

ETSI TR 137 901-5 V16.13.0 (2024-10)



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

[ETSI TR 137 901-5 V16.13.0 \(2024-10\)](https://standards.iteh.ai/catalog/standards/etsi/95a87afd-9fec-4343-b9b9-0baf0a745c6/etsi-tr-137-901-5-v16-13-0-2024-10)

<https://standards.iteh.ai/catalog/standards/etsi/95a87afd-9fec-4343-b9b9-0baf0a745c6/etsi-tr-137-901-5-v16-13-0-2024-10>



ReferenceRTR/TSGR-0537901-5vgd0

Keywords5G

ETSI

650 Route des Lucioles
F-06921 Sophia Antipolis Cedex - FRANCE

Tel.: +33 4 92 94 42 00 Fax: +33 4 93 65 47 16

Siret N° 348 623 562 00017 - APE 7112B
Association à but non lucratif enregistrée à la
Sous-Préfecture de Grasse (06) N° w061004871

Important notice

The present document can be downloaded from the
ETSI [Search & Browse Standards application](#).

The present document may be made available in electronic versions and/or in print. The content of any electronic and/or print versions of the present document shall not be modified without the prior written authorization of ETSI. In case of any existing or perceived difference in contents between such versions and/or in print, the prevailing version of an ETSI deliverable is the one made publicly available in PDF format on [ETSI deliver](#).

Users should be aware that the present document may be revised or have its status changed,
this information is available in the [Milestones listing](#).

If you find errors in the present document, please send your comments to
the relevant service listed under [Committee Support Staff](#).

If you find a security vulnerability in the present document, please report it through our
[Coordinated Vulnerability Disclosure \(CVD\)](#) program.

Notice of disclaimer & limitation of liability

The information provided in the present deliverable is directed solely to professionals who have the appropriate degree of experience to understand and interpret its content in accordance with generally accepted engineering or other professional standard and applicable regulations.

No recommendation as to products and services or vendors is made or should be implied.

No representation or warranty is made that this deliverable is technically accurate or sufficient or conforms to any law and/or governmental rule and/or regulation and further, no representation or warranty is made of merchantability or fitness for any particular purpose or against infringement of intellectual property rights.

In no event shall ETSI be held liable for loss of profits or any other incidental or consequential damages.

Any software contained in this deliverable is provided "AS IS" with no warranties, express or implied, including but not limited to, the warranties of merchantability, fitness for a particular purpose and non-infringement of intellectual property rights and ETSI shall not be held liable in any event for any damages whatsoever (including, without limitation, damages for loss of profits, business interruption, loss of information, or any other pecuniary loss) arising out of or related to the use of or inability to use the software.

Copyright Notification

No part may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm except as authorized by written permission of ETSI.

The content of the PDF version shall not be modified without the written authorization of ETSI.

The copyright and the foregoing restriction extend to reproduction in all media.

© ETSI 2024.
All rights reserved.

Intellectual Property Rights

Essential patents

IPRs essential or potentially essential to normative deliverables may have been declared to ETSI. The declarations pertaining to these essential IPRs, if any, are publicly available for **ETSI members and non-members**, and can be found in ETSI SR 000 314: "*Intellectual Property Rights (IPRs); Essential, or potentially Essential, IPRs notified to ETSI in respect of ETSI standards*", which is available from the ETSI Secretariat. Latest updates are available on the ETSI Web server (<https://ipr.etsi.org/>).

Pursuant to the ETSI Directives including the ETSI IPR Policy, no investigation regarding the essentiality of IPRs, including IPR searches, has been carried out by ETSI. No guarantee can be given as to the existence of other IPRs not referenced in ETSI SR 000 314 (or the updates on the ETSI Web server) which are, or may be, or may become, essential to the present document.

Trademarks

The present document may include trademarks and/or tradenames which are asserted and/or registered by their owners. ETSI claims no ownership of these except for any which are indicated as being the property of ETSI, and conveys no right to use or reproduce any trademark and/or tradename. Mention of those trademarks in the present document does not constitute an endorsement by ETSI of products, services or organizations associated with those trademarks.

