

Computer Networks Lab

Project Report

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[Project GitHub Link](#)

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First Part: RTP and RTCP Protocols

Required Questions:

- 1) *Explain the RTP and RTCP protocols in details.*

Created by the Internet Engineering Task Force (IETF), the Real-time Transport Protocol (RTP) is essential for transmitting audio and video streams across IP networks in real time. It is widely used in services such as video conferencing, live streaming, and Voice over IP (VoIP). RTP sits on top of the User Datagram Protocol (UDP), opting for fast delivery and low latency over reliability. To support real-time communication, RTP includes crucial functionalities like sequence numbering to preserve packet order, timestamps to enable synchronization, source identification, and payload type recognition. While RTP does not ensure packet delivery or prevent duplication, it is designed to work alongside the Real-time Transport Control Protocol (RTCP), which monitors network conditions, provides performance feedback, and helps align multiple media streams. By allowing some packet loss and avoiding retransmissions, RTP maintains smooth and timely playback, making it highly suitable for delay-sensitive applications.

The Real-time Transport Control Protocol (RTCP), developed as a companion to the Real-time Transport Protocol (RTP), is responsible for overseeing and managing the quality of media transmission over IP networks. While RTP focuses on delivering the actual audio and video content, RTCP complements it by gathering performance metrics such as packet loss, delay variation (jitter), and network latency. This statistical feedback allows users and systems to evaluate connection health and adapt streaming behavior accordingly. RTCP transmits several types of control messages—such as Sender Reports (SR), Receiver Reports (RR), Source Description (SDES), Goodbye (BYE), and Application-Defined (APP) packets—that help synchronize media streams, identify participants, and manage session dynamics. Though RTCP does not include built-in security mechanisms like encryption or authentication, it is often deployed in conjunction with protocols such as Secure RTP (SRTP) to protect media data. By collaborating with RTP, RTCP plays a vital role in delivering smooth, synchronized, and high-quality real-time media for applications like live streaming and video conferencing.

2) Filter the RTP and RTCP packets in Wireshark.

