SPANNING TREE PROTOCOL

Predmet: Računarske mreže

Predavač: dr Dušan Stefanović

STP – “nevidljiv” dok mreža radi, kritičan kada ne radi

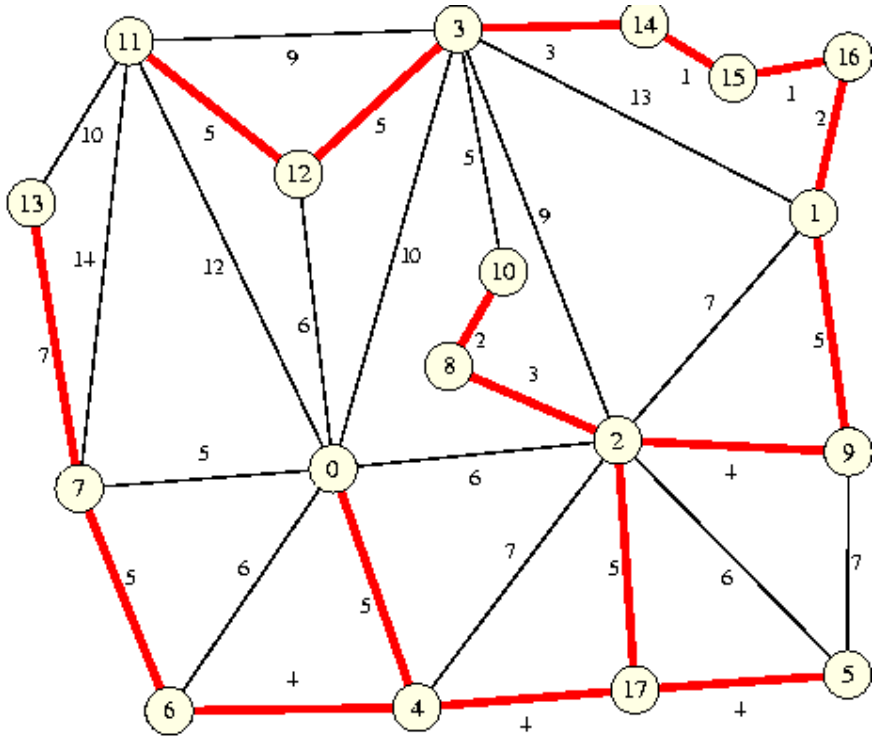
“Više od 50% problema u LAN mrežama zasniva se na STP protokolu (posebno ukoliko je LAN mreža loše dizajnirana).”

“Složen protokol koji većina administratora ne razume.”

Radia Perlman – STP developer

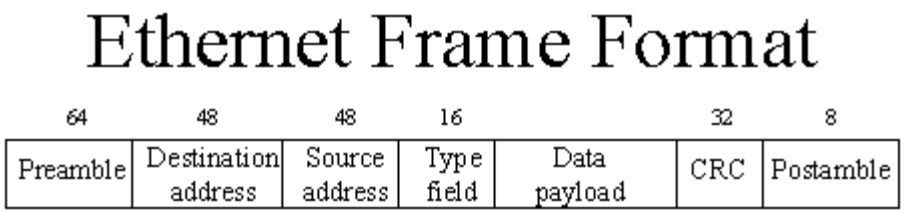
Spanning Tree Protocol (STP)

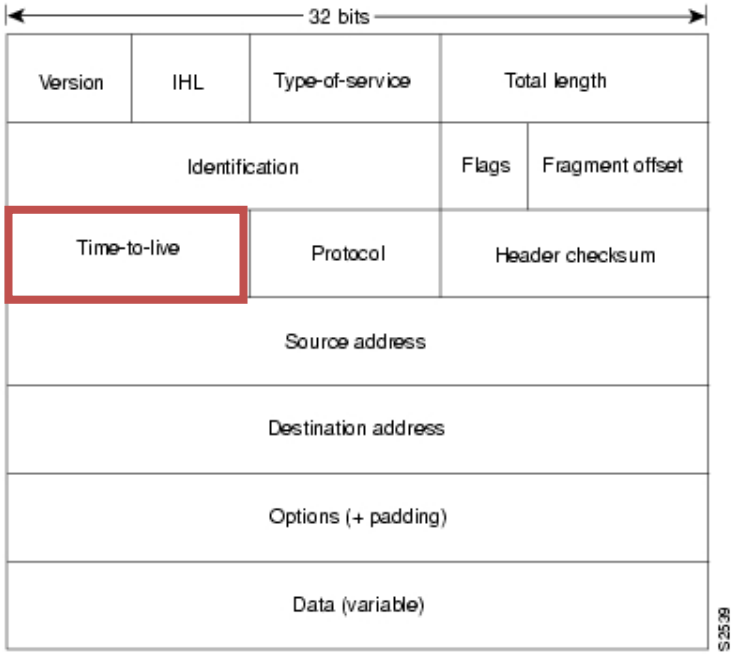
- IEEE 802.1D
- Layer 2 protokol koji sprečava petlje (loop-prevention) u LAN topologiji
- Pomoću ovog protokola Layer 2 uređaji komuniciraju međusobno da bi otkrili fizičke petlje u mreži
- Algoritam formira *loop-free logičku* topologiju.
- STP kreira stablo na Sloju 2, dok na fizičkom sloju su i dalje prisutne redudatne veze zbog pouzdanosti mreže.



L2/L3 PETLJE

- Broadcast i Layer 2 petlje su opasna kombinacija.
- Nakon što frejm uđe u petlju, kružiće u mreži sve dok se petlja ne prekine(isključivanjem jednog od sviča ili prekidanjem linka)
- IP ima načina da spreči petlju (TTL polje).
- Ethernet frejm nema TTL polje

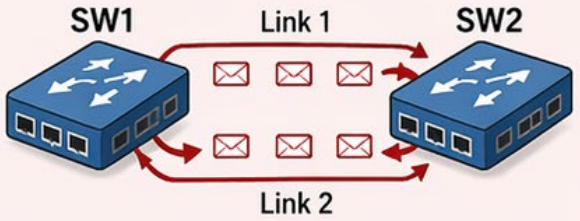




POSLEDICE L2 PETLJE

BROADCAST STORM

- Broadcast frejmovi se umnožavaju
- Linkovi se preplavljuju
- Korisnički saobraćaj ne može da prođe



MAC FLAPPING

MAC adresa	Port	Vreme
A	1/1	t1
A	1/2	t2
A	1/1	t3
A	1/2	t4
A	1/1	t5
...		

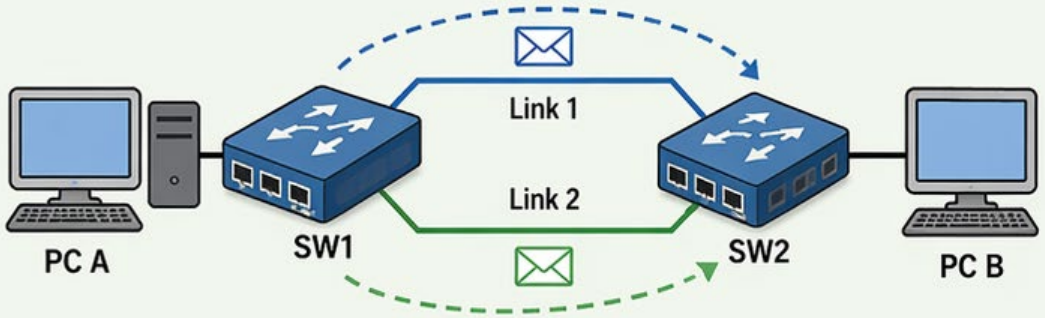
- Ista MAC adresa se uči na različitim portovima
- MAC tabela je nestabilna
- Svič ne zna gde da šalje unicast frejmove

POSLEDICE L2 PETLJE

CPU I LINKOVI POD OPTEREĆENJEM

- Svič mora da obradi ogroman broj frejmova
- Visoko korišćenje CPU-a
- Baferi se pune, dolazi do gubitka paketa
- Linkovi su zasićeni

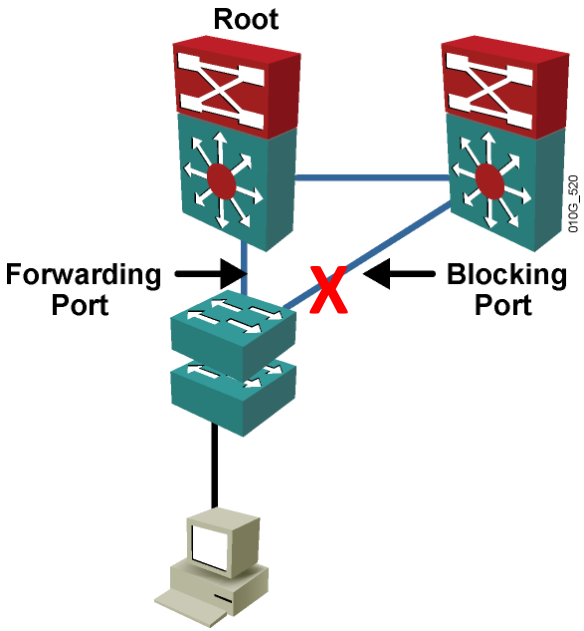
UREĐAJI PRIMAJU DUPLIKATE PAKETA



- Isti frejm stiže do uređaja više puta putem različitih putanja
- Aplikacije mogu da obrade duplikate (npr. više ARP odgovora, više DHCP ponuda)
- Može doći do nepredvidivog ponašanja aplikacija

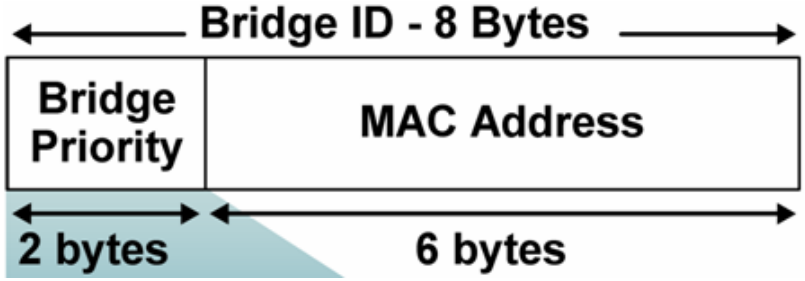
STP ALGORITAM

- STP izvršava algoritam koji se zove Spanning Tree Algorithm (STA).
  - STA bira referetnu tačku koja se zove **root bridge.**
  - Zatim se određuju najbolje putanje od svakog sviča do root bridge.
  - Ukoliko postoje više od dve putanje, STA bira najbolju putanju a ostale blokira



DVA KLJUČNA STP KONCEPTA

- STP proračun se oslanja na dva ključna koncepta u kreiranju loop-free topologije:
  - Bridge ID
  - Path Cost

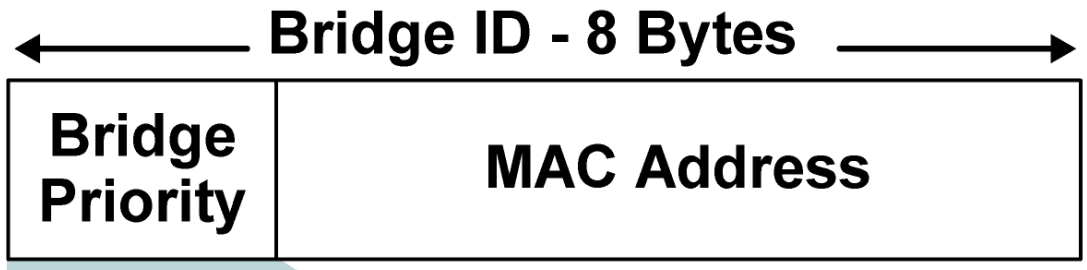


Brzina Linka	Cost (Revised IEEE Spec)	Cost (Previous IEEE Spec)
10 Gbps	2	1
1 Gbps	4	1
100 Mbps	19	10
10 Mbps	100	100

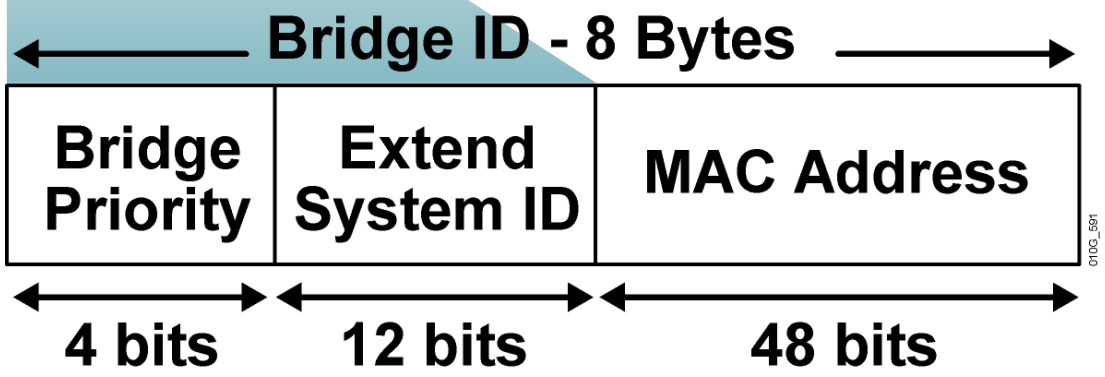
BRIDGE ID (BID)

- Bridge ID (BID) jedinstveno identifikuje svaki bridge/switch.
- BID se koristi za određivanje referetne tačke (centar mreže) ili root bridge.

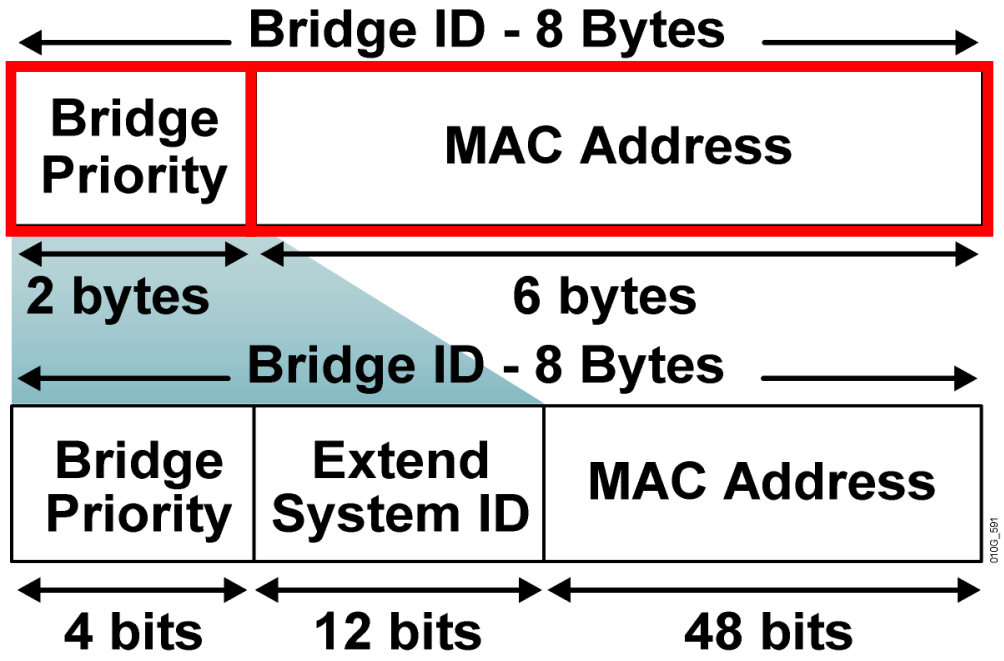
Bridge ID bez Extended System ID



Bridge ID sa Extended System ID



BRIDGE ID (BID)



- Sastoji se iz dve komponente:
  - **2-byte Bridge Priority**: Cisco switch default na 32,768 ili 0x8000.
    - Obično se iskazuje u **decimalnom formatu**
  - **6-byte MAC adresa**
    - Obično se iskazuje u **heksaadecimalnom formatu**.