DECT™, **PLUGTESTS™**, **UMTS™** and the ETSI logo are trademarks of ETSI registered for the benefit of its Members. **3GPP™** and **LTE™** are trademarks of ETSI registered for the benefit of its Members and of the 3GPP Organizational Partners. **oneM2M™** logo is a trademark of ETSI registered for the benefit of its Members and of the oneM2M Partners. **GSM®** and the GSM logo are trademarks registered and owned by the GSM Association.

Legal Notice

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

The present document may refer to technical specifications or reports using their 3GPP identities. These shall be interpreted as being references to the corresponding ETSI deliverables.

The cross reference between 3GPP and ETSI identities can be found under <https://webapp.etsi.org/key/queryform.asp>.

Modal verbs terminology

In the present document "**should**", "**should not**", "**may**", "**need not**", "**will**", "**will not**", "**can**" and "**cannot**" are to be interpreted as described in clause 3.2 of the [ETSI Drafting Rules](#) (Verbal forms for the expression of provisions).

"**must**" and "**must not**" are **NOT** allowed in ETSI deliverables except when used in direct citation.

Contents

Intellectual Property Rights	2
Legal Notice	2
Modal verbs terminology.....	2
Foreword.....	7
1 Scope	9
2 References	9
3 Definitions of terms, symbols and abbreviations	10
3.1 Terms.....	10
3.2 Symbols.....	10
3.3 Abbreviations	10
4 General	10
4.1 Background	10
4.2 Study Item Objective.....	10
5 Study on 5G NR UE Application Layer Data Throughput Performance	11
5.1 Definition of Application Layer Data Throughput Performance.....	11
5.1.1 Definition of End Points	11
5.2 Parameters for Measurement	12
5.2.1 Throughput	12
5.3 Test Configurations	12
5.3.1 5G NR UE Application Layer Data Throughput Test Equipment	12
5.3.2 UE Application Layer Data Throughput Connection Diagrams	12
5.3.2.1 UE Application Layer Data Throughput Connection Diagram for Tethered	12
5.3.2.2 UE Application Layer Data Throughput Connection Diagram for Embedded	12
5.3.3 RF Connection Diagrams for UE Application Layer Data Throughput	13
5.3.4 UE Specific Items	13
5.4 Transport and Application Layer Protocols.....	13
5.4.1 Transport Layer Protocol	13
5.4.2 Application Layer Protocol.....	13
5.4.2.1 TCP Settings	14
5.4.2.1.1 TCP advertised receiver window size setting	15
5.4.2.2 UDP Settings.....	15
5.4.3 Upper Layer impact on throughput measurements	16
5.4.3.1 Overview	16
5.4.3.2 TCP/UDP Layer	17
5.4.3.3 IP Layer.....	17
5.4.3.4 PDCP Layer	17
5.4.3.5 RLC Layer.....	18
5.4.3.6 Overhead between MAC and TCP/UDP layer.....	18
5.4.3.7 Overhead for LTE	18
5.4.3.8 SA, NSA and NSA split-bearer.....	18
5.4.4 Summary of Upper Layer Parameters and Overhead from MAC to Transport Layer	18
5.5 Test Environment	19
5.5.1 Conducted Testing for 5G NR FR1	19
5.5.1.1 Signal Levels	19
5.5.1.2 Fading Profiles	19
5.5.2 Radiated Testing for 5G NR FR2	20
5.5.2.1 Signal Levels	20
5.5.2.2 Fading Profiles	20
5.6 Data Transfer Scenarios	20
5.6.1 TCP Transfers	20
5.6.2 UDP Transfers	20
5.7 Statistical Analysis	21
5.7.1 Overview of Layer 1 throughput.....	21

