A Solution for Establishing Traffic Routes per Application in 5G-Advanced and 6G Mobile Networks

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***Abstract*—With the spread of technologies such as cloud computing, IoT, and AI, as well as 5G, future new services require more powerful programmability and simpler network solutions. SRv6 can better meet the diversified requirements of the services and offer great extensibility and programmability based on the scalable segment (SID) list of SRv6 header (SRH). In this paper, we define a new control plane function named route control function (RCF) to compute the traffic routes and generate the RIDs, and propose a solution for establishing the traffic routes per application using the RCF. As a way to implement the solution, we also present use cases in which the (R)ANs and SMF obtain the RIDs, the PCF utilizes the RIDs to generate the URSP rules or the PCC rules, and the RIDs are applied during data transfer. The proposed solution can evolve to support the dynamic service (and/or network) programming and slicing at the application level.**

Keywords*—*mobile core, 5G-Advanced, 6G, programmability, route control, SRv6, traffic routes per application

I. Introduction

With the advent of technologies such as cloud computing, IoT, and AI, as well as 5G, the requirements for future application services are dynamically diversifying in terms of bandwidth, delay, and security. In addition, the ever-increasing demand for high-quality and differentiated traffic requires a programmable network structure that can provide optimized routes and network services for applications, taking into account service characteristics and network requirements.

5G and beyond mobile networks are composed of a radio access network (RAN) and a mobile core network (MCN). The MCN is a key component for realizing mobile services that perform control functions (such as access and mobility, session, policy and QoS, etc.) and packet forwarding functions for providing these services through the RANs connected to the MCN for wireless connectivity and service delivery to UEs. Currently, mobile networks consist of a complex protocol stack that connects from the base stations to the data networks (DNs) via transport networks of an overlay type, and use a GTP-U tunneling protocol as a mechanism to ensure mobility [1]. The GTP-U tunneling structure must be managed separately from the transport network, and it is difficult to establish a path for protocol data unit (PDU) session traffic through traffic engineering or to handle dynamic in-network computing [1]. As a result, GTP-U protocol is limited in its ability to optimize and operate network routes based on the requirements of application services.

Segment Routing IPv6 (SRv6) is a technology that leverages the source routing paradigm to allow an ingress node to steer packets through an ordered list of instructions called segments [2, 3]. The SRv6 is a next-generation IP bearer protocol that combines IPv6 with segment routing that can program routing paths for packets [4]. Utilizing existing IPv6 forwarding technology, the SRv6 facilitates network programming through a flexible IPv6 extension header called the segment routing header (SRH) that allows the ingress to insert the segments to guide the forwarding or processing of data packet [2, 5]. A segment routing policy is instantiated in the routing header as an ordered list of segments (SIDs) [3]. Therefore, SRv6 is expected to reduce the number of required protocol types, offer great extensibility and programmability based on the scalable SID list of SRH, and meet the diversified requirements of more new services [4].

Unlike GTP-based PDU sessions, which provide a fixed route from the (R)AN to the user plane functions (UPFs), SRv6-based PDU sessions enables dynamically differentiated routes per application (through traffic and/or service engineering), supports service programming and QoS according to the requirements of the application services, and provides the services with routes composed of nodes that are appropriate for the characteristics of the user data. Each node can be bound to any service or feature in a router or computer instance, with specific examples being UPF and service nodes that perform different operations such as data forwarding, packet verification and firewalling, encoding/decoding operations, and in-network computing.

In this paper, based on the SRv6-based PDU session, we propose a solution for establishing traffic routes on per-application basis and controlling of user traffic forwarding using the route control function (RCF) which is a newly defined control plane function. The organization of this paper is as follows. In Section 2, we propose the concept of our solution, and in Section 3, we present its application in the process of signaling and data transfer. Finally, Section 4 discusses conclusions and future work.

II. A Proposed Solution for Establishing Traffic Routes per Application

To establish the traffic routes per application (or service data flow, hereafter referred to as application), we define a new control plane function, RCF that computes the traffic routes. Fig. 1 shows a flowchart outlining a method of establishing the traffic routes using the RCF. When the RCF receives a request from a consumer network function (NF), e.g., policy control function (PCF) or session management function (SMF), to calculate the traffic routes per application (in step 1), it requests and/or subscribes to the producer NFs to obtain the input data (in step 2).

