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Introduction to Spanning-Tree

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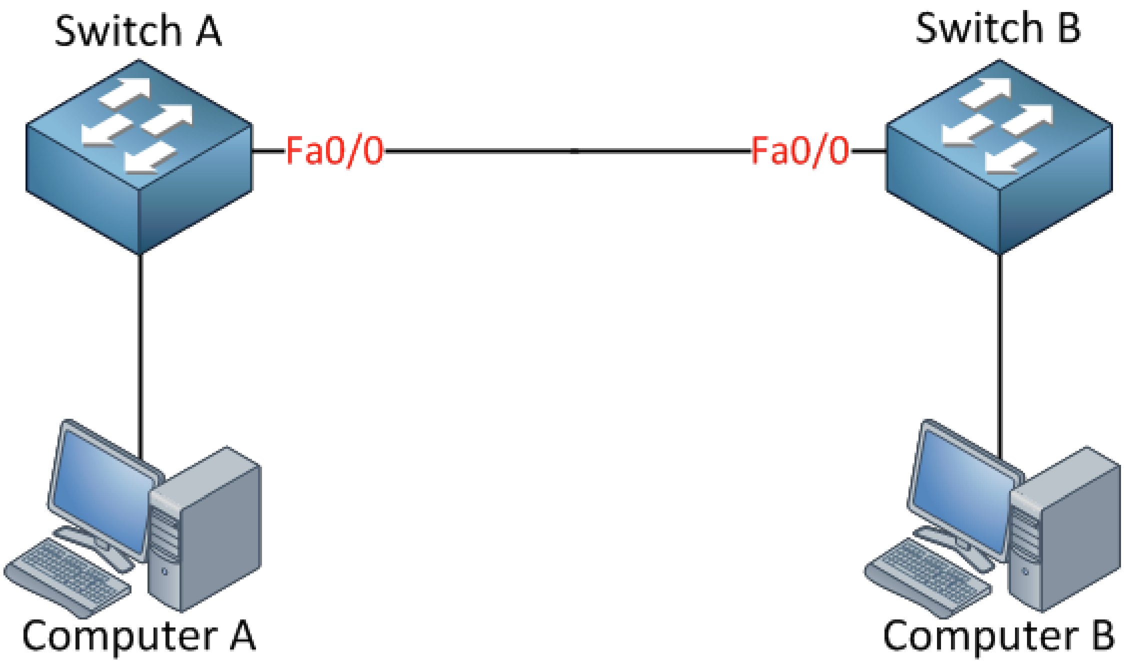
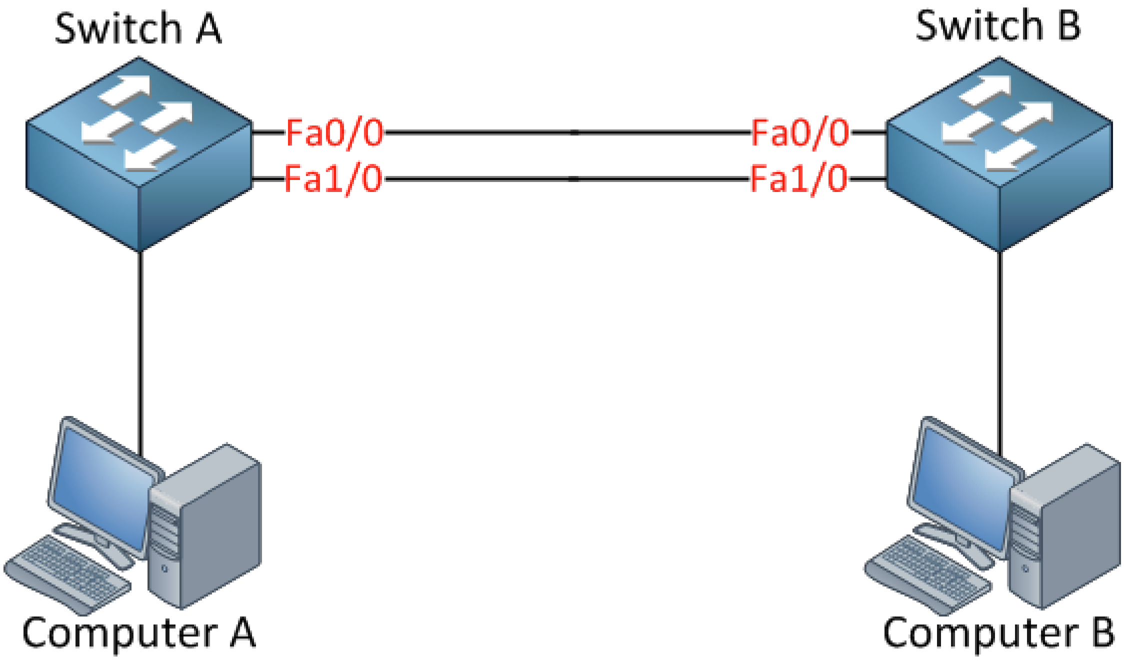
Spanning-tree is a protocol that runs on our switches that helps us to solve loops. Spanning-tree is one of the protocols that you must understand as a network engineer and you will encounter it for sure if you decide to face the Cisco CCNA R&S exam. This article is an introduction to spanning-tree, you will learn why we need it, how it works and how you can check the spanning-tree topology on your Cisco switches.

Why do we need spanning-tree?

What is a loop and how do we get one? Let me show you an example:



In the picture above we have two switches. These switches are connected to each other with a single cable so there is a **single point of failure**.To get rid of this single point of failure we will add another cable:



With the extra cable we now have **redundancy**. Unfortunately for us redundancy also brings **loops**. Why do we have a loop in the scenario above? Let me describe it to you:

1. Computer A sends an ARP request because it's looking for the MAC address of computer B. An ARP request is a **broadcast** frame.
2. Switch A will forward this broadcast frame on all it interfaces, except the interface where it received the frame on.
3. Switch B will receive both broadcast frames.

