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Evaluation Test Cases for Interactive Real-Time Media over Wi-Fi Networks
draft-fu-rmcat-wifi-test-case-01

Abstract

An increasing proportion of multimedia communication applications, including real-time interactive voice and video, are transported over Wi-Fi networks (i.e., wireless local area networks following IEEE 802.11 standards) today. It is therefore important to evaluate candidate congestion control schemes designed in the RMCAT Working Group over test cases that include Wi-Fi access links. This draft serves such a purpose, and is complementary to [I-D.ietf-rmcat-eval-test] and [I-D.draft-sarker-rmcat-cellular-eval-test-cases]

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1. Introduction

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

- 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 transmessions 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, retransmission, loss 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 will lead to different application-layer throughput.

- o Presence of legancy 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 cause packet delay and loss.

- 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).

As we can see here, presence of Wi-Fi network in different different network topologies and traffic arrival can exert different impact on the network performance in terms of video transport rate, packet loss and delay that, in turn, effect end-to-end real-time multimedia congestion control.

Currently, the most widely used IEEE 802.11 standards are 802.11g and 802.11n. The industry is moving towards 802.11ac and, potentially, 802.11ad. IEEE 802.11b is legency standard, and 802.11a has not been widely adopted. Throughout this draft, unless otherwise mentioned, test cases are described using 802.11g mostly due to its wide availability both in test equipments and network simulation platform. Whenever possible, it is recommended to extend some of the experiments to 802.11ac so as to reflect a more mordent Wi-Fi network setting.

Since Wi-Fi network normally connects to a wired infrastructure, either the wired network or the Wi-Fi network could be the bottleneck. In the following section, we describe basic test cases for both scenarios separately.

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 RFC2119 [RFC2119].

3. Test Scenarios with Wired Bottlenecks

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 the all-wired test cases (draft-sarker-rmcat-eval-test), it is worthwhile to run through these tests as sanity checks.

3.1. Single RMCAT Flow over Wired Bottleneck

This test case is designed to measure the responsiveness of the candidate algorithm when the Wi-Fi hop of the connection is uncongested.

Figure 1 illustrates topology of this test.

```
                              uplink
                         +--------------->+
       +-----+          +-----+          +-----+         +-----+
       | S   |))))))))))| AP  |==========|  B  |=========|  R  |
       +-----+          +-----+          +-----+         +-----+
```

Figure 1: Single Flow over Wired Bottleneck

Testbed attributes:

o Test duration: 100s

o Path characteristics:

   * Uplink 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%.

- Application-related:

    * Media Traffic:

        + Media type: Video

        + Media direction: forward.

        + Number of media sources: One (1)

        + Media timeline:

            - Start time: 0s.

            - End time: 99s.

    * Competing traffic:

        + Number of sources : Zero (0)

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

3.2. Bidirectional RMCAT Flow over Wired Bottleneck

This test case is designed to evaluate performance of the candidate algorithm when lack of enough feedback.

```
   +----+                                         +----+
   | R1 |))))))                             /=====| S1 |
   +----+      ))         uplink          //      +----+
                ))    +--------------->+   //
    +----+          +----+          +----+        +----+
    | S2 |)))))))))))| AP |==========|  B |========| R2 |
    +----+          +----+          +----+        +----+
                      +<---------------+
                          downlink
```

Figure 2: One Bi-directional Flow over Wired Bottleneck

Testbed attributes:

o Test duration: 100s

o Path characteristics:

   * uplink 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: forward and backward.

      + Number of media sources: Two (2)

      + Media timeline:

         - Start time: 0s.

         - End time: 99s.

* Competing traffic:

  + Number and Types of sources : zero (0)

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

3.3. RMCAT Flow Competing with Long TCP over Wired Bottleneck

This test case is designed to measure the performance of the candidate algorithm when lack of enough feedback.

```
      +-----+                                        +-----+
      | S1 |))))))                             /=====| R1 |
      +-----+     ))         uplink           //     +-----+
                   ))    +--------------->+  //
    +-------+          +-----+         +-----+       +-------+
    | S_tcp |))))))))))| AP |==========|  B |========| R_tcp |
    +-------+          +-----+         +-----+       +-------+
                         +<---------------+
                             downlink
```

Figure 3: RMCAT vs. TCP over Wired Bottleneck

Testbed attributes:

Test duratiion: 100s

Path characteristics:

* uplink 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%.