No.	Time	Source	Destination	Protocol	Length	Info
1	0.000000000	10.40.39.95	10.40.50.234	RTP	86	PT=DYNAMICRTP-TYPE-96, SSRC=0x4909FC81, Seq=296, Time=288366754
2	0.005810770	10.40.50.234	10.40.39.95	RTP	71	PT=DYNAMICRTP-TYPE-96, SSRC=0x95CA3193, Seq=288, Time=3063343393
3	0.020142066	10.40.39.95	10.40.50.234	RTP	86	PT=DYNAMICRTP-TYPE-96, SSRC=0x4909FC81, Seq=297, Time=2883657714
4	0.027552324	10.40.50.234	10.40.39.95	RTP	72	PT=DYNAMICRTP-TYPE-96, SSRC=0x95CA3193, Seq=281, Time=3063344453
5	0.034962324	10.40.50.234	10.40.39.95	RTP	73	PT=DYNAMICRTP-TYPE-96, SSRC=0x4909FC81, Seq=292, Time=2883658133
6	0.059411934	10.40.39.95	10.40.50.234	RTP	86	PT=DYNAMICRTP-TYPE-96, SSRC=0x4909FC81, Seq=287, Time=2883658074
7	0.066316027	10.40.50.234	10.40.39.95	RTP	71	PT=DYNAMICRTP-TYPE-96, SSRC=0x95CA3193, Seq=283, Time=3063346273
8	0.069571037	10.40.50.234	10.40.39.95	RTP	86	PT=DYNAMICRTP-TYPE-96, SSRC=0x4909FC81, Seq=299, Time=2883659634
9	0.087873922	10.40.50.234	10.40.39.95	RTP	73	PT=DYNAMICRTP-TYPE-96, SSRC=0x95CA3193, Seq=284, Time=3063347233
10	0.092101092	10.40.39.95	10.40.50.234	RTP	84	PT=DYNAMICRTP-TYPE-96, SSRC=0x4909FC81, Seq=290, Time=2883658994
11	0.097694069	10.40.39.95	10.40.50.234	RTP	73	PT=DYNAMICRTP-TYPE-96, SSRC=0x95CA3193, Seq=289, Time=2883658993
12	0.109727278	10.40.39.95	10.40.50.234	RTP	86	PT=DYNAMICRTP-TYPE-96, SSRC=0x4909FC81, Seq=301, Time=2883651554
13	0.1269989352	10.40.50.234	10.40.39.95	RTP	71	PT=DYNAMICRTP-TYPE-96, SSRC=0x95CA3193, Seq=289, Time=3063349153
14	0.129349342	10.40.39.95	10.40.50.234	RTP	89	PT=DYNAMICRTP-TYPE-96, SSRC=0x4909FC81, Seq=302, Time=2883662514
15	0.1329495612	10.40.39.95	10.40.50.234	RTP	85	PT=DYNAMICRTP-TYPE-96, SSRC=0x4909FC81, Seq=303, Time=2883663474
16	0.145071020	10.40.39.95	10.40.50.234	RTP	76	PT=DYNAMICRTP-TYPE-96, SSRC=0x95CA3193, Seq=280, Time=2883653313
17	0.159716424	10.40.39.95	10.40.50.234	RTP	86	PT=DYNAMICRTP-TYPE-96, SSRC=0x4909FC81, Seq=304, Time=2883654434
18	0.168266888	10.40.50.234	10.40.39.95	RTP	72	PT=DYNAMICRTP-TYPE-96, SSRC=0x95CA3193, Seq=288, Time=3063351973
19	0.187477729	10.40.50.234	10.40.39.95	RTP	72	PT=DYNAMICRTP-TYPE-96, SSRC=0x95CA3193, Seq=289, Time=3063352633
20	0.192424245	10.40.39.95	10.40.50.234	RTP	87	PT=DYNAMICRTP-TYPE-96, SSRC=0x4909FC81, Seq=305, Time=2883655394
21	0.197376133	10.40.39.95	10.40.50.234	RTP	71	PT=DYNAMICRTP-TYPE-96, SSRC=0x95CA3193, Seq=293, Time=2883653309
22	0.226912688	10.40.50.234	10.40.39.95	RTP	82	PT=DYNAMICRTP-TYPE-96, SSRC=0x4909FC81, Seq=306, Time=2883663554
23	0.229951287	10.40.39.95	10.40.50.234	RTP	72	PT=DYNAMICRTP-TYPE-96, SSRC=0x95CA3193, Seq=291, Time=30633533953
24	0.226912688	10.40.50.234	10.40.39.95	RTP	86	PT=DYNAMICRTP-TYPE-96, SSRC=0x4909FC81, Seq=307, Time=2883667314
25	0.229469597	10.40.39.95	10.40.50.234	RTP	69	PT=DYNAMICRTP-TYPE-96, SSRC=0x95CA3193, Seq=302, Time=306334913
26	0.249812213	10.40.50.234	10.40.39.95	RTP	89	PT=DYNAMICRTP-TYPE-96, SSRC=0x4909FC81, Seq=308, Time=2883663474
27	0.249812213	10.40.39.95	10.40.50.234	RTP	73	PT=DYNAMICRTP-TYPE-96, SSRC=0x95CA3193, Seq=293, Time=2863255973
28	0.267571526	10.40.50.234	10.40.39.95	RTP	83	PT=DYNAMICRTP-TYPE-96, SSRC=0x4909FC81, Seq=309, Time=2883669234
29	0.270693843	10.40.39.95	10.40.50.234	RTP	73	PT=DYNAMICRTP-TYPE-96, SSRC=0x95CA3193, Seq=294, Time=3063356833
30	0.289354753	10.40.50.234	10.40.39.95	RTP	85	PT=DYNAMICRTP-TYPE-96, SSRC=0x4909FC81, Seq=311, Time=2883678194
31	0.299876821	10.40.39.95	10.40.50.234	RTP	84	PT=DYNAMICRTP-TYPE-96, SSRC=0x95CA3193, Seq=310, Time=2883678154
32	0.300057459	10.40.50.234	10.40.39.95	RTP	60	PT=DYNAMICRTP-TYPE-96, SSRC=0x95CA3193, Seq=289, Time=2863255933
33	0.308824499	10.40.50.234	10.40.39.95	RTP	86	PT=DYNAMICRTP-TYPE-96, SSRC=0x95CA3193, Seq=312, Time=2883672114
34	0.319221399	10.40.39.95	10.40.50.234	RTP	73	PT=DYNAMICRTP-TYPE-96, SSRC=0x4909FC81, Seq=313, Time=2883672114
35	0.326124642	10.40.50.234	10.40.39.95	RTP	73	PT=DYNAMICRTP-TYPE-96, SSRC=0x95CA3193, Seq=296, Time=3063358753
36	0.3284348585	10.40.39.95	10.40.50.234	RTP	84	PT=DYNAMICRTP-TYPE-96, SSRC=0x4909FC81, Seq=313, Time=2883673874
37	0.348813234	10.40.50.234	10.40.39.95	RTP	71	PT=DYNAMICRTP-TYPE-96, SSRC=0x95CA3193, Seq=287, Time=2883653313
38	0.367212256	10.40.50.234	10.40.39.95	RTP	72	PT=DYNAMICRTP-TYPE-96, SSRC=0x95CA3193, Seq=289, Time=2863368973
39	0.376223484	10.40.39.95	10.40.50.234	RTP	83	PT=DYNAMICRTP-TYPE-96, SSRC=0x4909FC81, Seq=314, Time=2883674934
40	0.386968628	10.40.50.234	10.40.39.95	RTP	69	PT=DYNAMICRTP-TYPE-96, SSRC=0x95CA3193, Seq=299, Time=3063381633
41	0.389889847	10.40.39.95	10.40.50.234	RTP	89	PT=DYNAMICRTP-TYPE-96, SSRC=0x4909FC81, Seq=315, Time=2883674994
42	0.401719393	10.40.50.234	10.40.39.95	RTP	73	PT=DYNAMICRTP-TYPE-96, SSRC=0x95CA3193, Seq=309, Time=3063365293
43	0.408961393	10.40.39.95	10.40.50.234	RTP	91	PT=DYNAMICRTP-TYPE-96, SSRC=0x4909FC81, Seq=324, Time=2883674554
44	0.427878992	10.40.50.234	10.40.39.95	RTP	70	PT=DYNAMICRTP-TYPE-96, SSRC=0x95CA3193, Seq=301, Time=3063365353
45	0.429767661	10.40.39.95	10.40.50.234	RTP	85	PT=DYNAMICRTP-TYPE-96, SSRC=0x4909FC81, Seq=317, Time=2883676914
46	0.447271294	10.40.50.234	10.40.39.95	RTP	73	PT=DYNAMICRTP-TYPE-96, SSRC=0x95CA3193, Seq=302, Time=3063364513
47	0.447271294	10.40.39.95	10.40.50.234	RTP	85	PT=DYNAMICRTP-TYPE-96, SSRC=0x4909FC81, Seq=318, Time=2883677874
48	0.459861397	10.40.50.234	10.40.39.95	RTP	87	PT=DYNAMICRTP-TYPE-96, SSRC=0x4909FC81, Seq=334, Time=2883673904
49	0.468839968	10.40.50.234	10.40.39.95	RTP	71	PT=DYNAMICRTP-TYPE-96, SSRC=0x95CA3193, Seq=303, Time=3063365473
50	0.479319390	10.40.39.95	10.40.50.234	RTP	85	PT=DYNAMICRTP-TYPE-96, SSRC=0x4909FC81, Seq=320, Time=2883677974
51	0.486373237	10.40.39.95	10.40.50.234	RTP	71	PT=DYNAMICRTP-TYPE-96, SSRC=0x95CA3193, Seq=304, Time=3063366433
52	0.500308878	10.40.39.95	10.40.50.234	RTP	87	PT=DYNAMICRTP-TYPE-96, SSRC=0x4909FC81, Seq=321, Time=2883689774
53	0.500308878	10.40.39.95	10.40.50.234	RTP	76	PT=DYNAMICRTP-TYPE-96, SSRC=0x95CA3193, Seq=305, Time=2883689774
54	0.518769422	10.40.39.95	10.40.50.234	RTP	266	Sender Report Source description Extended report (RFC 3611)
55	0.525406513	10.40.50.234	10.40.39.95	RTP	230	Sender Report Source description Extended report (RFC 3611)
56	0.525406513	10.40.50.234	10.40.39.95	RTP	70	PT=DYNAMICRTP-TYPE-96, SSRC=0x95CA3193, Seq=306, Time=3063368353

> Frame 41: 89 bytes on wire (712 bits), 89 bytes captured (712 bits) on interface wlo1, id 0

> Frame 41: 89 bytes on wire (712 bits), 89 bytes captured (712 bits) on interface wlo1, id 0
> Ethernet II, Src: ChangmingFug_2f:4d:43 (4c:57:77:2f:4d:43), Dst: CloudNetwork_22:f6:29 (44:fa:66:22:f6:e9)
> Internet Protocol Version 4, Src: 10.40.39.95, Dst: 10.40.50.234
> User Datagram Protocol, Src Port: 37201, Dst: 62775
> Real-Time Transport Protocol
> [Stream setup by HEUR RTP (frame 1)]
10... = Version: IPv4 (1889 Version (2))
.... ..0.. = Padding: False
.... .0... = Extension: False
.... 0000 = Contributing source identifiers count: 0
0... = Marker: False
Payload type: DynamicRTP-Type-96 (96)
Sequence number: 33 [Extended sequence number: 65851]
Timestamp: 2883674994
Synchronization Source identifier: 0x4909fc81 (1225391233)
Payload: 40899475b8af05d72815e40cd4a7a5a236de52fac2f2f5cb4c3e429082256bb30c
0000 44 fa 66 22 f6 29 dc d5 77 2f 4d 43 08 00 45 00 D f" JL w/MC E
0010 00 4b 8e 5f 49 00 40 11 3d aa 08 28 27 5f 0a 28 K _@ _# _` _{ _`
0020 32 e9 91 51 f5 37 07 04 53 80 60 01 3b ab e1 2 _Q 7 _7 S _` _:
0030 63 72 49 09 fc 81 48 09 94 75 b8 7a f0 5d 72 01 crf .. H .. u z J r
0040 5e 40 cd 4a 48 75 a2 36 de 52 fa c2 f2 f5 cb 4c ^@ JJJ.. 6 .. R .. L
0050 4c 3e 42 98 82 25 6b 63 6c L>B .. %k ..

