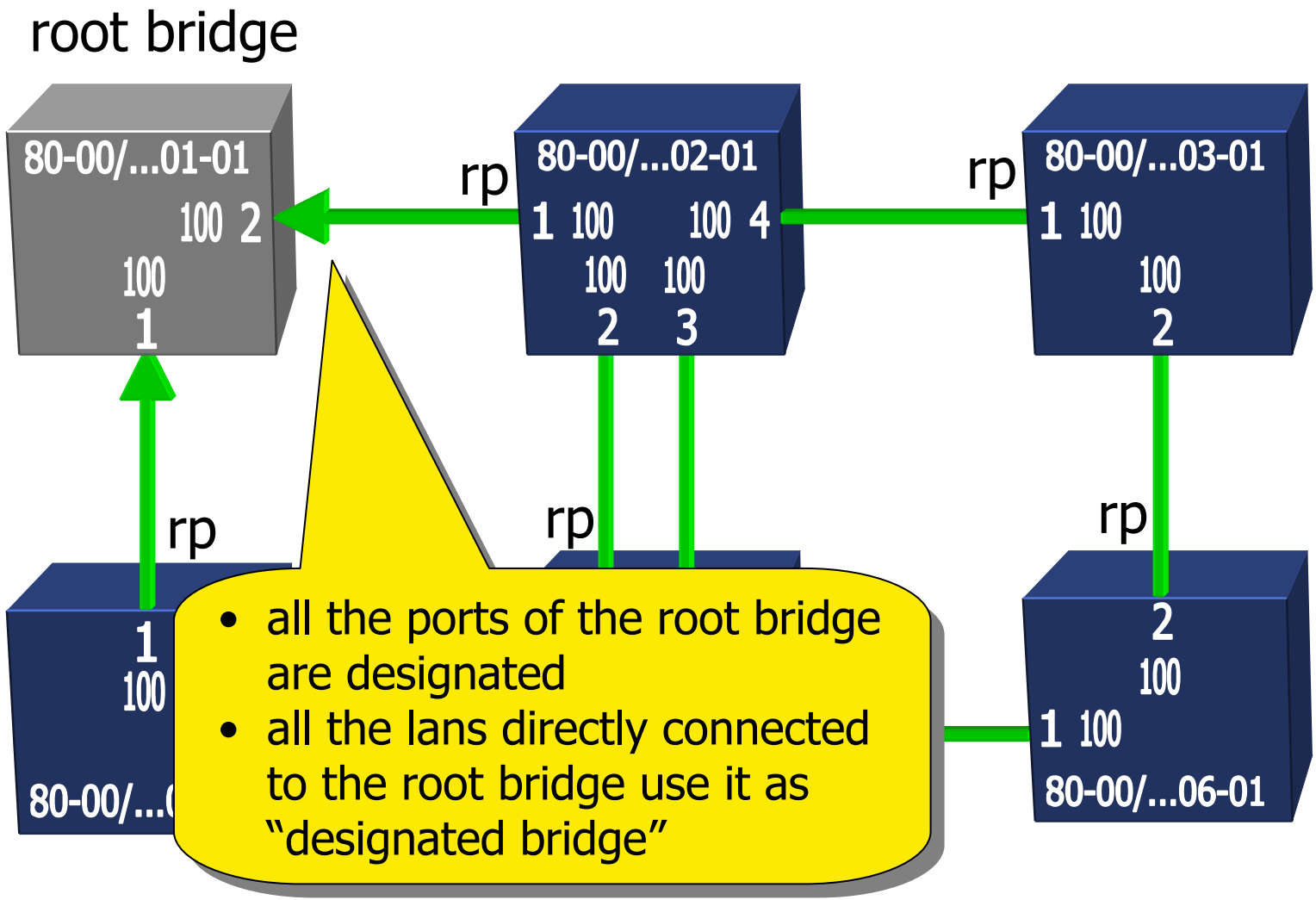
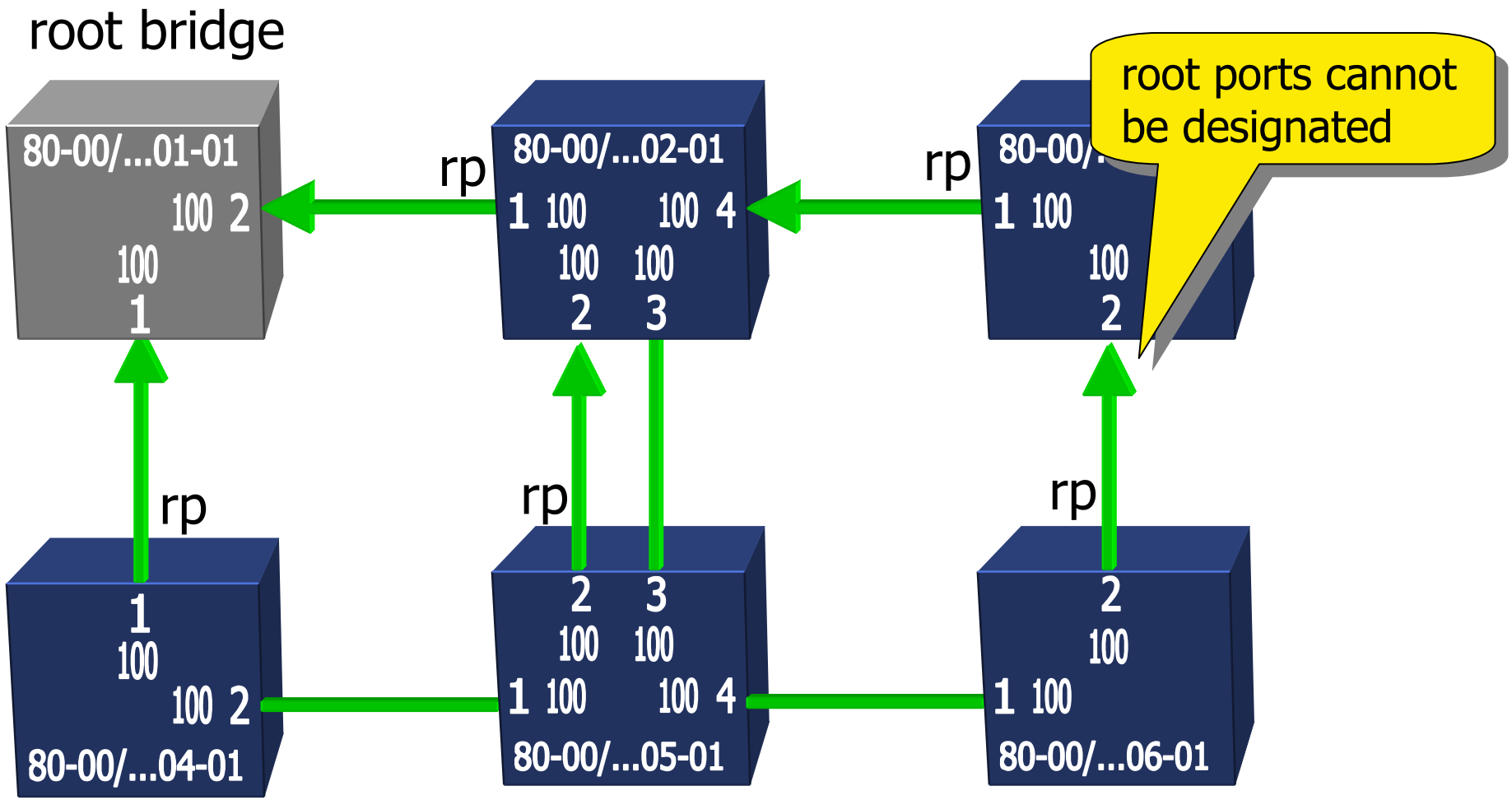
root ports identification



