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| 3GPP TR 23.700-93 V0.1.0 (2020-06) | |
| Technical Report | |
| 3rd Generation Partnership Project;  Technical Specification Group Services and System Aspects;  Study on Access Traffic Steering, Switch and Splitting support in the 5G system architecture Phase 2(Release 17) | |
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# 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.

# 1 Scope

This Technical Report investigates following aspects for UEs that can establish a MA PDU Session to 5GC over both 3GPP and non-3GPP accesses:

- Whether and how to support additional steering mode(s), with potential PMF extensions if needed.

- Whether and how to support additional steering functionality(ies). Proposed solutions shall be based on IETF protocols or extension of such protocols (i.e. QUIC/MP-QUIC).

- Whether and how to support multi-access PDU session with one 3GPP access leg over EPC and the other access leg over non-3GPP access 5GS.

# 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] IEEE Std 802.11-2012: "IEEE Standard for Information technology - Telecommunications and information exchange between systems - Local and metropolitan area networks - Specific requirements - Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications".

[3] 3GPP TS 23.501: "System Architecture for the 5G System; Stage 2".

[4] 3GPP TS 23.502: "Procedures for the 5G System; Stage 2".

[5] 3GPP TS 23.503: "Policy and Charging Control Framework for the 5G System; Stage 2".

[6] draft-ietf-quic-transport: "QUIC: A UDP-Based Multiplexed and Secure Transport".

Editor's note: The above document cannot be formally referenced until it is published as an RFC.

[7] draft-ietf-quic-recovery: "QUIC Loss Detection and Congestion Control".

Editor's note: The above document cannot be formally referenced until it is published as an RFC.

[8] draft-ietf-quic-datagram: "An Unreliable Datagram Extension to QUIC".

Editor's note: The above document cannot be formally referenced until it is published as an RFC.

[9] draft-piraux-quic-tunnel: "Tunneling Internet protocols inside QUIC".

Editor's note: The above document cannot be formally referenced until it is published as an RFC.

[10] draft-deconinck-quic-multipath: "Multipath Extensions for QUIC (MP-QUIC)".

Editor's note: The above document cannot be formally referenced until it is published as an RFC.

[11] IETF RFC1928. "SOCKS Protocol Version 5".

[12] 3GPP TS 23.316: “Wireless and wireline convergence access support for the 5G System (5GS); Stage 2”

# 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

For the purposes of the present document, the following symbols apply:

<symbol> <Explanation>

## 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 Architectural Assumptions and Requirements

Editor’s note: This clause will list general architectural assumptions and principles for this study.

For all objectives, the architectural requirements and assumption include:

- NG RAN, W-5GAN and any 5G AN shall not be impacted.

- The study is restricted to ATSSS support for traffic routed over one 3GPP access and one non-3GPP access.

- The study uses 5GS Release-16 ATSSS as a starting point: MA PDU Session shall be reused.

- Any additional steering functionality shall be based on IETF protocols or extensions of such protocols (i.e. QUIC/MP-QUIC), any differences from the existing IETF drafts shall be clearly specified and minimized

- the Rel-17 ATSSS work applies also to 5G-RG

For the support of additional steering mode(s) or of additional steering functionality(ies), the architectural requirements and assumptions include also:

- Any additional steering functionalities in the User Plane should reside in UE and UPF as shown in Figure -1 below.



Figure 4-1: Architecture assumption for ATSSS\_Ph2 support

## 4.1 Architecture Assumptions

## 4.2 Architectural Requirements

# 5 Key Issues

Editor’s note: This clause will describe the key issues for the enhancement of Network Slicing.

## 5.1 Key issue #1: Additional Steering Methods

### 5.1.1 Description

This key issue aims to study whether and how to support additional steering methods(s).

Traffic splitting for Ethernet and UDP based traffic is not fully supported in Rel-16: for example, traffic within an UDP/IP flow cannot be split since that would induce high risk of traffic mis-ordering.

NOTE: IETF is actively defining QUIC with the target to have the Core Protocol sent to IESG in July 2020 and planning for a Multipath extension document sent to IESG by end of 2021.

The key issue will study:

- whether and what additional steering methods(s) can be defined for ATSSS\_Ph2, and for these additional steering methods(s)

- how to negotiate the support of additional steering methods(s) between the UE and the network and potentially between NF(s) (e.g. between SMF and UPF)

- how to co-exist with MPTCP and ATSSS-LL from Rel-16

- what to enhance in PCC rules, ATSSS rules and N4 rules to support these additional steering methods(s)

- what type of traffic these new steering method(s) address (e.g. PDU Session type, Ethernet / UDP, whether and how to support latency sensitive and real time traffic, etc.)

If steering methods(s) defined as part of this key issue require new protocol(s) to be defined between the UE and the 5GC, the work on this key issue is to focus only on the usage of QUIC protocol and its extensions from IETF:

- security aspects, e.g. related with QUIC currently mandating usage of TLS 3.0 will be studied in conjunction with SA3;

- work on this key issue may trigger liaisons to IETF.

## 5.2 Key issue #2: Additional Steering Functionalities

### 5.2.1 Description

This key issue aims to study whether and how to support additional steering functionality(ies).

Traffic splitting for Ethernet and UDP based traffic is not fully supported in Rel-16: for example, traffic within an UDP/IP flow may not be split across multiple accesses without introducing out of order packet delivery.

NOTE: IETF is actively defining QUIC with the target to have the core protocol sent to IESG in July 2020 and planning for a Multipath extension document sent to IESG by end of 2021.

The key issue will study:

- whether additional steering functionality(ies) can be defined for ATSSS\_Ph2, and if defined study:

- use cases of traffic splitting for Ethernet and UDP;

- the impact on user plane performance of additional steering functionality(ies);

- how to negotiate the support of additional steering functionality(ies) between the UE and the network and potentially between NF(s) (e.g. between SMF and UPF);

- how it(they) co-exist with MPTCP and ATSSS-LL from Rel-16;

- whether and how to enhance PCC rules, ATSSS rules and N4 rules to support these additional steering functionality(ies);

- what type of traffic these new steering functionality(ies) address, e.g.

- PDU Session type,

- Ethernet / UDP,

- whether and how to support latency sensitive and real time traffic,

- etc.

- UE impacts in order to support additional steering functionality(ies).

If steering functionality(ies) defined require(s) new protocol(s) between the UE and the 5GC, the work will (as per study item scope) focus only on the usage of QUIC protocol and its extensions from IETF, considering the following:

- security aspects, e.g. related with QUIC currently mandating usage of TLS 3.0 for key exchange, authentication, and negotiation of security and performance parameters, will be studied in conjunction with SA3;

- work on this key issue may trigger additional liaison exchanges with IETF.

## 

## 5.3 Key Issue #3: Supporting MA PDU with 3GPP access leg over EPC and Non-3GPP access leg over 5GC

### 5.3.1 Description

This feature is already supported for 5G RG (as defined in TS 23.316 [12] clause 4.12.3) and the Key Issue is to extend the support to Ues in general.

This Key Issue addresses how to support a MA PDU session with its 3GPP access leg over EPC and its non-3GPP access leg over 5GC, including the following aspects:

1. How to establish a MA PDU session with its 3GPP access leg over EPC and its non-3GPP access leg over 5GC?

2. How to replace the 3GPP access leg of a MA PDU session (i.e. both access legs over 5GC) with a 3GPP access leg over EPC, or vice-versa?

3. Whether and how to enhance NAS signalling including ATSSS rules, PCC rules, and/or N4 rules to support traffic steering over both EPC and 5GC?

4. Identify gaps (if any) of the existing Rel-16 ATSSS interworking support for 5G-RG to support UEs in general. Additional solutions are not precluded but re-use of the Rel-16 solution is preferred assuming it meets the requirements.

NOTE: MA PDU session with its non-3GPP access leg over EPC is not in the scope of FS\_ATSSS\_Ph2.

## Impacts to R16.MME and SGW shall be minimized.

## 5.X Key Issue #<X>: <Key Issue Title>

### 5.X.1 Description

# 6 Solutions

## 6.0 Mapping Solutions to Key Issues

Table 6.0-1: Mapping of Solutions to Key Issues

|  |  |  |
| --- | --- | --- |
| Solutions | Title | Key Issue(s) |
| #1 | QUIC-LL Steering Functionality | 2 |
| #2 | New steering mode – Autonomous steering mode | 1 |
| #3 | New steering mode – Autonomous steering mode with advanced PMF | 1 |
| #4 | New steering mode – Redundant steering mode | 1 |
| #5 | Replacing 3GPP access leg of MA-PDU Session with PDN connection in EPC | 3 |
| #6 | MPQUIC-LL Steering Functionality | 2 |
| #7 | Proposed solution based on MP-QUIC | 2 |

## 6.1 Solution #1: QUIC-LL Steering Functionality

### 6.1.1 Introduction

This clause defines a new ATSSS steering functionality called QUIC-Low Layer (QUIC-LL). It is a "Low Layer" steering functionality because it operates below the IP layer (such as ATSSS-LL), in contrast to a high layer steering functionality that operates above the IP layer (such as MPTCP).

