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Evaluation Test Cases for Interactive Real-Time Media over Wireless Networks
draft-ietf-rmcat-wireless-tests-04

Abstract

   There is an ongoing effort in IETF RMCAT working group to standardize
   rate adaptation algorithm(s) for real-time interactive communication.
   To ensure seamless and robust user experience, the proposed rate
   adaptation algorithm(s) should work well across all access network
   types. This document describes test cases for evaluating
   performances of the proposed rate adaptation solutions over LTE and
   Wi-Fi networks.

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Table of Contents

1. Introduction

   Wireless networks (both cellular and Wi-Fi [IEEE802.11] local area
   network) are an integral part of the Internet. Mobile devices
   connected to the wireless networks generate huge amount of media
   traffic in the Internet. Application scenarios range from users
   having a video call in the bus to media consumption by someone
   sitting on a living room couch. It is well known that the
   characteristics and technical challenges for offering multimedia
   services over wireless are very different from those of providing the
   same service over a wired network. Even though RMCAT basic test
   cases as defined in [I-D.ietf-rmcat-eval-test] have covered many
   effects of the impairments also visible in wireless networks, there
   remains characteristics and dynamics unique to a given wireless
   environment. For example, in LTE networks the base station maintains
   queues per radio bearer per user hence it leads to a different nature
   of interaction from that over the wired network, where traffic from
   all users share the same queue. Furthermore, user mobility in a
   cellular network is different than user mobility in a Wi-Fi network.
   Therefore, It is important to evaluate performance of the proposed
   RMCAT candidate solutions separately over cellular mobile networks
   and over Wi-Fi local networks (i.e., IEEE 802.11xx protocol family).

   RMCAT evaluation criteria [I-D.ietf-rmcat-eval-criteria] document
   provides the guideline for evaluating candidate algorithms and
   recognizes the importance of testing over wireless access networks.
   However, it does not describe any specific test cases for evaluating
   performance of the candidate algorithm. This document describes test
   cases specifically targeting cellular networks such as LTE networks
   and Wi-Fi local networks.

2. Terminologies

   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 RFC2119 [RFC2119]

3. Cellular Network Specific Test Cases

   A cellular environment is more complicated than a wireline ditto
   since it seeks to provide services in the context of variable
   available bandwidth, location dependencies and user mobilities at
   different speeds. In a cellular network the user may reach the cell
   edge which may lead to a significant amount of retransmissions to
   deliver the data from the base station to the destination and vice
   versa. These network links or radio links will often act as a
   bottleneck for the rest of the network which will eventually lead to
   excessive delays or packet drops. An efficient retransmission or

link adaptation mechanism can reduce the packet loss probability but
there will still be some packet losses and delay variations.
Moreover, with increased cell load or handover to a congested cell,
congestion in transport network will become even worse. Besides,
there are certain characteristics which make the cellular network
different and challenging than other types of access network such as
Wi-Fi and wired network. In a cellular network -

o The bottleneck is often a shared link with relatively few users.

   * The cost per bit over the shared link varies over time and is
      different for different users.

   * Left over/ unused resource can be grabbed by other greedy
      users.

o Queues are always per radio bearer hence each user can have many
   of such queues.

o Users can experience both Inter and Intra Radio Access Technology
   (RAT) handovers ("handover" definition in [HO-def-3GPP]).

o Handover between cells, or change of serving cells (see in
   [HO-LTE-3GPP] and [HO-UMTS-3GPP]) might cause user plane
   interruptions which can lead to bursts of packet losses, delay
   and/or jitter. The exact behavior depends on the type of radio
   bearer. Typically, the default best effort bearers do not
   generate packet loss, instead packets are queued up and
   transmitted once the handover is completed.

o The network part decides how much the user can transmit.

o The cellular network has variable link capacity per user

   * Can vary as fast as a period of milliseconds.

   * Depends on lots of facts (such as distance, speed,
      interference, different flows).

   * Uses complex and smart link adaptation which makes the link
      behavior ever more dynamic.

   * The scheduling priority depends on the estimated throughput.

o Both Quality of Service (QoS) and non-QoS radio bearers can be
   used.