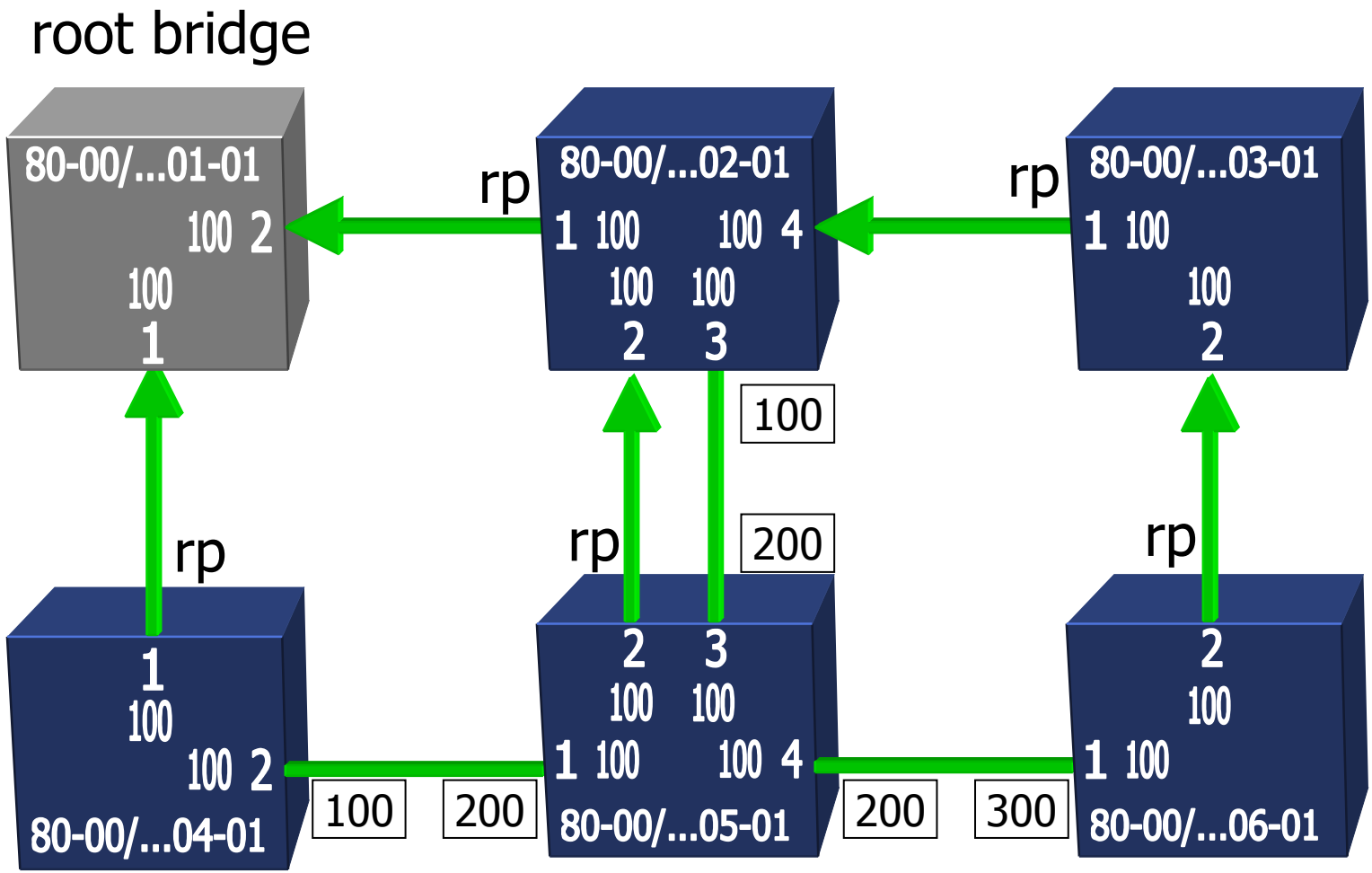
designated ports/bridges identification



designated ports/bridges identification



designated ports/bridges identification



