Network Working Group   Z. Sarker
Internet-Draft   Ericsson AB
Intended status: Informational   V. Singh
Expires: August 12, 2019   callstats.io
                                                             X. Zhu
                                                         M. Ramalho
                                                      Cisco Systems
                                                  February 08, 2019

Test Cases for Evaluating RMCAT Proposals
draft-ietf-rmcat-eval-test-09

Abstract

   The Real-time Transport Protocol (RTP) is used to transmit media in
   multimedia telephony applications. These applications are typically
   required to implement congestion control. This document describes
   the test cases to be used in the performance evaluation of such
   congestion control algorithms in a controlled environment.

Status of This Memo

   This Internet-Draft is submitted in full conformance with the
   provisions of BCP 78 and BCP 79.

   Internet-Drafts are working documents of the Internet Engineering
   Task Force (IETF). Note that other groups may also distribute
   working documents as Internet-Drafts. The list of current Internet-
   Drafts is at https://datatracker.ietf.org/drafts/current/.

   Internet-Drafts are draft documents valid for a maximum of six months
   and may be updated, replaced, or obsoleted by other documents at any
   time. It is inappropriate to use Internet-Drafts as reference
   material or to cite them other than as "work in progress."

   This Internet-Draft will expire on August 12, 2019.

Copyright Notice

Table of Contents

1. Introduction

This memo describes a set of test cases for evaluating congestion
control algorithm proposals in controlled environment for real-time
interactive media. It is based on the guidelines enumerated in
[I-D.ietf-rmcat-eval-criteria] and the requirements discussed in
[I-D.ietf-rmcat-cc-requirements]. The test cases cover basic usage
scenarios and are described using a common structure, which allows
for additional test cases to be added to those described herein to
accommodate other topologies and/or the modelling of different path
characteristics. The described test cases in this memo should be

used to evaluate any proposed congestion control algorithm for real-
time interactive media.

2. Terminology

The terminology defined in RTP [RFC3550], RTP Profile for Audio and
Video Conferences with Minimal Control [RFC3551], RTCP Extended
Report (XR) [RFC3611], Extended RTP Profile for RTCP-based Feedback
(RTP/AVPF) [RFC4585], and Support for Reduced-Size RTCP [RFC5506]
apply.

3. Structure of Test cases

All the test cases in this document follow a basic structure allowing
implementers to describe a new test scenario without repeatedly
explaining common attributes. The structure includes a general
description section that describes the test case and its motivation.
Additionally the test case defines a set of attributes that
characterize the testbed, for example, the network path between
communicating peers and the diverse traffic sources.

o Define the test case:

   * General description: describes the motivation and the goals of
      the test case.

   * Expected behavior: describes the desired rate adaptation
      behavior.

   * Define a list of metrics to evaluate the desired behavior: this
      indicates the minimum set of metrics (e.g., link utilization,
      media sending rate) that a proposed algorithm needs to measure
      to validate the expected rate adaptation behavior. It should
      also indicate the time granularity (e.g., averaged over 10ms,
      100ms, or 1s) for measuring certain metrics. Typical
      measurement interval is 200ms.

o Define testbed topology: every test case needs to define an
   evaluation testbed topology. Figure 1 shows such an evaluation
   topology. In this evaluation topology, S1..Sn are traffic
   sources. These sources generate media traffic and use the
   congestion control algorithm(s) under investigation. R1..Rn are
   the corresponding receivers. A test case can have one or more
   such traffic sources (S) and their corresponding receivers (R).
   The path from the source to destination is denoted as "forward"
   and the path from a destination to a source is denoted as
   "backward". The following basic structure of the test case has
   been described from the perspective of media generating endpoints

attached on the left-hand side of Figure 1. In this setup, the
media flows are transported in forward direction and corresponding
feedback/control messages are transported in the backward
direction. However, it is also possible to set up the test with
media in both forward and backward directions. In that case,
unless otherwise specified by the test case, it is expected that
the backward path does not introduce any congestion related
impairments and has enough capacity to accommodate both media and
feedback/control messages. It should be noted that depending on
the test cases it is possible to have different path
characteristics in either of the directions.

```
+---+                                                   +---+
|S1 |====== \              Forward -->          / ======|R1 |
+---+       \\                                  //       +---+
             \\                                //
+---+        +-----+                    +-----+        +---+
|S2 |======|  A  |------------------------------>|  B  |======|R2 |
+---+      |     |<------------------------------|     |       +---+
           +-----+                    +-----+
(...)         //                                  \\          (...)
             //           <-- Backward             \\
+---+       //                                       \\       +---+
|Sn |====== /                                   \ ======|Rn |
+---+                                                   +---+
```
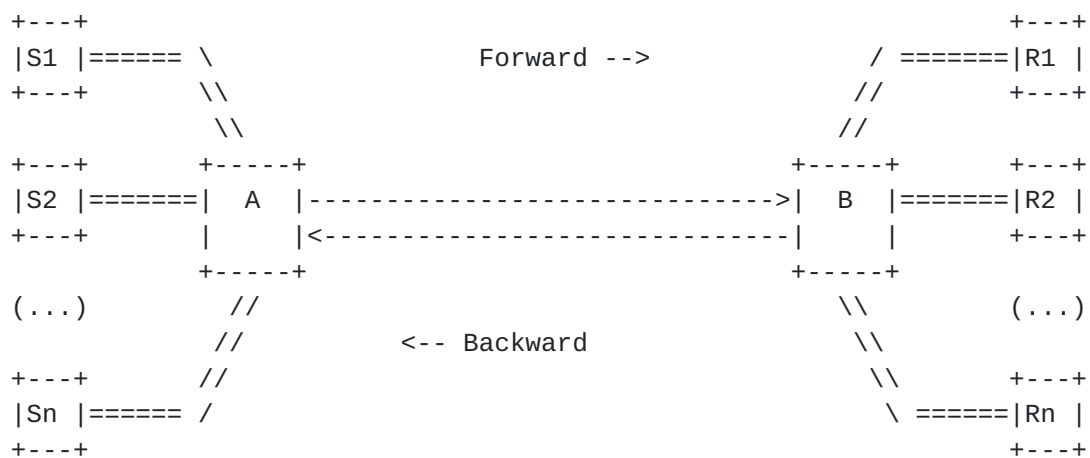
                 Figure 1: Example of A Testbed Topology

In a testbed environment with real equipments, there may exist a
significant amount of unwanted traffic on the portions of the
network path between the endpoints. Some of this traffic may be
generated by other processes on the endpoints themselves (e.g.,
discovery protocols) or by other endpoints not presently under
test. Such unwanted traffic should be removed or avoided to the
greatest extent possible.

o Define testbed attributes:

   * Duration: defines the duration of the test in seconds.

   * Path characteristics: defines the end-to-end transport level
      path characteristics of the testbed for a particular test case.
      Two sets of attributes describe the path characteristics, one
      for the forward path and the other for the backward path. The
      path characteristics for a particular path direction is
      applicable to all the Sources "S" sending traffic on that path.
      If only one attribute is specified, it is used for both path

directions, however, unless specified the reverse path has no
capacity restrictions and no path loss.

