# Support of a Multi-access Session in 5G Mobile Network

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*Abstract*— **The 5th Generation (5G) mobile network, being standardized in 3GPP, is a convergence network that supports both 3GPP Radio Access Technology (RAT) and a non-3GPP RAT. The 3GPP RAT is a new RAT to provide much increased data rate for enhanced mobile broadband service. Wi-Fi and fixed wireline are mainly considered for non-3GPP access technologies but we only discuss Wi-Fi as a non-3GPP RAT for the sake of simplicity. This paper discusses a multi-access packet data unit (PDU) session, whose traffic is sent over 3GPP access, or over non-3GPP access, or over both accesses. 3GPP specification group 2 (SA2) is studying technical problems and solutions for this issue with a name of Access Traffic Steering, Switching and Splitting (ATSSS). ATSSS is expected to enrich user experience by distributing user traffic across 3GPP RAT and non-3GPP access technologies. This paper shows an implementation of multiple-access PDU session (MAPS) to support ATSSS in 5G mobile network. We briefly introduce ATSSS concept and discuss design issues of ATSSS in our 5G trial system. The design issues focus on minimal modification to the existing signaling procedures in the architecture of the 5G system with a single-access PDU session. We designed legs on each access to extend a session, which are managed together as a single PDU session.**

***Keywords—5G Mobile Network; ATSSS; Multi-Access PDU session; Non-3GPP***

## I. Introduction

The 5th Generation (5G) mobile network is designed to support faster and more reliable data transmissions.[1] It supports much higher data rate, lower latency, and increased capacity than the current 4th Generation (4G) mobile network.

The 5G standardizing body, 3rd Generation Partnership Project (3GPP) who are developing new radio access technology (RAT) for 5G mobile network considers supporting of non-3GPP accesses as well. 3GPP classifies Wi-Fi and fixed wireline as non-3GPP access technologies but we do not include technical discussion of fixed wireline access for brevity of the paper. Wi-Fi, as a companion RAT, can help mobile operators deal with the explosive rate of growth in network traffic.[2] It can relieve the pressure on the mobile network and can offer fast indoor data connections. 3GPP specification group 2 (SA2), which works on 5G mobile network architecture, is studying ATSSS (Access Traffic Steering, Switching and Splitting) as a way to effectively utilize 3GPP access and non-3GPP access.[3] ATSSS makes it easier to dynamically direct user traffic flows between accesses. It will bring more dynamic distribution of data flows between two accesses compared to strictly separated independent sessions on each access. Harmonized traffic handling across 3GPP and non-3GPP accesses through ATSSS may not only reduces mobile network congestion but also improve user experience.

For a simple example, A user, named Erik, works from home can simultaneously connect to Wi-Fi and/or wireline residential gateway for listening internet music broadcasting and to 5G for office work data. Erik still can keep connected through 5G for both internet music and work data while he moves to an office meeting. At his office Erik uses only Wi-Fi for both music and work data preparing the meeting. 3GPP and non-3GPP multi-RAT environment can provide access network aggregation, selection of best access network and handover among access networks.

ATSSS is consisted of Access Traffic Steering, Access Traffic Switching, and Access Traffic Splitting. Access Traffic Steering is selecting a 3GPP or non-3GPP access network for transmitting a new data flow and transmits the corresponding data flow to the selected access network. The Access Traffic Switching is a procedure for moving a data flow(s) being transmitted from one of the 3GPP and non-3GPP access networks to the other access network and continues to transmit. Access Traffic Splitting is a procedure for distributing data flows between 3GPP and non-3GPP access networks. In order to support ATSSS, existing 5G Packet Data Unit (PDU) session concept in ref. [1] should be expanded. Since the existing PDU session is a transport association between a User Equipment (UE) and the core network over a single radio access, we need to have two PDU sessions or a single PDU session with some extensions. We propose to use the latter one and add a leg concept to the existing PDU session. We will discuss PDU session establishment and release procedures and other related issues of implementation. The proposed procedure focuses on minimal modification to the existing 5G PDU session management procedures.

The next section discusses network architecture for ATSSS and describes Multi-Access PDU Session (MAPS) for ATSSS. Section III represents protocol stacks to support ATSSS for 3GPP and non-3GPP accesses and explains MAPS setup and release procedures for ATSSS. Finally, conclusion is given in the last section.