Application-related:

* Media Traffic:

  + Media type: Video

  + Media direction: forward.

  + Number of media sources: One (1)

  + Media timeline:

    - Start time: 0s.

    - End time: 99s.

* Competing traffic:

  + Types of sources : long-lived TCP

  + Number of sources: One (1)

  + Traffic direction : forward

  + Congestion control: Default TCP congestion control [TBD].

  + Traffic timeline:

    - Start time: 0s.

    - End time: 119s.

Expected behavior: the candidate algorithm should be able to avoid congestion collapse, and get fair share of the bandwidth. In the worst case, the media stream will fall to the minimum media bit rate.

4. Bottleneck over Wireless Network

These test cases assume that the wired portion along the media path are well-provisioned. The bottleneck is in the Wi-Fi network over wireless. This is to mimic the enterprise/coffee-house scenarios.

4.1. Adaptive rate selection with single RMCAT flow

Since morden IEEE 802.11 standards supports far higher data rates than the maximum requirements of individual RMCAT flows, in this test the legacy standard 802.11b is chosen to test the single RMCAT flow case. 802.11b Adaptive rate selection can operate at 11 Mbps in terms of PHY-layer transmission rate, and falls back to 5.5 Mbps, 2 Mbps, and 1 Mbps when the wireless client moves away from the access point.

[Editor's Note: we may want to move this section to Section 5.4 instead.]

```
              uplink
         +--------------->+
       +-----+          +-----+          +-----+         +-----+
       | S  |))))))))))| AP |==========|  B |=========|  R |
       +-----+          +-----+          +-----+         +-----+
```

Figure 4: One RMCAT Flow over Wireless Bottleneck

Testbed attributes:

Test duratiion: 100s

Path characteristics:

* Wired path capacity: 100Mbps

* Wi-Fi PHY Rate: 1Mbps (PHY rate)

* One-Way propagation delay: 50ms.

* Maximum end-to-end jitter: 30ms

* Bottleneck queue type: Drop tail.

* Bottleneck queue size: 300ms.

* Path loss ratio: 0%.

Application characteristics:

* Media Traffic:

    + Media type: Video

    + Media direction: forward and backward.

    + Number of media sources: One (1)

    + Media timeline:

- Start time: 0s.

- End time: 99s.

* Competing traffic:

  + Number and Types of sources : zero (0)

Test Specific Information:

* This test will change the distance between station and AP (need some experiment), and incur the adaptive rate selection variation as listed in Figure 5.

Variation pattern index	Path direction	Start time	PHY-layer rate
One	Forward	0s	5.5 Mbps
Two	Forward	40s	2 Mbps
Three	Forward	60s	1 Mbps
Four	Forward	80s	2 Mbps

Figure 5: Adaptive rate variation pattern for uplink direction

Expected behavior: The rate adaptation algorithm run at application level should follow the adaptation in 802.11 mac layer.

4.2. Multiple RMCAT Flows Sharing the Wireless Downlink

This test case is for studying the impact of contention on competing RMCAT flows. Specifications for IEEE 802.11g with a physical-layer transmission rate of 54 Mbps is chosen. Not that retransmission and MAC-layer headers and control packets may be sent at a lower link speed. The total application-layer throughput (reasonable distance, low interference and small number of contention stations) for 802.11g is around 20 Mbps. Consequently, a total of 16 RMCAT flows are needed for saturating the wireless interface in this experiment.

```
        uplink
   +------------------->+
   +----+                                          +----+
   | R1 |))))))                             /=====| S1 |
   +----+      ))                          //     +----+
                ))                        //
    +----+          +----+          +----+        +----+
    | R2 |)))))))))))| AP |==========|  B |========| S2 |
    +----+          +----+          +----+        +----+
            ......                       ......
               ))                       \\
   +----+      ))                         \\      +----+
   |R16 |))))))                             \=====|S16 |
   +----+                                          +----+
   +<-------------------+
        downlink
```

Figure 6: Multiple RMCAT Flows Sharing the Wireless Downlink

Testbed attributes:

- o Test duratiion: 100s

- o Path characteristics:

   * Wired path capacity: 100Mbps

   * Wi-Fi PHY Rate: 54Mbps (PHY rate)

   * 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: backward.