The QUIC-LL provides an unreliable tunneling service between the UE and the UPF that is based on:

1. The QUIC protocol specified in *draft-ietf-quic-transport* [6] along with the loss detection and congestion control specified in *draft-ietf-quic-recovery* [7]; and

2. The QUIC extensions specified in *draft-ietf-quic-datagram* [8] for supporting unreliable datagram transport.

Editor's note: It is FFS if the tunneling mechanisms in *draft-piraux-quic-tunnel* [9] need to be considered.

Editor’s note: Whether the QUIC-LL can support reliable transport (i.e. using QUIC streams) is FFS.

Editor's note: it is FFS whether network bandwidth overhead and packet processing overhead caused by additional headers in the solution are significant or not.

Editor's note: the benefit of using QUIC-LL over using ATSSS-LL should be clarified.

### 6.1.2 Overview of QUIC-LL

The following list provides a brief overview of how QUIC-LL operates and how it is applied to support ATSSS in a MA PDU Session.

1. During the establishment of the MA PDU Session, the UE indicates whether it supports QUIC-LL and the network selects whether QUIC-LL will be used for routing (some or all) traffic of the MA PDU Session across 3GPP and non-3GPP accesses.
2. If the network selects to apply the QUIC-LL steering functionality for the MA PDU Session, then, after the establishment of the MA PDU Session, the UE ensures there are *N* QUIC connections over 3GPP access and *N* QUIC connections over non-3GPP access, where *N* is the number of QoS flows of the MA PDU Session.

Editor’s note: It is FFS if a QUIC connection between the UE and UPF is created right after the establishment of the MA PDU Session (as stated above), or when data arrives for this QUIC connection.

Editor’s note: It is currently assumed that the QoS flows of the MA PDU Session are bidirectional. In case there are downlink-only QoS flows, it is FFS how the QUIC connections for these QoS flows are established.

1. Each QUIC connection is mapped to one QoS flow. So, if for example two QoS flows are assigned to the MA PDU Session (as shown Fig. 6.X.2-1), then two QUIC connections are established between the UE and the UPF over 3GPP access and two QUIC connections are established between the UE and the UPF over non-3GPP access.

Editor’s note: How a QUIC connection is mapped to a QoS flow needs further clarification. More generally the interactions between QoS rules and QUIC connections are FFS.

NOTE 1: The QUIC protocol can multiplex several PDUs in a single QUIC packet. By using a separate QUIC connection for each QoS flow, we ensure that PDUs belonging to different QoS flows cannot be multiplexed in the same QUIC packet.

1. Each QUIC connection carries a sequence of QUIC packets and each QUIC packet carries one or more datagram frames (defined in *draft-ietf-quic-datagram* [8]). Each datagram frame encapsulates one PDU that is transmitted via the MA PDU Session. When the type of the MA PDU Session is “ethernet”, each PDU is an Ethernet frame, when the type of the MA PDU Session is “IPv4”, each PDU is an IPv4 packet, etc.
2. Each QUIC connection provides an unreliable transport service between the UE and the UPF, hence, it can carry any type of protocol traffic, such as UDP, TCP, SCTP, ICMP for IP PDU Session type, Ethernet, ARP for Ethernet PDU Session type, etc.
3. The QoS rules in the UE are used to steer the traffic of each QUIC connection to the associated QoS flow.
4. After the establishment of the QUIC connections between the UE and the UP:
   1. The UE applies the ATSSS rules to (a) steer each PDU (e.g. IP packet or Ethernet frame) to a specific access, and then (b) to steer each PDU to a specific QUIC connection on this access.
   2. The UPF applies the N4 rules in a similar way.

Editor's note: R16 UP processing does not require QoS selection before access selection. It is FFS whether the order of actions above: a) steer each to a specific QoS (MPQUIC connection), and then (b) to select the access fits with UP processing per N4 rules.

Editor's note: The UDP ports shown in Fig. 6.1.2-1 which are used per QUIC connection need further work.



Fig. 6.1.2-1: Tunneling MA PDU traffic via different QUIC connections

1. Fig. 6.1.2-2 explains (via an example) how the QUIC-LL steering functionality is applied to route the traffic of an MA PDU Session:
   1. The UE is assigned with three IP addresses: The IP@3, which is the IP address of the MA PDU Session, and two link-specific IP addresses, one for 3GPP access (IP@1) and one for non-3GPP access (IP@2). The scope of the link-specific IP addresses is local, i.e. they are used only for UE-UPF communication.
   2. In the example scenario shown in Fig. 6.1.2-2, it is assumed that two QoS flows are assigned to the MA PDU Session. Hence, the UE uses the IP@1 to establish two QUIC connections to UPF over 3GPP access and uses the IP@2 to establish two QUIC connections to UPF over non-3GPP access.
   3. On the UE side, each IP packet that enters the IP interface associated with the MA PDU Session:
      1. First, goes though an Access Selection, which selects the access on which the packet should be transmitted. This selection is based on the ATSSS rules and the measurements (e.g. RTT, loss rate, etc.) received by the QUIC protocol.
      2. Next, the IP packet goes through the QUIC Connection Selection (QCS), which sends the IP packet to a specific QUIC connection over the selected access. The QUIC connection is selected based on the ATSSS rules (see the QUIC Connection Selection Descriptor in the example ATSSS rules in Fig. 6.1.3-2).

Editor's note: It is currently assumed that a QUIC connection is selected based on the ATSSS rules. It is FFS if a QUIC connection can be selected based on the QoS rules.

* + 1. Finally, the IP packet goes through the QUIC protocol. It is encapsulated in a QUIC packet (possibly with other IP packets of the same QUIC connection) that has confidentiality and integrity protection and goes to an access interface (3GPP or non-3GGP) via the UDP/IP layers. The outer IP packet has source address IP@1 or IP@2 and destination address an IP address of UPF, which is provided to UE during the MA PDU Session establishment.

NOTE 2: Fig. 6.1.2-2 shows two instances of QCS and two instances of the QUIC protocol (one for each access). However, this is only for illustration purposes. In a real implementation, one QCS and one QUIC protocol instance could be used.

NOTE 3: The QCS is like an application that sends unreliable datagrams over one or more QUIC connections.

1. Normally, the QUIC-LL steering functionality does not split the packets of an IP flow (defined by a 5-tuple) across the two accesses. It is feasible to split an IP flow across the two accesses but, in this case, the QUIC-LL may not be able to avoid out-of-order delivery. Layers above the QUIC-LL (e.g. the application layer) could handle the out-of-order delivery. Note that QUIC Datagram frames are not retransmitted upon loss detection (see draft-ietf-quic-datagram [8]), hence, duplications are not possible.

Editor’s note: If the QUIC-LL creates out-of-order delivery, the value of QUIC-LL vs the ATSSS-LL should be further clarified.

1. The QUIC-LL can transfer an IP flow from one access to another access according with the ATSSS rules and the measurements (e.g. RTT) received from the QUIC protocol. For example, the blue IP flow in Fig. 6.1.2-2 can be transferred from QUIC connection #4 over 3GPP access to QUIC connection #2 over non-3GPP access, when the Access Selection determines e.g. that the RTT of QUIC connection #4 is higher than the RTT of QUIC connection #2. Note that when an IP flow is transferred to another access, the QoS flow used for this IP flows remains the same.



Fig. 6.1.2-2: Example of User-Plane operation (UL direction)

1. In summary, the QUIC-LL:
   1. Supports an unreliable and secure tunneling service between the UE and UPF.
   2. Does not support retransmission of lost QUIC datagram frames but supports loss detection, according to *draft-ietf-quic-datagram* [6].
   3. Supports congestion control per QUIC connection, i.e. it employs the QUIC connection's congestion controller. As a result, the UE and the UPF may stop sending datagram frames on a QUIC connection when congestion is detected by the QUIC protocol on this connection.
   4. Supports round-trip and packet loss measurements per QUIC connection, as specified in *draft-ietf-quic-transport* [6]. Since each QUIC connection is transmitted on a specific QoS flow, this means that QUIC-LL supports round-trip measurements per QoS flow and packet loss measurements per QoS flow.

Editor's note: As described above, the QUIC-LL steering functionality is not required to apply some QUIC protocol capabilities, such as connection migration, reliable streams, etc. It is FFS whether such capabilities are required for QUIC-LL.

Editor's note: It is FFS whether this solution needs double-layer security between the UE and the 5GS (radio level security + QUIC mandatory security). If that is the case, it needs to be clarified how QUIC/DTLS security is set-up.

### 6.1.3 Establishment of MA PDU Session using MPQUIC-LL

The following figure shows how an MA PDU Session using QUIC-LL can be established. It is based on the existing MA PDU Session establishment procedure defined in TS 23.502 [] clause with some additions shown in red.



