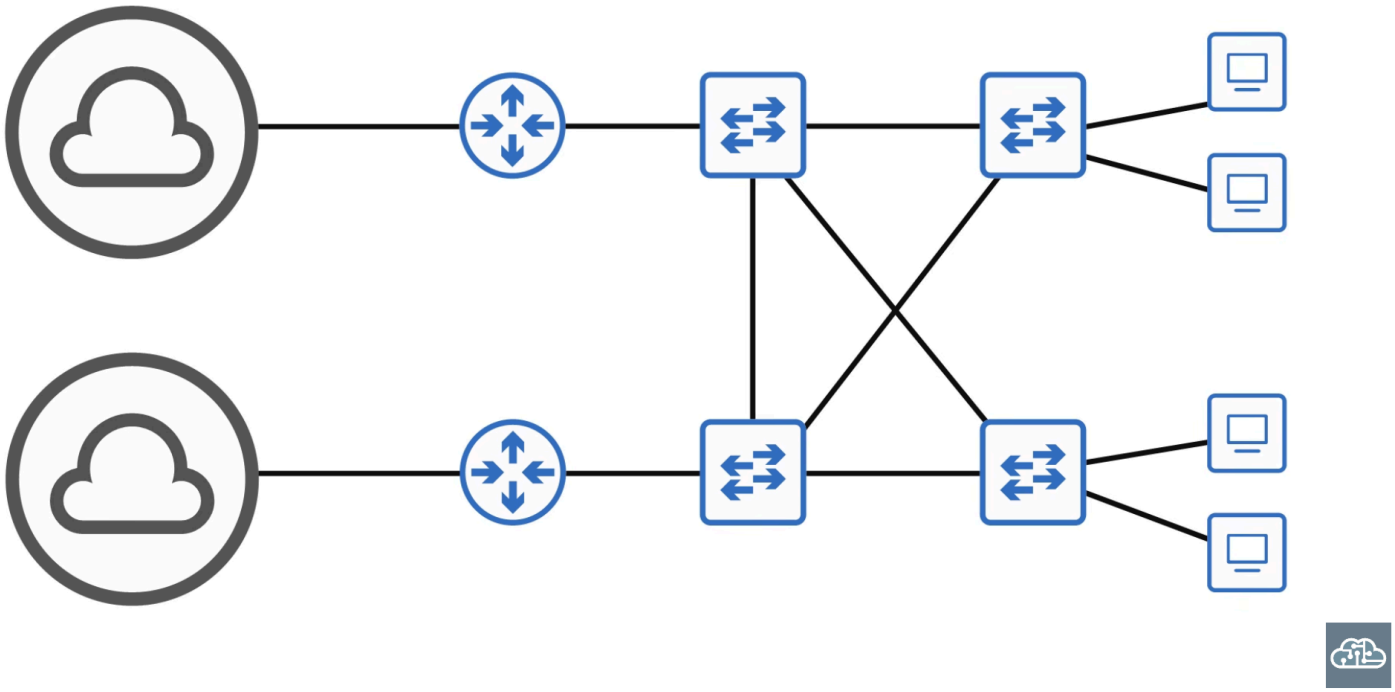
Introduction to First Hop Redundancy Protocols (FHRPs)

- **Exam Topic:** Topic 3.5: "Describe the purpose of first hop redundancy protocol"
- Note: No configuration is required for the exam, but this Lecture includes basic configurations for understanding.
- FHRP is a *type* of protocol, not a specific protocol name. There are three FHRPs to know for the CCNA.

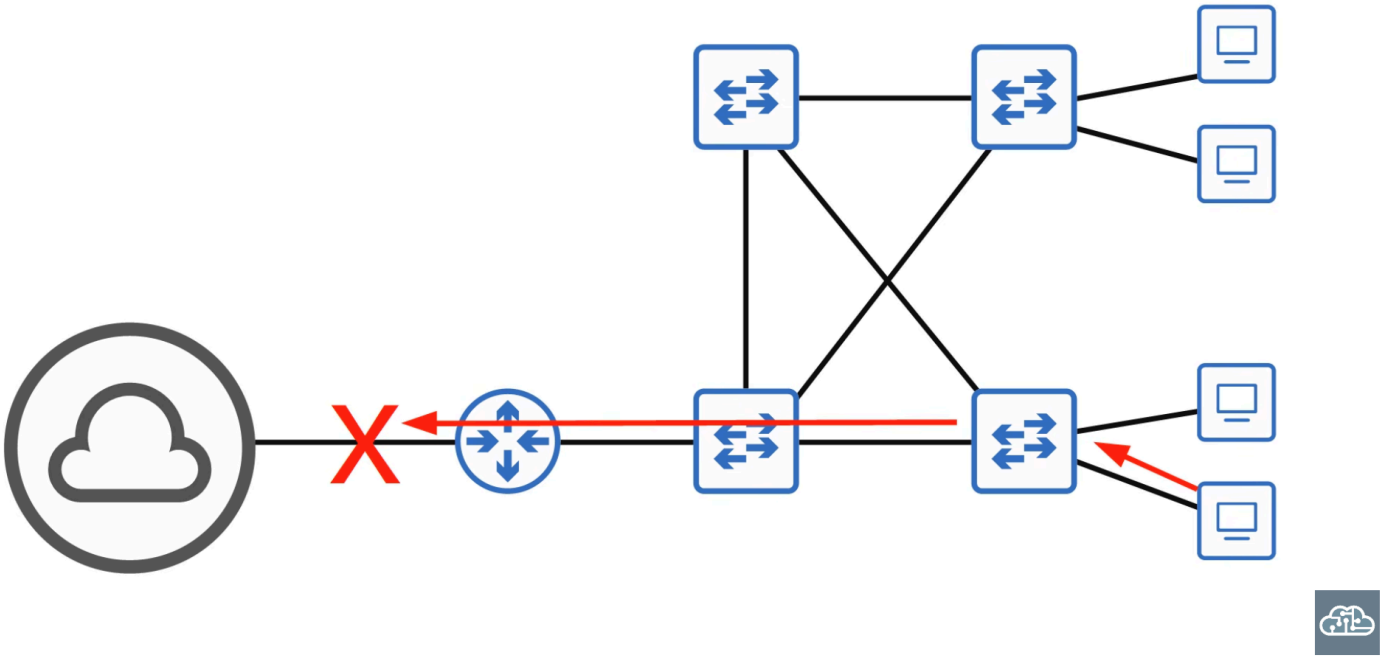
Lecture Outline

- Purpose of FHRPs.
- Introduction to three different FHRPs:
  - HSRP (Hot Standby Router Protocol)
  - VRRP (Virtual Router Redundancy Protocol)
  - GLBP (Gateway Load Balancing Protocol)
- Basic configurations for HSRP.

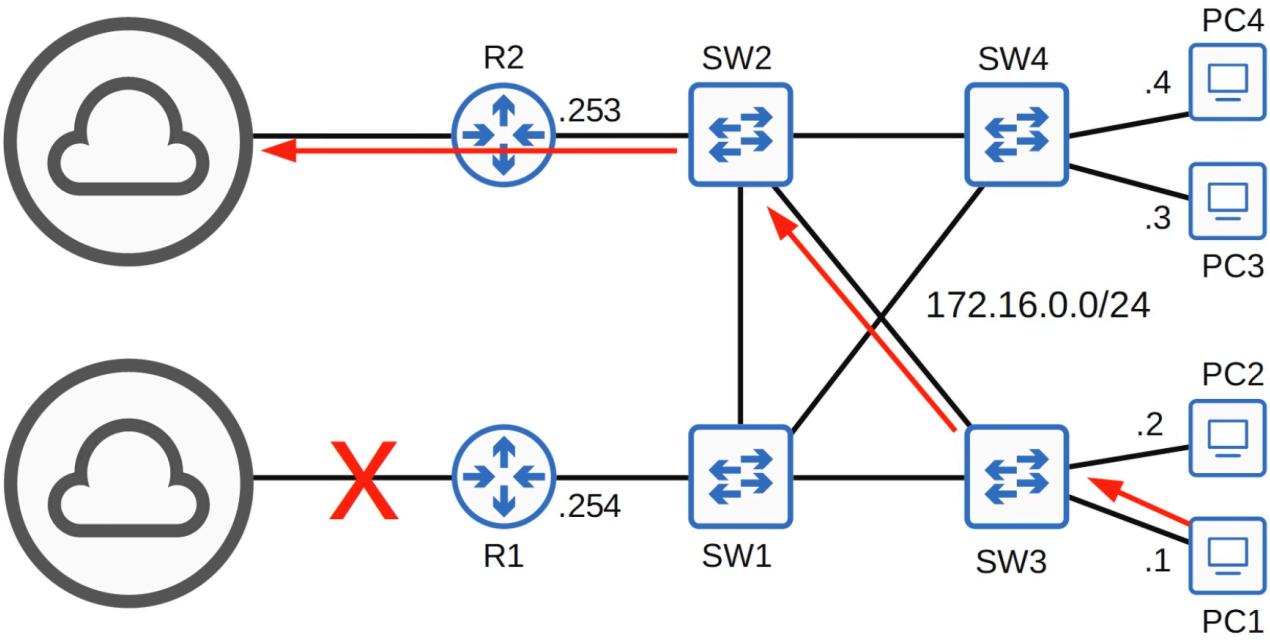
The Purpose of FHRPs



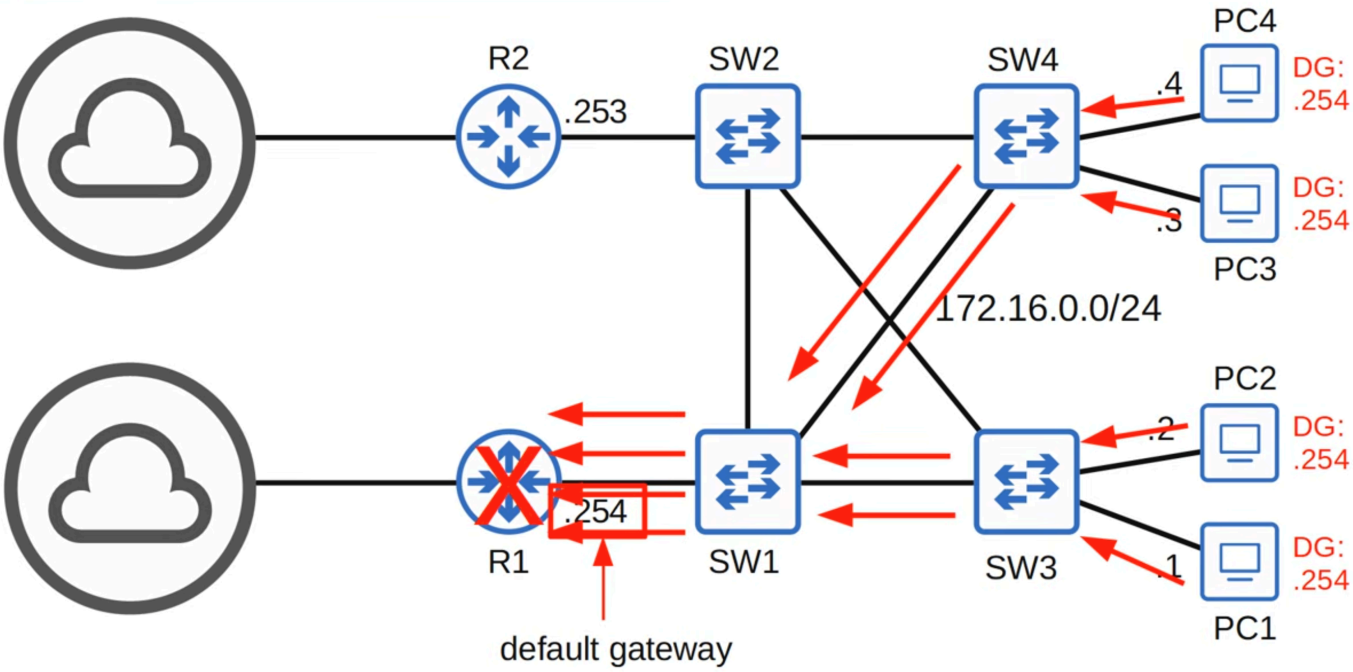
- Redundant connections are important to prevent loss of Internet access, which would be a big problem for modern businesses.