Now what does Switch B do with those broadcast frames?

1. It will forward it out of every interface except the interface where it received the frame on.
2. This means that the frame that was received on interface Fa0/0 will be forwarded on Interface Fa1/0.
3. The frame that was received on Interface Fa1/0 will be forwarded on Interface Fa0/0.

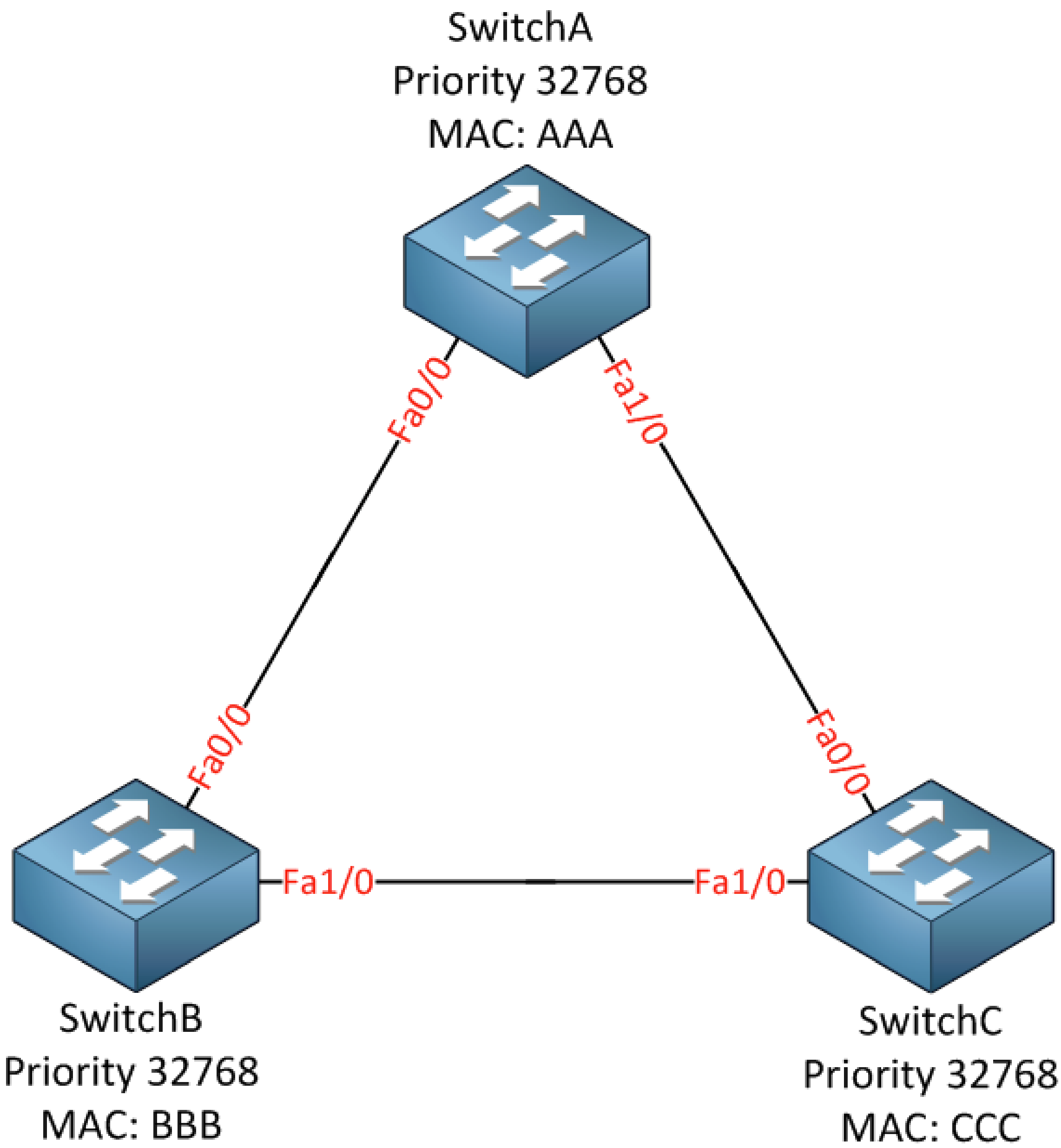
Do you see where this is going? We have a loop! Both switches will keep forwarding over and over again until the following happens:

- You fix the loop by disconnecting one of the cables.
- One of your switches will crash because they are overburdened with traffic.

Ethernet frames **don't have a TTL** (Time to Live) value so they will loop around forever. Besides ARP requests there are many frames that are broadcasted. For example whenever the switch doesn't know about a destination MAC address it will be flooded.

How spanning-tree solves loops

Spanning-tree will help us to create a **loop-free topology** by blocking certain interfaces. Let's take a look how spanning-tree works! Here's an example:



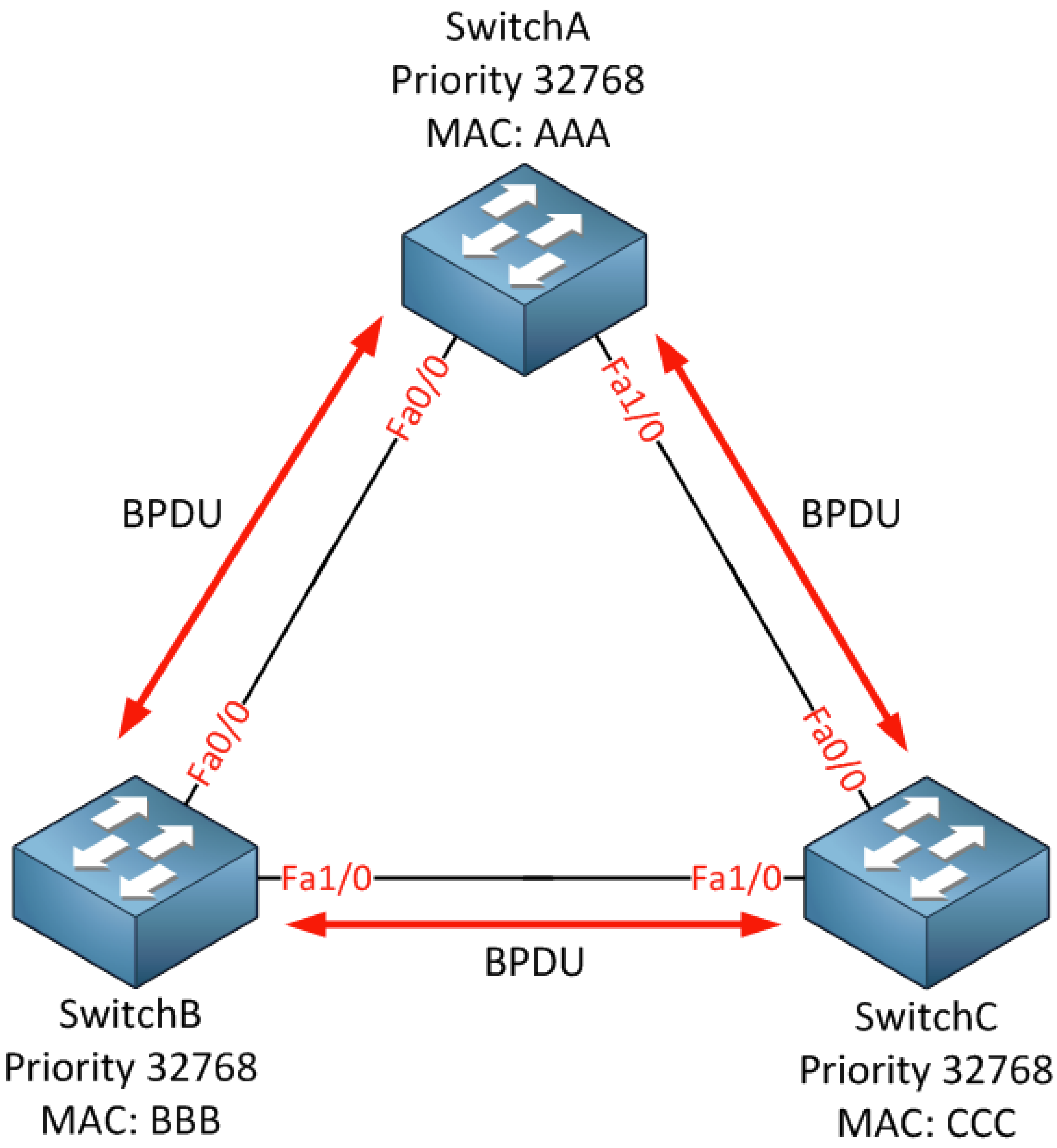
We have three switches and as you can see we have added redundancy by connecting the switches in a triangle, this also means we have a loop here. I have added the MAC addresses but simplified them for this example:

- Switch A: MAC AAA
- Switch B: MAC BBB
- Switch C: MAC CCC

Since spanning tree is enabled, all our switches will send a special frame to each other called a **BPDU (Bridge Protocol Data Unit)**. In this BPDU there are two pieces of information that spanning-tree requires:

- **MAC address**
- **Priority**

The **MAC address** and the **priority** together make up the **bridge ID**. The BPDU is sent between switches as shown in the following picture:



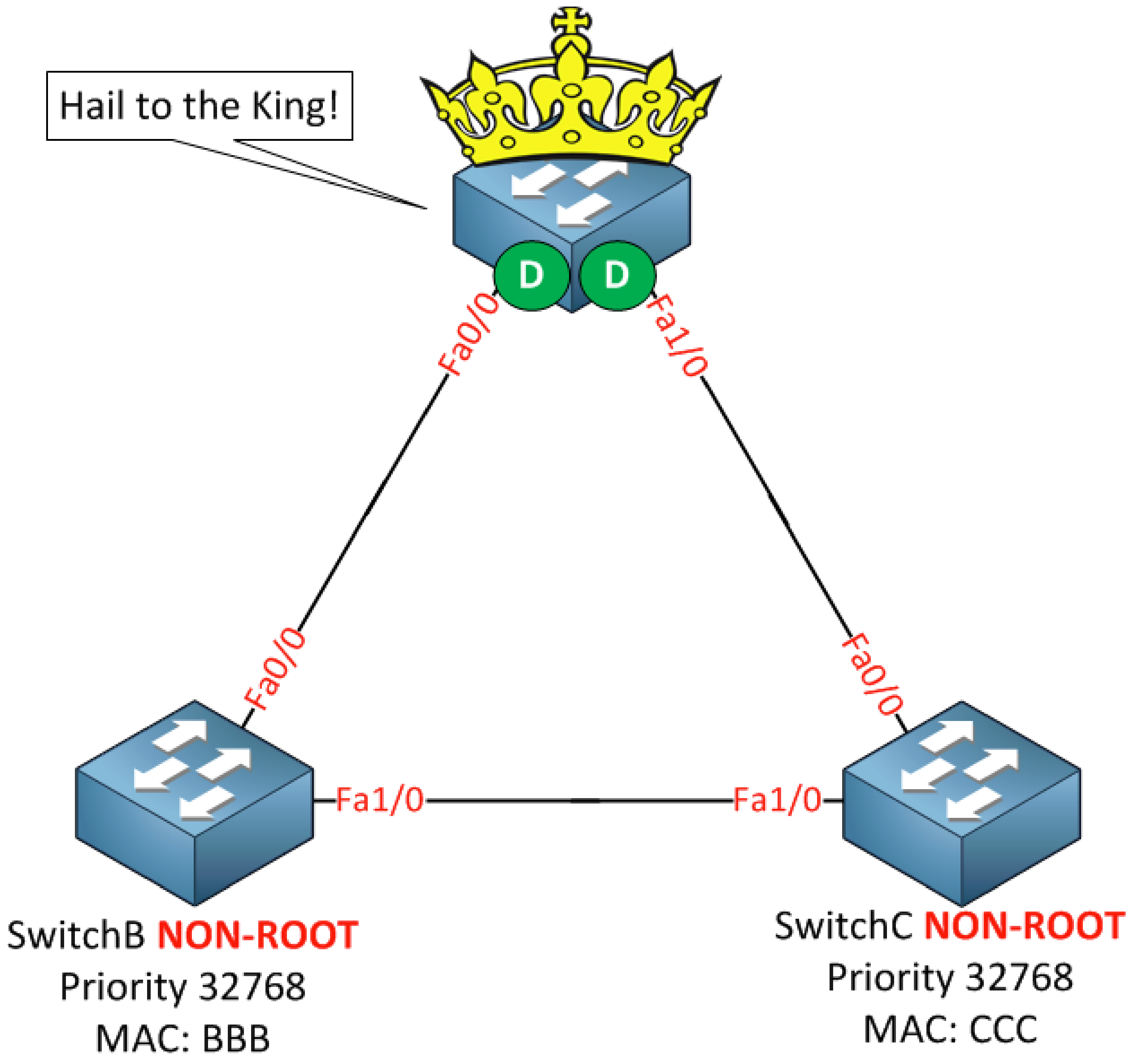
Spanning-tree requires the bridge ID for its calculation. Let me explain how it works:

- First of all spanning tree will **elect a root bridge**; this root-bridge will be the one that has the best "bridge ID".
- The switch with the **lowest bridge ID** is the best one.

- By default the priority is **32768** but we can change this value if we want.

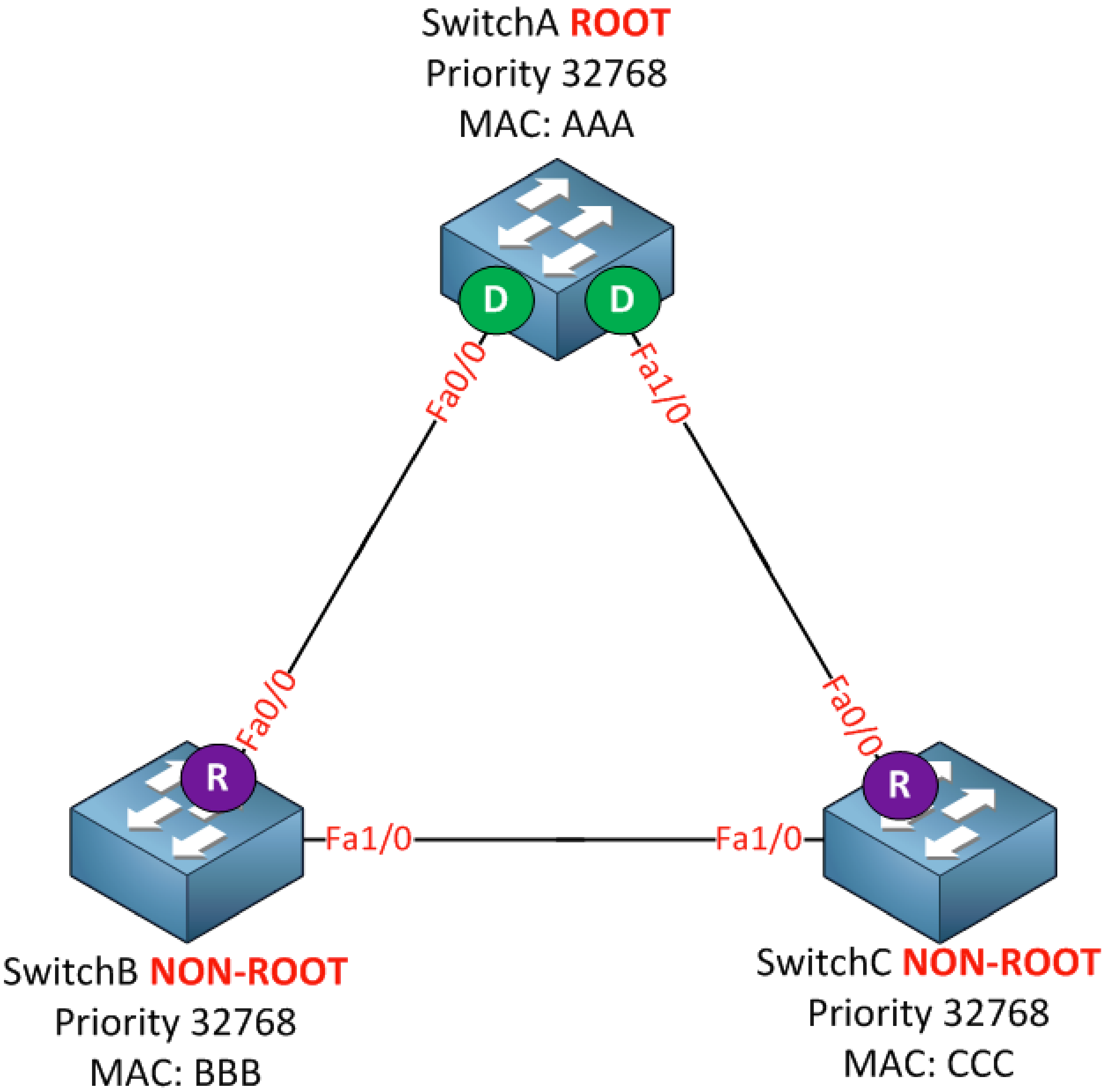
So who will become the root bridge? In our example switch A will become the root bridge! Priority and MAC address make up the bridge ID. Since the priority is the same on all switches it will be the MAC address that is the tiebreaker. Switch A has the lowest MAC address thus the best bridge ID and will become the root bridge.

The ports on our root bridge are always **designated** which means they are in a **forwarding** state. Take a look at the following picture:



Above you see that SwitchA has been elected as the root bridge and the “D” on the interfaces stands for designated.