## II. ATSSS and MAPS

### *A. 5G reference network architecture for ATSSS*

Table 1 lists abbreviations used in the paper. We show a simplified 5G reference architecture with 5G-Radio Access Network (RAN) and Wi-Fi Access Network (AN) in Fig. 1. For the purpose of brevity a very limited set

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TABLE I. ABBREVIATIONS

| Acronym | Meaning |
|---|---|
| 3GPP | The 3rd Generation Partnership Project |
| 3GPP SA2 | 3GPP specification group 2 |
| AMF | Access and mobility Management Function |
| AN | Access Network |
| ATSF | ATSSS Function |
| ATSSS | Access Traffic Steering, Switching and Splitting |
| BAR | Buffering Action Rule |
| CN | Core Network |
| CP | Control Plane |
| DL | Downlink |
| DN | Data Network |
| DRB | Data Radio Bearer |
| EAP | Extensible Authentication Protocol |
| FAR | Forwarding Action Rule |
| GTP-U | GPRS Tunneling Protocol User Plane |
| IKEv2 | Internet Key Exchange Protocol Version 2 |
| MAC | Media Access Control |
| MAflag | MAPS flag |
| MAPS | Multi-Access PDU Session |
| N3IWF | Non-3GPP Interworking Function |
| NAS | Non-Access Stratum |
| NAS-MM | NAS for Mobility Management |
| NAS-SM | NAS for Session Management |
| NGAP | Next Generation Application Protocol |
| PDCP | Packet Data Convergence Protocol |
| PDR | Packet Detection Rule |
| PDU | Packet Data Unit |
| PFCP | Packet Forwarding Control Protocol |
| PHY | Physical layer |
| PS | Packet Data Unit Session |
| QER | QoS Enforcement Rule |
| QFI | QoS Flow Identifier |
| RAN | Radio Access Network |
| RAT | Radio Access Technology |
| RLC | Radio Link Control |
| RRC | Radio Resource Control |
| S1AP | S1 Application Protocol |
| SA | Security Association |
| SBI | Service Based Interface |
| SCTP | Stream Control Transmission Protocol |
| SDAP | Service Data Adaptation Protocol |
| SM_ASTF | ATSF in SMF |
| SMF | Session Management Function |
| UDM | Unified Data Management |
| UE | User Equipment |
| UE_ASTF | ATSF in UE |
| UL | Uplink |
| UP | User Plane |
| UP_ASTF | ATSF in UPF |
| UPF | User Plane Function |
| URR | Usage Reporting Rule |
| URSP | UE Route Selection Policy |

of functional elements that are essential to ATSSS are chosen from 5G mobile network architecture. [1, 3] There are Control Plane (CP) and User Plane (UP) to provide PDU connectivity service between a UE and a DN to exchange PDUs in the 5G network. While UP entities handles users' PDUs, CP entities controls overall 5G core networks behavior by signaling. We show only Access and mobility Management Function (AMF), Session Management

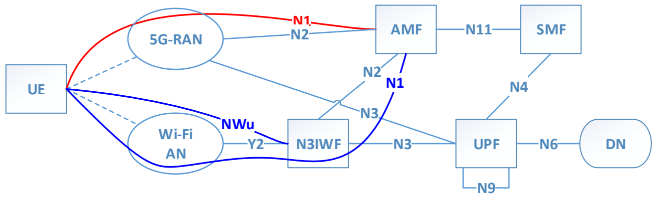


Fig. 1. 5G reference network architecture for ATSSS

Function (SMF), and Unified Data Management (UDM) from CP entities and User Plane Functions (UPFs) as a UP entity. AMF is in charge of handling connection and registration of UEs and routing of session management messages from UEs to an appropriate SMF. SMF controls sessions through a consistent signaling mechanism over different ANs. UDM manages user subscription data and authentication data. UPF handles user data packets, it receives and forwards PDUs to and from ANs and DNs. It matches packet headers with specified filters and forwards the packets to appropriate interface with or without creation of outer headers. Outer header is used for tunneling user packets between an AN and a UPF or between UPFs. AMF interfaces with ANs over N2 reference point. AMF interfaces with UE over N1 reference point through different ANs. This N1 is referred to NAS (Non Access Stratum), on which UE and core network communication is performed. UE and N3IWF (Non-3GPP Interworking Function) are connected over reference point NWu. Since Wi-Fi AN in this paper is considered as an untrusted one, where further mechanism for secure communication is required.