+ Path direction: forward or backward.

+ Bottleneck-link capacity: defines minimum capacity of the
   end-to-end path

+ Reference bottleneck capacity: defines a reference value for
   the bottleneck capacity for test cases with time-varying
   bottleneck capacities. All bottleneck capacities will be
   specified as a ratio with respect to the reference capacity
   value.

+ One-way propagation delay: describes the end-to-end latency
   along the path when network queues are empty, i.e., the time
   it takes for a packet to go from the sender to the receiver
   without encountering any queuing delay.

+ Maximum end-to-end jitter: defines the maximum jitter that
   can be observed along the path.

+ Bottleneck queue type: for example, "tail drop" [RFC7567],
   FQ-CoDel[RFC8290], or PIE[RFC8033].

+ Bottleneck queue size: defines the size of queue in terms of
   queuing time when the queue is full (in milliseconds).

+ Path loss ratio: characterizes the non-congested, additive,
   losses to be generated on the end-to-end path. This must
   describe the loss pattern or loss model used to generate the
   losses.

* Application-related: defines the traffic source behavior for
   implementing the test case

   + Media traffic Source: defines the characteristics of the
      media sources. When using more than one media source, the
      different attributes are enumerated separately for each
      different media source.

      - Media type: Video/Voice

      - Media flow direction: forward, backward or both.

      - Number of media sources: defines the total number of
         media sources

- Media codec: Constant Bit Rate (CBR) or Variable Bit Rate
  (VBR)

- Media source behavior: describes the media encoder
  behavior. It defines the main parameters that affect the
  adaptation behavior. This may include but is not limited
  to:

  o Adaptability: describes the adaptation options. For
     example, in the case of video it defines the following
     ranges of adaptation: bit rate, frame rate, video
     resolution. Similarly, in the case of voice, it
     defines the range of bit rate adaptation, the sampling
     rate variation, and the variation in packetization
     interval.

  o Output variation : for a VBR encoder it defines the
     encoder output variation from the average target rate
     over a particular measurement interval. For example,
     on average the encoder output may vary between 5% to
     15% above or below the average target bit rate when
     measured over a 100 ms time window. The time interval
     over which the variation is specified must be
     provided.

  o Responsiveness to a new bit rate request: the lag in
     time between a new bit rate request from the
     congestion control algorithm and actual rate changes
     in encoder output. Depending on the encoder, this
     value may be specified in absolute time (e.g. 10ms to
     1000ms) or other appropriate metric (e.g. next frame
     interval time).

  More detailed discussions on expected media source
  behavior, including those from synthetic video traffic
  sources, is at [I-D.ietf-rmcat-video-traffic-model].

- Media content: describes the chosen video scenario. For
  example, video test sequences are available at:
  [xiph-seq] and [HEVC-seq]. Different video scenarios
  give different distribution of video frames produced by
  the video encoder. Hence, it is important to specify the
  media content used in a particular test. If a synthetic
  video traffic souce [I-D.ietf-rmcat-video-traffic-model]
  is used, then the synthetic video traffic source needs to
  configure according to the characteristics of the media
  content specified.

- Media timeline: describes the point when the media source
  is introduced and removed from the testbed. For example,
  the media source may start transmitting immediately when
  the test case begins, or after a few seconds.

- Startup behavior: the media starts at a defined bit rate,
  which may be the minimum, maximum bit rate, or a value in
  between (in Kbps).

+ Competing traffic source: describes the characteristics of
  the competing traffic source, the different types of
  competing flows are enumerated in
  [I-D.ietf-rmcat-eval-criteria].

  - Traffic direction: forward, backward or both.

  - Type of sources: defines the types of competing traffic
    sources. Types of competing traffic flows are listed in
    [I-D.ietf-rmcat-eval-criteria]. For example, the number
    of TCP flows connected to a web browser, the mean size
    and distribution of the content downloaded.

  - Number of sources: defines the total number of competing
    sources of each media type per traffic direction.

  - Congestion control: enumerates the congestion control
    used by each type of competing traffic.

  - Traffic timeline: describes when the competing traffic
    starts and ends in the test case.

  * Additional attributes: describes attributes essential for
    implementing a test case which are not included in the above
    structure. These attributes must be well defined, so that the
    other implementers of that particular test case are able to
    implement it easily.

Any attribute can have a set of values (enclosed within "[]"). Each
member value of such a set must be treated as different value for the
same attribute. It is desired to run separate tests for each such
attribute value.

The test cases described in this document follow the above structure.

[4](). Recommended Evaluation Settings

   This section describes recommended test case settings and could be
   overwritten by the respective test cases.

[4.1](). Evaluation metrics

   To evaluate the performance of the candidate algorithms the
   implementers must log enough information to visualize the following
   metrics at a fine enough time granularity:

   1. Flow level:

       A. End-to-end delay for the congestion controlled media flow(s).
           For example - end-to-end delay overserved on IP packet level,
           video frame level.

       B. Variation in sending bit rate and throughput. Mainly
           observing the frequency and magnitude of oscillations.

       C. Packet losses observed at the receiving endpoint.

       D. Feedback message overhead.

       E. Convergence time - time to reach steady state for the
           congestion controlled media flow(s). Each occurance of
           convergence during the test period need to be presented.

   2. Transport level:

       A. Bandwidth utilization.

       B. Queue length (milliseconds at specified path capacity).

[4.2](). Path characteristics

   Each path between a sender and receiver as described in Figure 1 have
   the following characteristics unless otherwise specified in the test
   case.

   o Path direction: forward and backward.

   o Reference bottleneck capacity: 1Mbps.

   o One-Way propagation delay: 50ms. Implementers are encouraged to
      run the experiment with additional propagation delays mentioned in
      [I-D.ietf-rmcat-eval-criteria]

o Maximum end-to-end jitter: 30ms. Jitter models are described in
   [I-D.ietf-rmcat-eval-criteria]

o Bottleneck queue type: "tail drop". Implementers are encouraged
   to run the experiment with other AQM schemes, such as FQ-CoDel and
   PIE.

o Bottleneck queue size: 300ms.

o Path loss ratio: 0%.

Examples of additional network parameters are discussed in
[I-D.ietf-rmcat-eval-criteria].

For test cases involving time-varying bottleneck capacity, all
capacity values are specified as a ratio with respect to a reference
capacity value, so as to allow flexible scaling of capacity values
along with media source rate range. There exist two different
mechanisms for inducing path capacity variation: a) by explicitly
modifying the value of physical link capacity; or b) by introducing
background non-adaptive UDP traffic with time-varying traffic rate.
Implementers are encouraged to run the experiments with both
mechanisms for test cases specified in Section 5.1, Section 5.2, and
Section 5.3.