Now we have agreed on the root bridge our next step for all our **“non-root” bridges** (so that’s every switch that is not the root) will have to find the **shortest path to our root bridge**! The shortest path to the root bridge is called the **“root port”**. Take a look at my example:



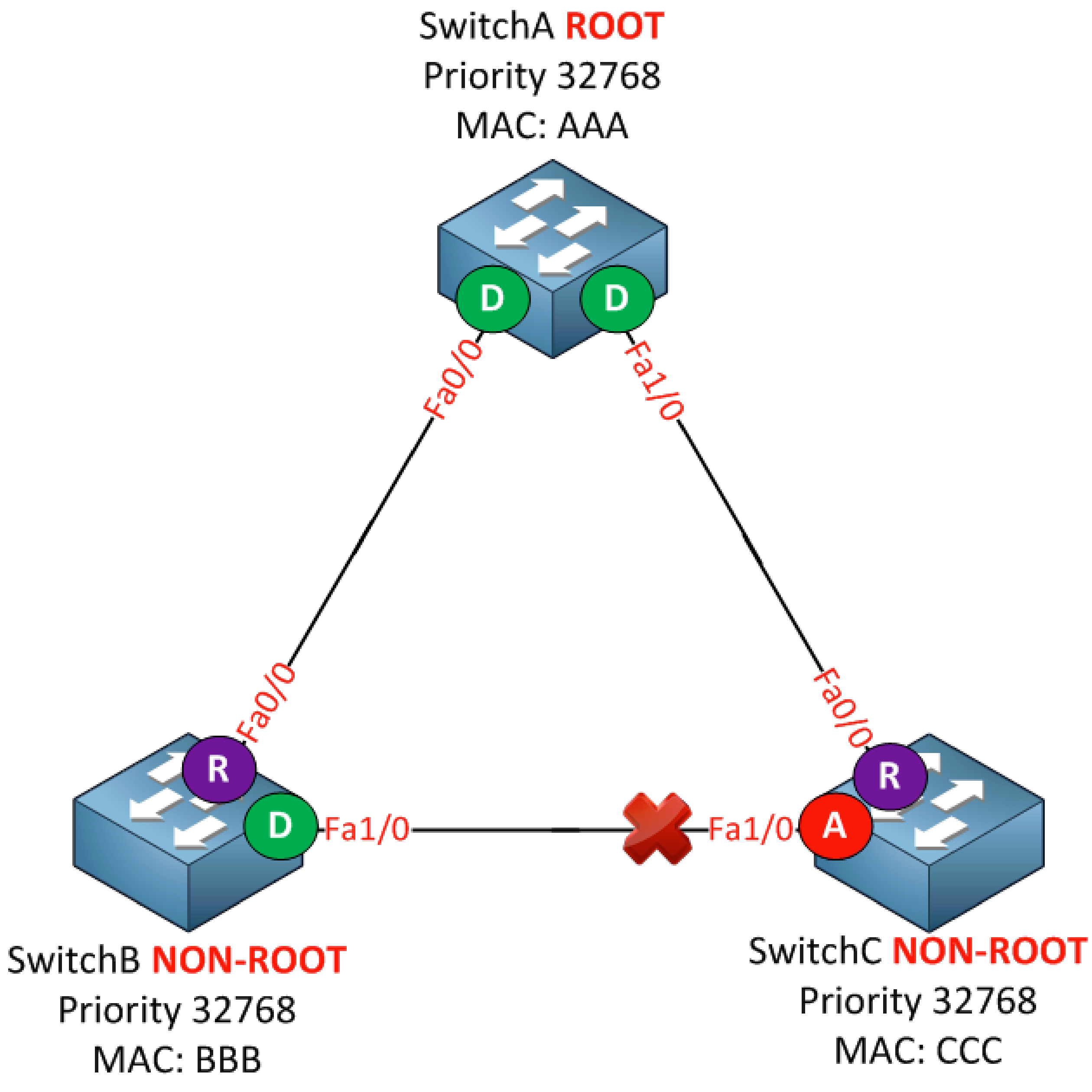
I've put an **"R" for "root port"** on switch B and switch C, their Fa0/0 interface is the shortest path to get to the root bridge. In my example I've kept things simple but "shortest path" in spanning tree means it will actually look at the **speed of the interface.** Each interface has a certain cost and the path with the lowest cost will be used. Here's an overview of the interfaces and their cost:

- 10 Mbit = Cost 100
- 100 Mbit = Cost 19
- 1000 Mbit = Cost 4

Excellent!…we have designated ports on our root bridge and root ports on our non-root bridges, we still have a loop however so we need to shut down a port between switch B and C to break that loop. So which port are we going to shut down? The one on switch B or the one on switch C? We'll look again at the best bridge ID:

- Bridge ID = MAC address + Priority.

Lower is better, both switches have the same priority but the MAC address of switch B is lower, this means that switch B will "win this battle". Switch C is our loser here which means it will have to block its port, effectively breaking our loop! Take a look at my example:



If you look at the link between switch B and switch C you can see that the Fa1/0 interface of switch C says **"A"** which stands for **alternate**. An alternate port is blocked! Sometimes the alternate port is called the **ND (Non Designated) port**.By shutting down this interface we have solved our loop problem.

Because the default priority is 32768 the tie-breaker for selecting the root bridge is the MAC address. In a production network what switch do you think will be elected as the root bridge?

Your brand spanking new switch or that dirty old switch that has been used as a dust collector for the last 8 years?