### *B. Access Traffic Steering, Switching and Splitting*

The following is simple description of ATSSS among ANs. Access Traffic Steering is the procedure that selects an AN for a new data flow and transfers the traffic of this new data flow over the selected AN. Fig. 2 shows an example of Access Traffic Steering. It steers a new traffic flow 3 to Wi-Fi, while the other traffic flow is directed to 5G-RAN.

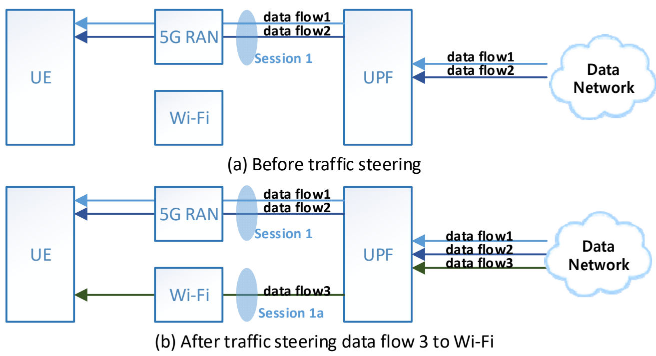


Fig. 2. An Access Traffic Steering Example

Access Traffic Switching is the procedure that moves all traffic of an ongoing data flow from one AN to another AN in a way that maintains the continuity of the data flow. Fig. 3 shows an example of Access Traffic Switching. It switches an existing data flow 3 to Wi-Fi, while the other traffic flow is still directed to 5G-RAN.

Access Traffic Splitting is the procedure that splits the traffic of a data flow across multiple ANs. When traffic splitting is applied to a data flow, some packets of the data flow is transferred via one access and the other packets of the

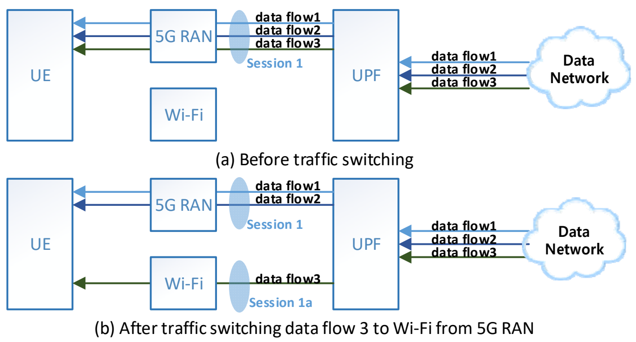


Fig. 3. An Access Traffic Switching Example

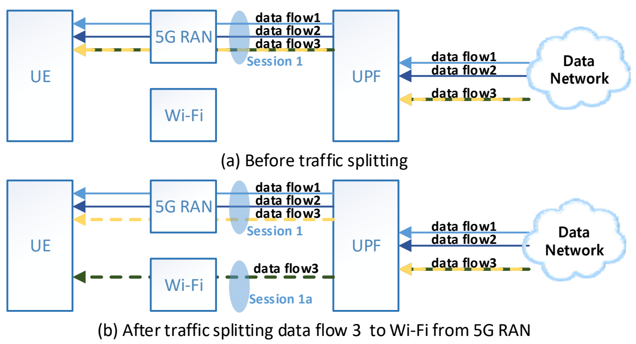


Fig. 4. An Access Traffic Spliting Example

same data flow is transferred via the other access. Fig. 4 shows an example of Access Traffic Splitting. An existing data flow 3 is split into both Wi-Fi and 5G-RAN.

Through Fig. 2 to Fig. 4, Session 1 and Session 1a are legs of a single session as to be discussed in section II-C. A PDU Session, defined in 5G system, is an association to provide a PDU connectivity service between a UE and a DN. An ordinary PDU session is assumed to pass through one single AN between a UE and a DN. The ordinary PDU session cannot support ATSSS through more than one ANs. Multi-Access PDU Session (MAPS) is to be defined to have a single PDU connectivity over more than one ANs. For simplicity we use two ANs for ATSSS; one is 5G new radio and the other one is Wi-Fi.

## C. *Multi-Access PDU Session (MAPS) for ATSSS*

There are two schemes of implementing MAPS as in Fig. 5 and Fig. 6. Fig. 5 shows a PDU session that is consisted of two correlated child PDU sessions: PS-child1 and PS-child2. A PDU session in Fig. 6 has two PDU session legs: PS-leg1 and PS-leg2. Managing two child session leads to inefficient session management since each child session has separate session IDs and maintains separate session context such as IP address. However, the session in Fig. 6 is managed as a whole unit while data flow can be steered, switched and split onto the two legs of the single session.

