Recommendation

# ITU-T Y.1540 (2019) Amd. 2 (03/2023)

SERIES Y: Global information infrastructure, Internet protocol aspects, next-generation networks, Internet of Things and smart cities

Internet protocol aspects – Quality of service and network performance

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## Internet protocol data communication service – IP packet transfer and availability performance parameters

### Amendment 2 – Revised Annex B: Additional search algorithms for IP-based capacity parameters and methods of measurement

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# Recommendation ITU-T Y.1540

## Internet protocol data communication service – IP packet transfer and availability performance parameters

## Amendment 2

## Revised Annex B: Additional search algorithms for IP-based capacity parameters and methods of measurement


### Summary

Amendment 2 revises Annex B, which provides a second, more capable search algorithm for the IP capacity method of measurement defined in Annex A.


### History

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| 3.1 | ITU-T Y.1540 (2007) Amd. 1 | 2009-03-19 | 12 | 11.1002/1000/9727 |
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| 4.1 | ITU-T Y.1540 (2011) Amd. 1 | 2016-01-21 | 12 | 11.1002/1000/12761 |
| 5.0 | ITU-T Y.1540 | 2016-07-29 | 12 | 11.1002/1000/12975 |
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**Recommendation ITU-T Y.1540**

# Internet protocol data communication service – IP packet transfer and availability performance parameters

## Amendment 2

## Revised Annex B: Additional search algorithms for IP-based capacity parameters and methods of measurement

1) Annex B

*Replace Annex B with the following:*

## Annex B

## Additional search algorithms for IP-based capacity parameters and methods of measurement

(This annex forms an integral part of this Recommendation.)

### B.1 Type B search algorithm

This measurement system meets requirements of clause A.2.2, and adds the following capabilities to support an alternate, and mandatory-to-implement, search algorithm, referred to as the Annex B search algorithm (which is test protocol agnostic):

1) The tester should make a recommendation on maximum test packet size, and allow for some unexpected overhead to avoid fragmentation.

2) A table of transmit rates, which are the number of packets sent during each time interval (corresponding to bits per second and a specified protocol layer) and packet sizes. The table has ascending values for offered load rates, between the minimum and maximum supported load rates, inclusive.

3) The receiver of the offered load shall measure the following metrics: received rate, loss, reordering, delay variation (as per this Recommendation), and round-trip delay [ITU-T Y.1565].

4) The receiver of the offered load shall periodically send a status feedback message to the sender with the results of the measured metrics.

5) Based on the results contained in the status feedback message, the sender shall adjust its offered load according to the flowchart in Figure B.1. In the flowchart, one step is a change in rate accomplished by using a new value (of the row above or below the current row for the sending rate and packet sizes) in the table of offered load rates.

The flow chart in Figure B.1 uses many variable names and, in some cases, configurable thresholds that determine the flowchart decisions. There are three main paths through the flowchart: when feedback indicates measured impairments are absent, or when impairments are first measured and some congestion may be present but sending rate change is deferred, or when measured impairments are confirmed by repeated measurement feedback.

