RTP Profile for TCP Friendly Rate Control

Status of this Memo

Copyright Notice

Abstract

This memo specifies a profile called "RTP/AVPCC" for the use of the
real-time transport protocol (RTP) and its associated control
protocol, RTCP, with the TCP Friendly Rate Control (TFRC). TFRC is
an equation based congestion control scheme for unicast flows

operating in a best effort Internet environment. This profile
provides RTP flows with the mechanism to use congestion control in
best effort IP networks.

1. Introduction

[Note to RFC Editor: All references to RFC XXXX are to be replaced
with the RFC number of this memo, when published]

This memo defines a profile called "RTP/AVPCC" for the use of the
real-time transport protocol (RTP) [RTP] and its associated control
protocol, RTCP, with the TCP Friendly Rate Control (TFRC) [TFRC].
TFRC is an equation based congestion control scheme for unicast flows
operating in a best effort Internet environment and competing with
TCP traffic.

Due to a number of inherent TFRC characteristics, the RTP/AVPCC
profile differs from other RTP profiles [AVP] in the following ways:

 o TFRC is a unicast congestion control scheme, therefore by
   extension the RTP/AVPCC profile can only be used by unicast RTP
   flows.

 o A TFRC sender relies on receiving feedback from the receiver
   either once per round-trip time (RTT) or per data packet. For
   certain flows (depending on RTTs and data rates) these TFRC
   requirements can result in control traffic that exceeds RFC 3550's
   bandwidth and/or timing recommendations for control traffic. The
   RTP/AVPCC profile recommends modifications to these
   recommendations in order to satisfy TFRCs timing needs for control
   traffic in a safe manner.

This memo primarily addresses the means of supporting TFRC's
exchange of congestion control information between senders and
receivers via the following modifications to RTP and RTCP: (1) RTP
data header additions; (2) extensions to the RTCP Receiver Reports;
and (3) modifications to the recommended RTCP timing intervals. For
details on TFRC congestion control readers are referred to [TFRC].

The current TFRC standard, RFC3448, only targets applications with
fixed packet size. TFRC-PS is a variant of TFRC for applications with
varying packet sizes. The RTP/AVPCC profile is applicable to both
congestion control schemes.

2. Relation to the Datagram Congestion Control Protocol

The Datagram Congestion Control Protocol (DCCP) is a minimal general
purpose transport-layer protocol with unreliable yet congestion

controlled packet delivery semantics and reliable connection setup
and teardown. DCCP currently supports both TFRC and TCP-like
congestion control. In addition DCCP supports a host of other
features, such as: use of Explicit Congestion Notification (ECN) and
the ECN Nonce, reliable option negotiation and Path Maximum Transfer
Unit (PMTU). Naturally an application using RTP/DCCP as its
transport protocol will benefit from the protocol features supported
by DCCP.

In contrast the RTP Profile for TFRC only provides RTP applications a
standardized means for using the TFRC congestion control scheme,
without any of the protocol features of DCCP. However there are a
number of benefits to be gained by the development and
standardization of a RTP Profile for TFRC:

   o Media applications lacking congestion control can incorporate
     congestion controlled transport without delay by using the
     RTP/AVPCC profile. The DCCP protocol is currently under
     development and widespread deployment is not yet in place.

   o Use of the RTP/AVPCC profile is not contingent on any OS level
     changes and can be quickly deployed, as the AVPCC profile is
     implemented at the application layer.

   o AVPCC/RTP/UDP flows face the same restrictions in firewall
     traversal as do UDP flows and do not require NATs and firewall
     modifications. DCCP flows, on the other hand, do require NAT
     and firewall modifications, however once these modifications
     are in place, they can result in easier NAT and firewall
     traversal for RTP/DCCP flows in the future.

   o Use of the RTP/AVPCC profile with various media applications will
     give researchers, implementors and developers a better
     understanding of the intricate relationship between media
     quality and equation based congestion control. Hopefully this
     experience with congestion control and TFRC will ease the
     migration of media applications to DCCP once DCCP is deployed.

Overall, the RTP/AVPCC profile provides an immediate means for
congestion control in media streams, in the time being until DCCP is
deployed.

Additionally, there are also a number of technical differences as to
how (and which) congestion control information is exchanged between
DCCP with CCID3 and the RTP/AVPCC profile:

   o A RTP/AVPCC sender transmits a send timestamp to the RTP/AVPCC
     receiver with every data packet. In addition to congestion

     control the send timestamp can be used by the receiver for
     jitter calculations.