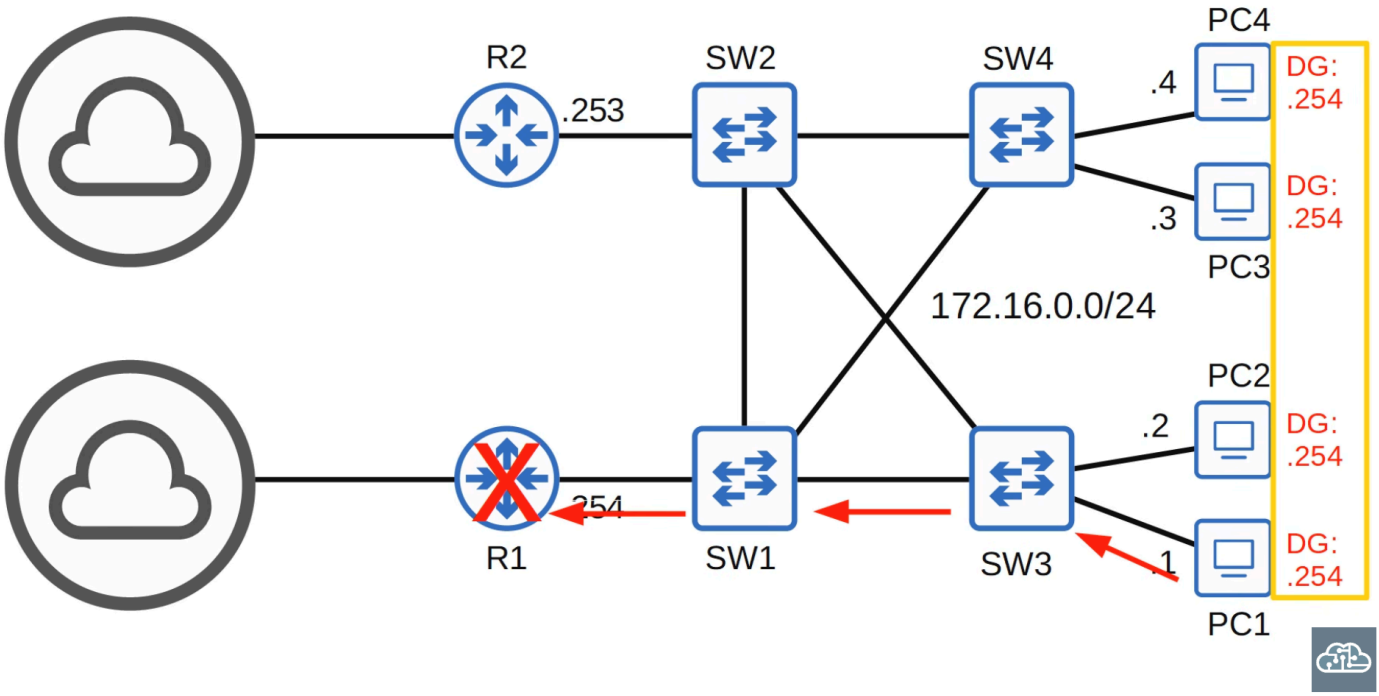
- **Example:** If there is only one connection to the Internet and it fails, the PCs will no longer be able to reach the Internet.



- If this connection fails, using redundant connections allows an alternate path. This could be for example a slower and cheaper connection until the original connection is recovered.



- In a network with a single default gateway (e.g., R1 at 172.16.0.254), if R1 fails, the PCs will lose connectivity even if a backup router (R2) is available.

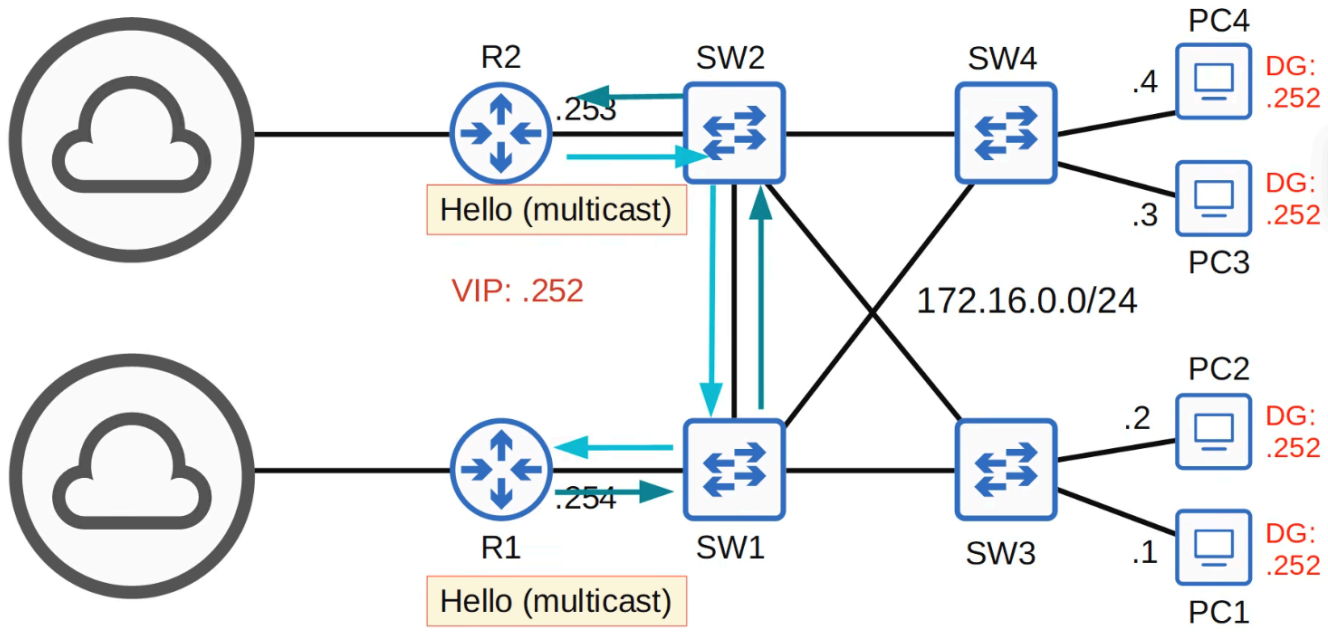


- **The Problem:** The PCs' default gateway is still set to R1's address (.254). They do not know that R1 is down and that they should switch to using R2 as their default gateway.
- **The Role of FHRPs:** To cause a backup router (R2) to automatically become the new default gateway if the primary router (R1) can no longer be used.

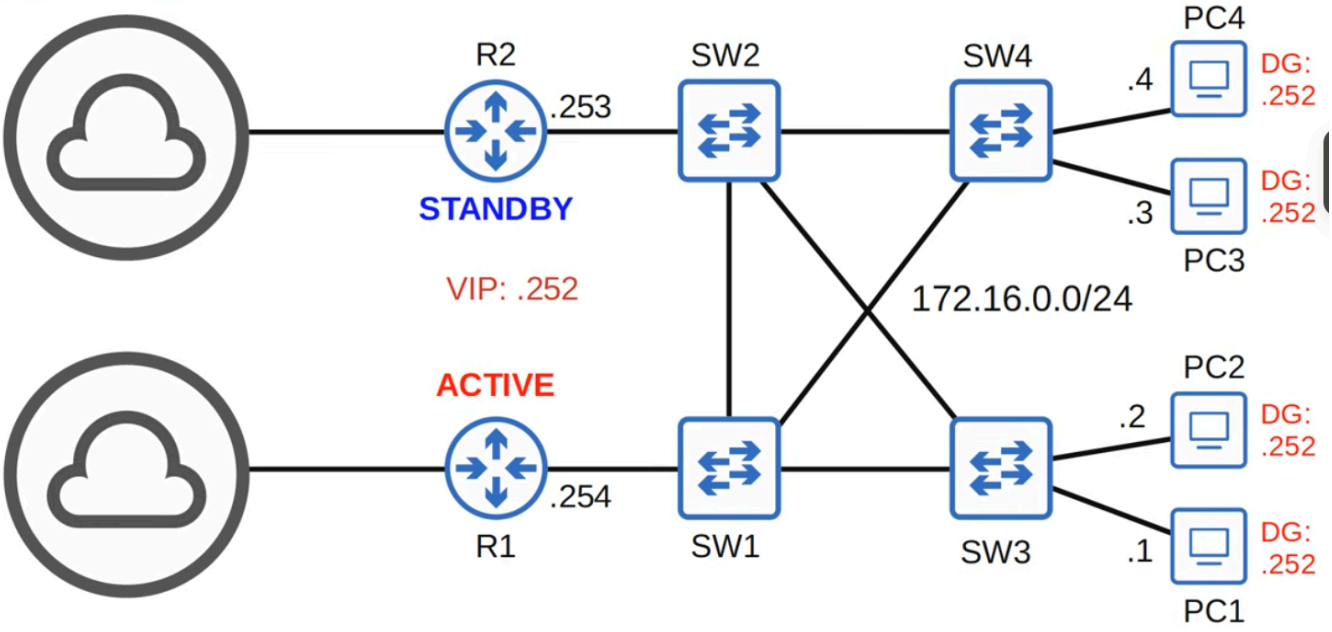
How FHRPs Work

- A first hop redundancy protocol (FHRP) is designed to protect the default gateway used on a subnetwork by allowing two or more routers to provide backup for that address.
- The name "first-hop" redundancy protocol is used because the default gateway is the "first hop", the first router in the path to whatever destination the PC is sending traffic to.