UPF-A is an anchor UPF that receives data packets to and from DNs for UEs. In Fig. 6, the anchor UPF deals with user packet steering, switching and splitting as it is branching point among accesses. UPF-1 and UPF-2 are optional UPFs that may be used according to network deployment and policy. 5G-RAN is an access network for 5G and Wi-Fi AN is an access network for Wi-Fi. Non-3GPP Interworking Function (N3IWF) connects Wi-Fi AN to AMF and UPF for CP and UP respectively. N3IWF handles IPsec tunnels for

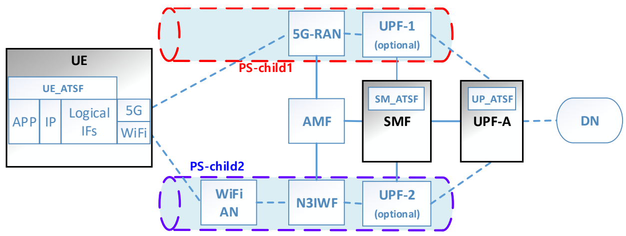


Fig. 5. Two child sessions for ATSSS

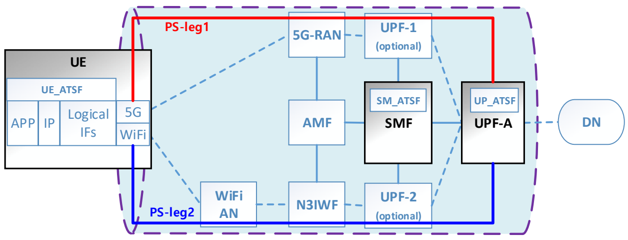


Fig. 6. A single session with two legs for ATSSS

untrusted Wi-Fi AN. UE, SMF and UPF have ATSFs (Access Steering, switching and splitting Functions) as further detail functional entities to handle ATSSS in them. SM_ATSF is main controlling entity of ATSSS. It enforces ATSSS policy and is responsible for management of all PDU sessions between 5G core network and UE. UP_ATSF and UE_ATSF set up multi-access connectivity and steer/switch/split traffic over multiple accesses based on the policies provided by the SM_ATSF. UE_ATSF steers/switches/splits traffic over multiple accesses. Uplink packets from applications are thrown to different ANs by using logical interfaces. An instance of PDU session has one or more logical interfaces. UE_ATSF manages logical interfaces and maps user packets onto proper logical interfaces based on UE Route Selection Policy (URSP). URSP is used by the UE to determine how to route outgoing traffic. It enables the UE to determine how a certain application should be handled in the context of an existing or new PDU session. [4]

## D. *UPF settings for ATSSS*

Since SMF and UPF interface with Packet Forwarding Control Protocol (PFCP) [5] we describe UPF settings with some of selected PFCP terminologies. Packet Detection Rule (PDR) has information for matching data packets. UPF matches and selects user packets according to PDRs. PDR includes rule identifier, tunnel identifier, outer header removal scope and packet filters. PDR also has Forwarding Action Rule (FAR) identifier that describes how the packet is dealt with. FAR describes how the packets are dropped, forwarded, buffered or duplicated. Further, it has outer header creation information to support tunneling of forwarding action as well as network interface to be used. Usage Reporting Rule (URR), Buffering Action Rule (BAR) and QoS Enforcement Rule (QER) are not discussed in this paper.

Fig. 7 and Fig. 8 show UPF-A settings examples for ATSSS. Let's assume that (1) optional UPF-1 and UPF-2 are not employed, (2) UPF-A has two network interfaces. One is to ANs and the other to DN and their respective IP addresses are *aAddr* and *cAddr*, and (3) ANs' IP addresses to core network side network interfaces are *b1Addr* and *b2Addr* and their corresponding tunnel endpoint identifiers are *b1Teid* and *b2Teid* respectively. The trapezoids in Fig. 7 and

