Computer Networks Lab

Report

Name: Donia Ghazy, Mohammed abuelwafa

ID: 900172124,   900172603

The goal of this project is to capture and analyze RTP and RTCP packets during a real-time conference session over a wireless network.

Difference between RTP and RTCP:

RTP:

- Real Time Protocol (RTP) is a real-time end-to-end transport protocol. It is mostly used upon UDP, which is also considered as a transport protocol. RTP is very closely coupled to the application it carries. So, RTP is best protocol that applications can use to implement a new single protocol.
- RTP doesn't guarantee timely delivery of packets, nor does it keep the packets in sequence.
- RTP gives the responsibility for recovering lost segments and resequencing of the packets for the application layer.
- **What RTP provides is:**
  - • Payload type identification
  - • Source identification
  - • Sequence numbering
  - • Timestamping
- **RTP packet format:**

V	P	X	CC	M	PT	Sequence number
Timestamp						
Synchronization source (SSRC) identifier						
Contributing source (SSRC_1) identifier						
...						
Contributing source (SSRC_n) identifier						
P A Y L O A D						

- • **The version number (V)** is currently 2.
- • **The padding bit (P)** indicates if there is padding octets inserted at the end of this packet. Padding may be required by some applications with fixed length packet sizes.
- • **The extension (X)** bit indicates if there is an experimental extension after the fixed header.
- • **The count field (CC)** tells the number of contributing source identifiers (CSRC) following the fixed header.
- • **The marker bit (M)** may be used as general marker, f.g. indicating the beginning of a speech burst.
- • **The payload type (PT)** field identifies the payload format, which are discussed in the chapter 2.2.
- • **The sequence number** is an incrementing counter which is started by a source from a random number.
- • **The timestamp** corresponds to the generation instant of the first octet in the payload.
- • **The synchronization source identifier (SSRC)** is a randomly generated value that uniquely identifies the source within a session.
- • **One or more contributing source identifiers** which are supplied by the mixer and the payload.

RTCP:

-   Real Time Control Protocol (RTCP) provides the RTP session participants feedback on the quality of the data distribution.

-   The underlying protocol must provide multiplexing of the data and control packets, with UDP this is usually implemented using separate port numbers.

-   The format of the RTCP packets is fairly similar to RTP packets, e.g. the type indication is at the same location.

-   It is responsible for QoS monitoring and congestion control, identification, and session size estimation and scaling.

-   The RTCP packets carry also a transport-level identifier (called a canonical name) for a RTP source, which is used to keep track of each participant.

-   **Its drawbacks are**
    -   Congestion due to floods of RTCP packets in highly dynamic groups.
    -   Large delays between receipt of RTCP packets from a single user
    -   Large size of the group membership tables

-   **RTCP packet format:** Each RTCP packet starts with a header similar to that of the RTP data packets. The payload type field identifies the type of the packet. There are five RTCP payload types defined as follows:
    -   Sender Report (SR) takes a value of 200
    -   Receiver Report (RR) takes a value of 201
    -   Source Description (SDES) takes a value of 202
    -   Goodbye (BYE) takes a value of 203
    -   Application-defined packet (APP) takes a value of 204

1. Part I: Real Network Implementation:

- Machine's IPs:

```
Wireless LAN adapter Wi-Fi:

   Connection-specific DNS Suffix  . : home
   IPv6 Address. . . . . . . . . . . : fdb4:f58e:ee4c:ea00:a9b6:8647:54f5:8066
   Temporary IPv6 Address. . . . . . : fdb4:f58e:ee4c:ea00:d4a6:f6d7:7d29:107b
   Link-local IPv6 Address . . . . . : fe80::a9b6:8647:54f5:8066%2
   IPv4 Address. . . . . . . . . . . : 192.168.1.3
   Subnet Mask . . . . . . . . . . . : 255.255.255.0
   Default Gateway . . . . . . . . . : 192.168.1.1

C:\Users\Donia Ghazy>
```

```
   Connection-specific DNS Suffix  . :
   Description . . . . . . . . . . . : Intel(R) Wireless-AC 9560
   Physical Address. . . . . . . . . : 08-71-90-45-6C-5D
   DHCP Enabled. . . . . . . . . . . : Yes
   Autoconfiguration Enabled . . . . : Yes
   IPv4 Address. . . . . . . . . . . : 192.168.1.5(Preferred)
   Subnet Mask . . . . . . . . . . . : 255.255.255.0
   Lease Obtained. . . . . . . . . . : Monday, November 30, 2020 1:19:11 AM
   Lease Expires . . . . . . . . . . : Tuesday, December 1, 2020 1:19:11 AM
   Default Gateway . . . . . . . . . : 192.168.1.1
   DHCP Server . . . . . . . . . . . : 192.168.1.1
   DNS Servers . . . . . . . . . . . : 163.121.128.134
                                       163.121.128.138
   NetBIOS over Tcpip. . . . . . . . : Enabled

C:\Users\Mohammed>
```

