           Port Mapping between Unicast and Multicast RTP Sessions

Abstract

   This document presents a port mapping solution that allows RTP
   receivers to choose their own ports for an auxiliary unicast session
   in RTP applications using both unicast and multicast services. The
   solution provides protection against denial-of-service or packet
   amplification attacks that could be used to cause one or more RTP
   packets to be sent to a victim client.

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1. Introduction

   In (any-source or source-specific) multicast RTP applications,
   destination ports (i.e., the ports on which the multicast receivers
   receive the RTP and RTP Control Protocol (RTCP) packets) are defined
   declaratively. In other words, the receivers cannot choose their
   receive ports, and the sender(s) use the predefined ports.

   In unicast RTP applications, the receiving end needs to choose its
   ports for RTP and RTCP since these ports are local resources and only
   the receiving end can determine which ports are available to use. In
   addition, Network Address Port Translation (NAPT, hereafter simply
   called NAT) devices are commonly deployed in networks; thus, static
   port assignments cannot be used. The receiving end may convey its
   request to the sending end through different ways, one of which is
   the Offer/Answer Model [RFC3264] for the Session Description Protocol
   (SDP) [RFC4566]. However, the Offer/Answer Model requires offer/
   answer exchange(s) between the endpoints, and the resulting delay may
   not be desirable in delay-sensitive real-time applications.
   Furthermore, the Offer/Answer Model may be burdensome for the
   endpoints that are concurrently running a large number of unicast
   sessions with other endpoints.

   In this specification, we consider an RTP application that uses one
   or more unicast and multicast RTP sessions together. While the
   declaration and selection of the ports are well defined and work well
   for multicast and unicast RTP applications, respectively, the usage
   of the ports introduces complications when a receiving end mixes
   unicast and multicast RTP sessions within the same RTP application.

   An example scenario is where the RTP packets are distributed through
   source-specific multicast (SSM) [RFC4607] and a receiver sends
   unicast RTCP NACK feedback [RFC4585] to a local repair server (also
   functioning as a unicast RTCP feedback target) [RFC5760] asking for a
   retransmission of the packets it is missing, and the local repair
   server sends the retransmission packets over a unicast RTP session
   [RETRANSMISSION-FOR-SSM].

   Another scenario is where a receiver wants to rapidly acquire a new
   primary multicast RTP session and receives one or more RTP burst
   packets over a unicast session before joining the SSM session; see
   [RFC6285] regarding Rapid Acquisition of Multicast RTP Sessions
   (RAMS). Similar scenarios exist in applications where some part of
   the content is distributed through multicast while the receivers get
   additional and/or auxiliary content through one or more unicast
   connections, as illustrated in Figure 1.

In this document, we discuss this problem and introduce a solution
that we refer to as port mapping. This solution allows receivers to
choose their desired UDP ports for RTP and RTCP in every unicast
session when they are running RTP applications using both unicast and
multicast services and offer/answer exchange is not available. The
solution includes a Token-based protection mechanism against denial-
of-service (DoS) or packet amplification attacks that could be used
to cause one or more RTP packets to be sent to a victim client. This
solution is not applicable in cases where TCP is used as the
transport protocol in the unicast sessions. For such scenarios,
refer to [RFC4145].

```
           -----------
          |  Unicast  |................
          |  Source   |............  :
          | (Server)  |           :  :
           -----------            :  :
                                  v  v
           -----------        ----------        -----------
          | Multicast |------->|  Router  |---------->|Client RTP |
          |  Source   |       |          |..........>|Application|
           -----------        ----------        -----------
                                 | :
                                 | :               -----------
                                 | :..............>|Client RTP |
                                 +---------------->|Application|
                                                   -----------


       -------> Multicast RTP Flow
       .......> Unicast RTP Flow
```
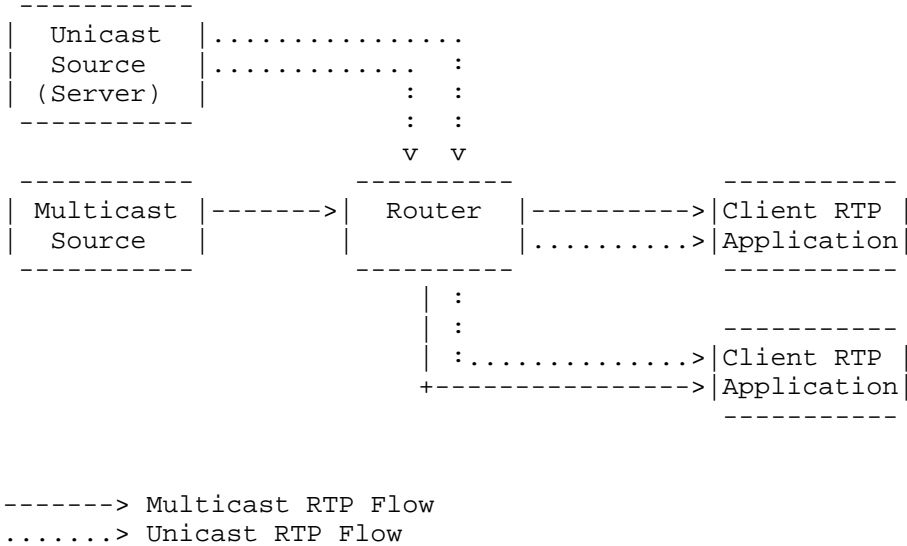
       Figure 1: RTP Applications Simultaneously Using Both Unicast and
                           Multicast Services

   In the remainder of this document, we refer to the RTP endpoints that
   serve other RTP endpoints over a unicast session as the Servers. The
   receiving RTP endpoints are referred to as Clients. This terminology
   also reflects the fact that when port mapping is used, the RTP
   packets can only flow in one direction (from the server to the
   client) in the unicast sessions.

2. Requirements Notation

   The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT",
   "SHOULD", "SHOULD NOT", "RECOMMENDED", "NOT RECOMMENDED", "MAY", and
   "OPTIONAL" in this document are to be interpreted as described in
   [RFC2119].

3. Token-Based Port Mapping

   Token-based port mapping consists of the server providing the client
   a Token that can be used to establish a unicast session without the
   possibility of an attacker redirecting traffic to an unsuspecting
   third party to create a DoS attack. The Token is essentially an
   opaque encapsulation that is based on the client's IP address (as
   seen by the server), a time-to-live value, and a random nonce
   provided by the client.

   Token-based port mapping consists of two steps: (i) Token request and
   retrieval, and (ii) unicast session establishment.

   When a Token request is received, the server creates a Token for this
   particular client and sends it back to the client.

   Once a Token is retrieved from a particular server, it can be used
   for all the unicast sessions the client will be running with this
   particular server until the Token expires. By default, Tokens are
   server specific. However, the client can use the same Token to
   communicate with different servers if these servers are provided with
   the same secret key and algorithm used to generate the Token and are
   at least loosely clock-synchronized.