Hence, a real-time communication application operating in such a
cellular network need to cope with shared bottleneck link and
variable link capacity, event likes handover, non-congestion related
loss, abrupt change in bandwidth (both short term and long term) due
to handover, network load and bad radio coverage. Even though 3GPP
define QoS bearers [QoS-3GPP] to ensure high quality user experience,
adaptive real-time applications are desired.

Different mobile operators deploy their own cellular network with
their own set of network functionalities and policies. Usually, a
mobile operator network includes 2G, EDGE, 3G and 4G radio access
technologies. Looking at the specifications of such radio
technologies it is evident that only 3G and 4G radio technologies can
support the high bandwidth requirements from real-time interactive
video applications. The future real-time interactive application
will impose even greater demand on cellular network performance which
makes 4G (and beyond radio technologies) more suitable access
technology for such genre of application.

The key factors to define test cases for cellular network are

o Shared and varying link capacity

o Mobility

o Handover

However, for cellular network it is very hard to separate such events
from one another as these events are heavily related. Hence instead
of devising separate test cases for all those important events we
have divided the test case in two categories. It should be noted
that in the following test cases the goal is to evaluate the
performance of candidate algorithms over radio interface of the
cellular network. Hence it is assumed that the radio interface is
the bottleneck link between the communicating peers and that the core
network does not add any extra congestion in the path. Also the
combination of multiple access technologies such as one user has LTE
connection and another has Wi-Fi connection is kept out of the scope
of this document. However, later those additional scenarios can also
be added in this list of test cases. While defining the test cases
we assumed a typical real-time telephony scenario over cellular
networks where one real-time session consists of one voice stream and
one video stream. We recommend that an LTE network simulator is used
for the test cases defined in this document, for example-NS-3 LTE
simulator [LTE-simulator].

3.1. Varying Network Load

   The goal of this test is to evaluate the performance of the candidate
   congestion control algorithm under varying network load. The network
   load variation is created by adding and removing network users a.k.a.
   User Equipments (UEs) during the simulation. In this test case, each
   of the user/UE in the media session is an RMCAT compliant endpoint.
   The arrival of users follows a Poisson distribution, which is
   proportional to the length of the call, so that the number of users
   per cell is kept fairly constant during the evaluation period. At
   the beginning of the simulation there should be enough amount of time
   to warm-up the network. This is to avoid running the evaluation in
   an empty network where network nodes are having empty buffers, low
   interference at the beginning of the simulation. This network
   initialization period is therefore excluded from the evaluation
   period.

   This test case also includes user mobility and competing traffic.
   The competing traffics includes both same kind of flows (with same
   adaptation algorithms) and different kind of flows (with different
   service and congestion control). The investigated congestion control
   algorithms should show maximum possible network utilization and
   stability in terms of rate variations, lowest possible end to end
   frame latency, network latency and Packet Loss Rate (PLR) at
   different cell load level.

3.1.1. Network Connection

   Each mobile user is connected to a fixed user. The connection
   between the mobile user and fixed user consists of a LTE radio
   access, an Evolved Packet Core (EPC) and an Internet connection. The
   mobile user is connected to the EPC using LTE radio access technology
   which is further connected to the Internet. The fixed user is
   connected to the Internet via wired connection with no bottleneck
   (practically infinite bandwidth). The Internet and wired connection
   in this setup does not add any network impairments to the test, it
   only adds 10ms of one-way transport propagation delay.

   The path from the fixed user to mobile user is defines as "Downlink"
   and the path from mobile user to the fixed user is defined as
   "Uplink". We assume that only uplink or downlink is congested for
   the mobile users. Hence, we recommend that the uplink and downlink
   simulations are run separately.

```
                       uplink
      ++)))        +------------------------->
      ++-+      ((o))
      |  |      / \      +-------+    +------+    +---+
      +--+     /   \----+       +-----+      +----+   |
              /     \   +-------+    +------+    +---+
        UE        BS        EPC        Internet   fixed
                  <-------------------------+
                         downlink
```
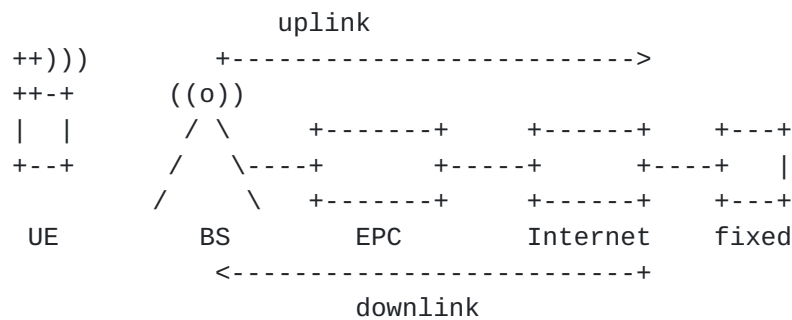
                    Figure 1: Simulation Topology