- ### Requirement 1:
  Some RTP and RTCP headers as follows:

```
Wireshark · Packet 469 · Wi-Fi                                                        —  □  ×

     0100 .... = Version: 4
     .... 0101 = Header Length: 20 bytes (5)
   > Differentiated Services Field: 0x00 (DSCP: CS0, ECN: Not-ECT)
     Total Length: 324
     Identification: 0xa067 (41063)
   > Flags: 0x0000
     Fragment offset: 0
     Time to live: 128
     Protocol: UDP (17)
     Header checksum: 0x0000 [validation disabled]
     [Header checksum status: Unverified]
     Source: 192.168.1.5
     Destination: 54.37.202.229
 ∨ User Datagram Protocol, Src Port: 7079, Dst Port: 6947
     Source Port: 7079
```

```
Wireshark · Packet 463 · Wi-Fi                                                        —  □  ×

     0100 .... = Version: 4
     .... 0101 = Header Length: 20 bytes (5)
   > Differentiated Services Field: 0x00 (DSCP: CS0, ECN: Not-ECT)
     Total Length: 59
     Identification: 0xa066 (41062)
   > Flags: 0x0000
     Fragment offset: 0
     Time to live: 128
     Protocol: UDP (17)
     Header checksum: 0x0000 [validation disabled]
     [Header checksum status: Unverified]
     Source: 192.168.1.5
     Destination: 54.37.202.229
 ∨ User Datagram Protocol, Src Port: 7078, Dst Port: 6946
     Source Port: 7078
```

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```
Wireshark · Packet 3983 · p3.pcapng                                      —    □   ×

         Total Length: 336
         Identification: 0xa610 (42512)
      >  Flags: 0x00
         Fragment Offset: 0
         Time to Live: 128
         Protocol: UDP (17)
         Header Checksum: 0xd0d6 [validation disabled]
         [Header checksum status: Unverified]
         Source Address: 192.168.1.3
         Destination Address: 54.37.202.229
    ∨ User Datagram Protocol, Src Port: 7079, Dst Port: 22309
         Source Port: 7079
         Destination Port: 22309
         Length: 316
         Checksum: 0x7aa0 [unverified]


    ∨ Internet Protocol Version 4, Src: 192.168.1.3, Dst: 54.37.202.229
         0100 .... = Version: 4
         .... 0101 = Header Length: 20 bytes (5)
      >  Differentiated Services Field: 0x00 (DSCP: CS0, ECN: Not-ECT)
         Total Length: 98
         Identification: 0xa629 (42537)
      >  Flags: 0x00
         Fragment Offset: 0
         Time to Live: 128
         Protocol: UDP (17)
         Header Checksum: 0xd1ab [validation disabled]
         [Header checksum status: Unverified]
         Source Address: 192.168.1.3
         Destination Address: 54.37.202.229
    ∨ User Datagram Protocol, Src Port: 7078, Dst Port: 22308
```

There are some techniques and filters that we used to separate these packets. They are explained as follows:

1- From Wireshark itself, we can choose Analyze, Enabled Protocols, enable rtp-udp: this will show the RTP and RTCP protocols separately from each other.

2- From the header itself, we can notice that RTCP destination port is always greater than RTP destination port by value of one as RTCP is always an odd number, while RTP is always an even number.

- <u>Requirement 2:</u>

Some filter results for the audio and video payloads as follows:

For both video and audio together:


```
▌ rtp
No.         Time       Source          Destination      Protocol   Length  Info
  172428 415.182970   54.37.202.229   192.168.1.3      RTP         127 PT=DynamicRTP-Type-96, SSRC=0x743D06, Seq=26487, Time=1289360999
  172429 415.182970   54.37.202.229   192.168.1.3      RTP         890 PT=DynamicRTP-Type-96, SSRC=0x877EBEB0, Seq=6916, Time=1300099353
  172430 415.183194   54.37.202.229   192.168.1.3      RTP        1294 PT=DynamicRTP-Type-96, SSRC=0x877EBEB0, Seq=6917, Time=1300099353
  172431 415.183326   54.37.202.229   192.168.1.3      RTP         574 PT=DynamicRTP-Type-96, SSRC=0x877EBEB0, Seq=6918, Time=1300099353
  172432 415.183469   192.168.1.3     54.37.202.229    RTP        1294 PT=DynamicRTP-Type-96, SSRC=0x92B08865, Seq=35463, Time=2679776696
  172433 415.183719   192.168.1.3     54.37.202.229    RTP         649 PT=DynamicRTP-Type-96, SSRC=0x92B08865, Seq=35464, Time=2679776696
  172434 415.183895   192.168.1.3     54.37.202.229    RTP        1294 PT=DynamicRTP-Type-96, SSRC=0x92B08865, Seq=35465, Time=2679776696
  172435 415.183921   192.168.1.3     54.37.202.229    RTP         131 PT=DynamicRTP-Type-96, SSRC=0x92B08865, Seq=35466, Time=2679776696
  172436 415.183934   192.168.1.3     54.37.202.229    RTP        1294 PT=DynamicRTP-Type-96, SSRC=0x92B08865, Seq=35467, Time=2679776696
  172437 415.183956   192.168.1.3     54.37.202.229    RTP          68 PT=DynamicRTP-Type-96, SSRC=0x92B08865, Seq=35468, Time=2679776696
  172438 415.183977   192.168.1.3     54.37.202.229    RTP        1161 PT=DynamicRTP-Type-96, SSRC=0x92B08865, Seq=35469, Time=2679776696
  172439 415.184146   192.168.1.3     54.37.202.229    RTP        1223 PT=DynamicRTP-Type-96, SSRC=0x92B08865, Seq=35470, Time=2679776696, Mark
  172440 415.189493   192.168.1.3     54.37.202.229    RTP         124 PT=DynamicRTP-Type-96, SSRC=0xDBB184CF, Seq=26499, Time=2647701735
  172442 415.197206   54.37.202.229   192.168.1.3      RTP        1294 PT=DynamicRTP-Type-96, SSRC=0x877EBEB0, Seq=6919, Time=1300099353
  172443 415.197206   54.37.202.229   192.168.1.3      RTP         505 PT=DynamicRTP-Type-96, SSRC=0x877EBEB0, Seq=6920, Time=1300099353
  172444 415.197206   54.37.202.229   192.168.1.3      RTP         303 PT=DynamicRTP-Type-96, SSRC=0x877EBEB0, Seq=6922, Time=1300099353
  172445 415.197418   54.37.202.229   192.168.1.3      RTP        1294 PT=DynamicRTP-Type-96, SSRC=0x877EBEB0, Seq=6921, Time=1300099353
  172446 415.210476   192.168.1.3     54.37.202.229    RTP         124 PT=DynamicRTP-Type-96, SSRC=0xDBB184CF, Seq=26500, Time=2647702695
  172448 415.229394   192.168.1.3     54.37.202.229    RTP         130 PT=DynamicRTP-Type-96, SSRC=0xDBB184CF, Seq=26501, Time=2647703655
  172449 415.232245   54.37.202.229   192.168.1.3      RTP        1294 PT=DynamicRTP-Type-96, SSRC=0x877EBEB0, Seq=6923, Time=1300099353
  172450 415.232245   54.37.202.229   192.168.1.3      RTP         346 PT=DynamicRTP-Type-96, SSRC=0x877EBEB0, Seq=6924, Time=1300099353, Mark
```

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For audio alone:

```
25 0.001962    54.37.202.229    192.168.1.3    RTP    157 PT=DynamicRTP-Type-96, SSRC=0x877EBEB0, Seq=13395, Time=1262729553, Mark
26 0.001962    54.37.202.229    192.168.1.3    RTP    129 PT=DynamicRTP-Type-96, SSRC=0x743D06, Seq=5727, Time=1269431399
27 0.001962    54.37.202.229    192.168.1.3    RTP    129 PT=DynamicRTP-Type-96, SSRC=0x743D06, Seq=5728, Time=1269432359
28 0.001986    54.37.202.229    192.168.1.3    RTP    124 PT=DynamicRTP-Type-96, SSRC=0x743D06, Seq=5729, Time=1269433319
29 0.010039    192.168.1.3    54.37.202.229    RTP    129 PT=DynamicRTP-Type-96, SSRC=0xDBB184CF, Seq=5740, Time=2627773095
30 0.024460    192.168.1.3    54.37.202.229    RTP    251 PT=DynamicRTP-Type-96, SSRC=0x92B08865, Seq=6195, Time=2642414096
31 0.024669    192.168.1.3    54.37.202.229    RTP    107 PT=DynamicRTP-Type-96, SSRC=0x92B08865, Seq=6196, Time=2642414096
32 0.024703    192.168.1.3    54.37.202.229    RTP    142 PT=DynamicRTP-Type-96, SSRC=0x92B08865, Seq=6197, Time=2642414096
33 0.024874    192.168.1.3    54.37.202.229    RTP     77 PT=DynamicRTP-Type-96, SSRC=0x92B08865, Seq=6198, Time=2642414096
34 0.024893    192.168.1.3    54.37.202.229    RTP     67 PT=DynamicRTP-Type-96, SSRC=0x92B08865, Seq=6199, Time=2642414096, Mark
35 0.030229    192.168.1.3    54.37.202.229    RTP    126 PT=DynamicRTP-Type-96, SSRC=0xDBB184CF, Seq=5741, Time=2627774055
37 0.050197    192.168.1.3    54.37.202.229    RTP    126 PT=DynamicRTP-Type-96, SSRC=0xDBB184CF, Seq=5742, Time=2627775015
39 0.070333    192.168.1.3    54.37.202.229    RTP    123 PT=DynamicRTP-Type-96, SSRC=0xDBB184CF, Seq=5743, Time=2627775975
```

For video alone:

```
No.    Time          Source        Destination      Protocol  Length  Info
2304.. 558.189605   192.168.1.5    54.37.202.229    RTP    1294 PT=DynamicRTP-Type-96, SSRC=0x877EBEB0, Seq=21153, Time=1311507753
2304.. 558.189619   192.168.1.5    54.37.202.229    RTP    1106 PT=DynamicRTP-Type-96, SSRC=0x877EBEB0, Seq=21154, Time=1311507753
2304.. 558.189636   192.168.1.5    54.37.202.229    RTP    1294 PT=DynamicRTP-Type-96, SSRC=0x877EBEB0, Seq=21155, Time=1311507753
2304.. 558.189651   192.168.1.5    54.37.202.229    RTP    1294 PT=DynamicRTP-Type-96, SSRC=0x877EBEB0, Seq=21156, Time=1311507753
2304.. 558.189666   192.168.1.5    54.37.202.229    RTP    1294 PT=DynamicRTP-Type-96, SSRC=0x877EBEB0, Seq=21157, Time=1311507753
2304.. 558.189681   192.168.1.5    54.37.202.229    RTP    1294 PT=DynamicRTP-Type-96, SSRC=0x877EBEB0, Seq=21158, Time=1311507753
2304.. 558.189707   192.168.1.5    54.37.202.229    RTP    1194 PT=DynamicRTP-Type-96, SSRC=0x877EBEB0, Seq=21159, Time=1311507753
2304.. 558.189764   192.168.1.5    54.37.202.229    RTP    1294 PT=DynamicRTP-Type-96, SSRC=0x877EBEB0, Seq=21160, Time=1311507753
2304.. 558.189783   192.168.1.5    54.37.202.229    RTP    1294 PT=DynamicRTP-Type-96, SSRC=0x877EBEB0, Seq=21161, Time=1311507753
2304.. 558.189798   192.168.1.5    54.37.202.229    RTP    1294 PT=DynamicRTP-Type-96, SSRC=0x877EBEB0, Seq=21162, Time=1311507753
2304.. 558.189814   192.168.1.5    54.37.202.229    RTP    1294 PT=DynamicRTP-Type-96, SSRC=0x877EBEB0, Seq=21163, Time=1311507753
2304.. 558.189829   192.168.1.5    54.37.202.229    RTP    1294 PT=DynamicRTP-Type-96, SSRC=0x877EBEB0, Seq=21164, Time=1311507753
```

There are some techniques we used to extract the payload types. We used three different methods and explained farther as follows:
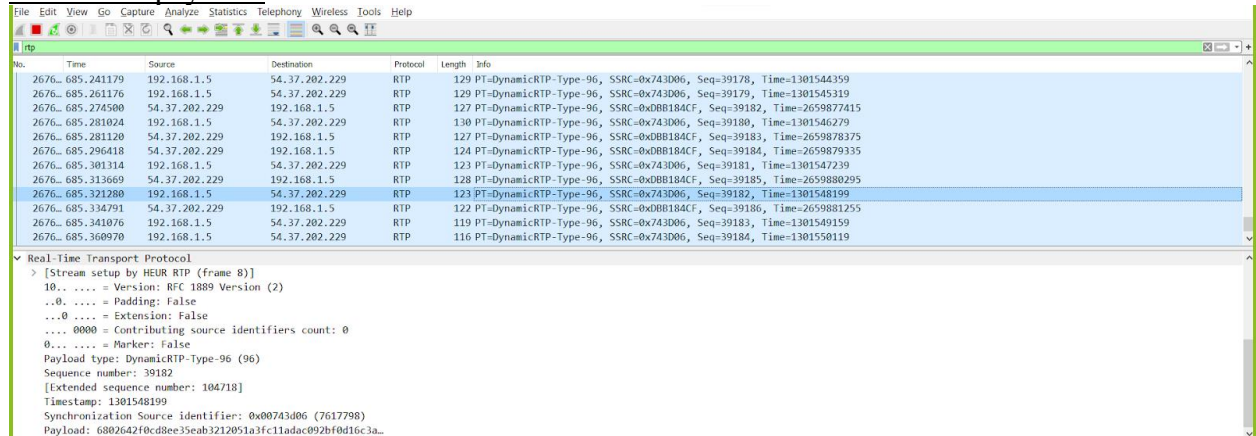
1. **Method no. 1:**

We managed to differentiate between the audio and video packets by observing the length of the packets, the video packets have more data than the audio packets as video packets have a length of 1294 bytes, while audio packets have a length of 116-130 bytes. This could be verified as follows:

RTP video payload:

```
File  Edit  View  Go  Capture  Analyze  Statistics  Telephony  Wireless  Tools  Help

No.    Time          Source        Destination      Protocol  Length  Info
2304.. 558.189605   192.168.1.5    54.37.202.229    RTP    1294 PT=DynamicRTP-Type-96, SSRC=0x877EBEB0, Seq=21153, Time=1311507753
2304.. 558.189619   192.168.1.5    54.37.202.229    RTP    1106 PT=DynamicRTP-Type-96, SSRC=0x877EBEB0, Seq=21154, Time=1311507753
2304.. 558.189636   192.168.1.5    54.37.202.229    RTP    1294 PT=DynamicRTP-Type-96, SSRC=0x877EBEB0, Seq=21155, Time=1311507753
2304.. 558.189651   192.168.1.5    54.37.202.229    RTP    1294 PT=DynamicRTP-Type-96, SSRC=0x877EBEB0, Seq=21156, Time=1311507753
2304.. 558.189666   192.168.1.5    54.37.202.229    RTP    1294 PT=DynamicRTP-Type-96, SSRC=0x877EBEB0, Seq=21157, Time=1311507753
2304.. 558.189681   192.168.1.5    54.37.202.229    RTP    1294 PT=DynamicRTP-Type-96, SSRC=0x877EBEB0, Seq=21158, Time=1311507753
2304.. 558.189707   192.168.1.5    54.37.202.229    RTP    1194 PT=DynamicRTP-Type-96, SSRC=0x877EBEB0, Seq=21159, Time=1311507753
2304.. 558.189764   192.168.1.5    54.37.202.229    RTP    1294 PT=DynamicRTP-Type-96, SSRC=0x877EBEB0, Seq=21160, Time=1311507753
2304.. 558.189783   192.168.1.5    54.37.202.229    RTP    1294 PT=DynamicRTP-Type-96, SSRC=0x877EBEB0, Seq=21161, Time=1311507753
2304.. 558.189798   192.168.1.5    54.37.202.229    RTP    1294 PT=DynamicRTP-Type-96, SSRC=0x877EBEB0, Seq=21162, Time=1311507753
2304.. 558.189814   192.168.1.5    54.37.202.229    RTP    1294 PT=DynamicRTP-Type-96, SSRC=0x877EBEB0, Seq=21163, Time=1311507753
2304.. 558.189829   192.168.1.5    54.37.202.229    RTP    1294 PT=DynamicRTP-Type-96, SSRC=0x877EBEB0, Seq=21164, Time=1311507753

