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RTP Profile for TCP Friendly Rate Control

Status of this Memo

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Abstract

This memo specifies a profile called "RTP/AVPFCC" for the use of the real-time transport protocol (RTP) and its associated control protocol, RTCP, with TCP Friendly Rate Control (TFRC). This profile extends the RTP/AVPF profile with RTP data header additions and new

AVPF feedback packets, in order to support TFRCs integration with RTP. 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/AVPFCC" 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]. RTP/AVPFCC extends the RTP profile for RTCP-based feedback (RTP/AVPF) to provide support for TFRC.

TFRC is an equation based congestion control scheme for unicast flows operating in a best effort Internet environment and competing with TCP traffic. TFRC computes a TCP-friendly data rate based on current network conditions, as represented by the latest round trip time and packet loss calculations. The complete TFRC mechanism is described in detail in [TFRC].

To calculate a TCP-friendly data rate and keep track of round trip times and packet losses, TFRC senders and receivers rely on exchanging specific information between each other, i.e: the sender provides the receiver with the latest updates to round trip time calculations, while the receiver provides feedback needed to compute round trip times and on packet losses. The RTP/AVPFCC profile, extends the RTP/AVPF profile with RTP data header additions and new AVPF feedback packets to support the TFRC feedback and information exchange requirements.

2. Terminology

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].

3. Relation to the Datagram Congestion Control Protocol

The TFRC congestion control mechanism is also supported by the Datagram Congestion Control Protocol (DCCP). In this section we detail the pros and cons of using TFRC with RTP versus DCCP.

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, and the protocol is structured to support new congestion control mechanisms defined in the future. 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.

However there are a number of benefits to be gained by the development and standardization of the RTP/AVPFCC profile:

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

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

- AVPFCC/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.

- Use of the RTP/AVPFCC 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/AVPFCC 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/AVPFCC profile:

- A RTP/AVPFCC sender transmits a send timestamp to the RTP/AVPFCC 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.

- A RTP/AVPFCC receiver only provides the RTP/AVPFCC 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.

- 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 AVPFCC profile.

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/AVPFCC 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: Additional RTCP packet types are defined by this profile per the RTP/AVPF profile [AVPF].

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: The SR/RR extensions are defined per RFC 3550. No changes are specified.

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 Information Exchange 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/AVPFCC 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/AVPFCC 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 send 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.

- 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/AVPFCC profile defines a new AVPF transport layer feedback message, as detailed in Section 7.

6. RTP Data Header Additions

The RTP/AVPFCC 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/AVPFCC 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/AVPFCC 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. TFRC-FB: A New AVPF Transport Layer Feedback Message

To support feedback to the RTP/AVPFCC receivers a new transport layer AVPF feedback message is defined: TFRC-FB. This message is depicted in Figure 3. It is defined according to [AVPF] and includes the following four fields:

Timestamp (t_i): 32 bits
  The send timestamp of the last data packet received by the RTP/AVPFCC 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/AVPFCC receiver, and the generation of this feedback report in microseconds. This is used by the TFRC RTP 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|  FMT=2  |  PT=RTPFB     |             length            |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |                     SSRC of packet sender                     |
 +=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+
 |                   SSRC (SSRC of first source)                 |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |                             t_i                               |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |                           t_delay                             |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |                  data rate at the receiver (x_recv)           |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |                    loss event rate (p)                        |
 +=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+
```
Figure 3

8. RTCP Transmission Intervals, TFRC and the AVPF Profile

The AVPFCC profile recommends setting RTCP transmission intervals according to the requirements of the TFRC algorithm. TFRC requires a receiver to generate a feedback packet at least once per RTT or per packet received (based on the larger time interval). These requirements are to ensure timely reaction to congestion.

Other requirements that AVPFCC must contend with are AVPF feedback

rules and AVP RTCP bandwidth constraints. In general the AVPFCC profile complies with the rules of AVPF for sending RTCP feedback packets with the following two exceptions:

- o allow_early is set to "true" at all times. Essentially, this means that a receiver can always generate an early feedback packet, and does not need to alternate between early and regular RTCP packets (see RFC 4585, Section 3.4,k).

- o T_rr_interval must not be set to a value larger than the current round trip time, as this would prevent generating feedback packets at least once per RTT (see RFC 4585, Section 3.4,m).

The TFRC requirements of receiving feedback once per RTT can at times conflict with the AVP RTCP bandwidth constraints, particularly at small RTTs of 20ms or less. Assuming only one TFRC-FB report per RTCP compound packet, Table 1 lists the RTCP bandwidths at RTTs of 2, 5, 10 and 20 ms and the minimum corresponding RTP data rates, where RTCP(X) <= (0.05)*RTP(X) is true. For example, according to Table 1, an AVPFCC flow of less than 3.2 Mbps and a RTT of 5 ms, can not comply with the 5% RTCP bandwidth constraints (Table 1 assumes each RTCP packet is 100 bytes).

The correct operation of TFRC at RTTs of 20ms and less, at data rates less than those list in Table 1 is an open issue and is TBD.

RTT	RTCP(X)	RTP(X)
20 ms	40 kbps	0.8 Mbps
10 ms	80 kbps	1.6 Mbps
5 ms	160 kbps	3.2 Mbps
2 ms	400 kbps	8.0 Mbps

Table 1

9. SDP Definitions

Applications using RTP integrated with TFRC and sending or receiving packets as defined in this document MUST use "AVPFCC" as part of their session description. The session will inherit the properties of the AVPF profile.

10. IANA Considerations

In this section we detail IANA registry values that need to be registered. In particular the new RTP/AVPF feedback packet, TFRC-FB. For the RTPFB range of packets, the following format (FMT) value needs to be registered:

Value name: TFRC-FB
Long name: TFRC feedback
Value: 2
Reference: RFC XXXX

11. Security Considerations

TBC

12. Acknowledgments

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Informative References

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