Fig. 6.1.3-1: Enhancement of MA PDU Session Establishment for QUIC-LL support

The following Fig. 6.1.3-2 shows an example of PCC rules provided by PCF to SMF in step 5b and illustrates how the SMF can derive the corresponding ATSSS rules and QoS rules for the UE. In a similar way, the SMF derives also N4 rules from the PCC rules.

Editor's note: The contents of the QUIC Connection Selection Descriptor (i.e. how the traffic of a specific QUIC connection is identified) need to be further studied.



Fig. 6.1.3-2: Example of PCC rules and ATSSS rules/QoS rules derived from the PCC rules

### 6.1.4 Impacts on services, entities, interfaces and IETF protocols

Editor's note: it is FFS the evaluation of the impacts of this solution on services, entities, interfaces and IETF protocols.

## 6.2 Solution #2: New steering mode - Autonomous steering mode

### 6.2.1 General

This solution addresses KI#1 on Additional Steering Modes.

As specified in ATSSS Rel-16, the traffic of MA PDU session could be distributed across both accesses by using different steering modes. There are four steering modes as defined in R16, i.e. Active-Standby, Smallest Delay, Priority-based and Load balancing. All the R16 steering modes are decided by the network side, and performed by the UE and UPF based on the link performance measurement. For example, if one access becomes unavailable, the UE and UPF can switch all the traffic to the other available access. However, except the access available/unavailable status, the UE and UPF cannot flexibility distribute the traffic over both accesses according to the link performance in real time. To be more specific, for the Load balancing mode, the traffic splitting weight is statically set by the network based on the operators’ requirement instead of the link performance measurement. For the Priority-based mode, the traffic can take over both access resources only when one access is congested. In sum, both of these steering modes do not allow the UE or the UPF to adjust the traffic splitting weight over both accesses dynamically based on the link status, not even mention Active-Standby and Smallest Delay.

### 6.2.2 Solution description

This steering mode, called Autonomous steering mode, provides to both the UE and the UPF flexibility on the traffic splitting control when two accesses are applicable for this traffic. See Figure 6.2.2-1 for details, where one single packet flow is shown as an example for UL and DL respectively. The weight factor for the traffic over each access, e.g. 30% for UL and 50% for DL on 3GPP access, and 70% for UL and 50% for DL on non 3GPP access, as shown in the figure, is decided by the UE and the UPF independently for both UL and DL, subject to link status.



Figure 6.2.2-1: Autonomous steering mode

Editor’s Note: it is FFS whether this steering mode applies to MPTCP, ATSSS-LL, (MP)QUIC steering methods

### 6.2.3 Procedures

Editor's note: This clause describes services and related high-level procedures for the solution.

### 6.2.4 Impacts on existing entities, interfaces and IETF Protocols

This solution will impact the following entities in 5GS:

- SMF: Supports to select the UPF with support of the new steering mode.

- PCF: Supports to authorize the new steering modes for the SDF

- UPF: Supports the new steering modes

- UE: Supports the new steering modes.

- 5G-AN/ NG RAN: No impact.

## 6.3 Solution #3: New steering mode - Autonomous steering mode with advanced PMF

### 6.3.1 General

This solution is like solution #2 but with advanced link performance measurement function (PMF)

To support these new steering modes, the link performance measurement function (PMF) defined in Rel-16 needs to be enhanced. The Rel-16 PMF can support the RTT measurement and access availability report per PDU session. Regarding the RTT measurement, a default QoS flow is used to transport the measurement traffic, and the RTT value detected on this QoS flow is treated as the RTT for this PDU session via this access. Obviously, it cannot reflect the accurate RTT for every traffic in this PDU session via this access. For some latency sensitive service traffic, the RTT measurement per QoS flow is needed. Furthermore, except the RTT, the loss ratio and jitter are also valuable to be measured for decision of the link performance, and consequently enable better traffic steering/switching/splitting. At the same time, some thresholds corresponding to these parameters, such as Maximum RTT, Maximum UL/DL Packet Loss Rate and jitter, can be sent to the UE and the UPF for triggering traffic steering/switching/splitting, similar as RAN support information defined for 3GPP access supporting the RAN for handover threshold decision.

The solution describes following different features

* RTT measurement per QoS flow
* Packet loss ratio measurement per QoS flow,
* Jitter measurement per QoS flow,
* Thresholds for traffic steering/switching/splitting

These features may be independently selected for normative phase.

### 6.3.2 Enhancement on link performance measurement

The Rel-16 PMF is enhanced to support the RTT measurement per QoS flow, and to support measurement of the loss ratio and jitter per QoS flow, with both the UE and the UPF sending PMF messages per QoS flow.

Editor’s Note: it is FFS for which steering methods these PMF enhancement are needed

1. RTT measurement per QoS flow

Same as in Rel-16, when an MA PDU Session is established, the network may provide the UE with Measurement Assistance Information.

The RTT measurement per QoS flow may be triggered by UE or the UPF independently. The Measurement Assistance Information contains the QFI(s) for which the RTT measurement is to be applied. Optionally, the RTT measurement frequency can also be decided by the network side and sent to UE if available via Measurement Assistance Information.

The following mechanism is used.

In the case of the MA PDU session of IP type:

- The PMF in the UE sends PMF messages via one QoS flow to the PMF in the UPF over UDP/IP. The destination IP address and UDP port are as defined in Rel-16, i.e. the destination IP address is the PMF IP address, and the UDP port number corresponds to the access via which this message is sent. When the message is received by the UPF, the UPF can identify the PMF message based on the destination IP address.

- The PMF in the UPF sends PMF messages to the PMF in the UE over UDP/IP. The source IP address is the same IP address as the one provided in the Measurement Assistance Information and the source UDP port is one of the two UDP ports as provided in the Measurement Assistance Information as defined in R16. The destination IP address is the MA PDU session IP address allocated by the UE, and the UDP port is also sent by the UE via user plane after the MA PDU session establishment as defined in R16. When the message is received by the UE, the UE can identify the PMF message based on the source IP address of the PMF.

In the case of the MA PDU session of Ethernet type:

- The PMF in the UE sends PMF messages to the PMF in the UPF over Ethernet. The destination MAC address is included in the Measurement Assistance Information as defined in R16. Then the UPF can identify the PMF message based on the destination MAC address.

- The PMF in the UPF sends PMF messages to the PMF in the UE over Ethernet. The source MAC address and destination MAC address are as defined in R16. Then the UE can identify the PMF message based on the source MAC address.

The UE and the UPF derive an estimation of the average RTT over an access type by averaging the RTT measurements obtained over this access.

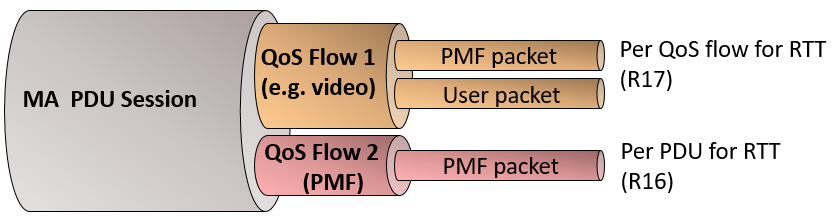


Figure 6.3.2-1: RTT measurement in R16 and enhancement for R17

It is not suggested to perform the RTT measurement for GBR QoS flow, considering the QoS parameters for GBR traffic are guaranteed, and the GBR traffic is only transported via one access resulting in no comparing with the other path RTT value.

Comparing with the RTT measurement per PDU session as defined in R16, this solution makes the RTT measurement more accurate. Because even for the non-GBR QoS flow, different QoS flow corresponding to the different 5QI has the different packet delay budget requirement, quote from TS 23.501 Table 5.7.4-1. For example, when the 5QI=5, the packet delay budget is 100ms, but if the 5QI=6, the packet delay budget is equal to 300 ms, three times than 5QI=5. Therefore it is incorrect to use one non-GBR QoS flow RTT representing all the other non-GBR QoS flows.

1. Packet loss ratio measurement per QoS flow, the same mechanism as described in the TR 23.793 subclause 6.3.1.4

UE and UPF exchange the packet counting information in certain period to calculate the packet loss ratio during the path performance measurement procedure.

- The UE counts the number of UL packets via one QoS flow between one PMF request message and the previous PMF echo request message, and provides the result to the UPF via this PMF request message.

- UPF also counts the number of received UL packets between one PMF request message and the previous PMF request message via one QoS flow. UPF calculates the UL packet loss ratio based on the local counting result and the number of UL packets send by UE.

- UPF sends the UL packet loss ratio result to the UE via PMF response message. In the same message, it can also include the counting number of DL packets between one PMF response message and the previous PMF response message if the DL packets loss ratio is measured.

- UE counts the number of received DL between one PMF response message and the previous PMF response message. The UE calculates the DL packet loss ratio based on the local counting result and the number of DL packets send by UPF, and sends the DL packet loss ratio to the UPF via the subsequent PMF message.