ODREĐIVANJA BID-A NA SVIČU

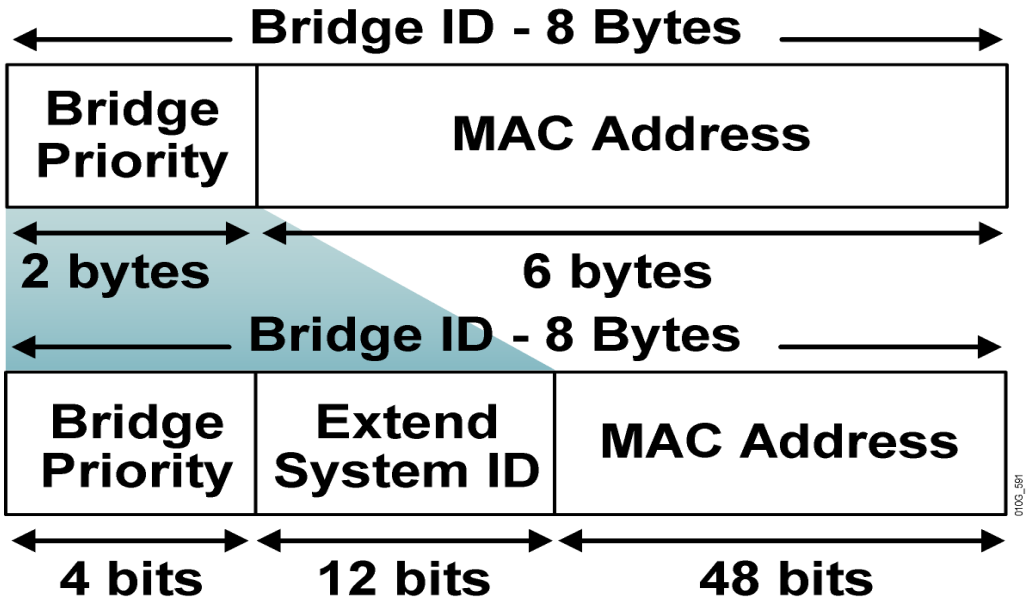
```
Core# show spanning-tree
VLAN0001
  Spanning tree enabled protocol ieee
  Root ID     Priority    32769
              Address     0001.964E.7EBB
              Cost        4
              Port        25(GigabitEthernet0/1)
              Hello Time  2 sec  Max Age 20 sec  Forward Delay 15 sec

  Bridge ID   Priority    32769  (priority 32768 sys-id-ext 1)
              Address     0001.C945.A573
              Hello Time  2 sec  Max Age 20 sec  Forward Delay 15 sec
              Aging Time  20
```

ODREĐIVANJE PRIORITY POLJA NA SVIČU

```
Access1#show spanning-tree
VLAN0001
  Spanning tree enabled protocol ieee
  Root ID     Priority    32769
              Address     0001.964E.7EBB
              Cost        19
              Port        5(FastEthernet0/5)
              Hello Time  2 sec  Max Age 20 sec  Forward Delay 15 sec
  Bridge ID   Priority    32769  (priority 32768 sys-id-ext 1)
              Address     0003.E461.46EC
              Hello Time  2 sec  Max Age 20 sec  Forward Delay 15 sec
              Aging Time  20


VLAN0010
  Spanning tree enabled protocol ieee
  Root ID     Priority    32778
              Address     0001.964E.7EBB
              Cost        19
              Port        5(FastEthernet0/5)
              Hello Time  2 sec  Max Age 20 sec  Forward Delay 15 sec
  Bridge ID   Priority    32778  (priority 32768 sys-id-ext 10)
              Address     0003.E461.46EC
              Hello Time  2 sec  Max Age 20 sec  Forward Delay 15 sec
```

Priority = Priority *(Default 32,768)* **+ VLAN**

ULOGA BRIDGE ID (BID)



- Koristi se za izbor root bridge
- Svič koji ima najmanji Bridge ID je root.
- Ukoliko svi svičevi imaju isti prioritet, bridge sa najmanjom MAC adresom je root bridge. (Problem)

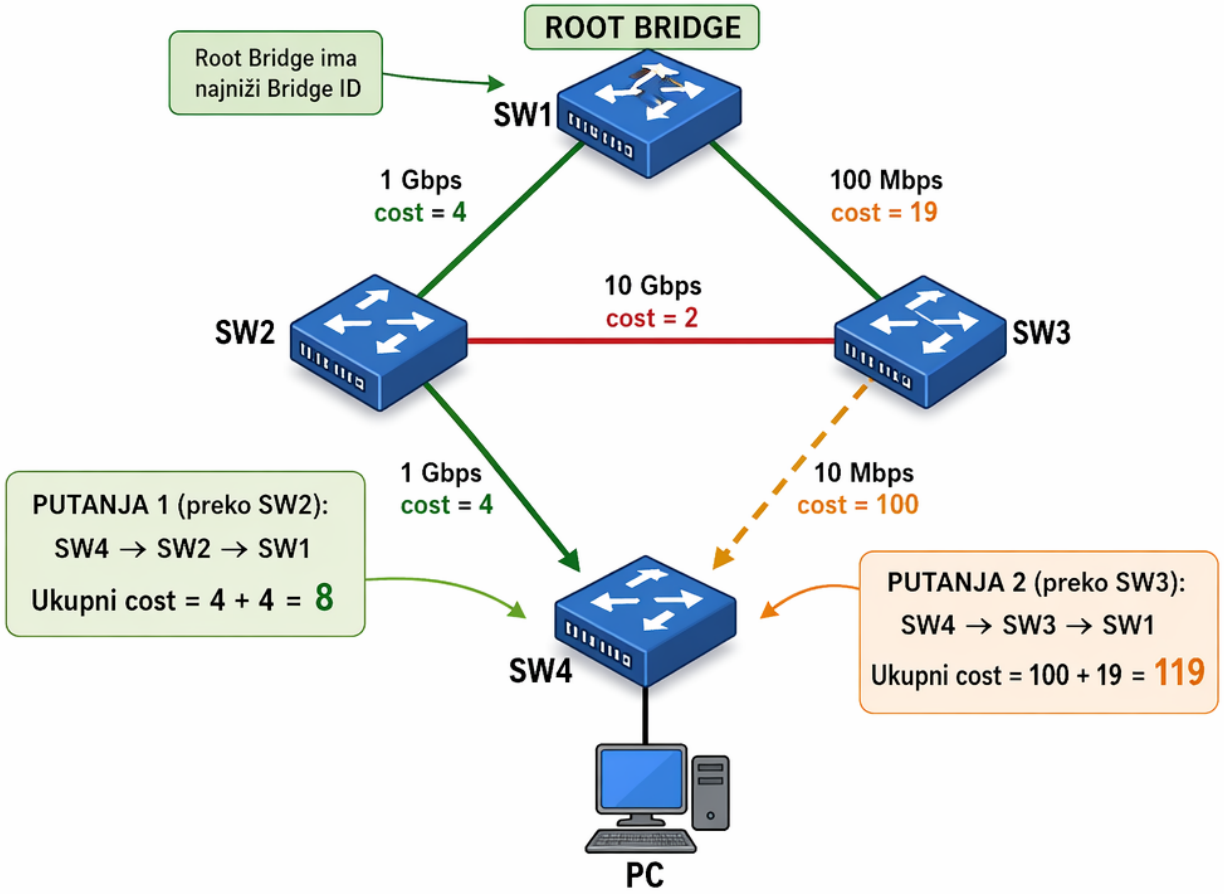
PATH COST

Link Speed	Cost (Revised IEEE Spec)	Cost (Previous IEEE Spec)
10 Gbps	2	1
1 Gbps	4	1
100 Mbps	19	10
10 Mbps	100	100

- Svičevi koriste koncept cene (**cost)** da procene koliko su blizu ili daleko od drugih svičeva
- Koristi se prilikom kreiranja loop-free topologije.
- Originalni, 802.1D standard definiše cost kao **10^9/bandwidth**.
  - Cost za 10 Mbps link je 100
  - Cost za 100 Mbps link je 10
  - Cost za 1 Gbps link je 1

PATH COST – KONKRETAN PRIMER

STP bira putanju sa NAJMANJIM ukupnim cost-om do root bridge-a (manji cost = bolji link)



Link Speed	Cost (Revised IEEE Spec)	Cost (Previous IEEE Spec)
10 Gbps	2	1
1 Gbps	4	1
100 Mbps	19	10
10 Mbps	100	100

Formula (802.1D):
cost = 10^9 / bandwidth (bps)

- Veća brzina = manji cost = bolji put
- STP sabira cost-ove duž putanje

KAKO STP KORISTI COST?

1. *Svaki switch računa sve putanje do root bridge-a*
2. *Sabira cost svakog linka na putanji*
3. *Bira putanju sa NAJMANJIM ukupnim cost-om*
4. *Port na toj putanji postaje* ROOT PORT

STP će izabrati PUTANJU 1 (preko SW2) jer ima MANJI ukupni cost (8 < 119)
Port na SW4 ka SW2 postaje ROOT PORT

STP ne bira putanju sa najmanjim brojem hop-ova, već sa najmanjim ukupnim cost-om.

STP LOOP FREE TOPOLOGIJA U PET KORAKA

- Prilikom kreiranja loop-free topologije, STP koristi uvek istih pet koraka:

Korak 1 - Najmanji BID

Korak 2 - Najmanja cena putanje do Root Bridge

Korak 3 - Najmanji BID pošiljaoca

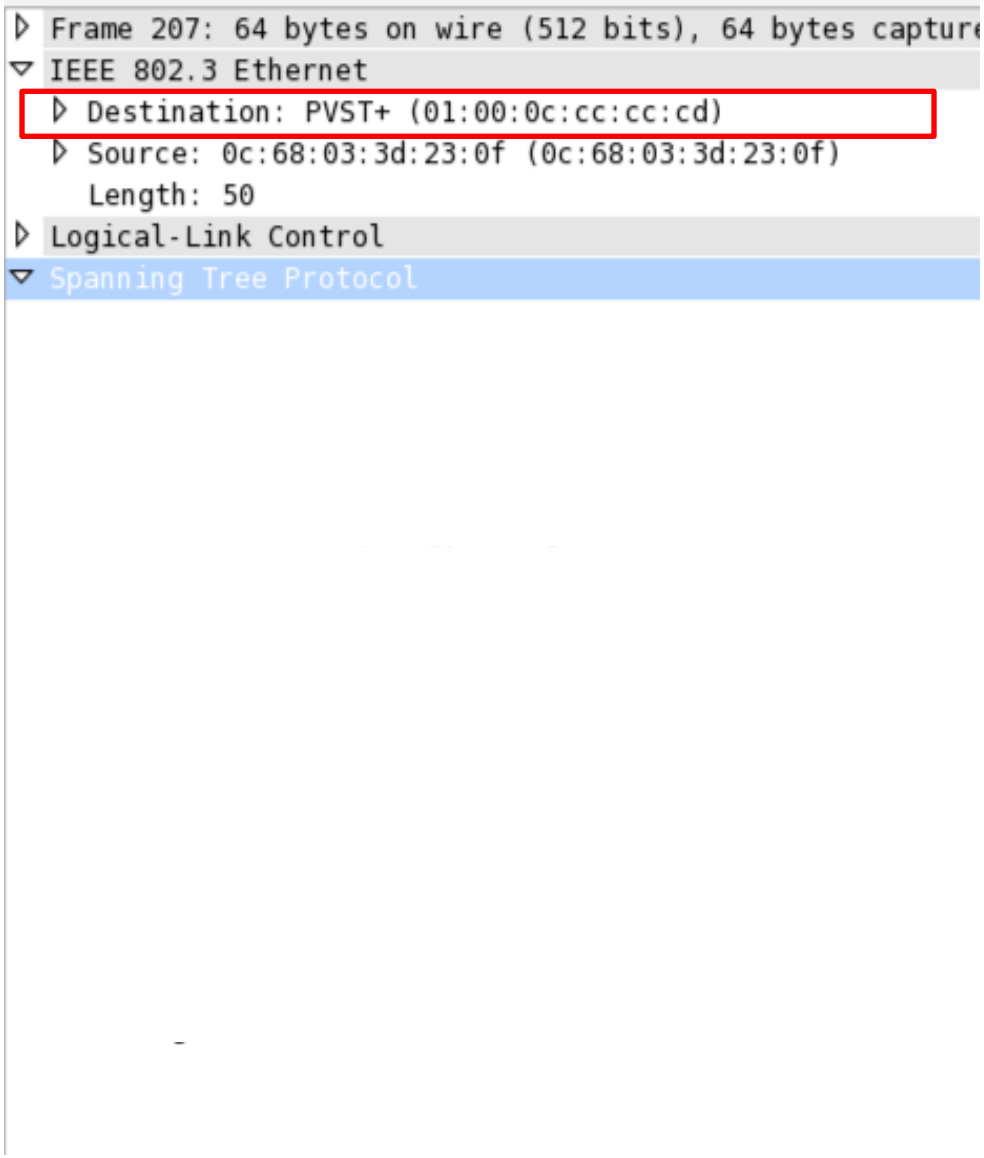
Korak 4 – Najmanji port priority

Korak 5 - Najmanji Port ID

- Svičevi koriste Configuration BPDU poruke prilikom kreiranja loop-free topologije.