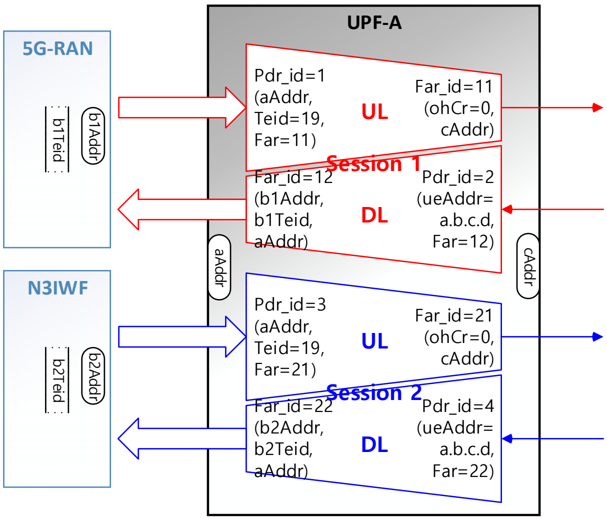


Fig. 7. UPF-A settings for two sibling sessions

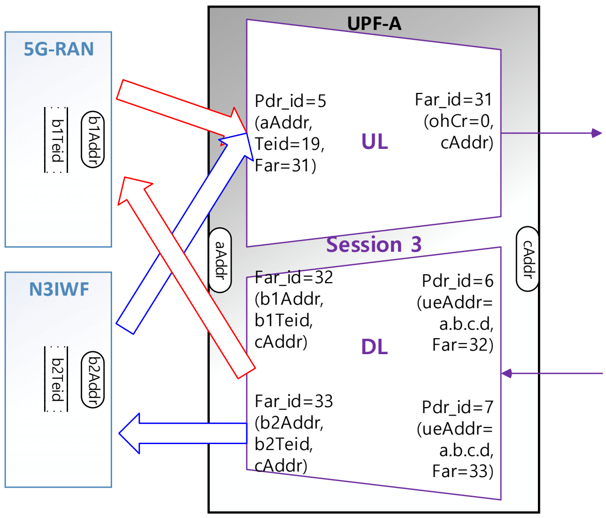


Fig. 8. UPF-A settings for a single session with two legs

Fig. 8 show Uplink (UL) and Downlink (DL) traffic paths implemented with PDRs and FARs. Traffic classifier and corresponding forwarding buffer are shown together in the trapezoid. Boxed and outlined arrows show tunneled traffic encapsulated with outer headers and normal arrows show traffic without outer headers. In Fig. 7, there are two child sessions: session 1 in red and session 2 in blue. Each session has traffic paths of UL and DL. UL of session 1 filters packets received at interface with *aAddr* and with tunnel endpoint identifier 19 is to be mapped to FAR 11, where FAR 11 indicates 'do not create outer header'. FAR 11's forwarding network interface is with *cAddr*. DL of session 1 filters packets with UE's IP address, which is *a.b.c.d*. UE's IP address is to be matched with destination address of IP header. This PDR maps the filtered packets to FAR 12, where FAR 12 action is to encapsulate the packets through to 5G-RAN with *b1Addr* and *b1Teid*. The UPF-A settings of session 2 works the same way as described for session 1.

One thing to note for session 2 is the UE IP address is same with session 1. Normally a session is allocated a unique IP address but sessions composing two sibling sessions are allocated the same IP address. The two sibling sessions may have a virtual parent session or may be implemented in correlated sessions. The virtual session only links the two sibling sessions as children and do not have session specific attributes. In the correlated sessions the session inherits some of parameters, such as IP address and QoS context. UPF-A settings of a single session with two legs is shown Fig. 8. In this setting UL PDR of the two legs of the session is shared and its corresponding FAR is shared. DL traffic path has two PDRs and two corresponding FARs. The UE IP address is allocated once and used twice in each PDR compared to that the same UP IP address is allocated twice and used separately in Fig. 7. PDRs with ID 6 and ID 7 have different packet filters which are not shown in the figure.

## III. ATSSS Implementation

Two different options of sub-session representation are being studied in 3GPP SA2. [2] The first one is having two child sessions and the other one is having a single session with two access types. The two sub-session of an MAPS shares a common DN name, network slice information, mobility mode and common IP address. Having two child sessions requires management of separate session IDs and further handling of two child sessions with common characteristics. Having two legs of a session enables simple management of a session but it requires leg management. Our implementation uses access types and manages the two sub-sessions as two legs of an MAPS.

### *A. Protocols for 3GPP access network*

NAS layer, N1 interface in Fig. 1, carries NAS-MM and NAS-SM messages between UE and AMF. NAS-MM carries connection and registration related NAS signaling messages. NAS-SM carries session related NAS signaling messages and it is relayed by AMF to and from UEs and SMFs through ANs. N11 protocol layers are to be implemented in service based interface (SBI) which makes use of HTTP2, JSON and OpenAPI. N2 and N11 reference points are common for 3GPP and non-3GPP ANs. NGAP (NG application part) is similar to S1AP in 4G system. NAS message is carried over PHY, MAC, RLC, RRC and PDCP between UE and 5G-RAN. User traffic between UE and 5G-RAN has another layer on top of PDCP. It is Service Data Adaptation Protocol (SDAP) for QoS flow handling. It marks QoS flow ID (QFI) on data packets and used in mapping between a QoS flow and a data radio bearer.