4.3. Media source

Unless otherwise specified, each test case will include one or more
media sources as described below.

o Media type: Video

   * Media codec: VBR

   * Media source behavior:

      + Adaptability:

         - Bit rate range: 150 Kbps - 1.5 Mbps. In real-life
            applications the bit rate range can vary a lot depending
            on the provided service, for example, the maximum bit
            rate can be up to 4Mbps. However, for running tests to
            evaluate the congestion control algorithms it is more
            important to have a look at how they are reacting to
            certain amount of bandwidth change. Also it is possible
            that the media traffic generator used in a particular
            simulator or testbed is not capable of generating higher
            bit rate. Hence we have selected a suitable bit rate

                  range typical of consumer-grade video conferencing
                  applications in designing the test case. If a different
                  bit rate range is used in the test cases, then the end-
                  to-end path capacity values will also need to be scaled
                  accordingly.

                  - Frame resolution: 144p - 720p (or 1080p). This
                     resolution range is selected based on the bit rate range.
                     If a different bit rate range is used in the test cases
                     then the frame resolution range also need to be selected
                     suitably.

                  - Frame rate: 10fps - 30fps. This frame rate range is
                     selected based on the bit rate range. If a different bit
                     rate range is used in the test cases then the frame rate
                     range also need to be adjusted suitably.

               + Variation from target bit rate: +/-5%. Unless otherwise
                  specified in the test case(s), bit rate variation should be
                  calculated over one (1) second period of time.

               + Responsiveness to new bit rate request: 100ms

         * Media content: The media content should represent a typical
            video conversational scenario with head and shoulder movement.
            We recommend to use Foreman video sequence[xiph-seq].

         * Media startup behavior: 150Kbps. It should be noted that
            applications can use smart ways to select an optimal startup
            bit rate value for a certain network condition. In such cases
            the candidate proposals MAY show the effectiveness of such
            smart approach as an additional information for the evaluation
            process.

      o Media type: Audio

         * Media codec: CBR

         * Media bit rate: 20Kbps

5. Basic Test Cases

5.1. Variable Available Capacity with a Single Flow

   In this test case the bottleneck-link capacity between the two
   endpoints varies over time. This test is designed to measure the
   responsiveness of the candidate algorithm. This test tries to
   address the requirements in [I-D.ietf-rmcat-cc-requirements], which

requires the algorithm to adapt the flow(s) and provide lower end-to-
end latency when there exists:

o   an intermediate bottleneck

o   change in available capacity (e.g., due to interface change,
    routing change, abrupt arrival/departure of background non-
    adaptive traffic).

o   maximum media bit rate is greater than link capacity. In this
    case, when the application tries to ramp up to its maximum bit
    rate, since the link capacity is limited to a value lower, the
    congestion control scheme is expected to stabilize the sending bit
    rate close to the available bottleneck capacity.

It should be noted that the exact variation in available capacity due
to any of the above depends on the underlying technologies. Hence,
we describe a set of known factors, which may be extended to devise a
more specific test case targeting certain behaviors in a certain
network environment.

Expected behavior: the candidate algorithm is expected to detect the
path capacity constraint, converge to the bottleneck link's capacity
and adapt the flow to avoid unwanted media rate oscillation when the
sending bit rate is approaching the bottleneck link's capacity. Such
oscillations might occur when the media flow(s) attempts to reach its
maximum bit rate but overshoots the usage of the available bottleneck
capacity then to rectify, it reduces the bit rate and starts to ramp
up again.

Evaluation metrics : as described in Section 4.1.

Testbed topology: One media source S1 is connected to the
corresponding R1. The media traffic is transported over the forward
path and corresponding feedback/control traffic is transported over
the backward path.

```
                         Forward -->
+---+        +-----+                              +-----+        +---+
|S1 |=======|  A  |------------------------------>|  B  |=======|R1 |
+---+        |     |<-----------------------------|     |        +---+
             +-----+                              +-----+
                         <-- Backward
```

        Figure 2: Testbed Topology for Limited Link Capacity

Testbed attributes:

o Test duration: 100s

o Path characteristics: as described in Section 4.2

o Application-related:

    * Media Traffic:

        + Media type: Video

            - Media direction: forward.

            - Number of media sources: one (1)

            - Media timeline:

                o Start time: 0s.

                o End time: 99s.

        + Media type: Audio

            - Media direction: forward.

            - Number of media sources: one (1)

            - Media timeline:

                o Start time: 0s.

                o End time: 99s.

    * Competing traffic:

        + Number of sources : zero (0)

o Test Specific Information:

    * One-way propagation delay: [50 ms, 100 ms]. on the forward
       path direction

    * This test uses bottleneck path capacity variation as listed in
       Table 1

    * When using background non-adaptive UDP traffic to induce time-
       varying bottleneck , the physical path capacity remains at
       4Mbps and the UDP traffic source rate changes over time as (4 -

(Y x r)), where r is the Reference bottleneck capacity in Mbps
and Y is the path capacity ratio specified in Table 1

```
+--------------------+-------------+-----------+------------------+
| Variation pattern  | Path        | Start     | Path capacity    |
| index              | direction   | time      | ratio            |
+--------------------+-------------+-----------+------------------+
| One                | Forward     | 0s        | 1.0              |
| Two                | Forward     | 40s       | 2.5              |
| Three              | Forward     | 60s       | 0.6              |
| Four               | Forward     | 80s       | 1.0              |
+--------------------+-------------+-----------+------------------+
```

Table 1: Path capacity variation pattern for forward direction

5.2. Variable Available Capacity with Multiple Flows

This test case is similar to Section 5.1. However in addition this
test will also consider persistent network load due to competing
traffic.

Expected behavior: the candidate algorithm is expected to detect the
variation in available capacity and adapt the media stream(s)
accordingly. The flows stabilize around their maximum bit rate as
the maximum link capacity is large enough to accommodate the flows.
When the available capacity drops, the flows adapt by decreasing
their sending bit rate, and when congestion disappears, the flows are
again expected to ramp up.

Evaluation metrics : as described in Section 4.1.

Testbed Topology: Two (2) media sources S1 and S2 are connected to
their corresponding destinations R1 and R2. The media traffic is
transported over the forward path and corresponding feedback/control
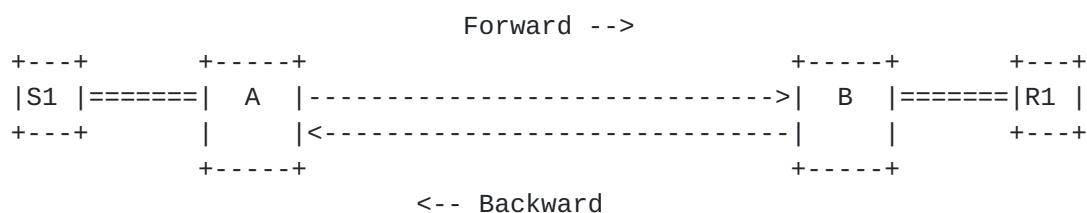traffic is transported over the backward path.

```
+---+                                                    +---+
|S1 |===== \                                      / ======|R1 |
+---+       \\              Forward -->          //        +---+
             \\                                //
              +-----+                    +-----+
              |  A  |----------------------------->|  B  |
              |     |<-----------------------------|     |
              +-----+                    +-----+
               //                              \\
              //              <-- Backward       \\
+---+        //                                    \\        +---+
|S2 |====== /                                       \ ======|R2 |
+---+                                                        +---+
```

        Figure 3: Testbed Topology for Variable Available Capacity

   Testbed attributes:

   Testbed attributes are similar as described in Section 5.1 except the
   test specific capacity variation setup.