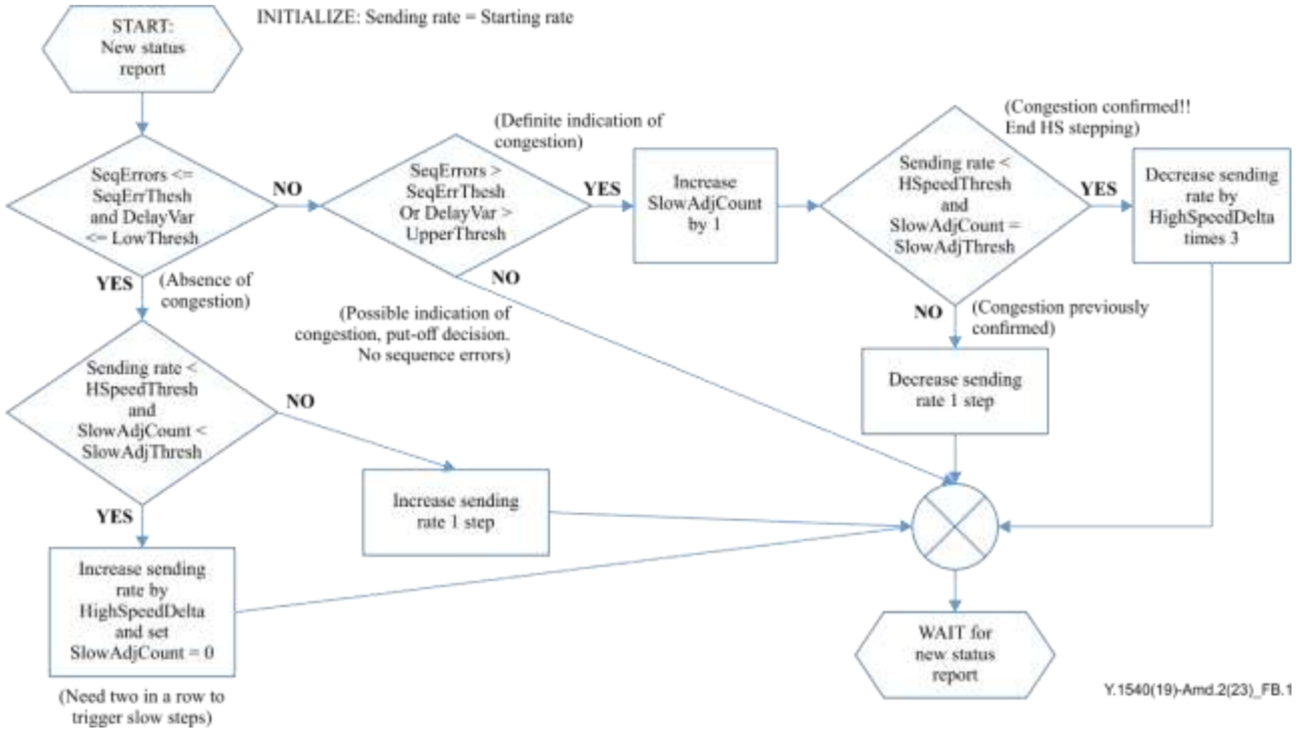


**Figure B.1 – Flowchart for offered load adjustment, Type B search Algorithm**

NOTE – The algorithmic decisions could be performed by one end of the measurement system's participating hosts, which would make implementation at the other host much less complex and independent of the algorithm version.

The variables and thresholds used in Figure B.1 are explained in Table B.1.

**Table B.1 – Flowchart variables, descriptions, ranges and default values**

| Category/ Variable name | Description | Unit | Range | Default value |
|---|---|---|---|---|
| Sending Rate | The current sending rate (equivalent to a row of the table), initialized at minimum Sending Rate in the Table of Sending Rates | kbit/s | 500 ≤ # ≤ 10 000 000 (10 Gbit/s) | See starting rate |
| Start sending rate | Initial value of sending rate | kbit/s | NA | 500 kbit/s |
| Seq Errors | Measurement of any of Loss or Reordering or Replication impairments measured (events where received packet sequence number did not increase by one) | Number of errors | NA | NA |

**Table B.1 – Flowchart variables, descriptions, ranges and default values**

| Category/<br>Variable name | Description | Unit | Range | Default value |
|---|---|---|---|---|
| SeqErrThresh | Threshold for Loss or Reordering or Replication impairments measured (events where received packet sequence number did not increase by one) | Number of errors | $0 \le \# \le 100$ | 10 |
| DelayVar | Range of round trip time, RTT (or 1-way packet delay variation, above minimum delay when DelayVar 1-way measurements are reliable) | ms | NA | NA |
| LowThresh | Low threshold on the range of round trip time variation, RTT (Range is values above minimum RTT) | ms | $5 \le ms \le 250$ | 30 ms default |
| UpperThresh | High threshold on the range of round trip time variation, RTT (Range is values above minimum RTT) | ms | $5 \le ms \le 250$ | 90 ms default |
| HighSpeedDelta | The number of rows to move in a single adjustment when initially increasing offered load (to ramp-up quickly) | Number of rows | $\ge 2$ | 10 table rows (10 Mbit/s currently) |
| SlowAdjCount | Number of consecutive status reports indicating loss and/or delay variation above UpperThreshold. | Count of occurrences | NA | See SlowAdjThresh |
| SlowAdjThresh | Threshold on SlowAdjCount used to infer congestion. Use values > 1 to avoid misinterpreting transient loss | Count of occurrences | > 1 | 3 |
| HSpeedThresh | Threshold for transition between low and high sending rate step sizes (such as 1 Mbit/s and 100 Mbit/s). MAY result in use of jumbo frames if permitted. | Gbit/s | | 1 Gbit/s |