   The Token becomes invalid if the client's IP address (as seen by the
   server) changes (note that the client cannot necessarily detect this
   in a timely manner) or if the server expires the Token. In these
   cases, the client has to request a new Token.

   As the second step, when the client wants to establish a unicast
   session, the client includes the Token with its RTCP feedback
   message. The server validates the Token, making sure that the IP
   address information matches. This is effective against DoS attacks,
   e.g., an attacker cannot simply spoof another client's IP address and
   start a unicast transmission towards random clients. If the
   validation passes, the unicast session gets established. Otherwise,
   the server notifies the client that the validation has failed, and in
   this case, the unicast session will not be established.

   Upon successful validation and once the unicast session is
   established, all the RTP and RTCP rules specified in [RFC3550] and
   other relevant specifications also apply in this session until it is
   terminated. During the lifetime of a unicast session, a client might
   need to send RTCP messages that require authorization. Since such
   messages require a valid Token for authorization, the client needs to
   include the Token along with such RTCP messages as explained in
   detail in later sections of this document.

   Below, we first present a motivating scenario for port mapping and
   then describe the normative behavior and requirements.

3.1. Motivating Scenario

   Consider an SSM distribution network where a distribution source
   multicasts RTP packets to a large number of clients, and one or more
   retransmission servers function as feedback targets to collect
   unicast RTCP feedback from these clients [RFC5760]. The
   retransmission servers also join the multicast session to receive the
   multicast packets and cache them for a certain time period. When a
   client detects missing packets in the multicast session, it requests
   a retransmission from one of the retransmission servers by using an
   RTCP NACK message [RFC4585]. The retransmission server pulls the
   requested packet(s) out of the cache and retransmits them to the
   requesting client [RETRANSMISSION-FOR-SSM].

   The RTP and RTCP flows pertaining to the scenario described above are
   illustrated in Figure 2. Between the client and server, we assume
   there exists at least one NAT device [RFC4787]. (If there are no NAT
   devices between the server and client, the method still works in the
   same fashion.) The multicast and unicast sessions are clearly
   identified with their individual RTP and RTCP flows and port numbers.

```
     --------------                      ---  ----------
    |              |------------------------------|   |-->|P1       |
    |              |-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-|   |.->|P2       |
    |              |                              |   |   |         |
    | Distribution |        ----------------      |   |   |         |
    |    Source    |       |                |      |   |   |         |
    |              |---->|P1               |      |   |   |         |
    |              |.-.->|P2               |      |   |   |         |
    |              |       |                |      |   |   |         |
     --------------        |            P3|<.=.=.=.|   |=.=|*c0      |
                           |            P3|<~~~~~~~|   |~~~|*c1      |
    MULTICAST RTP          |                |      |   |   |         |
    SESSION with           |                |      | N |   |         |
    UNICAST FEEDBACK       |                |      | A |   |         |
                           |  Retransmission |      | T |   |  Client |
    - - - - - - - - - -|-  - - - - - - -| - - - -| - |- -| - - - - -|-
                           |     Server     |      |   |   |         |
    PORT MAPPING           |            PT|<~~~~~~~|   |~~>|*cT      |
                           |                |      |   |   |         |
    - - - - - - - - - -|- - - - - - - -| - - - -| - |- -| - - - - -|-
                           |                |      |   |   |         |
    AUXILIARY UNICAST      |                |      |   |   |         |
    RTP SESSION            |                |      |   |   |         |
                           |            P3|........|   |..>|*c1      |
                           |            P3|=.=.=.=.|   |=.>|*c1      |
                           |            P4|<.=.=.=.|   |=.=|*c2      |
                           |                |      |   |   |         |
                            ----------------       ---  ----------
```
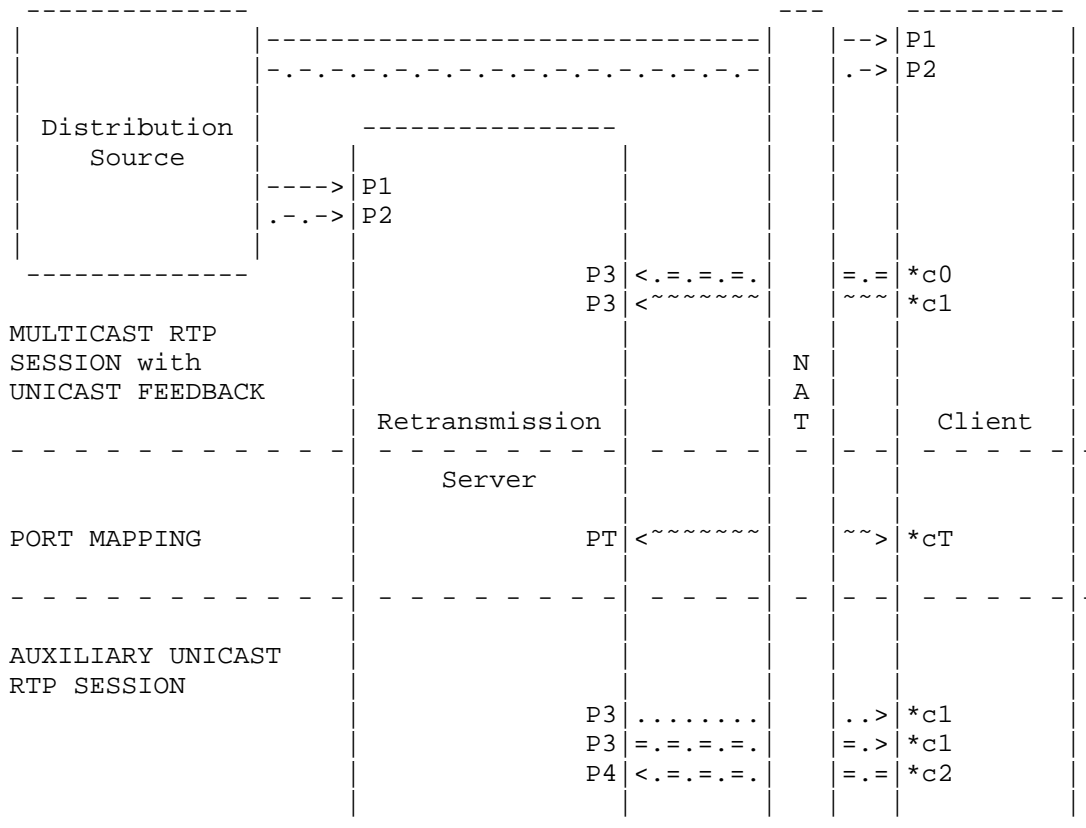
```
        -------> Multicast RTP Flow
        .-.-.-.> Multicast RTCP Flow
        .=.=.=.> Unicast RTCP Reports
        ~~~~~~~> Unicast RTCP (Feedback) Messages
        .......> Unicast RTP Flow
```

   Figure 2: Example Scenario Showing an SSM Distribution with Support
                   for Retransmissions from a Server