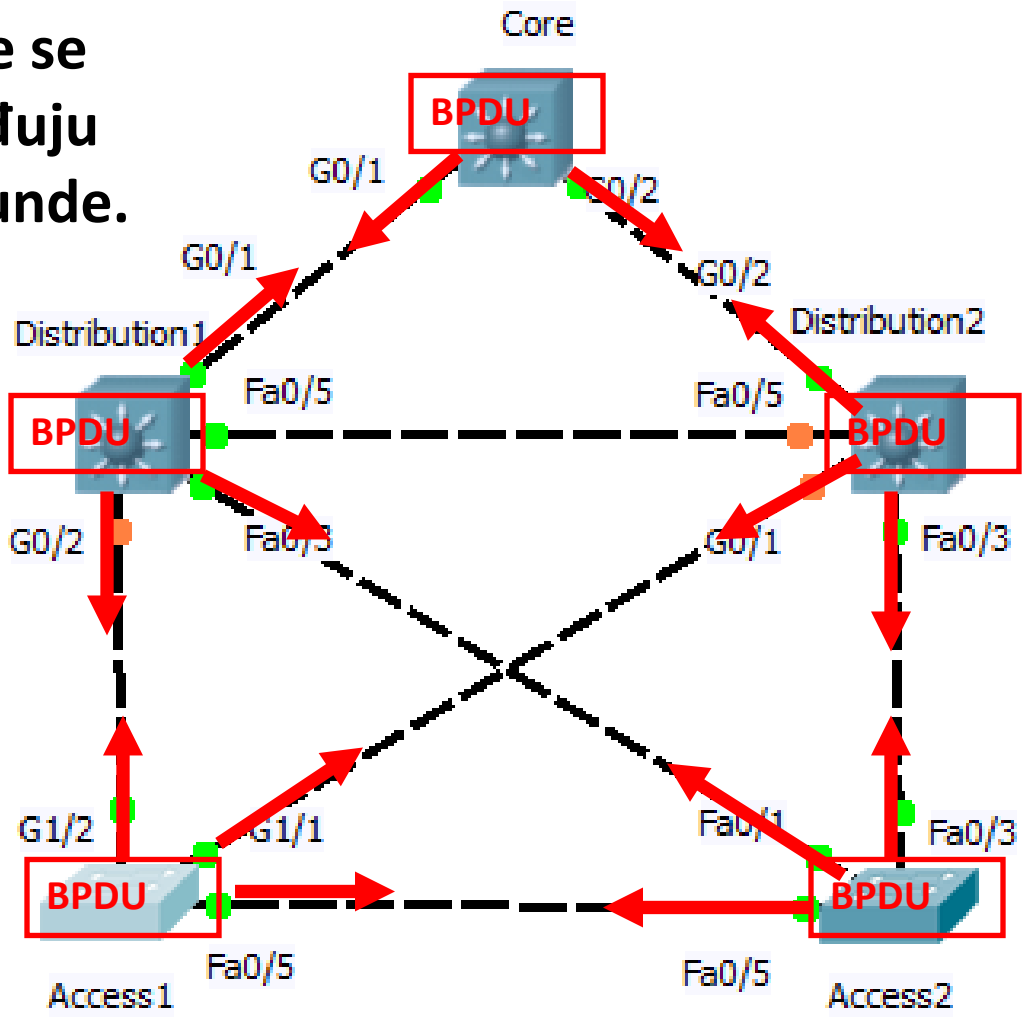
BRIDGE PROTOCOL DATA UNIT

Bytes	Field

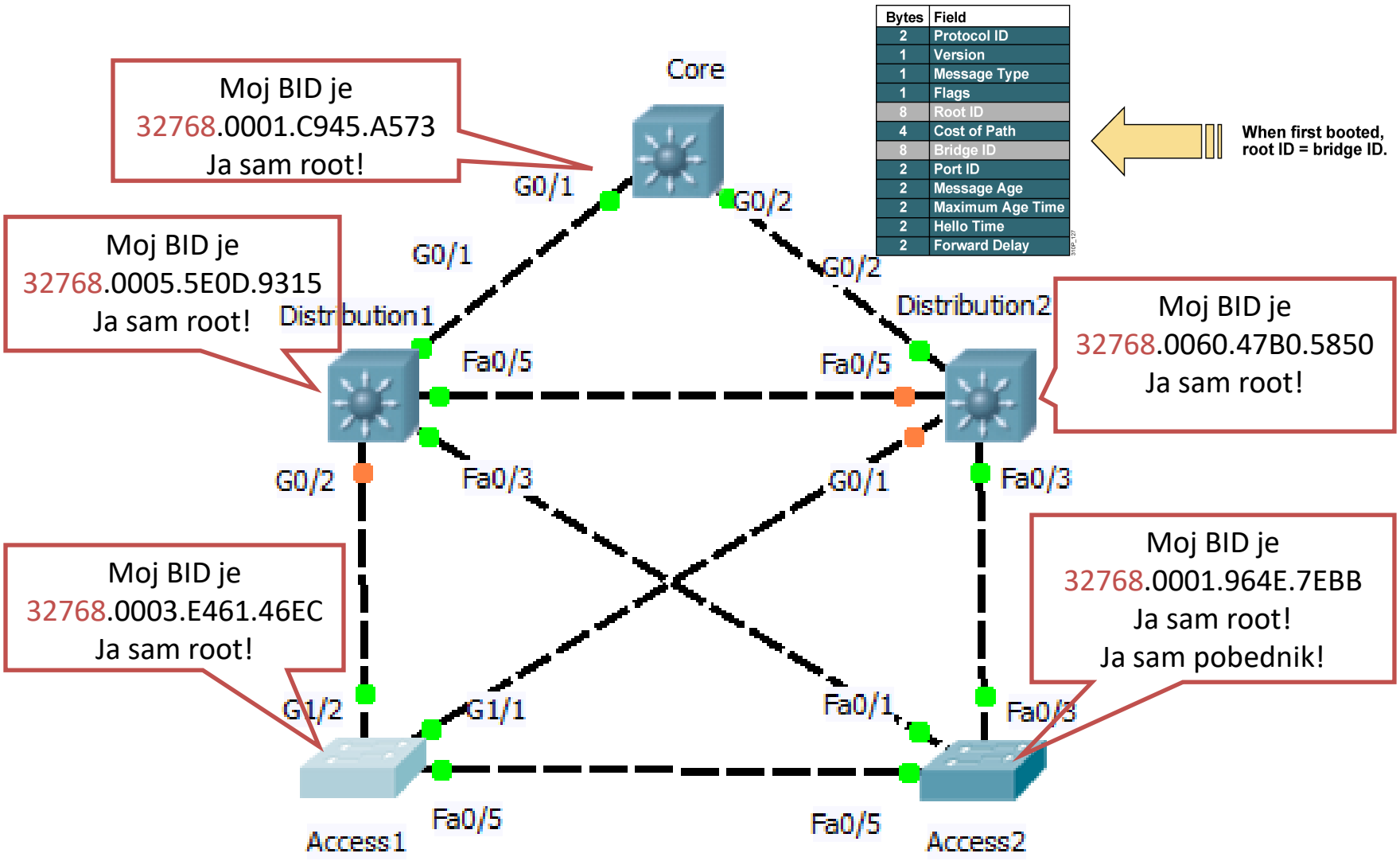


BPDU

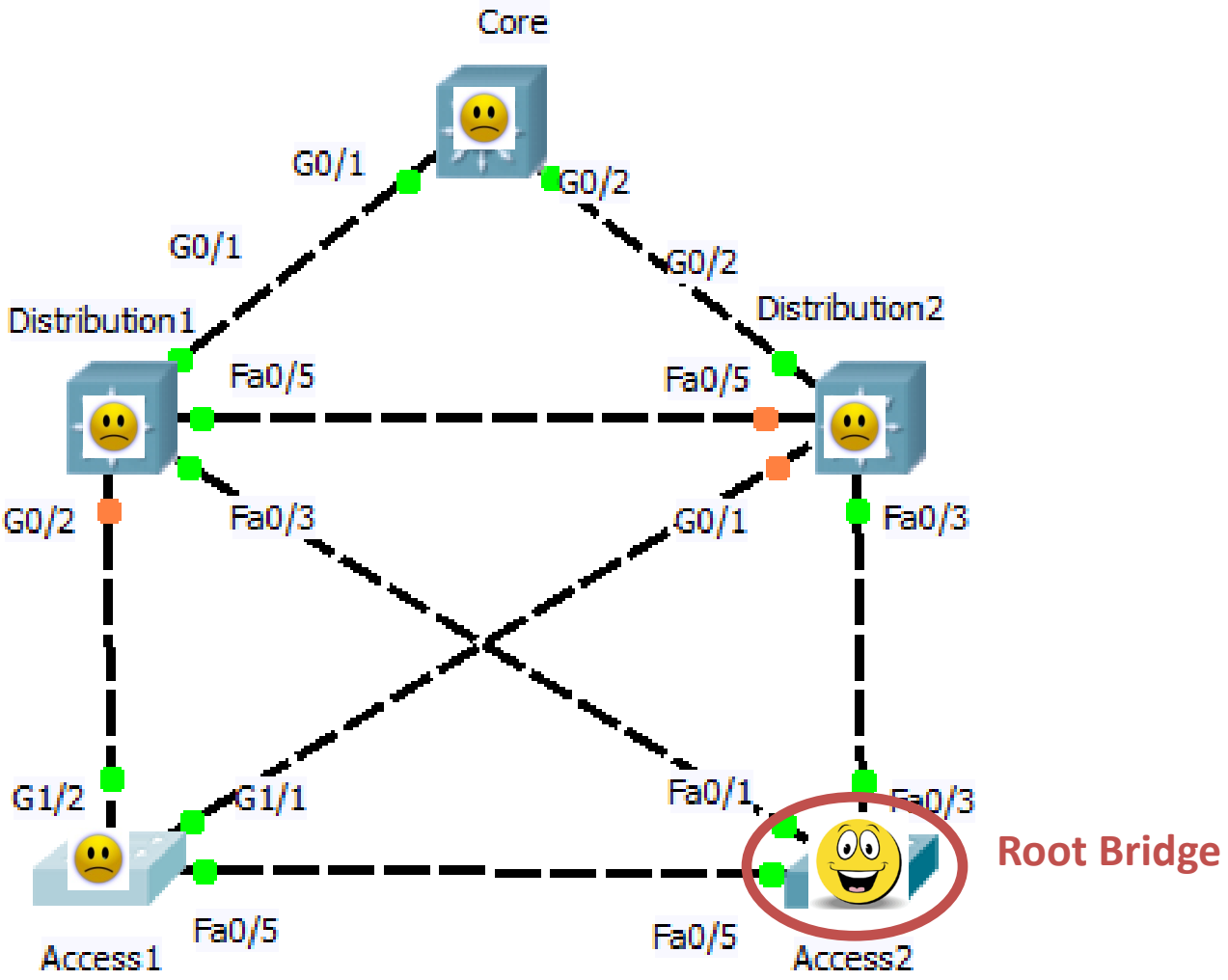
BPDU poruke se šalju/prosleđuju svakih 2 sekunde.



UTVRĐIVANJE ROOT BRIDGE



ROOT BRIGDE IZABRAN BEZ UTICAJA ADMINA



FORMAT BPDU PORUKE

Bytes	Field
2	Protocol ID
1	Version
1	Message type
1	Flags
8	Root ID
4	Cost of path
8	Bridge ID
2	Port ID
2	Message age
2	Max age
2	Hello time
2	Forward delay

310P_126

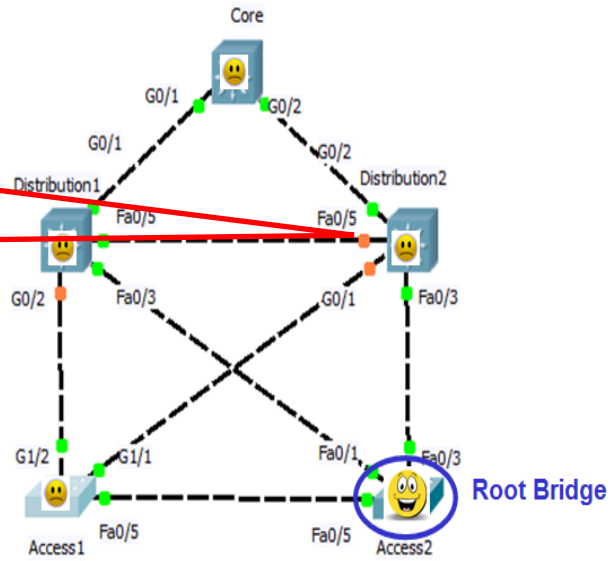
IZBOR ROOT PORT-A

STP Convergence

Step 1 Selekcija Root Bridge
Step 2 Selekcija Root Port-ova
Step 3 Selekcija Designated Port-ova

- Nakon izbora Root Bridge, svičevi biraju **Root Port-ove**.
- **Root Port** je port na Non-Root Bridge koji je najbliži Root-u.
- Svičevi koriste cenu(**cost)** da odrede rastojanje.
- **Svaki non-Root Bridge izabraće jedan Root Port!**

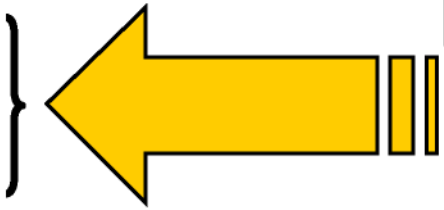
Ja ću izabrati jedan Root Port koji je najbliži root bridge.



Link Speed	Cost (Revised IEEE Spec)
10 Gbps	2
1 Gbps	4
100 Mbps	19
10 Mbps	100

ODREĐIVANJE ROOT PORT-A

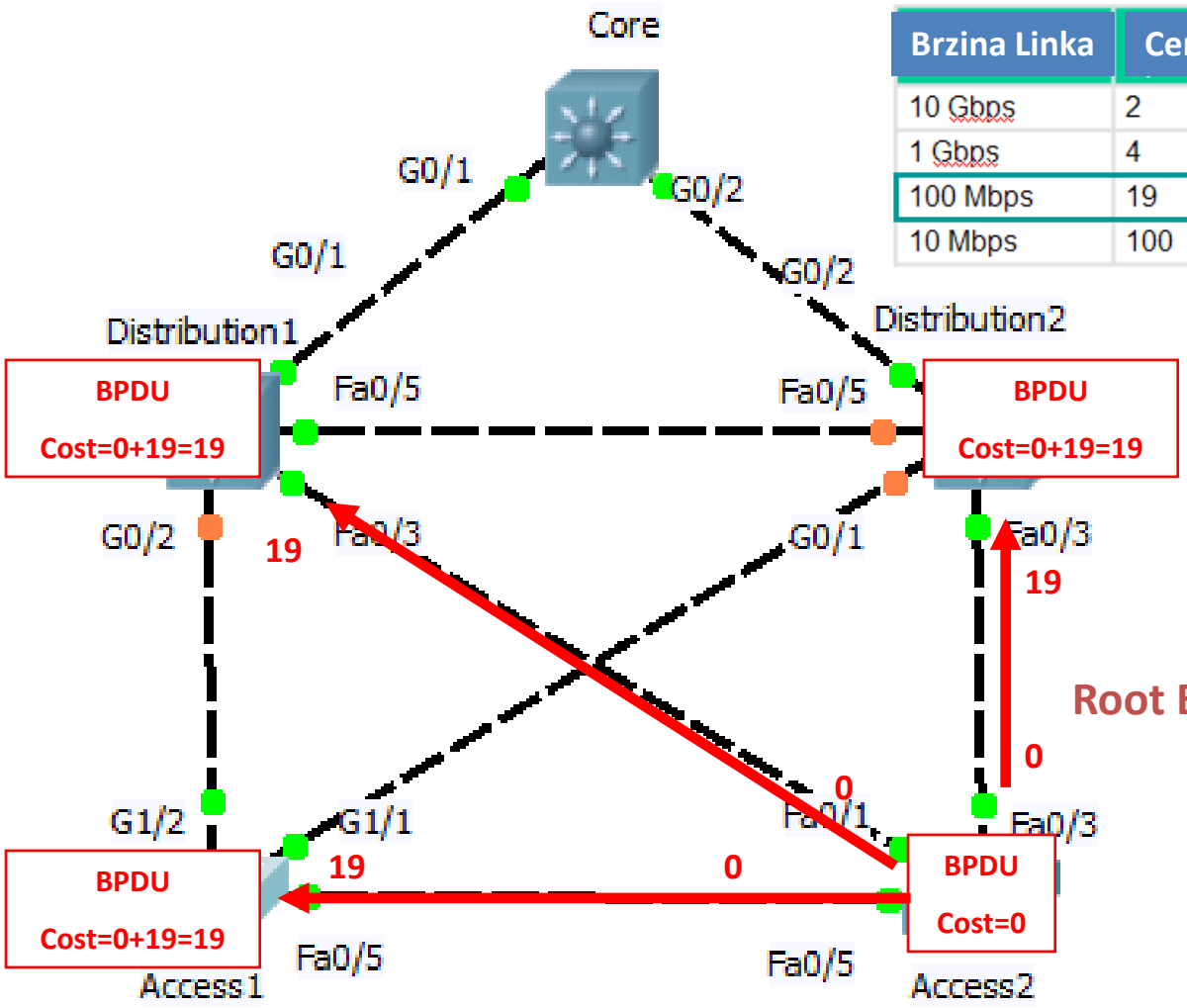
Bytes	Field
2	Protocol ID
1	Version
1	Message Type
1	Flags
8	Root ID
4	Cost of Path
8	Bridge ID
2	Port ID
2	Message Age
2	Maximum Age Time
2	Hello Time
2	Forward Delay



Najmanja
- Cena do root-a
- BID pošiljaoca
- Port ID pošiljaoca

Koja je najkraća putanja do root-a?

IZRAČUNAVANJE CENE PUTANJE



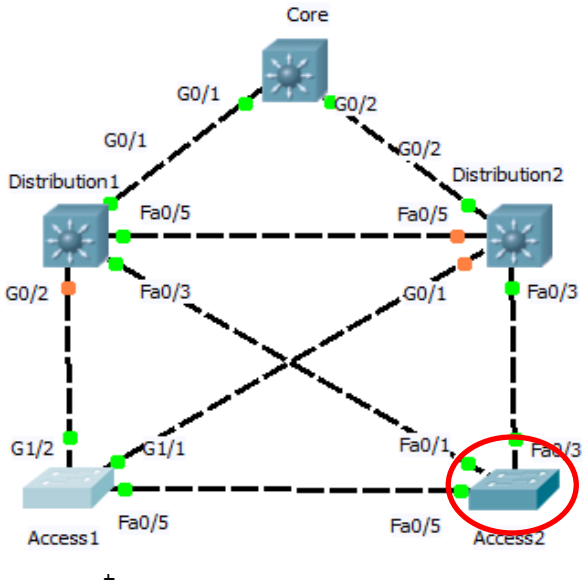
Brzina Linka	Cena Linka
10 Gbps	2
1 Gbps	4
100 Mbps	19
10 Mbps	100

Bytes	Field
2	Protocol ID
1	Version
1	Message type
1	Flags
8	Root ID
4	Cost of path
8	Bridge ID
2	Port ID
2	Message age
2	Max age
2	Hello time
2	Forward delay

PATH COSTS ZA ROOT BRIDGE (ACCESS2)

```
Access2# show spanning-tree
VLAN0001
  Spanning tree enabled protocol ieee
  Root ID     Priority    32769
              Address     0001.964E.7EBB
              This bridge is the root
              Hello Time  2 sec  Max Age 20 sec  Forward Delay 15
   sec

  Bridge ID   Priority    32769  (priority
              Address     0001.964E.7EBB
              Hello Time  2 sec  Max Age 20
   sec
              Aging Time  20

Interface        Role Sts Cost      Prio.N
---------------- ---- --- --------- ------
   --
Fa0/1            Desg FWD 19        128.1
Fa0/3            Desg FWD 19        128.3
Fa0/5            Desg FWD 19        128.5
```