**Table B.1 – Flowchart variables, descriptions, ranges and default values**

| Category/<br>Variable name | Description | Unit | Range | Default value |
|---|---|---|---|---|
| JumboFrames1GPermitted | Configuration for the measurement system permitting use of Jumbo-length Frames | NA | Boolean; [0:1] | 1 (True: permitted for sending rates above 1 Gbit/s)<br>Note – The table of sending rates will change, depending on the option chosen. |
| ReordDupIgnoreEnable | Configuration of SeqErrors counting to ignore Reordering and Duplication impairments measured (only Loss counts toward received packet sequence number errors) | NA | Boolean; [0:1] | 1 (True: enabled) |

Table B.2 gives the default input factors for Annex A method, for use with Annex B.

**Table B.2 – Measurement variables, ranges and default values**

| Category/<br>Variable name | Parameter | Unit | Range | Default value |
|---|---|---|---|---|
| Max IP-layer Capacity | | | | |
| | Number of parallel connections | # | $1 \leq \# \leq 10$ | 1 connection |
| | Duration of preamble to testing | s | $0 \leq s \leq 5$ | ~2 s |
| $\Delta t$ | Duration of the test (either downlink or uplink) with search algorithm in use, which serves as the maximum duration of the search process | s | $5 \leq s \leq 60$ | 10 s |
| *m*<br>*(NumberTestSubIntervals)* | Number of measurement sub-intervals, *dt*, in $\Delta t$ | # | UnsignedInt;<br>$1 \leq \# \leq 100$ | 10 (relates to *dt*) |
| *i*<br>*(NumberFirstModeTestSubIntervals)* | Number of measurement intervals, *dt*, included in the report of the initial Capacity mode. The remaining sub-intervals of the total m are reported separately. | # | UnsignedInt;<br>$0 \leq \# < m$ | 0 Bimodal analysis disabled.<br>Evaluate all sub-intervals in a single mode (meaning that $i > 0$ is un- |

**Table B.2 – Measurement variables, ranges and default values**

| Category/<br>Variable name | Parameter | Unit | Range | Default value |
|---|---|---|---|---|
| | "0" is used as the EnableBimodal parameter, and means the Bimodal analysis is NOT enabled. | | | specified by default) |
| *dt* | Duration of reporting sub-intervals | s | $0.1 \leq s \leq 10$ | 1 s (relates to *m*) |
| TimeoutNoTestTraffic | Timeout value, no test packets at Receiver since previous test packet | ms | UnsignedInt;<br>$500 \leq ms \leq 1000$ | 1000 ms, assuming $\Delta t$ = 10 s |
| TimeoutNoStatusMessage | Timeout value, no Status Messages at Sender since previous Status Message | ms | UnsignedInt;<br>$500 \leq ms \leq 1000$ | 1000 ms, assuming $\Delta t$ = 10 s |
| | Type of Test packet including header and payload lengths, headers and options present and any markings for special treatment in the network | NA | IPv4 or IPv6<br>UDP<br>DSCP | No default<br>UDP<br>00 = Best Effort |
| | Reference size of UDP Payload | KB | Minimum 1 kbyte, Maximum at 1472 bytes (Max 9000 with Jumbo Frames) | No default, recommend largest value that avoids fragmentation. |
| UDPPayloadContent | UDP Payload Content Type. If there is payload compression in the path and tests intend to characterize a possible advantage due to compression, then payload content SHOULD be supplied by a pseudo-random sequence generator, by using part of a compressed file, or by other means. Payload may also contain the test protocol PDUs.<br>Enumeration of:<br>• ones, | | String | All zeroes |