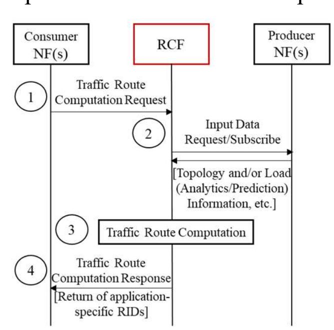

Fig. 1. Traffic routes establishment procedure using the RCF

The RCF computes the traffic routes for each application based on the input information obtained, generates application-specific routing identifiers (RIDs) based on the calculated traffic routes (in step 3), and then sends a traffic route computation response message containing the calculated traffic routes information to the consumer NFs (in step 4).

In step 1, the PCF may request the traffic routes computation from the RCF to generate the UE policy (specifically, UE Route Selection Policy, URSP) at the request of the access and mobility management function (AMF) for the UE policy association establishment in the registration procedure (see (a) in Fig. 2), and to generate the policy and charging control (PCC) rules (in particular, traffic routes for the service data flow) at the request of the SMF for the SM policy association establishment in the PDU session establishment procedure (see (b) in Fig. 2 and (i) in Fig. 4) [6, 7]. The SMF may also request the creation of a route from the UE to the PDU Session Anchor (PSA) (including the service nodes) as part of the UPF Selections in the PDU session establishment procedure (see (j) in Fig. 4) [6]. In step 2, the PCF may obtain topology information from the SMF/administration and maintenance (OAM) and load (analytics/prediction) information from the network data analytics function (NWDAF)/UPF. Even if we defined the RCF as a new NF to control the traffic routes, it can also be embedded as a functionality in other NFs (e.g., PCF or SMF) rather than operating as a standalone NF.

As a concrete example of the application-specific RID returned by the RCF, Fig. 3 shows a diagram illustrating an example of establishing the traffic routes per application in mobile networks. The RCF may compute the traffic routes and ensure that packets are forwarded along the route "(R)AN(G1) - UPF1(U1) - sNode1(S1) - UPF2(U2)" for the Application1 based on the RID1. The RCF may forward the RID1 to the (R)AN and SMF as well as to the PCF. For instance, when the (R)AN obtains the RID1 information from the RCF, it may configure the FIB/RIB, and when it receives packets for the Application1 from the UE based on the RID1, it may forward the packets via the route described above. Further, when the SMF and UPF2 (acting as a PSA) perform the N4 session establishment (or modification) procedure, the SMF may forward the traffic route to the UPF2 based on the obtained RID1, which enables the UPF2 to recognize the traffic route information. Similarly, the RCF may ensure that packets are forwarded along the route "(R)AN(G1) - UPF1(U1) - UPF2(U2)" for the Application2 based on the RID2.

If the PCF also obtains the application-specific RIDs information from the RCF as the traffic routes information to create the UE policies and PCC rules, the PCF may reflect the traffic routes information described above in them [7].