### *B. Protocols for Non-3GPP access network*

Protocol stacks between UE and N3IWF are different from protocols for 3GPP AN. NWu interface in Fig. 1 is considered as a non-secure channel and setting up IPSec tunnel is required. Fig. 9 and Fig. 10 show CP and UP protocol stack for CP NAS signal and user traffic. In order to authenticate mutually and setup IPSec security association(SA), EAP and IKEv2 is used. IKEv2 is used between UE and N3IWF to setup IPSec SA and EAP is used to carry NAS message between UE and AMF. N3IWF relays between NWu interface and N2 and N3 interface.

### *C. Establishment of Two Legs of a Session*

There are two methods of UE requested MAPS establishment: combined establishment and separate establishment. Use case and application of network requested MAPS establishment is under study. Fig. 11 shows separate establishment of two legs of an MAPS. In the example procedure the first leg is performed on 3GPP access and the latter leg on non-3GPP. Although UE's registration on both

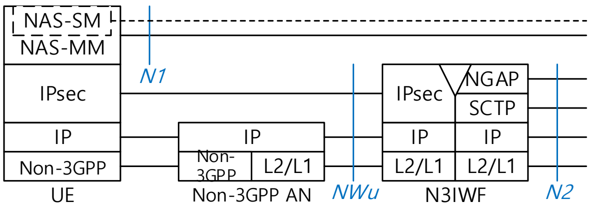


Fig. 9. CP protocol stack for untrusted non-3GPP access

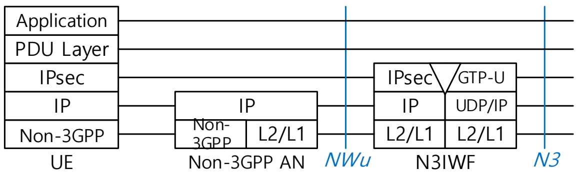


Fig. 10. UP protocol stack for untrusted non-3GPP access

accesses are represented as a precondition for brevity, UE's registration on an access type is only needed before its session establishment procedure on the access type.

(A1) UE sends PDU Session Establishment Request message to AMF. UE includes request type as 'initial request' and a new session ID, e.g. 1, in the message. The 'initial request' option asks SMF to setup a new session context for the UE with the requested session ID. (A2) AMF then finds an appropriate SMF and relays the message to the SMF in SBI format. AMF finds and adds access type into the relayed message. The access type is found from where the UE's message came from. SMF then performs authentication and authorization of the session and registers onto UDM, of which steps are not drawn in the figure. (A3) SMF sets up UPF with packet detection and enforcement rules. (A4) SMF asks AMF to relay SMF's NAS message, which is Session Establishment Accept message with UPF's CN tunnel information for uplink from RAN, to UE. (A5) AMF asks 5G-RAN to relay the NAS message as well as to setup radio resources and RAN tunnel. (A6) 5G-RAN sends the NAS message and sets up data radio bearer and RAN tunnel for downlink from UPF. (A7) 5G-RAN gives response to AMF with session information including session ID and RAN tunnel information. (A8) AMF relays session information from 5G-RAN to SMF. (A9) SMF modifies the established N4 session information set up at step (A3) with RAN tunnel information. (A10) SMF then finally responses to AMF.

Procedure B is quite similar to procedure (A). As UE wants to add a leg onto the session set up in procedure (A). (B1) UE specifies different options: request type as 'existing' and MAPS information. The 'existing' request type asks SMF to expand the existing session and session ID should be the existing one to add a leg. MAPS information holds MAflag and ATSSS preference. MAflag represents user's intention to add a leg and ATSSS preference represents how the user wants to use each legs. For example the user may specify five tuples to use each access. (B2) The access type found and set by AMF is non-3GPP. (B3) Considering ATSSS preference from UE, SMF decides ATSSS rules and sets up the rules on the session setup at step (A3). (B6) Compared to DRB setup in 3GPP, N3IWF and UE set up a child IPsec SA for non-3GPP traffic. Other steps are same with relative steps in procedure (A).