   Test Specific Information: This test uses path capacity variation as
   listed in Table 2 with a corresponding end time of 125 seconds. The
   reference bottleneck capacity is 2Mbps. When using background non-
   adaptive UDP traffic to induce time-varying bottleneck for congestion
   controlled media flows, the physical path capacity is 4Mbps and the
   UDP traffic source rate changes over time as $(4 - (Y \times r))$, where r
   is the Reference bottleneck capacity in Mbps and Y is the path
   capacity ratio specified in Table 2.

Variation pattern index	Path direction	Start time	Path capacity ratio
One	Forward	0s	2.0
Two	Forward	25s	1.0
Three	Forward	50s	1.75
Four	Forward	75s	0.5
Five	Forward	100s	1.0

        Table 2: Path capacity variation pattern for forward direction

5.3. Congested Feedback Link with Bi-directional Media Flows

   Real-time interactive media uses RTP hence it is assumed that RTCP,
   RTP header extension or such would be used by the congestion control
   algorithm in the backchannel. Due to the asymmetric nature of the

link between communicating peers it is possible for a participating
peer to not receive such feedback information due to an impaired or
congested backchannel (even when the forward channel might not be
impaired). This test case is designed to observe the candidate
congestion control behavior in such an event.

Expected behavior: It is expected that the candidate algorithms are
able to cope with the lack of feedback information and adapt to
minimize the performance degradation of media flows in the forward
channel.

It should be noted that for this test case: logs are compared with
the reference case, i.e, when the backward channel has no
impairments.

Evaluation metrics : as described in Section 4.1.

Testbed topology: One (1) media source S1 is connected to
corresponding R1, but both endpoints are additionally receiving and
sending data, respectively. The media traffic (S1->R1) is
transported over the forward path and corresponding feedback/control
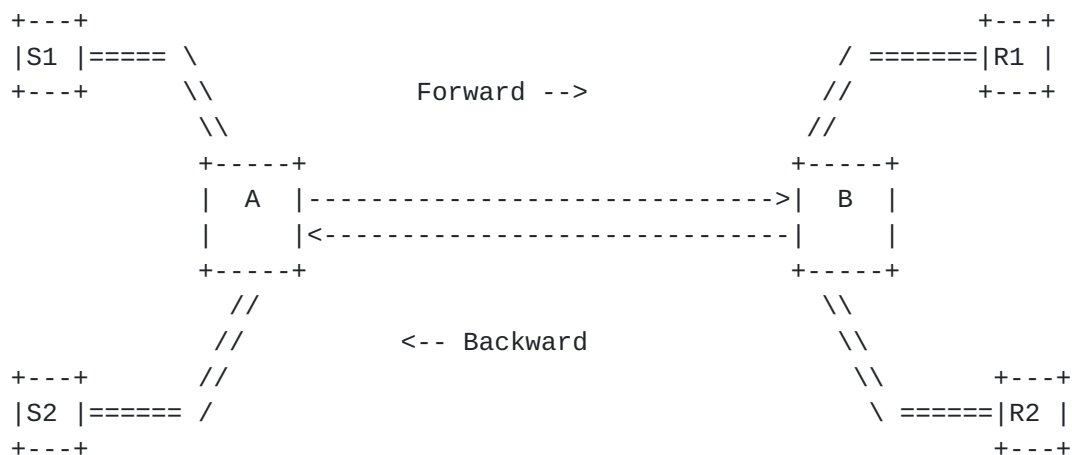traffic is transported over the backward path. Likewise media
traffic (S2->R2) is transported over the backward path and
corresponding feedback/control traffic is transported over the
forward path.

```
    +---+                                              +---+
    |S1 |===== \                Forward -->        / =======|R1 |
    +---+      \\                                  //        +---+
               \\                                 //
          +-----+                            +-----+
          |  A  |-------------------------------->|  B  |
          |     |<--------------------------------|     |
          +-----+                            +-----+
            //                                   \\
           //               <-- Backward          \\
  +---+    //                                       \\        +---+
  |R2 |===== /                                        \ ======|S2 |
  +---+                                                       +---+
```

        Figure 4: Testbed Topology for Congested Feedback Link

Testbed attributes:

o Test duration: 100s

o Path characteristics:

      * Reference bottleneck capacity: 1Mbps.

   o Application-related:

      * Media Source:

         + Media type: Video

            - Media direction: forward and backward

            - Number of media sources: two (2)

            - Media timeline:

               o Start time: 0s.

               o End time: 99s.

         + Media type: Audio

            - Media direction: forward and backward

            - Number of media sources: two (2)

            - Media timeline:

               o Start time: 0s.

               o End time: 99s.

      * Competing traffic:

         + Number of sources : zero (0)

   o Test Specific Information: this test uses path capacity variations
      to create congested feedback link. Table 3 lists the variation
      patterns applied to the forward path and Table 4 lists the
      variation patterns applied to the backward path. When using
      background non-adaptive UDP traffic to induce time-varying
      bottleneck for congestion controlled media flows, the physical
      path capacity is 4Mbps for both directions and the UDP traffic
      source rate changes over time as (4-x)Mbps in each direction,
      where x is the bottleneck capacity specified in Table 4.

```
+--------------------+-------------+-----------+------------------+
| Variation pattern  | Path        | Start     | Path capacity    |
| index              | direction   | time      | ratio            |
+--------------------+-------------+-----------+------------------+
| One                | Forward     | 0s        | 2.0              |
| Two                | Forward     | 20s       | 1.0              |
| Three              | Forward     | 40s       | 0.5              |
| Four               | Forward     | 60s       | 2.0              |
+--------------------+-------------+-----------+------------------+
```

       Table 3: Path capacity variation pattern for forward direction

```
+--------------------+-------------+-----------+------------------+
| Variation pattern  | Path        | Start     | Path capacity    |
| index              | direction   | time      | ratio            |
+--------------------+-------------+-----------+------------------+
| One                | Backward    | 0s        | 2.0              |
| Two                | Backward    | 35s       | 0.8              |
| Three              | Backward    | 70s       | 2.0              |
+--------------------+-------------+-----------+------------------+
```

       Table 4: Path capacity variation pattern for backward direction

5.4. Competing Media Flows with same Congestion Control Algorithm

   In this test case, more than one media flow share the bottleneck link
   and each of them uses the same congestion control algorithm. This is
   a typical scenario where a real-time interactive application sends
   more than one media flow to the same destination and these flows are
   multiplexed over the same port. In such a scenario it is likely that
   the flows will be routed via the same path and need to share the
   available bandwidth amongst themselves. For the sake of simplicity
   it is assumed that there are no other competing traffic sources in
   the bottleneck link and that there is sufficient capacity to
   accommodate all the flows individually. While this appears to be a
   variant of the test case defined in Section 5.2, it focuses on the
   capacity sharing aspect of the candidate algorithm. The previous
   test case, on the other hand, measures adaptability, stability, and
   responsiveness of the candidate algorithm.