4) Inspect the following different reports used by RTCP:

- *Sender Report (SR):*

Provides transmission and reception statistics from active senders, including NTP and RTP timestamps, useful for synchronization and delay calculations.

No.	Time	Source	Description	Protocol	Length	Info
354	10.000000	192.168.0.65	RTP/AVP 246 Sender Report	RTCP	246	Source description Extended report (RFC 3611)
711	6.280168	192.168.0.161	RTP/AVP 246 Sender Report	RTCP	246	Source description Extended report (RFC 3611)
889	7.722222	192.168.0.161	RTP/AVP 246 Sender Report	RTCP	246	Source description Extended report (RFC 3611)
1230	10.000000	192.168.0.161	RTP/AVP 246 Sender Report	RTCP	246	Source description Extended report (RFC 3611)
1424	12.280959	192.168.0.65	RTP/AVP 246 Sender Report	RTCP	246	Source description Extended report (RFC 3611)
1771	15.319915	192.168.0.161	RTP/AVP 246 Sender Report	RTCP	246	Source description Extended report (RFC 3611)
2607	19.000000	192.168.0.161	RTP/AVP 246 Sender Report	RTCP	246	Source description Extended report (RFC 3611)
2551	28.529558	192.168.0.161	RTP/AVP 246 Sender Report	RTCP	246	Source description Extended report (RFC 3611)
2765	23.727767	192.168.0.65	RTP/AVP 246 Sender Report	RTCP	246	Source description Extended report (RFC 3611)
2968	10.248723	192.168.0.161	RTP/AVP 246 Sender Report	RTCP	246	Source description Extended report (RFC 3611)
3138	27.100021	192.168.0.65	RTP/AVP 246 Sender Report	RTCP	246	Source description Extended report (RFC 3611)
3369	29.556862	192.168.0.161	RTP/AVP 246 Sender Report	RTCP	246	Source description Extended report (RFC 3611)
3739	32.886699	192.168.0.65	RTP/AVP 246 Sender Report	RTCP	246	Source description Extended report (RFC 3611)
4020	33.000000	192.168.0.161	RTP/AVP 246 Sender Report	RTCP	246	Source description Extended report (RFC 3611)
4220	37.854627	192.168.0.65	RTP/AVP 246 Sender Report	RTCP	246	Source description Extended report (RFC 3611)

- *Receiver Report (RR):*

Sent by participants not actively sending media, it includes statistics like packet loss, jitter, and feedback on sender streams.

```
- Real-time Transport Control Protocol (Receiver Report)
  - [Stream setup by SDP (frame 77)]
    [Setup frame: 77]
    [Setup Method: SDP]
    10... .... = Version: RFC 1889 Version (2)
    ...0. .... = Padding: False
    ...0 0001 = Reception report count: 1
    Packet type: Receiver Report (201)
    Length: 7 (32 bytes)
    Sender SSRC: 0x00294823 (2705443)
    - Source 1
      Identifier: 0x441bc0cf (1142669519)
      - SSRC contents
        Fraction lost: 0 / 256
        Cumulative number of packets lost: 0
      - Extended highest sequence number received: 31371
        Sequence number cycles count: 0
        Highest sequence number received: 31371
        Interarrival jitter: 4
      Last SR timestamp: 1430713739 (0x5546f58b)
      Delay since last SR timestamp: 125045 (1908 milliseconds)
```

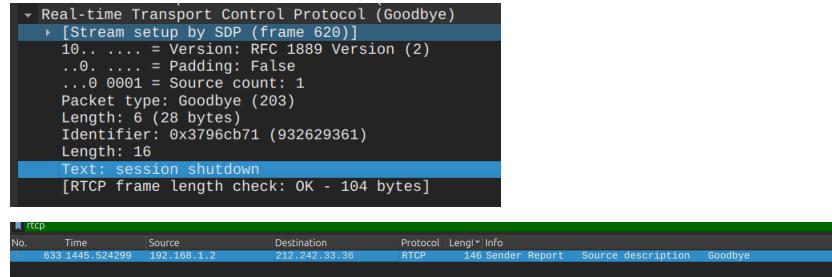
- *Source Description (SDES):*

Carries metadata about participants, such as canonical names (CNAMES), to help identify sources of RTP streams.

```
- Real-time Transport Control Protocol (Source description)
  10. .... = Version: RFC 1889 Version (2)
  ...0. .... = Padding: False
  ...0 0001 = Source count: 1
  Packet type: Source description (202)
  Length: 32 (132 bytes)
  - Chunk 1, SSRC/CSRC 0x493c7344 (1228698436)
    - SDES item
      Type: CNAME (user and domain) (1)
      Length: 28
      Text: siriadushsheny@192.168.0.104
    Type: TEL (name/version of source app) (6)
    Length: 88
    Text: Linphone-Desktop/5.2.6 (Nadas-MacBook-Pro-2.local) osx/13.7.0t/5.15.2 LinphoneSDK/5.3.2
    Type: END (6)
```

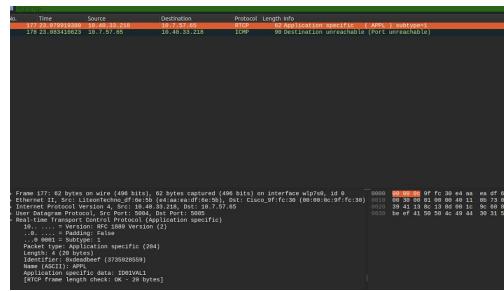
- *End of Participation (BYE):*

Signals that a participant is leaving the RTP session, allowing other participants to update session state accordingly.



- Application Specific (APP):

Used for custom, experimental, or proprietary messages that are not defined by standard RTCP packet types.



5) Examine and compute the end-to-end (E2E) delays.