+ Number of media sources: Sixteen (16)

+ Media timeline:

  - Start time: 0s.

  - End time: 99s.

* Competing traffic:

  + Number and Types of sources : Zero (0)

Expected behavior: All RMCAT flow should get fair share of the bandwidth. Overall bandwidth usage should be no less than same case with TCP flows (using TCP as performance benchmark). The delay and loss should be within acceptable range for real-time multimedia flow.

4.3. Multiple RMCAT Flows Sharing the Wireless Uplink

This test case is different with the previous section with mostly downlink transmissions. When multiple clients attempt to transmit video packets uplink over the wireless interface, they introduce more frequent contentions and potentially collisions. As a results, the per-client throught is expected to be lower than the downlink-only scenario.

```
     uplink
+----------------->+
+----+                                          +----+
| S1 |))))))                              /=====| R1 |
+----+      ))                            //     +----+
             ))                          //
 +----+          +----+          +----+        +----+
 | S2 |))))))))))| AP |==========|  B |========| R2 |
 +----+          +----+          +----+        +----+
        ......                        ......
            ))                      \\
+----+      ))                        \\      +----+
|S16 |))))))                            \=====|R16 |
+----+                                          +----+
+<-----------------+
     downlink
```

Figure 7: Multiple RMCAT Flows Sharing the Wireless Uplink

Testbed attributes:

- o Test duratiion: 100s
- o Path characteristics:
  - * Wired path capacity: 100Mbps
  - * Wi-Fi PHY Rate: 54Mbps (PHY rate)
  - * Maximum end-to-end jitter: 30ms
  - * One-Way propagation delay: 50ms.
  - * Bottleneck queue type: Drop tail.
  - * Bottleneck queue size: 300ms.
  - * Path loss ratio: 0%.
- o Application characteristics:
  - * Media Traffic:
    - + Media type: Video
    - + Media direction: forward and backward.
    - + Number of media sources: Sixteen (16)
    - + Media timeline:
      - - Start time: 0s.
      - - End time: 99s.
  - * Competing traffic:
    - + Number and Types of sources : Zero (0)

Expected behavior: All RMCAT flow should get fair share of the bandwidth, and the overall bandwidth usage should no less than same case with TCP flows (use TCP as performance benchmark). The delay and loss should be in acceptable range for real-time multimedia flow (might need rtp circuit breaker to guarantee that?).

4.4. Multiple Bi-Directional RMCAT Flows Sharing the Wireless Bottleneck

This one differs with previous contention cases because Wi-Fi share bandwdith between uplink and downlink.

```
           uplink
      +------------------>+
      +----+                                       +----+
      | R1 |))))))                             /=====| S1 |
      +----+      ))                          //     +----+
                   ))                        //
              ......                       ......
       +----+          +----+          +----+        +----+
       | R8 |))))))))))| AP |==========|  B |========| S8 |
       +----+          +----+          +----+        +----+
               ......                       ......
                  ))                       \\
      +----+      ))                         \\      +----+
      |S16 |))))))                             \=====|R16 |
      +----+                                       +----+
      +<------------------+
           downlink
```

Figure 8: Multiple Bi-Directional RMCAT Flows Sharing the Wireless Bottleneck

Testbed attributes:

o Test durattiion: 100s

o Path characteristics:

   * Wired path capacity: 100Mbps

   * Wi-Fi PHY Rate: 54Mbps (PHY rate)

   * One-Way propagation delay: 50ms.

   * Maximum end-to-end jitter: 30ms

   * Bottleneck queue type: Drop tail.

   * Bottleneck queue size: 300ms.

      * Path loss ratio: 0%.

- Application characteristics:

  * Media Traffic:

    + Media type: Video

    + Media direction: forward and backward.