- **Mechanism:**

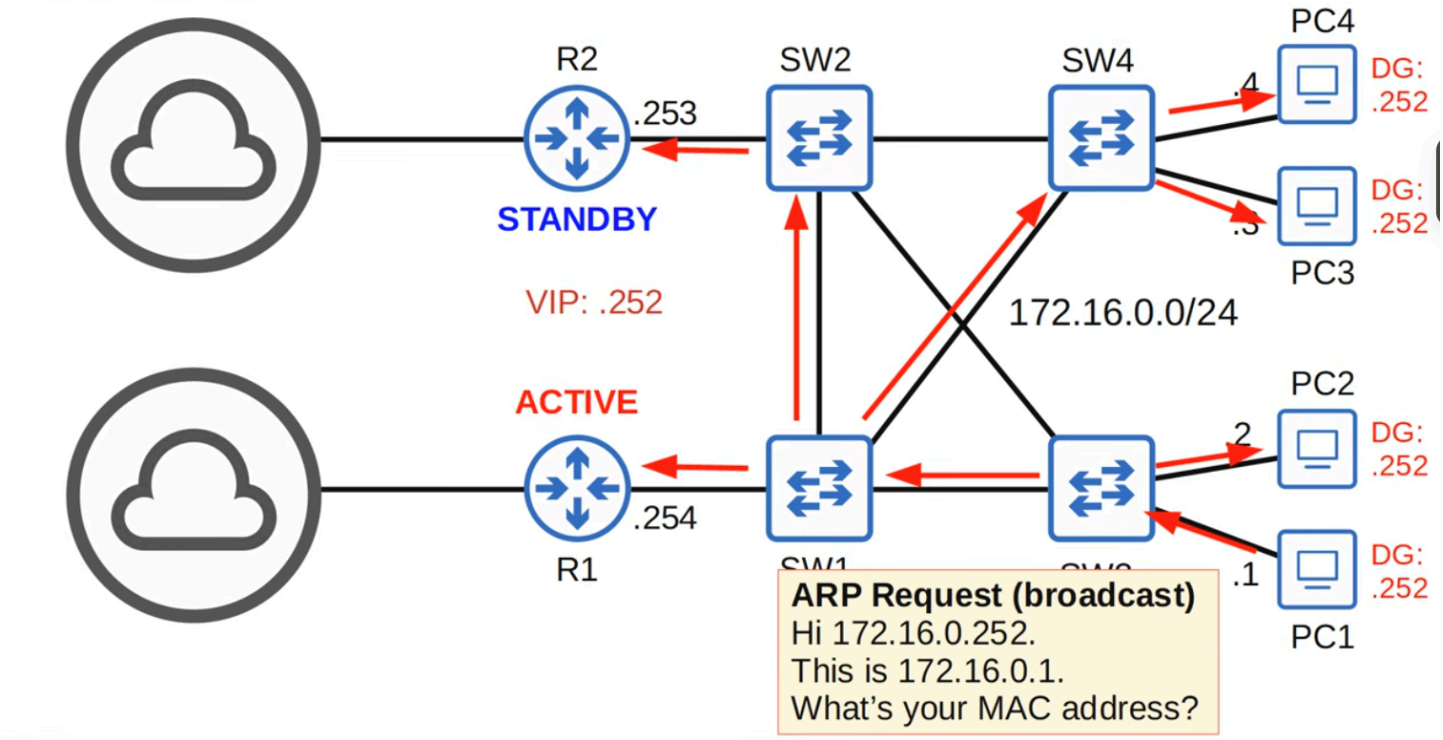


- The two routers share a VIP, a virtual IP address (e.g., 172.16.0.252).
- You configure the PCs in the network to use that virtual IP as their default gateway, instead of the actual IP address of R1.
- The routers negotiate their roles by sending multicast 'Hello' messages to each other.

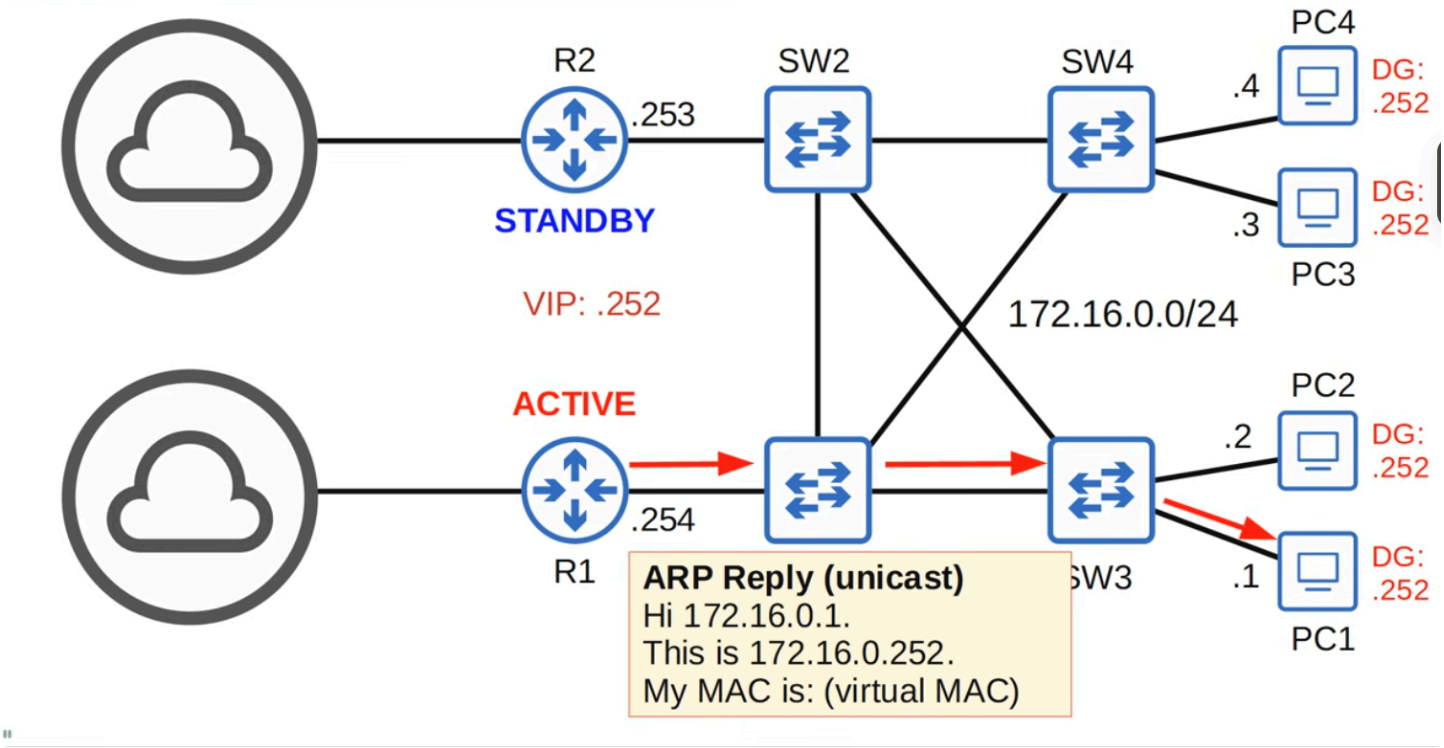


- One router becomes the **active router**, and the other becomes the **standby router**.
    - Note: The actual terms (e.g., active, standby) vary depending on which FHRP is being used.
- The **active router** acts as the default gateway for the network.
- The **standby router** does not function as the default gateway unless the active router fails, at which point it automatically takes over.

FHRP in Action: PC Sending Traffic

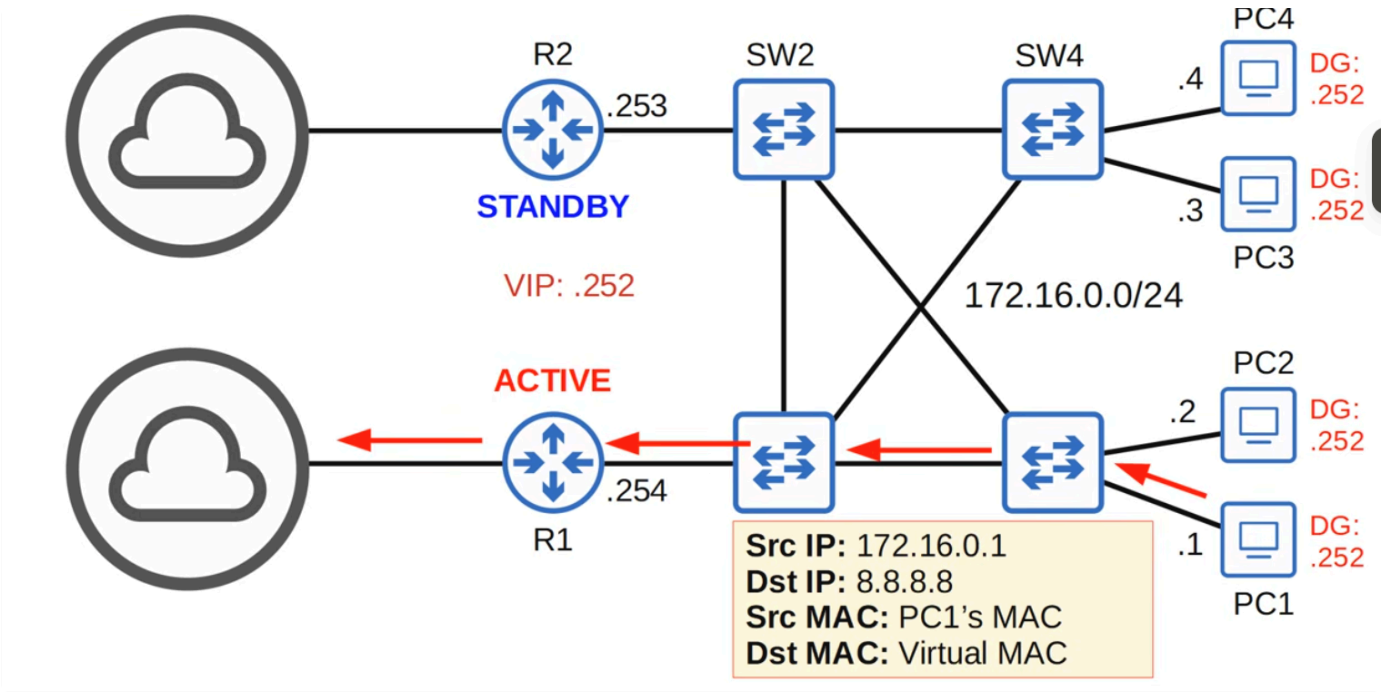


- When a PC (e.g., PC1) needs to send traffic to a destination in another network, it needs to encapsulate the packet in a frame destined for the default gateway.
- To do this, it must know the default gateway's MAC address. It uses ARP (Address Resolution Protocol) to learn the MAC address of the virtual IP address (172.16.0.252).
- **Example:** PC1 sends a broadcast ARP request: "Hi 172.16.0.252. This is 172.16.0.1. What's your MAC address?"