This is the packet stream analysis:

Destination Address	Destination Port	SSRC	Start Time	Duration	Payload	Perfcnt	Loss	Mn Delta (ms)	Mean Delta (ms)	Max Delta (ms)	Min Jitter	Max Jitter	Status
192.168.0.161	62855	0x4cc43d4f	0.000117	39.40	RTPType=96	1971	0 (0.0%)	0.000000	20.00028	78.862000	-1.000000	0.000000	
192.168.0.65	40374	0x220505bf	0.000000	39.38	RTPType=96	1970	0 (0.0%)	0.002000	20.000543	32.789000	-1.000000	0.000000	

An Alternative Solution:

From the RTCP Receiver Report and Sender Reports above:

- Last SR Timestamp (LSR): 1438701737
- Delay Since Last SR (DLSR): 125045, which corresponds to 1908 milliseconds

The round-trip time (RTT) can be estimated using the formula:

$$RTT = A - LSR - DLSR$$

$$\text{End-to-End Delay} \approx \frac{RTT}{2} \approx \frac{1908}{2} = 954 \text{ ms}$$

6) VoIP Test Between VM1 and VM2 Using Cisco IP Communicator

To perform a VoIP test between two virtual machines (VM1 and VM2) using Cisco IP Communicator, the following steps are carried out: To test VoIP communication, install and set up Cisco IP Communicator on both virtual machines (VM1 and VM2), making sure they were connected to the same network and could call each other either through a call controller or direct IP dialing. Open Wireshark on the correct network interface to capture all traffic between the two VMs. On VM1, initiate a call to VM2, which should be answered and kept active briefly while speaking to generate RTP traffic. After ending the call, stop the packet capture for analysis. The recorded data showed important VoIP components such as SIP signaling messages (like INVITE, 180 Ringing, 200 OK, ACK, and BYE) used to set up and end the call. Once the call began, we observed RTP packets carrying the audio in both directions between the VMs. In addition, RTCP packets—used for monitoring call quality—were present, including sender and receiver reports that gave information about packet loss, jitter, and timing. Finally, we could estimate end-to-end delay by looking at RTP packet timestamps or using RTCP data to assess how long it took for audio data to travel across the network.

Socket Programming for RTP and RTCP Protocols

GitHub Link

```
nadiadessouky@nadias-MacBook-Pro:~/Socket-Programming$ clang++ client.cpp server.cpp & ./program
[SERVER] Listening on RTP [CLIENT] RTCP bound to port 5000, RTCP 50016001

[CLIENT] Sending 5 RTP packets...
[SENT] SEQ=1;TIME=1746969452477
[RECV] From 127.0.0.1:6000 | SEQ=1;TIME=1746969452477 | Delay: 0ms | Loss: 0% | Jitter: 0ms
[SENT] SEQ=2;TIME=1746969452680
[RECV] From 127.0.0.1:6000 | SEQ=2;TIME=1746969452680 | Delay: 1ms | Loss: 0% | Jitter: 12.6875ms
[SENT] SEQ=3;TIME=1746969452885
[RECV] From 127.0.0.1:6000 | SEQ=3;TIME=1746969452885 | Delay: 0ms | Loss: 0% | Jitter: 23.8516ms
[SENT] SEQ=4;TIME=1746969453086
[RECV] From 127.0.0.1:6000 | SEQ=4;TIME=1746969453086 | Delay: 0ms | Loss: 0% | Jitter: 33.3701ms
[SENT] SEQ=5;TIME=1746969453291
[RECV] From 127.0.0.1:6000 | SEQ=5;TIME=1746969453291 | Delay: 0ms | Loss: 0% | Jitter: 42.0114ms
[RTCP SENT TO] 127.0.0.1:6001
[RTCP SENT] RTCP: delay=0ms, loss=0.0%, jitter=42.0ms, seq=5
[CLIENT] Waiting for RTCP feedback...
[RTCP RECEIVED] RTCP: delay=0ms, loss=0.0%, jitter=42.0ms, seq=5
```

Second Part: HSRP Protocol Configuration

HSRP Configuration

Using Cisco's Packet Tracer network simulation tool, build the given network topology and apply the following configurations: (Include all necessary screenshots in your report)

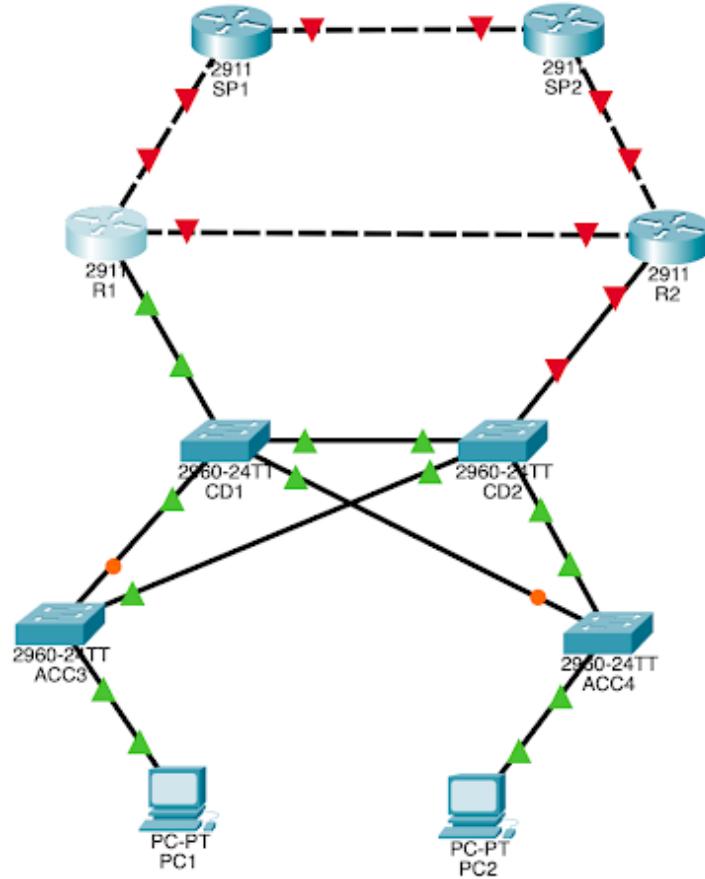


Figure 1: Network Topology for HSRP Configuration

Basic HSRP

- (a) Configure basic HSRP for the 10.10.10.0/24 network using the IP addresses shown in the topology diagram.

R1:

```
R1(config)#interface GigabitEthernet0/1
R1(config-if)#ip address 10.10.10.2 255.255.255.0
R1(config-if)#standby 1 ip 10.10.10.1
R1(config-if)#no shutdown
```

Figure 2: R1 HSRP Configuration

R2:

```
R2(config)#interface GigabitEthernet0/1
R2(config-if)#ip address 10.10.10.3 255.255.255.0
R2(config-if)#standby 1 ip 10.10.10.1
R2(config-if)#no shutdown
```

Figure 3: R2 HSRP Configuration

- (b) Wait for HSRP to come up on both routers and then check which is the active router.