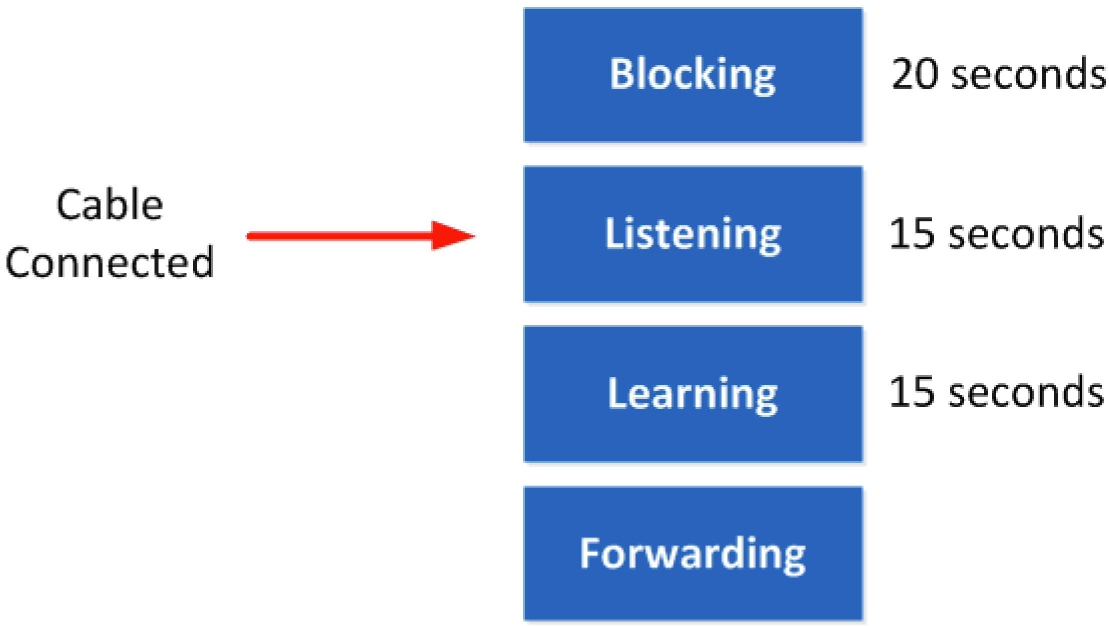
The old switch probably has a lower MAC address and thus will be elected as the root bridge. Doesn't sound like a good idea right? That's why we can **change the priority** to determine what switch will become the root bridge.

Are you following me so far? Good! You just learned the basics of spanning-tree. Let's add some more detail to this story…

Let's continue our spanning tree story and further enhance your knowledge. If you have played with some Cisco switches before you might have noticed that every time you plugged in a cable the led above the interface was orange and after a while became green. What is happening at this moment is that spanning tree is determining the state of the interface; this is what happens as soon as you plug in a cable:

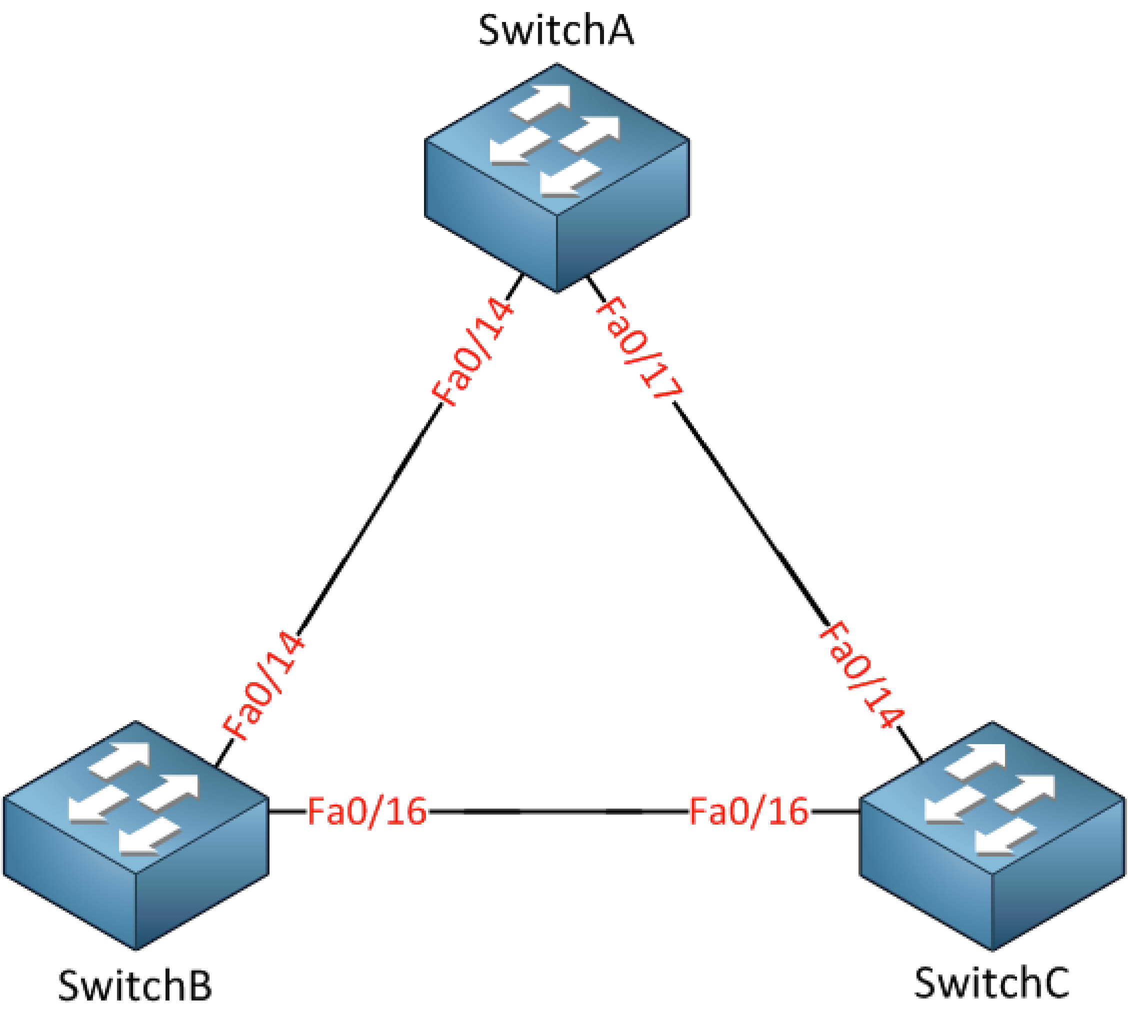
- The port is in **listening** mode for 15 seconds. In this phase it will receive and send BPDUs, still neither learning MAC addresses nor data transmission.
- The port is in **learning** mode for 15 seconds. We are still sending and receiving BPDUs but now the switch will also learn MAC addresses, still no data transmission though.
- Now we go in **forwarding** mode and finally we can start transmitting data!