xxx = min root-path-cost of bpdus received *by the lan* through a given port

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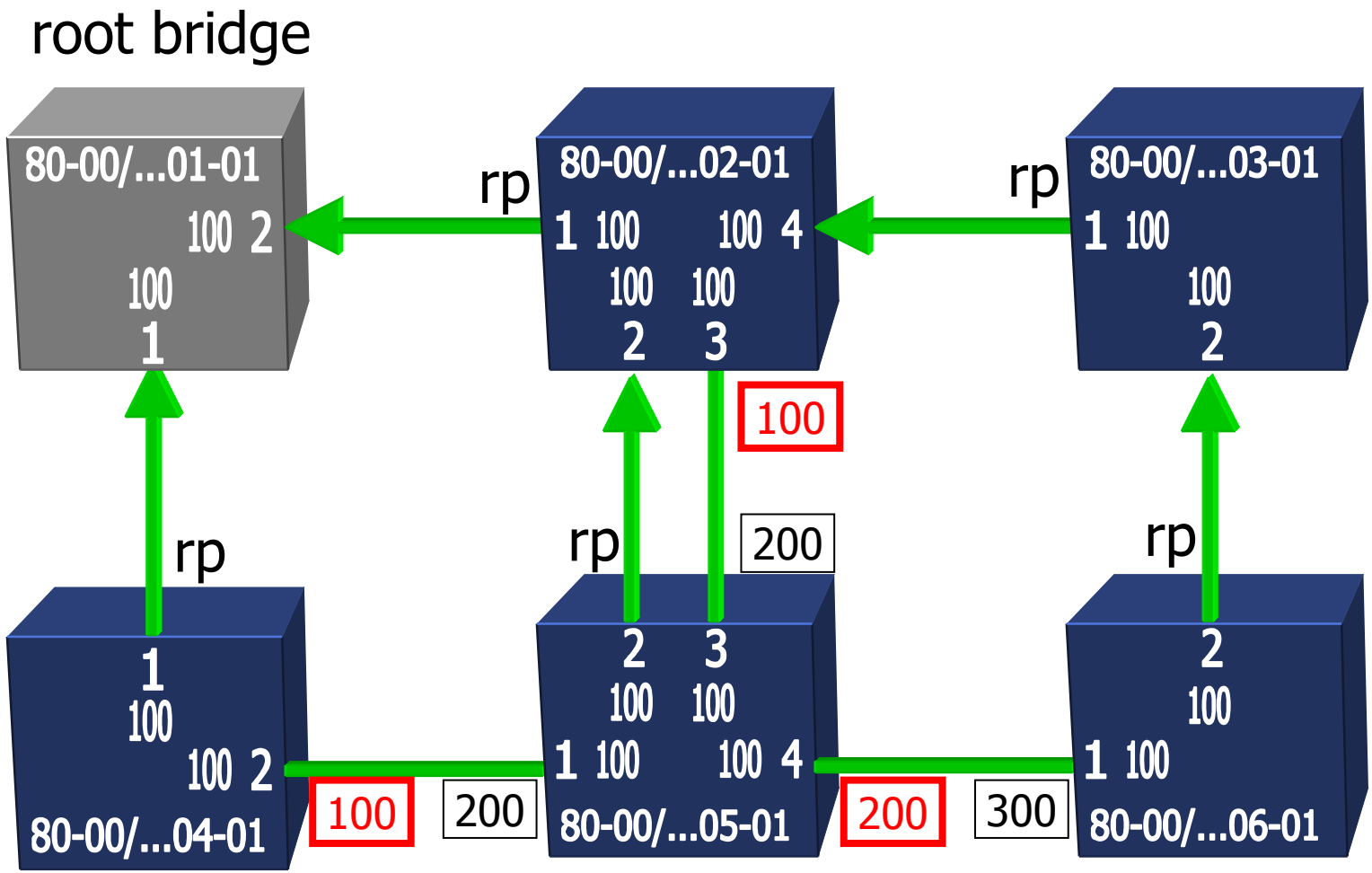
designated ports/bridges identification