R1:

```
R1#show standby brief
          P indicates configured to preempt.
          |
Interface  Grp  Pri  P State      Active           Standby           Virtual IP
Gig0/1     1    100   Standby    10.10.10.3       local            10.10.10.1
```

Figure 4: HSRP Status on R1

R2:

```
R2#show standby brief
          P indicates configured to preempt.
          |
Interface  Grp  Pri  P State      Active           Standby           Virtual IP
Gig0/1     1    100   Active     local            10.10.10.2       10.10.10.1
--
```

Figure 5: HSRP Status on R2

- (c) Verify that the PCs can ping their default gateway using the HSRP address 10.10.10.1.

PC1:

The screenshot shows a Cisco Packet Tracer window titled "PC1". The tab bar at the top has "Physical", "Config", "Desktop" (which is selected), and "Program". Below the tab bar is a blue header bar with the text "Command Prompt". The main area of the window is a black terminal window displaying the output of a ping command. The text in the terminal is as follows:

```
Cisco Packet Tracer PC Command Line 1.0
C:\>ping 10.10.10.1

Pinging 10.10.10.1 with 32 bytes of data:

Reply from 10.10.10.1: bytes=32 time<1ms TTL=255

Ping statistics for 10.10.10.1:
    Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
    Approximate round trip times in milli-seconds:
        Minimum = 0ms, Maximum = 1ms, Average = 0ms

C:\>
```

Figure 6: PC1 Pinging Default Gateway

PC2:

The screenshot shows a Cisco Packet Tracer window titled "PC2". The tab bar at the top has "Physical", "Config", "Desktop" (which is selected), and "Program". Below the tab bar is a blue header bar with the text "Command Prompt". The main area of the window is a black terminal window displaying the output of a ping command. The text in the terminal is as follows:

```
Cisco Packet Tracer PC Command Line 1.0
C:\>ping 10.10.10.1

Pinging 10.10.10.1 with 32 bytes of data:

Reply from 10.10.10.1: bytes=32 time<1ms TTL=255

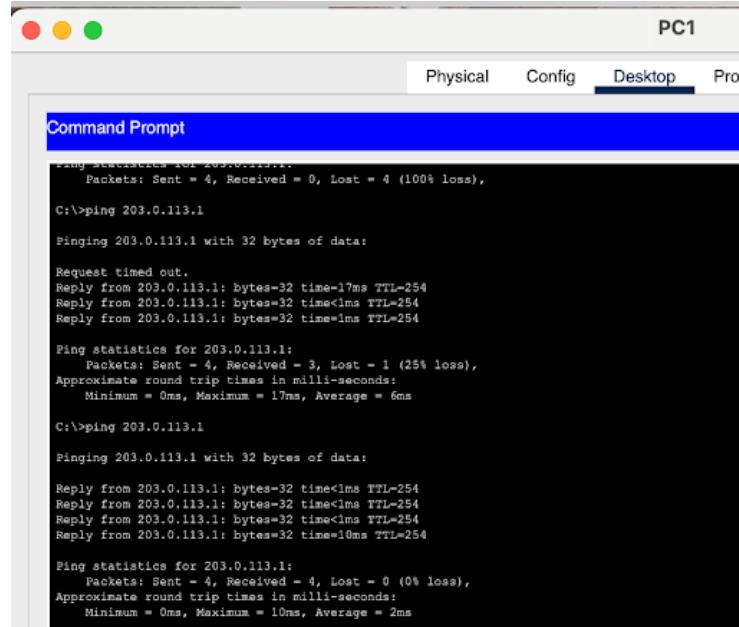
Ping statistics for 10.10.10.1:
    Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
    Approximate round trip times in milli-seconds:
        Minimum = 0ms, Maximum = 1ms, Average = 0ms

C:\>
```

Figure 7: PC2 Pinging Default Gateway

- (d) Verify that the PCs have upstream connectivity via their HSRP default gateway. Ping SP1 at 203.0.113.1

PC1:



```
ping statistics for 203.0.113.1:
    Packets: Sent = 4, Received = 0, Lost = 4 (100% loss),
C:\>ping 203.0.113.1

Pinging 203.0.113.1 with 32 bytes of data:

Request timed out.
Reply from 203.0.113.1: bytes=32 time=17ms TTL=254
Reply from 203.0.113.1: bytes=32 time<1ms TTL=254
Reply from 203.0.113.1: bytes=32 time=1ms TTL=254

Ping statistics for 203.0.113.1:
    Packets: Sent = 4, Received = 3, Lost = 1 (25% loss),
Approximate round trip times in milli-seconds:
    Minimum = 0ms, Maximum = 17ms, Average = 6ms

C:\>ping 203.0.113.1

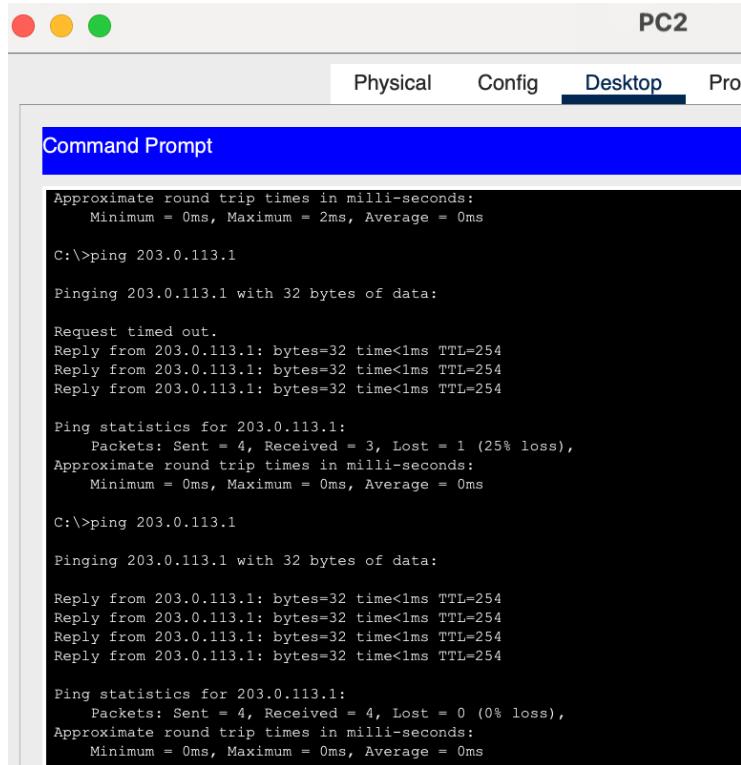
Pinging 203.0.113.1 with 32 bytes of data:

Reply from 203.0.113.1: bytes=32 time<1ms TTL=254
Reply from 203.0.113.1: bytes=32 time<1ms TTL=254
Reply from 203.0.113.1: bytes=32 time<1ms TTL=254
Reply from 203.0.113.1: bytes=32 time=10ms TTL=254

Ping statistics for 203.0.113.1:
    Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
Approximate round trip times in milli-seconds:
    Minimum = 0ms, Maximum = 10ms, Average = 2ms
```