     In contrast DCCP with CCID3 transmits a quad round trip
     counter to the receiver.

   o A RTP/AVPCC receiver only provides the RTP/AVPCC sender
     with the loss event rate as computed by the receiver.

     In contrast DCCP with CCID3, provides 2 other options for the
     transport of loss event rate. A sender may choose to receive
     loss intervals or an Ack Vector. These two options provide the
     sender with the necessary information to compute the loss event
     rate.

   o Sequence number: DCCP supports a 48 bit and a 24 bit sequence
     number, whereas RTP only supports a 16 bit sequence number. While
     this makes RTP susceptible to data injection attacks, it can be
     avoided by using the SRTP [SRTP] profile in conjunction with the
     AVPCC profile.

3. Conventions Used in this Document

   The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT",
   "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this
   document are to be interpreted as described in RFC 2119 [2119].

4. RTP and RTCP Packet Forms and Protocol Behavior

   The section "RTP Profiles and Payload Format Specifications" of RFC
   3550 enumerates a number of items that can be specified or modified
   in a profile. This section addresses each of these items and states
   which item is modified by the RTP/AVPCC profile:

     RTP data header: The standard format of the fixed RTP data
        header has been modified (see Section 6).

     Payload types: The payload type in the RTP data header is
        reduced to 6 bits, therefore payload types are restricted to
        values in the range of 0 to 63.

     RTP data header additions: Two 32 bit fixed fields, send
        timestamp and round trip time (RTT), are added to the RTP
        data header. The send time stamp is always present and
        the RTT field is present if the R bit is set.

RTP data header extensions: No RTP header extensions are
   defined, but applications operating under this profile
   MAY use such extensions. Thus, applications SHOULD NOT
   assume that the RTP header X bit is always zero and SHOULD
   be prepared to ignore the header extension. If a header
   extension is defined in the future, that definition MUST
   specify the contents of the first 16 bits in such a way
   that multiple different extensions can be identified.

RTCP packet types: No additional RTCP packet types are defined
   by this profile specification.

RTCP report interval: This profile is restricted to unicast
   flows, therefore at all times there is only one active sender
   and one receiver. Sessions operating under this profile MAY
   specify a separate parameter for the RTCP traffic bandwidth
   rather than using the default fraction of the session
   bandwidth. In particular this may be necessary for data
   flows were the the RTCP recommended reduced minimum interval
   is still greater than the RTT.

SR/RR extension: A 16 octet RR extension is defined for the RTCP
   RR packet.

SDES use: Applications MAY use any of the SDES items described
   in the RTP specification.

Security: This profile is subject to the security considerations
   discussed in the TFRC and RTP specifications [TFRC][RTP]. This
   profile does not specify any additional security services.

String-to-key mapping: No mapping is specified by this profile.

Congestion: This profile specifies how to use RTP/RTCP with TFRC
   congestion control.

Underlying protocol: The profile specifies the use of RTP over
   unicast UDP flows only, multicast MUST NOT be used.

Transport mapping: The standard mapping of RTP and RTCP to
   transport-level addresses is used.

Encapsulation: This profile is defined for encapsulation
   over UDP only.

5. **The TFRC Feedback Loop**

   TFRC depends on the exchange of congestion control information
   between a sender and receiver. In this section we reiterate which
   items are exchanged between a TFRC sender and receiver as discussed
   in [TFRC]. We note how the RTP/AVPCC profile accommodates these
   exchanges.

5.1. **Data Packets**

   As stated in [TFRC] a TFRC sender transmits the following information
   in each data packet to the receiver:

   o A sequence number, incremented by one for each data packet
     transmitted.

   o A timestamp indicating the packet send time and the sender's
     current estimate of the round-trip time, RTT. This information
     is then used by the receiver to compute the TFRC loss intervals.
     - or -
     A course-grained timestamp incrementing every quarter of a
     round trip time, which is then used to determine the TFRC loss
     intervals.

   The standard RTP sequence number suffices for TFRCs functionality.
   For the computation of the loss intervals the RTP/AVPCC profile
   extends the RTP data header as follows: a 32 bit field to transmit a
   send timestamp and an additional 32 bit field, present only when the
   RTT changes, to transmit the RTT. The presence of the RTT is
   indicated by the R bit in the RTP header (see Section 6).