**Table B.2 – Measurement variables, ranges and default values**

| Category/<br>Variable name | Parameter | Unit | Range | Default value |
|---|---|---|---|---|
| | • zeroes,<br>• alternates0and1<br>• random | | | |
| StatusFeedbackInterval | Period of status feedback message (Receiver of offered load returns messages to the sender with the results of the measured metrics) | s | 0.005 ≤ s ≤ 0.250 | 0.050 s |
| Supporting Metrics | These are metrics measured on the same stream as IP Capacity | | | |
| IPLR | Y.1540, RFC 7680 | | | |
| Tmax | Maximum Waiting time for packets to arrive | s | 0.05 ≤ s ≤ 3 | 1 s |
| Sampled RTT | Y.1545, RFC 2681: RTT uses feedback status messages from receiver. | | | |
| Tmax | Maximum Waiting time for packets to arrive | s | 0.05 ≤ s ≤ 3 | 3 s |
| | Resolution of Timestamps | ms | 0.001 ≤ ms ≤ 1 | Suggested for fixed access: .001 (based on current implementation) |
| Supporting Metric: IPDV | Y.1540, RFC 3393, RFC 5481 (PDV) | | | |
| Tmax | Maximum Waiting time for packets to arrive | s | 0.05 ≤ s ≤ 3 | 1 s |
| | Resolution of Timestamps | ms | 0.001 ≤ ms ≤ 1 | Suggested for fixed access: .001 (based on current implementation) |
| Supporting Metric: IPRR | Y.1540, RFC 4737 | | | |
| Tmax | Maximum Waiting time for packets to arrive | s | 0.05 ≤ s ≤ 3 | 1 s |
| | Resolution of Timestamps | ms | 0.001 ≤ ms ≤ 1 | Suggested for fixed access: .001 (based on |

**Table B.2 – Measurement variables, ranges and default values**

| Category/<br>Variable name | Parameter | Unit | Range | Default value |
|---|---|---|---|---|
| | | | | current implementation) |
| Supporting Metric: RIPR | Y.1540, RFC 5560 | | | |
| Tmax | Maximum Waiting time for packets to arrive | s | 0.05 ≤ s ≤ 3 | 1 s |
| | Resolution of Timestamps | ms | 0.001 ≤ ms ≤ 1 | Suggested for fixed access: .001 (based on current implementation) |

## B.2 Considerations for testing with parallel UDP streams

Parallel streams introduce complexity as well as the advantage of reaching higher rates.

Possible benefits include:

- Parallel systems may be used to produce the aggregate rate needed with parallel connections.
- Parallel streams may be used as a way to saturate the path under test with a single pair of test hosts.
- Additional information could be derived for diagnostic purposes, or to validate the testing process. For example, comparing the data rates on each connection could be informative, where very different data rates might reveal abnormal operation.

The current view is that each stream would have its own feedback channel, calculation of measurements and flowchart, and a report of the aggregate results over all connections.

## B.3 Considerations for testing with bimodal path performance

Clause 7.1 of [b-ITU-T Y-Suppl.60] gives guidance on measuring Maximum IP-Layer Capacity when the results indicate a bimodal distribution of capacities. The different modes may be intentional design features, or other phenomenon where the tester prefers to separate the measurement in two modes for further processing. For example, the tester might prefer to exclude the measurement time needed to "ramp-up" to sending rates near the Maximum IP-Layer Capacity, and only consider measurements during the second mode (and ignore the initial Capacity mode).

The *i* parameter described in Table B.2 above is the control for enabling and specifying bimodal reporting. The Description of *i* is as follows:

> Number of measurement intervals, *dt*, included in the report of the initial Capacity mode. The remaining sub-intervals of the total *m* are reported separately.

## B.4 Type C search algorithm

The flow chart in Figure B.2 below uses additional variable names, and in some cases, configurable thresholds that determine the flowchart decisions beyond those in Figure B.1 Type B flow chart. Three main paths through the flowchart remain: when feedback indicates measured impairments are absent, or when impairments are first measured and some congestion may be present but sending rate change is deferred, or when measured impairments are confirmed by repeated measurement feedback. However, the sending rate increases by a multiplicative factor (1.5) when impairments are effectively absent. Further, the "fast" sending rate increase and decrease configurations are de-coupled, allowing greater control. The Type C algorithm also introduces automatic retry of the "fast" sending rate increase mode, with increasing intervals between retries as the test proceeds.