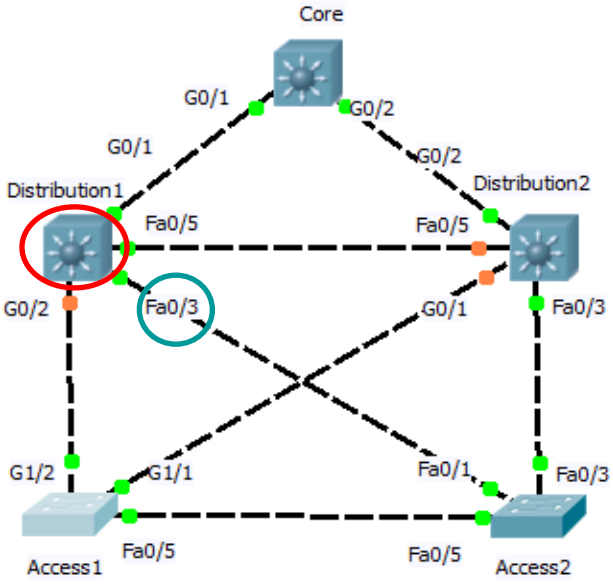
Brzina Linka	Cena Linka
10 Gbps	2
1 Gbps	4
100 Mbps	19
10 Mbps	100



PATH COST ZA DISTRIBUTION1

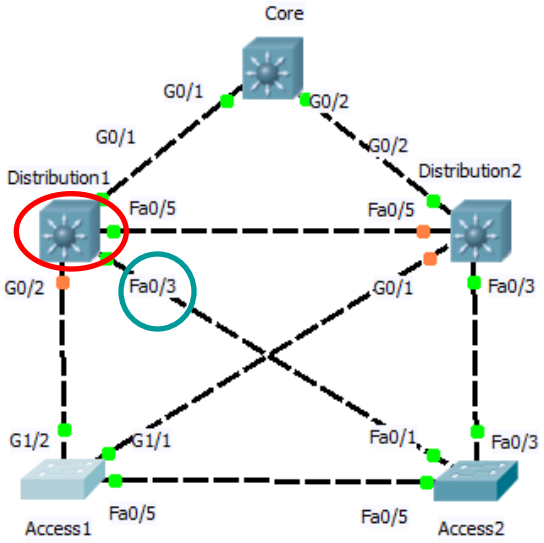
```
Distribution1# show spanning-tree
VLAN0001
  Spanning tree enabled protocol ieee
  Root ID     Priority    32769
              Address     0001.964E.7EBB
              Cost        19
              Port        3(FastEthernet0/3)
              Hello Time  2 sec  Max Age 20 sec  Forward Delay 15 sec

  Bridge ID   Priority    32769  (priority 327
              Address     0005.5E0D.9315
              Hello Time  2 sec  Max Age 20 se
              Aging Time  20

Interface        Role Sts Cost      Prio.Nbr
---------------- ---- --- --------- --------
Gi0/1            Desg FWD 4         128.25
Gi0/2            Altn BLK 4         128.26
Fa0/3            Root FWD 19        128.3
Fa0/5            Desg FWD 19        128.5
```

Brzina Linka	Cena Linka
10 Gbps	2
1 Gbps	4
100 Mbps	19
10 Mbps	100



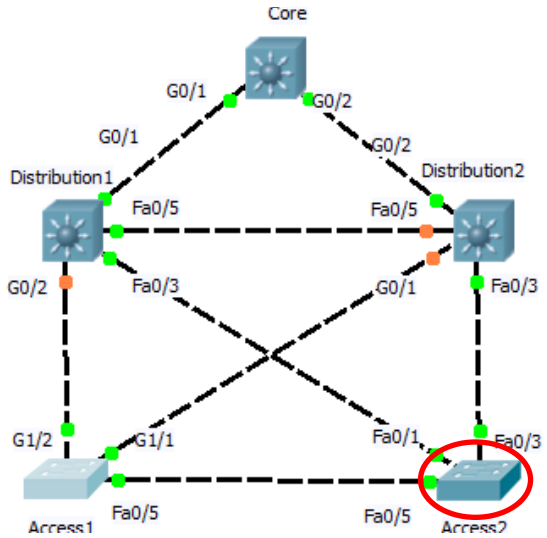
SHOW SPANNING-TREE DETAIL

Brzina Linka	Cena Linka
10 Gbps	2
1 Gbps	4
100 Mbps	19
10 Mbps	100




```
Distribution1# show spanning-tree detail

VLAN0001 is executing the ieee compatible Spanning Tree Protocol
  Bridge Identifier has priority of 32768, sysid 1, 0005.5E0D.9315
  Configured hello time 2, max age 20, forward delay 15
  Current root has priority 32769
  Root port is 3 (FastEthernet0/3), cost of root path is 19
  Topology change flag not set, detected flag not set
  Number of topology changes 0 last change occurred 00:00:00 ago
            from FastEthernet0/1
  Times:  hold 1, topology change 35, notification 2
          hello 2, max age 20, forward delay 15
  Timers: hello 0, topology change 0, notification 0, aging 300
```

SHOW SPANNING-TREE DETAIL

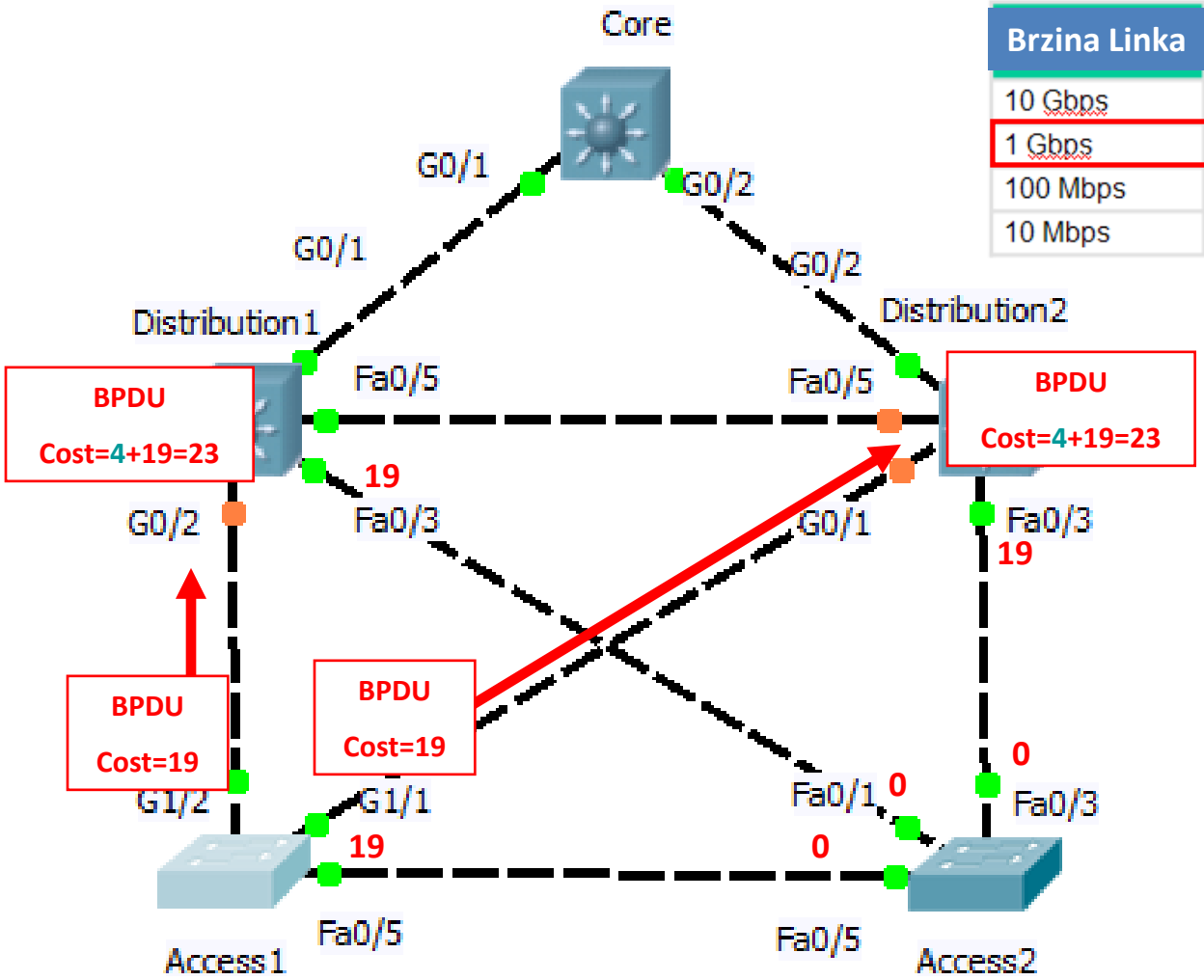



```
Access2# show spanning-tree detail

VLAN0001 is executing the ieee compatible Spanning
  Bridge Identifier has priority of 32768, sysid 1,
  Configured hello time 2, max age 20, forward delay 15
  Current root has priority 32769
  Topology change flag not set, detected flag not set
  Number of topology changes 0 last change occurred 00:00:00 ago
           from FastEthernet0/1
  Times:  hold 1, topology change 35, notification 2
         hello 2, max age 20, forward delay 15
  Timers: hello 0, topology change 0, notification 0, aging 300
```

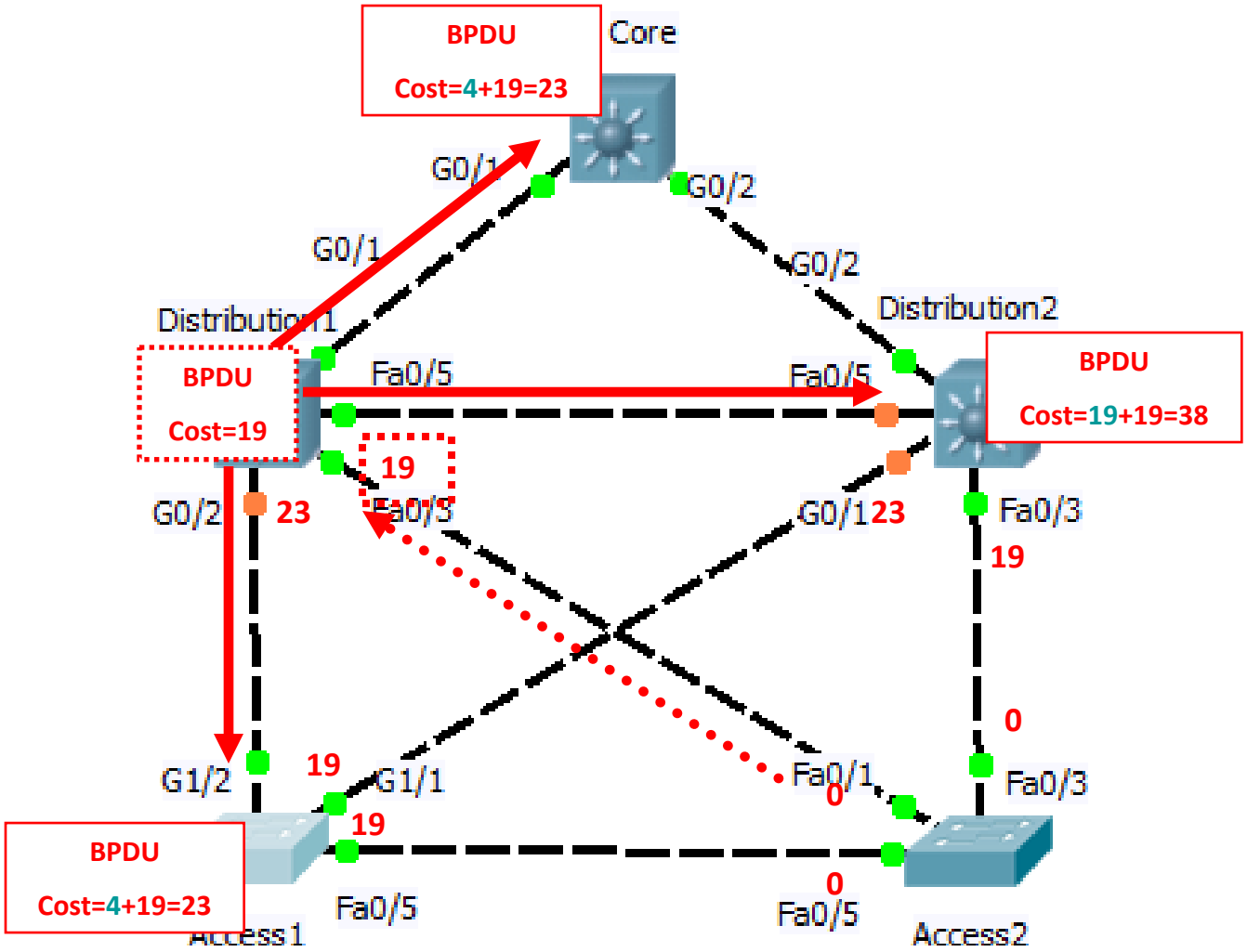
Nema Root porta – Ovaj svič je Root Bridge!

ACCESS1 PROSLEĐIVANJE BPDU-A

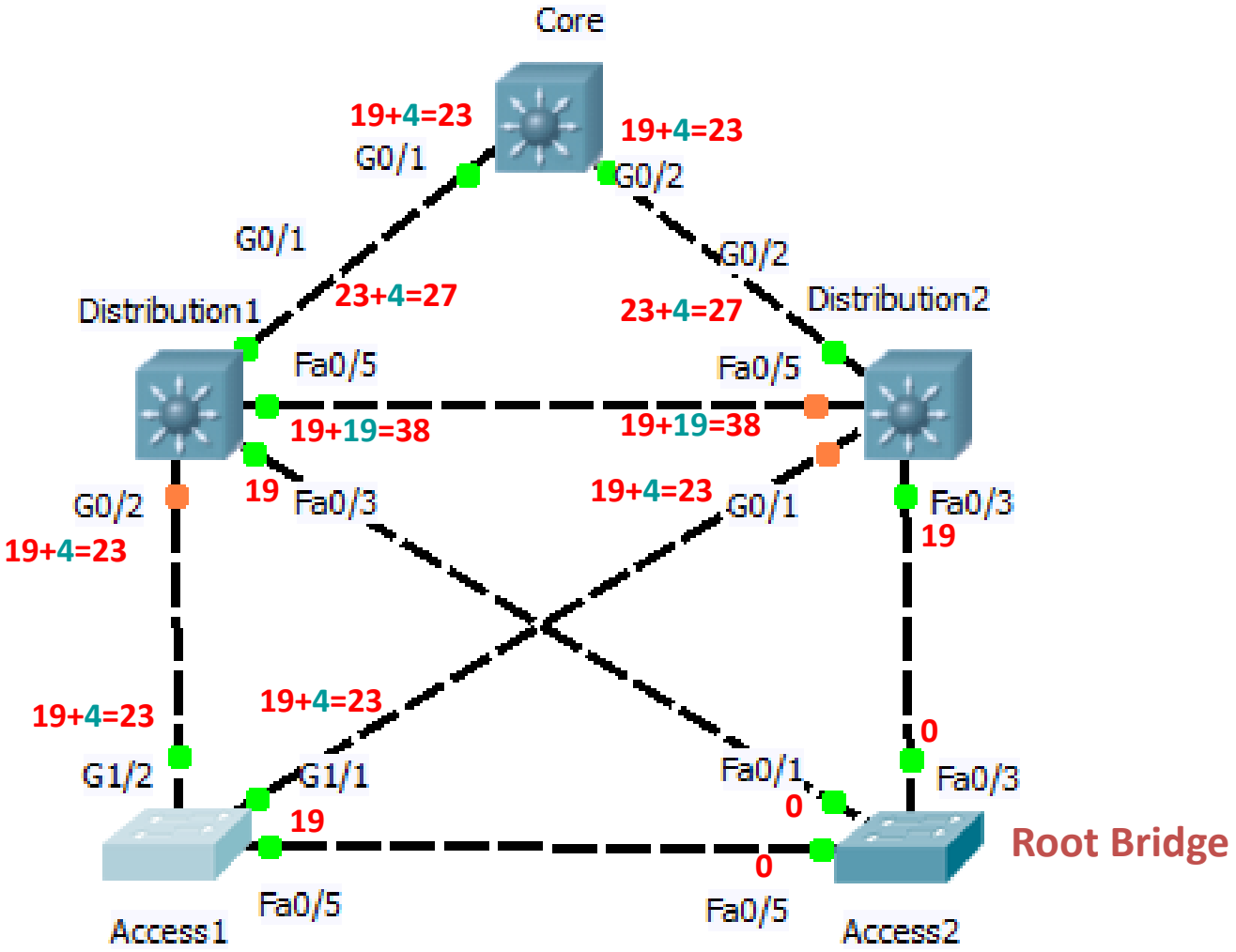
Brzina Linka	Cena Linka
10 Gbps	2
1 Gbps	4
100 Mbps	19
10 Mbps	100