   In Figure 2, we have the following multicast and unicast ports:

   o Ports P1 and P2 denote the destination RTP and RTCP ports in the
      multicast session, respectively. The clients listen to these
      ports to receive the multicast RTP and RTCP packets. Ports P1 and
      P2 are defined declaratively.

   o Port P3 denotes the RTCP port on the feedback target running on
      the retransmission server to collect any RTCP packet sent by the
      clients, including feedback messages and RTCP receiver and
      extended reports. This is also the port that the retransmission
      server uses to send the RTP packets and RTCP sender reports in the
      unicast session. Port P3 is defined declaratively.

   o Port P4 denotes the RTCP port on the retransmission server used to
      collect the RTCP receiver and extended reports for the unicast
      session. Port P4 is defined declaratively.

   o Ports *c0, *c1, and *c2 are chosen by the client. (Note: "*"
      indicates that the port can be chosen randomly; once chosen, the
      "*" is no longer used.) *c0 denotes the port on the client used to
      send the RTCP reports for the multicast session. *c1 denotes the
      port on the client used to send the unicast RTCP feedback messages
      in the multicast session and to receive the RTP packets and RTCP
      sender reports in the unicast session. *c2 denotes the port on the
      client used to send the RTCP receiver and extended reports in the
      unicast session. Ports c0, c1, and c2 could be the same port or
      different ports. There are two advantages of using the same port
      for both c0 and c1:

      1. Some NATs only keep bindings active when a packet goes from
          the inside to the outside of the NAT (see REQ-6 of Section 4.3
          of [RFC4787]). When the gap between the packets sent from the
          client to the server is long, this can exceed the timeout
          limit. If c0=c1, the occasional (periodic) RTCP receiver
          reports sent from port c0 (for the multicast session's RTCP
          port P3) will ensure the NAT does not time out the public port
          associated with the incoming unicast traffic to port c1.

      2. Having c0=c1 conserves NAT port bindings.

   o Ports PT and *cT denote the ports through which the Token request
      and retrieval occur at the server and client sides, respectively.
      Port PT is declared on a per-unicast-session basis, although the
      same port could be used for two or more unicast sessions sourced
      by the server. A Token once requested and retrieved by a client
      from port PT remains valid until its expiration time.

   We assume that the information declaratively defined is available as
   part of the session description information and is provided to the
   clients. The Session Description Protocol (SDP) [RFC4566] and other
   session description methods can be used for this purpose.

3.2. Normative Behavior and Requirements

   In this section, we describe the normative behavior and requirements.
   To simplify the presentation, we refer to the port numbers described
   in the example presented in Figure 2. However, the behavior and
   requirements described here are not specific to that particular
   example and can be applied to any scenario where analogous ports can
   be identified.

   First of all, a client compliant with this specification MUST be able
   to include a Token with any type of RTCP message (as described below)
   when it is needed.

   Second, the solution provided in this specification is not applicable
   in cases where there is RTP traffic flowing from the client to the
   server in the unicast session. In other words, the direction of RTP
   traffic MUST be only from the server to the client in the unicast
   session. If the client wants to send RTP traffic back to the server,
   the regular session establishment methods such as [RFC3264] need to
   be used.

   The following steps summarize the Token-based solution:

   1. The client ascertains server address and port numbers (P3, P4 and
       PT) from the session description. Port P4 MUST be different from
       port P3. Port PT MAY be equal to port P3.

   2. The client selects its local port numbers (*c0, *c1, *c2 and
       *cT). It is strongly RECOMMENDED that the client uses the same
       port for c0 and c1. Port cT MAY be equal to ports c0 and c1.

   3. If the client does not have a Token (or the existing Token has
       expired):

       A. The client first sends a Port Mapping Request message
           (Section 4.1) to port PT. This message is sent from port cT
           on the client side. The server learns the client's IP
           address from the received message. The client can send this
           message anytime it wants (e.g., during initialization) and
           does not normally ever need to resend this message (see
           Section 6).

       B. The server generates an opaque encapsulation (i.e., the
           Token) based on certain information, including the client's
           IP address.

       C.   The server sends the Token back to the client using a Port
          Mapping Response message (Section 4.2). This message MUST be
          sent from port PT towards port cT.

4.   The client needs to provide the Token to the server using a Token
    Verification Request message (Section 4.3) whenever the client
    sends an RTCP feedback message for triggering or controlling a
    unicast session (see Section 4.3.1). If the Token is invalid or
    missing, the server sends a Token Verification Failure message
    (Section 4.4) to the client.

    Note that the unicast session is only established after the
    server has received a feedback message (along with a valid Token)
    from the client for which it needs to react by sending unicast
    data. Until a unicast session is established, neither the server
    nor the client needs to send RTCP reports for the unicast
    session.

5.   Normal flows ensue as shown in Figure 2. It is strongly
    RECOMMENDED that the client uses the same port for both c0 and
    c1, as this causes the periodic RTCP reports to keep the NAT
    mapping alive. However, if the client uses different ports for
    c0 and c1, the client MUST keep its own NAT mapping alive for the
    P3->c1 session (see [RFC6263] for additional information).

    In the unicast session, traffic from the server to the client
    (i.e., both the RTP and RTCP packets sent from port P3 towards
    port c1) MUST be multiplexed on the same port [RFC5761].

    The client sends the RTCP receiver and extended reports in the
    unicast session from port c2 towards port P4. The server
    correlates these reports with the reports received in the
    multicast session based on the client's RTCP Canonical Name
    (CNAME). Thus, the client MUST use the same RTCP CNAME in both
    sessions, and its RTCP CNAME MUST be unique [RFC6222].

A unicast session on a particular receive port c1 can last as long as
the associated multicast session lasts. However, a client cannot
keep using the same receive port c1 for different subsequent unicast
sessions since there could be packet leakage when switching from one
unicast session to another unless each received unicast stream has
its own distinct Synchronization Source (SSRC) identifier to allow
the client to filter out the undesired packets. Unless this is
guaranteed (which is not often easy), a client SHOULD use separate
receive ports for subsequent unicast sessions. After a sufficient
time (two minutes is RECOMMENDED, similar to one TCP Maximum Segment
Lifetime specified in [RFC0793]), a previously used receive port can
be used again.

The established unicast session can be explicitly terminated by the
procedures specified by an application or extension using the port
mapping approach described in this document. In addition, the
unicast session can also be terminated by the procedure defined
below, which is based on timing all participants out following the
timeout rules of [RFC3550]. Both the server and client periodically
check the liveness of the other peer, and if there is no RTCP traffic
from the other peer for a certain amount of time (Section 6.3.5 of
[RFC3550] suggests five RTCP reporting intervals), the unicast
session SHOULD be considered terminated, and no further RTP and/or
RTCP packets SHOULD be sent in that session. The client can attempt
to establish a new unicast session if needed. If no explicit
procedure for session termination exists, the client MAY stop sending
RTCP to the server to accomplish session termination. However, the
server SHALL NOT stop sending RTCP until the unicast session is
terminated. If Token-based authentication is also signaled to be
allowed in the unicast session, i.e., in the RTCP messages sent from
port c2 towards port P4, the client SHOULD terminate the unicast
session by sending an RTCP BYE message for each SSRC it has used in
that unicast session.