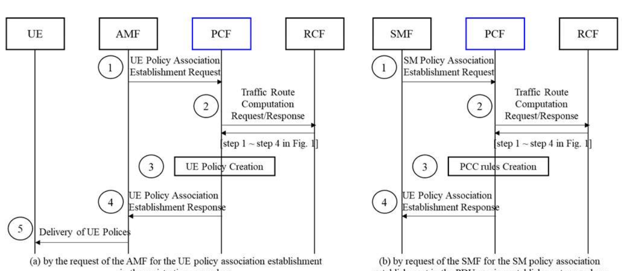

Fig. 2. Examples of the PCF requesting the RCF to compute the traffic routes

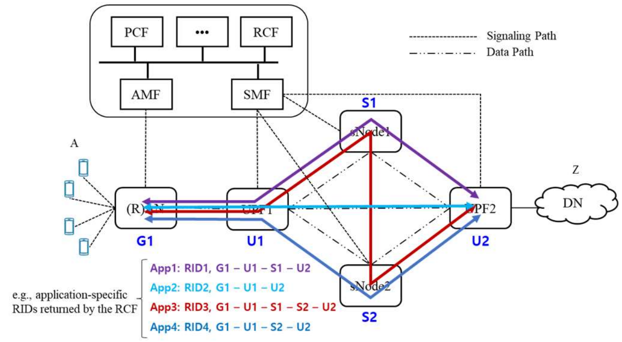

Fig. 3. Example of establishing the traffic routes on a per-application basis

Table 1 is an example of URSP rules (i.e., a policy on how the UE determines the traffic route) as a UE policy created by the PCF [7]. The RIDs information in the URSP may be further included in the route selection components (RSCs) as a policy related to Route Selection, as shown in the top part of Table 1. The RSC may additionally include settings for the route selection (including RID and/or traffic routes information), which can be configured as shown in the bottom part of Table 1. Table 2 also shows an example of PCC rule information generated by the PCF that further contains the traffic route information for service data flows [7].

TABLE I. EXAMPLE OF URSP RULES AS A UE POLICY GENERATED BY THE PCF

- **URSP rule precedence = 1**
  Traffic descriptor: APP1, DNN, IP 3tuples, ….
  Route selection components: Network Slice Selection, SSC Mode Selection, DNN Selection, **Route Selection (RID1, G1 – U1 – S1 – U2)**
- **URSP rule precedence = 2**
  Traffic descriptor: APP2, …
  Route selection components: **Route Selection (RID2: G1 – U1 – U2)**

Example URSP rules		Comments
Rule Precedence =1 Traffic Descriptor: Application descriptor= App1	Route Selection Descriptor Precedence=1 Network Slice Selection: S-NSSAI-a SSC Mode Selection: SSC Mode 3 DNN Selection: internet Access Type preference: 3GPP access **Route selection : RID 1** e.g. **Route selection : RID 1 (G1-U1-S1-U2)**	This URSP rule associates the traffic of application "App1" with S-NSSAI-a, SSC Mode 3, 3GPP access and the "internet" DNN. It enforces the following routing policy: The traffic of App1 should be transferred on a PDU Session supporting S-NSSAI-a, SSC Mode 3 and DNN=internet over 3GPP access. If this PDU Session is not established, the UE shall attempt to establish a PDU Session with S-NSSAI-a, SSC Mode 3 and the "internet" DNN over 3GPP access. **The traffic of App 1 should be transferred based on RID 1.**
. . .	. . ..	. . .

TABLE II. EXAMPLE OF PCC RULE INFORMATION GENERATED BY THE PCF

Information name	Description
Rule identifier	Uniquely identifies the PCC rule, within a PDU Session.
Service data flow detection	*This part defines the method for detecting packets belonging to a service data flow.*
Precedence	Determines the order, in which the service data flow templates are applied at service data flow detection, enforcement and charging.
Service data flow template	For IP PDU traffic: Either a list of service data flow filters or an application identifier that references the corresponding application detection filter for the detection of the service data flow.
Mute for notification	Defines whether application's start or stop notification is to be muted.
Traffic route	**The traffic routes for the service data flow** e.g. **RID1 (G1-U1-S1-U2)**
. . .	. . .

III. Use Cases in the Process of Signaling and Data Transfer

In addition to the RCF delivering the RID(s) to the (R)AN and SMF mentioned in Fig. 3, there are ways for (R)AN and SMF to obtain the RID(s). Fig. 4 shows a flowchart illustrating a method that the (R)AN and SMF acquire the route selection information consisting of the RID and the actual traffic route information described in Table 1 [6]. In the PDU Session Establishment procedure shown in Fig. 4, the UE may send a PDU Session Establishment Request message (including S-NSSAI(s), UE requested DNN, PDU Session ID, Request type, existing PDU Session ID, N1 SM container, QoS information, etc.) to the AMF for PDU session establishment. At this time, the PDU session establishment request may include the route selection information (e.g., RID1, G1-U1-S1-U2) (in step A). The AMF may transfer an (N2 PDU session) Request message containing UPF tunneling information, QoS information, etc. to establish an (N2) session with the (R)AN. The (N2) session establishment request message may also include the route selection information (in step B). Therefore, the (R)AN can obtain the RID and the traffic route information.