v Real-Time Transport Protocol
  > [Stream setup by HEUR RTP (frame 1)]
    10.. .... = Version: RFC 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: 21155
    [Extended sequence number: 152227]
    Timestamp: 1311507753
    Synchronization Source identifier: 0x877ebeb0 (2273230512)
    Payload: b380fae5b291e56745c84c1d000510018399354418ee0b26...
```
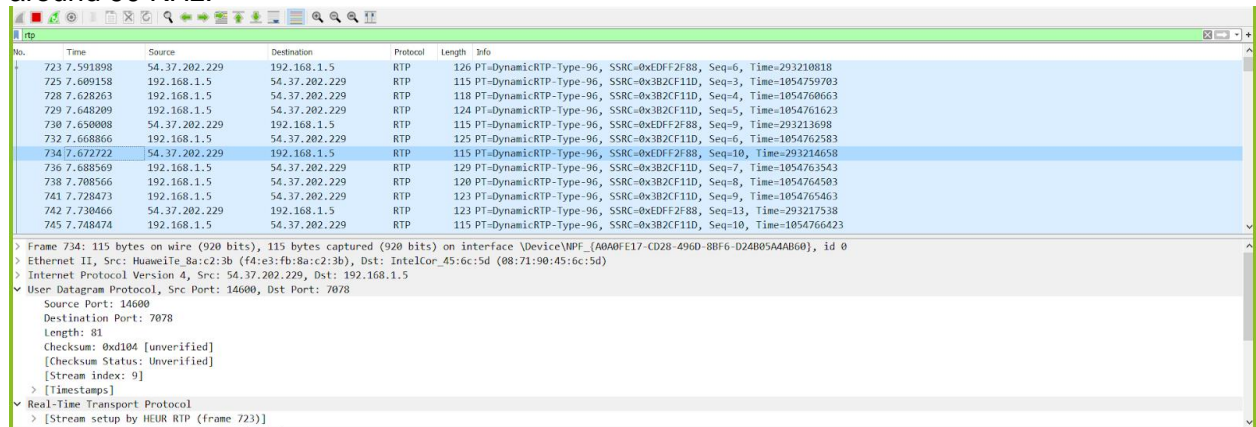
RTP audio payload:

2. **Method no. 2:**

We managed to differentiate between them analytically by calculating the sampling rate between two consecutive packets. For example, by taking sequence 10 and 9, we can find that:

$$T = \frac{\text{Trtp} - \text{Trtp} - 1}{\text{Tws} - \text{Tws} - 1} = \frac{2893214658 - 293213698}{7.672722 - 7.650008} = 42.266 \text{ KHz}$$

From the result, we can conclude that these packets are audio packets due to the sampling rate. Similarly, by calculating the sampling rate of two video consecutive packets. It was around 90 KHz.

3. **Method no. 3:**

We can differentiate between them by monitoring the sequence numbers. We can easily find that the sequence number of the audio payload has a different order than the video payload. The range of video sequence are around 700-800ish, while the range of audio sequence are around 33000ish.

- ## Requirement three:

  We managed to find three reports that were mentioned explicitly to get such as receiver, sender, and source description reports. Additionally, we found other additional reports such as payload-specific feedback and extended reports. The following screenshots display the headers of each.

```
> Frame 77095: 338 bytes on wire (2704 bits), 338 bytes captured (2704 bits) on interface \Device\NPF_{06C69427-AE9A-4151-9168-2841CDB7BA3E}, id 0
> Ethernet II, Src: HuaweiTe_ee:4c:ea (b4:f5:8e:ee:4c:ea), Dst: CyberTAN_14:97:3d (b0:fc:36:14:97:3d)
> Internet Protocol Version 4, Src: 54.37.202.229, Dst: 192.168.1.3
> User Datagram Protocol, Src Port: 65529, Dst Port: 7079
v Real-time Transport Control Protocol (Sender Report)
      10.. .... = Version: RFC 1889 Version (2)
      ..0. .... = Padding: False
      ...0 0001 = Reception report count: 1
      Packet type: Sender Report (200)
      Length: 12 (52 bytes)
      Sender SSRC: 0x00743d06 (7617798)
      Timestamp, MSW: 3815686112 (0xe36ebfe0)
      Timestamp, LSW: 2965009197 (0xb0ba732d)
      [MSW and LSW as NTP timestamp: Nov 30, 2020 00:48:32.690344999 UTC]
      RTP timestamp: 1278680039
      Sender's packet count: 15362
      Sender's octet count: 1191820
    v Source 1
        Identifier: 0xdbb184cf (3685844175)
      v SSRC contents
          Fraction lost: 0 / 256
          Cumulative number of packets lost: 91
        v Extended highest sequence number received: 15363
          Sequence number cycles count: 0
          Highest sequence number received: 15363
        Interarrival jitter: 994
        Last SR timestamp: 3219087722 (0xbfdf616a)
        Delay since last SR timestamp: 17712 (270 milliseconds)
> Real-time Transport Control Protocol (Source description)
> Real-time Transport Control Protocol (Extended report (RFC 3611))
> Real-time Transport Control Protocol (Extended report (RFC 3611))
> Real-time Transport Control Protocol (Extended report (RFC 3611))
```