3.1.2. Simulation Setup

   The values enclosed within " [ ] " for the following simulation
   attributes follow the notion set in [I-D.ietf-rmcat-eval-test]. The
   desired simulation setup as follows-

   1. Radio environment

       A. Deployment and propagation model : 3GPP case 1[Deployment]

       B. Antenna: Multiple-Input and Multiple-Output (MIMO), [2D, 3D]

       C. Mobility: [3km/h, 30km/h]

       D. Transmission bandwidth: 10Mhz

       E. Number of cells: multi cell deployment (3 Cells per Base
           Station (BS) * 7 BS) = 21 cells

       F. Cell radius: 166.666 Meters

       G. Scheduler: Proportional fair with no priority

       H. Bearer: Default bearer for all traffic.

       I. Active Queue Management (AQM) settings: AQM [on,off]

   2. End to end Round Trip Time (RTT): [40, 150]

   3. User arrival model: Poisson arrival model

   4. User intensity:

       * Downlink user intensity: {0.7, 1.4, 2.1, 2.8, 3.5, 4.2, 4.9,
          5.6, 6.3, 7.0, 7.7, 8.4, 9,1, 9.8, 10.5}

      * Uplink user intercity : {0.7, 1.4, 2.1, 2.8, 3.5, 4.2, 4.9, 5.6, 6.3, 7.0}

5. Simulation duration: 91s

6. Evaluation period : 30s-60s

7. Media traffic

    1. Media type: Video

       a. Media direction: [Uplink, Downlink]

       b. Number of Media source per user: One (1)

       c. Media duration per user: 30s

       d. Media source: same as define in section 4.3 of [I-D.ietf-rmcat-eval-test]

    2. Media Type : Audio

       a. Media direction: Uplink and Downlink

       b. Number of Media source per user: One (1)

       c. Media duration per user: 30s

       d. Media codec: Constant BitRate (CBR)

       e. Media bitrate : 20 Kbps

       f. Adaptation: off

8. Other traffic model:

    * Downlink simulation: Maximum of 4Mbps/cell (web browsing or FTP traffic)

    * Unlink simulation: Maximum of 2Mbps/cell (web browsing or FTP traffic)

3.2. Bad Radio Coverage

The goal of this test is to evaluate the performance of candidate congestion control algorithm when users visit part of the network with bad radio coverage. The scenario is created by using larger cell radius than previous test case. In this test case each of the

user/UE in the media session is an RMCAT compliant endpoint. The
arrival of users follows a Poisson distribution, which is
proportional to the length of the call, so that the number of users
per cell is kept fairly constant during the evaluation period. At
the beginning of the simulation there should be enough amount of time
to warm-up the network. This is to avoid running the evaluation in
an empty network where network nodes are having empty buffers, low
interference at the beginning of the simulation. This network
initialization period is therefore excluded from the evaluation
period.

This test case also includes user mobility and competing traffic.
The competing traffics includes same kind of flows (with same
adaptation algorithms) . The investigated congestion control
algorithms should show maximum possible network utilization and
stability in terms of rate variations, lowest possible end to end
frame latency, network latency and Packet Loss Rate (PLR) at
different cell load level.