The (R)AN may send a Response message containing the (R)AN tunneling information and the route selection information to the AMF for N2 session establishment after establishing the (R)AN related resources with the UE (in step Y). The SMF may generate a downlink traffic path based on the (R)AN GTP-U tunnel endpoint information, the route selection information, etc. and forward it to the UPF with the N4 session Modification Request. At this time, the downlink traffic path may be the reverse route (e.g., U2-S1-U1-G1) described above (in step Z). Eventually, similar to the (R)ANs, the SMF can also acquire the RID and the traffic route information.

Fig. 5 shows a diagram illustrating how the RID(s) are applied during data transfer. The format based on Fig. 5(a) allows the UE to instruct the RID to the (R)AN. The IPv6 headers may include the information about the source node (Source Address, e.g., the address of the UE) and the next destination node (Destination Address, e.g., RID1 information). Based on the DA value in the IPv6 header, the (R)AN can recognize the RID and the traffic route, and then forward the packet to the next destination node. As shown in Fig. 5(b), the format for directing the traffic route according to the RID recognized by the (R)AN may further include the SRv6 header (SRH) in addition to the IPv6 header and IPv6 payload [4, 5].

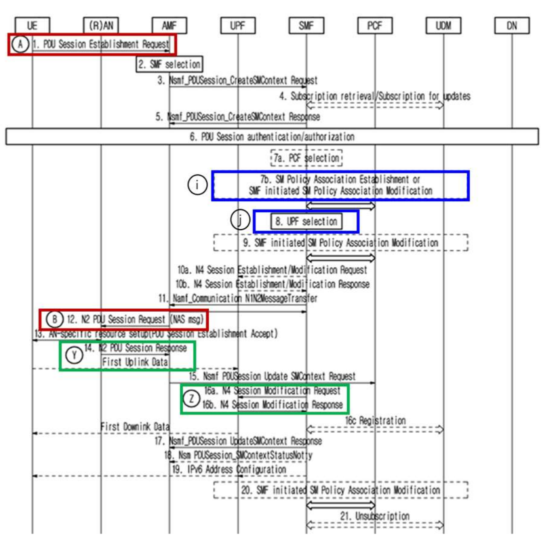

Fig. 4. A method for the R(AN) and SMF to obtain the route selection information

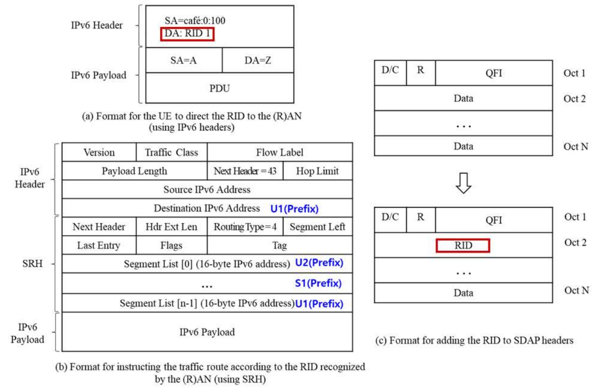

Fig. 5. Examples of applying the RID(s) during data transfer

The RID information also may be included in the service data adaptation protocol (SDAP) header to instruct the route, as shown in Fig. 5(c) [8].

IV. Conclusions and Future Work

Based on SRv6-based PDU session, we proposed a solution for establishing the traffic routes on per-application basis using newly defined RCF to compute the traffic routes and generate the RIDs (including the actual traffic route information). The following use cases were considered to implement the solution: the (R)AN and SMF obtaining the RIDs, the PCF utilizing the RIDs to generate the URSP rules or the PCC rules, and applying the RIDs during data transfer.

The proposed solution also has been implemented in the mobile network structure to perform basic functional verification. For further research, we plan to extend the proposed solution to support the dynamic service (and network) programming and slicing at the application level so that the diversified requirements of future new services can be supported.

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