Figure 8: PC1 Pinging SP1

PC2:



```
PC2
Physical Config Desktop Properties

Command Prompt

Approximate round trip times in milli-seconds:
    Minimum = 0ms, Maximum = 2ms, Average = 0ms

C:\>ping 203.0.113.1

Pinging 203.0.113.1 with 32 bytes of data:

Request timed out.
Reply from 203.0.113.1: bytes=32 time<1ms TTL=254
Reply from 203.0.113.1: bytes=32 time<1ms TTL=254
Reply from 203.0.113.1: bytes=32 time<1ms TTL=254

Ping statistics for 203.0.113.1:
    Packets: Sent = 4, Received = 3, Lost = 1 (25% loss),
Approximate round trip times in milli-seconds:
    Minimum = 0ms, Maximum = 0ms, Average = 0ms

C:\>ping 203.0.113.1

Pinging 203.0.113.1 with 32 bytes of data:

Reply from 203.0.113.1: bytes=32 time<1ms TTL=254

Ping statistics for 203.0.113.1:
    Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
Approximate round trip times in milli-seconds:
    Minimum = 0ms, Maximum = 0ms, Average = 0ms
```

Figure 9: PC2 Pinging SP1

- (e) What is the MAC address on the physical interface of the active router?

MAC address: 000a.f31c.2102

```
Group name is hsrp-Gig0/1 - (default)
R2#show interface g0/1
GigabitEthernet0/1 is up, line protocol is up (connected)
  Hardware is CN Gigabit Ethernet, address is 000a.f31c.2102 (bia 000a.f31c.2102)
  Internet address is 10.10.10.3/24
  MTU 1500 bytes, BW 1000000 Kbit, DLY 10 usec,
    reliability 255/255, txload 1/255, rxload 1/255
  Encapsulation ARPA, loopback not set
  Keepalive set (10 sec)
  Full-duplex, 100Mb/s, media type is RJ45
  output flow-control is unsupported, input flow-control is unsupported
  ARP type: ARPA, ARP Timeout 04:00:00,
  Last input 00:00:08, output 00:00:05, output hang never
  Last clearing of "show interface" counters never
  Input queue: 0/75/0 (size/max/drops); Total output drops: 0
  Queueing strategy: fifo
  Output queue :0/40 (size/max)
  5 minute input rate 96 bits/sec, 0 packets/sec
  5 minute output rate 94 bits/sec, 0 packets/sec
  1979 packets input, 62133 bytes, 0 no buffer
  Received 34 broadcasts, 0 runts, 0 giants, 0 throttles
  0 input errors, 0 CRC, 0 frame, 0 overrun, 0 ignored, 0 abort
  0 watchdog, 1017 multicast, 0 pause input
  0 input packets with dribble condition detected
  1964 packets output, 60292 bytes, 0 underruns
  0 output errors, 0 collisions, 2 interface resets
  0 unknown protocol drops
  0 babbles, 0 late collision, 0 deferred
  0 lost carrier, 0 no carrier
  0 output buffer failures, 0 output buffers swapped out
```

Figure 10: Mac Address of interface g0/1

- (f) What is the MAC address of the HSRP virtual interface?

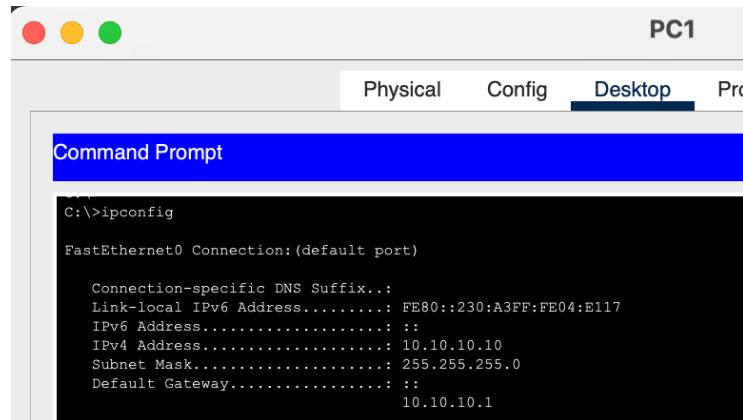
The HSRP virtual interface is using the MAC address: 0000.0C07.AC01

```
-----
R2#show standby
GigabitEthernet0/1 - Group 1
  State is Active
    6 state changes, last state change 02:17:24
  Virtual IP address is 10.10.10.1
  Active virtual MAC address is 0000.0C07.AC01
    Local virtual MAC address is 0000.0C07.AC01 (vl default)
  Hello time 3 sec, hold time 10 sec
    Next hello sent in 0.014 secs
  Preemption disabled
  Active router is local
  Standby router is 10.10.10.2
  Priority 100 (default 100)
  Group name is hsrp-Gig0/1-1 (default)
```

Figure 11: HSRP virtual interface g0/1

- (g) Verify the PCs are using the virtual MAC address for their default gateway.

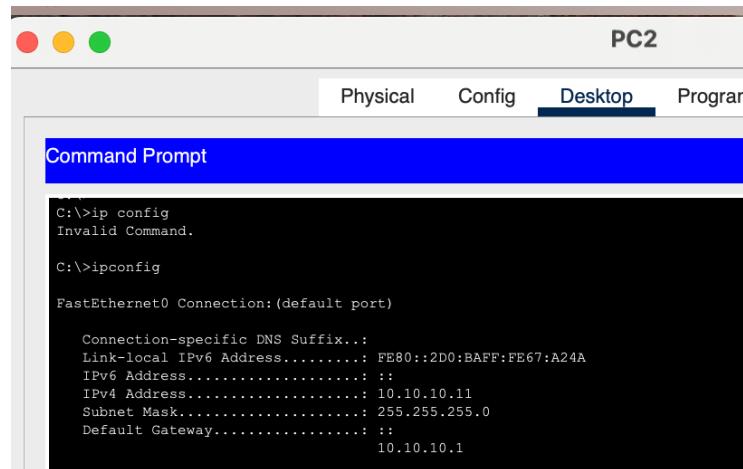
The default gateway for both PC2 and PC1 as we can see is 10.10.10.1:
PC1:



```
C:\>ipconfig
FastEthernet0 Connection:(default port)
  Connection-specific DNS Suffix...:
  Link-local IPv6 Address.....: FE80::230:A3FF:FE04:E117
  IPv6 Address.....: :::
  IPv4 Address.....: 10.10.10.10
  Subnet Mask.....: 255.255.255.0
  Default Gateway.....: :::
                                         10.10.10.1
```