   Expected behavior: It is expected that the competing flows will
   converge to an optimum bit rate to accommodate all the flows with
   minimum possible latency and loss. Specifically, the test introduces
   three media flows at different time instances, when the second flow
   appears there should still be room to accommodate another flow on the
   bottleneck link. Lastly, when the third flow appears the bottleneck
   link should be saturated.

Evaluation metrics : as described in Section 4.1.

Testbed topology: Three media sources S1, S2, S3 are connected to R1,
R2, R3 respectively. The media traffic is transported over the
forward path and corresponding feedback/control traffic is
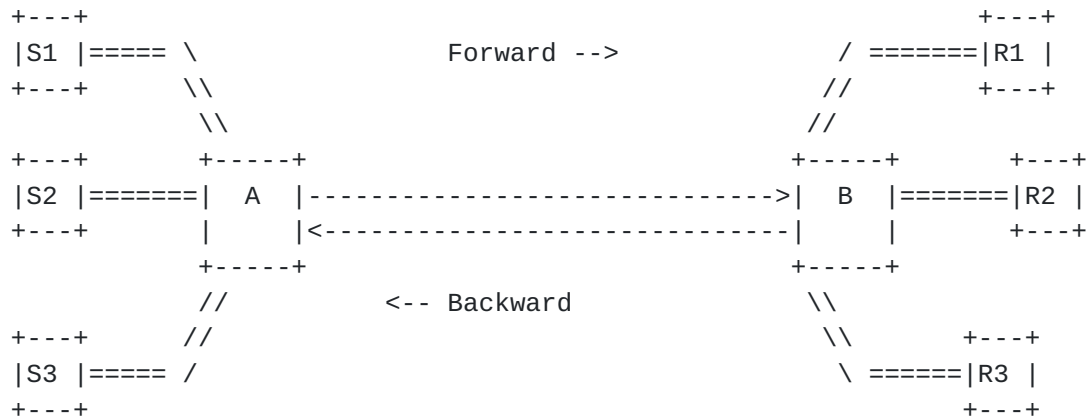transported over the backward path.

```
+---+                                                    +---+
|S1 |===== \                  Forward -->        / ======|R1 |
+---+      \\                                    //       +---+
            \\                                  //
+---+       +-----+                      +-----+       +---+
|S2 |=======|  A  |----------------------------->|  B  |=======|R2 |
+---+       |     |<-----------------------------|     |       +---+
            +-----+                      +-----+
             //           <-- Backward        \\
+---+       //                                 \\       +---+
|S3 |===== /                                    \ ======|R3 |
+---+                                                    +---+
```

           Figure 5: Testbed Topology for Multiple congestion controlled media
                                    Flows

Testbed attributes:

o Test duration: 120s

o Path characteristics:

   * Reference bottleneck capacity: 3.5Mbps

   * Path capacity ratio: 1.0

o Application-related:

   * Media Source:

      + Media type: Video

         - Media direction: forward.

         - Number of media sources: three (3)

         - Media timeline: new media flows are added sequentially,
            at short time intervals. See test specific setup below.

      + Media type: Audio

- Media direction: forward.

- Number of media sources: three (3)

- Media timeline: new media flows are added sequentially, at short time intervals. See test specific setup below.

* Competing traffic:

+ Number of sources : zero (0)

o Test Specific Information: Table 5 defines the media timeline for both media type.

```
+---------+------------+------------+----------+
| Flow ID | Media type | Start time | End time |
+---------+------------+------------+----------+
| 1       | Video      | 0s         | 119s     |
| 2       | Video      | 20s        | 119s     |
| 3       | Video      | 40s        | 119s     |
| 4       | Audio      | 0s         | 119s     |
| 5       | Audio      | 20s        | 119s     |
| 6       | Audio      | 40s        | 119s     |
+---------+------------+------------+----------+
```

Table 5: Media Timeline for Video and Audio media sources

5.5. Round Trip Time Fairness

In this test case, multiple media flows share the bottleneck link, but the one-way propagation delay for each flow is different. For the sake of simplicity it is assumed that there are no other competing traffic sources in the bottleneck link and that there is sufficient capacity to accommodate all the flows. While this appears to be a variant of test case 5.2, it focuses on the capacity sharing aspect of the candidate algorithm under different RTTs.

Expected behavior: It is expected that the competing flows will converge to bit rates to accommodate all the flows with minimum possible latency and loss. The effectiveness of the algorithm depends on how fast and fairly the comepting flows converge to their steady states irrespective of the RTT overserved.

Evaluation metrics : as described in Section 4.1.

Testbed Topology: Five (5) media sources S1,S2,..,S5 are connected to their corresponding media sinks R1,R2,..,R5. The media traffic is transported over the forward path and corresponding feedback/control

traffic is transported over the backward path. The topology is the
same as in Section 5.4.

Testbed attributes:

o Test duration: 300s

o Path characteristics:

   * Reference bottleneck capacity: 4Mbps

   * Path capacity ratio: 1.0

   * One-Way propagation delay for each flow: 10ms for S1-R1, 25ms
      for S2-R2, 50ms for S3-R3, 100ms for S4-R4, and 150ms S5-R5.

o Application-related:

   * Media Source:

      + Media type: Video

         - Media direction: forward

         - Number of media sources: five (5)

         - Media timeline: new media flows are added sequentially,
            at short time intervals. See test specific setup below.

      + Media type: Audio

         - Media direction: forward.

         - Number of media sources: five (5)

         - Media timeline: new media flows are added sequentially,
            at short time intervals. See test specific setup below.

   * Competing traffic:

      + Number of sources : zero (0)

o Test Specific Information: Table 6 defines the media timeline for
   both media type.

```
+---------+-----------+-----------+---------+
| Flow IF | Media type | Start time | End time |
+---------+-----------+-----------+---------+
| 1       | Video     | 0s        | 299s    |
| 2       | Video     | 10s       | 299s    |
| 3       | Video     | 20s       | 299s    |
| 4       | Video     | 30s       | 299s    |
| 5       | Video     | 40s       | 299s    |
| 6       | Audio     | 0         | 299s    |
| 7       | Audio     | 10s       | 299s    |
| 8       | Audio     | 20s       | 299s    |
| 9       | Audio     | 30s       | 299s    |
| 10      | Audio     | 40s       | 299s    |
+---------+-----------+-----------+---------+
```

Table 6: Media Timeline for Video and Audio media sources

5.6. Media Flow Competing with a Long TCP Flow

In this test case, one or more media flows share the bottleneck link
with at least one long lived TCP flow. Long lived TCP flows download
data throughout the session and are expected to have infinite amount
of data to send and receive. This is a scenario where a multimedia
application co-exists with a large file download. The test case
measures the adaptivity of the candidate algorithm to competing
traffic. It addresses the requirement 3 in
[I-D.ietf-rmcat-cc-requirements].