xxx = designated port (xxx is the root path cost)

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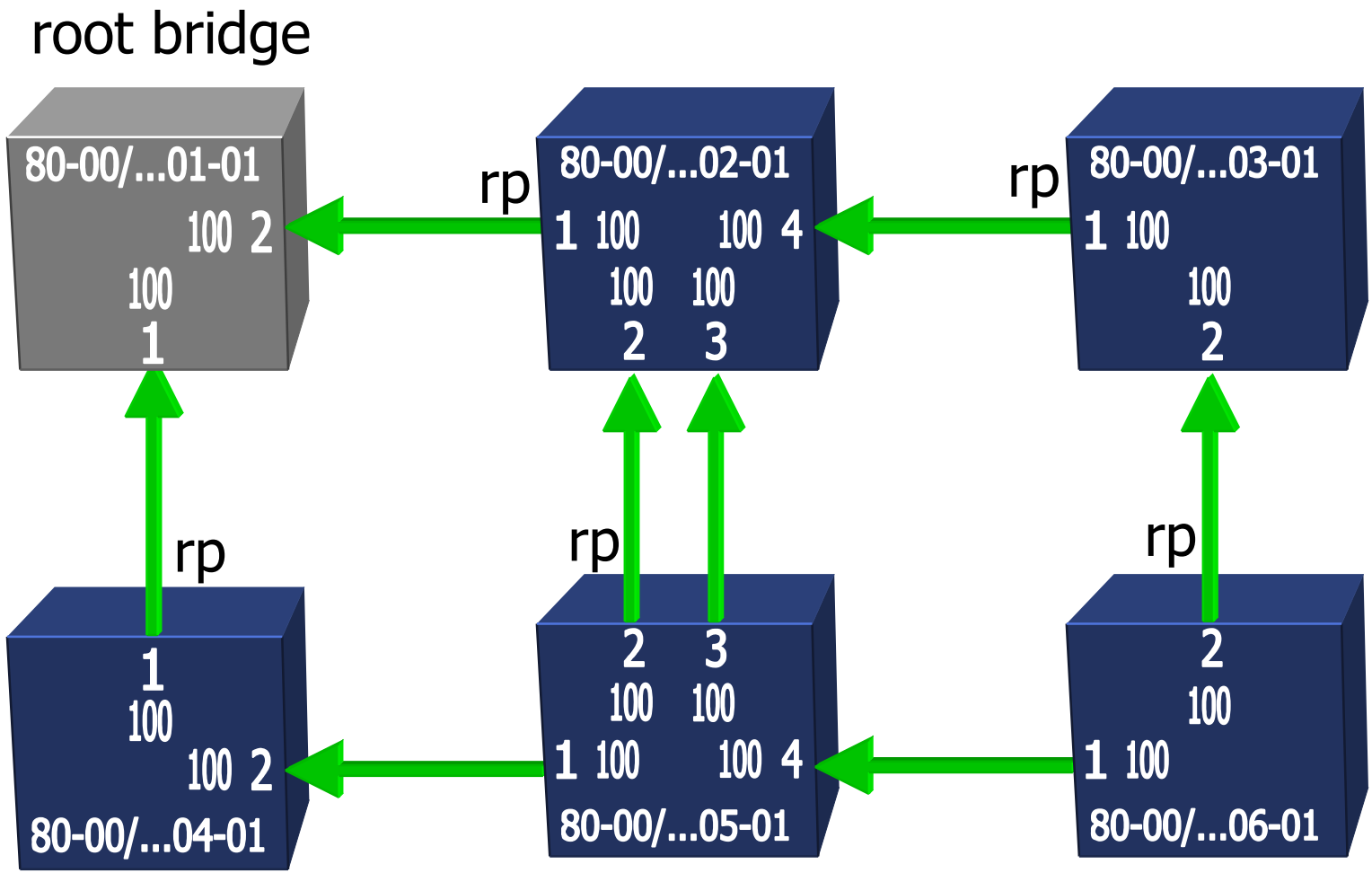
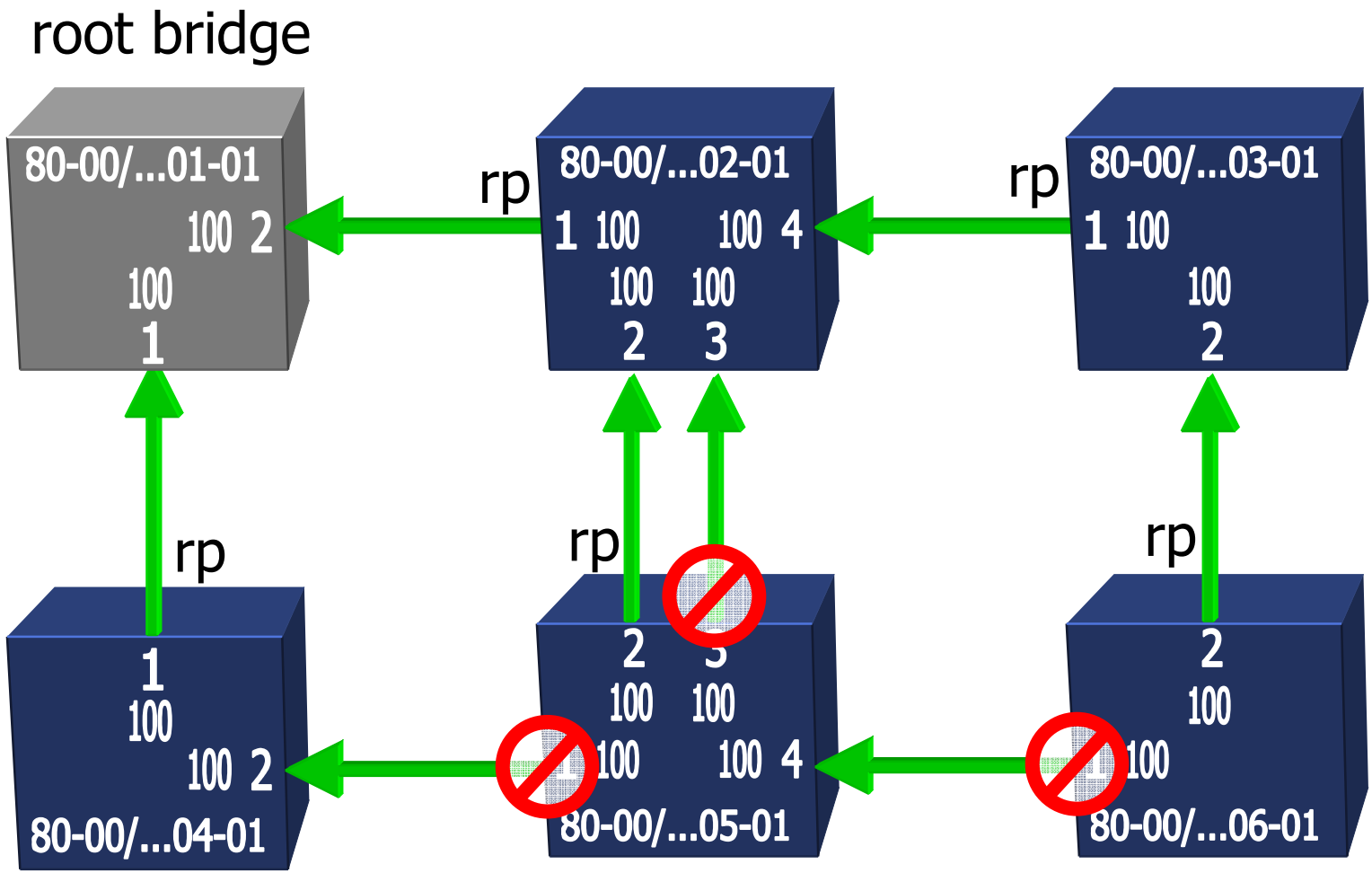
designated ports/bridges identification



blocking


root bridge
80-00/...01-01
100 2
100
1
rp
80-00/...02-01
1 100
100 4
100 100
2 3
rp
80-00/...03-01
1 100
100
2
rp
1
100
100 2
80-00/...04-01
rp
2 3
100 100
100
100 4
80-00/...05-01
rp
2
100
100
80-00/...06-01

lab4: a more complex scenario

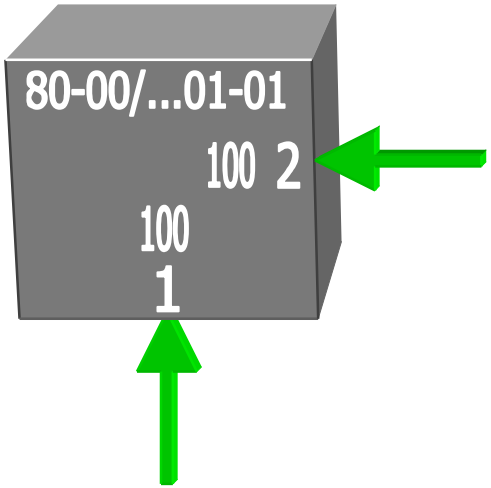
host machine

```
user@localhost:~$ cd netkit-lab_stp-complex
user@localhost:~/netkit-lab_stp-complex$ lstart
```