Editor’s Note: it is FFS whether the “between one PMF request message” corresponds to a dedicated PM message sent by a PMF peer to request Packet loss ratio measurement per QoS flow.

1. Jitter measurement per QoS flow, the same mechanism as described in the TR 23.793 subclause 6.3.1.4.

Jitter is regarded as the reflection of transfer quality stability within certain time interval. The UL jitter could be calculated by the UPF, and the DL jitter could be calculated by the UE. The following solution is an example method for calculating the UL jitter per QoS flow, and the DL jitter could be calculated using the similar method.

- It is assumed to calculate the jitter between one PMF request message and the Nth PMF request message after this certain PMF request message received by the UPF.

These continuous PMF request message could be numbered from n-N+1 to n.

The average expectation value of arriving time interval between any two PMF requests could be represented as Avg(n).

The value of variance of arriving time interval of N PMF echo request could be represented as .

In this example, the is regarded as the packet transport jitter for the corresponding QoS Flow. It is assumed that is the local time of UPF when receiving the PMF request message numbered by variable k between n-N+1 and n.

,

Editor’s note: How the PMF peer (sender) knows how to send PMF request messages (e.g. how frequently and with what QoS class) in order to allow the other PMF peer (receiver) to measure the jitter is FFS.

NOTE：The jitter measurement precision depends on the number of PMF messages sent within a certain time interval. It can be decided based on the requirement of the traffic. For example, the microsecond-level latency-sensitive services will need more PMF messages sent in a certain period than the millisecond-level delay-sensitive services.

### 6.3.3 Thresholds for traffic steering/switching/splitting

Some thresholds, such as Maximum RTT, Maximum UL/DL Packet Loss Rate and/or jitter, are provided to the UE and the UPF for triggering traffic steering/switching/splitting, similar as RAN support information defined for 3GPP access supporting the RAN for handover threshold decision.

In the existing specification, RAN support information is defined for 3GPP access supporting the RAN for handover threshold decision, quote from TS 23.503 subclause 6.3.1:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **RAN support information** | *This part defines information supporting the RAN for e.g. handover threshold decision.* |  |  |  |
| UL Maximum Packet Loss Rate | The maximum rate for lost packets that can be tolerated in the uplink direction for the service data flow. It is defined in TS 23.501 [2], clause 5.7.2.8. | Conditional (NOTE 13) | Yes | None |
| DL Maximum Packet Loss Rate | The maximum rate for lost packets that can be tolerated in the downlink direction for the service data flow. It is defined in TS 23.501 [2], clause 5.7.2.8. | Conditional (NOTE 13) | Yes | None |

Similarly, the PCF can provide the Maximum RTT, UL/DL Maximum Packet Loss Rate and jitter threshold paramters to the SMF, and SMF will forward these parameters to the UE and UPF via ATSSS rule or MAR rule. The threshold can be provided per QoS flow, working together with the link performance measurement per QoS flow as defined in subclause xxx. It can be applied to both the MPTCP functionality and ATSSS-LL functionality if the PMF is enhanced to support the RTT, loss rate and jitter measurement per QoS flow as defined in subclause 6.3.2.

* The *Maximum RTT* indicates parameter for the decision of access availability via 3GPP access and non-3GPP access, i.e. the maximum RTT threshold that can be tolerated in the round trip for the QoS flow.
* The *UL Maximum Packet Loss Rate* indicates parameters for the decision of UL access availability via 3GPP access and non-3GPP access, i.e. the maximum rate for lost packets that can be tolerated in the uplink direction for the QoS flow.
* The *DL Maximum Packet Loss Rate* indicates parameters for the decision of DL access availability via 3GPP access and non-3GPP access, i.e. the maximum rate for lost packets that can be tolerated in the downlink direction for the QoS flow.
* The *UL Maximum jitter* indicates parameters for the decision of UL access availability via 3GPP access and non-3GPP access, i.e. the maximum jitter that can be tolerated in the uplink direction for the QoS flow.
* The *DL Maximum jitter* indicates parameters for the decision of DL access availability via 3GPP access and non-3GPP access, i.e. the maximum jitter that can be tolerated in the uplink direction for the QoS flow.

The Maximum RTT, UL Maximum Packet Loss Rate or DL Maximum Packet Loss Rate parameters for 3GPP and non-3GPP access can be provided separately. If the parameters for non-3GPP access are not included in the PCC rule, the corresponding values for 3GPP access apply.

Taking the redundancy steering mode as an example by using the above thresholds, if one access packet loss rate does not reach the UL/DL Maximum Packet Loss Rate, then only one access is applied to transport the traffic. But when one access packet loss rate is equal to or higher than the UL/DL Maximum Packet Loss Rate, then the redundancy transmission mode is triggered, till one access performance is improved.

NOTE： These thresholds can also be applied to existing steering modes, such as Priority-based steering mode, Active-Standby steering mode.

Editor’s Note: It is FFS whether the above thresholds are applicable to GBR or non GBR or both.

### 6.3.4 Impacts on existing entities, interfaces and IETF Protocols

This solution will impact the following entities in 5GS:

- SMF: Supports to select the UPF with support of the new steering modes.

- PCF: Supports to authorize the new steering modes for the SDF

- UPF: Supports the new steering modes and the enhancement of the PMF.

- UE: Supports the new steering modes and the enhancement of the PMF.

- 5G-AN/ NG RAN: No impact.

## 6.4 Solution #4: New steering mode - Redundant steering mode

### 6.4.1 General

This solution addresses KI#1 on Additional Steering Modes.

### 6.4.2 Solution description.

During Rel-16 ATSSS study, the redundancy steering mode is documented (see subclause 6.3.1.1, 6.4.1 in the TR 23.793) for the loss rate sensitive traffic, such as IMS singling, video, and some TCP-based traffic. It allows the traffic transmitted via 3GPP and non-3GPP accesses in a redundant way to achieve the lowest latency and lower the loss rate. It is proposed to further enhance the redundancy steering mode as described in the TR 23.793, with which the traffic will always be transmitted over both accesses once applied, to make it possible that the traffic transmission goes via both accesses if necessary or via only one access to save the transport resource. In details, when the traffic is allowed on both accesses, the UE and the UPF can decide to transport the traffic via one access or both accesses based on the link performance measurement (e.g. based on the packet loss rate and the threshold of the loss rate). For example, if the loss rate on one access does not exceed the threshold, then only this one access is applied, otherwise, redundant transmission is triggered. Especially, the redundancy transmission solution may be triggered during the traffic switching phase to avoid the packet lost in the handover procedure. See below Figure 6.4.2-1 for details, where UL packet flow is taken as an example. The DL shares the same mechanism.

Editor’s Note: it is FFS whether this steering mode applies to MPTCP, ATSSS-LL, (MP)QUIC steering methods



Figure 6.4.2-1: Redundancy steering mode

The enhancement on link performance measurement as described in the subclause 6.3.2 and definition of thresholds for traffic steering/switching/splitting in the subclause 6.3.3 are also applicable to this Redundancy steering mode.

### 6.4.3 Impacts on existing entities, interfaces and IETF Protocols

This solution will impact the following entities in 5GS:

- SMF: Supports to select the UPF with support of the new steering mode.

- PCF: Supports to authorize the new steering mode for the SDF.

- UPF: Supports the new steering mode and the enhancement of the PMF.

- UE: Supports the new steering mode and the enhancement of the PMF.

- 5G-AN/ NG RAN: No impact.

## 6.5 Solution #5: Replacing 3GPP access leg of MA-PDU Session with PDN connection in EPC

### 6.5.1 Introduction

This solution enables a capable UE and network to replace the 3GPP access leg of a normal MA PDU Session with a PDU connection in EPC, while keeping the non-3GPP access leg in 5GC.

Editor's note: it is FFS to describe the benefit of creating a new solution with regard to adapting the solution defined in 23.316 [12] § 4.12.3 to other devices than 5G RG

### 6.5.2 High-level Description

In this solution, it is assumed that the UE is able to attach to the EPC over E-UTRAN and simultaneously register with the 5GC over non-3GPP access. Initially, the UE is registered with 5GC via both 3GPP access and non-3GPP access and has established a MA-PDU Session with UP resources for both 3GPP access and non-3GPP access in 5GC.

Editor's note: The UE may also establish from scratch a MA PDU with 3GPP access leg in EPC, i.e. without pre-existence of a normal MA-PDU. This case is not covered in this solution and may be addressed by other solutions.

For brevity, the scenario of 5GS to EPS mobility in IDLE mode without N26 interface is used to describe the solution.

The UE may indicate its support for 3GPP access leg in EPC for a MA-PDU Session as part of ATSSS capability during the MA-PDU Session establishment. If the network also supports it, and based on the network local policies, the network may indicate that the MA-PDU Session is allowed to have its 3GPP access leg replaced by a PDN connection in the EPC.