Expected behavior: depending on the convergence observed in test case
5.1 and 5.2, the candidate algorithm may be able to avoid congestion
collapse. In the worst case, the media stream will fall to the
minimum media bit rate.

Evaluation metrics : following metrics in addition to as described in
Section 4.1.

1. Flow level:

    A. TCP throughput.

    B. Loss for the TCP flow

Testbed topology: One (1) media source S1 is connected to the
corresponding media sink, R1. In addition, there is a long-live TCP
flow sharing the same bottleneck link. The media traffic is
transported over the forward path and corresponding feedback/control
traffic is transported over the backward path. The TCP traffic goes

over the forward path from, S_tcp with acknowledgment packets go over
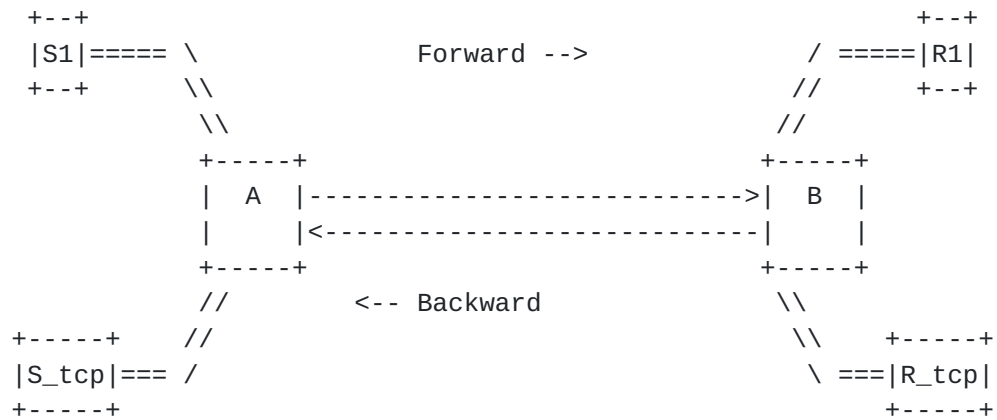the backward path from, R_tcp.

```
    +--+                                              +--+
    |S1|===== \              Forward -->        / =====|R1|
    +--+       \\                              //      +--+
                \\                            //
                +-----+                  +-----+
                |  A  |------------------------->|  B  |
                |     |<-------------------------|     |
                +-----+                  +-----+
                //        <-- Backward        \\
    +-----+    //                              \\    +-----+
    |S_tcp|=== /                                \ ===|R_tcp|
    +-----+                                          +-----+
```

            Figure 6: Testbed Topology for TCP vs congestion controlled media
                              Flows

   Testbed attributes:

   o Test duration: 120s

   o Path characteristics:

      * Reference bottleneck capacity: 2Mbps

      * Path capacity ratio: 1.0

      * Bottleneck queue size: [300ms, 1000ms]

   o Application-related:

      * Media Source:

         + Media type: Video

            - Media direction: forward

            - Number of media sources: one (1)

            - Media timeline:

               o Start time: 5s.

               o End time: 119s.

         + Media type: Audio

- Media direction: forward

- Number of media sources: one (1)

- Media timeline:

  o Start time: 5s.

  o End time: 119s.

* Additionally, implementers are encouraged to run the experiment
  with multiple media sources.

* Competing traffic:

  + Number and Types of sources : one (1) and long-lived TCP

  + Traffic direction : forward

  + Congestion control: default TCP congestion control[RFC5681].

  + Traffic timeline:

    - Start time: 0s.

    - End time: 119s.

o Test Specific Information: none

5.7. Media Flow Competing with Short TCP Flows

In this test case, one or more congestion controlled media flow
shares the bottleneck link with multiple short-lived TCP flows.
Short-lived TCP flows resemble the on/off pattern observed in the web
traffic, wherein clients (for example, browsers) connect to a server
and download a resource (typically a web page, few images, text
files, etc.) using several TCP connections. This scenario shows the
performance of a multimedia application when several browser windows
are active. The test case measures the adaptivity of the candidate
algorithm to competing web traffic, it addresses the requirements 1.E
in [I-D.ietf-rmcat-cc-requirements].

Depending on the number of short TCP flows, the cross-traffic either
appears as a short burst flow or resembles a long TCP flow. The
intention of this test is to observe the impact of short-term burst
on the behavior of the candidate algorithm.

Expected behavior: The candidate algorithm is expected to avoid flow
starvation during the presence of short and bursty competing TCP
flows, streaming at least at the minimum media bit rate. After
competing TCP flows terminate, the media streams are expected to be
robust enough to eventually recover to previous steady state
behavior, and at the very least, avoid persistent starvation.

Evaluation metrics : following metrics in addition to as described in
[Section 4.1](#).

1. Flow level:

    A. Variation in the sending rate of the TCP flow.

    B. TCP throughput.

Testbed topology: The topology described here is same as the one
described in Figure 6.

Testbed attributes:

o Test duration: 300s

o Path characteristics:

    * Reference bottleneck capacity: 2.0Mbps

    * Path capacity ratio: 1.0

o Application-related:

    * Media source:

        + Media type: Video

            - Media direction: forward

            - Number of media sources: two (2)

            - Media timeline:

                o Start time: 5s.

                o End time: 299s.

        + Media type: Audio

            - Media direction: forward

- Number of media sources: two (2)

- Media timeline:

    o Start time: 5s.

    o End time: 299s.

* Competing traffic:

    + Number and Types of sources : ten (10), short-lived TCP
      flows.

    + Traffic direction : forward

    + Congestion algorithm: default TCP Congestion control
      [RFC5681].

    + Traffic timeline: each short TCP flow is modeled as a
      sequence of file downloads interleaved with idle periods.
      Not all short TCP flows start at the same time, 2 of them
      start in the ON state while rest of the 8 flows start in an
      OFF state. For description of short TCP flow model see test
      specific information below.

o Test Specific Information:

  * Short-TCP traffic model: The short TCP model to be used in this
    test is described in [I-D.ietf-rmcat-eval-criteria].

5.8. Media Pause and Resume

In this test case, more than one real-time interactive media flows
share the link bandwidth and all flows reach to a steady state by
utilizing the link capacity in an optimum way. At this stage one of
the media flows is paused for a moment. This event will result in
more available bandwidth for the rest of the flows as they are on a
shared link. When the paused media flow resumes it would no longer
have the same bandwidth share on the link. It has to make its way
through the other existing flows in the link to achieve a fair share
of the link capacity. This test case is important specially for
real-time interactive media which consists of more than one media
flows and can pause/resume media flows at any point of time during
the session. This test case directly addresses the requirement
number 5 in [I-D.ietf-rmcat-cc-requirements]. One can think it as a
variation of test case defined in Section 5.4. However, it is
different as the candidate algorithms can use different strategies to
increase its efficiency, for example in terms of fairness,

convergence time, reduce oscillation etc, by capitalizing the fact
that they have previous information of the link.