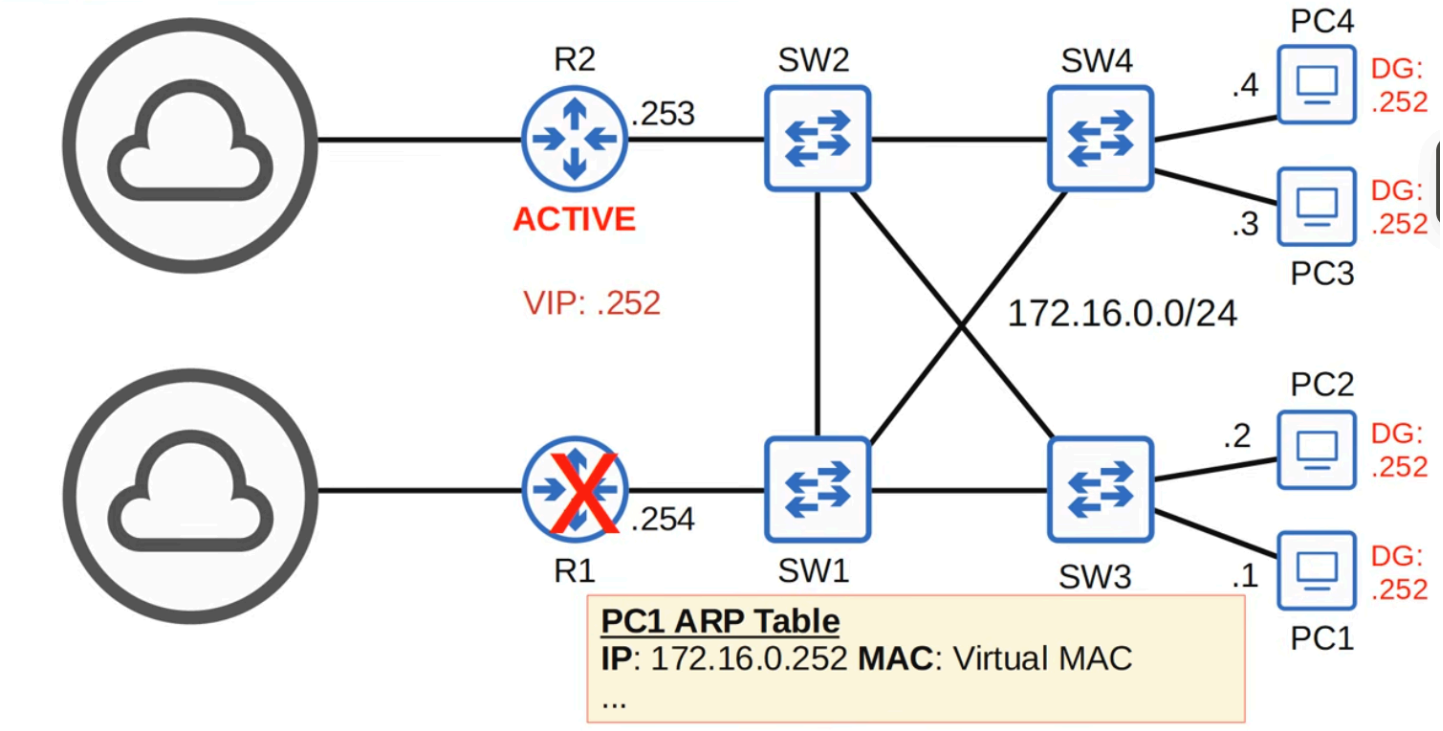
- Both R1 (active) and R2 (standby) receive the ARP request, but only R1 (the active router) sends the ARP reply.
- R1 sends a unicast ARP reply to PC1 with the **virtual MAC address**. (Each FHRP uses a different virtual MAC address format).

- Now, PC1 can send traffic. For example, to send traffic to a Google server at 8.8.8.8:



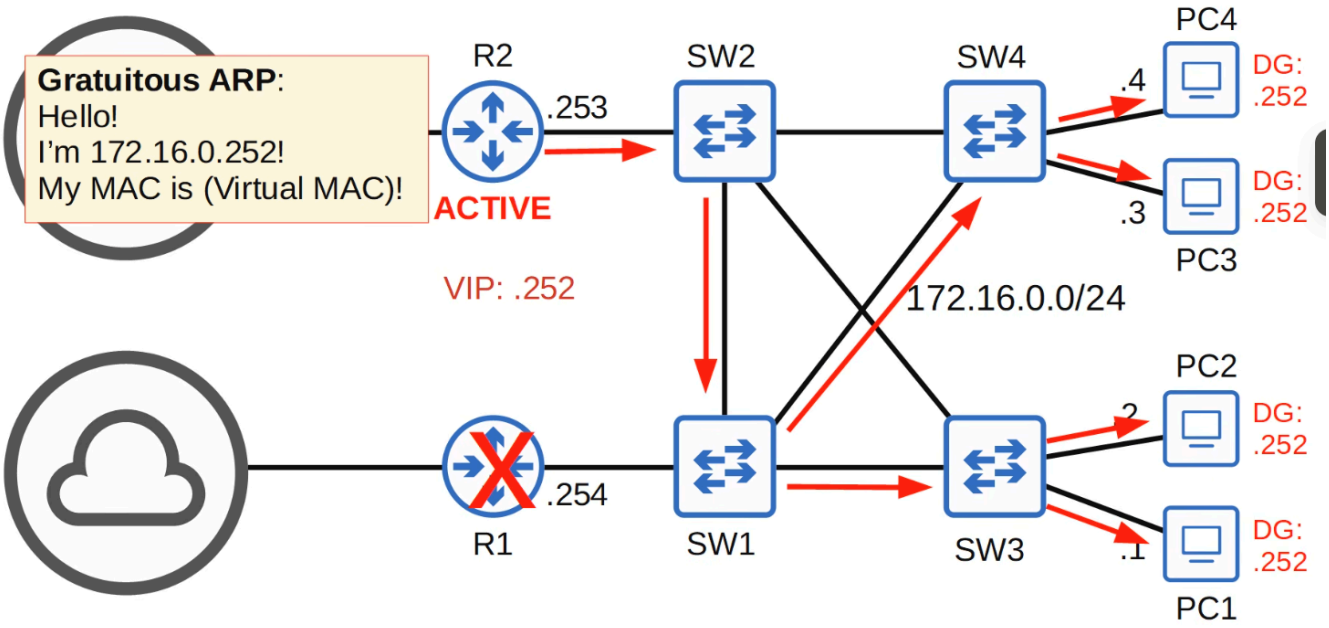
  - Source IP: PC1's IP (172.16.0.1)
  - Destination IP: Google server (8.8.8.8)
  - Source MAC: PC1's MAC address
  - Destination MAC: The FHRP's virtual MAC address
- The frame is sent to R1 (the active router), and then the packet is sent over the Internet.

FHRP in Action: Active Router Failure

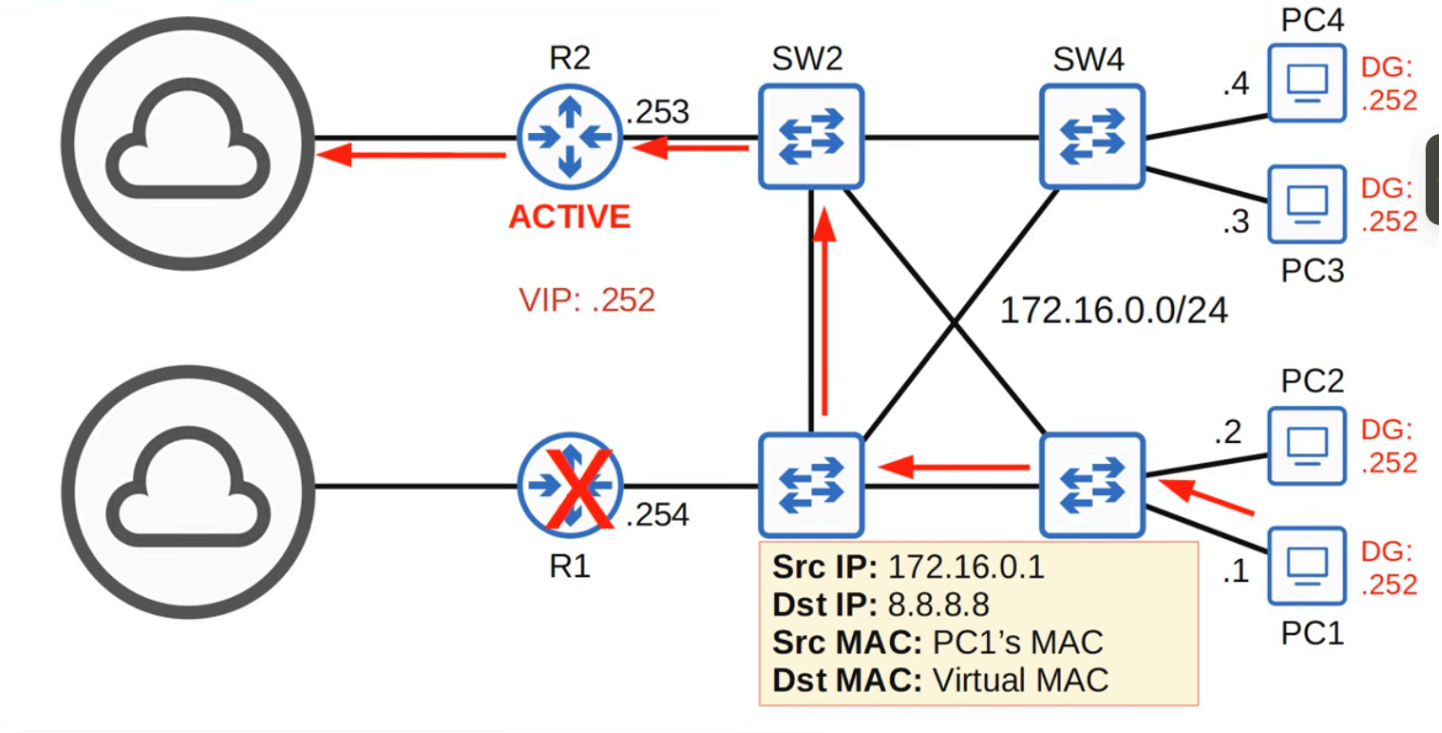


- If the active router (R1) goes down, the standby router (R2) will notice it has not received any 'Hello' messages from R1 and will become the new active router.
- **Updating the Network:** The end hosts (PCs) do not need to change their ARP tables because their ARP entry maps the virtual IP address to the virtual MAC address.
- The switches' MAC address tables need to be updated so that traffic destined for the virtual MAC address is sent to R2 instead of R1.

- **Gratuitous ARP:** The new active router (R2) sends gratuitous ARP replies.