During the 5GS to EPS mobility procedure, for the MA-PDU Session which is allowed to have 3GPP access leg in EPC, the UE may provide an indication of “MA PDU Request”, in addition to MA-PDU Session ID in PCO, in the UE initiated PDN Connectivity request (Step 13 of Figure 4.11.2.2.-1 in TS 23.502). The “MA PDU Request” indicates that the UE requests to keep the PDN Connection as the 3GPP access leg of the original MA PDU Session. If this is accepted by the network, the PGW-C/SMF should not release the UP resources of the non-3GPP access leg in 5GC.

After the PDN Connection is successfully established in the EPC, the network may initiate the session modification procedure with the PGW-U/UPF to associate the PDN Connection with the MA-PDU Session and modify the forwarding rules. The network may also initiate PDU Session Modification procedure in the 5GC over non-3GPP access. The network indicates to the UE that the 3GPP access leg of the MA-PDU Session has been replaced by the PDN connection. The UE then locally associates the PDN connection as the 3GPP access leg of the MA-PDU Session. The network may also update the ATSSS rules over the 5GC non-3GPP access.

At this point, the original MA PDU Session is converted to a new MA PDU Session with the 3GPP access leg in EPC. In the uplink, for the data associated with the PDN connection, if the PDN connection is part of a MA PDU Session, the UE further checks the ATSSS rules and according to the rules, the UE may steer the data toward the PDN connection in EPC, or non-3GPP connection in 5GC.

When the UE moves back from the EPS to 5GS, the UE may re-establish the MA-PDU Session over 3GPP access of 5GC.

### 6.5.3 Procedures



Figure 6.5.3-1: Replacing 3GPP access leg of MA PDU Session with PDN connection in EPC

Step 1: The UE is registered in the 5GS over both 3GPP access and non-3GPP access.

Step 2: The UE established a normal MA PDU Session in 5GS, with UP resources in 5G for both 3GPP access and non-3GPP access.

Step 3: The UE moves from 5GS to EPS due to mobility.

Step 4: Steps 1-12 of Figure 4.11.2.2-1 in TS 23.502.

Editor’s Note: Figure 4.11.2.2-1 in TS 23.502 refers to Interworking procedures without N26 interface. It is FFS whether SR mode with N26 is supported by the solution

Step 5: in Step 13 of Figure 4.11.2.2-1 in TS 23.502, the UE provides additional indication of “MA PDU request” (e.g. in PCO), and optionally with the MA-PDU Session ID. This indication informs the network that the UE hopes to keep the PDN Connection as the 3GPP access leg of the MA PDU Session.

If the MA-PDU session is the only PDU Session that needs to be handed over to the EPS, Step 5 may be realized in the PDN Connectivity Request combined in EPS Attach procedure of Step 4. And in this case Step 5 is not needed.

The network answers to the UE request

Step 6: if the network accepts the PDN Connection as the 3GPP access leg of the MA PDU Session, the PGW-C+SMF initiate the N4 session modification procedure to associate the PDN Connection with the MA-PDU Session and modify the forwarding rules accordingly.

Step 7: the network may optionally initiate the PDU Session Modification procedure over the non-3GPP access of 5GS and informs the UE that the 3GPP access leg of the MA PDU Session has been replaced by the PDN connection. The UE locally associates the PDN connection with the MA PDU Session. The network may also update the ATSSS rules to make them more adapted to the new MA PDU Session with one leg in EPC.

Editor’s Note: Step 7 is FFS

### 6.5.4 Impacts on services, entities, interfaces and IETF Protocols

FFS.

## 6.6 Solution #6: MPQUIC-LL Steering Functionality

### 6.6.1 Introduction

This clause defines a new ATSSS steering functionality called MPQUIC-Low Layer (MPQUIC-LL). It is a "Low Layer" steering functionality because it operates below the IP layer (such as ATSSS-LL), in contrast to a high layer steering functionality that operates above the IP layer (such as MPTCP).

The MPQUIC-LL provides a multipath unreliable tunneling service between the UE and the UPF that is based on:

1. The QUIC protocol specified in *draft-ietf-quic-transport* [6] along with the loss detection and congestion control specified in *draft-ietf-quic-recovery* [7];

2. The QUIC extensions specified in *draft-deconinck-multipath-quic* [10] for supporting multipath QUIC;

3. The QUIC extensions specified in *draft-ietf-quic-datagram* [8] for supporting unreliable datagram transport.

Editor's note: It is FFS if the tunneling mechanisms in *draft-piraux-quic-tunnel* [9] need to be considered.

Editor's note: it is FFS whether network bandwidth overhead and packet processing overhead caused by additional headers in the solution are significant or not.

Editor's note: the benefit of using MPQUIC-LL over using ATSSS-LL should be clarified.

### 6.6.2 Overview of MPQUIC-LL

The following list provides a brief overview of how MPQUIC-LL operates and how it is applied to support ATSSS in a MA PDU Session.

1. During the establishment of the MA PDU Session, the UE indicates whether it supports MPQUIC-LL and the network selects whether MPQUIC-LL will be used for routing (some or all) traffic of the MA PDU Session across 3GPP and non-3GPP accesses.
2. If the network selects to apply the MPQUIC-LL steering functionality for the MA PDU Session, then, after the establishment of the MA PDU Session, the UE ensures there are *N* MPQUIC connections with the UPF, where *N* is the number of QoS flows of the MA PDU Session. An example scenario is shown in Fig. 6.X.2-1.

Editor’s note: It is FFS if a MPQUIC connection between the UE and UPF is created right after the establishment of the MA PDU Session (as stated above), or when data arrives for this MPQUIC connection.

Editor’s note: It is currently assumed that the QoS flows of the MA PDU Session are bidirectional. In case there are downlink-only QoS flows, it is FFS how the MPQUIC connections for these QoS flows are established.

1. Each MPQUIC connection is mapped to one QoS flow. So, if for example two QoS flows are assigned to the MA PDU Session (as shown Fig. 6.6.2-1), then two MPQUIC connections are established between the UE and the UPF.

NOTE 1: The MPQUIC protocol can multiplex several PDUs in a single QUIC packet. By using a separate MPQUIC connection for each QoS flow, we ensure that PDUs belonging to different QoS flows cannot be multiplexed in the same QUIC packet.

Editor’s note: How a MPQUIC connection is mapped to a QoS flow needs further clarification. More generally the interactions between QoS rules and MPQUIC connections are FFS.

1. Each MPQUIC connection between the UE and UPF has two MPQUIC uniflows over 3GPP access (one UL and one DL uniflow) and two MPQUIC uniflows over non-3GPP access (one UL and one DL uniflow). As specified in *draft-deconinck-multipath-quic* [10], a uniflow is a “unidirectional flow of packets between a QUIC host and its peer. This flow is identified by an internal Uniflow ID.”
2. Each MPQUIC uniflow carries a sequence of QUIC packets and each QUIC packet carries one or more datagram frames (defined in *draft-ietf-quic-datagram* [8]). Each datagram frame encapsulates one PDU that is transmitted via the MA PDU Session. When the type of the MA PDU Session is “ethernet”, each PDU is an Ethernet frame, when the type of the MA PDU Session is “IPv4”, each PDU is an IPv4 packet, etc.
3. Each MPQUIC connection provides a multipath unreliable transport service between the UE and the UPF, hence, it can carry any type of protocol traffic, such as UDP, TCP, SCTP, ICMP for IP PDU Session type, Ethernet, ARP for Ethernet PDU Session type, etc.
4. The QoS rules in the UE are used to steer the traffic of each uniflow of a MPQUIC connection to the associated QoS flow.
5. After the establishment of the MPQUIC connections between the UE and the UP:
   1. The UE applies the ATSSS rules to (a) steer each PDU (e.g. IP packet or Ethernet frame) to a specific MPQUIC connection, and then (b) to steer each PDU to a specific MPQUIC uniflow, i.e. either on 3GPP access or on non-3GPP access.
   2. The UPF applies the N4 rules in a similar way.

Editor's note: R16 UP processing does not require QoS selection before access selection. It is FFS whether the order of actions above: a) steer each to a specific QoS (MPQUIC connection), and then (b) to select the access fits with UP processing per N4 rules.

Editor's note: The UDP ports shown in Fig. 6.6.2-1 which are used per MPQUIC connection need further work.