- the lab is configured to start the 6 bridges and to run the spanning tree protocol (stp) on all of them

stp status

root bridge



bridge1

```
bridge1:~# brctl showstp br0
br0
 bridge id              8000.000000000101
 designated root        8000.000000000101
 root port                 0                    path cost                  0
 max age                  20.00                 bridge max age            20.00
 hello time                2.00                 bridge hello time          2.00
 forward delay            15.00                 bridge forward delay      15.00
 ageing time             300.00
 hello timer                1.57                tcn timer                  0.00
 topology change timer 0.00                     gc timer                  91.36
 flags

eth0 (1)
 port id                8001                    state                forwarding
 designated root        8000.000000000101       path cost                  100
 designated bridge      8000.000000000101       message age timer          0.00
 designated port        8001                    forward delay timer        0.00
 designated cost           0                    hold timer                 0.57
 flags

eth1 (2)
 port id                8002                    state                forwarding
 designated root        8000.000000000101       path cost                  100
 designated bridge      8000.000000000101       message age timer          0.00
 designated port        8002                    forward delay timer        0.00
 designated cost           0                    hold timer                 0.57
 flags
```

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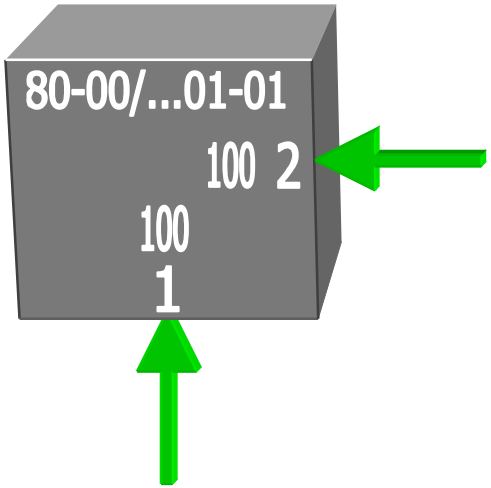
stp status

root bridge



bridge1

```
bridge1:~# brctl showstp br0
br0
 bridge id              8000.000000000101
 designated root        8000.000000000101
 root port                 0                    path cost                  0
 max age                                        bridge max age            20.00
 hello time                                     bridge hello time          2.00
 forward delay                                  bridge forward delay      15.00
 ageing time
 hello timer                                    tcn timer                  0.00
 topology change timer 0.00                     gc timer                  91.36
 flags

eth0 (1)
 port id              8001                      state                forwarding
 designated root      8000.000000000101         path cost                  100
 designated bridge    8000.000000000101         message age timer          0.00
 designated port      8001                      forward delay timer        0.00
 designated cost         0                      hold timer                 0.57
 flags

eth1 (2)
 port id              8002                      state                forwarding
 designated root      8000.000000000101         path cost                  100
 designated bridge    8000.000000000101         message age timer          0.00
 designated port      8002                      forward delay timer        0.00
 designated cost         0                      hold timer                 0.57
 flags
```

root bridge

root path cost

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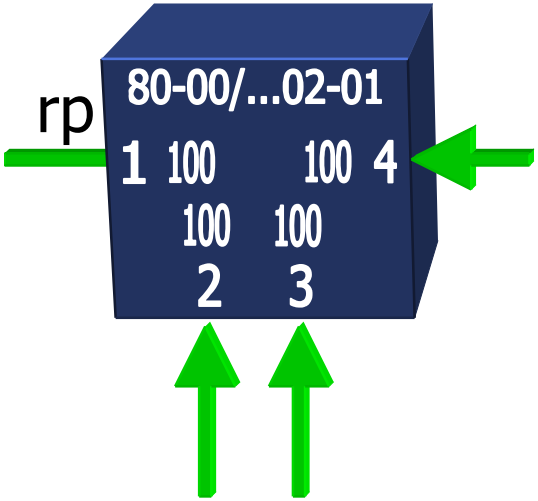
stp status



bridge2

```
bridge2:~# brctl showstp br0
br0
 bridge id              8000.000000000201
 designated root        8000.000000000101
 root port                 1                    path cost                  100
.....
eth0 (1)
 port id                8001                    state                forwarding
 designated root        8000.000000000101       path cost                  100
 designated bridge      8000.000000000101       message age timer        19.67
 designated port        8002                    forward delay timer       0.00
.....
eth1 (2)
 port id                8002                    state                forwarding
 designated root        8000.000000000101       path cost                  100
 designated bridge      8000.000000000201       message age timer         0.00
 designated port        8002                    forward delay timer       0.00
.....
eth2 (3)
 port id                8003                    state                forwarding
 designated root        8000.000000000101       path cost                  100
 designated bridge      8000.000000000201       message age timer         0.00
 designated port        8003                    forward delay timer       0.00
.....
eth3 (4)
 port id                8004                    state                forwarding
 designated root        8000.000000000101       path cost                  100
 designated bridge      8000.000000000201       message age timer         0.00
 designated port        8004                    forward delay timer       0.00
.....
```