```
v Real-time Transport Control Protocol (Extended report (RFC 3611))
      10.. .... = Version: RFC 1889 Version (2)
      ..0. .... = Padding: False
      Packet type: Extended report (RFC 3611) (207)
      Length: 11 (48 bytes)
      Sender SSRC: 0x00743d06 (7617798)
    v Block 1
        Type: Statistics Summary Report Block (6)
        0... .... = Loss Report Flag: False
        .0.. .... = Duplicates Report Flag: False
        ..0. .... = Jitter Report Flag: False
        ...0 0... = TTL or Hop Limit Flag: No TTL Values (0)
        Length: 9
      v Contents
          Identifier: 0xdbb184cf (3685844175)
          Begin Sequence Number: 15308
          End Sequence Number: 15364
          Lost Packets: 0
          Duplicate Packets: 0
          Minimum Jitter: 0
          Maximum Jitter: 0
          Mean Jitter: 0
          Standard Deviation of Jitter: 0
          Minimum TTL or Hop Limit: 0
          Maximum TTL or Hop Limit: 0
          Mean TTL or Hop Limit: 0
          Standard Deviation of TTL: 0
```

Source port no.	No. of packets	Packet type	SSRC	No. of packet loss
65529	15362	Sender report 200	0x00743d06	91
9079	40949	Receiver report 201	0x92b08865	925

Incoming and outgoing packets for participant 1:

<u>The usage of each report can be explained as follows:</u>

The sender reports (SR) and receiver reports (RR) exchange information on packet losses, delay and delay jitter. This information may be used to implement a TCP like flow control mechanism upon UDP at the application level using adaptive encodings.

Sender report: in the conference call, it shows the information for the outgoing packets. It contains the number of packets sent but it does not guarantee that all of these packets will be transmitted as some packets might be lost. In addition, it contains the packet type which is sender type and has the value of 200. In addition, it has the sender SSRC.
Format of sender report is as follows:

V	P	RC	PT=200	Length
		SSRC of the sender		
		NTP timestamp (MSB)		
		NTP timestamp (LSB)		
		RTP timestamp		
		Sender's packet count		
		Sender's octet count		
		First reception report block (SSRC_1)		
		...		
		Last reception report block (SSRC_n)		

- **The version number (V).**
- **Padding field (P)** are the same as in RTP packet.
- **The reception report count (RC)** indicates the number of receiver reports attached to this packet. The maximum number of receiver reports is 32.
- **The payload type (PT)** for sender report is 200.
- **SSRC of the sender.**
- **The high part** of the 64-bit NTP (Network Time Protocol) timestamp.
- **The low part** of the 64-bit NTP (Network Time Protocol) timestamp.
- **The RTP timestamp** indicates the relative sending time of this packet.

Receiver report: in the conference call, it shows the information for the ingoing packets. It contains the number of packets sent but it does not guarantee that all of these packets will be transmitted as some packets might be lost. In addition, it contains the packet type which is sender type and has the value of 201. In addition, it has the receiver SSRC.