Fig. 6.6.2-1: Tunneling MA PDU traffic via different MPQUIC connections

1. Fig. 6.6.2-2 explains (via an example) how the MPQUIC-LL steering functionality is applied to route the traffic of an MA PDU Session:
   1. The UE is assigned with three IP addresses: The IP@3, which is the IP address of the MA PDU Session, and two link-specific IP addresses, one for 3GPP access (IP@1) and one for non-3GPP access (IP@2). The scope of the link-specific IP addresses is local, i.e. they are used only for UE-UPF communication.
   2. In the example scenario shown in Fig. 6.6.2-2, it is assumed that two QoS flows are assigned to the MA PDU Session, hence, two MPQUIC connections are established between the UE and the UPF. The UE uses the IP@1 to establish MPQUIC UL uniflows to UPF over 3GPP access and it uses the IP@2 to establish MPQUIC UL uniflows to UPF over non-3GPP access. Similarly, the UPF uses the IP@1 to establish MPQUIC DL uniflows to UE over 3GPP access and it uses the IP@2 to establish MPQUIC DL uniflows to UE over non-3GPP access.
   3. On the UE side, each IP packet that enters the IP interface associated with the MA PDU Session:
      1. First, goes through the MPQUIC Connection Selection (MQCS), which sends the IP packet to a specific MPQUIC connection. The MPQUIC connection is selected based on the ATSSS rules (see the MPQUIC Connection Selection Descriptor in the example ATSSS rules in Fig. 6.X.3-2).
      2. Next, the IP packet goes through the MPQUIC protocol, which selects the MPQUIC UL uniflow for this packet. The selected MPQUIC UL uniflow indicates the access (3GPP or non-3GPP) over which the IP packet will be transmitted. The MPQUIC protocol selects the MPQUIC UL uniflow based on the steering mode (e.g. active/standby, smallest delay, etc.) in the ATSSS rules.
      3. Finally, the IP packet is encapsulated in a QUIC packet (possibly with other IP packets of the same MPQUIC connection) with confidentiality and integrity protection and goes to an access interface (3GPP or non-3GGP) via the UDP/IP layers. The outer IP packet has source address IP@1 or IP@2 and destination address an IP address of UPF, which is provided to UE during the MA PDU Session establishment.

NOTE 2: Fig. 6.6.2-2 shows two instances of the MPQUIC protocol (one for each access). However, this is only for illustration purposes. In a real implementation, one MPQUIC protocol instance could be used.

NOTE 3: The MQCS is like an application that sends unreliable datagrams over one or more MPQUIC connections.

1. The MPQUIC-LL steering functionality can route the IP packets having the same 5-tuple to different accesses (or to different uniflows), i.e. it can split an IP flow across the two accesses. This is enabled by the functionality supported by the MPQUIC protocol [10].
2. The MPQUIC protocol can transfer an IP flow from one access to another access according with the ATSSS rules and the obtained measurements (e.g. RTT, loss rate, etc.). When an IP flow is transferred to another access, the QoS flow used for this IP flows remains the same.
3. In summary, the MPQUIC-LL steering functionality:
   1. Supports a multipath, unreliable and secure tunneling service between the UE and UPF.
   2. Does not support retransmission of lost QUIC datagram frames but supports loss detection, according to *draft-ietf-quic-datagram* [6].
   3. Supports congestion control per MPQUIC uniflow, i.e. each uniflow of a MPQUIC connection has its own congestion control state (see *draft-deconinck-multipath-quic* [10]). As a result, the UE and the UPF may stop sending datagram frames on a MPQUIC uniflow when congestion is detected by the MPQUIC protocol on this uniflow.
   4. Supports round-trip and packet loss measurements per MPQUIC uniflow, as specified in *draft-deconinck-multipath-quic* [10]. Since each MPQUIC uniflow is transmitted on a specific QoS flow, this means that MPQUIC-LL supports round-trip measurements per QoS flow and packet loss measurements per QoS flow.



Fig. 6.6.2-2: Example of User-Plane operation (UL direction)

Editor's note: it is FFS whether the solution implies a double security between the UE and the 5GS (access level security + QUIC mandatory security). If that is the case, it needs to be clarified how QUIC/DTLS security is set-up.

### 6.6.3 Procedures, Architecture, Protocols and Performance Impacts

#### 6.6.3.1 Establishment of MA PDU Session using MPQUIC-LL

The following figure shows how an MA PDU Session using MPQUIC-LL can be established. It is based on the existing MA PDU Session establishment procedure defined in TS 23.502 [4] clause 4.22.2 with some additions shown in red.



Fig. 6.6.3.1-1: Enhancement of MA PDU Session Establishment for MPQUIC-LL support

The following Fig. 6.6.3.1-2 shows an example of PCC rules provided by PCF to SMF in step 5b and illustrates how the SMF can derive the corresponding ATSSS rules and QoS rules for the UE. In a similar way, the SMF derives also N4 rules from the PCC rules.

Editor's note: The contents of the MPQUIC Connection Selection Descriptor (i.e. how the traffic of a specific MPQUIC connection is identified) need to be further studied.

Editor's note: it is FFS whether the MPQUIC connection is selected based on the ATSSS rules or based on QoS rules (whether ATSSS rules need to contain a copy of the QoS rules).



Fig. 6.6.3.1-2: Example of PCC rules and ATSSS rules/QoS rules derived from the PCC rules

#### 6.6.3.2 ATSSS architecture update for MPQUIC-LL

In order to support the MPQUIC steering functionality the ATSSS architecture detailed in Section 4.2.10 of 3GPP TS 23.501 [5] is extended as shown in the following figure.

The UE and the UPF may support the MPQUIC-LL steering functionality, possibly, in addition to the ATSSS-LL and MPTCP steering functionalities.

Editor's note: It is FFS whether supporting for the same MA PDU Session both the MPQUIC-LL and the ATSSS-LL is necessary.

The PCF is enhanced to support PCC rules using MPQUIC steering functionality, as shown in Fig. 6.6.3.1-2, and the SMF is enhanced to support the ATSSS rules and the N4 rules with MPQUIC connection selection information as shown in Fig. 6.6.3.1-2.



Fig. 6.6.3.2-1: ATSSS architecture extended to support MPQUIC-LL steering functionality

#### 6.6.3.3 User plane protocol stack for MPQUIC-LL

The MPQUIC-LL steering functionality tunnels IP packets or Ethernet frames over a MPQUIC multipath transport. The associated protocol stack in the UE and UPF is shown in Fig. 6.6.3.3-1.



Fig. 6.6.3.3-1: User plane protocol stack for MPQUIC-LL

NOTE: Security is terminated at the network side via 5G AN security (this may include IPSec termination in the 5G AN) and possible NDS between network entities as defined in TS 33.210.

#### 6.6.3.4 Access Network Performance Measurements

Editor's note: it is FFS whether the PMF functionality is required when the MPQUIC-LL functionality is used for a MA PDU Session.

### 6.6.4 Impacts on services, entities, interfaces and IETF protocols

Editor's note: it is FFS the evaluation of the impacts of this solution on services, entities, interfaces and IETF protocols.

## 6.7 Solution #7: Proposed solution based on MP-QUIC

### 6.7.1 General

The ATSSS feature is to enable UE simultaneously connecting to the 3GPP access and non-3GPP access. Then the traffic can take advantage of both accesses resource to raise the bandwidth or/and access reliability. In release-16, for UDP traffic, it can only be supported by the ATSSS-LL functionality, thus an IP packet flow cannot be split over both accesses, so actually the increase of bandwidth requirement is not achieved. This solution is proposed to introduce a new steering method based on MP-QUIC to resolve this issue, referring to the KI#2 on additional steering methods.

This solution applies to UDP based application traffic only, with IP-based MA PDU Sessions (IPv4, IPv6, IPv4v6).

### 6.7.2 Function Description

The MP-QUIC protocol is being drafted in IETF draft-deconinck-quic-multipath-04 [y]: " Multipath Extensions for QUIC (MP-QUIC)". It is designed to support the multipath scenario, and except the QUIC connection ID, a Uniflow ID is defined for the MP-QUIC connection. When an uniflow is in use, each end host associates it with a network path. Each uniflow is an independent flow of packets over a given network path, it can experience very different network conditions (latency, packet loss rate, …). To handle this, each uniflow has its own packet sequence number space. When the MP-QUIC protocol is applied in 5G system, especially in the ATSSS architecture, the 3GPP and non-3GPP accesses are the different paths, and the different uniflows are bound to the different paths. With this uniflow, the MP-QUIC functionality can perform the congestion control on each path and support the traffic splitting per packet as MPTCP. Therefore, it is proposed to define the MP-QUIC functionality to be supported by the UE and UPF, see the following figure x.1.2-1 for the model on the UE side.

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Figure 6.7.2-1: Steering functionality of MP-QUIC in the UE

This MP-QUIC functionality can be applied to steer, switch and split the UDP traffic of applications allowed to use MP-QUIC. The MP-QUIC functionality in the UE communicates with an associated MP-QUIC Proxy functionality in the UPF, by using the MP-QUIC protocol over the 3GPP and/or the non-3GPP user plane. MP-QUIC functionality can support any steering modes as defined in Rel-16.

NOTE 1：If the application applies MP-QUIC with the server, there is no need to enable the MP-QUIC functionality between the UE and UPF. If the application applies QUIC with the server, the QUIC packets are encapsulated in the MP-QUIC data payload, i.e. the MP-QUIC is treated as the tunnel for the QUIC packets between the UE and UPF.