Expected behavior: During the period where the third stream is
paused, the two remaining flows are expected to increase their rates
and reach the maximum media bit rate. When the third stream resumes,
all three flows are expected to converge to the same original fair
share of rates prior to the media pause/resume event.

Evaluation metrics : following metrics in addition to as described in
Section 4.1.

1. Flow level:

    A. Variation in sending bit rate and goodput. Mainly observing
        the frequency and magnitude of oscillations.

Testbed Topology: Same as test case defined in Section 5.4

Testbed attributes: The general description of the testbed parameters
are same as Section 5.4 with changes in the test specific setup as
below-

o Other test specific setup:

   * Media flow timeline:

      + Flow ID: one (1)

      + Start time: 0s

      + Flow duration: 119s

      + Pause time: not required

      + Resume time: not required

   * Media flow timeline:

      + Flow ID: two (2)

      + Start time: 0s

      + Flow duration: 119s

      + Pause time: at 40s

      + Resume time: at 60s

   * Media flow timeline:

      + Flow ID: three (3)

      + Start time: 0s

      + Flow duration:119s

      + Pause time: not required

      + Resume time: not required

6. Other potential test cases

   It has been noticed that there are other interesting test cases
   besides the basic test cases listed above. In many aspects, these
   additional test cases can help further evaluation of the candidate
   algorithm. They are listed as below.

6.1. Media Flows with Priority

   In this test case media flows will have different priority levels.
   This will be an extension of Section 5.4 where the same test will be
   run with different priority levels imposed on each of the media
   flows. For example, the first flow (S1) is assigned a priority of 2
   whereas the remaining two flows (S2 and S3) are assigned a priority
   of 1. The candidate algorithm must reflect the relative priorities
   assigned to each media flow. In this case, the first flow (S1) must
   arrive at a steady-state rate approximately twice of that of the
   other two flows (S2 and S3).

   The candidate algorithm can use a coupled congestion control
   mechanism [I-D.ietf-rmcat-coupled-cc] or use a weighted priority
   scheduler for the bandwidth distribution according to the respective
   media flow priority or use.

6.2. Explicit Congestion Notification Usage

   This test case requires to run all the basic test cases with the
   availability of Explicit Congestion Notification (ECN) [RFC6679]
   feature enabled. The goal of this test is to exhibit that the
   candidate algorithms do not fail when ECN signals are available.
   With ECN signals enabled the algorithms are expected to perform
   better than their delay based variants.

6.3. Multiple Bottlenecks

In this test case one congestion controlled media flow, S1->R1,
traverses a path with multiple bottlenecks. As illustrated in
Figure 7, the first flow (S1->R1) competes with the second congestion
controlled media flow (S2->R2) over the link between A and B which is
close to the sender side; again, that flow (S1->R1) competes with the
third congestion controlled media flow (S3->R3) over the link between
C and D which is close to the receiver side. The goal of this test
is to ensure that the candidate algorithms work properly in the
presence of multiple bottleneck links on the end to end path.

Expected behavior: The candidate algorithm is expected to achieve
full utilization at both bottleneck links without starving any of the
three congestion controlled media flows and esuring fair share of the
available bandwidth at each bottlenecks.

```
                          Forward ---->


               +---+              +---+            +---+         +---+
               |S2 |              |R2 |            |S3 |         |R3 |
               +---+              +---+            +---+         +---+
                 |                  |                |             |
                 |                  |                |             |
     +---+       +-----+        +-----+        +-----+     +-----+       +---+
     |S1 |=======|  A  |------->|  B  |----->|  C  |---->|  D  |=======|R1 |
     +---+       |     |<-------|     |<-----|     |<----|     |         +---+
                 +-----+        +-----+        +-----+     +-----+

                    1st                        2nd
               Bottleneck (A->B)          Bottleneck (C->D)


                          <------ Backward
```
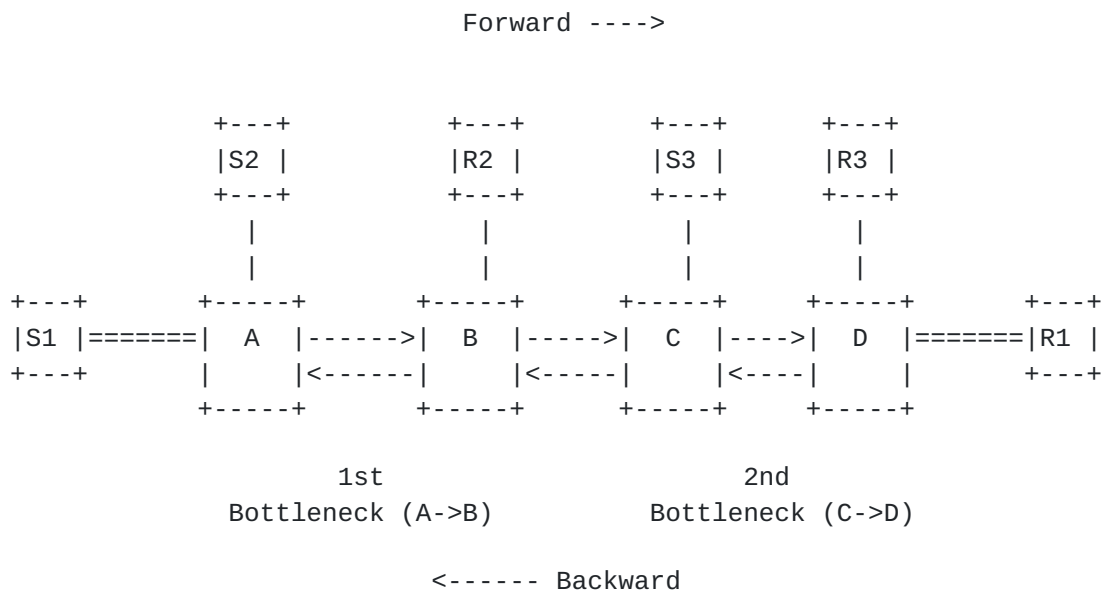
Figure 7: Testbed Topology for Multiple Bottlenecks

Testbed topology: Three media sources S1, S2, and S3 are connected to
respective destinations R1, R2, and R3. For all three flows the
media traffic is transported over the forward path and corresponding
feedback/control traffic is transported over the backward path.

Testbed attributes:

   o Test duration: 300s

   o Path characteristics:

      * Reference bottleneck capacity: 2Mbps.

      * Path capacity ratio between A and B: 1.0

      * Path capacity ratio between B and C: 4.0.

      * Path capacity ratio between C and D: 0.75.

      * One-Way propagation delay:

         1. Between S1 and R1: 100ms

         2. Between S2 and R2: 40ms

         3. Between S3 and R3: 40ms

   o Application-related:

      * Media Source:

         + Media type: Video

            - Media direction: Forward

            - Number of media sources: Three (3)

            - Media timeline:

               o Start time: 0s.

               o End time: 299s.