4. Message Formats

   This section defines the formats of the RTCP messages that are
   exchanged between a server and a client for the purpose of port
   mapping. A new RTCP control packet type is introduced, and four port
   mapping messages using this control packet are defined:

   1. Port Mapping Request

   2. Port Mapping Response

   3. Token Verification Request

   4. Token Verification Failure

   Each message has a fixed-length field for version (V), padding (P),
   sub-message type (SMT), packet type (PT), length, and SSRC of packet
   sender. Messages have other fields as defined below. In all
   messages defined in this section, the PT field is set to TOKEN (210).
   Individual messages are identified by the SMT field. The length
   field indicates the message size in 32-bit words minus one, including
   the header and any padding. This definition is in line with the
   definition of the Length field used in RTCP sender and receiver
   reports. In all messages, any Reserved field SHALL be set to zero
   and ignored.

Following the rules specified in [RFC3550], all integer fields in the
messages defined below are carried in network-byte order, that is,
most significant byte (octet) first, also known as big-endian.
Unless otherwise stated, numeric constants are in decimal (base 10).

Note that RTCP is not a timely or reliable protocol. The RTCP
packets might get lost or reordered in the network, and it is not
easy to detect these events. When sending a new Port Mapping Request
message, the scheduling rules that apply to sending initial RTCP
messages [RFC4585] apply. When a client sends a Port Mapping Request
or Token Verification Request message but it does not receive a
response back from the server (either a Port Mapping Response or
Token Verification Failure message), it MAY resend its request by
following the timer rules defined for RTCP feedback messages in
Section 3.5 of [RFC4585] as a good practice. However,
implementations are advised to avoid sending spurious RTCP messages
just because the timer rules (based on some RTCP configuration
parameters) allow. Reasonably safe practices are to be used to
detect RTCP message loss. When sending an RTCP (feedback) message
bundled with a Token Verification Request message, the timer rules of
[RFC4585] apply as usual.

4.1. Port Mapping Request

The Port Mapping Request message is identified by SMT=1. This
message is transmitted by the client to a dedicated server port (and
possibly a dedicated address) to request a Token. In the Port
Mapping Request message, the packet sender's SSRC is set to the
client's SSRC, which is chosen randomly by the client. The packet
format has the structure depicted in Figure 3.

```
    0                   1                   2                   3
    0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |V=2|P|  SMT=1  |    PT=TOKEN   |           Length=3            |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                     SSRC of Packet Sender                     |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                                                              |
   |                          Random                              |
   |                          Nonce                               |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

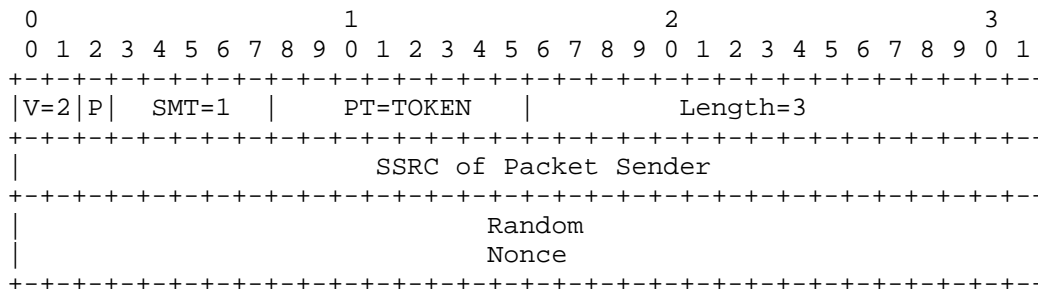   Figure 3: Packet Format for the Port Mapping Request Message

   o Random Nonce (64 bits): Field that contains a random value
      generated by the client following the procedures of [RFC4086].
      This nonce is taken into account by the server when generating a
      Token for the client to enable better security for clients that

      share the same IP address (such clients need to produce a random
      value extremely unlikely to collide with other clients sharing the
      same IP address). If the same Port Mapping Request message is
      transmitted multiple times for redundancy reasons, the random
      nonce value MUST remain the same in these duplicated messages.
      However, the client MUST generate a new random nonce for every new
      Port Mapping Request message.

4.2. Port Mapping Response

   The Port Mapping Response message is identified by SMT=2. This
   message is sent by the server and delivers the Token to the client as
   a response to the Port Mapping Request message. In the Port Mapping
   Response message, the packet sender's SSRC is set to the server's
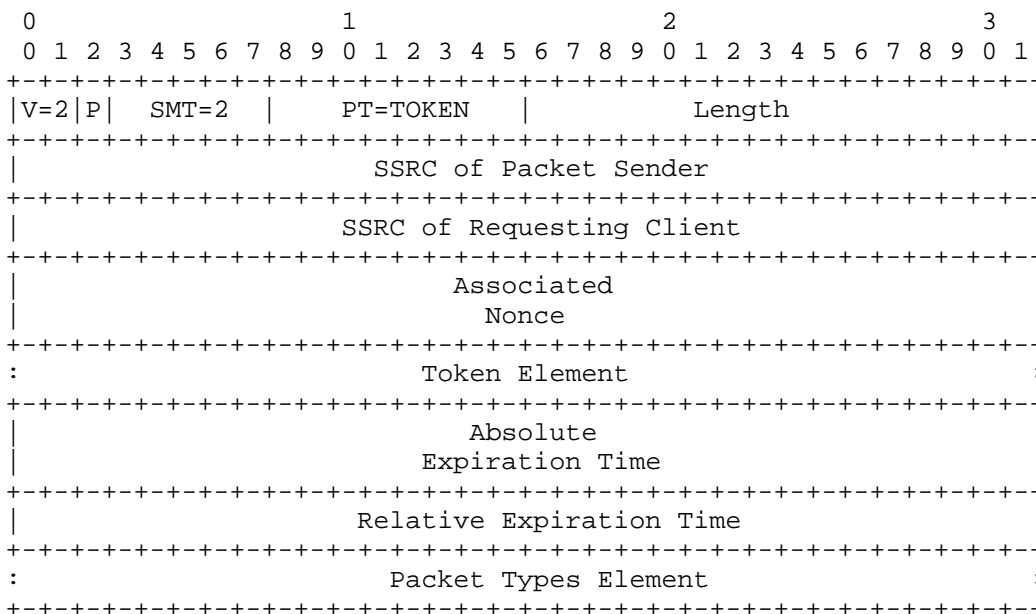   SSRC. The packet format has the structure depicted in Figure 4.