Figure 12: PC1 Default Gateway Configuration

PC2:



```
C:\>ip config
Invalid Command.

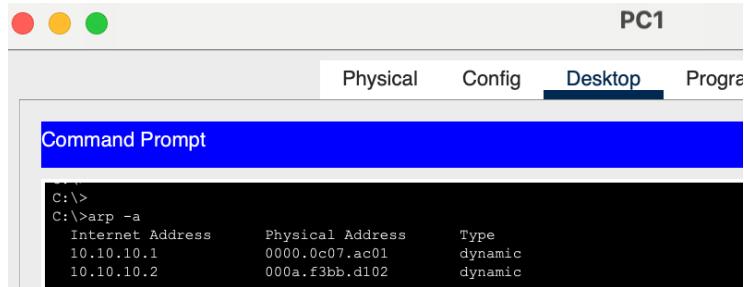
C:\>ipconfig
FastEthernet0 Connection:(default port)

  Connection-specific DNS Suffix...:
  Link-local IPv6 Address.....: FE80::2D0:BAFF:FE67:A24A
  IPv6 Address.....: :::
  IPv4 Address.....: 10.10.10.11
  Subnet Mask.....: 255.255.255.0
  Default Gateway.....: :::
                                         10.10.10.1
```

Figure 13: PC2 Default Gateway Configuration

Checking The arp cache to verify the default gateway uses the virtual MAC address for the gateway:

PC1:

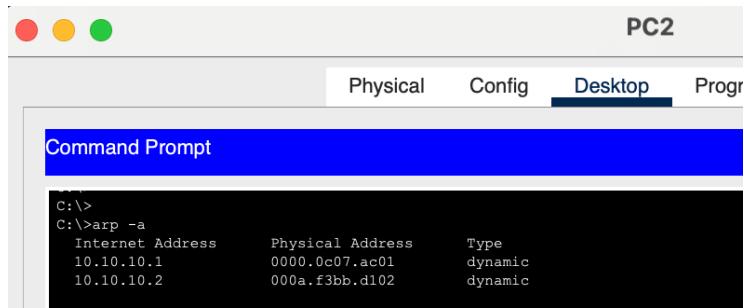


A screenshot of a Windows desktop environment titled "PC1". The taskbar includes icons for Physical, Config, Desktop (which is selected), and Programs. A blue Command Prompt window is open, displaying the output of the "arp -a" command. The output shows two entries in the ARP cache:

Internet Address	Physical Address	Type
10.10.10.1	0000.0c07.ac01	dynamic
10.10.10.2	000a.f3bb.d102	dynamic

Figure 14: PC1 ARP Cache

PC2:



A screenshot of a Windows desktop environment titled "PC2". The taskbar includes icons for Physical, Config, Desktop (which is selected), and Programs. A blue Command Prompt window is open, displaying the output of the "arp -a" command. The output shows two entries in the ARP cache:

Internet Address	Physical Address	Type
10.10.10.1	0000.0c07.ac01	dynamic
10.10.10.2	000a.f3bb.d102	dynamic

Figure 15: PC2 ARP Cache

Priority and Pre-emption

- (a) **Configure HSRP so that R1 will be the preferred router. Use a single command.**

We will make R1 be the preferred router by increasing its priority. We will make R1 have priority 150 and R2 have priority 100 (it is the default one).

```
R1(config)#interface GigabitEthernet0/1
R1(config-if)#standby 1 priority 150
R1(config-if)#exit
```

Figure 16: Configuring R1 Priority

- (b) **Which router do you expect will be active now? Verify this.**

Even though we raised R1's priority above R2's, R2 will stay active because, by default, HSRP doesn't allow a higher-priority router to take over unless you explicitly enable preemption. Moreover, without the standby 1 preempt command on R1, the router that first became active (R2) remains in control even after R1's priority is increased.

R1:

```
R1#show standby brief
          P indicates configured to preempt.
          |
Interface  Grp  Pri  P State      Active           Standby        Virtual IP
Gig0/1     1    150  Standby   10.10.10.3      local         10.10.10.1
```

Figure 17: R1 Status After Priority Change

R2:

```
R2#show standby brief
          P indicates configured to preempt.
          |
Interface  Grp  Pri  P State      Active           Standby        Virtual IP
Gig0/1     1    100  Active     local          10.10.10.2      10.10.10.1
```

Figure 18: R2 Status After Priority Change

- (c) **Ensure that R1 is the active router. Do not reboot.**

Doing preempt to ensure that R1 is the active router without rebooting:

```
R1(config)#interface GigabitEthernet0/1
R1(config-if)#standby 1 preempt
```

Figure 19: R1 Preempt Configuration

R1:

```
%HSRP-6-STATECHANGE: GigabitEthernet0/1 Grp 1 state Standby -> Active

R1#show standby brief
          P indicates configured to preempt.
          |
Interface  Grp  Pri P State      Active           Standby           Virtual IP
Gig0/1     1    150 P Active    local            10.10.10.2      10.10.10.1
...
```

Figure 20: R1 Status After Preempt

R2:

```
----- R2#
%HSRP-6-STATECHANGE: GigabitEthernet0/1 Grp 1 state Speak -> Standby
show standby brief
          P indicates configured to preempt.
          |
Interface  Grp  Pri P State      Active           Standby           Virtual IP
Gig0/1     1    100 Standby   10.10.10.2      local            10.10.10.1
```

Figure 21: R2 Status After R1 Preempt

Test HSRP

- (a) Run a continuous ping to the HSRP IP address from PC1 with the ping 10.10.10.1 -n 1000 command.

Here was the output without rebooting, all pings are received:

```
C:\>ping 10.10.10.1 -n 1000
Pinging 10.10.10.1 with 32 bytes of data:
Reply from 10.10.10.1: bytes=32 time<1ms TTL=255
Reply from 10.10.10.1: bytes=32 time=1ms TTL=255
Reply from 10.10.10.1: bytes=32 time<1ms TTL=255
Reply from 10.10.10.1: bytes=32 time=1ms TTL=255
```

Figure 22: PC1 Continuous Ping

```
Reply from 10.10.10.1: bytes=32 time<1ms TTL=255
Reply from 10.10.10.1: bytes=32 time=2ms TTL=255

Ping statistics for 10.10.10.1:
    Packets: Sent = 1000, Received = 1000, Lost = 0 (0% loss),
Approximate round trip times in milli-seconds:
    Minimum = 0ms, Maximum = 28ms, Average = 0ms
```

Figure 23: PC1 Continuous Ping Continued

- (b) Save the configuration on R1, then reboot.

