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**5G;**
**Study on 5G NR User Equipment (UE) application layer data throughput performance (3GPP TR 37.901-5 version 16.13.0 Release 16)**



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# Contents

# Foreword

This Technical Report has been produced by the 3rd Generation Partnership Project (3GPP).

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In the present document, modal verbs have the following meanings:

**shall** indicates a mandatory requirement to do something

**shall not** indicates an interdiction (prohibition) to do something

The constructions "shall" and "shall not" are confined to the context of normative provisions, and do not appear in Technical Reports.

The constructions "must" and "must not" are not used as substitutes for "shall" and "shall not". Their use is avoided insofar as possible, and they are not used in a normative context except in a direct citation from an external, referenced, non-3GPP document, or so as to maintain continuity of style when extending or modifying the provisions of such a referenced document.



**should** indicates a recommendation to do something

**should not** indicates a recommendation not to do something

**may** indicates permission to do something

**need not** indicates permission not to do something

The construction "may not" is ambiguous and is not used in normative elements. The unambiguous constructions "might not" or "shall not" are used instead, depending upon the meaning intended.

**can** indicates that something is possible

**cannot** indicates that something is impossible

The constructions "can" and "cannot" are not substitutes for "may" and "need not".

**will** indicates that something is certain or expected to happen as a result of action taken by an agency the behaviour of which is outside the scope of the present document

**will not** indicates that something is certain or expected not to happen as a result of action taken by an agency the behaviour of which is outside the scope of the present document

**might** indicates a likelihood that something will happen as a result of action taken by some agency the behaviour of which is outside the scope of the present document

**might not** indicates a likelihood that something will not happen as a result of action taken by some agency the behaviour of which is outside the scope of the present document

In addition:

**is** (or any other verb in the indicative mood) indicates a statement of fact

**is not** (or any other negative verb in the indicative mood) indicates a statement of fact

The constructions "is" and "is not" do not indicate requirements.

# 1 Scope

The present document contains the findings of the Study on 5G NR User Equipment (UE) application layer data throughput performance and the proposed test procedures.

# 2 References

The following documents contain provisions which, through reference in this text, constitute provisions of the present document.

- References are either specific (identified by date of publication, edition number, version number, etc.) or non-specific.
- For a specific reference, subsequent revisions do not apply.
- For a non-specific reference, the latest version applies. In the case of a reference to a 3GPP document (including a GSM document), a non-specific reference implicitly refers to the latest version of that document *in the same Release as the present document*.

[1] 3GPP TR 21.905: "Vocabulary for 3GPP Specifications".

[2] 3GPP TS 38.101-1: "NR; User Equipment (UE) radio transmission and reception; Part 1: Range 1 Standalone".

[3] 3GPP TS 38.521-4: "NR; User Equipment (UE) conformance specification; Radio transmission and reception; Part 4: Performance requirements".

[4] 3GPP TS 38.101-4: "NR; User Equipment (UE) radio transmission and reception; Part 4: Performance requirements".

[5] 3GPP TS 36.321: "Evolved Universal Terrestrial Radio Access (E-UTRA); Medium Access Control (MAC) protocol specification"

[6] 3GPP TS 36.322: "Evolved Universal Terrestrial Radio Access (E-UTRA); Radio Link Control (RLC) protocol specification"

[7] 3GPP TS 36.323: "Evolved Universal Terrestrial Radio Access (E-UTRA); Packet Data Convergence Protocol (PDCP) specification"

[8] 3GPP TS 38.323: "NR; Packet Data Convergence Protocol (PDCP) specification"

[9] 3GPP TS 38.523: "5GS; User Equipment (UE) conformance specification; Part 1: Protocol"

[10] 3GPP TS 38.321: "NR; Medium Access Control (MAC) protocol specification"

[11] 3GPP TS 38.322: "NR; Radio Link Control (RLC) protocol specification"

[12] RFC 768

[13] RFC 791

[14] RFC 793

[15] RFC 2460

[16] RFC 8200

[17] 3GPP TS 38.214: "NR; Physical layer procedures for data".

[18] 3GPP TS 38.508-1: "5GS; User Equipment (UE) conformance specification; Part 1: Common test environment"

# 3 Definitions of terms, symbols and abbreviations

## 3.1 Terms

For the purposes of the present document, the terms given in TR 21.905 [1] and the following apply. A term defined in the present document takes precedence over the definition of the same term, if any, in TR 21.905 [1].

## 3.2 Symbols

Void.