```
    0                   1                   2                   3
    0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |V=2|P|  SMT=2  |   PT=TOKEN    |             Length            |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                      SSRC of Packet Sender                    |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                    SSRC of Requesting Client                  |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                          Associated                           |
   |                            Nonce                              |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   :                        Token Element                          :
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                          Absolute                             |
   |                       Expiration Time                         |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                    Relative Expiration Time                   |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   :                     Packet Types Element                      :
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

        Figure 4: Packet Format for the Port Mapping Response Message

   o SSRC of Requesting Client (32 bits): Field that contains the SSRC
      of the client who sent the request.

   o Associated Nonce (64 bits): Field that contains the nonce received
      in the Port Mapping Request message and used in Token
      construction.

o Token Element (variable size): Element that is used to carry the
   Token generated by the server. This element is a 32-bit aligned
   Length-Value element. The Length field, which is 16 bits,
   indicates the length (in octets) of the Value field that follows
   the Length field. While a 16-bit length allows for Tokens with a
   size of up to 65535 bytes, using Tokens of sizes that make the
   RTCP compound packet larger than the MTU might have a negative
   impact on functionality because of IP fragmentation. Some NATs or
   other middleboxes do not pass IP fragments; thus, a large Token
   can cause the whole mechanism to fail. In addition, fragmentation
   increases the risk for packet loss.

   The length does not include any padding that is required for
   alignment. The Value field carries the Token (or more accurately,
   the output of the encoding process on the server). If the Token
   element does not fall on a 32-bit boundary, the last word MUST be
   padded to the boundary using further bits set to zero.

o Absolute Expiration Time (64 bits): Field that contains the
   absolute expiration time of the Token. The absolute expiration
   time is expressed as a Network Time Protocol (NTP) timestamp value
   in seconds since the year 1900 [RFC5905]. The client does not
   need to use this element directly and thus does not need to
   synchronize its clock with the server. However, the client needs
   to send this element back to the server along with the associated
   nonce in the Token Verification Request message and thus needs to
   keep it associated with the Token.

o Relative Expiration Time (32 bits): Field that contains the
   relative expiration time of the Token. The relative expiration
   time is expressed in seconds from the time the Token was
   generated. Whenever a server decides to not grant a Token to a
   requesting client, the relative expiration time will be set to
   zero (and hence, the accompanying Token will be invalid).

   The server conveys the relative expiration time in the clear to
   the client to allow the client to request a new Token well before
   the expiration time.

o Packet Types Element (variable size): Element that is used to
   signal which RTCP packet types require Token-based authentication.
   This element is a 32-bit aligned Length-Value element. The Length
   field, which is 8 bits, indicates the length (in octets) of the
   Value field that follows the Length field. This length does not
   include any padding that is required for alignment. The Value
   field carries zero or more 8-bit sub-fields, each carrying an RTCP
   packet type. If the Packet Types element does not fall on a

         32-bit boundary, the last word MUST be padded to the boundary
         using further bits set to zero. An example Packet Types element
         is shown in Figure 5.

         A server MAY change its policy on which RTCP packet types would
         require Token-based authentication based on observations,
         configuration, or other policies. However, upon such a change,
         the server SHALL NOT send a new Port Mapping Response message to
         the clients who requested a Token earlier. A client learns about
         this change when and if it gets a Token Verification Failure
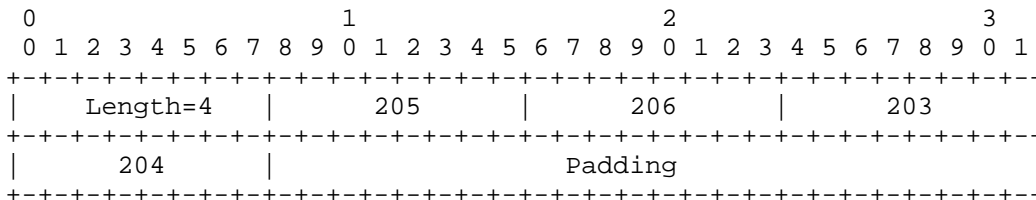   message.

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|    Length=4    |      205      |      206      |      203      |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|      204      |                    Padding                    |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

                  Figure 5: Example Packet Types Element

   4.3. Token Verification Request

      The Token Verification Request message is identified by SMT=3. This
      message contains the Token and accompanies any RTCP message that
      would trigger a new unicast session or control an existing unicast
      session. For a list of such messages, see Section 4.3.1.