Editor's note: In the NOTE 1 above, it needs to be clarified how “the QUIC packets are encapsulated in the MP-QUIC data payload” which hints at the usage of MPQUIC as a tunnel fits with the protocol stack below where a non tunnelled approach seems to be supported

One or more MP-QUIC connections between the UE and the UPF may be established based on the procedure described in subclause 6.7.3. These MP-QUIC connections can be encrypted or NULL encrypted.

Editor's note: its FFS whether “These MP-QUIC connections can be encrypted or NULL encrypted” requires IETF changes

The protocol stack for MP-QUIC is shown below, taking untrusted non-3GPP access as an example. (The “Application payload” in the protocol stack represents the application layer traffic carried on top of UDP, i.e. it does not include the UDP/IP headers):



Figure 6.7.2-3: Protocol stack of MP-QUIC

Editor's note: it is FFS whether the solution implies a double security between the UE and the 5GS (radio level security + QUIC mandatory security). If that is the case, it needs to be clarified how QUIC/DTLS security is set-up

Similar as MPTCP functionality, the MP-QUIC proxy functionality is deployed in the UPF, and the UPF can be transparent MP-QUIC proxy, or non-transparent MP-QUIC proxy.

For both transparent and non-transparent MP-QUIC proxy, the UPF allocates the link-specific IP addresses to the UE, and these link-specific IP addresses may be the same or different with link-specific IP addresses for MPTCP. The UPF can detect the MP-QUIC traffic based on the UE link-specific IP address and forward it to the MP-QUIC functionality. The MP-QUIC proxy terminates an MP-QUIC connection with UE and apply regular UDP transport to the remote host.

Editor's note: it is FFS what transparent MP-QUIC proxy means when anyhow the UE needs to play an active role in injecting a MP-QUIC stack in the data path. It is FFS whether Figure 6.7.2-3: Protocol stack of MP-QUIC is valid for both transparent and non-transparent MP-QUIC proxy

Editor’s note: It is FFS whether both transparent and non-transparent cases need to be supported.

In case of non-transparent MP-QUIC proxy, similar with MPTCP solution defined in Rel-16, the network sends the MP-QUIC proxy information to the UE, i.e. the MP-QUIC functionality IP address, and port number. The UE uses this MP-QUIC IP address as the destination IP address to encapsulate the user packets. The following IETF protocol is needed in this non-transparent MP-QUIC solution, e.g. to transport the IP address of the remote server to the UPF:

Socks v5: IETF RFC1928 [11]. "SOCKS Protocol Version 5".

NOTE 2：In case of transparent MP-QUIC proxy, the packet from the UE is encapsulated with the destination IP address of the remote server.

Editor’s note: In case of transparent proxy as in NOTE 2 above, it is FFS how the UE can accept TLS credentials that are not that of the final server’s.

Editor’s note: It is FFS how the UE instructs the proxy to forward traffic to the target server as well as how negotiating and requesting proxy capabilities and parameters it is being done.

### 6.7.3 Procedures

The signalling flow for a MA PDU Session establishment when the UE is not roaming, or when the UE is roaming and the PDU Session Anchor (PSA) is located in the VPLMN, is described as below. The flow relates to the case of non transparent proxy.



**Figure 6.7.3-1: MP-QUIC based MA PDU Sessioon establishment procedure**

- In step 1, the UE provides a "MA PDU Request" indication in UL NAS Transport message and an ATSSS Capability indicating support of "MP-QUIC Capability" in PDU Session Establishment Request message.

The "MA PDU Request" indicates to the network that this PDU Session Establishment Request is to establish a new MA PDU Session and to apply the MP-QUIC functionality, for traffic steering of this MA PDU session.

- In step 2, if the AMF supports MA PDU sessions, then the AMF selects an SMF, which supports MA PDU sessions, and forwards the MA PDU Session Establishment Request to the SMF.

- In step 3, if the MA PDU session is allowed and dynamic PCC is to be used for the MA PDU Session, the SMF sends an "MA PDU Request" indication and the ATSSS Capability of MA PDU Session to the PCF in the SM Policy Control Create message. The ATSSS Capability indicates the MP-QUIC functionality.

The PCF provides ATSSS policy if the MA PDU session is allowed. The PCF provides PCC rules for the MA PDU session, i.e. PCC rules that include ATSSS policy control information, which includes the MP-QUIC functionality indication. Additionally, the PCC rules may also indicate on whether the encryption of the MP-QUIC connection is needed or not based on operator policy and subscription data or access type for this MA PDU session.

- In step 4, the SMF establishes the user-plane resources over the 3GPP access and/or non-3GPP.

- the N4 rules derived by SMF for the MA PDU session are sent to UPF and one or two N3 UL CN tunnels info may be allocated by the UPF. If the ATSSS functionality for the MA PDU Session indicates "MP-QUIC functionality ", the SMF includes MP-QUIC functionality indication into the N4 rule to instruct the UPF to activate the MP-QUIC functionality for the traffic. If the MP-QUIC connection needs encryption or NULL encryption, the SMF also indicates it to the UPF.

- In step 5, the UPF allocates the UE "link-specific multipath" addresses/prefixes and MP-QUIC functionality information if the non-transparent MP-QUIC functionality is applied for this MA PDU session in the UPF. The UPF sends the "link-specific multipath" addresses/prefixes and MP-QUIC functionality information to the SMF. The MP-QUIC functionality information includes the MP-QUIC functionality IP address and UDP port number, uniflow ID with corresponding access type and the MP-QUIC connection ID.

- In step 6, for the MA PDU session, the SMF includes an "MA PDU session Accepted" indication and PDU Session Establishment Accept message which includes ATSSS rules for MA PDU Session, the "link-specific multipath" addresses/prefixes and the MP-QUIC functionality information in the Namf\_Communication\_N1N2MessageTransfer message to the AMF and the AMF marks this PDU session as MA PDU session based on the received "MA PDU session Accepted" indication, same as defined in Rel-16 specifications.

- In step 8, the UE receives a PDU Session Establishment Accept message, which indicates to the UE that the requested MA PDU session was successfully established. This message includes the ATSSS rules for the MA PDU Session, the "link-specific multipath" addresses/prefixes and the MP-QUIC functionality indication and the MP-QUIC connection ID and encryption or NULL encryption indication for the traffic.

- After step 8 in Figure xx, if the SMF was informed in step 2 that the UE is registered over both accesses, then the SMF initiates the establishment of user-plane resources over non-3GPP access too as specified in TS 23.502 clause 4.22.2.1.

The last step above is not executed when the UE is registered over one access only, in which case the MA PDU Session is established with user-plane resources over one access only. How user-plane resources can be added over an access of the MA PDU Session is specified in TS 23.502 clause 4.22.7.

Editor’s note: It is FFS whether more details, e.g. call flow, are needed to show how the UDP traffic is transported via the MP-QUIC proxy based solution.

### 6.7.4 Impacts on services, entities, interfaces and IETF protocols

Editor’s note: It is FFS the evaluation of the impacts of this solution on services, entities, interfaces and IETF protocols.

## 6.8 Solution #8: Proposed solution based on QUIC

### 6.8.1 General

This solution allows transport of the IP/UDP based application traffic by using QUIC protocol via multiple paths. It addresses two cases:

1) the QUIC functionality is supported by the UE, and with the QUIC proxy functionality enabled in the UPF, the QUIC connection can be established between the UE and UPF;

2) the QUIC functionality is implemented by the application layer between the UE and the application server.

As the QUIC connection cannot detect multiple paths, the Rel-16 ATSSS-LL, which supports four steering modes, Priority-based mode, Load-balancing mode, Smallest Delay mode and Active-standby mode, is still needed to perform traffic steering, switching, and splitting, Therefore, this solution proposes to apply a combination of QUIC functionality and ATSSS-LL functionality as a new steering method enabling UDP flows to use multiple paths, addressing the KI#8 on additional steering methods.

### 6.8.2 Function Description

The QUIC functionality in the UE applies the QUIC protocol defined by IETF draft-ietf-quic-transport-27: "QUIC: A UDP-Based Multiplexed and Secure Transport". It may be implemented by the operating system or by the application layer. This QUIC functionality in the UE will communicate with the QUIC Proxy functionality in the UPF or QUIC functionality in the remote server. The solution details for each case are described as below.

* QUIC connection between the UE and the UPF

The following Figure x.x.2.-1 shows the QUIC functionality in the UE model and its relationship with the other functionalities.