5.2. **Feedback Packets**

   As stated in [TFRC] a TFRC receiver provides the following feedback
   to the sender at least once per RTT or per data packet received
   (which ever time interval is larger):

   o The timestamp of the last data packet received, t_i.

   o The amount of time elapsed between the receipt of the last
     data packet at the receiver, and the generation of this feedback
     report, t_delay. This is used by the sender for RTT computations
     (see Section 9).

   o The rate at which the receiver estimates that data was received
     since the last feedback report was sent, x_recv.

   o The receiver's current estimate of the loss event rate, p, a real

value between 0 and 1.0.

To accommodate the feedback of these values the RTP/AVPCC profile
defines a 16 octet extension to the RTCP Receiver Reports (see
Section 7).

6. **RTP Data Header Additions**

The RTP/AVPCC profile makes the following changes to the RTP header
(other fields of the payload header are defined as in RFC 3550
[RTP]):

     o the profile uses a 6 bit payload type (PT) field,
     o defines a 1 bit R field in the second octet, and
     o defines two additional 32 bit fixed fields:
       1. the packets send timestamp,
       2. the round trip time (RTT) as measured by the sender. This
       field is present if the R bit is set (see Figures 1 and 2).

The additional fields of the RTP header are defined and used as
follows:

Round trip time indicator (R): 1 bit
  This field indicates the existence of the additional RTT field. If
  the R bit is set, the RTP payload header includes a 32 bit field
  representing the current round trip time (Figures 1 and 2).

Payload type (PT): 6 bits
  The RTP/AVPCC profile uses a 6 bit field for the payload type
  (instead of a 7 bit field).

Send timestamp: 32 bits
  The timestamp indicating when the packet is sent. This timestamp
  is measured in microseconds and is used for round trip time
  calculations. At microsecond granularity the send timestamp
  wraps around in approximately 71 minutes.

Round trip time (RTT): 32 bits
  The round trip time as measured by the RTP/AVPCC sender in
  microseconds. This field is only present if the R bit is set
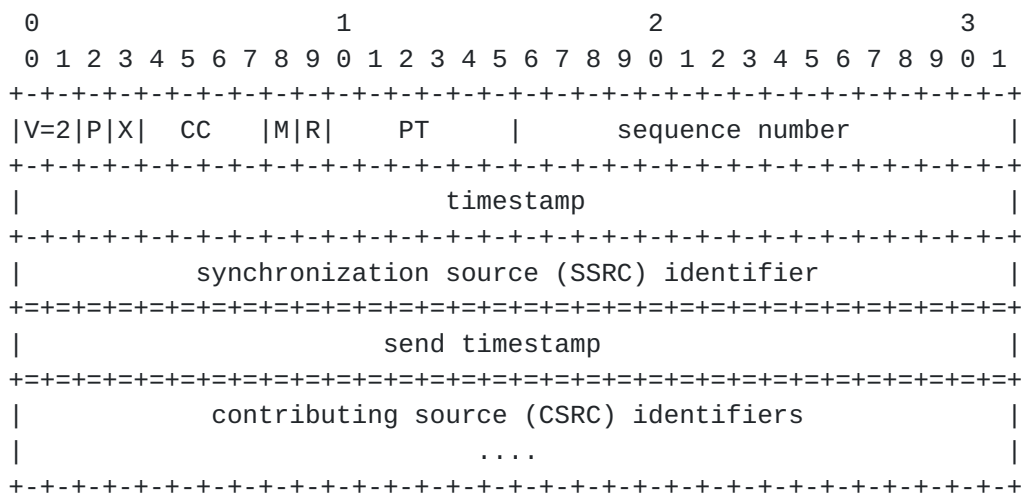 (Figure 2).

```
    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|X|  CC   |M|R|    PT       |       sequence number        |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                           timestamp                           |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |           synchronization source (SSRC) identifier            |
   +=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+
   |                        send timestamp                         |
   +=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+
   |            contributing source (CSRC) identifiers             |
   |                             ....                              |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```
   Figure 1: RTP header and additions with R=0, no RTT included.