## 3.3 Abbreviations

For the purposes of the present document, the abbreviations given in TR 21.905 [1] and the following apply. An abbreviation defined in the present document takes precedence over the definition of the same abbreviation, if any, in TR 21.905 [1].

# 4 General

## 4.1 Background



The newly-deployed 5G radio access technologies are providing a very large increase in data transmission capacity in mobile networks. This is being matched and even exceeded by a corresponding increase in the demand for data from users of the latest data-hungry devices and applications.

It is therefore essential that data devices achieve high efficiency when using data services and do not unduly load the network regardless of the maximum data rate that they are capable of achieving.



There is an interest to add 5G NR UE Application-Layer Data Throughput Measurements under various simulated network conditions to their Performance Items area of activity. As a result RAN5 recommending and produce the test procedures.

## 4.2 Study Item Objective

The technical objectives of this study item are:

Fixed reference measurement channels:

a) Use existing fixed reference measurement channels scenarios already defined in TS 38.101-4 [4] and TS 38.521-4 [3] test specifications to develop test procedures to measure 5G NR UE data throughput performance at the application-layer. Adaptation of existing test cases from the TS 38.521-4 [3] specification will be part of the study with goal to determine best test points candidates.

Variable reference measurement channels:

b) analysis of suitable link adaptation scenarios and development of corresponding 5G NR application layer throughout test procedures An analysis of upper layer protocols and parameters impacting application layer throughout measurements will also be provided.

NOTE 1: There is significant industry interest in performing application layer throughput measurements with variable reference measurement channels (link adaptation) as this represents a scenario closer to real world deployments.

The Rel-11 SI "Study on UE Application Layer Data Throughput" (FS_UE_App_Data_Perf) captured results for UMTS and LTE in a Technical Report TR 37.901. For the SI " Study on 5G NR User Equipment (UE) application layer

data throughput performance" that is proposed here it is intended to create a new Technical Report for which the following structure is proposed:

- Definition of 5G NR Application Layer Data Throughput Performance
- List of parameters to be measured:
  - Application Layer Throughput (Downlink and Uplink)
- Test configuration and upper layer parameters
- Transport Layer protocol used for data transfer
- Application Layer protocol used for data transfer
- Test environment (signal levels, fading profiles, fixed and link adaptation based scheduling, SA/NSA, FR1/FR2, etc.):
- Data transfer scenarios (TCP/UDP, DL/UL/Bidirectional)
- Minimum Test Time and Iterations (align with LTE)
- Test Procedures for 5G NR UE Application layer throughput performance

The test procedures developed will measure the achieved average application-layer data rates (e.g. using TCP or UDP) of the UE standalone or/and in combination with a laptop under simulated realistic network scheduling and radio conditions in a repeatable lab-based environment (i.e. using lab-based simulators and other necessary equipment).

NOTE 2: The point of measurement on the UE side will be either in a connected PC for terminals that support tethered mode only, or inside the UE in case of a terminal that does not support tethered mode (and supports embedded mode), or in both places for UEs that support both modes.



The test procedures will be developed in a flexible manner to accommodate various test conditions. The exact simulated network scheduling and down link radio conditions to be used will be determined during the study. It is envisaged that in addition to some measurements under "ideal conditions", an initial set of suitable scheduling/radio conditions to be used by the test systems, will be defined to simulate typical network conditions. Additional optional conditions may be developed later as and when required.



Other issues that the Study Item may investigate include:

- The definition of a reliable and repeatable test environment to ensure the best possible repeatability of the results. This could include the definition of a reference laptop configuration, applications in the UE or/and the Laptop that would measure the throughput, etc.
- The impact from the lower layers data throughput on the application-layer data throughput, especially when variable radio conditions are applied.

# 5 Study on 5G NR UE Application Layer Data Throughput Performance

## 5.1 Definition of Application Layer Data Throughput Performance

### 5.1.1 Definition of End Points

The test procedures defined will measure the throughput of data end to end from a server to the terminating end on the user side.

The termination on the user side will be:

A. Inside the terminal in case of a handset that can install an embedded client application. This is considered the default mode of testing as it provides an accurate measure of user experience.

B. Alternatively, in a connected PC in case of a handset or data module that does not support embedded mode (lacks UI, no embedded application installation possible, etc.).