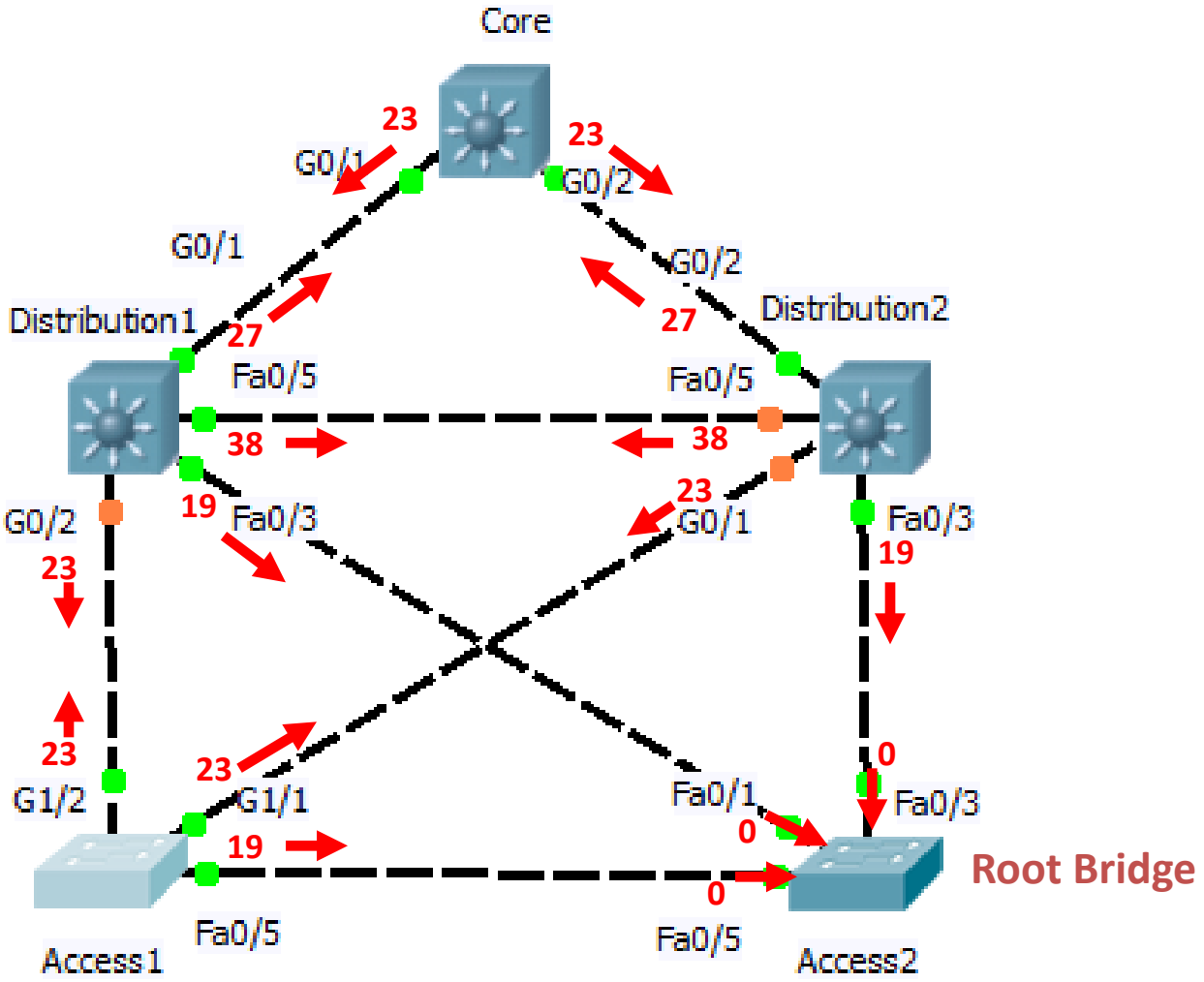
DISTRIBUTION1 SLANJE BPDU-A



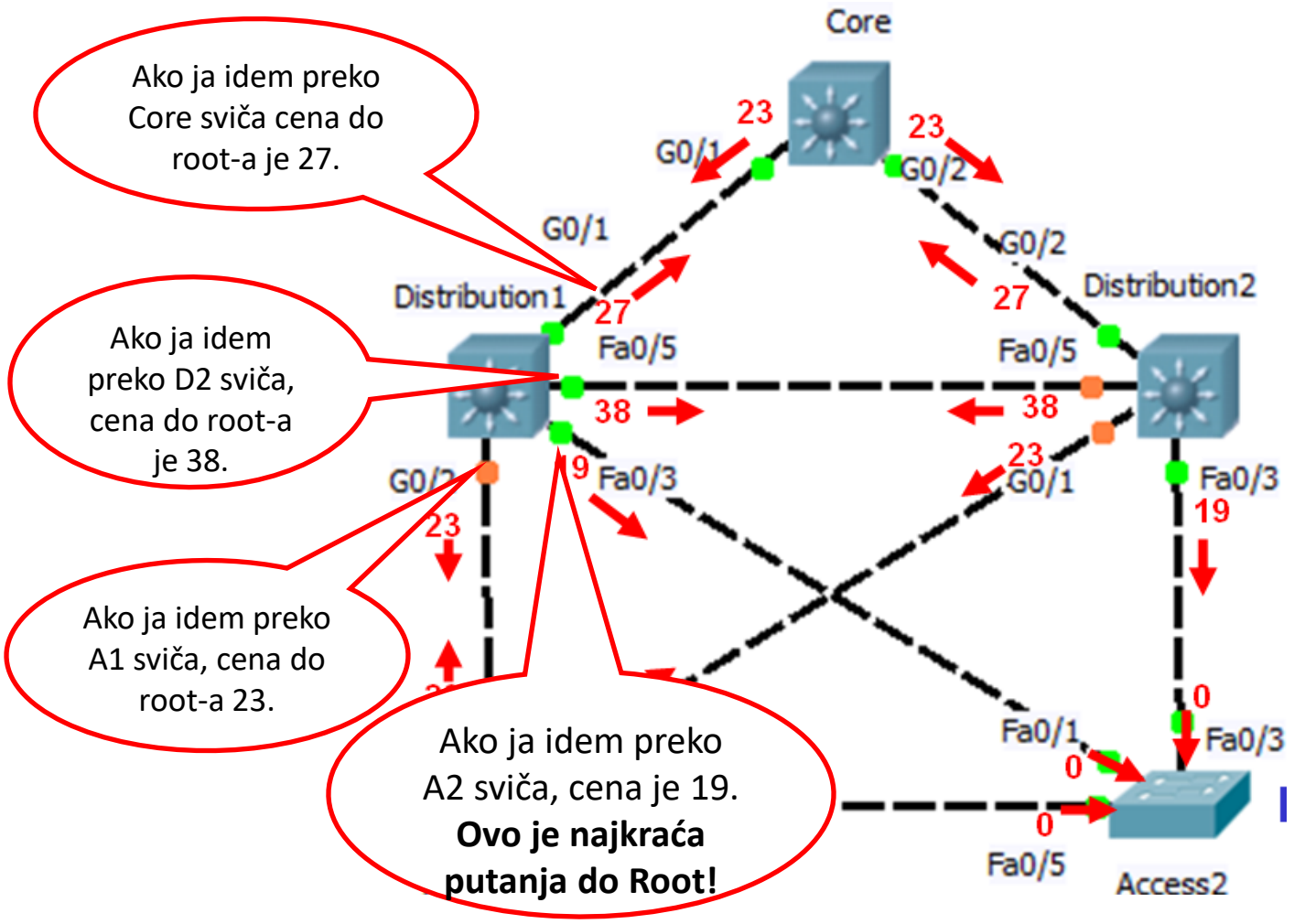
CENE DO ROOT BRIDGE



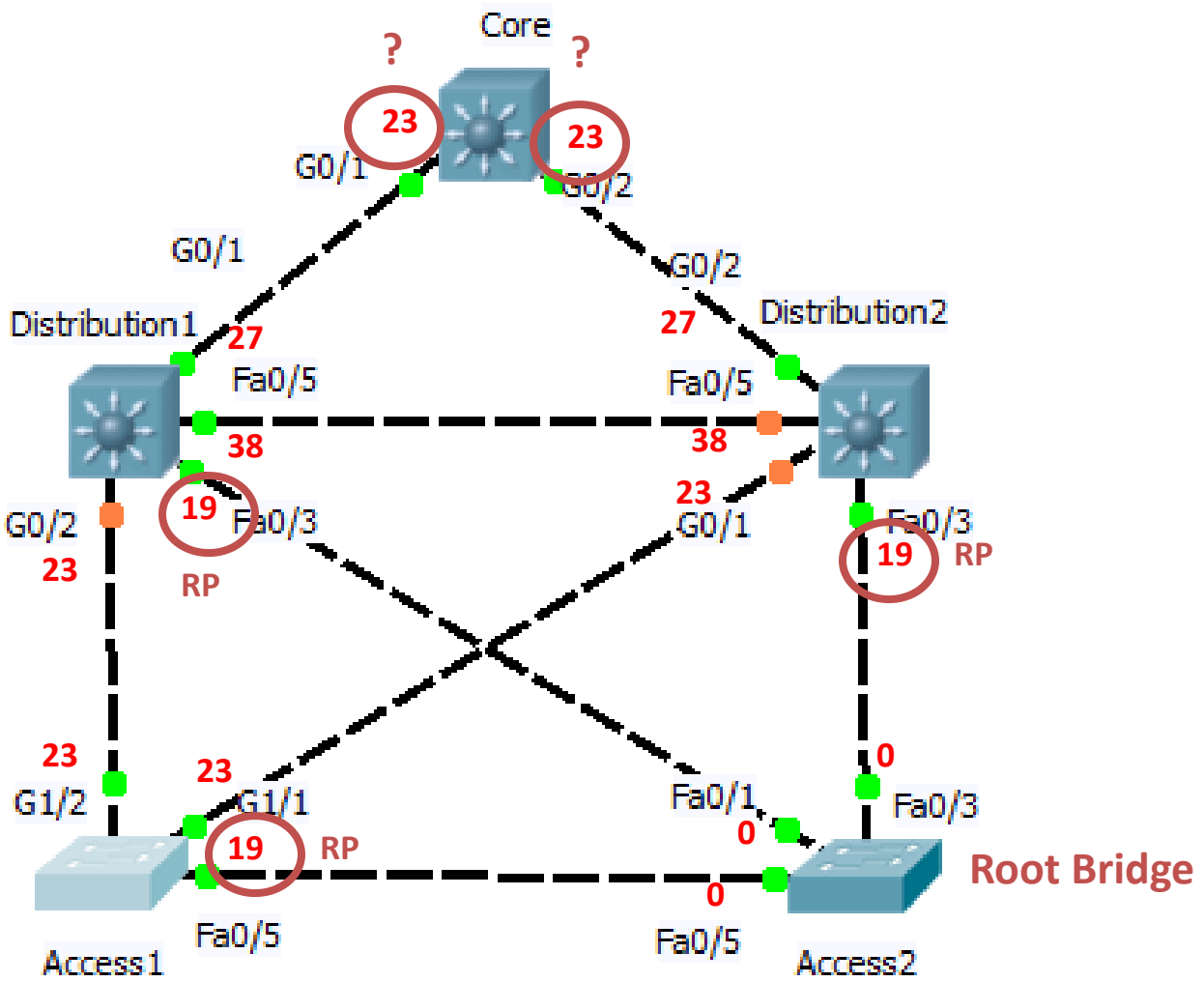
CENE DO ROOT BRIDGE NA SVIM SVIČEVIMA



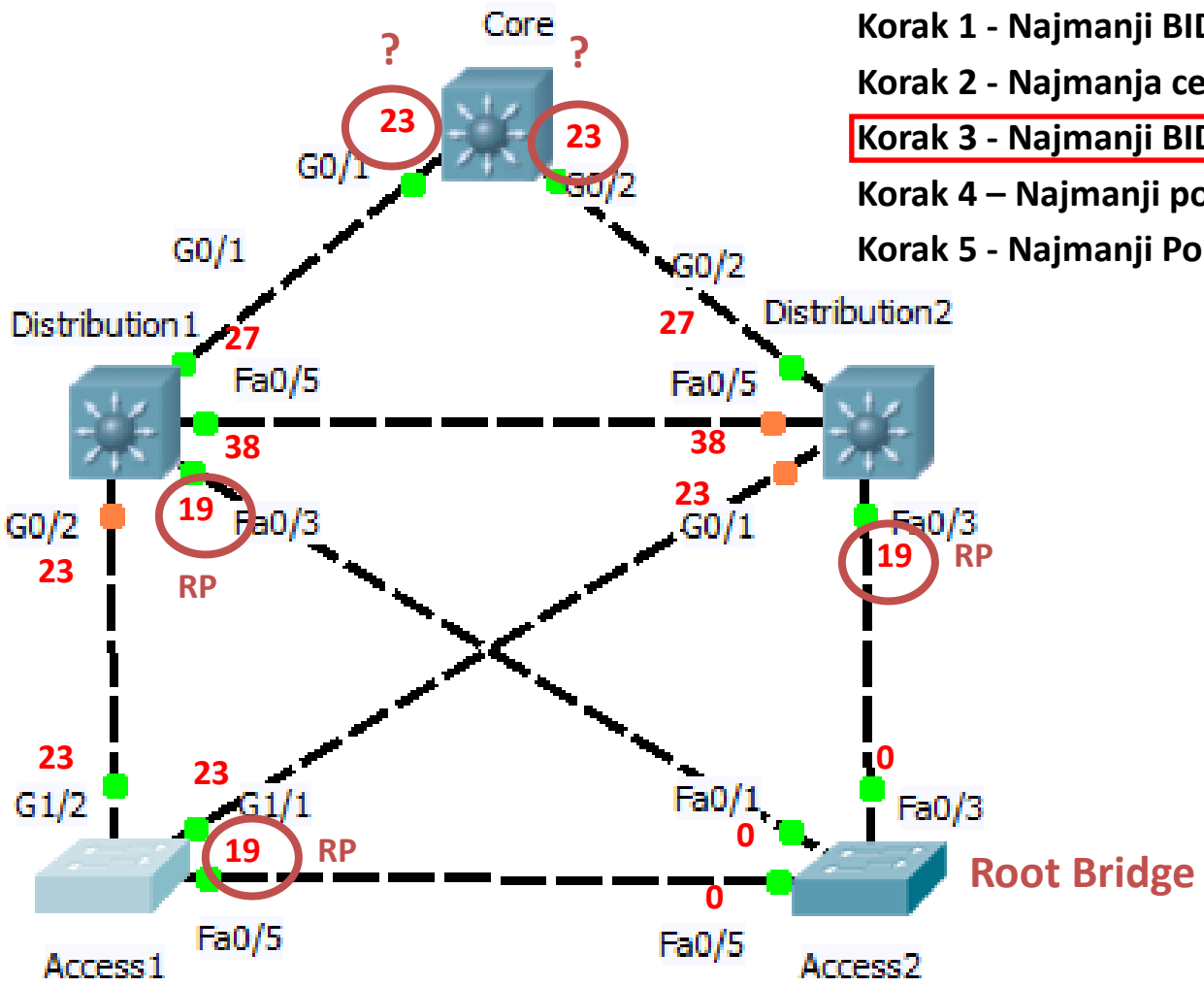
CENE NA PORTOVIMA DO RB NA DS1



IZBOR RP NA SVIM SVIČEVIMA



IZBOR RP NA CORE SVIČU



Korak 1 - Najmanji BID

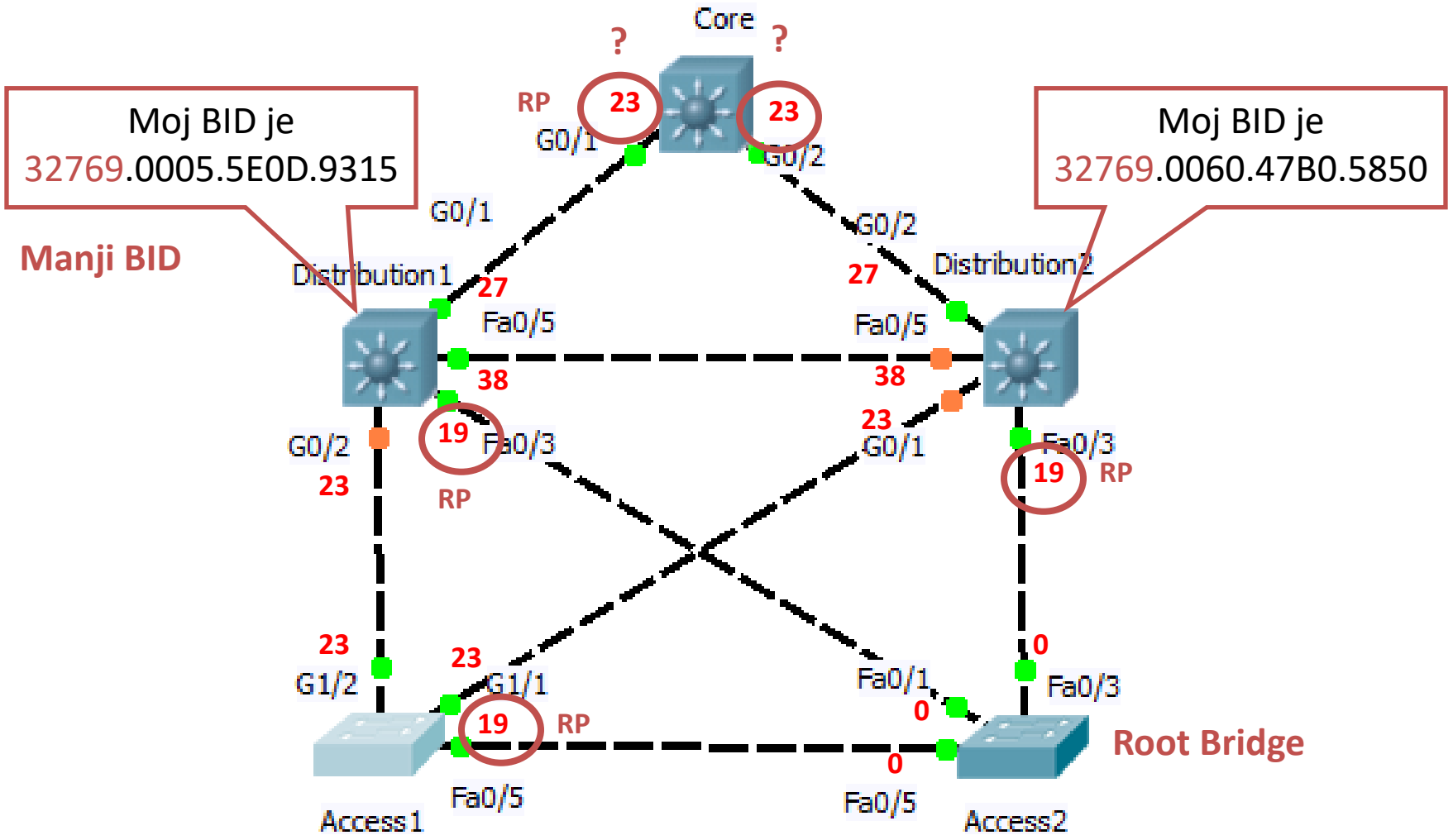
Korak 2 - Najmanja cena putanje do Root Bridge

Korak 3 - Najmanji BID pošiljaoca

Korak 4 – Najmanji port priority

Korak 5 - Najmanji Port ID

IZBOR RP NA CORE SVIČU