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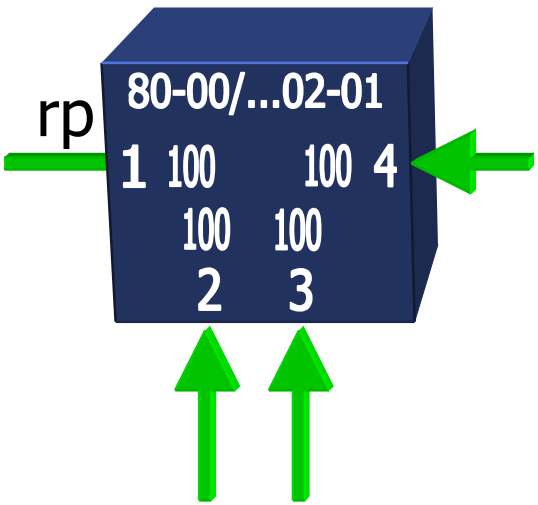
stp status



designated bridge for the lan connected to eth*x* (*x*+1)

bridge2

```
bridge2:~# brctl showstp br0
br0
 bridge id              8000.000000000
 designated root        8000.000000000101
 root port                 1                    path cost                  100
.....
eth0 (1)
 port id                8001                    state                forwarding
 designated root        8000.000000000101       path cost                  100
 designated bridge      8000.000000000101       message age timer        19.67
 designated port        8002                    forward delay timer       0.00
.....
eth1 (2)
 port id                8002                    state                forwarding
 designated root        8000.000000000101       path cost                  100
 designated bridge      8000.000000000201       message age timer         0.00
 designated port        8002                    forward delay timer       0.00
.....
eth2 (3)
 port id                8003                    state                forwarding
 designated root        8000.000000000101       path cost                  100
 designated bridge      8000.000000000201       message age timer         0.00
 designated port        8003                    forward delay timer       0.00
.....
eth3 (4)
 port id                8004                    state                forwarding
 designated root        8000.000000000101       path cost                  100
 designated bridge      8000.000000000201       message age timer         0.00
 designated port        8004                    forward delay timer       0.00
.....
```

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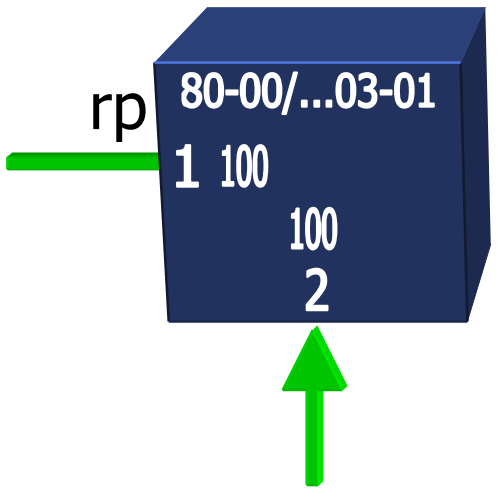
stp status



bridge3

```
bridge3:~# brctl showstp br0
br0
 bridge id              8000.000000000301
 designated root        8000.000000000101
 root port                 1                    path cost                  200
 max age                  20.00                 bridge max age            20.00
 hello time                2.00                 bridge hello time          2.00
 forward delay            15.00                 bridge forward delay      15.00
 ageing time             300.00
 hello timer               0.00                 tcn timer                  0.00
 topology change timer 0.00                     gc timer                 189.82
 flags


eth0 (1)
 port id                8001                    state               forwarding
 designated root        8000.000000000101       path cost                  100
 designated bridge      8000.000000000201       message age timer         19.91
 designated port        8004                    forward delay timer        0.00
 designated cost         100                    hold timer                 0.00
 flags

eth1 (2)
 port id                8002                    state               forwarding
 designated root        8000.000000000101       path cost                  100
 designated bridge      8000.000000000301       message age timer          0.00
 designated port        8002                    forward delay timer        0.00
```