5.7.2	Overview of Application Layer throughput.....	22
5.7.3	Test Time for Application Layer Throughput procedures	23
5.8	Impact of Modem Performance in Application Layer Throughput	23
5.8.1	Modem Performance in current TS 38.521-4 conformance tests.....	23
5.8.2	Modem Performance in Application Layer Data Throughput Tests	24
5.9	Test System Uncertainty and Test Tolerance	24
5.9.1	Test System Uncertainty and Test Tolerance for FR1 testing	24
5.9.1.1	Recommended Uncertainty of Test System	24
5.9.1.2	Test Tolerances	24
5.9.1.3	Impact of Test System Uncertainty on Test Results	24
5.9.1.4	Impact of Test System Uncertainty on Test Results for FR1	25
5.9.2	Test System Uncertainty and Test Tolerance for FR2 testing	26
5.9.2.1	Recommended Uncertainty of Test System	26
5.9.2.2	Test Tolerances	26
5.9.2.3	Impact of Test System Uncertainty on Test Results	26
5.9.2.4	Impact of Test System Uncertainty on Test Results for FR2	27
5.10	Feasibility of Defining Link Adaptation Absolute Physical Layer Requirements	27
5.10.1	General.....	27
5.10.2	Test Methodology	27
5.10.2.1	Simulation Alignment Criteria.....	27
5.10.2.2	Methodology for Requirements Definition	28
5.10.3	Simulation Assumptions	28
5.10.4	Simulation Results	31
5.10.5	Summary.....	32
6	Conclusions	32
Annex A:	Test Procedures.....	34
A.1	Purpose of annex	34
A.1.1	General	34
A.2	5G NR /TCP Downlink Throughput /Conducted/Static Peak Throughput for SA and NSA.....	35
A.2.1	5G NR /TCP Downlink Throughput /Conducted/Static Channel Peak Throughput tests for SA and NSA.....	35
A.2.1.1	5G NR /TCP Downlink Throughput /Conducted/Static Channel/ SA and NSA (no Downlink Split Bearer)	35
A.2.1.2	5G NR /TCP Downlink Throughput /Conducted/Static Channel/NSA (Downlink Split Bearer).....	37
A.3	5G NR /TCP Downlink Throughput /Conducted for Fixed Reference Channel (FRC) Scenarios with Fading for SA and NSA	38
A.3.1	5G NR /TCP Downlink Throughput /Conducted/Fading/FRC for SA and NSA	38
A.3.1.1	5G NR /TCP Downlink Throughput /Conducted/Fading/FRC/2Rx for SA and NSA.....	38
A.3.1.1.1	5G NR /TCP Downlink Throughput /Conducted/Fading/FRC/2Rx FDD/FR1 PDSCH mapping Type A performance - 2x2 MIMO for SA and NSA.....	38
A.3.1.1.2	5G NR /TCP Downlink Throughput /Conducted/Fading/FRC/2Rx TDD/FR1 PDSCH mapping Type A performance - 2x2 MIMO for SA and NSA.....	40
A.3.1.2	5G NR /TCP Downlink Throughput /Conducted/Fading/FRC/4Rx for SA and NSA.....	41
A.3.1.2.1	5G NR /TCP Downlink Throughput /Conducted/Fading/FRC/4Rx FDD/FR1 PDSCH mapping Type A performance - for SA and NSA.....	41
A.3.1.2.2	5G NR /TCP Downlink Throughput /Conducted/Fading/FRC/4Rx TDD/FR1 PDSCH mapping Type A performance - for SA and NSA.....	43
A.4	5G NR /UDP Downlink Throughput /Conducted/Static Peak Throughput for SA and NSA	44
A.4.1	5G NR /UDP Downlink Throughput /Conducted/Static Channel Peak Throughput tests for SA and NSA	44
A.4.1.1	5G NR /UDP Downlink Throughput /Conducted/Static Channel/ SA and NSA (no Downlink Split Bearer)	44
A.4.1.2	5G NR /UDP Downlink Throughput /Conducted/Static Channel/NSA (Downlink Split Bearer).....	46
A.5	5G NR /UDP Downlink Throughput /Conducted for Fixed Reference Channel (FRC) Scenarios with Fading for SA and NSA	48
A.5.1	5G NR /UDP Downlink Throughput /Conducted/Fading/FRC for SA and NSA	48
A.5.1.1	5G NR /UDP Downlink Throughput /Conducted/Fading/FRC/2Rx for SA and NSA	48
A.5.1.1.1	5G NR /UDP Downlink Throughput /Conducted/Fading/FRC/2Rx FDD/FR1 PDSCH mapping Type A performance - 2x2 MIMO for SA and NSA.....	48