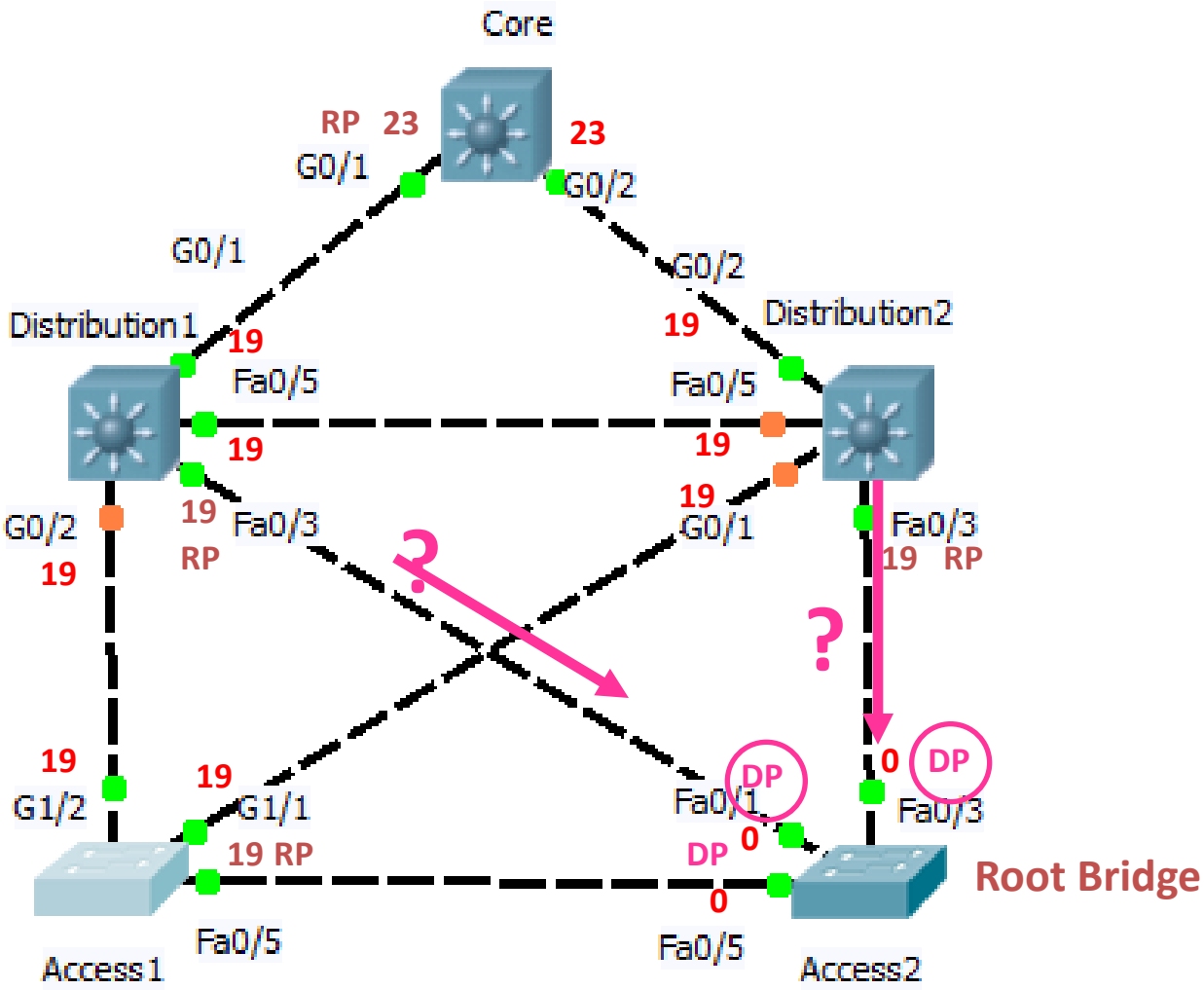
IZBOR DESIGNATED PORTA

STP Konvergencija

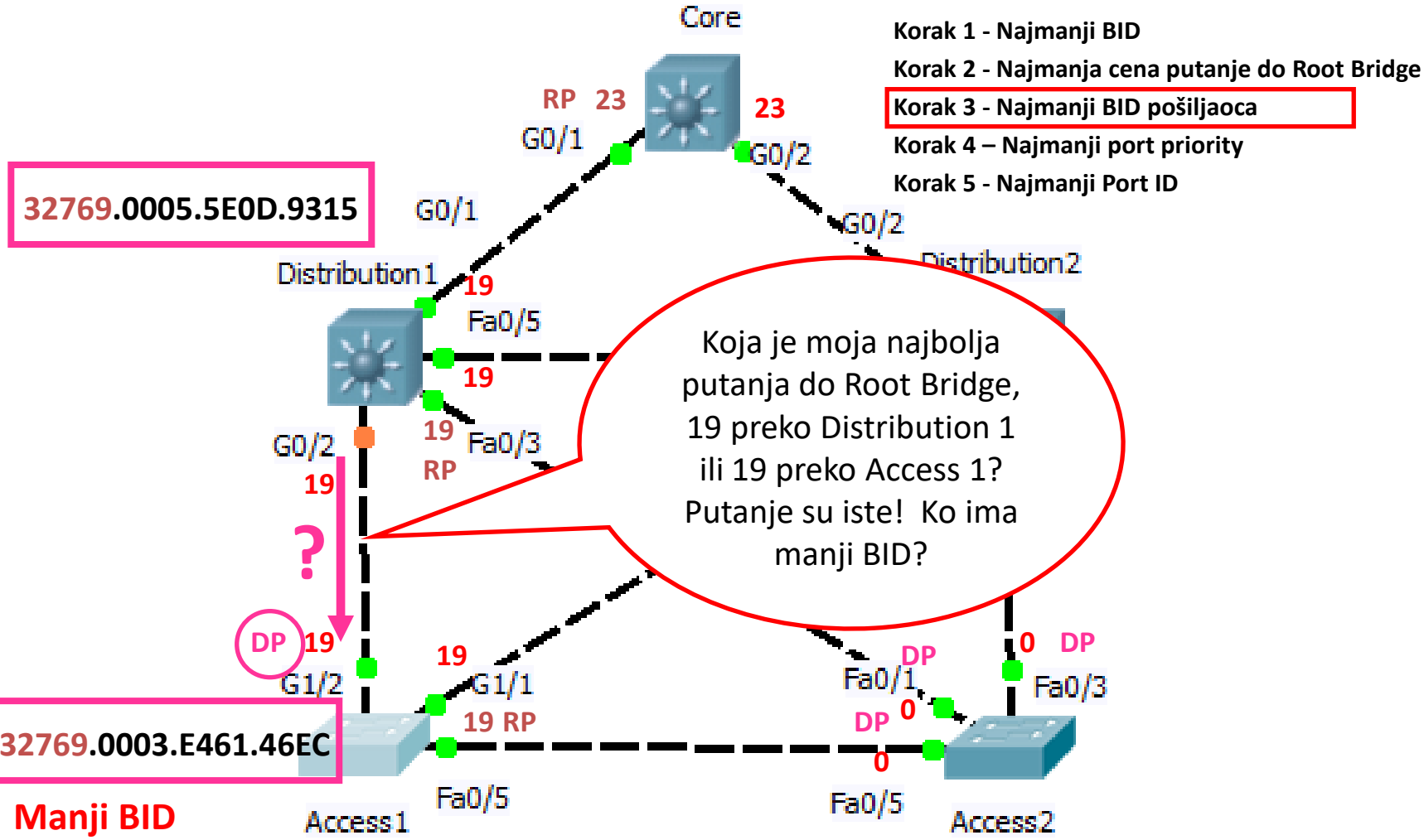
Korak 1 Izbor Root Bridge
Korak 2 Izbor Root Port-ova
Korak 3 Izbor Designated Port-ova

- Designated Port je port koji postoji na svakom segmentu (link koji povezuje dva sviča) koji prima i šalje saobraćaj i BPDU.
- **Odluka na segmentu o tome koji port će biti DP zavisi od Root Path Cost do Root Bridge.**
- DP na segmentu definiše koji svič je bliži Root Bridge.
  - **Root Path Cost** je kumulativna cena svih linkova do Root Bridge.