Here's a picture to visualize it:



Spanning-tree configuration on Cisco switches

Now you have an idea what spanning-tree is about. Let's take a look at some Cisco switches to see how we can configure it. I will use the same topology that I showed you earlier but we have different interfaces.



This is the topology we will use. Spanning-tree is enabled by default; let's start by checking some show commands.

```
SwitchA#show spanning-tree

VLAN0001
Spanning tree enabled protocol ieee
Root ID    Priority    32769
Address     000f.34ca.1000
Cost        19
Port        19 (FastEthernet0/17)
Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec

Bridge ID  Priority    32769  (priority 32768 sys-id-ext 1)
Address     0011.bb0b.3600
```

```
Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec
Aging Time 300

Interface           Role Sts Cost      Prio.Nbr Type
------------------- ---- --- --------- -------- ------------------------------
--
Fa0/14              Desg FWD 19        128.16   P2p
Fa0/17              Root FWD 19        128.19   P2p
```

The show spanning-tree command is the most important show command to remember. There's quite some stuff here so I'm going to break it down for you!

```
VLAN0001
  Spanning tree enabled protocol ieee
```

We are looking at the spanning-tree information for VLAN 1. Spanning-tree has multiple versions and the default version on Cisco switches is PVST (Per VLAN spanning-tree). This is the spanning-tree for VLAN 1

```
Root ID       Priority     32769
              Address      000f.34ca.1000
              Cost         19
              Port         19 (FastEthernet0/17)
```

Here you see the information of the root bridge. You can see that it has a priority of 32769 and its MAC address is 000f.34ca.1000. From the perspective of SwitchA it has a cost of 19 to reach the root bridge. The port that leads to the root bridge is called the root port and for SwitchA this is fa0/17.

```
Bridge ID  Priority    32769  (priority 32768 sys-id-ext 1)
              Address      0011.bb0b.3600
```

This part shows us the information about the local switch, SwitchA in our case. There's something funny about the priority here....you can see it show two things:

- Priority 32769
- Priority 32768 sys-id-ext 1

The sys-id-ext value that you see is the VLAN number. The priority is 32768 but spanning-tree will add the VLAN number so we end up with priority value 32769. Last but not least we can see the MAC address of SwitchA which is 0011.bb0b.3600.

```
Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec
```

Here's some information on the different times that spanning-tree uses:

- Hello time: every 2 seconds a BPDU is sent.
- Max Age: If we don't receive BPDUs for 20 seconds we know something has changed in the network and we need to re-check the topology.
- Forward Delay: This timer is used for the listening and learning states. We remain in each state for the duration of the forward delay which is 15 seconds by default.

```
Interface           Role Sts Cost      Prio.Nbr Type
------------------- ---- --- --------- -------- ------------------------------
--
Fa0/14              Desg FWD 19        128.16   P2p
Fa0/17              Root FWD 19        128.19   P2p
```

The last part of the show spanning-tree commands shows us the interfaces and their status. SwitchA has two interfaces:

• Fa0/14 is a designated port and in (FWD) forwarding mode.
• Fa0/17 is a root port and in (FWD) forwarding mode.

The prio.nbr you see here is the port priority that I explained earlier. We'll play with this in a bit.

Because only non-root switches have a root-port I can conclude that SwitchA is a non-root switch. I know that fa0/17 on SwitchA leads to the root bridge.

Let's take a look at SwitchB to see what we find:

```
SwitchB#show spanning-tree

VLAN0001
  Spanning tree enabled protocol ieee
  Root ID    Priority    32769
```

```
             Address     000f.34ca.1000
             Cost        19
             Port        18 (FastEthernet0/16)
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec

 Bridge ID  Priority    32769 (priority 32768 sys-id-ext 1)
             Address     0019.569d.5700
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec
             Aging Time 300

Interface           Role Sts Cost      Prio.Nbr Type
------------------- ---- --- --------- -------- ------------------------------
--
Fa0/14              Altn BLK 19      128.16   P2p
Fa0/16              Root FWD 19      128.18   P2p
```

What do we see here?

```
Root ID    Priority    32769
             Address     000f.34ca.1000
             Cost        19
             Port        18 (FastEthernet0/16)
```

Here we see information about the root bridge. This information is similar to what we saw on SwitchA. The root port for SwitchB seems to be fa0/16.

```
Bridge ID  Priority    32769  (priority 32768 sys-id-ext 1)
             Address     0019.569d.5700
```

This is the information about SwitchB. The priority is the same as on SwitchA, only the MAC address (0019.569d.5700) is different.

```
Interface           Role Sts Cost      Prio.Nbr Type
------------------- ---- --- --------- -------- ------------------------------
--
Fa0/14              Altn BLK 19        128.16   P2p
Fa0/16              Root FWD 19        128.18   P2p
```

This part looks interesting; there are two things we see here:

• Interface fa0/14 is an alternate port and in (BLK) blocking mode.
• Interface fa0/16 is a root port and in (FWD) forwarding mode.