```
    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|X|  CC   |M|R|    PT       |       sequence number        |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                           timestamp                           |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |           synchronization source (SSRC) identifier            |
   +=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+
   |                        send timestamp                         |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                            RTT                                |
   +=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+
   |            contributing source (CSRC) identifiers             |
   |                             ....                              |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```
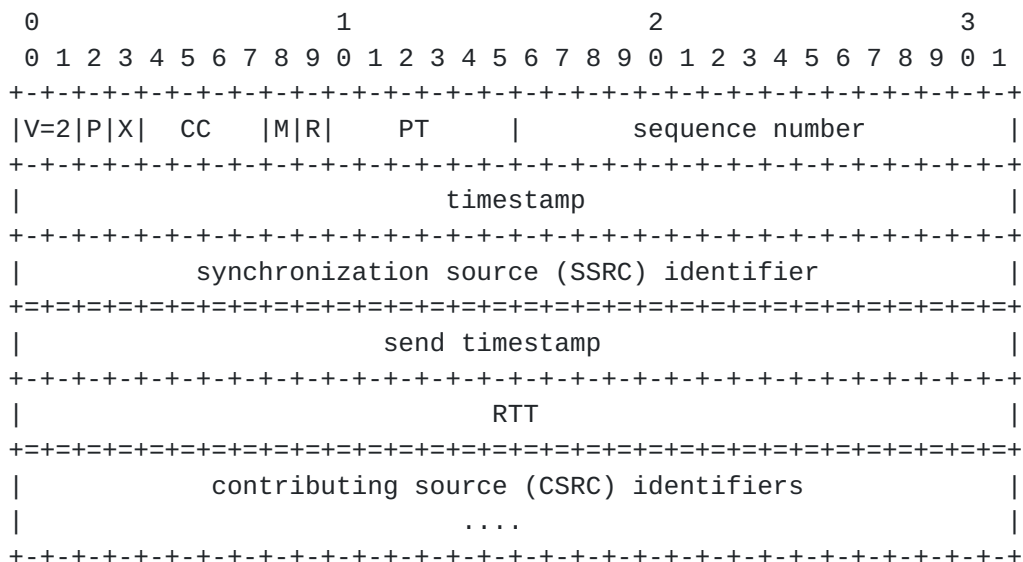   Figure 2: RTP header and additions with R=1, RTT included.

7. Receiver Report Extensions

   The RTP/AVPCC profile defines four 32 bit fixed fields as profile-
   specific extensions to the receiver reports (Figure 3). These four
   fields are:

Timestamp (t_i): 32 bits
   The timestamp of the last data packet received by the RTP/AVPCC
   receiver, t_i, in microseconds.

Delay (t_delay): 32 bits
   The amount of time elapsed between the receipt of the last data
   packet at the RTP/AVPCC receiver, and the generation of this
   feedback report in microseconds. This is used by the sender for
   RTT computations.

Data rate (x_recv): 32 bits
   The rate at which the receiver estimates that data was received
   since the last feedback report was sent in bytes per second.