A.5.1.1.2	5G NR /UDP Downlink Throughput /Conducted/Fading/FRC/2Rx TDD/FR1 PDSCH mapping Type A performance - 2x2 MIMO for SA and NSA.....	49
A.5.1.2	5G NR /UDP Downlink Throughput /Conducted/Fading/FRC/4Rx for SA and NSA.....	51
A.5.1.2.1	5G NR /UDP Downlink Throughput /Conducted/Fading/FRC/4Rx FDD/FR1 PDSCH mapping Type A performance - 4x4 MIMO for SA and NSA.....	51
A.5.1.2.2	5G NR /UDP Downlink Throughput /Conducted/Fading/4Rx TDD/FR1 PDSCH mapping Type A performance - 4x4 MIMO for SA and NSA.....	53
A.6	5G NR /TCP Downlink Throughput/Radiated/Static Peak Throughput for SA and NSA.....	55
A.6.1	5G NR /TCP Downlink Throughput /Radiated/Static Channel Peak Throughput tests for SA and NSA.....	55
A.6.1.1	5G NR /TCP Downlink Throughput /Radiated/Static Channel/ SA and NSA (no Downlink Split Bearer).....	55
A.7	5G NR /TCP Downlink Throughput /Radiated for Fixed Reference Channel Scenarios (FRC) with Fading.....	56
A.7.1	5G NR /TCP Downlink Throughput /Radiated/Fading/FRC.....	56
A.7.1.1	5G NR /TCP Downlink Throughput /Radiated/Fading/FRC/2Rx.....	56
A.7.1.1.1	5G NR /TCP Downlink Throughput /Radiated/Fading/FRC/2Rx TDD/FR2 PDSCH mapping Type A performance - for SA and NSA.....	56
A.7.1.2	5G NR /TCP Downlink Throughput /Radiated/Fading/FRC/4Rx.....	58
A.7.1.2.1	Void.....	58
A.8	5G NR /UDP Downlink Throughput/Radiated/Static Peak Throughput for SA and NSA.....	58
A.8.1	5G NR /UDP Downlink Throughput /Radiated/Static Channel Peak Throughput tests for SA and NSA.....	58
A.8.1.1	5G NR /UDP Downlink Throughput /Radiated/Static Channel/ SA and NSA (no Downlink Split Bearer).....	58
A.9	5G NR /UDP Downlink Throughput /Radiated for Fixed Reference Channel Scenarios (FRC) with Fading.....	59
A.9.1	5G NR /UDP Downlink Throughput /Radiated/Fading/FRC.....	59
A.9.1.1	5G NR /UDP Downlink Throughput /Radiated/Fading/FRC/2Rx.....	59
A.9.1.1.1	5G NR /UDP Downlink Throughput /Radiated/Fading/2Rx TDD/FR2 PDSCH mapping Type A performance - for SA and NSA.....	59
A.9.1.2	5G NR /UDP Downlink Throughput /Radiated/Fading/FRC/4Rx.....	61
A.9.1.2.1	Void.....	61
A.10	5G NR /TCP Downlink Throughput /Conducted for Variable Reference Channel (VRC) Scenarios with Fading for SA and NSA.....	61
A.10.1	5G NR /TCP Downlink Throughput /Conducted/Fading/VRC for SA and NSA.....	61
A.10.1.1	5G NR /TCP Downlink Throughput /Conducted/Fading/VRC/2Rx for SA and NSA.....	61
A.10.1.1.1	5G NR /TCP Downlink Throughput /Conducted/Fading/VRC/2Rx FDD /FR1 PDSCH mapping Type A performance - for SA and NSA.....	61
A.10.1.1.2	5G NR /TCP Downlink Throughput /Conducted/Fading/VRC/2Rx TDD /FR1 PDSCH mapping Type A performance - for SA and NSA.....	65
A.10.1.2	5G NR /TCP Downlink Throughput /Conducted/Fading/VRC/4Rx.....	69
A.10.1.2.1	5G NR /TCP Downlink Throughput /Conducted/Fading/VRC/4Rx FDD/FR1 PDSCH mapping Type A performance - for SA and NSA.....	69
A.10.1.2.2	5G NR /TCP Downlink Throughput /Conducted/Fading/VRC/4Rx TDD/FR1 PDSCH mapping Type A performance - for SA and NSA.....	73
A.11	5G NR /UDP Downlink Throughput /Conducted for Variable Reference Channel (VRC) Scenarios for SA and NSA.....	77
A.11.1	5G NR /UDP Downlink Throughput /Conducted/Fading/VRC.....	77
A.11.1.1	5G NR /UDP Downlink Throughput /Conducted/Fading/VRC/2Rx.....	77
A.11.1.1.1	5G NR /UDP Downlink Throughput /Conducted/Fading/VRC/2Rx FDD/FR1 PDSCH mapping Type A performance - for SA and NSA.....	77
A.11.1.1.2	5G NR /UDP Downlink Throughput /Conducted/Fading/VRC/2Rx TDD/FR1 PDSCH mapping Type A performance - for SA and NSA.....	80
A.11.1.2	5G NR /UDP Downlink Throughput /Conducted/Fading/VRC/4Rx.....	85
A.11.1.2.1	5G NR /UDP Downlink Throughput /Conducted/Fading/VRC/4Rx FDD/FR1 PDSCH mapping Type A performance - for SA and NSA.....	85
A.11.1.2.2	5G NR /UDP Downlink Throughput /Conducted/Fading/VRC/4Rx TDD/FR1 PDSCH mapping Type A performance - for SA and NSA.....	88