3.2.1. Network connection

Same as defined in Section 3.1.1

3.2.2. Simulation Setup

The desired simulation setup is same as Varying Network Load test
case defined in Section 3.1 except following changes-

1. Radio environment : Same as defined in Section 3.1.2 except
    followings

    A. Deployment and propagation model : 3GPP case 3[Deployment]

    B. Cell radius: 577.3333 Meters

    C. Mobility: 3km/h

2. User intensity = {0.7, 1.4, 2.1, 2.8, 3.5, 4.2, 4.9, 5.6, 6.3,
    7.0}

3. Media traffic model: Same as defined in Section 3.1.2

4. Other traffic model: None

3.3. Desired Evaluation Metrics for cellular test cases

   RMCAT evaluation criteria document [I-D.ietf-rmcat-eval-criteria]
   defines metrics to be used to evaluate candidate algorithms.
   However, looking at the nature and distinction of cellular networks
   we recommend at minimum following metrics to be used to evaluate the
   performance of the candidate algorithms for the test cases defined in
   this document.

   The desired metrics are-

   o Average cell throughput (for all cells), shows cell utilizations.

   o Application sending and receiving bitrate, goodput.

   o Packet Loss Rate (PLR).

   o End to end Media frame delay. For video, this means the delay
      from capture to display.

   o Transport delay.

   o Algorithm stability in terms of rate variation.

4. Wi-Fi Networks Specific Test Cases

   Given the prevalence of Internet access links over Wi-Fi, it is
   important to evaluate candidate RMCAT congestion control solutions
   over test cases that include Wi-Fi access lines. Such evaluations
   should also highlight the inherent different characteristics of Wi-Fi
   networks in contrast to wired networks:

   o The wireless radio channel is subject to interference from nearby
      transmitters, multipath fading, and shadowing, causing
      fluctuations in link throughput and sometimes an error-prone
      communication environment

   o Available network bandwidth is not only shared over the air
      between cocurrent users, but also between uplink and downlink
      traffic due to the half duplex nature of wireless transmission
      medium.

   o Packet transmissions over Wi-Fi are susceptible to contentions and
      collisions over the air. Consequently, traffic load beyond a
      certain utilization level over a Wi-Fi network can introduce
      frequent collisions and significant network overhead. This, in
      turn, leads to excessive delay, retransmissions, packet losses and
      lower effective bandwidth for applications.

o   The IEEE 802.11 standard (i.e., Wi-Fi) supports multi-rate
    transmission capabilities by dynamically choosing the most
    appropriate modulation scheme for a given received singal
    strength. A different choice of physical-layer rate leads to
    different application-layer throughput.

o   Presence of legacy 802.11b networks can significantly slow down
    the the rest of a modern Wi-Fi Network, since it takes longer to
    transmit the same packet over a slower link than over a faster
    link. [Editor's note: maybe include a reference here instead.]

o   Handover from one Wi-Fi Access Point (AP) to another may lead to
    packet delay and losses during the process.

o   IEEE 802.11e defined EDCA/WMM (Enhanced DCF Channel Access/Wi-Fi
    Multi-Media) to give voice and video streams higher priority over
    pure data applications (e.g., file transfers).

In summary, presence of Wi-Fi access links in different network
topologies can exert different impact on the network performance in
terms of application-layer effective throughput, packet loss rate,
and packet delivery delay. These, in turn, influence the behavior of
end-to-end real-time multimedia congestion control.

Throughout this draft, unless otherwise mentioned, test cases are
described using 802.11n due to its wide availability in real-world
networks. Statistics collected from enterprise Wi-Fi networks show
that the dominant physical modes are 802.11n and 802.11ac, accounting
for 73.6% and 22.5% of enterprise network users, respectively.

Typically, a Wi-Fi access network connects to a wired infrastructure.
Either the wired or the Wi-Fi segment of the network could be the
bottleneck. In the following sections, we describe basic test cases
for both scenarios separately. The same set of performance metrics
as in [I-D.ietf-rmcat-eval-test]) should be collected for each test
case.

While all test cases described below can be carried out using
simulations, e.g. based on [ns-2] or [ns-3], it is also recommended
to perform testbed-based evaluations using Wi-Fi access points and
endpoints running up-to-date IEEE 802.11 protocols. [Editor's Note:
need to add some more discussions on the pros and cons of simulation-
based vs. testbed-based evaluations. Will be good to provide
recommended testbed configurations.]