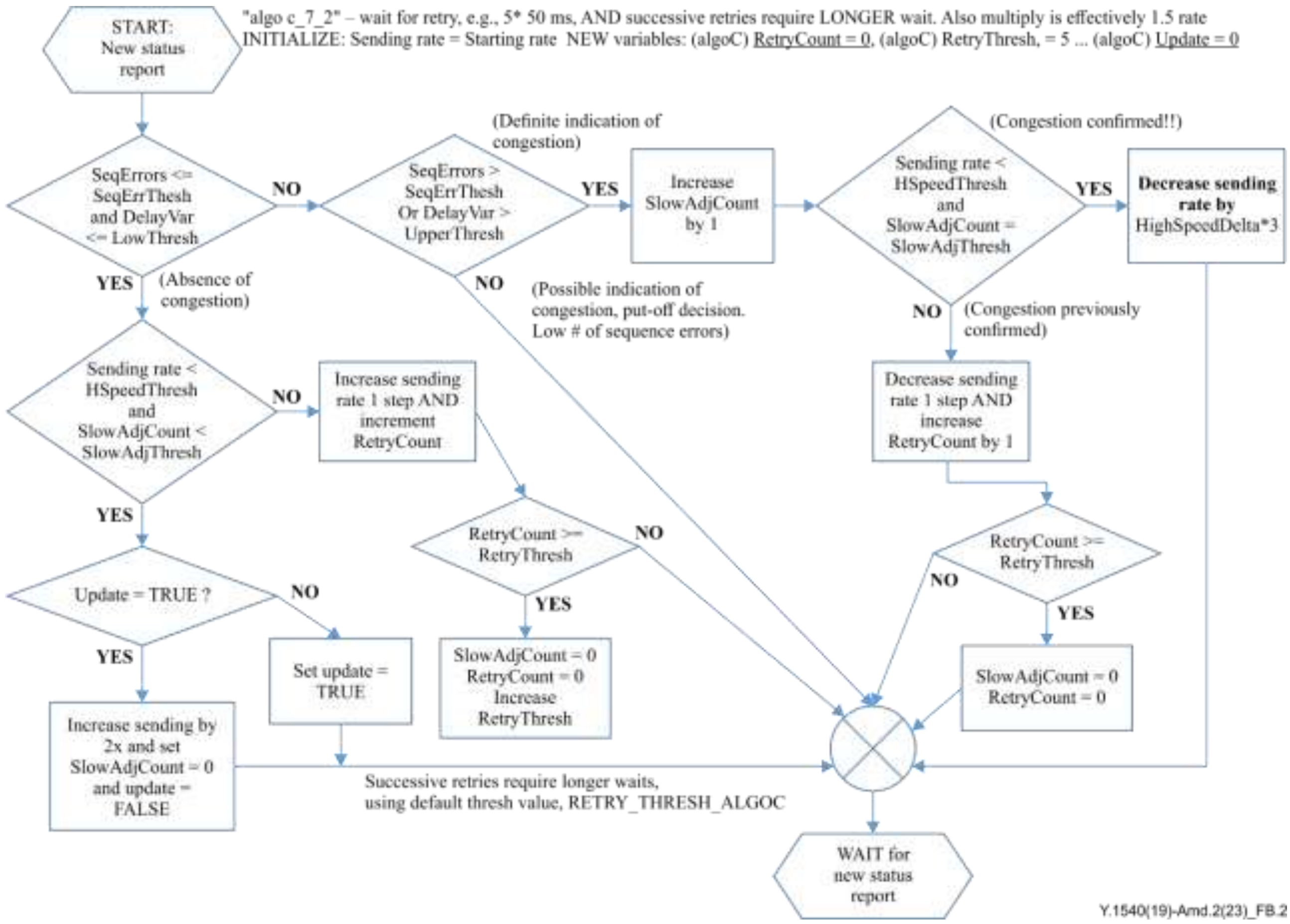


**Figure B.2 – Flowchart for offered load adjustment, Type C search algorithm**

The Type C algorithm uses Type B as a starting point to host the new features of multiplicative increases and retry of "fast" sending rate increase mode, thus the distinguishing moniker "Multiply and Retry" applies here.