I will run the ping again and reboot: it will be seen in the answer to the two following questions.

```

R1#wr
Building configuration...
[OK]
R1#reload
Proceed with reload? [confirm]
System Bootstrap, Version 15.1(4)M4, RELEASE SOFTWARE (fc1)
Technical Support: http://www.cisco.com/techsupport
Copyright (c) 2010 by cisco Systems, Inc.
Total memory size = 512 MB - On-board = 512 MB, DIMM0 = 0 MB
CISCO2911/K9 platform with 524288 Kbytes of main memory
Main memory is configured to 72/-1(On-board/DIMM0) bit mode with ECC disabled

Readonly ROMMON initialized

program load complete, entry point: 0x80803000, size: 0xb340
program load complete, entry point: 0x80803000, size: 0xb340

IOS Image Load Test

Digitally Signed Release Software
program load complete, entry point: 0x81000000, size: 0x3bcd3d8
Self decompressing the image :
#####
##### [OK]
Smart Init is enabled
smart init is sizing iomem
      TYPE      MEMORY_REQ
  Onboard devices &
    buffer pools   0x022F6000
-----
      TOTAL: 0x022F6000
Rounded IOMEM up to: 36Mb.
Using 6 percent iomem. [36Mb/512Mb]

Restricted Rights Legend

```

Figure 24: R1 Reboot

- (c) View the ping output on PC1. You should see a few dropped pings as R2 transitions to active following the outage of R1.

```

Reply from 10.10.10.1: bytes=32 time<1ms TTL=255
Reply from 10.10.10.1: bytes=32 time=2ms TTL=255
Reply from 10.10.10.1: bytes=32 time=1ms TTL=255
Request timed out.
Request timed out.
Request timed out.
Reply from 10.10.10.1: bytes=32 time<1ms TTL=255
Reply from 10.10.10.1: bytes=32 time<1ms TTL=255
Reply from 10.10.10.1: bytes=32 time=1ms TTL=255

```

Figure 25: PC1 Ping During Router Failover

There are successful replies from 10.10.10.1, then three "Request timed out" lines, then replies again. Those timeouts line up exactly with when R1 went down and R2 moved into the Active role. Here's a brief window where no router answers the virtual IP, so a few ICMP packets are lost before R2 finishes the HSRP transition and begins replying.

- (d) Verify R2 has transitioned to HSRP active.

Immediately after R1 fails, R2 logs: STATECHANGE: Standby → Active Standby=unknown shows that R2 does not have standby router now

```
%HSRP-6-STATECHANGE: GigabitEthernet0/1 Grp 1 state Standby -> Active
R2#
%LINKPROTO-5-UPDOWN: Line protocol on Interface GigabitEthernet0/2, changed state to up
show standby brief
    P indicates configured to preempt.
    |
Interface  Grp  Pri  P State      Active          Standby        Virtual IP
Gig0/1     1    100  Active local      unknown       10.10.10.1
```

Figure 26: R2 Status after transition

- (e) **Wait for R1 to complete booting and HSRP to come up. Verify R1 transitions to HSRP active because pre-emption is enabled.**

Speak → Standby: As soon as its interface came back up, R1 started sending HSRP hellos ("Speak") and heard R2's hellos. It then moved into the Standby state because R2 was still the Active router at that moment.

Standby → Active: Because we had enabled preemption and given R1 a higher priority (150), R1 immediately claimed the Active role once it realized it was eligible. That transition is logged as:

```
%HSRP-6-STATECHANGE: GigabitEthernet0/1 Grp 1 state Speak -> Standby
%HSRP-6-STATECHANGE: GigabitEthernet0/1 Grp 1 state Standby -> Active
```

Figure 27: R1 Reclaiming Active Role

Right after R1 came back up, its very first show standby brief showed Standby = unknown because it hadn't yet heard R2's hellos so it knew only that it itself was Active (local), but not yet who its backup was.

```
R1>enable
R1#show standby brief
    P indicates configured to preempt.
    |
Interface  Grp  Pri  P State      Active          Standby        Virtual IP
Gig0/1     1    150  P Active local      unknown       10.10.10.1
```

Figure 28: R1 Standby Status in Transition

Once R1 and R2 exchanged HSRP hellos:
R1 saw R2 advertising itself in Group 1
R1 recorded R2's real IP (10.10.10.3) as the Standby
Now show standby brief shows Standby = 10.10.10.3

```
R1#show standby brief
      P indicates configured to preempt.
      |
Interface  Grp  Pri P State      Active           Standby          Virtual IP
Gig0/1     1    150 P Active   local            10.10.10.3      10.10.10.1
```

Figure 29: R1 Final HSRP Status

- (f) Hit 'Ctrl-C' to cancel the ping on PC1. If you scroll back, you should see a dropped ping or two as R1 transitioned back to HSRP active.

```
Reply from 10.10.10.1: bytes=32 time<1ms TTL=255
Reply from 10.10.10.1: bytes=32 time=2ms TTL=255
Reply from 10.10.10.1: bytes=32 time=1ms TTL=255
Request timed out.
Request timed out.
Request timed out.
Reply from 10.10.10.1: bytes=32 time<1ms TTL=255
Reply from 10.10.10.1: bytes=32 time<1ms TTL=255
Reply from 10.10.10.1: bytes=32 time=1ms TTL=255
Reply from 10.10.10.1: bytes=32 time<1ms TTL=255
Reply from 10.10.10.1: bytes=32 time=1ms TTL=255
Reply from 10.10.10.1: bytes=32 time<1ms TTL=255
Request timed out.
Request timed out.
Request timed out.
Request timed out.
Reply from 10.10.10.1: bytes=32 time=1ms TTL=255
Reply from 10.10.10.1: bytes=32 time<1ms TTL=255
```

Figure 30: Effect of Dropped Pings During Second Transition (Part 1)

First gap of "Request timed out" → When we rebooted R1, R2 had to take over as Active. During that switchover, we lost a few pings.

Second gap of timeouts further down → after R1 finished booting, its higher priority + preemption kicked in and it reclaimed the Active role, causing another brief interruption.

Here is also a screenshot of the effect of the dropped pings:

```
Reply from 10.10.10.1: bytes=32 time<1ms TTL=255
Reply from 10.10.10.1: bytes=32 time<1ms TTL=255|
Reply from 10.10.10.1: bytes=32 time<1ms TTL=255

Ping statistics for 10.10.10.1:
    Packets: Sent = 1000, Received = 987, Lost = 13 (2% loss),
    Approximate round trip times in milli-seconds:
        Minimum = 0ms, Maximum = 18ms, Average = 0ms
```

Figure 31: Effect of Dropped Pings During Second Transition (Part 2)

References

- [1] GeeksforGeeks, "Real time transport protocol (RTP)," GeeksforGeeks, <https://www.geeksforgeeks.org/real-time-transport-protocol-rtp/> (accessed May 6, 2025).
- [2] GeeksforGeeks, "Real-time transport control protocol (RTCP)," GeeksforGeeks, <https://www.geeksforgeeks.org/real-time-transport-control-protocol-rtcp/> (accessed May 6, 2025).