Last but not least let's check Switch C:

```
SwitchC#show spanning-tree

VLAN0001
  Spanning tree enabled protocol ieee
  Root ID    Priority    32769
             Address     000f.34ca.1000
             This bridge is the root
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec

  Bridge ID  Priority    32769  (priority 32768 sys-id-ext 1)
             Address     000f.34ca.1000
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec
             Aging Time 300

Interface        Role Sts Cost      Prio.Nbr Type
---------------- ---- --- --------- -------- --------------------------------
Fa0/14           Desg FWD 19        128.14   P2p
Fa0/16           Desg FWD 19        128.16   P2p
```

Let’s break down what we have here:

```
Root ID    Priority    32769
             Address     000f.34ca.1000
             This bridge is the root
```

Bingo...SwitchC is the root bridge in this network. We already knew that because SwitchA and SwitchB are both non-root but this is how we verify it by looking at SwitchC.

```
Bridge ID    Priority    32769  (priority 32768 sys-id-ext 1)
             Address     000f.34ca.1000
```

We can also see the MAC address of SwitchC.

```
Interface        Role Sts Cost      Prio.Nbr Type
---------------- ---- --- --------- -------- --------------------------------
Fa0/14           Desg FWD 19        128.14   P2p
Fa0/16           Desg FWD 19        128.16   P2p
```

Both interfaces on SwitchC are designated ports and in (FWD) forwarding mode.

You have now seen what the spanning-tree topology looks like. Why was Switch C chosen as the root bridge? We'll have to verify the bridge ID for the answer:

```
SwitchA#show spanning-tree | begin Bridge ID
  Bridge ID  Priority    32769  (priority 32768 sys-id-ext 1)
             Address     0011.bb0b.3600
```

```
SwitchB#show spanning-tree | begin Bridge ID
  Bridge ID  Priority    32769  (priority 32768 sys-id-ext 1)
             Address     0019.569d.5700
```

```
SwitchC#show spanning-tree | begin Bridge ID
  Bridge ID  Priority    32769  (priority 32768 sys-id-ext 1)
             Address     000f.34ca.1000
```

The priority is the same on all switches (32768) so we have to look at the MAC addresses:

- SwitchA: 0011.bb0b.3600
- SwitchB: 0019.569d.5700
- SwitchC: 000f.34ca.1000

SwitchC has the lowest MAC address so that's why it became root bridge. Why was the fa0/14 interface on SwitchB blocked and not the fa0/14 interface on SwitchA? Once again we have to look at the bridge identifier. The priority is 32768 on both switches so we have to compare the MAC address:

- SwitchA: 0011.bb0b.3600
- SwitchB: 0019.569d.5700

SwitchA has a lower MAC address and thus a better bridge identifier. That's why SwitchB lost this battle and has to shut down its fa0/14 interface.

That's it! You have now learned how spanning-tree works and how you can check the spanning-tree topology on your Cisco switches. If you enjoyed this article please leave a comment or share it on facebook or twitter.

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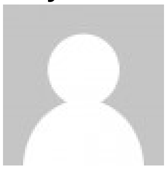
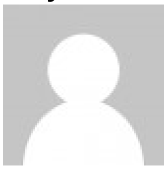
- May 14, 2013 at 04:26 #15618 Reply
  
  Alok Kumar
  Could you please post some details about RSTP and MSTP.

  Thanks In Advance.

  May 14, 2013 at 08:22 #15619 Reply

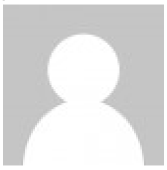
Rene Molenaar
Keymaster
I will add those in the future, no problem.

May 16, 2013 at 18:08 #15620 Reply



muffymeister
Possibly the best and simplest explanation I have read, excellent work

June 11, 2013 at 05:45 #15621 Reply



Karl
Rene,

Thanks for explaining this. It's very clear and informative.

I would like to ask you about what software or stencils (if you use Visio) you use for your diagrams? I really like them and I would like to use something like it for my own (personal) home network.

Looking at the picture quality, I'm going to assume it's a Mac OS X based software! Can you please advise?

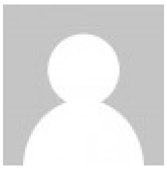
Thanks again mate.

June 11, 2013 at 19:31 #15622 Reply

Rene Molenaar
Keymaster
Hi Karl, you are welcome. I'm using Microsoft Visio 2010 to draw the pictures and the excellent free stencils from http://www.visiocafe.com/vsdfx.htm.

Rene

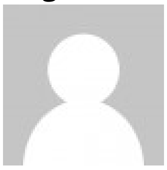
August 1, 2013 at 14:29 #15623 Reply



Zach

Thank you so much for this website,keep it going!

August 4, 2013 at 14:52 #15624 Reply



Vladimir

Thanks a lot

August 5, 2013 at 06:35 #15625 Reply

Jon

Hi Rene,

You say:

“Here’s an overview of the interfaces and their cost: 10 Mbit = Cost 10, 100 Mbit = Cost 19, 1000 Mbit = Cost 4”

…10 Mbit should be Cost 100 – I guess most people will know this already and/or it’s obvious, but might be worth changing.

And keep up the hard work with the articles – really enjoyable reading 🙂

August 5, 2013 at 19:33 #15626 Reply

Rene Molenaar

Keymaster

Hi Jon,

I just fixed this error, thanks for letting me know!

Rene

September 9, 2013 at 15:29 #15627 Reply

Manoj
Good Presentation…Keep up the Good Work

September 14, 2013 at 09:41 #15628 Reply

mustafa
thanks rene this website is very useful….keep going

October 6, 2013 at 15:29 #15629 Reply

Ryan
Super easy explanation. By far my favorite site for learning Cisco, Linux etc… Thanks as always and I.I keep spreading the word to purchase your material.

October 6, 2013 at 15:35 #15630 Reply

Rene Molenaar
Keymaster
Thanks Ryan!

October 12, 2013 at 23:13 #15631 Reply

PB
IMO your writing style is like talking about STP instead of reading about it. Easier to grasp and follow along.

Really diggin' the layout and flow of this new site too. Keep it up!

October 23, 2013 at 08:38 #15632 Reply

Rene Molenaar
Keymaster
Thanks PB. I try to explain things in my tutorials in the same way as if I were explaining it to you in person…no rocket science, just plain english 🙂

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