For tethered connections, the UE is tethered to a laptop using the appropriate UE to PC interface Modem or Network Interface Connection (NIC) drivers as recommended by the UE manufacturer for the intended use by the customer/user. In most cases, a laptop with an embedded modem is considered to be a tethered data configuration as opposed to an embedded data configuration due to the UE to PC interface. It is noted that the physical layer capabilities of the UE to PC Interface Connection can limit the UE Application Layer Data Throughput performance. Care should be taken to ensure that the physical layer capabilities of the UE to PC Interface Connection do not affect the performance results.

For non-tethered or embedded connections as in the case of embedded applications or applications running on the UE itself, the end points are the application running on the UE and a corresponding Data Server that is adjacent to the simulated lab-based Core Network and is the default mode of connection for devices that support this mode.

For tethered connections, the end points are the application running on the PC connected to the UE and a corresponding Data Server that is adjacent to the simulated lab-based Core Network. In this case, the PC drivers (typically USB) will also play a role in the UE Application Layer Data Throughput performance.

## 5.2 Parameters for Measurement

### 5.2.1 Throughput

The 5G NR UE Application Layer Data Throughput as defined in clause 5.1.1 shall be a parameter for measurement. The parameter would apply for any chosen application. The throughput can be measured in each direction (downlink and uplink).



## 5.3 Test Configurations

### 5.3.1 5G NR UE Application Layer Data Throughput Test Equipment



The test equipment utilized for 5G NR UE Application Layer Data Throughput shall consistent of the following items.

Data client test application(s) for the UE for embedded mode operation, which shall be default mode for devices supporting this mode.

- For tethered mode operation, Laptop/PC and appropriate UE to PC interface Modem or Network Interface Connection (NIC) drivers and any associated cabling as recommended by the UE manufacturer for the intended use by the customer/user.
- Data client test application for the PC for tethered mode operation.
- System Simulator(s) suitable for the 5G NR radio technology used for testing with necessary IP connectivity.
- Application Servers.
- Faders and AWGN Sources capable of supporting the radio environments defined.

### 5.3.2 UE Application Layer Data Throughput Connection Diagrams

#### 5.3.2.1 UE Application Layer Data Throughput Connection Diagram for Tethered

The UE Application Layer Data Throughput connection diagram for tethered operation is shown in Figure C.1.

#### 5.3.2.2 UE Application Layer Data Throughput Connection Diagram for Embedded

The UE Application Layer Data Throughput connection diagram for embedded operation is shown in Figure C.2.

### 5.3.3 RF Connection Diagrams for UE Application Layer Data Throughput

The RF connections between the SS and the UE shall be in compliance with the associated RF connection diagrams specified in the test procedure clauses in Annex A. As the RF connection diagrams vary based on device type and UE category, it is preferable to reference appropriate RF connection diagrams for similar test configurations in the core test specifications. The RF connection diagrams are to be based on the representative RF connection diagrams referenced in 38.521-4 [3].

### 5.3.4 UE Specific Items

There are no UE specific items identified at this time that are required to support the UE Application Layer Data Throughput testing herein. This item is FFS.

## 5.4 Transport and Application Layer Protocols

### 5.4.1 Transport Layer Protocol

For the transport layer protocol, TCP and UDP are considered. It is proposed to test with both TCP and UDP as measurements utilizing each transport protocol are relevant.

The following items highlight the need for TCP transport.

- Most of the applications that need reliable data transfers use TCP as transport layer.
- The throughput is sensitive to the end-to-end delay.
- Good for testing FTP/HTTP in bi-directional tests in asymmetric data rate links because the downlink speeds are limited by uplink speeds. For FTP/HTTP data transfers in one direction, the TCP ACKs are transmitted in the other direction, therefore delay in receiving TCP ACK in one direction negatively impacts FTP/HTTP throughput in the other direction.



The following items highlight the need for UDP transport.

- The performance of UDP based data transfer, unlike TCP based transfer, is Operating System agnostic
- Real-Time Transport Protocols used by most of Multi Media Applications are based on UDP protocol.
- UDP Data Transfer in one direction (uplink/downlink) is not dependent on the other direction characteristics, unlike with TCP.

### 5.4.2 Application Layer Protocol

The following items have been considered for appropriate application layer protocols that utilize TCP as a transport protocol.

- FTP
- TFTP
- SFTP
- HTTP
- VoIP (RTP-based)

To reduce the amount of testing, it is proposed to use [FTP or raw TCP data transfer]. FTP (File Transfer Protocol) runs on top of TCP/IP and is frequently used in applications where download/upload performance would be noticeable to the end user.

The following list identifies the reasons not to duplicate testing across the other application layer protocols.