Loss event rate (p): 32 bits
   The receiver's current estimate of the loss event rate, p,
   expressed as a fixed point number with the binary point at the
   left edge of the field. (That is equivalent to taking the integer
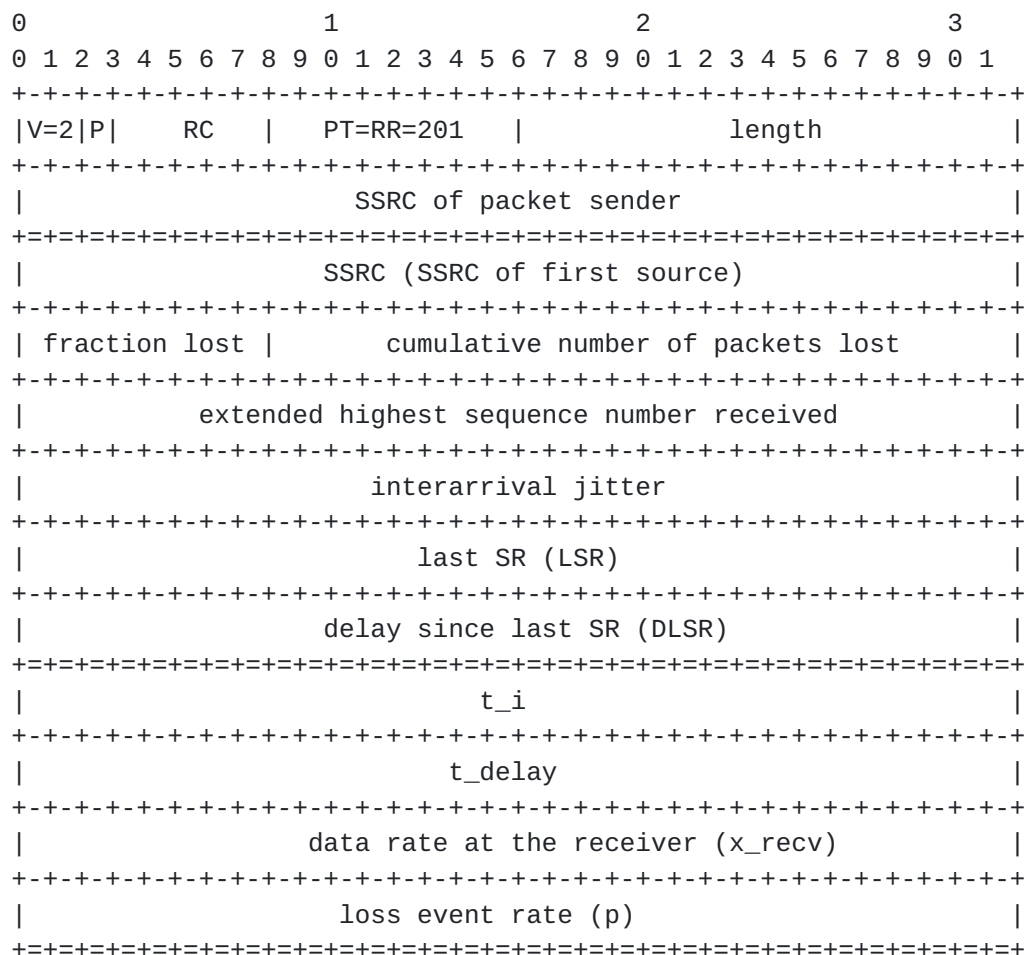   part after multiplying the loss event rate by 2^{32}.)

```
     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|   RC    |  PT=RR=201    |             length            |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |                     SSRC of packet sender                     |
    +=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+
    |                   SSRC (SSRC of first source)                 |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    | fraction lost |      cumulative number of packets lost        |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |            extended highest sequence number received          |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |                       interarrival jitter                     |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |                         last SR (LSR)                         |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |                    delay since last SR (DLSR)                 |
    +=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+
    |                             t_i                               |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |                           t_delay                             |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |                  data rate at the receiver (x_recv)           |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |                        loss event rate (p)                    |
    +=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+
```
    Figure 3: RTCP Receiver Report extensions.

8. RTCP Timing Intervals

   The RTP/AVPCC profile recommends the use of the TFRC timing feedback
   requirements for the RTCP timing intervals, only in instances where
   control traffic bandwidth does not exceed RFC 3550's recommended 5%
   of data traffic.

   A TFRC sender requires feedback from its receiver at least once per
   RTT or per packet received (based on the larger time interval). These
   requirements are to ensure timely reaction to congestion.

   In some instances TFRC's timing requirements may result in timing
   intervals for RTCP traffic that are smaller than RFC 3550's
   recommended scaled reduced minimum timing interval of 360 divided by
   session bandwidth in kilobits/second or $t(s) = 360/X(kbps)$.

   For example, Figure 4 depicts two AVPCC flows and their relationship
   with RTCP's reduced minimum interval: $t(ms) = 360/X$ (Mbps). The two

flows have data rates of 2 Mbps and 4 Mbps with RTTs of 70 ms and 130
ms, respectively.

The 4 Mbps flow's TFRC feedback requirements of 130 ms falls within
RFC 3550's recommended reduced minimum interval for RTCP traffic.
However the 2 Mbps flow's TFRC feedback requirement of once per 70 ms
is more frequent than the 180 ms recommended by RFC 3550.

