COVERING NOTE

GENERAL SECRETARIAT OF THE INTERNATIONAL TELECOMMUNICATION UNION

Geneva, 22 March 2021

ITU – TELECOMMUNICATION STANDARDIZATION SECTOR

Subject: Erratum 1 (03/2021) to Supplement 60 (2020) to the ITU-T Y-series Recommendations

This Erratum adds clauses 9 to 10.2 approved by SG12 at its meeting in September 2020.

9 Test results of note, following the publication of [ITU-T Y.1540]

Appendix X of [ITU-T Y.1540] gives a summary of IP-layer capacity test results up to May 2019. Testing has continued with the udpst utility as a basis (see clause 10).

9.1 New results on 5/100 DOCSIS Access

A new set of results are given in Figure 9-1.

```
$ udpst -d udp-speedtest.com
UDP Speed Test
Software Ver: 6.4, Protocol Ver: 6, Built: Aug 21 2020 17:44:21
Mode: Client, Jumbo Datagrams: Enabled, Authentication: Available
Downstream Test Interval(sec): 10, DelayVar Thresholds(ms): 30-90 [RTT], Trial Interval(ms): 50,
    SendingRate Index: <Auto>, Congestion Threshold: 2, High-Speed Delta: 10, SeqError Threshold: 0
Sub-Interval(sec):  1, Delivered(%): 100.00, Loss/OoO: 0/0, OWDVar(ms): 0/12/61, RTTVar(ms): 0-52, Mbps(L3/IP): 80.47
Sub-Interval(sec):  2, Delivered(%):  89.36, Loss/OoO: 1493/0, OWDVar(ms): 61/122/150, RTTVar(ms): 77-147, Mbps(L3/IP): 122.93
Sub-Interval(sec):  3, Delivered(%):  98.54, Loss/OoO: 192/0, OWDVar(ms): 54/93/125, RTTVar(ms): 62-118, Mbps(L3/IP): 123.10
Sub-Interval(sec):  4, Delivered(%): 100.00, Loss/OoO: 0/0, OWDVar(ms): 4/18/56, RTTVar(ms): 2-60, Mbps(L3/IP): 121.32
Sub-Interval(sec):  5, Delivered(%): 100.00, Loss/OoO: 0/0, OWDVar(ms): 4/28/71, RTTVar(ms): 1-64, Mbps(L3/IP): 123.96
Sub-Interval(sec):  6, Delivered(%):  97.25, Loss/OoO: 361/0, OWDVar(ms): 70/105/125, RTTVar(ms): 69-118, Mbps(L3/IP): 123.12
Sub-Interval(sec):  7, Delivered(%):  99.57, Loss/OoO: 56/0, OWDVar(ms): 37/84/117, RTTVar(ms): 33-110, Mbps(L3/IP): 122.99
Sub-Interval(sec):  8, Delivered(%): 100.00, Loss/OoO: 0/0, OWDVar(ms): 6/12/40, RTTVar(ms): 0-28, Mbps(L3/IP): 122.50
Sub-Interval(sec):  9, Delivered(%): 100.00, Loss/OoO: 0/0, OWDVar(ms): 12/53/101, RTTVar(ms): 10-98, Mbps(L3/IP): 123.47
Sub-Interval(sec): 10, Delivered(%):  96.78, Loss/OoO: 425/0, OWDVar(ms): 100/114/122, RTTVar(ms): 98-138, Mbps(L3/IP): 123.12
Downstream Summary Delivered(%):  98.15, Loss/OoO: 2527/0, OWDVar(ms): 0/64/150, RTTVar(ms): 0-147, Mbps(L3/IP): 118.70
Downstream Minimum One-Way Delay(ms): -562 [w/clock difference], Round-Trip Time(ms): 16
Downstream Maximum Mbps(L3/IP): 123.96, Mbps(L2/Eth): 125.80, Mbps(L1/Eth): 127.85, Mbps(L1/Eth+VLAN): 128.26
```

Figure 9-1 – 5/100 DOCSIS Access with Wi-Fi connected client

This is a Downstream test, with udpst 6.4 (currently targeted for open source release). The tests were conducted on 5/100 Mbps DOCSIS Access, using Wi-Fi connectivity in the home (reported to offer 144 Mbps link speed both receive and transmit, apparently sufficient for testing the subscribed IP-layer capacity). Note that calculated values align with relevant provisioned or theoretical maximums.

In the measurement above, the Wi-Fi network was not a handicap to measurement accuracy, as the result with a wired ETH network shows below:

```
Downstream Maximum Mbps(L3/IP): 123.16, Mbps(L2/Eth): 124.99, Mbps(L1/Eth): 127.03,
Mbps(L1/Eth+VLAN): 127.43
```

9.2 Comparison of measurement results with new tools

During July 2020, the BEREC code repository https://github.com/net-neutrality-tools/nntool and associated webpage https://net-neutrality.tools/ was announced.