A.12	5G NR /TCP Downlink Throughput /Radiated for Variable Reference Channel Scenarios (VRC) with Fading.....	93
A.12.1	5G NR /TCP Downlink Throughput /Radiated/Fading/VRC.....	93
A.12.1.1	5G NR /TCP Downlink Throughput /Radiated/Fading/VRC/2Rx TDD	93
A.13	5G NR /UDP Downlink Throughput /Radiated for Variable Reference Channel (VRC) Scenarios	97
A.13.1	5G NR /UDP Downlink Throughput /Radiated/Fading/VRC	97
A.13.1.1	5G NR /UDP Downlink Throughput /Radiated/Fading/VRC/2Rx TDD.....	97
Annex B:	Specific Test Conditions and Environment	101
B.1	Upper Layer configurations.....	101
B.1.1	MAC Configurations.....	101
B.1.2	RLC Configuration.....	101
B.1.3	PDCP Configuration.....	101
B.2	UL RMC.....	101
Annex C:	Specific Connection Diagrams	103
Annex D:	Reference Test Points	104
D.1	FR1 Reference Test Points	104
D.2	FR2 Reference Test Points	106
Annex E:	E-UTRA Anchor Configuration for NSA testing Diagrams	106
Annex F:	Embedded Data Client Recommendations.....	107
F.1	Purpose of annex	107
F.2	Embedded Data Client Automation.....	107
F.2.1	Embedded Data Client Functionality	107
F.2.2	Embedded Data Client Provisioning	107
F.2.3	Embedded Data Client Command Set and Operation	108
F.2.3.1	Poll for Task Command.....	108
F.2.3.2	Task List	108
F.2.3.3	Result Reporting	108
Annex G:	Applicability	109
Annex H:	Default message content for Application Layer Data Throughput.....	110
H.1	Radio resource control information elements.....	110
Annex I:	Change history	111
History		114

Foreword

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

The contents of the present document are subject to continuing work within the TSG and may change following formal TSG approval. Should the TSG modify the contents of the present document, it will be re-released by the TSG with an identifying change of release date and an increase in version number as follows:

Version x.y.z

where:

- x the first digit:
 - 1 presented to TSG for information;
 - 2 presented to TSG for approval;
 - 3 or greater indicates TSG approved document under change control.
- y the second digit is incremented for all changes of substance, i.e. technical enhancements, corrections, updates, etc.
- z the third digit is incremented when editorial only changes have been incorporated in the document.

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.

iTeh Standards
(<https://standards.iteh.ai>)
Document Preview

[ETSI TR 137 901-5 V16.13.0 \(2024-10\)](https://standards.iteh.ai/catalog/standards/etsi/95a87afd-9fec-4343-b9b9-0baf0a745c6/etsi-tr-137-901-5-v16-13-0-2024-10)

<https://standards.iteh.ai/catalog/standards/etsi/95a87afd-9fec-4343-b9b9-0baf0a745c6/etsi-tr-137-901-5-v16-13-0-2024-10>

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 consist 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.