4.1. Bottleneck in Wired Network

The test scenarios below are intended to mimic the set up of video
conferencing over Wi-Fi connections from the home. Typically, the
Wi-Fi home network is not congested and the bottleneck is present
over the wired home access link. Although it is expected that test
evaluation results from this section are similar to those from test
cases defined for wired networks (see [I-D.ietf-rmcat-eval-test]), it
is worthwhile to run through these tests as sanity checks.

4.1.1. Network topology

Figure 2 shows topology of the network for Wi-Fi test cases. The
test contains multiple mobile nodes (MNs) connected to a common Wi-Fi
access point (AP) and their corresponding wired clients on fixed
nodes (FNs). Each connection carries either RMCAT or TCP traffic
flow. Directions of the flows can be uplink, downlink, or bi-
directional.

```
                            uplink
                  +----------------->+
      +------+                                      +------+
      | MN_1 |))))                          /=====| FN_1 |
      +------+    ))                        //      +------+
         .          ))                     //          .
         .           ))                   //           .
         .            ))                 //            .
      +------+       +----+         +-----+       +------+
      | MN_N | )))))))|    |         |     |=======| FN_N |
      +------+        |    |         |     |        +------+
                      | AP |=========| FN0 |
   +----------+       |    |         |     |       +----------+
   | MN_tcp_1 | ))))  |    |         |     |=====| MN_tcp_1 |
   +----------+       +----+         +-----+       +----------+
         .           ))                 \\            .
         .            ))                 \\           .
         .             ))                 \\          .
   +----------+  ))                        \\     +----------+
   | MN_tcp_M |)))                          \=====| MN_tcp_M |
   +----------+                                   +----------+
               +<----------------+
                     downlink
```
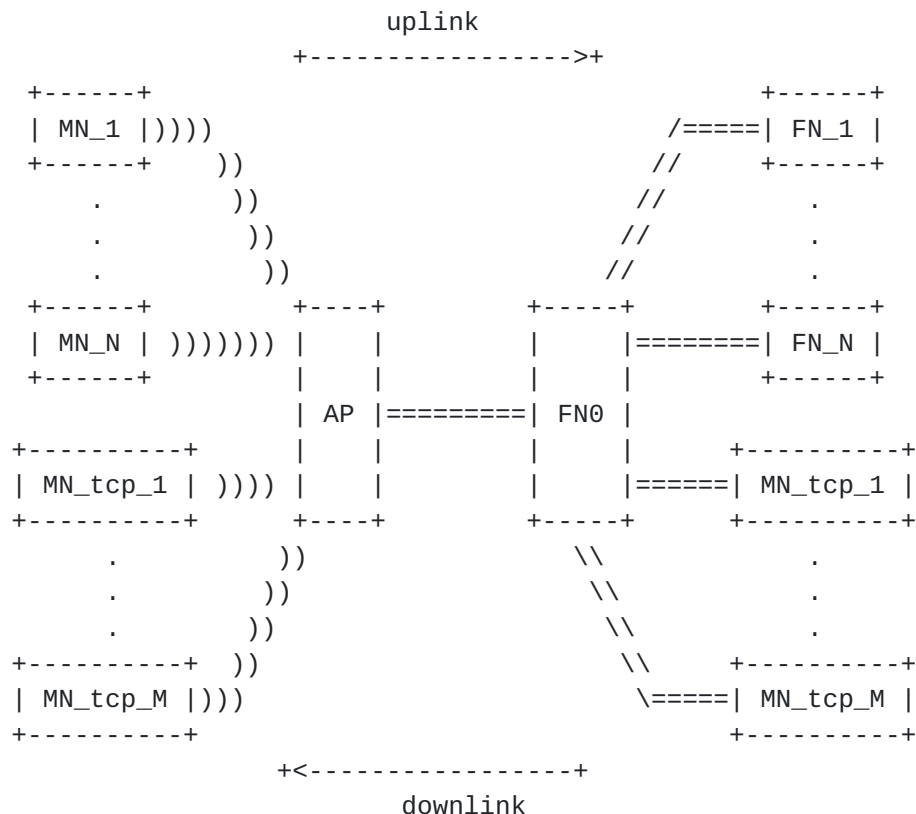
Figure 2: Network topology for Wi-Fi test cases

4.1.2. Test setup

o Test duration: 120s

o Wi-Fi network characteristics:

   * Radio propagation model: Log-distance path loss propagation
      model [NS3WiFi]

   * PHY- and MAC-layer configuration: IEEE 802.11n

   * MCS Index at 11: 16-QAM 1/2, Raw Data Rate@52Mbps

o Wired path characteristics:

   * Path capacity: 1Mbps

   * One-Way propagation delay: 50ms.