However in this case, it is safe to use TFRC's 70 ms interval, as at
the rate of roughly one 88 octet RTCP compound packet per 70 ms, the
feedback traffic for the 2 Mbps flow amounts to 10 kbps, that is less
than 1% of the data flow and well with the 5% recommended by RFC
3550.

```
 Bandwidth (Mbps)
       ^
       | \
       |  \
       |   \
       |    \                  360
       |     \        t(ms)= -------
       |      \               X (Mbps)
       |       \
       |        \_
     4 |          \__   x
       |             \___
     2 |        x        \____
       |                      _____
       +-------------------------------->
            70      130
              Time (ms)
```
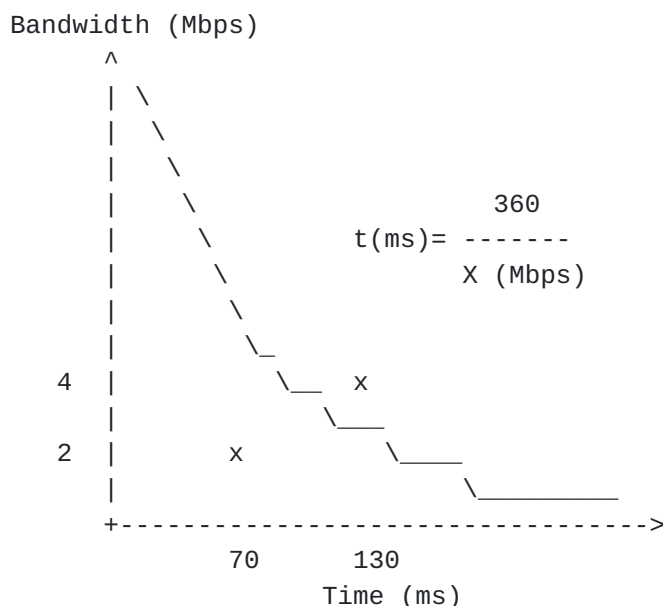
Figure 4: Relationship between RFC 3550 recommended reduced minimum
interval and session bandwidth (Mbps).

9. IANA Considerations

The RTP profile for TCP Friendly Rate Control extends the profile for
audio- visual conferences with minimal control and needs to be
registered for the Session Description Protocol [SDP] as "RTP/AVPCC".

SDP Protocol ("proto"):

```
  Name:              RTP/AVPCC
  Long form:         RTP Profile for TCP Friendly Rate Control
  Type of name:      proto
```

      Type of attribute: Media level only
      Purpose: RFC XXXX
      Reference: RFC XXXX

10. Security Considerations

   The RTP/AVPCC profile is subject to the security considerations
   discussed in the TFRC and RTP specifications [TFRC][RTP]. This
   profile does not specify any additional security services.

   To guard against spoofed feedback attacks using false RTCP packets,
   authentication can be used for all RTCP messages. This can be done
   by defining a combined secure SAVPCC profile, by using the AVPCC
   profile together with the Secure RTP profile [SRTP].

11. Acknowledgments

   This memo is based upon work supported by the U.S. National Science
   Foundation (NSF) under Grant No. 0334182. Any opinions, findings and
   conclusions or recommendations expressed in this material are those
   of the authors and do not necessarily reflect the views of NSF.

12. Author's Address

      Ladan Gharai <ladan@isi.edu>
      USC Information Sciences Institute
      3811 N. Fairfax Drive, #200
      Arlington, VA 22203
      USA

Normative References

   [RTP]   H. Schulzrinne, S. Casner, R. Frederick and V. Jacobson,
           "RTP: A Transport Protocol for Real-Time Applications",
           Internet Engineering Task Force, RFC 3550 (STD0064), July
           2003.

   [AVP]   H. Schulzrinne and S. Casner, "RTP Profile for Audio and
           Video Conferences with Minimal Control," RFC 3551 (STD0065),
           July 2003.

   [2119] S. Bradner, "Key words for use in RFCs to Indicate
           Requirement Levels", Internet Engineering Task Force,
           RFC 2119, March 1997.

   [2434]   T. Narten and H. Alvestrand, "Guidelines for Writing an IANA
            Considerations Section in RFCs", Internet Engineering Task
            Force, RFC 2434, October 1998.

   [TFRC]   M. Handley, S. Floyed, J. Padhye and J. widmer,
            "TCP Friendly Rate Control (TRFC): Protocol Specification",
            Internet Engineering Task Force, RFC 3448, January 2003.

   [SDP]   M. Handley and V. Jacobson, "SDP: Session Description
            Protocol", RFC 2327, April 1998.

   [SRTP]   M. Baugher, D. McGrew, M. Naslund, E. Carrara, K. Norrman,
            "The Secure Real-time Transport Protocol", RFC 3711, March
            2004.

Informative References

13. IPR Notice

14. Full Copyright Statement