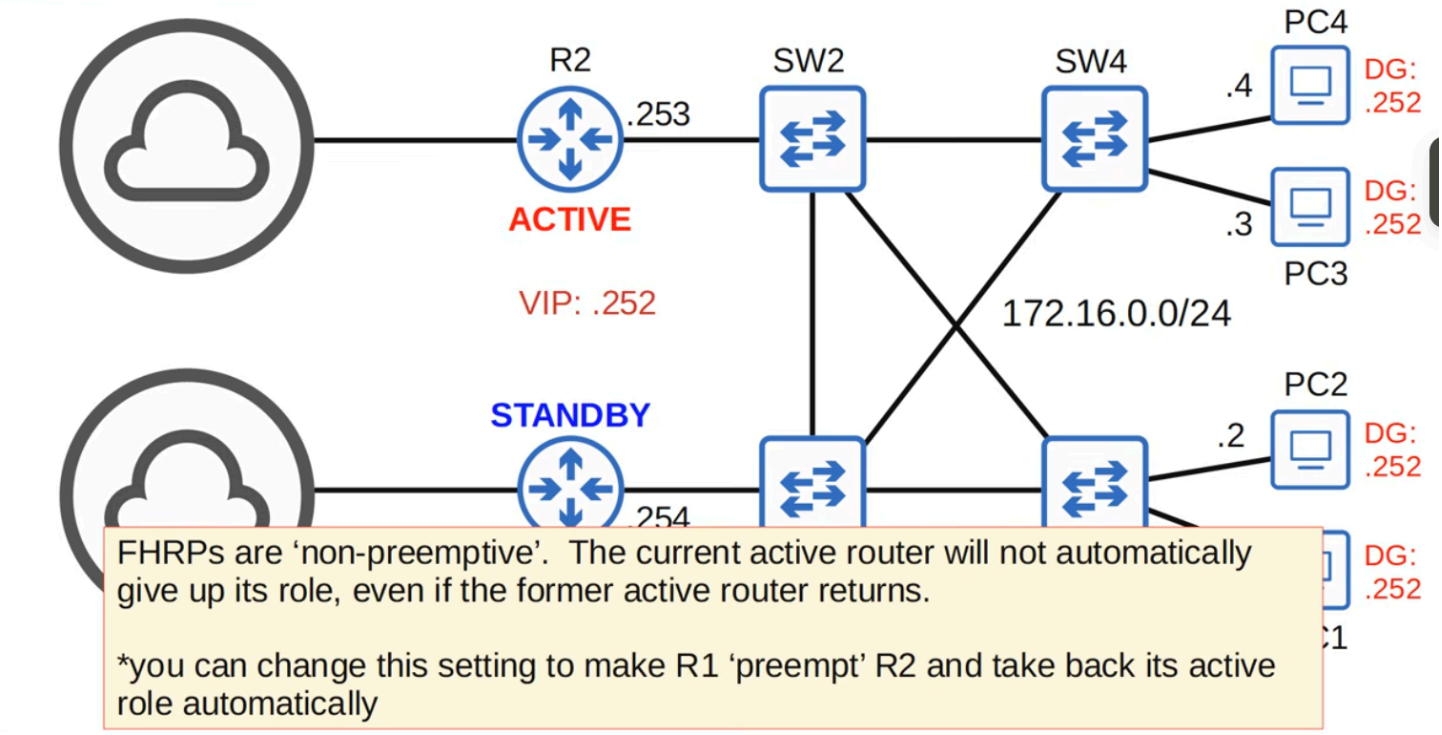


  - These are ARP replies sent without being requested.
  - Unlike normal unicast ARP replies, gratuitous ARP frames are broadcast to the MAC address of all Fs (FF:FF:FF:FF:FF:FF).
  - Because they are broadcast, all switches receive the frames and update their MAC address tables to point to the new active router (R2).
  - Spanning-tree protocol will prevent a broadcast storm.



- Now, when a PC sends traffic, the frame (with the same source and destination IP/MAC addresses as before) will be sent to R2, the new active router.

FHRP in Action: Router Returns



- When the original active router (R1) comes back online, it will **not** automatically take back its role as the active router. It will become the standby router.
- This behavior is "non-preemptive", similar to the DR and BDR in OSPF.
- However, you can configure **preemption** to change this default behavior, allowing the original active router to take back its role automatically.

FHRP General Review

- A virtual IP and a virtual MAC address are used. (Each FHRP uses a different format for the virtual MAC address).
- An active router and a standby router are elected. (Different FHRPs use different terms; some support an "active-active" setup).
- End hosts are configured to use the virtual IP as their default gateway.
- The active router replies to ARP requests using the virtual MAC address and functions as the default gateway.
- If the active router fails, the standby router becomes the new active router.
- The new active router sends gratuitous ARP messages so that switches update their MAC address tables.
- If the old active router comes back online, by default it won't take back its role (non-preemptive). Preemption can be configured to change this.

Overview of Three Major FHRPs

- The functionality of each FHRP is very similar, so this section will be quite brief, but make sure you learn these details for the exam.

HSRP (Hot Standby Router Protocol)

- HSRP is Cisco proprietary, so it only runs on Cisco devices. You can't run it on Juniper routers, for example.
- In HSRP, an **active** and **standby** router are elected. These are the two terms used previously, but the next FHRP uses different terms.

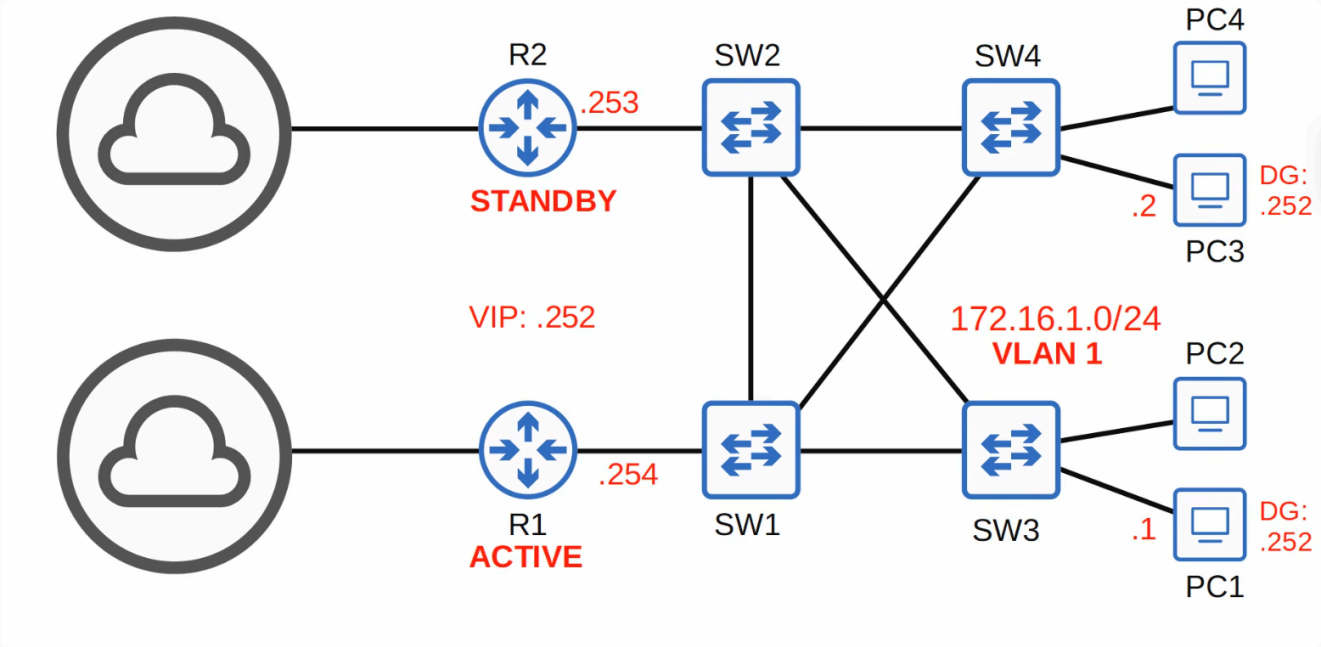
- **Versions:**
  - There are two versions of HSRP, version 1 and version 2.
  - Version 2 adds IPv6 support, and increases the number of 'groups' that can be configured.
- **Groups:**
  - In situations with multiple subnets and VLANs, you'll need to configure a virtual IP address for each subnet, because each subnet needs its own default gateway.
  - Each of those virtual IPs is configured in a separate HSRP group.
- **Multicast Hello Addresses:**
  - Routers communicate with each other by sending multicast hello messages.
  - **Version 1:** 224.0.0.2
  - **Version 2:** 224.0.0.102
- **Virtual MAC Address Formats:**
  - **Version 1:** 0000 0c07 acXX (where XX is the group number).
    - *Example:* If using HSRP version 1 and the group number is 1, the virtual MAC address would be 0000 0c07 ac01.
  - **Version 2:** 0000 0c9F Fxxx (where xxx is the group number).
    - Version 2 uses 3 hexadecimal digits for the group number instead of 2, allowing for more groups.
    - *Example:* If group number 1 is used in HSRP version 2, the virtual MAC address would be 0000 0c9f f001.

- **Load Balancing:**
  - In a situation with multiple subnets/VLANs, you can configure a different active router in each subnet to load balance.
  - This is similar to configuring a different root bridge in each VLAN so traffic is load balanced over the switches.
  - When you configure multiple HSRP groups (one for each subnet/VLAN), you can configure a different active router in each.
  - *Example:* R1 could be the active router in VLAN1 and standby in VLAN2, and R2 could be the standby in VLAN1 and active in VLAN2.

Load Balancing with Multiple HSRP Groups

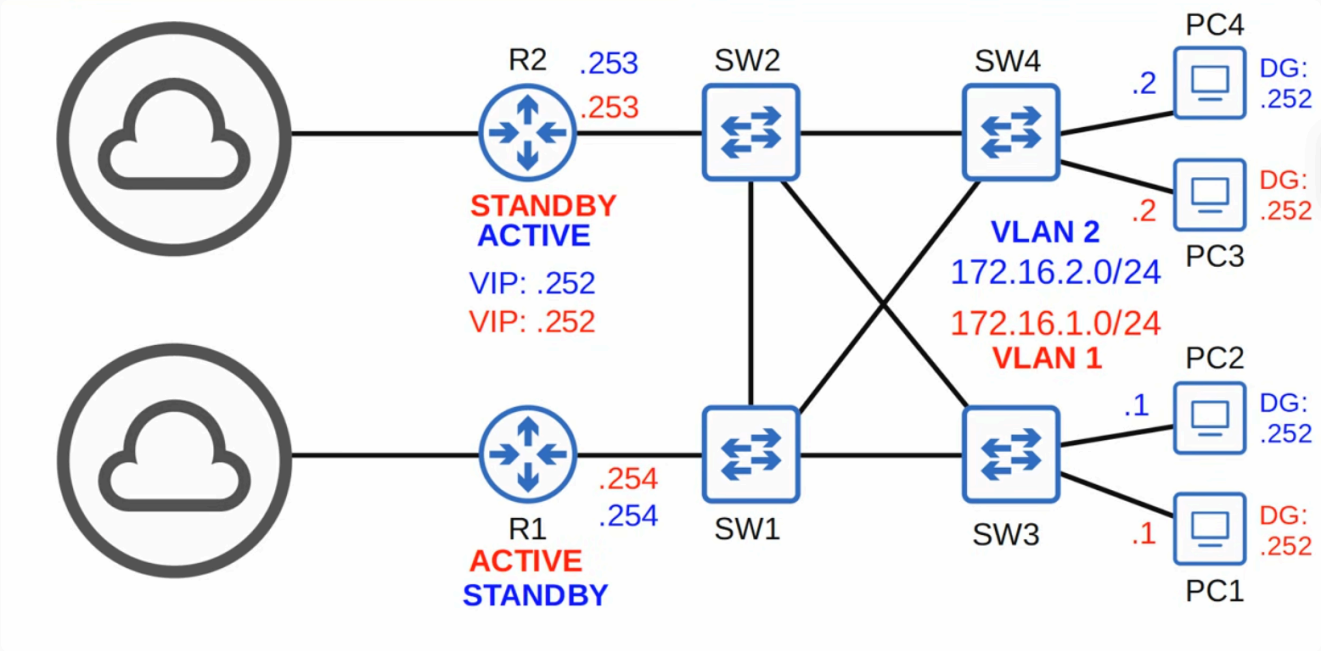
- This is probably beyond what you need to know for the CCNA, but this demonstrates the concept.