When it comes to combined establishment, steps (A1) and (A2) are used in common and steps (B1) and (B2) are skipped. Step (A1) has options with request type as 'initial request' and MAPS information discussed in step (A1). Then SMF automatically sets up a session with both 3GPP and non-3GPP legs after step (A2).

### *D. Release of Leg(s) of a Session*

There are also two methods of UE requested MAPS release: combined release and separate release. Fig. 12 shows a combined release procedure. While having two legs on each access, (1) UE sends PDU Session Release Request message to AMF. The message has session ID and access type to release. In this example, access type is 'both', meaning both 3GPP and non-3GPP accesses. Setting this access type to a single one, such as 3GPP or non-3GPP leads to a separate release procedure. (2) AMF then relays the NAS massage to SMF. (A3) SMF asks UPF to delete a leg, in this example 3GPP leg first, (A4) and responds to AMF with Session Release Command message to send to UE. SMF indicates access type to AMF so that AMF sends NGAP message to proper RAN. (A5) AMF asks 5G-RAN to release session resource of the session. (A6) 5G-RAN sends NAS message to UE and release data radio bearer of the session. (A7) 5G-RAN responds to AMF and (A8) AMF relays the response to SMF. (A9) UE's reply on the session leg release is sent to AMF. Although this message is related to a leg of a session, Session Release Complete message is used. (A10) This NAS message is relayed to SMF with access type indication.

Procedure B is also similar to procedure (A). Since this release of leg is the last leg of a session, (B3) SMF releases all session resources, e.g. IP address that was allocated to the session, and requests UPF with Session Delete message in contrast to Session Modification message is used in (A3) to release a leg of a session. In (B6) of Fig. 11 a child SA is released for a non-3GPP leg of a session. In order to delete the leg that child SA is to be deleted as (B6). When a UE is deregistered on a certain access, during the deregistration procedure AMF asks SMF to release the leg on the access as in step (2). Only a leg on the access is released and the other leg on other access is left in use.

## IV. Conclusion

We discussed ATSSS between 3GPP and non-3GPP accesses of 5G mobile network. ATSSS is considered to provide improved user experience utilizing multiple ANs. It may be used to optimize traffic distribution across various accesses by steering, switching and splitting traffic across ANs. In this paper, we introduced issues to support ATSSS in 5G network. CP and UP protocol stacks are described and signaling procedures to setup and release MAPS with single session ID and legs on each access. The proposed signaling illustrated both combined signaling and separated signaling procedures. The proposed signaling procedure is designed to minimize modification to existing session management signaling of 5G network.

## References

[1] 3GPP TS 23.501, "System Architecture for the 5G system", Jan. 2018.
[2] 3GPP, S2-171321, "Study on Access Traffic Steering, Switch and Splitting support in the 5G system architecture (FS_ATSSS)", Mar., 2017.

[3] 3GPP TR 23.793, "Study on Access Traffic Steering, Switching and Aplitting support in the 5G system architecture", Mar. 2018.

[4] 3GPP TS 23.503, "Policy and charging control framework for the 5G System", Jan. 2018.

[5] 3GPP TS 29.244, "Interface between the Control Plane and the User Plane Nodes", Mar. 2018.

[6] 3GPP TS 23.502, "Procedures for the 5G system", Jan. 2018.

[7] J. Ha and N. Park, "Access Traffic Steering, Switching and Splitting in 5G Convergence Network," The 28th Joint Conference on Communications and Information, May. 2018.