    + Number of media sources: Sixteen (16), 8 for uplink, 8 for downlink.

    + Media timeline:

      - Start time: 0s.

      - End time: 99s.

  * Competing traffic:

    + Number and Types of sources : zero (0)

Expected behavior: All (uplink/downlink) RMCAT flow should get fair share of the bandwidth, and the overall bandwidth usage should no less than same case with TCP flows (use TCP as performance benchmark). The delay and loss should be in acceptable range for real-time multimedia flow (might need rtp circuit breaker to guarantee that?).

4.5. Multiple RMCAT and TCP Flows Sharing the Wireless Uplink

This case having both long lived TCP and RMCAT sharing the uplink at the same time. This is for testing how RMCAT competing with long lived TCP flow in a congested Wi-Fi network.

```
          uplink
     +------------------>+
     +-----+                                              +-----+
     | S1 |))))))                                  /=====| R1 |
     +-----+      ))                               //     +-----+
                   ))                             //
             ......                             ......
      +-----+          +-----+          +-----+        +-----+
      | S8 |)))))))))))|     |==========|     |========| R8 |
      +-----+          |     |          |     |        +-----+
                       | AP |           |  B |
      +---------+      |     |          |     |        +---------+
      | S1_tcp |)))))))|     |          |     |========| R1_tcp |
      +---------+      +-----+          +-----+        +---------+
               ......                             ......
                   ))                           \\
     +---------+   ))                             \\     +---------+
     | S8_tcp |))))                                \=====| R8_tcp |
     +---------+                                        +---------+
     +<------------------+
          downlink
```

Figure 9: Multiple RMCAT and TCP Flows Sharing the Wireless Uplink

Testbed attributes:

o Test duratiion: 100s

o Path characteristics:

   * Wired path capacity: 100Mbps

   * Wi-Fi PHY Rate: 54Mbps (PHY rate)

   * 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: forward.

  + Number of media sources: Eigth (8).

  + Media timeline:

    - Start time: 0s.

    - End time: 99s.

* Competing traffic:

  + Type of sources: long-live TCP.

  + Number of sources : Eight (8)

  + Traffic direction : forward

  + Congestion control: Default TCP congestion control [TBD].

  + Traffic timeline:

    - Start time: 0s.

    - End time: 99s.

Expected behavior: All RMCAT flows should get comparable share of the network bandwidth with respect to competing TCP flows. The overall bandwidth usage should no less than same case with TCP flows (use TCP as performance benchmark). The delay and loss should be in acceptable range for real-time multimedia flow (might need rtp circuit breaker to guarantee that?).

4.6. Multiple RMCAT and TCP Flows Sharing the Wireless Downlink

This case having both long lived TCP and RMCAT on the downlink at the same time. This is for testing how RMCAT competing with long lived TCP flow in crowed Wi-Fi network. This differs from test scenario in the previous section becauase less contention on the Wi-Fi network because most media data is sent from AP to stations.

```
           uplink
      +------------------>+
      +----+                                          +----+
      | R1 |))))))                              /=====| S1 |
      +----+      ))                           //     +----+
                   ))                         //
               ......                        ......
       +----+          +----+          +----+        +----+
       | R8 |))))))))))|    |==========|    |========| S8 |
       +----+          |    |          |    |        +----+
                       | AP |          |  B |
       +--------+      |    |          |    |        +--------+
       | R1_tcp |))))))|    |          |    |========| S1_tcp |
       +--------+      +----+          +----+        +--------+
                ......                      ......
                   ))                      \\
      +--------+   ))                        \\     +--------+
      | R8_tcp |))))                          \=====| S8_tcp |
      +--------+                                    +--------+
      +<------------------+
           downlink
```

Figure 10: Multiple RMCAT and TCP Flows Sharing the Wireless Downlink

Testbed attributes:

- Test duratiion: 100s

- Path characteristics:

  * Wired path capacity: 100Mbps

  * Wi-Fi PHY Rate: 54Mbps (PHY rate)

  * One-Way propagation delay: 50ms.

  * Maximum end-to-end jitter: 30ms

  * Bottleneck queue type: Drop tail.

  * Bottleneck queue depth: 300ms.