- **Example:**
  - **VLAN1:**

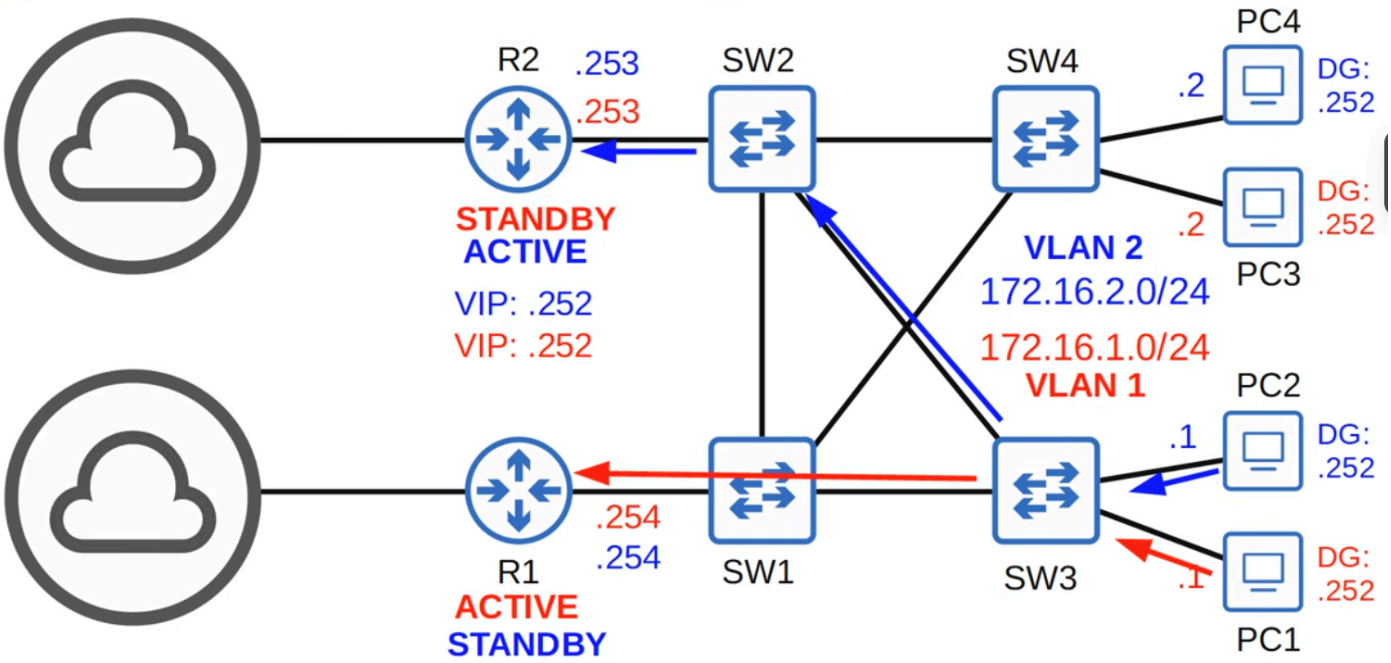


  - VLAN1 is assigned to hosts in the 172.16.1.0/24 subnet. PC1 and PC3 are in VLAN1.
  - R1 and R2 have their own IP addresses in VLAN1, but they also share the virtual IP 172.16.1.252, which is used as the default gateway of the subnet.
  - R1 is the active router and R2 is the standby router.

- **VLAN2:**



  - 172.16.2.0/24 is the subnet for VLAN2. PC2 and PC4 are in VLAN2.
  - R1 and R2 have their own IP addresses in VLAN2, connecting to the switches using 'router-on-a-stick'.
  - They also share the virtual IP address 172.16.2.252, which is used as the default gateway for the subnet.
  - R2 is the active router and R1 is the standby router.



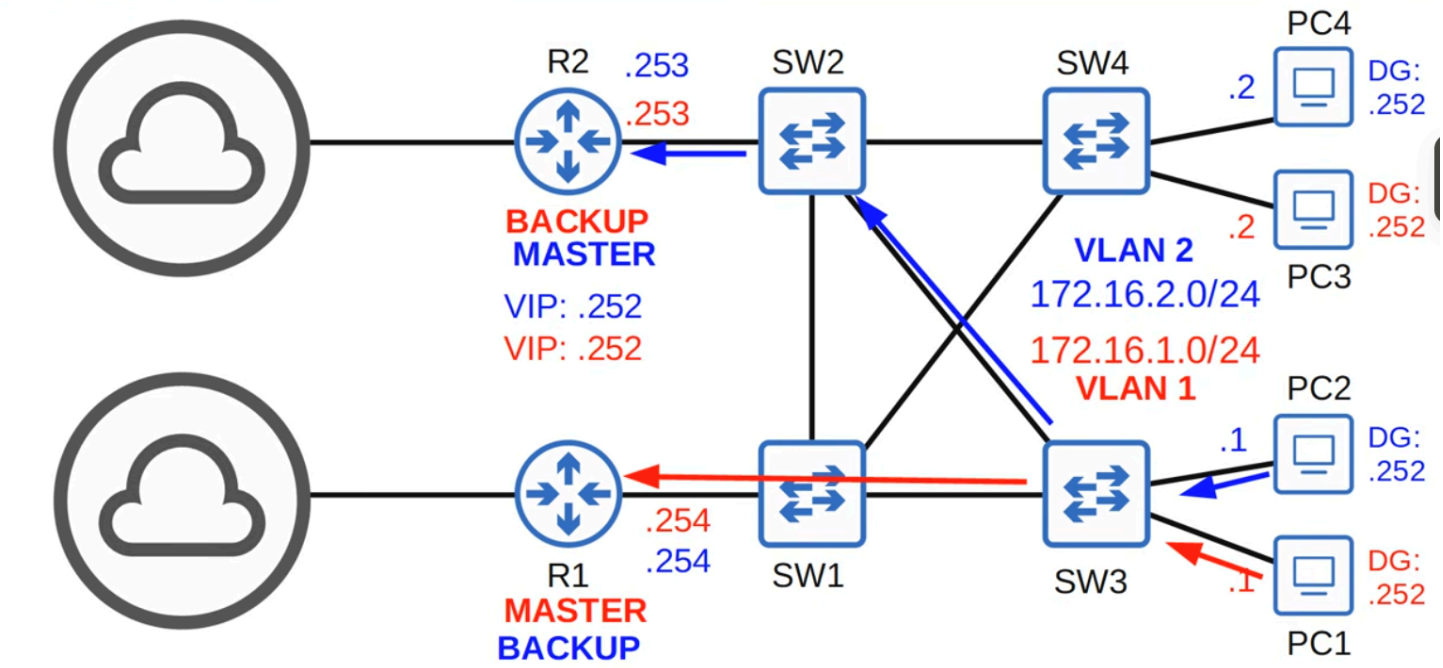
- Now traffic can be load balanced over the two paths: VLAN1 using R1 and VLAN2 using R2 as the default gateway, and each subnet has a standby router waiting if the active router fails.
- So, that's a basic overview of HSRP. Although it can't load balance within a single subnet, you can configure a different active router in each subnet so that traffic is load balanced between the routers.

VRRP (Virtual Router Redundancy Protocol)

- **General:**
  - Unlike HSRP, VRRP is an open standard, so it can be run on devices from any maker. Cisco routers run it too.
  - In terms of functionality, VRRP and HSRP are nearly identical, with just a few differences.
- **Roles:**
  - Instead of an active and standby router, a **master** and **backup** router are elected.
  - The function is the same, just the names are different.
  - **Master** is equivalent to HSRP's active, and **backup** is equivalent to HSRP's standby.

- **Multicast Hello Address:**
  - The IPv4 multicast address used is 224.0.0.18.
- **Virtual MAC Address Format:**
  - 0000 5e00 01XX (where XX is the VRRP group number).
  - *Example:* If VRRP group 200 is configured, the virtual MAC address would be 0000 5e00 01c8. Hexadecimal c8 is equal to 200 in decimal.
- **Load Balancing:**
  - Just like HSRP, although VRRP can't perform load-balancing for hosts in a single subnet, it can load balance between different subnets by configuring a different master router in each subnet.
  - *Example:* Here's the same diagram as before, showing load-balancing between the two subnets. All that's different is that 'master' and 'backup' are used instead of 'active' and 'standby'.

Additional Point: Subnets and VLANs



- Before moving on, one point separate from FHRPs.

- Notice that all hosts in VLAN1 are in the same subnet, 172.16.1.0/24, and all hosts in VLAN2 are in the same subnet, 172.16.2.0/24.
- This is how subnets and VLANs are used. Subnets divide the network at Layer 3, and VLANs divide the network at Layer 2, and they work together, each subnet being its own VLAN.

HSRP vs. VRRP Comparison

FHRP	Terminology	Multicast IP	Virtual MAC	Cisco proprietary?
HSRP	Active/Standby	v1: 224.0.0.2 v2: 224.0.0.102	v1: 0000.0c07.acXX v2: 0000.0c9f.fXXX	Yes
VRRP	Master/Backup	224.0.0.18	0000.5e00.01XX	No
GLBP				

- Before moving on to the last FHRP, here's a comparison chart of HSRP and VRRP.
- In terms of functionality, they're nearly the same.
- But remember the different terminology, multicast IP addresses, and virtual MAC addresses.
- Also remember that HSRP is Cisco proprietary, whereas VRRP is an open standard that can run on any network device that supports it.

GLBP (Gateway Load Balancing Protocol)

- **General:**
  - The final FHRP you should be aware of is GLBP, Gateway Load Balancing Protocol. This one is a bit different than HSRP and VRRP.
  - Like HSRP, it is Cisco proprietary, it only runs on Cisco devices.
  - **Big Difference:** It load balances among multiple routers within a single subnet.
    - *Example:* If PC1 and PC2 are both in VLAN1, PC1 can use R1 as its default gateway, and PC2 can use R2 as its default gateway.
    - This is different than HSRP and VRRP, in which all hosts in the same subnet must use the same router as the default gateway for the subnet.
- **Mechanism:**
  - A single **AVG (Active Virtual Gateway)** is elected for the subnet.
  - Then, up to four **AVFs (Active Virtual Forwarders)** are assigned by the AVG, and the AVG itself can be an AVF also.
  - Each AVF acts as the default gateway for a portion of the hosts in the subnet.
  - So, load balancing is achieved within a single subnet.
- **Multicast Hello Address:**
  - The multicast IPv4 address is 224.0.0.102, same as HSRP version 2.
- **Virtual MAC Address Format:**
  - The format is 0007 b400, followed by the GLBP group number and the AVF number.
  - *Example:* What is the virtual MAC address of AVF number 1 in GLBP group 1? It's 0007 b400 0101.
- **Exam Focus:**
  - So, the functions of GLBP are a bit more complicated than HSRP and VRRP, but for the purposes of the CCNA remember that GLBP allows multiple active routers to load balance traffic within a single subnet, and remember the multicast IP address and the virtual MAC address format.

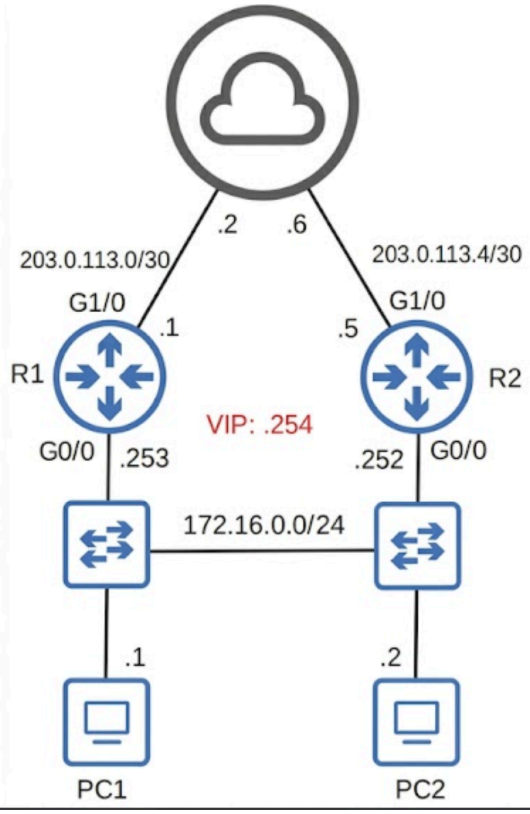
HSRP vs. VRRP vs. GLBP Comparison

FHRP	Terminology	Multicast IP	Virtual MAC	Cisco proprietary?
HSRP	Active/Standby	v1: 224.0.0.2 v2: 224.0.0.102	v1: 0000.0c07.acXX v2: 0000.0c9f.fXXX	Yes
VRRP	Master/Backup	224.0.0.18	0000.5e00.01XX	No
GLBP	AVG / AVF	224.0.0.102	0007.b400.XXYY	Yes

- Here's the comparison chart with GLBP filled in.
- If you remember the basic characteristics of HSRP, VRRP, and GLBP, and memorize the information in this chart, you'll be ready to answer any questions about FHRPs on the CCNA exam.