At the SG12 meeting in September 2020, it was deemed useful to share a few preliminary test results comparing udpst (see clause 10) and the Linux-nntool's abilities to measure a 1 Gbps access link under the circumstances where the comparative measurement was possible at present. As with the procedures described in Appendix X of [ITU-T Y.1540], the goal is to reliably measure the "ground truth" of maximum IP-layer capacity offered by the service. In this case, both nntool and udpst user's clients are located on a single host in the US, but two measurement servers are located in the same city in Germany. This allowed each tool to communicate with a server that was optimized by the tool designers, but it introduces some path differences at one end within the destination city. The udpst path involved 22 hops from user client to the server running on Amazon Web Services, while the nntool path involved only 11 hops to the peer-ias-de-01.net-neutrality.tools server. The round-trip time (RTT) on each path was ~87.5 msec.

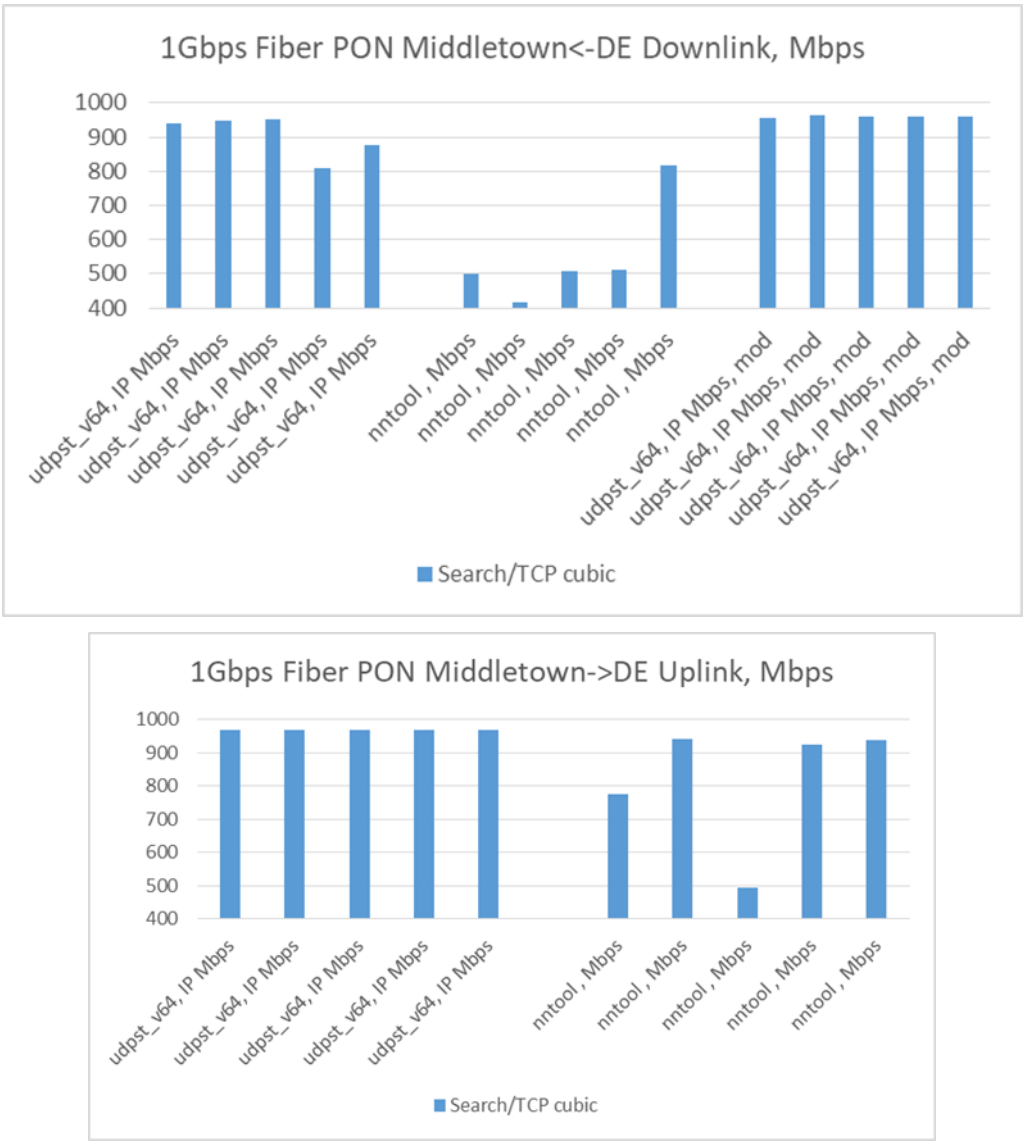

Figure 9-2 – Preliminary comparison of udpst and nntool with 1Gbps access and long RTT

Figure 9-2 provides the preliminary results, using the maximum of values reported by nntool in a 10 second test (similar to udpst). The top graph for downlink results shows that only five repeated tests were needed to illustrate TCP's variability as a basis for the measurement used in nntool. Default udpst approached the optimum maximum IP-layer 968 Mbps in most tests, especially when the rate adjustment algorithm was modified slightly to search more quickly (suffix "mod" in results on the right). In the bottom graph, uplink measurements were very accurate and reliable for 5 unmodified udpst tests, but nntool results underestimate the capacity and indicate considerable variation when repeated, even when using as many as 9 TCP threads.