  * Path loss ratio: 0%.

- Application characteristics:

* Media Traffic:

  + Media type: Video

  + Media direction: backward.

  + Number of media sources: Eight (8).

  + Media timeline:

    - Start time: 0s.

    - End time: 99s.

* Competing traffic:

  + Number of sources: Eight (8).

  + Types of sources : long-lived TCP.

  + Traffic direction : forward

  + Congestion control: Default TCP congestion control.

  + Traffic timeline:

    - Start time: 0s.

    - End time: 99s.

Expected behavior: All RMCAT flows should get comparable share of the network bandwidth with respect to competing TCP flows. The overall bandwidth usage should no less than same case with TCP flows (use TCP as performance benchmark). The delay and loss should be in acceptable range for real-time multimedia flow (might need rtp circuit breaker to guarantee that?).

4.7. Multiple Bi-Directional RMCAT and TCP Flows Sharing the Wireless Bottleneck

This case having both long lived TCP and RMCAT on the both direction at the same time. This is for testing how RMCAT competing with long lived TCP flow in a congested Wi-Fi network. This differs from previouss cases as both uplink and downlink flows share the same wireless bottleneck.

```
           uplink
      +------------------>+
      +----+                                       +----+
      | S1 |))))))                           /=====| R1 |
      +----+      ))                        //     +----+
                   ))                      //
               ......                     ......
       +----+          +----+          +----+        +----+
       | R8 |))))))))))|    |==========|    |========| S8 |
       +----+          |    |          |    |        +----+
                       | AP |          |  B |
       +--------+      |    |          |    |        +--------+
       | S1_tcp |))))))|    |          |    |========| R1_tcp |
       +--------+      +----+          +----+        +--------+
                ......                    ......
                   ))                    \\
      +--------+   ))                      \\     +--------+
      | R8_tcp |))))                        \=====| S8_tcp |
      +--------+                                  +--------+
      +<------------------+
           downlink
```

Figure 11: Multiple Bi-Directional RMCAT and TCP Flows Sharing the Wireless Bottleneck

Testbed attributes:

o Test duratiion: 100s

o Path characteristics:

   * Wired path capacity: 100Mbps

   * Wi-Fi PHY Rate: 54Mbps (PHY rate)

   * 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: forward and backward.

  + Number of media sources: Eight (8). Four (4) forward, Four (4) backward

  + Media timeline:

    - Start time: 0s.

    - End time: 99s.

* Competing traffic:

  + Number of sources : Eight (8). Four (4) forward, Four (4) backward.

  + Type of sources: long-live TCP.

  + Traffic direction : forward and backward.

  + Congestion control: Default TCP congestion control.

  + Traffic timeline:

    - Start time: 0s.

    - End time: 99s.

Expected behavior: All RMCAT flows should get comparable share of the network bandwidth with respect to competing TCP flows. The overall bandwidth usage should no less than same case with TCP flows (use TCP as performance benchmark). The delay and loss should be in acceptable range for real-time multimedia flow (might need rtp circuit breaker to guarantee that?).

5. Other potential test cases

5.1. Wi-Fi Roaming

Wi-Fi roaming need scanning, authentication and re-association which will cause packet drops and delay, and interrupt the network connection. RMCAT congestion control algorithms should at least recover (if affected by the transition process) after roaming.

5.2. Wi-Fi/Cellular Switch

The phone can switch automatically between Wi-Fi and Cellular network when the other is not available, and some phones like "Samsung Galaxy" have smart network switch to switching to network has better connectivity automatically. Unlike Wi-Fi Roaming, such kind of switch might or might not interrupt the network connection, and might change the route. RMCAT congestion control should be able to cope with the changes.

5.3. EDCA/WMM usage

EDCA/WMM is prioritized QoS with four traffic classes (or Access Categories) with differing priorities. RMCAT flow should have better performance (lower delay, less loss) 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. This is a topic worthy of further investigation.

5.4. Legacy 802.11b Effects

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 legancy devices on the performance of RMCAT congestion control algorithm.

6. IANA Considerations

There are no IANA impacts in this memo.

7. References

7.1. Normative References

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