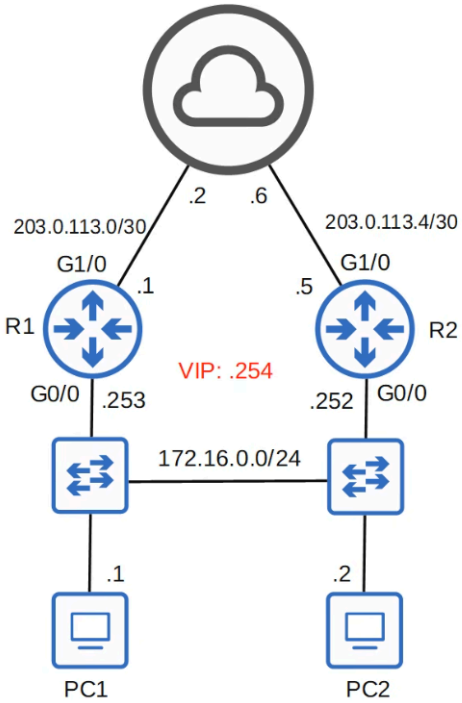
Introduction to HSRP Configuration

- **Exam Note:** Configuring HSRP isn't part of the CCNA exam topics, but hands-on experience helps understanding.



- **Network Setup:**
  - Simplified network for CLI demonstration.
  - Focus: Configuring R1 and R2 to provide a redundant default gateway for the 172.16.0.0/24 subnet.
  - Interface IP addresses are already configured.
  - Virtual IP used: .254 (172.16.0.254).

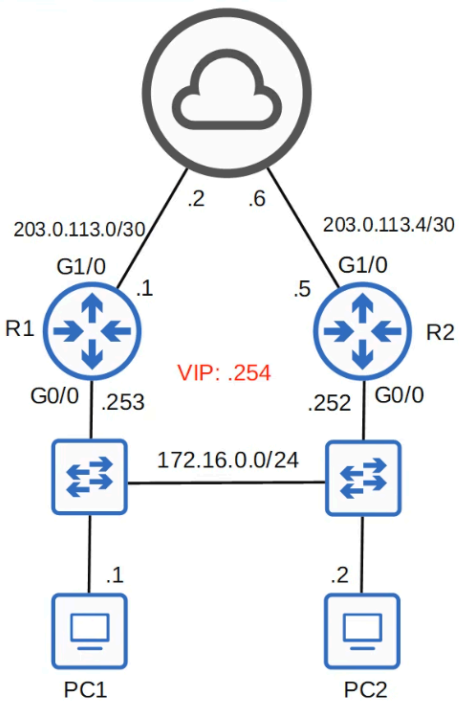
Configuring R1




```
R1(config)#interface g0/0
R1(config-if)#standby ?
  <0-255>          group number
  authentication   Authentication
  bfd              Enable HSRP BFD
```

- HSRP is configured directly on the interface (G0/0).
- **Note:** Must configure on the correct interface — the one connected to the network it is acting as the default gateway for.
- HSRP is configured with the `standby` command.
- **Group Number:** HSRP version 1 is the default, with group range 0–255. HSRP version 2 has group range 0–4095.

Enabling HSRP Version 2



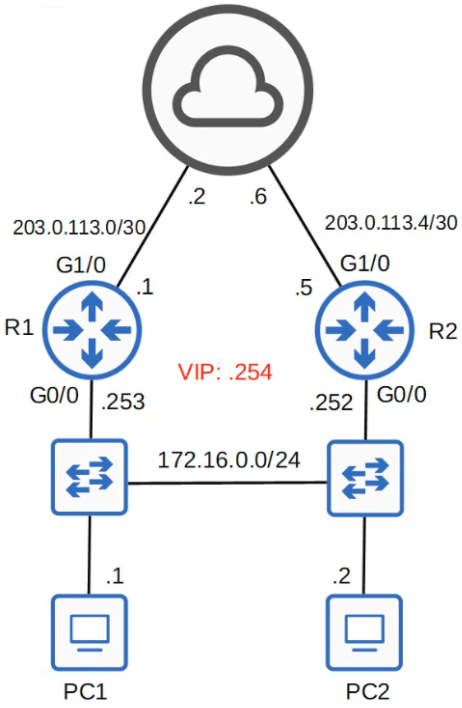

```
R1(config)#interface g0/0
R1(config-if)#standby ?
  <0-255>          group number
  authentication   Authentication
  bfd              Enable HSRP BFD
```

```
R1(config-if)#standby version 2
R1(config-if)#standby ?
  <0-4095>         group number
  authentication   Authentication
```

```
R1(config-if)# standby version 2
```

- After enabling, the group number range changes to 0–4095.

Setting the Group Number




```
R1(config)#interface g0/0
R1(config-if)#standby ?
  <0-255>         group number
  authentication  Authentication
  bfd             Enable HSRP BFD
```

```
R1(config-if)#standby version 2
R1(config-if)#standby ?
  <0-4095>        group number
  authentication  Authentication
```

```
R1(config-if)#standby 1 ?
  authentication  Authentication
  follow          Name of HSRP group to follow
  ip              Enable HSRP IPv4 and set the virtual IP address
  ipv6            Enable HSRP IPv6
  mac-address     Virtual MAC address
  name            Redundancy name string
  preempt         Overthrow lower priority Active routers
  priority        Priority level
  timers          Hello and hold timers
  track           Priority tracking
```

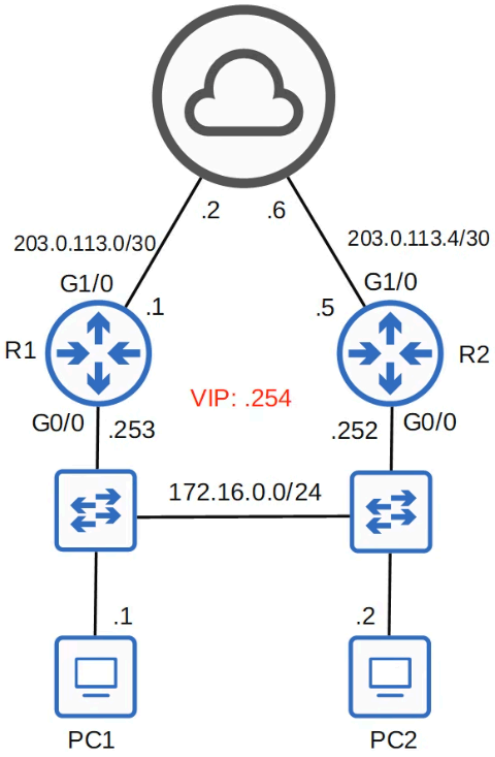
- Group number 1 was chosen to match VLAN1 (not a rule, but a preference).
- **Important:** The group number must match between the two routers.

Configuring Virtual IP, Priority, and Preemption

```
R1(config-if)#standby 1 ?
  authentication  Authentication
  follow          Name of HSRP group to follow
  ip              Enable HSRP IPv4 and set the virtual IP address
  ipv6            Enable HSRP IPv6
  mac-address     Virtual MAC address
  name            Redundancy name string
  preempt         Overthrow lower priority Active routers
  priority        Priority level
  timers          Hello and hold timers
  track           Priority tracking
```

- Three key options: IP, PREEMPT, and PRIORITY.

Virtual IP Configuration

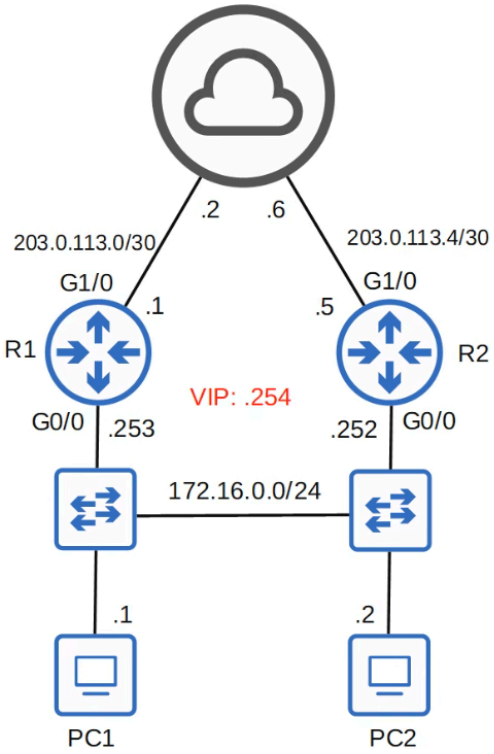



```
R1(config-if)#standby 1 ip 172.16.0.254
R1(config-if)#
R1(config-if)#standby 1 priority ?
  <0-255>  Priority value

R1(config-if)#standby 1 priority 200
R1(config-if)#
R1(config-if)#standby 1 preempt
R1(config-if)#
```

```
R1(config-if)# standby 1 ip 172.16.0.254
```

- Configures the virtual IP address used as the default gateway.

Priority Configuration



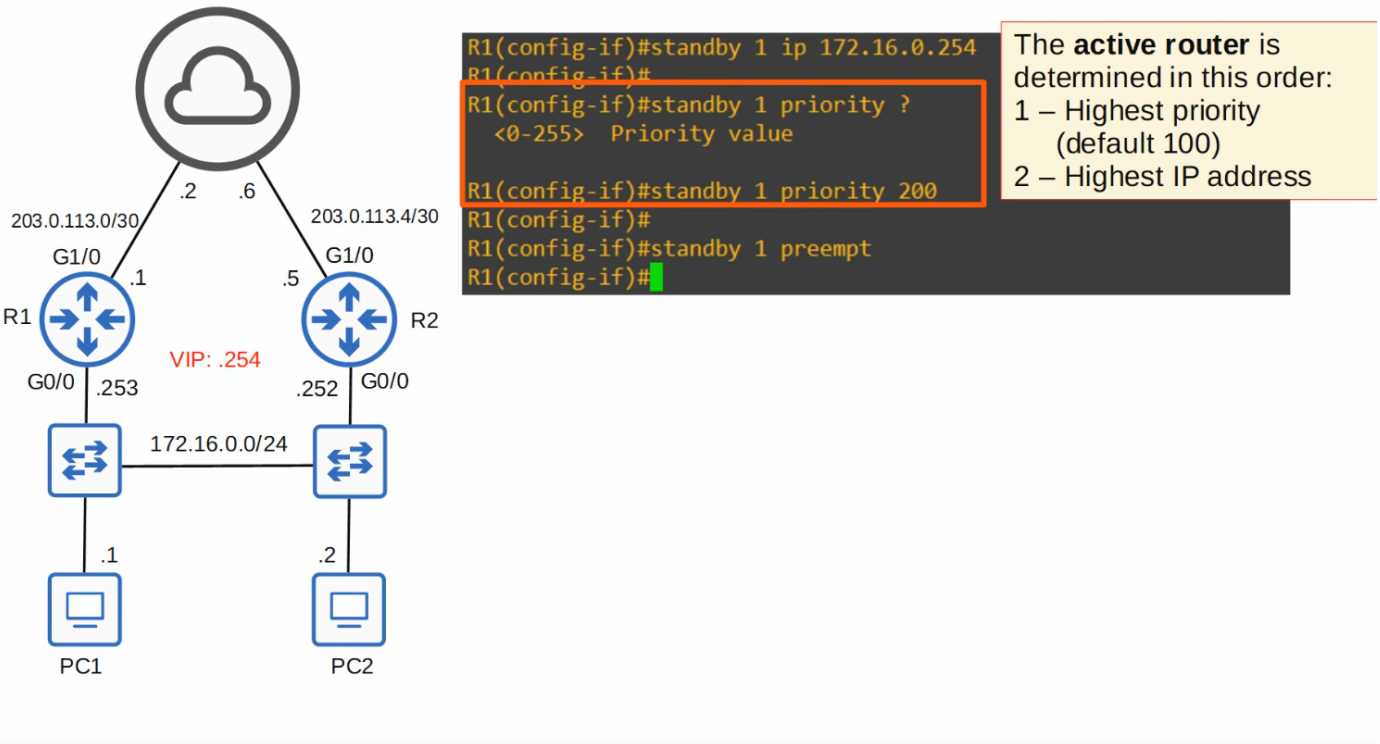

```
R1(config-if)#standby 1 ip 172.16.0.254
R1(config-if)#
R1(config-if)#standby 1 priority ?
  <0-255>  Priority value

R1(config-if)#standby 1 priority 200
R1(config-if)#
R1(config-if)#standby 1 preempt
R1(config-if)#
```