   * Maximum end-to-end jitter: 30ms

   * Bottleneck queue type: Drop tail.

   * Bottleneck queue size: 300ms.

   * Path loss ratio: 0%.

o Application characteristics:

   * Media Traffic:

      + Media type: Video

      + Media direction: See Section 4.1.3

      + Number of media sources (N): See Section 4.1.3

      + Media timeline:

         - Start time: 0s.

         - End time: 119s.

   * Competing traffic:

      + Type of sources: long-lived TCP or CBR over UDP

      + Traffic direction: See Section 4.1.3

+   Number of sources (M): See Section 4.1.3

+   Congestion control: Default TCP congestion control [TBD] or
    CBR over UDP

+   Traffic timeline: See Section 4.1.3

4.1.3. Typical test scenarios

o Single uplink RMCAT flow: N=1 with uplink direction and M=0.

o One pair of bi-directional RMCAT flows: N=2 (with one uplink flow
   and one downlink flow); M=0.

o One pair of bi-directional RMCAT flows, one on-off CBR over UDP
   flow on uplink: N=2 (with one uplink flow and one downlink flow);
   M=1 (uplink). CBR flow on time at 0s-60s, off time at 60s-119s.

o One pair of bi-directional RMCAT flows, one off-on CBR over UDP
   flow on uplink: N=2 (with one uplink flow and one downlink flow);
   M=1 (uplink). UDP off time: 0s-60s, on time: 60s-119s.

o One RMCAT flow competing against one long-live TCP flow over
   uplink: N=1 (uplink) and M = 1(uplink), TCP start time at 0s and
   end time at 119s.

4.1.4. Expected behavior

o Single uplink RMCAT flow: the candidate algorithm is expected to
   detect the path capacity constraint, to converge to bottleneck
   link capacity and to adapt the flow to avoid unwanted oscillation
   when the sending bit rate is approaching the bottleneck link
   capacity. No excessive rate oscillations should be present.

o Bi-directional RMCAT flows: It is expected that the candidate
   algorithm is able to converge to the bottleneck capacity of the
   wired path on both directions despite presence of measurment noise
   over the Wi-Fi connection. In the presence of background TCP or
   CBR over UDP traffic, the rate of RMCAT flows should adapt in a
   timely manner to changes in the available bottleneck bandwidth.

o One RMCAT flow competing with long-live TCP flow over uplink: the
   candidate algorithm should be able to avoid congestion collapse,
   and to stablize at a fair share of the bottleneck link capacity.

4.2. **Bottleneck in Wi-Fi Network**

   These test cases assume that the wired portion along the media path
   is well-provisioned whereas the bottleneck exists over the Wi-Fi
   access network. This is to mimic the application scenarios typically
   encountered by users in an enterprise environment or at a coffee
   house.

4.2.1. **Network topology**

   Same as defined in Section 4.1.1

4.2.2. **Test setup**

   o Test duration: 120s

   o Wi-Fi network characteristics:

      * Radio propagation model: Log-distance path loss propagation
         model [NS3WiFi]

      * PHY- and MAC-layer configuration: IEEE 802.11n

      * MCS Index at 11: 16-QAM 1/2, Raw Data Rate at 52Mbps

   o Wired path characteristics:

      * Path capacity: 100Mbps

      * One-Way propagation delay: 50ms.

      * Maximum end-to-end jitter: 30ms

      * Bottleneck queue type: Drop tail.

      * Bottleneck queue size: 300ms.

      * Path loss ratio: 0%.

   o Application characteristics:

      * Media Traffic:

         + Media type: Video

         + Media direction: See Section 4.2.3

         + Number of media sources (N): See Section 4.2.3

+ Media timeline:

- Start time: 0s.

- End time: 119s.