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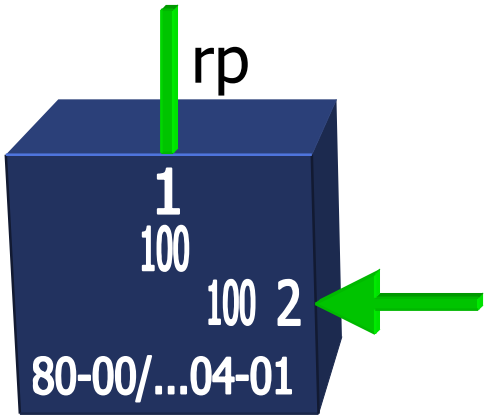
stp status



bridge4

```
bridge4:~# brctl showstp br0
br0
 bridge id              8000.000000000401
 designated root        8000.000000000101
 root port                 1                    path cost                  100
 max age                  20.00                 bridge max age            20.00
 hello time                2.00                 bridge hello time          2.00
 forward delay            15.00                 bridge forward delay      15.00
 ageing time             300.00
 hello timer               0.00                 tcn timer                  0.00
 topology change timer     0.00                 gc timer                 289.91
 flags


eth0 (1)
 port id                8001                    state                forforwarding
 designated root        8000.000000000101       path cost                  100
 designated bridge      8000.000000000101       message age timer         19.91
 designated port        8001                    forward delay timer        0.00
 designated cost           0                    hold timer                 0.00
 flags

eth1 (2)
 port id                8002                    state                forforwarding
 designated root        8000.000000000101       path cost                  100
 designated bridge      8000.000000000401       message age timer          0.00
 designated port        8002                    forward delay timer        0.00
 designated cost         100                    hold timer                 0.91
 flags
```

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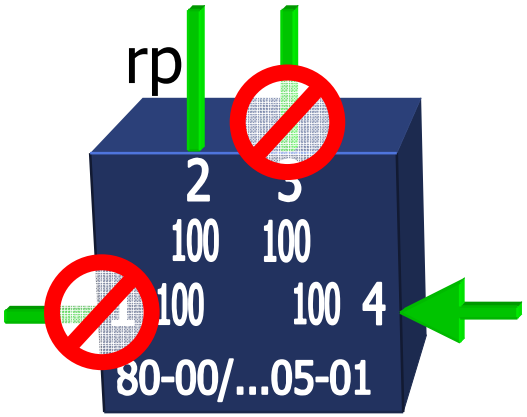
stp status



bridge5

```
bridge5:~# brctl showstp br0
br0
 bridge id              8000.000000000501
 designated root        8000.000000000101
 root port             2                    path cost            200
.....
eth0 (1)
 port id              8001                  state              blocking
 designated root      8000.000000000101     path cost             100
 designated bridge    8000.000000000401     message age timer    18.24
 designated port      8002                  forward delay timer   0.00
.....
eth1 (2)
 port id              8002                  state            forwarding
 designated root      8000.000000000101     path cost             100
 designated bridge    8000.000000000201     message age timer    18.24
 designated port      8002                  forward delay timer   0.00
.....
eth2 (3)
 port id              8003                  state              blocking
 designated root      8000.000000000101     path cost             100
 designated bridge    8000.000000000201     message age timer    18.24
 designated port      8003                  forward delay timer   0.00
.....
eth3 (4)
 port id              8004                  state            forwarding
 designated root      8000.000000000101     path cost             100
 designated bridge    8000.000000000501     message age timer     0.00
 designated port      8004                  forward delay timer   0.00
.....
```

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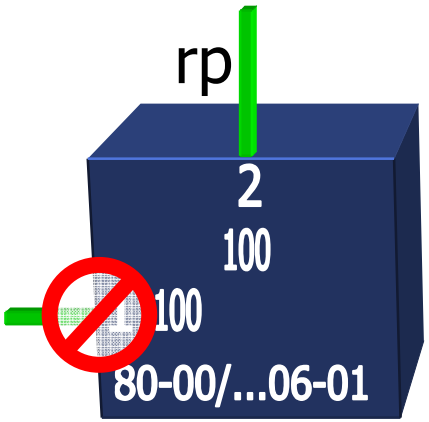
stp status



bridge6

```
bridge6:~# brctl showstp br0
br0
 bridge id              8000.000000000601
 designated root        8000.000000000101
 root port                 2                    path cost                  300
 max age                  20.00                 bridge max age            20.00
 hello time                2.00                 bridge hello time          2.00
 forward delay            15.00                 bridge forward delay      15.00
 ageing time             300.00
 hello timer               0.00                 tcn timer                  0.00
 topology change timer 0.00                     gc timer                 133.65
 flags

eth0 (1)
 port id                8001                    state                   blocking
 designated root        8000.000000000101       path cost                  100
 designated bridge      8000.000000000501       message age timer         19.82
 designated port        8004                    forward delay timer        0.00
 designated cost         200                    hold timer                 0.00
 flags

eth1 (2)
 port id                8002                    state                forwarding
 designated root        8000.000000000101       path cost                  100
 designated bridge      8000.000000000301       message age timer         19.71
 designated port        8002                    forward delay timer        0.00
 designated cost         200                    hold timer                 0.00
 flags
```

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further experiments

- try changing the root bridge by setting the bridge priorities
- try using both ports of a specified link by using port priority
  - why is this difficult?

bridge

```
bridge:~# brctl
commands:
.....
        setbridgeprio   <bridge> <prio>          set bridge priority
.....
        setportprio     <bridge> <port> <prio>   set port priority
```