The new variables and thresholds used in the Figure B.2 flowchart are explained below:

**Table B.3 – Type C flowchart variables, descriptions, ranges and default values**

| Category/ Variable name | Description | Unit | Range | Default value |
|---|---|---|---|---|
| RetryCount | Number of status reports since previous "fast" mode activation. The counting takes place whether impairments are present or not. | Count of occurrences | NA | RetryThresh |
| RetryThresh | Threshold on RetryCount used to delay successive activations of "fast" sending rate increase mode. Use values > 1 to increase the | Count of occurrences | > 1 | 5 |

**Table B.3 – Type C flowchart variables, descriptions, ranges and default values**

| Category/ Variable name | Description | Unit | Range | Default value |
|---|---|---|---|---|
| | delay. Note that the algorithm doubles the threshold each time RetryThresh is exceeded. | | | |
| Update | The Update variable operates in "fast" sending rate increase mode to temper the effective increase to a fractional value (1.5). The sending rate increases alternate between multiply by 1 and multiply by 2 for an average of 1.5. | | Boolean; [0:1] | 0 (False) starting value, the value alternates with each pass through the "fast" sending rate increase mode. |

## B.5 Considerations for testing with cellular mobile and other radio networks

**Reordering**: There appears to be an increased likelihood of reordered packets during tests on 5G service. Reordered packets are legitimate contributors to IP-Layer Capacity. However, the Type B and Type C algorithms treat reordering as an impairment, the same as packet loss. To measure the maximum capacity when packet reordering is present (and especially when prevalent), the configuration option to ignore reordering (and duplication) in the search algorithms should be used (this is now the default for all testing).

**Test Interval**: Mobile and other radio networks tend to exhibit variable transmission conditions and received bit rates, in addition to traffic from other users that is competing for the allocated capacity. It is suggested to use:

**Table B.4 – Mobile/radio testing variable names, descriptions, ranges and values**

| Category/ Variable name | Description | Unit | Range | Suggested value |
|---|---|---|---|---|
| $\Delta t$ | Duration of the fixed rate test (either downlink or uplink) | s | $5 \le s \le 60$ | 7 s for Mobile/radio |
| *i* *(NumberFirstModeTestSubIntervals)* | Number of measurement intervals, d*t*, included in the report of the initial Capacity mode. The remaining sub-intervals of the total m are reported separately.<br>"0" is used as the EnableBimodal parameter, and means the Bimodal analysis is NOT enabled. | # | UnsignedInt; $0 \le \# < m$ | 3 |
| *dt* | Duration of reporting sub-intervals | s | $0.1 \le s \le 10$ | 1 s (same as default) |

**Parameter Selection**: It is possible to produce a version of the search algorithms which maintains the path bottleneck in a saturated state by simply changing the SlowAdjThresh (or Slow Adjustment Threshold, the threshold on SlowAdjCount used to infer congestion) from its default value (3) to 65535. This parameter setting disables two paths in the flowchart when operating at sending rates < 1 Gbit/s: the single step sending rate increase and the multiple step decrease in response to confirmed congestion. The result is a simplified flow chart having only "fast" sending rate increases and single-step decreases. If using the Type B search algorithm, it is also suggested to increase the HighSpeedDelta parameter (the number of rows to move in a single adjustment when increasing offered load and ramp-up sending rate) from the default 10 to 50. The Type C search algorithm does not require this change, in fact the HighSpeedDelta parameter is only active in the congestion-confirmed aspect of flow chart operation.

*2) Bibliography*

Add the following entry to the bibliography:

[b-ITU-T Y-Suppl.60] ITU-T Y-series Recommendations – Supplement 60 (2022) – *Interpreting ITU-T Y.1540 maximum IP-layer capacity measurements*.

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