      In the Token Verification Request message, the packet sender's SSRC
      is set to the client's SSRC. The client MUST NOT send a Token
      Verification Request message with a Token that has expired. The
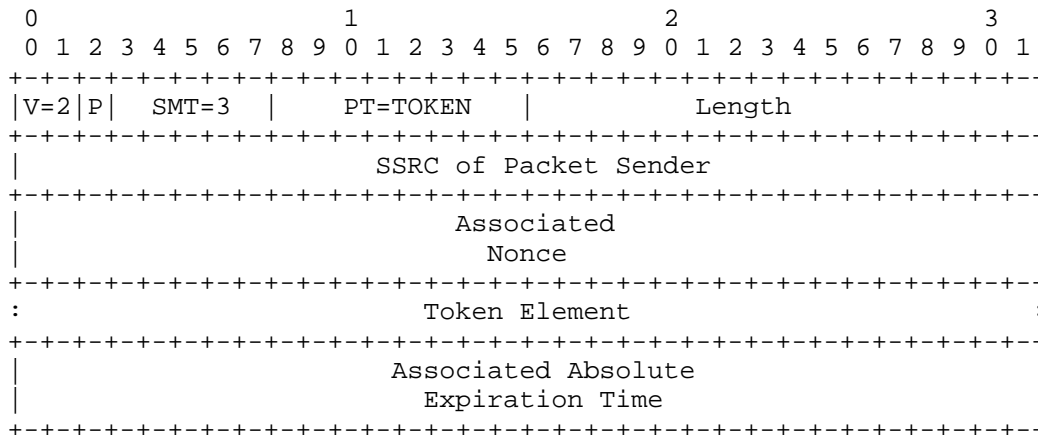   packet format has the structure depicted in Figure 6.

```
    0                   1                   2                   3
    0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |V=2|P|  SMT=3  |   PT=TOKEN    |            Length             |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                     SSRC of Packet Sender                     |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                         Associated                            |
   |                           Nonce                               |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   :                         Token Element                         :
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                     Associated Absolute                       |
   |                       Expiration Time                         |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

   Figure 6: Packet Format for the Token Verification Request Message

   o Associated Nonce (64 bits): Field that contains the nonce
      associated with the Token below.

   o Token Element (variable size): Token element that was previously
      received in the Port Mapping Response message.

   o Associated Absolute Expiration Time (64 bits): Field that contains
      the absolute expiration time associated with the Token above.

4.3.1. Where to Include Token

   This section provides guidelines about which RTCP packet types would
   need to be accompanied by a Token Verification Request message.
   However, since a server might determine in real time that other RTCP
   messages also need to be authenticated by a Token, a client MUST act
   according to the up-to-date list provided to the client in the Port
   Mapping Response message (in the Packet Types element). Clients need
   to support the use of Token-based authentication with any necessary
   RTCP message (see Section 3.2).

   As a general rule, when the Token capability is declared in the
   session description, the RTCP messages that trigger transmission of
   RTP packets in a port mapped unicast session are REQUIRED to be
   authenticated by using a Token. Such messages include but are not
   limited to:

   o NACK messages [RFC4585]

   o RAMS Request (RAMS-R) messages [RFC6285]

Additionally, some RTCP messages might directly or indirectly control
an existing unicast session associated with a multicast session.
Unless another authentication method as described in their respective
specifications is used, implementations MUST support authenticating
such RTCP messages by using a Token.

Examples are:

o BYE messages [RFC3550]

o RAMS Termination (RAMS-T) messages [RFC6285]

o Codec Control Messages (CCMs) [RFC5104]

Note that even if a packet type is listed to require Token-based
authentication, it does not need to be authenticated when it does not
control the unicast session. For example, if BYE (203) is listed in
the Port Mapping Response message as one of the packet types that
requires authentication, the client does not need to bundle the RTCP
BYE message with a Token when it is sending it for the multicast
session.

The Token Verification Request message might also be bundled with
packets carrying RTCP receiver and/or extended reports. While such
packets do not have a strong security impact, a specific application
might desire to have a more controlled reporting scheme from the
clients. In this case, the server lists the packet types for the
receiver (201) and/or extended reports (207) in the Port Mapping
Response message.

4.4. Token Verification Failure

The Token Verification Failure message is identified by SMT=4. This
message is sent by the server and notifies the client that the Token
was invalid or that the client did not include a Token Verification
Request message in the RTCP packet although it was supposed to (the
message is sent from port P3 towards port c1). The packet format has
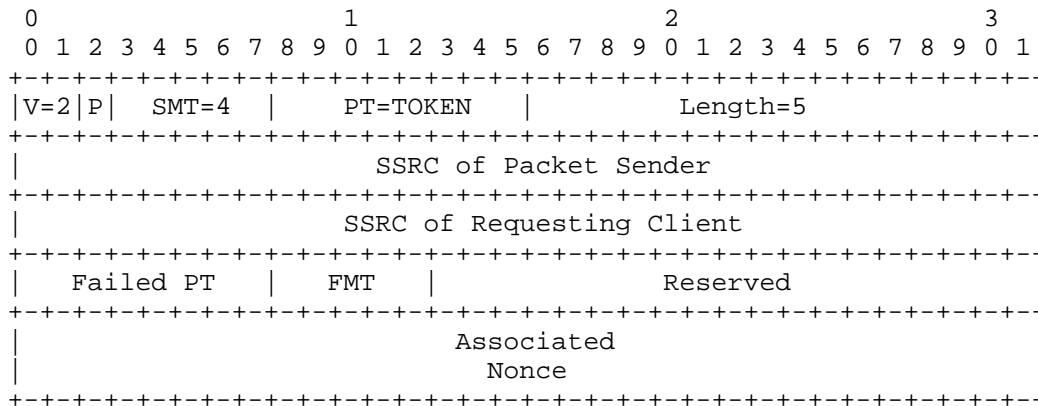the structure depicted in Figure 7.

```
    0                   1                   2                   3
    0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |V=2|P|  SMT=4  |    PT=TOKEN     |            Length=5           |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                   SSRC of Packet Sender                        |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                  SSRC of Requesting Client                     |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |   Failed PT  |   FMT   |              Reserved                  |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                         Associated                            |
   |                           Nonce                               |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

   Figure 7: Packet Format for the Token Verification Failure Message

   o SSRC of Packet Sender: This is the server's SSRC, which equals the
      SSRC of the respective multicast stream. Note that this SSRC
      value is from a different SSRC space than the one used in the
      unicast session.

   o SSRC of Requesting Client (32 bits): Field that contains the SSRC
      of the client.

   o Failed PT (8 bits): Field that indicates the type of the RTCP
      packet that caused this failure message.

   o FMT (5 bits): Field that indicates the feedback message type (FMT)
      value of the RTCP packet that caused this failure. Together with
      the field above, the client can infer which RTCP message it had
      previously sent caused this failure message to be sent by the
      server. For example, if the client did not include a valid Token
      with an RTCP NACK message, the Failed PT field will indicate 205
      (RTPFB) and the FMT field will indicate 1 (Generic NACK). If the
      RTCP message did not have an associated FMT value (such as an RTCP
      BYE message), the FMT field SHALL be set to zero.

   o Associated Nonce (64 bits): Field that contains the nonce received
      in the Token Verification Request message. If there was no Token
      Verification Request message included by the client, this field is
      set to zero.

5. Procedures for Token Construction

   The Token encoding is known to the server but opaque to the client.
   Implementations MUST encode the following information into the Token
   as a minimum, in order to provide adequate security:

    o Client's IP address as seen by the server (32/128 bits for IPv4/
       IPv6 addresses)

    o The nonce generated and inserted in the Port Mapping Request
       message by the client (64 bits)

    o The absolute expiration time chosen by the server indicated as an
       NTP timestamp value in seconds since the year 1900 [RFC5905] (64
       bits, to protect against replay attacks)

   The RECOMMENDED way for constructing Tokens is to perform HMAC-SHA1
   [RFC2104] on the concatenated values of the information listed above
   (implementations might adopt different approaches). If HMAC-SHA1 is
   used, the Hashed Message Authentication Code (HMAC) key MUST be at
   least 160 bits long and generated using a cryptographically secure
   random source [RFC4086].

   In addition to the information listed above, implementations are
   encouraged to encode whatever additional information is deemed
   necessary or useful. For example, key rollover is simplified by
   encoding a key-id into the Token. As another example, a cluster of
   anycast servers could find advantage by encoding a server identifier
   into the Token. As another example, while HMAC-SHA1 provides a level
   of security that is widely regarded as being more than sufficient for
   providing message authentication and it is secure against all known
   cryptanalytic attacks that use computational resources that are
   currently economically feasible, a replacement HMAC algorithm (e.g.,
   HMAC-SHA256) could be used instead if HMAC-SHA1 has been compromised.

   To protect from offline attacks, the server SHOULD occasionally
   choose a new HMAC key. To ease implementation, a key-id can be
   assigned to each HMAC key. This can be encoded as simply as one bit
   (where the new key is X (e.g., 1) and the old key is the inverted
   value of X (e.g., 0)), or if several keys are supported at once, the
   key-id could be encoded into several bits. As the encoding of the
   Token is entirely private to the server and opaque to the clients,
   any encoding can be used. By encoding the key-id into the Token
   element, the server can reject an old key without bothering to do
   HMAC validation (saving CPU cycles). The key-id can be encoded into
   the Value field of the Token element by simply concatenating the
   (plaintext) key-id with the hashed information (i.e., the Token
   itself).

   For example, the Value field in the Token element can be computed as:

           key-id || mac-alg (client-ip | nonce | abs-expiration)

During Token construction, the expiration time has to be chosen
carefully based on the intended service duration. Tokens that are
valid for an unnecessarily long period of time (e.g., several hours)
might impose security risks. Depending on the application and use
cases, a reasonable value needs to be chosen by the server. Note
that using shorter lifetimes requires the clients to acquire Tokens
more frequently. However, since a client can acquire a new Token
well before it will need to use it, the client will not necessarily
be penalized for the acquisition delay.