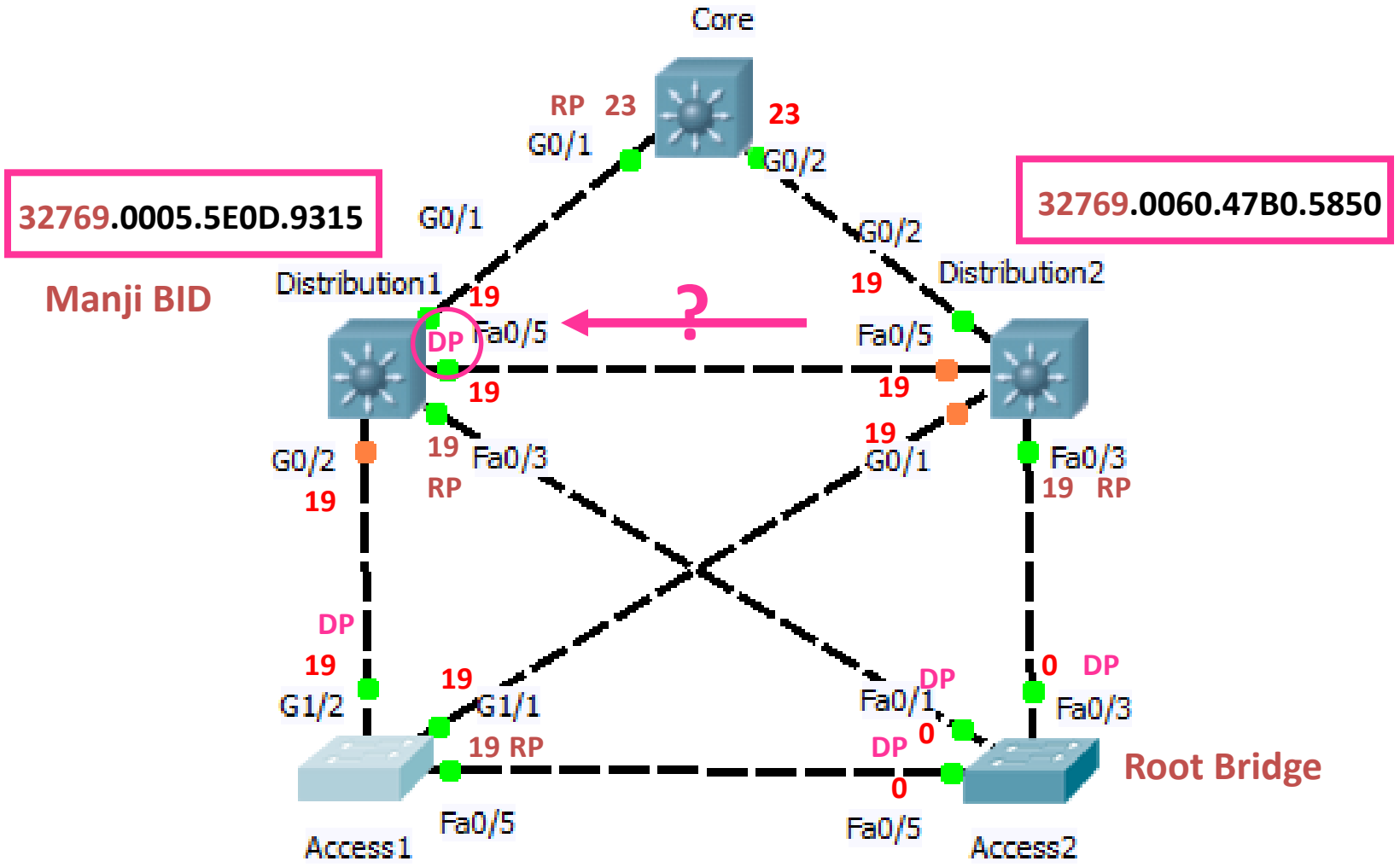
IZBOR DESIGNATED PORTA NA ROOT BRIDGE



IZBOR DP PORTOVA NA OSTALIM SVIČEVIMA



IZBOR DP PORTOVA NA OSTALIM SVIČEVIMA

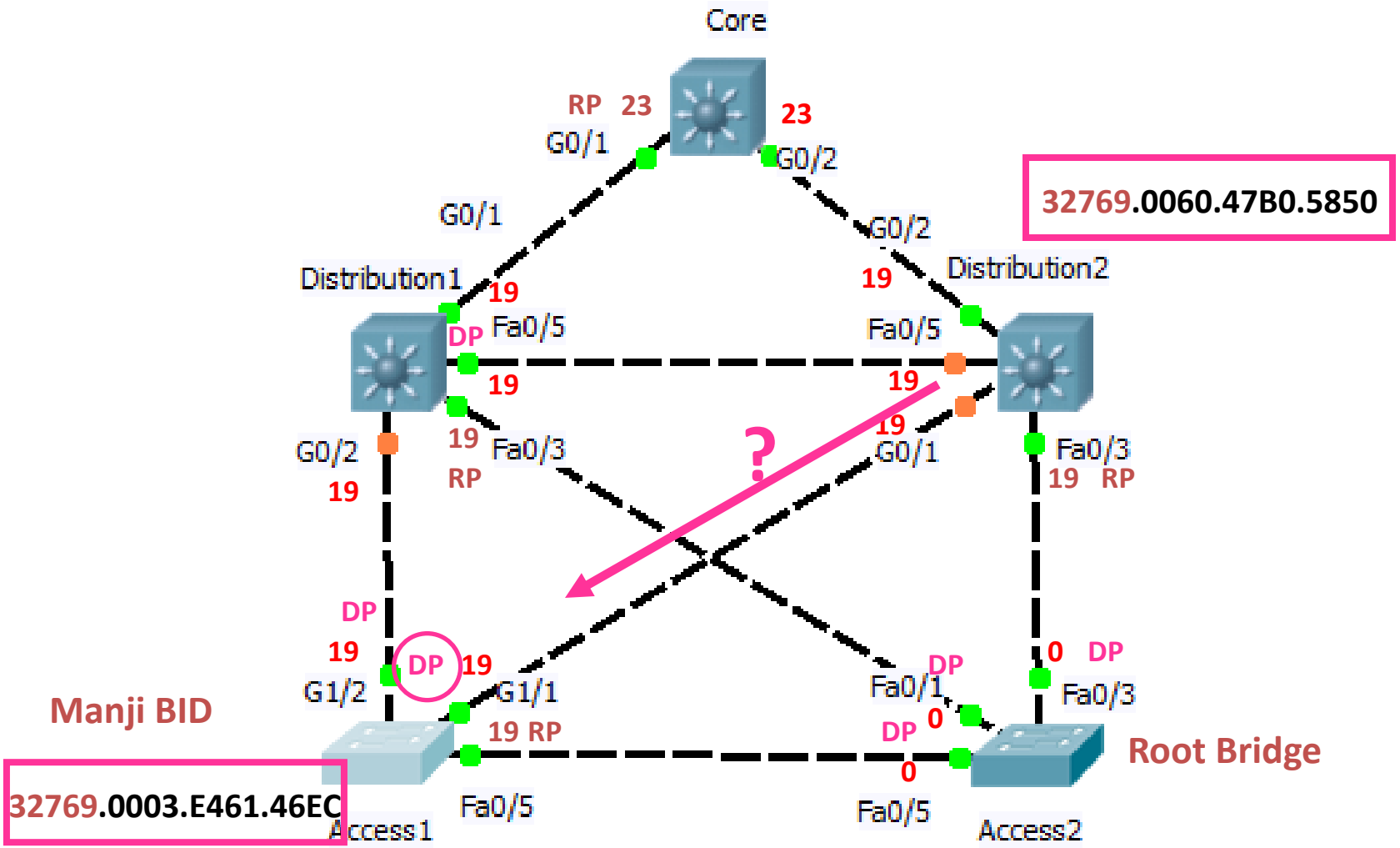


IZBOR DESIGNATED PORTA

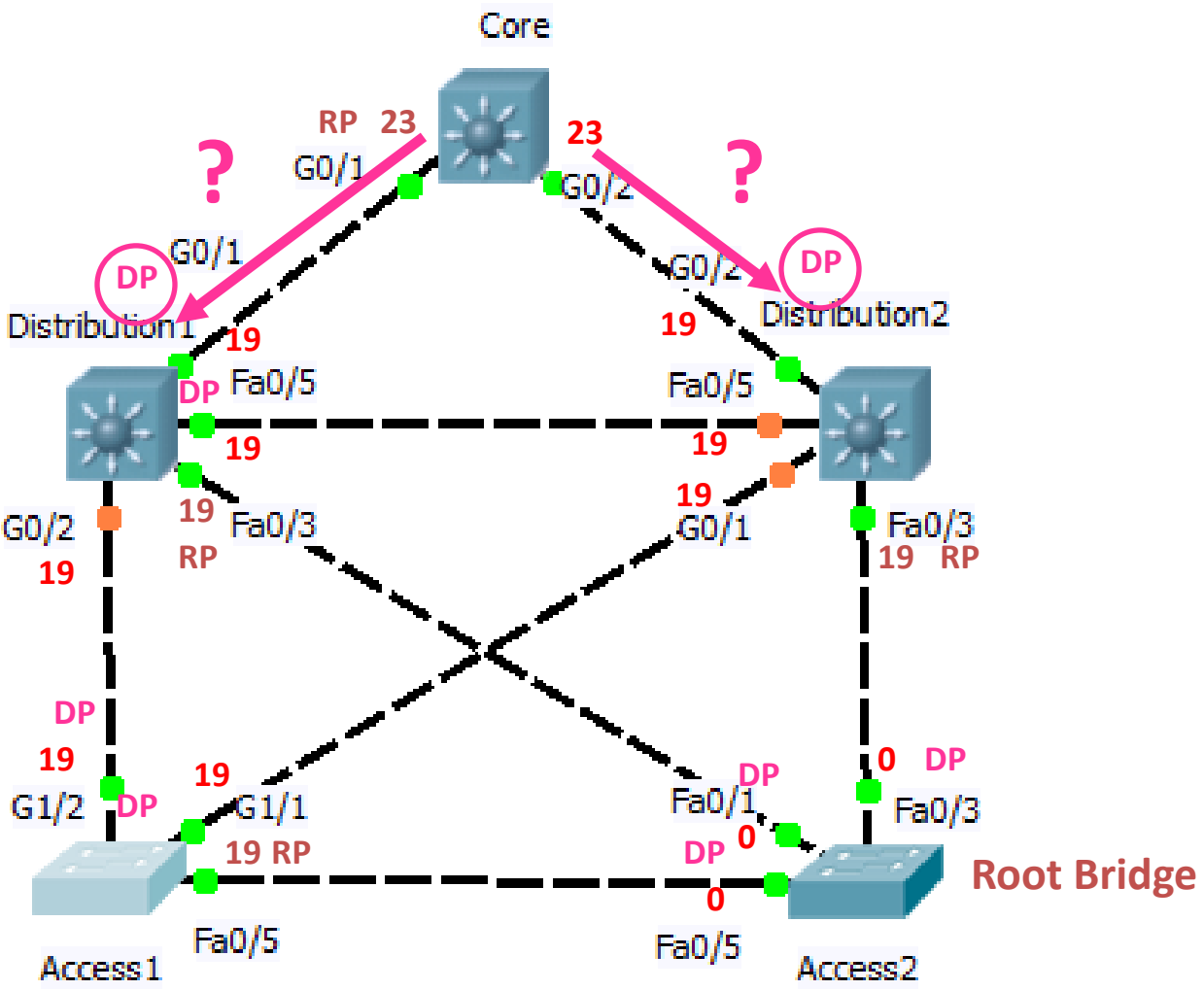
```
Distribution1# show spanning-tree detail
Port 5 (FastEthernet0/5) of VLAN0030 is designated forwarding
  Port path cost 19, Port priority 128, Port Identifier 128.5
  Designated root has priority 128, address 000C.CF0B.1503
  Designated bridge has priority 32769, address 0005.5E0D.9315
  Designated port id is 128.5, designated path cost 19
  Timers: message age 16, forward delay 0, hold 0
  Number of transitions to forwarding state: 1
  Link type is point-to-point by default
```


```
Distribution2# show spanning-tree detail
Port 5 (FastEthernet0/5) of VLAN0001 is designated blocking
  Port path cost 19, Port priority 128, Port Identifier 128.5
  Designated root has priority 128, address 000C.CF0B.1503
  Designated bridge has priority 32769, address 0005.5E0D.9315
  Designated port id is 128.5, designated path cost 19
  Timers: message age 16, forward delay 0, hold 0
  Number of transitions to forwarding state: 1
  Link type is point-to-point by default
```

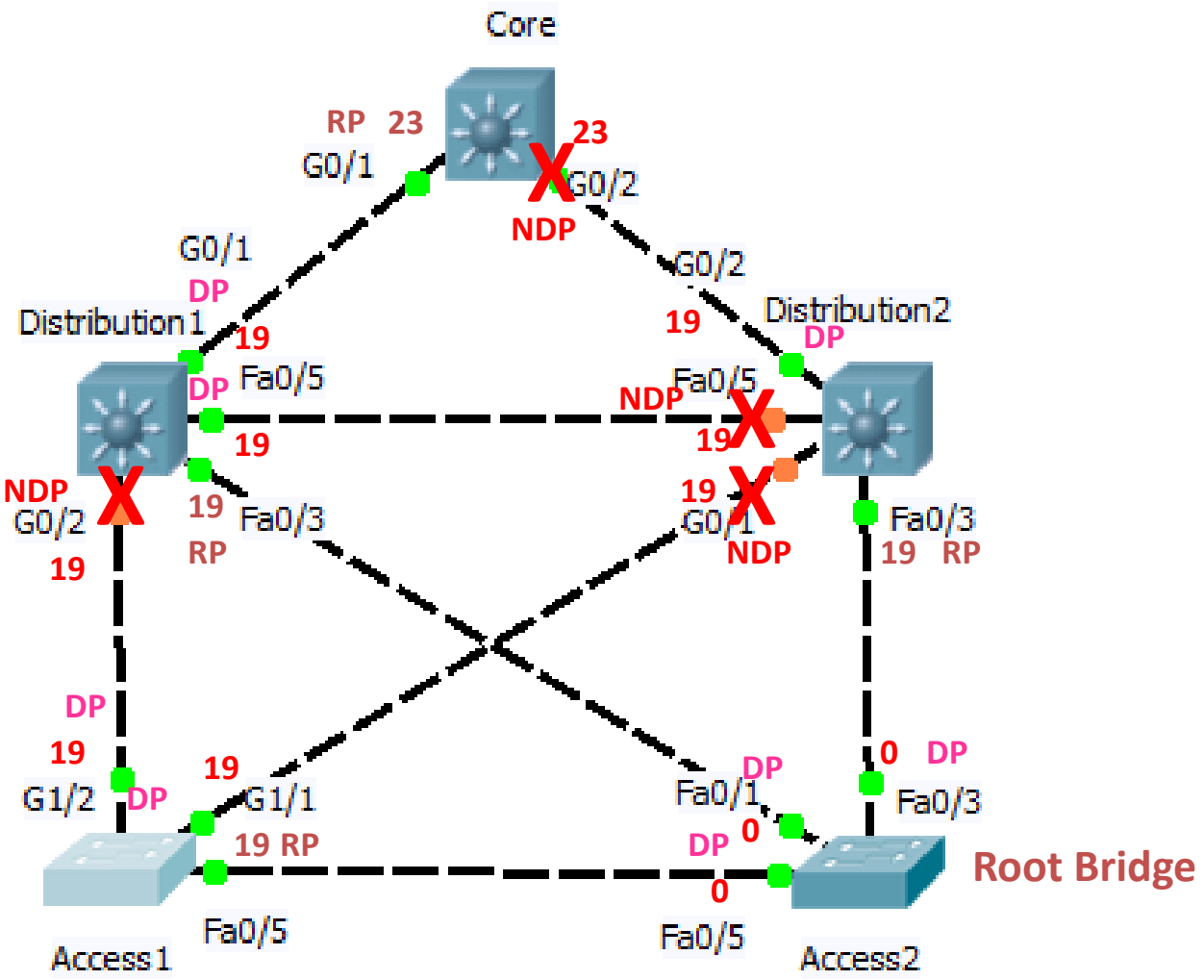
IZBOR DESIGNATED PORTA



IZBOR DESIGNATED PORTA

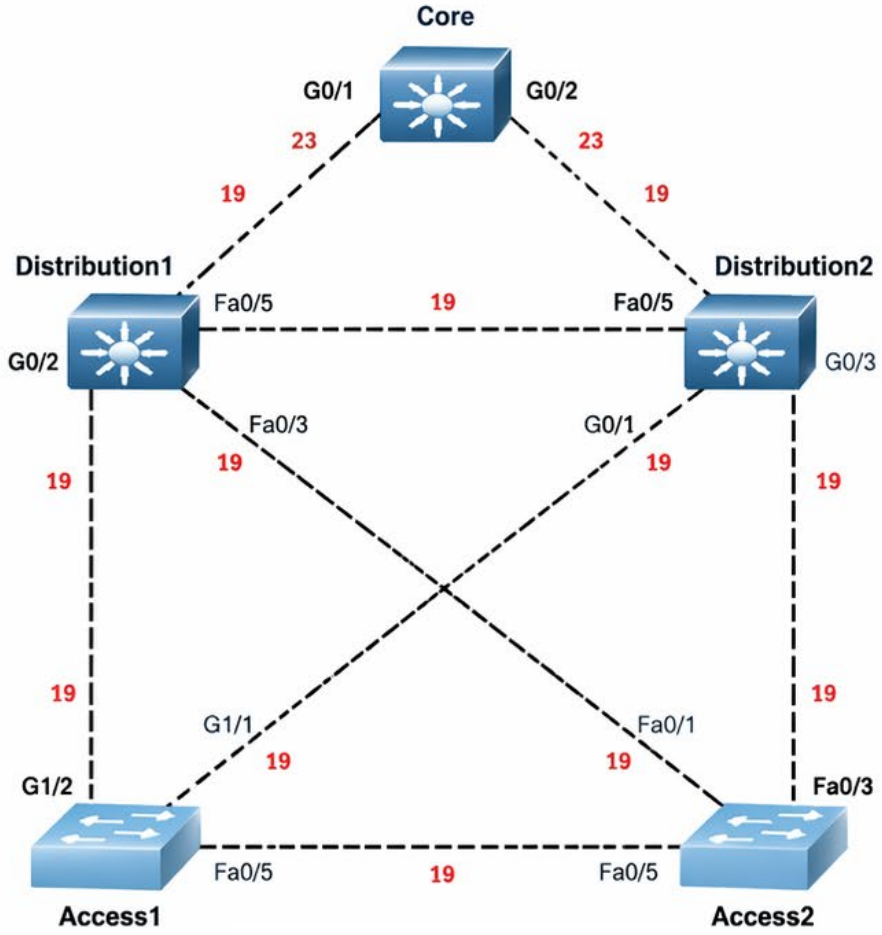


PRIKAZ BLOKIRANIH PORTOVA



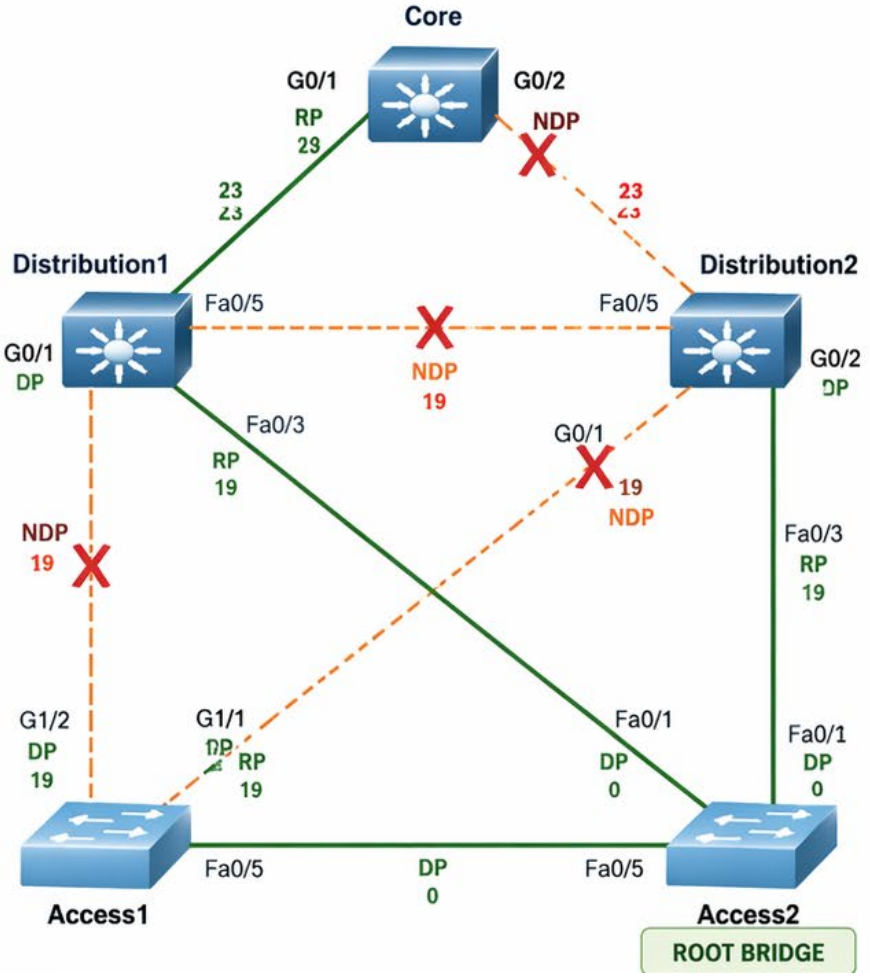
LAYER 1 – FIZIČKA TOPOLOGIJA

Svi fizički linkovi postoje



LAYER 2 – LOGIČKA TOPOLOGIJA (STP)