         + Media type: Audio

            - Media direction: Forward

            - Number of media sources: Three (3)

            - Media timeline:

               o Start time: 0s.

               o End time: 299s.

* Competing traffic:

    + Number of sources : Zero (0)

7. Wireless Access Links

Additional wireless network (both cellular network and WiFi network) specific test cases are defined in [I-D.ietf-rmcat-wireless-tests].

8. Security Considerations

The security considerations in [I-D.ietf-rmcat-eval-criteria] and the relevant congestion control algorithms apply. The principles for congestion control are described in [RFC2914], and in particular any new method must implement safeguards to avoid congestion collapse of the Internet.

The evaluation of the test cases are intended to be run in a controlled lab environment. Hence, the applications, simulators and network nodes ought to be well-behaved and should not impact the desired results. Moreover, proper measures must be taked to avoid leaking non-responsive traffic from unproven congestion avoidance techniques onto the open Internet.

9. IANA Considerations

There are no IANA impacts in this memo.

10. Acknowledgements

Much of this document is derived from previous work on congestion control at the IETF.

The content and concepts within this document are a product of the discussion carried out in the Design Team.

11. References

11.1. Normative References

[I-D.ietf-rmcat-cc-requirements]
          Jesup, R. and Z. Sarker, "Congestion Control Requirements
          for Interactive Real-Time Media", draft-ietf-rmcat-cc-
          requirements-09 (work in progress), December 2014.

   [I-D.ietf-rmcat-eval-criteria]
              Singh, V., Ott, J., and S. Holmer, "Evaluating Congestion
              Control for Interactive Real-time Media", draft-ietf-
              rmcat-eval-criteria-08 (work in progress), November 2018.

   [I-D.ietf-rmcat-video-traffic-model]
              Zhu, X., Cruz, S., and Z. Sarker, "Video Traffic Models
              for RTP Congestion Control Evaluations", draft-ietf-rmcat-
              video-traffic-model-06 (work in progress), November 2018.

   [I-D.ietf-rmcat-wireless-tests]
              Sarker, Z., Johansson, I., Zhu, X., Fu, J., Tan, W., and
              M. Ramalho, "Evaluation Test Cases for Interactive Real-
              Time Media over Wireless Networks", draft-ietf-rmcat-
              wireless-tests-06 (work in progress), December 2018.

   [RFC3550] Schulzrinne, H., Casner, S., Frederick, R., and V.
              Jacobson, "RTP: A Transport Protocol for Real-Time
              Applications", STD 64, RFC 3550, DOI 10.17487/RFC3550,
              July 2003, <https://www.rfc-editor.org/info/rfc3550>.

   [RFC3551] Schulzrinne, H. and S. Casner, "RTP Profile for Audio and
              Video Conferences with Minimal Control", STD 65, RFC 3551,
              DOI 10.17487/RFC3551, July 2003,
              <https://www.rfc-editor.org/info/rfc3551>.

   [RFC3611] Friedman, T., Ed., Caceres, R., Ed., and A. Clark, Ed.,
              "RTP Control Protocol Extended Reports (RTCP XR)",
              RFC 3611, DOI 10.17487/RFC3611, November 2003,
              <https://www.rfc-editor.org/info/rfc3611>.

   [RFC4585] Ott, J., Wenger, S., Sato, N., Burmeister, C., and J. Rey,
              "Extended RTP Profile for Real-time Transport Control
              Protocol (RTCP)-Based Feedback (RTP/AVPF)", RFC 4585,
              DOI 10.17487/RFC4585, July 2006,
              <https://www.rfc-editor.org/info/rfc4585>.

   [RFC5506] Johansson, I. and M. Westerlund, "Support for Reduced-Size
              Real-Time Transport Control Protocol (RTCP): Opportunities
              and Consequences", RFC 5506, DOI 10.17487/RFC5506, April
              2009, <https://www.rfc-editor.org/info/rfc5506>.

   [RFC6679] Westerlund, M., Johansson, I., Perkins, C., O'Hanlon, P.,
              and K. Carlberg, "Explicit Congestion Notification (ECN)
              for RTP over UDP", RFC 6679, DOI 10.17487/RFC6679, August
              2012, <https://www.rfc-editor.org/info/rfc6679>.

11.2. Informative References

[HEVC-seq]
          HEVC, "Test Sequences",
          http://www.netlab.tkk.fi/~varun/test_sequences/ .

[I-D.ietf-rmcat-coupled-cc]
          Islam, S., Welzl, M., and S. Gjessing, "Coupled congestion
          control for RTP media", draft-ietf-rmcat-coupled-cc-08
          (work in progress), January 2019.

[RFC2914] Floyd, S., "Congestion Control Principles", BCP 41,
          RFC 2914, DOI 10.17487/RFC2914, September 2000,
          <https://www.rfc-editor.org/info/rfc2914>.

[RFC5681] Allman, M., Paxson, V., and E. Blanton, "TCP Congestion
          Control", RFC 5681, DOI 10.17487/RFC5681, September 2009,
          <https://www.rfc-editor.org/info/rfc5681>.

[RFC7567] Baker, F., Ed. and G. Fairhurst, Ed., "IETF
          Recommendations Regarding Active Queue Management",
          BCP 197, RFC 7567, DOI 10.17487/RFC7567, July 2015,
          <https://www.rfc-editor.org/info/rfc7567>.

[RFC8033] Pan, R., Natarajan, P., Baker, F., and G. White,
          "Proportional Integral Controller Enhanced (PIE): A
          Lightweight Control Scheme to Address the Bufferbloat
          Problem", RFC 8033, DOI 10.17487/RFC8033, February 2017,
          <https://www.rfc-editor.org/info/rfc8033>.

[RFC8290] Hoeiland-Joergensen, T., McKenney, P., Taht, D., Gettys,
          J., and E. Dumazet, "The Flow Queue CoDel Packet Scheduler
          and Active Queue Management Algorithm", RFC 8290,
          DOI 10.17487/RFC8290, January 2018,
          <https://www.rfc-editor.org/info/rfc8290>.

[xiph-seq]
          Xiph.org, "Video Test Media",
          http://media.xiph.org/video/derf/ .

Authors' Addresses

Zaheduzzaman Sarker
Ericsson AB
Luleae, SE 977 53
Sweden

Phone: +46 10 717 37 43
Email: zaheduzzaman.sarker@ericsson.com

Varun Singh
Nemu Dialogue Systems Oy
Runeberginkatu 4c A 4
Helsinki 00100
Finland

Email: varun.singh@iki.fi
URI: http://www.callstats.io/

Xiaoqing Zhu
Cisco Systems
12515 Research Blvd
Austing, TX 78759
USA

Email: xiaoqzhu@cisco.com

Michael A. Ramalho
Cisco Systems, Inc.
6310 Watercrest Way Unit 203
Lakewood Ranch, FL 34202-5211
USA

Phone: +1 919 476 2038
Email: mramalho@cisco.com