Finally, be aware that NTP timestamps will wrap around in the year
2036. Refer to Section 6 of [RFC5905] for further details.

6. Validating Tokens

The server MUST validate the Token upon receipt of an RTCP feedback
message along with the Token Verification Request message that
contains a Token, nonce, and absolute expiration time.

The server first applies its own procedure for constructing the
Tokens by using the client's IP address from the received Token
Verification Request message and the nonce and absolute expiration
time values reported in the received Token Verification Request
message. The server then compares the resulting output with the
Token sent by the client in the Token Verification Request message.
If they match and the absolute expiration time has not passed yet,
the server declares that the Token is valid.

Note that if the client's IP address changes, the Token will not
validate. Similarly, if the client inserts an incorrect nonce or
absolute expiration time value in the Token Verification Request
message, validation will fail. It is also possible that the server
wants to expire the Token prematurely. In these cases, the server
MUST reply back to the client with a Token Verification Failure
message (that goes from port P3 on the server towards port c1 on the
client).

In addition to the Token Verification Failure message, it is
RECOMMENDED that applications define an application-specific error
response to be sent by the server when the server detects that the
Token is invalid. For applications using [RFC6285], this document
defines a new 4xx-level response code in the RAMS Response Code Space
Registry. A client that receives a Token Verification Failure
message can request a new Token from the server.

If a client receives a Port Mapping Response message with an invalid
Token (i.e., the relative expiration time is set to zero) two or more
times for a particular Port Mapping Request message or the client

receives a Token Verification Failure message two or more times for
the same Token Verification Request message, the client SHOULD do the
following:

1. Check whether or not the session description has been updated.
    If it was updated, act according to the new session description.

2. Exponentially back off for the third and subsequent attempts.
    Exponential back-off does not apply when the client sends a Port
    Mapping Request or Token Verification Request message to a new
    address and/or port.

7. SDP Signaling

7.1. The 'portmapping-req' Attribute

   This attribute is used declaratively in any media block that
   describes an RTP session that uses Token-based authentication for one
   or more RTCP messages relating to that session. It indicates the
   port and optionally the address for obtaining a Token.

   The presence of the 'portmapping-req' attribute indicates that (i) a
   Token MUST be included in certain RTCP messages sent to the server
   triggering or controlling a unicast session (see Section 4.3.1) and
   (ii) the client MUST receive the unicast session's RTP and RTCP
   packets from the server on the port from which it sent the RTCP
   message triggering the unicast session.

      Note: This does not imply that Token Verification Request messages
      always need to be sent in the unicast session. Token Verification
      Request messages accompany RTCP messages that trigger or control
      this unicast session and are sent either in the multicast session
      or the unicast session, depending on the RTCP message (see
      Section 4.3.1).

7.1.1. ABNF Definition of 'portmapping-req'

   The formal description of the 'portmapping-req' attribute is defined
   by the following ABNF [RFC5234] syntax:

      portmapping-req-attr = "a=portmapping-req:" port [SP nettype SP
                              addrtype SP connection-address] CRLF

   Here, 'port', 'nettype', 'addrtype', and 'connection-address' are
   defined as specified in Section 9 of [RFC4566].

   The 'portmapping-req' attribute SHALL only be used as a media-level
   attribute.

In the optional address value, only unicast addresses SHOULD be used
unless one wants to use a multicast address after evaluating the
additional security risks such as non-legit servers generating fake
Tokens. If the address is not specified, the (source) address in the
"c" line applicable to the media description SHALL be used.

7.1.2. Offer/Answer Model Considerations

When using the 'portmapping-req' attribute in SDP offer/answer
exchanges [RFC3264], the following considerations apply. When an
offerer sends an answerer an offer of an SDP description making use
of the Token approach described in this specification, the
'portmapping-req' attribute is included declaratively. There will
not be offer/answer exchanges between the answerer and the actual
server providing the unicast service(s).

When the answerer supports the Token approach, it MUST echo in its
answer back to the offerer the 'portmapping-req' attribute from the
offer including the same port number and address (if any). If the
answerer does not implement this specification, it follows normal SDP
parsing of unknown attributes (they are ignored and are not sent in
the answer). This means that the answerer can still join the
multicast session but will not be able to use the unicast service(s)
that require the use of Tokens.

7.2. Requirements

The use of SDP for the port mapping solution normatively requires
support for:

o The SDP grouping framework and flow identification (FID) semantics
   [RFC5888]

o The RTP/Audio-Visual Profile with Feedback (AVPF) profile
   [RFC4585]

o The 'rtcp-mux' attribute (to multiplex RTP and RTCP on a single
   port on both endpoints in the unicast session [RFC5761])

7.3. Example and Discussion

   The declarative SDP describing the scenario given in Figure 2 is
   written as:

```
v=0
o=ali 1122334455 1122334466 IN IP4 nack.example.com
s=Local Retransmissions
t=0 0
a=group:FID 1 2
a=rtcp-unicast:rsi
m=video 41000 RTP/AVPF 98
i=Multicast Stream
c=IN IP4 233.252.0.2/255
a=source-filter:incl IN IP4 233.252.0.2 198.51.100.1   ; Note 1
a=rtpmap:98 MP2T/90000
a=multicast-rtcp:41500                                  ; Note 1
a=rtcp:42000 IN IP4 192.0.2.1                           ; Note 2
a=rtcp-fb:98 nack                                       ; Note 2
a=portmapping-req:30000 IN IP4 192.0.2.1               ; Note 3
a=mid:1
m=video 42000 RTP/AVPF 99                               ; Note 4
i=Unicast Retransmission Stream
c=IN IP4 192.0.2.1
a=sendonly
a=rtpmap:99 rtx/90000
a=rtcp-mux                                              ; Note 5
a=rtcp:42500                                            ; Note 6
a=fmtp:99 apt=98; rtx-time=5000
a=portmapping-req:30001                                 ; Note 3
a=mid:2
```

         Figure 8: SDP Describing an SSM Distribution with Support for
                    Retransmissions from a Local Server

   In this description, we highlight the following notes:

   Note 1: The source stream is multicast from a distribution source
   with a source IP address of 198.51.100.1 to the multicast destination
   address of 233.252.0.2 and port 41000 (P1). The associated RTCP
   packets are multicast in the same group to port 41500 (P2).

   Note 2: A retransmission server including feedback target
   functionality with an IP address of 192.0.2.1 and port of 42000 (P3)
   is specified with the 'rtcp' attribute. The feedback functionality
   is enabled for the RTP stream with payload type 98 through the
   'rtcp-fb' attribute [RFC4585].