* Competing traffic:

+ Type of sources: long-lived TCP or CBR over UDP

+ Number of sources (M): See Section 4.2.3

+ Traffic direction: See Section 4.2.3

+ Congestion control: Default TCP congestion control [TBD] or
  CBR over UDP

+ Traffic timeline: See Section 4.2.3

4.2.3. Typical test scenarios

This section describes a few test scenarios that are deemed as
important for understanding the behavior of a RMCAT candidate
solution over a Wi-Fi network.

o Multiple RMCAT Flows Sharing the Wireless Downlink: N=16 (all
   downlink); M = 0. This test case is for studying the impact of
   contention on competing RMCAT flows. For an 802.11n network,
   given the MCS Index of 11 and the corresponding raw data rate of
   52Mbps, the total application-layer throughput (assuming
   reasonable distance, low interference and infrequent contentions
   caused by competing streams) is around 20Mbps. Consequently, a
   total of N=16 RMCAT flows are needed to saturate the wireless
   interface in this experiment. Evaluation of a given candidate
   solution should focus on whether downlink RMCAT flows can stablize
   at a fair share of total application-layer throughput.

o Multiple RMCAT Flows Sharing the Wireless Uplink: N = 16 (all
   downlink); M = 0. When multiple clients attempt to transmit video
   packets uplink over the wireless interface, they introduce more
   frequent contentions and potential collisions. Per-flow
   throughput is expected to be lower than that in the previous
   downlink-only scenario. Evaluation of a given candidate solution
   should focus on whether uplink flows can stablize at a fair share
   of application-layer throughput.

o Multiple Bi-directional RMCAT Flows: N = 16 (8 uplink and 8
   downlink); M = 0. The goal of this test is to evaluate

      performance of the candidate solution in terms of bandwidth
      fairness between uplink and downlink flow.

   o Multiple Bi-directional RMCAT Flows with on-off CBR traffic: N =
      16 (8 uplink and 8 downlink); M = 5(uplink). The goal of this
      test is to evaluate adaptation behavior of the candidate solution
      when its available bandwidth changes due to departure of
      background traffic. The background traffic consists of several
      (e.g., M=5) CBR flows transported over UDP, which are ON at times
      t=0-60s and are OFF at times t=61-120s.

   o Multiple Bi-directional RMCAT Flows with off-on CBR traffic: N =
      16 (8 uplink and 8 downlink); M = 5(uplink). The goal of this
      test is to evaluate adaptation behavior of the candidate solution
      when its available bandwidth changes due to arrival of background
      traffic. The background traffic consists of several (e.g., M=5)
      parallel CBR flows transported over UDP, which are OFF at times
      t=0-60s and are ON at times t=61-120s.

   o Multiple RMCAT flows in the presence of background TCP traffic.
      The goal of this test is to evaluate how RMCAT flows compete
      against TCP over a congested Wi-Fi network for a given candidate
      solution. TCP start time: 0s, end time: 119s. [Editor's Note:
      need to add the number of recommended RMCAT and TCP flows]

   o Varying number of RMCAT flows. The goal of this test is to
      evaluate how a candidate RMCAT solution responds to varying
      traffic load/demand over a congested Wi-Fi network. [Editor's
      Note: need to specify recommended arrival/departure pattern of
      RMCAT flows]

4.2.4. Expected behavior

   o Multiple downlink RMCAT flows: each RMCAT flow should get its fair
      share of the total bottleneck link bandwidth. Overall bandwidth
      usage should not be significantly lower than that experienced by
      the same number of concurrent downlink TCP flows. In other words,
      the performance of multiple concurrent TCP flows will be used as a
      performance benchmark for this test scenario. The end-to-end
      delay and packet loss ratio experienced by each flow should be
      within acceptable range for real-time multimedia applications.

   o Multiple uplink RMCAT flows: overall bandwidth usage shared by all
      RMCAT flows should not be significantly lower than that
      experienced by the same number of concurrent uplink TCP flows. In
      other words, the performance of multiple concurrent TCP flows will
      be used as a performance benchmark for this test scenario.

o Multiple bi-directional RMCAT flows with dynamic background
   traffic carry CBR flows over UDP: RMCAT flows should adapt in a
   timely fashion to the resulting changes in available bandwidth.

o Multiple bi-directional RMCAT flows with TCP traffic: overall
   bandwidth usage shared by all RMCAT flows should not be
   significantly lower than those achieved by the same number of bi-
   directional TCP flows. In other words, the performance of
   multiple concurrent TCP flows will be used as a performance
   benchmark for this test scenario. All downlink RMCAT flows are
   expected to obtain similar bandwidth with respect to each other.