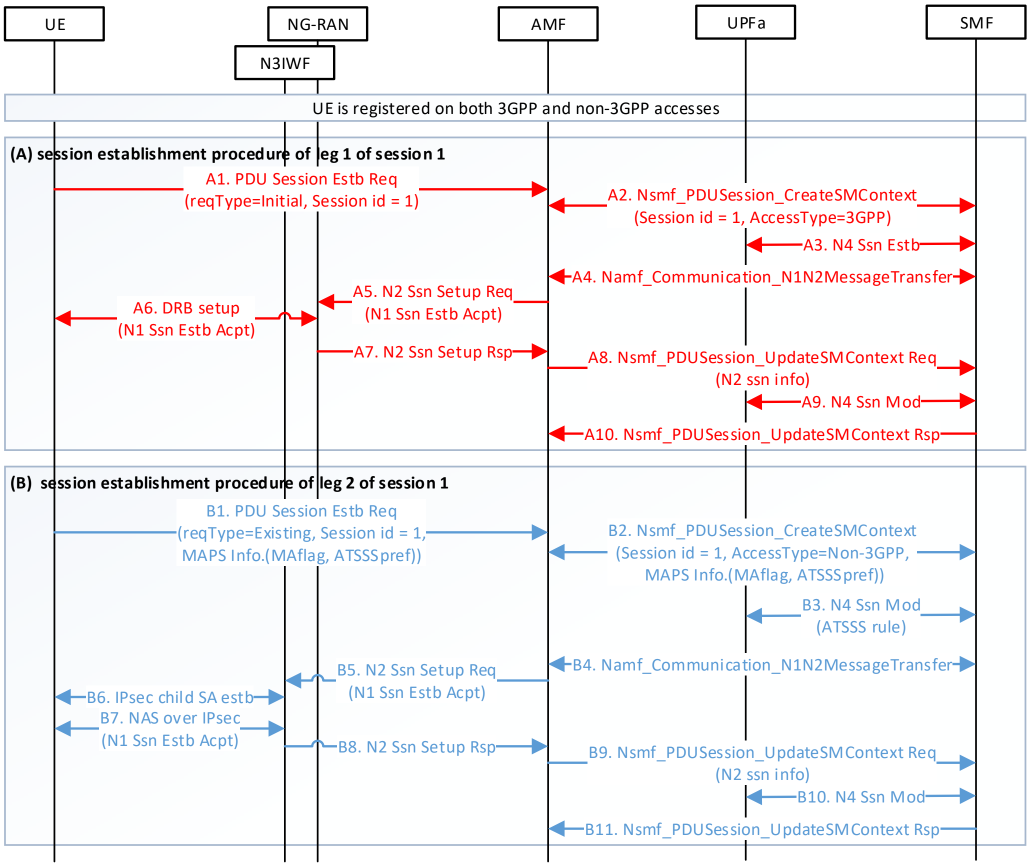


Fig. 11. Separate Establishment of Two Legs of a Session

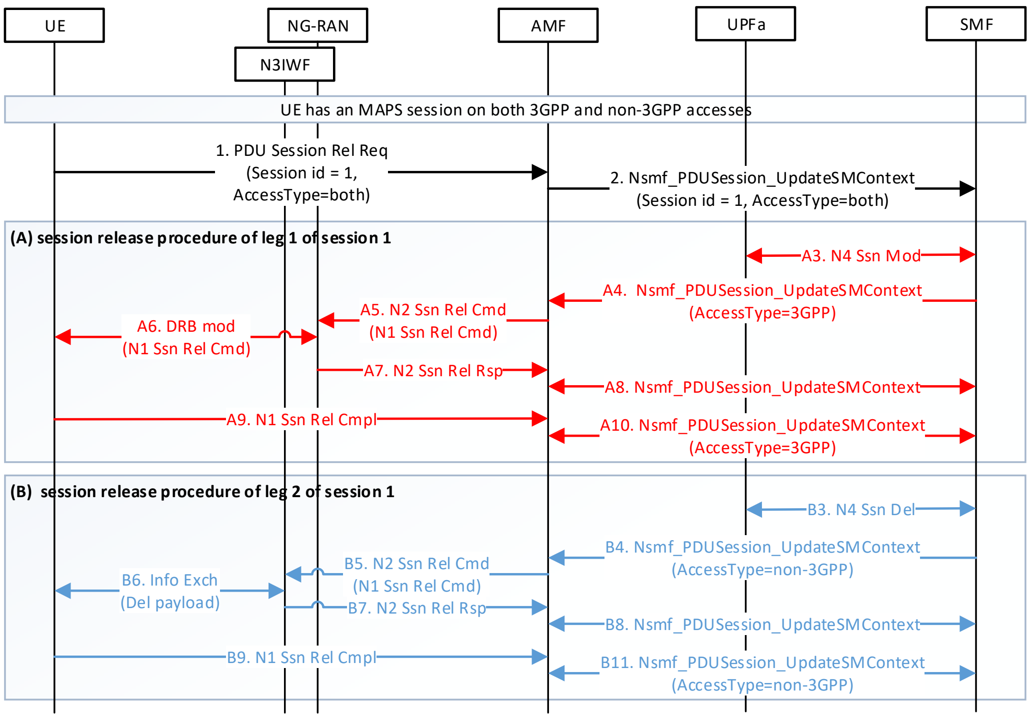


Fig. 12. Release of Legs of a Session