STP blokira redundantne linkove i kreira loop-free stablo



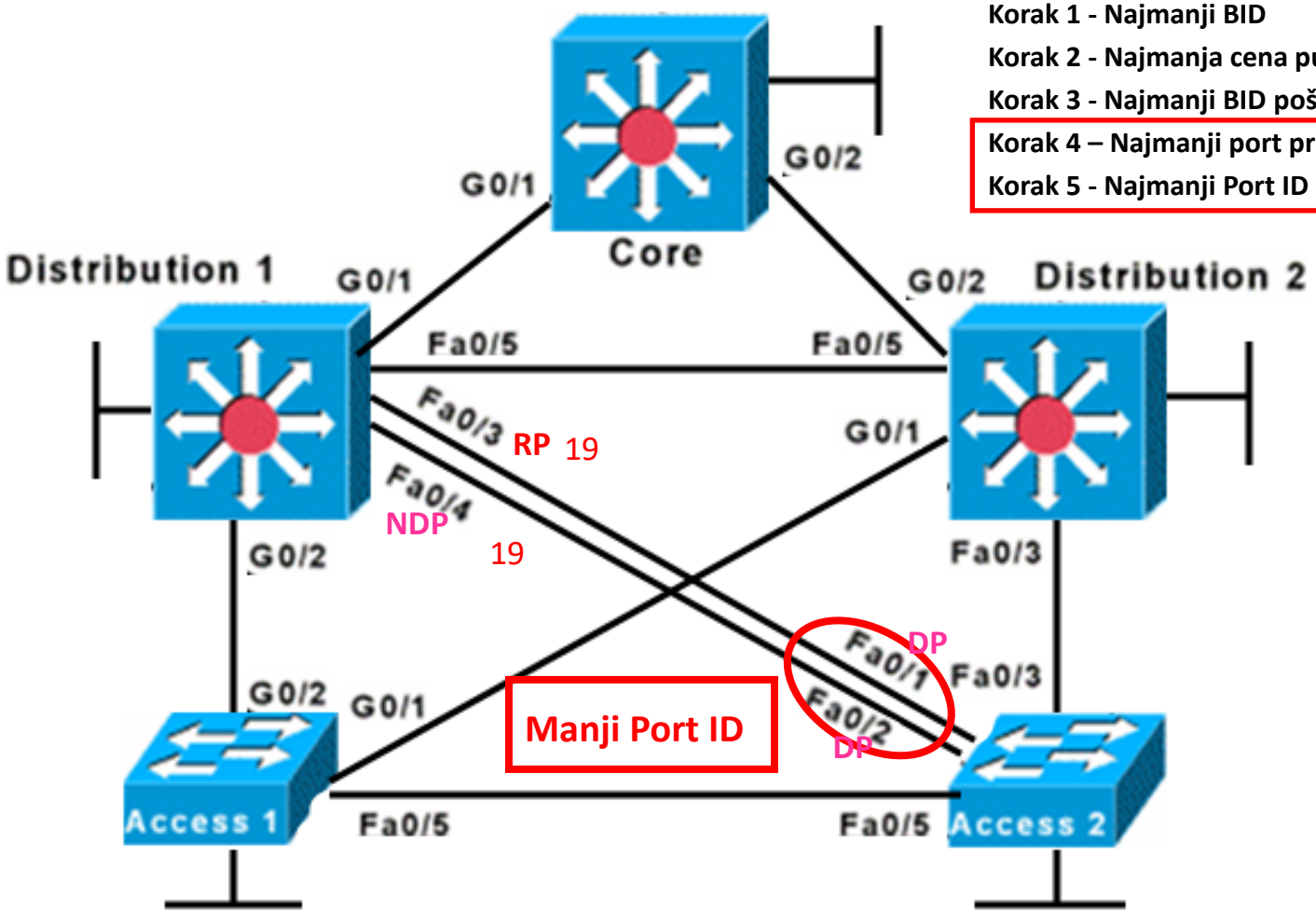
PORT COST / PORT ID

Pretpostavimo da su cene iste i da je na svim portovima port priority 32 (default). Port ID se koristi u ovom slučaju. Port 0/1 prosleđivaće frejmove jer ima manju numeraciju porta.

Korak 1 - Najmanji BID
Korak 2 - Najmanja cena putanje do Root Bridge
Korak 3 - Najmanji BID pošiljaoca
Korak 4 – Najmanji port priority
Korak 5 - Najmanji Port ID

- Ukoliko su cena putanje i bridge ID jednaki (slučaj sa paralelnim linkovima), svič će koristiti port priority da bi dodelio ulogu portu.
- Najmanji port priority pobeđuje (svi portovi su podešeni na 32).
- Port priority može da ima vrednost između 0 – 63.
- Ukoliko svi portovi imaju isti *priority*, port sa najmanjim numeracijom porta prosleđivaće frejmove.

PORT COST / PORT ID



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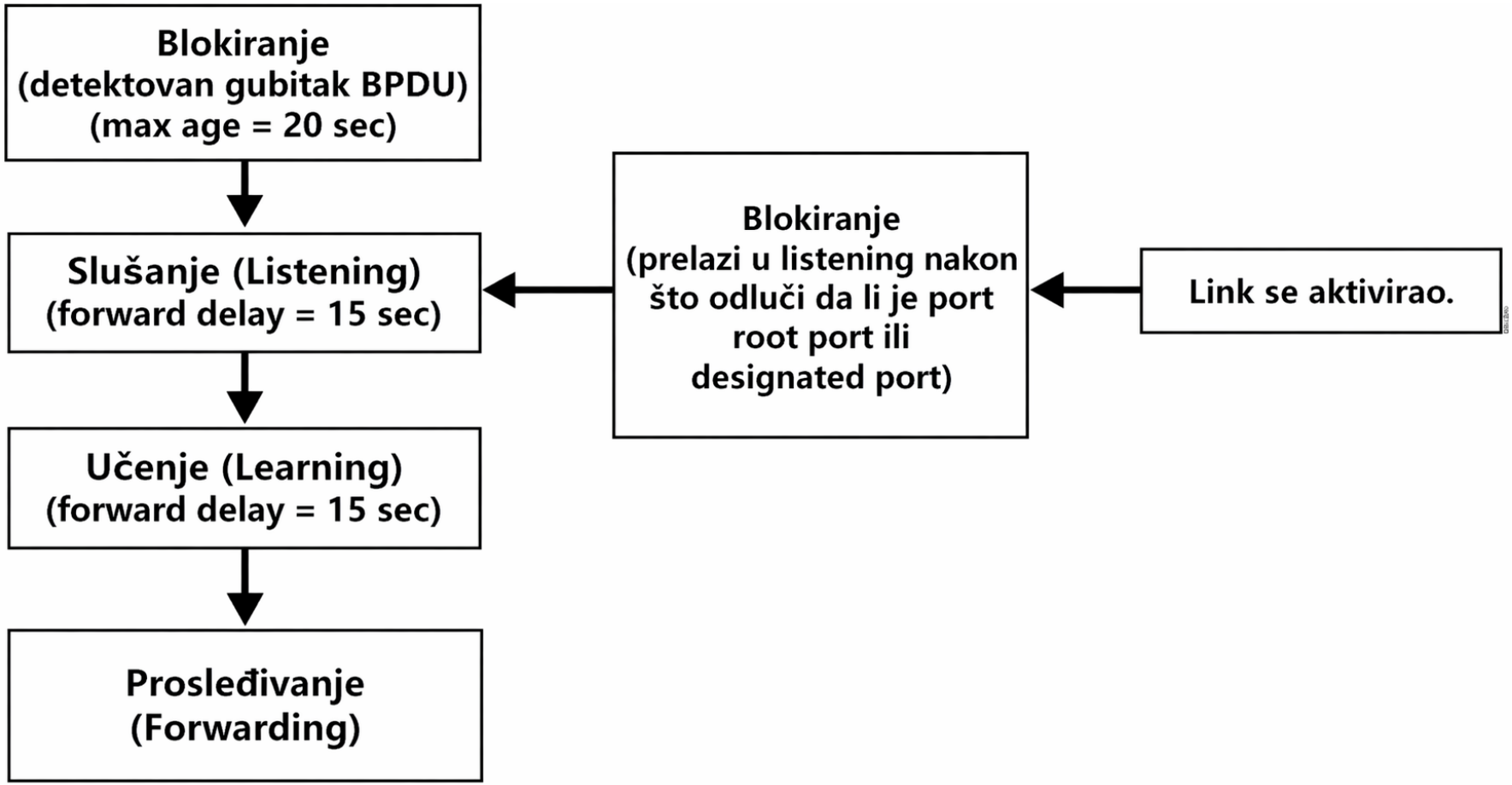
Korak 3 - Najmanji BID pošiljaoca
Korak 4 – Najmanji port priority
Korak 5 - Najmanji Port ID

STP STANJA NA PORTU



MAC Address Table

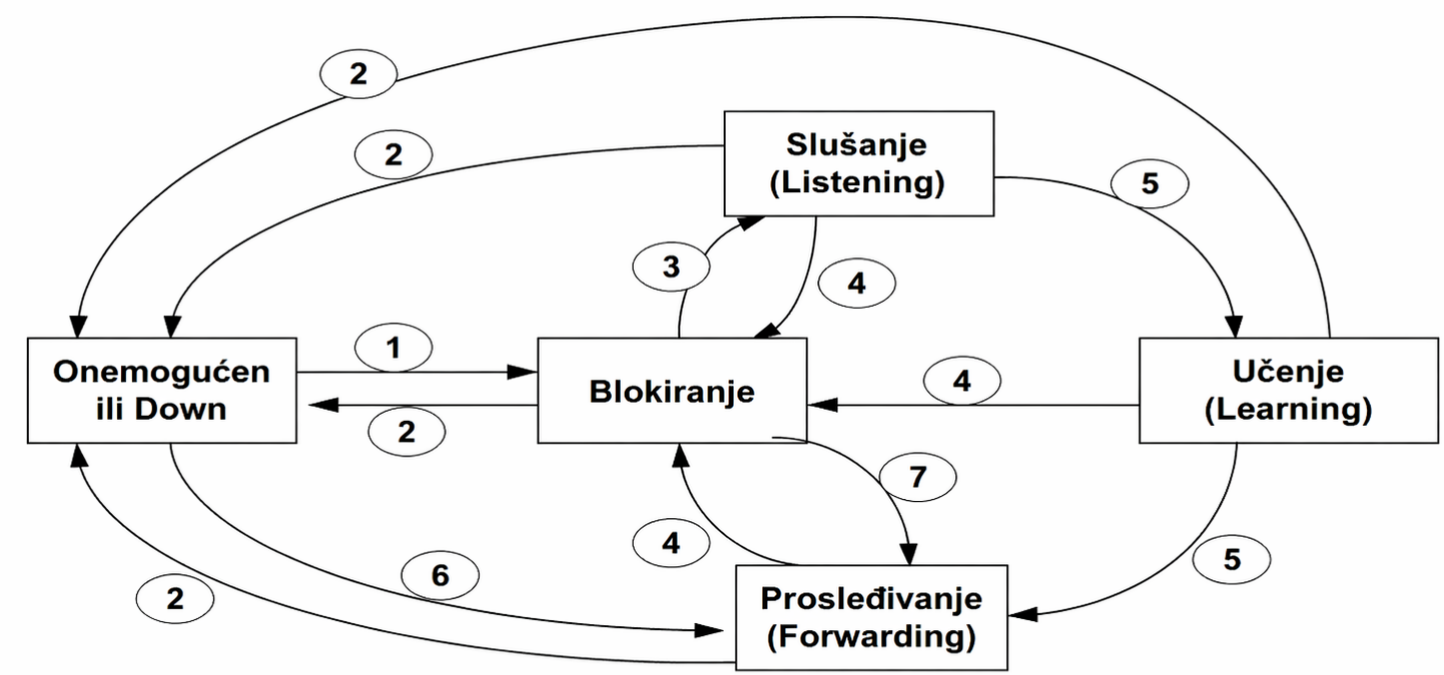
BPDUs

Data

Forwarding

Port State	BPDU	MAC-Add Table	Data frames	Duration

STP STANJA NA PORTOVIMA



Standardna stanja

(1) Port je omogućen ili inicijalizovan
(2) Port je onemogućen ili je otkazao (failed)
(3) Port je izabran kao Root port ili Designated port
(4) Port prestaje da bude Root port ili Designated port
(5) Ističe forwarding timer

Cisco specifična stanja

(6) PortFast
(7) Uplink Fast

STP TAJMERI

Timer	Primary Purpose	Default
Hello Time	Frekvencija slanja BPDU-a	2 Secs
Forward Delay	Trajanje Listening i Learning stanja	15 Secs
Max Age	Vremenski period čuvanja BPDU-a	20 Secs

HELLO TIMER

- IEEE definiše default od 2 sekunde.
- Interval između uzastopnih BPDU-ova.
- Hello Time vrednost se konfiguriše na root bridge
- Lokalno konfigurisan Hello Time koristi se samo za TCN BPDU.

Timer	Primary Purpose	Default
Hello Time	Frekvencija slanja BPDU-a	2 Secs
Forward Delay	Trajanje Listening i Learning stanja	15 Secs
Max Age	Vremenski period čuvanja BPDU-a	20 Secs

FORWARD DELAY TAJMER

- Default vrednost za forward delay (15 sekundi)
- *Ova vrednost određena je pod pretpostavkom da je maksimalna veličina mreže sedam svičeva povezanih jedan iza drugog*
  - *Maksimum tri izgubljena BPDU-a, za hello-time interval od 2 sekunde.*
- Forward delay određuje dužinu trajanja:
  - Listening stanja
  - Learning stanja

Timer	Primary Purpose	Default
Hello Time	Frekvencija slanja BPDU-a	2 Secs
Forward Delay	Trajanje Listening i Learning stanja	15 Secs
Max Age	Vremenski period čuvanja BPDU-a	20 Secs

MAX AGE TAJMER

- Max Age je vreme koje svič čuva BPDU pre nego što ga odbaci.
- Svaki port čuva najbolju primljenu kopiju BPDU-a.
- Ukoliko svič ne primi najbolju kopiju BPDU-a duže od **20 sekundi,** port prelazi u listening stanje.

Timer	Primary Purpose	Default
Hello Time	Frekvencija slanja BPDU-a	2 Secs
Forward Delay	Trajanje Listening i Learning stanja	15 Secs
Max Age	Vremenski period čuvanja BPDU-a	20 Secs

PROMENA STP TAJMERA

Ne preporučuje se promena podrazumevanih tajmera bez detaljne analize.

Promena STP tajmera se radi samo na Root bridge

BPDU prosleđuje ove vrednosti do svih svičeva u mreži.

Promena može da traje između 30-50 sekundi da bi se svič prilagodio promeni u topologiji.

```
Switch(config)# spanning-tree
vlan vlan-id [forward-time
seconds | hello-time hello-time |
max-age seconds |
priority priority | protocol
protocol | {root {primary |
secondary} [diameter net-diameter
[hello-time hello-time]]}]
```

vlan-id	VLAN identification number; valid values are from 1 to 4094.
forward-time *seconds*	(Optional) STP forward delay time; valid values are from 4 to 30 seconds.
hello-time *hello-time*	(Optional) Number of seconds between the generation of configuration messages by the root switch; valid values are from 1 to 10 seconds.
max-age *seconds*	(Optional) Maximum number of seconds that the information in a BPDU is valid; valid values are from 6 to 40 seconds.
priority *priority*	(Optional) STP bridge priority; valid values are from 0 to 65535.
protocol *protocol*	(Optional) STP; see the "Usage Guidelines" section for a list of valid values.
root primary	(Optional) Forces this switch to be the root bridge.
root secondary	(Optional) Forces this switch to be the root switch should the primary root fail.
diameter *net-diameter*	(Optional) Maximum number of bridges between any two points of attachment between end stations; valid values are from 2 through 7.

STP POBOLJŠANJA

- STP
  - PortFast
  - BPDU Guard
  - Root Guard
  - UplinkFast
  - BackboneFast
- Per VLAN Spanning Tree (PVST+)
- Rapid Spanning Tree Protocol (RSTP)
- Multiple Spanning Tree Protocol (MST)
  - MST is also known as Multiple Instance Spanning Tree Protocol (MISTP) on Cisco Catalyst 6500 switches and above