4.3. Other Potential Test Cases

4.3.1. EDCA/WMM usage

EDCA/WMM is prioritized QoS with four traffic classes (or Access
Categories) with differing priorities. RMCAT flows should achieve
better performance (i.e., lower delay, fewer packet losses) with
EDCA/WMM enabled when competing against non-interactive background
traffic (e.g., file transfers). When most of the traffic over Wi-Fi
is dominated by media, however, turning on WMM may actually degrade
performance since all media flows now attempt to access the wireless
transmission medium more aggressively, thereby causing more frequent
collisions and collision-induced losses. This is a topic worthy of
further investigation.

4.3.2. Effects of Legacy 802.11b Devices

When there is 802.11b devices connected to modern 802.11 network, it
may affect the performance of the whole network. Additional test
cases can be added to evaluate the affects of legacy devices on the
performance of RMCAT congestion control algorithm.

5. Conclusion

This document defines a collection of test cases that are considered
important for cellular and Wi-Fi networks. Moreover, this document
also provides a framework for defining additional test cases over
wireless cellular/Wi-Fi networks.

6. Acknowledgements

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7. IANA Considerations

   This memo includes no request to IANA.

8. Security Considerations

   Security issues have not been discussed in this memo.

9. References

9.1. Normative References

   [Deployment]
             TS 25.814, 3GPP., "Physical layer aspects for evolved
             Universal Terrestrial Radio Access (UTRA)", October 2006,
             <http://www.3gpp.org/ftp/specs/
             archive/25_series/25.814/25814-710.zip>.

   [HO-def-3GPP]
             TR 21.905, 3GPP., "Vocabulary for 3GPP Specifications",
             December 2009, <http://www.3gpp.org/ftp/specs/
             archive/21_series/21.905/21905-940.zip>.

   [HO-LTE-3GPP]
             TS 36.331, 3GPP., "E-UTRA- Radio Resource Control (RRC);
             Protocol specification", December 2011,
             <http://www.3gpp.org/ftp/specs/
             archive/36_series/36.331/36331-990.zip>.

   [HO-UMTS-3GPP]
             TS 25.331, 3GPP., "Radio Resource Control (RRC); Protocol
             specification", December 2011,
             <http://www.3gpp.org/ftp/specs/
             archive/25_series/25.331/25331-990.zip>.

   [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-06 (work in progress), September 2016.

   [NS3WiFi] "Wi-Fi Channel Model in NS3 Simulator",
             <https://www.nsnam.org/doxygen/
             classns3_1_1_yans_wifi_channel.html>.

   [QoS-3GPP]
             TS 23.203, 3GPP., "Policy and charging control
             architecture", June 2011, <http://www.3gpp.org/ftp/specs/
             archive/23_series/23.203/23203-990.zip>.

   [RFC2119] Bradner, S., "Key words for use in RFCs to Indicate
              Requirement Levels", BCP 14, RFC 2119,
              DOI 10.17487/RFC2119, March 1997,
              <http://www.rfc-editor.org/info/rfc2119>.

9.2. Informative 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-test]
              Sarker, Z., Singh, V., Zhu, X., and M. Ramalho, "Test
              Cases for Evaluating RMCAT Proposals", draft-ietf-rmcat-
              eval-test-05 (work in progress), April 2017.

   [IEEE802.11]
              "Standard for Information technology--Telecommunications
              and information exchange between systems Local and
              metropolitan area networks--Specific requirements Part 11:
              Wireless LAN Medium Access Control (MAC) and Physical
              Layer (PHY) Specifications", 2012.

   [LTE-simulator]
              "NS-3, A discrete-Event Network Simulator",
              <https://www.nsnam.org/docs/release/3.23/manual/html/
              index.html>.

   [ns-2]   "The Network Simulator - ns-2",
              <http://www.isi.edu/nsnam/ns/>.

   [ns-3]   "The Network Simulator - ns-3", <https://www.nsnam.org/>.

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