Figure 6.8.2-1: QUIC Functionality in the UE

As shown in the above Figure 6.8.2-1, the application data is encapsulated by the QUIC functionality and then transported to the ATSSS-LL functionality. The ATSSS-LL functionality decides on the path for transport of the QUIC packet based on the link performance measurement of PMF. But different from the R16 ATSSS solution, in which the ATSSS-LL could only split a SDF per traffic on both accesses, the ATSSS-LL functionality can split a traffic per packet on both accesses with combination of QUIC functionality, to take advantage of both access resource to raise bandwidth, since the QUIC functionality supports the packet reordering with the sequence number included in the QUIC header. Especially, compared with TCP, the QUIC ACK frame contains one or more ACK ranges. Each ACK range could identify acknowledged packets and also contain additional ranges of packets which are alternately not acknowledged (Gap). With such enhancement, the QUIC protocol can solve the packet disordering issue received from lower layer, e.g. ATSSS-LL.

The traffic steering, switching or splitting is performed by the ATSSS-LL functionality, so there is no need to allocate the link-specific IP address for the UE as MPTCP functionality. Therefore, only one UE IP address of the MA PDU session is applied.

The QUIC proxy functionality is enabled in the UPF, and it can be transparent QUIC proxy, or non-transparent QUIC proxy.

* Transparent QUIC proxy solution: The UE and UPF establish the QUIC connection, and the UPF apply regular UDP to the remote host. The packet from the UE is encapsulated with the destination IP address of the remote server. The QUIC packet is received in the QUIC connection. The UPF removes the QUIC header and then forward it to the remote host by using UDP.
* Non-transparent QUIC proxy solution: similar with MPTCP solution in R16, the network shall send QUIC proxy information to the UE, i.e. the QUIC functionality IP address, a port number. The UE will use this QUIC IP address as the destination IP address to encapsulate the user data and the UPF updates it to the remote host IP address. The following IETF protocol is needed in this non-transparent QUIC solution, e.g. to transport the IP address of the remote server to the UPF:

Socks v5: IETF RFC 1928 [11]. "SOCKS Protocol Version 5".

Editor's note: it needs to be clarified (with a call flow) how to transport the IP address of the remote server to the UPF in both cases: Transparent QUIC proxy solution / Non-transparent QUIC proxy solution.

One or more QUIC connections between the UE and the UPF may be established based on the procedure in subclause 6.8.3. These QUIC connections can be encrypted or be NULL encryption.

Editor's note: IETF QUIC has mandatory security so it needs to be clarified how These QUIC connections can be with NULL encryption. Otherwise, it is FFS whether the solution implies a double security between the UE and the 5GS (radio level security + QUIC mandatory security). If that is the case, it needs to be clarified how QUIC/DTLS security is set-up

Editor’s note: It is FFS how the UE instructs the proxy to forward traffic to the target server as well as how negotiating and requesting proxy capabilities and parameters it is being done.

The protocol stack is defined in Figure 6.8.2-2, taking untrusted non 3GPP access as an example:



Figure 6.8.2-2: Protocol stack of QUIC

* QUIC connection between the UE and remote server

If the QUIC functionality is implemented by the application layer, between the UE and the server (i.e. remote host), there is no need to enable the QUIC proxy functionality in the UPF. These QUIC packets can directly be handled by ATSSS-LL as described above when the UPF knows this is a QUIC connection. For example, the PCF is aware that the application supports QUIC, the PCF may allow the traffic splitting per packet for a SDF by indicating only one packet flow in this SDF. Otherwise, it depends on the UPF to identify the QUIC packet from the other UDP packets, e.g. based on DPI analysis. When the UPF identifies the QUIC packets, the traffic switching or splitting per packet based on the steering mode and link performance measurement of PMF can be performed by the ATSSS-LL functionality.

Editor’s note: it is FFS whether the PCF can be aware that the application supports QUIC.

### 6.8.3 Procedure

For the first case, i.e. QUIC connection is between the UE and the UPF, the signalling flow for a MA PDU Session establishment when the UE is not roaming, or when the UE is roaming and the PDU Session Anchor (PSA) is located in the VPLMN, is described as below.



Figure 6.8.3-1: QUIC based MA PDU Session establishment procedure

- In step 1, the UE provides a "MA PDU Request" indication in UL NAS Transport message and an ATSSS Capability indicating support of "QUIC Capability" in PDU Session Establishment Request message.

The "MA PDU Request" indicates to the network that this PDU Session Establishment Request is to establish a new MA PDU Session and to apply the QUIC functionality, for traffic steering of this MA PDU session.

- In step 2, if the AMF supports MA PDU sessions, then the AMF selects an SMF, which supports MA PDU sessions, and forwards the MA PDU Session Establishment Request to the SMF.

- In step 3, if the MA PDU session is allowed and dynamic PCC is to be used for the MA PDU Session, the SMF sends an "MA PDU Request" indication and the ATSSS Capability of MA PDU Session to the PCF in the SM Policy Control Create message and. The ATSSS Capability includes the QUIC functionality.

The PCF provides ATSSS Steering policy if the MA PDU session is allowed. The PCF provides PCC rules for the MA PDU session, i.e. PCC rules that include ATSSS policy control information, which includes the QUIC functionality and ATSSS-LL functionality indication if both QUIC functionality and ATSSS-LL functionality are supported. Additionally, the PCC rules may also indicate on whether the encryption of the QUIC connection is needed or not based on operator policy and subscription data or access type for this MA PDU session.

- In step 4, the SMF establishes the user-plane resources over the 3GPP access and/or non-3GPP.

- the N4 rules derived by SMF for the MA PDU session are sent to UPF and one or two N3 UL CN tunnels info may be allocated by the SMF or by the UPF. If the ATSSS functionality for the MA PDU Session indicates "QUIC functionality and ATSSS-LL functionality", the SMF includes QUIC functionality and ATSSS-LL functionality into the N4 rule to instruct the UPF to activate the QUIC functionality and ATSSS-LL functionality for the traffic. If the QUIC connection needs encryption or NULL encryption, the SMF also indicates it to the UPF.

- In step 5, the UPF allocates QUIC functionality information if the non-transparent QUIC functionality applied for this MA PDU session in the UPF. The UPF sends QUIC functionality information to the SMF. The QUIC functionality information includes the QUIC functionality IP address and UDP port number.

- In step 6, for the MA PDU session, the SMF includes an "MA PDU session Accepted" indication and PDU Session Establishment Accept message which includes ATSSS rules for MA PDU Session and the QUIC functionality information in the Namf\_Communication\_N1N2MessageTransfer message to the AMF and the AMF marks this PDU session as MA PDU session based on the received "MA PDU session Accepted" indication, same as defined in Rel-16 specifications.

- In step 8, the UE receives a PDU Session Establishment Accept message, which indicates to the UE that the requested MA PDU session was successfully established. This message includes the ATSSS rules for the MA PDU Session, which includes steering mode, the QUIC functionality and ATSSS-LL functionality indication and the QUIC connection ID and encryption or NULL encryption indication for the traffic.

Editor's note: QUIC connection ID is FFS

- After step 8 in Figure xx, if the SMF was informed in step 2 that the UE is registered over both accesses, then the SMF initiates the establishment of user-plane resources over non-3GPP access too as specified in TS 23.502 clause 4.22.2.1.

The last step above is not executed when the UE is registered over one access only, in which case the MA PDU Session is established with user-plane resources over one access only. How user-plane resources can be added over an access of the MA PDU Session is specified in TS 23.502 clause 4.22.7.

For the second case, i.e. QUIC connection between the UE and remote server, the existing procedure as specified in TS 23.502 clause 4.22.2 is applied.

Editor’s note: It is FFS whether more details, e.g. call flow, are needed to show how the UDP traffic is transported via the MP-QUIC proxy based solution.

### 6.8.4 Impacts on services, entities, interfaces and IETF protocols

Editor’s note: It is FFS the evaluation of the impacts of this solution on services, entities, interfaces and IETF protocols.

## 6.X Solution #<X>: <Solution Title>

### 6.X.1 Introduction

Editor's note: This clause lists the key issue(s) addressed by this solution.

### 6.X.2 High-level Description

Editor's note: This clause outlines solution principles, assumptions and high-level architectures, etc.

### 6.X.3 Procedures

Editor's note: This clause describes services and related high-level procedures for the solution.

### 6.X.4 Impacts on services, entities, interfaces and IETF protocols

Editor's note: This clause describes impacts to existing services and interfaces.

# 7 Evaluation

Editor's note: This clause will provide a general evaluation of the solutions.

# 8 Conclusions

Editor's note: This clause will capture conclusions from the study.

Annex A:  
Change history

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Change history** | | | | | | | |
| Date | Meeting | TDoc | CR | Rev | Cat | Subject/Comment | New version |
| 2020-06 | SA2#139E |  | - | - | - | S2-2004654 - Proposed skeleton agreed at SA2#139E | 0.1.0 |
| **2020-06** | **SA2#139E** | - | - | - | - | S2-2004655 – Scope | 0.1.0 |
| **2020-06** | **SA2#139E** |  |  |  |  | S2-2004656, S2-2004657, S2-2004658, S2-2004659, S2-2004660, S2-2004661, S2-2004662, S2-2004702, S2-2004703, S2-2004704 | 0.1.0 |