Note 3: The "a=portmapping-req" line indicates that one or more RTCP
messages relating to the RTP session described in this media block
uses Token-based authentication, and a Token needs to be retrieved
first from the designated port (PT) before the unicast session can be
established. In the first appearance, an explicit address is
provided. In the second appearance, there is no address indicated in
this line and the client needs to send the Token request to the
address specified in the "c" line in the unicast media block.

Note 4: The port specified in the second "m" line (for the unicast
stream) does not mean anything in this scenario as the client does
not send any RTP traffic back to the server.

Note 5: The server multiplexes RTP and RTCP packets sent towards c1
on the same port.

Note 6: The server uses port 42500 (P4) for the unicast session.

8. Address Pooling NATs

Large-scale NAT devices have a pool of public IPv4 addresses and map
internal hosts to one of those public IPv4 addresses. As long as an
internal host maintains an active mapping in the NAT, the same IPv4
address is assigned to new connections. However, once all of the
host's mappings have been deleted (e.g., because of timeout), it is
possible that a new connection from that same host will be assigned a
different IPv4 address from the pool. When that occurs, the Token
will be considered invalid by the server, causing an additional round
trip for the client to acquire a fresh Token.

Any traffic from the host that traverses the NAT will prevent this
problem. As the host is sending RTCP receiver reports at least every
5 seconds (Section 6.2 of [RFC3550]) for the multicast session it is
receiving, those RTCP messages will be sufficient to prevent this
problem.

9. Security Considerations

9.1. Tokens

The Token, which is generated based on a client's IP address and
expiration date, provides protection against off-path denial-of-
service (DoS) attacks. An attacker using a certain IP address cannot
cause one or more RTP packets to be sent to a victim client who has a
different IP address. However, if the attacker acquires a valid
Token for a victim and can spoof the victim's source address, this

approach becomes vulnerable to replay attacks. This is especially
easy if the attacker and victim are behind a large-scale NAT and
share the same IP address.

Multicast is deployed on managed networks, not the Internet. These
managed networks will choose whether or not to enable network ingress
filtering [RFC2827]. If ingress filtering is enabled on a network,
an attacker cannot spoof a victim's IP address to use a Token to
initiate an attack against a victim. However, if ingress filtering
is not enabled on a network, an attacker could obtain a Token and
spoof the victim's address, causing traffic to flood the victim. On
such a network, the server can reduce the time period for such an
attack by expiring a Token in a short period of time. In the extreme
case, the server can expire the Token in such a short period of time
that the client will have to acquire a new Token immediately before
using it in a Token Verification Request message. One should,
however, note that such a behavior might have an adverse effect on
the delay in establishing or controlling a unicast session.

RTCP messages could be subject to on-path or man-in-the-middle
attacks. For example, an attacker can modify a value in one or more
fields in the Port Mapping Response or the Token Verification Request
message that are used in Token construction. This will result in
Token validation failure. Consequently, the client ends up asking
the server to generate a new Token. The resulting delay and extra
processing on the server is undesirable.

Alternatively, the attacker can modify a value in a field that is not
used in Token construction. For example, the attacker can reduce the
value in the Relative Expiration Time field in the Port Mapping
Response message from two hours to two minutes. While the Token will
still validate, this attack will result in more frequent requests to
the server for a new Token. Oppositely, the attacker can increase
the value in the Relative Expiration Time field and make the client
think the Token will be valid for a longer time. This attack can be
only detected by monitoring the activity on the server. Note that
using the relative expiration time in Token construction does not
necessarily make this attack easier to detect since the attacker
might revert the modified value back to its original value in the
Token Verification Request message. This allows the Token to still
validate on the server. In this case, the attack is still only
detectable by monitoring the server activity.

If there is a risk or concern for on-path or man-in-the-middle
attacks, RTCP messages SHOULD be protected by Secure RTCP (SRTCP)
[RFC3711].

To minimize the risk of cross-protocol attacks, a server MUST NOT use
the same secret key it used for Token construction for other
purposes.

9.2. The 'portmapping-req' Attribute

The 'portmapping-req' attribute is not believed to introduce any
significant security risk to multimedia applications. A malevolent
third party could use this attribute to redirect the Port Mapping
Request messages by altering the port number or cause the unicast
session establishment to fail by removing it from the SDP
description. However, this requires intercepting and rewriting the
packets carrying the SDP description, and if an interceptor can do
that, many more attacks are possible, including a wholesale change of
the addresses and port numbers at which the media will be sent.

In order to avoid attacks of this sort, the SDP description needs to
be integrity protected and provided with source authentication. This
can, for example, be achieved on an end-to-end basis using Secure/
Multipurpose Internet Mail Extensions (S/MIME) [RFC5652] [RFC5751]
when SDP is used in a signaling packet using MIME types (application/
sdp). Alternatively, HTTPS [RFC2818] or the authentication method in
the Session Announcement Protocol (SAP) [RFC2974] could be used as
well.

10. IANA Considerations

The following contact information is used for all registrations in
this document:

Ali Begen
abegen@cisco.com

10.1. Registration of SDP Attributes

This document registers one new attribute name in SDP.

        SDP Attribute ("att-field"):
        Attribute name: portmapping-req
        Long form: Port and address for requesting Token
        Type of name: att-field
        Type of attribute: Media level
        Subject to charset: No
        Purpose: See this document
        Reference: [RFC6284]
        Values: See this document

10.2. Registration of RTCP Control Packet Types

   In accordance with Section 15 of [RFC3550], this specification adds
   the following value to the RTCP Control Packet types sub-registry in
   the Real-Time Transport Protocol (RTP) Parameters registry:

   Value   Abbrev.   Name   Reference
   --------   ---------   ------------------------------------   ---------
   210   TOKEN   Port Mapping   [RFC6284]

10.3. SMT Values for TOKEN Packet Type Registry

   This document creates a new sub-registry for the sub-message type
   (SMT) values to be used with the TOKEN packet type. The registry is
   called the SMT Values for TOKEN Packet Type Registry. This registry
   is managed by the IANA according to the IETF Review policy of
   [RFC5226].

   The length of the SMT field is five bits, allowing 32 values. The
   registry is initialized with the following entries:

   Value Name   Reference
   ----- -- ------------
   0   Reserved   [RFC6284]
   1   Port Mapping Request   [RFC6284]
   2   Port Mapping Response   [RFC6284]
   3   Token Verification Request   [RFC6284]
   4   Token Verification Failure   [RFC6284]
   5-30 Unassigned   IETF Review
   31   Reserved   [RFC6284]

   The SMT values 0 and 31 are reserved for future use.

10.4. RAMS Response Code Space Registry

   This document adds the following entry to the RAMS Response Code
   Space Registry.

   Code Description   Reference
   ----- -- ------------
   405   Invalid Token   [RFC6284]

   This response code is used when the Token included by the RTP_Rx in
   the RAMS-R message is invalid.

11. Acknowledgments

   The approach presented in this document came out after discussions
   with various individuals in the AVT and MMUSIC WGs and the breakout
   session held at the Anaheim meeting. We thank each of these
   individuals, particularly Magnus Westerlund and Colin Perkins.

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