Format of receiver report is as follows:

V	P	RC	PT=201	Length
			SSRC of the sender	
			SSRC of the first source	
	Fract. lost		Cum. no of packets lost	
		Ext. highest sequence number received		
		Interarrival jitter estimate		
		Last sender report timestamp (LSR)		
		Delay since last sender report (DLSR)		
		...		
		Last reception report block		

- **SSRC** of the source.
- **The fraction lost** field indicates the number of packets lost divided by the number of packets expected since last receiver report.

Source description: it contains a description of the packet type which is source description and has the value of 202. In addition, it holds SDEE items such as its name and type.

Format of source description is as follows:

| V	P	SC	PT=202	Length
		SSRC/CSRC of the sender		
	Type	length		text
		text continued		
		...		
		Last chunk		

- It is a three-level structure composed of a header and zero or more chunks
- It describes the source identified in that particular chunk.
- Each SDES item starts with an 8-bit type field followed by an 8-bit octet count, which identifies the length of the following text field.

- Requirement 4:

Taking two RTCP packets x, x+1 as examples for calculating the E2E delay.

Packet x
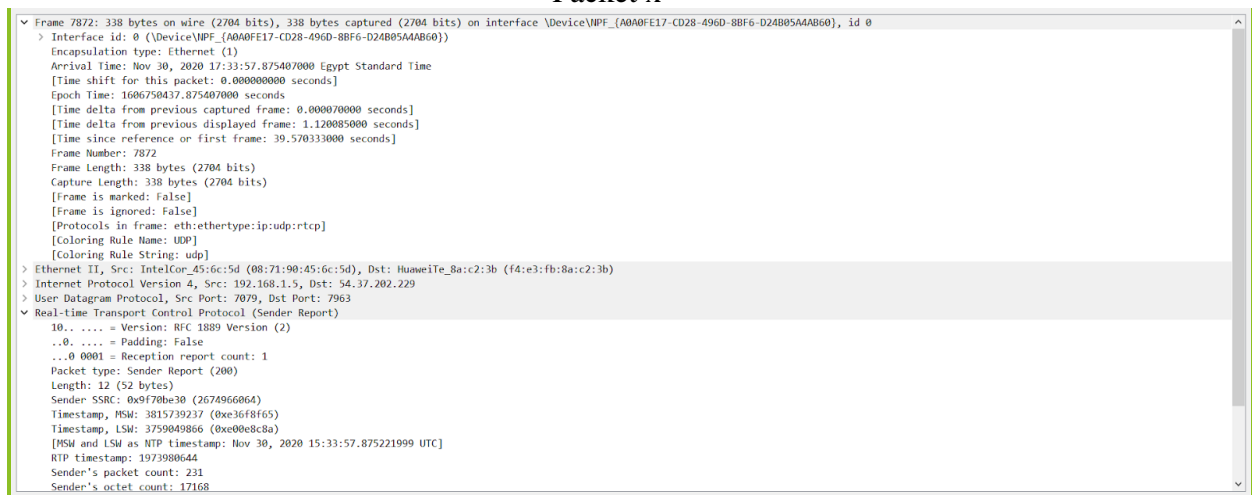
Packet x+1

For packet X:
NTP: Nov 30, 2020 15:33:55.714635999 UTC
RTP timestamp: 1973876964
RTP data audio sampling rate: 48 KHz (from line phone page)

For packet X+1:
NTP timestamp: Nov 30, 2020 15:33:57.875221999 UTC
RTP timestamp: 1973980644

- **Incremental difference in Number of units**:
- Packet$_x$ Timestamp –Packet$_{x+1}$ Timestamp= 1973980644 -1973876964= 103680 unit
- **Time difference**: $\dfrac{\text{incremental difference}}{\text{sampling rate}} = \dfrac{103680}{48 \text{ Khz}} = 2.16$ s

This time difference can also be verified using the difference in NTP timestamp as follows:
57.875221999 - 55.714635999 = 2.16 s

- **Wall clock time**: NTP time : Nov 30, 2020 17:33:57.875407000 Egypt Standard Time

In order to convert RTP time to NTP time for a packet:

$Packet_x (NTP) = packet_0 (NTP) + (Packet_x (RTP) - packet_0 (RTP))/ 48000)$

In order to calculate the E2E delay for the following
- **Arrival Time**: Nov 30, 2020 17:33:58.165097000 Egypt Standard Time
- **Timestamp**: 1973995044

Using the first RTCP packet as reference (Packet$_0$)
- **NTP for this RTP** = $55.714635999 + \frac{(1973950884 - 1973876964)}{48000} = 59.08$

- **E2E delay** = arrival time - NTP (RTP timestamp) =
        58.165097000 - 59.08= -0.009 s

Taking the absolute value of it so basically the delay value is 0.009 s.

2. **Part II: GNS3 Network Implementation**

We have designed the topology of the network in GNS3 and configured each component separately and defined the router as a DHCP server to dynamically assign each cloud (VM) an IP. The following screenshot shows the topology of the network.
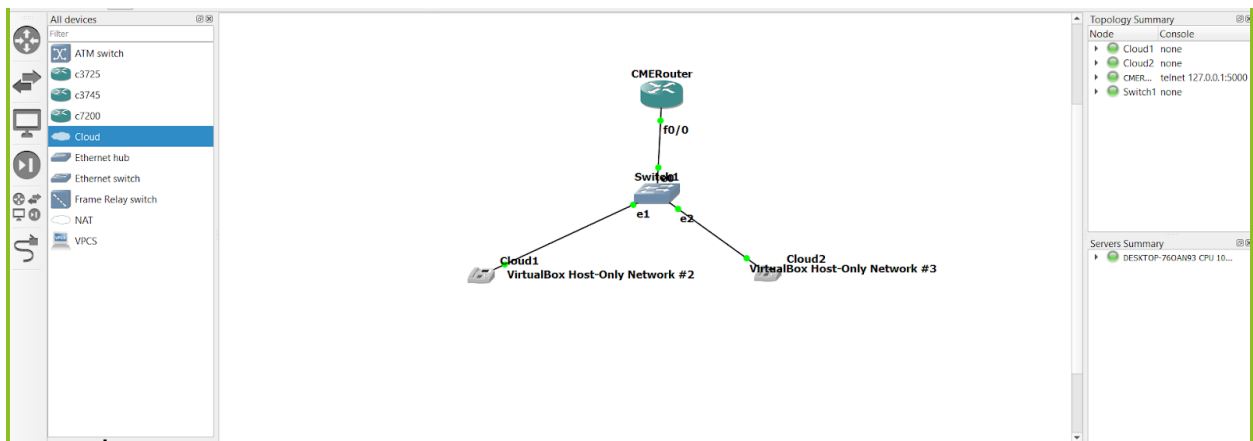
Dynamic configuration of the two VMs:

```
C:\WINDOWS\system32\cmd.exe

Windows IP Configuration

    Host Name . . . . . . . . . . . . : osos-uwjj7opr9t
    Primary Dns Suffix  . . . . . . . :
    Node Type . . . . . . . . . . . . : Unknown
    IP Routing Enabled. . . . . . . . : No
    WINS Proxy Enabled. . . . . . . . : No

Ethernet adapter Local Area Connection:

    Connection-specific DNS Suffix  . :
    Description . . . . . . . . . . . : Intel(R) PRO/1000 MT Desktop Adapter
    Physical Address. . . . . . . . . : 08-00-27-86-C2-39
    DHCP Enabled. . . . . . . . . . . : Yes
    Autoconfiguration Enabled . . . . : Yes
    IP Address. . . . . . . . . . . . : 192.168.1.5
    Subnet Mask . . . . . . . . . . . : 255.255.255.0
    Default Gateway . . . . . . . . . : 192.168.1.1
    DHCP Server . . . . . . . . . . . : 192.168.1.1
    DNS Servers . . . . . . . . . . . : 8.8.8.8
    Lease Obtained. . . . . . . . . . : Monday, November 30, 2020 9:00:00 PM
    Lease Expires . . . . . . . . . . : Tuesday, December 01, 2020 9:00:00 PM

C:\Documents and Settings\Administrator>
```

We have implemented all the steps successfully and were able to make a voice call from one VM to another and vice. These are the verification commands that we did in order to testify the correctness of the results.

```
CMERouter#show ephone

ephone-1 Mac:0800.275C.55CE TCP socket:[2] activeLine:0 REGISTERED in SCCP ver 2
0 and Server in ver 5
mediaActive:0 offhook:0 ringing:0 reset:0 reset_sent:0 paging 0 debug:0 caps:11
IP:192.168.1.4 1048 CIPC    keepalive 18 max_line 8
button 1: dn 1  number 1000 CH1    IDLE            CH2    IDLE
button 2: dn 2  number 2000 CH1    IDLE            CH2    IDLE


ephone-2 Mac:0800.2786.C239 TCP socket:[3] activeLine:0 REGISTERED in SCCP ver 2
0 and Server in ver 5
mediaActive:0 offhook:0 ringing:0 reset:0 reset_sent:0 paging 0 debug:0 caps:11
IP:192.168.1.5 1047 CIPC    keepalive 32 max_line 8
button 1: dn 3  number 1003 CH1    IDLE
```

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After applying the previous commands, we started the two communicators and we found that each one of the VMs could dial the number of the other VM and we can hear our voices clearly. The following screenshot shows the final setup for our environment.
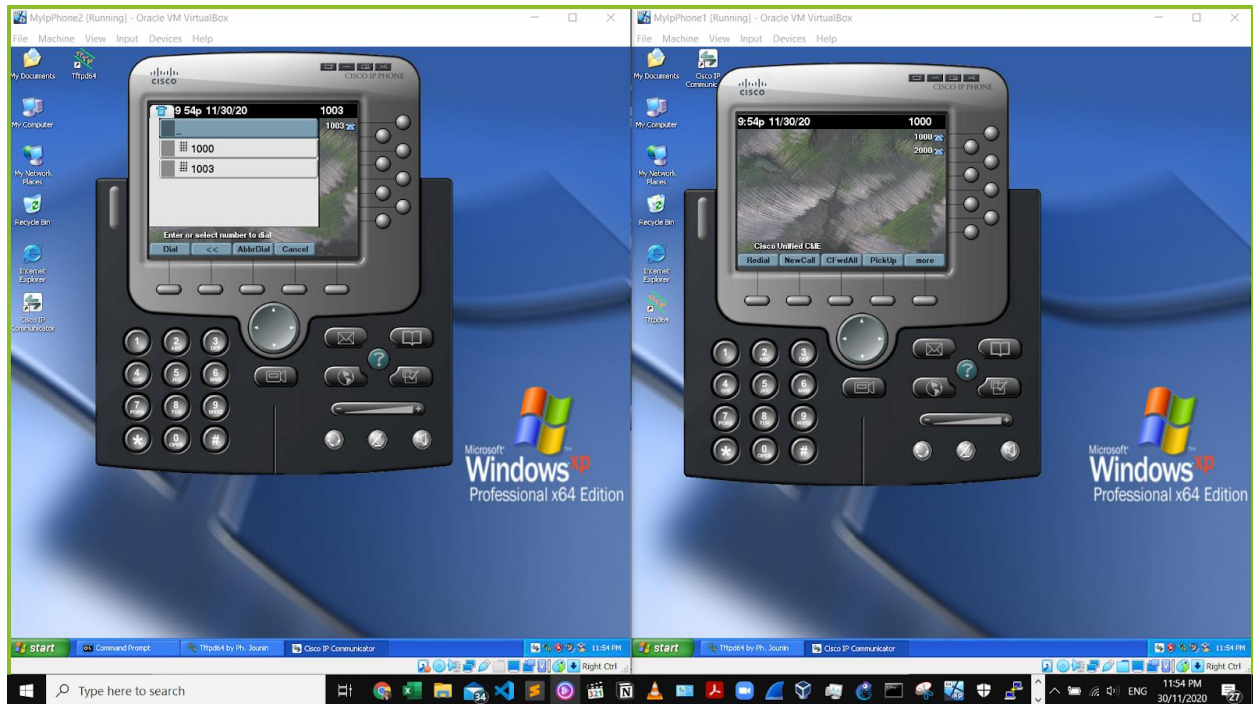
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