Additional test results will be included here, in the future.

10 Brief description of the udpst utility: an implementation of [BBF TR-471] and [ITU-T Y.1540]

Throughout the development and approval of the maximum IP-layer capacity method of measurement, there were many tests conducted to compare the performance of UDP and TCP-based methods of measurement, and various implementations of each transport-layer method. The reference implementation of the method chosen for standardization in [ITU-T Y.1540] and the subsequent development of [BBF TR-471] has now been released in open source form.

The udpst measurement tool runs on the Linux operating system and serves as a working reference for further development. The current project:

- is a utility that can function as a client or server daemon
- is written in C, and built with gcc (release 9.3) and its standard run-time libraries
- works with both IPv4 and IPv6 address families
- includes authentication functionality that accepts a command-line key which is used in the setup request to the server
- allows configuration of most of the measurement parameters described in Annexes A and B of ITU-T Y.1540.

10.1 udpst results display

An example of udpst client terminal output is illustrated in -Figure 10-1.

```
$ udpst -d -a foobar fe80::8639:beff:fe6c:1f90
UDP Speed Test
Software Ver: 6.5, Protocol Ver: 6, Built: Aug 20 2020 12:08:37
Mode: Client, Jumbo Datagrams: Enabled, Authentication: Available
Downstream Test Interval(sec): 10, DelayVar Thresholds(ms): 30-90 [RTT], Trial Interval(ms): 50,
    SendingRate Index: <Auto>, Congestion Threshold: 2, High-Speed Delta: 10, SeqError Threshold: 0, IPv6 TClass: 0
Sub-Interval(sec):  1, Delivered(%): 100.00, Loss/OoO: 0/0, OWDVar(ms): 0/0/1, RTTVar(ms): 0-1, Mbps(L3/IP): 96.47
Sub-Interval(sec):  2, Delivered(%): 100.00, Loss/OoO: 0/0, OWDVar(ms): 0/0/0, RTTVar(ms): 0-0, Mbps(L3/IP): 299.69
Sub-Interval(sec):  3, Delivered(%): 100.00, Loss/OoO: 0/0, OWDVar(ms): 0/0/0, RTTVar(ms): 0-0, Mbps(L3/IP): 502.87
Sub-Interval(sec):  4, Delivered(%): 100.00, Loss/OoO: 0/0, OWDVar(ms): 0/0/0, RTTVar(ms): 0-0, Mbps(L3/IP): 706.02
Sub-Interval(sec):  5, Delivered(%):  99.81, Loss/OoO: 170/0, OWDVar(ms): 0/0/2, RTTVar(ms): 0-2, Mbps(L3/IP): 905.51
Sub-Interval(sec):  6, Delivered(%):  99.88, Loss/OoO: 111/0, OWDVar(ms): 0/0/2, RTTVar(ms): 0-2, Mbps(L3/IP): 970.46
Sub-Interval(sec):  7, Delivered(%):  99.94, Loss/OoO: 61/0, OWDVar(ms): 2/2/2, RTTVar(ms): 2-2, Mbps(L3/IP): 970.81
Sub-Interval(sec):  8, Delivered(%):  99.97, Loss/OoO: 32/0, OWDVar(ms): 2/2/2, RTTVar(ms): 2-2, Mbps(L3/IP): 970.81
Sub-Interval(sec):  9, Delivered(%):  99.96, Loss/OoO: 36/0, OWDVar(ms): 2/2/2, RTTVar(ms): 2-2, Mbps(L3/IP): 971.09
Sub-Interval(sec): 10, Delivered(%):  99.97, Loss/OoO: 30/0, OWDVar(ms): 2/2/2, RTTVar(ms): 2-2, Mbps(L3/IP): 970.80
Downstream Summary Delivered(%):  99.95, Loss/OoO: 440/0, OWDVar(ms): 0/1/2, RTTVar(ms): 0-2, Mbps(L3/IP): 736.45
Downstream Minimum One-Way Delay(ms): 2 [w/clock difference], Round-Trip Time(ms): 0
Downstream Maximum Mbps(L3/IP): 971.09, Mbps(L2/Eth): 984.92, Mbps(L1/Eth): 1000.28, Mbps(L1/Eth+VLAN): 1003.36
```

Figure 10-1 udpst Client Results Using IPv6 addresses with 1Gbps Ethernet Local connection

Description:

- The first 5 lines below the "$ udpst …" command line provide a summary of the test configuration.

- Each line beginning “Sub-Interval(sec):” provides measurements for 1 second of the 10 second complete test in Figure 3.
- Loss and reordering (Out-of-Order packets) are tracked for each sub-interval.
- One-way and round-trip delay variation is measured while testing and reported in status feedback messages.
- Minimum one-way and round-trip absolute delay covers entire test.
- Mbps (L3/IP): rates are measured, lower-layer protocol rates are calculated.
- Mbps (L2/Eth): and other rates are calculated values, and usually align with relevant provisioned or theoretical maximums.

10.2 udpst project location

The udpst project is part of the Open Broadband series of projects, and available at the URL below:

https://github.com/BroadbandForum/obudpst