- Using the PRIORITY command, the range is 0 to 255, and R1's priority to 200.

```
R1(config-if)# standby 1 priority 200
```

- What does priority do? It's used to determine which router will be the active router.

- **The active router is determined in this order:**



1. Highest HSRP priority.
2. If equal priority, highest IP address.

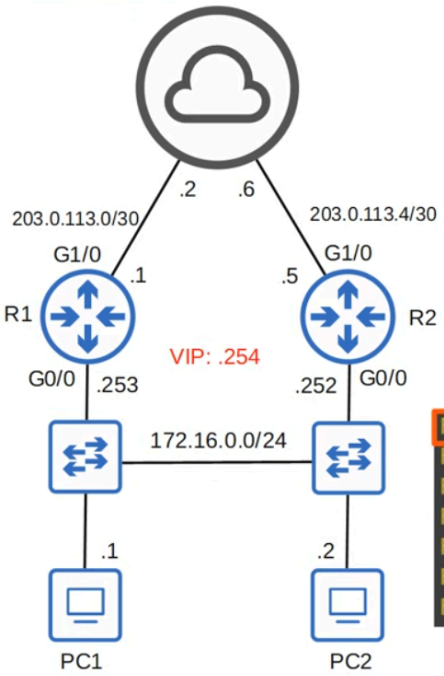
- *Example:* R1's IP (172.16.0.253) is higher than R2's IP (172.16.0.252). Even without configuring priority, R1 would still become active, but priority was configured anyway.

Preemption Configuration

```
R1(config-if)# standby 1 preempt
```

- Enables the router to reclaim the active role if it has a higher priority or IP address.
- *Example:* R1 is active, R2 is standby. R1 restarts → R2 becomes active. R1 comes back online → with preemption enabled, R1 takes back the active role due to higher priority.
- **Note:** Only need to configure preemption on the router intended to be active.

Configuring R2



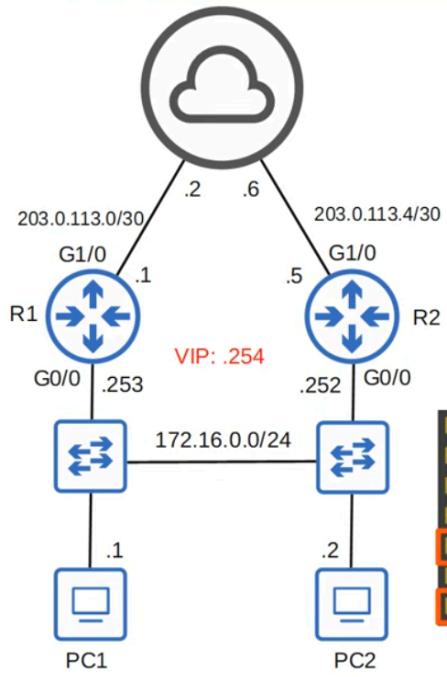

```
R1(config-if)#standby 1 ip 172.16.0.254
R1(config-if)#
R1(config-if)#standby 1 priority ?
  <0-255>  Priority value

R1(config-if)#standby 1 priority 200
R1(config-if)#
R1(config-if)#standby 1 preempt
R1(config-if)#
```

```
R2(config-if)#standby version 2
R2(config-if)#
R2(config-if)#standby 1 ip 172.16.0.254
R2(config-if)#
R2(config-if)#standby 1 priority 50
R2(config-if)#
R2(config-if)#standby 1 preempt
```

HSRP version 1 and version 2 are not compatible.
If R1 uses version 2, R2 must use version 2 also.

- **Important:** HSRP version 1 and version 2 are not compatible. If R1 uses version 2, R2 must also use version 2.

```
R2(config-if)# standby version 2
```




```
R1(config-if)#standby 1 ip 172.16.0.254
R1(config-if)#
R1(config-if)#standby 1 priority ?
  <0-255>  Priority value

R1(config-if)#standby 1 priority 200
R1(config-if)#
R1(config-if)#standby 1 preempt
R1(config-if)#
```

```
R2(config-if)#standby version 2
R2(config-if)#
R2(config-if)#standby 1 ip 172.16.0.254
R2(config-if)#
R2(config-if)#standby 1 priority 50
R2(config-if)#
R2(config-if)#standby 1 preempt
```

HSRP version 1 and version 2 are not compatible.
If R1 uses version 2, R2 must use version 2 also.

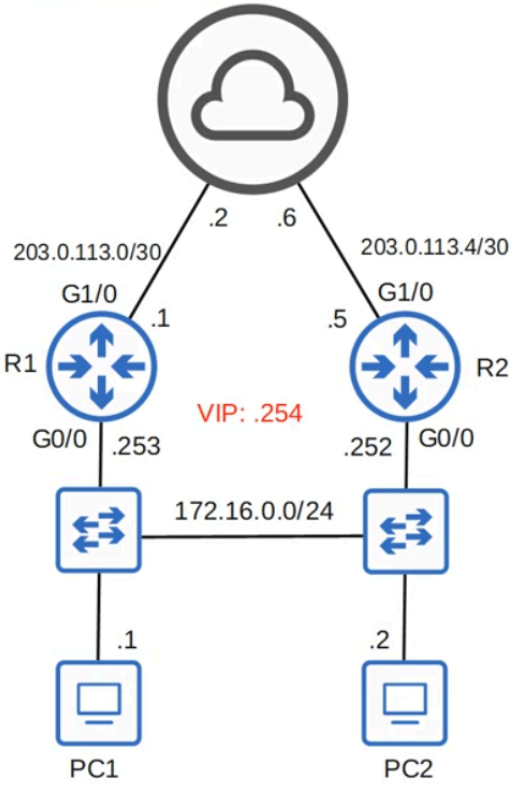
```
R2(config-if)# standby 1 ip 172.16.0.254
```

- Configure the same virtual IP as on R1.
- The next two commands, setting the priority and preemption, are actually unnecessary:
  - **Priority:** R1 already has a higher priority (200) than R2 (50). Since R1 is intended to be the active router, R2's lower priority doesn't need to be explicitly set — R2 will naturally become the standby router because its default priority (100) is already lower than R1's configured priority (200).
  - **Preemption:** Preemption doesn't need to be enabled on the standby router. Preemption is only useful on the router that you want to reclaim the active role. Since R2 is intended to be the standby router, there's no scenario where R2 needs to preempt R1.
- However, the commands were configured anyway so the configuration is consistent between the two routers, but it doesn't really matter.

```
R2(config-if)# standby 1 priority 50
R2(config-if)# standby 1 preempt
```

Verification

```
R1# show standby
```




```
R1#show standby
GigabitEthernet0/0 - Group 1 (version 2)
  State is Active
    2 state changes, last state change 00:16:30
  Virtual IP address is 172.16.0.254
  Active virtual MAC address is 0000.0c9f.f001
    Local virtual MAC address is 0000.0c9f.f001 (v2 default)
  Hello time 3 sec, hold time 10 sec
    Next hello sent in 1.536 secs
  Preemption enabled
  Active router is local
  Standby router is 172.16.0.252, priority 50 (expires in 9.280 sec)
  Priority 200 (configured 200)
  Group name is "hsrp-Gi0/0-1" (default)
R1#
```

```
R2#show standby
GigabitEthernet0/0 - Group 1 (version 2)
  State is Standby
    1 state change, last state change 00:17:05
  Virtual IP address is 172.16.0.254
  Active virtual MAC address is 0000.0c9f.f001
    Local virtual MAC address is 0000.0c9f.f001 (v2 default)
  Hello time 3 sec, hold time 10 sec
    Next hello sent in 1.472 secs
  Preemption enabled
  Active router is 172.16.0.253, priority 200 (expires in 10.160 sec)
    MAC address is 0c9f.6041.8800
  Standby router is local
  Priority 50 (configured 50)
  Group name is "hsrp-Gi0/0-1" (default)
R2#
```

- **Output Details (R1):**
  - **HSRP group number: 1, version: 2** — The HSRP group and version in use. Version 2 was set via `standby version 2`.
  - **State: active** — R1 is the current active router, forwarding traffic as the default gateway.
  - **Virtual IP address: 172.16.0.254** — The shared virtual IP used by hosts as their default gateway.
  - **Virtual MAC address: displayed (default)** — The MAC address hosts learn via ARP for the virtual IP. Default for HSRPv2 group 1.
  - **HSRP timers: default values** — Hello and hold timers. Not manually configured, so defaults are shown.
  - **Preemption: enabled** — R1 will reclaim the active role after recovering from a failure.
  - **Active router: local (R1)** — R1 is the active router. If another router were active, its IP would appear here instead.
  - **Standby router: 172.16.0.252 (R2)** — R2 will take over if R1 fails.
  - **Priority: 200** — R1's configured priority, the highest in the group, so it was elected active.

Lecture Review

- **Introduction to FHRPs:**
  - Covered the purpose and basic function of FHRPs: providing a redundant default gateway for a subnet.
- **Three FHRPs:**
  - Briefly introduced HSRP, VRRP, and GLBP.
  - Learn the basic characteristics of each.
  - Use the comparison chart to memorize their multicast IP addresses and virtual MAC addresses.
- **HSRP Configurations:**
  - Basic HSRP configurations were introduced.
  - These commands likely won't appear on the exam, but hands-on practice helps understanding.
  - The next lecture covers a simple HSRP lab with preemption.

Commands Used

- `STANDBY VERSION 2` — Configures the router to use HSRP version 2.
- `STANDBY IP` — Sets the virtual IP address used as the default gateway.
- `STANDBY PRIORITY` — Helps control which router becomes the active router.
- `STANDBY PREEMPT` — Causes the active router to take its role back if it recovers from a failure.